EXECUTIVE SUMMARY

I. Background and Introduction

A vast watershed connects the mountain streams surrounding California's Central Valley with San Francisco Bay and the ocean beyond. Over the course of the last two centuries, much of the natural productivity, biodiversity and ecological integrity of the watershed has been destroyed by modifying the environment without fully understanding the long-term environmental consequences. Long the site of some of the nation's most intensive conflicts over the use of land and water resources, this system is now emerging as the focus of one of the most ambitious ecological restoration efforts ever undertaken in the United States.

This report was designed to provide a coherent and defensible *ecological framework* and information base for restoration. The need for such an historical, broad-scale perspective on system ecology stems from two fundamental principles of ecological restoration - the need to manage toward a natural template and to manage at ecosystem and landscape levels.

> **(1)** ***Manage toward the natural template***. Natural conditions and processes shaped the life history requirements of native species. While we may not fully understand the requirements or inherent adaptability of any particular species, we do know that these were closely tied to the historic attributes and variability of the systems in which they lived and evolved. Therefore, this report attempts to provide a description of the natural ecosystem. The period prior to 1850 - a time before the system was significantly altered by human activities - was chosen as the basis for the "natural" undisturbed watershed. Comprehensive restoration in the truest sense of the term - a return to pre-disturbance conditions - is *not* a realistic goal, or even a possibility, for most of the watershed. Nonetheless, careful consideration of environmental conditions at a time when the system was in a relatively undisturbed state provides a necessary baseline from which to develop the conceptual framework and practical tools necessary for effective restoration and management planning at the ecosystem and landscape levels.
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> **(2)** ***Manage at ecosystem and landscape levels.*** The basic conservation and management unit for aquatic systems should be an area large enough to support self-sustaining populations of native species. Ecosystem and landscape-level approaches to restoration / management efforts focus upon large-scale spatial areas, and the habitats contained within. This

fundamentally differs from species-level efforts, which instead are based upon attempts to identify and address the "needs" or "limiting factors" of particular *species*. Broad-scale, area-based approaches address a number of essential conservation needs that single-species approaches do not. They provide a means to protect species about which little is known, and a means to protect a wide variety of species while they are still common. Nonetheless, it must be emphasized that broad ecosystem-level conservation strategies and restoration programs are meant to *complement* rather than *replace* species-level conservation strategies. Both are necessary to address conservation needs.

To provide the information necessary to support restoration efforts, this report addresses four fundamental areas:

(1) The natural system prior to 1850 is described in Chapter 2,

(2) Changes to the natural system are documented in Chapter 3,

(3) The resulting ecological response and contemporary system are described in Chapter 4, and

(4) Recommendations for guiding system-wide restoration efforts are presented in Chapter 5.

II. The Watershed: Two Centuries of Change

The watershed is far too large and ecologically heterogeneous to be considered a single ecosystem in the usual sense of the term. Rather, it is more appropriately (for management purposes) considered a mosaic of a number of different ecosystems that are integrated into a larger landscape. The watershed (and this report) are divided into five separate aquatic ecosystems -- upland river-floodplain, lowland river-floodplain, the Delta, San Francisco Bay, and the nearshore ocean. This report addresses only aquatic ecosystems, because the impetus for habitat restoration in this system is to provide habitat for declining fishes. The report also focuses on the lowland-river floodplain and the Delta because these are the current targets of most restoration activities. Other habitats not directly connected to these principal aquatic ecosystems, such as lowland prairies or mountain forests, are not addressed. This report documents each of these aquatic ecosystems and factors causing their decline using eyewitness accounts, scientific investigations, historic maps, and local and regional histories.

The Sacramento and San Joaquin Rivers collect water from a vast drainage area, stretching from the Cascades to the Tehachapi, and from the Sierra to the sea. These rivers first begin to mix with ocean waters in the Delta. From there, water flows into and through a series of large embayments collectively known as greater San Francisco Bay. The estuary discharges to the Pacific Ocean through the Golden Gate. This aquatic “circulatory system” is the life blood of the five major, interactive aquatic “ecosystem types” described in this report.

The natural landscape and associated biological communities have been drastically altered by California’s population boom of the last 150 years. Harvest of plants and animals, the introduction of exotic species, livestock raising, farming, mining, urbanization, development of navigable waterways, flood control, and the redistribution of water resources have altered the landscape and its native biota in many ways, both directly and indirectly. The precise linkages and mechanisms that have mediated any particular population or species-level change are unknown in many cases, but in total the effects of these combined human interventions on system ecology is staggering. The most severe of these are summarized below, at both the landscape and ecosystem levels.

II.A. A Watershed-Scale Perspective

Under natural conditions, flood waters in the lowland Central Valley spilled over natural levees and coursed through an intricate network of distributary sloughs into vast tule marshes that flanked the main river channels. Enormous flood plains and natural flood basins functioned similar to reservoirs, filling and draining every year. This delayed the transmission of flood flows, reducing peak flows and velocities, and increased summer flows as the waters spread out over the floodplain slowly drained back into the river later in the year. At the watershed scale, changes in system hydrology appear to have had the greatest and most pervasive effects. These changes include reclaiming the marshes to make way for agriculture, replumbing the entire valley to control flooding, and constructing one of the largest water delivery systems in the world. These changes, along with more localized interventions, have substantially altered the ecology of each of the watershed’s aquatic ecosystems, as summarized below.

Native vegetation was the first casualty of the rapid growth that followed in the wake of the Gold Rush. Riparian forests or woodlands occurred along virtually all of the streams and rivers of the Central Valley, including the broad natural levees of the Sacramento and Feather Rivers. These forests and woodlands were the most accessible woody vegetation on the valley floor and were rapidly used for fencing, lumber, and fuel by early settlers; they were also cleared to make way for farms. By the 1880s, a significant portion of the riparian forest had been harvested.

The freshwater marshes, which stretched from Willows to Bakersfield in a continuous swath of green, were nestled in river bottoms, in the Sacramento Valley flood basin, and in the Delta. They proved more intractable to the plow and engineering prowess than the riparian forests and did not succumb to the advance of civilization until the turn of the century. These marshes originally functioned as vast floodplains that were inundated by the tides in the Delta and overbank flooding in the Sacramento and San Joaquin Valleys, and were sustained throughout the year by an intricate network of sloughs that connected them with the main channels. The Delta marshes with their rich peat soil were reclaimed first. The valley marshes were not reclaimed until natural flooding was controlled in the 1920s by the complex system of weirs and bypasses that now drain the Central Valley, dredging technology and engineering skills advanced, and state laws were passed to finance and organize reclamation districts to carry out the work on a large scale. Most of the marshes were under cultivation by 1930, ushering in the rush to supply water to the farms and cities that replaced them.

Today, this once richly-endowed landscape is crisscrossed with a maze of aqueducts and canals that deliver water to farms and cities where formerly wildlife thrived. This "aqueduct empire," comprising some 31 million acre feet of reservoir storage, 100,000 groundwater pumps and 1,300 miles of aqueducts and canals, redistributes and transports 30 million acre feet of water every year, and together with marsh reclamation and flood control, has transfigured the "circulatory system" of the watershed. Almost no natural floodplain storage remains. Nearly every major waterway draining the encircling mountains has been interrupted by a series of dams, in most cases terminating in the foothills in a large "terminal" storage reservoir. These have disrupted wetland and riparian corridors and their native fishes and wildlife that formed the natural biological links among aquatic ecosystems. The main changes evident below the terminal storage dams are a pronounced reduction and temporal shift in flows, reduced monthly and inter-annual variability, and shifts in water quality. Average winter/spring flows are now substantially lower, and summer/fall flows slightly higher than they were under natural conditions, except in those drainages, particularly in the San Joaquin and Tulare Lake Basins, where much of the flow is diverted into canals.

On a valley-wide basis, the volumes of large floods remain largely unchanged, although only in very heavy snowpack years do flood flows approach historic levels in the San Joaquin Valley. Rather than regularly spilling out onto floodplains, flood flows today are instead confined to riprapped and artificially leveed river channels (or bypass channels) and quickly conveyed out of the river systems and into the lower estuary and the Pacific Ocean.

In addition to hydrologic changes, sediment transport through the system has been greatly altered. Sediment delivery rates for the upland rivers of the heavily-mined basins remain two to eight times greater than natural, and large deposits remain in some channels from hydraulic mining in the 19th century. Today, rivers below the dams have no source from which to replace sediments removed from their channels.

II.B. Upland River-Floodplain Systems

Riparian forest was naturally distributed along most of the entire length of upland river and stream channels, supporting highly diverse assemblages of insects, amphibians, reptiles, birds and mammals. There has been a widespread and substantial loss and degradation of riparian zones throughout the region. Perhaps as many as 25% of the species dependent upon riparian habitat of the upland region are now at risk of extinction.

It has been estimated that due to dams and other barriers, about 90% of historical salmon spawning habitat in the Sacramento-San Joaquin system is no longer accessible to these fishes. The amount of large woody debris in streams, which normally originates in nearby forests, has declined markedly throughout much of the Sierra, degrading in-stream habitat by reducing complexity. Non-native fishes are now widespread and abundant throughout much of the upland system, and continue to adversely affect the distribution of a wide range of native species.

Water quality problems plague much of the upper watershed. Downstream of dams, altered channel morphology and benthic sediment characteristics, as well as elevated turbidity and temperatures are widespread. Mining, logging, urbanization, and recreational use have increased sediments, nutrients, and bacterial and chemical pollution of once pristine mountain streams.

II.C. Lowland (Alluvial) River-Floodplain Ecosystems

Under natural conditions, vast riparian forests teeming with wildlife inhabited natural levees along every stream channel in the Central Valley, stretching like a green ribbon for miles on both sides of the channel in some areas. Permanent marshes, choked with tules, dotted with lakes, and crisscrossed with distributary sloughs, nestled between the riparian forests and oak woodlands/savannas and vernal pools that stretched across the plains as far as the eye could see.

This report estimates that there were about one million acres of potential riparian habitat, about 900,000 acres of tule marsh, and 415,000 acres of vernal pools in the Sacramento and San Joaquin Basins alone, and additional unquantified acreages of oak woodland/savanna. Huge expanses of this vegetation were also present in the Tulare, including some 477,000 acres of tule marsh and 256,000 acres of riparian oak woodland in the Kaweah delta alone. Today, this vegetation has been almost entirely lost, mostly converted to agricultural production. Less than 5% of historical wetlands, 11% of vernal pools, and about 6% of the riparian zone remain in a quilt of disconnected patches too small to sustain dependent species. Remaining patches of riparian forest, for example, exist as narrow, fragmented corridors less than 100 yards wide, and only a small fraction of those are in nearly pristine condition.

The naturally meandering rivers described above are today generally constrained in straightened leveed sections. Confinement of the main channel between riprapped levees eliminated most meander cutoffs and oxbows, pool/riffle sequences, sunken woody debris and other habitat complexities. Water quality remains severely degraded, due to the combined effects of inactive mine discharges and urban and agricultural runoff. The Tulare Basin lakes are but a faint memory, having been converted to agriculture and hydrologically disconnected from the east side tributaries and San Joaquin River, except in unusually wet years. Floodplain habitat that supported this landscape has been dramatically altered. Most of the natural flood basins are now effectively isolated from the river, except during major floods. Once miles-wide active floodplains are now limited to narrow terraces between levees and flood bypass channels.

Herds of large mammalian herbivores - deer, antelope and elk - and their mammalian predators once depended upon the forests and marshes. They have been reduced to a few scattered remnant populations, as have many of the small mammals that typically occupied these habitats. Birds have been particularly hard-hit, with many once-common species now reduced to remnant populations or extinct. Waterfowl no longer blacken the skies above the Central Valley marshes. Fish populations have dramatically declined due to a long succession of assaults, including marsh reclamation, hydraulic mining, pollution, flood control, and water resource development. The lowland rivers are now dominated by introduced species rather than native fish assemblages.

II.D. The Delta

Prior to 1850, the Delta was probably the richest ecosystem of the watershed in terms of abundance and diversity of game animals and birds. It was largely a vast, sea-level swamp, composed of huge tracts of intertidal wetlands transected by a complex network of waterways. The Delta of today bears little resemblance to its historical condition. Today, over 95% of the original 550 square miles of tidal wetlands are gone. Many miles of tidal sloughs no longer exist, nor does most of the riparian vegetation that once bordered the larger waterways. In its place is a patchwork of intensely-farmed "islands," riprapped and elevated levees, straightened and deepened channels, permanently flooded remnants of former wetlands now too far underwater to allow the re-establishment of emergent vegetation, and the center of one of the largest man-made water delivery systems in the world. Massive State, Federal, and local agency pumping plants, and over 1,800 unscreened agricultural diversions now transfer water, fish and drifting estuarine life out of the aquatic environment.

Pollution in the Delta is a serious concern today, because it is a source of drinking water and is occasionally toxic to aquatic organisms. Delta waters contain elevated concentrations of pathogens, pesticides, trace metals, salinity, and organic carbon which is a disinfection by-product precursor.

The combination of habitat loss and successful invasion by a virtual army of non-native species has almost completely obliterated the Delta's native biological community. Benthic assemblages are dominated by non-natives. The native resident fish fauna has been replaced by a largely introduced assemblage. Two of the three historically dominant fish species are no longer found here. Waterfowl, once extremely abundant in the Delta's tidal marshes, are now drastically reduced in numbers. Of the diverse and abundant native mammalian assemblage formerly found in the Delta, only a few aquatic species - otter and beaver , along with the raccoon - are still seen, though in vastly reduced numbers and at scattered locations. Nutrient and energy sources, and food webs have been greatly modified.

II.E. Greater San Francisco Bay

San Francisco Bay has undergone major habitat alterations over the course of the last two centuries. About 75% of the estimated 242,000 acres of highly productive native tidal marshes and mudflats has been converted to a variety of urban/industrial uses, altering trophic dynamics and food webs. Native biological assemblages of the Bay have been drastically altered by a combination of overharvesting, habitat loss and degradation, pollution, and the introduction of exotics. The topography of the Bay floor continues to be periodically disturbed by dredging to maintain shipping channels. Changes in upstream hydrology and erosion, sediment transport and deposition rates have affected sediment types and distribution - and therefore benthic invertebrate assemblages - throughout the Bay.

II.F. The Nearshore Ocean

Most substantive interactions (regular exchange of water, nutrients, and organisms) between the nearshore ocean and the rest of the watershed are concentrated within a comparatively restricted area near the Golden Gate. Some oceanic processes or events may occur beyond these boundaries that influence watershed ecology. These may include, for example, changes in oceanic conditions such as temperatures, currents, and water quality that affect the migration patterns of anadromous fish or marine density-dependent mechanisms, such as food supplies or predation, that limit populations. However, while these are generally considered well beyond the scope of practical management or restoration efforts, they must be recognized to understand the probable success of restoration efforts.

Shoreline habitats throughout the region have been severely modified in many cases. Pollution offshore is generally not high relative to inshore coastal sites of Central California but nevertheless exists from historic dumping. Over-harvesting of once-plentiful abalone and other shellfish has undoubtedly affected rocky intertidal communities. Ocean harvest of salmon has steadily increased at a rate of about 0.5% per year for the last 40 years, for a total increase of about 20%.

III. Applications: Building a Practical Framework for Ecosystem Restoration and Management

Restoration efforts in this highly developed and populated watershed must necessarily reflect a compromise between conflicting needs. Ensuring the long-term protection of the watershed's ecosystems and habitats requires comprehensive, ecosystem-level efforts. The comprehensive restoration of the *entire* geographic range of the watershed is neither feasible nor desirable. It is incompatible with the needs of 30 million human inhabitants of the state, needs which *also* must be met. Further, the degree of disturbance and (in some cases) irreversible changes in the watershed render it technically and economically unfeasible to undo two centuries of unchecked damage. What then might be the strategic solution to this apparent conflict? Two fundamentally different options are available: A limited number of particularly desirable ecological characteristics (e.g., increased population levels or production) can be rehabilitated.

This approach, called partial restoration or rehabilitation may provide substantial "*ecological benefits even though full restoration is not attained*" (NRC 1992). Alternatively, comprehensive restoration to full ecological integrity throughout the watershed can be attempted.

Planning efforts to date suggest that only *a combination of both approaches* - full-scale restoration at selected sites, and rehabilitation throughout the entire watershed - will achieve the diverse long and short-term biological conservation / resource enhancement goals encompassed by the CALFED program in a manner compatible with current and projected human population levels and their resource needs.

IV. Concluding Recommendations

This report examines the ecological history of the Bay-Delta-River watershed, and considers alternative strategic approaches to ecological restoration that might lead to long-term protection of the system's native species, ecological structure and function. Based upon these analyses, we make the following broad recommendations:

(1) An ecosystem approach to natural resource restoration and management is the most effective available means to meet the need for long-term protection of ecological integrity and biodiversity within the watershed. Specific long-term restoration actions should be primarily (although not exclusively) aimed at enhancing and protecting essential ecosystem processes and structural features. This approach must be complemented with efforts that address the immediate needs of threatened and endangered species. The granting of protected status and preparation of recovery plans for individual species must remain a viable tool in our comprehensive species protection strategies.

(2) A restoration strategy should be adopted to assure a connected network of representative areas of each of the ecosystem and habitat types defined herein.

(3) Flows, sediments, and water quality conditions must be adequate to support essential ecosystem functions. Sufficient connectivity must be provided among restored sites to allow the natural migration and movement of wide-ranging species.

(4) New restoration / management actions must address the needs of surviving remnant populations.

Adopting the recommendations of this report will not resurrect the rich, complex, undisturbed ecosystems of the San Francisco Bay-Delta-River system of 200 years ago. Nonetheless, applying an understanding of "natural" watershed ecology will serve as an invaluable guide to comprehensive restoration. The most successful restoration program for this watershed will ultimately be one that applies the precepts of modern restoration ecology within the practical limits of resources available and the constraints set by other legitimate societal needs. Such efforts - properly designed and executed - have the capacity to protect, restore and sustain native ecosystems, and the full range of remaining native plants and animals that depend on them. They will also reduce conflicts over protection of endangered species, provide for more economically and environmentally sound flood management, enhance recreational opportunities, ensure high water quality for urban and industrial uses, and create an aesthetically more pleasing environment. It is our best opportunity to preserve the unique ecological heritage of California's Bay-Delta-River watershed for ourselves and future generations.