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B. Gold

ATTACHMENT

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**THE GRAND CANYON MONITORING AND RESEARCH CENTER**

**FISCAL YEAR 2000**

**MONITORING AND RESEARCH PLAN**

by

**THE GRAND CANYON MONITORING AND RESEARCH CENTER**

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**FINAL**



**GRAND CANYON MONITORING AND RESEARCH CENTER  
FY 2000 MONITORING AND RESEARCH PLAN**

**TABLE OF CONTENTS**

<b>CHAPTER 1</b> .....	1
<b>FY 2000 ANNUAL MONITORING AND RESEARCH PLAN</b> .....	1
<b>INTRODUCTION</b> .....	1
<b>GEOGRAPHIC AND INSTITUTIONAL SCOPE</b> .....	1
<b>MISSION OF GCMRC</b> .....	4
<b>GCMRC SCIENTIFIC ACTIVITIES</b> .....	4
<b>STAKEHOLDER INFORMATION NEEDS     AND CRITICAL RESOURCE ATTRIBUTES</b> .....	5
<b>ENSURING OBJECTIVE, QUALITY SCIENCE</b> .....	5
<b>PROPOSED MONITORING AND SCIENCE PROGRAMS</b> .....	5
Conceptual Modeling .....	6
The Physical Resources Program .....	6
The Biological Resources Program .....	7
The Socio-Cultural Resources Program .....	7
The Information Technology Program .....	9
Contingency Planning for BHBFs .....	9
<b>SCHEDULE AND BUDGET</b> .....	10
<b>CHAPTER 2</b> .....	11
<b>MONITORING AND RESEARCH PLANNING</b> .....	11
<b>CRITICAL ATTRIBUTES</b> .....	11
Long-Term Monitoring .....	12
Research .....	12
<b>CHAPTER 3</b> .....	14
<b>DEFINING STAKEHOLDER OBJECTIVES AND INFORMATION NEEDS</b> .....	14
<b>INTRODUCTION</b> .....	14
Revision Process .....	14
<b>CHAPTER 4</b> .....	16
<b>FISCAL YEAR 2000 MONITORING AND RESEARCH ACTIVITIES</b> .....	16
<b>INTRODUCTION</b> .....	16
Conceptual Modeling .....	16

<b>THE PHYSICAL RESOURCES PROGRAM</b> .....	19
Introduction.....	19
Information Needs .....	26
Strategic Objectives .....	27
FY 2000 PHYSICAL RESOURCES PROGRAM.....	29
FY 2000 Physical Sciences Program Budget.....	33
<b>THE SOCIO-CULTURAL RESOURCES PROGRAM</b> .....	34
FY000 PROGRAM ACTIVITIES.....	34
Cultural Resources .....	34
Recreational Resources.....	38
Economic Market Activities .....	42
FY2000 Budget Summary .....	45
CONTRIBUTION OF THE FY2000 PROGRAM TO THE STRATEGIC PLAN .....	45
<b>THE BIOLOGICAL RESOURCES PROGRAM</b> .....	46
FY 2000 PROGRAM ACTIVITIES.....	46
Integrated Water Quality Monitoring and Research .....	46
Aquatic Ecosystem Resource Components Activities .....	48
Terrestrial Ecosystem Resource Components and Activities .....	52
Other GCMRC Biological Resources Program Activities.....	56
CONTRIBUTION OF THE FY 2000 PROGRAM TO THE STRATEGIC PLAN .....	58
FY 2000 Biological Sciences Program Budget .....	59
<b>INFORMATION TECHNOLOGY PROGRAM</b> .....	60
Introduction.....	60
FY 2000 INFORMATION TECHNOLOGY PROGRAM .....	61
Information Flow .....	61
Database Management System .....	62
Geographic Information System.....	64
Library Operations .....	67
Remote Sensing .....	69
Surveying .....	74
Data Standards and Protocols .....	78
System Administration of Computers and Networks .....	79
Total Information Technology Budget .....	82
<b>CHAPTER 5</b> .....	83
<b>PROGRAM ADMINISTRATION AND ORGANIZATIONAL STRUCTURE</b> .....	83
Tentative Program Schedule .....	85
Adaptive Management Program Budget.....	86

- APPENDIX: A. DRAFT: GLEN CANYON DAM MANAGEMENT OBJECTIVES
- B. PRIORITIZED INFORMATION NEEDS – OVERALL RANKINGS (4-23-98)
- C. DRAFT PROSPECTUS FOR EVALUATING GCMRC MONITORING PROTOCOLS FOR THE COLORADO RIVER ECOSYSTEM

FIGURES: 1.1. Geographic Scope of GCMRC Activities .....3

4.1. Step Down Approach to the Development of a Long-Term Monitoring and Research Program (Davis, 1994).....18

4.2. GIS sites 1-17 .....66



**CHAPTER 1**  
**THE GRAND CANYON MONITORING AND RESEARCH CENTER**  
**FY 2000 MONITORING AND RESEARCH PLAN**

**INTRODUCTION**

The Fiscal Year 2000 Grand Canyon Monitoring and Research Center (GCMRC) Monitoring and Research Plan (FY 2000 Annual Plan) describes the scientific activities proposed by the GCMRC for FY 2000 for the Colorado River ecosystem.<sup>1</sup>

The FY 2000 Annual Plan is designed to implement the adaptive management and ecosystem science approaches called for in the 1992 Grand Canyon Protection Act (GCPA), Glen Canyon Dam Environmental Impact Statement (GCDEIS, 1995) and the Record of Decision (ROD, 1996). Monitoring, research and information technology activities to be accomplished in FY 2000 are described for physical, biological, cultural, socioeconomic, and recreational resources.

**GEOGRAPHIC AND INSTITUTIONAL SCOPE**

The geographic scope of GCMRC's activities is the Colorado River ecosystem within Glen Canyon National Recreation Area and Grand Canyon National Park (Figure 1.1). The Colorado River ecosystem<sup>2</sup> 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 to the western boundary of Grand Canyon National Park, a distance of approximately 300 river miles. The scope of GCMRC activities also includes limited investigations into some tributaries (e.g., the Little Colorado and Paria Rivers). It also includes, in general, cultural resource impacts of dam operations for inundation levels associated primarily with flows up to 256,000 cubic feet per second (cfs) as addressed in the

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<sup>1</sup> The Management Objectives and Information Needs have been used by GCMRC as the basis for developing the FY 2000 Annual Plan.

<sup>2</sup> "Colorado River ecosystem" will be used throughout this document as the standard definition of the monitoring and study area for GCMRC.

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

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

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<sup>3</sup> The Programmatic Agreement, finalized in August 1994, is a legal agreement between federal and state agencies and tribal groups that specifies the responsibilities of the parties to comply with the National Historic Preservation Act (1996; 1992) and 36 CFR 800.

<sup>4</sup> As specified in the 1992 GCPA and in the Record of Decision for the Glen Canyon Dam EIS (DOI 1996).

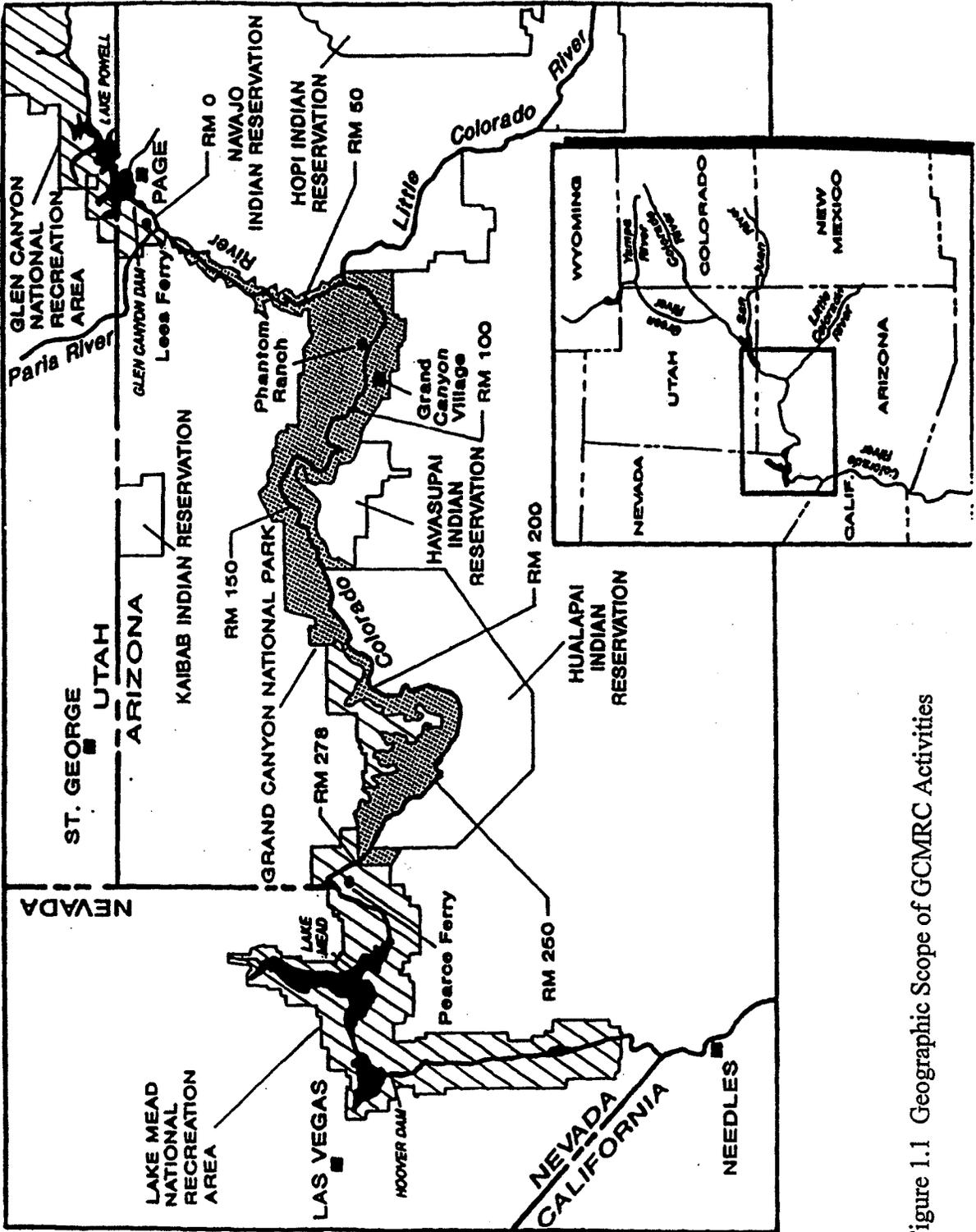


Figure 1.1 Geographic Scope of GCMRC Activities

### MISSION OF GCMRC

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

The mission of GCMRC is: to develop and implement long-term monitoring and related research and other scientific activities to determine "...the effects of the Secretary's actions..." on the physical, biological, recreational, socio-economic, and cultural resources of the Colorado River ecosystem within Grand Canyon National Park and Glen Canyon National Recreation Area, as well as to develop information which addresses other information needs specified by the Adaptive Management Work Group (AMWG) utilizing an ecosystem science approach.<sup>5</sup>

### GCMRC SCIENTIFIC ACTIVITIES

The FY 2000 Annual Plan draws distinction between monitoring and research activities which are to be initiated to address the management objectives (MOs) and prioritized information needs (INs)<sup>6</sup>. Research activities are intended to be funded for the duration needed to accomplish the specific research objectives while monitoring activities are expected to be ongoing. Both monitoring and research projects will be reviewed on an annual basis to evaluate their progress, and continued relevance to the MOs and INs given the state-of-knowledge at the point in time when they are reviewed.

Long-term monitoring is designed to determine changes in resource attributes. Research is used to interpret and explain trends observed from monitoring, to determine cause and effect relationships and research associations, and to better define interrelationships among physical, biological and social processes.

In addition to monitoring and research activities, the GCMRC operates an information techniques program to ensure information archiving and information transfer to managers and stakeholders and science organizations, a surveying department to provide

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<sup>5</sup> The report language which accompanies the GCPA indicates that the primary focus should be on "...the effects of the Secretary's actions..." on "downstream resources."

<sup>6</sup> The management objectives and prioritized information needs adopted at the July 1998 AMWG meeting serve as the basis for the monitoring and research activities called for in the FY 2000 Annual Plan. These can be found in Appendices A&B.

consistent, quality, cost-effective support to monitoring and research projects, and a logistics program to provide cost-effective support to monitoring and research field activities.

### **STAKEHOLDER INFORMATION NEEDS AND CRITICAL RESOURCE ATTRIBUTES**

The monitoring and research activities proposed in the FY 2000 Annual Plan are intended to address the management objectives and prioritized information needs approved by the AMWG for the Colorado River ecosystem. MOs and INS are specified in nine different resource areas including hydropower, water, sediment, fish and aquatic biology, riparian vegetation, threatened and endangered species, terrestrial wildlife, cultural, and recreational resources. Within each of the above resource areas specific MOs and INs have been developed by the Technical Work Group (TWG) and adopted by the AMWG. (See Appendix B.)

### **ENSURING OBJECTIVE, QUALITY SCIENCE**

The GCMRC was established to provide objective, high quality scientific information to the Secretary and to the AMWG. To accomplish these goals, specific protocols regarding science-planning, competition, peer-review, administration and publication have been established<sup>7</sup>.

An independent Science Advisory Board (SAB), will be established during FY 1999 to provide independent scientific review and technical advice to ensure that GCDAMP scientific and technical activities are efficient, unbiased, objective, and scientifically sound.

### **PROPOSED MONITORING AND SCIENCE PROGRAMS**

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

1. Conceptual modeling.
  2. Physical resource program.
  3. Socio-cultural resource program.
  4. Biological resource program.
-

5. Information technology program.
  - Remote Sensing evaluation and implementation.
6. Protocol Evaluation Program (PEP).
7. Contingency planning for Beach/Habitat-Building Flows (BHBFs).

### **Conceptual Modeling**

The conceptual model of the Colorado River ecosystem, developed during FY 1998 and 1999, will be refined and tested as an aid for examining potential management actions and their effects on downstream resources. The conceptual model will also be updated as additional data is obtained and our understanding of the Colorado River ecosystem is advanced.

### **The Physical Resources Program**

Streamflow and sediment are the two primary environmental attributes of concern in the physical resources area. Streamflow and sediment are dynamic in their responses to dam operations over both short and long time scales, and affect downstream ecosystem dynamics, either directly from dam operations, or indirectly from the interaction of differential discharges from dam operations with geomorphology and sediment and streamflows entering from tributaries. With respect to preservation of the ecosystem's sediment-based and sediment-related resources, long-term trends in the total sediment budget below Glen Canyon Dam and their relations to dam operations are of critical importance from a management perspective. Tracking long and short-term trends in the system-wide sediment budget, both for sand and coarser grains with respect to input, storage and export, is a primary objective of the GCMRC's long-term monitoring program. Ongoing evaluation and development of protocols useful in measuring and reporting changes in the sediment budget related to dam operations and natural streamflow and sediment events is one of the main goals in the FY 2000 period.

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<sup>7</sup> Operating Protocols for GCMRC, June, 1996 and GCMRC Peer Review Guidelines, May 31, 1997.

### **The Biological Resources Program**

Monitoring and research activities for biological resources are intended to develop information about the structure and function of the Colorado River ecosystem. The effort will provide the knowledge base required to evaluate "...the effects of the Secretary's action..." on downstream biological resources. In addition, it will provide information on the ability of future management actions/experiments to benefit biological resources. It is key that relationships between the biotic and abiotic components of the Colorado River ecosystem be addressed to predict impacts of current dam operations and possible future management actions/experiments on biological resources.

Monitoring activities will address management objectives and information needs within two programmatic areas: an aquatic and a terrestrial monitoring program. The protocol evaluation process (PEP) described in the strategic plan will be utilized to evaluate current monitoring protocols and to recommend specific protocols for implementation as part of the long-term monitoring program. Specific research projects will be initiated to address INs related to the aquatic food base, native and non-native fish species, wildlife and other riparian invertebrates and vertebrates that can't be addressed through the long-term monitoring program.

In FY 2000, the monitoring of water quality parameters in Lake Powell that are effected by dam operations and are thought to have effects primarily on biological components of the downstream aquatic ecosystem will be monitored as part of an integrated water quality monitoring program (IWQMP) under the direction of the Biological Resources program. As appropriate the biological resources monitoring and research program will consider and address information needs of the Biological Opinion.

### **The Socio-Cultural Resources Program**

The socio-cultural resources program incorporates the cultural resource program and socio-economic program into one resource program area. These resource areas have been combined to provide a more comprehensive treatment of resources that span prehistoric to current times and are meaningful to a broad group of stakeholders. This program describes the FY 2000 activities planned for cultural resources, such as prehistoric and historic archaeological resources and traditional tribal resources; and recreational resources.

Economic and hydropower issues are also included in this program. The socio-cultural program described in this Plan is complementary to, but separate from the Programmatic Agreement (PA) program that is the legal program of Reclamation pursuant to Section 106 of the National Historic Preservation Act (NHPA). Activities proposed under the GCMRC program constitute work that is outside the scope of the PA program.

In the cultural resource portion of the socio-cultural program, the proposed FY 2000 activities address the information needs specified by stakeholders. These include:

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

In the recreational portion of the program, activities are proposed that respond to stakeholder identified information needs that include:

1. Determine criteria and aspects that are important to, or detract from the recreational experience.
2. Determine adequate beach quality, character and structure for camping throughout the system.
3. Determine if operating criteria maintains safe and adequate power craft navigability in Glen Canyon and upper Lake Mead.
4. Determine flow regimes necessary to maintain fish populations of adult trout.
5. Define pattern of waterfowl and other wildlife use and conflicts to other uses.

In some cases, not all information needs can be addressed by within this planning period due to monetary constraints and projects may need to be programmed for future years. Hydropower supply, water resources and an economic assessment of resource impacts are briefly described, but no activities are proposed by the GCMRC in FY 2000.

### **The Information Technology Program**

Extensive data and information currently exists in the GCMRC relating to resource levels, quality, and relationship to other resources. Potentially equal amounts of data and information exists within museums, universities, state and Federal agencies, etc. However, much of this information has not been evaluated to assess the interrelationship of resource attributes and differing flow regimes.

Several areas of focus will be implemented through the information technology program, including the following:

1. Development of protocols for data collection, processing and use.
2. Continued development of extensive databases across all resources and a database management system.
3. Development of a robust geographic information system to accommodate multiple layers associated with all resources of interest to stakeholders.
4. Development of databases associated with remotely sensed data not yet incorporated in the GCES database system.
5. Stakeholder direct access to selected data and information in the database management system and GIS.
6. Development of outreach programs to make data and information available to stakeholders and train stakeholders in utilization of data and models incorporated in the information technology program.

### **Contingency Planning for BHBFs**

The TWG and AMWG have adopted hydrologic criteria and resource criteria for triggering a BHBF as a management action. When implemented, these criteria provide little lead time for research planning. In addition, hydrologic conditions can lead to unplanned release events which will also require GCMRC to implement BHBF specific monitoring and research activities with little to no lead time. The potential for these events to occur result in the need for monitoring and research contingency planning. GCMRC has developed a generic monitoring and research contingency plan for implementation of:

1. baseline assessments before and/or after unplanned events;

2. research assessments of "spills" or other short-duration high flow unplanned events; and
3. a monitoring and research program for planned events between January-July of a given year.

We believe this contingency plan represents well over 70 percent of the activities that would need to be initiated for any BHBF. Funding for implementing the FY 2000 contingency plan is not included in the FY 2000 budget.

### **SCHEDULE AND BUDGET<sup>8</sup>**

The Annual Plan and budget described in this document was reviewed by the TWG in the Fall of 1998 and the AMWG recommended at their January 15-16, 1999 meeting that it be approved by the Secretary of the Interior for implementation with a final review by the TWG in February 1999.

The GCMRC monitoring and research activities described in the FY 2000 Annual Plan will be implemented for approximately \$6.2 million. The remaining \$1.4 million expended by the GCDAMP are used to support the administration of the GCDAMP and the implementation of the Programmatic Agreement.

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<sup>8</sup> The budget for the FY 2000 Annual Plan was recommended to the Secretary for adoption by the AMWG at its July 21-22, 1998 meeting.

## **CHAPTER 2**

### **MONITORING AND RESEARCH PLANNING**

Glen and Grand canyons represent a unique, complex and dynamic environment. It is also a highly regulated system, in terms of river flows and use. Its uniqueness demands careful stewardship. To be successful, GCMRC's monitoring and research programs must ensure that data collection, analysis, and interpretation will address specific management needs and objectives. The design of an effective long-term monitoring program is not a trivial task. As pointed out by the NRC (1990) monitoring programs must be designed to discern change over time while accounting for variability and uncertainty in the system, and still produce data sets that can be analyzed to determine cause and effect relationships. In addition, monitoring needs to be dynamic so that monitoring needs can be prioritized and modified in response to what is learned from the ongoing monitoring and research activities, especially regarding the effectiveness of prescribed management actions, and in light of real-world scientific, logistical, and financial constraints (NRC, 1990). The approach being followed by GCMRC to design a long-term monitoring program is based on the work of Davis et al., (1994), NRC (1995), and Noon et al., (1997).

#### **CRITICAL ATTRIBUTES**

The monitoring and research programs emphasize measurement of attributes deemed critical for evaluating "...the effects of the Secretary's actions" on downstream resources. Monitoring of the entire ecosystem and all its resources is impossible, therefore selection of indicator components and processes is required. However, the debate as to which components or variables to measure is rarely resolved. Endangered, endemic, non-native and indicator resources should be considered as the first choices for monitoring. Indicators may include rare-but-otherwise-unprotected components and processes, and/or common, widely distributed components or processes that are considered sensitive to the stressors of interest. No single indicator (e.g., a single endangered species) can represent the entire ecosystem, and attention should be paid to representing various trophic levels among the selected indicators.

**Long-Term Monitoring**

Long-term monitoring is defined here as the repetition of measurement of selected environmental attributes over an extended period of time to determine status or trend in the environmental attributes being monitored. The distinguishing attribute of a monitoring effort is the measurement of change over time. Long-term monitoring in the Colorado River ecosystem is conducted to detect and project both expected and unexpected changes in this ecosystem, as related to the ROD-designated preferred alternative or other request from the Secretary or the AMWG.

The success of monitoring requires stability and consistent methodologies that are modified only after in-depth evaluations. Protocols will be developed and reviewed at different intervals for scientific relevance. Maintenance of long-term databases and archives is an essential element of the monitoring program.

Monitoring programs will be initiated through an open request for proposals. Proposals will be selected through an independent peer review process and evaluation by GCMRC staff in consultation with the AMWG/TWG. Criteria for selection will include support of management objectives and information needs, scientific capability and merit, and cost effectiveness. Projects and programs will be administered as contracts, cooperative agreements or interagency agreements, awarded for up to five years, as appropriate.

All monitoring data sets will be accessible to outside investigators and interested parties through developed information and technology services, except for selected sensitive data restricted by law, such as endangered species and cultural resource locations or proprietary information such as utility rate structures. All maps, databases, archiving, and retrieval procedures will conform to Federal standards.

**Research**

Research as defined here is the measurement of environmental attributes to test a specific hypothesis or provide descriptive assessments. 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. Research will play an important role in addressing information needs, development of integrated methods of monitoring, prediction of key physical and biological

processes, definition of resource interactions, and development of ecosystem models. The monitoring and research activities described in this Annual Plan are intended to measure attributes that reasonably might be affected by dam operations. Wherever possible, monitoring will be conducted using non-invasive means.

In addition, the development of specific monitoring protocols utilizing the protocol evaluation process (PEP) described in the draft FY 2000-2004 Strategic Plan is emphasized. For many resources the monitoring protocols (i.e., the specific parameters to be monitored and the method of monitoring) have been adequately described and evaluated and will be implemented as part of this Annual Plan. For other resources, the monitoring protocols will be completed as part of the scientific activities described in this Annual Plan. In all cases, the long-term monitoring programs implemented as part of this Annual Plan and any subsequent changes to those long-term monitoring programs resulting from the PEP will be implemented in such a way as to ensure data comparability over time.

## CHAPTER 3

### DEFINING STAKEHOLDER OBJECTIVES AND INFORMATION NEEDS

#### INTRODUCTION

In 1996 the Upper Colorado Regional Office of the Bureau of Reclamation worked with a subgroup of the Transition Work Group to develop management objectives (MOs) intended to guide the development of GCMRC monitoring and research activities. This group was disbanded with the release of their July, 1996<sup>9</sup> recommendations. Also in 1996, under the guidance of GCMRC, several workshops were held with scientists who had conducted research under the auspices of GCES to define information needs (INs) associated with the various MOs.

Many stakeholders that participated in the Transition Work Group are now in the AMWG and the TWG providing continuity for the GCDAMP. The purpose of the MOs is to define measurable standards of desired conditions which will serve as targets expected to be achieved by the participants in the GCDAMP. INs are more directly related to scientific activities implemented by GCMRC.

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

#### **Revision Process**

Starting in January 1998, an ad hoc group from the TWG met to address the Management Objectives and Information Needs as well as out year budget planning. Approximately 10 to 25 members of the TWG met several times to discuss these matters.

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<sup>9</sup> Adapted from *Glen Canyon Dam Management Objectives*, Bureau of Reclamation memorandum UC-205, ADM-1.10, July 1996, to Transition Work Group members.

Meetings were held to discuss general procedures for the revision process and the objectives and information needs by resource area. Five workshop sessions were held to discuss these issues. The purpose of the meetings was to review and revise MOs and INs, to establish relative priorities by study type, resource class, and research/monitoring question. The group was also tasked with reporting to the TWG during the process and to present recommendations on the revised information to the AMWG for adoption. The revised MOs and prioritized INs which are the foundation of this Annual Plan can be found in Appendices A and B.

**CHAPTER 4**  
**FISCAL YEAR 2000**  
**MONITORING AND RESEARCH ACTIVITIES**

**INTRODUCTION**

This chapter contains a description of the FY 2000 program activities to be conducted in the following areas:

1. Conceptual Modeling
2. Physical Resource Program
3. Socio-cultural Resource Program
4. Biological Resources Program
5. Information Technology Program
  - Remote Sensing Evaluation & Implementation

**Conceptual Modeling:**

An Adaptive Environmental Assessment Model (conceptual model) of the Colorado River ecosystem was developed in FY 1998 and FY 1999. This conceptual model focuses on the specific management objectives and prioritized information needs articulated by the AMWG, managers and other stakeholders. The conceptual model is being used to provide critical input into the selection of parameters to be monitored and is also being used, through "policy screening" exercises to evaluate proposed management actions for their potential effect on downstream resources of concern. Since the conceptual model represents a simplification of the Colorado River ecosystem, containing only the level of complexity needed to describe the behavior being modeled, predictions resulting from the conceptual model will often be incomplete and therefore require validation through monitoring, experimentation and testing.

The benefit of the conceptual modeling approach has been its ability to organize complicated relationships into an understandable framework of study. The process of building the conceptual model has provided an opportunity to test assumptions and to develop a shared view of the resources being managed and the potential effects of management actions. The conceptual model has also provided a general framework for

understanding how the Colorado River ecosystem works, requiring the organization of many scattered pieces of information into an integrated framework.

The step down approach proposed by Davis et. al. (1994), Figure 4.1 which incorporates a conceptual model, is being used to develop the long-term monitoring and research program. The conceptual model and long-term monitoring program are being designed to account for the spatial and temporal characteristics of the Colorado River ecosystem, and to provide information, over the long-run, on the responses of the Colorado River ecosystem to alternative dam operations.

In FY 2000, the conceptual model will continue to be refined, parameter estimates will be improved, and specific additional modules will be developed. For example, integration and analysis of the PIT tag database for humpback chub may result in refined parameter estimates and changes in the structural relationships contained in the model. Similarly, completion in FY 1999 of the humpback chub diet analysis work which will provide additional information on trophic linkages within the Colorado River ecosystem will yield new information that will be incorporated into the conceptual model. In addition, GCMRC will work to develop the in-house expertise needed to continue model development and to conduct "policy screening" exercises. These activities are funded from the individual program accounts.

# STEP-DOWN PLAN FOR DEVELOPMENT OF NATURAL RESOURCES MONITORING PROGRAMS IN NATURAL AREAS

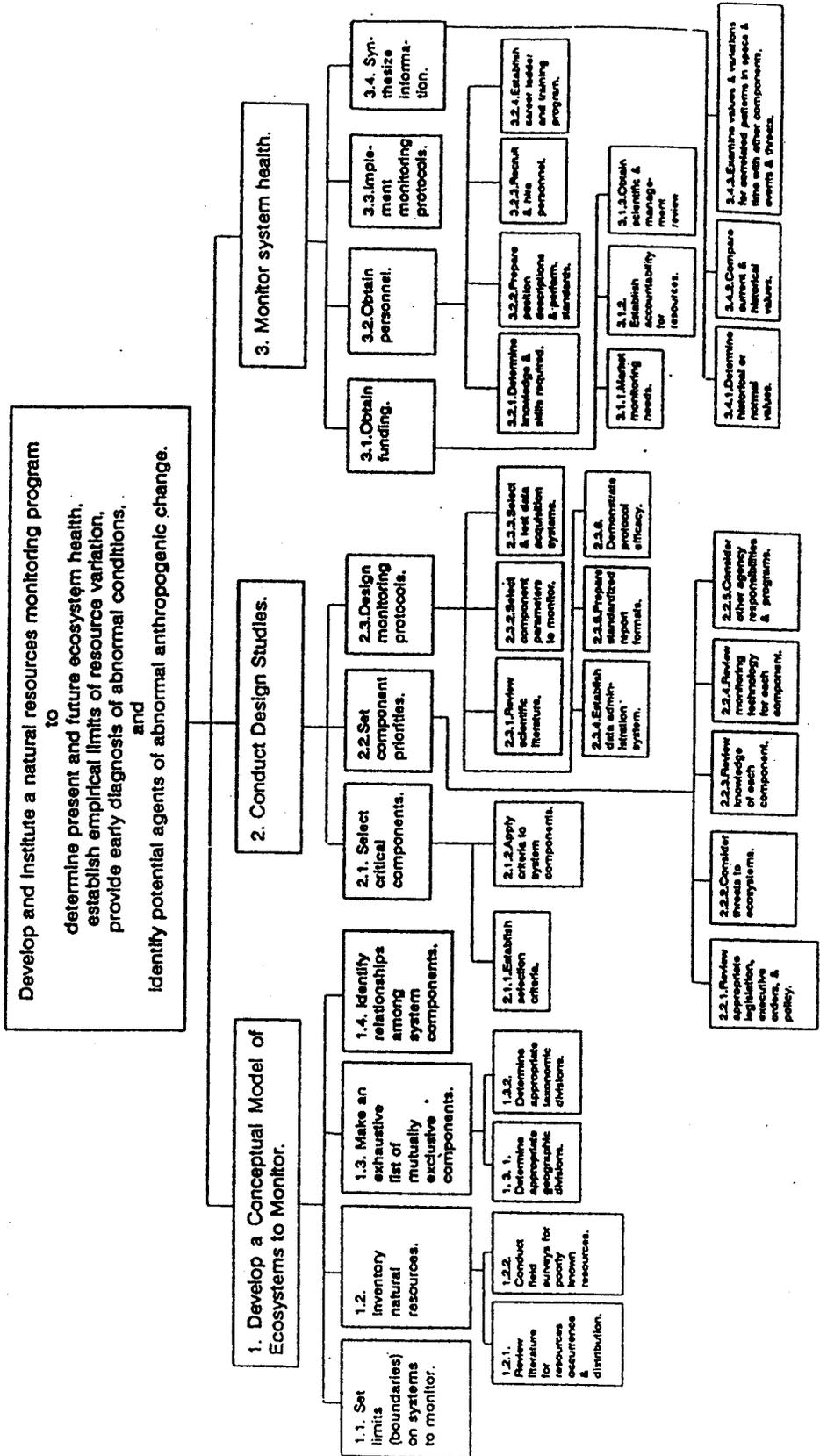


Figure 4.1 Step down Approach to the Development of a Long Term Monitoring and Research Program (Davis, 1994)

## THE PHYSICAL RESOURCES PROGRAM

### Introduction

The primary physical resources of the Colorado River ecosystem consist of sediment and streamflow. These resources interact within the geomorphic framework of an alluvial channel in some reaches, and a bedrock controlled channel in other reaches. In both of these settings, streamflow and sediment exhibit dynamic process responses to changes in operations of Glen Canyon Dam over relatively short and long time scales. Because of this fact, research and monitoring of sediment and streamflow is vital for establishing cause and effect relationships between releases from Glen Canyon Dam and changes in both sediment and related resource parameters of the ecosystem downstream. Where cause and effect can be established, physical resource trends may then be interpreted as being caused, at least partially, by dam operations. As a result, understanding how physical resources respond to the Secretary's actions under the ROD (DOI, 1996), is vital if linkages are to be understood between those actions and social, cultural and biological resources that depend on streamflow, sediment and their related geomorphic processes system-wide. Clear understanding of such relationships is required to determine whether dam operations under the ROD are effective over both short and long time scales at preserving downstream resources under law.

Streamflow in the mainstem occurs mostly from dam releases. However, dam releases interact with additional streamflow and sediment inputs from gaged and ungaged tributaries downstream, as well as reach-varied channel geomorphology, to structure aquatic and terrestrial habitats. Also influenced by these interactions are physical settings in which cultural resources are preserved and where social activities occur, such as recreation.

Water quality is another vital component of downstream ecology that relates mostly to social and biological resources, such as recreation, life histories of fish, and primary productivity. Because of the direct linkages between social and biological resources and water quality, monitoring and research of water quality will be moved into the biological resources program beginning in FY 2000. While water quality parameters, such as temperature, do alter geomorphic processes of sediment transport, these effects are not of great concern with respect to sediment budgeting at present. Additional information on

proposed water quality programming can be found in the section entitled "The Biological Resources Program."

Goals and Objectives - The primary objective for the physical resources program area during FY 2000 is to further develop long-term monitoring strategies and methods that support eventual implementation of an efficient and effective long-term monitoring program for tracking streamflow and sediment. The goal of long-term monitoring is to provide AMWG members with sufficient information to make recommendations to the Secretary on the effectiveness of his or her actions under the ROD, with respect to preservation of downstream resources. Once designed and implemented, the long-term monitoring program will provide key information on relationships between the Secretary's actions and physical resources of the ecosystem in a timely schedule that supports effective adaptive ecosystem management. Timely transfer of information on resource trends allows managers to make annual-to-semi-annual recommendations to the Secretary on critical management issues such as implementation of controlled flood flows (BHBFs), additional research and monitoring needs, or longer range strategies such as modification of the ROD to achieve the preservation of ecosystem resources.

A critical objective of the initial five-year strategic plan for the GCMRC (FY 1998 through 2002) is to develop a long-term monitoring plan for the physical resources of the Colorado River ecosystem. Decisions on how physical resources will be monitored under the long-term monitoring program, including individual protocols, sampling frequency, location and spatial scale strategy, are currently being considered through an ongoing process by the GCMRC using information from its Protocols Evaluation Program (PEP). These activities will continue during FY 2000.

Efforts aimed at achieving an effective and efficient streamflow and sediment monitoring program are being supported by at least four informational components:

- 1) *Review and Interpretation of Existing Knowledge* - about the physical resources and the processes that govern them in the Colorado River, including information found the final EIS, 1996 flood results, general science knowledge on hydrology and geomorphology of large rivers, and existing reports describing methods and results on effectiveness of currently used monitoring protocols below Glen Canyon Dam;

- 2) *Geomorphic Synthesis on the Ecosystem's Critical Reaches* – with emphasis on historical information that can better focus monitoring with respect to critical resource parameters that provide decision support on sampling strategies;
- 3) *External Peer Review (PEP)* - of existing, previously used and new alternative monitoring methodologies for physical resources;
- 4) *Conceptual Modeling Development* – including activities that focus existing knowledge about the ecosystem and allows for discussions on how to better monitor and manage the downstream resources of interest.

During FYs 1998 and 1999, the GCMRC established cooperative agreements with Federal, State, Native American Tribes and private institutions to monitor and research downstream resources. One Federal (USGS) and two academic institutions (USU and NAU) were given awards to monitor and conduct research on physical resources. Cooperation from these currently funded technical experts also supports the PEP process for evaluating the effectiveness of existing and alternative monitoring protocols for all resources below Glen Canyon Dam. The PEP, is described in a draft prospectus entitled "Draft Prospectus for Evaluating GCMRC Monitoring Protocols for the Colorado River Ecosystem," (Appendix C).

The PEP process for evaluating current and new alternative protocols in the physical resources area is scheduled for completion by the end of FY 2002, when the long-term monitoring program should be fully implemented. The first of two PEP review workshops on physical resource monitoring was completed in August 1998, and an interim review report has been submitted to the GCMRC and distributed to the Glen Canyon Adaptive Management Group. Ongoing physical resource PEP activities in FYs 1999 and 2000 are aimed at evaluating suggestions and recommendations from the review panel's interim report on how existing monitoring might be improved with respect to tracking the ecosystem's sediment budget. Where appropriate, new technologies and protocols are scheduled for field testing and assessment, such as multi-beam hydrographic survey applications for bathymetry, and remotely sensed methods for conducting change-detection analyses. These evaluations are currently being conducted in cooperation with GCMRC science cooperators, and remote-sensing contractors, and may be pursued further through competitive RFPs in FY 2000.

Because most of the management objectives for physical resources relate to sediment-based resources, the focus of long-term monitoring activities is on a robust strategy for tracking fine sediments; their inputs, storage throughout the ecosystem, and export to upper Lake Mead. Coarse sediment budgeting is also of interest because cobbles and boulders structure the basic geomorphic units of the river ecosystem, its cobble bars and debris-fan/eddy complexes where fine sediment and related resources reside. Time scales over which coarse sediments must be tracked are longer than fine sediments because the residence time of boulders is potentially much longer than for sand. However, results of the 1996 experimental flood (BHBF-Test), showed that additions of boulders to the main channel from tributary debris flows are also quickly transported over short distances when dam releases are rapidly increased above powerplant capacity. Long-term implications for aggradation of pools and runs by immobile boulders on the ecosystem are presently unknown.

To support monitoring activities, and to provide timely estimates about how the system-wide sediment budget evolves over various time scales, ongoing development of predictive, numerical modeling capabilities will also be pursued during design of the long-term monitoring program, beginning in FY 2001. Special emphasis during FY 2000 will be placed on verification and calibration of physically-based flow and sediment transport models recently designed for the Paria and Little Colorado Rivers by the U.S. Geological Survey, Water Resources Division; including both operations and National Research Program personnel. These efforts will continue during FY 2000 under competitively procured agreements with USGS scientists established in FY 1998.

As part of an effort to better understand the geomorphic history of lower Glen Canyon and Marble Canyon (river miles -15 to 0 [minus fifteen to zero]), synthesis efforts started in FY 1998, will be extended upstream into the most critical reach with respect to sediment resources (Glen Canyon), in FY 2000. This work will be highlighted by additional time series mapping of sandbars to identify changes in sand storage along shorelines and in the mainstem channel within GIS study site 14. This effort will build on the synthesis work presently being conducted in FY 1999 by Utah State University's Department of Geography. Synthesis efforts for geomorphology and hydrology are to be completed at the end of FY 2000.

Current State of Knowledge - Existing information indicates that fine sediment substrates support social and natural resources of the ecosystem, while coarse sediments structure the geomorphology of the physical habitats of the ecosystem located in numerous debris-fan/eddy complexes (DOI, 1995). Sustainability of fine sediment resources depends on long-term steady-state or increasing trends in the sand budget of inputs and storage that balance with net export; conditions that are controlled by both long-term average supply in combination with river geomorphology and flood frequency (DOI, 1995). The degree to which sand can be stored in the ecosystem below the dam also varies by reach depending on flows and channel geomorphology of pools above rapids and spacing and geometry of debris-fan/eddy complexes (Schmidt and Rubin, 1995; Melis, 1997). Generally, the greatest abundance of sand in the system is found downstream of the Little Colorado River, at river mile 61. As sediment inputs decrease upstream toward the location of the dam, the probability for a long-term sediment deficit increases under any given operational regime. From a sediment budget perspective, the reach between Glen Canyon Dam and Lees Ferry (river miles -15 to 0) is therefore the most critical. The second most critical reach occurs between Lees Ferry and the confluence of the Little Colorado River (river mile 61), the reach identified as Marble Canyon.

Recent results of monitoring and research suggest that there is only a limited range of sand-storage potential within the mainstem channel of the Marble Canyon reach (D. Topping, USGS, and T. Randle, Bureau of Reclamation, personal communication). Despite the high potential for occasional large sand inputs from the Paria River (river mile 1), limited storage space in the main channel may therefore limit the residence time of sand introduced into Marble Canyon, a critical reach with respect to sand supply and related resources. While sand storage potential may be somewhat greater in the Glen Canyon reach, sand inputs there are relatively minimal compared to the sand contributions of the Paria River to the Marble Canyon reach.

The underlying assumption of the *Operations of Glen Canyon Dam - Final EIS* (DOI, 1995), was that channel storage and residence time for sand in critical reaches was sufficient to restore terrestrial sand deposits through occasional controlled floods. If the potential for sand storage is relatively small relative average annual inputs, and the residence time in critical reaches is relatively short under ROD induced hydrology, then monitoring of sand

inputs, changes in channel storage and export rates will be of even more importance with respect to ecosystem preservation strategies.

The physical resources program for FY 2000 aims to improve the GCMRC's ability to track sediment budgets in meaningful and efficient way within the upstream critical reaches. This can best be accomplished through two methods: 1) daily suspended-sediment measurements at the Grand Canyon stream gage, or 2) through high-resolution bed-sediment classification and topographic profiling, obtained through such strategies as side-scan sonar and multi-beam hydrography, as well as testing and implementation of bed grain-size sampling, and bed elevation change detection procedures. To track bed elevation changes that result from tributary inputs of sand, new, more rigorous methods for three-dimensional bathymetry shall be field tested and assessed during FY 2000 for consideration for implementation in the long-term monitoring program. The alternative approach of collecting additional empirical data on daily streamflow and sediment transport requires re-establishment of protocols previously used by USGS before 1979, but may prove to be more accurate and less intrusive and costly compared with bathymetric field measurements made in critical reaches on perhaps a quarterly basis. One of the objectives of the FY 2000 program will be to determine which of these two approaches is best for determining long-term trends in the fine sediment budget of the ecosystem.

Relationship to Conceptual Model - Preliminary development of the physical sub-model of the conceptual ecosystem model utilized many previously developed modeling and database resources derived from GCES phases I and II, as well as long-term monitoring and research information developed by the U.S. Geological Survey and the Bureau of Reclamation. The current concern of physical scientists about the physical sub-model lies in the knowledge that many dynamic sediment and flow processes of the river occur on time scales of hours to days, while the conceptual model simulates physical changes in the ecosystem on a monthly time step. In addition, GCMRC cooperating physical scientists concluded after the first modeling workshop that evolution of site-specific river features such as return-current channel habitats, termed backwaters, and recreational camping sand bars could not presently be adequately simulated over monthly time steps, or in the absence of high-resolution channel topography. However, there was agreement that general trends in the conditions of such resources might be extrapolated from annual trends in reach-specific

and system-wide sediment budget trends. In other words, that such sediment resources features were more likely to be sustained under conditions of sediment surpluses.

One outcome from the effort to develop the physical sub-model of the conceptual model has been an increased focus on the present ability of scientists and decision makers to track changes in the fine sediment budget - primarily sand. Additional monitoring efforts and research-derived understanding will be needed in the future to track the evolution of fine sediment inputs as they enter and evolve during transported within the ecosystem. In FY 2000, GCMRC plans consultations with the TWG, National Park Service and USGS to determine the scientific and logistical feasibility of reinitiating daily suspended sediment measurements at the Grand Canyon stream gage located near Phantom Ranch. This will be explored as the preferred approach to tracking long-term trends in sand supplies within the most critical reaches of the ecosystem.

Presently, efforts to account for exchanges of sand between main channel storage areas (pools) and storage sites on shorelines and within eddies is based on empirical data in the physical sub-model, rather than on process derived rates that can be simulated. A major contribution to the physical resources program has been identification of these types of gaps in process knowledge that limit our current abilities to model sediment dynamics that have been documented to influence ecosystem resources related to sand bars.

Efforts to design a long-term monitoring program during FY 2000 will focus on developing protocols that allow sediment evolution in the channel bottom to be measured, quantified and reported in a timely manner, such as fine sediment volume, grain size and bed coverage. Also, there was agreement and recognition that the current paucity of 3-D channel topography greatly limits the potential for developing accurate predictions for the 2-D evolution of bar morphologies, such as backwaters and campable sandbar areas, in reaches and at specific sites of critical concern to native fishes. As a result, efforts will be made in FY 2000 to expand coverage of high-resolution channel topography within critical reaches between Glen Canyon Dam and the Grand Canyon streamgage (river mile 88), and in index sites, such as the existing GIS sites below that point that were established by GCES during phase II development. Such mapping coverage will allow for potential 2-D modeling of sandbars in critical reaches.

Main Focus of Resource Concerns - The primary resource of concern in the physical program during FY 2000 will be research and monitoring of sediment and streamflow relationships that occur in the major gaged tributaries, the Paria and Little Colorado Rivers, and bed evolution of coarse and fine sediments in the mainstem channel that result from the Secretary's actions under the ROD. These topics will be related to the overall goal of better quantification of the sediment budget of the main channel between Glen Canyon Dam and the Grand Canyon streamgage, located at river mile 87. The degree that these monitoring and research efforts provide new knowledge about the sediment budget will depend on the magnitude of new sediment inputs from tributaries during FY 2000, and whether or not additional controlled high releases from the dam occur. In addition, the results of research efforts undertaken in FY 1998 and 1999 related to synthesis of historical information, and estimation of ungaged tributary sediment inputs will influence the progress toward integrating information about the physical resources of the ecosystem.

Combining physical-resource synthesis information with new estimates on the inputs of all tributary sediments, information on suspended-load and channel-bed evolution, and shoreline, eddy and main-channel pool sand storage in FY 2000 will be the a major step forward in structuring a total sediment budget. Information on shoreline storage potential is critical data when deciding on implementation controlled flood flows (BHBFs) intended to rebuild beaches and conserve sand. The integration process (structuring and design of the sediment budget protocol) will also be a major step in forming better linkages between streamflow and sediment and non-physical resources. In FY 2000, additional synthesis of historical geomorphic data for the Glen Canyon reach will be accomplished by mapping and interpreting historical changes in sand bar characteristics and distributions developed from existing data, such as aerial and oblique photography, survey data, etc.

### **Information Needs**

A broad array of information needs are specified by stakeholders (Appendix A), on the basis of management objectives adopted by the Glen Canyon Dam Adaptive Management Program. As previously stated, most of the management objectives under physical resources are related to preservation of sediment in key settings throughout the main channel, such as maintenance of terrestrial sandbars useful as recreational sites and habitats. Water quality

information needs are also considered to be physical in scope, but monitoring and research activities related to water quality in FY 2000 and beyond will be achieved through the biological resources program. This change will better facilitate integration between water quality parameters and biological processes, such as temperature and productivity, etc.

A key element of sand storage along the main channel lies in shoreline deposits, such as separation, reattachment and channel-margin bars (INs 1.1-1.5). In FY 2000, emphasis will be placed on how to better monitor changes in shoreline storage of sand within index sites that represent reach-average geomorphic characteristics. Effectiveness of BHBFs in building sandbars at a given stage will depend on the volume of open storage space available along shorelines. This type of information, combined with antecedent sediment conditions of the mainstem channel, will allow scientists and managers to determine optimal duration and magnitude for BHBFs. This effort will also focus on critical upstream reaches. While there is an obvious linkage between terrestrial sand bars and recreational use in the ecosystem, information on campsite areas will be obtained through the socio-cultural program area in FY 2000 and beyond.

### **Strategic Objectives**

In addition, to individual information needs derived from stakeholder management objectives, larger scale monitoring and research objectives will be pursued that relate to physical and other resource areas during FY 2000. The first of these objectives, is capture of additional main channel geometry (topography) up to the top of the pre-dam flood elevation between Glen Canyon Dam and Pipe Creek, located at river mile 88. In this reach, shoreline topography between the elevation of the 5,000 cfs stage and the top of the pre-dam flood zone currently exists within previously established GIS reaches. To achieve additional channel coverage in the critical reaches of Glen, Marble and eastern Grand Canyons, additional shoreline topography will need to be obtained between existing GIS study sites. The second strategic objective, is to capture channel geometry data below the elevation of the 5,000 cfs stage within existing GIS reaches below Pipe Creek.

Once these main channel topographic data are obtained, they will allow several other strategic objectives to be accomplished in out years. These include, but are not limited to: predictive stage/discharge modeling at all locations where topographic coverage exists, 2-3

dimensional hydrodynamic sediment and flow modeling of sand bars features in specific geomorphic setting, such as campsites and return-current channel backwaters within debris-fan/eddy complexes, and sand deposits in the mouths of arroyos that drain pre-dam terraces where cultural resources are preserved. While these predictive modeling capabilities will take additional efforts to develop, the basic topographic coverage of the critical upstream reaches and downstream index reaches will greatly advance the GCMRC's ability to development of such models.

In terms of sediment resources, topographic coverage of the main channel supports current and proposed new long-term monitoring technologies intended as change-detection methodologies for:

- 1) Quantifying volume change in subaqueous channel-stored sand within pools and eddies,
- 2) Measuring grain-size evolution of the bed where fine sediment is stored,
- 3) Detecting three-dimensional changes in main channel bed coverage by sand and coarser sediment (bed classification),
- 4) Detecting volume and grain-size distribution changes in deposits of subaerial sand stored along shorelines (terrestrial sand bars), and
- 5) Providing 3-dimensional channel geometry of the mainstem channel needed to accomplish 2-dimensional hydrodynamic flow and sediment modeling of sandbars and related habitats.

Previous research indicates that all of these components are required to accurately evaluate the status of the system's sediment budget. Changes in mainstem channel sand storage may be mostly inferred from daily suspended sediment sampling at the Grand Canyon stream gage, but some additional bed sampling will be required at key locations throughout critical reaches upstream. Existing channel geometry (reach-averaged hydraulic geometry) combined with the above sediment parameters is required to develop predictive modeling capabilities for the main channel, such as a 1-dimensional sand transport that might be used to route sand from upstream to downstream reaches and estimate sand export from the ecosystem. In addition, the antecedent status of these combined sediment elements, especially channel-bed grain-size distribution greatly influences the effectiveness and design criteria for controlled high flows from Glen Canyon Dam intended to replenish sediment

related resources. These data will greatly support decisions on BHBF duration and magnitudes for optimal sediment and bar-building responses.

Finally, the topographic coverage of the main channel will greatly advance development of an integrated GIS database where all data from individual discipline areas can be geo-referenced in four dimensions; an initial necessity if data sets are to eventually be integrated and their ecosystem linkages interpreted (Wirth et al., 1993; Pucherelli et al., 1995).

### **FY 2000 PHYSICAL RESOURCES PROGRAM**

The FY 2000 program for physical resources at a level of \$700,000, will be divided into six program components, and will be implemented through a mixture of new competitive awards combined with some modifications of existing FY 1998-99 awards for monitoring. New research efforts will be awarded on the basis of RFPs released in spring 1999.

#### **Monitoring Main Channel and Tributaries**

Monitoring main channel and tributaries will be continued through a modification of existing the USGS interagency agreement (Anderson et al.) to achieve basic monitoring of sediment and flow in the mainstem and gaged tributaries meant to support sediment budgeting in critical reaches. Until more specific monitoring protocols are designed and reviewed that will support sediment budgeting, basic protocols for collecting streamflow and sediment data will be continued, including mainstem streamflow unit data at Lees Ferry (sediment only during flood flows from Glen Canyon Dam), above the confluence of the Little Colorado River (season sediment sampling), and Grand Canyon near Phantom Ranch (move toward resumption of daily or weekly sediment sampling). Streamflow and sediment data will also continue to be collected for the Paria River gage, and the Little Colorado River gage near Cameron.

#### **Design of Long-Term Monitoring Program**

Continuation from FY 1998-99 of ongoing planning for a long-term monitoring program for physical resources (streamflow and sediment), including continued protocols

evaluation, paired field testing, monitoring design, capital investments in new technologies and equipment, and initial implementation of some monitoring elements,

### **Advanced Conceptual Model Development**

Modification of existing, or design of alternative physical sub-model to simulate long-term geomorphic changes in main channel geometry of pools, rapids and related features that relate to system-wide storage of fine sediment, and long-term changes in habitat type and availability.

### **Verification of Paria and Little Colorado River Sediment and Flow Models**

Continued testing of sediment load estimates calculated from flow hydrographs in key sand contributing tributaries that input to critical reaches. Refinement and calibration of these two models allows for rapid estimation of sand and silt/clay loads input to the mainstem channel of the ecosystem within days to weeks of extreme tributary flood events that replenish the sediment supplies of critical reaches. Prior to development of such models, sediment loads were not reported until well after the end of each water year. Timely model estimates of sand inputs are useful to scientists and managers that need to make annual decisions on implementation of BHBFs, including details of duration and optimal magnitude. This work will be carried out for an additional year through modification of an existing agreement with USGS (the agency developing the physically based flow and sediment models).

### **Extended Geomorphic and Hydrologic Synthesis**

This project will extend synthesis by accomplishing additional historical sandbar mapping and those data to historically measured changes in mainstem channel storage conditions between Glen Canyon Dam and the confluence of the Paria River. This work will build on the FY 1998-99 synthesis project results conducted by Utah State University, and will move the focus of synthesis efforts upstream into the most critical reach with respect to sediment supply and effects of dam operations. This work will be achieved through a modification of the existing cooperative agreement.

### **Change Detection of Debris Fans and Rapids**

This work will consist of an ongoing annual assessment of significant changes that may occur to the mainstem channel geomorphology that result from periodic tributary streamfloods and debris flows. This effort will likely occur as an in-house project, but may also be conducted through an RFP process, depending on the perceived level of need, and whether or not a BHBF is implemented in FY 1999. In the event that a BHBF occurs, additional research on debris-fan reworking and coarse bedload movement may also be carried out through USGS as a modification of the current agreement to assess ungaged tributary inputs and impacts to mainstem channel resources.

It is also anticipated that the strategic goals of the physical program area will be partially accomplished, especially those related to reach main channel geometry, through testing and the development of products resulting from the "Remote Sensing Technologies" activities described within the Information Technology Program.

### **Implementing the FY 2000 Program and Beyond**

The mixed strategy for achieving the goals of the FY 2000 plan a combination of competitive solicitations, procurements from existing Federal contracts for services and products, and a variety of modifications to existing cooperative and interagency agreements, reflects mainly a need for additional time to complete the Protocols Evaluation Program in the physical resources area. This vital information is needed before a long-term monitoring plan for sediment and streamflow can be drafted and implemented. Future long-term monitoring of physical resources will be procured competitively once the monitoring plan is completed. Once the long-term monitoring plan is ready for implementation, monitoring awards will be made with options for annual modifications for up to five-year cycles. During FY 2000, all GCMRC cooperators will continue to work closely with GCMRC staff in obtaining monitoring data that are collected under specific guidelines and standards that are enforced by program management and outlined in the long-term monitoring plan and future RFPs.

In some cases, beginning in FY 2000, the frequency of monitoring of sediment and flow related resources will be altered from annual measurements to biennial, semiannual, quarterly, monthly, weekly, daily or even hourly time scales depending on protocols used,

budget limitation, or how the data are used to support predictive modeling and decision making procedures. For instance, between dam-induced high flow events, sand storage along shorelines has followed predictable patterns, on the basis of repeated measurements over the last decade. As a result, measurement of shoreline storage will be recorded in annual aerial overflights, and perhaps measured in the field on a biennial schedule, or in response to dam-controlled or large, unregulated tributary floods. In the event that a BHBF occurs in spring 1999, several existing physical science agreements may be modified to extend through FY 2000 to ensure that unique monitoring and research information is obtained and reported to stakeholders.

Existing time series on volume-depletion rates for bars between bar rebuilding events up to 45,000 cfs can provide estimates for the status of system-wide shoreline storage conditions in years when only area measurements may be available from aerial photographs. Additional estimates of volume changes in shoreline storage zones may also be made from stereo-photogrammetric analyses, presently being considered under PEP efforts. Alternatively, some volume-change measurements for shoreline storage might be made on weekly to hourly time scales for long-term and test release purposes using oblique, stereo-photogrammetric applications and remote cameras. Issues of monitoring frequency and sampling strategy system-wide will be described in the long-term monitoring plan prepared by the GCMRC. A draft of the Long-Term Monitoring Plan is scheduled for by the end of FY 2000.

#### **GCMRC Support of TWG Requests**

In FY 2000, the GCMRC anticipates that additional requests for information assessments, similar to the "Alternative BHBF, Load-Following" request made by the TWG in FY 1998, will arise. Such special requests that require significant amounts of staff time, or outside expertise, will require additional funds to complete. Such funds may be used to gather data, conduct analyses, support convening of a group of scientists to provide analysis of a given issue, or to obtain expertise not contained within the GCMRC staff or contractors (including flood-flow experimental design). The GCMRC intends to create a pool of funding that can be used by staff in support of such unanticipated requests during the course of the

fiscal year. Such funds may be carried over from one year to the next, depending on need and availability.

**Contribution of the FY 2000 Program to the Strategic Plan**

The physical resources program for FY 2000 is linked to stakeholder objectives and information needs; especially where it supports development of the long-term monitoring plan, and specific protocols that support tracking of the ecosystem's fine-sediment budget. As with the other program areas, information gained from proposed monitoring, protocols evaluation and synthesis will support further development of the conceptual model; a process that will foster better integration between resource areas, and understanding of physical and non-physical processes that structure the Colorado River ecosystem. Such information is vital for successful ecosystem assessment decision making based on science; the foundation of adaptive management practices.

**FY 2000 Physical Sciences Program Budgets**

**Monitoring Research**

A.	Conceptual Modeling	\$ -0-	\$50,000
B.	Extended Synthesis	\$ -0-	\$50,000
C.	Mainstem/Tributary Streamflow/Sediment	\$320,000	\$ -0-
D.	Tributary Model Verification	\$20,000	\$ -0-
E.	Protocols Evaluation Review, Field Testing and Capital Investment	\$ -0-	\$250,000
F.	Debris Fans and Rapids Change Detection	<u>\$10,000</u>	<u>\$ -0-</u>
	<b>Subtotal</b>	<b>\$350,000</b>	<b>\$350,000</b>

**TOTAL Monitoring & Research: \$700,000**

## THE SOCIO-CULTURAL RESOURCES PROGRAM

The socio-cultural resources program incorporates the cultural resource program and the socio-economic program into one resource program area. These resource areas have been combined to provide a more comprehensive treatment of resources that span prehistoric to current times and are meaningful to a broad group of stakeholders. This section describes the FY 2000 activities planned for cultural resources, such as prehistoric and historic archaeological resources and traditional tribal resources; and recreational resources. Economic and hydropower issues are also included in this section.

### FY 2000 PROGRAM ACTIVITIES

#### A. Cultural Resources: Prehistoric and Historic Archaeological Resources, Traditional Tribal Resources

The activities proposed for FY 2000 for the prehistoric and historic archaeological resources and traditional tribal resources address the Management Objectives and Information Needs developed by AMP stakeholders. The Management Objectives are:

1. Conserve *in situ* all the downstream cultural resources and take into account Native American cultural resource concerns in the Colorado River ecosystem.
2. If *in situ* conservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with a scientific approach.
3. Protect and maintain physical access to and use of traditional cultural properties and other cultural resources where such access and use may be impacted by dam operations.
4. Maintain, and integrate all appropriate cultural data recovered from monitoring, remedial and mitigative actions and incorporate these data into evolving research designs and mitigation strategies for understanding human occupation and use of the Colorado River ecosystem.

Information Needs were also developed and prioritized by the AMP stakeholders to assist in meeting the management objectives. The Information Needs are:

- 1.1. Develop data and monitoring systems to assess impacts to cultural sites potentially impacted by the operations of Glen Canyon Dam.
- 1.2. Develop data systems to assess risk of damage and loss from varying flow regimes
- 1.3. Characterize all cultural resource sites as to the specific associated management/research needs, i.e., preservation, stabilization, documentation etc. under differing flow regimes.
- 1.4. Preservation, stabilization and/or documentation of cultural resources as impacted by sediment resources associated with differing flow regimes.
- 1.5. Preservation, stabilization of flood terraces holding cultural resources.
- 1.6. Evaluate flood terrace stability necessary to maintain cultural resources and terraces at pre-dam condition.
- 1.7. Evaluate methodology for correlating recreational site use and cultural resource impacts.
  - 2.1. Characterize through scientific study and data development all assumed historical and current values, including scientific values, of resources to tribal nations and to the general public
  - 2.2. Develop research designs and costs associated with data recovery.
  - 3.1. Characterize historic and current traditional cultural associations of all sites associated with impacts of dam operating criteria.
  - 4.1. Develop evolving research designs and/or other methods including synthesis of existing available data and GIS for understanding human occupation and use.

Some of these information needs will be satisfied during portions of this plan while others will continue to be on-going. The FY 2000 activities are organized around these information needs.

**Information Need 1.1: Develop data and monitoring systems to assess impacts.**

**Project #1: Photographic Monitoring of Terraces within the Glen Canyon Reach containing cultural deposits** is expected to cost approximately \$35,000. This project will continue existing monitoring of these sites and synthesize the existing data to answer research questions related to the impacts of varying flow stages and operational ramping rates on the terraces and the associated cultural deposits. Study results that suggest mitigative

activities would be referred to the BOR PA program. This project also addresses Information Needs 1.4, 1.5, 1.6 and 2.1

**Project #2: Investigation of Isolated Occurrences (IOs)** is expected to cost about \$25,000 and extend for about one year. Data currently being synthesized under an existing project will be evaluated and assessed to determine if IO data represent the last remains of site materials, the first exposures of previously unknown buried sites, or artifacts representing individual episodes of use and occupation within the river corridor. Collectively, IOs yield information about past adaptations and how people interacted with their cultural landscapes. Neither IO distribution nor attribute data are being evaluated under existing programs. Based on these assessments, additional investigations may be suggested.

**Project #3: Tribal monitoring and assessment projects that assess traditional resources such as ethnobotanical resources where assessments are not included within other complementary programs.** Three projects have been submitted to the GCMRC that address evaluation of tribal traditional resources and total about \$125,000. These projects include 1) a project for \$80,000 that includes the participation of three tribal groups to assess and interpret traditional resources relative to dam operations and disseminate information using CD ROM technology; 2) a tribal project of \$25,000 to disseminate tribal ethnobotanical data through workshops for tribal members and other members of the public, and 3) a tribal project for ethnobotanical resource assessments and tribal field training for \$20,000. These projects are currently being revised to address review comments. These projects also address Information Needs 2.1 and 3.1

**Project #4: Continued Application of geomorphic hypothesis testing** is expected to cost approximately \$35,000 and be conducted for a period of one year. Work linking certain geomorphic process and archaeological site erosion is currently being evaluated and these data will be available in FY 2000. Refinements to the hypothesis, investigation of additional and/or unanswered questions, further field testing, and possible application to other areas will occur under this project.

**Project #5: Protocol Assessments** is estimated to cost \$15,000. The project costs for protocol assessments and related project evaluations represent the cultural contribution to the overall costs for protocol assessments. This project was initiated in FY 98 and is expected to

continue through FY 2000/2001 for the socio-cultural program. Protocol cost estimates do not include costs associated with protocol evaluations related to the BOR PA program.

**Project #6: Unanticipated Information Requests** are estimated at \$5,000 for FY2000. These requests include impromptu studies and information research at the request of the TWG or AMWG that cannot be accomplished using existing staff resources. If remaining funds exist at the end of FY2000, they will be obligated for FY2001.

**Information Need 1.2: Develop data systems to assess risk of damage at critical threshold levels, and loss from varying flow regimes.**

**Project #1: Investigation of remaining study questions related to the flow and deposition model, or the model application to other locations with cultural resources** is expected to cost about \$25,000 and be conducted over a one year period. This information would help to determine inundation frequency as well as critical threshold levels for triggering recommendations for remedial responses. The ongoing mainstem flow and deposition project is testing this model in one area of the river corridor where archaeological resources have been identified and these data will be available in FY 2000. Some research questions may require additional study. Also if the modeling work proves useful in this test area, the model can be applied to other areas and other types of important resources that appear to be at risk. In addition, flow regimes and deposition at various stages can be quantitatively modeled for previously unevaluated resources, such as traditional tribal resource locations.

**Information Need 4.1: Develop evolving research designs and or other methods including synthesis for existing available data and GIS for understanding human occupation and use.**

**Project #1: Continuation of the Development of Tribal Technology and Procedures for Dissemination and Access to GCMRC Data** is expected to cost \$35,000 and is a continuation of project efforts that were initiated and approved in FY 99. These efforts include continuing work with Tribal stakeholders to develop technological capabilities, and educational expertise to allow these stakeholders to access and interpret information in a timely cost efficient manner. Project elements include costs associated with working groups that assist the GCMRC, educational/information dissemination, assessment

of technological capabilities, and co-funding opportunities for continued implementation in future years.

**Information Need 2.2 : Develop research designs and costs associated with data recovery.** This information need is not addressed in this plan. At the present time, issues of data recovery at cultural sites are being designed under the Programmatic Agreement Program under the direction of Reclamation. No activities are planned in this area under the GCMRC cultural program. Information Need 1.7 (Evaluate methodology of correlating recreational site use and cultural resource impacts) is also not addressed in this plan for FY2000 because it received a low priority for scheduling by the TWG and the AMWG as of their July 1998 meeting.

## **B. Recreational Resources**

Management objectives for the recreational resources were developed by AMP stakeholders with the goal to provide quality recreation experiences that do not adversely affect natural or cultural resources within the Colorado River ecosystem. Recreation resources include sport fishing, white water rafting, boating, hiking, sightseeing, photography, and hunting.

The AMP management objectives include:

1. Provide quality recreation experiences consistent with other resource objectives;
2. Maintain flows (under approved operating criteria) and sediment processes that create an adequate quantity, distribution and variety of beaches for camping, as long as such flows are consistent with management of natural recreation and cultural resource values (other natural resource values);
3. Maintain flows (under approved operating criteria) that minimize impacts to navigability by authorized water craft and for boaters, waders, and campers in the riverine corridor;
4. Maintain flows (under approved operating criteria) and habitat suitable for quality cold water fishery opportunities in Glen Canyon;
5. Maintain flows (under approved operating criteria) and habitat suitable for waterfowl sport hunting and wildlife viewing opportunities in Glen Canyon.

The AMP Information Needs are:

- 1.1 Determine criteria and aspects that are important to, or detract from the recreational experience;
- 1.2 Determine the impacts of scientific study on recreational experience
- 1.3 Characterize procedures to mitigate those aspects of flows that detract from quality recreational experiences
- 1.4 Determine angler satisfaction, use and harvest
- 1.5 Determine potential impacts of increased heavy metals on sport fishing.
- 2.1 Determine adequate beach quantity, quality, distribution, character and structure for camping throughout the system;
- 2.2 Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resources, quality, character and structure.
- 2.3 Develop methodology to evaluate distribution, quantity and quality changes in all campable beaches through time.
- 2.4 Develop systems models to predict flow regimes (under approved operating criteria for building and maintaining beaches.
- 3.1 Determine if operating criteria maintains safe and adequate power craft navigability in Glen Canyon and upper Lake Mead;
- 3.2 Evaluate effects of operating criteria on recreation safety.
- 3.3 Determine if operating criteria maintains whitewater raft navigation in Grand Canyon
- 3.4 Define ecosystem and other resource impacts of flow regimes (under approved operating criteria) required to maintain navigation.
- 3.5 Develop methodology to evaluate potential conflicts of day rafting and other resources ( e.g., bank degradation, sport fishing, bird watching, etc.)
- 4.1 Determine flow regimes ( under approved operating criteria) necessary to maintain fish populations of 100,000 adult Trout (age class II plus);
- 5.1 Define pattern of waterfowl hunting use and satisfaction and other wildlife use and conflicts to other uses.

**Information Need 1.1: Determine criteria and aspects that are important to, or detract from the recreational experience.**

**Project #1: Conduct a Recreational user preferences and attitudes assessment.**

This project is ongoing and will be completed early in FY 2000. This project may also address Information Need 1.3.

**Project #2: Monitor trout anglers' use and satisfaction through creel survey and cooperative monitoring program with fishing guides and Trout Unlimited.** This program will be developed through a proposed cooperative program involving fishing guides, Trout Unlimited, Arizona Game and Fish Department, and GCMRC staff to compile and assess existing data and methodology. The goal is to establish a minimal cost but more robust monitoring of user sport fishing satisfaction in the Lees Ferry Reach. It is projected that approximately \$5,000 in total costs will be allocated to this project. The results of this study may suggest additional work in FY2001 with possible co-funding opportunities with State and Federal entities. This project will also address Information Need 1.4.

**Information Need 2.1: Determine adequate beach quantity, quality, distribution, character and structure for camping throughout the system**

**Project #1: Use past monitoring, research and cooperative studies to develop synthesis of campsite beach changes over 30 years under ROD Dam Operations.** This project will be developed through a one year RFP at a cost of \$25,000. This project will be developed with the following objectives: 1) Using aerial photography and FY 99 GCMRC study of beach changes define the changes that have occurred in beaches from the 1950s to present time in Glen Canyon and above and below LCR by area; 2) Using past and current research studies, identify and associate these change factors that are related to dam operations; and 3) Develop predicting methodologies to forecast possible future changes in beaches under ROD dam operations.

**Information Need 2.2: Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resources, quality, character and structure.**

**Project #1: Evaluate effectiveness of new monitoring protocols for Assessing Campsite Changes under Differing Dam Operations.** This project was initiated under a physical science RFP in FY 98 and has an FY 99 cost of \$20,000. In FY 2000, protocol assessments will cost \$20,000. Project objectives include a assessment of hydrography, videography and other potential cost effective protocols for monitoring beach changes in Glen and Grand Canyons through time under differing dam operations. This project partially addresses Information Need 2.3 and may be useful in addressing 3.5.

**Project #2: Monitor beach changes through cooperative programs with boating guides.** Boating guides are the primary contact for boater recreationists using the Colorado River of Grand Canyon. A pilot program has been initiated to monitor qualitative beach changes using photographs taken by boating guides in Grand Canyon at differing flow regimes. Monitoring of the Glen Canyon reach will be initiated using fishing guides This project that is expected to cost about \$5,000.

**Information Need 3.1: Determine if operating criteria maintains safe and adequate power craft navigability in Glen Canyon and upper Lake Mead** Information is currently being collected and evaluated in a cooperative effort by the National Park Service using accident data. No GCMRC project is currently proposed in this area. As information becomes available future studies may be suggested. This project may also address Information Needs 3.2, 3.3, and 3.4.

**Information Need 4.1: Determine flow regimes necessary to maintain fish populations of 100,000 adult Trout (age class II plus)**

Investigations into fish fecundity are currently being conducted in the Biological Resources Program area.

**Information Need 5.1: Define pattern of waterfowl and other wildlife use and conflicts to other uses** Information from on-going projects addressing recreational issues will be assembled to evaluate future projects in this area. However, no projects are proposed in FY 2000.

Information Need 1.2 is not addressed in this plan but will be scheduled in subsequent work plans. Information Need 2.4 is currently being addressed within the Physical Resources Program and in an on-going project modeling deposition at cultural site locations.

## **C. Economic Market Activities**

### **C. i. Hydropower Supply**

Hydropower supply is an integral part of the economy of the region. It is a product of the Glen Canyon Power plant electrical generation that contributes significant power to rural electrical associations, public municipalities, irrigation districts and Federal and State facilities in the Southwestern and Rocky Mountain areas of the United States. Changes in power operations resulting from changes in annual dam operations would affect the power supply and its costs to power users. The stakeholders' goal within this program is to maximize the value of long term power and energy generation within the criteria and operating plans established by the Secretary under Section 1804 of the 1992 GCPA. The AMP management objectives within this program are to determine the impact of changes in dam operations on hydropower outputs and the concomitant power marketing and economics of the region, a concern of those agencies and organizations associated with hydropower production.

#### The AMP Information Needs for hydropower include:

1. Continue to monitor the amount of revenues collected from the generation of electrical power at the Glen Canyon Power plant;
2. Continue to account for the financial/economic cost of the operational changes at Glen Canyon Dam due to the ROD including rate impacts to Colorado River Storage Project (CRSP) long-term firm electrical customers;
3. Calculate the financial costs of research flows so that these costs can be declared "non-reimbursable" (as defined by Section 1804 of the Grand Canyon Protection Act); and
4. Monitor any difficulties in operating an integrated electrical system, including regulating a load control area.

At the present time, the data needed to measure and evaluate power production is already routinely collected by the BOR and WAPA and no data gathering or activities by GCMRC are proposed in this area.

### **C. ii. Water Resources**

Water resources include all aspects of water quantity and quality. The "Law of the River" directs the operations of Glen Canyon Dam including monthly and annual release patterns and reservoir contents and elevations with the goal of operating Glen Canyon Dam for water supply and water quality consistent with existing law and policy. Although of more recent concern, water quality as it relates to changes over time is of specific concern. High water levels in reservoirs and rivers also normally maximize recreation benefit and values. High water quality can also create additional value in water supplies.

#### The AMP Management Objectives for water resources are:

1. The Secretary shall Operate Glen Canyon Dam in a manner fully consistent with the Record of Decision and subject to the "Law of the River," including but not limited to the following: Grand Canyon Protection Act of 1992, the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona vs. California, and the provisions of the Colorado River Storage Project Act of 1956, and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin.
2. Maintain water quality at levels appropriate to support physical, biotic, and human resource needs of various ecosystems downstream of Glen Canyon Dam as mandated by the Grand Canyon Protection Act and incorporated into the Record of Decision.

#### The AMP Information Needs for water resources are:

1. Annually collect and report Glen Canyon Dam (GCD) flow release information.
2. Monitor water quality, composition and temperature and compare to applicable standards.
3. Quantify current selenium levels in water discharged from Glen Canyon Dam. Determine how selenium concentrations are affected by dam operations.
4. Determine/quantify the dynamics of major cations, anions and nitrate/phosphate ratios resulting from dam operations.
5. Evaluate feasibility of short term or long term changes of water temperature through selective withdrawal.

Several activities are currently being conducted to address these information needs. These include the flow release information collected at GCD by the Bureau of Reclamation; the Bureau of Reclamation selective withdrawal study efforts; and the GCMRC comprehensive water quality program that studies the effects of water quality on downstream resources by monitoring chemical and biological parameters in Lake Powell, the GCD tailwaters, and at downstream locations. The GCMRC water quality program is described elsewhere in this plan.

### **C. iii. Economic Assessments of Resource Impacts**

A comprehensive assessment of market and non-market costs and values was conducted in Phase II of the GCES. That assessment established a baseline analysis of Grand Canyon resource values and it established a cost analysis relating to impacts of alternative dam operating criteria.

However, an effective Cost/Benefit Analysis (CBA) model that can easily accommodate new economic assessments of any alternative operating criteria proposed for the Dam was not developed. A proposed model should accommodate evaluation of all associated market and non-market costs and benefits, including intrinsic and existence values of key resources. The development of a CBA model should be along design parameters that permit eventual incorporation into a more robust decision support system. A synthesis of data should allow the development of the CBA model in the future and no GCMRC activities are proposed in this area for FY 2000.

## FY 2000 BUDGET SUMMARY

### Cultural Resource Projects:

Photographic Terrace Monitoring.....	\$35,000
Investigation of Isolated Occurrences.....	25,000
Protocol Assessments.....	15,000
Unanticipated Information Requests.....	5,000
Application of Flow/Deposition Model .....	25,000
Tribal Resource Projects (3) .....	125,000
Tribal Technologies .....	35,000
Application of Geomorphic Testing .....	<u>35,000</u>
<b>Total .....</b>	<b>\$300,000</b>

### Recreational Resource Projects:

Assessing 30-year Campsite Changes .....	\$25,000
Evaluating Trout Anglers' Satisfaction .....	5,000
Campsite Monitoring Protocols .....	20,000
Boater Adopt-a-Beach Program.....	<u>5,000</u>
<b>Total .....</b>	<b>55,000</b>

### CONTRIBUTION OF THE FY 2000 PROGRAM TO THE STRATEGIC PLAN

The GCMRC socio-cultural program is linked to the stakeholder objectives and information needs as formulated under the Adaptive Management Program. The information that is generated from these activities provides the necessary data for the long-term management of socio-cultural resources within the river corridor.

## THE BIOLOGICAL RESOURCES PROGRAM

The FY 2000 Biological Resources Program will represent extended contracts and competitively awarded contracts, as discussed in the Strategic Plan. The FY 2000 program will include monitoring and research activities associated with water quality; the aquatic food base; humpback chub and other native fish; Lees Ferry trout fishery; wetland and riparian vegetation; riparian avifauna and the endangered species: Southwestern willow flycatcher, the Kanab ambersnail. The program will also include protocol evaluations, staff activities in support of TWG requests (e.g., BHBFB resource criteria, State of the Canyon Resources Report, draft BA, etc.), contingency planning for a BHBFB, in-house studies, and unsolicited proposals.

### FY 2000 PROGRAM ACTIVITIES

#### Integrated Water Quality Monitoring and Research

**[NOTE: This will be modified pending agreement by the TWG with the recommendations of the Lake Powell AD-hoc group.]**

The FY 2000 annual plan contains a proposal by the GCMRC to integrate all water quality monitoring and research being performed by the GCMRC in Lake Powell, the forebay upstream of Glen Canyon Dam, the tailwater from the dam to Lees Ferry, and the Colorado River through Grand Canyon. The proposed integrated water quality monitoring program is designed to address both the MOs and INs for downstream resources as well as those MOs and INs for Lake Powell which the Ad hoc group has determined may have effects on downstream resources. In the past, some of this work (mainstem monitoring at the USGS gages of temperature, conductivity, and turbidity) has been under the Physical Sciences program, other work has been done under the Biological Resources program (forebay and mainstem monitoring of temperature, conductivity, and pH), while other work has been conducted under the Lake Powell program (monitoring of water quality in Lake Powell). This restructuring will ensure that the water quality information is collected consistently, using comparable methods and instrumentation, and is integrated into a

common data management system for accessibility by all interested researchers and other parties.

### **Program Background**

Water quality changes that occur in Lake Powell and are released downstream to the immediate tailwater have been documented by the existing Lake Powell program. It is generally recognized that water quality changes from Lake Powell through Grand Canyon primarily affect biological components of the aquatic ecosystem. For this reason, it is proposed that this integrated water quality program be moved under the direction of the Biological Resources Program.

The physical, chemical, and biological components of water quality in the Colorado River ecosystem define the conditions in which all biological processes in the aquatic ecosystem take place. Temperature and warming patterns in the Colorado River directly affect the life history of the various native and non-native fish species in Grand Canyon and affect microclimate in the riparian zone. Chemical concentrations of nutrient compounds in Glen Canyon Dam releases are a limiting factor in primary productivity in the tailwater below the dam. Hydrodynamic processes and operational patterns affect the physical and chemical water quality of dam releases as well as organic material and biological organisms which are exported to Grand Canyon. Future plans for selective withdrawal will further affect release water quality in a substantial manner.

This water quality program will be designed by GCMRC and coordinated with Reclamation and the Lake Powell MOU group. The scope of work developed by GCMRC will be submitted to a review by a Protocol Evaluation Panel (PEP) prior to submission to the AMWG/TWG for review and recommended adoption. Once the scope of work has been developed, additional detail will be added to this Annual Plan.

### **Water Quality Program Administration and Budget**

Monitoring and research activities, subject to the recommendations of the TWG Lake Powell Ad-hoc group, will comprise the current GCMRC water quality monitoring program for Lake Powell as well as the current GCMRC water quality and temperature monitoring program in the tailwater from the dam to Lees Ferry, and the Colorado River through Grand Canyon.

The GCMRC water quality budget for FY2000 is expected to be \$300,000. Under the Ad-hoc group proposal, monitoring and research activities in Lake Powell will be supported by Reclamation (e.g., O&M funds or other sources) and are expected to cost \$250,000. Monitoring and research activities in the mainstem will be supported by GCMRC within the Biological Resources Program budget and are expected to cost \$50,000. No additional programming or funds will be allocated unless revisions to the existing program are proposed by the AMWG.

### **Aquatic Ecosystem Resource Components and Activities**

Aquatic ecosystem resources include water quality parameters, the primary and secondary producers (e.g., algae, Gammarus and other invertebrates), secondary consumers (water fowl, fish), and predators (predatory birds) and the habitat (main channel, shoreline). Avifauna are included as a resource in the aquatic ecosystem, although monitoring and research may be conducted out of terrestrial ecosystem budgets.

### **Management Objectives**

Management objectives regarding aquatic resources include MO 1-10 (Appendix A) Within each resource category the information needs that are planned to be addressed in FY 2000 are separated into either monitoring or research information needs.

[NOTE: Once the **Integrated Water Quality** program is revised per the TWG, it will be moved here as the first element of the Aquatic Ecosystem.]

### **Aquatic Food Base**

Aquatic primary and secondary productivity (i.e., the aquatic food base) is the primary trophic link and energetic conduit throughout the Colorado River ecosystem. Fluctuations in the aquatic food base are associated with certain environmental stressors that include water temperature, turbidity, and flow fluctuations, to name a few. Understanding the relationships between dam operations and productivity of the aquatic food base is an important step towards understanding the effects of dam operations on higher trophic levels, especially the population dynamics and interactions of native and non-native fish species in the Colorado River ecosystem.

**Monitoring and Research Information need that will be addressed is 1.1., 1.2, and 1.3 -** Aquatic food base, monitoring activities will focus on community structure, density, distribution and total biomass 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. This data will be collected in a manner compatible with monitoring and research activities on fish and in such a way as to enable distinction between the effects of dam operations and natural variation on the aquatic food base. Research aspects will include developing linkages between water quality, dam operations, Lake Powell input and tributary influences on the aquatic food base in relationship to composition and energetic contribution to the system using stable isotope analysis of fish tissue. It is intended that the existing contract will be extended for at least one year. Total cost for this project is \$234,000.00.

### **Native Fish**

Native fish are an important part of the Colorado River ecosystem because of their trophic role, evolutionary significance, and inherent value for biodiversity. They are of critical importance because some are listed as threatened or endangered under the Endangered Species Act. 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.

An overall goal for GCMRC monitoring and research activities is to understand the processes that enable the maintenance and/or enhancement of native fish, especially the endangered humpback chub. Native fish populations depend on appropriate habitat for all life stages and an adequate food base for their continued survival. Both of these elements 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.

Native fish information needs will be addressed through a combination of monitoring and research activities. Knowledge gained from these scientific efforts, may negate the necessity of addressing some information needs which have been prioritized for subsequent research efforts, and may refine the direction taken for monitoring efforts and management actions. In addition, non-native fishes, in Grand Canyon are thought to pose a threat to the native species with competition for resources, predation, and the introduction of parasites and diseases. The various non-native species have different direct and indirect effects on multiple aquatic resources. Efforts to monitor the abundance of non-native species and their co-occurrence with native species of concern will be initiated.

The following are information needs that address minimal monitoring needs and primary research needs for native fish.

**Monitoring Information Needs that will be addressed include:**

3/4.1, 3/4.2, 8.1, 8.2, 8.3, 8.4, 9.3, 10.6 - Monitoring for native and non-native fish will occur within designated critical habitat for native fish in FY 2000 at an estimated cost of \$470,00. The monitoring will be accomplished through extending the existing contract.

**Research Information Needs that will be address include: 6.2, 6.3, 10.1 - Project 1.** Research project that examines the relationship between mainstem fish and LCR fish populations of HBC.

Effectively monitoring the status of native fish initially requires addressing information needs that are research oriented. In addition, the implementation of several management actions that intend to address Biological Opinion Statements are eminent. These actions primarily address mainstem spawning issues. Research in mainstem spawning and recruitment success of endangered fish relative to the LCR populations will be addressed in FY 2000. Funds allocated for this projects are estimated at 90,000 with funding for an additional years work at a similar or decreased level.

### **Lees Ferry Trout**

Rainbow trout were first introduced into tributaries of the Colorado River ecosystem in Grand Canyon during the 1920s. Currently, 90 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, large numbers of reasonably well-conditioned fish are being sustained by a high biomass of amphipods (Gammarus lacustris) and midges (Chironomidae).

Alternative dam operations and the resulting flow regime can directly and indirectly effect trout found in the dam tailwater. Direct effects include stranding of all life stages in isolated pools, dewatering of spawning and rearing habitats, and displacement of individuals from preferred habitats. Indirect effects involve ecosystem processes and lower trophic level interactions that provide the food base for the fish. Stranding and dewatering are sources of mortality for adults, juveniles, and larval fish, while displacement may cause increased energy expenditure, reduced food intake, and disruption of reproductive activities. Understanding the processes that enable the maintenance and/or enhancement of the rainbow trout fishery requires managers to be able to accurately predict the aquatic resource's response to ecological changes that are a (direct or indirect) result of GCD operations.

**Monitoring Information Needs that will be addressed include: 2.2, 2.3, 2.5** - Monitoring will be accomplished through extending the existing contract for one more year. Aspects of the monitoring program may be changed based on symposia and protocol evaluation results. Monitoring budget for trout in the Lees Ferry/Glen Canyon reach is estimated at \$130,000.

**Research Information Needs that will be addressed include: 2.4 -**

Research is needed to address historic data associated with native and non-native interactions and baseline information for fish. GCMRC will initiate an effort to consolidate data and to provide procedures for sharing data among researchers. Funds associated with this effort are estimated at \$30,000.

In FY 1999, GCMRC intends to conduct a symposia that evaluates the scientific understanding of cold tailwater fisheries in the western United States with a focus on creating a base of scientific information that could be used in the development of future management plans for the Lees Ferry trout fishery. The goal of the symposium is to provide a scientific forum to present and discuss the effects of flow regulation and management activities on the Lees Ferry trout fishery. The outcome of this symposium may result in a modification of the specific elements of the monitoring and research activities to be initiated in FY 2000. Funds of \$20,000 for this program were designated in FY1999 and these funds will be carried over into FY2000.

**Protocol Evaluation**

Protocol evaluation for monitoring of trout in the Glen Canyon reach will be conducted in FY 2000. The estimated cost for PEP is \$15,000.

**Terrestrial Ecosystem Resource Components and Activities**

Riparian vegetation prior to the construction of Glen Canyon Dam, was subject to periodic flooding. The destabilizing actions of historic flows resulted in a community that was often re-establishing itself rather than expanding. Since the establishment of Glen Canyon Dam, the hydrograph has become dampened and resulted in more stable riparian communities both with respect to those components associated with the old high water line (120,000 cfs), and those composing the new high water zone (5,000 cfs to 31,000 cfs). Additionally, reduced seasonal fluctuations associated with dam operations has established and expanded marsh communities that were rare prior to the dam. Terrestrial ecosystem resources include the primary and secondary producers (e.g., marsh and riparian vegetation and terrestrial invertebrates), consumers (avifauna, deer), and higher trophic level predators (predatory birds) and the habitat (near shore marsh and low- and upper-elevation riparian

communities). Avifauna represent a trophic level that utilizes both aquatic and terrestrial resources, but are included in terrestrial resource monitoring and research.

### **Management Objectives**

Management objectives for terrestrial resources include MOs 11-16. Information needs associated with specific resources are listed and separated into monitoring needs and research needs.

Monitoring and research efforts within the terrestrial ecosystem resources will vary from monitoring with little to no research to synthesis and little monitoring for some resources. This is reflective of the knowledge base associated with each resource.

### **Riparian Vegetation**

Riparian vegetation is recognized as an important resource serving many roles in the Colorado River ecosystem. The riparian vegetation stabilizes banks, provides aquatic and terrestrial faunal habitat, are botanical resources for tribal groups, and has aesthetic and recreational value. Today, three distinct riparian or marsh communities are represented along the mainstem of the Colorado River: the upper riparian zone; the lower riparian zone; and the near shore wetland communities. The preservation or restoration of riparian communities affected by dam operations is a management objective identified by the AMWG. In part, this is because riparian vegetation provides critical habitat for terrestrial invertebrates, that in turn, provide essential food resources for riparian insectivores (insects, amphibians, reptiles, birds and mammals), thereby linking vegetation, productivity and habitat conditions with secondary consumer population dynamics.

#### **Monitoring Information Needs that will be addressed include:**

**11.3** - Monitoring for vegetation during FY 2000 will take place only in that aerial photography of the river corridor will occur. In anticipation of implementing a long-term monitoring program for vegetation by FY 2002, a synthesis of previous vegetation data collection efforts will be conducted with the intent of summarizing the previous efforts within the context of the information needs and providing a focus for protocol evaluation regarding vegetation monitoring. Estimated costs for synthesis is \$55,000.

**Research Information Needs that will be addressed include: 11.1, 13.1, 13.2** - Project 1. Identification and evaluation of trophic level interactions for terrestrial

habitat. Continuing up the foodweb, trophic interactions between habitat conditions and availability, invertebrates and primary consumers (i.e., terrestrial/riparian vertebrates) affect the sustainability of higher level consumers. The river corridor supports high densities of terrestrial/riparian vertebrates. The populations of many of these animals are changing. More than a dozen native vertebrate taxa have been lost, or their status is unknown (e.g., river otter), while several native and non-native species populations have increased (e.g., waterfowl, beaver). Identifying and developing an understanding of trophic level interactions in the terrestrial environment is as important as understanding aquatic food base interactions. Estimated cost for the pilot project is \$30,000.

#### **Protocol Evaluation**

Protocol evaluation for vegetation monitoring will take place in FY 2000 after the synthesis has made sufficient progress to narrow the scope of the review panel. Estimated cost for PEP is \$15,000.

#### **Riparian Avifauna**

Terrestrial vertebrates have a significant influence on ecosystem structure and energy flow, and are recognized as a priority resource by the NPS. Fortunately the conspicuous nature of many of the vertebrates, make monitoring them relatively easy. Avifauna are especially conspicuous and are trophically significant secondary consumers. Their presence or absence can be an indicator of the status of habitat structure, food resource production, and predator populations.

Reduced flood frequency and sediment transport in this system has increased aquatic foodbase productivity, established trout populations, and promoted profuse stands of wetland and riparian vegetation. As a result, threatened or endangered Bald Eagle, Peregrine falcon, and Southwestern willow flycatcher (SWWF), other regionally significant Neotropical migrants, and other breeding bird species populations have increased in the post-dam river corridor.

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.

**Monitoring Information Needs that will be addressed include:**

**11.2, 11.4, 12.2, 12.4.** Monitoring of riparian avifauna will occur by extending the current contract. The focus of monitoring will be on habitat condition, habitat use and nesting success, including distribution and population trends of breeding birds in the river corridor. Costs for breeding bird surveys will be about \$81,000.

**Protocol Evaluation**

Protocol evaluation for bird survey monitoring will take place in FY 2000 with an estimated cost of \$15,000.

**Endangered Species**

The Colorado River ecosystem supports several species that are federally listed as threatened or endangered, including bald eagles, breeding peregrine falcons, Southwestern willow flycatchers and Kanab ambersnail.

**Southwestern willow flycatcher**

**Monitoring Information Needs that will be addressed include:**

**11.3, 12.1, 12.2, 13.1** - The Southwestern willow flycatcher (SWWF) has been the focus of intensive monitoring in upper Grand Canyon since 1983. Monitoring of SWWF will focus on SWWF habitat condition, habitat use and nesting success, and nesting fidelity, including their distribution and population trends in the river corridor. Monitoring of SWWF will occur on an annual basis.

**Kanab ambersnail at Vaseys Paradise**

**Monitoring Information Needs that will be addressed include:**

**14.1, 14.2, 14.3, 14.4, 14.5, 14.6** - The Kanab ambersnail (KAS) is a federally endangered snail. A population of this species exists at Vaseys Paradise in Marble Canyon, Arizona. Monitoring of Kanab Ambersnail at Vaseys Paradise will focus on habitat patch composition, area of cover, and condition; population distribution, abundance, age-class/size distribution,

population density, and condition (i.e., occurrence of KAS trematode parasite) as it relates to natural variation and to the local stage-discharge relationship.

GCMRC and Reclamation will continue to cooperate in their efforts to provide support for monitoring the establishment of a second population of KAS.

Monitoring for KAS at Vasey's paradise will be completed internally for the next year as a means to make funds available to other biological resource programs. The efficacy of conducting the work internally will be evaluated during the upcoming year.

#### **Protocol Evaluation**

Endangered species monitoring will undergo a PEP in FY 2000 with an estimated cost of \$10,000.

### **Other GCMRC Biological Resources Program Activities**

#### **GCMRC In-house Studies**

In addition to the studies described above, GCMRC staff will conduct studies in FY 2000 related to specific stakeholder objectives and information needs. These research studies will primarily be initiated to address gaps in understanding that have not been anticipated two years out in the planning cycle, or which utilize the unique expertise of the GCMRC staff. In addition, these studies may represent synthesis activities where GCMRC staff have unique access to disparate data sets. All GCMRC in-house studies will be reviewed by the TWG and will undergo independent, external peer review prior to there being initiated:

Support for GCMRC in-house studies will account for less than 10% of the budget of the GCMRC biological resources program and is in keeping with the recommendation of the National Research Council (NRC, 1996) that the majority of research funding go to support external activities. In addition, utilization of GCMRC scientific expertise to undertake these studies will contribute to effective synthesis and will contribute to the development and refining of conceptual and predictive models of Colorado River ecosystem processes and function.

#### **Protocol Evaluation**

In FY 2000, the GCMRC biological resources program staff propose to initiate protocol evaluation program (PEP) described in the FY 2000-2004 strategic plan as

a means of evaluating and developing the detailed protocols which will comprise the GCMRC long-term monitoring program. This will be done through the use of visiting committees of scientists with relevant expertise in the field of study.

The strategy will be to identify a lead reviewer with relevant expertise in the field of study and work with that reviewer to identify additional reviewers. These reviewers will be provided with the past two to three years of reports from a given project as well as the currently funded proposal to review. They will be invited to meet with the current PI(s) for a series of project briefings immediately before a scheduled river trip. Time permitting, they will accompany the PI(s) on a river trip to evaluate their field methodology and gain familiarity with the ecosystem.

The reviewers will be required to provide a rigorous review of the protocols currently in use and recommendations for changes in protocols, as appropriate. This information would be used to modify, as appropriate, the FY 2001 monitoring program.

The details of this approach can be found in Appendix C to the FY 2000-2004 strategic plan. To the extent possible, protocol evaluations will be completed in FY 2000.

### **Unsolicited Proposals**

For FY 2000, the Biological Resources Program intends to set aside some funds in support of unsolicited proposals. This will allow for flexibility in the program and help ensure that GCMRC can address critical issues in a timely fashion. It will also provide GCMRC the ability to fund a truly outstanding proposal that addresses a key concern which may be overlooked in the research planning process. All unsolicited proposals will be discussed with the TWG and will undergo independent, external peer review prior to funding.

### **GCMRC Support of TWG Requests**

In FY 2000, GCMRC intends to create a pool of money which can be used by GCMRC staff in support of requests for analysis that arise from the TWG during the course of the year. Such funds may be used to gather data, conduct analyses, support the convening of a group of scientists to provide an analysis of a given issue (i.e., the annual BHBF

resources evaluation) or to obtain expertise not contained within the GCMRC staff or contractors. Such funds may be carried over from one year to the next, depending upon need and availability.

#### **CONTRIBUTION OF THE FY 2000 PROGRAM TO THE STRATEGIC PLAN**

The FY 2000 program is 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 critical to the adaptive management process.

**FY 2000 BIOLOGICAL SCIENCES PROGRAM BUDGETS**

	<u>Monitoring</u>	<u>Research</u>	<u>PEP<sup>10</sup></u>
A. Conceptual Modeling.....	\$ -0-	\$70,000	\$ -0-
B. Integrated Water Quality.....	\$150,000	\$ 75,000	\$75,000
C. Aquatic Food Base.....	\$194,000	\$40,000	\$ - 0- <sup>11</sup>
D. Native Fish.....	\$470,000	\$90,000	\$20,000 <sup>12</sup>
E. Lees Ferry Trout.....	\$130,000	\$30,000	\$15,000
F. Riparian Vegetation.....	\$55,000	\$30,000	\$20,000
G. Terrestrial Endangered Species..... (SWWF & KAS)	\$-0-	\$ -0-	\$10,000 <sup>13</sup>
H. Avifauna (Breeding Birds).....	\$81,000	\$ -0-	\$15,000
I. In-House Monitoring and Research.....	\$ -0-	\$100,000	\$ -0-
J. Side-scan Sonar Pilot.....	\$ -0-	\$25,000	\$ -0-
K. Unsolicited Proposals.....	\$ -0-	\$100,000	\$ -0-
L. Technical Work Group Requests.....	\$ -0-	\$50,000	\$ -0-
	<u>\$1,080,000</u>	<u>\$610,000</u>	<u>\$155,000</u>
<b>Subtotal.....</b>			<b>\$1,845,000<sup>14</sup></b>

<sup>10</sup> Funds for the Protocol Evaluation Program (PEP) should not be viewed as add-ons to the base budget for a given resource area.

<sup>11</sup> PEP for the aquatic food base will be conducted in FY 2001 following receipt of FY 1998 & 99 monitoring and research results. This can't be done in FY 2000, because the results of their trophic synthesis won't be available until March 2000.

<sup>12</sup> The PEP in FY 2000 will focus on monitoring in the LCR and adjacent mainstem areas immediately above and below the mouth of the LCR. A PEP for the mainstem monitoring will be conducted in FY 2001 following the results of the pilot test of side-scan sonar.

<sup>13</sup> PEP for KAS may be done as part of the KAS panel in FY99 if that is initiated.

<sup>14</sup> Represents the \$1,500,000 recommended by the AMWG for the Biological Resources Program and an additional \$250,000 from Reclamation (e.g., O&M or other sources) which will be spent on the Lake Powell portion of the integrated water quality monitoring program. This will include water quality monitoring currently conducted by the USGS at their stream gages and paid for from the physical sciences program.

## THE INFORMATION TECHNOLOGY PROGRAM

### Introduction

The GCMRC Information Technology Program facilitates the adaptive management process of the Colorado River ecosystem by:

1. archiving and delivering scientific data and other information to stakeholders, scientists, and the public,
2. providing technology based solutions to data collection, manipulation, and analysis, and
3. providing support in areas of computers, surveying, and GIS.

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

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

1. a data base management system (DBMS) for tabular information and other electronic non-spatial information,
2. a geographic information system (GIS) for electronic spatial information, and
3. a library for hardcopy information. Content of these systems will consist of all information gathered as the result of GCMRC investigations, both past and present, and additional information relating to the Colorado River ecosystem.

The full exploitation of archived data requires sufficient information as to its context including quality, comparability, and temporal and spatial aspects. Therefore, data standards must be developed which preserve the context under which the data was collected and ensures its quality and comparability from year to year, place to place, researcher to

researcher, and discipline to discipline. Future data collection efforts supported by the GCMRC will incorporate strict data standards and protocols that provides consistency in data collection, storage, and delivery from disparate sources.

Delivery of electronic content will be automated where possible using user-friendly World Wide Web browser interfaces. Library content, while not currently deliverable across the Internet, will be cataloged with content titles, authors, and subject descriptions searchable electronically utilizing similar interfaces.

Electronically 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.

DBMS, GIS, and library operations together form the core information system infrastructure for storing and retrieving information at the GCMRC. Data standards and protocols ensure the quality and compatibility of the information contained within those systems. World Wide Web browsers provide intuitive, consistent interfaces to the information. However, information technology at the GCMRC goes beyond the content and delivery of information. In addition, the ITP also provides:

- Computer support to GCMRC staff
- Survey support to researchers
- Outreach to stakeholders, scientists, and the public
- Development of remote sensing applications

These ancillary services augment the core information infrastructures by providing the support, training, technology transfer, and development necessary to provide a comprehensive ITP.

## **FY 2000 INFORMATION TECHNOLOGY PROGRAM**

### **Information Flow**

The ITP becomes involved with scientific investigations at the point of contract award. At this point, information flows bi-directionally between the researchers and the ITP. The ITP provides the researcher with relevant background literature, scientific and remotely

sensed data, and survey and other spatial data. The researcher identifies to the ITP the type and attributes of tabular, spatial, and sensitive data they are collecting. Quality control and assurance plans are reviewed and approved. Appropriate protocols and standards for data collection and delivery are incorporated into the contract before award. When GCMRC receives a deliverable from a researcher containing data or other information, the ITP reviews it for completeness and conformance to the standards and protocols and incorporates it into the appropriate data system on a provisional basis. The data is quality assured and then made available to stakeholders, researchers, and the public through delivery systems.

### **Data Base Management System**

A comprehensive and versatile DBMS is the first of the three core information technologies being used by the GCMRC. Its purpose is to store and deliver all tabular and other electronic non-spatial information gathered as the result of GCMRC investigations, both past and present. The ITP of the GCMRC is currently charged with inventorying, organizing, archiving, and developing delivery systems for many years worth of environmental data collection activities representing a vast array of disparate data including physical, biological, cultural, socio-economic, and climatic information. Some data resides on mature DBMS systems but much of it is stored on floppy disks or hard disks on personal computers using PC type spreadsheet and database formats. Although the objective of the information technology program is to provide a centralized database management system (DBMS), it is our policy not to duplicate data warehousing already provided by other entities. In these circumstances it is preferable to interrogate the off-site database remotely 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. The challenge facing the ITP is how to bring together years of disparate historical data collected by multiple entities located in databases across the southwest in an organized fashion and then deliver it transparently to an equally disparate group of stakeholders for decision making and modeling purposes.

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.

Delivery of electronic content will be automated where possible using user-friendly World Wide Web browser interfaces. When possible, a common interface will be developed which will facilitate dissemination of data to all interested parties

The Oracle data base engine has been selected for GCMRC data base development. Oracle is a state-of-the-art data storage and delivery system that can function either as a centralized or distributed data base and incorporates a high degree of information technology integration. Important features of the DBMS are:

- All data will be ecologically integrated meaning that data will be stored in a consistent format relative to time, space, researcher, and discipline. This is essential for comprehensive ecological analysis. Appropriate data standards and protocols will be developed to regulate this feature.
- Spatial data will be geographically integrated. Although the data base will not contain a spatial data analysis engine, the GIS used by the GCMRC will be highly integrated with, and dependent upon, the data base for storing attribute data associated with spatial features. Data contained in the database will; however, be spatially referenced within the data base where appropriate.
- Public data will be freely available. Sensitive data will be protected. User accessibility will be configurable item by item.
- The data base will be searchable over the Internet using browser interfaces. Intuitive browser interfaces will be the primary method used to interrogate the database.

The GCMRC data base was originally scheduled to be implemented by December, 1999. However, due to the resignation of our database coordinator in August of 1998, the completion date for this activity will likely be pushed back to December of 2000. Eleven benchmarks have been established to track the progress of the data base development:

1. Select database software and hardware platform
2. Install software and document the installation procedure

3. Conduct data inventory and acquire example data sets
4. Evaluate existing environmental databases
5. Define data standards for tabular data
6. Identify attributes of data to be included in the data base
7. Design and program data base structure
8. Populate the data base
9. Develop user interfaces
10. Develop Web interfaces
11. Document administrative procedures

Benchmarks 1 and 2 are completed with work in progress on 7. It is anticipated that benchmarks 3 through 6 will be completed in FY 1999 with work being initiated on benchmark 7 depending upon when the Database Coordinator position is filled. Activities in FY2000 will largely consist of accomplishing benchmarks 7 through 11. Once the data base has been designed, populated, and documented, the cost of this effort will drop substantially.

**Projected FY2000 DBMS budget: \$150,000**

### **Geographic Information System**

A GIS is the second of the three core information technologies being used by GCMRC. Its purpose is to provide spatial analysis capabilities for trend detection to GCMRC staff and stakeholders and to maintain a library of GIS thematic coverages of the study area. The GIS will be tightly integrated with the remote sensing initiative and, in conjunction with image processing software, will be the primary analysis tools of remotely sensed data sets. The GIS is an integral component of the monitoring program and base data development is used to assess the impacts of variable flow rates within the Grand Canyon (B.O.R. Report: R-95-14, Patrick J. Wright, et al.). It is an objective of the GIS program to use geographically referenced base data to develop an integrated ecosystem-based monitoring program (B.O.R. Report: R-93-20, Lee F. Werth, et al.). The GIS is also an important analytical tool for integrating and comparing spatial data that has been collected in the past and data that will be collected in the future. The digital elevation models stored within the GIS and developed by the Survey Department will enable GCMRC to answer question regarding flow rates, water surface elevation and percent inundation. Questions

such as: "what is at?", "where is it true that?", "what has changed?", "which data are related?", and "what happens if?" along with many other TWG, AMWG, and staff question concerning spatial data, modeling and trend analysis can be answered with a GIS.

GCES had significant accomplishments in GIS system development and establishment of meta-data protocols. GIS activities were concentrated along 17 reaches of the Colorado River identified as GIS Sites 1-17 (Fig. 4.2). Each GIS Site has up to 20 thematic coverages associated with it depicting spatial relationships of physical, biological, and cultural resources. Considerable tabular attribute data exists as part of these data sets. These data sets are known as "base data". In addition, there exist other GIS data sets, which were constructed as part of past GCES supported investigations and delivered as part of a final product. These data sets are known as "contributor data." The base and contributor GIS coverages represent a significant effort by GCES that may have broad application for research and monitoring being conducted in the Grand Canyon. Efforts are now underway to catalog, describe and distribute base and contributor data. All coverage tabular attribute data will be linked to the ORACLE data base for easy data storage and retrieval. Presently, the GIS group is working to increase the GIS coverage of the Grand Canyon by using state-of-the-art mapping techniques discussed under the remote sensing and survey operations.

The GIS will be the workhorse behind the analysis of the remotely sensed data; hence, significant investments in hardware and software will be required to support the Remote Sensing Program. The GIS will be the consolidating tool of remotely sensed data to allow for integrating data and assessing impacts (B.O.R. Report: R-95-14). GIS activities in support of the remote sensing activities will be funded out of the remote sensing budget subsequently described.

GIS objectives to be addressed in FY 2000 include:

- development of an internet map server
- development of an ArcView user interface to base data
- in-house and contractor base data development
- development of dynamic links within the GIS for easy field retrieval of existing canyon control
- incorporating all FY 99 contributor base data into the GIS.

# Grand Canyon Monitoring and Research Center

## GIS Monitoring Sites

Long-Term Monitoring Sites			
SITE	LOCATION	RIVER MILE	REACH
1	UPPER CANYON	244 to 124.8	2
2	LEE'S FERRY	124 to 2	2
3	PRESTON'S	42 to 48	6
4	HANCOCK'S	81 to 84	6
5	COB	86 to 76	7
6	SHRIMPTON	93 to 86	8
7	BLANCHARD	120 to 128	2
8	SHRIMPTON	145 to 158	10
9	BLANCHARD	173 to 148	17
10	LAKE FALLS	178 to 181	12
11	GRANITE PARK	207 to 210	12
12	DIAMOND CREEK	246 to 250	17
13	COLUMBIAN FALLS	278 to 276	17

Special Study Sites	
14	UPPER CANYON - 124 to 127
15	LEE'S FERRY - 127 to 124
16	PRESTON'S - 48 to 42
17	HANCOCK'S - 84 to 81

**Legend**

- Location of Geographic Information and Long-Term Monitoring Sites
- Special Study Sites
- Colorado River Corridor
- Grand Canyon National Park
- Tributaries
- State Borders

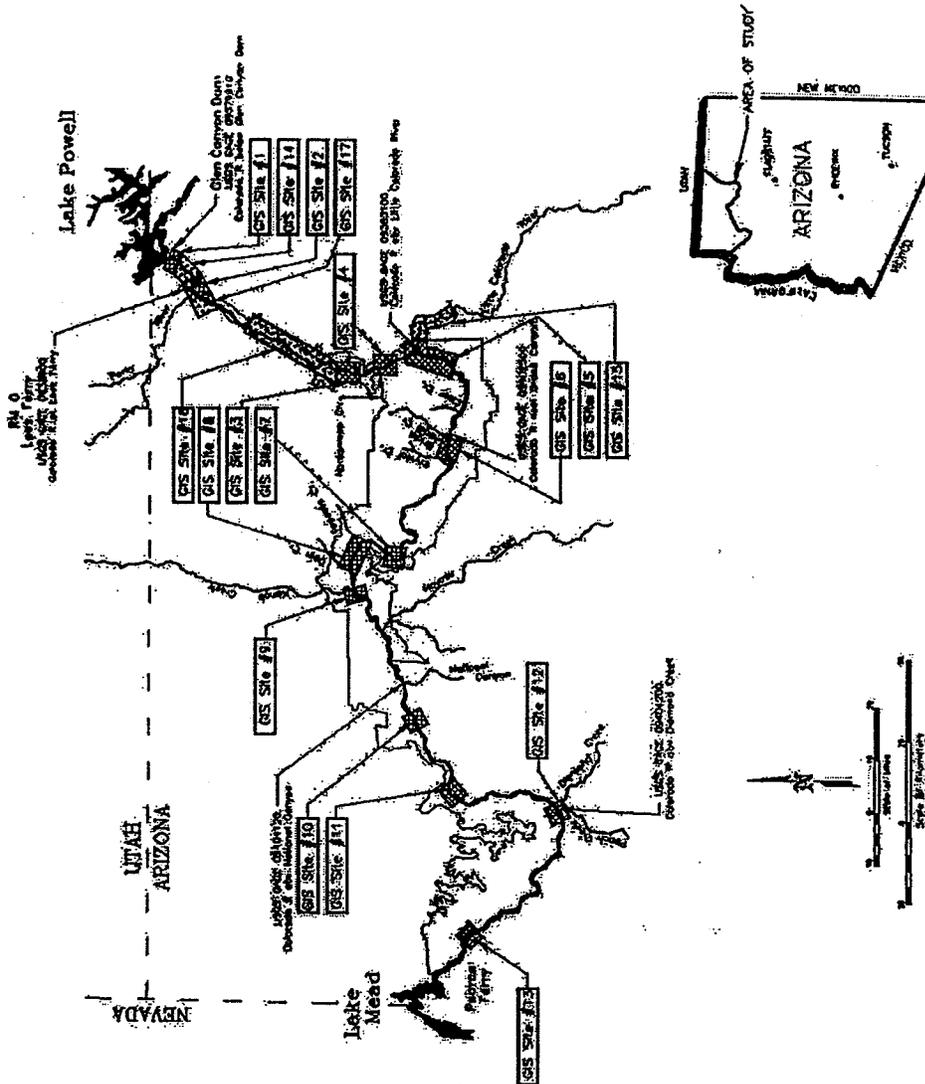


Figure 4.2 GIS Sites 1-17

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. All contributor and in-house data received in FY 2000 will have the appropriate metadata generated and stored within the DBMS.

**FY2000 GIS budget: \$10,000**

### Library Operations

Library operations provide the last of the three core information technologies being used by the GCMRC ITP. Its purpose is to facilitate research by providing a centralized repository for hard copy information such as books, reports, maps, photography, and videos. The scope and purpose of the library should be to collect, archive and deliver those materials that assist the center in its efforts to administer long-term monitoring and research.

Inherent in the administration of plans is the delivery of materials that facilitates monitoring and research activities. Ensuring that these materials, that form the basis for research and monitoring efforts, are available to researchers funded through GCMRC is a primary purpose of the library. Materials utilized in research and monitoring efforts include hard copy documents, photographs, slides, videotapes, and ARC/Info coverages. A loaning policy of these materials will be developed in a manner that is most parsimonious to all researchers, with underlying GCMRC staffing resources determining the ability to deliver and track loaned materials. Delivery of materials also emphasizes technologies that permit remote multi-user access.

Secondary to providing funded researchers access and use of the library's materials is providing non-funded researchers and the general public access to documents unique to GCMRC's holdings. The singularity of a document requires special policy concerning the borrowing of these materials. Because these unique documents are considered part of the public domain, their availability to the public is required. Lending policies concerning these documents and materials are developed to insure that the loss of these materials is minimized.

Collection of materials for the purpose of research and monitoring efforts are coordinated with program managers and information technology managers. Criteria for the accession of materials include:

- Applicability of materials to specific research efforts and to overall research and management goals; adequacy of the facility and equipment needs of the GCMRC to house materials;
- Ability of the staff to archive and deliver materials;
- Availability of funding for materials (e.g., general reference books, government publications, CD-ROM's, etc.).

Collection also includes the accessioning of documents that are the product of research funded by GCMRC.

Library holdings included the following:

- Hard copies and electronic copy of final funded research reports.
- Reprints of articles resulting from funded research.
- Books resulting from research efforts associated with GCMRC.
- Books and articles related to Grand and Glen Canyon.
- Books and articles related to natural and controlled riverine and environments.
- Photographs and slides developed by GCMRC staff (aerial and field documentation).
- CD-ROM versions of aerial photographs and slides.
- Videotapes (overflights, programs related to Glen and Grand Canyon).
- Maps (topographic, flightline maps, Arc/Info Coverages, Orthophotos).

Archival materials are one of a kind, or hard to replace items (e.g., original aerial photographs, slides, videotapes). Utilizing imaging technology (e.g., CD-ROM's) and electronic media to develop copies of archived materials should always be investigated and promoted so that copies of these materials can be made available to the general collection, and thus reducing the incidence of loss of unique and irreplaceable materials.

The GCES made great strides in the establishment of the library in 1993 when a research librarian was hired to organize and maintain it. However, the librarian resigned in May of 1997 during the transition from GCES to GCMRC and the position was not immediately backfilled. There have been valid concerns about the condition of the library

since that time. New holdings were being stacked on shelves, desks, or placed in boxes for safe keeping. There was no formal monitoring of the library or check out process to track the whereabouts of library materials. Fortunately, that situation has since been corrected and great strides have been made in making the library a functional entity within the GCMRC.

A library committee was assembled in October of 1998 and met to decide what actions should be taken to update and maintain the library. Over several months, the committee produced a strategic plan with recommendations for the restoration of the library. The library content and strategic plan was reviewed by two outside consultants who produced written comment and recommendations of their own. Since that time, a student has been hired from Northern Arizona University to oversee the day to day operations of the library and reorganize its content. Library automation software has also been obtained and the library content is being indexed using this software on a time available basis.

Current goals the library seeks to obtain are:

- Establish library policy for material use and checkout
- Catalog library contents using the Dewy Decimal system
- Facilitate the day to day library operations by using automation software
- Provide electronic searching capabilities of library content over the Internet
- Provide more information electronically over the Internet

It is anticipated that most of these goals will be achieved in FY99 with the exception of the cataloging of library contents being limited to books and reports. Library activities in FY 2000 will largely consist of library maintenance and cataloging photographs, videos, and maps. Once these goals have been achieved, the library will be able to serve a greater number of constituents in less time with better service at a reduced cost.

**Projected FY2000 Library budget: \$12,000**

### **Remote Sensing**

Remote sensing is a new initiative at the GCMRC that is intended to address concern over the expeditionary manner in which research has been conducted in the Canyon. The purpose of the initiative is to evaluate remote sensing techniques as a cost-effective means of resource monitoring in the Grand Canyon with the desire to reduce impact and expand monitoring in terms of resource components and geographic extent. A variety of remote

terrestrial and underwater data collection techniques will be evaluated including satellite and airborne imagery, global positioning systems, telemetry, hydroacoustics, and sonar. It is anticipated that at least some of the expeditionary resource monitoring activities will be replaced by remotely sensed data collection techniques which will result in reduced costs, less impact, and expanded coverage.

Remote sensing is dependent upon accurate geo-referencing and highly specialized analytical capabilities of the remotely collected data. Therefore, initial investments in geodetic control (surveying), image processing, and GIS capabilities are required. Survey control is required for rectification of collected aerial imagery, development of ortho-photography and bathymetric channel mapping. To allow for the storage and processing of the remotely sensed data the GIS will be used to store the collected data and provide modeling capabilities which are fundamental roles of a GIS (Wetland and Environmental Applications of GIS, Lyon, John G. and McCarthy, Jack, 1995). Although budgets for these activities have been proposed, it has not yet been determined if these activities will be undertaken in-house or by contract.

The remote sensing initiative is being driven by monitoring needs of the biological, cultural, and physical resource programs which are in turn derived from the management objectives and information needs identified by the AMWG and TWG. Monitoring needs will be (or in the case of the Physical Science Program, have been) reviewed by a protocols evaluation panel (PEP) comprised of resource specialist knowledgeable in remote sensing. The identified monitoring needs, management objectives, information needs, and PEP recommendations will provide direction for the GCMRC remote sensing, GIS, and surveying programs.

Remote sensing currently emphasizes applications in the Physical Science resource areas. This is primarily because the Physical Science program is further along its protocol evaluation process. Biological and cultural resource components will be incorporated into the remote sensing program as they develop. New components of the plan will be presented to the TWG/AMWG for endorsement as they are developed.

In May of 1998, the first remote sensing protocols evaluation panel (PEP) was assembled to evaluate remotely sensed monitoring and research methodology currently used by GCMRC. The panel was tasked with making recommendations for alternative remotely

sensed technologies that might better meet program information needs. There efforts resulted in a 17 page report with recommendations of remotely sensed technologies which may benefit resource monitoring and research in the Canyon (Final Report, GCMRC Remote Sensing Protocols Review Panel, June 15, 1998). Revised management objectives established by the TWG that could benefit from the application of various remotely sensed technologies were also identified in the report. Subsequent to the report, the GCMRC developed a matrix summarizing panel recommendations, applicable management objectives, timelines, and estimated costs. This matrix is now being prioritized based on monitoring needs and feasibility based on the literature. Only the sensors/technologies which show strong potential for resource monitoring in the Grand Canyon environment will be evaluated. Once a suitable sensor has been identified, other sensors of similar characteristics will be eliminated from the evaluation process.

The GCMRC remote sensing initiative will begin in FY 2000 and continue for three years. Remote sensing technologies selected for use in routine resource monitoring will be implemented in FY 2003. However, it is anticipated that some technologies will be evaluated on an accelerated schedule, perhaps as soon as FY 1999, due to pressing needs for technological development in specific monitoring areas or opportunistic circumstances. The GCMRC intends to continue the annual acquisition of aerial photography until other remotely sensed data sets are identified and implemented into the monitoring program. The total estimated cost of the program is \$1,200,000 over a three-year period and includes:

- the evaluation of airborne terrestrial mapping technology
- establishing control in the canyon
- the literature review and possible evaluation of multi-spectral/hyper-spectral airborne sensors, airborne photographic techniques, and high resolution satellite imagery for resource monitoring
- analysis of existing remotely sensed data sets
- evaluation of image processing techniques and software
- the development of remotely sensed data collection protocols

Selected sensors and mapping techniques will be evaluated over selected representative reaches of the Grand Canyon to reduce costs. The sensors must be able to answer the questions formulated by the revised management objectives. The information

gathered will be assessed for accuracy and utility. The results of the assessment will enable the center to answer key questions about the future use and application of the tested images and collection techniques. The images will be evaluated for their ability to be used in the analysis and mapping of the Grand Canyon. It is anticipated that one to five year rotating schedule of data acquisition. However, the frequency and resolution necessary for specific resource monitoring in the Colorado River corridor has yet to be determined.

Remote sensing technologies recommended by the PEP and proposed to be initiated in FY 1999-2000 timeframes are:

- photogrammetric monitoring of terrace stability of archeological sites and sand bar volumes
- stream-bed classification using QTC-view digital processing system
- color infrared aerial photography for determining vegetative changes
- multi-beam hydrographic data collection for bathymetric channel mapping
- HYDICE hyperspectral remote sensing data processing for resource monitoring
- LIDAR remotely sensed terrestrial topographic mapping of the canyon corridor

FY 2000 activities include the following work to be completed by the Survey group in support of remote sensing:

- Complete a high precision Control Network from Glen Canyon dam to Phantom Ranch for spatial-positioning of research sites in the river corridor and geo-referencing topographic, hydrographic, and remotely sensed data such as multispectral, hyperspectral, aerial photography. To date there is continuous control from Glen Canyon dam to the end of GIS area 5. It is necessary that this control be established to achieve the objectives outlined in the Physical Resource Program.
- Ground truthing, geo-referencing, and image rectification of remotely sensed data.
- Hydrographic channel map of all GIS sites and between GIS sites as needs dictate and control is established in support of the Physical Resource Program sediment and flow modeling.
- Continue development of terrestrial ground topography maps. Terrestrial ground mapping in the Canyon is difficult and expensive. Technologies are currently being evaluated for achieving this objective as part of the Remote sensing

initiative. The GCMRC will use only the most cost effective method which conforms to National Mapping Standards accuracy. Accurate terrestrial ground topography maps are essential for the sediment and hydrology model development being proposed by the Physical Resource Program.

FY 2000 remote sensing activities also include the purchase of image processing software and hardware and/or consulting services by the GIS group for the purpose of doing image analysis in support of remote sensing. The plan includes the development of a comprehensive topographic/hydrographic map and ortho-photography from the Glen Canyon Dam to Phantom Ranch. The mapping effort is in direct support of the Physical Resource Program desire to provide sediment and river stage modeling capabilities from the Glen Canyon Dam to Phantom Ranch.

The proposed remote sensing plan together with the GIS and Survey plans represent an integrated undertaking by GCMRC which, when completed, will provide the basis for comprehensive resource monitoring in the Colorado River system. Initial costs associated with the process evaluation and development of the remotely sensed data sets and a GIS database designed to answer the revised management objectives may appear to be high; however, the long term benefit associated with remote sensing may more than offset the initial cost. Remote sensing means: less river trips, less impact, more resource monitoring components and greater geographic area monitored per dollars spent. The GIS will provide a predictive tool for management decisions. Historical data sets can be evaluated to help solve unanswered question. Furthermore, the cost of remotely sensed data has continued to decline over recent years and should continue to decline in the future. New sensors are being developed and data inventories grow. The present high costs of data cannot be expected to continue throughout the long term monitoring program of the Grand Canyon.

**FY2000 Remote Sensing budget:**

Remote Sensing Evaluation .....	\$200,000
GIS image processing software, hardware, and consulting .....	\$90,000
Survey control and bathymetry pilot test results will be used for the for physical science program .....	<u>\$110,000</u>
<b>Total:</b> .....	<b>\$400,000</b>

**Surveying**

The Survey department's mission is to provide survey support for spatial measurement and referencing of scientific data collected in the Colorado River ecosystem by GCMRC programs. This support may be in the form of precise measurement of geographic coordinates of a sample collected in the Canyon or in the generation of topographic maps used for erosion monitoring of terraces adjacent to the Colorado river. The Survey department is also responsible for establishing and maintaining accurate geodetic control in the Canyon that is essential for accurate geo-referencing of remotely sensed data and spatial analysis of resource data using modern image processing and GIS technologies. These technologies are critical to the integration and analysis of the diverse scientific data that have been collected in the Canyon over the past 15 years. Products of the Survey department include precise sample location coordinates, topographic maps, river channel maps and cross sections, digital elevation models, and digital terrain models. This information provides the basis for spatial analysis of data within the ecosystem using GIS software that in turn provides area and volumetric change detection capabilities of resources.

The Survey department was initiated in 1990 when GCES began the development of the GIS sites (Fig. 4.1). It became necessary to establish topographic control for these sites as well as all other research related mapping in the Grand Canyon. The development of sound topographic and mapping control required good survey control to build these spatial data sets. However, as a result of extremely difficult logistics and access to the river corridor, a reliable geodetic control network had never been established.

BOR remote sensing division contracted Horizon's mapping to establish GIS map coverage's using photogrammetric methods. David Evan's and Associates established GPS

control points, and ground control points were traversed and paneled by Banner and Associates.

In 1991 Joseph Mihalko (NPS surveyor) occupied the Banner ground control points for a soil mapping project by the USGS. He found that the control points did not meet their claimed accuracy and precision. As a result, GCES established a survey department to correct all previously established survey control as well as meeting all the research needs of the future.

The Survey department uses a variety of technology to assist in accomplishing its mission in a timely, cost effective manner that utilizes a minimum amount of personnel. These technologies include:

#### Global Positioning Systems

To include hand-held autonomous units, Static Differential, DGPS, RTK, as well as post-processed solutions.

- Conventional Survey Technology

To include Total Stations, electronic data collectors, Rangefinders, EDM's, etc.

- Hydrographic Technology

To include hydroacoustic and scan sonar, GPS and range/azimuth positioning, automated hi-speed data collection, seabed classification, and acoustic doppler data.

- Maps and Mapping Products

To include Plannimetric maps, Digital Terrain Models, Area and surface calculations, Volume calculations, change detection, habitat maps, and predictive modeling.

FY2000 objectives the Survey department intends to achieve are:

- Satisfy all RFP requirements. Based on 1998, the survey department will deploy crew and equipment for 4 separate RFP down-river trips for terrestrial and hydrographic data collection. The individual programs funding the research cover the survey costs of these trips.
- Development of a survey database for easy access and a seamless GIS interface.
- Development of archival protocols for GIS/Database interface for control, mapping products, and metadata
- Research and implement any current or developing management objectives in the execution of sound survey practices and procedures

The following FY2000 Survey operations support the remote sensing initiative:

- Complete a high precision Control Network from Glen Canyon Dam to Phantom Ranch for spatial-positioning of research sites in the river corridor and geo-referencing topographic, hydrographic, and remotely sensed data such as multispectral, hyperspectral, aerial photography. To date there is continuous control from Glen Canyon Dam to the end of GIS area 5. It is necessary that this control be established to achieve the objectives outlined in the *Physical Resource Program*.
- Ground truthing, geo-referencing, and image rectification of remotely sensed data.
- Hydrographic channel map of all GIS sites and between GIS sites as needs dictate and control is established in support of the Physical Resource Program sediment and flow modeling.
- Continue development of terrestrial ground topography maps. Terrestrial ground mapping in the Canyon is difficult and expensive. Technologies are currently being evaluated for achieving this objective as part of the Remote sensing initiative. The GCMRC will use only the most cost effective method which conforms to National Mapping Standards accuracy. Accurate terrestrial ground topography maps are essential for the sediment and hydrology model development being proposed by the *Physical Resource Program*.

Survey support of research activities funded by the GCMRC largely consist of trained GCMRC surveyors, assistants, and professional volunteers accompanying scientists in the field operating total station, GPS, or other sophisticated survey equipment. However, in circumstances where precise survey control or measurement is not needed (i.e. sub-meter), survey support may be limited to providing instruments and training to scientist for the collection of survey data. This allows for more efficient use of the limited GCMRC survey resources.

All survey control points, data, site maps, and other survey related information is documented and archived in the GCMRC survey department. GIS sites are archived using FGDC standards of metadata. All positional survey coordinates are archived in the AZ State Plane Coordinates (Central) system. Control points are photo documented as well as described by river mile, GIS site, etc. All survey control is made available to anyone with a legitimate need for spatial positioning. Survey products are usually submitted to specific research projects funded by GCMRC. Independent survey operations such as control are archived internally and provided to researchers as needed.

The GCMRC survey department tries to minimize all potential impacts to the Grand Canyon river environment. Whenever possible, we try to utilize all existing control/survey monumentation. This includes bolts, X-cuts, nails, and survey monuments. However, in some cases it is necessary to set new points. These points are very carefully selected to be unnoticeable by the average person. We try to select natural features in the rock to use as control points. On occasion, when absolutely necessary, we will scribe a small X on a rock. Extreme care is always taken to avoid any survey operations on or near cultural sites unless that site is specifically being mapped. While mapping cultural sites we are almost always accompanied by an archaeologist, usually NPS.

Another potential impact on the environment is the deployment of photogrammetry targets as ground control. These targets are laid on known control points for stereo rectification of aerial photography as well as other remote sensing applications. These panels provide a much less intrusive operation on a site than physically doing a ground survey. The panels are usually removed from the site within a month or the next GCMRC river trip.

**FY2000 Survey budget: \$16,000**

(not including remote sensing initiative support funded under Remote Sensing)

### Data Standards and Protocols

The purpose of data standards and protocols is to provide consistency in data collection, delivery, and presentation from disparate sources. 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 at different places at different times by different researchers in different disciplines. 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. A data standards committee will be formed which regulates this activity.

The ITP embraces the principles and objectives of the National Information Infrastructure, the National Biological Information Infrastructure, and the National Spatial Data Infrastructure. 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 ITP 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. Cooperation among contributing Tribes, institutions, and state and federal agencies investigating resources in the canyon concerning timely transmittal of data relating to the GCMRC study area is essential. Scientists will be expected to provide their data to GCRMC after a reasonable period of exclusive use, which is currently being addressed by the TWG working group on data protocols. Concerning some data, such as archaeological-site data which the Indian Tribes define as sensitive, or information on localized endangered species, a level of confidentiality will be necessary.

Data standard and protocol development will commence in FY99 and fall over into FY2000. Data standard and protocol development is primarily a manpower effort and is not

anticipated to have budget needs other than already programmed salaries to complete with the exception of perhaps travel and meetings.

**FY2000 Data Standards and Protocols budget: \$12,000**

**System Administration of Computers and Networks**

The GCMRC computing environment presently consists of multiple servers, workstations, laptops, printers, and other peripherals. The environment is spread across two separate computer networks, one at the Bank of America building and one at the USGS building. The two networks are linked together by a T1 telecommunications line between the two buildings. Most of the computers are PC types running the Windows NT operating system. In addition, over 30 applications are maintained on most systems. Applications are primarily off-the-shelf products.

Prior to 1997 and the hiring of an Information Technology Program Director, computer systems and networks at the GCMRC were largely maintained contractually with the BOR office in Salt Lake City. The computing environment consisted of several 486 and first generation Pentium class systems which were networked using thin ether net media and a Novell file server. The Bank of America building employee's were networked to the Salt Lake City office and Internet through a 56KB dedicated telecommunications line to SLC.

The USGS building computing environment evolved separately but was heavily influence by the methods and practices of the BOR SLC computer group except that the network infrastructure was provided and maintained by the USGS. The USGS was also delegated limited administration of the networked computing environment that was largely maintained by SLC. The network infrastructure provided by the USGS was 10baseT with T1 access to DOINet and the Internet. Local network support, 10baseT network media, and faster T1 telecommunication line provided for a much more robust networking environment than that at the Bank of America Building.

During the transition GCES to GCMRC, 20, then state-of-the-art, Pentium Pro systems were purchased for both the Bank of America building employees and USGS building employees ( 10 a piece). A Novell file server was also purchased for the USGS building employees. While this represented a considerable improvement in the GCMRC computing environment, the lack of dedicated local support and unreliable network

infrastructure at the Bank of America building contributed to a difficult computing environment. The contracted remote computer support was expensive and often did not lend itself to timely correction of problems encountered in the everyday operation of the environment.

In the summer of 1997, an Information Technology Program Director was hired and, among other things, assumed responsibility for the administration of the GCMRC computing and networking environment. A plan was developed to improve the internal GCMRC computing environment and extend its capabilities to facilitate the AM process.

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.

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.

Current goals for systems administration of computers and networks are:

- Remove the Novell servers from the Bank of America and USGS building networks. This will eliminate two, more or less, redundant servers from the GCMRC computing environment reducing cost and administration.
- Combine the two networks into one. This will drastically reduce maintenance and further standardize the environment. This is likely only to occur once the two offices are combined.
- Standardize all software applications and serve from an NT server. This will help reduce computer administration.
- Develop a standard configuration for all workstations. This will help reduce administration and allow user to maintain their personalized computing environment across systems.
- Develop and integrate a World Wide Web publishing environment into our overall computing environment to help make activities and data more accessible to constituents.
- Perform year 2000 check and correct deficiencies.
- Correct DOI EOI management control plan deficiencies.
- Continue to incorporate automation and enhancements capabilities into the overall computing environment as time and products become available.

It is anticipated that most of these activities will be completed in FY99. FY2000 activities will be primarily maintenance of the developed environment with enhancements. FY2000 System administration of computers and networks budget: \$120,000

**Total Information Technology Budget for FY2000: \$720,000**

Projected FY2000 DBMS budget: .....	\$150,000
FY2000 GIS budget: .....	\$ 10,000
Projected FY2000 Library budget: .....	\$12,000
FY2000 Remote Sensing budget: .....	\$400,000
FY2000 Survey budget: .....	\$16,000
FY2000 Data Standards and Protocols budget: .....	\$12,000
FY2000 System administration of computers and networks budget: .....	<u>\$120,000</u>

**Total Information Technology Budget for FY2000:.....\$720,000**

## **CHAPTER 5**

### **PROGRAM ADMINISTRATION AND ORGANIZATIONAL STRUCTURE**

The GCMRC organizational structure has been developed in response to GCMRC's mission and roles and responsibilities within the AMP and to ensure successful implementation of the FY 2000 Annual Plan. The GCMRC will be administered by a Chief and four program managers (physical, biological, socio-cultural, and information technologies) to oversee the individual resource areas and an extensive program of data analysis and management, GIS technology and information transfer, surveying and evaluation of remote sensing technologies. Together with the Chief, they will focus on program integration and evaluation of Colorado River ecosystem resource interactions in response to dam operations. One of these program managers will also serve as a deputy to the Chief and as Acting Chief in his/her absence.

In addition to their program management responsibilities, the program managers are also expected to remain subject area experts in their respective fields through the conduct of their own research on the Colorado River ecosystem, and to provide technical assistance in the form of expert analysis, opinion, and advice to the TWG and the AMWG as requested. This will include but is not limited to the annual State of the Canyon Resources Report, evaluation of the BHBF resource criteria, preparing draft biological assessments and other such synthesis and activities which may be requested. As appropriate, they will supervise additional technical staff.

The GCMRC will continue to conduct all logistics for its programs internally in FY 2000, with direct coordination with appropriate NPS offices. This approach has proven its cost-effectiveness in FY 1998 and similar cost savings are expected in FY 1999. In addition to cost savings, by running the logistics program in-house, GCMRC is able to ensure compliance with all NPS directives, consolidate and coordinate river trips, and create a level playing field so all researchers have an equal chance at competing for proposals and successfully implementing their projects. All river trip logistics and permitting, air photography, rescue, etc, is overseen by the logistics coordinator in cooperation with the

NPS. In FY 1997 and FY 1998 GCMRC initiated approximately 60 river trips annually. While an effort is being made to reduce the number of trips in FY 1999, GCMRC still expects to initiate between 50 and 60 river trips. Running these many river trips requires a full-time logistics coordinator and a full-time warehouse technician.

All completed proposals, Principal Investigator reports, GCMRC reports, cooperative programs, etc. are subject to independent peer review according to GCMRC's peer-review protocols. Monitoring and research proposals are subjected to independent external peer-review and awards are made competitively based on these reviews. All research proposed by GCMRC program managers and scientists also undergoes an independent external review. Similarly, all PI reports and GCMRC reports are subject to independent external review. Managing GCMRC's peer-review process requires 3 to 6 person months and is the responsibility of the Review Coordinator, currently a member of the Biological Resources Program staff. The Review Coordinator reports directly to the Chief and serves to see that the peer-reviews are overseen by someone one-step removed from the program activities to ensure the objectivity of the review, as specified in the DOI peer-review guidelines. In FY 2000, the Review Coordinator position will be filled by the GCMRC librarian.

A Cultural Resources Task Group operates to facilitate articulation between the Cultural Resource Program and the Programmatic Agreement program. The Task Group consists of the GCMRC Cultural Resources Program Manager, Reclamation's regional Archaeologist, NPS managers, and tribal representatives.

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

The Information Technologies program has personnel with specific responsibility for its Systems Administration, Data Base Management, GIS, Remote Sensing, and surveying activities. These personnel will assure critical timely support to managers and other stakeholders in their interactions with the GCMRC, especially in their requests for information. For example the surveying department is staffed by two full-time surveyors who provide GCMRC and PIs with high quality, cost-effective, and timely support of their

program and activities in the areas of terrestrial and bathymetric surveying, as well as remote sensing. Having in-house capability ensures familiarity with the challenges of surveying in the canyon and promotes reproducible, quality data critical to sound monitoring and research programs.

As called for in the GCDEIS, independent review panels will be utilized to evaluate GCMRC's Annual Plan, review proposals submitted to GCMRC for potential funding, review reports resulting from GCMRC sponsored activities, and provide advice to GCMRC and the AMWG. These panels may include the National Research Council, independent external peer-reviewers and review panels, and the SAB which can provide advice to both the AMWG and GCMRC on the effectiveness of the overall science program. With respect to the SAB, GCMRC proposes to designate a staff person to serve as the Executive Director who can provide leadership to the SAB and serve as the liaison officer to the AMWG and the GCMRC. It is anticipated that the role of Executive Director will require one to three person months annually.

#### **Tentative Program Schedule**

The tentative schedule for implementation of the FY 2000 annual plan is as follows:

January 12-13, 1999	AMWG review of FY 2000 Annual Plan and recommendations for implementation
January 29, 1999	Announcement of intent to issue RFPs
March 1, 1999	Review of FY 1998 program accomplishments and new monitoring and science protocols
March 1, 1999	Release of RFPs
March 15, 1999	Develop Overview package for potential researchers and reviewers
April 5, 1999	First Progress Report due on FY 1999 program activities
June 1, 1999	Receipt of Proposals for FY 2000 program
July 5, 1999	Second Progress Report due on FY 1999 program activities
August 2, 1999	Panel Review of FY 2000 Proposals
August 23, 1999	Notification of Intent to Award FY 2000 Contracts
September 17, 1999	Draft Final Report due on FY 1999 program activities

October 1, 1999	Award FY 2000 Contracts
October 1, 1999	Develop Logistics Plan for FY 2000 program
October 15, 1999	Draft FY 2001 Annual Plan and FY 2000 "State of the Colorado River Ecosystem Resources" report for review by TWG/AMWG
December 17, 1999	Final "State of the Colorado River Ecosystem Resources" report to AMWG.
December 31, 1999	Final Reports on FY 1999 programs with all contract deliverables
January 2000	AMWG approval of FY 2001 Annual Plan and recommendations for implementation

### **Adaptive Management Program Budget**

The FY 2000 budget for the Glen Canyon Dam Adaptive Management Program is \$7,672,000. Of this total, \$1,443,000 is programmed for the management and administration of the AMP and the PA, with the remaining \$6,229,000 programmed for GCMRC and its implementation of the FY 2000 Annual Plan.

Following are the proposed budget allocations for the FY 2000 AMP and the GCMRC FY 2000 Annual Plan.

### AMP Program and Programmatic Agreement

• Bureau Administration of AMWG .....	116,000
• Bureau Administration of TWG .....	80,000
• Bureau Administration of SAB .....	47,000
• Bureau Administration of AMP:	
A. Program Management .....	106,000
B. Biological Opinion .....	71,000
C. Programmatic Agreement .....	973,000
• Bureau/Native American Support .....	50,000 <sup>15</sup>
<b>Subtotal</b> .....	<b>1,443,000</b>

### GCMRC Program and Operating Costs

A. Bureau Support Services .....	123,000
B. Operations, Personnel, Contract Services .....	2,023,000
C. Physical Resources Science .....	700,000
D. Biological Resources Science .....	1,500,000
-- Integrated water quality monitoring plan <sup>16</sup>	
E. Socio-cultural Resources Science .....	355,000
F. Information Technologies Program .....	320,000
G. Remote Monitoring Technology .....	400,000
H. Independent Review Panels .....	155,000
I. Logistics .....	<u>653,000</u>
<b>Subtotal</b> .....	<b>6,229,000</b>
 <b>TOTAL</b> .....	 <b>\$7,672,000</b>

<sup>15</sup>These funds are obtained by Reclamation from Native Affairs Office appropriated funds.

<sup>16</sup> The Integrated water quality activities, which includes monitoring and research in Lake Powell and the Colorado River ecosystem will be primarily funded out of Reclamation O&M funds, coordinated with Reclamation and the Lake Powell group, and conducted by GCMRC, and/or its contractors. That portion of the Integrated water quality activities conducted in the mainstem of the Colorado River below Glen Canyon dam will be funded primarily out of GCMRC funds.



## **Appendix A**

### **DRAFT GLEN CANYON DAM MANAGEMENT OBJECTIVES June 10, 1998**

#### **INTRODUCTION**

Initial development of Objectives, Information Needs and Management Actions can and usually does occur by individual stakeholders. However, discussion and agreement on Management Objectives, Information Needs, and Management Actions to be included in the Adaptive Management Program must occur in an open forum of the Technical Work Group (TWG). Final approval of Management Objectives, Information Needs and Management Actions to be used in developing Grand Canyon Monitoring and Research Center (GCMRC) monitoring and research plans is by the Adaptive Management Work Group (AMWG).

#### **PURPOSE**

The purpose for developing Management Objectives is to define measurable standards of desired future resource conditions which will serve as objectives to be achieved by all stakeholders in the Glen Canyon Dam Adaptive Management process. These Management Objectives are framed within the Preferred Alternative and implemented by specific dam operating criteria and other actions taken by the Secretary to protect, mitigate adverse impacts to, and improve the values for which the Glen Canyon National Recreation Area and Grand Canyon National Park were established.

Stakeholder Information Needs define the specific scientific understanding required to obtain specified Management Objectives. These will be reviewed by the National Research Council for FY97 and FY99.

Management Objectives and Stakeholder Information Needs are the basis for development and implementation of long-term strategic and annual monitoring and research programs. Research plans are developed annually and must address specified Stakeholder Information Needs.

The GCMRC and TWG will report annually on progress related to individual Management Objectives, Information Needs, and Management Actions, and will revise Management Objectives, Information Needs and Management Actions as needed.

## BACKGROUND

The Glen Canyon Dam Final Environmental Impact Statement states that an Adaptive Management Program (AMP) will be initiated following the issuance of a Record of Decision by the Secretary of the Interior. The concept of adaptive management is based on the recognized need for operational flexibility to respond to future monitoring and research findings and varying resource conditions. The AMP will monitor the effect of the operating criteria adopted by the Secretary pursuant to the Grand Canyon Protection Act of 1992 and determine if the anticipated results (Management Objectives) in the Preferred Alternative of the Environmental Impact Statement and the Record of Decision are being reached. If it is found that the objectives are not being reached, the AMP will develop proposals for modifying to the Glen Canyon Dam Operations, modifying the Management Objectives, and/or the exercise of other authorities under existing laws to achieve the anticipated results (Management Objectives).

Principles which guided the design of the Adaptive Management Program (AMP) include:

1. Monitoring and research programs will be designed by GCMRC in direct response to objectives and information needs of the Adaptive Management Work Group (AMWG).
2. A process is required to coordinate and communicate AMWG information needs to researchers and to develop recommendations for decision making.

The AMWG recognized the desirability of beginning the process of clarifying and consolidating the management objectives of organizations that participate in the AMP in order to clearly identify information needs to researchers. Initiating this process facilitates and expedites monitoring and research designs.

## PROCESS

The procedure selected for development and approval of (Stakeholder) Management Objectives and Information Needs is as follows:

Defining Goals, Objectives and Information Needs. Defining terms were developed by Stakeholders as a guide to articulation of Goals, Objectives, Information Needs and Management Actions as follows:

<u>TERM</u>	<u>DESCRIPTORS</u>
Goals	<ul style="list-style-type: none"> <li>- Directional Statement</li> <li>- Qualitative</li> <li>- Rarely Attained</li> <li>- Generic</li> </ul>
Objectives	<ul style="list-style-type: none"> <li>- Defines desired Future Resource Condition</li> <li>- Quantifiable</li> <li>- Has Timelines with Target Dates</li> </ul>

- Concise
  - Within Legal Boundaries
- Information Needs**
- Uses Information Collection Process
  - Results in Product, Outcome, Report, Model, Data
  - Incorporates Data Collection, Analysis, Synthesis, etc.
  - Accomplishment associated with Management Objective
- Management Actions**
- A Management Activity:
  - Has Timeline and Target Completion Date
  - Help achieve a Management Objective
- Within Legal Boundary

Development of Objectives, Information Needs and Management Actions. The Management Objectives are initially designed to be in accord with the Environmental Impact Statement: these objectives do not necessarily define the ideal desired future resource condition. Rather, they describe, clarify and detail the resource objectives described in the EIS for the preferred alternative. Under the operating criteria signed by the Secretary, the GCMRC will monitor the resources and periodically inform the TWG and AMWG regarding the condition of the resources. If the operation of Glen Canyon Dam under the criteria fail to meet these objectives the AMWG will either recommend operational changes to the Secretary

The following draft Management Objectives, Information Needs and Management Actions are still in development and will be presented to the AMWG at its July 1998 meeting for approval. They are being designed to guide GCMRC program planning through the period FY1999-2003 and will be reviewed annually.

## ECOSYSTEM ASSESSMENTS

**MO 1:** Develop a conceptual model of the Colorado River ecosystem.

IN 1.1 The 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 changes in the systems.
- (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 Lake Powell and the Colorado River ecosystem and associated resources.

## BIOLOGICAL RESOURCES

### A. AQUATIC RESOURCES

Goal: To protect, restore, and enhance native fish populations in Glen and Grand Canyons, as well as recreationally-important cold water sportfish populations in Glen Canyon, and the aquatic foodbase upon which they depend.

Definition: Aquatic resources include invertebrates, algae, macrophytes, and fish, with specific concerns for Threatened and Endangered Species, and plant and animal matter contributing to the primary food base.

### MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

#### A.1 - Aquatic Food Base

Definition: The aquatic food base is comprised of organisms originating from aquatic and riparian sources. It includes organisms such as *Cladophora* and other aquatic plants including macrophytes, diatoms, detritus, aquatic and terrestrial insects, and may include fish.

**MO 1:** Maintain and enhance the aquatic food base in the Colorado River ecosystem to support desired populations of native and non-native fish. At a minimum, maintain continuously inundated areas for *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge levels from Glen Canyon Dam.

- IN 1.1 Determine status and trends in aquatic food base species composition and population structure, density and distribution and the influence of ecologically significant processes.
- IN 1.2 Determine the effects of past, present, and future dam operations under the approved operations criteria on the aquatic food base species composition, population structure, density, and distribution in the Colorado River ecosystem.
- IN 1.3 Determine the aquatic food base species composition, population structure, density, and distribution required to maintain desired populations of native and non-native fish in the Colorado River ecosystem.

*(IN's 1.7 through 1.12 were moved to Appendix Biological Resources 1)*

## A.2 - Trout

**MO 2:** In the Colorado River downstream of Glen Canyon Dam to the confluence of the Paria river, sufficient ecological conditions (such as habitat, foodbase and temperature) should be maintained, which in conjunction with management by Arizona Game and Fish will produce a healthy self-sustaining population of at least 100,000 Age II+ rainbow trout that achieve 18 inches in length by Age III with a mean annual relative weight (Wr) of at least 0.90.

- IN 2.1 Determine ecosystem requirements, population character and structure to maintain naturally reproducing populations of Age II plus fish at 100,000 population levels in Glen Canyon.
- IN 2.2 Determine trends in rainbow trout population size, character and structure in Glen Canyon.
- IN 2.3 Evaluate harvested and field sampled rainbow trout to determine the contribution of naturally reproduced fish to the population in Glen Canyon.
- IN 2.4 Determine the availability and quality of spawning substrates in the Glen Canyon reach, necessary to sustain the rainbow trout fishery.
- IN 2.5 Determine the growth and condition of rainbow trout in Glen Canyon.
- IN 2.6 Define criteria (e.g., temperatures, flow regimes, contaminants, metals, nutrients) for sustaining a healthy rainbow trout population in Glen Canyon.
- IN 2.7 Determine the trophic relationship between trout and the aquatic food base including the size of the aquatic food base required to sustain the desired trout population in Glen Canyon.

## A.3 - Native Fish:<sup>1</sup>

### HUMPBACK CHUB (HBC)

**MO 3:** Enhance the Little Colorado River population of HBC above 1987 levels determined by April/May hoop-net monitoring in the lower 1,200 meters of the Little Colorado River. (Focused at fish >200mm, and should include a fish health assessment.) Maintain or enhance levels of recruitment of HBC in the Little Colorado River.

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<sup>1</sup>Note that Critical Habitat has been designated in GC for both razorback sucker and humpback chub. As Critical Habitat for razorback sucker, GC may have a role in recovery as a reintroduction site. Such actions would need to be guided by the recovery plan (now in prep) or regional implementation plans.

**MO 4:** Maintain or enhance levels of recruitment of HBC in the mainstem as indexed by size frequency distributions and presence and strength of year-classes. (Focused at young-of-year and juvenile fish, and should include a fish health assessment.)

*(IN 3/4 relates to MO's 3 & 4)*

- IN 3/4.1 Determine adult HBC populations and evaluate life history schedules, population health, and reproductive success. *(Fall 97 RPM 1)*
- IN 3/4.2 Determine levels of recruitment of humpback chub in the mainstem and the LCR.
- IN 3/4.3 Develop and implement a program to evaluate effects of factors limiting overwintering survival of young-of-year HBC in the Grand Canyon (Fall 97, RPM 1). The program shall evaluate the effects of future test flows (i.e., 25,000 cfs and greater) from October through February on young-of-year HBC recruitment and over-wintering survival, habitat restrictions, predation, reduced sediment loads, and cold water temperatures. (Fall 97 Test Flow T&C 1) This is to include specific hypotheses as follows:
  - a. test flows do not significantly reduce densities of young-of-year HBC; and (Fall 97 Test Flow T&C2)
  - b. test flows do not significantly affect/alter nearshore habitats used by native fishes. (Fall 97 Test Flow T&C 2)
- IN 3/4.4 Determine and identify surrogate native or non-native fishes for evaluation of health factors for HBC and investigate trends in diseased fish.
- IN 3/4.5 Develop a habitat suitability and availability index, which may include backwaters and near shore habitat, using existing data for HBC. Determine the effects of mainstem hydrology on the number of nearshore rearing habitats, environmental conditions in these habitats, and their successful utilization by HBC. (RPM 1.C.iii)
- IN 3/4.6 Evaluate impacts of sampling methods and recreation use (e.g., habitat change, hooking mortality) on humpback chub populations.
- IN 3/4.7 Determine origins of fish food resources, energy pathways, and nutrient sources important to their production, and the effects of Glen Canyon Dam operations on these resources. (RPM 1.C.vi) Evaluate linkages between the aquatic food base and the health and sustainability of HBC populations.

- MA 4.1 Limit future test flows (i.e., 25,000 cfs and greater) from October through February until a program has been designed and implemented to evaluate and assess factors determining young-of-year HBC recruitment and overwintering survival. (*Fall 1997 RPM 1*)
- MA 4.2 Conduct BHBFs during periods that avoid concentrations of young-of-year HBC (*1996 BHBF, HBC RPM 1*)
- MA 4.3 Report the results of the monitoring, including complete and accurate records of all incidental take that occurred during the course of the 1996 BHBF to the Service the same date that a draft and final is submitted to Reclamation. Progress reports provided to Reclamation will also be provided to the Service. This report will also describe how the terms and conditions of all reasonable and prudent measures in this incidental take statement were implemented, including any deviations from the test flow and explanation for need to change. (*1996 BHBF T&C 2*)
- IN 3/4.8 Determine effects on physical habitat used by young fishes, food base, and direct effect on larval, juvenile, and adult native and non-native fishes of 1996 BHBF. Develop methods to detect changes in numbers of HBC or their habitat from 1996 BHBF. (*1996 BHBF HBC RPM 3*)
- IN 3/4.9 Develop a method to determine the number of HBC suspected to be lost during special flows and the relationship of this loss to the Grand Canyon population. (*T&C 2*)
- IN 3/410 Develop a strategy to sustain notable year classes of HBC that are susceptible to being transported downstream into unfavorable habitats. (*T&C 2*)
- IN 3/4.11 Acquire an understanding of the frequency of HBC year classes in the system susceptible to being transported downstream into unfavorable habitats and impact of flows on that year class. (*T&C 2*)
- IN 3/4.12 Determine impacts of flows on young HBC during study flows, and develop methods of detecting changes in numbers, to assist in establishing levels of incidental take. (*RPM*)
- IN 3/4.13 Develop biological criteria governing the implementation of special flows that will assure that the level of incidental take of HBC is not exceeded. (*RPM*)
- IN 3/4.14 Evaluate all test flows in RPM, using monitoring and research programs and, determine potential impacts to threatened and endangered fish.

**MO 5:** Remove jeopardy for the HBC in the Colorado River ecosystem (*B.O. 1994*).

- MA 5.1 Evaluate and implement, as appropriate, a selective withdrawal program for Lake Powell waters (RPM 1.B).
- IN 5.1 Determine a set of possible temperature changes in the mainstem Colorado River resulting from implementing selective withdrawal (RPM 1.B.i).
- IN 5.2 Determine the anticipated effects on HBC and other native populations which may result from installing a selective withdrawal structure for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam. Determine the range of temperatures for successful larval fish development and recruitment and the relationship between larval/juvenile growth and temperature (RPM 1.B.ii).
- IN 5.3 Determine the effects of dam operations under the approved operating criteria, including installing a selective withdrawal structure for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam, on:
- a. reproductive success, growth, and survivorship of Grand Canyon fishes;
  - b. parasites and disease organisms of endangered and native fishes in the Colorado River ecosystem;
  - c. temperature induced interactions between native and non-native fish competitors and predators; and
  - d. the effects of temperature, including seasonality and degree, on *Cladophora* and associated diatoms, *Gammarus*, and aquatic insects. (RPM 1.B.iii, 1.B.iv, 1.C.i and 1.C.vii)
- IN 5.4 Evaluate effects of withdrawing water on the heat budget of Lake Powell, effects of potentially warmer inflow into Lake Mead, and the concomitant effects on the biota within both reservoirs. Evaluate the temperature profiles along with heat budget for both reservoirs Evaluate effects of reservoir withdrawal level on fine particulate organic matter and important plant nutrients to understand the relationship between withdrawal level and reservoir and downstream resources. (RPM 1.B.v and 1.B.vi)
- IN 5.5 Evaluate when to release warmer temperature water, what seasonal pattern of releases to use to avoid establishment of permanent backwater areas, and how best to use floods, to limit expansion or invasion of non-native fish species. (RPM 1B)

MA 5.2 Develop a management plan for the LCR to protect HBC spawning population and habitat.

**MO 6:** Establish a second spawning aggregation of HBC downstream of Glen Canyon Dam (RPM 4).

IN 6.1 Develop criteria for defining self-sustaining populations of HBC.

IN 6.2 Assess feasibility of establishing a second population of HBC downstream of Glen Canyon Dam including other current aggregations.

MA 6.1 Develop and implement, as appropriate, a plan for establishing a second population of HBC.

### **RAZORBACK SUCKER (RBS)**

**MO 7:** Remove jeopardy for the Razorback Sucker in the Colorado River ecosystem.

IN 7.1 Determine opportunities to establish RBS in the Grand Canyon (e.g., possible development of spawning and rearing areas). (RPM 3)

### **FLANNELMOUTH SUCKER (FMS) & OTHER NATIVE FISH**

**MO 8:** Achieve healthy, self-sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem, with special emphasis on flannelmouth sucker in Glen Canyon based upon the capability of the habitat to support those fishes.

IN 8.1 Determine the status of flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem, with special emphasis on flannelmouth sucker in Glen Canyon.

IN 8.2 Determine population dynamics, distribution, and other life history traits of native fish species.

IN 8.3 Determine historic and current character and structure of native fish populations.

IN 8.4 Determine historic and current ecosystem requirements (habitat, spacing, food source, interdependencies, etc.) of native fish species.

IN 8.5 Determine and define impacts of alternative flow regimes on native fish population character and structure.

IN 8.6 Determine requirements to maintain/enhance self-sustaining populations of native fish.

*(IN's 10.1 through 10.14 were moved to Appendix Biological Resources 2)*

**MO 9:** Attain riverine conditions, including appropriate habitat, that support all life stages of endangered and native fish species.

- IN 9.1 Design experimental flows and studies to include high steady flows in the spring and low steady flows in the summer and fall during low water years (RPM 1.A). Improve the mean for determining the definition of a "low water year" that would initiate research flows in a given year.
- IN 9.2 Quantify to the extent possible the effects of spring high steady flows and summer and fall low steady flows on endangered and native fish (RPM 1.a).
- IN 9.3 Determine relationships among tributary hydrology, reproductive success of fishes, and the abundance of fishes in mainstem rearing habitats (RPM 1.c.ii).
- IN 9.4 Assess biotic interactions between native and non-native fishes, particularly those that occur in nearshore rearing habitats affected by dam operations (RPM 1.C.iv).

#### **A.4 - Native /Non-Native Fish Interactions**

**MO 10:** Minimize, to the extent possible, competitive and predatory interactions between native and non-native fishes.

- IN 10.1 Define areas and conditions of existing and potential interactions
- IN 10.2 Determine key attributes associated with competitive and predatory interactions
- IN 10.3 Determine methods for minimizing competitive and predatory interactions with or without isolation
- IN 10.4 Determine the species composition, relative abundance, and size class structure of non-native fishes in the Colorado River ecosystem and important tributaries
- IN 10.5 Identify existing and potential sources of interaction (predatory, competitive) between extant non-native fishes and native fishes of the Colorado River ecosystem and important tributaries

- IN 10.6 Evaluate the effects of various flow regimes under the approved operating criteria, including beach/habitat building flows, habitat maintenance flows, and endangered fish research flows on the distribution and abundance of native and non-native fishes in the Colorado River ecosystem and important tributaries

## **B. TERRESTRIAL and RIPARIAN RESOURCES**

Goal: To maintain a diversity of terrestrial and riparian species, including where possible existing remnants of native communities, associated with ongoing natural evolutionary and ecological processes giving priority to native species (i.e., those occurring not directly because of man).

Definition: Terrestrial and riparian resources include, among other things: vegetation, insects, amphibians, reptiles, avifauna, and mammals. Riparian and terrestrial vegetation includes both native and non-native plant species, and include natural species; balanced successional stages; unique plants and threatened and endangered plants.

### **MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS**

#### **B.1 - General Terrestrial Resources**

**MO 11:** Protect, restore, and enhance survival of native and special status species (federal, tribal, and state designations). Ensure that the required habitat for these species is preserved.

- IN 11.1 Define and specify ecology of native faunal components, especially threatened and endangered species; including evolutionary and environmental changes, natural range of variation, linkages, interdependencies, and requirements.
- IN 11.2 Determine species population characteristics to detect departures from natural range of variation.
- IN 11.3 Determine changes, declines in special status species and characterize ecosystem changes to benefit species.
- IN 11.4 Identify and characterize riparian wildlife habitat types along the river corridor.
- IN 11.5 Develop a comprehensive wildlife habitat map (using remote sensing and GIS) for the river corridor for high priority species (mammals, amphibians, reptiles, birds).
- IN 11.6 Evaluate/monitor leopard frog populations within Glen Canyon. Determine effects of dam operations on these populations (flooding, desiccation, loss of habitat).

- IN 11.7 Determine feasibility of establishing other populations of leopard frogs within the river corridor.
- IN 11.8 Identify and evaluate other sensitive amphibian and aquatic reptilian species, i.e., red spotted toads, Woodhouses toads, canyon tree frogs.

**MO 12:** Maintain a natural age-class distribution of wildlife species throughout the majority of natural range in Glen and Grand Canyons, emphasizing the need to recruit into breeding age classes.

- IN 12.1 Identify terrestrial species potentially affected by dam operations and determine effects on distribution, abundance, and population structure.
- IN 12.2 Determine species' natural ranges (pre and post dam).
- IN 12.3 Determine historic age class distribution (pre and post dam).
- IN 12.4 Assess natural range and age class disruption, changes, constraints, probable long-term viability implications to species; assess alternate habitat, ecology associations (specifically age class); and ecosystem associations.
- IN 12.5 Determine impacts of alternative operating criteria on ecosystem and ecology requirements of species.

### **B.1. - Avifauna**

**MO 13:** Protect, restore, and enhance survival of native and special status avifauna.

- IN 13.1 Define and evaluate food chain associations, interdependencies, requirements, etc. for native avifauna, including the Peregrine Falcon, Southwestern Willow Flycatcher, and other special status species (e.g., Yellow-billed Cuckoo).
- IN 13.2 Determine impacts of dam operations under approved operating criteria on avifauna food chain associations.
- IN 13.3 Determine peregrine falcon breeding sites in Glen Canyon and Grand Canyon. (Conservation Recommendation 2)
- IN 13.4 Study peregrine falcon population dynamics and determine their relationship to the changing riparian ecosystem for meeting life stage requirements. (Conservation Recommendation 3)

- IN 13.5 Determine bald eagle habitat utilization and foraging patterns and their relationship to dam operations under approved operating criteria and perform additional bald eagle monitoring where deemed feasible. (Conservation Recommendation 4)

## **B.2 - Kanab Ambersnail**

**MO 14:** Sustain populations of Kanab ambersnail wherever they currently exist within the Colorado River ecosystem.

- IN 14.1 Determine specific habitat characteristics required by the KAS. (T&C 3--p.41)
- IN 14.2 Determine special flow impacts on Kanab ambersnail to assure that the level of incidental take is not exceeded. (I. T. - p.40)
- IN 14.3 Complete a census of the population and characterize the habitat. Once habitat requirements are determined, other potential habitat sites within the Grand Canyon corridor will be surveyed to determine species presence and recovery potential. (Conservation Recommendation 5--p.43)
- IN 14.4 Survey KAS habitat before and after any flow greater than 25,000 cfs to determine population and its species response to disturbance and ability to recover. (T&C 4, p.42; and RPM)
- IN 14.5 Determine Kanab Ambersnail life history schedule for populations in the Colorado River ecosystem. (Conservation Recommendation 5)
- IN 14.6 Evaluate and monitor KAS populations within the Colorado River ecosystem. Determine ecological characteristics susceptible to changes in dam operations, i.e., population size, habitat needs, life history requirements.
- MA 14.1 Protect the habitat necessary for the survival of the existing population of Kanab ambersnail. (Incidental Take--p.40)
- MA 14.2 Do not allow high flows, or a controlled flood, to destroy more than 10% of the existing KAS occupied habitat in Grand Canyon. (Incidental Take--p.40)
- MA 14.3 Develop agreed upon research protocol and conduct research in such a manner as to minimize disturbance to the KAS population and habitat. (T&C 3--p.41)
- MA 14.4 Before another BMBF (45,000 cfs or greater), Reclamation will enter into informal consultation with the U.S. Fish and Wildlife Service and Arizona Game and Fish Department to:

- MA 14.4a evaluate the test flow studies (RPM 2, 1996 BHBF);
- MA 14.4b evaluate the establishment or discovery of a second population of Kanab ambersnail in Arizona (RPM 2, 1996 BHBF); and
- MA 14.4c evaluate incidental take. (RPM 2, 1996 BHBF)
- MA 14.5 Continue coordination with the Interagency Kanab Ambersnail Working Group to establish or discover a second population of the Kanab ambersnail in Arizona. (Fall 97 Flow T&C 4)
- MA 14.6 Monitoring of the project area and other areas that could be affected by the proposed action shall be done to ascertain take of individuals of the species and/or of its habitat that causes harm, harassment, or death to the species. This monitoring will be accomplished using the following protocol:
  - MA 14.6.a "A Draft Proposal to Assess, Mitigate and Monitor the impacts of an Experimental High Flow from Glen Canyon Dam on the Endangered Kanab Ambersnail at Vaseys Paradise, Grand Canyon, Arizona" (Stevens *et al.* 1995b).
  - MA 14.6.b In order to more accurately determine elevation of river stage at the range of flow that will be experienced during the test flow, and for use in developing a stage discharge relationship for future flow, the placement of a stage recorder, such as a pressure transducer coupled to a recorder should be deployed, if possible, in the mainstem at an appropriate site near the Kanab ambersnail population. The U.S. Geologic Survey should be contacted regarding the possibility of changing the location of a stage recorder to be used in test flow studies to the Kanab ambersnail site.
  - MA 14.6.c SALVAGE PROTOCOL. Kanab ambersnail specimens found dead, or taken as part of research activities, shall be collected and held as specified in the AGFD and NPS permit, with final deposition in a suitable museum collection such as at Northern Arizona University (1996 BHBF KAS T&C 1)
- IN 14.7 Determine changes in populations, health, and character of Kanab ambersnail, due to dam operations(?)

**MO 15:** Establish or discover and ensure the continued existence of a second population of Kanab Ambersnail in Arizona.

- IN 15.1 Determine genetic similarities and differences among populations of Kanab ambersnail.
- IN 15.2 Investigate the transplant success of vegetation important to the Kanab ambersnail:
- IN 15.2a Investigate success of temporarily removing *Mimulus*, *Nastertium*, or other appropriate vegetation into a temporary holding facility, and replanting. (1996 BHBF CM 5a)
  - IN 15.2b Investigate success of temporarily/permanently relocating *Mimulus*, *Nastertium*, or other appropriate vegetation. (1996 BHBF CM 5b)
- MA 15.1 Minimize future take and support salvage and refugia population(s) of KAS (Fall 97 Test Flow CM 1)
- MA 15.2 Provide logistical support to the Arizona Game and Fish Department's proposal to establish vegetation for the refugium population of the Kanab ambersnail at the Phoenix Zoo, and subsequent support for the transfer of ambersnails when permit and weather conditions permit. (Fall 97 Flow T&C 2)

#### B. 4 - Vegetation

**MO 16:** Maintain, enhance or restore vegetative communities made up of diverse groups of native riparian and upland species with special emphasis on preservation of unique plant communities and special status species at different stages of succession and at different elevations above the water line.

- IN 16.1 Determine distribution and abundance of native and non-native riparian and upland vegetation, including federal-, state- and tribal-listed sensitive species, old high water zone, new high water zone, and nearshore marshes.
- IN 16.2 Identify and quantify the OHWZ (above 150,000 cfs) and NHWZ (between 45,000 and 150,000 cfs) vegetation types (communities) within the Colorado River ecosystem:
- (a) Develop a comprehensive vegetation map for the Colorado River ecosystem.
  - (b) Determine populations dynamics and changes due to dam operations under approved operating criteria.
  - (c) Determine habitat requirements and reproductive biology of principal species.

- IN 16.3 Determine change in extent or abundance of the OHWZ and NHWZ plant communities. Link monitoring to site specific studies to determine species diversity.
- IN 16.4 Determine the effects of current and proposed dam operations under approved operating criteria on these communities.
- IN 16.5 Determine the ecology of the principal woody species (reproduction, establishment) within the OHWZ. Quantify the effects of dam operations under approved operating criteria on this ecology.
- IN 16.6 Evaluate impacts of dam operations under approved operating criteria on establishment of and impacts from exotic plant species.

## CULTURAL RESOURCES

Goal: To preserve cultural resource in situ wherever possible, and develop, knowledge of the resource for future generations.

Definition: Cultural resources include prehistoric and historic archaeological sites, structures and properties of interest to all Americans. Of particular importance are traditional cultural properties, sacred sites, collection areas, and other resources that are important to Native Americans in maintaining their cultural heritage, lifeways, and practices. Cultural resources are nonrenewable and irretrievable if lost.

### MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

**MO 1:** Conserve *in situ* all the downstream cultural resources and take into account Native American cultural resource concerns in the Colorado River ecosystem.

- IN 1.1 Monitor cultural sites potentially impacted by Glen Canyon Dam operations to determine present condition and rate of change to assess: types of degradation, threats; rates of degradation; define immediacy of threats to resources; protection methodologies; protection, monitoring and research costs
- IN 1.2 Develop data systems to assess variable risk of damage/loss of differing resources/sites from preferred and alternative strategies and operating criteria
- IN 1.3 Characterize all cultural resource sites as to the specific associated management/research needs, i.e.; preservation, stabilization, documentation, etc.; under alternative operating criteria
- IN 1.4 Preservation, stabilization and/or documentation of cultural resources as impacted by sediment resources associated with alternative operating criteria
- IN 1.5 Preservation, stabilization of flood terraces holding cultural resources
- IN 1.6 Evaluate flood terrace stability necessary to maintain cultural resources and terraces at pre-dam conditions
- IN 1.7 Evaluate methodology for correlating recreational sites use and cultural resource impacts.

**MO 2:** If *in situ* conservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with a scientific approach.

IN 2.1 Characterize through scientific study and data development all assumed historical and current values, including scientific values, of resources to tribal nations and to general public

IN 2.2 Develop research designs and costs associated with data recovery

**MO 3:** Protect, and maintain physical access to and use of traditional cultural properties and other cultural resources, where such access and use may be impacted by dam operations.

IN 3.1 Characterize historic and current traditional cultural associations of all sites associated with impacts of dam operating criteria

**MO 4:** Maintain and integrate all appropriate cultural data recovered from monitoring, remedial, and mitigative action and incorporate these data into the evolving research designs and mitigative strategies for understanding the human occupation and use of the Colorado River ecosystem.

IN 4.1 Develop evolving research designs and/or other methods including synthesis of existing available data and GIS for understanding human occupation and use.

## SOCIO-ECONOMIC (HYDROPOWER)

Goal: To maximize the value of long term firm power and energy generation within the criteria and operating plans established by the Secretary under Section 1804 of the Grand Canyon Protection Act.

Definition: A product of the Glen Canyon Power plant is electrical generation. The facility contributes significant power to rural electrical associations, public municipalities, irrigation districts and Federal and State facilities in the Southwestern and Rocky Mountain areas of the United States.

### MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

**MO 1:** Maximize the value of long-term power and energy generation within the criteria and operating plans established by the Secretary under Section 1804 of the Grand Canyon Protection Act<sup>2</sup>.

- IN 1.1 Continue to monitor the amount of revenues collected from the generation of electrical power at the Glen Canyon Power plant.
- IN 1.2 Continue to account for the financial/economic cost of the operational changes at Glen Canyon Dam due to the ROD including rate impacts to CRSP long-term firm electrical customers.
- IN 1.3 Calculate the financial costs of research flows so that these costs can be declared "non-reimbursable" (as defined by Section 1804 of the Grand Canyon Protection Act)
- IN 1.4 Monitor any difficulties in operating an integrated electrical system, including regulating a load control area  
(*Recommendation: Dave Garrett will clarify this with Clayton Palmer*)

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<sup>2</sup>The data needed to measure and evaluate power production is already routinely collected by the USBR and WAPA (no data gathering is required of GCMRC).

## PHYSICAL

### WATER RESOURCES

Goal: To operate Glen Canyon Dam for water supply and water quality consistent with existing law and policy.

Definition: Water resources include all aspects of water quantity and quality. The "Law of the River" directs the operations of Glen Canyon Dam including monthly and annual release patterns and reservoir contents and elevations. Although of more recent concern, water quality as it relates to changes over time is of specific concern.

### MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

**MO 1:** The Secretary shall Operate Glen Canyon Dam in a manner fully consistent with the Record of Decision and subject to the "Law of the River," including but not limited to the following: Grand Canyon Protection Act of 1992, the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona vs. California, and the provisions of the Colorado River Storage Project Act of 1956, and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin.

IN 1.1 Annually collect and report Glen Canyon Dam flow release information.

**MO 2:** Maintain water quality at levels appropriate to support physical, biotic, and human resource needs of various ecosystems downstream of Glen Canyon Dam as mandated by the Grand Canyon Protection Act and incorporated into the Record of Decision.

IN 2.1 Monitor water quality, composition and temperature and compare to applicable standards.

IN 2.1a Quantify current selenium levels in water discharged from Glen Canyon Dam. Determine how selenium concentrations are affected by dam operations.

IN 2.1b Determine/quantify the dynamics of major cations, anions and nitrate/phosphate ratios resulting from dam operations.

IN 2.2 Evaluate feasibility of short term or long term changes of water temperature through selective withdrawal.

## SEDIMENT RESOURCES

Goal: To maintain a range of sediment deposits over the long-term, including an annually flooded bare-sediment (unvegetated) active zone, a less frequently flooded vegetated zone, terraces (within the 45,000 cfs river stage), and backwater channels. Managing sediment resources will be on a reach-scale basis. Should significant and localized adverse impacts occur, site-specific mitigation would be considered.

Definition: Sediment resources include a broad array of material, ranging from suspended fines to coarse gravels. Primary interest relates to both material in suspension, which affects benthic capability, as well as stored sediment in beaches and channel margins, which affects recreation.

## MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

**MO 1:** Maintain a long-term balance of river-stored sand to support maintenance flow (in years of low reservoir storage), beach/habitat-building flow (in years of high reservoir storage), and unscheduled flood flows. Maintain system dynamics and disturbance by annually (in years which Lake Powell water storage is low) redistributing sand stored in the river channel and eddies to areas inundated by river flows between 20,000 cfs and maximum power plant capacity.

- IN 1.1 Define historical and current (character and structure) levels of river stored sediment in system and associated flow regimes
- IN 1.2 Define minimal levels of river stored sediments necessary to maintain long term sandbar, backwater, instream sediment deposits
- IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches
- IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources
- IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment.

**MO 2:** As a minimum for each reach, maintain the number and average size (area and thickness) of sandbars and backwaters between the stages associated with flows of 8,000 and 45,000 cfs that existed during the 1990/91 research flows.

- IN 2.1 Characterize sandbar/backwater baselines and character and structure in 1990/91
- IN 2.2 Working with various resource agencies and specialists, select most appropriate flow levels/regimes under the approved operating criteria to determine baseline for comparisons for all resources
- IN 2.3 Monitor future changes in sediment and define balances (channel, banks, bars) and hydraulic processes necessary to maintain 1990/91 sandbar levels
- IN 2.4 Evaluation of flow regime (under the approved operating criteria) impacts on terrace and cultural resources
- IN 2.5 Evaluate historical sandbar/backwater change, and develop methods for predefining beach and sandbar change under operating criteria
- IN 2.6 Determine implications of dam operating criteria on beach and sandbar and backwater character and structure, including suitability of camping beaches
- IN 2.7 Quantify the extent and location of existing sandbars, beaches and backwaters along the Colorado River corridor
- IN 2.8 Assess the effects and use of the spillways on bed morphology in the front of the dam and its effects on power production and biota

**MO 3:** Periodically increase the average size of sandbars above the 20,000 cfs river stage and number and average size of backwaters to the amounts measured during the high period of 1990/91 or the 1996 test of the beach/habitat-building flow in as many years as reservoir and downstream conditions allow.

- IN 3.1 Define 1996 and 1990/91 backwater ecosystems and associated flow regimes
- IN 3.2 Define historical variation in backwater number and character
- IN 3.3 Define changes between 1990/91 and 1996 in sediment and backwater resources character and structure associated with dam operating criteria
- IN 3.4 Define all linkages, associations, interdependencies, etc., of physical sediment resource and backwater resources to biotic entities
- IN 3.5 Define processes necessary to maintain backwaters at 1990/91 or 1996 levels

**MO 4:** Maintain system dynamics and disturbance by redistributing sand stored in the river channel and eddies to areas inundated by river flows up to 45,000 cfs in as many years as possible when BHBH hydrologic and resource criteria are met.

- IN 4.1 Define character and structure of all beaches and backwaters in system after 1996 test flows
- IN 4.2 Develop methodologies to define future flow regimes under approved operating criteria to maximize benefit to sediment and backwater character and structure
- IN 4.3 Develop an assessment of dam operations under approved operating criteria impacts on range of variation in sediment and other resources within Colorado River ecosystem and the associated processes that created these ranges

**Norm Henderson's Comments for Sediment Information Needs:**

- IN 1. Quantify the available sediment in the river channel within the Glen Canyon reach to build beaches within Marble Canyon
- IN 2. Determine the relative importance of high terrace erosion to beach building within the Glen Canyon reach
- IN 3. Quantify the sediment inputs within the Glen Canyon reach from unregulated side channels
- IN 4. Assess the impact of current and anticipated dam operations under approved operating criteria on the high terraces within Glen Canyon. Define the relative importance of natural erosion of high terraces as compared to that experienced due to current dam operations
- IN 5. Develop an understanding of bed morphology dynamics within Glen Canyon
- IN 6. Determine the relative importance of sediment grain size within Glen Canyon compared to downstream reaches
- IN 7. Summarize the historical changes in river banks and sandbars within the Glen Canyon reach and determine long term changes in size
- IN 8. Comprehensively quantify the extent and location of existing sandbars and beaches along the river corridor

**GIS**

**MO 1:** (Management Objective to be added.)

IN 1.1 Develop a comprehensive GIS base map for topography, geology and soils for the Colorado River ecosystem.

IN 1.2 Develop an integrated data/GIS structure for the storage and retrieval of all GCMRC studies.

## RECREATION

**Goal:** To provide quality recreation experiences that do not adversely affect natural or cultural resources within the river corridor.

**Definition:** Recreation resources include sport fishing, white water rafting, boating, hiking, sightseeing, photography, and hunting.

### MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

**MO 1:** Provide quality recreation experiences consistent with other resource objectives.

- IN 1.1 Determine criteria and aspects that are important to or detract from recreational experience
- IN 1.2 Determine the impacts of scientific study on recreational experience
- IN 1.3 Characterize procedures to mitigate those aspects of flows that detract from quality recreational experiences
- IN 1.4 Determine angler satisfaction, use and harvest
- IN 1.5 Determine potential impacts of increased heavy metals on sport fishing
- MA 1.1 Utilize approaches for monitoring and research that are appropriate to maintain or improve the character of the recreational experience as defined in NPS management plans for those areas.
- MA 1.2 Ensure water release strategies and communications systems that support and enhance the full range of river recreation experiences allowed under NPS management plans for those areas.

**MO 2:** Maintain flows (under approved operating criteria) and sediment processes that create an adequate quantity, distribution and variety of beaches for camping, as long as such flows are consistent with management of natural recreation and cultural resource values (other natural resource values).

- IN 2.1 Determine adequate beach quantity, quality, distribution, character and structure for camping throughout system
- IN 2.2 Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resources, quality, character and structure

- IN 2.3 Develop methodology to evaluate distribution, quantity and quality changes in all campable beaches through time
- IN 2.4 Develop systems models to predict flow regimes (under approved operating criteria) for building and maintaining beaches

**MO 3:** Maintain flows (under approved operating criteria) that minimize impacts to navigability by authorized water craft and for boaters, waders, and campers in the riverine corridor.

- IN 3.1 Determine if operating criteria maintains safe and adequate powercraft navigability in Glen Canyon and upper Lake Mead
- IN 3.2 Evaluate effects of operating criteria on recreation safety
- IN 3.3 Determine if operating criteria maintains whitewater raft navigation in Grand Canyon
- IN 3.4 Define ecosystem and other resource impacts of flow regimes (under approved operating criteria) required to maintain navigation
- IN 3.5 Develop methodology to evaluate potential conflicts of day rafting and other resources (e.g., bank degradation, sport fishing, bird watching, etc.)

**MO 4:** Maintain flows (under approved operating criteria) and habitat suitable for quality cold water fishery opportunities in Glen Canyon.

- IN 4.1 Determine flow regimes (under approved operating criteria) necessary to maintain fish populations of 100,000 adult Trout (age class II plus)

**MO 5:** Maintain flows (under approved operating criteria) and habitat suitable for waterfowl sport hunting and wildlife viewing opportunities in Glen Canyon.

- IN 5.1 Define pattern of waterfowl hunting use and satisfaction and other wildlife use and conflicts to other uses

## LAKE POWELL

Goal: To understand impacts of Dam operations and where possible minimize these impacts, consistent with other resource objectives.

Definition: Lake Powell includes natural, biological and cultural resources impacted by operation of Glen Canyon Dam.

### MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

The protocol for Lake Powell Management Objectives and Information Needs are related to Upstream Effects Only. (Downstream effects are included under the specific resource sections.)

#### **Lake Powell Water Quality**

**MO 1:** Prevent impacts that adversely affect the water quality (physical, chemical, biological) of Lake Powell due to dam operations and ensure that fully informed AMWG decisions are possible both now and in the future.

#### **Physical/Chemical (Limnology)**

- IN 1.1 Determine the effect of current dam operations (under approved operating criteria) on reservoir water quality, including but not limited to the following:
- (a) Determine near dam hydrogen sulfide levels (and other hazardous chemical constituents) within the hypolimnion occurring under current dam operating criteria.
  - (b) Determine the dynamics of lake stratification and advective flows and their effects on chemical constituents
  - (c) Determine/quantify the dynamics of major cations, anions, and nitrate/phosphate ratios resulting from dam operations
  - (d) Determine the effects of dam operations (under approved operating criteria) on the physical/chemical dynamics of Lake Powell side channels and embayments
  - (e) Quantify/model the heat budget for Lake Powell to determine near-term and long-term (monthly/weekly and annual summaries respectively) effects of a selective withdrawal system
  - (e) Determine the effect of current dam operations on reservoir levels of selenium.

## Biological

- IN 1.1 Determine the impacts of dam operations and resulting water quality on primary and secondary productivity of Lake Powell, including:
- a. algae (phytoplankton, periphyton)
  - b. Macrophytes
  - c. Zooplankton
  - d. macroinvertebrates
- IN 1.2 Quantify levels of selenium and describe effects of these levels on primary and secondary productivity, fish and waterfowl, and human consumption.

## Lake Powell Aquatic Ecosystem (Fishery)

### Definition:

**MO 2:** Protect Lake Powell aquatic ecosystem from adverse impacts due to dam operations and subsequent effects, including but not limited to: temperature, reservoir surface elevations, elevated selenium levels, advective flow patterns, predator/prey relationships, and fish movements.

- IN 2.1 Determine the effects of water temperature caused by dam operations
- IN 2.2 Determine the effects of fluctuations in the reservoir surface elevations caused by dam operations (under approved operating criteria)
- IN 2.3 Determine the effects of elevated selenium levels caused by dam operations (under approved operating criteria)
- IN 2.4 Determine the effects of advective flow patterns on Lake Powell aquatic ecosystem caused by dam operations (under approved operating criteria)
- IN 2.5 Determine the effects of predator/prey relationships caused by dam operations (under approved operating criteria)
- IN 2.6 Determine the effects of fish movements caused by dam operations

## APPENDIX

## Biological Resources 1

**From Aquatic Food Base Management Objective**

- IN 1.7 Identify and characterize the available aquatic habitat of the Colorado River and significant tributaries, such as the LCR (riffle, run, pool, backwater, etc.)
- IN 1.8 Develop a comprehensive aquatic habitat map (with GIS) for the river corridor at various water levels.
- IN 1.9 Quantify and evaluate changes in river habitat caused by dam operations over time
- IN 1.10 Determine the effect of sediment exposure time on benthic community mortality
- IN 1.11 Effects of sediment removal and transport on hyporheic communities
- IN 1.12 Effects of selenium on benthic/hyporheic communities.

**From Flannemouth Sucker Management Objective**

- IN 1. Establish whether Flannemouth Suckers/native fish are actually spawning in the mainstem Colorado River within Glen Canyon under current conditions. If spawning occurs, do any eggs hatch or larvae survive? Determine the current and past (before Glen Canyon Dam) importance of mainstem Glen Canyon spawning habitat (in relationship to tributary spawning).
- IN 2. Determine the origin of adult Flannemouth Suckers/native fish that are attempting to spawn in the mainstem Colorado River within Glen Canyon? Are the old pre-dam adults? Are the post-dam adults from the tributaries, i.e., Paria River, that find certain mainstem habitat factors preferable? Are they mainstem adults from the Grand Canyon?
- IN 3. Determine the location of all spawning beds within Glen Canyon (related to flows) and summarize the important characteristics. Determine the relative importance of Glen Canyon habitat in relationship to other mainstem habitat within Grand Canyon.
- IN 4. Specifically determine the cause(s) for mainstem spawning failure within Glen Canyon:
  - a. Eggs not deposited, or if deposited not viable because of low water temperature or fluctuating flows, i.e., drying of spawning beds or removal of eggs by strong currents.
  - b. Fertile eggs deposited and hatch but larvae can't grow because of limited or no nursery habitat for food and shelter (again, due to cold temperatures and fluctuating flows).
  - c. Eggs laid and hatch and some survive and move downstream to warmer water and return much later to spawn.
- IN 5. Describe the specific role of flow levels and fluctuations on reproduction and survival of eggs, larvae, young-of-year, and adults. Specifically, determine the availability of moderate near-shore habitat that might be used by larvae, young-of-year, or adults.
- IN 6. Describe the relative importance of various tributaries to flannemouth survival (spawning, recruitment, predation).
- IN 7. What is the food source in the mainstem now? Is there a sufficient food base for adequate growth and a healthy population in the mainstem? What was historic food source?

- IN 8. Determine the optimal habitat conditions for flannelmouth sucker. reproductions, survival, recruitment, etc., i.e., temperature, flow, food, shelter. What habitat factors in the mainstem attract adult Flannelmouth suckers to spawn? What is the attraction over tributaries, i.e., Paria River?
- IN 9. Determine the fidelity of Flannelmouth suckers to certain areas and spawning beds.
- IN 10. Determine if possible the current and historic use of Flannelmouth sucker habitat for spawning, foraging, cover, etc., within the Colorado River and Paria Rivers as well as other tributaries.
- IN 11. Develop a Flannelmouth sucker conceptual model for the Colorado River ecosystem, i.e., food, habitat, predation.
- IN 12. What habitat modifications could be made to improve Flannelmouth sucker population levels and overall health, i.e., substrate modification, nursery habitat establishment (warm backwaters), flow modification, etc.
- IN 13. Assess the influence of non-native fish on native fish species.
- IN 14. Determine the effect of current selenium levels discharged from Glen Canyon Dam on native fish species.

APPENDIX B		APPENDIX B									
Resource Category	Short Name	Resource Order #	Info Need	Resource Category	Mgt Obj	Info Need	O	X	Mon or Res	Status	
Conceptual model	Conceptual model	1	IN 1.1	Ecosystem Assessments	MO 1:	IN 1.1	7	14	R		
Aquatic foodbase	Aquatic foodbase - monitor	2	IN 1.1	A1 - Aquatic Food Base	MO 1:	IN 1.1	10	9	M	Binn et al. in prep; AGFD in prep.	
Aquatic foodbase	Aquatic foodbase - dam FX	2	IN 1.2	A1 - Aquatic Food Base	MO 1:	IN 1.2	10	9	R	Binn et al. in prep; AGFD in prep.; Stevens et al. 1997.	
Aquatic foodbase	Aquatic foodbase for fish	2	IN 1.3	A1 - Aquatic Food Base	MO 1:	IN 1.3	10	10	R		
Trout	Trout population dynamics	3	IN 2.1	A2 - Trout	MO 2:	IN 2.1	8	9	R		
Trout	Trout population trends	3	IN 2.2	A2 - Trout	MO 2:	IN 2.2	5	5	M		
Trout	Trout condition #1	3	IN 2.3	A2 - Trout	MO 2:	IN 2.3	2	1	M		
Trout	Trout spawning habitat availability	3	IN 2.4	A2 - Trout	MO 2:	IN 2.4	4	4	R		
Trout	Trout condition #2	3	IN 2.5	A2 - Trout	MO 2:	IN 2.5	4	0	M&R		
Trout	Trout maintenance FX#1	3	IN 2.6	A2 - Trout	MO 2:	IN 2.6	4	3	R		
Trout	Trout/foodbase trophic dynamics	3	IN 2.7	A2 - Trout	MO 2:	IN 2.7	3	4	R		
Native Fish	HBC population dynamics	4	IN 3/4.1	A3 - Native Fish	MO 3/4:	IN 3/4.1	10	10	M&R		
Native Fish	HBC recruitment	4	IN 3/4.2	A3 - Native Fish	MO 3/4:	IN 3/4.2	11	8	M&R		
Native Fish	HBC winter survival	4	IN 3/4.3	A3 - Native Fish	MO 3/4:	IN 3/4.3	10	8	R		
Native Fish	HBC hiron with NN fish	4	IN 3/4.4	A3 - Native Fish	MO 3/4:	IN 3/4.4	2	0	RAM		
Native Fish	HBC habitat availability	4	IN 3/4.5	A3 - Native Fish	MO 3/4:	IN 3/4.5	10	6	R		
Native Fish	HBC protocol and recreation FX	4	IN 3/4.6	A3 - Native Fish	MO 3/4:	IN 3/4.6	2	1	Protocol R		
Native Fish	HBC trophic dynamics	4	IN 3/4.7	A3 - Native Fish	MO 3/4:	IN 3/4.7	7	6	R		
Native Fish	HBC YOY habitat and NNS interts	4	IN 3/4.8	A3 - Native Fish	MO 3/4:	IN 3/4.8	7	6	R		
Native Fish	HBC population loss to flows	4	IN 3/4.9	A3 - Native Fish	MO 3/4:	IN 3/4.9	6	5	R		
Native Fish	HBC good year strategy	4	IN 3/4.10	A3 - Native Fish	MO 3/4:	IN 3/4.10	4	2	Admin.		
Native Fish	HBC downstream transport	4	IN 3/4.11	A3 - Native Fish	MO 3/4:	IN 3/4.11	6	3	R		
Native Fish	HBC flow-related lake	4	IN 3/4.12	A3 - Native Fish	MO 3/4:	IN 3/4.12	9	8	R		
Native Fish	HBC flow criteria to limit take	4	IN 3/4.13	A3 - Native Fish	MO 3/4:	IN 3/4.13	8	7	Admin.		
Native Fish	Threatened fish - RPM test flows	4	IN 3/4.14	A3 - Native Fish	MO 3/4:	IN 3/4.14	5	4	R		
Native Fish	Native fish - mainstem thermal model	4	IN 5.1	A3 - Native Fish	MO 5:	IN 5.1	6	2	R		
Native Fish	Native fish - thermal mod FX#1	4	IN 5.2	A3 - Native Fish	MO 5:	IN 5.2	10	10	R		
Native Fish	Native fish - thermal mod FX#2	4	IN 5.3	A3 - Native Fish	MO 5:	IN 5.3	14	14	R		
Native Fish	Thermal mod impacts on LP fish	4	IN 5.4	A3 - Native Fish	MO 5:	IN 5.4	7	2	R		
Native Fish	NN fish control - temperature and floods	4	IN 5.5	A3 - Native Fish	MO 5:	IN 5.5	9	9	R		
Native Fish	HBC population mgmt. Criteria	4	IN 6.1	A3 - Native Fish	MO 6:	IN 6.1	8	8	R		
Native Fish	HBC 2nd pop. feasibility study	4	IN 6.2	A3 - Native Fish	MO 6:	IN 6.2	9	7	R		
Native Fish	RBS 2nd pop. feasibility study	4	IN 7.1	A3 - Native Fish	MO 7:	IN 7.1	7	5	R		
Native Fish	Native fish pop. status	4	IN 8.1	A3 - Native Fish	MO 8:	IN 8.1	8	8	M		
Native Fish	Native fish pop. dynamics#1	4	IN 8.2	A3 - Native Fish	MO 8:	IN 8.2	7	4	M		
Native Fish	Native fish historic pop. dynamics #1	4	IN 8.3	A3 - Native Fish	MO 8:	IN 8.3	3	1	M&R		
Native Fish	Native fish historic pop. dynamics#2	4	IN 8.4	A3 - Native Fish	MO 8:	IN 8.4	5	2	M&R		
Native Fish	Native fish low regime FX	4	IN 8.5	A3 - Native Fish	MO 8:	IN 8.5	7	4	R		
Native Fish	Native fish maintenance criteria	4	IN 8.6	A3 - Native Fish	MO 8:	IN 8.6	7	4	R		
Native Fish	Native fish experimental flows design #1	4	IN 9.1	A3 - Native Fish	MO 9:	IN 9.1	3	2	R		
Native Fish	Native fish experimental flows design #2	4	IN 9.2	A3 - Native Fish	MO 9:	IN 9.2	5	1	R		
Native Fish	Native fish trib. flows and recruitment	4	IN 9.3	A3 - Native Fish	MO 9:	IN 9.3	7	3	M&R		

APPENDIX B

Resource Category	Short Name	Resource Order #	Info Need	Resource Category	Mgt Obj	Info Need	O	X	Mon or Res	Status
Native Fish	Native - NN fish nearshore inrxns	4	IN 9.4	A.3 - Native Fish	MO 9:	IN 9.4	6	1	R	
Native Fish	Native/NN fish inrxns #1	4	IN 10.1	A.3 - Native Fish	MO 10:	IN 10.1	6	5	R	
Native Fish	Native/NN fish inrxns #2	4	IN 10.2	A.3 - Native Fish	MO 10:	IN 10.2	4	3	R	
Native Fish	Native/NN fish mitigation inrxns	4	IN 10.3	A.3 - Native Fish	MO 10:	IN 10.3	3	3	R	
Native Fish	NN fish distrib. and natural history	4	IN 10.4	A.3 - Non-native Fish	MO 10:	IN 10.4	5	2	M	
Native Fish	Native/NN fish inrxns #3	4	IN 10.5	A.3 - Native Fish	MO 10:	IN 10.5	6	2	R	
Native Fish	Native and NN fish autecology	4	IN 10.6	A.3 - Native Fish	MO 10:	IN 10.6	6	2	M&R	
Riparian	Autecology of riparian species	5	IN 11.1	B. Terrestrial and riparian resources	MO 11:	IN 11.1	9	9	M&R	
Riparian	Riparian population variability	5	IN 11.2	B. Terrestrial and riparian resources	MO 11:	IN 11.2	4	6	M&R	
Riparian	Riparian SOC population changes	5	IN 11.3	B. Terrestrial and riparian resources	MO 11:	IN 11.3	2	4	M&R	
Riparian	Riparian species habitat distribution	5	IN 11.4	B. Terrestrial and riparian resources	MO 11:	IN 11.4	5	7	M&R	
Riparian	Riparian habitat map	5	IN 11.5	B. Terrestrial and riparian resources	MO 11:	IN 11.5	5	4	R	
Riparian	Monitor leopard frogs	5	IN 11.6	B. Terrestrial and riparian resources	MO 11:	IN 11.6	6	8	R	
Riparian	Feasibility of 2nd leopard frog populations	5	IN 11.7	B. Terrestrial and riparian resources	MO 11:	IN 11.7	1	1	Admin.	
Riparian	Evaluate amphibian sensitivity	5	IN 11.8	B. Terrestrial and riparian resources	MO 11:	IN 11.8	2	3	R	
Riparian	Riparian spp - dam FX on demography #1	5	IN 12.1	B. Terrestrial and riparian resources	MO 12:	IN 12.1	6	8	R	
Riparian	Riparian spp - ranges	5	IN 12.2	B. Terrestrial and riparian resources	MO 12:	IN 12.2	1	1	R	
Riparian	Riparian spp - age classes	5	IN 12.3	B. Terrestrial and riparian resources	MO 12:	IN 12.3	0	0	R	
Riparian	Riparian spp - dam FX on demography #2	5	IN 12.4	B. Terrestrial and riparian resources	MO 12:	IN 12.4	2	2	R	
Riparian	Riparian spp - general dam FX	5	IN 12.5	B. Terrestrial and riparian resources	MO 12:	IN 12.5	1	1	R&M	
Riparian	Riparian food webs: SOC	5	IN 13.1	B. Terrestrial and riparian resources	MO 13:	IN 13.1	7	7	R&M	
Riparian	Riparian food webs: birds	5	IN 13.2	B. Terrestrial and riparian resources	MO 13:	IN 13.2	6	8	R	
Riparian	Pera - aene distribution	5	IN 13.3	B. Terrestrial and riparian resources	MO 13:	IN 13.3	1	1	R&M	
Riparian	Pera - population dynamics	5	IN 13.4	B. Terrestrial and riparian resources	MO 13:	IN 13.4	2	2	R	
Riparian	Bald eagle - dam FX	5	IN 13.5	B. Terrestrial and riparian resources	MO 13:	IN 13.5	3	3	R&M	
Riparian	KAS - habitat RX #1	5	IN 14.1	B. Terrestrial and riparian resources	MO 14:	IN 14.1	9	8	M	
Riparian	KAS - special flow impacts	5	IN 14.2	B. Terrestrial and riparian resources	MO 14:	IN 14.2	7	7	R&M	
Riparian	KAS - monitor exceptional flow impacts	5	IN 14.3	B. Terrestrial and riparian resources	MO 14:	IN 14.3	8	8	R&M	
Riparian	KAS - life history schedule	5	IN 14.4	B. Terrestrial and riparian resources	MO 14:	IN 14.4	7	7	M	
Riparian	KAS - monitor #1	5	IN 14.5	B. Terrestrial and riparian resources	MO 14:	IN 14.5	7	7	R&M	
Riparian	KAS - monitor #2	5	IN 14.6	B. Terrestrial and riparian resources	MO 14:	IN 14.6	11	10	R&M	
Riparian	KAS - genetic relationships	5	IN 14.7	B. Terrestrial and riparian resources	MO 14:	IN 14.7	5	6	M	
Riparian	KAS - habitat propagation	5	IN 15.1	B. Terrestrial and riparian resources	MO 15:	IN 15.1	7	5	R	
Riparian	Riparian veg - distribution: all #1	5	IN 15.2	B. Terrestrial and riparian resources	MO 15:	IN 15.2	6	4	R	
Riparian	Riparian veg - distribution: OHW	5	IN 16.1	B. Terrestrial and riparian resources	MO 16:	IN 16.1	5	6	M	
Riparian	Riparian veg - maintain and restore	5	IN 16.2	B. Terrestrial and riparian resources	MO 16:	IN 16.2	4	5	R&M	
Riparian	Riparian veg - dam FX	5	IN 16.3	B. Terrestrial and riparian resources	MO 16:	IN 16.3	0	0	M	
Riparian	Riparian veg - life histories	5	IN 16.4	B. Terrestrial and riparian resources	MO 16:	IN 16.4	4	4	R&M	
Riparian	Riparian veg - NNS and dam FX	5	IN 16.5	B. Terrestrial and riparian resources	MO 16:	IN 16.5	2	2	R	
Cultural	Cultural sites - monitor	6	IN 11.1	Cultural Resources	MO 1:	IN 11.1	12	13	M	
Cultural	Cultural sites - risk assessment	6	IN 1.2	Cultural Resources	MO 1:	IN 1.2	6	4	R	
Cultural	Cultural sites - info needs	6	IN 1.3	Cultural Resources	MO 1:	IN 1.3	7	7	Admin.	

Stevens and Keim, in progress  
 Stevens, Price and Nelson, in progress  
 Stevens and Ayers 1994  
 Stevens and Ayers 1994  
 Stevens et al. In prep (1986 BHRF)  
 Stevens et al. 1985, in prep (1986 BHRF), Ayers and Kearsley 1995-97  
 Stevens, in press  
 Stevens, in press  
 NPS/PA annual reports  
 NPS/PA annual reports  
 PA

APPENDIX B

Prioritized Information Needs

Resource

Resource Category	Short Name	Resource Order #	Info Need	Resource Category	Mgt Obj	Info Need	O	X	Mon or Res	Status
Cultural	Cultural sites - monitor risk	6	IN 1.4	Cultural Resources	MO 1:	IN 1.4	6	5	R&M	Monitoring through PA/NPS
Cultural	Cultural sites - preserve terraces #1	6	IN 1.5	Cultural Resources	MO 1:	IN 1.5	5	2	M	Monitoring through PA/NPS
Cultural	Cultural sites - preserve terraces #2	6	IN 1.6	Cultural Resources	MO 1:	IN 1.6	6	2	R&M	Monitoring through PA/NPS
Cultural	Cultural sites & recreation FX	6	IN 1.7	Cultural Resources	MO 1:	IN 1.7	1	0	R	Monitoring through PA/NPS
Cultural	Cultural sites - mitigation strategies	6	IN 2.1	Cultural Resources	MO 2:	IN 2.1	9	9	Admin.	PA
Cultural	Cultural sites - data recovery strategies	6	IN 2.2	Cultural Resources	MO 2:	IN 2.2	5	2	Admin.	PA
Cultural	Cultural sites - characterize dam FX	6	IN 3.1	Cultural Resources	MO 3:	IN 3.1	9	6	R	PA
Cultural	Cultural site data management	6	IN 4.1	Cultural Resources	MO 4:	IN 4.1	7	5	Admin.	PA
Socioeconomic	Socioeconomics - monitor hydropower \$	7	IN 1.1	Socioeconomic (Hydropower)	MO 1:	IN 1.1			M	Not currently reported
Socioeconomic	Socioeconomics - costs of ROD	7	IN 1.2	Socioeconomic (Hydropower)	MO 1:	IN 1.2			M	Not currently reported
Socioeconomic	Socioeconomics - research oasis	7	IN 1.3	Socioeconomic (Hydropower)	MO 1:	IN 1.3			M	Not currently reported
Socioeconomic	Socioeconomics - integrated systems mgmt.	7	IN 1.4	Socioeconomic (Hydropower)	MO 1:	IN 1.4			Admin.	Not currently reported
Water	Flow - monitor releases	8	IN 1.1	Water Resources	MO 1:	IN 1.1			M	BOR Lake Powell program; USGS; Lake Powell, Lees Ferry - on-going
Water	Flow - monitor WQ and dam FX on major ions	8	IN 2.1	Water Resources	MO 2:	IN 2.1	9	9	M	Not planned
Water	Flow - thermal modification	8	IN 2.2	Water Resources	MO 2:	IN 2.2	6	6	R&M	Schmidt et al. syntheses
Sediment	Sediment - historic distribution & flow FX: all #1	9	IN 1.1	Sediment Resources	MO 1:	IN 1.1	5	7	R&M	
Sediment	Sediment - minimum storage for sustainability	9	IN 1.2	Sediment Resources	MO 1:	IN 1.2	7	10	R	
Sediment	Sediment - monitor flow FX by reach	9	IN 1.3	Sediment Resources	MO 1:	IN 1.3	7	10	R	
Sediment	Sediment - monitor inputs: all	9	IN 1.4	Sediment Resources	MO 1:	IN 1.4	8	10	R&M	
Sediment	Sediment - GCNRA bar distribution, sand input	9	IN 1.5	Sediment Resources	MO 1:	IN 1.5	5	6	R&M	Kapinski et al. 1992-1998; Stevens and Hoffmagle, in prep.
Sediment	Sediment - bar & backwater distribution: 90-91	9	IN 2.1	Sediment Resources	MO 2:	IN 2.1	1	1	M	Not planned
Sediment	Sediment - establish baselines	9	IN 2.2	Sediment Resources	MO 2:	IN 2.2	3	2	Admin.	Kapinski et al., on-going
Sediment	Sediment - monitor sand bar distribution #1	9	IN 2.3	Sediment Resources	MO 2:	IN 2.3	3	5	R&M	GCNRA and Manone, on-going
Sediment	Cultural - monitor terraces	9	IN 2.4	Sediment Resources	MO 2:	IN 2.4	2	3	M	
Sediment	Sediment - bar & backwater distribution: model	9	IN 2.5	Sediment Resources	MO 2:	IN 2.5	3	3	R&M	Kapinski et al. 1992-1998; Stevens and Hoffmagle, in prep.
Sediment	Sediment - bar & backwater and camp distribution	9	IN 2.6	Sediment Resources	MO 2:	IN 2.6	6	8	R&M	
Sediment	Sediment - bar & backwater distribution	9	IN 2.7	Sediment Resources	MO 2:	IN 2.7	2	5	R	
Sediment	Flow - spillway impacts on bed and benthos	9	IN 2.8	Sediment Resources	MO 2:	IN 2.8	1	1	R&M	Stevens and Hoffmagle, in prep.
Sediment	Backwater distribution: 90-91, 96-97 #1	9	IN 3.1	Sediment Resources	MO 3:	IN 3.1	4	3	R	
Sediment	Backwater distribution: 90-91, 96-97 #2	9	IN 3.2	Sediment Resources	MO 3:	IN 3.2	3	2	R	
Sediment	Sediment - bar & backwater distribution #2	9	IN 3.3	Sediment Resources	MO 3:	IN 3.3	3	4	R&M	
Sediment	Sediment - linkage to biota	9	IN 3.4	Sediment Resources	MO 3:	IN 3.4	7	8	R	
Sediment	Backwater distribution: 90-91, 96-97 #3	9	IN 3.5	Sediment Resources	MO 3:	IN 3.5	2	3	R	Stevens and Hoffmagle, in prep.
Sediment	Backwater distribution: 90-91, 96-97 #4	9	IN 4.1	Sediment Resources	MO 4:	IN 4.1	6	6	R&M	Stevens and Hoffmagle, in prep.
Sediment	Sediment - assess dam FX on bars, backwaters	9	IN 4.2	Sediment Resources	MO 4:	IN 4.2	4	6	Admin.	Schmidt et al. synthesis reports?
Sediment	Sediment - monitor inputs: Marble Canyon	9	IN 4.3	Sediment Resources	MO 4:	IN 4.3	5	5	Admin.	Use Schmidt et al. synthesis reports?
Sediment	Sediment - GCNRA high terrace erosion #1	9	IN NH1	Sediment Resources	MO 4:	IN NH1	3	3	R&M	Topping, in prep.; Rubin et al. in prep.
Sediment	Sediment - monitor inputs: GCNRA	9	IN NH2	Sediment Resources	MO 4:	IN NH2	1	1	R	PA + Kapinski et al., in prep.
Sediment	Sediment - GCNRA high terrace erosion #2	9	IN NH3	Sediment Resources	MO 4:	IN NH3	2	2	R	
Sediment	Sediment - GCNRA bed morphology dynamics	9	IN NH4	Sediment Resources	MO 4:	IN NH4	2	1	R&M	
Sediment	Sediment - GCNRA grain size distribution	9	IN NH5	Sediment Resources	MO 4:	IN NH5	2	4	R	
Sediment	Sediment - historic distribution & low FX: GCNRA	9	IN NH6	Sediment Resources	MO 4:	IN NH6	1	1	R	Topping ? in prep.
Sediment	Sediment - historic distribution & low FX: GCNRA	9	IN NH7	Sediment Resources	MO 4:	IN NH7	0	2	R&M	Not planned

APPENDIX B

Prioritized Information Needs

Resource Order

Short Name

Resource Category	Resource Order	Short Name	Info Need	Resource Category	Mgt Obj	Info Need	O	X	Mon or Res	Status
Sediment	9	Sediment - historic distribution & flow FX; all #2	IN 1.1	Sediment Resources	MO 4:	IN 1.1	2	3	R	Schmidt et al. syntheses
GIS	10	GIS - map topography, geology, soils	IN 1.2	GIS	MO 1:	IN 1.2	0	2	R	Shelby et al. 1970s; NPS in prep.; GCMRC contract underway.
Recreation	11	Recreation - experience	IN 1.1	Recreation	MO 1:	IN 1.1	4	9	R&M	Not planned
Recreation	11	Recreation - monitoring and research impacts	IN 1.2	Recreation	MO 1:	IN 1.2	2	5	R	Not planned
Recreation	11	Recreation - mitigate negative flow FX	IN 1.3	Recreation	MO 1:	IN 1.3	4	0	R&M	AGFD creel census - ongoing
Recreation	11	Recreation - angler satisfaction, use and harvest	IN 1.4	Recreation	MO 1:	IN 1.4	2	3	R	AGFD trout contract; Taylor et al. report
Recreation	11	Water - heavy metal impacts on fish	IN 1.5	Recreation	MO 1:	IN 1.5	0	0	R	
Recreation	11	Recreation - camp distribution, carrying capacity	IN 2.1	Recreation	MO 2:	IN 2.1	1	10	R&M	
Recreation	11	Recreation - dam FX on camp distribution	IN 2.2	Recreation	MO 2:	IN 2.2	6	8	Admin.	
Recreation	11	Recreation - develop campsite monitoring strategy	IN 2.3	Recreation	MO 2:	IN 2.3	1	3	Admin.	
Recreation	11	Recreation - model flow FX on campsites	IN 2.4	Recreation	MO 2:	IN 2.4	2	2	R	
Recreation	11	Recreation safety - boating; GCMRA	IN 3.1	Recreation	MO 3:	IN 3.1	1	3	R&M	FBRs, GCMES Phase II
Recreation	11	Recreation safety - boating; all	IN 3.2	Recreation	MO 3:	IN 3.2	3	3	R&M	Myers et al. in prep.
Recreation	11	Recreation safety - boating; Grand Canyon	IN 3.3	Recreation	MO 3:	IN 3.3	2	1	R&M	GRCA in prep.
Ecosystem Assess	11	Ecosystem Assessment - FX of flows for safety on ecosystem	IN 3.4	Recreation	MO 3:	IN 3.4	1	0	Admin.	Conceptual model, in prep.
Recreation	11	Recreation - Resource conflicts with day raiting	IN 3.5	Recreation	MO 3:	IN 3.5	2	7	Admin.	Not planned
Recreation	11	Trout - flows FX for 100K trout	IN 4.1	Recreation	MO 4:	IN 4.1	2	1	R	Trout symposium, in prep.
Recreation	11	Waterfowl - hunter use, satisfaction, conflicts	IN 5.1	Recreation	MO 5:	IN 5.1	1	2	R	Not planned
Lake Powell	12	Water - Lake Powell WQ	IN 1.1 (Phys)	Lake Powell	MO 1:	IN 1.1 (Phys)	10	14	R&M	Lake Powell assessment, USGS contract, in prep.
Lake Powell	12	Water - dam FX on Lake Powell WQ & productivity	IN 1.1 (Bio)	Lake Powell	MO 1:	IN 1.1 (Bio)	5	12	R	Lake Powell assessment, in prep.
Lake Powell	12	Water - Lake Powell, selenium impacts #1	IN 1.2	Lake Powell	MO 1:	IN 1.2	1	0	R	Not planned
Lake Powell	12	Water - water temperature impacts in Lake Powell	IN 2.1	Lake Powell	MO 2:	IN 2.1	1	9	R	Blinn et al. Reports; Stevens et al. 1997; Vernieu and Kom 1998.
Lake Powell	12	Water - Lake Powell, selenium impacts #2	IN 2.2	Lake Powell	MO 2:	IN 2.2	0	1	R&M	
Lake Powell	12	Water - Lake Powell, selenium impacts #2	IN 2.3	Lake Powell	MO 2:	IN 2.3	0	0	R	
Lake Powell	12	Lake Powell - dam FX on advective flow	IN 2.4	Lake Powell	MO 2:	IN 2.4	0	1	R&M	
Lake Powell	12	Lake Powell - fish; dam FX on movement	IN 2.5	Lake Powell	MO 2:	IN 2.5	1	1	R	
Lake Powell	12	Lake Powell - fish; dam FX on pred-prey rels.	IN 2.6	Lake Powell	MO 2:	IN 2.6	1	5	R	
Aquatic foodbase	2	Fisheries - habitat distribution; mainstreams; trbs	IN 1.7 (App.)	A.1 - Aquatic Food Base	MO 1:	IN 1.7 (App.)	1	3	R	Valdez et al. 1995; Carothers et al. 1998; Stevens and Hofmagle in prep.; Gorman in prep.
Aquatic foodbase	2	GIS - aquatic habitat map by stage	IN 1.8 (App.)	A.1 - Aquatic Food Base	MO 1:	IN 1.8 (App.)	1	1	R	Not planned
Aquatic foodbase	2	Fisheries - dam FX on habitat distribution	IN 1.9 (App.)	A.1 - Aquatic Food Base	MO 1:	IN 1.9 (App.)	2	4	R	Not planned
Aquatic foodbase	2	Aquatic foodbase - exposure FX	IN 1.10 (App.)	A.1 - Aquatic Food Base	MO 1:	IN 1.10 (App.)	2	3	R	Angradi and Kubly 1994; Blinn et al. 1995; Stevens et al. 1997
Aquatic foodbase	2	Aquatic foodbase - dam FX on hypolimnetic conms.	IN 1.11 (App.)	A.1 - Aquatic Food Base	MO 1:	IN 1.11 (App.)	0	0	R	Not planned
Native fish	4	Water - selenium impacts on benthos/hypolimnetic	IN 1.12 (App.)	A.1 - Aquatic Food Base	MO 1:	IN 1.12 (App.)	1	0	R	
Native fish	4	FMS spawning hab. distrib. #1; recruitment	IN 1.1 (App.)	A.3 - Native Fish	MO 8:	IN 1.1 (App.)	3	1	R&M	
Native fish	4	FMS adult origins	IN 2.1 (App.)	A.3 - Native Fish	MO 8:	IN 2.1 (App.)	2	2	R&M	
Native fish	4	FMS spawning hab. distrib. #2; Glen Canyon	IN 3.1 (App.)	A.3 - Native Fish	MO 8:	IN 3.1 (App.)	3	1	R&M	
Native fish	4	FMS mechanisms of spawning failure	IN 4.1 (App.)	A.3 - Native Fish	MO 8:	IN 4.1 (App.)	2	1	R	
Native fish	4	Native fish - FMS dam FX on recruitment	IN 5.1 (App.)	A.3 - Native Fish	MO 8:	IN 5.1 (App.)	3	2	R	
Native fish	4	Native fish - spawning and trib. Moults	IN 6.1 (App.)	A.3 - Native Fish	MO 8:	IN 6.1 (App.)	2	1	R&M	
Native fish	4	Aquatic foodbase - dam FX on distribution	IN 7.1 (App.)	A.3 - Native Fish	MO 8:	IN 7.1 (App.)	0	0	R	
Native fish	4	Native fish - FMS habitat FX	IN 8.1 (App.)	A.3 - Native Fish	MO 8:	IN 8.1 (App.)	1	0	R	Stevens et al. 1997
Native fish	4	Native fish - FMS spawning hab. distrib. #3; site fidelity	IN 9.1 (App.)	A.3 - Native Fish	MO 8:	IN 9.1 (App.)	1	0	R&M	

APPENDIX B		Prioritized Information Needs					APPENDIX B		
Resource Category	Short Name	Resource Order #	Info Need	Resource Category	Mgt Obj	Info Need	C X	Mon or Res	Status
Native fish	Native fish - MS spawning hab. disimb. #4; historic use	4	IN 10. (App.)	A.3 - Native Fish	MO 8:	IN 10. (App.)	0	0	R&M
Native fish	Native fish - FMS population model	4	IN 11. (App.)	A.3 - Native Fish	MO 8:	IN 11. (App.)	2	1	R
Native fish	Native fish - FMS habitat modification RX	4	IN 12. (App.)	A.3 - Native Fish	MO 8:	IN 12. (App.)	1	0	Admin.
Native fish	Native/AN fish in toxics #4	4	IN 13. (App.)	A.3 - Native Fish	MO 8:	IN 13. (App.)	2	0	R
Native fish	Water - selenium FX on native fish	4	IN 14. (App.)	A.3 - Native Fish	MO 8:	IN 14. (App.)	0	0	R

## APPENDIX C

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

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

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

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

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

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

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

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

## **PART II. Key Components of the PEP**

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

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

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

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

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

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

Regardless of the diversity of monitoring approaches considered, other topics such as replication, sampling interval and spatial distribution for a long-term monitoring program also need to be evaluated by CRE-resource category. For instance, during FY98, external review panels will also assist the GCMRC-PEP in

reviewing and identifying ideal sampling strategies for existing efforts such as channel-storage changes, monitoring channel-bed grain-size evolution and bed coverage through time (SEDS), Lake Powell water quality monitoring (WETS), and for GARST. Information from recent high-flow experiments suggests that monitoring data on grain-size evolution of channel-stored sediment may significantly influence management decision making, but has not previously been a component of physical-resource monitoring.

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

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

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

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

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

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

### **Part III. Proposed PEP Schedule**

A) **General Schedule and Timing for PEP** - The GCMRC proposes that the PEP be staggered over three-four years, and fully realizes that the PEP process will and should vary somewhat in approach by individual

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

The time line for preliminary reports on GARST, SEDS and WETS is September 1998 (see attachment 1 for a more detailed work plan and time line). Information gained from the initial phase of the process may be used in two ways: 1) where analyses of existing data have been suitable for comparison, and results/conclusions have been derived, the results will be externally reviewed in detail; 2) where scoping information has led to questions about the appropriateness of one protocol over another, but no existing data are available for analyses, the information will be used to develop RFP(s) intended to have specific protocols field tested and evaluated as competitive research effort(s) in FY99 and beyond.

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

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

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

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

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

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

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

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

**Physical Resources and Remote Sensing - FY98-99 - *Scoping* [FY98] and *Field Testing Pilot Studies* [FY99],**

**FY2000 and Beyond - *Implementation* in GCMRC Monitoring Program through competitive RFP process;**

**Biological and Cultural Resources - FY99-2000 - *Scoping* [FY99] and *Field Testing Pilot Studies* [FY2000],**

**FY2001 and Beyond - *Implementation* in GCMRC Monitoring Program through competitive RFP process.**

ATTACHMENT I. - GENERALIZED STEPS FOR PEP: A PILOT STUDY

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

**INTRODUCTION:**

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

**PLANNING PHASE:**

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

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

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

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

Due Date for Tasks I.a-c: March 6, 1998 - ACHIEVED

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

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

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

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

The following are approaches that the GCMRC (headed by Mike L. and Ted M.) will utilize to scope appropriate expertise and alternative technologies: 1) telephone and face-to-face interviews with program

managers and research-group leaders from major agencies that work with remote sensing technologies and databases; especially those who focus on river, lake or near coastal ecosystems; 2) literature review, 3) attendance of the national remote-sensing conference set for Tampa, FL in late March; 4) internal scoping and discussions with survey personnel (Gonzales and others) who have already identified interesting new remote-sensing technologies.

Due Date for Tasks II.a-b: April 10, 1998 - ACHEIVED

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

### **FIRST REVIEW PHASE:**

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

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

Reviewers will have at least three weeks to prepare for the meeting (their ability to work within this time window will be one additional requirement for their selection).

Due Date for Task III.a: COMPLETED

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

Due Date for Task III.b: May 28, 1998 - COMPLETED

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

Due Date for Task III.c: COMPLETED

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

### **PROCUREMENT PHASE:**

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

**Task IV.a.** (Mike L.) - The GCMRC Information Technologies Director will have all of summer 1998 to procure the standard overflight for Labor Day still photography and videography, and any additional protocols that were identified through the scoping and review panel process for paired field testing. The present contractual agreement for aerial photography may be used to procure additional protocols for testing during the overflight, depending on the contractor's willingness and ability to provide them directly or subcontract for them through another party within the designated time frame. Standard videography may be conducted by the

Bureau of Reclamation with permitted helicopter deployment, and additional videography formats may also be used for testing purposes using existing cooperative and interagency agreements.

Due Date for Task IV.a: August 31, 1998

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

Due Date for Task IV.b: October 15, 1998

#### **EVALUATION PHASE:**

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

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

Draft Report Due on August 15, 1999

#### **SECOND REVIEW PHASE:**

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

Due Date for Task V.b: October 1, 1999

#### **DECISION-MAKING AND IMPLEMENTATION PHASE:**

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

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

**BUDGET AND TIMELINE, PEP-I:**

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

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

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

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

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

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

End GARST Component of PEP Assessments

OR,

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

**ATTACHMENT 2. - PROPOSED STEPS FOR [SEDS] PEP: A REVIEW PROCESS**

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

**INTRODUCTION:**

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

**PLANNING PHASE:**

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

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

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

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

Due Date for Tasks I.a-c: March 6, 1998 - ACHIEVED

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

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

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

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

The following are approaches that the GCMRC (headed by Mike L. and Ted M.) will utilize to scope appropriate expertise and alternative technologies: 1) telephone and face-to-face interviews with program

managers and research-group leaders from major agencies that work with remote sensing technologies and databases; especially those who focus on river, lake or near coastal ecosystems; 2) literature review, 3) attendance of the national remote-sensing conference set for Tampa, FL in late March; 4) internal scoping and discussions with survey personnel (Gonzales and others) who have already identified interesting new remote-sensing technologies.

Due Date for Tasks II.a-b: April 10, 1998 - ACHEIVED

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

### **FIRST REVIEW PHASE:**

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

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

Reviewers will have at least three weeks to prepare for the meeting (their ability to work within this time window will be one additional requirement for their selection).

Due Date for Task III.a: COMPLETED

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

Due Date for Task III.b: May 28, 1998 - COMPLETED

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

Due Date for Task III.c: COMPLETED

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

### **PROCUREMENT PHASE:**

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

**Task IV.a.** (Mike L.) - The GCMRC Information Technologies Director will have all of summer 1998 to procure the standard overflight for Labor Day still photography and videography, and any additional protocols that were identified through the scoping and review panel process for paired field testing. The present contractual agreement for aerial photography may be used to procure additional protocols for testing during the overflight, depending on the contractor's willingness and ability to provide them directly or subcontract for them through another party within the designated time frame. Standard videography may be conducted by the

Bureau of Reclamation with permitted helicopter deployment, and additional videography formats may also be used for testing purposes using existing cooperative and interagency agreements.

Due Date for Task IV.a: August 31, 1998

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

Due Date for Task IV.b: October 15, 1998

#### **EVALUATION PHASE:**

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

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

Draft Report Due on August 15, 1999

#### **SECOND REVIEW PHASE:**

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

Due Date for Task V.b: October 1, 1999

#### **DECISION-MAKING AND IMPLEMENTATION PHASE:**

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

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

**BUDGET AND TIMELINE, PEP-I:**

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

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

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

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

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

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

End SEDS Component of PEP Assessments

**OR,**

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

