CENTRAL VALLEY PROJECT IMPROVEMENT ACT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT TECHNICAL APPENDIX

Summary of Pre-CVPIA Conditions

September 1997

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

af	acre-feet
Bay-Delta Estuary	San Francisco Bay/Sacramento-San Joaquin Delta Estuary
CEQA	California Environmental Quality Act
cfs	cubic feet per second
COA	Coordinated Operations Agreement
CVGSM	Central Valley Ground-Surface Water Simulation Model
CVHJV	Central Valley Habitat Joint Venture
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley Project Model
D-	State Water Resources Control Board Decision
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
ESA	Endangered Species Act
GWh	gigawatt-hour
M&I	municipal and industrial
msl	mean sea level
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NWR	National Wildlife Refuge
OID	Oakdale Irrigation District
PEIS	Programmatic Environmental Impact Statement
PG&E	Pacific Gas and Electric Company
ppm	parts per million
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Bureau of Reclamation
Secretary	Secretary of the Interior
Service	U.S. Fish and Wildlife Service
SSJVID	South San Joaquin Valley Irrigation District
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
USFS	U.S. Forest Service
Western	Western Area Power Administration
WMA	Wildlife Management Area
WR	Water Rights

LIST OF ABBREVIATIONS AND ACRONYMS

af	acre-feet
Bay-Delta Estuary	San Francisco Bay/Sacramento-San Joaquin Delta Estuary
CEQA	California Environmental Quality Act
cfs	cubic feet per second
COA	Coordinated Operations Agreement
CVGSM	Central Valley Ground-Surface Water Simulation Model
CVHJV	Central Valley Habitat Joint Venture
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley Project Model
D-	State Water Resources Control Board Decision
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
ESA	Endangered Species Act
GWh	gigawatt-hour
M&I	municipal and industrial
msl	mean sea level
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NWR	National Wildlife Refuge
OID	Oakdale Irrigation District
PEIS	Programmatic Environmental Impact Statement
PG&E	Pacific Gas and Electric Company
ppm	parts per million
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Bureau of Reclamation
Secretary	Secretary of the Interior
Service	U.S. Fish and Wildlife Service
SSJVID	South San Joaquin Valley Irrigation District
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
USFS	U.S. Forest Service
Western	Western Area Power Administration
WMA	Wildlife Management Area
WR	Water Rights

C-080962

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

The development of water supply and hydro-power generation projects in the Central Valley occurred over an extended period, primarily between the late 1800s and into the 1970s. The earliest projects were primarily for local agricultural and power needs. Later in the 1940s and 1960s, construction of the states two major water projects, the Central Valley Project (CVP) and the State Water Project (SWP), were initiated to provide water supplies to users throughout California. Since the late 1800s, fishery resources in the Central Valley have been impacted through the reduction of fishery habitat, modification of flow and water quality conditions, introduction of non-native species, and the development of river and ocean commercial fisheries. Vegetation and wildlife resources have also declined during this period due to reduction in the amount of wetland and riparian habitat, continuing agricultural and urban land development, and other factors.

Since the late 1970s, the establishment of regulatory policies for the protection of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Estuary) and for the protection of endangered species has required changes in the operation of the CVP and SWP, and has resulted in a reduction in water delivery capabilities of both projects. During the period between the late 1970s and present time, annual CVP operations have also varied in response to changing hydrologic conditions including a six-year drought from 1987 though 1992, increasing water demands, reduced available supplies, and the implementation of additional regulatory requirements.

This report presents a summary of historical fishery and vegetation and wildlife resources in the Central Valley, describes regulatory actions that were undertaken since the late 1970s to protect these resources prior to the Central Valley Project Improvement Act (CVPIA), identifies changes in water demands and available supplies, and evaluates the resulting changes in the CVP's ability to provide water.

The effects of these changes on CVP operations are evaluated through the analysis of three distinct simulation scenarios. Each scenario evaluates long-term operational conditions under a different set of demands, available supply, and regulatory requirements. The evaluation also includes assessment of associated changes in groundwater conditions in the CVP service area, CVP power generation and Project Use, and agricultural land use and economics in the CVP service area.

CHAPTER II

CHANGES IN WATER AND BIOLOGICAL RESOURCES

Chapter II

CHANGES IN WATER AND BIOLOGICAL RESOURCES

HISTORICAL BACKGROUND

This chapter provides a brief overview of water resources development in California, from the late 1800s to the present, followed by a discussion of the resulting changes to biological resources including fisheries, vegetation, and wildlife. This background information is provided to give a general perspective of the changes that occurred in natural ecosystems preceding the enactment of the CVPIA.

From the time of recent recorded history in California in the 1800s to the present, there has been a continued increase in water and land development, and a corresponding decrease in the natural ecosystems that support both aquatic and upland species of plants and animals. Historic information is available to document changing environmental conditions in the Central Valley since the late 1800s through the present.

Water supply development in the Central Valley began as early as the 1840s, when streams and rivers were modified by hydraulic mining and dredging, the construction of diversion dams and flumes, and the construction of levees in the Delta and along the rivers. Many of the levees originally built in the mid-1800s were raised in the 1910s to minimize flooding that occurred when the river bed elevations were rising due to deposition of mining debris. It was recognized at an early date that these water resource projects adversely impacted the environment. In 1878, Kern Lake was eliminated due to diversions of upstream water. In the 1880s, the University of California reported that the Kern River had excessive salts and that Tulare Lake had poor water quality due to return flows. Drains were installed through the San Joaquin Valley in the 1920s and 1930s to remove poor quality flows from intensive irrigation of farm lands. The drainage flows and return flows were conveyed to the rivers that had been reduced in volume by upstream diversions.

During that time period, a noticeable decrease in existing populations of fish, wildlife, and natural vegetation occurred. In 1870, the State Fish Commission was created to require the use of fish ladders and enforce catch restrictions. However, in spite of these efforts, fish populations continued to decline. In 1872, the U.S. Fish Commission recognized the need to improve salmon populations and opened the first salmon hatchery on the McCloud River. A striped bass hatchery was opened in 1906 in the Sacramento-San Joaquin Delta (Delta) to support the fish population resulting from the introduction of that species into the Delta in the 1870s. A shad hatchery was opened on the Feather River in 1916.

Wildlife and vegetation also were reduced during the growth period in California. Feral livestock introduced in the 1770s by the Spaniards consumed much of the native vegetation and indirectly introduced non-native grasses. During this period, increased hunting depleted the native stocks of wildlife populations. Many of the riparian forest areas were destroyed for use as fences and fuel. The Hudson Bay Company determined that in 1846 the remaining beaver and antelope populations were not adequate to support their business. By the 1890s, populations of swan, mink, gray fox, weasel, bighorn, and antelope had significantly declined from pre-European settlement populations. Waterfowl also were hunted which led to the State Fish Commission establishment of bag limits of 50 birds per day in 1901.

As development of California continued, water resources continued to be developed and ecological resources continued to be adversely impacted. From the early 1900s through the early 1970s, there was a major effort to develop supplemental and reliable water supplies by constructing water resources storage and conveyance facilities. Most of the existing water resource projects had been constructed by the early 1970s, including the CVP and the SWP facilities. During the 1960s and 1970s, California was also changing to accommodate significant population growth. That growth frequently resulted in conversion of agricultural and natural lands to municipal uses. In addition, population growth increased the use of the state's limited water resources, which are shared with agricultural users and the natural habitat.

Similar issues elsewhere in the United States raised concerns about the need for methods to ensure that adequate review was completed for each project and that the public had an opportunity to review and provide comments to the decision makers. Due to this concern, many special interest groups were formed to support environmental protections, the Congress passed the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA). The California State Legislature passed the California Environmental Quality Act (CEQA) and the California Endangered Species Act. Implementation of these actions in the 1970s helped raise awareness of the interactions between environmental conditions and specific actions associated with agricultural and urban development, operations of water supply facilities and flood control facilities, waste disposal practices, air emissions, and other human activities.

As part of this increased awareness, the U.S. Fish and Wildlife Service (Service) and others began to formally evaluate the impacts to habitat associated with water supply facilities operations, including operations of the CVP and SWP. Through this process, it was recognized that the CVP and other water resource projects had been constructed and placed into use without the current level of knowledge and consideration for environmental concerns. As a result of these early studies and reports in the 1980s, there was the beginning of an adjustment phase that started the effort to consider impacts and benefits to the natural environment as well as the human environment. This effort resulted in new policies and legislation that were aimed at protecting the natural environment primarily through obtaining reliable water supplies and providing for habitat restoration for mitigation purposes.

Policies that are directed towards obtaining reliable water supplies for fish and wildlife purposes have included programs that increased minimum instream flow releases from the most recent water rights holders as defined through the State of California water rights permits process. Two of the more recent large water rights permits holders are the CVP and SWP. In addition, the State Water Resources Control Board (SWRCB) has determined that operations by these water suppliers have a major impact on flow and water quality patterns in the Delta and major rivers in northern California.

As growth has occurred in California, many water rights holders have changed land uses from agricultural uses to municipal uses. As water demands have increased, use of groundwater and surface water has increased. In addition, areas historically dry-farmed or minimally irrigated are being used for municipal development, requiring water throughout the year and frequent use of surface water rights for water supply. As upstream users have increased their use of upstream water rights and/or CVP or SWP contracts, the CVP and the SWP have lost some of their ability to provide for Delta water quality conditions, to minimize impacts on the fish and wildlife resources of the Delta and other areas, and to meet existing contractual supplies.

FISHERY RESOURCES

The streams of the Central Valley of California have historically supported a diverse and highly productive aquatic ecosystem, including resident and anadromous fisheries. Major human-induced modifications of fish habitats began during the first major settlement of California that followed the 1849 gold rush. Since that time, many native species have declined in abundance and distribution, and several introduced species have become well established. As a result, historical fishery resources within the Central Valley were quite different from the fishery resources present today.

FACTORS AFFECTING FISHERIES

Many historical actions have affected fisheries resources during the past 150 years; major factors include habitat modification, the introduction of non-native species, and overfishing. Due to the multiple factors that have cummulatively played a role in the reduction of fisheries populations, it is not possible to correlate fisheries impacts to specific historical actions based on existing data. Therefore, this section briefly describes these actions, and the types of impacts that they have generally had on Central Valley fisheries. For a more detailed discussion of fisheries refer to the Fisheries Technical Appendix.

Fishery Habitat

The construction of major dams on most rivers in the Central Valley permanently altered the chinook salmon stock composition in the Central Valley and eliminated some wild stocks of spring-run chinook salmon, once the dominant race of chinook salmon in California. Steelhead runs also were reduced to a fraction of historical levels. Available spawning habitat was restricted to main river channels and small tributaries at lower elevations, habitat best suited for fall- and late-fall-run chinook salmon. The dams also blocked recruitment of spawning gravels from upstream sources to the portions of rivers still available for salmon and steelhead spawning. Gravel mining also eliminated spawning habitat.

Shasta and Keswick dams, built on the Sacramento River in 1944 and 1950, respectively, blocked approximately 190 miles of spawning habitat on the upper Sacramento, Pit, and McCloud river drainages. The Red Bluff Diversion Dam (RBDD), built in the mid-1960s on the Sacramento River 60 miles downstream of Keswick Dam, has been an impediment to the upstream migration of adult salmon. Nimbus and Folsom dams blocked approximately 61 miles of spawning habitat on the American River. A like amount of spawning habitat on the Feather River was blocked by the SWP construction of the Oroville Dam. Friant Dam on the San Joaquin River blocked access to approximately 35 miles of upstream spawning habitat, and reduced flows in the San Joaquin River.

The large dams altered the temperature regime in the rivers downstream, which affected chinook salmon, steelhead trout, and other game and non-game species. For a period after the large dams were constructed, reservoirs were kept relatively full, and the cold water released from the hypolimnion provided cooler summer temperatures in the downstream reaches. Fall-run chinook salmon populations responded to the colder flows and began to spawn earlier than historical salmon runs. In the early 1980s, however, the reservoirs have been drawn down farther because of increased water demands, resulting in warmer water releases and higher egg mortality rates. Winter-run chinook salmon, which spawn in spring and summer, have been especially harmed by the warmer water temperatures.

In addition to blocking spawning migrations of chinook salmon and steelhead, the operation of the dams for water supply purposes changed the timing of water flow patterns in the rivers and Delta affecting most fish species. Because resident fish populations above dams were reproductively isolated, outbreeding and natural recolonization in the event of extinction were no longer possible. Diversions, especially for irrigation, entrained and killed many millions of young chinook salmon, steelhead, and other fish species. Diversions also dewatered sections of streams to the point that insufficient flow prevented migrating adult salmon and steelhead from passing through, eggs from incubating, or juvenile salmon and other fish from rearing successfully.

The abundances of many Delta and Bay species are strongly related to the magnitude of flows into and out of the Delta. The timing and magnitude of high flows in fall, winter, and spring influence migrations and spawning of many fishes in the rivers and estuary. Flows also affect food supply and water temperature and therefore influence growth. Reverse flows in the Delta due to export pumping may distort normal transport and migration patterns of many fish species, resulting in high mortalities from predation, entrainment, and other causes. Flow regulation can create complex adverse impacts that reduce fishery potential in a cumulative fashion.

The operations of upstream dams and in-Delta pumping facilities and diversions have altered natural flow regimes by changing the frequency, magnitude, timing, and direction of flow. These changes potentially affect all fish species in the rivers, Delta, and Bay. The operation of CVP and SWP export facilities in the South Delta and the Delta Cross Channel have greatly altered flow patterns in the Delta and cause entrainment and mortality of young fish of all resident and anadromous species.

Additional diversions by agricultural, municipal, and industrial interests in the Delta and the Sacramento and San Joaquin rivers are thought to entrain many millions of young fish annually. During spring and early summer, many emigrating juvenile chinook salmon and steelhead die at improperly screened and unscreened irrigation diversions and pumping facilities.

Modifications of fish habitat resulting from levee construction and channel dredging have continued into the present period. Fish species diversity is generally much lower in channelized sections of streams than in undisturbed sections. By the mid-1960s, the Sacramento River Flood Control Project consisted of more than 440 miles of river, canal, and stream channels, 1,000 miles of levees, and 95 miles of bypasses. Additions to the project are ongoing and proposed for the future.

Contamination of fish habitats by agricultural drainage, urban runoff, and industrial and municipal discharges is a continuing problem. High salinity and pesticide runoff from agricultural lands have been especially severe in the San Joaquin River. Pesticides in drainage from rice fields have been implicated in the mortality of striped bass and may have played a role in their decline. Dredging to maintain ship channels in the Bay and Delta creates turbidity and resuspends contaminants present in the sediments.

Species Introductions

Exotic species were first introduced in the Sacramento-San Joaquin river system shortly after the gold rush. Most of the species were introduced to improve fishing or provide forage for game species. Striped bass were introduced from the Atlantic coast in 1879 and 1882, and the population quickly multiplied to millions of adults. American shad were introduced from New York between 1871 and 1881 and were well established by 1879. Largemouth and smallmouth bass, catfishes, and sunfishes were also introduced.

In some instances, exotic species were introduced because the native fishes were no longer productive in habitats altered by human activities. The introduced species adversely affected native species through predation, competition for habitat and food, and hybridization. Introduced species became more abundant than native species in some parts of the Sacramento-San Joaquin river system.

The introduction of exotic species has continued into the present period, and introduced species are now more abundant than native species in many areas of the Central Valley. The major difference between recent introductions and those of the earlier period is that most of the recent introductions have been accidental. Many species were introduced into the estuary by ships discharging ballast water that contained exotic species.

Commercial And Sport Fishing

Commercial fishing may have been a major contributor to the depletion of chinook salmon stocks following the gold rush . The first organized commercial fishery in the Sacramento-San Joaquin river system was developed between 1848 and 1850. Chinook salmon were taken in gill nets and seines in the rivers, the Delta, and the Bay; and sardines, herring, and flatfishes were captured with seines in the Bay. Commercial fishing expanded rapidly after the gold rush. From 1873 to 1910, more than 20 canneries processed 5 million pounds of chinook salmon annually from the Sacramento and San Joaquin river system. The river fishery for salmon peaked in 1910 at more than 10 million pounds and then began a somewhat continuous decline until gill netting was abolished by legislative action in 1957.

A commercial ocean salmon fishery was developed in the 1890s and early 1900s and largely replaced the collapsed river fishery. Fishing has potentially contributed to the declines of salmon, steelhead, striped bass, and American shad as commercial salmon fishing effort and effectiveness have increased substantially. Ocean harvest of Central Valley chinook salmon was at an all-time high in 1988, both in terms of harvest rate and number of salmon caught. High ocean harvests result in lower returns and smaller sizes of spawning salmon. Figure II-1 shows the variability in the annual total California commercial landings of chinook salmon for the period 1935 through 1992. Landing estimates do not differentiate between natural and hatchery reared salmon.

Commercial and sport fisheries for striped bass also developed in the late 1800s and early 1900s, but a decline in the population resulted in an end to the commercial striped bass fishery in the 1930s. Commercial fishing for striped bass was banned in 1935; however, annual striped bass landings by the sport fishery may have been much larger than the commercial harvest. The striped bass population declined in the 1930s and was severely depleted by 1970.

Although it is clear that the catches have significant adverse effects on the number of returning adults each year, to what extent fishing mortality affects future year-classes has not been adequately addressed. The extent to which fishing contributed to the decline of the chinook salmon and striped bass populations is unknown.

FISHERIES RESOURCES SINCE THE LATE 1970s

As discussed previously, there are multiple actions that have affected California fisheries resources since the mid 1800s. In the last 20 years California has experienced continued population growth along with agricultural and urban development. This growth in combination with other factors has resulted in the continued decline in fisheries resources, including fall-run and winter-run chinook salmon, steelhead trout, striped bass, delta smelt, and other species of concern.

The fall-run and winter-run chinook salmon have both experienced a decline in natural spawning stocks during the 1980s and 1990s. Figures II-2 and II-3 show the annual estimates of spawning escapement in the mainstem Sacramento River for fall-run and winter-run chinook salmon. In August 1989, the National Marine Fisheries Service (NMFS) listed the Sacramento River winter-run chinook salmon as "threatened" under emergency provisions contained in the Federal Endangered Species Act, and formally listed the species as threatened in November 1990. In June 1992, NMFS proposed reclassification of this species as "endangered". In June 1993, NMFS designated the Sacramento River from Keswick Dam to Chipps Island as critical habitat for the winter run chinook salmon under the ESA.

Annual estimates of adult steelhead trout abundance in the upper Sacramento River, as presented in Figure II-4, show a continued decline in population. Annual estimates of adult striped bass abundance in the Central Valley also show reduced population levels since the late 1970s, as shown in Figure II-5.

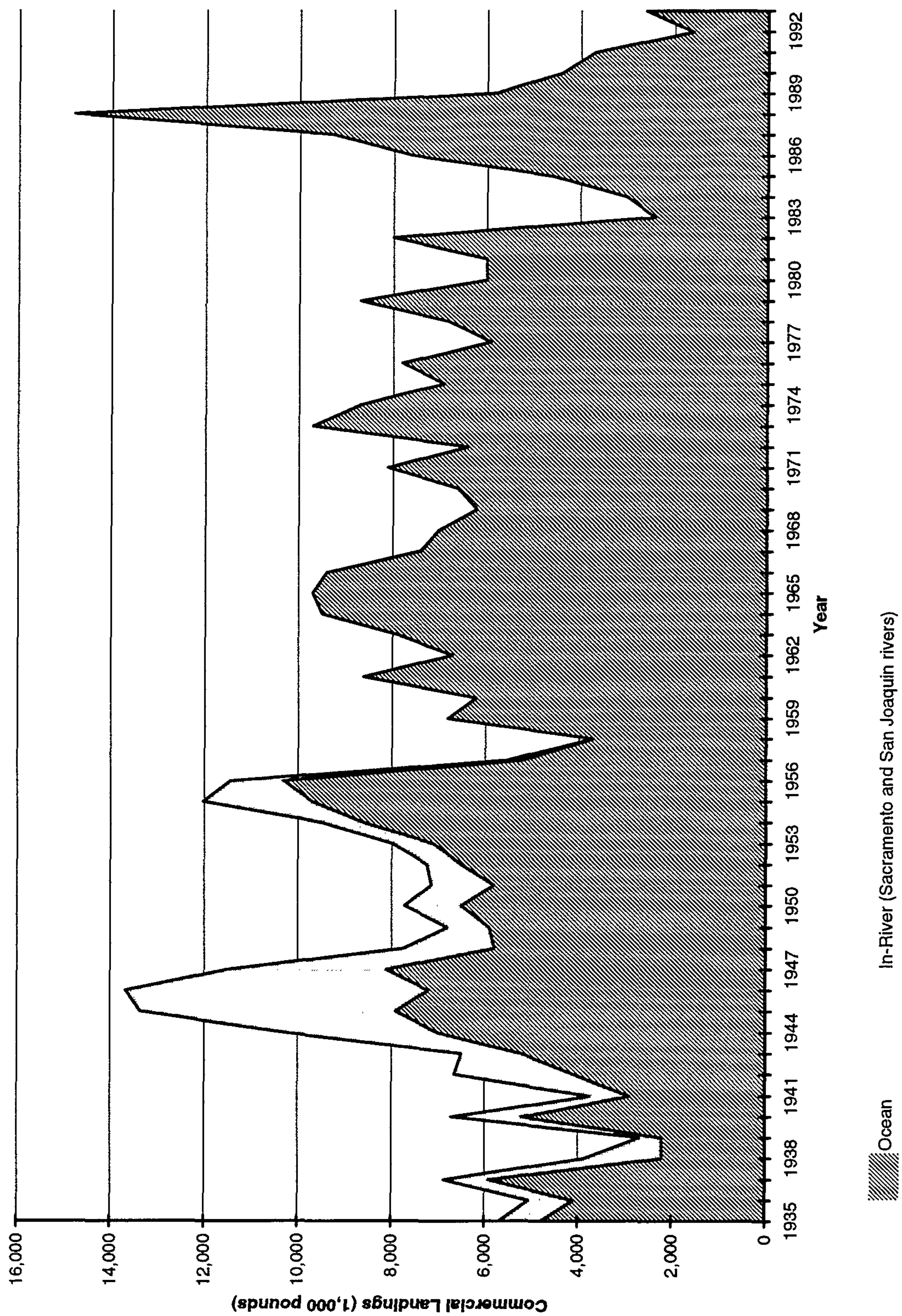
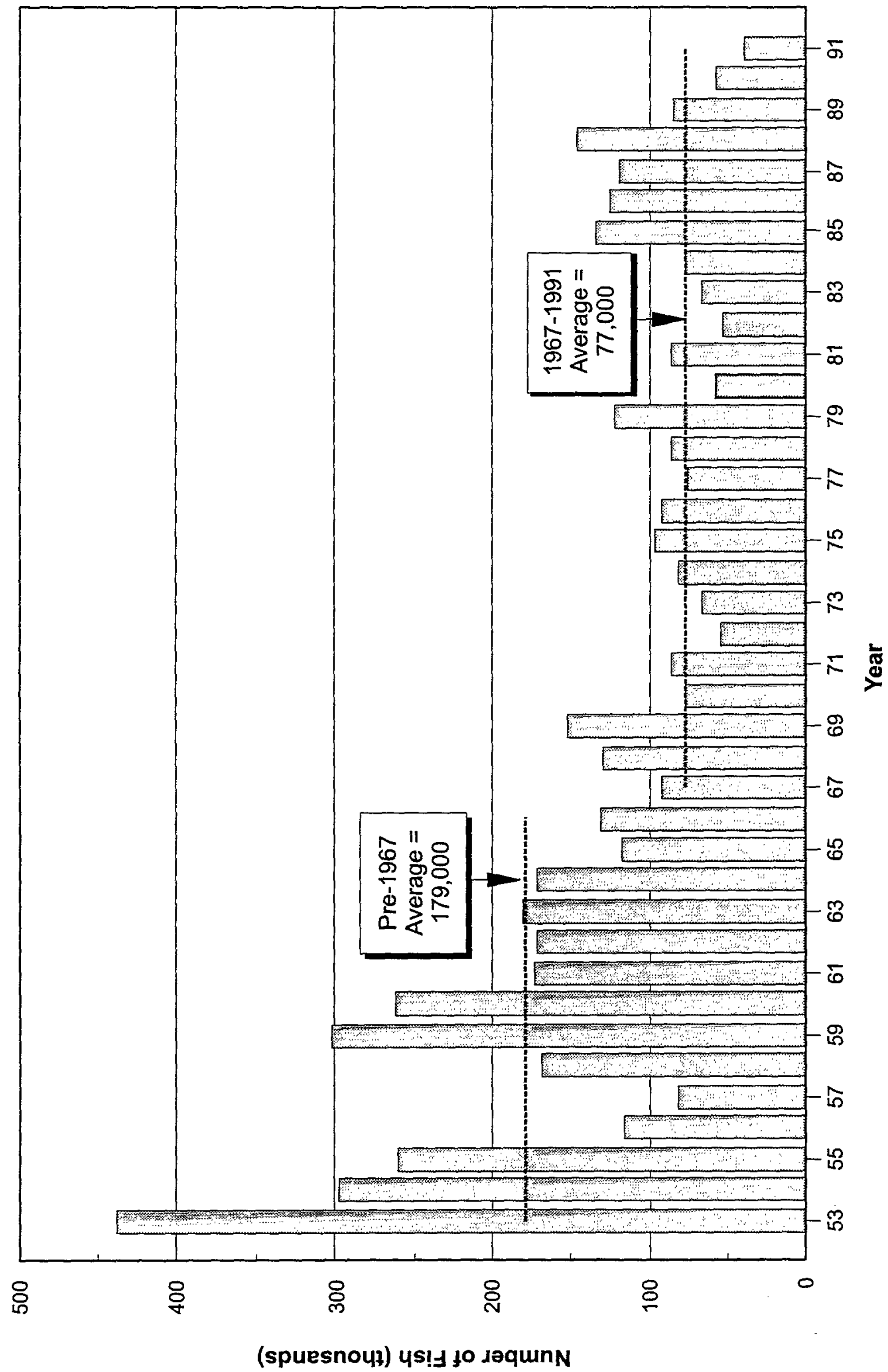


FIGURE II-1
TOTAL CALIFORNIA COMMERCIAL LANDINGS OF CHINOOK SALMON IN THOUSAND POUNDS (1935-1992)

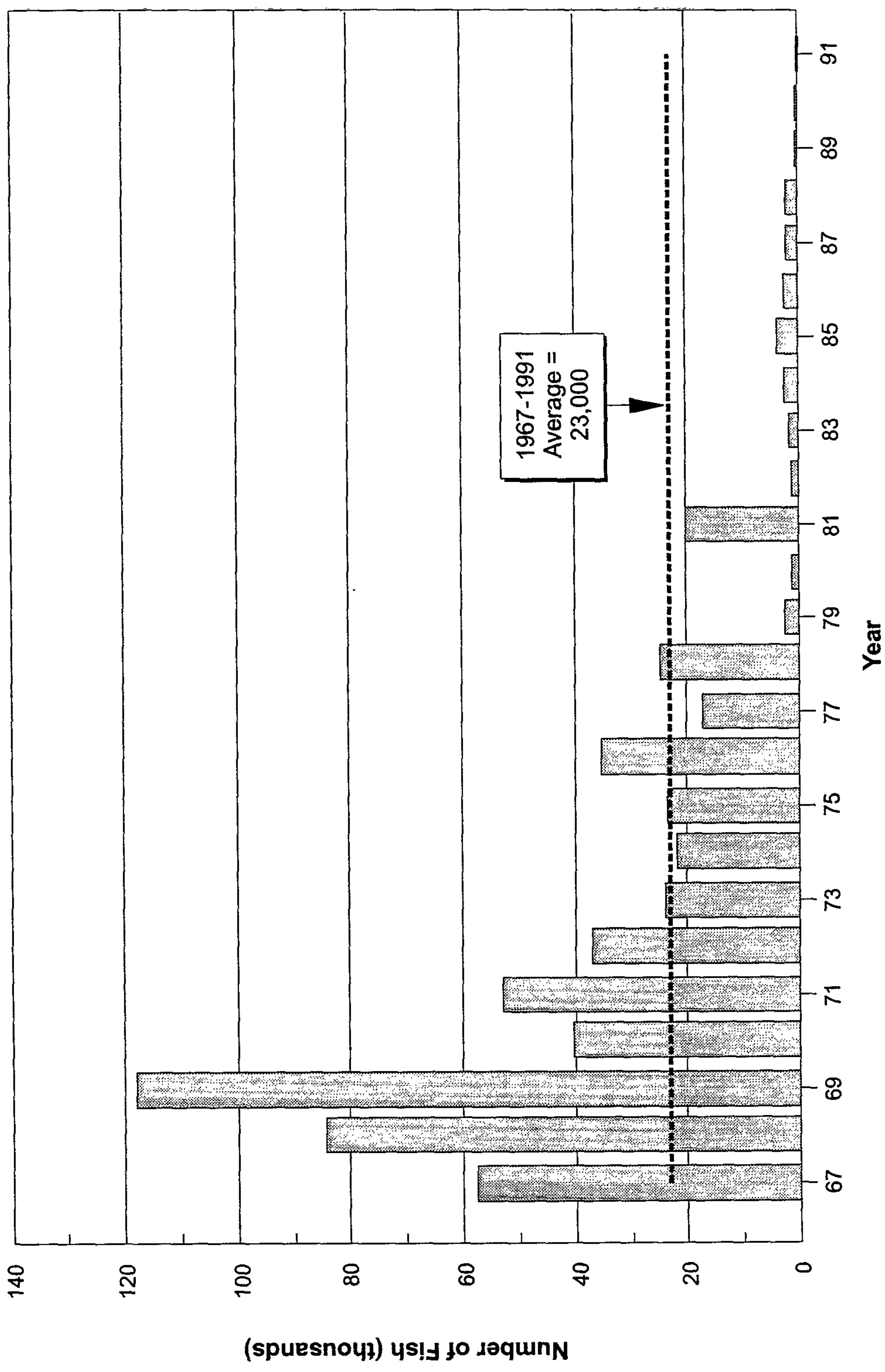


NOTE:
Population estimates prior to 1967 may not be comparable to post-1967 estimates because counting methods changed after completion of RBDD.

SOURCES:
Hallock, n.d.; Mills and Fisher, 1993.

FIGURE II-2

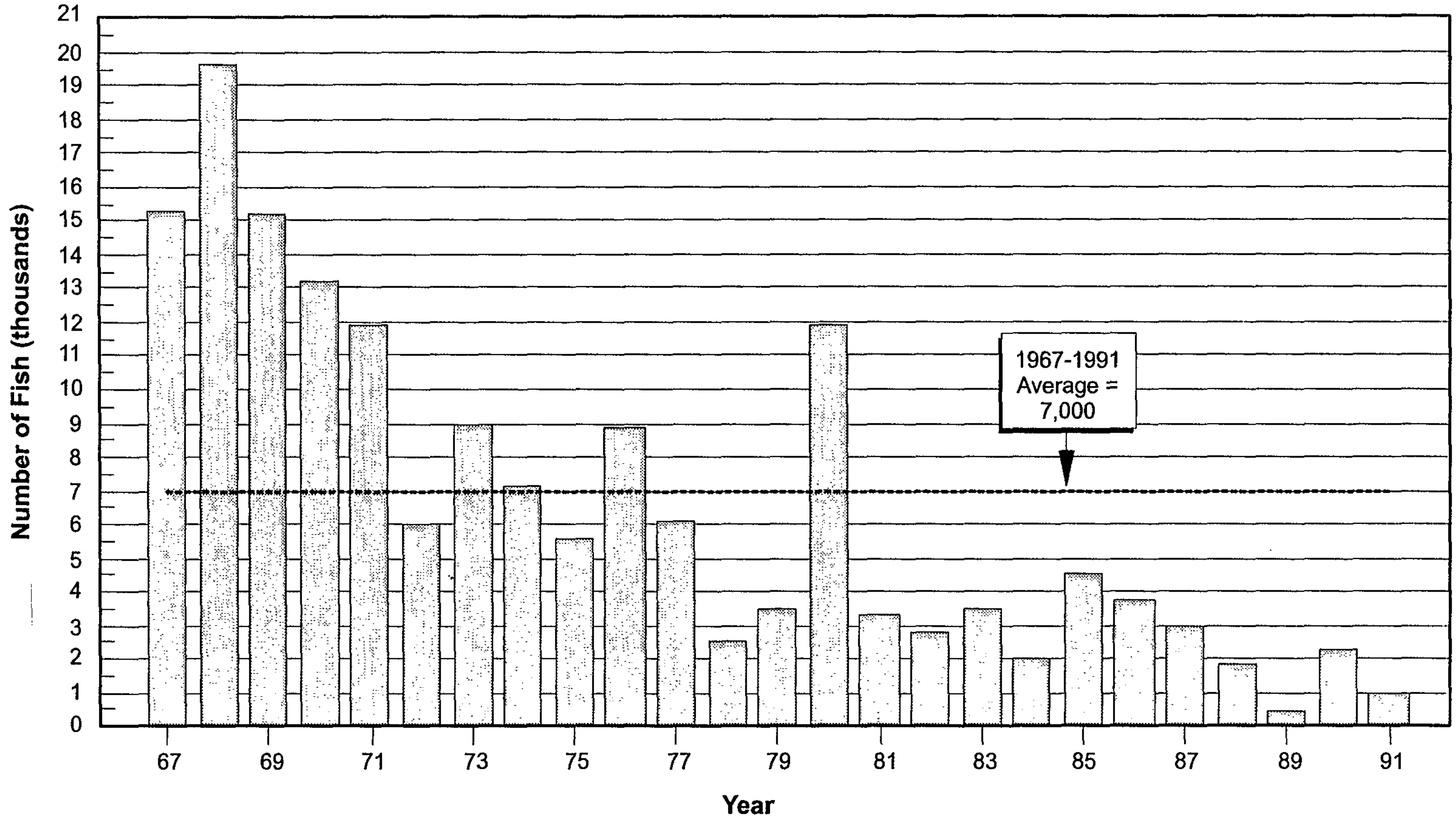
ESTIMATES OF FALL-RUN CHINOOK SALMON ANNUAL SPAWNING ESCAPEMENT IN THE MAINSTEM SACRAMENTO RIVER (1953-1991)



SOURCE:
Mills and Fisher, 1993.

FIGURE II-3

ESTIMATES OF WINTER-RUN CHINOOK SALMON ANNUAL SPAWNING ESCAPEMENT IN THE MAINSTEM SACRAMENTO RIVER (1967-1991)



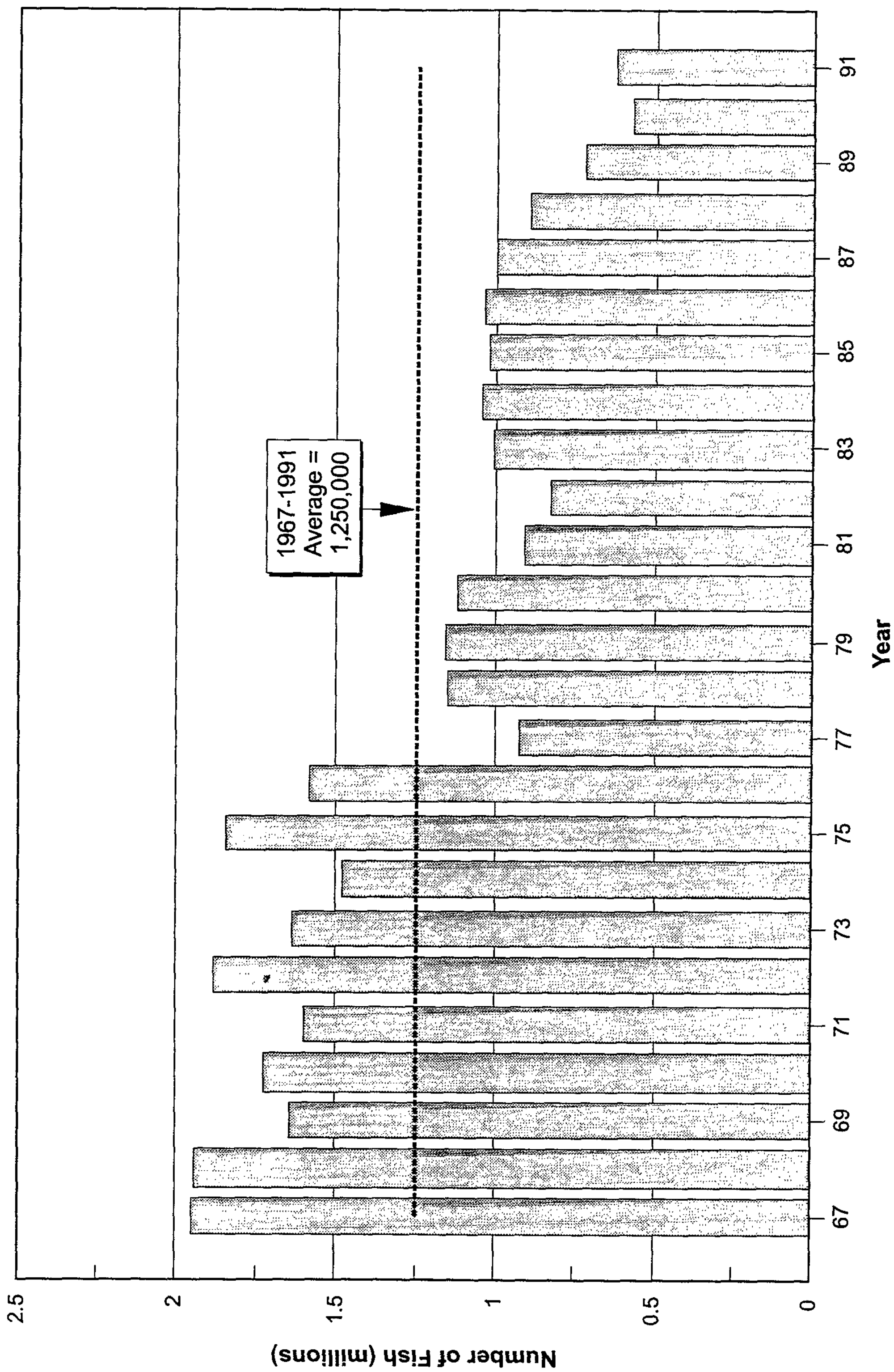
SOURCE:
Mills and Fisher, 1993.

FIGURE II-4

ESTIMATES OF ADULT STEELHEAD TROUT ANNUAL ABUNDANCE IN THE UPPER SACRAMENTO RIVER (1967-1991)

C-080976

C—080976



SOURCE:
Mills and Fisher, 1993.

FIGURE II-5

ESTIMATES OF ADULT STRIPED BASS ANNUAL ABUNDANCE IN THE CENTRAL VALLEY (1967-1991)

VEGETATION AND WILDLIFE RESOURCES

The Central Valley contains some of the most varied natural habitats and the highest biodiversity anywhere in North America. Many of these resources have been severely reduced or degraded by human settlement, population growth, and economic development since the mid 1800s, but they remain a prominent part of California's natural and cultural landscapes.

When Shasta Dam, the first large CVP facility, became operational in 1944, many of California's natural habitats had been altered dramatically and irrevocably from their near-pristine conditions of 150 years earlier. Extensive herds of grazing animals and their associated predators had been eliminated from the Central Valley. Approximately 30 percent of all natural habitats in the Central Valley had been converted to urban and agricultural lands.

By 1985, only 5 percent of the original riparian vegetation in the Central Valley remained. Approximately 90 percent of the riparian vegetation was eliminated before 1940, prior to the construction of CVP facilities. The loss of riparian vegetation significantly reduced important wildlife habitat, and has contributed to the listing of several species in the Central Valley as threatened or endangered. The major causes of decline in Central Valley riparian vegetation and wildlife habitat include conversion of land for irrigated agricultural and urban uses made possible by surface and groundwater supply development, river flow regulation, and construction of levees and channels for flood control protection.

CENTRAL VALLEY HABITAT AND WILDLIFE

This discussion includes the Sacramento River, Delta, San Joaquin River, and Tulare Lake regions. As described in the Vegetation and Wildlife Technical Appendix, 12 common natural communities in the Central Valley have been affected by water resources development in California. These natural communities include:

- mixed conifer forest
- Montane hardwood
- Pinyon-juniper
- valley foothill hardwood
- chaparral
- sagebrush scrub
- alkali and desert scrub
- grassland
- riparian
- freshwater and saline emergent wetland
- open water
- barren

For the purposes of this document, the discussion focuses on three of the habitats that have been substantially affected by development in the Central Valley: riparian, freshwater emergent wetlands, and grasslands. For each of the three habitat types a description of changes in vegetation and a description of the typical wildlife associated with that habitat is provided. For a more detailed discussion of Central Valley habitat and wildlife, refer to the Vegetation and Wildlife Technical Appendix.

RIPARIAN HABITAT AND ASSOCIATED WILDLIFE

Vegetation

The Sacramento and San Joaquin valley floodplains originally supported vast riparian woodlands along their major rivers. Historical maps and accounts indicate the existence of continuous forests up to 5 miles wide along the Sacramento River, plus extensive forests on high terraces even farther from the river. The riparian forests were diverse in composition and structure and were often dominated in size and number by valley oaks.

Estimates of the presettlement extent of riparian vegetation along the Sacramento River range from 800,000 to 1 million acres, not including the extensive forests along some tributaries. Katibah (1984) estimated that another 50,000 acres of riparian habitat occurred in the San Joaquin Valley.

On the Sacramento River, riparian forests were extensively cleared within a few decades of the discovery of gold. Trees were cut to fuel boats; build and heat towns; and make way for levees, farms, and harbors. Massive erosion from hydraulic mines in the Sierra Nevada filled the rivers and Delta with sediment; when the rivers were dredged to permit navigation, the spoils were deposited as levees in the riparian zone. During the first half of this century, more forests were lost to large-scale placer mining using dredges. Levee building was nearly continuous in the Central Valley, except during the Great Depression of the 1930s. By 1939, the amount of woody riparian habitat in the Central Valley had been reduced to less than 100,000 acres (Frayer et al., 1989). By 1944, the Sacramento Valley Flood Control Project was nearly complete, with 980 miles of levees, 438 miles of channels and canals, and 95 miles of bypasses.

In the mid-1980s, the area of mature riparian forest in the entire Central Valley was estimated to total about 34,600 acres (Frayer et al., 1989). Along the Sacramento River, an estimated 2 percent of the estimated historical riparian forest remained. Today, the cumulative loss of historical Central Valley riparian habitat may exceed 90 percent.

Factors contributing to this loss include continued conversion of non-irrigated land to irrigated agricultural land, levee construction and maintenance, bank erosion, bank protection, groundwater extraction, and flow regulation. Dams have flooded riparian vegetation in their impoundments and degraded it downstream by altering flows and geomorphic processes. Flood control has interfered with natural processes that affect forest regeneration. Because of the many factors involved, the specific contribution of the CVP to riparian habitat loss cannot be quantified.

C-080978

Wildlife

Gravel bar habitats are subject to seasonal flooding and are sensitive to changes in flow volumes, timing, and rates of change in flow volumes. Species common to gravel bar habitat along creeks and rivers include the California ground squirrel, Botta's pocket gopher, California vole, California quail, mourning dove, European starling, American goldfinch, and Brewer's blackbird. Aquatic areas within the river channels also provide foraging habitat for carnivores and omnivores such as river otter, common merganser, common goldeneye, and a variety of gulls. Ground insectivores of the gravel bar riparian community include the western fence lizard, killdeer, spotted sandpiper, western kingbird, and broad-footed mole. Vertebrate predators include the gopher snake, red-tailed hawk, and striped hawk.

Low terrace habitats develop as sediment accumulates on gravel bars and elevates them above the flood plain. Cottonwood trees provide nesting support for larger birds such as hawks, owls, American crow, great egret, and great blue heron. Cavity nesting species such as woodpeckers, wood ducks, bats, western gray squirrels, raccoon, and ringtail require mature stands. Common wildlife species in mixed scrub areas include Anna's hummingbird, scrub Jay, black-headed grosbeak, lazuli bunting, rufous-sided towhee, house finch, Virginia opossum, striped skunk, and gray fox.

High terrace habitats are typified by mixed and valley oak riparian forest. Mixed riparian forests support the most dense and diverse wildlife communities in the Central Valley. Wildlife present include most of the species that occur in cottonwood forest and riparian scrub habitats. Valley Oak riparian forests provide nesting sites for red-tailed hawk, Swainson's hawk, and herons and egrets. Valley oak stands also provide habitat for the acorn woodpecker, plain titmouse, and western gray squirrel.

EMERGENT WETLANDS AND ASSOCIATED WILDLIFE

Vegetation

In normal rainfall years, vast portions of the Central Valley flooded as winter and spring runoff collected in the low areas. Extensive wetlands formed behind natural river levees, especially in the Butte Creek sink, Colusa basin, the Delta, and the Tulare Lake basin. The Sacramento and San Joaquin rivers merged in an inland Delta containing more than 60 islands and more than 700 miles of waterways. Most of the Delta islands were marshy and some had a shrub overstory. Numerous other types of wetlands also existed in the CVP service area. Seasonal wetlands such as vernal pools, alkali meadows, and valley sink scrub developed in the Sacramento Valley. Montane meadows were common in canyon bottoms along rivers and creeks.

Estimates of the original extent of California's wetland and open-water habitats range from 2 to 5 million acres (California Department of Fish and Game [DFG], 1983; Frayer et al., 1989). The Central Valley contained an estimated 4 million acres of permanent, seasonal, and tidal wetlands (Frayer et al., 1989). Marsh occupied approximately 500,000 acres, 60 percent of this in the Delta (Kahrl, 1979; DFG, 1983). These estimates do not include areas of vernal pool, alkali meadow, alkali sink scrub, and montane meadow habitat.

By 1939, Central Valley wetlands had declined from about 4 million to approximately 483,000 acres (Frayer et al., 1989), an 88 percent loss. Statewide, the highest rate of wetland loss occurred between 1906 and 1922. The many reasons for these declines parallel those described earlier for riparian habitats. The largest declines occurred early in this century, when reclamation and flood control combined to accelerate conversion of wetlands to irrigated agricultural land.

The area of freshwater emergent wetlands in the Central Valley declined from about 483,000 acres in 1939 to about 243,000 acres in 1985 (Frayer et al., 1989), a 50 percent decline. In the San Joaquin Valley, an estimated 92 percent of the historical permanent and seasonal wetlands have been drained and reclaimed for agriculture; only 85,000 to 91,000 acres of managed wetlands remain. The most dramatic decline has been in the Tulare Lake Region, where only 4 percent of historical wetlands remain. The cumulative loss in the Central Valley now exceeds 90 percent. In addition, Holland (1978) estimated that 70 to 95 percent of historical vernal pool wetlands have been lost.

Waterfowl

Accounts by early settlers and explorers indicated that wetlands of the Central Valley supported a significantly larger and more dispersed waterfowl population than has occurred in recent times. Extensive reductions in wetlands and increases in market hunting contributed to a significant decline in these populations prior to 1900. A survey conducted in 1913 estimated that duck populations had declined from historical levels by 50 percent and goose populations by 75 percent.

Market hunting, conversion of natural habitats to agricultural and urban uses, and drought conditions all contributed to declines in Central Valley waterfowl populations. Market hunting ceased in the early 1920s when federal and state legislation banned the sale of waterfowl. The largest loss of wetland acreage, approximately 2.5 million acres, occurred between 1906 and 1922 with the advent of large-scale agriculture in the Central Valley. State and federal wildlife refuges were created to prevent crop depredation by waterfowl and to provide waterfowl sanctuaries. Despite concerted efforts to manage waterfowl, populations declined dramatically by 1935 due to prolonged drought on the Canadian prairies.

Central Valley waterfowl populations increased rapidly for the next 20 years. Several factors, including favorable weather patterns on the Canadian breeding grounds and a reduction in hunters during World War II, contributed to this increase. Labor shortages also extended the time required for harvesting rice and other grains, which provided additional forage for waterfowl. Rice production increased from 162,000 acres in 1920 to 240,000 acres in 1945. This additional rice production, coupled with increasing waterfowl populations, resulted in significant crop losses due to waterfowl depredation. However, subsequently increased farming of refuges and leasing and farming of private lands to produce waterfowl foods significantly reduced the levels of crop depredation. Additional federal and state refuges were established and enlarged between 1945 and 1955 to provide waterfowl habitat and minimize crop depredation.

By 1945, most of California's natural wetlands had been lost. Concurrently, rice production increased from 240,000 acres in 1945 to approximately 555,000 acres in 1980. Wintering waterfowl populations in the state increased until 1957, when drought conditions on the Canadian breeding grounds again reduced their populations, as shown in Figure II-6. Waterfowl populations recovered by 1970 as a result of favorable conditions on their nesting grounds. For the next decade, California's wintering waterfowl population averaged approximately 6 million birds. The population declined through the 1980s, again due to drought conditions on the Canadian prairies.

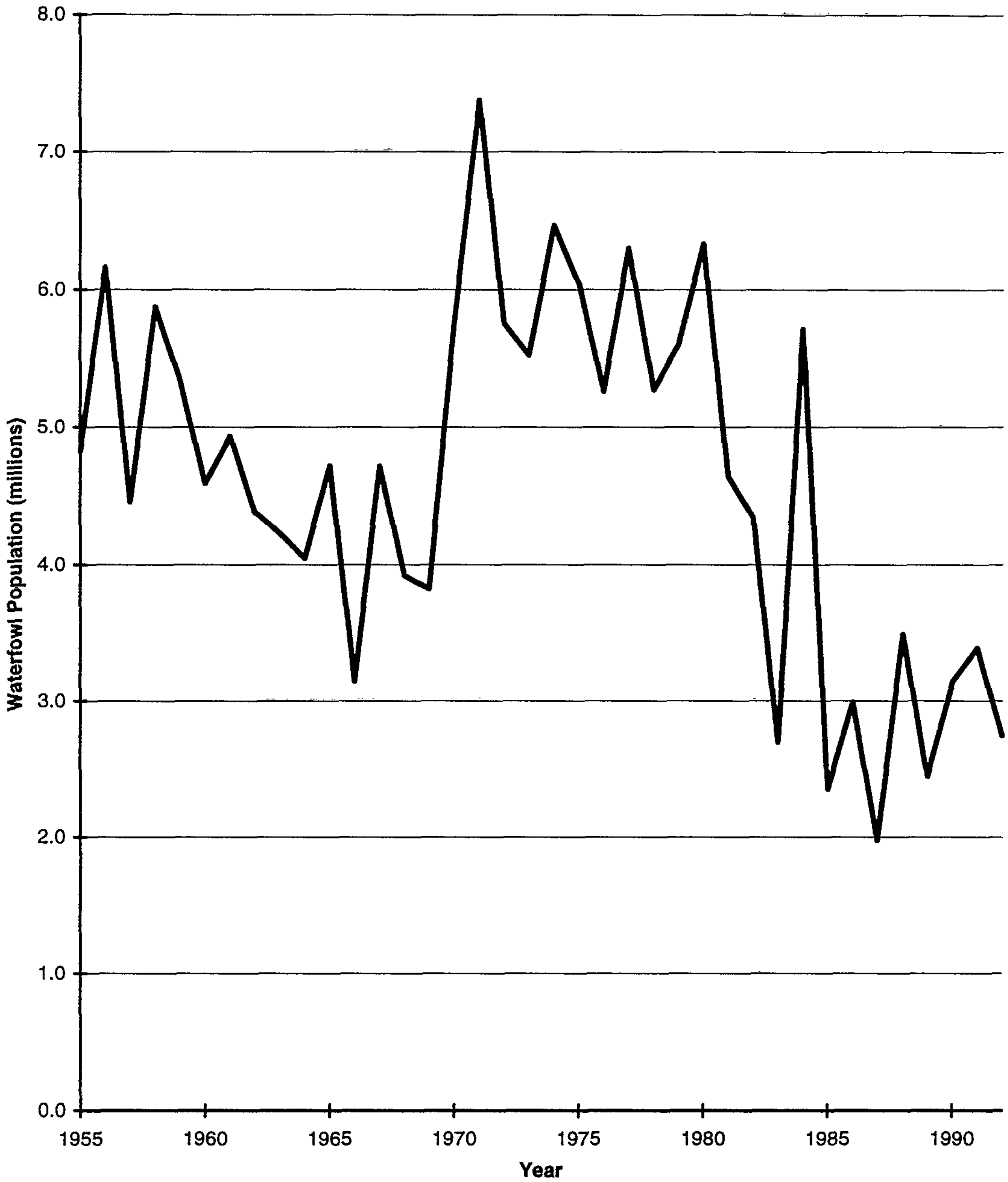
As discussed previously, more than 90 percent of the Central Valley's wetlands have been destroyed and many of the remaining areas are degraded. Currently, about 290,000 acres of wetlands remain in the Central Valley (CVHJV, 1990). Approximately 30 percent of the wetland habitat is protected in federal and state wildlife refuges; 168,775 acres of wetlands occur on private land, 49,875 acres of which are permanently protected through conservation easements (CVHJV, 1990). Winter habitat for waterfowl (natural and agricultural habitats) is limited to 345,000 acres of private lands, 55,000 acres of federal National Wildlife Refuges (NWRs), and 37,500 acres of state Wildlife Management Areas (Service, 1978).

Wildlife

Freshwater marshes in the Central Valley provide important habitat for a variety of other wildlife species, including grebes, herons, egrets, bitterns, coots, shorebirds, rails, hawks, owls, muskrat, raccoon, opossum, and beaver. Many other upland species such as ring-necked pheasant, California quail, black-tailed hare, and desert cottontail take cover and forage at the margins of wetland habitats. Many reptiles and amphibians such as the common garter snake, aquatic garter snake, Pacific treefrog, and bullfrog also breed and feed in freshwater habitats.

Although vernal pools are an ephemeral aquatic habitat, invertebrates and amphibians have adapted to this resource. When standing water is available, California tiger salamander, western spadefoot toad, and Pacific treefrog may use the pools for egg-laying and for the development of young. Aquatic invertebrates such as fairy shrimp, tadpole shrimp, cladocerans, copepods, and crawling water beetles, may also inhabit vernal pools.

Saline emergent wetlands provide habitat for a variety of bird, mammal, reptile, and amphibian species. Birds that commonly use this habitat include salt marsh yellow throat, song sparrow, marsh wren, Virginia rail, American coot, and several species of shore birds, including ducks, herons, egrets, and swallows. Raccoon, opossum, striped skunk, red fox, and coyote forage along the edges of saline emergent wetlands.



NOTE: Small differences in annual population estimates may be due to changes in inventory procedures, areas of inventory, coverage, and seasonal weather conditions.

SOURCE: Service.

FIGURE II-6
CENTRAL VALLEY WATERFOWL POPULATION DURING MID-WINTER INVENTORY 1955-1992

GRASSLANDS AND ASSOCIATED WILDLIFE

Vegetation

Grasslands once covered more than 14 million acres in California. They were dominated by a wide variety of native species, including many perennial bunch grasses, such as needlegrass, wild rye, melic grass, alkali sacaton, and deer grass. Native wildflowers and other herbs were also abundant. Some ecologists believe that nearly all of the state's original grasslands were dominated by perennial needlegrasses; others argue that annual grasses and wildflowers were dominant in many areas. In either case, grasslands were composed entirely of indigenous species until the late 1700s.

Changes in the composition of California's grasslands began in the 1770s, when Spanish settlers introduced a wide variety of annual grasses and forbs from the Mediterranean region. Throughout the 1800s and up to the present, hundreds of non-native plants arrived in the state from around the world. Many were aggressive enough to outcompete the native species and settle permanently into the California landscape. Grasslands were particularly hard hit by the introduction of non-natives, especially during times of heavy grazing and drought. By 1945, most of California's grasslands were no longer dominated by native plants.

Jensen (1947) estimated that grasslands of all types occupied about 10.4 million acres throughout the state in 1945, a decline of 26 percent from presettlement times. Most of this decline resulted from the expansion of croplands. Wieslander's (1945) map of California vegetation shows about 5.8 million acres of grassland in the Central Valley.

Today grasslands occupy about 8.7 million acres statewide, a 38 percent decline from historical times. The loss of grasslands dominated by native bunch grasses has been much greater; only a few small remnants of this type remain. Grassland losses have continued to result from urban expansion and conversion to irrigated croplands. The degradation of grassland quality has also continued, especially on heavily grazed rangelands.

Wildlife

Grasslands habitats are important foraging areas for black-shouldered kite, red-tailed hawk, Swainson's hawk, northern harrier, American kestrel, yellow-billed magpie, loggerhead shrike, savannah sparrow, American pipit, mourning dove, Brewer's blackbird, red-winged blackbird, and a variety of swallows. Birds such as killdeer, ring-necked pheasant, western kingbird, western meadowlark, and horned lark nest in grassland habitats.

Grasslands also provide important foraging habitat for the coyote and badger because this habitat supports large populations of small prey species, such as the deer mouse, California vole, pocket gopher, and California ground squirrel. Common reptiles and amphibians of grassland habitats include western fence lizard, common kingsnake, western rattlesnake, gopher snake, common garter snake, western toad, and western spadefoot toad.

CHAPTER III

CENTRAL VALLEY PROJECT OPERATING REQUIREMENTS

Chapter III

CENTRAL VALLEY PROJECT OPERATING REQUIREMENTS

This chapter provides a brief summary of the major authorities and regulatory actions that have historically affected the operations of the CVP since it was first authorized in 1935. The primary focus of this chapter is on the more recent changes in regulatory actions that have affected CVP operations since the early 1980s. Many of these actions were attempts to improve conditions for fisheries and wildlife, based on the declining trends discussed in Chapter II.

HISTORIC AUTHORITIES AND REGULATORY REQUIREMENTS

The CVP facilities, shown in Figure III-1 and described in the Surface Water Supplies and Facilities Operations Technical Appendix, are operated in accordance with requirements of Federal statutes; policies developed by the Department of the Interior, U.S. Bureau of Reclamation (Reclamation), and the Service; SWRCB water rights permits; and CVP operations policies. These authorities, policies, and constraints relate to management of the CVP as well as other water resources projects in California. Many of the more significant authorities and regulatory requirements that affect CVP operations are summarized in Table III-1. A detailed description of these authorities and regulatory requirements is included in the Surface Water Supplies and Facilities Operations Technical Appendix. It is recognized that passage of CVPIA in 1992 also would affect CVP operations, as discussed in other technical appendices.

OPERATING REQUIREMENTS IN THE EARLY 1980s

REGULATORY CONDITIONS LEADING UP TO THE 1980s

CVP operations in the early 1980s were a function of the authorities and the legislative actions that were passed in previous years leading up to this period. The major SWRCB and legislative actions prior to the 1980s that affected CVP operations are discussed below.

SWRCB Decisions

To protect water quality conditions in the Delta, the SWRCB adopted Decision 1485 (D-1485) in 1978 to modify the CVP and SWP water rights permits to include specific flow and export requirements and water quality standards for specific locations throughout the Delta. The water quality control plan was designed to protect the water quality of Delta water supplies and fish and wildlife needs. The plan identified beneficial uses and ongoing and future actions that could adversely impact the beneficial uses.

The water quality control plan recognized that the CVP and SWP held the largest water rights to export water from the Delta, and that these export activities could influence both salinity and

FIGURE III-1

CENTRAL VALLEY PROJECT AND OTHER RELATED FEDERAL FACILITIES

TABLE III-1
NON-CVPIA ACTIONS THAT AFFECT THE CENTRAL VALLEY PROJECT OPERATIONS

Authorities and Regulatory Requirements	Year	Impact on CVP Operations
Reclamation Act	1902	Formed legal basis for subsequent authorization of the CVP.
Reclamation Act Amendments	1935 1937 1940	First authorization of CVP for construction, and provision that dams and reservoirs be used first for river regulation, improvement of navigation, and flood control; second for irrigation and domestic users; and third for power.
Water Rights Permit for CVP	1937	SWRCB issued initial water right permit for CVP.
Reclamation Project Act	1939	Provided for repayment of construction charges and authorized sale of CVP water to municipalities and other public corporations and agencies, plant investment, for certain irrigation water deliveries to leased lands.
Water Service Contracts	1944	Provided for delivery of specific quantities of irrigation and municipal and industrial water to contractors.
SWRCB Decision 893	1949	Established minimum flow requirements on lower American River.
American River Basin Development Act	1949	Authorized development of Folsom Dam, powerplants, and Sly Park Reservoir.
Water Rights Settlement Contracts	1950	Provided diverters holding riparian and senior appropriative rights on the Sacramento and American rivers with CVP water to supplement water that historically would have been diverted from natural flows.
Sacramento Valley Canals Act	1950	Authorized development of Tehama-Colusa Conduit and Facilities.
Grasslands Development Act	1954	Added authority for use of CVP water for fish and wildlife purposes. Also authorized development of facilities in cooperation with the state for furnishing water to the Grasslands area for waterfowl conservation.
Trinity River Act	1955	Provided for operation of the Trinity River Division to be integrated and coordinated with operation of other CVP features to allow for the preservation and propagation of fish and wildlife.
Reclamation Project Act	1956	Provided a right of renewal of long-term contracts for agricultural contractors for a term not to exceed 40 years.
Fish and Wildlife Coordination Act (as amended by P.L. 89-72 in 1965)	1958	Provided for integration of Fish and Wildlife Conservation programs with federal water resources developments; authorized the Secretary of the Interior to include facilities to mitigate CVP-induced damages to fish and wildlife resources. Required consultation with the Service.
Authorization for the San Luis Unit	1960	Provided for development of the federal share of the San Luis Reservoir, San Luis Canal, and Pleasant Valley Canal.
Rivers and Harbors Act	1962	Provided for New Melones, Hidden, and Buchanan dams.

TABLE III-1. CONTINUED

Authorities and Regulatory Requirements	Year	Impact on CVP Operations
Reclamation Project Act	1963	Provided a right of renewal of long-term contracts for municipal and industrial contractors.
Authorization of Auburn-Folsom South Unit	1965	Provided for development of Auburn Dam, powerplant, Sugar Pine Dam, County Line Dam, Folsom-South Canal, and other facilities.
Pacific Gas and Electric Company Contract 14-06-200-2948A	1967	Agreement provides for sale, interchange, and purchase of power; transmission services; and interconnection of transmission facilities.
Authorization of the San Felipe Division	1967	Provided for development of the San Felipe Division including Pacheco and Hollister conduits.
National Environmental Policy Act	1969	Established policy, set goals, and provided means for ensuring scientific analysis, expert agency participation, and public scrutiny and input are incorporated into the decision- making process regarding the actions of the federal agencies.
Council on Environmental Quality Regulations	1970	Provided directives for compliance with NEPA.
SWRCB Decision 1400	1972	Established lower American River minimum flow requirements associated with the proposed construction of Auburn Dam. The decision was never conformed to. Reclamation currently attempts to meet portions of requirements as part of a historical practice known as "Modified D1400".
SWRCB Decision 1375	1971	Established Delta water quality standards to be met by both the CVP and the SWP.
Endangered Species Act	1973	Provided protection for animal and plant species that are currently in danger of extinction (endangered) and those that may become so in the foreseeable future (threatened).
SWRCB Decision 1422	1973	Established operational requirements for New Melones Reservoir, including responsibilities 1) to release specified quantities of water for instream fisheries on the Stanislaus River; and 2) for Reclamation to maintain water quality conditions on the Stanislaus and San Joaquin rivers.
SWRCB Decision 1485	1978	Ordered CVP and SWP to guarantee certain conditions for water quality protection for agricultural, municipal and industrial, and fish and wildlife use.
Energy and Water Development Appropriation Act	1980	Provided for energy and water development at New Melones Reservoir and archaeological recovery at the reservoir site.

TABLE III-1. CONTINUED

Authorities and Regulatory Requirements	Year	Impact on CVP Operations
Rivers and Harbors Act	1962	Provided for New Melones, Hidden, and Buchanan dams.
Reclamation Reform Act	1982	Provided for full-cost pricing, including interest on the unpaid pumping plant investment, for certain irrigation water deliveries to leased lands.
Coordinated Operations Agreement (COA)	1986	Agreement between the U.S. Government and the State of California. Determined the respective water supplies and methods to share conveyance facilities of the CVP and the SWP while allowing for a negotiated sharing of Delta excess outflows and the satisfaction of in-basin obligations between the two projects.
Public Law 99-546	1986	U.S. Department of the Interior and Reclamation directed to include total costs of water and distributing and servicing it in CVP contracts (both capital and operation and maintenance costs); and ensures repayment of the plant-in-service costs at the end of FY80 by FY2030.
Public Law 102-575	1986	Provided authority to execute Suisun Marsh Preservation Agreement.
Stanislaus River Interim Instream Flow Study	1987	Agreement between Reclamation and DFG to participate in a seven-year study to evaluate range of flows for fisheries benefits. Results of the study recommended minimum instream flows of 155,700 acre-feet per year.
Stanislaus River Water Rights Agreement and Stipulation	1988	Agreement between Reclamation and South San Joaquin Irrigation District (SSJID) and Oakdale Irrigation District (OID) to 1) establish a maximum diversion quantity of 600,000 acre-feet for use by both districts; 2) guarantee delivery to the districts of at least the inflow to New Melones Reservoir plus 33.3 percent of the difference between the inflow and 600,000 acre-feet; and 3) established a Conservation Account in New Melones Reservoir for the districts.
SWRCB WR90-05 and WR91-01	1990 1991	Water Rights Orders that modified Reclamation water rights to incorporate temperature control objectives in Upper Sacramento River.
Tracy Pumping Plant and Fish Facility Agreement with DFG	1992	Agreement with DFG to reduce and offset fish losses associated with operation of Tracy Pumping Plant and Fish Facility.
Draft Water Rights Decision 1630	1992	SWRCB circulated a draft water rights order to modify Decision 1485 to protect Bay-Delta water quality.
National Marine Fisheries Service Biological Opinion	1992 1993 1995	Established operation under the Reasonable Prudent Alternative for operations to protect winter-run chinook salmon.
U.S. Fish and Wildlife Service Biological Opinion	1993 1994 1995	Established operation under the Reasonable Prudent Alternative for operations to protect delta smelt.

TABLE III-1. CONTINUED

Authorities and Regulatory Requirements	Year	Impact on CVP Operations
Bay-Delta Plan Accord, SWRCB Water Quality Control Plan, and SWRCB Water Rights 95-01	1994 1995	Agreement and associated SWRCB order to provide for operations of the CVP and SWP to protect Bay-Delta water quality. Also provided for further evaluation and development of a new Bay-Delta operating agreement which is being pursued under the CALFED process.

flows in the Delta. Increases in salinity concentrations at Delta water supply diversions could adversely impact the use of the Delta water for stated beneficial uses. In addition, high salinity concentrations or changes in flow patterns could adversely impact fish habitat conditions, including habitat for anadromous fish.

The CVP was also operated in accordance with other SWRCB water rights permits for the Sacramento, Trinity, American, Stanislaus, and San Joaquin rivers. For the Trinity River, the minimum instream release from Lewiston Reservoir was established at 120,500 acre-feet per year when the Trinity River Division began operations in 1963. On the American River, Reclamation was operating to the SWRCB Decision 893 (D-893) minimum flows, but attempting to meet the higher SWRCB Decision 1400 minimum flows when possible.

On the Stanislaus River, the SWRCB adopted D-1422 in 1973 to: 1) specify releases from New Melones Reservoir to satisfy downstream water rights of 654,000 acre-feet per year at Goodwin Dam by OID and SSJID as limited by inflow to New Melones Reservoir per a 1972 Agreement and Stipulation with Reclamation, 2) provide for releases to meet the demands of downstream riparian water rights holders, to provide 98,300 acre-feet per year for instream fishery requirements on a pattern specified by the DFG, 3) maintain dissolved oxygen concentrations in the Stanislaus River consistent with the San Joaquin Basin Plan requirements, and 4) maintain a total dissolved solids concentration at or below 500 parts per million (ppm) in the San Joaquin River near Vernalis throughout the year.

Legislative Actions

In 1969, Congress passed the NEPA, which established policies and goals for a process that ensures the public that scientific analyses, expert agency participation, and public scrutiny will occur prior to adoption of federal decisions that significantly affect the environment.

A similar environmental law was passed by the California Legislature in 1973, the CEQA, to provide for similar development and review procedures for projects undertaken or approved by the State of California or public agencies in California. Actions that could significantly impact the environment would require adequate environmental documentation to provide the decision-maker with information concerning both the benefits and impacts of the decision.

In addition, the environmental documentation must be adequate to allow the public to become informed on the issues so they may provide input and comments to the decision-maker. Implementation of the provisions of these laws has allowed for more informed and active participation by many interest groups and affected publics in the decision-making process for the CVP.

In 1973, Congress passed the ESA to provide for protection of animal and plant species that were in danger of imminent extinction (endangered) or possible extinction in the foreseeable future (threatened).

REGULATORY CONDITIONS IN THE EARLY 1980s

In the early 1980s, CVP operations were modified due to changes in the minimum instream releases on the Stanislaus River and the adoption of the COA. In the early 1980s, prior to the signing of the COA in 1986, Reclamation and the SWP were operating on a year-to-year basis to preliminary criteria that were developed as part of the studies conducted for the COA negotiations.

Stanislaus River Operations

In the early 1980s, operations of New Melones Reservoir began and Reclamation entered into long-term contracts for delivery of up to 155,000 acre-feet of water to agricultural water service contractors from the Stanislaus River. During that period, no water was delivered pursuant to those contracts, because conveyance facilities had not been completed. Operations of New Melones Reservoir were guided by requirements of D-1422. Water was released from New Melones Reservoir for downstream water rights, instream flows, and water quality conditions in the San Joaquin River at Vernalis. Operations in the early 1980s did not include specific releases from New Melones Reservoir to maintain dissolved oxygen at or above 7.0 milligrams per liter in the Stanislaus River.

American River Operations

In 1972, the SWRCB issued D-1400 to allow for operations of the American River when the Auburn Dam was constructed and placed into operation. Many of the goals in D-1400 were considered helpful to fish habitat even if Auburn Dam were not constructed. Over the years, when hydrologic conditions were favorable, Reclamation attempted to meet some of the flow targets specified in D-1400. This operational practice became known as "Modified D-1400" operations. The D-893 minimum flow objectives continued to be implemented during drier hydrologic conditions. Under these operations, Folsom Lake releases range from 250 cubic feet per second (cfs) in months with severely low lake storage to 3,000 cfs in spring months with high lake storage and hydrologic projections of good runoff.

Coordinated Operations Agreement

The COA is the mechanism by which the CVP and SWP coordinate operations. The COA was completed in 1986 to implement CVP and SWP operations as defined by the SWRCB D-1485 standards and other regulatory permits circa 1978. The COA includes provisions concerning the joint obligations and operations in the Delta, including methods to ensure that water rights demands in the Sacramento Valley and Delta are met prior to exporting water to areas south of the Delta. In addition, COA provisions include formulas for the sharing of water resources entering the Delta that are available for export, and for sharing of the obligation to provide storage withdrawals to meet water rights demands and SWRCB standards in the Delta.

OPERATING REQUIREMENTS IN THE EARLY 1990s

In the early 1990s, CVP operations were modified due to changes in the minimum instream releases on the Trinity and Sacramento rivers, issuance of a biological opinion to protect winter run chinook salmon in the Sacramento River and Delta, and changes in operations of the Stanislaus River.

TRINITY RIVER OPERATIONS

Projected operations on the Trinity River changed in the 1980s and early 1990s. In 1981, the Secretary of the Interior (Secretary) determined through a Secretarial Decision the need for a Trinity River study to evaluate methods to meet temperature requirements on the river and stabilize instream flows. For a 12-year period, the Secretary allocated yield to maintain 340,000 acre-feet per year in normal water years, 220,000 acre-feet per year in dry years, and 140,000 acre-feet per year in critically dry years. In 1991, the Secretarial Decision was amended to provide a minimum of 340,000 acre-feet annually for all year types. During critically dry water years, 340,000 acre-feet would be released if at all possible until the study is completed.

SACRAMENTO RIVER BASIN OPERATIONS

In 1990 and 1991, SWRCB issued Water Rights Orders (WR) 90-5 and 91-01 modifying CVP water rights for the Sacramento River. The orders include a daily average water temperature objective of 56 degrees Fahrenheit in the Sacramento River at RBDD during critical periods when high temperatures could be harmful to fish. The WR 90-5 also specified a minimum release of 3,250 cfs from Keswick Dam in normal years in September through February. The CVP attempts to maintain the daily average water temperature in the Sacramento River at no more than 56 degrees Fahrenheit within the winter-run chinook salmon spawning grounds below Keswick Dam during April through September. This temperature is critical because the eggs and pre-emergent fry require temperatures at or below 56 degrees Fahrenheit for survival.

In 1992, operations in the Sacramento River system were modified when NMFS, in formal consultation with Reclamation, issued a specific 1992 one-year Winter-Run Chinook Salmon Biological Opinion. In 1993, NMFS, through a formal consultation, issued a Long-Term Winter-Run Chinook Salmon Biological Opinion. The biological opinion required the CVP to maintain a minimum Shasta Lake September storage of at least 1.9 million acre-feet, except in the 10 percent driest years. The opinion also called for minimum instream flows in the Sacramento River of 3,250 cfs below Keswick Dam from October 1 through March 31 for rearing and downstream passage of winter-run chinook salmon, and to minimize stranding of juveniles.

The biological opinion also affected operations of the RBDD and the Delta Cross Channel gates. At the RBDD, the biological opinion required opening of the gates that allow diversion of water into the Tehama-Colusa Canal from September 15 through May 15. This operation reduces the time period when water can be provided to CVP water service contractors from the canal. In the Delta, the biological opinion specified the closure of the Cross Channel gates from February 1 to April 30 to prevent salmon from being diverted into the interior Delta, where they are subject to increased losses due to predation and entrainment.

The biological opinion also required the CVP to use a 90 percent (i.e., 10 percent driest) exceedence probability to determine shortage criteria for CVP water service contractors each year, especially in planning forecasts that are issued between February and May each year. The use of the 90 percent exceedence as compared to the traditional 50 percent exceedence criteria conservatively limits the water allocations until the winter and spring precipitation periods are completed in May. This delay in water allocations may impact agricultural water users that make operational decisions in the early spring based on projected water allocations.

TRACY PUMPING PLANT OPERATIONS

The 1993 Long-Term Winter-Run Chinook Salmon Biological Opinion also required the CVP and SWP to limit the incidental take of the estimated number of out migrating smolt winter-run salmon to 1 percent, during the period October 1 through May 31. The take limitation may restrict the operation of Tracy Pumping during this period. The CVP was also required to ensure that the fish collection facility at Tracy Pumping Plant was fully staffed and operational October 1 through May 31.

STANISLAUS RIVER OPERATIONS

In 1988, Reclamation entered into an Agreement and Stipulation with SSJID and OID that superceded the 1972 Agreement and Stipulation for annual diversion quantities at Goodwin Diversion Dam. The 1988 Agreement and Stipulation requires Reclamation to release inflows to New Melones Reservoir, up to 600,000 acre-feet annually, for diversion at Goodwin Diversion Dam by SSJID and OID. In years when inflow to New Melones Reservoir is less than 600,000 acre-feet, Reclamation must provide the entire annual inflow plus one-third the difference between the inflow and 600,000 acre-feet. As compared to early 1980s conditions, this operation would increase the amount of water available for other project purposes in wetter years, but would decrease the amount of available water during drier years.

During the late 1980s and early 1990s, interim operations of New Melones Reservoir were developed in response to severe drought conditions, which occurred soon after the filling of New Melones Reservoir. The objective of the interim operations was to allocate the limited water supply among authorized project purposes, including water rights, instream flow releases, water quality, and CVP water service contracts.

RECENT OPERATING REQUIREMENTS

Recent conditions include CVP operating requirements as described above, as modified to take into account changes in operating requirements due to the signing of the Bay-Delta Plan Accord in December 1994, and the release of the 1995 Draft Water Quality Control Plan.

The Bay-Delta Plan Accord included an interim agreement that provided for the CVP and SWP to meet the water quality goals in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Estuary). The purpose of the Bay-Delta Plan Accord is to establish water quality control measures that contribute to the protection of beneficial uses in the Bay-Delta Estuary, including objectives for salinity, water project operations, and dissolved oxygen. The protected beneficial uses include municipal and industrial (M&I), agriculture, and fish and wildlife. The CVP and SWP are operated under the Bay-Delta Plan Accord as defined in SWRCB WR95-01.

In December 1994, the Bay-Delta Plan Accord was signed as an interim agreement until a coordinated effort was completed between all parties interested in Delta water quality. The Bay-Delta Plan Accord provided for the CVP and SWP to meet the water quality goals in the San Francisco Bay/Sacramento Delta Estuary. The SWRCB adopted the water quality goals and associated beneficial use objectives in the 1995 Water Quality Control Plan under WR95-01, including water quality requirements in the Sacramento, Stanislaus, and San Joaquin rivers.

The May 1995 Draft Water Quality Control Plan includes M&I water quality objectives for the reasonable protection of beneficial uses from salinity intrusion. These objectives are year-type-based maximum chloride concentration standards for various compliance locations within the Delta. Agricultural water quality objectives are included for the reasonable protection of beneficial uses from salinity intrusion and agricultural drainage in the western, interior, and southern Delta.

The fish and wildlife water quality objectives are for the reasonable protection of beneficial uses in the Bay-Delta Estuary. The objectives are established for the following parameters: dissolved oxygen, salinity, Delta outflow, river flows, export limits, and Delta Cross Channel gate operation. Delta outflow objectives are for the protection of estuarine habitat for anadromous fishes and other estuarine-dependent species. Sacramento and San Joaquin river flow objectives are to provide attraction and transport flows and suitable habitat for various life stages of aquatic organisms, including Delta smelt and chinook salmon.

Objectives for export limits are included to protect the habitat of estuarine-dependent species by reducing the entrainment of various life stages by the major export pumps in the southern Delta. An objective for closure of the Delta Cross Channel gates is included to reduce the diversion of aquatic organisms into the interior Delta where they are more vulnerable to entrainment by the major export pumps and local agricultural diversions.

CHAPTER IV

SIMULATION OF CENTRAL VALLEY PROJECT OPERATIONS AND ASSOCIATED RESPONSES

Chapter IV

SIMULATION OF CENTRAL VALLEY PROJECT OPERATIONS AND ASSOCIATED RESPONSES

This chapter presents computer model simulation results for the three general time periods described under CVP Operating Requirements in Chapter III. The simulations conducted for the Early 1980s, Early 1990s, and Recent Conditions scenarios are representative of CVP operations at three different points in time over the past 15 years. The simulation results presented in this chapter for each scenario include comparisons of CVP water deliveries, CVP power generation and Project Use, groundwater storage levels, and irrigated acreage and cropping patterns.

SIMULATION OF CVP OPERATIONS

It is difficult to review CVP water delivery records over the past 15 years and determine the impacts of the major non-discretionary policy and legislative actions on water deliveries. During this time period, CVP operations have been affected by a six-year drought, changes in markets and farm commodity programs, and changes in regional and statewide economic conditions, as well as implementation of regulations to improve environmental conditions in the Central Valley. Because it would be difficult to isolate the changes in CVP deliveries specifically due to the change in regulatory conditions, computer models were used to simulate the responses. The computer models provided tools to evaluate the impacts of the major modifications to regulatory requirements governing CVP operations and the addition of new CVP water service contract demands. The models also allowed evaluation of the indirect economic responses, such as changes in cropping patterns due to increased costs of alternative water supplies when CVP water availability is reduced.

DEFINITION OF SCENARIOS

Three simulations were conducted: Early 1980s, Early 1990s, and Recent Conditions (mid-1990s). The regulatory conditions that were assumed for each of these simulations are based upon the conditions discussed in Chapter II for these time periods, and summarized in Table IV-1. It should be noted, that for modeling purposes, the COA was included in all three simulations as the mechanism by which the CVP and SWP coordinate operations.

For each of these simulations, historical CVP water deliveries were evaluated to develop water allocations for the simulation. Maximum amounts of water used or maximum contract amounts, whichever was smaller, were used for agricultural and most municipal users, as shown in Table IV-2. Water rights allocations were based upon schedules submitted by the users to the SWRCB or information from DWR Bulletin 160-93. Refuge water supplies were based upon average historical deliveries from the CVP and other water suppliers to the NWRs and WMAs discussed in the 1989 and 1992 Refuge Water Supply Studies and the San Joaquin Basin Action Plan, as shown in Table IV-3 from the late 1970s through the mid-1980s. The primary

TABLE IV-1

SUMMARY OF CENTRAL VALLEY PROJECT OPERATIONAL CRITERIA IN EACH SIMULATED SCENARIO

Criteria	Early 1980s Scenario	Early 1990s Scenario	Recent Conditions Scenario
Trinity River Minimum Instream Flow Requirement	120,500 acre-feet annual minimum instream flow pattern (same for all year types)	340,000 acre-feet annual minimum instream flow pattern (same for all year types)	340,000 acre-feet annual minimum instream flow pattern (same for all year types)
Sacramento River Operations	DFG 1960 Memorandum of Agreement	SWRCB Water Rights Orders 90-05 and 91-01; NMFS Winter-Run Biological Opinion	SWRCB Water Rights Orders 90-05 and 91-01; NMFS Winter-Run Biological Opinion
American River Operations	Practice known as Modified SWRCB Decision 1400	Practice known as Modified SWRCB Decision 1400	Practice known as Modified SWRCB Decision 1400
Stanislaus River Operations	SWRCB Decision 1422	SWRCB Decision 1422; 1988 Stipulation Agreement with SSJID and OID; drought management	SWRCB Decision 1422; SWRCB Water Rights Order 95-06; 1988 Stipulation Agreement with SSJID and OID; drought management
Delta Operations	SWRCB Decision 1485	SWRCB Decision 1485 and NMFS Winter-Run Biological Opinion	NMFS Winter-Run Biological Opinion and SWRCB Water Rights Order 95-06 (Bay-Delta Plan Accord)
Coordinated Operations Agreement	Included in simulation (1)	Included in simulation	Included in simulation
CVP Contract Allocations for the Simulated Scenarios	San Felipe Division not constructed; see Table IV-2	Added the San Felipe Division; see Table IV-2	Added the San Felipe Division, See Table IV-2
Refuge Water Supplies	Average annual historical levels from the period 1974 through 1981 from historical supplies; see Table IV-3	Level 2 surface water supply from historical supplies; see Table IV-3	Level 2 surface water supply from historical supplies; see Table IV-3

NOTE:
The COA is included in the Early 1980s Scenario because Reclamation and the SWP were operating to preliminary criteria that were developed as part of the COA negotiations.

TABLE IV-2

CVP CONTRACT AMOUNT AND DIVERSION OBLIGATION ASSUMPTIONS

Water Users	Early 1980s Scenario (1,000 acre-feet)	Early 1990s and Recent Conditions Scenarios (1,000 acre-feet)
North of the Delta		
CVP Agricultural Water Service Contractors	480	480
Sacramento River Water Rights Contractors	1,870	1,870
CVP Municipal/Industrial Water Service Contractors	250	250
Municipal/Industrial Water Rights Holders	530	530
Water Service Contractors and Water Rights Holders that use Stoney Creek	4	4
Water Service Contractors that use Sly Park and Sugar Pine Units	26	26
CVP Refuge Water Supplies	77	92
South of the Delta		
CVP Agricultural Water Service Contractors	1,890	1,980
San Joaquin River Exchange Contractors	880	880
CVP Municipal/Industrial Water Service Contractors	20	140
CVP Refuge Water Supplies	54	158
Water served from the Stanislaus River		
CVP Water Service Contractors with firm water supply	49	49
CVP Water Service Contractors with interim water supply	106	106
CVP Water Rights Holders served at Goodwin Dam	600	600
Other Riparian Water Rights Holders	48	48
Friant Division		
Madera Canal Water Service Contractors	490	490
Buchanan and Hidden Unit Water Service Contractors	50	50
CVP Friant-Kern Canal Agricultural Water Service Contractors (includes Class I and Class II waters)	1,720	1,720
CVP Friant-Kern Canal Municipal/Industrial Water Service Contractors	65	65

TABLE IV-3

REFUGE WATER SUPPLY CONTRACT AMOUNTS (in 1,000 acre-feet)

Refuge	Early 1980s Scenario	Early 1990s and Recent Conditions Scenarios: At Boundary	Conveyance Loss	To Be Diverted	Notes
Sacramento Valley Refuges					
Sacramento NWR	43.0	34.8	11.6	46.4	Source: CVP per annual contracts.
Delevan NWR	16.7	15.7	5.2	20.9	Source: CVP per annual contracts.
Colusa NWR	17.4	18.8	6.2	25.0	Source: CVP per annual contracts.
Sutter NWR	15.2	23.5	0.0	23.5	Source: Return flows and periodic purchases from Sutter Extension District.
Grey Lodge NWR	37.9	35.4	0.0	35.4	Source: Biggs-West Gribley Irrigation District, groundwater, water rights, and beneficial use water.
Total for Sacramento Valley Refuges	**130.2**	**128.2**	**23.0**	**151.2**	
San Joaquin Valley Refuges					
San Luis NWR	10.0	19.0	6.3	25.3	Source: CVP per 1990 Agreement and 1954 Act.
Kesterson NWR	0.0	10.0	0.0	10.0	Source: CVP contract and CVP per 1990 Agreement and 1954 Act.
Volta WMA	0.0	13.0	0.0	13.0	Source: CVP contract and CVP water through a DFG lease agreement.
Los Banos WMA	16.3	16.7	0.0	16.7	Source: 6,200 af through CVP contract, remaining Level 2 amounts per annual CVP contracts.
San Joaquin Basin Action Plan Lands	0.0	21.5	0.0	21.5	Source: CVP per 1954 Act
Grasslands Resource Conservation District	0.0	47.8	0.0	47.8	Source: CVP.
Mendota WMA	18.2	18.5	0.0	18.5	Source: CVP. Amount reduced from Level 1 because weirs need to be modified to allow full use of water.
Merced NWR	13.5	15.0	5.0	20.0	Source: Merced ID in accordance with interim agreements and FERC agreement.
Kern NWR	9.8	10.0	0.0	10.0	Source: SWP per annual contracts.
Pixley NWR	1.0	1.0	0.0	1.0	Source: Well water
Total for San Joaquin Valley Refuges	**68.8**	**172.5**	**11.3**	**183.8**	
TOTAL	**199.0**	**300.7**	**34.3**	**335.0**	

differences in contract amounts in the scenarios is due to the addition of the San Felipe Division and additional refuge water supply commitments between the Early 1980s and Early 1990s scenarios.

SIMULATION OF WATER SUPPLY DELIVERIES

The PROSIM and SANJASM computer models were used to simulate responses to changes in CVP operational criteria. The simulations were developed using a normalized 1990 land-use scenario developed by DWR for Bulletin 160-93 to represent "1995 Conditions". A 1995 level of development was used for these scenarios because a comparable data set representative of earlier conditions was not available. A comparison of the 1980 level of development land use and the 1995 level of development land use indicated that for most agricultural areas in the Central Valley, the land use was extremely similar. One exception to the use of the 1995 level of development was that the San Felipe Division was not included in the Early 1980s Scenario because the facilities had not yet been completed.

The surface water and groundwater simulations were based upon a monthly 69-year hydrologic simulation using hydrologic data from the period 1922 through 1990 adjusted for a 1995 level of development.

Subsequent to the completion of the surface water modeling conducted for the PEIS, Reclamation and the Service have discovered an inconsistency in the PROSIM input hydrology that may cause the model to over estimate the potential flexibility of CVP operations. As a result, current PROSIM simulations may under estimate the use of CVP storage and conversely over estimate water deliveries in some critical dry years. This inconsistency affects all of the PEIS simulations and has a minimal impact on the relative differences between the simulations. Therefore, there is little affect on the comparison of surface water issues in the PEIS, due to the general programmatic nature of the PEIS analyses and the comparative use of the PROSIM simulation results.

The assumptions used in the simulations were discussed in Chapter III. Model specific assumptions and the results of the analysis are presented in the following paragraph.

COMPARISON OF AVERAGE ANNUAL WATER DELIVERIES

A comparison of simulated average annual CVP water deliveries for the three scenarios is presented in Table IV-4. These deliveries were compared to provide a general indication of the impacts resulting from the operational criteria changes in each of the three scenarios.

Under the Early 1990s Scenario, average annual deliveries to CVP agricultural water service contractors located north and south of the Delta decreased by about 4 percent, or 215,000 acre-feet per year over the 69-year simulation, as compared to the Early 1980s Scenario. As shown in Table IV-4, the majority of this reduction is to contractors south of the Delta. These reductions are primarily due to increased minimum instream flow releases on the Trinity and Sacramento rivers, and the implementation of deliveries to the San Felipe Division. Under the Recent

TABLE IV-4

COMPARISON OF ANNUAL CONTRACT AMOUNTS AND AVERAGE ANNUAL DELIVERIES IN THE EARLY 1980s, EARLY 1990s, AND RECENT CONDITIONS SCENARIOS (SIMULATED CONTRACT YEARS 1922 - 1990) (IN 1,000 ACRE-FEET)

	Early 1980s Scenario		1990s Scenarios		
				Early 1990s Scenario	Recent Conditions Scenario
Type of Water User	**Annual Contract Amount**	**Average Annual Delivery**	**Annual Contract Amount**	**Average Annual Delivery**	**Average Annual Delivery**
CVP Agricultural, North of Delta	2,550 (1)	2,430	2,550 (1)	2,400	2,390
CVP Municipal, North of Delta	440	440	440	440	440
CVP Refuges, North of Delta	80	80	90	90	90
CVP Stanislaus	155	52	155	59	51
CVP Agricultural, South of Delta	2,770 (2)	2,720	2,860 (2)	2,540	2,430
CVP Municipal, South of Delta	20	20	140	140	140
CVP Refuges, South of Delta	50	50	160	150	150
CVP Madera and Friant-Kern	1,940	1,270	1,940	1,270	1,270
CVP Total	**8,005**	**7,060**	**8,335**	**7,089**	**6,959**
SWP Total	4,000	3,350	4,000	3,280	3,270

NOTES:

(1) Demand north of the Delta is based on DWR Consumptive Use/Depletion Analysis - which may be less than the annual amount depending upon hydrologic conditions.

(2) Demand south of the Delta is based on annual contract amounts.

CVP Agricultural, North of Delta: Includes agricultural water service contracts, water rights, and settlement contracts.

CVP Municipal, North of Delta: Includes water rights on the American River, municipal water service contracts, including Contra Costa Water District, and Vallejo.

CVP Agricultural, South of Delta: Includes agricultural water service contracts, exchange contracts, Cross Valley Canal contracts, and San Felipe Division contracts.

CVP Municipal, South of Delta: Includes municipal water service contracts and San Felipe Division contracts.

CVP Stanislaus: Includes long-term water service contracts that use water from New Melones Reservoir.

CVP Madera and Friant-Kern : Includes Class I and II water service contracts that use water from Lake Millerton.

Conditions Scenario, average annual deliveries to CVP agricultural water service contractors located north and south of the Delta decreased by about 6 percent, or 330,000 acre-feet per year over the 69-year simulation, as compared to the Early 1980s Scenario due to changes in operations to meet WR 95-01.

Under the Early 1990s Scenario, average annual deliveries to CVP Stanislaus water service contractors increased by about 13 percent, or 7,000 acre-feet per year over the 69-year simulation, as compared to the Early 1980s Scenario, due to drought management operations that were implemented in the late 1980s and early 1990s. As discussed in Chapter III, the interim drought management operations shared the water reductions among all beneficial uses, including water rights, water quality requirements, and water service contracts. Deliveries under the Early 1980s Scenario provided first for the legal requirements under D-1422 and other water rights requirements. The remaining water was delivered to the Stanislaus CVP agricultural water service contractors for direct agricultural use. Under the Recent Conditions Scenario as compared to the Early 1980s Scenario, the amount of water available for water service contracts was reduced by about 2 percent, or 1,000 acre-feet per year over the 69-year simulation. This reduction was primarily due to changes in the operations of New Melones Reservoir to meet WR 95-01 and due to changes in minimum releases for adjusted Stanislaus River water rights deliveries.

Deliveries did not change for water rights holders, contractors that rely upon the Shasta shortage criteria, and CVP water service contractors on the Madera and Friant Kern canals.

Average annual deliveries to the SWP were similar but slightly higher under the Early 1990s Scenario than under the Early 1980s Scenario. However, average annual deliveries to the SWP decreased by about 50,000 acre-feet year under the Recent Conditions Scenario as compared to the Early 1980s Scenario, primarily due to implementation of the Bay-Delta Plan Accord.

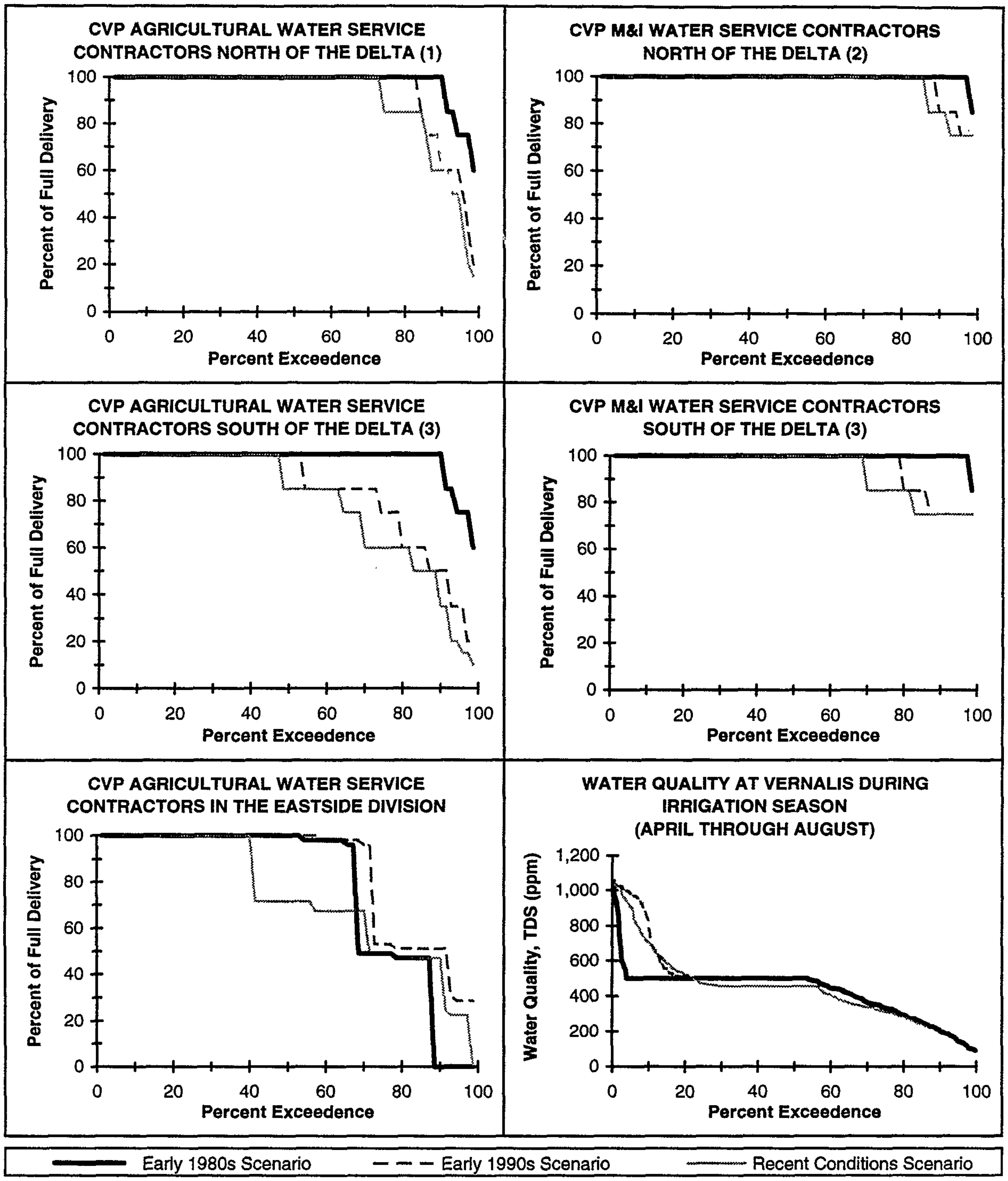
COMPARISON OF FREQUENCIES OF WATER DELIVERIES

The frequency of the delivery of full contract allotments and the minimum percent delivery are summarized in Figure IV-1. The reduction in delivery frequency is shown as the curves in Figure IV-1 shift to the left, indicating a decrease in the percent of the time a given level of delivery is achieved. The reduction in supply reliability is shown as the curves shift down, indicating a lower percent of full delivery for a given frequency level.

In previous Reclamation studies completed in the 1980s, the delivery capability of the CVP was based on the assumption that no more than a cumulative 100 percent of contract delivery would be lost to shortage deficiency over the critical drought period of 1928 through 1934. These shortages were generally allocated as a 25 percent cut in contract deliveries in four years over the critical period. These previous studies assumed that the shortages would be a result of hydrologic circumstances and that the critical dry periods would be infrequent.

In actual operations in the 1990s, there has been an increase in shortages because of the cumulative effects of reduced water supply due to dry hydrologic conditions, as well as increased system and water rights demands, and additional project objectives, including

C-081003



NOTES:
(1) Includes Sacramento River and American River divisions.
(2) Includes Sacramento River and American River divisions plus Contra Costa exports.
(3) Includes Delta (Delta-Mendota Canal only), West San Joaquin, and San Felipe divisions.

FIGURE IV-1
SIMULATED FREQUENCY OF PERCENT OF FULL ANNUAL DELIVERIES AND WATER QUALITY AT VERNALIS 1922-1990

increased releases to improve water quality, fish habitat, and water temperature conditions. The increased shortages have and could continue to reduce water deliveries to levels that were not anticipated when the CVP was constructed or water service contracts were initially signed. This may be especially true for CVP agricultural water service contractors because it may be necessary to maintain a maximum shortage criteria of 25 percent for municipal water service contractors. For the simulations used in this study, it was assumed that this 25 percent maximum shortage criteria would be continued for municipal water service contractors.

CVP Water Service Contractors Located North of the Delta

Full contract deliveries to CVP agricultural water service contractors located north of the Delta occur approximately 90 percent of the years in Early 1980s Scenario, 85 percent of the years in Early 1990s Scenario, and 75 percent of the years in Recent Conditions Scenario. The minimum water delivery also decreases between the scenarios. In the Early 1980s Scenario, the minimum delivery is 60 percent of full water service contracts. In the Early 1990s and Recent Conditions scenarios, the minimum deliveries are 20 and 15 percent of water service contract allotments, respectively. The reductions in agricultural water service contract deliveries in the Early 1990s Scenario are due to the cumulative effects of increased contract amounts, revised instream flow and temperature requirements, and decreased imports from the Trinity River. Further reductions in agricultural water service contract deliveries in the Recent Conditions Scenario are due to implementation of the Bay-Delta Plan Accord.

Full contract deliveries to CVP municipal water service contractors located north of the Delta also change between the scenarios. Under the Early 1980s Scenario, full contract deliveries occurred 98 percent of the years. The frequency was reduced to 90 and 85 percent under the Early 1990s and Recent Conditions scenarios, respectively. As with agricultural water service contractors, the minimum deliveries also change in addition to the frequency of shortages. Under the Early 1980s Scenario, the minimum delivery was 85 percent of full contract allotments. However, this minimum was reduced to 75 percent under both the Early 1990s and Recent Conditions scenarios.

CVP Water Service Contractors Located South of the Delta

Similar patterns occur for water service contractors located south of the Delta. Full contract deliveries occur to agricultural water service contractors approximately 90 percent of the years in the Early 1980s Scenario, 55 percent of the years in the Early 1990s Scenario, and 50 percent of the years in the Recent Conditions Scenario. In the Early 1980s Scenario, the minimum delivery is 60 percent of the full water service contract amount. However, in Early 1990s and Recent Conditions scenarios, the minimum deliveries are reduced to 20 and 10 percent of the full water service contract amount, respectively.

Full contract deliveries occur for municipal contractors located south of the Delta 98 percent of the years under the Early 1980s Scenario, 80 percent of the years under Early 1990s Scenario, and 70 percent of the years under Recent Conditions Scenario. The minimum delivery is 85 percent of full water service allotments in only one year under the Early 1980s Scenario.

However, under the Early 1990s and Recent Conditions scenarios, the minimum delivery is 75 percent of full water service allotments.

CVP Stanislaus Water Service Contractors

Simulated deliveries to CVP agricultural water service contractors that receive water from the Stanislaus River are shown in the plot of Eastside Division deliveries in Figure IV-1. As shown on the figure, deliveries under the Early 1980s Scenario vary widely, and range from 100 percent of contract amount in approximately 10 percent of the simulated years to zero percent of the contract amount in approximately 10 percent of the simulated years.

Under the Early 1990s Scenario, deliveries would slightly increase, and would be reduced to zero in approximately 2 percent of the years in the simulation period. This would occur in response to the allocation of water to all project purposes based on available supplies. Similarly, deliveries during wet and dry periods would increase under the Recent Conditions Scenario as compared to the Early 1980s Scenario, but would decrease in below and above normal conditions as a portion of the available water supply would be allocated to help meet pulse flow objectives on the San Joaquin River at Vernalis.

San Joaquin River Water Quality at Vernalis

In both the Early 1980s and Early 1990s scenarios, the simulated water quality objective in the San Joaquin River at Vernalis is an average monthly concentration at or below 500 ppm total dissolved solids (TDS) throughout the year. In the Early 1980s Scenario, New Melones Reservoir would be operated to maintain water quality conditions throughout the year before CVP contract deliveries would be made. In years when water quality objectives could not be met throughout the year, New Melones Reservoir would be operated to attempt to meet water quality objectives during the irrigation season months (April through August) before water quality releases would be made during non-irrigation season months. In years when available supplies could not maintain water quality objectives throughout the year, CVP contract deliveries would not be made.

In the Early 1990s Scenario, New Melones Reservoir would be operated to utilize the limited available water supply for all authorized purposes. Under the Early 1990s Scenario, the quantity of water that would be released from New Melones Reservoir specifically for water quality purposes is limited based on storage and inflow conditions between March and September each year. As a result, water quality objectives at Vernalis would not be met at often under the Early 1990s Scenario as under the Early 1980s Scenario. Figure IV-1 shows that the TDS concentration at Vernalis would exceed the objective in less than 5 percent of irrigation season months under the Early 1980s Scenario and up to 10 percent of the irrigation season months under the Early 1990s Scenario.

In the Recent Conditions Scenario, the management of water in New Melones Reservoir for downstream water quality objectives is similar to the Early 1990s Scenario. The water quality objectives at Vernalis, however, are different. The water quality objective under the Recent Conditions Scenario is approximately 455 ppm TDS during the irrigation season and 650 ppm during the non-irrigation season, as compared to year-round 500 ppm in the Early 1980s and Early 1990s scenarios. As shown in Figure IV-1, water quality conditions would exceed the standard more frequently under the Recent Conditions Scenario than under either the Early 1980s or Early 1990s scenarios.

SIMULATION OF CVP POWER PRODUCTION

In 1967, Reclamation and Pacific Gas and Electric Company (PG&E) signed an agreement (Contract 2948A) which allowed the sale, interchange, and transmission of electrical power and energy between the federal government and PG&E. The CVP has historically been operated, to the extent possible, to meet the requirements of this contract and receive the benefits thereof. Power produced in excess of project use load and preference customer deliveries is delivered to PG&E.

The Early 1990s and Recent Conditions scenarios assume that during critical periods Reclamation would make releases bypassing the generators at Shasta Dam to attempt to release colder water to meet the Winter-Run Chinook Salmon Biological Opinion water temperature requirements on the Sacramento River below Keswick Dam. The Early 1980s Scenario does not include any bypass operations.

Under the Recent Conditions and Early 1990s scenarios, simulated average annual CVP power generation decreases from about 5,580 gigawatt-hours (GWhs), in the Early 1980s Scenario, to about 4,940 and 4,930 GWh, respectively. This change represents a reduction of about 12 percent, as compared to the Early 1980s Scenario. This decrease in average annual power generation is due primarily to the increase in minimum flow requirements on the Trinity River and the bypass of the generators at Shasta Dam. Figure IV-2 shows the reduction in simulated average annual generation at Carr, Spring Creek, and Shasta powerplants. Simulated average monthly total CVP generation for the long-term average and dry period 1929 through 1934 is shown in Figure IV-3. As shown, the CVP average monthly generation decreases in the Recent Conditions and Early 1990s scenarios in June through November under the long-term average and dry conditions. The Recent Conditions and Early 1990s CVP average monthly generation increase slightly in the winter under dry conditions due to greater Shasta Lake releases for increased downstream minimum flow requirements.

The average annual CVP Project Use energy of 1,480 and 1,430 GWh in the Recent Conditions and Early 1990s scenarios is similar to the 1,430 GWh in the Early 1980s Scenario. The comparison of simulated average monthly CVP Project Use energy for the long-term average and dry period 1929 through 1934 is presented in Figure IV-4. The distribution of long-term average monthly CVP Project Use energy in the Recent Conditions and Early 1990s scenarios is fairly similar to the Early 1980s Scenario, with a slight increase in winter Project Use energy due to increased exports for refuges and the demands San Felipe Division. During the dry period 1929 through 1934, average monthly CVP Project Use energy in the Recent Conditions and Early 1990s scenarios decreases in the summer due to the reduction in Tracy Pumping Plant exports, resulting from less available water supply.

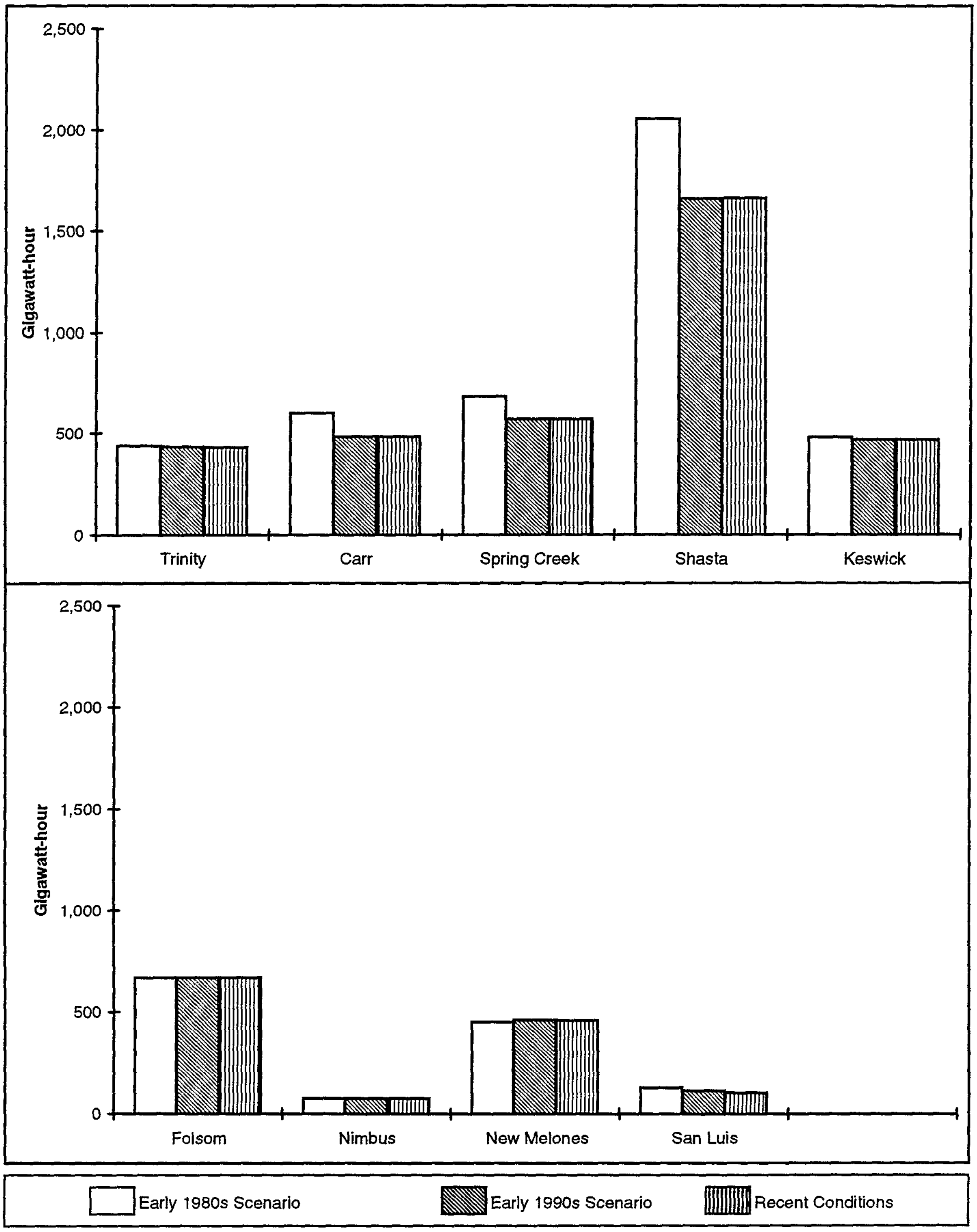


FIGURE IV-2

SIMULATED AVERAGE ANNUAL GENERATION AT CVP POWERPLANTS

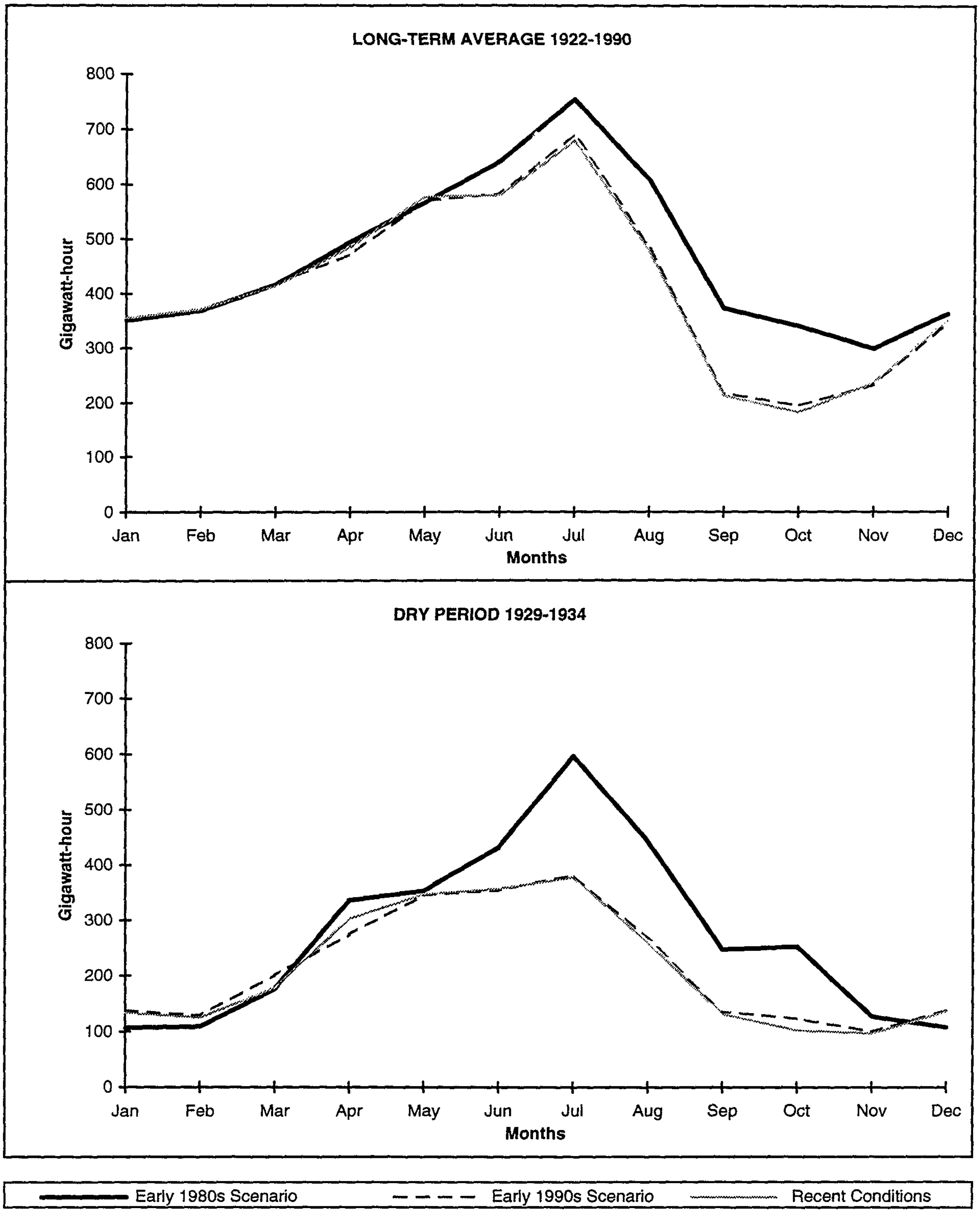


FIGURE IV-3

SIMULATED AVERAGE MONTHLY CVP GENERATION

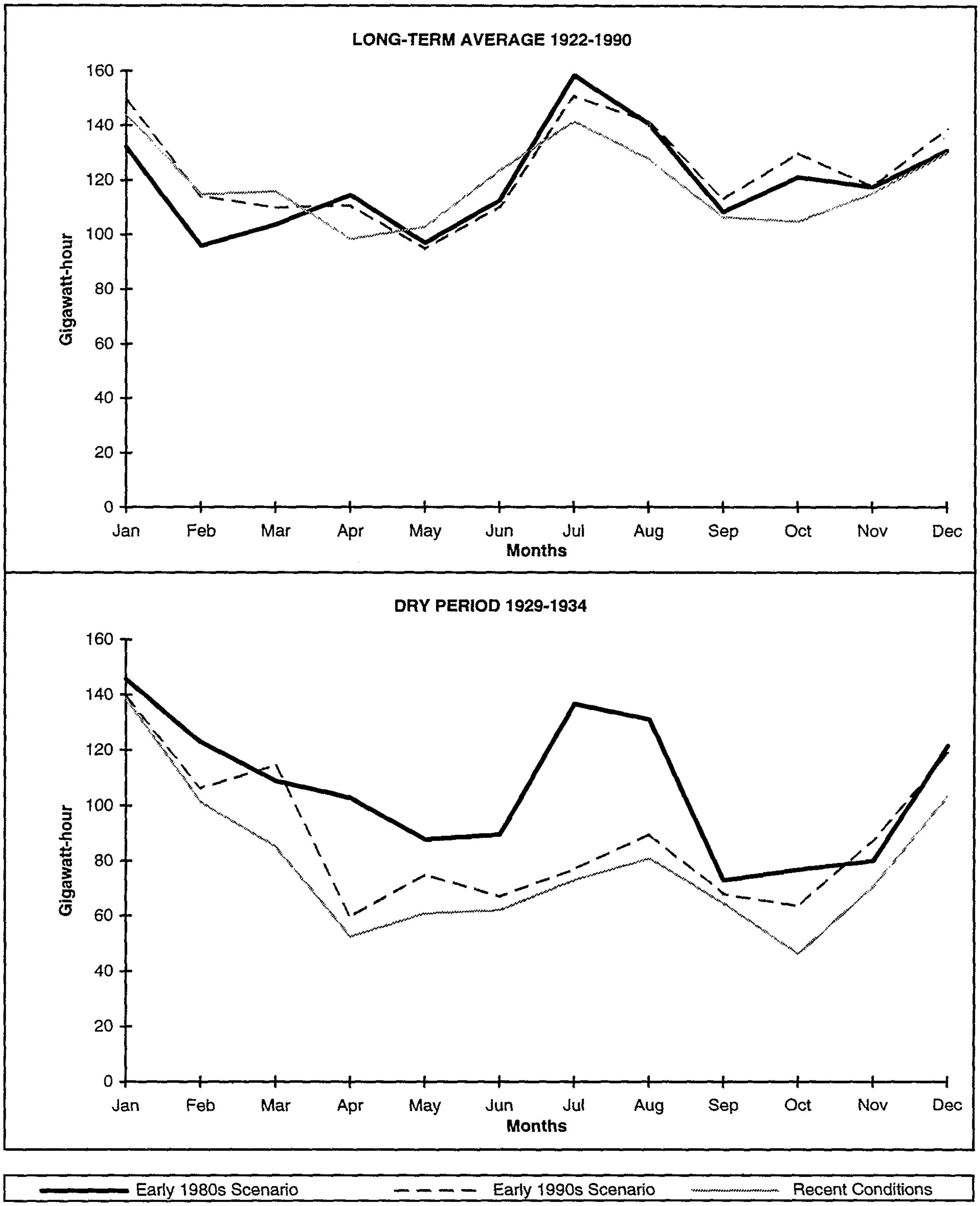


FIGURE IV-4

SIMULATED AVERAGE MONTHLY CVP PROJECT USE ENERGY

C —0 8 1 0 1 0

C-081010

SIMULATION OF GROUNDWATER USE

In most portions of the Central Valley, imported surface water is used to supplement existing local supplies, and the total water supply is provided through a combination of surface water deliveries and groundwater pumping. As surface water deliveries change from year to year, groundwater pumping quantities also change in order to maintain the land use base. This results in variations of groundwater levels and storage through the simulation period.

Groundwater levels vary throughout the 69-year simulation as groundwater is recharged and withdrawn. The evaluation was completed in an iterative manner through the use of the CVGSM and CVPM models. The results are presented here as changes in groundwater storage between Year 1 and Year 69 for each simulation. In general terms, this comparison provides an indication of the ability of a groundwater basin to sustain the land use on a long-term basis. Groundwater simulation results are presented for three geographic regions: the Sacramento River Region, the San Joaquin River Region, and the Tulare Lake Region which are shown in Figure IV-5. In addition, potential changes in the San Francisco Bay Region, which was not simulated, are qualitatively discussed. A description of model simulation runs is provided in the CVGSM Methodology/Modeling Technical Appendix.

GROUNDWATER RESOURCES IN THE SACRAMENTO RIVER REGION

For this analysis, the groundwater analysis for the Sacramento River Region was divided into west and east subdivisions because of the unique groundwater responses in these areas. In the western portion of the Sacramento River Region, the average annual groundwater pumping increased by about 25,000 acre-feet under the Early 1990s Scenario as compared to the Early 1980s Scenario. This increase is due to the reduction in deliveries to CVP water contractors. However, the increased flows in the rivers also increased groundwater recharge by 24,000 acre-feet per year. Therefore, as in the Early 1980s Scenario, groundwater storage did not noticeably change during the simulation under the Early 1990s Scenario. Under the Recent Conditions Scenario in the west side of the Sacramento River Region, average annual groundwater pumping increased 34,000 acre-feet per year more than under the Early 1980s Scenario due to reductions in CVP water deliveries. In the eastern portion of the Sacramento River Region, the average annual groundwater pumping did not vary among the Early 1980s, Early 1990s, and Recent Conditions scenarios.

Groundwater levels under all three scenarios were at the lowest levels along the valley axis and declined during the simulation period in the central and southern portions of Yolo County and in areas located to the north and south of Sacramento, as shown in Figures IV-6 and IV-7.

Because groundwater levels did not experience major declines between the scenarios, there was little potential of additional land subsidence under the Early 1980s , Early 1990s, and Recent Conditions scenarios.

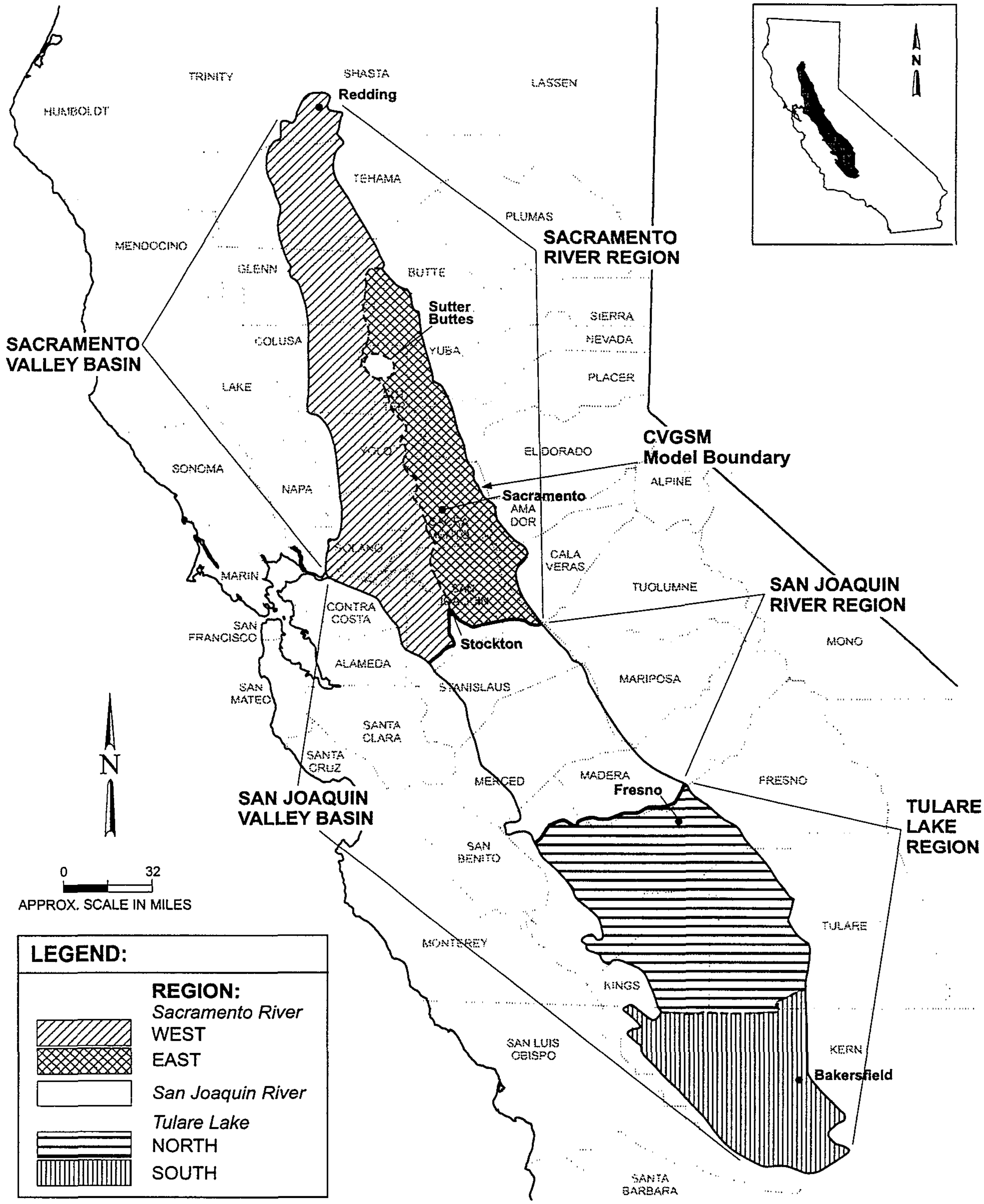


FIGURE IV-5

CVGSM MODEL AREA AND SUBREGION BOUNDARIES

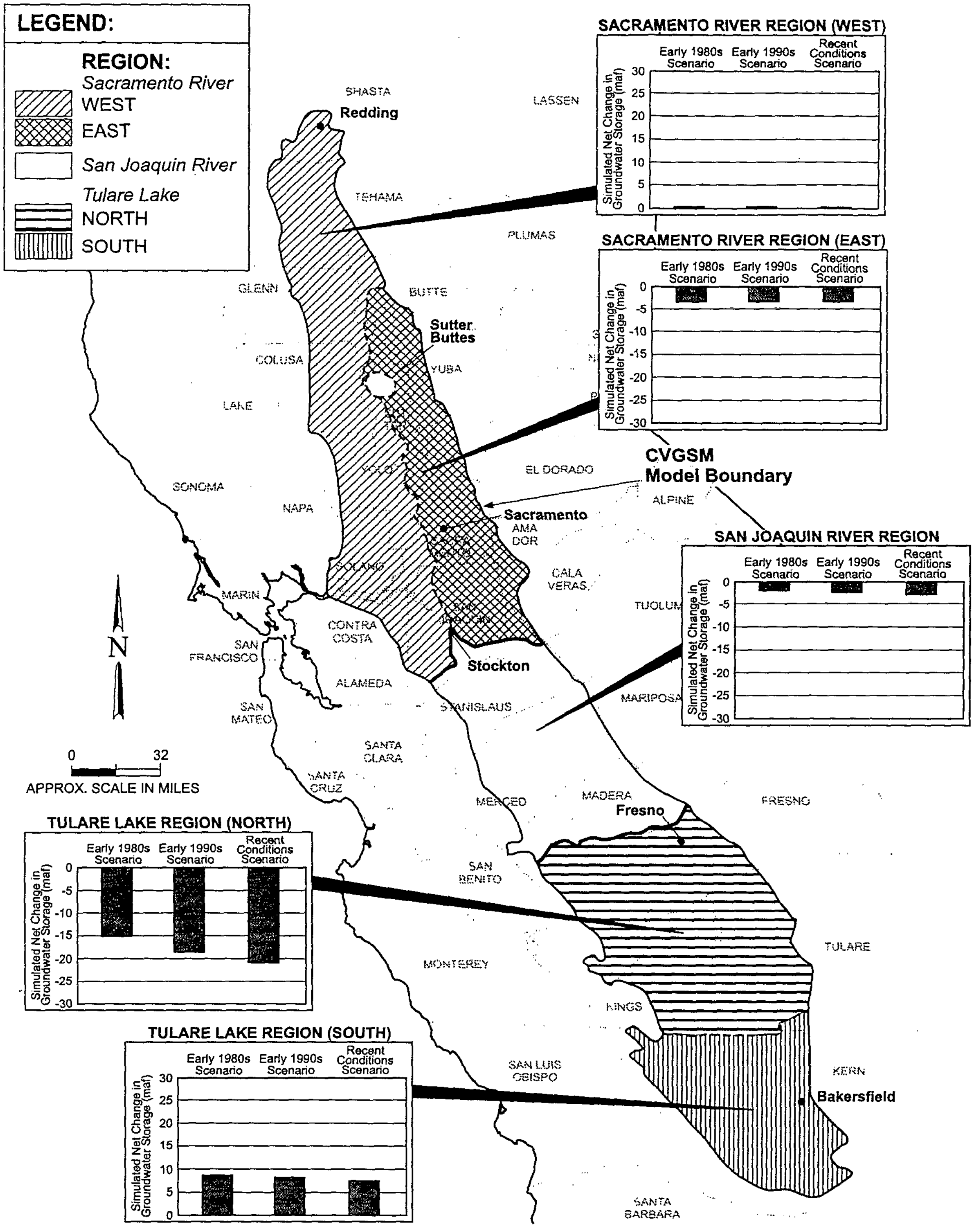


FIGURE IV-6

NET CHANGE IN GROUNDWATER STORAGE FOR THE SIMULATION PERIOD OF 1922 TO 1990

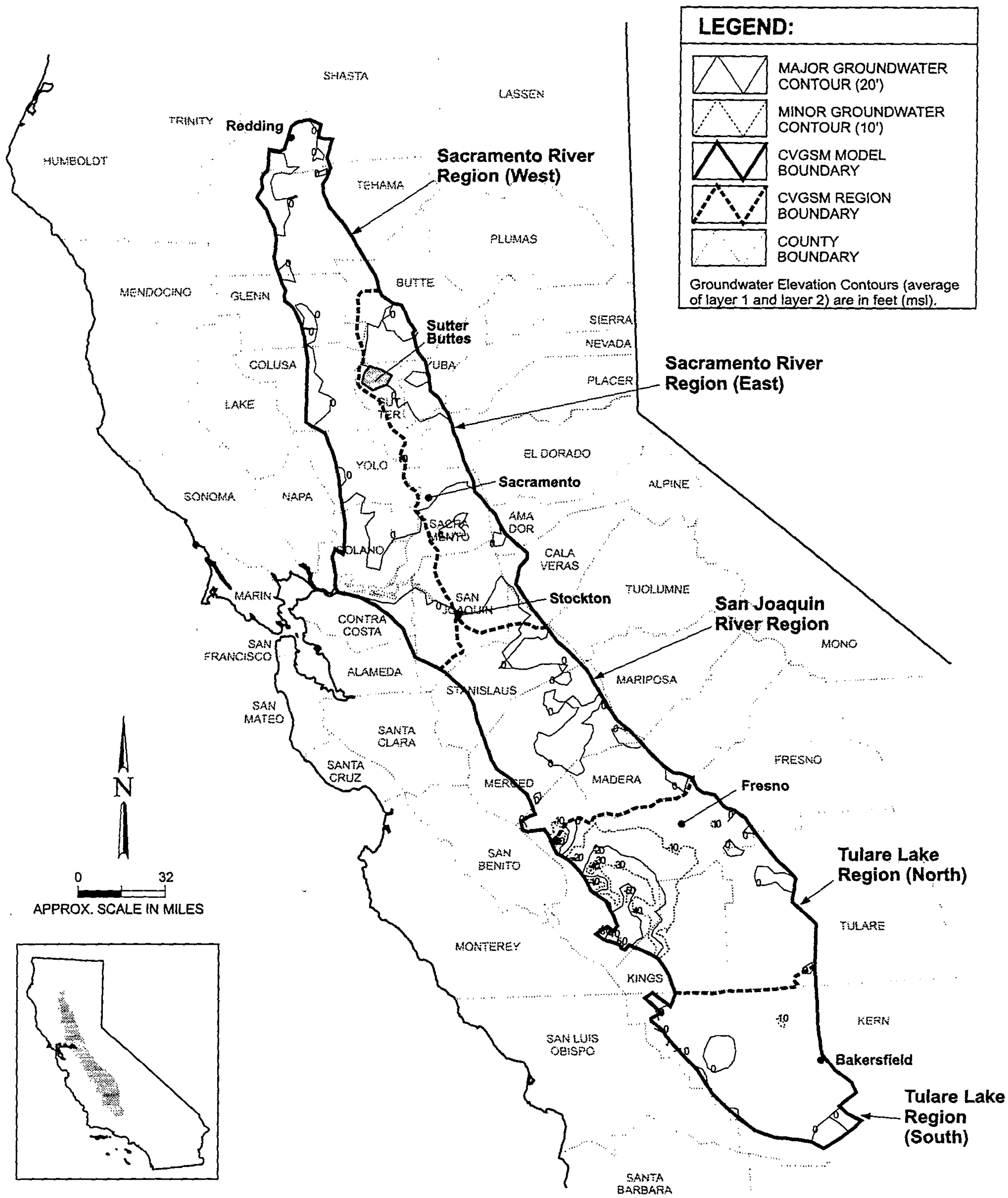


FIGURE IV-7

DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS FOR EARLY 1990s SCENARIO AS COMPARED TO EARLY 1980s SCENARIO

GROUNDWATER RESOURCES IN THE SAN JOAQUIN RIVER REGION

In the San Joaquin River Region, groundwater response was more uniform across the entire region and is therefore presented in a single region. Average annual groundwater pumping increased by 28,000 acre-feet per year under the Early 1990s Scenario as compared to the Early 1980s Scenario. The average annual total groundwater recharge was approximately the same under each scenario. The groundwater pumping increased under the Early 1990s Scenario as compared to the Early 1980s Scenario primarily due to reductions in CVP water service contract deliveries. Under the Recent Conditions Scenario, average annual groundwater pumping increased by 43,000 acre-feet per year due to continued decline in CVP water service contract deliveries, and groundwater recharge also increased by 25,000 acre-feet per year as compared to the Early 1980s Scenario. Groundwater recharge increased in all three scenarios because the lower groundwater levels adjacent to the streams caused more water to move from the surface waters to the groundwater. However, the groundwater pumping exceeded the recharge rate under all three scenarios.

As a result of the groundwater withdrawals exceeding the recharge rate, groundwater storage declined over the course of the simulation period, as shown in Figure IV-6. For the San Joaquin River Region, groundwater storage declined by approximately 10 and 20 percent more under the Early 1990s and Recent Conditions scenarios as compared to the Early 1980s Scenario. Groundwater levels were comparable between the Early 1980s and Early 1990s scenarios as shown in Figure IV-7. Average groundwater levels were 5 to 10 feet lower along the westside of the region under the Recent Conditions scenario as compared to the Early 1980s Scenario.

The simulation did indicate that additional subsidence of up to 1 and 2 feet over the 69-year simulation occurred along the west side of northern Fresno County in the Early 1990s and Recent Conditions scenarios as compared to the Early 1980s Scenario.

GROUNDWATER RESOURCES IN THE TULARE LAKE REGION

The Tulare Lake Region was divided into north and south areas because of the unique groundwater responses in these areas. In the northern portion of the Tulare Lake Region, under the Early 1990s Scenario, average annual groundwater pumping was increased by 112,000 acre-feet per year as compared to the Early 1980s Scenario. Total groundwater recharge under the Early 1990s Scenario was 65,000 acre-feet per year more than under the Early 1980s Scenario. Groundwater storage for the northern area declined by approximately 20 percent under the Early 1990s Scenario as compared to the Early 1980s Scenario. Under the Recent Conditions Scenario, the average annual groundwater pumping was 170,000 acre-feet per year more than under the Early 1980s Scenario. The total average annual groundwater recharge was 88,000 acre-feet per year more than under the Early 1980s Scenario. Groundwater storage declined by 35 percent under the Recent Conditions Scenario as compared to the Early 1980s Scenario. The increase in groundwater pumping between scenarios was due to a decrease in CVP water service contract deliveries. The increase in groundwater recharge was due to an increase in the movement of water from surface waters to the lowered groundwater levels. A decline in groundwater storage occurred because groundwater pumping exceeded the recharge rate.

In the southern portion of the Tulare Lake Region, the average annual groundwater pumping and recharge was similar under the Early 1980s and Early 1990s scenarios. Average annual pumping increased by 32,000 acre-feet per year under the Recent Conditions Scenario, as compared to the Early 1980s Scenario, due to reductions in both CVP and SWP water deliveries. Total average annual groundwater recharge increased by 20,000 acre-feet per year under the Early 1980s Scenario as compared to the Recent Conditions Scenario. The increase in groundwater recharge was due to an increase in the movement of surface water into the lowered groundwater.

The southern part of the Tulare Lake Region is also largely dependent on surface water supplies, particularly on imported supplies delivered by the CVP and SWP. As depicted in Figure IV-6, groundwater storage increased over the simulation period in all three scenarios due to the use of imported SWP water. This storage response is consistent with findings of DWR planning studies, which suggest that with greater imported surface water supplies, future groundwater use in this area could decrease, reducing the areas long-term groundwater overdraft condition (DWR, 1994). Groundwater storage was similar in the Early 1980s and Early 1990s scenarios. Under the Recent Conditions Scenario, groundwater storage declined by approximately 7 percent as compared to the Early 1980s Scenario.

Groundwater levels under the Early 1980s Scenario for the entire Tulare Lake Region gradually declined towards an area of groundwater depression in the northern central portion of the region. In the northern part of the region, groundwater levels decreased up to 50 and 70 feet more along the west side under the Early 1990s and Recent Conditions scenarios, respectively, as compared to the Early 1980s Scenario. Groundwater levels also declined in the Recent Conditions Scenario in the southern portion of the Tulare Lake Region.

The reduction in groundwater levels under the Early 1990s Scenario as compared to the Early 1980s Scenario caused additional subsidence of up to 5 feet between the scenarios, primarily within western Fresno County and portions of northwestern Kings County. Similar levels of subsidence occurred under the Recent Conditions Scenario as compared to the Early 1990s Scenario; however, the areal extent of subsidence was approximately 5 to 10 percent greater.

GROUNDWATER RESOURCES IN THE SAN FRANCISCO BAY REGION

Groundwater impacts discussed in this section are limited to CVP service areas in the counties of Santa Clara, San Benito, Alameda, and Contra Costa. Groundwater conditions in these counties were not simulated, and are assessed qualitatively based on changes due to reductions in CVP surface water deliveries.

Santa Clara And San Benito Counties

Groundwater resources in Santa Clara and San Benito counties are managed to minimize groundwater overdraft, land subsidence, and groundwater quality degradation. This goal is partially met by CVP project water imports via the San Felipe Division.

The San Felipe Division received no CVP water under conditions of the Early 1980s Scenario, and received an average annual delivery of approximately 75,000 acre-feet per year under the

Early 1990s Scenario. The imported surface water is assumed to replace groundwater pumping. This would stabilize groundwater storage, prevent additional land subsidence, and avoid further groundwater quality degradation. Under the Recent Conditions Scenario, the average annual delivery would be approximately 68,000 acre-feet per year, and would have similar benefits to the groundwater conditions in the area.

Alameda And Contra Costa Counties

Groundwater resources in parts of Alameda and Contra Costa counties have poor water quality, and can suffer from groundwater overdraft and land subsidence in the absence of alternative supplies. The continued importation of CVP water supplements these limited supplies.

Under the Early 1990s and Recent Conditions scenarios, CVP deliveries to Alameda and Contra Costa counties would be similar to the Early 1980s Scenario. Under these conditions, no net impact to groundwater storage, levels, and quality would occur, and no additional land subsidence would occur in these areas.

SIMULATION OF AGRICULTURAL PRACTICES AND ECONOMICS

Changes in agricultural practices and economics were evaluated in terms of on-farm water application practices, irrigated acres, gross revenue, net revenue for irrigated acreage production, and risk and financial impacts. The evaluation of Central Valley changes was completed in an iterative manner through the use of the CVGSM and CVPM models. Because the San Felipe Division only began to receive CVP water during the 1980s, its analysis is discussed separately from Central Valley analysis.

CENTRAL VALLEY REGIONS

On-Farm Water Application

The immediate impact of the policy changes discussed above was to reduce CVP water deliveries in the Central Valley. These reductions are shown in Figure IV-8, and are measured here as net changes in water deliveries to the fields. Total surface water applied for irrigation in the Early 1980s Scenario averaged 12,310,000 acre-feet per year over the 69-year simulation. In the Early 1990s Scenario, the simulated average delivery declined to about 12,140,000 million acre-feet per year, a reduction of about 170,000 acre-feet per year. About 140,000 acre-feet of that reduction occurred in the area of the San Joaquin River Region with CVP water service contractors. In the Recent Condition Scenario, the reduction in agricultural deliveries is about 280,000 acre-feet per Early 1980s Scenario year on average as compared to the Early 1980s Scenario. About 210,000 acre-feet of that reduction occurred in the San Joaquin River Region.

During the dry conditions of the simulation (the simulation years of 1928 through 1934), deliveries were reduced by a higher amount than under the average conditions in the Early 1990s and Recent Conditions scenarios. In the Early 1990s Scenario, surface water deliveries were reduced by 470,000 acre-feet per year as compared to the Early 1980s Scenario, with a 336,000

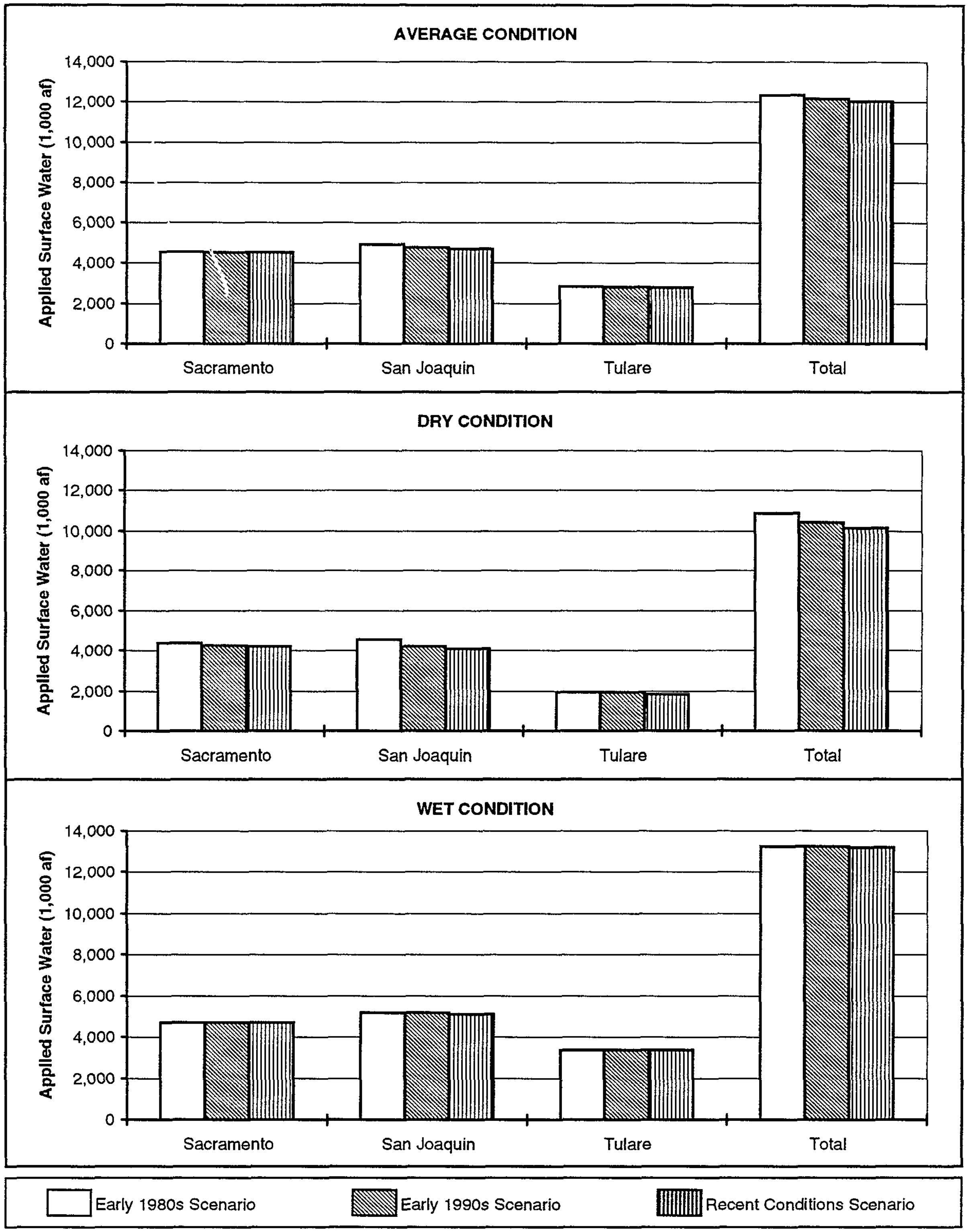


FIGURE IV-8

SURFACE WATER APPLIED FOR IRRIGATION IN THE CENTRAL VALLEY

acre-feet per year reduction in the San Joaquin River Region and 137,000 acre-feet per year in the Sacramento River Region. A slight increase occurred in the Tulare Lake Region due to a slight increase in SWP deliveries. Under the Recent Conditions Scenario, the total deliveries were reduced by about 730,000 acre-feet per year as compared to the Early 1980s Scenario, with about 460,000 acre-feet of reduction in the San Joaquin River Region and 170,000 acre-feet per year reduction in the Sacramento River Region.

This evaluation simulated the most cost-effective response to the reduction in surface water deliveries. The results indicated that most of the reduction would be replaced by additional groundwater pumping, as shown in Figure IV-9. Of the 170,000 acre-foot reduction in surface water applied on average in the Early 1990s Scenario, almost 160,000 acre-feet was replaced by increased groundwater pumping. In the Recent Conditions Scenario, the average reduction of about 280,000 acre-feet of surface water applied was offset by an increase of about 260,000 acre-feet in groundwater pumping, as compared to the Early 1980s Scenario.

Under the dry conditions, groundwater replacement was similar. Under the Early 1990s Scenario, about 450,000 acre-feet of groundwater was used to replace 470,000 acre-feet of applied surface water. Under the Recent Conditions Scenario, about 700,000 acre-feet of groundwater was used to replace 730,000 acre-feet of applied surface water.

Irrigated Acres and Gross Revenue

The estimated reduction in irrigated acreage as a result of reduced surface water supplies under the Early 1990s and Recent Conditions scenarios was small as compared to the Early 1980s Scenario due to the use of groundwater to replace the surface water supplies. As shown in Figure IV-10, only about 6,000 and 10,000 additional acres would be fallowed in the Early 1990s and Recent Conditions scenarios as compared to the Early 1980s Scenario. Almost all of the fallowed acreage was in the San Joaquin River Region where the loss in surface water supply was the highest. The reduction is less than 1 percent of irrigated acreage in the San Joaquin River Region. Results are similar for the dry conditions.

Gross revenue from irrigated acres followed the pattern of change in the irrigated acres, as summarized in Figure IV-10. About $6 million per year and $10 million per year would be lost on average in the Early 1990s and Recent Conditions scenarios as compared to the Early 1980s Scenario. Almost all of the loss would occur in the San Joaquin River Region. These estimated losses would represent less than 1 percent of value in the San Joaquin River Region.

Net Revenue From Irrigated Production

Impacts on net revenue occur due to the loss of net income on fallowed acres and the cost of additional groundwater pumping. These impacts are summarized in Figure IV-10 for the 69-year simulation. Valley-wide loss of net income was estimated to be about $20 million per year for the Early 1990s Scenario and about $35 million per year for the Recent Conditions Scenario as compared to the Early 1980s Scenario. Most of this loss would occur in the San Joaquin River Region.

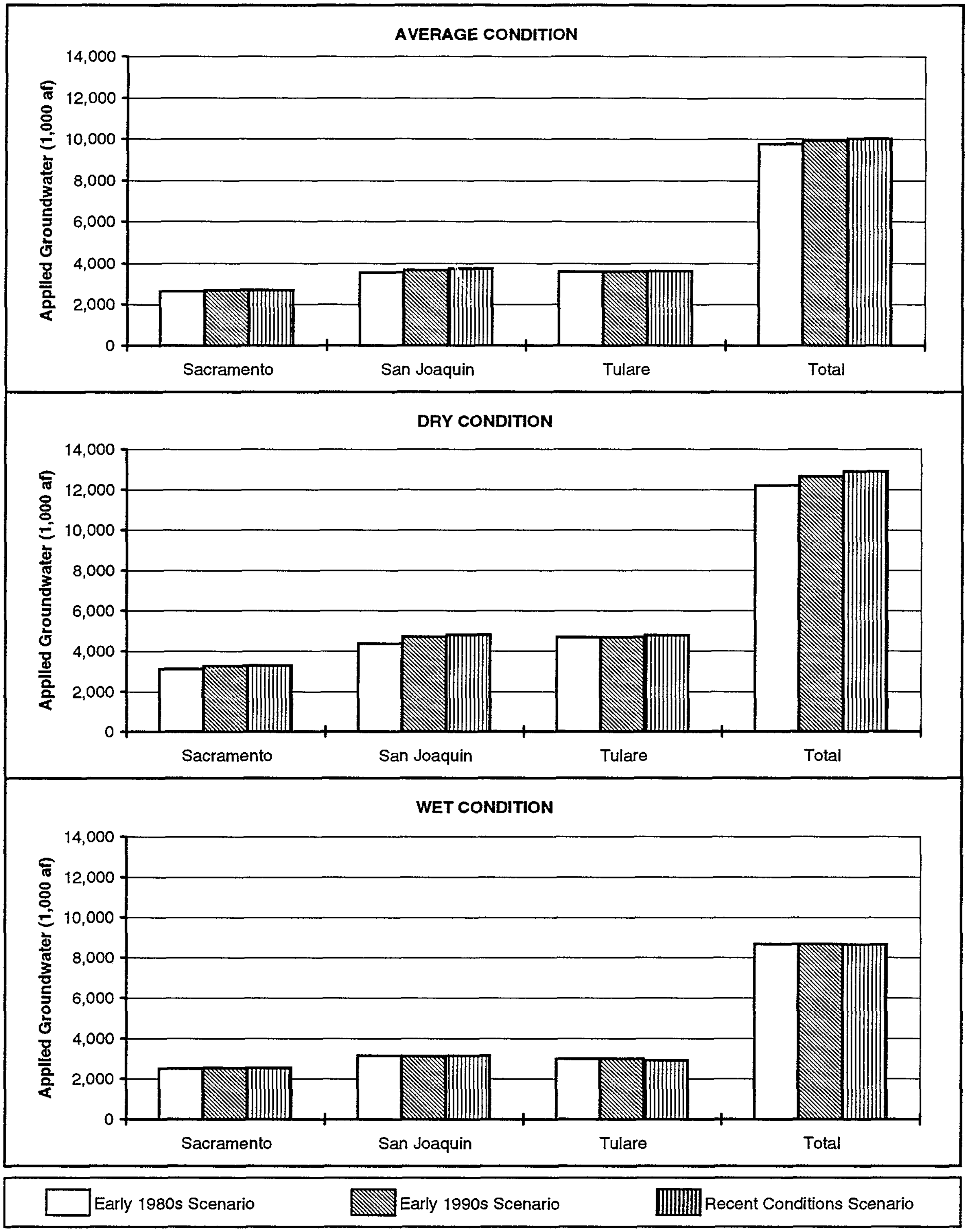


FIGURE IV-9

GROUNDWATER APPLIED FOR IRRIGATION IN THE CENTRAL VALLEY

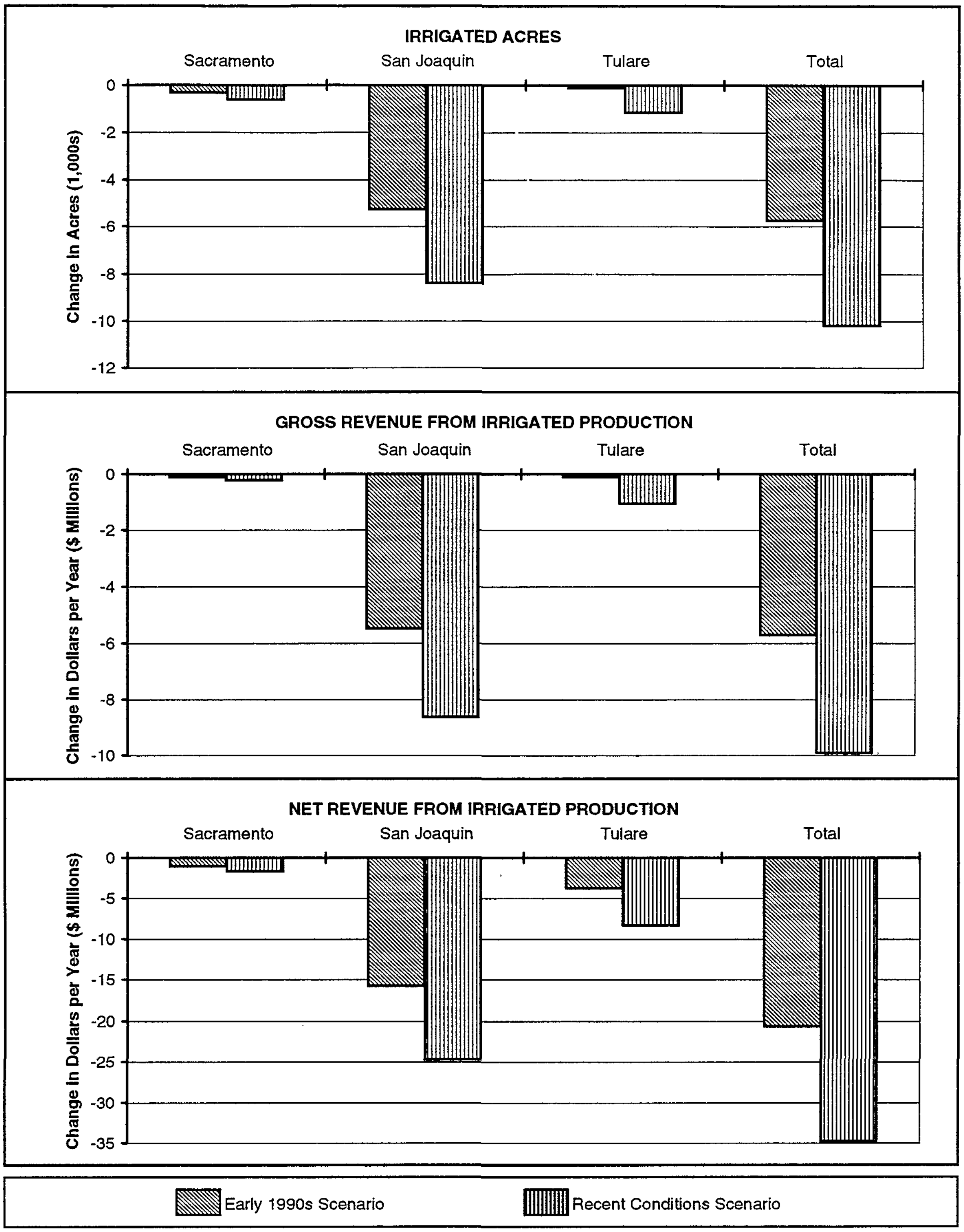


FIGURE IV-10
SIMULATED CHANGE FROM EARLY 1980s SCENARIO IN THE CENTRAL VALLEY

Risk, Financial, and Other Impacts

Changes in water operations reflected in the three scenarios affect the variability of surface water delivery. This often causes farmers to invest more in groundwater pumping capacity to increase the reliability of the water supply. Availability of credit for farming depends largely on the expected profitability of production, the risk or variability of profitability, and the collateral available to secure the lender's money. Therefore, changes in conditions that reduce net revenue, increase risk, or reduce the value of land can be expected to reduce the lenders' willingness to lend money or to increase the interest rates. Archibald and Kuhnle in a 1992 report entitled "An Economic Analysis of Water Availability in California Central Valley Agriculture, Phase III Preliminary Draft Report," for the Center for Economic Policy Research, Stanford University, reported that growers were finding it more difficult to obtain affordable credit because of reduced water supplies and increased costs and variability of water supplies. That study also found evidence of increased scrutiny of water supplies by potential lenders.

Reductions in water supply to Central Valley agriculture can also affect land values. Reduced opportunity for profit (net revenue) generally is reflected in lower land values. Much of the response to CVP supply reduction in the Central Valley is to increase groundwater pumping. Increased variability of water supply, especially downside variability, can increase the investment needed to for additional groundwater pumping capacity. In addition to direct losses in revenue to producers, consumers of irrigated crops bear losses due to higher prices and reduced availability. Some savings may accrue to the federal treasury from lower farm program payments that would have gone to lands idled from lack of water supply.

SAN FRANCISCO BAY REGION

Most of the CVP agricultural water deliveries in the San Francisco Bay Region are in the San Felipe Division. The San Felipe Division received no CVP water under the Early 1980s Scenario. It began receiving CVP water during the 1980s, and received an estimated 75,000 acre-feet under the simulated average condition of the Early 1990s Scenario. This increase in delivery to the San Felipe Division is included in the overall reductions in CVP agricultural delivery south of Delta shown in Table IV-4 and Figure IV-1. Estimated average delivery under the simulated Recent Conditions Scenario is about 68,000 acre-feet.

Delivery of CVP water to the San Felipe Division was assumed in this analysis to replace groundwater pumping, avoiding long-term deterioration in groundwater storage and quality. Under this assumption, no direct change in irrigated acreage or gross revenue occurred in this region from the delivery of CVP water in the Early 1990s or Recent Conditions scenarios. Over the long term, CVP water is expected to prevent the loss of productivity that could result from groundwater depletion or quality deterioration. The region produces crops with a high gross and net revenue, so the value of avoiding future loss of productivity is high.

CHAPTER V

BIBLIOGRAPHY

C — 0 8 1 0 2 3

Chapter V

BIBLIOGRAPHY

California Department of Fish and Game, 1983, A Plan for Protecting, Enhancing, and Increasing California's Wetlands for Waterfowl: Sacramento, CA.

__________, 1992, 1991 Annual Report on the Status of California State-Listed Threatened and Endangered Animals and Plants: Sacramento, CA.

California Department of Forestry and Fire Protection and California Department of Fish and Game, Sacramento, CA, 1992, Reassembling the Pieces: a Strategy for Maintaining Biological Diversity in California.

California Department of Water Resources, 1994, The California Water Plan Update, Volume I, Bulletin 160-93, October 1994: Sacramento, CA.

Central Valley Habitat Joint Venture, 1990, Central Valley Joint Venture Implementation Plan, A Component of the North American Waterfowl Management Plan: Sacramento, CA.

Dawson, W. L., 1923, The Birds of California: San Francisco, CA, South Monltare Company.

DWR, see California Department of Water Resources.

Frayer, W. E.; Peters, D. D.; and Powell, H. R., 1989, Wetlands of the California Central Valley Status and Trends, 1939 to Mid-1980s: Portland, OR, U.S. Fish and Wildlife Service, Region 1.

Hallock, R.J., n.d., Status of the Sacramento River System Salmon Resource and Escapement Goals: Red Bluff, CA California Department of Fish and Game.

Hansen, G. E., and Brode, J. M., 1980, Status of the Giant Garter Snake, *Thamnophis couchi gigas* (Fitch), Inland Fisheries Endangered Species Program Special Publication 80-5: Sacramento, CA, California Department of Fish and Game.

Holland, R. F., 1978, Geographic and Edaphic Distribution of Vernal Pools in the Great Central Valley, California: Berkeley, CA, California Native Plant Society, Special Publication Number 4.

Jensen, H. A., 1947, A System for Classifying Vegetation in California: California Fish and Game 33(4):199-266.

Kahrl, W. L., 1979, The California Water Atlas: Sacramento, CA, Governor's Office of Planning and Research, in Cooperation with California Department of Water Resources.

Katibah, E. F., 1984, A Brief History of Riparian Forests in the Central Valley of California, in Warner, R. E., and Hendrix, K. M. eds., California Riparian Systems: Ecology, Conservation, and Productive Management: Berkeley, CA, University of California Press, p. 23-29.

Mills, T.J., and Fisher, F., 1993, Central Valley Anadromous Sport Fish Annual Run-Size, Harvest Estimates, and Population Trends, 1967 through 1991, Preliminary draft, June (Inland Fisheries Technical Report): Sacramento, CA, California Department of Fish and Game.

Service, See U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service, 1978, Concept Plan for Waterfowl Wintering Habitat Preservation, Central Valley, California: Portland, OR.

Wieslander, A. E., 1945, Vegetation Types of California (Map): Berkeley, CA, U.S. Forest Service, California Forest and Range Experiment Station.