# Building Gulf Coast Resilience

## Lessons from the Glen Canyon Dam Adaptive Management Program

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# Building Gulf Coast Resilience: Lessons from the Glen Canyon Dam Adaptive Management Program

## Executive Summary

### Background

Just south of the Utah-Arizona border, the Glen Canyon Dam, managed by the Department of the Interior's (DOI) Bureau of Reclamation (Reclamation), supplies water and generates power for seven western states and parts of Mexico. Historically, the dam's prioritization of water storage and power delivery had negative impacts on natural and cultural resources and recreational uses in Grand Canyon National Park and Glen Canyon National Recreation Area (both of which are under the National Park Service's [NPS] jurisdiction). As a result, in 1996, DOI established the Glen Canyon Dam Adaptive Management Program (Program) as a decisionmaking framework to adjust dam operations to improve the condition of downstream resources while satisfying water and power allocation requirements. To balance these competing interests, the Program draws from long-term research and monitoring activities and a robust stakeholder engagement process.

Originally, Reclamation conducted individual reviews under the National Environmental Policy Act (NEPA) and other statutes each time a negative change in the condition of downstream resources, like insufficient sediment to maintain or build sandbars, necessitated an operational change known as an "experimental" action at the dam to adjust the amount of water (or "flow") released. This ad hoc process was cumbersome and time consuming for Reclamation and delayed resource protection. In 2016, Reclamation and NPS utilized the Program's framework to adopt a new, comprehensive update — the Long-term Experimental and Management Plan (LTEMP) — to carry out operational changes at the dam and environmental compliance (e.g., NEPA) for a 20-year period. The LTEMP streamlined environmental compliance for a range of experimental actions to allow for variations in flows in response to fluctuating environmental conditions, such as sediment. The LTEMP also included "non-flow" (i.e., non-water related) experiments, such as manual invasive species removal, that can similarly minimize the dam's impacts on the endangered humpback chub (one endemic fish species native to the Colorado River).

Collectively, the Program and LTEMP provide transferable lessons and recommendations for establishing an inclusive, science-based approach to adaptive management that can result in administrative and environmental review efficiencies and improved environmental outcomes. These lessons and recommendations are especially relevant for novel or "first of their kind" restoration projects in the Gulf.

## Lessons and Recommendations

Drawing from the Glen Canyon Dam's more than 20-year history of adaptive management, this case study presents recommendations for how federal agencies and states in the Gulf Coast might apply these lessons to the long-term operation and management of Deepwater Horizon (DWH) projects:

### Invest in and identify potential funding sources and partners for long-term research and monitoring.

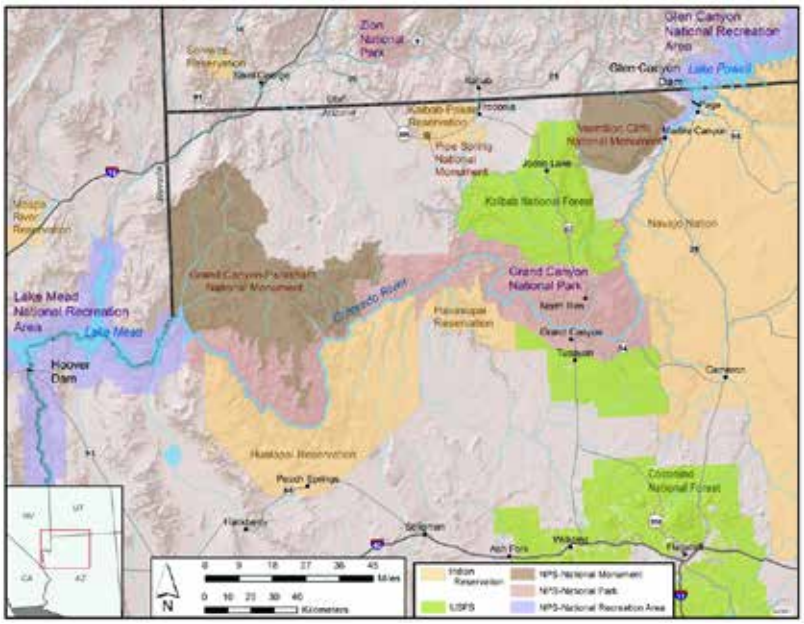
Decisions at Glen Canyon Dam, including the LTEMP, have benefitted from a long-term research and monitoring program that evaluates the dam's impacts on downstream resources. The Glen Canyon Dam Adaptive Management Program has also benefited from the input of external experts that serve as additional outside resources and provide feedback on DOI's processes. Monitoring and review are critical to adjust the operations of a project to address negative impacts, but they also require a significant investment in data collection. At Glen Canyon Dam, hydropower revenues provide most of the funding for research, monitoring, and data analysis. Although some DWH funding is available for monitoring and adaptive management, project proponents will need to identify potential funding sources and partners and prioritize long-term research and data collection objectives.

### Provide opportunities for expert and stakeholder engagement throughout a project's life span.

The Glen Canyon Dam Adaptive Management Work Group, which is one part of the Program's decisionmaking framework, enables governmental and nongovernmental experts and stakeholders to have a "seat at the table" to inform DOI's decisions on the dam's operations and management. In turn, DOI gives the Work Group simplified syntheses of complex monitoring data to provide advice and recommendations regarding management. For the LTEMP, outreach and engagement were expanded to engage the public through the environmental review process. Adaptive management approaches in the Gulf should similarly include opportunities for expert and stakeholder engagement throughout a project's life span, but in ways that are tailored to the scope and purpose of individual projects. Like Glen Canyon Dam, DWH project proponents should also provide decision-support resources to educate lay stakeholders about the technical aspects of adaptive management that could otherwise act as a knowledge barrier to their input. In addition to monitoring costs, funding will be needed to support this type of engagement with stakeholders.

### Develop and evaluate a robust range of adaptive management alternatives (or "experiments") through environmental review processes.

DOI's approach shows how federal agencies can use NEPA and other environmental statutes to account for long-term adaptive management. The LTEMP is noteworthy because it was used to evaluate a range of well-modeled "experimental" actions that will allow Reclamation to vary dam operations to minimize impacts to different resources and recreational uses. By including a range of experimental actions as alternatives in its NEPA analysis, DOI front-loaded this work, which will streamline environmental compliance for 20 years and avoid future delays in initiating experimental actions that would otherwise need to "pause" for standalone environmental reviews. To the extent that data and funding are available, DWH project proponents should explore the possibility of running models and creating programmatic NEPA analyses that can govern a range of adaptive management and experimental actions over multiple years. Similarly, for DWH projects, adaptive management approaches may help federal agencies become more comfortable with projects where *exact* impacts to habitats and species are uncertain but *potential* impacts, and corresponding operational changes that can minimize those impacts, can be anticipated through experimental models.




Map of Glen Canyon Dam and Adjacent Area.

A map of Glen Canyon Dam and adjacent areas including Lake Powell and nationally-protected lands, like Glen Canyon National Recreation Area (upstream from the dam) and Grand Canyon National Park (downstream).

Credit: Glen Canyon Dam Long-term Experimental and Management Plan, Final Environmental Impact Statement, Bureau of Reclamation and National Park Service, U.S. Department of the Interior

# Background

## Glen Canyon Dam Overview

Just south of the Utah-Arizona border, the 710-foot Glen Canyon Dam regulates flow along the Colorado River by storing water in Lake Powell, the second largest reservoir in the U.S.[1] The dam is part of the Colorado River Storage Project[2] constructed to control and preserve water access and use rights for seven states in the American West and parts of Mexico.[3] Lake Powell has capacity to store more than 26 million acre-feet of water.[4] The dam also hosts a hydroelectric power plant, which has a total capacity of 1,320 megawatts and generates about five billion kilowatt-hours of power annually to meet the demands of nearly 5.8 million customers.[5] The dam is managed by the Department of the Interior (DOI) through the Bureau of Reclamation (Reclamation).

In addition to water and power, the operations and management of the Glen Canyon Dam and its surrounding environment require Reclamation to work with several federal, state, local, and tribal governments and members of the public in order to balance a range of interests and competing uses. For instance, Grand Canyon National Park and Glen Canyon National Recreation Area, both managed by the National Park Service (NPS), preserve natural, historical, and cultural resources and allow responsible tourism and recreation, like sport fishing and whitewater rafting.[6] Annually, rafting alone is estimated to bring $83 million and 600 jobs to the local economy[7] and Glen Canyon National Recreation Area draws two million visitors.[8] The Colorado River System around the dam is home to several endangered and threatened fish and other wildlife species protected under the Endangered Species Act.[9] The humpback chub and other endemic fish species are of particular conservation concern because they are only found in the Colorado River Basin.[10] Additionally, six American Indian tribes have long-standing, intrinsic historical and religious ties to the lands in this region.[11] The range of affected interests also includes the federal Western Area Power Administration, state water and resource management agencies, and environmental interest groups. Adding to the complexity of managing the dam to balance these different interests, Reclamation is frequently confronted by external uncertainties, including fluctuations in annual precipitation that can lead to droughts and reduced stream flows.

## History of the Glen Canyon Dam Adaptive Management Approach

Over the years, Reclamation has changed management and operations of the dam based upon shifting priorities and an evolving understanding of the environmental impacts of dam operations. When the dam was first constructed between 1956 and 1963, its "primary purposes" were to manage water supply in the region and generate hydroelectric power.[12] In these early years, water allocations and power generation were prioritized.[13] This management approach, however, had negative consequences for the Colorado River ecosystem, cultural and tribal resources, and the river's

recreational users. Large releases scoured sediment from the river system and eroded beaches affecting habitats, populations of endangered fish species, and archaeological sites.[14] These dramatic fluctuations in water levels also hindered recreational uses on the river, such as fishing and rafting.

Statutory changes in later years required DOI to take a more comprehensive approach to dam management.[15] In 1995, Congress passed the Grand Canyon Protection Act specifically directing DOI to look at and minimize the downstream impacts of dam management on the natural, historical, and cultural resources and recreational uses at Grand Canyon National Park and Glen Canyon National Recreation Area.[16] The Act requires DOI, through Reclamation and NPS, to "establish and implement long-term monitoring programs and activities"[17] that must include "any necessary research and studies to determine the effect of [its actions] on the natural, recreational, and cultural resources".[18] DOI adopted an adaptive management approach to meet the Act's long-term monitoring requirement.[19] DOI defines adaptive management as "a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood" that necessitates "careful" scientific monitoring and iterative "learning while doing".[20] The Act also mandates that DOI consult with specified stakeholders representing various governmental and public interests impacted by the dam's operations as a part of its long-term monitoring and adaptive management.[21]

In 1996, DOI created the Glen Canyon Dam Adaptive Management Program (Adaptive Management Program or Program) as a streamlined and flexible decisionmaking framework that integrates long-term scientific monitoring with governmental and non-governmental engagement. The Program allows Reclamation to operate and manage the dam in a way that satisfies legal water and power requirements while minimizing impacts to downstream resources in Grand Canyon National Park. In 2016, Reclamation and NPS updated how the Program was implemented when it adopted a Long-term Experimental and Management Plan (LTEMP or Plan) in accordance with the National Environmental Policy Act (NEPA) to govern the operations and management of Glen Canyon Dam over a 20-year period.[22] The LTEMP involved intensive collaboration across a range of federal agencies, state and tribal governments, and private interest groups. The Plan also shows how a well-established adaptive management program can be utilized to better understand and minimize adverse human impacts on the environment.

The LTEMP will allow the agencies to proceed according to a comprehensive adaptive management plan, but it did not alter the Program itself. The Glen Canyon Dam Adaptive Management Program still provides the procedural, decisionmaking framework through which DOI takes actions or make changes, like the LTEMP, regarding the dam's operations. For example, Reclamation and NPS selected the final NEPA alternative for the LTEMP by utilizing the Program's decisionmaking framework. However, given their interconnectivity, both actions will be presented collectively in this case study as the "Glen Canyon Dam adaptive management approach" unless otherwise distinguished.

As federal agencies and state and local governments work to establish and implement adaptive management for DWH restoration projects, they may benefit from the lessons that can be learned from the Glen Canyon Dam adaptive management approach. While this case study is particularly relevant to the sediment diversion projects in Louisiana, it can also inform the many other restoration projects where adaptive management was identified as a priority.[23]

# Legal Context

## Funding

Compared to Gulf Coast restoration efforts, which are funded by different and multiple sources of funding, including legal settlements, long-term research and monitoring at Glen Canyon Dam is funded mostly[24] by hydropower revenues from the Colorado River Storage Project. The Grand Canyon Protection Act of 1992 authorized a dedicated, non-appropriated source of funding for the dam.[25] Revenues generated from the sale of the dam's hydroelectric power are used to pay for annual operation and maintenance costs, including the Glen Canyon Dam Adaptive Management Program.[26]

## Environmental Review and Permitting

As a complex infrastructure project with competing uses and impacts to natural, historical, and cultural resources, Glen Canyon Dam is subject to environmental review and permitting requirements under both federal and state laws, in addition to water rights agreements and special considerations for lands or natural features with a protected status (e.g., national parks). The main federal laws affecting dam operations and management, include the following:

- **Law of the River for the Colorado River Basin** — A series of legal documents and agreements that governs allocations and rights to water from the Colorado River; the Grand Canyon Protection Act (below) requires that the dam continue to be operated in a manner that will ensure compliance with these documents and agreements on water rights and allocations.[27]
- **Colorado River Storage Project Act of 1956** — Authorized comprehensive development of the water resources of the Upper Basin states (Colorado, New Mexico, Utah, and Wyoming) by providing for the long-term regulatory storage of water, including construction of the Glen Canyon Dam and Lake Powell, to meet the legal needs of the Lower Basin states (Arizona, California, and Nevada).
- **Grand Canyon Protection Act of 1992** — Called for the development of a long-term research and monitoring (i.e., adaptive management) approach for operating the Glen Canyon Dam in a way that would minimize conflicts among competing interests. The Act requires that resource protection and recreation be considered among the dam's other priorities and that the public participate in the dam's management.
- **Endangered Species Act (ESA)** — Section 7 of the ESA requires federal agencies to consult with the U.S. Fish and Wildlife Service (USFWS) when their actions "may affect" protected species or their critical habitat.
- **National Historic Preservation Act (NHPA)** — Section 106 of the NHPA requires federal agencies to take into account the effects of their "undertakings" (i.e., directed, authorized, or funded actions) on historic properties and consult with states, tribes, and other interested parties.
- **National Environmental Policy Act (NEPA)** — NEPA requires that federal agencies evaluate the environmental impacts of activities they direct, authorize, or fund and consider alternative actions to avoid, minimize, or mitigate those impacts.
- **Clean Water Act (CWA)** — Section 402 of the CWA requires that those who discharge waste or storm water into a "surface water of the United States" obtain a permit from the U.S.

Federally endangered Humpback Chub.

The federally endangered humpback chub is one fish species endemic to the Colorado River. Historical declines in the species and changes to its habitat have occurred as a result of the dam's construction and operation. These concerns were and continue to be one of the environmental factors that drive adaptive management and research and monitoring at Glen Canyon Dam, especially given requirements to comply with the National Environmental Policy Act and Endangered Species Act.

Credit: Bureau of Reclamation, U.S. Department of the Interior

Environmental Protection Agency (or state delegee) in order to achieve specific Water Quality Standards. The Glen Canyon Dam releases water into a surface water of the United States: the Colorado River. These releases must comply with and not negatively impact the river's overall Water Quality Standards for human uses, such as fishing.

## Agency Roles

Given the range of jurisdictions and interests implicated by the dam, a number of federal agencies and state and tribal governments have a role in its operation and management. Reclamation and NPS, both within DOI, have two primary responsibilities: Reclamation manages the dam and NPS manages the areas surrounding the dam including the Grand Canyon National Park, Glen Canyon National Recreation Area, and Lake Mead National Recreation Area. As the principles for the dam, Reclamation and NPS were joint co-leads on the LTEMP Environmental Impact Statement (LTEMP EIS). In addition, more than three federal and six non-federal agencies and six American Indian Tribes either have jurisdiction over or are impacted by the dam and its effects on downstream resources and therefore, participated in the development of the LTEMP.[28]

# Lessons Learned

Glen Canyon Dam provides a range of lessons in adaptive management, beginning with the need for long-term research and monitoring that can support stakeholder engagement and comprehensive, long-term planning through required environmental reviews. By integrating a monitoring program, stakeholder engagement, and long-term planning, Reclamation can both manage the dam's multiple, competing interests more efficiently through informed decisionmaking and better adapt to future events, like drought, while being legally compliant.

## An Inclusive Approach to Adaptive Management

In 1997, DOI created the Glen Canyon Dam Adaptive Management Program[29] that provides a decisionmaking framework regarding the dam's operations and management. The Program was designed to account for, and attempt to balance, multiple, often-competing purposes using operational changes and experiments guided by long-term monitoring data. The Program's three-part decisionmaking framework integrates science and stakeholder engagement to inform DOI's dam operations and management actions:[30]

- **Monitoring** — The U.S. Geological Survey's Grand Canyon Monitoring and Research Center (Center) conducts research and monitoring activities in the Grand Canyon ecosystem.[31]
- **Peer review** — The Center's work is reviewed by an independent scientific review panel as a "check and balance" to ensure the integrity of its procedures and results and provide additional expert input.[32]
- **Stakeholder input** — The Center's panel-reviewed results inform the Adaptive Management Work Group's advice and recommendations to DOI. The Adaptive Management Work Group (Work Group) is a 25-member body[33] that fulfills the Grand Canyon Protection Act's requirement for DOI to engage stakeholders in the dam's long-term monitoring and management.[34] The Work Group also includes a subcommittee, the Technical Work Group, to provide expert technical support that enables all members to understand the scientific outputs generated by the Center.[35]

Using information and recommendations developed through these three parts, DOI makes necessary changes to the dam's operations and management, while simultaneously complying

High-flow Experiments.

Water is released from the dam and into the Colorado River during a high-flow experiment in 2016.

Credit: Bureau of Reclamation, U.S. Department of the Interior

with all laws governing the dam and the Colorado River's water use agreements. If DOI makes a new decision as a result of the Program, that decision re-initiates the adaptive management process, beginning with new research and monitoring activities by the Center.

The Program is a flexible and inclusive adaptive management framework that has not been significantly revised in its more than 20-year history.[36] Regardless, the Program has been subject to some critique that could be noteworthy for other agencies interested in developing similar frameworks.[37] For example, while the Adaptive Management Work Group includes 25 governmental and non-governmental members, some external reviewers and constituencies have found the body's composition to be either under-representative of necessary stakeholders, which can detract from the validity of final advice and recommendations,[38] or have suggested that it is too large and unwieldy to operate by consensus.[39]

## Benefits of Comprehensive, Long-term Environmental Reviews

Early on at the dam, several "experimental actions" were pursued by the Program to test operational measures that could minimize impacts to natural resources.[40] Experiments consisted of both "flow" (i.e., water) and "non-flow" (i.e., non-water related) actions. The majority of experimental actions evaluated different flows, such as "high flows" — or artificial or controlled floods where large-volumes of water were released on a schedule to mimic pre-dam flooding by the Colorado River — designed to encourage sandbar building downstream for campers and whitewater rafters, native fish and wildlife habitat, and to provide a source of windblown sand that may help protect some archaeological sites.[41] Additionally, the Program conducted non-flow actions, such as physically removing non-native fish (e.g., trout) from the Colorado River to benefit the endangered humpback chub.[42] Prior to the LTEMP, for experimental actions not covered by an existing NEPA document, DOI had to conduct new, independent environmental reviews under NEPA and other statutes, like the Endangered Species Act.[43] While the experimental actions were necessary to inform and improve the dam's operations and management, especially for purposes of resource protection, these compliance obstacles for individual experiments were costly and time-consuming. Thus, DOI pursued a more programmatic approach that will ideally end the need for standalone reviews.

In 2011,[44] DOI initiated its first comprehensive update[45] to adaptive management at the dam with the LTEMP. Ultimately, DOI found that it had collected enough scientific information since 1996 to proceed with new operational standards for the dam for a 20-year period.[46] In 2016, DOI finalized the LTEMP and it will govern dam operations and experimental actions through 2036.[47]

The LTEMP allows DOI to continue to meet existing legal requirements and energy demands and, to the greatest extent practicable, also be responsive to different interests in the face of a changing environment. For purposes of adaptive management, the LTEMP calls for changes in the dam's flow and non-flow actions if physical or biological conditions are triggered.[48] Specifically, if monitored physical (e.g., sediment) or biological (e.g., number of adult or subadult fish) conditions are triggered, new operational or management actions may be pursued to minimize adverse impacts or maximize environmental benefits; however, data relevant to these conditions do not automatically result in operational changes. Before DOI makes any decisions, it will evaluate the effects of a triggered condition on other resources to determine the best holistic course of action through the Program's framework.[49] Going forward, the LTEMP's long-term research and monitoring will also enable DOI to evaluate operational changes needed to adjust to climate[50] and drought-related impacts. For instance, in the final LTEMP, DOI stated how individual experiments will be selected and implemented annually.[51] This yearly evaluation of potential experiments can take into account and be responsive to long-term environmental impacts.[52]

### Interagency and Stakeholder Engagement in the LTEMP NEPA Process

Reclamation and NPS were co-leads on the LTEMP EIS. This joint effort was new for the Glen Canyon Dam and assembled an interdisciplinary team of experts from two parts of DOI that were reflective of the dam's diverse uses and interest groups (e.g., dam managers, biologists, historians). Previously, Reclamation was the only NEPA lead. The two agencies expanded on, and sometimes diverged from, the existing structure of the Adaptive Management Program to encompass NEPA's specific scope and legal requirements.[53] Regardless, the LTEMP NEPA review similarly incorporated science and stakeholder engagement to garner input from 15 cooperating agencies and the public. To help guide development of the LTEMP, Reclamation and NPS hired external scientists to synthesize the large volume of research and studies produced since the 1990s to present scientific information in a simplified way. Specifically, the synthesized studies allowed Reclamation and NPS to more easily discuss the science with governmental and non-governmental stakeholders. Being responsive to stakeholder concerns, Reclamation and NPS, in conjunction with other entities including the U.S. Geological Survey and the Western Area Power Administration, even re-ran scientific models to generate a new alternative for the LTEMP that had greater buy-in; this alternative was ultimately selected for the final LTEMP.[54] Similar to the Glen Canyon Dam Adaptive Management Program, the LTEMP NEPA process was able to adapt procedures as needed to ensure stakeholders had access to and an ability to understand the best-available science and inform the final LTEMP.

## Timeline of Events

### Glen Canyon Dam Background

1950s–1970s

**April 11, 1956** — Colorado River Storage Project Act of 1956 (43 U.S.C. § 620) enacted; authorized the construction of Glen Canyon Dam and specifies the dam's water management and power generation goals.

**1963** — Construction of Glen Canyon Dam completed.

**January 1, 1970** — National Environmental Policy Act (NEPA) (42 U.S.C. §§ 4321 *et seq*.) enacted.

### Glen Canyon Dam Studies

1980s–1996

**December 1982** — Bureau of Reclamation initiated study on the effects of dam operations.

**November 1989** — Secretary of the Interior directed development of Environmental Impact Statement (EIS) for authorizing operational changes at the dam.

**October 30, 1992** — Grand Canyon Protection Act of 1992 (GCPA) (106 Stat. 4669) enacted requiring the Secretary of the Interior to prepare an EIS under NEPA in two years and prioritize long-term research and monitoring, resource protection, and recreational uses.

**March 1995** — Final EIS entitled, *Operation of Glen Canyon Dam: Colorado River Storage Project, Arizona*, was published and incorporated 40 different projects undertaken by more than 15 different agencies.

**October 9, 1996** — Record of decision for the final EIS signed by the Secretary of the Interior mandating the development of an adaptive management approach.

### Developing an Adaptive Management Approach

1997–2016

**January 1997** — Glen Canyon Dam Adaptive Management Program and Adaptive Management Work Group established.

**September 10-11, 1997** — Adaptive Management Work Group held its first meeting and established the Technical Work Group subcommittee.

**2011** — Scoping initiated for Long-term Experimental and Management Plan (LTEMP) and draft EIS based on sufficiency of data from the Glen Canyon Dam Adaptive Management Program that could better inform and authorize a more comprehensive approach for operations and management of the dam over a 20-year period.

**2016** — Glen Canyon Dam LTEMP final EIS published (in **October**) and record of decision signed (in **December**).

# Recommendations

This section provides recommendations from Glen Canyon Dam for Deepwater Horizon (DWH) projects where adaptive management is a component of restoration.

## Environmental Review and Planning for Adaptive Management

### Design and run robust scientific models to produce a range of experimental actions.

In adaptive management, experimental actions allow managers to adjust how a project is operated for purposes of mitigating harm over time as operations are adjusted based upon the response of ecosystems and resources. For example, with the Glen Canyon Dam adaptive management approach, experimental flows are monitored to determine if sandbars are being created to achieve goals related to natural and cultural resource protection and recreational uses. If not, Reclamation can adjust the dam's flows to a degree during high-flow periods in order to attempt to increase sandbar building. Experimental actions are determined by designing and running scientific models that help managers anticipate the environmental effects of operational changes. Additionally, the LTEMP EIS used historical data to model several hydrological scenarios for the river system, like droughts, that will help managers anticipate the full range of likely environmental conditions over a 20-year period. DWH restoration projects with an adaptive management priority should similarly consider and evaluate a host of environmental conditions that could be encountered over the life of restoration, such as sea-level rise or changes in salinity, and select a range of experimental actions for maximizing the benefits of the project in light of anticipated changes in environmental conditions. This may require the collection of additional baseline data and the development of models to evaluate different potential environmental scenarios. For example, with the Mississippi River sediment diversion projects, monitoring and evaluation can help managers adjust flows to manage changes in salinity to reduce impacts to marine mammals and to ensure that the diversion of sediment is meeting the primary goal of rebuilding land.

### Include a range of experimental actions in programmatic NEPA documents.

NEPA documents (i.e., EISs and environmental assessments) for adaptive management programs, like the LTEMP EIS, should evaluate a broad range of experimental actions. Comprehensively evaluating experimental actions through the NEPA process can have many important benefits including: helping to improve the effectiveness and efficiency of management decisions; helping managers better respond to anticipated and unanticipated changes in the environment; decreasing the potential length or severity of environmental harms; and preventing the need for subsequent NEPA reviews. Because the LTEMP EIS analyzed multiple, different experimental actions and scenarios, DOI will likely avoid the need to conduct standalone environmental reviews for most operational changes through 2036.

### Adaptive management can be used to get federal agencies comfortable with a project that has uncertain environmental consequences.

With the Glen Canyon Dam, adaptive management provided agencies with more flexibility because they did not need to have all the answers upfront to authorize operational changes. Robust monitoring is used to adjust operations annually to minimize the negative consequences of dam management on various interests. Adaptive management has also helped DOI address complexities in the system; for example, in response to a drought, dam operations can be adjusted to address conflicts between water supply needs, streamflow for fish,

and energy production. Similarly, with some of the DWH projects, adaptive management approaches may help federal regulatory agencies move ahead with projects where potential negative impacts to habitats and species are uncertain but can be minimized through operational changes.

**Set expectations upfront about the different roles of scientists and policymakers in an adaptive management context.**

While designing adaptive management programs, DWH project proponents should delineate and educate one another about the respective roles of scientists and policymakers or managers in an adaptive management context. Understanding the differences between disciplines and roles can set professional expectations upfront and avoid potential conflicts or misunderstandings when a project is implemented. For example, each discipline conducts different types of analyses: "Scientists ask: how does the world work? Policymakers and managers, by contrast, ask: what values do we care about, what priorities should we set, and how do we allocate which resources to what priorities?"[55] Specifically, scientists can set expectations upfront about the roles and limitations of how data can inform decisionmaking, minimize environmental consequences, and address uncertainties. Agency staff managing or permitting these projects must evaluate whether the proposed modeling, monitoring protocol, and adaptive management approach satisfy legal requirements under environmental compliance or other statutes, like NEPA and the Endangered Species Act. By accounting for these differences early on, project proponents can start with a "bigger picture" awareness of the roles of different team members in implementing adaptive management approaches.

## Long-term Research and Monitoring

**Establish a long-term research and monitoring program in order to enhance the effectiveness of decisionmaking.**

As DWH projects are implemented, those with an adaptive management component will require a strong long-term monitoring protocol for collecting and analyzing data to inform future management decisions. Monitoring is critical to address the environmental impacts of a project through operational changes. Without a long-term monitoring protocol to evaluate and respond to changing environmental conditions, project proponents will struggle to maximize the environmental benefits delivered and minimize harms. Likewise, long-term monitoring will be particularly important for DWH restoration projects where sea-level rise and land loss may necessitate management changes to address changing environmental conditions.

**Integrate feedback loops and external "checks and balances" with long-term research and monitoring.**

The Glen Canyon Dam Adaptive Management Program benefits from the independent, external review of its long-term research and monitoring protocols and results. This review allows DOI to accrue additional expert support and objectivity that enhances the value and credibility of the science it produces. DWH project proponents should consider incorporating an external review element to adaptive management processes in order to similarly ensure the validity and utility of intra-governmental research and monitoring and operational changes.

Kayaking on Lake Powell.

A man kayaking on Lake Powell showcases one of the area's recreational pastimes and stakeholders that inform the dam's operations and management.

Credit: National Park Service, U.S. Department of the Interior

**Identify a funding source and develop public-private partnerships to support long-term research and monitoring.**

Long-term research and monitoring requires a significant investment in data collection. With Glen Canyon Dam, monitoring and data analysis is mostly funded with hydropower revenues. For DWH, project proponents may need to find additional funding sources or partnerships (e.g., public, private, academic, non-profit) to support long-term research and monitoring and should prioritize research and data collection objectives. Project proponents could also explore building on existing data collection efforts in a given ecosystem or area, for example from the National Oceanic and Atmospheric Administration's Centers of Excellence or fisheries science centers, different state agencies, or citizen science programs.

## Adaptive Management Expert and Stakeholder Engagement

**Establish a transparent adaptive management approach that is inclusive of experts and stakeholders who can inform decisionmaking.**

Like the Glen Canyon Dam approach, DWH restoration projects with an adaptive management component should integrate opportunities for stakeholders to have a say in management decisions. Although DWH restoration projects may differ in their scale and available funding, they could benefit from an inclusive decision-making process or structure that is informed by relevant experts and affected members of the public. To the extent practicable, DWH projects should include transparent, defined processes or structures that can span a project's life cycle and evolve, as needed. Moreover, selected engagement vehicles should ensure that enough of and the right experts and stakeholders are present and that their voices are not outnumbered or overpowered by governmental representatives. A diversity of voices, even if small in number or influence, can help encourage creative compromises in accordance with a project's primary purposes. Inclusivity can improve decision outcomes for a greater number of people and reduce implementation risks or delays, such as from litigation. For example, Louisiana will have to evaluate how to hear from constituents, like fishermen, that are concerned about how the land-building objective of the sediment diversion projects will impact their ability to fish and continue current coastal uses. As the Glen Canyon Dam example shows, multiple interests can be balanced through an adaptive management approach, particularly when distinct interests are given a "seat" at the decisionmaking "table." The need for expert and stakeholder involvement will become particularly important as coastal environments change in response

to natural (e.g., sea-level rise) and man-made changes and the trade-offs of different management approaches are better understood.

**Create a decision-support system to educate stakeholders about the experimental nature of adaptive management and present science in a publicly digestible format.**

Often, people look to science for a single, prescribed solution to an environmental problem; however, that assumption is not always realistic, especially for complex or novel projects, like dam operations, the Mississippi River sediment diversions, or fisheries management. In order to increase understanding of, and the level of comfort with, adaptive management, DWH project managers can set expectations early on by educating decisionmakers and other stakeholders about adaptive management principles and priority outcomes. For example, stakeholders can learn that operational changes will be iteratively evaluated based upon real-time monitoring and that projects will not be implemented in a "one and done" fashion. Accordingly, stakeholders should be given multiple opportunities for input throughout an adaptive management process and the life cycle of a project. Moreover, decisionmakers and other stakeholders need to build a tolerance for uncertainty — experiments may not achieve intended results or may have unforeseen effects on resources — but adaptive management can help minimize the consequences of those uncertainties as operational changes can be reevaluated on a regular basis. Additionally, policymakers should work with scientists to provide information in a publicly digestible format. Although these actions will require that agencies make front-end investments in education and outreach, these investments can encourage stakeholders to contribute to and inform decisions that best balance competing interests and priorities.

# Conclusion

The Glen Canyon Dam adaptive management approach provides useful lessons for the DWH restoration projects. The Glen Canyon Dam model can be incorporated into longer-term or novel restoration projects, such as the sediment diversion projects, where long-term research and monitoring are necessary to understand the effects of restoration on the environment. Adaptive management is a growing field which applies science to management decisions. Federal agencies and Gulf Coast states must thoroughly research best practices and already-defined legal boundaries in order to proceed most effectively. Regardless, this upfront investment beginning with environmental review under the National Environmental Policy Act should not deter agencies. Instead, it should serve as an incentive to better manage resources based upon real-time monitoring of site-specific conditions. Adaptive management also provides an opportunity for project proponents to consider and integrate stakeholder input on the management of projects where the restoration outcomes can have pronounced effects on communities and economies. Adaptive management itself is not an "end game" but, as the Glen Canyon Dam example demonstrates, it is a good way of "doing business" to maximize benefits and minimize harms. Ideally, the federal and state agencies applying these methods to DWH projects will share additional guidance and lessons so that adaptive management approaches can continue to be refined and improved in the future.

# Endnotes

1 Grand Canyon Trust v. U.S. Bureau of Reclamation, 623 F. Supp. 2d. 1015 (May 26, 2009).

2 *Reclamation: Managing Water in the West, Projects & Facilities Glen Canyon Dam*, Bureau of Reclamation, U.S. Dep't of the Interior, **https://www.usbr.gov/projects/index.php?id=144** (last visited on Feb. 22, 2018).

3 Lawrence Susskind, Alejandro E. Camacho & Todd Schenk, *Collaborative Planning and Adaptive Management in Glen Canyon: A Cautionary Tale*, 35 Colum. J. Envtl. L. 1, 7 (2010) [hereinafter Susskind et al.].

4 Bureau of Reclamation & Nat'l Park Serv., U.S. Dep't of the Interior, Long-term Experimental and Management Plan Final Environmental Impact Statement ch. 1, § 1.8.1, p. 1-19 (Oct. 2016) [hereinafter LTEMP FEIS], *available at* **http://ltempeis.anl.gov/documents/final-eis/.** Congress authorized the construction of the Glen Canyon Dam in 1956 and the statutory purpose for the dam was "regulating the flow of the Colorado River, storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize . . . the apportionments made to and among them." 43 U.S.C. § 620. The Colorado River Basin Protection Act of 1968 required the Secretary of Interior to consider other factors in the development of a long-range operation regime for the Glen Canyon Dam (43 U.S.C. § 1552(b)) and operating criteria were adopted in 1970 requiring the annual release of 8.23 million acre feet of water. 70 Fed. Reg. 15,873 (Mar. 29, 2005).

5 LTEMP FEIS, *supra* n.4, at ch. 1, § 1.8.1, p. 1-19.

6 Susskind et al., *supra* n.3, at 17.

7 *Id.* at 16.

8 *Id.*

9 *Id.* at 13; *see also* LTEMP FEIS, *supra* n.4, at ch. 3 ("Affected Environment").

10 Susskind et al., *supra* n.3, at 13.

11 *Id.* at 14-15.

12 Colorado River Storage Project Act of 1956, 43 U.S.C. § 620. Although environmental interests, such as conserving the recreational facilities, scenery, and resources on land and water acquired for or surrounding the dam, were included as part of the original authorization calling for its construction and operation, Congress explicitly stated that these were not the dam's "primary purposes." *Id.* at § 620g.

13 Susskind et al., *supra* n.3, at 18-21; Roger S. Pulwarty & Theodore S. Melis*, Climate Extremes and Adaptive Management on the Colorado River: Lessons from the 1997–1998 ENSO Event*, 63 J. Envtl. Mgmt. 307, 311 ("The planning process focused on balancing water supply and flood control requirements but did not address environmental issues [citation omitted]. Power generation itself was second to the need to generate revenue for other water projects primarily in the Upper Basin. More recently, major changes in Glen Canyon Dam operations have resulted from increasing concerns regarding downstream ecosystem resources.").

14 The Grand Canyon Protection Act's preamble states that "widely fluctuating releases of water from Glen Canyon Dam severely damage the river corridor downstream by eroding beaches, destroying wildlife habitat, killing native endangered fish, and endangering archaeological sites." Michael Connor, *Extracting the Monkey Wrench from Glen Canyon Dam: The Grand Canyon Protection Act — An Attempt at Balance*, 15 Pub. Land. L. Rev. 135, 136 (1994).

15 For example, in the 1970s, the National Environmental Policy Act and Endangered Species Act were enacted requiring federal agencies to take a closer look at the environmental impacts of federal actions and impacts to endangered and threatened species, respectively.

16 *See generally* Grand Canyon Protection Act (GCPA) of 1992, 106 Stat. 4669, §§ 1801 *et seq.* (Oct. 30, 1992). The GCPA in effect amended the statutory purpose of Glen Canyon Dam and required operation of the dam "in such a manner as to pro[t]ect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established including, but not limited to natural and cultural resources and visitor use." *Id.* at § 1802(a) ("Protection of Grand Canyon National Park").

17 *Id.* at § 1805(a).

18 *Id.* at § 1805(b).

19 LTEMP FEIS, *supra* n.4, at ES-2.

20 *Id.* at ch. 1, § 1.6, p. 1-16 (definition from the National Research Council's Panel on Adaptive Management for Resource Stewardship) ("Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals; increases scientific knowledge; and reduces tensions among stakeholders.").

21 GCPA at § 1805(a).

22 LTEMP FEIS, *supra* n.4.

23 For example, the Deepwater Horizon Natural Damage Assessment Trustee Council identified adaptive management as an overarching priority for many restoration projects in the Final Programmatic Damage Assessment and Restoration Plan/Programmatic Environmental Impact Statement (PDARP/PEIS) Deepwater Horizon Natural Resource Damage Assessment Trustees, Monitoring and Adaptive Management Procedures and Guidelines Manual, Version 1.0 1 (Dec. 2017) (Appendix to the Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the Deepwater Horizon Oil Spill) [hereinafter NRDA Trustees Monitoring and Adaptive Management Guidance] ("Given the unprecedented temporal, spatial, and funding scales associated with the DWH oil spill restoration effort, the Trustees have recognized the need for robust monitoring and adaptive management (MAM) to support restoration planning and implementation. As such, one of the programmatic goals established in the PDARP/PEIS is to 'Provide for Monitoring, Adaptive Management, and Administrative Oversight to Support Restoration Implementation' to ensure that the restoration portfolio of projects provides longterm benefits to the resources and services injured by the spill. Therefore, the Trustees have committed to monitor and evaluate restoration outcomes within an adaptive management framework (Appendix 5.E of PDARP/PEIS; DWH NRDA Trustees, 2016a)."), *available at* **http://www.gulfspillrestoration.noaa.gov/sites/default/files/2018_01_TC_MAM_Procedures_Guidelines_Manual_12-2017_508_c.pdf.**

24 Since 2004, nearly $1,000,000 of U.S. Geological Survey (USGS) appropriated funds have been added to the annual power revenue budget to augment the science done by the Grand Canyon Monitoring and Research Center, in support of the Glen Canyon Dam Adaptive Management Program; this is typically referred to as the "USGS cost share component."

25 GCPA at § 1807 ("The Secretary is authorized to use funds received from the sale of electric power and energy from the Colorado River Storage Project to prepare the environmental impact statement described in section 1804, including supporting studies, and the long-term monitoring programs and activities described in section 1805 . . . .").

26 U.S. Geological Survey Circular 1366: Effects of Three High-flow Experiments on the Colorado River Ecosystem Downstream from Glen Canyon Dam, Arizona ch. 1, p. 3 (Theodore S. Melis ed., 2011), *available at* **https://pubs.usgs.gov/circ/1366/.**

27 Water delivery agreements include: Colorado River Compact; the Upper Colorado River Basin Compact; the Water Treaty of 1944 with Mexico; the decree of the U.S. Supreme Court in *Arizona v. California*; and the provisions of Colorado River Storage Project Act and the Colorado River Basin Project Act of 1968 that govern the allocation, appropriation, development, and exportation of the waters of the Colorado River Basin and in conformance with the Criteria for Coordinated Long-Range Operations of Colorado River Reservoirs, which are currently implemented by the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead. LTEMP FEIS, *supra* n.4, at ES-4.

28 In addition to Reclamation and NPS, 15 cooperating agencies participated in the development of the LTEMP EIS. These agencies illustrate the number of governments and interests that need to be accounted for in the dam's operational and management actions. Specifically, the 15 cooperating agencies included the Bureau of Indian Affairs, U.S. Fish and Wildlife Service, Western Area Power Administration, Arizona Game and Fish Department, Colorado River Board of California, Colorado River Commission of Nevada, Upper Colorado River Commission, Salt River Project, Utah Associated Municipal Power Systems, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Navajo Nation, and the Pueblo of Zuni. LTEMP FEIS, *supra* n.4, at ES-1-ES-2.

29 *See generally Reclamation: Managing Water in the West, Upper Colorado Region, Adaptive Management Program*, Bureau of Reclamation, U.S. Dep't of the Interior, **https://www.usbr.gov/uc/rm/amp/** (last visited on Feb. 23, 2018).

30 LTEMP FEIS, *supra* n.4, at ch. 1, § 1.6, pp. 1-16-1-17.

31 *Id.*; *see generally Grand Canyon Monitoring and Research Center*, U.S. Geological Survey, **https://www.gcmrc.gov/** (last visited on Feb. 23, 2018).

32 LTEMP FEIS, *supra* n.4, at ch. 1, § 1.6, pp. 1-16-1-17.

33 The Work Group was established in 1997 under the Federal Advisory Committee Act (5 U.S.C. §§ 1 *et seq.*).

34 Bureau of Reclamation, U.S. Dep't of the Interior, Glen Canyon Dam Adaptive Management Work Group Charter 1 & 3 (signed Sept. 18, 2017; filed Sept. 19, 2017), *available at* **https://www.usbr.gov/uc/rm/amp/amwg/pdfs/amwg_charter.pdf.** The Work Group is chaired by the Secretary of the Interior (or his/her designee) and includes the following seats: four federal DOI bureaus; seven basin states; six American Indian tribes; two environmental groups; two recreational interests; two federal power purchase contractors; and "other stakeholders". *Id.* As of February 23, 2018, the environmental group seats are held by the National Parks Conservation Association and the Grand Canyon Wildlands Council; the two recreational interests are the Federation of Fly Fishers/Trout Unlimited and Grand Canyon River Guides; and the "other stakeholders" are the Arizona Game and Fish Department and the U.S. Department of Energy. *Reclamation: Managing Water in the West, Upper Colorado Region, Adaptive Management Program, Adaptive Management Work Group Members*, Bureau of Reclamation, U.S. Dep't of the Interior, **https://www.usbr.gov/uc/rm/amp/** (last visited on Feb. 23, 2018).

35 LTEMP FEIS, *supra* n.4, at ch. 1, § 1.6, pp. 1-16-1-17.

36 This approach helped DOI develop and apply adaptive management standards in its work beyond the Glen Canyon Dam. In 2009, DOI published technical guidance written by the Adaptive Management Work Group for how and when adaptive management may be utilized. *See* Byron K. Williams, Robert C. Szaro & Carl D. Shapiro, Adaptive Mgmt. Work Grp., U.S. Dep't of the Interior, Adaptive Management: The U.S Department of the Interior Technical Guide (2009), *available at* **https://www2.usgs.gov/sdc/doc/DOI-%20Adaptive%20ManagementTechGuide.pdf.** Similarly, DOI regulations implementing NEPA requirements include a provision that promotes the use of adaptive management "as appropriate, particularly in circumstances where long-term impacts may be uncertain and future monitoring will be needed to make adjustments in subsequent implementation decisions." 43 C.F.R. § 46.145.

37 To conceive of adaptive management in a broader context, it should be noted that Glen Canyon Dam marks an early and prominent example of "collaborative adaptive management" (CAM). CAM is a scholarly model for a sub-field of adaptive management in a conservation and resource management context with a high degree of uncertainty, multiple, interconnected variables (e.g, environmental, regulatory) and stakeholders, and dynamic changes. Susskind et al., *supra* n.3, at 2 (CAM could similarly be defined as a "dynamic process that changes overtime to adjust to new information and shifting ecological and social conditions" where the government jointly involves stakeholders to make decisions.); Lynn Scarlett, *Collaborative Adaptive Management: Challenges and Opportunities*, 18 Ecol. & Soc'y pp. 1-4 (2013) (CAM essentially combines collaborative decisionmaking and adaptive management) [hereinafter Scarlett], *available at* **https://www.ecologyandsociety.org/issues/view.php?sf=77**. CAM itself is generally characterized by three features: (1) science, (2) collaboration, and (3) a focus on results that incorporates stakeholders into an otherwise top-down, regulatory process. Scarlett, *supra*, at 1; Susskind et al., *supra* n.3, at 2. Glen Canyon Dam has received mixed reviews regarding whether it meets the CAM ideal, particularly as it pertains to stakeholders. Note that the CAM ideal, however, appears to be a high standard that few adaptive management programs have achieved en total, according to academics specializing in this research.

38 *See, e.g.*, Susskind et al., *supra* n.3, at 32-34 ("Ultimately, the AMP's process for determining representation was neither complete nor transparent, and likely the unfortunate result of lobbying behind closed doors. . . . This lack of transparency raises substantial questions regarding the adequacy of AMWG representation and ultimately the legitimacy of subsequent AMWG decisions."); Nathan D. Schott, *Adaptive Management in Grand Canyon: Towards A More Sustainable Approach*, 4 Ariz. J. Envtl. L. & Pol'y 160, 177 (2014) ("the AMWG consists of an unrepresentative group of stakeholders, and their recommendations, although sometimes a product of consensus, are improperly seen as a proxy for the public interest.").

39 *The Challenges Facing Grand Canyon National Park: Hearing Before the H. Subcomms. on Nat'l Parks, Forests, & Public Lands & Water & Power* 5-6 (Apr. 8, 2010) (statement of Dr. Steven W. Carothers, Senior Scientist, SWCA Environmental Consultants), *available at* **https://naturalresources.house.gov/calendar/eventsingle.aspx?EventID=178477**. Additionally, the work group's appointment and vetting process could benefit from greater transparency, as the public is unclear how the Secretary of the Interior selects people to fill broadly defined seats. *See also supra* n.38.

40 *The Challenges Facing Grand Canyon National Park: Hearing Before the H. Subcomms. on Nat'l Parks, Forests, & Public Lands & Water & Power* 8 (Apr. 8, 2010) (statement of Dr. Herbert C. Frost, Assoc. Dir., Natural Res. Stewardship & Science, Nat'l Park Serv., U.S. Dep't of the Interior), *available at* **https://naturalresources.house.gov/calendar/eventsingle.aspx?EventID=178477.**

41 U.S. Geological Survey Circular 1366: Effects of Three High-flow Experiments on the Colorado River Ecosystem Downstream from Glen Canyon Dam, Arizona ch. 1, p. 1 (Theodore S. Melis ed., 2011) (DOI conducted three high-flow experiments at Glen Canyon Dam in March 1996, November 2004, and March 2008.), *available at* **https://pubs.usgs.gov/circ/1366/.** Other types of flow experiments have occurred in the fall and summer with lower and steadier flows with the hope that flow stability would benefit native fish conservation. For a complete list of all experimental flow treatments from 1996 to 2014, see table 17.1 in Theodore S. Melis et al., *Using Large-scale Flow Experiments to Rehabilitate Colorado Ecosystem Function in Grand Canyon: Basis for an Adaptive Climate-resilient Strategy*, *in* Water Policy and Planning in a Variable and Changing Climate ch. 17, § 17.1, p. 318 (Kathleen A. Miller et al., eds., 2016).

42 *The Challenges Facing Grand Canyon National Park: Hearing Before the H. Subcomms. on Nat'l Parks, Forests, & Public Lands & Water & Power* 8 (Apr. 8, 2010) (statement of Dr. Herbert C. Frost, Assoc. Dir., Natural Res. Stewardship & Science, Nat'l Park Serv., U.S. Dep't of the Interior), *available at* **https://naturalresources.house.gov/calendar/eventsingle.aspx?EventID=178477.**

43 *See id.*

44 DOI initiated public scoping for the LTEMP in 2006; however, the process that led to the final LTEMP did not technically begin until 2011/2012. In the intervening period, environmental compliance requirements under National Environmental Policy Act and

Endangered Species Act for the endangered humpback chub regarding experimental high-flow actions and litigation brought by the Grand Canyon Trust delayed it. *See* Long-term Experimental Plan for the Operation of Glen Canyon Dam and Other Associated Management Activities, 73 Fed. Reg. 8062, 8063 (Feb. 12, 2008); *see also* Grand Canyon Trust v. U.S. Bureau of Reclamation et al., 623 F. Supp. 2d 1015 (D. Ariz. 2009), 691 F.3d 1008, 1014 (9th Cir. 2012), *as amended* (Sept. 17, 2012).

45 Notice of Availability for the Final Environmental Impact Statement for the Long-term Experimental and Management Plan for the Operation of Glen Canyon Dam, Page, Arizona, 89 Fed. Reg. 69,850, 69,850 (Oct. 7, 2016) ("This will be the first EIS completed on the monthly, daily, and hourly operations of Glen Canyon Dam since 1995, which was a major point of demarcation in attempting to achieve a balance between project purposes and natural resources protection.").

46 *Id.* ("The need for the proposed Federal action stems from the need to use scientific information developed since the 1996 ROD to better inform the public of Department of the Interior decisions on dam operations and other management and experimental actions . . . ."); Bureau of Reclamation & Nat'l Park Serv., U.S. Dep't of the Interior, Record of Decision for the Glen Canyon Dam Long-term Experimental and Management Plan Final Impact Statement § 2, p. 3; § 4.1, p. 5 (Dec. 2016) [hereinafter LTEMP FEIS ROD].

47 *See supra* n.45; *see also generally* LTEMP FEIS, *supra* n.4 & LTEMP FEIS ROD, *supra* n.46.

48 *See* LTEMP FEIS ROD, *supra* n.46, at app. B, § 1.3 ("Implementation Process for Experiments Under Alternative D").

49 *See id.*

50 In the LTEMP FEIS, DOI treated the effects of climate change on the LTEMP as "an uncertainty in the analyses of hydrology and downstream resource impacts, rather than by means of a full-fledged climate analysis and adaptation approach." LTEMP FEIS, *supra* n.4, ch. 4, § 4.16.1.2, p. 4-413. Regardless, DOI's LTEMP analysis is noteworthy because it included a look at projected climate impacts on humans and resources at Glen Canyon Dam that can be considered over the Program's next 20 years. *See, e.g., id.* at ch. 4, § 4.16.2.2 ("Effects of Climate Change on Hydrology and Downstream Resources"). Climate change may even be the greatest uncertainty facing the Glen Canyon Dam, and possibly other adaptive management programs and thus, long-term monitoring and responsive management actions could become increasingly important. *See* Theodore S. Melis et al., *Using Large-scale Flow Experiments to Rehabilitate Colorado Ecosystem Function in Grand Canyon: Basis for an Adaptive Climate-resilient Strategy*, *in* Water Policy and Planning in a Variable and Changing Climate ch. 17, § 17.3, p. 333 (Kathleen A. Miller et al., eds., 2016).

51 LTEMP FEIS ROD, *supra* n.46, at app. B, § 1.4, p. B-17 ("Communication and Consultation Process for Alternative D").

52 *Id.*

53 Reclamation and NPS had to navigate legal differences between the Glen Canyon Dam Adaptive Management Program and LTEMP. For example, there are different requirements under NEPA regarding when and what information can be shared with a cooperating agency, compared to requirements under the Federal Advisory Committee Act, which governs the Adaptive Management Work Group, in terms of when and what information can be shared at a public Work Group meeting.

54 *See* LTEMP FEIS ROD, *supra* n.46, at app. B, p. B-1.

55 Scarlett, *supra* n.37, at 4.

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