MEMORANDUM

TO: Members of the Glen Canyon Dam Adaptive Management Work Group (AMWG)

FROM: Members of the Technical Work Group (TWG)

CC: AMWG Alternates and interested parties

DATE: December 20, 2002

RE: Report for your January 2003 meeting

Direction from AMWG

At your April 25, 2002 meeting, you directed the Technical Work Group (TWG) to do the following:

- use a paired comparison exercise for putting Information Needs (INs) in sequence order,
- approve the INs they have consensus on, and forward these to AMWG, and
- finish its work on INs in time for a recommendation to AMWG for final approval at its January 2003 meeting

TWG Action

The TWG passed the following motion at its meeting on November 7, 2002:

"The Technical Work Group has sequenced the entire set of Information Needs as directed by AMWG. The TWG is unable to recommend approval of the INs, absent the criteria for what is in and out of the program. Therefore, TWG recommends that this list be approved by AMWG only after it has been subjected to AMWG-approved criteria for what is in and out of the AMP."

Please find attached the following documents:

1. A document entitled "Action Taken on the Strategic Plan by the TWG, November 7, 2002," which details proposed changes by the TWG to the Information Needs and their sequence order, as well as a proposed change to a Management Objective.

2. A document entitled "Glen Canyon Dam Adaptive Management Program, Final Draft Information Needs, November 7, 2002," which shows Goals, Management Objectives, and Information Needs, organized by Goal and Management Objective, with the proposed sequence order of the Information Needs. This document incorporates all the proposed changes noted in document #1, "Action Taken on the Strategic Plan by the TWG, November 7, 2002."

3. A document entitled "Information Needs Sequencing Exercise Results, Organized by Sequence Order, Updated November 7, 2002," which shows only Information Needs, organized by sequence order.

Information Needs Sequencing Exercise Results Organized by Sequence Order
Updated November 7, 2002

Sequence Order 1
(***2 Information Needs***)

RIN 2.1.2 Quantify sources of mortality for humpback chub < 51 mm in rearing habitats in the LCR and mainstem and how these sources of mortality are related to dam operations.

RIN 12.3.3 What are the best scientific methods to determine cause and effect relationships in experiments and other management actions conducted under the GCDAMP?

Sequence Order 1.5
(***1 Information Need***)

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

Sequence Order 2
(***13 Information Needs***)

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

RIN 2.1.5 Determine the timing and quantity of young-of-year humpback chub dispersal (passive and active) from the LCR.

RIN 2.2.3 What are the measurable criteria that need to be met in order to remove jeopardy for humpback chub in the Colorado River ecosystem?

RIN 2.2.5 What are the appropriate habitat conditions for HBC spawning? Where are these found? Can they be created in the mainstem?

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

RIN 2.2.9 What is the appropriate role of humpback chub augmentation as a management strategy to establish mainstem spawning aggregations?

RIN 2.3.2 How will warming mainstem temperatures affect the abundance and distribution of parasites/disease?

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

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

RIN 2.6.1 What is a viable population? What is the probability of extinction over what management time period for species of concern? What is the appropriate method to assess viability?

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

RIN 5.2.2 How does the size and quality of the habitat used by Kanab ambersnail change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

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RIN 12.9.2 What is the best combination of dam operations and other management actions to achieve the vision, mission, goals, and objectives of the GCDAMP?
RIN 12.9.3 What are the relationships between dam operations and other management actions in their effects on resources addressed by GCDAMP management objectives?
Sequence Order 2.5 (***7 Information Needs***)
RIN 2.1.1 What is the minimum population size of HBC that should be sustained in the LCR, to ensure a viable spawning population of HBC in the LCR?
RIN 2.2.4 What is the relationship between the "aggregations" in the mainstem and LCR? Are mainstem aggregations "sinks" of the LCR? Are aggregations real or due to sampling bias?
RIN 2.4.2 Determine if suppression of non-native predators and competitors increases native fish populations?
RIN 2.4.6 What are the population dynamics of those non-native fish that are the major predators and competitors of native fish?
RIN 4.2.1 What is the rate of emigration of rainbow trout from the Lees Ferry reach?
RIN 4.2.2 What is the most effective method to detect emigration of rainbow trout from the Lees Ferry reach?
RIN 5.1.5 What is the taxonomic identity of the *Oxyloma* snails at Vasey's Paradise? Is a change to the existing taxonomic status warranted?
RIN 5.1.6 What is the range of occurrence of the ambersnail taxon found at Vasey's Paradise? [NOTE: Intended to address the issue of whether this is an endemic population or a relict population or part of a metapopulation.]
Sequence Order 3 (***12 Information Needs***)
RIN 1.5.3 How has the value and availability of drift as a food source for Humpback chub changed with the implementation of Record of Decision operations?
RIN 2.2.7 Determine if implementation and operation of the TCD and/or steady flows represent a technically feasible, ecologically sustainable, and practical option for establishing mainstem spawning.
RIN 2.2.10 What techniques are available to determine natal stream of fishes in the Colorado River ecosystem?
RIN 2.2.12 What are the impacts of research activities on mortality, recruitment and the population size of humpback chub?
RIN 2.3.1 How do parasite/disease loads affect population viability?
RIN 2.4.4 What are the target population levels, body size and age structure for non-native fish in the Colorado River ecosystem that limit their levels to those commensurate with the viability of native fish populations?
RIN 2.4.5 What are the sources (natal stream) of nonnative predators and competitors?
RIN 5.1.9 How can incidental take for Kanab ambersnail at Vasey's Paradise be minimized?

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RIN 7.1.3 What are the potential ecological effects of increasing mainstem water temperatures?
RIN 7.4.4 How does flow rate and fluctuation affect habitat availability and utilization by fish and other organisms?
RIN 11.1.3 What are the thresholds triggering management actions?
RIN 12.2.4 What historic data sets currently exist for all resources targeted by management objectives in the GCDAMP?
IN 12.1 Develop information that can be used by the TWG, in collaboration with GCMRC, to establish current and target levels for all resources within the AMP as called for in the AMP strategic plan.
RIN 12.9.1 What is the impact on downstream resources of short-term increases to maximum flow, daily fluctuations and downramp limits?
Sequence Order 3.5 (***6 Information Needs***)
RIN 2.2.1 What is a viable population and what is the appropriate method to assess population viability of native fish in the Colorado River ecosystem? What is an acceptable probability of extinction over what management time period for humpback chub throughout the Colorado River ecosystem?
RIN 2.3.3 How does non-native fish control affect disease/parasite loads? [Note: The concept is if there are fewer hosts, there will be a lower incidence of parasites.]
RIN 4.2.7 What dam release patterns most effectively maintain the Lees Ferry RBT trophy fishery while limiting RBT survival below the Paria River?
RIN 11.1.2 What are the historic properties within the area of potential effects?
RIN 11.1.2.a For each tribe and living community, what are the register eligible traditional cultural properties?
RIN 12.2.1 What is the most appropriate field sampling method(s) (e.g., sampling size, spatial and temporal distribution, analysis, explicit assumptions, limitations and uncertainties) and statistical analysis to monitor the status and trends of resources targeted by management objectives?
RIN 12.2.6 What are the acceptable detection levels for change in Colorado River ecosystem resources? How should those levels most appropriately be determined and who should make the determinations?
Sequence Order 4 (***19 Information Needs***)
RIN 1.1 What are the fundamental trophic interactions in the aquatic ecosystem?
RIN 1.4 What is the current carbon budget for the Colorado River ecosystem?
RIN 2.2.2 Determine if a population dynamics model can effectively predict viability of native fish under different flow regimes and environmental conditions.
RIN 2.2.6 What are the criteria for establishment of spawning aggregations (i.e., how does one determine its "established")?

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RIN 2.6.4 How are movement patterns for flannel-mouth sucker, blue-head sucker and speckled dace in the Colorado River ecosystem affected by age, natal stream and dam operations?
RIN 2.6.5 How is the rate of mortality for flannel-mouth sucker, blue-head sucker and speckled dace in the Colorado River ecosystem related to individual body size? What are the sources of mortality for flannel-mouth sucker, blue-head sucker and speckled dace in the Colorado River ecosystem?
RIN 5.1.4 Identify and evaluate alternative Management Actions to ensure viability of Kanab ambersnail at Vasey's Paradise where (1) the population dynamic model predicts loss of population viability, or (2) monitoring discovers substantial habitat or Kanab ambersnail population declines.
RIN 5.1.8 What are the measurable criteria that need to be met to remove jeopardy for Kanab ambersnail at Vasey's Paradise?
RIN 6.4.1 How has the abundance, composition, and distribution of the sand beach community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?
RIN 6.5.3 How has the abundance and distribution of non-native species changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?
RIN 7.1.2 What are the most likely downstream temperature responses to a variety of scenarios involving a TCD on Glen Canyon Dam?
RIN 7.2.3 Which metals should be measured? Where and how often?
RIN 7.4.3 How do changes in flow volume and rate of change affect food base and energy productivity in the Colorado River ecosystem?
RIN 8.5.1 What elements of Record of Decision operations (upramp, downramp, maximum and minimum flow, MLFF, HMF, and BHBF) are most/least critical to conserving new fine-sediment inputs, and stabilizing sediment deposits above the 25,000 cfs stage?
SIN 8.5.3 What is the relationship between turbidity and biological processes?
SIN 8.5.6 What are the grain-size characteristics of sand bars associated with designated riparian vegetation zones?
RIN 11.1.1 What are the sources of impacts to historic properties?
RIN 11.1.3.b How should adverse effects to historic properties be mitigated?
RIN 11.2.3 Determine acceptable methods to preserve or treat traditionally important resources within the Colorado River ecosystem.
Sequence Order 4.5 (***17 Information Needs***)
RIN 2.5.3 What characteristics define suitable habitat for razorback sucker? Does suitable habitat for razorback sucker occur in the Colorado River ecosystem?
RIN 2.6.3 What is the age structure, including relationship between age and size of flannel-mouth sucker, blue-head sucker and speckled dace in the Colorado River ecosystem?

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RIN 4.1.3 To what extent is there overlap in the Lees Ferry reach of RBT habitat and native fish habitat?
RIN 4.2.3 How is the rate of emigration of RBT from the Lees Ferry reach to below the Paria River affected by abundance, hydrology, temperature, and other ecosystem processes?
RIN 4.2.5 To what extent is there overlap in the Colorado River ecosystem below the Paria River of RBT habitat and native fish habitat?
RIN 6.2.1 How has the patch number, patch distribution, composition and area of the NHWZ community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?
RIN 6.5.1 Determine if non-native species are expanding or contracting at a local scale (patch or reach).
SIN 7.2.2 Which water quality variables influence food base and fisheries in the Colorado River ecosystem?
IN 8.1 If sediment cannot be preserved in the system using available management actions, what is the feasibility (including technical, legal, economic, and policy issues) of sediment augmentation as a means of achieving this goal?
SIN 8.5.4 What is the role of turbidity and how can it be managed to achieve biological objectives?
RIN 8.6.2 How do ongoing inputs of coarse sediment from tributaries alter the distribution of main channel habitats needed by benthic organisms within pools, runs and eddies throughout the Colorado River ecosystem?
RIN 11.2.1 What are traditionally important resources and locations for each tribe and other groups?
RIN 11.2.2 What is the baseline measure for resource integrity?
RIN 12.1.1 What is the necessary quantity and quality of cultural and socioeconomic information for adequate decision-making?
RIN 12.3.1 What are the most effective method(s) to integrate and synthesize resource data to increase our understanding of the past and for ongoing interactions of humans with the Colorado River ecosystem.
RIN 12.4.1 What are the most effective methods to maintain or attain the participation of externally-funded investigators?
RIN 12.5.5 Identify the desired level of information, education, and outreach provided for Glen and Grand Canyon river users and the general public?
Sequence Order 5 (***52 Information Needs***)
RIN 1.2 How is the production, composition, density and biomass of the benthic invertebrate community affected by primary productivity vs. allochthonous inputs?
RIN 1.3 What foodbase criteria do other agencies use to assess aquatic ecosystem health?
RIN 1.1.1 How are the composition and biomass of primary producers between Glen Canyon Dam and the Paria River affected by flow and water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), and water borne diseases, or other factors.

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RIN 1.1.4 What are the habitat characteristics between Glen Canyon Dam and the Paria River that most affect primary productivity? How are these characteristics affected by Glen Canyon Dam operations?
RIN 1.2.1 How are the composition and biomass of benthic invertebrates between Glen Canyon Dam and the Paria River affected by flow, water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), new invasive species, and water borne diseases, or other factors?
RIN 1.2.2 What is the estimated productivity of benthic invertebrates for the reach between Glen Canyon Dam and the Paria River? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]
RIN 1.4.1 How are the composition and biomass of benthic invertebrates in the Colorado River ecosystem below the Paria River affected by flow, water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), new invasive species, and water borne diseases, or other factors? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]
RIN 1.5.2 How do top-down effects (grazing and predation) affect the abundance and composition of drift?
RIN 2.6.6 How does temperature modification in the mainstem affect recruitment and mortality for flannel-mouth sucker, blue-head sucker and speckled dace originating from tributary spawning efforts?
RIN 5.1.2 What parameters have the greatest influence on population viability of Kanab ambersnail at Vasey's Paradise (e.g., parasites, predation, discharges, habitat size, quality, and human use/visitation)?
RIN 5.1.3 Develop a population dynamic model to predict Kanab ambersnail viability under different flows and environmental conditions.
RIN 5.2.1 How does the size, quality, and recovery time of Kanab ambersnail habitat change following natural scours, or other events?
IN 6.4 How much allochthonous material (e.g., leaf litter) is exchanged between the terrestrial and aquatic systems?
RIN 6.1.1 How has the abundance, composition, distribution, and area of the marsh community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?
RIN 6.3.2 What management actions have the potential to maintain the OHWZ community at the current stage elevation, or establish the community at a lower stage elevation?
RIN 6.5.2 What management actions have the potential to increase or decrease the distribution and abundance of non-native species?
RIN 6.6.2 Which seeps and springs are culturally important or occupied by rare and endemic species?
RIN 7.1.1 What are the desired ranges of spatial and temporal patterns of water temperatures for the Colorado River ecosystem?
RIN 7.2.1 Which major ions should be measured? Where and how often?
RIN 7.2.2 Which nutrients should be measured? Where and how often?

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SIN 7.2.1 How do the hydrodynamics and stratification of Lake Powell influence the food base or fisheries downstream?
RIN 7.3.1 Develop simulation models for Lake Powell and the Colorado River to predict water quality conditions under various operating scenarios, supplant monitoring efforts, and elucidate understanding of the effects of dam operations, climate, and basin hydrology on Colorado River water quality.
RIN 7.4.2 What is the desired pattern of seasonal and annual flow dynamics associated with powerplant operations, BHBFs, HMFs, or other flows to meet AMP Goals and Objectives?
RIN 8.1.1 What is the longitudinal variability of fine-sediment inputs, by reach?
RIN 8.1.2 What is the temporal variability of fine-sediment inputs, by reach?
RIN 8.1.3 What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]
RIN 8.2.1 What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]
RIN 8.3.1 What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]
RIN 8.4.1 What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]
RIN 8.5.4 What is the significance of aeolian processes in terrestrial sandbar reworking?
RIN 8.5.6 What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]
SIN 8.5.2 What is the relationship between the fine-sediment budget and turbidity?
SIN 8.5.5 How can the ongoing fine sediment supply be managed to achieve sustainable habitats?
RIN 9.3.1 What is the desired target level of camping beaches by reach?
RIN 10.1.2 What would be the effects on the Colorado River ecosystem and marketable capacity and energy of increasing the upramp and downramp limit?
RIN 10.1.3 What would be the effects on the Colorado River ecosystem and marketable capacity and energy of raising the maximum power plant flow limit above 25,000 cfs?
RIN 10.3.1 What are the effects of providing financial exception criteria?
RIN 11.1.1.a What and where are the geomorphic processes that link loss of site integrity with dam operations as opposed to dam existence or natural processes?
RIN 11.1.1.b What are the terrace formation processes and how do dam operations affect current terrace formations processes?

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RIN 11.1.1.c Determine if and where dam operations cause accelerated erosion to historic properties?
RIN 11.1.1.d What are the potential threats to historic properties relative to integrity and significance?
RIN 11.1.2.b How do specific sites meet National Register Criteria for Evaluation?
RIN 11.1.2.c Identify AMP activities that affect National Register eligible sites?
RIN 1.1.3.a Determine the necessary information to assess resource integrity.
RIN 11.2.4 What changes are occurring in cultural resource sites, and what are the causes of those changes?
RIN 12.3.4 How well do research designs and workplans do in incorporating Tribal perspectives and values into the standard western science paradigm? Is it more beneficial to keep the perspective separated?
RIN 12.3.5 How effective is the AMP in addressing the EIS statement "Long-term monitoring and research are … implemented to measure how well the selected alternative meets resource management objectives."?
RIN 12.5.1 What are the most effective means to build AMP public support through effective public outreach?
RIN 12.5.2 What are the most effective means to attain and maintain effective communication and coordination with other resource management programs in the Colorado River basin to ensure consideration of their values and perspectives into the AMP and vice versa?
RIN 12.5.4 What is the most effective way to distribute information to our stakeholders and the public in a secure and accessible fashion?
RIN 12.7.1 How effective are the current strategies to achieve tribal consultation?
RIN 12.7.2 How well do the current strategies to achieve tribal consultation meet legal and AMP protocols?
RIN 12.8.1 How well does current tribal participation in the AMP research and long-term monitoring programs meet tribal needs and desires?
Sequence Order 5.5 (***15 Information Needs***)
RIN 1.2.4 What are the habitat characteristics between Glen Canyon Dam and the Paria River that most affect benthic invertebrates? How are these characteristics affected by Glen Canyon Dam operations?
RIN 1.3.1 How are the composition and biomass of primary producers in the Colorado River ecosystem below the Paria River affected by flow and water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), and water borne diseases, or other factors.
RIN 1.4.3 How do top-down effects (grazing and predation) affect the abundance and composition of benthic invertebrates?
RIN 1.5.1 How are the composition and biomass of drift in the Colorado River ecosystem affected by flow and water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), and water borne diseases, or other factors?

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RIN 4.2.4 What is the target population size of RBT appropriate for the Lees Ferry reach that limits downstream emigration?
IN 6.4 How much allochthonous material (e.g., leaf litter) is exchanged between the terrestrial and aquatic systems?
RIN 6.3.1 How has the abundance, composition, and distribution of the OHWZ community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?
RIN 6.7.5 What is the need, feasibility, and priority of maintaining habitat suitability for southwestern willow flycatcher in the Colorado River ecosystem?
RIN 8.5.2 What is the reach-scale variability of fine-sediment storage throughout the main channel?
RIN 8.5.5 What are the historic and ongoing longitudinal trends of fine-sediment storage, above 25,000 cfs?
SIN 8.5.7 What are the limiting factors that regulate substrate availability and its distribution?
RIN 9.4.1 Identify the elements of wilderness experience specific to the Colorado River ecosystem.
RIN 10.1.4 What would be the effects on the Colorado River ecosystem and marketable capacity and energy of lowering the minimum flow limit below 5,000 cfs?
RIN 11.1.2.d Identify NPS permitted activities that affect National Register eligible sites.
RIN 11.1.5 What are appropriate strategies to preserve resource integrity?
RIN 12.2.8 Determine accurate, reliable, and standardized methods for measuring erosion at historic sites.
Sequence Order 6 (***15 Information Needs***)
RIN 1.1.3 How do top-down effects (grazing and predation) on primary producers affect food base productivity?
RIN 1.2.3 How do top-down effects (grazing and predation) affect the abundance and composition of benthic invertebrates?
RIN 1.3.3 How do top-down effects on primary producers (grazing and predation) affect food base productivity?
RIN 1.3.4 What are the habitat characteristics in the Colorado River ecosystem below the Paria River that most affect primary productivity? How are these characteristics affected by Glen Canyon Dam operations?
RIN 1.4.4 What are the habitat characteristics in the Colorado River ecosystem below the Paria River that most affect benthic invertebrates? How are these characteristics affected by Glen Canyon Dam operations?
RIN 2.2.11 What are the impacts of current recreational activities on mortality, recruitment and the population size of humpback chub?
RIN 2.6.2 What are the physical and biological characteristics of habitats that enhance recruitment of flannel-mouth sucker, blue-head sucker and speckled dace populations in the Colorado River ecosystem?

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IN 6.1 Develop GIS coverages of natural communities in the Colorado River ecosystem to use in identification of status and trends.
IN 6.3 How is the abundance of vertebrate consumers affected by seasonal shifts in food base abundance in the Colorado River ecosystem?
SIN 7.3.1 Measure appropriate water quality parameters to determine the influence of these parameters on biological resources in the Colorado River ecosystem.
SIN 8.5.8 What is the total area of different aquatic habitat types (cobble, gravel, sand, talus, etc,) in the Colorado River ecosystem?
SIN 8.5.9 How are sandbar textures related to cultural site stability?
RIN 10.1.1 What would be the effects on the Colorado River ecosystem and marketable capacity and energy of increasing the daily fluctuation limit?
RIN 10.4.1 What are the effects on the Colorado River ecosystem and marketable power and energy of increasing Automatic Generation Control at Glen Canyon Dam?
RIN 12.2.3 What digital, or other, technologies exist and should be used to record field observations and spatially reference these data to facilitate their integration into GCMRC databases and use by PI's and stakeholders?
RIN 12.3.2 What are the differences between western science and tribal processes for design of studies and for gathering, analyzing, and interpreting data used in the adaptive management program?
RIN 12.5.3 To what extent does the public understand and support the GCDAMP?
Sequence Order 6.5 (***6 Information Needs***)
RIN 5.1.1 What constitutes population viability for Kanab ambersnail at Vasey's Paradise?
RIN 5.2.3 How can remote sensing technologies be used to less intrusively and more cost effectively characterize and monitor Kanab ambersnail habitat at Vasey's Paradise (vegetation type and distribution)?
IN 6.2 Develop or adopt an existing ecological community classification system. The system should describe the composition and frequency of vascular plants, vertebrates, arthropods, and mollusks to an appropriate taxonomic level.
RIN 7.2.4 What are the water-borne pathogens that are a threat to human health? How should they be monitored? Where and how often?
RIN 8.6.1 How do ongoing inputs of coarse sediment from tributaries influence storage of fine sediment within pools, runs and eddies throughout the Colorado River ecosystem?
RIN 12.2.2 What remote sensing technologies are available to less intrusively and more cost effectively monitor, characterize and map: (a) the aquatic food base, (b) fish, (c) fish habitat features, (d) Kanab ambersnail habitat, (e) water quality parameters, (f) bathymetry and associated substrates and (g) cultural sites?

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Sequence Order 7
(***4 Information Needs***)

RIN 6.5.4 How can remote sensing assist in the development of a map of non-native species distributions in the Colorado River ecosystem including characterization of the types of habitat that supports non-native species?

RIN 9.5.1 What effects do administrative trips, including research and monitoring activities have on recreational users?

IN 10.1 Determine and track the impacts to power users from implementation of Record of Decision dam operations and segregate those effects from other causes such as changes in the power market.

RIN 12.2.5 What remote sensing data are available or can be obtained that will support the production of a system-wide resource map?

RIN 12.2.7 How can GIS be used to designate and stratify habitats to improve system-wide extrapolation of population estimates and habitat in the Colorado River ecosystem?

Sequence Order 7.5
(***2 Information Needs***)

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

SIN 8.5.10 How are sandbar textures related to recreational site stability?

Sequence Order 8
(***6 Information Needs***)

RIN 1.3.2 What is the estimated primary productivity in the Colorado River ecosystem below the Paria River? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]

RIN 1.4.2 What is the estimated productivity of benthic invertebrates in the Colorado River ecosystem below the Paria River? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]

RIN 2.5.4 What is the feasibility and advisability of augmenting razorback sucker in the Colorado River ecosystem to attain a viable population including technical/legal/policy constraints?

RIN 6.7.1 What is the function of the Colorado River ecosystem as a migratory corridor for southwestern willow flycatcher?

RIN 6.7.2 What is the foodbase that supports southwestern willow flycatcher and other terrestrial vertebrates?

RIN 6.7.3 What constitutes suitable southwestern willow flycatcher habitat?

Sequence Order 8.5
(***1 Information Need***)

RIN 6.6.3 How has the composition, abundance and distribution of seep and spring communities changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?

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Sequence Order 9
(***9 Information Needs***)

RIN 1.1.2 What is the estimated productivity for the reach between Glen Canyon Dam and the Paria River? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]
RIN 2.5.5 What are the genetic and ecological criteria for reintroducing razorback sucker into the Colorado River ecosystem?
RIN 4.1.2 What is the minimum quantity and quality of spawning substrate necessary for maintaining a wild reproducing rainbow trout population in the Lees Ferry reach?
RIN 5.1.7 What is the historic range of Oxyloma haydeni? Can this range be determined from subfossil or fossil evidence? [NOTE: This is intended to determine if this is a relict species and the initial work would be done at Vasey's Paradise, South Canyon and other probable sites within the Colorado River ecosystem.]
RIN 6.6.1 How is seep and spring habitat affected by variation in dam operations, variation in seep or spring flow, and variation in water quality? How do flow rates and water quality parameters at seeps and springs compare with historic measurements?
RIN 6.6.4 What is the distribution, patch size, total area, and composition of seep and spring communities and the flow rate and water quality of all seeps and springs within the Colorado River ecosystem?
RIN 6.7.4 How has the abundance, distribution and reproductive success of southwestern willow flycatcher changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?
RIN 7.3.3 How do dam operations affect reservoir limnology?
SIN 8.5.1 How do sandbar textures influence biological processes?
EIN 11.3.1 Determine if and how experimental flows and other AMP actions restrict tribal access.
EIN 11.3.2 Determine reasonable management actions that should be taken to facilitate tribal access.

Sequence Order 9.5
(***2 Information Needs***)

RIN 3.1.1 What information (including technical, legal, economic, and policy issues) should be considered in determining the feasibility and advisability of restoring pikeminnow, bonytail, roundtail chub, river otter, or other extirpated species?
RIN 8.5.3 What is the pre- and post-dam range of grain-size in fine-sediment deposits, by reach?

Sequence Order 10
(***2 Information Needs***)

RIN 4.1.1 What is the target proportional stock density (i.e., trade-off between numbers and size) for rainbow trout in the Lees Ferry reach?
RIN 4.1.4 How does the genetics or "strain" of rainbow trout in the Lees Ferry reach influence the average size of fish creeled by anglers?

Information Needs Sequencing Exercise Results
Organized by Sequence Order
Updated November 7, 2002

Sequence Order 10.5
(***0 Information Needs***)

Sequence Order 11
(***9 Information Needs***)

RIN 2.5.1 If razorback suckers were stocked into the Colorado River ecosystem, what is the risk that hybridization with flannelmouth suckers would compromise the genetic integrity of either species?

RIN 2.5.2 How does existing hybridization between razorback suckers and flannelmouth suckers affect the genetic integrity of either species? What are the factors contributing to this ongoing hybridization?

RIN 2.5.6 What are the measurable criteria that would need to be met to remove jeopardy for razorback sucker in the Colorado River ecosystem?

RIN 7.3.2 How accurately can modeling predict reservoir dynamics and operational scenarios?

RIN 9.1.1 What are the attributes of a quality river experience? (How do you define a quality river experience?)

RIN 9.1.2 Determine the appropriate carrying capacity for recreational activities within the Colorado River ecosystem.

RIN 9.1.3 How do ongoing inputs of coarse sediment from tributaries diminish or enhance navigability of rapids throughout the Colorado River ecosystem?

RIN 12.1.3 What are the use (e.g., hydropower, trout fishing, rafting) and non-use (e.g., option, vicarious, quasi-option, bequest and existence) values of the Colorado River ecosystem

RIN 12.1.4 How does use (e.g., hydropower, trout fishing, rafting) and non-use (e.g., option, vicarious, quasi-option, bequest and existence) values change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Sequence Order 11.5
(4 Information Needs)

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

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

RIN 10.1.5 How do power-marketing contract provisions affect Glen Canyon Dam releases?

RIN 12.1.2 What is the economic value of the recreational use of the Colorado River ecosystem downstream from Glen Canyon Dam?

Glen Canyon Dam Adaptive Management Program
FINAL DRAFT INFORMATION NEEDS

November 7, 2002

NOTE: This version of the draft Information Needs reflects recommended sequence order and changes developed by the TWG at their November 7, 2002 meeting. When approved by AMWG for recommendation to the Secretary of the Interior, the Information Needs and other information included in this document will be incorporated into the next version of the Strategic Plan.

Core Monitoring INs are not sequenced because the core monitoring function is ongoing. EINs are not sequenced, with the exception of the two EINs that do not have a corresponding RIN: 11.3.1 and 11.3.2.

Introduction
The Information Needs (INs) provided in this document represent data needed to meet management objectives and programmatic goals. The Information Needs are nested within Management Objectives and are categorized as: core monitoring information needs (CMIN), effects monitoring information needs (EIN), or research information needs (RIN), defined below. In an effort to reflect integration across resource programs, some Information Needs are supporting information needs for other resources (SIN). Information Needs that do not fit under any particular management objective, but are necessary to achieve the goal are placed above the Management Objectives for that goal.

The process for developing these INs is described in Appendix 1.

Glossary
NOTE: Glossary entries that are already included in the Strategic Plan have been deleted. The glossary entries below should be added to the next version of the Strategic Plan.

Management Objectives (MOs): Management Objectives define desired future resource conditions. They should be: 1) Specific; 2) Measurable; 3) Achievable; 4) Results-oriented; 5) Time-specific, and 6) within the legal and policy framework of the Adaptive Management Program.

Information Needs (INs): Information Needs define the specific knowledge or understanding (i.e., information) one needs for accomplishing a management objective. They define what one needs to know. The information may be needed to:

a) quantify or define a management objective (i.e., help determine a target level);

b) assess whether or not a management objective is being achieved (i.e., help determine why the system is not responding as predicted);

c) develop basic understanding about cause and effect relationships;

d) meet the legal/policy requirements of consultation; and

e) test more effective ways to achieve desired resource conditions.

Information Needs are categorized as follows:

- Core Monitoring Information Need (CMIN): Core monitoring consists of consistent, long-term, repeated measurements using set protocols, and is designed to establish status and trends in meeting specific management objectives. Core monitoring is implemented on a fixed schedule regardless of variable factors or circumstances (e.g., water year, experimental flows, temperature control, stocking strategy, non-native control, etc.) affecting target resources.

- Effects Monitoring Information Need (EIN): Effects monitoring is the collection of data associated with an experiment performed under the Record of Decision, unanticipated event, or other management action. Changes in resource conditions measured by effects monitoring generally will be short-term responses. The purpose of effects monitoring is to supplement the fixed schedule and variables collected under core monitoring. This will both increase the understanding of the resource status and trends and provide a research opportunity to discover the effect of the experiment or management action.

- Research Information Need (RIN): Research can be descriptive or experimental. When descriptive it describes relationships in the Colorado River ecosystem (e.g., describe trophic interactions in the aquatic ecosystem). When experimental it tests specific hypotheses for determining and understanding cause and effects relationships between dam operations, or other driving variables, and resource responses (e.g., how is the abundance and composition of benthic invertebrates affected by grazers, predators and dam operations?). Research requires a purposeful design with established statistical criteria, including allowable errors for accepting and rejecting null hypotheses. Research may also result in the collection of data that can be used to help determine or refine Core Monitoring Information Needs.

- Supporting Information Need (SIN): A SIN contributes to understanding the basis for a resource response and its link to other resource management goals.

- Status and Trends: Status refers to the condition of a resource at a given time or place. Trends refer to a statistically based temporal or spatial series for a given resource, during the periods and at the locations where data were collected.

- Cause and Effect: Cause and effect assigns a resource response to a particular event(s) or driving variable(s).

- Glen Canyon Dam Operations: Glen Canyon Dam operations refers to the operation of the power plant and other release structures, such as bypass structures, spillways, and potentially a temperature control device among others. Their uses conform to applicable law. The AMWG develops recommendations for all of the dam's structures to further the purposes of the GCPA and meet the environmental commitments in the EIS/Record of

Decision on the operations of Glen Canyon Dam. This is done within the limits of the Record of Decision and/or through experimentation.

- Record of Decision Operations: Record of Decision operations are defined as the modified low fluctuating flow alternative described in the Record of Decision including restrictions on upramp and downramp rates, the allowable range of daily fluctuations and the allowable minimum and maximum daily flows. In addition operations include beach/habitat-building flows (up to 45,000 cfs) habitat maintenance flows (up to power plant capacity) and any flows defined as experiments within the environmental commitments of the Record of Decision.

NOTE: *The MOs presented in this document represent language that has been extracted and paraphrased from the original MOs table. It is included here to provide a context for reviewing the INs without having to embed them in the original Goals and MOs table. In the next version of the Strategic Plan, approved Information Needs and their sequence order will be incorporated into the MOs table.*

Goal 1. Protect or improve the aquatic foodbase so that it will support viable populations of desired species at higher trophic levels.

Sequence Order	Research INs
4	**RIN 1.1** What are the fundamental trophic interactions in the aquatic ecosystem?
5	**RIN 1.2** How are the production, composition, density, and biomass of the benthic invertebrate community affected by primary productivity vs. allochthonous inputs?
5	**RIN 1.3** What foodbase criteria do other agencies use to assess aquatic ecosystem health?
4	**RIN 1.4** What is the current carbon budget for the Colorado River ecosystem?

M.O. 1.1 Maintain or attain primary producers (algae, macrophytes) biomass and community composition in the Glen Canyon Reach.

Core Monitoring INs

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

Sequence Order	Research INs
5	**RIN 1.1.1** How are the composition and biomass of primary producers between Glen Canyon Dam and the Paria River affected by flow and water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), and water borne diseases, or other factors.
9	**RIN 1.1.2** What is the estimated productivity for the reach between Glen Canyon Dam and the Paria River? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]
6	**RIN 1.1.3** How do top-down effects (grazing and predation) on primary producers affect food base productivity?
5	**RIN 1.1.4** What are the habitat characteristics between Glen Canyon Dam and the Paria River that most affect primary productivity? How are these characteristics affected by Glen Canyon Dam operations?

Effects INs

EIN 1.1.1 How does primary productivity for the reach between Glen Canyon Dam and the Paria River change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 1.2 Maintain or attain benthic invertebrates biomass and community composition in the Glen Canyon Reach.

Core Monitoring INs

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

Sequence Order	Research INs
5	**RIN 1.2.1** How are the composition and biomass of benthic invertebrates between Glen Canyon Dam and the Paria River affected by flow, water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), new invasive species, and water borne diseases, or other factors?
5	**RIN 1.2.2** What is the estimated productivity of benthic invertebrates for the reach between Glen Canyon Dam and the Paria River? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]
6	**RIN 1.2.3** How do top-down effects (grazing and predation) affect the abundance and composition of benthic invertebrates?
5.5	**RIN 1.2.4** What are the habitat characteristics between Glen Canyon Dam and the Paria River that most affect benthic invertebrates? How are these characteristics affected by Glen Canyon Dam operations?

Effects INs

EIN 1.2.1 How do benthic invertebrates in the reach between Glen Canyon Dam and the Paria River change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 1.3 Maintain or attain adequate levels of energy sources (algae, macrophytes) in the Colorado River ecosystem (to the extent primary producers in the tributaries are influenced by dam operations) below the Paria River.

Core Monitoring INs

CMIN 1.3.1 Determine and track the composition and biomass of primary producers in the Colorado River ecosystem below the Paria River.

Sequence Order	Research INs
5.5	**RIN 1.3.1** How are the composition and biomass of primary producers in the Colorado River ecosystem below the Paria River affected by flow and water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), and water borne diseases, or other factors.

8 **RIN 1.3.2** What is the estimated primary productivity in the Colorado River ecosystem below the Paria River? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]

6 **RIN 1.3.3** How do top-down effects on primary producers (grazing and predation) affect food base productivity?

6 **RIN 1.3.4** What are the habitat characteristics in the Colorado River ecosystem below the Paria River that most affect primary productivity? How are these characteristics affected by Glen Canyon Dam operations?

Effects INs

EIN 1.3.1 How does primary productivity in the Colorado River ecosystem below the Paria River change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 1.4 Maintain or attain benthic invertebrates biomass and community composition in the Colorado River ecosystem (to the extent benthic invertebrates in the tributaries are influenced by dam operations) below the Paria River.

Core Monitoring INs

CMIN 1.4.1 Determine and track the composition and biomass of benthic invertebrates in the Colorado River ecosystem below the Paria River in conjunction with measurements of flow, nutrients, water temperature, and light regime.

Sequence Order

Research INs

5 **RIN 1.4.1** How are the composition and biomass of benthic invertebrates in the Colorado River ecosystem below the Paria River affected by flow, water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), new invasive species, and water borne diseases, or other factors? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]

8 **RIN 1.4.2** What is the estimated productivity of benthic invertebrates in the Colorado River ecosystem below the Paria River? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]

5.5 **RIN 1.4.3** How do top-down effects (grazing and predation) affect the abundance and composition of benthic invertebrates?

6 **RIN 1.4.4** What are the habitat characteristics in the Colorado River ecosystem below the Paria River that most affect benthic invertebrates? How are these characteristics affected by Glen Canyon Dam operations?

Effects INs

EIN 1.4.1 How do benthic invertebrates in the Colorado River ecosystem below the Paria River change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 1.5 Maintain or attain drift (Diptera, CPOM, FPOM, DOC) in the mainstem and tributaries (to the extent drift in the tributaries is influenced by dam operations).

Core Monitoring INs

CMIN 1.5.1 Determine and track the composition and biomass of drift in the Colorado River ecosystem.

Sequence Order	Research INs
5.5	**RIN 1.5.1** How are the composition and biomass of drift in the Colorado River ecosystem affected by flow and water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), and water borne diseases, or other factors?
5	**RIN 1.5.2** How do top-down effects (grazing and predation) affect the abundance and composition of drift?
3	**RIN 1.5.3** How has the value and availability of drift as a food source for Humpback chub changed with the implementation of Record of Decision operations?

Effects INs

EIN 1.5.1 How does drift in the Colorado River ecosystem change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

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

M.O. 2.1 Maintain or attain humpback chub abundance and year-class strength in the LCR and other aggregations at appropriate target levels for viable populations and to remove jeopardy.

Core Monitoring INs

CMIN 2.1.1 Determine and track year class strength of HBC between 51 – 150 mm in the LCR and the mainstem.

CMIN 2.1.2 Determine and track abundance and distribution of all size classes of HBC in the LCR and the mainstem.

Sequence Order	Research INs
2.5	**RIN 2.1.1** What is the minimum population size of HBC that should be sustained in the LCR, to ensure a viable spawning population of HBC in the LCR?
1	**RIN 2.1.2** Quantify sources of mortality for humpback chub < 51 mm in rearing habitats in the LCR and mainstem and how these sources of mortality are related to dam operations.
1.5	**RIN 2.1.3** What is the relationship between size of HBC and mortality in the LCR and the mainstem? What are the sources of mortality (i.e., predation, cannibalism, other) in the LCR and the mainstem?
2	**RIN 2.1.4** What habitats enhance recruitment of native fish in the LCR and mainstem? What are the physical and biological characteristics of those habitats?
2	**RIN 2.1.5** Determine the timing and quantity of young-of-year humpback chub dispersal (passive and active) from the LCR.

Effects INs

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

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

EIN 2.1.3 How does the abundance and distribution of recruiting HBC in the LCR and mainstem change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 2.2 Sustain or establish viable HBC spawning aggregations outside of the LCR in the Colorado River ecosystem below Glen Canyon Dam to remove jeopardy.

Sequence Order	Research INs
3.5	**RIN 2.2.1** What is a viable population and what is the appropriate method to assess population viability of native fish in the Colorado River ecosystem? What is an acceptable probability of extinction over what management time period for humpback chub throughout the Colorado River ecosystem?
4	**RIN 2.2.2** Determine if a population dynamics model can effectively predict viability of native fish under different flow regimes and environmental conditions.
2	**RIN 2.2.3** What are the measurable criteria that need to be met in order to remove jeopardy for humpback chub in the Colorado River ecosystem?
2.5	**RIN 2.2.4** What is the relationship between the "aggregations" in the mainstem and LCR? Are mainstem aggregations "sinks" of the LCR? Are aggregations real or due to sampling bias?
2	**RIN 2.2.5** What are the appropriate habitat conditions for HBC spawning? Where are these found? Can they be created in the mainstem?
4	**RIN 2.2.6** What are the criteria for establishment of spawning aggregations (i.e., how does one determine its "established")?
3	**RIN 2.2.7** Determine if implementation and operation of the TCD and/or steady flows represent a technically feasible, ecologically sustainable, and practical option for establishing mainstem spawning.
2	**RIN 2.2.8** What combination of dam release patterns and non-native fish control facilitates successful spawning and recruitment of humpback chub in the Colorado River ecosystem?
2	**RIN 2.2.9** What is the appropriate role of humpback chub augmentation as a management strategy to establish mainstem spawning aggregations?
3	**RIN 2.2.10** What techniques are available to determine natal stream of fishes in the Colorado River ecosystem?
6	**RIN 2.2.11** What are the impacts of current recreational activities on mortality, recruitment and the population size of humpback chub?
3	**RIN 2.2.12** What are the impacts of research activities on mortality, recruitment and the population size of humpback chub?

M.O. 2.3 Monitor HBC and other native fish condition and disease/parasite numbers in LCR and other aggregations at an appropriate target level for viable populations and to remove jeopardy.

Core Monitoring INs

CMIN 2.3.1 Determine and track the parasite loads on HBC and other native fish found in the LCR and in the Colorado River ecosystem.

CMIN 2.3.2 Determine and track status and trends in the condition (Kn or Wr) of HBC and other native fish found in the LCR and in the Colorado River ecosystem?

Sequence Order	Research INs
3	**RIN 2.3.1** How do parasite/disease loads affect population viability?
2	**RIN 2.3.2** How will warming mainstem temperatures affect the abundance and distribution of parasites/disease?
3.5	**RIN 2.3.3** How does non-native fish control affect disease/parasite loads? [Note: The concept is if there are fewer hosts, there will be a lower incidence of parasites.]

Effects Monitoring INs

EIN 2.3.1 How do disease/parasite loads on HBC and other native fish found in the LCR and in the Colorado River ecosystem change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 2.4 Reduce native fish mortality due to non-native fish predation/competition as a percentage of overall mortality in the LCR and mainstem to increase native fish recruitment.

Core Monitoring INs

CMIN 2.4.1 Determine and track the abundance and distribution of non-native predatory fish species in the Colorado River ecosystem and their impacts on native fish.

Sequence Order	Research INs
2	**RIN 2.4.1** What are the most effective strategies and control methods to limit non-native fish predation and competition on native fish?
2.5	**RIN 2.4.2** Determine if suppression of non-native predators and competitors increases native fish populations?

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

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

3 **RIN 2.4.5** What are the sources (natal stream) of nonnative predators and competitors?

2.5 **RIN 2.4.6** What are the population dynamics of those non-native fish that are the major predators and competitors of native fish?

Effects Monitoring INs

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

M.O. 2.5 Attain Razorback sucker abundance and critical habitat condition sufficient to remove jeopardy as feasible and advisable in the Colorado River ecosystem below Glen Canyon Dam.

Sequence Order	Research INs
11	**RIN 2.5.1** If razorback suckers were stocked into the Colorado River ecosystem, what is the risk that hybridization with flannelmouth suckers would compromise the genetic integrity of either species?
11	**RIN 2.5.2** How does existing hybridization between razorback suckers and flannelmouth suckers affect the genetic integrity of either species? What are the factors contributing to this ongoing hybridization?
4.5	**RIN 2.5.3** What characteristics define suitable habitat for razorback sucker? Does suitable habitat for razorback sucker occur in the Colorado River ecosystem?
8	**RIN 2.5.4** What is the feasibility and advisability of augmenting razorback sucker in the Colorado River ecosystem to attain a viable population including technical/legal/policy constraints?
9	**RIN 2.5.5** What are the genetic and ecological criteria for reintroducing razorback sucker into the Colorado River ecosystem?
11	**RIN 2.5.6** What are the measurable criteria that would need to be met to remove jeopardy for razorback sucker in the Colorado River ecosystem?

M.O. 2.6 Maintain (flannelmouth sucker, bluehead sucker and speckled dace) abundance and distribution in the Colorado River ecosystem below Glen Canyon Dam for viable populations.

Core Monitoring INs

CMIN 2.6.1 Determine and track the abundance and distribution of flannel-mouth sucker, blue-head sucker, and speckled dace populations in the Colorado River ecosystem.

Sequence Order	Research INs
2	**RIN 2.6.1** What is a viable population? What is the probability of extinction over what management time period for species of concern? What is the appropriate method to assess viability?
6	**RIN 2.6.2** What are the physical and biological characteristics of habitats that enhance recruitment of flannel-mouth sucker, blue-head sucker, and speckled dace populations in the Colorado River ecosystem?
4.5	**RIN 2.6.3** What is the age structure, including relationship between age and size of flannel-mouth sucker, blue-head sucker, and speckled dace in the Colorado River ecosystem?
4	**RIN 2.6.4** How are movement patterns for flannel-mouth sucker, blue-head sucker, and speckled dace in the Colorado River ecosystem affected by age, natal stream, and dam operations?
4	**RIN 2.6.5** How is the rate of mortality for flannel-mouth sucker, blue-head sucker, and speckled dace in the Colorado River ecosystem related to individual body size? What are the sources of mortality for flannel-mouth sucker, blue-head sucker, and speckled dace in the Colorado River ecosystem?
5	**RIN 2.6.6** How does temperature modification in the mainstem affect recruitment and mortality for flannel-mouth sucker, blue-head sucker, and speckled dace originating from tributary spawning efforts?

Effects Monitoring INs

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

Goal 3. Restore populations of extirpated species, as feasible and advisable.

M.O. 3.1 Restore Colorado pikeminnow, bonytail, and roundtail chub and river otter abundances in the Colorado River ecosystem as feasible and advisable.

Sequence Order	Research INs
9.5	**RIN 3.1.1** What information (including technical, legal, economic, and policy issues) should be considered in determining the feasibility and advisability of restoring pikeminnow, bonytail, roundtail chub, river otter, or other extirpated species?

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

M.O. 4.1 Maintain or attain RBT abundance, proportional stock density, length at age, condition, spawning habitat, natural recruitment and prevent or control whirling disease and other parasitic infections.

Core Monitoring INs

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

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

CMIN 4.1.3 Determine annual rainbow trout growth rate in the Lees Ferry reach**.**

CMIN 4.1.4 Determine annual standard condition (Kn) and Relative weight of rainbow trout in the Lees Ferry reach**.**

CMIN 4.1.5 Determine if whirling disease is present in the Lees Ferry reach. Determine annual incidence and relative infestation of trout nematodes in rainbow trout in the Lees Ferry reach.

CMIN 4.1.6 Determine quantity and quality of spawning habitat for rainbow trout in the Lees Ferry reach as measured at 5-year intervals.

CMIN 4.1.7 Determine annual percentage of naturally recruited rainbow trout in the Lees Ferry reach**.**

Sequence Order	Research INs
10	**RIN 4.1.1** What is the target proportional stock density (i.e., trade-off between numbers and size) for rainbow trout in the Lees Ferry reach?
9	**RIN 4.1.2** What is the minimum quantity and quality of spawning substrate necessary for maintaining a wild reproducing rainbow trout population in the Lees Ferry reach?
4.5	**RIN 4.1.3** To what extent is there overlap in the Lees Ferry reach of RBT habitat and native fish habitat?
10	**RIN 4.1.4** How does the genetics or "strain" of rainbow trout in the Lees Ferry reach influence the average size of fish creeled by anglers?

Effects Monitoring INs

EIN 4.1.1 How does RBT abundance, proportional stock density, length at age, condition, spawning habitat, natural recruitment, whirling disease and other parasitic infections change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 4.2 Limit Lees Ferry RBT distribution below the Paria River of the Colorado River ecosystem to reduce competition or predation on downstream native fish.

Sequence Order	Research INs
2.5	**RIN 4.2.1** What is the rate of emigration of rainbow trout from the Lees Ferry reach?
2.5	**RIN 4.2.2** What is the most effective method to detect emigration of rainbow trout from the Lees Ferry reach?
4.5	**RIN 4.2.3** How is the rate of emigration of RBT from the Lees Ferry reach to below the Paria River affected by abundance, hydrology, temperature, and other ecosystem processes?
5.5	**RIN 4.2.4** What is the target population size of RBT appropriate for the Lees Ferry reach that limits downstream emigration?
4.5	**RIN 4.2.5** To what extent is there overlap in the Colorado River ecosystem below the Paria River of RBT habitat and native fish habitat?
2	**RIN 4.2.6** To what extent are RBT below the Paria River predators of native fish, primarily HBC? At what size do they become predators of native fish, especially HBC, i.e. how do the trophic interactions between RBT and native fish change with size of fish?
3.5	**RIN 4.2.7** What dam release patterns most effectively maintain the LEES Ferry RBT trophy fishery wile limiting RBT survival below the Paria River?

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

MO 5.1 Attain and maintain Kanab ambersnail population at Vasey's Paradise from the current level to the target level.

Core Monitoring INs

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

Sequence Order	Research INs
6.5	**RIN 5.1.1** What constitutes population viability for Kanab ambersnail at Vasey's Paradise?
5	**RIN 5.1.2** What parameters have the greatest influence on population viability of Kanab ambersnail at Vasey's Paradise (e.g., parasites, predation, discharges, habitat size, quality, and human use/visitation)?
5	**RIN 5.1.3** Develop a population dynamic model to predict Kanab ambersnail viability under different flows and environmental conditions.
4	**RIN 5.1.4** Identify and evaluate alternative Management Actions to ensure viability of Kanab ambersnail at Vasey's Paradise where (1) the population dynamic model predicts loss of population viability, or (2) monitoring discovers substantial habitat or Kanab ambersnail population declines.
2.5	**RIN 5.1.5** What is the taxonomic identity of the *Oxyloma* snails at Vasey's Paradise? Is a change to the existing taxonomic status warranted?
2.5	**RIN 5.1.6** What is the range of occurrence of the ambersnail taxon found at Vasey's Paradise? [NOTE: Intended to address the issue of whether this is an endemic population or a relict population or part of a metapopulation.]
9	**RIN 5.1.7** What is the historic range of Oxyloma haydeni? Can this range be determined from subfossil or fossil evidence? [NOTE: This is intended to determine if this is a relict species and the initial work would be done at Vasey's Paradise, South Canyon and other probable sites within the Colorado River ecosystem.]
4	**RIN 5.1.8** What are the measurable criteria that need to be met to remove jeopardy for Kanab ambersnail at Vasey's Paradise?
3	**RIN 5.1.9** How can incidental take for Kanab ambersnail at Vasey's Paradise be minimized?

Effects Monitoring INs

EIN 5.1.1 How does Kanab ambersnail population abundance and recovery change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

MO 5.2 Maintain Kanab ambersnail habitat at Vasey's Paradise from the current level to the target level.

Core Monitoring INs

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

Sequence Order	Research INs
5	**RIN 5.2.1** How does the size, quality, and recovery time of Kanab ambersnail habitat change following natural scours, or other events?
2	**RIN 5.2.2** How does the size and quality of the habitat used by Kanab ambersnail change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?
6.5	**RIN 5.2.3** How can remote sensing technologies be used to less intrusively and more cost effectively characterize and monitor Kanab ambersnail habitat at Vasey's Paradise (vegetation type and distribution)?

Effects INs

EIN 5.2.1 How does Kanab ambersnail habitat at Vasey's Paradise change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Goal 6. Protect or improve the biotic riparian and spring communities within the Colorado River ecosystem, including threatened and endangered species and their critical habitat.

6 **IN 6.1** Develop GIS coverages of natural communities in the Colorado River ecosystem to use in identification of status and trends.

6.5 **IN 6.2** Develop or adopt an existing ecological community classification system. The system should describe the composition and frequency of vascular plants, vertebrates, arthropods, and mollusks to an appropriate taxonomic level.

6 **IN 6.3** How is the abundance of vertebrate consumers affected by seasonal shifts in food base abundance in the Colorado River ecosystem?

5 **IN 6.4** How much allochthonous material (e.g., leaf litter) is exchanged between the terrestrial and aquatic systems?

M.O. 6.1 Maintain marsh community abundance, composition, and area in the Colorado River ecosystem in such a manner that native species are not lost.

Core Monitoring INs

CMIN 6.1.1 Determine and track the abundance, composition, distribution, and area of the marsh community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

Sequence Order

Research INs

5 **RIN 6.1.1** How has the abundance, composition, distribution, and area of the marsh community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?

Effects INs

EIN 6.1.1 How do marsh community abundance, composition, distribution, and area change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 6.2 Maintain NHWZ community patch number and distribution, composition and area to be no lower than values estimated for 1984.

Core Monitoring INs

CMIN 6.2.1 Determine and track the patch number, patch distribution, composition and area of the NHWZ community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

Sequence Order

Research INs

4.5 **RIN 6.2.1** How has the patch number, patch distribution, composition and area of the NHWZ community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?

Effects INs

EIN 6.2.1 How does the patch number, patch distribution, composition and area of the NHWZ community change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 6.3 Maintain OHWZ community abundance, composition, and distribution in the Colorado River ecosystem.

Core Monitoring INs

CMIN 6.3.1 Determine and track the abundance, composition and distribution of the OHWZ community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

Sequence Order

Research INs

5.5 **RIN 6.3.1** How has the abundance, composition, and distribution of the OHWZ community changed since dam closure (1963), high flows (1984), interim flows (1991), and the implementation of Record of Decision operations (1996)?

5 **RIN 6.3.2** What management actions have the potential to maintain the OHWZ community at the current stage elevation, or establish the community at a lower stage elevation?

Effects INs

EIN 6.3.1 How do the abundance, composition, and distribution of the OHWZ community change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 6.4 Maintain sand beach community abundance, composition, and distribution in the Colorado River ecosystem at the target level.

Core Monitoring INs

CMIN 6.4.1 Determine and track composition, abundance, and distribution of the sand beach community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

Sequence Order

Research INs

4 **RIN 6.4.1** How has the abundance, composition, and distribution of the sand beach community changed since dam closure (1963), high flows (1984), interim

flows (1991), and the implementation of Record of Decision operations (1996)?

Effects INs

EIN 6.4.1 How does the abundance, composition, and distribution of the sand beach community change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 6.5 Reduce invasive non-native species abundance and distribution.

Core Monitoring INs

CMIN 6.5.1 Determine and track the distribution and abundance of non-native species in the Colorado River ecosystem as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

Sequence Order	Research INs
4.5	**RIN 6.5.1** Determine if non-native species are expanding or contracting at a local scale (patch or reach).
5	**RIN 6.5.2** What management actions have the potential to increase or decrease the distribution and abundance of non-native species?
4	**RIN 6.5.3** How has the abundance and distribution of non-native species changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?
7	**RIN 6.5.4** How can remote sensing assist in the development of a map of non-native species distributions in the Colorado River ecosystem including characterization of the types of habitat that supports non-native species?

Effects INs

EIN 6.5.1 How does the abundance and distribution of non-native species change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 6.6 Maintain seep and spring habitat in the Colorado River ecosystem.

Core Monitoring INs

CMIN 6.6.1 Determine and track the composition, abundance, and distribution of seep and spring communities as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

Sequence Order	Research INs
9	**RIN 6.6.1** How is seep and spring habitat affected by variation in dam operations, variation in seep or spring flow, and variation in water quality? How do flow rates and water quality parameters at seeps and springs compare with historic measurements?
5	**RIN 6.6.2** Which seeps and springs are culturally important or occupied by rare and endemic species?
8.5	**RIN 6.6.3** How has the composition, abundance and distribution of seep and spring communities changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?
9	**RIN 6.6.4** What is the distribution, patch size, total area, and composition of seep and spring communities and the flow rate and water quality of all seeps and springs within the Colorado River ecosystem?

Effects INs

EIN 6.6.1 How do the composition, abundance, and distribution of seep and spring communities change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 6.7 Maintain riparian habitat in the Colorado River ecosystem capable of supporting Southwest willow flycatcher.

Core Monitoring INs

CMIN 6.7.1 Determine and track the abundance, distribution, and reproductive success of southwestern willow flycatcher in the Colorado River ecosystem?

Sequence Order	Research INs
8	**RIN 6.7.1** What is the function of the Colorado River ecosystem as a migratory corridor for southwestern willow flycatcher?
8	**RIN 6.7.2** What is the foodbase that supports southwestern willow flycatcher and other terrestrial vertebrates?
8	**RIN 6.7.3** What constitutes suitable southwestern willow flycatcher habitat?
9	**RIN 6.7.4** How has the abundance, distribution and reproductive success of southwestern willow flycatcher changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?

5.5 **RIN 6.7.5** What is the need, feasibility, and priority of maintaining habitat suitability for southwestern willow flycatcher in the Colorado River ecosystem?

Effects INs

EIN 6.7.1 How do the abundance, distribution and reproductive success of southwestern willow flycatcher change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

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

M.O. 7.1 Attain water temperature ranges and seasonal variability in the mainstem necessary to maintain or attain desired levels of desirable biological resources (e.g., native fish, foodbase and trout).

Core Monitoring INs

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

CMIN 7.1.2 Determine and track LCR discharge near mouth (below springs).

Sequence Order	Research INs
5	**RIN 7.1.1** What are the desired ranges of spatial and temporal patterns of water temperatures for the Colorado River ecosystem?
4	**RIN 7.1.2** What are the most likely downstream temperature responses to a variety of scenarios involving a TCD on Glen Canyon Dam?
3	**RIN 7.1.3** What are the potential ecological effects of increasing mainstem water temperatures?

Effects INs

EIN 7.1.1 How does water temperature change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 7.2 Maintain water quality in the mainstem of the Colorado River ecosystem.

Core Monitoring INs

CMIN 7.2.1 Determine the seasonal and yearly trends in turbidity, water temperature, conductivity, DO, and pH, (decide below whether selenium is important) changes in the mainstem throughout the Colorado River ecosystem?

Sequence Order	Research INs
5	**RIN 7.2.1** Which major ions should be measured? Where and how often?
5	**RIN 7.2.2** Which nutrients should be measured? Where and how often?
4	**RIN 7.2.3** Which metals should be measured? Where and how often?

6.5 **RIN 7.2.4** What are the water-borne pathogens that are a threat to human health? How should they be monitored? Where and how often?

Sequence Order — Supporting INs

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

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

Proposed New **M.O. 7.3** Maintain suitable quality of water in Glen Canyon Dam releases to meet downstream management objectives.

Core Monitoring INs

CMIN 7.3.1 What are the status and trends of water quality releases from Glen Canyon Dam?

Sequence Order — Research INs

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

7.5 **7.3.1.a** Determine the status and trends of chemical and biological components of water quality in Lake Powell as a function of regional hydrologic conditions and their relation to downstream releases.

11.5 **7.3.1.b** Determine stratification, convective mixing patterns, and behavior of advective currents in Lake Powell and their relation to Glen Canyon Dam operations to predict seasonal patterns and trends in downstream releases.

11 **RIN 7.3.2** How accurately can modeling predict reservoir dynamics and operational scenarios?

9 **RIN 7.3.3** How do dam operations affect reservoir limnology?

Sequence Order — Supporting INs

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

Effects INs

EIN 7.3.1 How does the water quality of releases from Glen Canyon Dam change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 7.4 Maintain flow dynamics associated with power plant operations, BHBF and habitat maintenance flows.

Core Monitoring INs

CMIN 7.4.1 Determine and track releases from Glen Canyon Dam under all operating conditions.

CMIN 7.4.2 Determine and track flow releases from Glen Canyon Dam, particularly related to flow duration, upramp, and downramp conditions.

Sequence Order	Research INs
11.5	**RIN 7.4.1** What is the desired range of seasonal and annual flow dynamics associated with powerplant operations, BHBFs, and habitat maintenance flows, or other flows that meet AMP goals and objectives?
5	**RIN 7.4.2** What is the desired pattern of seasonal and annual flow dynamics associated with powerplant operations, BHBFs, HMFs, or other flows to meet AMP Goals and Objectives?
4	**RIN 7.4.3** How do changes in flow volume and rate of change affect food base and energy productivity in the Colorado River ecosystem?
3	**RIN 7.4.4** How does flow rate and fluctuation affect habitat availability and utilization by fish and other organisms?

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

4.5 **IN 8.1** If sediment cannot be preserved in the system using available management actions, what is the feasibility (including technical, legal, economic, and policy issues) of sediment augmentation as a means of achieving this goal?

M.O. 8.1 Maintain or attain fine sediment abundance, grain-size, distribution in the main channel below 5,000 cfs

Core Monitoring INs

CMIN 8.1.1 Determine and track **t**he biennial fine-sediment, volume, and grain-size changes below 5,000 cfs stage, by reach.

CMIN 8.1.2 What are the monthly sand and silt/clay -export volumes and grain-size characteristics, by reach, as measured at Lees Ferry, Lower Marble Canyon, Grand Canyon, and Diamond Creek Stations?

CMIN 8.1.3 Track, as appropriate, the monthly sand and silt/clay -input volumes and grain-size characteristics, by reach, as measured or estimated at the Paria and Little Colorado River stations, other major tributaries like Kanab and Havasu creeks, and "lesser" tributaries?

Sequence Order	Research INs
5	**RIN 8.1.1** What is the longitudinal variability of fine-sediment inputs**,** by reach?
5	**RIN 8.1.2** What is the temporal variability of fine-sediment inputs, by reach?
5	**RIN 8.1.3** What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]

Effects INs

EIN 8.1.1 How do fine sediment abundance, grain-size, and distribution in the main channel below 5,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 8.2 Maintain or attain fine sediment abundance, grain-size, and distribution within channel margins (not eddies) from 5,000 to 25,000 cfs

Core Monitoring IN

CMIN 8.2.1 Track, as appropriate, the biennial sandbar area, volume and grain-size changes outside of eddies between 5,000 and 25,000 cfs stage, by reach?

Sequence Order

5 Research IN

RIN 8.2.1 What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]

Effects INs

EIN 8.2.1 How does fine sediment abundance, grain-size, and distribution within channel margins (not eddies) from 5,000 to 25,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 8.3 Maintain or attain fine sediment abundance, grain-size, and distribution, within eddies below 5,000 cfs

Core Monitoring INs

CMIN 8.3.1 Track, as appropriate, the biennial sandbar area, volume and grain-size changes within eddies below 5,000 cfs stage, by reach?

Sequence Order

5 Research IN

RIN 8.3.1 What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]

Effects INs

EIN 8.3.1 How does fine sediment abundance, grain-size, and distribution, within eddies below 5,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 8.4 Maintain or attain fine sediment abundance, grain-size, and distribution within eddies between 5,000 to 25,000 cfs

Core Monitoring IN

CMIN 8.4.1 Track, as appropriate, the annual sandbar area, volume and grain-size changes within eddies between 5,000 and 25,000 cfs stage, by reach?

Sequence Order

5 Research INs

RIN 8.4.1 What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]

Effects INs

EIN 8.4.1 How does fine sediment abundance, grain-size, and distribution, within eddies between 5,000 to 25,000 cfs change in response to an experiment

performed under the Record of Decision, unanticipated event, or other management action?

M.O. 8.5 Maintain or attain fine sediment abundance, grain-size, and distribution on shorelines between 25,000 cfs and the uppermost effects of maximum dam releases.

Core Monitoring INs

CMIN 8.5.1 Track, as appropriate, the biennial sandbar area, volume and grain-size changes above 25,000 cfs stage, by reach?

Sequence Order	Research INs
4	**RIN 8.5.1** What elements of Record of Decision operations (upramp, downramp, maximum and minimum flow, MLFF, HMF, and BHBF) are most/least critical to conserving new fine-sediment inputs, and stabilizing sediment deposits above the 25,000 cfs stage?
5.5	**RIN 8.5.2** What is the reach-scale variability of fine-sediment storage throughout the main channel?
9.5	**RIN 8.5.3** What is the pre- and post-dam range of grain-size in fine-sediment deposits, by reach?
5	**RIN 8.5.4** What is the significance of aeolian processes in terrestrial sandbar reworking?
5.5	**RIN 8.5.5** What are the historic and ongoing longitudinal trends of fine-sediment storage, above 25,000 cfs?
5	**RIN 8.5.6** What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]

Effects Monitoring INs

EIN 8.5.1 How does fine sediment abundance, grain-size, and distribution on shorelines between 25,000 cfs and the uppermost effects of maximum dam releases change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Sequence Order	Supporting INs
9	**SIN 8.5.1** How do sandbar textures influence biological processes?
5	**SIN 8.5.2** What is the relationship between the fine-sediment budget and turbidity?

4	**SIN 8.5.3** What is the relationship between turbidity and biological processes?
4.5	**SIN 8.5.4** What is the role of turbidity and how can it be managed to achieve biological objectives?
5	**SIN 8.5.5** How can the ongoing fine sediment supply be managed to achieve sustainable habitats?
4	**SIN 8.5.6** What are the grain-size characteristics of sand bars associated with designated riparian vegetation zones?
5.5	**SIN 8.5.7** What are the limiting factors that regulate substrate availability and its distribution?
6	**SIN 8.5.8** What is the total area of different aquatic habitat types (cobble, gravel, sand, talus, etc,) in the Colorado River ecosystem?
6	**SIN 8.5.9** How are sandbar textures related to cultural site stability?
7.5	**SIN 8.5.10** How are sandbar textures related to recreational site stability?

Proposed NEW **M.O. 8.6** Maintain or attain coarse sediment (greater than 2 mm) abundance, grain-size and distribution throughout the Colorado River Ecosystem needed to achieve GCDAMP ecosystem goals.

Core Monitoring INs

CMIN 8.6.1 Determine and track the change in coarse sediment abundance and distribution.

Sequence Order	Research INs
6.5	**RIN 8.6.1** How do ongoing inputs of coarse-sediment from tributaries influence storage of fine sediment within pools, runs and eddies throughout the Colorado River ecosystem?
4.5	**RIN 8.6.2** How do ongoing inputs of coarse-sediment from tributaries alter the distribution of main channel habitats needed by benthic organisms within pools, runs, and eddies throughout the Colorado River ecosystem?

Effects INs

EIN 8.6.1 How does coarse sediment (greater than 2mm) abundance, grain-size and distribution change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

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

MO 9.1 Maintain or improve the quality and range of recreational opportunities in Glen and Grand Canyons within the capacity of the Colorado River ecosystem to absorb visitor impacts consistent with the NPS and tribal river corridor Management Plans.

Core Monitoring INs

CMIN 9.1.1 Determine and track the change in recreational quality, opportunities and use, impacts, and perceptions of users in the Colorado River Ecosystem.

CMIN 9.1.2 Determine and track the frequency and scheduling of river-related use patterns.

CMIN 9.1.3 Determine and track the level of satisfaction for river-related recreational opportunities in the Colorado River ecosystem.

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

Sequence Order	Research INs
11	**RIN 9.1.1** What are the attributes of a quality river experience? (How do you define a quality river experience?)
11	**RIN 9.1.2** Determine the appropriate carrying capacity for recreational activities within the Colorado River ecosystem.
11	**RIN 9.1.3** How do ongoing inputs of coarse-sediment from tributaries diminish or enhance navigability of rapids throughout the Colorado River ecosystem?

Effects INs

EIN 9.1.1 How do recreational use trends, impacts, and perceptions change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

MO 9.2 Maintain or improve the quality and range of opportunities in Glen and Grand Canyons in consideration of visitor safety, and the inherent risk of river-related recreational activities.

Core Monitoring INs

CMIN 9.2.1 Determine and track the change in quality and range of opportunities in consideration of visitor safety, and the inherent risk of river-related recreational activities.

CMIN 9.2.2 Determine and track accident rates for visitors participating in river-related activities including causes and location (i.e. on-river or off-river), equipment type, operator experience, and other factors of these accidents in the Colorado River ecosystem.

M.O. 9.3 Increase the size, quality and distribution of camping beaches in critical and non-critical reaches in the mainstem within the capacity of the Colorado River Ecosystem to absorb visitor impacts consistent with NPS and tribal river corridor Management Plans.

Core Monitoring INs

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

CMIN 9.3.2 Determine and track the effects Record of Decision operations on the size, quality, and distribution of camping beaches in the Colorado River ecosystem.

Sequence Order	Research INs
5	**RIN 9.3.1** What is the desired target level of camping beaches by reach?

Effects INs

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

M.O. 9.4 Maintain or enhance the wilderness experience in the Colorado River ecosystem in consideration of existing management plans.

Core Monitoring INs

CMIN 9.4.1 Determine and track the effects of Record of Decision operations on elements of wilderness experience specific to the Colorado River ecosystem.

Sequence Order	Research INs
5.5	**RIN 9.4.1** Identify the elements of wilderness experience specific to the Colorado River ecosystem.

M.O. 9.5 Maintain or enhance visitor experiences as a result of GCDAMP research and monitoring activities.

Core Monitoring INs

CMIN 9.5.1 Determine and track the frequency and scheduling of research and monitoring activity in Glen and Grand Canyons.

Sequence Order	Research INs
7	**RIN 9.5.1** What effects do administrative trips, including research and monitoring activities have on recreational users?

Goal 10: Maintain power production capacity and energy generation, and increase where feasible and advisable, within the framework of GCDAMP ecosystem goals.

7 **IN 10.1** Determine and track the impacts to power users from implementation of Record of Decision dam operations and segregate those effects from other causes such as changes in the power market.

M.O. 10.1 Maintain or increase power with respect to marketable capacity and energy at Glen Canyon Dam.

Core Monitoring INs

CMIN 10.1.1 Determine and track the effects on marketable capacity and energy of implementation of Record of Decision components (daily fluctuation limit, upramp and downramp limits, list components, maximum flow limit of 25,000 cfs, minimum flow limit of 5,000 cfs).

Sequence Order	Research INs
6	**RIN 10.1.1.** What would be the effects on the Colorado River ecosystem and marketable capacity and energy of increasing the daily fluctuation limit?
5	**RIN 10.1.2.** What would be the effects on the Colorado River ecosystem and marketable capacity and energy of increasing the upramp and downramp limit?
5	**RIN 10.1.3** What would be the effects on the Colorado River ecosystem and marketable capacity and energy of raising the maximum power plant flow limit above 25,000 cfs?
5.5	**RIN 10.1.4** What would be the effects on the Colorado River ecosystem and marketable capacity and energy of lowering the minimum flow limit below 5,000 cfs?
11.5	**RIN 10.1.5** How do power-marketing contract provisions affect Glen Canyon Dam releases?

M.O. 10.2 Maintain or increase power within the existing emergency criteria for Western Area Power Administration systems.

Core Monitoring INs

CMIN 10.2.1 Determine the effects of reserve group obligations on power.

M.O. 10.3 Maintain or increase power within the existing emergency criteria for the western interconnected electrical system.

Core Monitoring INs

CMIN 10.3.1 Determine the full range of effects of Glen Canyon Dam responses to western interconnected electrical system emergencies.

Sequence Order	Research INs
5	**RIN 10.3.1** What are the effects of providing financial exception criteria?

M.O. 10.4 Maintain or increase power regulation at Glen Canyon Dam.

Core Monitoring INs

CMIN 10.4.1 Determine and track the effects on the Colorado River ecosystem and marketable power and energy of maintaining Automatic Generation Control at Glen Canyon Dam.

Sequence Order	Research INs
6	**RIN 10.4.1** What are the effects on the Colorado River ecosystem and marketable power and energy of increasing Automatic Generation Control at Glen Canyon Dam?

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

M.O. 11.1 Preserve historic properties in the area of potential effect via protection, management, and/or treatment (e.g., data recovery) for the purpose of federal agency compliance with NHPA, and AMP ~~and AMWG~~ compliance with GCPA.

Core Monitoring INs

CMIN 11.1.1 Determine the status of historic properties under Record of Decision operations.

11.1.1a Determine periodically whether the essential physical features are visible enough to convey their significance or retain their information potential.

CMIN 11.1.2 Determine the efficacy of treatments for mitigation of adverse effects to historic properties.

CMIN 11.1.3 What are the thresholds for impacts that threaten the~~ir~~ integrity and eligibility of historic properties?

11.1.3a Are the current monitoring programs collecting the necessary information to assess resource integrity?

CMIN 11.1.4 How effective is monitoring, what are the appropriate strategies to capture change at an archaeological site - qualitative, quantitative?

Sequence Order	Research INs
4	**RIN 11.1.1** What are the sources of impacts to historic properties?
5	**11.1.1.a** What and where are the geomorphic processes that link loss of site integrity with dam operations as opposed to dam existence or natural processes?
5	**11.1.1.b** What are the terrace formation processes and how do dam operations affect current terrace formations processes?
5	**11.1.1.c** Determine if and where dam operations cause accelerated erosion to historic properties?
5	**11.1.1.d** What are the potential threats to historic properties relative to integrity and significance?
3.5	**RIN 11.1.2** What are the historic properties within the area of potential effects?
3.5	**11.1.2.a** For each tribe and living community, what are the register eligible traditional cultural properties?

5	**11.1.2.b** How do specific sites meet National Register Criteria for Evaluation?
5	**11.1.2.c** Identify AMP activities that affect National Register eligible sites?
5.5	**11.1.2.d** Identify NPS permitted activities that affect National Register eligible sites.
3	**RIN 11.1.3** What are the thresholds triggering management actions?
5	**11.1.3.a** Determine the necessary information to assess resource integrity.
4	**11.1.3.b** How should adverse effects to historic properties be mitigated?
5.5	**RIN 11.1.5** What are appropriate strategies to preserve resource integrity?

Effects Monitoring INs

EIN 11.1.1 Determine the effects of experimental flows on historic properties.

M.O. 11.2 Preserve resource integrity and cultural values of traditionally important resources within the Colorado River Ecosystem.

Core Monitoring INs

CMIN 11.2.1 Are the traditionally important resources and locations for each tribe and other groups being affected?

Sequence Order	Research INs
4.5	**RIN 11.2.1** What are traditionally important resources and locations for each tribe and other groups?
4.5	**RIN 11.2.2** What is the baseline measure for resource integrity?
4	**RIN 11.2.3** Determine acceptable methods to preserve or treat traditionally important resources within the Colorado River ecosystem.
5	**RIN 11.2.4** What changes are occurring in cultural resource sites, and what are the causes of those changes?

M.O. 11.3 Protect and maintain physical access to traditional cultural resources through meaningful consultation on AMP activities that might restrict or block physical access by Native American religious and traditional practitioners.

Sequence Order	Effects INs
9	**EIN 11.3.1** Determine if and how experimental flows and other AMP actions restrict tribal access.
9	**EIN 11.3.2** Determine reasonable management actions that should be taken to facilitate tribal access.

Goal 12: Maintain a high quality monitoring, research, and adaptive management program.

3	**IN 12.1** Develop information that can be used by the TWG, in collaboration with GCMRC, to establish current and target levels for all resources within the AMP as called for in the AMP strategic plan.

M.O. 12.1 Maintain or attain socio-economic data for adequate decision-making.

Sequence Order	Research INs:
4.5	**RIN 12.1.1** What is the necessary quantity and quality of cultural and socioeconomic information for adequate decision-making?
11.5	**RIN 12.1.2** What is the economic value of the recreational use of the Colorado River ecosystem downstream from Glen Canyon Dam?
11	**RIN 12.1.3** What are the use (e.g., hydropower, trout fishing, rafting) and non-use (e.g., option, vicarious, quasi-option, bequest and existence) values of the Colorado River ecosystem
11	**RIN 12.1.4** How does use (e.g., hydropower, trout fishing, rafting) and non-use (e.g., option, vicarious, quasi-option, bequest and existence) values change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

M.O. 12.2: Attain or improve monitoring and research programs to achieve the appropriate scale and sampling design needed to support science-based adaptive management recommendations.

Sequence Order	Research INs
3.5	**RIN 12.2.1** What is the most appropriate field sampling method(s) (e.g., sampling size, spatial and temporal distribution, analysis, explicit assumptions, limitations, and uncertainties) and statistical analysis to monitor the status and trends of resources targeted by management objectives?
6.5	**RIN 12.2.2** What remote sensing technologies are available to less intrusively and more cost effectively monitor, characterize and map: (a) the aquatic food base, (b) fish, (c) fish habitat features, (d) Kanab ambersnail habitat, (e) water quality parameters, (f) bathymetry and associated substrates and (g) cultural sites?
6	**RIN 12.2.3** What digital, or other, technologies exist and should be used to record field observations and spatially reference these data to facilitate their integration into GCMRC databases and use by PIs and stakeholders?

3 **RIN 12.2.4** What historic data sets currently exist for all resources targeted by management objectives in the GCDAMP?

7 **RIN 12.2.5** What remote sensing data are available or can be obtained that will support the production of a system-wide resource map?

3.5 **RIN 12.2.6** What are the acceptable detection levels for change in Colorado River ecosystem resources? How should those levels most appropriately be determined and who should make the determinations?

7 **RIN 12.2.7** How can GIS be used to designate and stratify habitats to improve system-wide extrapolation of population estimates and habitat in the Colorado River ecosystem?

5.5 **RIN 12.2.8** Determine accurate, reliable, and standardized methods for measuring erosion at historic sites.

M.O. 12.3 Attain or maintain an integrated and synthesized "ecosystem-science"- based adaptive management program.

Sequence Order	Research INs
4.5	**RIN 12.3.1** What are the most effective method(s) to integrate and synthesize resource data to increase our understanding of the past and for ongoing interactions of humans with the Colorado River ecosystem.
6	**RIN 12.3.2** What are the differences between western science and tribal processes for design of studies and for gathering, analyzing, and interpreting data used in the adaptive management program?
1	**RIN 12.3.3** What are the best scientific methods to determine cause and effect relationships in experiments and other management actions conducted under the GCDAMP?
5	**RIN 12.3.4** How well do research designs and workplans do in incorporating Tribal perspectives and values into the standard western science paradigm? Is it more beneficial to keep the perspective separated?
5	**RIN 12.3.5** How effective is the AMP in addressing the EIS statement "Long-term monitoring and research are … implemented to measure how well the selected alternative meets resource management objectives."?

M.O. 12.4 Attain or maintain an integrated and synthesized "ecosystem-science"-based adaptive management program.

Sequence Order	Research INs
4.5	**RIN 12.4.1** What are the most effective methods to maintain or attain the participation of externally-funded investigators?

M.O. 12.5 Foster effective two-way communication between scientists, external reviewers, managers, decision-makers, and the public.

Core Monitoring INs

CMIN 12.5.1 Determine whether effective two-way communication between AMP participants and individuals outside the program is occurring on a regular basis.

Sequence Order	Research INs
5	**RIN 12.5.1** What are the most effective means to build AMP public support through effective public outreach?
5	**RIN 12.5.2** What are the most effective means to attain and maintain effective communication and coordination with other resource management programs in the Colorado River basin to ensure consideration of their values and perspectives into the AMP and vice versa?
6	**RIN 12.5.3** To what extent does the public understand and support the GCDAMP?
5	**RIN 12.5.4** What is the most effective way to distribute information to our stakeholders and the public in a secure and accessible fashion?
4.5	**RIN 12.5.5** Identify the desired level of information, education, and outreach provided for Glen and Grand Canyon river users and the general public?

M.O. 12.6 Attain and maintain an effective adaptive management program, composed of informed stakeholders.

M.O. 12.6a Maintain or attain funding from multiple sources.

M.O. 12.7 Attain and maintain effective tribal consultation to ensure inclusion of tribal values and perspectives into the AMP.

Sequence Order	Research INs:
5	**RIN 12.7.1** How effective are the current strategies to achieve tribal consultation?
5	**RIN 12.7.2** How well do the current strategies to achieve tribal consultation meet legal and AMP protocols?

M.O. 12.8 Attain and maintain tribal participation in the AMP research and long-term monitoring activities.

Sequence Order	Research INs
5	**RIN 12.8.1** How well does current tribal participation in the AMP research and long-term monitoring programs meet tribal needs and desires?

M.O. 12.9 Recommend experiments of dam operations and other management actions to gain critical understanding of ecosystem function under different dam operations scenarios and other management actions.

Sequence Order	Research INs
3	**RIN 12.9.1** What is the impact on downstream resources of short-term increases to maximum flow, daily fluctuations, and downramp limits?
2	**RIN 12.9.2** What is the best combination of dam operations and other management actions to achieve the vision, mission, goals, and objectives of the GCDAMP?
2	**RIN 12.9.3** What are the relationships between dam operations and other management actions in their effects on resources addressed by GCDAMP management objectives?

M.O. 12.10 Maintain or attain adequate funding from power revenues, foundations and corporations, appropriations, and State agencies to meet AMP goals.

M.O. 12.11 Maintain or attain participation from externally funded investigators that can help address the information needs and meet AMP goals.

Appendix 1
Process for Developing the Information Needs

The INs have been developed thorough a collaborative process led by the Grand Canyon Monitoring and Research Center (GCMRC). This process was initiated with GCMRC developing a draft set of INs for review and comment at a meeting of the Technical Work Group (TWG) and principal investigators held at the Phoenix Airport on April 3, 2001. A second meeting to discuss cultural INs was held in Flagstaff on May 8, 2001. Following these meetings, GCMRC revised the INs and discussed them at the May TWG meeting. Following this meeting the INs were put in a table and electronically mailed to the TWG for additional comment. Very few comments were provided by the TWG. At this point, the INs and the process for developing the INs was discussed in a number of conference calls and it was agreed that the INs would be reformatted into the nested outline form used in the current document. It was also agreed that the reformatted INs would be mailed to the TWG for review and comment and that a second workshop for reviewing and revising the INs would be held at GCMRC on August 8-9, 2001.

This current document results from the work conducted at the August 8-9, 2001 INs workshop and the subsequent review at the September 6 TWG meeting. On the first day of the August 8-9 INs workshop the TWG, PIs, and GCMRC staff divided into 4 concurrent breakout groups and reviewed the draft INs. Each group addressed the following questions during their review:

1) Do the INs for a given MO provide the information that is needed to address that MO? If not, please indicate how they should be revised and what should be added or deleted.

2) Are the INs written at the appropriate level of detail and correctly categorized with respect to the categories of "core monitoring," "effects monitoring," and "research"?

3) Taken together as a set do the INs and MOs represent the information needed to address a given goal?

On the second day of the August 8-9 INs workshop, a representative of each breakout group presented their proposed changes to the group as a whole. In response to these comments, the INs were either modified or the comments were captured in a table for subsequent consideration. The revised draft and the comments table were e-mailed to the TWG on August 20 for review prior to the September 6-7, TWG meeting. The National Park Service, Colorado River Energy Distributors Association, and Western Area Power Administration provided written comments on the INs. The INs were subsequently reviewed and revised at the September 6, 2001 TWG meeting.

A revised Draft INs document was e-mailed by GCMRC to the TWG on Friday September 14, 2001. Recommendations for deleting INs, for specific language changes to the existing INs, or specific language for adding new INs were provided by TWG members to GCMRC by October 5, 2001. These were collated into a comments table, organized sequentially beginning with comments on the first IN, and sent back to the TWG on October 12 for review prior to an October 22-23 ad-hoc TWG workshop to revise the INs. At the October 22-23 TWG workshop, the first day was spent discussing overarching concerns relating to the scope of the AMP as expressed in the Goals and Management Objectives and concerns over the definitions used in the

document. Only the INs for Goal 11, Cultural Resources were addressed. It was also agreed that a small group would work on revising the definitions and would send them to GCMRC. The definitions agreed to by the small group are included in this document. On the second day, INs for Goals 7, 8, 9, and 10 were addressed.

GCMRC has taken all of the comments included in the October 12th table and added changes agreed to at the October 22nd meeting to forge a November 2nd Draft of the Information Needs. The November 2nd Draft was sent to the TWG for review at the November 13-14 TWG meeting. Limited detailed review occurred at the November 13-14 meeting with the majority of the time being spent on over arching issues. As a result, TWG members were asked to submit their comments to GCMRC by close of business November 16th. Another draft, dated November 26th that included those comments as red-line and strike-out changes to the November 2nd draft was mailed to the TWG for review on November 26th. The TWG was asked to provide GCMRC with their final comments by December 7th. This FINAL DRAFT incorporates comments received by GCMRC as of December 7th.

Action Taken on the Strategic Plan by the TWG

November 7, 2002

The following changes were accomplished during discussion throughout the meeting and from recommendations from GCMRC that were requested by TWG at its last meeting:

1. **Edited** RIN 1.2.1 – How are the composition and biomass of benthic invertebrates between Glen Canyon Dam and the Paria River affected by flow, ~~and~~ water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), new invasive species, and water borne diseases, or other factors?

2. **Edited** RIN 1.3.3 – How do top-down effects on primary producers (grazing and predation) ~~on primary producers~~ affect food base productivity?

3. **Edited** RIN 1.4.1 – How are the composition and biomass of benthic invertebrates in the Colorado River ecosystem below the Paria River affected by flow, ~~and~~ water quality (including nutrients, temperature, light regime, toxins, dissolved oxygen), new invasive species, and water borne diseases, or other factors? [Note: If the cost of obtaining this data, relative to the benefit of the information suggests the information is not worth the expense, this RIN will not be pursued.]

4. **Edited** MO 2.1 – Maintain or attain humpback chub ~~(>51 to <200 mm)~~ abundance and year-class strength in the LCR and other aggregations at appropriate target levels for viable populations and to remove jeopardy.

5. **Edited** RIN 2.1.2 – ~~What are the~~ Quantify sources of mortality for humpback chub <51 mm in rearing habitats in the LCR and mainstem and how are ~~they~~ these sources of mortality related to dam operations.~~?~~

6. **Added** RIN 2.1.5 – Determine the timing and quantity of young-of-year humpback chub dispersal (passive and active) from the LCR.

7. **Edited** RIN 2.2.2 – ~~Can~~ Determine if a population dynamics model ~~be developed to~~ can effectively predict viability of native fish under different flow regimes and environmental conditions.~~?~~

8. **Edited** RIN 2.2.7 – Determine if implementation and operation of ~~a~~ the TCD and/or steady flows represent a technically feasible, ecologically sustainable, and practical option for establishing mainstem spawning.~~?~~

9. **Edited** RIN 2.2.9 – ~~Is~~ What is the appropriate role of humpback chub augmentation ~~a viable and advisable~~ as a management strategy to establish mainstem spawning aggregations.~~?~~

10. **Edited** RIN 2.2.10 – What techniques are available to determine natal stream of ~~native~~ fish<u>es</u> in the Colorado River ecosystem?

11. **Added** RIN 2.2.12 – What are the impacts of research activities on mortality, recruitment and the population size of humpback chub?

12. **Edited** RIN 2.3.3 – <u>How</u> does nonnative fish control affect disease/parasite loads?

13. **Edited** RIN 2.5.1 – ~~Would the introduction of~~<u>If</u> razorback suckers <u>were stocked</u> into the Colorado River ecosystem<u>, what is the risk that hybridization with flannelmouth suckers would</u> compromise the genetic integrity of <u>either species</u> ~~flannelmouth suckers due to hybridization~~?

14. **Edited** RIN 2.5.2 – <u>How does</u> ~~Is the~~ existing hybridization between razorback sucker<u>s</u> and flannelmouth sucker<u>s affect</u> ~~a source of concern for~~ the genetic integrity of either species? What are the factors contributing to this ongoing hybridization?

15. **Edited** RIN 4.1.4 – <u>How does</u> ~~Has there been a change in~~ the genetics or "strain" of rainbow trout in the Lees Ferry reach ~~that might account for the decrease in~~ <u>influence the</u> average size of fish creeled by anglers?

16. **Edited** RIN 5.1.6 – ~~Does the Vasey's Paradise~~ <u>What is the range of occurrence of the ambersnail</u> taxon ~~occur outside of~~ <u>found at</u> Vasey's Paradise?

17. **Edited** RIN 5.2.3 – <u>How</u> can remote sensing technologies be used to less intrusively and more cost effectively characterize and monitor Kanab ambersnail habitat at Vasey's Paradise (vegetation type and distribution)?

18. **Deleted** IN 6.4: How do ecosystem processes shape community dynamics?

19. **Edited** IN 6.5 – How much allochthonous material <u>(e.g., leaf litter)</u> is exchanged between the terrestrial and aquatic systems?

20. **Edited** RIN 6.5.1 – ~~Are~~ <u>Determine if</u> nonnative species <u>are</u> expanding or contracting at a local scale (patch or reach).~~?~~

21. **Edited** SIN 7.2.1 – <u>How</u> do the hydrodynamics and stratification of Lake Powell influence the food base or fisheries downstream?

22. **Edited** SIN 8.5.1 – <u>How</u> do sand bar textures influence biological processes? ~~If so, then how?~~

23. **Edited** SIN 8.5.4 – ~~Can~~ <u>What is the role of</u> turbidity <u>and how can it</u> be managed to achieve biological objectives?

24. **Edited** SIN 8.5.5 – <u>How</u> can the ongoing fine sediment supply be managed to achieve sustainable habitats?

25. **Edited** SIN 8.5.9 – How are sandbar textures related to cultural site stability? ~~If so, then how?~~

26. **Edited** SIN 8.5.10 – How are sand bar textures related to recreational site stability? ~~If so, then how?~~

27. **Edited** RIN 8.6.1 – How do ongoing inputs of coarse sediment from tributaries influence storage of fine sediment within pools, runs, and eddies throughout the Colorado River ecosystem?

28. **Edited** RIN 8.6.2 – How do ongoing inputs of coarse-sediment from tributaries alter the distribution of main channel habitats needed by benthic organisms within pools, runs, and eddies throughout the Colorado River ecosystem?

29. **Edited** RIN 9.1.2 – Determine appropriate carrying capacity for recreational activities within the Colorado River ecosystem. ~~Are the visitor capacities for recreational activities consistent with NPS management plans? Are NPS management plans consistent with Colorado River ecosystem capacities to absorb visitor impacts?~~

30. **Edited** RIN 9.1.3 – How do ongoing inputs of coarse sediment from tributaries diminish or enhance navigability of rapids throughout the Colorado River ecosystem?

31. **Edited** RIN 11.2.4 – ~~If there is a resource change, what are the sources?~~ What changes are occurring in cultural resource sites, and what are the causes of those changes?

32. **Edited** RIN 12.2.7 – How can GIS be used to designate and stratify habitats to improve system-wide extrapolation of population estimates and habitat in the Colorado River ecosystem? ~~Can habitat designation using a GIS application be utilized as an effective method to adjust site-specific population estimates (e.g., mark-recapture or depletion methods) to system-wide extrapolations by using catch-per-unit-effort values that are scaled relative to the proportion of different habitat types available in Glen Canyon?~~

33. **Edited** RIN 12.7.1 – How effective are the current strategies to achieve tribal consultation ~~effective~~?

34. **Edited** RIN 12.7.2 – How well do the~~se~~ current strategies to achieve tribal consultation meet legal and AMP protocols?

35. **Edited** RIN 12.8.1 – ~~Is~~ How well does current tribal participation in the AMP research and long-term monitoring programs ~~sufficiently meeting~~ meet tribal needs and desires?

The following sequence orders were determined through a paired comparison exercise:

36. **Newly sequenced** to sequence level 2: RIN 2.1.5 – Determine the timing and quantity of young-of-year humpback chub dispersal (passive and active) from the LCR.

37. **Newly sequenced** to sequence level 3: RIN 2.2.12 – What are the impacts of research activities on mortality, recruitment and the population size of humpback chub?

38. **Newly sequenced** to sequence level 6: IN 6.1 – Develop GIS coverages of natural communities in the Colorado River ecosystem to use in identification of status and trends.

39. **Newly sequenced** to sequence level 6.5: IN 6.2 – Develop or adopt an existing ecological community classification system. The system should describe the composition and frequency of vascular plants, vertebrates, arthropods, and mollusks to an appropriate taxonomic level.

40. **Newly sequenced** to sequence level 6: IN 6.3 – How is the abundance of vertebrate consumers affected by seasonal shifts in food base abundance in the Colorado River ecosystem?

41. **Newly sequenced** to sequence level 5, and re-numbered to IN 6.4: IN 6.5 – How much allochthonous material (e.g., leaf litter) is exchanged between the terrestrial and aquatic systems?

42. **Newly sequenced** to sequence level 4.5: IN 8.1 – If sediment cannot be preserved in the system using available management actions, what is the feasibility (including technical, legal, economic, and policy issues) of sediment augmentation as a means of achieving this goal?

43. **Newly sequenced** to sequence level 7: IN 10.1 – Determine and track the impacts to power users from implementation of Record of Decision dam operations and segregate those effects from other causes such as changes in the power market.

44. **Newly sequenced** to sequence level 9: EIN 11.3.1 – Determine if and how experimental flows and other AMP actions restrict tribal access.

45. **Newly sequenced** to sequence level 9: EIN 11.3.2 – Determine reasonable management actions that should be taken to facilitate tribal access.

46. **Newly sequenced** to sequence level 3: IN 12.1 – Develop information that can be used by the TWG, in collaboration with GCMRC, to establish current and target levels for all resources within the AMP as called for in the AMP strategic plan.

The following changes in sequence order were determined a fatal flaw analysis by TWG members:

47. **Changed the sequence order** from 6.5 to 4: RIN 1.4 – What is the current carbon budget for the Colorado River ecosystem?

48. **Changed the sequence order** from 4 to 2.5: RIN 4.2.2 What is the most effective method to detect emigration of rainbow trout from the Lees Ferry reach?

49. **Changed the sequence order** from 4.5 to 3.5: RIN 11.1.2.a For each tribe and living community, what are the register eligible traditional cultural properties?

The following motion was passed by TWG at the end of the meeting:

50. The Technical Work Group has sequenced the entire set of Information Needs (attached) as directed by AMWG. The TWG is unable to recommend approval of the INs, absent the criteria for what is in and out of the program. Therefore, TWG recommends that this list be approved by AMWG only after it has been subjected to AMWG-approved criteria for what is in and out of the AMP.