Strategic Plan for the Ecosystem Restoration Program

Prepared by the Strategic Plan Core Team
for the CALFED Bay-Delta Program

September 30, 1998

CALFED
BAY-DELTA
PROGRAM

1416 Ninth Street, Suite 1155
Sacramento, California 95814

(916) 657-2666
FAX **(916) 654-9780**

Date: September 28, 1998

To: BDAC Ecosystem Restoration Members and Invited Participants

From: Roberta Borgonovo, Chair

Subject: BDAC Ecosystem Restoration Work Group

The next meeting of the BDAC Ecosystem Restoration Work Group will be held on **Tuesday, October 6, 1998 from 10:00 a.m. to 12:00 p.m. in Room 1131 of the Resources Building, at 1416 Ninth Street, Sacramento, CA.** An agenda for the meeting is attached (Attachment 1). Please note that there will be a joint Assurances and Ecosystem Restoration Work Group meeting from 1:00 p.m. to 4:00 p.m. to discuss the functions necessary to implement the Ecosystem Restoration Program. The agenda and background materials for the afternoon meeting was mailed in a separate packet.

The meeting is dedicated to a discussion of the Strategic Plan prepared by the Core Team. The discussion will focus on the August 31st version of the plan. A revised plan will be completed by October 1, but unfortunately, we will not be able to mail the revised plan in advance of the meeting. Copies of the October 1st plan will be available at the meeting and we will highlight and summarize new or significantly changed sections for discussion at the meeting.

If you need additional information, please contact Peter Kiel at (916) 657-2666.

We look forward to your participation at the next meeting.

Attachments

Attachment 1

BDAC ECOSYSTEM RESTORATION WORK GROUP
Tuesday, October 6, 1998
10:00 a.m. to 12:00 p.m.

Location:
Room 1131
Resources Building
1416 Ninth Street, Sacramento, CA

Agenda

10:00 to 10:10	**1.**	**Welcome** - ***Roberta Borgonovo***
10:10 to 11:40	**2.**	**Review of Strategic Plan Document** - ***Dick Daniel and Roberta Borgonovo***
11:40 to 11:50	**3.**	**Future Meeting Agenda Items** - ***Roberta Borgonovo***
11:50 to 12:00	**4.**	**Public Comment** - ***Roberta Borgonovo***

Strategic Plan for the Ecosystem Restoration Program

Prepared for:

CALFED Bay-Delta Program
1416 Ninth Street
Sacramento, CA 95814
Contact: Dick Daniel, Program Manager
Ecosystem Restoration Program
916/657-2666

Prepared by:

Strategic Plan Core Team -
Dr. Michael Healey, Dr. Wim Kimmerer,
Dr. G. Mathias Kondolf, Rod Meade,
Dr. Peter B. Moyle, and Dr. Bob Twiss

Strategic Plan Project Manager -
Steven Chainey

Prepared with Technical Assistance from:

Dick Daniel, Terry Mills, and Peter Kiel
CALFED Bay-Delta Program
1416 Ninth Street
Sacramento, CA 95814
916/657-2666

and

Jones & Stokes Associates, Inc.
2600 V Street, Suite 100
Sacramento, CA 95818-1914
Contact: Steven Chainey
916/737-3000

September 30, 1998

DATE: September 30, 1998

TO: Lester Snow, CALFED Executive Director

FROM: Core Team (Michael Healey, Wim Kimmerer, Matt Kondolf, Rod Meade, Peter Moyle, and Bob Twiss) and Project Manager (Steve Chainey)

WITH THE SUPPORT AND ASSISTANCE OF: Dick Daniel (Ecosystem Restoration Program Manager) and Peter Kiel and Terry Mills (ERP Staff Members)

SUBJECT: Submittal of the Final Draft Strategic Plan for the Ecosystem Restoration Program

The enclosed final draft strategic plan culminates our efforts over the past 4 months to describe a coherent framework and consistent guidelines for implementing the CALFED Ecosystem Restoration Program (ERP). In this effort, we have collaborated with several CALFED and ERP program managers; agency staff members, including staff members from the U.S. Army Corps of Engineers and DWR flood managers; numerous stakeholders interested in the quality of the ERP; and, when possible, other scientific experts and colleagues. On August 31, we circulated a preliminary draft to the Bay-Delta Advisory Council Ecosystem Restoration Work Group participants and to CALFED staff members and solicited review and comments on this as well as earlier versions of specific sections of the plan. Furthermore, many of our 12 days of Core Team meetings included dialogue with stakeholders and agency staff members and a low-altitude overflight of the Delta and Sacramento and San Joaquin River valleys. Under the unavoidable time constraints of meeting CALFED's programmatic environmental impact statement/environmental impact report (EIS/EIR) schedule, we have considered only those comments received by September 24 and cannot guarantee that even those comments received adequate attention. We have tried our best to improve organization, clarify the components of the plan, and anticipate major questions and concerns about ERP implementation, approach, and priorities.

We are honored that CALFED has extended to us the opportunity to help delineate an overarching strategy for this singular effort to conserve and rehabilitate one of our nation's richest and most complex ecosystems. In the face of the overwhelming complexity of the physical and biological environment of the Bay-Delta ecosystem and the challenge of finding a balance for the coexistence of natural systems and endangered species with economic uses of resources for human needs, we submit our best though abbreviated effort to assist CALFED staff members and stakeholders in your next courageous step forward.

We understand that CALFED and ERP staff members must now integrate the adaptive management and ecosystem-based approach and recommendations contained in this plan into the overall framework of the programmatic EIS/EIR and the initiation of a Stage 1 CALFED program and decision-making process. Over the next few months, we are available to answer questions or help staff members to clarify or refine components of the strategic plan if our participation is requested.

Table of Contents

Page

Chapter 1. Summary **1-1**

Chapter 2. Introduction **2-1**
PURPOSE OF THE STRATEGIC PLAN FOR ECOSYSTEM RESTORATION 2-1
THE STRATEGIC PLAN IN THE CONTEXT OF THE CALFED BAY-DELTA PROGRAM 2-2
THE PROBLEM: THE DECLINE OF THE BAY-DELTA ECOSYSTEM 2-2
SCOPE OF CALFED RESTORATION 2-3
RELATIONSHIP OF THE STRATEGIC PLAN TO OTHER ECOSYSTEM RESTORATION ACTIVITIES 2-4
Ecosystem Restoration Program 2-4
Early Implementation of Ecosystem Restoration Projects 2-5
Conservation Strategy 2-5
Regulatory Compliance Strategy 2-5
AN ECOSYSTEM APPROACH USING ADAPTIVE MANAGEMENT 2-6
Ecosystem-Based Approach 2-6
Adaptive Management 2-8
The Practice of Adaptive Management 2-11

Chapter 3. Opportunities and Constraints **3-1**
IMPLICATIONS OF HISTORICAL CHANGES 3-1
PRESENT CONDITIONS AND TRENDS 3-2
Present Conditions 3-2
Environmental Trends 3-2
Important Legislative Actions Affecting Environmental Trends 3-4
Land Use Patterns and Trends 3-6
DEVELOPING A STRATEGY THAT ADDRESSES EXISTING AND FUTURE REGULATORY, ECONOMIC, AND POLITICAL CONDITIONS AND TRENDS 3-6
IMPLICATIONS FOR RESTORATION OF ECOSYSTEM-LEVEL DIFFERENCES IN FUNCTIONS 3-8
TWELVE IMPORTANT ISSUES AND OPPORTUNITIES 3-10
Other Related Issues 3-14
OPPORTUNITIES FOR ECOSYSTEM RESTORATION 3-15
Introduction 3-15
Opportunities in the Delta 3-16
Opportunities for Rivers 3-18

Chapter 4. Goals and Objectives **4-1**
ECOSYSTEM RESTORATION GOALS 4-1
General CALFED Goals 4-1
CALFED Ecosystem Restoration Program Goals 4-1
What Are the Goals Designed to Achieve? 4-6
ECOSYSTEM RESTORATION OBJECTIVES 4-7

Chapter 5. The Strategic Plan **5-1**
ELEMENTS OF THE STRATEGIC PLAN 5-1
DEFINING ECOSYSTEM RESTORATION 5-3
THE ECOSYSTEM APPROACH 5-3
PROGRAM COMPONENTS 5-5
STAGED IMPLEMENTATION 5-6
USE OF CONCEPTUAL MODELS IN DECISION MAKING AND DIRECTING INVESTIGATIONS 5-7
Development of Conceptual Models 5-8
Uses of Conceptual Models 5-8
Examples of Conceptual Models 5-9

Chapter 6. Adaptive Management **6-1**
ECOSYSTEM MANAGEMENT IN AN EXPERIMENTAL MODE 6-1
Building Adaptive Management into the ERP 6-1
Modes of Adaptive Management 6-4
Selection process 6-6
Experimental Opportunities 6-8
MONITORING, RESEARCH, AND SCIENTIFIC OVERSIGHT 6-11
Monitoring and Research Program 6-11
Scientific Review of the Adaptive Management Process 6-13
INSTITUTIONAL CONSIDERATIONS 6-14
Duties of the ERP Governing Body 6-15
Attributes of the ERP Governing Body 6-16
DISPUTE RESOLUTION 6-18
Dispute Management 6-18
Dispute Management as Part of the Internal CALFED Structure 6-18
Additional Measures 6-19
Information Storage, Collation, and Dissemination 6-20
Outreach 6-23

Chapter 7. Recommended Regulatory Compliance Strategy: Demonstrating That the Ecosystem Restoration Program Complies with Applicable State and Federal Laws, Regulations, and Programs **7-1**
OVERVIEW OF THE STRATEGIC PLAN ERP COMPLIANCE DISCUSSION 7-1
NEED FOR A LONG-TERM COMPLIANCE STRATEGY 7-2
PURPOSES OF THE COMPLIANCE STRATEGY 7-3
Identify Agencies With Regulatory Authority 7-3

E-026126

E-026126

Identify Regulatory Requirements 7-3
Provide a Framework for Tiered Compliance with CEQA and NEPA 7-4
Sufficiently Define ERP Actions for Regulatory Purposes 7-4
Define an Adaptive Management Framework for Compliance 7-4
Determine Compliance Requirements for Stage 1 Actions 7-5
Integrate Compliance Across CALFED Programs 7-5
Provide the Basis for Assurances to Program Participants 7-5
REGULATORY PROGRAMS AND REVIEWING PUBLIC AGENCIES 7-5
STATE OF CALIFORNIA REGULATORY PERMITS AND APPROVALS 7-7
Federal Laws/Programs 7-8
FORMULATING A LONG-TERM REGULATORY STRATEGY 7-10
ENVIRONMENTAL DOCUMENTATION APPROACH UNDER CEQA AND NEPA 7-12
Program Implementation under the Programmatic EIS/EIR 7-12
Defining an Environmental Documentation Strategy 7-13
STAGED ERP IMPLEMENTATION AND PROVISION FOR ASSURANCES ... 7-14
Need to Define "Adequate Progress" among Program Elements 7-15
Illustrative Compliance and Assurance Milestones 7-15
Specific Assurances for CALFED Elements 7-18
CONCLUSIONS 7-21

Chapter 8. Recommended Strategy for Implementing Stage 1 of the Ecosystem Restoration Program 8-1
VISION FOR STAGE 1 OF THE ERP 8-1
ERP STAGE 1 CHARACTER AND OBJECTIVES 8-2
DEVELOP A LIST OF ERP ACTIONS AND DECISIONS FOR INCLUSION IN STAGE 1 8-3
Identify Actions Covered by the Final Programmatic EIS/EIR and ROD 8-4
Review of the Restoration Coordination Program Projects 8-4
Status of the Existing CALFED Stage 1 List of ERP Actions 8-4
Develop a Process for Finalizing Stage 1 Actions 8-5
SELECT CRITERIA FOR STAGE 1 ERP ACTIONS AND RESTORATION COORDINATION PROGRAM PROJECTS 8-6
RECOGNIZE THE PROBABLE NEED FOR PHASING STAGE 1 ERP ACTIONS AND DECISIONS 8-7
ERP STAGE 1 PHASING PLAN 8-8
Phase A of Stage 1: Actions and Decisions Targeted for Year 1 (2000) 8-9
Phase B of Stage 1: Actions and Decisions Targeted for Years 2-4 (2001-2003) 8-11
Phase C of Stage 1: Actions and Decisions Targeted for Years 5-7 (2004-2006) 8-12
COMPLETING STAGE 1 AND THE TRANSITION TO STAGE 2 8-13

Chapter 9. Long-Term Vision for Implementation of the Ecosystem Restoration Program 9-1

E-026127

E-026127

Chapter 10. About the Strategic Plan Core Team **10-1**

Chapter 11. Citations **11-1**

Appendix A. Defining the Opportunities and Constraints: A Historical Perspective .. **A-1**

Appendix B. Restoration Objectives **B-1**

Appendix C. Further Examples of Conceptual Models **C-1**

Appendix D. An Example of Adaptive Management Using Conceptual Models: Chinook Salmon and Deer Creek **D-1**

E —0 2 6 1 2 8

E-026128

List of Tables and Figures

Follows Page

Table

3-1 Approximate Major Natural Community and Agricultural Crop Acreages in the CALFED Study Area 3-2

4-1 Summary of Strategic Plan Goals and Objectives 4-8

7-1 Summary of Potential Environmental Compliance Needs and Regulatory Agencies for Ecosystem Restoration Program Actions 7-6

Figure

2-1 Suisun Bay, Suisun Marsh, and the Sacramento-San Joaquin River Delta Regions . . . 2-4

2-2 Ecosystem Restoration Program Focus Area 2-4

2-3 Major Hydrologic and Flood Control Features of the Bay-Delta System 2-6

2-4 Diagram of the Adaptive Management Process 2-10

5-1 Schematic Diagram Showing Potential Causative Pathways Underlying the "Fish-X2" Relationships 5-10

5-2 Estuarine Ecology Team's Summary of Potential Causes Underlying "Fish-X2" Relationships 5-10

E —0 2 6 1 3 0

E-026130

Chapter 1. Summary

The purpose of the Strategic Plan for the Ecosystem Restoration Program (strategic plan) is to guide the implementation of the CALFED Bay-Delta Program Ecosystem Restoration Program (ERP) for the Bay-Delta system, one of the largest ecosystem restorations ever attempted. The strategic plan does this by providing operational definitions of the two philosophies underpinning the ERP, ecosystem-based management and adaptive management, defining a strategy for regulatory compliance and describing elements of institutional design for adaptive learning. It addresses in detail the scientific and regulatory aspects of ecosystem restoration; it does not address societal or economic aspects, nor does it deal with conflicts between ecosystem restoration and other human values. Furthermore, it stops short of recommending particular projects, presenting instead a rational way of selecting projects.

The CALFED Bay-Delta Program (CALFED) problem area is narrowly defined to include only Suisun Bay, Suisun Marsh, and the legal Delta and the species dependent on these areas; however, the solution area is much broader and includes the watersheds upstream of the Delta and, potentially, all of San Francisco Bay and the nearby nearshore ocean. Connections to the Delta are interpreted broadly because many important species spend only part of their lives in the Delta and may migrate widely between the ocean, the estuary, and freshwater habitats.

The listing under state and federal endangered species legislation of fish and other species dependent on the aquatic ecosystem has resulted in intense conflicts, particularly over competing uses of fresh water. The declines in species are symptomatic of more fundamental problems of habitat loss and degradation that cannot be solved through piecemeal approaches.

These ecosystem-level problems and the attendant reductions in abundance of species have resisted solution for several reasons. The problems are extraordinarily complex and there is lack of scientific consensus about what actions will restore the system. Furthermore, the range of potential solutions is constrained by the fact that some changes to the ecological system are irreversible (e.g., changes caused by the many large dams on the rivers) and institutional arrangements that are highly resistant to change (e.g., the water rights system). A comprehensive and adaptable approach is needed to address the problem of ecological decline within the constraints and context of domestic and industrial uses of water in central California. The approach adopted by CALFED for the ERP is adaptive management. Using an adaptive-management approach, uncertainty is tackled head on by learning from the ecosystem as actions are taken to manipulate it. The power of the scientific method is used in designing restoration actions as experiments to determine the effectiveness of new forms of management, just as, in medicine, new therapies are tested in scientifically based clinical trials. Adaptive management does not mean that real restoration actions are postponed until more is known. On the contrary, it means that restoration is initiated as soon as possible, based on the best available knowledge. Additionally, restoration actions are organized and implemented in ways that

maximize the opportunity to learn more about the ecological system and improve future management. The Vernalis Adaptive Management Project is an example of this kind of approach in which large-scale experimentation is used to learn about the behavior of the ecological system.

Adaptive management begins with a careful definition of the problem to be addressed and clear, measurable goals and objectives. Six goals were identified for ecosystem restoration that address the entire spectrum of problems:

1. Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recover of at-risk native species in San Francisco Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

   The strategic plan emphasizes native species in preference to non-native or introduced species and places greatest emphasis on species most heavily dependent on the Bay-Delta system.

2. Rehabilitate the capacity of the Bay-Delta system to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities.

   The strategic plan favors the use of natural processes over continuing intervention to maintain ecological processes and species.

3. Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with goals 1 and 2.

   The strategic plan recognizes that harvest is a desirable ecosystem service that should be supported provided it does not result in elevated risk of extinction of native species.

4. Protect or restore functional habitat types throughout the watershed for public values, such as recreation, scientific research, and aesthetics.

   The strategic plan recognizes that habitat restoration serves many functions in addition to species recovery.

5. Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.

   The strategic plan identifies non-native species introductions as one of the greatest impediments to ecological restoration and one of the greatest threats to the success of the ERP; further introductions must be stopped.

6. Improve and maintain water and sediment quality to eliminate, to the extent possible, toxic impacts on organisms in the system, including humans.

   The strategic plan highlights the poorly understood effects of toxic contaminants introduced from both point and non-point sources throughout the Bay-Delta system, and their potential to jeopardize ecological recovery.

Conceptual models provide the explicit link between goals and objectives and restoration actions. Conceptual models are simple depictions of how different parts of the ecosystem are believed to work and how they might respond to restoration actions. These models are explicit representations of scientists' or resource managers' tacit understandings and beliefs. Conceptual models are then used to develop restoration actions that have a high likelihood of achieving an objective while providing information to increase understanding of ecosystem function and, in some instances, to resolve conflicts among alternative hypotheses about the ecosystem. The process of adaptive management can be enhanced when conceptual models are developed into simple computer simulations that can be used to explore the consequences of alternative options for restoration.

Adaptive management is an action-oriented approach to resource management. Various types or combinations of action are possible depending on the particular circumstances. For example, adaptive management may lead to full-scale restoration of a particular ecosystem, pilot projects to test different approaches, targeted research to explore uncertainties, or any combination of these activities. Whatever the action taken, it should be designed to maximize the opportunity for learning and to carry forward the objective of ecosystem or species restoration.

Thorough monitoring and evaluation of adaptive management actions is critical to successful learning. The Comprehensive Monitoring and Research Program (CMARP) currently being designed will provide for the necessary monitoring and evaluation of ERP projects. Results of monitoring and evaluation will be used to redefine the problem, reexamine goals and objectives, or refine conceptual models to ensure efficient learning and adaptation of management techniques and understanding. Using this process, management evolves in response to increased knowledge and understanding in an active rather than a passive way.

Adaptive management differs from more traditional approaches to resource management in the degree to which it acknowledges uncertainty in the outcome of any management intervention. A useful analogy is that adaptive management is more like medical science and traditional management is more like engineering in their approach to uncertainty. Because adaptive management requires flexibility and openness, it can create conflicts with regulatory legislation, particularly endangered species legislation, which requires certainty and assurances. The strategic plan addresses this potential stumbling block by laying out a comprehensive strategy for compliance and assurances within the adaptive management framework. The strategy is based on early communication with regulatory agencies, a nested and hierarchical approach to satisfying compliance and assurance requirements, and building trust through collaboration with regulatory agencies.

For a variety of reasons, including fiscal limitations, regulatory and institutional constraints, uncertainty about outcomes, and the need to coordinate with the water quality, water supply, and

E-026133

E-026133

levee integrity components of CALFED, not all restoration actions can be implemented at the same time. Restoration will be staged over the 25-30 years of CALFED, giving ample time for evaluation and adaptation of restoration activities. Staging and the long timeframe for the ERP will help ensure that regulatory and compliance needs can be met and restoration will not be held up because of the need to satisfy regulatory requirements. The ERP is divided into two stages, with important decisions about water quality and water conveyance to be made after 7-10 years, at the end of Stage 1. As a consequence, the management actions taken during Stage 1 must be designed, in part, to prepare for decisions to be taken at the end of Stage 1.

The two-stage nature of the ERP places considerable emphasis on successful implementation of Stage 1 actions. The strategic plan provides guidelines for the design and implementation of Stage 1 actions to facilitate this process. It also offers a preliminary list of restoration actions that could form part of the Stage 1 action plan. The list is not identical to the list in the most recent version of CALFED's "preferred alternative" document but is quite consistent with the theme and intent of that list. Neither the strategic plan list nor that in the preferred alternative document has been subject to the process of screening and prioritization that have been laid out in this document for adaptive management. It is extremely important that this process be applied before any substantive actions are implemented.

Stage 1 marks the beginning of a decision process in which initial actions are taken and the stage is set for future decisions. These decisions will involve the construction of facilities for storage and conveyance of water, which will ultimately be irreversible; therefore, the selection process for Stage 1 must emphasize, not only projects that are likely to provide significant ecosystem benefits relative to their cost, but also projects that provide the greatest opportunity to learn and to distinguish among likely outcomes of alternative actions. Additionally, project selection should emphasize self-sustainability, complementarity, and public support and visibility.

Adaptive management does not mesh easily into the structure and culture of most regulatory agencies. For ecosystem restoration to proceed on a framework of adaptive management, a new kind of institution may be needed. This institution must be sufficiently independent to maintain scientific credibility, while remaining engaged in the policy and political discussions about the restoration program. It must also embody the flexibility needed for the adaptive management process while providing assurances as to its overall direction and needs. A number of characteristics that this new institution should have are defined below:

1. **Considerable fiscal and administrative independence.** The institution should have authority over staffing and be able to enter into contracts; obtain and hold permits; purchase and sell property, water rights, and other capital acquisitions; administer restoration projects; and have its own data management and communications capability. It should not have any regulatory power or responsibilities.

2. **Scientific and public involvement.** Involvement by scientists from a variety of backgrounds and affiliations is essential to provide broad perspectives on restoration and to ensure against a narrowing of scope. This involvement can also help to assure stakeholders of the continuing scientific integrity of the program. Equally important is

a program of public involvement that can inform the public while fostering continuing public support.

3. **Dispute resolution.** Disagreements on purely scientific issues can be addressed straightforwardly under the adaptive management framework through peer review, expert analysis of critical issues, and design of interventions to resolve differences. Additionally, many of the potential conflicts in a restoration program, such as those between species or between habitats, are resolved through the priorities set in the objectives. More difficult disputes are likely to arise between conflicting societal goals, such as between urban growth and ecosystem restoration. These must be resolved through a formal process of dispute resolution in which the scientific and technical issues are clearly separated from the societal issues.

This strategic plan, if followed, should lead to an orderly and successful program of adaptive ecosystem restoration. Expectations about the future state of the ecosystem should be tempered by the degree to which these recommendations are incorporated into the culture of the ERP; however, the Strategic Plan Core Team has high expectations for the ERP. There is no turning back and the team anticipates that, in 20-30 years, many habitats will be restored, endangered species will become abundant enough to be delisted, and conflicts will be lessened, even in face of population growth and increasing demands on resources.

E —0 2 6 1 3 6

E-026136

Chapter 2. Introduction

PURPOSE OF THE STRATEGIC PLAN FOR ECOSYSTEM RESTORATION

The purpose of the strategic plan is to guide restoration of the Bay-Delta ecosystem. It defines an ecosystem-based approach that is comprehensive, flexible, and iterative, designed to respond to changes in the complex, variable Bay-Delta system and changes in the understanding of how this system works. The strategic plan:

- establishes "adaptive management" as the primary tool for achieving ERP objectives and preparing to make future decisions for large-scale ecosystem restoration;
- describes the opportunities and constraints to be considered in developing a restoration program;
- presents broad goals and specific objectives for ecosystem restoration;
- presents a stepwise procedure for selecting restoration actions in which goals are linked through objectives to actions with appropriate consideration of the degree of confidence that objectives will be achieved;
- describes how conceptual models should be used in developing restoration programs and defining information needs, with examples of their development and use;
- defines a coordinated and comprehensive regulatory compliance and permitting strategy that facilitates ecosystem restoration; and
- outlines a strategy for implementing Stage 1 actions and a longer term vision for ecosystem management.

The strategic plan does not:

- attempt to resolve issues of land use or conflicts with activities outside the ecosystem restoration program;
- attempt to resolve conflicts between species or between habitats, except for priorities implied by the statement of objectives; or

- recommend specific projects for implementation, although general classes of projects and a method for selecting projects are presented.

THE STRATEGIC PLAN IN THE CONTEXT OF THE CALFED BAY-DELTA PROGRAM

The mission of the CALFED is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta system (CALFED web page, http://www.calfed.water.ca.gov.).

CALFED arose as a result of intense conflicts over ecosystem condition, water quality, water supply, and levee integrity. These four topics are addressed by four elements of CALFED. Ecosystem restoration is therefore part of a larger program of activities to address a broad range of problems. The ERP must agree with the broad range of activities and objectives contained in CALFED as a whole, and each of the other program elements.

This strategic plan is intended to guide implementation of the ERP, and is expected to become an integral part of CALFED; however, little effort has been made to specifically integrate the strategic plan with the other program elements. Furthermore, the extensive development of adaptive management within the strategic plan may not parallel other program elements. These discontinuities will need to be resolved as planning progresses.

THE PROBLEM: THE DECLINE OF THE BAY-DELTA ECOSYSTEM

Declining fish populations and endangered species designations have generated major conflicts among beneficial uses of water in the Bay-Delta system. The underlying problems, however, are much broader and more far-reaching than a decline in fish. An entire suite of problems confronts the ecosystem, including:

- reduction throughout the system in quantity, quality, and diversity of habitat for a variety of fish, plants, birds, reptiles, amphibians, and other species, resulting from, in part, to alterations in amounts and patterns of water and sediment movement, disconnection of rivers from their floodplains by levees and from their headwaters by dams, and alteration of channels;

- alteration of the movement patterns of fish and other organisms by dams, channel modifications, changes in hydrology, and water diversions;

- introduction of numerous non-native species, some with tremendous capacity for damage to the extant ecosystem, and establishment of conditions that favor these species; and

- degradation of water quality from pesticides, herbicides, industrial and municipal discharges, non-point-source discharges, and concentration of natural toxins through leaching from farms.

Together, these problems indicate poor ecosystem quality or "health" (i.e., general condition of the ecosystem). Unless these problems can be solved, actions to restore fish populations and minimize the conflicts over water will be palliative at best.

Additional problems facing ongoing human use of the Bay-Delta river system will require solutions that must account for their ecological effects. These problems include:

- increasing human population,
- frequent floods that require management to protect human lives and property,
- poor quality of drinking water,
- unreliable water supply, and
- levees that provide unreliable protection during earthquakes and floods.

Solving the ecosystem problems and addressing the additional problems raised in dealing with human uses of the system will be quite difficult. The difficulty is heightened by the complexity of the Bay-Delta watershed system and the uncertainty about the causes of many of the changes that have occurred, particularly the declines in fish that provided the initial impetus for CALFED. This uncertainty is an uncomfortable fact in dealing with complex ecosystems; however, restoration programs have tended to neglect uncertainty at their peril. History is replete with examples of management of natural systems having failed because of incorrect conceptual models, assumptions, or beliefs about causes of problems. CALFED cannot afford to repeat this tendency.

The difficulties in addressing this suite of problems and the uncertainty about their solutions suggest that ordinary modes of restoration are unlikely to make much progress. The scope of the problem demands a sweeping approach to the solution, ensuring that real progress will surpass rhetoric about solving the problems. The adaptive management approach that is presented in this strategic plan encompasses sufficient flexibility and scientific integrity to maximize the likelihood of success while minimizing the extent of unproductive activities.

SCOPE OF CALFED RESTORATION

The first dimension of scope is geographic. CALFED has chosen as its problem area the legally defined Delta of the Sacramento and San Joaquin Rivers, Suisun Bay, and Suisun Marsh (Figure 2-1). This area was chosen because it was recognized that the Delta is not only the key locus for problems of water supply and water quality, but it is also important to numerous species in the area. Additionally, many of the problems involving conflicts between ecosystem health and water supply are most closely focused on the Delta, such as the limits on export pumping to reduce entrainment of apparent winter-run salmon smolts in the export facilities. CALFED recognizes, however, that solutions to problems manifest in the Delta will extend to a much broader region of

primary interest, comprising north San Francisco Bay and the Sacramento and San Joaquin Rivers and their tributaries below major dams, or in even a wider area encompassing the coastal nearshore ocean and tributaries above dams. This acknowledges that actions far from the Delta (e.g., restoration of spawning habitat, rebuilding marshes in San Francisco Bay, or altering ocean harvest regulations) may help reduce conflicts arising mainly in the Delta.

Another dimension of scope is the species included in restoration. Species dependent on the Delta, as defined above, for all or part of their life history are included in this scope; however, the species included in CALFED's range of interest includes salmon and steelhead, which may spend little time in the Delta. ERP actions will therefore focus primarily on Delta-dependent species and those that migrate through the Delta, although CALFED will also include species outside the Delta in its conservation strategy.

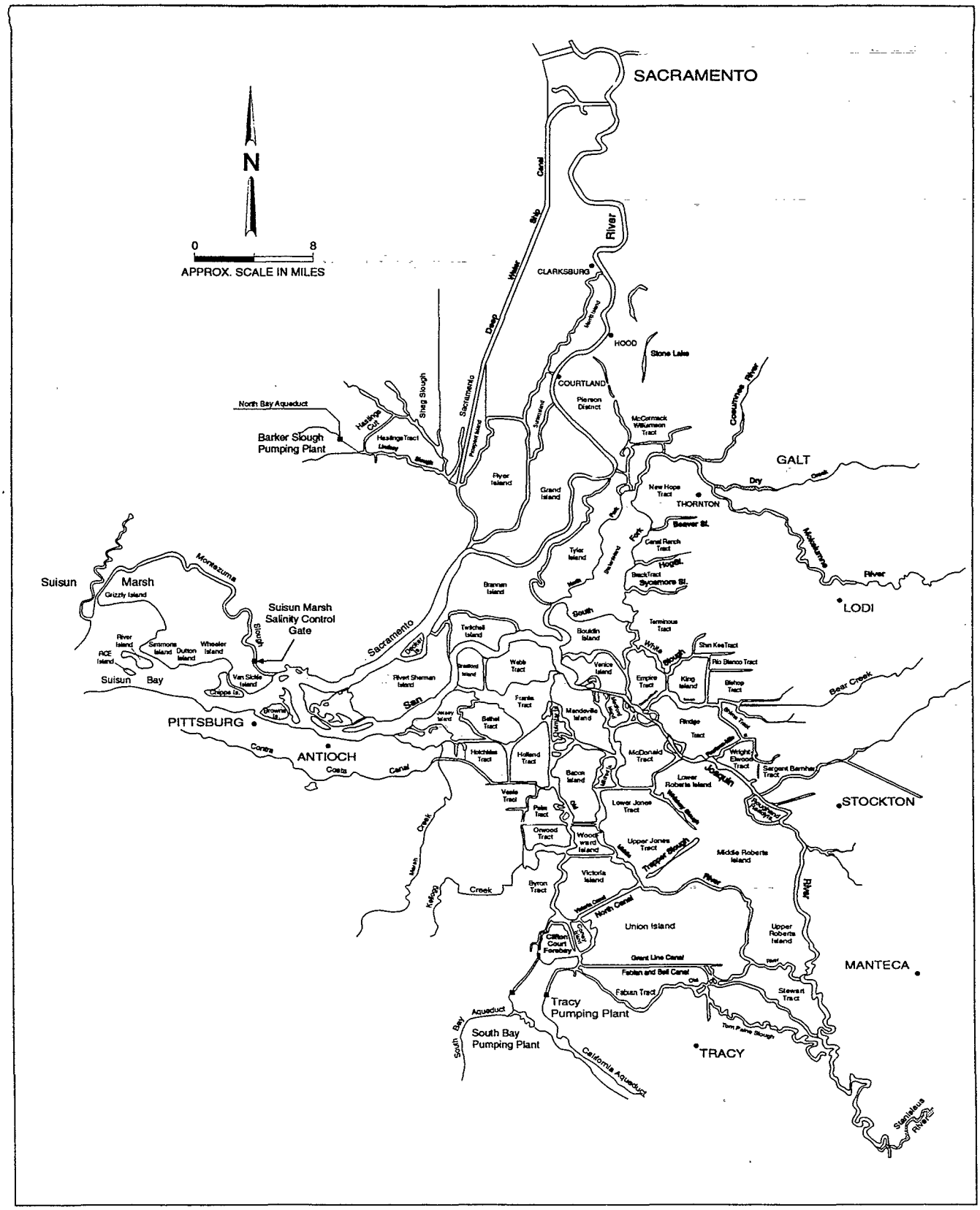
A third dimension of restoration is time. CALFED has defined Bay-Delta problem resolution using several timescales. For example, CALFED plans an initial period of implementation of 7-10 years (Stage 1), after which a critical review of specific decisions about water conveyance will be made. But the ERP has a planning horizon of 25-30 years. Species and ecological processes have their own timescales that dictate how quickly one can expect to observe changes after restoration actions have been implemented. At the species level, for example, Delta smelt, with a 1-year life cycle, should respond to ecological restoration quickly. Chinook salmon, with a 3- to 5- year life cycle, will take much longer to respond. Floodplain meander belts may not establish a long-term rhythm for decades, although evidence of channel migration should be apparent sooner. Planning for restoration needs to be sensitive to these natural timescales.

RELATIONSHIP OF THE STRATEGIC PLAN TO OTHER ECOSYSTEM RESTORATION ACTIVITIES

The strategic plan provides a framework for the ERP, as well as the program of early ecosystem restoration (Category III), the conservation strategy for threatened and endangered species, and the regulatory compliance strategy.

Ecosystem Restoration Program

The ERP represents one of the most ambitious and comprehensive ecosystem restoration efforts ever undertaken in the United States. It encompasses a wide range of aquatic, riparian, and upland habitats in the Bay-Delta system and nearshore ocean environment (Figure 2-2). The goal of the ERP is to increase and improve aquatic and terrestrial habitat in the Bay-Delta to support healthy, self-sustaining populations of diverse plant, fish, and wildlife species. The ERP describes CALFED's vision of a restored, healthy, and functioning Bay-Delta ecosystem (Volume I) and defines restoration objectives and targets (Volume II). Because of the complexity of the Bay-Delta



Strategic Plan for the Ecosystem Restoration Program

Figure 2-1
Suisun Bay, Suisun Marsh, and the Sacramento-San Joaquin River Delta Regions

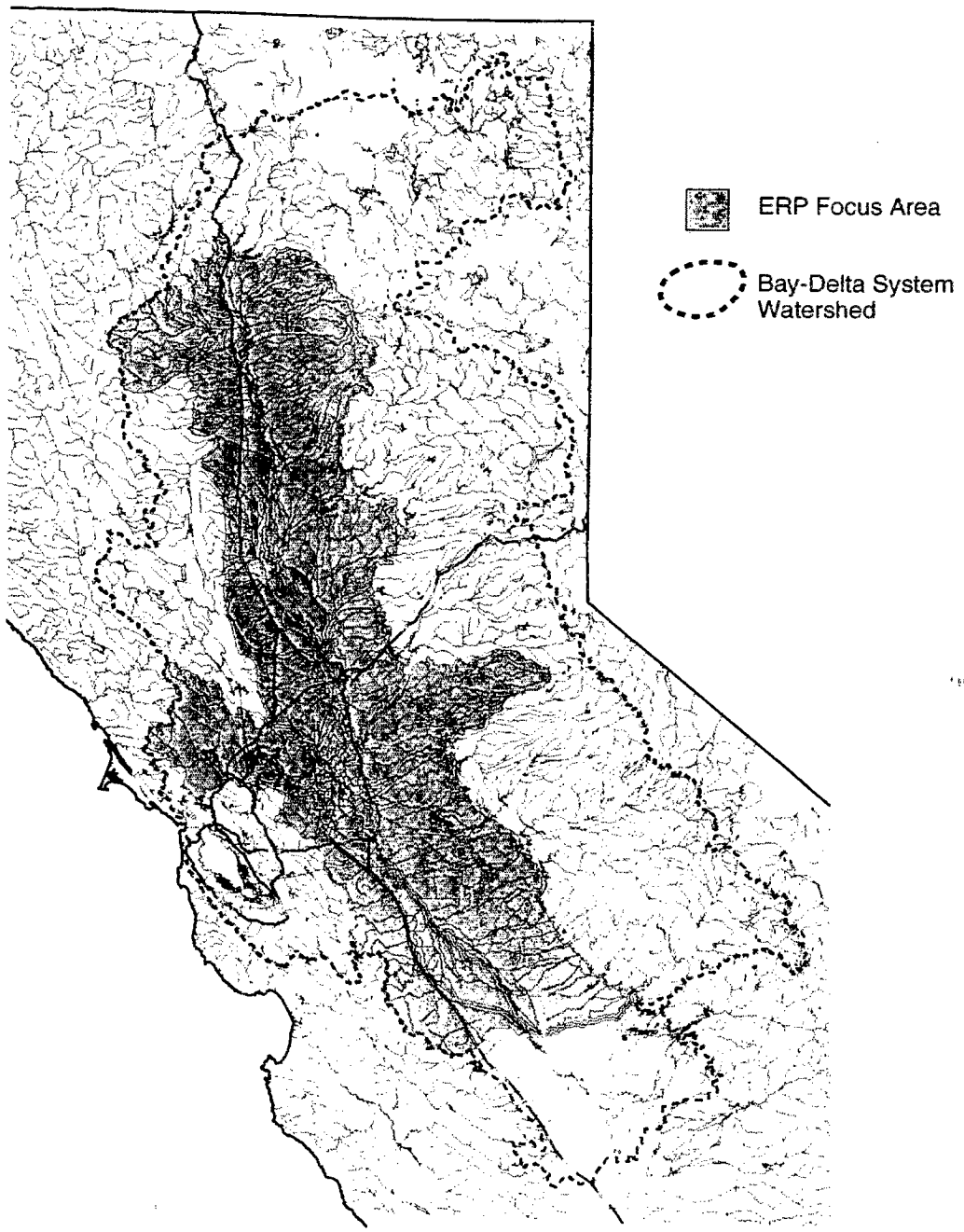


Figure 2-2
Ecosystem Restoration Program Focus Area

river system (Figure 2-3) and the large scope of the ERP (Figure 2-2), the ERP will be implemented in phases over several decades.

The strategic plan establishes a framework for defining and refining ERP objectives and targets and should be used to guide the phased implementation of ERP actions.

Early Implementation of Ecosystem Restoration Projects

State agency, federal agency, and stakeholder signatories to the historic Bay-Delta Accord of 1994 recognized that the Bay-Delta ecosystem was in critical condition. Declines in the populations of species already designated as endangered and threatened had necessitated restrictions on human activities, which aggravated long-standing conflicts among Bay-Delta resource users. Accordingly, the signatories agreed on a program to fund high-priority ecosystem restoration projects, unrelated to flow, in the interim between the signing of the Bay-Delta Accord and implementation of the ERP. This program, referred to as "Category III", has financed hundreds of projects consistent with the priorities and scope of the ERP.

The strategic plan will help guide the selection of upcoming Category III projects during the transition to the long-term ERP, as well as the collection and analysis of data that will be produced from projects already selected in earlier rounds of Category III funding.

Conservation Strategy

Many species that rely on the Bay-Delta for all or part of their life cycles have sustained population declines, and several have been designated as threatened or endangered under state or federal statutes. CALFED is developing a conservation strategy to protect species and habitats to ensure program compliance with the federal Endangered Species Act (ESA), California Endangered Species Act (CESA), and Natural Communities Conservation Planning Act (NCCPA). The conservation strategy relies principally on implementation of the ERP to achieve its primary conservation goals.

The strategic plan describes an ecosystem-based adaptive management framework for achieving conservation goals that will be consistent with state and federal statutes.

Regulatory Compliance Strategy

Implementation of many ERP actions will require prior approval from state and federal agencies having regulatory responsibilities in the Bay-Delta system. For example, to ensure that ERP actions comply with the federal Clean Water Act (CWA), CALFED must obtain permits from

the U.S. Army Corps of Engineers (Corps), the U.S. Environmental Protection Agency (EPA), and the California State Water Resources Control Board (SWRCB). Anticipating the need for regulatory permits and environmental documentation, and estimating the time involved for obtaining them, will expedite the implementation of ERP actions.

The strategic plan provides a strategy for obtaining these regulatory approvals in a timely and coordinated manner to avoid unnecessary delays and to maximize efficient implementation of the ERP.

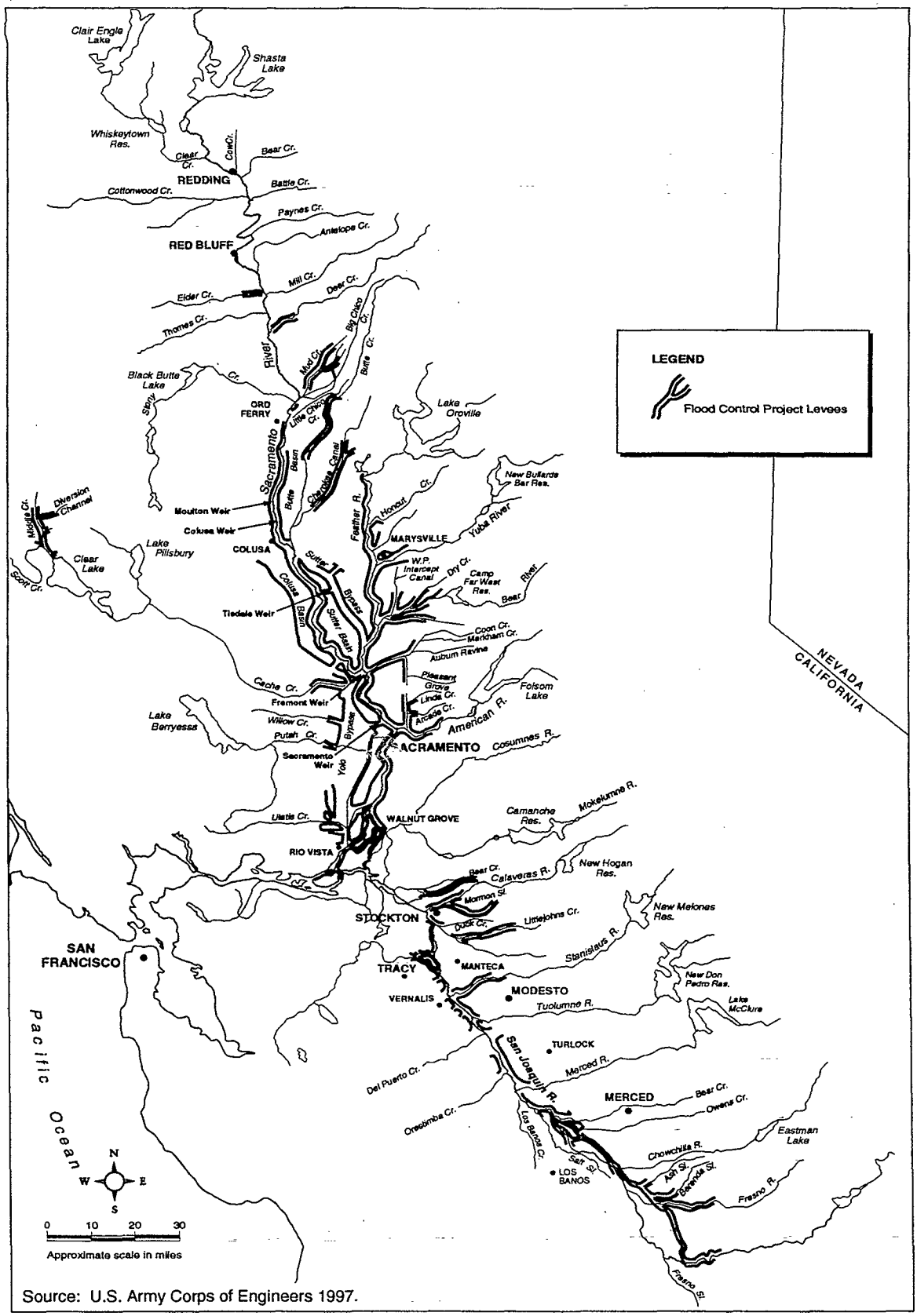
AN ECOSYSTEM APPROACH USING ADAPTIVE MANAGEMENT

Both the ERP and the strategic plan have adopted an ecosystem-based approach and adaptive management framework, which are relatively new concepts in resource management. Within the past few years, major state and federal resource agencies have adopted an ecosystem-based philosophy of resource management, although this philosophy has yet to permeate completely into the culture and practices of these agencies. The primary goal of the strategic plan is to describe an implementation and management framework that clarifies how CALFED agencies can use ecosystem-based management, with an emphasis on adaptive management, to manage the Bay-Delta system's resources.

By incorporating an ecosystem-based approach and adaptive management framework, the ERP and the strategic plan signal a fundamental shift in the way the ecological resources of the Bay-Delta system will be managed. In the past, efforts to combat population declines of threatened and endangered species focused on specific factors in a species' environment believed to affect birth or death rates. Such an approach resulted in piecemeal attempts that usually failed to recover and stabilize populations of threatened and endangered species. Additionally, this species-based approach failed to address the needs of unlisted species also declining in population that might necessitate their future listing.

Ecosystem-Based Approach

The Bay-Delta ecosystem does not comprise simply a large number of species. It is a complex, living system influenced by innumerable climatic, physical, chemical, and biological factors, both within and outside of the Bay-Delta system. The ERP and strategic plan go beyond traditional efforts at individual species regulation and management. They propose an integrated-systems approach that attempts to protect and recover multiple species by restoring or mimicking the natural physical processes that create and maintain diverse and healthy habitats. This ecosystem-based approach provides the following advantages over the traditional species-based approach:



Source: U.S. Army Corps of Engineers 1997.

Strategic Plan for the Ecosystem Restoration Program

Figure 2-3
Major Hydrologic and Flood Control Features of the Bay-Delta System

- Restoration of physical processes reproduces subtle elements of ecosystem structure and function in addition to the more obvious elements, thereby possibly enhancing the quality of restored habitat.

- Restoration of physical processes can benefit not only threatened and endangered species, but unlisted species, thereby reducing the likelihood of future listings.

- Restoration of physical processes reduces the need for ongoing human intervention to sustain remnant or restored habitats.

- Restoration of physical processes may produce a more-resilient ecosystem capable of withstanding future disturbances.

By replacing the traditional species-based approach with an ecosystem-based approach, CALFED is not relinquishing its responsibility to recover threatened and endangered species. Ecosystem-based management encompasses species management by sustaining and enhancing the fundamental ecological structures and processes that contribute to the well-being of the species. Under CALFED's ERP, threatened and endangered species will be rehabilitated not only through restoration of habitats, but also through restoration of ecological processes and functions that help create and sustain those habitats.

The difference between process-based restoration and conventional species-based management can be illustrated by the contrast between using hatcheries and ecosystem-based approaches to restore salmon. Hatcheries were initially constructed to compensate for habitat lost behind dams, but they are now used to compensate for a broad range of impacts on salmon production, including habitat degradation. This conventional, engineering-oriented, species-based approach yields an increase in fish populations, at least in the short term; however, hatcheries are extremely vulnerable to disease and impose a variety of selection pressures that may make the fish less successful in the wild. Hatchery-produced fish compete with, and interbreed with, wild fish, thereby affecting the gene pool and possibly reducing the fitness and overall vigor of local populations.

By contrast, a process-based ecosystem management approach seeks to restore the dynamic processes of flow, sediment transport, channel erosion and deposition, and ecological succession that create and maintain the natural channel and bank conditions favorable to salmon. If the processes that create the habitat for salmon can be restored, ecosystem restoration can be truly sustainable and can result in a system that benefits a range of other species as well, thereby avoiding future need for further listings of endangered species.

Further discussion of ecosystem-based management is found in Chapter 5.

Adaptive Management

Although much is known about the Bay-Delta ecosystem and the species that depend on it, we are far from understanding all the ecological processes and interactions that animate this large, diverse ecosystem. Research can greatly improve our understanding but cannot provide all the answers to the uncertainties inherent in such a large and complex natural system, and does nothing to restore the ecosystem.

Ecosystem processes, habitats, and species are continually modified by changing environmental conditions and human activities, and the ecosystem is extraordinarily complex; therefore, it is impossible to predict exactly how the Bay-Delta will respond to implementation of the ERP and other CALFED components.

Restoring and managing the Bay-Delta ecosystem requires a flexible management framework that can generate, incorporate, and respond to new information. Adaptive management provides the necessary flexible, learning-based management system. Within an adaptive management framework, natural systems are managed in such a way as to ensure their recovery and improvement and simultaneously ensure the increased understanding of how they function so that future management actions can be more effective. Because adaptive management is so important to the strategy for ecosystem restoration, the process is described in some detail here. Further description of the theoretical underpinnings and application of adaptive management to specific issues is presented in Chapter 6.

There is no way to guarantee the success of a given restoration or management action. In an adaptive management framework, ecosystem restoration and management actions are provisional, subject to revision as new information becomes available. In this respect, adaptive management treats all management interventions as experiments. This does not suggest that management interventions are conducted on a trial-and-error basis, but that management actions are guided by the best understanding of the ecosystem at the time of implementation. In treating the interventions as experiments, managers simply employ the power of the scientific method to ensure that management is as efficient and successful as possible in achieving its objectives. In adaptive management, treating interventions as experiments involves:

- making management decisions based on the best available analyses and modeling of the system;
- being clear about what management intervention is expected to achieve in terms of restoring ecological structure and function and the implications for species conservation;
- designing management intervention to help distinguish among alternative hypotheses about ecosystem behavior, where practical and compatible with the long-term goals of the program;

- monitoring the effects of management intervention and communicating the results widely so that progress relative to expectations can be evaluated, adjustments made, and learning achieved.

Adaptive management is not an engineering solution to ecosystem problems, but is more analogous to the "clinical trial" in medicine. In a clinical trial, a new therapy is tested on many patients, the trial is carefully monitored, and the progress of the trial is evaluated at regular intervals to determine whether to continue with the trial, abandon the trial, or declare the new therapy a success. Clinical trials are not initiated unless there is a reasonable expectation of success. Similarly, CALFED will not initiate large-scale ecological restoration unless there is a reasonable expectation of success.

The key to successful adaptive management is learning from all management actions. Learning allows resource managers and the public to evaluate and update the problems, objectives, and models used to direct restoration actions. Subsequent restoration actions can then be revised or redesigned to be more effective or instructive. In an adaptive management process, learning must be continuous so that ecological restoration continuously evolves as the ecosystem responds to management actions and to unforeseen events, and as management actions are revised in light of new information. Without effective learning, ineffective management programs are likely to be perpetuated, unanticipated successes will go unrecognized, and resources will not be efficiently allocated.

Limited information is often seen as a constraint to establishing specific objectives. Under adaptive management, however, objectives are linked to hypotheses about ecosystem function and are subject to revision as new information becomes available. Hypotheses are provisional and are a statement of our best understanding at the time. Part of the design for adaptive management is deciding how best to proceed with management while increasing the information base for decision making. In some cases, the best solution would be to maintain the status quo while gaining more information through targeted research. In other cases, the best solution would be a bold restoration project that offers the promise of significant ecological benefits and can be designed to generate information about the unknown.

Typically, many actions or collections of actions could accomplish one or more objectives. Individual experts may have very strong beliefs about which actions would be most effective, although overall consensus among experts is rare. Even when a consensus exists on important actions, it is seldom possible to specify exactly how much of an action will be necessary, where the action should be carried out, or how actions should be distributed in space and time to achieve maximum benefits (i.e., there is considerable uncertainty as to what should be done and conflicting or alternative hypotheses about the effects of particular actions). The relationships that link actions through ecological processes to consequences or outcomes for species or ecosystems constitute a set of models about the behavior of the species or ecological system being managed. In adaptive management, it is crucial that these models be documented as a set of conceptual models or hypotheses about the effects of restoration measures (Figure 2-4). These models provide the basis for informed management actions from which a better understanding of the ecological system can be derived.

The knowledge and hypotheses about ecosystem responses summarized in conceptual models lead directly to potential restoration actions, although each model is likely to suggest many possible courses of action. In evaluating alternative actions, it is usually very helpful to conduct exploratory simulation modeling based on the conceptual models to flesh out the expectations and make testable predictions (Figure 2-4).

To facilitate learning from management actions, an adaptive management framework requires conceptual models, identification of indicators of ecosystem condition, comprehensive monitoring of those indicators, targeted research, and phased implementation of actions:

- **Conceptual models** are descriptions of beliefs about how the ecosystem works, how it is affected by environmental conditions, and how it will respond to management interventions. Such models, and simulation models developed from them, are essential for conveying why certain management actions are expected to produce desirable effects. Alternative, competing conceptual models can illustrate areas of uncertainty, paving the way for suitably-scaled experimental manipulations designed to both restore the system (according to more widely accepted models) and explore it (to test the models).

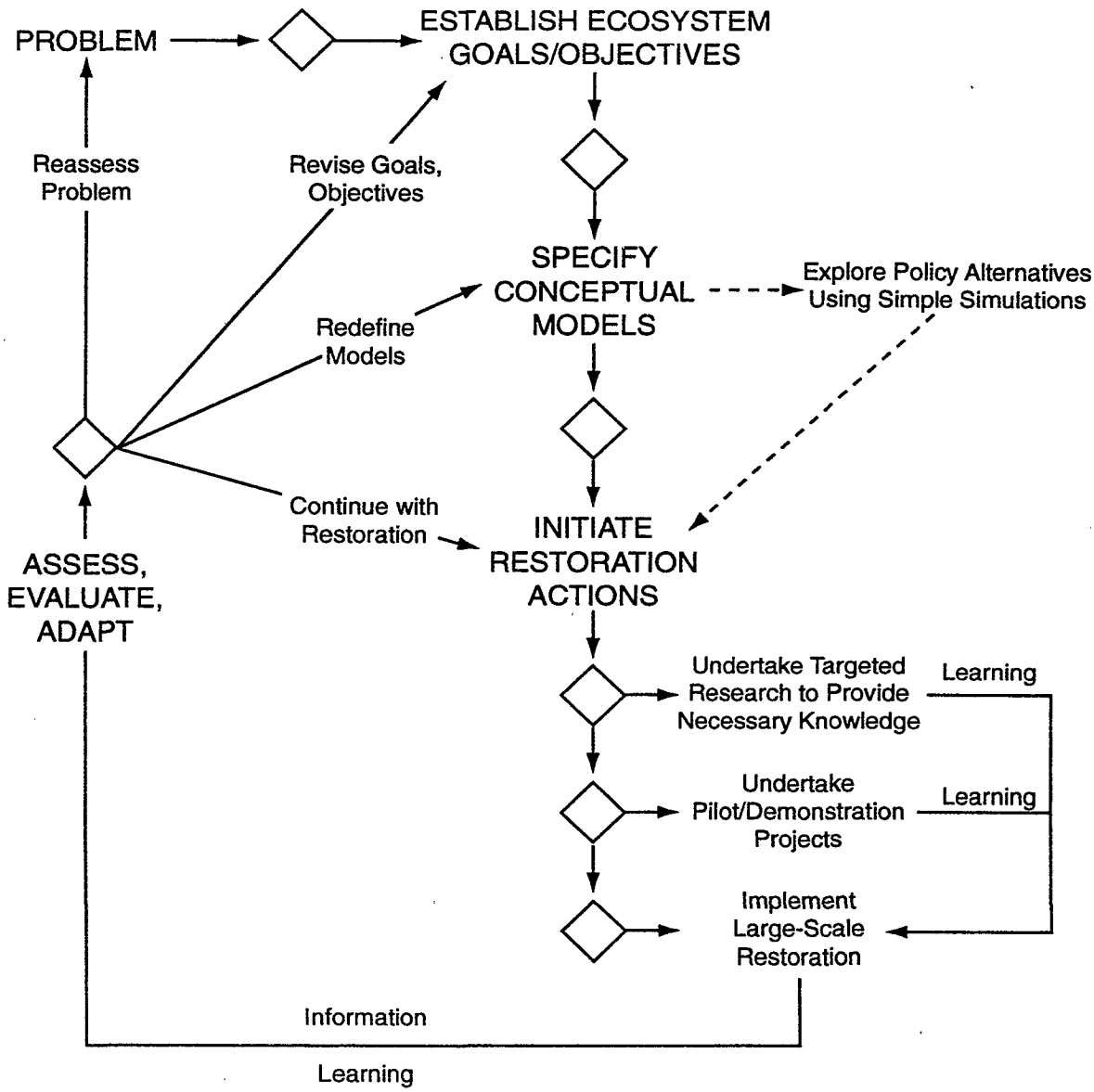
- **Indicators** are features or attributes of the ecosystem that are expected to change over time in response to restoration actions. They provide measurable evaluations of the important ecological processes, habitats, and species, and can be used collectively to evaluate ecosystem condition. Indicators are developed by considering objectives and using conceptual models. They can be general (e.g., ratio of the total area of riparian forest to historical coverage) or specific (e.g., abundance index of delta smelt).

- **Comprehensive monitoring** is the process of measuring the abundance, distribution, change, or status of indicators. Monitoring provides the information necessary to evaluate and update restoration actions and allows progress toward restoration objectives to be assessed. Managing the large amount of data, however, will be a critical aspect of monitoring, which must be designed and implemented with due regard for data management, dissemination, permitting and compliance requirements, assessment of trends, and data analysis.

- **Targeted research** is necessary to improve the understanding of processes and interactions that are not yet fully understand. By focusing research on significant information gaps, the ability to define the problems affecting the Bay-Delta system and the restoration actions necessary to address those problems can be improved.

- **Phased implementation** of restoration actions allows resource managers to evaluate actions implemented early so that future restoration will benefit from the knowledge gained.

Adaptive management also requires institutional arrangements that are sufficiently flexible to accommodate and respond to new information produced by ecosystem monitoring and new ideas about how to manage natural resources. In an adaptive management framework, it is important that



Note: ◇ indicates important decision node in the process.
See text for description of the various stages.

Strategic Plan for the Ecosystem Restoration Program

Figure 2-4
Diagram of the Adaptive Management Process

decisions about the effectiveness of a management intervention not be the sole responsibility of the agency or individuals responsible for a restoration project. Scientific oversight is essential to ensure the credibility of the restoration program, and public involvement in decision making is necessary to build public support for the long-term restoration program. Chapter 6 describes essential elements necessary to adaptively manage Bay-Delta resources: efficient information management, flexible institutional design, and scientific oversight.

The Practice of Adaptive Management

The steps taken in developing and implementing an adaptive management program are briefly described below, which provides a basis for the following three chapters.

The first step in adaptive management, known as "bounding the problem" (Figure 2-4), is to clearly define the set of problems to be addressed, including the geographic scope and the timescale of the problem and the resources.

Once a problem has been bounded, clear restoration goals and objectives must be stated (Figure 2-3 and Chapter 4). Objectives must be tangible and measurable so that progress toward achieving them can be clearly assessed. For example, the following objective statement is too vague: "Improve the quality of habitat for winter-run chinook salmon." By contrast, a more specific statement is: "Restore flows and accessibility of Battle Creek to winter-run chinook salmon spawning within 7 years". Although objectives may sometimes be stated broadly (as was done in the draft objectives in Chapter 4), they must ultimately be made specific through models and hypotheses that translate the objectives into restoration actions.

Based on expert opinion, analysis of historical and current information, conceptual models, and simulations, three types of management actions can be selected for implementation (Figure 2-4):

1. targeted research to gain knowledge essential for decisions about particular restoration options,

2. pilot or demonstration projects to determine the practicality or effectiveness of restoration actions, and

3. large-scale adaptive implementation of restoration.

These three types of actions are not mutually exclusive, and all might be used to address a particular problem. Furthermore, they are a set of options and not necessarily progressive.

Adaptive management includes several crucial decision nodes (Figure 2-4), which have the potential to be bottlenecks in the adaptive management system. Decisions about which projects to implement and which to postpone, when to gather more information and when to proceed with large-scale restoration, when to terminate projects and when to change direction, and when to declare

the success or failure of a particular intervention are difficult and contentious. Although rigorous data analysis and modeling can help with these decisions, they cannot determine the decisions. Efficient progress in adaptive ecological restoration will depend on having institutional arrangements that facilitate effective communication and decision making (Chapter 6). A significant element of subjectivity in decisions about whether to proceed will always exist. Open discussion may help to resolve many contentious issues and decisions; nevertheless, in such a large, complex public program there will always be a need for a formal dispute resolution process. Dispute resolution is discussed in Chapter 6.

The bottleneck in decision nodes is also important for regulatory compliance (Chapter 7). Many of the decision points in the adaptive management system will require state and federal agency approvals for actions recommended by the adaptive management process. Early identification of the decision points requiring public agency approvals can reduce the potential for delays or the creation of "cul-de-sacs" resulting from a disconnect between the adaptive management process and applicable regulatory requirements. Adaptive management decisions made within a regulatory context also will be less vulnerable to challenges.

Ecological restoration of the Bay-Delta system and watershed presents managers, decision makers, stakeholders, and the public with a significant challenge. Much that needs to be done has never been attempted, and the scale of the project is unprecedented. The strategic plan gives direction to this bold program. Its ultimate success will depend on the commitment of all participants and their willingness to keep a clear focus on the ultimate goal of a healthy and self-sustaining ecosystem within the Bay-Delta system.

Chapter 3. Opportunities and Constraints

IMPLICATIONS OF HISTORICAL CHANGES

The ERP will succeed only to the extent that it is based on a solid understanding of natural physical and ecosystem processes and habitats, and how these have been changed, so that restoration actions can be effective, adequate, and realistic. To be most effective, restoration actions should restore processes that maintain conditions favorable to native species so that ecological benefits are sustainable and will not disappear in the next flood or from other impacts on artificially-created habitats. We must know the former extent of habitats and the former range of hydrologic and ecological processes to understand the habitat needs of important species, and to therefore judge the scale of restoration needed to bring about recovery and to establish healthy populations.

Historical conditions and changes in the Bay-Delta system and their ecological relevance are reviewed in some detail in Appendix A. It is not an exaggeration to say that the San Francisco Bay-Delta ecosystem has been completely transformed since 1850 in terms of populations of species, their habitats, and the physical and ecological processes that supported them. Some implications of the findings are considered in Appendix A.

Many restoration actions have been very small-scale affairs when viewed in context with the losses in habitat and changes in processes since 1850. Although these projects may be very worthwhile, they should not be considered as having "restored" the ecosystem just because 10 acres of tidal marsh have been restored at a given site. Similarly, the irreversible changes that have occurred to hydrology and ecology of the Bay-Delta system must be recognized so that restoration goals are realistic. For example, the hydrology of the Bay-Delta system has been fundamentally transformed by massive reservoirs and diversions. Reservoir storage capacity in the Sacramento-San Joaquin River system now totals about 30 million acre-feet (MAF), with storage equivalent to over 80% of runoff in the Sacramento River Basin and nearly 140% of San Joaquin River Basin runoff (San Francisco Estuary Project 1992, Bay Institute 1998). As a result, frequent floods (important for maintaining channel form, cleaning spawning gravels, and providing periodic disturbances needed to maintain native species) have been eliminated or drastically reduced on many rivers. Most of these reservoirs are permanent, at least for the lifetimes of the structures, so restoration efforts must be designed to account for the changes wrought by the dams or must involve changes in the operation of the reservoirs. Although dam removal may be possible (with considerable ecological benefits) in a limited number of cases, as is now being considered for Englebright Dam on the Yuba River, in most cases restoration actions must be designed with the reservoirs in mind.

E-026153

E-026153

PRESENT CONDITIONS AND TRENDS

Present Conditions

The status of the ecosystem is described in detail in the affected environment chapters of the Fisheries and Aquatic Ecosystems Technical Appendix and Vegetation and Wildlife Technical Appendix to the CALFED Programmatic EIS/EIR. Table 3-1 summarizes the approximate acreages of terrestrial and agricultural habitats in the CALFED study area.

Environmental Trends

Specific currently discernable environmental trends are likely to continue during the next few decades. These trends would largely result in continued environmental degradation, although some positive trends are also apparent. Population growth will lead to an increase in the demands on water and other resources in California (e.g., gravel, petroleum, and wood products). Other possible sources of increased environmental degradation include conversion of agricultural lands to urban land uses, a likely shift in agricultural practices to more intensive crops, flood control activities, new introductions and expansion of non-native species, sea-level rise, and global climate change. On the positive side, several legislative and policy initiatives could result in improvements in habitat and water quality.

These trends in the demand for natural resources present constraints and opportunities on the extent to which CALFED can successfully rehabilitate elements of ecosystems that are critical to achieving the goals and objectives of the ERP (e.g., recovery of endangered species and maintenance of populations of other native species at levels sufficient to prevent potential future listings of species). The effect of these trends (along with the current commitment of land and natural resources to other uses) is to necessarily preclude wholesale rehabilitation of the ecosystem to a semblance of its historical condition. Instead, these trends will most likely limit CALFED to successful rehabilitation of representative "islands" within the Bay-Delta system in which most or all of the ecological processes associated with the historical ecosystem have been restored and to partial rehabilitation of some attributes historically associated with the ecosystem throughout the Bay-Delta system.

Trends in Population and Water Usage

The California Department of Finance projects California's population to grow from its 1995 level of 32.1 million to 47.5 million in 2020, an increase of approximately 48%. Irrigated crop acreage is expected to decrease slightly from 9.5 million acres to 9.2 million acres. These factors (as well as changes in use rates) are expected to lead to a slight decrease in agricultural water use (from 33.8 MAF to 31.5 MAF), but significant increases in urban water uses over the same period

Table 3-1. Approximate Major Natural Community and Agricultural Crop Acreages in the CALFED Study Area

	Acres
Natural habitats	
Mixed conifer forest	5,342
Montane hardwood	623
Pinyon-juniper	139
Valley foothill hardwood	4,023
Chaparral	2,108
Sagebrush scrub	50
Alkali desert scrub and desert scrub	481
Grassland	3,089
Riparian	50
Freshwater and saline emergent	352
Open water	240
Barren	253
Subtotal	**16,750**
Agriculture	
Grains	1,480
Pasture	1,930
Rice	436
Orchards and vineyards	1,674
Vegetables	1,124
Cotton	1,185
Subtotal	**7,829**
Urban and other	
Urban	709
Other	2,029
Subtotal	**2,738**
Total	**27,317**

Source: CALFED Bay-Delta Program 1998

(from 8.8 MAF to 12.0 MAF). These numbers are estimates from DWR's State Water Plan Update (California Department of Water Resources 1997) and are subject to different assumptions regarding the size and effectiveness of water conservation programs.

Increasing demand on water for urban uses will lead to increasing competition for water between agricultural, urban, and environmental uses, particularly during drought periods. Additionally, because the greatest population increases are projected to occur in southern California, an area dependent on water exported from the Delta, there is the potential to intensify the environmental impacts created by the existing water supply system. Population increases may also intensify environmental degradation through increased urbanization (conversion of natural and agricultural lands to urban uses) and increased demand for resources (such as sand and gravels, petroleum, wood products and other construction materials).

In view of this, attempts to restore the ecosystem in the future or increase the extent of natural habitats in the Bay-Delta system that are dependent on fresh water, including the physical processes associated with its flow, is likely to be more difficult than under current circumstances. Recognition that the availability of water for all uses is ultimately limited underscores the necessity of the ERP to focus the use of environmental water on rehabilitation of sufficient portions of the Bay-Delta system that are critical to meeting the goals and objectives of the ERP. Recognition of this trend also underscores the necessity for the ERP to secure sufficient environmental water in balance with other uses sooner, rather than later, to ensure success of the ERP.

Changes in Agricultural Cropping Patterns

Agricultural cropping patterns are expected to shift away from field and forage crops to higher intensity crops, such as vegetables, vineyards, and orchards, which typically provide less wildlife habitat for listed species such as the Swainson's hawk and greater sandhill crane. Because these more intensively managed crops are more profitable, agricultural land is expected to become more expensive and difficult to purchase for habitat restoration. These trends will place greater demands on remaining and restored native habitats to support displaced wildlife populations and constrain the quantity and location of habitat that can be restored.

Increases in Flood Protection

As discussed in Appendix A, periodic flooding is an important river function that sustains ecological functions by creating a matrix of diverse habitats, by replenishing nutrients in the system, and by transporting sediments and biota through the system. Plans for increased flood protection could lead to greater constraints on ecological structure and functions.

Increased flood protection can directly affect ecological functions by decreasing habitat diversity; creating barriers to the movement of sediment, nutrients, and species; removing riparian habitat; and reducing or eliminating floodplain inundation. Indirect impacts can also result. As the perceived threat of flooding is reduced, more floodplain lands are subject to urban and agricultural

development. The increasing demand for flood control increases the urgency to provide innovative flood management solutions that increase the flood conveyance capacity of the rivers by restoring meander belts and enlarging the floodplain area.

Non-Native Species

As discussed elsewhere in this strategic plan, the introduction and spread of non-native species into the Bay-Delta system has affected native species by competing with them for food and habitat, preying on native species, and interfering with restoration efforts. For example, the non-native mitten crab can clog fish screens, reducing their effectiveness or completely blocking flows. In spite of efforts to address this problem, it is likely that new species will continue to be introduced into the ecosystem and that non-native species introduced in the past will continue to expand their range.

Global Climate Change and Sea-Level Rise

In spite of expectations of more extreme weather patterns, sea-level rise, and the potential for these changes to affect the structure and functioning of the ecosystem, the rate and nature of global climate change are still too poorly understood to be explicitly considered in this document, but as such information improves, it should accounted for in decision making under the adaptive management framework.

Important Legislative Actions Affecting Environmental Trends

Although the pressures created by increasing population and urbanization, by changes in agricultural cropping patterns, and the introduction and spread of non-native species will most likely continue to exert negative forces on the environment and on ecological processes in the Bay-Delta system, several recent and important legislative actions have been initiated that will serve to moderate potential effects of these adverse trends.

Central Valley Project Improvement Act

The Central Valley Project Improvement Act (CVPIA) is a federal law passed in 1992 that adds the maintenance of fish and wildlife to the list of objectives of the Central Valley Project (CVP). CVPIA provides resource managers with a large number of tools to aid in the recovery of fish and wildlife species, including the dedication of water to instream flows and Delta outflow, the creation of a fund to pay for further water purchases for habitat restoration, the allocation of CVP water supply to improve the reliability of deliveries to wildlife refuges, the retirement of agricultural lands to improve water quality, and the creation of a program to provide incentives for farmers to maintain habitat values on their lands. Among the goals of CVPIA is to double the population of

naturally reproducing target fish species. Although it is not yet clear whether the tools provided by CVPIA will lead to the achievement of this goal or how the various provisions of it will ultimately be implemented, it is very likely that implementation will lead to improvement in habitat conditions for many fish and wildlife species.

1995 Water Quality Control Plan

In 1995, the SWRCB adopted a water quality control plan for the Bay-Delta that includes rules governing Delta exports and Delta outflows. This plan intended to maintain salinity in the Delta at levels needed to maintain the health of the ecosystem. Since 1995, it has been the responsibility of CVP and the State Water Project (SWP) to comply with these rules, but SWRCB is now holding hearings to decide how the responsibility for compliance should be allocated among all water users in the Bay-Delta system. The results of these hearings will most likely lead to increases in instream flows in most, if not all, of the tributaries to the Delta. This change would improve conditions for fish and other aquatic species in those tributaries.

U.S. Army Corps of Engineers Comprehensive Study

The Corps has undertaken a comprehensive study of flood control throughout the entire Central Valley. The purpose of the study is to find a means of improving flood control in areas still prone to periodic flooding using floodplain management instead of the structural solutions (e.g., construction of new levees) traditionally used. The Corps, in cooperation with DWR, is studying the use of such techniques as creating floodways and setting levees back to allow natural inundation of floodplains within the levees. If successfully implemented, this change in the way flood control is approached could reintroduce natural flooding to river stretches where it has not existed for many decades.

This study is also indicative of a change in policy at both state and federal agencies regarding the environment. Agencies that historically have focused exclusively on developing water supply or improving flood protection are now incorporating the maintenance or enhancement of environmental values into their missions. This change in approach will most likely lead to more environmentally friendly solutions to water supply and flood control problems.

Cleanup of the Sources of Toxic Pollutants

The role of toxic pollutants in the decline of ecosystem functions in the Bay-Delta system is not yet well understood, but it is clear that these pollutants do contribute to morbidity and mortality in some aquatic species. Several efforts are currently underway under the EPA's Superfund program to clean up major sources of these pollutants. Although the solution to problems such as the Iron Mountain Mine will not easily be achieved, if successful, they could contribute considerably to restoring the health of the Bay-Delta system.

Land Use Patterns and Trends

The Bay-Delta system is undergoing major changes in land use and intensification (San Francisco Estuary Project 1992b). The San Francisco Bay itself and the central Delta are under the jurisdiction of the San Francisco Bay Conservation and Development Commission (BCDC) and the Delta Protection Commission, respectively. Land use in the periphery of the Delta and in the lower watersheds are the prerogative of local governments, with the federal government (U.S. Forest Service, U.S. Bureau of Land Management, National Park Service) managing a larger proportion of the upper watersheds.

Urbanization of the periphery and immediate watersheds of San Francisco Bay are relatively stable, but other areas are undergoing rapid change, especially the watershed of Suisun Marsh, eastern Contra Costa County and the western Delta (residential subdivisions, "New Towns"); the south-Delta/lower San Joaquin River historical floodplain ("New Town" proposals); the east-Delta periphery (low-density residential, "New Towns", and very-low-density residential). Fairfield, Oakley, Brentwood, Tracy, Lathrop, Stockton, Lodi, Elk Grove, Sacramento, Winters, and other cities within the periphery of the Delta are experiencing strong growth pressures. Rural areas above the Delta and below dams are expanding, with both residential subdivisions (e.g., three to five dwelling units/acre), and very-low-density residential development (e.g., five to 20 acres/dwelling unit). Land use is also changing in the lower watershed/intertidal zone where sea-level rise and flooding are an issue.

Urbanization and concomitant increased motor vehicle use are a major contributor of contaminants (especially heavy metals). Residential development, even at very low densities, raises important land use considerations, including habitat fragmentation, loss of the use of fire as a vegetation management tool, and increased demand for flood protection.

Although CALFED's focus is on state and federal activities in ecosystem restoration, the program must be cognizant of land use issues that may help or hinder these activities and work with those responsible to encourage and support land use patterns that are compatible with ecosystem protection and restoration. Collaborative work in flood management, waterfront development, stream-corridor management, park and recreation design, and watershed management and planning will be especially important.

DEVELOPING A STRATEGY THAT ADDRESSES EXISTING AND FUTURE REGULATORY, ECONOMIC, AND POLITICAL CONDITIONS AND TRENDS

The ERP needs to be implemented in a flexible manner that allows it to respond to a number of external, nonbiological factors, including political, regulatory, and economic events/trends. Over time, these external factors could offer opportunities or they could constrain future actions. The ERP strategic plan focuses on designing and implementing a flexible and interactive approach to

ecosystem protection, management, and restoration that would maximize the opportunities presented by future trends/events while, to the extent feasible, minimizing the constraints. This flexible approach is called "adaptive management" and it is integrated into the overall CALFED implementation program. Chapter 6 provides a detailed description and discussion of adaptive management.

Three main nonbiological opportunity/constraint factors are discussed briefly in this section: (1) time—the length of time required to implement the ERP, (2) the political factor—its potential influence on state/federal environmental policies and regulatory programs, and (3) the volatile nature of global economics.

The ERP and non-ERP components of CALFED will be implemented in stages that are expected to take up to 30 years to complete. Adaptive management is, by definition, a learning process and cannot be defined at the outset by a specific set of identifiable actions set to occur according to a predetermined schedule. Even after CALFED is "completed", adaptive management measures and decisions will continue to be modified and, therefore, adaptive learning within the Bay-Delta ecosystem and other biozones will continue.

In addition to time, another external variable with the potential to affect the ERP involves changes in the state and national political and regulatory environments. Based on the projected CALFED 30-year schedule, there will be eight presidential and gubernatorial elections before CALFED is completed. These state and national elections will inevitably affect the way existing public policies and programs are interpreted and implemented. Changes in administrations could lead to new state/federal laws, regulations, and programs relating to the regulation and management of water resources, endangered/threatened species, habitat, and ecosystem protection. Current debates concerning the need for new species listings and legal challenges relating to federal measures, such as Habitat Conservation Plans (HCPs), "No Surprise" Rule and "Safe Harbor" provisions, and the state's Natural Community Conservation Planning Act (NCCPA) process, reflect the potential for changes in law, regulation, and policy that could affect implementation of both the ERP and CALFED overall.

Beyond the local, state, and national political and regulatory realms, global economic influences must be recognized and accommodated. Recent events in Asia and elsewhere demonstrate that other national economies and global economic events can quickly become factors capable of influencing policy decisions at all levels of our government, including decisions affecting the protection and management of critical biological resources. These external events cannot be accurately predicted and the resulting impacts cannot be quantified in advance, and they demand a strategic plan approach that is flexible and based on a systematically acquired understanding of the Bay-Delta system.

The strategic plan's application of the adaptive management framework to the ERP decision-making process could help to minimize unnecessary and harmful programmatic changes during implementation of the ERP that could result from the adverse effects of some external nonbiological events and trends. Decisions made within a science-based, adaptive management framework will be less vulnerable to adverse effects generated by external events than would be the case if a more

typical restoration strategy were applied (e.g., decisions cannot be demonstrated to be science-based, fail to consider identifiable alternatives, or appear to be politically influenced/motivated).

IMPLICATIONS FOR RESTORATION OF ECOSYSTEM-LEVEL DIFFERENCES IN FUNCTIONS

In developing objectives, indicators, and specific restoration actions for the Bay-Delta system, it is important to bear in mind certain fundamental differences between estuarine and riverine systems, which will influence the likely response of biota to restoration activities and therefore help to select the most suitable strategies for different parts of the Bay-Delta system.

In riverine systems, most flows are unidirectional: water, sediment, nutrients and other dissolved constituents, organic material, debris, and biota such as small fish. The habitat in a given reach of river is strongly influenced by the flows it receives from upstream, which, in turn, are influenced by watershed factors such as basin geomorphology and vegetation, upstream floodplain storage, etc. Seasonal and interannual variations in flow are important aspects of flows. Most significantly, the magnitude, composition, and timing of various fluxes from upstream (e.g., runoff, sediment load, nutrients, large woody debris) have been altered by human actions such as land use changes, dam construction, levee construction, and clearing of riparian vegetation.

In an estuarine ecosystem, flows are not unidirectional and differences in salinity give rise to important ecological effects directly and by affecting flow patterns. In a macrotidal estuary, such as San Francisco Bay, tidal flows are by far the most significant source of physical forces at shorter timescales (2 weeks or less). Tides produce mixing, break down stratification, cause periodic changes in flow direction and inundation of intertidal areas, and daily and spring-neap variations in estuarine volume and depth. Tidal flux can be influenced by changes in tidal prism, the volume of water exchanged during a tidal cycle. In some small tidal inlets along southern California, filling or diking of tidal marshes so reduced the tidal prism that the remaining tidal flows were inadequate to keep the inlets open. In the Bay-Delta system, filling and diking of tidal marshes has reduced the tidal prism somewhat, but the effect is small relative to the overall patterns of tidal exchange.

Although flows in tidal marshes are generally tidal, unidirectional floodflows may affect these systems as well. The effect of unidirectional freshwater flows increases with increasing distance from the mouth of the estuary. Seasonal and year-to-year variations in flow affect the inflow of sediments and nutrients into tidal marshes. Both diking and upstream hydrologic changes resulting from agricultural and urban development have affected the extent and nature of tidal marshes.

The unidirectional flow in riverine systems can be measured, although floodflows (in many respects the most important flows in the riverine system) remain essentially impossible to measure directly because of logistical problems. In the bidirectional flow of tidal systems, flux estimates are notoriously difficult. Estuarine circulations are further complicated by salinity, which, in addition to obvious constraints on aquatic ecology related to salt tolerance, also provides the density gradients

E-026161

E-026161

that allow for strong stratification and gravitational circulation, features absent from rivers. These circulation features influence the residence time and movement patterns of living and other nonliving particles in the estuary.

Although migrating fish may sometimes reverse direction in rivers, their overall movements are either upstream or downstream. Estimating the flux of fish in rivers is complicated by difficulties in sampling at the locations and timing of important migrations although, in some cases, fish are funneled through constrictions, where they can be counted. In estuaries, however, it is more difficult to estimate fluxes of migrating fish because fish almost certainly change migration rate or direction on a tidal timescale. Because the ultimate success of the restoration efforts will probably be judged on future populations of important fish species (many of which are migratory), estimates of fluxes of fish will be important, and the limitations imposed on these numbers by physical conditions should be kept under consideration.

Much of ecological theory is based on terrestrial habitats in which space can be a limiting factor. Habitat area is often limiting in upstream riverine environments and in nearshore environments of estuaries, where physical space for the organisms constrains the carrying capacity for organisms. (Whether physical habitat is actually limiting depends on the status of other potential limiting factors.) In upstream river environments, the area (and volume) of aquatic habitat are limited by the size of the channel, extent of potentially suitable habitat within the channel (e.g., overhanging bank cover, clean gravelbeds), and extent to which the channel is filled with water. Nearshore estuarine systems are limited by the extent of area of attached algae and macroinvertebrates and by available territory for fish; therefore, similar principles (e.g., competition for space) probably apply in those areas as they do in terrestrial habitats.

In open-water oceanic and estuarine habitats, physical space is not likely to be a limiting factor for any given species, although it indirectly limits the total abundance of organisms in an area. Two consequences, both relevant to restoration, arise from the nonlimiting nature of space. First, density-dependent effects on a population must occur either through food supply or predator response (including cannibalism). These effects can be more difficult to detect than those involving space limitation and they can occur at any life stage, making modeling of these effects difficult. Second, because space may not be a limiting factor, adding more of it may not increase the abundance of open-water species. For example, when fish-aggregation devices are placed offshore to attract pelagic fish such as tuna, there may not be an increase in abundance, but merely an increase in vulnerability to fishing. Because of strong tidal forcing, few, if any, habitats in the open-water regions of an estuary can be truly considered isolated from each other.

Food supply can be an important limitation in riverine systems as well. In upstream reaches, leaves, insects, etc. falling into streams (and even the decay of spawned-out salmon carcasses) are important sources, although with distance downstream and increasing river size, these (allochthonous) sources become less important than primary productivity (autochthonous) (Vannote et al. 1980). The upstream reaches important for salmonid reproduction are clearwater streams with little primary productivity and are dependent on allochthonous sources of carbon. Adult spawners generally do not feed (relying on stored food reserves in their bodies); however, rearing juveniles require food, therefore, the health of the riparian corridor is important for the food it provides, and

projects that improve the riparian vegetation along channels should increase food supply and consequently lift a potential constraint on rearing.

In estuarine reaches of the Bay-Delta system, the invasion of non-native species is probably the single most important limitation on ecological restoration because these species have fundamentally altered ecological interactions and even some physical characteristics, such as water clarity (Cohen and Carlton). In riverine reaches, however, human-induced alterations to physical processes are probably the most important limitation on restoration. Although non-native species have established, and may even be dominant, in riverine reaches, they tend to thrive in environments where physical processes and/or habitat have been altered, such as in reaches downstream of dams (Baltz and Moyle 1993).

Salinity and tidal inundation regime tend to be major determinants of community structure along the elevational gradient of tidal wetlands, although at any given elevation, habitat area may be limiting. Elevation and morphology of sloughs and larger channels tend to be dynamic and important determinants of plant community structure, as in riverine riparian systems. High-elevation marsh is invaded by introduced species such as ice plant and a number of other non-native plants, while predation and competition by introduced fish and invertebrate species affect the fauna of low-elevation tidal marsh. Tidal marshes tend to be affected by a combination of the types of forces that shape estuarine and river systems. Their restoration is notoriously difficult because of small but important differences in elevation and the complexity of forces that affect tidal marshes.

The fundamental differences (physical and ecological) between riverine and estuarine systems should be taken into consideration when contemplating potential restoration actions. For example, restoration of processes such as flooding, sediment transport, and large organic debris transport may be more effective in riverine reaches (where these processes have been fundamentally altered by dams and levees) than in estuarine reaches where the most important physical processes are tidally- and salinity-driven circulations.

TWELVE IMPORTANT ISSUES AND OPPORTUNITIES

Twelve important issues to consider in developing an adaptive management framework are listed below. A successful restoration program will be demonstrated by the ability to resolve or gain a higher level of understanding of how these factors affect the ecosystem early in the program. A blueprint for restoration can be created and expanded only as CALFED becomes more confident that restoration measures are likely to result in a desired effect. Resolving substantial uncertainties should therefore be an integral part of the priority Stage 1 actions and monitoring programs. These issues are not merely academic, but cut to the heart of both the kinds and sequence of restoration actions and the degree to which adaptive management must become the basis for the ERP. Where possible, actions should focus on restoring ecosystem processes that create and maintain habitats, providing greater system durability and more sustainable conditions for target species.

The issues described below are listed in approximately increasing order of specificity but not ordered by importance. These issues are not the only ones to consider but must be taken into account to help ensure a successful program. Many of the issues deal with uncertainty resulting from incomplete information and unverified conceptual models, sampling variability, and highly variable system dynamics. Much of this uncertainty is unavoidable and must be taken into account in the adaptive management approach to ecosystem restoration; therefore, because answers to the questions implied by these issues are not known, the need for adaptive management and probing early in the implementation of Stage 1 is underscored.

1. **Introduced species.** The ERP is designed to shift the ecosystem from its present state to a new, more desirable state. The single most likely impediment to the ability to make that shift in the Bay and Delta is introductions of non-native species to the system. In the last 3 decades, introduced species have had a greater impact on the species composition and function of this region than any other single human activity. Upstream, establishment of non-native species, facilitated by changes in habitat, has altered the ecosystem with unknown consequences to the ability to restore it. It is imperative that the ERP quickly put into action a robust, thorough program to reduce the flow of invasive species to the lowest possible level, as stated in goal 5, and to establish habitat conditions that favor native over non-native species.

2. **Natural flow regimes.** Restoration of natural flow regimes in regulated rivers has become the new paradigm in stream restoration. It is based on the assumption that desired species of fish (usually salmonids), high aquatic biodiversity, and preferred riparian conditions depend on variable flow regimes that maintain active channels and floodplains and keep non-native species at bay. A completely natural flow regime for a river reach below a dam is not possible, however, (because of human water demand) and may not even be particularly desirable because the predam sediment supply has been cut off. If upstream coldwater habitat is inaccessible, higher summer flows may be needed. Nevertheless, native species are usually favored by flow regimes that at least resemble the historical flow regime in the pattern of natural, seasonal variability, if not in magnitude. The desired conditions below every major dam are likely to be different, suggesting a need for experimental manipulations of flows, including moderate annual floodflows, and habitat to find the right combination of factors that will maximize ecosystem benefits or assist endangered species in ways that are compatible with other uses of water and river corridors.

3. **Channel dynamics, sediment transport, and riparian vegetation.** There is growing recognition that dynamic river channels, free to overflow onto floodplains and migrate within a meander zone, provide the best riverine habitats. The dynamic processes of flow, sediment transport, channel erosion and deposition, periodic inundation of floodplains, establishment of riparian vegetation after floods, and ecological succession create and maintain the natural channel and bank conditions favorable to salmon and other important species. These processes also provide important inputs of food and submerged woody substrates to the channel. The most sustainable approach to restoring freshwater aquatic and riparian habitats is by restoring dynamic channel processes;

however, restoration of natural channel processes is now hampered by the presence of levees and bank protection along many miles of rivers. Below reservoirs, the reductions in high flows, natural seasonal flow variability, and supply of sand and gravel have further exacerbated the constraining effect on rivers with levees and rock banks. It is therefore a priority to identify which parts of the system still have (or can have) adequate flows to inundate floodplains and sufficient energy to erode and deposit, and to identify floodplain and meander zone areas for acquisition or easements to permit natural flooding and channel migration. Sediment deficits from inchannel gravel mining should also be identified and the feasibility or efficacy of augmenting the supply of sand and gravel in reaches below dams should be evaluated.

4. **Flood management as ecosystem tool.** The current approach is to control floods using dams, levees, bypass channels, and channel clearing. This approach is maintenance intensive, and the underlying cause of much of the habitat decline in the Bay-Delta system since 1850. Not only has flood control directly affected ecological resources, but confining flows between closely spaced levees concentrates flow and increases flood problems downstream. With continued deterioration of flood control infrastructure, further levee failures are likely. Emergency flood repairs are stressful to local communities and resources and often result in degraded habitat conditions. An alternative approach is to manage floods, recognizing that they will occur, they cannot be controlled entirely, and have many ecological benefits. Allowing rivers access to more of their floodplains actually reduces the danger of levee failure because it provides more flood storage and relieves pressure on remaining levees. Valleywide solutions for comprehensive flood management are essential to ensure public safety and restore natural, ecological functioning of river channels and floodplains. The Corps Comprehensive Study now underway provides CALFED with an opportunity to integrate an ecosystem perspective and adaptive management into the new approach to flood management, and help to redesign the flood control infrastructure to accommodate more capacity for habitat while reducing the risks of flood damage.

5. **Bypasses as habitat.** The Yolo and Sutter Bypasses along the Sacramento River are remarkably successful in reducing flooding in urban areas. They are also important areas for farming. The realization of their relatively low-cost benefits to flood control is leading to the consideration of additional bypasses, especially in the San Joaquin Valley. There is also a growing realization that bypasses can be important habitat for waterfowl, for fish spawning and rearing, and possibly as a sources of food and nutrients for estuarine foodwebs. For example, when the Yolo Bypass is flooded, it effectively doubles the wetted surface area of the Delta, mostly in shallow-water habitat. Managing the bypasses for the benefit of fish and wildlife, however, may conflict with their use for flood control and farming. There is therefore a major need for an evaluation of existing bypasses as habitat to reduce management conflicts. New or expanded bypasses and managed floodbasins should also be designed with the needs of fish and wildlife in mind.

6. **Shallow-water tidal and freshwater marsh habitat.** Restoration of shallow-water tidal and freshwater marsh habitat has received substantial support as a method by which

species restoration goals can be achieved. The underlying assumption is that physical habitat of the kind and at the locations proposed is limiting to the populations of interest and therefore that additional like habitat will increase these populations. This assumption is fundamental to many ecosystem restoration projects, but it has not been tested for many species in this estuary. Furthermore, it is possible that restored habitat will be used by other than the target species, with unknown consequences for natives. The high degree of uncertainty regarding this important topic makes a strong case for an adaptive management approach in which options for design and location, and the species-specific benefits of such restoration, are assessed. Large-scale pilot projects, accompanied by intensive monitoring of the successional changes in physical conditions, vegetation cover, and species utilization, are most likely needed to resolve these uncertainties.

7. **Contaminants in the Central Valley.** Researchers frequently discover in bioassays that waters and sediments in various parts of the system are toxic to fish and invertebrates. Although there is only limited evidence connecting these conditions to reductions in abundance, this chronic condition does not seem conducive to long-term restoration. Furthermore, there is an ongoing debate over the long-term consequences to human health of chronic exposure to low concentrations of many organic contaminants. Concern over this general topic has prompted the Core Team to elevate resolution of problems from contaminants to the status of a specific goal for the ERP.

8. **Limiting factors.** For most aquatic species, the factors that limit abundance and production are not known. Density-dependent limits on abundance can be very subtle and episodic, and data are typically available for only portions of their life cycle. Without knowing the limiting factors, the likelihood that particular actions will benefit a species is, at best, speculative. Actions directed at individual species may be ineffective because of other, possibly unknown, limits. This suggests the need for action at the ecosystem level by which multiple restoration objectives can be achieved without the clear understanding of the mechanisms. The X2 standards are a good example of ecosystem-based actions without a clear understanding of mechanisms. Under the ecosystem approach, restoration actions must be partially based on empirical models, which may have limited predictive capability, or on a general understanding of ecosystem-level processes.

9. **X2 relationships.** Current management of the Bay-Delta system is based largely on a salinity standard (the "X2" standard). This standard is based on empirical relationships between various species of fish and invertebrates and X2 (or freshwater flow in the estuary). As with all empirical relationships, these are not very useful to predict how the system will respond after it has been altered by various actions in the Delta, including altered conveyance facilities. This implies a need to determine the underlying mechanisms of the X2 relationships so that the effectiveness of various actions in the Delta can be put in context with this ecosystem-level restorative measure.

10. **Decline in productivity.** Productivity at the base of the foodweb has declined throughout the Delta and northern San Francisco Bay. Although some of this decline can be attributed to the introduced clam *Potamocorbula amurensis*, or Asia clam, not all of the decline is explained. The decline at the base of the foodweb has been accompanied by declines in several (but not all) species and trophic groups, including mysids and longfin smelt. The long-term implications of this seem to be a reduction in the capacity of the system to support higher trophic levels. This implies a limit on the extent to which Bay-Delta fish populations can be restored unless creative solutions can be found to increase foodweb productivity.

11. **Entrainment of fish at pumps.** A major impetus behind CALFED is concern over the effects of entrainment of fish and other biota in the pumps of the major water projects and, to a lesser extent, the numerous smaller agricultural water diversions in the Delta and along rivers; however, there is no clear idea of the extent to which entrainment affects population size of any one species of fish or invertebrate (Diversion Effects on Fish Team 1998). More information on the effects of entrainment will help determine to what extent an "isolated facility" can be expected to alleviate any problems; therefore, it is pivotal in choosing facilities for water conveyance. Reducing this uncertainty is also essential to the most efficient allocation of resources for ecological restoration because proposed solutions to this problem include potentially tens of millions of dollars spent constructing fish screens and new intake facilities throughout the Bay-Delta system, not all of which may be as effective as intended at reducing population declines.

12. **The importance of the Delta for salmon.** Scientific opinion varies on the suitability and use of the Delta for rearing by juvenile salmon and steelhead. Although chinook salmon use other estuaries for rearing, most research on salmon in the Delta, and resulting protective measures, focus on smolt passage; however, if substantial numbers of salmon fry rear in the Delta and these fish contribute substantial recruitment to the adult population, actions to enhance Delta rearing of fry would be warranted. Current actions to protect migrating smolts (e.g., pulse flows) might be supplanted by actions designed to protect resident fry (e.g., extended high flows to flood shallow areas). This topic requires research, including adaptive probing and pilot projects.

Other Related Issues

Two issues do not fit into this list but warrant discussion. One issue that transcends all of the ERP has to do with the institutional structure for adaptive management. The culture and regulatory guidelines of most government agencies may discourage, or at least not easily embrace, full integration of adaptive management. Establishing an entity capable of implementing or coordinating real adaptive management will be one of the biggest challenges of the ERP and is discussed further in Chapter 6.

The second issue concerns the geographic extent of restoration implemented under the ERP. There may be compelling reasons to expand the scope of restoration activities downstream of the CALFED problem area to the mouth of the estuary, potentially including actions in parts of San Francisco Bay. The reasons are many, but include the following important points:

- Several species of concern spend much of their time in San Pablo Bay and seaward, including longfin smelt and striped bass.
- Young chinook salmon spend considerable amounts of time in the lower bays on their seaward migration.
- Reduction in productivity of the lower bays probably has significant effects on Delta species such as Delta smelt, and has apparently caused a reduction in productivity in the Delta through tidal mixing.
- Many species significantly affected by CALFED actions and frequently residing in the Delta enter the bay as juveniles, including starry flounder, bay shrimp, and Pacific herring.

In considering these important points, restoration of targeted habitats throughout San Francisco Bay might be part of an effective strategy for restoring species of interest when combined with restoration in the Delta itself and on major upstream tributaries of the Delta.

OPPORTUNITIES FOR ECOSYSTEM RESTORATION

Introduction

Although there are many constraints on what can be accomplished with ecological restoration in the Bay-Delta system, there are also many opportunities. This section identifies some promising opportunities for initiating large-scale ecological restoration in Stage 1 of the ERP. These are only a sample of the opportunities for ecological restoration that would potentially benefit endangered species, as well as other native species. A different list of opportunities might be crafted by other parties interested and familiar with the rivers and the Delta. Nevertheless, the list below is illustrative of the range of opportunities that the ERP provides. The choice of specific examples was guided by the principles that were established in the strategic plan: that restoration of endangered species is best approached through restoration of the ecological structures and processes on which the species depend and that habitat restoration and maintenance is a dynamic not a static process. In light of these principles, opportunities have been selected that focus on ecological processes and that could be implemented in ways that would be largely self-sustaining. Examples have also been selected that would generate results within the short timeframe of stage. In presenting this list, to some extent, the strategic plan is contradicted. The plan lays out a process for screening, prioritizing, and designing projects within an adaptive management framework. The restoration activities

suggested below have not been subject to this process; however, they should be put through the process before being implemented. A more rigorous assessment of their costs and benefits than has been done for this report might indicate that some of these projects are less promising than imagined. The screening process that is outlined in this strategic plan provides the means by which to choose projects with the best opportunity of success and with the greatest potential to assist with learning and adaptation. Application of this method is recommended as the best and most objective means by which to select projects for implementation.

It is useful to illustrate the Core Team's belief in the opportunity that ERP represents with some specific examples of restoration. For rivers, restoration of physical and ecological processes is emphasized, rather than artificial measures to maintain populations, such as hatcheries or creation of habitats that will not be sustained by ongoing processes. For example, earlier in the century, hatcheries were viewed optimistically as a panacea to mitigate for effects of dams in cutting off upstream salmon habitats; however, it is now widely recognized that hatcheries (an engineering-oriented, species-based approach to increasing fish populations) had, at best, limited success in salmon conservation. Similarly, efforts to physically modify river channels to better resemble natural salmon spawning and rearing areas may often be prone to failure because the processes that created the scarcity of spawning and rearing habitat continue to affect the channel. For example, spawning-size gravels have been added to riverbeds to create potential spawning riffles in sediment-starved reaches downstream of dams, but these artificially-created riffles have commonly been washed away in subsequent high flows (even moderate flows, such as the 1.5-year flow) because the underlying problem of sediment deficit was not addressed.

Measures for improving watersheds upstream of large reservoirs are not recommended here because the upper watersheds are hydrologically disconnected from the lowland alluvial rivers by the reservoirs and therefore cannot contribute to ERP goals; however, rivers that are largely unregulated are considered to be a high priority for conservation and enhancement of ecological structure and function. Examples include Cottonwood Creek, Cosumnes River, and eastside tributaries of the northern Sacramento Valley (Cow, Battle, Paynes, Deer, Mill, Big Chico, and Butte Creeks).

Opportunities in the Delta

1. **Reduce the introduction of ballast-water organisms from ships to 5% of 1998 levels.** As discussed in the next chapter and appendix B (goal 5, objective 1), the shipping industry can be required to greatly reduce and eventually eliminate the introduction of organisms through ballast water using existing technology. Significant progress could also be made in reducing the introduction of non-native species from other sources as well (goal 5, objectives 2-7). This is a preventative rather than a restorative activity. Given the impacts that introduced invasive species have already had on the ecology of the Bay-Delta system, however, eventual halting of all additional species introductions is crucial to the ultimate success of the ERP.

2. **Expand or enhance seasonal shallow-water habitat in the bypasses (e.g., Yolo Bypass) and near-Delta floodplains** (goal 4, objective 6). The bypasses and other "artificial" floodplains that flood during wet years are demonstrably productive places for juvenile salmon and splittail, as well as waterfowl. By engineering the weirs that release water into the bypasses, the bypasses presumably can be flooded (at least partially) on a more regular basis and could therefore be productive in most years. Habitat creation in flood bypasses presents one of the best opportunities for ecosystem restoration because large areas of habitat can probably be created at small cost while retaining the flood management functions of the bypasses.

3. **Initiate several large-scale pilot projects using different approaches to restoring tidal marshes in the north Delta (around Prospect Island), Suisun Marsh, and the North Bay.** These projects could be designed as experiments to assess the benefits for marsh-dependent species and the most effective techniques of restoration, as well as providing an opportunity to evaluate options for minimizing or controlling invasive plant species (goal 4, objectives 1-4). Note also that this kind of project represents an implementation of the three levels of adaptive management action; targeted research, pilot testing of techniques, and large-scale restoration.

4. **Develop means to control invasive aquatic plants in the Delta.** Invasive plants, such as water hyacinth and *Egeria densa* (Brazilian water weed), are clogging many sloughs and waterways of the Delta, not only impeding boat traffic, but creating environments that are unfavorable for native fishes. The California Department of Boating and Waterways has an *Egeria* control program, but has not yet received CEQA approval for use of chemical controls. There is an immediate need to develop ways by which to control these plants that are not, in themselves, environmentally harmful (goal 5, objective 9). An opportunity exists for the ERP to join forces implementing ambitious eradication and control measures with agencies, organizations, and water districts concerned with the deleterious effects of these water weeds on navigation in the Delta, clogging of water intakes and fish screens. and diminished recreational uses.

5. **Initiate targeted research on major restoration issues, such as: (1) how to control problem invasive species such as the Asia clam (*Potamocorbula amurensis*), which has a negative effect on foodweb dynamics in the estuary; (2) factors limiting the abundance of high-priority endangered species; and (3) design of habitats for shallow-water tidal marsh and bypasses.** Use such research to begin addressing issues raised in "Twelve Important Issues and Opportunities" above. Ultimately, the limited funds available for restoration will be much more effectively spent if there is a clear understanding of the relative seriousness of the diverse problems facing the estuarine and riverine ecosystems and of the ability to solve those problems. Where the research can be linked to pilot or large-scale restoration projects, the benefits will be multiplied.

6. **The ERP should immediately coordinate with the various levee and flood control state, local, and federal programs to establish design criteria and standards that ensure that levee rehabilitation projects incorporate features beneficial to the**

aquatic and riparian environments of the Delta. The majority of the approximately 50 Delta islands are hydrologically disconnected by levees from the primary channel, open-water estuarine environment. Most of these levees are likely to remain in future years and to be reinforced with rock riprap, raised and widened, or rehabilitated in other ways to prevent levee failure. Potentially beneficial projects that could be incorporated into these programs include levee setbacks and creation of broad submerged benches, as well as the construction of broader levees to support riparian vegetation. The ERP should also work with the agencies to develop contingency plans for responses to major and multiple levee failures in different parts of the Delta.

7. **Large-scale pilot projects could be established on both leveed Delta islands and on submerged islands (e.g. Frank's Tract) to test and monitor techniques for returning subsided Delta islands to shallow-water and marsh habitats.** On leveed islands, areas could be diked off, partially flooded, and planted with tules to examine the potential for natural deposition of organic matter to raise island levels. On submerged islands, dredge spoils and other materials could be used to create shallow-water habitats. One potential benefit of a project to convert Frank's Tract to shallow-water habitat would be reduction of wave erosion affecting Delta island levees surrounding the tract.

8. **Develop large-scale pilot projects that examine the relationship between variable salinity and the maintenance of native species in the Delta, especially in shallow-water habitats.** Historically, the Delta and other parts of the estuary had salinity regimes that fluctuated from year to year as well as from month to month and, often, daily with tides. The native organisms presumably evolved in such variable conditions and should be favored by them. Many of the non-native species (e.g., freshwater aquatic plants, freshwater and marine clams), in contrast, may be favored by the more stable conditions now present as the result of regulation of freshwater inflows into the Delta. Opportunities exist to restore large tracts of former tidal shallow-water habitat in the north Delta, lower Yolo Basin, and along river channels and sloughs in the vicinity of Sherman Island. Once these shallow-water habitats are in place, it may be possible to vary the position of the salinity gradient in these areas, thereby testing the effects of variable salinity on native and introduced organisms in the shallow-water habitats. This action would provide valuable information on such things as: (1) the extent to which physical habitat may be limiting native and introduced species, (2) how salinity gradients and variability affect conditions and species within the shallow-water habitats, and (3) calibration of models to evaluate the changes in the hydraulics of the Delta that would result from having more extensive tidelands and more breached Delta islands.

Opportunities for Rivers

1. **Mimic natural flow regimes through innovative methods to manage reservoir releases.** There is underutilized potential to modify reservoir operations rules to create more dynamic, natural high-flow regimes in regulated rivers without seriously impinging

E-026171

E-026171

on the water storage purposes for which the reservoir was constructed. Water release operating rules could be changed to ensure greater variability of flow, provide adequate spring flows for riparian vegetation establishment, simulate effects of natural floods in scouring riverbeds and creating point bars, and increase the frequency and duration of overflow onto adjacent floodplains. In some cases, downstream infrastructure of river floodways may require upgrading to safely accommodate a more desirable natural variability and peak discharge magnitude associated with moderate floodflows (e.g., strengthen or set levees back).

2. **Mimic natural flows of sediment and large woody debris.** Dams disrupt the continuity of sediment and organic-debris transport through rivers, with consequent loss of habitat, and commonly, river incision, downstream. In some cases, such as Englebright Dam on the Yuba River, dam removal should be considered as a sustainable solution to reestablishing continuity of sediment and debris transport, as well as opening access to important spawning and rearing areas. Most dams, however, cannot be removed, so methods must to sought to reestablish continuity of sediment and wood transport with the dam in place. Coarse sediment can be artificially added below dams to at least partially mitigate for sediment trapping by the dam and ameliorate the impacts of sediment-starved flows. This approach has been successfully used in Europe, using sediment from natural (landslide) and artificial sources (injected from barges). On the River Rhine, enough gravel and sand are added below the lowest dam to satisfy the present sediment transport capacity of the Rhine to prevent further incision of the bed (an average of over 200,000 cubic yards annually). On the Sacramento River, gravels have been added at a rate much below the river's transport capacity so they are vulnerable to washout at high flows. A more sustainable approach would be to add gravel (and sand) on a regular basis and at a much larger scale to better mimic natural sediment loads and therefore provide the sediment from which the river would naturally create and maintain spawning riffles. This latter approach requires a large commitment of resources and should be undertaken only in rivers where other factors (e.g., temperature regime) are favorable (or can be made favorable) for recovery of species (such as the upper Sacramento). Such opportunities will be more economical where sources of dredger tailings or reservoir Delta deposits are available nearby.

   While recognizing the navigation and flood safety issues associated with large woody debris in rivers, the importance of this debris to the foodweb and structural habitat for fish should not be overlooked. There is an opportunity to investigate ways by which to pass debris safely through dams and bridges. This may require replacing some existing bridges with those less prone to trapping woody debris.

3. **Identify and conserve remaining unregulated rivers and streams and take actions to restore natural processes of sediment and large woody debris flux, overbank flooding, and unimpaired channel migration.** Most rivers in the Central Valley are regulated by large reservoirs and therefore require considerable investment to recreate the natural processes needed to sustain true ecosystem restoration; however, a few large unregulated rivers still exist, such as the Cosumnes River and Cottonwood Creek.

Lowland alluvial rivers and streams with relatively intact natural hydrology should be identified and made a high priority for acquisition of conservation and flooding easements, setting back of levees, and other restoration actions because such actions on these rivers are likely to yield high returns in restoration of natural processes and habitats and, ultimately, fish populations.

4. **Undertake fluviogeomorphic-ecological studies of each river before making large investments in restoration projects.** River ecosystem health depends not only on the flow of water, but on the flow of sediment, nutrients, and coarse woody debris and on interactions between channels and riparian vegetation, variability in flow regime, and dynamic channel changes. It is only through interdisciplinary, watershed, and historical scale studies that the constraints and opportunities particular to each river can be understood. For example, it was only after a fluviogeomorphic study of Deer Creek that the impact of flood control actions on aquatic and riparian habitat was recognized, a recognition that has lead to a proposal for an alternative flood management approach designed to permit natural river processes to restore habitats along Lower Deer Creek.

5. **Undertake floodplain restoration on a broad scale, where land or easements can be acquired and where the river hydrology includes (or can be made to include) sufficiently high flows to inundate floodplain surfaces.** Restoration of floodplain function has many benefits, such as reducing stress on remaining levees, reducing excessive channel scour, and encouraging establishment of riparian vegetation over a larger area within the adjacent floodplain. A range of possible measures will need to be employed to fit local conditions, such as widening flood bypasses or creating new ones; setting levees back, creating backup levee systems, or deauthorizing specific levee reaches; constructing armored notch weirs in levees and purchasing flood easements to restore floodbasin storage functions; or implementing measures described in item two above to increase the frequency and duration of overbank flow onto existing floodplains. Floodplain restoration is presently underway on a large scale along the River Rhine between Basel and Mannheim. Engineers now recognize that the loss of floodplain storage by levees along this reach has increased the risk of flooding to a massive chemical complex in Mannheim-Ludwigshafen. The most effective, reliable, and cost-effective solution is to reactivate the historical floodplain.

6. **Reduce or eradicate invasive non-native shrubs and trees from riparian corridors.** Of particular importance is the control of the spread of tamarisk and giant reed, two introduced species that displace native flora, offer marginal value to fish and wildlife, and cause channel instability and reduced floodway capacity. Some rivers, such as Stony Creek and Cache Creek and the lower San Joaquin River, have undergone large expansions of these non-native species, even in the past 10-15 years. A combination of large-scale eradication pilot projects and targeted research on several streams will help to temporarily reduce the rate of expansion of their range, identify the most vulnerable stream environments, and determine whether valleywide eradication or suppression measures are warranted or feasible.

7. **Remove barriers to anadromous fish migration where feasible.** Significant progress has been made in recent years to improve salmon passage on several spawning streams (e.g., Butte Creek, Battle Creek) by removing barriers, consolidating diversion weirs, or constructing state-of-the-art fish passage structures. This encouraging process, with considerable landowner and stakeholder support, as shown so far, should be expanded to include all remaining potential spawning reaches in the ERP focus area that are not obstructed by major reservoir dams. Existing and potential spawning areas currently obstructed by barriers should be identified and action taken to restore anadromous fish spawning upstream.

8. **Develop a partnership of the ERP with the Corps and DWR to fully integrate river and floodplain ecological restoration with floodplain management measures being considered in the 4-year comprehensive planning study underway for the entire Sacramento and San Joaquin River basins.** The strategic plan recognizes that many of the ecological approaches to river restoration listed above are feasible only if and when the overall capacity of the Valley flood control system is expanded and the risk of flooding farms and cities has been significantly reduced. In other words, more room within the managed floodways must be made available for the "roughness" of habitats and the ecologically desirable tendency of alluvial river channels to migrate by eroding of banks or spread high flows onto natural floodplains. To initiate this partnership, ERP should join with the Corps and DWR to jointly sponsor pilot projects and studies that test innovative solutions to improve floodplain management with significant ecosystem benefits, such as the proposed floodplain restoration projects under evaluation along the lower San Joaquin and Cosumnes Rivers.

9. **Promote and support river-based conservancies and broad coalitions to resolve conflicts and achieve local consensus over the restoration and management of river corridors.** As referred to in item eight above, local coalitions with technical and financial support from CALFED, CVPIA, and other state and federal programs have been most successful at reaching broad agreement on solutions and implementing projects to restore river habitats and recover threatened fish populations. Although not all ERP measures can be implemented in this way, this model of local interest-based solutions with ERP funding and technical participation or facilitation should be formalized and expanded throughout the ERP focus area.

E-026175

E-026175

Chapter 4. Goals and Objectives

ECOSYSTEM RESTORATION GOALS

General CALFED Goals

The mission of CALFED is to develop a long-term, comprehensive plan that will restore ecosystem health and improve water management for beneficial uses of the Bay-Delta system. CALFED addresses problems in four resource areas: ecosystem quality, water quality, levee system integrity, and water supply reliability.

The goal for ecosystem quality is to improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta system to support sustainable populations of diverse and valuable plant and animal species. The ERP addresses this goal.

CALFED Ecosystem Restoration Program Goals

This document is a guide for achieving a reasonable level of ecosystem quality for the Bay-Delta system in a way that still allows sufficient water to be available to drive the diverse California economy. The key term "ecosystem quality" is not well defined and is presumably defined the same as the similar terms "ecosystem health" and "ecosystem integrity" (e.g., Woodley et al. 1993). All these terms imply the desirability of ecosystems that not only will maintain themselves through natural processes with minimal human interference (i.e., at low cost) but will be aesthetically attractive and produce goods and services in abundance for humans.

Although many specific actions and goals to achieve a high level of ecosystem quality for the parts of the estuary and watershed within the purview of CALFED are identified in the ERPP, the broader, overall goals are less clear. CALFED's goals for ecosystem restoration are as follows:

1. Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recover of at-risk native species in San Francisco Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

E-026176

E-026176

2. Rehabilitate the capacity of the Bay-Delta system to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities.

3. Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with goals 1 and 2.

4. Protect or restore functional habitat types throughout the watershed for public values, such as recreation, scientific research, and aesthetics.

5. Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.

6. Improve and maintain water and sediment quality to eliminate, to the extent possible, toxic impacts on organisms in the system, including humans.

Goal 1: Endangered Species

Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recover of at-risk native species in San Francisco Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

This goal is listed first because the conflict between protecting endangered species and providing reliable supplies of water for urban and agricultural uses was a major factor leading to the formation of CALFED. "At-risk species" are those native species that are either formally listed as threatened or endangered under state and federal laws or that have been proposed for listing. It places highest priority on restoring populations of at-risk species that most strongly affect the operation of the SWP and CVP diversions in the south Delta, such as delta smelt, all runs of chinook salmon, steelhead rainbow trout, and Sacramento splittail. The goal gives highest priority to the legal recovery of species formally listed under the federal and California ESAs because of the high degree of legal protection given the species, especially under federal law.

The strategic plan also supports actions that will lead to the restoration of large, self-sustaining populations of these endangered species and encourages and supports restoration of populations of species whose listing has less direct impacts on water diversions from the estuary, such as salt marsh harvest mouse (marshes along San Francisco Bay) and yellow-billed cuckoo (riparian areas along the Sacramento River). Because many other native species, especially aquatic species, are also in long-term decline, the strategic plan overall seeks to create conditions in the estuary and watershed that increase the distribution and abundance of native species or at least stabilize populations so that trends toward endangerment and extinction are halted.

Although the overall goal of the strategic plan is ecosystem rehabilitation, it is highly appropriate that native species be a major focus of the rehabilitation efforts for the following reasons:

1. The federal and state ESAs mandate recovery of species, but because there are often multiple at-risk species in a region, ecosystem recovery is usually necessary for achieving recovery of all the species.

2. The habitats that make up the ecosystem contain mixtures of native and non-native species, and often the non-native species are part of the reason for declines of the native species (see goal 5).

3. Although ecosystem recovery can be difficult to assess, the abundance and distribution of multiple sensitive native species are easier to determine and can indicate whether or not ecosystem processes have recovered.

Goal 2: Ecosystem Processes and Biotic Communities

Rehabilitate the capacity of the Bay-Delta estuary and its watershed to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities.

Biotic communities are dynamic assemblages of species that typically occur together, in part because of common physiological tolerances, and interact with one another. This goal recognizes that an ecosystem restoration plan must include restoration and maintenance of ecosystem processes, such as seasonal fluctuations in flow of streams and salinity of the estuary, cycling of nutrients, predator-prey dynamics, and food web structure. Although these processes will occur no matter what organisms make up the biotic communities, they may not function within the constraints identified with "healthy" ecosystem functioning. Particular assemblages of organisms within defined sets of conditions (the biotic communities) therefore become indicators that the ecosystem is functioning in ways regarded as desirable. For example, if the system is managed to sustain high-flow events in March and April, conditions may favor a suite of native fishes (e.g., splittail, hitch, chinook salmon) that respond positively to the increase in shallow-water habitat by flooding. Two key aspects of this goal are (1) to have self-sustaining biotic communities that will persist without continual high levels of human manipulation of ecosystem processes and species abundances and (2) to have communities in which the dominant species, as much as possible, are native species.

This goal emphasizes rehabilitation rather than restoration because so many of the physical and chemical processes in the watershed have been fundamentally altered by human activity. Dams, diversions, levees, and changing patterns of land use have altered the way water, sediments, nutrients, and energy cycle through the system. These changes, largely irreversible within human time scales, set constraints on the nature of the biotic communities that can be maintained. They will allow rehabilitation of ecosystem functioning in ways we find desirable but not restoration of the communities to some pristine state.

Goal 3: Harvestable Species

Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with goals 1 and 2.

This goal recognizes that maintaining some species in numbers large enough to sustain harvest by humans is important, even if the species are non-native. For native species such as chinook salmon, steelhead, and splittail this means maintaining populations at levels considerably higher than those required to keep them from going extinct. For non-native species such as striped bass, signal crayfish, and channel catfish, this means managing populations at harvestable levels but only as long as such management does not interfere with the restoration of large populations of endangered native fishes or disrupt the structure and function of established, desirable biotic communities.

This goal neither precludes nor encourages hatchery programs to enhance populations of sport and commercial fishes. However, hatchery programs that enhance populations of top predators in the Bay-Delta system are likely to have negative effects on other species. The goal refers to "selected" species because some species that may be harvested (e.g., Corbicula clams, mitten crabs) are also nuisance species whose populations should be reduced. The species selected for harvest management must be chosen in ways that recognize that the species regarded as harvestable vary considerably among ethnic groups and can change with time. For example, most native cyprinids (e.g., splittail, blackfish, hitch) are held in high regard by many people of Chinese heritage even though they are disdained by many fishers of European heritage.

Goal 4: Habitats

Protect or restore functional habitat types throughout the watershed for public values, such as recreation, scientific research, and aesthetics.

Habitats are usually defined through some combination of physical features and conspicuous or dominant organisms, usually plants (e.g., salt marsh, riparian forest). Plants are often highly visible natural features and have important roles in the function of the ecosystems of which they are part (e.g., salt marshes can fix large amounts of carbon, which may cycle through the entire system). The ERPP identifies major habitat types in the estuary and watershed, and Moyle and Ellison (1991) identify, at a finer scale, freshwater habitat types. By definition, different habitats support different species or combinations of species and play different roles (usually poorly understood) in the dynamics of the Bay-Delta system. It therefore becomes important to protect and restore large expanses of the major habitat types identified in the ERPP and at least representative "samples" of other habitat types as identified by Moyle and Ellison (1991) and others.

Many direct benefits arise from protecting a wide array of habitats, including the recovery of endangered species and the production of economically important wild species (e.g., fish, ducks). Equally important are the aesthetic values of natural landscapes containing mosaics of habitats. Less appreciated, but also important, are the ecosystem services provided by natural habitats, such as

purification of water and air and delivery of nutrients to systems producing fish and other economically important aquatic organisms (Daily 1997).

Goal 5: Introduced Species

Prevent establishment of additional non-native species, and reduce the negative biological and economic impacts of established non-native species.

This goal is arguably part of the first four goals because protecting and enhancing species, communities, and habitats in an estuary and its watershed implicitly includes reducing the impact of invasive non-native species. However, the introduction of new species into the system is still occurring so frequently, and the potential for ecological damage by further invasions is so high, that the necessity for halting (not just reducing) further introductions needs to be emphasized. Hobbs and Mooney (1998) document how invasions by non-native species are a major ecological force for change in California. Cohen and Carlton (1998) have labeled the San Francisco estuary as the most invaded estuarine ecosystem in the world and document the accelerating rate at which new species continue to become established, mostly as the result of their deliberate release through the dumping of ballast water of ships. Other sources include illicit introductions by anglers (e.g., northern pike) and aquarists (e.g., *Hydrilla*). This problem needs to be dealt with quickly and directly because new invading species can negate the effects of millions of dollars spent on habitat or ecosystem restoration. Likewise, already established non-native species, such as water hyacinth and the Asiatic clam (*Potamocorbula*), continue to have major negative impacts on more desirable species in the system, and methods of control have to be devised. It is important that the control methods not be as harmful as the invading species they are designed to control.

Goal 6: Toxics

Improve and maintain water and sediment quality to eliminate, to the extent possible, toxic impacts on organisms in the system, including humans.

Like solving the problems related to introduced species, solving the problems of toxic materials in the ecosystem could be considered part of the first four goals. Once again, this problem is so pervasive and poorly understood that it deserves recognition as a distinct goal. Major potential problems associated with toxins include the following:

1. Persistent toxins, such as heavy metals, accumulate through food chains, creating health problems not only for carnivorous fish but for the animals that eat them, such as birds and humans.

2. New, highly toxic biocides are periodically flushed into the ecosystem through agricultural and urban drains, creating water that is temporarily toxic to small invertebrates and fish. Such toxic events may go unnoticed because of the brevity of each event and the small size of the organisms immediately affected.

3. Pesticide use in the Central Valley is increasing, with increased potential for negative effects on aquatic ecosystems.

4. Considerable potential exists for ecological disasters caused by large, sudden influxes of toxic materials, such as might be caused by flood-released toxic mine wastes (e.g., Iron Mountain Mine) or by spills of a pesticide carrier (e.g., the Cantara spill on the upper Sacramento River).

5. Toxic materials accumulate in sediments where they can affect benthic organisms directly (and the food webs they support) or sit as "time bombs" waiting to go off when the sediment is disturbed.

6. Substances once thought to be harmless can have harmful effects in subtle ways (e.g., as carcinogens or hormone disruptors). The impact of toxic substances is also an area in which there is high public awareness. Considerable concern exists regarding the risks of consuming harvested organisms or of drinking water from the system.

What Are the Goals Designed to Achieve?

The goal statements provide the basis for a vision of a desired future condition of the Bay-Delta system. Basically, they lead to a definition of what is meant by "ecosystem quality" as applied to the CALFED region.

First, the goals reflect a desire for ecosystems that are not continually being disrupted by unpredictable events, such as the invasion of non-native species capable of altering ecosystem processes, massive levee failures, or the collapse of populations of native species. The ecosystems should be dynamic but function within known limits, be resilient in the face of severe natural conditions, and be capable of changing in a more or less predictable fashion in response to global climate change.

Second, the goals reflect the desire for ecosystems that incorporate humans as integral parts of them, as managers, participants, and beneficiaries. According to this description, the ecosystems under the purview of CALFED are not "natural" ecosystems in which humans are primarily observers. Instead, they are systems that continue to be altered by human activity, but in a less harmful way; they include people who live and make a living in them; and they produce products that benefit the larger society, such as water, power, and food.

Third, the goals reflect a desire for ecosystems that maintain substantial self-sustaining populations of the remaining native species and some high-value non-native species (e.g., striped bass, crayfish), with large numbers of species with high cultural, symbolic, or economic value (e.g., salmon, raptors, tules).

Fourth, the goals reflect a desire for a landscape that is aesthetically pleasing and that contains large-scale reminders of the original "primeval" ecosystem, such as salt marshes, tidal sloughs, and expanses of clean, open water.

Fifth, the goals recognize that the ecosystems that will result from CALFED actions will be unlike any ecosystems that have previously existed. They will be made up of mixtures of native and non-native species that will interact in an environment in which many of the basic processes have been permanently altered by human activity and will continue to be regulated by humans. At the same time, the templates for the new ecosystems are the tattered remnants of the original systems and the natural processes that made these systems work.

ECOSYSTEM RESTORATION OBJECTIVES

Associated with each of the six strategic goals for the ERP is a series of objectives. The objectives, presented in Appendix B, are intended to assess progress toward achieving the associated goal. A summary of the objectives identified for each goal is presented in Table 4-1. The objectives are stated primarily in terms of management actions designed to have a favorable impact on the Bay-Delta system. However, some are also stated in terms of studies that will teach us how the ecosystem behaves so that principles of adaptive management can be better employed. For either purpose, the objectives must be tangible and measurable (e.g., a net increase in the abundance of a species or a successfully completed experimental study).

Objectives can be both short term and long term. *Short-term objectives* (e.g., recovery of an endangered species) should be clearly feasible, relatively easy to measure, and achievable in reasonable lengths of time (usually less than 25 years). The time period is not the same as Stage 1 of the CALFED process. *Long-term objectives* (e.g., achieving a large, self-sustaining population of a species) may be more difficult to determine and may require additional resources and knowledge to achieve. They usually take longer than 25 years to attain.

Stage 1 expectations are meant to be measures of the progress toward meeting short-term objectives made in the first 7-10 years of implementation of the ERP. These expectations have two basic components: improvements in information to allow better management of the ecosystem and improvements in physical and biological properties of the Bay-Delta system. Frankly, it is unlikely that the expectations under every objective will be met, yet failure to meet a significant proportion of the expectations will be regarded as a major reason to reevaluate and redirect the ERP process.

Individual objectives in the strategic plan are (or will be) linked to conceptual models that indicate how they fit into the bigger picture of ecosystem restoration. Implicit in all the long-term objectives (and many of the short-term objectives) is the idea they will be achieved and may be changed through adaptive management. For example, several long-term objectives are designed to achieve numbers or densities of spawning salmon equivalent to those of some time in the past. However, we will not know if such numerical objectives are realistic until one or more regulated rivers have been manipulated on a fairly large scale.

One way that the success of achieving objectives may be determined is through the use of indicators that are fairly easy to measure. According to the CALFED Ecological Indicators Workgroup, "Ecological indicators translate program goals and objectives into a series of specific measurements that can be used to determine whether the goal and objectives have been met." Some potential indicators are implied or given in the objectives and Stage 1 expectations in Appendix B, but most will have to be developed.

The objectives under the six goals often overlap each other broadly or are closely linked. Some may even seem contradictory. Such problems (if they are indeed problems) are inherent in any program designed to make major changes at the ecosystem level. They provide yet another argument for the use of adaptive management as a basic principle to use in implementing restoration programs.

The catalog of objectives in Appendix B was generated by examining goals in the ERPP, reviewing existing species recovery plans and drafts of various documents produced by stakeholders, and holding discussion among the Core Team and CALFED staff members. However, it is not complete. Therefore, the objectives presented should be considered models for other objectives not presented here. It is not unreasonable to expect that as we learn more about the system, some established objectives will change in focus and additional objectives will be established.

Table 4-1. Summary of Strategic Plan Goals and Objectives

Goal	Objective
Goal 1: Endangered Species	**Priority Group I Species**
Achieve, first, recovery and then large self-sustaining populations of at-risk native species dependent on the delta and Suisun Bay, support similar recovery of at-risk native species in San Francisco Bay and the watershed above the estuary, and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.	Objective 1: Restore Delta Smelt to the Delta and Suisun Bay
	Objective 2: Restore Winter-Run Chinook Salmon to the Sacramento River and the Bay-Delta Estuary
	Objective 3: Restore Spring-Run Chinook Salmon to Central Valley Streams and the Bay-Delta Estuary
	Objective 4: Restore Late-Fall-Run Chinook Salmon to Central Valley Streams and the Bay-Delta Estuary
	Objective 5: Restore Self-Sustaining Fall-Run Chinook Salmon to Central Valley Streams and the Bay-Delta Estuary
	Objective 6: Restore Self-Sustaining Central Valley Steelhead to Central Valley Streams and the Bay-Delta Estuary
	Objective 7: Restore Longfin Smelt to the Delta and Suisun Bay
	Objective 8: Restore Green Sturgeon to the Delta and Suisun Bay
	Objective 9: Restore Sacramento Splittail to the Delta, Suisun Bay, and the Central Valley

Table 4-1. Continued

Goal	Objective
	Priority Group II Species
	Objective 1: Restore Anadromous Lampreys Dependent on the Delta and Suisun Bay
	Objective 2: Restore At-Risk Endemic Brackish Water Tidal Marsh Plants
	Objective 3: Restore California Clapper Rail
	Objective 4: Restore Swainson's Hawk
	Objective 5: Restore California Black Rail
	Objective 6: Restore Suisun Song Sparrow
	Objective 7: Restore Suisun Ornate Shrew
	Objective 8: Restore Salt Marsh Harvest Mouse
	Objective 9: Restore San Pablo Vole
	Objective 10: Restore Valley Elderberry Longhorn Beetle

Table 4-1. Continued

Goal	Objective
Goal 1: Endangered Species (cont'd)	**Priority Group III Species**
	Objective 1: Restore California Red-Legged Frog to Representative Habitats throughout Its Former Range
	Objective 2: Restore California Tiger Salamander to Representative Habitats throughout Its Range
	Objective 3: Restore Sacramento Perch within Its Native Range
	Objective 4: Restore Populations of Native Anuran Amphibians throughout the CALFED Region
	Objective 5: Restore Self-Sustaining Populations of Western Pond Turtles to Habitats throughout the CALFED Region
	Objective 6: Restore Populations of Giant Garter Snake throughout its Historical Range
	Objective 7: Restore the Wintering Population of Western least Bittern in the Central Valley to Historic Levels
	Objective 8: Restore Least Bell's Vireo Populations to Habitats throughout Its' Former Range in Central California
	Objective 9: Restore Little Willow Flycatcher Populations to Habitats throughout Its' Former Range in Central California
	Objective 10: Restore Populations of Western Yellow-Billed Cuckoo throughout Its' Historical Range in California
	Objective 11: Increase Greater Sandhill Crane Populations in California
	Objective 12: Restore Breeding Colonies of Bank Swallows throughout the Central Valley
	Objective 13: Restore Populations of Riparian Brush Rabbit throughout Its' Historical Range
	Objective 14: Restore the San Joaquin Valley Woodrat to the Full Extent of Its' Habitat
	O

Table 4-1. Continued

Goal	Objective
	Objective 15: Restore Lange's Metalmark Butterfly to Multiple Populations within Its' Natural Range
	Objective 16: Restore Delta Green Ground Beetle to Multiple Populations within Its' Presumed Natural Range
	Priority Group IV Species
	Objective 1: Reverse the Decline of Native Resident Fishes
	Objective 2: Restore Spadefoot Toad Populations to Representative Habitats throughout Its Range
	Objective 3: Restore Assemblages of Planktonic Organisms in the Delta and Suisun Bay to States of Increased Abundance and Greater Predictability in Composition
	Objective 4: Prevent Further Human-Caused Irreversible Changes to the Benthic Invertebrate Assemblages in the Bay-Delta Ecosystem
	Objective 5: Maintain or Expand Populations of Bird Species That Are Members of the Wading Bird Guild
	Objective 6: Ensure That Members of the Shorebird Guild Continue to Be abundant, Diverse, and Important Members of the Local Fauna
	Objective 7: Restore and Protect habitats Used by Neotropical Migrant Birds for Breeding and Foraging in the CALFED Area

Table 4-1. Continued

Goal	Objective
Goal 2: Ecosystem Processes and Biotic Communities *Rehabilitate natural processes in the Bay-Delta estuary and its watershed to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities.*	Objective 1: Manage the Hydrologic Regime for the Bay-Delta Estuary in Ways That Favor Native Species, Desirable Non-Native Species, and Natural Habitats Objective 2: Increase Estuarine Productivity Objective 3: Manage Channels in the Delta and Suisun Marsh in Ways That Allow Natural Processes to Create and Maintain In-Channel Islands and Shallow Water Habitat Objective 4: Create Flow and Temperature Regimes in Regulated Rivers That Favor Native Aquatic Species Objective 5: Make Sure That High Flows Occur Frequently Enough in Regulated Streams to Maintain Channel and Sediment Conditions Favorable to Native Aquatic and Riparian Organisms Objective 6: Reestablish Frequent Inundation of Floodplains by Removing, Breaching, or Setting Back Levees and, in Regulated Rivers, by Providing Flow Releases Capable of Inundating Floodplains Where Feasible Objective 7: Restore Coarse Sediment Supplies to Sediment-Starved Rivers Downstream of Reservoirs Objective 8: Increase the Extent of Freely Meandering Reaches and Other Pre-1850 River Channel Forms

Table 4-1. Continued

Goal	Objective
Goal 3: Harvestable Species	**Priority Group I Species**
Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with goals 1 and 2.	Objective 1: Maintain Fisheries for Striped Bass
	Objective 2: Maintain Fisheries for American Shad
	Objective 3: Enhance Fisheries for White Sturgeon
	Objective 4: Maintain Fisheries for Non-Native Warmwater Game Fishes
	Objective 5: Alter Practices to Augment Chinook Salmon and Steelhead Populations by the Entire State, Federal, and Private Hatchery System in Light of CALFED Goals
	Objective 6: Enhance Populations of Waterfowl for Harvest by Hunting and for Nonconsumptive Recreation
	Priority Group II Species
	Objective 1: Enhance Fisheries for Pacific Herring
	Objective 2: Maintain Fisheries for Signal Crayfish in the Delta
	Objective 3: Maintain Fisheries for Grass Shrimp in the San Francisco Bay
	Objective 4: Develop Fisheries for Abundant Underutilized Non-Native Species in the Bay-Delta System
	Objective 5: Change the Role of Trout Hatchery and Planting Programs to Make Them More Compatible with CALFED Goals
	Objective 6: Maintain or Enhance Fisheries for Marine Fishes and Shellfishes in San Francisco and San Pablo Bays
	Objective 7: Enhance Fisheries for Native Cyprinid Fishes

Table 4-1. Continued

Goal	Objective
Goal 4: Habitats *Protect or restore functional habitat types throughout the watershed for public values such as recreation, scientific research, and aesthetics.*	Objective 1: Restore Large Expanses of All Major Habitat Types in the Delta Objective 2: Restore Large Expanses of All Major Habitat Types in Suisun Bay, Suisun Marsh, and San Francisco Bay Objective 3: Restore Large Expanses of All Aquatic, Wetland, and Riparian Habitats in the Central Valley and Its Rivers Objective 4: Increase the Area of Tidal Marsh (Freshwater, Brackish, Salt) by Removing or Breaching Levees (Opening Them to Tidal Action) and by Increasing the Elevation of Subsided, Leveed Former Marsh Objective 5: Halt as Much as Is Possible the Conversion of Agricultural Land to urban and Suburban Uses in Areas Adjacent to Restored Aquatic, Riparian, and Wetland Habitats and Manage These Lands in Ways That Are Favorable to Birds and Other Wildlife Objective 6: Manage the Yolo and Sutter Bypasses as Major Areas of Seasonal Shallow Water Habitat

Table 4-1. Continued

Goal	Objective
Goal 5: Introduced Species *Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.*	Objective 1: Eliminate Further Introductions of New Species in Ballast Water of Ships Objective 2: Eliminate the Use of Imported Marine Baits Objective 3: Halt the Introduction of Freshwater Bait Organisms into the Waters of Central California Objective 4: Halt the Deliberate Introduction and Spread of Potentially Harmful Species of Fish or Other Aquatic Organisms in the Bay-Delta and Central Valley Objective 5: Halt the Release of Fish and Other Organisms from Aquaculture Operations into Central California Waters, Especially Those Imported from Other Regions Objective 6: Halt the Introduction of Invasive Aquatic and Terrestrial Plants into Central California Objective 7: Halt the Release and Spread of Aquatic Organisms from the Aquarium and Pet Trades into the Waters of Central California Objective 8: Reduce the Impact of Exotic Mammals on Native Birds and Mammals Objective 9: Develop Focused Control Efforts on Those Introduced Species for Which Control Is Most Feasible and of Greatest Benefit Objective 10: Prevent the Invasion of the Zebra Mussel into California

Table 4-1. Continued

Goal	Objective
Goal 6: Toxic Substances *Improve and maintain water and sediment quality to eliminate, to the extent possible, toxic impacts on organisms in the system, including humans.*	Objective 1: Reduce the Concentrations and Loadings of Contaminants in All Aquatic Environments in the CALFED Region Objective 2: Develop Regional Plans to Reduce the Effects of Nonpoint Source Contaminants Objective 3: Reduce Contaminant Loads in Harvested Organisms Objective 4: Reduce Contaminant Loads in At-Risk Organisms Objective 5: Reduce to Acceptable Levels the Release of Oxygen-Depleting Substances into Aquatic Systems throughout the CALFED Region

Chapter 5. The Strategic Plan

ELEMENTS OF THE STRATEGIC PLAN

The strategic plan provides a framework and guidance for achieving ecosystem restoration in the Bay-Delta system. This strategy has eight elements:

1. **Clear, measurable goals and objectives.** A clear and measurable set of goals and objectives establish the broad expectations of the ecosystem restoration program and provide a set of criteria by which success or failure of the ecosystem restoration may be judged. ERP goals and preliminary objectives are presented in Chapter 4 and Appendix B.

2. **Ecosystem-based approach.** Both the ERP and the strategic plan embody an ecosystem-based approach to restoring and managing natural resources. The ecosystem approach dictates that the program will have certain elements (e.g., integration of environmental, economic, and social issues; an adaptive approach to management and restoration) and suggests ways that other elements should be organized (e.g., a nested, hierarchical approach to compliance). The ecosystem approach is described in more detail in Chapter 2.

3. **Adaptive management.** Adaptive management will be the means by which habitat and species restoration objectives are achieved. The ecosystem approach acknowledges that because of uncertainty in the behavior of ecological processes, best management practices cannot be predetermined. When management initiatives are treated as experiments, the act of managing itself provides the information necessary to achieve restoration objectives. Comprehensive monitoring and evaluation of programs and an efficient system of information management and dissemination provide a positive environment for learning and adaptation. Adaptive management, monitoring and evaluation, and information management are described in more detail in Chapters 2 and 6.

4. **Conceptual models.** Conceptual models provide a heuristic basis for designing adaptive management initiatives. Such models assist in describing and explaining ecosystem structure and function, define explicit hypotheses about the linkages between management interventions and restoration outcomes, and provide a framework for quantitative simulation and evaluation of alternative hypotheses in adaptive management. The design and use of conceptual models are described in Chapter 6, Appendix C, and Appendix D.

5. **Staged implementation.** Staged implementation allows early implementation of actions that are relatively uncontroversial or that offer substantial restoration benefits. More uncertain and controversial activities may be delayed until targeted research, modeling, or demonstration experiments reveal the likelihood that benefits will outweigh costs. In addition, because CALFED actions related to water quality, water supply, and levee integrity may affect ecological restoration, the ERP must be linked to and coordinated with the other components of CALFED. Thus, ERP projects will be staged as part of coordination with other activities in CALFED. Some aspects of staging are discussed later in this chapter and in Chapter 6.

6. **Compliance strategy.** Complying with regulations and legislative mandates allows for smooth and timely approval of management actions by providing solid scientific and legally defensible bases for proposed actions. Compliance with the regulatory framework is crucial because formal challenges to management actions can create costly and destructive delays in meeting program objectives. Compliance in the context of ecosystem management and adaptive management is discussed in detail in Chapter 7.

7. **Scientific and public involvement.** Routine external scientific and professional review of programs and monitoring results, coupled with peer-reviewed publication of major findings, will ensure the scientific credibility of the program. Open and efficient consultation with the public and stakeholders will ensure that the program meets public and stakeholder expectations as well as regulatory requirements. Information management and communication are discussed in Chapter 6.

8. **Dispute resolution.** The program will include an effective dispute resolution system to address issues where consensus cannot be reached. The management of water and resources can generate considerable conflict. Invariably, competing interests will be unable to agree about some issues. In such instances, the options are to set the issue aside or invoke some form of dispute resolution. Where uncertainty is high and restoration is at stake, setting aside the issue may not be an option. The means of resolving disputes should be credible and agreed to in advance of substantive management action. Dispute resolution is discussed in Chapter 6.

How these eight elements will work together in ecosystem restoration is illustrated, by an example of ecological restoration to benefit spring-run chinook salmon in Deer Creek (Appendix D) and an outline and action plan for Stage 1 of the program (Chapter 8). Finally, comment and guidance on the long-term development of the program are presented in Chapter 9. The long-term development of the program is sketched in very broad terms because what can or should be done in the future depends entirely on the outcome of Stage 1 activities.

DEFINING ECOSYSTEM RESTORATION

Although the ERP is about ecosystem restoration, ecosystem restoration is not defined in either Volume I or II of the ERPP. Ecosystem restoration is a contentious issue in resource management, and a significant amount of confusion surrounds the concept (Richardson and Healey 1996). The term itself seems to imply that the ecosystem will be put back into a structural and functional configuration defined by some historic baseline. Historic analysis of ecosystem transformation is important in defining how the system has changed over time and in helping to identify patterns of structure and function that may be useful in restoration. However, ecosystem restoration is not regarded as the process of recreating any particular historic configuration. Rather, ecosystem restoration is the process by which resource managers ensure that the capacity of the system to provide valued ecological goods and services to society is maintained or enhanced.

Historically, water and land use have emphasized certain kinds of economic and social benefits without sufficient consideration for the concomitant loss of other benefits when ecological systems were altered and transformed (Healey 1998). As a consequence, the Bay-Delta system is home to an increasing number of introduced nuisance species, many native species have been reduced to the status of threatened or endangered under the federal Endangered Species Act or California Endangered Species Act, economic values associated with many native species and habitats have been lost or severely degraded, and biodiversity and natural amenity values have been lost.

In this context, ecosystem restoration means reestablishing a balance in ecosystem structure and function so that the lost ecological goods and services may be regained in some reasonable measure while the kind of diverse and vibrant socioeconomic climate for which the region is famous are maintained. Although change and adjustment will be required, there is no benefit to ecosystem restoration if it destroys the fabric of the society it is intended to serve. The broad goal of ecosystem restoration, therefore, is to find patterns of human use and interaction with the natural environment that provide greater overall long-term benefits to society as a whole.

THE ECOSYSTEM APPROACH

Since 1992, each of the primary land management agencies in the United States (National Park Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Forest Service) has independently announced that it is implementing an ecosystem approach to managing the resources under its stewardship (Hennessey 1997). Although ecosystem management has become the underlying management philosophy of these agencies, there is still considerable controversy regarding what, exactly, constitutes ecosystem management (Healey 1998, Hennessey 1997). In its monograph on the scientific basis of ecosystem management, the Ecological Society

of America (1995) identified eight elements of ecosystem-based management that illustrate well the character of this emerging paradigm:

1. **Long-term sustainability is a fundamental value.** This element highlights the importance of intergenerational equity. Resources should be managed today to ensure that the needs of future generations will not be compromised (World Commission on Environment and Development 1987). In ecological terms, this is coming to be defined as passing on to future generations a set of natural capital resources equivalent to that which the present generation has available (Costanza and Daly 1992). Ecosystem restoration under CALFED addresses this element in its emphasis on recovering native species and biodiversity and in its emphasis on naturally sustaining ecosystem processes.

2. **Decisions must be based on clearly defined goals and objectives.** This element highlights the need to be clear about what we want to achieve through management. Goals and objectives are to be stated in terms of desired future states, behaviors, or trajectories for ecosystem structure and function. Objectives are also to be stated in terms that can be measured and monitored. In this way, ecosystem management is not tied to an undefinable and unattainable "pristine" condition but provides considerable latitude for negotiating and defining desirable future conditions. Furthermore, because goals are to be stated in terms of measurable criteria, progress can be explicitly evaluated. The ERP and the strategic plan have developed tangible and measurable goals and objectives.

3. **Decisions must be based on sound ecological models and understanding.** This element highlights the importance of rational, science-based models to decision making in ecosystem-based management. However, because humans are integral to the ecosystem to be managed, it also highlights the importance of models that integrate social, economic, and environmental components of the larger system. Conceptual models as heuristics and as a foundation for modeling expected outcomes in adaptive management are part of the strategic plan.

4. **Complexity and connectedness are fundamental characteristics of healthy ecosystems.** Evidence from management failures of the past suggests that there is considerable risk in attempting to manage individual resources independently of one another. By focusing attention on connectedness, ecosystem management reduces the risk of such failures. Restoration of Delta and estuarine ecosystems inevitably involves a concern with connectedness because of the importance of fluvial and tidal dynamics to their functioning. Recognition of the importance of interconnected habitats is also paramount when anadromous salmonids are one subject for restoration. The nested hierarchy of ecosystem units in the solution zone is a further acknowledgment of the interconnectedness among elements of structure and function in the solution area.

5. **Ecosystems are dynamic.** This element highlights the fact that ecosystems are complex, self-organizing systems. With complexity comes uncertainty and imprecision in prediction. Ecosystem-based management cannot eliminate surprises or uncertainty.

Rather, it acknowledges that unlikely and even unimagined events may happen. The management process must be designed to cope with such events. Adaptive management is one powerful tool for embracing uncertainty, which is integral to CALFED. The program also recognizes the importance of dynamic processes in its concern over effects of the seasonal hydrograph on particular species and in its plan to recreate meander corridors along river courses. Other dynamic elements may have to be built into the restoration program over time, however, and adaptive experimentation can help to define the necessary degree of dynamic change to maintain ecosystem function.

6. **Context and scale are important.** This element highlights the fact that each aspect of ecosystem structure and function has its own time and space scale. Spatial and temporal domains of management planning and implementation need to be made congruent with those of critical ecological processes in the system to be managed. This element of ecosystem management is still relatively weak in the ERP. Management activities tend to be tied to social and economic schedules, not ecological schedules. Staged implementation, monitoring, and assessment schedules and adaptive experimentation all provide tools for strengthening the spatial and temporal patterning of restoration.

7. **Humans are integral components of all ecosystems.** This element highlights the fact that humans are the single greatest modifier of ecosystem structure and function. Humans will also suffer the most serious consequences of changes that make ecosystems less able to sustain human life. Therefore, management of human activities must be an integral component of plans to manage ecosystems. This element may seem rather obvious but serves to emphasize the importance of linking the ERP with activities related to water quality, water supply reliability, and levee integrity. This element also reminds us that ecosystem management is a human problem, not an ecological one.

8. **Ecosystem management must be adaptable and accountable.** This element highlights the fact that our understanding of ecosystems is incomplete and subject to change so that management planning and programs cannot be categorical. Every program of management is an experiment and should be treated as such. Again, we emphasize that in calling management programs "experiments", we are simply recognizing the opportunity to integrate the problem-solving power of the scientific method into resource management. Management actions will still be taken because they are believed to be the best solutions to perceived problems. Treating the actions as experiments, however, means that we deliberately plan to take advantage of the opportunity to learn from each management action so as to improve the process of management over time. This is adaptive management, and it is at the core of ecosystem management.

PROGRAM COMPONENTS

Within the ERP, program components are described as implementation objectives, targets, and programmatic activities. The targets and programmatic activities provide a very broad set of

activities related to restoration and management of habitats and target species. Targets are both quantitative and qualitative, and programmatic actions specify how each target is to be achieved. Targets and their associated programmatic activities can be further divided into three classes:

- those that have sufficient certainty of success to justify full implementation in accordance with adaptive management, program priority setting, and phased implementation;
- those that will be implemented in stages with appropriate monitoring to judge benefit and success; and
- those for which additional research demonstration and evaluation are needed to determine feasibility or ecosystem response.

Each of the 14 ecological zones has its own set of implementation objectives and targets based on the particular problems and opportunities inherent in each zone.

The ecosystem restoration activities described in the ERP fall broadly into four categories: making more habitat, improving existing habitat, restoring ecological processes, and reducing human-caused stresses. Although all categories are probably important to the range of species, restoring ecological processes and reducing human-caused stresses are more frequently identified in the rehabilitation of fish species, whereas increasing and improving habitat are more frequently noted for insects, amphibians, reptiles, birds, and mammals.

Although the ERP provides an important description and rationale for a wide range of activities to benefit target species and rehabilitate ecosystem functions, several critical elements of a strategy are missing. The listed activities need to be revisited and reprioritized in terms of the objectives and procedures outlined in the strategic plan. In this way, they can be developed in the context of conceptual models of ecosystem function and explored as alternative policies in simulation models. This process, which is central to adaptive management, provides an objective basis for prioritizing the various activities in terms of perceived benefits and costs; for determining appropriate quantities of restoration to achieve stated objectives; and for determining whether to proceed with large-scale restoration, pilot projects, or targeted research. Viewed in this way, the ERP provides a list of opportunities, whereas the strategic plan provides a means to analyze, prioritize, and implement those opportunities in the most effective way.

STAGED IMPLEMENTATION

The strategic plan envisions three levels of staging to accomplish ecosystem restoration in an efficient manner. At the highest level, the ERP must be integrated with other CALFED actions so that restoration activities will not be compromised by activities aimed at water quality, water supply, or levee integrity. Furthermore, activities related to water quality, water supply, and levee integrity may open up opportunities by which ecosystem restoration could benefit. It is our view that

all components of CALFED would benefit from an adaptive approach, not just ecological restoration. An adaptive management framework could provide an effective means for linking, integrating, and staging projects in all aspects of CALFED. In addition, ecosystem restoration may be linked to and benefit from activities outside CALFED, such as the CVPIA and the Corps' plans for flood management in the Central Valley. For example, making Battle Creek accessible to chinook salmon is being undertaken under the CVPIA, and this action is important to ecosystem restoration under CALFED. The Corps' plans for flood management will have significant implications for projects such as levee setback, ecosystem restoration in flood channels, and Deer Creek restoration.

At the second level is the staging of projects in the ERP. Although the strategic plan does not attempt to analyze this in any formal way, it seems obvious that there is an optimal sequencing of projects to achieve species and ecosystem goals within ecosystem restoration. For example, floodplain restoration on the San Joaquin River may not be effective until, or unless, sufficient water is available to inundate floodplains and restore channel activity. Similarly, restoring channel migration as a means of augmenting bedload supply may not be effective if downstream gravel mining removes much of what is added. These are simply obvious examples. Simulation modeling of alternative conceptual models may reveal more subtle connections that would require appropriate staging of projects.

At the lowest level is staging within projects. This refers to the relationships among research, pilot projects, and large-scale restoration, as well as rules for moving among these levels of activity. The information flow within adaptive management provides only a partial basis for such decisions. For example, it can always be argued that information is insufficient to justify large-scale implementation. The uncertainty associated with this decision can be partially mitigated by designing the large-scale intervention as an adaptive experiment so that additional information is derived from the large-scale project. Often more difficult, however, are decisions about when to scale back or stop certain restoration activities. The individuals and agencies involved in such projects naturally develop ownership and personal investment in the projects and often find it difficult to judge them objectively. Decisions at this level and, indeed, at the other levels will be greatly assisted by having an independent scientific review committee to help keep the program on track and proceeding toward a successful conclusion.

USE OF CONCEPTUAL MODELS IN DECISION MAKING AND DIRECTING INVESTIGATIONS

Restoration or rehabilitation programs for complex ecosystems must be based on clear concepts about how the system is believed to function, how it has been altered or degraded, and how various actions might improve conditions in the system. This section discusses the uses (and abuses) of conceptual models in this context and provides examples of how conceptual models can be used to explore management alternatives and identify needs for research and monitoring.

Conceptual models are simplified illustrations of what we think are the most critical cause-and-effect pathways (i.e., how ecosystems function). There is no unique set of conceptual models that provides a basis for ecosystem restoration and that can be determined a priori. We sound a note of caution, therefore, about the enthusiasm over conceptual modeling that has swept the CALFED community. Developing a comprehensive suite of conceptual models would be a dry and uninformative exercise and would not advance our ability to understand or manage the ecosystem. The first rule of conceptual or quantitative modeling is that the model should be designed for a particular purpose and should contain only those elements relevant to solving a particular problem, including alternative explanations that might yield alternative solutions. The models presented below and in Appendix C are, therefore, simply illustrations of such models and their uses.

Development of Conceptual Models

There is no recipe for developing conceptual models, nor is there a template for what they should look like. A conceptual model is simply an explicit representation of a set of concepts held by its author(s). Everyone has implicit conceptual models about the world, and most people working in Bay-Delta system science or management have implicit models about how the ecosystem works and how it might respond to manipulations. Conceptual modeling is the process of making these implicit models explicit.

Conceptual models are based on concepts that can and should change as monitoring, research, and adaptive probing provide new knowledge about the ecosystem. When key concepts change, the conceptual models should be updated to reflect those changes, thereby paving the way toward changes in management. This will not happen by itself but must be accomplished through a systematic, periodic (e.g., every 3 years) reevaluation of the conceptual models.

Uses of Conceptual Models

Conceptual models can be used as heuristic tools to explain theories. They also can provide a basis for quantitative modeling or identify critical information needs for research or monitoring. In ecosystem restoration, they can be used to link human activities or management actions to outcomes important to society. In adaptive management, the most important uses of conceptual models are for: (1) linking human activities to valued outcomes, (2) highlighting key uncertainties where research or adaptive probing might be necessary, and (3) identifying monitoring needs. However, it is also useful to develop conceptual models with a view to their further elaboration into quantitative numerical models. These can be used as a basis for predicting, and thereby testing, the amount of intervention required to produce a desired result in a program of adaptive management.

In developing conceptual models for adaptive management, it is helpful to include reasonable alternative hypotheses about how the system works. This can foster acceptance by interested parties whose alternative views of the scientific basis for management have been included. Including

alternative hypotheses also helps to identify areas where uncertainties preclude a single, possibly irreversible, management action. Finally, including alternative hypotheses in the models provides a framework for preliminary evaluation of the costs and benefits of conducting adaptive experiments to distinguish between the competing hypotheses.

Conceptual models of the links between management actions and valued ecosystem products also provide a basis for designing monitoring and evaluation programs to assess the benefits of management interventions. For monitoring and evaluation to be effective, it is essential that they be tied to explicit models of system behavior.

Examples of Conceptual Models

This section provides an explicit example of a conceptual model (the effects of freshwater flow on fish and invertebrates in the upper estuary) to illustrate the ways such models can be used. Several additional examples of conceptual models are described in Appendix C. The models presented here and in the appendix cover the hierarchy of spatial scales important to ecological restoration, from the landscape scale to the scale of specific ecological processes.

In the "Fish-X2" relationships (Jassby et al. 1995), abundance or survival of several estuarine and anadromous species is related to X2, the distance up the axis of the estuary at which daily average near-bottom salinity is 2 practical salinity units (psus). Because X2 is controlled by freshwater outflow from the Delta, it varies with both inflow and export flows. However, the relationship is entirely empirical and provides no indication of the mechanism controlling abundance or survival. The principal issue addressed here is how different concepts of the mechanism underlying the Fish-X2 relationship define different management tools for maintaining or enhancing populations of estuarine species.

Figure 5-1 illustrates the diverse mechanisms that could account for the X2 relationship for different species. The principal causative variables are freshwater flow and exports, both controllable at least to some extent, and tides, which are not under human control. Briefly, the relationships could arise (as similar ones do in estuaries in other parts of the world) as a result of stimulation of growth at the bottom of the food chain, which then propagates upward, eventually to fish. On the other hand, evidence from this estuary suggests that two kinds of direct physical effects on fish are the more likely mechanisms (Kimmerer 1998). First, flow conditions in the estuary set up by tides and freshwater input, and in some cases by export flows, may alter the retention of some species in the estuary, thereby affecting population size. Second, the amount of physical habitat may change with freshwater flow through such effects as inundation of floodplains or expansion of low-salinity shallow water habitat.

Now consider how potential management interventions are affected by these three scenarios. If the mechanism is stimulation at the base of the food chain, appropriate management actions include addition of nutrients or organic matter to the estuary. If retention is the issue, flows could be manipulated to lengthen or shorten the period of retention in the estuary. If habitat is the issue,

E-026201

E-026201

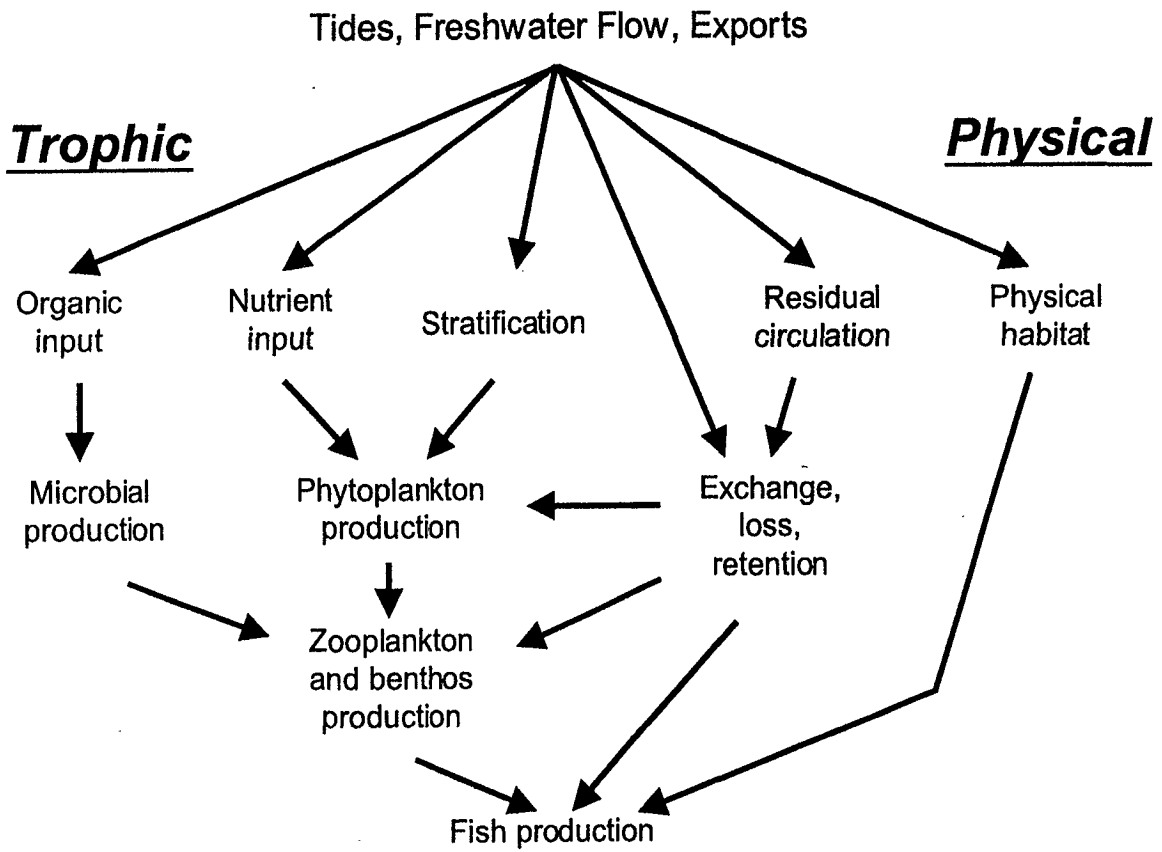
physical restoration of habitat or judicious use of flow to increase the amount of habitat at critical times might be in order.

Thus, a very simple model illustrates how critically the management options depend on the assumed cause-and-effect mechanism as well as how various kinds of management interventions can be suggested by a conceptual model. To provide further detail, we use part of the Estuarine Ecology Team's report on the Fish-X2 relationships (Estuarine Ecology Team 1997). That report included a matrix (Figure 5-2) that summarized knowledge about each of the potential mechanisms underlying the Fish-X2 relationships. For each mechanism and each species, the importance of the mechanism is denoted by the size of the symbol. In addition, open symbols denote mechanism for which there is some scientific information, and closed symbols denote mechanisms about which virtually nothing is known.

Each of the mechanisms has a precise definition (Estuarine Ecology Team 1997), but we consider only a few of them here. First, examine the row labeled "Reduced Entrainment (CVP-SWP)". In addition to a number of smaller symbols, large open symbols are given for all the anadromous species except for splittail. Thus, the Estuarine Ecology Team believed that for these species, entrainment could explain at least part of the observed Fish-X2 relationships. Now examine the row labeled "Gravitational Circulation Strength". There are six large filled circles, including those for species that recruit from the ocean as well as several for those that move down-estuary during development and then reside primarily in Suisun or San Pablo Bay and the Delta. In this case, the team believed gravitational circulation to be an important mechanism although there was virtually no specific information on its effects. Similarly, "Rearing Habitat Space" was considered an important probable mechanism for the largest number of species although knowledge of this topic is limited. In these latter two examples, the Estuarine Ecology Team was exercising professional judgment in the absence of hard scientific information. Similar kinds of judgments will have to be made in decisions about ecological restoration. However, in employing adaptive management, CALFED will be able to design its approach to management to learn about the mechanisms governing ecological function and species abundance while restoration is proceeding.

E-026202

E-026202



Note: The labels "trophic" and "physical" indicate that causative pathways on the left side of the diagram are more biological, based on feeding relationships, whereas those on the right side describe mechanisms that arise through interactions with physical conditions and abundances of species of interest. Tides, freshwater flow, and exports influence organic and nutrient inputs, stratification and gravitational circulation, and the extent of physical habitat with various characteristics. Organic and nutrient input can stimulate growth at the bottom of the food web, which may progress to higher trophic levels, such as fish. Export flow, together with residual and tidal circulation in the estuary, may interact with behavior to affect losses from the estuary or, alternatively, retention. Thus, fish may benefit from increased flow through increased food supply, improved retention in their habitat, or an increase in the quantity or availability of physical habitat.

Figure 5-1
Schematic Diagram Showing Potential Causative Pathways Underlying the "Fish-X2" Relationships

E-026203
E-026203

E-026204

Species

X_2 Mechanisms	CF	PH	SF	WS	AS	SB	LF	DS	ST	CS	NM
Spawning habitat space		○		●	⬤	○	●	⬤	○	○	
Spawning habitat access				●	◉	○			○	○	
Cooccurrence of food		⬤		●	●	⬤	⬤	⬤	⬤	●	●
Rearing habitat space	○	⬤	⬤	⬤	⬤	○	○	⬤	⬤	●	●
Predation avoidance: turbidity		●			●	○	●	●	●	○	⬤
Predation avoidance: shallow	●	●	●						●	○	
Predation avoidance: encounter	●						●	⬤	●	●	
Reduced entrainment (CVP-SWP)			●	○	○	○	○	○	●	○	○
Reduced entrainment (PG&E)	●		●		○	○	⬤	⬤	●	○	●
Reduced entrainment (agricultural)			●		●	○	●	⬤	●	●	●
Toxic dilution	●	●	●	●	●	○	●	●	⬤	●	●
Transport	●			○	○	○	○	●	●		
Gravitational circulation strength	⬤	○	⬤			⬤	⬤	⬤			⬤
Entrapment zone residence time						⬤	⬤	⬤			⬤
Temperature (as affected by flow)					●	●				○	●
Strong migratory cues	●	●	●	◉	○	●			●	○	
Higher production of food	●	●			⬤	⬤	⬤	⬤	●		⬤

Relative Uncertainty

● Higher

○ Lower

Importance

⬤ High

● Low

◉ Upstream effect

Note: Symbols indicate a potential mechanism according to the key at right. Several minor mechanisms have been eliminated to simplify the diagram. "Upstream" effects refer to flow effects that occur entirely upstream of the Delta. The species abbreviations are defined as follows:

CF = bay shrimp, *Crangon franciscorum*
PH = Pacific herring
SF = starry flounder
WS = white sturgeon
AS = American shad
SB = striped bass
LF = longfin smelt
DS = delta smelt
ST = splittail
CS = Chinook salmon (note: few major effects are in the Delta)
NM = *Neomysis* and other mysids

Figure 5-2
Estuarine Ecology Team's Summary of Potential Causes Underlying "Fish-X2" Relationships

E—026204

Chapter 6. Adaptive Management

ECOSYSTEM MANAGEMENT IN AN EXPERIMENTAL MODE

Holling (1998) classified the practice of ecology according to two cultures, a dichotomy that can also describe management of ecological systems. The first, traditional culture, is analytical and based on formally testing hypotheses to assess single causative relationships and attempting to find the single correct answer to questions and the single correct approach to solving problems. The second culture is integrative and exploratory, based on a comparative analysis of multiple hypotheses and an acknowledgment of uncertainty in management. Previous management of the Bay-Delta system has proceeded according to the first set of cultural practices. The recommendation of the strategic plan is to adopt the second culture for future management of the Bay-Delta system. A description of how that can be done is provided in this chapter and some institutional attributes that will ease the transition are proposed.

Building Adaptive Management into the ERP

Restoring ecosystem quality in the Bay-Delta system presents a tremendous challenge. First, the problem is not well defined. What does "restoring ecosystem quality" mean in the practical sense, and how will we know if we have achieved it? Who decides what constitutes acceptable ecosystem quality? What kinds of intervention and how much intervention will restore ecosystem quality? The Core Team has attempted to address this uncertainty by specifying clear goals and objectives, but this is only one important step toward defining the problem.

Second, whatever the real problem is, it is manifest at various time and space scales. Human intervention at any scale will propagate inward and outward to have consequences at all scales. It is not at all clear at what scale it is most advantageous to intervene to achieve any particular objective, and the most advantageous kinds of interventions are neither well known or tested.

Third, any intervention will be costly in resources spent or opportunities foregone. Without some effective and objective means of prejudging interventions and evaluating the consequences of those that are implemented, scarce resources may be wasted in ineffectual management actions.

These characteristics, a diffuse problem that is manifest in various ways and for which remedial actions are highly uncertain, are typical of issues in natural resources management. Historically, we have disregarded most of this complexity in resource management and treated such problems as though they were well defined in time and space and amenable to analysis

E-026205

E-026205

(understanding) and remediation by standard methods. As failures in resource management based on this approach have become more visible and more serious, resource managers have shown increasing interest in methods that explicitly recognize the uncertainty inherent in management actions (Holling 1998).

A suite of techniques collectively termed "adaptive environmental assessment and management" or simply "adaptive management" (Holling 1978, Walters 1986) is gaining popularity as a practical approach to management under uncertainty. Although by no means universally accepted, adaptive management has been used in the design of large-scale environmental restoration projects (Lee 1993). Because the present depleted state of many valued species and habitats in the Bay-Delta system is largely a consequence of the application of the traditional form of analysis and remediation in resource management, it is doubtful that more of the same will be sufficient to restore the ecosystem. Adaptive management is the most promising alternative approach available.

According to Walters (1986), designing an adaptive management strategy involves four basic issues:

1. bounding the management problem in terms of objectives, practical constraints on action, and the breadth of factors to be considered in designing and implementing management policy and programs;

2. representing the existing understanding of the system(s) to be managed in terms of explicit models of dynamic behavior that spell out both assumptions and predictions clearly enough that errors or inconsistencies can be detected and used as a basis for learning about the system;

3. representing uncertainty and how it propagates through time and space in relation to a range of potential management actions that reflect alternative hypotheses about the system and its dynamics; and

4. designing and implementing balanced management policies and programs that provide for continuing resource production while simultaneously probing for better understanding and untested opportunity.

Put another way, adaptive management involves: 1) having clear goals and objectives for management that take into account constraints and opportunities inherent in the system to be managed; 2) using models to explore the consequences of a range of management policy and program options in relation to contrasting hypotheses about system behavior and uncertainty; and 3) selecting and implementing policies and programs that sustain or improve the production of desired ecosystem services while, at the same time, generating new kinds of information about ecosystem function.

All of these steps are rooted in what is known about the species and ecosystems to be managed, and all involve careful evaluation and synthesis of existing information. The collation, analysis, and interpretation of existing information is another critical preliminary activity in adaptive

management; however, the definition of what constitutes information is quite broad. The perceptions of experienced individuals, qualitative observation, and historical anecdote can be part of the information base, supplementing systematically collected scientific observations. The information base must be open and subject to scrutiny by all interests, and hypotheses about the system and management actions follow logically from the information base.

The critical variable in adaptive management is uncertainty: uncertainty in the dynamics of complex systems and uncertainty in the consequences of various potential management interventions. In a program such as CALFED, the uncertainty is compounded by the need to effect change at large time and space scales. The only way to learn about such systems and their dynamics is through large-scale manipulations of the system. CALFED is such a large-scale manipulation of the environment that it is impractical, in fact, impossible, to gather the information necessary to predict the consequences of the program without undertaking it; therefore, the program to solve the problem becomes the means by which to learn about the problem. The trick in adaptive management is to design the management program to ensure that potentially beneficial actions are not postponed because of uncertainty, and to structure the projects so that alternative concepts are probed and learning is an active consequence of management. As Lee (1993) argued, information has value both as a stimulus for action and as a product of action. The information value of the product of action is the component of value routinely ignored in traditional approaches to management (Healey and Hennessey 1994).

To realize the full information value of management actions, they should be designed and evaluated as experiments in the same way that new medical therapies are first implemented as clinical trials to ensure their effectiveness. Clinical trials are initiated only if there is a reasonable expectation that new therapies will be successful, but success cannot be guaranteed. Therefore the therapies are tested on many patients, the trial is carefully monitored, and the progress of the trial is evaluated at regular intervals to determine whether to continue with the trial, abandon the trial, or declare the new therapy a success.

Also as in clinical trials, an adaptive management program should incorporate Bayesian statistical techniques to judge progress and update probabilities among competing hypotheses. These techniques differ from the traditional hypothesis-testing approaches that play such a dominant role in ecological practice. Bayesian techniques are used to determine the probability that a hypothesis is true given the available information; when more than one hypothesis is proposed, probabilities can be compared among hypotheses. Decision rules can therefore be built into the program that are more socially and ecologically relevant than the 0.05 significance criterion commonly used in ecology. This approach is more in keeping with the notion of the second alternative culture of ecology (Holling 1998).

Following the analogy with clinical trials, it would be prudent to approach large-scale ecosystem interventions as experiments so that unsuccessful interventions will not be perpetuated and expanded and successful interventions can be modified to use resources efficiently (e.g., land, water, tax dollars). Designing management interventions as experiments can have significant benefits when it comes to evaluating success or failure, increasing understanding of system

dynamics, and making better decisions in the future (Walters et al. 1988, 1989; Walters and Holling 1990).

Modes of Adaptive Management

Walters (1986) recognized three approaches to management:

- trial and error, in which early management options are chosen at random and later choices are made from a subset of the early options that performed best;
- passive adaptive, in which a best management option is chosen on the basis of the current beliefs about system dynamics and this option is fine-tuned in relation to experience; and
- active adaptive, in which two or more alternative hypotheses about system dynamics are explored through management actions.

The first approach is illustrated by early attempts at stream habitat rehabilitation in which supposedly beneficial alterations were made to streams, and those that proved successful (e.g., stayed in the stream, attracted fish) became favored interventions. Some element of trial and error is a part of virtually every management policy.

Passive adaptive management is perhaps the most common form of management intervention these days. It is highly defensible in that the best management action is chosen based on the best available scientific information (although which information is best may be subject to debate). It fits well with the incremental remedial approach to policy evolution that is common to public agencies (Lindblom 1959). It is administratively simple because all "units" are treated alike, and information needs and information management are relatively simple. Learning about the system using this approach, however, is confined to a very narrow window, and there is practically no possibility of determining whether the underlying hypothesis about the system is right or wrong; therefore, although passive adaptive management takes uncertainty into account, it has only limited capacity to reduce uncertainty.

Passive adaptive management will be an important component of the ERP's adaptive management strategy. CALFED itself, complex as it is, can be implemented only in a passive adaptive way. There is no alternative "policy" to the program that can be implemented as a contrasting experiment. Many elements of the ERP may have to be implemented as passive adaptive projects. Passive adaptive management may be dictated because the value of knowing that option A is a better description of system dynamics than option B is less than the cost of obtaining the information, or the alternative action poses too great a threat to public safety or valuable infrastructure, or for a variety of other reasons. Despite its limitations as a tool for learning about the system, a properly designed passive adaptive experiment can provide important insights into workable, if not optimal, solutions.

Unfortunately, strict adherence to experimental protocols is impossible in such a large-scale, passive adaptive program such as the ERP. There is, after all, only one Bay-Delta system, and its various component parts are all strongly interconnected. Independent replication of control and treatment measures is impossible in either space or time, violating an important principle of experimental design. The degree to which cause and effect can be determined should be tempered by this unavoidable limitation. All manipulations within the ERP should be based on careful and creative design to enhance the opportunity for learning and an analytical program that will allow as much distinction between confounded effects as possible.

Active adaptive management is the most powerful approach for learning about the system under management but also is often the most contentious. Active adaptive management programs tend to create the impression that managers or scientists are going to toy with the resources on which other people's livelihoods depend. Nevertheless, there is an important role for active adaptive management in the ERP, notwithstanding the critical status of many of the species the ERP is intended to benefit. It is important to realize that the purpose of active adaptive management is not to push the system to its limits and see how it responds. The purpose is to use management as a tool to generate information about the system when the long-term value of the information clearly outweighs the short-term costs of obtaining it.

It may be useful to distinguish between two kinds of active adaptive management. For many situations, it may be clear what kind of intervention is needed (e.g., increased spring and summer flows into the Delta for salmonid conservation), but the magnitude of the intervention is uncertain. The concern is not with the form of the model relating flow to conservation, but with the parameters of the model. An active adaptive management experiment could be designed to improve the estimation of parameters by manipulating spring and summer flow in appropriate ways. For purposes of this discussion, this kind of adaptive experiment will be referred to as "adaptive probing". In some instances, adaptive probing can be designed around natural fluctuations in environmental variables. A good example is the experiment conducted to improve estimates of optimal sockeye salmon escapement to the Fraser River. The principal issue was the level of escapement that would maximize yield to the fishery. The benefit-cost ratio of the experiment to test the benefits of higher escapements was very high, but involved fishers foregoing catch to achieve higher escapements in the short term. The experiment was initiated in the 1980s with very positive results in terms of yields in the late 1980s and early 1990s. Another example of adaptive probing is the Vernalis Adaptive Management Program (VAMP).

In other instances, the greatest uncertainty may be about the best kind of intervention. For example, which would be the preferable conservation measure for spring-run chinook: increased spawning escapement or reduced cross-channel transport? In this case, the concern is with the form of the model (although obviously the size of the intervention is also important). Again, an adaptive probing experiment could be designed to determine which model (escapement or Delta transport) was the more important in chinook conservation. For purposes of this discussion, experiments designed to distinguish among fundamentally different models (hypotheses) will be referred to as "adaptive exploration". The Bay-Delta ecosystem is replete with such unresolved alternatives. The ERP should capitalize on opportunities to distinguish among such alternatives through active adaptive experimentation. Tools for assigning probabilities to models and updating probabilities in

the light of new information, as well as rules for efficient design of adaptive experiments, are provided in Walters (1986) and Hilborn and Mangel (1996).

Selection process

The ERP is not a single project but hundreds of actions that must be interlinked into a coherent whole. The size and complexity of the ERP introduces additional dimensions into the problem of adaptive design. Because it is quite possible that the success of some projects may depend on the outcomes of others and that some interventions may be synergistic while others are antagonistic, both the sequencing of projects and their arrangement in space and time are potentially important to the success of the ERP. A hierarchical set of rules for deciding among projects needs to be developed to guide decision making. These rules might be incorporated into formal models of decision making. As a preliminary list, the decision rules might emphasize projects that:

- will have the greatest absolute benefits and the greatest benefit-cost ratio for native species;
- will provide the most useful information about system dynamics;
- will provide results within a short timeframe;
- will be the most self-sustaining in the long term;
- are complementary in their effects unless the conflict provides important information about system dynamics; and
- have high public support and visibility.

Given the opportunities for ecosystem restoration under the ERP, it is likely that many individual projects will not have measurable consequences for the species of concern; therefore, it may be helpful to classify projects into three types: 1) small projects that individually will have small impacts on the system or species recovery but that collectively may have important overall impacts or serve complementary functions (e.g., small-scale riparian restoration, screening of irrigation intakes), 2) large-scale projects that individually should have measurable impacts on the system or target species and can be implemented as passive adaptive experiments, and 3) adaptive probing or adaptive exploration projects designed to distinguish among competing hypotheses.

For smaller projects, the criterion of success should be more modest than species recovery. Suitable criterion for small projects might be that the desired habitat attributes (ecological structure and function) were created, the desired habitat attributes were maintained over time with limited human intervention, or the species of concern made use of the habitat in the ways hypothesized. Even at this level of evaluation, it should be possible to build some important learning opportunities

into management with little overall risk to any sensitive species. For example, experiments designed to test competing hypotheses about the most efficient and effective kinds of habitat design could be done at this scale with the provision that there is an important limitation on interpretation (e.g., population-level effects cannot be inferred from local responses [Riley and Fausch 1995]); however, groups of smaller projects might constitute a significant intervention that collectively would qualify them as large-scale projects for which population-level effects may be detectable.

Large projects provide the opportunity for evaluating overall population responses, as well as creating and maintaining structural and functional aspects of habitat. Because of the diversity of activities contemplated under the ERP and its relatively short time horizon compared to the timescale for ecosystem response, incorporating efficient experimental design of even large projects may be difficult, and the effects of different projects are likely to be uninterpretable. Opening up the floodplain, changing hydrographs, and removing dams to provide access to significant amounts of habitat would constitute large-scale projects with potentially dramatic effects. Whether and how large-scale projects should be staged to ensure that their independent effects can be distinguished is not obvious. Such decisions could be assisted by modeling outcomes based on the expected value of perfect information (e.g., Walters 1986).

As noted earlier, adaptive probing or adaptive exploration experiments are likely to be contentious; however, in some instances they may be the only way to determine the practical benefits of specific kinds of management interventions. For example, if it is hypothesized that increasing spring and summer flows through the Delta will benefit anadromous salmon, an adaptive probing experiment seems to be the only feasible way to determine how large a flow will be required to achieve a particular benefit. Because any manipulation or reallocation of water is likely to be costly, experiments with flow must have a very high information value. By comparison, smaller scale experiments may be relatively easy to implement and can provide significant learning opportunities.

The knowledge and hypotheses about ecosystem structure and function summarized in conceptual models can lead directly to potential restoration actions; however, each model is likely to suggest many possible courses of action. In evaluating alternative actions, it is usually very helpful to conduct exploratory simulation modeling based on the conceptual models (Figure 2-3). These simulations are not intended to capture the complexity and richness of ecological processes, but to capture the essential elements of ecological structure and function that underlie management decision making. They are greatly simplified, clear caricatures of the system, just as the conceptual models are clear caricatures. Their purpose is to allow explicit exploration of the main pathways of causal interaction and feedback processes in the conceptual models and provide preliminary predictions of the consequences of different management actions. The simple simulations can aid the decision-making process in many ways. For example, simulation modeling can:

- identify logical inconsistencies in the conceptual models,
- clarify where the nodes of greatest uncertainty are in the conceptual models and where new information would be most useful to decision making,

- allow comparison of the benefits and costs of alternative models of the system and alternative management actions,

- provide a basis for determining how much of a particular kind of restoration action will be required to achieve measurable benefits within a specified period of time,

- provide a basis for determining the value to the ecosystem of new information that might be obtained through adaptive experimentation, and

- help communicate to a broader audience the current understanding of the problem and the explicit rationale for particular restoration measures or targeted research.

The following example illustrates the process. as well as how targeted research, pilot projects, and large-scale restoration might go hand in hand. Two models for creation of shallow-water, shaded nearshore habitat in river and Delta channels might be either to set levees back to widen the channel and encourage shallow vegetated habitat along the margins of the newly widened channel or to infill portions of the existing channel and encourage vegetation so that new shallow-water, shaded habitat is created within the existing channel. Each model involves different assumptions about ecological process and function and has different implications for such factors as cost and maintenance and long-term benefits to a range of species.

Simulation modeling of these alternatives might suggest that, although both types of restoration have the potential to be effective, levee setback has a much higher potential benefit but also a much higher cost. Uncertainty in the parameters of the models is also sufficiently high that the models cannot be easily distinguished on the basis of present information. Creating new habitat in existing channels, however, will not preclude future levee setbacks if this proves worth the cost. In this example, the best approach might be to proceed with fairly large-scale creation of shallow-water, shaded habitat in existing channels, but also to undertake pilot projects to test the benefits of levee setback and targeted research to learn about specific points of uncertainty in ecological function under the different models. For other problems and models, other kinds of decisions are possible. For example, if uncertainty is high enough, it might be considered prudent to conduct research on major sources of uncertainty before proceeding with either pilot projects or large-scale restoration.

Experimental Opportunities

Some of the experimental opportunities available to the ERP and general protocols for these experiments are discussed below.

E-026212

E-026212

Experimental Opportunities at the Landscape Level

The Scientific Review Panel (October 1997) recommended that every opportunity be taken to experiment at the landscape scale. If we define the landscape as the CALFED solution area, then the ERP is a landscape-scale experiment, but it can be pursued only as a passive adaptive experiment. Within the ERP design, there will be many levels of manipulation and defining expected outcomes at each stage will be an important part of the passive adaptive experiment.

Experimental Opportunities at the Ecosystem Level

The collection of ecosystems within the Bay-Delta and the solution area that will be subject to manipulation as part of the ERP is reasonably large. Most of the large-scale ecosystem restoration interventions anticipated under CALFED are manipulations at the ecosystem level (e.g., removal or setback of levees, changes in hydrology, reduction in toxic or nutrient inputs). There will be opportunities for both passive and active adaptive experimentation at the ecosystem level. The problem will be to ensure experimental designs that yield results that confused as to be uninterpretable. Once again, this demands careful definition of the problem boundaries and modeling to explore alternative designs before implementation. An unresolved issue is whether it is better to concentrate management within a few watersheds to ensure measurable results, recognizing that the independent effects of individual manipulations may not be identifiable, or to spread interventions among watersheds to be able to evaluate them independently. Again, simple numerical models may help resolve this issue.

Experimental Opportunities at the Habitat Level

Habitat manipulations are most likely to be among the most numerous activities under the ERP. Individually, they may not have large impacts on critical aquatic species, but may be significant for less wide-ranging species (e.g., amphibians, reptiles, insects, plants) and may have significant cumulative effects on aquatic species. These kinds of small-scale manipulations provide many obvious opportunities for experimentation and active learning. They may also provide the easiest ways to get communities and interest groups directly involved with ERP activities.

Experimental Opportunities at the Species Level

Species-level projects might include both attempts to reduce adverse impacts of certain introduced species (e.g., harvesting of *Potamocorbula*) and attempts to increase abundance and/or distribution of desirable native species (e.g., through introductions or short-term culture to get local populations above critical levels). The information value of such management actions can also be considerable if actions are designed as proper experiments.

Experimental Protocols

For all experiments, whether passive or active, the general protocol should be as follows:

- **Model the system in terms of current understanding and speculation about system dynamics** and use the model to explore issues, such as the magnitude of effects that will derive from particular manipulations, how uncertainty affects outcomes, efficiency of various experimental designs, and the value of information about alternative dynamics. As we noted in the introduction (Figure 2-4), models of the system may suggest that the most efficient approach is large-scale intervention, pilot or demonstration projects, targeted research, or some combination of these.

- **Design the management intervention to maximize benefits in terms of both conservation and information.** Where the modeling of management options suggests that more research is needed before any intervention should be attempted, other management measures may be necessary in the short term to ensure that endangered species do not suffer further declines.

- **Implement management and monitor system response.** In the case of large-scale manipulations, this must go beyond merely monitoring the response variables of interest (e.g., fish abundance) to provide a report at the end on whether they changed in the desired direction. Monitoring, modeling, and analysis, perhaps together with targeted research, must be designed specifically to determine the extent to which the manipulation affected the variable of interest.

- **Update probabilities of alternative hypotheses** based on analytical results and, if necessary, adjust management policy.

- **Design new interventions based on improved understanding.**

At the heart of adaptive management is the intimate and hierarchical connection between hypotheses about system dynamics, critical variables that will permit testing of hypotheses, and analysis of monitoring and other data. Although specific kinds of information will be generally useful and will form a part of monitoring and evaluation regardless of the management program, many kinds of information will be specific to particular hypotheses and experiments. As a consequence, there will be no universally applicable set of indicators or monitoring program. Both will be specific to the particular models and management interventions that form the ERP. Any monitoring and evaluation program therefore needs to be an integral and flexible component of the management program.

MONITORING, RESEARCH, AND SCIENTIFIC OVERSIGHT

Monitoring and Research Program

Monitoring and research are essential components of the strategic plan and of CALFED's operational philosophy of adaptive management. Monitoring is essential for evaluating progress toward ERP objectives and provides the empirical basis for learning under adaptive management; however, monitoring alone is insufficient. Adaptive management includes targeted research to address fundamental questions relevant to CALFED and adaptive probing to distinguish among alternative hypotheses about the best management solutions. Furthermore, even routine restoration actions with broadly accepted projected benefits should be carefully designed to provide a good opportunity for learning. Such actions need to incorporate careful experimental design with an integral monitoring component to ensure that changes are detectable and attributable to the actions.

Ecological Indicators

Ecological indicators are measures of ecological attributes, populations, or processes that can be used to measure aspects of ecosystem condition and the success of restoration efforts. They are essential in adaptive management to track effects of adaptive probing and exploration and, if well selected, they may help to discern among outcomes so that competing hypotheses can be distinguished. Indicators include:

- response variables, such as abundance of important species, used to assess trends and measure progress;
- input variables that can be manipulated directly, such as salinity and temperature;
- summaries of habitat characteristics, such as dimensions of river meanders or area of tidal marsh habitat, that indicate progress toward objectives under goal 4 (habitat), or summarize actions toward achievement of the other goals;
- other variables, such as birth, survival, or migration rates, that can be used to interpret the other data and assess the effects of particular manipulations; and
- intermediate variables that may help to understand the trajectory of response variables and some of which might eventually serve to indicate ecosystem condition (e.g., primary or secondary production, inputs or turnover rate of organic carbon or nutrients, or aspects of foodweb structure).

Ideally, ecological indicators should be based on the ERP's goals and objectives, and on important elements of conceptual models. The CALFED Indicators Work Group has put a substantial effort into developing ecological indicators for the Bay-Delta system, which has helped

to focus attention on landscape- and ecosystem-scale processes and problems; however, this process has proceeded in parallel with, and to some degree has preceded, the development of goals, objectives, and particularly conceptual models. Indicators developed by the group will need to be adjusted to conform with these prerequisites as they are further developed. More importantly, all indicators will need to be reevaluated as the system develops and models change.

Comprehensive Monitoring, Research, and Assessment Program

The U.S. Geological Survey (USGS), San Francisco Estuary Institute (SFEI), and Interagency Ecological Program (IEP) are developing a CMARP. This program is described in the Stage I report and proposal for Stage II, developed by the CMARP steering committee (April 24, 1998). CMARP is intended to address needs for monitoring and research of CALFED and its member agencies. Additionally, it will incorporate elements of existing monitoring and special studies programs, such as the SFEI Regional Monitoring Program, the Department of Interior Comprehensive Assessment and Monitoring Program, the CALFED Operations Group Real-Time Monitoring, the Vernalis Adaptive Management Program, and the IEP environmental monitoring activities. CMARP is therefore intended to meet many of the monitoring needs in the estuary.

Below are several additional aspects of a successful program that should be integrated with CMARP.

Science Oversight Group. The main concern is to ensure that the principles and practices of adaptive management be incorporated in CMARP administration because CMARP has no control over system design or operations. The adaptive management program will require an organizational framework that has sufficient scope, depth and breadth of understanding, and authority to recommend changes in CALFED operations and in the CMARP program. This implies a standing oversight group that is independent but sufficiently familiar with CALFED operations to offer insightful review. This group is described further below under "Institutional Framework".

Peer Review. This is always an issue in using science to guide management. The Bay-Delta system arena has seen decades of management based on studies that have not passed peer review. Although these studies may have considerable scientific merit, they have not been subject to the process of quality control concerning the relevance of the findings and the accuracy of the interpretation that characterize mainstream science. This kind of legitimacy is provided in science through peer review.

Science used to justify CALFED management decisions should be published in national, peer-reviewed journals. This approach, used in management of the Everglades and Chesapeake Bay, provides a means of obtaining review from technical experts, free of charge, in a reasonably timely manner. It also provides important contact with the broader scientific community that will be very useful in establishing review teams (see "Institutional Framework" below); however, because publication can take 1-2 years from initial submission of manuscripts, management decisions depending on particular findings should proceed once those findings have been reviewed internally.

Staff scientists need the time to write and publish their findings in more than just internal technical reports, and their career progress should be judged, in part, on such publication. They also need ample opportunities for collaboration with university and other scientists to help get their findings out into the broader arena. Both of these requirements demand commitment by the overseeing institution to provide the necessary time and opportunities.

Scientific Review of the Adaptive Management Process

The adaptive management process comprises three levels of review: 1) review of progress toward the goals of the ERP, 2) review of proposed and ongoing adaptive management actions, and 3) review of individual research and monitoring projects within CMARP. These levels are in addition to the peer review of individual projects discussed above. The entire program should be reviewed annually, possibly in conjunction with an annual meeting of the science oversight group, to assess progress toward goals of the ERP. The reviewers would comprise a body of scientists similar in makeup (and perhaps identical) to the CALFED Scientific Review Panel convened in October 1997. This review should produce a report summarizing the state of the CALFED region, or status of the scientific basis for CALFED actions.

Individual actions will be reviewed annually as well, but with a rotation schedule so that not all actions are thoroughly reviewed every year; each action would be reviewed periodically. The interval between reviews will depend on the nature of the action, but should be based on the timescale of expected system response determined through preliminary modeling. Additionally, actions would be reviewed for new information that may become available and that may impinge on action outcomes.

Individual research and monitoring programs under CMARP should be reviewed on the rotating basis as the CALFED actions. Additionally, these programs should be peer reviewed at the proposal stage. Targeted research projects under CMARP should additionally be held to some minimum standard of publication of findings. For example, specific questions should be answered in the scientific literature within 2 years of completion of the project, or 2 years of completion of the stage of the project investigating the questions. These reviews should be separate, and performed by different people, from the reviews of ERP actions.

Many pilot projects and large-scale interventions may be difficult to approach as subjects of independent scientific peer review. The projects should be reviewed at the proposal stage, but it may be unrealistic for a "peer scientist" in Michigan, for example, to comment on a proposal to flood Delta islands or set levees back on the San Joaquin River. To judge these projects (except for specific design aspects) requires considerable local knowledge. For many projects, the ERP will have to depend on internal review with oversight by the scientific oversight group or locally constituted committees made up of individuals with both technical background and local experience or familiarity with the affected resources and the geographic context.

Reviews of actions and CMARP programs should address several important questions about the progress and direction of the program and the need to occasionally correct course. These questions are:

- Is this program doing what it was intended to do (i.e., was the action taken, was the monitoring or research conducted more or less as proposed)?
- Is the program accomplishing its objectives (i.e., is the action having the desired effect, are the questions being answered, are the results being published)?
- Does this continue to have the priority it had when first proposed and authorized (i.e., if CALFED priorities change or substantial new knowledge becomes available, should resources continue to flow to this program)?
- Should the action or program be expanded to encompass larger scale projects, or designed to affect a larger geographic area, or be implemented on more subsets of the system?
- Should the action or program be continued, but modified and refined in particular ways, based on lessons from the initial implementation results and on evaluation by the oversight group and others?

INSTITUTIONAL CONSIDERATIONS

CALFED must develop an institutional structure for implementing all of its programs into which the ERP implementation must fit. Additionally, CMARP is developing institutional structures for monitoring and research that must fit with the ERP framework. The strategic plan provides suggestions for both of these efforts.

Adaptive management imposes requirements on the ERP governing body that differ substantially from the needs of most resource agencies. It must be able to learn and adapt based on the new information and understanding obtained. Limitations on active adaptive management will include institutional culture and inertia, availability of resources (water, money, people) to carry out the experiments, and restrictions based on endangered species and other regulations. Inertia can be overcome only with a sincere commitment on the part of the ERP governing body to take active steps to improve knowledge about the system, and close contact between scientists responsible for understanding and overseeing the scientific activities and managers responsible for integration with other CALFED programs and with overseeing system operations.

As discussed above with regard to program design, the clinical trial in medicine can serve as a model for the institution governing the adaptive management program. A committee oversees these large experiments with new treatments and decides whether to terminate early when the

E-026218

E-026218

evidence shows that the new treatments are better or worse than the existing methods or to justify further testing on the basis of results to date.

Because of the uncertainty about the outcomes of various interventions (uncertainty in the science, but also inherent unpredictability of an ecological system), actions that have either no effect or are actually harmful cannot be avoided. The adaptive management process requires that the ERP governing body learn from what could be seen in hindsight as mistakes and that it be prepared to alter course once the evidence suggests it. This will require an almost heroic insistence on flexibility and an ability to defend individual actions as part of the overall program, even when they turn out badly.

Endangered-species regulations limit or prohibit actions believed to reduce protection of listed species, regardless of the value of these actions for increasing knowledge or the certainty that protection will actually be reduced. These limitations can be replaced by substantial ecosystem-based programs that can demonstrate a strong likelihood of maintaining or increasing protection over the long term. The analogy with clinical trials is useful here too: if standard treatments are ineffective, a trial of new treatments can be justified but must be closely monitored and either abandoned if harmful, or used in place of the standard treatment if protection is improved.

Duties of the ERP Governing Body

The ERP governing body must fit into the entity designed to manage all CALFED programs. Its principal duty will be to oversee ecosystem management and ensure that the principles and practices of adaptive management are followed in taking actions, evaluating their effects, conducting research on important issues, and revising actions to respond to changing conceptual models or system responses. Specific duties may include the following:

- Oversee the adaptive management design of the ERP and CALFED as a whole and the essential contribution of CMARP to this design. This is envisaged as an active, ongoing activity requiring familiarity with all of the major CMARP and CALFED activities.

- Conduct workshops and public meetings annually, or more frequently if necessary, with CMARP scientists and the CALFED staff to disseminate findings, assimilate new understanding, and discuss changes to the program. Additionally, revise or update conceptual models during these workshops as new information becomes available.

- Conduct or direct analyses to evaluate effectiveness of CALFED actions.

- Based on the above, develop proposals for active adaptive management manipulations and submit them to the CALFED management entity for approval and implementation.

- Make important decisions depicted in Figure 2-4 regarding the kinds of actions to be initiated, how those actions change over time, and when to start new projects and

abandon old ones. Oversee CMARP, working with its top scientists to review programs, evaluate the development of knowledge, and ensure adequate peer review.

- Coordinate with other CALFED programs. Because it is not clear whether the other programs will incorporate adaptive management, there may be friction between the ERP and the other programs over the need for flexibility and changing practices based on new knowledge. Additionally, the ERP governing body must be consulted by other programs {by managers of other programs?} proposing actions that may affect the ecosystem and must be allowed to develop an adaptive management alternative to an action proposed by another program.

- Ensure scientific quality in the ERP, which will include (at a minimum) setting up a process whereby all scientific personnel are expected to publish scientific findings in peer-reviewed journals and holding periodic outside reviews of the adaptive management program (see below).

- Ensure accessibility of results of adaptive management actions and of CMARP data and findings to all interested individuals and institutions both inside and outside CALFED.

- Provide public outreach about ERP activities, including workshops, an up-to-date Internet web page, and newsletters.

- Determine permitting requirements for anticipated future activities, including CMARP sampling, and establish schedules for early application to prevent delays of actions. Apply for and process applications and serve as the "permittee" for necessary regulatory permits and approvals including CEQA/NEPA documents.

- Have resource and budgetary control. The ERP governing body must have the capability to hire personnel, establish contracts, set up and administer budgets for projects, receive funds, acquire or purchase property, acquire permits, issue grants, and undertake all the other administrative activities associated with managing a diverse suite of projects. It should also have authority to receive and control lands and easements and water for ERP implementation.

- Establish and manage the information database needed to support implementation of the adaptive management framework and overall ERP operations.

Attributes of the ERP Governing Body

There is an inherent tension between several pairs of attributes that the governing body must have:

- **Assurances vs. adaptive management.** The governing body must be structured to provide assurances about actions it will take and demands it will make for resources. This is in fundamental conflict with the need for flexibility that is an essential attribute of an adaptive management program.

- **Independence vs. connection.** The governing body must be independent to prevent political and other concerns from interfering with the scientific aspects of the program, yet it must retain connections with stakeholders, agencies, and the other CALFED programs to ensure coordination.

- **Science vs. other activities.** The practice of adaptive management requires scientific expertise in several fields. Many of the other activities (e.g., public outreach, project management, coordination) will have little, if any, scientific content. Although these disparate needs can be accommodated in a standard organizational structure (e.g., any of the resource agencies), this structure may fail to elevate scientific decision making to the level required by the ERP.

Based on the duties and the tensions described above, the ERP governing body should have the following attributes:

- It should be nonregulatory, which will eliminate the inherent conflict of interest that occurs when regulatory organizations also incorporate scientific investigations of the subjects of their regulation.

- The structure should provide for an independent scientific oversight group responsible for reviewing and advising on the scientific duties above. The purpose of the scientific oversight group is to help ensure ERP actions are not taken if they do not have suitable scientific backing. This can occur through a process of both informal advice and formal recommendations from the group to ERP management staff and other CALFED program managers.

- On advice from the scientific oversight group, it would be empowered to establish, on short notice, one or more teams whose purpose would be to respond rapidly to new findings or new developments (e.g., levee failures) that may affect the success of ERP actions or to take advantage of opportunities for improving management of increasing knowledge (e.g., through unusual flow events).

- It should comprise from eight to 12 accomplished individuals not directly connected with CALFED activities (at least two should be from outside California) capable of understanding, analyzing, and deciding on important technical issues. These individuals should serve on this committee for 2 years or more to allow for an adequate level of commitment and familiarity with the program. They should be authoritative experts in a variety of fields related to the problems at hand, such as ecology, oceanography, hydrology, toxicology, and geochemistry.

DISPUTE RESOLUTION

Dispute Management

This strategic plan recommends that specific amplified procedures be adopted for dispute management and resolution. This is necessary for two reasons:

- There will be substantial continuing uncertainty in managing dynamic ecosystems.
- The breadth of the CALFED mission is such that widely disparate values are at stake and there is a long history of conflict that no amount of planning and coordination can completely overcome.

Dispute Management as Part of the Internal CALFED Structure

The CALFED administrative structure in itself is designed for conflict resolution. Policy makers and stakeholders representing disparate interests are involved in early identification of problems before they fully develop and become difficult to modify. Many aspects of current and planned CALFED operations also help to defuse conflicts:

- a robust information system, which helps "level the playing field" for participating agencies and interest groups;
- stakeholder involvement at the earliest stages of planning;
- participatory design (as in Category III projects), which can help make projects noncontroversial;
- care in preparation of records of decision (RODs), coupled with sunshine information policies; and
- third-party evaluation of information (e.g., Independent Scientific Review, peer review of publications).

The need for extraordinary dispute resolution measures may still arise because of:

- a logjam in the decision process, coupled with the need for prompt action (natural disaster, short-term opportunities, or impending actions that are outside the CALFED purview);
- external impacts requiring that new stakeholders be involved; or

E-026222

E-026222

- controversy, including legal or technical challenges, over high-profile actions such as selection of an "isolated transfer facility".

Additional Measures

A special structure for dispute resolution may be needed to provide for a level of review that is beyond the scope of normal procedures and is invoked to preclude the use of courts and legislation to resolve the dispute. Litigation commonly forces each side in the dispute to take an extreme position, which does not lend itself to efficient resolution. Dispute resolution is expressly designed to provide all parties with lower risk ways of exploring more central positions. Purely technical issues will most likely be resolved through the normal process of adaptive management under the institutional structure discussed above, which is expressly designed to accommodate alternative hypotheses; therefore the dispute resolution process will generally be invoked for issues that do not have a technical solution.

It is recommended that CALFED create a formal process for dispute resolution and that this framework should be established before it is needed. Although specific approaches to dispute resolution will be dictated by the dispute at hand, the process should generally proceed under the same set of guidelines, including the following.

- Formal announcement would be made that an issue is being subjected to the dispute resolution process.
- Each dispute resolution process would be run by a neutral facilitator. For disputes over highly controversial topics, this person should be a widely known and respected judge or statesman who could act impartially to help resolve the dispute.
- The scope of the issue would be made clear, with specification of the "decision space" consistent with legislative mandates and limits on delegation of authority.
- There would be a clear statement of the means by which the final recommendation or decision is to be rendered (administrative decision, arbitration, consensus, majority vote).
- The process should be less that of a formal hearing, and more that of an informal but professional workshop, with briefings, discussion, and interpretation of the information at issue.
- The main decision makers, including agencies with regulatory authority, should be involved.
- Stakeholders to be included would be named, and procedures set up for involving those on the perimeter (for example, the opportunity to observe or to make comments at

specified intervals). Each stakeholder's position would undergo formal description and analysis to ensure that concerns and priorities are clear to all parties.

- The process would normally conclude with a report covering points of agreement and an agenda for resolution of remaining issues. Conclusions might be in the form of a written agreement, with a white paper giving the details and usually a public forum to disseminate results. When necessary, a process for additional regulatory or environmental documentation would be spelled out.

At least two alternative approaches are available for dispute resolution. The first is an expert, blue ribbon panel. In this approach, CALFED's Scientific Review Panel could be augmented by further expertise, for example, by a panel formed by the National Academy of Sciences. This has the advantage of added credibility, but may not be timely or efficient.

Another approach is joint fact finding. Differing viewpoints in science are inevitable, particularly when these viewpoints are colored by the perceptions of stakeholders. A structure can be provided to try to move beyond a battle of experts, and to define common ground and points on which progress can be built. The key to this process is to bring experts into face-to-face communication (that is, without intervening translation of their methods and findings by lawyers and administrators). This helps the experts to explore disputed scientific questions and to recommend means for clarification and resolution. Any one of a number of techniques can be used to help overcome barriers to neutral scientific dialog (e.g., Delphi to deal with power and personality factors).

The outcome of the dispute resolution process will usually be a set of points of agreement and an enumeration of points where interpretation of the available information leads different scientists to different conclusions. An important element of the dispute-resolution process will therefore be to demand from the participants a road map for resolving the remaining issues. The outcome will therefore include recommendations for additional manipulations of the system or research projects.

Information Storage, Collation, and Dissemination

Information System Requirements

CALFED is committed to a decision process and to outcomes that are placing extraordinary demands on its information system.

Under phased decision making, important actions (including conveyance and storage) are predicated on specific conditions being met. In some cases, the degree of compliance will be obvious, but, more commonly, the decision to proceed will be in large part a matter of judgment on the part of stakeholders and their technical, scientific, and legal advisors. Judgments will commonly have to be made using information that is incomplete and imperfect. Deficiencies at critical turning

points can lead to conflict and delay. To the extent that new information may be needed to refute a prestated conclusion, deficiencies will lead to acquiescence.

Stakeholder involvement places special demands on the system. Many organizations and individuals must review important CALFED actions, and these participants expect full, quick access to all the information being used to evaluate or justify a proposed action, which means ready access not only to results and conclusions, but also to baseline information, monitoring data, models and their parameters, and assumptions.

CALFED's administrative environment is an issue in itself. Not only does the organization span a number of state and federal agencies (which need constant day-to-day participation), but experts from disparate disciplines must review and comment across geographic and institutional barriers.

Adaptive management, by its very nature, requires information. Nearly every environmental intervention offers an opportunity (and obligation) to document the ecosystem's prior condition and response to intervention and offers an opportunity to validate or revise hypotheses. Adaptive management involves continuing inventory, analysis, and interpretation. Such rational, comprehensive, science-based decision making requires an extremely robust, responsive information system, especially as compared to the more traditional form of incremental decision making.

System Characteristics

To meet the needs itemized above, the ERP information system should be developed using modern, widely available and tested communications systems as outlined below.

- It should provide for rapid production and dissemination of reports and publications and facilitated review and comment. This implies a shift from a traditional, paper-based system to one based largely on electronic communication.
- To acknowledge that not all interested parties would be capable of using the above tools, it should continue use of traditional means of communication (paper documents and graphics, land mail, fax, telephone) for communication with the public and for technical use during a transition to more widespread use of advanced technology.
- Procedures for disseminating scientific information should be developed to strike a balance between the public's right to the information and the scientists' professional interest in timely publication.
- Any information used to support or challenge an ERP action must be available to all free of charge (or at the minimal cost of preparation). Proprietary information purchased by

CALFED or cooperating agencies (e.g., satellite imagery) should be paid for once, with the provision that subsequent distribution is free.

- It should include a distributed digital library, not only to help manage day-to-day information, but to build the archive to support RODs.

Electronic Communications

To meet the needs and objectives above, the CALFED information system should have e-mail services, which would include address lists, and e-mail reflectors for work groups and stakeholders.

Internet services need to include a web page much like the present one (at http://calfed.ca.gov) with notices of meetings, hearings, and technical workshops. Reports could be put on line with text, graphics, and maps and links to data, tables, models, and GIS layers. The web server could also provide protected virtual work space for teams and advisory panels in which a number of participants might engage in simultaneous, remote writing and review. The web page could provide links to sources of information on CALFED activities and on the regional environment. This aspect could be as simple as a link to the California Resources Agency's CERES Information Catalogue (http://ceres.ca.gov/catalog/) or, preferably, would offer strengthened coverage of CALFED issues and sources of scientific and planning information. Digital library services should provide web-based access to reports in common use within the CALFED community. These could include digital copies of traditional reports.

In the future, CALFED documents should be prepared in both standard and Hyper Text Markup Language (HTML) format so as to exploit web capabilities for presentation of complex material (color tables and maps) over standard web connections to the general public. The Bureau of Land Management has developed an online EIR/EIS that serves as a good example (The Golden Queen/Soledad Mountain Mine: http://www.ca.blm.gov/GoldenQueen/). Given the breadth and depth of CALFED issues, GIS is absolutely essential for a number of critical functions, including simple project tracking, database management, monitoring, analysis of connections between actions, and geographic visualization of complex scientific and planning information. The system should link and integrate the map libraries of all CALFED agencies and collaborators, instead of creating a new central repository. Traditional stand-alone GIS operations should be linked through web-based GIS capabilities (as described at http://www.regis.berkeley.edu/deltapub/GIScore5.html). GIS data layers should be thought of not as separate maps in an atlas, but as graphic objects that can be integrated with text and databases (e.g., monitoring locations, or restoration site lists).

Outreach

The public is paying for the ERP and should be informed as to whether is it getting its money's worth. The information management system should therefore include a public outreach office. Staff from this office should contact schools, universities, and other institutions to present information on the progress of the ERP. Educational kits, press releases, and brochures should be prepared to describe ecosystem restoration and apprise the public of progress. The outreach office should also be charged with initial coordination of groups developing local restoration projects and with organizing site visits, school trips, and celebrations to mark particular events in the program.

The public outreach office should also have the capability to contact individual scientists to arrange for lectures or school visits. ERP scientists would be under obligation to cooperate with the public outreach office for a reasonable level of effort in outreach activities.

Public outreach is not only a service provided by CALFED to the public but is also a vehicle by which the public can become engaged in ecosystem restoration. To the extent that the program engages public support, it will increase its likelihood of success, minimize conflicts over land and water use, and enhance its long-term viability.

E-026228

E-026228

Chapter 7. Recommended Regulatory Compliance Strategy: Demonstrating That the Ecosystem Restoration Program Complies with Applicable State and Federal Laws, Regulations, and Programs

OVERVIEW OF THE STRATEGIC PLAN ERP COMPLIANCE DISCUSSION

CALFED is developing a comprehensive regulatory compliance strategy to ensure that implementation of the ERP will comply with existing laws and regulatory requirements. This chapter discusses the regulatory compliance issues that must be addressed by ERP managers to obtain necessary regulatory agency approvals before initiating ERP actions.

The ERP identifies more than 700 actions for consideration, many of which require approvals from regulatory agencies. It will be necessary to demonstrate that the ERP meets the requirements and standards of applicable state and federal laws and regulations. Typically, compliance is achieved in two ways: 1) by obtaining necessary permits from agencies responsible for regulating activities (e.g., impacts on threatened or endangered species or regulated habitats, such as waters of the United States) and 2) by obtaining environmental clearances from lead agencies responsible for approving the overall action or project (e.g., certification of documents required under CEQA and NEPA).

Some ERP actions that were adequately covered by the CALFED Bay-Delta Program Programmatic Environmental Impact Statement/Environmental Impact Report (Programmatic EIS/EIR) and related approvals obtained before the beginning of Stage 1 may not require additional permits or environmental clearances. The purpose and need for these actions and their benefits and impacts are understood at a level of detail sufficient for implementation during Stage 1; however, the overwhelming majority of proposed ERP actions are not described in sufficient detail to obtain required permits and environmental clearances. These actions cannot be implemented until they are reviewed within the adaptive management framework and regulatory approvals are obtained.

In recognition of the need to implement the ERP and other CALFED actions in stages, the discussion of the long-term regulatory compliance strategy begins with this chapter and continues through Chapter 8. This chapter describes the need for a long-term compliance strategy and outlines strategy objectives. It identifies the primary regulatory agencies that must issue permits/approvals for proposed ERP actions, describes how environmental documentation requirements should be addressed, and describes how the adaptive management approach can be embedded in the regulatory process to make it more efficient and defensible. The chapter concludes with a discussion of how

progress on the ERP and on CALFED overall throughout the next 30 years needs to be "linked" to provide "assurances" that CALFED is performing according to its stated intentions and that progress on program elements is reasonably balanced. Chapter 8 outlines a Stage 1 strategy (covering approximately the first 7 years of ERP implementation).

Although the compliance strategy, as discussed in the strategic plan, is presented in two chapters, it is important to understand that each chapter discusses elements of a single, comprehensive and coordinated compliance strategy. Because Stage 1 is discussed separately in Chapter 8, there may be a tendency for reviewers to conclude that Stage 1 is a "short-term" strategy, separate and distinct from the "long-term" compliance strategy. This is not the case. Stage 1 of the comprehensive strategy is discussed separately for two reasons.

- First, it is essential to provide for an orderly and understandable strategy capable of translating program-level approvals received under the Programmatic EIS/EIR into project-level approvals and documentation during Stage 2 of the ERP. This transition strategy needs to provide the technical, procedural, and institutional foundation for subsequent decisions of major actions proposed as part of Stage 2 and subsequent stages.

- Second, it is difficult to look at compliance issues beyond Stage 1 with any degree of precision because of the lack of specific ERP action descriptions. Without specific descriptions, there can be only a limited (and possibly misleading) understanding of the benefits, impacts, mitigation, and alternative actions related to each of the hundreds of actions proposed.

NEED FOR A LONG-TERM COMPLIANCE STRATEGY

Compliance with applicable state and federal regulatory requirements for more than 700 potential ERP actions is made more challenging by the variety of regulated resources and activities involved. Proposed ERP actions are specifically intended to protect threatened and endangered species and to enhance, rehabilitate, and restore ecosystem values and functions within the Bay-Delta system; nevertheless, the ERP must demonstrate regulatory compliance. Actions considered in the ERP include, but are not limited to:

- acquisition of private land easements for ecosystem restorations purposes;

- enhancement and restoration of existing riverine, wetland, and upland habitats;

- creation and restoration of a variety of habitats; and

- specific measures designed to address the biological needs of a wide range of species, particularly those protected under state and federal law and dependent on habitats in the Delta.

A coordinated and comprehensive long-term compliance strategy is necessary because of the need to implement the ERP in conjunction with other interrelated CALFED elements over 30 years. The ERP must be implemented in stages that allow program managers to identify "linkages" among ERP actions and among ERP and non-ERP actions. Linkages occur where one action or one decision is dependent on or related to completion of other actions or decisions. A long-term compliance strategy would enable ERP managers to identify and incorporate the regulatory requirements into the adaptive management decision process before adaptive management decisions are made so that approvals can be obtained in a more timely and predictable fashion.

Failure to develop and implement a comprehensive long-term compliance strategy will most likely result in:

- unnecessary and irretrievable adverse environmental impacts,
- loss of restoration opportunities,
- significant program delays,
- waste of public and private funds, and
- loss of public trust and confidence in the program.

PURPOSES OF THE COMPLIANCE STRATEGY

To address the needs described in the previous section, the ERP compliance strategy should be designed to accomplish the purposes described below.

Identify Agencies With Regulatory Authority

Identify all state and federal agencies with regulatory authority over activities required to implement ERP actions. These agencies include the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), California Department of Fish and Game (DFG), U.S. EPA, Corps, and SWRCB.

Identify Regulatory Requirements

Identify specific regulatory compliance requirements under applicable environmental laws and regulations to implement ERP actions. These requirements may include surveys, disclosure documents, consultations, approvals, permits, and public participation. Applicable laws include CEQA, NEPA, the ESA, CESA, and CWA.

Provide a Framework for Tiered Compliance with CEQA and NEPA

Provide a framework to facilitate effective compliance with CEQA and NEPA for individual actions using the Programmatic EIS/EIR to the extent feasible through tiering of documents. The framework for CEQA and NEPA compliance should recognize the special circumstances and needs involved in implementing the ERP and other CALFED programs in stages over 30 years.

Sufficiently Define ERP Actions for Regulatory Purposes

Define proposed ERP actions in sufficient detail so that each action can be evaluated to determine:

- needed regulatory and environmental approvals (many actions will require multiple approvals);
- specific purpose, location, and character of the action so that potential impacts and benefits can be determined;
- environmental impacts and feasible alternatives and mitigation measures; and
- linkages among actions within the ERP and among ERP and non-ERP actions within CALFED overall.

Linkage refers to functional connections between proposed actions that could serve to enhance or be essential to the success of one or both actions. Examples of linkages would be an action proposed to restore a wetland that could be dependent on another ERP or CALFED action that increases flow or a proposed action could be contingent on the completion of a particular research or monitoring program.

Define an Adaptive Management Framework for Compliance

Define an adaptive management framework for regulatory compliance for ERP actions and for non-ERP actions that affect ERP actions. The adaptive management framework should evaluate and select actions to be undertaken during Stage 1 and subsequent stages and provide guidance for implementation of selected actions consistent with the adaptive management decision framework described in Chapter 6 and illustrated in Figure 2-4.

Determine Compliance Requirements for Stage 1 Actions

Determine whether actions proposed for Stage 1 are adequately covered by the Programmatic EIS/EIR and other programmatic compliance documents completed by CALFED and whether additional regulatory compliance is required. If necessary, develop a plan for phasing Stage 1 activities and decisions to ensure that needed permits and environmental approvals are obtained and Stage 1 actions are completed in a timely manner.

Integrate Compliance Across CALFED Programs

At all stages of the CALFED implementation process, integrate the adaptive management approach for ERP actions with the approach for non-ERP actions through consultation between ERP program managers and non-ERP managers early in the decision-making process for non-ERP actions that:

- could affect significant biological resources, or
- are determined to be essential actions that must precede ERP actions. Coordination among managers should begin at the conceptual and early facility design/decision stages so that potential purposes, impacts, and benefits associated with a proposed action can be assessed and alternative solutions can be considered before committing to specific solutions.

Provide the Basis for Assurances to Program Participants

Provide the basis for assurances to program participants and others affected by or interested in the ERP and CALFED that the ERP and other CALFED elements are progressing in a reasonably balanced, timely, and equitable manner capable of achieving CALFED restoration and other programmatic goals.

REGULATORY PROGRAMS AND REVIEWING PUBLIC AGENCIES

An ERP compliance strategy designed to achieve the above purposes would enable program managers to obtain necessary state and federal permits and approvals in an efficient and timely manner. Several state, federal, and local regulatory approvals could be required to implement ERP actions and most ERP actions will require multiple regulatory approvals. Table 7-1 lists the state, federal, and local laws, policies, and regulations with which ERP actions must comply. Because of

the scope of state and federal regulatory programs, it is important to understand that some regulatory programs are more critical to the success of the ERP than others. The ERP compliance strategy should focus on compliance processes that:

- involve species, habitat, and ecosystem issues, including water quality;
- require a high level of agency coordination;
- require a long time to complete;
- involve major expenditures of funds or staff time; or
- affect a large number of proposed ERP actions.

Other regulatory programs identified in Table 7-1 are not included as major compliance processes because they may:

- affect only a small number of actions (e.g., California Department of Transportation [Caltrans] encroachment permits);

- affect a large number of ERP actions but not result in significant delays or additional costs for most actions (e.g., Clean Air Act);

- involve an important approval but are mostly satisfied by approval of major compliance processes (e.g., DFG Streambed Alteration Agreements and San Francisco Bay Conservation and Development Commission [BCDC] development permits are often approved rapidly following approvals of major compliance processes such as ESA, CESA, and Section 404/401 of the CWA);

- involve approvals that are likely to be satisfied at the programmatic level and would not need to be addressed for individual ERP actions (e.g., water rights approvals for actions involving flow).

Approvals such as those discussed above are addressed as part of a strategy separate from the strategic plan.

The critical regulatory compliance processes discussed below are complex, and a comprehensive discussion of these processes is not practical. A list of major compliance processes, as well as of other regulatory programs is provided in Table 7-1, (Jones & Stokes Associates and CALFED 1996) Major compliance processes involving state and federal agencies and related program requirements are addressed briefly below at a level of detail designed to capture the range and complexity of requirements without becoming immersed in them. CEQA and NEPA requirements are addressed in a following section.

Table 7-1. Summary of Potential Environmental Compliance Needs and Regulatory Agencies for Ecosystem Restoration Program Actions

Federal Laws

National Environmental Policy Act (federal lead agency)
Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act (Corps, NRCS, EPA)
Sections 4, 7, or 10 of the Endangered Species Act (USFWS, NMFS)
Fish and Wildlife Coordination Act (USFWS, NMFS, DFG)
National Wild and Scenic Rivers Act (NPS, USFS)
Coastal Zone Management Act (CCC, BCDC)

Federal Executive Orders and Administrative Policies

Farmland Protection Policy Act (NRCS)
Executive Order 11988 - Floodplain Management (federal lead agency)
Executive Order 11990 - Protection of Wetlands (federal lead agency)
Executive Order 12898 - Environmental Justice in Minority and Low-Income Populations
American Indian Religious Freedom Act of 1978 (federal lead agency)
Indian Trust Assets (BIA)

Other Federal Agency Authorities

Encroachment approvals (Reclamation, BLM, NPS, USFS, NRCS, BIA)

State Laws and Implementing Regulations:

California Endangered Species Act, Native Plant Protection Act, Fully Protected Species, California Fish and Game Code (DFG)
Natural Community Conservation Planning Act (DFG)
California Fish and Game Code Section 1601 or 1603 Stream and Lake Bed Alteration Agreement (DFG)
California Environmental Quality Act (state lead agency)
Section 401 of the Clean Water Act (SWRCB, RWQCBs)
National Pollutant Discharge Elimination System (RWQCBs)
Waste discharge requirements (RWQCBs)
Water rights (SWRCB)
Section 106 of the National Historic Preservation Act (SHPO)
Public trust land use lease (SLC)
State Reclamation Board floodway encroachment permit (SRB)
Approval to construct a dam or reservoir, store water, or repair or alter a dam or reservoir (DWR)
Transportation encroachment permit/right-of-way (Caltrans)
Air district authority to construct and permit to operate (APCD, AQMD)
California Coastal Act and local coastal programs (CCC, local cities and counties)

Table 7-1. Continued

McAteer-Petris Act and Suisun Marsh Preservation Act/Bay Conservation and Development Commission (BCDC)
Williamson Act - agricultural land preservation (CDC)

Local Regulatory Compliance

City or county approvals and entitlements (city or county planning commission, city council, or county board of supervisors)
Local coastal program land use plans (city or county planning commission, city council, or county board of supervisors)

Notes:

Acronyms of Agencies

APCD = Air Pollution Control District
AQMD = Air Quality Management District
BCDC = San Francisco Bay Conservation and Development Commission
BIA = U.S. Bureau of Indian Affairs
BLM = U.S. Bureau of Land Management
Caltrans = California Department of Transportation
CCC = California Coastal Commission
CDC = California Department of Conservation
Corps = U.S. Army Corps of Engineers
DFG = California Department of Fish and Game
DWR = California Department of Water Resources
EPA = U.S. Environmental Protection Agency
NMFS = National Marine Fisheries Service
NRCS = Natural Resources Conservation Service
NPS = National Park Service
Reclamation = U.S. Bureau of Reclamation
RWQCB = Regional Water Quality Control Board
SHPO = State Historic Preservation Officer
SLC = State Lands Commission
SRB = State Reclamation Board
SWRCB = State Water Resources Control Board
USFS = U.S. Forest Service
USFWS = U.S. Fish and Wildlife Service

Sources: Jones & Stokes Associates 1997, CALFED Bay-Delta Program 1996.

STATE OF CALIFORNIA REGULATORY PERMITS AND APPROVALS

Under the California Government Code, the primary source of regulations and permitting authority for projects affecting biological and water resources is the Fish and Game Code. The CESA, NCCPA, and streambed alteration agreements discussed below are part of the California Fish and Game Code.

California Endangered Species Act

The 1984 CESA sets forth the state policy to conserve, protect, restore, and enhance any endangered or any threatened species and its habitat (Sec. 2052). DFG is responsible for authorizing take of threatened and endangered species under CESA and the California Fish and Game Code. Section 2081 of CESA authorizes "take" of endangered, threatened, or candidate species under specific conditions through permits or memoranda of understanding issued by DFG. In addition to the above provisions, implementing the ERP will require that CESA requirements dealing with species identified as "fully protected species" under the California Fish and Game Code be addressed. Take for the latter species may not be authorized by DFG, except for scientific purposes, and this could conflict with "take" authorized under Sections 2081, 2825, and 2835 of CESA.

Natural Community Conservation Planning Act

The NCCPA was adopted in 1991 to encourage voluntary, collaborative public/private ecosystem protection efforts on a regional or subregional basis. Although not a regulatory program, it may be particularly important to the ERP compliance strategy because, instead of focusing on species-by-species protection, it is designed to function at an ecosystem level by protecting the natural communities that provide habitat for listed species (threatened and endangered) and unlisted species. Protection for unlisted species and their habitats is the main concern of the NCCPA because these species and habitats are not protected under the ESA or CESA. Sections 2825(c) and 2835 provide take authorization for listed and unlisted species addressed by DFG under NCCPA plans.

Streambed and Lakebed Alteration Agreements

Sections 1601 and 1603 of the California Fish and Game Code address protecting the value to fish and wildlife of the states' rivers, steams, and lakes. These sections of the code require anyone proposing a project that would "divert, obstruct, or change the natural flow or the bed, channel, or bank of any river, stream or lake designated by the department...to notify and consult with DFG to develop a proposal that is acceptable to DFG and, in the opinion of DFG," will not substantially adversely affect an existing fish or wildlife resource...."

Bay Conservation and Development Commission

The BCDC, under the McAteer-Petris Act and the Suisun Marsh Preservation Act, has jurisdiction over all areas of San Francisco Bay subject to tidal action and the primary management area of Suisun Marsh. Some ERP activities would involve impacts on lands/waters within the regulatory jurisdiction of the BCDC that would require BCDC approval before implementation.

State Reclamation Board Floodway Encroachment Permit

Any individual or agency conducting activities that encroach on federally funded flood control levees or channels and on designated floodways must receive a floodway encroachment permit from the State Reclamation Board. The State Reclamation Board is responsible for ensuring that encroachment will not threatened levee stability or adversely affect floodflow capacity.

Federal Laws/Programs

The primary federal regulatory programs that would influence implementation of the ERP are the ESA and the CWA. These acts and their relevant programs are briefly discussed below.

Federal Endangered Species Act

The ESA was adopted by Congress in 1973 and amended in 1982. With regard to endangered and threatened species, Section 9(1)(b) of the ESA declares that it is unlawful for any person to "take any such species within the United States or the territorial sea of the United States"; however, the ESA also provides for exceptions to Section 9 prohibitions in accordance with the provisions contained in Section 7 (federal actions) and Section 10 (nonfederal actions). Sections 7 and 10, in combination with Section 4(d) (defined below), provide the basis for permitting requirements that must be addressed by the ERP.

Section 7 requires that any action "authorized, funded, or carried out ... by a federal agency cannot...jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is ... determined to be critical...." Under this section, federal agencies consult with USFWS or NMFS if a biological assessment indicates that endangered/threatened species may be affected by the proposed action. USFWS or NMFS would prepare a biological assessment describing effects on a listed species and must reach a "no jeopardy" decision before authorizing take of a listed species. The majority of the ERP and other CALFED actions now being considered qualify as federal actions based on one of the three criteria cited in the ESA (i.e., they are authorized, funded, or carried out by a federal agency); therefore, the majority of the actions proposed must meet the standards/requirements contained in Section 7 and receive a no-jeopardy determination by USFWS and NMFS.

Section 10 authorizes nonfederal entities to obtain permits to take threatened and endangered species by preparing habitat conservation plans (HCPs). An HCP must meet requirements of Section 10 for content and specific findings by the Secretary of the Interior. Under Section 10, USFWS and NMFS may authorize the take of listed species that is incidental to otherwise lawful activities. The Section 10 process also involves an "internal" Section 7 consultation.

For species listed as threatened, Section 4(d) of the ESA may need to be addressed as part of the regulatory strategy for the ERP. This section declares that "the Secretary shall issue such regulations as he deems necessary and advisable to provide for the conservation of such species...." This section allows USFWS and NMFS to issue rules that allow impacts on threatened species that otherwise would be prohibited under Section 9. The provisions in Section 4(d) have been used as part of the joint Natural Community Conservation Plan/HCP planning process in the state. NMFS recently listed the Central Valley Steelhead Evolutionarily Significant Unit as a threatened species, but has not published a Section 4(d) rule. It is possible that the ERP would be involved in carrying out the provisions of a future Section 4(d) rule affecting steelhead.

Section 404 of the Federal Clean Water Act

The federal CWA, also known as the Federal Water Pollution Control Act, was originally adopted by Congress in 1972 to control water pollution. CWA case law uniformly defines wetlands as "waters of the United States" and treats filling of wetlands as a discharge into those waters subject to CWA requirements. The ERP and other CALFED elements propose a variety of actions that will involve placement of dredged or fill material into waters of the United States regulated under Section 404 of the CWA. These ERP actions must comply with Section 404 requirements through existing applicable general permits or by obtaining new individual permits. Individual permits require analysis of alternatives in accordance with the EPA Section 404(b) Guidelines. Section 404 permitting authority rests with the Corps and, under specific circumstances, EPA. The Natural Resources Conservation Service (NRCS) is responsible for jurisdictional determinations on agricultural lands. The Corps regularly consults with EPA, USFWS, and state agencies during its deliberations on permit issues.

The Rivers and Harbors Act of 1899 (RHA) regulates specific activities that affect navigable waters, as defined by federal regulations. The Corps issues permits under Section 10 of the RHA in conjunction with its permitting under Section 404 of the CWA. Although, in most instances, navigable waters regulated under Section 10 are encompassed within the broader category of waters of the United States regulated under Section 404 of the CWA, some activities are regulated under Section 10 (e.g., dredging, construction of structures in or over navigable waters) that are not regulated under Section 404.

Section 401 of Federal Clean Water Act

Section 401 of the CWA addresses potential impacts on water quality (e.g., the levels of sediments, toxic and hazardous substances, nutrients or other pollutants). ERP actions requiring Section 404 permits and will also require a Section 401 waiver or certification from SWRCB or the Regional Water Quality Control Boards (RWQCBs).

Section 401 permits are issued by SWRCB and its regional boards under authority delegated to the state by the CWA and oversight by EPA. In addition to the normal permitting needs under Section 401, ERP and CALFED managers will need to address the requirements of the Clean Water Action Plan (CWAP) now being formulated for the state. This plan is being prepared jointly by SWRCB and the U.S. Department of Agriculture (USDA) to guide federal resource allocations for coordinated watershed protection. Many of the watersheds within the CALFED study area are designated as priority watersheds (Category 1 out of four categories) for protection and enhancement.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act requires that all federal agencies consult with USFWS, NMFS, and the state's wildlife agency (i.e., DFG in California) for activities that affect, control, or modify waters of any stream or other bodies of water. Under this act, USFWS and NMFS review application for Section 404 permits and provide comments to the Corps about the environmental impacts of proposed projects. In some cases, a separate Fish and Wildlife Coordination Act report is prepared by the federal lead agency or project applicant.

FORMULATING A LONG-TERM REGULATORY STRATEGY

As previously discussed, the primary reasons for discussing Stage 1 implementation in a separate chapter are related to the lack of specific descriptions of proposed ERP actions and the need for a transition strategy capable of translating the existing program-level information and decisions into project-level regulatory approvals and documentation. Because of the programmatic nature of existing descriptions of ERP actions and related environmental documentation, it is difficult to outline a specific, step-by-step long-term regulatory strategy for the next 30 years.

It is possible to outline steps that should be part of a conceptual long-term regulatory strategy for the ERP. These steps include:

1. The immediate need is for detailed descriptions for each proposed ERP action. These descriptions must include the purpose(s) of the action, potential biological impacts, mitigation measures, and alternatives capable of achieving comparable purposes.

2. Project descriptions should be compiled and recorded as part of the ERP information management system so that individual actions can be evaluated and monitored as part of an overall ERP compliance strategy and adaptive management framework.

3. Using the 10 adaptive management selection criteria set forth in Chapter 8, proposed actions would be evaluated, prioritized, and selected for implementation as part of Stage 1 or subsequent stages.

4. Before Stage 1, ERP and Category III actions that do not require additional permitting or environmental documentation and that are consistent with the selection criteria would be implemented.

5. Other ERP actions would be identified and implemented that are consistent with adaptive management selection criteria that potentially could receive regulatory permits and environmental certification either before or during the first year following certification of the Programmatic EIS/EIR.

6. Responsible regulatory agencies would be identified. Generally, the two critical regulatory "tracks" exist. One comprises agencies responsible for regulating activities that affect species (e.g., USFWS, NMFS, and DFG) and the other includes agencies responsible for regulating impacts on waters and habitats (e.g., Corps, EPA, SWRCB, and DFG). Most ERP actions will require a strategy to obtain multiple regulatory approvals involving both of these regulatory tracks.

7. Within the species regulatory track, ERP managers would determine whether to pursue individual permits for take of individual species under Section 2081 or obtain Section 2835 take permits under the NCCPA. NCCPA permits are provided under the provisions an NCCP that typically addresses species protection at the natural community and ecosystem levels, rather than on a species-by-species basis. For an ecosystem-based program such as the ERP, the NCCPA approach (Section 2835 permits) appears to provide distinct advantages.

8. Consistent with the selection criteria and illustrative phasing plan outlined in Chapter 8, ERP actions that could commence during Stage 1 would be evaluated and selected. As feasible, each action would be assigned to one of the three Stage 1 phases.

9. Selected ERP actions would be identified that cannot be initiated during Stage 1 because of: (a) the time required for permitting or environmental documentation, or (b) the need to complete other ERP actions before initiation of the subject action. ERP managers would begin preparing the Stage 2 phasing plan.

10. Consistent with the discussion in Section G, necessary environmental documentation would be prepared for individual Stage 1 ERP actions or groups of actions under an environmental document designed to cover multiple related ERP actions.

11. Following certification of related Stage 1 environmental documents, approvals would be obtained for proposed actions or, as necessary, actions would be modified to obtain needed permits.

ENVIRONMENTAL DOCUMENTATION APPROACH UNDER CEQA AND NEPA

CALFED is a joint state and federal program. To address the requirements of CEQA and NEPA, CALFED prepared a draft Programmatic EIS/EIR. Evaluation of the potential environmental impacts associated with ERP actions and other CALFED actions must continue to be conducted jointly in accordance with the requirements of CEQA and NEPA. NEPA requires every federal agency to disclose the environmental effects of its actions for public review and for assisting the federal lead agency in assessing alternatives to and the consequences of the proposed action. CEQA requires state, regional, and local lead agencies to prepare environmental impact assessments of proposed projects with significant environmental effects and to circulate these documents to other agencies and the public for comment before making decisions.

Program Implementation under the Programmatic EIS/EIR

As previously discussed, staged implementation of the ERP is necessary because of the complexity of the Bay-Delta system, limits on available scientific data, and an inability to predict future events and how the ecosystem will respond to specific ERP actions. Additionally, most program actions being considered are not yet precisely defined. CALFED therefore elected to prepare a programmatic environmental document. The draft Programmatic EIS/EIR describes and evaluates the potential environmental consequences of actions at a programmatic level of detail rather than at a site-specific level of detail. The draft Programmatic EIS/EIR is intended to support the selection of a preferred program alternative rather than the selection of a specific action (CALFED Bay-Delta Program 1997). As a result, the scope of environmental documentation covered by the draft Programmatic EIS/EIR limits the number of specific ERP actions that can be implemented without completing additional environmental documentation.

The State CEQA Guidelines (Section 15168) identify a number of advantages to using a programmatic environmental document for large, complex projects where individual actions may be linked geographically or functionally. Advantages include: (1) providing a future occasion for more exhaustive consideration of effects and alternatives, (2) ensuring consideration of cumulative impacts that might be missed in a project-by-project analysis, (3) avoiding duplicative reconsideration of basic policies, and (4) allowing the lead agency to consider broad policy alternatives and programwide mitigation measures early and with greater flexibility.

Consistent with the language in the Guidelines, the draft Programmatic EIS/EIR proposes that second tier or site-specific environmental documents be prepared for individual projects after the final Programmatic EIS/EIR is certified. The concept of tiering or "nesting" subsequent environmental documentation and approvals based on a program-level document is consistent with both CEQA and NEPA; therefore, the compliance strategy proposes to use the Programmatic EIS/EIR as a basis for simplifying the task of preparing future CEQA and NEPA environmental documents. For example, under this approach, policy-level decisions and impacts that were addressed in the Programmatic EIS/EIR generally would not be reexamined Specific ERP actions that were not addressed in the Programmatic EIS/EIR could be the subject of an initial study or environmental assessment to determine whether the proposed action could have significant environmental effects not previously considered. If the initial study/environmental assessment determines that significant effects not previously reviewed might occur, the environmental documentation found in the programmatic document could be incorporated by reference to address regional influences and secondary and programmatic-level effects, while the scope of the subsequent document could be focused on significant new impacts.

Defining an Environmental Documentation Strategy

Preparation of environmental documents under CEQA and NEPA involves considerable time, generally ranging from a few months for a CEQA negative declaration or a NEPA finding of no significant impact (FONSI), to more than a year for a relatively simple EIR/EIS and several years for more complicated projects. One of the most important tasks for program managers will be to track actions being considered for implementation and identify future environmental documentation needs far enough in advance of needed permit approvals (see previous discussion on permitting) to allow each ERP action to be reviewed and approved by regulatory agencies without unnecessary delays related to missing or inaccurate environmental documentation.

At this time, proposed actions and potential impacts are not sufficiently defined for program managers to apply the adaptive management decision framework and identify specific documentation requirements; therefore, to effectively plan for environmental documentation under the adaptive management and programmatic tiering approaches described above, the following steps should be completed:

1. After individual ERP actions are reviewed, prioritized, and selected using the selection criteria (see previous regulatory strategy steps), identify likely regulatory requirements and documentation needs based on each project's purposes, potential biological impacts and mitigation requirements, and potential for alternatives that could achieve action purposes with reduced biological impacts.

2. For selected actions, prepare an initial study or environmental assessment to determine whether the action involves significant environmental impacts not addressed in the Programmatic EIS/EIR and ROD.

3. Identify significant new impacts, if any, and related environmental documentation requirements for each action.

4. Evaluate opportunities for grouping several ERP actions so that they can be covered by a single environmental document.

5. Draft environmental documents should be prepared and distributed for public review. As part of the concurrent regulatory approval process for proposed actions, responses to comments received during the public review period should be prepared and incorporated into final environmental documents.

6. Following certification of the environmental document(s) and receipt of all necessary regulatory approvals, the proposed ERP action should be initiated.

7. Consistent with the discussion of adaptive management in Chapters 2 and 6, and the process shown in Figure 2-4, implementation of the approved actions should be monitored and, as appropriate, modified.

8. If an approved action is modified, it may be necessary to reevaluate the adequacy of certified environmental document. If changes in the action are dictated by the adaptive management framework while the action is in progress and significant new impacts that were not addressed in the certified document(s) result, the preceding steps may need to be repeated for this action.

The adaptive management decision framework will be an important tool for enabling ERP program managers and others to track individual ERP actions and identify information needs in a timely manner. Under the adaptive management framework, program managers can periodically identify changing information needs for specific projects at successive stages of the decision-making process (Figure 2-4).

STAGED ERP IMPLEMENTATION AND PROVISION FOR ASSURANCES

One of the most challenging aspects of the CALFED process for the ERP involves the need to maintain a reasonable balance in terms of progress toward completing ERP actions and other components of CALFED. After the Programmatic EIS/EIR is certified and USFWS and other agency RODs are prepared, program participants will monitor the program to determine whether it is being implemented and operated as agreed. Water users have made it clear that it would not be acceptable for CALFED to spend a billion dollars on restoration without the water operating rules being defined for users and water conveyance and storage alternatives resolved. Other interests have been equally adamant in declaring that decisions must not be made on the conveyance and storage issues without sufficient progress on the ERP and adaptive management.

Need to Define "Adequate Progress" among Program Elements

Nearly all parties agree that for CALFED to succeed, there must be some degree of symmetry or balance in terms of progress among program elements. There is no common understanding of what constitutes adequate progress for any specific component, let alone for comparing progress on the ERP with other components, such as water supply reliability (including conveyance and storage); therefore, there is a critical need to:

- identify measurable levels of progress (i.e., thresholds) toward ecosystem restoration and other program goals;
- identify tools capable of facilitating attainment of identified performance thresholds; and
- link ERP progress to attaining measurable progress (threshold decisions or performance levels) for other program components such as financing, governance, water project operating rules, water storage and conveyance, water quality, and levee protection.

Facilitating progress will require developing specific tools. These tools could include incentives or alternative solution pathways (e.g., funding for water purchases) that would contribute to meeting performance standards and maintaining incentives for all parties to stay involved at each stage of the implementation process.

These tools are not yet available; therefore, a primary compliance objective during Stage 1 should be to formulate such incentive and solution options. Preferably, these tools would be developed before decisions on major program features, such as conveyance or surface storage alternatives. At a minimum, these tools should be developed concurrent with a final decision on the preferred program alternative.

Illustrative Compliance and Assurance Milestones

The ability of the ERP to address endangered species requirements under ESA and CESA and to achieve overall ecosystem restoration goals is directly related to progress in other CALFED elements. If the ERP progresses satisfactorily but other program elements do not (e.g., the water supply or water quality components), support for CALFED overall will not be sustainable and the ERP would not be able to achieve its ecosystem restoration goals and objectives. It is therefore necessary for the strategic plan to underscore the interrelatedness between an effective ERP compliance strategy and programmatic assurances.

The following discussion provides a selective look at other program elements to identify some of the interrelationships between the ERP and other program actions. It does not attempt to address the full range of CALFED assurances issues.

The Assurances Work Group, stakeholders, and others within the CALFED structure will be responsible for preparing the assurances package and are already working to systematically identify and resolve the full range of assurances issues raised by CALFED. Resolution of the relationship between compliance and assurances issues must result from the collaborative efforts of these CALFED participants. The purpose of this discussion is to highlight the importance of the assurances/compliance relationship and to emphasize the urgent need to establish a workable framework for resolving assurances before certification of the Programmatic EIS/EIR and issuance of the ROD.

The CALFED solution is based in part on the expectation that certification of the final Programmatic EIS/EIR and issuance of the ROD(s) for CALFED would provide the basis for extending the current accord on Bay-Delta flow standards and operating rules for 1 year. Following the 1-year extension, CALFED envisions that the accord would be replaced by the provisions of the programmatic ROD. Before discussing Stage 1 implementation issues and priorities, examples of compliance decisions, assurances, and information needs that must be considered as part of a staged implementation program are discussed, including concerns that could be addressed as part of the Section 7 programmatic consultation for CALFED. This discussion emphasizes: (1) linkages between operations and environmental assurances during Stage 1 and (2) assurances regarding information needs and decisions that would affect specific program elements under future Section 7 consultations.

Given the variety of CALFED activities that may be undertaken during Stage 1, it may be helpful to define categories of assurances that relate to the broader implementation program and assurances that involve interrelationships between ERP/ESA considerations and other CALFED elements. The following discussion illustrates some of the distinct categories of assurances and assurance considerations that need to be resolved in relation to ESA Section 7 consultation(s) and prior to the Programmatic ROD .

Programmatic Assurances for Environmental and Operations Linkages During the Stage 1 Implementation Program

Two illustrations of programmatic assurances considerations are addressed: (1) assurances required to extend the accord without any change in the current Bay-Delta standards and rules and (2) procedures that would be followed in the event of a significant decline in the population(s) of ESA-listed species that could potentially lead to a reinitiation of consultation under ESA Section 7 regulations.

Extension of the Current Bay-Delta Accord. Clearly, a decision on whether to extend the Bay-Delta Accord is critical to providing certainty and stability for the Stage 1 implementation program. Significant questions have been raised regarding the effectiveness of the current standards in the accord for assuring no jeopardy to federally and state-listed species.

Any changes in the substantive provisions of the Bay-Delta Accord would have a major impact on the interests of all stakeholders. For example, any change in the export-inflow ratio (E-I ratio) designed to protect fisheries resources from February through June could have significant impacts on water supply opportunities. According to the Phase II Interim Report, for Alternatives 1 and 2, more protective E-I ratios can have significant water supply impacts in both the critical period and the longer average period (Phase II Interim Report, p. 19). The Phase II report notes that without new storage, average annual critical-period supply decreases by about 400 thousand acre-feet (TAF) under Alternatives 1 and 2 with the more-protective E-I ratios in place while the net average annual critical-period supply benefit of the new storage with the more-protective E-I ratios in place is only about 350 TAF, compared to a net benefit of about 650 TAF with existing E-I ratios in place (Phase II Interim Report, p. 19).

Extension of the accord provisions could provide certainty for all elements of the Stage 1 implementation program, including the ERP; however, given current questions concerning implementation and enforcement of the accord, an accord extension may need to address the following additional requirements:

- consistency with the future provisions of the proposed fall-run and spring-run chinook salmon listings under ESA;
- confirmation that the current E-I ratio and other Bay-Delta substantive standards are consistent with ESA requirements;
- adoption of an effective Stage 1 ERP implementation program that: (1) provides measurable benefits for listed species, (2) tests important hypotheses necessary to make future decisions regarding ERP restoration priorities and phasing, and (3) provides for ecosystem-level benefits on major streams and tributaries;
- adoption and implementation of an adaptive management program for the ERP that includes a peer-reviewed set of ecological indicators for both listed species and broader ecosystem changes;
- firm assurances regarding supplying the water necessary to carry out Stage 1 ERP measures and progress toward identifying sources and acquiring water supplies necessary for ERP Stage 2;
- a specific budget for Stage 1 ERP implementation and an ERP accounting model both for tracking fund inflows and outflows with an annual accounting report assessing reasonable further progress.

Assurances Regarding Reinitiation of Section 7 Consultation during Stage 1. The recent federal rule-making for the Section 10 no-surprises policy indicates that federal agencies have a continuing species conservation obligation under Section 7. As stated in the no-surprises rule, the types of assurances available under Section 10 of the ESA are not available with respect to

commitments where federal agencies fund, authorize, or undertake discretionary actions. ESA Section 7 regulations contain provisions requiring the reinitiation of Section 7 consultations under specific circumstances involving significant declines in listed species. It is therefore useful to consider the potential need for a set of workable assurances for the overall CALFED Stage 1 implementation program in the event such a decline in a listed species occurs.

USFWS and NMFS are authorized to define procedures for reinitiation of Section 7 consultation. CALFED should, in conjunction with the Section 7 consultation for Stage 1 implementation, consider formulating proposed procedures that would be employed in response to future marked declines in populations of or habitat conditions for listed species. These procedures could include actions initiated under an informal Section 7 consultation when population levels of specific listed species fall below predefined threshold levels, and before a decision by federal agencies to reinitiate formal consultation. In response to a significant decline in populations of aquatic species possible procedures could include:

- immediate use of standby water supply contracts obtained by stakeholders to provide supplemental fisheries water supplies where such water supplies can benefit a species in decline; and

- other corrective measures undertaken under the purview of a short-term corrective action program approved by the state and federal resources agencies that would use water under the control of the ERP program or stakeholders in CALFED, including redirection of ERP-acquired water supplies, the use of CVPIA (b)(2) water, or changes in water supply/conveyance operations.

Under such an approach, formal Section 7 reinitiation of consultation would occur if, and only if, corrective actions such as those identified above failed to achieve measurable and significant species benefits within a timeframe established by the informal Section 7 consultation short-term corrective action program

Specific Assurances for CALFED Elements

The following assurances address unique attributes of specific CALFED elements that are intertwined with ERP and ESA considerations. These examples illustrate the types of considerations that may be involved in finalizing a set of assurances for each element. They also illustrate how to incorporate assurances into a ROD to provide a basis for a Section 7 programmatic consultation and biological opinion conditions capable of covering the CALFED Stage 1 Implementation Program.

1. Water Supply Management Options Relating to ESA-Listed Species and ERP Implementation Assurances

The latest CALFED staged decision-making document states that because of regulatory requirements, the major financial commitments, and the potential environmental impacts, new surface storage requires special consideration (CALFED Bay-Delta Program, August 5, 1998). It further states that CALFED believes more efficient use must be made of existing water supplies systemwide before building new surface storage and that, in addition, there must be enhanced opportunities for water transfers before building new surface storage. Accordingly, stakeholder and CALFED assurances relating to ESA-listed species could include defining a specific water acquisition program for ERP implementation that:

- includes alternatives considered in the CVPIA analysis, and
- describes the extent to which water efficiency and water transfer market performance standards must be met before final decisions on water storage and related conveyance proposals.

As decisions on water supply management options are finalized, a process could be defined whereby the considerations outlined immediately above could be related to south-Delta improvements, south-of-Delta storage improvements, and north-of-Delta storage improvements.

South-Delta improvements appear to provide potential operational flexibility that could benefit CESA-listed and ESA-listed species with or without a long-term increase in water supply exports from the Delta. Assurances regarding final decisions for such facilities could include defining the information needs and process for assessing benefits to CESA/ESA-listed species and ERP program implementation resulting from south-of-Delta storage operations:

- with and without the proposed SWP/CVP intertie under current E-I ratio standards,
- with the more-protective E-I ratio standard outlined in the Phase II Interim Report, and
- scenarios involving increased exports.

The decision-making process could also incorporate relevant factors relating to the final decision under the current chinook salmon proposed listings. Construction of new south-of-Delta storage and the SWP/CVP intertie could be keyed to assuring ERP water supply contracts and operations modifications for dry periods and critically dry periods affecting ESA-listed species and the overall function of ERP measures.

North-of-Delta water storage improvements rely heavily on increasing fisheries and other riverine/estuarine habitat benefits for their justification; however, according to the Phase II Interim Report the validity and appropriate role for time-value-of-water concept in California water management have not been fully discussed within the broader stakeholder and scientific communities. and additional work remains to identify and resolve controversy related to the concept, determine specific parameters (flow rates and timing), and scientifically evaluate the potential effects

of this approach. Assurances relating to potential impacts on ESA-listed species and effective implementation of the ERP could involve:

- defining the scope of scientific analysis of potential peak flow diversions on the geomorphology of riverine systems, including those of importance to ESA-listed species;

- comparing new storage with operations modifications, b(2) water use scenarios, and water acquisition alternatives considered in the current CVPIA EIS; and

- identifying projected timing, cost, and operational flexibility considerations of north-of-Delta water storage options in relation to other means of increasing water supply for ERP purposes.

2. Conveyance Alternatives Related to ESA-Listed Species and ERP Implementation Assurances

In its Phase II Interim Report, CALFED states that it cannot rule out the potential need for a dual conveyance facility to achieve its mission and neither can it conclude, based on current information, that the facility is necessary for fulfilling that mission. CALFED also notes that, because of the long lead time, the existing Delta channels must be used almost exclusively for a minimum of 10 years, even if a decision is ultimately made to proceed with an isolated facility conveyance option; therefore, there would be a 10-year period within which ERP contributions to the health of listed species could be measured and during which the potential contributions of future ERP implementation stages could be more effectively addressed. Whether or not CALFED chooses what it refers to as "on-ramp" or "off-ramp" approaches, CALFED should formulate specific criteria that would be applied in a decision to build or not build an isolated facility.

It is likely that a final decision on an isolated facility alternative would require a Section 7 consultation. It would make sense to include decision criteria for consideration as part of the Section 7 consultation for Stage 1 implementation to provide an information base and increased predictability for a future Section 7 consultation on the isolated facility. The Section 7 decision criteria for Stage 1 could include the following:

- definition of listed species habitat evaluation criteria that would be used to assess the success of ERP Stage 1 implementation and to estimate the likely success of future ERP implementation stages;

- evaluation of the status of the Anadromous Fish Restoration Plan implementation program undertaken pursuant to CVPIA statutory obligations to take reasonable measures to double the populations of anadromous fishes, many of which are ESA-listed species; and

- evaluation of measures available to achieve or make substantial progress toward the recovery of listed species dependent on the Delta.

3. Levee Improvements Assurances Relating to ESA-Listed Species and ERP Implementation

Many levee improvement activities will require Section 7 ESA consultation for actions authorized under RHA Section 10 or CWA Section 404 permit programs. Habitat supporting listed species may be affected, particularly within portions of the Delta. If ESA-listed species are affected, Section 7 consultations would be triggered. To the extent that specific levee improvements can be incorporated into the Section 7 consultation for the CALFED Stage 1 implementation program, assurances could be provided that Section 7 consultation would cover, to the extent feasible, RHA and CWA permit actions. If specific levee improvements are not covered by the Section 7 consultation, the programmatic Section 7 consultation could at least define parameters for future Section 7 consultations.

4. Flood Control Issues and Current Corps Studies Affecting the ERP

Many ERP alternatives involve modifying prior flood control measures to improve stream geomorphology conditions to enhance anadromous fisheries habitats. In such cases, specific flood control planning will be required. ERP-related flood control issues, including hydrologic studies for island restoration within the Bay-Delta, could be specifically identified and ESA-species concerns addressed as part of the programmatic Stage 1, Section 7 consultation. This would provide greater certainty for subsequent site-specific Section 7 consultations related to flood control activities.

5. CVPIA EIS and Trinity Diversion EIS Considerations Potentially Relating to the ERP

The federal government is currently engaged in major environmental analyses relating to CVPIA statutory mandates and proposed enhancement of Trinity River flows for anadromous fisheries. Commitments pursuant to these two EIS reviews should be correlated with assurances provided in conjunction with a CALFED programmatic consultation.

CONCLUSIONS

This chapter has provided a wide ranging description of a long-term regulatory compliance strategy for the ERP and has attempted to capture the scope and variety of issues that must be addressed as the ERP and CALFED are implemented in stages over 30 years. The discussion of linkages and assurances that bind the ERP to other elements of the program is useful for ensuring coordination and prioritizing specific actions. It is difficult, if not impossible, to draw hard lines separating the ERP from other elements of CALFED. Although assurances and compliance issues start from different baselines, it is nearly as difficult to separate the issue of assurances from the

compliance strategy. The interrelatedness of CALFED compliance problems, assurances, and solutions across program boundaries is pervasive and, ultimately, commands attention.

The following chapter discusses a strategy for implementing Stage 1 of the ERP.

Chapter 8. Recommended Strategy for Implementing Stage 1 of the Ecosystem Restoration Program

VISION FOR STAGE 1 OF THE ERP

In its recent document, Developing a Draft Preferred Program Alternative, (CALFED Bay-Delta Program August 5, 1998), CALFED described Stage 1 as the beginning of a series of actions that would form the basis for the long-term CALFED solution. Stage 1 does not lead to a set of specific, predefined future outcomes; it begins an adaptive management implementation process where future outcomes of all program components are dependent on the results of decisions and outcomes that have not yet been defined. The adaptive management approach is described in some detail in Chapter 6.

If Stage 1 progresses as planned, the biological, procedural, and institutional components necessary for effective long-term implementation of the ERP would be in place at the beginning of Stage 2. Successful completion of Stage 1 would allow ERP program managers to draw on the following resources as they begin to implement Stage 2.

- The institutional entity responsible for implementing the ERP would be fully operational and have the authority and independence needed to successfully implement the ERP.
- Funding necessary to fully implement the ERP would be identified and available as needed during completion of the program. A specific budget for the other ERP and other CALFED components would be updated at the end of Stage 1.
- An assurances framework covering the ERP and other components of CALFED would be in place to guide implementation of Stage 2 actions and decisions, particularly those decisions involving major water conveyance and storage facilities and levee integrity.
- The adaptive management framework, including research, monitoring, and conceptual modeling components, would be fully functional. This program would have generated several years of data through its focused research, conceptual modeling, monitoring, and habitat restoration and enhancement actions. Additionally, independent scientific review provided throughout Stage 1 and the "scientific assessment" proceedings to be held at the end of Stage 1 would provide important critical comment and guidance concerning how well the ecosystem restoration program is progressing. Progress toward achieving ERP Stage 1 objectives would be evaluated and could be used to refine or redirect adaptive management priorities.

E-026253

E-026253

- Information generated under the adaptive management framework would be compiled, stored, readily available, and easily accessible to program participants, the public, and scientists through CALFED's online information management system.

- ERP actions selected for Stage 1 would be completed or substantially completed, including those ERP actions and decisions identified as being critical to guiding decisions on major Stage 2 decisions.

- Priority ERP actions proposed for Stage 2 would be identified and precise project descriptions (including specific purpose, impact, mitigation, and alternative discussions) would be available for priority actions scheduled for Stage 2.

- Environmental documentation and permitting requirements would be identified and integrated into an overall compliance strategy that addresses the specific permitting and environmental documentation of projects and would be consistent with the assurances component of the program.

The following sections provide a focused description of the process that led to the preceding vision statement.

ERP STAGE 1 CHARACTER AND OBJECTIVES

Strategic plan recommendations for Stage 1 are based on the adaptive management decision approach discussed in Chapter 6. Recommendations are not based on presumptions that would limit future ERP alternative actions or solutions considered during the adaptive management decision-making process (e.g., presumptions regarding future conveyance or surface storage solutions). Stage 1 marks the beginning of the long-term decision and implementation process where ERP actions and alternatives are evaluated within an adaptive management framework. In this context, Stage 1 should be considered as the initial phase of the long-term implementation strategy, not as a discrete, short-term action plan designed to begin restoring the ecosystem. Stage 1 provides the critical transition period that will be necessary to translate programmatic-level decisions and approvals provided under CALFED's Programmatic EIS/EIR and ROD to the major project-level decisions and actions that must be completed under the long-term implementation strategy.

The strategic plan strategy for Stage 1 of the ERP is aimed at carrying out the following tasks as part of the adaptive management decision-making process.

- Provide the ecological and procedural foundation (i.e., adaptive management approach) for future stages of ERP implementation.

- Identify critical CALFED decisions in the ERP and other program components that will be linked to or dependent on ERP information and actions.

- Identify and refine the understanding of linkages between ERP actions.
- Identify linkages between ERP and non-ERP actions where either functional/technical linkages are identified or the need for assurances is present.
- Select criteria for identifying and prioritizing actions considered for Stage 1 and subsequent stages of implementation.
- Identify a comprehensive list of specific ERP actions and decisions to be included in Stage 1, and immediately identify Category III and other projects that could be used as pilot projects for immediately moving forward on the adaptive management process;
- Establish joint planning with the Corps to integrate flood-management planning with ERP Stage I actions, and vice versa.
- Immediately identify pilot projects to increase the knowledge gained from flood management actions and the flood safety of ERP actions.
- Develop a shared database and geographic information system (GIS) capability.
- Identify substages or phases within Stage 1 that reflect the time required to complete necessary environmental documentation and/or obtain permits for recommended actions, thereby enabling Stage 1 to progress in a balanced, defensible manner and provide an effective foundation for Stage 2 decisions and actions.
- Identify "transition" tools and procedures, including measures of progress that relate to decisions on major program elements and can assist program managers in completing Stage 1 and beginning Stage 2 of the ERP and overall CALFED implementation efforts.

Based on the above work program elements, the following discussion addresses actions and decisions that should begin and, in some cases, be completed, in Stage 1.

DEVELOP A LIST OF ERP ACTIONS AND DECISIONS FOR INCLUSION IN STAGE 1

To compile a list of actions for inclusion in Stage 1 of the ERP, the following factors and actions must be considered and/or completed:

- Identify proposed ERP actions already covered adequately by the final Programmatic EIS/EIR and ROD.
- Understand the status of the prior list of Stage 1 ERP actions compiled by staff member.

- Develop criteria to guide the selection of proposed Stage 1 actions that carry out the adaptive management decision rules set forth in Chapter 6.

- Provide a process whereby CALFED and stakeholders can work collaboratively to agree on a list of actions.

Identify Actions Covered by the Final Programmatic EIS/EIR and ROD

A review of the actions included in the latest CALFED documents indicates that, even if the suggested program-level actions were precisely defined and reviewed within an adaptive management decision framework, most of these actions could not proceed in Stage 1 without additional environmental approvals and agency review and permitting; therefore, one of the first tasks for program managers between now and the publication of the "revised" draft Programmatic EIS/EIR would be to systematically review the proposed ERP actions to determine whether and to what extent additional documentation or permits would be required.

Review of the Restoration Coordination Program Projects

As part of an effort to commence ecosystem restoration actions as soon as possible, CALFED's Restoration Coordination Program projects (formerly known as Category III projects) should be reviewed immediately to identify actions that have already obtained necessary approvals, are ready to be implemented, and would address ERP goals and objectives. By reviewing these projects early, those determined to be consistent with ERP goals and objectives could be started immediately. Additionally, such projects could be augmented, where appropriate, with design modifications, conceptual modeling, and monitoring features. Conducting preconstruction baseline studies could also serve to enhance the value of these projects.

Status of the Existing CALFED Stage 1 List of ERP Actions

The list of Stage 1 ERP actions compiled by CALFED staff members addresses the need to identify programmatic actions for inclusion in the CALFED project description (CALFED Bay-Delta Program 1997). This list will be reviewed with stakeholders, the Strategic Plan Core Team, or others as part of the adaptive management decision framework for Stage 1. This review would be the first step in preparing a list of Stage 1 actions that will be finalized during Stage 1. The final list will be based on a review of all potential ERP actions within an adaptive management framework as described in Chapter 6 (including the more than 700 actions in Volumes I and II of the Ecosystem Restoration Program Plan and other proposals). The 16 actions proposed by CALFED staff members were described at a program level so that CALFED could prepare the project description for the revised draft Programmatic EIS/EIR scheduled to be completed later this year. Proposed actions on

the list prepared by CALFED staff members do not provide specific project locations, precise descriptions of expected benefits and potential impacts, or details explaining how the action would be implemented. These purposes and characteristics will be addressed as part of the process for finalizing Stage 1 actions.

Develop a Process for Finalizing Stage 1 Actions

For Stage 1 to be successful, a formal process should be established as soon as possible to review previously proposed actions (including the more than 700 actions in Volumes I and II of the Ecosystem Restoration Program Plan) and to set the ground rules for identifying all potential new actions. Project proponents should be invited to elaborate on the purpose of the action and on underlying conceptual models. The locations of a number of proposed Stage 1 projects have been entered into a GIS. This effort should be expanded to include review of CALFED Restoration Coordination Program projects for possible modification and augmentation for additional monitoring and research. A simple project tracking database should be established to provide access to project descriptions, permit requirements, project status, implementation responsibilities, and other information.

Once this material has been organized, a step-by-step review will be undertaken to define each action in terms of its goals, objectives, monitoring and research, and relation to other projects. Projects will be evaluated to identify ways by which to increase the information gained from that project during Stage 1. The evaluation might result in a recommendation to expand the monitoring and research component of the action itself, or initiate focused research on a related ecosystem process, or could identify a landscape-level issue. Finally, using the selection criteria outlined in the following section, projects will be ranked and prioritized, most likely by categories of activity. This process could use any one of a number of ranking techniques (lexicographic, simple value analysis) to avoid making decisions by rote and to help clarify each action's role in ecosystem restoration.

The review process would conclude with specific recommendations on: (a) actions to be initiated during Stage 1, and (b) the longer term process for CALFED's consideration of new proposals. Because of the complexity and variety of potential ERP actions, it is likely that refinement of the Stage 1 list of actions will need to continue into at least the first year of Stage 1. After the first year, the list of recommended actions would continue to be refined on an ongoing basis in accordance with evolving adaptive management findings/recommendations and the Stage 1 selection criteria for actions discussed below.

SELECT CRITERIA FOR STAGE 1 ERP ACTIONS AND RESTORATION COORDINATION PROGRAM PROJECTS

Under an ecosystem-based, adaptive management approach, it is important to reevaluate previously proposed actions and to set procedures for evaluating and prioritizing future actions. The CALFED Restoration Coordination Program projects have evolved over a number of years and are based on a large number of goals and objectives. In only a few cases, the proposals are supported by explicitly stated goals, objectives, and criteria for evaluation of their success. None of the proposed actions contained in Volumes I and II of the Ecosystem Restoration Program Plan were evaluated within the context of the adaptive management approach recommended for the ERP; therefore, it is important for the strategic plan to: (1) introduce new criteria designed to help make Stage I ecosystem-based and adaptive, and (2) suggest a process for further evaluating both previously proposed and newly proposed actions.

The selection criteria below should be applied throughout the process of nominating, evaluating, and selecting ERP actions for Stage 1 implementation. The recommended criteria include amplified versions of the six decision rules identified in Chapter 6 and four additional criteria that could be of special relevance to the adaptive management process during Stage 1. The 10 selection criteria are to emphasize projects that:

1) will have the greatest absolute benefits and the greatest benefit-cost ratio for native species and habitats;

2) will provide the most useful information about system dynamics (e.g., is the project replicable? can the results be generalized? will it contribute to a better understanding of the ecosystem and the effects of stressors? will implementation of this action restore and help understand an important ecosystem process (e.g., nutrient cycling, fluvial dynamics)? will it help future decisions about large-scale ecological restoration and species conservation?);

3) are complementary in their effect, unless noncomplementary projects can provide important information about system dynamics;

4) will provide results within a short timeframe, thus providing important information during Stage 1 that may be needed for transition to Stage 2;

5) will be the most self-sustaining;

6) provide information richness (e.g., does the action include some control over detailed design and location for research purposes? does the proposed site of the action have good background information and historical data?);

7) are based on ecosystem modeling (e.g., did its need arise from conceptual modeling or science-based inquiry? is the action supported by conceptual and simulation modeling of underlying ecological processes?

8) address causes rather than symptoms (e.g., does it address the causes of ecosystem degradation or just the symptoms? can the environment and outside forces be controlled or manipulated so that cause-and-effect relationships can be illuminated?);

9) are designed to achieve explicit, tangible, and measurable objectives; and

10) have high public support and visibility.

The above criteria should be used and, in some cases, may take precedence over more traditional criteria. For example, under some circumstances, it might make sense to undertake a fairly costly and uncertain pilot project, even one with only minor benefits to the ecosystem, if the action is needed to shed light on an important ecosystem process. The decision to undertake such a project would depend on such things as a benefit-cost analysis that weighed the value of the information gained and the benefits to the ecosystem against the potential costs (environmental costs in the event of failure of the action and financial cost of the action). This is not to say that adaptive management inevitably leads to speculative projects, only that it does not rule them out.

It also may be advisable to consider criteria that, although not related specifically to adaptive management, would aid in the Stage I selection process. For example, project consideration could favor projects that provide for: (1) geographic coverage—filling out coverage of ecological zones within the Delta, tributary streams, or watersheds that enable a broader understanding of the regional environment; or (2) fungibility—selecting an action because it creates an asset (such as new water rights or land ownership) that would retain value and could be sold or traded at a later date if the result of the proposed action does not meet expectations or is not needed.

RECOGNIZE THE PROBABLE NEED FOR PHASING STAGE 1 ERP ACTIONS AND DECISIONS

A review of actions identified by CALFED or stakeholders for possible inclusion in Stage 1 reveals that more information is needed for many actions before final Stage 1 decisions can be made. For many actions, the detail available in the project description and the level of understanding of project benefits and impacts is limited. Additionally, there are other candidate actions that have not been discussed and may need to be considered before finalizing the Stage 1 action list. Potential Stage 1 actions being compiled in accordance with the earlier selection criteria should therefore also be concurrently identified and categorized based on the following factors:

- amount of new documentation and permitting required to obtain final agency approvals;
- time required to complete documentation and permitting;

- timing considerations of linkages to other ERP or non-ERP CALFED actions; and

- potential to group ERP and non-ERP Stage 1 actions for environmental documentation and permitting.

By compiling Stage 1 actions according to the above factors, program managers could estimate when an action would be ready for implementation. This information will be useful in screening actions in three ways.

- First, screening will almost certainly demonstrate that a phasing plan will be needed to organize and implement Stage 1 ERP actions. Different action characteristics and regulatory approval requirements will result in actions being implemented in a logical and sequential manner, not all at once.

- Second, screening would identify actions that should not be considered for Stage 1 because of timing limitations (i.e., if it would take too long to get approvals or complete other necessary linked actions, the action would not occur until Stage 2).

- Third, screening would enable program managers to identify and organize actions included in Stage 1 based on timing considerations. For example, screening could provide the initial forecast of actions that could be initiated in year 1 of Stage 1 and other actions that would have to occur later in Stage 1.

This evaluation process should be initiated immediately and continue concurrent with compilation and finalization of the list of recommended actions for Stage 1.

ERP STAGE 1 PHASING PLAN

Stage 1 actions would be reviewed and screened using the selection criteria discussed earlier in this chapter. The factors and processes outlined in the previous discussions suggest that a phasing plan should be prepared to guide restoration actions during designated phases of Stage 1. Although the following discussion of phasing is conceptual, it is helpful to outline a sequence of actions that would be involved in formulating and implementing a specific Stage 1 phasing program.

As a starting point, a phasing plan would recognize several factors:

- under the current CALFED schedule, Stage 1 does not commence until 2000, roughly 16 months following release of the draft strategic plan;

- it would not be desirable to delay implementation of ERP restoration activities such that a significant time gap occurs between certification of the final Programmatic EIS/EIR and issuance of the ROD and the initiation of adaptively managed restoration activities;

- some restoration actions would be adequately covered under the Programmatic EIS/EIR and ROD and could begin in the first year of Stage 1;

- other restoration actions that were previously approved could be modified or augmented to further support the program;

- some actions would require additional regulatory approvals, but might be ready for implementation before completion and distribution of the final Programmatic EIS/EIR for public review and before certification of the final Programmatic EIS/EIR certification and issuance of the ROD;

- other actions would require considerable additional environmental documentation and regulatory approvals, resulting in an approval process of up to 3 years for individual actions or sets of actions; and

- many restoration actions could not begin before completion of Stage 1.

With the above factors in mind, an example phasing approach is outlined below identifying some of the actions and decisions that need to be considered by CALFED, stakeholders, and the public as the programmatic documentation is being prepared for agency approval by the end of next year. The phasing example approach establishes three phases within the Stage 1 timeframe (Phase A, Phase B, and Phase C). Phase C also serves to provide a transition between Stage 1 and Stage 2 ERP implementation.

Phase A of Stage 1: Actions and Decisions Targeted for Year 1 (2000)

Purpose

Following certification of the final Programmatic EIS/EIR and issuance of the ROD, either CALFED or a new successor entity will begin implementing the ERP. Phase A would take place during the first year of Stage 1. The purpose of Phase A of Stage 1 is to ensure that the essential first steps necessary to enable the ERP to be implemented occur as soon as possible to avoid delays in ecosystem management restoration activities.

Activities During Phase A

CALFED Restoration Coordination Program projects initiated before certification of the final Programmatic EIS/EIR documents will continue into Phase A of Stage 1. Between now and the beginning of Phase A, steps should be taken to ensure that, on obtaining programmatic approvals, CALFED, either as a transition entity or a successor entity, is in place to commence Stage 1 ERP restoration. To the extent feasible, startup tasks necessary to initiate monitoring, research,conceptual

modeling, and information system management under the adaptive management approach should be completed.

CALFED's information system should be strengthened before or during Phase A, especially in the areas of Internet-based communication, GIS, regionwide inventories, project tracking, digital document management, and digital library services. Developing these information systems will take time and should be started as soon as possible to ensure completion during Stage 1. Products of the CALFED's Indicators Work Group should be integrated with efforts in conceptual modeling and monitoring. CMARP should have the architecture for monitoring and research in place by the end of Phase A. Depending on CMARP's actions, CALFED may need to give further support to the development of conceptual models during Phase A. Models should be prepared to identify the management direction for each ERP ecological zone. Conceptual models underlying proposed Stage 1 actions should be nested within higher level modeling to help determine how restoration efforts are expected to contribute to goals and objectives.

Restoration actions initiated in Phase A would be limited and probably restricted to four types of activities:

1) Actions that would not involve additional environmental documentation or regulatory approvals, such as creation of partnerships with universities; research efforts not affecting regulated resources; and adaptive management actions involving short-term changes in flow releases below dams, within safety parameters and operating rules.

2) Actions that are adequately covered by CALFED's programmatic documentation and approvals;

3) Previously approved projects being augmented; and

4) Actions requiring only limited additional environmental documentation and regulatory approvals (e.g., requiring less than 8 months to complete).

The last category of actions could be implemented in Phase A only if: (1) Stage 1 actions could be selected before the end of 1998, and (2) regulatory documentation and approval requirements would be completed in time to be addressed in the final Programmatic EIS/EIR released for public review and comment in early 1999. Given these restrictions, the number of restoration actions that can begin in Phase A will be limited.

Decisions and Products Necessary Before and During Phase A

In 1999, activities before the beginning of Phase A of Stage 1 would include:

- finalizing a preliminary list of Stage 1 actions and assigning preliminary phasing designation (e.g., Phases A-C);

- agreeing on a strategy with the Corps, EPA, and SWRCB for processing and obtaining CWA Section 404 permits and CWA Section 401 certifications at a regional, programmatic, or multiproject level rather than having a project-by-project review; and

- beginning preparation of supporting environmental documentation for actions identified for implementation during the Phase B (years 2-4).

Activities during Phase A of Stage 1 could include:

- submitting documentation and permit applications to appropriate reviewing agencies and beginning preparation of supporting environmental documentation for actions intended to commence in year 4;

- refining, if necessary, the Stage 1 list of ERP actions;

- completing the Section 7 consultation(s) for federal actions scheduled for Phase B; and

- identifying opportunities to group actions into consolidated environmental documentation and regulatory approval processes.

Phase B of Stage 1: Actions and Decisions Targeted for Years 2-4 (2001-2003)

Purpose

Substantial implementation of the ERP would begin in Phase B of Stage 1. The focus during Phase B would be to commence the substantive restoration, monitoring, modeling, and research actions identified for Stage 1 implementation. Based on potential refinements to the list of actions completed during Phase A, Phase B should initiate implementation of activities focused on resolving the critical questions and issues.

Activities during Phase B

All elements of the ERP should be functioning by the middle of the second year. At this time, some of the "second tier" supplemental regulatory approvals should be obtained and significant restoration actions should begin within the adaptive management framework. Phase B activities would include:

- continuation of actions that do not require additional approvals (e.g., implementing an outreach program, building university or private/public partnerships, coordinating activities and outreach to water districts/authorities and farm bureaus, completing the information management system);

- beginning acquisition of easements and progress on developing a water market and acquiring water for critical ecosystem activities;

- initiating pilot projects designed to test major restoration and management hypotheses (such as those relating to stream geomorphology and Delta hydrology) to address critical questions and issues relating to future ERP and non-ERP actions;

- implementing actions that have received regulatory approvals during Phase A or years 2-3 that are not dependent on or linked to other ERP or non-ERP actions scheduled to occur later in the implementation process;

- completing project-level environmental documentation and regulatory approvals for actions scheduled under Phase C; and

- completing Section 7 consultation(s) for Phase C actions.

Decisions and Products during Phase B

By year 2 of Stage 1, the long-term managing entity for the ERP should also be operational. By year 4 of Stage 1, the last year in Phase B, the restoration program should be fully staffed and operational.

Phase C of Stage 1: Actions and Decisions Targeted for Years 5-7

(2004-2006)

Purpose

Phase C should fulfill at least two important purposes. First, to the extent feasible, Phase C should provide for completion of those critical actions (e.g., restoration, research, monitoring, and modeling activities) identified in the programmatic documentation and refined during Stage 1 under the adaptive management framework that function as conditions that must precede decisions made on major Stage 2 actions. Other actions included in Stage 1 should be completed in accordance with adaptive management priorities and principles. Second, Phase C should provide for a smooth operational transition between Stage 1 and future stages of CALFED implementation. This transition would be achieved, to the extent feasible, by completion of Stage 1 actions and preparation of reports and analyses that document findings and recommendations on major guidance and decisions (e.g., relating to decisions on surface storage and conveyance facility alternatives).

Activities, Decisions, and Products during Phase C

To the extent feasible, all actions on the final Stage 1 action list should be initiated and either completed or progressing according to schedule by the end of Phase C. As noted, particular attention and focus should be given to actions identified as being critical to decisions on major facilities or programs scheduled for implementation following Stage 1.

Specific actions initiated during this phase would include those for which regulatory approvals were obtained during Phase B or early in Phase C. Phase C would establish the framework (e.g., program administrative, regulatory compliance, restoration management and assurances) necessary to provide for a smooth transition from the short-term Stage 1 ERP actions to the long-term ERP actions. Included among activities at the close of Phase C should be:

- a formal workshop or hearing comprising a week-long set of proceedings dedicated to evaluating all aspects of adaptive management during Stage 1 and addressing questions such as: What did we learn? What worked and what did not work? What critical uncertainties remain? What efforts should be abandoned? What did we get for what was spent? How are listed species doing?;

- preparation and presentation of a "state of the ecosystem" report by the managing entity; and

- an assessment by independent scientists/professionals of the status of and progress made under Stage 1, including progress on important adaptive management and linkage issues identified for resolution (or significant progress) during Stage 1 and other issues/questions (see above) recognized during adaptive management activities that should be considered during Stage 2 implementation.

The independent scientific assessment would be reviewed by ERP program managers and others as part of a formal review of the effectiveness of the Stage 1 of the ERP and consideration of possible refinements in the adaptive management approach. The assessment would also be considered by decision makers involved in planning, designing, and implementing solutions to major project-level and program-level issues in Stage 2.

COMPLETING STAGE 1 AND THE TRANSITION TO STAGE 2

Although Stage 1 is normally discussed as a 7-year stage, it may take longer to complete; therefore, the timing for Stage 1 should not be considered in terms of an arbitrary, preset number of years. The phasing discussion presented above does not reflect information that will be generated by the adaptive management process and should be considered illustrative. Under the adaptive management approach, the timing for each phase of Stage 1 should relate to the time needed to complete critical tasks and prepare the findings and recommendations needed to guide decisions on major facilities being considered for implementation during Stage 2 and subsequent stages. Under

this process, Stage 1 will be able to fulfill the objectives and tasks outlined in "ERP Stage 1 Character and Objectives" above and provide a sound technical, procedural, and institutional foundation for subsequent stages of the ERP.

Chapter 9. Long-Term Vision for Implementation of the Ecosystem Restoration Program

The strategic plan provides a set of guidelines for implementing the ERP consistent with ecosystem-based management and adaptive management. The Stage 1 implementation plan (Chapter 8) describes a series of expectations for institutional development and project implementation at the end of Stage 1. Nowhere, however, do the previous chapters provide an overview or a vision of what is expected to be accomplished in ecological terms by the end of Stage 1 or throughout the 30-year timeframe of the ERP. This chapter attempts to provide that vision. The Core Team does not, of course, know exactly what will happen in future years; however, the team does have high expectations for the ERP, and its vision is an optimistic one.

At the landscape level, there could be considerable riparian corridor along the main river channels and a number of the tributaries, as well as the restoration of significant acreages of seasonally and tidally flooded shallow-water habitats in the Delta and upper San Francisco Bay. The rivers would flow freely and meander along substantial portions of their mainstems and tributaries so that sediment dynamics and floodplain dynamics would be more typical of natural rivers. The rivers would flow with a more natural hydrograph, which would help to ensure that patterns of deposition and erosion are properly timed with the seasons of reproduction and migration of aquatic and riparian organisms.

Delta marshes would be connected with upland ecosystems and would provide nursery and feeding habitats for fish, invertebrates, and waterfowl. Water management regimes and salinity management in tidal marshes would allow for better control of invasive non-native plants so that the habitats would be more suitable for native species, although non-native species would still be present in substantial numbers.

More creative approaches to flood management would prove to be successful, and redistribution of levees and other flood protection structures would allow several tributaries greater freedom to migrate within their floodplains than would otherwise be the case. Seasonal use of floodplain lands for agriculture would still be profitable, and new approaches to multiple land use would increase opportunities for wildlife. Greater intensification of agriculture would lead to some reduction in acreage devoted to agriculture, returning additional acreage to fallow land. The wildlife gains from this change would, to some extent, be offset by the reduction in wildlife value of intensive agriculture practices.

The increased acreages of riparian ecosystems, seasonally flooded marshes, and tidal marshes would expand the overall amount of seminatural green space in the Central Valley, Bay, and Delta regions, increasing tourism and recreational values. Local municipalities would realize that having these kinds of habitats accessible to the community increases local quality of life and makes the

E-026267

E-026267

community more attractive as a place to live and conduct business. Property values would increase, especially values of property adjacent to the new green space. Communities would compete to establish greater amounts of riparian and wetland habitats in their jurisdictions.

Reconnecting the rivers and Delta with floodplain and marginal wetland habitats would increase water, sediment, and chemical retention times in the drainage basins, smoothing hydrographs somewhat and reducing flood peaks. Toxic substances from agricultural and urban runoff would be filtered through riparian communities, and the longer transit time for sediments and toxic substances from the source to the Delta would somewhat reduce the problem of accumulation of toxic substances in the Delta and estuary marshes. The occasional pulses of toxicity that occurred in the past would be extremely rare.

Threatened and endangered species would respond favorably. The abundance of most populations would stabilize, and some populations would increase sufficiently to warrant delisting. No new listings of species dependent on the Delta would have been proposed for the last 10 years. Native species would increase in abundance, and many would recolonize locations from which they had been extirpated. Legislation, regulations, voluntary guidelines, and education would be successful at virtually eliminating industry-related introduction of non-native species.

Ecosystem-based and adaptive management would be fully integrated into the operating procedures of both state and federal regulatory agencies. These techniques would provide an enriched set of procedures for management complementary to the more traditional species-based approaches.

Through outreach, education, and partnerships, most residents of the Central Valley would recognize ecosystem restoration activities as an important part of their lives and well-being. Water users and other stakeholders would agree that the program is highly successful and, coupled with improvements in water use technology and a new water conservation ethic, would permit continued growth and evolution of the local economy without jeopardizing environmental values.

Toward the end of the third decade of the 21st century, CALFED would have developed an effective working partnership with individual state and federal agencies and local communities. A foundation would have been created that administers a significant endowment for further experimentation and restoration through collaborative programs with government agencies, the universities, and the communities of the Central Valley.

Although extremely optimistic, this vision is within the realm of possibility if CALFED and the ERP achieve their potential. Not all of the above outcomes will materialize, but there is a potential for each to occur, and it is important to understand that the stakeholders and communities can proceed and decide how much of this can be achieved.

Chapter 10. About the Strategic Plan Core Team

Michael Healey - Salmonid Fisheries Biology and Adaptive Management

Dr. Michael Healey is an expert in the ecology of salmon and in the application of adaptive management to the management of natural resources. Dr. Healey began his career as a research scientist with the Canadian government, first in Winnipeg and later at the Pacific Biological Station in Nanaimo, British Columbia, where he conducted ground-breaking research on the ecology of salmonid fishes and their responses to human exploitation. While at the Pacific Biological Station, he headed up several large, multidisciplinary studies of the estuarine and marine ecology of Pacific salmon. In 1990, he joined the faculty of the University of British Columbia as director of the Westwater Research Centre, where he initiated large-scale studies of riverine and coastal ecosystems and their management. Since 1996, he has been a professor in the newly created Institute for Resources and Environment and holds cross appointments in Earth and Ocean Sciences, the Fishery Centre, and the Zoology Department. He has been a consultant on issues of resource management and resource management policy for the National Park Service, the U.S. Biological Service, the States of California and Montana, the Province of Alberta, the Yukon Territory, and the Canadian government.

Wim Kimmerer - Bay-Delta Estuarine Ecology

Dr. Wim Kimmerer received his B.S. degree in chemistry from Purdue University and his Ph.D. in biological oceanography from the University of Hawaii. After positions at the Hawaii Institute of Marine Biology, University of Melbourne, and BioSystems Analysis, an environmental consulting firm, he became a senior research scientist at the Romberg Tiburon Center, San Francisco State University. Dr. Kimmerer's expertise is in marine and aquatic ecosystems, including physical, chemical, and biological oceanography; ecology of estuarines and lagoons; fisheries management; simulation modeling; and statistical analysis of data. His current research interests include estuarine ecology; zooplankton ecology; population dynamics of fish such as salmon and striped bass; and the effect of anthropogenic influences, such as freshwater flow and sewage discharge, on estuarine and marine systems. He has particular expertise in the integration of information from diverse disciplines to develop models of ecosystems and biological populations. Dr. Kimmerer has written more than 80 papers and technical reports on these and related topics.

In the San Francisco Bay Area, he has been closely involved with the Interagency Ecological Program, acting as chair of the Estuarine Ecology Team and the Entrapment Zone Study Team. He is principal investigator of a project to design an advanced simulation model for chinook salmon in the Sacramento Basin for the U.S. Fish and Wildlife Service. Previous activities include serving as chair of the Central Valley Project Improvement Act Fish Team, responsible for developing

measures for using water for environmental and fish restoration purposes; principal investigator of a modeling study of the ecosystem of a coastal lagoon in northern Alaska; and principal investigator of a major study of the ecosystem of Tarawa Atoll Lagoon, which led to the development of a comprehensive management plan.

G. Mathias Kondolf - Fluvial Geomorphology

Dr. G. Mathias Kondolf is an associate professor of environmental planning and geography at the University of California, Berkeley, where he teaches Hydrology for Planners, Restoration of Rivers and Streams, Ecological Analysis in Urban Design, and Introduction to Environmental Sciences. His research concerns include environmental river management, especially technical and policy issues regarding management of gravel in regulated rivers, and geomorphic influences in river and stream restoration. Recent research projects include evaluations of flushing flow requirements for the Trinity River and Rush Creek, California; evaluation of aquatic habitat restoration projects in the San Joaquin River Basin; changes in alluvial channels and riparian vegetation downstream of reservoirs in the Sado River basin of Portugal; and historical geomorphological studies of the Egyues River, France, and Deer Creek, California. He has published more than 100 technical papers, book chapters, and reports on these and related topics. Dr. Kondolf was a member of the Core Team that prepared the Strategic Plan for the CALFED Ecosystem Restoration Program. He received his Ph.D. from the Johns Hopkins University in geography and environmental engineering, his M. Sc. from University of California, Santa Cruz, in earth sciences, and his bachelor degree (cum laude) from Princeton University in geology.

Rod Meade - State and Federal Regulatory Compliance

Mr. Rod Meade is a geographer and president of R. J. Meade Consulting, an environmental policy, planning, and regulatory consulting firm. Before starting his company in 1980, Meade served as a senior analyst with the California Coastal Commission and acted as its liaison to the California Legislature in 1976, the year the California Coastal Act was adopted. After leaving the coastal commission, Mr. Meade consulted on several large-scale planned communities that involved coastal resource, wetland, and endangered species management issues. He directed regulatory and entitlement efforts involving projects for the Mission Viejo Company (Mission Viejo and Aliso Viejo planned communities, Orange County), Howard Hughes Estate (Playa Vista Planned Community, City of Los Angeles), and Disney Development Company (Long Beach DisneySea Project). He also directed preparation of the County of Orange Central/Coastal Natural Community Conservation Plan/Habitat Conservation Plan (NCCP/HCP), approved in 1996. Currently, Mr. Meade directs work on two NCCP/HCPs and consults on endangered species issues for the Tejon Ranch, a large ownership located in the southern San Joaquin Valley and Tehachapi Mountains.

Peter Moyle - Native Fish Biology and Management

For approximately 30 years, Dr. Peter B. Moyle has been working on the ecology and conservation of freshwater and estuarine fishes in California, subjects on which he has published widely. His long-term research program on Bay-Delta fishes led to the listing of the delta smelt as an endangered species. His reward for this activity was to be appointed head of the Delta Native Fishes Recovery Team by the U.S. Fish and Wildlife Service (completed in 1994). Dr. Moyle also served as member of the Sierra Nevada Ecosystem Project science team, working on strategies for fish, amphibian, and watershed conservation. One of his major activities, working with his postdoctoral and graduate students, is to document the status of native fishes, including coho and chinook salmon, as well as the status of fish communities. He is also involved in documenting the effects of invasions of non-native aquatic species. He is a professor of fish biology in the Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, where he has taught since 1972.

Bob Twiss - Environmental Planning and Geographic Environmental Information

Dr. Bob Twiss is a land and environmental planner and professor emeritus at the University of California, Berkeley. Dr. Twiss is one of the pioneers in the application of geographic information systems in environmental planning and resource management. He has served as a consultant in environmental planning to numerous regional, state, and federal agencies and foreign governments and institutions.

E-026271

E-026271

E —0 2 6 2 7 2

E-026272

Chapter 11. Citations

Atwater, B. F., S. G. Conard, J. N. Dowden, C. W. Hedel, R. L. MacDonald, and W Savage. 1979. History landforms and vegetation of the estuary's tidal marshes. Pp. 347-385 in: Conomos, T. J. (ed.). San Francisco Bay: The Urbanized Estuary. Pacific Division. American Association for the Advancement of Science. San Francisco CA.

Bailey, H. C., S. Clark, J. Davis, and L. Wiborg. 1995. Effects of toxic contaminants in waters of the San Francisco Bay and Delta. Final report prepared for Bay/Delta Oversight Council.

Baltz, D. M., and Moyle, P. B. 1993. Invasion resistance to introduced species by a native assemblage of California stream fishes. Ecological Applications 3(2):246-255.

Bay Institute. 1998. From the Sierra to the sea: the ecological history of the San Francisco Bay-Delta Watershed. San Francisco, CA.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

Brice, J. 1977. Lateral migration of the middle Sacramento River. U.S. Geological Survey Water-Resources Investigations 77-48.

Brookes, A. 1988. Channelized rivers. John Wiley. Chichester.

Broughton, J. M.. 1994. Late Holocene resource intensification in the Sacramento Valley, California: the vertebrate evidence. J. Arch. Science 21:501-514.

Brusven, M. A., W. R. Meehan, and J. F. Ward. 1986. Summer use of simulated undercut banks by juvenile chinook salmon in an artificial Idaho channel. North American Journal of Fisheries Management 6:32-37.

Buer, K. 1984. Middle Sacramento River spawning gravel study. California Department of Water Resources, Northern District. Red Bluff, CA.

CALFED Bay-Delta Program. 1996. Handbook of regulatory compliance for the CALFED Bay-Delta Program. November 8, 1996. Sacramento, CA.

_____. 1997. Ecosystem restoration program plan. Appendix A: Programmatic actions. Draft. May. Sacramento, CA.

_____. 1998. Ecosystem restoration program plan. Vol. 1 (Technical appendix to programmatic EIS/EIR). March. Sacramento, CA.

California Department of Fish and Game. 1993. Restoring Central Valley streams: a plan for action. Sacramento, CA.

California Department of Water Resources. 1998. The California water plan update. (Bulletin 160-98.) Public review draft. January. Sacramento, CA.

California State Lands Commission. 1993. California's rivers, a public trust report. Sacramento, CA.

Cederholm, C. J., and K. V. Koski. 1977. Effects of stream channelization on the salmonid habitat and population of lower Big Beef Creek, Kitsap County, Washington 1969-73. University of Washington, Washington Cooperative Fishery Research Unit, Seattle, WA.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 in T. G. Northcote (ed.), Symposium on Salmon and Trout in Streams. University of British Columbia Press, Vancouver, B.C. (H.R. MacMillan Lectures in Fisheries).

Chapman, D. W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in small streams of western Washington. Transactions of the American Fisheries Society 109:357-363.

Cohen, A. N., and J. T. Carlton. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and delta. Report to the U.S. Fish and Wildlife Service, available at http://nas.er.usgs.gov/sfinvade.htm.

_____. 1998. Accelerating invasion rate in a highly invaded estuary. Science 279:555-558.

Costanza, R., and H. Daly. 1992. Natural capital andsustainable development. Conservation Biology 1:37-45.

Cronin, T. W., and R. B. Forward, Jr. 1979. Tidal vertical migration: an endogenous rhythm in estuarine crab larvae. Science 205:1020-1022.

Dailey, G. C. (ed.). 1997. Nature's services: societal dependence on natural ecosystems. Island Press. Covelo CA.

Deer Creek Watershed Conservancy. 1998. Deer Creek watershed existing conditions report. Vina, CA.

Dietrich, W. E., J. W. Kirchner, H. Ikeda, and F. Iseya. 1989. Sediment supply and development of coarse surface layer in gravel bedded rivers. Nature 340:215-217.

Dunne, T., and L. B. Leopold. 1978. Water in Environmental Planning. W. H. Freeman and Sons. San Francisco, CA.

EA Engineering, Science, and Technology. 1992. Don Pedro Project fisheries studies report (FERC Article 39, Project No. 2299.) Report to Turlock Irrigation District and Merced Irrigation District.

Estuarine Ecology Team. 1996. An assessment of the likely mechanisms underlying the "fish-x2" relationships. Interagency Ecological Program for the San Francisco Bay/Delta, Sacramento, Technical Report.

Ecological Society of America. 1995. The scientific basis for ecosystem management. Ad Hoc Committee on Ecosystem Management. Washington, DC.

Gilbert, G. K. 1917. Hydraulic mining debris in the Sierra Nevada. U.S. Geological Survey Professional Paper no. 105.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones: focus on links between land and water. Bioscience 41(8):540-551.

Healey, M. C. 1982. Juvenile Pacific salmon in estuaries: the life support system. Pages 315-341 in V. S. Kennedy (ed.), Estuarine comparisons. Academic Press. New York, NY.

_____. 1991. Life history of chinook salmon. Pages 313-393 in C. Groot and L. Margolis (eds.), Pacific salmon life histories. UBC Press. Vancouver, B.C.

_____. 1998. Paradigms, policies and prognostication about watershed ecosystems and their management. To appear in R. J. Naiman and R. E. Bilby (eds.), Ecology and management of streams and rivers in the Pacific Northwest Coastal Ecoregion. Springer-Verlag. New York, NY.

Healey, M., and T. Hennessey. 1994. The utilization of scientific information in the management of estuarine ecosystems. Ocean and Coastal Management 23:167-191.

Helley, E. J., and D. S. Harwood. 1985. Geologic map of the late Cenozoic deposits of the Sacramento Valley and northern Sierran foothills, California. U.S. Geological Survey Miscellaneous Field Studies, Map MF-1790.

Hennessey, T. M. 1997. Ecosystem management: the governance dimension. Western Social Sciences Association Symposium, Albuquerque, April 23-26, 1997.

Herbold, B., A. D. Jassby, and P. B. Moyle. 1992. Status and trends report on aquatic resources in the San Francisco estuary. San Francisco Est Project.

Hey, R. D., G. L. Heritage, and M. Patteson. 1994. Impact of flood alleviation schemes on aquatic macrophytes. Regulated Rivers 9:103-119.

Hilborn, R., and M. Mangel. 1996. The ecological detective. Princeton University Press. Princeton, NJ.

Hobbs, R. J., and H. A. Mooney. 1998. Broadening the extinction debate: population deletions and additions in California and western Australia. Conservation Biology 12: 271-283.

Holling, C. S. 1978. Adaptive environmental assessment and management. John Wiley. London, England.

_____. 1998. Two cultures of ecology. Conservation Ecology [online] 2(2): 4. Available from the Internet. URL: http://www.consecol.org/vol2/iss2/art4

Hortle, K. G., and P. S. Lake. 1983. Fish of channelized and unchannelized sections of the Bunyip River, Victoria. Australian Journal of Marine and Freshwater Research 34:441-450.

Interagency Floodplain Management Review Committee. 1994. Sharing the challenge: floodplain management into the 21st Century. U.S. Government Printing Office. Washington DC.

James, A. 1991. Incision and morphologic evolution of an alluvial channel recovering from hydraulic mining sediment. Geological Society of America Bulletin 103:723-736.

Jassby, A. D., W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel, and T. J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 5:272-289.

Johnson, W. C. 1992. Dams and riparian forests: case study from the upper Missouri River. Rivers 3:229-242.

Jones & Stokes Associates, Inc. 1997. Handbook of regulatory compliance for the Anadromous Fish Restoration Program. (JSA 96-119.) October. Sacramento, CA. Prepared for U.S. Fish and Wildlife Service, Stockton, CA.

Kahrl, W. L., et al. 1978. The California water atlas. California Governor's Office of Planning and Research. Sacramento, CA.

Kelley, R. 1989. Battling the inland sea. University of California Press. Berkeley, CA.

Kimmerer, W. J. (ed.). 1998. 1994 entrapment zone report. Interagency Ecological Program for the San Francisco Bay/Delta, Sacramento, Technical Report 56.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1982. Life history of fall-run juvenile chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. Pages 393-411 in V. S. Kennedy (ed.), Estuarine comparisons. Academic Press. New York, NY.

Knudsen, E. E., and S. J. Dilley. 1987. Effects of riprap bank reinforcement on juvenile salmonids in four western Washington streams. North American Journal of Fisheries Management 7:351-156.

Kondolf, G. M. 1997. Hungry water: effects of dams and gravel mining on river channels. Environmental Management 21(4):533-551.

Kondolf, G. M., R. Kattelmann, M. Embury, and D. C. Erman. 1996. Status of riparian habitat. Chapter 36 in Sierra Nevada Ecosystem Project: Final Report to Congress, Vol. II, Assessments and scientific basis for management options. Report No. 88, Centers for Water and Wildland Resources, University of California, Davis, p.36-1 - 36-22.

Kondolf, G. M., and Larson, M. 1995. Historical channel analysis and its application to riparian and aquatic habitat restoration. Aquatic Conservation: Marine and Freshwater Ecosystems 5:109-126.

Kondolf, G. M., and W. G. V. Matthews. 1993. Management of coarse sediment in regulated rivers of California. University of California Water Resources Center, Riverside. Report No.80.

Kondolf, G. M., J. C. Vick, and T. M. Ramirez. 1996. Salmon spawning habitat rehabilitation in the Merced, Tuolumne, and Stanislaus Rivers, California: an evaluation of project planning and performance. University of California Water Resources Center Report No. 90, Davis, CA.

Kondolf, G. M., and P. R. Wilcock. 1996. The flushing flow problem: defining and evaluating objectives. Water Resources Research 32(8): 2589-2599.

Lee, K. 1993. Compass and gyroscope. Island Press. Washington, DC.

Lindblom, C. 1959. The science of muddling through. Public Administration Review 19:79-88.

Lister, D. B., and H. S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada 27:1215-1224.

Michny, F., and M. Hampton. 1984. Sacramento River Chico Landing to Red Bluff project: 1984 juvenile salmonid study. Draft report. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. Prepared for U.S. Army Corps of Engineers, Sacramento, CA.

Mills, T. J., and F. Fisher. 1994. Central Valley anadromous sport fish annual run-size, harvest, and population estimates, 1967 through 1991. California Department of Fish and Game, Inland Fisheries Technical Report. Sacramento, CA.

E-026277

E-026277

Mitch, W. J., and J. G. Gosselink. 1993. Wetlands. Second edition. Van Nostrand Reinhold. New York NY.

Mount, J. F. 1995. California rivers and streams. University of California Press. Berkeley, CA.

Moyle, P. B., and J. P. Ellison. 1991. A conservation-oriented classification system for the inland waters of California. California Fish and Game 77: 161-180.

Mullen, J. R., W. F. Shelton, K. L. Markham, and S. W. Anderson. 1991. Water resources data for California water year 1990, Volume 4. U.S. Geological Survey Water-Data Report CA-90-4, Sacramento.

Murphy, M. L., and W. R. Meehan. 1991. Stream ecosystems. Pp. 17-46 in Influernces of forest and range management on salmonid fishes and their habitats. W. R. Meehan, ed., American Fisheries Society Special Publication 19. Bethesda, MD.

National Marine Fisheries Service. 1997. NMFS proposed recovery plan for the Sacramento River winter-run chinook salmon. Southwest Region. Long Beach, CA.

Nichols, F. H., J. E. Cloern, S. N. Louma, and D. H. Peterson. 1986. Modification of an estuary. Science 231:567-573.

Parfitt, D., and K. Buer. 1980. Upper Sacramento River spawning gravel study. California Department of Water Resources, Northern Division. Red Bluff, CA.

Resh, V. H., A. V. Brown, A. P. Covich, M. E. Gurtz, H. W. Li, G. W. Minshall, S. R. Reice, A. L. Sheldon, J. B. Wallace, and R. C. Wissmar. 1988. The role of disturbance in stream ecology. Journal of the North American Benthological Society 7:433-455.

Reimers, P. E. 1973. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Research Reports of the Fish Commission of Oregon 4:1-43.

Richardson, J. S., and M. Healey. 1996. A healthy Fraser River? How will we know when we achieve this state? Journal of Aquatic Ecosystem Health 5:107-115.

Riley, S., and K. Fausch. 1995. Trout population responses to habitat enhancement in six northern Colorado streams. Canadian Journal of Fisheries and Aquatic Sciences 52:34-53.

San Francisco Estuary Project. 1992a. State of the estuary.

_____. 1992b. The effects of land use change and intensification on the San Francisco estuary. San Francisco Estuary Project, Oakland, California. Available on line through the University of California, Berkeley Digital Library Project # 642.

Sato, G. M., and P. B. Moyle. 1989. Ecology and conservation of spring-run chinook salmon. Annual report, Water Resources Center, Project w-719, University of California. Davis, CA.

Schaffter, R. G., P. A. Jones, and J. G. Karlton. 1983. Sacramento River and tributaries bank protection and erosion control investigation: evaluation of impacts on fisheries. Final report. California Department of Fish and Game, Sacramento, CA. Prepared for U.S. Army Corps of Engineers, Sacramento, CA.

Skinner, J. E. An historical view of the fish and wildlife resources of the San Franciso Bay Area. California Department of Fish and Game, Water Projects Branch Report.

Sparks, R. E. 1995. The need for ecosystem management of large rivers and their floodplains. Bioscience 45:168-182.

Sparks, R. E., and P. B. Bayley, S. L. Kohler, and L. L. Osborne. 1990. Disturbance and recovery of large floodplain rivers. Environmental Management 14:699-709.

Stanford, J., and J. V. Ward. 1993. An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. Journal of the North American Benthological Society 12:48-60.

Tepordei, V. V. 1992. Construction sand and gravel: annual report, U.S. Bureau of Mines. Washington DC.

Thelander, C. G., and M. Crabtree (eds.). Life on the edge: a guide to California's endangered natural resources. BioSystems Books. Santa Cruz, CA.

U.S. Fish and Wildlife Service. 1995. Working paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volume 3. May. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group, Stockton.

Vick, J. 1995. Habitat rehabilitation in the lower Merced River: a geomorphological perspective. Masters thesis in Environmental Planning, Department of Landscape Architecture, and Report No. 03-95, Center for Environmental Design Research, University of California. Berkeley, CA.

Walling D. E., P. N. Owens, G. J. L. Leeks. 1998. The role of channel and floodplain storage in the suspended sediment budget of the River Ouse, Yorkshire UK Geomorphology 22:225-242.

Walters, C. 1986. Adaptive management of renewable resources. MacMillan. New York, NY.

Walters, C., J. Collie, and T. Webb. 1988. Experimental designs for estimating transient responses to management disturbances. Canadian Journal of Fisheries and Aquatic Sciences 45:530-538.

_____. 1989. Experimental designs for estimating transient responses to habitat alterations: is it practical to control for environmental changes? Canadian Special Publication of Fisheries and Aquatic Sciences 105:13-20.

Walters, C., and C. S. Holling. 1990. Large scale management experiments and learning by doing. Ecology 71:2060-2068.

Ward, J. V., and J. A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. Regulated Rivers: Research and Management 11:105-119.

Wootten, J. T., M. S. Parker, and M. E. Power. 1996. Effects of disturbance on river food webs. Science 273:1558-1561.

Woodley, S., J. Karr, and G. Francis (eds.). 1993. Ecological integrity and the management of ecosystems. St. Lucie Press, Boca Raton, FL.

World Commission on Environment and Development. 1987. Our common future. Report of the World Commission on Environment and Development (Gro Harlem Bruntland Chair). Oxford University Press. Oxford, England.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical abundance and decline of chinook salmon in the Central Valley region of California. North American Journal of Fisheries Management (in press).

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 1996. Historical and present distribution of chinook salmon in the Central Valley drainage of California. Pages 309-362 in Sierra Nevada ecosystem project: final report to Congress , Vol. III, assessments, commissioned reports, and background information. Davis: University of California, Centers for Water and Wildland Resources. Davis, CA.

Appendix A. Defining the Opportunities and Constraints: A Historical Perspective

Appendix A. Defining the Opportunities and Constraints: A Historical Perspective

THE IMPORTANCE OF A HISTORICAL PERSPECTIVE

The CALFED Ecosystem Restoration Program will succeed only to the extent that it is based on a solid understanding of natural physical and ecosystem processes and habitats, and how these have been changed, so that restoration actions can be effective, adequate, and realistic.

We need to understand the nature and extent to which humans have altered the original conditions in order to figure out both the goals for restoration and the factors that limit our ability to achieve these goals. If we understand, even sketchily, how the natural hydrological and ecological systems once worked, we gain a better feeling for our ability to return the systems to their historic state and for the desirability of doing so. Thus, although historical studies indicate that massive flooding was an important ecological process in the creation of instream habitat for salmon and other fish, we clearly are not going to remove our cities to allow this process to restore itself on a large scale. On the other hand, it is possible to restore flooding as a hydrologic process on a smaller scale, potentially reconnecting floodplain and channel habitats, and permitting natural processes to shape channels and floodplains. To be effective and sustainable, restoration must be based on a real understanding of geomorphic and ecological processes, which can inform restoration goals and choice of implementation strategy. Creation of idealized meandering channels in streams where such channels never existed is unlikely to be sustainable, as illustrated by the failure of recent projects in California.

A historical perspective can be important for putting restoration projects in proper context: A wetland may have little value for native plants and animals if it is isolated from other wetlands, is too small to support viable populations of species of interest, or is maintained primarily by artificial means. On a broader scale, we should know if our restoration efforts are going to recreate 10%, 1%, 0.1%, or 0.01% of a lost habitat and what that means if the goal is partly to restore species that require considerable space for feeding or breeding or that occupy habitats maintained by ecological processes that require considerable room to operate. This in turn can help us to set priorities for habitat restoration and acquisition. Endangered clapper rails, for example, require large expanses of tidal marsh that also contain high ground for roosting when high tide floods the habitat. Thus, clapper rail restoration funds may be best spent acquiring and restoring tidal marsh lands that are contiguous and contain upland habitat, rather than restoring more isolated pieces of habitat, even if the total area of the pieces was larger than the contiguous marshlands.

A historical perspective is also needed to understand how much human activity has changed natural systems and how irreversible that change is likely to be, especially over large areas. By

taking a combined historical and watershed level perspective, we can understand the synergistic and cumulative effects of human actions that will constrain restoration objectives. For example, reservoirs halt the natural process of gravel and sediment movement to downstream areas, resulting in streambeds armored by large rocks. Such streambeds are poor habitat for insects and cannot be dug up by spawning salmon trying to bury their eggs. This change is largely irreversible and is only temporarily alleviated by the dumping of gravel into the river. In other cases, the changes may be reversible. For example, setting back, breaching, or removing levees can restore frequent inundation of floodplains, provided there are still adequate floodflows in the river to inundate the floodplain. This approach to restoration of riparian habitat is much more likely to be sustainable than the construction of new riparian habitats without regular flooding.

CONDITIONS BEFORE EUROPEAN COLONIZATION

The landscape of the Central Valley has changed on such a vast scale in the past 150 years that it is difficult to even imagine what it was originally like (see Kahrl et al. 1978, Kelley 1989, Bay Institute 1998). Arguably, the most important ecological features were the aquatic and riparian ecosystems, which covered huge areas, supported high concentrations of fish and wildlife, gave rise to many endemic species, and were the cultural focus of the Native American peoples. Before European colonization, the Sacramento and San Joaquin Rivers and their tributaries carried water, sediment, nutrients, other dissolved and suspended constituents, wood, organisms, and other debris from basins (of more than 25,000 and 14,000 square miles, respectively) to their confluence in an inland delta, thence through Suisun, San Pablo, and San Francisco Bays to the Pacific Ocean. The channels of these rivers served as habitats and migration routes for fish and other organisms, notably several distinct runs of chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*O. mykiss*), and Pacific lamprey (*Lampetra tridentata*). These species evolved to take advantage of the hydrologic and geomorphic characteristics of these river systems, some of which are discussed below. There are no firm data on pre-1850 salmon runs, but anecdotal accounts (and the large canning industry that later developed in coastal and inland cities) imply that runs were substantial, probably between 2 and 3 million per year.

The Mediterranean climate ensured that the aquatic and riparian systems were highly dynamic, driven by strong annual patterns of wet and dry seasons and longer periods of extreme drought and extreme wet. The high peaks of the Sierra Nevada intercepted much of the moisture coming off the ocean and stored it as snow and ice, which melted gradually, generating cold rivers that flowed throughout the dry summers. During periods of high snow and rain fall, the Central Valley would become a huge shallow lake, taking months to drain through the narrows of the Bay-Delta system. In periods of drought, the main rivers would be reduced to shallow, meandering channels, and salty water would push its way to the upstream limits of the Delta. The dry tule marshes would burn, perhaps with fires deliberately set by the native peoples, and the dry air would be filled with smoke for months at a time.

The marshes were a major feature of the lowlands of the Central Valley, especially the San Joaquin Valley, where they surrounded the huge, shallow lakes at the southern end of the valley,

Lakes Buena Vista and Tulare. The Delta itself was a vast marshland, the present-day islands vaguely defined by natural levees of slightly higher ground. The river channels meandered through this marsh, making trips by boat long and arduous. Suisun, San Pablo, and San Francisco Bays were also lined with large marshes that penetrated far inland in the estuaries of inflowing streams and in the shallows now called Suisun Marsh. The flood basins of the Sacramento River also supported extensive marshes. Upstream, the river channels were defined by thick riparian forests, with dense stands of willow, cottonwood, and sycamore close to the water, yielding to valley oak on the higher terraces. Above these woodlands were first oak savannas and then bunch grass prairies, supporting herds of pronghorn, elk, and blacktail deer.

Hydrology and Landforms and How They Interact to Form Habitat

Runoff Processes and Riverine Forms

The largest rivers of the Sacramento-San Joaquin River system head in the high elevations of the Sierra Nevada (or Cascades) and receive runoff from snowmelt, which is at a maximum in late spring-early summer, as well as rainfall in their lower elevations, with maximum flows (typically with higher peaks) in winter during storms. The highest peak flows are produced when warm rains fall on a large snowpack, such as occurred in December-January 1997. There is considerable variation in precipitation (and therefore riverflows) from year to year, but snowmelt reliably produced moderately high flows in most years. The seasonal low flows typically occurred in late summer and fall, after snowmelt had been exhausted and before the onset of winter rains. Seasonal flow variability was greatest in rainfall-dominated rivers draining the Coast Ranges, somewhat less in rivers with snowmelt contributions, and substantially less in rivers draining volcanic formations, such as the regions of Mt. Shasta and Mt. Lassen (where runoff is dominated by springflow). In the Delta, inflows from the Sacramento and San Joaquin Rivers mixed, with probable intrusions of salt water during dry periods, in a complex, often stratified pattern.

The upper reaches of the rivers are typically bedrock or boulder controlled, with cascade and step pool habitats, and with little opportunity for sediment storage. In their lower reaches, the rivers flow through the alluvial Central Valley in braided, wandering, or meandering channels, historically with broad, largely forested, floodplains. Braided channels were common where streams passed from bedrock-controlled channels onto the flatter Sacramento Valley floor, depositing gravel and sand. Flatter floodplain reaches were characterized by large, meandering channels, which frequently overflowed onto the adjacent floodplains, depositing sandy natural levees along the channel, with silty (and fertile) overbank sediments behind.

In the Delta, a complex of low-gradient, multiple channels was flanked by natural levees and low-elevation, frequently inundated islands (composed largely of organic-rich sediments). The tidal estuaries of Suisun, San Pablo, and San Francisco Bays were flanked by extensive tidal marshes and mudflats.

Each of these geomorphic features, interacting with a variable flow regime, created a distinct suite of aquatic or riparian habitats, as illustrated by an actively migrating meander bend (Figure A-1). As flow passes through a meander bend, the highest velocities and greatest depths are concentrated near the outside bank, which erodes, producing a steep cut bank, commonly with overhanging vegetation. These pools are important holding habitats for adult salmon and trout. In between the meander bend pools, where flow crosses over from one side of the channel to the other, a riffle typically occurs, with shallow flow over gravel or cobble substrate, providing habitat for invertebrates (which are food for fish). Gravel riffles provide spawning habitat for salmon and trout. Shallow margins of these channels, protected areas behind exposed roots and large woody debris, and the interstices between large cobbles, provide habitat for juvenile salmon.

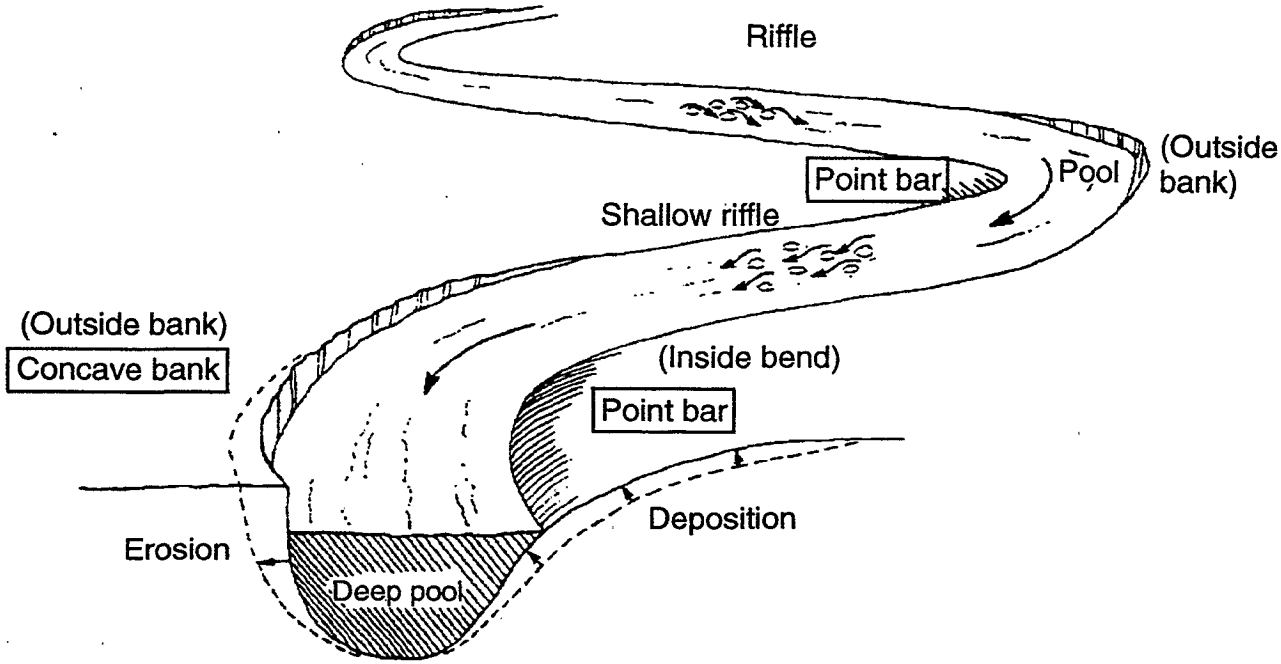
Native Species and How They Used the Landscape

The productive marshlands and intervening waterways were extremely attractive to waterfowl. The abundant and diverse resident populations of ducks, geese, shorebirds, herons, and other birds were augmented by millions of ducks, geese, shorebirds, and cranes migrating down in fall and winter from summer breeding grounds in the north. The migratory birds would take advantage of the expanded wetlands that were the result of the winter rains and floods. Arguably, the Pacific Flyway, one of the major migratory routes for birds recognized for North America, owes its existence to the Central Valley and its wetlands. No matter how severe the drought, there would be wetlands somewhere in the valley.

Migratory fishes also found the region to be very favorable habitat. Two to three million anadromous chinook salmon spawned in the system each year, along with large numbers of steelhead, sturgeon, and lamprey. The four distinct runs of salmon reflect a fine-tuning of this species to a fluctuating yet productive environment. Fall-run chinook were the lowland run. They came up in fall months as soon as water temperatures were cool and spawned in low-elevation rivers in time to allow their young to emerge from the gravel and leave the rivers before conditions became unfavorable in early summer. Spring-run chinook, perhaps the largest of the runs, beat the summer low flows and high temperatures by migrating far upstream in the spring and holding in deep cold pools through summer, to spawn in fall. Late-fall-run and winter-run chinook took advantage of the unusual conditions in the little Sacramento, McCloud, and Pit Rivers, where cold glacial-melt water flowed from huge springs, keeping temperatures cool even in the hottest summers, so the fish could spawn late in the season.

Steelhead migrated up in winter, when flows were high, even higher in the watersheds than spring-run chinook, and sought out smaller streams not used by salmon.

The annual influx of millions of salmon weighing 8-20 kilograms each represented a tremendous shot of oceanic nutrients injected into the stream systems, enhancing the productivity of the aquatic and riparian ecosystems and increasing their ability to support juvenile salmon and steelhead. The juveniles of all these salmon would move downstream gradually in winter and spring, taking advantage of the abundant invertebrates in flooded marshlands and the shallow waters of the



Source: California State Lands Commission 1993.

Strategic Plan for the Ecosystem Restoration Program

Figure A-1
Diagram of Meander Bend, Showing Variety of Forms (and thus Habitats) Associated with Actively Migrating Meander Bend

both hatchery and wild populations in the Sacramento River proper are hybridized with fall-run chinook. The only streams maintaining small runs of wild, unhybridized spring-run chinook salmon are Deer, Mill, Butte and Big Chico Creeks. Spring-run chinook have been listed as threatened by the California Fish and Game Commission (September 1998). They were listed as a threatened species by the California Fish and Game Commission in September 1998 and were proposed for federal listing in 1997. It is uncertain whether additional subpopulations can be reestablished in other Sacramento River basin streams or in the San Joaquin River basin, but the possibilities need to be investigated. If establishing additional subpopulations is impossible, the long-term objective may have to be modified downward.

Stage 1 Expectations. Better methods for estimating population sizes should be developed. Populations in Deer, Mill, and Butte Creeks should remain within numbers found in the streams in 1990-1998, with a cohort replacement rate greater than 1. Factors limiting survival of outmigrating smolts should be determined. The ability of Big Chico Creek to sustain a spring-run chinook population should be evaluated and measures taken to improve its capacity to support salmon. The potential for other streams, including Battle Creek, to support runs of spring-run chinook salmon should be evaluated.

Objective 4: Restore Late-Fall-Run Chinook Salmon to Central Valley Streams and the Bay-Delta Estuary

Long-Term Objective: Restore wild, naturally reproducing populations of late-fall-run chinook salmon to numbers or spawning densities in the Sacramento River equal to those that existed in 1967-1976, as measured over a period of at least 25 years, and reestablish a self-sustaining population in the San Joaquin River drainage.

Short-Term Objective: Achieve recovery, as defined by the Delta Native Fishes Recovery Plan or in a federal recovery plan developed if the species is formally listed as threatened.

Rationale. Late-fall-run chinook salmon have long been recognized as a distinct run in the Sacramento River and, formerly, in the San Joaquin River although their numbers were not quantified until Red Bluff Diversion Dam was completed in 1967. The dam was a major factor contributing to their most recent decline. The NMFS does not distinguish late-fall-run from fall-run chinook salmon in its listing proposal, but the two forms represent distinct life history patterns in the Sacramento River and therefore need to be managed separately. Late-fall-run chinook were mainstem spawners and probably were separated from their principal spawning grounds by Shasta and Friant Dams. Restoration may be possible in rivers that have had their flow regimes adjusted to accommodate the oversummering of juveniles (e.g., the Tuolumne River).

Stage 1 Expectations. Late-fall-run chinook salmon numbers should not fall lower than they have been in the 1990s. Factors limiting their abundance should be determined, and methods to determine their abundance should be developed.

Objective 5: Restore Self-Sustaining Fall-Run Chinook Salmon to Central Valley Streams and the Bay-Delta Estuary

Long-Term Objective: Restore self-sustaining populations of fall-run chinook salmon to all their native streams, except those above Shasta Reservoir, with numbers of fish of wild origin equal to or exceeding the average numbers of fish of both hatchery and wild origin from 1980-1998.

Short-Term Objective: Recover San Joaquin fall-run chinook salmon to levels identified in the Delta Native Fishes Recovery Plan, and in the Sacramento River, have wild salmon spawners number 75,000-100,000 fish each year, assuming that salmon of wild origin make up 50% of the fall run.

Rationale. When Shasta and Friant Dams were built, implicit promises were made that fisheries for salmon would not decline. It was assumed that hatcheries and habitat improvements would make up for any losses caused by the dams. The hatchery system has been at best a partial success even though it has focused heavily on fall-run chinook salmon. Because of the hatcheries, the status of wild populations in the Central Valley is uncertain, and concerns exist about genetic and other effects of hatchery programs on the wild-spawning stocks.

Much of the habitat previously available for wild-spawning fish is permanently disconnected from the migration corridors. However, the remaining habitat or the "new" habitat in the tailwaters of large dams should be usable for spawning at densities (fish per unit of habitat, either area or distance) as great as those that existed before the construction of Shasta, Friant, and other dams. The objective, therefore, is to restore the spawning densities of fall-run chinook salmon to values existing before Shasta and Friant Dams were built. The restoration of salmon to predam densities using primarily currently available habitat depends on assumptions about habitat quality and the biology of the fish that need to be tested.

Stage 1 Expectations. Numbers of wild fall-run chinook salmon should not fall lower than they have been in the 1990s. Factors limiting their abundance in each major river should be determined, including the impact of hatchery fish. Programs (e.g., mass marking of hatchery juveniles) should be instituted to allow hatchery fish to be distinguished from wild fish, and surveys should be made to determine the contribution of hatchery fish to natural spawning.

Objective 6: Restore Self-Sustaining Central Valley Steelhead to Central Valley Streams and the Bay-Delta Estuary

Long-Term Objective: Restore self-sustaining populations of steelhead to all streams still likely to support populations, with numbers of fish of wild origin equal to or exceeding the average numbers of fish of both hatchery and wild origin from 1980 to 1998.

Short-Term Objective: Determine the abundance and genetic identity of existing steelhead populations, and develop measures to enhance remaining wild populations.

Rationale. When dams were built on all Central Valley rivers, steelhead were denied access to their historic spawning grounds in upstream areas. It was generally assumed that hatchery production would make up for any losses caused by the dams; however, hatchery production of steelhead has been limited by numerous problems. For example, one major hatchery (Nimbus) raises steelhead derived from fish imported from the Eel River and other sources because native steelhead were in short supply (perhaps depleted by removal of wild individuals for use in the hatchery). Because of the hatcheries and changes to the rivers, the exact status of wild populations in the Central Valley is unclear, but the populations are certainly at low levels. The biggest remaining populations of wild steelhead appear to be in the Yuba River and in Deer and Mill Creeks (Tehama County), but the status of these runs is uncertain. For these reasons, the NMFS has listed Central Valley steelhead as threatened. The objective, therefore, is designed to restore the numbers and spawning densities of wild steelhead to a point where the species can sustain a substantial sport fishery. The restoration of steelhead to reasonably high numbers and densities in currently available habitat depends on assumptions about habitat quality and the biology of the fish that need to be tested. It is likely that restoration of this fish will require providing it with access to upstream areas now blocked by dams (e.g., Yuba River upstream of Englebright Dam).

Stage 1 Expectations. Central Valley steelhead numbers should not fall lower than they have been in the 1990s. The status of steelhead in the Yuba River and in Deer and Mill Creeks should be determined. A research program on factors limiting their abundance should be initiated, including a study of the impact of hatchery fish. Available spawning and rearing habitat should be identified, and programs (e.g., mass marking of hatchery juveniles) should be instituted to allow hatchery fish to be distinguished from wild fish.

Objective 7: Restore Longfin Smelt to the Delta and Suisun Bay

Long-Term Objective: Restore longfin smelt abundance to levels that existed in the 1960s and 1970s, as measured over a period of at least 10 years.

Short-Term Objective: Achieve the recovery goals for longfin smelt identified in the Delta Native Fishes Recovery Plan.

Rationale. The longfin smelt is arguably one of the most endangered fishes in the estuary although the petition for listing it as an endangered species was declined (largely for genetic reasons). Longfin smelt were extremely abundant in the estuary when the fall midwater trawling program began in the 1960s. This period is used as a standard simply because it was during this period that the data available for comparative purposes begin, and the period covers a series of wet and extremely dry years. Evidence suggests that longfin smelt were abundant enough in the 19th century to support a fishery. Because longfin smelt abundance has a strong relationship to X2[1],

[1] The distance from the mouth of the estuary to the point where the daily-averaged salinity is 2 practical salinity units, X2 is used as an indicator of the physical response of the estuary to freshwater flow.

future abundance may be tied closely to available fresh water and the ability to manipulate outflows to favor the species. Achieving the long-term objective may be impeded by the presence of several introduced species, notably the clam *Potamocorbula amurensis*. If future investigations determine that substantial reductions in longfin smelt are attributable to the introduced species currently established, then this objective may need to be scaled back.

Stage 1 Expectations. In 7-10 years, the longfin smelt population indices should stay within the same range that they have been in during the period 1990-1998 unless there is an exceptionally long period of drought. The basic factors limiting their distribution and abundance should be determined.

Objective 8: Restore Green Sturgeon to the Delta and Suisun Bay

Long-Term Objective: Maintain populations of green sturgeon large enough to allow commercial, subsistence, and sport fisheries to be maintained for them, both inside and outside the estuary.

Short-Term Objective: Learn as much as feasible about the life history requirements and population dynamics of green sturgeon in the Sacramento River and estuary, including its relationship to other green sturgeon populations, to determine whether the recovery goals identified in the Delta Native Fishes Recovery Plan are realistic. If the goals are determined to be realistic, they should be implemented.

Rationale. The green sturgeon is relatively uncommon in the Bay-Delta system compared to the white sturgeon and probably always has been. However, the population appears to be one of only three still in existence in North America, so it needs special consideration. Very little is known about the requirements of this species in the system, and the recovery goals identified in the Delta Native Fishes Recovery Plan are based on knowledge gained from their incidental catch in white sturgeon studies and fisheries. Thus, restoration and management of this species requires much better knowledge than currently exists. Because it is so long lived (50+ years) and current exploitation levels seem to be low, there is time to conduct systematic research on its biology to determine the best ways to increase its populations.

Stage 1 Expectations. Basic facts about the population structure, distribution, and life history of green sturgeon should be determined, and a management plan should be developed to ensure its survival in cooperation with state fisheries agencies in Oregon and Washington (sites of fisheries for green sturgeon).

Objective 9: Restore Sacramento Splittail to the Delta, Suisun Bay, and the Central Valley

Long-Term Objective: Restore the Sacramento splittail so that it is one of the most abundant fish species in the Delta, Suisun Bay and marsh, the lower Sacramento River, and the lower San Joaquin River.

Short-Term Objective: Achieve the recovery goals for splittail identified in the Delta Native Fishes Recovery Plan.

Rationale. The Sacramento splittail was once widespread in lowland waters of the Central Valley but is today largely confined to the estuary, except during wet years. The Sacramento splittail population dropped to a low point in the estuary during the drought of the 1980s but rebounded to high levels in the estuary during wet years of the 1990s. It is likely that reproductive success of this species is tied to the timing and duration of flooding of the Yolo and Sutter Bypasses and to flooding of riparian zones along the major rivers of the Central Valley, so a return to its former abundance and distribution will require special management of these areas.

Stage 1 Expectations. At least one additional strong year class should have developed to maintain splittail populations, while factors limiting splittail spawning and recruitment success are determined and accounted for in a management plan.

Priority Group II Species

Objective 1: Restore Anadromous Lampreys Dependent on the Delta and Suisun Bay

Long-Term Objective: Restore wild self-sustaining populations of anadromous lampreys to all accessible rivers in which they historically occurred.

Short-Term Objective: Evaluate the status and life history requirements of Pacific lamprey and river lamprey in the Central Valley and determine their use of the Delta and Suisun Bay for migration, breeding, and rearing.

Rationale. Lampreys are anadromous species that clearly have declined in the Central Valley although the extent of the decline has not been documented. Pacific lamprey probably exist in much of the accessible habitat available today but this is not known. The decline of lampreys is presumably due to the decline of salmonids (major prey species), to deterioration of their spawning and rearing habitat, to entrainment in diversions, and to other factors affecting fish health in the system. As for salmonids, much of the habitat previously available for wild-spawning lampreys is permanently disconnected from the migration corridors. However, the remaining habitat or, the "new" habitat in the tail waters of large dams, should be useable for spawning. Presumably, restoration of salmonid populations will also benefit lampreys, although this assumption should be regarded as a hypothesis, not a fact. If the assumption is not true, lampreys may have to be treated as Priority Group I species.

Stage 1 Expectations. Surveys should be conducted to determine the status of lampreys in the Central Valley and a status report should be in place that recommends restoration actions.

Objective 2: Restore At-Risk Endemic Brackish Water Tidal Marsh Plants

Long-Term Objective: Have self-sustaining populations of Mason's lilaeopsis, Suisun Marsh aster, Suisun thistle, soft birds-beak, alkali milk vetch, Delta mudwort, and Delta tule pea and similar declining endemic species located throughout their original native range in marshes associated with the Bay-Delta system.

Short-Term Objective: Protect existing populations of the species and restore habitat to provide sites for expansion of all rare native species that require tidal or brackish water marshes.

Rationale. The seven species listed here are examples of plants that are largely endemic to brackish water marshes of Suisun Bay and elsewhere in the estuary. The likelihood of extinction among these species varies from very high for Suisun thistle, known from only four occurrences, to moderate for Mason's lilaeopsis, which is widely distributed throughout the Delta. In combination, these seven species require a range of declining tidal marsh habitats in the Bay-Delta system. Although only two of the species (Suisun thistle and soft bird's beak) are formally listed as endangered, restoration of all these species to the point where they are fairly common would indicate that major marsh restoration projects in the region had succeeded.

Stage 1 Expectations. The status of the seven species listed here should have improved. Surveys of present ranges of the species (and other rare marsh plants), studies of their ecological requirements, and identification of key restoration sites should be completed. Ongoing marsh restoration projects in the Bay-Delta system should be evaluated according to their success at restoring rare native plant species and lessons learned applied to new projects.

Objective 3: Restore California Clapper Rail

Long-Term Objective: Have self-sustaining populations of California clapper rail located throughout their original native range in tidal marshes of the Bay-Delta system.

Short-Term Objective: Protect existing populations of the species and restore habitat to provide sites for expansion of present populations.

Rationale. The California clapper rail requires tidal salt marshes for all phases of its life cycle. Its populations have declined as these marshes have been eliminated and fragmented, permitting easier access of non-native predators (e.g., house cats, red fox), people, and other intruders to their nesting and high-tide roosting areas. These birds should recover as tidal salt marshes are allowed to re-expand and as marsh restoration efforts proceed.

Stage 1 Expectations. Habitat for all existing populations should be protected and management plans should be in place to further improve existing habitats for clapper rails. Potential additional restoration sites should be identified.

Objective 4: Restore Swainson's Hawk

Long-Term Objective: Have self-sustaining breeding and wintering populations of Swainson's hawk located throughout their original native range in the Delta and the Central Valley.

Short-Term Objective: Determine the status of all California populations of Swainson's hawk and institute protection plans for key breeding areas. Determine the importance to the species of the small numbers that overwinter in the Delta should be determined and develop plans to expand the number of overwintering birds, if desirable and feasible.

Rationale. Swainson's hawk is listed as a threatened species by the state of California because its numbers have declined to a small (<2%) percentage of its original population. It nests in riparian areas and forages in upland grasslands and crop lands. The decline has been caused by the combined loss of riparian nesting habitat and foraging habitat and by large mortalities in its overwintering habitat in Argentina. A small number of these hawks overwinter in the Delta rather than migrating, for unknown reasons. If restoration of breeding habitat does not significantly reverse the decline of these birds because of mortality during their long migrations, then there may be a need to find ways to encourage more overwintering in the Delta.

Stage 1 Expectations. A recovery plan for Swainson's hawk in the Central Valley and Delta should be instituted, with key habitats identified and initial protective steps taken.

Objective 5: Restore California Black Rail

Long-Term Objective: Have self-sustaining populations of California black rail located throughout their original native range in tidal marshes of the Bay-Delta estuary.

Short-Term Objective: Restore the population of California black rails to levels necessary to have its status down-graded from a threatened species.

Rationale. The California black rail is a state-listed threatened species and is considered a species of concern by the federal government. The leading cause of its decline is the degradation and loss of emergent wetland habitat throughout its range. The California black rail builds nest on the ground and is susceptible to predation by terrestrial species. Non-native species such as the red fox and feral domestic animals (cats and dogs) in some areas have raided nests and contributed to their decline. To develop improve the status of this species, it will be necessary to restore and enhance suitable habitat throughout the wetlands of the estuary. It will also be very important to develop methods to control the non-native predators.

Stage 1 Expectations. Plans should be developed and implemented to restore and protect emergent wetlands within the Napa and Suisun marshes and along San Francisco Bay; develop strategies for controlling problem predators.

Objective 6: Restore Suisun Song Sparrow

Long-Term Objective: Restore populations of Suisun song sparrow to habitats throughout its native range by creating/restoring enough brackish tidal marsh habitat to support 40,000 nesting pairs.

Short-Term Objective: With existing populations, find ways to connect fragmented brackish and freshwater habitats to increase the gene flow among population segments and reduce the likelihood of extirpation of isolated population segments.

Rationale. The Suisun song sparrow occurs only in and near Suisun Marsh, in about 13 isolated populations. Populations of this unusual subspecies are declining for a variety of reasons but mainly the degradation of their habitat. Reductions in fresh water outflow from the Sacramento-San Joaquin Rivers and diking and channelization of marsh lands have contributed to their decline. Restoration of their populations is likely to be a good indicator of the success of restoration of brackish tidal marshes in the Suisun Marsh area.

Stage 1 Expectations. All Suisun song sparrow populations should be identified and protected from further development and habitat alterations; plans should be developed and implemented to connect isolated populations by means of habitat restoration projects.

Objective 7: Restore Suisun Ornate Shrew

Long-Term Objective: Restoration of Suisun ornate shrew to tidal wetland habitats throughout its native range.

Short-Term Objective: Identify the remaining population of suisun shrew and develop a conservation plan to stop the decline of this species.

Rationale. The Suisun ornate shrew is a listed as a species of special concern by DFG, but its limited habitat and distribution indicate it may qualify as a threatened species. Long term survival of this subspecies is dependent upon tidal wetland, as opposed to diked wetlands, and has to have adequate physical structures and plant communities for survival. Its tidal marsh habitat has to have adjacent upland habitat for survival of the species during periods when the marsh is inundated. The upland habitat has to have relatively low densities of exotic predators. Restoring habitat would not only benefit the Suisun ornate shrew but other species, such as the salt marsh harvest mouse, that also use tidal marsh and upland marsh habitats.

Stage 1 Expectations. All remaining populations of Suisun ornate shrew should be identified and protection plans developed and implemented.

Objective 8: Restore Salt Marsh Harvest Mouse

Long-Term Objective: Restore salt marsh harvest mouse to tidal marsh throughout their historical range.

Short-Term Objectives: Reestablish populations in newly created or restored marshland and protect existing populations as outlined in the salt marsh harvest mouse recovery plan.

Rationale. This species is listed as endangered by both state and federal governments and exists in small isolated populations in Bay salt marshes . Historically, about 107,000 acres of habitat suitable for the salt marsh harvest mouse existed. Degradation of habitat due to agricultural practices, diking, and human disturbance has limited greatly what is available today. It is important that this degradation and loss of any more habitat be stopped. Existing habitat is susceptible to flooding and silting in, as well as new building projects. New wetlands have to be created to outweigh disappearing marsh in other areas if the small isolated populations are to be enhanced. Created habitat would also benefit other species that use tidal marsh environments.

Stage 1 Expectations. Key items in the salt marsh harvest mouse recovery plan should be identified, followed by implementation of those that would have immediate benefits to the species, including stopping population decline and increasing genetic flow between isolated populations. The existing populations should be studied to determine their size and their habitat requirements. Limit the activities that would further increase erosion of Bay marshes and therefore reduce existing population sizes.

Objective 9: Restore San Pablo Vole

Long-Term Objective: Restore San Pablo vole to tidal marsh throughout their historical range.

Short-Term Objective: Determine the distribution and taxonomic status of the vole while maintaining existing salt marsh habitat known to contain populations.

Rationale. The San Pablo vole is a DFG California Special Concern species. Although little is known about is distribution, biology, or taxonomy, it appears to be a distinct form that is confined to salt marshes and adjoining grasslands in Contra Costa County. To limit the decline of the populations even further, measures salt marsh and adjoining grassland habitats in Contra Costa County need to be protected and further degradation and loss of habitat halted. Because present populations appear to be isolated from one another, there is a need to expand salt marsh habitats to maintain population sizes and increase gene flow between the isolated populations.

Stage 1 Expectations. All known localities for this species should be protected and a thorough search made for other populations. A restoration plan should be developed and implemented that includes genetic studies to determine its relationship to the widely distributed California vole.

Objective 10: Restore Valley Elderberry Longhorn Beetle

Long-Term Objective: Restore riparian habitat throughout the Central Valley that includes components (i.e., elderberry thickets) suitable for populations of valley elderberry beetle throughout its native range.

Short-Term Objective: Develop a comprehensive plan for the recovery of this species and its habitat and include habitat for the species in riparian restoration projects in its native range where feasible.

Rationale. The valley elderberry longhorn beetle is listed as threatened by the federal government, although its status and factors limiting its populations are poorly understood. These beetles depend on elderberry bushes for breeding and rearing of young and will sometimes occupy bushes growing in degraded habitat (e.g., levees). Presumably, its populations will respond positively to riparian restoration projects in the lower Central Valley.

Stage 1 Expectations. Minimize clearing of levees and maintain existing habitat. Do a comprehensive study to locate populations of the beetle and assess their size. Maintain existing habitat and plant new elderberry bushes where possible.

Priority Group III Species

Objective 1: Restore California Red-Legged Frog to Representative Habitats throughout Its Former Range

Long-Term Objective: Develop refuges in habitats throughout its former range that will each maintain 100+ breeding pairs of red-legged frogs, established from reintroductions.

Short-Term Objective: Locate and protect any remaining populations of red legged frogs in the CALFED region.

Rationale. Red-legged frogs are virtually extinct in the region, with just a handful of tenuous populations remaining in the Central Valley and bay region (none near the estuary). Their inability to recover from a presumed major population crash in the 19th century (due to overexploitation) has been the result of a combination of factors (in approximate order of importance): (1) predation and competition from introduced bullfrogs and fishes; (2) habitat loss, (3) pesticides and other toxins, (4) disease, and (5) other factors. Because of the poor condition of the few remaining frog populations and the continued existence of major causes of their decline, this objective may not be achievable in either the short or long term. Any refuge developed for this species will require continuous intensive management and development of experimental barriers to exclude non-native species. The long-term goal will be achievable only if the refuge experiments work and are cost-effective (e.g., it might be better to put dollars into restoring areas outside the region where red-

legged frogs still maintain populations naturally). Refuges for red-legged frogs will benefit other at-risk species as well, such as giant garter snakes, Pacific pond turtles, and tiger salamanders.

Stage 1 Expectations. All red-legged frogs populations in the region should be located and protective measures taken where feasible. At least one experimental population should be established.

Objective 2: Restore California Tiger Salamander to Representative Habitats throughout Its Range

Long-Term Objective: Establish refuges for California tiger salamander throughout its range that will maintain its present genetic and ecological diversity.

Short-Term Objective: Identify and protect remaining California tiger salamander populations in the CALFED region.

Rationale. California tiger salamander populations are disappearing rapidly in the CALFED region because of habitat alteration, especially urban development, and introductions of non-native fishes into their breeding ponds. They require fish-free breeding ponds next to upland habitat containing rodent burrows in which they can over-summer. Patches of suitable habitats are naturally somewhat isolated from one another, promoting genetic diversity within the species which presumably reflects adaptations to local conditions. Long-term survival of these diverse populations depends on numerous protected areas containing both breeding ponds and upland habitats.

Stage 1 Expectations. A thorough survey of tiger salamander populations in the CALFED region should be completed and actions taken to protect remaining populations in counties bordering the Bay-Delta system.

Objective 3: Restore Sacramento Perch within Its Native Range

Long-Term Objective: Establish multiple, self-sustaining populations of Sacramento perch within the Central Valley region.

Short-Term Objective: Evaluate the status and biology of Sacramento perch to see if restoration of wild populations within its native range is feasible.

Rationale. The Sacramento perch was once one of the most abundant fish in lowland habitats of the Central Valley. With the exception of a small population in Clear Lake, it has been extirpated from natural habitats within its native range, apparently because of competition and predation from introduced centrarchid fishes, such as black bass. It would be certainly be formally listed as an endangered species except that it has been widely introduced into reservoirs, lakes, and ponds outside its native habitats in California and other western states. Although some of these introduced populations are probably secure, most are in artificial waters subject to dewatering and

other perturbations and a number have disappeared in recent years. There is thus a need to establish populations in places within their native range that can be closely monitored to be sure this species persists in the future. It is quite likely that many, if not all, of these places will be artificial habitats (e.g., ponds, reservoirs).

Stage 1 Expectations. A thorough status review of the Sacramento perch should be completed and a plan for its long-term preservation in the Central Valley developed. At least one experimental population should be established in the Delta.

Objective 4: Restore Populations of Native Anuran Amphibians throughout the CALFED Region

Long-Term Objective: Have self-sustaining populations of all native anuran amphibians (frogs, toads) present throughout their native ranges, in all major watersheds in the CALFED area.

Short-Term Objective: Determine the causes of anuran amphibian declines in the CALFED area, develop restoration strategies, and implement them where feasible.

Rationale. The frogs and toads of California are in a general state of decline, but especially in the Central Valley watershed. The ranid frogs (red-legged frog, foothill yellow-legged frog, mountain yellow-legged frog, cascades frog) are in steep decline. Foothill yellow-legged frogs, for example, have virtually disappeared from the San Joaquin drainage since the 1970s (when they were still common). Red-legged frogs have become so rare they are federally listed as endangered (and are treated separately as a consequence). Although the decline of these amphibians can be tied to global amphibian declines, the principal causes are probably regional: introduced species and airborne pesticides. Because pesticides also have effects on human health, any changes in farming practices to protect humans also should be designed to protect amphibians.

Stage 1 Expectations. Complete status surveys of all anuran amphibians should be made and the major causes of declines should be determined. Long-term plans should be developed and instituted to create conditions that will allow populations to recover throughout their ranges.

Objective 5: Restore Self-Sustaining Populations of Western Pond Turtles to Habitats throughout the CALFED Region

Long-Term Objective: Restore self-sustaining populations of western pond turtles to habitats throughout the CALFED region, including the Delta.

Short-Term Objective: Determine the status and habitat requirements of pond turtles throughout the region and develop a conservation strategy in concert with habitat protection measures.

Rationale. The western pond turtle is the only turtle native to the Central Valley region and to much of the western United States. Although considered to be just one widely distributed species, it is likely that the pond turtle is a complex of closely related species, each adapted for a different region. The Pacific pond turtle is still common enough in the CALFED region so that it is not difficult to find them in habitats ranging from sloughs of the Delta and Suisun Marsh to pools in small streams. The problem is that most individuals seen are large, old individuals; hatchlings and small turtles are increasingly rare. The causes of the poor reproductive success are not well understood but factors that need to be considered include elimination of suitable breeding sites, predation on hatchlings by non-native predators (e.g., largemouth bass, bullfrogs), predation on eggs by non-native wild pigs, diseases introduced by non-native turtles, and shortage of safe upland over-wintering refuges. If present trends continue, the western pond turtle will deserve listing as a threatened species (it may already).

Stage 1 Expectations. Populations of turtles that appear to still have successful reproduction should be located and protected, in conjunction with other habitat protection measures. Causes of the decline should be determined and a recovery plan developed based on the findings.

Objective 6: Restore Populations of Giant Garter Snake throughout Its Historical Range

Long-Term Objective: Establish or restore populations of giant garter snake in restored marshlands through out its original range.

Short-Term Objective: Maintain present populations with no further declines in size by ensuring that waterways known to being used by giant garter snakes have water in them year round.

Rationale. The giant garter snake is listed by both state and federal governments as a threatened species. Most of the original giant garter snake habitat, freshwater marshes, has been lost to agriculture. This snake resides in marsh habitat where there are pools and sloughs that exist year round to provide the frogs and invertebrates on which they feed. This snake survives today because small numbers live in rice fields and along irrigation ditches. Survival of the species, however, is likely to depend upon increasing its natural habitat through marsh restoration combined with special protection measures on the agricultural land it currently inhabits.

Stage 1 Expectations. Existing natural habitats that have available water all year should be maintained, and key habitats in agricultural areas identified for special management. Sites for freshwater marsh restoration should identified and a restoration program established.

Objective 7: Restore the Wintering Population of Western Least Bittern in the Central Valley to Historic Levels

Long-Term Objective: Restore the western least bittern to the status as a common overwintering marsh bird in the Central Valley and Delta.

Short-Term Objective: Develop wintering habitat for least bitterns by creating "no disturbance" refuges along the central corridor of the Central Valley and Delta for all shore and wading birds.

Rationale. The western least bittern, a DFG Species of Special Concern nests in emergent wetlands of cattails and tules in the upper and lower reaches of the Central Valley but winters in marshlands along the main rivers and in the Delta. Least bitterns were apparently once a common wintering bird in the Central Valley but are now scarce. The loss of wintering habitat as a result of channelization and reclamation of marsh lands along the major rivers and Delta has been a major factor in their decline. Therefore, to increase their overwintering survival, there needs to be an increase in contiguous areas of emergent marsh along both the Sacramento and San Joaquin rivers. Important, but less critical, is the need protect breeding habitats not only in the Central Valley but along the Colorado River and Salton Sea.

Stage 1 Expectations. A thorough review of the status and habitat requirements of western least bittern should be conducted. Areas within the Central Valley should be set aside as "no disturbance" refuges to protect wintering habitat of bitterns and other wading and shore birds from human disturbance.

Objective 8: Restore Least Bell's Vireo Populations to Habitats throughout Its Former Range in the Central Valley

Long-Term Objective: Restore populations of least Bell's vireo to riparian areas throughout California.

Short-Term Objective: Recovery least Bell's vireo populations to the point where it can be removed from state and federal endangered species lists.

Rationale. The least Bell's vireo was once quite common throughout the coastal and Sacramento and San Joaquin Valleys. The current distribution of least Bell's vireo in California is in isolated pockets in Southern California and along the Colorado River. Currently, the least Bell's vireo is listed as an endangered species by both the state and federal governments due to its rapid decline in population and distribution. The least Bell's vireo's decline has been attributed to degradation and destruction of nesting habitat among riparian thickets. Nest parasitism by cowbirds, a side effect of the narrowing and isolation of riparian habitats, has also contributed to the decline of least Bell's vireo.

Stage 1 Expectations. Determine the current distribution and population of least Bell's vireo within California and develop strategies for reintroducing it into central California. Expand riparian restoration programs with the idea of recreating habitat for this bird.

Objective 9: Restore Little Willow Flycatcher Populations to Habitats throughout Its Former Range in Central California

Long-Term Objective: Restore little willow flycatcher to abundance throughout its native range by protecting and restoring contiguous expanses of montane riparian habitats in the Sierra Nevada and Cascade ranges.

Short-Term Objective: Have enough self-sustaining populations of little willow flycatcher so that the species can be removed from the state list of endangered species.

Rationale. The little willow flycatcher is a neotropical migrant bird that is listed by the state as endangered and by federal government as a species of concern. Little willow flycatchers nest and roost in montane riparian habitats in the Sierra Nevada and Cascade ranges consisting of dense willow thickets. Lower exposed perches provide singing and hunting platforms. In areas that are heavily grazed by cattle little willow flycatchers are absent from areas that appear to provide suitable habitat. Restoration of this bird will presumably require restoring large expanses of riparian thickets within the habitat ranges of the little willow flycatcher, in part by excluding cattle grazing.

Stage 1 Expectations: Determine the range within California of the little willow flycatcher and protect and enhance remaining habitat areas.

Objective 10: Restore Populations of Western Yellow-Billed Cuckoo throughout Its Historical Range in California

Long-Term Objective: Have breeding populations of western yellow-billed cuckoo in riparian areas throughout the Central Valley.

Short-Term Objective: Restore enough populations to western yellow-billed cuckoo so it can be removed from the list of California endangered species.

Rationale. The yellow-billed cuckoo is listed as an endangered species in California because it has disappeared from most of the riparian areas it once inhabited. The cause of their decline seems too have been loss and alteration of riparian forests, combined with heavy pesticide use in adjacent farmland. Yellow-billed cuckoos have strict habitat requirements for successful breeding, including humid conditions and dense strands of willows and cottonwoods along riverbeds. Yellow-billed cuckoos do not just inhabit old growth trees so reforested areas can be used as successful breeding areas. Limiting pesticide use in the area is needed so there is an ample food supply of insects to feed the young.

Stage 1 Expectations. Existing populations should be stabilized and any further loss of feeding and nesting habitat should be prevented. Riparian areas suitable for yellowbilled cuckoo should be identified and prioritized for restoration and, if necessary, reintroduction of cuckoos.

Objective 11: Increase Greater Sandhill Crane Populations in California

Long-Term Objective: Restore the greater sandhill crane to a bird with significant breeding populations in the Central Valley.

Short-Term Objective: Restore populations to the point where the crane can be removed from the state threatened species list. Increase annual and perennial grassland habitat as well as emergent wetlands where greater sandhill cranes can feed and brood.

Rationale. The greater sandhill crane is a spectacular bird that listed as threatened in California and fully protected under the Fish and Game Code. It is a year around resident, nesting in grasslands and wetlands. Much of their nesting habitat has been lost to agricultural conversion and intensive cattle grazing. They will forage in moist cropland and as well as in emergent wetlands but they need a safe place to brood. Greater sandhill cranes prefer open areas with fresh water for drinking and bathing. Most winter in the Delta region and require protected roosting habitat near dormant agricultural fields in which they forage.

Stage 1 Expectations. Protect wintering and breeding habitat that already exists and maintain population size. Monitor current populations within the Central and northern valleys and protect nesting sites from cattle grazing to increase survival rates of young.

Objective 12: Restore Breeding Colonies of Bank Swallows throughout the Central Valley

Long-Term Objective: Create the conditions that will allow nesting colonies of bank swallows to thrive along the Sacramento and San Joaquin Rivers, as well as their major tributaries, especially the Feather River.

Short-Term Objective: Recover sufficient populations so that the bank swallow can be removed from the state list of threatened species.

Rationale. The bank swallow is listed as a state threatened species. It has declined because of the progressive loss of its prime nesting habitat: freshly exposed steep riverbanks, in which it digs burrows. Stabilization of river channels, placement of rip-rap on eroding banks , and other factors which decrease the availability of fresh-cut banks have reduced potential spawning areas throughout the Central Valley. This is a species that will benefit from the creation of "meander zones" in large rivers and other actions that increase the ability of rivers to find their natural channels.

Stage 1 Expectations. Inventory which areas of dynamic river bank meet requirements for bank swallow nesting habitat and develop ways to maintain the creation of fresh-cut banks in these regions to keep the creation of new nesting habitat at least even with the natural deterioration of old habitat.

Delta. In this environment, they could grow rapidly on diets of insects and shrimp, reaching sizes large enough to enhance ocean survival.

In the estuary, the abundant longfin and delta smelts could also move up and down with seasons, seeking favorable conditions for spawning and rearing of young. The short (1- to 2-year) life cycles of these fish testifies that no matter how dry or wet the year, the appropriate conditions were present somewhere in the system. The resident fishes, in contrast, were largely stream or floodplain spawners and apparently did not necessarily find appropriate conditions for spawning and rearing of young to be available every year. As a consequence, they adopted the basic life history strategy of living long enough (5 or more years) to be around when favorable conditions were present and to flood the environment with large numbers of young. Middens near native American village sites indicate that these fishes (e.g., thicktail chub, Sacramento perch, splittail, hitch, and Sacramento blackfish) were extremely abundant and easy to harvest.

The abundance of fish in the middens also indicates that the native peoples were major predators on the fish, including salmon. The abundance of fish was presumably one of the reasons why these people were able to exist in relatively high densities (compared to other areas of North America). Although they may have depleted some of the resources they used (Broughton 1994), some abundant fishes were lightly used if at all. For example, the principal salmon run harvested was the fall run, both because of its accessibility and because the fish were less oily than fish of other runs, making them easier to dry for long-term storage. Other salmon runs were harvested less intensively and steelhead hardly at all.

The native species in this productive ecosystem were adapted to hydrologic extremes, with specific salmon runs adapted to take advantage of different parts of the annual hydrograph. A range of species and life stages used different habitats in different parts of the system.

Critical Aspects of Landscape and Ecological Functions

From our knowledge of the functioning of the natural system, we can identify critical aspects that would need to be addressed in a successful restoration program.

Habitat Area and Diversity

Minimum habitat areas are needed to maintain viable populations of native species. This habitat also has to contain the complex features needed to maintain multiple species and multiple life stages of each species. For example, high-quality brackish and freshwater tideland (including shallow-water habitats, such as mudflats, tule marsh, small sinuous sloughs and distributaries, upper tidal marsh types [e.g. pickleweed], and riparian scrub) historically occurred along the Sacramento and San Joaquin River channels, in the west Delta and Yolo Basin (north Delta), and in the North Bay tidelands of Napa and Sonoma Valleys. Also historically, the salinity gradient of the estuary varied greatly seasonally and between water years, but because these habitats were well distributed

along the estuarine system, there were always large expanses of shallow-water habitat associated with the saline/fresh water mixing zone (hydrologically connected). Today, these habitats occur primarily in Suisun Bay, Suisun Marsh, and lower Sherman Island. In all, the area of tidal marsh and active floodplain habitat has been reduced to probably less than 5% of its pre-1850 extent. Such massive reductions in habitat imply a substantial change in the ability of the species dependent on those habitats to sustain their population levels.

Physical and Ecological Processes

The habitats of the pristine Bay-Delta system can be viewed as forms that developed and were maintained by processes such as flooding, sediment transport, establishment and scour of vegetation, channel migration, large woody debris transport, groundwater seepage, tidal circulation, and sedimentation. For these habitats to be sustainable in the long term, restoration of processes will be more effective than physical creation of forms no longer maintained by processes. Floodplain inundation and forest succession are two such processes along alluvial rivers.

Floodplain forests depended on periodic inundation of the floodplain to maintain appropriate moisture and disturbance regimes, which also discouraged invasion by upland species. Along many rivers, the floodplain is now leveed, and upstream dams have reduced the frequency of high flows. Thus, restoration of floodplain forests will require more than grading floodplain surfaces and planting suitable trees. Levees may need to be removed, breached, or set back, and the river will need periodic high flows capable of inundating the floodplains.

As alluvial river channels migrated across the valley bottoms (through erosion and deposition), they created new (sandy) surfaces on which pioneer riparian species (willow and cottonwood) could establish. Over time, silty overbank sediments deposited and built up the site, and later successional stage trees, such as sycamore, ash, and eventually valley oak, would establish and mature. Thus, the channel migration and its attendant erosion, deposition, and ecological succession were important processes in maintaining habitat diversity along alluvial rivers.

Temporal Variability

The rivers of the Sacramento-San Joaquin system were dynamic environments, with temporal variations from seasonal and interannual variations in flow and sediment load, often resulting in changes to the channels themselves during floods. Such temporal variability is recognized to be important ecologically, with the periodic disturbances of floods playing an important role in maintaining riverine ecological communities (Resh et al. 1988, Wootten et al. 1996) and their habitats. Periodic droughts may also have been important, with upstream migration of salt water into Delta channels likely. This implies that seasonal and interannual variability, especially high flows, are important for restoration of the ecosystem.

In the Bay and Delta, the intrinsic value of brackish and freshwater tidelands is well documented, including high primary and secondary productivity, fish rearing and foraging habitat,

and habitat for a high diversity of native animals and plants, including many at-risk species (general avian and semiaquatic mammal [e.g., otter] habitats). Less understood are the functional relationships and interdependencies of open water (pelagic) habitats and species of the Delta to these formerly more common peripheral shallow water habitats. Moreover, these habitats were subjected to a temporally variable salinity gradient (seasonally and year to year), with saline water intruding far upstream into the Delta during periods of low flow (especially droughts) and fresh water extending far downstream into San Francisco Bay during floods. This dynamic, temporal variability presumably favored native species, and the current reduction of such variability may have facilitated establishment of non-native species.

Spatial Variability

The river channels were also characterized by spatial variability (or complexity), arising from irregularities in channel form, both transverse to and longitudinal with the flow direction. For example, in meander bends the channel is typically deeper on the outside of the bend, shallowing toward the inside bank onto a point bar. This variation in water depth is accompanied by variations in grain size of bed sediment and in water velocity. Longitudinally, irregularities include large-scale alternations between bedrock to alluvial reaches, steep (riffle) and low-gradient (pool) reaches, transitions between reaches of differing widths, passage over and around channel bars, and effects of boulders and large woody debris in the channel. The riverbanks were typically irregular in outline and often were made more irregular by protruding trees (living and dead). Such spatial irregularities were ecologically important because they created a diversity of habitats, which in turn supported a diversity of species and life stages of those species. The importance of complexity in physical habitat implies that in many artificially straightened or deepened channels, it may be advantageous to physically restructure the channel or to add elements likely to induce scour or deposition or both.

Continuity

The longitudinal continuity of water flow, sediment transport, nutrient transport, and transport and migration of biota through the river system, as well as the longitudinal continuity of riparian and aquatic habitat along the length of a river, were important attributes of the ecosystem. The transport of gravel from mountainous source areas provided spawning habitat in alluvial channels downstream, and the continuity of channels allowed for upstream migration of spawning salmon, waterborne dispersal of seeds, and invertebrate colonization. Similarly, the longitudinal continuity of riparian vegetation flanking the stream was an important attribute of the riparian habitat for wildlife, as well as for shading the channel and providing carbon to the aquatic system. The importance of continuity implies that conservation and restoration projects should be prioritized, in part, to maximize continuity of habitat, so that sites whose restoration would connect different habitats would have priority over other, similar sites.

Floodplain Inundation

Alluvial channels and their floodplains behaved as functional units, with floodplains accommodating flows in excess of channel capacity. This had important ecological implications. First, as water overflowed from the channel onto the floodplain, it slowed down, because overbank flow was shallow and the floodplain was hydraulically rough, offering greater resistance to flow. Floodwaters charged with suspended sediment deposited some of the coarser part of their sediment load as they flowed overbank, typically leaving deposits of sand immediately adjacent to the channel (where the water velocity first slows) and finer grained sediment further away from the channel. Floodplain sedimentation is known to be important in alluvial rivers, responsible for measurable decreases in suspended sediment loads (Walling et al. 1998). From the point of view of water quality, the removal of suspended sediment from the water column is a potentially important effect.

Floodwater on the floodplains reduced the volume of floodwater in the channels and moved more slowly than water in the main channel. The net effect was to reduce the height of the flood wave as it moved downstream. Overflow onto the floodplain also served to limit the height of water in the channel, thus limiting the shear stress exerted on the bed. In essence, the floodplains acted as "pressure relief valves", which prevented a continuous increase in shear stress in the channel with increasing discharge. This permitted a larger range of sediment grain sizes to remain on the channel bed than would have been the case without overbank flooding because without overbank flooding, gravel may be mobilized and lost at the confined channel's higher shear stress. Similarly, overbank flows make more refuge habitat available to fish because there are zones of lower shear stress in the channel and because fish can seek refuge in the inundated floodplain.

Other important ecological interactions between the floodplain and channel include shading, food, and large woody debris provided by floodplain vegetation (Gregory et al. 1991, Murphy and Meehan 1991). During prolonged inundation of the Cosumnes River floodplain in 1997, salmon and other fish were observed feeding on the inundated floodplain, one illustration of the important migrations and interchanges of organisms, nutrients, and carbon that would have occurred frequently in the Bay-Delta system before 1850. Even along rivers where floodplain inundation was typically brief, interactions could be nonetheless important for recharging the alluvial water table, dispersing seeds of riparian plants, and increasing soil moisture on surfaces elevated above the dry season water table. Inundation of floodplains and maintenance of high alluvial water tables contributed to maintenance of floodplain aquatic habitats, such as side channels, oxbow lakes, and phreatic channels (Ward and Stanford 1995).

Floodplain soils and vegetation can also improve water quality in rivers by filtering sediments from runoff and by contributing to chemical reactions in the floodplain alluvium that can remove nitrogen and other constituents from agricultural or urban runoff.

ECOLOGICAL TRANSFORMATIONS FOLLOWING COLONIZATION

Threshold Events Leading to Present Conditions

Grazing

Cattle were introduced in 1770 and rapidly expanded under Spanish rule. Along with the introduction of non-native annual grasses (which replaced most native bunch grasses), the reduction in upland plant cover, soil compaction, and reduction in riparian vegetation resulted in higher peak runoff for a given rainfall and higher erosion rates. This hydrologic transformation probably initiated a cycle of channel incision, with consequences on alluvial groundwater tables and wetlands.

Gold Mining

Beginning about 1850, the extraction of gold transformed the channels and floodplains of many rivers, especially in the Sierra Nevada. Hydraulic mining, in which high-pressure jets of water were directed at gold-bearing gravel deposits (mostly on ridgetops), produced more than 1.67 billion cubic yards of debris, most of which was flushed from steep bedrock canyons onto the Sacramento Valley floor (Gilbert 1917). This massive influx of coarse sediment filled the river channels and spread out over floodplains, converting formerly silty farmland into gravel and sand deposits. Along the Yuba River upstream of Marysville, hydraulic mining debris created the Yuba River Debris Plain, encompassing more than 40 square miles. The bed of the Yuba River near Marysville aggraded about 90 feet, inducing the town to build levees. These could not contain the continually aggrading channel and were overtopped numerous times starting in 1875, resulting in extensive damage to the town. The increased sediment in the Sacramento River interfered with shipping and required dredging. Finer grained parts of the debris settled out in the San Francisco Estuary, adding to mudflats along the bay margins. Because of its downstream impacts, hydraulic mining was prohibited by court order in 1884, but the wave of hydraulic mining debris already in the system continued to progress downstream; the bed elevation of the Yuba River at Marysville peaked in 1905 and returned to estimated premining levels by about 1950 (James 1991).

Gold-bearing floodplain and terrace gravels, including deposits of hydraulic mining debris, were extensively reworked by dredgers, which left linear mounds of tailings along many river channels in the Sacramento-San Joaquin River system. These dredger tailings have only coarse cobbles on the top, preventing establishment of vegetation except in low swales in between the tailings piles.

Channelization for Navigation

The Sacramento, Feather, and San Joaquin Rivers were important navigation routes, with ocean-going vessels reaching Marysville and Stockton in the 1850s. The influx of hydraulic-mining sediment caused the rivers to become shallower, interfering with navigation. In response, riverbeds

were dredged and levees were constructed along riverbanks (to concentrate flow and induce bed scour) to deepen channels. To facilitate navigation, large woody debris was cleared from many channels. To provide fuel for steamers, valley oaks and other trees were cleared from accessible areas near rivers.

Artificial Bank Protection

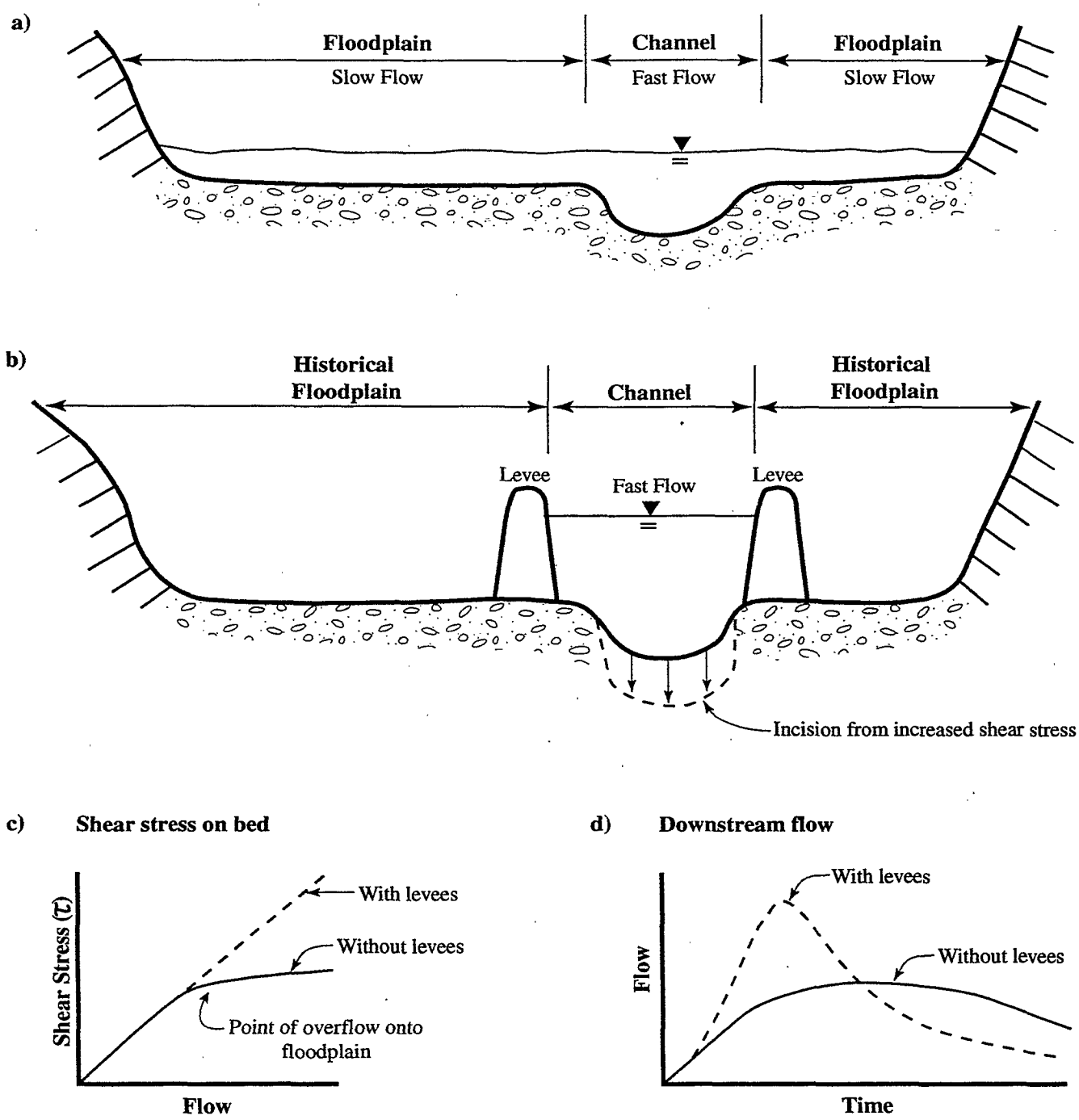
With increased agriculture and human settlement on the floodplain, it became more likely that natural channel migrations would threaten to undermine structures or productive agricultural land. To protect these resources, banks have been protected by riprap (and other artificial protection) along many reaches, including most of the Sacramento River downstream of Chico Landing. Riprapped banks effectively lock the channel in place, eliminate the contribution of gravels and woody debris from actively eroding river banks, and prevent the creation of new riverine habitats through meander migration. Moreover, the protected banks lack the overhanging vegetation and undercut banks (often termed "shaded riparian aquatic habitat") so important as fish habitat in natural channels (California State Lands Commission 1993).

Levee Construction

To protect floodplains against flooding, more than 5,000 miles of levees have been built in California, most of which are in the Bay-Delta system, and 1,100 of which are in the Delta itself (Mount 1995). Most of these are "close levees": levees built adjacent to the river channel itself (often on top of natural levees), in some cases to concentrate flow for navigation. By preventing overbank flows, levees reduce or eliminate interaction between channel and floodplain and thus reduce important ecological interactions. In addition, by eliminating overbank flows and natural floodplain storage, levees concentrate flow in the main channel, which results in greater depths, faster flow, and higher flood peaks downstream (Figure A-2) (IFMRC 1994).

Floodplain Conversion

Most floodplains, with their fertility enhanced by overbank silt deposits, were converted from alluvial forest or riparian marsh to agricultural land, with subsequent conversion of many areas to urban use. Valley oak woodlands were cleared extensively because they tended to occur on good soils. First cleared along the Sacramento River were the well-drained, broad, linear ridges (natural levees) developed along the current and former channels from overbank deposits. Then of lower flood basin areas were converted as they were drained and diked off from frequent floods. The floodplains of the Sacramento and San Joaquin Rivers were extensively cleared in the second half of the 19th century for dryland wheat farming, which occupied 3.75 million acres in 1880s (Kelley 1989). In the Sacramento Valley, rice growing developed since 1910 with levee construction and availability of irrigation water, with 600,000 acres of rice in flood basins by 1981 (Bay Institute 1998).



Note: With natural floodplain functioning, much of the floodwaters are accommodated on the floodplain, where high hydraulic roughness leads to slower flows and thus slower downstream transmission of floodwaters (a). Levees concentrate floodwaters in the channel (b), resulting in deeper water and higher velocities, faster downstream transmission of floodwaters, and higher flood peaks downstream (d). Deeper and faster flows lead to higher shear stresses (force per unit area) on the channel bed (c), which may lead to bed incision (b).

Strategic Plan for the Ecosystem Restoration Program

Figure A-2
Effect of Levees on Floodflows and Channel Geomorphology

Unfortunately, no reliable data exist on the actual extent of riparian forest before 1850, and estimates vary widely. The potential maximum area of riparian forest in the Sacramento Valley (based on soils and historically mapped riparian forest) was 364,000 acres. Only about 38,000 acres exist today, approximately 10% of the historical value. However, it is unlikely that the forest ever occupied the full 364,000 acres at one time (Bay Institute 1998). In the San Joaquin Valley, soils and historical accounts suggest a potential pre-1850 riparian zone of 329,000 acres, contrasting with a current 55,000 acres of wetlands and 16,000 acres of riparian forest (Bay Institute 1998). The area currently mapped as riparian forest includes areas of poor quality, heavily affected by human action. An illustration of a relatively recent conversion of floodplain habitats in the San Joaquin River basin is shown in Figure A-3. On the floodplain of the Merced River, a complex of side channel habitats were eliminated for agriculture between 1937 and 1967.

Tidal Marsh Conversion

In the Delta and Suisun, San Pablo, and San Francisco Bays, similar transformations were underway, with most former tidal marsh and mudflats converted to agricultural lands (and some to urban uses). In the Delta, there was an estimated 380,000 acres of intertidal wetlands, 145,000 acres of nontidal wetland, and 42,000 acres of riparian vegetation on higher ground (Bay Institute 1998). Today, about 21,000 acres of wetland remain, of which about 8,200 acres are tidal (San Francisco Estuary Project 1992). The tidal wetland loss was largely finished by 1940 (Atwater et al. 1979).

The loss of these wetlands can be considered one of the most significant human-caused functional modifications of the Bay-Delta ecosystem. The Delta tidal marshes probably formed an important link in the nutrient transfer between the riverine and open-water estuarine components of the watershed. Delta tidal marshes had the highest primary productivity and biodiversity of any comparably sized area in pre-Columbian California. Although exports from marshes to adjacent open water systems have been difficult to demonstrate (Mitch and Gosselink 1993), it is likely that the Delta tidal marshes functioned as a filter that trapped sediment and removed inorganic nutrients supplied by the rivers from the upstream watershed and produced organic inputs that were transferred to the bay. Currently, tidal marshes probably still remove inorganic and organic compounds (including toxins) from the rivers, but this function has been greatly reduced because the existing river system largely bypasses the marshes.

The loss of networks of shallow dendritic slough channels in the tidal marsh has greatly reduced the length of the linear interface between open water and vegetated marsh. Historical topographic maps show that the drainage pattern in historical tidal marshes was much more complex than in current, remnant tidal marshes. Historically, tidal marshes probably provided important feeding and reproduction habitat for many vertebrate species. Restoration of tidal marsh will be most beneficial to vertebrate species if both tidal marsh area and habitat complexity are restored. Similarly, these shallow-water habitats were formerly exposed to a variable salinity regime to which native species were adapted.

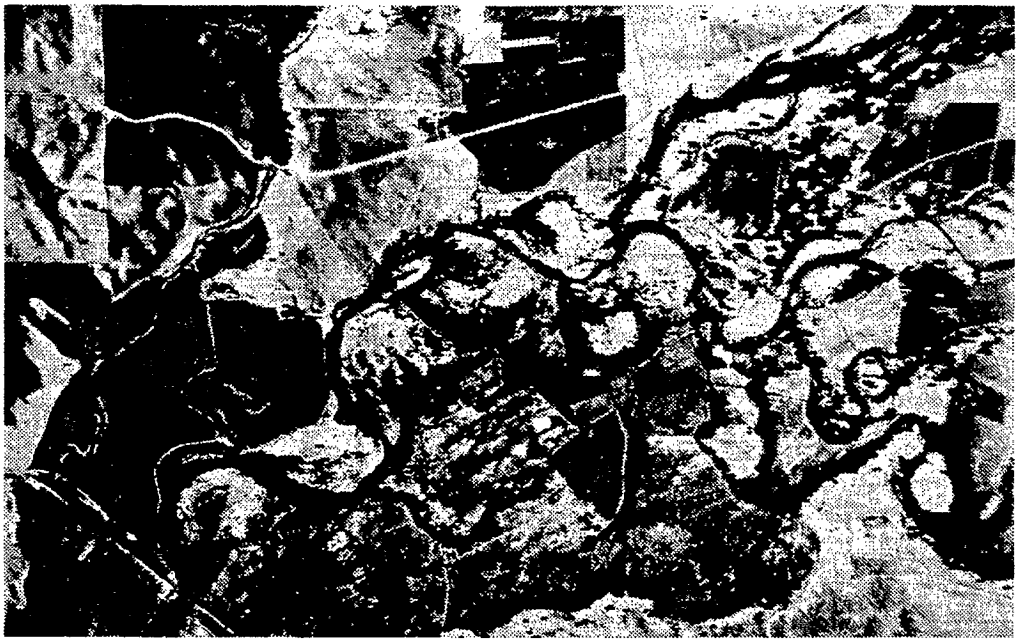
Reservoirs and Diversions

Dams constitute important discontinuities in rivers, altering riverflows, eliminating the continuity of aquatic and riparian habitat, and blocking migration of fish and other organisms. Reservoirs impound water for many reasons, such as generation of hydroelectric power; flood storage; and controlling flow to allow diversions, increased consumptive use, and export. Dams have cut off upper reaches of rivers, hydrologically isolating them (Figure A-4). One implication of this fact is that most of the channels of concern to CALFED lie downstream of large reservoirs and are thus hydrologically isolated from changes in runoff or sediment load in the upper reaches of the watersheds. For example, increased erosion from timber harvest or changes in water yield from changes in vegetative cover in the upper Feather River tributaries will not affect conditions in the CALFED area downstream of Oroville Dam as long as the reservoir continues to trap sediment and regulate flows.

As barriers to migration, dams have had an especially hard impact on spring-run chinook salmon and steelhead trout, which formerly migrated to upstream reaches to spawn. The extent of river channel inhabited by spring-run salmon has decreased dramatically since the early 19th century (Figure A-5). Overall, reservoirs were found to be the most important gaps in riparian habitat in rivers draining the Sierra Nevada (Kondolf et al. 1996). Diversions also entrain fish, resulting in direct mortality, especially of juveniles.

By 1940, most rivers in the Sacramento-San Joaquin River system had dams large enough to block fish passage, reduce flows during critical baseflow periods, and reduce frequent floods. However, reservoir size and cumulative reservoir storage increased dramatically with construction of the Central Valley Project, the State Water Project, and other large dams. From 1920 to 1985, total reservoir storage capacity increased from about 2 million acre-feet to 30 million acre-feet (Figure A-6) (San Francisco Estuary Project 1992, Bay Institute 1998). Reservoir storage in the Sacramento River system is now equivalent to 80% of annual average runoff; in the San Joaquin River system, reservoir storage is equivalent to 135% of runoff. As a result of dams, diversions, consumptive use, and export out of the watershed, the total runoff to the San Francisco Bay from the Delta has been reduced from pre-1940 runoff by 30-60% in all but wet years (Nichols et al. 1986, Bay Institute 1998). The seasonal distribution of flows has fundamentally changed, and flood magnitude and frequency profoundly decreased. The mean annual flood (the average of annual peak flows) has decreased by 20-65 % from predam values (depending on reservoir capacity in relation to runoff) (Table A-1).

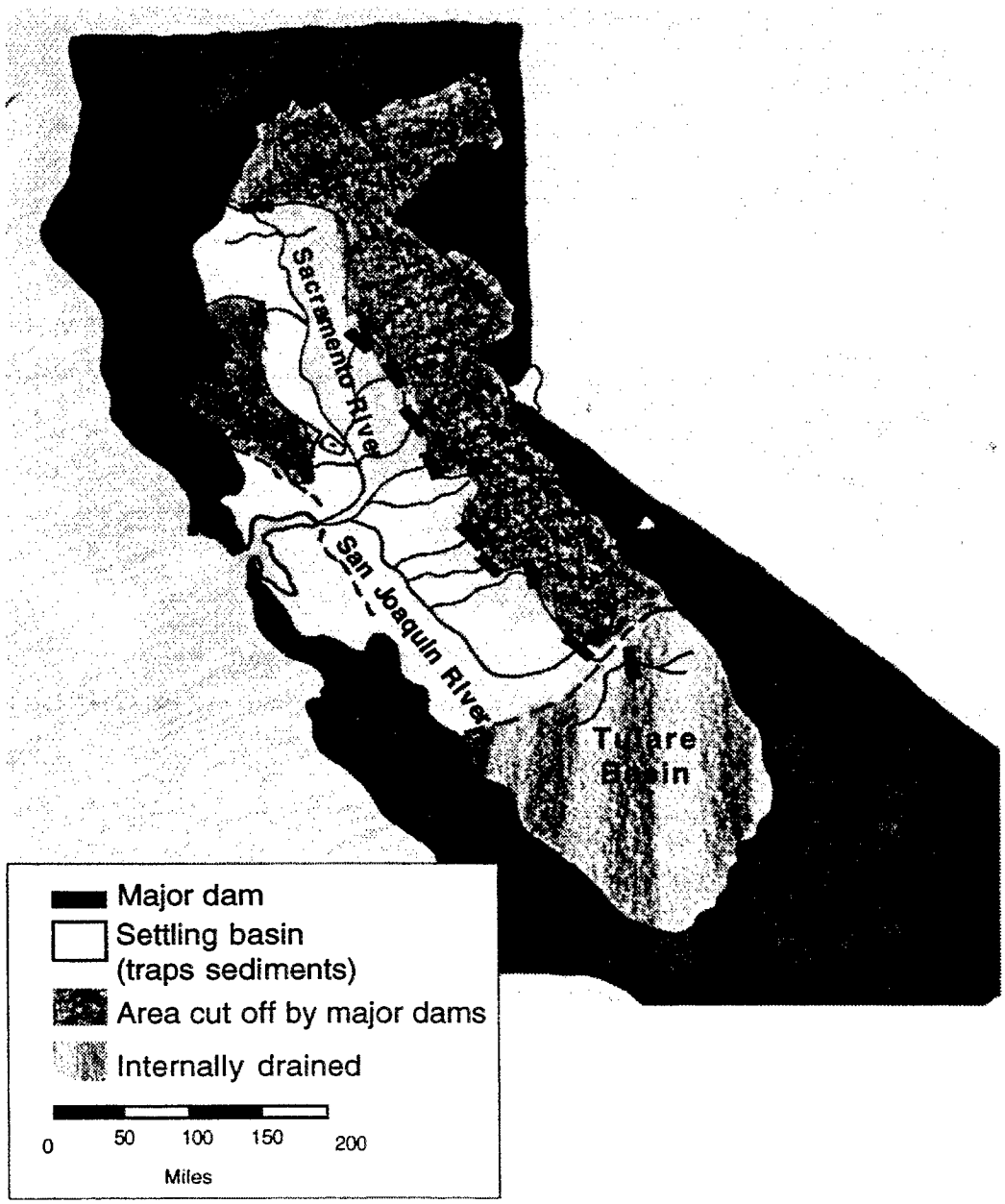
The reduction in floodflows has transformed river channels of the Sacramento-San Joaquin system. Rates of bank erosion and channel migration in the Sacramento River have declined because of dam construction and construction of downstream bank protection projects (Brice 1977, Buer 1984). The channel sinuosity (ratio of channel length to valley length) has also decreased because of numerous meander cutoffs (Brice 1977), reducing total channel length and thus total in-channel habitat. Moreover, the diversity of riparian and aquatic habitats is directly related to the processes of bank erosion, point bar building (creating fresh surfaces for riparian establishment), and overbank deposition, resulting in a mosaic of different-aged vegetation and contributing to the complexity of in-channel habitat and shaded bank cover (California State Lands Commission 1993). The reduction



1937

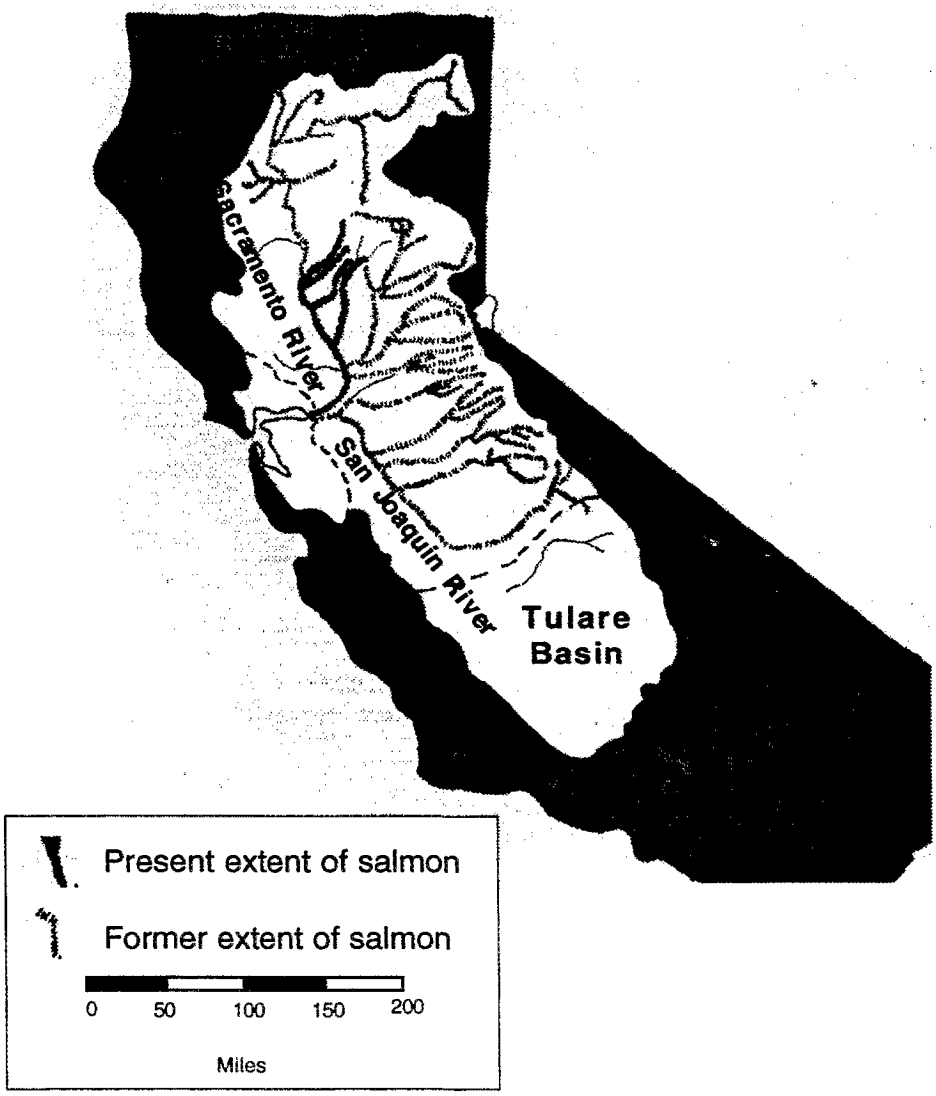
1967

Figure A-3
Aerial Photographs of the Merced River Floodplain, Showing Loss of Floodplain Side Channel Habitats from 1937 to 1967



Strategic Plan for the Ecosystem Restoration Program

Figure A-4
Upper Watersheds in the CALFED Solution Area Cut off from the Lowland Alluvial Rivers by Dams

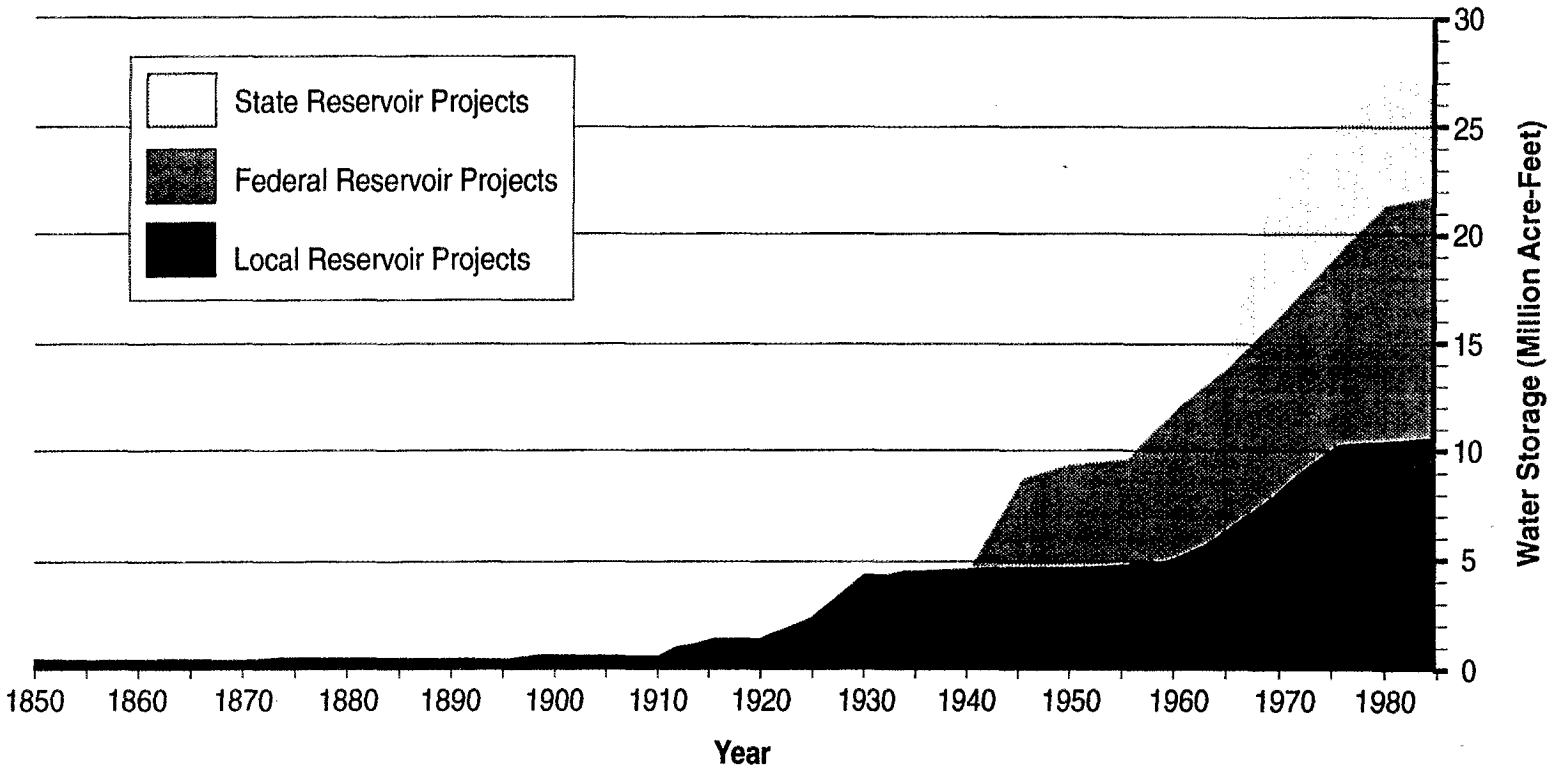


Source: Kondolf pers. comm.

Strategic Plan for the Ecosystem Restoration Program

Figure A-5
Present versus Historic Extent of Spring-Run Chinook Salmon

E-026315



Source: San Francisco Estuary Project 1992.

E—026315

Figure A-6
Cumulative Increase in Reservoir Storage in the Bay-Delta System

Table A-1. Changes in Mean Annual Flows for Selected Rivers in the Sacramento-San Joaquin River System

River	Dam	Date Constructed	Gauge Number	Period of Gauge Record	Mean Annual Flood (cubic feet per second)		Percent Reduction
					Predam	Postdam	
Sacramento River	Shasta	1945	11377100	1938-1996	120,911	78,885	65
Feather River	Oroville	1968	11407000	1902-1996	69,641	22,929	33
American River	Folsom	1956	11446500	1904-1996	53,459	29,651	55
Stony Creek	Black Butte	1963	11388000	1955-1990	13,744	7,959	58
Mokelumne River	Camanche	1963	11323500	1904-1996	7,395	2,431	33
Stanislaus River	New Melones	1979	11302000	1957-1996	10,016	3,135	31
Merced River	New Exchequer	1967	11270900	1901-1996	8,287	4,560	55
San Joaquin River	Friant	1942	11251000	1908-1996	18,614	3,718	20

Source: U.S. Geological Survey.

E-026316

E-026316

in active channel dynamics is compounded by the physical effects of riprap bank protection structures, which typically eliminate shaded bank habitat and associated deep pools, as well as halting the natural processes of channel migration.

Reduced floodflows below dams have also rendered inactive much of the formerly active channel, "fossilizing" gravel bars and permitting establishment of woody riparian vegetation within the formerly active channel, narrowing the active channel and reducing its complexity (Peltzman 1973, Kondolf and Wilcock 1996). The reduced frequency of (formerly periodic) flood disturbance in channels downstream of dams has created conditions favorable to establishment of exotic species (Baltz and Moyle 1993).

Elimination of annual floodflows below dams may permit fine sediment to accumulate in gravel beds and cobble beds, reducing the quality of spawning and juvenile habitat for salmonids, and invertebrate production (Kondolf and Wilcock 1996). Reduced mobility of gravel beds may also favor invertebrate species less desirable as food for salmonids (Wootten et al. 1996).

Dams also trap sediment derived from upstream, commonly releasing sediment-starved water downstream, as discussed below.

Extraction of Sand and Gravel for Construction Aggregate

The rapid urbanization of California has required massive amounts of sand and gravel for construction aggregate (e.g., road fill, drain rock, concrete for highways, bridges, foundations), with annual production of more than 100 million tons, 30% of the national production (Tepordei 1992). Nearly all this sand and gravel is drawn from river channels and floodplains. Mining in channels disrupts channel form, causes a sediment deficit and channel incision, with resulting loss of spawning gravels and other habitats. Floodplain gravel pits commonly capture the river channel (i.e., the river changes course to flow through the pits). The pits are excellent habitat for warmwater species that prey on salmon smolts; the California Department of Fish and Game estimates that 70% of the smolts in the Tuolumne River are lost to predation annually (EA Engineering, Science, and Technology 1992). Refilling these pits to eliminate predator habitat and restore channel confinement is expensive, with $5 million recently budgeted to fix two such pits on the Tuolumne River.

Sediment Starvation from Dams and Gravel Mining

Dams and gravel mining can result in a sediment deficit downstream, especially when mining occurs downstream of dams. The cumulative effect of sediment trapping by dams has been enormous. Using published reservoir sedimentation rates, and assuming sand and gravel to be 10% of total sediment load, we estimate that the mountainous reaches of the Sacramento, San Joaquin, and tributary rivers formerly delivered an annual average of about 1.3 million cubic meters to the Sacramento and San Joaquin Valleys. (This is the estimated sediment yield to the large foothills reservoirs, or to the equivalent point in an unregulated river, near the transition from mountainous upland to valley floor.) Construction of reservoirs has cut this amount to about 0.24 million cubic

meters, a reduction of about 83%. This does not account for the further reduction in sediment budget from gravel mining in the channels in the valley floor.

Overall, the rate of gravel mining from rivers in California is at least 10 times greater than the natural rates at which gravel and sand are eroded from the landscape and supplied to the rivers (Kondolf 1997). On the Merced River, an estimated 150,00-300,00 tons of sediment have been trapped behind the Exchequer Dam since 1926, and 7-14 million tons of sand and gravel have been excavated from the channel and floodplain since the 1950s (Kondolf et al. 1996). This constitutes a profound alteration in the regime of rivers tributary to the Bay-Delta. Although some of the sediment deficit is made up in the short term through bank erosion and channel downcutting and the transport capacity of most rivers has been reduced by reduced floodflows, the magnitude of the overall reduction in sediment supply to the system is such that long-term adjustments in channel, floodplain, and intertidal marsh/mudflat habitats are inevitable.

Dams, gravel mining, and bank protection have so reduced the supply of gravel in the Sacramento River system that many reaches of river that formerly had suitable gravels for salmon spawning are no longer suitable for spawning (e.g., Parfit and Buer 1980). In the CALFED area alone, millions of dollars have already been spent and will be spent to add gravels (and create spawning riffles) in the Sacramento, Feather, American, Mokelumne, Stanislaus, Tuolumne, and Merced Rivers and in Clear and Mill Creeks, all in attempts to compensate for the loss of spawning habitat (Kondolf and Matthews 1993, Kondolf et al. 1996).

Overfishing

Fish populations have been directly affected by harvest rate, most notably the intensive harvesting of the late 19th century, with development of major commercial fisheries for salmon in the estuary and the rivers. Gill nets strung across the Sacramento River at times completely blocked access to spawning grounds. Dozens of salmon canneries sprang up along the estuary, but the last one had closed by 1916, after the runs were depleted. Sturgeon were caught in the salmon nets in large numbers and most were killed and discarded because of the damage done to the nets. Commercial fisheries also developed to catch resident fishes, such as Sacramento perch, thicktail chub, and others, which were sold as fresh fish in the markets of San Francisco.

The early 1900s marked the beginning of the era of some of the first conservation legislation at state and national levels, the sturgeon fishery was banned, salmon populations were allowed to recover, and refuges were set aside for waterfowl.

Effects of Water Diversions from the Delta on Native Fishes

With construction of the Central Valley Project, Shasta Dam completely changed the hydraulic regime of the Sacramento River by storing winter flows and increasing summer flows. The construction of massive pumps in the south Delta to deliver Sacramento River water to the San Joaquin Valley essentially turned the Delta into a freshwater system because brackish water was kept

at bay (usually) by the inflows. In the San Joaquin Valley, Friant Dam delivered the entire flow of the upper San Joaquin River south, abruptly eliminating a major run of chinook salmon. The fish fauna of the rivers and Delta changed abruptly as well because resident non-native fishes were favored over native fishes, resident and anadromous. Thicktail chub and Sacramento perch gradually were driven to extinction in the system.

In the 1960s, the State Water Project went into operation with the completion of Oroville Dam on the Feather River (1967) and the construction of another set of big pumps in the south Delta. By this time, nearly every major river and creek feeding the Central Valley and the estuary was dammed. Not only was the water available for natural ecosystem processes increasingly diminished in amount, but it was increasingly polluted, the result of the ever-increasing urbanization of the region and more intensive agriculture.

Native resident and anadromous fishes continued to decline, as did the native flora and fauna of riparian areas and wetlands as water diversions increased and as wetland and riparian habitats continued to be diminished. (In dry years, migratory waterfowl were largely confined to artificial wetlands and showed marked downward trends as well.)

Pollution

Industrial, municipal, and agricultural wastes have been discharged into waters of the Bay-Delta system, with major historical point sources including wastes from fish and fruit/vegetable canneries and municipal sewage. The large-scale pollution of the estuary and rivers was partially relieved by the passage of the Clean Water Act, resulting in the construction of sewage treatment plants in all cities. Mines such as the Penn Mine on the Mokelumne River and the Iron Mountain Mine on the Sacramento River continue as serious sources of contaminants, with some releases from Shasta Dam made explicitly to dilute Iron Mountain leachate below lethal levels in the river to avoid fish kills. Nonpoint sources of pollution, such as urban runoff and agricultural runoff, continue to impair water quality. Agricultural drainage (often highest in summer from irrigation return flow) typically has elevated temperatures and contains excessive loads of constituents such as organic carbon, nitrates, phosphates, as well as herbicides and pesticides toxic to phytoplankton, invertebrates, and larval fish (Bailey et al. 1995).

Introduction of Non-Native Species

As the native fishes became depleted in the late 19th century, non-native species were brought in (especially following the completion of the transcontinental railroad in 1872): American shad, striped bass, common carp, and white catfish. As their populations boomed, those of native fishes declined further. Introduction of non-native species accelerated in the 20th century through deliberate introductions of fish and unintended introductions of harmful invertebrates and fish, mainly through ballast water of ships. Establishment of non-native species was probably facilitated by altered hydrologic regimes and reduction in habitats suitable for native species.

Changes in Populations of Native Species Resulting from Human Alteration to the Ecosystem

Populations of a number of species have declined sufficiently since the 19th century to have warranted their listing under the federal Endangered Species Act of 1973. Twenty-one species of plants, seven species of invertebrates, four fish species, one amphibian species, one reptile species, six bird species, and one mammal species present in the Bay and Delta region alone that are listed as threatened or endangered, with a number of others proposed for listing or listed under the equivalent state law. Perhaps the most significant of these listings have been those for winter-run chinook salmon, delta smelt, and steelhead trout because their recovery is likely only if there is a significant reallocation of water for environmental purposes, as well as significant improvements in their remaining habitats.

Appendix B. Restoration Objectives

Appendix B. Restoration Objectives

This appendix identifies objectives corresponding to each of the goals enumerated and discussed in Chapter 4, "Goals and Objectives". They are organized by goal below. We reiterate that this list is not exhaustive and that some of the objectives need to be expanded to cover numerous species or habitats.

Goal 1: Endangered Species

Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recover of at-risk native species in San Francisco Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

Because so many species are covered under this goal, they have been divided into four groups in terms of priority for CALFED attention. Many are "at-risk" species, which are in danger of extinction if present trends continue. The priorities are similar, but not identical, to those established in draft form by the CALFED Conservation Strategy Team. The team's designations are included for reference but should not be regarded as final.

Priority Group I species are at-risk native species dependent on the Bay-Delta system, most of them listed under the Endangered Species Act (ESA) or proposed for listing, whose management for restoration implies substantial manipulations of the ecosystem (e.g., requiring large amounts of fresh water at certain times of year). Priority Group I species are those for which CALFED takes major responsibility for recovery ("R" species of the CALFED Conservation Strategy Team), removing them from the threat of extinction, at a minimum.

Priority Group II species are at-risk native species dependent on the Bay-Delta system whose restoration is not likely to require large-scale manipulations of ecosystem processes because they have limited habitat requirements in the estuary and watershed (e.g., brackish water plants). Priority Group II species are a mixture of species for which CALFED will take direct responsibility for recovery ("R" species) and species to which CALFED will "contribute to recovery" to remove them from the threat of extinction (i.e., assist in recovery where possible but not make the recovery a major focus of CALFED). This latter group of species is the "R" species of the Conservation Strategy Team.

Priority Group III species are at-risk species that primarily live upstream of the estuary or in local watersheds of San Francisco Bay. CALFED will contribute to their recovery (also "R" species).

Priority Group IV species are native species in the estuary and watershed not yet at risk of extinction that have the potential to achieve that status if steps are not taken to reverse their declines or keep populations at present levels. Their rehabilitation either does not depend on conditions in the Bay-Delta system or depends on unknown factors. CALFED will try to maintain these species at present levels or higher ("M" species of the Conservation Strategy Team).

The objectives and expectations for this goal are narrowly aimed, for the most part, on actions that benefit individual at-risk species. In the short run, this approach is appropriate because ecosystem restoration requires that we keep all the pieces for the rebuilding process. However, simultaneously with species recovery actions, it is essential to be working on actions that restore habitats (goal 4) and ecosystem processes (goal 2). In fact, for species not in immediate danger of extinction, the preferred method of working toward the goal of self-sustaining populations should be to improve or increase the habitats that support them, in part by restoring natural ecosystem processes.

Priority Group I Species

Objective 1: Restore Delta Smelt to the Delta and Suisun Bay

Long-Term Objective: Restore delta smelt abundance to levels that existed in the 1960s and 1970s, as measured over a period of at least 10 years.

Short-Term Objective: Achieve the recovery goals for delta smelt identified in the Delta Native Fishes Recovery Plan (U.S. Fish and Wildlife Service 1995).

Rationale. Delta smelt were extremely abundant in the system when the "standard" trawling program in the Delta began in the 1960s. This period is used as a standard simply because that is when the data available for comparative purposes begin. Conditions in the estuary were clearly favorable for the species in that period. Achieving the long-term objective may be impeded by the presence of several introduced species, notably the clam *Potamocorbula amurensis*, inland silversides, and wakasagi. If future investigations determine that substantial reductions in delta smelt are attributable to the introduced species already established, this objective may need to be scaled back.

Stage 1 Expectations. In 7-10 years, the delta smelt population indices should be within the same range that they have been in during the period 1990-1998. The basic factors limiting delta smelt distribution and abundance should be determined (e.g., reduced food supply, interactions with non-native species, negative effects of diversions) and, where feasible, overcome through habitat and ecosystem process restoration.

Objective 2: Restore Winter-Run Chinook Salmon to the Sacramento River and the Bay-Delta Estuary

Long-Term Objective: Create self-sustaining populations of winter-run chinook salmon in both the mainstem Sacramento River and in Battle Creek at abundance levels equal to or greater than those identified in the National Marine Fisheries Service (NMFS) Winter Run Chinook Recovery Plan (National Marine Fisheries Service 1997).

Short-Term Objective: Achieve recovery as defined in the NMFS Winter Run Chinook Recovery Plan.

Rationale. Winter-run chinook salmon are unique to the Sacramento River and are adapted to spawn in the cold, spring-fed rivers now located above Shasta Dam. They are maintained through extraordinary effort in artificial cold-water habitat below Keswick Dam in the Sacramento River and in a special hatchery program. Because they are so vulnerable to disasters (e.g., a toxic spill from Iron Mountain mine, just upstream), at least one other naturally reproducing population needs to be established to reduce the probability of extinction. Battle Creek, a cold-water stream to which winter-run chinook have been deliberately denied access in the past, is the best and probably only site available for such restoration. It is unlikely, however, that winter-run chinook salmon will ever be much more abundant than specified in the recovery plan goals because available habitat is so limited.

Stage 1 Expectations. The cohort replacement rate (the number of future spawners produced by each spawner) in 7-10 years should exceed 1.0, and average abundance should increase. Battle Creek restoration (a Cental Valley Project Improvement Act project) should have proceeded to a point where winter-run chinook will have spawned in the creek two to three times.

Objective 3: Restore Spring-Run Chinook Salmon to Central Valley Streams and the Bay-Delta Estuary

Long-Term Objective: Restore wild, naturally reproducing populations of spring-run chinook salmon to numbers or spawning densities in the Sacramento River system equal to those that existed in the 1940s (average of 70,000-80,000 per year), as measured over a period of at least 25 years.

Short-Term Objective: Achieve recovery, as defined by the Delta Native Fishes Recovery Plan (or in a federal recovery plan developed after they are formally listed as a threatened species).

Rationale. Spring-run chinook salmon were historically the most abundant run of salmon in central California. Unfortunately, they spawned primarily in stream reaches that are now above major dams. The biggest blows to their abundance came when Shasta and Friant Dams were built. A run of 50,000 spring-run chinook salmon was stranded when Friant Dam shut off San Joaquin River flows alone. Attempts to rear spring-run chinook salmon in hatcheries have largely failed, and

Objective 13: Restore Populations of Riparian Brush Rabbit throughout Its Historical Range

Long-Term Objectives: Establish multiple self-sustaining populations of riparian brush rabbits along the San Joaquin River and in the Delta.

Short-Term Objective: Recover brush rabbit populations to the point where the species can removed from the state endangered species list.

Rationale. The riparian brush rabbit a distinct subspecies of cottontail rabbit that historically lived in riparian areas along the San Joaquin River and Delta. It is listed an endangered by the state of California and have been proposed for federal listing. It currently exists as one tiny remnant populations in Caswell State Park that is in continuous threat of extinction. It has declined because of the loss of riparian habitats and the conversion of adjacent upland habitats from conversion to cropland.. This species requires high ground, with extensive cover that it can move to when its primary riparian habitat floods. Due to the possibility of being extirpated by floods and wildfires it is important to develop other self-sustaining populations and restore riparian areas. Develop more brush habitat within the park to allow for good coverage and areas of minimal disturbance.

Stage 1 Expectations. The existing population should be protected from further decline by protect the species from seasonal flooding. More brushy riparian habitat within the park should be developed to provide good cover and areas of minimal disturbance. An inventory of potential restoration sites should be made and work begun on making them suitable for brush rabbit reintroduction.

Objective 14: Restore the San Joaquin Valley Woodrat to the Full Extent of Its Habitat

Long-Term Objective: Establish San Joaquin Valley woodrat populations in riparian areas throughout its former range along the San Joaquin River.

Short-Term Objective: Increase the population sizes along the San Joaquin River in Stanislaus, Merced, and San Joaquin Counties to the point where the woodrat will no longer be regarded as threatened.

Rationale. The San Joaquin Valley woodrat is a riparian-dwelling species whose distribution and ecology is poorly understood, but it apparently is confined to riparian areas in the San Joaquin Valley. It has been proposed for federal endangered status and is a state Species of Special Concern. Because this population is known to exist in such a limited area in which most riparian habitat has been degraded, its long-term survival is likely to depend upon creation of more riparian habitat along the San Joaquin River, especially in Stanislaus, Merced, and San Joaquin counties. Any additional loss of habitat would have a significant negative impact on this species.

Stage 1 Expectations. A thorough survey of all riparian areas in the San Joaquin Valley should be undertaken, both to identify the extent of existing populations and to identify habitats that

would be good restoration sites for the woodrat and other riparian species. All precautions should be taken to protect the existing populations from further decline.

Objective 15: Restore Lange's Metalmark Butterfly to Multiple Populations within Its Natural Range

Long-Term Objective: Restore Lange's metalmark butterfly to populations throughout its inland dune scrub habitat, to the point where it can be removed from the federal endangered species list.

Short-Term Objective: Create multiple populations of Lange's metalmark butterfly within the Antioch Dunes region.

Rationale. Lange's metalmark butterfly is listed as endangered by the federal government because it exists as just one small population in one small protected area, Antioch Dunes Ecological Reserve. The reserve is a remnant of the coastal dune scrub habitat that was once widespread in the Antioch area. This butterfly depends on one host plant species, naked buckwheat, for the survival of its young. Thus protection of this site from disturbance, fires and invasions of exotic plant species is paramount for the survival of the butterfly.

Stage 1 Expectations. The population size and area inhabited by Lange's metalmark butterfly in Antioch Dunes Ecological Reserve should both be increased substantially. Restoration of the native dune scrub plant community and naked buckwheat populations should continue both in the reserve and in suitable areas outside the reserve.

Objective 16: Restore Delta Green Ground Beetle to Multiple Populations within Its Presumed Natural Range

Long-Term Objective: Expand the existing population of delta green ground beetle and establish at least three additional populations to remove it from the federal threatened species list.

Short-Term Objective: Expand the existing population levels of delta green ground beetle by increasing and improving habitat for it

Rationale. The delta green ground beetle is federally listed as a threatened species that is currently known only from Jepson Prairie Preserve (Solano County). Habitat requirements for this species are not clearly understood but the beetles seem to require open places near vernal pools. A better knowledge would help restoration efforts. Limiting pesticide use in adjacent areas and increasing habitat are two ways to increase population size but until we know what the ideal habitat is, a mixture of habitats that could be used by this species is essential.

Stage 1 Expectations. The existing population of delta green ground beetle should be studied in order to develop a clearer idea of what its habitat requirements are. Additional areas of

vernal pool habitat in Solano County should be acquired and managed for the beetle and other native species.

Other Priority Group III Species for Which Objectives Should Be Developed

Objectives should be developed for Conservancy fairy shrimp, Solano grass, and Contra Costa goldfields.

Priority Group IV Species

Objective 1: Reverse the Decline of Native Resident Fishes

Long-Term Objective: Within 25 years, all resident native fishes will have stable or increasing populations, in multiple localities, with localities interconnected as much as feasible.

Short-Term Objective: Determine the distribution, status, and habitat requirements of all native resident fishes in the CALFED region to see if species-specific strategies are needed to reverse declines or if habitat-oriented restoration strategies will be adequate.

Rationale. The Central Valley has a native resident fish fauna that is largely endemic to the region. Some species are extinct (thicktail chub) or nearly extinct (Sacramento perch) in the wild. While some native species (e.g., Sacramento pikeminnow [squawfish], Sacramento sucker) are clearly thriving under altered conditions, others are not (e.g., hitch, Sacramento blackfish, hardhead). Although most of these species may benefit from actions listed under goal 2, there is a need to determine if some have unique problems or requirements that will prevent them from responding to general habitat improvements.

Stage 1 Expectations. A distribution and status survey of native stream fishes should be completed. Sites with high species richness or containing rare species should be identified for special management. A recovery strategy for native fish assemblages should be developed.

Objective 2: Restore Spadefoot Toad Populations to Representative Habitats throughout Its Range

Long-Term Objective: Establish refuges for California spadefoot toad throughout its range.

Short-Term Objective: Identify and protect remaining spadefoot toad populations in the CALFED region.

Rationale. Spadefoot toad populations are disappearing rapidly in the CALFED region because of habitat alteration, especially urban development, and introductions of non-native fishes

into their breeding ponds. They require fish-free breeding ponds next to upland habitat in which they can burrow for over summering. These habitats are naturally somewhat isolated from one another, promoting genetic diversity within the species which presumably reflects adaptations to local habitat conditions. Long-term survival of these diverse populations depends on protected areas containing both breeding ponds and upland habitats.

Stage 1 Expectations. A thorough survey of spadefoot toad populations in the CALFED region should be completed and actions taken to protect remaining populations in counties bordering the Bay-Delta system.

Objective 3: Restore Assemblages of Planktonic Organisms in the Delta and Suisun Bay to States of Increased Abundance and Greater Predictability in Composition

Long-Term Objective: Increase abundance of zooplankton to the levels that existed prior to the introduction of the Asiatic clam, *Potamocorbula amurensis*, with zooplankton communities containing native species as significant components.

Short-Term Objective: Maintain the planktonic assemblages at roughly the range of variability of abundance and composition that they have been since the Asiatic clam became established by preventing new introductions and determining conditions that favor native organisms such as *Neomysis mercedis*.

Rationale. The long-term objective is quite likely impossible to achieve because recent invading species, from the Asiatic clam to various crustacean zooplankters, will continue to play major ecological roles in the system, to the detriment of native organisms. However, at the very least it is possible to stop further introductions of non-native species which have the potential to further change the system unpredictably. This objective is also a call to develop a thorough understanding of the planktonic portion of the Bay-Delta system to predict and understand the impacts of large-scale ecosystem alteration projects on the plankton.

Stage 1 Expectations. Major steps should be taken to halt activities (e.g., dumping of contaminated ballast water) that result in the establishment of new species of invertebrates and fish in the estuary. Further development of our understanding of the how the Bay-Delta system functions should allow recommendations on how to maintain native zooplankton species, in the context of broader ecosystem management goals.

Objective 4: Prevent Further Human-Caused Irreversible Changes to the Benthic Invertebrate Assemblages in the Bay-Delta System

Long-Term Objectives: Have diverse benthic assemblages throughout the estuary that contain the same species that are present today, including the remaining native species, and that are not dominated by one or two non-native species.

Short-Term Objectives: Halt further introductions of non-native species, determine conditions that favor remaining desirable species, and find methods (if any) to reduce dominance by single non-native species, especially the Asiatic clam in Suisun Bay.

Rationale. The benthic assemblages of invertebrates in the Bay-Delta system are made up largely of non-native species, although a few native crustaceans still are present in numbers. Many of these non-native invertebrates are thoroughly integrated into the food webs of the region and are major prey of native birds, mammals, and fishes. New benthic invasions, largely from ballast water introductions, are constantly occurring, however, and some, such as the invasion of the Asiatic clam, have caused major alterations to the benthic (and planktonic) assemblages. If present trends continue, further invasions can be expected with the potential to once again generate major changes in the benthos, most likely with unfavorable effects on at-risk or harvested species. In order to stabilize benthic assemblages to conditions of reasonable and desirable diversity and abundance, it is necessary to (1) halt further invasions, (2) create water quality and hydraulic conditions that favor desired assemblages (e.g., those containing abundant native *Corophium* spp.), and (3) reduce the dominance of single non-native species, especially the Asiatic clam. None of these actions is easy to do and the latter two will require considerable research to institute.

Stage 1 Expectations. All introductions of non-native invertebrates into the estuary should be halted. Investigations into the biology of benthic assemblages should continue, in order to find ways to create more desirable assemblages in an ecosystem context.

Objective 5: Maintain or Expand Populations of Bird Species That Are Members of the Wading Bird Guild

Long-Term Objective: Provide sufficient high-quality breeding and foraging habitat for all species in guild so that the wading bird guild will continue to be diverse and abundant.

Short-Term Objective: Maintain wading bird numbers and diversity at their present level, as a minimum.

Rationale. The wading bird guild is a group of mostly conspicuous birds (herons, egrets, bitterns, ibis) that wade in the water to forage on fish and other aquatic organisms. Because egrets and herons are so conspicuous along the waterways of the CALFED region, they have high symbolic value for ecosystem restoration. Some members of the guild (least bittern [treated separately] and white-faced ibis) are state species of special concern. Habitats suitable for foraging of wading birds are still common throughout the CALFED region. However, human disturbance and degradation has caused many of these habitats to become isolated, polluted, or subject to high levels of disturbance. For many of the species, the principal limiting factor is availability of adequate nesting (rookery) habitats. Long-term persistence of this group of birds in abundance depends on extensive areas of shallow water (less than 1.5 feet deep)containing abundant food, in conjunction with riparian habitats suitable for breeding.

Stage 1 Expectations. CALFED should work in conjunction with the Central Valley Habitat Joint Venture to implement the venture's goal and objectives that would increase foraging habitat for this guild. In addition, existing heron and egret rookeries should be protected and other potential rookery areas identified.

Objective 6: Ensure That Members of the Shorebird Guild Continue to Be Abundant, Diverse, and Important Members of the Local Fauna

Long-Term Objective: Provide sufficient high-quality tidal and shallow water foraging habitat and upland roosting habitat to maintain large populations of all members of this guild that now occur in central California, while also providing sufficient nesting habitat for species that breed in the state.

Short-Term Objective: Maintain wintering and breeding populations at their present levels and increase populations of all threatened species sufficiently to be able remove them from lists of threatened species.

Rationale. The shorebird guild is an extremely diverse group of migratory and resident species (e.g., sandpiper, plover, curlew, avocet) that forage, often in mixed flocks, on invertebrates in tideflats, beaches, shallow ponds, and other shallow water areas. The Central Valley, Delta, Suisun Bay and Marsh, and San Francisco Bay are a major wintering areas for birds that breed in more northern areas, as well as staging areas for birds headed further south. Habitats suitable for shorebirds were once abundant throughout the region. However, human disturbance, filling of shallow water areas, and other forms of degradation have caused suitable foraging habitats to become diminished. These smaller and more disjunct patches of habitat have made concentrations of shorebirds more susceptible to human disturbance and to increased predation. This guild contains species that are listed as threatened by both state and federal governments (e.g., snowy plover) while others are considered to be species of special concern.

Stage 1 Expectations. CALFED should work in conjunction with the Central Valley Habitat Joint Venture to implement the Venture's goals and objectives that relate to creating habitat for shore birds. An evaluation of threats to foraging and breeding habitats should be conducted and ways found to alleviate threats. Areas that can restored as foraging areas, especially tide flats, should be identified and restoration work begun.

Objective 7: Restore and Protect Habitats Used by Neotropical Migrant Birds for Breeding and Foraging in the CALFED Area

Long-Term Objective: Substantially improve breeding and migration habitats for all neotropical migrant birds to increase their rates of reproduction and survival.

Short-Term Objective: Maintain breeding populations at present levels and develop restoration projects that will benefit migrating individuals.

Rationale. Neotropical migratory birds constitute a diverse group of largely passerine songbirds that overwinter in the tropics but breed in or migrate through the Central Valley and Bay-Delta region. As a group, they are in decline because of loss of habitat on their breeding grounds, in their migratory corridors, and in their wintering grounds. The species within this group are good indicators of habitat quality and diversity and their popularity with birders means that populations are tracked and have high public interest. They can also be good indicators of contaminant levels, by monitoring reproductive success and survival in areas near sources of contamination. Riparian forests are particularly important to this group because they are major migration corridors and breeding habitat for many species. By providing improved nesting and migratory habitat, it may be possible to partially compensate for increased mortality rates in the wintering grounds. Improved habitat for songbirds also provides habitat for many other species of animals and plants.

Stage 1 Expectations. Develop a "master plan" for the conservation of neotropical migrants in the CALFED area that includes status reports and habitat requirements for all species. Use this information to integrate neotropical migrant conservation into various CALFED restoration projects or to develop restoration projects specifically aimed at improving migration and breeding habitat for selected members of this group.

Other Priority Group IV Species for Which Objectives Should Be Developed

Objectives should be developed for special-status plants and invertebrates.

Goal 2: Ecosystem Processes and Biotic Communities

Rehabilitate natural processes in the Bay-Delta estuary and its watershed to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities.

Arguably, the objectives to restore species in Goal 1 are just subsets of the objectives below. Ultimately, recovery to abundance of at-risk species requires restoration of their habitats, which in turn requires the rehabilitation of the ecosystem processes discussed here, over broad areas. These objectives are not in order of priority.

Objective 1: Manage the Hydrologic Regime for the Bay-Delta System in Ways That Favor Native Species, Desirable Non-Native Species, and Natural Habitats

Long-Term Objective: Have a hydrologic regime in the Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay that is favorable to maintenance of large, self-sustaining populations of species and habitats treated separately under goals 1, 3 and 4.

Short-Term Objective: Continue to adjust and evaluate X2 as a standard for the hydrologic regime in the Bay-Delta system. Evaluate other measures and actions designed to create favorable conditions for depleted species and implement them where feasible.

Rationale. The restoration to abundance of most, if not all, of the native species and habitats in the Sacramento-San Joaquin estuary depends on having a dynamic hydrologic regime (and associated hydraulic processes) that creates conditions favorable for all portions of the life cycles of the "key" species (those listed in goals 1 and 3). The principal measure in place today of the suitability of the hydrologic regime for key species is X2, which indicates the position of the salinity gradient in the estuary. The suitability of X2 is still being tested and studies are underway to determine why it seems to be a reasonably good predictor of the annual success of many species. As more is learned about the hydrodynamics of the estuary, especially about the importance of the low-salinity zone, direct and indirect modifications of estuarine processes (in an adaptive management context) should continue.

One area in which the hydrologic regime could be altered to favor native species is the Delta. Before the development of water projects allowed salinity to be excluded, the Delta may have become much more saline during droughts than it does now. Highly variable flow and salinity conditions, including infrequent high-salinity events in the Delta, would therefore presumably favor native over introduced species. Reverting to such a regime would invoke intense conflicts with water supply; therefore, thorough investigations of the likely historical condition and the effects of high salinity on native species should be investigated before pilot studies can be conducted.

Stage 1 Expectations. Studies on the factors affecting the relationship between X2 and the abundance of key organisms should be ongoing, but a basic understanding for the at-risk species should be developed and used to implement strategies for their recovery. In addition, studies should be conducted on the historical frequency of high-salinity events in the Delta and the likely effect they had on native species. If these studies suggest substantial benefits, pilot studies should be designed and executed in coordination with water diverters.

Objective 2: Increase Estuarine Productivity

Long-Term Objective: Using knowledge gained in the shorter term, raise the level of ecosystem productivity to lift limits on production of desirable species of fish and invertebrates.

Short-Term Objectives: Determine the limits on productivity and the major sources of organic carbon contributing to the estuarine ecosystem. Generate hypotheses as to the actions that might be effective at increasing productivity, and conduct pilot studies based on those findings.

Rationale. The abundance of many species in the estuary may be limited by low productivity at the base of the food web in the estuarine ecosystem. The causes of this are complex and not well understood, but may include a shortage of productive shallow-water regions such as marshes, high turbidity in open-water regions of the estuary, and consumption and sequestering of available organic carbon by the Asiatic clam. Solving the problem directly is difficult but presumably other actions

taken as part of the ERP, such as increasing the acreage of tidal marshlands, will contribute to the solution. A major obstacle to solving problems of estuarine productivity is our poor understanding, so solutions will have to come from research and monitoring of effects of various ecosystem restoration projects.

Stage 1 Expectations. Studies on organic carbon sources and cycling should be encouraged to generate and test hypotheses as to factors limiting their availability. These hypotheses (and findings generated from testing them) should be considered in setting priorities for restoration actions.

Objective 3: Manage Channels in the Delta and Suisun Marsh in Ways That Allow Natural Processes to Create and Maintain In-Channel Islands and Shallow Water Habitat

Long-Term Objective: Have large expanses of shallow water habitat, both on the edges of channels and on small channel islands, maintained by natural processes.

Short-Term Objective: Set priorities for channels in terms their importance for shallow water habitat; develop and implement protection strategies for existing and restored shallow water habitat in those channels; investigate the value of shallow-water habitat in supporting and increasing abundances of desirable species.

Rationale. There is widespread agreement that more shallow water habitat needs to be created in the Delta and that existing shallow water habitat needs to be maintained. However, opinions differ on whether creating more habitat will actually increase abundance of desirable species. Ecosystem-based restoration is predicated on this assumption, but adaptive management demands that it be rigorously tested. Staged implementation will allow an increase in confidence in whether or not habitat restoration in the estuary will result in higher abundance of desirable species. Ultimately much of this shallow water habitat will be along Delta and Suisun Marsh channels (recreating some of the original channel-marsh system) or on small islands in the channels. The desirable physical and biotic characteristics of these habitats may be created artificially at first, but the expectation is that they will be maintained by natural processes (e.g., tidal flux, sediment inputs from upstream). This will require restrictions on human activities in these channels that have negative impacts on the habitats, such as boating at speeds that generate erosive wakes or channel dredging.

Stage 1 Expectations. Channels or channel reaches most suited for restoration and protection of shallow water habitats should be identified and given priorities for restoration activities. Detrimental human activities in these channels should be eliminated through a phased program associated with restoration activities. Major studies of the use of shallow water habitats by native and non-native species should be undertaken to test the assumption that shallow water habitat is indeed the key to restoring many of the native species.

Objective 4: Create Flow and Temperature Regimes in Regulated Rivers That Favor Native Aquatic Species

Long-Term Objective: Native fish and invertebrate assemblages will be restored to regulated streams where feasible, using methods developed during the short-term objective phase.

Short-Term Objective: Provide adequate flows, temperatures, and other conditions to double the number of miles (as of 1998) of regulated streams that are dominated (>75% by numbers and biomass) by assemblages with four or more native fish species.

Rationale. Virtually all streams in the region are regulated to some degree, and the regulated flow regimes frequently favor non-native fishes. The native fish assemblages (including those with anadromous fishes) are increasingly uncommon. Recent studies in Putah Creek, the Stanislaus River, and the Tuolumne River demonstrate that native fish assemblages can be restored to sections of streams if flow (and temperature) regimes are manipulated in ways that favor their spawning and survival, usually by having flow regimes that mimic natural patterns in winter and spring but that increase flows during summer and fall months (to make up for loss of upstream summer habitats). Native invertebrates and riparian plants may also respond positively to these flow regimes. Achievement of this objective will require additional systematic manipulations of flows below dams (or the re-regulation of existing flow regimes) to determine the optimal flow and habitat conditions for native organisms, as part of the short-term goal. Part of the studies should be to determine if the objective can be achieved without "new" water, by just altering the timing of releases or by developing conjunctive use agreements that allow more water to flow down the stream channel. Ways to restore native fish communities that do not involve changed flows should be developed (where feasible) to be used in place of or synergistically with changed flows. These findings can then be applied opportunistically to achieve the long-term goal of restoring native fish communities.

Stage 1 Expectations. Surveys should be completed to determine the status of native fishes in all regulated streams of the Central Valley and flow recommendations made to restore native fishes where feasible. During negotiations for relicensing of dams, agency personnel should request flow regimes favorable for native fishes.

Objective 5: Make Sure That High Flows Occur Frequently Enough in Regulated Streams to Maintain Channel and Sediment Conditions Favorable to Native Aquatic and Riparian Organisms

Long-Term Objective: For regulated rivers in the region, establish scientifically based high-flow events necessary to maintain dynamic channel processes, channel complexity, bed sediment quality, and natural riparian habitats where feasible.

Short-Term Objective: Through management of the reservoir pool or deliberate reservoir releases, provide a series of experimental high-flow events in regulated rivers to observe flow effects on bed mobility, bed sediment quality, channel migration, invertebrate assemblages, fish abundance, and riparian habitats over a period of years. Use the findings of these studies to reestablish natural

stream processes where feasible, including restoration of periodic inundation of remaining undeveloped floodplains.

Rationale. Native aquatic and riparian organisms in the Central Valley evolved under a flow regime with pronounced seasonal and year-to-year variability. Frequent (annual or longer term) high flows mobilized gravel beds, drove channel migration, inundated floodplains, maintained sediment quality for native fishes and invertebrates, and maintained complex channel and floodplain habitats. By deliberately releasing such flows from reservoirs, at least some of these physical and ecological functions can probably be recreated. A program of such high-flow releases, in conjunction with natural high-flow events, lends itself well to adaptive management because the flows can easily be adjusted to the level needed to achieve specific objectives. However, it should be recognized that channel adjustments may lag behind hydrologic changes by years or decades, requiring long-term monitoring. Also, on most rivers, reservoirs are not large enough to eliminate extremely large, infrequent events so these will continue to affect channel form at irregular, often long, intervals; artificial high-flow events may be needed to maintain desirable channel configurations created during the natural events. This objective is similar to the previous one but differs in its focus on flows that are likely to be higher than those needed to maintain most native fish species but that are important for maintaining in-channel and riparian habitats for fish as well as other species (e.g., invertebrates, birds, mammals). Experimental flow releases also will have to be carefully monitored for negative effects, such as encouraging the invasion of unwanted non-native species.

Stage 1 Expectations. Studies should be conducted on five to 10 regulated rivers in the Central Valley to determine the effects of high-flow releases. Natural floodplains should be identified that can be inundated with minimal disruption of human activity. Where positive benefits are shown, flow recommendations should be developed and instituted where feasible.

Objective 6: Reestablish Frequent Inundation of Floodplains by Removing, Breaching, or Setting Back Levees and, in Regulated Rivers, by Providing Flow Releases Capable of Inundating Floodplains

Long-Term Objective: Reestablish active inundation of floodplains with area targets and inundation frequencies (1-5 years) to be set for each major alluvial river (where feasible) based on probable pre-1850 floodplain inundation regimes and on existing opportunities to modify existing land uses.

Short-Term Objective: Reestablish active inundation of at least half of all remaining unurbanized floodplains in the Central Valley, where feasible.

Rationale. Frequent (often annual) floodplain inundation was an important attribute of the original aquatic systems in the Central Valley and was important for maintaining diverse riverine and riparian habitats. Important interactions between channel and floodplain include overflow onto the floodplain, which (1) reduces the cutting down of the channel, (2) acts as a "pressure relief valve", permitting a larger range of sediment grain sizes to remain on the channel bed, (3) increases the complexity and diversity of instream and riparian habitats, and (4) stores floodwater (thereby

decreasing flooding downstream). The floodplain also provides shading, food organisms, and large woody debris to the channel. Floodplain forests serve as filters to improve the quality of water reaching the stream channel by both surface flow and groundwater. The actions necessary to reestablish active inundation will probably require major land purchases or easements, and financial incentives to move existing floodplain uses elsewhere, as has been done in the Midwest since 1993. Obviously, artificial inundation events will have to be planned to take into account other needs for stored water, including increased summer flows.

Stage 1 Expectations. All existing unurbanized floodplains in the Central Valley should be identified and a priority list for floodplain restoration projects developed. Strategies for the restoration of natural channel and floodplain dynamics should be developed and implemented in at least two large demonstration projects. Use initial floodplain reactivation projects to increase understanding of channel-floodplain interactions and the potential for restoration of processes.

Objective 7: Restore Coarse Sediment Supplies to Sediment-Starved Rivers Downstream of Reservoirs

Long-Term Objective: Implement a comprehensive sediment management plan for the Bay-Delta system that will minimize problems of reservoir sedimentation and sediment starvation, shift aggregate extraction from rivers to alternate sources, and restore continuity of sediment transport through the system to the extent feasible.

Short-Term Objective: Develop methods and procedures to end gravel deficits below dams and mining operations; prioritize for correction existing streams with major deficit problems and initiate action on at least 10 streams.

Rationale. One of the major negative effects of dams is the capture of coarse sediments that naturally would pass on to downstream areas. As a result, the downstream reaches can become sediment starved, producing "armoring" of streambeds in many (but not all) rivers to the point where they provide greatly reduced habitat for fish and aquatic organisms and are largely unsuitable for spawning salmon and other anadromous fish. This objective can be accomplished by a wide variety of means, but most obviously through artificial importation of gravel and sand. Other possible actions include: (1) explore the feasibility of passing sediment through small reservoirs; (2) remove nonessential or low-value dams; (3) eliminate instream gravel mining on channels downstream of reservoirs, and limit extraction on unregulated channels to 50% of estimated bedload supply or less (or to levels determined not to negatively impact fish and other ecological resources); (4) develop incentives to discourage mining of gravel from river channels and adjacent floodplain sites; and (5) develop programs for comprehensive sediment management in each watershed, accounting for sediment trapped by reservoirs, availability of sediment from tributaries down stream of reservoirs, loss of reservoir capacity, release of sediment-starved water downstream, channel incision and related effects, and the need for sources of construction aggregate.

Stage 1 Expectations. Identify sediment-starved channels in the Bay-Delta system; develop strategies to mitigate sediment starvation, such as shifting mining of gravel from river channels to

alternate sources, adding gravel below dams, and removing nonessential dams; implement (and monitor) demonstration projects to mitigate sediment starvation in at least six rivers; and introduce legislation to prohibit or relocate instream gravel mining in rivers below dams.

Objective 8: Increase the Extent of Freely Meandering Reaches and Other Pre-1850 River Channel Forms

Long-Term Objective: Reestablish active meander belts on all formerly meandering alluvial reaches in the Central Valley except those densely urbanized or with infrastructure whose relocation would have a high cost-to-benefit ratio.

Short-Term Objectives: Inventory (at 1:1,200 scale or better) along all major river reaches bank conditions and land uses on adjacent floodplains. Prioritize for acquisition land or easements in rural areas with high potential for urbanization, especially around meander bends. Begin an acquisition program.

Rationale. Freely meandering rivers have the highest riparian and aquatic habitat diversity of all riverine systems. Through the process of meandering, eroding concave banks and building convex banks, the channel creates and maintains a diversity of surfaces that support a diversity of habitats, from pioneer riparian plants on newly deposited point bars to gallery riparian forest on high banks built of overbank silt deposits. Similarly, wandering or braided rivers support distinct habitat types and thus are beneficial to aquatic biota. Floodplain restoration can also increase flood protection for urban areas and increase the reliability of stored water supplies in reservoirs (because reservoirs can be maintained at higher levels because of reduced need to catch floodwaters). This objective is compatible with and parallel to objective 2.

Stage 1 Expectations. Plans for meander belts should be developed for all major river corridors and priorities for land acquisition and easements established. Development of a meander belt should begin on at least one river.

Goal 3: Harvestable Species

Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with goals 1 and 2.

Somewhere between 40 and 50 species of fish and invertebrates are harvested in significant numbers in the CALFED region, as are a number of species of birds (waterfowl, mourning doves, ring-necked pheasants). The Ecosystem Restoration Program has the potential to affect the harvest of many of these species, improving most of them in the long run. For the purposes of the ERP, the harvested species are divided into three groups according to their priority for attention by the CALFED program. Priority Group I species are those whose abundance is likely to be strongly affected by CALFED actions or whose enhancement is likely to generate conflicts with the

restoration of native species. Priority Group II species are those that support important fisheries or harvests but whose populations are not likely to be affected strongly by CALFED actions in the short run or whose enhancement is not likely to generate major conflicts with the restoration of native species. Low priority species, not treated here, are species that support relatively small or incidental fisheries or harvests and whose enhancement (if any) is not likely to generate major conflicts with the restoration of native species. Note: within each category, objectives are not listed in order of priority.

Priority Group I Species

Objective 1: Maintain Fisheries for Striped Bass

Long-Term Objective: Allow striped bass numbers (and harvest) to increase gradually as conditions in the restored estuary favor its reproduction and survival. Use harvest and other management measures to ensure that increases in striped bass populations do not jeopardize programs to sustain native species.

Short-Term Objective: Maintain the fishery for striped bass at its present levels but without special intervention (e.g., hatcheries).

Rationale. The striped bass is a non-native species that is a favorite sport fish in the estuary. It is also the most abundant and voracious piscivorous fish in the system and it has the potential to limit the recovery of native species, such as chinook salmon and steelhead. Therefore, the management for striped bass must juggle the objectives of providing opportunities for harvest while not jeopardizing recovery of native species. An appropriate policy may be to allow striped bass to increase in numbers as estuarine conditions permit but not to take any extraordinary measures to enhance its populations, especially artificial propagation. Artificially reared bass have the potential to depress not only native fish populations but also populations of wild striped bass through cannibalism. If increases in bass numbers appear to adversely affect recovery of native species, additional management measures may be required to keep bass numbers below the level that pose a threat to native species.

Stage 1 Expectations. Investigations into competing (or interacting) hypotheses about the causes of striped bass decline should continue. If rearing programs for juvenile striped bass are continued then investigations should be conducted on the impact of artificially reared fish on both other fishes of concern and on wild-spawned striped bass.

Objective 2: Maintain Fisheries for American Shad

Long-Term Objective: Allow American shad numbers (and harvest) to increase gradually as conditions in the restored estuary and streams favor its reproduction and survival. Use harvest and

other management measures to ensure that increases in American shad populations do not jeopardize programs to sustain native species.

Short-Term Objective: Maintain the fishery for American shad at its present levels but without special intervention (e.g. special flow releases).

Rationale. The American shad is a non-native species that is an important sport fish in the estuary and its spawning streams, although less seems to be known about its life history in the estuary than any other major game fish. It is a common planktivore and occasional piscivore in the system and it may have the potential to limit the recovery of native species, such as chinook salmon. Therefore, the management for American shad must juggle the objectives of providing opportunities for harvest without jeopardizing recovery of native species. An appropriate policy may be to allow American shad to increase in numbers as estuarine conditions permit but not to take any extraordinary measures to enhance its populations, especially flow releases specifically to favor shad reproduction. If increases in shad numbers appear to adversely affect recovery of native species, additional management measures may be required to keep shad numbers below the level that pose a threat to native species.

Stage 1 Expectations. No special efforts to increase American shad numbers should be made. Their impact on juvenile salmon (predation) in the Sacramento River should be investigated.

Objective 3: Enhance Fisheries for White Sturgeon

Long-Term Objective: Increase white sturgeon numbers (and harvest) by improving habitat conditions for spawning and rearing.

Short-Term Objective: Continue to manage white sturgeon for the sustainable sport fishery, without artificial propagation.

Rationale. White sturgeon represent an unusual situation: a success story in the management of the fishery for a native species. Numbers of sturgeon today are probably nearly as high as they were in the nineteenth century before they were devastated by commercial fisheries. The longevity and high fecundity of the sturgeon, combined with good management practices of the California Department of Fish and Game (DFG), have allowed it to sustain a substantial fishery since the 1950s, without a major decline in numbers. Numbers of white sturgeon could presumably be increased if the San Joaquin River once again contained suitable habitat for spawning and rearing.

Stage 1 Expectations. White sturgeon will continue to support a significant sport fishery in the estuary and will not experience a significant decline in abundance.

Objective 4: Maintain Fisheries for Non-Native Warmwater Game Fishes

Long-Term Objective: Non-native warmwater game fishes will continue to be abundant enough in many parts of the estuary and river systems to support a substantial sport fishery.

Short-Term Objective: Increase our knowledge about warmwater sport fishes in the Delta, Suisun Marsh, riverine backwaters, and elsewhere to find out their interactions with native fishes, limiting factors, and their contaminant loads (for both fish and human health).

Rationale. White catfish, channel catfish, brown and black bullhead, largemouth bass, and various sunfishes are among the most common fishes caught in the sport fishery in the Delta, Suisun Marsh, riverine backwaters, reservoirs, and other lowland waters. Although this fishery is poorly documented, it is probably the largest sport fishery in central California in terms of people engaged in it and in terms of numbers of fish caught. There is no sign of overexploitation of the fishes, although some (e.g., white catfish) have remarkably slow growth rates, indicating vulnerability to overexploitation. The fishes and the fishers are always going to be part of the lowland environment and deserve support of the management agencies. However, habitat improvements that favor native fishes, especially improvements that increase flows or decrease summer temperatures, may not favor these game fishes. The effects of the various CALFED actions on these fish and fisheries need to be understood, as do the interactions among the non-native fishes and the native fish CALFED is trying to protect.

Stage 1 Expectations. Studies should be conducted to find out how major CALFED actions are likely to affect the warmwater fish and fisheries and how the fishes affect the recovery of native at-risk species. In particular, the potential of the non-native fishes to use and dominate newly created warmwater habitat should be investigated.

Objective 5: Alter Practices to Augment Chinook Salmon and Steelhead Populations by the Entire State, Federal, and Private Hatchery System in Light of CALFED Goals

Long-Term Objective: Develop a hatchery system and hatchery practices that augment salmon and steelhead populations without having detrimental effects on wild populations of salmon.

Short-Term Objective: Evaluate closely all salmon and steelhead hatcheries and hatchery practices in the CALFED region to determine their effects on wild populations of salmon and steelhead. Take steps to change these practices if needed.

Rationale. The hatchery system in the Central Valley for salmon and steelhead was developed with the best of intentions, to maintain the fishery for these species that would be otherwise be lost as the result of dams and diversions blocking access to spawning habitat. To a certain extent, it has succeeded by maintaining the commercial and sport fishery for chinook salmon. Unfortunately, the focus on hatcheries, which have been successful mainly for fall-run chinook salmon, has been associated with the continued decline of other runs of salmon, of wild runs of fall chinook, and of native steelhead stocks. Salmon and steelhead originating from hatcheries may

actually have aggravated this problem by interacting with wild fish and by encouraging high harvest levels in fisheries. A major emphasis of the ERP is to restore wild runs of salmon and steelhead by improving habitat conditions for them and by augmenting flows in spawning streams. The role that state, federal, or private hatcheries can play in this recovery is uncertain. For severely depleted stocks (e.g., winter run chinook) hatchery rearing can provide temporary insurance against extinction due to major natural and unnatural events. For more abundant stocks, however, hatcheries producing large numbers of salmon have the potential to confuse and contravene efforts to restore salmon and steelhead using natural means. Clearly the role of hatcheries on every run of salmon and steelhead needs to be carefully evaluated to determine if and how hatchery practices should be changed or if artificial propagation of some stocks should be halted completely.

Stage 1 Expectations. An independent panel of experts should investigate the role of every hatchery in the Central Valley in restoring salmon populations and the potential for alternative hatchery practices that support fisheries at minimal cost to the natural stocks. Where information is lacking, research programs should be conducted. No new hatcheries or hatchery programs should be started until the evaluation for the entire system is completed.

Objective 6: Enhance Populations of Waterfowl for Harvest by Hunting and for Nonconsumptive Recreation

Long-Term Objective: Substantially increase the numbers of resident and migratory ducks and geese that use the CALFED region by increasing habitat available to them.

Short-Term Objective: Continue restoration of wetlands suitable for waterfowl production and over-wintering, while developing strategies for management of waterfowl areas that are compatible with other species, habitat, and ecosystem process restoration goals in CALFED.

Rationale. For decades, the principal motivation for the protection and enhancement of wetlands in the Central Valley, Delta, Suisun Marsh, and the rest of the estuary has been to provide habitat for migratory and resident waterfowl, especially for hunting. Many of these wetlands are on private land developed specifically for hunting. In recent years, the impressive flocks of ducks and geese from the Pacific Flyway that use the Central Valley and the estuary have become major attractions for large numbers of wildlife viewers, helping to make wetland restoration a much more publically-supported activity. Many of the wetlands, both permanent and seasonal, are intensely managed specifically for waterfowl and such management may at times conflict with broader ecosystem restoration goals or with goals to recover endangered species. Some examples: Flooding of rice paddies for waterfowl in winter may require water needed by migratory salmon. Management of waterfowl areas along the estuary for plants favored as food by ducks and geese may discriminate against native plants or animals that require marshlands less favorable to waterfowl (e.g., salt marsh harvest mouse). Emergency levee repairs to protect waterfowl habitat may disturb clapper rails seeking high ground during the flood. Such conflicts need to be resolved for the benefit of all species, mainly by greatly increasing the amount and variety of wetland habitat and by developing management strategies for existing waterfowl areas that provide benefits to at-risk species.

Stage 1 Expectations. Acquisition and development of wetlands favorable for waterfowl (e.g., Yolo Basin Wildlife Area) should be continued. For existing public wildlife areas, plans to reduce conflicts between waterfowl management and management for other native species, including provisions for emergency situations (e.g., levee repairs), should be developed. For private waterfowl areas, incentives for implementing broader, ecosystem-based management goals should be improved.

Priority Group II Species

Objective 1: Enhance Fisheries for Pacific Herring

Long-Term Objective: Maintain a high level of harvest management that will allow for sustainable fisheries for Pacific herring and their roe.

Short-Term Objective: Continue, with caution, the present limited-entry fishery and determine the major factors that limit both the fishery and herring spawning in San Francisco Bay.

Rationale. Pacific herring support the most valuable commercial fishery in San Francisco Bay. This seasonal, limited-entry fishery focuses on spawning fish, for the fish themselves, their roe, and kazunoko kombu (herring eggs on eel grass). It seems to be an example of successful fishery management because it has been able to sustain itself through a series of years with highly variable ocean and bay conditions. An important connection to the ERP is that highest survival of herring embryos (which are attached to eel grass and other substrates) occurs during years of high outflow during the spawning period; the developing fish seem to require a relatively low-salinity environment. There is also some indication that populations have been lower since the invasion of the Asiatic clam into the estuary, with the subsequent reduction in planktonic food organisms. Given the frequent collapse of commercial fisheries (including those for herring) in the modern world, it is best to manage this fishery very cautiously to make sure it can continue indefinitely.

Stage 1 Expectations. In the next 7-10 years the fishery should continue at roughly present levels and investigations should continue to determine factors limiting herring abundance and spawning success, especially as tied to Bay-Delta physical processes.

Objective 2: Maintain Fisheries for Signal Crayfish in the Delta

Long-Term Objective: Allow signal crayfish numbers (and harvest) to increase gradually as conditions in the restored estuary favor its reproduction and survival. Use harvest and other management measures to ensure that increases in crayfish populations do not jeopardize programs to sustain native species.

Short-Term Objective: Maintain signal crayfish populations at present levels, in order to support the existing fisheries.

Rationale. The signal crayfish is an introduced species that supports a small commercial fishery, as well as a recreational fishery, in the Delta. It has been established in the Delta for nearly a century and appears to be integrated into the Bay-Delta system, appearing as a major food item for otters and some fish. The signal crayfish has fairly high water quality requirements so its populations will presumably increase as water quality in the freshwater portions of the Delta improves. Its role in the ecosystem and the effects of the fishery on that role need to be investigated.

Stage 1 Expectations. An investigation of the ecological requirements of the crayfish and the effects of the fishery should be conducted, to find out if any special management for either is needed.

Objective 3: Maintain Fisheries for Grass Shrimp in the San Francisco Bay

Long-Term Objective: Allow grass shrimp (*Crangon* spp., *Paleomon*) numbers (and harvest) to increase as conditions in the restored estuary favor their reproduction and survival.

Short-Term Objectives: Maintain grass shrimp populations at present levels as a minimum to support the existing commercial fisheries. Determine factors regulating their populations in order to discover if the fisheries conflict with other ecosystem restoration objectives.

Rationale. Grass shrimp are a mixture of native and introduced species that support a small commercial fishery in San Francisco Bay, largely for bait. The relative abundance of the various species as well as their total abundance appears to be tied in part to outflow patterns. It is likely that these abundant shrimp are important in Bay-Delta food webs leading to many other species of interest. The role of these shrimp in the Bay-Delta system and the effects of the fishery on that role need to be investigated.

Stage 1 Expectations. An investigation of the ecological role and requirements of the shrimp species and the effects of the fishery should be conducted, to find out if any special management for either is needed.

Objective 4: Develop Fisheries for Abundant Underutilized Non-Native Species in the Bay-Delta System

Long-Term Objective: Develop fisheries that harvest abundant non-native species, in part to reduce the abundance of nuisance species.

Short-Term Objective: Investigate the abundance and biology of potentially harvestable non-native species and encourage the development of fisheries that do not have negative effects on ecosystem restoration programs.

Rationale. Non-native species, some actually or potentially harmful to native species, are extremely abundant in some parts of the Bay-Delta system yet are at best only lightly harvested.

Examples include various species of clams, mitten crab, several species of gobies, and common carp. Harvest of these species could potentially have positive effects on native or more desirable species, although some of the species may be so deeply imbedded in the ecosystem their removal could cause significant, perhaps undesirable, changes. A first step in developing a harvest of abundant non-native species is to discover their fisheries potential (e.g., areas of concentration, contaminant loads, market), how a fishery might interact with ecosystem recovery efforts, and whether or not development of a fishery might have negative consequences to native species (e.g., through by-catch, introduction of the species into new areas).

Stage 1 Expectations. A list of un-harvested or lightly harvested species that have commercial potential should be developed and their potential for supporting fisheries established. If high potential can be demonstrated, then experimental fisheries should be encouraged.

Objective 5: Change the Role of Trout Hatchery and Planting Programs to Make Them More Compatible with CALFED Goals

Long-Term Objective: Make sure that trout hatcheries and their associated planting programs do not interfere with or negate ERP actions.

Short-Term Objective: Evaluate the trout hatchery and stocking program in California to determine its impact on populations of wild trout and other fish.

Rationale. State, federal, and private trout hatcheries have long attempted to satisfy angler demands for catchable trout by rearing domesticated fish for planting in streams, reservoirs, and lakes. There is little question that these planting programs are successful in providing angling for many people, especially in reservoirs and their tailwaters. However, in some streams angling for domestic trout may put artificially high pressure on wild stocks of trout and steelhead, or planting of domestic trout may introduce diseases to which other trout (and other organisms, including native frogs) are not immune. In some alpine lakes, regular plantings of trout are endangering native frog populations. There is thus a need to closely evaluate all trout stocking programs that take place in the CALFED area to make sure they are compatible with the CALFED goals.

Stage 1 Expectations. A team of experts should be appointed to formally evaluate all aspects of the state and federal trout hatchery programs and issue recommendations in 1-2 years.

Objective 6: Maintain or Enhance Fisheries for Marine Fishes and Shellfishes in San Francisco and San Pablo Bays

Long-Term Objective: Keep sport fisheries for diverse fish species in San Francisco and San Pablo Bays at levels at least comparable to those of 1985-1995, or higher.

Short-Term Objective: Evaluate the status and trends of the major fish and fisheries in the bays to determine management strategies.

Rationale. San Francisco and San Pablo Bays support a rich fauna of native marine fishes, from sharks to surfperches to flounders, as well as of invertebrates such as Dungeness crab and rock crab. These species in turn support sport fisheries within the bay and commercial fisheries outside the bay, because of the movement of fish and crabs between the bays and the ocean. The abundances of some species, especially several species of surfperch, have apparently declined in recent years for reasons that are uncertain. The DFG has a long-term bay study program that is addressing questions of the distribution and abundance of bay species. It needs to be continued and the data analyzed in depth to determine causes of any declines.

Stage 1 Expectations. The DFG Bay study program should continue and in-depth analysis of existing data should be performed, to develop management strategies for the fisheries of the bays.

Objective 7: Enhance Fisheries for Native Cyprinid Fishes

Long-Term Objective: Increase populations of native cyprinids so they can support special fisheries for them.

Short-Term Objective: Maintain fisheries at their present levels while evaluating factors that limit the abundance of the target species.

Rationale. Sacramento blackfish, hitch, and splittail support small commercial or sport fisheries, as do non-native common carp and goldfish. Other large native minnows also have the potential to support fisheries (e.g., pikeminnow, tui chub). The commercial fisheries, aimed at supplying fish to Asian markets in the big cities of California, are largely unstudied and lightly regulated. Likewise, there is little information on the recreational fishery for splittail in the Delta. Because the ERP seeks to increase populations of native fishes, finding ways to make sure the native cyprinids can support fisheries for speciality markets seems very compatible with the other objectives. The fisheries may also have to be regulated more closely to prevent overfishing or impacts on nontarget species.

Stage 1 Expectations. The fisheries for native cyprinids should be evaluated and management strategies devised to maintain both the fish and the fisheries.

Goal 4: Habitats

Protect or restore functional habitat types throughout the watershed for public values such as recreation, scientific research, and aesthetics.

The objectives listed here strongly overlap with those for individual species, which need appropriate habitats to thrive. This section recognizes that habitats have many values to human beyond the "important" species they support and need to be restored, in abundance, to satisfy those

values. Most of the objectives here are general rather than specific and call for more specific restoration objectives to be developed for each type of habitat.

Objective 1: Restore Large Expanses of All Major Habitat Types in the Delta

Long-Term Objective: Restore major habitat types in the Delta to a substantial fraction of their presettlement areas, or to a point where all at-risk species that depend on the habitats are no longer at risk.

Short-Term Objective: Develop and begin implementation of action plans for restoring large and significant examples of major habitat types in the Delta.

Rationale. All major natural habitat types in the Delta have been reduced to a small fraction of the area they once occupied, resulting in a large number of at-risk plant and animal species and an increased susceptibility of the remaining areas to irreversible degradation (e.g., invasion by non-native species). The reduction trend is continuing and will have to be reversed if self-sustaining examples of these habitats, and the diverse organisms they support, are to persist into the future. This reversal will require a large number of diverse and localized actions, from levee setbacks to land acquisition to better management of existing sites. The major habitat types to be restored include tidal shallow water habitat, freshwater emergent wetland, channel islands and associated habitats, tidal sloughs, nontidal freshwater emergent wetlands, seasonal upland wetlands, vernal pools and surrounding uplands, riparian forests and associated upland areas, perennial grassland, and inland dune scrub. In order to make restoration actions systematic and cost-effective, specific objectives need to be established for each of the habitat types, as well as subsets of them that have distinctive biological characteristics, and then priorities set within each objective for protection and restoration activities.

Stage 1 Expectations. A classification system for Delta habitats that can be used as a basis for conservation actions will have been developed. Specific, numeric objectives should be formulated for each habitat type, with restoration objectives based on clearly stated conceptual models. Within and among habitat types, conservation and restoration activities should be prioritized. Work should begin on those projects given highest priority within a year of adoption of the strategic plan.

Objective 2: Restore Large Expanses of All Major Habitat Types in Suisun Bay, Suisun Marsh, and San Francisco Bay

Long-Term Objective: Restore major tidal or upland habitat types in Suisun Bay, Suisun Marsh, and San Francisco Bay to a substantial fraction of their presettlement areas or to a point where all at-risk species that depend on the habitats are no longer at risk.

Short-Term Objective: Develop and begin implementation of action plans for restoring large and significant examples of major habitat types in the estuary.

Rationale. All major habitat types in Suisun Bay, Suisun Marsh, and San Francisco Bay have been reduced to a small fraction of the area they once occupied, resulting in a large number of at-risk plant and animal species and in increased susceptibility of the remaining areas to irreversible degradation (e.g., invasion by non-native species). The reduction trend is continuing and will have to be reversed if self-sustaining examples of these habitats, and the diverse organisms they support, are to continue exist in the future. This reversal will require a large number of diverse and localized actions, from levee setbacks to land acquisition to better management of existing sites. The major habitat types to be restored include tidal shallow water habitat (including tide flats), tidal saline emergent wetland, tidal sloughs, nontidal perennial aquatic habitat (adjacent to wetlands), seasonal upland wetlands, vernal pools and surrounding uplands, riparian habitats and associated upland areas, and perennial grassland. Within these broad habitat types are more narrowly defined habitats that also need special attention. For example, among the tidal shallow water habitats are intertidal mudflats which are major foraging and resting habitat for migratory and resident shorebirds and waterfowl. Ideally, the mudflats should be dynamic, changing in area and composition in response to freshwater flow and tides. Many are being invaded by non-native cordgrasses which turns mudflat into marsh with relatively low biodiversity. The tendency of this habitat to disappear needs to be reversed through active programs such as cordgrass control. In order to make restoration actions systematic and cost-effective, specific objectives need to be established for each of the habitat types, as well as subsets of them that have distinctive biological characteristics, and then priorities set within each objective for protection and restoration activities.

Stage 1 Expectations. A classification system for habitats in Suisun Bay, Suisun Marsh, and San Francisco Bay that can be used as a basis for conservation actions will have been developed. Objectives should be formulated for each habitat type, with restoration objectives based on clearly stated conceptual models. Within and between habitat types, conservation and restoration activities should be prioritized. Work should begin on those projects given highest priority within a year of adoption of the strategic plan.

Objective 3: Restore Large Expanses of All Aquatic, Wetland, and Riparian Habitats in the Central Valley and Its Rivers

Long-Term Objective: Protect and manage, on a self-sustaining basis throughout the watershed, multiple large areas containing all aquatic, wetland, and riparian habitat types in the Central Valley and its rivers to a point where all at-risk species that depend on the habitats are no longer at risk.

Short-Term Objectives: Systematically identify and locate the best remaining areas containing the aquatic, wetland, and riparian habitat types, and prioritize them for conservation. Develop and begin implementation of action plans for restoring significant examples of each habitat type.

Rationale. Moyle and Ellison (1991) and Moyle (1996) developed a scheme for classifying the aquatic habitats of California for the purposes of conservation. Other classification schemes of aquatic habitats also exist, as do schemes for classifying riparian and wetland habitats. Whatever

the system, it is obvious that the diversity of aquatic habitats is declining in Central Valley watersheds, especially in lowland areas. Each habitat supports a different assemblage of organisms, and quite likely many of the invertebrates and plants are still unrecognized as endemic forms. Thus, systematic protection of examples of the entire array of habitats in the region provides some assurances that rare and unusual aquatic organisms will also be protected, preventing contentious endangered species listings.

Stage 1 Expectations. A classification system for riverine and riparian habitats that can be used as a basis for conservation actions will have been developed. Inventory of habitat types should be completed and areas prioritized for conservation actions. Restoration actions should be evaluated and initiated where feasible.

Objective 4: Increase the Area of Tidal Marsh (Freshwater, Brackish, Salt) by Removing or Breaching Levees (Opening Them to Tidal Action) and by Increasing the Elevation of Subsided, Leveed Former Marsh

Long-Term Objective: Restore the amount and diversity of tidal wetlands to the level that existed in 1906 or similar reference date.

Short-Term Objectives: Inventory and prioritize for restoration diked former marsh sites and develop techniques for restoration through large-scale manipulations of high-priority areas, especially on Delta islands.

Rationale. Tidal wetlands are a diverse group of habitats included under Objectives 1 and 2 in this series. However, they merit additional attention beyond those objectives because their restoration is urgently needed for the benefit of many species. They also represent, by acreage, some of the largest restoration projects that are likely to be attempted in the system. Restoration of tidal marshes in the Delta in particular will require major effort and innovation, because so many of the islands that could be restored to tidal marsh now have elevations considerably below sea level. If flooded, they will be too deep for marsh restoration at present. Therefore, restoration will require large-scale pilot projects to find ways to restore marsh lands to such islands.

Stage 1 Expectations. Ongoing efforts to restore large expanses of tidal marsh should continue and experimental pilot projects to restore tidal marshes to Delta islands should be undertaken.

Objective 5: Halt as Much as Is Possible the Conversion of Agricultural Land to Urban and Suburban Uses in Areas Adjacent to Restored Aquatic, Riparian, and Wetland Habitats and Manage These Lands in Ways That Are Favorable to Birds and Other Wildlife

Long-Term Objective: Prevent agricultural land near or adjacent to restored habitats from being converted to urban and suburban uses likely to have a negative effect on natural areas, while encouraging agricultural practices that favor birds and other wildlife and that minimize runoff of contaminants into nearby waterways.

Short-Term Objectives: Identify agricultural lands in the region that are likely candidates for urban or suburban conversion and that are likely to have strong interactions with nearby wetlands, riparian areas, or aquatic habitats or that are important as habitat for waterfowl and other birds. Prioritize such lands for actions that discourage their conversion to uses inimical to nearby natural habitats. Acquire conservation easements on high-priority lands and provide incentives to farmers to use farming methods and crops favorable to wildlife.

Rationale. The CALFED region is one of the most productive agricultural areas in the world, so agricultural lands and practices will always have a big influence on natural habitats in the area. The agricultural land is important as winter feeding grounds for sandhill cranes, various species of geese, and many ducks. It is also frequently important for foraging raptors, such as Swainson's hawk, and other birds. These benefits are lost if the land becomes urbanized and intense land use disturbs or alters adjacent wetlands or aquatic systems. The negative aspects of modern agriculture from an ecological perspective include its heavy use of pesticides, its efficiency of crop harvest (leaving little for wildlife), its capacity to change land use quickly (e.g., from row crops to vineyards) and its ability to use every scrap of available land. Thus, there should be a buffer zone of agricultural land that is farmed in environmentally friendly ways between the natural habitats and more industrial agriculture lands or urban areas.

Stage 1 Expectations. High-priority agricultural lands should be identified and the process begun to acquire easements from willing sellers; incentive programs should be developed to encourage the planting of crops favored by wildlife and to farm in ways that minimize environmental damage particularly in areas adjacent to high-quality existing or restored habitat.

Objective 6: Manage the Yolo and Sutter Bypasses as Major Areas of Seasonal Shallow Water Habitat

Long-Term Objective: Make the Yolo and Sutter bypasses into regions that are intensely managed to favor native fish and wildlife on a seasonal basis.

Short-Term Objectives: Develop strategies for keeping water in the bypasses or in portions of them during periods critical for the life cycles of at-risk fish and wildlife. Conduct experimental manipulations of relatively small regions to test potential restoration methods. Use the information learned to develop strategies for managing new bypasses in the San Joaquin Valley.

Rationale. The Yolo and Sutter bypasses are artificial floodplains constructed in the 1920s to reduce or eliminate flooding of Sacramento and other towns. When not flooded, these immense areas are devoted largely to agriculture. When flooded (mostly during wet winters), the Yolo Bypass alone doubles the wetted surface area of the Delta. Recent studies indicate that the bypasses are potentially important spawning areas for splittail and rearing areas for juvenile chinook salmon, as well as for other species. Their potential as seasonal floodplain habitat that essentially replaces habitat lost from diking and urbanization is just beginning to be appreciated. A major wildlife area has just been established in the Yolo Bypass. Managing the bypasses at least in part for fish and wildlife therefore has considerable potential and is worth investigating closely. Major problems to overcome are making improvements for fish and wildlife compatible with flood control and with agriculture. Because additional bypasses are being planned, the lessons learned in managing the Yolo and Sutter Bypasses may have broad implications.

Stage 1 Expectations. Studies of the bypasses and how they are used by fish and wildlife should be continued and expanded. Experimental flooding of small portions of the Yolo Bypass should be attempted, in order to test ideas of the use of artificially flooded areas in dry years by at-risk species, such as splittail and salmon. CALFED or its member agencies should work with farmers in the bypasses to find ways to make agriculture as compatible as possible with fish and wildlife conservation.

Goal 5: Introduced Species

Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.

The 10 objectives below, when taken together, are a call to limit as much as possible a major and continuing environmental problem: invasions by non-native species. If the problem is not addressed, many of the CALFED ecosystem restoration efforts may not succeed. The objectives show that new invaders have many sources and that even reducing the problem substantially is likely to impact many businesses that involve non-native species in one way or another. Solving the problem will also necessarily involve a high degree of public involvement and some sacrifices.

Objective 1: Eliminate Further Introductions of New Species in Ballast Water of Ships

Long-Term Objective: Eliminate the dumping of all organism-contaminated ballast water and ballast sediment into the estuary.

Short-Term Objective: Eliminate the dumping of all ballast sediment into the estuary. Reduce the amount of ship ballast water contaminated with estuarine organisms from other ports that is dumped into the estuary to 5% of 1998 levels by the year 2005, and to 1% of 1998 levels by 2008.

Rationale. The introduction of non-native species in the ballast water of ships has made the estuary the most invaded estuary in the world; a new species is being added about every 14 weeks. The new species greatly increase the expense and difficulty of restoring the estuary. A new invader can effectively destroy the value of a restoration project. Aquatic invasions also have harmed public health, decimated fisheries, and impeded or blocked water deliveries. Substantial reductions in the number of organisms released via ballast water are readily achievable. Around the world, restrictions and regulations governing management of ballast water and other ballast materials are being promulgated to reduce the introduction of non-native species by this means. Strict controls on ballast water exchange should be enacted and enforced on shipping into San Francisco Bay at the earliest possible time. If prevention cannot work, the shipping industry must be made responsible for the damage caused by ballast water organisms because such introductions must be regarded as deliberate and unauthorized, rather than "accidental".

Stage 1 Expectations. Same as short-term objectives. In addition, better mechanisms to treat ballast water to eliminate unwanted organisms should be developed. Baseline monitoring of the organisms released in ballast water should be immediately initiated so we can assess progress and monitor compliance. Studies should be completed to investigate the ecological and economic impacts of introductions into the Bay-Delta system to demonstrate that strong action is warranted.

Objective 2: Eliminate the Use of Imported Marine Baits

Short-Term and Long-Term Objective: Eliminate the use of imported live non-native marine species for bait in San Francisco Bay and elsewhere in California.

Rationale. At the present time, polychaete worms are shipped live from New England and southeast Asia to the San Francisco Bay Area for use as bait in marine sport fisheries. The New England worms are packed in seaweed which contains many non-native organisms, some of which have been established in San Francisco Bay as a result. This is thus an example of small activity that has the potential for large-scale economic damage (see ballast water rationale). It should be banned by the Fish and Game Commission and the baits replaced by local organisms or by artificial bait.

Stage 1 Expectations. The importation of live marine baits and their associated shipping materials should be banned, unless the industry can demonstrate that all the organisms imported cannot become established in California.

Objective 3: Halt the Introduction of Freshwater Bait Organisms into the Waters of Central California

Long-Term Objective: Halt the introduction of additional species of bait organisms in the CALFED area and the further spread of species already established.

Short-Term Objective: Develop and institute strategies, working with the bait industry, the fishing community, and interests representing the environment and other sectors that may be affected

by such introductions, to halt the introduction and spread of organisms used as bait in fresh and brackish water.

Rationale. Many kinds of aquatic organisms are used for bait. Bait fishes like the red shiner have been spreading rapidly and now dominate many streams, with unknown impacts on native fishes and on fisheries. They continue to be spread by anglers releasing unused bait. Other new organisms may be brought in as "hitch-hikers" in shipments of bait fishes. There is also a need to better educate the fishing public on the adverse impacts of invasive species (see objective 4).

Stage 1 Expectations. Working with the bait industry and other interested parties, a plan should be developed and instituted to greatly reduce, and eventually eliminate, the introduction of unwanted bait organisms into natural waters.

Objective 4: Halt the Deliberate Introduction and Spread of Potentially Harmful Species of Fish or Other Aquatic Organisms in the Bay-Delta and Central Valley

Long-Term Objective: Prevent the establishment through deliberate introductions of any additional fish species from outside the state or from other watersheds within the state, into Central California.

Short-Term Objective: Develop a program to educate the public (especially anglers) about the dangers of moving fish and other organisms around.

Rationale. The DFG has long had a policy of not bringing new aquatic species into California to improve fishing. However, illegal introductions continue, such as that of northern pike into Davis Reservoir. If the highly predatory pike had become established in Sacramento River and Delta, it is quite likely it would have had devastating impact on salmon and native fish populations. There is a need to develop stronger prevention strategies for illegal introductions. The conflict that developed around the necessary elimination of pike from Davis Reservoir demonstrates the need for the development of better public understanding of the need to halt invasions. Education is also needed to make the point that any movement of fish and aquatic organisms by humans to new habitats is potentially harmful, even if the species is already established nearby. Brook trout introduced into a fishless mountain lake, for example, can eliminate the population of mountain yellow-legged frog that lives there, pushing the species further towards endangered species listing.

Stage 1 Expectations. An aggressive public information program should be developed in regard to species introductions.

Objective 5: Halt the Release of Fish and Other Organisms from Aquaculture Operations into Central California Waters, Especially Those Imported from Other Regions

Long-Term Objective: Halt the non-deliberate introduction into natural waters of aquatic organisms from aquaculture facilities that is often a by-product of aquaculture operations. Prevent

the importation from other regions of organisms from other regions into aquaculture facilities in the Bay-Delta system unless major quarantine regulations or facilities are in place.

Short-Term Objective: Institute an independent, scientific assessment of the pathways and risks of the introduction into the environment of organisms imported from other regions by aquaculture and of any changes needed in California's current management of the industry to prevent such introductions. Develop and institute strategies, working with the aquaculture industry and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of invasive or harmful non-native species via aquaculture.

Rationale. Stocks of fishes and invertebrates are imported from other regions for rearing in aquaculture facilities in the Bay-Delta system, and permits are occasionally approved to bring in new species for aquaculture. Numerous examples exist of organisms escaping from aquaculture facilities and becoming established outside of their range. These include, or potentially could include, fish, crayfish and other shellfish that could compete with or prey on native California fish and aquatic organisms, and on sport and commercial fish in central California waters. Of greater concern is the potential for the introduction of parasites and diseases of commercial, recreational, and native fish and shellfish. There are also many examples of such diseases introduced by aquaculture into various parts of the world, sometimes with devastating impact on commercially important species.

Stage 1 Expectations. An independent assessment of the pathways, risks and needed management of aquaculture introductions should be completed; management measures to eliminate by-product introductions should be adopted and implemented.

Objective 6: Halt the Introduction of Invasive Aquatic and Terrestrial Plants into Central California

Long-Term Objective: Halt the importation, sale, and use of aquatic and terrestrial plants that can have potentially harmful impacts on ecosystems in the CALFED region.

Short-Term Objective: Develop and institute strategies, working with the horticulture industry and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of invasive plant species.

Rationale. Many areas of the Central California landscape are dominated by non-native plant species (e.g., annual grasslands, eucalyptus forests) that have displaced native species and have unexpected negative impacts. Parrot's feather, for example, is an ornamental aquatic plant that is now widespread, clogging ponds and ditches in the CALFED area, thereby creating breeding habitat for mosquitoes. Many harmful species (e.g., water hyacinth) can easily be purchased in plant nurseries and so continue to be spread into natural systems. New species and varieties of plants from all over the world are constantly being brought into California with little evaluation of their invasive qualities. Some species (e.g., Atlantic and English cordgrass) have even been imported for marsh restoration projects! There clearly is a need to evaluate the plants imported into California from other regions and to better regulate the horticultural industry to make sure potentially invasive plants are

not available for spreading by gardeners, landscapers, and people engaged in restoration or reclamation activities. There is also a need to better educate the public on the adverse impacts of invasive species and the need to not to allow garden plants to escape into natural environments.

Stage 1 Expectations. Plants sold in California by the horticulture industry that pose a threat to ecosystems in the CALFED region should be identified and evaluated for invasive potential. Special attention should be paid to plants imported into the region from other areas. Working with the horticulture industry and affected interests, a plan should be developed and instituted to greatly reduce, and eventually eliminate, the introduction of additional invasive plant species into natural environments.

Objective 7: Halt the Release and Spread of Aquatic Organisms from the Aquarium and Pet Trades into the Waters of Central California

Long-Term Objective: Halt the release and spread of aquarium organisms and aquatic pets in the CALFED area.

Short-Term Objective: Develop and institute strategies, working with the aquarium industry and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of non-native species from the aquarium and pet trades.

Rationale. Many kinds of aquatic organisms are sold in aquarium and pet stores. It is likely that some species of nuisance aquatic plants (e.g., *Hydrilla*) became established through aquarists dumping them in local waterways. Non-native turtles originating in pet stores are frequently present in ponds and have the potential to displace and spread diseases to native pond turtles. Although many organisms sold in aquarium stores are tropical and unlikely to survive in Central California (with some surprising exceptions), the industry is constantly searching for and bringing in new species from a variety of habitats. As indicated in the ballast water rationale, new species can have unexpected and sometimes large-scale negative impacts on aquatic ecosystems and can make restoration much more expensive and difficult. There clearly is a need to make sure that potentially harmful organisms are not available to aquarists and that new organisms are not brought in as "hitch-hikers" in shipments of aquarium fishes. There is also a need to better educate the public on the adverse impacts of invasive species and the need to not release aquatic pets into natural environments. A good model for this could be the program now in place in Hawaii, which (among other things) has a big public education component and requires all aquarium stores to have a special tank into which people can release unwanted aquatic organisms.

Stage 1 Expectations. Species in the aquarium and pet trades should be identified and evaluated for their ability to establish populations in the Bay-Delta system. With the cooperation of the aquarium/pet industry and affected interests, a plan should be developed and instituted to greatly reduce, and eventually eliminate, the introduction of unwanted aquatic organisms from these sources into natural waters.

Objective 8: Reduce the Impact of Non-Native Mammals on Native Birds and Mammals

Long-Term Objective: Establish mechanisms to minimize the negative effects of house cats, red fox, domestic dogs, roof rats, house mice and other non-native predators and competitors on populations of native birds and mammals, especially at-risk species.

Short-Term Objective: Develop both the means and the public support for limiting the invasion and impacts of non-native mammals into natural areas.

Rationale. Probably few issues are as potentially contentious to the public as programs to control the numbers of house cats (both tame and feral), red fox (introduced in the Central Valley and spread to marshes throughout the Bay-Delta system), and domestic dogs in natural areas. The fact remains that such predators can have a major impact on the ability of natural areas to support wildlife, including threatened native species such as clapper rails, salt marsh harvest mice, and salt marsh song sparrows. Likewise, non-native rats and mice can impact populations of native rodents and songbirds. Thus there is a major need to educate the public about the tradeoffs in protecting abundant and conspicuous predators that prey on native species, as well as programs to rid areas of other non-native mammals. Economical but lethal means of control (poisons, traps) are often controversial for many of these species and may also affect native species. There is thus a need to focus on prevention (e.g., containment and neutering of pets), on non-lethal means of removal (e.g., live-trapping) where feasible, and on developing support and methods for lethal control where necessary. Prevention and nonlethal methods are typically labor intensive, continuous, and more costly than limited agency budgets can endure. Therefore, there is a need to develop either better methods or bigger budgets for control if self-sustaining populations of many native birds and mammals are to be maintained.

Stage 1 Expectations. An aggressive public information program on the impacts of such non-native mammals in wildlife areas should be conducted. Plans for long-term control of invasive mammals should be developed, with alternatives clearly spelling out the impact of no or low control.

Objective 9: Develop Focused Control Efforts on Those Introduced Species for Which Control Is Most Feasible and of Greatest Benefit

Long-Term Objective: Eliminate, or control to a level of little significance, all undesirable non-native species, where feasible.

Short-Term Objective: Eradicate or contain those species for which this can readily be done, gaining thereby the largest benefit for the least economic and environmental cost; and to monitor for the arrival of new invasive species and, where feasible, respond quickly to eradicate them.

Rationale. Non-native species are now part of most aquatic, riparian, and terrestrial ecosystems in California. In most instances, control is either not possible or not desirable. However, in some instances, control of invasive species is needed to protect the remaining native elements or

to support human uses. Four factors should be considered in focusing control efforts. First, an introduced species is often not recognized as a problem by society until it has become widespread and abundant. At that point, control efforts are likely to be difficult, expensive, and relatively ineffective, while producing substantial environmental side effects or risks, including public health risks. Second, some organisms, by nature or circumstance, are more susceptible to control than others. Rooted plants are in general more controllable than mobile animals, and organisms restricted to smaller, isolated water bodies are in general more controllable than organisms free to roam throughout large, hydrologically connected systems. Third, although biological control is conceptually very appealing, it is rarely successful and always carries some risk of unexpected side effects, such as an introduced control agent "controlling" desirable native species. And fourth, physical or chemical control methods used in maintenance control rather than eradication require an indefinite commitment to ongoing environmental disturbance, expense, and possibly public health risks. Overall, the most efficient, cost-effective, and environmentally beneficial control programs may be those that target the most susceptible species, and species that are not yet widespread and abundant. This suggests a need to (1) assess the array of introduced species and focus on those that are most amenable to containment and eradication, rather than focusing just on those that are currently making headlines, and (2) responding rapidly to eradicate new introductions rather than waiting until they spread and become difficult or impossible to eradicate.

An example of a "rare" introduced species needing eradication that is not being dealt with is English cordgrass in the bay. It has been described by some scientists as the most aggressive and invasive salt marsh plant in the world. It has been in the bay, its only known California location, for 20 years without spreading, so it has not generated concern. However, in other parts of the world it has also sometimes sat around for a few decades without doing much of anything, then suddenly taken off and taken over entire estuaries in a few years. In San Francisco Bay, it is known from one site only, where it was planted, and where it exists in a single patch. It could readily be eradicated.

An example of an abundant species needing immediate attention is the water weed *Egraria densa*. This plant has been spreading rapidly through the Delta, where it clogs sloughs and channels with its dense growth, creating problems for navigation. From a biological perspective, it is undesirable because *E. densa* beds appear to exclude native fishes and favor introduced species.

Stage 1 Expectations. Assess existing introductions to identify those with the greatest potential for containment or eradication, and consider this in prioritizing control efforts. Monitor for, and respond quickly to contain and eradicate new invasions, where this is possible. Develop a mechanism where by new invasions can be dealt with quickly and effectively.

Objective 10: Prevent the Invasion of the Zebra Mussel into California

Long-Term and Short-Term Objectives: Develop an emergency response strategy to quickly contain and eradicate zebra mussels should they arrive in California. Continue to inspect trailered boats at the California border to intercept zebra mussels attached to boats.

Rationale. The zebra mussel has done enormous damage to water supply infrastructure and to natural ecosystems in the eastern United States, through which they are spreading rapidly. It is likely that at some point a live population of zebra mussels will appear in California waters through any one of several means. Studies have already demonstrated that it will likely thrive in many parts of the California water system. Therefore, it is highly desirable to have in place a strategy to deal with a localized invasion, along with a commitment of resources from agencies so that rapid action is possible.

Stage 1 Expectations. A determination should be made as to which waters which are most likely to serve as an initial site of invasion for zebra mussels (taking into account both water quality and other environmental factors and the mechanisms likely to transport zebra mussels); a zebra mussel monitoring program for these waters should be developed; and a rapid response strategy should be developed to contain and eradicate an incipient zebra mussel invasion. In addition, the most likely source for introducing zebra mussels is boats carried by trailer from areas where zebra mussels are abundant. California already has an agricultural inspection program, and this program now includes inspection of boats for mussels.

Goal 6: Toxic Substances

Improve and maintain water and sediment quality to eliminate, to the extent possible, toxic impacts on organisms in the system, including humans.

The objectives within this goal are very broad, in part because they should overlap with more specific objectives developed in the Water Quality Program (WQP) of CALFED. The WQP, however, is focused on improving water quality for human health, so the reason for this section of the ERP is to make sure that water quality goals developed for human health are compatible with those needed for improving ecosystem health.

Objective 1: Reduce the Concentrations and Loadings of Contaminants in All Aquatic Environments in the CALFED Region

Long-Term Objective: Reduce concentrations and loadings of contaminants that affect the health of organisms and ecosystems in water and sediments by 90% as measured against current average levels.

Short-Term Objective: Reduce concentrations and loadings of contaminants that affect the health of organisms and ecosystems in water and sediments by 25-50% as measured against current average levels.

Rationale. A wide variety of herbicides, pesticides, fumigants, and other toxic materials enter the aquatic environment of the CALFED region from many sources. The number and variety of contaminants entering the rivers and estuary is poorly known, as are their toxic effects, in part

because the amounts and kinds are constantly changing. However, there is good reason to think that toxic compounds are having many negative effects on aquatic organisms, both acute and chronic. These same compounds can have effects on human health, so reducing their entry into the aquatic systems should have positive health benefits as well. Reducing concentrations of toxic contaminants is not easy because it will require broad changes in land management practices and in the chemical dependency of agricultural and urban areas for pest control. It will require reductions in the amounts and kinds of pesticides applied for many purposes and changes in the way they are applied to reduce their ability to contaminate aquatic ecosystems. Changes in industrial practices that result in contaminants being released (e.g., hydrocarbons from oil refineries) will also be required.

Stage 1 Expectations. Strategies and financial incentives should be developed and implemented that reduce the use or the rate of discharge into the water of herbicides, pesticides, fumigants, and other toxic materials in urban and agricultural areas. The monitoring of contaminants should be substantially increased, both as applied and in the environment to get a better handle on what is going where and on the association of contaminants with declines of aquatic species. Annual goals should be established for the reduction of selected contaminants (e.g., carbofuran, chlorpyifos, diazinon, hydrocarbons, selenium) and monitoring programs set up to determine success of reduction programs.

Objective 2: Develop Regional Plans to Reduce the Effects of Nonpoint Source Contaminants

Long-Term Objective: Implement for all watersheds in the Central Valley, as well as in the Delta, watershed management plans to reduce or eliminate contaminant loads flowing into aquatic ecosystems.

Short-Term Objective: Develop watershed management plans to reduce or eliminate contaminant loads flowing into aquatic ecosystems.

Rationale. Contaminants from agricultural, industrial, and urban runoff are potentially major sources of mortality to aquatic organisms and can cause damage to aquatic ecosystems that is often hard to detect and regulate. Therefore, the best approach to the regulation of non-point source contaminants seems to be cooperative watershed plans with built-in incentives for reducing contaminant loadings of waterways.

Stage 1 Expectations. Using existing data and analyses, major watersheds in the Central Valley should be rated or ranked according to the amount they are impaired by contaminants. Plans to reduce contaminant loads in at least 10 watersheds for which such plans do not exist at the present time should be developed an implemented.

Objective 3: Reduce Contaminant Loads in Harvested Organisms

Long-Term Objective: Eliminate the need for health warnings as the result of contaminants in fish and invertebrates from the Bay-Delta system.

Short-Term Objective: Identify major sources of contaminants (e.g., heavy metals) in the flesh of harvested fish and invertebrates to see if reduction in sources of contaminants is likely to reduce contaminant loads in fish and invertebrates.

Rationale. Many resident fish and invertebrates contain high levels of heavy metals and other contaminants, resulting in warnings that their consumption may be hazardous to human health. Elimination of this contamination in the short run is unlikely, but systematic reduction of sources may eventually make all harvested organisms in the estuary and watershed safe to eat. In some cases, such as mercury, reduction of loads to safe levels may be extremely difficult because of deposits in sediments but strategies to reduce concentrations are still needed.

Stage 1 Expectations. Major sources of contaminants in fish should be identified and drainage-specific plans developed to reduce their entry into the ecosystems.

Objective 4: Reduce Contaminant Loads in At-Risk Organisms

Long-Term Objective: Reduce contaminant loads in at-risk species in the Bay-Delta system to the point where they do not have adverse sublethal effects (e.g., reduce reproduction, change feeding behavior, make more susceptible to disease) on the species.

Short-Term Objective: Identify major sources of contaminants (e.g., heavy metals) in the flesh of at-risk species to see if reduction in sources of contaminants is likely to reduce contaminant loads in their flesh; determine sublethal effects of contaminants on selected at-risk species.

Rationale. Many at-risk fish and invertebrates may contain high levels of heavy metals and other contaminants that may affect their ability to reproduce, feed, navigate, or fight off disease. The impact of such contaminants on at-risk species in the region is poorly known. Elimination of this contamination in the short run is unlikely, but systematic reduction of sources (e.g., of selenium) may eventually improve the survival rates of at-risk species. In some cases, such as mercury, reduction of loads to safe levels may be extremely difficult because of deposits in sediments but strategies to reduce concentrations are still needed.

Stage 1 Expectations. Major sources of contaminants in at-risk species should be identified and drainage-specific plans developed to reduce their entry into the ecosystems. Studies should be conducted to determine sublethal effects of major contaminants to help set priorities for reduction actions.

Objective 5: Reduce to Acceptable Levels the Release of Oxygen-Depleting Substances into Aquatic Systems throughout the CALFED Region

Long-Term Objective: Eliminate runoff and discharges that contain undesirable concentrations of animal wastes, sewage, and other substances that can deplete oxygen levels in streams and sloughs.

Short-Term Objective: Identify major sources of oxygen-depleting substances throughout the CALFED region and develop strategies for their reduction; reduce the aquatic areas regarded as degraded by animal waste, sewage, and other organic substance by at least 50%.

Rationale. As a result of the Clean Water Act, local, regional, state and federal agencies have greatly decreased the amount of contamination of California's waters by sewage, animal wastes, and other substances that deplete oxygen in the water. These organic materials cause rapid eutrophication, resulting in fish kills and dominance by undesirable organisms. Such contamination, although diminished, is still common and needs to be reduced further, especially from agricultural sources. For example, low oxygen levels in the lower San Joaquin River are often a barrier to the movement of salmon and other fish. It is worth noting, however, that release of organic nutrients into aquatic systems is not necessarily always harmful, especially if the nutrients derived from human sources essentially replace those no longer entering the system from natural sources.

Some East Coast estuaries have experienced problems with pathogens that appear to be related to eutrophication and oxygen depletion. Although there are reasons not to expect these problems in the Bay-Delta system, any indication of such problems should elicit a rapid response to investigate and control these problems.

Stage 1 Expectations. Sources or areas of problem releases of oxygen-depleting substances should be identified and incentive programs developed to reduce the amount of organic contamination coming from agricultural and urban areas.

E-026361

E-026361

Appendix C. Further Examples of Conceptual Models

Appendix C. Further Examples of Conceptual Models

LANDSCAPE LEVEL MODEL

Figure C-1 illustrates a landscape level conceptual model. This model applies to chinook salmon, but its principles also could be applied to striped bass, other anadromous fish, and several species that spawn in the coastal ocean and rear in the estuary. These species link the system across boundaries by migrating between the rivers and the estuary or between the estuary and the ocean. Through their migrations, they expose themselves to variable human and environmental forces well outside the boundaries of the Bay-Delta ecosystem. The principal landscape level issue for managing these populations is the relative importance of events in each region in affecting their abundance. For example, chinook salmon experience rigorous conditions in their spawning and freshwater nursery regions, during migration through the Delta, and in the ocean. If the Delta causes a substantial fraction of their mortality, the opportunity exists for restoration that will be effective in reducing mortality and increasing salmon production. On the other hand, if mortality in the Delta is small, restoration of conditions there may have little effect on salmon production. Similar issues exist for the other species although the lack of direct human influence on oceanic conditions (except harvest) limit the opportunities for restoration in that region. A detailed example of ecosystem restoration for chinook that makes use of this model is discussed in Appendix D.

CONCEPTUAL MODEL OF ENTRAINMENT

We present two alternative conceptual models of how anadromous fish can be entrained in the state and federal water projects under low-flow conditions (Figure C-2). The upper part of the figure shows schematic maps of the Delta with the key nodes identified at which water and anadromous species diverge into separate pathways. Conceptual model A is the "old" model, in which the emphasis is on net flow. Water moves downstream in the rivers and either toward the ocean or toward the pumps in the Delta, including a landward net flow in the lower San Joaquin River ("QWEST").

Conceptual model B is based on more recent developments in understanding of hydrodynamics of the Delta and on the realization that fish are not passive particles but are capable of quite complex behavior. Flow in the rivers is downstream, but as we move into the Delta, the flow becomes increasingly dominated by tides. The further west in the Delta we go, the more important the tides are and the less important is riverflow in terms of instantaneous velocity. For example, at Chipps Island under low-flow conditions, net flow is only 1-2% of tidal flow.

E-026363

E-026363

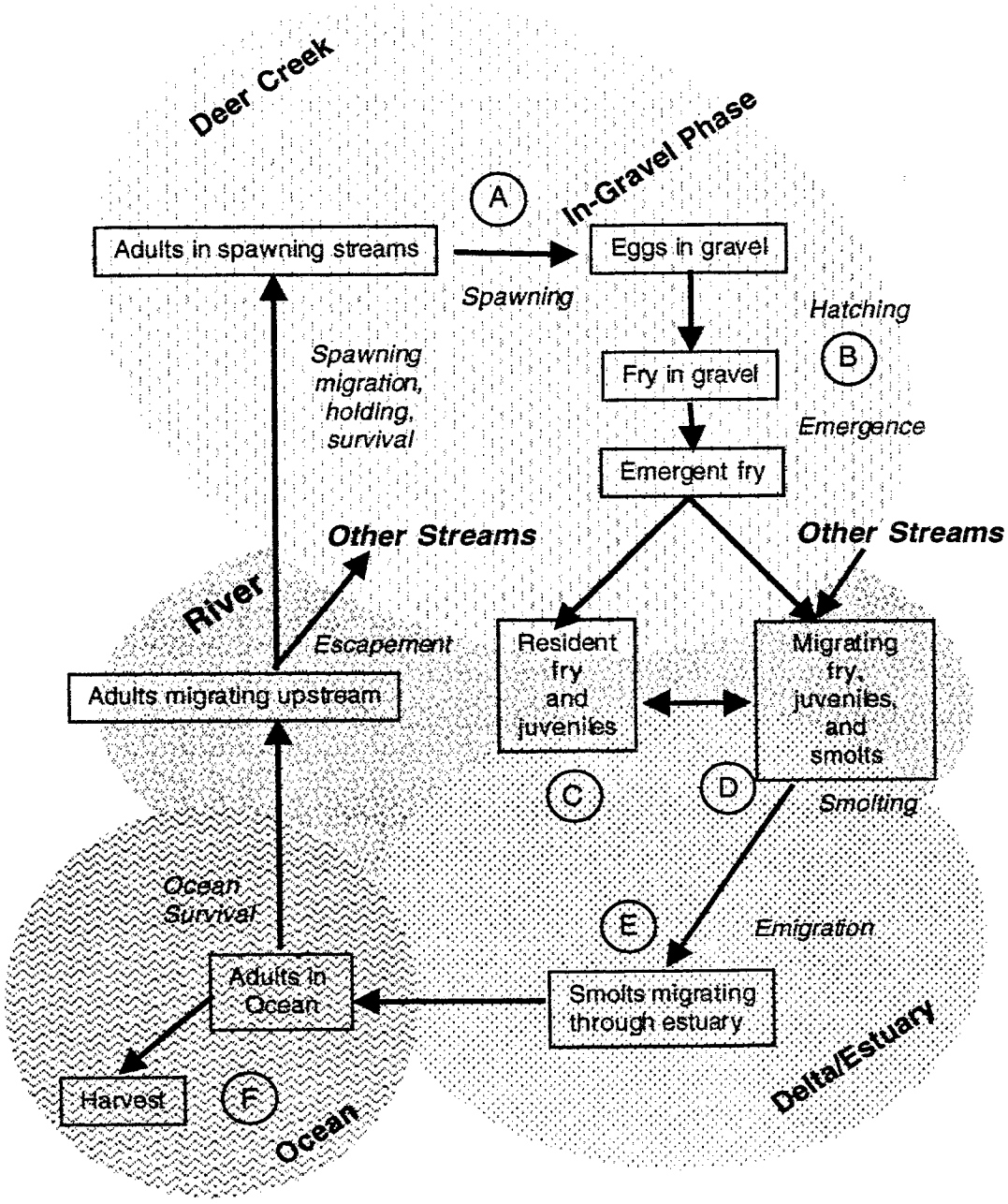
The bottom panel in Figure C-2 illustrates how the selection of models determines the factors influencing the proportions of fish that take one course or another at each of the numbered nodes in the upper panel. Starting from the left-most bar chart, according to conceptual model A, striped bass larvae are largely subject to net flow, with tides affecting them to some degree at the confluence of the rivers (node 3). Salmon smolts, by contrast, are affected more by their own behavior. Still, the major influence is net (river) flow. Under conceptual model B, by contrast, striped bass larvae are affected mainly by tidal flows and to a lesser extent by net flows. Furthermore, the influence of net flows is nearly gone by the time the larvae reach node 3 (i.e., the low-salinity zone, which under low-flow conditions in late spring is at about the confluence). Behavior of the larvae plays an important role in this model, particularly when they reach brackish water and begin to migrate vertically.

In model B, the fate of salmon smolts is governed primarily by whether they migrate along the shore or distributed across the river. If they migrate along the shore, they are more vulnerable to diversions such as at the Delta Cross-Channel than if they are distributed across the channel. In addition, we assume that, like other organisms living in tidal environments, salmon smolts are exquisitely sensitive to the tidal movements and phasing and are capable of moving downstream rapidly using the tidal currents. At the more landward modes, therefore, tidal flow rather than net flow has the most influence on smolt movement patterns.

These alternative models make radically different predictions about the effects of entrainment on salmon and the most effective measures to minimize these effects (Figure C-2). According to model A, losses can be minimized by reducing exports and maximizing flow. Moving the intake up into the Sacramento River would have a clear benefit. According to model B, on the other hand, export flows are not very important in killing salmon, and the most important issue is the strength of the environmental cues available to guide the salmon to sea. Note that this model is more consistent with recent statistical modeling results, which do not find that variation in salmon smolt survival is statistically related to export flows (Newman and Rice in prep.).

For young striped bass, model A again predicts that increasing flow and reducing exports would increase early survival. Model B, on the other hand, predicts a probability of entrainment that depends on the initial position of the fish and the strength of tidal and net flows, including export flows. The further seaward the larvae, the less likely it is to be entrained. Moving the salt field seaward (i.e., moving X2 seaward) reduces the exposure of the fish to entrainment and is therefore more effective than curtailing exports. Note the sharp contrast in the two models' predictions of the effects of moving the intake site.

For delta smelt, the picture is less clear. Under model A, minimizing exports is very important, and moving the intake facility would be very helpful for the species. Minimizing the ration of exports to inflows is believed to reduce the proportion of the smelt population that is entrained. Under model B, X2 determines the position of the bulk of the population and, therefore, the exposure to entrainment, while variation in export flow has little effect unless X2 is far upstream. Thus, moving the intake facility would have little effect except under very low-flow conditions.

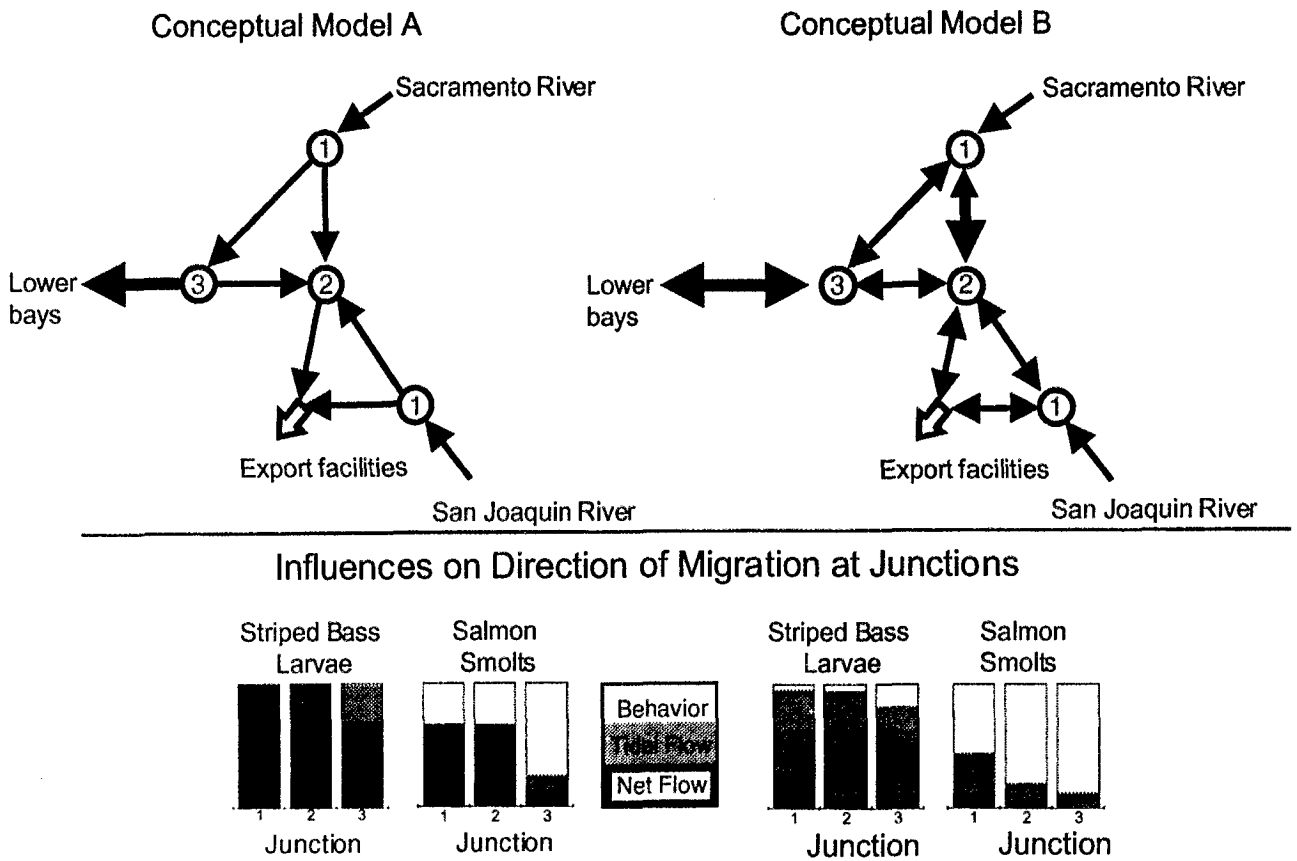


Note: The four oval areas represent the four major geographic regions. Arrows indicate a change of state of surviving salmon, with only ocean harvest mortality displayed explicitly. Terms in italics indicate the major transformations occurring in each phase.

Strategic Plan for the Ecosystem Restoration Program

Figure C-1
Landscape Level Conceptual Model Of Chinook Salmon

E-026366



Note: Arrows and circles comprise a schematic of the Delta, with the circles representing key nodes where flow and fish diverge. Single arrows indicate river inputs, and double arrows indicate flows that are partly or mostly tidal, with the sizes of the arrowheads reflecting relative flow velocities for each location. Conceptual model A depicts net flows, with arrows indicating how fish would move under the influence of these flows. Conceptual model B illustrates how water moves in response to both tides and net flow. Fish move under the influence of these flows and their own behavior. Bar charts in the bottom panel illustrate how these conceptual models differ in their prediction of the relative influence of fish behavior, tidal flow, and net flow on the proportion of fish taking alternative pathways at each of the nodes.

Figure C-2
Alternative Conceptual Models of Flow and Fish Movement in the Delta under Low-Flow, High-Export Conditions

E—026366

These models, along with the findings of the Diversion Effects on Fish Team (1998), suggest that we have a great deal to learn about entrainment effects before a decision can be made on the construction of large-scale water transfer facilities.

MODEL OF CONTRASTING MECHANISMS UNDERLYING X2 RELATIONSHIPS

In this section, we contrast two mechanisms believed to be important for species that enter the estuary from the ocean as young or spawn in the lower bays and rear in the estuary. These models look in more detail at aspects of the Fish-X2 relationship described in the main body of the text. The two mechanisms are gravitational circulation and extent of physical habitat for rearing.

Recent developments in understanding of the physical characteristics of the estuary have altered our perception of how the biota use their environment (e.g., Burau 1998 in Kimmerer 1998). Figure C-3 provides a conceptual model of estuarine circulation patterns designed to illustrate these concepts. For the purposes of this exercise, the main points are as follows. Flow in the brackish parts of the estuary can be considered to have three components as illustrated. First, there must be a cross-sectionally averaged residual (i.e., averaged over the tides) flow to seaward that is equal to the river flow. Second, vertical and lateral asymmetries in residual flow occur through the interaction between stratification, tides, and bathymetry. Third, the strongest flows in most of the estuary are reversing tidal flows, which induce strong longitudinal and lateral dispersion.

Freshwater flow introduces a pressure or level gradient that directs water seaward through the estuary. At the same time, tides drive the denser ocean water into the estuary through a combined pressure and density gradient. These opposing forces determine the length of the salinity gradient and therefore the density gradient. High freshwater flow over a period of time compresses the longitudinal density gradient, enhancing stratification and possibly gravitational circulation. The opposing density gradient acts like a compressed spring, moving salt landward when freshwater flow (and the accompanying pressure gradient) declines.

Gravitational circulation (Figure C-4) can occur throughout the estuary if stratification occurs. This happens primarily in deep regions, such as beneath the Golden Gate Bridge, in the main channel through northern San Francisco and San Pablo Bays, and in Carquinez Strait. It is rare in the main channel of Suisun Bay (Burau 1998 in Kimmerer 1998). We assume (this theory has not been tested) that stratification is stronger when freshwater input is high because of the compression of the longitudinal density gradient (Figure C-3). Under low-flow conditions (Figure C-4, top), stratification is slight. Near-bottom currents are weaker than near-surface currents. Surface currents are stronger on the ebb than on the flood, whereas bottom currents are stronger on the flood than on the ebb. When freshwater flow is high, the density gradient is compressed and stratification is stronger, causing gravitational circulation to intensify. Under these conditions, the asymmetry in ebb-flood currents is greater, particularly near the bottom.

Certain species of bay organisms may use gravitational circulation to enter the estuary and to move landward. This is a common mode of transport for flatfish, crab, and shrimp larvae (e.g., Cronin and Forward 1979). Essentially, all they need to do is move down in the water column, and gravitational circulation will take them landward. Presumably, the stronger the gravitational flow the more rapid the movement and the larger the abundance of animals that will arrive at the rearing habitat. If correct, this model could explain the X2 relationships for bay shrimp, starry flounder, and possibly Pacific herring.

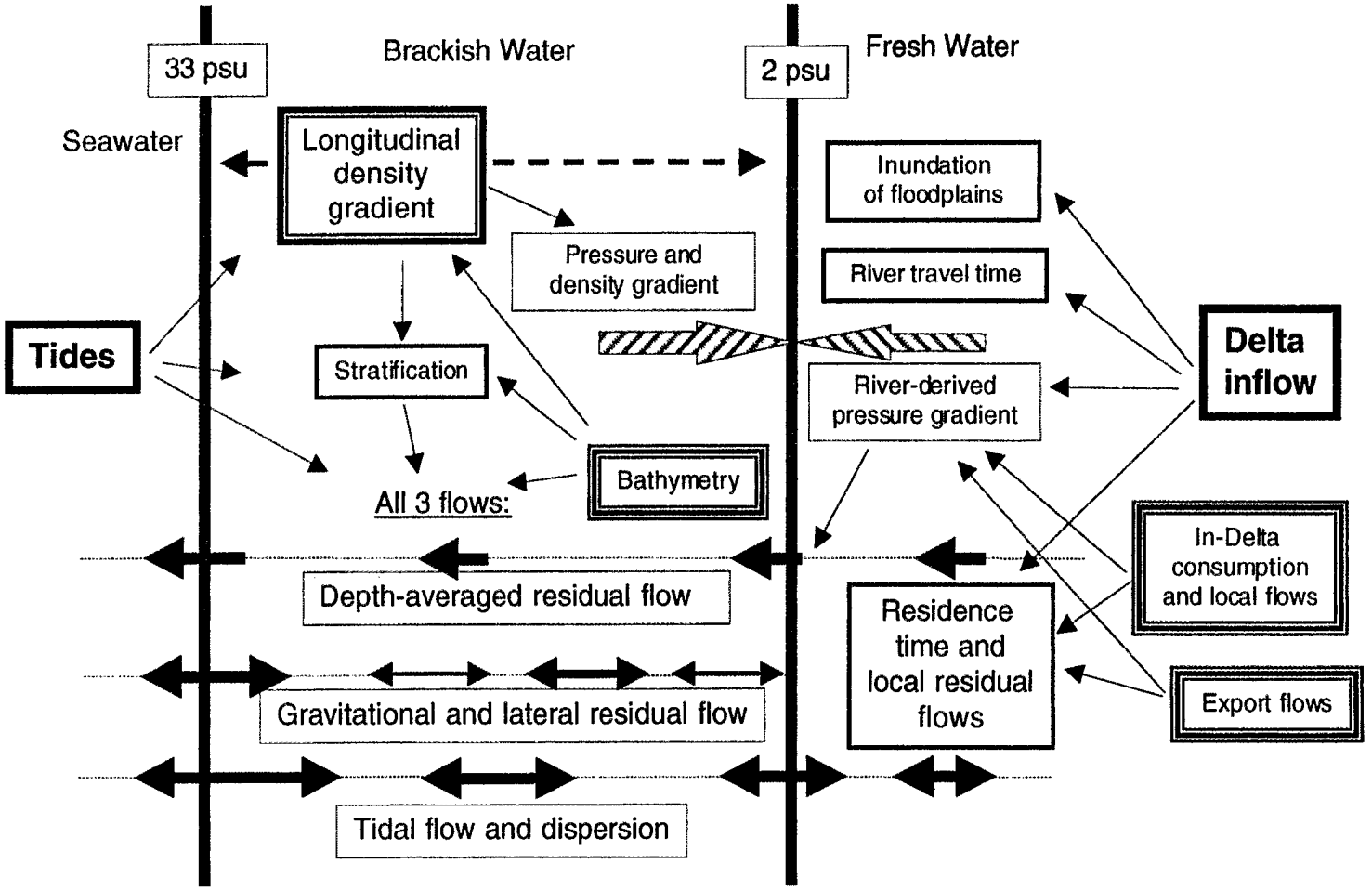
The alternative model holds that the physical extent of nursery habitat increases with increasing flow. This model is supported by a preliminary analysis of the area in the estuary encompassed by selected salinity values (Unger 1994). If habitat is limiting the development of some populations, and if it does indeed increase with flow, then this too could explain the observed relationships.

Actions to protect and enhance the abundance of these species that correlate with X2 (and the predatory species that depend on them) differ depending on which mechanism is most important. If the most important mechanism is gravitational circulation, little can be done to enhance these populations other than to increase freshwater flow (note that dredging channels also may accomplish this, but an additional result may be greater salt penetration). However, if limiting habitat is the key issue, then it may be possible to provide more, better, or more accessible habitat and achieve a suitable level of protection or enhancement with the same or less flow.

CONCEPTUAL MODEL OF MEANDER MIGRATION IN A REGULATED RIVER

This conceptual model (Figure C-5) illustrates factors influencing meander migration, habitats created as a consequence of migration, and influence of management actions. River meanders migrate through a combination of eroding the outside (concave) bank and simultaneously depositing a point bar on the opposite (convex) bank. The highest velocity flows are concentrated on the outside of the bend, and a pool forms at the outside of the meander bend. Right and left bends alternate, with the highest current shifting from one side of the channel to the other at the "crossover" point between bends, where a gravel riffle forms (Figure C-6). As the meander bend migrates across the valley bottom, the channel dimensions remain essentially constant because erosion of the outside bend is compensated for by deposition on the point bar.

The process of meander migration is ecologically important because it creates and maintains channel and floodplain forms with a diversity of habitats (e.g., undercut banks, overhanging vegetation, scour pools, gravel riffles), delivers large woody debris to the channel, and maintains a diverse assemblage of riparian vegetation at different succession stages. As the outside bend erodes, late-stage successional riparian trees are typically eroded and fall into the channel, providing large woody debris to the stream, which in turn increases channel complexity through providing cover and inducing scour. On the newly deposited point bar surface, pioneer riparian species establish and undergo gradual succession to species adapted to finer grained soils and less frequent inundation as

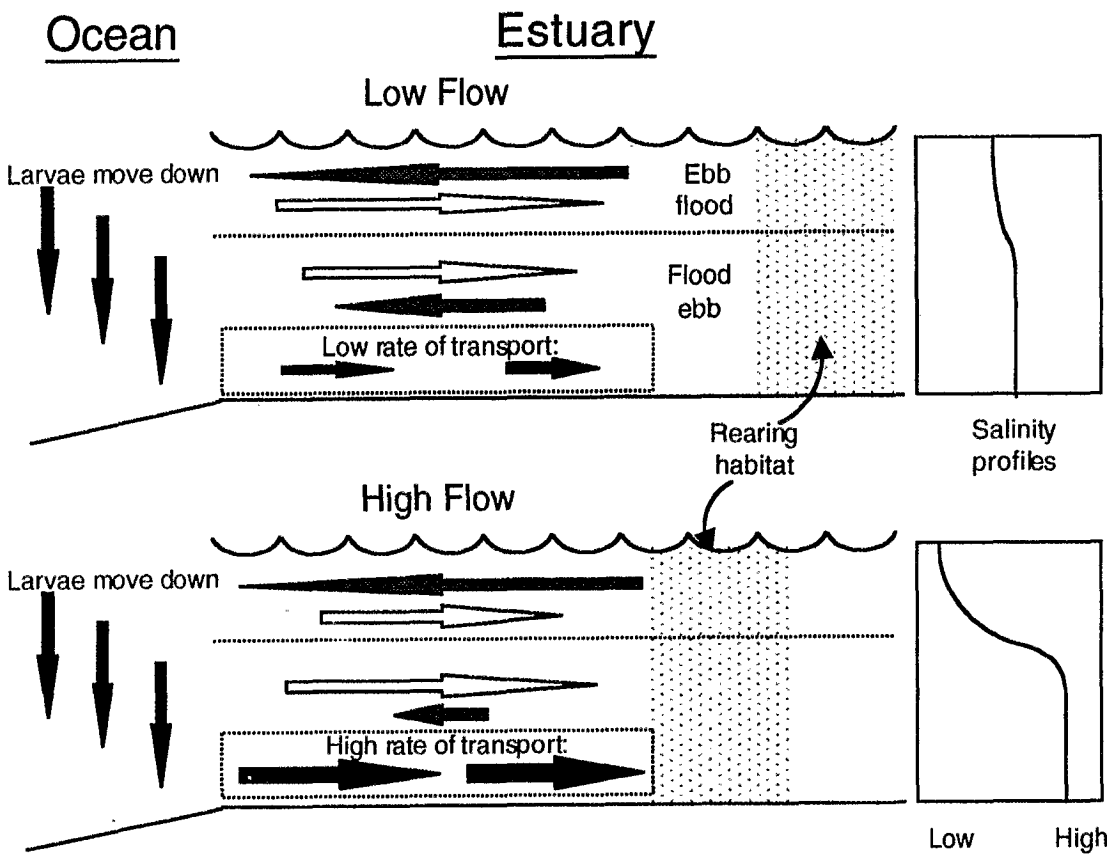


Notes: Freshwater inflow and tides are the major forcing functions. The principal role of freshwater input is in setting up a pressure (level) gradient along the axis of the estuary, which forces the depth-averaged residual flow throughout the estuary. Tides introduce a pressure gradient that varies in time, and the salinity gradient attributable to tidal mixing between fresh water and saltwater sets up a density gradient. This interacts with tidal mixing and bathymetry to produce various degrees of stratification and gravitational circulation.

psu = practical salinity units.

Figure C-3
Conceptual Model of Flow Effects with Emphasis on the Brackish Parts of the Estuary

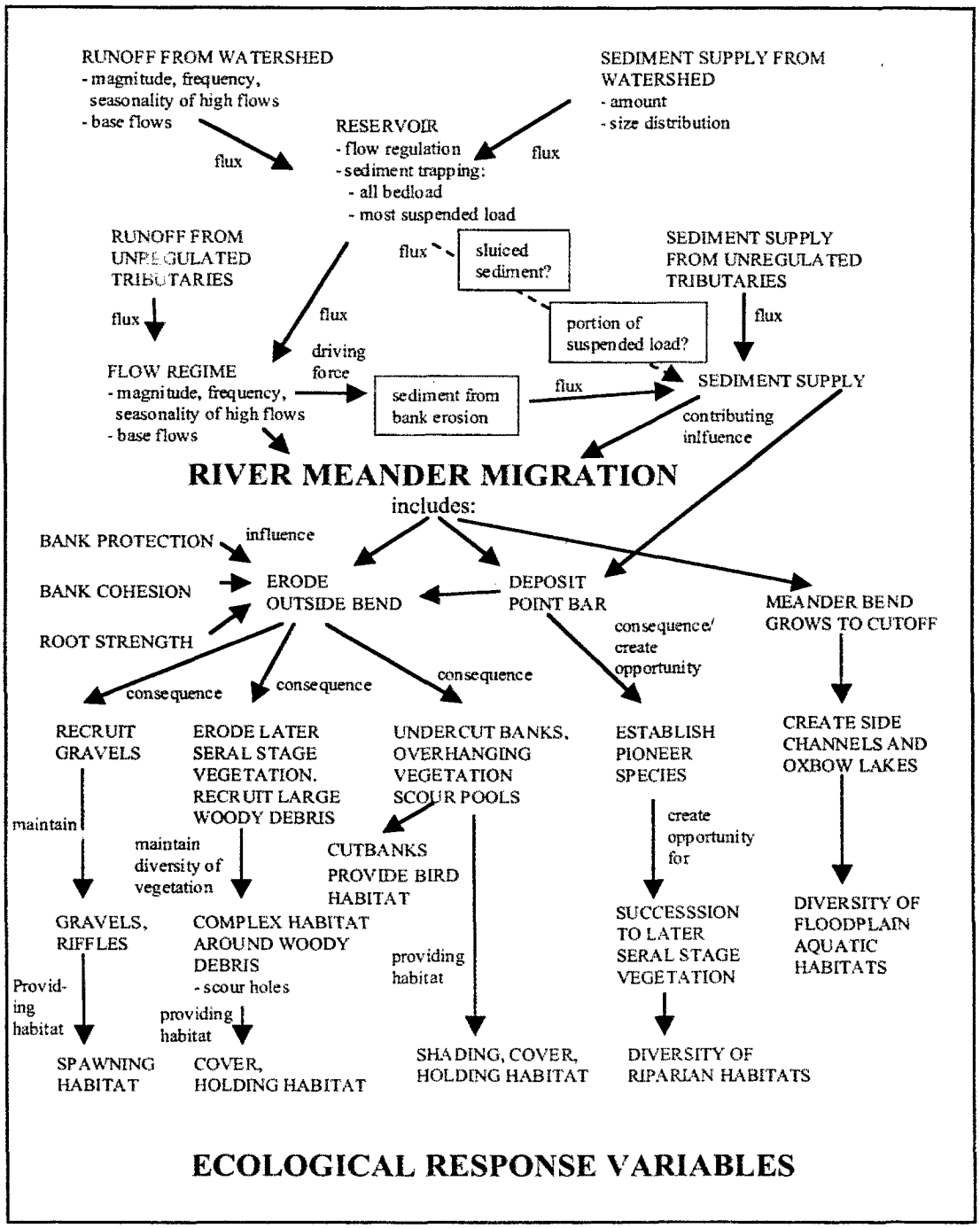
E-026369
E—026369



Note: Several species recruit from outside the estuary and must enter the bay to reach nursery areas; some other species reproduce in the bay but then move up the estuary for rearing. Tidal flows in the low-salinity and high-salinity layers are shown as arrows, with gray representing ebb and white representing flood. Black arrows indicate larval movement. Under low-flow conditions, stratification and gravitational circulation are weak; landward transport of larvae is slow. High flow compresses the longitudinal density gradient (Figure 5-3), increasing stratification and gravitational circulation and increasing the rate of larval transport. Note that this model has not been tested.

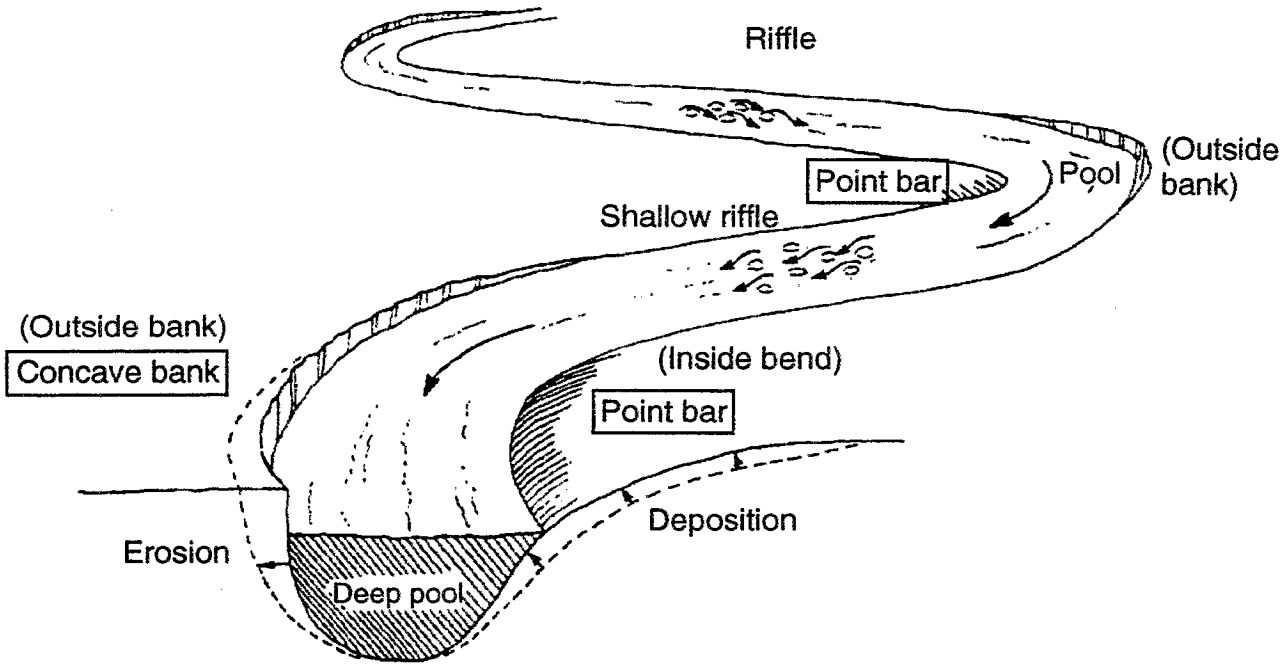
Figure C-4
Conceptual Model of the Mechanism for the X2 Effect Based on Gravitational Circulation

E-026370
E—026370



Strategic Plan for the Ecosystem Restoration Program

Figure C-5
River Meander Migration Model



Source: California State Lands Commission 1993.

Strategic Plan for the Ecosystem Restoration Program

Figure C-6
Diagram of Meander Bend, Showing Variety of Forms (and thus Habitats) Associated with Actively Migrating Meander Bend

the surface builds up through overbank sedimentation, which occurs as the channel migrates away from the site. The evolution from point bar to floodplain is accompanied by frequent inundation and a high connectivity with the channel.

Meander migration rate is driven largely by flow and is influenced by sediment supply. In an unregulated river, runoff and sediment load are derived from the watershed and upstream reaches. Below a reservoir, high flows are typically reduced, reducing the stream energy and slowing the rate of the erosion and deposition through which meander migration occurs. The system becomes less active overall although with distance downstream of the dam and increasing input from tributaries, the river typically becomes more dynamic because the effects of the dam are moderated by runoff from the drainage area downstream. Because the reservoir traps all gravel and sand from upstream, sediment supply is reduced, which can lead to channel enlargement as sediment-starved water erodes the bed and banks. Both of these effects are illustrated on the upper Missouri River below Harrison Dam. Rates of erosion and deposition were formerly high and roughly balanced, but after dam construction, the rates of erosion and deposition dropped sharply, and the erosion rates now greatly exceed deposition rates (Johnson 1992).

Management actions can influence meander processes and habitats in a variety of ways. In some cases, high flows can be released from dams to reactivate dynamic channel processes. However, if the high flows are not accompanied by an augmented supply of sand and gravel, the result may be further degrading of the channel and a paucity of gravel deposits. A recognition of the ecological importance of riparian zones (Gregory et al. 1991) and the role of dynamic channel-floodplain interactions (notably meander migration) suggests that restoration of salmon habitat should be undertaken, wherever possible, by restoring the dynamic river processes that create and maintain the desirable habitats.

E-026374

E-026374

Appendix D. An Example of Adaptive Management Using Conceptual Models: Chinook Salmon and Deer Creek

Appendix D. An Example of Adaptive Management Using Conceptual Models: Chinook Salmon and Deer Creek

OVERVIEW

This appendix provides an example of how Ecosystem Restoration Program (ERP) actions should be formulated and selected. The example given is for spring- and fall-run chinook salmon in the Deer Creek ecosystem. Chinook salmon are a useful focus for this example because they are a valuable fish species, are sensitive to environmental conditions throughout the system, and integrate across the entire landscape of the Bay-Delta system. Spring-run salmon are of particular interest because their populations are a tiny fraction of their historical numbers and they have been proposed for listing as a threatened species. Fall-run chinook also have been proposed for listing, but their overall abundance is much higher than that of spring-run. The Deer Creek ecosystem is of interest because it is a relatively undisturbed stream, one of the last drainages in the Bay-Delta system to support spring-run chinook salmon, and because several specific restoration measures have been proposed for Deer Creek in recent years. In this appendix, we show how simple conceptual models can be used to evaluate various possibilities for rehabilitating salmon populations and habitat and how these might fit into the larger context of spring-run chinook life history and factors limiting its population.

BACKGROUND

Species-Based vs. Ecosystem-Based Restoration

This example also illustrates the different assumptions underlying species-based and ecosystem-based restoration. Species-based restoration attempts to identify and remove limiting factors and bottlenecks to production. It requires specific knowledge about the species' life history and ecology that may be difficult to obtain and provides little progress toward ancillary objectives. On the other hand, it is easier to understand and justify and can capitalize on specific opportunities (e.g., harvest limits). Species-based approaches may be especially important for fishes such as chinook salmon that move between major ecosystems because removing limiting factors in one area may be offset by increased mortality in another area. Finally, state and federal endangered species legislation is essentially species based, although efforts are growing to apply them using ecosystém-based approaches.

Ecosystem-based restoration uses knowledge of the ecological context in which individual species thrive and attempts to restore that ecological context (structure and function) under the assumption that a species' well-being will emerge from a well-functioning ecosystem. It requires less knowledge about the species but incorporates the (often untested) assumption that restoring the ecosystem will benefit the species. It can be used to achieve multiple objectives but also can be difficult to justify as a method for restoring individual species. As illustrated in this appendix, a comprehensive approach to ecosystem restoration, emphasizing an understanding and then restoration of physical and ecological processes affecting habitat, is likely to be more sustainable in the long term than attempts to create habitat features.

Deer Creek Chinook Salmon Life Histories

The life histories of spring- and fall-run chinook salmon are the same except for the seasonal timing of migration and spawning, the typical locations with the river system, and the length of time spent rearing in fresh water.

Spring-run chinook enter the rivers from the ocean from March through May. While migrating and holding in the river, spring-run chinook do not feed, relying instead on stored body fat reserves. They are fairly faithful to the home streams in which they were spawned, using visual and chemical cues to locate these streams; however, some ascend other streams, especially during high-water years; in dry years, they may be blocked from their streams and forced to remain in main rivers.

Adult spring-run chinook migrate up Deer Creek from April through June (Vogel 1987a, 1987b), aggregate in the middle reaches (Airola and Marcotte 1985), and spawn from late August to mid-October. In Deer Creek, most hold and spawn between the Ponderosa Way bridge and upper Deer Creek falls, which is a natural barrier to migrating fish (Marcotte 1984). When they enter fresh water, spring-run chinook are immature; their gonads mature during the summer holding period (Marcotte 1984). Eggs are laid in large depressions (redds) hollowed out in gravel beds. The embryos hatch following a 5- to 6-month incubation period and the alevins (yolk-sac fry) remain in the gravel for another 2-3 weeks. After their yolk sac is absorbed, the juveniles emerge and begin feeding.

Historically, spring-run adults were a mixture of age classes ranging from 2 to 5 years old. Possibly because of fishing in the ocean, most of the fish now are probably 3 years old. During the summer holding period in freshwater pools, many large adult salmon may be caught by anglers (who snag them accidentally with spinning lures), and some by poachers The importance of this source of mortality is indicated by the distribution of the fish; they are most abundant in the more remote canyon areas and scarce in pools close to roads.

Fall-run chinook salmon ascend Deer Creek from October through November (when they are sexually mature) and spawn immediately (October to early December), using gravels in lower

elevation reaches, primarily in lower Deer Creek. Fall-run chinook spend less time in fresh water as adults and as juveniles, leaving their natal stream soon after emergence.

During most years, juvenile spring-run salmon in Deer Creek spend 9-10 months in the streams, where they feed on drift insects. The timing of emigration from Deer Creek has not yet been clearly determined, but it seems to be much more variable than for fall-run chinook. Some juveniles may move downstream soon after hatching in March and April, others may hold in the streams until fall, and still others may wait for more than a year and move downstream the following fall as yearlings (Harvey pers. comm.). The outmigrants may spend time in the Sacramento River or estuary to gain additional size before going out to sea, but most have presumably left the system by mid-May. Once in the ocean, salmon are largely piscivorus and grow rapidly. During downstream migrations in the Sacramento River and Delta, the smolts presumably stay close to the banks during the day (near cover) and then move out into open water at night, to migrate. Historically, they may have moved into flooded marshy areas in the Delta to feed, but there is little evidence of such activity today.

Status of Chinook Salmon Populations

Spring-run chinook salmon are in a state of decline and probably will soon be listed as a threatened species (see Appendix B, objective 3 under goal 1, Priority Group I species); therefore, actions likely to protect and enhance this stock should receive high priority. At the same time, actions to protect and improve habitat should help not only spring-run chinook, but other fish, such as fall-run chinook, steelhead, Pacific lamprey eel, and a complete assemblage of native foothill fishes and native amphibians. Similarly, actions to benefit spring-run chinook habitat probably would achieve other objectives at the ecosystem level. The principal assumption is that restoration of habitat will be effective in improving conditions for this stock.

Spring-run chinook salmon of the Sacramento-San Joaquin River system historically comprised one of the largest set of runs on the Pacific coast. Campbell and Moyle (1991) reported that more than 20 "historically large populations" of spring-run chinook have been extirpated or reduced nearly to zero since 1940. The three largest remaining runs (Butte, Deer, and Mill Creeks) have exhibited statistically significant declines during the same period. The only substantial, essentially wild populations of spring-run chinook remaining in California are in Deer and Butte Creeks in the Sacramento River drainage and in the Salmon River in the Klamath-Trinity River drainage (Campbell and Moyle 1991).

In Deer Creek, spring-run chinook abundance has been low since the early 1980s (Figure D-1). The Mill and Big Chico Creek populations have suffered similar declines, but the Butte Creek population has not, for reasons that are uncertain. These declines are the reason for concern over the status of the spring-run chinook and the proposed listing.

Fall-run chinook populations have also declined, but not so precipitously. In large part, this decline has been less severe because, unlike for the spring-run chinook, access to the fall-run chinook's (lower elevation) spawning grounds has not been cut off.

Habitat Restoration Proposed for Deer Creek

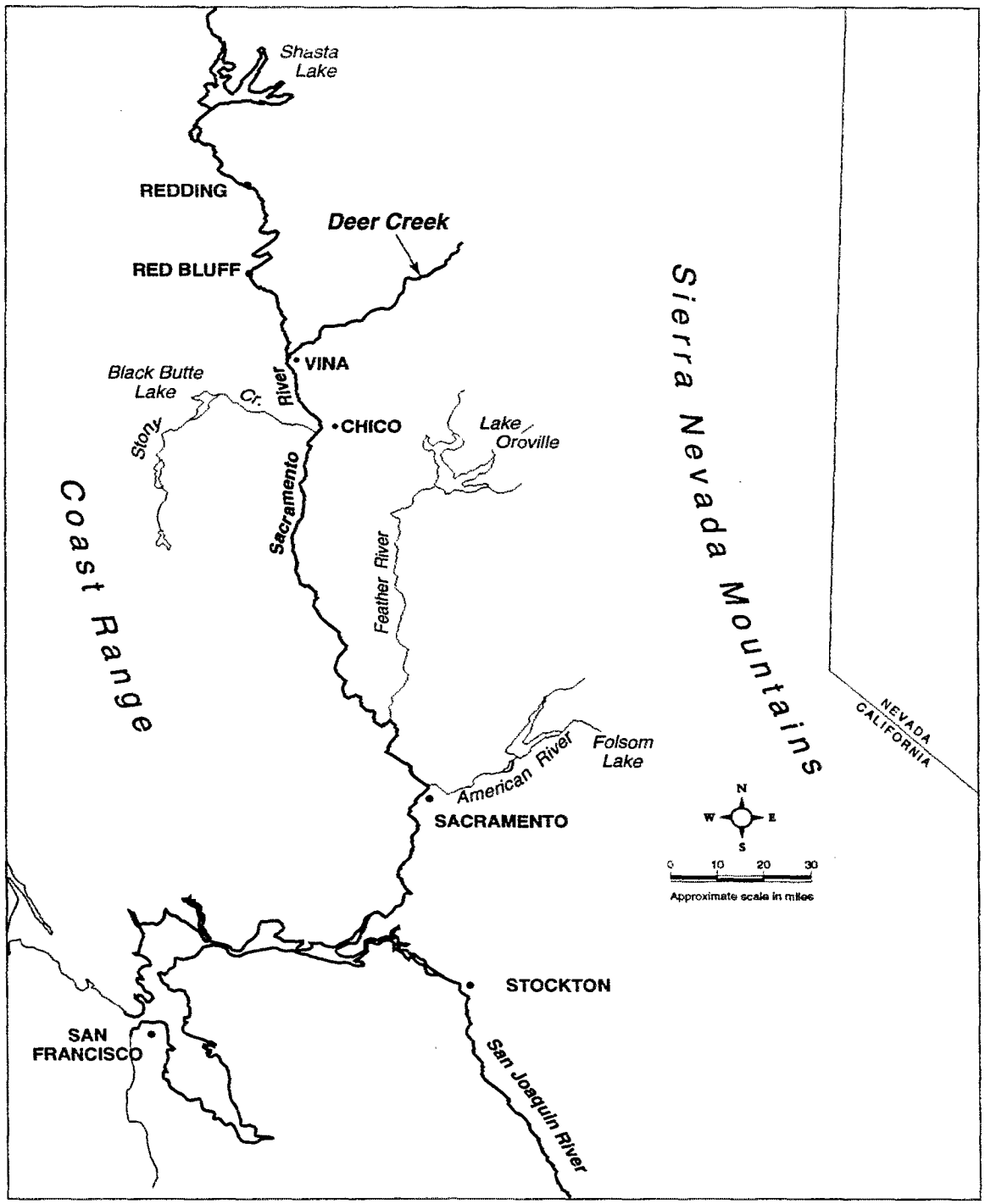
With declining salmon returns throughout the Bay-Delta system and the extinction of spring-run chinook in most of the rivers they formerly inhabited, Deer Creek and the other remaining spring-run chinook streams have attracted attention, and various proposals have been put forth to enhance salmon habitat and passage. These proposals have included measures such as minimum flow requirements in reaches formerly dewatered below irrigation diversions. Although there may be argument about the amounts of water needed, minimum flows in the reach are clearly required.

Other proposed measures have addressed the apparent armoring of the bed of Deer Creek, through mechanical ripping of the gravelbed, artificial addition of smaller gravel, and installation of log structures to hold the imported gravel in place (California Department of Fish and Game 1993, U.S. Fish and Wildlife Service 1995, CALFED Bay-Delta Program 1997). The relative lack of riparian vegetation on the banks along most of lower Deer Creek was addressed by the proposed planting of riparian trees. Although measures such as adding smaller gravel to the channel may provide short-term benefit, the shear stresses in the channel are so high that the gravels would be likely to wash downstream during the next flood. Similarly, inchannel structures and even riparian bank plantings may be washed out during high flows under present channel conditions.

OVERALL CONCEPTUAL MODEL FOR SPRING-RUN CHINOOK SALMON

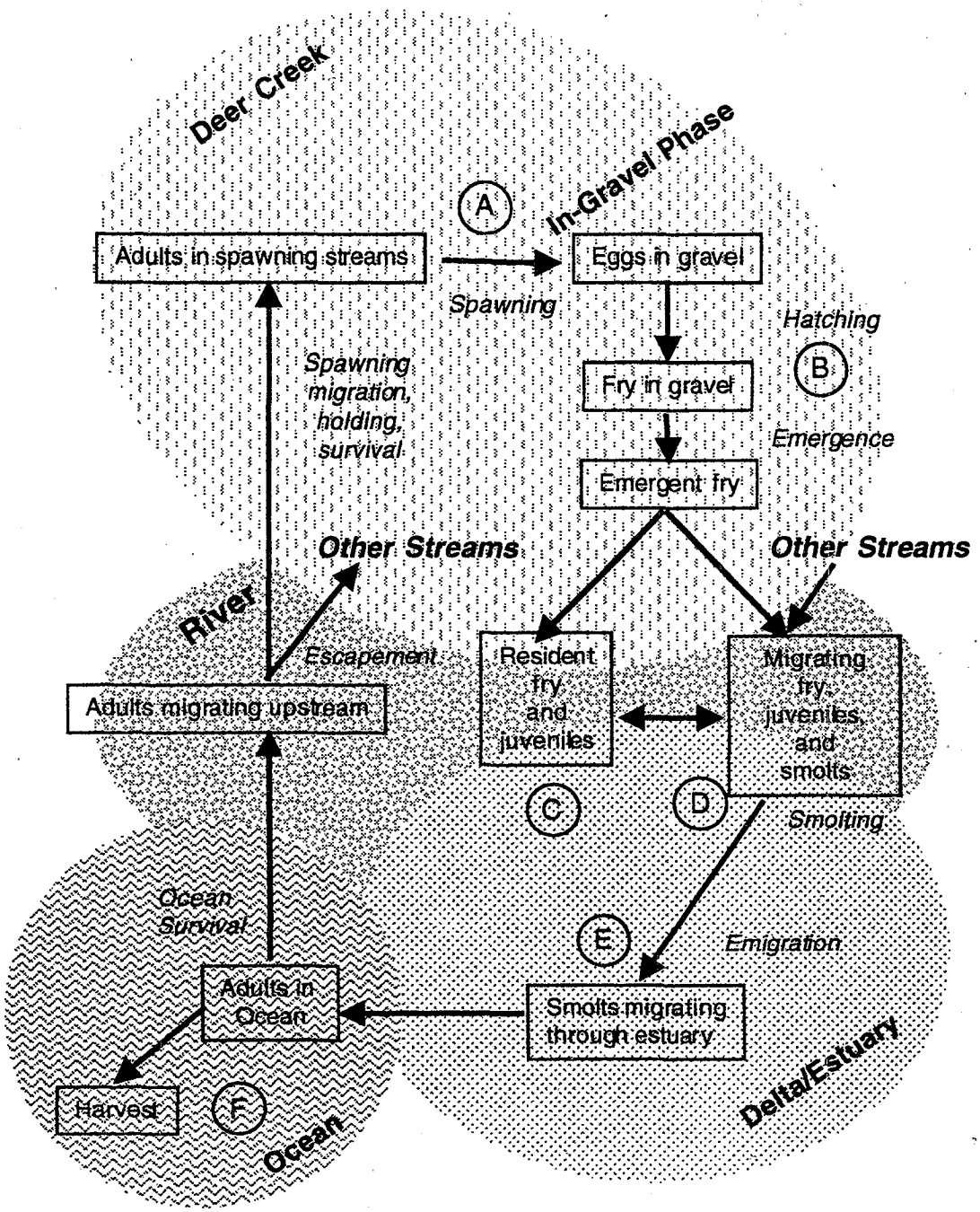
Figure D-2 shows a schematic diagram of the life cycle of spring-run chinook salmon in Deer Creek. Beginning with the ocean phase, surviving adults migrate upstream to hold through the summer and then spawn. Spawning, hatching, and initial rearing take place within Deer Creek. Rearing juveniles may remain in Deer Creek or begin moving downstream, some moving as far as the Delta. The distribution of spring-run juveniles that survive is not known. Spring-run salmon may smolt and migrate to sea in their first winter-spring, or the following winter as yearlings.

Efforts to restore habitat for spring-run, Deer Creek must be placed in the context of the life cycle. Restoration of habitat for one life stage may have little effect if other life stages are limiting. Furthermore, different stages in the life cycle could be limiting at different times, and releasing a limit at one part of the life cycle could result in another part of the life cycle becoming the limiting point. Circled letters on Figure D-2 show points in the life cycle at which interventions might be possible to restore habitat and conditions: (A) survival during migration to and holding near spawning areas, which may be affected by flow conditions or mortality including fishing; (B) spawning habitat, which may be affected by area of gravel of suitable quality in suitable hydraulic



Strategic Plan for the Ecosystem Restoration Program

Figure D-1
Deer Creek Location Map



Note: The four oval areas represent the four major geographic regions. Arrows indicate a change of state of surviving salmon, with only ocean harvest mortality displayed explicitly. Terms in italics indicate the major transformations occurring in each phase.

Strategic Plan for the Ecosystem Restoration Program

Figure D-2
Summary of the Life Cycle of Deer Creek Chinook Salmon

conditions, flow and variability in flow, and temperature; (C) rearing habitat including Deer Creek, the Sacramento River, and the Delta, which may be affected by flow, connection to floodplains, riparian vegetation, diversions, and temperature; (D) survival during migration down the river, which may be affected by flow, temperature, hatchery releases, predators, and diversions; (E) passage through the Delta, which may be affected by flow in the river, net flow across the Delta, temperature, contaminants, agricultural diversions, and possibly export flow; and (F) ocean survival, which is affected by ocean conditions and the percentage of salmon harvested.

Density-dependent and density-independent factors affect salmon populations differently. Of the factors limiting the abundance of salmon, saturation of spawning habitat by high densities of redds, or possibly saturation of favorable rearing habitat by large numbers of juveniles, may result in density-dependent effects. In the case of spawners, this happens because females spawn in fairly restricted areas of high-quality habitat, and the resulting crowding, which can occur even at fairly low numbers of spawners, results in lower survival of the early-spawned eggs (superimposition). If this happens, providing more habitat or improving habitat quality should increase population size by increasing carrying capacity, thereby lifting the limit; however, if the population is too low for significant density-dependent mortality to occur, density-independent factors, mainly downstream, will predominate. In that case, habitat restoration upstream will have little if any effect on population size.

The current low abundance of spring-run salmon suggests that the population may not be greatly influenced by density-dependent effects, but until specific studies are made of this issue it cannot be resolved. In the meantime, ecosystem restoration can also be justified, along with actions designed to reduce density-independent mortality in other parts of the life cycle, because of other objectives (e.g., goal 2, objectives 5 and 6; goal 4, objective 3).

A conceptual model of fall-run chinook salmon would be similar to that of spring-run except that the length of residence of juveniles and adults in the stream and use of the Delta for rearing by juveniles would be much less and the seasonal timing of migration would differ.

Geomorphic and Hydrologic Setting

Deer Creek drains 208 square miles of volcanic rocks on the west slope of Mount Lassen. It flows through canyons cut into volcanic strata before debouching onto the Sacramento Valley floor, flowing across its alluvial fan, and joining the Sacramento River near Vina (Figure D-1). For its first 2 miles, lower Deer Creek (the alluvial reach on the Sacramento Valley floor) migrates across an active channel 1,000-2,000 feet wide, bounded by bluffs (typically 5 meters [m] high) of older, cemented river gravels (Helley and Harwood 1985). Downstream of the bluffs, the multiple channels characteristic of alluvial fans can be clearly seen in the contour lines (Figure D-3). These contour lines reflect the process by which alluvial fans build up: A channel (or more than one channel) is active at a given time, carrying sediment from the watershed, and (because of the flattening of the gradient on the valley floor) aggrades (builds up with sediment) until the creek abandons that channel in favor of another channel, which now offers a higher gradient, until it too

aggrades and the channel shifts again. Thus, over centuries or millennia, the locus of deposition shifts around the entire alluvial fan such that a low-gradient cone of sediment is created.

Strong, cold base flows are maintained in Deer Creek by springs in the volcanic rocks. The average flow at the U.S. Geological Survey gauge (located at the transition from the bedrock canyon to the valley floor) is 317 cfs (Mullen et al. 1991). Despite the base flows from the watershed, parts of Lower Deer Creek have been dry during the summer and fall of many years because of irrigation diversions. Dewatering of the stream no longer occurs thanks to voluntary releases by the irrigation districts, but the dewatered reach has been a barrier to migration until recently, and adequate flow to maintain cool temperatures remains an issue.

There is a high snowmelt flow virtually every year (forty percent of the Deer Creek watershed lies above 4,000 feet), but most big floods result from warm winter rains, and the biggest floods derive from warm rain on snow events. Deer Creek experienced such a rain-on-snow flood of 20,800 cfs in January 1997, which damaged farmland, and nearly washed out the under-sized Leininger Road bridge. The 1997 flood was only the third largest flood in the period of continuous record for the stream gauge, 1921-present, and is thus considered a 25-year flood (following standard formulae for flood frequency analysis) (Dunne and Leopold 1978). Other important floods occurred in December 1937 (23,800 cfs), 1940 (21,600 cfs), December 1964 (20,100 cfs), and 1970 (18,800 cfs) (published records and preliminary estimates of the U.S. Geological Survey). It is during such large floods that Deer Creek would historically shift channels. About ten miles of levees were built by the U.S. Army Corps of Engineers along Lower Deer Creek in 1949 to control flooding. During the 1997 flood and others, Deer Creek overflowed its banks, washing out levees on the south bank, and flowed across the floodplain for about 2 miles down to U.S. Highway 99, following another of the many distributary channels of the alluvial fan.

Habitat Change from Historical Geomorphic Analysis

Historical aerial photographs taken in 1939 clearly show Lower Deer Creek was highly sinuous, with small-scale bends, point bars, and alternating pools and riffles. For much of its course, the low-flow channel was against cut banks with overhanging trees, which provided the channel with habitat under cut banks and roots, shading of the stream, input of nutrients and carbon, and large woody debris. The bends in the channel created secondary circulations and complex flow patterns, which produced zones of higher and lower shear stress distributed through the channel, which in turn led to deposition of gravels and other sediments (Deer Creek Watershed Conservancy 1998). The complexity of channel form resulted in a diversity of microhabitats for invertebrates and fish. During floods, Deer Creek would regularly overflow its banks and inundate adjacent floodplains, a process which prevented continued build-up of water depth in the channel and thus limited the increase in shear stress on the channel bed. Inundation of the floodplain had numerous other ecological benefits, such as providing fish with refuge from high velocities and abundant food sources on the floodplain, and watering the floodplain to maintain vegetation and floodplain water bodies (Stanford and Ward 1993, Sparks 1995).

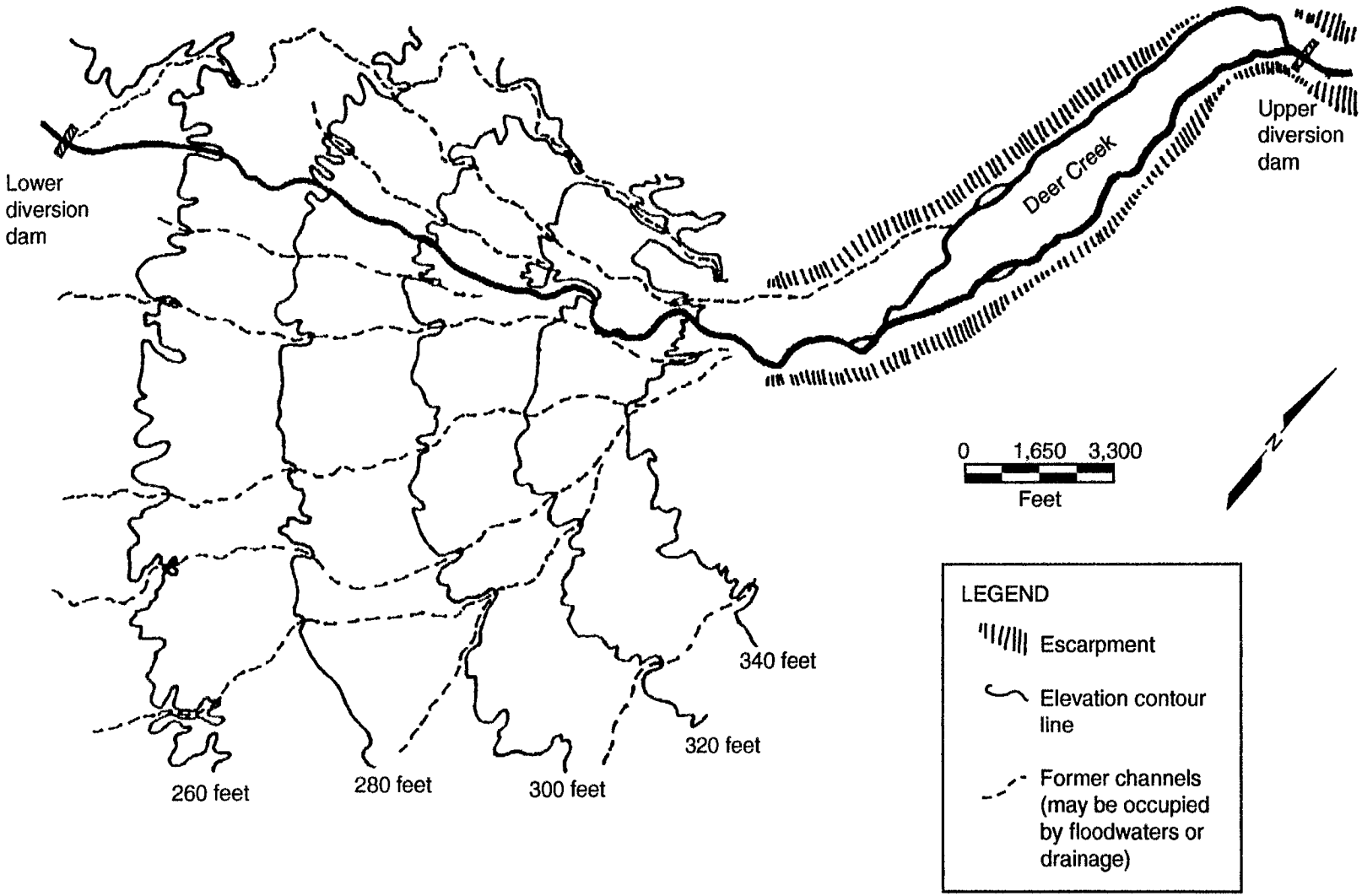


Figure D-3
Characteristic Multiple Channels Radiating from the Apex of the Alluvial Fan on Deer Creek

E-026384
E—026384

Habitat conditions in Deer Creek were profoundly changed in 1949 by a U.S. Army Corps of Engineers flood control project, which built over 10 miles of levees along Deer Creek and straightened and cleared the low-flow channel. In effect, the flood control project sought to confine flood flows to the main channel, which required levees to prevent overflow, and increasing the capacity of the main channel by reducing its hydraulic roughness through straightening and clearing vegetation and large woody debris. Since 1949 there have been repeated efforts to maintain the flood control channel and levees by the U.S. Army Corps of Engineers, the California Department of Water Resources, and Tehama County Flood Control. After each major flood, heavy equipment was usually used to repair levees and clear the channel of gravel bars and large woody debris, with a particularly large gravel removal project after the 1983 flood by the Department of Water Resources (Deer Creek Watershed Conservancy 1998). Gravel removal and levee repair in the early 1980s cost about $1 million, and similar work in 1997 cost about half that amount.

Beginning with the aerial photographs of 1951 (the first available after the flood control project) and continuing to the present, the low-flow channel of Deer Creek is visibly less sinuous and less vegetated than it was in 1939. The alternating pool-riffle sequences visible on the 1939 aerial photographs have been largely replaced with long riffles and runs. There is less riparian vegetation bordering the low-flow channel, partly because there is less riparian vegetation on the banks and partly because there are fewer points where the (now straightened) low-flow channel is undercut at the base of a wooded bank.

Although there are no data on the bed material sizes before 1949, a number of reports have speculated that the gravels of Deer Creek are "armored" (California Department of Fish and Game 1993, U.S. Fish and Wildlife Service 1995, CALFED 1997). While Deer Creek probably does not fit the geomorphic definition of 'armored' (Dietrich et al. 1989), it is very likely true that the bed material is substantially coarser now than before 1949. The reason is that smaller gravels (which would be preferred by most spawning salmon) are now transported out of Deer Creek to the Sacramento River due to the increased shear stresses in the straightened and leveed channel.

The 1949 flood control project and subsequent maintenance efforts were undertaken with good intentions and reflected the best thinking at the time, but there is increasing recognition worldwide that channelization and other river control efforts are frequently detrimental to aquatic and riparian habitat, and often expensive to maintain because they are, in effect, "fighting" river processes. The literature is replete with evidence that natural, complex channels (i.e., channels with irregular banks, undulating bed morphology, and large roughness elements such as large woody debris) provide better aquatic habitat than simplified, channelized reaches (see Brookes 1988 for a review). It should come as no surprise that aquatic habitat is usually maximized with an unfettered, naturally migrating river channel (Ward and Stanford 1995), as these are the freshwater stream conditions with which the fish evolved.

Impacts of channelization include loss of aquatic habitat area and diversity, reduction in shading of the channel with attendant increase in water temperature, loss of riparian habitat for wildlife, specifically loss of undercut banks and overhanging vegetation, loss of pool-riffle structure, and loss of spawning habitat. These relations are visible from field observation on Deer Creek, and would probably be evident from detailed habitat mapping within channelized/leveed vs. more natural

reaches of Deer Creek. One way in which channelization and levees reduce the quality of habitat in Deer Creek is by eliminating refuge from high flows: all the flow is concentrated between the levees, leading to increased shear stress in this narrow band. Not only do fish have no place to hide in such channelized/leveed reaches, but the resulting channel typically becomes simpler as well. Thus, the initial 1949 channelization project and subsequent channel clearing, gravel removal, and levee repairs (including post-1997-flood emergency work) were detrimental to aquatic habitat in Deer Creek.

Channel modifications are commonly accompanied by installation of rip-rap on banks. Rip-rapped banks lack bank overhangs, trees and roots, and other irregularities. Although the interstices of rip-rap can provide some habitat for juveniles, overall there is a loss of habitat when a natural bank is converted to rip-rap. Numerous studies have shown that rip-rapped banks support lower densities of fish (e.g., Cederholm and Koski 1977, Chapman and Knudsen 1980, Hortle and Lake 1983, Knudsen and Dilley 1987). Moreover, hardening river banks in one location typically produces a reaction elsewhere along the channel, because flows speed up, slow down, or change in direction. As a result, erosion is initiated elsewhere, and bank protection may be proposed for the new site of erosion, initiating a cycle of erosion and costly rip-rap projects, ultimately with substantial, negative, cumulative effects on aquatic habitat.

Channel maintenance for flood control has included removing accumulated gravel deposits and large woody debris. The gravel removed from the channel is important for building complexity of channel forms (e.g., point bars, riffles) and as part of the gravel delivered to the Sacramento River by Deer Creek. Large woody debris is increasingly recognized as providing important habitat in streams (Angermeier and Karr 1984, Dolloff 1986, Fausch and Northcote 1992, Fausch et al. 1995), so the loss of this wood from the system reduces habitat complexity and contributes to the rapid transmission of flow downstream.

Upstream reaches of Deer Creek most used for spawning and rearing by spring-run chinook salmon (the canyon reaches between the Lower Falls and the Ponderosa Way bridge) have remained largely unchanged since the 1930s. Farther upstream, the Deer Creek Meadows have experienced substantial erosion and channel widening and incision, which has caused the alluvial water table to drop, drying the meadow, and changing the distribution of pools, riffles, and other habitat features. The amount of sediment from the channel erosion, and from road construction, timber harvest, and landslides in the upper basin has no doubt increased in recent decades, and most of this sediment has passed downstream. However, important spring-run salmon habitats do not appear negatively affecting by excessive fine sediments at this time, implying that most of this sediment has been transported through the system during flows sufficiently high to maintain suspension.

A SYSTEMIC, PROCESS-BASED STRATEGY FOR ECOSYSTEM RESTORATION OF LOWER DEER CREEK

With an understanding of the effects of the flood control project (and its maintenance) on Deer Creek, we can see that many of the problems in Deer Creek are, in effect, symptoms of the

underlying geomorphic effects of the flood control strategy. Many of the restoration actions proposed for Deer Creek can be viewed as treatments of these symptoms, rather than addressing the underlying problem. If the style of flood management were changed to set levees back, permit overbank flooding, and eliminate channel clearing, Deer Creek would, in the course of one or more floods, reestablish a more natural channel form with better habitat.

The Deer Creek Watershed conservancy is now exploring alternative flood management strategies. One concept is to let Deer Creek overflow its south bank at the same point it overflowed in 1997 (and in previous floods) and flow across a swath of the south bank floodplain (bounded along the south by set-back levees), through enlarged culverts under Highway 99, and past the town of Vina and into the Sacramento River through an enlarged China Slough. Vina, the Abbey of New Clairvaux, and other buildings on this floodplain would be protected by ring levees. This strategy would aim to manage floods rather than control them, to let Deer Creek release pressure during floods by overflowing as it has historically done, but to set back or protect vulnerable infrastructure.

Along many rivers and streams, it is too late to reestablish natural floodplain processes because intensive urbanization of the floodplain precludes its inundation, or upstream dam construction has reduced flood frequency. Fortunately, along Deer Creek, this is not the case, and a number of landowners have expressed willingness to consider periodic flooding of their agricultural lands. The Nature Conservancy and other organizations and programs could purchase easements or title to flood-vulnerable lands, compensating the landowners. Similarly, bank protection could be removed, destabilized, or not maintained, so that Deer Creek would become free to migrate across the floodplain. In the long run, this approach (of stepping back from the river and giving it a corridor in which to flood and erode) would reduce maintenance costs, in addition to improving habitat.

Because Deer Creek is a high energy channel with essentially unaltered flow and sediment yield from its watershed, it is capable of reforming its bed and banks from channelized to natural quickly, once the disturbing factors of levees and channel clearing were removed. We could expect to see substantial return to natural conditions in one large flood, as was illustrated by some of the channel changes effected by the 1997 flood.

Taking a systemic approach such as this need not preclude short-term measures such as planting riparian trees along devegetated channels, or even additions of spawning sized gravel to the channel, but these measures should be undertaken with the understanding that they are unlikely to be sustainable until the channel of Deer Creek can evolve to a more complex, natural form.

Limiting Factors in the Life Cycle of Spring-Run and Fall-Run Chinook Salmon

Spawning

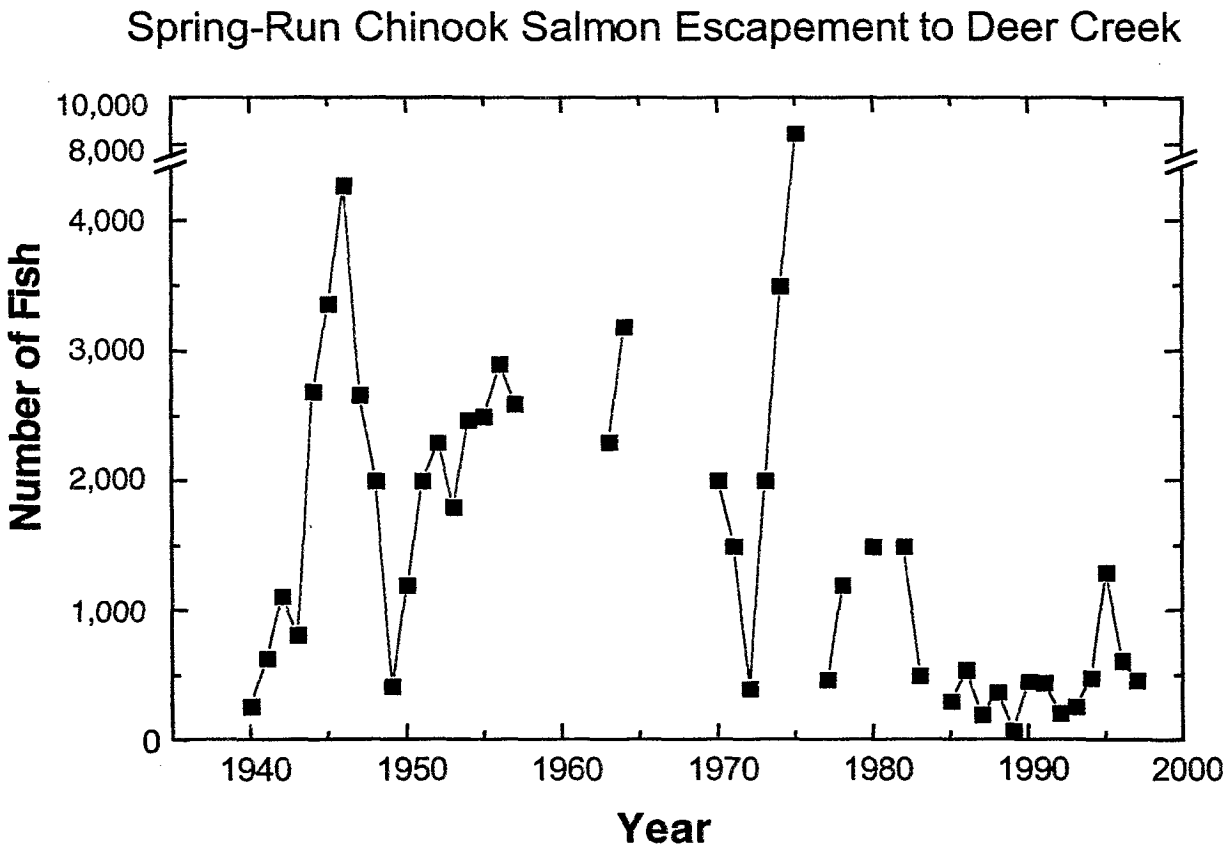
Gravels in Lower Deer Creek are used for spawning by fall-run chinook, despite grain sizes considered somewhat coarser than ideal. Spring -run spawning is concentrated upstream, where the gravels occur in smaller deposits. Restoration efforts in Lower Deer Creek would benefit spawning for fall-run chinook and rearing habitat for both runs. However, there may be other, less-visible, limitations on salmon at other stages of their life cycles. For example, if abundance is very low, spawning habitat may not be limiting, because even the limited spawning habitat is adequate for the depressed populations. In this case, restoration efforts directed at other parts of the life cycle may be more effective. This has probably been the case in some years of low abundance (Figure D-4). For some of these life cycle stages, ecosystem restoration seems like a logical and supportable way to proceed; for others, species- or even stock-specific actions are more likely to yield tangible results. Limitations at different stages of the life cycle are discussed below, with letters referring to Figure D-2.

Fry Rearing in Rivers (C)

In general, chinook fry tend to disperse downstream after emergence, taking up residence along edges of streams and rivers, and selecting habitat of increasing velocity as they develop (Chapman and Bjornn 1969, Lister and Genoe 1970, Reimers 1973, Healey 1991). Habitat characteristics seem to be important, particularly the availability of cover at the banks, and riprapped banks seem to provide especially poor habitat for rearing (Michny and Hampton 1984, Schaffter et al. 1983, Brusven et al. 1986). Under the assumption that these characteristics apply equally well to Deer Creek spring-run salmon, then restoration activities in both the creek and the Sacramento River should increase growth and survival of Deer Creek spring-run by an unknown amount. These improvements may include increasing the extent of meander belts, increasing riparian vegetation and woody debris, and reducing the effect of structures that impede migration and concentrate predators. Continuing to maintain Red Bluff Diversion Dam gates open will eliminate what had been believed to be an important concentration of predators.

Habitat Conditions in the Delta (D)

Data on conditions for juvenile salmon in the Delta is largely confined to fall-run smolts and, to a lesser extent, fry. Although many brackish estuaries provide important rearing habitat for chinook salmon (Healey 1982), spring-run races tend to rear more in rivers. Rearing of fall-run salmon in the Sacramento-San Joaquin estuary is believed to occur in freshwater regions of the Delta (Kjelson et al. 1982). Survival of migrating hatchery-reared smolts is lower if they are released in the interior Delta than if they are released on the Sacramento River, suggesting poor conditions for survival within the Delta (USFWS data). To the extent that these poor conditions are due to



Note: *Data from Candidate Species Status Report 98-01 to the Fish and Game Commission.*

Strategic Plan for the Ecosystem Restoration Program

Figure D-4
Time Course of Spring-Run Chinook Salmon Escapement

inadequate habitat, ecosystem-based restoration efforts may help smolt survival as well as that of fry. Too many unknown factors exist, however, to suggest large-scale restoration efforts on behalf of salmon (e.g., the extent and importance of rearing in the Delta, the characteristics of favorable habitat, and the degree to which habitat may be occupied by either salmon or their predators). This suggests that a stepwise, adaptive-management approach to this restoration be used to begin to test assumptions about how habitat in the Delta may be improved and what affect that has on key species such as salmon.

Fish Passage through the Delta (E)

Although this is included as an illustration of potential effects on salmon, improvement of fish passage through the Delta is an ecosystem-level action which should benefit other species and stocks. Most of the emphasis in the Delta has been on survival of fall-run salmon smolts passing through on their seaward migration (Newman and Rice in prep.). The principal factors affecting survival appear to be flow in the Sacramento River, salinity distribution, and Delta cross-channel gate position (Newman and Rice in prep.). If spring-run salmon respond similarly to conditions in the Delta (except that temperature should not be a factor), there may be opportunities for improving their survival. Proposals in the Central Valley Improvement Act Anadromous Fish Restoration Plan included closing the Delta Cross-Channel gates in winter, and conducting adaptive management experiments (as in the Vernalis Adaptive Management Program), manipulating flow and exports during experimental releases of tagged late-fall-run fish to represent spring-run. Additional actions that improve the effectiveness of directional cues should benefit all salmon stocks as well.

Adult Passage and Survival (A)

Adult passage into Deer Creek is probably not a limiting factor under most flow conditions. However, high temperature in the Sacramento River could result in physiological damage or exhaustion with resulting poor survival or egg viability. Because adults hold in the stream through summer, spring-run chinook may be particularly vulnerable to poaching, which may have contributed to their decline (Sato and Moyle 1989).

Ocean Conditions (E)

Survival of salmon in the ocean is reduced by natural mortality(an ecosystem condition) and fishery mortality (largely a species-based condition). Natural mortality is a function of ocean conditions, out of the control of CALFED. The fraction of fall-run salmon caught (harvest fraction) has been increasing by 0.5% per year for the last 40 years to values over 70% (based on data in Mills and Fisher 1994). This value seems excessive if it applies also to spring-run salmon, given their population size. Thus an obvious management option is to reduce harvest, particularly if it can be done in a way that uses the different migratory patterns to reduce impacts on spring-run fish.

Alternative Conceptual Models for Salmon Restoration in Decision Making

With these limiting factors in mind, we now illustrate the application of conceptual models to formulating ERP actions, by identifying key events in the life cycle that affect production. We first present alternative models for spring-run chinook salmon systemwide, which lead to alternative restoration approaches, depending on the relative importance of each life stage. Second, we present a conceptual model of fall-run spawning in Lower Deer Creek, which provides a basis for choosing restoration actions in Deer Creek.

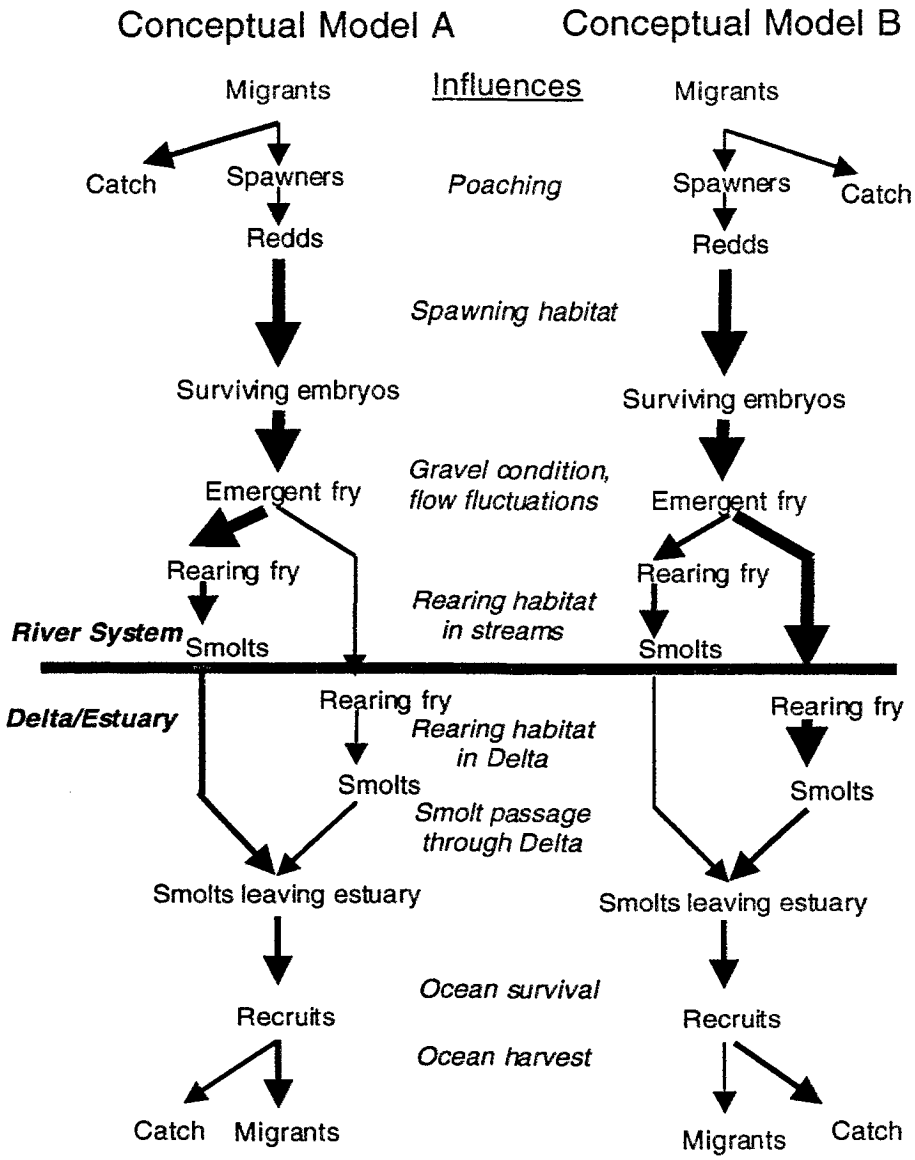
Example 1: Conceptual Models for Spring-Run Salmon

Alternative Points in the Life Cycle. For illustration, we have selected just two qualitatively-different models of the life cycle of spring-run chinook salmon (Figure D-5). These models are briefly summarized in Table D-1. According to Model A, spring-run salmon could be restored through control of poaching in the streams and improvement of rearing habitat in the streams and river. Model B suggests restoration by improving spawning habitat and Delta rearing habitat, and reducing ocean harvest. Both models indicate a moderate improvement through reduction of mortality on passage through the Delta. Delta conditions are discussed further below.

Table D-1. Summary of Differences Between Alternative Conceptual Models A and B in Figure D-5 in Relative Importance of Various Life Stages to Potential Improvement in Production of Deer Creek Spring-Run Chinook Salmon.

		Relative Importance	
Life Stage or Event	Density-Dependent	Model A	Model B
Poaching	Yes?	High	Low
Availability of spawning habitat	Yes	Low	High
Rearing in stream/river	No?	High	Low
Rearing in the Delta	No	Low	High
Passage through the Delta	No	Moderate	Moderate
Ocean harvest	No?	Low	High

Clearly the expected benefits due to improvements in different locations differ greatly among these and other possible alternatives. The only way to resolve these issues is through modeling of the life cycle. With a model containing the various mortality factors, their expected response to restoration actions, and the degree of uncertainty about each, one could estimate the effectiveness of various actions and how well that effectiveness is known. The principal output of such a



Note: Arrows represent transformations of fish from one life stage to the next, and thickness of arrows indicates relative magnitude of population undergoing transformation. Conceptual models A and B differ in the importance of effects at several stages of the life cycle (Table 7-1).

Strategic Plan for the Ecosystem Restoration Program

Figure D-5
Alternative Conceptual Models of Salmon Smolt Production for Deer Creek Spring-Run Chinook

modeling effort would be a set of constraints on the improvement to be expected from each action. The model would not need to be very complicated, and in this case a simple model would most clearly distinguish among scenarios.

Survival in the Delta. Because conditions in the Delta have received a lot of attention, and because this is the centerpiece of CALFED, we illustrate several important issues regarding survival and passage through the Delta.

Again, we use alternative conceptual models, but in this case the models differ in only one important respect: the degree of importance of tidal vs. net flows within the Delta channels (Figure D-6). Conceptual model N (for Net) holds that net flows are more important than tidal flows. According to this model, young salmon are diverted off the Sacramento River mainstem in approximate proportion to estimated net flow splits. Reverse flows such as QWEST (net flow in the lower San Joaquin River) are important either in drawing young fish toward the export pumps, or in altering salinity or other cues, confusing migrating fish as to the correct direction in which to migrate. The influence of Delta agricultural diversions (not shown in the figure) is to remove salmon in approximate proportion to the diversion flow. This model has predominated over the last few decades, despite a lack of data suggesting a strong influence of reverse flows, results of a recent study showing low abundance of salmon in agricultural diversion flows, and relatively low rates of capture of tagged salmon at the export pumps.

The alternative model T (for Tides) holds that water movement is asymmetric, with dominance by ebb or flood due to net flow and tidally-driven residual flow; the further west in the Delta, and the lower the freshwater flow, the more predominant the tidal effects. A passive particle released in the Sacramento River has a high probability of eventually moving into Suisun Bay, a moderate probability of entering the central Delta or being entrained in Delta agricultural diversions, and a low but non-zero probability of being entrained in the pumping plants. Salmon behavior complicates this in unknown ways: e.g., splits at Delta channel junctions are a complex, at present unpredictable, function of tidal flow splits and fish behavior. Furthermore, adult salmon (and probably juveniles) use tides to assist in migration. Net flows probably have little effect except where they set up or obliterate gradients (e.g., in salinity) that may provide cues for seaward migration. QWEST and other small (relative to tidal) net flows have little or no effect, although they may be related to the environmental gradients referred to above. Finally, losses to agricultural diversions depend on the size and location, as well as the flow rate, of each diversion, and because of avoidance by fish these losses may be generally low.

In the conceptual models presented thus far, we have referred to habitat restoration in a general way, implicitly assuming that restoration projects will actually benefit salmon. However, the effectiveness of restoration projects is highly variable, depending upon the degree to which their design accounts for physical and ecological processes. In the following conceptual model, we consider in more detail the factors affecting spawning success of fall-run chinook salmon, and potential strategies for restoration.

Example 2: A Conceptual Model for Fall-Run Chinook Salmon Spawning Habitat Restoration in Lower Deer Creek

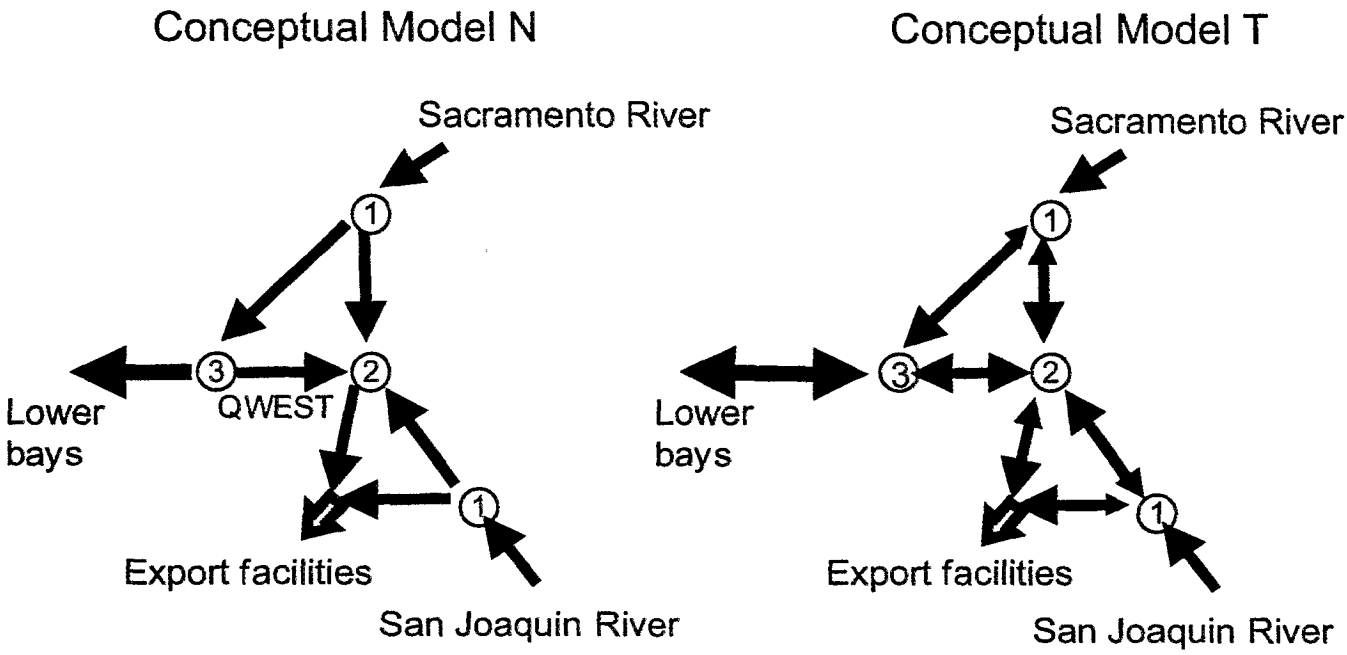
Although Deer Creek is probably most important as habitat for spring-run chinook salmon, Lower Deer Creek also provides spawning habitat for fall-run chinook (and, potentially, rearing habitat for spring-run). A number of the proposed restoration measures in Deer Creek (e.g., gravel ripping, addition of spawning gravels, installation of retaining structures) relate to spawning habitat for fall-run. Thus, an understanding of the processes and factors controlling the distribution of this habitat, and how management decisions can affect them, is important.

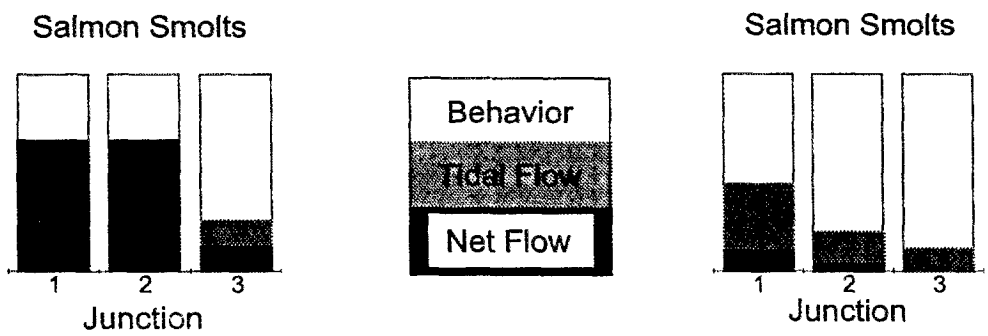
The conceptual model shown in Figure D-7 lays out the life stage functions involved in migration, spawning, incubation, fry emergence from gravels, and juvenile rearing. The model also discusses management and restoration actions in light of their effects on the requirements of each life stage. Under Upstream Migration, the fish must be able to swim from the ocean to their natal spawning grounds, which requires a path free of migration barriers. Barriers include dams, diversions, dewatered reaches, or reaches with high temperatures, contaminant concentrations, or low dissolved oxygen. For management, this implies that all dams and diversions below potential spawning grounds be evaluated for passage or removal, and adequate flows be provided to insure sufficient water quantity and quality to permit migration.

Under Digging Redds, the fish must be able to move the gravel, which is mostly a question of gravel size. Larger fish can move larger gravels, with the maximum size (median grain diameter) moveable being about 10 percent of the fish's body length. The sizes of gravel available is largely a function of the balance between the amount and size of gravel supplied by the watershed and local channel transport capacity. Below dams, the supply of gravel is usually reduced, so gravel may need to be added to make up for the lack of supply from upstream. In channelized and leveed reaches, the transporting power is locally increased, so gravels that might formerly have been stable are likely to be washed downstream.

Under Incubation, the eggs must have their metabolic wastes removed and adequate dissolved oxygen, both of which depend on adequate intragravel flow past the eggs, which in turn depend on sufficient hydraulic gradient to drive the flow and sufficient permeability in the gravels to permit the flow. The hydraulic gradient depends upon the location within the longitudinal profile and local channel geometry, with the pool-riffle transition typically creating an excellent gradient for intragravel flow (water wells down into the bed at the tail of the pool, upwells from the riffle). For ecological management, this implies that undulation in the streambed are important ecologically, and should be maintained. The permeability depends upon the amount of fine sediment (finer than 1 mm) in the gravel, which in turn is affected by the amount of fine sediment present before the fish spawned, the cleaning effect of the fish, and fine sediment infiltration after spawning. This implies that gravels with initially high levels of fine sediment can be improved during spawning, but subsequent high suspended sediment concentrations can be detrimental. Thus, the timing of fine sediment delivery to the channel may be as important as the amount.

Also under Incubation, redds must remain underwater, so they must be located where they do not dry up (or, in other climates, freeze). This is controlled by the streamflow (especially any

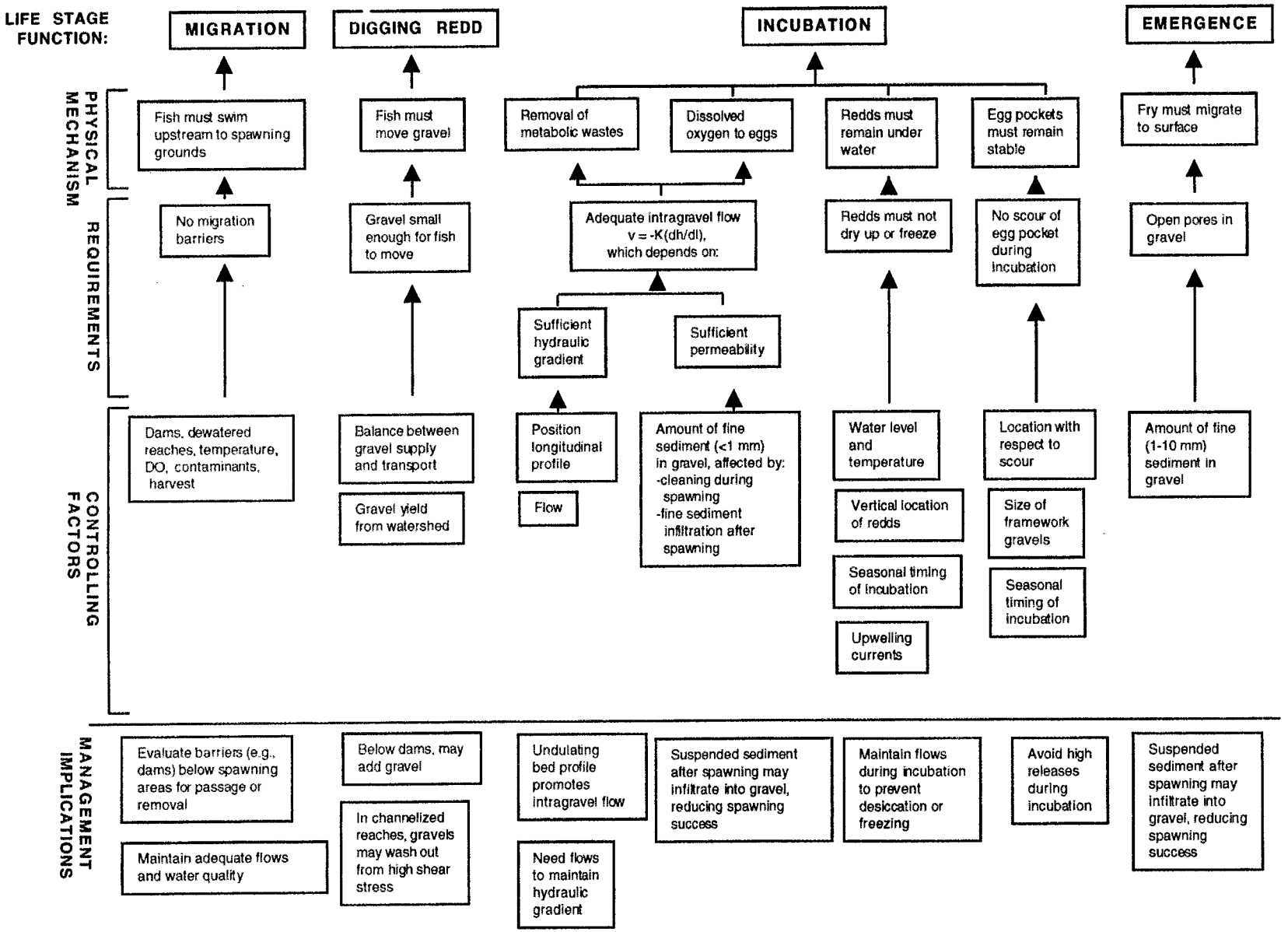




Note: Arrows and circles comprise a schematic of the Delta, with the circles representing key nodes where flow and fish diverge. Single arrows indicate river inputs, and double arrows indicate flows that are partly or mostly tidal, with the sizes of the arrowheads reflecting relative flow velocities for each location. Conceptual model A depicts net flows, with arrows indicating how fish would move under the influence of these flows. Conceptual model B illustrates how water moves in response to both tides and net flow. Fish move under the influence of these flows and their own behavior. Bar charts in the bottom panel illustrate how these conceptual models differ in their prediction of the relative influence of fish behavior, tidal flow, and net flow on the proportion of fish taking alternative pathways at each of the nodes.

Strategic Plan for the Ecosystem Restoration Program

Figure D-6
Alternative Conceptual Models of Flow and Salmon Movement in the Delta under Low-Flow, High-Export Conditions



Strategic Plan for the Ecosystem Restoration Program

Figure D-7
Conceptual Model of Salmon Spawning, Showing Factors Affecting Success at Various Life Stages

E-026396
E-026396

drops during incubation), the location of individual redds with respect to seasonal low water levels, and the timing of incubation with respect to seasonal flows. For management this implies that adequate flows are needed during the spawning and incubation season. For successful incubation, the egg pockets of the redds must remain stable, i.e., the gravel must not be scoured (at least down to the depth of the egg pocket), because salmon eggs are vulnerable to crushing if the gravel moves. This is controlled by the location of redds in the channel with respect to bed mobility, the size of the gravel, and the timing of incubation with respect to high flows. For management, this implies that on channelized reaches with increased shear stress for a give discharge, redds are more likely to be scoured than in unchannelized, natural reaches.

Under Emergence, the fry must be able to migrate through interstices in the gravel upward to the surface, so the interstices must not be filled with fine sediment (1-10 mm). This depends on the amount of fine sediment (1-10 mm) in the gravel, which is controlled by the factors discussed above.

Under rearing, the juveniles require habitats with suitable temperatures, adequate cover, refugia from high velocity flows, and food. The habitats provided by a sinuous channel, with an undulating bed and dense riparian trees along the banks and floodplain are ideal for rearing, as they meet these requirements. For management, this implies that either the characteristics of natural, sinuous channels be artificially recreated and maintained, or that the processes which maintained those conditions be reestablished.

IMPLEMENTING ADAPTIVE MANAGEMENT

In adaptive management, we select actions, implement, and monitor ecosystem response. However, because our primarily target species in Deer Creek, chinook salmon, is affected by many factors besides the physical habitat we modify, we should not only monitor salmon population levels in Deer Creek and nearby drainages (which is already done). We need to monitor a suite of ecosystem responses, such as growth and survival of juvenile salmon, abundance of amphibians, abundance of native fishes, sprouting and establishment of cottonwoods.

The two spring-run chinook salmon conceptual models lead to very different choices of restoration actions. For example, Model N would suggest that moving the point of diversion might be effective in reducing losses in the Delta, and that screening agricultural diversions is an obviously effective means of improvement. By contrast, Model T implies that survival may be more a function of flow in the Sacramento River and tidal and possibly habitat conditions in the interior Delta, so that moving the point of diversion would have no measurable effect. Furthermore, agricultural diversions may have a small effect on salmon, and altering the intakes or diversion schedules to account for salmon behavior may be as effective as the far more expensive alternative of screening diversions.

The fall-run chinook spawning conceptual model illustrates the needs of different freshwater life stages of fall-run chinook salmon, and can be used to evaluate various restoration actions. For example, gravel adding gravel to the specific sites in the channel may provide localized, short-term

benefits to spawning habitat, but a more sustainable approach to increasing habitat lies in re-establishing natural processes of channel migration, erosion, and deposition, overbank flooding, natural establishment of riparian vegetation, and transport of large woody debris. Moreover, a successful restoration approach must look beyond the site to account of watershed-level influences. if high suspended sediment concentrations occur while eggs are incubating, incubation success may be reduced. While such problems have not been documented on Deer Creek to date, the interaction suggested by the model implies that attention be paid to potential sources of suspended sediment from upstream, particularly during incubation periods.

The conceptual models also help to identify gaps in our understanding, and thus focused research and adaptive probing that would help resolve uncertainties to improve future management. For example, proportional entrainment of salmon in agricultural diversions and its dependence on location of intakes and timing of water withdrawal is not well understood and should be the subject of focused research before a large commitment of funds is made to expensive screening projects. Similarly, more needs to be known about spring-run adult mortality during summer, which can be approached by mark-recapture or other techniques. If mortality is significant, we should evaluate the potential magnitude of poaching, and design strategies to limit poaching if it is appreciable. In addition, the extent to which salmon, particularly spring-run, use the Delta for rearing should be investigated, and salmon passage through the Delta under winter conditions should be modeled using various alternative assumptions about behavior in response to environmental cues.

If ecosystem restoration is undertaken by setting back levees and permitting a dynamic, irregular channel to develop on Lower Deer Creek, the evolution of channel form should be carefully monitored. After each flood capable of moving bed material, the channel should be resurveyed, and the distribution of habitats inventoried from detailed aerial photographs and compared with similar information from 1939 aerial photographs as a way to measure recovery back to the favorable conditions that existed before the flood control project.

Improvements to freshwater habitat should be accompanied by reductions in ocean harvest to a level consistent with restoration, and we should monitor both harvest and total escapement of salmon to gauge success.

CONCLUSIONS

Implementing an effective restoration program will require more than developing site-specific restoration projects. It is essential that we step back and look at the big picture, and the big picture can be defined in more than one way Conceptual models can provide a useful approach to look at the big picture. We have illustrated species-based and river-ecosystem-based conceptual models and demonstrated their use in decision making. Each kind of approach is useful, and each provides different information.

In any restoration program, the complex nature of river systems and multiple causes for declines in populations of important must be acknowledged and planned for. Because of this

complexity, restoration actions may not yield the anticipated results. For example, habitat restoration measures for fall-run chinook salmon may not result in increased populations due to downstream factors such as over-harvesting, but the habitat restoration may increase populations of yellow-legged frogs. If the downstream problems are addressed, eventually salmon populations may increase as a delayed result of habitat improvements. Meantime, there are other benefits from habitat restoration, including, for example, hydrologic benefits from restoration of meadows in the upper watershed.

On Deer Creek, spawning and rearing habitat for spring run (in the canyon reaches) is in generally good condition. This implies that we should not undertake habitat enhancements in this reach to increase populations (if it ain't broke, don't fix it), but also that protection of this habitat becomes a top priority. One potential threat to spring-run habitat would be spills of hazardous materials into the creek from trucks on Highway 32 (upstream of the best spring-run habitat). In the past, diesel fuel has spilled into the creek, demonstrating the potential for more serious accidents. Restrictions on or elimination of truck traffic in hazardous materials on this highway should be considered.

E —0 2 6 4 0 0

E-026400

Printed by
Department of Water Resources
Reprographics

E —0 2 6 4 0 1

E-026401