STUDY PLAN

For the Implementation and Evaluation Of Flow and Temperature Recommendations for Endangered Fishes in the Green River Downstream of Flaming Gorge Dam

Final Report February 8, 2007

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Prepared by

Green River Study Plan *ad hoc* Committee

Coordinated by

Upper Colorado River Endangered Fish Recovery Program

Final Report

February 8, 2007

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EXECUTIVE SUMMARY

The 2005 *Final Biological Opinion on the Operation of Flaming Gorge Dam* identified this Study Plan as one component of nondiscretionary terms and conditions associated with Reasonable and Prudent Measures to avoid and minimize the impacts of incidental take of the four listed Colorado River fishes: Colorado pikeminnow (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), and bonytail (*Gila elegans*). This Study Plan was developed by an *ad hoc* Committee, which included representatives from the Bureau of Reclamation, Western Area Power Administration, and U.S. Fish and Wildlife Service. Development of the Study Plan was coordinated by the Upper Colorado River Endangered Fish Recovery Program (Recovery Program), and benefited greatly from input by members of the Biology and Water Acquisition committees and principal investigators conducting studies in the Green River Subbasin.

The purpose of this Study Plan is to identify and recommend to the Recovery Program those monitoring or research projects necessary for implementation and evaluation of flow and temperature recommendations for endangered fishes in the Green River downstream of Flaming Gorge Dam. Those projects include studies to evaluate the anticipated effects of implementing the recommendations (including potential adverse effects identified in the 2005 Flaming Gorge Dam Biological Assessment and Biological Opinion) and studies to examine recognized uncertainties of the recommendations. Objectives of this Study Plan are to: (1) demonstrate how results of Recovery Program studies evaluate the flow and temperature recommendations; (2) identify deficiencies in monitoring or research, and prioritize and recommend to the Recovery Program revised ongoing or new studies to fill important information needs; (3) develop and recommend a timeline and approach for periodically assessing implementation and evaluation of the flow and temperature recommendations; and (4) recommend to the Recovery Program modifications to the Recovery Implementation Program Recovery Action Plan (RIPRAP).

This Study Plan identifies 41 anticipated effects or uncertainties (hypotheses) associated with implementation of the flow and temperature recommendations. Of the 41 identified hypotheses, recently completed, ongoing, or pending Recovery Program studies are fully addressing 20 and partially addressing 21. Thirty-four primary or supporting studies are related to flow and temperature recommendations, including 27 Recovery Program studies and 7 studies being conducted by Recovery Program partners or participants.

Eighteen hypotheses were considered of highest priority for evaluating the flow and temperature recommendations. These were grouped into three resources categories: (1) floodplain inundation for larval entrainment, rearing, and subsequent movement of subadult razorback suckers into the mainstem in Reach 2, (2) backwater formation and maintenance for the rearing of young Colorado pikeminnow, and (3) nonnative fish management in Reach 1 and upper Reach 2. Existing studies were compared with needed information to determine if the studies fully addressed those needs. Any necessary studies to fill those needs were then identified. These studies were recommended to the Recovery Program for revisions to the RIPRAP. For floodplains, recommended studies fall into three subject areas: (1) evaluation of survival and recruitment, (2) entrainment rates, and (3) the timing of larval drift. For

backwaters, recommended studies fall into two subject areas: (1) backwater habitat formation and (2) backwater habitat maintenance and quality. For nonnatives, recommended studies fall into two subject areas: (1) the influence of flow and temperature on life history components of nonnative fish, and (2) spillway entrainment rates.

An integrated approach is fundamental to the implementation of this Study Plan. This integrated approach is necessary in order to better understand dynamics of physical and biological resources and to review the scientific basis for the flow and temperature recommendations. Many anticipated effects and uncertainties are interrelated, and specific study designs and results will need to be integrated to gain a better understanding of the effects of the flow and temperature recommendations. Consideration should be given to tradeoffs among potential effects; e.g., base flow magnitudes and temperatures that maximize benefits to endangered fish may also benefit nonnative species that in turn prey upon and compete with endangered forms; spillway use that enhances larval entrainment in floodplains may allow for escapement of nonnative fish from the reservoir into the river downstream.

More integration and synthesis of historic and current information is urged as a first step in the development of sound scientific studies that best evaluate these tradeoffs, address hypotheses, and make greater use of existing information. Furthermore, study refinements are important under the principles of adaptive management to ensure that studies remain focused on the current most vital information needs.

Results from studies recommended in this Study Plan would be used to evaluate and, if deemed appropriate, potentially revise the flow and temperature recommendations in a manner consistent with an adaptive-management approach. Such revisions approved by the Service and the Recovery Program could be implemented directly into the annual operating plan or could require a more formal regulatory process requiring National Environmental Policy Act or Endangered Species Act compliance.

1.0 INTRODUCTION

1.1 Purpose and Objectives

The purpose of this Study Plan is to identify and recommend to the Upper Colorado River Endangered Fish Recovery Program (Recovery Program) those monitoring or research projects necessary for implementation and evaluation of flow and temperature recommendations for endangered fishes in the Green River downstream of Flaming Gorge Dam (Muth et al. 2000). Those projects include studies to evaluate the anticipated effects of implementing the recommendations (including potential adverse effects identified in the 2005 Flaming Gorge Dam Biological Assessment and Biological Opinion) and studies to examine recognized uncertainties of the recommendations. Objectives of this Study Plan are to:

1. demonstrate how results of recently completed, ongoing, or pending Recovery Program monitoring or research projects (studies) are being or will be used to implement and evaluate the flow and temperature recommendations;

2. identify deficiencies in monitoring or research studies, and prioritize and recommend to the Recovery Program revised ongoing or new studies to satisfy important information needs[1];

3. develop and recommend a timeline and approach for periodically assessing implementation and evaluation of the flow and temperature recommendations; and

4. recommend to the Recovery Program modifications to the Recovery Implementation Program Recovery Action Plan (RIPRAP) to incorporate the approved Study Plan and associated studies following standard Recovery Program procedures.

This Study Plan was identified as a requirement of the 2005 *Final Biological Opinion on the Operation of Flaming Gorge Dam* (U.S. Fish and Wildlife Service 2005; see Section 1.2.1). The Study Plan was prepared by the Green River Study Plan *ad hoc* Committee, which included representatives from the Bureau of Reclamation (Reclamation), Western Area Power Administration (Western), and U.S. Fish and Wildlife Service (Service). Development of the Study Plan was coordinated by the Recovery Program, and benefited greatly from input by members of the Biology and Water Acquisition committees and principal investigators conducting studies in the Green River Subbasin. The Study Plan was developed under the principles of adaptive management in which monitoring and research results are used to revise ongoing studies and guide new studies.

This Study Plan identifies information needs to implement and evaluate the flow and temperature recommendations. The Study Plan does not determine if the operation of Flaming Gorge Dam is meeting the flow and temperature recommendations, nor does it identify modifications to dam operations. Those determinations are contingent on an interagency,

[1] Information needs were defined as those topics considered relevant to anticipated effects or uncertainties that had not been addressed in previous or ongoing studies.

adaptive-management process in which the flow and temperature recommendations are implemented, evaluated, and revised based on information from scientific studies (Figure 1). Information feedback into the revision process occurs both at the project level, in which individual projects are revised to address information needs identified from information syntheses, and at the flow recommendation level, in which response of fish populations guides the revision process.

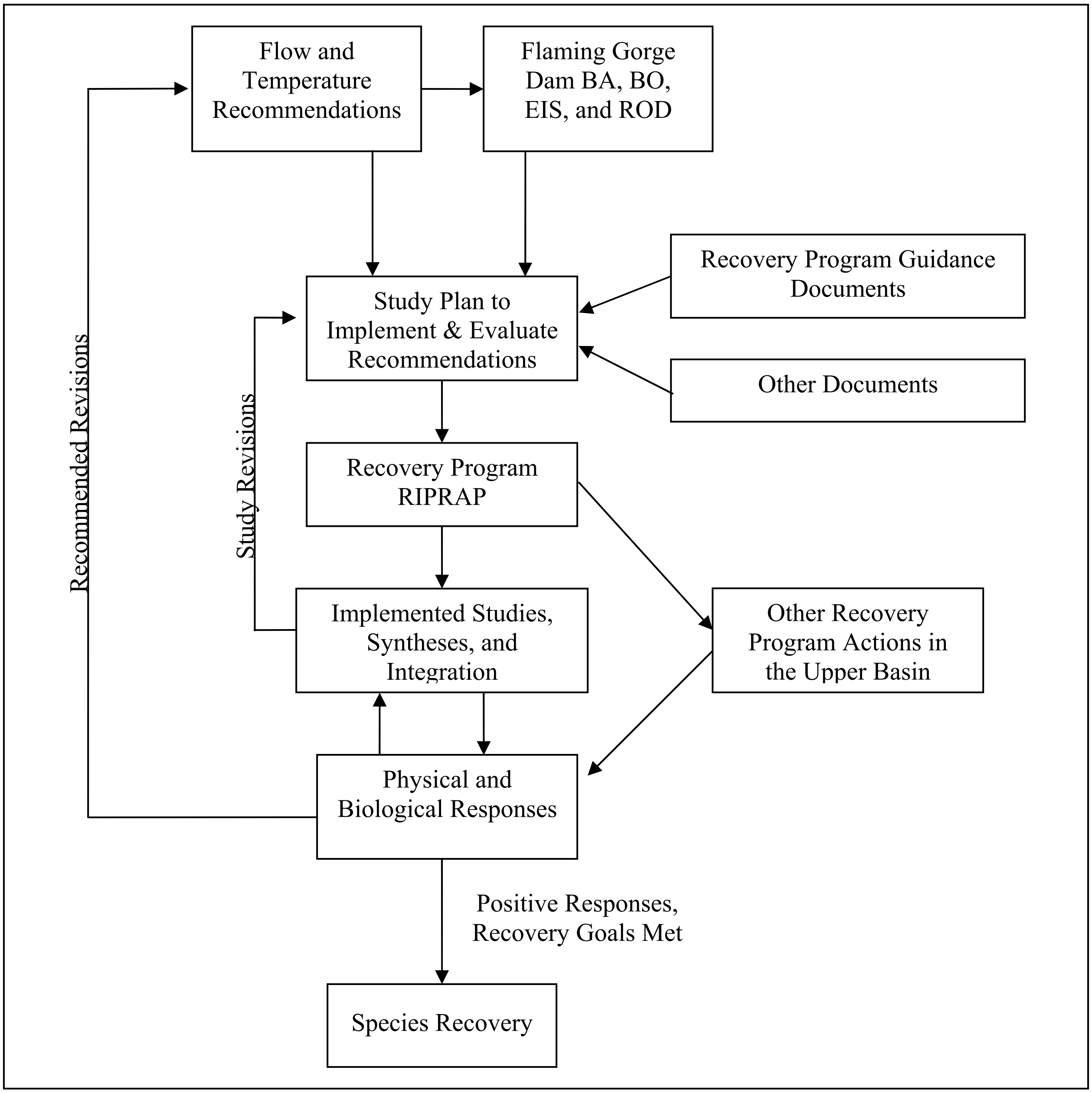

Figure 1. Conceptual process for evaluation and revision of flow and temperature recommendations.

The Study Plan and Flaming Gorge Dam operations are but one part of the program to achieve species recovery in the Upper Colorado River Basin. Results from studies recommended in this Study Plan would be used to evaluate and, if deemed appropriate, potentially revise the flow and temperature recommendations in a manner consistent with an adaptive-management approach. Such revisions approved by the Service and the Recovery Program could be implemented directly into the annual operating plan or could require a more formal regulatory process requiring National Environmental Policy Act or Endangered Species Act (ESA) compliance.

1.2 Authority and Guidance Documents

1.2.1 Authority Documents

The following describes each of the "authority" documents that led to the development of this Study Plan, and the principal anticipated effects or uncertainties associated with implementation of the flow and temperature recommendations identified by each document.

Green River Flow and Temperature Recommendations

In 2000, the Recovery Program issued *Flow and Temperature Recommendations for Endangered Fishes in the Green River Downstream of Flaming Gorge Dam* (Muth et al. 2000). The purpose of that report was to assess flow-habitat relationships of Colorado pikeminnow (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), and bonytail (*Gila elegans*), and refine flow and temperature recommendations specified in the 1992 *Final Biological Opinion on the Operation of Flaming Gorge Dam* (U.S. Fish and Wildlife Service 1992). Recommendations presented in that report were intended to address recovery elements identified by the Recovery Program. Information on each endangered fish species was used to develop integrated flow and temperature recommendations for the Green River downstream of the dam.

The overall goal of the flow and temperature recommendations was to "Provide the seasonal and annual patterns of flow and temperature in the Green River that enhance populations of the endangered fishes." Objectives of the recommendations were to:

1. "*provide appropriate conditions that allow gonadal maturation and environmental cues for spawning movements and reproduction;*

2. *form low-velocity flooded habitats for pre-spawning staging and post-spawning feeding and resting areas;*

3. *inundate floodplains and other off-channel habitats at the appropriate time and for an adequate duration to provide warm, food-rich environments for fish growth and conditioning and to provide river-floodplain connections for the restoration of natural ecosystem processes;*

4. *restore and maintain the channel complexity and dynamics needed for formation and maintenance of high-quality spawning, nursery, and adult habitats;*

5. *provide base flows that promote favorable conditions in low-velocity habitats during summer, autumn, and winter;* and

6. *minimize differences in water temperature between the Green River and Yampa River in Echo Park to prevent cold shock and possible mortality to larval Colorado pikeminnow transported from the Yampa River into the Green during summer."*

The recommendations included target flows and temperatures specific to reaches of the Green River downstream of Flaming Gorge Dam because habitats of the endangered fishes, hydrology, and geomorphology vary longitudinally by these reaches. Flow and temperature recommendations and their anticipated effects on the endangered fishes and their habitats were presented for each of three reaches (Figure 2):

- Reach 1 — Flaming Gorge Dam to Yampa River confluence;

- Reach 2 — Yampa River confluence to White River confluence; and

- Reach 3 — White River confluence to Colorado River confluence.

The flow and temperature recommendations identified uncertainties associated with their implementation and recognized the importance of managing for unanticipated effects. Following are uncertainties summarized from Muth et al. (2000).

1. The paradigm in river management suggests that the ecological integrity of river ecosystems is linked to their natural dynamic character and that restoring a more natural flow regime to an impaired system is the cornerstone of rehabilitation. This paradigm and the response by the endangered fishes of the Green River system are largely untested.

2. The recommendations assumed that future changes in flow, temperature, and sediment regimes of Green River tributaries will be consistent with existing or known pending biological opinions. Unanticipated changes in current tributary conditions could result from modifications in the operation of existing water projects or from the development of new water projects.

3. The physical response of the system to flows is fairly well understood, and the flow recommendations are of the magnitude, duration, and frequency needed to restore much of the dynamic character of the Green River downstream of Flaming Gorge Dam. It was assumed that restoring physical processes and improving habitat conditions will elicit positive responses from endangered fish populations, but responses of the long-lived endangered fishes to the recommendations will take time and need to be monitored.

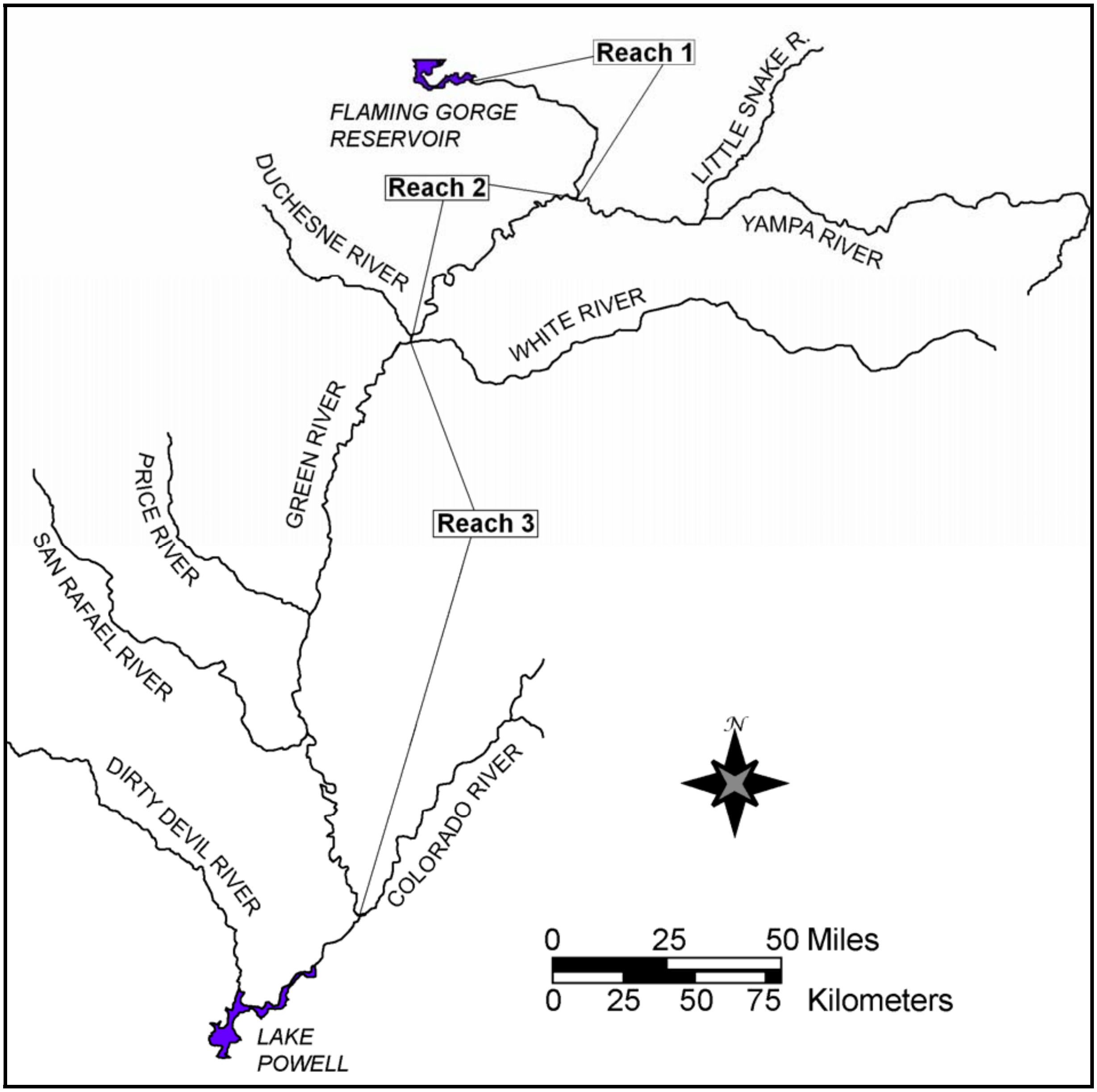

Figure 2. Green River Subbasin and the three reaches of the Muth et al. (2000) flow and temperature recommendations.

4. Flaming Gorge Reservoir will not have water of sufficient temperature and quantity to achieve target conditions in Lodore Canyon in all years. Availability will depend on the hydrologic year, season, and climatic conditions. Although warmer water temperatures in Lodore Canyon may be attainable through flow management, target temperatures may not be achieved in wetter years.

5. Uncertainty exists regarding the responses of nonnative warm-water fishes to the flow and temperature recommendations and subsequent competition or predation effects on the endangered fishes. Monitoring the responses of nonnative fishes to the flow recommendations is needed to ensure benefits to the endangered fishes.

6. There is uncertainty associated with base flow recommendations. Base flows that optimize conditions for endangered fishes will likely vary from year to year because of the effect of antecedent conditions on sediment processes and habitat conditions. To incorporate the effects of antecedent conditions, the recommended mean annual base flows are tied to the hydrologic conditions and the magnitude of the spring peak flow.

7. Effects of base-flow variation on backwater quality are unknown. Variability in base flows occurs at various scales including between years, within a year, between days, and within a day. It was assumed that recommended fluctuation restrictions will protect habitat quality and improve growth, conditioning, and survival of endangered fish. However, the effects of within-day fluctuations on habitat conditions warrant further investigation.

The flow and temperature recommendations also identified the need for research and monitoring. In addition to the need to collect real-time biological and physical data each year to refine how the recommendations are implemented, there is a need to conduct additional research and long-term monitoring of fish responses to address the identified uncertainties (Figure 1). The recommendations suggested that the collection of additional data on endangered fishes and their habitats should focus on the evaluation and possible modification of the recommendations by following an adaptive management process. Research should be conducted by using carefully designed experiments based on hypothesis testing.

The flow and temperature recommendations further recognized the need to assess overall responses by the endangered fish populations. These responses include many aspects of the life histories of these species (e.g., reproduction, survival of young, recruitment to adults, etc.), with establishment and maintenance of self-sustaining populations as the goal of recovery (U.S. Fish and Wildlife Service 2002a, 2002b, 2002c, 2002d). Responses by various life-history aspects to flow and temperature recommendations may be observable over a short time span, but because the endangered fishes are long-lived, population responses (i.e., self-sustainability) may be observable only over longer time spans. Short-term monitoring should focus on responses of specific life history aspects, but long-term monitoring must detect differences in population sizes and sustainability. Flow and temperature recommendations and any revisions should be based on sound scientific information for the current status of populations, sediment resources, and other relevant ecological factors.

Biological Assessment and Biological Opinion on Operation of Flaming Gorge Dam

As part of ESA compliance, Reclamation and Western developed the *Biological Assessment on the Operation of Flaming Gorge Dam* (BA) for the proposed action of modifying the operation of Flaming Gorge Dam to achieve the flow and temperature recommendations (U.S. Department of the Interior and Western Area Power Administration 2005). The BA determined that the proposed action may adversely affect the four endangered fish species and their critical habitat, and a list of conservation measures was developed to offset those effects. These measures were later incorporated into reasonable and prudent measures in the biological opinion.

The *Final Biological Opinion on the Operation of Flaming Gorge Dam* (BO; U.S. Fish and Wildlife Service 2005) concurred with the effects determination of the BA, but determined that the proposed action is not likely to jeopardize the continued existence of the four endangered fishes and will not result in the destruction or adverse modification of their critical habitat if the reasonable and prudent measures are implemented. Implementation of the proposed action is expected to result in overall beneficial effects to the endangered fishes and their critical habitat in the Green River downstream of Flaming Gorge Dam and induce a positive response as a result of a more natural hydrologic regime.

Some of the conservation measures identified in the BA stemmed from uncertainties associated with the proposed action that Reclamation identified in the *Final Environmental Impact Statement on the Operation of Flaming Gorge Dam* (FEIS) and the *Record of Decision* (ROD), and as identified in the flow and temperature recommendations. Because some of those uncertainties are linked to potential take of the endangered fishes, the conservation measures served as the basis for Reasonable and Prudent Measures (RPMs) identified by the Service as necessary and appropriate to avoid and minimize the impacts of incidental take of the listed Colorado River fishes. The following five RPMs were identified in the BO (abbreviated from text in the BO).

1. Implementation and refinement of the proposed action will occur through an adaptive management process.

2. The Recovery Program will assess the need for and implement, as necessary, nonnative fish control programs in the Green and Yampa River systems in accordance with the RIPRAP and scopes of work approved by the Recovery Program.

3. Reclamation has committed to develop a process for operating the selective withdrawal structure consistent with the objectives of improving temperature conditions for the endangered fish.

4. Reclamation and the Recovery Program should determine if temperature gaging in Reach 1 and Reach 2 is adequate to ensure temperature recommendations are met.

5. Reclamation will produce a summary report each year to document annual operations and the information used to develop those operations.

In order to implement RPM #1, Reclamation established a Technical Working Group (TWG; recommended by Muth et al. [2000]) in coordination with the Recovery Program. The TWG consists of biologists and hydrologists from Reclamation, Western, and the Service who help refine release plans for each year and provide advice on modifying releases during changing hydrologic conditions. Yearly release patterns from Flaming Gorge Dam to meet the recommended flows and temperatures for each hydrologic condition are adjusted on the basis of information about hydrology, the status of endangered fish life stages and populations, and habitat conditions. The Recovery Program can request flows to fulfill research needs and the TWG considers those requests along with the specific flow recommendations for the annual hydrologic condition. The TWG provides comments and input on the proposed flows relative to all resource concerns, and Reclamation determines how to incorporate the additional information into the Annual Flaming Gorge Dam Operational Plan.

The BO further requires Reclamation, Western, and the Service to work through the Recovery Program technical committees to develop a Study Plan to evaluate the flow and temperature recommendations. This document is that Study Plan and it focuses on previously identified anticipated effects or uncertainties related to floodplain inundation, nonnative fish impacts, effects of temperature, and geomorphic processes. Whereas the intent of the Study Plan is to guide future evaluation of the flow and temperature recommendations, it also draws heavily on the direction provided in Section 7 consultation documents, including the BA and BO, Recovery Program guidance documents, and ongoing studies.

FEIS and ROD on Operation of Flaming Gorge Dam

The FEIS was completed by Reclamation in 2005 (U.S. Department of the Interior 2005), and a ROD was signed in February 2006 (U.S. Department of the Interior 2006). The FEIS addresses the potential effects of modifying the operation of Flaming Gorge Dam to assist in the recovery of the four endangered fish species and prevent the destruction or adverse modification of their critical habitat downstream from the dam.

The FEIS describes how Reclamation will implement the proposed action by modifying the operation of Flaming Gorge Dam, to the extent possible, to achieve the flow and temperature recommendations of Muth et al. (2000). Reclamation's goal is to implement the proposed action and, at the same time, maintain and continue all authorized purposes of the Colorado River Storage Project, including those related to the development of water resources in accordance with the Colorado River Compact.

The FEIS summarized the uncertainties associated with implementation of the flow and temperature recommendations, and acknowledged that these uncertainties would be monitored and addressed through an adaptive-management process. That adaptive-management process would consist of an integrated method for addressing uncertainty in natural resource management that not only reduces but benefits from uncertainty. Following are uncertainties summarized from the FEIS.

1. Hydrology.—There were many uncertainties associated with the Flaming Gorge Dam Hydrology Model that were dealt with through modeling assumptions detailed in the FEIS.

2. Operational limitations for temperature of water released from the dam.—Reservoir modeling showed that desired reservoir water temperatures for endangered fish are available for release, when needed, through the Flaming Gorge Dam selective withdrawal structure. However, release water is used to cool turbine bearings, and temperature limitations associated with the bearings may, at times, limit the ability to release warmer water.

3. Uncertainties associated with increased spillway use.—Increased spillway use from releases to meet some flow and temperature recommendations may degrade the concrete in the spillway and cause structural damage. Use of the spillway may need to be limited, based on observed degradation of the concrete.

4. Fish response to flow and temperature recommendations.—As acknowledged in the flow and temperature recommendations, response by native and nonnative fishes to implementation of these recommendations is not known with certainty. Monitoring and research will be necessary to evaluate fish response for specific life history aspects (e.g., reproduction, survival of young, recruitment to adults, etc.) and for population self-sustainability. Because the endangered fish are long-lived species, it may require several years to determine successful recruitment to the adult population.

5. Uncertainties associated with floodplain inundation.—The relationship of flow magnitude/duration and area of floodplain inundation is not known with certainty. To increase effectiveness of resolving these uncertainties, controlled experiments and associated studies could be performed that capitalize on hydrologic conditions in a given year and that address as many uncertainties as practicable in any one year.

6. Riparian/Vegetation.—Response by invasive riparian species, particularly plants, into the floodplain is not known with certainty if the flow and temperature recommendations are implemented.

The ROD identified environmental commitments to clarify Reclamation's intentions in establishing the process for implementing the flow and temperature recommendations. The second and ninth environmental commitments of the ROD apply to the development of this Study Plan.

- Environmental Commitment 2.—"*The adaptive management process will rely on ongoing or added Recovery Program activities for monitoring and studies to test the outcomes of modifying the flows and release temperatures from Flaming Gorge Dam, and will rely on the Flaming Gorge Working Group meetings for exchange of information with the public.*"

- Environmental Commitment 9.—"*Reclamation will support the Recovery Program, in coordination with the Service and Western, in developing and conducting Recovery Program studies associated with floodplain inundation. Such studies would include improving connectivity of floodplain habitats, identifying ways to improve entrainment of larval razorback suckers into floodplain habitats, maintain the river channel, restore natural variability of the river system, and analyze possibilities for meeting the goals of the flow and temperature recommendations at lower peak flow levels where feasible*."

1.2.2 Recovery Program Guidance Documents

In addition to the authority documents (Section 1.2.1), certain Recovery Program "guidance" documents were used to clarify, confirm, and expand, as necessary, the anticipated effects or uncertainties or to identify opportunities to address those uncertainties. Following are descriptions of each of the Recovery Program guidance documents.

Recovery Action Plan (RIPRAP)

The *Recovery Implementation Program Recovery Action Plan* (RIPRAP) was developed by Recovery Program participants in support of the Section 7 Agreement using the best and most current scientific information available. The RIPRAP identifies specific actions and time frames currently believed to be required to recover the endangered fishes in the Upper Colorado River Basin, consistent with species recovery goals.

The RIPRAP is the Recovery Program's long-range operational plan that is reviewed and revised annually. It contains dates for accomplishing specific actions over the next 5 years and beyond. The RIPRAP tracks accomplishments to ensure that the Recovery Program can continue to serve as a reasonable and prudent alternative for water projects undergoing Section 7 consultation to avoid the likelihood of jeopardizing the continued existence of the endangered fishes as well as to avoid the likely destruction or adverse modification of their critical habitat.

Species Recovery Goals

Recovery goals for each of the four endangered fish species were approved by the Region 6 Director of the Service in 2002 (U.S. Fish and Wildlife Service 2002a, 2002b, 2002c, 2002d). These recovery goals amend and supplement the respective species recovery plans and identify site-specific management actions and objective, measurable criteria for recovery.

Recommended Priorities for Geomorphology Research

In 2003, the Recovery Program convened two workshops attended by researchers from various agencies, universities, and consulting firms, and produced *Recommended Priorities for Geomorphology Research in Endangered Fish Habitats of the Upper Colorado River Basin* (LaGory et al. 2003). The goal of this project was to identify priorities for geomorphology research in endangered fish habitats of the Upper Colorado River Basin. Recommended priorities were provided to the Recovery Program to help develop a comprehensive research and monitoring program for endangered fish habitats in the Upper Basin.

The geomorphology report focused on reaches and habitats used by life stages (larvae, juveniles, subadults, adults, and spawning) of Colorado pikeminnow, humpback chub, and razorback sucker, and identified the following primary information needs in the Green River Subbasin for overall reach-habitat priorities and for species-specific reach-habitat priorities.

Reach-Habitat Priorities

1. "*Connected backwaters and side channels (Split Mountain Canyon to Desolation Canyon and Labyrinth and Stillwater Canyons)*
    - *Role of peak flow (magnitude, duration, and frequency) and sediment on formation and maintenance of habitats.*
    - *Effects of antecedent conditions (flow and sediment) and base-flow magnitude on habitat availability.*
    - *Effects of base-flow variability on inter-annual availability, intra-annual stability, and within-day stability.*

2. *Flooded bottomlands (Split Mountain Canyon to Desolation Canyon)*
    - *Effects of peak flow (magnitude, duration, and frequency), sediment, and configuration of connection to main channel on maintenance of connection and sediment deposition effects.*

3. *Spawning bar complexes (Desolation and Gray Canyons)*
    - *Effects of peak flow (magnitude, duration, frequency, and timing), base flow (magnitude and duration), and sediment on habitat conditions during the spawning period.*"

Species-Specific Reach-Habitat Priorities

1. **"***Colorado Pikeminnow*
    a. *Connected backwaters and side channels (Split Mountain Canyon to Desolation Canyon, Gray Canyon to Labyrinth Canyon, Labyrinth and Stillwater Canyons)*
        - *Same as those identified for Split Mountain Canyon to Desolation Canyon reach under overall reach-habitat priorities above.*

    b. *Spawning bar complexes (Desolation and Gray Canyons)*
        - *Same as those identified for Desolation and Gray Canyons reach under overall reach-habitat priorities above.*

2. *Humpback Chub*
    a. *Spawning bar complexes (Desolation and Gray Canyons)*
        - *Same as those identified for Desolation and Gray Canyons reach under overall reach-habitat priorities above.*

3.

<u>*Razorback Sucker*</u>

a. Spawning bar complexes (Split Mountain Canyon to Desolation Canyon)
  - *Same as those identified for Desolation and Gray Canyons reach under overall reach-habitat priorities above.*
  - *Location of additional potential spawning areas in reach.*

b. Flooded bottomlands (Split Mountain Canyon to Desolation Canyon)
  - *Same as those identified for Split Mountain Canyon to Desolation Canyon reach under overall reach-habitat priorities above.*"

Green River Subbasin Floodplain Management Plan

In 2004, the Recovery Program issued *Green River Subbasin Floodplain Management Plan* (Valdez and Nelson 2004). This plan was developed in order for the Recovery Program to establish goals, identify management actions, and to gage progress on habitat restoration and protection. Implementation of this management plan is one means by which the Recovery Program achieves floodplain-related recovery criteria and management actions. The goal of this plan was to provide adequate floodplain habitats for all life stages of razorback sucker, particularly to serve as nursery areas for larvae and juveniles, for establishment and maintenance of self-sustaining populations.

The floodplain management plan identified the following uncertainties, research needs, and recommendations (summarized).

Uncertainties

1. Effectiveness and alternatives for the "reset theory" in which floodplains are allowed to inundate and desiccate on a 12 or 24-month cycle to provide productive habitats for maximum growth of razorback sucker with escapement to the river, and to periodically kill nonnative fishes that are entrained in these habitats.

2. Entrainment of wild razorback sucker larvae is critical to species recovery, but drift characteristics and entrainment are not well understood.

3. Growth and survival over a 12 to 24-month period must be sufficient to minimize the risk of predation and for razorback sucker to recruit to the adult portion of the population.

4. Short-term floodplains may have little value as nurseries but may be used transiently by large juvenile and adult razorback sucker, bonytail, and Colorado pikeminnow.

5. The reset strategy of cyclic inundation/desiccation of floodplains may enhance growth and survival of razorback sucker and negate the effect of production of nonnative fishes in these habitats.

6. Levee breaches and possibly inlet and outlet control gates may erode unless they are located strategically to minimize effects of flow.

7. Effects of selenium levels on fish health are not thoroughly understood.

Research Needs

1. Evaluate the effectiveness of the "reset theory."

2. Describe larval drift and entrainment of razorback sucker in floodplains.

3. Assess growth and survival of razorback sucker and bonytail in floodplains.

4. Evaluate the effects of nonnative fishes to endangered fishes in floodplains.

Recommendations

1. Coordinate management of floodplain restoration and management with Ouray National Wildlife Refuge.

2. Continue to monitor, evaluate, and manage restored floodplains.

3. Continue stocking hatchery razorback sucker and bonytail to evaluate floodplain habitats.

4. Evaluate characteristics of water and larval entrainment in floodplains.

1.2.3 Other Documents

In addition to the authority and guidance documents (Sections 1.2.1 and 1.2.2), the following are examples of other documents that were used to further evaluate studies and how well those studies address the flow and temperature recommendations.

- *Procedures for Stocking Nonnative Fish Species in the Upper Colorado River Basin* (Upper Colorado River Endangered Fish Recovery Program 1996).

- Nonnative fish management and control workshops held annually since 2002.

- *Protocols for Colorado Pikeminnow and Humpback Chub Population Estimates* (Upper Colorado River Endangered Fish Recovery Program. 2002b).

- *Evaluation of Population Estimates for Colorado Pikeminnow and Humpback Chub in the Upper Colorado River Basin* (Upper Colorado River Endangered Fish Recovery Program 2005b).

- *An Evaluation of Ecosystem Restoration and Management Options for the Ouray National Wildlife Refuge, Utah* (Heitmeyer and Fredrickson 2005).

- *Final Programmatic Biological Opinion on the Management Plan for Endangered Fishes in the Yampa River Basin* (U.S. Fish and Wildlife Service 2004).

- *Consideration of Site-specific Floodplain Inundation Thresholds in Implementing Peak Flow Magnitude and Duration Recommendations in the Middle Green River, Utah* (Hayse et al. 2005).

2.0 METHODS

2.1 Steps in Study Plan Development

The following steps were taken to develop this plan (Figure 3).

1. Anticipated effects or uncertainties were identified from the authority or guidance documents described in Sections 1.2.1 and 1.2.2.

2. Ongoing or pending studies were identified that were related to each anticipated effect or uncertainty.

3. With input from the principal investigators, goals and objectives of each study were examined to determine how well the studies address an anticipated effect or uncertainty.

4. Important information needs associated with each anticipated effect or uncertainty were identified and revised ongoing or new studies were recommended to fill those needs.

5. Authority, guidance, and other documents were used to screen information needs and to prioritize studies.

6. Recommendations were formulated for the Recovery Program to incorporate into the RIPRAP.

2.2 Linkage of Studies to Anticipated Effects and Uncertainties

This Study Plan identifies primary and supporting monitoring or research studies that evaluate to varying degrees the anticipated effects or uncertainties related to the flow and temperature recommendations. The anticipated effects and uncertainties are identified in Appendix Tables A1-A3 for each reach of the Green River and for spring peak and base flow periods. The language for the general flow and temperature recommendations was taken from Muth et al. (2000). The anticipated effects were taken from the flow and temperature recommendations. Uncertainties were taken from the flow and temperature recommendations, BA, BO, FEIS, ROD, and various other documents.

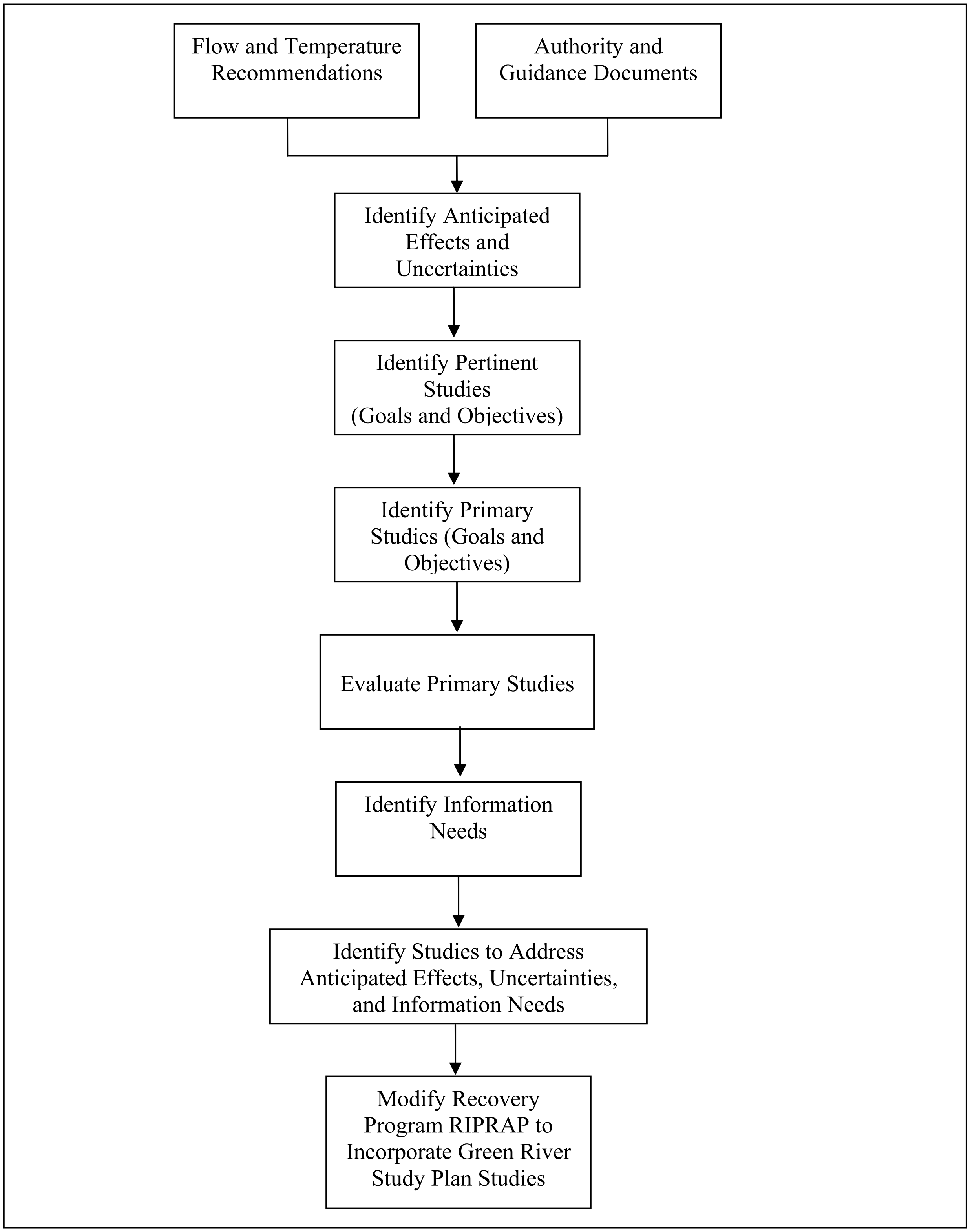

Figure 3. Steps to developing the Green River Study Plan and formulation of recommendations.

Each anticipated effect or uncertainty is fundamentally a hypothesis statement about the expected or unknown outcome of a given flow or temperature recommendation. Relevant and recently completed, ongoing, or pending monitoring or research Recovery Program studies, as well as non-program studies, whose results are being or will be used to implement and evaluate the flow and temperature recommendations are linked to these hypotheses in Tables A1–A3.

2.3 Evaluation of Studies

Primary studies that most directly address the anticipated effects or associated uncertainties were distinguished from the supporting studies. The goals and objectives, status, and schedules for each primary study are provided in Table A4. Details of each Recovery Program study identified in this Study Plan can be found on the Recovery Program web site at: http://www.r6.fws.gov/crrip/index.htm.

Objectives described for each study were used to determine how well a particular study or several studies taken together address each hypothesis. Tables A5 through A7 were constructed to compare study objectives to hypotheses for each river reach and flow/temperature recommendation combination. How well as particular study or group of studies addressed a given hypothesis was determined from the aggregate of objectives.

Preliminary assessments of how well each study addresses specific hypotheses were made and each evaluation was classified as follows:

- N/A = study not designed to address hypothesis;
- P = study partially addresses hypothesis; or
- Y = study addresses hypothesis.

A "P" was used to indicate that a study or group of studies only partially addresses a given hypothesis. A "Y" indicates that a study or group of studies cumulatively addresses a given hypothesis. However, those studies that addressed an anticipated effect or uncertainty (i.e., denoted as "Y") would have to be completed before it could be determined that a particular hypothesis had been appropriately addressed, or if additional uncertainties remained.

A summary evaluation for each anticipated effect and uncertainty was determined and indicated as either "P" or "Y." These summary evaluations were used to identify information needs or deficiencies in existing scopes of work.

2.4 Information Needs, Revised or New Studies, and Prioritization

Information needs were identified from the above evaluation, and new studies or modifications of existing studies were recommended (Table A8). This evaluation was done for all hypotheses to ensure that studies designed to address information needs are providing a comprehensive assessment.

Each hypothesis was prioritized categorically as High (H), Medium (M), or Low (L) based on the criteria: (1) concurrence with environmental commitments identified in the ROD, (2) risk or benefit to the endangered fish, (3) urgency of information for management decisions, and (4) the applicable reach of river (Reach 3 is furthest from Flaming Gorge Dam and less likely to be affected by dam operations). This prioritization was assisted by screening priorities and recommendations from the authority and guidance documents (Section 1.2).

Hypotheses associated with anticipated effects or uncertainties rated as “H” were considered as the most important for successful evaluation of the flow and temperature recommendations, and may include hypotheses with information needs not being addressed by existing studies. Hypotheses that were well understood or of lesser importance to an evaluation of the recommendations were of medium (M) or low (L) priority. Although some effects or uncertainties were identified as not being fully addressed by studies (see Section 2.3), those hypotheses were not necessarily considered high priority because it was concluded that other hypotheses were more important for evaluation of the flow and temperature recommendations.

3.0 RECOMMENDATIONS

This section describes: (1) adequacy of studies to address hypotheses, (2) prioritization of hypotheses and integration, (3) recommended studies, (4) timeline for recommended studies and integration of information, and (5) recommended RIPRAP revisions.

3.1 Adequacy of Studies to Address Hypotheses

A total of 41 anticipated effects or uncertainties (hypotheses) associated with implementation of the flow and temperature recommendations were identified (Table 1; see also Tables A1–A3). Further evaluation determined that existing Recovery Program studies are fully addressing 20 of the 41 anticipated effects or uncertainties and partially addressing 21 (see Table A8). A total of 34 individual studies were identified that are either primary or supporting studies related to the flow and temperature recommendations, including 27 Recovery Program studies and 7 studies being conducted by Recovery Program partners or participants (i.e., Reclamation, Western, U.S. Geological Survey, Utah Division of Wildlife Resources; Table A4).

3.2 Prioritization of Hypotheses and Integration

Hypotheses were prioritized to focus on issues of greatest importance for evaluating the flow and temperature recommendations. Eighteen hypotheses were considered of highest priority (Table 2). Because many anticipated effects or uncertainties are interrelated, the hypotheses and associated studies were organized into three resource categories that related both physical and biological aspects to the flow and temperature recommendations.

Table 1. Anticipated effects and uncertainties (hypotheses) associated with flow and temperature recommendations for the Green River downstream of Flaming Gorge Dam. "Summary" shows the determination on how the studies cumulatively satisfy the hypothesis; Y=hypothesis being addressed by study; P=study partially addresses hypothesis. "Priority" is the prioritization of the importance of evaluating the hypothesis; L=low, M=medium, H=high.

Anticipated Effects and Uncertainties (Hypotheses)	**Summary**	**Priority**
Reach 1—Spring Peak		
A1. Significant channel maintenance (i.e., rework and rebuild in-channel sediment deposits, increase habitat complexity, and prevent or reverse channel narrowing) in Lodore Canyon in wet years or in other years when peak releases are greater than 244 m3/s (8,600 cfs) (Muth et al. 2000).	Y	L
A2. Channel maintenance will improve habitat conditions for endangered fishes and could favor potential spawning of Colorado pikeminnow in this portion of the river (Muth et al. 2000).	Y	M
U1. The increased frequency of bypassing water (spills) would result in increased entrainment of reservoir nonnative species. Reach 1 monitoring should include specific efforts to evaluate the potential for establishing undesirable reservoir fishes, such as smallmouth bass in the tailwater (U.S. Fish and Wildlife Service 2005).	Y	M/H
U2. The response of nonnative fish populations to spring peak flows (U.S. Fish and Wildlife Service 2005).	Y	H
Reach 1—Summer Through Winter Base		
A3. Target water temperatures in Lodore Canyon are expected to be achieved in 7 of 10 years (average and drier years) and could result in Colorado pikeminnow spawning in this portion of the river (Muth et al. 2000).	Y	M
A4. More favorable water temperatures also could result in expansion of humpback chubs into this portion of the river (Muth et al. 2000).	Y	M
U3. If warmer water (16^{o}C) could be released at the dam during wetter years, recommended temperature targets could be achieved more frequently (U.S. Fish and Wildlife Service 2005).	Y	L
U4. The effect of base flows and release temperatures on nonnative fish populations (U.S. Fish and Wildlife Service 2005).	Y	H
Reach 2—Spring Peak		
A5. <u>Wet and Moderately Wet</u>: Significant inundation of floodplain habitat and off-channel habitats (e.g., tributary mouths and side channels) to establish river-floodplain connections and provide warm, food-rich environments for growth and conditioning of razorback suckers (especially young) and Colorado pikeminnow. <u>Average</u>: Significant inundation of floodplain habitat and off-channel habitat in at least 1 of 4 average years; some flooding of off-channel habitats in all years. <u>Moderately Dry and Dry</u>: No floodplain inundation, but some flooding of off-channel habitats. May benefit recruitment of Colorado pikeminnow in some years (Muth et al. 2000).	P	H
A6. <u>Wet and moderately wet years</u>. Significant channel maintenance to rework and rebuild in-channel sediment deposits (including spawning substrates), increase habitat complexity, form in-channel sand bars, and prevent or reverse channel narrowing. <u>Average years</u>. Significant channel maintenance in at least 1 of 2 average years. <u>Moderately dry and dry years</u>. Significant channel maintenance in at least 1 of 2 average years (Muth et al. 2000).	P	L/M

Table 1. Continued.

Anticipated Effects and Uncertainties (Hypotheses)	Summary	Priority
A7. Provide conditions for gonadal maturation and cues for spawning migrations and reproduction by the endangered fishes (Muth et al. 2000).	Y	L
U5. The area of terrace and depression floodplains inundated at different flows (U.S. Department of the Interior 2006).	Y	H
U6. Flow and stage at which floodplains with levee breaches become sufficiently inundated (area, depth, volume) to provide nursery habitat for razorback suckers (U.S. Fish and Wildlife Service 2005).	P	H
U7. Area, depth, volume, and persistence of floodplain depression habitat after peak flows recede and the relationship, if any, between these and the magnitude of the peak flow (U.S. Fish and Wildlife Service 2005).	P	H
U8. Abundance and entrainment of drifting razorback sucker larvae as a function of distance from the razorback sucker spawning bar (U.S. Department of the Interior and Western Area Power Administration 2005).	Y	L/M
U9. Entrainment and retention of larvae in floodplain nursery habitats as a function of the physical characteristics of the habitat including size, volume, local hydraulic conditions, inlet(s), and outlet(s) (U.S. Fish and Wildlife Service 2005).	Y	H
U10. Temporal relationships between drifting larvae and hydrology during the runoff period with a focus on the peak flow characteristics (magnitude, duration, ramp rate) needed to entrain most drifting larvae (U.S. Department of the Interior and Western Area Power Administration 2005).	Y	H
U11. The frequency of connection needed to successfully recruit razorback sucker larvae into the adult population, including the frequency needed to sustain adequate water quantity and quality and allow escapement of subadults and adults to the main channel (U.S. Department of the Interior and Western Area Power Administration 2005).	P	H
U12. Nonnative fish colonization of inundated floodplain depressions may interfere with recovery of endangered fish in those habitats (U.S. Fish and Wildlife Service 2005).	Y	L
U13. The frequency of total drying (reset) needed to control nonnative fish populations (U.S. Department of the Interior and Western Area Power Administration 2005).	P	M
U14. For a given volume, what is the optimum combination of flow magnitude and duration to maximize larval fish entrainment (e.g., lower peak flows for a longer duration could maintain connection to floodplain nursery habitats for a longer period of time and entrain as many or more razorback sucker larvae as higher peak flows for shorter duration. With recent modifications of levees and intake structures, flows less than the recommended 18,600 cfs may provide significant connection and inundation to floodplain nursery habitats, and subsequent entrainment of razorback sucker larvae; U.S. Department of the Interior and Western Area Power Administration 2005).	Y	H
U15. Rates of sediment deposition and erosion in breaches and floodplain depressions as a function of breach configuration, peak flow, and connecting flow magnitude and duration (Muth et al. 2000).	P	H
U16. The response of nonnative fish populations to spring peak flows (U.S. Fish and Wildlife Service 2005).	Y	M
Reach 2—Summer Through Winter Base		
A8. Base flows in summer and autumn scaled to the hydrologic condition favor the formation of backwaters and other low-velocity shoreline nursery habitats (Muth et al. 2000).	P	H
A9. Maintenance of the mean base flow within recommended levels of seasonal and within-day flow variability throughout summer, autumn, and winter will promote favorable conditions for all life stages of endangered fishes that use low-velocity habitats (Muth et al. 2000).	P	H

Table 1. Continued.

Anticipated Effects and Uncertainties (Hypotheses)	Summary	Priority
A10. Gradually declining flows after the spring peak will provide reproductive cues to Colorado pikeminnow and humpback chub adults (Muth et al. 2000).	Y	L
A11. Limiting differences in water temperature between the Green and Yampa rivers at their confluence in Echo Park will prevent cold shock to Colorado pikeminnow larvae drifting out of the Yampa River and into the Green River (Muth et al. 2000).	Y	L
A12. Warmer temperatures will promote better growth of endangered fishes in the upper portion of Reach 2 (Muth et al. 2000).	Y	L
U17. The effect of peak flows, sediment availability, and antecedent conditions on the relationship between base flow level and backwater habitat availability (Muth et al. 2000).	P	H
U18. The effect of base flow variability (within-day, within-season, within-year, between years) on backwater habitat quality (e.g., temperature, productivity) (U.S. Department of the Interior and Western Area Power Administration 2005).	P	H
U19. The relationship between base flow magnitude and temperature at the confluence (higher base flow targets in wetter years could result in higher temperature differential at the Yampa-Green River confluence) (U.S. Department of the Interior and Western Area Power Administration 2005).	P	M
U20. The need for real-time temperature data at the confluence to achieve temperature targets (U.S. Department of the Interior and Western Area Power Administration 2005).	P	L
U21. The effect of base flows on nonnative fish populations (Muth et al. 2000).	Y	H
Reach 3—Spring Peak		
A13. The anticipated effects of peak flows in Reach 3 for each hydrologic condition are qualitatively similar to those in Reach 2. However, since less floodplain and backwater habitat exists in Reach 3, quantitative differences in the effect of peak flows are expected. Benefits of overbank flooding to razorback suckers are expected to be most important in the upper portions of the reach (between the White River and upper end of Desolation Canyon) where most floodplain inundation will occur (Muth et al. 2000).	P	L
A14. Flooded off-channel habitats will benefit young Colorado pikeminnow and razorback suckers in lower Reach 3 and humpback chub in Desolation and Gray Canyons (Muth et al. 2000).	P	L
A15. Gradually declining flows after the spring peak flow will provide reproductive cues to Colorado pikeminnow and humpback chub adults (Muth et al. 2000).	P	L
U22. The response of nonnative fish populations to spring peak flows (U.S. Fish and Wildlife Service 2005).	P	L
Reach 3—Summer Through Winter Base		
A16. Wet and Moderately Wet: Lower water temperatures at higher base flows in the wettest years may reduce growth and survival of young endangered fish. Average, Dry, and Moderately Dry: Higher water temperatures at lower base flows will enhance growth and survival of young endangered fish, particularly Colorado pikeminnow and humpback chubs (Muth et al. 2000).	P	L
U23. The effect of peak flows, sediment availability, and antecedent conditions on the relationship between base flow level and backwater habitat availability (Muth et al. 2000).	P	M
U24. The effect of base flow variability (within-season, within-year, between years) on backwater habitat quality (e.g., temperature, productivity) (U.S. Department of the Interior and Western Area Power Administration 2005).	P	H
U25. The effect of base flows on nonnative fish populations (U.S. Fish and Wildlife Service 2005).	P	M

Table 2. Eighteen highest ranked anticipated effects and uncertainties (hypotheses), listed by resource category (i.e., floodplains, backwaters, etc.), related to flow and temperature recommendations for the Green River downstream of Flaming Gorge Dam, studies that address hypotheses, and topics not addressed by existing studies.

Anticipated Effects and Uncertainties (Hypotheses)	Primary Studies That Address Hypothesis	Topic Not Addressed by Studies (information needs)
Floodplains in Reach 2		
U6. Flow and stage at which floodplains with levee breaches become sufficiently inundated (area, depth, volume) to provide nursery habitat for razorback suckers (U.S. Fish and Wildlife Service 2005).	• Cap 6-rz • Cap 6-bt/rz • Cap 6-rz/bt • Cap 6-rz/entr • Cap 6 HYD • Western aerial photography	• Movement of subadult RBS (razorback sucker) into the river. • Habitat quality.
A5. Wet and Moderately Wet: Significant inundation of floodplain habitat and off-channel habitats (e.g., tributary mouths and side channels) to establish river-floodplain connections and provide warm, food-rich environments for growth and conditioning of razorback suckers (especially young) and Colorado pikeminnow. Average: Significant inundation of floodplain habitat and off-channel habitat in at least 1 of 4 average years; some flooding of off-channel habitats in all years. Moderately Dry and Dry: No floodplain inundation, but some flooding of off-channel habitats. May benefit recruitment of Colorado pikeminnow in some years (Muth et al. 2000).	• Cap 6-rz • Cap 6-bt/rz • Cap 6-rz/bt • Cap 6-rz/entr • Cap 6 HYD • Western aerial photography • Stocked fish evaluation • Project 128	• Movement of subadult RBS into the river. • Habitat quality.
U7. Area, depth, volume, and persistence of floodplain depression habitat after peak flows recede and the relationship, if any, between these and the magnitude of the peak flow (U.S. Department of the Interior 2005; U.S. Fish and Wildlife Service 2005).	• Cap 6-rz • Cap 6-bt/rz • Cap 6-rz/bt • Cap 6-rz/entr • Cap 6 HYD • Western aerial photography • Evaluation of restoration and management options for Ouray NWR	• Intra and inter-annual persistence of water in floodplains.
U9. Entrainment and retention of larvae in floodplain nursery habitats as a function of the physical characteristics of the habitat including size, volume, local hydraulic conditions, inlet(s), and outlet(s) (U.S. Fish and Wildlife Service 2005).	• Cap 6-rz • Cap 6-rz/entr • Cap 6 HYD • Evaluation of restoration and management options for Ouray NWR	• None.

Table 2. Continued.

Anticipated Effects and Uncertainties (Hypotheses)	Primary Studies That Address Hypothesis	Topic Not Addressed by Studies (information needs)
Floodplains in Reach 2. Continued.		
U15. Rates of sediment deposition and erosion in breaches and floodplain depressions as a function of breach configuration, peak flow, and connecting flow magnitude and duration (Muth et al. 2000).	• Cap 6 HYD • Western aerial photography • Stocked fish evaluation • Project 85f • Evaluation of restoration and management options for Ouray NWR	• Monitoring of geomorphic changes through time.
U11. The frequency of connection needed to successfully recruit razorback sucker larvae into the adult population, including the frequency needed to sustain adequate water quantity and quality and allow escapement of subadults and adults to the main channel (U.S. Department of the Interior and Western Area Power Administration 2005).	• Cap 6-rz • Cap 6-bt/rz • Cap 6-rz/bt • Stocked fish evaluation • Evaluation of restoration and management options for Ouray NWR	• Movement of subadult RBS into the river. • Habitat quality.
U10. Temporal relationships between drifting larvae and hydrology during the runoff period with a focus on the peak flow characteristics (magnitude, duration, ramp rate) needed to entrain most drifting larvae (U.S. Department of the Interior and Western Area Power Administration 2005).	• Cap 6-rz/entr • Project 22f	• None.
U5. The area of terrace and depression floodplains inundated at different flows (U.S. Department of the Interior 2006).	• Cap 6 HYD • Western aerial photography	• None.
U14. For a given volume, what is the optimum combination of flow magnitude and duration to maximize larval fish entrainment (e.g., lower peak flows for a longer duration could maintain connection to floodplain nursery habitats for a longer period of time and entrain as many or more razorback sucker larvae as higher peak flows for shorter duration. With recent modifications of levees and intake structures, flows less than the recommended 18,600 cfs may provide significant connection and inundation to floodplain nursery habitats, and subsequent entrainment of razorback sucker larvae; U.S. Department of the Interior and Western Area Power Administration 2005).	• Cap 6-rz/entr • Cap 6 HYD • Western aerial photography • Project 22f • Evaluation of restoration and management options for Ouray NWR	• None.

Table 2. Continued.

Anticipated Effects and Uncertainties (Hypotheses)	Primary Studies That Address Hypothesis	Topic Not Addressed by Studies (information needs)
Backwaters in Reach 2		
U18. The effect of base flow variability (within-day, within-season, within-year, between years) on backwater habitat quality (e.g., temperature, productivity) (U.S. Department of the Interior and Western Area Power Administration 2005).	• Project 138 • Project 22f • Western backwater topography • Project 128 • Project 144 • Project 85f	• Effect of baseflow variability on backwater habitat quality.
A8. Base flows in summer and autumn scaled to the hydrologic condition favor the formation of backwaters and other low-velocity shoreline nursery habitats (Muth et al. 2000).	• Project 138 • Project 22f • Western backwater topography • Project 128 • Project 144 • Project 85f	• Relationship between peak flow, sediment and habitat development.
U17. The effect of peak flows, sediment availability, and antecedent conditions on the relationship between base flow level and backwater habitat availability (Muth et al. 2000).	• Western backwater topography • Project 85f	• Relationship between peak flow, sediment and habitat development.
A9. Maintenance of the mean base flow within recommended levels of seasonal and within-day flow variability throughout summer, autumn, and winter will promote favorable conditions for all life stages of endangered fishes that use low-velocity habitats (Muth et al. 2000).	• Project 138 • Project 22f • Western backwater topography • Project 128 • Project 133 • Project 144 • Stocked fish evaluation	• Habitat conditions at beginning of baseflow period.
Backwaters in Reach 3		
U24. The effect of base flow variability (within-season, within-year, between years) on backwater habitat quality (e.g., temperature, productivity) (U.S. Department of the Interior and Western Area Power Administration 2005).	• Project 138 • Project 128	• Backwater habitat availability and characteristics in Reach 3.
Nonnative Fishes in Reach 1		
U1. The increased frequency of bypassing water (spills) would result in increased entrainment of reservoir nonnative species. Reach 1 monitoring should include specific efforts to evaluate the potential for establishing undesirable reservoir fishes, such as smallmouth bass in the tailwater (U.S. Fish and Wildlife Service 2005).	• Project 115 • UDWR trout • Project C18/19	• Spillway entrainment rates.

Table 2. Continued.

Anticipated Effects and Uncertainties (Hypotheses)	Primary Studies That Address Hypothesis	Topic Not Addressed by Studies (information needs)
Nonnative Fishes in Reach 1 (continued)		
U2. The response of nonnative fish populations to the spring peak flows (U.S. Fish and Wildlife Service 2005).	• Project 115	• Nonnative fish life history components affected by flows (e.g., spawning locations, timing, temperature, fish concentration areas).
U4. The effect of base flows and release temperatures on nonnative fish populations (U.S. Fish and Wildlife Service 2005).	• Project 115 • Project 8 • Project 19	• Nonnative fish life history components affected by flows.
Nonnative Fishes in Reach 2		
U21. The effect of base flows on nonnative fish populations (Muth et al. 2000).	• Project 138 • Project 144 • Project 123	• Nonnative fish life history components affected by flows.

The following three resource categories represent the most important issues for evaluating the flow and temperature recommendations.

1. Floodplain inundation for larval entrainment, rearing, and subsequent movement of subadult razorback suckers into the mainstem in Reach 2.

2. Backwater formation and maintenance for the rearing of young Colorado pikeminnow.

3. Nonnative fish management in Reach 1 and upper Reach 2.

The order of the three resource categories does not imply prioritization or greater importance of one group of studies over another. Integration of these study components provides a more comprehensive strategy for evaluating the flow and temperature recommendations that is more closely allied to species recovery. Because some anticipated effects and uncertainties are either closely linked, redundant, or overlapping, isolating a single hypothesis or study risks fragmentation that could inadvertently exclude important ecological issues vital to species recovery.

It should be noted that the identified categories and studies are necessary for evaluating the flow and temperature recommendations, and are not necessarily inclusive of all of the most important issues and studies necessary for recovery of the four endangered fish species in the Upper Basin. Other Recovery Program actions are addressing those issues not related to the flow and temperature recommendations (Figure 1). The ultimate goal of all of the Recovery Program actions, including these flow and temperature recommendations, is to elicit a positive response by the endangered fishes.

An integrated approach is necessary when implementing this Study Plan. Anticipated effects or uncertainties are interrelated and must be considered together to gain a better understanding of the effects of the flow and temperature recommendations. It is also noted that information needs and recommended studies ally closely with priorities identified in the Recovery Program guidance documents (Section 1.2.2).

Nonnative fish management is vital to species recovery, and lower priority of some hypotheses related to this topic in this Study Plan does not diminish their importance, but rather reflects the focus of the Study Plan, i.e., the effects of flow recommendations or the degree to which an anticipated effect was understood. As mentioned above, an integrated approach is vital to program success, and nonnative fish response to flows and/or temperature modifications should be a priority study objective. For example, nonnative response to floodplain inundation threatens to over shadow benefits to endangered species and ignoring that threat would not be wise when designing and implementing such studies and recovery actions. Likewise, nonnative fish responses should be an integral consideration in any flow and temperature recommendation.

Consideration should be given to tradeoffs among potential effects (e.g., base flow magnitudes and temperatures that maximize benefits to endangered fish may also benefit nonnative species that in turn prey upon and compete with endangered species; spillway use that enhances larval entrainment in floodplains may allow for escapement of nonnative fish from the reservoir into the river downstream, etc.). More integration and synthesis of historic and current information is urged as a first step in the development of sound scientific studies that best address hypotheses and make greater use of existing information. A synthesis of information is also needed to continue to review the scientific basis for the flow and temperature recommendations. Furthermore, study refinements through adaptive management are important to ensure that studies remain focused on the current most vital information needs.

3.3 Recommended Studies

This section identifies the studies recommended to address anticipated effects, uncertainties, and information needs. Recommended approaches for implementing studies are also provided. The recommended studies are designed to more fully evaluate the flow and temperature recommendations. These recommended studies are either new studies or revisions of existing studies and are provided to the Recovery Program for revising the RIPRAP. Specific flows to evaluate one or more of these research areas may be requested for the TWG to consider along with the specific flow recommendations for the annual hydrologic condition.

3.3.1 Floodplain Inundation for Larval Entrainment, Rearing, and Subsequent Movement of Subadult Razorback Suckers into the Mainstem in Reach 2

Inundated floodplain bottomlands have been identified as the most important nursery habitat for young razorback suckers. Razorback suckers spawn in spring near the peak of runoff, and their newly hatched larvae drift downstream and into bottomlands that are flooded annually by the river. These floodplains provide shelter from swift river currents, are highly productive, and provide warm sheltered habitats for growth. Larval and age-0 bonytails may also use these habitats as nurseries. Additionally, juvenile and adult razorback suckers, Colorado pikeminnows, and bonytails use these habitats for feeding and shelter. Floodplains tend to be warmer than the main channel in the spring, and gonadal maturation is enhanced in adult fish that use them. Reach 2, especially from Split Mountain to the White River confluence, is the most important reach of the Green River for floodplain habitat (Valdez and Nelson 2004). The only known spawning bar for wild razorback suckers is located near the upstream end of this reach, and downstream floodplains are vital nurseries for entrained larvae.

The quality of these floodplains is important to the survival, growth, and subsequent movement of subadult razorback suckers to the mainstem. The importance of a floodplain as nursery habitat is thought to be related to the river stage at which it connects to the mainstem, depth of water remaining after peak flows recede, water quality, length of time water sufficient to support fish is retained, frequency of connection from year to year, rate of sediment deposition and erosion in the habitat, larval entrainment rates into the habitat, survival and growth of young fish in the habitat, the ability of fish to move into the mainstem once they have reached sufficient size, and species and numbers of nonnative fish that occur in the habitat.

Recent studies of floodplains in both the Upper Basin and Lower Basin have yielded much information about various aspects of floodplains, but information needs remain that must be filled before flow and temperature regimes can be developed to assist in species recovery. Ongoing and planned studies help to address some of these needs, but information needs remain that preclude best management of flow and temperature for properly functioning floodplains. The positive response by nonnative fish to floodplain restoration continues to be problematic and should be considered and addressed as part of any habitat restoration effort. Nonnative fish are an integral factor in determining the quality of a floodplain.

Floodplain inundation for larval entrainment, rearing, and subsequent movement of subadult razorback suckers into the mainstem in Reach 2 were identified as the most important issues related to evaluation of the flow and temperature recommendations. The upper end of Reach 3 (i.e., White River confluence to Sand Wash) also has large floodplain terraces that may be important razorback sucker nurseries. Floodplain nursery habitats in Reach 3 downstream of Desolation/Gray Canyons are not plentiful and are only available at very high flows (> 39,000 cfs).

Nine high priority hypotheses related to floodplains were identified for evaluation (Table 2). The recommended studies that address each identified anticipated effect, uncertainty, and information need are identified in the remainder of this section. Recommended studies include continuation of ongoing studies that need to be completed before decisions on future studies are made through an adaptive learning process. Recommended studies fall into three subject areas: (1) evaluation of survival and recruitment, (2) entrainment rates, and (3) the timing of larval drift.

1: Evaluate annual survival of young and movement of subadult razorback suckers from floodplains into the mainstem in response to flow recommendations.

Description

The purpose of this study should be to evaluate survival of young razorback suckers in floodplains and subsequent movement of subadults into the mainstem. This study should evaluate persistence of floodplain habitat and habitat quality after peak flows recede, and include evaluation of survival of razorback suckers in floodplains through fall and winter. The continuation of this study should be contingent on the results.

The study "C6-rz recruitment" was approved in 2001 but was not completed. This study should be revisited and potentially revised if deemed appropriate to quantify the relationship between the frequency, magnitude, and duration of peak flows and movement of subadult razorback suckers from floodplains into the mainstem. Where appropriate, flows should be experimentally manipulated to ensure timely completion of studies with adequate consideration of the full range of recommended flows.

Densities of fish by cohort in floodplains should be tracked over time (i.e., among seasons and successive years) to determine their movement into the mainstem and to determine if there is need for annual inundation of floodplains to refresh water quality. Survival of endangered fish entrained in floodplains in spring should be measured through the fall and winter. Water quality and survival of native and nonnative fish also should be monitored year-around where possible, but especially over winter.

Hypotheses to Be Evaluated and Information Needs to Be Filled

- Frequency of floodplain inundation relative to the hydrologic cycle (A5).
- Persistence of floodplains after peak flows recede (U7).
- Frequency of floodplain connection needed to recruit razorback sucker to the river (U11).
- Area of terrace and depression floodplains at different flows (U5).
- Rates of movement into the river of subadult razorback suckers reared in floodplain nursery habitats (information need).
- Quality of floodplain nursery habitats (including water quality, nonnative fish) (information need).
- Intra- and inter-annual persistence of water in floodplains (information need).
- Monitoring of geomorphic changes associated with floodplain nursery habitats through time (information need).

Implementation

- *New Start*.—The study should begin as an evaluation of floodplain nursery habitat availability and quality during the winter of 2007-2008 (FY 2008). Depending on the availability of hatchery-reared fish and peak flows of sufficient magnitude to inundated floodplain habitats, a study of habitat quality, survival of young-of-the-year razorback suckers, and survival and movement of subadult razorback suckers into the main stem river would be initiated and continued for three successive years. Assuming fish and flows are available in the spring of 2008, the study would continue through 2011. A final report would be prepared in the following year (2012).

2: Complete evaluation of recent peak flow studies related to floodplain inundation and entrainment of larval razorback suckers, and determine the need for additional studies.

Description

A three-year study of entrainment and floodplain inundation is in its third year, and a final report is expected at the end of 2007. The results of this study should be evaluated to determine if additional studies are needed. Among the issues that should be addressed by the final report are the flows at which key floodplains with levee breaches become connected to the mainstem and inundated, entrainment rates at different flows, levee breach configuration that enhances larval entrainment, and the effect of river flows on associated channel geomorphology.

The magnitude and duration of spring flows necessary to optimize larval entrainment under the full range of hydrologic conditions (e.g., wet, moderately wet, average, etc.) is an outstanding information need. This includes, but is not limited to, the analysis of possibilities for meeting the goals of the flow recommendations at various peak flows (including peak flows that minimize spillway use and the risk of nonnative fish escapement from Flaming Gorge Reservoir). The synthesis of these studies should be used to assess differences in floodplains that translate to year-to-year variability in configuration and larval entrainment. Understanding annual variability of floodplains will help to better understand timing and magnitude of dam releases that most benefit the endangered fish.

Data collected on floodplain habitat connection and inundation (aerial photography, inlet surveys), sediment deposition and erosion in floodplain habitats, and entrainment studies should be integrated to determine how entrainment is affected by flow and physical characteristics of floodplain habitats (Table 2; e.g., Western aerial photography, Cap 6 HYD physical evaluation of floodplain habitat, 85f sediment monitoring, evaluation of ecosystem restoration and management options for the Ouray NWR). The synthesis report will provide important information to determine the effectiveness of existing flow recommendations, and identify opportunities for refinement of flow management strategies to entrain larvae, provide sufficient floodplain nursery habitat, and maintain floodplain habitats over the long-term. As necessary, additional studies that address priority hypotheses and information needs should be planned for subsequent years.

Hypotheses to Be Evaluated and Information Needs to Be Filled

- Flow and stage at which floodplains with levee breaches become sufficiently inundated (U6).
- Frequency of floodplain inundation relative to the hydrologic cycle (A5).
- Persistence of floodplains after peak flows recede (U7).
- Rates of sediment deposition and erosion in breaches and floodplain depressions (U15).
- Entrainment and retention of larvae as a function of physical characteristics of floodplains (U9).
- Temporal relationships between drifting larvae and hydrology needed to entrain larvae in floodplains (U10).
- Area of terrace and depression floodplains at different flows (U5).
- Benefits of lower peak flows for longer duration vs. higher peak flow for a shorter duration for a given volume (U14).

Implementation

- *Ongoing Project Cap 6 rz/entr*.─A final report for bead and larvae entrainment studies is due at the end of 2007 (FY 2008).
- *Ongoing Project 85f.—* S*ediment monitoring final report is due in FY2008.*
- *New Start*.─A synthesis report that summarizes and integrates all physical and biological floodplain inundation and entrainment studies should be started in FY 2008 and completed in FY 2009. The results of this synthesis should be used to determine the need for additional studies.

3: Continue annual monitoring of razorback sucker larvae in the mainstem, and synthesize existing information on drift and its relationship to flows and other environmental conditions.

Description

Annual larval monitoring provides useful information relevant to a variety of ongoing studies and for evaluating the effects of flow recommendations. By determining the presence of larvae in the system and correlating that with the connection of floodplain nursery habitats to the mainstem, it may be possible to develop dam operational strategies that optimize larval entrainment. This evaluation, should, among other things, assess the possibilities for meeting the goals of the flow recommendations for larval entrainment at various peak flows.

Integration and synthesis of existing data on larval presence in the river and a correlation of these data with flow and temperature conditions plus sediment dynamics (e.g., project 85f, SWMS model) is recommended to gain a better understanding of this relationship. Otolith analyses performed as part of this study should be continued to determine the age and growth of young razorback suckers (e.g., Muth et al. 1998; Bestgen et al. 2002). This information will help to determine the timing of reproduction by razorback suckers and hatching of larvae to better understand cues for spawning, and to more accurately pinpoint factors that affect availability and abundance of naturally produced larvae. In addition, this sampling will provide ancillary data to evaluate reproductive viability of stocked razorback suckers.

Hypotheses to Be Evaluated and Information Needs to Be Filled

- Temporal relationships between drifting larvae, hydrology, and sediment dynamics needed to entrain larvae in floodplains (U10); and

- Benefits of lower peak flows for longer duration vs. higher peak flow for a shorter duration for a given volume (U14).

Implementation

- *Ongoing Project 22F*.─Project 22F (annual larval monitoring) should be revised to include an evaluation of temporal patterns of larval presence in the river and the relationship of larval presence to flow and temperature conditions. Monitoring would continue indefinitely. The need for modifications of monitoring protocols and the need for continued monitoring would be evaluated periodically.

- *New Start*.─Perform analysis of historical monitoring data (2001 and later) to determine temporal patterns of larval presence in the river and the relationship of larval presence to flow, sediment, and temperature conditions. This project should be started in FY 2008 and completed in FY 2009.

3.3.2 Backwater Formation and Maintenance for Young Colorado Pikeminnow

Backwaters are important in-channel habitats for endangered Colorado River fishes particularly in Reaches 2 and 3, although releases from Flaming Gorge Dam primarily affect habitats in Reaches 1 and 2. Backwaters are low-velocity, productive environments that serve as nursery habitat for age-0 Colorado pikeminnow. Colorado pikeminnow spawn from late June to early August, and newly emerged larvae drift downstream during the descending limb of spring runoff to become entrained in main channel backwaters. These fish generally remain in backwaters until the following spring runoff when these habitats are inundated by high flows.

Young Colorado pikeminnow frequently use these habitats for shelter and feeding. Nonnative fish also use these habitats and compete with and prey on especially the young pikeminnow. Peak flows reshape the channel annually, and are important in the formation and maintenance of these habitats. Peak flows and the descending limb of the peak flow hydrograph are also important in establishing the elevation at which backwaters form. This elevation determines the base flows at which backwater habitat availability is optimized. The effect of base-flow variability (within-season, within-year, between years) on backwater habitat quality (e.g., temperature, productivity) remains an uncertainty that needs to be addressed. As with floodplain habitats, responses by nonnative fish should be considered and addressed when managing backwater habitat formation and maintenance. Recommended studies fall into two subject areas: (1) backwater habitat formation and (2) backwater habitat maintenance and quality.

4: Determine the relationship of backwater habitat development to sediment availability and peak flows in Reach 2.

Description

Understanding the relationship of habitat development to sediment availability and spring peak flows will help to determine peak flow regimes necessary to maximize backwater habitat development. The principal backwater nursery areas for age-0 Colorado pikeminnow are in Reaches 2 and 3; however, releases from Flaming Gorge Dam have less effect on flow and sediment process in Reach 3. Consequently, this study should focus on integration and synthesis of existing information on backwater topography, sediment, and physical conditions for Reach 2.

The Surface Water Modeling System (SWMS) developed and used by the USGS (Project 85F) should be evaluated to determine if this model can be used to better understand this relationship. This synthesis should incorporate the SWMS information, USGS data on sediment transport patterns at the Jensen gage (Project 85F), and Western's backwater topography studies. The evaluation of existing data should be used to determine the need for additional studies including continuation or modification of existing studies (i.e., 85f) and new studies designed to fill information needs.

Hypotheses to Be Evaluated and Information Needs to Be Filled

- Base flows in summer and autumn scaled to hydrologic condition favor formation of backwaters (A8).
- Effect of peak flows, sediment availability, and antecedent conditions on relationship of base flow and backwater availability (U17).
- Relationship between peak flow, sediment, and habitat development (information need).
- Habitat conditions at beginning of baseflow period (information need).

Implementation

- *New Start.*—Integration and synthesis of existing information on backwater topography, sediment, and other physical conditions should be started in FY 2008 and completed in FY 2009. This synthesis should incorporate SWMS findings, USGS sediment transport data, and Western's backwater topography studies. The results of this synthesis should be used to determine the need for additional studies.

5: Evaluate the effect of base flow variability on backwater habitat maintenance and quality.

Description

This study should begin as a synthesis of physical and biological information already collected in Reaches 2 and 3, including evaluating potential links between past and recent physical measurements and Colorado pikeminnow age-0 monitoring. This ongoing work should be evaluated to refine, as necessary, studies to gain a better understanding of how base flows and base flow variability affect backwater maintenance and quality in Reaches 2 and 3.

Western's annual studies of backwater topography in the Ouray reach are relevant to this evaluation and should be used to determine how base flow variability affects physical habitat characteristics (depth, volume, surface area). Integration of the backwater topography information with concurrent age-0 Colorado pikeminnow monitoring should be explored as a way to link biological information with backwater variability. Upon completion of existing data synthesis and integration, the need for continuation of studies or additional studies to quantify other habitat characteristics (e.g., temperature and productivity) should be determined.

Past studies have documented fish communities in backwater habitats, but there has been little integration of these data, and little attempt to determine the relationship between fish communities and flow. This recommended study should synthesize physical and biological information already collected on backwaters to better understand physical habitat relationships and fish communities. Age-0 monitoring currently collects samples of fish from backwaters. Project 144 (native response to nonnative control) supplements age-0 Colorado pikeminnow monitoring with additional information on fish communities in backwaters.

Following completion of analyses of data from these studies, a decision should be made regarding the need for additional or continuing studies to fill information needs and address uncertainties.

Hypotheses to Be Evaluated and Information Needs to Be Filled

- Effect of base flow variability (within-day, within-season, within-year, between years) on backwater quality in Reach 2 (U18).
- The effect of base flows on nonnative fish populations in Reach 2 (U21).
- Base flows in summer and autumn scaled to hydrologic condition favor formation of backwaters in Reach 2 (A8).
- Maintenance of mean base flow within recommended levels of season and daily flow variability will promote favorable backwater conditions in Reach 2 (A9).
- The effect of base flow variability (within-season, within-year, between years) on backwater habitat quality in Reach 3 (U24).

- Habitat conditions at beginning of baseflow period in Reach 2 (information need).

Implementation

- *Ongoing Project 138.*—Annual age-0 Colorado pikeminnow monitoring is ongoing, and a final report on monitoring results is due in August 2008. This report will use past and current data to evaluate the relationship of age-0 Colorado pikeminnow size and relative numbers to backwater characteristics, flow, and temperature.

- *Ongoing Project 22f.*—Annual monitoring of Colorado pikeminnow is ongoing, and used to determine timing and duration of spawning by Colorado pikeminnow and presence and abundance of larvae in the system as measured by capture of larvae downstream of spawning areas in the lower Yampa River. Monitoring would continue indefinitely. The need for modifications of monitoring protocols and the need for continued monitoring would be evaluated periodically.

- *Ongoing Project 144.* This study *evaluates response of native fish to nonnative predator removal with a synthesis report due in 2007.*

- *New Start.*—This study should integrate data collected under Projects 138, 144, and Western's backwater topography studies to further evaluate the effects of flow variability on Colorado pikeminnow abundance and condition and nonnative fish communities. This integration report should be started in FY 2008 and completed in FY 2009.

3.3.3 Nonnative Fish Management in Reach 1 and Upper Reach 2

Nonnative fish are considered a major impediment to recovery of the endangered fish species throughout the Colorado River Basin. The Recovery Program has implemented numerous programs to manage and control the more problematic species, including northern pike, smallmouth bass, and channel catfish. Many of these programs are ongoing and are not directly related to the flow and temperature recommendations for the Green River.

Flow and temperature options may be available for managing nonnative fish populations and reducing their threat to endangered fish species. Aspects of the life history of nonnative fish that may be affected by flow and temperature conditions should be investigated.

The fish community in Reach 1 is most directly affected by Flaming Gorge Dam releases. Research and monitoring should continue in this portion of the river (e.g., Study #115) to evaluate the effects of flow and temperature recommendations. Information from this study coupled with experimental releases in the future may lead to flow and temperature recommendations to control nonnative fish populations. Relationships established in Reach 1 between flow and temperature and various aspects of nonnative species life history could assist Recovery Program efforts throughout the Upper Basin.

Entrainment of nonnative fish in the spillway at Flaming Gorge Dam should be evaluated and escapement through the dam needs to be determined to understand the risk of spills. In Reach 2, fish populations should continue to be monitored in Whirlpool and Split Mountain canyons to evaluate the effects of flow and temperature recommendations on the fish communities in those areas. Although Reach 3 is too far downstream from Flaming Gorge Dam for effective flow regulation, it should be determined if flows to benefit endangered fish in Reaches 1 and 2 also benefit nonnative fish in Reach 3. Nonnative fish in floodplains and backwaters are also important concerns that need to be further investigated to determine if flows and temperatures can be managed to affect various life stages of these invasive species and to ensure that management of these habitats does not exacerbate the threat of nonnative fish.

Recommended studies fall into two subject areas: (1) the influence of flow and temperature on life history components of nonnative fish, and (2) spillway entrainment rates.

6: Determine the influence of flow and temperature recommendations on nonnative fish life history components in lower Reach 1 and upper Reach 2.

Description

This study should evaluate the effect of recommended flows and temperatures on the life history of particularly problematic nonnative fish species (e.g., smallmouth bass and northern pike). Ongoing Project 115 should be continued and revised, as needed, to evaluate the effects of recommended flows and temperatures in lower Reach 1 and upper Reach 2 on nonnative fish. Information from other studies and available data should be integrated and synthesized to determine the effects of flow and temperature on species life histories (timing and controls on spawning, hatching, swim-up, etc). The data should be evaluated to identify opportunities for managing nonnative fish using Flaming Gorge Dam releases.

Hypotheses to Be Evaluated and Information Needs to Be Filled

- Response of nonnative fish populations to spring peak flows in Reach 1 and upper Reach 2 (U2).
- Effect of base flows and release temperatures on nonnative fish populations in Reach 1 and upper Reach 2 (U4).
- The effects of flow and temperature recommendations on life histories of nonnative fish (information need).
- Operations that optimize flow and temperatures to maximize benefit to endangered fish and minimize benefit to nonnative fish (information need).

Implementation

- *Ongoing Project 115.*—Project 115 is an ongoing study that examines the response of the fish community in lower Reach 1 and upper Reach 2 to flow and temperature recommendations and is currently scheduled to continue through 2007. The study should be revised as needed to continue through 2009, and address the uncertainties and information needs identified above.

7: Determine spillway entrainment rates of nonnative fish at Flaming Gorge Dam.

Description

Spillway releases from Flaming Gorge Dam are hydrologically driven events that occur when excessive water volumes from flows into the reservoir exceed the ability to make controlled releases through the turbines and bypass tubes. Under certain circumstances, spillway releases also could be used to meet flow and temperature recommendations. Spillway releases may allow nonnative fish (especially smallmouth bass) from Flaming Gorge Reservoir to escape into the river below the dam and eventually into habitat occupied by endangered fish further downstream.

The species and approximate numbers of fish that escape from the reservoir need to be determined to evaluate the risks of using spillway releases to meet the flow and temperature recommendations. The Recovery Program should coordinate with the Utah Division of Wildlife Resources (UDWR) and Reclamation to secure baseline information. It is expected that UDWR will continue to collect data as part of their annual monitoring programs, and this data can be used to determine rates of entrainment from the reservoir. Sampling immediately following spill events should also be conducted as a means to assess entrainment and escapement of nonnative species. Results of the isotope study (Project C18/19) should be evaluated in reference to reservoir entrainment rates.

Hypotheses to Be Evaluated and Information Needs to Be Filled

- Increased frequency of bypassing water (spills) at Flaming Gorge Dam would result in increased entrainment of reservoir nonnative fish species (U1).

- Spillway entrainment rates (information need).

Implementation

- *Ongoing Project C18/19*.─Isotope data are scheduled to be collected through 2009. These data would provide baseline information that can be used to determine rates of entrainment should spills occur in the future. Because spillway use is hydrologically driven and cannot be predicted, studies to evaluate entrainment rates cannot be scheduled. Isotope data should be collected following spill events and compared to baseline data to determine rates of entrainment.

3.4 Timeline for Recommended Studies and Integration of Information

A timeline for the implementation, conduct, and completion of studies recommended in this Study Plan is presented in Table 3. The seven subject areas, as described in Section 3.3 are identified by each of the three resource categories and shown as new starts or ongoing studies.

Table 3. Timeline for recommended studies.

	Fiscal Year and Study Type[1]						
Recommended Subject Areas	**07**	**08**	**09**	**10**	**11**	**12**	**Out Years**
Floodplains							
1. Evaluate annual survival of young and movement of subadult razorback suckers from floodplains into the mainstem in response to flow recommendations.		**N[2]**					
2. Complete evaluation of recent peak flow studies related to floodplain inundation and entrainment of larval razorback suckers, and determine the need for additional studies.		**O[3]**					
	O[4]						
		N[5]					
3. Continue annual monitoring of razorback sucker larvae in the mainstem, and synthesize existing information on drift and its relationship to flows and other environmental conditions.	**O[6]**						
		N[7]					
Backwaters							
4. Determine the relationship of backwater habitat development to sediment availability and peak flows in Reach 2.		**N[8]**					
5. Evaluate the effect of base flow variability on backwater habitat maintenance and quality.	**O[9]**						
	O[6]						
	O[10]						
		N[11]					
Nonnatives							
6. Determine the influence of flow and temperature recommendations on nonnative fish life history components in lower Reach 1 and upper Reach 2.	**O[12]**						
7. Determine spillway entrainment rates of nonnative fish at Flaming Gorge Dam.	**O[13]**						

[1] Study types: N = new start, O = ongoing study.
[2] New field study.
[3] Final report for ongoing Project Cap 6 rz/entr.
[4] Project 85f, sediment monitoring.
[5] Synthesis of existing physical and biological information.
[6] Project 22F, annual larval monitoring.
[7] Analysis of historical monitoring data.
[8] Integration of backwater topography, sediment, and other physical data.
[9] Project 138, age-0 Colorado pikeminnow monitoring; final report of results to date due in August 2008.
[10] Project 144, response of native fish to nonnative predator removal.
[11] Integration of data collected under Projects 138, 144, and backwater topography study.
[12] Project 115, response of fish community in lower Reach 1 and upper Reach 2.
[13] Project C18/19, isotope study.

The recommended studies include a number of integration or synthesis reports. These reports are "checkpoints" that should be used by the Recovery Program to evaluate the efficacy of the flow and temperature recommendations and to reassess, as necessary, the direction of the studies, as well as reduce extraneous data needs. These integration efforts should bring together data collected by principal investigators for related studies (Figure 4). Recovery Program Coordinators (with possible assistance from a*d hoc* committees and the Research Framework project) should integrate and synthesize these and other reports within the three resource categories (floodplains, backwaters, and nonnative fish).

The Recovery Program should provide overall integration of these category-based syntheses and perform a comprehensive assessment of the effects of flow and temperature recommendations. Based on the study timelines presented in Table 3, such integration among categories should begin in FY 2009 and end in FY 2010. Consistent with the principles of adaptive management, data integration and evaluation should be used to reduce data needs and determine the need for additional study and revision of flow and temperature recommendations.

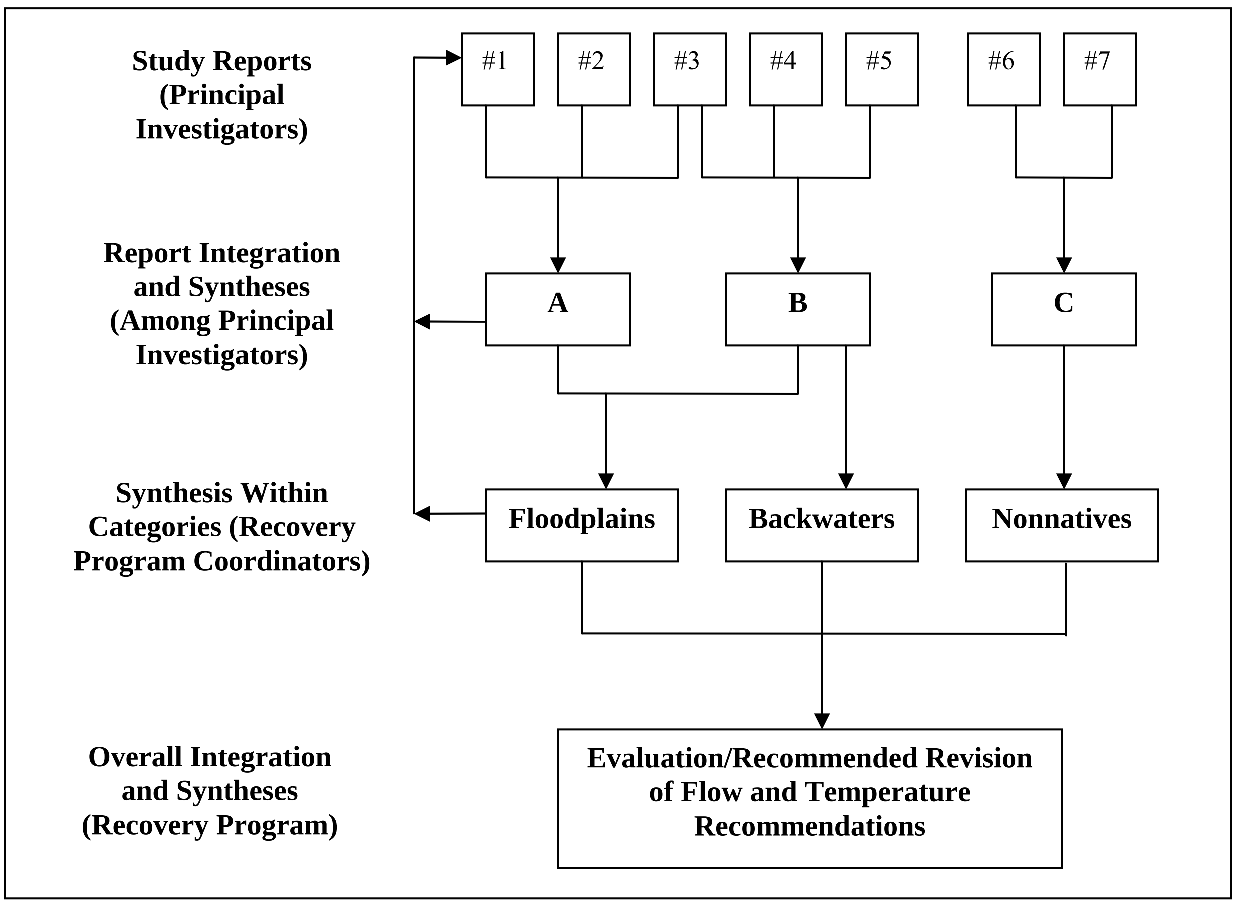

Figure 4. Strategy for integration and synthesis of study reports for evaluation and recommended revision of flow and temperature recommendations. Study numbers and integration report letters are for illustration purposes only.

3.5 Recommended RIPRAP Revisions

Study Plan recommendations (Table 4) for the *Green* River *Action Plan: Mainstem* section of the RIPRAP will be incorporated when the RIPRAP is reviewed in spring 2007.

Table 4. Recommended changes to the *Green River Action Plan: Mainstem* section of the RIPRAP.

	ACTIVITY	WHO	STATUS	07	08	09	10	11	12	OUT-YEARS
I.D.	Evaluate and revise flow regimes to benefit endangered fish populations.	Program	Ongoing	X	X	X	X	X	X	X
I.D.1.	Develop study plan to evaluate flow and temperature recommendations.	FWS/BR/ WAPA	Pending	X						
I.D.1.a.	Evaluate survival of young and movement of subadult razorback suckers from floodplains into the mainstem in response to flows.	TBD	New Start		X	X	X	X	X	
I.D.1.b.	Evaluate recent peak flow studies related to floodplain inundation and entrainment of larval razorback suckers.									
I.D.1.b.(1)	Complete final report on entrainment of larval razorback suckers in floodplains.	UDWR/ LFL	Ongoing		X					
I.D.1.b.(2)	Monitor changes in the magnitude, timing, and size distribution of sediment	USGS	Ongoing	X	X					
I.D.1.b.(3)	Synthesize physical and biological data from recent peak flow studies related to floodplain inundation and entrainment of larval razorback suckers.	TBD	New Start		X	X				
I.D.1.c.	Monitor larval razorback suckers in mainstem, and synthesize information on drift as related to flows and other conditions.									
I.D.1.c.(1)	Conduct annual monitoring of larval razorback suckers.	FWS/LFL	Ongoing	X	X	X	X	X	X	X
I.D.1.c.(2)	Analyze historic monitoring data.	TBD	New Start		X	X				
I.D.1.d.	Determine relationship of backwater development to sediment availability and peak flows in Reach 2.	TBD	New Start		X	X				
I.D.1.e.	Evaluate effect of base flow variability on backwater maintenance and quality.									
I.D.1.e.(1)	Conduct annual monitoring of larval Colorado pikeminnow.	LFL	Ongoing	X	X	X	X	X	X	X
I.D.1.e.(2)	Monitor age-0 Colorado pikeminnow in backwaters.	UDWR	Ongoing	X	X	X	X	X	X	X
I.D.1.e.(3)	Evaluate response of native fish to nonnative predator removal	UDWR	Ongoing	X	X	X	X	X	X	X
I.D.1.e.(4)	Integrate biological and physical data on backwaters.	TBD	New Start		X	X				
I.D.1.f.	Determine influence of flow and temperature recommendations on nonnative fish life history in lower Reach 1 and upper Reach 2.	LFL/FWS	Ongoing	X	X	X				
I.D.1.g.	Determine spillway entrainment of nonnative fish at Flaming Gorge Dam.	CDOW/ UDWR	Ongoing	X	X	X				
I.D.2.	Integrate and synthesize reports for evaluation and recommended revision of flow and temperature recommendations.	Program	New Start			X	X			X

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Table A1. Goals, objectives, and status for studies (**primary studies in bold text**) relevant to evaluation of the Green River flow and temperature recommendations. See Tables A2–A4 for links of studies to flow and temperature recommendations, and anticipated effects or uncertainties.

Studies	Study Goal and Objectives	Status	FY
Gunnison and Green River sediment monitoring (Project 85f)	**<u>Goal</u>** The goal of the sediment monitoring program is to provide information with which to evaluate changes in the magnitude, timing, and size distribution of sediment delivery to the Gunnison and Green River systems and their potential effects on the riverine ecosystem, specifically as they relate to recovery of the endangered fishes. **<u>Objectives</u>** 1. A retrospective analysis of historic sediment data will be done to determine the availability of historic sediment data for the key sites on the Colorado, Gunnison, and Green River near Green River Utah. This objective also includes an evaluation of the data to determine their utility for developing sediment-transport equations (These were completed and presented at the habitat workshop in March 2005). In addition, an evaluation of trends in sediment transport, and how variations (wet vs. dry years) in annual hydrographs affect sediment transport will be included in the SIR (to be written in FY 2008). 2. To support the evaluation of the effects of streamflow and sediment movement on the morphometric and bed material characteristics of Gunnison and Green River. 3. Determine if there is any distinction between sediment load estimates computed from daily sediment data, sediment transport equations, and empirical bedload transport equations. 4. Evaluate the dynamics of sediment movement in the study reaches by collecting and analyzing data to compute sediment load, including suspended sediment using daily samples and sediment transport equations. Water-surface slope and bed-material samples will be collected at two sites to support bedload calculations. These data will be collected at the Whitewater gage and the Green River near Jensen Utah (Jensen). These sites represent the range in sediment conditions found in other habitat monitoring reaches (primarily cobble bottom in the Gunnison R. at Whitewater and a sand cobble mixture, primarily sand, found in the Green R. near Jensen). 5. Collect necessary topology data near the Jensen site for use in a Surface Water Modeling System (SWMS) Demonstration Project to determine the suitability of this type of modeling of sediment transport as it relates to current and future efforts to monitor habitat for the endangered fishes. An added utility of the proposed work is the opportunity, at a later date, to incorporate output from the SWMS into existing habitat models to further relate streamflow and sediment transport to recovery efforts for the endangered fishes.	Ongoing	2004 - 2008

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Effects of Flaming Gorge Dam releases on fish communities (Project 115)	**Goal** Determine if changes in Green River flow and thermal regimes are associated with changes in distribution and abundance patterns of native and nonnative fishes in Browns Park, Lodore and Whirlpool canyons, and Island-Rainbow Park. **Objectives** 1. Determine if shifts in distribution and abundance of large-bodied fishes have occurred in Lodore Canyon and Whirlpool Canyon by comparing the results of shoreline electrofishing and trammel net surveys with the results of previous studies, particularly Bestgen and Crist (2000) and results of the 2002-2004 study. An ancillary benefit will be removal of warm water nonnative fishes captured during sampling. 2. Determine if shifts in the distribution and abundance of small-bodied fishes have occurred in Brown's Park, Lodore and Whirlpool canyons, and Island-Rainbow Park by comparing results of low-velocity, nearshore seining with the results of previous studies, particularly Bestgen and Crist (2000) and results of the 2002 to 2004 study. An ancillary benefit will be removal of warm water nonnative fishes captured during sampling efforts. 3. Determine if Colorado pikeminnow spawn in the Green River upstream from the Yampa River confluence by sampling with drift nets in lower Lodore Canyon, and by summer sampling to determine presence of ripe adults. Drift net sampling will be done only occasionally when Green River flows are low and warm (conditions when pikeminnow spawning might be expected) and will be done in conjunction with drift-net sampling in the Yampa River (project 22f). 4. Analyze hydrological records as recorded by the USGS at their gaging station (09234500) near Greendale, Utah, to compare differences in current and historical operations. 5. Analyze temperature records of the Green River through Browns Park, Lodore Canyon, and Whirlpool Canyon to compare differences in current and historical operations. 6. Based on results of objectives 1–5, determine physical effects of new operations and subsequent effects on the fish community of the Green River downstream of Flaming Gorge Dam.	Ongoing	2002 - 2007
Operation and maintenance of gages (Project 8)	**Goal** Provide a basis for refining the flow recommendations for the important stream reaches of the Colorado, Yampa, Price and Duchesne rivers. **Objectives** 1. Provide a benchmark for future monitoring by video or aerial photography. 2. Aid in scheduling releases from Ruedi, Wolford, Williams Fork and Green Mountain Reservoirs and other water sources which may be acquired by the Recovery Program. 3. Provide basic information for sediment modeling for the Little Snake and Yampa Rivers.	Ongoing	1990 - TBD

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Recovery Program Hydrology Support (Project 19 Hydro)	**Goal** To support, identify, evaluate and protection of instream flows to benefit Colorado River endangered fish. **Objectives** 1. To negotiate contracts and leases of water for endangered fish. 2. To collect temperature and hydrological data in support of Recovery program research priorities. 3. To provide water management services to the Recovery Program and Service to manage water the Service has secured for endangered fish augmentation. 4. To provide staff support to the Recovery Program Directors Office on an as-needed basis in the area of instream flow identification, delivery and protection.	Ongoing	1988 - TBD
Evaluation of larval razorback suckers stocked into floodplain depressions of the Middle Green River (Project Cap-6 RZ)	**Goal** Evaluate stocked larval razorback sucker survival and growth in floodplain environments with abundant nonnative fish species. **Objectives** 1. Stock larval razorback suckers in selected floodplain depressions. 2. Determine growth and survival of larval razorback sucker stocked into seasonal floodplain wetlands.	Completed	1999 - 2001
Larval bonytail and razorback sucker survival in floodplain habitats (Project Cap-6 bt/rz)	**Goal** To increase survival and growth of larval and juvenile razorback sucker and bonytail in off-channel floodplain wetlands in the Green River using the reset concept to control nonnative fish impacts. This scope of work expands the use of the 'reset' approach to a management scale that examines those wetlands where razorback sucker and bonytail larvae are most likely to survive, and includes the newly acquired Thunder Ranch easement property.	Completed	2003 - 2005
Cap-6 bt/rz (continued)	**Objectives** 1. Determine first year growth and survival of stocked razorback sucker and bonytail larvae in large floodplain wetlands of the middle Green River under the 'reset' and partial 'reset' conditions. 2. Relate stocked razorback sucker and bonytail abundance to nonnative fish abundance and composition, temperature, turbidity, pH, dissolved oxygen, depth, size of wetland, type and vegetative cover. 3. Use larval survival and growth results to facilitate prioritizing wetland sites and management actions to maximize razorback sucker and bonytail recruitment.		
Larval razorback and bonytail survival in Baeser (Project Cap-6 rz/bt)	**Goal** Provide an estimate of the density of larval razorback sucker and bonytail necessary to survive predation in a "reset" floodplain. Also, evaluate survival and growth of stocked larval razorback sucker and bonytail in "reset" floodplain depressions of the middle Green River	Completed	2003 - 2005

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Project Cap-6 rz/bt (continued)	**Objectives** 1. Evaluate survival and growth of larval razorback sucker in the presence of nonnative predators by stocking larvae into experimental enclosures at four stocking densities. 2. Evaluate survival and growth of larval razorback sucker and bonytail in the presence of nonnative predators by stocking together at equal densities into experimental enclosures.		
Entrainment of larval razorback sucker (Project Cap-6 rz/entr)	**Goal** Evaluate larval razorback sucker drift characteristics and use the data to revise management for middle Green River floodplains based on potential larval razorback sucker entrainment. **Objectives** 1. Evaluate larval drift and entrainment patterns downstream from Razorback bar. 2. Evaluate larval drift and entrainment into floodplains from other potential spawning sites. 3. Continue to evaluate the effectiveness of breach connections for entraining drift at various points on the hydrograph. 4. Use data to refine the Floodplain Drift Model and for testing floodplain management scenarios.	Ongoing	2004 - 2008
Green River native fish response to nonnative control (Project 144)	**Goal** A reliable estimate of native fish response to an estimated level of nonnative predator removal. **Objectives** 1. Implement removal of northern pike from Island Park to the confluence of the White River and smallmouth bass from Split Mountain to Sand Wash. This objective will be implemented under the projects: Northern pike control in the middle Green River (Project 109) and smallmouth bass control in the Green River (Project # 123). 2. Assess abundance of northern pike and smallmouth bass in the middle Green River to determine removal effect. 3. Estimate response of small-bodied and early life-stage native fish to removal of northern pike and smallmouth bass.	Ongoing	2006 – 2007 (synthesis report)
Assessment of endangered fish reproduction in relation to Flaming Gorge operations (Project 22f)	**Goal** The goal of this project is to detect timing of reproduction by razorback sucker and Colorado pikeminnow, and determine patterns of presence of larvae and their relative abundance downstream of potential spawning sites in the middle Green River system. A second goal is to monitor temperature regimes of the Green and Yampa rivers in order to comply with Flaming Gorge flow recommendations.	Ongoing	1990 - TBD

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Project 22f (continued)	**Objectives** 1. To determine timing and duration of spawning by razorback suckers and presence and abundance of larvae in the system as measured by capture of larvae in light traps. 2. To determine timing and duration of spawning by Colorado pikeminnow and presence and abundance of larvae in the system as measured by capture of larvae downstream of spawning areas in the lower Yampa River.		
Management of easements acquired for the Recovery Program (Project C-6-EM)	**Goal** To monitor and manage easements acquired by the Recovery Program for the purpose of supporting and sustaining recovery of the endangered fishes **Objectives** 1. To restore, enhance, and/or protect floodplain habitats to benefit endangered fishes. 2. To maintain positive relationships with Colorado River Wildlife Management Area landowners.	Ongoing	1999 - TBD
Annual fall monitoring for Colorado pikeminnow YOY (Project 138)	**Goal** Determine size and relative numbers of YOY Colorado pikeminnow at the end of their first growing season to complement larval and juvenile sampling data. **Objectives** 1. Using new and existing data, determine relationship between larval and YOY Colorado pikeminnow CPE abundance estimates with respect to flow and temperature. 2. Using new and existing data, develop predictive model that relates larval and YOY Colorado pikeminnow abundance. 3. Using new and existing data, determine relationship between YOY and juvenile Colorado pikeminnow CPE abundance estimates with respect to YOY size, flow, and temperature. 4. Using new and existing data, develop predictive model that relates YOY and juvenile Colorado pikeminnow abundance.	Ongoing	1986 - 2008
Abundance estimates for Colorado pikeminnow in the Green River Basin (Project 128)	**Goal** Obtain an accurate (unbiased) and reliable (precise) estimate of the adult population abundance and survival of Colorado pikeminnow that occupy the Green River study area. **Objectives** 1. Complete a minimum of three sampling passes through the five Green River Basin reaches listed to capture sub-adult and adult Colorado pikeminnow: a) Green River between the confluence of the White River upstream to the lower end of Whirlpool Canyon (i.e., upper Rainbow Park). b) White River between the confluence of the Green River upstream to Taylor Draw Dam, c) Yampa River between Deerlodge Park and Craig, excluding Cross Mountain Canyon, d) Green River from the White River confluence downstream to near Green River, Utah, and,	Ongoing, periodic	2000 - TBD

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Project 128 (continued)	e) Green River from downstream of Green River, Utah, to the confluence with the Colorado River. The LFL and CDOW will attempt up to six sampling passes in the Yampa River, in part associated with bass and northern pike removal projects, in order to obtain a more precise and accurate Colorado pikeminnow abundance estimate. 2. Obtain highest possible rates of capture of Colorado pikeminnow within concentration habitats and maximize number of individuals marked and captured on each sampling occasion. 3. Obtain estimates of probability of capture and abundance for Colorado pikeminnow in each of five reaches and for entire study area.		
Population estimation of humpback chub in Desolation and Gray Canyon (Project 129)	**Goal** To estimate the population size of humpback chub in Desolation/ Gray Canyon with confidence intervals of less than 20%. **Objectives** 1) To obtain a population estimate of late juvenile/adult humpback chub in Desolation/Gray Canyon. 2) To determine mean estimated recruitment of naturally produced subadult humpback chub (150-199 mm) in Desolation/Gray Canyon.	Ongoing, periodic	2001 - TBD
Evaluation of Yampa River humpback chub population (Project 133)	**Goal** The goal of this study is define the distribution, length frequency and size of the Yampa humpback chub population, and determine the relative rate of recruitment. **Objectives** 1. Determine the geographical distribution of the Yampa humpback chub population. 2. Determine the number of adults and subadults in the Yampa humpback chub population. 3. Determine and length frequency and relative numbers of juveniles in the Yampa humpback chub population.	Ongoing, periodic	1998 - TBD
Middle Green River northern pike control (Project 109)	**Goal** The goal of northern pike control in the middle Green River is to sufficiently reduce the abundance of adults such that predatory and competitive impacts on growth, recruitment, and survival of endangered and other native fishes are minimized. **Objectives** 1. Capture and remove (lethal) adult northern pike from reaches of the middle Green River. 2. Maintain low occurrence of adult northern pike in the middle Green River. 3. Determine the efficiency of removal efforts. 4. Identify the means and levels of northern pike control necessary to minimize the threat of predation/competition on endangered and other native fishes.	Ongoing	2001 – 2007 (synthesis report)

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Lower Yampa smallmouth bass and channel catfish control (Project 110)	**<u>Goal</u>** The goal is to sufficiently reduce the abundance of smallmouth bass and channel catfish such that predatory and competitive impacts on growth, recruitment, and survival of resident humpback chub and Colorado pikeminnow are minimized. **<u>Objectives</u>** 1. Reduce the abundance of smallmouth bass and channel catfish in Yampa Canyon by capture and removal (lethal). 2. Compare the catch rates of smallmouth bass and channel catfish to determine the efficacy of removal efforts.	Ongoing	2001 – 2007 (synthesis report)
Middle Yampa northern pike and smallmouth bass removal (Project 98a)	**<u>Goal</u>** 1) To reduce the number of northern pike occupying 47.3 river miles of critical habitat within the Yampa River downstream of Craig, Colorado (RM 134.2 – RM 60.6), thereby benefiting native fishes of the Yampa River Basin, as well as native fish communities downstream within the Green River Basin. 2) To transport live northern pike collected from the study reach for release in Loudy Simpson ponds (Craig) and Rio Blanco Lake (White River Basin, near Meeker, Colorado), thereby increasing angler opportunities to harvest northern pike. 3) To reduce the number of smallmouth bass occupying 10.2 river miles of critical habitat within the Yampa River downstream of Craig, Colorado (RM 134.2 – RM 124), thereby benefiting native fishes of the Yampa River Basin, as well as native fish communities downstream within the Green River Basin. 4) To transport live smallmouth bass (>10” in total length) collected from the study reach for release in City of Craig municipal pond, thereby increasing angler opportunities to harvest smallmouth bass. **<u>Objectives</u>** 1) To remove and translocate as many northern pike as possible within the study area via three or more removal passes. 2) To estimate the number of northern pike occupying the study area by generating a population estimate for northern pike utilizing a mark/recapture methodology (1 marking pass, 3 removal passes), or regression analysis (4 removal passes). 3) To calculate the proportion of the estimated northern pike population that was removed. 4) To remove and translocate as many smallmouth bass as possible within the study reach via a minimum of four removal passes.	Ongoing	2005 – 2007 (synthesis report)
Upper Yampa northern pike removal (Project 98b)	**<u>Goal</u>** Improve survival of endangered fish in the Yampa and Green Rivers. **<u>Objectives</u>** 1) Reduce numbers of adult northern pike in the study reach.	Ongoing	2001 – 2007 (synthesis report)

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Project 98b (continued)	2) Determine population size and structure of northern pike in the study reach and the subsequent changes in the population size and structure after translocation. 3) Monitor movement of northern pike into and out of the study area and within the study area. Movements will be monitored within years, between years, and seasonally. 4) Maintain public support for the Recovery Program by providing off-channel angling opportunity to Yampa Valley anglers with northern pike removed from the Yampa River. 5) Monitor the native fish community in the study area. 6) Monitor smallmouth bass in the study area.		
Starvation escapement (Project 119)	**Goal** Obtain an estimate of the rate of escapement of walleye and smallmouth bass from the spillway and outlet works of Starvation Reservoir. **Objectives** 1. Review and synthesize available data and reports on smallmouth bass populations and other fish species of the Duchesne River adjacent to Starvation Reservoir. 2. Complete an initial draining of the outlet works stilling basin prior to the irrigation season (March) Completed in 2002 and 2004. 3. Complete an evaluation draining of the spillway stilling basin following spill (July). 4. Complete three sampling passes through the three-mile river reach below Starvation Reservoir (Pre-spill, during spill and post-spill; May - July). Completed in 2002 5. Complete an evaluation draining of the outlet works stilling basin following the irrigation season (October). The outlet works stilling basin was drained in 2002 and 2004. 6. Obtain an estimate of the rate of escapement of target species through the spillway and outlet works of Starvation Reservoir (Jan).	Completed	2002 - 2006
Middle Green River smallmouth bass control (Project 123)	**Goal** Control smallmouth bass populations in the Green River. **Objectives** 1. Calculate an annual population estimate of smallmouth bass in the Green River. 2. Remove smallmouth bass in the Green River from Echo Park (RM 344) to Swasey's Rapid (RM 132). 3. Determine efficiency of smallmouth bass removal efforts.	Ongoing	2004 – 2007 (synthesis report
Duchesne River nonnative fish removal, fish composition monitoring, and riffle habitat measurements (Project 124)	**Goal** Improve survival of endangered fish in the Lower Duchesne and Green Rivers, monitor the fish community in the Lower Duchesne River, and measure riffle habitat changes since implementation of base flows.	Ongoing	2003 – 2007 (synthesis report)

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Project 124 (continued)	**Objectives** 1. Reduce the abundance of adult smallmouth bass, channel catfish, and northern pike in the Duchesne River reach between the Myton Diversion (RM 41) and the confluence of the Green River. 2. Maintain public support for the Recovery Program by providing angling opportunity to the Ute Tribes' Elders Pond with nonnative fish removed from the Duchesne River. 3. Monitor fish composition in the lower Duchesne River. 4. Evaluate the physical habitat characteristics of riffles and compare to historic data.		
Evaluation of smallmouth bass and northern pike management in Middle Yampa River (Project 125)	**Goal** The goal is to remove as many smallmouth bass as possible from a 24-mile treatment reach and a 5-mile concentration reach and estimate the proportion of the population removed from each reach. **Objectives** Smallmouth Bass: 1. Obtain an estimate of the number of smallmouth bass in a 24-mile treatment reach in Little Yampa Canyon and a 5-mile reach in Lily Park using a mark-recapture abundance estimator. 2. Remove a large portion of the estimated population of smallmouth bass from the 24-mile treatment reach in Little Yampa Canyon and the 5-mile concentration area in Lily Park. 3. Calculate the proportion of smallmouth bass removed from each study area based on initial population size and compare capture rates between control and treatment reaches. 4. Remove large numbers of age-0 and age-1 smallmouth bass from a 12-mile treatment reach in Little Yampa Canyon. 5. Understand movement of recaptured smallmouth bass tagged in previous years or during the first (tagging) pass each year. Northern Pike: 1. Obtain an estimate of the number of northern pike that reside in the 95-mile study reach in the Yampa River using a mark-recapture abundance estimator. (This will be done by Project 98a). 2. Remove a large portion of the estimated population of northern pike from the smallmouth bass study reaches and from other reaches opportunistically as needed to support Project 98a. 3. Calculate the proportion of northern pike removed based on initial population size.	Ongoing	2003 – 2007 (synthesis report)
Yampa native fish response to nonnative fish management (Project 140)	**Goal** The goal is to reliably estimate the response of resident native fishes to a known, relatively large, and well-estimated level of predator removal.	Ongoing	2004 – 2007 (synthesis report)

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Project 140 (continued)	**Objectives** 1. Select treatment and reference areas for study. 2. Implement removal of smallmouth bass and northern pike in treatment reaches in spring (mostly conducted in a different study). 3. Assess abundance of predators in treatment and reference reaches to determine removal effects. 4. Conduct additional removals prior to summer if removals were not sufficient or if the removal effect was transitory. 5. Estimate response of native fishes in autumn after spring-summer predator removal.		
Chemically fingerprinting nonnative fishes in reservoirs (Project C18/19)	**Goal** To determine chemical "fingerprints" of nonnative fishes in reservoirs that are potential sources of nonnative fishes to critical habitat. **Objectives** 1. Quantify chemical "fingerprints" of fishes within study reservoirs and evaluate degree of inter-annual variation in those fingerprints. 2. Determine if fish sampled in rivers the vicinity of study reservoir possess otoliths core signatures that identify them as having originated from one of the study reservoirs. 3. Improve our understanding of the degree to which immigration or transfers from reservoirs contributes to the load of nonnative fishes in critical habitat of the Upper Colorado River Basin. 4. Provide recommendations to guide management efforts to reduce the influx of nonnative fishes from reservoirs.	Ongoing	2006 - 2009
Yampa River pike sources (Project 143)	**Goal 1.** Map degree of movement of pike within the Yampa River system via otoliths microchemistry. **Objectives 1.** 1. Demonstrate differences in chemical signatures of otoliths of age-0 pike from various sources. 2. Evaluate how quickly differences can be detected via laser ablation. 3. Estimate the proportion of pike recruited from reservoirs and other spawning areas in the Yampa River. 4. Estimate the extent of pike movement from spawning sources and reservoirs to other habitats within the Yampa River system. **Goal 2.** Evaluate trophic relationships of pike within Stagecoach Reservoir, Lake Catamount, Elkhead Reservoir, and portions of the Yampa River using stable isotope analysis.	Ongoing	2005 – 2006

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Project 143 (continued)	**<u>Objectives 2.</u>** 1. Collect adult pike and take dorsal flesh samples at each reservoir and in the Yampa River. 2. Utilize stable isotope analysis to evaluate diet composition.		
Physical evaluation of floodplain habitat (Project Cap-6HYD)	**<u>Goal</u>** To restore floodplain habitats in a manner that will benefit endangered fishes, minimize potential adverse effects, and be cost-effective. **<u>Objectives</u>** 1. To determine bankfull flood flows, with and without excavation; 2. To determine area of inundation as a function of flow, with and without excavation; 3. To compare historical versus existing frequency, duration, and timing of flood flows, with and without excavation; 4. To characterize pre-restoration baseline channel and site morphology, and post-restoration morphology; 5. To develop design options for enhancing floodability; 6. To oversee construction activities; 7. To monitor results	Ongoing	1996 - TBD
Western aerial photography of 2005 peak flow	**<u>Goal</u>** Document areas and elevations of inundation for floodplains with aerial photography during spring peak flows. **<u>Objectives</u>** 1. Determine areas of floodplain inundation at various river flows. 2. Determine approximate elevations of inundation with various river flows.	Completed	2005
Western backwater topography study	**<u>Goal</u>** Evaluate effect of seasonal and daily flow variability on backwater availability and quality. **<u>Objectives</u>** 1. Monitor backwater dimension and depth as affected by seasonal and daily flow variability.	Ongoing	2003 - TBD
USGS razorback spawning bar study	**<u>Goal</u>** Assess effect of river flows on sediment deposition at the razorback sucker spawning bar on the Green River. **<u>Objectives</u>** 1. Measure sediment deposition on spawning cobbles at various river flows.	Ongoing	1998 – 2008 (data will be incorporated in Project 85f)
Utah State University/Reclamation channel monitoring studies	**<u>Goal</u>** Describe geomorphic changes with flow, sediment transport and vegetation encroachment.	Ongoing	1995 - TBD

Table A1. Continued.

Studies	Study Goal and Objectives	Status	FY
Utah State University/Reclamation channel monitoring studies (continued)	**Objectives** 1. To monitor flow, sediment transport, and channel form of the Green River in Dinosaur NM; and 2. To document geomorphic effects of tamarisk on channel form and dynamics.		
Evaluation of stocked fish (Program)	**Objectives** 1. Summarize stocking information by species, year, size and facility; 2. Compare this summarized information with the numbers described in the stocking plan; 3. Identify the field programs that have captured hatchery-produced fish; 4. Quantify the number of hatchery-produced fish captured during these studies and describe their distribution, movement, growth and begin to assess their survival; 5. Evaluate the ability to utilize ongoing activities to assess the success of the stocking program and make recommendations for specific studies if possible.	Ongoing	2004 - TBD
Evaluation of ecosystem restoration and management options for the Ouray National Wildlife Refuge	**Goal** Analyze options for restoring and managing native ecosystems and habitats at Ouray NWR. **Objectives** 1. Synthesize information on the geologic formations, geomorphic features, hydrologic condition, and natural history of the Green River ecosystem in the vicinity of Ouray NWR. 2. Identify how the structure and function of the Green River ecosystem at Ouray NWR have been altered. 3. Identify restoration approaches and ecological attributes needed to restore and manage specific habitats and ecological conditions on Ouray NWR.	Completed	2004 - 2005
Reclamation Program Management (Project 1)	**Goal** Provide for Reclamation participation in Recovery Program activities not covered by specific scopes of work.	Ongoing	
UDWR tailwater fisheries studies	**Goal** Monitor fish populations in the tailwater fishery below Flaming Gorge Dam. **Objectives** 1. Sample periodically to determine approximate numbers of trout and their condition. 2. Monitor movement of trout. 3. Document all fish species in the tailwater below Flaming Gorge Dam.	Ongoing	

Table A2. Matrix of flow and temperature recommendations, hypotheses, and relevant studies for Reach 1 (Flaming Gorge Dam to Yampa River confluence) of the Green River. Language for anticipated effects and uncertainties was taken from Muth et al. (2000), U.S. Department of the Interior and Western Area Power Administration (2005), U.S. Fish and Wildlife Service (2005), or U.S. Department of the Interior (2006). See Table A4 for details of specific studies. Primary studies (bold) and supporting studies are linked to Anticipated Effects (A) or Uncertainties (U) and ordered sequentially.

General Flow and Temperature Recommendations (Muth et al. 2000)	**Anticipated Effects and Uncertainties (Hypotheses)**	**Relevant Studies (Primary studies in bold)**
Reach 1—Spring Peak		
Peak flows in Reach 1 should be of the magnitude, timing, and duration to achieve recommended peak flows in Reaches 2 and 3. In wetter years, peak flows should be of sufficient magnitude to restore and rebuild habitats currently occupied by adult Colorado pikeminnow in Lodore Canyon. No upper limits are placed on recommended peak-flow releases in any hydrologic condition.	**Anticipated Effects** A1. Significant channel maintenance (i.e., rework and rebuild in-channel sediment deposits, increase habitat complexity, and prevent or reverse channel narrowing) in Lodore Canyon in wet years or in other years when peak releases are greater than 244 m3/s (8,600 cfs) (Muth et al. 2000).	**A1-1. USU channel monitoring studies**
	A2. Channel maintenance will improve habitat conditions for endangered fishes and could favor potential spawning of Colorado pikeminnow in this portion of the river (Muth et al. 2000).	**A2-1. Project 115.**
	Uncertainties U1. The increased frequency of bypassing water (spills) would result in increased entrainment of reservoir nonnative species. Reach 1 monitoring should include specific efforts to evaluate the potential for establishing undesirable reservoir fishes, such as smallmouth bass in the tailwater (U.S. Fish and Wildlife Service 2005).	**U1-1. Project 115** **U1-2. UDWR tailwater fisheries studies** **U1-3. Projects C-18/19** U1-4. Project 119
	U2. The response of nonnative fish populations to spring peak flows (U.S. Fish and Wildlife Service 2005).	**U2-1. Project 115** **U2-2. Projects C-18/19** U2-3. Project 110 U2-4. Project 109 U2-5. Project 98a U2-6. Project 98b U2-7. Project 123 U2-8. Project 125 U2-9. Project 140

Table A2. Continued.

General Flow and Temperature Recommendations (Muth et al. 2000)	Anticipated Effects and Uncertainties (Hypotheses)	Relevant Studies (Primary studies in bold)
Reach 1—Summer Through Winter Base		
The mean flow for the summer–winter period should be established each year on the basis of anticipated hydrologic conditions, but adjustments can be made if hydrologic conditions change. Releases from the dam should gradually decline from peak flow to base flow, with the base flow reached by early to middle summer (depending on hydrologic conditions) and maintained through February.	**Anticipated Effects** A3. Target water temperatures in Lodore Canyon are expected to be achieved in 7 of 10 years (average and drier years) and could result in Colorado pikeminnow spawning in this portion of the river (Muth et al. 2000).	**A3-1. Project 8** **A3-2. Project 19** **A3-3. Project 115** A3-4. Reclamation Program Management (Project 1).
	A4. More favorable water temperatures also could result in expansion of humpback chubs into this portion of the river (Muth et al. 2000).	**A4-1. Project 115**
	Uncertainties U3. If warmer water (16°C) could be released at the dam during wetter years, recommended temperature targets could be achieved in more frequently (U.S. Fish and Wildlife Service 2005).	**U3-1. Project 8** **U3-2. Project 19** **U3-3. Project 115** U3-4. Reclamation Program Management (Project 1).
	U4. The effect of base flows and release temperatures on nonnative fish populations (U.S. Fish and Wildlife Service 2005).	**U4-1. Project 115** U4-2. Project 110 U4-3. Project 123 U4-4. Project 125 U4-5. Projects C-18/19

Table A3. Matrix of flow and temperature recommendations, hypotheses, and relevant studies for Reach 2 (Yampa River confluence to White River confluence) of the Green River. Language for anticipated effects and uncertainties was taken from Muth et al. (2000), U.S. Department of the Interior and Western Area Power Administration (2005), U.S. Fish and Wildlife Service (2005), or U.S. Department of the Interior (2006). See Table 4 for details of specific studies. Primary studies (bold) and supporting studies are linked to Anticipated Effects (A) or Uncertainties (U) are ordered sequentially.

General Flow and Temperature Recommendations (Muth et al. 2000)	**Anticipated Effects and Uncertainties (Hypotheses)**	**Relevant Studies (Primary studies in bold)**
Reach 2—Spring Peak		
Peak flows in Reach 2 should be of the magnitude, timing, and duration to provide floodplain inundation in the Ouray portion of the river for at least 2 weeks in 4 of 10 years and at least bankfull flows in 1 of 2 years. In all years, peak flows should be of sufficient magnitude and duration to provide at least some in-channel habitat maintenance throughout the reach. No upper limits are placed on recommended peak flows in any hydrologic condition. The duration of peak flows less than 527 m^3/s (18,600 cfs) should be limited, because neither floodplain nor backwater habitats are available at these flows.	**Anticipated Effects** A5. Wet and Moderately Wet: Significant inundation of floodplain habitat and off-channel habitats (e.g., tributary mouths and side channels) to establish river-floodplain connections and provide warm, food-rich environments for growth and conditioning of razorback suckers (especially young) and Colorado pikeminnow. Average: Significant inundation of floodplain habitat and off-channel habitat in at least 1 of 4 average years; some flooding of off-channel habitats in all years. Moderately Dry and Dry: No floodplain inundation, but some flooding of off-channel habitats. May benefit recruitment of Colorado pikeminnow in some years (Muth et al. 2000).	**A5-1. Project Cap-6 RZ** **A5-2. Project Cap-6 bt/rz** **A5-3. Project Cap-6 rz/bt** **A5-4. Project Cap-6 rz/entr** **A5-5. Project Cap-6HYD** **A5-6. Evaluation of stocked fish** **A5-7. Western aerial photography of 2005 peak flow** **A5-8. Project 128** A5-9. Project 22f A5-10. Project C-6-EM
	A6. Wet and moderately wet years. Significant channel maintenance to rework and rebuild in-channel sediment deposits (including spawning substrates), increase habitat complexity, form in-channel sand bars, and prevent or reverse channel narrowing. Average years. Significant channel maintenance in at least 1 of 2 average years. Moderately dry and dry years. Significant channel maintenance in at least 1 of 2 average years (Muth et al. 2000).	**A.6-1. Project 85f** **A6-2. Western backwater topography study** A6-3. USGS razorback spawning bar study
	A7. Provide conditions for gonadal maturation and cues for spawning migrations and reproduction by the endangered fishes (Muth et al. 2000).	**A7-1. Project 22f** A7-2. Project 128 A7-3. Evaluation of stocked fish

Table A3. Continued.

General Flow and Temperature Recommendations (Muth et al. 2000)	Anticipated Effects and Uncertainties (Hypotheses)	Relevant Studies (Primary studies in bold)
Reach 2—Spring Peak (continued)		
Peak flows in Reach 2 should be of the magnitude, timing, and duration to provide floodplain inundation in the Ouray portion of the river (continued)	**Uncertainties** U5. The area of terrace and depression floodplains inundated at different flows (U.S. Department of the Interior 2006).	**U5-1. Western aerial photography of 2005 peak flow** **U5-2. Evaluation of restoration and management options for Ouray NWR** U5-3. Project Cap-6HYD
	U6. Flow and stage at which floodplains with levee breaches become sufficiently inundated (area, depth, volume) to provide nursery habitat for razorback suckers (U.S. Fish and Wildlife Service 2005).	**U6-1. Western aerial photography of 2005 peak flow** **U6-2 Project Cap-6HYD** **U6-3. Project Cap-6 rz/entr** **U6-4. Evaluation of restoration and management options for Ouray NWR** **U6-5. Project Cap-6 RZ** **U6-6. Project Cap-6 bt/rz** **U6-7. Project Cap-6 rz/bt**
	U7. Area, depth, volume, and persistence of floodplain depression habitat after peak flows recede and the relationship, if any, between these and the magnitude of the peak flow (U.S. Department of the Interior 2005; U.S. Fish and Wildlife Service 2005).	**U7-1. Western aerial photography of 2005 peak flow** **U7-2. Evaluation of restoration and management options for Ouray NWR** **U7-3. Project Cap-6 RZ** **U7-4. Project Cap-6 bt/rz** **U7-5. Project Cap-6 rz/bt**
	U8. Abundance and entrainment of drifting razorback sucker larvae as a function of distance from the razorback sucker spawning bar (U.S. Department of the Interior and Western Area Power Administration 2005).	**U8-1. Project Cap-6 rz/entr** **U8-2. Project 22f** U8-3. Project Cap-6 bt/rz
	U9. Entrainment and retention of larvae in floodplain nursery habitats as a function of the physical characteristics of the habitat including size, volume, local hydraulic conditions, inlet(s), and outlet(s) (U.S. Fish and Wildlife Service 2005).	**U9-1. Project Cap-6 rz/entr** **U9-2 Project Cap-6HYD** U9-3. Project Cap-6 RZ **U9-4. Evaluation of restoration and management options for Ouray NWR**

Table A3. Continued.

General Flow and Temperature Recommendations (Muth et al. 2000)	Anticipated Effects and Uncertainties (Hypotheses)	Relevant Studies (Primary studies in bold)
Reach 2—Spring Peak (continued)		
Peak flows in Reach 2 should be of the magnitude, timing, and duration to provide floodplain inundation in the Ouray portion of the river (continued)	U10. Temporal relationships between drifting larvae and hydrology during the runoff period with a focus on the peak flow characteristics (magnitude, duration, ramp rate) needed to entrain most drifting larvae (U.S. Department of the Interior and Western Area Power Administration 2005).	**U10-1. Project 22f** **U10-2. Project Cap-6 rz/entr**
	U11. The frequency of connection needed to successfully recruit razorback sucker larvae into the adult population, including the frequency needed to sustain adequate water quantity and quality and allow escapement of subadults and adults to the main channel (U.S. Department of the Interior and Western Area Power Administration 2005).	**U11-1. Project Cap-6 RZ** **U11-2. Project Cap-6 bt/rz** **U11-3. Project Cap-6 rz/bt** U11-4. Evaluation of stocked fish U11-5. Evaluation of restoration and management options for Ouray NWR
	U12. Nonnative fish colonization of inundated floodplain depressions may interfere with recovery of endangered fish in those habitats (U.S. Fish and Wildlife Service 2005).	**U12-1. Project Cap-6 bt/rz** **U12-2. Project Cap-6 rz/bt** U12-3. Project 109 U12-4. Project 98a U12-5. Project 98b U12-6. Project 143 U12-7. Evaluation of stocked fish
	U13. The frequency of total drying (reset) needed to control nonnative fish populations (U.S. Department of the Interior and Western Area Power Administration 2005).	**U13-1. Project Cap-6 bt/rz** **U13-2. Project Cap-6 rz/bt** U13-3. Project 109 U13-4. Project 98a U13-5. Project 98b
	U14. For a given volume, lower peak flows for a longer duration could maintain connection to floodplain nursery habitats for a longer period of time and entrain as many or more razorback sucker larvae as higher peak flows for shorter duration. (With recent modifications of levees and intake structures, flows less than the recommended 18,600 cfs may provide significant connection and inundation to floodplain nursery habitats, and subsequent entrainment of razorback sucker larvae.) (U.S. Department of the Interior and Western Area Power Administration 2005).	**U14-1. Project 22f** **U14-2. Project Cap-6 rz/entr** **U14-3. Western aerial photography of 2005 peak flow** U14-4. Project Cap-6HYD U14-5. Evaluation of restoration and management options for Ouray NWR

Table A3. Continued.

General Flow and Temperature Recommendations (Muth et al. 2000)	Anticipated Effects and Uncertainties (Hypotheses)	Relevant Studies (Primary studies in bold)
Reach 2—Spring Peak (continued)		
Peak flows in Reach 2 should be of the magnitude, timing, and duration to provide floodplain inundation in the Ouray portion of the river (continued)	U15. Rates of sediment deposition and erosion in breaches and floodplain depressions as a function of breach configuration, peak flow, and connecting flow magnitude and duration (Muth et al. 2000).	**U15-1 Project Cap-6HYD** **U15-2. Evaluation of restoration and management options for Ouray NWR** U15-3. Project 85f U15-4. Western aerial photography of 2005 peak flow
	U16. The response of nonnative fish populations to spring peak flows (U.S. Fish and Wildlife Service 2005).	**U16-1. Project 109** **U16-2. Project 123** **U16-3. Project 144** U16-4. Project 110 U16-5. Project 98a U16-7. Project 98b U16-8. Project 125 U16-7. Project 140 U16-8. Projects C-18/19 U16-9. Project 124
Reach 2—Summer Through Winter Base		
The mean flow for the summer–winter period should be established each year on the basis of anticipated hydrologic conditions, but adjustments can be made if hydrologic conditions change. Flow should gradually decline from peak flow to base flow, with the base flow reached by early to middle summer (depending on hydrologic conditions) and maintained through February.	**Anticipated Effects** A8. Base flows in summer and autumn scaled to the hydrologic condition favor the formation of backwaters and other low-velocity shoreline nursery habitats (Muth et al. 2000).	**A8-1. Project 138** **A8-2. Western backwater topography study** A8-3. Project 128 A8-4. Project 133 A8-5. Project 144
	A9. Maintenance of the mean base flow within recommended levels of seasonal and within-day flow variability throughout summer, autumn, and winter will promote favorable conditions for all life stages of endangered fishes that use low-velocity habitats (Muth et al. 2000).	**A9-1. Project 138** **A9-2. Project 128** **A9-3. Project 133** **A9-4. Project 144** **A9-5. Western backwater topography study** **A9-6. Evaluation of stocked fish**

Table A3. Continued.

General Flow and Temperature Recommendations (Muth et al. 2000)	Anticipated Effects and Uncertainties (Hypotheses)	Relevant Studies (Primary studies in bold)
Reach 2—Summer Through Winter Base (continued)		
The mean flow for the summer–winter period should be established each year on the basis of anticipated hydrologic conditions (continued)	A10. Gradually declining flows after the spring peak will provide reproductive cues to Colorado pikeminnow and humpback chub adults (Muth et al. 2000).	**A10-1. Project 22f** A10-2. Project 128 A10-3 Project 133 A10-4. Project 138
	A11. Limiting differences in water temperature between the Green and Yampa rivers at their confluence in Echo Park will prevent cold shock to Colorado pikeminnow larvae drifting out of the Yampa River and into the Green River (Muth et al. 2000).	**A11-1. Project 22f** **A11-2. Project 8** **A11-3. Project 19** **A11-4. Project 115** A11-5. Reclamation Program Management (Project 1).
	A12. Warmer temperatures will promote better growth of endangered fishes in the upper portion of Reach 2 (Muth et al. 2000).	**A12-1. Project 115** A12-2. Project 8 A12-3. Project 19 A12-4. Project 128 A12-5. Project 133 A12-6. Evaluation of stocked fish
	Uncertainties U17. The effect of peak flows, sediment availability, and antecedent conditions on the relationship between base flow level and backwater habitat availability (Muth et al. 2000).	**U17-1. Western backwater topography study** **U17-2 Project 85f**
	U18. The effect of base flow variability (within-day, within-season, within-year, between years) on backwater habitat quality (e.g., temperature, productivity) (U.S. Department of the Interior and Western Area Power Administration 2005).	**U18-1. Project 138** **U18-2. Western backwater topography study** **U18-3. Project 144** U18-4. Project 128 U18-5 Project 85f
	U19. The relationship between base flow magnitude and temperature at the confluence (higher base flow targets in wetter years could result in higher temperature differential at the Yampa-Green River confluence) (U.S. Department of the Interior and Western Area Power Administration 2005).	**U19-1. Project 8** **U19-2. Project 19** U19-3. Reclamation Program Management (Project 1).

Table A3. Continued.

General Flow and Temperature Recommendations (Muth et al. 2000)	Anticipated Effects and Uncertainties (Hypotheses)	Relevant Studies (Primary studies in bold)
Reach 2—Summer Through Winter Base (continued)		
The mean flow for the summer–winter period should be established each year on the basis of anticipated hydrologic conditions (continued)	U20. The need for real-time temperature data at the confluence to achieve temperature targets (U.S. Department of the Interior and Western Area Power Administration 2005).	**U20-1. Project 8** **U20-2. Project 19** U20-3. Reclamation Program Management (Project 1).
	U21. The effect of base flows on nonnative fish populations (Muth et al. 2000).	**U21-1. Project 138** **U21-2. Project 123** **U21-3. Project 144** U21-4. Project 110 U21-5. Project 124 U21-6. Project 125 U21-7. Projects C-18/19

Table A4. Matrix of flow and temperature recommendations, hypotheses, and relevant studies for Reach 3 (White River confluence to Colorado River confluence) of the Green River. Language for anticipated effects and uncertainties was taken from Muth et al. (2000), U.S. Department of the Interior and Western Area Power Administration (2005), U.S. Fish and Wildlife Service (2005), or U.S. Department of the Interior (2006). See Table 4 for details of specific studies. Primary studies (bold) and supporting studies are linked to Anticipated Effects (A) or Uncertainties (U) are ordered sequentially.

General Flow/Temperature Recommendations (Muth et al. 2000)	Anticipated Effects and Uncertainties (Hypotheses)	Relevant Studies (Primary studies in bold)
Reach 3—Spring Peak		
Peak flows in Reach 3 should be of the magnitude, timing, and duration to provide floodplain inundation, especially in the upper portion of the reach (between the White River confluence and upper end of Desolation Canyon). In all years, peak flows should be of sufficient magnitude and duration to provide at least some in-channel habitat maintenance throughout the reach. No upper limits are placed on recommended peak flows in any hydrologic condition.	**Anticipated Effects** A13. The anticipated effects of peak flows in Reach 3 for each hydrologic condition are qualitatively similar to those in Reach 2. However, since less floodplain and backwater habitat exists in Reach 3, quantitative differences in the effect of peak flows are expected. Benefits of overbank flooding to razorback suckers are expected to be most important in the upper portions of the reach (between the White River and upper end of Desolation Canyon) where most floodplain inundation will occur (Muth et al. 2000).	**A13-1. Project 138** **A13-2. Western aerial photography of 2005 peak flow** A13-3. Project 128 A13-4. Evaluation of stocked fish (Program)
	A14. Flooded off-channel habitats will benefit young Colorado pikeminnow and razorback suckers in lower Reach 3 and humpback chub in Desolation and Gray Canyons (Muth et al. 2000).	**A14-1. Project 138** A14-2. Project 129 A14-3. Project 128
	A15. Gradually declining flows after the spring peak flow will provide reproductive cues to Colorado pikeminnow and humpback chub adults (Muth et al. 2000).	A15-1. Project 138 A15-2. Project 128 A15-3. Project 129
	Uncertainties U22. The response of nonnative fish populations to spring peak flows (U.S. Fish and Wildlife Service 2005).	**U22-1. Project 123** U22-2. Project 109 U22-3. Projects C-18/C-19 U22-4. Project 144 U22-5. Project 124

Table A4. Continued.

General Flow/Temperature Recommendations (Muth et al. 2000)	Anticipated Effects and Uncertainties (Hypotheses)	Relevant Studies (Primary studies in bold)
Reach 3—Summer Through Winter Base		
Rate of decline from peak flow to base flow should be gradual but will depend largely on rates of decline in tributary flows. Base flow should be reached by early to middle summer (depending on hydrologic conditions) and maintained through February. Actual base flows in Reach 3 will depend on flows targeted for Reach 2 and contributions from intervening tributaries.	**Anticipated Effects** A16. Wet and Moderately Wet: Lower water temperatures at higher base flows in the wettest years may reduce growth and survival of young endangered fish. Average, Dry, and Moderately Dry: Higher water temperatures at lower base flows will enhance growth and survival of young endangered fish, particularly Colorado pikeminnow and humpback chubs (Muth et al. 2000).	**A16-1. Project 138** **A16-2. Project 128** A16-3. Project 129
	Uncertainties. U23. The effect of peak flows, sediment availability, and antecedent conditions on the relationship between base flow level and backwater habitat availability (Muth et al. 2000).	**U23-1. Project 138** **U23-2. Project 85f**
	U24. The effect of base flow variability (within-season, within-year, between years) on backwater habitat quality (e.g., temperature, productivity) (U.S. Department of the Interior and Western Area Power Administration 2005).	**U24-1. Project 138**
	U25. The effect of base flows on nonnative fish populations (U.S. Fish and Wildlife Service 2005).	**U25-1. Project 123** U25-2. Project 109 U25-3. Projects C-18/19 U25-4. Project 144 U25-5. Project 124

Table A5. Evaluation of primary studies as to how well they address flow and temperature recommendations in Reach 1. Y=Anticipated Effect (A) or Uncertainty (U) being addressed by study; P=study partially addresses A or U; NA=study not designed to address A or U; Summary shows how the studies cumulatively satisfy the anticipated effect or uncertainty.

Anticipated Effects (A) and Uncertainties (U)	Primary Studies					
	Project 115	USU Channel Monitoring	UDWR Trout	C18/19	Projects 8 and 19	Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?
Peak Flows						
A1. Channel Maintenance/Complexity	N/A	Y	N/A	N/A	N/A	Y
A2. Channel Maintenance/Spawning	Y	P	N/A	N/A	N/A	Y
U1. Nonnative Entrainment in Spills	Y	N/A	Y	Y	N/A	Y
U2. Peak Flows & Nonnatives	Y	N/A	N/A[2]	N/A	N/A	Y[2]
Base Flows						
A3. CPM Spawning	Y	N/A	N/A	N/A	Y	Y
A4. HBC Expansion	Y	N/A	N/A	N/A	Y	Y
U3. Release of Warmer Water	N/A	N/A	N/A	N/A	Y	Y
U4. Nonnative Response to Base Flows	Y	N/A	N/A	N/A	Y	Y[1]

[1]Indicates need for historic data integration and synthesis.

[2]Recovery Program should contact UDWR to procure data on escapement and to ensure trout monitoring tracks other fish species below Flaming Gorge Dam.

Table A6a. Evaluation of primary studies as to how well they address flow and temperature recommendations at peak flows in Reach 2. Y=Anticipated Effect (A) or Uncertainty (U) being addressed by study; P=study partially addresses A or U; NA=study not designed to address A or U; Summary shows how the studies cumulatively satisfy the anticipated effect or uncertainty.

Anticipated Effect (A) or Uncertainty (U)	Primary Studies								
	Cap 6-rz	Cap 6 bt/rz	Cap 6 rz/bt	Cap 6 rz/entr	Cap 6 HYD	Stocked Fish Evaluation	Western Aerial Photography	Project 128	Project 85f
Peak Flows									
A5. Floodplain Inundation	P	Y	P	P	P	P	P	P	N/A
A6. Channel Maintenance	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	P
A7. Spawning Cues/Reproduction	N/A	N/A	N/A	P	N/A	P	N/A	P	N/A
U5. Habitat Area	N/A	N/A	N/A	N/A	P	N/A	Y	N/A	N/A
U6. Sufficient Inundation of Floodplains	P	P	P	P	Y	N/A	P	N/A	N/A
U7. Floodplain Habitat Persistence	P	P	P	P	P	N/A	Y	N/A	N/A
U8. Entrainment and Distance	N/A	P	N/A	Y	N/A	N/A	N/A	N/A	N/A
U9. Entrainment and Habitat Characteristics	P	N/A	N/A	Y	Y	N/A	N/A	N/A	N/A
U10. Larval Drift and Hydrology	N/A	N/A	N/A	Y	N/A	N/A	N/A	N/A	N/A
U11. Connection Frequency	P	P	P	N/A	N/A	P	N/A	N/A	N/A
U12. Nonnatives in Floodplains	P	Y	Y	N/A	N/A	P	N/A	N/A	N/A
U13. Reset Frequency	P	Y	Y	N/A	N/A	N/A	N/A	N/A	N/A
U14. Lower Target	N/A	N/A	N/A	Y	P	N/A	P	N/A	N/A
U15. Sediment Deposition and Erosion in Floodplains	N/A	N/A	N/A	N/A	Y	N/A	P	N/A	P
U16. Peak Flows & Nonnatives	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[1] Indicates need for historic data integration and synthesis.

Table A6a. Continued.

Anticipated Effect (A) or Uncertainty (U)	Primary Studies (continued)						Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?
	Western Back-water Topography	Project 22f	Ouray NWR Restoration and Manage-ment	Project 109	Project 123	Project 144	
Peak Flows							
A5. Floodplain Inundation	N/A	N/A	N/A	N/A	N/A	N/A	P
A6. Channel Maintenance	P	N/A	N/A	N/A	N/A	N/A	P
A7. Spawning Cues/Reproduction	N/A	Y	N/A	N/A	N/A	P	Y[1]
U5. Habitat Area	N/A	N/A	N/A	N/A	N/A	N/A	Y
U6. Sufficient Inundation of Floodplains	N/A	N/A	N/A	N/A	N/A	N/A	P
U7. Floodplain Habitat Persistence	N/A	N/A	Y	N/A	N/A	N/A	P
U8. Entrainment and Distance	N/A	Y	N/A	N/A	N/A	N/A	Y
U9. Entrainment and Habitat Characteristics	N/A	N/A	P	N/A	N/A	N/A	Y
U10. Larval Drift and Hydrology	N/A	Y	N/A	N/A	N/A	N/A	Y
U11. Connection Frequency	N/A	N/A	P	N/A	N/A	N/A	P
U12. Nonnatives in Floodplains	N/A	N/A	N/A	P	N/A	N/A	Y
U13. Reset Frequency	N/A	N/A	N/A	P	N/A	N/A	P
U14. Lower Target	N/A	Y	P	N/A	N/A	N/A	Y
U15. Sediment Deposition and Erosion in Floodplains	N/A	N/A	Y	N/A	N/A	N/A	P
U16. Peak Flows & Nonnatives	N/A	N/A	N/A	P	P	P	Y[1]

Table A6b. Evaluation of primary studies as to how well they address flow and temperature recommendations at base flows in Reach 2. Y=Anticipated Effect (A) or Uncertainty (U) being addressed by study; P=study partially addresses A or U; NA=study not designed to address A or U; Summary shows how the studies cumulatively satisfy the anticipated effect or uncertainty.

Anticipated Effect (A) or Uncertainty (U)	Primary Studies						
	Project 138	Western Backwater Topography	Project 128	Project 133	Project 144	Stocked Fish Evaluation	Project 22f
Base Flows							
A8. Habitat Availability and Base Flow	P	Y	P	P	P	N/A	N/A
A9. Base Flow Maintenance	Y	Y	Y	Y	Y	P	N/A
A10. CPM and HBC Reproduction/Declining Flows	P	N/A	P	P	N/A	N/A	Y
A11. Cold Shock	N/A	N/A	N/A	N/A	N/A	N/A	Y
A12. Temperatures and Growth	N/A	N/A	Y	Y	N/A	P	N/A
U17. Backwater Habitat Availability and Flow	N/A	Y	N/A	N/A	N/A	N/A	N/A
U18. Base Flow Variability Effects	Y	Y	P	N/A	Y	N/A	N/A
U19. Base Flow and Temperature Tradeoff	N/A	N/A	N/A	N/A	N/A	N/A	N/A
U20. Real Time Temperature Data	N/A	N/A	N/A	N/A	N/A	N/A	N/A
U21. Base Flows and Nonnatives	Y	N/A	N/A	N/A	Y	N/A	N/A

[1]Indicates need for historic data integration and synthesis.

Table A6b. (Continued).

Anticipated Effect (A) or Uncertainty (U)	Primary Studies (continued)				Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?
	Project 8 and 19	Project 115	Project 85f	Project 123	
Base Flows					
A8. Habitat Availability and Base Flow	N/A	N/A	P	N/A	P
A9. Base Flow Maintenance	N/A	N/A	N/A	N/A	P
A10. CPM and HBC Reproduction/Declining Flows	N/A	N/A	N/A	N/A	Y
A11. Cold Shock	Y	P	N/A	N/A	Y
A12. Temperatures and Growth	Y	Y	N/A	N/A	Y
U17. Backwater Habitat Availability and Flow	N/A	N/A	P	N/A	P
U18. Base Flow Variability Effects	N/A	N/A	P	N/A	P
U19. Base Flow and Temperature Tradeoff	P	N/A	N/A	N/A	P
U20. Real Time Temperature Data	P	N/A	N/A	N/A	P[1]
U21. Base Flows and Nonnatives	N/A	N/A	N/A	Y	Y[1]

Table A7. Evaluation of primary studies as to how well they address flow and temperature recommendations in Reach 3. Y=Anticipated Effect (A) or Uncertainty (U) being addressed by study; P=study partially addresses A or U; NA=study not designed to address A or U; Summary shows how the studies cumulatively satisfy the anticipated effect or uncertainty.

Reach 3 Anticipated Effects/Uncertainties	Primary Studies						Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?
	Project 138	Project 128	Western Aerial Photography	Project 129	Project 123	Project 85f	
Peak Flows							
A13. Floodplain Inundation	P	P	P	P	N/A	N/A	P
A14. Flooded Off-channel Habitats	Y	P	N/A	P	N/A	N/A	P
A15. Spawning Cues/Reproduction	P	P	N/A	P	N/A	N/A	P
U22. Peak Flows & Nonnatives	N/A	N/A	N/A	N/A	P	N/A	P
Base Flows							
A16. Base Flow and Temperature	P	P	N/A	P	N/A	N/A	P
U23. Backwater Habitat Availability and Flow	P	N/A	N/A	N/A	N/A	P	P
U24. Base Flow Variability Effects	P	N/A	N/A	N/A	N/A	N/A	P
U25. Base Flows and Nonnatives	N/A	N/A	N/A	N/A	P	N/A	P

Table A8. Evaluation, information needs, recommended studies, and priorities associated with anticipated effects and uncertainties identified for the flow and temperature recommendations. Y=Anticipated Effect (A) or Uncertainty (U) being addressed by study; P=study partially addresses A or U; NA=study not designed to address A or U; Y, P, or N/A show how the studies cumulatively satisfy the anticipated effect or uncertainty.

Anticipated Effects/Uncertainties	Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?	Topic Not Addressed by Studies (information needs)	Recommended Studies	Priority
Reach 1 – Peak Flows				
A1. Channel Maintenance/Complexity	Y	• None	• Continue occasional channel monitoring	L
A2. Channel Maintenance/Spawning	Y	• None	• Continue occasional channel monitoring • Continue larval CPM monitoring in lower Lodore	M
U1. Nonnative Entrainment in Spills	Y	• Spillway entrainment rates	• Program Coordination with UDWR sampling • Continue fish community monitoring in Lodore • Drift net and sample spillway waters • Continue isotope work	M/H
U2. Peak Flows & Nonnatives	Y[1]	• What part of the life history aspect of nonnative fish do flows impact?	• Continue fish community monitoring in Lodore • Program Coordination with UDWR sampling	H
Reach 1 – Base Flows				
A3. CPM Spawning	Y	• None	• Continue larval CPM monitoring in lower Lodore • Continue flow and temperature monitoring • Continue fish community monitoring in Lodore	M
A4. HBC Expansion	Y	• None	• Continue fish community monitoring in Lodore • Continue flow and temperature monitoring	M
U3. Release of Warmer Water	Y	• None	• Continue flow and temperature monitoring	L
U4. Nonnative Response to Base Flows	Y[1]	• What part of the life history aspect of nonnative fish do flows impact?	• Continue fish community monitoring in Lodore • Continue flow and temperature monitoring	H

Table A8. Continued.

Anticipated Effects/Uncertainties	Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?	Topic Not Addressed by Studies (information needs)	Recommended Studies	Priority
Reach 2 – Peak Flows				
A5. Floodplain Inundation	P	• Escapement of RBS to the river • Habitat quality.	• Continue occasional aerial photography • Measure connection elevations and river flows for floodplains • Continue larval entrainment, growth, and survival studies • Initiate study on escapement of razorback sucker to the river • Initiate study of floodplain habitat quality	H
A6. Channel Maintenance	P	• Channel narrowing • Channel complexity	• Evaluate application of SWMS model to evaluate channel narrowing and complexity • Continue occasional aerial photography	M/L
A7. Spawning Cues/Reproduction	Y[1]	• None	• Continue larval drift studies • Continue taking weight and condition measures of fish from population estimates • Continue CPM YOY monitoring	L
U5. Habitat Area	Y	• None	• Continue occasional aerial photography • Establish bankfull reference	H
U6. Sufficient Inundation of Floodplains	P	• Escapement of RBS to the river • Habitat quality.	• Continue occasional aerial photography • Measure connection elevations and river flows for floodplains • Continue larval entrainment, growth, and survival studies • Initiate study on escapement of razorback sucker to the river • Initiate study of floodplain habitat quality	H
U7. Floodplain Habitat Persistence	P	• Intra and inter-annual persistence of water in floodplains	• Initiate study of floodplain habitat quality; e.g., monitor inundated floodplains in fall, winter (may be new study or addition)	H
U8. Entrainment and Distance	Y	• None	• Analyze historic data and, as needed, continue larval drift and bead entrainment studies	M/L

Table A8. Continued.

Anticipated Effects/Uncertainties	Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?	Topic Not Addressed by Studies (information needs)	Recommended Studies	Priority
Reach 2 – Peak Flows (continued)				
U9. Entrainment and Habitat Characteristics	Y	• None	• Determine levee breach configuration that enhances entrainment (ongoing revised)	H
U10. Larval Drift and Hydrology	Y	• None	• Continue larval drift studies • Integrate larval drift, flow, and temperature data	H
U11. Connection Frequency	P	• Escapement of RBS to the river • Habitat quality.	• Measure connection elevations and river flows for floodplains • Continue larval entrainment, growth, and survival studies • Initiate study on escapement of razorback sucker to the river • Initiate study of floodplain habitat quality	H
U12. Nonnatives in Floodplains	Y	• None	• Continue to evaluate escapement of razorback sucker to the river • Investigate alternatives to the reset theory, if necessary	L
U13. Reset Frequency	P	• Escapement of RBS to the river • Evaluate partial reset.	• Measure connection elevations and river flows for floodplains • Continue larval entrainment, growth, and survival studies • Initiate study on escapement of razorback sucker to the river (possibly actively test with experiments; line item under RBS escapement category as bigger issue)	M
U14. Lower Target	Y	• None	• Continue larval and bead entrainment studies • Continue larval monitoring in the mainstem (light traps, first appearance of larvae) • Continue occasional aerial photography	H
U15. Sediment Deposition and Erosion in Floodplains	P	• Monitoring of geomorphic changes through time.	• Monitor of geomorphic changes through time • Continue occasional aerial photography	H

Table A8. Continued.

Anticipated Effects/Uncertainties	Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?	Topic Not Addressed by Studies (information needs)	Recommended Studies	Priority
Reach 2 – Peak Flows (continued)				
U16. Peak Flows & Nonnatives	Y[1]	• What part of the life history aspect of nonnative fish do flows impact?	• Evaluate historic data sets • Continue nonnative fish management and evaluate endangered fish response	M
Reach 2 – Base Flows				
A8. Habitat Availability and Base Flow	P	• Relationship between peak flow and sediment and habitat development.	• Evaluate application of SWMS model to understand relationship between backwater habitat development and peak flow events • Aerial photography at base flows • Continue backwater studies • Continue sediment studies • Continue to collect physical habitat data on backwaters during fall age 0 CPM monitoring	H
A9. Base Flow Maintenance	P	• Habitat conditions at beginning of baseflow period	• Continue CPM YOY monitoring • Continue CPM population estimates • Continue monitoring of backwater topography and physical conditions (consider measuring earlier) • Synthesize physical and biological information already collected • Consider evaluation of fish communities in backwater habitats at beginning of baseflow period (concerns regarding sampling impacts) • Link physical measurements with YOY monitoring	H
A10. CPM and HBC Reproduction/Declining Flows	Y	• None	• Continue larval drift studies • Continue CPM YOY monitoring • Continue CPM population estimates • Continue monitoring HBC in Whirlpool Canyon	L

Table A8. Continued.

Anticipated Effects/Uncertainties	Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?	Topic Not Addressed by Studies (information needs)	Recommended Studies	Priority
Reach 2 – Base Flows (continued)				
A11. Cold Shock	Y	• None	• Continue larval drift studies • Continue temperature monitoring • Continue monitoring of fish community in Whirlpool Canyon	L
A12. Temperatures and Growth	Y	• None	• Continue monitoring of fish community in Whirlpool Canyon with possibly greater emphasis on growth	L
U17. Backwater Habitat Availability and Flow	P	• Relationship between peak flow, sediment, and habitat development.	• Evaluate application of SWMS model to understand relationship between backwater habitat development and peak flow events • Aerial photography at base flows • Continue physical measurements of backwaters • Continue sediment studies • Continue to collect physical habitat data on backwaters during fall age 0 CPM monitoring	H
U18. Base Flow Variability Effects	P	• Habitat conditions at beginning of baseflow period	• Continue CPM YOY monitoring • Continue CPM population estimates • Continue monitoring of backwater topography and physical conditions (consider measuring earlier) • Synthesize physical and biological information already collected • Consider evaluation of fish communities in backwater habitats at beginning of baseflow period (concerns regarding sampling impacts) • Link physical measurements with YOY monitoring	H
U19. Base Flow and Temperature Tradeoff	P	• Optimum solution that maximizes flow and temperature conditions	• Continue temperature monitoring • Continue backwater studies identified for U18	M

Table A8. Continued.

Anticipated Effects/Uncertainties	Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?	Topic Not Addressed by Studies (information needs)	Recommended Studies	Priority
Reach 2 – Base Flows (continued)				
U20. Real Time Temperature Data	P[1]	• Effect of release temperature and flow on temperature at the Yampa River confluence	• Evaluate historical temperature data • Use existing model or modify model to better predict temperature at confluence	L
U21. Base Flows and Nonnatives	Y[1]	• What part of the life history aspect of nonnative fish do flows impact?	• Evaluate historic data • Continue CPM YOY monitoring • Continue evaluation of endangered fish response to nonnative control • Continue nonnative studies • Continue backwater studies identified for U18	H
Reach 3 – Peak Flows				
A13. Floodplain Inundation and Backwater Habitat Formation	P	• Backwater habitat availability and characteristics	• Continue occasional aerial photography • Continue CPM YOY monitoring • Continue to collect physical habitat data on backwaters during fall age 0 CPM monitoring • Continue CPM population estimates • Continue HBC population estimates	L
A14. Flooded Off-channel Habitats	P	• None	• Continue CPM population estimates • Continue HBC population estimates	L
A15. Spawning Cues/Reproduction	P	• Larval drift information	• Continue taking weight and condition measures of fish from population estimates • Continue CPM YOY monitoring • Continue larval drift studies	L
U22. Peak Flows & Nonnatives	P	• None	• Continue nonnative studies • Continue documenting nonnative fish occurrence during CPM population estimates	L
Reach 3 – Base Flows				
A16. Base Flow and Temperature	P	• None	• Continue CPM population estimates • Continue HBC population estimates • Continue CPM YOY monitoring	L

Table A8. Continued.

Anticipated Effects/Uncertainties	Taken Together, Do Studies Fully Address Anticipated Effects and Uncertainties?	Topic Not Addressed by Studies (information needs)	Recommended Studies	Priority
Reach 3 – Base Flows (continued)				
U23. Backwater Habitat Availability and Flow	P	• Backwater habitat availability and characteristics • Relationship between peak flow, sediment, and habitat availability	• Continue to collect physical habitat data on backwaters during fall age 0 CPM monitoring	M
U24. Base Flow Variability Effects	P	• Backwater habitat availability and characteristics	• Continue to collect physical habitat data on backwaters during fall age 0 CPM monitoring	H
U25. Base Flows and Nonnatives	P	• What part of the life history aspect of nonnative fish do flows impact?	• Continue CPM YOY monitoring • Continue nonnative studies • Evaluate historic data	M

[1]Indicates need for historic data integration and synthesis.