Future Challenges for Science and Resource Management of the Colorado River

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I'm going to get out of my Grand Canyon box a little bit today and provide some basinwide perspective on the future challenge for science and resource management in the Colorado River Basin. Since the early 1980s four major science and restoration programs have been developed for the Colorado River Basin, primarily to address the conservation of native fishes and other wildlife pursuant to the Endangered Species Act. These programs include the Recovery Implementation Program in the Upper Colorado River Basin, which was developed in 1988, the San Juan Recovery Implementation Program, which was developed in 1992, the Glen Canyon Adaptive Management Program in 1997 and the Lower Colorado River Multi-Species Conservation Plan in 2005. For simplicity's sake I'm going to refer to these as the four Colorado River Basin restoration programs. Today, these conservation efforts span the entire length of the Colorado River Basin and involve scores of state and local, and federal agencies, Native American tribes and diverse stakeholder interests. They have had an increasingly important influence on both water management and conservation in the Colorado River Basin.

The programs have many commonalities, including similar and overlapping goals and objectives. They deal with many of the same resources and threats to those resources. They employ similar monitoring research and restoration strategies. In spite of these commonalities until very recently there had been no formal opportunity for information exchange among those four programs. To address this need, USGS, in

coordination with the four restoration programs and several other state and federal agencies, organized the first Colorado River Science and Resource Management Symposium in Scottsdale, Arizona in November 2008. [The Water Education Foundation organized the event.] Its purpose was to promote an exchange of information on research and management activities related to restoration of and conservation of the Colorado River. A total of 283 scientists, managers and stakeholders attended the three-day event. There were about 87 presentations and 27 posters. It included a variety of plenary talks on topics related to overviews of the four programs, water management actions aimed at restoring native fish habitat, climate change, and assessments of the status of native and non-native fishes in the Basin and Native American perspectives on the restoration programs. Intermixed with the plenary talks were several concurrent technical sessions related to the effects of dam and reservoir operations on native fish, native fish propagation and genetics management, the challenges we face in co-managing both native and non-native fishes, and monitoring program design and linkages to management. There were additional sessions on riparian system restoration of exotic plants.

In the opening remarks Kameran Onley, the Department of Interior's Acting Assistant Secretary of Water Science, encouraged ongoing interaction between scientists and managers from the various recovery and restoration programs. She recounted the history of water management in the Basin and emphasized the complex challenges for finding strategies for balancing the needs of water development in environmental protection, and emphasized the need for independent science as a critical element in the decision making process. At the end of her opening remarks she asked USGS to provide recommendations on how science and restoration efforts could be enhanced collectively through better basinwide coordination and integration. Hopefully the information that I'm providing here today will address this need. And while Kameran has moved on to greener pastures, I think her request still seems relevant to the Obama Administration as they consider water, energy and environmental priorities for the Colorado River Basin.

My focus today will be to highlight what I felt were some of the more compelling issues and themes that emerged from the symposium. As such, I need to acknowledge the many conference presenters because the information and conclusions I'm presenting here are largely theirs. USGS will publish the papers in 2010.

The leaders of the four restoration programs provided overviews of each of their programs. All four programs are compliance driven, meaning they are designed to address the requirements of the Endangered Species Act and, in the case of the Glen Canyon Dam Adaptive Management Program, the 1992 Grand Canyon Protection Act. All of the programs are designed to conserve endangered species and mitigate the impacts of water development. Each program has implemented an impressive list of actions to conserve native fish, including extensive efforts to control non-native fish that compete with or prey on native fish. Other efforts include construction of fish ladders to expand the range of native fish and installing fish screens on diversions, and in the Lower Basin the restoration of riparian and marsh habitat. Hundreds of thousands of native fish have been raised in hatcheries and isolated in predator-free ponds and stocked in various locations in the Basin. Some documented evidence of survival and recruitment of those hatchery raised fish exists, although overall survival rates are generally very low.

The San Juan and Upper Colorado Basin recovery programs are regulating flows from a variety of reservoirs to more closely mimic a natural hydrograph by increasing the reservoir releases to maximize spring peaks, the hypothesis being that the natural flow regime is best suited to fish recovery. Spring releases from Flaming Gorge are timed to the peak releases from the Yampa River to maximize peak flows in the Green River near Jensen, Utah. Rather than mimicking the natural hydrograph like the Upper Basin Recovery programs, limits have been placed on the daily fluctuations from Glen Canyon Dam. And several experimental high flow tests have been conducted since 1996 to restore sandbars in the Grand Canyon. The Glen Canyon Dam Adaptive Management Program has also conducted stable flow tests designed to benefit humpback chub and promote better understanding about the effects of those stable flows on humpback chub recovery.

A common challenge of all restoration programs, in general, is to assess the effectiveness of recovery or conservation actions.

The annual release volumes from Glen Canyon Dam are determined by the Upper Colorado River Basin hydrology and system wide water storage in combination with the downstream water delivery requirements tied to the Law of the River and the recently finalized interim guidelines for coordinated reservoir operation of Lake Powell and Lake Mead. Monthly and daily flows are designed to generate

hydropower at times of peak demands, although those diurnal have been attenuated since the early 1990s to minimize downstream impacts in Grand Canyon National Park.

Populations of native fish have responded variably to this extensive suite of recovery actions that have been implemented throughout the Basin although none has achieved any of the recovery goals. While it is difficult to get a complete picture of the population status of native fish, based on information presented at the 2008 symposium, Colorado pikeminnow have decreased in the Green River and increased in the Upper Colorado River. According to the U.S. Fish and Wildlife Service, humpback chub populations have declined in the Yampa River and the Upper Colorado River (Black Rocks and Westwater Canyon). After more than a decade of decline, adult (age 4-plus) have increased by 50 percent in the Grand Canyon (Coggins and Walter, 2009). Populations of razorback suckers are being maintained in Lower Basin reservoirs and the Green and San Juan rivers through active stocking programs, and limited natural reproduction and recruitment is evident in some locations.

A common challenge of all restoration programs, in general, is to assess the effectiveness of recovery or conservation actions. The fact that multiple recovery actions are being implemented simultaneously in combination with natural variability in the ecosystem and the period of time it takes to document successful recruitment of native species make it extremely difficult to evaluate the success of any individual experiment or management action.

One of the consistent features of science necessary to assess progress in restoration programs is monitoring. When coupled with experiments or management actions that purposely introduce change to the system, monitoring is critical to the assessment of cause and effect relationships. This assessment of cause and effect is an important part of the learning process to determine what works and what does not in achieving restoration objectives of a given program. The importance of monitoring cannot be overstated, yet, historically, it has not been included consistently in restoration programs. Additionally, when monitoring has been completed, it has often been done qualitatively or anecdotally and not sustained for sufficient time or intensity to adequately track resource conditions. Several papers were presented on monitoring programs used to track the status of endangered bats, fish, and camp sites used by river runners. And it is encouraging to see the increasing commitment by government agencies to document resource change over expended periods, particularly as they engage in large scale restoration efforts where the effects of those actions are difficult to ascertain.

One of the most compelling issues discussed at the plenary session included the influence of climate change and protracted drought on water supplies in the Western United States. Climate change represents a significant threat that restoration programs throughout the Colorado River Basin must contend with. Output from regional global climate change models indicates that the Colorado River Basin will become hotter and drier during the next 100 years. Climate change is likely to reduce the total discharge and increase the water temperature of the Colorado River. McCabe and Wolock (2008) reported that a continuation of the 20th century warming trends in the Upper Colorado River Basin with no change in precipitation would produce a century of stream flows that are similar to the driest century since 1500. These impacts will be superimposed on a river already heavily impacted by regulation and water extraction. However, impacts of climate change and hydrology in water temperature will depend on the position of the reach in the drainage network and the degree of water regulation and extraction. For example, the impacts of reduced precipitation in headwater rivers like the Yampa in Northwest Colorado will be direct with altered hydrology and increased temperatures resulting in lower overall discharge. In contrast, flows in water temperatures in the Grand Canyon are linked to the reservoir elevation of Lake Powell. Decreased inflows and increased evaporation from Lake Powell could lead to releases from the water warm epillimnion and result in water temperatures in the Grand Canyon approaching 30 degrees centigrade – temperatures similar to pre-dam conditions (William Vernieu, USGS, oral communication, 2008)

The recent basinwide drought (2000 to 2007) has markedly different effects on native fish populations in the unregulated Upper Colorado River Basin relative to the regulated section of the Grand Canyon. In the Yampa, the recent drought has been associated with large increases in non-native fish populations in a concomitant decrease in native fish populations. From 2000 to 2007, annual peak discharge and base flows in the Yampa River were significantly reduced and water temperatures were significantly higher. Spring floods, which are believed to clean spawning gravels of fine sediment, inundate back waters and otherwise contribute to native fish spawning and recruitment, were attenuated. Very low summer base flows may have reduced habitat volume, increasing the potential for competition and predation by non-native fishes. Humpback chub declined in the Yampa River during the recent drought. In contrast, the humpback chub population in the Grand Canyon increased during the recent drought. From 2000 to 2007 release volumes from Glen Canyon Dam declined to the minimum

allowed by law. During this period, rainbow trout populations declined by about 50 percent and humpback chub populations increased by approximately 50 percent. Water temperatures during this period of low reservoir elevations were as much as five degrees centigrade higher than the 40-year average because withdrawal structures were drawing water close to the surface of Lake Powell. Warm water releases may have allowed for faster growth rates of humpback chub and the reduction of predacious rainbow trout may have tipped the system in favor of native fish.

The Fish and Wildlife Service has expressed extreme concern that warm water releases from Glen Canyon Dam could result in the proliferation of warm water fishes that would seriously threaten the largest remaining humpback chub population in the Basin. One effective strategy may be to install a temperature control device on Glen Canyon Dam, not to increase temperatures but to actually provide the capability to release cold water as a means of preventing the proliferation of warm water fish.

At the 2008 symposium, Terry Fulp reported that Reclamation has an active research and development program to evaluate the impacts of climate change on water supplies, water delivery and power operations in the Basin. However, so far, there has been no parallel effort to evaluate the likely impacts of prolonged drought and climate change on water quality or the natural and recreation resources in the Colorado River Basin. This kind of gap will make it difficult to assess the implications of those changes to current recovery in conservation strategies.

Changing topics to non-native fish, which was a major theme in the conference. The ongoing threat from more than 60 non-native species presents one of the most serious challenges to achieving native fish goals for each of the four programs. A large body of researchers concludes that the establishment of non-native fishes in the Southwest is the primary cause of the deteriorating status of native fishes in the region and prevents their recovery (Clarkson and Marsh). However, each of the restoration programs is attempting to recover native fish while maintaining politically and economically sensitive non-native sports fisheries.

Numerous papers were presented that documented how non-native fish threaten the long-term sustainability of native fish populations. Kevin Bestgen and Angela Kantola reported significant declines in endangered humpback chub in the Yampa River associated with the dramatic increase in smallmouth bass populations in that some river. Mike Yard and others reported that rainbow and brown trout prey on endangered humpback chub in the Grand Canyon and estimated that more than 20,000 chub would have been consume by the trout removed as the result of their study. Lew Coggins and Mike Yard reported success in reducing rainbow trout populations in experimental reaches of the Colorado River in the Grand Canyon using intensive electro-fishing over a four-year period. During the same time, humpback chub populations increased, although it is unclear whether the increase is directly attributed to the removal of trout.

Robert Clarkson and Paul Marsh concluded that segregating native and non-natives fishes is the only viable tactic to conserve and recover imperiled warm water fishes in the Gila River Basin in Arizona. They described several projects involving the construction of instream barriers to prevent upstream migrations in conjunction with the chemical eradication of non-native fishes that were effective at restoring native fishes on several small streams. Unfortunately, they noted, this type of approach is not technically or politically feasible in large rivers.

A new invasive species, the quagga mussel was found in Lake Mead in January 2007 and had spread to more than 30 Colorado River lakes and reservoirs by the end of 2008 (Nalpea). Quagga mussels are filter feeders and when they attain high densities in an ecosystem they can dramatically alter water quality in the food web structure including, reducing fish populations. Quagga mussels are not expected to attain high densities in riverine sections of the Colorado River Basin (Nalpea) but they are expected to attain those high densities in reservoirs and could impact sports fisheries there. Quagga mussels may impact downstream ecosystems by changing the composition of water and water quality that comes from the reservoirs.

From the perspective of a geoscientist with long experience working throughout the Colorado River Basin, Jack Schmidt surveyed the highly varied range of geomorphic responses that have occurred following dam construction in reaches of the Colorado River and its tributaries and noted that some reaches have developed significant sediment deficits while other reaches are experiencing surpluses. His plea was for decision makers to think more strategically and at a more regional scale about various restoration (or, as he refers to them, "rehabilitation" program) objectives currently being pursued at a very substantial cost and with varied successes – and consider in a more integrated way how costs and benefits might be reasonably and efficiently balanced.

He asked two compelling questions. 1) What environmental goals, management goals ought to be established for each part of the Basin? 2) Should decisions about goals be made at a segment scale by local stakeholders or at a watershed scale by regional or national interests?

Schmidt's assessment suggests that there may be more "bang for the buck" by focusing rehabilitation

efforts in the Upper Basin; but, currently most of the funding is being directed at Lower Basin restoration efforts. While models for such regional assessments exist in the Columbia River, Schmidt pointed out there is no regional process for the Colorado River by which the goals of each rehabilitation program are compared, nor is there a consideration of the tradeoffs between rehabilitation efforts and the level of recovery.

The luncheon talk by Christopher Konrad provided an overview of several site-based restoration projects outside the Colorado River Basin that are currently being evaluated by The Nature Conservancy in collaboration with USGS. Dr. Konrad's presentation offered some perspective and hope for moving from site-based to basin-scale river conservation on the basis of lessons he learned from several projects he evaluated. One of his main observations and conclusions is that integrating dam operations with other types of river management, such as floodplain, land use and water quality, throughout a basin can better align conservation with management of the river to meet water, hydropower and human needs. He acknowledged that basin-scale coordination is difficult, controversial and time consuming to implement. He concluded that integrated management depends on an alliance of stakeholders with shared ecological goals who are willing to work together rather than simply comply with the regulatory requirements applicable to their individual site.

Meeting the environmental challenges in the Colorado River in the face of increasing water demands will stress existing programs and demand new approaches. A long-term commitment to rely on sound science will be one of the keys to an effective sustainable conservation effort throughout the Basin.

In his talk titled "Changing the Law Science Paradigms for the Colorado River," University of Utah law professor Robert Adler questioned whether it is possible to meet the economic goals of water law and development and the environmental goals of the Endangered Species Act in the Grand Canyon Protection Act fully and simultaneously. He acknowledged that one possibility is that more time is needed to study and fine tune restoration programs until success is achieved. Another, more sobering, possibility is that the current "law-science paradigm," as he referred to it, seeks impossible results. In other words, it is impossible to achieve the goals of each of the programs within the existing legal frameworks. He challenged the audience to consider a full range of possible alternatives to the existing "law-science paradigm" that underlies each of the current programs. One of the suggested alternatives included the idea for shifting dependence on large reservoirs for water storage to a variety of off-channel options, such as storing more of the river's flow in aquifers where underground storage might be available.

Another plenary topic with far-reaching implications included the complex challenges faced by Native Americans and their experience of tribal participation in the Glen Canyon Dam Adaptive Management Program. Kurt Dongoske, who represents the Zuni Tribe, and his co-presenters, representing the Hualapai and Southern Paiute tribes, expressed concerns that heavy reliance on Western science has the unintended effect of disenfranchising participating Native Americans. The presenters concluded that their traditional knowledge of the ecosystem is equivalent to the scientific knowledge, however, their perspective or concerns get little attention in the decision making process. Communication problems also arise with the use of language that is unfamiliar to tribes and the sometimes argumentative nature of the discussions that occur in committee meetings, which is foreign to the tribes that he represents. He recommended that the Adaptive Management Programs needs to include a social science component that works toward development of a holistic integration of Native American perspectives and values into the Adaptive Management Program.

Kirk Emerson, in her talk on the "Promise and Perils of Collaboration in the Colorado River Basin," addressed the difficult challenges associated with maintaining collaborative partnerships and the jeopardy that can occur when attempts at collaboration go south. She highlighted the characteristics of "process fatigue" that can influence the effectiveness of collaborative partnerships that have been in existence for 10 or more years. Emerson urged the new Obama Administration to embrace the principles of environmental conflict resolution in the 2005 Policy Memo issued by the Office of Management and Budget and the Council of Environmental Quality.

These are a few highlights of the broader and perhaps more provocative topics that were discussed at the Science and Resource Management Symposium.

In conclusion I would like to return to the request of the Assistant Secretary to provide recommendations on how science and restoration efforts could be enhanced collectively through better basinwide coordination and integration. From a coordination perspec-

tive, the hope was that the exchange of information that occurred at the 2008 Symposium would improve the effectiveness of the restoration programs individually and collectively. Reviews of the conference were generally very positive. The general conclusion was that the Symposium provided an excellent opportunity and forum for information exchange among the individuals working on similar issues in different parts of the Basin. Our current plan is to sponsor another symposium in the Fall of 2011 or Winter of 2012 as a means of promoting additional basinwide coordination and cooperation. Our intent would be to extend the scope of the new symposium to address environmental issues associated with the Colorado River not just in the United States but also in Mexico.

Determining the appropriate level of integration among the four programs is a more complicated question. All four programs have evolved independently, which has probably contributed to their current success and the broad agency and stakeholder support that currently exists. In addition, the large geographic scope of the Basin and the diversity of stakeholders warrant maintaining several distinct programs. As such, I would not recommend merging the four programs in any way. However, it is worth noting that the combined annual costs of the four programs is about $40 million a year, and it's projected to be nearly $1 billion over the life of these programs. These facts, along with several significant basinwide challenges like climate change and invasive species which transcend program boundaries, suggest that it is time to consider developing a broader framework to guide overall efforts.

In my view, some form of an overarching framework and an independent science organization would be useful to establish some fundamental science practices to guide overall restoration efforts throughout the Basin, conduct regional scale analysis and assessments of the status of the important resources, establish indices of ecosystem health and develop the necessary data to inform those indices, and serve as a clearing house for reports and provide information on the best available management practices. Such a framework would also facilitate the kind of basinwide assessments that were advocated by Christopher Konrad and promote a more effective balancing between environmental and water supply objectives. It would also allow for setting basinwide priorities and tradeoff analysis to insure limited funds are spent on the highest priority resources with the highest restoration potential as advocated by John Schmidt.

I suspect that there may be some that would argue that such proposals go beyond the compliance requirements of the Endangered Species Act or the Grand Canyon Protection Act.

That may be true, but I believe that it will lead to what is needed – a more sustainable and effective science-based conservation effort throughout the Basin. There are examples where current programs have exceeded the minimum compliance requirements to head off future problems. Most notably, the San Juan and Upper Basin Program go beyond the basic Section 7 ESA requirements of avoiding jeopardy to achieve full recovery of the endangered fish. The Lower Colorado River Multi-Species Conservation Plan has an objective of avoiding listing of candidate and sensitive species. This same kind of forward-looking, broad scale approach is now needed to ensure a more integrated adaptable overall effort in the Colorado River Basin.

With nine national parks that include probably one-third of the entire Basin and five or six major national wildlife refuges that encompass a larger portion of the rivers in the Basin, and the large number of threatened and endangered and sensitive species dependent on the Colorado River, the importance of maintaining a healthy Colorado River ecosystem is unlikely to go away.

Meeting the environmental challenges in the Colorado River in the face of increasing water demands will stress existing programs and demand new approaches. A long-term commitment to rely on sound science will be one of the keys to an effective sustainable conservation effort throughout the Basin.

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