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Prepared in cooperation with the Glen Canyon Dam Adaptive Management Program

Glen Canyon Dam Adaptive Management Program Biennial Budget and Work Plan—Fiscal Years 2011–12

Prepared by

Bureau of Reclamation
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and

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Flagstaff, Arizona

TWG Review Draft

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Preface

This document was prepared by the Bureau of Reclamation's Upper Colorado Regional Office and the U.S. Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC) in cooperation with members of the Glen Canyon Dam Adaptive Management Program's Adaptive Management Work Group (AMWG) and Technical Work Group.

[to be completed later]

Grand Canyon Monitoring and Research Center
June 11, 2010
U.S. Geological Survey

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Chapter 1. Bureau of Reclamation, Upper Colorado Region Biennial Budget and Work Plan—Fiscal Years 2011–12

Introduction

The Glen Canyon Dam Adaptive Management Program (GCDAMP) is a science-based process for continually improving management practices related to the operation of Glen Canyon Dam (GCD) by emphasizing learning through monitoring, research, and experimentation. The Bureau of Reclamation's (Reclamation) Upper Colorado Region (BRUC) is responsible for administering funds for the GCDAMP and providing those funds for monitoring, research, and stakeholder involvement. The majority of program funding is derived from hydropower revenues; however, supplemental funding is provided by various Department of the Interior (DOI) agencies that receive appropriations. These agencies include Reclamation, the U.S. Geological Survey (USGS), the National Park Service (NPS), the U.S. Fish and Wildlife Service (USFWS), and the Bureau of Indian Affairs (BIA).

The budget and work plan for fiscal years (FY) 2011-12 was developed on the basis of previous budgets and work plans, the Grand Canyon Monitoring and Research Center (GCMRC) Strategic Plan, and the GCMRC Monitoring and Research Plan—all of which have been approved by the Adaptive Management Work Group (AMWG). In FY2011-12, additional consideration was given to meeting the commitments outlined in the conservation measures sections of two biological opinions issued by the USFWS: (1) the *2007 Biological Opinion for the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (known as the shortage criteria biological opinion) and (2) the *2008 Final Biological Opinion for the Operation of Glen Canyon Dam*.

The process used to arrive at the FY2011-12 budget and work plan was adopted by the AMWG in 2004 and revised in 2010 to a 2-year fixed budget. In summary, the Budget Ad Hoc Group (BAHG) of the Technical Work Group (TWG), with input from the Cultural Resources Ad Hoc Group (CRAHG), worked with the BRUC and the GCMRC to develop a proposal for the TWG. The TWG then reviews the proposed budget and work plan and develops a recommendation to the AMWG (this document).

The projected hydrograph for Lake Powell release (fig. 1) for water year (WY) 2010 is based on forecasted inflows to Lake Powell and GCD releases determined by the 1996 Record of Decision on the operation of Glen Canyon Dam, the 2007 Record of Decision on interim guidelines for coordinated operation of Lake Mead and Lake Powell, and the 2008 Finding of No Significant Impact on the environmental assessment of experimental releases for the period 2008–12. It also observes commitments made in the 2007 and 2008 biological opinions. The projected hydrograph is based on best estimates available from Reclamation's 24-month study released in June 2010; however, the forecast is subject to change as further data becomes available.

This document consists of two chapters: Chapter 1, the BRUC budget and work plan, and Chapter 2, the GCMRC budget and work plan. A comprehensive budget spreadsheet is provided in Appendix E.

A.1. Personnel Costs

General Project Description

This project represents Reclamation staff costs to perform the daily activities required to support the AMWG. The work includes completing assignments resulting from AMWG meetings, consulting with stakeholders on a variety of GCDAMP issues relating to the operation of GCD, disseminating pertinent information to the AMWG, preparing and tracking budget expenses, and updating Reclamation's Web page. Reclamation also responds to regular requests from the General Services Administration (GSA) to complete Federal Advisory Committee Act (FACA) reports and incorporate meeting and member information into the FACA database. Reclamation is now required to complete all stakeholder travel, activities that range from preparing travel authorizations to completing travel vouchers. Additionally, Upper Colorado Region staff must provide documentation related to litigation involving the Department of the Interior's operation of Glen Canyon Dam to various solicitors; these efforts often require many hours of work not programmed into the fiscal year budget(s).

Project Goals and Objectives

The primary goal is to perform all work associated with the AMWG in a timely and efficient manner, while using the funds available as prudently as possible. Secondary goals include increasing each stakeholder's awareness of significant budget and legislative issues related to the GCDAMP, improving working relationships with the AMWG members/alternates, finding constructive ways to resolve differences, and addressing individual concerns in an open and accepting forum of discussion.

Expected Results

Personnel costs will not exceed what has been proposed in the budget unless Federal employee salaries are increased above the consumer price index (CPI). Reclamation staff will provide budget information to the AMWG on a regular basis. Completed work products will be of high quality and promptly distributed to AMWG members/alternates and interested parties. Budget reports will be presented in a format conducive to AMWG needs.

Budget

FY2011 = $178,810 FY2012 = $184,175

Reclamation Project A.1. Personnel Costs—Funding History							
Activity	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	116,375	119,866	123,223	132,892	131,165	134,443	138,477
Subtotal	116,375	119,866	123,223	132,892	131,165	134,443	138,477
DOI Customer burden (33% for FY09-12)	40,043	34,762	35,735	43,855	43,284	44,367	45,698
Project total	159,418	154,628	158,958	176,747	174,449	178,810	184,175
Total outsourced (%)							

A.2. AMWG Member Travel Reimbursement

General Project Description

This project covers the costs to reimburse AMWG members or alternates to attend regularly scheduled AMWG meetings.

Project Goals and Objectives

Reimbursing AMWG members or alternates for travel expenses is done to encourage their attendance at all meetings. Many members live outside of Phoenix, Ariz., where meetings are often held. As a result, many members must incur travel costs. Having Reclamation provide reimbursement to AMWG members or alternates for air travel or mileage for the use of private vehicles, as well as other related travel costs such as hotel, per diem, and rental car increases opportunities for members to participate in a variety of AMWG assignments. Because Reclamation can purchase airline tickets at the Federal Government rate, there are additional cost savings to the program.

Expected Results

The GCDAMP benefits from having all AMWG members participating in regularly scheduled meetings. As a collective body, they address and resolve concerns associated with the operation of GCD and make recommendations to the Secretary of the Interior for continued science efforts performed below the GCD.

Budget

FY2011 = $17,671 FY2012 = $18,201

Reclamation Project A.2. AMWG Travel Reimbursement—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	15,725	16,197	16,651	17,467	17,240	17,671	18,201
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	15,725	16,197	16,651	17,467	17,240	17,671	18,201
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	15,725	16,197	16,651	17,467	17,240	17,671	18,201
Total outsourced (%)	—	—	—	—	—	—	—

A.3. Reclamation Travel

General Project Description

This project supports travel expenses Reclamation staff incur to attend AMWG and ad hoc group meetings. In order to work on AMWG/ad hoc assignments, the meetings are often held in Phoenix, Ariz. As such, Reclamation staff must make additional trips throughout the year in completion of those assignments.

Project Goals and Objectives

The primary goal is for Reclamation staff to be able to travel to meetings and participate in completing AMWG/TWG assignments. By doing so, the program benefits from greater interaction among its members as well as continued improvement and commitment to operating GCD in the best manner possible and obtaining the results from science being conducted in the study area.

Expected Results

Reclamation staff will be involved with AMWG/TWG members in completing work assignments and resolving issues that affect the GCDAMP. They will develop better working relationships with all involved and work toward consensus on a variety of sensitive issues.

Budget

FY2011 = $14,344 FY2012 = $14,774

Reclamation Project A.3. Reclamation Travel—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	13,000	13,390	13,765	14,439	13,994	14,344	14,774
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	13,000	13,390	13,765	14,178	13,994	14,344	14,774
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	13,000	13,390	13,765	14,178	13,994	14,344	14,774
Total outsourced (%)	—	—	—	—	—	—	—

A.4. Facilitation Contract

General Project Description

This project supports a facilitator who is under contract to Reclamation to provide facilitations services for AMWG meetings. This person may also assist AMWG ad hoc groups in completing assignments.

Project Goals and Objectives

The facilitator's primary responsibility is to keep the AMWG meetings organized and help the members reach consensus on important issues. The facilitator creates a setting that allows all members and the public to express their views.

Expected Results

The facilitator will create an atmosphere in which the members and other participants at AMWG meetings feel comfortable expressing their individual viewpoints. The facilitator will help bring the AMWG members to consensus on pertinent issues affecting the GCDAMP when possible.

Budget

FY2011 = $27,274 FY2012 = $28,092

Reclamation Project A.4. Facilitation Contract—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	25,000	25,000	25,700	26,959	26,609	27,274	28,092
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	25,000	25,000	25,700	26,959	26,609	27,274	28,092
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	25,000	25,000	25,700	26,959	26,609	27,274	28,092
Total outsourced (%)	—	—	—	—	—	—	—

A.5. Public Outreach

General Project Description

This project covers the expenses for Reclamation staff and the Public Outreach Ad Hoc Group (POAHG) to develop materials for the GCDAMP public outreach efforts.

Project Goals and Objectives

Reclamation public affairs staff and the POAHG will work jointly in developing materials to inform and educate the public on the goals and administration of the GCDAMP. They will keep other GCDAMP members advised of progress and expenditures.

Expected Results

Products will include fact sheets, Web site information, tribal outreach materials, video B-roll, special events, conference participation, and other pertinent means of advising the public and program members on the achievements of the GCDAMP. The POAHG will maintain accurate records of payments made against the contracts and will keep Reclamation staff informed of discrepancies or concerns.

Budget

FY2011 = $ 56,184 FY2012 = $57,870

Reclamation Project A.5. Public Outreach—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training				2,000	2,000	2,000	2,000
Operations/supplies	—	—	—	—	2,500	2,500	2,500
Reclamation salaries	50,000	51,500	41,040	38,846	36,714	37,744	39,011
Subtotal	50,000	51,500	41,040	40,846	41,214	2,244	43,511
DOI Customer burden (33% for FY09-12)			11,902	13,684	13,600	13,940	14,359
Project total	50,000	51,500	52,942	55,536	54,814	56,184	57,870
Total outsourced (%)	—	—	—	—	—	—	

A.6. Other

General Project Description

This project represents some of the other "miscellaneous" expenses incurred in operation of the AMWG, including the following expenses:

- Overnight mailings of AMWG meeting packets
- Copying of reports
- Purchasing meeting materials (cassette tapes, markers, paper, software upgrades for GCDAMP Web site posting, etc.)
- Purchasing equipment (audio recording/transcribing machines)

In addition to the expenses noted above, training courses are often required for staff to keep current on environmental issues, FACA changes, computer technology improvements, etc. Also included in this category are monetary awards given to Reclamation staff who have contributed significantly to the success of the GCDAMP.

Project Goals and Objectives

The primary goal is to limit spending on "other" items as much as possible. By doing so, more money can be applied to science and research.

Expected Results

Other expenses will be kept to a minimum in an effort to reduce the administrative portion of the GCDAMP budget.

Budget

FY2011 = $8,062 FY2012 = $8,303

Reclamation Project A.6. Other—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	5,000	5,390	5,597	5,969	5,865	6,062	6,303
Operations/supplies	2,175	2,000	2,000	2,000	2,000	2,000	2,000
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	7,175	7,390	7,597	7,969	7,865	8,062	8,303
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	7,175	7,390	7,597	7,969	7,865	8,062	8,303
Total outsourced (%)	—	—	—	—	—	—	—

B.1. Personnel Costs

General Project Description

This project represents Reclamation staff costs to perform the daily activities required to support the TWG, a subgroup of the AMWG. The work includes completing assignments resulting from TWG meetings, consulting with stakeholders on a variety of GCDAMP issues relating to the operation of GCD, disseminating pertinent information to TWG members, preparing and tracking budget expenses, and updating the Web pages Reclamation maintains for the program. Reclamation also completes all stakeholder travel activities, which range from preparing travel authorizations to completing travel vouchers.

Project Goals and Objectives

This project represents Reclamation staff costs to perform the daily activities required to support the TWG. The work includes completing assignments resulting from AMWG or TWG meetings, consulting with stakeholders on a variety of GCDAMP issues relating to the operation of GCD, disseminating pertinent information to TWG members, preparing and tracking budget expenses, and updating the Web pages Reclamation maintains for the program.

Expected Results

Personnel costs will not exceed what has been proposed in the budget unless Federal employee salaries are increased above the CPI. Reclamation staff will provide budget information to the TWG on a regular basis. Completed work products will be promptly distributed to TWG members/alternates and interested parties.

Budget

FY2011 = $87,201 FY2012 = $89,817

Reclamation Project B.1. Personnel Costs—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	53,178	54,773	56,306	64,808	63,965	65,565	67,532
Subtotal	53,178	54,773	56,306	64,808	63,965	65,565	67,532
DOI Customer burden (33% for FY09-12)	19,669	15,884	16,329	21,387	21,109	21,636	22,285
Project total	72,847	70,657	72,635	86,195	85,074	87,201	89,817
Total outsourced (%)	—	—	—	—	—	—	—

B.2. TWG Member Travel Reimbursement

General Project Description

This project provides funds to reimburse TWG members or alternates for expenses incurred to attend regularly scheduled TWG meetings.

Project Goals and Objectives

Reimbursing TWG members or alternates for travel expenses is done to encourage their attendance at all meetings. Many members live outside of Phoenix, Ariz., where meetings are often held. As a result, many members must incur travel costs. Having Reclamation provide reimbursement to TWG members or alternates for air travel or mileage for the use of private vehicles, as well as other related travel costs such as hotel, per diem, and rental car increases opportunities for members to participate in a variety of TWG assignments. Because Reclamation can purchase airline tickets at the Federal Government rate, there are additional cost savings to the program.

Expected Results

The GCDAMP will benefit from having all the TWG members participate in regularly scheduled meetings. As a collective body, TWG members address and resolve concerns associated with the operation of GCD and make recommendations to the AMWG for continued research.

Budget

FY2011 = $24,232 FY2012 = $24,959

Reclamation Project B.2. TWG Member Travel Reimbursement—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	20,836	22,211	22,833	23,952	23,641	24,232	24,959
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	20,836	22,211	22,833	23,952	23,641	24,232	24,959
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	20,836	22,211	22,833	23,952	23,641	24,232	24,959
Total outsourced (%)	—	—	—	—	—	—	—

B.3. Reclamation Travel

General Project Description

This project covers travel expenses that Reclamation staff will incur to prepare for and attend TWG meetings and ad hoc group meetings resulting from AMWG/TWG assignments. Meetings needed to advance AMWG/TWG efforts are often held in Phoenix, Ariz., because it is centrally located to those entities/States represented on the AMWG/TWG. As a result, Reclamation staff members who are not located in Phoenix are required to make additional trips throughout the year in completion of AMWG/TWG assignments.

Project Goals and Objectives

The primary goal is for Reclamation staff to be able to travel to meetings and participate in completing AMWG/TWG assignments. By doing so the program benefits from greater interaction among its members as well as continued improvement and commitment to operating GCD in the best manner possible and for obtaining the necessary results from science being conducted in the study area.

Expected Results

Reclamation staff will continue to be involved in meeting with AMWG/TWG members to complete work assignments and resolve issues that affect the operation of GCD. They will develop better working relationships with all involved and work toward consensus on a variety of GCDAMP issues.

Budget

FY2011 = $17,864 FY2012 = $18,400

Reclamation Project B.3. Reclamation Travel—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	15,898	16,375	16,834	17,658	17,428	17,864	18,400
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	15,898	16,375	16,834	17,658	17,428	17,864	18,400
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	15,898	16,375	16,834	17,658	17,428	17,864	18,400
Total outsourced (%)	—	—	—	—	—	—	—

B.4. TWG Chair Reimbursement/Facilitation

General Project Description

This project supports a person who is under contract to Reclamation to serve as the chairperson for TWG meetings. This person may also assist AMWG/TWG ad hoc groups in completing assignments. In the event that the TWG chair salary is covered through funding outside the GCDAMP, these funds can be used by Reclamation for administrative purposes or to cover professional facilitation of TWG issues.

Project Goals and Objectives

The chairperson's primary responsibility is to conduct regularly scheduled TWG meetings. The chairperson also participates in ad hoc group assignments and works closely with Reclamation and GCMRC staff in setting meeting agendas. The chairperson follows up on TWG and ad hoc group assignments and ensures that information is shared with the members and alternates in a timely manner.

Expected Results

The chairperson creates an atmosphere in which the members and other participants at TWG meetings feel comfortable expressing their individual viewpoints. The chairperson will bring the TWG members to consensus on sensitive issues with the ultimate goal of making recommendations to the AMWG that incorporate the best scientific information available to the GCDAMP. The chairperson will follow up on action items and make assignments as necessary to accomplish TWG objectives.

Budget

FY2011 = $24,305 FY2012 = $25,660

Reclamation Project B.4. TWG Chair Reimbursement—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	22,171	22,836	23,474	24,625	24,305	24,913	25,660
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	22,171	22,836	23,474	24,625	24,305	24,913	25,660
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	22,171	22,836	23,474	24,625	24,305	24,913	25,660
Total outsourced (%)	—	—	—	—	—	—	—

B.5. Other

General Project Description

This project represents some of the other "miscellaneous" expenses incurred in support of the TWG, including the following expenses:

- Overnight mailings of TWG meeting packets
- Copying of reports
- Purchasing meeting materials (cassette tapes, markers, paper, etc.)
- Purchasing equipment (audio recording/transcribing machines)

Project Goals and Objectives

The primary goal is to limit spending on "other" items as much as possible. By doing so, more money can be spent on science and research.

Expected Results

Other expenses will be kept to a minimum in an effort to keep within the GCDAMP budget.

Budget

FY2011 = $2,303 FY2012 = $2,372

Reclamation Project B.5. Other—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	2,050	2,112	2,171	2,277	2,247	2,303	2,372
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	2,050	2,112	2,171	2,277	2,247	2,303	2,372
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	2,050	2,112	2,171	2,277	2,247	2,303	2,372
Total outsourced (%)	—	—	—	—	—	—	—

C.1. Compliance Documents

General Project Description

This project covers the costs for preparing documents for GCDAMP-proposed actions required to comply with the Endangered Species Act (ESA), National Environmental Policy Act (NEPA), and National Historic Preservation Act (NHPA). In FY2010 funds not expended were carried forward and FY2011 funds will be carried forward for anticipated use in FY2012, unless the Secretary of the Interior agrees to a recommendation for a large-scale experiment.

Project Goals and Objectives

Reclamation staff will keep informed on changes to the ESA, NEPA, and NHPA and will consult with AMWG stakeholders to ensure appropriate compliance is undertaken for actions taken in support of the GCDAMP.

Expected Results

Reclamation staff will be involved in all compliance issues related to the GCDAMP, using travel expenses to meet with the GCDAMP stakeholders to resolve any differences.

Budget

FY2011 = $399.933* FY2012 = $52,101

Reclamation Project C.1. Compliance Documents—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	22,450	263,622	210,080	37,594	37,105	300.701	39,174
Subtotal			60,923	37,594	37,105	300,701	39,174
DOI Customer burden (33% for FY09-12)				12,406	12,245	99,232	12,927
Project total	22,450	263,622	271,003	50,000	49,350	399.933	52,101
Total outsourced (%)	—	—	—	—	—	—	—

*Reclamation anticipates there will be $300,000 available from Canyon Treatment Plan and implementation unexpended funds. In addition, the funds allocated for FY10 ($49,350) and FY11 ($50,583) are being included for a total of $399,933.

C.2. Administrative Support for NPS Permitting

General Project Description

This project provides funding to support the Grand Canyon National Park permitting of research and monitoring projects conducted under the GCDAMP. Grand Canyon National Park employs a permitting specialist and staff who review all proposals for projects to be completed in the park under the auspices of the GCDAMP. The program provides these funds to offset the park's administrative burden in providing these services.

Project Goals and Objectives

The primary goal is to ensure that projects conducted under the GCDAMP are reviewed and permitted by the NPS.

Expected Results

Projects conducted under the GCDAMP will receive permits from the NPS in a timely manner.

Budget

FY2011 = $120,240 FY2012 = $123,847

Reclamation Project C.2. Administrative Support for NPS Permitting—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	100,000	110,000	113,300	118,852	117,307	120,240	123,847
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	100,000	110,000	113,300	118,852	117,307	120,240	123,847
Total outsourced (%)	—	—	—	—	—	—	—

C.3. Contract Administration

General Project Description

This project covers the expenses for Reclamation staff to prepare and monitor contracts associated with the GCDAMP. Specifically, these contracts are for AMWG facilitation, TWG chairperson reimbursement, Tribal participation, Tribal resource monitoring, and programmatic agreement (PA) work.

Project Goals and Objectives

Reclamation contract specialists will accurately apply funds spent on individual contracts to ensure costs do not exceed contract limits. They will keep other Reclamation staff informed as to those charges so accurate reporting can be made to both AMWG and TWG members.

Expected Results

Contract specialists will ensure that individual contractors are fulfilling the requirements of their contracts. They will maintain accurate records of payments made against the contracts and will keep Reclamation staff informed of discrepancies or concerns. Work will be completed on time and within the limits of the contract.

Budget

FY2011 = $40,420 FY2012 = $41,632

Reclamation Project C.3. Contract Administration—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	24,394	32,413	25,830	30,040	29,650	30,391	31,302
Subtotal	24,394	32,413	25,830	30,040	29,650	30,391	31,302
DOI Customer burden (33% for FY09-12)			7,491	9,913	9,784	10,029	10,330
Project total	24,394	32,413	33,321	39,953	39,434	40,420	41,632
Total outsourced (%)	—	—	—	—	—	—	—

C.4. Experimental Carryover Funds

General Project Description

This budget item reserves funds for conducting experiments under the GCDAMP. Given previous experience, the estimated cost of large-scale experiment, or high-flow experiment (HFE), is approximately $1.5 million. This amount will be reserved over the course of several years to minimize the budgetary impacts of conducting a large-scale experiment on any individual annual budget.

Project Goals and Objectives

See above.

Expected Results

The funds will be available to conduct a large-scale experiment when conditions are appropriate.

Budget

FY2011 = $493,500 FY2012 = $21,013

Reclamation Project C.4. Experimental Carryover Funds—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—		—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	424,675	500,000	500,000	500,000	493,500	505,838	521,013
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	424,675	500,000	500,000	500,000	493,500	505,838	521,013
Total outsourced (%)	—	—	—	—	—	—	—

C.5. Integrated Tribal Resources Monitoring

General Project Description

This budget item provides funds to identify traditional cultural properties (TCPs) and implement Native American monitoring protocols that were developed in FY2007 and recommended by the TWG as part of efforts to develop a core-monitoring program.

In addition, the five GCDAMP Tribes (Hopi Tribe, Hualapai Tribe, Kaibab-Paiute Tribe, Pueblo of Zuni, Navajo Nation) will work with Reclamation and the NPS to implement monitoring of historic properties in Glen and Grand Canyons. This will be accomplished by adding an additional 3 days to the annual GCDAMP monitoring trips.

Project Goals and Objectives

The primary goal of this activity is to evaluate the effects of dam operations and other actions under the authority of the Secretary of the Interior on resources of value to Native American Tribes. A secondary goal is to conduct condition monitoring of historic properties to assist Reclamation in compliance with Section 106 of the National Historic Preservation Act.

Expected Results

Annual reports will be prepared detailing activities, findings, and monitoring data that result from implementing core-monitoring protocols for historic properties. Condition monitoring data will be provided to Reclamation to assist in prioritization of historic properties for treatment in subsequent years. In addition, monitoring data will be used to update NPS databases.

Budget

FY2011 = $144,553 (Power revenues)
FY2012 = $148,889 (Power revenues)

FY2011 = $75,000 (Appropriated fund)*

NOTE: FY10–11 $75k Appropriated Funds received in previous years were reallocated in both FY10 and FY11

*Appropriated funds for this project are unexpended Tribal funds from previous years.

Reclamation Project C.5. Integrated Tribal Resources Monitoring—Funding History							
Activity	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal (power revenues)	125,000	132,500	136,210	142,884	141,027	144,553	148,889
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Appropriated Funds	—	—	—	—	75,000	75,000	—
Project total	125,000	132,500	136,210	142,884	216,027	219,553	148,889
Total outsourced (%)	—	—	—	—	—	—	—

C.6. Nonnative Fish Suppression Contingency Fund

General Project Description

This budget item establishes a nonnative fish suppression contingency fund to ensure that funds are available for the control of nonnative fish should the need arise. Efforts to control nonnative fish, particularly warm water species that reproduce rapidly, may be required to protect native fish populations more expeditiously than can be accommodated by the standard biennial budget process. The 2008 Final Biological Opinion for the Operation of Glen Canyon Dam expressed concern about the threats posed to native fish by nonnative fish species and called for planning to address the potential threat. This fund will be incrementally increased with future carryover dollars when available. A plan of action for nonnative fish control is being developed by the GCMRC and will be used to determine when and how these funds will be used after the plan has been recommended by AMWG and accepted by the Secretary of the Interior.

Project Goals and Objectives

The goal of this budget item is to ensure that funds are available for nonnative fish control, particularly the control of rapidly reproducing warm water species that can become problematic at time scales unsuitable for addressing with the standard biennial GCDAMP process.

Expected Results

Funds will be available for nonnative fish control efforts as a contingency for addressing rapidly developing populations of problematic species.

Budget

FY2011 = $49,049 FY2012 = $50,521

Reclamation Project C.6. Non-native Fish Suppression Contingency Fund—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	—	—	—	48,483	47,853	49,049	50,521
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total	—	—	—	48,483	47,853	49,049	50,521
Total outsourced (%)	—	—	—	—	—	—	—

D.1. Programmatic Agreement: Reclamation Administrative Costs

General Project Description

This project funds the salary and travel expenses of the PA program administrator and indirect costs of PA program administration. Reclamation's regional archeologist administers the PA program and tribal contracts. The project integrates the PA and Tribal consultation into the larger GCDAMP.

Project Goals and Objectives

- Management of five tribal sole source contracts from appropriated funds for participation in the GCDAMP and management of five tribal sole source contracts from power revenues to implement Native American monitoring protocols.
- Management of the treatment plan including monitoring and data recovery of at-risk historic properties.
- Chair one PA meeting and attend TWG and AMWG meetings.

Expected Results

Compliance with the National Historic Preservation Act, Sec. 106 is the administration of the Glen and Grand Canyon treatment plans is the primary outcome of this project, which also ensures accountability for the ten tribal contracts and appropriate use of both appropriated dollars and power revenues.

Budget

FY2011 = $60,252 FY2012 = $62,060

Reclamation Project D.1. Programmatic Agreement: Reclamation Administrative Costs—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	3,000	3,000	3,000	3,000
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	54,107	71,892	57,354	42,236	41,633	42,302	43,662
Subtotal	54,107	71,892	57,354	45,236	44,633	45,302	46,662
DOI Customer burden (33% for FY09-12)	—	—	—	14,928	14,729	14,950	15,398
Project total	54,107	71,892	57,354	60,164	59,362	60,252	62,060
Total outsourced (%)	—	—	—	—	—	—	—

D.2. Canyon Treatment Plan and Implementation

General Project Description

In consultation with Grand Canyon National Park, the Arizona State Historic Preservation Office (SHPO), and the remainder of the PA signatories, Reclamation completed a scope-of-work for the development of a treatment plan for the cultural resources of Grand Canyon. A request for proposal based on this scope-of-work was issued in FY2008 and the contract was awarded to Utah State University. Four sites were targeted for data recovery in FY2008 and five were excavated in FY2009. A final report, analyses of all recovered materials and curation at the GRCA museum facility will be completed in FY10. An in-depth assessment and reorientation of this project will be undertaken in FY2011.

Project Goals and Objectives

- Compliance with the National Historic Preservation act through execution of the 1994 PA. Government-to-government consultation with Tribal councils regarding Glen and Grand Canyon resources including archeological sites, traditional cultural properties and natural resources important to the tribes.
- Completion of a historic preservation plan and research design. Collaboration with NPS archeologists in carrying out field activities.

Expected Results

This effort will result in the prioritization, based on significance, of all affected Glen and Grand Canyon properties and implementation of an MOA for treatment of adverse effects. Detailed and comprehensive reports on consultant activities, results, and recommendations will be produced. Evaluation and implementation of mitigative measures or total data recovery, following the Secretary of the Interior Standards and Guidelines for Historic Preservation and guidance of the Advisory Council on Historic Preservation, will be completed.

Budget

FY2011 = $205,838 FY2012 = $521,013

Reclamation Project D.2. Canyon Treatment Plan and Implementation—Funding History

Activity	2006	2007	2008	2009	2010*	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal			300,000	500,000	493,500	205,838	521,013
DOI Customer burden (33% for FY09-12)	—	—	—	—	—	—	—
Project total			300,000	500,000	493,500	205,838	521,013
Total outsourced (%)	—	—	—	100%	100%	100%	100%

*The FY2010 total is being negotiated based on a modified SOW. Reclamation estimates that $300,000 of the $493,500 previously in that line item will be available for expenditure toward the long term experiment and management plan EIF in FY2011, since the treatment plan is being revised to better include Native American Tribal perspective. Therefore, $300,000 is being proposed to being moved to the Compliance document line item.

E. Tribal Participation in the GCDAMP: Sole-Source Reimbursable Contracts with Tribes

General Project Description

As a result of this project, participation in GCDAMP meetings, resource monitoring, and government-to-government consultation will be accomplished in concert with the five GCDAMP Tribes (Hopi Tribe, Hualapai Tribe, Kaibab Paiute Tribe, Pueblo of Zuni, Navajo Nation) and five DOI agencies (U.S. Geological Survey, National Park Service, Reclamation, U.S. Fish and Wildlife Service, and Bureau of Indian Affairs), with Reclamation serving as lead agency.

Project Goals and Objectives

The purpose of funding of tribal contracts is to ensure tribal viewpoints are integrated into continuing GCDAMP dialogs, votes, and in the final recommendations made to the Secretary of the Interior.

Expected Results

The most important product is the incorporation of tribal perspectives into the recommendations forwarded to the Secretary. In addition, the Tribes prepare annual reports on activities funded under these contracts. Continued funding of government-to-government consultation through the agreements ensures enhanced communication and understanding of the GCDAMP issues and concerns.

Budget

FY2011 = $475,000 FY2012 = $475,000 (appropriated funds)

Reclamation Project E. Tribal Participation in the GCDAMP: Sole-Source Reimbursable Contracts with Tribes—Funding History

Activity	2006	2007	2008	2009	2010	2011	2012
Outside Reclamation science/labor	—	—	—	—	—	—	—
Logistics field support	—	—	—	—	—	—	—
Project-related travel/training	—	—	—	—	—	—	—
Operations/supplies	—	—	—	—	—	—	—
Reclamation salaries	—	—	—	—	—	—	—
Subtotal	477,375	475,000	475,000	475,000	475,000	475,000	475,000
DOI Customer burden (33% for FY0-12)							
Project total	477,375	475,000	475,000	475,000	475,000	475,000	475,000
Total outsourced (%)	100%	100%	100%	100%	100%	100%	100%

Chapter 2. U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center Biennial Budget and Work Plan—Fiscal Years 2011–12

Introduction

The Glen Canyon Dam Adaptive Management Program (GCDAMP) is a science-based process for continually improving management practices related to the operation of Glen Canyon Dam (GCD) that emphasizes learning through monitoring, research, and experimentation. The U.S. Geological Survey's (USGS) Grand Canyon Monitoring and Research Center (GCMRC) is responsible for the scientific monitoring and research of the GCDAMP. GCMRC staff worked cooperatively with GCDAMP participants and the Bureau of Reclamation (Reclamation) to develop this document, the *Glen Canyon Dam Adaptive Management Program Biennial Budget and Work Plan—Fiscal Years 2011–12* (hereafter BWP).

Purpose

This BWP describes the core-monitoring, long-term experimental, research and development, and related activities by project that will be implemented in fiscal years (FY) 2011–12 to address priority goals, questions, and information needs specified by the GCDAMP. This document also provides budget information for each project.

Overview of the GCMRC Strategic Science Plan and Monitoring and Research Plan

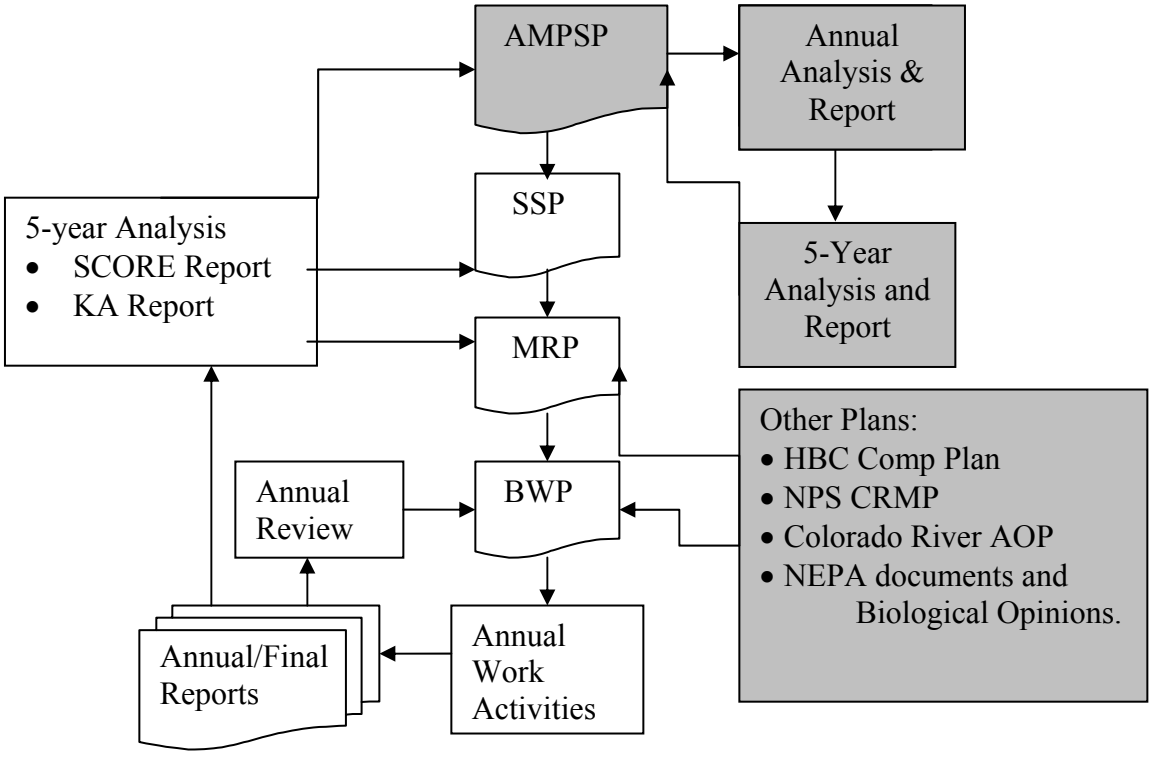
This BWP is designed to implement and be consistent with the GCMRC SSP Strategic Science Plan (SSP) and Monitoring and Research Plan (MRP) that have been approved by the AMWG and the Secretary of the Interior. The primary elements of the MRP and SSP addressed by this BWP include

- employing the adaptive environmental assessment and management approach to resources management that was developed by Holling (1978) and Walters (1986), and articulated in the Adaptive Management Program Strategic Plan (AMPSP);
- using GCDAMP priority questions and associated strategic science questions (SSQs) to provide the primary (but not exclusive) basis for designing the science program (appendix A);
- implementing an interdisciplinary, integrated river science approach to better understand the factors contributing to native fish population status and trends, and updating key elements of the Grand Canyon Ecosystem Model (GCEM) to assist in long-term experimental planning such as future high-flow experiments (HFE); and
- working collaboratively with managers and stakeholders to better integrate the use of scientific information (Figure 1) into the GCDAMP process.

In FY2011-12, the GCMRC will update the 2005 Knowledge Assessment and *State of the Colorado River Ecosystem in Grand Canyon* (SCORE) report for managers and stakeholders for planning management actions and the next phase of research and experimentation. The KA and SCORE report will provide the technical basis for updating the SSP and MRP.

Figure 1

Diagram outlining the collaborative science planning and implementation process. The Glen Canyon Dam Adaptive Management Program and the U.S. Department of the Interior have lead responsibility for the shaded boxes. The USGS Grand Canyon Monitoring and Research Center has lead responsibility for the boxes that are not shaded.



Overview of Biennial Work Plan and Budget

In April 2009, the Adaptive Management Work Group (AMWG), the Federal Advisory Committee that facilitates the GCDAMP, recommended approval of amendments to the SSP and MRP—the documents that are the basis of this BWP—that reflect the requirements of two biological opinions prepared by the U.S. Fish and Wildlife Service (USFWS). As a result, projects presented in this work plan incorporate requirements of the *2007 Final Biological Opinion for the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (known as biological opinion for shortage criteria) and the *2008 Final Biological Opinion for the Operation of Glen Canyon Dam*.

Additionally, GCMRC staff members discussed FY2011–12 budget priorities with the Budget Ad Hoc Work Group (BAHG), the Technical Work Group (TWG), and the AMWG. The results of those discussions were considered in the development of this BWP.

This BWP assumes that the FY2011-12 hydrograph will consist of modified low fluctuating flow (MLFF) operations, including experimental steady flows in October 2010/110 and September 2011/2012.

The BWP provides for the evaluation of a potential high flow experiment (HFE) in FY20110 and/or FY20121. Currently, the Bureau of Reclamation is preparing and Environmental Assessment (EA) for a HFE Protocol that will specify the conditions under which future HFE's will be conducted. The BWP provides for the scientific evaluation of the effects of future HFE's primarily through reliance on existing resource monitoring programs for native fishes, Lee's ferry trout, riparian vegetation, sediment storage, sand bars, camping beaches, archaeological sites, and hydropower. The monitoring and research activities conducted in support of the HFE protocol may be revised based on (a) the results of the HFE Protocol EA, and (b) the results of the synthesis of the scientific findings for HFEs conducted in 1996, 2004, and 2008 that will be completed by USGS by December 31, 2010.

This BWP includes several new and expanded projects as well as the continued implementation of a number of ongoing projects included in the approved *Glen Canyon Adaptive Management Program Biennial Budget and Work Plan—Fiscal Year 2010-11*. Funding for ongoing projects was adjusted to reflect cost of living increases, increased salary costs, logistical support, past performance, etc. The FY2011 budget assumed a 2.5 percent increase in funding based on the consumer price index (CPI) and a 3 percent CPI increase from FY2011 to FY2011. The proposed budget addresses all of the conservation measures included in the 2007 and 2008 USFWS biological opinions that are within the purview of the GCMRC (see appendix C for a summary of the conservation measures). Addressing conservation measures was accomplished, in part, with additional appropriations from Reclamation for the Near Shore Ecology Study.

Table 1 summarizes the project and activities that are include in the BWP, including changes that were included in the approved FY 2010-11 BWP.

Two major new projects are included in the BWP:

A new initiative to investigate trout movement below Lees Ferry and the feasibility or effectiveness of alternatives approaches for reducing the impacts of rainbow trout on the humpback chub population in the Little Colorado Reach of the Colorado River.

The aquatic food base, Lees Ferry trout, and sediment monitoring programs were enhanced to facilitate the scientific evaluation of future HFE's on these resources. In addition, a new monitoring effort is recommended to assess how Lee Ferry angler satisfaction is affected by HFE's and other experimental activities.

To achieve a balanced budget, a number of ongoing projects had to be scaled back to accommodate new projects described above and non-discretionary cost increases for continuing projects. In addition, based on direction from DOI and recommendations for the AMWG, approximately $ 617,000 was moved from the USGS budget to the Bureau of Reclamation budget (Chapter1) to increase funding available for nonnative fish suppression and the development of a Long Term Experimental and Management Plan EIS. This shift in funds was accomplished by reducing funding for the following project:

Aquatic food base monitoring
Mainstem fish monitoring
Science support for nonnative fish management
Native fish stock assessment
Science advisor support
GCMRC program management

Table 1

GCMRC FY11-12 Project Summaries

Project	FY11 Summary	FY12 Summary
1. Food Base		
Aquatic Food base monitoring	Focus on completion of research, reports, PEP review, and development of core monitoring plan; Monthly drift and benthos monitoring at Lees Ferry and Diamond Creek only	Monthly drift and benthos monitoring at Lees Ferry and Diamond Creek only, Implementation of core monitoring plan subject to approval
2. Native Fishes		
LCR Monitoring	Repeat FY10 monitoring, revise based on analysis of PEP recommendations;	Repeat FY10 monitoring, revise based on analysis of PEP recommendations;
Mainstem Monitoring	Mainstem monitoring reduced from 4 to 2 trips (to support nonnative control work by BOR)	Mainstem monitoring restored to 4 trips
HBC Translocation & Monitoring	Monitor HBC status and translocate fish above Chute Falls; include funding for GCMRC oversight	Monitor HBC status and translocate fish above Chute Falls; include funding for GCMRC oversight
Stock Assessment of Native Fish	Continued analysis of fish stock data at reduced level; Complete & publish. ASMR estimate humpback chub adult population	Continued analysis of fish stock data at reduced level; No ASMR
Remote PIT Tag Reading	Operate & maintain equipment and analyze data with graduate student and advisor; Defer expansion of the system	Operate & maintain equipment and analyze data with graduate student and advisor; Defer expansion of the system
Near Shore Ecology	Implement project per work plan; Increase logistics funding	Implement project per work plan; Field work ends in October, 2011; (FY12) Increase logistics funding for October river trip; prepare final report
Mainstem Nonnative Fish Control	Deleted from GCMRC budget; $600K identified in BOR budget to determine scope of work, if any	Deleted from GCMRC budget; $300K identified in BOR budget to determine scope of work, if any
Nonnative Control Plan Science Support	Monitor and synthesize nonnative capture data in Open File Report and conduct 2011 nonnative workshop	Monitor and synthesize nonnative capture data in Open File Report and conduct 2011 nonnative workshop
NEW Evaluation of Trout Movement, Natal Origins and Alternatives for Controlling Rainbow Trout Populations	Investigate RBT movement patterns between Paria R. and Badger Rapid.	Investigate RBT movement patterns between Paria R. and Badger Rapid
Biometrics & General Analysis (Vice Coggins)	ASMR, ecosystem modeling, and biometric support	ASMR, ecosystems modeling, and biometric support

Project	FY11 Summary	FY12 Summary
3. Extirpated Species		
	No funded projects; GCMRC will participate in extirpated species ad hoc group and razorback workgroup	No funded projects; GCMRC will participate in extirpated species ad hoc group and razorback workgroup
4. Rainbow Trout		
	Continue monitoring of fish community in Lees Ferry reach including YOY, juvenile and adult RBT monitoring	Continue monitoring of fish community in Lees Ferry reach including YOY, juvenile and adult RBT monitoring
5. Kanab Ambersnail		
	Continue annual monitoring	Continue annual monitoring
6. Springs / Riparian		
	Implement vegetation transect monitoring (assumes approval of core monitoring plan); Analyze 2009 imagery for vegetation change	Analyze 2009 imagery and prepare report; Defer bird and/or arthropod monitoring
7. Quality of Water		
Lake Powell & Tailwaters	Continue monitoring; PEP review; Increase emphasis on analysis and modeling	Continue monitoring; Prepare core monitoring plan; Implementation of core monitoring plan subject to approval Increase emphasis on analysis and modeling
Downstream	Continue monitoring flow, temperature and sediment, etc.; PEP review of water quality component	Prepare core monitoring plan; Implementation of core monitoring plan subject to approval Continue monitoring flow, temperature and sediment, etc.;
Modeling support	Operate & maintain models; no new model development	Operate & maintain models; no new model development
8. Sediment		
	Conduct SedTrend core monitoring. Monitor sandbar study sites. Report on 2009 SedTrend monitoring and 2009 remote sensing for sandbar area.	Conduct SedTrend core monitoring. Report on 2011 SedTrend monitoring.
9. Recreation		
Grand Canyon	Conduct biennial campsite monitoring; Continue river guide monitoring; Analyze campsite atlas data as part of integrated image analysis project; Update & maintain campsite atlas on website	Camp area field monitoring does not resume until FY13; Continue river guide monitoring; Analyze campsite atlas data as part of integrated image analysis project; Update & maintain campsite atlas on website; Campsite PEP review
Glen Canyon	New Project: Evaluate visitor use values and satisfaction in the Lees Ferry Reach (HFE Experimental funds). Assumes matching funds / shared costs with AZGFD	Year 2: Evaluate visitor values and satisfaction in the Lees Ferry Reach (HFE Experimental funds). Assumes matching funds / shared costs with AZGFD

Project	FY11 Summary	FY12 Summary
10. Hydropower		
	New Project: Evaluate GTmax model as a tool for assessing economic costs to hydropower in the context of the western electrical grid. Prepare report. Serve data via website; Annual report	Use model to assess economic costs to hydropower from alternative flow regimes; Prepare report. Serve data via website; Annual report
11. Cultural		
	Implement pilot monitoring with reduced scope (fewer sites, etc), which may extend length of project	Implement pilot monitoring with reduced scope (fewer sites, etc), which may extend length of project
12. DASA		
Overflights	Contribute $116k to overflight fund	Contribute $84k to overflight fund
Oracle Database	Update & maintain Oracle database, develop custom data management applications, provide data modeling, data mining, and architecture support	Update & maintain Oracle database, develop custom data management applications, provide data modeling, data mining, and architecture support
Library Operations / Scanning	Maintain GCMRC library reduced to ½ time position; Defer online library system	Maintain GCMRC library reduced to ½ time position; Defer online library system
GIS Support	Provide spatial database and analysis support to GCMRC projects; continue supporting all mapping functions, and expand on spatial web applications	Provide spatial database and analysis support to GCMRC projects; continue supporting all mapping functions, and expand on spatial web applications
Integrated Image Analysis & Change Detection	Coordinate analysis of 2009 imagery; Map & analyze sandbars, campsites, backwaters & vegetation	Final reporting of 2009 imagery; Plan for 2013 overflight
12. Planning		
Ecosystem Modeling	Working with senior ecologist, continue to update & refine ecosystem models, focusing on aquatic resources; including development of news Lees Ferry rainbow trout production model; Defer LCR [downstream ecopath w/ ecosim] model expansion, publication of results, & MATA workshop	Working with senior ecologist, continue to update & refine ecosystem models, focusing on aquatic resources; complete Lees Ferry rainbow trout production model; Defer LCR [downstream ecopath w/ ecosim] model expansion, publication of results, & MATA workshop
Knowledge Assessment & SCORE Report	Complete KA & initiate S.C.O.R.E. report; use results of KA to support ongoing efforts to develop Desired Future Conditions, as requested	Finalize S.C.O.R.E. report; use results of KA to support ongoing efforts to develop Desired Future Conditions, as requested
HFE Protocol Science	Evaluate HFE protocol implementation using existing and expanded monitoring projects. Open file report prepared after each HFE	Evaluate HFE protocol implementation using existing and expanded monitoring projects. Open file report prepared after each HFE
12. Support		
Logistics Base	Provide base logistics support to field operations	Provide base logistics support to field operations

Project	FY11 Summary	FY12 Summary
Survey & Control Network	Provide survey support to GCMRC projects (through contract); Maintain & expand network as needed	Provide survey support to GCMRC projects (through contract); Maintain & expand network as needed
12. Administrative		
Operations	Continue to provide administrative support	Continue to provide administrative support
Program Planning & Management	Continue to provide planning & management support	Continue to provide planning & management support
AMWG/TWG Travel	Continue to provide funding to attend AMWG & TWG meetings	Continue to provide funding to attend AMWG & TWG meetings
Independent Reviews	Peer review all publications; Integrated Water Quality and Food Base PEP	Peer review all publications; Campsite & Sediment PEPs
Science Advisors	Reduce SA support by 25%	Continue SA support at reduce level
Computer Systems Support	Maintain IT support for GCMRC	Maintain IT support for GCMRC
Synthesis of High Flow Experiment	Complete HFE synthesis by 01/01/11	

FY2011–12 Funding Sources

A summary of anticipated GCMRC support in FY2011 and FY2012 by funding source is provided in tables 2 and 3, respectively and summarized below.

- Lake Powell water-quality monitoring ($182,002 in FY2011 and $188,063 in FY2011)—Power revenue funding received under a separate interagency agreement from Reclamation to monitor water quality in Lake Powell.
- Nearshore fish ecology ($697,039 in FY2011 and $423,475 in FY 2012)—Appropriated funds received from Reclamation under a separate agreement to conduct research on the nearshore ecosystem.
- GCDAMP power revenues ($7,797,725 in FY2011 and $7,948,282 in FY2012)—GCDAMP power revenues are capped by Congress and adjusted annually based on the CPI. For the purposes of this budget, the CPI is estimated at 2.5 percent in FY2011 and 3 percent in FY2012. The budget will be adjusted in fall 2011 and 2012 to reflect the actual CPI for FY2011 and 2012 respectively.
- Experimental funds—$617,673 in FY2011 and $731,770 in FY2012
- USGS appropriations (approximately $1,000,000 annually)—These funds are used to provide a reduced USGS overhead rate for the GCDAMP. Overhead rates vary annually. With the approximately $1,000,000 in support appropriations, the GCMRC is able to maintain the Department of Interior (DOI) customer rate of 15 percent plus facilities for science activities in the GCDAMP agreement. In FY2011–12, the DOI customer rate is estimated to be 21percent.
- Non science activities (management actions and compliance activities) will be assess the full USGS overhead rate in FY 2011and 2012.

Table 2

Total anticipated funding to support the U.S. Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC) in fiscal year (FY) 2011.

Funding source	Agreement title	Type of funds	Estimated FY2010 carry forward funds	FY2011 Funds	Gross funding total	Percent of FY2011 GCMRC budget	Notes
Bureau of Reclamation (Reclamation)	Lake Powell water quality	Power revenues not under cap	$0	$ 182,002	$ 182,002	1.77%	
Reclamation	Nearshore fish ecology	Appropriated funds	$0	$ 697,039	$ 697,039	6.78%	
Reclamation	Glen Canyon Dam Adaptive Mgmt Program	Power revenues under cap (GCDAMP)	$0	$ 7,797,725	$ 7,797,725	75.74%	
Reclamation	Glen Canyon Dam Adaptive Management Program	Experimental Funds held by Reclamation	$0	$ 617,673	$ 617,673	6.00%	Supplement FY2011 project funding
Subtotal of funding received from Reclamation			$0	$ 9,294,439	$ 9.294,439		
USGS Headquarters	Cost-share burden assistance	USGS appropriated funds for cost-share use for GCMRC annual work plan	$0	$ 1,000,000	$ 1,000,000	9.71%	
Total of estimated funding to be received for FY2011			$0	$ 10,294,439	$ 10,294,439	100.00%	

Table 3

Total anticipated funding to support the U.S. Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC) in fiscal year (FY) 2012.

Funding source	Agreement title	Type of funds	Estimated FY2011 carry forward funds	FY2012 Funds	Gross funding total	Percent of FY2012 GCMRC budget	Notes
Bureau of Reclamation (Reclamation)	Lake Powell water quality	Power revenues not under cap	$0	$ 188,063	$188,063	1.83%	
Reclamation	Nearshore fish ecology	Appropriated funds	$0	$ 423,475	$423,475	4.12%	
Reclamation	Glen Canyon Dam Adaptive Mgmt Program	Power revenues under cap (GCDAMP)	$0	$ 7,948,282	$7,948,282	77.22%	
Reclamation	Glen Canyon Dam Adaptive Management Program	Experimental Funds held by Reclamation	$0	$ 731,770	$731,770	7.11%	Supplement FY2012 project funding
Subtotal of funding received from Reclamation	$0	$ 9,291,590	$9,291,590				
USGS Headquarters	Cost-share burden assistance	USGS appropriated funds for cost-share use for GCMRC annual work plan	$0	$ 1,000,000	$1,000,000	9.72%	
Total of estimated funding to be received for FY2012	$0	$ 10,291,590	$ 10,291,590	100.00%			

Figure 2 summarizes the GCMRC's FY2010, FY2011, and FY2012 budgets by GCDAMP goal. A breakout of the projects included as part of goal 12 is summarized in Figure 3. The budget for each project in the work plan is included in the project descriptions and summarized for the entire budget in the separate budget attachment.

Figure 2

Bar chart showing a comparison of Grand Canyon Monitoring and Research Center (GCMRC) fiscal year FY2009 approved budget, FY2010 approved budget revised with <-1.3> CPI and FY2011 and FY2012 budget by Glen Canyon Dam Adaptive Management Program (GCDAMP) Goal.

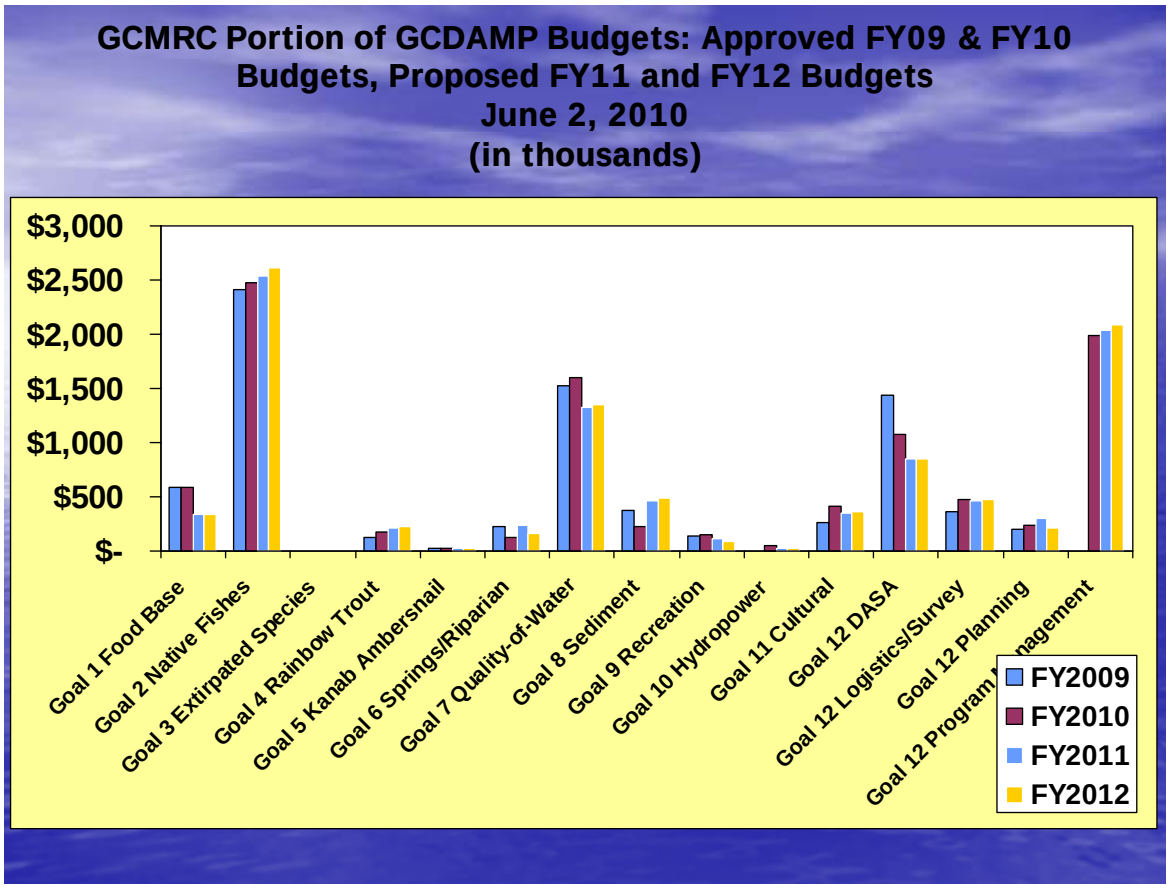
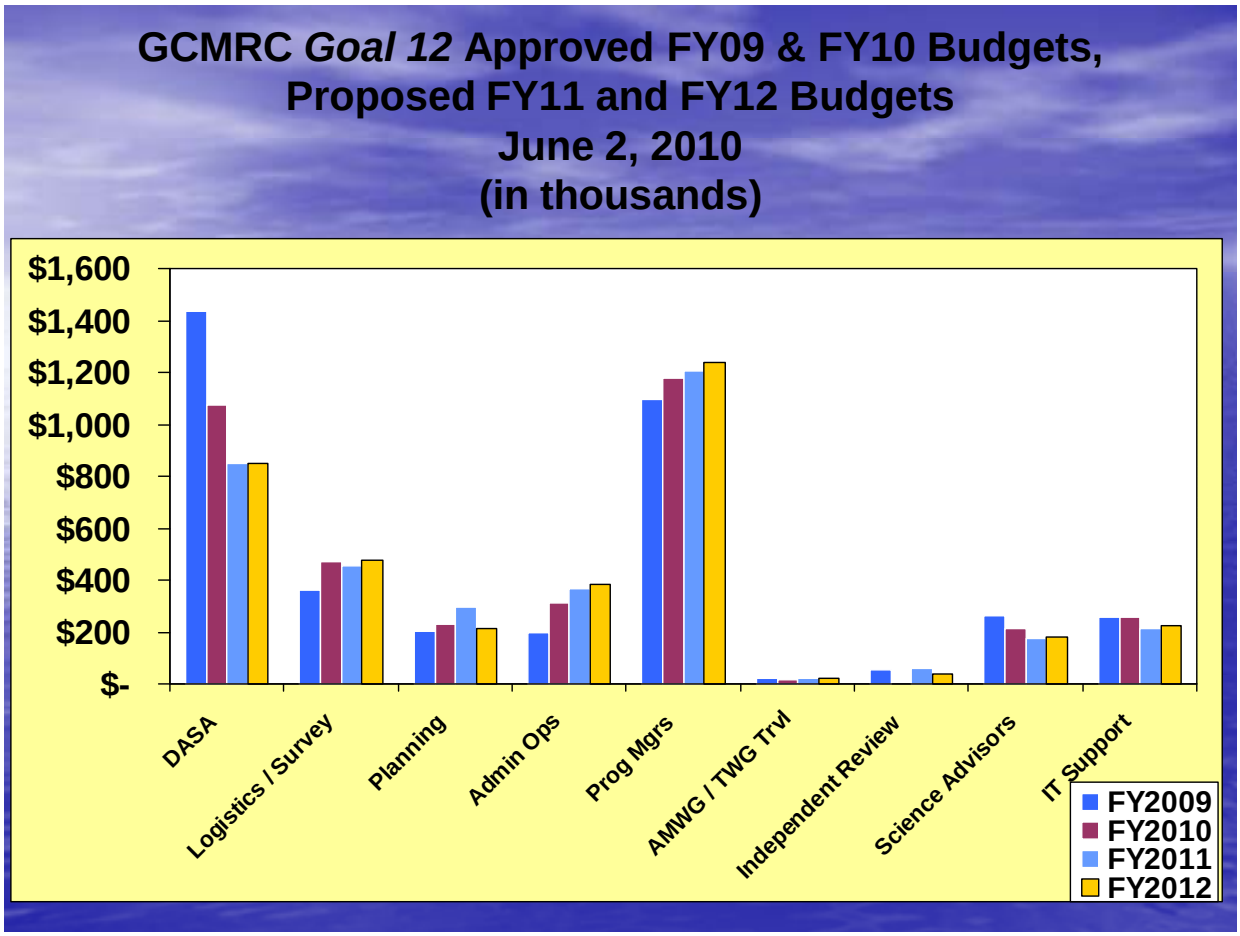


Figure 3

Bar chart comparing the Grand Canyon Monitoring and Research Center (GCMRC) fiscal year FY2009 approved budget, FY2010 approved budget revised with <-1.3> CPI and FY2011 and FY2012 budgets for Glen Canyon Dam Adaptive Management Program (GCDAMP) efforts by project for goal 12.



Annual Reporting

Annual reports for projects included in this BWP will be completed by December 15, 2011 and 2012. The reports will summarize the work accomplished, project shortfalls, and recommendations for additional studies or project modifications. The GCMRC will host a meeting in mid-January 2011and 2012 for GCDAMP stakeholders to review the annual reports and discuss their implications for the next BWP.

Project Descriptions

Detailed descriptions of each project included in the FY2011–12 BWP are provided in the following section. Activities are presented based on the GCDAMP goal they are designed to address. Activities included in the BWP will be carried out in an integrated, interdisciplinary fashion. Integration efforts are described as an element of each project description.

Since its inception, the GCDAMP has attempted to ensure appropriate science program continuity and balance across all goals adopted by the program. The current focus of the GCDAMP is on monitoring resource status and trends, answering SSQs associated with high-priority AMWG information needs and on meeting the conservation measures included in the 2007 and 2008 USFWS biological opinions. Other GCDAMP goals will still be pursued but with less intensity until priority issues of concern are resolved and monies can be reprogrammed or obtained through alternative sources. This includes at least one activity to address each GCDAMP goal.

GCDAMP Goal 1—Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels

BIO 1.R1.10 – Aquatic Food Base

BIO 1.R4.10 – Impacts of Various Flow Regimes on the Aquatic Food Base

BIO 1.M1.11, 12—Aquatic Food Base Monitoring

Start Date

October 2010

End Date

BIO 1.R1.10 and BIO 1.R4.10 end in September 2010, with BIO 1.M1.11 ongoing beginning in October 2010

Principal Investigators

Theodore Kennedy, U.S. Geological Survey, Grand Canyon Monitoring and Research Center; Robert Hall, University of Wyoming; Emma Rosi-Marshall, Cary Institute of Ecosystem Studies; and Colden Baxter, Idaho State University

Geographic Scope

Colorado River below from Lees Ferry at Ferry at river mile (RM) 0 and Diamond Creek, Ariz., about RM 225

Project Goals

The overall goal of food base research (BIO 1.R1.10 and BIO 1.R4.10) was to determine the role that food plays in the distribution, condition, and abundance of fish throughout the Colorado River in Grand Canyon. Quantifying the density and production of basal resources (that is, algae, terrestrial leaf litter, etc.) and invertebrates determines the amount of energy that is available to support fish production. Trophic basis of production calculations, where the types and amounts of different food items eaten by invertebrates and fish are quantified, determines the relative contribution of basal resources, invertebrates, and other food items to fish production. The results of this work will establish the degree to which native fish are limited by food resources, by either low production at the base of the food web or via shunting of energy to nonnative animals such as New Zealand mudsnails or rainbow trout. This information, in turn, provides guidance to managers considering various management options.

The overall goal of the aquatic food base monitoring (BIO 1.M1.11) is to determine whether dam operations or experimental flow regimes affect food resources for fish. In FY11 we will complete analysis of food base research results and, based on these findings, implement food base monitoring that is informed by the findings of food base research. The goal of monitoring will be to estimate algae and invertebrate production and drift at two accessible sites along the Colorado River. Algae and invertebrates are both high quality food items that are consumed by fish throughout the system. Estimating production of these two key food resources will provide a quantitative estimate of the amount of food that is available to support fish growth. These methods were employed during food base research efforts and were able to detect statistically significant changes in production due to the March 2008 controlled flood. Thus, these metrics are sensitive enough to determine the net effect (that is, increase or decrease in available food) of management actions and experimental flow regimes, e.g., any future high flow experiments, on available food for aquatic organisms.

The specific objectives addressed by this project include:

- Estimate algae production continuously at Lees Ferry and Diamond Creek using open-system metabolism methods developed by the food base research project
- Make monthly estimates of algae and organic matter biomass at Lees Ferry and Diamond Creek
- Estimate annual invertebrate production at Lees Ferry and Diamond Creek using monthly invertebrate collections
- Estimate invertebrate and organic drift at Lees Ferry and Diamond Creek

Specific goals for FY20111 include:

- Produce a final report and peer-reviewed publications that summarize food base research project findings
- Implement monitoring protocols at Lees Ferry and Diamond Creek in October 2010
- Participate in joint water quality and food base Protocol Evaluation Panel (PEP) in Summer 2011
-

Specific goals for FY2012 include:

- Produce a core monitoring report based on the recommendations of the PEP
- Continue monitoring at Lees Ferry and Diamond Creek with potential to modify monitoring based on PEP

Need for Project

Monitoring ecosystem properties such as algae and invertebrate production and invertebrate drift is critical to understanding mechanisms underlying the response of fish populations to dam operations. For example, rainbow trout monitoring in Lees Ferry conclusively demonstrated that survival and growth of juvenile rainbow trout increased in response to the March 2008 high flow experiment (HFE), which in turn led to a substantial increase in rainbow trout populations. But with the rainbow trout monitoring data alone it was impossible to say *why* the HFE had led to substantially higher growth, survival, and numbers — was it due to improvements in habitat quality, food resources, or some other factor? Data from the foodbase research project provided the missing link—the HFE had caused a shift in the

invertebrate assemblage towards higher quality taxa (fewer New Zealand mudsnails and more midges and blackflies) that were more prone to drifting than the taxa they replaced. Thus, even though total invertebrate biomass and production in Lees Ferry decreased following the HFE, the amount of invertebrates available to fish in the drift actually increased by a factor of two and it was this increase in drifting food resources that allowed for substantially higher rainbow trout growth and survival. Thus, food base monitoring complements fish monitoring, and together these projects provide a comprehensive picture of how the aquatic ecosystem is affected by dam operations and experimental flow regimes. The monitoring program described in this project will provide baseline data in years without a HFE, and will provide the necessary monitoring to assess aquatic food base changes, if any, during years that include a HFE.

Strategic Science Questions

Primary SSQ addressed:

SSQ 3-5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?

Information Needs Addressed

CMIN 1.1.1. Determine and track the composition and biomass of primary producers below Glen Canyon Dam in conjunction with measurements of flow, nutrients, water temperature, and light regime.

CMIN 1.2.1. Determine and track the composition and biomass of benthic invertebrates below Glen Canyon Dam in conjunction with measurements of flow, nutrients, water temperature, and light regime.

CMIN 1.5.1. Determine and track the composition and biomass of drift in the Colorado River in conjunction with measurements of flow, nutrients, water temperature, and light regime.

Methods and Tasks

In October 2010 we will launch the food base monitoring project with monthly sampling at Lees Ferry and Diamond Creek. Parameters sampled will include algae production, benthic organic matter, drifting organic matter, and invertebrates.

In FY2011 we will collect quantitative samples of benthic invertebrates monthly at Lees Ferry and monthly at Diamond Creek. Daily estimates of algae production will be made based on dissolved oxygen data that is being collected at both locations with continuously logging water quality monitors. Invertebrate drift will be collected at Lees Ferry at the same time that benthic samples are collected. Primary production and ecosystem respiration will be quantified using whole-stream metabolism calculations. With this procedure, continuous measurements of dissolved oxygen are used to make estimates of algae production for an entire reach of river (that is, a section of river several miles long). Nighttime sags in dissolved oxygen concentration in the Lees Ferry reach will be used to determine ecosystem respiration, a measure of total resource consumption. If the quantity of carbon consumed through respiration exceeds the quantity of carbon produced through algal photosynthesis, this indicates detrital (non-living) resources may be fueling the aquatic food web. It is not possible to estimate ecosystem respiration along downstream segments because dissolved oxygen is always above saturation due to high rates of air-water gas exchange in rapids. Nevertheless, diel peaks in dissolved oxygen can still be used to estimate rates of algae production. YSI water quality monitors deployed in the Lees Ferry

reach and near Diamond Creek record dissolved oxygen concentrations. Data are being collected every 5 minutes and will allow daily estimates to be made of algae production and ecosystem respiration. Instruments will be downloaded and recalibrated monthly. Twenty samples will be collected at each location (Lees Ferry and Diamond Creek) across a range of habitat types (depositional environments, cobble, cliff, talus). Organic matter and chlorophyll content of each sample will be determined and will complement the algae production measurements.

Benthic invertebrate samples will be collected from the same locations as drift samples using similar collection techniques. In the lab, organisms will be counted and measured to the nearest millimeter and length—mass regressions will be used to estimate biomass. These data will be used to estimate annual invertebrate production for Lees Ferry and Diamond Creek.

Invertebrates that are drifting are more vulnerable to consumption by fish than benthic invertebrates, so drifting invertebrate samples will also be collected from both locations to determine concentrations of drift. Ten-to-fifteen such samples will be collected each month and processed as above for organic content and invertebrate biomass. Samples will be collected across a range of discharges, including high flow experiments, should they be conducted.

Links/Relationships to Other Projects

Physical Sciences

The Diamond Creek area is a fine-grained integrated sediment transport (FIST) and integrated water-quality (IWQ) monitoring site. Algae and invertebrate production estimates will be compared with sediment transport and water-quality data to determine the relationship between these key physical drivers and food production. The temperature model that is being developed by the Physical Science and Modeling Program will be a valuable tool for estimating system wide growth rates of algae and invertebrates because temperature is an important determinant of algae and invertebrate growth rates.

Fisheries

Data on algae and invertebrate production can be used to support interpretation of the trends in fish abundance or composition.

Logistics

Monthly sampling will be conducted at Lees Ferry and Diamond Creek.

Products/Reports

Publications

At least seven publications in peer-reviewed journals will be produced as a result of food base research projects. Tentative subjects for these publications include:

- Measuring air-water gas exchange and whole-system metabolism in a large, regulated river (proof-of-concept paper)
- Assessing the seasonal and spatial variation in organic matter inputs to the Colorado River, Grand Canyon (synthesis paper of metabolism, allochthonous inputs, lake inputs, tributary inputs, etc.)

- Determining spatial variation of secondary production of invertebrates in the Colorado River
- Analyzing the spatial variation in the relative importance of basal resources to invertebrate and fish production in the Colorado River
- Linking whole-river carbon flows with food webs in the Colorado River
- Determining impacts of New Zealand mudsnails on invertebrate production in the Colorado River (in press), and
- Effects of dam operations on rates of invertebrate drift

Reports

The following reports will be produced as a result of these projects:

- Brief trip reports are completed and submitted to Grand Canyon National Park shortly after each trip to comply with permitting requirements

A draft final report summarizing major results and recommendations will be submitted by June 2011

- Annual progress report will be submitted by December 31 of each year
- A core-monitoring report will be produced by January 2012

Budget

FY2011 $343,744

FY2012 $332,692

GCDAMP Goal 2—Maintain or attain viable populations of existing native fish, remove jeopardy from humpback chub and razorback sucker, and prevent adverse modification to their critical habitat.

BIO 2.R1.10—Little Colorado River Humpback Chub Monitoring Lower 13.6 km (Population Estimates)

BIO 2.R2.10—Little Colorado River Humpback Chub Monitoring Lower 1,200 m

BIO 2.M1.11, 12—Little Colorado River Humpback Chub Monitoring

Start Date

2011

End Date

Ongoing

Principal Investigators

D.R. Van Haverbeke, U.S. Fish and Wildlife Service and W. Stewart, Arizona Game and Fish Department

Geographic Scope

Little Colorado River up to 13.6 km upstream from the confluence with the Colorado River

Project Goals

This project seeks to continue monitoring of humpback chub *Gila cypha* in their primary spawning tributary in Grand Canyon, the Little Colorado River (LCR) using five monitoring trips in FY2011. If a review of the data confirms the recommendation of the 2009 Protocol Evaluation Panel for Grand Canyon fishes (PEP) to make protocol changes, a modified plan will be developed for Fall 2011 or Spring 2012 sampling with the continued goal of implementing an ongoing core monitoring of humpback chub in the LCR.

The specific objectives this project addresses include:

Providing an annual assessment of the humpback chub population in the LCR by collecting mark-recapture data and making closed population estimates of humpback chub in the lower 13.6 km of the LCR

Collecting and reporting biological data for native and nonnative fishes including recording PIT tag numbers in tagged fish, length-frequency data, community composition, sexual condition and characteristics of fish (gender, ripeness, tuberculate, etc.), and frequency of external parasites (primarily *Lernaea cyprinacea*)

Collecting other pertinent information related to physical parameters of the LCR, especially temperature and turbidity, and

Determining the critical physical and biotic factors that may be limiting to, or supportive of, the humpback chub and other native fish populations in Grand Canyon so as to develop strategies that reduce, eliminate, or control limiting factors

Need for Project

The endangered status of humpback chub makes the species a resource of concern for the GCDAMP and natural resource managers. The data collected by this project has been essential to modeling the Grand Canyon population of humpback chub (Coggins and Walters, 2009). Monitoring of the Grand Canyon humpback chub population is also critical to meeting the important, ongoing need for status and trends information for this endangered fish. Because most humpback chub in Grand Canyon are found either in or near the LCR (Paukert and others, 2006), monitoring in the LCR is an efficient way to gather data on the population.

Since 2000, the research efforts of this project have included an annual spring and fall mark-recapture effort and annual monitoring in the lower 1,200 m of the LCR. The 2009 PEP noted that the spring sampling of humpback chub in the LCR is one of the most important fish monitoring projects that the GCMRC and its cooperators conduct on behalf of the GCDAMP and recommended that it continue in the future. While the PEP recognized that much good humpback chub information had been generated by the fall monitoring effort and monitoring the lower 1,200 m during the spring, the PEP did not identify these projects as critical to a core-monitoring effort. The PEP did observe, however, that these two projects might have other benefits, including occasional increased tagging efforts, in the future. The PEP did recommend that elements of monitoring conducted in the lower 1,200 m of the LCR—such as sampling protocol, gear types, and analysis—were suitable for continuation. The PEP recommended a thorough analysis of impacts of sampling protocol changes on Age-Structured Mark-Recapture (ASMR) model output and of our ability to assess accurately the status and trends of the entire LCR fish community. That analysis is ongoing, and is expected to be completed in late 2010.

The established program of five LCR monitoring trips will be continued in FY2011 to allow sufficient time to determine the ramifications of possible protocol changes on monitoring and modeling. The evaluation of proposed changes is being conducted in FY2010, and a meeting of the cooperating agencies and interested GCDAMP parties will be convened after completion of the data analyses to discuss results. This meeting will help identify the specific monitoring objectives, techniques, and analyses to support core monitoring.

Strategic Science Questions

Primary SSQ addressed:

SSQ 1-1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year (YoY) and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

Additional science question addressed by these projects:

SSQ 1-2. Does a decrease in the abundance of rainbow trout and other cold- and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population?

GCDAMP Science Advisors (SAs) have summarized the SSQs with the following question (the projects outlined here specifically address this question, especially their evaluation of annual spawning success):

SA 1. What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

Information Needs Addressed

Primary information needs addressed:

CMIN 2.1.2. Determine and track recruitment (identify life stage), abundance, and distribution of humpback chub in the LCR.

Methods and Tasks

Annual Spring Humpback Chub Abundance Assessments in the Lower 13.6 km of the Little Colorado River (FY 2011)

In the spring, two mark-recapture trips (10 days) are conducted annually in the lower 13.6 km of the LCR to generate a closed population estimate of humpback chub (>100 mm total length). This program has been ongoing since 2000 using passive integrated transponder (PIT) tags. Additionally, this sampling effort provides much of the data for the ASMR stock assessment model, an open population model.

During each LCR trip, three camps are used: Salt Canyon, Coyote Canyon, and Boulders Camps. Unbaited hoop nets (0.5–0.6 m diameter, 1.0-m length, 6-mm mesh, single 10-cm throat) are set from shorelines to capture and PIT tag humpback chub as part of a mark-recapture program. Each camp is responsible for fishing hoop nets throughout an approximately 5-km reach from 0 to 13.6 km. Sixty hoop nets spaced 80 to 150 m apart are fished throughout the reach. Each hoop net is positioned in habitat suspected to yield good catches of humpback chub. Nets are repositioned as needed. On average, each hoop net is checked once every 24 hours. Each reach is divided into three sub-reaches and nets are fished for three net checks (3 days) in each sub-reach. In addition to fishing hoop nets as detailed above, personnel are responsible for the tasks including:

- Measuring and recording the fork and total lengths, sex, sexual condition, and sexual characteristics for all captured native fish (except speckled dace)
- Measuring and recording the total length, sex, and sexual condition of all other captured fish
- Implanting PIT tags in all humpback chub ≥100 mm total length and all other native fish ≥150 mm total length and fin clipping tagged fish recaptured on the same marking effort. In

order to reduce PIT tagging, but still obtain population information, bluehead suckers will only be tagged during the first (April) trip), and

- Recording the location, shoreline habitat, hydraulic unit, set and pull time, and map locations for each hoop net set

Personnel at Boulders Camp will make daily measurements of turbidity with the Hach 2100 turbidimeter and water temperature.

Annual Fall Humpback Chub Abundance Assessments in the Lower 13.6 km of the Little Colorado River (FY2011)

The fall sampling primarily provides an estimate of the abundance of subadult fish rearing in the LCR. These data support the ASMR model to assess humpback chub population numbers. Two trips are used to collect the mark-recapture data used for closed population estimates in the fall (September and October). Sampling uses hoop nets evenly distributed throughout the lower 13.6 km of the LCR as in the spring sampling.

Mainstem Hopi-Salt Site

At the conclusion of the October LCR effort, two people from the LCR crew proceed down the mainstem by boat to the Hopi-Salt site (~RM 63.5). Thirty hoop nets are set along standardized sites within this reach. Each net is fished for 3 nights and checked daily.

Annual Spring Native and Nonnative Fishes Relative Abundance Assessment in the Lower 1,200 m of the Little Colorado River (FY2011)

This program, established by the Arizona Game and Fish Department (AZGFD) in 1987, has operated continuously, except from 2000 to 2001 (Arizona Game and Fish Department, unpub. data, 2010). The program produces annual assessments of the relative abundance (that is, catch-per-unit effort) of all size classes of humpback chub, flannelmouth suckers, bluehead suckers, speckled dace, and a host of nonnative fish in the lower 1,200 m of the LCR. Data are collected during a 30- to 40-day period in spring (April and May) using hoop nets set in standardized locations throughout the reach. Results of this monitoring provide an independent comparison to the mark-recapture assessments. The statistical power of this portion of the monitoring program has not yet been assessed, but statistically significant differences in relative abundance are apparent in current data.

Annual Spring Humpback Chub Monitoring in the Lower 13.6 km of the Little Colorado River (FY2012)

Analysis of all the historical data of humpback chub monitoring generated by the three projects listed above will be conducted in FY2010 and early FY2011. The three cooperating agencies (USGS, USFWS, and AZGFD) will provide their data and participate in the analysis process. In particular, the analyses will focus on how closed population efforts and the ASMR (open) population estimate performs using only subsets of tagging data. Specific sampling methods, gears, and analyses for core monitoring beginning in FY2012 will be developed in FY2011 for GCDAMP consideration.

Links/Relationships to Other Projects

Improvement of the status of the humpback chub will be necessary for the species to be considered for downlisting or delisting. The most recent iteration of the recovery goals for the humpback chub (initiated in 2007) required a minimum of 2,100 adults in Grand Canyon, a steady or increasing trend in the population, and control of environmental threats, among other requirements. One element of humpback chub conservation in Grand Canyon could be a Glen Canyon Dam flow-release regimen that supports this species. These flows can be expected to affect many elements of the canyon resources, including sediment, cultural resources, and recreation. Therefore, releases that benefit one resource like the humpback chub must also be consistent with conservation of other resources. Conservation of LCR resources, especially water, and protection from catastrophic events is important not only to protecting the spawning humpback chub population in the LCR, but also to protecting other organisms found there.

Logistics

FY2011

Two spring mark-recapture trips, and two fall mark-recapture trips subject to outcome of PEP analyses and cooperator/stakeholder input, helicopter support

Lower 1,200 m: One spring trip, subject to outcome of PEP analyses and cooperator/stakeholder input, helicopter support

FY2012

Two spring mark-recapture trips, and two fall mark-recapture trips subject to outcome of PEP analyses and cooperator/stakeholder input, helicopter support

Lower 1,200 m: One spring trip, subject to outcome of PEP analyses and cooperator/stakeholder input, helicopter support

Products/Reports

The USFWS will deliver two trip reports annually within 60 days of completion of the fieldwork, including data collected, to the GCMRC. The trip reports will be summarized and analyzed in a final report delivered to the GCMRC in January of the following year. These reports address the lower 15-km monitoring and the monitoring above Chute Falls (see project description for BIO 2.M3.11–12)

An annual report will be prepared by USFWS in cooperation with GCMRC, in USGS Open File Report format following USGS Fundamental Science Practices

The AZGFD will deliver one annual report on the results of their monitoring of the lower 1,200 m of the LCR to the GCMRC

An annual report will be prepared by AZGFD in cooperation with GCMRC, in USGS Open File Report format following USGS Fundamental Science Practices

A core-monitoring report, summarizing core-monitoring efforts, 2009 PEP recommendations, and results of analyses recommended by the 2009 PEP will be completed in FY2011

Budget

FY2011	$576,135
FY2012	$604,940

BIO 2.M3.11–12—Humpback Chub Translocation and Monitoring Above Chute Falls

Start Date

2003

End Date

Ongoing

Principal Investigator

D.R. Van Haverbeke, U.S. Fish and Wildlife Service

Geographic Scope

The Little Colorado River (LCR) above Chute Falls

Project Goals

The goals of this project in FY2011–12 include:

- Determining the critical physical and biotic factors that may be limiting to, or supportive of, humpback chub and other native fish populations in Grand Canyon to identify strategies to reduce, eliminate, or control limiting factors
- Identifying the habitat characteristics that are most important to all life stages of humpback chub to identify methods that maintain, and possibly replicate, suitable habitats
- Reducing predation risk to humpback chub from nonnative species that may ascend the LCR from the mainstem Colorado River
- Allowing opportunity for translocated humpback chub to grow and survive in additional habitat

Specific objectives of the project includes:

Translocating small humpback chub from near the confluence with the Colorado River to above Chute Falls

- Obtaining population estimates for humpback chub ≥100 mm and ≥200 mm above Chute Falls
- Coordinating the production of a document that establishes a written framework for translocation, including overall goals, specific objectives, and objective measures of success. This framework should be consistent with the Genetics Management Plan, when it becomes available

Need for Project

Translocation is a management action designed to help conserve humpback chub. In 2003, as a conservation measure to the Biological Opinion on the 2002 experimental flows and nonnative fish removal proposal, the U.S. Fish and Wildlife Service (USFWS) began a translocation program funded by Reclamation for humpback chub above Chute Falls in the LCR. Chute Falls is a series of waterfalls approximately 16 km upstream on the LCR above the confluence with the Colorado River. Despite evidence that fish do move above Chute Falls, the potential exists for genetic drift, or a change in the genetic makeup of the population when compared to the main humpback chub population farther downstream on the LCR, owing to the "founder effect," a situation managers wish to avoid. Genetic drift was considered in the *Draft Humpback Chub Genetics Management Plan* (U.S. Fish and Wildlife Service, unpub. data, 2008).

Translocating humpback chub above Chute Falls was conducted six times between 2003 and 2010. Because the LCR above Chute Falls contains fewer nonnative fish than the lower portion of the LCR, translocation above Chute Falls is thought to allow humpback chub opportunity for better survival than in the lower LCR. Translocation also increases the demographic range for the species by nearly 5 km. Researchers have documented movement of humpback chub from below Chute Falls to above the barrier, providing new information about the movement capabilities of humpback chub. Monitoring above Chute Falls is important for evaluating the effectiveness of translocating humpback chub.

The 2009 PEP report clearly stated that management objectives for Chute Falls and other translocations should be specified in measurable terms to guide monitoring and reporting. The panel could not comment on current monitoring activities with available information. The need for additional translocations and the timing of those efforts should be compared to recommendations made in the *Final Humpback Chub Genetics Management Plan*, which is being prepared by the USFWS, when it is available. In addition, translocations to Shinumo Creek and Havasu Creek, which are planned for the near future, should be incorporated into translocation planning efforts. The GCMRC will work with USFWS and other cooperators to develop a translocation framework to help guide future translocation efforts.

Strategic Science Questions

The Glen Canyon Dam Adaptive Management Program Science Advisors have summarized strategic science questions related to humpback chub with the following question, which this project specifically addresses, especially annual spawning success:

SA 1. What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

Information Needs Addressed

Primary information need addressed:

CMIN 2.1.2. Determine and track recruitment (identify life stage), abundance, and distribution of humpback chub in the LCR.

Methods and Tasks

Two mark-capture trips will be conducted in the summer above Chute Falls in the LCR to monitor translocated fish and potential offspring and to generate a closed population estimate for humpback chub. These trips occur during late May or early June when the LCR discharge is at base flow. In addition to the annual population estimate, these data can be incorporated into ASMR and other open population models. All fish $\geq$ 100mm TL are implanted with PIT tags.

A camp has been established on Navajo lands 16.2 km above the LCR and Colorado River confluence, which is used to temporarily house project staff during the field work. The camp has an established helicopter pad and offers protection from most floods.

Baited hoop nets (0.5–0.6-m diameter, 1.0-m length, 6-mm mesh, single 10-cm throat) are fished in the LCR corridor above Chute Falls (13.6 km), which is the upstream extent of the current downstream LCR monitoring. The overall reach is divided into two subreaches and each subreach fished for 3 days. Approximately 50 hoop nets are fished throughout this upper reach from 13.6 to 18.0 km, with an average spacing between nets of approximately 100 to 150 m. Hoop nets are positioned in favorable habitats for catching humpback chub and repositioned as needed. On average, each hoop net is checked once every 24 hours. Each net is baited near its cod end by attaching a nylon mesh bag (30- by 30-cm, 6-mm mesh) containing AquaMax™ Grower 600 for Carnivorous Species (Purina Mills Inc., Brentwood, MO). All captured humpback chub are checked for colored elastomer tags and PIT tags. Individuals not previously PIT tagged, but of sufficient size to tag without injury, are held overnight offshore in an aerated tank, or in the LCR in a secured holding pen to allow time for digestion of any consumed bait, and thereafter tagged and released.

In addition to fishing baited hoop nets and PIT-tagging humpback chub as detailed above, staff will be responsible for:

- Measuring and recording the fork and total lengths, gender, spawning condition, and sexual characteristics for all captured fish (except speckled dace)
- Recording the location, shoreline habitat, hydraulic unit, set and pull time, and map locations for each hoop net set, and
- Measuring daily turbidity (using the Hach 2100 turbidimeter), water temperature, and CO_2 (using titration)

Links/Relationships to Other Projects

Projects such as this one that investigate potential strategies for expanding the Grand Canyon humpback chub population support the basin wide goal of conserving humpback chub with the long-term goal of downlisting and delisting the species from the Federal endangered species list. Chute Falls translocations and monitoring inform additional translocations to other tributaries, currently expected to be Shinumo Creek, and perhaps Havasu Creek.

Logistics

Both the translocation trip and the monitoring trip for this effort require helicopter support. Translocation is anticipated in the summer with follow-up monitoring in the fall.

Products/Reports

The USFWS will deliver two trip reports annually within 60 days of completion of the fieldwork, including data collected, to the GCMRC. The trip reports will be summarized and analyzed in a final report delivered to the GCMRC in January of the following year. These reports address the lower 15-km monitoring and the monitoring above Chute Falls (see project description for BIO 2.M1.11–12)

An annual report will be prepared by USFWS in cooperation with GCMRC in USGS Open File Report following USGS Fundamental Science Practices

Budget

FY2011	$131,051
FY2012	$137,602

BIO 2.M4.11–12—Monitoring Mainstem Fish

Start Date

2010

End Date

Ongoing

Principal Investigators

A.S. Makinster, Arizona Game and Fish Department; D.R. Van Haverbeke, U.S. Fish and Wildlife Service; and W.R. Persons and K.D. Hilwig, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

The mainstem Colorado River in Grand Canyon between Lees Ferry and upper Lake Mead

Project Goals

This project is intended to increase knowledge of native and nonnative fish in the Colorado River mainstem. It is also intended to be responsive to the recommendations of the 2009 PEP for Grand Canyon Fishes. The project seeks to advance the following goals:

- Monitor the documented humpback chub aggregations in the mainstem Colorado River
- Continue to monitor native and nonnative fish in the mainstem Colorado River
- Provide presence/absence and distribution information on Colorado River native and nonnative fish
- Conduct three monitoring efforts (four trips in total) in years without mechanical removal in the Little Colorado River reach (or other, comparably large control effort) subject to additional funding being made available by Reclamation from the Nonnative fish control contingency fund or other funding source. In years when a large mechanical removal trip is conducted in the Little Colorado River reach then the personnel and equipment will be shifted from the two full mainstem monitoring trips to the mechanical removal effort, collecting intensive monitoring data for that reach. Monitoring is intended to be responsive to advances in data analysis, sampling design, and gear selection. A flexible approach that builds on prior knowledge is needed to develop monitoring of the Colorado River fish population that is responsive to continuing changes in dam operations, climate, local meteorology, species population sizes, and management actions. Primary emphasis is on broad sampling, with a secondary emphasis on developing high statistical confidence in species-specific trends. If this monitoring suggests changes in either native or nonnative populations, future monitoring can be directed at gathering more data on a specific species or location
- Provide annual monitoring and timely reporting that allows for annual review of specific sampling design, gear, and data analyses. The cooperating agencies will meet formally at least once a year with interested Grand Canyon Adaptive Management Program (GCDAMP) members to review and potentially modify sampling design, gear, and data

analyses. The three lead cooperators— Arizona Game and Fish Department (AZGFD), U.S. Fish and Wildlife Service (USFWS), and Grand Canyon Monitoring and Research Center (GCMRC)—will assume responsibility, with other cooperators as assigned, for data reporting and analysis

Tasks to address the goals described above will be phased in over the FY2010–12 period and are to be included in analysis of existing fish data recommended by the 2009 PEP.

Need for Project

Native fish populations in Grand Canyon are key resources of concern influencing decisions on both the operation of Glen Canyon Dam and non-flow actions. To inform these decisions, it is imperative that accurate and timely information on the status of fish populations, particularly the endangered humpback chub, be available to managers. A suite of adaptive experimental management actions are being contemplated to better understand the mechanisms controlling the population dynamics of native fish and to identify policies that are consistent with the attainment of management goals. The assessments generated from this project provide a baseline from which to assess the effects of implemented experimental actions. This information is therefore crucial to (1) inform the program as to attainment of identified goals, (2) provide baseline status and trend information to be used as a backdrop to further understand mechanisms controlling native and nonnative fish population dynamics, and (3) evaluate the efficacy of particular management policies in attaining program goals. The results of this project are potentially useful in assessing changes to the Federal Endangered Species Act listing status of humpback chub in Grand Canyon.

Nonnative fish are among the greatest threats to native fish in western North American rivers (Miller, 1961; Minckley and Deacon, 1991; Tyus and Saunders, 2000; Coggins, 2008). Nonnative fish may threaten native fish by direct predation, by competing for available food and other resources, and by habitat modification (Minckley, 1991; Hawkins and Nesler, 1991). Nonnative fish were introduced into Grand Canyon not later than early in the 20th century (Woodbury, 1959; Valdez and Ryel, 1995). While native fish survived these initial introductions at least long enough to be described by early researchers, other system stressors, especially the modification of natural flows as a result of dam installation and operations, appear to have increased the threats to native fish from nonnative fish (Minckley, 1991; Clarkson and Childs, 2000).

The GCDAMP has recognized nonnative fish as a threat that needs to be addressed, proceeding with implementation of a nonnative fish control experiment around the Little Colorado River (LCR) inflow reach from 2003 to 2006. The 2003 to 2006 control project was most successful at removing rainbow trout. This work plan builds on that effort. As the Colorado River mainstem becomes warmer because of climate effects (Seager and others, 2007), the potential for an increased threat from warm water adapted nonnative fish increases (Eaton and Scheller, 1996; Chu and others, 2005; Rahel and Olden, 2008). There is an immediate need to investigate which species pose the greatest threats to natives in Grand Canyon, to understand how those species might be better monitored and controlled, and to test control approaches for efficacy.

In response to identified GCDAMP goals, the 2009 PEP for Grand Canyon Fishes concluded that it is important to conduct mainstem fish monitoring with a variety of sampling designs and gear types. The experts involved with the PEP determined that fine resolution of confidence in species-specific mark-recapture population estimates could only be accomplished

with large amounts of personnel time, sampling gear and equipment, and funding that is not currently available. Further, the PEP determined that even if more resources could be employed, fine-scale data collection every year was not warranted and could cause harm to native fish. Therefore, the PEP recommended a broad approach to use multiple gear types at various times of the year and over a broad geographic range to give scientists and managers the most useful data on an annual basis.

Strategic Science Questions

Primary SSQ addressed:

SSQ 1-1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

SSQ 1-2. Does a decrease in the abundance of rainbow trout and other cold- and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population?

Additional SSQs addressed:

SSQ 1-4. Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.

SSQ 1-8. How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling?

SSQ 5-6. Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance?

The GCDAMP Science Advisors articulated the following summary science questions addressed by this project:

SA 1. What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on young of year and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

SA 2. What are the most probably positive and negative impacts of warming the Colorado River on humpback chub adults and juveniles?

Information Needs Addressed

Primary information needs addressed:

CMIN 2.1.2. Determine and track recruitment of all life stages, abundance, and distribution of humpback chub in the Colorado River.

CMIN 2.4.1. Determine and track the abundance and distribution of nonnative predatory fish species in the Colorado River.

CMIN 2.6.1. Determine and track the abundance and distribution of flannelmouth sucker, bluehead sucker, and speckled dace populations in the Colorado River ecosystem.

RIN 2.4.2. Determine if suppression of nonnative predators and competitors increases native fish populations.

RIN 2.4.3. To what degree, which species, and where in the system are exotic fish a detriment to the existence of native fish through predation or competition?

RIN 2.4.4. What are the target population levels, body size, and age structure for nonnative fish in the Colorado River ecosystem that limit their levels to those commensurate with the viability of native fish populations?

Methods and Tasks

The methods described below are intended to be consistent with the 2009 PEP for Grand Canyon Fishes and will be compared to the PEP final analysis report to ensure consistency when that document is available. Annual review may indicate alternative methods are required, especially if expanding humpback chub populations or expanding nonnative fish populations are indicated by the data from this and other trips collected in these and previous years. This approach is intended to sample species and habitats as broadly as possible in order to give managers and scientists diverse information on which to direct this and other projects in future years. If the analyses conducted by GCMRC, USFWS, and AZGFD in 2010 and 2011 indicate that the methods described herein and the recommendations of the 2009 PEP are not warranted, alternative approaches to monitoring will be developed and implemented.

Mainstem Spring Electrofishing

Mainstem fish monitoring, including the monitoring below Diamond Creek, has used boat-operated electrofishing to provide information on status and trends of native and nonnative fish in the Colorado River between Lees Ferry and Lake Mead since 2001. Data from these trips supports annual analyses of species catch-rate data, species distribution data, and species length frequency and size data. Electrofishing remains the most important tool for providing an overall assessment of the mainstem fish community. Two electrofishing trips will be conducted at stratified random sites not in immediate proximity to campers. This protocol applies only to years in which a large mechanical removal project (or similar large scale effort) is not conducted. If management agencies determine that a mainstem mechanical removal of nonnative fish in the Little Colorado River reach, or similar effort, is desired, then the personnel and equipment used for mainstem spring electrofishing will be shifted to the mechanical removal project. Mainstem spring electrofishing is included in this work plan because no mechanical removal project has been planned or scheduled at the time of work plan preparation. Mechanical removal would result in intensive fish community sampling in the LCR reach and so could substitute for mainstem spring electrofishing, at least for a limited number of years. If no mechanical removal is conducted then the funding for personnel and equipment will have to be transferred from the Reclamation portion of the GCDAMP budget to pay for these expenses.

Mainstem Fall Humpback Chub Aggregation Monitoring

Several known aggregations of humpback chub (Valdez and Ryel, 1995) will be sampled with a variety of nets by this project. Additional sites selected by a stratified random selection will also be sampled. The primary humpback chub aggregations that will be sampled include 30 Mile, near the confluence of the LCR, and Inner Granite Gorge. The project will also sample at and below the mouth of Shinumo Creek, a tributary to the Colorado River, to investigate whether humpback chub translocated to this tributary have moved into the mainstem. Gear types may include, but are not limited to, the following: hoop nets, trammel nets (when water temperature below 20 deg. C), and seines. Gear selection is dependent on habitats sampled.

This project makes use of trammel nets when water temperatures are below 20 degree C to limit stress on captured fish. Trammell net sets are for 2 hours or less. Because working trammel nets requires use of motor boats, this monitoring will emphasize use of trammel nets in locations determined in advance of the trip, but other gear types may be deployed as time and

opportunity is available. Sampling in the LCR reach is not conducted in areas where the nearshore ecology project is working. Data from this monitoring will provide data for the ASMR model for humpback chub.

Mainstem Fall Monitoring

This project will conduct multi-gear monitoring at potential nonnative fish aggregations, especially near humpback chub aggregations, tributary inflow areas and also stratified random sites. Gear types may include, but not be limited to, hoop nets, trammel nets, backpack and oar-powered electroshockers, seines, minnow traps and angling. Gear selection is dependent on habitats sampled. This trip is launched late in September and will be non-motorized.

The primary site selection for this trip will be conducted using a stratified random design. As additional information is gathered regarding nonnative species, this trip may also be focused on areas where nonnative concentrations may be found, such as near the mouth of warm water tributaries. Data from these trips supports annual analyses of species catch rate data; species composition and distribution; species size class composition, and may also support the update of the ASMR model for humpback chub.

Links/Relationships to Other Projects

Understanding the factors influencing the dynamics of the Grand Canyon native fish populations, especially the endangered humpback chub, is important to evaluating the effects of management and conservation activities, especially GCD operations. To determine these factors, a combination of large scale manipulations (for example, experimental removal of nonnative fish or long-term implementation of contrasting flow regimes) and smaller scale process oriented research (for example, assessment of juvenile fish growth rates under various temperature regimes or availability of particular food items) will likely prove most efficient in determining the key mechanisms regulating native fish populations. In each of these endeavors, it is critical that baseline trends in population abundance and recruitment be known. Only with this knowledge is it possible to assess the population level effects of large-scale manipulations. Although it is informative to assess the effects of experimental management on processes thought to be important, like growth or survival at particular life stages, this is not enough to determine the efficacy of particular management actions. Linkages between these processes and ultimate recruitment to populations must be established. Again, these linkages can only be made if baseline trends in population abundance and recruitment are available.

Logistics

The logistical needs for the project are as follows:

- Mainstem Fall Humpback Chub Monitoring—1 trip in FY2011 and FY2012, September, motorized; GCMRC, USFWS, AZGFD
- Mainstem Fall Fish Monitoring—1 trip in FY2011 and FY2012, October, float; GCMRC
- Mainstem Spring Electrofishing Monitoring—2 trips in FY2012, February and March, motorized; AZGFD

Products/Reports

Annual reporting on the catch rates, species encountered, size class distributions, and locations of captures for the fall HBC monitoring will be the responsibility of the agency leading the effort, currently anticipated to be GCMRC in FY2011 and USFWS in FY2012

- All fish data will be submitted to GCMRC for inclusion in the fish database. These data are used for other projects, especially the stock assessment project, and to support nonnative fish monitoring

Annual reports will be delivered in USGS Open File Report format

Budget

FY2011 $280,503

FY2012 $558,449

BIO 2.R7.11–12—Stock Assessment of Grand Canyon Native Fish

Start Date

2007

End Date

Ongoing

Principal Investigators

W.R. Persons, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, and C.J. Walters, University of British Columbia

Geographic Scope

Colorado and Little Colorado Rivers in Glen, Marble, and Grand Canyons

Project Goals

This project will provide annual updates of population size composition and capture rates of humpback chub and other Grand Canyon fish to the Glen Canyon Dam Adaptive Management Program (GCDAMP) and other managers. Reporting will include retrospective time series to allow for comparison with previous years' data. The assembled humpback chub data from the Grand Canyon fish monitoring projects will be incorporated into updates of the Age-Structured Mark-Recapture (ASMR) model approximately every 3 years. The next ASMR update is anticipated for publication in 2011.

This project will lead the analyses of existing fish capture information recommended by the 2009 Protocol Evaluation Panel for Grand Canyon Fishes (PEP). The goal of these analyses is to evaluate whether the fish monitoring project changes recommended by the PEP, especially to reduce some efforts and increase others, are consistent with the available data.

This project will seek to develop and implement methods for making the humpback chub database available electronically. Data serving must be done in a manner consistent with USGS Fundamental Science Practices.

This project will develop an annual reporting framework for native and nonnative fishes that includes results of current and historic fisheries monitoring. As recommended by the 2009 PEP, we will develop a single, concise report that includes information from all fishery-monitoring projects, including the Little Colorado River monitoring as well as mainstem monitoring at both Lees Ferry and downstream. The report may include closed population estimates for the LCR, catch rate indices for commonly captured species, size composition information, recruitment indices, species distribution information, and pertinent information regarding fishery responses to experimental treatments such as High Flow Experiments and mechanical removal.

Need for Project

Native fish populations in Grand Canyon are key resources of concern influencing decisions on both the operation of Glen Canyon Dam and other non-flow actions. To inform

these decisions, it is imperative that accurate and timely information on the status of native fish populations, particularly the endangered humpback chub, be available to managers.

Several experimental and management actions are being contemplated to understand the mechanisms controlling the population dynamics of native and nonnative fish and to identify policies that are consistent with management goals. This project will support assessment of experimental actions. This information is therefore crucial to:

Inform the program as to attainment of identified goals and objectives

Provide baseline status and trend information to be used as a backdrop to understand the mechanisms controlling native fish population dynamics, and

Evaluate the efficacy of particular management policies in attaining program goals

Contribute to Federal Endangered Species Act listing status of humpback chub in the Colorado River

Strategic Science Questions

Primary SSQ addressed:

SSQ 1-1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning, and incubation in the mainstem, survival of YoY and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

Additional SSQ addressed:

SSQ 1-8. How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling?

The Adaptive Management Program Science Advisors have articulated the following science question, which is partially addressed by this project:

SA 1. What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

Information Needs

RIN 2.2.8. What combination of dam release patterns and nonnative fish control facilitates successful spawning and recruitment of humpback chub in the Colorado River ecosystem?

RIN 2.4.2. Determine if suppression of nonnative predators and competitors increases native fish populations.

Methods and Tasks

To provide humpback chub status and trend information, the Grand Canyon Monitoring and Research Center (GCMRC) mark-recapture database will be updated annually with the most recent data collected during monitoring efforts. Following this update, the humpback chub mark-recapture database will be reanalyzed using (where appropriate) both open and closed mark-

recapture-based abundance estimators and catch rate indices to provide the most current information on humpback chub status and trends. In particular, the ASMR models (Coggins and others, 2006a and 2006b; Coggins, 2007; Coggins and Walters, 2009) will be used to determine trends in humpback chub abundance and recruitment over multiyear time scales. Over annual time scales, this project will assemble and deliver summaries of annual catch rate and size-class composition of humpback chub and other species from the Little Colorado River (LCR) and mainstem to the GCDAMP and managers. It will also deliver other species metrics, likely to include results of closed population estimates and juvenile abundance from the LCR.

This project was reviewed by the 2009 PEP. The panel recommended that because of the inherent variability in the ASMR (for example, estimates of growth and mortality rates limit its ability to detect fine scale changes), preparing annual updates of the model was an inefficient use of personnel time, especially for the long-lived humpback chub. The PEP observed that the ASMR has only limited sensitivity to detect small annual population changes and that it requires tremendous personnel and computer resources to generate. Based on these observations, the PEP recommended that the ASMR be updated every 3 to 5 years. Because the GCMRC is planning to prepare the next *State of the Colorado River Ecosystem in Grand Canyon* (SCORE) report in FY2011, the GCMRC will accelerate this recommendation for the next iteration and include an update of ASMR in the FY2011 SCORE report. This update is being prepared as part of the evaluation of data recommend by the 2009 PEP. In the future, the GCMRC intends the next iteration of the ASMR following the FY2011 update will be scheduled for FY2014, consistent with the PEP recommendation. Updates will be developed in the stock assessment framework previously reported.

The 2009 PEP for Grand Canyon Fishes made a series of recommendations that direct shifting monitoring efforts to decrease efforts in the LCR and increase efforts in the mainstem of the Colorado River, subject to an analysis of the existing data to see if their recommendations are consistent with the data. The GCMRC fisheries biologist working on this project will be responsible for assembling and/or conducting the analyses necessary to evaluate the recommendations. AZGFD and USFWS personnel to support this effort will also conduct data analyses of individual projects. If the recommendations are found to be warranted, the shift to different monitoring may be initiated in late FY2011. The full analysis of all the data will not be required in FY2011, so there will be some shifting of the fisheries biologist time to other projects.

As recommended by the 2009 PEP, we will develop a single concise report that includes information from all fishery-monitoring projects, including the Little Colorado River monitoring as well as mainstem monitoring at both Lees Ferry and downstream.

Links/Relationships to Other Projects

The status and trends of the Grand Canyon humpback chub population are two of the key metrics utilized in GCDAMP to evaluate the success of the GCDAMP and actions undertaken under the sponsorship of the GCDAMP. Therefore, an annual stock assessment report that includes all fishery monitoring is related to many other GCDAMP work plan elements, especially experimental actions such as the March 2008 High Flow Experiment, other flow experiments, or removal of nonnative fish. The annual humpback chub population status will be important to projects studying biotic and abiotic aspects of the system—including the aquatic food base, and nearshore ecology projects—because changes in the parameters measured by these projects can be compared to trends in the humpback chub population to search for relevant correlations.

Logistics

There are no logistical needs for this project.

Products/Reports

- This project will be the lead for retrospective analysis of the fish catch rate data, especially for humpback chub. The analyses will also be supported by AZGFD and USFWS personnel as part of the reporting for their respective projects. Under this project, GCMRC will convene an annual fish meeting to review these analyses and to develop a single annual stock assessment report.
- A single stock assessment report will be delivered to the GCDAMP during the winter of each year
- The next update of the ASMR model will be in FY2011 to coincide with the next SCORE report, with the next scheduled update anticipated in FY2014
- This project will pursue making the humpback chub data base information available electronically in a manner consistent with USGS Fundamental Science Practices

Budget

FY2011 $57,665

FY2012 $60,541

BIO 2.R13.11–12—Remote PIT Tag Reading

Start Date

October 2006

End Date

Ongoing

Principal Investigator

W.R. Persons, U.S. Geological Survey, Grand Canyon Monitoring and Research Center and Graduate Student (to be determined)

Geographic Scope

Little Colorado River

Project Goals

This project is planned for FY2011–12 and seeks to advance the following goals:

- Determine and refine the most appropriate method(s) for estimating the population size of humpback chub and other Grand Canyon fish, including sampling design and development of remote monitoring methods
- Determine movement patterns of fish in Grand Canyon using the Little Colorado River LCR

This project will test monitoring methods that do not require repeated handling of fish, capture of evasive species, or additional field fish sampling trips. Remote antennae can read the passive integrated transponder (PIT) tags as tagged fish pass the station. PIT tags are already implanted in a large proportion of the adult population of humpback chub in Grand Canyon. Because one PIT-tag antennae array was installed in the LCR in FY2009, this project also seeks to provide maintenance and upgrades to the equipment already in place.

Need for Project

A limited number of humpback chub and other native fish are present in the modern day Colorado River in Grand Canyon. Nonnative fish species are also present and are important to study because of the known predatory and competitive threats they pose to native fish. Scientists and managers wish to know the spatial and temporal movement patterns of these species and the effectiveness of sampling gears in sampling populations. Obtaining population information in the least intrusive manner(s) possible, especially when sampling the endangered humpback chub, is also desirable. Remote PIT-tag antennae have been shown in other rivers and streams, which have generally been smaller than the LCR, to be very effective at continuous monitoring, alleviating the need for additional field sampling trips and multiple fish handling events.

The 2009 PEP reviewed the initial implementation of this project and recommended that it be continued and expanded. This project description is designed to be consistent with the panel's recommendations.

Strategic Science Questions

Primary SSQ addressed:

SSQ 1-8. How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling?

Information Needs Addressed

CMIN 2.1.2. Determine and track recruitment (identify life stage), abundance and distribution of humpback chub in the LCR.

RIN 2.2.2. Determine if a population dynamics model can effectively predict response of native fish under different flow regimes and environmental conditions.

Methods and Tasks

In FY2009, personnel from Grand Canyon Monitoring and Research Center (GCMRC), Arizona Game and Fish Department (AZGFD), and the USGS Columbia River Research Lab experimented with the use of remote antennae to read PIT tags. The equipment installed generally performed as anticipated, although some improvements will be sought, especially increasing detection distance and increasing equipment stability in high flows. PIT-tag antennae are initially evaluated with passing tags over the antennae, which is followed by assessing whether the antennae are reading and recording deployed tags. The study area will focus on the LCR because humpback chub spawn and are concentrated there. Progressively more sophisticated equipment and deployments have been tested over time. This incremental approach has allowed for efficient use of funds, specific evaluation of equipment and methods, and consultation with Tribes that must permit the deployment.

In FY2010 an additional array will be deployed in the LCR (June 2010) to increase coverage of the width of the river, increasing the probability of detections, and increasing ability to detect movement. Personnel from USGS and AZGFD will cooperate to expand the coverage and detection capabilities beyond those already observed. USGS Columbia River Research Lab personnel will assist with array design, installation and data analysis.

Together with AZGFD, the GCMRC will seek to identify an appropriate graduate student to work on this project, both as the primary person for maintenance and for data analysis. The USGS Cooperative Unit Leader from Colorado State University has indicated interest in serving as the major advisor for this person, and would contribute to data analysis.

Remote data telemetry is being attempted in FY2010. This will allow biologists to remotely download the data from the remote PIT-tag detector and determine operational status and maintenance needs instead of visiting the site regularly throughout the year.

Links/Relationships to Other Projects

If the PIT-tag readers continue to be successful, more ‘recapture’ data on individual tagged native and nonnative fish will be available without concurrent expenditures on personnel, supplies, and logistics. Currently about one-half of the fish detected have been humpback chub, with native suckers and a few common carp making up the remainder. These data will be important for support of the annual catch-rate indexes and multiyear model updates. More information on movement into and out of the LCR will also inform open population models.

Logistics

Trips that require large equipment transport will require helicopters into and out of the LCR. In FY2011 and FY2012, 6 days of helicopter transport are budgeted. Four to five trips for two people are expected to conduct servicing, maintenance, and downloading; as many of the trips as possible will be combined with existing trips.

Personnel will schedule appropriate servicing and downloading trips using a combination of hiking and boat travel, ideally in combination with other science trips, but this project includes logistics costs to support the minor additional demands of small crews in the LCR to service the PIT antennae.

Products/Reports

Annual reporting on the installation and operation of the equipment and collected data will be delivered to the GCMRC by December of each year. These data are to be discussed in at least one annual meeting by the fish cooperators, managers, and interested Glen Canyon Dam Adaptive Management Program committee members.

GCMRC will pursue the identification of an appropriate graduate student and institution to support cooperative additional data analysis. The USGS Cooperative Unit at Colorado State University has expressed initial interest in having such a graduate student enrolled there. A graduate student would be expected to provide a thesis and one or more peer reviewed reports analyzing the data collected by this project. The emphasis of possible graduate research may include detailed descriptions of the movement patterns of humpback chub in to and out of the LCR.

Budget

FY2011	$145,828
FY2012	$152,594

BIO 2.R15.10–11—Nearshore Ecology / Fall Steady Flows

Start Date

2008

End Date

September 2012

Principal Investigators

William E. Pine, III, University of Florida; M.D. Yard, U.S. Geological Survey, Grand Canyon Monitoring and Research Center; and C.J. Walters, University of British Columbia

Geographic Scope

The mainstem Colorado River in Grand Canyon below the mouth of the Little Colorado River

Project Goals

The primary goal of the nearshore ecology study is to relate river flow variables and ecological attributes of nearshore habitats to better understand the relative importance of the biotic and abiotic attributes of these habitats to juvenile (< 200mm total length) native and nonnative fish

The objectives addressed by this project are as follows:

- Develop sampling approaches and analytical methods to use for determining abundance, density, or occurrence of native and nonnative fish among different nearshore habitat types
- Assess past and current data and integrate data across multiple sources and disciplines to determine small-bodied and juvenile fish nearshore habitat selection at local, geomorphic, and landscape scales
- Evaluate past habitat classification schemes and associated data collection efforts, using both habitat information associated with the fisheries database and Data Acquisition, Storage and Analysis (DASA) Program GIS habitat classification methods
- Develop methods for measuring and estimating small-bodied and juvenile fish vital rates (growth and survival) among different nearshore habitat types and during steady versus fluctuating flow operations
- Determine the key factors (abiotic and biotic) influencing nearshore habitat selection among small-bodied and juvenile fish
- Determine the effect(s) of fluctuating and steady flow releases on nearshore habitat selection, movement, growth, and survival of native and nonnative fish
- Design and implement a multiyear (FY2009–12) experimental plan (process oriented) to determine the effect(s) of fluctuating and steady flow releases (September–October) on nearshore habitat selection, movement, growth, and survival of native and nonnative fish

- Develop a contingency plan for releases above peak power plant capacity that details how these releases will affect the proposed research and a research plan for assessing the potential impacts of these releases on nearshore habitat selection among small-bodied and juvenile fish

The goal of this project is to provide information for developing future models with the capability to predict small-bodied and juvenile fish composition, distribution, and abundance in relation to changes in management actions (for example, flows, temperatures, and nonnative fish interactions) and nearshore habitat availability.

Need for Project

The mainstem Colorado River life-history requirements of HBC are not well understood. The habitat selection of HBC, and how those habitats may or may not be affected by human activities such as dam operations, are of particular interest to the Glen Canyon Dam Adaptive Management Program (GCDAMP) and managers. To help meet these information needs, this project is intended to identify juvenile native fish habitat requirements, and how habitat selection, preference, and availability affect native fish vital rates such as growth and survival. Findings from this project are intended to provide information on native fish habitat requirements and guide future GCDAMP recommendations for the Department of the Interior to consider as management or experimental actions.

Strategic Science Questions

Primary SSQs addressed:

SSQ 1-1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year (YoY) and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

SSQ 1-7. Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made useable and maintained?

SSQ 3-2. To what extent could predation impacts by nonnative fish be mitigated by higher turbidities or dam-controlled high-flow releases?

SSQ 4-2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possibly mortality of young humpback chub) associated with high flows?

SSQ 5-4. What is the relative importance of increased water temperature, shoreline stability, and food availability on the survival and growth of YoY and juvenile native fish?

SSQ 5-6. Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance?

Information Needs Addressed

RIN 2.1.3 What is the relationship between size of HBC and mortality in the LCR and the mainstem? What are the sources of mortality (that is, predation, cannibalism, other) in the LCR and the mainstem?

RIN 2.1.4 What habitats enhance recruitment of native fish in the LCR and mainstem? What are the physical and biological characteristics of those habitats?

RIN 2.4.3 To what degree, which species, and where in the system are exotic fish a detriment to the existence of native fish through predation or competition?

RIN 4.2.6 To what extent are RBT below the Paria River predators of native fish, primarily HBC? At what size do they become predators of native fish, especially HBC, that is, how do the trophic interactions between RBT and native fish change with size of fish?

RIN 2.4.4 What are the target population levels, body size and age structure for nonnative fish in the Colorado River ecosystem that limit their levels to those commensurate with the viability of native fish populations?

RIN 12.9.1 What is the impact on downstream resources of short-term increases to maximum flow, daily fluctuations, and downramp limits?

RIN 2.6.6 How is the rate of mortality for flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem related to individual body size? What are the sources of mortality for flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem?

RIN 4.2.5 To what extent is there overlap in the Colorado River ecosystem below the Paria River of RBT habitat and native fish habitat?

RIN 7.4.1 What is the desired range of seasonal and annual flow dynamics associated with power plant operations, BHBFs, and habitat maintenance flows, or other flows that meet GCDAMP goals and objectives?

EIN 2.1.1 How does the abundance and distribution of all size classes of HBC in the LCR and mainstem change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 2.1.2 How does the year class strength of HBC (51–150 mm) in the LCR and mainstem change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 2.4.1 How does the abundance and distribution of nonnative predatory fish species and their impacts on native fish species in the Colorado River ecosystem change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 2.6.1 How does the abundance, distribution, recruitment and mortality of flannelmouth sucker, bluehead sucker and speckled dace populations in the Colorado River ecosystem change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

SIN 8.5.4 What is the role of turbidity and how can it be managed to achieve biological objectives?

Methods and Tasks

The potential effects of fall steady flows on biological resources are being investigated with three Grand Canyon Monitoring and Research Center (GCMRC) projects: aquatic food base (goal 1), rainbow trout monitoring (goal 4), and nearshore ecology (goal 2). Descriptions of the

first two projects are found under the goal they are intended to address elsewhere in this work plan.

This nearshore ecology study is to incorporate findings from ongoing studies and to develop new sampling and analytical approaches that examine the effects of the March 2008 high-flow experiment on nearshore habitats and to address the effects of modified low fluctuating flows (MLFF), including September–October steady flows, on juvenile HBC and other native fish.

1. This project will investigate sampling methods to estimate fish habitat use, growth, and survival. Estimation of juvenile abundance, survival rate, growth rate, and habitat use is fundamental to resolving uncertainties in the conceptual model and the two key research questions outlined and identified above. Sampling trips are proposed in late July and late August to characterize abundance, habitat use, growth, and survival rate of juvenile fish over the summer under MLFF operations. These trips would be followed by sampling trips in early September and late October to characterize juvenile fish responses during the MLFF-fall steady experimental flow transition and steady flow period. Differences in abundance in each habitat type between sampling trips would be used to estimate habitat specific, reach-wide survival rates across flow events.
2. Two basic sampling approaches are proposed for estimating these characteristics: (1) reach-wide abundance estimation and (2) robust-design mark-recapture at replicate sites.
3. The site selection for this project is expected to utilize existing data and models from the GCMRC Physical Science and Modeling Program to quantify habitat availability over the study reach that contains the robust-design mark-recapture sites, habitat availability within the sites, and how habitat changes with flow. The existing GCMRC shoreline GIS database and other surveys can be used to stratify habitat into classes such as talus slopes, open sandbars, vegetated sandbars, cobble bars, and backwaters. The working hypothesis is that unstable habitat types will be used only minimally during the summer unsteady flow period, but that use of these habitats will increase during the fall steady period when flows are stabilized. If this difference in habitat use is ecologically important, the prediction would be an increase in growth and survival of fish during the fall steady flow period relative to the summer.
4. Any mark-recapture approach to estimating abundance and density depends on recapturing sufficient numbers of marked individuals to draw inferences on the parameters of interest. Closed population models generally have fewer parameters (and assumptions) than open models and are thus better able to estimate parameters of interest (capture probability and abundance) when recaptures are low. The closure assumption will be evaluated in our mark-recapture experiments using methods similar to Korman and others (2009). Additionally, recaptures of fish marked on previous trips will provide useful information on growth and movement (for example, movement into backwaters during periods of steady flow) between sampling trips and associated flow conditions. The Nearshore Ecology project pilot sampling data from 2008 should provide some information on closure and also provide information on capture probability that is necessary to fully assess how violation of the closure assumption biases abundance estimates. This project will evaluate occupancy models (MacKenzie and others, 2006) and sonic tags to support habitat-use assessment. This project will use otoliths (inner ear bones) from humpback chub and other natives to investigate habitat use and origin of fish.

Otoliths may also prove useful for determining growth and survival rates of humpback chub and other fish.

These methods are discussed in greater detail in the project proposal submitted to the GCMRC by Pine and others. These methods require repeated sampling at multiple mainstem locations below the mouth of the Little Colorado River. Repeated sampling is needed to develop statistical confidence in abundance estimation, which in turn is needed to draw conclusions about habitat use. Repeated sampling will require use of motorboats and electroshocking equipment, including generators.

Links/Relationships to Other Projects

This project uses habitat information developed largely by the Physical Science and Modeling Program and the Data Acquisition, Storage, and Analysis (DASA) Program. The results of this project will help evaluate responses of small-size classes of fish to various dam release flows and will provide some of the information needed to assess the status and trends of humpback chub in the mainstem Colorado River.

Logistics

This project will require four trips, one each in July, August, September, and October for 3 years, FY2009–11, subject to permit approval. All four trips are to be motor supported. The first three are scheduled to launch in the motor season, but the October trip will require authority from Grand Canyon National Park to use motors during the non-motor season. Sampling in October supports investigation of the possible effects of steady flows on fish habitat use and so authority to conduct the trip will be requested.

Products/Reports

Annual reports of project results will be delivered in December of each year. A final, synthetic report will be delivered by September 2012.

Budget

FY2011	$697,039
FY2012	$423,475

BIO 2.R16—Mainstem Nonnative Fish Control

Funds for mainstem nonnative fish control are to be assembled in a nonnative contingency budget to be administered by Bureau of Reclamation. The use of these funds is subject to determination of the appropriate method(s) in consultation with affected parties, development of a protocol and logistics, and award of necessary permits. The Bureau will lead these activities. GCMRC proposes the establishment of a $600,000 nonnative contingency fund in FY 2011 and an additional $300,000 in FY 2012. No specific nonnative fish control project is proposed in this work plan because the environmental compliance and tribal consultation has not been completed as this work plan is written.

BIO 2.R17.11-12—Nonnative Control Plan Science Support

Start Date

October 2009

End Date

Ongoing

Principal Investigator

K.D. Hilwig, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Colorado River ecosystem in Grand Canyon

Project Goals

This project implements components of the nonnative fish technical document developed by the Grand Canyon Monitoring and Research Center (GCMRC). This includes efforts to improve monitoring of nonnative fish in Grand Canyon and to recommend appropriate control options, if monitoring results indicate control is necessary. Monitoring improvements will initially focus on capturing nonnative fish during the fall mainstem monitoring with multiple gear types (see BIO 2.M4.11–12 Monitoring Mainstem Fish). This project includes the development of a synthesis report of nonnative fish information from monitoring and research data available in the GCMRC fish database, project reports and peer reviewed literature. Capture information provided by all fish-sampling and monitoring projects (Lees Ferry, Little Colorado River (LCR) and mainstem Colorado River) will be used to assess the presence or absence of nonnative species at various locations and the potential need for nonnative control efforts. Updates on the status and trends of nonnative fish in Grand Canyon will be presented to scientists and managers during the annual Nonnative Fish Workshop.

Specific project goals for this project are the following:

- Development of a synthesis report on nonnative fish in Grand Canyon
- Inform scientists and managers on an annual basis of nonnative fish issues in Grand Canyon

Need for Project

Nonnative fish are among the greatest threats to native fishes in western North American rivers (Miller, 1961; Minckley and Deacon, 1991; Tyus and Saunders, 2000; Coggins, 2008). Nonnative fish may threaten native fish by direct predation, by competing for available food and other resources, and by habitat modification (Minckley, 1991; Hawkins and Nesler, 1991). Nonnative fish were introduced into Grand Canyon not later than early in the 20th century (Woodbury, 1959; Valdez and Ryel, 1995). While native fish survived these initial introductions at least long enough to be described by early researchers, other system stressors, especially the modification of natural flows as a result of dam installation, appear to have increased the threats to native fish from nonnative fish (Minckley, 1991; Clarkson and Childs, 2000). As the Colorado

River mainstem becomes warmer because of climate effects (Seager and others, 2007) and the GCDAMP considers implementation of a temperature control device (TCD), the potential for an increased threat from warm water-adapted nonnative fish increases (Eaton and Scheller, 1996; Chu and others, 2005; Rahel and Olden, 2008). There is a need to improve monitoring of nonnative fish posing threats to native fish in Grand Canyon to provide managers with information to evaluate control needs. Dissemination of this information to scientists and decision makers during annual workshops is important because it will foster the use of best professional judgment to identify nonnative fish issues of concern and provide a platform for the development of a timely response.

Strategic Science Questions

Primary SSQs addressed:
SSQ 1-4. Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.
SSQ 5-6. Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance?

Information Needs Addressed

Primary information needs addressed:
CMIN 2.4.1. Determine and track the abundance and distribution of nonnative predatory fish species in the Colorado River.
RIN 2.4.1. What are the most effective strategies and control methods to limit nonnative fish predation and competition on native fish?
RIN 2.4.3. To what degree, which species, and where in the system are exotic fish a detriment to the existence of native fish through predation or competition?

Methods and Tasks

In FY2011 and FY2012, this project will include the following:

- A synthesis report summarizing historical captures and the recent status and trends of nonnative fish in Grand Canyon
- Conduct Annual Nonnative Fish Workshops

Links/Relationships to Other Projects

This project links to several ongoing projects. Nonnative fish are captured during the Monitoring Mainstem Fish Project (BIO 2.M4.11–12), the Little Colorado River Humpback Chub Monitoring Project (BIO 2.M1.11-12), the Nearshore Ecology/Fall Steady Flows Project (BIO 2.R15.11-12), and the Monitoring Lees Ferry Fish Project (BIO 4.M2.11-12). These projects gather information on all fish species captured in Grand Canyon, including the relative abundance of these species and their size distribution. Nonnative fish capture information from these projects will be assembled and presented during the annual nonnative fish workshops.

Logistics

There are no logistics requirements for this project.

Products/Reports

Synthesis report of nonnative fish information from monitoring and research data available in GCMRC fish database, project reports and peer reviewed literature will be delivered in USGS Open File Report format

Conduct nonnative fish workshops annually

Budget

FY2011 $65,204

FY2012 $63,389

BIO 2.E18.11-12: Detection of rainbow trout movement from the upper reaches of the Colorado River below Glen Canyon Dam

Start Date

November 2010

End Date

June 2012

Principal Investigators

A.S. Makinster, W. Stewart, Arizona Game and Fish Department, J. Korman, Ecometric Research, Inc., K.D. Hilwig, W.R. Persons, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Colorado River between Paria River inflow and Badger Rapid, River Mile 8

Project Goals

The goal of this project is to collect baseline information on movement of rainbow trout *Oncorhynchus mykiss* between the Paria River and Badger Rapid at River Mile 8 (PBR). This information is a necessary component of determining the potential feasibility and efficacy of removing rainbow trout in the PBR as an alternative to removal in the Little Colorado River reach of the Colorado River. Additional studies will be necessary to completely determine the feasibility and efficacy of this approach. This project is predicated on existing information (Coggins, 2008; Coggins and others, in review) that concludes that rainbow trout reared in the Lees Ferry reach of the Colorado River (Glen Canyon Dam to Lees Ferry) move out of that reach under some conditions. Our working hypothesis is that rainbow trout moving out of the Lees Ferry reach could be captured and removed from the river, thereby providing a benefit to native fish downstream by reducing predators and competitors of native fish. This project will use mark-recapture methods to estimate downstream movement of rainbow trout from the Lees Ferry reach.

Primary project objectives are to:

Estimate age stratified **downstream movement** of rainbow trout from the Lees Ferry reach to Badger Rapid

Estimate age stratified **capture probability** of rainbow trout in the Lees Ferry reach and in the reach from the Paria River to Badger Rapid

Estimate age stratified **abundance** of rainbow trout in the Lees Ferry reach and in the reach from the Paria River to Badger Rapid

If the hypothesized movement of rainbow trout out of the Lees Ferry reach, passing the mouth of the Paria River, is correct, this project will provide information about the age classes of fish that may be moving downstream. Understanding population movement characteristics is an

important first step in being able to assess the potential for successful control of rainbow trout immediately below Lees Ferry, a potential alternative to removing rainbow trout from the Little Colorado River reach as has been conducted previously. Information from this project will be integrated with ongoing monitoring of rainbow trout upstream from Lees Ferry to assess any potential correlation between rainbow trout density in the Lees Ferry reach and potential emigration out of the reach.

The most complete understanding of potential rainbow trout movement patterns is most likely achievable with multiple observations over multiple years. Based on downstream observations, Coggins (2008) predicted rainbow trout movement is seasonal, with most of the movement taking place in the fall and winter months. Additional sampling in additional years would be necessary to fully address the seasonal component of movement, as well as potential correlation with rainbow trout population sizes upstream. This project is proposed as an experimental research project to be conducted in FY 2011 and FY 2012 to increase knowledge of rainbow trout movement patterns, a necessary precursor to any attempts to act on rainbow trout movement, such as removal in the miles immediately below the mouth of the Paria River.

This project would be useful for immediately assessing potential effectiveness of rainbow trout capture and/or removal in the PBR reach, but fully determining the most effective times of the year to conduct the work will require sampling in different seasons in multiple years. Because rainbow trout density in the Lees Ferry reach is hypothesized to play a role in rainbow trout movement, it would be useful to conduct this study with various rainbow trout densities in the Lees Ferry reach. Density is relatively high in 2010 (Makinster and others, in review).

Need for Project

The risk posed to endangered humpback chub *Gila cypha* from predation by rainbow trout is an ongoing management and conservation concern (GCMRC, 2008). In part to address this risk, the 2008 Biological Opinion on the Operation of Glen Canyon Dam called for a resumption of mechanical removal in the vicinity of the Little Colorado River. However, several Native American tribes have advised that they find the large scale taking of life in Grand Canyon to be offensive. Additionally, mechanical removal of nonnative fish in the Little Colorado River reach is expensive. Because of the cultural concerns two mechanical removal trips scheduled for 2010 in GCMRC's final FY2010 Work Plan were cancelled. To partially address the cultural concerns for taking of life in Grand Canyon, and also to potentially reduce costs, GCMRC is working with Arizona Game and Fish and other agencies to investigate alternative rainbow trout control methods.

The current fish community of the Colorado River in Grand Canyon is numerically dominated by rainbow trout and brown trout *Salmo trutta* (Gloss and Coggins, 2005; Makinster and others, in review). There is a growing body of scientific literature that hypothesizes and/or demonstrates the deleterious effects of rainbow trout and brown trout on native Colorado River fishes by means of direct predation (Valdez and Ryel, 1995; Marsh and Douglas, 1997; Mueller and Marsh, 2002; Yard and others, in review), exploitative and interference competition (Minckley, 1991; Valdez and Ryel, 1995; Marsh and Douglas, 1997; Petersen and Paukert, 2005), and habitat displacement (Robinson and others, 2003). Interactions with nonnative species have been implicated as a major cause in the decline of native species in the Colorado River (Tyus and Saunders, 2000; Mueller and Marsh, 2002). Recent and historical data have shown that trends in Grand Canyon native species abundance, particularly the endangered humpback chub *Gila cypha*, declined in the 1990s, then increased 2000 - 2008 (Coggins and Walters, 2009). This pattern is inversely proportional to (i.e., the opposite of) the trend in rainbow trout catch rates in the

Colorado River below the Glen Canyon Dam (Makinster and others, in review), suggesting that large rainbow trout populations have a deleterious effect on humpback chub in Grand Canyon. The population size trends of the two species are consistent with the findings of Yard and others (in review) demonstrating that rainbow trout and brown trout eat humpback chub and other native fishes.

Concern over the decline of humpback chub in Grand Canyon in the early 2000s caused the Glen Canyon Dam Adaptive Management Program to investigate possible methods for increasing their population size. One of these methods was to use electrofishing to mechanically remove rainbow trout in the vicinity of the Little Colorado River, anticipating that this would reduce predation risk for humpback chub. This project ran for four years, 2003-2006 (Coggins, 2008; Coggins and others, in review). In 2005, the Arizona Game and Fish Department (AGFD) entered into a cooperative agreement with the GCMRC to conduct the remaining field work, data analysis, and project reporting for this experiment. The 2003-2006 mechanical removal effort reduced the proportion of nonnative fish captured in the reach from 90% in 2003 to 50% in 2006. Rainbow trout were nearly 90% of the captures in this reach in 2003, but were less than 10% of the catch in 2006 (Coggins, 2008; Coggins and others, in review).

Monitoring of rainbow trout relative abundance in 2008 and 2009 throughout the Colorado River suggests the population has rebounded to levels observed prior to the initiation of the mechanical removal project in 2003. The majority of rainbow trout in Grand Canyon occur above Lees Ferry in the relatively cooler and clearer tailwaters below Glen Canyon Dam (Gloss and Coggins, 2005). The majority of humpback chub occur in and around the Little Colorado River with only limited movement upstream (Valdez and Maslich, 1999; Paukert and others, 2006). The two species must come into contact for interactions (i.e., predation, competition) to be observed. Coggins (2008) observed changes in rainbow trout age class structures in different reaches, suggesting that most rainbow trout are spawned upstream of Lees Ferry. Coggins reached this conclusion because the majority of rainbow trout that were observed in the Little Colorado River reach 2003 – 2006 were adults, but multiple age classes were captured above Lees Ferry. Based on Coggins' (2008) observations, rainbow trout must be leaving the Lees Ferry reach, at least in some years. This project seeks to better understand rainbow trout movement patterns. If scientists and managers can develop a more complete understanding of how rainbow trout move downstream from Lees Ferry, then additional control options may become available that could be employed to restrict interactions between rainbow trout and humpback chub. This project will mark and attempt to recapture fish in the upper river to assess movement and survival of rainbow trout. Because of the interest in understanding movement patterns, the work is proposed for the Colorado River between the mouth of the Paria River (just below Lees Ferry) and Badger Rapid.

Stakeholders in the GCDAMP have expressed the need for controlling rainbow trout farther upstream from the culturally sensitive Little Colorado River inflow reach. Many alternatives are being discussed, including dam operation approaches, disrupting rainbow trout redds (nests), capturing rainbow trout for live removal, and other options. Whether one of these options or another is eventually selected, this project, together with ongoing fish monitoring in the Lees Ferry reach (see goal 4) are fundamental to all approaches. This is because scientists and managers need a better understanding of how and why rainbow trout may move below the mouth of the Paria River.

Strategic Science Questions

This project will provide preliminary information that will be necessary to answer the following strategic science questions.

SSQ 1-2. Does a decrease in the abundance of rainbow trout and other cold and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population?

SSQ 1-3. Do rainbow trout immigrate from Glen to Marble and eastern Grand Canyons, and, if so, during what life stages? To what extent do Glen Canyon immigrants support the population in Marble and eastern Grand Canyons?

SSQ 1-4. Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.

Information Needs Addressed

The primary research information needs that are informed by the project are the following.

RIN 4.2.1 What is the rate of emigration of rainbow trout from the Les Ferry reach?
RIN 4.2.2 What is the most effective method to detect emigration of rainbow trout from the Lees Ferry reach?
RIN 4.2.3 How is the rate of emigration of rainbow trout from the Lees Ferry reach to below the Paria River affected by abundance, hydrology, temperature, and other ecosystem processes?

General Methods/Tasks

We will employ multiple passes using electrofishing to capture rainbow trout from the left and right shorelines of the river in the Lees Ferry reach and between the Paria River inflow (river mile [RM] 1) and Badger Rapid (RM 8). Sampling efforts needed to complete the project objectives will be similar to efforts used during mechanical removal sampling. However, this project will differ from mechanical removal efforts in that captured rainbow trout will be tagged with individually numbered tags rather than euthanized. No fish will be purposely killed or removed in this study.

This project is a pilot effort with two field trips in FY 2011 and FY 2012 in June and November. If the project proves effective at capturing rainbow trout additional efforts would be proposed for future fiscal years. Additional trips conducted during different seasons, river conditions, and rainbow trout population sizes will all provide more basis on which to draw conclusions about the hypothesized movement of rainbow trout out of the Lees Ferry reach. Therefore, subject to the anticipated success of the pilot effort, we recommend this effort to be applied over several years. A multi-year approach will maximize our ability to evaluate movement of rainbow trout from the Lees Ferry area, the majority of which may occur during winter. Future detection of tagged rainbow trout could occur during annual Arizona Game and Fish Department Lees Ferry and river-wide monitoring surveys as well as Near Shore Ecology project sampling.

The PBR reach will be separated into two approximately 4-mile sub-reaches. Individual electrofishing stations approximately 500 m in length will be established on each side of the river within each sub-reach. We will complete a total of 3 electrofishing passes over the entire PBR reach in 6 nights of sampling and 3 passes over randomly selected subsections of the Lees Ferry reach in 3 nights of sampling. Sampling is proposed for November 2010, June and November 2011, and June 2012; sampling in future years will be dependent on outcome of the first sampling efforts and input from the Adaptive Management Program. All data will be collected at night using four 16´ sport boats outfitted for electrofishing with a Coeffelt CPS unit, with one netter and one driver per boat. The boats will apply between 350 and 500 volts and 10 to 15 amps to spherical steel electrodes. Two additional 16' inflatable sport boats will be used in the PBR reach to handle and tag fish captured during electrofishing surveys.

We will record maximum total length (TL mm) of all fish captured. Brown trout greater than 149 mm TL will be implanted with passive integrated transponder (PIT) tags and receive an adipose fin clip following standard methods. We will investigate tagging rainbow trout less than 149 mm using individually numbered Floy FD68B fingerling T-bar anchor tags. Rainbow trout and common carp greater than 149 mm TL will receive an individually numbered Floy tag and a right pelvic fin clip for rainbow trout or a dorsal spine clip for common carp. The fin clips will be used as a secondary mark to evaluate tag loss. Rainbow trout have also been marked with Floy tags since 2007 during standardized Lees Ferry electrofishing monitoring. Sampling between the Paria River and Badger Rapid may enable detection of downstream movement of those tagged fish from the Lees Ferry reach. We will record TL and fork length (FL) of all native fish captured and implant native fish greater than 149 mm TL, and humpback chub greater than 99 mm TL, with PIT tags if none were found on capture (Ward and Hangsleben, in review). All tag numbers will be recorded on hardcopy and PIT scanners will be downloaded to verify tag numbers.

Data analysis will include the following:

Estimate age stratified abundance using mark-recapture methods

Estimate age stratified capture probability using mark-recapture estimates in the LF and PBR reaches

Estimate age stratified net immigration rate (fish/day)

Estimate initial and secondary tag loss rates following the methods of Coggins (2008)

Explore association between turbidity and catchability – record daily NTU's (turbidity metric)

Estimate age stratified movement between the LF and PBR reaches and across 500 m sections within the PBR study reach among trips

The success of this project depends on our ability to mark and recapture a sufficient number of trout to draw meaningful conclusions related to capture probability, abundance, and immigration rates. For example, preliminary analyses of 2009 catch rate data suggest that we can mark approximately 2,860 rainbow trout in the study area on each trip. Assuming a capture probability of .25, we would extrapolate a population estimate of 11,440 trout in the study area. The probability of detecting a fish tagged in the study area varies with movement and survival rates, among other factors. If we assume a range of immigration or emigration, the probability of

detecting a marked fish is relatively low (see Table, below). As more fish are marked in the Lees Ferry reach the probability of detecting movement from the Lees Ferry reach to the Paria/Badger reach will increase approximately 25%.

Table 4

Modeled probability of detecting a fish in the PBR Reach that was Floy tagged in the Lees Ferry reach.

Downstream Emigration rate scenarios	Single pass detection probability in PBR Reach	Single pass detection probability in LCR Reach during mainstem monitoring
0.025	0.005	0.020
0.05	0.01	0.041
0.1	0.02	0.082
0.5	0.1	0.41

Links/Relationships to Other Projects

The work proposed in this project is closely linked with rainbow trout monitoring in the Lees Ferry reach because of the hypothesized linkage of rainbow trout movement to density of this species in the Lees Ferry reach. Because of the effect of rainbow trout on humpback chub there is a close linkage of this project to the status and trends of humpback chub.

Products/Reports

Standard trip report within 30 days of completion of each trip with summary statistics and preliminary analysis

Draft annual report with full analysis by September 30, 2012

Data delivered in standard USGS annual report format

Final report in USGS Open File Report format by December 1, 2012

Budget

FY2011 $437,201

FY2012 $459,061

BIO 2.R19.11-12—Biometrics and General Analysis

Start Date

2010

End Date

Ongoing

Principal Investigator

Statistician, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Associated projects within the Colorado River ecosystem

Project Goals

The primary goal of the GCMRC Biometrics position is to provide necessary and relevant statistical and modeling support in planning and analyzing science projects conducted or supported by GCMRC and the AMP. Additionally, the GCMRC biometrician will conduct focused research in areas such as model development and analytical techniques to further the science capability of the GCMRC.

Need for Project

GCMRC has identified the need for greater technical oversight and rigor with regard to study planning and analysis of some AMP sponsored projects. This need includes both projects conducted primarily by GCMRC staff and cooperating scientists. To meet this need GCMRC will employ a staff biometrician whose role will be to provide analysis and modeling support for AMP sponsored projects, particularly in the biological discipline. As needed, this support will focus primarily in assisting in the development and review of research and study plans as well as data analysis and modeling. Additionally, GCMRC recognizes the need to provide additional training opportunities in analytical techniques for GCMRC staff and cooperating scientists. The biometrician position will support this need by conducting workshops (4-5 days) on topics relevant to current statistical and modeling challenges faced by GCMRC staff and cooperating scientists. Recently identified topics include: basic probability models and likelihood based inference, occupancy rate estimation, capture-recapture models, hierarchical Bayes modeling, simulation techniques to inform study design, and ecosystem modeling using Ecopath/Ecosim models. This position will be the lead for updates of the Age-Structured Mark-Recapture model, and/or other models, to estimate the adult humpback chub population.

Strategic Science Questions

This project is a primary support project that provides study design and data analysis guidance to the projects, so provides secondary support to a number of SSQs. The role of the biometrician is to support GCMRC and cooperating scientists in developing greater certainty about their study designs and results, so it is anticipated that many SSQs will be addressed in this and future years. For example, the primary SSQs this project will support is:

SSQ 1-1: To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the main stem, survival of young-of-year and juvenile stages in the main stem, or by changes in growth and maturation in the adult population as influenced by main stem conditions?

SSQ 1-2. Does a decrease in the abundance of rainbow trout and other cold- and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile HBC to the adult population?

Information Needs Addressed

This project is a primary support project that provides study design and data analysis guidance to the projects, so provides secondary support to a number of information needs. As an example of the RINs most directly addressed by this project, in FY2010 task 1 below will support modeling to investigate patterns in native and nonnative fish population abundance and distribution allowing for comparison with various environmental factors. Other RINs about fish responses to environmental conditions that can be partially addressed with this modeling effort include the following:

RIN 2.2.8. What combination of dam release patterns and nonnative fish control facilitates successful spawning and recruitment of humpback chub in the Colorado River ecosystem?
RIN 2.4.2. Determine if suppression of nonnative predators and competitors increases native fish populations.

Methods and Tasks

Anticipated tasks for this project during FY2011 include:

Conduct ASMR population estimate of adult humpback chub (see BIO 2.R7.11)
Assist in the continued development of Ecopath/Ecosim models for key reaches of the Colorado River associated with project PLAN 12.P1.10.

Assist GCMRC fisheries biologist, cooperating scientists, and the biology program manager in evaluating implications to the ability to detect changes in fisheries resources associated with recommended changes to the fisheries monitoring program by the 2009 Fisheries Monitoring Protocol Evaluation Panel.

Assist Arizona Game and Fish Department cooperating scientists in analyzing fisheries mechanical removal data from project BIO 2.R17.10. This effort may employ hierarchical Bayes depletion models.

Assist in study planning and analysis of PIT tag data collected from project BIO 2.R13.10.

Assist with study design and analysis of fish capture-recapture data from the Nearshore Ecology Project (BIO 2.R15.10) to estimate fish abundance and occupancy rate among various habitat types.

Assist with analysis of terrestrial, aquatic food base, or other data from AMP sponsored projects as needed.

Conduct two or three approximately 5-day workshops on the following or related topics: basic probability models and likelihood-based inference, occupancy-rate estimation, capture-recapture models, hierarchical Bayes modeling, simulation techniques to inform study design, and ecosystem modeling using Ecopath/Ecosim models.

Anticipated tasks for this project during FY2012 include:

Assist in the continued development of Ecopath/Ecosim models for key reaches of the Colorado River associated with project PLAN 12.P1.11.

Assist Arizona Game and Fish Department cooperating scientists in analyzing fisheries mechanical removal data from project BIO 2.R17.10. This effort may employ hierarchical Bayes depletion models.

Assist in study planning and analysis of PIT tag data collected from project BIO 2.R13.10.

Assist with study design and analysis of fish capture-recapture data from the Nearshore Ecology Project (BIO 2.R15.11) to estimate fish abundance and occupancy rate among various habitat types.

Assist with analysis of terrestrial, food base, or other data from AMP sponsored projects as needed.

Conduct two or three approximately 5 day workshops on the following or related topics: basic probability models and likelihood-based inference, occupancy-rate estimation, capture-recapture models, hierarchical Bayes modeling, simulation techniques to inform study design, and ecosystem modeling using Ecopath/Ecosim models.

Links/Relationships to Other Projects

This project is primarily a support project to the projects listed above.

Logistics

There are no logistical needs for this project.

Products/Reports

This project will contribute to and co-author, as appropriate, reports and manuscripts associated with the tasks above and other projects associated with Goals 1, 2, 4, and others as needed.

Budget

FY2011 $149,627

FY2012 $157,089

GCDAMP Goal 4. Maintain a naturally reproducing population of rainbow trout above the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish.

BIO 4.M2.11-12—Monitoring Lees Ferry Fish

Start Date

2010

End Date

Ongoing

Principal Investigator

A.S. Makinster, Arizona Game and Fish Department, K.D. Hilwig, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Colorado River from Glen Canyon Dam (GCD) to Lees Ferry

Project Goals

The goals of this project are as follows:

Monitor the rainbow trout recreational fishery between Glen Canyon Dam and the Paria River

Monitor rainbow trout redds and early life stages to support assessment of experimental flow releases from Glen Canyon Dam

Monitor for presence or absence of other nonnative fish in this reach

Rainbow trout

Operation of Glen Canyon Dam affects the ecology of rainbow trout and the aquatic food base in the Lees Ferry reach (McKinney and others, 1999, 2001). The Lees Ferry recreational fishery was recognized as a resource of concern in the *Operation of Glen Canyon Dam Final Environmental Impact Statement* (U.S. Department of the Interior (DOI), 1995), which concluded: "Glen Canyon Dam Adaptive Management Program (GCDAMP) goals for the trout fishery are to provide a recreational resource while maintaining and conserving native fish in Grand Canyon". Components of this project provide monitoring information, such as relative

abundance, recruitment, survival, growth and condition, to evaluate the influence of GCD operations, including experimental flows, on the Lees Ferry rainbow trout.

The recreational fishery and early life stage monitoring components of this project were reviewed by the 2009 PEP for Grand Canyon Fishes. The panel recommended that it was not cost effective or necessary to conduct multiple recreational fishery monitoring trips each year. Rather, the panel recommended a single electrofishing trip at randomized sites each year to physically observe the adult population and perhaps to tag fish, if tagging was desired for more data collection. The panel also did not recommend maintaining the monitoring of early life stages of rainbow trout that has been conducted for 5 of the last 7 years. Analysis of long-term data sets for these two components will be completed in FY2010 to determine impacts of the recommended reduction in effort on the ability to monitor management objectives. In the interim, these monitoring techniques may be useful for studying the response of the rainbow trout to experimental dam releases.

Warm water nonnative fish

The 2009 PEP for Grand Canyon Fishes also recognized the importance of sampling other fish in the Lees Ferry reach. Lees Ferry is an area where nonnative species introductions likely occur as a result of illegal stocking, movement from Lake Powell through Glen Canyon Dam and from the Paria River. The introduction of fish species into Lees Ferry is a concern because nonnative species that are introduced or become established in this reach can then disperse throughout the river system below Glen Canyon Dam. The panel suggested that at least one surveillance trip be conducted annually to focus on known or suspected warm water nonnative fish concentrations. Information from tagging warm water species, such as growth and movement, will help inform fish management decisions.

Need for Project

Rainbow trout

The Arizona Game and Fish Department (AZGFD) has managed the Lees Ferry recreational fishery since 1964. Lees Ferry serves as a popular destination fishery for international, national, and local anglers. As such, it provides significant contributions to the Marble Canyon business community. The fishery is regulated by biotic and abiotic mechanisms that may in turn be affected by the operations of GCD. The monitoring of basic fish population elements, including relative abundance, distribution and recruitment of native and nonnative fish, provides the information necessary to assess the status of these resources and to inform the GCDAMP.

Warm water nonnative fish

Nonnative fish are among the greatest threats to native fishes in western North American rivers (Miller, 1961; Minckley and Deacon, 1991; Tyus and Saunders, 2000; Coggins, 2008). Nonnative fish may threaten native fish by direct predation, by competing for available food and other resources, and by habitat modification (Minckley, 1991; Hawkins and Nesler, 1991). Nonnative fish were introduced into Grand Canyon not later than early in the 20th century (Woodbury, 1959; Valdez and Ryel, 1995). While native fish survived these initial introductions at least long enough to be described by early researchers, other system stressors, especially the modification of natural flows as a result of dam installation, appear to have increased the threats

to native fish from nonnative fish (Minckley, 1991; Clarkson and Childs, 2000). Surveillance of suspected or known concentrations of warm water nonnative fish in Lees Ferry will help identify nonnative fish issues of management concern and tagging efforts may provide information on movement of nonnative fish captured in Lees Ferry into downstream reaches.

Strategic Science Questions

Primary SSQ addressed:

SSQ 3-6. What GCD operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability?

This project also seeks to inform the following SSQs:

SSQ 1-3. Do rainbow trout immigrate from Glen to Marble and eastern Grand Canyons, and, if so, during what life stages? To what extent do Glen Canyon immigrants support the population in Marble and eastern Grand Canyon?

SSQ 5-6. Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance?

Information Needs Addressed

Information needs are the basis for developing and implementing the long-term strategic and annual monitoring and research programs. Identified below are the current information needs pertinent to the monitoring plan for the Lees Ferry Glen Canyon trout fishery.

Rainbow trout information needs addressed:

CMIN 4.1.1. Determine annual population estimates for age 2+ rainbow trout in the Lees Ferry reach

CMIN 4.1.2. Determine annual proportional stock density of rainbow trout in the Lees Ferry reach.

CMIN 4.1.4. Determine annual growth rate, standard condition (Kn), and relative weight of rainbow trout in the Lees Ferry reach.

RIN 4.1.1. What is the target proportional stock density (that is, tradeoff between numbers and size) for rainbow trout in the Lees Ferry reach?

Other nonnative fish information needs addressed:

CMIN 2.4.1. Determine and track the abundance and distribution of nonnative predatory fish species in the Colorado River.

RIN 2.4.1. What are the most effective strategies and control methods to limit nonnative fish predation and competition on native fish?

Methods and Tasks

Lees Ferry Electrofishing Monitoring

Starting in FY2010, adult rainbow trout monitoring was reduced from 3-4 times per year to twice a year using standardized random electrofishing samples. This is consistent with the 2009 PEP recommendations. Information from these samples is used to estimate biological parameters and to assess the status and trends of the fishery. The sampling design, methods, and analyses provide sufficient information on the relative abundance, size composition, and condition of the fish community in the Lees Ferry to detect population trends and to precisely estimate status of the rainbow trout population (Urquhart and others, 1998). Fish specimens are also collected annually for whirling disease examination. Work is currently underway to assess the statistical power of intra- and inter-annual comparisons. Data from this project are also used in a Lees Ferry rainbow trout stock-assessment model which will be updated and revised as needed.

The 2009 PEP stated that assessing abundance using catch-rate indices is a suitable surrogate for indexing abundance if catchability is proportional to population density. Project BIO 2.E18.11-12 will help determine if catchability is proportional to population density. If managers require an actual annual population estimate, rather than the catch-rate index currently used, modification of the project will be necessary.

Early Life History Monitoring

In FY2011–12, the AZGFD will conduct four rainbow trout early life history trips annually and work cooperatively with Ecometric Research, Inc. to transfer the age-0 and redd survey techniques and data analysis for this project from the contractor to the agency. AZGFD will be completely responsible for the conduct of any early life stage monitoring that may be necessary in FY2012 and beyond. Surveys of rainbow trout redd and early life stages of rainbow trout in the Lees Ferry reach have been conducted for the last 7 years by Ecometric Research, Inc. These studies have been useful in evaluating dam operations on rainbow trout recruitment and this work will be maintained for FY2011–12 to evaluate the effect of fall steady flows on rainbow trout. Flow treatments to manage rainbow trout recruitment in Lees Ferry could be effectively evaluated through this project and include fluctuating flows targeting young-of-year rainbow trout and stranding flows (Gloss and Coggins, 2005).

Warm-water Nonnative Fish Monitoring

Consistent with the recommendations of the 2009 PEP for Grand Canyon Fishes, this project will conduct annual surveillance trips in Lees Ferry at warm water nonnative fish concentrations. Sampling locations will include areas such as the warm slough (RM -12) and warm spring inputs. Common carp captured during this effort will be tagged and other warm water nonnative fish will be harvested for otolith analysis to evaluate age and growth and possibly origin if microchemistry tools are available (see BIO 2.R15.11-12, Near Shore Ecology). Surveys will be combined with other field efforts to reduce logistics costs. Tagging information from this survey may provide information on movement of nonnative fish captured in Lees Ferry into downstream reaches.

Links/Relationships to Other Projects

This project links to Monitoring Mainstem Fish (BIO 2.M4.11-12), Near Shore Ecology (BIO 2.R15.11-12), Mainstem Nonnative Fish Control (BIO 2.R16.11-12, if conducted) and Detection of rainbow trout movement from the upper reaches of the Colorado River below Glen

Canyon Dam (BIO 2.E18.11-12) projects. Understanding factors affecting rainbow trout and warm water nonnative fish populations is important for evaluating the risk that these species may pose to young humpback chub in the Little Colorado River reach. With the recent increase in catch rates of age-1 rainbow trout, monitoring the status and trends of rainbow trout in Lees Ferry and the mainstem Colorado River will be important to evaluate movement of rainbow trout into downstream reaches.

Logistics

This project will include annual trips as follows:
Two annual standardized random electrofishing surveys
Four annual early life history trips (may extend below Paria River)
One annual nonnative surveillance trip (may extend below Paria River)
All trips are motor supported, launching from, and returning to, Lees Ferry just upstream of the mouth of the Paria River.

Products/Reports

The AZGFD will deliver one annual report on the results of their Lees Ferry monitoring (rainbow trout fishery and early life history data) to the GCMRC

A Lees Ferry Monitoring annual report will be prepared by AZGFD and Ecometric in cooperation with the GCMRC in USGS Open File Report following USGS Fundamental Science Practices

GCMRC will develop an annual report summarizing warm water nonnative fish surveillance trip findings

Budget

FY 2011 $216,846

FY 2012 $226,552

GCDAMP Goal 5—Maintain or attain viable populations of Kanab ambersnail.

BIO 5.R1.11—Monitor Kanab Ambersnail

Start Date

April 2007

End Date

September 2012

Principal Investigator

J.A. Sorensen, Arizona Game and Fish Department

Geographic Scope

Vaseys Paradise, located 31.5 river miles (RM) downstream of Lees Ferry

Project Goals

This project is proposed for FY2011–12. The goals of this project are to determine the extent and kind of vegetation that exists as habitat for the Kanab ambersnail (KAS) and to track the abundance and distribution of KAS at Vaseys Paradise.

Need for Project

Knowing the extent of habitat is needed in the event of a high flow experiment to develop a biological opinion and to determine snail densities. Changes in snail numbers can be associated with changes in vegetation. Vegetation monitoring at Vaseys Paradise indirectly monitors the snails by assuming that if the preferred habitat is present, snails are present. Total habitat can be measured using remote methods, but the composition of the habitat may still require on-the-ground sampling. Sampling at Vaseys Paradise can also provide data for Glen Canyon Dam Adaptive Management Program (GCDAMP) goal 6, which refers to the protection and improvement of riparian and spring communities.

The KAS is a federally listed endangered species; however, the legal status is under review by U.S. Fish and Wildlife Service (USFWS). Conducting this project in FY2011 and FY2012 permits consistent surveying during the review period. If it is determined that the KAS no longer merits an endangered species listing, the GCDAMP will need to consider the extent of its support for monitoring this taxon.

Strategic Science Questions

There are no directly related SSQs associated with the goal of maintaining or attaining viable KAS populations.

Information Needs Addressed

Primary information needs addressed:

CMIN 5.1.1. Determine and track the abundance and distribution of Kanab ambersnail at Vaseys Paradise in the lower zone (below 100,000 cfs) and the upper zone (above 100,000 cfs).

CMIN 5.2.1. Determine and track the size and composition of habitat used by Kanab ambersnail at Vaseys Paradise.

Methods and Tasks

Determine percent cover, diversity, and distribution of vegetation that constitutes KAS habitat. Random samples of habitat document percent cover, plant height of dominant plants, and soil moisture. Quantify total habitat and plots using conventional survey methods. The Grand Canyon Monitoring and Research Center (GCMRC) survey department calculates habitat area. Data are analyzed using univariate and multivariate approaches. This project will:

- Monitor relocated vegetation associated with high-flow experimental conservation measures
- Sample vegetation plots at Vaseys Paradise to determine patch composition and areal extent (fall of each year) and sample for the presence of KAS in plots
- Enter data and conduct quality control on data entry, providing the data to the GCMRC for vegetation analysis
- Compare previous vegetation composition to previous vegetation/habitat surveys to assess habitat
- Provide abundance estimates of snails
- Write reports for the GCMRC during the winter of each year

Links/Relationships to Other Projects

Riparian vegetation, including vegetation at springs, is a critical interface between aquatic and terrestrial environments around the world. There are multiple components that riparian and spring communities either contribute to or influence (for example, food base and available habitat). In the Colorado River ecosystem, the spring vegetation itself serves as a host for invertebrates like KAS, provides breeding and foraging habitat for small mammals and birds, provides cover in the heat of the day, and provides spring water that may be used for ceremonial purposes. Changes in the composition or structure of riparian spring communities, such as the expansion of an exotic species, may alter these interactions. Riparian and spring vegetation regulates nutrient exchange between the land and water, and leaf litter is a terrestrial carbon source that may influence in-stream invertebrate production. The relative importance of terrestrial carbon in the aquatic food web is being addressed in part through the Aquatic Food Base Project (BIO 1.M1.11-12). Studies that focus on terrestrial productivity and processes further define this linkage.

Logistics

The survey work described for this project requires two scientists to have a full day at Vaseys Paradise in the fall. This work is conducted in conjunction with fall fish monitoring effort (BIO 2.M4.11-12) led by the GCMRC.

Products/Reports

The AZGFD will produce an annual report for KAS habitat and density estimates by Arizona Game by December 15 of each year.

High Flow Experiment Compliance Needs

In the event of a high-flow experiment, the Arizona Game and Fish Department can conduct necessary onsite monitoring and compliance at Vaseys Paradise (VP), Grand Canyon, to meet legal and regulatory requirements for the endangered Kanab ambersnail—in coordination with the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, and/or National Park Service. Compliance and mitigation efforts will follow stipulations outlined in the most recent Biological Opinion regarding the operation of Glen Canyon Dam and its effects on the Kanab ambersnail population and habitat at VP. The methods repeat those used from the November 2004 high flow habitat mitigation effort for VP KAS habitat (referenced in the December 6, 2002 Biological Opinion, which proposes the temporary removal and replacement of 25%−40% of ambersnail habitat). Additional costs would be approximately $16,400

Logistics is coordinated with gaging work that takes place at 30 mile during the experiment.

Budget

FY2011	$20,637
FY2012	$21,470

GCDAMP Goal 6—Protect or improve the biotic riparian and spring communities, including threatened and endangered species and their critical habitat.

BIO 6.M1.11-12 —Vegetation Mapping

BIO 6.M2.11-12—Vegetation Transects

Start Date

October 2009

End Date

Ongoing

Principal Investigators

B.E. Ralston, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, and other cooperators, to be determined

Geographic Scope

The geographic extent is the riparian zone, including the old high-water zone (OHWZ; >97,000 cubic feet per second (cfs)), in the Colorado River corridor from Glen Canyon Dam to Lake Mead.

Project Goals

Quantifying the extent of total riparian vegetation along the corridor and among hydrologic and geomorphic features (for example, debris fans, and old high water zones), including change detection

Separating effects of Glen Canyon Dam (GCD) operations on vegetation cover, richness, and diversity from local climate effects or other non-dam related agents (for example, tamarisk leaf beetle defoliation).

Analyzing remotely sensed data (collected every 4-years) and mapping vegetated area for the corridor achieves the first goal. Biennial sampling of vegetation across stage elevations and among geomorphic features throughout the corridor achieves the second goal. Mapping and transect sampling evaluate vegetation change at both the landscape scale and the community scale over time and distinguishes between operational effects and other factors affecting vegetation change. The protection or improvement of riparian and spring communities is the objective of goal 6. Dam operations, over time, result in an ebb and flow of vegetation expansion, with vegetated area generally increasing (Turner and Karpiscak, 1980; Waring, 1995; Ralston and others, 2008). The increase in vegetation contributes to above ground primary productivity, arthropod densities, and associated food resources for terrestrial and aquatic vertebrates. Riparian

and spring environments provide habitat for the endangered species Southwestern willow flycatcher (*Empidonax traillii extimus*) and support other species of interest (for example, warblers, peregrine falcons, lizards, and snakes). Vegetation expansion affects recreational resources by encroachment into camping area. Some of the vegetation is also culturally important. Because riparian vegetation is linked to multiple resources, knowing how vegetation is changing through monitoring (for example, which species are expanding or declining and where) is an important source of data when monitoring the effect of dam operations.

Addressing the Adaptive Management Work Group (AMWG) information needs associated with riparian vegetation requires system wide assessment of vegetation change at the broad scale (for example, vegetation mapping) and at the local scale (stage-elevation transect sampling). Accounting for vegetated area in the river corridor is a basic need of the program. It is equally important to note the number and types of plants that make up the vegetated area and identify changes in these variables over time. Riparian systems are highly susceptible to exotic species introductions (Nilsson and Jansson, 1995). A most recent introduction to the riparian system is the tamarisk leaf beetle (*Diorhabda elongata)*. The leaf beetle, a biocontrol agent for tamarisk, eats tamarisk leaves and reduces the trees' ability to photosynthesize. Tamarisk cover provides habitat for nesting birds and some food resources. A reduction in tamarisk cover may affect both nesting birds and food quality. Because riparian vegetation contributes to aquatic productivity (Naiman and others, 2005) and serves as a host to terrestrial invertebrates and higher order vertebrates (for example, lizards and birds), assessing the quality of these plants can help explain changes observed in higher order vertebrate abundances, including fish species (Nakano and Murakami, 2001).

Stage-elevation based transects can assess how operations inhibit or encourage invasive species colonization and expansion. Changes in invasive, herbaceous plants cannot be determined through remote-sensing techniques because the scale is too small for image resolution. Monitoring changes in the composition of vegetation requires on-the-ground sampling. Remotely sensed data can assess changes in overstory woody species, including tamarisk cover, that change more slowly. The two projects are complementary because they provide information about changes in riparian habitat at different ecological scales that affect riparian community constituents like invertebrate biomass and riparian bird abundances.

Strategic Science Questions

Primary SSQs addressed:

SSQ 2-1. Do dam-controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?

SSQ 4-2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possible mortality of young humpback chub) associated with high flows?

SSQ 5-7. How do warmer releases affect viability and productivity of native/nonnative vegetation?

Information Needs Addressed

The primary information needs addressed by these projects are CMINs 6.1.1., 6.2.1, 6.5.1, and 6.6.1, which are summarized as the following:

- Determine and track the abundance, composition, distribution, and area of terrestrial native and nonnative vegetation species in the CRE
- Determine parameters and metrics to be measured, and the information needs that address each element
- Determine how the abundance, composition, and distribution of the OHWZ, NHWZ, and sand beach community have changed since dam closure (1963), high flows (1984), interim flows (1991), and the implementation of ROD operations (RIN 6.2.1, 6.3.1, 6.4.1, 6.5.1, 6.5.2, 6.5.3)

These information needs will be addressed through the following actions:

- Quadrennial color infrared digital imagery mapping that quantifies (1) area change of dominant overstory species, (2) community composition and possibly changes in understory community composition through ground truthing associated with mapping, and (3) coarse primary productivity estimates for riparian vegetation.
- Vegetation transects conducted at an appropriate frequency correlated with river stage elevations zones to quantify cover, richness, and diversity, and community composition at each zone. This work is most informative for herbaceous annuals and perennials, including invasive species. This component may incorporate marsh-monitoring needs of Tribes.

Methods and Tasks

Vegetation Mapping

Vegetation community identification in the field will be conducted using the 50 m² plot data obtained from the vegetation transect monitoring. In these plots, the presence and cover values of the species are recorded. Cover values are a categorical scale similar to Daubenmire scale (<1% cover; 1-5% cover; 5-25% cover; 25-50% cover; 50-75% cover; 75-95% cover; >95% cover). Plant height of the dominant species is also recorded. Transect samples are stratified within geomorphic reach, and include geomorphic features (for example, debris fans, sandbars, and channel margins). These data are analyzed using nonmetric multidimensional scaling (McCune and Grace, 2002), per the 2007 PEP recommendations (Cooper and others, 2008) to identify the dominant communities along the river corridor. Classification follows the National Vegetation Classification System. Field efforts include initial vegetation sampling to identify vegetation classes that is coincident with the quadrennial overflight. Subsequent accuracy assessment occurs the year following data acquisition and analysis and is coincident with vegetation transect sampling.

Vegetation classification will use supervised classification routines that are available in an image-processing software package ENVI (ITT, 2005). Training areas will use previously ground-truthed areas. Previous class categories include tamarisk, *seepwillow/coyote willow*, marsh/wetlands, mesquite/acacia, arrowweed, and bare ground (Ralston and others, 2008). User and producer accuracies will be determined and class aggregation may be required to meet national vegetation-mapping standards. The 2009 overflight data and subsequent overflight data will be compared with previously mapped imagery (for example, 2005 and 2002) for vegetation area change-detection purposes.

Quantification of changes in riparian communities will use a Geographic Information Systems (GIS) platform (ArcMap; Environmental Systems Research Institute, 2002).

The following tasks are designed to reach the goal for vegetation mapping in FY2011 and FY2012:

- FY2011 Determine the capabilities of the 2009 imagery for vegetation classification (FY2011)
- FY2011 Identify community types from 2009 field samples (FY2011)
- FY2011 Use 2002 and 2005 vegetation data to compare total vegetation change (FY2011)
- FY2011 Develop draft report of community change and accuracy assessment based on May 2009 ground-truth data (FY2011)
- FY2012 Compare revised vegetation map to 2002 vegetation map (Ralston and others, 2008) to determine area change for vegetation classes. Write draft report

Vegetation Transects

A biennial, canyon-wide, stratified sampling approach tied to hydrologic zones and geomorphic features will be used for the vegetation transect work, following the PEP recommendations (Cooper and others, 2008). Plots will be approximately 50 m² in size to ensure comprehensive sampling of species found within a hydrologic zone. Zones encompass a range of stage elevations: 8–20k cfs, 20–31k cfs, 31–45k cfs, and >45k cfs. The first two zones are generally affected by annual dam operations and the last two zones are affected by local climate factors or an HFE experiment (Kearsley and Ayers, 1999; Ralston, 2010). Geomorphic features sampled include debris fans, sandbar eddies, and channel margins. Each of these features can consist of somewhat different riparian species assemblages (Stevens and Ayers, 1995).

At each sampling plot and within each hydrologic zone a list of species encountered and cover value is given using a categorical scale of cover. These data are included in the univariate measures (cover, richness, diversity) and in developing community descriptions for vegetation mapping purposes.

The biennial sampling schedule coincides with vegetation mapping overflights and accuracy assessments that occur on a biennial basis. In the event of a HFE, transects will be conducted around the event to supplement monitoring as per the PEP recommendations (Cooper and others, 2008).

Possible Additional High Flow Experiment Support

In the event that a high flow experiment occurs in a year that is not coincident with biennial sampling, an additional trip in September will be required to asses vegetation change following the HFE event, assuming the HFE occurs in the spring and the hydrograph is similar to previous hydrographs. For example, vegetation transect sampling is anticipated to occur in September 2011 and an HFE occurring in spring 2011 would not require an additional trip. An HFE occurring in 2012 would require a trip in September 2012 that is not currently scheduled. The cost of the additional trip would be the cost of a 4-boat row trip (30,000) and a field crew ($17,000), beyond the salary costs of Ralston.

Links/Relationships to Other Projects

Riparian vegetation is a critical interface between aquatic and terrestrial environments around the world. In the CRE, the vegetation itself serves as a host for invertebrates, provides breeding and foraging habitat for birds, provides cover in the heat of the day, and may be harvested for cultural purposes. Changes in the composition or structure of riparian vegetation, such as the expansion of an exotic species, may alter these interactions. Riparian vegetation regulates nutrient exchange between the land and water, and leaf litter is a terrestrial carbon source that may influence in-stream invertebrate production. The relative importance of terrestrial carbon in the aquatic food web is being addressed in part through the food base initiative. The linkage could be further defined through studies that focus on terrestrial productivity and processes. Changes in abundance or kind of riparian carbon sources may influence aquatic productivity processes.

Logistics

Logistics for Vegetation Transect sampling require a 4-boat oar trip or a single snout and sport boat trip in September 2011. These projects will produce the following and will be reported on at the annual reporting meeting:

FY2011 Status report of vegetation mapping and transect sampling
FY2011 Species list by hydrologic zone of plant encountered in sampling conducted in May 2009
FY2012 USGS draft report on vegetation change from 2002 to 2009
FY2012 update the vegetation base layer for GIS
FY2012 A core-monitoring report for vegetation transect monitoring

Budget – BIO 6.M1

FY2011 $86,763

FY2012 $62,242

Budget – BIO 6.M2

FY2011 $153,203

FY2012 $94.997

GCDAMP Goal 7—Establish water temperature, quality, and flow dynamics to achieve the Adaptive Management Program ecosystem goals.

BIO 7.R1.11–12—Water-quality Monitoring of Lake Powell and the Glen Canyon Dam Tailwater

Start Date

1991

End Date

Ongoing

Principal Investigator

William S. Vernieu, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Lake Powell and its major tributary arms, inflow tributaries entering Lake Powell, and the tailwater from Glen Canyon Dam to Lees Ferry

Project Goals

This project seeks to

- maintain a water-quality monitoring program for Lake Powell to predict and track processes in the reservoir that may influence Glen Canyon Dam (GCD) release water quality;
- maintain water-quality monitoring in tailwater to directly evaluate the quality of GCD releases, the effects of GCD operations, and suitability for downstream aquatic resources;
- contribute to ongoing modeling efforts by the Bureau of Reclamation (Reclamation), currently the CE-QUAL-W2 model, to predict future changes in the water quality of Lake Powell and GCD releases by simulating the effects of various proposed and hypothetical climate, experimental, and operational scenarios; and guide future monitoring program revisions;
- compile and publish biological information from the long-term database of Lake Powell water-quality information and provide further interpretation, synthesis, and analysis of this and previously published chemical and physical data;
- implement a revised monitoring program in conjunction with development of the CE-QUAL-W2 model and historical data analysis; and
- conduct a protocol evaluation panel (PEP) review of the monitoring program to ensure scientific credibility and adequate linkages with other downstream resources.

Need for Project

Processes within Lake Powell, climate changes in the upper Colorado River Basin, the structure of GCD, and various aspects of dam operations affect the quality of water released from GCD to the Colorado River in Grand Canyon. Temperature, dissolved oxygen concentrations, nutrient concentrations, biological composition, and other characteristics of GCD releases can have a profound effect on the aquatic ecosystem below the dam.

Since 1999, inflow to Lake Powell has been below average in every year except water years (WY) 2005 and 2008. The 5-year period of below-normal inflows in the upper Colorado River Basin from 2000 to 2004 resulted in a drawdown of Lake Powell by more than 140 ft, decreasing total capacity of the reservoir to 38 percent. The increasing influence of Lake Powell surface layers on GCD releases caused warmer release temperatures, decreased release nutrient concentrations, and increased the export of aquatic biota from Lake Powell. The lower level of warm surface layers in relation to withdrawal levels at the penstock resulted in above normal late summer release temperatures from WY2003 to WY2007. Release temperatures of 16°C were recorded in October 2005, representing the warmest releases since 1971. Resuspension of exposed deltaic sediments from reservoir drawdown by WY2005 inflow currents resulted in a plume of hypoxic water that appeared at GCD and began to be incorporated in dam releases in July 2005. As a result, dam releases contained the lowest concentrations of dissolved oxygen on record, only 3.3 milligrams per liter in October 2005. Changes to individual turbine operations at GCD in September and October 2005 were shown to have a significant impact on the reaeration of hypoxic releases.

Differential routing of winter inflow currents can cause longer term changes to the water quality of Lake Powell and eventual dam releases. For the period WY2000–07, with the exception of WY2006, winter underflow density currents moved along the bottom of the reservoir and refreshed oxygen concentrations in the deepest layers of Lake Powell, displacing older hypolimnetic water upward to be entrained in penstock releases. In contrast, from WY1994 to WY1999 and during other periods in Lake Powell's history, winter density currents moved through the reservoir in intermediate layers as an interflow, which caused stagnation and a reduction of dissolved oxygen concentrations in the deepest hypolimnetic water of the reservoir. This interflow pattern again appeared in WY2006. Exceptionally cold winter inflows caused an underflow in January 2007, increasing hypolimnetic density and increasing the likelihood of future interflow conditions, which may cause reductions in hypolimnetic dissolved oxygen in future years. A weak underflow current was observed in early WY2008, but was absent in WY2009.

Since 2007, the western United States has experienced a rapid invasion of the nonnative quagga (*Dreissena rostriformis bugensis*) and zebra mussel (*Dreissena polymorpha*) and has been found in several Colorado River reservoirs above and below Lake Powell. These mussels have the potential to drastically alter reservoir and lake ecosystems and as yet, have not been documented in Lake Powell. Zooplankton and phytoplankton sampling at Lake Powell has been conducted since 1990. The analyses from these samples forms a rich database from which to establish a pre-invasion baseline at Lake Powell and evaluate changes to the ecosystem if these mussels become established at Lake Powell.

The Grand Canyon Monitoring and Research Center (GCMRC) works in cooperation with Reclamation on the development of the CE-QUAL-W2 model by providing monitoring data to be used for model calibration and verification. This monitoring data consists of information describing the quality of water in GCD releases, Lake Powell, and tributary inflows into Lake

Powell. In addition, the GCMRC provides comments on the direction of model development so that a product can be developed that meets the needs of both Reclamation and the Glen Canyon Dam Adaptive Management Program (GCDAMP). A functional model is expected to provide reliable simulations of hydrodynamic processes and water-quality conditions in the reservoir, including validation with historical observations. It is also expected to provide reasonable predictions of these processes and conditions under various projected and hypothetical operational and climatological scenarios. Comparison of these predictions with monitoring observations may help to verify or refute the sensitivity of the model to various input factors. Beyond simulations of historical and future conditions, many questions may be posed that could be addressed by a well-constructed and calibrated model. It is likely that GCMRC, Reclamation, and other parties will have different priorities and research interests for questions to be addressed by the model. A functional, calibrated model with a common set of input files would provide a common basis from which the research needs of these various entities could be met.

As model development progresses, many components of the water-quality monitoring program and Lake Powell data synthesis can be facilitated with results from the model, such as identifying parameters for which the model is more or less sensitive and restructuring monitoring efforts appropriately. Results can be used to identify the need for more detailed inflow water-quality monitoring, establish and maintain additional meteorological stations at the reservoir, and modify sampling methods and frequency for biological parameters such as chlorophyll and plankton, in order to refine the model's ability to simulate productivity processes in the reservoir.

Strategic Science Questions

While the 2005 knowledge assessment workshop specified many SSQs addressing the effects of water quality on various resources (sediment, food base, fisheries, recreation), no SSQs were proposed that dealt directly with tracking and predicting changes in water quality in Lake Powell or GCD releases. The following questions are the SSQs most closely related to the effects of water quality on key resources:

AMWG Priority 3: What is the best flow regime?

SSQ 3-5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?

AMWG Priority 5: What will happen when we test or implement the temperature control device (TCD)? How should it be operated? Are safeguards needed for management?

SSQ 5-1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE?

SSQ 5-3. To what extent do temperature and fluctuations in flow limit spawning and incubation success for native fish?

Information Needs Addressed

The following information needs (including synthesis information needs (SINs)) (as updated June 23, 2003) relate directly to water-quality monitoring in Lake Powell and the GCD tailwater.

CMIN 7.1.1. Determine the water temperature dynamics in the mainstem, tributaries (as appropriate, temperature only in mainstem and LCR), backwaters, and near-shore areas throughout the Colorado River ecosystem.

CMIN 7.2.1. Determine the seasonal and yearly trends in turbidity, water temperature, conductivity, DO, and pH changes in the main channel throughout the Colorado River ecosystem.

SIN 7.2.1. How do the hydrodynamics and stratification of Lake Powell influence the food base or fisheries downstream?

SIN 7.2.2. Which water-quality variables influence food base and fisheries in the Colorado River ecosystem?

RIN 7.3.1. Develop simulation models for Lake Powell and the Colorado River to predict water-quality conditions under various operating scenarios, supplant monitoring efforts and elucidate understanding of the effects of dam operations, climate, and basin hydrology on Colorado River water quality.

7.3.1.a. Determine status and trends of chemical and biological components of water quality in Lake Powell as a function of regional hydrologic conditions and their relation to downstream releases.

7.3.1.b. Determine stratification, convective mixing patterns, and behavior of advective currents in Lake Powell and their relation to GCD operations to predict seasonal patterns and trends in downstream releases.

RIN 7.3.3. How do dam operations affect reservoir limnology?

SIN 7.3.1. Measure appropriate water-quality parameters to determine the influence of these parameters on biological resources in the Colorado River ecosystem.

EIN 7.3.1. How does the water quality of releases from GCD change in response to an experiment performed under the ROD, unanticipated event, or other management action?

Other information needs (as updated June 23, 2003) require supporting information from water-quality monitoring in Lake Powell and the GCD tailwater:

RIN 7.1.1. What are the desired ranges of spatial and temporal patterns of water temperatures for the CRE?

RIN 7.1.2. What are the most likely downstream temperature responses to a variety of scenarios involving a TCD on GCD?

RIN 7.1.3. What are the potential ecological effects of increasing mainstem water temperature?

RIN 7.2.1. Which major ions should be measured? Where and how often?

RIN 7.2.2. Which nutrients should be measured? Where and how often?

RIN 7.2.3. Which metals should be measured? Where and how often?

General Methods/Tasks

Lake Powell monitoring is conducted monthly in the GCD forebay and quarterly at 25–30 sites throughout the reservoir. Profiles of physical parameters (temperature, specific conductance, pH, dissolved oxygen, and turbidity) are collected through the water column at each site in the reservoir. Chemical (major ions and nutrients) and biological samples (chlorophyll and plankton) are collected at selected sites to characterize major strata and advective currents in the reservoir.

GCD tailwater monitoring consists of continuous monitoring (temperature, specific conductance, pH, dissolved oxygen, turbidity) with monthly chemical and biological sample collection. Lake Powell monitoring parameters include temperature, conductance, pH, dissolved oxygen, and turbidity. Chemical analyses include determination of major ionic constituents and nutrient compounds of phosphorus and nitrogen. Plankton analyses include enumeration and identification of species, biomass estimates, and relative abundance calculations. All measurements and laboratory analyses are performed in accordance with standard approved methods.

In FY2009, the Hydrolab H20/Surveyor III multiparameter water-quality monitoring system was lost at Lake Powell. The system has been the primary monitoring instrument for Lake Powell since 1993. A Eureka Environmental Manta/Amphibian monitor is currently being used as a replacement. An oceanographic CTD profiler will be acquired in FY 2010 and will become the primary instrument for reservoir profiling. With the data acquired from the new instrument, analysis of historical data, and simulation modeling, the monitoring program will be restructured to maximize the effectiveness of the monitoring program. Part of the restructuring will be the reduction of some of the chemical sampling, higher spatial resolution of in situ monitoring and establishment of meteorological and inflow water-quality monitoring stations.

Reservoir modeling is performed cooperatively between Reclamation and the GCMRC to achieve predictive capabilities, and guide, redirect, or supplant some aspects of monitoring. Current model development has progressed to include calibrations for dissolved oxygen concentration, algal components, and oxygen demand from deltaic resuspension.

In 2011, a protocol evaluation panel (PEP) will be convened which will evaluate the Lake Powell and tailwater monitoring programs, along with foodbase and water quality monitoring programs. A previous PEP was conducted for the Lake Powell and tailwater monitoring programs in 2000.

Links/Relationships to Other Projects

The quality of dam releases and subsequent in-stream changes can have a profound effect on various aspects of the aquatic ecosystem in Grand Canyon. Temperature affects metabolic rates of various organisms, including bacteria, plants, invertebrates, and vertebrates. It also affects reproductive processes, larval development, and behavior of native and nonnative fish. Nutrient concentrations in dam releases can influence primary productivity processes in the clear water Lees Ferry reach. Dissolved oxygen is essential to maintaining healthy fish and invertebrate populations throughout Grand Canyon. Temperature and dissolved oxygen have the most direct effect on native and nonnative fish populations. Suspended sediment concentrations limit the light available for primary productivity and affect the behavior of various fish. Tracking status and trends of these water-quality parameters represent a direct link with various food base and fishery studies currently underway in Grand Canyon.

Logistics

The current Lake Powell monitoring program provides its own logistic support and does not require support from the GCMRC Logistics program, with the exception of the use of GCRMC vehicles for transportation of personnel and equipment between Flagstaff and Lake Powell. Lake Powell logistics consists of operation, fuel, maintenance, and repair costs for the Uniflite limnology vessel. Food costs and procurement for field monitoring crews are borne by the monitoring crew travel costs.

Products/Reports

- A comprehensive report describing the 43-year history of Lake Powell water-quality monitoring was published in FY2009.
- A compilation of existing biological data, analysis of the existing backlog of biological samples, and a preliminary analysis of the existing data will be performed in FY2010
- An interpretive data synthesis report will be developed in FY2010 to build upon the monitoring data and provide insights into how climatological, meteorological, and hydrodynamic processes, and the operation of GCD, affect inflow routing and stratification in the reservoir and the quality of releases from GCD.
- Periodic reports of water-quality conditions will be posted on the GCMRC Web site.
- Updates on water-quality conditions will be provided to the Adaptive Management Work Group, Technical Work Group, and other interested parties through written reports or oral presentations periodically.

Budget

FY2011	$182,002
FY2012	$188,063

PHY 7.M1.11–12—Integrated Quality of Water Monitoring (below Glen Canyon Dam)

Start Date

October 2006

End Date

Ongoing. FY2011 and FY2012 will be the fifth and sixth years of a project that was initiated to perform core monitoring to meet the information needs related to GCDAMP goals 7 and 8. This monitoring project follows a 6-year research and development phase conducted from FY2001 to FY2006. If sufficient funding is available from outside sources (USGS Arizona Water Science Center and Bureau of Land Management) during FY2011, streamflow and sediment records will be maintained on the two remaining major tributary suppliers of sand that were not monitored in FY2010, Kanab and Havasu Creeks. As discussed in the stakeholder-approved goal 7 core monitoring plan, monitoring these tributaries is required to accurately construct mass-balance sediment budgets for Grand Canyon downstream from River Mile 87. No other substantive difference is anticipated between FY2010, FY2011, and FY2012 activities.

Principal Investigator

David Topping, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

The downstream integrated quality of water (IQW) project focuses on the main channel of the Colorado River from the tailwaters of Glen Canyon Dam (RM -15) downstream to the upper end of Lake Mead (as measured at the gaging station above Diamond Creek at RM 225). The project also includes a combination of monitoring and modeling of tributary sediment inputs. Sediment- and flow-monitoring activities are conducted for the Paria River at the Highway 89 crossing in Utah, the Paria River at Lees Ferry, the Little Colorado River (LCR) near Cameron, Arizona, LCR above the Colorado River confluence, Kanab Creek above its mouth, Havasu Creek above its mouth, and various lesser tributaries in Glen, Marble, and Grand Canyons.

Project Goals

The primary objectives of the downstream IQW monitoring project concern the measurement of water stage and discharge throughout the river ecosystem and measurement of quality-of-water parameters of water temperature, specific conductance, dissolved oxygen, turbidity, and suspended-sediment concentration and grain size. Although the focus is on monitoring, the project also supports research related to stable-flow testing, evaluation of alternative fluctuating flows, tests of high flows, and ongoing development and evaluation of numerical modeling. In some instances monitoring activities are closely related to experimental activities. For example, monitoring of the sediment budget may be considered core monitoring, but it is also required to assess a trigger for high flows such that this monitoring may also be considered experimental research support. In the section on project tasks, the individual project elements are described.

In addition, the IQW monitoring project directly supports achievement of the following GCDAMP goals:

- **Goal 7:** Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals

- **Goal 8:** Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals

Because this monitoring project addresses the physical framework of the ecosystem, which underlies many biological, cultural, and recreational resource objectives, it indirectly supports achievement of almost all other GCDAMP goals, including:

- **Goal 1:** Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels

This project supports this goal by providing information on flows, water temperature, and turbidity that aids in food base studies, such as the assessment of primary productivity and allochthonous inputs.

- **Goal 2:** Maintain or attain a viable population of existing native fish, remove jeopardy for HBC and razorback sucker, and prevent adverse modification to their critical habitats

This project supports the native fish program by providing nearshore water temperature data for the assessment of growth rates, sediment concentration data that are used to adjust for catch efficiency in population models, flow and stage data that are important to understanding the effects of nearshore habitat disruption caused by fluctuating flows, and data on sandbars and resulting backwater habitats that are helpful in understanding the importance of sandbars for native fish.

- **Goal 4:** Maintain a wild reproducing population of RBT above the Paria River to the extent practicable and consistent with the maintenance of viable populations of native fish

This project monitors dam releases and Glen Canyon IQW, which are critically important when dissolved oxygen levels are low, requiring modifications to release patterns in order to raise oxygen levels.

- **Goal 6:** Protect or improve the biotic riparian and spring communities within the CRE, including threatened and endangered species and their critical habitat

The downstream IQW monitoring project also tracks the transport and fate of fine sediment, which provides the substrate for riparian vegetation and marsh communities.

- **Goal 9**: Maintain or improve the quality of recreational experiences for users of the CRE within the framework of GCDAMP ecosystem goals

This project also produces monitoring data and supports experimental and modeling research to understand flow dynamics and the size and abundance of sandbars, which are resources that affect the recreational experiences of Colorado River users such as rafters and fishermen.

- **Goal 11:** Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations

This project also provides monitoring data on riverine sandbars, which are a source of sediment, through aeolian transport, to high elevation sand deposits that contain archaeological resources. In addition, the downstream IQW monitoring project has also developed stage modeling capabilities that can assess the flow level inundating a given cultural site.

In August 2004, the AMWG reviewed these goals and identified priority questions. The top five priority questions are as follows:

Priority 1: Why are HBC not thriving, and what can we do about it? How many HBC are there and how are they doing?

Priority 2: Which cultural resources, including TCPs, are within the area of potential effect (APE), which should we treat, and how do we best protect them? What is the status and trends of cultural resources and what are the agents of deterioration?

Priority 3: What is the best flow regime?

Priority 4: What is the impact of sediment loss and what should we do about it?

Priority 5: What will happen when a TCD is tested or implemented? How should it be operated? Are safeguards needed for management?

The downstream IQW monitoring project provides direct support to some of the priority questions, while indirectly supporting others. Monitoring and research on flows, sediment transport, and water temperature support priority questions 3, 4, and 5 directly and indirectly support priority questions 1 and 2 by providing information on the general physical framework of the riverine environment.

Need for the Project

Information on flow, water quality, and suspended-sediment transport is critical to understanding the physical environment upon which biological and sociocultural resources depend. In order to understand the responses of these resources to dam operations, we must understand and monitor the effects of dam operations on the physical environment. The goal of the downstream IQW project is to provide this information and link dam operations to changes in the physical environment.

Strategic Science Questions

The downstream IQW monitoring project is designed with the goal of providing data that supports answering the two primary physical resources questions identified during the knowledge assessment workshop conducted in the summer of 2005, as follows:

SSQ 4-1. Is there a "Flow-Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales?

SSQ 5-1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE?

Also, as detailed throughout this project description, this project provides information on the physical environment that is critical to other resource areas and will thus contribute indirectly to answering a variety of other science questions related to other resources.

Information Needs Addressed

The downstream IQW monitoring project directly addresses several of the CMINs and RINs related to GCDAMP goals 7 and 8. Selections of the information needs that are addressed by downstream IQW monitoring project are listed below. The downstream IQW monitoring project addresses many more CMINs, but the ones listed below are considered most relevant to answering the science questions outlined above.

> **CMIN 7.4.2.** Determine and track flow releases (gage data and SCADA data; time interval still TBD) from Glen Canyon Dam, under all operating conditions, particularly related to flow duration, upramp, and downramp conditions (parameters are upramp and downramp rates, volume, daily minimum and maximum).
> **CMIN 7.1.2.** Determine and track LCR discharge and temperature near the mouth (below springs).
> **CMIN 7.1.1.** Determine the water temperature dynamics in the mainstem, tributaries (as appropriate, temperature only in mainstem and LCR), backwaters, and near shore areas throughout the Colorado River ecosystem.
> **CMIN 8.1.3.** Track, as appropriate, the monthly sand and silt/clay volumes and grain-size characteristics, by reach, as measured or estimated at the Paria and LCR [near Cameron, Ariz., and above the confluence] stations, other major tributaries like Kanab and Havasu Creeks, and "lesser" tributaries?
> **CMIN 8.1.2.** What are the monthly sand and silt/clay export volumes and grain-size characteristics, by reach, as measured or estimated at Lees Ferry, Lower Marble Canyon, Grand Canyon, and Diamond Creek Stations?
> The monitoring data from this project not only fulfill the CMINs listed above, but are also intended to feed new information directly into modeling efforts (see PHY 7.R2) that will allow sediment transport modelers the opportunity to address RINs related to GCDAMP goals 7 and 8.
>
> **RIN 7.4.1.** What is the desired range of seasonal and annual flow dynamics associated with power plant operations, BHBFs, and habitat maintenance flows, or other flows that meet GCDAMP goals and objectives?
> **RIN 7.3.1.** Develop simulation models for Lake Powell and the Colorado River to predict water-quality conditions under various operating scenarios, supplant monitoring efforts, and elucidate understanding of the effects of dam operations, climate, and basin hydrology on Colorado River water quality.
> **RIN 8.5.1.** What elements of ROD operations (upramp, downramp, maximum and minimum flow, MLFF, high modified flow (HMF), and BHBF) are most/least critical to conserving new fine sediment inputs, and stabilizing sediment deposits above the 25,000 cfs stage?

Methods and Tasks

FY2011

Discharge, stage, water temperature, specific conductance, turbidity, and suspended-sediment data are collected using standard USGS protocols with quality assurance/quality control

(QA/QC) (Rantz and others, 1982a). Suspended-sediment sampling is supplemented through the use of emerging technologies, including acoustics and laser-diffraction (Melis and others, 2003; Topping and others, 2004, 2006, 2007). Stage, water temperature (Voichick and Wright, 2007), specific conductance (Voichick, 2008), turbidity, and suspended-sediment surrogates (acoustics and laser-diffraction) are monitored with in situ instrumentation recording at 15-minute intervals. Water discharge is measured episodically and used to develop a stage-discharge rating curve, providing 15-minute flow records (Rantz and others, 1982b). Similarly, suspended-sediment concentration is measured episodically using standard USGS protocols (Edwards and Glysson, 1999) and used to calibrate and evaluate acoustic and laser diffraction instrumentation, providing 15-min records of concentration (sand and silt/clay), and sand grain size.

Flow and Stage Monitoring

Continued monitoring of flow and stage at established mainstem locations and major tributaries (RM -15, RM 0, RM 30, RM 61, RM 87, RM 166, RM 225, Paria River at the Highway 89 bridge and near Lees Ferry, two sites on the LCR, Kanab Creek above its mouth, and Havasu Creek above its mouth). Category(s): core monitoring. Schedule: ongoing. Official surface water records are collected at Paria River near Kanab, UT (at the Highway 89 bridge) and published by the USGS Utah Water Science Center. Official surface-water records are collected and published by the USGS Arizona Water Science Center at the following tributary gage sites: Paria River at Lees Ferry, AZ; LCR near Cameron, AZ; LCR above the mouth near Desert View, AZ; Kanab Creek above the mouth near Supai, AZ; Havasu Creek above the mouth near Supai, AZ; and at the mainstem gages at RM 0, RM 87, and RM 225, AZ. The dam-released RM -15 discharge is reported by Reclamation. Stage data are also collected at sites in the following lesser tributaries: Water Holes Canyon, Badger Creek, Tanner Wash, House Rock Wash, North Canyon, Shinumo Wash, and Bright Angel Creek; these data are converted to discharge using methods described in Griffiths and others (2010).

Quality-of-Water Monitoring

Monitoring of water temperature is conducted at established mainstem locations and major tributaries (RM -15, RM 0, RM 30, RM 61, RM 87, RM 166, RM 225, RM 246, Paria River at Lees Ferry, two sites on the LCR, and Kanab and Havasu Creeks). Continuation of a new near shore/backwater-temperature monitoring program is conducted at selected sites. Continued monitoring of specific conductivity is conducted at established stations (RM -15, RM 0, RM 30, RM 61, RM 87, and RM 225). Continued monitoring of turbidity at established stations (RM 30, RM 61, RM 87, and RM 225). Continued monitoring of dissolved oxygen is also conducted at established stations (RM -15, RM 0, and RM 225).

Suspended-Sediment Flux Monitoring

Monitoring of suspended-sediment flux will continue at established mainstem locations and major tributaries (RM 30, RM 61, RM 87, RM 166, RM 225, Paria River at Lees Ferry, and several sites along the lower LCR and it major sand-supplying tributary, Moenkopi Wash). Because sediment-based high-flow triggers are based on sediment retention within the mainstem and tributary-supplied sand is exported quickly downstream under all but the lowest dam releases, it is insufficient to monitor tributary sand inputs only. To provide the information required to construct accurate mass-balance sand budgets in key reaches of the Colorado River, suspended-sediment data are also collected on the above-mentioned lesser-tributary sites.

Coordination with Other Resource Areas

Regular meetings and interaction with other resource area personnel, particularly at the program manager level, will be done in order to facilitate an ecosystem approach to our scientific studies and ensure that the downstream IQW monitoring project is providing useful information regarding the physical environment to the other resource areas.

Monitoring Program Review

The program for monitoring non-sediment water quality parameters (temperature, specific conductance, dissolved oxygen, and turbidity) will be reviewed by a Protocol Evaluation Panel in Summer 2011 to be conducted jointly with a review of the food base monitoring program.

FY2012

The tasks and methods are expected to be the same for FY2012 as for FY2011, with the possible incorporation of recommendations based on the FY2011 Protocol Evaluation Panel review.

Links/Relationships to Other Projects

Monitoring and Research for Potential High Flow Experimental Protocol

Monitoring of sediment (sand and finer) flux during future high flows will be conducted as part of the regular goal 7 downstream integrated quality of water program as described above. Some added work during a high flow is necessary to maintain the monitoring record because the instrumentation is vulnerable to high dam releases and additional samples are required to maintain instrument calibration. Budget implications are addressed in PLAN 12.P6.

Long-term Monitoring for Changes in Sediment Storage -- SedTrend

The downstream IQW monitoring project is closely related to the SedTrend component of the program for long-term monitoring of sediment storage that is described under goal 8. The downstream IQW monitoring includes the tracking of sediment fluxes entering and exiting each of the five sediment monitoring segments over short time scales (up to ~ 5 years) for planning high flows or other dam operations designed to improve or maintain sandbars. The SedTrend program uses direct measurements of channel topography and bathymetry to track long-term (5 years and longer) changes in sediment storage for the same monitoring segments.

Aquatic Food Web Research

This project supports research focused on the food web of the river ecosystem by providing continuous data on surface flow in the main channel and major tributaries, as well as related quality-of-water data, such as water temperature, specific conductivity, dissolved oxygen, and suspended-sediment concentrations and grain size for suspended particles in transport.

Fisheries Monitoring and Research

This project also supports science activities in the fisheries program by providing flow and quality-of-water data that may be used by fisheries biologists in evaluating their fish catch data, as well as growth, movement, and habitat use information.

Links to Monitoring and Research Activities Outside the GCDAMP

Funding for streamflow and water quality monitoring conducted by the USGS Arizona Water Science Center is supplemented by contributions from the USGS National Stream Information Program, the Bureau of Reclamation in Boulder City, NV, and the Southern Nevada Water Authority. Additional outside funds provided by the Bureau of Land Management are anticipated to support monitoring of Kanab Creek and Havasu Creek.

Logistics

This project requires two motorized river trips annually. Project needs require that the trips occur at approximately 6-month intervals. Motors are required for sampling activities and servicing the instrumented gage sites. Typically, the trips have two support boats and one technical boat. The current plan is to continue with one trip in February and one trip in August.

Products/Reports

FY2011

- Streamflow, stage, and tributary sediment data will be published annually in Arizona and Utah Water Resources Data reports (surface water and sediment records published by the USGS Utah and Arizona Water Science Centers) and served through the GCMRC Web page (http://www.gcmrc.gov/products/) (data delivered on or before February 28, 2012)
- Mainstem sediment transport and IQW data will be served through the GCMRC web page and a web-based application will be implemented to provide stakeholders and interested public with the ability to perform interactive online data visualization and analysis
- Conference abstracts and proceedings articles (2–4 annually), journal articles (1–3 annually), and presentations at stakeholder meetings
- All work conducted under the IQW project will be summarized in annual reports, with the FY2011 report to be completed by January 1, 2012

FY2012

- Streamflow, stage, and tributary sediment data will be published annually in Arizona and Utah Water Resources Data reports (surface water and sediment records published by the USGS Utah and Arizona Water Science Centers) and served through the GCMRC Web page (http://www.gcmrc.gov/products/) (data delivered on or before February 28, 2013).
- Mainstem sediment transport and water-quality data will be served through the GCMRC web page and a web-based application will be implemented to provide stakeholders and interested public with the ability to perform interactive online data visualization and analysis
- Conference abstracts and proceedings articles (2–4 annually), journal articles (1–3 annually), and presentations at stakeholder meetings
- All work conducted under the IQW project will be summarized in annual reports, with the FY2012 report to be completed by January 1, 2013

Budget

FY2011	$999,236
FY2012	$1,020,911

PHY 7.R3.11–12—Modeling Support

Start Date

October 2010

End Date

Ongoing. Fiscal year 2010 is the end of a 2-year model development period. The FY2011-12 project provides support for model maintenance and implementation that is intended to occur in parallel to the monitoring programs. As new data are collected, the existing models will be continuously tested, improved, and applied. However, due to budget constraints further development of new models is deferred.

Principal Investigator(s)

Scott A. Wright, U.S. Geological Survey, California Water Science Center; Jonathan Nelson, U.S. Geological Survey, National Research Program; David J. Topping, U.S. Geological Survey, Grand Canyon Monitoring and Research Center; Paul E. Grams, U.S. Geological Survey, Grand Canyon Monitoring and Research Center; and David M. Rubin, U.S. Geological Survey, Marine Geology Team

Geographic Scope

The one-dimensional flow, temperature, and sediment-transport modeling activities are spatially parallel to the IQW project and also focus on the main channel of the CRE between GCD (RM -15) to Diamond Creek (RM 226). Multidimensional modeling efforts will be applied at specific locations where appropriate topographic, bathymetric, and other calibration data have been collected.

Project Goals

The purpose of the modeling support project is to apply both commercial and custom models for the prediction of flow, water temperature, sediment flux, and sediment deposition and erosion. The model predictions will be used to estimate sediment inputs from tributaries in support of the goal 7 IQW project, predict the effects of dam releases on downstream water temperature, and predict the fate of fine sediment that enters the ecosystem from tributaries. Both detailed multidimensional models, which can only be applied to a few specific locations, and general one-dimensional models, which can be applied to the entire CRE, will be used.

Ongoing application of models to simulate flow, sediment transport, and downstream water temperature are intended to be closely interfaced with ongoing monitoring activities throughout the science program. The downstream IQW monitoring project includes measurements of surface flow throughout the river ecosystem, as well as monitoring of quality-of-water parameters such as temperature, specific conductivity, dissolved oxygen, and suspended-sediment transport. These projects directly support achievement of the following GCDAMP goals:

Goal 7: Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals.

Goal 8: Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

Need for Project

Modeling capability is needed to provide predictive capacity in linking dam operations with changes in the physical environment, including water flow, sediment conditions, and temperature. Better models for water flow are needed to predict the depth and velocity of flow for specified locations for specified dam operations. Models for sediment transport are needed to help determine the optimal magnitude and duration for high flow releases and estimate the potential long-term impact of changes in dam operations or sediment supply conditions. Temperature models are needed to link dam operations with temperature dynamics in the downstream channel and near shore habitats. Thus, the goal of modeling activities is to provide increased predictive capabilities in the form of simulations that can be used as planning tools for linking dam operations to changes in the physical environment. Models of the physical system are also needed to develop and expand interdisciplinary relationships with biological, cultural, economic, and recreational elements of GCDAMP.

Strategic Science Questions

The integrated modeling activities are designed with the objective of providing predictive capability that supports answering the two primary physical resource questions identified during the KAW conducted in the summer of 2005:

SSQ 4-1. Is there a "Flow-Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales?

SSQ 5-1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE?

In the process of developing a formal project proposal in 2009, the 2009-2010 modeling team listed five related science and related management questions that the project was designed to address:

1) Science question: How do eddy sandbars evolve for a given sediment supply and flow hydrograph, including short duration high flow releases?
   Related management question: What is the "optimal" high flow hydrograph (peak and duration) for a given supply condition?

2) Science question: How are tributary sediment inputs transported through the mainstem for a given flow hydrograph?
   Related management question: How long will tributary sediments be available (and where will they be) for a given operation (i.e. monthly volume, daily peak, daily range)?

3) Science question: How does the long-term (i.e. decadal scale) sand budget evolve for a given flow hydrograph and tributary sediment supply (and/or sediment augmentation)?
   Related management question: How do different operations compare with respect to long-term sustainability?

4) Science question: What controls the slope stability of sandbars that fill and drain on a daily basis due to fluctuating flows?
   Management: How do various ramping rates affect the stability of sandbars?

5) Science question: How does channel complexity and habitat type affect shoreline water temperature distribution and dynamics?
Related management question: Do various fluctuating and steady flow regimes affect shoreline water temperature differently?

Information Needs Addressed

The modeling project directly addresses several of the RINs related to GCDAMP goals 7 and 8:

RIN 7.4.1. What is the desired range of seasonal and annual flow dynamics associated with power plant operations, BHBFs, and habitat maintenance flows, or other flows that meet GCDAMP goals and objectives?

RIN 7.3.1. Develop simulation models for Lake Powell and the Colorado River to predict water-quality conditions under various operating scenarios, supplant monitoring efforts, and elucidate understanding of the effects of dam operations, climate, and basin hydrology on Colorado River water quality.

RIN 8.5.1. What elements of ROD operations (upramp, downramp, maximum and minimum flow, MLFF, HMF, and BHBF) are most/least critical to conserving new fine sediment inputs, and stabilizing sediment deposits above the 25,000 cfs stage?

Methods

The modeling support project will include use of previously existing models and models developed during the FY 2009-10 modeling initiative. It is necessary to use a suite of modeling tools, because the questions outlined above span a wide range of time and space scales. For example, models appropriate for simulating the evolution of an individual sandbar during a high flow release are not appropriate for simulating the long-term (decadal) sand budget for the canyon. In general, models of short time scales and high spatial resolution can apply fundamental governing equations (though some empiricism is always required), whereas models of longer time scales require increasing degrees of simplifying assumptions and substantially more empirical data. Thus, a variety of modeling approaches are required to address the disparity in scales, potentially with information sharing between the models. To this end, we will continue to apply multiple modeling approaches, although time and budget constraints may not permit work on all approaches in every year.

Local/Eddy scale modeling (ESM): This approach is designed to simulate flow, sediment transport, morphology, and temperature dynamics at the scale of short reaches or individual eddies. Resolution of these finer spatial scales limits the length of simulation that can be performed due to computational constraints, such that this modeling approach is appropriate for time scales of days to weeks. The short time scale and high spatial resolution allows for the use of numerical modeling tools based on basic conservation equations. In the simplest application, these models may be used to estimate discharge for locations where it cannot or has not been measured directly, such as ungaged tributaries. In more complicated applications, these models may be used to predict detailed temperature distributions and patterns of sandbar deposition.

Bar stability modeling (BSM): The ESMs predict transport, erosion, and deposition based on shear stress imparted from the flow onto the bed of the river, but do not account for slope failures resulting from elevated pore water pressures during rising and falling river stages. Because normal hydropower dam operations include daily flow fluctuations, this bar failure

mechanism is important to understand when considering alternative flow ramping rates. The bar stability model is applied to an individual bar in a two-dimensional profile (i.e. a vertical cut through the bar face). In the future, the model could be linked to the ESMs to incorporate the failed material back into the flow.

Reach scale modeling (RSM): The ESMs are not applicable to broader spatial scales and longer time scales. For these scales, further simplifications are required in order to be computationally feasible. There are several potential applications for reach scale models in Grand Canyon. One application is modeling the cross-sectional averaged (i.e. one-dimensional) mainstem sediment transport and temperature dynamics. These models can be used to simulate the fate of tributary inputs as they move downstream through the mainstem, and the downstream warming of dam releases that occurs for most of the year. This information can be used to evaluate various dam release scenarios (for flow and possibly temperature control), and the models can also be used to deliver boundary conditions to the ESMs. The RSM for mainstem temperature has already been developed, tested, and documented (Anderson and Wright, 2007). A RSM for sediment transport (the 1-D sand routing model) has been developed and documented (Wiele and others, 2007).

Decadal scale modeling (DSM): This modeling approach is designed to simulate the long-term sand budget for the river at relatively low spatial resolution. The unsteady, one-dimensional RSMs described above, while substantially simplified from the ESMs, are still too complex to apply to decadal time scales particularly if the goal is to simulate a range of potential future conditions with, for example, Monte Carlo simulation. This approach relies heavily on high-resolution sand transport data that is currently collected at several sites along the river (PHY 7.M1). The basic methodology is to allow the relationship between sand concentration and discharge to shift up and down depending on the level of sand supply in the system (i.e. a "shifting rating curve"), a phenomenon that has been documented since the 1996 controlled flood. Because of the empirical nature of the approach, the sand budget can only be resolved at the same spatial resolution as the sand transport monitoring, currently ~30 mile reaches encompassing upper Marble Canyon (river miles 0 to 30), lower Marble Canyon (river miles 30 to 61) and Eastern Grand Canyon (river miles 61 to 87).

The modeling approaches and many of the specific models that are either available for use are still in development are listed in Table 4 along with brief descriptions of how the models can be applied to meet stakeholder and management needs. Integration of these modeling approaches will provide a suite of tools that incorporates appropriate processes over short and long time scales, thereby allowing predictions of water temperature dynamics, the long-term sand budget, or the response of eddy morphology to hypothetical hydrographs, dam release temperatures, and tributary sand supply rates. This approach captures the importance of tributary inputs, the local storage of sediment in the mainstem that can be made available by higher flows for storage in eddies, the processes of exchange between the eddies and mainstem over short time scales, and the potential for mechanical failure of the eddy deposits.

Table 5

Summary of modeling approaches and models. Shaded rows indicate models that are currently available for application in FY2011 and FY2012. Other models are still in development and may or may not be ready for application in FY2011 and FY2012.

Modeling approach	Model	Time scale	Spatial scale and resolution	Brief description	Primary questions addressed	Work to occur in FY2011-12
Local or Eddy scale (ESM)	3-D eddy model (Delft 3D or similar)	Days to weeks	Individual eddies or short reaches resolved on meter scale grids	Multi-dimensional model of flow, sediment, and heat; Physically-based with relatively little	How do eddy sandbars evolve? What is the "optimal" high flow shape (peak and duration)?	Application to additional sites and additional verification, pending outcome of work in FY2010
Local or Eddy scale (ESM)	MD-SWMS	Days to weeks	Short reaches resolved on meter to 10-meter scale grids	Multi-dimensional model of flow; Physically-based with relatively little empiricism	What is the discharge of ungaged tributary flows?	Application of the model to ungaged tributaries to improve estimates of tributary sediment input volumes
Local or Eddy scale (ESM)	MD-SWMS	Days to weeks	Short reaches resolved on meter to 10-meter scale grids	Multi-dimensional model of flow; Physically-based with relatively little empiricism	What are the physical characteristics (e.g. velocity, bed mobility) of fish habitat in the Lees Ferry reach?	Application of the model to selected reaches to quantify physical habitat
Bar stability (BSM)	Slope stability model	Days	2D slices of individual sandbar faces	Slope stability modeling in the presence of rising and falling water stage	How do various ramping rates affect the stability of sandbars?	Potential application and integration with ESM pending outcome of ongoing work
Reach scale (RSM)	HEC-RAS 1-D steady flow model	Days to weeks	Long reaches resolved at closely spaced (~100 m) interpolated cross-sections	One-dimensional model of flow; Physically-based but with substantial empiricism	What is the water surface elevation for any steady discharge at any location of interest?	Model application as needed

Modeling approach	Model	Time scale	Spatial scale and resolution	Brief description	Primary questions addressed	Work to occur in FY2011-12
Reach scale (RSM)	CRFSS 1-D unsteady flow model	Days to years	Long reaches resolved at widely spaced (~0.1-1 km) cross-sections	One-dimensional model of flow. Physically-based but with substantial empiricism.	What is the discharge at any given location during fluctuating flows?	Model application, as needed.
Reach scale (RSM)	1-D sand routing model	Months to years	Long reaches resolved at widely spaced (~0.1-1 km) cross-sections	One-dimensional model of flow and sediment. Physically-based but with substantial empiricism.	How are tributary sediments transported and distributed throughout the mainstem?	Potential application pending outcome of calibration and testing that is ongoing in FY 2010.
Reach scale (RSM)	1-D water temp. model	Months to years	Long reaches resolved at widely spaced (~0.1-1 km) cross-sections	One-dimensional models of flow and heat. Physically-based but with substantial empiricism.	At what rate does downstream warming occur in the mainstem?	Model application, as needed.
Decadal scale (DSM)	Shifting rating curve model	Years to decades	Long reaches resolved at the resolution of the monitoring sites	Sand budget calculations using shifting rating curves. Highly empirical with a minimum	How do various dam operations compare with respect to the long-term sand budget?	Application of model to predict fate of tributary inputs for alternative dam operation scenarios.

Specific modeling applications must be devised in close cooperation with stakeholders of the GCDAMP. This cooperation requires information sharing so that (1) the stakeholders clearly understand the capabilities of the models, and (2) the modelers clearly understand the desired scenarios to be modeled. Below are three examples of potential applications of the models:

Example 1: Predicting the long-term sand budget for a range of dam release scenarios. This type of question is ideally suited for the shifting rating curve model, and was the motivation for development of such a model. The model can also evaluate the effects of a range in tributary sand supply conditions. Once up and running, it will be relatively easy to evaluate a wide range of flow conditions on the long-term sand budget due to the simplicity of the model formulation.

Example 2: Designing a hydrograph for a high flow event. If substantial tributary inputs occur in the future and a high flow event is scheduled, the suite of models can be used to evaluate various proposals for the hydrograph (i.e. peak, duration, ramping rates). First, the shifting rating curve and/or 1-D sand routing model would be run to estimate the distribution of new tributary sand throughout the canyon and the concentrations during the high flow. The 3-D eddy model would then be run for the quantification sites to evaluate the sandbar responses to the various hydrographs, allowing for tradeoff analysis and selection of a hydrograph.

Example 3: Modeling in support of near shore ecology. Over the next several years, extensive field work will occur in the reach below the Little Colorado River for the study of the ecology of near shore habitats, in particular their importance to native fish. The 1-D temperature and 3-D eddy models can be used to interpolate and extrapolate estimates of water temperature in space and time throughout the study reach. Thus, high resolution (space and time) estimates of water temperature (as well as depth and velocity) can be developed and used to assist interpretation of native fish habitat use.

Tasks – 2011

Application of the models as outlined in Table 4. Prioritization of tasks will be based on the needs of other research and monitoring projects and on stakeholder input.

Finalization of papers and reports from the FY2009-10 modeling initiative (see FY2010 work plan)

Tasks – 2012

Continued application of the models as outlined in Table 4

Links/Relationship to Other Projects

Because ongoing modeling efforts are linked to the downstream IQW monitoring project, it is also intended to address and support elements of the physical framework of the ecosystem, which underlies many biological, cultural, and recreational resource objectives. As a result, the modeling efforts indirectly support achievement of almost all other GCDAMP goals, as described in PHY 7.M1. The ongoing activities associated with the development of simulation capabilities and verification of existing models can benefit from monitoring data from the downstream IQW project. These simulation models include flow routing, suspended-sediment transport, sandbar evolution, and downstream thermal simulations throughout the main channel. Improved predictive capabilities for physical resources related to dam operations will be of great value as a support tool in planning future experimental treatments, as well as evaluating proposed management actions in the river ecosystem that generally relate to GCDAMP goal 1, goal 2, goal 4, goal 6, goal 8, goal 9, and goal 11. In addition, goal 12 is also supported by efforts to advance modeling activities for the ecosystem.

Aquatic Food Web Research

Both the downstream IQW monitoring project and its modeling support link to thermal and suspended-sediment transport can help to support new research on the river ecosystem food web by providing continuous data on surface flow in the main channel and major tributaries, as well as related quality-of-water data such as water temperature, specific conductivity, dissolved oxygen, suspended-sediment concentrations, and suspended particle grain size. This project and its modeling support link can also provide simulations for predicting downstream boundary conditions that limit in-stream productivity.

Fisheries Monitoring and Research

The downstream IQW modeling activities provide support beyond IQW data by making simulations for physical habitat changes, such as backwaters, available to fishery scientists before future HFE tests. Such information can assist scientists in planning better integrated studies.

Logistics

There are no logistics requirements for the modeling support project.

Products/Reports – FY2011

- Preparation of conference abstracts, proceedings articles, and journal articles (at least one per year)
- Presentations at GCDAMP meetings and stakeholder workshops (as appropriate)
- All work conducted under the integrated modeling project will be summarized in annual reports to be completed by January 1, 2012

Products/Reports – FY2012

- Preparation of conference abstracts, proceedings articles, and journal articles (at least one per year)
- Presentations at GCDAMP meetings and stakeholder workshops (as appropriate)
- All work conducted under the integrated modeling project will be summarized in annual reports, to be completed by January 1, 2013

Budget

FY2011 $139,864

FY2012 $145,679

GCDAMP Goal 8—Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve the Adaptive Management Program ecosystem goals.

PHY 8.M2.11-12 — Integrated Long-term Monitoring of Systemwide Changes in Sediment Storage

Start Date

October 2008

End Date

Ongoing

Principal Investigator(s)

Matt Kaplinski, Joseph E. Hazel, Jr., and Roderic Parnell, Northern Arizona University, Department of Geology; David J. Topping and Paul E. Grams, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

The primary purpose of goal 8 is to track the status of fine sediment that is stored in sandbars over multi-year periods that include normal dam operations and high flows. Thus, goal 8 activities consist of research and monitoring of alluvial deposits of the banks and bed of the Colorado River from Glen Canyon Dam to the upper end of Lake Mead. The geographic scope for any given year varies depending on that year's activity. Quadrennial remote sensing overflights cover the entire project area, sandbar monitoring focuses on specific study sites between GCD and Diamond Creek, and channel mapping focuses on discrete reaches between Lees Ferry and Diamond Creek.

Project Goals

Achieving the goal of maintaining or expanding sandbars and associated habitats requires balance between the two competing effects of dam releases on fine sediment. High releases in excess of power plant capacity are needed to build sandbars above the zone associated with normal dam operations. However, in the absence of tributary sediment inputs, both normal dam operations and high flows result in net export of fine sediment. Thus, high flows conducted during periods of relative fine sediment enrichment in the main channel that occur following tributary sediment inputs have the greatest chance of resulting in sandbar deposition. The magnitude of tributary inputs and main channel enrichment are tracked by the goal 7 IQW program, which provides the information needed to appropriately time high flows. Yet, the continued effectiveness of high flows to build sandbars also requires that total fine sediment storage is maintained or increased over periods spanning multiple high flows and intervening dam operations. Progressive depletion of fine sediment storage is likely to result in a decrease in the ability of high flows to build sandbars. Because uncertainties in sediment flux measurements accumulate over time, goal 7 monitoring cannot be used to monitor trends in storage over these five-year to decadal periods. The purpose of goal 8 monitoring is to collect the data that will demonstrate whether the net result of dam operations, including power plant operations and high flows, and tributary sediment inputs is accumulation, maintenance, or depletion of sand storage.

More specifically, the "SedTrend" monitoring is designed to determine magnitudes and trends in fine sediment storage throughout the CRE in the main channel and eddies for three major sand-storage elevation zones: (1) below the stage associated with a discharge of 8,000 cfs where over 90 percent of the fine sediment in the CRE is typically stored, (2) between the stages associated with discharges of 8,000 and 25,000 cfs, and (3) above the stage associated with a discharge of 25,000 cfs.

Additional goals of this project include tracking trends in sandbar area, sandbar volume, and sandbar distribution, which supports goal 9; measurements of backwater geometry and distribution, which supports goal 2; and monitoring of the availability of open dry sand on sandbars that can be transported by the wind upslope into archeological sites, which supports goal 11.

The sediment monitoring program directly supports achievement of the following Glen Canyon Dam Adaptive Management (GCDAMP) goals:

1. **Goal 8**: Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals

2. **Goal 9:** Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem within the framework of GCDAMP ecosystem goals; the monitoring provides information on the size and abundance of sandbars, which are resources that affect the recreational experiences of Colorado River users

3. **Goal 11:** Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations; the program includes monitoring sandbars that provide a source of sediment, through aeolian transport, to high-elevation sand deposits that contain archaeological resources

Because sediment monitoring addresses the physical framework of the ecosystem, which underlies many biological resource objectives, it also indirectly supports achievement of the following GCDAMP goals:

- **Goal 1:** Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels; the SedTrend monitoring supports this goal by providing information on the size and distribution of channel substrate

- **Goal 2:** Maintain or attain a viable population of existing native fish, remove jeopardy for humpback chub and razorback sucker, and prevent adverse modification to their critical habitats; SedTrend and sandbar monitoring supports this goal by providing information on sandbars which create backwater habitats

- **Goal 6:** Protect or improve the biotic riparian and spring communities within the Colorado River ecosystem, including threatened and endangered species and their critical habitat; the SedTrend and sandbar monitoring tracks the status of the fine sediment deposits which provides the substrate for riparian vegetation and marsh communities

Need for Project

Closure of Glen Canyon Dam has resulted in at least a 90% reduction in sediment supply to the CRE in Grand Canyon (Topping and others, 2000). Moreover, operations of the dam tend to result in net export of sand and finer sediment in most years (Topping and others, 2000). In response to this reduction in sand supply and the alteration of the natural hydrograph by dam operations, sandbars in

Marble Canyon and the upstream part of Grand Canyon have substantially decreased in size (Schmidt and others, 2004) and are still in decline under normal power plant operations at the dam (Wright and others, 2005).

The primary signal for fine sediment is the change in storage volume of the fine sediment below the 8,000 cfs water stage. While the IQW monitoring program tracks the fluxes of fine sediment and enables calculation of the change in storage, the uncertainty in these estimates accumulates and restricts the use of that method to time scales of ~5 years or less. The essential data to detect trends in storage change over periods longer than ~5 years are repeat measurements of channel bathymetry that are compared to determine change in storage between the measurement intervals. Changes in the area and volume of sand exposed above the 8,000 cfs stage are monitored to track whether management actions are achieving desired results.

Growing concern about the effects of the operations of Glen Canyon Dam on the CRE led to the initiation of systematic measurements of sandbars in the 1970s (Dolan and others, 1974; Howard, 1975; Howard and Dolan, 1981). This sandbar-monitoring program was revisited in the 1980s (Schmidt and Graf, 1990; Beus and others, 1992), and eventually led to the sandbar-monitoring program conducted by NAU during the 1990s (Hazel and others, 1999; Schmidt and others, 2004). Evaluation begun in the 1990s and finalized in the geomorphic synthesis of Schmidt and others (2004) indicated that the observations of change made during these site-based programs were not necessarily representative of changes in the fine-sediment resource over longer reaches of the Colorado River because these programs utilized surveys of relatively small areas and the variability between sites was large. Moreover, the fact that substantial positive changes in sediment volume were observed in these site-based programs during periods when no sediment entered the system called into question the value of sediment budgeting based on monitoring of small sites (Hazel and others, 2006). In contrast to the large variability within the site-based NAU data, analysis of cross-section data collected by the USGS indicated near-universal scour of sediment from the CRE during the 1990s (Flynn and Hornewer, 2003). These observations led to the initiation in 1999 of flux-based monitoring. By 2001, research and development activities led to the current reach-based IQW project that combines conventional sediment transport sampling with sediment surrogate techniques to provide a high resolution sand flux monitoring dataset used for calculating the fine sediment mass balance systemwide.

These previous research and monitoring efforts guided the development of the current fine sediment core monitoring plan. Results from the 2002 to 2005 period of the IQW project demonstrated that 90% or more of the fine sediment is stored in the eddies and channel at elevations lower than the 8,000 cfs stage (Hazel and others, 2006). This study also demonstrated that change in low-elevation sediment storage computed from repeat measurements over short (~ 15 km) reaches is not consistent with the change in storage computed based on the measurements of sediment transport over longer (~50 km) reaches (Topping and others, 2006). While the measurements of sediment transport that are made as part of the goal 7 IQW are used to detect changes in sediment storage in long reaches over short timescales (up to ~ 5 years), accumulated uncertainty in these measurements will prevent the determination of longer-term trends in sediment storage with adequate certainty. Transport monitoring is necessary to track the accumulation and fate of tributary inputs and provide information needed to plan high flow events. However, in order to determine whether sediment storage in the system as a whole is increasing, decreasing, or stable requires repeat measurements of sand storage throughout the entire system (Figure 4). For these reasons, goal 8 fine sediment monitoring includes system-wide measurements of channel and eddy sand storage in addition to monitoring related to high-elevation sandbars, campsites, and backwaters.

Figure 4

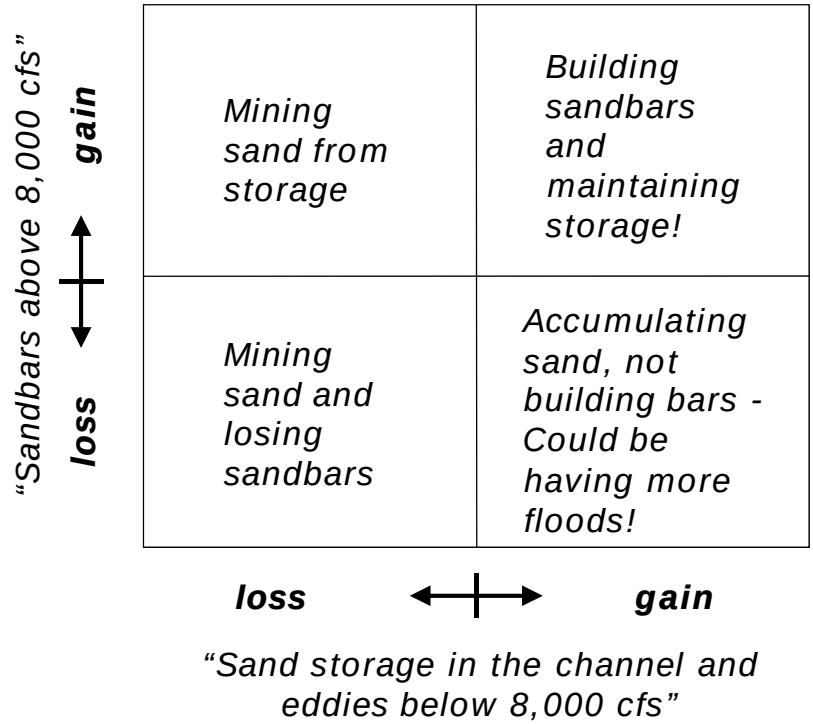


Figure 4 Conceptual plot showing how long-term trends in sand storage detected by the goal 8 SedTrend monitoring program will inform management for sandbars. In the event that sandbars are increasing in size above the 8,000 cfs stage, the SedTrend monitoring of sand below the 8,000 cfs stage will enable distinction between net depletion, "mining" from storage, and net gain, or "maintenance" of sand. If sandbars above the 8,000 cfs stage are decreasing in size, the SedTrend monitoring will be used to determine whether this is also associated with net decrease in storage or an increase in storage. The later would mean that more high flows could be used to achieve management goals of building sandbars while the former would mean that sandbar goals are unlikely to be met without additional sediment.

At the 2004 Adaptive Management Work Group (AMWG) priority-setting workshop, questions relating specifically to sediment were identified within three of the top five priorities of the GCDAMP:

GCDAMP Priority 4: What is the impact of sediment loss and what should we do about it?

GCDAMP Priority 3: What is the best flow regime?

GCDAMP Priority 2: Which cultural resources, including traditional cultural properties, are within the Area of Potential Effect, which should we treat, and how do we best protect them? What is the status and trends of cultural resources and what are the agents of deterioration?

Strategic Science Questions

Several SSQs were identified by scientists and managers during the knowledge assessment workshop conducted in the summer of 2005 (Melis and others, 2006). The SedTrend monitoring project provides valuable information to help answer several of the questions related to sediment conservation, and in particular the following primary sediment question:

SSQ 4-1. Is there a "Flow Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal timescales?

Information Needs Addressed

The 2003 GCDAMP Strategic Plan identified Core Monitoring Information Needs (CMINs) related to sediment storage (goal 8). The CMINS that are addressed by the SedTrend and sandbar monitoring are listed below. For each, the prioritization ranking applied by the GCDAMP Science Planning Group (SPG) in 2006 is also included.

CMIN 8.1.1. Determine and track the biennial sandbar area and fine-sediment volume and grain-size changes within eddies below 5,000 cfs stage, by reach. (fourth-ranked goal 8 CMIN).
CMIN 8.2.1. Track, as appropriate, the biennial or annual sandbar area, volume. and grain-size changes within and outside of eddies between 5,000 and 25,000 cfs stage, by reach. (second-ranked goal 8 CMIN).
CMIN 8.5.1. Track, as appropriate, the biennial sandbar area, volume, and grain-size changes above 25,000 cfs stage, by reach (fifth-ranked goal 8 CMIN).
SedTrend monitoring also addresses this unranked goal 8 CMIN:
CMIN 8.6.1. Track, as appropriate, changes in coarse sediment (> 2 mm) abundance and distribution.
The SedTrend and sandbar monitoring also directly address this top-ranked goal 9 CMIN priority (jointly with REC 9.R1: Sandbar and Campable Area Monitoring):
CMIN 9.3.1. Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons (top-ranked goal 9 CMIN).
Developing and testing monitoring protocols for these CMINs was the primary focus of research and development conducted during FY1998–2006, and was reviewed during the physical sciences protocols evaluation program, SEDS-PEP III (Wohl and others, 2006).

Methods and Tasks –FY 2011 and FY2012

During FY2011 and FY2012, SedTrend and sandbar monitoring will include work on all three tasks described below. The task 1 sandbar monitoring will be completed using protocols described by Hazel and others (1999); Task 3 is conducted using standard ground-based surveying protocols and multibeam-sonar bathymetric surveying protocols described in Kaplinski and others (2000, 2007). The grain-size data collected under task 3 (recommended by the final PEP, Wohl and others, 2006) are collected and processed using protocols described in Rubin and others (2006, 2007) and Rubin (2004). The data collection for task 2 systemwide inventory of high-elevation sand deposits was described in section DASA 12.D9 of the FY2010 work plan.

Task 1. Monitoring High-Elevation Sandbar Study Sites

Task 1 consists of monitoring the area and volume of fine sediment above the stage associated with 8,000 cfs for subsets of sandbars and campsites throughout the CRE using conventional ground-based surveying methods. This dataset is commonly referred to as the “Northern Arizona University (NAU) sandbar time series” and is the longest running dataset on the state of sandbars currently available (initiated in 1990). For budget reasons, to better facilitate reporting, and because previous results have shown steady declines in sandbar area and volume between high flow events (Wright and others, 2005), sandbar monitoring was put on a biennial schedule beginning in FY2010 when no sandbar monitoring was scheduled in the FY2010 work plan. Thus, except around high flows, biennial monitoring will be sufficient to document future trends in sandbar area and volume. Sandbar monitoring will occur in September-October 2011 and will not occur in 2012. This task is conducted in coordination with goal 9 campsite monitoring. The sandbar monitoring sites are also monitored by daily photographs taken by remote digital cameras. These images provide a record of sandbar changes between surveys, allowing more precise determination of the relation between changes in sandbar size and flow regime. These remote cameras will provide the only direct monitoring of sandbar condition immediately before and after future high flows. Currently, 18 sites are monitored by remote camera.

Additional cameras will be installed as funds are available (see high flow contingency, below). The images will be used to create movies for each sandbar for the period of photographic record.

An important aspect of the long-term sandbar data series is how the size of sandbars at the initiation of monitoring in 1990 compares with sandbar size (area and volume) prior to 1990. In FY2012, we will begin extending the sandbar data series backward in time by analysis of aerial photographs for sandbar area and volume. This project will proceed with technical assistance from the survey support project (SUP 12.S2) and is contingent upon staff availability in FY2012. The degree to which this project can be implemented in FY2012 will be addressed in the review of the FY2012 work plan during FY2011.

Task 2. Repeat Systemwide Inventory of High-Elevation Sand Deposits

Approximately once every 4 years (but only in years without high flows), the systemwide area of fine sediment above the stage associated with a discharge of 8,000 cfs (that is, approximately 10 percent of the fine sediment in the CRE) will be monitored using orthrectified aerial photography images collected during quadrennial overflights (the volume of fine sediment may also be monitored if light detection and ranging [LiDAR] sensors are deployed). Although these data only monitor sand that is above the 8,000 cfs water surface and, therefore, cannot be used to quantify changes in sand storage volume, they do provide a robust assessment of the systemwide distribution of bare sand and the distribution of riparian vegetation. The most recent overflight consisting of 4-band images occurred in May 2009. Analysis of these images for sandbar area will occur in FY2011 and a pilot evaluation of their use in determining sandbar volume will occur in FY2012, as described in the coordinated image analysis project in the FY 2010 work plan, DASA 12.D9.

Task 3. Monitoring In-Channel Sediment Storage--SedTrend

Monitoring of the area and volume of fine sediment at all elevations over long reaches is designed to occur each year that a high flow does not occur using multibeam bathymetric surveys, ground-based topographic surveys, underwater video transects, and underwater camera measurements of bed grain size. Although this monitoring is not designed to monitor the results of any single high flow, it is designed to monitor the cumulative results of multiple high flows over a 5 to 10 year period. The results from previous high flow monitoring demonstrate that high flows build sandbars and that the magnitude of bar building is greatest when sand concentrations are highest. The question that is unresolved, which this program seeks to address, is whether repeated high flows and intervening dam operations can result in maintenance or increase in sandbars over longer periods of time. Site-based monitoring does not include enough study sites to address this question and remote sensing is not able to capture submerged sand, which is 80 percent or more of the active storage.

Because deposits at all elevations are mapped, this monitoring provides a comprehensive assessment of changes in sandbar area, volume, and morphology. Thus, in addition to tracking the amount of low-elevation sand stored in the channel, this monitoring will also provide the first robust assessment of changes in sandbar size and morphology above the 8,000 cfs stage.

This task is planned to be performed on a systemwide basis every 5 to 10 years in order to calculate fine-sediment budgets over timescales for which the goal 7 mass-balance sediment budgets likely become inconclusive due to accumulating measurement errors. In addition to providing this key sediment budget information (that is, the status of the fine sediment “bank account”), these data will provide maps of the river bed that can be used for flow and sediment transport models, information to allow mapping of bed texture, which is an essential component for interpreting the results of research on the aquatic food base, and information on the location and geometries of backwaters thought to be important habitat for native fish. It is not possible within current budgetary and personnel constraints to survey the bathymetry of the entire river in any given year. Therefore, a different reach of the river will be surveyed each year on a rotating basis. The reaches will correspond to the segments outlined in

the goal 7 IQW project, such that upon completion of a repeat survey for a given reach, all components of the sediment budget for that reach will have been measured directly. The reaches are as follows: reach 1, RM 0 to RM 30 (upper Marble Canyon); reach 2, RM 30 to RM 61 (lower Marble Canyon); reach 3, RM 61 to RM 87 (eastern Grand Canyon); reach 4, RM 87 to RM 166 (central Grand Canyon); reach 5, RM 166 to RM 226 (western Grand Canyon).

These surveys are scheduled for late spring and will only be completed in years without high flows. In the absence of high-flow tests, each reach would be surveyed every 5 years, or, if a high-flow test occurred on average every other year, then each reach would be surveyed on average every 10 years. This 5 to 10 year interval between repeat bathymetric and topographic surveys coupled with the goal 7 IQW flux monitoring will provide a robust quantification of long-term trends in the fine sediment budget. Because reaches 4 and 5 are much longer than reaches 1 through 3, it is possible that portions of these reaches will not be surveyed. Existing data will be used to identify the portions of these reaches that are most likely to store fine sediment. It is also possible that technological advancements and improvements in methods will allow for complete surveys of these reaches in the future.

The schedule for SedTrend monitoring under goal 8 is complicated by the potential for high-flow tests. It is advantageous for task 2 remote-sensing missions and task 3 channel monitoring surveys to occur in years without tests so that the monitoring data are not dominated by the effects of a single high-flow test. Rather, remote-sensing and reach survey monitoring should represent the integral response of the system to several years of dam operations and tributary inputs. Further, logistical constraints would make it difficult to conduct the remote-sensing and channel mapping in addition to high-flow monitoring. Thus, without knowing the exact frequency of tests, it is impossible to outline the exact schedule for SedTrend monitoring.

In FY2009, channel mapping data were collected in reach 2 (RM 30 to RM 61). Analyses of these data are underway to ensure the data meet the needs of the planned monitoring program within acceptable ranges of certainty. The desired outcome of a computation of change in storage over a long reach requires that we have a thorough examination of error and uncertainty such that we can apply confidence levels to these computations. Although repeat measurements of topographic and bathymetry have been used routinely in the GCMRC monitoring over the past 10 years and longer, the channel mapping project represents a significant scaling upwards of these methods. For FY2010, data collection was suspended to allow finalization of 2008 high flow reporting and analysis and reporting on FY2009 channel mapping data.

Data collection will resume in FY2011 with either the segment between RM 61 and RM 87 or the segment between RM 166 and RM 226. The segment not mapped in FY2011 will be mapped in FY2012. A high flow in either of these years would result in deferment of channel mapping to the next year without a high flow.

Summary Schedule of Goal 8 Tasks

Table 5 presents two possible 10-year schedules based on different assumptions regarding high flow frequency for illustrative purposes. The first is the schedule in the absence of high-flow tests where the exact schedule can be delineated. The second schedule assumes that high-flow tests occur every other year, which would be the approximate frequency under previous triggers based on tributary sediment supply. In reality, even if the frequency were every other year on average, there would likely be periods with successive years of tests and successive years without tests such that the core-monitoring schedule for remote-sensing and reach surveys must be flexible. The sequence of the channel mapping surveys is based on priority for long-term monitoring. Reaches 2 and 5 are likely to be the best indicators of long-term trends because they are not immediately downstream from major tributaries and are, therefore, likely to have smaller fluctuations in storage resulting from tributary inputs. The sequence is interrupted by an early resurvey of reach 2. This will allow calculation of a

change in fine sediment storage for this reach over a time period for which the uncertainty in the goal 7 mass balance is well constrained. This will also provide an early demonstration of how the long-term SedTrend monitoring data will be analyzed and presented.

Table 6

Alternative schedules for the completion of the tasks outlined under project PHY 8.M1.11-12

Year	Schedule without high-flow test			With high-flow tests every other year		
	Task 1: subsample campsites/ sandbars	Task 2: 4-year overflights	Task 3: SedTrend channel mapping	Task 1: subsample campsites/ sandbars	Task 2: 4-year overflights	Task 3: SedTrend channel mapping
2009	X	X	Reach 2	X	X	Reach 2
2010 (high-flow test)			Suspend data collection	*		
2011	X		Reach 3 (or 5)	X		Reach 3 (or 5)
2012 (high-flow test)			Reach 5 (or 3)	*		
2013	X	X	Reach 2	X	X	Reach 5 (or 3)
2014 (high-flow test)			Reach 1	*		
2015	X		Reach 4	X		Reach 2
2016 (high-flow test)			Reach 5	*		
2017	X	X	Reach 3	X	X	Reach 1
2018 (high-flow test)			Reach 2	*		

* Additional sandbar/campsite monitoring that occurs if high flow occurs in year without scheduled biennial monitoring.

Links/Relationships to Other Projects

SedTrend monitoring provides data (that is, maps showing the topography and distribution of sediment types over about 30-mile reaches of the river) that are essential to the development and testing of numerical predictive models of discharge, stage, sediment transport, and sandbar morphology. These predictive models can be used to evaluate a wide range of resource responses, such as the fate of sandbar habitats to various dam release scenarios, controlled floods, steady flows, fluctuating flows, etc.

SedTrend monitoring provides data to be used to evaluate the effectiveness of dam operations (including high-flow tests) for rebuilding and maintaining sandbars in the CRE. Additionally, SedTrend monitoring will provide the data showing whether dam operations continue to mine the long-term fine-sediment reserve stored at elevations below the stage associated with a discharge of 8,000 cfs (more than 90 percent of the fine sediment in the system is currently stored below this elevation). If the amount of sediment in this "bank account" continues to decrease, then operations will ultimately not be able to sustain fine-sediment resources at higher elevations.

Campsite Monitoring

Sandbar monitoring supports the campsite inventories conducted under goal 9 by characterizing the status and trends of the sandbars used as campsites (covered under project REC 9.R1: sandbar and campable area monitoring).

Cultural Resources

SedTrend and sandbar monitoring support goal 11 by characterizing the status of fine sediment at higher elevations in and around cultural sites, and by characterizing the amount of open dry sand available to be transported by the wind into these cultural sites. SedTrend monitoring also supports new research focused on the food web of the river ecosystem by providing data on the input of gravel used as a substrate by the aquatic food web.

Aquatic and Riparian Habitat

SedTrend monitoring provides information on the distribution of the fine-sediment deposits that form the substrate for the riparian ecology.

Finally, SedTrend and sandbar monitoring supports science activities in the fisheries program by providing the data to characterize the locations and geometries of backwaters thought to be important habitat for native fish.

Monitoring and Research for Potential High Flow Experimental Protocol

As described above, the SedTrend project is designed to monitor the cumulative effect of multiple high flows, but is not conducted in years with high flows because the channel mapping component is not designed to monitor the effects of individual high flows. Individual high flows and subsequent sandbar erosion are monitored by remote cameras and the repeat surveys of the sandbar monitoring sites. Details of the high flow monitoring plan and budget implications are addressed in PLAN 12.P6.

Products/Reports – FY2011

The SedTrend channel mapping will ultimately result in decadal-timescale sediment budgets for each of the five channel mapping segments, providing information on the long-term status of the fine-sediment reserve. These sediment budgets will also be compared to the sediment budgets computed for these reaches under the complementary mass-balance project described under goal 7. These comparisons, however, cannot be made until the segment mapped in 2009 is repeated. Collection of channel mapping data for the SedTrend project and sandbar monitoring will both occur in FY2011. These data will not be fully processed and reported until FY2012.

Collection and processing of SedTrend channel mapping data for an additional one of the five channel mapping segments. Currently, this work is planned to occur in the segment between RM 61 and RM 87 or between RM 166 and RM 225

Repeat surveys of the NAU sandbar study sites

Finalization of reports outlined in the FY 2010 work plan, which include:

Data series report and journal article on the Northern Arizona University sandbar data, 1990-2009

Topographic/bathymetric maps of the RM 29 to RM 61 segment mapped during the FY2009 SedTrend field work

Analysis of uncertainty in the SedTrend topographic/bathymetric maps. This analysis is necessary to demonstrate that maps generated over long reaches have sufficient accuracy that they can be used to compute changes in fine sediment storage within acceptable levels of uncertainty; this analysis will result in one or more peer-reviewed reports and journal articles

Comparisons between the data collected in lower Marble Canyon in FY2009 and multibeam-sonar data collected in parts of lower Marble Canyon between 2000 and 2008 to evaluate volume changes in the fine-sediment reserve, resulting in at least one peer-reviewed report or journal article

- Analysis and preliminary reporting on system-wide monitoring of sand area above the 8,000 cfs stage with remote sensing collected in 2002, 2005, and 2009 in coordination with DASA 12.D9
- Preparation of conference abstracts and/or proceedings articles
- Presentations at GCDAMP meetings (as necessary)
- All work conducted for the SedTrend and sandbar monitoring project will be summarized in annual reports to be completed by January 1, 2012

Products/Reports – FY2012

Reporting and publication of the data collected in FY2011 will occur in FY2012.

Collection and processing of SedTrend channel mapping data for an additional one of the five channel mapping segments; currently, this work is planned to occur in the segment between RM 166 and RM 225 or RM 61 and RM 87

Topographic/bathymetric maps of the segment mapped during the FY2011 SedTrend field work with comparisons between these data and earlier data collected in this reach

- Final reporting on system-wide monitoring of sand area above the 8,000 cfs stage with remote sensing collected in 2002, 2005, and 2009 in coordination with DASA 12.D9
- Preparation of conference abstracts and/or proceedings articles
- Presentations at GCDAMP meetings (as necessary)
- All work conducted for the SedTrend and sandbar monitoring project will be summarized in annual reports to be completed by January 1, 2013

Budget

FY2011 $468,060

FY2012 $486,260

GCDAMP Goal 9—Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.

REC 9.R1.11–12—Campsite Area Monitoring

Start Date

October 1998

End Date

Ongoing

Principal Investigators

R. Parnell, M. Kaplinski, and J. Hazel, Northern Arizona University, Geology Department, in cooperation with U.S. Geological Survey, Grand Canyon Monitoring and Research Center staff.

Geographic Scope

Campable area monitoring for GCDAMP has historically focused on monitoring campable space at approximately 31 sandbars located along the main channel of the Colorado River between Lees Ferry (RM 0) and Diamond Creek (RM 226). In FY2011, these long term study sites will continue to be the focus of campable area monitoring.

Campsites in the reach below Diamond Creek are of interest to National Park Service (NPS) and Hualapai tribal managers due to the increasing recreational use of the "Diamond Down" reach and the fact that persistent sandbars are now exposed along a flowing river reach as a result of the recent years of lower reservoir elevations and sand storage in Lake Mead. Therefore, 1-3 additional sandbar campsites between RM 226 and the western boundary of the geographical scope of the GCDAMP program (approximately RM 278) may be included in this monitoring project starting in FY2011.

Project Goals

The goal of this project is to track changes in campable area using established monitoring protocols (repeat total station surveys) while alternative monitoring approaches using remotely sensed data are being explored and evaluated (see project REC 9.R3/DASA 12.D9):

The specific objectives of this study include the following:

- Measure campsite area at a series of long-term monitoring sandbar sites
- Evaluate changes in campsite area in relation to changes in sandbar volume and topography
- Evaluate how changes in campsite area affect other attributes that relate to camp site quality and visitor experience

Need for Project

Public concern with the ongoing loss of sandbar "beaches" and recreational capacity in the Colorado River corridor was a key factor leading to the development of the 1995 Glen Canyon Dam Final Environmental Impact Statement and passage of the Grand Canyon Protection Act (GCPA) in 1992. With the supply of new sand below the dam estimated to be about 6 percent of the pre-dam supply in Marble Canyon and about 16 percent of the pre-dam supply below the confluence with the LCR (RM 61–278), there is considerable uncertainty about the future fate and long-term sustainability of sandbar campsites below GCD under proposed operational strategies intended to promote sand conservation of tributary inputs. The protection of visitor use values is specifically identified as a goal of GCPA and is a stated goal of the GCDAMP. This project directly addresses one element of the top priority core-monitoring information need (change in campsite size) for goal 9 of the GCDAMP Strategic Plan (2003), and indirectly addresses aspects of campsite quality and visitor experience quality. This project will provide data to managers about the status and trend of campsite area throughout the CRE below GCD at sites that were monitored annually since 1998, and that are now proposed for monitoring every other year, with FY2011 being the next year when monitoring will occur.

Strategic Science Questions

In terms of questions that are specific to the AMP goals for recreation, this project directly addresses the following SSQ:

> **SSQ 3-9.** How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

Because campsite size can affect visitor experience, this project also indirectly addresses two other important science questions related to recreation in the CRE:

> **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?

Indirectly, this project is also relevant to resolving the primary strategic science question for sediment, in that it provides another measurement of sandbar habitat (in this case, human habitat):

> **SSQ 4-1.** Is there a "Flow Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales?

Information Needs Addressed

This project directly addresses one part of the top priority CMIN for goal 9 (campsite size):

> **CMIN 9.3.1.** Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons. (This project specifically addresses the part of the CMIN concerned with campsite size.)

This project partially addresses a second campsite CMIN (9.3.2) that is closely related to the top priority CMIN for camping beaches (Note: The Science Planning Group of the TWG recommended that CMINs 9.3.1 and 9.3.2 be combined as one):

CMIN 9.3.2. Determine and track the effects of ROD operations on the size, quality, and distribution of camping beaches in the CRE.

This monitoring project also is designed to track the short- and long-term effects of experimental flows on camping beaches (campable area), as defined by EIN 9.3.1:

EIN 9.3.1. How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the ROD, unanticipated event, or other management action?

Methods and Tasks

Repeat surveys of sandbars have been conducted since 1990 using trained field personnel under the joint direction of the GCMRC's physical program staff and scientists from the Northern Arizona University (NAU) Department of Geology. Campable area survey protocols were subsequently established in 1998 and have been applied consistently to a sub-set of these long-term sandbar monitoring sites by the same team of NAU scientists since 1998 (Kaplinski and others, 2005). As described in the SCORE report (Kaplinski and others, 2005, p. 196), in the past, campable area surveys were conducted annually in the fall, at the conclusion of the prime river recreation season. Survey crews from NAU Department of Geology measure the study sites using standard total station survey techniques (U.S. Army Corps of Engineers, 1994). Starting in FY2010, GCMRC decided to reduce the frequency of sand bar and campable area monitoring to every other year. FY2010 was the first year since 1998 that sand bar and campsite monitoring did not occur. In the FY2011-12 work plan, FY2011 will be an "on" year, in which campsite monitoring will occur again, while FY2012 will be an "off" year, in which the focus will be limited to further analysis of legacy data and reporting.

Following established protocols, topographic data will be collected and referenced to Arizona State Plane Coordinates generated through the GCMRC's survey control network throughout the CRE. Data will be reduced and analyzed by the NAU team in cooperation with GCMRC and presented in a variety of formats. The campable areas will also be assessed relative to flow and stage elevations linked to dam operations. These data will be integrated with, and analyzed in relation to, sandbar measurement data (area and volume relative to stage elevations) that are being collected as a component of the core-monitoring program for sediment (see project PHY 8.M2).

Surveyors follow the criteria of Kearsley (1995) and Kearsley and Quartaroli (1997) to identify campable area. Campable area is defined as "a smooth substrate (preferably sand) with no more than 8 degrees of slope with little or no vegetation" (Kaplinski and others, 2005, p.196). Although the goal is to capture the total campable area at each site, camping areas located at considerable distance (>100 m) from the main mooring/cooking areas are generally not included in the totals. In the future, these protocols may be adjusted to measure all campable area with variable slope criteria within the NPS-defined campsite boundaries using remotely sensed data (see REC 9.R3/DASA 12.D9); however, until new protocols are tested and refined, the existing monitoring program will continue.FY2011

In the FY2010-11 work plan, GCMRC originally proposed to hold a PEP in FY2011 to review and potentially refine campsite monitoring protocols; however, the analysis of remote sensing data has been delayed due to delays processing the 2009 overflight data. Therefore, FY2011 will be another "on" year, in which the long-standing approach to campsite monitoring will occur, and the PEP will be deferred to FY2012..

In addition, GCMRC will continue to support Grand Canyon River Guides with a small amount of funding (~$8k) to continue the collection, analysis, digitizing, and archiving of photographic records documenting changes occurring at 45 popular campsites. These data, which are collected by river guides on a volunteer basis and compiled, digitized, and analyzed by a paid staff person, provide

another form of monitoring data at minimal cost for tracking changes in campsite area, shoreline/mooring characteristics, and overall camp quality through time.

FY2012

In FY2012, GCMRC will convene a PEP to review existing monitoring protocols for campsites, as well as to consider the results of analyzing remotely sensed data to evaluate campsite changes (see project REC 9.R3/DASA 12.D9). Upon completion of this PEP, monitoring of campsites will recommence in FY2013, subject to revisions recommended by the PEP. In addition, GCMRC will continue to support Grand Canyon River Guides with a modest amount of funding (~$8k) to continue the collection, analysis, digitizing, and archiving of photographic records at 45 popular campsites. These data, which are collected by river guides on a volunteer basis and compiled, digitized, and analyzed by a paid staff person, provide another form of monitoring data targeted at tracking changes in campsite area, shoreline/mooring characteristics, and overall camp quality through time.

Links/Relationships to Other Projects

Sandbar Monitoring

This monitoring project will continue in conjunction with, and will be analyzed in relation to, the data collected from NAU's long-term sandbar monitoring sites, a project that has been underway since the early 1990s. The campable area surveys that this project focuses on have occurred annually at a subset of the NAU sandbar sites since 1998. Both the NAU sandbar survey and campable area monitoring projects are concerned with monitoring sandbar sediment, but in different respects. The sandbar survey tracks changes in total area and volume of sandbars above the 5,000 cfs level, while the campable area monitoring project specifically evaluates changes in the amount of campable area available at a subset of these sandbar sites. In combination, these two projects provide a relatively holistic assessment of how flows are affecting the sandbar habitats used by recreational boaters for camping.

Campsite Inventory and GIS Atlas

The sites being assessed by this monitoring project constitute a relatively small and non-random, but fairly representative (Schmidt and others, 2004) subset of the total number of campsites located throughout the river ecosystem. Data resulting from this monitoring project will be incorporated into the GIS campsite atlas in FY2012 (REC 9.R3). In addition, these directly surveyed campable area measurements will be used to assess the quality and accuracy of campable area data derived from remotely sensed imagery (see REC 9.R3/DASA 12.D9).

Changes in High Elevation Sand Availability

In addition to recreation resources, sandbars are closely linked with other resources of GCDAMP concern, such as terrestrial and aquatic habitats related to native fish rearing areas (backwaters) and cultural sites. Campable area monitoring provides information on changes in area of open sand above the active fluctuating flow operating zone (above 25,000 cfs stage) and indirectly provides information about whether sand storage in those areas is stable, increasing, or decreasing through time in response to normal dam operations or experimental high flows that are intended to promote conservation of new sand supplies. The abundance of open sand areas along shorelines provides another indirect measurement of the potentially available sand for transport by wind to higher elevations where archaeological sites are located. In the future, studies at cultural sites may incorporate data derived from monitoring sandbars and campable area to estimate changes in sand flux at nearby cultural sites.

Logistics

In FY2011, fieldwork will require a single oar powered river trip planned for late September–early October 2011 in conjunction with the sandbar monitoring project (PHY 8.M2). No field work is planned for FY2012 unless a high flow occurs, in which case one trip would occur within 6 months following the flow in conjunction with sandbar monitoring (see HFE Protocol experiment project.)

Products/Reports

A comprehensive, synthetic, peer reviewed report documenting the change in campable area over the past 10 years and relating these changes to other monitored changes, such as sandbar area and volume, is being prepared in FY2010. This report will be served through the GCMRC web site and Campsite GIS Atlas in FY2011. Results of FY2011 fieldwork will be reported in a USGS fact sheet or Open-File Report and served through the GCMRC website in FY2012.

Budget

FY2011 $74,704

FY2012 $40,864

REC 9.R3.10–11—Expand and Analyze Campsite Data in the GIS Atlas

Start Date

2007

End Date

September 30, 2012

Principal Investigators

Helen Fairley, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, with GCMRC staff support

Geographic Scope

Entire Colorado River ecosystem (CRE), from base of Glen Canyon Dam (GCD) to Lake Mead (River Mile [RM] 277)

Project Goals

The goals of this project are to expand the existing GIS campsite atlas database and use the atlas as a foundational tool for analyzing and documenting changes in campsite attributes that are potentially affected by dam controlled flows. These goals will be accomplished by:

Adding recently collected campsite data to the atlas database

Continuing to expand the legacy data component of the atlas

Analyzing the currently compiled campsite data to document changes in the spatial extent, geographic distribution, and associated attributes of campsites located throughout the CRE. In FY2011, the focus will be on evaluating vegetation encroachment at a random sample of currently used campsites in the atlas using a combination of remotely sensed imagery and oblique photography analyzed in relation to GIS data that defines current campsite boundaries.

The atlas currently contains tabular data on current campsite attributes that are important to maintaining a high quality recreation experience in the CRE and that have the potential to be affected by flows (for example, campable area, amount of open sand area, type and amount of vegetation cover, and shoreline/mooring characteristics under varying flows). The atlas also documents the locations and attributes of past campsites identified in previous inventories that have since disappeared due to loss of sediment and/or vegetation encroachment. The atlas is designed to serve as the primary electronic repository for all data that have been collected on campsites over the past few decades (for example, repeat photographs, campable area survey data, vegetation transect data, human impact data, etc.). It also serves as the baseline "status" record for future monitoring and research projects. It defines the boundaries of current campsites in a GIS environment so that future evaluations that rely on remotely sensed data and statistical samples to quantify change in campsite attributes relative to dam operations (e.g., DASA 12.D9) have a common spatial basis for evaluating change through time.

Need for Project

Baseline inventories provide the foundation for long-term monitoring programs and research studies. Comprehensive campsite inventories in the CRE conducted initially in 1973 were repeated in

1984 (Weeden and others, 1975; Brian and Thomas, 1984) and again in the 1990s. The last comprehensive campsite inventory was completed 18 years ago in 1991 (Kearsley and Warren, 1993). The 1991 inventory showed a dramatic decline in number and size of campsites compared with previous inventories (Kaplinski and others, 2005). As conditions change, additional comprehensive inventories are needed periodically to assess status and trends related to camp size, quality, and distribution throughout the CRE. The atlas provides the baseline data against which future changes can be assessed. This atlas will also serve as the central repository for all campsite data collected during future inventory and monitoring projects. The 2005 recreation PEP identified the development of this atlas as the highest priority research need under management objective 9.3. In addition to assessing overall changes in campsite area and distribution, there is a need to understand the specific factors contributing to changes in campsite area through time. The work proposed in FY2011–12 will focus on analyzing remotely sensed data using GIS tools in the atlas to evaluate the role of vegetation in affecting available camping area and influencing the quality of campsites through time.

Strategic Science Questions

This project directly addresses the following strategic science question:

> **SSQ 3-9.** How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

Indirectly, this project will also provide information that is relevant for addressing a second strategic science question about the effects of flows on the quality of 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?

Information Needs Addressed

This project is designed to address management objective 9.3 and specifically, the AMP's top priority CMIN for Goal 9:

> **CMIN 9.3.1.** Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons.

CMIN 9.3.1 is very closely related to a second CMIN under Management Objective. 9.3

> **CMIN 9.3.2.** Determine and track the effects of ROD operations on the size, quality, and distribution of camping beaches in the CRE.

The current monitoring program for campsites (REC 9.R1) focuses primarily on one aspect of CMIN 9.3.1: campsite size. Task 3 of this project will contribute information about the role of vegetation encroachment on campsite size. In addition, this project is developing a comprehensive database relevant to tracking other key relevant campsite variables, such campsite distribution and quality throughout the CRE. Through analyzing the FY2002, FY2005, and FY2009 post-experimental flows imagery in relation to campsites, this project is also designed to contribute valuable information relative to interpreting the effects of experimental flows on camping sites, as defined by EIN 9.3.1.

> **EIN 9.3.1.** How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the ROD, unanticipated event, or other management action?

Methods and Tasks

The work proposed in FY2011–12 will involve three primary components:Incorporate data from FY2009 and11 campsite monitoring efforts into the GIS atlas

Tabular data, survey data, supporting metadata, and photographs collected in FY2009 and FY2011 will be scanned and linked to GIS/spatial data

Scan additional maps, slides, and photographs and incorporate additional legacy data from past campsite monitoring projects into the atlas

Analyze vegetation encroachment at both the NAU long-term sandbar sites and at a random sample of campsites the campsite polygon data overlaid on 2002, 2005, and 2009 overflight imagery and oblique photographic records from a sample of campsites

- Using aerial imagery collected in 2002, 2005, and 2009, we will analyze the amount of vegetation contained within the established polygon boundaries at the NAU sandbar sites and at a randomly-selected sample of other campsites to determine how much vegetation encroachment has contributed to changing campable area through time

Links/Relationships to Other Projects

The GIS atlas is designed to serve as the definitive source for information on prior and current campsite inventory data. It provides a foundation and repository for all future research and monitoring projects related to CRE campsites. In addition to meeting GCDAMP information needs, data from this project will be used by the National Park Service as they develop implementation plans and resource monitoring projects tied to the Colorado River Management Plan. For example, in addition to documenting areas used for recreational camping, the GIS campsite layer documents areas of the CRE most heavily used and impacted by humans. This information will be useful for assessing human impacts rates on nearby cultural resources such as archaeological sites and traditional cultural properties.

Logistics

Fieldwork required to verify or update the atlas will be accomplished by participating on other scheduled GCMRC river trips.

Products/Reports

An assessment of the role of vegetation in affecting campsite area will be published as a Scientific Investigation Report in FY2012

Budget

FY2011 $39,465

FY2012 $41,640

REC 9.R4.11–12—Evaluate Recreation Values and Visitor Experience Quality in the Glen Canyon Reach

Start Date

2011

End Date

2012

Principal Investigator

TBD, in cooperation with Arizona Game and Fish Department (AZGFD) and National Park Service (NPS)

Geographic Scope

Colorado River from Glen Canyon Dam (GCD) to Lees Ferry

Project Goals

The goals of this project are as follows:

Evaluate the recreational values and visitor experience quality under varying flow regimes, including high flow experiments, of anglers and other visitors who benefit from fishing and pursuing other recreational activities in the Glen Canyon reach

Work with AZGFD to refine the creel survey to gather basic recreation experience quality data and economic (expenditure) data and to serve as a tool for future periodic monitoring of visitor satisfaction associated with trout fishing in the Lees Ferry reach

Need for Project

Operation of Glen Canyon Dam (GCD) affects the ecosystem of the Glen Canyon reach, including the ecology of RBT, the resulting quality of the trout fishery, the condition of camping beaches, and other physical and biological attributes that are important to having and maintaining a high quality visitor experience. The Lees Ferry recreational fishery was recognized as a resource of concern in the *Operation of Glen Canyon Dam Final Environmental Impact Statement* (U.S. Department of the Interior (DOI), 1995), which concluded: "Glen Canyon Dam Adaptive Management Program (GCDAMP) goals for the trout fishery are to provide a recreational resource while maintaining and conserving native fish in Grand Canyon". The management objective of the GCDAMP is to maintain a blue ribbon trout fishery that produces a healthy, self-sustaining population of at least 100,000 age-2 RBT. The Glen Canyon Reach is also a popular day use rafting area.

The Arizona Game and Fish Department (AZGFD) has managed the Lees Ferry-Glen Canyon recreational fishery since 1964, while the National Park Service (NPS) manages visitor use in this area. Lees Ferry and the 15 mile long corridor upstream of Lees Ferry (hereafter referred to as the Glen Canyon Reach) serves as a popular destination fishery for international and national anglers. As such, it provides significant contributions to the Marble Canyon business community. The fishery is regulated by biotic and abiotic mechanisms that may in turn be affected by the operations of GCD.

In addition to recreational fishing, the Glen Canyon Reach is a popular destination for day use rafting and it is also used occasionally by canoeists and kayakers for day use boating and overnight camping.

This project responds to recommendations that have been made to the AMP by numerous independent PEP panels, including the 2005 Recreation PEP (Loomis and others, 2005), the 2009 Fish Pep (2009) and the review panel at the 2009 Socioeconomic workshop (Hamilton and others, 2009). This project is designed to complement existing monitoring programs in the Lees Ferry reach that focus on monitoring the condition, recruitment, population and other biological parameters of the Lees Ferry rainbow trout population. Unlike existing monitoring programs in the Lees Ferry Reach, however, the focus of this project is not on monitoring additional biological parameters but on assessing the full suite of recreational values and biophysical attributes that contribute to visitor enjoyment of the Glen Canyon reach under varying flows and resource conditions. This study will lay the foundation for evaluating changes in recreational experience quality resulting from future dam operations, including implementation of a future high flow protocol as well as other experimental flow regimes that may be implemented in the future.

Strategic Science Questions

Primary SSQs addressed:

SSQ 3-6. What GCD operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability?

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?

Information Needs Addressed

Information needs are the basis for developing and implementing long-term strategic and annual monitoring and research programs. Identified below are the current information needs pertinent to the recreational experience monitoring in the Glen Canyon Reach:

Primary information needs addressed include the following:

CMIN 9.1.1 Determine and track the changes attributable to dam operations in recreational quality, opportunities and use, impacts, serious incidents, and perceptions of users, including the level of satisfaction, in the Colorado River Ecosystem

CMIN 9.1.4 Determine and track the economic benefits of river related recreational opportunities

RIN 9.1.1 What are the attributes of a quality river experience?

Methods and Tasks

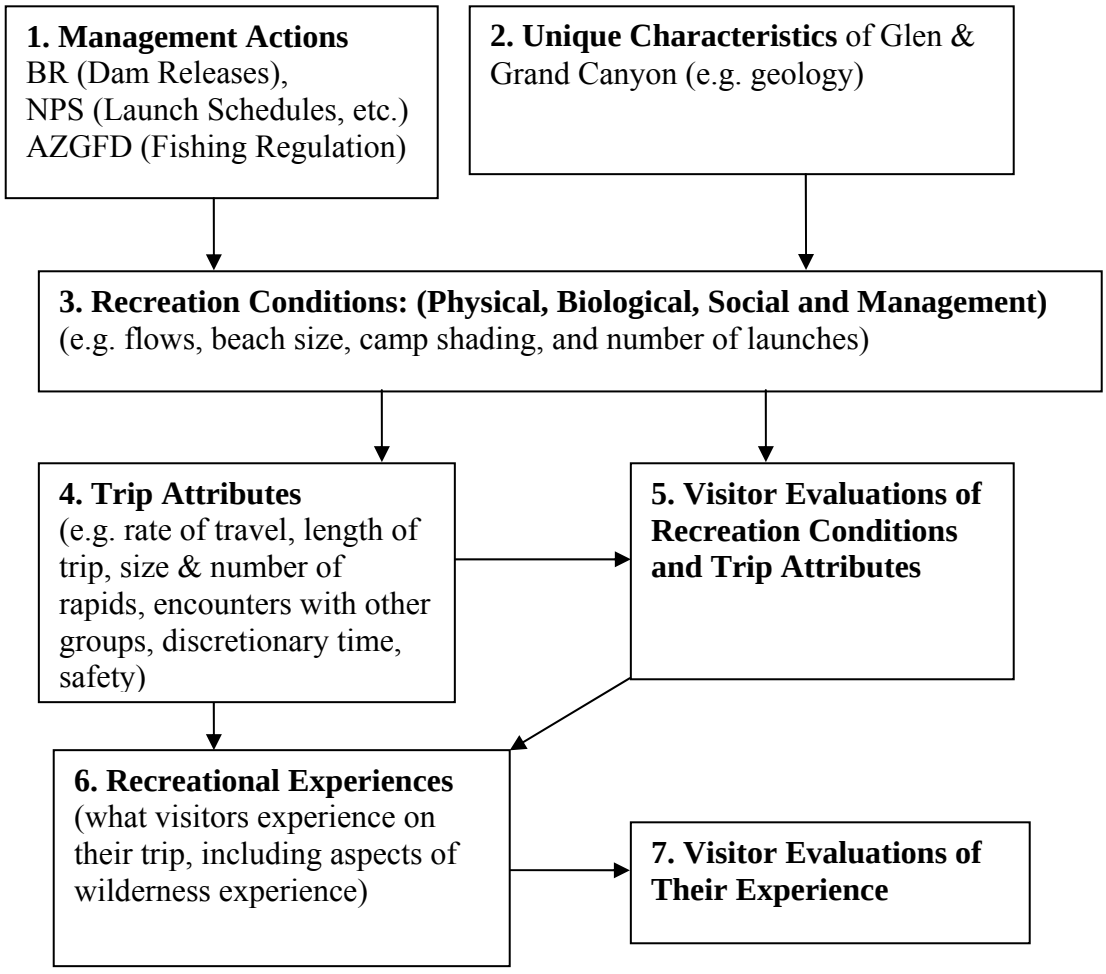
The following description of methods reflects the recommendations of the 2005 Recreation PEP and is adapted directly from their report (Loomis and others, 2005). In addition, this project responds to recommendations from the independent panel at the December 2009 Socioeconomic Workshop (Hamilton and others, 2010).

As previously mentioned, a key core monitoring need of the AMP is to determine and track visitor satisfaction for river-related recreational opportunities. Conceptually, visitor satisfaction is an important element of a recreation monitoring program. However, monitoring overall visitor satisfaction has several important weaknesses, including its currently undefined nature and problems of visitor displacement and other coping mechanisms whereby overall visitor satisfaction may be high even though the type of recreation experience provided is considerably different than what was intended or is considered appropriate by managers of the resource. Consequently, monitoring overall visitor satisfaction by itself is not recommended or proposed; instead, we propose to conduct some

basic research to identify relationships between dam operations, recreation resource conditions, recreation trip attributes, and visitor satisfaction with specific resource conditions and trip attributes.

AMWG management objectives can best be met by conducting initial research that relates dam operations directly to trip attributes that influence visitor satisfaction (see Figure 5 below). Once these relationships are established, there should be less need for annual monitoring of visitor satisfaction; instead we can focus on monitoring the dam operations that have been shown to influence the resource conditions and trip attributes that determine visitor satisfaction. After completing this baseline study, we anticipate that only periodic (e.g., every five years) monitoring of visitor experience quality and satisfaction would be necessary to ensure that the relationships among dam-related trip attributes and the visitor satisfaction remain unchanged.

Conceptual Model of River Recreation to Guide Monitoring
Figure 5



Knowing how each recreation resource condition and trip attribute contributes to visitor satisfaction and how these conditions are related to dam operations and other management actions provides the information Reclamation, NPS and AZGFD need to maintain recreation experience quality in the Glen Canyon Reach. Once these relationships are known, the GCMRC and others can focus monitoring on the relevant resource conditions and trip attributes and be able to reliably infer what is occurring to the visitor experience. This approach also provides the information needed to modify management actions that may be leading to a decrease in visitor satisfaction or to mitigate adverse effects of such actions.

An additional advantage of the trip attribute model is that it provides managers an understanding of how visitors trade-off different levels of trip attributes in terms of their experience satisfaction or quality. For example, lower flows often mean rockier shoals but denser concentrations of fish at certain locations. Using a quantitative trip attribute model (described below), the relative effect of different changes in trip attributes can be compared in terms of relative contribution to overall trip satisfaction. As also described in more detail below, organizing monitoring around a trip attribute model can simultaneously allow for quantifying the economic benefits received by the visitors. This allows addressing CMIN 9.1.4 with mostly additional statistical analysis rather than a separate data collection effort.

Ideally, we would like to be able to monitor visitor experiences directly (Box 6) and understand the relationships between management actions, particularly dam operations, and visitor experiences. While there have been a multitude of studies of outdoor recreation experiences, many of them conducted on rivers, and several of them focused specifically on the Colorado River in Grand Canyon (SWCA, 2002, Stewart et al. 2000), these studies have not specifically identified the cause and effect relationships between management actions, trip attributes and recreational experiences in the context of the Colorado River. Therefore, we propose to initially focus research on determining the recreation resource conditions such as physical, biological, social and management conditions (Box 3), trip attributes (Box 4) and visitor evaluation of resource conditions and attributes (Box 5) that are important to providing the types of visitor experiences that make recreation in the Glen Canyon Reach a world-class experience. This essentially involves estimating the linkages in the conceptual model in Figure 5 for Glen Canyon day use rafters and Glen Canyon anglers.

The first step in this recommendation is to synthesize the work done to date. Extending the work of Hall and Shelby (2000), Stewart et al. (2000) and Shelby and Whittaker (2005) on the importance of biophysical characteristics and trip attributes to high quality experiences is needed. For example, Hall and Shelby (2000) had visitors identify attributes that make the Colorado River in Grand Canyon better than other rivers. Stewart et al. (2000) asked visitors to rate the importance of various attributes they experienced on their Grand Canyon trip. A similar survey tailored specifically to the Glen Canyon reach and the types of trips conducted there would be undertaken for this project. The next phase would involve estimating how flows and NPS management influence these important characteristics and trip attributes. By understanding these relationships, it is possible to predict how dam flows and NPS management affects visitor experience, recreation quality and visitor satisfaction. Thus, instead of focusing monitoring solely on overall visitor satisfaction (which can problematic, as noted earlier), future core monitoring could focus on monitoring the resource conditions such as flows and trip attributes that are known to affect visitor experience in predictable ways. Using this approach, direct surveys of visitors would only be necessary every five years or so to reevaluate visitor perceptions of resource conditions and trip attribute relationships in the conceptual model.

The economic benefits of recreation can be measured as part of the trip attribute model presented in Figure 5, especially Box 5. For example, a typical trip attribute survey would have visitors rate the satisfaction they would have on a 1-10 scale associated with different trip profiles or would have them choose between two or more different trip profiles that have different levels of the trip attributes relevant for that activity/setting (e.g., fly fishing in Glen Canyon or flat water rafting in Glen Canyon).

In terms of economic value of trip attributes to visitors, since the trip cost attribute is denominated in dollars, the monetary value of other attributes can be calculated by dividing the other trip attribute regression coefficients by the coefficient on trip cost (Holmes and Adamowicz, 2003). Separate trip attribute surveys and models would need to be estimated for Glen Canyon day use rafting and Glen Canyon angling.

Visitor spending related to commercial outfitters, guides, land and air shuttles, hotels, restaurants, etc. supports a substantial industry in northern Arizona, Utah, Las Vegas, etc. As part of a survey aimed at obtaining visitor values ascribed to specific trip attributes, the same survey can obtain information regarding visitor expenditures. This information would be by expenditure category and by geographic area of spending. This information can be analyzed in a series of input-output models to calculate the multiplier effects in regions of varying size. Like past analyses, it can be done to reflect the multi-county income and employment in northern Arizona only (Douglas and Harpman, 1995). However, the 2005 PEP felt that limiting the analysis to just this small geographic area did not fully reflect the extent of the outfitting and guiding industry and tourism related to lower Glen Canyon. The 2005 PEP therefore recommended (and the 2009 socioeconomic panel concurred) that in addition to northern Arizona, it was appropriate to include an adjacent state regional model composed of Arizona and Utah, or perhaps a multi-state model reflecting the same geographic area as encompassed for the hydropower marketing (i.e., CRSP Area).

Links/Relationships to Other Projects

This project fulfills a long-standing recommendation of the 2005 Recreation PEP and also fulfills one recommendation of the 2009 Fish PEP and a Phase I recommendation of the socioeconomic panel resulting from the 2009 Socioeconomic workshop. In addition to addressing a fundamental intent of GCPA to research and monitor visitor use values potentially affected by operations of Glen Canyon Dam, it will provide a solid foundation for evaluating potential effects of future high flows and other experimental operating regimes on recreational values in the Glen Canyon reach of the CRE. Thus, it is a key component of the science plan proposed for the High Flow Protocol experiment.

This project will complement and be informed to some degree by the biological monitoring data being collected through project BIO 4.M2.

Logistics

This project will require multiple road trips to Lees Ferry and at least one on-river trip launching from, and returning to, Lees Ferry just upstream of the mouth of the Paria River.

Products/Reports

AZGFD and GCMRC will work together to develop a survey instrument for implementation in FY201. Peer-reviewed products documenting the recreational values and the status and trends of visitor experience quality tied to those values in the Lees Ferry Reach will be produced in FY2012.

Budget

FY2011	$25,000
FY2012	$25,000

GCDAMP Goal 10—Maintain power production capacity and energy generation, and increase where feasible and advisable, within the framework of the Adaptive Management ecosystem goals.

HYD 10.R2.11–12—Evaluate the Suitability of the GTMax Model for Modeling Economic Implications of Power Generation under Current and Future Dam Operations and Conduct Initial Analyses

Start Date

October 2010

End Date

October 2012

Principal Investigators

Western Area Power Administration staff and cooperators will work with GCMRC staff and cooperators to complete this project

Geographic Scope

The geographic extent of the western electrical grid

Project Goals

The immediate primary goal of this project is to objectively evaluate the suitability of Western Area Power Administration (WAPA)'s GTMax model for assessing how changes in GCD operations affects hydropower economics within the context of the Nation's western power grid. The longer term goal is to use this model (or if necessary, another more suitable model) to monitor, do economic forecasting of, and conduct post hoc analyses of, the economic implications of changing dam operations, in terms of hydropower production costs. This project specifically focuses on conducting a thorough evaluation of the suitability of the GTMax model for performing the kinds of economic analyses recommended by the independent panel at the December 2009 socioeconomic workshop.

Need for Project

WAPA has recently offered to conduct future economic analyses for the Adaptive Management Program on the economic implications of altering hydropower operations using its existing GTMax model. They have offered to do this using a fully transparent, peer reviewed process at no additional cost to the AMP. This generous offer is fraught with a number of uncertainties, however, including the degree to which the model has been previously independently peer reviewed and its suitability for assessing economic costs and benefits within the larger context of the Nation's western electrical grid. The western electrical grid, which is overseen by the Western Energy Coordinating Council and is therefore hereafter referred to as the WECC, defines the economic context in which hydropower values at Glen Canyon Dam need to be evaluated.

The GTMax model was originally developed by Argonne National Laboratories at the request of WAPA for modeling optimal operational scenarios to maximize power generation and minimize costs under changing hydroelectric demands or environmental conditions that affect power generation in the Colorado River Storage Project (CRSP) system. The model has never been explicitly or systematically evaluated as tool for conducting economic assessments for the GCDAMP within the larger context of the Nation's western electrical grid. One recommendation from the December 2009 panel was to conduct a thorough, fully transparent evaluation of the GTMax model in terms of its suitability for use in this larger economic context. The following project description reflects the recommendations of the independent panel at the December 2009 workshop:

The main effect of any future changes in the operation of GCD will most likely be a change in the timing of hydropower generation during the course of the day, the week and the year, rather than any change in the total Kwh generated at GCD over the course of the year. Because electric power has a different economic value at different times of the day, the week, and the year, this can translate into an economic cost. To assess the economic cost it is necessary to look at the real economic value of the power generated at GCD rather than the contract prices at which much of the power is sold. Also the GCD contract prices may involve economic transfers and therefore understate the economic value of this resource.

GCD and the Colorado River Storage Project (CRSP) system are embedded in the larger western power grid (the WECC). Similarly, the utilities to which CRSP sells power are embedded in the WECC. Therefore, in principle, the market by reference to which the economic value of GCD power is determined is not the CRSP system but the WECC. At any point in time, it is the marginal price of electricity in the WECC that determines the economic value of power generated at GCD.

The capital costs of existing power plants, whether in CRSP or the WECC generally, do not constitute a net economic cost to society of changes in operations. They are sunk costs, and they do not count as an economic cost of the existing power plants' operations. As a general statement, there currently exists excess capacity in the WECC. But, to the extent that, at some point in the future, reductions in power generation at GCD require an increment in generating capacity somewhere in the WECC system, the marginal cost of this extra capacity *does* count as a real economic cost. Again, it is not necessarily the cost of additional capacity in CRSP that matters; it is the cost of additional capacity anywhere in the WECC system to which WAPA and/or WAPA contractors have access. Moreover, such costs would be determined by the capital cost associated with the cheapest alternative source of additional capacity, which could be based on non-fossil fuel or could take the form of investments in the promotion of energy conservation (a.k.a., "negawatts"). The point is that these costs need to be considered within the larger economic framework of the WECC.

The existing power contracts for GCD expire in 2024. This creates the possibility that, when new contracts are negotiated for post-2024, it would be possible (and desirable) for WAPA to seek contract modifications that take into account the power generation impacts of any modification in GCD operations. The opportunity for contract adaptation should be factored into the economic assessment of the economic costs of changes in GCD operations for the period after 2024.

Given the alternatives, an analysis of the existing GTMax model used by WAPA to optimize the operation of the integrated CRSP system of generation resources appears to offer the most practical and expedient option for determining if all consequences of changed operations can be managed within the WAPA marketing area, or if electrical (and thus economic) "spill-over" effects will alter generation patterns, market prices or transmission bottlenecks elsewhere in the WECC system. If the effects of changed operations at Glen Canyon can be managed by WAPA without economically significant changes in the rest of the western U.S., then the economic consequences of such operations will be limited to WAPA's customers, and future modeling efforts can also be limited in scope. However, at this point there is no way to know if such changes will spill over into the rest of the WECC system beyond WAPA without actually checking this by using a model of the WAPA system and checking changes at flowgates where WAPA interconnects with the rest of the WECC.

In addition to the above information needs, there are currently no ongoing core-monitoring activities related to goal 10. Although data on GCD hydropower generation and opportunity costs under MLFF operations are currently being gathered by Reclamation and WAPA as routine agency functions, these data are not readily accessible to the GCDAMP. The need for this information in a readily accessible format has been identified as a program need for many years. Therefore, in addition to fulfilling the primary project purpose, this project will help to fill the long standing core monitoring information need gap through making the raw data used in WAPA analyses available to the AMP program via the web in a much more open transparent manner than it has occurred in the past.

Strategic Science Questions

Primary SSQs addressed:

SSQ 3-4. What are the projected hydropower costs associated with the various alternative flow regimes being discussed for future experimental science (as defined in the next phase experimental design)?

Information Needs Addressed

In addition to addressing a critical SSQ, this project responds to a core Information Need (IN) for goal 10, as originally articulated in the FY2003 version of the GCDAMP Strategic Plan, and a core-monitoring information need (CMIN) as redefined by the SPG in 2005:

IN 10.1. Determine and track the impacts to power users from implementation of ROD dam operations and segregate those effects from other causes such as changes in the power market.

CMIN 10.1.1 (as redefined by SPG). Determine and track the marketable capacity and energy produced through dam operations in relation to the various release scenarios (daily fluctuation limit, upramp and downramp limits, etc.).

Methods and Tasks

WAPA will provide the GCMRC with a copy of the GTMax model and any specialized software needed to run the model. The GCMRC will organize and host a workshop involving technical staff from WAPA, a representative from National Argonne Laboratories, and a small group of independent hydropower modeling experts. During this workshop, the functions, assumptions, and data needed to run the model will be described in detail and demonstrated through hands-on involvement of all subject experts. GCDAMP stakeholders will be invited to observe the workshop, but the focus of this workshop will be on providing an opportunity for independent experts to become thoroughly familiar with and be able to independently assess the model in terms of its potential suitability for use as an economic forecasting tool and post hoc assessment tool in the AMP.

Once the model has been fully peer reviewed, and assuming it passes peer review for continuing use in the AMP, WAPA will proceed to use the model to analyze if effects of changed operations at Glen Canyon can be managed by WAPA without economically significant changes in the rest of the WECC. If WAPA's power flow models demonstrate changes in flows at the border of WAPA's system, or at interconnection points with other systems, then a more extensive modeling effort will be required to check for changes in four indicators (generation, transmission, reliability, and hub prices) throughout the WECC. A near-term year and a long-term year should be modeled. After the analysis has been completed and a report fully documenting the work and results has been prepared, the report on this analysis will be subject to a separate round of peer review managed through the normal GCMRC peer review process.

After the structure and suitability of the GTMax model has been thoroughly evaluated, the next step will be to establish a "base case" against which various scenarios for hydroelectric operations

can be compared. The base case, and all scenarios, must be developed in sufficient detail that existing modeling tools can be used to estimate economic effects. Given the nature of markets in the western U.S., such detail should include at a monthly level, peak (hourly) demand, and peak and off-peak energy output. More sophisticated analyses may require even more detail (e.g., within-hour energy production in the base case and relevant scenarios). Current operations will be considered the "base case", but in keeping with the recommendations of the socioeconomic panel, operations in some historical period prior to 1990, defined by a lack of environmental constraints, should also be modeled so that arguments about cumulative changes in equity can be adequately considered. Once a base case is established, alternative scenarios for future operations must be clearly defined at the same level of detail (e.g., peak demand and peak and off-peak energy).

Whatever existing power flow model is found to be most suitable will be used to analyze the expected effects of changes in generation at Glen Canyon Dam, including effects on (a) generation (federal or non-federal) within the WAPA system, (b) loadings on transmission lines, (c) ability to meet reliability criteria, and (d) spot market prices at the Palo Verde Hub. These effects should be estimated for a near-term year (e.g., 2012) and a long-term year (e.g., 2020), because in the long-run more changes can typically be made via investments that could mitigate any short-term effects.

Any economic effects will be identified with specific parties, both inside WAPA and elsewhere in the WECC system. Candidates for such identification include the following: WAPA's customers, end-users of WAPA's customers, other end-users in the WECC, other producers inside the WAPA marketing area, and producers outside the WAPA marketing area but inside WECC. Because western power markets do not meet the definition of "perfect competition", some effort must be taken to account for market imperfections, since it is at least theoretically possible that changes in operations at Glen Canyon Dam will provide opportunities for some suppliers to exercise market power, at least in the short run. (Additional generation and transmission resources may be built in the long run and thus *may* eliminate such concerns.)

The analysis will also incorporate an assessment of the *financial* effects on individual WAPA contractors. The analysis of financial effects tracks flows of funds (e.g., changes in WAPA's overall revenue requirement or transfers between WAPA customers). Financial effects are important to those who are actually paying the bills (or those who are being told what the bills are without having adequate information to assess the basis of those numbers) while economic effects are important from a national policy perspective.

Links/Relationships to Other Projects

This project is specifically related to the current overall long-term planning needs of the GCDAMP. As recommended by the independent panel at the December 2009 socioeconomic workshop, if analysis of the existing model shows effects outside the WAPA marketing area, additional analyses for the entire WECC will need to be performed in future, potentially requiring the involvement of additional outside cooperators and substantial modification of the above plan. To the extent that repeated analyses of power market impacts are required as part of the future decision-making during the extended experimentation contemplated by the Adaptive Management Program, it may be possible to ease complexity of calculating economic and financial impacts in the future by developing a simplified response-surface model, embodied in a spreadsheet, linking changes within the CRSP service area to impacts on prices and capacity requirements within WECC.

Logistics

There are no field logistics associated with this project.

Products/Reports

FY2011:

A written assessment of the GTMax model will prepared by a team of independent experts as one outcome of the initial workshop

WAPA will prepare a detailed report on its analysis of the initial model assessment conducted to ascertain the extent to which economic impacts extend beyond the CRSP system and have economic effects on the larger WECC

FY2012:

WAPA will produce a report summarizing its "base case" scenarios and any impacts to the base case that may result under different operating scenarios; the scenarios that will be evaluated will be determined through workshops conducted for other projects, such as the Long Term Experimental Plan initiative

Copies of the GTMax model, the actual data used to populate and run models, as well as final raw data resulting from individual modeling runs discussed in final reports, will be provided to the GCMRC for archiving and distribution through the GCMRC website

In addition, the hourly flow, power generation data, and non-proprietary financial data normally collected by WAPA and any additional data used by WAPA in modeling economic costs of alternative flow scenarios will be made available to the AMP via a web link provided on GCMRC's website. Flow and power generation data will be made available on a daily basis, while financial data, including the Basin Fund balance, will be updated monthly.

Budget

FY2011	$30,758
FY2012	$20,149

GCDAMP Goal 11—Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations.

CUL 11.R1.11–12—Cultural Research and Development towards Core Monitoring, Phase II

Start Date

October 2005

End Date

September 2013

Principal Investigators

Helen Fairley, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Colorado River ecosystem as defined in the Glen Canyon Dam Adaptive Management Program Strategic Plan

Project Goals

The overarching goal of this project is to develop an interrelated suite of objective, quantitative monitoring protocols for assessing the effects of GCD operations and the efficacy of various management actions (e.g., future dam operating regimes or future stabilization treatments) at archaeological sites and other cultural resources that are valued by the American people. Monitoring protocols are being specifically designed to track status and trends in archaeological site conditions on an ecosystem-wide basis and to assess where, how rapidly, and in what respects cultural sites are changing under current (and future) dam operations. Establishing quantitative methods for objectively tracking status and trends is a pre-requisite for being able to establish cause and affect relationships in the future. The protocols are being evaluated in terms of their suitability for being applied in a routine, systematic manner in the logistically challenging field setting of Grand Canyon National Park. The monitoring program is also being designed to:

Generate data useful for studying and understanding effects of ROD operations, experimental flows, and non-flow actions on cultural resources in the CRE

Provide data useful for determining future treatment needs at archaeological sites and the most effective treatment methods, regardless of the ultimate cause of the deterioration

Provide data suitable for informing and/or building future geomorphic models

Be integrated with, complement, and enhance other monitoring and management-related data being collected by the National Park Service (NPS) (e.g., data being collected by Grand Canyon National Park for the Archaeological Sites Management and Information System)

Need for Project

Grand Canyon is one of the iconic erosional landscapes of the world. Recent geomorphic studies (e.g., Lucchitta and others, 2000; Pederson and others, 2006) document a dynamic landscape that is continuously changing in response to tectonic forces, climatic factors, and ongoing erosion by the Colorado River. While some erosion of unconsolidated deposits in the Colorado River corridor and the cultural resources contained in them is inevitable given these dynamic environmental conditions, past studies (e.g., Hereford and others, 1993) indicate that erosion of the Holocene-age sediment that forms the substrate of many cultural sites in the CRE appears to have increased within the past few decades relative to the decades immediately preceding construction of Glen Canyon Dam (GCD). Several hypotheses have been proposed to explain this purported increase in erosion, including changes in the intensity of rainfall and regional precipitation patterns during the late 1970s-early 1980s, the ongoing removal of sediment and lack of sandbar replenishment due to dam operations, and secondary effects related to increased visitation and cumulative impacts from recreational use of the river corridor (Hereford and others, 1993; Thompson and others, 2000; Fairley 2005). Regardless of what ultimately is causing observed changes in cultural resource condition (e.g., Leap and others, 2000), having quantitative methods and data for objectively tracking status and trends in erosion rates and other key indicators of resource condition is a basic pre-requisite for being able to establish cause and effect relationships. The stated goals of the AMP are to track the status and trends of cultural resources in the CRE, evaluate the role that dam operations play in influencing resource condition, and determine how best to mitigate effects due to dam operations. Development of an accurate, reliable, and objective monitoring program to track the amount and rate of change occurring at cultural sites in the CRE is therefore a key need of this program.

The National Park Service began monitoring cultural sites in the river corridor during the late 1970s and continues to do so to meet its statutory responsibilities as a Federal land managing agency; however, past NPS monitoring programs were not specifically designed to objectively assess dam effects or track the efficacy of management actions undertaken to control erosion. In 2000, a cultural PEP convened by GCMRC on behalf of the GCDAMP recommended (along with many other suggestions) redesigning the National Park Service's 1994–2000 Programmatic Agreement Monitoring Program to focus more specifically on tracking effects of dam operations and evaluating the efficacy of erosion control efforts (Doelle, 2000); the current R&D project was initiated to address these specific PEP recommendations. Subsequently, the Science Planning Group (SPG) and Cultural Resources Ad Hoc Group (CRAHG) redefined the primary core monitoring need for historic properties in the CRE to be the following: track status and trends of site condition and integrity through monitoring rates of erosion, visitor impacts, and other variables or processes known to affect cultural site condition. For the past several years, this project has been exploring and evaluating various options for measuring change and achieving these defined monitoring objectives. Starting in FY2011, we will initiate a pilot monitoring program to apply the knowledge gained during Phase I of this project in a more formalized manner at a stratified random sample of sites located throughout the CRE. The pilot program will continue through FY2013, after which a PEP review will be conducted to evaluate and possibly refine the final protocols for implementation on a long-term basis.

Strategic Science Questions

This research and development project, and the future cultural monitoring program, is designed to address two primary SSQs:

> **SSQ 2-1.** Do dam-controlled flows affect (increase or decrease) rates of erosion, and vegetation growth, at archaeological sites and TCP sites in the CRE, and if so, how?
> **SSQ 2-4.** How effective are various treatments (e.g., experimental flows, check dams, vegetation management, etc.) in slowing rates of erosion at archaeological sites over the long term?

Information Needs Addressed

This project is a research and development effort aimed at addressing the highest priority CMIN for historic properties (as revised by the CRAHG and SPG in fall 2005), specifically, the properties known as archaeological sites:

> **CMIN 11.1.1 (**SPG revised**).** Determine the condition and integrity of prehistoric and historic sites in the CRE through tracking rates of erosion, visitor impacts, and other relevant variables. Determine the condition and integrity of TCPs in the CRE.

A high quality monitoring program is also essential for determining whether management actions designed to stabilize or improve site conditions are working as intended. Therefore, this project also directly addresses EIN 11.1 (formerly CMIN 11.1.2 of the GCDAMP Strategic Plan, subsequently redesignated by CRAHG/SPG as EIN 11.1):

> **EIN 11.1.** Determine the efficacy of treatments for mitigation of adverse effects to historic properties.

Additionally, this project addresses an AMP research IN (formerly identified as CMIN 11.1.4 in the 2001 GCDAMP Strategic Plan):

How effective is monitoring, what are the appropriate strategies to capture change at an archaeological site—qualitative, quantitative?

In conclusion, this project is being designed to be responsive to the stated goals of the AMP, the recommendations of the 2000 PEP, the various needs of the NPS and Bureau of Reclamation (BOR) related to compliance with Sections 110 and 106, and the strategic science questions identified in the 2007 Monitoring and Research Plan for developing monitoring methods to track and detect in an accurate, reliable, efficient manner changes in the condition and stability of archaeological sites related to a variety of dam operations, with a particular focus on monitoring changes that may trigger the need for taking additional management actions in the future. The protocols are also being designed to be useful for assessing the effects and effectiveness of experimental management actions such as HFEs, as well as other management actions that may be initiated in the future to achieve the National Park Service's management goals for in situ resource preservation of archaeological sites or other desired future conditions.

Methods and Tasks

This cultural research and monitoring project is part of a phased program of research and development towards implementation of a long-term core-monitoring program. The first phase of this project (Phase I) began in the spring of 2006 and initially focused on completing a comprehensive assessment of the geomorphic and archaeological attributes of sites to aid in the development of the long-term monitoring approach. It also involved testing a variety of survey techniques for objectively measuring change in resource condition (e.g., Collins and others, 2008; Collins and others, 2009).

When the project was initially conceived, Phase I was intended to continue for 2 years (FY2006–07), and FY2008 was intended to be the first year of a 3-year monitoring cycle employing the refined protocols developed during the preceding phase. However, a later than anticipated start date in FY2006, coupled with the high-flow experiment in 2008, delayed the project schedule by approximately 8 months. Therefore, FY2008 became a transitional year, in which we continued to build on several research and development activities initiated in FY2006, including:

Continuing to gather data on several short term, small scale studies to evaluate the effectiveness, efficiency, and accuracy of various field measurement techniques before implementing

them as part of a long-term monitoring program (weather monitoring, LiDAR mapping, and Thalweg survey measurements at a subset of sites)

Compiling, analyzing, and preparing reports on all the data collected during the previous 2 years of field work

Compiling and evaluating legacy data needed for assessing geomorphic characteristics related to site stability and preparing the GIS foundation for the future monitoring program

Permitting concerns of the NPS led to a halt of all project field work starting in FY2008 and continuing through FY2009. In April, 2010 Grand Canyon National Park permitted the work to resume, and it is now (FY2010) anticipated that following another round of field work in September 2010, Phase I of this project will be brought to conclusion. Reports documenting the results of Phase I work will be completed in the fall and winter of 2010-2011, with Phase II (the pilot monitoring program) scheduled to commence immediately thereafter.

In April-May 2011, we will begin implementing the pilot monitoring program. The scope of this project encompasses the full range of archaeological resources located in the area of potential affect from dam operations. The actual number of archaeological sites that will be included in the pilot monitoring program will be determined upon completion of the data analysis phase of this project (currently underway), but is anticipated to include approximately 30 sites. These sites will be selected using a stratified random sampling approach, with strata based on constellations of geomorphic and archaeological attributes that will be determined through clustering the data using both geomorphic and archaeological attributes. The rationale for this approach is to ensure that the sample population captures the full range of site types and geomorphic settings within the Area of Potential Effects from dam operations. The ultimate outcome of this research and development effort will be a final report recommending specific monitoring protocols. The program will ultimately be subject to a final review by a PEP in FY2013, with additional refinement of protocols (if necessary) before being implemented as the long-term program.

Continue to Monitor Topographic Change Using Technical Survey Methods to Establish Baseline Topographic Records for Future Change-detection Purposes

In FY2011, we will develop initial baseline data at the selected sample sites to serve as the basis for future comparisons of changes occurring over the long term. These data will be collected using a combination of conventional total station mapping or RTK GPS for establishing control and gully surveys and ground based high density LiDAR for mapping total site surfaces at a sample of study sites. Ground based surveys will be directed by either GCMRC personnel or by cooperating scientists following methods employed and refined in Phase I to capture topographic and other types of surface changes using high density data collection methods (e.g., Yeatts, 1996; Hazel and others, 2000; Pederson and others, 2003; Collins and others, 2008, 2009). LiDAR data will be manually edited and filtered to produce a “bare-earth” terrain model without reflections from vegetation canopy. These highly accurate three-dimensional surface maps will be duplicated in future years using the same methodology to document the amount, rate, and location of erosion and deposition, vegetation encroachment, and structural deterioration that is occurring at sites. Depending on the outcome of exploratory work conducted in FY2010, we may also use LiDAR data for tracking changes in soil crust cover and artifact movement, both of which are strong indicators of site stability.

Weather Monitoring

In FY2007-08, 11 weather monitoring stations and 14 sand traps were established at 9 study sites throughout the CRE. In FY2011–12, these stations will continue to collect data on precipitation amount and intensity, wind direction and velocity, temperature, humidity, barometric pressure, and sediment transport rates. Because of the spatially isolated nature of monsoon thunderstorms and the significant role that precipitation and wind play in downcutting and backfilling gullies, weather

stations and sand traps have been distributed throughout the length of the river corridor, in proximity to several sites that will continue to be monitored periodically in future years, so that changes detected from repeat topographic mapping can be related to timing and duration of local or regional weather events. The GCMRC staff is managing equipment maintenance, data collection, and sediment sample processing tasks internally; data processing and analysis is being handled through an internal USGS sub-allocation to USGS Western Coastal Geology and Marine Division.

Protocol Integration Workshop

Opportunities for integrating the results of the pilot monitoring program with those of the tribal monitoring projects and NPS CRMP monitoring efforts will be explored through a workshop hosted by the GCMRC early in FY2011 (fall 2010), after completing the initial research and development phase of this project. This delay in integration is necessary in order for the needs and approaches of the tribal monitoring programs and the Federal agencies to be defined and fully documented in written reports and the specific protocols identified. Integration of monitoring efforts, as appropriate, will occur during implementation of the pilot monitoring phase in 2011.

Links/Relationships to Other Projects

This project builds upon several past research efforts, including the previous work of Draut and Rubin (2005, 2008), Pederson and others (2003), and Damp and others (2007). Specifically, it builds upon the work of Draut and Rubin (2005, 2006) by extending the weather monitoring record and measurements of Aeolian sand transport at selected locations in the CRE. It also expands information on gully erosion rates initiated by Utah State University (USU) in FY2001–02 and continued in FY2006–07, and it expands on the geomorphic baseline data set collected for the 151 site treatment plan (Damp and others, 2007).

This study is also closely linked to the NPS CRMP implementation effort. Monitoring protocols for assessing impacts of human visitation at archaeological sites are being developed independently by NPS to serve the monitoring needs of the Park Service's CRMP. The quantitative approaches for monitoring change in archaeological site condition that are being developed through the current R&D project are designed to complement and supplement the observational monitoring protocols proposed by NPS for CRMP compliance purposes.

Other ongoing projects that have benefited or are likely to benefit from the work being undertaken for the cultural monitoring research and development effort include:

The integrated flow, temperature, and sediment modeling project (temperature data from the weather stations)

The vegetation monitoring program (the full suite of weather data which may be useful for interpreting observed changes in vegetation)

The conceptual modeling project (data on terrestrial/geomorphic processes)

The geomorphic model project (specific monitoring data related to geomorphic processes and rates of change can be used to populate the model)

Logistics

Two motor-supported river trips will occur during the motor season (April and September) in FY2011 and FY2012.

Products/Reports

- A report synthesizing the results of the Phase I research (2006–09) will be completed in spring 2011

Cooperators will prepare annual descriptive reports during Phase II of the pilot monitoring program

A synthetic peer-reviewed report summarizing the entire project will be prepared at the conclusion of this study

Budget

FY2011 $354,766

FY2012 $366,361

GCDAMP Goal 12—Maintain a high-quality monitoring, research, and adaptive management program

DASA 12.D1.11-12—Quadrennial Remote-Sensing Overflight

Start Date

October 2007

End Date

Ongoing

Principal Investigator

Philip A. Davis, U.S. Geological Survey, Western Mineral Resources Science Center

Geographic Scope

Entire Colorado River ecosystem corridor from forebay of Glen Canyon Dam to upper Lake Mead and, for specific resources, site specific

Project Goals

Conduct aerial overflights to acquire digital imagery and topography of the CRE: mission planning, contract solicitation, mission execution, and ground support

Need for Project

The next quadrennial overflight will be conducted in FY2013. The airborne data to be collected are multispectral orthorectified images of the CRE. Area and volumetric analysis of these data sets are used to identify and classify elements of interest. Comparison of data sets acquired over time allow for change detection as long as the data continue to be collected. Airborne data is the basis for many of the science questions and research activities conducted in the Grand Canyon. Application examples include the following:

- Characterization of nearshore habitat used by small fish may lead to new directions in population estimates and life stage resource preference
- Shoreline location and character at different flow regimes and the distance to cultural sites
- Document possible loss of vegetation at old high water zone
- Geomorphic characteristics of the CRE 8,000 to 25,000 cfs at 23-m resolution may be applied to quantifying biomass and production estimates
- Existence and change detection of areas of possible terrestrial organic input contributing to the carbon budget, riparian zone community composition, sandbar habitat including vegetation encroachment on camp site areas, backwaters, marshes, debris fans, cobble bars, and talus
- Maps used for positioning the GCMRC monitoring areas are a few of the applications of airborne data

A primary fiscal objective is to reserve sufficient funding to cover mission costs during implementation. No salaries are funded for this project; work performed will be addressed by GIS personnel funded by the GIS general support project (DASA 12.D5) and the Integrated Image Analysis and Change Detection project (DASA 12.D9). Because of the dependent nature of remote sensing and GIS technologies, products described in this project will result from a combination of efforts across multiple DASA projects.

In addition, we anticipate performing an airborne data collection that addresses more specific issues. The following instrument is currently being considered with its purpose and funding source identified:

- Hyperspectral deferred
- $200k variable funding across multiple fiscal cycles is proposed to set aside $600k total for the FY2013 overflight.

Strategic Science Questions

Some of the resource areas and science questions identified during the 2005 Knowledge Assessment and found within the GCMRC's Strategic Science Plan and Monitoring and Research Plan that can be addressed with airborne image data include those listed below.

Additional SSQs addressed:

SSQ 4-1. Is there a "Flow-Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales?

- Sandbar detection and analysis comparisons between data sets (that is, 2002, 2004, 2005, 2009, 2013)

SSQ 5-1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE?

- If funding allows, a Forward Looking Infrared instrument returns a data set that may be used to characterize river temperatures throughout the CRE

SSQ 1-7. Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made useable and maintained?

- Fine resolution shoreline geomorphic mapping may provide nearshore habitat characteristics linking resource preference with native fish

SSQ 2-1. Do dam-controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?

- Detection and change analysis of vegetation presence and density may be linked to erosion studies

SSQ 2-2. How do flows impact old high-water zone terraces in the CRE (where the majority of archaeological sites occur), and what kinds of important information about the historical ecology and human history of the CRE are being lost due to ongoing erosion of the Holocene sedimentary deposits?

- Sand detection and change analysis may provide further insight

SSQ 3-9. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

- Sand/Vegetation and encroachment detection and change analysis are a key factor

Information Needs Addressed

Numerous GCDAMP goals and resource area programs that are concerned with remote sensing analysis are the chief beneficiaries.

IN 12.1. Develop information that can be used by the TWG, in collaboration with the GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.

- Canyonwide detection and change analysis of detectable resources such as sand and vegetation propagate to provide information on campsite areas, cultural sites, and food base potentials in the 8-25k zone

CMIN 4.1.6. Determine quantity and quality of spawning habitat for RBT in the Lees Ferry reach as measured at 5-year intervals.

- Two meter resolution shoreline geomorphic mapping may provide nearshore habitat characteristics to provide quantitative estimates RBT spawning habitat

CMIN 6.1.1. Determine and track the abundance, composition, distribution, and area of the marsh community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

- Marsh detection algorithms may be developed for tracking this resource

CMIN 6.4.1. Determine and track composition, abundance, and distribution of the sand beach community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

- Sand detection methodologies may quantify areas where these communities exist

CMIN 9.3.1. Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons.

- Sand and vegetation detection / change methodologies may quantify these areas for tracking

RIN 6.1.1. How have the abundance, composition, distribution, and area of the marsh community changed since dam closure (1963), high flows (1984), interim flows (1991), and the implementation of ROD operations (1996)?

- Marsh detection algorithms modified for legacy overflights may provide a quantitative analysis.

RIN 8.6.1. How do ongoing inputs of coarse-sediment from tributaries influence storage of fine sediment within pools, runs and eddies throughout the CRE?

- Inventory of eddies combined with sand detection may provide part of the picture

EIN 4.1.1. How does RBT abundance, proportional stock density, length at age, condition, spawning habitat, natural recruitment, whirling disease and other parasitic infections change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Two meter resolution geomorphic mapping may provide new insight to resource preference and stock assessments

EIN 6.1.1. How do marsh community abundance, composition, distribution, and area change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

- Marsh detection algorithms may be developed for tracking this resource

EIN 6.4.1. How do the abundance, composition, and distribution of the sand beach community change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

- Sand detection methodologies may quantify areas where these communities exist

EIN 9.3.1. How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

- Sand and vegetation detection / change methodologies may quantify these areas for tracking

In total, approximately one-third of the GCDAMP information needs may be directly or indirectly addressed through analysis and use of the systemwide digital imagery.

Methods and Tasks

FY2011–14

- Project will closely coordinate with Reclamation on flows and the overall project will be coordinated closely with the National Park Service (NPS), as well as NPS and Department of Interior (DOI) Aviation Officers
- Remote sensing instruments deployed in fixed wing aircraft or helicopters are flown over the CRE to produce canyon-wide data sets
- A steady flow for a period of 8-10 days is required for full coverage of the CRE (weather conditions are a large factor and required extending constant flows for 10 days during the 2009 overflight). A steady flow rate of 8,000 cfs is required to allow comparisons/change detection

with previous overflight data sets. Regulation and Spinning Reserves to be picked up by other dams in the Colorado River Storage Project

- Optimally, the overflight occurs as close to the summer solstice (June 21 in non-leap years) as possible to minimize shadowing in the optical sensor data sets. Several previous overflights have been conducted around the Memorial Day holiday to minimize Glen Canyon Dam revenue loss; this same timeframe is proposed for the FY2013 overflight

- Efforts will be focused on obtaining a contractor that can provide greatest accuracy, greatest number of spectral bands, and a variety of onboard imaging instruments. Delivery of orthorectified images is expected early in FY2014
- A data collection permit must be reviewed and updated through Grand Canyon National Park to reflect the types of remote sensing technologies that will be required to help fulfill the core-monitoring and experimental research needs for all GCMRC programs
- DASA and survey support will include deploying Rim GPS Reference points during overflight

Links/Relationships to Other Projects

Acquisition of systemwide digital images in this project supports addressing numerous resource questions within other programs, such as abundance and systemwide distribution of both aquatic and terrestrial habitats related to fish, vegetation, and availability and status of campsites along the CRE. The digital products procured by the DASA directly support a varied array of projects within GCDAMP goals 1–11, such as detecting shoreline habitat and changes tied to dam operations and high-flow experiments. Additionally, these data are used in terrestrial vegetation and sandbar mapping projects for determining surface texture and land cover classifications within designated study reaches, as well as canyonwide over subsequent years following the overflights (trend analysis).

Logistics

This will require rim support by the GCMRC personnel to occupy multiple nearby base stations throughout the entire mission.

Products/Reports

FY2011-12

- Data sets are proposed to be served through an instance of Environmental Systems Research Institute (ESRI) ArcGIS Server
- Annual progress report summarizing major results will be provided by December 15, 2010 and 2011

FY2014-15

- Overflight data will be documented with metadata files conforming to the Federal Geographic Data Committee (FGDC) standards
    - The data sets are proposed to be served through an instance of Environmental Systems Research Institute (ESRI) ArcGIS Server

Budget

FY2011	$116,501
FY2012	$83,499

DASA 12.D2.11-12—Grand Canyon Integrated Oracle Database Management System

Start Date

2007

End Date

Ongoing

Principal Investigator

Paul Alley, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Entire Grand Canyon Monitoring and Research Center study area, from the forebay of Lake Powell to upper Lake Mead

Project Goals

The goal of the database management system at the GCMRC is to provide an organized, secure, and readily available electronic repository for all scientific data collected in the ongoing research and monitoring activities of the GCMRC. The relational database management system (RDBMS) also serves as the electronic storage foundation of the GCMRC's GIS, providing the repository for all aerial photography, survey control, and geographic layers. The program is therefore a vital component of the decision support process and for the adaptive management of the Glen Canyon Dam.

Need for Project

This project establishes the electronic repository and tools necessary to analyze and interpret scientific data collected by the GCMRC, thereby providing a fundamental support service to the GCMRC scientific investigations and decision support processes.

Strategic Science Questions

This project provides the foundation for all projects concerned with scientific data analysis.

Information Needs Addressed

Provides access for analysis for all the GCMRC data sets

RIN 12.1. Develop information that can be used by the TWG, in collaboration with the GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.

RIN 12.3.1. As necessary, investigate the most effective methods to integrate and synthesize resource data.

RIN 12.5.4. What is the most effective way to distribute information to our stakeholders and the public in a secure and accessible fashion?

Methods and Tasks

The GCMRC integrated database project is tasked with the following core project support duties:

Providing data management consulting and support for GCMRC projects and programs
Maintaining a centralized relational database system for archiving, managing, and serving the GCMRC spatial and tabular data
Developing software and custom applications for end user data management, automated data retrieval, and analysis and modeling

As a result of these core roles of providing data management support to projects on an as-needed basis and ensuring the long term viability and archiving of the GCMRC science data, the ability of the GCMRC integrated database project to develop annual 'products and reports' is highly dependent on the level of support and assistance required by other GCMRC projects throughout the year.

The following are ongoing support activities associated with the integrated database project:
Electronically archive all incoming data sets in their original form
Provide queries and format data subsets for scientific data analysis
Error check and import newly collected data sets to the centralized RDBMS
Administer database, including backup, recovery, and security
Coordinate and extend FGDC metadata for legacy and current GCMRC datasets
Continue to consolidate and import legacy data to the system
Continue to support data acquisition, import, and analyses of datasets such as fish, water sampling in the Colorado River, and survey control
Extend database structure to incorporate newly acquired data sets, such as aquatic food base and daily downstream water quality
Extend routines to automate the process of error checking and importing data sets
Extend Web application architecture to distribute newly collected data sets
Provide data analysis support for scientific monitoring and research analyses
Integrate tabular and spatial data sets in conjunction with DASA GIS staff

Links/Relationships to Other Projects

Table 7

Level of Support for Goals 1-12

Goal	Project	Level of Support Expected		
		Basic < 1 week	Intermediate > 1 week < 1 month	Advanced > 1 month
GCDAMP Goal 1—Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels				
	BIO 1.M1—Aquatic Food Base Monitoring		X	
GCDAMP Goal 2—				

Goal	Project	Level of Support Expected		
		Basic < 1 week	Intermediate > 1 week < 1 month	Advanced > 1 month
Maintain or attain viable populations of existing native fish, remove jeopardy from humpback chub and razorback sucker, and prevent adverse modification to their critical habitat.				
	BIO 2.R1—Little Colorado River Humpback Chub Monitoring Lower 13.6 km (Population Estimates)		X	
	BIO 2.M1—Little Colorado River Humpback Chub Monitoring	X		
	BIO 2.M3—Humpback Chub Translocation and Monitoring Above Chute Falls	X		
	BIO 2.M4—Monitoring Mainstem Fish		X	
	BIO 2.R7—Stock Assessment of Grand Canyon Native Fish	X		
	BIO 2.R13—Remote PIT Tag Reading		X	
	BIO 2.R15—Nearshore Ecology / Fall Steady Flows		X	
	BIO 2.R16—Mainstem Nonnative Fish Control	X		
	BIO 2.R17—Nonnative Control Plan Science Support	X		
	BIO 2.E18—Natal Origins of Rainbow Trout in Grand Canyon			
GCDAMP Goal 4. Maintain a naturally reproducing population of rainbow trout above the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish				

Goal	Project	Level of Support Expected		
		Basic < 1 week	Intermediate > 1 week < 1 month	Advanced > 1 month
	BIO 4.M2—Monitoring Lees Ferry Fish	X		
GCDAMP Goal 5—Maintain or attain viable populations of Kanab ambersnail				
	BIO 5.R1—Monitor Kanab Ambersnail	X		
GCDAMP Goal 6—Protect or improve the biotic riparian and spring communities, including threatened and endangered species and their critical habitat				
	BIO 6.M1—Vegetation Mapping			
	BIO 6.M2—Vegetation Transects			
GCDAMP Goal 7—Establish water temperature, quality, and flow dynamics to achieve the Adaptive Management Program ecosystem goals				
	BIO 7.R1—Water-quality Monitoring of Lake Powell and the Glen Canyon Dam Tailwater	X		
	PHY 7.M1—Integrated Quality of Water Monitoring (below Glen Canyon Dam)		X	
	PHY 7.R3—Modeling Support			
GCDAMP Goal 8—Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve the Adaptive Management Program ecosystem goals				
	PHY 8.M2— Integrated Long-term Monitoring of Systemwide Changes in Sediment Storage			
GCDAMP Goal 9—Maintain or improve the quality of recreational				

Goal	Project	Level of Support Expected		
		Basic < 1 week	Intermediate > 1 week < 1 month	Advanced > 1 month
experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals				
	REC 9.R1—Campsite Area Monitoring			
	REC 9.R3—Expand and Analyze Campsite Data in the GIS Atlas	X		
GCDAMP Goal 10—Maintain power production capacity and energy generation, and increase where feasible and advisable, within the framework of the Adaptive Management ecosystem goals				
	HYD 10.M1— Evaluate the Suitability of the GTMax Model for Modeling Economic Implications of Power Generation under Current and Future Dam Operations and Conduct Initial Analyses	X		
GCDAMP Goal 11—Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations				
	CUL 11.R1—Cultural Research and Development towards Core Monitoring, Phase II			
GCDAMP Goal 12—Maintain a high-quality monitoring, research, and adaptive management program				
	DASA 12.D1—Quadrennial Remote-Sensing Overflight			
	DASA 12.D3—Library Operations		X	

Goal	Project	Level of Support Expected		
		Basic < 1 week	Intermediate > 1 week < 1 month	Advanced > 1 month
	DASA 12.D5—GIS Support for Integrated Analyses and Projects, GIS Lead			
	DASA 12.D8— Biometrics and General Analysis	X		
	DASA 12.D9— Integrated Image Analysis and Change Detection			
Planing				
	PLAN 12.P1— Support and Enhancement of Ecosystem Modeling Efforts			
	PLAN: 12.P4—Update of Knowledge Assessment and SCORE Report			

Logistics

There are no logistical needs for this project.

Products/Reports

Since ongoing support of GCMRC science projects, as described in the "Methods and Tasks" section above, is the primary focus of the GCMRC database project, the following products will be completed by the GCMRC integrated database project as time permits:

FY2011

Upgrade Oracle spatial database to version 11g coinciding with ESRI ArcServer upgrade

Develop interactive DASA website for internal and external users to retrieve data, maps, imagery, etc.

Dynamic generation of graphics based on tabular data

Photo database (Stanton repeat, Schmitt USU sandbars, Grams time series, Fairley campsite photos, control network photos)

NSE data analysis and data collection software

Annual progress report summarizing activities will be provided by December 15, 2010

FY2012

Foodbase sample inventory and tracking system

Application to integrate power data, as provided by WAPA, into DASA data management system

Version 2 Refactor of DASA mSystem Data-Sync-Web-Server application

Version 2 Refactor of Mark–recapture specimen tag synchronization

Online interactive data visualization and analysis tools on GCMRC Web site

Annual progress report summarizing activities will be provided by December 15, 2011

Budget

FY2011	$128,168
FY2012	$134,560

DASA 12.D3.11-12—Library Operations

Start Date

October 2007

End Date

Ongoing

Principal Investigator

Esther Hamilton, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Entire Grand Canyon Monitoring and Research Center study area—forebay of Glen Canyon Dam to upper Lake Mead

Project Goals

Library operations facilitate monitoring and research by providing a centralized repository for hard copy information such as books, reports, maps, photography, and videos. The library converts hard copy materials to digital format and stores the digital files on long-term optical media for preservation and for on-line distribution. The library maintains the on-line catalogue of library materials to facilitate information search and retrieval or digital reports. The library houses original and duplicate copies of all digital remote-sensing data and selectively converts historical aerial photography to digital format in order to preserve and to use such data to extend research and monitoring back in time. DASA library staff has been reduced from two full time positions to one halftime position. Library functions will be continued at a reduced level.

Need for Project

The GCMRC library acts as the physical repository for reports and data generated by the GCMRC scientists as well as materials related to the Colorado River, Grand Canyon, and adaptive management. The digital conversion of historical data not only preserves the data, but also makes it available for scientific analysis.

Strategic Science Questions

This project provides a research materials and remote-sensing data (recent and historical) that allow all programs access to data covering a large timeframe in order to address scientific issues over decadal scales in the past.

Information Needs Addressed

The library provides access to current and historical scientific findings of the GCDAMP.

RIN 12.5.4. What is the most effective way to distribute information to our stakeholders and the public in a secure and accessible fashion?

IN 12.1. Develop information that can be used by the TWG, in collaboration with the GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.

CMIN 6.1.1. Determine and track the abundance, composition, distribution, and area of the marsh community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

RIN 6.1.1. How have the abundance, composition, distribution, and area of the marsh community changed since dam closure (1963), high flows (1984), interim flows (1991), and the implementation of Record of Decision operations (1996)?
RIN 6.4.1. How have the abundance, composition, and distribution of the sand beach community changed since dam closure (1963), high flows (1984), interim flows (1991), and the implementation of Record of Decision operations (1996)?

EIN 6.1.1. How do marsh community abundance, composition, distribution, and area change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Methods and Tasks

The library catalogs all new materials that come from staff scientists, contractors, and cooperators as well as items related to Grand Canyon, the Colorado River, and adaptive management. Library staff provides support to cooperators, contractors, and staff scientists by researching and obtaining current and legacy articles and reports related to science projects.

Library operations facilitate monitoring and research by providing a centralized repository for hard copy information such as books, reports, maps, photography, and videos, which will someday be completely digital. The following are specific functions of the library:

- Scanning and converting paper reports into digital PDF files, making the documents searchable by using optical character recognition software (depending on quality of hardcopy and as time allows), and then posting the files in the library database on the GCMRC Web site
- Scanning relevant analog aerial film and photos using the Vexcel Ultrascan 5000, allowing the digital images to be used for 2-D and 3-D analyses, for detection of changes in area, height, volume, and surface material, as well as investigations of cause-effect relations
- Digitizing flight line maps to provide a searchable mechanism to locate individual scanned aerial photos
- Converting VHS tapes to DVDs
- Scanning legacy slides to create digital images using the Nikon SuperCoolScan scanner

Links/Relationships to Other Projects

This project supports all other projects.

Logistics

There are no logistical needs for this project.

Products/Reports

FY2011

- Up-to-date on-line library catalog, which provides access to more than 8,000 publications

- Catalog records of all materials (continually updated)
- Assist cooperators, stakeholders, media contacts, and the public by providing access to reports, aerial photos, maps, slides, and photos in hard copy and digital form
- Research in locating contemporary and legacy materials
- A research facility for researchers, the GCMRC employees, cooperators, and the public
- Access to 17,652 aerial photographs, 9,000 digital aerial images, 8,000 hard-copy reports, 8,000 photos and slides, and 700 videos in broadcast and VHS format. In addition, once the library scanning project is complete, this information will be available in digital format from the library via digital media such as DVD and online via the Web
- Scientific appraisal of all available historical data in order to prioritize the scanning process and to obtain a firm understanding of the schedule required to complete digital conversions based on established priorities; as these conversion products are produced, they are cataloged and made available
- Annual progress report summarizing major results will be provided by December 15, 2010

FY2012

- Same as FY2011
- Annual progress report summarizing major results will be provided by December 15, 2011

Budget

FY2011 $38,680

FY2012 $40,614

DASA 12.D5.11-12—GIS Support for Integrated Analyses and Projects, GIS Lead

Start Date

2007

End Date

Ongoing

Principal Investigator

Thomas Gushue, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Entire Colorado River ecosystem corridor between Glen Canyon Dam and Lake Mead, and the greater Colorado River Basin

Project Goals

Advanced spatial analysis in support of the GCMRC projects; Creation of specialized maps and intuitive data retrieval specific to individual project needs; consultation and instruction related to GIS operation and spatial data analysis for the GCMRC staff; management and dissemination of spatial data.

Need for Project

The role of GIS has grown within the GCMRC over the past few years, providing for extended applications across all resource programs and allowing for advanced spatial data analysis in support of on-going GCMRC projects. The demand for spatial analysis and customized GIS applications continues to increase ever year as technology matures and becomes integrated with strategic science efforts. Given this increased demand, the GIS program must also expand the level of expertise and support to specific projects. The GIS program is inherently service oriented, providing spatial database development, programming and analysis support to the science programs and their cooperators on both a planned and an as-needed basis.

GIS general support benefits core-monitoring, experimental programs, and research and development projects alike in the form of GIS and remote-sensing software installation, maintenance and support, creation and maintenance of spatial databases used by science projects, and the development of mapping and analysis tools for use by the GCMRC staff and cooperators across all resource programs. A need also exists for more advanced support directed at specific GIS application development and analysis of available spatial data. This higher level of support is often achieved through automation of data processing and manipulation procedures to standardize and streamline repetitive tasks as well as provide a basis for standard operating procedures. Additional field support that exists outside the scope of traditional GIS functions is also made available to the GCMRC staff and cooperators. This support comes in the form of electrical engineering and programming expertise that has proven to be invaluable is assisting other projects in vital field instrumentation deployment and adhering to proper safety protocols for powering equipment in the field.

DASA projects: DASA 12.D1: Quadrennial and Resource-Specific Remote Sensing Overflight and DASA 12.D9: Integrated Image Analysis and Change Detection are dependent on efforts funded through this project.

Strategic Science Questions

The spatial aspects of Grand Canyon investigations are addressed in this project.

Information Needs Addressed

IN 12.1. Develop information that can be used by the TWG, in collaboration with the GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.

RIN 12.3.1. As necessary, investigate the most effective methods to integrate and synthesize resource data.

RIN 12.5.4. What is the most effective way to distribute information to our stakeholders and the public in a secure and accessible fashion?

Methods and Tasks

The collection of spatial data is achieved through a variety of methods that include, but are not limited to, remote sensing data collection missions, traditional survey and global positioning system (GPS) operations, field mapping using hard copy map or pen tablet computers, onscreen digitizing using previously collected remote sensing data as source information, and through other standard data entry methods. Spatial data are generally stored in one of the standard ESRI file types (shape file, coverage, geodatabase) as well as in ASCII format. Methods used for spatial data processing and analysis will vary depending on the questions that need to be answered.

Links/Relationships to Other Projects

Most GCMRC projects have a spatial component tied to the data being collected in support of the science questions developed for each project. The GIS provides a stable platform upon which all data collected along the CRE are catalogued within a consistent spatial reference system and maintained in consistent file formats with appropriate metadata. At the most basic level, this allows for the overlaying and querying of data sets collected from any and all projects within the GCMRC. At the most advanced level, the utilization of these technologies goes beyond this, creating a platform for conducting fully integrated spatial analysis in support of scientific research.

Below is a key that categorizes the level of GIS support anticipated over the upcoming 2011 – 2012 fiscal cycle.

Key to Level of GIS Support

Basic (~1 week)

1. Develop, create, edit and maintain representative thematic GIS layers for a project.
2. Produce river map atlases to be used for data collection efforts in the field.
3. Create professional-quality maps, figures and other data relating to spatial elements of a project.

Intermediate (1 to 4 weeks)

Perform routine, mid- to low-level analyses in support of project objectives.

Provide advice and instruction on proper analytical techniques for spatial data and operation of GIS and remote sensing software.

Review existing and newly created spatial data sets and associated metadata for accuracy, completeness and adherence to federal standards.

Advanced (4+ weeks)

1. Direct the application of spatial concepts and analytical techniques to drive sampling designs.
2. Create customized mapping programs and other field implementations designed for improving accuracy and efficiency during data collection and database development phases of project.
3. Perform high-level spatial analyses and modeling for project-specific information needs.

Provide expertise on appropriate uses of spatial data for integrated analyses involving different resource projects.

Develop and implement advanced web mapping applications that provide access to spatial and tabular data sets for specific projects.

The following Goals and Projects will be dependent upon the level of GIS support indicated below for maintaining high-quality monitoring and research throughout the entire program:

Table 8

Level of GIS Support Expect for GCDAMP Goals 1-12

GOAL	PROJECT	LEVEL GIS SUPPORT EXPECTED		
		ASIC	INTERMEDIATE	ADVANCED
GCDAMP Goal 1—Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels	BIO 1.M1—Aquatic Food Base Monitoring		X	X
GCDAMP Goal 2—Maintain or attain viable populations of existing native fish, remove jeopardy from humpback chub and razorback sucker, and prevent adverse modification to their critical habitat	BIO 2.M1—Little Colorado River Humpback Chub Monitoring		X	X
	BIO 2.M3—Humpback Chub Translocation and Monitoring Above Chute		X	

GOAL	PROJECT	LEVEL GIS SUPPORT EXPECTED		
		ASIC	INTERMEDIATE	ADVANCED
	Falls			
	BIO 2.M4—Monitoring Mainstem Fish		X	X
	BIO 2.R7—Stock Assessment of Grand Canyon Native Fish			
	BIO 2.R13—Remote PIT Tag Reading			X
	BIO 2.R15—Nearshore Ecology / Fall Steady Flows		X	X
	BIO 2.R16—Mainstem Nonnative Fish Control		X	X
	BIO 2.R17—Nonnative Control Plan Science Support			
	BIO 2.E18—Natal Origins of Trout		X	X
	BIO 2.R19—Biometrics and General Analysis		X	
GCDAMP Goal 4. Maintain a naturally reproducing population of rainbow trout above the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish.	BIO 4.M2—Monitoring Lees Ferry Fish		X	X
GCDAMP Goal 5—Maintain or attain viable populations of Kanab ambersnail.	BIO 5.M1—Monitor Kanab Ambersnail			
GCDAMP Goal 6—Protect or improve the biotic riparian and spring communities, including threatened and endangered species and their critical habitat.	BIO 6.M1—Vegetation Mapping		X	X
	BIO 6.M2—Vegetation Transects			
GCDAMP Goal 7—Establish water temperature, quality, and	BIO 7.R1—Water Quaility of Lake Powell			

GOAL	PROJECT	LEVEL GIS SUPPORT EXPECTED		
		BASIC	INTERMEDIATE	ADVANCED
flow dynamics to achieve the Adaptive Management Program ecosystem goals.				
	PHY 7.M2—Integrated Flow, Temperature, and Sediment Modeling		X	
	PHY 7.R3—Modeling Support		X	
GCDAMP Goal 8—Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve the Adaptive Management Program ecosystem goals.	PHY 8.M2—Integrated Long term Monitoring of Systemwide Changes in Sediment Storage		X	X
GCDAMP Goal 9—Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.	REC 9.R1—Campsite Area Monitoring		X	
	REC 9.R3—Expand and Analyze Campsite Data in the GIS Atlas		X	X
HYD 10.M1.10–11—Monitor Power Generation and Market Values under Current and Future Dam Operations	HYD 10.R2--Evaluate the Suitability of the GTMax Model for Modeling Economic Implications of Power Generation under Current and Future Dam Operations and Conduct Initial Analyses			
GCDAMP Goal 11—Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations.	CUL 11.R1—Cultural Research and Development towards Core Monitoring, Phase II			
GCDAMP Goal 12—Maintain a high quality monitoring, research, and adaptive	PLAN 12.P1—Support and Enhancement of Ecosystem Modeling Efforts		X	X

GOAL	PROJECT	LEVEL GIS SUPPORT EXPECTED		
		ASIC	INTERMEDIATE	ADVANCED
management program				
	PLAN: 12.P4—Update of Knowledge Assessment and SCORE Report			
	SUP 12.S2—Survey Operations			
	SUP 12.S3—Control Network		X	X

Logistics

There are no logistical needs for this project.

Products/Reports

In addition to the project support highlighted above, the GIS staff will also produce a wide range of products as time permits over the next two fiscal cycles:

- Maps for publications; generation and printing of maps and graphics for posters outside of scheduled project work
- Improved web-based map applications for Lake Powell and Grand Canyon
- Instructional sessions for staff, cooperators, and contractors on GIS layer development, integration and analysis on an as-needed basis
- Development of spatial models and scripts for improving overall efficiency of GIS tasks
- Spatial models and associated report describing accuracy assessment of remotely-sensed imagery and elevation data sets
- Annual progress report summarizing major results will be provided by December 15, 2010 and 2011

Budget

FY2011 $318,759

FY2012 $334,675

DASA 12.D9.11-12—Integrated Image Analysis and Change Detection

Start Date

October 2006

End Date

Ongoing

Principal Investigators

Philip A. Davis, U.S. Geological Survey, Western Mineral Resources Science Center; and Glenn Bennett, Paul Grams, Barbara Ralston, and Helen Fairley, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Colorado River ecosystem corridor between the forebay of Glen Canyon Dam and upper Lake Mead

Project Goals

The purpose of this project is to provide coordinated, comprehensive analyses of the remotely sensed data that were acquired in May 2009 to address a diverse set of monitoring and research questions. The primary data sets that will be analyzed consist of the 4-band digital images and a digital surface model (DSM) of elevation of the river corridor between Glen Canyon Dam and Lake Mead. The primary objectives of the analyses are to:

Produce a systemwide land cover map that depicts bare sand (and sandbars), cobble bars, debris fans, bedrock, cliff, and gross vegetation above the 8,000 cfs (the flow stage at which the data were acquired); these data depict shoreline habitats

Produce a vegetation map up to the old high water zone at the community classification level or better

Determine if the photogrammetric DSM provides a sufficient accuracy to examine volumetric change in the sandbars and, if so, determine those volumetric changes

Determine if changes in vegetation have affected established campsites

All four of these objectives will include a temporal analysis of changes observed from such databases derived from similar airborne data acquired during 2002, 2005, and 2009.

Additional project components consider other remotely sensed databases previously collected as aerial photographs or planned for collection as digital imagery or topography in FY2011-12. These components include:

Photogrammetric analyses of historical aerial photography – Deferred

Detailed analyses of hyperspectral imagery – Deferred

Evaluation of DSM and image data from 2002, 2005, and 2009 as a remote sensing surrogate for ground surveys to determine and monitor campable area on a systemwide basis and to determine the effects of vegetation encroachment on campable area

Analysis of historical aerial photography to determine pre- and post-dam erosion near selected archaeological sites

Analysis of historical aerial color-infrared photography to classify the vegetation within selected areas during allowable periods in order to extend temporal vegetation change analyses to be extended back in time

There are few processing aspects of any particular remote-sensing data set that are considered standard and can be applied without some modification and judgment. The DASA program will continue efforts to increase accuracy and precision of derived data set products. It is possible that the development of new algorithms and processing techniques needed to improve results and better meet program requirements may delay the delivery of the analysis.

Need for Project

Remotely sensed data are essential to provide a robust tracking of the status of certain physical, biological, and cultural attributes of the CRE. Ground based monitoring provides detailed observations but is limited by the number of study sites, resulting in under sampling and poor ability to infer systemwide trends.

Monitoring Vegetation

To support analysis of the impacts of dam operations, climate, and meteorology on riparian vegetation, airborne image data collected in 2009 will be used to update the vegetation map published in 2008 (Ralston and others, 2008) that was produced using 2002 airborne image data. This analysis will address questions such as: What is the total gain or loss of riparian vegetation in the new and old high water zones relative to 2002, 2005, and 2009? How are the gains or losses in vegetation represented among the vegetation classes within each hydrologic zone? What are the limitations of 4-band imagery on riparian vegetation monitoring? Can hyperspectral imagery provide vegetation classification at the community level, provide species compositions of classes, correctly classify woody and senescent vegetation as to their species, and map crytogamic soil?

Monitoring Sediment, Sandbars, and Shoreline Habitats

To support the analysis of impacts of dam operations, climate, and meteorology on the stability of sand deposits, especially different sediment deposits that provide wildlife habitats, airborne image and DSM data and historical aerial photographic imagery and derived topographic data will be used to evaluate cause-effect relations and to determine various protocols for mitigation of adverse effects, where possible.

Monitoring Campable Beaches

To support the analysis of impacts of dam operations, climate, and meteorology on campable beaches systemwide, airborne image and DSM data will be used to evaluate campsite quality (determined by surface area and slope), as well as the factors that have affected quality, such as vegetation encroachment, surface water and wind erosion of sand, dissection by erosional processes, etc.

Monitoring Archaeological Sites

To support the analysis of impacts of dam operations, climate, meteorology, and visitors on selected archaeological sites, high resolution airborne photography and photogrammetric derived from these imagery will be used to examine erosion rates and surface modifications within the pre-dam and post-dam eras. High-resolution LiDAR topography and imagery will be analyzed in order to monitor present day surface changes, causal processes, and mitigation efforts.

Strategic Science Questions

Riparian Vegetation

SSQ 2-1. Do dam-controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?

SSQ 4-2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of young-of-year (YoY) and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possible mortality of young humpback chub) associated with high flows?

SSQ 5-7. How do warmer releases affect viability and productivity of native/nonnative vegetation?

GCDAMP Goal 6 is directed at the protection or improvement of riparian and spring communities. This goal is based on the recognition that the riparian and spring environments are hosts for some endangered species like the Southwestern willow flycatcher (*Empidonax traillii extimus*). The protection of these species' critical habitats is part of this goal. Riparian plant communities can be viewed at either a single resource level without ecosystem linkages, or at an integrative level where riparian vegetation is linked to aquatic and terrestrial ecosystem processes (for example, when it contributes to secondary production and cover). Riparian plant communities interact with cultural resources associated with recreation (for example, camping sites) and TCPs, or affects aeolian sand transport and possibly archaeological site erosion rates. Understanding how riparian vegetation responds to flows and affects other resources of concern forms a basis for managing critical resources like native fish, archaeological properties, and recreational resources.

Sandbar and Backwater Habitats

SSQ 3.1. Is there a "Flow-Only" operation (that is, a strategy for dam releases, including managing tributary inputs with HFEs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales?

SSQ 4.2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possibly mortality of young humpback chub) associated with high flows?

Campable Beaches

In terms of questions that are specific to the AMP goals for recreation, this project directly addresses the following SSQ:

SSQ 3-9. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

Because campsite size can affect visitor experience, this project also indirectly addresses two other important science questions related to recreation in the CRE:

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?

Archaeological Sites

This research and development project, and the future cultural monitoring program, is designed to addresses two primary SSQs:

SSQ 2-1. Do dam-controlled flows affect (increase or decrease) rates of erosion, and vegetation growth, at archaeological sites and TCP sites in the CRE, and if so, how?
SSQ 2-4. How effective are various treatments (e.g., check dams, vegetation management, etc.) in slowing rates of erosion at archaeological sites over the long term?

Other Science Questions

- What is the rate of change in eddy storage (erosion) during time intervals between high-flow tests?
- What are the most appropriate methods for detecting change in shoreline habitat along the entire CRE, given the available data sets collected using different technologies (scanned analog vs. digital), different platforms (Leica ADS-40/ISTAR vs. DMC/3001, Inc.), and different image resolutions (30 cm, 22 cm, or 18 cm)? What is the most appropriate scale/minimum mapping unit to map the shoreline habitat for all years in order to support related science questions?
- What level of change can be detected in shoreline habitat using remotely sensed data collected in the past 5 years? What changes have occurred to the shoreline habitat across the CRE in the past 5 years?
- Where have the most significant changes taken place in shoreline habitat along the CRE in the past 5 years, and within which shoreline habitat classes are the most noticeable changes seen? How does the shoreline habitat relate to backwater environments/habitats? What have changes in backwater abundance/size/shape occurred over the past 5 years?
- As historical analog overflights become available in digital format, can the timeline be extended back to previous years?

A time-series comparison of shoreline characteristics may prove quite useful for the following SSQ:

SSQ 1-7. Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made useable and maintained?

Information Needs Addressed

Riparian Vegetation

The primary information needs for riparian vegetation addressed by tasks within this project are CMINs 6.1.1., 6.2.1, 6.5.1, and 6.6.1, which are summarized as the following:

- Determine and track the abundance, composition, distribution, and area of terrestrial native and nonnative vegetation species in the CRE.
- Determine parameters and metrics to be measured, and the information needs that address each element.
- Determine how the abundance, composition, and distribution of the OHWZ, NHWZ, and sand beach community have changed since dam closure (1963), high flows (1984), interim flows (1991), and the implementation of ROD operations (RIN 6.2.1, 6.3.1, 6.4.1, 6.5.1, 6.5.2, 6.5.3).

These information needs will be addressed through the following actions:

- Semidecadal color infrared digital imagery mapping that quantifies (1) area change of dominant overstory species, (2) community composition and possibly changes in understory community composition through ground truthing associated with mapping, and (3) coarse primary productivity estimates for riparian vegetation.

Vegetation transects/grid surveys conducted at an appropriate frequency that correlate with river stage elevations of 15,000, 25,000, 35,000, 45,000, and 60,000 cubic feet per second quantifies cover, richness and diversity, and wetland species scores at each stage elevation. This work is most informative for herbaceous annuals and perennials, including invasive species. This component may incorporate marsh-monitoring needs of Tribes.

Sandbar and Backwater Habitats

IN 12.1. Develop information that can be used by the TWG, in collaboration with the GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.

CMIN 2.1.2 Determine and track recruitment (identify life stage), abundance and distribution of HBC in the LCR
CMIN 2.6.1 Determine and track the abundance and distribution of flannelmouth sucker, bluehead sucker, and speckled dace populations in the Colorado River ecosystem.
CMIN 8.2.1. Track, as appropriate, the biennial sandbar area, volume, and grain-size changes outside of eddies between 5,000 and 25,000 cfs stage, by reach.
CMIN 8.4.1. Track, as appropriate, the biennial or annual sandbar area, volume, and grain-size changes within eddies between 5,000 and 25,000 cfs stage, by reach.

EIN 6.4.1. How does the abundance, composition, and distribution of the sand beach community change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Campable Beaches

This project directly addresses one part of the top priority CMIN for goal 9 (campsite size):

CMIN 9.3.1. Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons. (This project specifically addresses the part of the CMIN concerned with campsite size.)

This project partially addresses a second campsite CMIN (9.3.2) that is closely related to the top-priority CMIN for camping beaches (Note: The Science Planning Group of the TWG recommended that-CMINs 9.3.1 and 9.3.2 be combined as one):

CMIN 9.3.2. Determine and track the effects of ROD operations on the size, quality, and distribution of camping beaches in the CRE.

This monitoring project also contributes to tracking the long-term effects of the 2008 experimental flow on camping beaches (campable area), as defined by EIN 9.3.1:

EIN 9.3.1. How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the ROD, unanticipated event, or other management action?

Archaeological Sites

This project is a research and development effort aimed at addressing the highest priority CMIN for historic properties (as revised by the CRAHG and SPG in fall 2005), specifically, the properties known as archaeological sites:

CMIN 11.1.1 (SPG revised**).** Determine the condition and integrity of prehistoric and historic sites in the CRE through tracking rates of erosion, visitor impacts, and other relevant variables. Determine the condition and integrity of TCPs in the CRE.

This project also directly addresses EIN 11.1 (formerly CMIN 11.1.2 of the GCDAMP Strategic Plan renumbered by CRAHG/SPG as EIN 11.1):

EIN 11.1. Determine the efficacy of treatments for mitigation of adverse effects to historic properties.

This project also addresses an AMP research IN (no number) (formerly identified as CMIN 11.1.4 in the GCDAMP Strategic Plan):

How effective is monitoring, what are the appropriate strategies to capture change at an archaeological site—qualitative, quantitative?

Methods and Tasks

FY2011

Monitoring Systemwide Trends in Subaerial Sandbar Area (Lead Scientist – P. Grams)

Annual or biennial monitoring of approximately 45 sandbars (PHY 8.M2) provides monitoring information on the area and volume of sand for these long-term study sites, many of which are also important recreation sites. The ground based monitoring does not, however, adequately sample the over 2,000 sandbars that have been identified by analysis of the 2002 and 2005 overflight images. This project will analyze the 2009 overflight images to provide long-term monitoring of exposed sand above the 8,000 cfs stage throughout the CRE. This project will also provide an updated shoreline habitat classification based on the 2009 images. The updated shoreline habitat classification will be used by the nearshore ecology project to assist in associating fish capture data with physical habitat characteristics.

The images will first be analyzed to classify the extent of sand and vegetation (discussed below) using methods developed to classify the 2002 and 2005 images. The sand classification uses image-processing algorithms that rely on roughness and brightness characteristics to distinguish sand from other surface material (Gushue and others, in press). Following these automated routines, sand areas are manually inspected for error and consistency. More stable features such as bedrock, talus, and debris fans will not be reclassified but will be inspected. The updated shoreline habitat classification will require updating the modeled shorelines for a range of discharges. This will be

accomplished using existing modeled water-surface elevations (Magirl and others, 2008) and the May 2009 digital elevation model that will be provided by the contractors responsible for the collection and processing of the 2009 overflight data.

This project will result in:
Digital surficial geologic maps showing areas of sand and other map units
Updated "virtual" shorelines based on the May 2009 digital elevation model
Updated shoreline habitat classification for a range of discharges
A peer reviewed report or journal article describing the results

Monitoring Systemwide Trends in Vegetation (Lead Scientist – B. Ralston)

This task will use the 2009 airborne imagery to classify all vegetation up to the old-high-water flow stage to at least the association level. This classification will use the 4-band reflectance data and vegetation texture (derived from a statistical analysis of the near-infrared band imagery) and the same classification methods established for and performed on the 2002 image data. The 2009 image data should be better than previous imagery, thus improved (more detailed) vegetation compositional data may be derived from this analysis. This analysis may be completed in FY2010. When completed, the biological program will perform change detection analyses within FY2011, which should provide insights into systemwide vegetation changes at the association level. The 2009 vegetation map database will be published as a USGS Digital Data Series.

Analysis of Historical Aerial Photographs to Determine 1984 Sandbar Topography (Lead Scientist – P. Grams)

Deferred

Evaluation of Airborne DSM and Imagery Data as a Surrogate for Ground-based Surveys to Calculate Campable Area on a Systemwide Basis (Lead Scientist – H. Fairley)

Campable area is defined as an open, smooth substrate measuring at least 1x2 m with a slope of less than 8 degrees. Changes in campable area in the CRE are currently being monitored as part of the Northern Arizona University (NAU) long-term sandbar monitoring project. However, this sampling is limited in scope due to logistical issues. This task will explore the feasibility of using the systemwide airborne DSM data, in combination with its imagery, to define campable area throughout the entire CRE, in lieu of or in addition to repeat ground surveys. The initial analysis will be conducted between river miles 30 and 50 where there are multiple campable areas with 2009 ground survey data. In FY2010, DASA will provide the initial bare sand land-cover map and the slope map generated from the DSM derived from the 2009 airborne data collection. If the remote sensing results show a strong correlation with the survey data, campable area will then be calculated for the system as a whole using the remotely sensed data by the cultural program, but their systemwide analysis will probably be performed in FY2011, when the systemwide land-cover database is completed. Cultural resources personnel will publish results.

Digital Analysis of Historical Aerial Photography to Determine Erosion Near Archaeological Sites within the Pre- and Post Dam Era (Lead Scientist – H. Fairley)

Deferred

Methods and Tasks

FY2012

Evaluation of 2009 Airborne Photogrammetric Elevation Data to Detect Systemwide Trends in Sandbar Elevation (Lead Scientist – P. Grams)

The project for high elevation sandbar monitoring, described above, uses established methods to monitor trends in sand area. It is known that significant changes in sandbar volume can occur while area does not change significantly (Hazel and others, 1999), which can affect the utility of sandbars as campsites or habitats. The purpose of this task is to evaluate the feasibility of monitoring sandbar elevation and volume changes throughout the CRE using remotely sensed data. The 2009 airborne data collection provides a DSM (elevation model) derived by digital photogrammetric methods. If the DSM meets our requested 30-cm vertical accuracy, this task will use that DSM to evaluate its potential for monitoring systemwide changes in sand elevation. This analysis will use the ground-based measurements of sandbar topography made immediately before the May 2009 overflight as a basis for the evaluation. This project will result in topographic maps of sand areas system wide and an annual report. Our 2002 DSM has a vertical accuracy of 25 cm; if the 2009 DSM has similar or better accuracy, we will perform systemwide sand elevation change detection within this 7-year interval, and will produce a peer reviewed report or journal article.

Analysis of Historical Aerial Photographs to Determine 1984 Sandbar Topography (Lead Scientist – P. Grams)

Deferred

Analysis of Hyperspectral Imagery for Improved Vegetation Mapping and Monitoring (Lead Scientist – B. Ralston)

Deferred

Analysis of Historical Aerial Photography to Determine Vegetation Changes Since 1980s (Lead Scientist – B. Ralston)

GCMRC has 1988 color-infrared photographic film at a scale of 1:4,800 (7 cm resolution) for the entire CRE, which is the oldest image data useful for mapping vegetation. These data will be visually examined relative to 2002 and 2009 imagery to determine areas with large diverse vegetation patches where there has been both notable change and little to no change. Currently, there are about 50 large vegetation patches within the Canyon; such patches may have been more or less abundant or in different locations in 1988. The 1988 analog photographs that cover these selected areas will be digitally scanned, georectified to 2002/2009 image data, and classified, similar to the 2002 and 2009 digital imagery, to produce a 1988 vegetation maps of the areas. Change analyses will be performed in order to determine what changed, the areal amount, and possible causes. The registered digital data will be stored in the GCMRC archives and the results of the investigation will be published within the USGS or in a journal.

Digital Analysis of Historical Aerial Photography to Determine Erosion Near Archaeological Sites within the Pre- and Post Dam Era (Lead Scientist – H. Fairley)

Deferred

Investigation of How Changes in Vegetation have Affected Campable Areas (Lead Scientist – H. Fairley)

According to analysis of long-term monitoring data collected by NAU, campable area is declining faster than sandbar area, suggesting that factors other than sandbar erosion are contributing to loss of campable area in the CRE. Researchers have speculated that the loss of campable area may be due in large measure to vegetation encroachment (Kaplinski and others, 2005), but reliable, objective data to support or refute this assumption is currently lacking. The goal of this analysis is to compare vegetated areas in 2002, 2005, and 2009 aerial imagery at a random sample of campsite areas identified in the GIS campsite atlas and calculate the amount of vegetated area change within each campsite polygon and within the sample as a whole from one year to the next. We will also compare changes in campable area calculated by NAU using total station surveys at long-term sandbar/campsite sites with changes in vegetated areas in the aerial imagery. Oblique photo records will also be analyzed to supplement analyses using aerial digital imagery. Cultural resources personnel will report the findings.

Links/Relationships to Other Projects

A number of projects over the past years have used the shoreline habitat classification data developed from the May 2002 and 2005 imagery data sets. Shoreline habitat type is being applied to native and nonnative downstream fish sampling in the mainstem of the Colorado River, and it has also been used as a guide to delineate sampling sites of redds in Glen and Marble Canyons. Similarly, these data are currently being used by a substrate mapping effort within the aquatic food base project at the GCMRC. The Table 8 below summarizes the link from integrated image analysis to other projects within the GCMRC for FY2011-12. Project linkage is rated as low or high depending on the project. Projects with a high linkage are explicitly dependent on intermediate or final image analysis products to conduct further advanced analysis from the derived data sets, while projects rated as low linkage will depend on intermediate or final results for mapping, field sampling site selection or possibly some amount of additional spatial analysis.

Table 9

Links from integrated image analysis to other projects within the GCMRC for FY2011-12

GOAL	PROJECT	Integrated Image Analysis Project Links	
		Low	High
GCDAMP Goal 1—Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels	BIO 1.M—Aquatic Food Base		
GCDAMP Goal 2—Maintain or attain viable populations of existing native fish, remove jeopardy from humpback chub and razorback sucker, and prevent adverse modification to their critical habitat	BIO 2.M4—Monitoring Mainstem Fish		
	BIO 2.R15—Nearshore Ecology / Fall Steady Flows		
	BIO 2.R16—Mainstem Nonnative Fish Control		
	BIO 2.R17—		

GOAL	PROJECT	Integrated Image Analysis Project Links	
		Low	High
	Nonnative Control Plan Science Support		
	BIO 2.R18—Natal Origins of Rainbow Trout in Grand Canyon		
GCDAMP Goal 4. Maintain a naturally reproducing population of rainbow trout above the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish.	BIO 4.M2—Monitoring Lees Ferry Fish		
GCDAMP Goal 6—Protect or improve the biotic riparian and spring communities, including threatened and endangered species and their critical habitat.	BIO 6.M1—Vegetation Mapping		X
GCDAMP Goal 8—Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve the Adaptive Management Program ecosystem goals.	PHY 8.M2—Integrated Long term Monitoring of Systemwide Changes in Sediment Storage		X
GCDAMP Goal 9—Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.	REC 9.R1—Campsite Area Monitoring		X
	REC 9.R3—Expand and Analyze Campsite Data in the GIS Atlas		X

Products/Reports

FY2011

- Digital land-cover maps based on the 2009 data showing sand units, gross vegetation, and other map units will be published as a USGS Digital Data Series and the subsequent temporal change results will be published as a journal article
- Updated "virtual" shorelines based on the May 2009 digital elevation model will be produced and placed on the ArcGIS Server
- Updated shoreline habitat classification for a range of discharges will be published as a USGS Open-File Report
- The 2009 vegetation map database derived from the 2009 image data will be published as a USGS Digital Data Series and Open-File Report, along with subsequent temporal change analysis using the 2002 vegetation map
- Published USGS report or journal article on the use of remote sensing data to determine campsite suitability and its changes over time

FY2012

- Topographic maps produced from the 2009 image data will be published as a USGS Digital Data Series and in an annual report. Results from our systemwide sand elevation change detection between 2002 and 2009 will be published in a peer reviewed report or journal article
- Results from our integrated, long-term topographic analyses for sandbars will be included in an annual report and in a peer reviewed report or journal article produced in cooperation with project PHY 8.M2
- Published USGS report or journal articles describing long-term surficial and volumetric changes within archaeological sites
- Published USGS report on the observed effects of vegetation encroachment on campable area over time
- All data sets that have cleared USGS Fundamental Science Practices review and approval are proposed to be served through an instance of Environmental Systems Research Institute (ESRI) ArcGIS Server

Budget

FY2011 $246,243

FY2012 $258,556

PLAN 12.P1.11–12— Continued Support and Enhancement of Ecosystem Modeling Efforts

Start Date

August 2008

End Date

December 2012

Principal Investigators

Carl Walters, University of British Columbia
CO-I(s): Scott Wright, U.S. Geological Survey, California Water Science Center, William Pine, University of Florida, Karen Limburg, University of New York, Syracuse (SUNY), Robert Hall, University of Wyoming, Emma Rossi-Marshall, Cary Institute, Colden Baxter, Idaho State University, Josh Korman, Ecometric Research, Inc. Ted Kennedy, Kara Hilwig and Mike Yard, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Dale Robertson, U.S. Geological Survey, Wisconsin Water Science Center

Geographic Scope

Continued research and decision support for review, revision, upgrade and use of various ecosystem models in collaboration with Senior Ecologist and other cooperators; includes additional support from the GCMRC staff. Pending further guidance to the GCMRC from USDOI in FY2011, additional emphasis in this project may be focused in the area of supporting AMWG activities aimed at determining Desired Future Conditions for the various resources of interest within the Colorado River ecosystem.

Entire Grand Canyon Monitoring and Research Center study area, from the forebay of Lake Powell to upper Lake Mead. During FY2011–12, the work will focus mainly in the Lees Ferry and LCR confluence reaches of the Colorado River, where current aquatic ecosystem values and monitoring (rainbow trout, native fish) are concentrated. Some monitoring evaluations and data analysis will extend from GCD to Lake Mead, especially to evaluate longitudinal changes in aquatic system productivity and carrying capacity for native fish. Reaches of the CRE where additional emphasis will be placed on aquatic food and rainbow trout production include Glen and Marble Canyons, river miles minus 15 to 61. Particular focus shall be made in these reaches with respect to the influence of high flow experimental releases, native and nonnative fish interactions, as well as downstream migration of rainbow trout from the Glen to Marble Canyon reaches.

Project Goals

The main aim of this project continues to be to provide advisory assistance to the GCMRC scientists and cooperators on data analysis methods and integration of physical and biological research data into models for response of aquatic ecosystem indicator variables to possible management actions. The goal of such modeling is to provide screening of alternative adaptive management proposals (experimental policies) for improving responses of performance indicators such as abundance of humpback chub, aquatic food production, etc. Two ecosystem models (referred to informally as the Lees Ferry and Little Colorado River confluence, respectively) were developed during FY2009-10 in an Ecopath/Ecosim platform by the Senior Ecologist and GCMRC team and have since resulted in development of other types of related models, such as a rainbow trout production and downstream dispersal models.

A secondary objective of the Senior Ecologist continues to be to assist the GCMRC scientists and cooperators in communicating research results and quantitative modeling analyses to each other and to GCDAMP stakeholders (TWG, AMWG), via structured workshops that use advanced ecosystem modeling as a means to enhance communication and explore policy options. Emphasis in the initial phase of the research (FY2009–10) was focused on the aquatic elements of the CRE below GCD (primarily GCDAMP goals #1-4 and 7–8).

During FY2010, the flow and sediment submodel of the existing Grand Canyon Ecosystem Model (GCEM) was replaced by a new shifting rating curve for suspended sand transport (1-D routing of Paria and Little Colorado Rivers sand inputs downstream through current monitoring reaches upstream of Lake Mead) by Wright and others (in press). This 1-dimensional sand routing model was used during FY2010 to develop preliminary sand simulation scenarios for a range of hydrologic and sand supply conditions within the CRE and these preliminary results were shared with cooperators and stakeholders during a spring 2010 ecosystem workshop.

Need for Project

While a variety of experimental management policies have been implemented in recent years, analysis and communication of results and responses of indicators to policies have not been completed. More complete analysis and subsequent communication of the results of analysis (including modeling) will allow more effective selection of further experimental tests. For example, the LSSF flow experiment of summer 2000 was not fully evaluated until 2008, and likewise there have not been definitive reviews of all high-flow experimental results (1996 to 2008) or the effects of mechanical removal of nonnative fish, although the synthesis of flow tests and nonnative control analyses are now forthcoming. Such analyses have been hampered by confounding of multiple factors in causing changes (for example, temperature changes have made it hard to interpret fish responses to mechanical removal). Modeling tools, such as Ecopath w/ Ecosim provided by the Senior Ecologist (Walters), can help to at least clarify alternative hypotheses about the possible roles and relative importance of the factors.

Additional advancement of the flow and sediment elements of the existing GCEM is also planned as an additional element of the new Integrated Flow, Sediment, and Temperature Modeling research project (Wright and others in collaboration with Korman and Walters) as a further means of assessing fine sediment dynamics associated with various stakeholder planning needs and associated tasks tied to developing desired future conditions for GCDAMP goals. During late FY2010, the new 1-D sand routing modeling was being used by the GCMRC and its cooperators to support sediment analyses intended to inform environmental compliance related to a new High Flow Experimental Protocol at Glen Canyon Dam.

Strategic Science Questions

The ecological modeling efforts will be directed at addressing priority AMWG questions, SSQs, and additional science questions (SAs) - provided by the Science Advisors (SA) in the integrated modeling efforts, as follows:

Abundance trends of rainbow trout in the Lees Ferry reach:

SSQ 1-4. Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will re-colonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action?
This question also applies to future nonnative control and removal programs targeting other nonnative species.

SSQ 1-8. How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling?
Abundance trends in native fish below the Lees Ferry reach:
SSQ 1-1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?
SA 1. What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on young of year and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?
SA 2. What are the most probably positive and negative impacts of warming the Colorado River on humpback chub adults and juveniles?]
Linkages between (productivity) food web changes and fish population changes:

SSQ 3-5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?

SA 1. What are the most limiting factors to successful HBC adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

Responses of native fish to mechanical removal of nonnative fish, fall steady flows, and backwaters created by high flow experiments:

SSQ 1-2. Does a decrease in the abundance of rainbow trout and other cold- and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile HBC to the adult population?
SSQ 5-1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE?
Using the new shifting rating curve method for routing suspended sand through the CRE in FY 2010, the project has already produced preliminary advanced simulations for flow operations at Glen Canyon Dam and fate of tributary supplied sand inputs:
SSQ 4-1. Is there a "Flow Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal timescales?

Note: Results from element 5, now provides the potential to integrate suspended-sand simulations with aquatic/fish simulations within the Ecopath w/ Ecosim modeling developed by Walters and others during FY 2010.

Methods and Tasks

1. Senior Ecologist (Walters) will continue to lead fisheries team (the GCMRC fish biologist and Biometrician) in advanced development of stock assessment for native suckers (flannelmouth, bluehead) in Grand Canyon to complement existing assessments for HBC and to provide more accurate abundance trends for use in testing ecosystem models that represent competition and predation interactions among native and nonnative fish. This will involve completing work with the GCMRC scientists to develop and publish an ASMR model using the flannelmouth and bluehead sucker data, and analysis of historical length-frequency data to provide growth curve inputs for the ASMR back-calculation of age at tagging.
2. Senior Ecologist (Walters) will continue to lead the GCMRC staff and key foodweb and fisheries research cooperators in ongoing development and testing of Ecopath/Ecosim (EwE)

models for food web interactions in the aquatic communities of the Lees Ferry and Little Colorado reaches of Grand Canyon. This ongoing work will involve continued development and fitting to historical abundance trend data of EwE models developed during FY2010 in cooperation with the GCMRC scientists. Model parameter estimates will be refined using information provided by GCMRC cooperators, and formal parameter estimation procedures will be applied to estimate key production parameters by fitting the models to historical fish population trend data for 1990–2010.

3. Senior Ecologist (Walters) will lead in use of the existing GCEM ecosystem model to reconstruct historical changes in the Colorado River food base for native and nonnative fish, associated with changes in diurnal flow regimes and turbidity conditions caused by tributary sediment inputs. The EwE food web models in task 2 above need to be fitted to historical abundance trend data, and that model fitting will be misleading unless the EwE models are provided with realistic time forcing data on past changes in primary and secondary (insect, amphipod) production owing to change in turbidity. The GCEM model will be run with historical tributary inputs, along with refined estimates of regrowth rates of primary producers following periods of low productivity due to high turbidity, to provide monthly estimates for 1990–2010 of food biomass likely to have been available to native and nonnative fish in reaches of Grand Canyon near and below the LCR.

Continue ongoing collaboration with University of Florida and University of New York at Syracuse – Phase II valuation of pilot study results from flannelmouth sucker otolith analyses resulting from cooperative research with University of Florida and SUNY (Pine and Limburg). This ongoing task will continue to employ geochemical signatures in water and native fish otoliths to infer natal origin, tributary habitat use, and migration patterns. The project conducted pilot analyses of flannelmouth sucker otoliths and water samples collected in FY2008. Preliminary analyses of the water samples suggest promising uniqueness among Colorado River tributaries for describing patterns in flannelmouth sucker otoliths associated with ontogenetic shifts in tributary versus Colorado River occupancy. Owing to the fact that these pilot analyses were fruitful, additional analyses with HBC otoliths are now proposed in FY2011 to better understand changes in HBC rearing habitat and tributary use. One use of the knowledge gained in pursuit of this task will be to better parameterize and justify relationships imbedded in aquatic ecosystem models (for example, Ecopath/Ecosim) that describe ontogenetic shifts in native fish use of tributaries during early life history stanzas. This effort is tied in with the next task also.

4. Senior Ecologist (Walters) will continue to be involved in review and consultation on field work and analysis of the Nearshore Ecology (NSE) project with objective of troubleshooting field methods and data analysis procedures, with particular emphasis on assessment of changes in native fish dispersal and survival rates in relation to changes from fluctuating to fall steady flows.

5. Senior Ecologist (Walters) has participated in high-flow experimental synthesis reporting as advisor to the GCMRC staff biologists and fishery cooperator (Valdez) during FY2010 and reviewer on biological outcomes report. In this role, the senior ecologist will continue to work with the GCMRC and cooperators to provide decision support to stakeholders concerning high flow experimental design and related Desired Future Conditions for native and nonnative fish, as well as aquatic food production and linkages with sandbar conservation objectives, etc.

6. During FY2011, cooperators (Ecometric Research and Arizona Game and Fish) will collaborate with the Senior Ecologist (Walters) and the GCMRC staff to develop a new submodel (rainbow trout production in the Glen Canyon reach) utilizing two decades of rainbow trout monitoring data collected by the Arizona Game and Fish Department. In addition, efforts may also focus on development of a second rainbow trout model intended to predict downstream movement of trout from Glen to Marble Canyons.

Links/Relationships to Other Projects

This project will use data from all studies that collect information on the aquatic biota of Glen, Marble, and Grand Canyons, including the aquatic food web, HBC monitoring, Lees Ferry trout monitoring, mechanical removal, nonnative fish monitoring, and the NSE project. The main benefits to the projects listed will be to provide novel analyses of data and methods for linking project results into overall conceptual and quantitative models for response of the Colorado River aquatic ecosystem to management changes. The flow and sediment modeling elements of this project are linked most closely to the Integrated Flow, Sediment, and Temperature Modeling project.

Logistics

There are no logistical needs for this project. Products/Reports

FY2010-2012

Completed - ChubIBM.exe computer program, narrative review for the GCMRC fish scientists on probable biases and precision of future population estimates (Walters and Hilwig).Completed - Spreadsheets for use by the GCMRC scientists in checking ASMR results from existing assessment programs, stock assessment report providing abundance trend estimates for sucker species (Walters and others).

- Completed - New 1-dimensional flow and suspended-sand model including the recently innovated “shifting rating curve” for sand transport that was reported by Wright and others at two meetings with TWG members during FY2010. This work is being integrated with ongoing modeling research funded in FY2010 (Wright and others, in press).
- Phase I completion with ongoing development - Ecopath/Ecosim (EwE) Access database (mdb) with improved models and historical forcing data, including forcing time series data from updated GCEM.
- In March 2010, Senior Ecologist (Walters) led a science workshop for the GCMRC scientists and cooperators March 1-5, 2010, to evaluate ecosystem model performance and produce a consensus scientific report on role of trophic interactions (food base changes, predator-prey interactions) in causing recent changes in native and nonnative fish abundances. The outcome of this workshop provided most of the basis for the workshop with stakeholders in April 2010.
- An oral presentation by Carl Walters was given on the ecosystem modeling progress in a workshop/retreat for GCDAMP stakeholders (TWG, AMWG) April 14-15, 2010 (Saguaro Lake Ranch, Ariz).
- Oral presentations were made by both Wright and Logan to TWG members on progress of physical submodel upgrade (shifting sand rating curve model), along with simulations of suspended-sediment concentrations between Lees Ferry and Phantom Ranch gage, as well as progress made in sandbar evolution modeling within eddies on April 13, 2010 at the Saguaro Lake Ranch ecosystem modeling workshop.
- A series of oral presentations were made by Korman related to recently published rainbow trout modeling and high flow experimental research results derived from the March 2008 HFE. The various findings were reported to the TWG at the January 2010 Annual Reporting Meeting, and again shared with science cooperators at the March 2010 Cedar Key, FL ecosystem workshop. These results were also presented again to the TWG members at the Saguaro Lake ecosystem workshop in April 2010, as well as at an international conference in May 2010.
- Preliminary results of Phase I isotopic analyses of 2008 flannelmouth sucker otoliths from Limburg’s SUNY laboratory were presented to the GCMRC staff and cooperators by Limburg Hayden at the March 1-5, 2010 Cedar Key, FL ecopath w/ ecosim workshop. In response to

the Phase I results, a Phase II proposal was received from these SUNY researchers and reviewed by the GCMRC and its Senior Ecologist, resulting in a recommendation that the next phase of otolith work be funded if possible as part of the NSE research project in FY2011.

- Completion and submission of refereed journal article with Josh Korman on "Surprise and opportunity in Grand Canyon ecosystem management Planning" for FY2011. Follow up ecosystem workshop with scientists and stakeholders in fall 2010, with possibility for using existing data and ecosystem models to support efforts by GCDAMP to develop Desired Future Conditions for the Colorado River ecosystem below Glen Canyon Dam.

FY2011

- Implementation in FY2011 (October 2010) of a follow up ecosystem workshop with scientists and stakeholders, with possibility for using existing data and ecosystem models to support efforts by GCDAMP to develop Desired Future Conditions for the Colorado River ecosystem below Glen Canyon Dam. This workshop may include the support for developing DFCs, but is contingent upon request from the AMWG and further guidance from the DOI leadership.

- Manuscript submitted to journal for possible publication on ASMR modeling of flannelmouth and bluehead suckers in Grand Canyon (Walters and Coggins)

FY2012

- January 2012 annual report on various ongoing ecosystem modeling initiatives,

Manuscript describing development and attributes of Lees Ferry rainbow trout production model, including various analyses of historical monitoring data used in developing the model.

Budget

FY2011 $122,573

FY2012 $115,997

PLAN: 12.P4.11-12—Update of Knowledge Assessment and SCORE Report

Start Date

October 2010

End Date

October 2012

Principal Investigators

U.S. Geological Survey, Grand Canyon Monitoring and Research Center staff and various cooperators, including Carl Walters, Fisheries Centre, University of British Columbia

Geographic Scope

Entire Grand Canyon Monitoring and Research Center study area, from the forebay of Lake Powell to upper Lake Mead.

Project Goals

Five years after the first knowledge assessment (KA) (Melis and others, 2006a) and Status of Colorado River Ecosystem (SCORE) report published by the GCMRC (Gloss and others, 2005), the GCMRC proposes to conduct a second knowledge assessment to inform the FY2012–16 Monitoring and Research Plan. The second SCORE report, following the FY2011 knowledge assessment is intended to:

Update the status and trends of GCDAMP resource goals

Report results of all experimental treatments implemented under the GCDAMP since completion of the 1995 EIS.

In contrast to the approach taken in the first SCORE report, which focused mainly on reporting status and trends of each of the resources of importance to the GCDAMP, the FY2011 SCORE report shall identify critical information that ties resource responses (monitoring and research data) to experimental flow and non-flow treatments associated with the 1996 Record of Decision operations and other treatments implemented by the Department of the Interior since 1996 at the recommendation of the GCDAMP. Experimental research topics will include record of decision MLFF, experimental winter fluctuations of 2003–05, the 2000 LSSF testing, various fall steady flow tests, three HMF tests, three HFEs, mechanical removal of nonnative fish, and translocation of HBC and Kanab ambersnail. These experimental treatments will be evaluated relative to the resource goals of the GCDAMP strategic plan as part of a knowledge assessment conducted in advance of the SCORE reporting, similar to the approach taken in 2005 (see Table 9).

Need for Project

A key element of the collaborative science planning process outlined in the FY 2007-11 Strategic Science Plan (SSP) (USGS 2006) and Monitoring and Research Plan (MRP) (USGS 2007) is a synthesis at 5 year intervals of new science information in an updated SCORE report and knowledge assessment. The SCORE report and KA are a critical part of the adaptive management process that are needed to inform the review and revision of the GCDAMP Strategic Plan and the FY 2012-17 SSP and MRP. The KA and SCORE report will incorporate, summarize and evaluate new information regarding statues and trends of AMP resources and responses of those resources to various

experimental treatments in a format useful by managers, stakeholders and scientists as they consider new directions in the GCDAMP science and management activities.

A priority need in the FY2011 knowledge assessment will be to identify resource responses that were not predicted in the 1995 EIS or identified in the last knowledge assessment. One example that provides an excellent opportunity for learning is the arrested decline of the HBC adult population (Melis and others, 2006b) and the recent increasing trend in this endangered fish (Coggins, 2009). The turnaround in HBC population has occurred despite a high level of uncertainty about limiting its early life history below GCD. Fine sediment, another example of resource response that was not well anticipated in the 1995 EIS, will also be a major focus of the FY2011 knowledge assessment and FY2012 SCORE report following recent modeling research advances in FY2009–10 (Wright and others, 2008).

Strategic Science Questions

The FY2011 knowledge assessment and resulting FY2012 SCORE report will be aimed at addressing priority AMWG questions identified by the GCDAMP in 2004, the Strategic Science Questions derived from the 2005 knowledge assessment and additional questions identified since then by the Science Advisors:

SSQ 4-1. Is there a "Flow Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal timescales?
SSQ 1-4. Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.
SSQ 1-8. How can native and nonnative fish
best be monitored while minimizing impacts from capture and handling or sampling?
SSQ 1-1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?
SSQ 3-5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?
SSQ 1-2. Does a decrease in the abundance of rainbow trout and other cold- and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile HBC to the adult population?
SSQ 5-1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE?
SA 1. What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on young of year and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?
SA 2. What are the most probably positive and negative impacts of warming the Colorado River on humpback chub adults and juveniles?

Methods and Tasks

FY2011-12

The GCMRC will work with the GCDAMP stakeholders, Science Advisors and science cooperators to develop the FY20011 knowledge assessment process. It is anticipated that the KA process will involve one or more workshops with scientists and stakeholders. Alternative approaches will be reviewed to determine the most appropriate method for summarizing knowledge, characterizing the level of certainty associated resource responses to treatments or management actions and engaging scientists, managers and stakeholders in the process. New information that will be addressed in the KA workshops and FY2012 SCORE report includes:

- 2008 HFE results
- Synthesis of the 1996, 2004 and 2008 HFE's
- Campsite and sandbar monitoring results
- Results of the Aquatic Food Base Research and Develop Project
- Ecosystem modeling and workshop results (including two new Ecopath w/ Ecosim models for Lees Ferry and the Little Colorado River confluence area)
- Integrated sediment, flow, and temp modeling results
- Vegetation mapping and transects synthesis results
- Low Summer Steady Flows synthesis results

Results of the RTELSS studies of 2003 through 2009

Assessment of the effects of experimental flow and non-flow treatments would encompass the topics shown in the matrix below. The **X**s shown in Table 9 denote the resource response topics that would be addressed in the knowledge assessment and reported by goal in the FY2012 SCORE report.

Table 10

Matrix of various flow and nonflow experimental treatments implemented within the Colorado River ecosystem and the response of resources identified within the Glen Canyon Dam Adaptive Management Program's Strategic Plan to be addressed by knowledge assessment and *State of the Colorado River Ecosystem in Grand Canyon* report

N/A = not applicable

Resources	MLFF	EXP winter-fluctuations	BHBF	HMF	Steady Flows	Nonnative fish control	Translocating HBC and KAS
Food Availability	X	X	X	X	X	X	N/A
Native Fish	X	X	X	X	X	X	X
Extirpated Species	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lees Ferry Rainbow Trout	X	X	X	X	X	N/A	N/A

Resources	MLFF	EXP winter-fluctuations	BHBF	HMF	Steady Flows	Nonnative fish control	Translocating HBC and KAS
Springs and Related Species (KAS)	X	X	X	X	X	N/A	X
Riparian Community	X	X	X	X	X	N/A	N/A
Downstream Quality of Water	X	X	X	X	X	N/A	N/A
Sediment	X	X	X	X	X	N/A	N/A
Recreational Experiences	X	X	X	X	X	N/A	N/A
Hydropower	X	X	X	X	X	N/A	N/A
Cultural Resources - TCPs	X	X	X	X	X	N/A	N/A

Links/Relationships to Other Projects

The FY2012 SCORE report would be linked with a second knowledge assessment conducted in the first through third quarters of 2011 through implementation of at least two workshops involving scientists and stakeholders. The 2011 KA workshop(s) and FY2012 Score report will provide updated status and trends information, including the effects of experimental treatments, for all GCDAMP resource goals.

Logistics

None, excepting travel to workshop locations, most likely to be held in Phoenix and Flagstaff, AZ

Products/Reports

FY2011-12

- Proceedings (USGS Open File Report) that documents the 2011 knowledge assessment workshop(s).
- Multi-chapter USGS Circular that updates resource status and trends, following after the 2005 SCORE report, but with additional content on modeling development and cause and effect relationships between various experimental treatments and resource responses

Budget

FY2011 $175,000

FY2012 $100,138

Monitoring and Research Plan for Potential High Flow Experimental Protocol

PLAN 12.P6.11-12

Start Date

October 2010

End Date

Ongoing (as defined in the HFE protocol Environmental Assessment)

Principal Investigator(s)

Matthew Andersen, Helen Fairley, Paul Grams, Kara Hilwig, Theodore Kennedy, Bill Persons, Barbara Ralston, David Topping, and Bill Vernieu: U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

The Colorado River from Glen Canyon Dam to the upper end of Lake Mead

Project Goals

The goal of this experimental project is to test the hypothesis that a series of sand-enriched high flows will be an effective strategy for rebuilding and maintaining sandbars using dam operations (Topping and others, 2006). Testing this hypothesis requires that high flows occur each time the sand input triggering criteria are met. The details of high flow triggering criteria are currently being developed in the context of an Environmental Assessment for a High Flow Protocol (see below).

The second goal will be to evaluate the effects of implementation of the High Flow Protocol on a variety of other priority AMP resources including aquatic food base, native fish, Lees' Ferry trout and angler satisfaction, riparian vegetation, and archaeological sites.

Need for Project

Previous high flow experiments from Glen Canyon Dam were conducted in 1996, 2004, and 2008. These experiments generally concluded that one of the best tools available for rebuilding sand bars using dam operations is to release short duration high flows after tributary floods deposit new sand into the main channel of the Colorado River. On December 31, 2009, a Federal Register Notice was issued for development of an experimental protocol for high flow releases from Glen Canyon Dam (FR vol 74, no 250 p 69361). As described in the Federal Register, the high flow protocol will be designed to further evaluate the hypothesis that repeated high flow releases conducted under conditions of sand enrichment may result in cumulative increases in sand bar area and volume. Currently, the details of the high flow protocol are being developed in an Environmental Assessment (EA) process pursuant to NEPA. However the Federal Register Notices indicates the Protocol is anticipated to be a multi-year experimental that will address such factors as the appropriate number of experiments, the appropriate sand input triggering criteria, the timing and duration of high flow releases to optimize sand conservation, the interval between high flows releases as well as the

anticipated approach to monitoring results and the effectiveness of the experiment. The purpose of this work plan is to outline how current monitoring projects will address the evaluation of the effectiveness of the HFE protocol. Some changes to this work plan may be needed once the Protocol is finalized pursuant to the EA process. Additional revisions may be required to address additional experimental activites that may be identified in the Long Term Experimental and Management Plan EIS.

The proposed approach will rely on existing quality of water, sediment, and other resource monitoring projects to assess the effects of the HFE protocol. No new studies would be added, however, some existing monitoring efforts will be expanded.

In the Methods and Tasks Section below, high flow monitoring associated with each GCDAMP project is summarized with references to the section in the work plan where the details of the respective monitoring program are contained. Budget implications are discussed where appropriate.

Strategic Science Questions

The science activities conducted to evaluate the HFE protocol will address the following strategic science question(s) and associated HFE protocol science questions (listed within the task descriptions). The HFE protocol science questions are considered preliminary and subject to revision in the course of the planning process.

SSQ 4-1. Is there a "Flow Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal timescales?

Methods and Tasks

Tasks related to high flow monitoring are summarized below. Please refer to the individual project descriptions in the work plan for more detailed descriptions. The budget figures provided in the task descriptions and the summary table are in gross dollars and reflect a differential cost to the respective project, not a total project cost. The budget figures assume that the respective annual work plan projects are funded at the level indicated in this work plan. Changes to budgets in the work plan would require revising the cost estimates, below.

Task 1. Monitoring In-Channel Sediment Storage—SedTrend

Information Needs

HFE protocol science question 1: Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume (time domain to be addressed in the course of HFE protocol development)? *This question is related to CMIN 8.2.1. -- Track, as appropriate, the biennial or annual sandbar area, volume, and grain-size changes within and outside of eddies between 5,000 and 25,000 cfs stage, by reach; CMIN 8.5.1. -- Track, as appropriate, the biennial sandbar area, volume, and grain-size changes above 25,000 cfs stage, by reach; CMIN 8.1.1. -- Determine and track the biennial sandbar area and fine-sediment volume and grain-size changes within eddies below 5,000 cfs stage, by reach; and CMIN 9.3.1. -- Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons.*

HFE protocol science question 2: With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable? *This question is related to all of the CMIN's listed for question 1 and the following: CMIN 7.4.2. -- Determine and track flow releases from Glen Canyon Dam, under all operating conditions, particularly related to flow*

duration, upramp, and downramp conditions; CMIN 8.1.3. -- Track, as appropriate, the monthly sand and silt/clay volumes and grain-size characteristics, by reach, as measured or estimated at the Paria and LCR stations, other major tributaries like Kanab and Havasu Creeks, and "lesser" tributaries; and CMIN 8.1.2. -- What are the monthly sand and silt/clay export volumes and grain-size characteristics, by reach, as measured or estimated at Lees Ferry, Lower Marble Canyon, Grand Canyon, and Diamond Creek Stations?

Project Description

This project addresses the HFE protocol science question 1 by tracking net changes in the area and volume of sandbars at stages above and below 8,000 cfs. This project also address HFE protocol science question 2 by tracking changes in sand storage for the study period. The SedTrend channel mapping project is designed to monitor the cumulative results of multiple high flows over a 5 to 10 year period. The results from previous high flow monitoring demonstrate that high flows build sandbars and that the magnitude of bar building is greatest when sand concentrations are highest. The question that is unresolved, which this program seeks to address, is whether repeated high flows and intervening dam operations can result in maintenance or increase in sandbars over longer periods of time. This objective of the project is described in detail in the goal 8 project description (PHY 8.M2). In summary, these monitoring data will allow us to determine at the end of the experimental period whether the continued use of high flows is likely to be a sustainable approach to building and maintaining sandbars or whether more sand than the tributaries supply is required to avoid progressive sand export and erosion. Because the objective is to monitor sandbars and the channel in a "typical" condition, the channel mapping should occur 6 months or more following a high flow. To simplify the scheduling, the channel mapping is currently scheduled to occur only in years that do not have high flows. Deferment of channel mapping in these years makes available about $110,000 in logistical and other expenses. Personnel are retained to continue with data processing and reporting.

Task 2. Monitor High-Elevation Sandbar Study Sites

Information Needs

HFE protocol science question 1: Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume? (see above for CMINs)

Project Description

This project addresses HFE protocol science question 1 by tracking changes in sandbar area and volume at the long-term sandbar monitoring sites above the stage of 8,000 cfs. See the goal 8 project description for a summary of the methods and the Goal 9 project description for a summary of the campsite monitoring component. In the absence of high flows, the repeat surveys of these sites have documented that the sandbars gradually erode. For this reason, the monitoring is scheduled to occur every two years unless a high flow occurs. Similarly, the surveys done immediately before and after high flows have repeatedly documented deposition. While continued quantification of the precise magnitude of deposition associated with each high flow would be beneficial, it is not critical monitoring. Instead, we propose to perform a survey approximately 6 months following each flood and use that as the benchmark monitoring record. This monitoring would be accomplished by the regular biennial sandbar survey unless the high flow occurs in an off year. In that case, an additional monitoring trip would be required at an added cost to Goal 8 of about $50,000. A sandbar monitoring trip is currently planned for FY 2011, so FY 2012 is the first year that this need could occur. Monitoring of the immediate response of future high flows would be limited to information gained by daily photographs taken by remote cameras. The photographic data would allow comparison of the degree of sandbar building between past and future high flows. Currently 18 sandbar monitoring sites are instrumented with remote cameras. We propose installing cameras at an additional 20 sites before the next high flow. This would require a one-time cost (prior to the next high flow) of about $50,000.

Task 3. Monitor Campable Area at High-Elevation Sandbar Study Sites

Information Needs

HFE protocol science question 3: Will multiple high flows conducted over a period of several years result in net increases in campable area within the Colorado River ecosystem (time domain to be addressed in the course of HFE protocol development)? *This question is related to CMIN 9.3.1. --Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons (top-ranked goal 9 CMIN); EIN 9.3.1. -- How do the size, quality and distribution of camping beaches change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?; and SSQ 3-9. -- How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?*

Project Description

Monitoring the high-elevation campsite study sites (a subset of the NAU sandbar time series) is necessary to maintain continuity in the campable area monitoring record. Monitoring is currently scheduled to occur every two years unless a high flow occurs (see the goal 9 project description under REC 9.R1.11-12 for a summary of the planned campsite monitoring component.) In the absence of high flows, repeat surveys of the campable area at these sites have documented that the lower elevation portions of the sandbars erode while vegetation encroaches on the higher elevation open sand areas that form the major component of campable area in the CRE. While continued quantification of the precise magnitude of deposition and erosion associated with each high flow would be beneficial, it is not critical; instead, we propose to perform a campable area survey approximately 6 months following each high flow in conjunction with the proposed sand bar monitoring program following each HFE and will use that as the benchmark monitoring record. This monitoring would be accomplished by the regular biennial sandbar survey unless the high flow occurs in an off year. In that case, an additional monitoring trip would be required at an added cost (to Goal 8) of about $58,745. A sandbar monitoring trip is currently planned for FY 2011, so FY 2012 is the first year that this need for supplementary funding could occur.

Task 4. Repeat Systemwide Inventory of High-Elevation Sand Deposits

Information Needs

HFE protocol science question 1: Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume? (See above for CMINs)

Project Description

This project addresses HFE protocol science question 1 by tracking changes in sandbar area throughout the CRE between Lees Ferry and the upper end of Lake Mead above the stage of 8,000 cfs. Remote sensing can provide a systemwide quantitative measure of the area of sand exposed above the water surface at the time of imagery collection (usually about 8,000 cfs). Collection and processing of these data will provide the long-term monitoring of the area of exposed sand to evaluate the cumulative result of multiple high flows and intervening operations over the experimental period. These data will also be used to quantify changes in vegetation distribution that may result in increases or decreases in the area of exposed sand. See Goal 8 (PHY 8.M2) and goal 12 (DASA 12.D9) for more detailed project descriptions. This is part of the regular monitoring program that addresses high flows and does not require additional funding when high flows occur.

Task 5. Monitor Archaeological Site Condition and Stability in Response to Repeated HFEs at a Sample of Sites in the CRE

Information Needs

HFE protocol science question 4: Will multiple high flows conducted over a period of several years improve archaeological site condition as reflected in increased sand deposition, increased site stability, and reduction in rates of erosion (time domain to be addressed in the course of HFE protocol development)? *This question is related to CMIN 11.1.1 -- Determine the condition and integrity of prehistoric and historic sites in the CRE through tracking rates of erosion, visitor impacts, and other relevant variables; EIN 11.1 -- Determine the efficacy of treatments (e.g., alternative flows) for mitigation of adverse effects to historic properties; SSQ 2-1. -- Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites in the CRE, and if so, how?; and SSQ 2-4. -- How effective are various treatments (e.g., repeated high flow events) in slowing rates of erosion at archaeological sites over the long term?*

Project Description

The monitoring protocols being developed and piloted by GCMRC as part of project CUL 11.R1.11-12 are specifically designed to be applicable for evaluating physical changes at archaeological sites tied to changes in sediment supply under a variety of dam operations. The planned monitoring program, which will be piloted starting in FY11, will allow GCMRC and AMP stakeholders to objectively determine whether changes in sand bar area and volume resulting from repeated high flows translate into measurable changes in the amount and rates of sediment being deposited at or eroded from a sample of archaeological sites distributed throughout the CRE. In the current work plan, baseline measurements will be collected in FY11 at approximately 30 sites selected from a stratified population of cultural sites in the CRE; this stratified random sample will serve as the initial sample population for evaluating system-wide changes at archaeological sites due to dam operations, including changes resulting from any high flows conducted as part of the HF protocol or any subsequent alternative flow experiments. Completing a robust evaluation of high flow effects on archaeological sites requires implementation of the cultural monitoring project (CUL11.R1.11-12) as currently planned; no additional monitoring beyond what is already described in project CUL 11.R1.11-12 is anticipated to be needed to evaluate the effects of an HF protocol experiment at archaeological sites.

Task 6. Monitoring Sediment Flux

Information Needs

HFE protocol science question 2: With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable? (see above for CMINs)

Project Description

This project addresses HFE protocol science question 2 by tracking sand inputs and export, by reach. Monitoring of sediment (sand and finer) flux during future high flows will be conducted as part of the regular goal 7 downstream integrated quality of water program. The methods, monitoring sites, and planned products are described in the goal 7 (PHY 7.M1) project description. This task does require added work during a high flow to maintain the monitoring record because the instrumentation is vulnerable to high dam releases and additional samples are required to maintain instrument calibration. This added work requires about $110,000 in addition to the regular Goal 7 budget.

Task 7. Monitoring the Aquatic Food Base

Information Needs

SSQ 3-5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?

Project Description

The aquatic food base project has been working since 2006 to establish a monitoring protocol that accurately captures key metrics that are relevant to other resources in the Colorado River, especially rainbow trout and humpback chub. Based on their work to date the aquatic food base research scientists have determined that monthly monitoring of benthic organisms and Lees Ferry and at Diamond Creek, and monthly monitoring of drifting organisms is critically important information that supports assessment of all Glen Canyon Dam release regimes, whether modified low fluctuating flows, an experimental high flow, or other flows. Therefore, the aquatic food base project presented in this FY 11-12 work plan (BIO 1.1M.11) includes the sampling strategies described above. Collecting these data in years without a high flow provides important baseline information, including assessment of seasonal variability. Collecting these data in years when a high flow release occurs allows the scientists to assess the amount of change, if any, that occurs as a result of the high flow.

Task 8. Lees Ferry Fish Monitoring

Information Needs

RIN 4.2.7. What dam release patterns most effectively maintain the Lees Ferry rainbow trout trophy fishery while limiting rainbow trout survival below the Paria River?

Project Description

Monitoring of the adult rainbow trout population in the Lees Ferry reach has been conducted regularly since the closure of Glen Canyon Dam in 1963. In 2010, in response to the 2009 Protocol Evaluation Panel for Monitoring Grand Canyon Fishes, GCMRC and cooperating agencies, but especially the Arizona Game and Fish Department, made some adjustments to the protocols for monitoring fish between Glen Canyon Dam and Lees Ferry. Monitoring of stratified random sites continues to be conducted as a tool to monitor adult rainbow trout, but now also collects data that help monitor other native and nonnative fishes. A monitoring trip to specifically look for nonnative fishes is now also conducted. The monitoring of rainbow trout redds (nests) and age-0 abundance, conducted in the 2000s as a research project, has now been added to the Lees Ferry fish monitoring, specifically because of the utility of this monitoring in assessing impacts of dam flows on young life stages of rainbow trout. A new research project proposed in this budget adds additional fish monitoring below Lees Ferry. Continuing to conduct all of this monitoring is important to understanding the existing variability of the fish community in the Lees Ferry reach; when a high flow is conducted, this monitoring should still be conducted to allow for assessment of changes that may occur in this fish community. This additional work is intended to evaluate the timing and age structuring of rainbow trout movement, when it occurs. The new work below Lees Ferry, conducted from the mouth of the Paria River to Badger Rapid, is also intended to begin establishing the relationship, if any, between the size and condition of the Lees Ferry rainbow trout population to downstream movement, as might occur in response to a high flow. The new monitoring between the Paria and Badger Rapid would be a precursor to any new removal efforts, including potentially removing rainbow trout alive. Please see projects BIO 2.18R.11 and BIO 4.1M.10 for more details.

Task 9. Evaluate Lees Ferry Recreation Experience Quality

Information Needs

HFE protocol science question 5: How will multiple high flows conducted over a period of several years affect recreational experience quality in the Colorado River corridor (time domain to be addressed in the course of HFE protocol development)? *This task is related to CMIN 9.1.1 -- Determine and track the changes attributable to dam operations in recreational quality, opportunities and use, impacts, serious incidents, and perceptions of users, including the level of satisfaction in the Colorado River Ecosystem; EIN 9.1.1 -- How do recreational use trends, impacts, and perceptions change in response to an experiment performed under the Record of Decision, unanticipated events, or other management action?; SSQ 3-6. -- What Glen Canyon Dam operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability?; 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?; and 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?*

Project Description

In FY2011-2012, GCMRC proposes to initiate a recreation experience valuation study for the Glen Canyon reach of the CRE. This study will evaluate the value and relative importance of a suite of biophysical attributes that are affected by dam releases and which anglers and other visitors determine to be important to maintaining a high quality recreation experience in the uppermost reach of the CRE. This study will also update monetary values associated with current recreational activities in the Glen Canyon reach. The intent of this study is to provide a foundation for evaluating how different dam operations, including future high flow experiments, affect the biophysical attributes of the Glen Canyon reach that visitors value and consider to be important for maintaining a high quality recreation experience in the Glen Canyon reach. See project REC 9.R4 for specific details of the proposed study approach.

Task 10. Mainstem Fish Monitoring

Information Needs

RIN 2.2.8. What combination of dam release patterns and nonnative fish control facilitates successful spawning and recruitment of humpback chub in the Colorado River ecosystem?

Project Description

Monitoring of the Colorado River mainstem fish community has been conducted by various researchers on an irregular schedule since the 1940s. More consistent, systematic monitoring began with BOR's Grand Canyon Environmental Studies that began in the 1990s. Since 1996 mainstem monitoring has been conducted by GCMRC and cooperating agencies, especially the Arizona Game and Fish Department. The principal long-term, full river monitoring has been 2 river-wide electroshocking trips, usually conducted in the spring. For many of the years in the decade of the 2000s this regular pair of trips was accompanied by intensive monitoring collected as a component of the mechanical removal project conducted between river miles 55 and 75. Together these data provide a picture of the distribution and relative abundance of the most common large bodied fish species in the mainstem. Backwater seining trips, conducted during the mid 1990s and from 2003 to present, have provided a picture of the relative abundance, distribution, and species composition of small-bodied fishes (juveniles and adults) in backwater habitats. Together these efforts have provided the currently available Grand Canyon fish data, and have also shown where additional data are needed. The existing fish data show where larger concentrations of the more common species are most likely

to be found and how those populations have fluctuated over time. The constraints and challenges of sampling widely in a large, turbid river are also highlighted in these data because the methods show that only some gear types are effective in the Colorado River, making some aquatic habitat types difficult, if not impossible, to sample. However, GCMRC and cooperators, primarily the University of Florida, have established an intensive habitat-specific monitoring program, the Near Shore Ecology project, to help define small-bodied fish distributions and responses to flow changes in the mainstem just below the mouth of the Little Colorado River. The NSE project will be conducting field studies in 2011 and this intensive effort has the best potential for detecting any localized effects on small-bodied fishes in the mainstem. Analyses of all fish community monitoring data are continuing, but some relative abundance, population size, and distributional trends are evident. These monitoring programs should continue and be expanded as recommended by the 2009 Protocol Evaluation Panel to help assess any changes that result from a high flow released from Glen Canyon Dam. This 2011-12 work plan includes expanding monitoring of humpback chub aggregations and testing other gear types. The springtime mainstem monitoring is planned for years when a large-scale mechanical removal trip is not conducted because a mechanical removal effort will require the people, time, and equipment that would otherwise be available for the spring mainstem monitoring. All of these mainstem sampling efforts are proposed for implementation in all years to help assess fish responses with and without a high flow release. See BIO 2.4M.10 for more details.

Task 11. Riparian Vegetation

Information Needs

RIN 12.9.1 What is the impact on downstream resources of short-term increases to maximum flow, daily fluctuations, and downramp limits?

Project Description

Together with cooperators, GCMRC has been monitoring the riparian vegetation community in the 2000s. Because of the distribution and extent of the vegetation community, GCMRC has been developing methods that use remotely sensed overflight imagery to assess vegetation changes. Part of this development has included identification of the limitations of the overflight data. An important limitation is that understory plants and herbaceous species, are difficult if not impossible to detect from aerial data. Therefore, the GCMRC monitoring program includes a field component that monitors vegetation at established vegetation transects on a biennial schedule. Repeated sampling at established vegetation transects allows for the establishment of natural variability versus changes associated with a large-scale disturbance, like a controlled flood. Vegetation monitoring using transects is scheduled to take place in 2011 and odd-numbered years thereafter. Supplemental monitoring of vegetation in 2012 would be needed if a controlled flood occurred in 2012. Monitoring vegetation in years with a high flow release allows for assessment of high flow impacts to riparian vegetation. The current budget for this work plan allows covers the cost of field transect monitoring in 2011. See BIO 6.1M.10 for details. A monitoring trip in 2012 if a controlled flood occurred would cost $50,000 and would cover the cost of a field crew and single trip taking place in the fall following the flood event.

Task 12. KAS Monitoring

Information Needs

RIN 5.1.9. How can incidental take for Kanab ambersnail at Vasey's Paradise be minimized?

RIN 5.2.2. How does the size and quality of the habitat used by Kanab ambersnail change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Project Description

In prior experimental high flows the low-elevation habitat for Kanab ambersnail has been temporarily moved during the experiment, then replaced so as to maintain this habitat. This conservation effort has proved successful in previous experiments and so is planned for future experiments.

Task 13. Lake Powell

Information Needs

Existing monitoring of Lake Powell water quality provides an important baseline. Leading up to a high flow release this standard monitoring is particularly important for establishing antecedent conditions, which vary from year to year. Immediately following a high flow release, additional water quality monitoring is needed to assess changes in water quality that may occur. Changes to the released water quality, especially dissolved oxygen, were observed in previous high flow releases.

Project Description

Monitoring of the water quality in Lake Powell, the reservoir impounded by Glen Canyon Dam, provides an important piece of information in the assessment of any high-flow release impacts to the reservoir itself or to downstream resources that rely on the water released from the dam. Data from the Lake Powell monitoring program provides a basis from which the effects of a high-flow release can be evaluated. As part of the GCDAMP work plan, regular water-quality monitoring of the Lake Powell forebay is conducted on a monthly basis. The entire reservoir is sampled at multiple locations on a quarterly basis. This monitoring will be conducted in years without a high flow release to support continued characterization of the reservoir and effects to its water quality. See BIO 7.1M.10 for details.

In years with a high flow release, some additional monitoring will be conducted so that high flow impacts to the water-quality of the reservoir and dam releases can be assessed. This includes: 1) additional reservoir monitoring shortly after the high-flow release to assess the short-term effect of high-flow releases on the water quality of the reservoir; 2) the establishment of additional monitoring sites in the Glen Canyon Dam tailwater during the high-flow release to assess changes in combined releases between the dam and Lees Ferry; and 3) further study to resolve temperature anomalies that were observed in the 2008 HFE monitoring of river outlet works releases. Anticipated costs associated with additional monitoring for high-flow releases are estimated at $9,300.

Task 14. Evaluate Effects to Hydropower from Repeated HFEs

Information Needs

CMIN 10.1. Determine and track the marketable capacity and energy produced through dam operations in relation to various release scenarios.
SSQ 3-4. What are the projected hydropower costs associated with the various alternative flow regimes being discussed for future experimental science (as defined in the next phase experimental design)?

Project Description

In FY2011-2012, GCMRC proposes to undertake an evaluation of WAPA's GTMax model and explore the utility of this model and potentially other existing models for assessing economic costs associated with alternative operating scenarios at Glen Canyon Dam. Depending on the outcome of this assessment, the GTMax model or an alternative model may be used to assess potential costs and benefits to hydropower from implementing a series of HFEs, as well as for evaluating other alternative

experimental operational scenarios in the future. See project: HYD 10.R1 for specifics about the proposed study.

Products/Reports

Primary reporting of monitoring activities and results will be performed in the context of annual reporting and publications as described in the work plans associated with each individual monitoring project (see individual project descriptions). A summary of monitoring results and relevant findings specific to each individual HFE will be provided in USGS Open-file Reports and/or Fact Sheets in the following fiscal year. A thorough analysis and synthesis of results of the multi-year experiment will be provided at the conclusion of the HFE protocol experiment.

Budget

The monitoring projects described above are funded primarily through the annual work plan. Some projects are supplemented with experimental funds and there are some differences in how these funds are used in years with high flows (Table 10).

Table 11

Use of Experimental Funds to support monitoring for high flow experimental protocol

Task	No HFE	With HFE
Task 1 – SedTrend	$250,000	$140,000
Task 2 – Sandbar monitoring	50,000	50,000
Task 3 – Campable area monitoring	*	*
Task 4 – Remote sensing	*	*
Task 5 – Archeological site monitoring	*	*
Task 6 – Sediment flux	*	110,000
Task 7 – Aquatic food base	100,000	100,000
Task 8 – Lees Ferry fish	22,709	22,709
Task 9 – Lees Ferry recreation experience	25,000	25,000
Task 10 – Mainstem fish monitoring	*	*
Task 11 – Riparian vegetation	*	*
Task 12 – Kanab ambersnail	*	*
Task 13 – Lake Powell	*	*
Task 14 – Hydropower	*	*
Total	$447,709	$447,709

* Project cost covered entirely by biennial work plan.

SUP 12.S1.11-12—Logistics Base Costs

Start Date

Ongoing

End Date

Ongoing

Principal Investigator

Carol Fritzinger, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Entire Colorado River ecosystem corridor between Glen Canyon Dam and Lake Mead, and the greater Colorado River Basin

Project Goals

Provide cost effective, efficient, and complete logistical support for all the GCMRC funded projects

Need for Project

The GCMRC provides complete logistical support for 25–40 research, monitoring, administrative, and tribal river trips through the Grand Canyon annually. These trips range in length from 7–21 days and from 4–24 people in size. Trips utilize a variety of motor- and oar-powered boats operated by contracted boat operators. Projects operating in the Glen Canyon reach of the Colorado River (GCD to Lees Ferry) are supported by a variety of motor-powered boats operated by the GCMRC researchers and contracted boat operators. Additionally, research activities on the Little Colorado River and at other locations outside of the Grand Canyon National Park boundaries are supported by helicopter services contracted with Reclamation. Ground based support for other research activities outside of the river corridor are also coordinated with the GCMRC logistics program.

Strategic Science Questions

Not applicable

Information Needs Addressed

Not applicable

Methods and Tasks

The GCMRC utilizes government-owned boats and river logistical equipment in conjunction with a contracted vendor who supplies technical and logistical boat operators. Put-in and takeout transportation is provided with the use of General Service Administration (GSA) leased vehicles and contracted shuttle drivers.

Effective communication with principal investigators and sensitivity to, and awareness of, the challenges they face in implementing their studies enable the GCMRC to offer more customized (and therefore more cost effective and productive) logistical support than other support strategies utilized previously. Retaining control over the process of supporting trips also facilitates compliance with NPS

regulations and allows greater control over issues sensitive to the general public and the “recreational river community”.

Links/Relationships to Other Projects

The GCMRC logistics program supports all GCMRC projects that have field data collection components.

Logistics

There are no logistical needs for this project.

Products/Reports

Not applicable

Budget

FY2011	$208,996
FY2012	$219,505

SUP 12.S2.11–12—Survey Operations

Start Date

Ongoing

End Date

Ongoing

Principal Investigator

Keith Kohl, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Survey operations occur throughout the CRE in support of scientific activities.

Project Goals

We must supply the GCMRC principal investigators with all necessary information, equipment, and survey knowledge to address their scientific needs. In some cases, that means performing collection, processing, and documentation of all spatial data required by their research. The principal investigators and researchers must be educated regarding accuracies and the limits of various mapping techniques. Data sets used for change detection analysis must be conscientiously evaluated for precision to provide accurate scientific analysis and resulting decision making.

Need for Project

Spatial measurements are required for any long-term monitoring program. The measurements are made using a variety of survey methods and stored in a variety of formats. All measurements reference a position of greater confidence whether the measurement is made using the GPS, LiDAR, digital or analog imagery, conventional survey angles and distances to reflective prisms, or sub aqueous bathymetry. With consistent reference, and explicit protocols, survey operations ensure the integrity of spatial data sets, which increases confidence in scientific analysis.

Strategic Science Questions

Many strategic science questions require stage discharge relationships to determine inundation extents under various flows. These relationships must be collected in the field using consistent survey methods and be referenced to validated control. Answers to questions relating to habitat (for example, sandbar, sand terraces, old and new high water zones, reach morphology, etc) will all require survey measurements. All SSQ's addressed in projects supported by Survey Operations are applicable.

Information Needs Addressed

Accurate and consistent spatial positioning of scientific data is necessary for facilitating change detection. Change detection methods are applied to spatial data collected within the cultural, biological, and physical programs to determine impacts on habitat, validate models, and to determine fine and course sediment storage. Survey protocols also provide spatial data as the foundation of the GIS database. All information needs addressed in projects supported by Survey Operations are applicable.

Methods and Tasks

Survey marks are typically stable on bedrock or large boulders with positions preserved by chiseled or scribed marks, or by physical attachment of foreign substances (nails, caps, screws, bolts, rebar, etc.). These stations were placed in a manner that allows for tripods and conventional or GPS survey equipment to set up over the control point. The points that are occupied regularly are located above the stage reached by the flow of 30,000 cubic feet per second (ft3/s) and have fair but diminishing line of sight due to expanding vegetation. Some stations may be lower in elevation and are occasionally inundated by water during normal dam operations. The survey marks provide spatial reference for measurements of:

- Sandbar and backwater sites located throughout the CRE, many of which have a spatial data set of topographic / bathymetric data collected yearly since 1990
- Long-term monitoring reaches where topography, bathymetry, and LiDAR, digital imagery were collected between 2000 and 2009
- Line-of-site network between GCD and Bright Angel Creek along with 15 miles of traverse points from Blue Springs to the LCR / Colorado River confluence; the traverses used acceptable distances for conventional optical equipment (typically 600 meters and consistently less than 1,000 meters)
- Photo-identifiable fixed points used for remote sensing evaluation and historical imagery rectification
- Cultural sites including locations of features, artifacts, and erosion controls
- USGS stage gages 09380000 : “Colorado River at Lee’s Ferry” and 09402500 “Colorado River near Grand Canyon”
- Instrumentation sites (weather, LISST, Acoustic Doppler, water quality, pump samplers)

FY2011

The survey support will aid in the spatial data collection related to physical, cultural and biological resource programs. The physical program will require equipment and survey support for goal 8 channel mapping in March, 2011. Cultural projects require geo-referencing of ground based LiDAR along with surface creation and analysis for goal 11 site monitoring in April and September, 2011. Terrestrial biology requires office processing and mapping of surface areas of vegetation polygons. Aquatic biology will benefit from channel mapping products within fish study sites.

FY2012

The physical program will require equipment and survey support for Northern Arizona University (NAU) time series in October, 2011, goal 8 channel mapping in March, 2012. Cultural projects require geo-referencing of ground based lidar along with surface creation and analysis for goal 11 site monitoring in April and September. Depending on the level of field support required in FY2012, the survey department may contribute to the development of methods for photogrammetric interpretation of pre-1990 aerial photographs (see PHY 8.M2). This work would support aspects of goal 8, goal 9, and goal 11.

Links/Relationships to Other Projects

Any and all spatial data collection required by GCDAMP is supported through this program.

Logistics

Survey support is provided for GCMRC projects as required by specific project needs, no stand-alone logistics are required.

Products/Reports

Control monuments are established at consistent intervals throughout the CRE and at locations required for accurate positions and elevations of past, current, and future data sets. Stable control monuments and accurate coordinates should be completed prior to spatial data acquisition to reduce post-processing efforts, conserving considerable manpower. Documentation of station information, coordinate history and network accuracy are provided. Current and historical data sets are accurately prepared for integration into the GIS database. All work conducted under the survey support project will be summarized in annual reports, with the FY2011 report to be completed by January 1, 2012 and the FY2012 report to be completed by January 1, 2013.

Budget

FY2011	$51,885
FY2012	$51,885

SUP 12.S3.11–12—Control Network

Start Date

Ongoing

End Date

Ongoing

Principal Investigator

Keith Kohl, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

High accuracy geodetic control now encompasses the entire Colorado River ecosystem (CRE) corridor between Glen Canyon Dam and Lake Mead, and the greater Colorado River Basin. Substantial areas of the CRE, however, do not yet have geodetic controls.

Project Goals

Document methods and results of the geodetic control network developed within Grand Canyon's CRE

Maintain the integrity of the network and all future spatial data referenced to the network by proposing data collection, processing, adjustment and documentation standards

Provide reference and methods for consistent and accurate error determination for several spatial data measurement types

Provide valid reference for emphasis on spatial data collection and evaluation of remote sensing surveying techniques for river monitoring; data sets used for change detection analysis must be conscientiously evaluated for accuracy and blunders so as not to skew scientific analysis and resulting decision making

Need for Project

According to Executive Order 12906 (OMB< 2002), Federal agencies must:

Prepare, maintain, publish, and implement a strategy for advancing geographic information and related spatial data activities appropriate to their mission

Allocate agency resources to fulfill the responsibilities of effective spatial data collection, production, and stewardship

Coordinate and work in partnership with Federal, state, tribal and local government agencies, academia and the private sector to efficiently and cost-effectively collect, integrate, maintain, disseminate, and preserve spatial data, building upon local data wherever possible

Use Federal Geographic Data Committee (FGDC) data standards, such as the Geospatial Positioning Accuracy Standards and the Content Standard for Digital Geospatial Metadata, and other appropriate standards to ensure all relevant data and metadata are appropriately documented before finally making the metadata available to the public online

These standards include publications on reporting methodology, standards for geodetic networks, and the National Standard for Spatial Data Accuracy (NSSDA). It is the purpose of this effort to document adherence to these standards and add recommendations that will ensure policy decisions based on long-term monitoring data and analysis are based on accurate and quality assured data sets.

Strategic Science Questions

Accurate and consistent spatial positioning of scientific data is necessary for facilitating change detection. Change-detection methods are applied to spatial data collected within the cultural, biological, and physical programs to determine impacts on habitat, validate models, and determine fine and course sediment storage. Many strategic science questions require stage discharge relationships to determine inundation extents under various flows. These relationships must be collected in the field using consistent survey methods and be referenced to validated control. Answers to questions relating to habitat (for example, sandbar, sand terraces, old and new high-water zones, reach morphology, etc.) will all require survey measurements. All SSQ's addressed in projects supported by Control Network Operations are applicable.

Information Needs Addressed

Accurate and consistent spatial positioning of scientific data is necessary for facilitating change detection. Change-detection methods are applied to spatial data collected within the cultural, biological, and physical programs to determine impacts on habitat, validate models, and determine fine and course sediment storage. Survey protocols also provide spatial data as the foundation of the GIS database. All information needs addressed in projects supported by Control Network Operations are applicable.

Methods and Tasks

The geodetic control network establishes the foundation for all spatial measurements within the CRE. The survey stations are all referenced to the most accurate and up-to-date coordinates available designated as NSRS2007. The National Spatial Reference System (NSRS) is the most recent realization of the North American Datum of 1983 as determined in a multiyear nationwide readjustment performed by the National Geodetic Survey (NGS) and completed in 2007. These stations provide the primary reference for both kinematic GPS positioning of aircraft during remote sensing flights and static GPS surveys to hundreds of monuments along the river corridor. This consistent framework allows for accurate and reliable accuracy assessment of all spatial data collected within the CRE and assures the integrity of spatial analysis and resulting management decisions.

FY2011

The control network will expand to areas in support of AMWG projects (e.g. goal 8 channel mapping and goal 11 cultural site monitoring). Redundant GPS measurements are necessary to improve accuracy and confidence in results. Terrestrial control measurements made during project surveys are included in the network least squares adjustment. Additional photo-identifiable points are positioned as the time and manpower allows. These known positions are included in remote sensing evaluations according to NSSDA standards, and are used as constraints when scanning and rectifying analog imagery.

FY2012

The control network will expand to support goal 8 channel mapping between Bright Angel Creek and National Canyon.

Links/Relationships to Other Projects

Any and all spatial data collection required by GCDAMG is supported through this program.

Logistics

FY2011

The control network project will require one motor trip to support field data collection of single beam and multi beam sonar and shoreline topography.

Month	Boats	Length	Personnel	Budget
March	2-33', 1-sport 1-22' snout, 1-18' mini snout	18 days	12	$40,000

FY2012

The control network project will require one motor trip to support field data collection for goal 8 channel mapping

Month	Boats	Length	Personnel	Budget
April	2-33', 2-sport	18 days	12	$52,000

Products/Reports

Work with the GCMRC staff to identify realistic and achievable accuracies using existing technologies and theory; this will also include meeting with the GCMRC scientists to establish accuracy requirements that are appropriate for supporting CRE scientific investigations

Generate a comprehensive report on the survey control network, including collection and processing methodologies, analysis and discussion of results, accuracy validation per FGDC requirements, and recommendations for ensuring the network meets the positioning needs of the GCMRC for current and future scientific endeavors

All work conducted under the control network project will be summarized in annual reports, with the FY2011 report to be completed by January 1, 2012 and the FY2012 report to be completed by January 1, 2013

Budget

FY2011 $195,560

FY2012 $203,422

ADM 12.A1.11-12 (A)—Administrative Operations

Start Date

1996

End Date

Ongoing

Principal Investigator

John Hamill, Chief, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Grand Canyon Monitoring and Research Center

Project Goals

Provide budgetary oversight and support to the chief, program managers, and all employees of the GCMRC so that they may conduct their responsibilities in the most efficient, ethical, and professional manner possible

Unburden the scientists, to the largest extent possible, of mundane administrative matters

Support the USGS and the GCMRC missions of conducting scientific research in support of the GCDAMP

Need for Project

It is necessary to have smooth running, transparent administrative operations that ensure that the GCMRC scientists can focus on their research rather than on the administrative details involved with the payment of rent and utilities, timekeeping concerns, filing, and various other administrative topics. Administrative operations activities provide the oversight and management of facilities, burden, and overhead, personnel issues, expenditure tracking, processing and financial management of cooperative and interagency agreements, processing of contracts, timekeeping, bank card tracking and reconciliation, travel plans and voucher processing, and liaison activities between the USGS administrative groups (e.g. Flagstaff Science Center Administration, Western Region Budget and Fiscal Services and Contracting Offices, Biological Headquarters in Reston, VA). In addition, this project is innately involved with the USGS nationwide budget tracking and reporting system known as BASIS+, which is used by the USGS Headquarters and Regional offices to make their annual reports to Congress, as well as to respond to Congressional inquiries with short turnaround times. (As part of the GCDAMP, GCMRC administrators have been called upon to provide information of this type from the system on many occasions.)

Many standard overhead charges, including facilities, space, general office supplies, costs for the USGS local network and support for the Flagstaff Science Center and USGS regional services (including contracting and personnel, as well as salaries and general travel for the GCMRC secretary and budget analyst) are paid for out of the Southwest Biological Science Center's (SBSC) overhead account. Only charges directly tied and traceable to the GCMRC continue to be directly charged to the administrative operations account. These charges include General Services Administration vehicle lease and maintenance, Department of the Interior vehicle gas, maintenance, and replacement costs, safety and/or other non-project-specific mandated training, GCMRC non-project-specific personnel

support (e.g. Publications and Outreach Coordinator), telecommunications and shipping charges, and others.

Strategic Science Questions

Not applicable

Information Needs Addressed

Not applicable

Methods and Tasks

General methods will include standard accounting procedures and regulatory and legal standards as required by the USGS and other Federal agencies with legal oversight. At least monthly updates to program managers will be provided, as well as budgetary and other information provided upon request. The GCMRC will follow USGS guidelines as for personnel, travel, and other processes. Administrative personnel will focus on how to accomplish requests most efficiently within Federal laws and regulations. The GCMRC Budget Analyst will report biannually to the AMWG/TWG on mid-year and year-end projections and on the actual expenditures for the previous fiscal year. GCMRC expanded their Publications and Outreach Coordinator services due to a large volume of publications in progress and planned for FY2011-12 and later; this expanded role will oversee the GCMRC peer-review process under guidelines of the USGS Fundamental Science Practice protocols and will better streamline the publication process.

Links/Relationships to Other Projects

This project is innately linked to all other projects. All project budgets are impacted by burden charges that are tracked and managed through administrative operations, all employees are required to track their time through a USGS personnel system, and many program managers use cooperative or interagency agreements that are processed and tracked financially via administrative operations. Every project is given an account number and must be entered into and tracked, via its budget and its narrative, through the BASIS+ system. Administrative operations activities are tied to each project at the project's earliest development. Coordination of publications includes tracking documents from draft to final publication. Outreach services provide the GCMRC with coordination and communication between the GCMRC and the media.

Logistics

There are no logistical needs for this project.

Products/Reports

The GCMRC Budget Analyst will produce a projection report (usually at the August AMWG meeting) for fiscal year end. In addition, a report in actual expenditures for the previous fiscal year will normally be presented at the March AMWG meeting. The GCMRC Publications and Outreach Coordinator will assist with publications that are project-specific and related to general GCMRC activities and updates on an as needed basis. In addition, this position will provide responses to media inquiries.

Budget

FY2011	$266,298
FY2012	$277,891

ADM 12.A1.11-12 (B)—Administrative Operations—GSA Vehicle Costs

Start Date

1996

End Date

Ongoing

Principal Investigator

John Hamill, Chief, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Grand Canyon Monitoring and Research Center

Project Goals

Provide reliable transportation for the GCMRC

Need for Project

It is necessary to have reliable transportation for GCMRC.

Strategic Science Questions

Not applicable

Information Needs Addressed

Not applicable

Methods and Tasks

General methods will include standard accounting procedures and regulatory and legal standards as required by the USGS and other Federal agencies with legal oversight.

Links/Relationships to Other Projects

This project is innately linked to all other projects.

Logistics

There are no logistical needs for this project.

Products/Reports

Not applicable

Budget

FY2011	$66,550
FY2012	$69,878

ADM 12.A1.11-12 (C)—Administrative Operations—Interior Vehicle Costs

Start Date

1996

End Date

Ongoing

Principal Investigator

John Hamill, Chief, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Grand Canyon Monitoring and Research Center

Project Goals

Provide reliable transportation for GCMRC

Need for Project

It is necessary to have reliable transportation for GCMRC.

Strategic Science Questions

Not applicable

Information Needs Addressed

Not applicable

Methods and Tasks

General methods will include standard accounting procedures and regulatory and legal standards as required by the USGS and other Federal agencies with legal oversight.

Links/Relationships to Other Projects

This project is innately linked to all other projects.

Logistics

There are no logistical needs for this project.

Products/Reports

Not applicable

Budget

FY2011	$33,880
FY2012	$35,574

ADM 12.A2.11-12—Program Planning and Management

Start Date

1996

End Date

Ongoing

Principal Investigator

John Hamill, Chief, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Grand Canyon Monitoring and Research Center

Project Goals

Deliver a comprehensive ecosystem science program over the next 5 years that is effective in responding to management needs articulated through the GCDAMP and by the Department of Interior; utilizing productive, well-qualified personnel are critical to achieving this goal

Need for Project

Strong and effective leadership enhances successful scientific research and reporting and working relationships between managers and employees and between the GCMRC and the GCDAMP stakeholders. In addition to their program management responsibilities, the GCMRC program managers are subject area experts in their respective fields. It is important that the GCMRC program managers and scientific staff maintain this expertise so they can provide high-quality technical assistance in the form of expert analysis, opinion, and advice to the Chief, TWG, and AMWG, as requested. The program managers supervise additional technical and support staff, and act as project leads with their cooperators.

Beginning in FY2006, in an effort to simplify distribution of program planning and management salaries and travel, the Program Manager salaries were assigned to this category exclusively. Salaries and travel costs, separate from TWG and AMWG meeting travel, are included in the program planning and management budget. Position descriptions are provided below.

Strategic Science Questions

Not applicable

Information Needs Addressed

Not applicable

General Methods/Tasks

In order to provide strong leadership of a quality science program that is responsive to the needs of the GCDAMP, the GCMRC will be administered by a core program management staff that includes the following key positions:

Center Chief

Establishes the GCMRC science policies and strategic direction and provides accountability for the GCMRC budget. Interfaces with USGS management, the Secretary of the Interior's GCDAMP Designee, and GCDAMP managers to ensure that quality science is provided in a timely manner on priority issues identified by the GCDAMP leadership.

Deputy Chief

The Deputy Chief shall be responsible for oversight of the Physical Science and Modeling and Data Acquisition, Storage, and Analysis (DASA) Programs, GCMRC publications coordination and the Senior Ecologist (Dr. Carl Walters). In addition, the Deputy Chief ensures that integrated ecosystem science methods and procedures are utilized in science design and analysis and coordinates the HFE synthesis, the Knowledge Assessment and the SCORE report projects.

Program Managers

Responsible for the timely execution of the science program within their program area; interaction with other program areas to ensure integrated ecosystem approaches, quality control of products and contractors/cooperators; contract/agreement management; management of budget within their program area, and production of reports to GCDAMP work groups as needed. The GCMRC activities now encompass five major program areas:

5. The Physical Science and Modeling Program conducts research and monitoring activities on physical elements of the CRE, including studies of sediment storage and transport in the regulated river, and integrated downstream water-quality monitoring and research. The program has been responsible for monitoring several experimental high-flow releases from GCD to conserve sediment resources for building beaches and improving habitat for native aquatic species in the Colorado River. More recent tasks have included development of a downstream temperature model for the ecosystem. The Physical Science and Modeling Program also provides survey support to various program and activities, as well as maintains integrity of the network and spatial data of the geodetic control network.
6. The Data Acquisition, Storage, and Analysis Program provides GIS, data quality control, data management, and library services support to all program areas. In addition, DASA also participates in collaborative science analyses with the GCMRC program staff and cooperators to help achieve better integrated science outcomes.
7. The Biological Program provides scientific information that supports the conservation of native species in the Grand Canyon and the Lees Ferry trout fishery. Elements of the program include assessing the effects of GCD on fishery resources, characterizing the aquatic food base, evaluating terrestrial contributions to the aquatic food base, improving fish community monitoring, developing, and testing of techniques to control nonnative fish, evaluating the nearshore ecology of native fish and the effects of fall steady flows on native fish recruitment, evaluating terrestrial vegetation changes as a result of dam operations, and water-quality monitoring and modeling in Lake Powell and the Colorado River below GCD.
8. The Cultural and Socioeconomic Program develops research and monitoring projects to determine the effects of Glen Canyon Dam on culturally significant sites and recreation activities. The current focus is on development of comprehensive monitoring programs to assess the condition of the culturally significant sites and recreation campsites affected by the operation of GCD. In addition, the program oversees research and monitoring related to assessing the economic effects of Glen Canyon Dam operations on recreation, hydropower, and other program elements and coordinates Native American consultation activities on behalf of the GCMRC.
9. The Logistics and Survey Support Program supports up to 40 river trips per year and coordinates research permit management for the GCMRC.

Links/Relationships to Other Projects

This project is linked by nature to all other projects, since each project must be managed by a program manager or the Chief.

Logistics

There are no logistical needs for this project.

Products/Reports

All products and reports produced by the GCMRC are a result of this project.

Budget

FY2011 $1,207,228

FY2012 $1,240,745

ADM 12.A3.11-12—AMWG/TWG Meeting Travel Funds

Start Date

1996

End Date

Ongoing

Principal Investigator

John Hamill, Chief, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Grand Canyon Monitoring and Research Center

Project Goals

Provide travel funds for employees who participate in AMWG and TWG meetings

Need for Project

This project is an account to hold funds for travel expenses for the GCMRC employees who participate in AMWG and TWG meetings. Project-related travel expenses are accounted for by projects, and administrative travel (for example, general safety and security training) is planned under the Administrative Operations budget.

Strategic Science Questions

Not applicable

Information Needs Addressed

Not applicable

General Methods/Tasks

Methods used are standard USGS travel authorizations and vouchers.

Links/Relationships to Other Projects

Not applicable

Logistics

There are no logistical needs for this project.

Products/Reports

Not applicable

Budget

FY2011	$20,455
FY2012	$21,478

ADM 12.A4.11-12 (A)—Independent Reviews

Start Date

1996

End Date

Ongoing

Principal Investigator

John Hamill, Chief, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Grand Canyon Monitoring and Research Center

Project Goals

To increase the efficiency and quality of the science being developed by the GCMRC and used by the AMWG and the Secretary of the Interior, the GCMRC will establish a peer review process to ensure that all unsolicited, solicited, or in-house proposals and all draft reports received by the GCMRC undergo independent, external peer review

Need for Project

Independent external review is at the heart of the GCMRC's approach to program management and implementation. Together with the competitive process, independent external peer review ensures the quality and objectivity of the GCMRC's programs. Independent review panels are used to evaluate the GCMRC's plans and activities. All proposals, reports, and programs are subject to independent peer review according to the GCMRC's peer review protocols.

Strategic Science Questions

Not applicable

Information Needs Addressed

Not applicable

Methods and Tasks

Peer Review

All of the GCMRC's scientific activities undergo an independent, external peer review, including all unsolicited, solicited, or in-house proposals. Similarly, all draft reports received by the GCMRC undergo independent external peer review. The peer review protocols developed by the GCMRC meet or exceed the standards articulated by the Secretary of the Interior for DOI agencies.

Peer review for proposals received by the GCMRC in response to an RFP is conducted through a panel process, while peer reviews for unsolicited and in-house proposals, as well as project reports, are conducted through correspondence. In all cases, the reviewers are offered anonymity, and the individual and panel reviews, where applicable, are provided to the principal investigators along

with comments from the GCMRC. In addition, the GCMRC conducts PEPs to review and assess the GCMRC's projects and methodologies. To date, PEPs have been held for remote sensing, physical, survey control, terrestrial and aquatic, cultural resource, biological, and water-quality programs.

FY2011 includes PEP reviews for:
Aquatic food base in conjunction with Lake Powell and Downstream Integrated Quality of Water Monitoring
FY2012 includes PEP reviews for:
Campsite
Sediment

The GCMRC review process is designed by a Southwest Biological Science Center to ensure that the peer-review process is not under the immediate supervision of individual GCMRC program managers to guard against any conflicts of interest—real or perceived. Strict conflict-of-interest guidelines are adhered to. The GCMRC annually recruits new peer reviewers and maintains a database of almost 500 potential reviewers, organized by area of expertise. The GCMRC peer reviewers come from academia, Federal, State, and Tribal governmental and nongovernmental organizations, and the private sector. Reviewers are selected on the basis of their record of scientific accomplishment and expertise.

Links/Relationships to Other Projects

Not applicable

Products/Reports

Not applicable

Budget

FY2011	$58,900
FY2012	$36,300

ADM 12.A4.11-12 (B)—Coordination and Review of Services Provided by Science Advisors

Start Date

FY2009

End Date

Ongoing

Principal Investigator

Lawrence D. Garrett, Principal M3 Research and Executive Coordinator of the Science Advisors

Project Overview

The Science Advisors (SAs) provide two types of science support: (1) review of scientific and planning documents and (2) advise on a range of scientific issues and questions related to the Glen Canyon Dam Adaptive Management Program (GCDAMP). The SAs review a wide range of scientific research and planning documents, including multiyear and annual strategic and operational plans, budgets, and special project science plans for activities such as the 2008 high-flow experiment (HFE). The SAs also provide advisory services to the Grand Canyon Monitoring and Research Center (GCMRC), Adaptive Management Work Group (AMWG), and Technical Work Group (TWG) on topics ranging from adaptive management and long-term experimental approaches to the development of new ecosystem science approaches and technical projects such as a temperature control device (TCD).

In FY2011-12, the SAs will include 4-6 interdisciplinary senior scientists, primarily from universities supporting natural resource research programs.

Need for Project

The SAs contribute to the overall science support needs of the GCDAMP as one of the Independent Review Panels (IRPs), serving special functions not provided by other IRPs. SAs service is enlisted to increase the efficiency and quality of the science being developed by the GCMRC and used by the AMWG and the Secretary of the Interior. SAs provide independent scientific oversight and technical advice to ensure that the GCMRC science programs are efficient, unbiased, objective, and scientifically sound.

The SAs are expected upon request to review and comment on the following:

- Results of ongoing and completed monitoring and research program activities, as well as any synthesis and assessment activities initiated by the GCMRC
- The appropriateness of the GCMRC's Requests for Proposals (RFPs), especially their responsiveness to management objectives
- Protocols used in the GCMRC-sponsored scientific activities, including a 5-year review of GCMRC monitoring and research protocols
- The GCMRC's long-term monitoring plan
- The GCMRC's biennial monitoring and research plans

- The GCMRC's biennial budget proposals, to ensure that the science program is efficiently and effectively responding to AMWG goals (that is, management objectives)

The SAs and Executive Director also provide other program-specific scientific and technical advice when asked by the AMWG, the GCMRC, or the Secretary of the Interior.

General Methods/Tasks

Administrative Services

In FY2009, the GCMRC and GCDAMP requested a significant revision of the composition of the SAs, which resulted in the replacement of all but three disciplines and recruiting three to five new SA members in full- or part-time positions. Several administrative activities to support new positions occurred in 2010. The SA Executive Coordinator worked with GCMRC staff to screen specialists to fill three to five SA positions, award positions, develop briefing materials, issue contracts, revise procedures, and other activities, as needed. The new SAs will also be provided an orientation and opportunity to meet the GCMRC staff and stakeholders.

Independent Reviews

Based on activities presented in this work plan, it is anticipated that the SAs will review the following planning and science documents and activities in FY2011-12:

- Proposed 2011–12 science program and related activities, including the integration of these activities into the existing Strategic Science Plan and Monitoring and Research Plan
- Proposed 2011 science program budget
- 2000 low summer steady flows synthesis report
- Core-monitoring plans for (1) Aquatic Food Base/Lake Powell and Downstream Water-quality Monitoring, (2) Native and Nonnative Fish Monitoring, (3) Vegetation Monitoring; and (4) Camping Beaches Monitoring
- Overall fisheries science and modeling direction
- Overall sediment science and modeling direction
- Proposed socioeconomic science request for proposals and science plan
- Humpback chub translocation and trout abatement science plan
- Review of HFE synthesis report

Advisory Services

The SAs provide reviews and advisory service to the GCMRC, the TWG, the AMWG, and the Secretary's Designee. SAs communicate in a variety of ways (emails, phone conversations, reports, and workshops) with the GCMRC and the GCDAMP members, facilitators, outside scientists and managers to clarify review positions, provide information, develop prospectus for collaborative efforts, and assist with the evaluation and development of program direction. The scope of the advisory services will be scaled back due to funding constraints.

FY2011-12, the SAs anticipate providing the following advisory services:

- Participate in GCMRC science workshop on aquatics/fisheries ecosystem modeling led by Senior Ecologist

- Work with GCMRC Chief, leadership team, and Senior Ecologist to assess opportunities for greater integration and improved overall system assessments of biology programs
- Participate in January 2011 and 2012 annual reporting workshop/TWG meeting on HFE Synthesis
- Participate in combined final quality-of-water (including Lake Powell) and aquatics protocol evaluation panel in FY2011
- Participate in final recreational protocol evaluation panel in FY2012
- Assist GCMRC in development of advanced knowledge assessment procedures to support workshop(s) and participation in the workshop(s) in FY2011
- Participate in development of *State of the Colorado River Ecosystem in Grand Canyon* II report as outcome of knowledge assessment in FY2011

Budget

The M3 Research 5-year award included a base year and 4 option years for reviews and services. Due to budget constraints, the GCMRC will significantly reduce the scope of services for FY11-12.

FY2011 $173,850

FY2012 $179,900

ADM 12.A5.11-12—GCMRC Component of SBSC Computer Systems Support

Start Date

FY2005

End Date

Ongoing

Principal Investigator

John Hamill, Chief, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Geographic Scope

Grand Canyon Monitoring and Research Center

Project Goals

It is the Information Technology (IT) Department's goal to ensure that the GCMRC and all stations within the SBSC are able to conduct scientific and administrative functions smoothly and with the least amount of disruption in service as possible. It is the IT Department's task to make IT functions as transparent as possible, to ensure each program has adequate current and future storage, and to provide excellent customer service at all times. IT maintains the security of the GCMRC and the SBSC networks up to current Federal standards and ensures that all those who access the systems meet Federal security standards in order to protect personal information and scientific research that has not yet been released to the public. At the same time, the IT Department ensures that the public has full and easy access to publicly released data via the GCMRC's Web sites and works closely with the DASA program to make this possible.

Need for Project

The IT Department of the SBSC supports a variety of technology needs of the GCMRC's various program areas: computer security, systems administration and procurement of new servers and computers, as well as Web site development and Web page maintenance. These support, development, and maintenance services costs are shared between the GCMRC, the SBSC, and the IT Department, and coordinated by the Center's Deputy Director to meet the IT needs of all SBSC research stations.

Strategic Science Questions

Not applicable

Information Needs Addressed

Not applicable

Methods and Tasks

The IT Department follows all Federal, DOI, and USGS regulations regarding purchase of, access to, and distribution and release of electronic information. Methods also include the following:

- Network environment: Computer interconnectivity is provided using transmission control protocol/Internet protocol (TCP/IP) network communication protocol running on 1000baseT

and 100baseT network media. Network traffic is arbitrated by 6 3COM switches and hubs operating at 1 gigabyte per second (Gbps).

- Internet connectivity: The GCMRC computer network is linked to the Internet through the Flagstaff Science Center GEOnet-3 router that provides a DS-3 (45 Megabytes [Mbps]) virtual circuit to Menlo Park, where it joins the USGS GEOnet network. Also located in Menlo Park is a network portal to the Internet operated by the USGS and NASA through a peering partnership. GEOnet provides a secure Surveywide networking environment that interconnects headquarter region, district, and field offices located throughout the United States.
- Intranet Web site: The GCMRC's intranet offers a secure centralized medium for information exchange among the GCMRC employees. Among things to be internally shared via the intranet are standard operating procedures, personnel availability and contact info, vehicle and equipment checkout, and an IT support system. The GCMRC intranet is served from a Windows 2003 Server utilizing Active Server Pages (ASP).
- GCMRC.GOV: The GCMRC Web site will continue to be redesigned in FY2010-11 to improve functionality and provide direct user/stakeholder access to all GCMRC products.
- Computer security: Network security is provided by firewalls, routers, a patch management server, a systems management server (SMS), and antivirus software. Firewalls and routers are configured and maintained to restrict outside access to authorized systems. Operating systems are updated monthly to minimize vulnerabilities using Software Update Services (SUS), which automates a central delivery system for patch management. Antivirus updates are downloaded from the Web as released and pushed to all systems the same night.
- Desktop and servers: The GCMRC's computing environment is based upon the PC platform, Microsoft Windows operating system, and Microsoft Office automation software. Systems maintenance is performed using a combination of warranty service, service contracts, and in-house service as needed to facilitate quick turnaround, minimize downtime, and reduce costs.
- System backup and disaster recovery: System backup and disaster recovery is accomplished using dual linear tape open (LTO) tape drives in a 30-slot carriage with a capacity of 12 Terabytes (Tbytes) native up to 24 Tbytes compressed before swapping tapes. Tapes are stored locally in a fire vault and archival tapes are stored offsite. Server disks are configured to run either a raid-5 array or mirrored for redundancy.
- Troubleshooting and maintenance: Helpdesk support is provided as requested/required. Requests are received via the Web, email, and telephone.
- Assistance with the GCMRC's data storage: Over 30 Tbytes of online disk storage is provided by multiple servers with small computer system interface (SCSI) disk arrays. Server disk arrays are hot swappable to minimize downtime. The GCMRC also utilizes networked attached storage (NAS) devices. Integrated Drive Electronics (IDE) and Serial Advanced Technology Attachment (STA) drives connected to a SCSI backplane. NAS units are used to provide bulk storage capacity at less expense. Servers are connected via a Fiber 1Gbps backbone to multiple NAS units.

Links/Relationships to Other Projects

All projects are integrated with IT support. Refer to the DASA section for more information on integration with these projects.

Products/Reports

The primary products and services of the SBSC Information Technology Department with respect to ongoing support of the GCMRC's needs are as follows:

- Comprehensive and fully functional Web site development and maintenance, with access to all nonsensitive digital data and information relating to the effects of dam operations on the CRE. The GCMRC Web sites to make the mission and findings of the GCMRC accessible to the public (Sites offer our updated work plan, descriptions of our program areas, and various interactive stores of data including an Internet Map Server and an online library)
- Coordination with the GCMRC's DASA program to ensure and support a comprehensive and fully functional library containing all hard copy and digital media (cataloged and accessible) with data and information relating to the effects of dam operations on the CRE (Sensitive and nonreleasable data and information will be archived and secured separately from releasable data and information)
- Fully functional and integrated computing environment

Budget

FY2011 $214,610

FY2012 $221,954

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Appendix A. Key Strategic Science Questions Addressed in the FY2007–11 Science Program

AMWG Priority 1: Why are the humpback chub not thriving, and what can we do about it? How many humpback chub are there and how are they doing? (GCDAMP goal 2)

Key Strategic Science Questions

1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year (YoY) and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions? [FY2006–11]

2. Does a decrease in the abundance of rainbow trout (RBT) and other cold- and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population? [FY2006–11]

3. Do RBT immigrate from Glen to Marble and eastern Grand Canyons, and, if so, during what life stages? To what extent do Glen Canyon immigrants support the population in Marble and eastern Grand Canyons? [FY2007–11]

4. Can long-term decreases in abundance of RBT in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species. [FY2007–11]

5. What are the important pathways, and the rate of flux among them, that link lower trophic levels with fish and how will they link to dam operations? [FY2006–09]

6. Are trends in the abundance of fish populations, or indicators from fish such as growth, condition, and body composition (for example, lipids), correlated with patterns in invertebrate flux? [FY2006–09].

7. Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made useable and maintained? [FY2008–09].

8. How can native and nonnative fish best be monitored while minimizing impacts from capture and handling or sampling? [FY2007–11].

AMWG Priority 2: Which cultural resources, including traditional cultural properties, are within the Area of Potential Effect, which should we treat, and how do we best protect them? What is the status and trends of cultural resources and what are the agents of deterioration? (GCDAMP Goal 11)

Key Strategic Science Questions

1. Do dam-controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and traditional cultural properties (TCP) sites, and if so, how? [FY2007–11]

2. How do flows impact old high-water zone terraces in the Colorado River ecosystem (CRE) (where the majority of archaeological sites occur), and what kinds of important information about the historical ecology and human history of the CRE are being lost due to ongoing erosion of the Holocene sedimentary deposits? [FY2004–11]

3. If dam-controlled flows are contributing to (influencing rates of) archaeological site/TCP erosion, what are the optimal flows for minimizing future impacts to historic properties? [FY2009–11]

4. How effective are various treatments (for example, check dams, vegetation management, etc.) in slowing rates of erosion at archaeological sites over the long term? [FY2006–11]

5. What are the TCPs in the CRE, and where are they located? [FY2006–11]

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? [FY2006–08]

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? [FY2006–11]

AMWG Priority 3: What is the best flow regime? (GCDAMP goals 1–11)

Key Strategic Science Questions

1. Is there a "Flow-Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales? [FY2008–11]

2. To what extent could predation impacts by nonnative fish be mitigated by higher turbidities or dam-controlled high-flow releases? [FY2007–08]

3. What are the hydropower replacements costs of the modified low fluctuating flow (MLFF) (annually, since 1996)? [FY2007–08]

4. What are the projected hydropower costs associated with the various alternative flow regimes being discussed for future experimental science (as defined in the next phase experimental design)? [FY2006–07]

5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations? [FY2006–08]
6. What Glen Canyon Dam operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability? [FY2007–08]

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? [FY2007–08]

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? [FY2007–09]

9. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience? [FY2009–11]

10. How can safety and navigability be reliably measured relative to flows? [FY2007–08]

11. How do varying flows positively or negatively affect visitor safety, health, and navigability of the rapids? [FY2007–09]

12. How do varying flows regimes positively or negatively affect group encounter rates, campsite competition, and other social parameters that are known to be important variables of visitor experience? [FY2007–09]

AMWG Priority 4: What is the impact of sediment loss and what should we do about it? (GCDAMP goal 8)

Key Strategic Science Questions

1. Is there a "Flow-Only" operation (that is, a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales? (FY2008–11)

2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possibly mortality of young humpback chub) associated with high flows? [FY2007–11]

AMWG Priority 5: What will happen when we test or implement the temperature control device (TCD)? How should it be operated? Are safeguards needed for management? (GCDAMP goals 1–4 and 7–10)

Strategic Science Questions

1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE? [FY2006–08]

2. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations? [FY2006–08]

3. To what extent do temperature and fluctuations in flow limit spawning and incubation success for native fish? [FY2003–08]

4. What is the relative importance of increased water temperature, shoreline stability, and food availability on the survival and growth of YoY and juvenile native fish? [FY2003–08]

5. Will increased water temperatures increase the incidence of Asian tapeworm in humpback chub or the magnitude of infestation, and if so, what is the impact on survival and growth rates? [FY2003–08]

6. Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance? [FY2007–11]

7. How do warmer releases affect viability and productivity of native/nonnative vegetation? [FY2007–11]

Appendix B—Deferred Projects

Monitoring

BIO 1.M1 Aquatic Food Base Monitoring
BIO 2.M4 Increased Monitoring of Mainstem Fishes
BIO 6.M2 Bird Monitoring / Alternating Years with Vegetation Transect Monitoring
DASA 12.D1 Hyperspectral Overflight for Vegetation Mapping

Experimental Research

BIO 2.tbd NEW NSE / FSF Thermal Imaging
BIO 4.E2 Monitoring Lees Ferry Fishes for Annual Recruitment

Research & Development

BIO 6.R4 Arthropod Monitoring R &D
PHY 7.R2 Further Develop Integrated Flow, Temperature & Sediment Model
REC 9.R5 Evaluate Relation between Flows and Recreation Experience
REC 9.R6 1973 Weeden Survey Revisited
REC 9.R7 Update Regional Recreation Economic Study
HYD 10.tbd NEW Phase I - Results of Economic Value Workshop
CUL 11.R1 Cultural Research & Development towards Core Monitoring, Phase II
CUL 11.R3 Geomorphic Model of Archaeological Site Vulnerability
PLAN 12.P1 Expanded Ecosystem Modeling (Walters, et al)
DASA 12.D9 1984 Sandbar Image Analysis

Program Planning

PLAN 12.P1 Support and Enhancement of Ecosystem Modeling Efforts MATA Workshop
PLAN 12.P5 NEW Desired Future Conditions Facilitation & Decision Support

Administrative

SUP 12.S2 NEW Assessment of Vertical Accuracy & Precision for High-resolution Topographic Surfaces (Survey Ops)
DASA 12.D3 Library Operations Support
DASA 12.D3 Implement New GCMRC Library System
ADM 12.A5 NEW Expanded Website Development (Component of SBSC Sys Admin Support)
ADM 12.A4 (A) Independent Reviews
ADM 12.A tbd NEW Tribal Consultation Staff Support

Appendix C. Conservation Measures from 2008 Biological Opinion

Pursuant to Section 7 of the Endangered Species Act of 1973, as amended, the U.S. Fish and Wildlife Service (USFWS) consulted with the Bureau of Reclamation (Reclamation) on the operation of Glen Canyon Dam and developed Conservation Measures. The following conservation measures are extracted directly from the USFWS February 27, 2008, Final Biological Opinion for the Operation of Glen Canyon Dam.

Conservation Measures

Reclamation has included the following conservation measures for listed species in the action area as part of its proposed action. As described above, the AMP provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and using the results to develop recommendations for modifying dam operations and other resource management and conservation actions. The AMP also provides for long-term monitoring and research activities to evaluate the effectiveness of the operational modifications to Glen Canyon Dam and other management actions. Many of the conservation measures listed below have already been occurring through the AMP at various levels. We believe conservation measures carried out through the AMP have resulted in significant conservation benefits to humpback chub and Kanab ambersnail. The existence of the AMP and the history of conservation of these species through the AMP serve to substantiate that the following conservation measures will be implemented as proposed by Reclamation. Implementation of some of these conservation measures may require additional compliance. USFWS is currently investigating the feasibility of developing a recovery program for humpback chub in Grand Canyon. All of the conservation measures listed here could fall under such a program. Agreements would need to be developed to facilitate cost sharing with other agencies and organizations, both within and outside of the AMP, to fully implement a recovery program.

Humpback Chub

Humpback Chub Consultation Trigger

Pursuant to 50 CFR § 402.16 (c), reinitiation of formal consultation is required and shall be requested by the Federal agency or by the USFWS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered. Reclamation and USFWS agree to specifically define this reinitiation trigger relative to humpback chub, in part, as being exceeded if the population of adult humpback chub (≥200 mm [7.87 in] TL) in Grand Canyon declines significantly, or, if in any single year, based on the age-structured mark recapture model (ASMR; Coggins 2007), the population drops below 3,500 adult fish within the 95 percent confidence interval. USFWS and Reclamation have agreed on this trigger based on the current estimated population size and past population trend, genetic considerations, and the capabilities of the ASMR model to estimate population size. This number was derived as a conservative approach to preventing the population from declining to the minimum viable population size for humpback chub, estimated to be 2,100 adult fish (U.S. Fish and Wildlife Service 2002a), with consideration for a buffer and acknowledging the variance inherent in the ASMR resulting from age estimation based on recent results from this model (Coggins 2007). This trigger provides additional protection against possible adverse affects to humpback chub from the proposed action. If the population of humpback

chub declines to this level, Reclamation and USFWS will consider appropriate actions through reinitiated section 7 consultation, for example, extending the period of steady releases to include July and August. Conversely, if the population of humpback chub expands significantly, USFWS and Reclamation will consider the potential for reinitiation of consultation to determine if steady flows continue to be necessary.

Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon

Reclamation has been a primary contributor to the development of the AMP's Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation will continue to work with AMP cooperators to develop a comprehensive approach to management of humpback chub. Reclamation has committed to specific conservation measures in this biological opinion, but will also consider funding and implementing other actions not identified here to implement the plan.

Humpback Chub Translocation

In coordination with other Department of the Interior (DOI) AMP participants and through the AMP, Reclamation will assist NPS and the AMP in funding and implementation of translocation of humpback chub into tributaries of the Colorado River in Marble and Grand canyons. Nonnative control in these tributaries will be an essential precursor to translocation, so Reclamation will help fund control of both cold and warm-water nonnative fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo and Bright Angel creeks will initially be targeted for translocation, although other tributaries may be considered. Reclamation will work with USFWS, NPS and other cooperators to develop translocation plans for each of these streams, utilizing existing information available such as SWCA and Grand Canyon Wildlands (2007) and Valdez and others. (2000a). These plans will consider and utilize genetic assessments (Douglas and Douglas 2007, Keeler-Foster in prep.), identify legal requirements and jurisdictional issues, methods, and assess needs for nonnative control, monitoring and other logistics, as well as an implementation schedule, funding sources, and permitting. Reclamation and the AMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls in 2008 if USFWS determines that a translocation is warranted. Reclamation and the AMP will continue to monitor humpback chub in the reach of the Little Colorado River above Chute Falls for the 5-year period of the proposed action, and will undertake additional translocations above Chute Falls as deemed necessary by USFWS.

Nonnative Fish Control

As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

Humpback Chub Nearshore Ecology Study

In coordination with other DOI AMP participants and through the AMP, Reclamation will implement a nearshore ecology study that will relate river flow variables to ecological attributes of nearshore habitats (velocity, depth, temperature, productivity, etc.) and the relative importance of such habitat conditions to important life stages of native and nonnative fish. This study will incorporate

planned science activities for evaluating the high-flow test on nearshore habitats as well as the 5-year period of steady flow releases in September and October. A research plan will be developed with US via the AMP for this study by August 1, 2008, and a 5-year review report will be completed by 2013. The plan will include monitoring of sufficient intensity to ensure significant relationships can be established, as acceptable to the USFWS. This conservation measure is consistent with the Sediment Research conservation measure in the Shortage Guidelines biological opinion. This study will help clarify the relationship between flows and mainstem habitat characteristics and availability for young-of-year and juvenile humpback chub, other native fish, and competitive or predaceous nonnative fish, and support continued management to sustain mainstem aggregations. The feasibility and effectiveness of marking small humpback chub (<150 and <100 mm TL [5.91 and 3.93 in]) will also be evaluated as part of the study, and if effective, marking young fish will be utilized in the study. Marking young humpback chub, if feasible and effective, could greatly aid in developing information on the early life history, growth and survival of young humpback chub.

Monthly Flow Transition Study

Transitions between monthly flow volumes can often result in drastic changes to nearshore habitats. For example, past transitions from August to September in some years have consisted of a transition from a lower limit of 10,000 cfs in August to an upper limit of 10,000 cfs in September. Such a transition results in a river stage level that is below the varial zone of the previous month's flow, and may be detrimental to fish and food base for fish. Reclamation has committed to adjusting daily flows between months to attempt to attenuate these transitions such that they are more gradual, and to studying the biological effects of these transitions, in particular to humpback chub. If possible, Reclamation will work to adjust September and October monthly flow volumes to achieve improved conditions for young-of-year, juvenile, and adult humpback chub, as acceptable to the USFWS.

Humpback Chub Refuge

Once appropriate planning documents are in place, and refuge populations of humpback chub are created (as a conservation measure of the Shortage Guidelines biological opinion), Reclamation will assist USFWS in maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing funding to assist in annual maintenance. In case of a catastrophic loss of the Grand Canyon population of humpback chub, a humpback chub refuge will provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species. This action would also be an important step toward attaining recovery.

Little Colorado River Watershed Planning

Reclamation will continue its efforts to help other stakeholders in the Little Colorado River watershed develop watershed planning efforts, with consideration for watershed level effects to the humpback chub in Grand Canyon.

Kanab Ambersnail

Habitat Protection

Reclamation will, through the AMP, temporarily remove and safe-guard all Kanab ambersnails found in the zone that would be inundated during the high-flow test, as well as approximately 15 percent (17 m2 [180 ft2]) of the Kanab ambersnail habitat that would be flooded by the experimental high-flow test. The ambersnails would be released above the inundation zone, and habitat would be held locally above the level of inundation until the high-flow test has ended (approximately 60 hours). Habitat will be replaced in a manner that will facilitate regrowth of vegetation. Subsequent monitoring of this conservation measure will be coordinated with GCMRC.

Appendix D. Fiscal Years 2011-12 Budget Explanatory Material

The draft budget for the Glen Canyon Dam Adaptive Management Program (GCDAMP) for fiscal years (FY) 2011 and 2012, which includes budgets for GCDAMP activities preformed by Reclamation and the U.S. Geological Survey (USGS) Grand Canyon Monitoring and Research Center (GCMRC), is attached separately. Table D.1 explains the information found in various columns of the budget document. Following the table is an explanation of USGS policy on cost-recovery accounting and cost share.

Table D.1. Explanation of information found in columns of draft fiscal year (FY) 2011-12 Glen Canyon Dam Adaptive Management Program (GCDAMP) budget.

Column	Title	Key
A	Grand Canyon Monitoring and Research Center (GCMRC) Project ID	Characters 1–3 Identify program area BIO: Biology PHY: Physical Science REC: Recreation HYD: Hydropower CUL: Cultural DASA: Data Acquisition, Storage and Analysis SUP: Support (Logistics and Survey) ADM: Administration and Management PLAN: Planning Characters 4–5 Identify GCDAMP goal number Characters 6–7 Identify GCMRC project number Characters 8–9 Identify fiscal year
B	Status	O: Ongoing N: New C: Complete D: Deferred NA: Not applicable
C	Funding emphasis	APM: Administrative program management. Activities/projects that are administrative in nature or are conducted in support of the overall GCMRC science program, including base funding for program managers, logistics staff and permanent DASA staff. COR: Core-monitoring project. Monitoring projects that have been piloted, subjected to initial and secondary protocols evaluation panel (PEP) reviews, documented through a core-monitoring report and formally adopted as a core-monitoring project by the Technical Work Group (TWG). CRD: Core-monitoring research and development project. Monitoring projects that are currently undergoing research and development, including projects that have been piloted and peer reviewed but which have not yet been formally documented with a core-monitoring report or formally adopted as a core-monitoring project by the TWG. LTE: Long-term experiment. Projects specifically undertaken as part of or in direct support of the Long-Term Experimental Plan.

D	Project description	ORD: Other research and development projects. Other research projects or research and development work that is NOT directly tied to the development of Project title (start date–end date)
E	Actual FY2010 budget	Actual GCDAMP FY2010 gross budget figures as of this revision date
F	Previously submitted FY11 Budget	Previously submitted proposed FY2011 budget (submitted with FY2010-11 budget
G	REVISED Proposed FY2011 or FY2012 budget	Proposed FY2011 or FY2012 gross cost of project as of this revision date

Explanation of USGS Policy on Cost Share

In FY2003, the U.S. Geological Survey (USGS) began full-cost recovery accounting and instituted a Department of the Interior (DOI) customer rate of 15 percent against all DOI agency reimbursable funding. In FY2011-12, the customer rate is estimated at the 15-percent DOI customer rate with an additional 6 percent added to achieve the required additional facilities costs. The DOI customer rate was established by the USGS Headquarters and is considered a 'preferred customer' rate offered to other DOI agencies. In addition to the DOI rate, a special "pass through" rate of 6 percent was also instated. USGS approved the special rate of 6 percent for a portion of GCMRC's power revenue funding. This rate is applied to approximately $3 million of funding that is directly "passed through" to GCMRC cooperators.

USGS will continue to provide cost share on science activities. However, management actions (such as mainstem mechanical fish removal) not tied to a specific scientific study design will be assessed full burden. Any unused portion not needed for cost share will be used to support science activities that would be complimentary to the GCDAMP science program.

Appendix E. GCDAMP Fiscal Year 2011–12 Budget

Oversized budget sheets follow this page.

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FOR DRAFT FY2011/12 GCDAMP BUDGET for the USBR and the USGS GCMRC

APPENDIX E-1

Reclamation AMP Budget with GCMRC Recommended Redirection of Funds

	Project Descriptions	FY10 GROSS Actual Budget (incl FY09 Carryover & <1.3%> CPI)	FY11 Previously Submitted Budget (incl 0% CPI)	FY11 REVISED Gross Proposed Budget (incl 2.5% CPI)	FY12 Gross Proposed Budget (incl 3% CPI)	Comments
	Adaptive Management Work Group			-	-	
	Personnel Costs	174,449	174,449	178,810	184,175	
	AMWG Member Travel Reimbursement	17,240	17,240	17,671	18,201	
	Reclamation Travel	13,994	13,994	14,344	14,774	
	Facilitation Contract	26,609	26,609	27,274	28,092	
	POAHG Expenses	54,814	54,814	28,092	28,935	GCMRC recommends redirection of 1/2 funds: **FY11 = $28,092, FY12 = $28,935** **SEE APPENDIX E-5**
	Other	7,865	7,865	8,062	8,303	
		294,971	**294,971**	**274,253**	**282,480**	
	Technical Work Group					
	Personnel Costs	85,074	85,074	87,201	89,817	
	TWG Member Travel Reimbursement	23,641	23,641	24,232	24,959	
	Reclamation Travel	17,428	17,428	17,864	18,400	
	TWG Chair Reimbursement	24,305	24,305	24,913	25,660	
	Other	2,247	2,247	2,303	2,372	
		152,695	**152,695**	**156,512**	**161,208**	
	Other					
	Compliance Documents (includes LTEMP EIS)	49,350	49,350	250,000	250,000	Assumes approval of GCMRC recommended redirection of funds. **SEE APPENDIX E-5**
	Administrative Support for NPS Permitting	117,307	117,307	60,120	61,923	GCMRC recommends redirection of 1/2 funds: **FY11 = $60,120, FY12 = $61,924** **SEE APPENDIX E-5**
	Contract Administration	39,434	39,434	40,420	41,632	
**	Experimental Funds Carryover - to be held by BOR	493,500	493,500	286,672	48,366	Reflects amount available for carryover to next fiscal year based on GCMRC projected contributions and expenditures. **SEE APPENDIX E-4**
*	Integrated Tribal Resources Monitoring	141,027	141,027	144,553	148,889	Add'l $75k available in FY10 and FY11 due to reallocation of previous years' appropriated funds
	Mainstem Non-native Mechanical Removal	-	-	-	-	
*	Non-native Fish Suppression Contingency Fund	47,853	47,853	600,000	300,000	Assumes approval of GCMRC recommended redirection of funds. **SEE APPENDIX E-5**
		888,471	**888,471**	**1,381,765**	**850,811**	
		1,336,137	**1,336,137**	**1,812,530**	**1,294,499**	
	Programmatic Agreement Cultural Resources					
	Reclamation Administration	59,362	59,382	60,273	62,081	
	Canyon Treatment Plan and Implementation	493,500	493,500	205,838	521,013	GCMRC recommends redirection of funds: **FY11 = $300k** **SEE APPENDIX E-5**
		552,862	**552,882**	**266,110**	**583,094**	
		1,888,999	**1,889,019**	**2,078,640**	**1,877,593**	

***FY11 budget includes $96,966 Power Revenue funds carried forward from FY10 + $75k Appropriated funds carried forward from prior years**

****FY11 & FY12 budgets reflect amounts available for carryover to next fiscal year based on GCMRC projected contributions and expenditures (not BOR contributions)**

APPENDIX E-1

Reclamation AMP Budget with GCMRC Recommended Redirection of Funds

Project Descriptions	FY10 GROSS Actual Budget (incl FY09 Carryover & <1.3%> CPI)	FY11 Previously Submitted Budget (incl 0% CPI)	FY11 REVISED Gross Proposed Budget (incl 2.5% CPI)	FY12 Gross Proposed Budget (incl 3% CPI)	Comments
Development of a LCR Management Plan	-	-	-	-	
Financial Agreements with Tribes					
Hopi Tribe	95,000	95,000	95,000	95,000	Proposal put forth to increase by CPI funds for those tribes fully expended in previous years (not captured in this budget pending approval)
Hualapai Tribe	95,000	95,000	95,000	95,000	
Navajo Nation	95,000	95,000	95,000	95,000	
Pueblo of Zuni	95,000	95,000	95,000	95,000	
Southern Paiute	95,000	95,000	95,000	95,000	
DOI Handling Fee	-	-	-	-	
	475,000	**475,000**	**475,000**	**475,000**	
	475,000	**475,000**	**475,000**	**475,000**	
	2,363,999	**2,364,019**	**2,553,640**	**2,352,593**	

***FY11 budget includes $96,966 Power Revenue funds carried forward from FY10 + $75k Appropriated funds carried forward from prior years**

****FY11 & FY12 budgets reflect amounts available for carryover to next fiscal year based on GCMRC projected contributions and expenditures (not BOR contributions)**

	A	B	C	D	E	F	G	H	I
76	APPENDIX E-2								
77	GCMRC AMP Budget - Capped Power Revenues								
78	**GCMRC Project ID**	**STATUS**	**Funding Emphasis**	**Project Descriptions**	**FY10 GROSS Actual Budget (incl FY09 Carryover & <1.3%> CPI)**	**FY11 Previously Submitted Budget (incl 3% CPI)**	**FY11 REVISED Gross Proposed Budget (incl 2.5% CPI)**	**FY12 Gross Proposed Budget (incl 3% CPI)**	**Comments**
79	U.S. Geological Survey - Biological Resource Division - GCMRC - Capped Power Revenues Funded Projects								
80	**GOAL 1 - FOOD BASE**								
81	BIO 1.R1.10	C	CRD	Aquatic Food Base (FY05--FY10)	531,183	-	-	-	
82	BIO 1.M1.11	N	COR	Aquatic Food Base Monitoring (FY11--Ongoing)	-	250,712	343,744	332,692	FY11 Focus compl of research, rpts, PEP review, develop CMP; FY11/12 Monthly drift, benthos monitor at LF & DC only; FY12 Impl CMP subj to appl; Budgets include add'l $100k Experimental Funds to support HFE in FY11 & FY12 **SEE APPENDIX E-4.**
83	BIO 1.R4.10	C	CRD	Impacts of Various Flow Regimes on the Aquatic Food Base (FY08--FY10)	61,782	-	-	-	
84				**SUB-TOTAL GOAL 1**	**592,965**	**250,712**	**343,744**	**332,692**	
85	**GOAL 2 - NATIVE FISHES**								
86	BIO 2.R1.10	C	CRD	LCR HBC Monitoring Lower 13.6km (HBC Population Est) (FY00--FY10)	454,282	-	-	-	
87	BIO 2.R2.10	C	CRD	LCR HBC Monitoring Lower 1,200m (FY00--FY10)	57,259	-	-	-	
88	BIO 2.M1.11	N	COR	LCR Fish Monitoring (FY11--Ongoing)	-	308,824	576,134	604,940	**BOCM** Repeat FY10 monitoring, revise based on analysis of PEP recommendations
89	BIO 2.M3.11	O	CRD	HBC Translocation & Monitoring Above Chute Falls (Ongoing)	142,129	145,494	131,051	137,602	**BOCM** Monitor HBC status and translocate fish above Chute Falls; include funding for GCMRC oversight
90	BIO 2.M4.11	O	COR	Monitoring Mainstem Fish (Ongoing)	619,402	798,930	280,503	558,449	**BOCM** FY11 Mainstem monitoring reduced from 4 to 2 trips (to support nonnative control work by BOR; FY12 Mainstem monitoring restored to 4 trips
91	BIO 2.R7.11	O	ORD	Stock Assessment of Grand Canyon Native Fish (Ongoing)	94,118	103,776	57,665	60,541	Continued analysis of fish stock data at reduced level; Complete & publish. ASMR estimate humpback chub adult population; FY12 Continued analysis of fish stock data at reduced level; No ASMR
92	BIO 2.R13.11	O	CRD	Remote PIT Tag Reading (Ongoing)	225,177	224,557	145,828	152,594	Operate & maintain equipment and analyze data with graduate student and advisor; Defer expansion of the system
93	BIO 2.R15.11	O	CRD	Near Shore Ecology / Fall Steady Flows (FY08--FY12)		-	-	-	**SEE APPENDIX E-3**
94	BIO 2.R16.11	O	ORD	Mainstem Nonnative Fish Control (Ongoing)	104,765	-	-	-	FY11 $600K identified in BOR budget to determine scope of work, if any; FY12 $300K identified in BOR budget to determine scope of work, if any **SEE APPENDIX E-5**

	A	B	C	D	E	F	G	H	I
95	APPENDIX E-2								
96	GCMRC AMP Budget - Capped Power Revenues								
97	**GCMRC Project ID**	**STATUS**	**Funding Emphasis**	**Project Descriptions**	**FY10 GROSS Actual Budget (incl FY09 Carryover & <1.3%> CPI)**	**FY11 Previously Submitted Budget (incl 3% CPI)**	**FY11 REVISED Gross Proposed Budget (incl 2.5% CPI)**	**FY12 Gross Proposed Budget (incl 3% CPI)**	**Comments**
98	BIO 2.R17.11	O	ORD	Nonnative Control Plan Science Support (Ongoing)	60,697	138,599	65,204	63,389	FY11 Monitor and synthesize nonnative capture data in Open File Report and conduct 2011 nonnative workshop; FY12 Monitor and synthesize nonnative capture data in Open File Report and conduct 2011 nonnative workshop
99	BIO 2.E18.11	O	EXP	Detection of Rainbow Trout Movement from the Upper Reaches of the Colorado River below Glen Canyon Dam	-	-	437,201	459,061	FY11 & FY12 Investigate RBT movement patterns between Paria R. & Badger Rapid; Budgets include add'l Experimental Funds to support HFE: FY11 $198,631; FY12 $311,610 **SEE APPENDIX E-4**
100	BIO 2.R19.11	O	ORD	Biometrics & General Analysis (Vice Coggins) (Ongoing)	-	165,840	149,627	157,089	1/3 time BIO 2.R7, 1/3 time PLAN 12.P1, 1/3 time general biology support ASMR, ecosystem modeling, and biometric support
101				**SUB-TOTAL GOAL 2**	**1,757,829**	**1,886,020**	**1,843,213**	**2,193,665**	
102	**GOAL 3 - EXTIRPATED SPECIES**								
103	07.3.00	-	NA	None Identified	**-**	**-**	-	-	No funded projects; GCMRC will participate in extirpated species ad hoc group and razorback workgroup
104				**SUB-TOTAL GOAL 3**		**-**	**-**	**-**	
105	**GOAL 4 - RAINBOW TROUT**								
106	BIO 4.M2.11	O	COR	Monitoring Lees Ferry Fish (Ongoing)	173,259	182,819	216,846	226,552	Continue monitoring of fish community in Lees Ferry reach including YOY, juvenile and adult RBT monitoring; Budgets include add'l $22,709 Experimental Funds to support HFE in FY11 & FY12 **SEE APPENDIX E-4**
107				**SUB-TOTAL GOAL 4**	**173,259**	**182,819**	**216,846**	**226,552**	
108	**GOAL 5 - KANAB AMBERSNAIL**								
109	BIO 5.R1.11	O	CRD	Monitor Kanab Ambersnail (FY07--FY11)	20,117	25,700	20,637	21,470	**BOCM** Continue annual monitoring
110				**SUB-TOTAL GOAL 5**	**20,117**	**25,700**	**20,637**	**21,470**	
111	**GOAL 6 - SPRINGS / RIPARIAN**								
112	BIO 6.M1.11	O	COR	Vegetation Mapping (Ongoing)	86,842	106,211	86,763	62,242	FY11 Implement vegetation transect monitoring (assumes approval of core monitoring plan); Analyze 2009 imagery for vegetation change; FY12 Analyze 2009 imagery and prepare report
113	BIO 6.M2.11	N	COR	Vegetation Transects (FY11--Ongoing)	36,821	142,917	153,203	94,997	FY12 Defer bird and/or arthropod monitoring
114				**SUB-TOTAL GOAL 6**	**123,663**	**249,128**	**239,966**	**157,239**	

	A	B	C	D	E	F	G	H	I
115	APPENDIX E-2								
116	GCMRC AMP Budget - Capped Power Revenues								
117	**GCMRC Project ID**	**STATUS**	**Funding Emphasis**	**Project Descriptions**	**FY10 GROSS Actual Budget (incl FY09 Carryover & <1.3%> CPI)**	**FY11 Previously Submitted Budget (incl 3% CPI)**	**FY11 REVISED Gross Proposed Budget (incl 2.5% CPI)**	**FY12 Gross Proposed Budget (incl 3% CPI)**	**Comments**
118	**GOAL 7 - QUALITY-OF-WATER**								
119	BIO 7.R1.11	O	CRD	Water Quality Monitoring of Lake Powell and the Glen Canyon Dam Tailwaters (BUDGET PRESENTED BELOW) (Ongoing)	-	-	-	-	**SEE APPENDIX E-3**
120	PHY 7.M1.11	O	COR	Integrated Quality of Water Monitoring (Downstream of GCD) (Ongoing)	1,011,523	1,025,906	999,236	1,020,911	FY11 Continue monitoring flow, temperature and sediment, etc.; PEP review of water quality component; FY12 Prepare core monitoring plan; Implementation of core monitoring plan subject to approval Continue monitoring flow, temperature and sediment, etc.
121	PHY 7.R2.10	D	CRD	Integrated Flow, Temperature, and Sediment Modeling of the CRE (FY09--FY10)	316,696	-	-	-	
122	PHY 7.R3.11	N	CRD	Modeling Support & Temperature Models (FY11--Ongoing)	-	138,028	139,864	145,679	Operate & maintain models; no new model development
123				**SUB-TOTAL GOAL 7**	**1,328,219**	**1,163,934**	**1,139,100**	**1,166,590**	
124	**GOAL 8 - SEDIMENT**								
125	PHY 8.M2.11	O	COR	Integrated Longterm Monitoring of System-wide Changes in Sediment Storage (Ongoing)	223,478	381,990	468,060	486,260	FY11 SedTrend core monitoring, sandbar study sites. rpt on '09 monitor & remote sensing for sandbar area; FY12 SedTrend core monitor, rpt on '11 monitor; Budgets incl add'l $300k Exper Funds to support HFE in FY11 & FY12. **SEE APPENDIX E-4**
126				**SUB-TOTAL GOAL 8**	**223,478**	**381,990**	**468,060**	**486,260**	
127	**GOAL 9 - RECREATIONAL EXPERIENCE**								
128	REC 9.R1.11	O	CRD	Campsite Area Monitoring (Ongoing)	79,684	78,082	74,704	40,864	FY11 Conduct biennial campsite monitoring; Continue river guide monitoring; FY12 Camp area field monitoring does not resume until FY13; Continue river guide monitoring
129	REC 9.R3.11	O	CRD	Expand and Analyze Campsite Data in the GIS Atlas (FY07--FY12)	73,769	60,500	39,465	41,640	FY11 Analyze campsite atlas data as part of integrated image analysis project; Update & maintain campsite atlas on website; FY12 Same as FY11 + Update & maintain campsite atlas on website; Campsite PEP review
130	REC 9.R4.11	N	CRD	Evaluate Recreation Values and Visitor Experience Quality in the Glen Canyon Reach	-	-	25,000	25,000	NEW FY11 & FY12 Evaluate visitor use values & satisfaction in Lees Ferry Reach; Assumes matching funds / shared costs with AZGFD; Budgets include $25k Experimental Funds to support HFE in FY11 & FY12.**SEE APPENDIX E-4**
131				**SUB-TOTAL GOAL 9**	**153,453**	**138,582**	**139,169**	**107,504**	

	A	B	C	D	E	F	G	H	I
132	APPENDIX E-2								
133	GCMRC AMP Budget - Capped Power Revenues								
134	**GCMRC Project ID**	**STATUS**	**Funding Emphasis**	**Project Descriptions**	**FY10 GROSS Actual Budget (incl FY09 Carryover & <1.3%> CPI)**	**FY11 Previously Submitted Budget (incl 3% CPI)**	**FY11 REVISED Gross Proposed Budget (incl 2.5% CPI)**	**FY12 Gross Proposed Budget (incl 3% CPI)**	**Comments**
135	**GOAL 10 - HYDROPOWER**								
136	HYD 10.M1.10	O	CRD	Monitor Power Generation and Market Values under Current and Future Dam Operations (Ongoing)	45,281	10,890	-	-	
137	HYD 10.R2.11	O	CRD	Evaluate the Suitability of the GTMax Model for Modeling Economic Implications of Power Generation under Current and Future Dam Operations and Conduct Initial Analyses	-	-	30,758	20,149	NEW FY11 Eval GTMax model as tool to assess econom costs to hydropower in context of western electrical grid. Rpt, Serve data, Annual rpt; FY12: Use model to assess econom costs to hydropower from alternative flow regimes; Rpt. Serve data; Annual rpt
138				**SUB-TOTAL GOAL 10**	**45,281**	**10,890**	**30,758**	**20,149**	
139	**GOAL 11 - CULTURAL**								
140	CUL 11.R1.11	O	CRD	Cultural Research & Development towards Core Monitoring, Phase II (FY06--FY12)	415,582	361,989	354,766	366,361	Implement pilot monitoring with reduced scope (fewer sites, etc), which may extend length of project
141	CUL 11.R2.11	O	CRD	Implement Tribal Monitoring Projects (See funding in BOR section above)	-	-	-	-	
142				**SUB-TOTAL GOAL 11**	**415,582**	**361,989**	**354,766**	**366,361**	
143	**GOAL 12 - HIGH QUALITY MONITORING, RESEARCH & ADAPTIVE MANAGEMENT PROGRAM**								
144	DASA 12.D1.11	O	CRD	Quadrennial Remote Sensing Overflight (Ongoing)	200,000	-	116,501	83,499	FY11 Contribute $116k to overflight fund; FY12 Contribute $84k to overflight fund
145	DASA 12.D2.11	O	APM	Grand Canyon Integrated Oracle Database Management System (Ongoing)	179,141	166,858	128,168	134,560	Update & maintain Oracle database, develop custom data management applications, provide data modeling, data mining, and architecture support
146	DASA 12.D3.11	O	APM	Library Operations / Scanning Support (Ongoing)	78,924	78,709	38,680	40,614	Maintain GCMRC library reduced to ½ time position; Defer online library system
147	DASA 12.D5.11	O	APM	GIS Support for Integrated Analyses and Projects, GIS Lead (Ongoing)	280,196	366,171	318,759	334,675	Provide spatial database and analysis support to GCMRC projects; continue supporting all mapping functions, and expand on spatial web applications
148	DASA 12.D8.10	C	ORD	Biometrics & General Analysis Staff Position (FY10) (Moved to Biology FY11)	107,036	-	-	-	Moved project to BIO 2.R19.11
149	DASA 12.D9.11	O	APM	Integrated Image Analysis and Change Detection (Ongoing)	228,074	245,482	246,243	258,556	FY11 Integrated Image Analysis & Change Detection Coordinate analysis of 2009 imagery; Map & analyze sandbars, campsites, backwaters & vegetation; FY12 Final reporting of 2009 imagery; Plan for 2013 overflight
150				**Sub-total Goal 12 DASA Portion**	**1,073,371**	**857,220**	**848,351**	**851,904**	

	A	B	C	D	E	F	G	H	I
151	APPENDIX E-2								
152	GCMRC AMP Budget - Capped Power Revenues								
153	**GCMRC Project ID**	**STATUS**	**Funding Emphasis**	**Project Descriptions**	**FY10 GROSS Actual Budget (incl FY09 Carryover & <1.3%> CPI)**	**FY11 Previously Submitted Budget (incl 3% CPI)**	**FY11 REVISED Gross Proposed Budget (incl 2.5% CPI)**	**FY12 Gross Proposed Budget (incl 3% CPI)**	**Comments**
154	PLAN 12.P1.11	O	CRD	Support and Enhancement of Ecosystem Modeling Efforts (FY08--FY12)	215,895	148,945	122,573	115,997	Working with senior ecologist, continue to update & refine ecosystem models, focusing on aquatic resources; Defer model expansion, publication of results, & MATA workshop
155	PLAN 12.P3.10	C	LTE	Low Steady Summer Flows Data and Research Compilation, Synopsis and Synthesis (FY08--FY10)	15,470	-	-	-	
156	PLAN 12.E4.11	N	APM	Update of Knowledge Assessment & SCORE Report (FY11--FY12)	-	175,000	175,000	100,138	FY11 Complete KA & initiate S.C.O.R.E. report; FY12 Finalize S.C.O.R.E. report
157	PLAN 12.P6.11	N	PP	NEW HFE Implementation - Evaluation of Effects of the High Flow Experiment Protocol	-	-	-	-	Evaluate HFE protocol implementation using existing and expanded monitoring projects. Open file report prepared after each HFE
158				**Sub-total Goal 12 Planning Portion**	**231,365**	**323,945**	**297,573**	**216,135**	
159	SUP 12.S1.11	O	APM	Logistics Base Costs (See each project for project related logistics costs) (Ongoing)	206,748	223,626	208,996	219,505	Provide base logistics support to field operations
160	SUP 12.S2.11	O	APM	Survey Operations (Ongoing)	86,770	90,122	51,885	51,885	Provide survey support to GCMRC projects (through contract)
161	SUP 12.S3.11	O	APM	Control Network (Ongoing)	177,449	185,704	195,560	203,422	Maintain & expand network as needed
162				**Sub-total Goal 12 Support Portion**	**470,967**	**499,452**	**456,441**	**474,812**	
163	ADM 12.A1.11 (A)	O	APM	Administrative Operations (Ongoing)	218,972	167,995	266,298	277,891	Continue to provide administrative support
164	ADM 12.A1.11 (B)	O	APM	Administrative Operations - GSA Vehicle Costs (Ongoing)	62,466	66,550	66,550	69,878	GSA vehicle fleet
165	ADM 12.A1.11 (C)	O	APM	Administrative Operations - Interior Vehicle Costs (Ongoing)	31,530	33,880	33,880	35,574	Interior vehicle fleet
166	ADM 12.A2.11	O	APM	Program Planning & Management (Ongoing)	1,176,794	1,238,435	1,207,228	1,240,745	Continue to provide planning & management support
167	ADM 12.A3.11	O	APM	AMWG/TWG Meeting Travel Funds (Ongoing)	19,156	19,965	20,455	21,478	Continue to provide funding to attend AMWG & TWG meetings
168	ADM 12.A4.11 (A)	O	APM	Independent Reviews (Ongoing)	1,785	73,205	58,900	36,300	FY11 Peer review all publications; Integrated Water Quality and Food Base PEP; FY12 Peer review all publications; Campsite & Sediment PEPs
169	ADM 12.A4.11 (B)	O	APM	Coordination and Review of Services Provided by Science Advisors (Ongoing)	214,168	223,850	173,850	179,900	FY11 Reduce SA support by 25%; FY12 Continue SA support at reduce level
170	ADM 12.A5.11	O	APM	GCMRC Component of SBSC Sys Admin Support (IT Support) (Ongoing)	259,906	225,181	214,610	221,954	Maintain IT support for GCMRC
171	ADM 12.A6.11	O	APM	2012 Colorado River Basin Science and Management Symposium (Biennial--Ongoing)	-	-	-	-	Symposium in Fall, 2012; No GCMRC / AMP funding identified; will seek outside funds from cooperators
172				**Sub-total Goal 12 Administrative / Management**	**1,984,777**	**2,049,061**	**2,041,771**	**2,083,720**	
173				**SUB-TOTAL GOAL 12**	**3,760,480**	**3,729,678**	**3,644,136**	**3,626,571**	
174	**GCMRC Capped Power Revenues Funded Projects Sub-totals**				**8,594,326**	**8,381,442**	**8,440,395**	**8,705,053**	

	A	B	C	D	E	F	G	H	I
175	APPENDIX E-3								
176	GCMRC AMP Budget - Other Agreement Funding								
177	**GCMRC Project ID**	**STATUS**	**Funding Emphasis**	**Project Descriptions**	**FY10 GROSS Actual Budget (incl FY09 Carryover & <1.3%> CPI)**	**FY11 Previously Submitted Budget (incl 3% CPI)**	**FY11 REVISED Gross Proposed Budget (incl 2.5% CPI)**	**FY12 Gross Proposed Budget (incl 3% CPI)**	**Comments**
178	**GCMRC Other Agreement Funding**								
179	BIO 7.R1.11	O	CRD	Water Quality Monitoring of Lake Powell and the Glen Canyon Dam Tailwaters (Ongoing)	270,766	286,342	182,002	188,063	FY11: Continue monitoring; PEP review; Increase emphasis on analysis and modeling; FY12 Continue monitoring; Prepare core monitoring plan; Implementation of core monitoring plan subject to approval Increase emphasis on analysis and modeling
180	BIO 2.R15.11	O	CRD	Near Shore Ecology / Fall Steady Flows (FY08--FY12)	718,826	556,911	697,039	423,475	**BOCM** FY11 Implement project per work plan; Increase logistics funding; FY12 Implement project per work plan; Field work ends in October, 2011; (FY12) Increase logistics funding for October river trip; prepare final report
181	SUP 12.S4.11	O	CRD	Tribal River Trips (Ongoing)	94,324	-	-	-	Provide as needed
182	ADM 12.A6.10	C	CRD	Science Symposium Proceedings (FY09--FY10)	60,555	-	-	-	
183	Exp 1	C	EXP	Experimental Study 1.A - Sand Budgeting	2,374	-	-	-	
184	Exp 1	C	EXP	Experimental Study - 1.C Response of Sandbars	6,530	-	-	-	
185	Exp 1	C	EXP	Experimental Study - 1.D Backwater Habitats	44,661	-	-	-	
186	Exp 3	C	EXP	Experimental Study - 3 Aquatic Food Base	5,936	-	-	-	
187	Exp 7	C	EXP	Experimental Study - 7 - Synthesis of Knowledge	299,192	-	-	-	Complete HFE synthesis by 01/01/11
188	**GCMRC All Other Agreement Funding Projects Subtotals**				**1,503,164**	**843,253**	**879,041**	**611,538**	
189									
190	**GCMRC TOTAL AMP PLANNED PROGRAM COSTS All Fund Sources**				**10,097,490**	**9,224,695**	**9,319,436**	**9,316,591**	
191					**+210,148 Mech Removal**	**+309,251 Mech Removal**			
192					10,228,100	9,533,946			

	A	B	C	D	E	F	G	H	I
193	APPENDIX E-4								
194	AMP Experimental Funds Summary (as proposed by GCMRC)								
195	**BOR Experimental Fund Summary**				**FY10 Approval Contributions & Expenditures**	**FY10 Actual Contributions & Expenditures**	**FY11 REVISED Proposed Contributions & Expenditures**	**FY12 Proposed Contributions & Expenditures**	**Comments**
196				**Beginning Balance at Start of Fiscal Year**	**-**	**-**	**427,174**	**286,672**	
197				**Power Revenue Contributions**	**500,000**	**493,500**	**505,838**	**521,013**	
198	BIO 2.E18.11	N	EXP	Detection of Rainbow Trout Movement from the Upper Reaches of the Colorado River below Glen Canyon Dam	-	-	198,631	311,610	FY11 Total project = $437,201; FY12 Total project = $459,061
199	BIO 1.M1.11	N	EXP	HFE Science Plan Implementation Aquatic Food Base	-	-	100,000	100,000	$100k per year Goal 1 FY11 & FY12
200	BIO 4.M2.11	N	EXP	HFE Science Plan Implementation Monitoring Lees Ferry Trout	-	-	22,709	22,709	$22,709 per year Goal 1 FY11 & FY12
201	PHY 8.M2.11	N	EXP	HFE Science Plan Implementation Sediment Storage	-	-	300,000	250,000	$250k per year Goal 8 FY11 & FY12
202	PHY 8.M2.11	N	EXP	HFE Science Plan Implementation Sediment Storage	-	-	-	50,000	$50k per year Goal 8 FY11 & FY12 (will remain in experimental fund if HFE is not conducted)
203	REC 9.R4.11	N	CRD	Evaluate Recreation Values and Visitor Experience Quality in the Glen Canyon Reach	-	-	25,000	25,000	New Project: FY11 & FY12 Evaluate visitor use values and satisfaction in the Lees Ferry Reach (HFE Experimental funds); Assumes matching funds / shared costs with AZGFD
204	EXP 7	C	EXP	HFE Synthesis of Knowledge (Study 7)	108,674	66,326	-	-	
205	**BOR Experimental Fund Expenditures Summary**				**108,674**	**66,326**	**646,340**	**759,319**	
206	**Projected BOR Experimental Fund Balance at End of Fiscal Years**				**391,326**	**427,174**	**286,672**	**48,365**	Reflects amount available for carryover to next fiscal year based on GCMRC projected contributions and expenditures.

APPENDIX E-5

GCMRC Recommended Redirection of FY11 & FY12 Reclamation & GCMRC AMP Power Revenues Funds for use in LTEMP EIS & Nonnative Fish Suppression Contingency Funds

Recommended Redirection of Reclamation & GCMRC Funds	**FY11**	**FY12**	**Comments**
Reclamation's POAHG funding redirected	28,092	28,935	1/2 POAHG budget FY11 $28,092, FY12 $28,935
Reclamation's 1/2 Admin Support for NPS Permitting funds redirected	60,120	61,924	1/2 NPS Permitting budget FY11 $60,120, FY12 $61,924
Reclamation's Compliance Documents funding redirected	50,584	52,101	FY11 $50,584, FY12 $52,101
Reclamation's Nonnative Fish Suppression Contingency Plan funds redirected	144,819	50,521	FY11 = $96,966 FY10 not transferred to GCMRC + FY11 $47,853 = $144,819, FY12 = $50,521
Reclamation's Canyon Treatment Plan funds redirected	300,000	-	
GCMRC's funds redirected	266,385	356,519	
TOTAL GCMRC Recommended Redirection of FY11 & FY12 Funds for use in LTEMP EIS & Nonnative Fish Suppression Contingency Funds	**850,000**	**550,000**	
LTEMP EIS	250,000	250,000	
Non-native Fish Suppression Contingency Fund	600,000	300,000	

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222	APPENDIX E-6								
223	GCMRC Deferred Projects								
224	**DEFERRED / Unfunded Projects**				**Deferred / Unfunded FY11 Budget**	**Deferred / Unfunded FY12 Budget**			
225	BIO 1.M1.11	D	COR	Aquatic Food Base Monitoring	84,200	84,200			
226	BIO 2.M4.11	D	COR	Increased Monitoring of Mainstem Fishes	518,427	239,300			
227	BIO 6.M2.11	D	COR	Bird Monitoring / Alternating Years with Vegetation Transect Monitoring	-	53,000			
228	DASA 12.D1.11	D	COR	Hyperspectral Overflight for Vegetation Mapping - Specific Remote Sensing Overflight	95,200	95,200			
229				**Sub-total Deferred Monitoring**	**697,827**	**471,700**			
230	BIO 2.tbd	D	EXP	NEW NSE / FSF Thermal Imaging	86,200	86,200			
231	BIO 4.E2.11	D	EXP	Monitoring Lees Ferry Fishes for Annual Recruitment	79,568	79,568			
232				**Sub-total Deferred Experimental Research**	**165,768**	**165,768**			
233	BIO 2.R7.11	D	CRD	Stock Assessment of Grand Canyon Native Fish	48,700	49,000			
234	BIO 2.R13.11	D	CRD	Remote PIT Tag Reading	84,500	84,500			
235	BIO 2.R17.11	D	CRD	Nonnative Control Plan Science Support	76,900	76,900			
236	BIO 6.R4.11	D	CRD	Arthropod Monitoring R & D	-	95,400			
237	PHY 7.R2.11	D	CRD	Further Develop Integrated Flow, Temperature & Sediment Model	145,200	145,200			
238	REC 9.R5.11	D	CRD	Evaluate Relation between Flows and Recreation Experience	225,000	225,000			
239	REC 9.R6.11	D	CRD	1973 Weeden Survey Revisited	75,000	75,000			
240	REC 9.R7.11	D	CRD	Update Regional Recreation Economic Study	250,000	250,000			
241	HYD 10. tbd	D	CRD	NEW Phase I - Results of Economic Value Workshop	117,300	117,300			
242	CUL 11.R1.11	D	CRD	Cultural Research & Development towards Core Monitoring, Phase II	45,000	45,000			
243	CUL 11.R3.11	D	CRD	Geomorphic Model of Archaeological Site Vulnerability	266,100	266,100			
244	PLAN 12.P1.11	D	CRD	Expanded Ecosystem Modeling (Walters, et al)	109,800	109,800			
245	DASA 12.D9.11	D	ORD	1984 Sandbar Image Analysis	89,600	89,600			
246				**Sub-total Deferred Research & Development**	**1,533,100**	**1,628,800**			
247	PLAN 12.P1.11	D	PP	Support and Enhancement of Ecosystem Modeling Efforts MATA Workshop	33,200	33,200			
248	PLAN 12.P5.11	D	PP	NEW Desired Future Conditions Facilitation & Decision Support (FY11--FY12)	60,500	60,500			
249				**Sub-total Deferred Program Planning**	**93,700**	**93,700**			
250	SUP 12.S2.11	D	APM	NEW Assessment of Vertical Accuracy & Precision for High-resolution Topographic Surfaces (Survey Ops)	31,276	31,276			
251	DASA 12.D0.11	D	APM	Quadrennial Remote Sensing Overflight	83,500	116,500			
252	DASA 12.D3.11	D	APM	Library Operations Support	42,000	42,000			
253	DASA 12.D3.11	D	APM	Implement New GCMRC Library System	24,200	24,700			
254	ADM 12.A5.11	D	APM	NEW Expanded Website Development (Component of SBSC Sys Admin Support)	72,900	72,900			
255	ADM 12.A4.11 (A)	D	APM	Independent Reviews	12,705	-			
256	ADM 12.A4.11 (B)	D	APM	Coordination and Review of Services Provided by Science Advisors (Ongoing)	50,000	50,000			
257	ADM 12.A tbd	D	APM	NEW Tribal Consultation Staff Support	119,600	119,600			
258				**Sub-total Deferred Administrative**	**436,181**	**456,976**			
259				**Total GCMRC Deferred Projects**	**2,926,576**	**2,816,944**			

APPENDIX E-7

AMP Program Costs & Funding Overview

	BOR Power Revenues Under Cap Program COSTS	FISCAL YEAR 2010	FISCAL YEAR 2011	FISCAL YEAR 2012
PROGRAM COSTS	BOR Power Revenues Under Cap Program COSTS	1,888,999	2,078,640	1,877,593
	GCMRC Power Revenues Under Cap Program COSTS	9,013,574	8,440,395	8,705,053
	Subtotal BOR & GCMRC Power Revenue Under Cap Program COSTS	**10,902,573**	**10,519,035**	**10,582,646**

	BOR Power REVENUES Under Cap Program Funding	FISCAL YEAR 2010	FISCAL YEAR 2011	FISCAL YEAR 2012
PROGRAM FUNDING	BOR Power REVENUES Under Cap Program	1,888,999	2,078,640	1,877,593
	GCMRC Power REVENUES Under Cap Program	8,283,092	8,440,395	8,705,053
	GCMRC FY2009 Carryover to FY2010 Power REVENUES Under Cap	730,482	-	-
	Subtotal BOR & GCMRC Power REVENUES Under Cap Program	**10,902,573**	**10,519,036**	**10,582,646**
	Subtotal - Difference between FY2010-2012 Estimated Costs and Estimated Revenues Under Cap	**(0)**	**0**	**0**

	BOR Appropriated and Other Program COSTS	FISCAL YEAR 2010	FISCAL YEAR 2011	FISCAL YEAR 2012
PROGRAM COSTS	BOR Appropriated and Other Program COSTS	475,000	475,000	475,000
	GCMRC Appropriated and Other Program COSTS	1,083,916	879,041	611,538
	Subtotal BOR & GCMRC Power Revenue (Non-Capped) and Other Funded Program COSTS	**1,558,916**	**1,354,041**	**1,086,538**

	BOR Appropriated and Other Program Funding	FISCAL YEAR 2010	FISCAL YEAR 2011	FISCAL YEAR 2012
PROGRAM FUNDING	BOR Appropriated and Other Program FUNDING	475,000	475,000	475,000
	GCMRC Appropriated and Other Program FUNDING	480,949	879,041	611,538
	GCMRC FY2009 Carryover to FY2010 Appropriated and Other Program FUNDING	602,967	-	-
	Subtotal - BOR & GCMRC Power REVENUE (Non-Capped) and Other Funded Program FUNDING	**1,558,916**	**1,354,041**	**1,086,538**
	Difference between Projected COSTS and REVENUE for FY2010-2012 POWER REVENUES UNDER CAP	**-**	**-**	**-**

APPENDIX E-8

Explanation of information found in columns A through I of the GCDAMP FY2011-12 Preliminary Draft Budget for the GCMRC

Column			
GCMRC Project ID Program Areas	A	1-3	BIO: Biology PHY: Physical Science REC: Recreation HYD: Hydropower CUL: Cultural DASA: Data Acquisition, Storage and Analysis SUP: Support PLA: Planning ADM: Administration
		4-5	GCDAMP Goal Number
		6-7	Project Number within GCMRC Biennial Work Plan
		7-8	Fiscal Year of Proposed Budget / Biennial Work Plan
Column Status	B	O: Ongoing N: New C: Complete D: Deferred	
Column Category	C	APM Admin & Program Mgmt COR Core Monitoring CRD Core Monitoring Research & Development EXP Experimental Research LTE Longterm Experiment MA Management Action NA Not Applicable PP Program Planning ORD Ongoing Research and Development Anticipates completion of the Core Monitoring plan according to the process defined in the MRP (including AMP Committed review and approval by the Secretary)	
Column Project Description	D	Project Title (Start Date -- End Date)	
Column FY10 Revised Budget	E	FY 2010 GDAMP Budget Approved 08/13/2009, Revised including <1.3%> CPI + FY2009 Carryover	
Column FY11 Previous Budget	F	FY 2011 GCAMP Previously Submitted Budget, Preliminarily Approved 08/13/2009	
Column FY11 Revised Budget	G	FY 2011 GDAMP Proposed (Revised) Draft Budget	
Column FY12 Revised Budget	H	FY 2012 GDAMP Proposed Draft Budget	
Column Comments	I	Comments; BOCM represents Biological Opinion Core Monitoring items	