GRAND CANYON MONITORING AND RESEARCH CENTER

Protocols Evaluation Program (PEP – SEDS)

"Final Report of the Physical Resources Monitoring Peer Review Panel"

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U.S. Geological Survey Field Center
Flagstaff, AZ

FINAL PROCEEDINGS OF THE EXTERNAL PEER REVIEW WORKSHOP II ON LONG-TERM MONITORING OF WATER AND SEDIMENT RESOURCES OF THE COLORADO RIVER ECOSYSTEM

WORKSHOP-II DATES: August 29-31, 1999

MEETING LOCATION: USGS Field Center, Bldg. #3, 2255 N. Gemini Dr., Flagstaff, AZ

PHYSICAL SCIENCE PEER REVIEW (SEDS) PANEL:

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I. OVERVIEW

The Grand Canyon of the Colorado River is a vast and awe-inspiring landscape. More than a billion years of geologic history are recorded in the Canyon's rock units and these rocks, together with the river that has incised deeply into them, support a complex ecosystem containing several species unique on Earth. Human activities have impacted the Canyon ecosystem for centuries, but these impacts greatly increased following the completion of Glen Canyon Dam in 1963. During the intervening 35 years, public concern over these impacts has increased, leading to the establishment of the Glen Canyon Environmental Studies (GCES) Program (1982-1996), an Environmental Impact Statement on dam operations (1990-1995), and the present Glen Canyon Dam Adaptive Management Program (AMP), which includes the Grand Canyon Monitoring and Research Center (GCMRC) as its science component. A Peer Review Panel initially convened in Flagstaff, Arizona during August 1998, was charged with evaluating past and current protocols used by the former GCES and the GCMRC in its physical science monitoring program of the Colorado River ecosystem, and with making recommendations to better address information needs that support management objectives of the AMP.

A preliminary report summarizing the outcomes of that initial meeting was completed in September 1998. The Peer Review Panel was subsequently convened in Flagstaff during August 1999, and charged with evaluating (1) recommendations contained within the National Research Council final report (1999) on the GCMRC strategic plan, (2) monitoring strategies and methods tested since the 1998 meeting, and (3) the specific recommendations by cooperating physical scientists for long-term monitoring of streamflow, sediment transport and geomorphic processes.

This final report carries forward items from the preliminary report which summarize issues that the Panel still considers vital to the success of the GCMRC in administering a program of physical resources monitoring and research, and then addresses the specific monitoring issues and recommendations that the Panel was asked to consider.

Design of the monitoring program

The Panel is generally impressed with the GCMRC physical resources monitoring program as it is presently designed and operated. Important progress has been made in understanding the response of the physical resources to dam operations. The program is well-managed and the talented investigators participating in the program have worked effectively to integrate and cross-reference their work so that there are productive and complementary links between, yet little overlap among individual studies. The rapid response in addressing issues raised in the 1998 preliminary report is particularly impressive.

Although the research and monitoring are generally well focused and useful, the Panel believes that future program decisions will benefit from a clearer and more direct statement of the program's objectives. A specific statement regarding the processes requiring understanding and the associated modeling and monitoring capabilities will help in the choice among alternative possibilities such as system-wide monitoring versus a focus on specific study reaches.

In defining a monitoring framework, developing research objectives and hypotheses related to physical processes may be relatively straightforward, but there remain critical disconnects between the physical resources program and the biological and cultural/socioeconomic programs. To address these connections, the physical program requires input from program managers and scientists in the biological and cultural/socioeconomic programs so that physical monitoring can effectively address information needs related to management of biological and cultural/socioeconomic resources of Grand Canyon. The ecosystem model being developed by Korman and Walters should provide an effective tool to facilitate integration among the three monitoring programs.

As previously recommended by the Panel, joint research trips by physical, biological, and cultural/socioeconomic scientists may help to increase collaborative efforts. Also useful would be joint workshops focusing on particular ecological questions, such as the habitat requirements and probable life-history bottlenecks of focal (e.g. native) species, or physical conditions that may create a barrier to introduced species while providing habitat for native species, and means of enhancing such physical conditions. A focus on identifying and quantifying changes in pre- and post-dam physical conditions that affect native and introduced species would be another means of enhancing collaboration between biologists and physical scientists. The connection between physical and cultural resources is clearly defined in terms of the potential erosion of cultural sites.

Monitoring requirements

The Panel finds that the monitoring requirements developed by the Technical Work Group (TWG) for the physical resources program are, in general, imprecise, repetitive, and difficult to understand. Inasmuch as the monitoring requirements are used by the Technical Work Group and the Adaptive Management Work Group (AMWG) to prioritize research and monitoring needs, it is imperative that the monitoring requirements be clear, precise, and complete. Before further decisions are made regarding research priorities, the Panel suggests that GCMRC staff be given the opportunity to redraft the monitoring requirements into a more consistent and clear form. This could be accomplished following a two-part procedure: the TWG and the AMWG define broader goals, whereas the scientists more precisely define the data needed and the theory that must be developed to reach those goals.

Geographic boundaries of research

The Panel still recommends that research not be artificially constrained to the apparent geographic boundaries of the Colorado River in Grand, Glen, and Marble Canyons. In order for scientific questions regarding the Colorado River ecosystem to be effectively addressed, flexibility is needed regarding the geographical boundaries of the work conducted. The Panel recognizes that the GCMRC program is one of applied research, and that there is appropriate concern about extending research outside the scope of application. However, there are cases in which answers to the applied questions concerning the Colorado River ecosystem require work outside the ecosystem's immediate boundaries. A good example is work done on the sand supply to the mainstem Colorado River. In order to understand the long term trend of sand content in the Canyon (which provides the basis for forecasting bar size and prescribing management actions), the input of sand from tributaries must be known. The same argument applies to water quality in Lake Powell. In order to understand the ecological impact of different release options, the quality of the released water must be known, which means that the distribution and variation of water quality within the reservoir must be understood. Other examples of work outside of the immediate river corridor will undoubtedly be appropriate. For example, the post-dam reduction in sand supply would be better defined if the deposition in the Lake Powell delta were used to define the long-term average sand input to the Canyon. The important point is that the required information is the limiting and driving concern for the scope of studies, not the geographic boundaries.

As mechanisms, responses and interactions among system components are clarified and developed formally from the ecosystem model, attention must be given to the possibility of an evolving condition or an extreme event that could create a resource crisis. Examples of a potential evolving condition include the downstream progression of a scour wave that greatly decreases sand availability, or the accumulation of coarse sediment. An extreme event is most likely to take the form of a large flood either from headwater areas as in 1983, or from local debris flows from the canyon walls during heavy precipitation.

II. SPECIFIC CHARGES TO THE PHYSICAL RESOURCES MONITORING PEER REVIEW PANEL (Appendix 1.)

Panel comments on the National Research Council Report

The Panel concurs with the NRC report's emphasis on developing a sediment budget for the Grand Canyon, an issue on which the Panel's preliminary report focused. The Panel concurs with the recommendations to focus on tracking sediment storage rather than input and output, and to focus on the coarser grain-size fractions (medium sand to pebbles) relative to fine sand. The Panel also concurs that event-based storage changes be tracked in order to test the hypotheses regarding the impact of major tributary inputs. These inputs should be tracked with gages that record suspended sediment concentration and grain size, and with other new technology that may expand the spatial and temporal resolution capabilities of tracking inputs. It is imperative that the suspended sediment sampling program be prepared to respond to large sand inputs from the Paria and Little Colorado Rivers, particularly during the late summer and early autumn (and to a lesser extent in the spring) when these inputs are most likely.

Because the physical sciences peer review panel includes an aquatic ecologist, the Panel will comment on the biological portions of the report. With respect to these portions, the Panel notes that the proposed goal of 100,000 Age II+ trout in the reach between Glen Canyon Dam and Lees Ferry would produce an unnaturally high density of trout, causing the normal territoriality of these large fish to break down, and increasing their susceptibility to disease outbreaks and population crashes. Although the NRC report criticizes the biological program for a lack of information on native fish, such as what they eat, a more important hole in the program is the lack of information on fish abundance and habitat use, resulting from a lack of any systematic censusing. Repeated, site-based monitoring should be conducted so that the direction of change of population(s) of these fish (chub and suckers) over time can be ascertained, even if the monitoring must be based on relative estimates such as sightings per effort per area. Non-harmful visual censuses, with standardized location, time of day, effort (person hours), and area traversed (along with notes on non-standardized co-variates such as visibility or extent of bed vegetation) would begin to remedy the lack of information regarding native fish. Visual censuses might also be supplemented with counts from electronic surveillance.

GCMRC long-term monitoring and research elements

A) Glen Canyon geomorphology vs. Marble/Grand Canyons

* A key question with respect to the Glen Canyon reach is whether there are any limits to terrace retreat. The monitoring program needs to develop and test hypotheses of the processes of bank erosion at culturally important sites (such controls could include boat wakes, rates of flow rise and recession, and underlying coarse substrate), determine which sites are presently eroding, and estimate how far and how fast the terrace erosion might proceed. The program might consider some form of mitigation, such as artificial debris fans or underwater stone berms, to protect the terraces in this stretch of river.

* The Panel suggests that the program consider reconnaissance-level mapping of in-channel sand deposits anchored by macrophytes, and the effectiveness of this vegetation anchoring during high and low discharges.

B) Main channel and gaged tributary streamflow and fine sediment discharge

* Steve Wiele's research on 1d and 2d sediment modeling is critical to this element, and should continue. The evolving outcomes of his work should drive both monitoring and study-site selection. The Panel recommends focusing on multiple-kilometer (perhaps-10 km-long) reaches for which bathymetry obtained from multi-beam sensors during high flow and LIDAR or stereo-photogrammetry data obtained during low flow are merged. Monitoring during times of rapid change (event-driven monitoring and sampling) is likely to be most useful, and resulting data should be used to evaluate the accuracy of the sediment models. It would be useful to define triggering events in response to which monitoring and sampling would be initiated, and to define the necessary monitoring response protocols.

* Daily suspended sediment samples should be collected at the lower Marble Canyon and Grand Canyon gages until the inputs from a time period incorporating at least two sizeable tributary floods have been sampled. These samples can be used to track the input of sediment and evolution of sand waves as modeled by Wiele. Bed-material samples and grain-size distribution data should be collected over the same time period and at a high temporal resolution (daily).

* David Topping's ongoing work designed to predict sediment output from the Little Colorado River should be completed.

C) Main channel and shoreline fine-sediment storage

* Interstitial spaces and pools may provide important sediment storage space in the channel bed. It is important to develop and implement a method to quantify this storage.

* The Panel was impressed that Wiele's 2d model may be able to predict bar geometry as a function of flow recession. The model, or an alternative research approach, should be used to evaluate the effects of hydrograph characteristics on habitat availability; for example, how do bar morphology and grain size affect vegetation and aquatic ecology?

* The Panel supports Roberto Anima's development of a synoptic picture of the river bed, and emphasizes that sufficient funding be provided to allow these data to be processed in a timely fashion.

* Shoreline sampling should be stratified into frequently (ground-based cameras, focusing on campsites) and less frequently (aerial photographs of reaches) visited sites. Sites downstream from Phantom Ranch may be less intensively monitored using the Adopt-A-Beach program or daily photographs (without photogrammetry) from ground-based cameras. The Panel suggests that reaches downstream from Phantom Ranch not be completely neglected because the habitat dynamics in these reaches may exert an important control on secondary populations of humpback chub.

* The frequency of aerial photographs suggests that the monitoring program is oversampling above-channel features relative to below-channel features. It may be appropriate to use different types of imagery, such as color infrared every year for in-water features, vegetation mapping above water, and debris-flow features, and normal photographs every third year for other above-channel features.

* The multi-beam sensor is most appropriate for detailed study reaches rather than for the entire channel, unless used at a more reconnaissance level without precise positioning, in which case it might be appropriate for a rapid channel-wide reconnaissance during high-flow conditions with a 120-degree field-of-view setting. This sensor might be purchased and used in conjunction with other groups.

D) Ungaged tributaries and geomorphic framework

*It would be appropriate to sample a subset of ungaged tributaries by establishing staff gages and expanding the Adopt-A-Beach program to include sediment sampling. Placing buckets in tributary channel beds, to be emptied by river-guide volunteers as available, is one example of how the program could include sediment sampling.

* DEM and weekly NDVI (normalized difference vegetation index) data could be used to model the dynamics among precipitation, vegetation, and erosion in the drainage basins of ungaged tributaries. Existing high temporal resolution (low spatial resolution) image data can be used to monitor basin-wide climate-related changes, and to correlate these with sediment inputs

on the Colorado River.

E) Construction of high-resolution 3d channel-geometry data for the main channel

* A high priority should be given to developing a one-time, continuous topographic-bathymetric map for use as a base map. The bathymetric component of this map will be the most important component, and should be obtained during high flow.

* The Panel recommends that the program consider the SHOALS option for above- and below-water imaging during conditions of low flow and low sediment influx. SHOALS is a LIDAR system designed for bathymetric information rather than above-water topography if dense vegetation is present.

* After the multi-beam sensor has been used to map the length of the channel, 1-pass LIDAR could be used along the length of the channel, with multiple passes at sites of interest if the budget permits. With the relatively low vegetation cover along the main channel, a test might be useful to determine whether under-water and above-water topography with acceptable resolution can be collected simultaneously during a single flight through the Canyons. The Panel recommends that the biology program contribute to the cost of obtaining LIDAR data because of the usefulness of these data in monitoring tamarisk.

Comments on specific researchers' recommendations

John Gray:

Gray reviewed U.S. Geological Survey activities in streamflow and sediment monitoring. The Panel has no specific comments, but supports the implementation of new techniques for monitoring water and sediment discharge, as these become available.

David Rubin and David Topping:

It is important to continue collecting suspended sediment data. The Panel does not necessarily agree with the hypothesis that tributary inputs are quickly moved through the main channel, and it is important to test the hypothesis by evaluating coarser as well as the very fine grain-size fractions. After the main channel storage areas (spaces between cobbles; eddies; pools) are full of sand, tributary-supplied sands will move through the main channel relatively fast. However, a flood would tend to erode the system of previously stored sands. Sand supplied from tributaries after a flood may be more likely to re-deposit in the main channel storage areas, and sand loads would thus tend to decrease in the downstream direction until sand storage areas once again became full. The present sample techniques may not adequately estimate the sand component present on the bed. The Panel agrees with Topping's list of six primary data needs and recommends that these be addressed, subject to budgetary constraints. These primary data needs are:

1) channel shape and slope in tributaries (measured repeatedly), and in the mainstem channel
2) storage/erosion measurements repeatedly in the tributaries, and in the mainstem channel
3) fine-sediment thickness at 5-year intervals in the tributaries, and annually in the mainstem

channel (measured as continuously as possible along the mainstem)
4) grain-size distribution of fine sediment on bed
5) suspended-sediment measurements with grain-size analysis (event-based in tributaries, daily at Grand Canyon)
6) crest-stage gages and U-59 samplers on selected ungaged tributaries

The Panel supports Rubin and Topping's current and planned future work.

Stephen Wiele:

As noted previously, the Panel considers Wiele's 1d and 2d sediment modeling to be crucial to the physical resources monitoring program.

The Panel supports Wiele's current and planned future work.

Nancy Hornewer:

The Panel is puzzled by the inability to complete at least initial on-site processing of sediment samples from the Grand Canyon gage, thus avoiding unnecessary shipping expenses. The USGS and NPS should cooperate with the Grand Canyon sampling team by permitting on-site initial sample processing and access to sample lab facilities, respectively. If the GCMRC biology program can fund periodic analyses of nutrients and dissolved organic matter in the samples, it might be valuable to expand the sampling program to include these components.

The Panel supports Hornewer's current and planned future work.

Pat Chavez:

Chavez makes two basic recommendations with respect to mapping and monitoring suspended sediment concentrations and turbidity using remotely sensed images and field instruments:

1) Wherever possible, remotely sensed images and field instrumentation should play a role in helping to map and monitor the Colorado River ecosystem. These types of investigations should be continued and expanded in the coming years.
2) Other possible applications of remote sensing not currently under investigation include: regional 'snapshot' views of the spatial distribution of suspended sediment concentration using aerial photography collected during high sediment runoff condition and/or high controlled floods; water volume and discharge measurements; underwater cover-type mapping from the Dam to Lees Ferry using airborne images/photos; vegetation change detection and mapping; and spatial variability analysis to detect changes related to debris flows. These applications should be included in future remote sensing investigations.

The Panel supports the recommendations by Chavez. The Panel also supports Chavez' current and planned future work.

Laura McCarthy:

McCarthy summarized the application of digital photogrammetry to monitoring sandbar evolution. Photogrammetry seems most appropriately applied at the reach scale rather than at the site scale.

Jack Schmidt:

Schmidt made the following recommendations –

Using Canyon-wide inventories of large bars used as campsites, establish monitoring reaches and discontinue monitoring elsewhere. The most important sites will be between the Dam and Bright Angel Creek. Because the low-elevation sand storage in eddies is highly variable, monitoring should focus on deposits exposed above a stage of approximately 20,000 ft^3/s. Also, the eddy-complex scale is too short; monitoring sites should be approximately 10 km in length. Suggested sites include Lees Ferry-Badger Creek; Redwall; Point Hansbrough; Tapeats Gorge above the Little Colorado River; below the Little Colorado River; and Granite Gorge near the gage. Activities in these reaches should include mapping the surficial geology of the entire reach; determining the boundaries of persistent eddies; mapping channel-bed bathymetry; photogrammetry of channel margins; mapping bed material; modeling behavior; and a historical synthesis.

* The Panel concurs with most of Schimdt's recommendations, including

- consolidating monitoring efforts to the level of approximately 10-km-long reaches
- focusing monitoring on geomorphic processes
- the use of metrics to indicate the direction of change

* In general, the Panel recommends that a joint workshop of ecologists and geomorphologists might be convened to select the study reaches. The Panel also recommends that someone be designated "sand master" and tasked with overseeing all the components of channel morphology research within the context of a sand budget. The frequency/intensity of sampling should be decreased downstream from Phantom Ranch, but this portion of the Grand Canyon should not be completely neglected.

The Panel supports Schmidt's current and planned future work.

Robert Webb:

Webb is developing a model for sediment yields from tributary debris flows. He recommends that GCMRC (a) develop water-surface profile data using LIDAR equipment; (b) continue Anima's work on bed grain-size distribution; and (c) obtain low-discharge aerial photographs annually or biannually (in early October).

The Panel supports Webb's current and planned future work.

Roberto Anima:

Anima is overseeing system-wide side-scan sonar surveys, and he recommends (a) testing other technologies, and (b) starting change analysis between data sets.

The Panel supports Anima's current and planned future work.

Matt Kaplinski:

Kaplinski is currently monitoring channel-margin sand deposits. He recommends integrating multi-beam and side-scan sonar mapping; establishing long-term monitoring sites; monitoring sand bars seasonally or based on flow events; and maintaining two monitoring measurements per year (spring and autumn), plus measurements during BHBF/HMF events.

The Panel supports Kaplinski's current and planned future work.

Mark Manone:

Manone is conducting stereo photogrammetry studies of beaches.

The Panel supports Manone's current and planned future work.

Patrick Wright and Mike Lizsewski:

The Panel recommends that LIDAR be used for the length of the entire channel, photogrammetry at the reach scale, and ground-based photography at the site scale.

In general, the Panel supports program director T.S. Melis' three research objectives of (1) predicting sand bar evolution, (2) quantifying and modeling reach-averaged sand transport relative to sand supply and geology, and (3) predicting channel evolution. These research objectives are important, and require a total-channel perspective of channel geometry and habitat evolution over long time scales. Predicting sand bar evolution requires knowledge of reach-averaged responses of main-channel bars under varied operations and sediment conditions. One-dimensional and 2D model predicted reach-by-reach responses can be verified against actual channel topography. Sand bar dynamics in turn affect the size and structure of both aquatic and terrestrial habitats, the stability of cultural resources and campsites, and the scouring or burial of the aquatic food base.

Quantifying and modeling reach-averaged sand transport involves coupling unsteady streamflow with 1D sand transport under varied sand inputs. This should allow prediction of reach-averaged fine sand exports for actual and hypothetical dam operations. By tracking the sediment budget in real time for "events" after large sand inputs, measured and modeled sand transport can be compared. Sand transport in turn impacts the aquatic food base, the evolution of habitat morphologies, and the potential for campsite restoration. Predicting channel evolution involves predicting the style of main channel changes likely to occur in specific channel settings, by reach. This requires characterization of reach physical habitat characteristics; long-term simulations to assess local and reach-average changes; and relating changes in physical habitat to productivity. Evolution of main channel morphology directly structures aquatic and terrestrial habitats.

These three research objectives represent a large step toward addressing the Panel's concerns regarding the need for a better statement of program objectives. If implemented, these research objectives will strengthen the sediment budget conceptual framework of the physical resources program, and provide the opportunity for strong linkages between the physical and biological and cultural/socioeconomic resources programs.

The prediction, quantification, and modeling components of understanding sediment dynamics in the Grand Canyon will require further research, and the program is not yet ready for a static monitoring plan. For example, continued field observations are needed to track the fate of tributary-derived sediment waves as a function of time and distance along the channel. The residence time of the sediment waves must be determined as a function of volume of input sediment and main channel discharge. In addition to the mean velocity of the sediment wave, its dispersion and sorting must be determined. These data are needed to test the multiple-grain-size 1d transport model currently under development. The model will provide a basis for evaluating different management scenarios and will be a key component of the long-term monitoring program. With time, point samples of suspended sand concentration and grain size should be able to replace more comprehensive sampling. Remotely sensed observations may be possible, although calibration for both suspended sediment concentration and grain size are needed and will require careful verification under a wide range of conditions.

III. SUMMARY

The impacts of the Glen Canyon Dam originate in processes that are primarily physical; changes in flow magnitude, timing and temperature, and changes in sediment supply. The suite of management options available to address impacts of the dam are also primarily physical; the timing, magnitude and, possibly, temperature of the released water. Prescription of any changes in dam operations must ultimately be translated into physical conditions in the tailwaters reach. Therefore, an understanding of the ecosystem response to dam operations must begin with an understanding of the controls on its physical condition. Information on the nature of the physical setting and its controls also provides the framework needed to formulate and test hypotheses regarding the controls and mechanisms of biological response to dam operations.

The key resources in Grand Canyon are endangered species, riparian vegetation, cultural resources, campsites, navigable rapids and, in the reach between Glen Canyon Dam and Lees Ferry, introduced trout. In order to balance management of flow regime for these resources, the GCMRC will need to develop hypotheses about how flow regime will affect each resource. These hypotheses must be articulated within a consistent ecosystem description encompassing all resources. In developing these hypotheses, it is important that the full range of release options be considered, regardless of current restrictions on the magnitude and timing of releases.

The Panel finds that excellent progress has been made in developing an understanding of the physical behavior of the Colorado River in Grand Canyon. The physical resources program is currently very well managed and integrated. The quality of the overall research and monitoring effort is exceptionally high. The primary tasks now facing the program managers are discussed in this report:

- development of a conceptual framework that will guide research and monitoring efforts
- integration of the physical resources, biology, and cultural/socioeconomic programs
- clarification of information needs

- development of a synoptic picture of the river bed
- selection of monitoring reaches
- continuation of 1d and 2d sediment modeling in the main channel
- collection of daily sediment samples along the main channel
- expansion of sediment sampling and monitoring for principal tributary channels
- a greater emphasis on event-driven monitoring and sampling

Certain parameters should always be measured with consistent methodologies for long-term monitoring. In addition, it will be critical to maintain flexibility in monitoring such that the monitoring is focused on evolving research questions and hypotheses. The complex and continuously changing Grand Canyon ecosystem cannot be adequately characterized or managed as a static “landscape scene.” As the system continues to respond to changing physical conditions and biological interactions along the main channel and its tributaries, and as new technology becomes available for monitoring, the GCMRC and its associated scientists and stakeholders will need to maintain a breadth of vision and an awareness of possibilities suitable to one of the grandest landscapes on Earth.

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