Part 1. Strategic Plan

1-1 Introduction

Part 1 of this document describes a strategic approach to adaptive environmental management (AEM) for the Lower Columbia River (LCR) and estuary. The development of the strategic Plan for the LCR and estuary was based in part on existing AEM Plans for other major ecosystems including the Florida Everglades, the Chesapeake Bay, the Upper Mississippi River, and Glen Canyon. Part 1 begins with a brief overview of adaptive management. The discussion continues by describing the necessary components of an AEM Plan in the context of the management goals and objectives associated with Columbia River Channel Improvement Project (CRCIP). The proposed AEM Plan and Process for the LCR and estuary are developed in the context of decision analysis and risk assessment.

Part 2 of this report presents a proposed AEM Plan developed specifically to address environmental issues related to Channel Improvement Project. The AEM Plan is developed in the context of engineering control theory. Part 2 presents the details of implementing the strategic Plan outlined in Part 1. Central to the proposed Plan and process is the establishment of the necessary feedback mechanisms that inform management and decision-making through comparisons of current conditions with decision criteria for selected performance measures and risk endpoints. Part 2 also describes the proposed MA and ecosystem evaluation actions (EEA) as providing the fundamental information base for establishing the feedback that characterizes adaptive management and decision-making. Part 2 discusses possible technical and organizational barriers to adaptive management and outlines potential solutions to overcome them. Part 2 concludes by considering the contribution of the proposed Channel Improvement AEM Plan to a more comprehensive adaptive management program that could be designed for the LCR and estuary.

The AEM Plan describes a process for adaptive management regarding channel modifications performed under the CRCIP. This Plan is not a decision-making document; however, it describes a process for decision-making within an adaptive management framework. Outcomes of the adaptive management process are not intended to compromise the legislative mandates or authorities of the participating federal or state agencies; their authorities shall prevail as applicable.

Adaptive Management

As implied by the term, “adaptive management” prescribes a management process wherein management activities can be changed in relation to their efficacy in restoring and/or maintaining an ecological system in a specified desired state or ecological potential (Gunderson and Holling 2002). Desired state may specify some precisely defined structural condition or, more realistically, a range of structural conditions, desired state can also specify rates of ecological processes or some description of biotic potential (e.g., energy capture and processing or production). A key component in AEM is the establishment of a feedback mechanism wherein characterization of current conditions (monitoring) can be used in conjunction with an understanding (model) of the system dynamics to alter management actions, if necessary, to produce future system conditions compatible with the desired conditions that derive from management goals and objectives.

AEM is an iterative process for managing natural resources (Gunderson and Holling 2002, Gray 2000, Walters 1986, Holling 1978). AEM recognizes that decisions are often based on the best available, yet incomplete and imperfect, scientific data, information, and understanding. Competing interests and constraints on time and resources can further complicate the management and decision-making process. Under these circumstances, there is no best approach to decision-making (Anderson et al. 2003). Importantly, AEM provides a decision-making process that can adjust management actions based on newly acquired science and monitored responses of performance measures in relation to previous decisions. This iterative process can increase the likelihood that management goals and objectives (e.g., ecosystem restoration, sustainability) will be achieved.

Walters (1986) offers three ways to structure environmental management as an adaptive process: (1) evolutionary (trial and error), (2) passive adaptive, and (3) active adaptive. Evolutionary AEM defines a management approach that attempts to achieve desired conditions through educated guesses and accumulated knowledge of system response to previous management activities. The benefits of this largely trial and error approach include comparatively low costs in implementation. The main drawback is the potentially low effectiveness in achieving management goals and objectives. Another negative aspect of this approach is the informal and minimal investment in gaining an understanding of system dynamics as the result of management.

Passive AEM describes a management approach that uses current understanding of the system to change management actions in response to monitoring conditions that change as a result of the “natural” range of perturbations to the system. An advantage of passive AEM is learning to manage effectively by monitoring system conditions (including patterns of disturbance), undertaking management actions in light of current understanding, and determining the utility of the management actions in relation to obtaining conditions consistent with management goals and objectives. One limitation of this approach lies in developing management capabilities that are effective only within the range of disturbance regimes experienced during management. Passive AEM may provide sufficient management capability for a reasonable range of system conditions and disturbances yet preclude the development of management skills necessary to correctly respond to highly unusual circumstances) that are not likely to be encountered during the management period.

Active AEM views management actions as purposeful and scientific experimental manipulations of the system (e.g., Walters and Holling 1990) to increase understanding of system behavior in the short term and as a result, achieve management goals and objectives in the long term. Active AEM encumbers a “dual control” problem, where trade-offs between short term gains in understanding through system manipulation must be weighed against the probability that such manipulations might produce substantial and irreversible changes that reduce the likelihood of achieving the desired conditions.

System State

Fundamental to AEM is the specification of desired conditions for valued resources in the system(s) of interest. In the vernacular of systems analysis, each (e.g., reach-specific, ecosystem type, community structure) desired condition specified for the ecosystem of interest (e.g., LCR and estuary) defines a point (x^*_t) in a multidimensional space, where each specified structural and functional attribute delineates a single dimension in this space. The current system condition (x_t) can be similarly located in this space. AEM operates to move x_t through the multidimensional space towards x^*_t and maintain minimal (acceptable) deviation of x_t from x^*_t.

In open, complex, and dynamic ecological systems, it may be more realistic to describe the desired condition as a set of points or a region in a multidimensional space. Integration of the range (or distribution) of acceptable values for each dimension (system attribute) will define the desired region in this space. Importantly, natural spatial-temporal variation in each attribute combined with imperfect measurement (sampling, data analysis) will determine how precisely the desired conditions can be specified, as well as how precisely the current system condition can be described. In this sense, AEM operates to create and maintain as much overlap as possible between the current region and desired region in this space.

Environmental (e.g., seasonality) or ecological (e.g., competition, predation) factors can introduce dynamics to the system condition that are not necessarily manageable. Such dynamics may cause the desired condition to be more accurately described as a trajectory or set of trajectories in this multidimensional space. AEM can then operate to create and maintain as much similarity (overlap) between the current and desired system trajectory or sets of trajectories.

This multidimensional description of system state might be used to assist in defining desired river and floodplain conditions (or configurations, as in Walker et al. 2002). The desired system configuration can be described in tabular or spreadsheet form, where each row corresponds to one of the structural/functional attributes of the desired configuration. One column of values (or ranges, distributions) would be defined for each location for which desired conditions were specified. A matrix of described desired configurations would result from the inclusion of additional locations. Depending on the selected scale and resolution of management actions, a matrix could be constructed for each river reach, ecosystem type, or habitat. Companion matrices that quantified current conditions could be constructed in a parallel effort to specifying desired system configurations.

1-2 Components of the AEM Plan

The strategic Plan for AEM is designed to be consistent with the guidance provided in 65 FR 35242. This Federal Register document identifies specification of alternative management actions, addressing uncertainties, and the establishment of critical feedback mechanisms between monitoring results and subsequent management actions as necessary features of AEM. Based on 65 FR 35242 and items specified in the National Oceanic and Atmospheric Administration (NOAA) terms and conditions [National Marine Fisheries Service (NMFS) 2002], this proposed AEM Plan emphasizes the following components:

- statement of management goals and objectives,
- delineation of the management and decision-making process,
- identification of existing and proposed MA that will quantify the specified performance measures and assessment endpoints,
- identification of models that may prove useful in assessing outcomes of management decisions,
- a methodology for examining uncertainties to determine the value of new information in supporting the AEM decision-making process, and
- consideration of opportunities for stakeholder input and overall transparency of the AEM Process.

1-3 Management Goals and Objectives

A useful and effective AEM program requires the specification of desired resource conditions. The statements of vision, principles, and goals are vitally important components in developing an AEM program.

Vision and Mission

Vision and mission statements provide the necessary strategic cultural and technological context in defining overarching goals and objectives for specific AEM Projects (e.g., Everglade’s restoration, Glen Canyon Dam Project). If carefully crafted, these statements can also serve to generate support and enthusiasm and more importantly, galvanize management actions towards realization of the strategic goals and objectives.

As an example, the following are selected excerpts from the combined vision and mission statement for the Glen Canyon AEM Project:

> "The Grand Canyon is a homeland for some, sacred to many, and a national treasure for all. In honor of past generations, and on behalf of those of the present and future, we envision an ecosystem where the resources and natural processes are in harmony under a stewardship worthy of the Grand Canyon. This will be accomplished through our long-term partnership utilizing the best available scientific and other information through an adaptive ecosystem management process."

While it might be presumptuous to offer such statements as part of this AEM Plan development, the above example identifies several key aspects of a vision or mission statement relevant to the Channel Improvement Project: an envisioned ecosystem, harmony between resource utilization and natural processes, recognition of responsibility for stewardship, long-term partnerships, and use of best scientific and other information. Even in the absence of an explicit vision or mission, these aspects were addressed in the development and are hopefully evident in the description of the AEM Plan and Process described in Part 2 of this document.

The mission and vision implied in the proposed Channel Improvement AEM Plan emphasize the direct management of potential physical-chemical impacts associated with channel deepening. Importantly, the proposed AEM Process can contribute to the development of a more comprehensive adaptive management effort ultimately focused on enhancing the survival, growth, and ocean entry of juvenile salmonids that utilize the LCR and estuary.

Principles

The following principles are offered in support of the LCR Adaptive Management Program. These principles derive in part from similar considerations developed in relation to the Glen Canyon, Upper Mississippi River, Chesapeake Bay, and Florida Everglades AEM programs tailored to the specific needs of the LCR and estuary:

1. The programmatic goals define a set of desired management outcomes that can ensure achievement of the stated vision concerning valued resources in the LCR and estuary.

2. The historical human modifications of the Columbia River watershed have dramatically and perhaps irreversibly impacted the distribution and abundance of valued habitat and ecological resources both in the river and within the watershed.

3. The LCR and estuary remains imperfectly understood from an ecosystem perspective. Inadequate ecosystem understanding and incomplete data will impact the success of an AEM program.

4. The stated ecological complexity of the river and estuary requires an ecosystem management approach. Management efforts should be designed to prevent local extinctions of native species as the result of further human modifications to the Columbia River watershed.

5. An adaptive management approach will be designed and implemented to achieve the AEM program goals. This approach will emphasize passive adaptive management through monitoring the impacts of channel improvements on valued habitat and resources.

6. Management actions that benefit multiple resources in relation to the stated desired conditions will be pursued first. If this is not possible due to conflicting resource requirements, management actions will be implemented that have neutral or minimal negative impacts on resources that fail to benefit from these actions.

7. Particular management goals will be reevaluated if they prove to be inappropriate, unrealistic, or unattainable in the course of implementation of the AEM Plan.

Importantly, it must be emphasized that the primary management principles for the Channel Improvement AEM Plan focus on the historical physical, hydrodynamic, and selected water quality characteristics of the river and estuary. These principles pertain to the dynamics of bathymetry, flows, salinity, and temperature in relation to management goals and objectives. Adaptive management directed at ecosystem resources (e.g., habitat, food webs, ecological production, juvenile salmonids, other species), as previously outlined, practically refer to a second level of management. This management level might be pursued if channel deepening results in demonstrated impacts in relation to the primary physical-chemical management principles.

Goals

One of the major goals of the AEM Process in the LCR is to evaluate the effectiveness of compliance measures, monitoring program, and research to ensure that Project construction, operation, and maintenance have impacts no greater than those predicted in the Biological Assessment (BA) or the Biological Opinion (BO) (NMFS 2005, 2002).

While the primary AEM emphasis remains on physical impacts of the channel deepening, secondary goals and objectives underlying the main ecosystem management activities include:

- provision of additional shallow water and intertidal marsh habitat,
- increased connectivity among habitat types and habitat complexity,
- additional rearing habitat for ocean-type salmonids,
- increased detrital export,
- sustaining native tidal marsh plant communities,
- increased benthic invertebrate productivity,

- increases access/egress for ocean-type salmonids, and
- improved access to headwaters for spawning salmonids.

The above objectives more directly refer to the long-term recovery and sustainability of listed salmonids (Bottom et al. 2001, Kareiva et al. 2000). Specific management actions directed at these objectives may become increasingly important in the proposed Channel Improvement AEM Process if it is determined that channel deepening has demonstrable negative impacts in relation to salmonid utilization of the LCR.

1-4 Management and Decision-making Process

Perfect information may be of little use if managers undertake an *ad hoc* decision-making process. Thus, perhaps the most critical component in implementing the management framework is the specification of how the performance measures or assessment endpoints will be used to make decisions in relation to the management goals and objectives.

The description of the decision process should clearly state the management actions that can be taken to achieve the desired goals and objectives. The Process should also describe how management actions will be selected or developed in relation to expected outcomes of specific decisions. The value of information (i.e., utilities) to be used in directing the decision process should also be articulated in specification of the decision process.

Decision Framework

In general, making a decision involves identifying and evaluating a set of management alternative actions and choosing those actions that will best achieve the desired goals and objectives. The overall effectiveness of the framework in supporting management needs will depend critically on the precise delineation of the decision-making process in relation to the channel improvement Project. Regardless of the details of any specific decision, a decision making process can be structurally decomposed into the fundamental components outlined in Table 1.1.

Table 1.1. Components of a decision-making process (Rubenstein 1975).

Goals and Objectives	What the decision maker desires to achieve.
Alternatives	Alternative actions that the decision maker controls and selects among, actions taken by the decision maker.
States of nature	The broader environmental context where the selected alternatives or management actions manifest themselves.
Outcome	The combination of a management alternative or management action and states of nature.
Utility	The value of an outcome in relation to the goals and objectives.

Figure 1.1 illustrates the interrelations among goals and objectives, decision-making, and the modeling and monitoring activities that support the AEM Process. Figure 1.1 also identifies risk and uncertainty as key components inherent to managing complex environmental systems. The components and their interrelations define an overall AEM management framework. The framework links the activities for assembling information about the ecosystem, formulating ecological forecasts, and assessing risks and uncertainties. The framework adopts the paradigm of AEM as the overall context for decision-making. This contributes to defining the types of information that must be assembled through monitoring and modeling activities. The framework uses risk analysis to account for uncertainty in the process of evaluating and comparing alternative actions. The risk-based approach influences how management goals are translated into decision-making, and this approach also sets the objectives for data analysis and predictive modeling in support of the decision process.

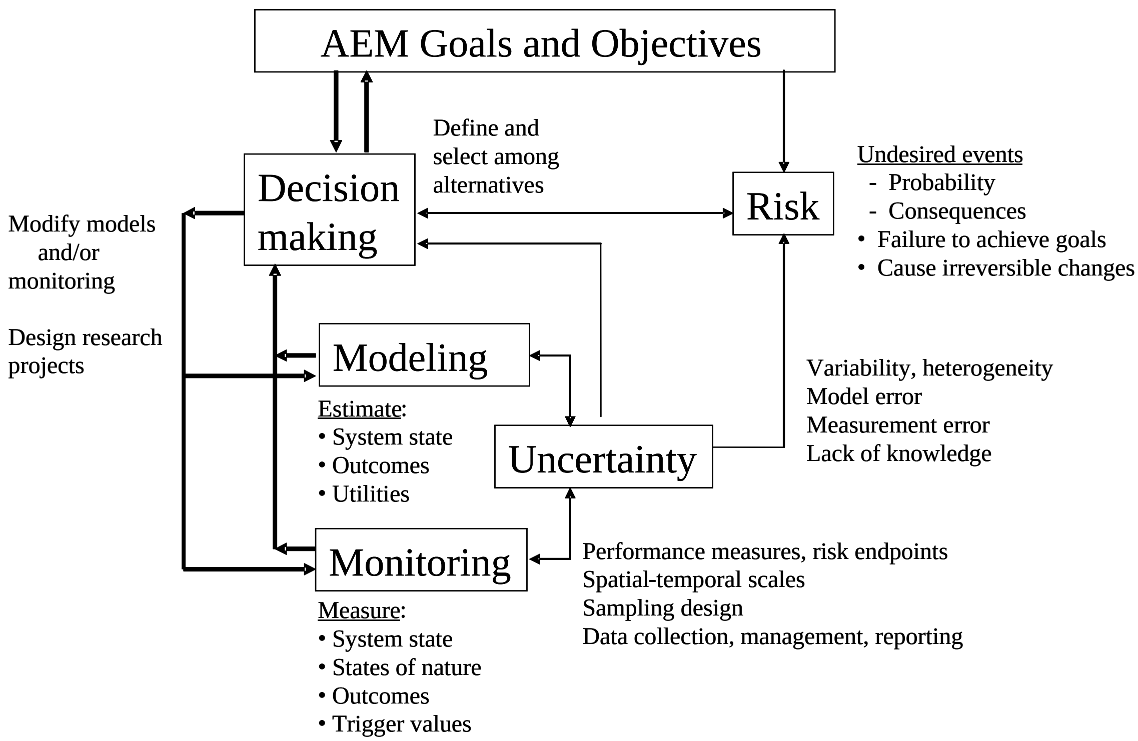

Figure 1.1. General framework for AEM in the context of risk-based decision-making and decision making under uncertainty.1

The adaptive nature of the framework links directly to setting priorities for research, and this provides an operational connection between the goals for resource management and the funding of necessary research to support the AEM Process. A key aspect of implementing the framework will be to establish feedback mechanisms to modify monitoring programs and models as needed during the course of management and decision-making—such feedback mechanisms are central to AEM. Within the framework, these technical support "tools" can be used to define a baseline for performance measures (e.g., historical conditions, desired future conditions), project the expected effects of alternative management actions, periodically track and assess performance, and provide managers with updated information on the effectiveness of management actions (i.e., current conditions) in achieving the desired goals and objectives.

It is recognized that managing complex ecological systems cannot always be conveniently put into the precise framework of decision analysis. Therefore, the decision process might be more loosely defined in some cases. A good test of the specified decision process, however derived, is whether independent teams of similarly skilled managers, given the same goals/objectives and information, would arrive at similar decisions (i.e., coherency). If not, the decision process should be revised until such coherency obtains. The decision process should also be "transparent"—that is, all of the data limitations, model assumptions, input values, and analyses are laid out plainly for review and evaluation (Reinert et al. 1998).

Goals and Objectives

Initially, goals and objectives are established outside of or before the advent of the decision-making process. Resource management goals are established either directly by legislated mandates or through a strategic planning exercise to determine requirements for operating within the United States Army Corps of Engineers (USACOE) mandate. Importantly, the decision-making process may result in subsequent evaluation and modification of goals and objectives, depending in part on the success of management actions in achieving them.

Goals and objectives influence the choice of ecosystem characteristics that are important and how these characteristics will be evaluated. In turn, these choices influence what ecological information must be assembled from studies and monitoring and how this information is applied to evaluate the management alternatives.

Goals and objectives orient the decision-making process. They influence the selection of what information is needed to describe the behavior of the ecosystem in response to management activities, what data must be gathered and how these data are interpreted. In a risk-based approach, goals and objectives contribute to identifying the specific events or conditions for which risk is determined. Goals and objectives influence derivation of the decision criteria in relation to the selected ecosystem characteristics.

Decision Alternatives

The decision alternatives constitute the actions that are under the control of the managers and decision-makers. At the level of ecosystem management, the decision alternatives consist of the specific actions (e.g., collect additional data, perform critical experiments, restore or create habitat) that can be undertaken by decision-makers to protect, restore, and otherwise manage the resources entrusted to their care. The decision framework provides an organized process for assembling and analyzing information to determine appropriate actions aimed at achieving desired ecosystem conditions consistent with AEM goals and objectives.

Development of the decision-support system will be successful in direct proportion to the close collaboration among the adaptive management team (AMT) members to develop and understand their decision-making processes and to identify the necessary and sufficient sets of decision alternatives for managing a complex ecosystem in relation to stated goals and objectives.

States of Nature

Environmental factors not directly related to the proposed AEM Process that can influence the outcome of a decision and that are not controlled by the decision-maker define the environmental context (states of nature) of the decision-making process. For example, climate change, periodic drought conditions, floods, and toxic chemicals (e.g., polychlorinated biphenyls, herbicides, and pesticides) might realistically affect the expected success of the USACOE' projects in achieving management goals. Similarly, the population dynamics of predators or exotic species not directly influenced by the USACOE' projects might nonetheless determine the project effectiveness. Functional relationships can be developed and incorporated into the decision-support model in an attempt to characterize the effects of these other factors on the expected outcomes of the channel-deepening project.

Modeling studies can be performed for different scenarios of these factors, the scenarios can be developed using existing information and understanding of these factors (e.g., periodicity of drought cycles, distributions of contaminants, distribution and abundance of predators on juvenile salmonids). To the extent possible as dictated by available data and understanding, the spatial-temporal variability in these kinds of factors can be quantified and included as part of the overall structure of the decision-support model for AEM. The expected outcomes of alternative decisions or management actions concerning the USACOE' Projects can be estimated in probabilistic terms with the associated capability for performing sensitivity and uncertainty analyses.

Outcomes

In decision analysis, an outcome is the result of a particular decision as influenced by the states of nature. In this framework (i.e., Figure 1.1), outcomes are the values of ecological indicators or performance measures projected in relation to expected impacts of alterations to channel bathymetry, for example, and in relation to probable states of nature.

Ecological and environmental (e.g., hydrodynamic) models developed to support the AEM management framework can be used to estimate outcomes of management actions. The models can translate potential environmental changes in flows, water levels, or salinities into estimates of decision outcomes for the selected ecological resources (indicators or performance measures). The projected outcomes based on model results can then be evaluated in terms of their utility in informing the decision-making process.

Utility

The utility of an alternative management action under consideration prior to making a decision is defined by its effectiveness in either reducing risk or increasing benefits in the ecosystem. The goals and objectives of the project help define the particular risk endpoints or performance measures to be used. For example, the utilities of proposed management alternatives with respect to the resulting habitat changes (e.g., tidal marsh, swamp, flats) can be defined by the impacts of these habitat changes on juvenile salmonid foraging habitat, growth, survival, and subsequent ocean entry. Utility is often expressed in monetary terms, either as economic benefits or as avoided costs. In the present framework for juvenile salmonids, utility might be expressed as increases in habitat opportunity, increased growth, higher rates of survival, and increased numbers of juvenile salmon entering the ocean phase of their life cycle.

The evaluation of a management action's effectiveness must take into account the various sources of uncertainty in forecasting, planning, and monitoring the ecosystem's response after the management action is initiated. An important aspect of the decision-making framework described in the previous section is that it is designed to be applied within an overall management approach that incorporates uncertainties and embraces AEM (Walters 1986, Walters and Hilborn 1978).

Ecological Risk Assessment

An ecological risk is the probability that an undesired ecological impact will occur in relation to one or more environmental stressors [Bartell et al. 1992, United States Environmental Protection Agency (USEPA) 1992, Bartell 1996]. In engineering analysis, the definition of risk is sometimes expanded to include the product of the probability of an undesired event and the costs or losses associated with the event (Kaplan and Garrick 1981). Ecological impacts of concern to natural resource managers might include the local extinction of an ecologically important species, reduced population size in a commercial fishery, or reduced species diversity. Impacts of concern might also include the increase in population of undesired species, such as blue-green algae that are responsible for noxious blooms in coastal water bodies.

Ecological risk assessment provides a conceptual and operational framework for characterizing the responses of complex ecological systems to natural and human-induced disturbances. Ecological risk assessment, through quantification and evaluation of uncertainty in estimating probably impacts, can serve as the basis for informed and adaptive management of natural resources.

The risk component of the adaptive management and decision framework (Figure 1.1) refers to two kinds of risk in implementation. The first category corresponds to more traditional considerations of the probability of obtaining (or failing to obtain) the desired conditions as the outcomes of management and decision-making. To address these risks, the available data and models will focus on estimating the expected (i.e., average, modal, median) values for each of the assessment endpoints or performance measures as a function of the alternative management activities. Ideally, the desired decision is made in terms of the management action that will likely result in the highest expected value of ecosystem performance and/or the lowest risk of an undesired impact. Realistically, the decision may reflect some compromise between increased ecosystem performance and reducing the risk of undesired impacts.

The second category of risk addresses the probability of driving the ecosystem (perhaps irreversibly) to an undesired condition as an unintended consequence of management. The same data and tools might be used to estimate the unanticipated consequences of management alternatives. However, these methods would emphasize estimating the probability of extreme outcomes or surprise ecosystem responses, or those events that characterize the tails of the distribution of expected outcomes. Qualitatively different outcomes not described by the distributions resulting from current models, data, and understanding would have to be addressed using other approaches developed expressly for analyzing extreme events. Considerations of these unexpected results of management actions might reasonably include assessments of the consequences of management actions on ecosystem resources not currently part of the assessment. For example, use of dredged materials potentially contaminated by agrochemicals or industrial pollutants to help restore or create habitat might have a beneficial effects on those organisms directly and positively affected (e.g., salmonids), yet pose unacceptable risks of decreased production of benthic invertebrates or associated food web transfers and bioaccumulation of toxic chemicals by juvenile salmonids. The key to a risk-based approach is formulating ecosystem management objectives as risk assessment endpoints.

The process of assessing risk to ecosystems organizes and presents scientific information in a way that is consistent with the context established by adaptive ecological management that also accounts for uncertainty. The USEPA guidelines divide this process into three phases: problem formulation, exposure and effects analysis, and risk characterization. When these are applied to a particular ecosystem, resources managers can use the risk assessment process to identify vulnerable and valued resources, determine important data needs, and investigate the potential effects of various management actions.

Generally, the three phases of risk assessment identified by the USEPA guidelines have direct parallels in elements of the decision-making framework described here. The problem formulation phase includes a characterization of the ecosystem, identifying performance measures and the development of a conceptual model that describes its response to management interventions, i.e., stressors. The analysis phase corresponds to the processes of collecting survey and monitoring data and formulating predictive models to link management activities with response of the chosen ecological performance measures. The risk characterization phase corresponds to application of the predictive models to forecast and evaluate ecological impacts associated with each management alternative under consideration.

Table 1.2 attempts to compare the implementation of the decision framework schematically outlined in Figure 1.1 with the generalized implementation of an AEM Plan for the LCR and estuary. Part 2 of this report presents a more detailed AEM Plan specific to the Channel Improvement Project.

Table 1.2. Comparison of the decision framework to the LCR AEM Plan.

Implementing the Decision Framework	**Implement the LCR AEM Plan**
Identify goals and objectives.	Specify problems and opportunities. Goals and objectives: • manage physical attributes of channel and estuary, • manage river flows and velocities, and • manage salinity and temperature.
Define the decision-making procedures.	Formulate desired conditions: • goals and objectives, • decision criteria. Identify performance measures. Identify risk endpoints. Compare current conditions to desired conditions. Evaluate decision criteria. Continue current management or adapt management actions.
Identify and apply models.	Inventory and understand current conditions. Forecast future conditions. Project outcomes of management alternatives.
Establish monitoring program.	Baseline data collection and analysis. Effects of channel deepening. Identify data gaps and data needs.
Assess risks.	Risk analysis: • monitoring data, and • model forecasts.
Identify and describe uncertainties.	Focus on uncertainties: • Project construction, • monitoring results, • model bias and imprecision, and • states of nature.