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**RIVER AND DAM MANAGEMENT: A REVIEW OF THE
GLEN CANYON ENVIRONMENTAL STUDIES**

GLEN CANYON ENVIRONMENTAL
STUDIES OFFICE

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SUPPLEMENTARY REPORT

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FLAGSTAFF A**

At the invitation of the Bureau of Reclamation, a committee of the Water Science and Technology Board (WSTB) of the National Research Council (NRC) completed a review of the bureau's Glen Canyon Environmental Studies (GCES) last December entitled, River and Dam Management: A Review of the Glen Canyon Environmental Studies (National Academy Press, 1987).

Upon receipt of the review, arrangements were made for the committee to continue to work in a scientific advisory role, to follow up on the recommendations it had made and to provide review and advice for future work plans and products of the GCES program. The bureau's Executive Review Committee will make recommendations shortly to the Secretary of the Interior on the direction of future GCES research and operations of the Glen Canyon Dam. Therefore the bureau requested advice in three areas: (1) interim research activities (for summer and fall 1988); (2) identification of which of the NRC's 1987 review recommendations has the highest priority, and (3) future research activities to be conducted in Glen Canyon during the next decade or so.

This letter report includes recommendations to assist the bureau as requested. The committee has agreed to review further work plans and to meet again with the GCES program manager and other Bureau of Reclamation/Department of the Interior (DOI) personnel as appropriate to communicate its critique.

Recommendation 1. Establish a Science Research Advisory Group at the Department of the Interior Level. The Secretary of the Interior should establish a single science research advisory group to the four DOI agencies involved in this work, i.e., the Bureau of Reclamation, the Park Service, the Fish and Wildlife Service, and the U.S. Geological Survey (12, 13, 42).*

The NRC committee makes this recommendation for the following reasons: the skills, talents, and experience required to plan and perform ecosystem investigations cannot be assembled from DOI agencies under the present way of doing things: some skills simply are not available, and budget pressures force a sort of "turf protection," whereby skills, talent, and experience already on hand are used, even if not applicable to the needed tasks. Planning in the face of these limitations is difficult. The GCES, as conducted between 1982 and 1987, suffered seriously from shortcomings in the planning phases (2, 33 et seq.). The four "sister" agencies (and some Arizona agencies) were requested to advise on the subject of what research should be performed. The advice consisted of recommending tasks that agency personnel were capable of performing whether or not the tasks were of high priority to the investigation,

* The numbers in parentheses throughout this report refer to pages in the 1987 NRC review River and Dam Management: A Review of the Glen Canyon Environmental Studies that provide further explanation.

e.g., overlap of aerial photo interpretations with little integration between studies. Also numerical models of alluvial rivers were used in the GCES even though alternative approaches appear to be better suited to the canyon environment.

The result was that many subtasks in the GCES were of only marginal value to the integrated result required by the original purpose of the studies. Other subtasks necessary for coherent synthesis were omitted, e.g., the hydrodynamics of beach building. In addition, while debris flows in the canyon were expertly analyzed, their connection to the movement of sediment in the entire system remains unknown. Therefore the study plan was driven more by the needs of the agencies than by objectives of ecosystem investigation (2, 11).

Senior scientists experienced in the design and conduct of ecosystem research and without pressures and biases imposed by their employer will be more likely to state objectives succinctly, develop the study, and complete a work plan more appropriate to the objectives. An independent chief scientist is likely to write the necessary requests for proposals more objectively than someone from within the agencies. The function of this advisory group would lie mostly in planning, selection of scientific talent, and help with analysis and interpretation.

A few of the preliminary considerations, discussed by the committee are:

1. The group should be composed of from three to five senior scientists not presently associated with the DOI.
2. The chief scientist, principal investigator, or chairperson of this group might be retained on salary (full or part-time). Perhaps an Interagency Personnel Agreement is a mechanism by which this could be done. The objective of this is to provide long-term continuity for the investigation.
3. Other members of the group might be expected to serve without compensation (except for reimbursement for travel and a subsistence allowance) though a consulting fee might allow DOI to attract more competent people and would stimulate more attentiveness to the task.
4. Membership in this advisory group might rotate (perhaps on staggered terms) to provide for new ideas and experience to deal with mid-course corrections in the investigation.
5. The committee believes that the scientific advisory group should be assembled, and the disciplines represented should include:
 - sediment transport/hydrology/geomorphology
 - fishery science/aquatic ecology
 - ecosystem science/arid lands ecology
 - resource economics/water resource operations
 - conservation biology

6. The early activities of the advisory group should include:

- Focusing attention on the NRC's 1987 review recommendations.
- Developing a work plan for an ecosystem investigation of the Colorado River in the Grand Canyon with attention focused on the relationship between the operation of Glen Canyon Dam and (1) endangered native species and the trout fishery and (2) the fate of riverside beaches in the Grand Canyon. These two elements of the Grand Canyon/Colorado River ecosystem have been judged as centrally critical by the current GCES Executive Review Committee. An ecosystem investigation, of course, would include other connected elements, especially Lake Powell (6, 8).
- With a work plan in hand and RFPs written, the scientific advisory group should guide the search for appropriate skills and scientific talent to conduct the work. There is concern that if the tasks (subprojects) are opened to public bidding, scientists in the government agencies will be precluded from bidding (even if they are best suited for the task). However, the committee is also concerned that if the subprojects are kept "inhouse," scientists in the private sector or in academe will be precluded from bidding (even if they are best suited for the task). Rules that prevent the best scientists from participating must be changed, or another mechanism for selecting the most appropriate scientists must be developed. If there are some tasks that can best be performed by people employed by the agencies, then they should be identified and selected through review by the independent scientific advisory group, before the remaining tasks (for which appropriate skill and talent cannot be found in the agencies) are advertised through requests for proposals.

The committee offers these ideas sincerely, but recognizes that there are administrative, budgetary and political issues to be considered.

The remaining recommendations refer to activities that can proceed immediately while the recommended scientific advisory group is being recruited and while it conducts its initial planning tasks.

Recommendation 2. Continue Monitoring. Monitoring efforts in the following areas should be continued until a fully planned investigation can be implemented. The committee cautions here that there is some danger that these monitoring efforts can become expensive, can lose purpose and tend to become routine data gathering all of which tend to subvert the integrated investigation being recommended. However, the risk is worth taking because time gaps in important data series would be even more damaging to interpretation and management decisions.

Sediment Gages. The committee believes that understanding the long-term trends in sediment transport and storage phenomena is central to understanding the natural functioning of the Colorado River ecosystem. Failure to maintain sediment transport monitoring will prove to be an obvious shortcoming and may result in faulty interpretation and conclusions (7, 89, 107).

The long-term gaging sites (Lee's Ferry, Phantom Ranch and Little Colorado) were discontinued when Lake Powell was full. These long-term gaging sites

should be reinstated because data collected there will help in understanding beach dynamics, sediment export to Lake Mead, and storage in Grand Canyon deposits.

The committee recommends continued sediment data collection at the following sites:

1. Colorado River at Lee's Ferry. These data will extend a valuable long-term data set and document the incoming sediment load.
2. Paria River near Lee's Ferry. These data represent the incoming sediment from the first major tributary downstream from the Glen Canyon Dam.
3. Colorado River above its confluence with the Little Colorado River. These data document the sediments imported from the tributaries to Marble Canyon plus the sediment stored in Marble Canyon that is being eroded.
4. Little Colorado River at Cameron. These data document the sediment contribution from the Little Colorado, the largest potential source, and are part of a long-term record.
5. Colorado River at Phantom Ranch. These data document the movement of sediment in the Grand Canyon, extending an important historic data set for time series and uncertainty analysis.
6. Colorado River at Diamond Creek. These data document the loss of sediment to Lake Mead.

These monitoring points are chosen to provide the maximum amount of useful information at minimal logistic cost. Unfortunately, the elimination of one or more sites seriously damages the utility of the remaining sites because of the need for a system-wide sediment budget.

These data can be used to assess sediment movement through the Grand Canyon or as part of investigations of the dynamics of beach building and degradation. However, there are problems associated with the use of such data that must be acknowledged and carefully considered. The best use of them will require analyses of (1) the errors associated with the measurements and (2) the uncertainties associated with records from this spatially variable and temporally unpredictable system. Such analyses should accompany the continued monitoring effort.

The following analyses should be completed before the data are used for modeling and predictive purposes:

- Assess the error in the estimates of water discharge because this error magnifies the error in the estimate of sediment in transport.
- Assess the uncertainty in the relation of sediment transport rate to water discharge rate because the same sediment transport rate is not uniquely determined by a particular water discharge rate.

- Assess the time sampling uncertainty because major flow events carry most of the sediment. Estimates of change of storage and movement of sediment during steady state conditions may not be good predictors during periods of spill. In particular, they may not be good predictors during major events that cannot be measured.
- Assess bias that results from analysis of (1) the empirical relationship between discharge and sediment transport and (2) the fact that most sediment is transported at high discharges.

Endangered Species Populations and Trout Populations. The fishes are involved in several controversies. On the one hand, endangered species legislation demands attention to the relationship between the operation of Glen Canyon Dam and well-being of endangered endemic populations. A species of central interest is the humpback chub because its continued survival may be affected by operating the dam. Records of the population trends reflect only a few years, so data from a single reproductive season are extraordinarily important.

Much more ambitious studies of the native fishes, and particularly of the humpback chub, will be required in the future. The goal of the Endangered Species Act is to maintain native species in perpetuity within their natural environments. In a managed system, this goal cannot be achieved without good definitions of habits, life history requirements, and definition of critical stages for maintenance of a minimum viable population. This information does not now exist for the humpback chub or for most native species. A major commitment must be made by the Bureau of Reclamation to establish both intensive studies and long-term monitoring of the native fish populations. Examples of the kind of information that will be needed are as follows.

1. Although numerous weighty legal questions may hinge on the survival and welfare of the humpback chub in the Grand Canyon area, very little is known of the basic life history of the fish in the Grand Canyon. Still to be established are time of reproduction, fecundity, survival of young, maturation time, longevity, age structure, and control of life history variables by environmental factors. Much basic descriptive work yet remains to be done.
2. The genetic uniformity of the Little Colorado River population of humpback chub, which appears to be the largest population remaining anywhere, has not been established. It is unknown whether or not this species was influenced by hybridization with other related species (Gila spp.). The relationship to other populations in the Colorado River basin are also unknown.
3. The reason for exceptional survival of the humpback chub in the Little Colorado River has not been clearly identified. Prediction of the humpback chub's response to further changes in the Colorado River system would be more feasible if this problem were better studied.
4. The relationship between humpback chub found in the main stem to those in the Little Colorado River is unknown.

Although numerous other questions could be posed, these should provide some idea of the scope of inquiry that would be appropriate for future studies of the humpback chub and other native species, and of the degree of institutional and financial commitment that will be required.

Additionally, the trout populations in the river are exotic and new since the construction of the dam. The cold water that contributed to the disappearance of the native species provided an important feature of the environment for the trout that are popular with recreational anglers. The recent hydrologic regime and recent changes in angling regulations are influencing trout populations. Again, the record is short, so data from each season are important. (57 et seq.)

Surveys of Aggradation and Degradation of Grand Canyon Beaches. One of the controversial effects of dam operations most apparent to the public is likely to be the fate of the camping beaches in the Grand Canyon. Some beaches may be degrading as a result of the interruption by Lake Powell of the sediment source from the Colorado River. Beaches may be stabilizing because of vegetation growth that was not present in the Grand Canyon under annual flooding conditions before the Glen Canyon Dam was built. Some beaches are growing as sediment from canyon tributaries reaches them. Sediment transport and storage in the river are in disequilibrium as a result of the closure of the dam, the filling of Lake Powell, and the operations since Lake Powell filled in the early 1980s.

Tracking the condition of extant beaches is a simple activity that can be tied to monitoring, and to future investigations of the mechanisms controlling beach formation. Knowledge about beach dynamics will provide important information about the potential for management of sediment deposition through the manipulation of river discharges.

Recommendation 3. Perform an Economic Analysis. An operations analysis should be developed to evaluate both the costs of lost power revenues and the cost of buying additional peak period energy from alternative sources, as well as the potential benefits to other user sectors, e.g., recreation and environment (99 et seq.).

The committee believes that all subsequent GCES studies should be based on a firm understanding of the range of operational options for the Glen Canyon Dam. This requires that the Bureau of Reclamation define the maximum legal and physical breadth of the operations options. The definition should be based on analyses that should include (1) diurnal fluctuation in terms of both timing and amplitude of the fluctuations, (2) the potential for control of spills and the use of planned maximum flows, and (3) the potential for manipulation of temperature with multiple outlet withdrawal of water from Lake Powell.

The committee believes that the analysis must be based on the results from a model in which the operating rule is treated as a variable that is explicit in the model (stated formally and completely in mathematical terms). The logic of the model structure should be available to the user so that sensitivity of results (frequency of spills and target release shortages) to changes in the

operating rule can be obtained by changing the rule. The method of selecting monthly release targets as function of current storage, snowpack, in addition to minimum flows at night, and so on, should be stated.

The models should be consistent with the "Law of the River" but should also be capable of simulating releases that might deviate from the bureau's understanding of the "Law." Models will necessarily include the effects from all other upstream reservoirs and the Western Area Power Administration (WAPA) network, but must be able to isolate and focus upon the impact of changes in the operation of Glen Canyon Dam (104-105).

With such analysis the Bureau of Reclamation should then move to (1) identify the costs and benefits of the various operational options from the viewpoint of hydroelectric power and water storage and delivery and (2) study and identify the system-wide effects of the full range of options on other uses such as sport fishery, habitat for endangered species, other recreation, other flora and fauna (especially associated with the mission of the National Park Service). The Bureau of Reclamation should program into its operations of the dam one or more protocols for controlled releases to be used to test hypotheses critical to (or generated by) the GCES in the immediate and longer-range future. Operating potentials for Glen Canyon Dam provide the opportunity to vary volume, timing, intensity, and predictability of flooding, or drought, to test ideas on impacts of those riverine parameters on biotic and abiotic features ranging from sandbars, through aquatic invertebrates and fishes to riparian vegetation and beyond.

Recommendation 4. Insure Data Preservation and Establish Data Base Management System. The DOI should make it a priority to ensure the physical preservation of all GCES data, records, and research results. Beyond their preservation, resources should be allocated to permit the documentation of these materials to perfect the record of the GCES program and enhance its effectiveness to future researchers. Looking to the future, a data base management system should be established for the dual purpose of archiving and cataloging the information that has been developed and expediting its retrieval for use in new analyses (5, 108).

Publication of information in scientific journals enhances the credibility of the work because of the referee process. It also provides interpretation by the original investigators and, then, for the archiving and cataloging of the information for use by other scholars who may need to interpret future investigations. The NRC committee encourages further efforts to submit manuscripts for this traditional mechanism of scholarly review. Publication of the results is the surest route to broad scientific acceptance of the bureau's research.

Then, in preparation for continued investigation, protocols of data base management should be developed that include (1) methods of quality assurance and quality control, (2) explicit documentation of data sets, (3) documentation of methods, sample sites, sample schedules, units of measure, use history of data, and so on.

Data base management techniques are evolving rapidly and offer dramatic opportunities for linking management to research. The task is not a trivial one, however, and should include the establishment of a data base management facility for the GCES, including adequate personnel, appropriate space, and equipment to meet modern standards of data management.