ADAPTIVE MANAGEMENT IN THE SACRAMENTO-SAN JOAQUIN DELTA:

HOW IS IT USED AND HOW CAN IT BE IMPROVED?

A Report from the
Delta Independent Science Board

July 14, 2015

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Executive Summary

[to be written]

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I. The Context

The Sacramento-San Joaquin Delta ecosystem, its resources, and the water that passes through it are highly variable in time and space. Consequently, management of the Delta requires flexible, adaptive management. Science is central to this effort.

The Sacramento-San Joaquin Delta Reform Act of 2009 (SBX7 1) directed the Delta Stewardship Council to develop a Delta Plan that would serve as the blueprint for achieving the coequal goals of (1) providing a more reliable water supply for California and (2) protecting, restoring, and enhancing the Delta ecosystem. The Act stipulated that the Plan "include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions" (Water Code section 85308(f)). The Delta Plan further stated, "Ecosystem restoration and water management covered actions must include adequate provisions, appropriate to the scope of the covered action, to assure continued implementation of adaptive management" (Delta Plan G P1; 23 CCR section 5002(4)). In establishing the Delta Independent Science Board (hereafter, DISB or "we"), the Act further required that the DISB "provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews…" (Water Code section 85280(a)(3)).

This report summarizes a DISB review of how adaptive management is currently being conducted in the Delta. We also offer some perspectives and recommendations on how we believe adaptive management can be incorporated into programs more effectively and how its application may be affected by future changes such as climate change, land-use alterations, and habitat restoration. Adaptive management in the Delta was previously reviewed by the Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management (2009)[1]. The findings and recommendations of that report remain pertinent.

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[1] Available at http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Independent_Science_Advisors_Report_on_Adaptive_Management_-_Final_2-1-09.sflb.ashx.

We emphasize at the outset that many agency staff, practitioners, and decision-makers in the Delta recognize the importance of adaptive management and appreciate the value of basing management practices and decisions on a solid foundation of science, data, and knowledge. Many individuals and programs would like to manage adaptively, yet find it difficult to do so. Accordingly, in this report we consider how adaptive management is perceived and used in the Delta and how its application might be made more efficient and effective. Our focus is on the process of adaptive management itself, rather than on the specifics of the science that supports adaptive management.

To provide the context for this review, we begin with a brief background on adaptive management: what it is, when it may be most useful, and what factors have limited its applications. Additional background on adaptive management may be found in the references and suggested readings listed in Appendix A.

What is adaptive management?

Simply stated, adaptive management is a structured approach to environmental management and decision-making in the face of uncertainty. It involves taking risks, assuming that plans may not always turn out as intended, having a backup plan, and continuing to evaluate progress toward goals.

The Delta Reform Act offers a more detailed definition: “a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives” (Water Code section 85052).

Adaptive management thus involves more than just “learning by doing” or watching to see what happens after a management action. It is the antithesis of continuing to perpetuate existing management of a system regardless of what happens. Unlike trial-and-error, adaptive management has an explicit structure. It entails having clearly stated goals, identifying alternative management practices or objectives, framing hypotheses about ecological causes and effects, systematically monitoring outcomes, learning from the outcomes, sharing information with key players and decision-makers, and being flexible enough to adjust management practices and decisions in light of what is learned. Computer models often are used in adaptive-management programs to integrate available knowledge and, as learning occurs, to provide synthesis and a means of developing and exploring promising management actions before they are attempted as field experiments. Adaptive management is a way of undertaking actions when knowledge about a system is incomplete and then modifying the approach as knowledge is gained and uncertainty is reduced.

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Adaptive management is most powerful in reducing uncertainty when management actions are thought of as experiments. By using a structured design that includes appropriate controls (or references) and replication, the factors that produced the observed outcomes can be disentangled from a welter of potentially confounding factors. As a result, one can have a good idea of *why* a management action did or did not work as expected. For example, restoration of the Tijuana Estuary in southern California involved partitioning the area into a series of modules that could be subjected to different, replicated experimental treatments (e.g., planting of different combinations of marsh plants). The results could then be used to adjust subsequent restoration efforts (Zedler and Callaway 2003).

In most cases, however, there is only one action that can be undertaken at one place and time and there can be no replication, so the best one can do is to monitor the previous and subsequent states of the system. Adaptive management may still be used in such situations if the basic requirements noted above—setting goals, monitoring, learning, and flexible decision-making—are met.

It is useful to distinguish between *proactive* and *reactive* adaptive management. The former involves planning ahead for surprises, doing the monitoring and analyses to see them coming, and having a Plan B (and C, D, …) ready and waiting. The latter is what happens when it becomes apparent that management actions aren't having the desired effects and something else should be done. In practice, however, management decisions are often based on a combination of hindsight, reaction to events, and anticipation of future changes.

When is adaptive management most useful?

The Delta Reform Act implies that adaptive management should be used in science-based management of the Delta and its resources. Conducting comprehensive active adaptive management, however, can be demanding, expensive, and time-consuming. Adaptive management should not be undertaken if there is no opportunity to apply what is learned, if there is little uncertainty about what actions to take, or if there is little agreement among parties about goals and objectives (Williams and Brown 2012).

Adaptive management is most likely to be useful and effective when:

1. There is considerable uncertainty, making it difficult to predict with confidence the outcomes of management actions, but when actions must nonetheless be taken (i.e., waiting for better knowledge is not an option);

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2. The system is complex, which means that many direct and indirect pathways can affect outcomes and identifying cause(s) and effect(s) is difficult;
3. The system is changing rapidly, which means that the conditions when the desired outcomes are expected may differ from those when the management actions are first applied;
4. There is the potential to learn (and reduce uncertainty) by observing and recording what happens in response to management actions;
5. There are technical and institutional means to incorporate what is learned into revised (i.e., adaptive) management practices and a commitment to sustain adaptive management; and
6. The management actions and their effects on the system are not irrevocable and management is flexible.

Most of these criteria are met most of the time in the management of most ecological systems, although the fifth point may require greater institutional flexibility and openness to change than is often the case. Only the last point is absolute—if an action results in a permanent alteration of the system (e.g., construction or removal of a dam, installation of a large pumping station, filling a wetland, or extinction of a species), the "adaptive" part of adaptive management may no longer be possible.

What factors limit the use of adaptive management?

Despite the incorporation of adaptive management into the guidelines for many governmental agencies and the hundreds of papers and books written on the subject, actual examples of effective adaptive management are distressingly rare. For example, of the 1,336 published papers dealing with adaptive management reviewed by Westgate et al. (2013), fewer than 5% explicitly claimed to do adaptive management, and of these only a few actually met the criteria for adaptive management. Nonetheless, several restoration projects show that, with sufficient funding and continuing communication and collaboration, adaptive management is possible in large, complex ecosystems.

Ecological restoration in San Diego Bay provides a model of many of the elements of effective adaptive management (Zedler and Callaway 2003). The restoration project was prompted by the need to mitigate damages from highway and flood-channel construction and to provide habitat for endangered species. The work entailed close collaboration of scientists with state and federal agencies. Frequent meetings ensured that information was shared among all parties. Restoration actions, standards, and eventually the design of the mitigation program itself were adjusted based on the results of ecosystem monitoring.

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In other cases, the goals are long-term and there has not been sufficient time for the effectiveness of the adaptive-management process to be determined. The Delta Plan used restoration of the Kissimmee River as an example of adaptive management. Although this project involved planning, design, monitoring, and evaluation, it was (understandably) not structured as an experiment and has yet to incorporate what has been learned into adaptive decision-making. Restoration of the Everglades is also often cited as an example of adaptive management of a complex ecosystem. Doremus et al. (2011) and LoSchiavo et al. (2013) provide summaries of what has been learned so far; because there are close parallels between restoration efforts in the Everglades and adaptive-management challenges in the Delta, we include a synopsis from Doremus et al. (2011) as Appendix B.

Why are there so few examples of successful adaptive management? There are several barriers (see page C-4 in the Delta Plan):

1. Complex systems require multiple disciplines that are typically housed in different agencies, and have different responsibilities, different agendas, and different approaches; transcending these boundaries is difficult;
2. Funding needed to support the phases of adaptive management is not secure;
3. Mechanisms and approaches for designing and implementing large-scale ecosystem experiments are not well-developed;
4. Support for adaptive management and its goals may shift with the political winds, creating administrative uncertainty that inhibits implementation;
5. Managers are often risk-adverse, reluctant to take actions that might not work as planned and could be regarded “failures”;
6. Key stakeholders have not been involved in the planning and design of a project, do not understand the underlying rationale, and consequently do not buy in to the process;
7. The regulatory environment (e.g., restrictions under the Endangered Species Act) precludes conducting the experiments or gathering the data from which one might learn for future improvements;
8. The need to obtain multiple permits from multiple entities to conduct complex adaptive management causes delays, during which time the system changes, requiring adjustment of plans or goals, which may then require additional permitting;
9. Human resources (i.e., expertise, time) needed to plan, implement, monitor, or evaluate the actions and outcomes are unavailable;
10. Communication among all parties, especially among scientists, managers, decision-makers, and stakeholders, is not accorded a high priority.

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These barriers impede the implementation of adaptive management. Unless they can be resolved, adaptive management will continue to be a fine-sounding aspiration that is rarely realized. We will return to consider the major impediments to implementing adaptive management in the Delta in Section VI.

II. The Structure of this Report

The Review Process

Our assessment of adaptive management in the Delta is based on the results of a questionnaire distributed to several agencies (Appendix C), in-person interviews with individuals directly involved in managing the Delta and its resources, and a review of pertinent scientific and management literature. Respondents to the questionnaire and individuals interviewed are listed in Appendix D. They provided thoughtful, detailed, and candid responses to our questions, and we much appreciate their willingness to help us understand how and why adaptive management seems to be such a hard thing to do in the Delta. We used this approach because so little is documented about how adaptive management is actually done in the Delta; we felt that evaluating impressions and perceptions of adaptive management by the professionals doing management in the Delta may reveal needs and solutions to adaptive-management implementation and challenges.

Four members of the DISB conducted the review with the assistance of the Delta Science Program. However, the entire DISB reviewed drafts of the report and approved this final version.

The Sections

We begin by describing how the adaptive-management process is perceived by the people we interviewed. We then delve into a more detailed treatment of how adaptive management is or is not implemented in the Delta, organized by the nine steps of the process as described in the Delta Plan. We follow this with comments on factors that appear to constrain or impede the application of adaptive management in the Delta. We then take a broader view of adaptive management—how can the process be streamlined; how can it be made more responsive to rapid changes in the physical, ecological, and social environments, especially when systems encounter thresholds and undergo state transitions; and what does “best available science” really means in the context of adaptive management? We conclude with recommendations for what we think is needed to make adaptive management more achievable and effective in the Delta.

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The raw materials for this report are the responses, comments, and insights provided by the individuals and groups we consulted. Throughout this report we indicate direct, verbatim quotes from questionnaire respondents or interviewees in *italics*.

III. General Responses

To get a sense of how respondents to the questionnaire viewed adaptive management, we initially presented a series of statements to be rated on a scale of 1 (strongly disagree) to 5 (strongly agree). These statements were modified from a nationwide survey of adaptive management reported by Benson and Stone (2013). The results are tabulated in Appendix E and are summarized here.

Respondents generally agreed that adaptive management requires a high degree of collaboration, that conceptual models should include human (i.e., sociopolitical) as well as ecological factors, and that it is important to communicate the results to stakeholders. However, there was not as much agreement about whether baseline information is usually gathered or conceptual models are usually built before action is undertaken, the degree to which results from monitoring and assessment are used in decision-making, and whether adaptive management leads to changes in management and actions. There was even greater variation in responses to other questionnaire statements—some agreed, others disagreed about whether their agency did or did not use adaptive management; whether the agency's management was flexible enough to do adaptive management; whether laws and regulations did or did not restrict management options; and whether laws and regulations could be changed to make adaptive management more successful.

The most uniform response, however, was strong disagreement with the statement that "Monitoring is adequately funded to support adaptive management." This concern will emerge often in this report, and we will consider it further in Section VI.

IV. Perceptions of Adaptive Management: How is it Useful?

If adaptive management is not perceived to be useful, then it will not become a common practice, even in situations that cry out for an adaptive-management approach. Several individuals questioned whether adaptive management really yields any benefits beyond those of normal, non-adaptive management. For example, one respondent wondered whether "*the results of adaptive management are worth the effort*" and another asked, "*Does the cost and effort to implement adaptive management take resources away from implementing the actual project?*"

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Most of the people we surveyed, however, saw value in at least in some elements of the process, if not in the entire process itself. They recognized the potential for adaptive management to promote discussion among parties with opposing views, clarifying the problem to be solved, and articulating the decisions that need to be made. For example, adaptive management can help to identify areas and sources of uncertainty and target where additional research or knowledge is needed. In this way, the process emphasizes the importance of an "*upfront investment in knowledge*" to increase the likelihood that the actions will yield the desired results and prompt discussion of how this knowledge can inform decisions. By developing hypotheses of how and why a system might respond to management actions, the process can help to determine "*What does one do at a fork in the road?*" The conceptual framework or model developed as part of the adaptive-management process can focus thinking about a project and its possible outcomes. Moreover, this approach can help to determine reasons why things might not have worked as planned and provide the basis for looking for a mechanistic understanding of the issues of concern.

Adaptive management can also provide insights into causes of ecological changes and system linkages beyond the object(s) of management interest, such as whether there is a need to examine other stressors and connectivity pathways. In practical terms, it can be used to determine which disciplines or agencies need to be involved to address a problem or engage in collaborative work on a project. Consequently, it can help to avoid mistakes that might result from a failure to consider a full range of system dynamics and mechanisms. Finally, some respondents felt that adaptive management can facilitate communication by transmitting scientific knowledge about a system and its performance to managers and policy makers.

These and other responses demonstrate broad recognition among Delta scientists and managers that adaptive management can aid in identifying knowledge gaps and sources of uncertainty; using knowledge about the Delta to consider alternative courses of action; fostering clarity and transparency in developing management plans and making decisions; understanding and anticipating how a system may respond to management actions; identifying both direct and indirect consequences of those actions; engaging multiple parties in discussions and planning; and fostering communication among scientists, managers, and decision-makers.

At a conceptual level, then, most people whom we interviewed have a general understanding of what adaptive management is and how it can benefit management. The real question is whether this understanding translates into actually <u>doing</u> adaptive management.

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V. Implementation of Adaptive Management: How is it Being Done?

One questionnaire respondent stated that "*We include actions to conduct studies and monitoring to resolve uncertainties and to verify assumptions made in establishing standards, limits, or performance measures, and also consider opportunities to revisit and revise decisions, pathways, and milestones based on new information or unforeseen circumstances*." If this process were widespread in the Delta, this report would be unnecessary. But such statements tend to obscure the reality—that adaptive management in the Delta has scarcely begun.

Results from a survey conducted by the Delta Science Program illustrate this point. In 2011, when the implications of the Delta Reform Act were just beginning to become apparent, the Program surveyed state and federal agencies and several non-governmental organizations to determine whether they were including adaptive management in their programs. Of the 46 programs that were surveyed, 7 had no response to whether they used adaptive management, 10 indicated that they did not use it, 8 said they planned to use it sometime in the future, and 21 claimed to use it in some form. The latter responses, however, included such things as managing program administration to respond to change, using data to make decisions, reviewing programs for performance, or adjusting programs on the basis of experience. In other words, almost any process that might lead to change in a program was regarded as adaptive management. [is this report available? Where?]

From the 2011 report and our surveys and interviews, it is clear that adaptive management is perceived in multiple ways. Different agencies and programs often modify their definition and approach to adaptive management to suit their own purposes. One interviewee observed that "*there is no agreement about what adaptive management is, but everyone thinks they are doing it.*" Although it may be appropriate to tune the process to focus on the specific needs and responsibilities of program or agency, the divergence of approaches and interpretations can impede the communication and collaboration that is needed to achieve adaptive management of the Delta.

In an effort to clarify and standardize how adaptive management should be structured, the Delta Plan described a cyclic, nine-step process. Many versions of the adaptive-management cycle exist in the literature, embodying anywhere from three to more than a dozen steps, some depicting a circular sequence and others a web of interacting processes. However, all are founded on science and involve the same basic activities: *Plan* (identify the problem and design the management approach(es)); *Do* (implement the management action(s) and monitor the results); and *Evaluate and respond*

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(analyze and synthesize the results, communicate the findings to appropriate parties, and make any necessary adjustments).

The nine-step framework of the Delta Plan is shown here (Figure 1).
[NEED AN UPDATED VERSION OF FIGURE]
[OR USE THE EXPANDED VERSION IN THE DELTA SCIENCE PLAN?]

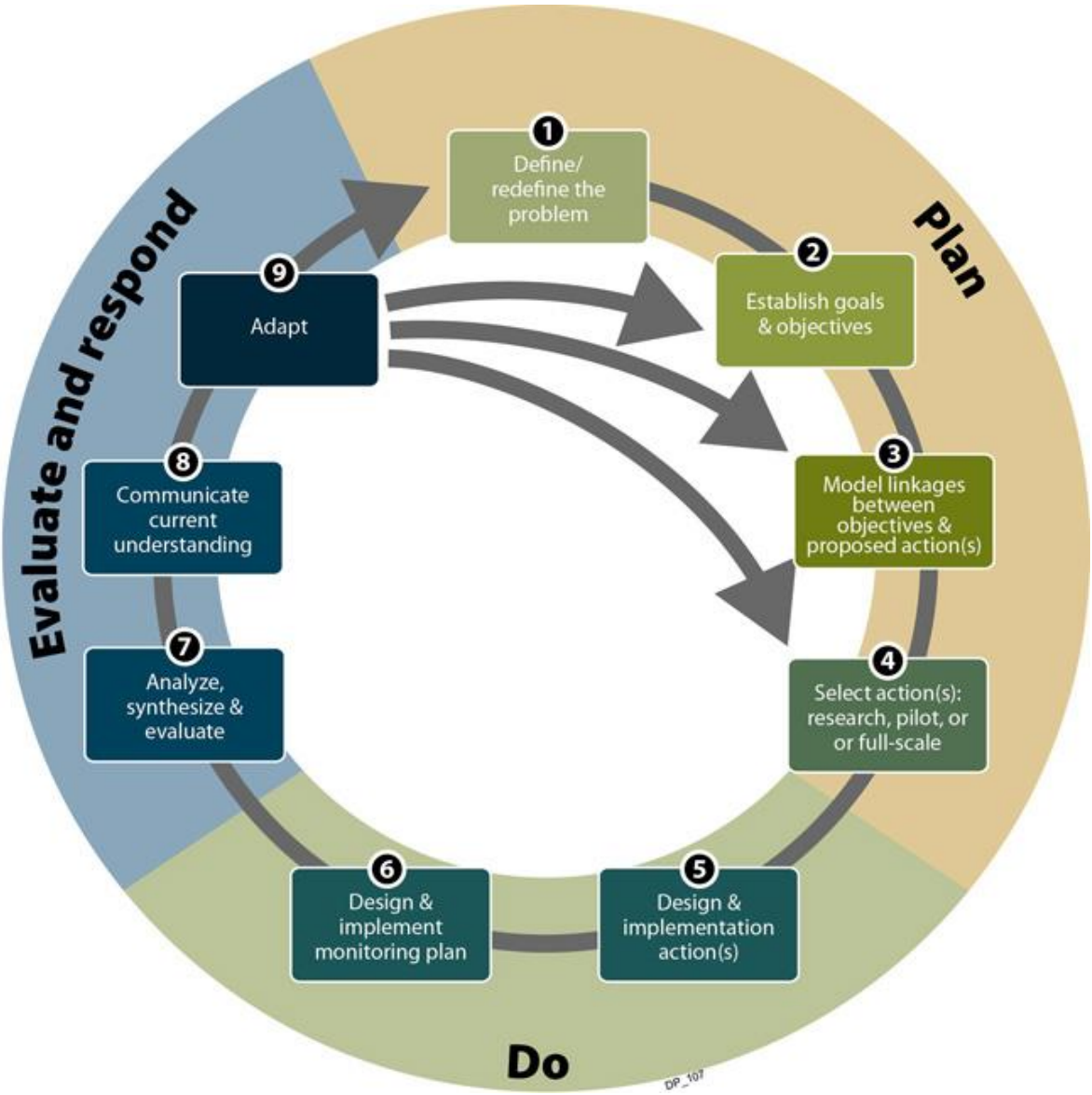

Figure 1. The nine-step framework for adaptive management depicted in the Delta Plan, Boxes represent steps in the process, and the circular arrow represents the general sequence of steps. The additional arrows indicate possible next steps to address the problem or revise the selected action based on what has been learned.

To assess perceptions about the 9-step approach, we asked questionnaire respondents and interviewees to comment from their experience on how the nine steps are expressed in practice; the discussions and implications for management in the Delta are summarized for each step below.

1. ***Define/redefine the problem***

Although managers and scientists usually have an idea of the problem to be addressed through their planning and actions, disagreements and uncertainties may develop if the problem is not clearly articulated. Everyone involved needs to agree about what the problem is and see it in the same way. Defining the problem is central to effective management.

Everyone we interviewed considered their work to begin with a clear understanding of the problem, although they went about it in different ways. Clear definition of the problem can indicate at the outset the array of collaborators needed to address the problem and establish the baseline conditions for management—which is the starting point against which progress (or at least change) can be measured. Often, however, the problem is defined by entities other than those designing and doing the management. As one respondent observed, "*We are typically told what the 'problem' is by other agencies. Our job is to figure out how to fix the problem.*" In at least some cases, the problem statement is accompanied by an identification of key uncertainties, which helps define knowledge gaps that need to be filled. Appropriately, the problems are defined by perceived management, political, or societal needs rather than science needs. The role of science, after all, is to help address the specified problem in a rigorous way—"*the science should be relevant to the problem*."

Overall, our impression is that the various agencies and programs do a good job, individually, of framing the problem (even if it is not "their" problem), in many cases setting the stage for the subsequent steps in the adaptive-management cycle. Sometimes there is clear coordination and collaboration among agencies or entities to address a common problem, although this is not nearly as prevalent as it should be.

2. ***Establish goals and objectives***

Clear goals and objectives are essential to adaptive management; as Yogi Berra once observed, "If you don't know where you are going, you'll end up someplace else." With clear goals and objectives, reliance on subjective feelings that "things just aren't right" or "this isn't working" can be avoided.

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Most problems are considered in terms of outcomes; managers "*look first at the outcomes and then ask what is needed to ensure getting there*." The desired outcomes, in turn, dictate what performance measures will be used to determine the "success" of a program (and thus the need to adaptively manage). When the goals and objectives are set by administrative or regulatory criteria (e.g., meeting water-quality standards or permit specifications), as is often the case, the targets or outcomes of actions are clearly specified but the mechanistic understanding of causes (*why* did the actions produce the observed outcomes) needed to conduct adaptive management may remain elusive. Some programs and agencies are able to identify ecologically sensitive performance measures (e.g., juvenile fish migration survival rates, spawning density, dissolved oxygen), but obtaining information on such measures requires detailed monitoring. As one respondent commented, "*Performance measures have generally been established in federal ESA biological opinions or State water rights decisions and are often too broad, too difficult, and too costly to measure*."

This statement indicates the challenge faced by scientists, managers, and decision-makers in the Delta. It is important to frame clear goals and objectives that are (in keeping with the State's coequal goals) relevant to managing both water availability and the integrity of Delta ecosystems. However, if progress toward meeting those goals and objectives cannot be assessed because the outcomes are difficult to measure (e.g., juvenile fish survival) or the indicators are not directly related to the goals (e.g., salinity at some locations), it will be difficult to determine whether it is appropriate to stay the course of action or adaptively change practices.

Overall, all of the programs and agencies we reviewed have a clear sense of their goals and objectives even though many struggle with meeting objectives that are not their own and are under constraints that limit their ability to measure progress toward meeting those objectives.

*3. **Model linkages between objectives and proposed action(s)***

Conceptual and quantitative models are key component of this step. Through this process, cause-effect pathways are established. Models help to define the mechanisms underlying causal pathways that often determine whether a management decision meets expectations or does not. Typical responses were: "*We use conceptual models to guide our understanding of the complex nature of ecological systems and to help identify data gaps*" and "*We ultimately decide which models to use based on the state of the science, availability of appropriate models and modeling expertise, cost/benefit of modeling versus not modeling an action, and project budget.*" There is also a general recognition of the need to develop quantitative modeling expertise and tools to implement adaptive

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management and balance long-term benefits against short-term costs. Even when quantitative models are used, however, there is often little follow-up and no adjustment of models based on new information. Developing quantitative models that capture the complexity of Delta systems requires data (and data management) and modeling or quantitative staff who are well-versed in systems thinking, but such staff are difficult to attract and retain and "*are often pulled off to address immediate needs*."

While most respondents use conceptual models and recognize at least the desirability of complex, quantitative, systems models, others question the value of modeling in addressing problems in the Delta. There is a perception that even conceptual modeling may not be needed to conduct adaptive management, particularly when the ecological or physical processes are well known; "*we need to ask what a model can tell us that we don't already know that will add value to management.*" As one respondent put it, "*we model to exhaustion, modeling begets more modeling.*" Another noted that "*having models is great, but not at the expense of delaying action*."

Thus, while many individuals and entities working in the Delta embrace (albeit sometimes reluctantly) the role of modeling and its value in organizing thinking, identifying critical uncertainties, and communicating options to decision-makers, others prefer to base their actions instead on experience, expert opinion, or intuition. Although sophisticated, quantitative modeling is not necessary in all situations, we believe that conducting adaptive management must at a minimum entail the development of a comprehensive conceptual model, organized in relation to the overall problem being addressed, the goals and objectives, the uncertainties involved, and the desired or anticipated outcomes. For example, in developing guidance for ecosystem restoration for the Army Corp of Engineers, Fischenich et al. (2012) suggested that conceptual models for adaptive management should (1) identify causes of degradation (i.e., the problem); (2) indicate how the causal factors influence key system components; (3) indicate how management can reduce stresses or restore the system (i.e., meet the objectives); (4) incorporate hypotheses to be tested; and (5) indicate what needs to be monitored, and why.

As complexity, the need for quantitative predictability, and/or the risk of unintended consequences of actions increase, more sophisticated models may be needed. Because such models are demanding of expertise, time, and money, they should be developed in a collaborative framework. The collaborative development of CALSIM by the US Bureau of Reclamation and the California Department of Water Resources is a good example. [mention the collaborative modeling workshops and perhaps the restoration hub?] Models may therefore play an additional role of fostering inter-agency

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collaboration, which in turn may reveal knowledge, insights, or knowledge gaps apparent to one agency but not to others.

4. ***Select action(s): (research, pilot, or full-scale) and develop performance measures***

Adaptive management often identifies alternative actions that might be undertaken to address a problem. Models may help to select among these, but uncertainty may remain about which actions will produce the desired outcomes. When the actions are expensive, difficult to change, or have the potential to produce unwanted side effects, additional research or a small-scale pilot study may be appropriate before undertaking full action. One respondent indicated that "*if outcomes are fairly uncertain and time sensitivity is not an issue, then a small scale implementation (pilot) study is generally conducted before a larger scale project is undertaken*," generally involving consultations among multiple agencies and stakeholders. Some programs use decision support tools (e.g., DRERIP Action Evaluation Procedure and Decision Support Tool) to help determine what actions may be most appropriate in a particular situation. Others view conducting a pilot study before full-scale action as an alternative to implementing adaptive management after the action is taken—an approach that could be described as "plan, do a pilot study, and then forge ahead and don't look back!".

Clearly, information and knowledge can be obtained in many ways, and an experiment or hypothesis test isn't always necessary for adaptive management. One interviewee noted that "*management decisions are typically made in response to regulatory requirements and to short-term crisis situations, so they are often made without considering targeted research or adaptive management*." There is a perception that "*there is a tradeoff between implementing actions and conducting the science to evaluate the actions,*" In some situations involving critical knowledge gaps or uncertainties, research may be necessary, but several respondents questioned whether the adaptive-management framework is simply another way for scientists to justify doing more research. Thus, "*there should be a very clear division between adaptive management and scientific research*," or, more bluntly, adaptive management "*will make projects more costly, complicated, and promote further implementation delays. In the end, less gets done, [we] go to more meetings, the resources continue to suffer, while the scientists wait for irrefutable answers*." Another respondent cautioned, "*Adaptive management should focus on finding out if the broad project objectives are being met, not with discovering answers to detailed scientific questions*."

Overall, then, there appears to be considerable angst about including additional scientific research under the banner of adaptive management, even though everyone

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seems to agree that science is central to the process and an important way to fill knowledge gaps and reduce uncertainties. Understandably, people in agencies with management responsibilities in the Delta feel "*the curse of the immediate*," the push to take action without the luxury of first getting more information to increase the likelihood of long-term success. Despite this, some programs are committed to conducting pilot studies (and perhaps even more research) when the situation warrants and they can justify (and fund) it. In practice, "*the lack of funding and staff resources for science is the primary limiting factor for targeted research and pilot studies*."

5. ***Design and implement action(s)***

The final stage of planning in the adaptive-management process is designing actions and monitoring. All of the programs we considered included project design, often in considerable detail, although not always in the sequence outlined by the previous stages of the adaptive-management process. Differences in goals and objectives among projects can lead to divergences in design, especially in monitoring. If a project is designed to address regulatory needs, for example, the monitoring protocols are generally not designed to answer scientific questions. It is compliance monitoring rather than performance or scientific monitoring. Consequently, although the monitoring design may tell one whether a project has complied with regulations or permit requirements, "*this monitoring data is typically useless to answer any questions.*" Even when the emphasis is on monitoring ecosystem performance, the focus tends to be on outcome measurements rather than mechanistic understanding of why actions succeeded or failed.

To be most effective, the planning and design of project actions should be developed in tandem with the plan and design of monitoring—project design and monitoring design are inseparable. This is especially important when the adaptive management process is structured as an experiment or designed to test hypotheses. Linking monitoring with project design will also help to ensure that the monitoring is targeted, informative, and cost-effective rather than broad-based and unfocused. Unfortunately, monitoring details "*are often worked out as the project proceeds and funding becomes available.*" Not surprisingly, the design of monitoring protocols generally receives less attention than the design of the management actions to be taken. This can lead to ineffective monitoring or monitoring the wrong things.

6. ***Design and implement monitoring plan***

Almost all programs and agencies implement projects more or less as the projects were designed, within the framework of the goals and objectives. Once initiated, most projects stick to the original design unless it is overwhelmingly obvious that something is

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amiss. Usually when this happens it is a result of external forces such as changes in funding or administrative support rather than problems with the project design itself.

Monitoring is another matter. Programs often find it difficult to maintain ongoing monitoring while implementing actions, much less after the actions are thought to have been completed. In some cases, predetermined protocols may be inappropriate for the situation being monitored. Because monitoring is so central to adaptive management, we discuss it more fully in Section VI.

If the performance or results of actions are to be assessed, data must be collected, whether they are for compliance, assessing outcomes, or to determine underlying mechanisms. Some respondents and interviewees reported that their data are assembled in one or another data bank or data-management system that is available to others, although this was more often than not a work in progress. In other situations, however, "*database linkages outside individual projects are generally not worked out very well or at all*." The management of Delta data is a topic of active consideration by the Delta Science Program (cite data white paper).

*7. **Analyze, synthesize, and evaluate***

Several respondents indicated that the analysis of the results of an action is often done "*within a year or two*" of project completion or occasionally during implementation of the actions if conditions warrant. Where the actions are undertaken in a regulatory setting or have permitting conditions attached, however, there may be built-in checkpoints or triggers for assessing status. For example, "*when adaptive management triggers are met, we respond accordingly, with varying degrees of effort, detail, and adequacy.*" In other words, mid-project assessments are generally done to comply with reporting timelines and permit requirements rather than to assess whether the system is responding to management as hoped. Other respondents or interviewees said that "*the most common project evaluation is a qualitative assessment of whether a project has been implemented as designed*" or "*on the ground observations and assessment of habitat conditions and consideration of changes in environmental conditions are continually analyzed, but likely not well documented.*"

There seems to be a general pattern related to analysis, synthesis, and evaluation. If projects are related to a multi-agency effort (the Interagency Ecological Program was frequently mentioned), then prompt, ongoing, and thorough analyses may be conducted, as for the POD, MAST, or Fall Low-Salinity studies. More often, the burden (and it is often perceived in this way) of analysis and synthesis falls within a program or agency, and it may be delayed or not done at all unless there are specific requirements and

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appropriately trained staff to do so. It is important to emphasize that this is *not* the result of a disregard for the importance of analysis and synthesis or a lack of intent to do so; rather, it reflects the incessant, multiple demands that are made on programs, staff, and agencies that are understaffed or lack the expertise to conduct basic data analyses. The difficulty is exacerbated when monitoring is inadequate or piecemeal, not targeted on the most appropriate response variables, or the data are not managed in a way that facilitates appropriate analysis.

In short, this phase is where the adaptive-management process, when it is actually undertaken, most often begins to break down. The failure to conduct the necessary analysis, synthesis, and evaluation of the results of management actions, particularly while the actions are underway (and thus potentially amenable to adaptive adjustment), is a major barrier to achieving adaptive management. To some degree, this situation is created by the imperative to move ahead on other actions or projects once one project is completed. This, in turn, reflects the perception that a project is "completed" when the action is done; as a result, analysis, synthesis, and evaluation are regarded as an add-on to be done as time and resources permit. Although it is clear that some (perhaps many) programs and agencies *want* to do the analysis, synthesis, and evaluation needed to gauge the effectiveness of their actions (and thus follow through with adaptive management), even the best intentions may be overwhelmed by the immediacy of management challenges in the Delta. Ecosystem-level, performance-based analysis and synthesis is especially important for creating an integrated system of actions over time, rather than planning opportunistic actions that tend to occur today without regard for future plans or changes. Without timely analysis, synthesis, and communication, little is learned, at least in a way that can be incorporated into science-based management.

*8. **Communicate current understanding***

The Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management (2009) identified a lack of communication as a major impediment to implementing adaptive management. If scientific findings are not translated into clear and understandable language, managers and decision-makers will be unlikely or unable to use the information to respond adaptively.

Everyone we surveyed recognized the importance of communicating the results of their actions to decision-makers, other agencies, stakeholders, and the public. In some cases there is frequent communication among managers and agency staff about habitat and management conditions for a specific project. Scientific findings are generally reported in conferences and briefings, some of which are directed toward the public. Translation of the science, however, "*is often not done until managers/decision-makers*

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identify a specific question(s) they need answered" and often the communication is to upper-level administrators about budgets rather than assessing what has or hasn't worked or coupling the communications with informative and up-to-date performance measures. One respondent noted "*the information that drives management decisions seems to be more based in local politics and whose land is being sought after for what purposes or with specific conflicts between parties that could result in lawsuits*" and another felt that "*there has not seemed to be an interest in what science-based actions might be assisting in the recovery of specific animal populations as marker of progress to species recovery as it related to water/flood/land management decisions*."

Tailoring communication to facilitate adaptive management isn't easy. Managers and decision-makers have many responsibilities, so the challenges are to distill the results of all the previous phases of the adaptive management process and to determine how much information, of what sort, is needed to inform decisions. Briefings lack detail and substance, while lengthy reports or scientific papers are ineffective or are ignored. The Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management (2009) recognized the need for individuals skilled in communication *and* science to translate scientific findings for managers and decision-makers. This need remains unfilled.

9. ***Adapt***

The agency representatives we interviewed repeatedly brought up the questions of who makes the decisions and how they should do it. In some programs, the process is adaptive but informal. If the results are desirable, then the actions and techniques are applied elsewhere; if not desirable, the practices are assessed and changes may occur. Gauging what is or is not a desirable outcome should be related to the initial goals and objectives, although who deems what is a desirable outcome at the end of a project may not be the same person as the one who initially framed the goals and objectives, which may have been done years earlier. As conditions change, what looks undesirable now may look more desirable as time passes. One respondent mentioned that "*we need tools to assist programs to conduct that critical but usually missing link in the cycle: adapt and then re-evaluate and change program goals and objectives*." In some instances, determining whether change is necessary may be based on the use of models to inform decision-making, although this may be slow because data needed to run the models are insufficient; in this case, best professional judgment, stakeholder input, or external peer review may substitute. The trickiest part of the adaptive-management process may be determining when a mismatch between the results of management actions and the original goals and expectations of a project is great enough to warrant changing the actions, models, goals and objectives, or restating the initial problem (Figure 1).

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Overall, it is our impression that decisions about whether to continue or change management approaches and actions are often based on some level of monitoring and analysis, combined with experience and professional judgment. The process varies tremendously among and within agencies, however, and it is often an informal rather than a systematic process. There is a tendency to regard any process that might result in change as adaptive management, which may be why so many think they are doing it.

VI. Why is Adaptive Management Not Done More Often in the Delta?: Constraints and Impediments

In Section I we listed factors highlighted in Appendix C of the Delta Plan that generally impede applications of adaptive management. Several of these apply with particular force to management in the Delta and were mentioned frequently (or in some cases, always) by questionnaire respondents and interviewees. Making adaptive management a common practice in the Delta requires that these impediments be lessened or removed, so we comment on them here.

Aversion to taking risks

Adaptive management addresses uncertainty. Dealing with uncertainty entails risk. Risk carries with it a probability of failing to achieve goals and objectives—in other words, failure. Failure is an anathema to a results-driven and political culture, which any management agency must be. How can a manager risk or decision-maker spending money on a project with uncertain results, especially a risky one? How would she or he explain it to their superiors, or to politicians, or to the public? Perhaps these constraints and anxieties have encouraged managers to believe that it is better to err on the side of caution and be conservative in modifying actions.

While this characterization does not describe the approach of many programs, managers, and agencies working in the Delta, it may not be too far off the mark for others. As one respondent observed, "*Agencies and agency staff are risk adverse. They would rather not act, if there is a possibility that they may make the wrong decision, and having it attributed to them*." The tendency of managers, decision-makers, policy specialists, and engineers to be risk-adverse or to strive to maximize certainty in what they do contrasts with the culture of science, in which uncertainty and risk are the *sine qua non.* To a scientist, doing an experiment or conducting a study in which the results were certain and there were no risks of surprises would be unexciting and pointless. This difference in perspectives may contribute to communication difficulties between scientists and managers.

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The curse of immediacy

Conducting comprehensive adaptive management will often be ponderously slow. Once the problem, goals, and objectives have been defined (which itself can be slow and contentious if multiple parties and interests are involved), doing the planning, modeling, designing, and permitting can easily take years before all is set to implement an action. Litigation can add further delays, and risk-aversion by managers or decision-makers can create additional excuses for delaying action. It is little wonder that carrying the adaptive-management process through even one entire cycle is rare.

Even if steps can be taken to reduce some of these delays, the orderly, sequential process of adaptive management is susceptible to being repeatedly sidetracked in the environmentally, politically, and socially dynamic setting of the Delta. Crises arise often, derailing attempts at long-range planning or continued monitoring. Staff assigned to data analysis, modeling, or monitoring may be shifted to address more immediate concerns, so knowledge to inform adaptive management may be obtained sporadically, in fits and starts. As one respondent put it, "*the need to make decisions outpaces information flow*." Put simply, the pace of adaptive management does not match the pace of events and management decisions in the Delta.

Regulations impede flexibility

Management of a system as complex as the Delta, with multiple local, state, and federal agencies involved in decisions about water and the environment, is suffused with an array of regulations and permit requirements. These regulations and requirements reflect a desire and need to establish order, certainty, and stability; they set standards and limits and prescribe the legal and operational domain within which management must operate. In contrast, the targets of management—smelt or salmon, water quality, incoming flows, demands on water exports, salinity intrusion, and the like—are anything but orderly, certain, and stable. The targets are assumed to be stationary, but in fact they are constantly moving. The flexibility needed to deal with changing conditions or to implement the "adaptive" part of adaptive management may be precluded by regulations. Listing of species under the Endangered Species Act, for example, places restrictions on experiments or pilot studies that might lead to improved management and leads to a focus on single species rather than the larger ecosystem. Once permits have been issued for management actions it is difficult to change directions in mid-project, even if new knowledge indicates that change is needed. The need to modify permits or obtain new ones may bring a project to a halt, particularly if it prompts litigation.

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Monitoring is difficult to maintain

Science is the lynchpin of adaptive management and the foundation of monitoring. Without monitoring, of the right things, at the right times, at the right places, there is little way to know whether a project is on track, whether it is moving toward the desired goal or toward an alternative outcome. In short, there is no way to manage adaptively. Consequently, monitoring needs to be done before and during a project, not after the project is completed or when it is too late to make changes. Because the outcomes of actions are frequently not immediately apparent, monitoring also may need to be continued for some time after project completion to gauge the effectiveness of the management actions. All of this emphasizes the importance of a continuing, long-term commitment to monitoring if adaptive management is to deliver on its potential.

However, developing the needed long-term vision and commitment in the crisis-driven setting of the Delta is challenging. As one respondent noted, "*Unless there are legal or regulatory mandates to do monitoring, it is often the first thing to go when money gets tight.*" Others suggested "*monitoring is typically [of] discrete elements for a short duration to meet regulatory requirements*" and "*not designed to answer science questions*." More generally, "*Adaptive management science efforts are not funded. They get added to a project and other resources and staff are depleted to meet the new requirements*."

There is also a perception—perhaps more widespread than is admitted—that the level of monitoring required by adaptive management is excessive and may not add value commensurate with its costs. Such monitoring "*takes away from other resource management obligations and needs*." For example, "*Monitoring for a 300-acre restoration project far exceeds the costs of doing the restoration, so one can't blend implementation with monitoring or the project becomes too expensive.*" This may be particularly true if the monitoring must generate sufficient statistical power to detect responses to management actions in the complex and variable environment of the Delta. The success of the Interagency Ecological Program in catalyzing continuing, long-term monitoring of aquatic resources in the Delta shows that it can be done, although it requires dedicated and stable funding.

Adequate long-term funding is unreliable

Without exception, the individuals and agencies we canvassed identified the lack of reliable, long-term funding as the greatest single impediment to adaptive management and monitoring in the Delta. Thus, "*little to no money is available or designated for developing and implementing monitoring to determine outcomes.*" Or, "… *funding occurs*

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for those programs mandated by law"; otherwise, "*details of adaptive management and monitoring are often worked out as the project proceeds and the funding becomes available.*" Or, "*There is insufficient funding to conduct the science and collaboration necessary for evaluating actions and developing a response.*" Or, "*Funding for monitoring of habitat enhancement after construction is not typically a priority or directive of fund sources*."

The difficulty of funding adaptive management is in part a result of priorities, but even if some funding is available to support the adaptive management that programs or agencies want to do, the funds often come in ebbs and flows that render the process inefficient or ineffective. "*Support comes in pulses that put a premium on showing progress, rather than deliberate, long-term projects.*" Bond funding such as that from Proposition 1, for example, may provide money to do things, but not to follow up and determine the outcomes. General Fund allocations to conduct adaptive management and monitoring are difficult to obtain and there is a perception among some that these activities are thinly disguised ways to fund scientific research that does not address real problems.

Thus, adaptive management is often viewed as an unfunded mandate. We believe that people and programs generally want to, and try to, practice adaptive management, but without dedicated and reliable funding they are reluctant to do it at the expense of existing projects and programs. But adaptive management is not something that can be done now and then, in fits and starts—it must be built on the intent to follow through and requires an underlying commitment to long-term stewardship of the Delta and its resources.

VII. Standing Back and Looking Forward: Broadening the Perspective on Adaptive Management

So far, our review has focused on the details of the adaptive-management process and how it is used and perceived by those working in the Delta, relying heavily on their own words. Now we will take a broader view, offering some thoughts prompted by those comments and responses. We hope that these thoughts will provide some guidance for making adaptive management more user-friendly, and thus more widely used in dealing with resource issues in the Delta.

Adaptive management may not always be appropriate

As we noted in Section I, adaptive management is not appropriate for every situation. Adaptive management should not be forced upon a project that is unsuited for

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it, either because the actions do not warrant it or the institutional or stakeholder support is lacking. In the Department of Interior Applications Guide for Adaptive Management, Williams and Brown (2012) suggest that adaptive management is appropriate to situations in which both uncertainty and controllability are high, when the approach may reduce uncertainty by controlling (i.e., adapting) the actions that are taken. Rist et al. (2013) indicate that the key determinants of adaptive management are its appropriateness, feasibility, and likelihood of success, and they provide a useful decision tree for evaluating whether and when the approach might meet these criteria.

Perhaps the most important factor influencing the decision to use adaptive management is funding. It makes little sense to initiate an elaborate and expensive adaptive-management process if the money isn't there to do it properly. Rigorous adaptive management may be essential in situations where the stakes, costs, and economic impacts are high. Here the value in investing in upfront knowledge acquisition to increase the likelihood that the actions will yield the desired results may justify the expense, especially if an action once started cannot easily be changed. Such situations call for comprehensive adaptive management, and the nine-step process shown in Figure 1 provides clear guidance.

In many situations, however, the nine-step process might better be regarded as aspirational rather than prescriptive. Can the adaptive-management process be streamlined to require fewer resources and to move more quickly, and in doing so have less potential to disrupt a program? Steps 1 (defining the problem), 2 (establishing goals), 4 (selecting action(s)), and 5 (designing and implementing actions) are the core of any management, whether adaptive or not. It is important that they be done thoughtfully, with an eye toward flexibility. Step 3 (modeling) is often considered a barrier, but this depends on the kind and level of modeling required. It should not take much time or effort to assemble enough of what is known about a system to develop a reasonable conceptual or quantitative model, which can quickly reveal unrecognized linkages and critical knowledge gaps and can suggest alternative actions (the "Plan Bs"). The impediments to such modeling are more institutional than they are intrinsic to the modeling process.

Likewise, step 6 (monitoring) needn't involve assessing all components of a system using rigorous and demanding procedures. A good conceptual model may help to identify usable indicators of system responses to management actions, and planning ahead to think about the circumstances that might lead to a change in management ("adaptation") could help to determine where, when, and with what level of detail the targets should be monitored. Finally, steps 7 through 9 (analyze, communicate, and adapt) can be adjusted to the complexity and quantitative level of the information gathered and what changes, if any, are suggested and therefore need to be justified. The

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"synthesize and evaluate" part of step 7, especially, requires careful, focused thought and discussion among project participants (including stakeholders).

The bottom line is that there are ways to manage adaptively, whether or not one does comprehensive Adaptive Management following the steps of Figure 1. The key is to understand the value and advantages of the process and to be looking ahead rather than reacting or, worse, avoiding the risk of an approach that might not work or clinging to an approach that isn't working.

Conditions change

"Looking ahead" is important not just so one can gauge the effectiveness of an action and make changes before it is too late, but also because the Delta, like the rest of California and most of the world, is undergoing rapid change. All coastal areas will be affected by sea-level rise, and models of future climate change predict higher temperatures and different rainfall and snowfall patterns, with changed hydrological flows in the Delta. New, non-native species will arrive. Regulatory requirements and the economic values of land and water also will continue to change. Consequently, even the most thoughtfully planned and carefully designed management actions may no longer be appropriate by the time they are completed (or even by the time they are implemented, if planning, permitting, and the like take as long as they sometimes do). If the system changes rapidly and unpredictably, an action may not produce the desired outcomes or it may be difficult to determine whether a change in the system is due to the action itself or to changes in other factors. Although some people question whether the rapidity of these environmental changes may preclude the effective use of adaptive management, others suggest that it may be the best approach to dealing with these rapid changes because they require flexibility, which is an essential element of decision making in a rapidly changing world.

Adaptive management also provides a way of anticipating changes through modeling and monitoring. Some plans for tidal wetland restoration, for example, are incorporating projections of sea-level rise, hydrology, and sedimentation to target actions at appropriate tidal elevations for future conditions. It may be useful to consider developing "anticipatory adaptive management," in which the management actions are designed with reference to future conditions when the actions will be completed and the outcomes are expected, rather than the conditions existing at the time the actions are planned or initially implemented. Vleig and Zandvoort (2013) described such an approach to adaptive management in the Rhine-Meuse Delta of The Netherlands and compared it with the approach outlined for the Sacramento-San Joaquin Delta in the Delta Plan.

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Another consequence of environmental change impinges on how or whether adaptive management is implemented. If change is great enough or rapid enough, it may overwhelm any inherent resilience and push a system over a threshold. Once a threshold is passed, the system may enter an alternative state from which it may be difficult or impossible to return, even with intense management. In such cases, the dynamics of the system may have been fundamentally altered, changing cause-effect relationships. Consequently, the previous understanding of the system, on which management relies, may no longer apply—the rules of the game have changed. The problem with thresholds, of course, is that you generally don't know they are there until you've passed them, when it may be too late to do much about it. In a complex ecosystem that has undergone massive alteration, such as the Delta, some thresholds may already have been passed; the Pelagic Organism Decline (POD) may be an example. We found little evidence that much thought has been given to the complications that might be posed by thresholds. The possibility of thresholds heightens the need to incorporate flexibility and adaptability into planning and management.

The bottom line is that future changes should always be considered in planning management actions, even though (as Yogi Berra said), "It's tough to make predictions, especially about the future." Nonetheless, future changes will determine the effectiveness of management whether or not the approach is adaptive, whether or not there are legal or regulatory requirements to consider the future, and whether or not the approach is explicitly anticipatory.

"Best available science" may not always be best

The use of "best available science" is a common requirement for management actions in an uncertain environment. It is explicitly mandated in the Delta Reform Act and is discussed at some length in the Delta Plan. Best available science "requires scientists to use the best information and data to assist management and policy decisions" (Delta Plan, page C-1). In essence, it is the gold standard for applied science.

We do not intend to challenge the importance of using current and well-tested scientific knowledge to support management or the desirability of aspiring to the criteria established for best available science (Delta Plan, Table C-1). It may be worthwhile, however, to reflect on whether it is always the most appropriate or productive goal for science-based management in the Delta. We have several concerns.

First, what is really intended is that the best available *knowledge* be brought to bear on an issue or used to support a proposed action. Knowledge comes in many forms,

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of which science is only one. The learning that is the aim of adaptive management involves increasing the quality and quantity of knowledge, not just adding more science to the mix. Admittedly, "best available knowledge" doesn't have the same cachet as "best available science," but it may more accurately capture what is really being sought.

Second, the emphasis on "best" and the criteria used to define it appropriately sets a high bar. It may be set so high, in fact, that actions may sometimes be delayed while the search goes on for better data, better analyses, or additional scientific publications, all in the interests of meeting the goal of "best." There are already excuses available for delaying actions (especially controversial ones); aiming for "best" should not be one of them.

Third, adaptive management involves a succession of steps that build on what is good enough to take action—further reduction in uncertainty is not needed to move ahead. In fact, it is often necessary to initiate a management action when the available knowledge is just "good enough," rather than being the "best available." The same criteria used to identify "best available" science might also be used, in a somewhat more relaxed form, to define what is "good enough" science. Essentially, thinking of the science as "good enough" allows a manager or decision-maker flexibility in considering the additional costs, risks, uncertainties, effort, and potential benefits of attaining "best available." There is a legitimate concern that using a "good enough" standard may weaken the role of science in informing management and policy or open the door to all sorts of pseudo-science or advocacy entering the fray and influencing decisions. Realistically, however, even the most stringent definition of "best available science" is still susceptible to the inclusion of suspect or subjective science.

All of this may be quibbling about words. Words matter, however. "Best available science" implies (correctly or not) that scientific certainty is as good as currently possible. Science that is just "good enough" doesn't sound nearly so rigorous. Yet, as Voltaire said, "The best is the enemy of the good," and striving for the best may not always be the most prudent approach.

VIII. Overall Findings

[a short paragraph or two summarizing what we think]

IX. Recommendations

Science, management, and policy in the Delta are in a state of flux, brought on by the proposal to build new water-conveyance facilities, the heightened imperilment of

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several species at risk of extinction, the specter of increased salinity intrusion into the Delta, changes in hydrology and sea-level rise due to climate change, and increasing conflicts over who gets the water—all exacerbated by the ongoing drought. This cauldron of change provides an unusual window of opportunity—and an imperative—to develop a more thoughtful and effective approach to achieving the coequal goals highlighted in the 2009 Delta Reform Act for the future of the Delta. The Delta Plan and Delta Science Plan provide frameworks for capitalizing on this opportunity, and the theme of "One Delta, One Science" offers the prospect to bring coherence to the science currently fragmented among agencies and disciplines, which thwarts effective adaptive management. A more holistic and integrated approach to science-based management in the Delta is needed.

Despite legislated mandates to use adaptive management, this is unlikely to happen spontaneously. We offer the following recommendations; if implemented, they can move adaptive management beyond being an abstract label to something that is a common and valued element of management programs and projects in the Delta.

1. **Create a Delta Adaptive Management Team (DAMT).** This is not a new recommendation; similar suggestions have been made in the past. In the context of the CALFED program, for example, Zedler and Callaway (2003) proposed developing an adaptive management team that "meets annually, identifies priority research needs, prioritizes sites where adaptive restoration might take place, reviews research results, and recommends future actions." Subsequently, the Delta Science Plan developed by the Delta Science Program in 2013 recommended (1) the creation of several "adaptive management liaison" positions to provide advice to their counterparts engaged in adaptive management in agencies and organizations; and (2) convening an annual "adaptive management forum" to share lessons learned and provide training in adaptive management. Currently, two interrelated programs operate under Court Orders to develop a science and adaptive-management program to inform the implementation and development of Biological Opinions (BiOps) related to listed species, particularly smelt and salmon. The Collaborative Science and Adaptive Management Program (CSAMP) is a policy group composed of agency directors, regional directors, and general managers. The Collaborative Adaptive Management Team (CAMT), which includes senior scientists and high-level managers, is embedded within CSAMP. The revised draft RDEIR/SDEIS for California WaterFix that replaces BDCP proposes formation of a Collaborative Science and Adaptive Management Program that would absorb the functions of CSAMP and CAMT, focusing primarily on the design and operation of water-conveyance facilities and habitat restoration and other mitigation measures.

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We envision something greater—a full-time team of individuals knowledgeable in the nuances of all phases of the adaptive management process. With strong leadership, it will foster the mutual trust and respect among scientists, managers, stakeholders, decision-makers, and agencies that are needed to design and conduct coordinated adaptive management. The DAMT will provide guidance, expertise, and support to enhance the application of adaptive management in the Delta and integrate agencies' efforts.

Among its functions, the DAMT will:

- Provide leadership in aligning adaptive management with the needs and context of projects. There is no "one-size-fits-all" approach for applying adaptive management to a project. Some large-scale, complex projects may require comprehensive adaptive management; for smaller, site-specific projects a condensed adaptive process may be most useful; and some projects may be unsuited to adaptive management at all. The scope and level of adaptive management should be aligned to improve project outcomes and reduce or accommodate critical uncertainties. The adaptive-management plan for a project should explain why adaptive management is needed (or not), likely benefits, and which steps of the adaptive-management process will be undertaken, abbreviated, or omitted. By articulating the pros and cons of alternative management scenarios, the DAMT may help programs and agencies decide on the best course of action.

- Consider how expected changes in future conditions should be incorporated into adaptive management plans and actions. The Delta is a dynamic place. Climate change and sea-level rise will make it more so. Adaptive-management plans need to be designed to consider likely impacts of future changes on project outcomes and should include contingency plans and resources if changes are likely to be great.

- Support agencies in using adaptive governance and identify potential synergies among agencies. Adaptive management requires flexibility. Managers must be willing to take reasonable risks on actions that may not work out as planned; to reassign staff to needs that arise during adaptive-management implementation or in response to unplanned experiments; and to share resources and staff expertise with other agencies or programs in response to shared needs. We expect that the DAMT will work with

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programs and agencies to develop collaborations and realize economies of scale.

- Advise the Delta Stewardship Council and other regulators on compliance issues. The Council is responsible for evaluating whether covered actions are in compliance with the Delta Plan, which includes the application of adaptive management. As needed, the DAMT can evaluate whether the adaptive-management plan for an action is appropriate to the scope and context of the action.

- Encourage a greater emphasis on whole ecosystems and functioning landscapes. Most projects in the Delta address the ecology of single species or deal with the management or restoration of specific sites. Such actions will be more effective and more amenable to adaptive management if they take into account the broader landscape and ecosystem contexts. The DAMT will develop case studies and facilitate research to document these benefits.

- Assemble, synthesize, and communicate information about adaptive management. Adaptive management is being undertaken in many places in the world to address diverse problems. The DAMT will act as a conduit to convey the findings and experiences of these efforts to managers and practitioners in the Delta. The adaptive-management process must itself be adaptive.

- [NOTE 1: THE DAMT WILL NOT BE SUCCESSFUL OR EVEN GET STARTED UNLESS AGENCIES, MANAGERS, DECISION-MAKERS, ETC. VIEW IT AS SOMETHING USEFUL AND HELPFUL, WHILE NOT INFRINGING ON THEIR DECISION SPACE. WE NEED TO THINK CAREFULLY ABOUT HOW TO ADD VALUE WITHOUT BEING YET ANOTHER BODY THAT PROVIDES ADVICE AND GUIDANCE. CAN THE DAMT DEVELOP INCENTIVES FOR DOING ADAPTIVE MANAGEMENT?]

- [NOTE 2: ALL OF THESE RECOMMENDATIONS USE VERBS SUCH AS “ASSIST,” “CONSIDER,” “SUPPORT,” “ADVISE,” OR “ENCOURAGE.” SHOULD THE DAMT PLAY A MORE PROACTIVE ROLE IN LEADING ADAPTIVE MANAGEMENT EFFORTS? IF SO, HOW?]

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2. **Ensure reliable, flexible, long-term funding.** The greatest impediment to implementation of adaptive management in the Delta is the paucity and unpredictability of funding to support critical stages of the process, especially modeling, monitoring, and data management, along with analysis, synthesis, interpretation, and communication. Radical approaches to funding adaptive management are needed. The past and present piecemeal approaches will not provide the long-term support needed to reach the "adaptive" part of the process, without which there is only a business-as-usual management approach. We suggest that project budgets should include a line-item allocation at a fixed proportion (10-20%) to support Delta adaptive management above and beyond monitoring. The dollars would be the foundation of a general Delta Adaptive-Management Fund that could assist high-priority projects or programs and support the activities of the Adaptive Management Team. Coordination of planning and actions for adaptive management should realize overall cost savings.

3. **Capitalize on unplanned experiments.** Large, ecosystem-level experiments are expensive, difficult to design and replicate, and require burdensome permitting. But unplanned experiments, such as extreme and prolonged droughts, large floods, levee breaks, construction of salinity barriers, or cold-water releases (or their absence) from upstream dams do happen. These provide opportunities to learn and to implement adaptive management. Capitalizing on these opportunities requires being prepared—having contingency plans, monitoring protocols, and modeling capability in place and identifying funds and staff that can be shifted to respond. The DAMT could coordinate such preparations.

4. **Integrate science and regulation to enhance flexibility.** Rigid regulations and permitting rules inhibit the nimble flexibility required to change directions quickly as it becomes apparent that a project is not developing as planned. Opportunities are lost. Regulations should be interpreted or, if necessary, revised to allow sufficient flexibility to implement adaptive management, within legal limits.

5. **If the impediments to conducting adaptive management are insurmountable, revisit or revise the legislation.** Adaptive management has been difficult to achieve in the Delta, for the reasons highlighted in this report. Yet inclusion of adaptive management is often legally mandated, whether it is appropriate for the situation or not. We believe that our recommendations will help to remedy this situation. However, if they cannot be implemented and

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adaptive management continues to be perceived as an onerous burden that yields no benefits, or if it is simply too difficult to implement in practice, the legislated mandate to use adaptive management in the Delta should be revised. There is no reason to impose a requirement on agencies and managers that they cannot meet, even with the best of intentions. In this case, other means should be examined to achieve the original legislative intent of adaptive management.

X. What Next?

It is beyond the capacity, responsibility, or authority of the DISB to move these suggestions from recommendations to actual implementation. Such changes require leadership in science and policy from programs and agencies. However, the work of the DISB on fostering wider and more nimble application of adaptive management to Delta management should not end with this report. We envision continuing DISB involvement in several follow-up activities:

1. Meet with several individuals and respondents who provided the raw material for our review to discuss our findings, how to address the impediments, and how best to progress from words and plans to adaptive actions;

2. Present and discuss these findings and recommendations with multiple audiences (e.g., State of the Estuary Conference, a perspective paper in San Francisco Estuary and Watershed Science, others?);

3. In partnership with the Delta Science Program, the Delta Conservancy, CAMT, the Public Policy Institute of California, and others, organize and host an Adaptive Management Forum, including local and invited experts and multi-perspective panels to discuss and evaluate what is needed to do adaptive management in a system as complex as the Delta;

4. Work with the Delta Science Program (and eventually the Delta Adaptive Management Team) to track progress on the implementation of adaptive management and the recommendations in this report; and

5. Work with the Delta Stewardship Council and others to create the Adaptive Management Team, as proposed in recommendation 1.

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Appendix B. Adaptive Management in the Everglades. From Doremus et al. (2011).

The Everglades: Without Clear Goals, Adaptive Management Goes Nowhere

The Comprehensive Everglades Restoration Plan (CERP) illustrates one instance where adaptive management has failed primarily because it was mandated by Congress in an inappropriate context. The CERP was adopted in 2002 in an effort to restore the ecological functioning of the Florida Everglades.[2] Congress intended "to restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection."[3] The $8 billion cost of the restoration plan was to be shared equally by the federal government, through the Army Corps of Engineers, and the non-federal sponsor, the South Florida Water Management District (SFWMD).

Heavy emphasis has been placed on satisfying stakeholders' economic interests rather than the environmental mandates, and this imbalance places a chokehold on experimentation, learning, and adaptation. In response to stakeholders' demands, the CERP devotes a great deal of attention to the use of ever more heroic engineering techniques to expand water supplies and ensure flood control for South Florida's exploding population. Meanwhile, it gives low priority to the improvement of necessary sheet water flows—the primary ecological hallmark of the Everglades. As a result, the CERP remains in a planning mode, rather than an adaptive implementation mode. In a 2007 review, the Government Accountability Office observed that no CERP projects had been completed and that the only progress that had been made involved a few, select CERP-related pilot projects designed to understand nutrient removal in abandoned agricultural fields.[4]

Why has such a well-funded attempt at adaptive management faltered? One factor is the articulated goal of the CERP, which strives to have it all: ecosystem restoration as well as uninterrupted water supply and flood protection. As in other cases where private economic stakes are high, regulated entities and other stakeholders want certainty and stability. If scientists cannot predict outcomes with a great degree of certainty, experimentation in many instances, if not most, simply will not take place. As a result, the Everglades plan is stuck on modeling and data collection rather than learning through active experimentation and resolving uncertainties in favor of ecological resilience.

A second factor is the basic congressional directive for all Corps' decision-making, which gives the agency discretion to proceed with a project whenever benefits "to whomsoever they accrue" exceed costs.[5] These grants of broad discretion free the Corps to establish priorities based on politics instead of principled reasoning and evidence. As a result, the American public has been saddled with hundreds of questionable dams, levees, and other structures justified only by dubious cost-benefit analyses. In a study of Mississippi River management in 2004, the National Research Council issued a sweeping indictment of the misguided methodology used by the Corps to justify replacing locks and dams on the upper river.[6] The CERP appears to suffer from similar flaws.

Appendix C. The Questionnaire Distributed to Agencies Involved in the Delta

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Appendix D. Agencies and Individuals Consulted for this Report

Agencies responding to the questionnaire

- California Department of Fish and Wildlife – Ecosystem Restoration Service
- California Department of Water Resources – FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO)
- Central Valley Regional Water Control Board
- San Francisco Bay Regional Water Quality Control Board
- Suisun Resource Conservation District
- U.S. Bureau of Reclamation, Bay-Delta Office

Individuals interviewed personally

- Dan Castleberry, U.S. Fish & Wildlife Service
- Joshua Collins, San Francisco Estuary Institute
- Val Conner, Collaborative Adaptive Management Team
- Steve Culberson, U.S. Fish & Wildlife Service
- Ted Frink, California Department of Water Resources – FESSRO
- Les Grober, California State Water Resources Control Board
- Bruce Herbold, Environmental Protection Agency (retired)
- Campbell Ingram, Delta Conservancy
- Gail Newton, California Department of Water Resources – FESSRO
- Kim Webb, U.S. Fish & Wildlife Service
- Carl Wilcox, California Department of Fish and Wildlife
- Leo Winternitz, Collaborative Adaptive Management Team

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Appendix E. Responses to Questionnaire Statements about Adaptive Management (1 = strongly disagree, 5 = strongly agree)

The statements:

1. My entity uses adaptive management as an organizing framework for its activities.
2. In my entity's experience, adaptive management efforts often require collaborations among multiple agencies and stakeholders.
3. My entity's broad management plans (e.g., resource management plans) include the flexibility necessary to engage in adaptive management.
4. Laws and other administrative and regulatory requirements often constrain our entity's efforts to engage in adaptive management.
5. Changes could be made in existing legal requirements to make adaptive management more successful.
6. We usually build a conceptual model of the management action before implementing the action.
7. Conceptual models should include both human and ecological systems.
8. We gather baseline information and/or data about the relevant system(s) before management actions are implemented.
9. Monitoring is adequately funded to support adaptive management.
10. Monitoring and assessment results are integrated into adaptive management decision-making.
11. It is important to communicate the results of adaptive management experiments to stakeholders.
12. In my entity's experience, when adaptive management experiments tell us something new, management actions are changed to reflect what is learned.

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The responses:

	Respondent							
Question	Agency A	Agency B	Agency C	Agency D	Agency E	Agency F	Mean	Range
1	4	5	4	2	3	2	3.3	2 to 5
2	5	4	4	5	4	5	4.5	4 to 5
3	4	5	4	2	3	4	3.6	2 to 5
4	3	2	4	5	4	4	3.6	2 to 5
5	2	3	3	5	2	3	3	2 to 5
6	3	4	4	2	4	2	3.2	2 to 4
7	5	5	4	5	5	5	4.8	4 to 5
8	5	4	4	3	3	4	3.8	3 to 5
9	2	2	2	3	2	1	2	1 to 3
10	3	4	3	3	3	3	3.2	3 to 4
11	5	5	4	5	5	5	4.8	4 to 5
12	3	4	3	4	3	4	3.5	3 to 4

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