Attachment 1. POTENTIAL STUDY TOPICS FOR THE SCIENCE PROGRAM 2004 CALL FOR PROPOSALS

WHAT WE NEED TO LEARN

This attachment describes in detail the study topics that are of particular interest to the Science Program under this solicitation. These science topics have been developed using a process that began with identifying important questions from the perspective of CALFED agencies and stakeholders. Science Program staff then used reviews of current knowledge and suggestions about potential scientific approaches to answer core management questions to develop three priority topic areas:

- water operations and biological resources,
- ecological processes and their relationship to water management and key species, and
- improving tools for performance assessment and evaluating implications of future changes.

These topics represent what we need to learn to support short- and long- term decision making in CALFED.

Life Cycle Models and Population Biology of Key Species

Construction of biological models requires a detailed understanding of population biology, the physical and biological mechanisms underlying population dynamics, and the responses of various life stages of key species to natural and human perturbations. The more robust our understanding of why environmental processes affect growth, survival, longevity, recruitment, and migration, the more effective life cycle models will be at predicting population dynamics under different management conditions. Quantitative life cycle models could enable us to better understand the effects of water exports on native fish populations. The long-term goal for this study topic is to develop quantitative models for key species and ecosystems that allow us to examine overall population changes in response to multiple stressors across different life stages and locations. We expect most efforts to focus on processes and responses of key fish species and populations, including salmonids, delta and longfin smelt, Sacramento splittail, and green sturgeon. It is also important to better understand fish communities, with an emphasis on better understanding the interrelationship between native and nonnative species.

The Science Program is soliciting research that will add critical knowledge to answer these questions at a range of spatial and temporal scales in the Bay-Delta System. Efforts to develop a conceptual model of salmonids in the Sacramento and San Joaquin Valleys, annotated with the available knowledge of their biology, are especially encouraged. These models should be amenable to use in developing or refining a research plan in order to better understand salmonid life cycles and the associated research priorities. The Science Program is also soliciting proposals that use models to test alternative hypotheses about movement and rearing in the Delta and Suisun Marsh (Figure 1A), vulnerability to pumping, habitat use, and migration timing.

Environmental Influences on Key Species and Ecosystems

Ecosystems and species respond to a wide range of environmental factors. It is important to learn more about environmental processes and their influences on key species for several reasons. To more effectively answer management questions, knowledge is needed that supports interpretations of observed changes in the abundance and distribution of key species, creates effective life cycle models, helps

separate natural variability from anthropogenic forcing, and provides key information about our management assumptions. The Science Program is therefore soliciting research that will build our knowledge of the links between a wide range of environmental processes (physical, chemical, and biological) and key species and ecosystems. We need to increase our knowledge of these connections in all components of the Bay-Delta System.

Relative Stresses on Key Fish Species

Export pumping has long been considered by many to be the primary anthropogenic threat to fish in the Delta and Suisun Marsh. Actions in response to formal "listing" of fish under federal and State endangered species laws often emphasize managing direct mortality at the pumps through take and export restrictions. Partly as a result of this emphasis, relatively little is known about alternative threats to populations of at-risk species. A more complete view of vulnerabilities in the life cycle and environmental influences will require direct consideration of other sources of stress. Life cycle models (see above) that place a range of different stressors and benefits into a common framework ultimately depend on the quality of information supporting each piece of the model. Specific, quantified information on the effect of different stressors, including predation, food availability, contaminants, and habitat, are key information gaps for both key species and many other Delta resources. The long-term goal is to increase the credibility of management discussions about different upstream and downstream restoration and management actions by and testing alternative hypotheses about the relative importance of different stressors. The Science Program is soliciting proposals to fill such information gaps with the integrated application of existing approaches and new tools to a range of stressors, including (i.e., not limited to) the following four stressors.

- **Predation.** Predation on native fish by exotic species, such as striped bass, is thought to exert a significant stress on native populations. Despite its significance, we know very little about the magnitude of predation or about the processes that affect it. We are seeking studies that would build our understanding of this important stressor.
- **Food.** The overall supply of food to aquatic organisms in the estuary and Delta ecosystems may limit the restoration of key fish species. To fill a critical information gap, we are seeking studies that would improve our understanding of the environmental processes that control carbon fluxes and food availability throughout the system and how these, in turn, influence key species.
- **Contaminants.** Chemical contaminants (e.g., pesticides, metals, and metalloids) are an important potential threat to ecosystem restoration in the Bay-Delta System. We are seeking studies that would improve our understanding of the relative importance of this stressor compared to other stressors.
- **Habitat.** Many CALFED actions are based on assumptions about links between habitat creation and management, aquatic species recovery, and water operations. To help place the benefits of habitat restoration in a context where it can be compared to other management options, we are seeking studies that will improve our understanding of why specific habitats support different species in different ways and what factors control population dynamics.

Direct and Indirect Effects of Diversions on At-Risk Species

A significant effort aimed at reengineering large sections of the State and federal diversion facilities is underway to reduce the effects of project diversions on at-risk species. CALFED is in the process of considering a wide range of engineering changes, such as the installation of screens to prevent entrainment of fish, shifts in pumping regimes, and large-scale facilities designed to salvage and protect fish that are entrained in diversions (Figure 2). The understanding of causal links between export pumping and changes in hydrodynamic, transport, and biological processes, including predation and in-channel

primary production, however, is limited, and the result is a critical gap in knowledge that, if filled, could help place the value of these large-scale engineering efforts into a broader population-level context for at-risk species.

Examples of study topics that would fill these gaps in our knowledge of diversion effects are described below.

- **Direct and Indirect Effects in the "Zone of Influence" Near Intakes.** The Delta environment (Figure 1A) is actively managed to change salinity patterns, preserve fish migratory pathways, and modulate the flow of water coming into the Delta and Suisun Marsh from the Sacramento River system. The Science Program is seeking proposals that will improve our understanding of how these activities influence environmental conditions, hydrodynamics, and fish abundance and behavior in the immediate vicinity of the State and federal diversion facilities.
- **Environmental Factors That Lead to Entrainment.** The relationships between environmental factors (such as water temperature, day-night differences, and migration patterns) and entrainment in State, federal, and other Delta diversions have long been observed, or at least been hypothesized. The Science Program is seeking proposals for detailed studies targeted at determining the underlying mechanisms that lead to entrainment.
- **Entrainment and Salvage of Fish in Existing Diversion Facilities.** Research is needed to better understand whether and to what degree entrainment can be reduced and how the entire salvage process can be made more efficient. The Science Program is seeking proposals for studies that can provide the CALFED management community with assessments of existing salvage activities in the context of population-level effects on at-risk species **and a framework for evaluating** ranges of probable environmental benefits associated with combinations of engineering and operational modifications.

Processes Controlling Delta Water Quality

Improving water quality in the Delta and Suisun Marsh is one of CALFED's four major program objectives, and Delta water quality concerns cut across many CALFED activities. Several regulatory standards and programmatic goals describe desired water quality conditions in the Delta and Suisun Marsh—primarily focusing on salinity, bromide, organic carbon, and dissolved oxygen. Answering key management questions related to water quality requires building a base of scientific knowledge designed to enable CALFED to clearly distinguish between the effects of multiple activities, including project operations, channel modifications, restoration activities, upstream load reduction (source control), establishment of introduced species, and variable hydrology. The following water quality issues are of particular concern.

- **Data Analyses for Strategic Improvements in the Delta Water Quality Monitoring Network.** The Science Program is seeking studies that would develop further knowledge using monitoring data on a wide range of water quality attributes, including long-term and short-term variation over space and time, effects of climatic and other regional-scale stressors, processes and operations controlling water quality between regions, and fluxes at major input and exit points in the Delta.
- **Organic Carbon.** Organic carbon in the Delta and Suisun Marsh waters is a complex mixture of a variety of carbon compounds that reflects upper watershed processes and inputs as well as Delta biological processes and human activity. The Science Program is seeking proposals for studies on the distribution, origin, modification, and transport of these compounds. These topics are of critical interest to CALFED as they relate to the Estuarine food web and the supply of safe drinking water.
- **Dissolved Oxygen.** Periods of low dissolved oxygen concentration occur each year in the Stockton Deep Water Ship Channel, which branches off the San Joaquin River in the eastern Delta. The

channel is thought to act as a barrier to Chinook salmon migration and may impact other fish species. Although substantial research is being done on this problem, the Science Program is seeking proposals to study the factors that control the transport of oxygen-consuming material and give rise to low dissolved oxygen conditions throughout the Delta. The studies of these factors should further our understanding of the potential interactions between different CALFED activities, such as habitat restoration and the installation of barriers, and low dissolved oxygen conditions.

Implications of Future Change on Regional Hydrology, Water Operations, and Environmental Processes

CALFED has launched many projects supporting water conservation, surface water and groundwater storage and management, ecosystem restoration, and refinements in water operations to support the broad objectives of water supply reliability, ecosystem protection and restoration, improved Delta water quality, and increased levee reliability. Understanding the magnitude and reliability of projected climate, population, and land-use changes will be critical for long-term management of resource use and ecosystem protection in the Bay-Delta System. The Science Program is seeking proposals for research in four areas that will help fill information needs related to future change.

- **Developing Quantitative Models That Link Climate Change Scenarios to Regional Hydrologic-Based Models.** Quantitative models are needed to develop scenarios for potential climate and land-use change, including downscaling from existing climate models and linking these to regional hydrologic-based models and the reliability of models for prediction.
- **Quantitatively Assessing Regional Climate-Driven Hydrologic Changes on Ecosystem Processes.** It is crucial to understand how climate change will alter several key environmental factors, such as rainfall and snowmelt patterns in California's mountains, related reservoir inflows, flood frequencies and floodplain hydrology, sediment transport, and conditions in the Delta and Suisun Marsh, including inflow and circulation patterns, salinity, and water temperature.
- **Improving Our Understanding of Project Operations and Ecosystem Processes.** Changes in environmental factors will also have significant implications for water operations, water availability, water quality, flood control, and other operations parameters. Applying scenarios of probable regional hydrologic shifts to current operations and assessing how these scenarios might differ under probable changes in infrastructure would provide basic information about how currently planned actions might fare under reasonably likely climate shifts.
- **Evaluating the Combined Implications of Climate Change on Water Operations and Environmental Processes.** Two important questions associated with climate change are what are the implications of likely shifts on key environmental factors and how do they relate to operational regimes, regulations, water management, key species, and ecosystem structure and function. We also need to know how these changes affect prospects for restoring aquatic habitats, sustaining water quality, and managing species of special concern. Modeling or inferring these implications and clearly defining the uncertainties inherent in such projections would begin to fill in critical information about long-term performance of CALFED projects.

Water Management Models for Prediction, Optimization, and Strategic Assessments

Needs in water operations modeling across CALFED and the broader California water management arena are wide-ranging. At the systemwide level, California's water system is being asked to operate in an increasingly integrated manner across local and regional scales, with multiple local water demands and supplies being considered in the context of operations of statewide aqueducts and storage infrastructure.

A critical question about the long-term performance of CALFED actions is how well can we predict what might happen in the future with sets of hydrological and meteorological conditions that have not yet been experienced and may be substantially different from the past if climate variability and climate change are considered. The CALFED community could use models to explore hypotheses about specific policies and priorities and move beyond project assessments based on fixed regulatory regimes. Several specific study areas would serve to enhance current model capability and allow support for these kinds of questions.

- **Improving Water Management Optimization: Calibration, Mass Balances, and Groundwater Input Data.** Water managers and policymakers are faced with a plethora of feasible decisions regarding water management. Sorting through the range of feasible decisions to identify a subset that represents optimal solutions requires a mathematically based "map" of the water supply system that reflects all of the interconnections and constraints. The CALSIM II model collaboratively developed by the California Department of Water Resources and the Bureau of Reclamation provides a means to calculate optimal solutions for economic efficiency, supply reliability, and environmental protection. Improving CALSIM II's ability to define optimal solutions under changing regional climatic conditions is one potential topic of study.
- **Improving Our Understanding of Relationships between Project Operations and Ecosystem Processes.** Using water system modeling tools such as CALSIM II is a common practice across CALFED to answer management questions. Although these types of questions are at the forefront of the program and water policy development, the modeling tools mainly use specific regulatory operational constraints as surrogates for desired environmental conditions. To enable CALFED to design and use more robust regulatory tools (linked, for example, to complex dynamic processes like salmon population dynamics), modeling tools must be developed that better link nonlinear biological and hydrologic processes to linear water supply models. This need also extends to development of models for those environmental processes.
- **Improving Understanding of Water Supply, Demand, and Hydrologic Interdependencies.** Current models assume that facilities, land use, water supply contracts, and regulatory requirements are fixed. In reality, these systems are not independent—they also vary in response to hydrologic and policy changes. Studies examining these interdependencies and how to model them and link the impact of surface water use on groundwater extractions will be extremely useful in future management.
- **Improving Real Time Strategic Assessments.** The CALSIM II model in its current form is most useful as a long-term planning tool. However, models are needed that enable strategic assessments of operations on a real-time basis. Studies are needed to support development of graphical user interfaces for CALSIM II and incorporating these interfaces into gaming processes, and approaches to link the existing systemwide optimization model with modules that run at much shorter time steps and are more closely linked to tidal timescale Delta hydrology.
- **Improving Assessment of Water Supply Reliability.** Improving water supply reliability is a core CALFED objective. Evaluating whether individual actions or collections of actions have measurable effects on reliability and at what scale those effects are manifest (local, regional, or interregional) is a critical research area. We need to improve our ability to both predict changes in reliability and assess how differences in policies, hydrology, and operational configurations may affect reliability.

Assessment and Monitoring

Much effort is dedicated to monitoring a wide range of biologic and physical parameters in the Bay-Delta System. This monitoring is bolstered by a large but somewhat more limited applied research effort. The resulting data and information have been valuable in managing and establishing trends in the system, but there is widespread agreement that further monitoring and more complete analysis of existing monitoring

data are needed. The Science Program is soliciting proposals for research that will identify weakness in the existing programs and how best to improve them. Projects that examine types of monitoring, modeling with monitoring data, or types of analyses that could benefit future management are examples of research that would better allow for changes and responses to be clearly identified and quantified.

For example, more than 100 species of native and introduced fish inhabit Central Valley streams. Research programs to test monitoring and assessment strategies for these species are needed. Actual population sizes of key species are not well known, and population estimates suffer from serious, and largely unquantified, uncertainties. In most cases in the Delta, species abundance indices are used to describe relative population size. General abundance trends can be discerned, but data are usually not adequate to determine whether specific actions (e.g., the Environmental Water Account use) are responsible for, or even contribute to, the observed trends. Ways to better determine population size are needed for almost all key species and phytoplankton, aquatic macrophytes, zooplankton, and other important organisms. Comparisons of existing abundance and distributions to historical data could provide further insight into the ways communities have changed over time and how best to monitor that change. In streams, benthos may also be key indicators of restoration progress in stream environments. Research to evaluate how best to use benthic communities in streams, floodplains (e.g., Yolo Bypass), or the Delta and Suisun Marsh is needed. Evaluations of how best to quantify the trends in the invasive species with comparisons to historical data are also needed.

Similar needs exist for a wide range of parameters, and organisms cross all programs in CALFED. There is a need to better define the methods of assessment for all endeavors to monitor physical, chemical, and biological change in the Bay-Delta System. We are looking for proposals to thoroughly address methodology as well as assess actual change in this system.

Salmonid-Related Projects

It is likely that much of the research proposed for this solicitation will focus on Chinook salmon and steelhead because a significant portion of CALFED's restoration efforts is directed toward these species; they use a variety of habitats throughout the entire system, and many management and regulatory actions are tied to their protection and recovery. Because Chinook salmon and steelhead are dispersed throughout the Bay-Delta System, it is critical that a common organizational structure be used for studies over the whole geographic region. The Science Program is seeking proposals for studies that will accelerate joint analysis of data sets from different parts of the region, jointly develop models by researchers who have not previously worked together, and/or relate ongoing salmonid studies in the Bay-Delta System with studies conducted elsewhere (e.g., the northwestern United States). Specific salmonid-related research areas are also of interest to CALFED. The following list provides perspective on a few of the more important science needs but is not meant to be a comprehensive list of the needs of salmonid research in CALFED.

- **Escapement.** Although we now have estimates of the number of adults escaping to Central Valley streams, the quality of these estimates varies widely. The Science Program is seeking proposals that evaluate and compare escapement methodologies, develop clear descriptions of uncertainty, and relate different protocols to historical data.
- **Naturally Spawning Fry.** The fate of fry from naturally spawning fall-run Chinook salmon is largely unknown and poorly understood. Where these fry rear and whether they make a significant contribution to the fishery and adult escapement remain pressing questions. The Science Program is seeking proposals for research to frame important questions and successful monitoring strategies on this topic.
- **Hatchery and Natural Stocks.** Although all four races of Chinook salmon and steelhead have some level of hatchery supplementation, relatively little is known about the effects of this production.

Better knowledge of the proportion of hatchery-reared fish occurring in Central Valley streams is critically needed. The Science Program is seeking proposals that examine hatchery-related effects, evaluate different marking and management techniques, or review strategies used elsewhere in the CALFED institutional context.

- **Juvenile Salmonid Emigration and Movement through the Delta.** The questions of how juvenile salmon are using the Delta, where they go, and how they fare while in the Delta are important for many CALFED agencies, especially as a means of improving the biological basis of water management actions. The Science Program is seeking proposals that will help further our understanding of growth and mortality rates, use of specific habitats, movement patterns and transit routes, influences of tidal flows, and losses as a result of the stressors listed above (like predation). Analyses of existing data, use of models such as the Particle Tracking Model, or new studies/observations are possible approaches that could advance learning.
- **Systemwide Central Valley Chinook Salmon.** The Science Program is seeking proposals that will lead to better estimates of juvenile production and survival to help improve our understanding of the relationships between adult escapement, habitat features, and juvenile production and survival. Studies could also add to knowledge of juvenile migration and survival rates. Although the escapement estimates provide an overall measure of trends for the entire system and for individual runs, they do not isolate the specific processes that may contribute to the overall population condition. More sophisticated indices or metrics, such as overall smolt production or juveniles per spawning female, could be developed to provide an additional level of resolution about the function of instream processes.
- **Ocean Conditions and Fishery Relationship to Survival.** The Science Program is seeking proposals to research linkages between salmon fate in the oceans and processes/stresses in the estuary, Delta and Suisun Marsh, and watershed. A critical aspect of this type of research would be to define the relative importance of stressors in these areas and the need for CALFED to expand studies off the California coast.

Delta Smelt–Related Projects

The legal status of the population of delta smelt (i.e., whether it is in jeopardy or ready for delisting) is based on the abundance and distribution of the adult population and the magnitude and reversibility of threats to the species. The various sampling programs that take place in the San Francisco Bay Estuary are often examined to determine the relative abundance and distribution of various life stages within each year. Basic biology, including physiology and population dynamics, forms the backdrop for explaining year-to-year variations in abundance and distribution. The recently developed ability to spawn and rear delta smelt in the lab offers the possibility of further progress in understanding their biology and physiology. The principal conservation action for delta smelt has been modification of water management operations. Quantitative measurements of the benefits of these actions have been difficult to assess, and the relative impacts of other stressors on the population of delta smelt have only recently begun to be investigated. The possible impacts of contaminant reductions in food supply, increases in predation, and changes in the ecosystem have drawn much discussion about their implications for the conservation and eventual recovery of this species.

Fundamental research is needed to bring to light additional potential management tools and to help determine the relative effectiveness of protecting smelt through habitat enhancement, improved screening and salvage facilities, and manipulation of water management practices. Collaborative work between agency biologists and outside researchers through the Interagency Ecological Program Delta Smelt Project work team and ongoing delta smelt workshops held to address issues raised during the implementation and review of the Environmental Water Account program have been effective at synthesizing and publicly discussing new knowledge and its implications, as well as developing tools

such as life cycle models. The Science Program is seeking proposals that foster further collaboration through joint investigations. We also need studies that will yield information on a relatively short time frame and others that will form the basis for longer-term management of smelt and the system. The list of topics presented below presents a portfolio for potential projects related to delta smelt.

- **Conceptual and Mechanistic Models.** A long-term research goal is to have several different quantitative models that allow us to examine overall population changes in response to multiple stressors across different life stages and locations. The Science Program is seeking proposals to refine and further develop quantitative life-cycle models for delta smelt. These models would be most valuable in investigating the consequences of various assumptions such as changes in carrying capacity and density dependence, changes in the size and fecundity of spawning adults, and the role of environmental factors such as water temperature in relation to spawning period duration and growth. Existing data and hydrodynamic models might also offer opportunities to evaluate conditions that lead to substantial entrainment events of delta smelt at export facilities in the Delta.
- **Temperature, Spawning, Spatial, and Abundance Relationships.** The Science Program is seeking proposals for research to investigate the apparent importance of water temperature and other environmental variables on spawning, abundance, location, and overall population risk. Analyses that result in refined designs of temperature monitoring networks stations and link hydrodynamic and temperature models to existing abundance data would also be of interest.
- **Basic Biological and Ecological Research.** Although there have been great strides in gaining understanding about basic biology of delta smelt over the past few years, there is still a great deal of knowledge that could be helpful for long-term management. For example, although we have some theories of where and when smelt spawn, it has never been observed in the field. There is also some evidence to suggest that food supply in the Delta might play a significant role in the survival of certain life stages, but our knowledge of the processes that control carrying capacity and food web shifts is not detailed enough to determine why this might happen and its relative importance to the population. The Science Program is seeking proposals to further our understanding of delta smelt biology.