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GCMR-700  
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June 17, 1998

**MEMORANDUM**

**To:** Adaptive Management Work Group

**From:** L. David Garrett, Chief, Grand Canyon Monitoring and Research Center

**Subject:** Proposed Long-Term Monitoring and Research Program for Lake Powell (GC, PRJ 5.10-AMWG, GCMRC)

The Adaptive Management Work Group (AMWG) at the September 1997 meeting received an executive summary of the Grand Canyon Monitoring and Research Center's (GCMRC) assessment of past dam operations on Lake Powell water quality. Based on the GCMRC's findings of dam operation impacts to Lake Powell water quality, the AMWG recommended that the TWG and the GCMRC complete several tasks. One of the tasks is to prepare a 5-year Lake Powell monitoring and research plan for the AMWG to review and approve at its July 1998 meeting. The tasks are as follows:

1. Continue the current GCMRC monitoring program for the period of October 1997 to October 1998.
2. Conduct additional assessments of existing data relating to Lake Powell and release water quality, including analyses of chemical and biological data that were not performed due to time and monetary constraints.
3. Review with the Technical Work Group, in January 1998, all existing knowledge related to the effects of Glen Canyon Dam operations on the water quality in Lake Powell and downstream releases.
4. Develop, with the Technical Work Group, objectives and information needs for any future Lake Powell water quality monitoring and research programs. This activity would occur in January to March 1998.
5. Develop for the Adaptive Management Work Group and Technical Work Group approval, a proposed monitoring and research plan for any specified future Lake Powell water quality monitoring programs. The draft plan would be produced by June 1, 1998.

All tasks have been completed, and the TWG and GCMRC propose the attached plan for your consideration. The monitoring and research plan focuses on two aspects of dam operation impacts to Lake Powell, water quality and ecosystem assessment.

The plan also includes, over the next 5 years, a complete synthesis of all past science that can contribute to a better understanding of dam operation impacts. This data and information will contribute to the concurrent development of a conceptual ecosystem model for the lake.

The total annual estimated costs to complete the GCMRC's commitments to the plan are approximately \$325,000 per year. Significant additional program costs will be borne by other parties including the Glen Canyon National Recreation Area.

Attachment: Lake Powell Monitoring and Research Five-Year Program  
(Cover letter and attachment received by email June 17)

# **LAKE POWELL MONITORING AND RESEARCH FIVE-YEAR PROGRAM**

## **INTRODUCTION**

### Goals and Objectives

The goal of this strategic plan is to establish a framework to develop and implement appropriate monitoring and research programs related to dam operations and their effects on various resources in Lake Powell. The plan develops priorities and strategies for accomplishing this goal and determines appropriate responsibilities and assignments. The plan also articulates the relationship between the Grand Canyon Monitoring and Research Center (GCMRC) monitoring program and ongoing monitoring and research efforts by other agencies.

### Background

The Grand Canyon Protection Act, Glen Canyon Environmental Impact Statement, and the resulting Record of Decision (ROD) specify the need to assure protection and enhancement of resources in the Glen Canyon National Recreation Area (GCNRA) and the Grand Canyon National Park as related to operations of Glen Canyon Dam.

The stakeholder groups within the Adaptive Management Program (AMP) include managers and interested parties from various federal, state, tribal, and private organizations. These groups identify the management objectives and information needs of the AMP. The GCMRC formulates monitoring and research programs that address stakeholder objectives and the specified information needs.

In fiscal year 1996, the GCMRC lacked clear definition of its authority for continuing the AMP-funded monitoring and research programs in Lake Powell. The Transition Work

Group accepted a proposal by the GCMRC to conduct a six-month assessment of Lake Powell long-term water quality data to determine if dam operations under the ROD exhibited any impact on the physical, chemical, and biological resources of Lake Powell. The Transition Work Group reviewed and approved the GCMRC proposal to conduct the evaluation.

A draft of the Lake Powell impact assessment was completed and externally reviewed by leading limnologists for validation. The findings were presented to the Adaptive Management Work Group (AMWG) at its first meeting on September 9-10, 1997. The report findings and limnologists' review determined that dam operations specified under the ROD did produce impacts to the physical, chemical and biotic resources in Lake Powell.

Based upon the GCMRC's findings of resource impacts to Lake Powell resulting from operations of Glen Canyon Dam, the AMWG requested the GCMRC to:

1. Continue the current GCMRC monitoring program for the period of October 1997 to October 1998.
2. Conduct additional assessments of existing data relating to Lake Powell and release water quality, including analyses of chemical and biological data that were not performed due to time and monetary constraints.
3. Review with the Technical Work Group, in January 1998, all existing knowledge related to the effects of Glen Canyon Dam operations on the water quality in Lake Powell and downstream releases.
4. Develop, with the Technical Work Group, objectives and information needs for any future Lake Powell water quality monitoring and research programs. This activity would occur in January to March 1998.
5. Develop for the Adaptive Management Work Group and Technical Work Group approval, a proposed monitoring and research plan for any specified future Lake Powell water quality monitoring programs. The draft plan would be produced by June 1, 1998.

The GCMRC has in coordination with the TWG completed all of the above activities as requested by the AMWG. Monitoring and research activities of the GCMRC beyond October 1, 1998 (FY 1999) is based on the approved FY 1999 Monitoring and Research Plan and AMWG review and approval of this long-term Lake Powell Water Quality Monitoring and

Research Plan in July 1998. The five-year long-term plan for monitoring and research activities in Lake Powell covers the fiscal year period 2000-2004.

### Ongoing Lake Powell Monitoring and Research

In addition to the ongoing GCMRC Lake Powell Water Quality Monitoring Program, several other agencies currently conduct monitoring and research on a broad range of resource issues. Much of the monitoring and research is not directly related to Glen Canyon Dam operations. These programs are funded independent of the AMP and exceed expenditures for Lake Powell activities that are currently funded by the AMP (Table 1).

**Table 1.** Current ongoing monitoring and research programs on Lake Powell independent of the AMP

<b>Research Group</b>	<b>Program Area</b>
National Park Service	Bacterial water quality watershed studies
Bureau of Reclamation	Colorado Basin selenium studies (beginning FY99) Selective withdrawal feasibility Colorado River water quality (salinity)
Utah Division of Wildlife Resources	Sport fishery monitoring, management, and research
Arizona Game and Fish Department	Sport fishery management and monitoring
USGS/BRD	Native fish research
San Juan Recovery Implementation Program	Endangered fish research
NPS/USGS	Side channel dynamics (proposed for FY99))

## **MANAGEMENT OBJECTIVES AND INFORMATION NEEDS**

Management objectives and information needs were developed to help guide design of the Lake Powell monitoring and research programs for the GCMRC for the period FY2000 to FY2004. In the September 1997 meeting of the Adaptive Management Work Group, the AMWG requested the Technical Work Group (TWG) to proceed with evaluation and revision of Management Objectives and Information Needs for the AMP, including those relating to Lake Powell. The revision represents a concerted effort by the stakeholders to articulate their objectives for desired resource conditions and the associated information needs related to specific monitoring and science activities. These activities are necessary to determine the condition of these resources, and how conditions are affected by management actions.

Because the AMWG had not formally approved a long-term monitoring and research plan for Lake Powell, the objectives and information needs for Lake Powell have been specified as separate and distinct from other AMP management objectives and information needs developed for resources below Glen Canyon Dam. Management objectives and information needs for Lake Powell (revised May 1, 1998), were agreed upon by the TWG management objectives *ad hoc* group and presented to the TWG for review and use in development of the long-term plan (Appendix A).

## **FIVE-YEAR MONITORING AND RESEARCH PROGRAM**

The Lake Powell management objectives and information needs (Appendix A) can be addressed with a monitoring and research program of \$325,000 in fiscal year 2000, if the additional programs noted above are funded from outside sources. The proposed GCMRC out-year programs are planned for similar levels of budget support as FY2000, but actual annual programs and budgets are dependent on GCMRC accomplishments and program reviews by TWG and AMWG.

The following list of monitoring and research projects (Table 2) respond to all TWG-proposed Lake Powell management objectives and information needs identified in Appendix A.

Projects are identified as being funded by GCMRC (GCMRC), partially funded by GCMRC (Partial), or funded by outside sources (Outside).

Monitoring and research projects under Management Objective 1: (Water Quality) are addressed first. Projects IA-IC in Table 2 comprise the current GCMRC water quality monitoring program for Lake Powell (Appendix B) and represent ongoing monitoring through the period of the five-year plan. The remaining items represent research projects which will be scheduled for specific time periods during the period of the five-year plan. Many of the information needs related to the water quality management objective (MO1) are addressed by the current GCMRC water quality monitoring program, which would continue through the five-year plan period, at a funding level of approximately \$250,000 per year. Annual work plans would be reviewed by the TWG and/or an external review panel prior to implementation.

Information needs for the aquatic ecosystem management objective (MO2) will be addressed by conceptual modeling, information synthesis, GCMRC cooperative research efforts, and monitoring and research conducted by other supporting agencies.

The GCMRC's primary research activities under MO2 are development of a conceptual model of the Lake Powell ecosystem (Table 2, 2.A) and integration and synthesis of all historic research and data (Table 2, 2.B). These two projects account for approximately \$75,000 per year for the period 2000-2003. The remaining important projects are currently programmed for only partial support or no support from the GCMRC.

**Table 2.** Proposed five-year monitoring and research program for Lake Powell.

General Monitoring/ Research Area	Specific Monitoring or Research Program	Funding Source	FY Project Schedule				
			2000	2001	2002	2003	2004
1. Water Quality (Addresses MO 1)	A. Evaluate impacts of dam operations on changes in temperature regimes in main channel of Lake Powell.	GCMRC	■	■	■	■	■
			2000-2004				
	B. Evaluate impacts of dam operations on lake chemistry, and how chemocline structures form and change through time. Monitor cations, anions, and nitrate/phosphate ratios.	GCMRC	■	■	■	■	■
			2000-2004				
	C. Evaluate dam operation impacts to primary and secondary productivity including phytoplankton and zooplankton.	GCMRC	■	■	■	■	■
			2000-2004				
	D. Computer simulation model study to model relative effects of dam operations and non-operational factors	Partial	■	■			
			2000-2001				
	E. Assessment of Impacts of dam operations to physical, chemical and biological resources in lake side channels and embayments.	Outside	■	■			
			2000-2001				
2. Aquatic Ecosystem Assessments (Addresses MO 2)	A. Develop Conceptual Model to simulate interrelationship and impacts of dam operations on physical, chemical and biotic resources and other resources (fish, aquatic vegetation, habitat, etc.).	GCMRC	■	■	■		
			2000-2002				
	B. Integration, validation and synthesis of all historic science and monitoring information and data relating dam operations to water quality and other resource change.	GCMRC	■	■	■	■	
			2000-2003				
	C. Determine linked impacts of changing temperature and chemical regimes due to dam operations on primary and secondary productivity and fish energy cycle.	Partial		■	■	■	■
			2002-2004				
	D. Determine effects of physical, chemical and biological water quality changes due to dam operations on long-term fish populations.	Partial		■	■	■	■
		2001-2004					
	E. Determine probable relationship of dam operations, selenium levels and lake primary productivity.	Outside	■				
			2000				
	F. Determine effects of fluctuating lake levels from dam operations on aquatic factors and shoreline vegetation.	Partial				■	■
			2003				
	G. Determine effects of water temperature changes due to dam operations on recreation (swimming, sport fishing).	Outside				■	■
			2003				

Over the last year, a significant effort has been initiated by GCNRA to bring other funding support to the Lake Powell program. Much of that funding supports other research to better understand the full range of potential impacts of dam operations on Lake Powell resources.

### **PROGRAM SUPPORT**

The GCMRC Lake Powell program is proposed to be funded in FY2000 at \$325,000. As noted above, it is assumed funding levels will be maintained through the period of the five-year plan from FY2000 to FY2004, and that other outside funding support will be maintained.

The annual costs to support research vessels, equipment, instrumentation, laboratory analysis, supplies, support staff, etc. and conduct monthly and quarterly water quality monitoring programs to address stated information needs is approximately \$220,000 to \$250,000 per year. The additional \$75,000 to \$105,000 annual proposed funds will be allocated to four areas over the next five years: science and data synthesis, conceptual ecosystem modeling, aquatic ecosystem impact assessments, and fish impacts from dam operations. It is anticipated that approximately \$75,000 will be needed for years 2000-2003 to conduct information synthesis and conceptual ecosystem modeling.

Over the period of the five-year plan, significant outside funding will be necessary to assist the GCMRC and GCNRA in understanding the impacts of Glen Canyon Dam operations on other Lake Powell resources not included in the long-term plan. To accomplish needed comprehensive analysis of impacts of dam operations on all facets of the lake's physical,

chemical and biotic resources, the GCNRA will be required to develop programs from outside funding sources that are equal or greater than GCMRC's program in total annual budget.

These efforts will be in addition to the GCMRC scheduled efforts over the period 2000-2004.

As noted above, the GCNRA is currently pursuing a comprehensive lake program effort with several cooperating agencies and the GCMRC will actively coordinate with these efforts.

## APPENDIX A

# Lake Powell Management Objectives and Information Needs

(Revised 5/1/98)

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.
- f. 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. macro invertebrates
- 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)**

**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 B

### **GCMRC Lake Powell Water Quality Monitoring Program**

The current Lake Powell Water Quality Monitoring Program is linked closely with other water quality monitoring programs below Glen Canyon Dam, which address other downstream management objectives. The Lake Powell program consists of **monthly surveys of the forebay** above Glen Canyon Dam and **quarterly surveys of the entire reservoir**. The objective of the program is to characterize the chemical and physical parameters of the water in Lake Powell to determine the effects of Glen Canyon Dam operations and separate these effects from other natural processes affecting reservoir water quality. This program is linked to a long-term record of similar measurements collected by the Bureau of Reclamation and Glen Canyon Environmental Studies since 1965, which describes the entire history of Lake Powell since its impoundment by Glen Canyon Dam.

Pending formal approval by the Adaptive Management Work Group, this program represents an ongoing water quality monitoring effort by GCMRC that would remain in place throughout the five-year period of this work plan.

Monitoring activities are designed to meet the stated information needs of Management Objective 1 for Lake Powell Water Quality:

**MO 1: Lake Powell Water Quality** Prevent unacceptable effects on 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.

Field activities include collecting a profile of measurements throughout the water column at each station for temperature, specific conductance (an indirect measure of salinity), pH, dissolved oxygen, turbidity, and oxidation-reduction potential. This profile describes the degree of stratification, or mixing, and the range of temperature, salinity, and dissolved oxygen concentrations at a particular station. This information is used to describe the behavior and fate of inflow currents, advective and convective mixing processes, and the effect of Glen Canyon Dam withdrawal currents under different operational scenarios. It is also used to characterize the overall quality of the reservoir as well as that of the major strata within the reservoir. For example, monitoring of dissolved oxygen levels in the deepest stratum of the reservoir, or hypolimnion, can be used to predict when significant levels of hydrogen sulfide could occur.

In addition to the profile of physical and chemical characteristics, several samples may be collected at a station for further chemical analysis. Analysis of major cation and anion concentration is performed to quantify the individual components of salinity and to identify the origin of a parcel of water to further understand reservoir hydrodynamics. Analysis of

nutrient compounds of phosphorus and nitrogen is also performed to determine the level of primary productivity that the reservoir can support and describe nutrient levels in reservoir releases or zones of potential release.

Quarterly lake-wide surveys include the major tributary arms of the Colorado, San Juan, and Escalante Rivers. Occasional sampling is done in mid-Navajo Canyon because of its potential for frequent hypolimnetic hypoxia. Other work on Lake Powell side channels and embayments has not been part of past programs but could be included in future work. An assessment of the potential effects of dam operations to the water quality of side channels and embayments should be conducted before establishing a long-term monitoring program for side channels and embayments. A study by the USGS for this work has been proposed by the GCNRA with external funding.

Heat budget quantification of modeling has been performed to a limited degree by the Upper Colorado Region of the Bureau of Reclamation as part of preliminary studies for selective withdrawal feasibility. The extent of this modeling has been to determine the effects over a two-year period of selective withdrawal. A more elaborate approach to reservoir modeling is needed to determine heat budget effects over a longer period and to help quantify the relative effects of dam operations and those of other hydrodynamic, hydrologic, and climatologic processes. This modeling effort would be very valuable to test the effects of various operational scenarios on short and long-term water quality conditions in Lake Powell.

Biological sampling is performed routinely as a component of the current Lake Powell Water Quality Monitoring Program. Several analyses are performed at the forebay and other selected stations on the reservoir. Chlorophyll concentrations are measured at the reservoir surface to describe the overall levels of primary productivity from photosynthesizing plankton. Discrete samples are taken near the surface for analysis of phytoplankton concentration and community structure. Composite samples are collected by vertical tows through the water column for analysis of zooplankton concentration and community structure. This information is used to describe long-term and seasonal changes in primary and secondary productivity and describe the type and amount of these organisms in Glen Canyon Dam releases. No work is currently being performed on macrophytes, periphytes, or macro-invertebrates. Evaluation of these shallow-water organisms is more appropriately addressed with a side channel and embayment water quality assessment.

No work is currently being performed by GCMRC to determine levels of selenium in reservoir water, sediment, or biota. Work is planned, however, on a Colorado River basin-wide selenium study to be performed by the Upper Colorado Region of the Bureau of Reclamation. It is expected that Lake Powell selenium issues will be addressed by BOR and that it will be linked with the existing Lake Powell Water Quality Monitoring Program.

A final component of the Lake Powell Water Quality Monitoring Program is the development of extensive science synthesis and database management systems for water quality information. This project supports the Lake Powell water quality management objective and addresses the GCMRC objective of establishing a comprehensive information technology program. These science and data assessments will be directly linked with other hydrologic and water quality databases and will be available by means of direct access and data warehousing products by various means including World Wide Web access. Its development has been ongoing and is being enhanced as other information technology programs progress.

Costs associated with this program include operating and maintenance for the sampling vessel, maintenance and repair of instrumentation and other equipment, analysis of chemical and biological samples, and travel and salary costs for personnel. The research vessels and all necessary equipment is outdated, and will need refurbishment or replacement in the next 2 to 3 years.

The vessel from which the majority of sampling is performed is a 31-foot Uniflite Sedan, which has been in use on Lake Powell for water quality sampling and other activities since 1970. The primary instrument for collecting water quality profiles is a Hydrolab H20/Surveyor 3. Chemical analyses of water samples is currently being performed by Reclamation's Water and Soil Laboratory in Denver, CO. Chlorophyll is analyzed by Reclamation's Boulder City water quality lab. A crew of 4-6 people is commonly used for quarterly reservoir surveys, comprising two GCMRC staff limnologists, an employee from Reclamation's Upper Colorado Region, an employee of the Glen Canyon National Recreation Area, and other ancillary personnel as needed.