

## Project 13. Socioeconomic Monitoring and Research

Initial Estimate: FY15: \$176,100; FY16: \$220,300; FY17: \$356,100

GCDAMP Funding: FY15: \$176,100; FY16: \$204,900; FY17: \$338,300

### A. Investigators

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### B. Project Summary

During the past three decades, socioeconomic monitoring and research in the Glen Canyon Environmental Studies and Glen Canyon Dam Adaptive Management Program (GCDAMP) have been limited (Hamilton and others, 2010). Previous research has indicated that the economic value of recreation and other downstream resources are impacted by Glen Canyon Dam (GCD) operations; however, because these studies were conducted 20 to 30 years ago, the findings are out-of-date, as dam operations and resource conditions have changed since that time (Bishop and others, 1987; Welsh and others, 1995; U.S. Department of Interior, 1996; USGS, 2005).

This project is designed to identify recreation and tribal preferences for, and values of, downstream resources and evaluate how preference and value are influenced by GCD operations. In addition, the research will integrate economic information with data from long-term and ongoing physical and biological monitoring and research studies led by the Grand Canyon Monitoring and Research Center (GCMRC) to develop a decision support system that will improve the ability of the GCDAMP to evaluate and prioritize management actions, monitoring and research (Hamilton and others, 2010).

This project involves three related socioeconomic monitoring and research studies. These studies include: (a) evaluation of the impact of GCD operations on regional economic expenditures and economic values associated with angling in the Glen Canyon National Recreation Area (GCNRA) downstream from GCD, and whitewater floating in Grand Canyon National Park (GCNP) that begins at Lees Ferry (Project Element 13.1); (b) assessment of the impact of GCD operations on tribal preference for and value of downstream resources (Project Element 13.2); and (c) development of decision methods, using economic metrics, to evaluate management actions and prioritize monitoring and research on resources downstream of GCD (Project Element 13.3).

This project will be coordinated with related economic research efforts implemented by the National Park Service (NPS) and U.S. Bureau of Reclamation (Reclamation) in conjunction with the Glen Canyon Dam Long-Term Experimental and Management Plan Environmental Impact Statement (LTEMP EIS). The NPS is conducting research to provide current economic values of ecosystem resources downstream of GCD. In addition, Argonne National Laboratory, contracted through Reclamation, has made significant advancements in the power system analysis modeling for the LTEMP EIS that provide information on the economic value of hydropower production at GCD under different management alternatives. These coordinated efforts to determine individual preferences for and economic values of downstream resources, and the development of decision methods to improve decision making abilities of GCDAMP are necessary to evaluate and prioritize management, monitoring, and research decisions.

## C. Background

### *Recreation*

The Grand Canyon Protection Act (GCPA) of 1992 states that, “long-term monitoring of Glen Canyon Dam shall include any necessary research and studies to determine the effect of the Secretary's actions under section 1804(c) on the...recreational...resources of Grand Canyon National Park and Glen Canyon National Recreation Area” (GCPA, sec. 1805(b)). Bishop and others (1987) were the first to establish a relationship between dam operations and recreational preferences and economic values related to angling in GCNRA and whitewater floating in GCNP. Nearly 30 years have passed since this comprehensive study of regional recreational expenditures and preferences for and economic values of releases at GCD. The characteristics of recreational resources have changed significantly since this research was conducted. Specifically, alteration of diurnal flow patterns and greater whitewater floating opportunities resulting from The Operation of Glen Canyon Dam, Record of Decision (ROD) (U.S. Department of Interior, 1996), and the Colorado River Management Plan (NPS, 2006), respectively, have changed the whitewater floating experience. The angling experience has also changed in Glen Canyon since the Bishop and others (1987) study as a result of fluctuations in catch rates and fish condition and modifications to angling regulations (Loomis and others, 2005).

Additional research was conducted in GCNP to assess whitewater floater trip preferences; although the research did not identify specific economic values of flows for whitewater floating trips (Stewart and others, 2000). Furthermore, the economic information related to recreation will not be updated through empirical research for the LTEMP EIS (Harpman, 2013). Because it is important to understand the potential effects of dam operations on the recreational experiences in GCNRA and GCNP, there is a need to update and extend the original Bishop and others (1987) study. Undoubtedly, this research will contribute to a primary GCDAMP goal, which is to “maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of the GCDAMP ecosystem goals” (USGS, 2006).

### *Native American Tribes*

The operation of GCD also has direct and indirect effects on downstream resources of cultural value and traditional use in GCNRA and GCNP. The GCPA of 1992 states that, “...monitoring programs and activities conducted under subsection (a) shall be established and implemented in consultation with...Indian tribes...” (GCPA, sec. 1805(c)). The GCDAMP has

also recognized a need to maintain effective consultation with tribes to appropriately incorporate tribal values into the GCDAMP.

“Because culture defines the roles that resources play in that culture, only members of that culture can assess the status or health of the resources. Therefore, measures for resource status or health and appropriate management will need to be determined individually by the federal agencies in consultation with the traditionally associated peoples (AMWG, 2012a).”

Research concerning tribal preferences for and values of downstream resources, and assessment of the influence of dam operations on these resources, is lacking (Hamilton and others, 2010). This research, in coordination with the tribes, is critical for furthering the understanding of tribal preferences for and socioeconomic impacts associated with resource management decisions within the GCDAMP.

### ***Decision Theory***

It is the “absence of decision making mechanisms” in adaptive management (AM) programs that make systematic prioritization of investment in monitoring, research, and management alternatives difficult (Scarlet, 2013). Decision making mechanisms, including the economic assessment of investment in monitoring and research, are important components of AM programs (Doremus, 2010). Recent studies have highlighted the shortcomings of traditional cost-benefit methods when facing the state-dependency and inherent uncertainty in AM programs (Loomis and other, 2009, Bond 2010). Given these shortcomings, optimal control or stochastic dynamic optimization methods have been proposed to evaluate the economics of management actions and monitoring and research efforts (Bond, 2010; Bond and Loomis, 2009; Epanchin-Niell and Hasting, 2010; Springborn and Sanchirico, 2013). These methods use mathematical techniques to identify optimal management actions, including monitoring and research, given an objective (e.g., minimize economic costs) and a set of physical, biological and/or institutional constraints (e.g., humpback cub recovery goals).

Previous research has developed a decision support system for the Colorado River ecosystem (CRE) in GCNRA and GCNP downstream from GCD. Walters and others (2000) developed a decision support system to screen the effect of various management options on downstream resources. While some predictions of resource responses to various management scenarios were accurate, responses to management scenarios of other resources (e.g., sediment storage, native fish) were very uncertain, due to limited empirical data (Walters and others, 2000). More recent analysis in the LTEMP EIS used structured decision analysis to identify alternative future management scenarios, but this process is not comparable to an economically based decision support system (Reclamation, 2014). ***This project element would take the next step in the development of a decision support system to inform the GCDAMP in the organization and evaluation of management actions, monitoring, and research.***

It is pertinent that monitoring and research in the physical science (see FY15–17 Workplan, Projects 1, 2, 3, and 11), biological science (see FY15–17 Workplan, Projects 6, 7, 8, 9, and 10), cultural (see FY15–17 Workplan, Project 4 and 12), and socioeconomic (see FY15–17 Workplan, Project Elements 13.1 and 13.2) programs be integrated into an analytical framework that can inform the GCDAMP in evaluation of future monitoring and research. Developing a decision support system based on analytical methods, such as predictive, integrated dynamic

models, is essential when answering questions such as, “how do we quantify and integrate the full range of socio-economic concerns into dam re-regulation, in addition to hydropower concerns (GCDAMP, 2004)?” Therefore, there is a critical need to develop a decision support system within the GCDAMP to assist in the organization, evaluation and prioritization of investment in monitoring and research and improve the economic efficiency of long-run management decisions under uncertainty.

### C.1. Scientific Background

The following hypotheses and research questions support the proposed project elements. Given that project elements are a synthesis of monitoring and research, there are components that are not hypothesis driven.

#### **Recreation**

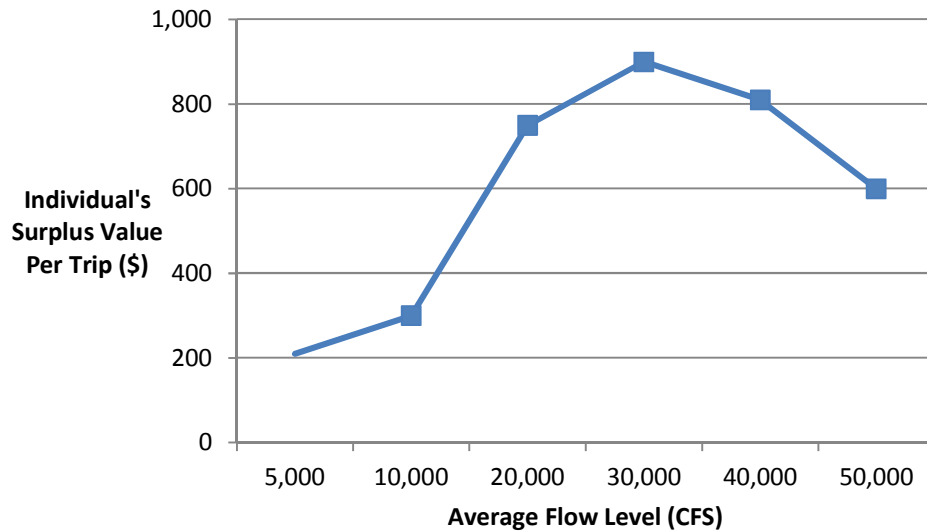
**Hypothesis 1 (H1)** *The operation of GCD influences the economic value of angling in GCNRA, between GCD and Lees Ferry.*

**Hypothesis 2 (H2)** *The operation of Glen Canyon Dam influences the economic value of whitewater floating in GCNP.*

**Hypothesis 3 (H3)** *The changes in operation of GCD, since the ROD, have influenced the economic value of angling in GCNRA, between GCD and Lees Ferry.*

**Hypothesis 4 (H4)** *The changes in operation of GCD, since the ROD, have influenced the economic value of angling in whitewater floating in GCNP.*

Demand for recreation is determined by (a) socioeconomic characteristics (e.g., income, education, age, etc.), (b) quality, (c) substitutes, (d) travel time, (e) crowding, and (f) tastes and preferences (Loomis and Walsh, 1997). Operation of GCD directly impacts the quality of angling in GCNRA and whitewater floating in GCNP (Bishop and others, 1987). For example, different flows affect the ability to operate watercraft during angling and whitewater floating activities and influence trip attributes such as catch rate for anglers and length of time spent on the river for whitewater floaters. Similar to findings by Bishop and others (1987), **H1** and **H2** posit that both anglers’ and whitewater floaters’ economic values increase with increased flows, until an inflection point is reached, at which time economic value decreases with increased flow. Figure 1 is an example of the relationship between an individual whitewater floater’s surplus economic value per trip and average flows.



**Figure 1.** Theoretical Flow Value Curve for an Individual Whitewater Floater (Bishop and others, 1987)

**H3** and **H4** posit that both anglers' and whitewater floaters' economic values have increased with the changes in operation of GCD, since the ROD. These hypotheses are based on the findings of Bishop and others (1987), large fluctuations at moderate flows are not preferred by anglers or whitewater floaters.

While the primary objective of this research is to evaluate the relationship between operation of GCD and economic values of recreational angling and whitewater floating, this project element will also provide information about; (a) regional expenditures, (b) trip attributes of importance, and (c) direct recreational use values (see section D.1). This information is important when conducting short and long-term impact, and other policy related analysis.

### ***Native American Tribes***

**Hypothesis 3 (H3)** *Tribal preferences for and values of downstream resources differ among downstream resource attributes.* To test this hypothesis, the relative ranking, marginal rate of substitution, and parameter estimates of preference relationships among resource attributes (e.g., hydropower, native fish) will be generated and assessed. **H3** posits that there will be significant variation in the preferences for and values of downstream resources by resource attribute. Because tribes may have specific culturally determined “decision processes” and approaches to resource valuation that may limit aggregation of individual preferences, the choice of elicitation methods, and comparison of preferences among tribes (Adamowicz and others, 1998), additional hypotheses to be tested in Project Element 13.2 will be generated following tribal consultation. An additional hypothesis that may be addressed in this project element is:

- Tribal preferences for and values of downstream resources differ among tribes.

This research will enhance understanding of tribal preferences for and values of downstream resources, and perspectives associated with tradeoffs that occur when evaluating management actions and prioritizing monitoring and research decisions within the GCDAMP. This research will develop methods to clearly identify preference for and economic value of resource management decisions, independent of non-economic Tribal cultural values associated with Glen and Grand Canyons.

## ***Decision Theory***

This project element will improve the GCDAMP's ability to organize scientific information and evaluate and prioritize, monitoring, research and management alternatives specific to the operation of GCD. For example, in the Non-native Fish Control Downstream from Glen Canyon Dam Environmental Assessment (NNFC) (Reclamation, 2011), it is informally hypothesized that in mitigation of the effects of rainbow trout (*Oncorhynchus mykiss*) on humpback chub (*Gila cypha*) (Reclamation 2011), flow actions may be more cost-effective in the long-run relative to the proposed non-native removal efforts in the Paria-Badger Creek Rapid and Little Colorado River reaches (Reclamation, 2011). This is the type of question this project element will address.

One of the twelve goals of the GCDAMP is to “maintain a high-quality monitoring, research, and adaptive management program” (USGS, 2006). In order to accomplish this goal, it is important to prioritize management actions, including monitoring and research. In fact, several of the eleven other goals of the GCDAMP specify desired resource states and stress actions to achieve these states where “practicable”, “feasible”, or “within the framework” of other resource goals (e.g., ecosystem goals). This direction calls for a balanced approach to managing resources downstream of GCD. Identifying economic values of downstream resources and establishing a decision support system will assist in the evaluation of actions the GCDAMP recommends and implements through GCMRC to answer research questions specific to its goals.

### C.2. Key Monitoring and Research Questions Addressed in this project

This project is organized around hypotheses and research questions (see section C.1) that are based on Strategic Science Questions (SSQs), Core Monitoring Information Needs (CMINs), and Research Information Needs (RINs) previously identified by the GCDAMP. The project also supports the evaluation and prioritization of Desired Future Conditions as identified by the AMWG (2012a.)

Primary SSQ addressed:

- SSQ 2-6. How can tribal values/data/analyses be appropriately incorporated into a science driven adaptive management process in order to evaluate the effects of flow operations and management actions on TCPs?
- SSQ 2-7. Are dam controlled flows affecting TCPs and other tribally-valued resources in the CRE, and, if so, in what respects are they being affected, and are those effects considered positive or negative by the tribes who value these resources?
- SSQ 3-7. How do dam controlled flows affect visitors' recreational experiences, and what is/are the optimal flows for maintaining a high quality recreational experience in the CRE?
- SSQ 3-8. What are the drivers for recreational experiences in the CRE, and how important are flows relative to other drivers in shaping recreational experience outcomes?

Primary Core Monitoring Information Needs addressed:

- CMIN 11.2.1 (SPG revised). Determine the condition of traditionally important resources and locations using tribal perspectives and values.

Research Information Needs addressed:

- RIN 12.1.1 What is the economic value of the recreational use of the CRE downstream from GCD?
- RIN 12.3.2 What are the differences between western science and tribal processes for design of studies and for gathering, analyzing, and interpreting data used in the adaptive management program? How well do research designs and work plans incorporate tribal perspectives and values into the standard western science paradigm? Is it more beneficial to keep the perspective separated?

The development of the proposed project has occurred through communication with and cooperation from the GCDAMP Socioeconomics Ad Hoc Group (SEAHG). The SEAHG has repeatedly identified the proposed project elements as critical information needs (AMWG 2012b). The proposed project elements are also based on coordinated activities with the NPS and Reclamation in conjunction with the LTEMP EIS. The proposed project elements will compliment current economic analysis associated with the LTEMP EIS.

## D. Proposed Work

### D.1. Project Elements

*Project Element 13.1. Economic Values of Recreational Resources along the Colorado River – Grand Canyon Whitewater Floater and Glen Canyon Angler Values – Recommended for Funding (FY15 \$69,801; FY16 \$73,525; FY17 \$0)*

Lucas Bair, Economist, USGS, GCMRC

John Duffield, Research Professor, Department of Mathematical Sciences, University of Montana

Chris Neher, Researcher, Department of Mathematical Sciences, University of Montana

David Patterson, Professor, Department of Mathematical Sciences, University of Montana

The objective of this project element is to determine preferences, regional expenditures, and economic values of anglers in GCNRA<sup>2</sup> and whitewater floaters in GCNP<sup>3</sup>, as affected by operation of GCD, to provide the GCDAMP and federal decision-makers with current recreation resources information for decision making. This project element has been initiated with FY13–14 funds from Project K, Economist and Support (\$241,305). Survey printing and mailing costs are included in the FY13-14 Project K funds. The funding request for FY15–16 is only for continued involvement of the GCMRC economist, Lucas Bair.

To accomplish the project objective, a series of economic surveys will be conducted to obtain current information on recreationists' preferences, expenditures, and economic values associated with angler and whitewater floater trips. Specifically, surveys of anglers in GCNRA and whitewater floaters in GCNP will include questions addressing:

- Regional expenditures associated with trip activities such as the cost of transportation, lodging, guide services, and various other local purchases.

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<sup>2</sup> For purposes of this project element, anglers in GCNRA include walk-in anglers from Lees Ferry to Badger Creek Rapid.

<sup>3</sup> This project does not include whitewater floaters that begin their trip at Diamond Creek.

- Trip attributes of importance such as crowding, fish catch characteristics, overall trip enjoyment, and other trip qualities.
- Direct recreational use values (i.e., net economic benefits) to the recreationist, as measured by willingness to pay over and above trip costs.
- Variation in direct recreational use values related to a range of flow levels presented in the surveys.

As was the case with the original Bishop and others (1987) study, the proposed project will use a mail survey contact method with a follow-up protocol for non-responders. The respondents will be sent a mail survey packet, followed by a postcard reminder, and, later, by a second survey packet for non-responders. Non-respondents to the second survey packet will be contacted to complete non-response questions.

A random sample from the most recent year's whitewater floaters will be obtained with the assistance of GCNP and outfitters. GCNP maintains a comprehensive mailing list of all members of private whitewater floater parties. Additionally, commercial outfitters maintain mailing lists of the commercial clients. The survey will include: 1) private party floaters, 2) commercial motor powered floaters, and 3) commercial oar powered floaters. The target sample size will be 2,850 whitewater floaters divided equally between private and commercial trip participants. The commercial sample will be further divided equally between oar and motor-powered trips.

Anglers in Glen Canyon, using Lees Ferry downstream to Badger Creek Rapid as access points, will be contacted, in cooperation with Arizona Department of Game and Fish, during high use periods, spring (April-May) and fall (October-November), to participate in the surveys. No *a priori* attempt will be made to stratify the sampling based on guided or non-guided status. However, preferences, expenditures, and economic values of guided and non-guided anglers will be compared within the data analysis. Anglers contacted at Lees Ferry will be asked questions regarding demographics and attributes of their trip. In addition, anglers will be asked to provide contact information. The target sample size is 750 anglers.

Statistical models appropriate for the experimental design and elicitation format of the surveys will be developed to evaluate the relationship between preferences, economic value and trip attributes (e.g., flow levels). The models will provide information on the relative preferences and economic value for trip attributes and the marginal rates of substitution between trip attributes. This information is necessary for the GCDAMP to make informed decisions about the economic tradeoffs that occur, with regard to recreation, when evaluating future management actions (see FY15–17 Workplan, Project Element 13.3).

***Project Element 13.2. Tribal Perspectives for and Values of Resources Downstream of Glen Canyon Dam – Funding Uncertain (FY15 \$0; FY16 \$136,580; FY17 \$128,065)***

Lucas Bair, Economist, USGS, GCMRC

John Duffield, Research Professor, Department of Mathematical Sciences, University of Montana

Chris Neher, Researcher, Department of Mathematical Sciences, University of Montana

David Patterson, Professor, Department of Mathematical Sciences, University of Montana

The objective of this project element is to identify tribal preferences and values associated with management of resources downstream of GCD in order to inform decision making processes in the GCDAMP. Defining individual tribe's preferred actions or constraints



associated with management of downstream resources is important when evaluating potential actions and associated trade-offs. Emphasis will be placed on resources of tribal significance that are directly or indirectly affected by dam operations, experiments, and ongoing management. The assessment of tribal preferences and values will be achieved through focus group meetings with individual tribes, where choice experiment methods will be conducted to explicitly evaluate resource attributes tradeoffs that occur from management of GCD. The project will be implemented in in FY16, with continued dialogue and informational presentations provided by GCMRC staff throughout FY15 to facilitate the proposed research.

The individual project elements will consist of four major tasks:

1. Cooperate with GCDAMP Tribal representatives and Tribal members to review previous studies and tribal programs relating to tribal preferences for and values of resources downstream of GCD and obtain necessary permits to conduct research on tribal land.
2. Conduct initial meetings with individual tribes to obtain permission and gauge interest in participation, identify focus group participants, and develop and pretest focus group survey content to ensure culturally appropriate methodology.
3. Conduct focus group meetings with individual Tribal members to explore preferences for and values of downstream resources.<sup>4</sup> The meetings will use choice experiment methods (Brefle and Rowe, 2002; Harpman, 2008), which are commonly applied in marketing and resource economics studies, to identify these preferences and values. When appropriate, nominal compensation will be provided to Tribal members for their participation in focus groups. Focus groups provide an open forum for clarifying survey methods and participant questions. However, in-person, mail or alternative survey methods will be used if individual tribes discourage the use of focus groups.
4. Analyze survey results and prepare manuscript for publication. Reports and presentations specific to the research methods and results of Project 13.2 will be provided to individual Tribes as requested.

For the choice experiment methods, downstream resource attributes of tribal importance (e.g., hydropower, humpback chub) and their potential variation with different future management actions will be defined in Task 2 and will shape the experimental design. The experimental design will be based on the number of possible scenarios to choose from, where respondents may be asked to evaluate all possible scenarios or just a subset of randomly chosen scenarios if the number of choices are unwieldy. Based on input during tribal consultation, future attribute levels will be either ranked, rated, or evaluated in a choice-based format (two alternative future scenarios compared and one is selected). It is important to note that comparisons among resource attributes can contain explicit cost information (e.g., forgone hydropower revenue) when comparing future resource attributes, or may just compare resource attributes alone. Statistical models appropriate for the experimental design and elicitation format will be developed to evaluate the relationship between preferences, or values, and resource attributes. ***The models will provide information on the relative preferences and values for resource***

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<sup>4</sup> Focus groups are considered “qualitative” research and require less time-intensive review by the Office of Management and Budget.

*attributes and the rates of substitution between resource attribute tradeoffs.*<sup>5</sup> Information gained through this research is necessary for evaluation of management decisions and development of applied decision methods that accommodate tribal preferences for and values of downstream resources (see FY15–17 Workplan, Project Element 13.3). The anonymity of individual focus group participants and scientific integrity of the research is concomitant with the Office of Management and Budget survey review as part of the Paperwork Reduction Act and peer review, respectively.

***Project Element 13.3. Applied Decision Methods for the Glen Canyon Adaptive Management Program – Recommended for Funding (FY15 \$106,803; FY16 \$147,640; FY17 \$228,984)***

Lucas Bair, Economist, USGS, GCMRC

Charles Yackulic, Research Statistician, USGS, GCMRC

Michael Springborn, Assistant Professor, University of California at Davis

Craig Bond, Economist, Pardee RAND Graduate School

The objective of this project element is to improve the GCDAMP’s ability to consider, organize and prioritize monitoring, research, and long-term management alternatives related to the operation of GCD. A decision support system comprised of analytical models, that incorporate economic parameters, will provide prompt assessment capabilities in science and management program planning.

To accomplish this, existing published approaches to resource management under uncertainty will be evaluated. Specific attention will be paid to methods that improve decision making processes when evaluating resource tradeoffs related to monitoring, research, and management decisions. Evaluation efforts will focus on decision frameworks and analytical tools that best apply to the GCDAMP when considering the need for collaboration, complex biophysical/socioeconomic interactions, and constraints on GCDAMP resources.

There are multiple analytical approaches used in decision frameworks that address resource management under uncertainty. These include maximizing expected utility, applying the precautionary principle and other robust decision making processes such as dynamic stochastic programming, optimal control, or simulation methods (Lempert and Collins, 2007). The various approaches differ in the types of scientific information utilized and the way in which decision process outcomes are framed and communicated (Lempert and Collins, 2007).

There are also various types of decision support system frameworks that are important to consider when interdisciplinary teams of scientists and stakeholder groups that hold divergent views, or core values, are involved in the decision process. It is as important to address the decision process, or context, as it is to develop the scientific foundation, or content, of the analytical methods (Norton, 2005; Clifford and Sagoff, 2009).

This project element will develop and implement a decision support system specific to the GCDAMP in a series of model development tasks. Analytical model development of downstream resources will be prioritized for resources that:

1. Contain significant economic value and/or that garner a significant portion of the GCMRC annual budget;
2. Are impacted by operational decisions at GCD; and

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<sup>5</sup> Model results will not quantify the economic value of the resource attribute. However, if price based attributes (e.g. hydropower costs) are assessed in the surveys, economic values can be ascertained.

3. Have sufficient predictive modeling frameworks developed to assess future resource states.

The initial focus of this project element will be the development of a bioeconomic model to identify the economically preferred management strategy for established nonnative fish, in relation to humpback chub survival.<sup>6</sup> This is a question explicitly identified in the NNFC (Reclamation, 2011). This task follows the model prioritization structure, (1) ecosystem values (including humpback chub) exhibit significant economic value (Welsh and other, 1995); (2) dam operation impacts non-native fish populations (see FY15-17 Workplan, Project 9), and (3) recent advancements in predictive models of rainbow trout and humpback chub survival have led to opportunities to evaluate humpback chub population management from an economic perspective (Yackulic and others, 2014). This task will evaluate economic outcomes, as part of the Yackulic and others (2014) model, to minimize the cost of rainbow trout removal over time, under different future scenarios. While the exact methodological approach will be determined through model development, the likely approaches include optimization (stochastic dynamic programming or optimal control) and/or simulation based approaches (Epanchin-Niell and Hasting, 2010). Incorporating future scenarios allows for modeling humpback chub recovery goals in various conditions while identifying strategies that are both cost-effective and robust to uncertain future conditions (e.g., climate). This analytical model, and accompanying documentation, will be completed in FY15.

This proposed bioeconomic model utilizes cost-effectiveness analysis. Like cost-benefit analysis, cost-effectiveness analysis is a standard economic practice. However, cost-effectiveness fundamentally asks a different question than cost-benefit analysis. Cost-benefit analysis assigns an overall net benefit (or net cost) to a future management action. Cost-effectiveness analysis in turn identifies the least cost alternative, when faced with competing or complimentary management actions, to reach a defined objective. In this case, the objective is humpback chub recovery, as defined by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service, 2002). Implementing cost-effectiveness analysis is consistent with the ROD's goal, not to maximize benefits but to determine an operation at GCD that limits impact to hydropower while meeting recovery and long-term sustainability of downstream resources (Reclamation, 1996).

There are several other implications when using cost-effectiveness analysis that are important to recognize. For example, it must be determined that the defined goal is worth achieving. This is demonstrated by either verifying the economic benefit of the objective outweighs the costs associated with achieving the objective or the objective is mandated through a public process. In the case of the humpback chub recovery goals, both the economic value of recovery exceeds the cost of proposed recovery actions and recovery goals are mandated through public process (Welsh and others, 1995; U.S. Fish and Wildlife Service, 2002). Conducting cost-effectiveness analysis also implies that the defined goal will be reached across all possible alternative future scenarios. Again, this is a reasonable assumption based on the recovery mandate (U.S. Fish and Wildlife Service, 2002). This implication is important because it essentially removes the onerous, or in some cases contentious, identification of economic value of downstream resources. The focus is shifted from establishing the benefit of the objective to identifying the most cost-effective way to meet the objective (Sagoff, 2009). This is an important distinction when stakeholders may fundamentally reject attempts to economically value aspect of ecosystem

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<sup>6</sup> Management strategies would consider constraints with respect to tribal concerns and other factors (e.g., whirling disease).

resources. Cost-effectiveness analysis isn't appropriate in every context. However, it lends itself to the GCDAMP's task of evaluating and prioritizing management actions, monitoring and research where incremental decisions must be made, under uncertainty, understanding that many overarching objectives are set through public processes.

While the initial task is focused on research to identify the most cost-effective management actions with respect to non-native fish management policies, as identified in the NNFC (Reclamation, 2011), the modeling effort will be expanded in FY16–17 to include other downstream resources that impact rainbow trout and humpback chub populations, better facilitating decision making in the GCDAMP. Specifically, in FY16–17, subsequent tasks in model development will include:

1. Identify the importance of parameter uncertainty on the sensitivity of cost-effective outcomes in the bioeconomic model. Evaluating parameter uncertainty will aid in the identification of the value and prioritization of monitoring and research (i.e., how scientific discovery and monitoring, and reducing model parameter uncertainty, decreases expected management costs) and demonstration of how modeling can prioritize future monitoring and research. This advancement in the analytical model, and accompanying documentation, will be completed in FY16–17.
2. Incorporate additional management variables and associated costs, such as trout management flows at GCD, to improve humpback chub survival, again identifying the most cost-effective management alternatives under different future scenarios. This advancement in the analytical model, and accompanying documentation, will be completed in FY16–17.

The decision support system will be developed over FY15–17 in cooperation with stakeholders, according to stakeholder's expressed needs and the advancement of scientific knowledge at GCMRC. For example, updating the economic value of whitewater floating in GCNP will provide insight into modeling the tradeoffs between flow regimes and recreational experiences (see FY15–17 Workplan, Project Element 13.1). This deliberate process of building a decision support system through the development of individual analytical, predictive models will enable analysts to identify monitoring and scientific information needs and screen policy options as the GCDAMP advances its goals. This process is essential in enabling the GCDAMP to better organize and evaluate the scientific monitoring and research that is provided by GCMRC.

#### D.2 Personnel and Collaborations

The project lead is Lucas Bair. Collaborators for Project Elements 13.1 and 13.2. include John Duffield and Chris Neher, economists at the University of Montana, and David Patterson, a statistician at the University of Montana. These collaborators will assist with the development and implementation and analysis of recreational and tribal surveys. Collaborators for Project Element 13.3. will include Charles Yackulic and other biology and physical-sciences program staff at the GCMRC, mostly in supporting roles, Michael Springborn, an economist specializing in adaptive management, at the University of California at Davis, and Craig Bond, an economist specializing in adaptive management, at the RAND Corporation. These collaborators will assist with development of applied decision methods.

### D.3. Deliverables

Products from this project, led by Lucas Bair, will include annual reports to the GCDAMP, presentations at TWG and AMWG meetings when appropriate, presentations at scientific meetings, and peer-reviewed scientific journal articles. Reports and presentations specific to the research methods and results of Project 13.2 will be provided to individual Tribes as requested.

- In FY16–17, one or two manuscripts will be prepared from the results of Project Element 13.1 for submission to peer-reviewed scientific journals.
- In FY17, one manuscript will be prepared from the results of Project Element 13.2 for submission to a peer-reviewed scientific journal.
- In FY15–17, two or three manuscripts will be prepared from the results of Project Element 13.3 for submission to peer-reviewed scientific journals.

## E. References

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## F. Budget

Monitoring		Research					Project Identifier	Project Description	Salaries	Travel & Training	Operating Expenses	Logistics	Coop-erators (non-USGS)	USGS Coop-erators	USGS/SBSC Burden	Total
Core activities	Support implementation and evaluation of HFE Protocol and Non-Native Fish Control	Technical and analytical innovations in monitoring	Improving predictive modeling capacity	Resolving scientific uncertainty	Independent science oversight and review	Integrating tribes in monitoring and research										
<b>FY15</b>																
						13	<b>Socio-economic Monitoring and Research</b>		\$118,800	\$12,500	\$1,000	\$0	\$22,500	\$0	\$21,300	\$176,100
				X		13.1	Economic Values of Recreational Resources Along the Colorado River – Grand Canyon Whitewater Floater and Lees Ferry Angler Values	Bair et al.	\$54,700	\$5,000	\$500	\$0	\$0	\$0	\$9,400	\$69,600
				X		13.2	Tribal Values and Perspectives of Resources Downstream of Glen Canyon Dam	Bair et al.	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
		X				13.3	Applied Decision Methods for the Glen Canyon Adaptive Management Plan	Bair et al.	\$64,100	\$7,500	\$500	\$0	\$22,500	\$0	\$11,900	\$106,500
<b>FY16</b>																
						13	<b>Socio-economic Monitoring and Research</b>		\$124,900	\$12,500	\$11,100	\$0	\$171,500	\$0	\$36,900	\$356,900
				X		13.1	Economic Values of Recreational Resources Along the Colorado River – Grand Canyon Whitewater Floater and Lees Ferry Angler Values	Bair et al.	\$57,500	\$2,500	\$300	\$0	\$0	\$0	\$12,900	\$73,200
				X		13.2	Tribal Values and Perspectives of Resources Downstream of Glen Canyon Dam	Bair et al.	\$0	\$2,500	\$10,300	\$0	\$117,500	\$0	\$6,300	\$136,600
		X				13.3	Applied Decision Methods for the Glen Canyon Adaptive Management Plan	Bair et al.	\$67,400	\$7,500	\$500	\$0	\$54,000	\$0	\$17,700	\$147,100

Monitoring		Research																
Core activities	Support implementation and evaluation of HFE Protocol and Non-Native Fish Control	Technical and analytical innovations in monitoring	Improving predictive modeling capacity	Resolving scientific uncertainty	Independent science oversight and review	Integrating tribes in monitoring and research	Project identifier	Project Description	Salaries	Travel & Training	Operating Expenses	Logistics	Coop-erators (non-USGS)	USGS Coop-erators	USGS/SBSC Burden	Total		
<b>FY17</b>																		
						13	<b>Socio-economic Monitoring and Research</b>		\$127,400	\$12,500	\$1,000	\$0	\$171,500	\$0	\$43,700	\$356,100		
				X		13.1	Economic Values of Recreational Resources Along the Colorado River – Grand Canyon Whitewater Floater and Lees Ferry Angler Values	Bair et al.	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0		
				X		13.2	Tribal Values and Perspectives of Resources Downstream of Glen Canyon Dam	Bair et al.	\$0	\$5,000	\$500	\$0	\$117,500	\$0	\$5,000	\$128,000		
		X				13.3	Applied Decision Methods for the Glen Canyon Adaptive Management Plan	Bair et al.	\$127,400	\$7,500	\$500	\$0	\$54,000	\$0	\$38,700	\$228,100		