FIRST ANNUAL REVIEW OF THE ENVIRONMENTAL WATER ACCOUNT FOR THE CALFED BAY-DELTA PROGRAM

EWA REVIEW PANEL
(PARTICIPANT LIST ATTACHED)
FINAL REPORT

INTRODUCTION

The first meeting of the EWA Technical Review Panel (Panel) of the Environmental Water Account (EWA) convened on October 22–24, 2001 at the Ryde Hotel in Ryde, California. Under its charge (Appendix 1) from CALFED's Lead Scientist, the Panel was asked to "consider the overall concept of EWA and the plans, EWA actions (uses of water and actions to protect fish), and justifications for actions that took place during the year." The thirteen members of the Panel are listed in Appendix 2.

This summary report provides the Panel's conclusions and recommendations concerning the results of the first year of the EWA. Written documents that described the first year's activities were distributed to the Panel and reviewed prior to the Panel meeting. At the meeting, oral presentations by both management and agency participants and stakeholders provided important additional information that supplemented the written documents. Following the public sessions, the Panel met to discuss and critically review all of the information that it had received. In doing so, they elected James H. Cowan, Jr. and Pete Rhoads as Chair and Vice-Chair, respectively. The Panel divided into subcommittees to facilitate discussion and review, and began preparation of this report. The charge to the Panel was not necessarily to reach consensus and alternative opinions were solicited from each Panel member.

Our report is presented in five main sections, including a summary of Panel conclusions. The main body of the report is organized as follows: 1) Positive findings; 2) Goals and objectives; 3) Scientific credibility and suggestions for additional research, monitoring, and staffing; 4) Flexibility and adaptive management; and, 5) Conclusions.

POSITIVE FINDINGS

On the basis of this review, the Panel found several positive aspects of the EWA in its first year of operation. We begin our review with listing these accomplishments, then move on to recommendations for improving the EWA in subsequent years.

Important in this first year was the successful purchase of the full amount of programmed water from willing sellers for use in accomplishing the EWA's purposes. Purchased water was used as intended to reduce pumping during periods of mortality of winter-run chinook salmon and Delta smelt, and to facilitate a preplanned biological experiment. Despite diverse missions, the management and project agencies jointly solved problems and developed timely, collaborative solutions to the many problems encountered by the program during its start-up year. The cooperation and collaboration between agency biologists and project operators is a highlight of the first year that has broad, positive implications for the subsequent years of the EWA. We were also encouraged by the involvement of stakeholders in the process of managing water in California. As the number of people and perspectives involved in making a decision increases, the process is bound to take more time. The temptation to reduce involvement in order to speed up decision-making was likely high, yet the structure appeared stable in terms of the parties involved and continued through the year. This attribute may be one reason why, even though difficulties arose late in the season with the number of fish taken, the process was generally accepted. The Panel also notes that the EWA stayed within its budget both in terms of funds and water.

The EWA Team was required to make difficult decisions in the face of high uncertainty with serious consequences. The high "take" of juvenile winter-run chinook salmon at the project pumps is an example of the difficult challenges that faced the EWA team. We consider the ability to make such decisions in difficult circumstances a very positive characteristic of the process. The EWA Team made the necessary decisions in a timely fashion.

An important beginning in the EWA process was the formulation of decision trees to guide EWA decision-making. While clearly a work in progress, and in need of additional refinement as discussed later in this report, these decision trees are a significant step beyond ad hoc decision making. Most importantly, the decision trees reveal the criteria used by the managers and give insight into the conceptual models used

in decision making. Thus, they provide a starting point for scientific review and critique, and ultimately the refinement of the EWA process.

The EWA Team produced a number of timely, useful reports to document the first year's outcome. This was a particularly noteworthy accomplishment, given the heavy workload of critical personnel. Knowing the results of the previous year's efforts is an essential step in improving efforts for subsequent years. Insightful feedback is impossible unless each year's results are summarized and integrated before planning the next year's activities. Without these reports, the Panel's charge also could not have been successfully completed. The EWA Team, as part of the larger CALFED program, has also begun to post information and data from the project on the world-wide web.

The positions of Science Advisors, created by CALFED to assist the Lead Scientist, clearly have had a beneficial effect on the EWA process. Not only did the two individuals holding these positions produce timely, insightful reports, but they also stimulated debate and broadened discussion of key points. The Panel found it extremely helpful to have a succinct integration of the various elements of EWA with the scientific underpinnings. We note, however, that at present there is no formal mechanism in the EWA program to act on, or respond to, critical findings noted by the Science Advisors. Other commissioned reviews were also helpful to the team in assessing the outcome of the first year. Written analyses by stakeholders were delivered at the meeting and in future years, if concisely written, could profitably be added to material given to the Panel before the meeting.

GOALS AND OBJECTIVES

As with most projects addressing complex issues of public policy, the EWA has multiple goals. The Panel has identified several key issues with respect to these goals and their consequent management objectives, which have broad impacts on the scientific basis of the EWA. These are discussed in the following paragraphs.

Based on the written documentation of the EWA, along with the comments of the participants during the workshop, we understand the EWA to have three coupled goals, simply stated here as:

1) ***To protect Bay-Delta estuary fisheries from the adverse effects of water operations, thus leading to restoration/recovery of the Bay-Delta fishery.***
2) ***To improve water supply reliability for Central Valley Project (CVP) and State Water Project (SWP) operations in the Delta.***
3) ***To reduce conflict in the management of the Delta simultaneously for ecosystem health and water supply.***

The first goal is a general goal of the entire CALFED program, and reveals the origin of the EWA as a component of CALFED. The latter two goals are somewhat more specific to the EWA. The four-year "EWA experiment" is fundamentally a test of the compatibility of these goals. Therefore, the Panel considered these goals from the perspective of the clarity with which they have been articulated and translated into management objectives, the degree to which achieving the goals can be measured and evaluated, and the interplay of the goals with the scientific knowledge, tools, and activities supporting the EWA.

Fish (or fishery) protection

In 2001, a primary goal of the EWA was reducing fish loss at the CVP and the SWP pumps. The EWA targeted winter-run chinook salmon, reducing water exports when smolt take, defined as the pre-and post screen losses and salvage, at the pumps exceeded a threshold expressed as above a certain percentage of the estimated total run. The EWA attempted to schedule water export reductions through a real-time decision tree, and the Panel realizes this was the necessary first step in the long-term management of the Delta. Although the 2001 EWA management protected part of the winter-run chinook run and some Delta smelt, the Panel concludes that additional analytical methods set in an adaptive management context that includes learning and flexibility in the year-to-year objectives and across-year planning will improve species protection. Improving the effectiveness of the EWA to protect fish species will require a better understanding of the life cycle of these species and the indirect mortality factors associated with water export and Delta hydraulics. Furthermore, flexibility in water acquisitions across years will also yield increased EWA efficiencies. The continuing goal should be to develop a

flexible and adaptive structure to meet future needs and challenges presented by increasing demands of California water and ecosystem restoration.

In 2001, CALFED tracked fish loss as a cumulative percent loss, calculated by dividing an estimate of cumulative export loss (take) by a preseason juvenile population estimate (JPE). The EWA recommended water export reductions when the cumulative salmon take exceeded a set percentage of the JPE. Early in the season, the EWA used a decision tree to coordinate management. As the season progressed, however, events occurred so rapidly and the run was so large that take far exceeded the maximum allowable take, such that the assumptions on which the decision tree was based no longer held true. The decision tree was replaced with an endangered species consultation with the management agencies and stakeholder biologists. The EWA succeeded in the sense that it did not overspend the water account. About 232,000 acre-feet of water were used from January through April in about seven major export reduction actions. However, because the EWA team had difficulty identifying the timing of the salmon run, nearly half the water account was spent on the first 10% of the chinook salmon run. Although this problem should not surprise us in the first year of a complex process, it points up the need for more and better information to support EWA operations.

In 2001, the National Marine Fisheries Service may have underestimated the JPE, which in turn may have resulted in setting the number of fish needed to trigger export reductions too low. Essentially, juvenile production apparently was far larger than expected, thus the EWA interpreted the early arrival of fish from a very large run as the peak migration of what was expected to be a much smaller run. Consequently, the EWA called for export reductions before the run peak appeared, expending a relatively large portion of its water for a relatively small ecological benefit. The Panel notes, however, that the ecological consequences of overestimating the JPE during a small run would be greater, because it would result in a greater loss of a small population. Until more reliable methods of estimating run size are developed, the current method, which may underestimate a large run, is preferable to a method prone to the opposite type of error.

Water supply reliability

The Panel understands that this goal can be articulated in several ways. As stated in the Operating Principles, there are to be no uncompensated water costs to SWP and

CVP water users from EWA actions. In other words, there are to be no curtailments in water deliveries below the necessarily inexact regulatory baseline defined by Tier 1, which includes the 1995 Delta Water Quality Control Plan, the Central Valley Project Improvement Act, the 1993 winter-run salmon biological opinion, and the 1995 Delta smelt biological opinion. Therefore, reliability of water supply is defined by Tier 1 conditions. If exports are curtailed below Tier 1 levels at the request of the Management Agencies (MAs), then EWA water replaces the export curtailment, such that the water users suffer no additional water supply costs.

At the level of Tier 1 and Tier 2, this goal is clearly articulated. Although determination of water costs is complex and labor intensive, it appears possible to define appropriate measures, and adequate data and understanding are available to quantify these measures in such a way that achievement of the goal is verifiable on a year-to-year basis.

It is apparent to the Panel that this goal loses clarity at the level of Tier 3. In particular, there is clear disagreement among project participants on the purpose(s) of Tier 3 water and on the frequency with which it may be used. It is our understanding that on the basis of the pre-project gaming it is expected that the current level of Tier 2 water will not be adequate to meet fish protection goals, while fully compensating water users, in all future scenarios, i.e., with no risk. Tier 3 water appears to be intended to provide compensation in those cases. However, the frequency with which Tier 3 water will be required has not been estimated, nor has the appropriate size of the Tier 3 reserve been defined on the basis of a scientifically grounded risk analysis. Furthermore, there was some suggestion that Tier 3 water would not be included in a risk-based allocation of both Tier 2 and Tier 3 waters, but rather would only be invoked under "extraordinary circumstances". The result is that the overall water supply reliability, and the cost of providing that reliability, is not defined.

Specifically, the Panel was concerned that the absence of Tier 3 funding adversely affected the willingness of management agencies to expend Tier 2 resources for salmon protection in 2001. At least in the beginning years of EWA experience, a sufficient safety net must be in place to secure against extreme unexpected events. Over time, provided any problems with carrying over assets can be resolved, it is reasonable to expect that the EWA will build up sufficient assets to provide self-insurance against the

inevitable surprises and extreme events likely to occur when dealing with natural phenomena. In the early years of the EWA before such assets can be saved up, however, Tier 3 funding is important if management agencies are to make effective decisions under conditions of uncertainty. Absent Tier 3 funding, management agencies are likely to make overly conservative decisions that will prevent experimentation and thus learning.

In connection with the adequacy of funding, CALFED management may want to give greater thought to the appropriate allocation of EWA water between Tier 2 and Tier 3. Based on presentations to the Panel, it appears that CALFED determined the needed amount of Tier 2 water based on the amount of water needed in 13 of the 14 years on which games were run. It then proposed additional Tier 3 water to cover the outlying year. It is unclear, however, why CALFED chose a 13-out-of-14 rule in determining the appropriate levels of Tier 2 and Tier 3 water. Tier 2 and Tier 3 quantities should be set at levels that are adequate to protect the Delta fish species and that require the management agencies to be careful in their decision making without being overly cautious. In a careful reevaluation of the data, CALFED may conclude that decision making would be improved by having more Tier 3 and less Tier 2 water or vice-versa. By reallocating water between the tiers, CALFED amy also be able to achieve greater effectiveness with the limited funding provided to the EWA.

Conflict reduction

The Panel understands this goal, which is not articulated in written documentation but was emphasized by a number of participants in the workshop, to be an important one. It centers at the operational level on managing and reducing conflict between water users, fishery managers, and other stakeholders by increasing communication and creating a structure for the mutual understanding of the hydrologic, hydraulic, biologic, economic, and institutional complexities in simultaneously managing the Delta water resource for ecosystem health and water supply. This is likely to enhance both the use of scientific information in the management of the Delta and the development of new knowledge during the EWA experiment through the sharing of data, models, and other scientific and management tools. It is clearly complementary to the other articulated goals of the EWA.

The anecdotal evidence presented to the Panel suggests that the EWA process is well on its way to achieving this goal. With that said, the Panel encourages CALFED to develop clear, effective methods to document this success over the course of the four EWA years of operation.

SCIENTIFIC CREDIBILITY AND SUGGESTIONS FOR ADDITIONAL RESEARCH, MONITORING, AND STAFFING

The Panel was asked to provide thoughts about issues that have the potential to threaten the continued effectiveness and/or existence of the EWA. The foremost issue that emerged in Panel discussions was concern about the rigor and strength of the scientific foundation from which EWA decisions and actions are being implemented. However, if conflict reduction and water supply reliability are as, or more, important than fishery protection, then the EWA might easily continue to exist even if it were not particularly effective at fishery protection.

Why focus on scientific credibility?

The rationale for concern is the threat to the scientific credibility of EWA actions. Ultimately, CALFED will be asked to provide the burden of proof of the science underlying the EWA. CALFED should launch a dedicated research effort to produce a rigorous scientific foundation to guide EWA actions and increase the likelihood of the EWA meeting its goals. Toward this end, the Panel feels strongly that additional resources (personnel and research dollars) should be dedicated to EWA-related research tasks. Implementation of the research tasks within the remaining three years of the EWA requires that the recommended analyses and tasks be performed as soon as possible. Because the existing CALFED-related staff simply does not have the time, CALFED resources must be allocated to new scientific personnel. Our rationale is as follows.

Adaptive management is a human-capital intensive activity. Adaptive management requires the continuous involvement of participants from many diverse perspectives, and for that as well as many other reasons it would be undesirable for CALFED to become yet another natural resources bureaucracy. At the same time, a small permanent staff associated with the EWA has many advantages. Interagency cooperation and coordination activities are likely to be understaffed because most personnel are on loan from other agencies and their time and loyalties are divided. Such

collaborative efforts have a much higher record of achievement when there is a permanent staff dedicated to taking a more comprehensive view than is likely to come from purely agency-affiliated participants. Permanent staff who are continuously involved facilitate the development of trust among parties, which is essential to bargaining, exchange, and conflict resolution. Permanent staff also can specialize in areas of expertise essential to EWA but which might not be available or so well developed in staffing on loan from other agencies. Further, the continuity of such a staff provides the basis for institutional memory. Understanding previous organizational experience, preferably first hand, is basic to the organizational learning supposed to take place in adaptive management.

Recommendations regarding staffing

Recommendation 1: CALFED should release sufficient agency staff time to support the development of the EWA, and to put as high priority CALFED projects that address EWA needs. This does not involve additional expenditures of funds, but it does require rescheduling of staff time.

Recommendation 2: In support of EWA-related research, CALFED should recruit and support as appropriate: visiting senior scientists, post-doctoral and graduate students, targeted contracting, and requests for proposals for research outlined in a science workshop. New hires must work in close collaboration with the existing staff members of agencies comprising the EWA, as well as the new water market specialists described in a later Action Item.

Recommendations regarding scientific credibility

Based upon our review of the EWA 2001 operations and our rudimentary understanding of the complex issues and management restrictions involving Delta hydrology and ecology, the Panel understands the need for the EWA to focus on fish take at the pumps. However, the Panel agrees with the Brown and Kimmerer Summary Report (September 2001) in calling for new in-season management tools and improved data reliability. The Panel also believes that flexibility in EWA management is

fundamental to improving learning and protecting Delta fish stocks. As noted, the focus on reducing direct mortality at the pumps is a compelling objective, because the benefits are demonstrable. However, this singular goal limits flexibility, learning, and ultimately the long-term effectiveness of the EWA. Managers should consider a wider set of management objectives. Below is a list of general science recommendations that were specifically identified in the course of Panel deliberations. Each of these general recommendations is discussed in more detail, followed by specific action items designed to address and outline specific research objectives that will result in achievement of recommendations.

Recommendation 3: Synthesize in a quantitative manner and a readily accessible location all available data on the salmonid species of concern. This databank should include information on life history and the effects of Delta habitat conditions and hydrodynamics on threatened species of salmonids.

Recommendation 4: Establish a research thrust to fill fundamental gaps in knowledge of the biology of Delta smelt.

Understanding fundamentals: In this early stage in the evolution of the EWA, there are fundamental and limiting gaps of knowledge with regard to recruitment "bottlenecks" and processes that regulate population size of chinook salmon and, particularly, Delta smelt. The Panel believes that management must be prepared to adapt to changing biological conditions; the ability to adapt requires more knowledge. For example, in a year with large salmon out-migration, but a small and protracted Delta smelt recruitment, it may be prudent to target the EWA to the needs of the smelt. Thus, the EWA needs better population and life history information for the species of concern in order to target populations with the greatest need on a year-to-year basis. A significant problem with the 2001 EWA resulted because of uncertainty in the winter-run chinook JPE, which in turn made it difficult for managers to predict the timing of the winter run of chinook into the Delta and eventually their arrival at CVP/SWP pumps. In 2001, the EWA used a single preseason prediction of the JPE for the entire season. In fact, real-time information on fish passage through the Delta and fish entrainment at the pumps provides

information that should be used to update the JPE within the season. In-season run-size updates could be developed similar to the smolt passage prediction made for Snake River salmon (see website at the address given below). Each day during the smolt migration, a forecaster could match real-time passage and entrainment information to historical cumulative distributions to determine the current percent passage, cumulative passage pattern through the remainder of the season, and the total run size. The system could be incorporated into a real-time decision tree (see worldwide website for further details: www.cbr.washington.edu/crisprt/documents.html).

Action Item: Evaluate the existing sampling and monitoring efforts to determine if additions or modifications would provide improved data on the target species. The planned analysis and evaluation of current JPE estimation techniques is a very good place to begin. In addition, we recommend that new research topics should be identified and prioritized in a CALFED sponsored workshop to describe current understanding and additional research needs.

More detailed and sophisticated analyses: Analyses of data as presented at the EWA review would greatly benefit from more sophistication. For example, uncertainty and the importance of stochastic processes were not explicitly represented. The Panel realizes that many EWA benefits may be large in absolute fish counts but relatively small and often not measurable in terms of effects on population numbers. Although ocean, climate, and demographic processes dominate fish productivity, the existence of the EWA is testimony to its societal value as a management tool. However, quantitative estimates of the EWA's impacts are essential to justify management decisions and best allocate the water, irrespective of their absolute population effect. The Panel suggests quantifying all sources of direct and indirect mortality associated with water management in terms of absolute fish numbers and percent changes in population levels and recruitment. The Panel also suggests demonstrating quantitative impacts through several analytical approaches including direct measurements, and statistical and model analyses, and reporting of numerical estimates and associated uncertainties. Specific areas where fish imports to the Delta and pump-related exports needing to be quantified include: winter-run chinook smolt flux through the Delta cross channel, fish residence time and mortality in the Clifton Court Forebay, fish impingement in pumps, effectiveness of salvage, fish population estimates (at various locations), and real-time projections of fish

migration and residence in critical regions of the Delta. The Panel suggests that first order estimates of fish loss for each critical issue are needed to prioritize important research and management actions.

Action Item: Further analyze the monitoring and field data using statistical and simulation modeling techniques that explicitly include uncertainty and stochasticity.

Action Item: Obtain better estimates of growth and mortality rates in the Delta and pre-salvage mortality rates in the Clifton Court Forebay.

Flexibility and adaptability: A strategic plan for learning and adapting as the EWA proceeds was not described to the Panel. The Panel feels strongly that such a plan is necessary and critical to the successful evolution of an adaptive management process such as EWA, because flexibility in EWA management is fundamental to learning about, and protecting Delta fish stocks. As noted, the focus on reducing direct pump mortality is a compelling objective because the benefits are demonstrable. However, this singular goal limits flexibility, learning, and ultimately the long-term effectiveness of the EWA. Managers should consider a wider set of management objectives.

Action Item: The Panel recommends that a scientifically-based risk analysis, using synthetically generated scenarios based on historical data analysis, be used to estimate the water supply reliability afforded by the EWA over the long term and to define Tier 3 asset size and the protocol for its use. The explicit analysis of hydrologic, climatic, and biologic variability required for such an analysis will significantly enhance understanding of the Delta system.

Using EWA water in scientific experimentation: Scientific experimentation is of critical value to the long term protection and promotion of Delta fish species. Scientific experimentation provides management agencies with the information that they need to make the best use of the current flexibility that the EWA provides.

Scientific experimentation directed toward the protection of fish species require not only expertise and funding but, in many cases, water resources. The Panel therefore strongly encourages the management agencies to identify and pursue opportunities to use EWA water for valuable scientific experiments involving Delta fish species. Although the management agencies must ensure that the fish species are not currently jeopardized by project operations, the long-term value of the information that can be obtained from

scientific experiments in an adaptive management framework often can outweigh the short-term advantage to species of reduced takes at the pumps. The importance of scientific experiments reaffirms the importance of providing adequate funding for the EWA; with less funding, the management agencies will have less water available for experimentation. The importance of allocating some water for experimentation, however, does not diminish if the EWA is not fully funded. Even if the EWA is only partially funded, it is important that the management agencies use some of the EWA water for critical scientific experiments that will help improve future management of the Delta fish species. For example, it is critical that CALFED determines whether or not, or on what time scale, a pumping curtailment reduces the entrainment of fish into the south Delta, not just at the pumps themselves. I.e., does reducing pumping allow fish to pass out of the Delta, or does it simply effect when they get entrained by the pumps?

Action Item: The management agencies should actively identify, evaluate and pursue if appropriate, opportunities to use EWA water (5% to 15%) for scientific experimentation likely to generate information that will guide future management decisions. Experiments should be based upon the research priorities identified in the CALFED science workshop.

Robust forecasting: Because comprehensive measurements of fish movements and mortalities within the Delta are beyond our ability and resources, the Panel sees a need to develop mechanistically-based models that describe Delta hydraulics and fish movements. Such models, which are individual-based and track fish as particles with behavior, should help synthesize the complex Delta dynamics and suggest critical areas related to management actions. Such models can provide quantified estimates of the impacts of alternative EWA scenarios on both direct and indirect mortality of the target species. Only with such models, constrained by assumptions of fish behavior, can the EWA evaluate the potential significance of water export schedules and channel operations across a spectrum of ecological and hydrological goals.

The presentations before the Panel also suggest that the EWA can make better use of water and hydrologic forecasts in managing its water resources. Equally important are smolt out-migration and Delta smelt productivity forecasts. First, the EWA should be provided with the resources to make more robust forecasts of future conditions. Interpretation of current forecasts makes little effort to take into account the uncertainty

involving weather and hydrologic forecasting. If provided the resources, the EWA could use Monte Carlo analysis or similar techniques to better recognize the probabilities of each of the various possible future conditions.

Second and more importantly, the management agencies may be able to make greater use of the forecasts in deciding when and how to use EWA water. In deciding during the 2000-2001 hydrologic season to save water for the Delta smelt, for example, it is unclear whether and to what degree the management agencies considered the likelihood of various hydrologic conditions and the relevance of these conditions to the smelt and the need to reserve water for the smelt. Similarly, the decision-making tree that the management agencies used to determine when to use water to protect winter-run chinook salmon appeared to remain the same in all hydrologic conditions and not to depend on the probability of the water being needed for other uses later in the year based upon current forecasts.

Action Item: Quantify the losses of Delta smelt larvae at the pumping facilities.

Action Item: Investigate how knowledge of salmon and smelt behavior could be incorporated into physical transport models of the Delta. Further strengthening of the fisheries-physics link may be crucial to addressing the specific entrainment problem.

Action Item: The management agencies should consider using formalized, probabilistic decision-making trees or other criteria that better factors in changing conditions and uncertainty.

Improve decision trees: The decision-making process and its rationale, which is central to the success and scientific creditability of the EWA, should be clearly documented and quantitatively evaluated. The Panel realizes reduction of export loss is the most demonstrable goal over the four-year EWA evaluation. However, CALFED should consider the benefits of directing some resources away from the immediate goal and into long-term knowledge gain. Would an effort to understand and limit indirect mortality eventually protect more fish than a continued focus on direct export mortality? For example, with reductions in pump entrainment and Clifton Court Forebay predation rates, and reduced losses from handling and transport, the EWA water might be used more productively in other ways. Developing these schemes may involve ecological experiments within the operational decision tree. Because such experiments typically

take years to plan and deploy the Panel sees the need to begin planning and implementing these experiments as soon as possible. Experiments pertaining to effects of pumping curtailment should involve *a priori* use of modeling to assess changes in transport patterns and possible entrainment. This work might also be able to identify which aspects of behavior are most critical to any modeling effort.

Action Item: Analyze the data used in the gaming with the specific goal of improving the decision trees used to guide EWA actions. Extend the range of variability considered in refining and testing the decision trees by incorporating as much of the historical record as possible and by developing synthetic stochastic time series data based on the historic record.

Ecosystem benefits: As presented to the Panel, the relationship between EWA and the Ecosystem Restoration Program (ERP) is unclear. This makes it difficult to understand the EWA in a "big picture" context that recognizes interactions among all processes operating in all habitats that regulate population size of target species. There is too little mechanistic understanding of the effects of export pumping and/or EWA operations on population dynamics of endangered species, especially with regard to the poorly defined notion of "ecosystem benefits." The Panel sees the need to quantify and reduce the indirect mortality associated with water exports. Because smolt survival through the Delta appears to be lower than survival through the Sacramento River mainstem, the population suffers additional mortality indirectly. Another example of indirect mortality is associated with smolt predation in the Clifton Court Forebay. Although this mortality is based upon empirical estimates, there appears to be considerable uncertainty about the predation mortality rates used to calculate export losses.

FLEXIBILITY AND ADAPTIVE MANAGEMENT

This section of the report concerns flexibility, one of the most valuable structural features of the EWA. The Panel believes that it is important to maximize the EWA's flexibility within the confines of overall policy goals and constraints, and to ensure that the EWA team effectively uses this flexibility to promote the EWA's goals.

Why focus on flexibility?

The Panel regards flexibility as essential to achieving the three fundamental goals of the EWA: fishery protection and restoration; water supply reliability; and reduction of conflict in project management. The effective and creative use of flexibility, along with public accountability for progress toward the EWA's goals, ultimately will determine the success of the EWA. Flexibility can contribute to the goals in several distinct, but interrelated, respects.

First, a flexible process can allow more effective and efficient use of resources than a rigid, inflexible one. Prior to implementation of the CALFED Bay-Delta Program, protection of sensitive fish species in the Delta relied almost entirely on command-and-control curtailment of CVP/SWP exports from the Delta when incidental take levels of Endangered Species Act (ESA)-listed species were exceeded. If implemented flexibly, the EWA could improve fishery protection above this baseline by allowing use of EWA assets for stream-flow augmentation or for other strategies that might provide greater benefit to fish populations. Flexibility also could improve efficiency by redistributing water reductions to those that value their water least and are thus willing to sell it at lowest cost to EWA managers.

Second, flexibility can help defuse conflict. Delta water management in recent years has been characterized by a high degree of political conflict, with water users strongly objecting to export curtailments imposed to protect fish species. Where curtailment has been threatened, conflict sometimes also has flared over how to allocate the resulting reductions in water supplies. By providing an alternative water source, which ensures that export curtailment does not come at the expense of water users who are relying on exports, the EWA should greatly reduce these sources of conflict. Conflict reduction should, in turn, make it politically easier to reduce exports or take other actions necessary to protect fishery resources.

Third, flexibility maximizes the ability to learn and to incorporate learning into future operations. This is extremely important to the long-term goal of restoring the Delta fisheries. Flexibility can be used to facilitate learning by deliberate experimentation (adaptive management). EWA assets, for example, might be used to vary stream flows or exports experimentally in order to determine how the fish species of concern respond to such changes. Flexibility and scientific knowledge are to some extent

interdependent. While the flexibility to experiment can increase knowledge, increased knowledge can also enhance operational flexibility.

Fourth, flexibility allows managers to cope with uncertainty and to adapt to changing circumstances. The experience of the past year with winter-run chinook salmon highlights the significant gaps in our knowledge of sensitive Delta fish species. Future surprises of a similar magnitude are virtually certain. In a flexible system, such surprises can be managed as they become apparent. Circumstances also are likely to change in the future. Global warming, for example, may dramatically alter the extent and geographic and temporal distribution of rainfall in California. The more flexible the system for distributing water resources, the better it should be at adapting to such changes.

Important dimensions of management flexibility

Two broad types of flexibility are important in enabling the EWA to meet its goals. First, the EWA must have the flexibility to decide what types of water assets to acquire and when to acquire them. In order to maximize the environmental value of the funding provided to the EWA, its managers need to continuously evaluate the costs of various types of assets relative to the environmental benefits that they might provide. At some points in time, for example, the EWA might be able use its funding to achieve the greatest environmental good by purchasing water south of the Delta; at other times, purchases north of the Delta might offer a better environmental opportunity. If the exact percentage of purchases north and south of the Delta were fixed in advance, the EWA would not be able to respond to changing market and environmental conditions. The EWA also would be at a disadvantage when negotiating prices with potential sellers, who would know that the EWA could not seek water from another region if their price were too high.

The EWA similarly should enjoy the temporal flexibility to determine when to make purchases. Both the cost and the value of acquiring EWA water will vary throughout a year and also from year to year, based on the prevailing price of water resources, the ability to store water assets, and the predicted environmental need for the water. In maximizing environmental benefits, the EWA therefore needs continually to reevaluate and change its relative holdings of water, cash, and other assets – sometimes purchasing additional water, while at other times retaining cash or even selling existing

water assets. Rather than making spot purchases of water, the EWA also might find that it could obtain greater environmental protection with the same funding by acquiring options on water rights to be exercised under specified conditions.

Second, the management agencies must possess flexibility to determine when and how to use the EWA's water assets to achieve the greatest benefit to Delta fish species. In its first year, management agencies took advantage primarily of the EWA's temporal flexibility to use EWA water to reduce pumping operations when management agencies believed that key Delta fish species would benefit most. Although the management agencies' decision this year, during a period when winter-run chinook salmon were in the vicinity of Delta pumps, to save water for later use in protecting Delta smelt was potentially controversial, the management agencies were exercising the type of judgment that the EWA is designed to promote – real time evaluation of how best to use a limited resource to protect and preserve fish species under conditions of uncertainty. By permitting reallocation of water from times of perceived low need to times of perceived high need, the EWA provides the management agencies with the ability to try to maximize the water's environmental value.

Flexibility in how EWA water is used also can help management agencies maximize the water's environmental value. The need for scientific experimentation is crucial to the long-term viability of the Delta fish species, and water resources are often needed in order to engage in the most valuable experiments. Various factors, including political accountability, an interest in measurable progress, and concerns over jeopardy, might call for some constraints on how the EWA uses its water to help Delta fish species, but greater flexibility within these constraints will permit management agencies to maximize the benefits to these species.

Recommendations regarding flexibility

The Panel concludes that several steps could help increase the advantages that flexibility provides the EWA. First, the management and project agencies should evaluate remaining constraints on EWA flexibility to see if any should be modified or reduced. Second, the federal and state governments should ensure that the EWA has the resources and information needed to use its flexibility effectively. Finally, the management and project agencies should work to improve their use of the flexibility that

the EWA provides. Each of these general recommendations is discussed in more detail below.

Recommendation 5: The management and project agencies should evaluate existing constraints on EWA flexibility.

Recommendation 6: Provide the EWA with resources and information needed to use flexibility effectively.

Recommendation 7: Improve the ways in which agencies are currently using the flexibility that the EWA provides.

Limits on flexibility: The presentations to the Panel suggested that the flexibility of the EWA is currently constrained in several important respects. Some of these constraints may be removable with reasonable efforts by the management and project agencies themselves and without sacrificing important policy objectives; other constraints may not be removable without legislative approval or modifications of the Record of Decision; yet other constraints might have strong policy objectives that, upon evaluation, outweigh the advantages of increased flexibility. Furthermore, the importance of various constraints, and the ease with which they can be eliminated, may change with time and increasing knowledge.

Currently, there appear to be three significant constraints on EWA flexibility that should be evaluated. The first is the focus on incidental take limits at the export pumps as a measure of benefits to fish. Nearly all of the EWA assets expended in the first year were devoted to curtailing pumping in order to limit take at the pumps. Yet, as discussed earlier, there remains significant scientific uncertainty about the population-level effects of export take. Scientific research leading to alternative measures of benefits could significantly enhance EWA flexibility and thus the long-term prospect of species recovery.

Another limit on EWA flexibility is the complicated overlay of rules – statutory, regulatory, and contractual – that govern operation of the projects. These rules restrict the number of tools available to project managers to redistribute water. The clearest

example this past year was the inability to use the Joint Point of Diversion to shift pumping from the SWP to the CVP.

Flexibility may also be limited with respect to the temporal allocation of EWA assets. Ideally, the EWA should be able to carry forward both water and funds to future years without fear of loss. In order to fully respond to year-to-year variations in hydrology, the EWA should also be able to borrow water or funds from future years for current use. Although the EWA enjoys some flexibility in the timing of its water use, the EWA's ability to carry over resources to future years still faces constraints, particularly in the case of funds. Without a secure long-term source of funding, moreover, the EWA cannot effectively borrow assets from future years. We believe provision of a secure long-term source of funding would improve the functioning of the EWA, as would the identification and reduction of any operational constraints that currently limit the ability of the EWA to save resources for use in future years or to enter into long-term water contracts.

Action Item: Management and project agencies should continue to work to identify rules of operation that limit EWA operations and to evaluate the extent to which those rules can and should be modified to increase adaptive management and experimentation.

Funding: The EWA needs both reliable and adequate funding for purchases of water. Original estimates of the amount of water needed for the EWA relied on the 14 years of data available at the time of the Record of Decision. The EWA needs a reasonably certain multi-year revenue stream in order to facilitate flexibility in the face of variations in hydrology, biology, economics, and other changing conditions. The exercise of flexibility in the face of uncertainty is greatly constrained when assets are insufficient or insecure. Seasonal and year-to-year variations in conditions mean that multi-year planning and multi-year resources must go hand-in-hand.

The adequacy of Tier 2 and Tier 3 water objectives, and the corresponding funding, also should be continually assessed in light of new information and new water project developments. As new biological or hydrological information becomes available, the appropriate amount of Tier 2 and Tier 3 water may change; as water prices change, the required funding also will change. As new water projects are built, the appropriate amounts of Tier 2 and Tier 3 water are likely to increase. Where possible, the cost of the

additional EWA water should be built into the cost of the new projects and thus borne by the beneficiaries of the new projects.

The human capital requirements of the EWA involve expertise and skills not easily found among conventional management agencies. Water marketing is a relatively new tool for government agencies and the protection and growth of assets depends upon astute portfolio management. A balance between options to exercise long-term leases for blocks of water and the short-term spot market is necessary to accumulating sufficient assets to cover unavoidable risks. It is unlikely that this kind of balancing skill can be found in staff borrowed from management or project agencies.

Accounting for EWA impacts on water project operations also is a labor-intensive and time-consuming process requiring a good deal of sophistication about water project operations and the amounts of discretion that operators reasonably exercise. Accounting for EWA water expenditures involves understanding probable operators' choices given the occurrence of particular hydrologic and regulatory conditions absent EWA water availability. To ensure transparency and even-handedness, such accounting insights need to be shared by both the operating and the managing agencies.

Action Item: As new biological, hydrologic, and economic information becomes available, CALFED should reexamine the amount of water, and the equivalent funding, that the EWA needs. Additional water and funding will be needed if and when water projects are expanded.

Action Item: CALFED should clearly articulate the basis for its allocation of water between Tier 2 and Tier 3. In light of what is now known about EWA implementation, CALFED should determine whether the existing allocation of Tier 2 and Tier 3 water best serves EWA objectives.

Action Item: At least two additional experts should be added to the permanent staff of the EWA: an expert in water markets and portfolio management who can help in the acquisition and administration of the EWA's water assets, and an expert in project operations who can both provide advice on operational options and ensure that EWA water is properly accounted for. Both experts should be assigned directly to the EWA.

Baselines: In order to take maximum advantage of the flexibility in the EWA, the managers must understand the baselines from which the ESA operates. If managers

cannot determine the amount of water that would have been pumped absent restrictions, for example, pumping reductions might be improperly charged to the EWA account, diminishing the amount of EWA water that can be used for environmental purposes at a later date. If managers do not understand how ERP water will be used and thus do not carefully coordinate the use of EWA and ERP water, some EWA water may be wasted for unnecessary purposes.

Presentations to the Panel suggested that the project agencies are working to ensure that EWA water is properly credited against pumping restrictions and that the management agencies recognize the importance of coordinating EWA, ERP, and other sources of environmental water. More attention, however, can be devoted to both tasks. It also is important that the EWA itself have the expertise to review and audit its water accounts. This is one of the major reasons that we recommend that an expert in project operations be assigned to the EWA.

Information: In order to take maximum advantage of the EWA's flexibility, the managers also must have the information needed to evaluate how to use that flexibility in both acquiring and using water assets. This information includes market data, biological information on the effects of project operations on Delta fish species, and an understanding of key project operations. The need for this information highlights the importance of scientific research, discussed elsewhere in this report, as well as monitoring and analysis of species and operations. The informational demands of the EWA also increase the value of using EWA water for experimental purposes; in some cases the long-term value of the information gained from experiments will heavily outweigh the short-term value of using the EWA water for other, more immediate and direct protection efforts.

Action Item: CALFED should target a research effort that is likely to produce information that will support and increase management flexibility.

A creative and open environment: Flexibility is most likely to result in good decisions when there is a creative and open decision-making environment. As explained above, adequate and reliable funding, human capital, and information are all essential to management agency willingness to take risks and ability to make effective decisions. They are not enough, however, to make the most of flexibility. The environment also needs to be rich in diverse perspectives. A wide range of alternatives and points of view

encourages participants in the EWA to think “out of the box." Moreover, the cost of mistakes, as well as the cost of making decisions that don’t maximize the values of all participants, declines as public participation increases. The more diverse and widely representative the participation in the decision making process, the more likely it is that all parties will find decisions understandable even when the values of all the parties are not completely served. It is also more likely that costly errors can be avoided if EWA decision-makers understand the likely stakeholder perceptions related to choices among various alternatives, as well as the concrete and scientifically documented consequences of possible actions to all the parties with legitimate stakes.

Transparency as well as participation builds support for the EWA, and public acceptance and trust is critical to flexibility. Hard choices must be as thoroughly and openly discussed as time allows. The options considered, decision criteria adopted, and choices made must be clear and such information needs to be widely disseminated. The assumptions on which decisions are based and the nature of the evidence and values considered must be explicit. While CALFED and the EWA have successfully documented their actions thus far, a clear paper trail needs to exist so that successes and failures can be revisited and evaluated, and should include well-designed world-wide website.

Flexibility and risk-taking in the acquisition and disposition of water resource assets must be accompanied by full accountability. The stakes in buying and selling water in markets with public money requires accountability which goes far beyond the bottom-line. The public must know how and why particular choices were made. Further, adaptive management requires the retrospective review of decisions in order to learn from experience. Traditionally it has been difficult for management agencies to openly admit to taking risks associated with the protection of endangered or threatened species even though some such risk is unavoidable. Adaptive management theory assumes not only that risk is a natural part of environmental processes, but also that managers, like the species they are assigned to protect, must become resourceful in the face of uncertainty. Over time it should be possible for the public to hold management agencies accountable for resourcefulness in their use of flexibility rather than to demand error-free action. The bottom line, however, is that management agencies must be held accountable for how they use the flexibility that the EWA provides.

Using flexibility: The Panel was pleased with the degree to which the management and project agencies already are beginning to use the flexibility in the EWA to protect and promote Delta fish species. The EWA already has encouraged a valuable change in the manner in which the agencies seek to promote environmental goals. The Panel, however, believes that the agencies could further improve their use of the EWA's flexibility in three important manners: 1) by using the flexibility to pursue adaptive experimentation; 2) by more fully integrating the experience of each year into their future decision making and forecasts of future conditions; and, 3) by preparing and using more robust forecasts of future conditions, opportunities, and needs. Also needed is real-time updating of conditions so in-season information is available to permit in-season flexibility.

Making better use of experience: One of the potential advantages of the EWA over traditional regulation is that management agencies can readily use the experience that they gain in one year in managing EWA assets in future years. Management agencies do not need to go through a lengthy and contentious political process to adapt their management to their experience. The EWA both enables and promotes adaptive management – or learning through experience.

The management agencies have begun to use this critical opportunity under the EWA. In their presentations to the Panel, the management agencies noted that, in light of the unexpected arrival of winter-run chinook salmon in large numbers at the pumps, the agencies were reassessing the models that they use in projecting population movements. The presentations, however, suggested that there still is tremendous opportunity for the agencies to engage in a greater degree of adaptive management. The management agencies, for example, had not considered reevaluating their decision-making criteria for using EWA water in light of last year's experience.

Thus, the Panel believes that the management agencies should conduct a retrospective analysis and workshop each summer. In this analysis, the management agencies should ask what lessons they have learned over the year and whether their current management tools and decision-making criteria could be improved based on their experience. The analysis should include a public workshop, in which stakeholders and other members of the public can both suggest potential lessons and learn from the agencies' own analysis. Second, the management agencies should periodically run

games on updated Delta data to examine how best to use EWA water to protect and promote the Delta fish species.

Action Item: The Panel suggests that the management agencies should make a more systematic effort at reviewing their management of EWA water in light of each year's experience.

CONCLUSIONS

The following brief statements are meant to highlight major Panel findings, and thus do not address all of the recommendations included in the body of the report.

1). CALFED and the EWA have made a good start in buying water and making allocations within the time (and dollar/water) limits required.

2). The cooperation and collaboration between agency biologists and project operators is a highlight of the first year that has broad, positive implications for subsequent years of the EWA. We were also encouraged by the involvement of stakeholders in the process of managing water in California.

3). The EWA Team produced a number of timely, useful reports to document the first year's outcome. This was a particularly noteworthy accomplishment, given the heavy workload of critical personnel.

4). While the goals of the EWA are clearly stated, there appear to be large differences in how the goals are "weighted" by scientists, resource managers, water managers and stakeholders.

5). The foremost issue that emerged in the technical review was that the scientific basis for EWA decisions and actions must be statistically rigorous and based on sound science. In the Panel's opinion, there remain some critical gaps in knowledge needed to correctly forecast "jeopardy" for endangered fish species (related to water management operations) and to evaluate the ecological consequences of EWA and other water management activities in the Delta.

6). Adaptive management is a human-capital intensive activity. The current make-up of the CALFED team is probably inadequate in terms of amount and kinds of expertise to fill needed gaps in knowledge, and the team needs to be strengthened.

7). It is important to maximize the EWA's management flexibility within the confines of overall policy goals and constraints, and to ensure that the EWA team effectively uses this flexibility to promote the EWA's goals.

Appendix 1

Panel Charge for Annual Review of the Environmental Water Account

CALFED's Lead Scientist has been assigned the responsibility for a technical evaluation of the Environmental Water Account (EWA) at the end of every water year. That evaluation is to be conducted by a standing panel of distinguished scientists who have not been involved in the process. It is expected that the evaluation will be an on-going four year process, with an annual review each October. The panel will be expected to produce a short summary report, each year, at the end of their deliberations. The panel will be convened by the Lead Scientist, but we will ask the panel to elect a chair after the first day of the first annual review, and the discussions on the second day will be independent of facilitation by the Science Program. The Science Program will provide a note taker to help keep track of the discussions, if that suits the panel.

Evaluation is defined for this purpose as exchanging information among panel, participants (EWA practitioners) and the public/stakeholders with regard to the state of the science that applies to the EWA concepts, actions and justification. For example, do the concepts, actions, justifications and evaluation of outcomes that accompany the EWA incorporate the established science; are there new science advances (or established scientific knowledge) that could be better incorporated; are there ways to advance the state of the science while implementing the EWA? The Science Program is not seeking conclusions from the panel about the validity of the EWA or the validity of specific actions. We are seeking advice about approaches, relative to the state of the science; but we are not necessarily seeking consensus advice in that regard. Where a diversity of opinion or contradictory conclusions arise in the panel discussions we ask that they be expressed in the report; where consensus occurs that should be noted.

The first review will provide a balanced and constructive evaluation of EWA implementation in 2001 (in general).
During this review and following four year period, the reviewers are asked to discuss:

- The concept of the EWA and the uses of "gaming".
- The institutional design of the EWA.
- Conceptual models, criteria, and data analyses.
- The general (explicit and implicit) strategies employed to manage water, protect fish and protect water quality in each year.
- Key information needs and recommendations for advancing knowledge in key areas, including performance measures and testing key working assumptions.
- Factors that have limited success of EWA-type experiences in other settings (e.g. uncertainties about accounting or baselines) and how do they apply to the Bay-Delta Program's EWA.

The EWA Standing Technical Panel

The panel will be comprised of an interdisciplinary group scientific experts who can bring a balance among the issues relevant to the EWA. Independent scientists were invited to participate who are experienced, have a history of leadership activities and who have a demonstrated ability to deal with complex issues in a balanced manner. The group will incude some scientists with local expertise and some with relevant discipline knowledge but experience outside the Delta or Bay-Delta water issues. The Lead Scientist and his science advisors designed the overall charge to the panel. Criteria for individuals selected for the panel incude:

Individual Criteria

•nationally and internationally recognized
•strong publication record and/or record of scientific leadership
•experience with program-level reviews of resource management and complex interagency programs
•track record of fair and unbiased, yet constructive criticism

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Criteria for the board overall include:

•Board Criteria

•balance between local and outside experts
•range of expertise that spans program-wide scientific issues.
•continuity with existing Boards

Public Involvement

The review proceedings will be open to the public, although there will be periods for internal panel discussions that will not be open. Selected stakeholders will be invited to participate in the presentations as part of the review. Open discussion will be restricted to the panel and the participants during the presentation period. Time will also be set aside for open discussion with the public but the format will not favor long, spontaneous presentations from the public.

Support Materials

It is recognized that the panel will begin its initial review without much understanding of EWA. To overcome this challenge written materials will be provided before the review. Two senior independent advisors were contracted by the CALFED Science Program to work with water managers and agency biologists through the year (Drs. Randall Brown and Wim Kimmerer); they will act as an information source for the panel, using their knowledge of day-to-day activities that guided the EWA. The advisors are providing a written overview document that includes conceptual models for the fish species of concern. CALFED's EWA manager will provide a written description of the water management aspeces of the EWA, a diary of actions through the year and be an information source. Biologists from the regulatory agencies will provide a written description of the basis of the critieria used to manage fish and water quality protection; they will also provide a written description or justification of each action taken to protect threatened fish species. The chairs of the performance measure groups will be available for questions; and the Science Program will provide any other information as requested. In addition, oral presentations will summarize the above and explain the rationale behind each decision or group of decisions: conceptual models, goals, and objectives linking use of the water to environmental benefits, and other summaries of the state of knowledge that inform EWA decisions.

APPENDIX 2

EWA Review Panel Participants

James Cowan (chair)
-Senior Marine Scientist, Alabama Center for Estuarine Studies.
-Recruitment dynamics of marine and estuarine fishes with emphasis on early life stages, and predator-prey interactions

Pete Rhoads (retired) (Vice-Chair)
-Early involvement in Florida Water issues then Metropolitan Water District of LA; participated in development of CALFED ROD; balanced observed of CALFED process.

James Anderson
U of Washington Associate Professor, Columbia Basin Research, University of Washington, School of Fisheries.
-Uses of mathematical mdoels in study of salmonid fisheries and ecological systems. Extensive experieince with Northwest salmonid issues.

Ed Chesney
Louisiana Universities Marine Consortium-LUMCOM
- Fisheries and fish ecology especially as they relate to the early life history or larval stages of fish. Culture, foraging behavior, and growth of larval fishes.

James Cloern
USGeological Survey
- Senior Research Hydorolgist with international experience in aquatic ecology. emphasis on interdisciplinary ecosystem studies and plankton ecology of Bay-Delta.

Holly Doreamus
Univ. Calif. Davis School of Law
Environmental Law with training in biology. Numerous publications on endangered species act and listings. Interests in Adaptive Management

Don C. Erman
UCD-Professor Emeritus of Aquatic Ecology; ,former director of the UC Centers for Water and Wildland Resources; Science Team Leader for the Sierra Nevada Ecosystem Project.
-Research experience in freshwater ecosystems and policy level studies of ecosystems in California.*

David Freyberg
Stanford University)- Professor Civil and Environmental Engineering.
-Hydrogeologist with knowledge of Delta and its natural as well as human history.

Helen Ingram
Univ. Calif. Irvine
-Research on institutional change with strong knowledge of Bay-Delta process.

Steven Monismith
Stanford University-Director Environmental Fluid and Mechanics Lab. ---Knowledge of turbulence and mixing in natural water bodies; helped establish new approaches to three dimensional and tidally-based hydrodynamic modeling of Bay-Delta

Kenneth A. Rose
Louisiana State University-LSU
-Mathematical and computer modeling of aquatic populations, communities, food webs, and ecosystems; use of models for both theoretical and applied analyses, such as ecological risk assessment and fisheries management.

K.T. Shum
Contra Costa Water District
- Water quality and local knowledge of water issues in the Bay-Delta

Barton "Buzz" Thompson
Stanford University School of Law- Robert E. Paradise Professor of Natural Resources Law and Vice Dean.
-Principal topics of interest natural law, environmental resources, water resources and property