TRINITY RIVER RESTORATION PROGRAM SCIENTIFIC FRAMEWORK

Adaptive management and restoration of the Trinity River requires that reliable scientific information is collected, synthesized and provided to decision makers. The Record of Decision (ROD) recognized this need when it integrated an adaptive environmental assessment and management (AEAM) program into the Trinity River Restoration Program (TRRP).

The Trinity River Flow Evaluation Study (TRFES) provided the historical perspective, initial conceptual models, science and recommendations that form the basis of the ROD. A shift from developing the flow study to implementing the ROD necessitates a shift in emphasis from developmental to assessment and validation science. Organizing to effectively direct restoration projects, measuring success of implementation and reducing uncertainties requires a planning process to prioritize monitoring, modeling and research within an adaptive management context. A solid scientific framework is essential for defensible science in support of the ROD.

The Technical Modeling and Analysis Group within the TRRP AEAM program is responsible for implementing the science component of the ROD and carrying out and improving elements outlined in the TRFES. The proposed scientific framework will begin the process of refining the conceptual models, priority uncertainties, study approaches, monitoring protocols and priority study needs. These activities are paramount to ensuring the science of the TRRP has a solid scientific basis as intended in the ROD.

The Scientific Framework will build on, complement and improve existing science, monitoring, and analysis efforts. The overall process will promote cooperation and partnership among agencies, organizations and the public to minimize policy conflicts and to assure the financial and technical resources necessary to continue a successful program. The proposed framework is a comprehensive integrated approach based on a systematic methodology that emphasizes learning from the outcomes of management actions *as a continuing process*. The basic elements of this approach include:

- Characterization of the System and Definition of Problem (identify management questions)
- Diagnosis of Causes (concentrating on cause-effect interactions)
- Identification and Understanding of Interactions (conceptual model, monitoring, modeling, analysis)
- Synthesis and Predictions (integrated assessments, decision analysis, risk assessment)

Typically management of natural resources is difficult for two fundamental reasons: (1) the understanding of the structure and behavior of the system is limited or (2) management policies are not designed to cope with the uncertainties inherent in both the environmental and human systems. The AEAM program will work to address these potential pitfalls by implementing a process that emphasizes designing experiments to address key uncertainties, monitoring the outcomes, analyzing and learning, improving management actions and continually evaluating and repeating the process. An equally important focus of the AEAM process includes scientists working closely with managers and stakeholders to facilitate incorporation of new tools and methodologies that bridge the gap between science and policy to better support management decision making.

Although decision making involves consideration of values and weighing risks and benefits of alternatives with imperfect information, it is critical that good scientific guidance informs the process. Decision framing and decision analysis are useful tools for bridging and integrating scientific and management activities. Decision framing provides context and boundaries for both potential management actions and necessary scientific support. Decision analysis is a more formalized method of breaking down complex decisions into manageable components, clearly identifying tradeoffs among objectives, and taking uncertainties into account when evaluating management options and determining research and monitoring priorities. Decision framing and decision analysis will be valuable tools for: identifying alternatives to an action; estimating outcomes (or ranges out outcomes) and assigning probabilities to the outcome of action (or range of outcomes); and deciding on specific action based on probable results and value judgments of decision makers.

SCIENTIFIC FRAMEWORK--PROCESS AND COMPONENTS:

The focus of the Scientific Framework process is to create a "living document" that summarizes goals of the TRRP, our current understanding of the system, the tools and methods we use to monitor and model the systems, assumptions and uncertainties, and a method for incorporating and documenting new and revised information gained over time.

I. Initial Steps of the Scientific Framework Process:

Big picture framing questions to consider.

Addressing these types of questions raises issues about the scale of data and analyses, availability of existing information and relevance of data. Scientists need to address these issues to "frame" or place bounds on their considerations and decision makers who are aware of these issues make more informed choices. For example:

- *What do we need to know about the system to make decisions?*
    - Impending decisions (flow schedule modification, validation of hydrograph objectives, selection of restoration sites, monitoring and evaluation of success and failure) determine the type and extent of information collected, the tools used in the analysis, and the types of conditions one hopes to achieve or maintain.

- *What are relevant background conditions for the system, restoration sites, and flow decisions?* (including how these conditions may change in the future)

- *At what scale(s) will the decision impact the system/environment?* (Any management decision may affect a number of landscape elements at varying temporal and spatial scales)

- *How might proposed changes influence future conditions?* (e.g., projections of future conditions under different management scenarios, consider primary and secondary effects that might occur)

Summarize and review scientific and management guidelines (for example):

- Summarize TRRP goals and objectives
- Summarize key issues and relevant constraints if any (short and long term)
- Summarize management questions/actions (and bounds of actions)
- Review existing information, define data and knowledge gaps
- Form testable hypotheses of possible cause-effect relationships
- Determine how to obtain necessary information (i.e., monitoring, modeling, research)
- Identify outcomes of monitoring, modeling, research activities and integrated assessments, and timing and feedbacks among them.
- Describe adaptive management process and plan, and how to capitalize on unexpected 'opportunities'

II. Scientific Framework Components ("Dynamic Products")

A) Conceptual Model:

"A detailed conceptual model of the system to be monitored is recognized as an essential component of a scientifically credible monitoring strategy. A conceptual model expresses ideas about components and processes deemed to be important in a system, along with preliminary thoughts on how the components and processes are connected. It is a statement about system form and function." (From "Development of an Ecosystem Monitoring Plan for the Sierra Nevada")

The way we represent concepts and organize our understanding of a system is dependent on the purpose. Conceptual models are often used to communicate understanding through a visual or narrative summary that describes the important components of a system and the interactions among them. Types of conceptual models range from simple qualitative visualizations of linkages to quantitative mathmatical conceptual models that quantifiy these linkagès. An AEAM program is best served by a more quantitative approach that explictly identifies functional physical-biological linkages, categories of uncertainties, and outcome probabilities thereby allowing managers to more clearly relate a management action with specific physical responses and predicted biologic responses. The conceptual model for the Trinity will be developed at two scales, a general model for overall system description and a detailed model for more direct applications.

Development of the conceptual model will be one of the initial efforts in the Scientific Framework process to summarize our current scientific understanding of how diverse components of the system function, to identify linkages among those components, and to promote integration and communication among scientists and managers from different disciplines and with the public. The conceptual model will also be useful for developing hypotheses about how the system responds to management actions and identifying adaptive management experiments. For AEAM programs such as TRRP, decision analysis provides a method to organize our conceptual model into a framework for assessing alternative actions.

B) Adaptive Environmental Assessment and Management:

The field of river restoration is still relatively young and somewhat exploratory in nature. This provides a wonderful opportunity, as well as a huge challenge, to an AEAM-based program such as the TRRP to assure that the projects we fund and data collected help to increase our knowledge; reduce uncertainties; and incorporate adaptive management into their planning, design, implementation and monitoring phases. The AEAM plan and team should provide direction to TRRP through recommendations of specific projects to fill critical knowledge gaps and reduce uncertainties, as well as guidance (i.e., project design and monitoring techniques) to organizations and individuals who actually carry out program-funded projects. Assuring that adaptive management is central to the TRRP Scientific Framework and integrated into the Monitoring and Modeling Strategies is a fundamental step toward providing direction and demonstrating leadership by actively looking for opportunities to incorporate adaptive management into both new and existing projects.

Adaptive environmental analysis and management requires an interdisciplinary framework to integrate research, planning and management, and to facilitate an effective collaborative process. An ecosystem approach can provide a template for organizing and integrating research, planning, and management. To do so successfully, both the substance and the process of system-based adaptive management must be addressed.

Substance:
Comprehensive studies using theory and detailed knowledge
Ongoing, multi-scale and multi-disciplinary monitoring
Multidisciplinary studies and analysis including integrative modeling and geospatial methods
Use of expert and public knowledge to develop hypotheses and models
Modeling management scenarios, forecasting and backcasting (working backward from desired futures)

Process:
Facilitated multi-disciplinary workshops and ongoing expert consultation
Incentives and methods for institutional cooperation
Ongoing stakeholder and public meetings for communication and input
Goal definition and related planning for their achievement
Testing and revising results and processes
Developing visions of desired futures, scenario-development exercises/workshops

Decision analysis is a method for taking uncertainties into account explicitly when evaluating management options. In the context of adaptive management, decision analysis is a powerful tool for answering crucial questions such as: *is it worth varying flows to reduce key uncertainties that block the reliable identification of worthwhile restoration actions?* The answer depends on several variables (i.e., the management objective, the inherent sensitivity of the optimal action to key uncertainties, the quality of prior data/information, the magnitude of natural variation exhibited by the system, etc.) Ultimately, a management experiment is worthwhile when the new information on key uncertainties from doing adaptive management leads to the choice of *a different* management action that better satisfies a particular management objective over the long-run (pers comm., Dave Marmorek). Decision analysis also helps identify the areas where more study and investment would provide the best pay off both scientifically and financially.

The basic components of decision analysis are[1]:

- a set of alternative ***management actions*** (i.e., alternative sets of long term actions, alternative experiment management actions and monitoring designs)
- a set of ***management objectives*** composed of performance measures (desired levels of various population or ecosystem indicators, to rank management actions)
- ***uncertain states of nature*** (alternative hypotheses that describe different ways in which the management actions could affect the performance measures)
- ***probabilities*** of the alternative states of nature (to account for uncertainty, relatively easy to estimate for flows based on historical data, but often hard to estimate for biophysical uncertainties having less information)
- a ***model*** to forecast changes in performance measure under different management actions and states of nature (e.g., how will smolts/spawners change with different flow regimes and hypotheses about gravel management)
- a ***decision tree*** to link the above
- ***ranking of actions*** for different management objectives based on the expected value of performance measures (the expected value considers all combinations of hypotheses, and the probabilities)
- detailed ***sensitivity analysis*** to determine how much difference alternative hypotheses make to the ranking of actions (particularly biophysical hypotheses whose probabilities cannot easily be estimated)

C) Monitoring Strategy:

To achieve system-level scientific understanding of the relationships between resources of the Trinity River and related dam operations, integration of long-term monitoring between physical, biological and cultural resources is necessary. A basic understanding of the Trinity River system dynamics is essential to design effective monitoring strategies that are grounded in the overall scientific framework and linked to a detailed conceptual model. The Monitoring Strategy should include nested multi-scale designs to allow regional, site specific and agency specific issues to be addressed, as well as cross-system comparisons to address those variables that are most uncertain and most sensitive to independent variables.

The "Trinity River AEAM Sampling and Monitoring Workshop", held in February of 2002 initiated this process prior to the TRRP staff being hired. The workshop summary document (in revision, McBain and Trush) provides an valuable summary of broad scale sampling philosophies and strategies to test scientific concepts and companion hypotheses that underlie the ROD's restoration strategy and objectives, and a discussion of sampling issues and next steps for the TMAG to address to formalize an integrated sampling and monitoring plan.

[1] Alexander, C, and D. Marmorek and C. Peters. 2000. Results of a Model Design Workshop held January 24th-26th 2000. Draft report.

Monitoring is done to: (1) evaluate whether objectives are being achieved and (2) to improve our understanding via the AEAM process. The first step in developing the monitoring strategy is identifying the objectives for collecting data. The objectives guide the development of the monitoring program and help determine: which attributes will be measured, where, how often, and for how long, and what analyses will be done on the results.

The strategy should incorporate the following key elements:

- a comprehensive conceptual model and goals that provide an organizational framework for all monitoring
- a strategic iterative process that fosters interaction of scientists with management for integrating their perspectives and expertise and
- on-going review and consideration of monitoring policies, programs, implementation to assure an active adaptive management process.

The Scientific Framework process could develop a more robust set of nested objectives to include, for example: improving management, reducing adaptive management response time, learning now the system works, not 'wasting' water, model calibration and improvement in predictive capability, evaluating "design performance" and "project performance" of restoration projects (how well did we design it to design criteria, and how well did the design and implementation achieve project objectives).

Several types of monitoring are necessary in a well managed program, such as trend and process monitoring. Process monitoring involves choosing a process-based independent variable (i.e., flow, shear stress) rather than time, as in trend monitoring. Process monitoring is less common because it is difficult (both mentally and field-wise), yet it has several advantages. For example, process monitoring helps establish strong causal linkages, while trend monitoring often does not relate treatment (or lumps treatments) to the dependent variable of interest. This forces the researcher to speculate on what caused the response, and requires significant time to establish (i.e., 10-12 years are often required to establish a trend in biological monitoring data), whereas process monitoring can often establish relationships in a year or so.

Monitoring strategy *product*: A report describing the monitoring strategy and the various tasks and decisions that contributed to the final selection of indicators to be monitored . This document should include the following:

- An overview of natural and physical resources, including a summary of relevant legislation, the natural resources in a regional context; **(why)**
- A summary of management issues and scientific issues, including management actions, stressors or other agents of change that affect resources;
- A summary of the understanding of the system, including conceptual models developed during the scoping and review process;
- Descriptions of indicators to be monitored **(what)** and sampling protocols **(how)** that will be used, including justification for why these were selected. The report should also list and describe the indicators that were considered but not selected for monitoring, and the reasons why they were not selected;
- The overall statistical sampling design **(where and when);**
- Identification of appropriate entity to accomplish task(s); **(who)**
- Data management plan, including how often reports will be generated and who will be responsible for ensuring that results are provided to TRRP in a timely manner.

Results of the monitoring and modeling components should represent a summary of scientific understanding that includes the current status, past and current trends, and expected future conditions of the river system. The product of the monitoring program is information that shows the extent and magnitude of change occurring in the system – the significance and causes of these changes are then assessed to determine future modifications. Monitoring data can also help evaluate models that may form the basis for some planning decisions and help users understand their accuracy.

D) Modeling Strategy:

Models are tools that simulate key features of the environment. Modeling may be used to help understand patterns and processes in the landscape, or to do simulations to examine potential impacts and effects of a management decision.

Conceptual models were described under Section B. Mathematical models depict quantitative relationships with equations. Part of the science and art of modeling is making sure that the relationships are appropriate, the assumptions are realistic, and that the model process, assumptions and output can be communicated (and visually portrayed) to the public, decision makers and the courts.

Modeling strategy products: A description of the modeling strategy and various tasks and decisions that contributed to the final selection of questions to be addressed and models to be used. It should include:

- An overview of natural and physical resources, including a summary of relevant legislation, the natural resources in a regional context; **(why)**
- A summary of management issues and scientific issues, including management actions, stressors or other agents of change that affect resources;
- A summary of the understanding of the system, including conceptual models developed during the scoping and Framework process;
- A brief summary of the draft Scientific Framework and draft Monitoring Strategy and a description of how the Modeling Strategy directly links to both.
- Descriptions of processes to be modeled, what questions they address at what spatial and temporal scales **(what),** and **(how)** that will be used, including justification for why these were selected. The report should also list and describe the models that were considered but not selected, and the reasons why they were not selected;
- The geographical extent, and spatial and temporal scales of the models and the physical and biological processes they simulate **(where and when);**
- Identification of appropriate entity to accomplish task(s); **(who)**
- Data management plan, including how often model runs and associated results and reports will be generated, and who is responsible for ensuring that results are provided to TRRP in a timely manner.
- Strategies and protocols for model calibration and validation.