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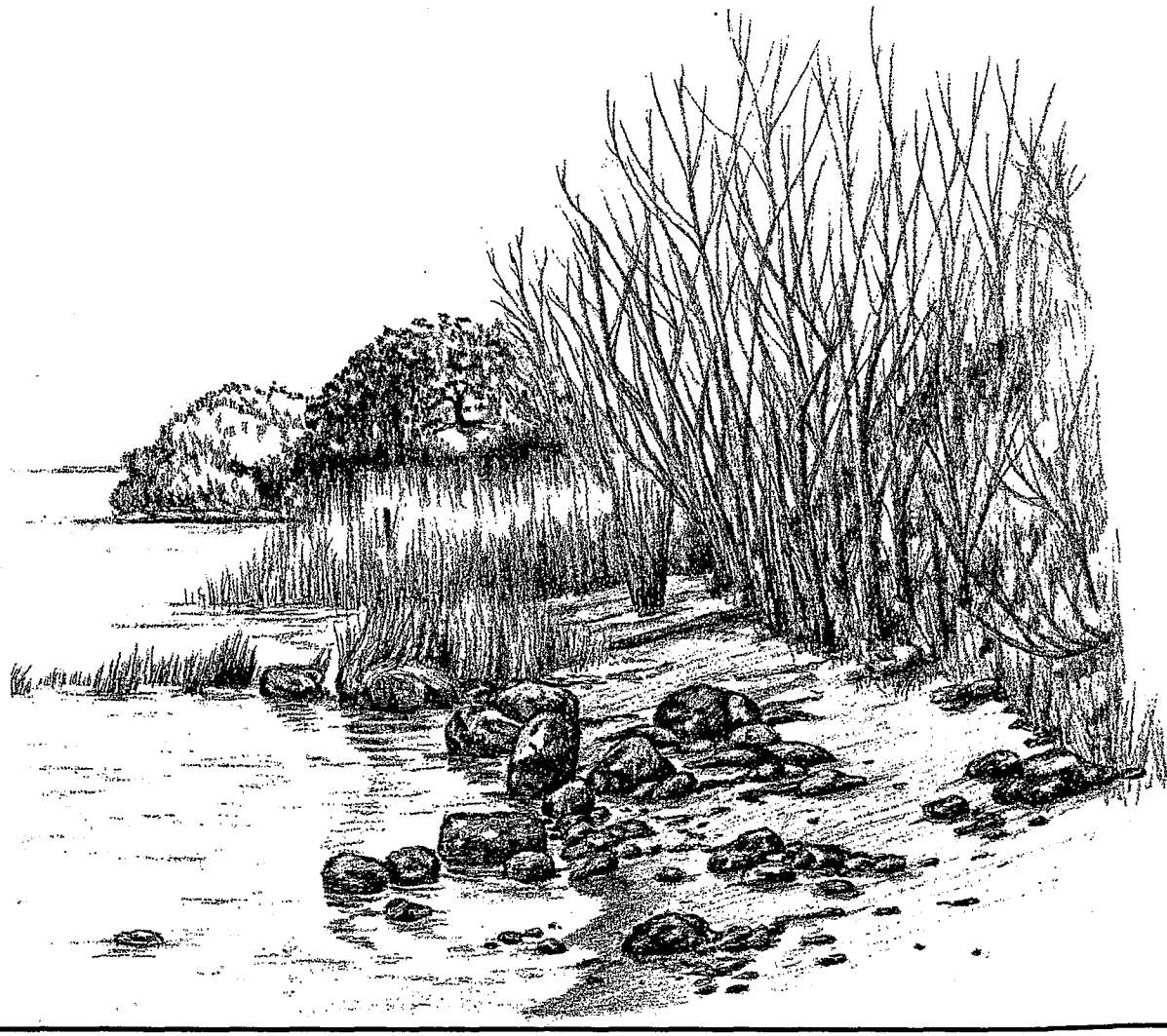
California's Rivers
A Public Trust Report



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Acronyms

ADMA	Aquatic Diversity Management Areas
ARB	California Air Resources Board
ARP	Archaeological Resources Protection Act
BLM	U.S. Bureau of Land Management
BMP	Best Management Practices
BOD	biological oxygen demand
BOR	U.S. Bureau of Reclamation
B&W	California Department of Boating and Waterways
CALEPA	California Environmental Protection Agency
CALTRANS	California Department of Transportation
CARCD	California Association of Resource Conservation Districts
CCMP	Comprehensive Conservation Management Plan
CDFFP	California Department of Forestry and Fire Protection
CDMG	California Division of Mines and Geology
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CNDDB	California Natural Diversity Data Base, Department of Fish and Game
COE	U.S. Army Corps of Engineers
CRMP	Coordinated Resource Management Planning
CSSTRF	California Salmon, Steelhead and Trout Restoration Federation
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
CWE	Cumulative Watershed Effect
DDT	dichlorodiphenyltrichloroethane (pesticide)

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DFG	California Department of Fish and Game
DHS	California Department of Health Services
DOC	California Department of Conservation
DOM	dissolved organic matter
DPC	Delta Protection Commission
DPR	California Department of Parks and Recreation
DTSC	California Department of Toxic Substances Control
DWP	Los Angeles Department of Water and Power
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
EC	electrical conductivity
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FDA	U.S. Food and Drug Administration
GIS	Geographical Information System
IPM	Integrated Pest Management
MCWRA	Monterey County Water Resources Agency
MWD	Metropolitan Water District of Southern California
NCRCD	Napa County Resource Conservation District
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	U.S. National Park Service
NPS	Nonpoint source pollution
NRA	National Recreation Area
OPR	California Office of Planning and Research
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
PFMC	Pacific Fishery Management Council
PG&E	Pacific Gas and Electric
POM	particulate organic matter
ppb	parts per billion
ppm	parts per million

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ppt	parts per thousand
PRC	California Public Resources Code
RWQCB	Regional Water Quality Control Boards
SCS	U.S. Soil Conservation Service
SHPO	California State Office of Historic Preservation
SLC	California State Lands Commission
SMARA	Surface Mining and Reclamation Act
SRA	Shaded Riverine Aquatic Cover
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
THP	Timber Harvest Plan
TMDL	total maximum daily load
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geologic Survey
WCB	Wildlife Conservation Board
WHR	Wildlife Habitat Relationship System

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Foreword

The State Lands Commission holds title to and manages some four million acres of sovereign land held in trust for the people of California. These lands, consisting of coastal and tidelands and all navigable rivers, streams and lakes, became state sovereign or public trust lands when California joined the Union in 1850. Because the Commission holds these lands in trust, they cannot be sold and must be used for water-dependent or water-oriented purposes such as navigation, boating, recreation, fishing, natural habitat and ecological preservation. In managing these sovereign lands under applicable trust principles, the Commission is a trustee or steward, charged with preserving the unique and irreplaceable character of the lands for the use and enjoyment of current and future generations.

This report is another of a series which examines the status of and trends affecting the public trust lands under the jurisdiction of the Commission. The series of reports has three purposes: 1) to mark the status of the public trust resources of California's rivers, lakes, bays, estuaries and tidelands; 2) to explore the likely future of those resources if present trends continue; and 3) to identify means by which such resources can be protected and restored.

The most recent of these reports was published by the Commission in 1991 when it released *Delta Estuary—California's Inland Coast: a Public Trust Report*. The *Delta Estuary* report detailed the historical and current land and water use activities in the region and documented the need for better coordinated and more comprehensive approaches to the management of its resources. The Legislature responded with the passage of the *Delta Protection Act of 1992* which recognized the significance of the Delta region and established a nineteen-member commission to prepare a resource management plan for its protection and preservation.

As the Delta report characterized the region's unique and vital public trust resources and various dependent uses, so does this report for the rivers in California and their watersheds.

It is worth noting that the terms of the trust which govern the management of sovereign or trust lands, whether in the Delta, riverbeds or elsewhere, are found in the statutes and the decisions of the judiciary and collectively comprise what is commonly referred to as

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the Public Trust Doctrine. This Doctrine originated in early Roman law and, as incorporated into English common law, held that certain resources were available in common to all humankind by "natural law." Among those common resources were "the air, running water, the sea and consequently the shores of the sea." Navigable waterways were declared to be "common highways, forever free," and available to all of the people for whatever public uses may be made of those waterways.

In California, the Public Trust Doctrine historically has referred to the right of the public to use California's waterways to engage in "commerce, navigation, and fisheries." More recently, the doctrine has been defined by the courts as providing the public the right to use California's water resources: for navigation, fisheries, commerce, environmental preservation and recreation; as ecological units for scientific study; as open space; as environments which provide food and habitats for birds and marine life; and as environ-ments which favorably affect the scenery and climate of the area.

The Doctrine was described by the California Supreme Court in its historic *National Audubon Society v. Superior Court* (1983) decision as "an affirmation of the duty of the state to protect the people's common heritage of streams, lakes, marshlands and tidelands, surrendering the right of protection only in rare cases when the abandonment of that right is consistent with the purposes of the trust."

The *Audubon* decision also stated the principle that the State has "an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible."

The importance of maintaining irreplaceable public trust resources was eloquently expressed by the State of Oregon Court of Appeals:

> The severe restriction upon the power of the state as trustee to modify water resources is predicated not only upon the importance of the public use of such waters and lands, but upon the exhaustible nature of the resources and its fundamental importance to our society and to our environment. These resources, after all, can only be spent once.
>
> Therefore, the law has historically and consistently recognized that rivers and estuaries once destroyed or diminished may never be restored to the public, and accordingly, has required the highest degree of protection from the public trustee. *Morse v. Oregon Div. of State Lands,* (1979).

It is with these judicial declarations and admonitions in mind that the State Lands Commission has undertaken its examination of how the public's trust resources have fared since statehood.

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As indicated, the subject of this report is the condition of the rivers of California and their watersheds: it documents the causes of their alteration and the nature and extent of their degradation; it identifies the means by which their degradation can be reduced, if not avoided; and it suggests some measures to be taken for their restoration.

The report clearly demonstrates the health of California's rivers to be stressed and their viability as sustainable ecosystems in peril. It should no longer be disputed that there exists an urgent need for state agencies to undertake a comprehensive program of river basin and watershed protection and restoration. Until such a program can be enacted or adopted, individual agencies should undertake to phase out or alter those activities presently permitted or tolerated which are revealed to be degrading the state's rivers and their watersheds; concurrently, such agencies should sponsor and implement actions conducive to the restoration of such rivers and watersheds.

Recently, the prestigious National Research Council released its seminal study and report entitled *Restoration of Aquatic Ecosystems*. In it, the Council urged a new national priority be given to the restoration and protection of the nation's rivers. The Council is the principal operating agency of the National Academy of Sciences in providing services to the government, the public, and the scientific and engineering communities. California should heed the data and analysis provided by the Council and accept the opportunity afforded by the call for a new national priority for the protection and restoration of rivers as ecosystems by establishing its own river restoration and protection program.

The Legislature should schedule public hearings to consider the findings and recommendations of this report and the National Research Council's report on *Restoration of Aquatic Ecosystems*. All federal and state agencies whose activities directly or indirectly affect rivers, together with academic and scientific groups and private sector interests, should be asked to participate in the hearings and to recommend actions for the protection and restoration of California's river resources.

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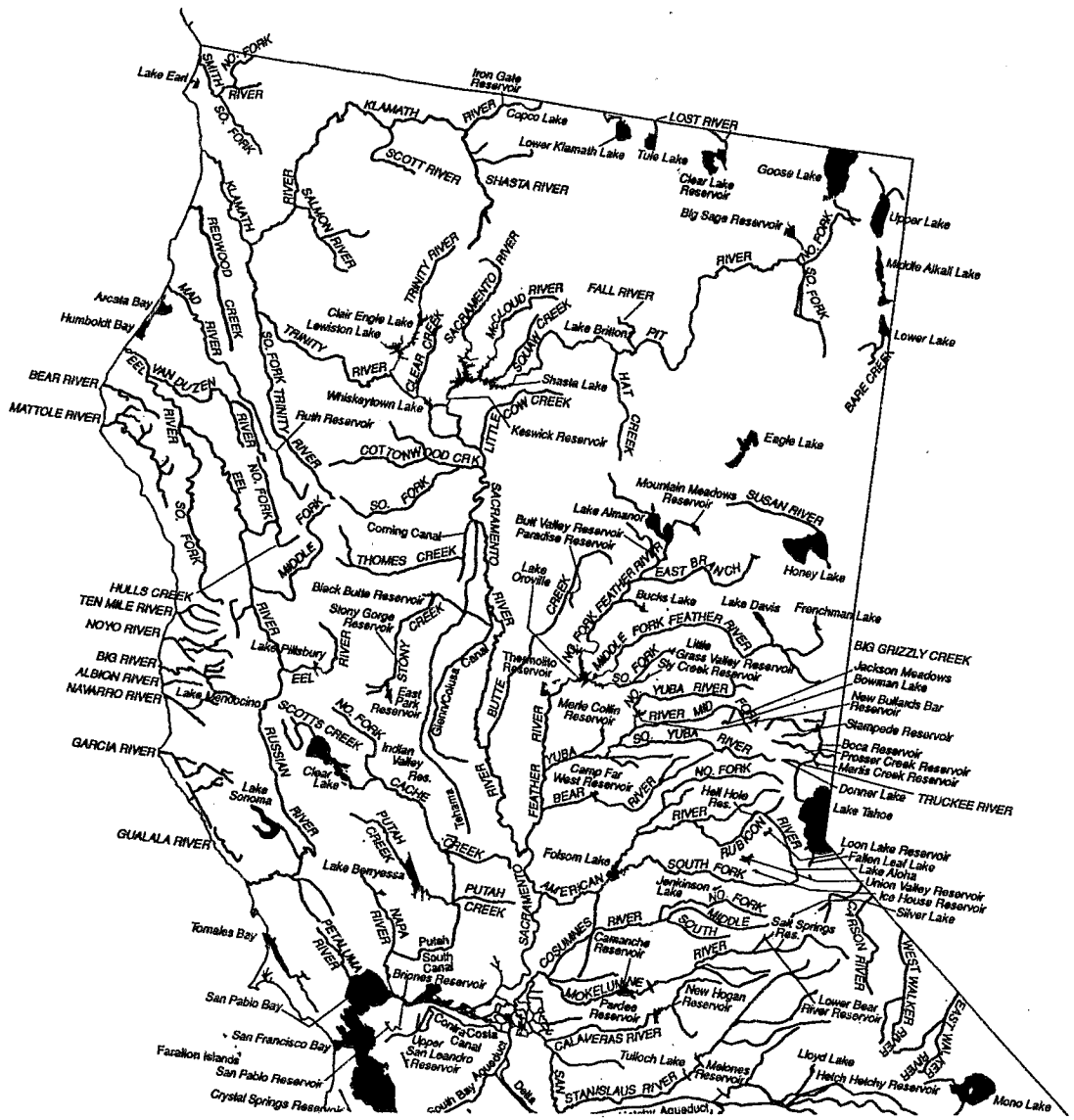

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California Rivers: Then and Now

1

A river is more than an amenity, it is a treasure.
Justice Oliver Wendell Holmes, *New Jersey v. New York,* 283 U.S. 336, 342 (1931)

From the time when people first arrived in what became California, the state's rivers have served their needs. Over the length and breadth of the state, from the Smith River on the Oregon border to the Sweetwater River near Mexico, from the once-powerful Colorado to the quieter Gualala on the coast, rivers have transported people and their goods, they have given food and water, they have served as convenient borders and as sources of wealth.

This chapter provides a brief history of the relationship between people and their streams. The portrait of the Native Americans' use of the rivers is a painting of vibrant rivers flowing through riparian forests full of life; a picture few Californians today can visualize. Following this early history is a description of the arrival of the Europeans. Much of this history, insight and valuable information on Native Americans' uses of rivers is found in Arthur McEvoy's comprehensive and thoughtful analytical works on both historic and contemporary fishing activities of the Native American. The Natives' benign effects on the rivers are distinguished from the Euro-americans' use of fisheries and of other river uses for mining, navigating, timber harvest, grazing, flood control and water development. The aftermath of these activities and the current status of rivers are described in Chapters 2 and 3.

Native Californian Settlements on the Rivers

When California's first settlers arrived from the north, perhaps 10,000 to 12,000 years ago, they invariably settled near water. Their principal villages were often maintained for a long time. The limits of the territory of the "group" were well defined, comprising in most cases a natural drainage area (Heizer, 1978). But it was the rivers and streams that appealed to the Natives (Kroeber, 1925); these rivers

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included the Klamath River of the Northwest, the Sacramento River and its tributaries in Central California and the Colorado River. The South Coast area is the exception, with an ocean orientation of the native people.

So fertile were the habitats where they hunted, gathered and fished that the most densely populated lands anywhere in North America were the valleys and coastal areas of California (Cook, 1976). The natural diversity, in combination with the geographical diversity, contributed to the remarkable variety and extent of the Natives civilization (McEvoy, 1986). The best estimate of the Indian population which existed prior to colonization and settlement by Euro-americans is about 310,000 (Cook, 1976; McEvoy, 1986). The Indian population numbers were lower in the deserts and high mountains (Kroeber, 1939) as would be expected. Overall California supported a higher population density of Indians than any other place on the continent north of central Mexico (Kroeber, 1925; McEvoy, 1986).

Native Indians depended mostly upon plant sources for food, especially acorns, but fish, shellfish and game were also important, depending upon local conditions (Kroeber, 1935). The Indians with the most sophisticated social organization appear to be those who relied upon fisheries, such as the Indians of the lower Klamath River in the northwestern part of the state (Kroeber, 1925; McEvoy, 1986).

Seasonal variation provided abundant game, fish and plants to the Native Americans. Riparian forests and river valley marshes provided many plants used for food, clothing, implements, baskets, and other objects. The Pomo, renowned for their basketry, used resources of the Russian River and coastal rivers in what is now Sonoma and Mendocino Counties. Their basket making made use of the strong yet pliable branches of the sandbar willow, a common riparian species of the area's rivers and streams (Tripp, 1984).

Chowchilla, Cosumnes, Cuyama, Gualala, Huasna, Kaweah, Klamath, Mattole, Mohave, Mokelumne, Napa, Noyo, Otay, Petaluma, Shasta, Sisquoc, Truckee, Tuolomne and Yuba are river names derived from the Native Americans (Kroeber, 1925).

Northwest Settlements

The rivers became especially important for the tribes that took up residence in the northwest part of the state. The old Hokan-speaking tribes of Karok, Chimariko and Shasta and the newer Athabascan Tolwa, Hupa, Mattole, Wailaki and Algonkin Yurok considered the rivers central to their existence. These tribes' life cycles, religions and wars focused on the rivers and, particularly, the salmon in those rivers. Even their language focused on the river: Karok means "upriver people," while Yurok means "downriver people" (Figure 2).

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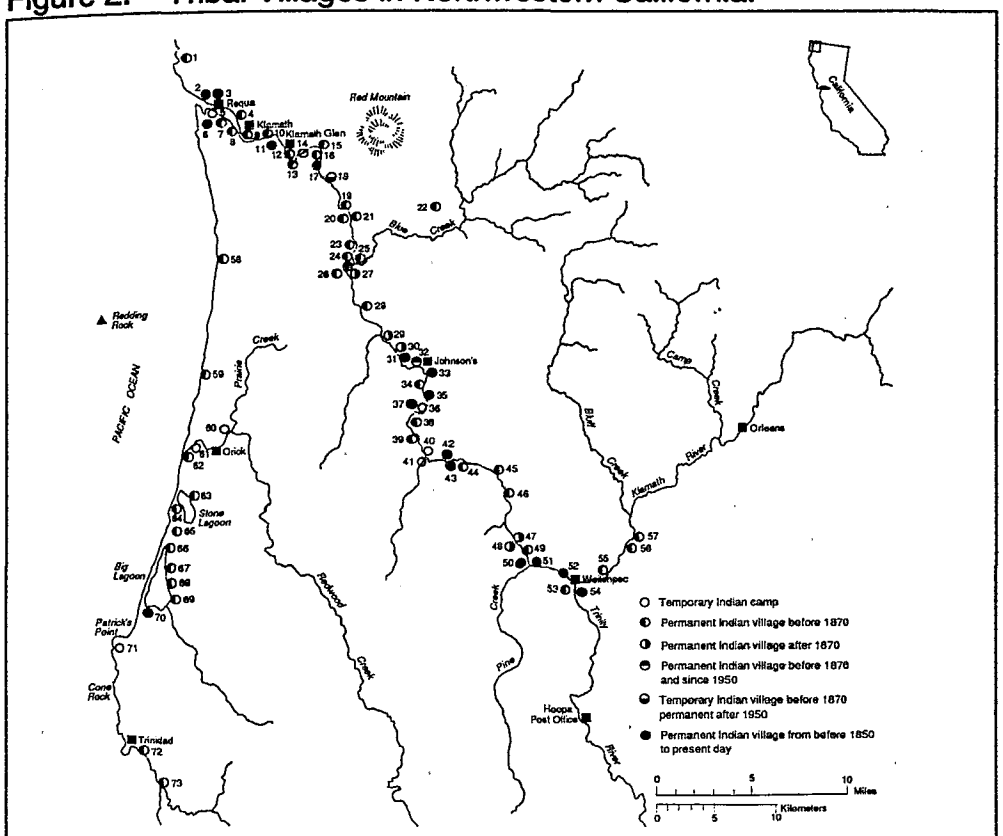
Figure 2. Tribal Villages in Northwestern California.



Tribal villages and camps: 1, Omen; 2, *rek'ʷoy*; 3, *tmɹy*; 4, A·menok; 5, Otwego; 6, *welkʷew*; 7, Tsekweł; 8, Kere; 9, O·menok; 10, *hop̓ew*; 11, Wo·kel; 12, A·lo·ł; 13, Yo·ktɹ; 14, Tɹwɹ; 15, *saʾal*; 16, *kohpey*; 17, *turip*; 18, Sta·wen; 19, Rliʾkenpets; 20, Howego; 21, To·ctɹ; 22, O·luʾuk; 23, Tora·; 24, Nageł; 25, Rnɹ; 26, Oʾpo·; 27, Oyoł; 28, *sɹpɹh*; 29, Tekta; 30, *wohkeroh*; 31, *wohtekʷ*; 32, *ko·tep*; 33, *pekʷon*; 34, Yoktɹ; 35, *sreyon*; 36, Keikem; 37, *metah*; 38, Wɹʾgɹ; 39, Nacko; 40, Himet; 41, Weikem; 42, *murekʷ*; 43, *kep̓el*; 44, *saʾał*; 45, *waʾaey*; 46, *meri·p*; 47, Okweya; 48, Kenekpul; 49, Tsetskwi; 50, *kenek*; 51, *wahsekʷ*; 52, *wečpus*; 53, *ʾɹłɹyɹʾ*; 54, *pekʷtuł*; 55, Loʾolego; 56, *ʾekoʾoh* (?); 57, *ʾočepor*; 58, Osegon; 59, *ʾespew*; 60, Oraw; 61, Sikwets; 62, *ʾorekʷ*; 63, Hɹkwɹ; 64, Ca·pekw; 65, Tsotskwi; 66, Paʾar; 67, Ołokw; 68, Keikem; 69, Maʾac; 70, *ʾoketey*; 71, Olem; 72, *čurey*; 73, Metskwo.

Source: Heizer (ed.) *Handbook of North American Indians*, Smithsonian.

The cultures of these two tribes were, in many ways, the least Californian of our native tribes, reflecting more closely the Northwest Coast cultures of coastal Oregon and Washington. Environmentally the northwestern part of California differs from the rest of state in that it has a greater rainfall (up to 100 inches annually), it is covered almost completely with dense timber (redwood or Douglas-fir forests) and had some of the best fish resources in California. These factors, combined with their cultural heritage, made these people predominately fishers rather than hunters or gatherers. Permanent villages were established almost exclusively along the major salmon streams.

While the total population of these northern tribes was not large, and the overall density (about 4.25 people per square mile) was not high, it cannot be said to have been sparse in a normal sense, since settlements were very dense along the streams. There were obvious effects of the ecology on their tools and techniques, with a high development of fishing gear such as spears, nets, dams and weirs.

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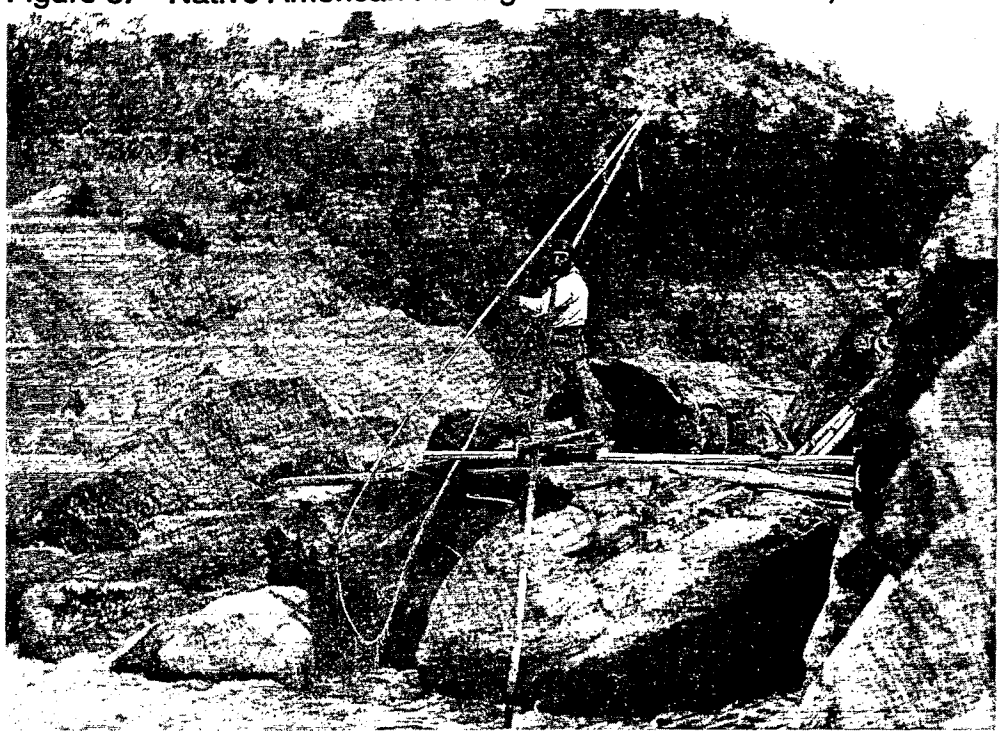
Figure 3. Native American Fishing on the Klamath River, 1880s.



Courtesy of NAA Smithsonian.

The somewhat unpredictable, cyclical nature of the salmon's annual migrations over the centuries profoundly influenced Yurok life. Religion, lore, law and tribal technology all evolved from the Indians' relationship with their fishery resources (Lufkin, 1991).

The effects of the environment on the Native population size is not well understood. For reasons not entirely clear, the tribal groups in this part of California seem to top out at about 3,000 individuals. Possibly the superabundance of fish in some areas was more apparent than real. For example, the Yurok at the mouth of the Klamath would appear to have almost unlimited fish resources, but failed to exploit them. One reason might be that full utilization of the resource would have deprived upstream tribes, who probably would have initiated some action to redress the balance.

The extreme crowding of these rivers may have had something to do with the litigious characteristic of the Northwestern California societies; for example, one was entitled to use any boat beached on the river bank in order to cross a stream, but one was liable for the value of the boat if anything happened to it while in use. These tribes also had a view of land "ownership" that was more similar to their European successors than did tribes in other parts of the state.

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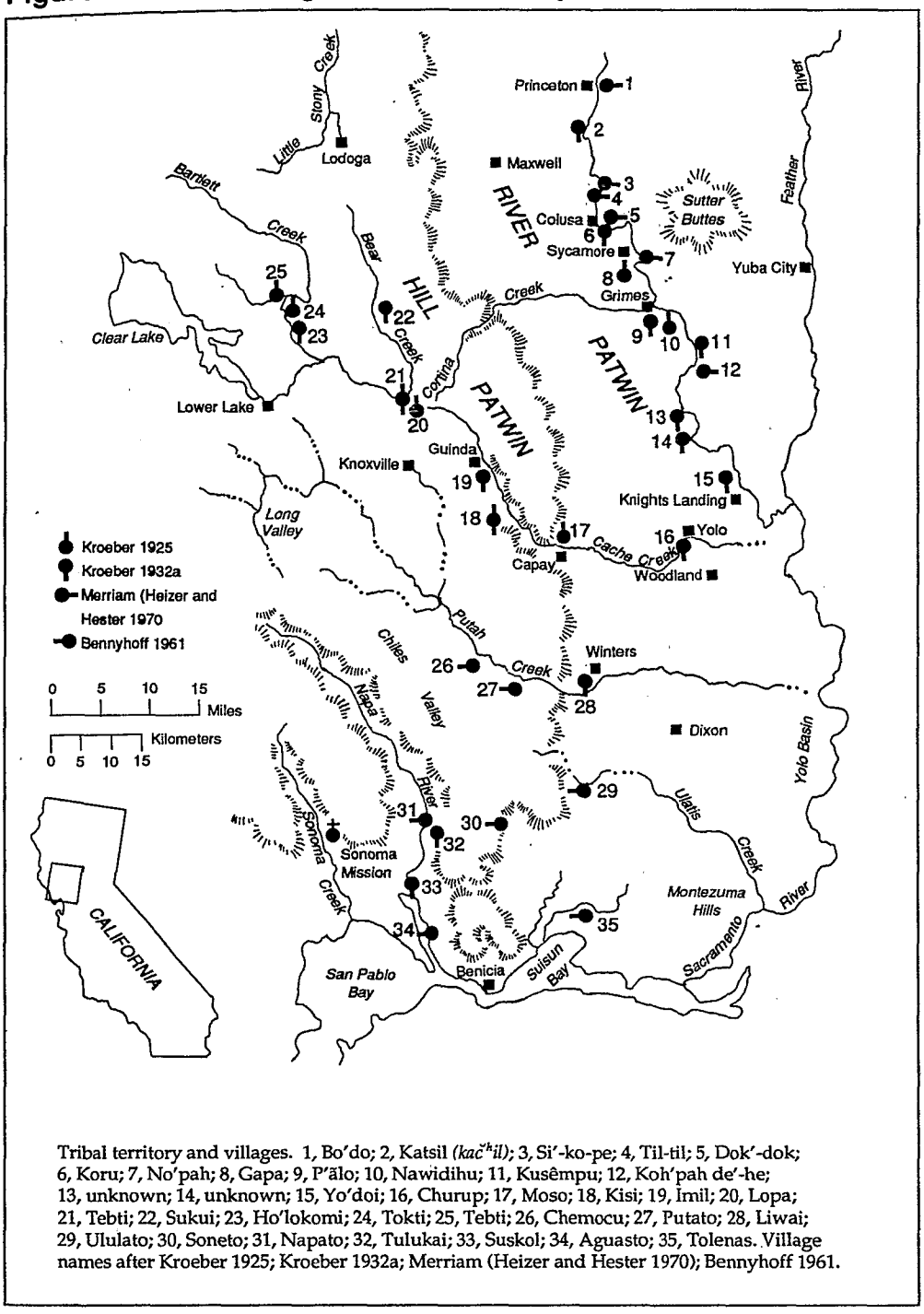
Figure 4. Tribal Villages in Central Valley.



Tribal territory and villages. 1, Bo'do; 2, Katsil (*kač^h il*); 3, Si'-ko-pe; 4, Til-til; 5, Dok'-dok; 6, Koru; 7, No'pah; 8, Gapa; 9, P'ālo; 10, Nawidihu; 11, Kusêmpu; 12, Koh'pah de'-he; 13, unknown; 14, unknown; 15, Yo'doi; 16, Churup; 17, Moso; 18, Kisi; 19, Imil; 20, Lopa; 21, Tebti; 22, Sukui; 23, Ho'lokomi; 24, Tokti; 25, Tebti; 26, Chemocu; 27, Putato; 28, Liwai; 29, Ululato; 30, Soneto; 31, Napato; 32, Tulukai; 33, Suskol; 34, Aguasto; 35, Tolenas. Village names after Kroeber 1925; Kroeber 1932a; Merriam (Heizer and Hester 1970); Bennyhoff 1961.

Source: Heizer (ed.) *Handbook of North American Indians*, Smithsonian.

Sacramento and San Joaquin Rivers and Delta Settlements

California's rivers were important to the tribes living along the Sacramento and San Joaquin rivers, and the Delta which formed where the two come together. Vast areas of grassland, fair quantities

of variable woodland and chaparral, combined with rivers to provide one of the richest habitats in California. The woodland/chaparral provided deer, vegetables and the staple acorns; the grasslands provided antelope; and the rivers provided salmon and other fish and the large gallery forests along the riparian corridors provided more acorns.

The dense populations fostered by such a favorable environment led to stronger kinship groups than other parts of California, with individual status often being ascribed at birth. Both strong matrilineal and patrilineal systems developed in the area, often to the confusion of later anthropologists (Heizer and Whipple, 1951).

The Native lines of communication followed the large streams (Figure 4). For example, the relationships of the Nisenan were to the north and northwest in the Sacramento Valley, while the San Joaquin portion of the Great Valley was unknown territory to them. In the same way, their neighbors to the south, the Eastern Miwok, had communication lines to the south and into the Sierra, but very little to do with the north. Fishing was important to both these groups, if not as central as it was to the Northwestern tribes. Salmon, sturgeon and lampreys were taken, primarily in nets. Dip nets, seines, set nets and casting nets were all used, often in conjunction with the reed raft.

Sierra Settlements

The rivers had less importance for the early dwellers in the Sierran foothills and for the southern San Joaquin Valley. There was too little water, and the streams were often only intermittent. Many of these groups migrated seasonally throughout their range, camping near the rivers when they were running full, and working the upland drainage as hunters in the summer and fall when the rivers were low.

Desert Settlements

In the southern deserts, as well, rivers were generally not central to the tribal lifestyle, with one important exception. All along the Colorado River several tribes lived permanently on the river's edge, and used its fish resources as an escape from the harsher life of desert hunter-gatherers. It is clear that the Yuma, Chemehuevi and Mohave lived better than their neighbors who had no access to the river. In addition to the fishing practices of these tribes, the use of the river flood plain for crops gave them a food surplus that allowed for trade with groups as far away as the Hopi, in central Arizona.

Central and South Coast Settlements

The tribes of the Central and South Coast used the mouths of rivers and streams as harbors, but otherwise turned more to the sea than to the inland waters. The immediate predecessors to the

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Chumash were known from midden remains to take salmon from these coastal streams, but the fishing pressure appears to have been too much for the fish populations at the edge of their range and by the time the Europeans arrived the Chumash were oriented more towards the sea and less toward their rivers.

Exploration and Exploitation—The Coming of the European

The Spanish Padres and Conquistadors came by sea or over land from Mexico, and they found the east-west running rivers more of a barrier than a help in their primarily north-south travels. Francisco Ulloa proved California was not an island, and discovered the mouth of the Colorado in 1739. Juan de Offate had explored a route from Santa Fe to the Colorado, and downstream as far as the Gila River in 1604.

Later the Spanish established what became known as the "Old Spanish Trail," which left Santa Fe and went north, crossed the Colorado River upstream of the Grand Canyon, and entered California below Death Valley. The trail followed the course of the Mojave River, and entered the Los Angeles basin over Cajon Pass. Major exploration of California's principle inland rivers did not begin until after the mission of San Jose and Presidio of San Francisco were founded.

European exploration and use of the Sacramento-San Joaquin Delta waterways began early, but grew slowly. Father Juan Crespi and Don Pedro Fages stood on the top of Mount Diablo and described the meeting of what are now called the Sacramento and San Joaquin rivers in 1772. Explorers from the new Presidio at San Francisco in small boats reached the mouth of the Sacramento in 1776, and called it the San Roque. In 1808 Lieutenant Moraga ascended the river to the mouth of the Feather River, which he called the Sacramento. He then went overland from the Sutter Buttes and made it back to the river near Stony Creek. He gave the Sacramento another name, the Jesús Maria.

Larger vessels began exploration in 1811, as Fathers Abella and Fortini took a short trip up the "northern river of San Francisco," and then explored the mouth of the San Joaquin River. Land expeditions by the Spanish Fathers and soldiers through 1820 wandered about Montezuma Slough, up the Sacramento as far as present-day Redding, and along the southern edge of the Delta to where Stockton now stands.

Other Europeans entered the picture soon thereafter. The Russians, under Captain Kotzebue, sailed up the Sacramento in 1824. The British navy sent H.M.S. *Sulphur* in 1837, which produced the oldest surviving chart of the lower Sacramento. The Americans were represented by Jedediah Smith, who walked along the upper Sacramento in 1828, believing it to be the legendary Buenaventura River,

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which many thought flowed west from the Rocky Mountains to the Pacific.

Hunters followed the explorers. By 1820, British and French trappers appeared in the Delta, often taking their pelts to Yerba Buena Cove, but they only left some scattered place names, such as French Camp, in the Delta proper. But in 1832 a more permanent change was brought about by the trappers. A Hudson's Bay Company party, led by John Work, came down the Sacramento River in that year and returned up the river the following year. They brought malaria with them, and in and near the wetlands of the valley the results were fatal to the Native inhabitants. Within four years over 75 percent of the Patwin were dead, the Bay Miwok had disappeared, and the Plains Miwok had lost over 80 percent of their people. By the time the Europeans decided to try settling in the Delta, there were no Natives to displace.

Real river commerce depended on settlement, and the Delta was surrounded by settlements in the early 1840s. Dr. John Marsh was first, settling at the foot of Mount Diablo in 1837. Then John Sutter built New Helvetia on the American River in 1841. Juan Peña and Juan Vaca settled Lagoon Valley, near present day Fairfield, in 1842. The Berryessa brothers obtained a grant of land on Cache Creek in 1843. And Charles M. Weber settled first at French Camp in 1844, then founded Stockton on the San Joaquin River a few years later.

The Sacramento River had more traffic than the San Joaquin because of upriver settlements by Peter Lassen, John Bidwell, William Knight and the Wolfskill clan. When Sutter bought out the Russians at Fort Ross in 1841, the purchase included a sailing launch, renamed the *Sacramento*. This little vessel was the first to carry on regular service between New Helvetia and Yerba Buena, now Sacramento and San Francisco. The trip usually took about two weeks, round trip.

Although major ocean-going sailing ships regularly docked at Sacramento, and later at Stockton, everyone realized that the rivers needed steam power. The "steam era" began on a summer day in 1847, when the Russian bark *Nasednich* dropped anchor in Yerba Buena cove and began unloading her "general cargo." Out of her hold, in several pieces, came a 37-foot steamboat, the *Sitka* (sometimes called "Little Sitka"). She was consigned to an early merchant, William Leidesdorff, who had her quickly assembled. He tested out his purchase on San Francisco Bay for awhile. But on November 29, 1847, the *Sitka* headed upriver for New Helvetia. The trip was not an unqualified success. It took six days, seven hours to reach the upriver destination, and on the return trip she was beaten to Benicia by an oxcart. Beaten by four days, in fact. While this was an indication of their demise, sailing ships were not yet threatened.

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All That Glitters. . . .

But it was gold that really brought the world to California, and the gold was in the rivers, at least at first. The early settlers had brought disease, and had displaced some Indians, but the gold miners essentially eliminated those who were left.

Particularly in the northwest part of the state, where the rivers were so important to the Natives, bitter conflict erupted. The Chimariko, for example, for a short while got the upper hand. But the whites ultimately:

> . . . taught (them) that they must not presume to discuss with American miners the question of the proper color for the water in the Trinity River. [The Chimariko] were hunted to the death, shot down one by one, massacred in groups, driven over precipices. . . In the summer of 1871. . . there was not an Indian left. The gold was gone too, and the miners for the greater part, and amid the stupendous ripping-up and wreck of the earth which miners leave behind them, in this grim and rock-bound canyon. . . one finds himself indulging in this reflection: The gold is gone, to return no more; the white man wanted nothing else; the Trinity now has nothing but its salmon to offer; the Indian wanted nothing else (Powers, 1877a).

Figure 5. Hydraulic Mining in the Sierra Nevada.

Courtesy of Sacramento Archives and Museum Collection Center.

In the Sierra, too, it was the water that attracted the gold seekers. Every river, stream and rill was buried under the hordes that came from all corners of the globe, settling on the bends, bars and flats of the Mother Lode. When the panning died out, the miners

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turned to dredges and then to hydraulic mining, which used the waters of the rivers to wash the mountain sides and turned the rivers into giant sluice boxes that literally carried the soil of the mountains downstream, filling river beds with tragic consequences.

Hydraulic Mining

Hydraulic mining involves directing a high-pressure jet of water onto an exposed placer deposit (gravel, sand or silt) and running the sediment through sluices to remove the gold (Figure 5). From the 1850s until it was prohibited in California by court decisions in 1884 (*People v. Gold River Ditch and Mining Co.*, 66 Cal. 138 1884), hydraulic mining was intensively practiced on placer deposits in the Sierra Nevada, especially in the Yuba, Feather and American river drainages (Yeend, 1974).

Large portions of mountains were washed away, leaving canyon-like landscapes, some of which are now state historic parks (Malakoff Diggins and Columbia). The sediment was washed through sluices and thence into steep canyons, from which the sediment was readily flushed by high flows (especially the record floods of 1862) into lower reaches of the rivers in the Sacramento Valley. This influx of hydraulic mining debris increased the sediment load of the rivers beyond their transport capacity, resulting in extensive deposits of tailings in the Sacramento Valley. The "debris plain" of the Yuba River was particularly noteworthy, covering over 40 square miles. As river channels filled with sediment, navigation was affected and rivers flooded farmland, inundating many fields with fresh deposits of hydraulic mining debris. Agricultural interests successfully halted the practice of hydraulic mining in the courts.

The passage of this wave or "slug" of sediment through the Yuba River was well documented by Gilbert (1917) and Adler (1980). At Marysville, aggradation had peaked and the bed began incising by 1905. Stabilization of the bed of the Yuba River continued for decades, influenced in large part by channel training works and the construction of Englebright Dam in 1940 upstream of the debris plain (Kondolf, 1988).

Dredger Mining

The flood plains of many California rivers display a distinctive pattern of parallel ridges and swales, with relief commonly ranging up to 40 feet. These features are the tailings piles of gold dredgers, large floating barges that reworked alluvial deposits for gold (Figure 6). The dredgers operated in temporary lakes, and created a stratigraphy in which fine sediments were overlain by coarse sediments. The resulting ridges consist of well-drained cobbles and gravel on which vegetation is typically unable to establish. In between the ridges, near-surface water tables may support riparian plant species.

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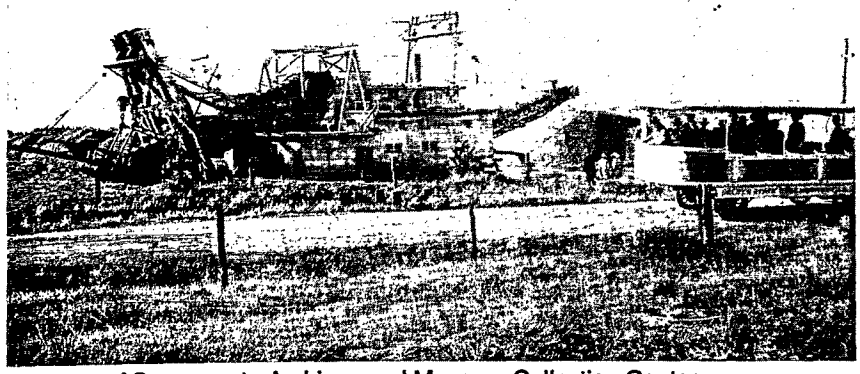
The Yuba River debris plain has been worked repeatedly by dredgers, producing a distinctive landscape of gravel ridges many feet high. The flood plains of the Feather, American, Tuolumne and other major rivers draining gold-bearing terrain have also been dredged.

Figure 6. Gold Dredger on the Sacramento River.



Courtesy of Sacramento Archives and Museum Collection Center.

Fishing and Fisheries

The Beginning - Native Americans

Native Americans had the ability to change their world by significantly influencing the natural environments they inhabited and the resources they utilized, including fisheries. Their dependence on the fisheries in nearly every way required conservation of the resource. Evidence suggests they practiced active management to protect against resource depletion through exploitation and the vagaries of weather (McEvoy, 1986). Tribal conservation practices, such as removing fish dams to allow the fish to spawn up-river ensured that stocks would remain plentiful (Lufkin, 1991). Where fisheries were an important part of the resource base, such as on northwest rivers, Indian culture included especially elaborate social or legal controls over fishing, as well as major ceremonies, rituals, and other spiritual traditions centered on the rivers and their fish (Kroeber, 1925; Roberts, 1932).

Natives fished over most of the state, from lakes, rivers, streams and the ocean. Salmon was the predominant catch on the larger rivers from Monterey Bay northward. Lamprey eels and sturgeon were also caught, especially in the North Coast region (Kroeber, 1925). Delta Indians fished a number of warm water fish, including the Sacramento perch, thicktail chub and hitch, which inhabited the lakes, marshes and backwater sloughs of the Delta and valley lowlands (Schulz and Simons, 1973). On the Colorado River,

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the native fishes were rather bony and mushy-fleshed, but were caught and eaten by the Yuma and Mohave people (Kroeber, 1925).

Fishing technology among California Native people included a variety of gear and practices. Various modes of netting and entrapment were widespread and common, including gill nets, seining (encircling) nets, dip nets, weirs (dams) and traps (Kroeber, 1925; Kroeber and Barrett, 1960; Roberts, 1932). Harpoons were also used throughout the state except on the Colorado River, where the water was too turbid. Often, scaffolds were built out over rivers, from which dip nets or harpoons were used. In smaller streams and pools, poison derived from plant materials, such as the California buckeye was sometimes used (Kroeber, 1925). Hook and line fishing was known, but seems to have been employed relatively infrequently (Kroeber, 1925; Schulz and Simons, 1973). Aboriginal fishers also shared with their successors fishery management problems that are still challenging today: coping with natural fluctuations in resources, controlling fish harvest and promoting economic viability at the same time. Many Native American salmon fishing groups worked at the southern-most limit of the habitat, where small climate changes can drastically alter the size of salmon runs from year to year. In southern coastal California, moreover, environmental change forced some Indian villages to change their fishing strategies and others to abandon fishing altogether.

The First Salmon Fishery

Salmon was a large portion of the diet of the Yurok, Karok, and Hupa (Hoopa) peoples of the lower Klamath and Trinity rivers. As a consequence, the salmon fishery of these northwestern Indians was an integral part of all aspects of their culture, including religion, economics and law (McEvoy, 1986). "First Salmon" ceremonies to herald a new season were held in the spring or fall (Kroeber, 1925). These ceremonies were to ensure the bounty of the salmon. The ceremonies, usually with dance, were the most elaborate in the Northwest, where salmon was of great importance.

Other great ceremonies and dances accompanied the establishment each year of major fishing sites on the Klamath. At certain narrow spots on the river, huge weirs of posts and branches were placed across the river to block salmon passage so they could be netted or trapped (Kroeber, 1925). Such weirs were major community projects, as was the dip netting at the pools below Ishi Pishi Falls (Rogers, 1932). A huge weir was placed at Kepel on the Klamath below Weitchpec at the confluence of the Trinity River. This weir took 60 people 10 days to build and the accompanying dance carried on for weeks after (Kroeber, 1925).

In addition to group fishing efforts, individuals or families held ownership rights to fishing places on the river. These rights

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were well respected and could be sold or passed down in families (Rogers, 1932). No new fishing places could be established at or below existing ones; this controlled the number of fishing sites (Kroeber, 1925).

There have been efforts to estimate the size of the salmon harvest of the Native Americans prior to the coming of the Europeans. One example, from the Bureau of Indian Affairs, conservatively places consumption in the Klamath-Trinity basin at 36,000 chinooks, or some 50,000 pounds, each winter. Other estimates for the same area run as high as 2 million pounds per year (McEvoy, 1986). Of these and other estimates it is interesting to note that they approximate the highest yields that the same regions ever produced commercially under the Euro-americans' hands. On the Klamath "the greatest run of salmon known to white men" produced only 1.4 million pounds of salmon, in 1912, while yields from the Sacramento peaked at roughly 10 million pounds per annum between 1880 and 1883 (Snyder, 1931). Thus the evidence suggests that the Native Americans' harvest of fish was at least at comparable levels with the Euro-american commercial fishers who followed them. In spite of this obviously significant pressure on the resource, the Native Americans sustained their yields for centuries.

Natural climatic variation must have resulted in poor salmon runs occasionally, and Indian tales and legends refer to such times (Rogers, 1932). However, McEvoy's (1986) analysis of Native American fishing concluded that Indians developed and maintained a productive salmon fishery that divided the resources among many peoples and was sustainable in the long term. This is in dramatic contrast to the Euro-american societies which followed.

The End of the Original Fishery

The decimation of the Native Americans parallels the subsequent decline of fisheries which followed European settlement. It took 65 years from the establishment of the first Spanish mission, in 1769, to render the Native population in the coastal strip between San Diego and Sonoma to 75 percent of its former numbers. The Euro-american miners and farmers who came in later decades wiped out wholesale any Natives they found. "Between 1845 and 1855 alone, two-thirds of the remaining Natives lost their lives" (McEvoy, 1986). When the gold fever ended so had the Native Americans—only 50,000 still lived (McEvoy, 1986). By 1900 their population was estimated at about 16,000 (Kroeber, 1925). Stephen Powers wrote in 1871:

> Never before in history has a people been swept away with such terrible swiftness, or appalled into utter and unwhispering silence forever, as were the California Indians. . . let a tribe complain that the miners muddied

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their salmon streams, or steal a few pack mules, and in twenty days there might not be a soul of them living (Powers, 1872a).

The European's impact on the Native population mirrors the exploitation of the state's natural resources. Most California Natives "simply could not get out of the way. Because they had spread their economies so broadly over their habitats and adjusted their harvesting so closely to capacity, the sudden interruption of their seasonal rounds at any point brought privation" (McEvoy, 1986).

The Wintu Fishery

For the Wintu tribe, conflict over salmon streams usually was not a direct conflict over the use of salmon. Gold mining and logging damaged the salmon streams to the point where the Native Americans could no longer support themselves on the diminished harvest. This, and being pushed into the unproductive surrounding mountains, away from the water, was the core of conflict. By the 1870s, mining had rendered the American and Feather rivers all but useless for salmon. Only the Little Sacramento and McCloud rivers remained of all Central Valley streams as viable spawning grounds, and the Natives were only allowed near the McCloud. There a band of Wintu were still operating a successful subsistence fishery in August of 1872, when a U.S. Fishery Commission biologist found them. The biologist, Livingston Stone, had arrived to collect salmon eggs for the commission. His initial meetings with the Natives were not auspicious, but he developed a relationship with the tribe where he could take the eggs as long as the Natives got the fish. Stone believed very soon that the cooperation of biologists and Indians was necessary if the salmon was to survive as a resource. President Grant reserved, for government use, 280 acres as a fish hatchery. In 1877, a small garrison of soldiers arrived to prevent friction with the settlers who, by then, were arriving in larger numbers. The Native Americans and the government worked well together, supplying eggs and fry to the East Coast, Sacramento and abroad. Stone's arrangements protected the heart of the system very well, but progress on the lower river soon caught up with him. On August 7, 1883, where they were used to counting 6,000 to 8,000 fish jumping every hour, after the fall run had begun as usual, he could see no more fish in the river. Several miles below the station, at the

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mouth of the Pit River, the Central Pacific Railroad had begun blasting to clear a bed for its line. Stone was convinced that, although some of the workers had been blowing charges in the river itself and collecting the dead fish, the blasting by Central Pacific had driven the fish back. There were no more fish for the rest of the season. The hatchery itself did not reopen for five more years, and when it did, the Wintu fishery was dead. They held their last communal fish drive at Baird "about 1886." The historic fish hatchery now lies at the bottom of Shasta Lake.

Source: Case law and McEvoy, 1986.

The Yurok, Hupa and Karok of the North Coast region survived far better than other groups in the state (Kroeber, 1925). Further, these people managed to hang on to their historic fishery, in contrast to the complete disruption of native economies and societies which occurred elsewhere. McEvoy (1986) postulates that the inaccessibility of the area in combination with the tight and well-ordered society of the Natives effectively delayed the onslaught of white culture and economic development in the area.

North Coast Indians ultimately faced tremendous conflicts with white immigrants after 1850. Many were killed, lost their land, or contracted disease (sources reviewed by McEvoy, 1986).

Navigating the Klamath

Fishing on the Klamath River has occurred since the earliest days of California. Native American Indians used seine nets and other devices to fish for salmon, which was a staple of their existence. In 1855, President Pierce created the Klamath River Indian Reservation which encompassed lands within one mile of either side of the river and upstream for a distance of 20 miles. After the devastating floods of 1861, the United States Bureau of Indian Affairs relocated the local Indians to a newly created Smith River Reserve. Longing for their native lands, the Indians returned to the Klamath River basin. In 1876 President Grant created the Hoopa Indian Reservation at the confluence of the Klamath and Trinity rivers.

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As in many other areas of the nation and the state conflict arose between the Indians and whites who wanted to settle on Indian lands. Squatters kept moving into the Klamath Valley, claiming the army had abandoned the reservation in 1862. And the army kept sweeping them out of the Native lands. R. D. Hume, a salmon entrepreneur from Oregon with the idea of packing salmon out of the river, precipitated (1887) the following events: Hume was prepared to fish without permission—the Interior Department had denied his offer to buy land along the river and a request for a 10-year lease on fishing rights. Crossing the bar in a light steam tug prepared to build a floating cannery in the estuary, Hume, armed, warned the commander of the local army garrison not to interfere. To supplement his own fishing crews, he purchased fish from the Yurok with goods stored aboard his tug. The Yurok, however, had worked hard to clear the estuary bottom for their nets, and complained to the local agent and the Army that Hume's operation "very much" disturbed their own fishing rights (Dodds, 1959).

The U. S. Attorney General received the complaints and ruled that, since the waters were stipulated navigable by the state, the Indians had no exclusive right to fish them, but only a right to fish in common with the public at large. Whether or not the lower river was "Indian Country" and whether Hume could be excluded on that basis were questions "clearly justiciable in the appropriate courts at the suit of the Indians themselves. . . ." At that point the army seized Hume's tug with its store under a law prohibiting unlicensed trading in "Indian Country." (Humboldt Times, June 9, 1887)

The "appropriate court"—the federal district court in San Francisco—decided the matter in the case of *United States vs. Forty-Eight Pounds of Rising Star Tea, etc.* The government's prosecution was badly handled: The U.S. attorney did not appear in court to present Interior Department's side of the issue, and the local agent for the Native Americans was the government's only witness. The judge agreed with Hume that the Klamath was by law a navigable river, and that the land ceased to be a reservation when it was abandoned in 1862. On appeal, the judgement was upheld. Hume freely packed and traded salmon (35F 403, ND Cal 1888).

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Hume never realized a profit, and after a few years, sold out to Bomhoff's Klamath River Packer's Association. The vulnerability of the Natives' fishing rights had been shown, and demands for land along the lower river became more insistent every year. To circumvent the *Rising Star Tea* decision, and on the basis of a report from the Interior Department, President Harrison extended the Hoopa Valley Reservation down to the ocean in 1891 (Executive Order, October 16, 1891). This act secured the Indians' rights to lands surrounding the river and their ability to fish in it.

Source: 35F 403, ND Cal 1888 and McEvoy, 1986.

For several decades in the late 1800s numerous congressional bills and treaties were attempted to create and maintain some sort of reservation for Klamath and Trinity river-dwelling Indians. At the same time legal questions were being addressed regarding Native American fishing rights on the river, mainly as a result of competition with white commercial fishing interests (Pierce, 1991a and b).

The rights of the Native Americans of the extended Hoopa Valley Reservation, although having been recognized as preferential for the Klamath River salmon fishery, nonetheless remained undefined and increasingly controversial during the early decades of this century. Until the state's closure of the river to commercial fishing in 1933, the Yurok were either employed in several canneries or supplied those canneries with salmon. The Yurok gradually began using modern boats and gill nets and became commercial fishermen. "Between 1915 and 1928, an average of 82 boats harvested some 52,000 chinooks, or about 725,000 pounds of salmon each year" (McEvoy, 1986).

Euro-American Fisheries Management and Mismanagement

Prior to the 1849 Gold Rush, there was little commercial fishing on California's rivers or oceans. The huge influx of settlers in Central California after the start of Gold Rush found a natural world teeming with wild game and fish—of which they quickly took advantage. Hunters, especially those in the market trade, wiped out whole populations of species, including the grizzly bear, pronghorn antelope and tule elk. Fish were hauled easily out of the rivers, caught in gill nets, fyke traps or seines (Reynolds et al., 1990).

During the late 1840s and early 1850s, gold seekers of Italian, Chinese and other nationalities, survived the treacherous land or sea trip to California and made their way to the state's valleys and hills.

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Some of these "pioneers" seeking their fortunes in the Golden State turned to commercial fishing. The waters of the rivers began to yield fish for profit. Some have suggested this was the real gold.

In the beginning, gold mining activities and investment offered more profitable outlets for venture, leaving the harvesting end of commercial fishing to poorer immigrants—Chinese, Greeks, Italians, Portuguese and others. The immigrant fishers adapted their Old World skills and marketed their products among those from the same countries and cultures (McEvoy, 1986). At this early stage in commercial fishing, fishers, though bound by cultural ties, worked isolated from others without organization or regulation.

River fishing in the Central Valley almost ended as soon as it had started. By 1852, the sediment from the mines—not over-fishing—nearly destroyed spawning grounds and resting pools on the Sacramento River. Gills clogged with mud impaired the adult salmons' ability to complete their journey upstream. If the fish survived to reach the spawning ground, their eggs were either covered with mud or exposed to air because of low water levels from mining water diversions. The system's tributaries also began losing their salmon to similar fates: the Yuba in 1853, the Mokelumne in 1855 and the Feather and American in 1862 (McEvoy, 1986).

Declines in fish, especially salmon, led to the creation of the State Board of Fish Commissioners in the 1870s. Although the board recognized early on that mining was the major cause of fish disappearance, their attempt to "restore" the fisheries was to establish salmon hatcheries and introduce exotic species, including American shad, striped bass and catfish (McEvoy, 1986).

Protecting the People's Fish

With the concern of increasing numbers of fishers pulling resources from the California rivers unchecked, the state saw compelling reasons to create the State Board of Fish Commissioners in 1870. It was the board's duty to provide for the restoration and preservation of fish. Around this time efforts were started to bring the fisheries under state control, but this was not to be an easy task.

The first fishing statute in 1852, which prohibited the erection of salmon weirs and other obstructions by other than Indians, was ignored by the commercial fishing industry. Other attempts to preserve and protect the fishery, such as the closed season on salmon in 1853, were met with much resistance. Fishing proceeded virtually unchecked and uncontrolled for another 25 years.

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The State Legislature gave the State Board of Fish Commissioners responsibility for protecting terrestrial game animals and fish in 1878. However it was not for another 12 years, with the newly obtained power to hire game wardens (including Jack London patrolling the San Francisco Bay and Delta), that the commissioners possessed both the authority and power to enforce state regulations requiring operators of irrigation ditches to maintain fishways, fish ladders and fish screens, and to enforce fishing restrictions. By 1893, the State Board of Fish Commissioners began taking violators to court.

At the same time that the commission began to collect annual license fees and send its wardens out to inspect fishermen's catches, court actions gave the state additional authority and indeed responsibility for state involvement in the protection of fisheries.

Major early legal decisions included *Ex parte Simon Maier 103 Cal. 476 (1894)* and *Geer v. Connecticut 161 U.S. 519 (1896)*. In 1894, the California supreme court stated in *Ex parte Simon Maier*:

> . . . .the wild game within a state belongs to the people in their collective, sovereign capacity; it is not the subject of private ownership, except in so far as the people may elect to make it so; and they may, if they see fit, absolutely prohibit the taking of it, or any traffic or commerce in it, if deemed necessary for its protection or preservation, or the public good.

Enforcement activity and judicial authority gave the State Board of Fish Commissioners enough clout to begin actively and more effectively regulating the fisheries. An historic early battle was *People v. Truckee Lumber Company 116 Cal. 397 (1897)* in 1897. In this case, the state Supreme Court upheld the regulatory authority of the state to protect fish in the Truckee River against pollution by a lumber mill.

State regulation of right to fish was incorporated into the California Constitution by Article I, Section 25 (1910), giving the Legislature increased power to control fishing. The U.S. Supreme Court's decision in *Hughes v. Oklahoma* 441 U.S. 322 (1979) seems to indicate that under current state and federal law, wildlife is deemed to be incapable of *private* ownership, and that a

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state has a public trust responsibility to manage and protect its wildlife resources for the benefit of the public and the long-term protection of the species.

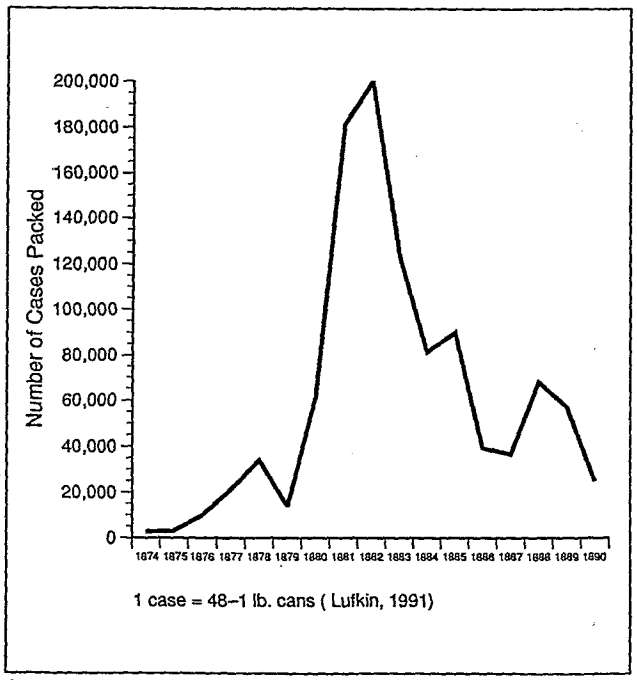
Source: McEvoy, 1986.

Within a decade of the slowdown of the Gold Rush in the late 1860s, the fish habitats which had been so devastated by sedimentation began to recover. Commercial fishing had another growth spurt. The first Central Valley cannery, established in 1864, was joined by another 20 by 1883 (Reynolds et al., 1990). The earliest canneries began processing fish in time to take advantage of a rise in prices in the late 1870s, which coincided with good fish runs. Approximately 10 million pounds of chinook per year were harvested between 1880 and 1883 (McEvoy, 1986).

The bountiful canning harvests lasted four years, the equivalent of one salmon generation, and then the staggering depletion of resources by the fishing industry began to catch up to it in the fall of 1884 (Figure 7). Light runs in that fall caused the profitable fishery to nearly collapse (McEvoy, 1986).

In the following decades surrounding the turn of century, Central Valley and Bay-Delta fisheries fluctuated wildly up and down, varying with the impact of over-harvesting, mining and pollution, as well as natural weather variation—especially important in controlling oceanic conditions (Lufkin, 1991). Meanwhile, conflicts abounded over the government regulation of various fisheries due to competition among immigrant fisher groups. For example, the Chinese, who fished primarily for Bay-Delta resident fish and shrimp, were unjustly blamed for declines in the migratory salmon. In fact, Bay and Delta Chinese fisheries

Figure 7. Sacramento River Salmon Cannery Output, 1874–1890.



Source: McEvoy, 1986

suffered greatly from mining sedimentation and marsh reclamation. (McEvoy, 1986).

Beyond the Sacramento and San Joaquin Rivers

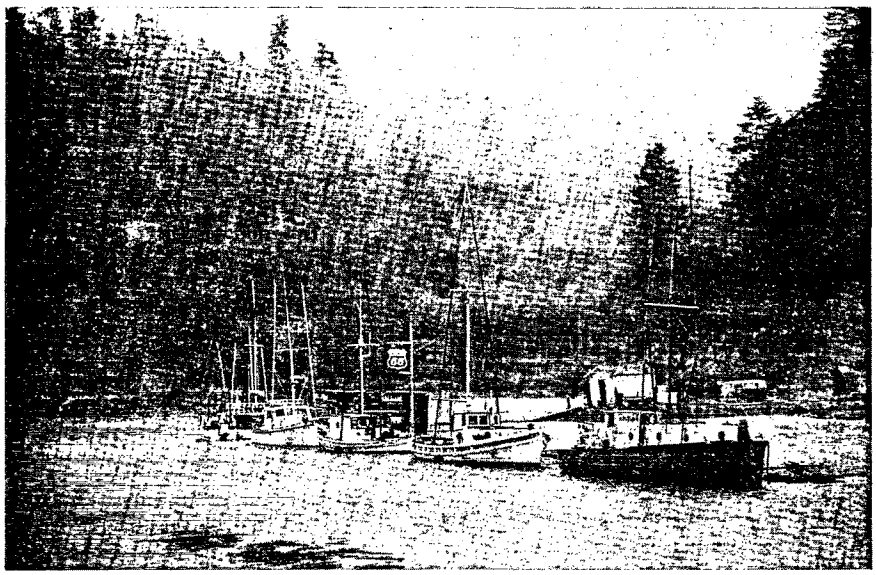
Settlement of the Sierran eastside in the 19th century led to the development of a commercial fishery there for the Lahontan cutthroat trout. The Lahontan cutthroat was a landlocked version of the salmon—it lived and grew in interior lakes, attaining sizes up to 40 pounds (Moyle, 1976) but spawned up the eastside rivers, the Truckee, Carson and Walker (Minshall et al., 1989). Despite the precedent-setting anti-pollution court victory against the Truckee Lumber Company (see "Protecting the People's Fish" above) on the Truckee River, the cutthroat fishery was eventually extinguished due to water diversions, obstructions and introductions of nonnative fish in eastside rivers (Minshall et al., 1989; Moyle, 1976).

The North Coast rivers were fished commercially beginning in 1876. White-owned salmon canneries employed many Native Americans, who supplied fish from their gill nets and worked in the canneries. The new salmon industry became at least a temporary economic salvation to the small Indian populations who had survived the devastation by the first Euro-american settlers (Pierce, 1991a and b).

The New Frontier

Declining Central Valley river fisheries during the period of 1890 to 1920 and the successful use of fishing boats dependent on engine power rather than wind power opened up a new frontier—the Pacific Ocean. Fishermen modified their boats and gear for ocean

Figure 8. Fishing Boats on the Albion River.



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work and were once again able to harvest abundant quantities of fish. These fishermen caught many species of fish including tuna, sardines and the river-bred salmon (McEvoy, 1986).

Between the dying river fishery and the newly emerging ocean fishery, California was able to take advantage of plentiful salmon runs from 1901 to 1905 and the state was again a net exporter of salmon. California's inland and ocean salmon harvests became roughly equal and by 1919, the ocean salmon fishery harvests had far surpassed the inland harvests. From 1920 on, the focus of commercial fishing in California was placed on the ocean fisheries, and on fresh fish rather than canned. The last salmon cannery on the Sacramento River closed in 1919 (McEvoy, 1986).

Although this new harvest took place offshore, the river salmon runs were affected by unregulated ocean fishing. Salmon were taken without regard to maturity or their stream of origin. Central Valley river salmon runs and ocean catch continued to rise and fall, depending on the economy and the environmental conditions at the time.

Change for the Klamath

In the Klamath basin, the 1920s brought new rail and road access to the North Coast, which opened up ocean and sport river fishing to the area (McEvoy,1986). Commercial trollers lined up at the mouth of the Klamath to intercept fish before their river migration. A new phenomenon began occurring, huge congregations of recreational salmon fishers at the mouth. Competition between commercial and sportfishers and the Native Americans of the area increased harvesting pressure on the precipitously declining salmon fishery. In 1933, under pressure from sports fishers the state banned commercial fishing in the Klamath River, and local canneries shut down. The commercial closure was aimed at the Indian net fishery, an important industry to local tribal groups. Meanwhile, ocean trollers outside the mouth went unregulated (Pierce, 1991a and b). When the Klamath was closed to commercial fishing many of the Indians who had lost their jobs at the closed canneries continued to attempt to fish both for subsistence and commercially. Over the decades until the 1970s, numerous legal tangles ensued over the dealing with Indian rights to fish. The state made many attempts to control Indian gill netting, but eventually the U.S. Supreme Court upheld the rights of Indians to fish freely on reservation lands (Pierce, 1991a and b).

What Happened to the Habitat

The earliest ups and downs in the state's fisheries from overharvest and habitat losses due to mining sediment and marsh recla-

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mation were to be dwarfed by the environmental changes wrought during the post-depression economic boom in the state. By the 1940s, Shasta and Friant dams of the federal Central Valley Project eliminated much of the historic salmon spawning grounds upstream. Diversions and other water management practices degraded habitat downstream. By 1951, after water diversions started in earnest at Friant Dam, the San Joaquin River spring-run salmon was eliminated forever.

As the North Coast region became accessible by roads, the lumber industry began intensive harvesting of the timber on inland watersheds. Lands that had been logged or crisscrossed by dirt roads were vulnerable to erosion during the not-uncommon heavy rainfall years of the North Coast. Logjams and sediment clogged most of the area's salmon and steelhead habitat by the 1960s. Much of the area is still recovering today.

As discussed in elsewhere in this report, aquatic habitats in California have been severely damaged in the past and, unfortunately, continue to be degraded in the present, by a multitude of human activities. Fish habitats have been affected by logging, grazing, agriculture, urbanization and the water development projects built to support them.

Changes in Fishing

As noted above, the Klamath River became famous as early as the 1920s for its sport salmon fishery. Recreational anglers became a powerful economic—and thus political—force. In the 1930s and 1940s recreational fishing began to take over other rivers. By the 1940s the sport fishing for salmon and the introduced striped bass and American shad in the Central Valley was generating three times the economic value of commercial river fishery (McEvoy, 1986). In fact, it was due to complaints of the recreational striped bass anglers that commercial gill-netting on the Sacramento River was finally banned in 1957 (Lufkin, 1991).

Recreational fishing in the ocean became popular in the 1930s, with a rapid growth after World War II. Most ocean "recreational" fishing is done by chartered party boats, a hybrid of commercial and sport activity.

Another change to California fishing was the new federal environmental regulations of the 1970s, e.g. National Environmental Policy Act, the Endangered Species Act and, of great importance to salmon fishing, the Magnuson Fishery Conservation and Management Act of 1976. This act established federal authority over ocean fishing in U.S. waters from three to 200 miles from the shore.

Current Regulatory Status

Under the federal Magnuson Fishery and Conservation Management Act, regional councils were set up to develop fishery man-

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agement plans and regulations for ocean fishing, including salmon. California, Oregon, and Washington are governed by the Pacific Fishery Management Council (PFMC). (Technically, management councils only make recommendations for regulation to the U.S. Secretary of Commerce, but these are usually adopted with little or no change.)

The California Fish and Game Commission, with technical advice from the Department of Fish and Game, sets ocean fishing regulations within the three-mile zone of state waters, consistent with the fishery plans developed by the PFMC. The commission also regulates inland fishing except for Indian fishing within a reservation, which is controlled by the Bureau of Indian Affairs (Barsh and Henderson, 1980). State regulations placed on all recreational fishing include possession and size limits, license requirements, gear restrictions, and season and area closures.

With the authority of the state and federal governments to control fishing firmly established, the serious declines of fisheries due to over-exploitation may be past. Current regulation by the PFMC and the state are still not without controversy, however.

With serious problems of projected spawning-run size in the Klamath and Sacramento rivers for chinook, severe cut-backs on ocean harvest have been instituted in recent years. Ocean commercial fishers have complained vociferously, pointing to habitat problems on the rivers caused by water diverters and others as the real culprits. As for the state's fishery management on inland waters, private angling or fish conservation groups are often critical of state regulations. California Trout, Inc., for example, often suggests rules which are more limiting on anglers than those originally recommended by the Department of Fish and Game.

Today there is no longer any allowable commercial fishing of fin fish in California's rivers, except for the small amount of the Native American fishery on the Klamath River. Crayfish are still caught and sold commercially in the Central Valley.

Three Native American tribes—the Hoopas, Yuroks and Karuks—currently fish for anadromous fishes from the Klamath River Basin, mainly using gill-nets. The Hoopa-Yurok Settlement Act (1988) divided the former Hoopa Indian Reservation into two reservations. The act reverted the lower 40 miles of the Klamath River back to Yurok tribal domain. The Yuroks fish from the mouth of the Klamath to the Trinity River. The Hoopa fish on the Trinity River within the Hoopa Valley Reservation, and the Karuk have fishing privileges in a half-mile stretch of the Klamath mainstem below Ishi Pishi Falls, near the Humboldt-Siskiyou county line (Klamath River Basin Fisheries Task Force, 1991).

Only the Yurok sell their fall Chinook salmon catch commercially. The gill net catches of the Yurok were valued at $3 million dollars for 1987, 1988 and 1989 in total (Klamath River Basin Fisheries Task Force, 1991).

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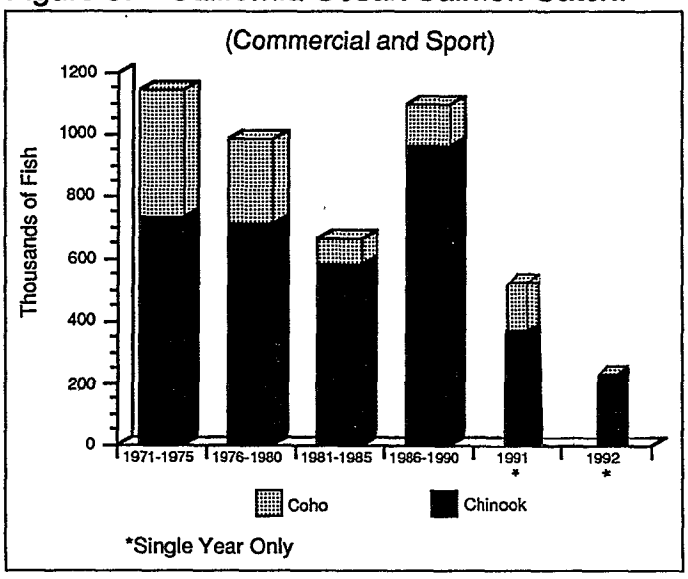
Salmon Fishery Today

In the last 30 years, California ocean salmon harvest has averaged over 7 million pounds a year. Interestingly, the lowest and highest landings for this period were recorded within five years of each other, with 2.4 million pounds in 1983 and 14.7 million pounds in 1988. Trends for the 1990s look bleak as recent landings were only one-half to one-quarter of recent averages (See Figure 9 below).

The ocean salmon fishery contributed about $67 million a year (in 1991 dollars) to the California economy in recent decades. The 1990 and 1991 figures show a decline to $41 million and $34 million per year, respectively (PFMC, 1992).

Chinook dominates the California ocean fishery, averaging about 78 percent of the total ocean catch of about a million fish, but the proportion of coho has been steadily declining (Figure 9). Central Valley chinook alone comprise about 90 percent of the total ocean harvest south of Point Arena, 40 percent of the North Coast harvest, and 40 percent of the Oregon harvest (Reynolds, 1992). In the last few years essentially all of the Central Valley chinook production has been from the Sacramento River system, primarily the fall-run.

Figure 9. California Ocean Salmon Catch.



The question of the impact of fishing on salmon stocks is always present and often controversial. The fishery management agencies and the commercial and sport fishers generally claim that the major problem for fish populations is not controlled harvest, but rather, habitat loss. On the other hand, water diverters, polluters and others who may be damaging aquatic habitats point at over-fishing, which is accepted by all to have been a problem for fish populations in the past.

The total ocean catch relative to the river escapement for a particular river system is difficult to ascertain. (See Chapter 4, page 215 for discussion of the term escapement.) Salmon stocks mix up and down the coast as they feed and grow in their ocean stage of life. The PFMC uses several surrogate abundance indexes to estimate the relative ocean harvest impact on river escapement. For the

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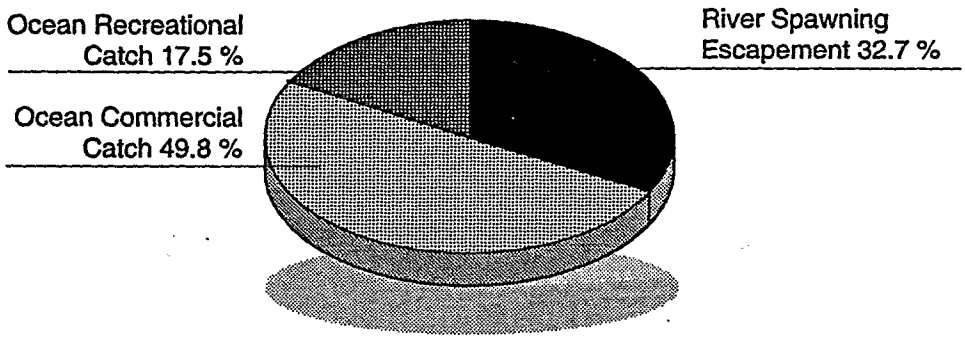
Central Valley chinook, the ocean catch from the coast south of Point Arena is used to indicate ocean abundance for these stocks.

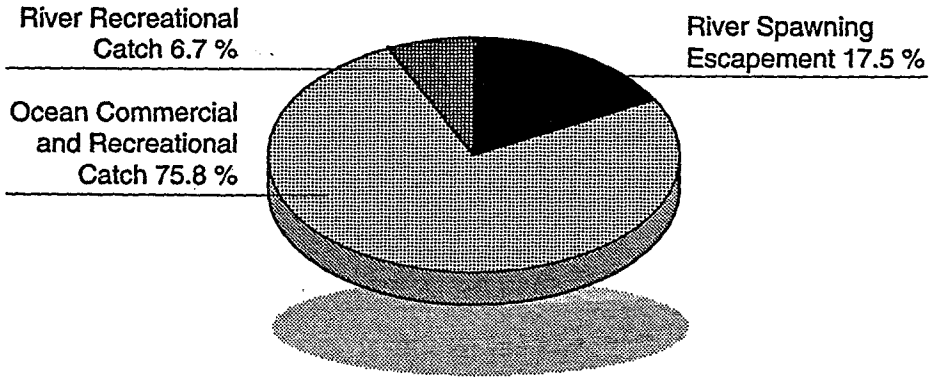
In the last 20 or so years, the combined ocean commercial and sport harvest of Central Valley chinook has been about two times larger than the run size which escaped to the river. Ocean commercial catch has been about three times larger than the sport catch (Figure 10). The California ocean sport salmon fishery is dominated by charter party boats. Private boats take less than a third of the total "recreational" ocean catch.

Figure 10. Central Valley Chinook, 1970-1991.



The impact of in river sport catch on spawning escapement varies between rivers, and has varied over time. In the period 1977-1981 recreational fishing for Sacramento fall-run chinook took less than 2 percent of the total in river run (Allan and Hassler, 1986). However, in 1990 and 1991 the sport catch has been much higher, nearly 40 percent of the total river run. Recreational river catch is still far below ocean catch however. (Figure 11).

Figure 11. Central Valley Chinook, 1990-1991.



For the Klamath River, the proportion of ocean catch and river sport catch are both less than that for Central Valley stocks. The Indian gill net fishery takes a significant amount of the total in river population, but it is small compared to recent ocean catch rates (Figure 12).

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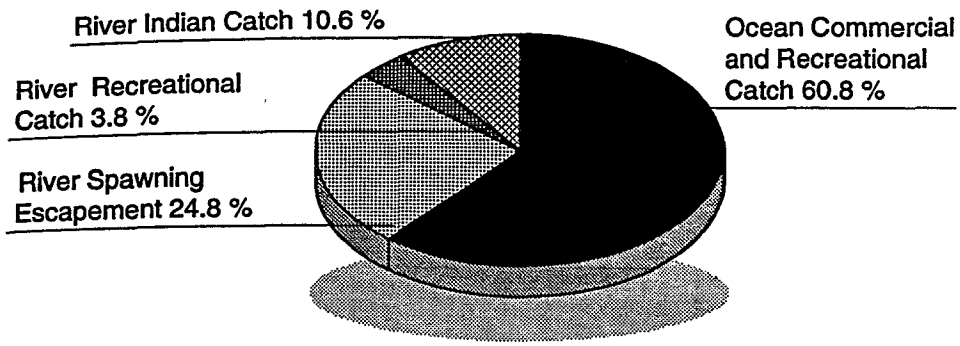
Figure 12. Klamath River Fall-run Chinook, 1981-1991.



Source for Figures 10, 11 and 12: PFMC, 1992.

Fishing results in a certain amount of mortality for fish that are not landed, and thus not counted. For the Klamath River, non-landed catch mortalities have been estimated by the Klamath River Technical Advisory Team at two percent for river recreational fishing and 8 percent for Indian river net harvest (DFG, 1992b).

Since 1981 both Central Valley and Klamath ocean catches have fluctuated enormously, some of which probably can be explained by variation in oceanic conditions (Figure 13). For example, many scientist believe the 1983 El Niño event had a significant effect on salmon populations, although there is disagreement in the literature. Of greatest concern to fisheries managers is the very recent decline in river runs, starting in 1990, to levels below desired spawning escapement levels, especially on the Klamath (Figure 14). In the Central Valley, 1990-1991 fall-run chinook spawning escapement was two-thirds the size of the previous 20-year average. On the Klamath, 1990 and 1991 fall-run chinook spawning numbers were only one-fourth the average size of runs from 1978-1989.

The ocean commercial fishery in northern California and southern Oregon was closed completely in 1992 to protect the Klamath Run. In central California, ocean commercial and recreational fishing were limited to protect the winter-run Chinook on the Sacramento, as well as Klamath Chinook fall-run, and river fishing seasons and limits have been limited by the state as well (Note: also see Recreational Fishing in this chapter).

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Figure 13. Central Valley Chinook Catch—Recent Trends.

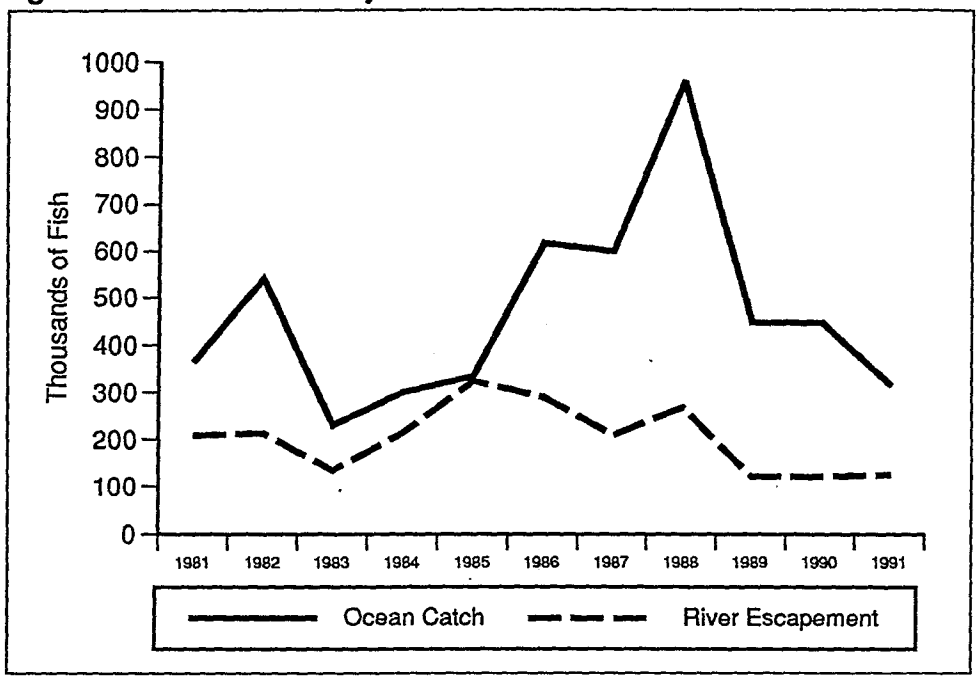
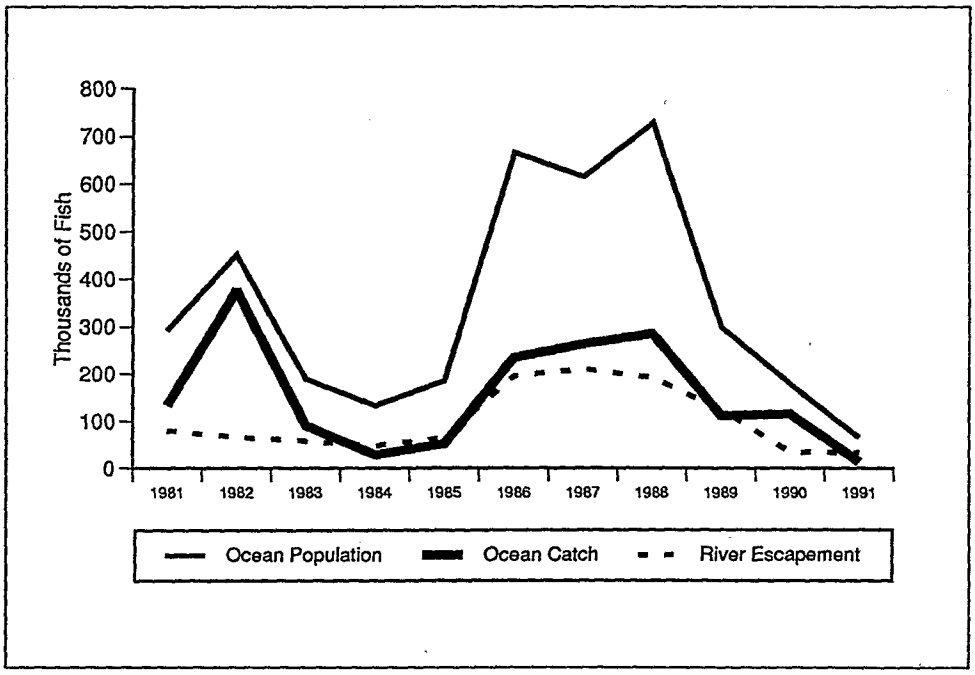


Figure 14. Klamath River Fall-run Chinook Catch—Recent Trends.



Source for Figures 13 and 14: PFMC, 1992.

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Navigation

The Steamboat Era

Delta Traffic

The steamboat trade was born, as was so much else in California, of the Gold Rush. John Marshall's 1848, gold discovery propelled the followers of the steamboat *Sitka* into prominence. The Delta became the 19th century equivalent of a freeway. Anything that could float was used to get prospective miners and their camp followers from San Francisco to Sacramento, but it was the steamboats that carried the day.

Large eastern side-wheelers often started their California careers by staggering out of New York or Boston with as much fuel as they could carry, touched at a few ports in the South, the West Indies and Rio de Janeiro to load more coal (or even wood), fought the winds through the Straits of Magellan, and clawed their way up the Pacific Coasts of South America, Mexico and California. Oddly enough, most of them made it in good enough condition to be useful.

Smaller steamers were taken apart, put on windjammers, shipped to San Francisco and assembled on the nearest beach. The *Lady Washington* was "assembled" at Sutter's Embarcadaro and took to the water August 9, 1849. She was the first steamboat on the American River, and she sank on a return trip from Coloma after hitting a snag. Raised later, she became the *Ohio* and kept on going. Also in August of 1849, the *Pioneer*, built at Benicia, began the San Francisco-to-Sacramento run. In October the *Senator*, a famous Boston-to-New Brunswick liner, arrived in San Francisco and started regular service to Sacramento.

Profits were high, and the number of boats and shipping companies kept on growing. Charging $30 for a one-way trip to Sacramento, and $30 a ton for freight, the *Senator* made a monthly profit of $60,000. By the end of 1850 there were 203 vessels working the Sacramento and San Joaquin rivers, as well as the various tributaries.

Competition dropped fares to $1 a trip, and $1 a ton. Races were common, as "the fastest boat on the River" could claim higher prices. Ramming was frequent as well; it was a sure way to get a competitor off the river. To maintain profits and reduce ships "sinking," the major boat owners got together in 1854 and formed the California Steam Navigation Company which held a near monopoly on river traffic through the 1930s.

The era of the big boats ended in 1878. The gold mines, which were responsible for its birth also killed it through the influx of sediment from hydraulic mining. Dry years in the 1850s kept the hydraulic mining debris—sand, mud and tailings—in the upper reaches of the rivers until the floods of 1862, 1875 and 1878 brought down the whole accumulated mass—destroying fishing, covering

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agricultural lands, wrecking water supplies and significantly raising the beds of the Feather, American, Bear and Sacramento rivers. For example, Steamboat Slough averaged 12 feet deep in 1853. In 1879 it was only five feet deep, and it was closed to the steamboats. The Sacramento River lost 15 feet of depth. Suisun Bay was virtually filled.

As the number of people and farms grew along the rivers and sloughs, the small, shallow draft steamboat took over where the bigger boats could no longer go. Every slough had its share of landings, and anyone could flag down a steamer almost anywhere along the rivers. Using combinations of the rivers and sloughs the boats could travel over 600 miles on California's inland waterways, from Fresno to Red Bluff, without ever leaving fresh water.

And travel they did, on schedule and off. Even after the railroads bought out the steamship lines they continued to run, for there were cargos that were better shipped by water than by rail, and there were places the rails did not run. Not until paved roads penetrated to the banks of the rivers up and down the valley did the steamers fade away. Some of them went in glory, like during the night of August 28, 1932, when six boats were involved in a fire at Broderick, opposite the City of Sacramento, that almost took all the bridges with them (SLC Shipwreck Database, 1993). But most were simply run up on mud banks and abandoned where they lay—around Government Island in Alameda, off Tiburon or along the shores of Point Richmond.

Colorado Steamer

The Colorado River forming the eastern border of the state, is part of the history of the state's navigable rivers. Surprisingly it too was home to a fleet of steamers. And the headquarters of this operation, Yuma, has not always been exclusively in Arizona; part of it at one time was in San Diego County, and several early steamboats paid their taxes there.

This odd situation came about as follows: Under the terms of the Treaty of Guadalupe Hidalgo, the boundary between the United States and Mexico was set as a line running from a point three marine leagues below the southerly tip of San Diego Bay, easterly to the confluence of the Colorado and Gila rivers. After leaving the Gila, the Colorado does some fancy meandering, to the extent that it actually runs northwest—therefore inside the San Diego-Gila line—for a short distance. Several hundred acres of what is now Yuma lie to the north of the old boundary line. Before there was an Imperial County, Yuma was in San Diego County, the eastern boundary of which was the state border.

In 1851, the year after Fort Yuma was established to protect travelers from the Indians, the U.S. Army let a contract to Captain George A. Johnson to transport freight from San Francisco to this outpost in the desert. The schooner *Sierra Nevada* brought the first load of cargo to the head of the Gulf of California, and also brought the mini-steamer *Uncle Sam*. Little more than a powered launch, she arrived with her first cargo at Yuma in December of 1852.

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The next steamboat to appear on the river was the *General Jessup*, a side-wheeler brought to the Gulf sectionally by a coastal windjammer. She was assembled and began running the river in early 1854. She towed barges up from Port Isabel to Yuma and beyond. Now only a memory, Port Isabel once boasted a machine shop and dry dock, and was the point where the schooners unloaded cargos for northern Mexico and the southwestern United States. The dry dock was something unusual in itself, being completely without the usual pumps associated with normal docks. Owing to the fact that there is a tidal range of 22 feet at the head of the Gulf of California, the job of filling and emptying the basin was simple. One merely left the dock gate open when the tide was out and let the waters of the next flood fill the dock. At the same time, one ran the barge or boat into the dock, and got it up on the keel blocks as the water receded. Then the gate was closed, keeping out succeeding tides until the repair job was completed, when the filling process was repeated and the boat serenely paddled away.

Transport began in earnest with the founding of the Colorado Steam Navigation Company in 1853. Not only was there tonnage to carry on the last leg of the voyage from San Francisco to Yuma, but also troops, mining equipment, prospectors and groceries to be taken to points far up the river. It was tricky navigation, for the ceaseless meandering of the river meant that this week's channel might well become next week's sandbar. Wisely, there was not much travel by night, and during the day there was a great deal of sounding with long poles, usually done by the Cocopah Indian deck hands. But good runs were still made, such as the trip by the *Cocopah No. 2* in 1878, from a camp 220 miles up river to Yuma at an average speed of just under 20 miles per hour.

Navigating the Colorado

The Colorado River was first surveyed in 1852 by Lieutenant Derby. But the most famous survey was done six years later, after the river had been in commercial use for some years. In 1858, the government decided to prove once and for all that the river was or was not "available for navigation," despite the growing fleet of steamers that were navigating on the river every day. And it was decided, perhaps because the owners would have billed Uncle Sam $500 per day, not to use one of the boats working the river, but to special-build a vessel. The resulting maritime monstrosity was an iron-hulled affair called the *Explorer*. It is hard to describe this vessel, for she was unlike

Continued on next page.

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anything else afloat at the time. She was built in the East, and shipped to Yuma in pieces, where she was reassembled. The *Explorer* was totally open, with a high stern-wheel and pulpit-like arrangement for the pilot far aft, and she was only 50 feet in length.

The *Explorer's* adventures started on January 11, 1858, under the command of Lieutenant Joseph C. Ives. They left Yuma and started up-river. It took them until March 12 to get as far as Black Canyon, now the site of Hoover Dam, some 300 miles upstream. They finally made it to the mouth of the Virgin River in Nevada. For most of the trip, the intrepid explorers were not pleased by their reception by the locals, which was less than respectful. The Native Americans trotted happily along the banks of the river; whenever the *Explorer* found a new mud bank by the simple expedient of getting hung up on it, they would burst into gales of coarse laughter. This seems, from the journals kept by the expedition members, to have gotten on their nerves, as well it might. Not only is it unpleasant at best to be twitted by the locals, but in those days one could never tell when the Indians would tire of the joke, and decide to send an assortment of blunt and sharp objects in one's direction. And it didn't help when, on the return trip, they met one of the regular steamers, the occupants of which seemed as amused as the Indians had been as the surveyors bounced from mud bank to sand bar. Perhaps it was in reaction to being laughed at for so long, but when Lt. Ives returned to civilization he penned an official report stating that "the Colorado is no decent place for navigation."

Source: MacMullen, 1944.

No river steamboat company ever existed for long, or made any amount of money, without someone starting an opposition line, and the Colorado followed the same pattern. Soon the *Esmeralda* was on the river, and the impressive *Mohave* and the *Nina Tilden*. But in 1867, the Colorado Steam Navigation Company bought out all rivals, and operated as a monopoly into the late 1870s.

Callville petered out about 1869. The railroad reached Yuma in 1877. And little Port Isabel had pretty much been abandoned by 1878. The boats still operated north of Yuma for some time, but the backbone of the river business had been broken by the railroads. An irrigation dam across the river ended it once and for all in 1908.

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Big Men in Little Boats—The North Coast

Some of the smaller rivers of the North Coast had their vessels as well. The little schooner *Centennial* was built at the Eagle Prairie shipyard for the Eel River trade and operated for nearly a year, running from Rio Dell to Painter's Springs. On a rare ocean trip from Crescent City to the mouth of Klamath River, on April 21, 1877, she capsized in the breakers at the Klamath Bar, and was pounded to pieces on the rocks.

Most of the rivers of the North Coast were too small and too shallow to carry major shipping, but settlements grew up at their mouths and small schooners called regularly. After the wreck of the *Frolic* in 1850, at Pt. Cabrillo on the Mendocino coast, the survivors marched into San Francisco telling "tall tales" of the great redwood forests. A new rush was on, and lumber towns sprang up all along the North Coast. With the lumber trade came more shipping, and the era of the "dog-hole" schooners, a special ship type developed in and for California, was born. So called because "a dog couldn't turn" in the ports and coves used by these intrepid little ships, these schooners were seen on the Albion, Navarro, Smith, Big and Klamath rivers.

Sailing schooners soon gave way to small, steam-powered "lumber schooners," another class of vessels unique to the California coast. Hundreds of these little vessels plied the North Coast and its rivers until the railroad and highway systems worked their way to the coastal towns in the mid 20th century.

Timber Harvest and Grazing

The First Clear-cut

Native Americans and early European settlers to California thrived in an environment of plenty, with neither the need nor ability to over-exploit the land and waters. With the Gold Rush in 1849, the rapidly growing population began exploiting huge amounts of the state's wealth-its natural resources. In addition to mining, grazing and logging forever changed California's watersheds.

Early California timber harvest started slowly. The predominant forest trees near Spanish settlements in the coastal region were redwood, but these were barely touched because the early colonists lacked the equipment to cut down these giants (Adams, 1969). With progress and more infusion of other Euro-american settlers, logging began in a few spots in the redwood region in the 1820s. A trickle of redwood timber in trade soon became a flood as demand for lumber increased with the Gold Rush.

Flat river flood plains with rich alluvial soils and high productivity have always been attractive to human enterprises. With the advent of Euro-american cultures in California, riparian forests and

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woodlands experienced immense losses. After the start of the Gold Rush in 1849, Sacramento Valley riparian forests were rapidly cut down for fuelwood (especially for steamships), as well as for fencing and other uses. By 1868, an early writer on California noted that the riparian woods were nearly gone in many areas on the Sacramento River and lower tributaries (Thompson, 1961). Extensive clearing for agriculture followed the Gold Rush period, further decimating much of the Central Valley riparian forests by early this century.

On the North Coast, riparian forests included redwood and Sitka spruce and many riverside forests were among the first areas to be logged for timber production because of their easy accessibility. On the huge fertile delta lands of the Eel, Smith and other rivers of the north, thousands of acres of riparian woodlands and forests were cleared for pasture and other agricultural use (Ray et al., 1984).

In the redwood forests of Central and North Coast California, the speed with which the forests were harvested, as well as the location of the demolition, were functions of the logging technology of the day. In the early- and mid-1800s, trees near the coast and rivers were the first taken because water transport was the only way to get the logs out (Adams, 1969). Near the coast, logs were slid directly downhill and dragged to ocean cliffs, to be loaded on ocean ships. Further inland, logs were dragged to streams and rivers and stockpiled until the channels filled with water with winter storms. Logs were floated downstream, hopefully to waiting ships, but they sometimes escaped to the sea.

Log driving was done on streams and rivers in Del Norte, Humboldt, Mendocino and Santa Cruz counties (Sedell et al., 1991), and was a common practice for moving redwood logs until railroads finally provided other means of transportation in the 1880s. The last big redwood log float was in 1936 on the Big River in Mendocino County (Leydet, 1969). Log rafts were towed down the Klamath River at least until the late 1950s (Felix Smith, pers. comm, 1993).

Sierran pine forests also began to be logged after the start of the Gold Rush, to provide timbers for mining operations (Dasman, 1965). In addition, many logs were driven down the Truckee, Carson and Walker river systems on the eastern Sierra to provide California wood products to Nevada silver mines (Timberman, 1941 *in* Sedell et al., 1991). With the construction of railroads in the late 1800s, Sierran logging could start to supply lowland urban markets in competition with coastal redwood. However, extensive logging was curtailed in the Sierra with the creation of the National Forests, leaving most commercial logging to the North Coast region (Dasman, 1965).

And what logging it was in the north woods—huge stands of ancient redwood forests were cut as fast as possible. Logs were initially moved by teams of oxen (always called bulls by the loggers), dragged along "skid roads" (Adams, 1969). With the advent of mechanized cable logging around the turn of the century, logging

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could be done much faster. It also became more damaging to the land, as logs could be pulled every which way, tearing up the soil. Finally, bulldozers, instead of bull teams, were used beginning in the 1930s, further speeding up forest cutting (Leydet, 1969).

Logging on the North Coast continued with the steady growth of the state, until World War II. After the war, the accelerated growth spurred a tremendous burst of logging on the North Coast, this time in the Douglas-fir forests inland of the redwoods. Although no concern was given to environmental harm done by the early logging in the redwoods, many of the forests did grow back in time, at least to a certain extent, due to the sprouting ability of redwood trees. For the most part Douglas fir forests do not reproduce as do the redwood forests. The quick and thoughtless logging in the 1940s to 1960s led to significant watershed and stream damage in the North Coast, compounded by the big floods in 1955-56 and 1964 which hit the region (Downie, 1991).

From the beginning, logging was carried out under a program of just getting the logs out. Little thought was given to protection of other forest values or the health of streams and rivers. California's first forest practices regulations in 1945 addressed protection of the forest productivity for timber production, but little else. By the 1960s a few harvest rules were added to protect streams, but it was not until the modern Z'Berg-Nejedly Forest Practice Act of 1973 that riparian corridor protection was seriously addressed (Bramhall, 1989). Today, regulations by the state on private land and by the federal government on federal lands attempt to avoid environmental harm, but most logging operations, whether by design or by accident, result in some degree of impact to watershed and streams.

Cottonwood forests along the lower Colorado River were also extensively cut for steamship fuel wood, primarily between 1855 and 1890. When steamship demand abated, cottonwood forests began to recover, until a pair of huge floods in 1905 and 1907, which set back plant succession and forest growth. The riparian habitat might still have recovered after these floods, but for the introduction of the invasive salt cedar, or tamarisk tree. Competition by the tamarisk, as well as the numerous dams and channelization projects which eventually tamed the Colorado in this century, all but eliminated natural riparian habitats, which now remain only as isolated fragments (Ohmart et al., 1977).

Grazing

Livestock grazing by sheep and cattle was introduced by Spanish and Mexican colonists in the late 1700s and early 1800s. Huge ranchos spread over the land, fueled by the trade in hides

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bringing about one of the most significant ecological changes ever to affect the California landscape. The combination of overgrazing, a series of droughts, and the introduction of exotic Mediterranean annual grasses and weeds led to the almost complete loss of native grasslands.

After the Gold Rush started, livestock numbers in the state increased over ten-fold (CDFFP, 1988). As lowlands were overgrazed, cattle and sheep were moved into foothills and forests. By the late 1880s livestock grazing had invaded almost every corner of the state with devastating results, including soil erosion and the conversion of grasslands into range dominated by poor quality weedy species. Although some government control over public lands was begun in the 1930s, overgrazing impacts to watersheds and streams continued unabated until the environmental movement of the 1970s and 1980s.

Water Development for Farms and Cities

The Franciscan missions, established one day's travel apart in the coastal region, were the first sites of California's earliest intensive agriculture. From the late 1700s to the early 1800s, mission farms produced an amazing abundance and diversity of crops and livestock, including the state's first orange grove at San Gabriel Mission in 1804. Outside the missions, the early settlers were ranchers, more interested in cattle than crops.

Draining and Irrigating the Land

After the gold rush, early settlers—a backwash of disappointed miners and the left over Chinese labor from the railroad projects—took a new look at the Central Valley, beginning in the Delta region. They saw cheap land, and dreamed of levees and farms. The first crude levees were built by hand, basketful by basketful. It was enough to trigger the imagination, however, and unleash Yankee ingenuity. The first land schemes and private development appeared together in the mid-1860s, while the first dredge companies started work just 20 years later. The hand-built levees, the early dredge companies and the first Delta colonies all died in the great floods of the early 1890s.

Power dredges and reclamation districts appeared at the turn of the century, and Delta settlement was here to stay. The modern Delta took shape during the 1910s and 1920s; most islands were drained and put under the plow before the Great Depression took hold. There have been losses since then, but only Frank's Tract, lower Sherman, Little Franks, Big Break and Mildred have flooded permanently (DWR, 1993).

Elsewhere other "reclamation" projects were underway. Fields of wheat prospered in the San Joaquin Valley and Bay Area counties.

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Throughout the 1850s and 1860s small towns grew up along the San Joaquin River and its tributaries, and vast tracts of land were put into production. The crops were sent north on the river, and shipped all over the world from ports along the west end of the Delta. Port Costa in Contra Costa County, in particular, became the world's largest wheat shipping port for many years.

In addition to the promise of agriculture, San Joaquin Valley large landholders sought irrigation projects because it could appreciate their land value to as much as $100 an acre in the latter half of the 19th century (Historical Atlas, 1974).

The first irrigation ditches in Kern County were built in 1858 and tapped into the Kern River. Utilizing provisions of the 1850 Swamp Land Act, Miller and Lux (the largest farming conglomerate in California history) controlled a tract of land extending 50 miles along the river equalling 100,000 acres (Historical Atlas, 1974). Through litigation over riparian water rights, an out-of-court settlement, the Miller-Haggin Agreement (1886), divided Kern River water between 31 corporations and 58 individuals and remains in force today (Historical Atlas, 1974).

Diversions of the Kern River began through several canals built in the 1870s and 1880s: the Fresno Canal, the Peoples, Last Chance and Lemore canals irrigated some 85,000 acres in 1882 in Kings, Fresno, Kern and Tulare counties.

The Merced and Tuolumne rivers were the source for the irrigation of Fresno, Madera, Merced and Stanislaus counties. The largest single irrigation system in the state in the 1880s was the 100-mile-long San Joaquin and Kings River Canal starting in Mendota. There were other significant private water companies but the federal Central Valley Project (CVP) of the 1930s ended the large companies.

Agricultural Expansion

Plains and valleys up and down the coast were also developed for agriculture in the last part of the 19th century. Grapes brought from Europe created the famous California wine industry in central-state counties, while orange groves were planted in the south. By the 1890s, irrigated orange groves and vineyards dominated the economy of southern California, and Los Angeles was growing rapidly (Dasman, 1965). A series of dry years at the turn of the century, in combination with urban and agricultural expansion, forced the City of Los Angeles to look far afield for a water supply. William Mulholland found it—in the Owens River hundreds of miles away on the other side of the mountains. The Owens River was tapped by the Los Angeles Aqueduct in 1917.

Meanwhile, other irrigation entrepreneurs had their sights on "making the desert bloom" in the southeastern part of the state. They set about bringing in water from the Colorado River to the arid, yet

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fertile lands in the Imperial, Palo Verde and Coachella valleys. In fact, the name "Imperial Valley" was coined as a promotional gimmick at this time to emphasize the great agricultural potential rather than the natural desert condition of this region (California Water Atlas, 1979).

But while water for agriculture appeared to be good business at the time, the water withdrawn to feed the increasing irrigated acreage put the final end to shipping on many rivers. There just was not enough water, even then, for everyone to have all they wanted. The San Joaquin River steamboat traffic went first, and Stockton became the practical head of navigation by the end of the 1890s, except in very wet years.

The Thirsty Cities

Control of a water supply has been the single most important factor in the explosive development of California, as the following brief history illustrates.

The founding of El Pueblo de Nuestra Señora la Reina de Los Angeles de Porciúncula (the town of Our Lady the Queen of Angels of Porciúncula) in 1781 was part of a last-ditch scheme by the king of Spain to colonize California, remotest of outposts, to protect it from seizure by czarist Russians who were as far "south" as Fort Ross. The settlement site was the broad flood plain of the Los Angeles River depicted by contemporaries (Cohen, 1990) as an Eden of cottonwoods, sycamores and ponds filled with fish—an oasis in the parched Southwest.

El Pueblo de Los Angeles was established after the missions to supplement the production of the missions and to reduce the need for importing foodstuffs to support the colony.

In 1784, the provincial governor began awarding grazing lands to retired Mexican Army veterans who had served for a specified time. Subsequent governors gave away nearly all of coastal California from Sonoma County south, and scattered grants in the Sacramento Valley, in a jigsaw puzzle of vast landholdings. Cattle raised on these rancheros provided the income for a life of gracious ease for some of the largest holders, and of bare subsistance for others.

Americans arrived and coveted the paradise. The Republic of Mexico provided an excuse for war and the pueblo was ceded to the United States in 1848. Change came slowly as development gradually spread across the agricultural valleys. By 1876 the Southern Pacific railroad had arrived, followed by the Santa Fe nine years later. Los Angeles was connected across deserts and mountains to the Midwest and Eastern states.

The first artificial water system conceived for a city was not for Los Angeles but rather for San Francisco. Growth as a result of the Gold Rush left the future of the city dependent on imported

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water. Plans in 1901 called for dams and reservoirs on the Tuolumne River in the Hetch Hetchy Valley of Yosemite National Park (established by President Lincoln in 1864). Conservationists vigorously opposed the desecration of what some have observed was a valley more beautiful than the Yosemite that remains. They lost. The first water to flow in the 186-mile aqueduct reached San Francisco in 1931. Other major projects included the Pardee Reservoir on the Mokelumne River to bring water to other regions of the Bay Area.

As in the days of the missions, plentiful water was a life-or-death necessity for Los Angeles, the city built in a land of little rain. Completely dependent on imported water, semi-arid Los Angeles, with only .06 percent of the natural stream flow in the state, reached out three times in this century to far away sources.

A rapid increase in Los Angeles' population from 100,000 to 200,000 in the last two decades of the 19th century and several years of below average rain initiated a search for a reliable water source other than the Los Angeles River. The Owens River aqueduct, completed in 1913, was 233 miles long and passed over foothills, through mountains and across the Mojave Desert. Considered a remarkable engineering feat, the 142 tunnels brought 320,000 acre-feet of water annually to Los Angeles. Reservoirs built in Long Valley and Grant Line tapped the Mono Basin in 1940 and extended the original system to 338 miles. The 1940 addition shortened the original route and added 152,000 acre-feet per year.

Because of the manner in which these lands were acquired, the Owens River Valley development engendered open hostility by enraged citizens. (See Chapter 2 for an update on the original water diversions and still-bitter controversy.)

Colorado River water was also diverted through an aqueduct in 1941 to Los Angeles. A branch aqueduct conveys water to the San Diego area. Some of the Colorado diversion was used for irrigating Imperial Valley farmlands beginning in 1901. Settlers sought relief from the river's flooding during 1903 to 1907 by building the All American Canal. This canal takes water just before the river flows into Mexico.

The most auspicious water project—the Central Valley Project (CVP)—grew out of the 1920 proposal of Robert Bradford Marshall, chief hydrographer of the U.S. Geologic Survey. The concept seemed simple: redistribute water from the wet north to the dry south with a series of canals. Barely approved by voters in 1931, bonds were not aggressively marketed, in part because of the depression at that time. The project was taken up by the Roosevelt administration and promoted as a New Deal program to provide water for small farm development in the San Joaquin Valley.

Following the CVP, the State Water Project (SWP) originated as the Feather River Project—a flood control program to "manage" the 3,600-square-mile Feather River watershed. The SWP was touted

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as the most elaborate system of water control in the world (Historical Atlas, 1974).

Controlling Rivers–Big Dams and Straight Channels

From the 1870s to 1920s, scientific and technological approaches in government, academia and public policy emerged which drove natural resource management and public works for most of this century. Civil engineers came to dominate the formulation and implementation of resource management policy. Their design and construction of bridges, canals and dams which reorganized natural environments for the benefit of economic growth helped develop the faith of the American public in the capabilities of the engineering profession (Kelley, 1989).

In 1878, the Office of State Engineer was created, with a salary equal to the Governor's. The position was charged with the task of developing solutions to flooding and irrigation problems. It symbolized and emphasized the dominance that "engineering" solutions had come to represent in the name of "efficiency," despite their destructive logging and mining practices (Kelley, 1989).

To many engineers a lake was "more efficient" than a river, and being able to store and release water was viewed as efficiency realized through planning, foresight and conscious purpose. The U.S. Bureau of Reclamation and the Army Corps of Engineers were given responsibility for implementing federal (and state) policy. Water that flowed freely down a river to the sea was considered "wasted" and "dangerous." River management meant the transformation of waste and inefficiency running rampant into planned and directed systems to meet a complex world with efficiency and purpose (Kelley, 1989).

With the benefit of experience, the efficiency of dams has been challenged. Their inefficiencies include increased evaporation, increased seepage, costly effects on the environment and loss of wildlife habitat. Nonetheless, California water policy makers embraced "big dam" building from the early 1920s through the 1970s. O'Shaughnessy Dam on the Toulumne River, was first in 1923 (Figure 15), Hoover Dam, the largest at the time, was built on the Colorado River in 1936. Shasta Dam was next, in 1945, controlling the Sacramento River, and flooding most of the lower Pit River. Then the streams of the Sierra's west slope were tapped, with Pine Flat Dam on the Kings (1954), Friant Dam on the San Joaquin (1942) with Mammoth Pool above that, Oroville Dam on the Feather (1968), New Bullard's Bar on the North Yuba (1970), Don Pedro Dam on the lower Tuolumne (1971), and New Melones Dam, in 1979, on the Stanislaus. The Kings River now ends in a dismal series of dikes, sinks and channels, rather than filling Tulare Lake, once California's largest lake.

There are some 3,700 entities collecting and distributing water to users in California (California Water Atlas, 1979). The majority are

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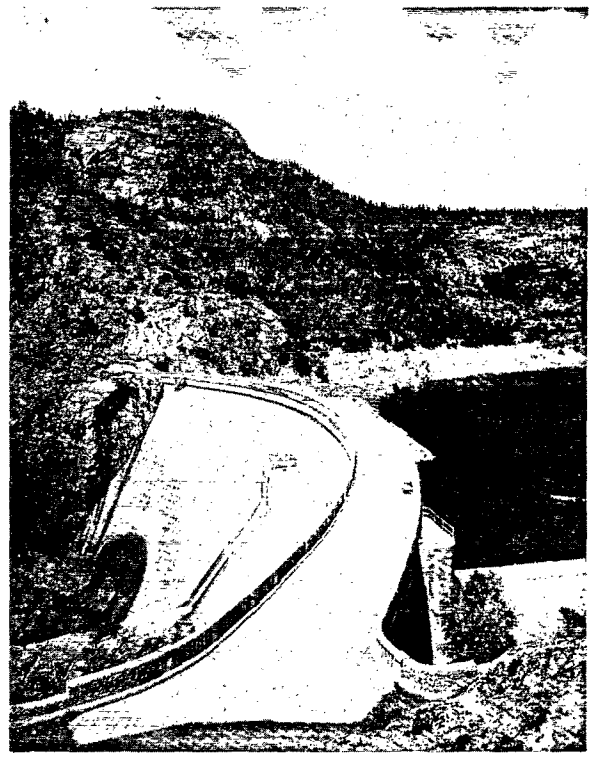
local water districts. The two largest entities are the CVP and the SWP, both consisting of dams, power plants, canals, pipelines and pumps. This assemblage of hardware extends from Plumas to Riverside counties. The SWP alone has 648 miles of aqueducts for water movement (DWR, 1992a). It distributes the runoff from northern and central California to a water-hungry market including agriculture, homes and industry in the Central Valley, Bay and southern metropolitan areas. Four additional major water entities are the Pacific Gas & Electric Company with reservoirs and power plants, San Francisco Water District, East Bay Municipal Water District and the Metropolitan Water District of Southern California, which wholesales water to other Southern California water retailers.

Figure 15. O'Shaughnessy Dam on the Tuolumne River.



Courtesy of *California Trout.*

The U.S. Bureau of Reclamation and state Department of Water Resources (DWR) operate the CVP and SWP, respectively, to meet the water demands of Californians. Additionally, they are responsible for flood control, maintaining minimum habitat, water quality and fish spawning conditions in the Delta and its tributary rivers and streams, maintaining excess reservoir capacity for continuing spring run-off and preventing or reversing salinity encroachment in the Delta. This "plumbing system" must operate for the benefit of all these needs amid a mosaic of other agency jurisdictions, contracts, laws, lawsuits, court decisions and political pressures (Figure 16).

All in all there are about 1,400 federal, state and private dams in California each at least 25 feet high or holding back a minimum or 50 acre-feet of water (DWR 1992b) (Figure 17). One hundred and one of these dams contain 90 percent of the total capacity of all California dams. Including dams on the Colorado River, these dams collectively can impound 42.2 million acre-feet of water. This is enough water to cover all of California south of San Luis Obispo, Kern and San Bernardino counties, to the Mexican border with over a foot of water. This impoundment amount is subject to considerable fluctuation

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Figure 16. Water Management Distribution Projects in California.

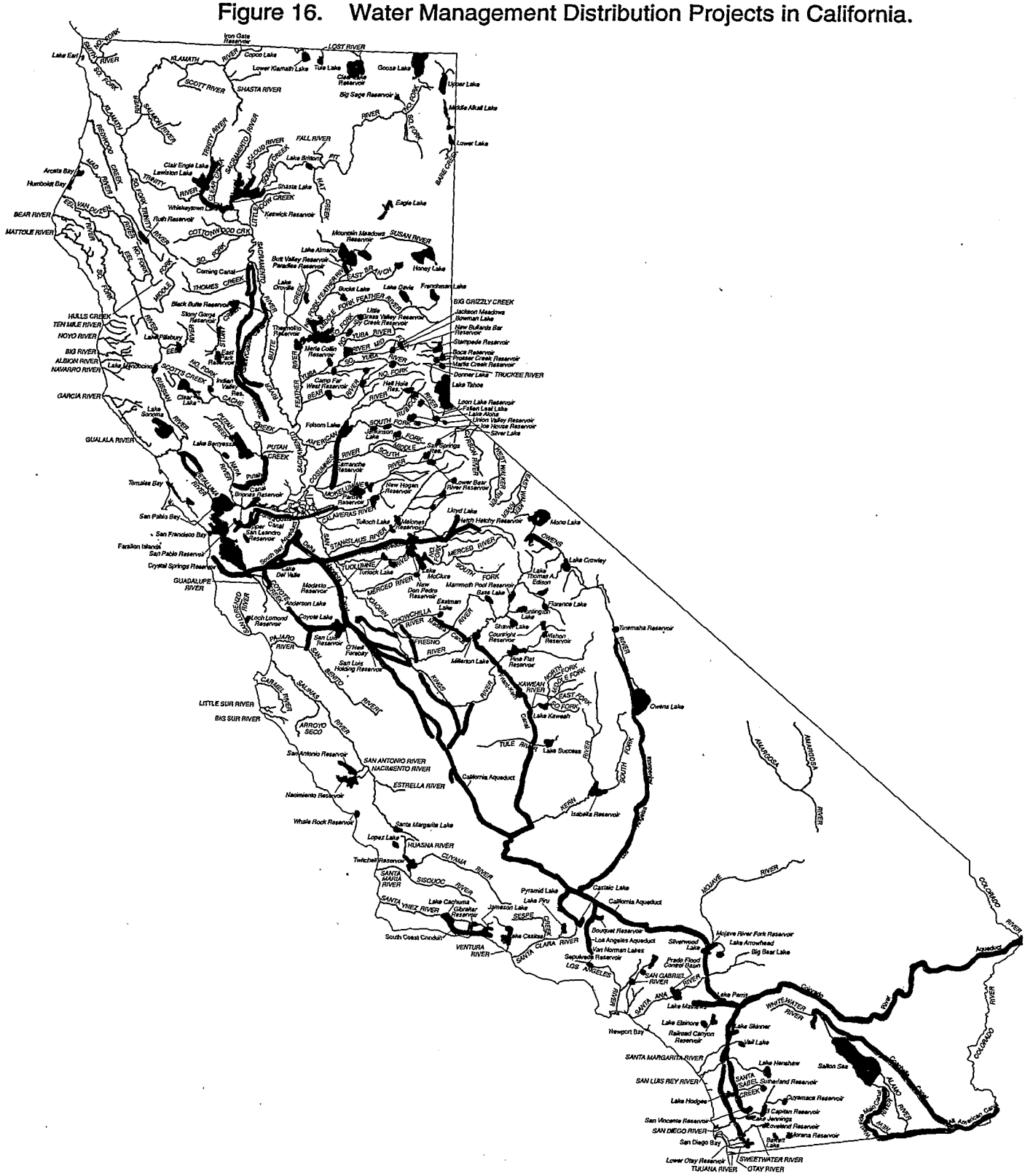

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Figure 17. Dams Throughout California.

■ = Dams 25 feet high or with capacity greater than 50 acre feet.

Source: DWR Division of Dam Safety, 1992.

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because, among other reasons, trapped sediments reduce capacity and ultimately end the effective life of the dam. Political factors, such as federal agreements to return most of the Colorado's water to six other states and Mexico, mean that much of the impoundment capacity is not realized. Alternative water management—necessitated by the law, recent legislation and increasing interest in aquatic and riparian habitat restoration—has meant changes in dam operations which in effect "reduces" capacity.

Other public works for water management include flood control. Channelization—the straightening and paving of river channels—has been the traditional engineering solution to flooding. The intent is to move flood waters out of harm's way as quickly as possible. Rivers and streams are lined with concrete or riprap, the bends are taken out, trees and vegetation are removed and revegetation is limited in the general belief that the trees and shrubs will damage flood control structures or impair their functioning.

The history of flood control on the Sacramento River provides a nearly complete picture of the philosophical and technical evolution of approaches for controlling rivers. This effort at control was to fulfill the promise of a bountiful agricultural never before imagined by the settlers. The Sacramento Valley had abundant water, a long warm growing season unlike other parts of the country, rich soils and a ready market. Here the settlers discovered that during the winter and spring, torrential storms from the Pacific and the Sierra melting snowpack filled the Sacramento River and its tributaries and flowed over the river and stream banks to spread water over 100 miles and millions of acres. These periodic floods denied a great agricultural bounty by destroying property, obliterating crops, drowning livestock and creating a great inland sea that took months to drain.

The first efforts at flood control depended on strengthening natural levees where possible. As more miners ended their brief careers in the Gold Rush, more lands were claimed for agriculture in the fertile valley adding more pressure for flood prevention efforts. The farmers' and towns peoples' need to control the Sacramento River and the dramatic effects of hydraulic mining debris filling the riverbed led to the state's most altered environments (Kelley, 1989). The Sacramento Valley today was created from decades of efforts to manage the great river. The valley is filled with farms and growing urban communities in an historic flood plain that historical filled with water for months. This inland sea was home to dense flocks of birds, tule marshes and riparian forests from the Delta to Red Bluff. Today, the flood control program to keep the river confined depends on foothill dams, hundreds of miles of high levees and an intricate system of overflow weirs and bypasses. The half-million acres of marshlands, and million acres of riparian forests have been reduced to remnant fragments.

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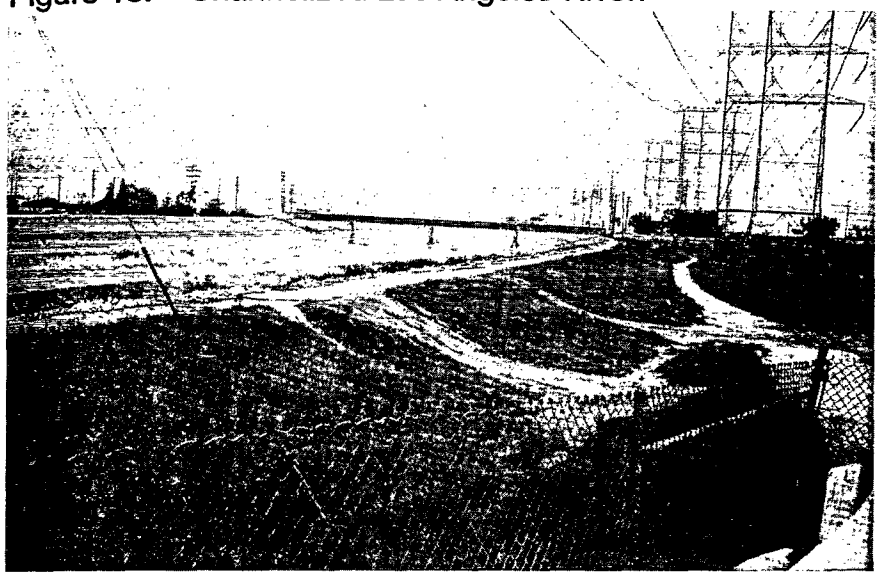
Figure 18. Channelized Los Angeles River.



Courtesy of Prentiss Williams.

The Sacramento experience was repeated in the Central Valley, the Delta, the Russian River and many other regions. In Southern California the control of floods in the vast flood plains was tackled by the quintessential engineered channel—the Los Angeles River (Figure 18). Its main design function is to convey storm water runoff from its drainage area to the ocean. When water does appear in the concrete trough, it is a hazard since it moves so quickly and the slippery cement walls of the channel makes escape difficult. In southern coastal California, extensive flood control works allowed urban and agricultural development in the flood plain and directly destroyed riparian vegetation, much by the 1920s (Faber et al., 1989).

Channelization has been the standard method of flood control. But this single purpose approach has been questioned in recent years by engineers and the public. The traditional designs may not work as intended and fail during floods. The public has become increasingly dissatisfied with the environmental destruction associated with channelization.

Recreating on Rivers

> *Nature's most important function in recreation is the aspects of performance it provides: beauty, refreshment, serenity.* — *The Nature of Recreation: A handbook in honor of Frederick Law Olmsted*, 1972.

Run to the Rivers

Californians have flocked to the state's rivers searching for recreation in ever increasing numbers since the end of World War II,

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as California's population grew and as the prospering post-war economy granted them more leisure time and money. They met the surviving Native Americans—the first Californians—whose historic use of rivers for food and water and as a place to live remains; they saw evidence of the Europeans' use of the rivers as transportation routes and sources of mineral wealth; and they were stunned at the effect of the singular use of rivers as sources of water for agriculture and the cities and their needs for flood control.

Rivers are recreational and educational assets. Rivers provide a way to break away from the routine of work. Even the enjoyment of other people is increased by the time one spends alone. When alone, people are free to be themselves, to let their imaginations roam, to remember, to dream, or to make plans. Because cities and even the suburbs are more crowded and more dangerous, it seems natural that people seek to be away from their responsibilities and other people. It is understandable that this solitude can be enhanced by the vastness and restfulness of the nature of rivers: coolness of the water and the shade of a tree.

Thus, rivers lend themselves to increasing recreational use because of their beauty, opportunities for activity and the promise of seclusion from the hectic pace of modern life. And rivers are more. Rivers are the best of classrooms: for learning about the functions of rivers; the life of the waters and adjacent riparian habitats; and abuse to rivers and its causes. Recognizing the opportunities of rivers, Californians go to rivers in impressive numbers: Californians in 1992 spent an estimated 2.2 billion visitor days recreating in the out-of-doors on rivers and lakes (DPR, 1992). The overall recreation demand is expected to increase between 42 to 64 percent by the year 2000 (BLM,1990).

As more people use the rivers, awareness of the loss of much of the rivers' amenities grows. Now there is a strong grassroots movement to protect and restore the rivers. The restoration efforts range from retrieving creeks from rock-lined channels to establishing river meander belts based on a more limited historic flood zone. Many of the efforts share the goal of riparian restoration and public access. These common efforts have come together in the California Association of Riparian Parkways (CARP) consisting of elected officials involved in greenway planning.

"Friends of the river" groups have materialized in reaction to the threat of new dams and the results of flood control projects. At the state and federal levels came special legislation to designate parts of some rivers as "Wild and Scenic," and to protect them from further development. The river restoration movement has fostered alternative approaches to river management.

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Significance of Recreational River Use

George B. Hartzog, National Park Service director on the 100th anniversary of the National Parks identified the central issue of recreation as one of perspective:

> The real crunch coming in this county is to articulate an environmental ethic to guide corporate and human conduct—and this speaks basically to the issue that man [sic] is part of his environment. The practical problem is that we know how many elk a park can handle ecologically but not how many people.

Recreation benefits California in its economy as well. According to the *California Outdoor Recreation Plan of 1988*, Californians spend more than $30 billion each year on recreation and leisure. Recreation and tourism are California's largest industries. California's rivers draw more of these users than any other location, except for its beaches. It has been noted that "tourism" as such generates no money, but rather the money is generated by the attractions that people travel to see. Rivers are major attractions and should get prime credit for generating tourist dollars (DPR, 1993).

Nearly all facets of California's economy are in some way influenced by or related to recreation and leisure activity (DPR, 1984). Dollars pumped into California's economy from river recreation include not only the direct value of licenses for fishing, registration of boats, equipment purchased and hiring of guides or rafts, but also the value of lodging or campsites, money generated by travel to and from the rivers, and the maintenance and repair of river-related equipment. Estimates of the monies generated from recreational activities around sport fishing and white water rafting can be inferred by the levels of spending associated with the activities. The National Forest Service estimates that the sport fishery resources of the National Forests of California generates $309 million and supports approximately 8,657 jobs through associated expenditures. California anglers provided $34 million from license fees (not including Pacific Ocean licenses) in 1992; this figure was up from 1988 figures by approximately $1,182,000. Boater registration fees were $6,495,000 in 1991/92. Bird watchers pursuing their interests in bird counts and sightings contribute to the economy by spending an estimated $13 per day (Loomis, 1989).

Recreational Uses: Active and Passive

Defining recreation is often more difficult than cataloging it. Recreational activities may be arranged within two general groups: active and passive. Active uses include activities of exertion such as

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bicycling, swimming, water-skiing, fishing and boating; while passive activities include picnicking, inner tubing and nature and bird watching. These activities can be done on or around rivers.

However these activities are defined, it is important to have statistical information for planning and development purposes. Park and recreation planners must understand the needs and uses of our rivers. Basic recreation use data is lacking for most public lands adjacent to California rivers. Often this is due to the lack of available funding.

Recreational Fishing

> *Coolidge became an enthusiastic angler, but his skill did not match his keenness. Asked how many trout there were in one of his favorite fishing places, Coolidge replied that there were estimated to be about 45,000. Then he added, "I haven't caught them all yet, but I've intimidated them." The Little Brown Book of Anecdotes,* 1985.

Fishing is an extremely popular outdoor recreational activity in California. Over the last ten years, an average 2.35 million fishing

Figure 19. Shoreline Fishing.

licenses have been sold annually. According to recent surveys by DFG, anglers spent almost 3.4 million hours pursuing fish on the Sacramento, Feather and American rivers in 1991. Statewide surveys of angler preference indicate that anglers fish mostly for trout, followed by black bass, steelhead and salmon (Fletcher and King, 1988).

Sport fishing contributes substantial money to the state's economy. Expenditures for sport fishing (such as travel, food, lodging, gear, guides and rentals) contribute in excess of $2.2 billion to the state annually (Sport Fishing Institute, 1989). The yearly economic

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gain from salmon and steelhead recreational fishing on rivers is over $100 million, according to values used by Meyer (1988) in a report to the California Advisory Committee of Salmon and Steelhead.

Angler surveys have found that the beauty of the surrounding environment is the most important factor in providing a good fishing experience (Fletcher and King, 1988). This is so despite the loss of fish and increasing crowds which are often blamed for discouraging anglers. This may explain why fishing remains the biggest recreational use of California rivers.

The primary inland fisheries include anadromous fish, resident trout and warm water game fishes. The most significant species of the anadromous group is the salmon family (salmonids). California salmonids commonly sought today are steelhead, chinook (king salmon) and coho (silver salmon).

Sport fishing for steelhead is very popular on North Coast rivers. Steelhead were once found in all coastal rivers and most coastal streams of decent size, but now approximately 90 percent of the state's wild steelhead occur north of San Francisco Bay (DFG, 1991b). The Klamath, Eel and Smith, Trinity, Mad, Russian, Gualala, American, Feather and Upper Sacramento are the most popular steelhead rivers in the state, although the Sacramento run is currently in woeful shape. All of these rivers except the Smith and Gualala have major hatcheries (DFG, 1991a).

Steelhead sport harvest studies have been sporadic over the years. In 1993, the Department of Fish and Game instituted a new steelhead "report card" requirement, following the lead of Oregon and Washington. Steelhead are rarely caught in California's ocean waters, partly because they migrate far out into the Pacific. River fishing for chinook salmon is concentrated in the Sacramento River and tributaries, especially the American River, and in the Klamath system, including its major tributary, the Trinity River. Coho in the past have had large enough runs to support fishing activity in the Klamath and Eel systems, as well as numerous other coastal streams. Recently, native strains of coho spawning within California have declined drastically and the species is now considered to be at risk in California (Moyle and Yoshiyama, 1992). Salmon and steelhead are prized for their tremendous fighting qualities and excellent taste. Even though anadromous salmonids do not actively feed in freshwater, fishers use natural baits and artificial lures to catch them. Fly fishing, spinning, bait casting, drift fishing and plug pulling from drift or power boats, and plunking from the banks are the leading methods used in salmon and steelhead fishing. The total recreational catch of salmon along the Sacramento, American and Feather rivers was estimated to be 47,557 fish in 1991 according to the Sacramento River Angler Survey Estimate Summary (Figure 20). This translates into 705,906 hours or 21 percent of the angler hours spent by fishers along those waterways.

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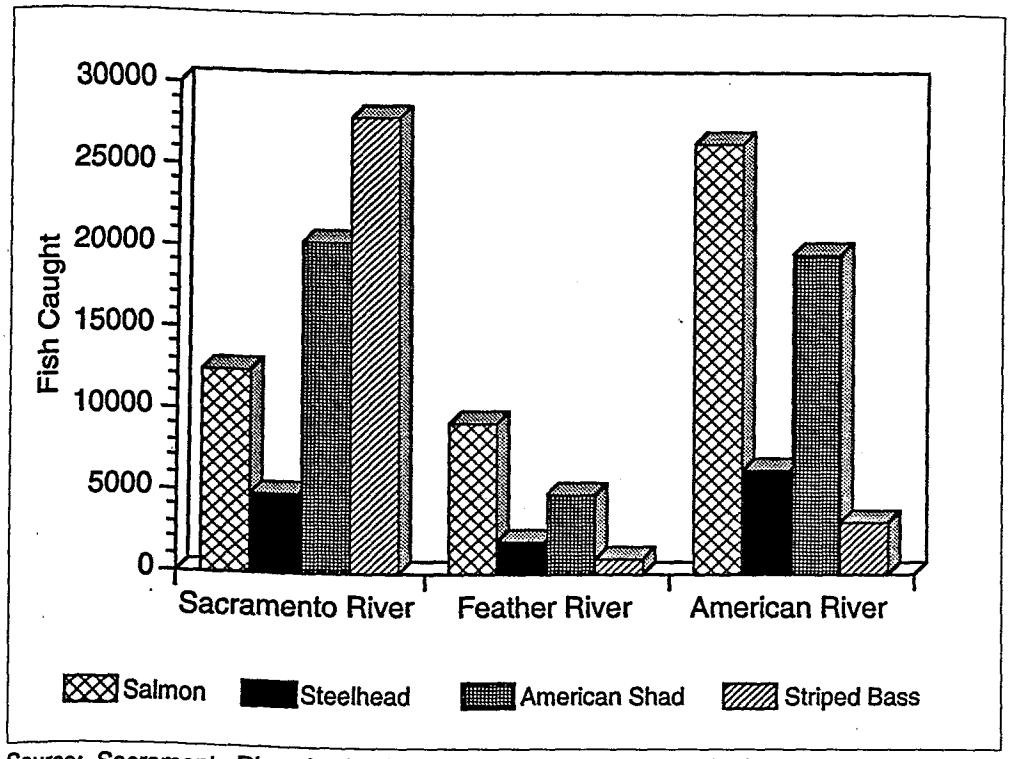
Figure 20. Sacramento River Watershed Angler Fish Counts, 1991.



Source: Sacramento River Angler Survey Estimate Summary, 10/14/92, DFG.

Other important anadromous game fish are the nonnative striped bass and American shad, found primarily in the Sacramento River system and Delta. Today striped bass support an extensive sport fishery in the Sacramento River, Delta, San Francisco Bay, and out into ocean waters. Angling for stripers occurs year-round from private and charter boats, and shore.

For a century after they were first introduced into the state, striped bass populations were abundant, supporting first a commercial, then later a huge recreational fishery. However, the Delta population declined rather suddenly in the 1980s, with adult bass numbers only one-quarter to one-third of levels in the 1960s (DFG, 1991a). This precipitous drop in adults was accompanied by a decline in the Striped Bass Index, a measure of young bass present in the system.

For years, the striped bass has been considered an indicator species for the Bay-Delta Estuary. Department of Fish and Game biologists believe the decline in striped bass is due to a complicated set of human caused influences, the primary being diversions from the Delta and reduced Delta outflows (DFG, 1991a). The Department of Fish and Game has supervised the raising and releasing of young striped bass since 1981, funded by PG&E and DWR for mitigation of their facilities. Planting of striped bass has been recently suspended, due to possible impacts on the Winter-run Chinook in the Delta (DFG, 1992b).

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Nonnative American shad is another popular recreational fish. The runs of American shad are sometimes so large that when the fish migrate, sportfishers can be found on the banks of the Yuba and Feather rivers standing literally shoulder to shoulder. American shad are commonly taken with flies, jigs and small spinners and give a spectacular fight on light tackle. Although there is little available data on current shad population sizes, the sport catch has been low in recent years (DFG, 1991b).

Another popular anadromous sport fish is the native white sturgeon, which spawns in the Sacramento-San Joaquin River systems, and is fished in the Bay and Delta.

Major resident cold water fishes caught by recreational anglers in California include the rainbow trout, brown trout and brook trout, all of which are widely planted. The rainbow is native to California, and the brook and brown trout have been introduced, although because of planting most rainbow populations have varying degrees of genetic contamination. Trout are found primarily in smaller streams and in lakes, especially in the mountains, rather than rivers. Trout fishing is the most popular type of fishing in California (DFG, 1991d).

The Sacramento River has a popular resident rainbow trout fishery in addition to its anadromous steelhead fishery. However, because of elevated dioxin levels from paper mills, the Department of Health Services advises against eating resident trout from the Sacramento between Keswick Dam (just downstream of Shasta Dam) and Red Bluff.

Large warm water fisheries in state rivers exist in the Central Valley and on the Colorado River. The most numerous warm water game fishes are members of the sunfish family (*Centrarchidae*), including black bass, sunfish, perch and crappie, almost all of which are not native to California. Several catfishes, all introduced species, are also important for sport fishing. The record flathead catfish in California weighed in at 55 pounds, caught in the Colorado River (DFG, 1991c).

Recreational Boating

California rivers provide all manner of boating experiences from white water rafting to yachting the twisted channels of the Sacramento and San Joaquin rivers in the Delta. Riparian vegetation and excellent fishing make some rivers a boater's paradise. For instance, in the Delta, thousands come to use the marinas, fueling docks, restaurants and bait shops which have sprung up around the edges of all the islands. There it is as easy to rent a boat as it once was to hail a steamer. The main commercial traffic now flows on purposely built deep water channels to Stockton and Sacramento, while the sloughs and cuts belong to the weekenders and vacationers.

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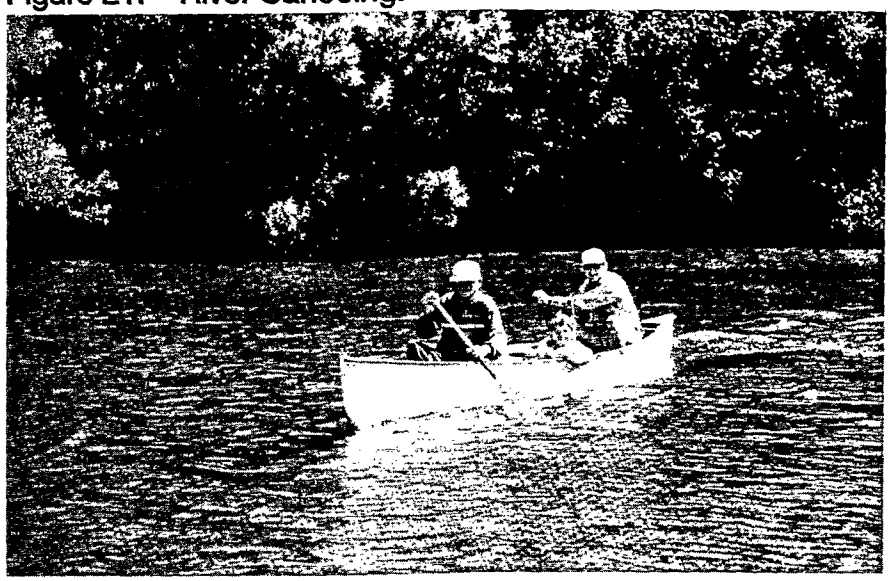
Figure 21. River Canoeing.



Boating is another category of river use that begs for subdivision. From inner tubes to large cruising sailboats, anything that floats can be found on California's rivers, and usually is. One division that is often made is that between the white water users and the smooth water users.

Rafts, kayaks and canoes are taken long distances by individuals or commercial groups to run the rapids and canyons of California's white water rivers. These people are looking for the thrill of fast water, rushing rapids and waterfalls. A large commercial river-running industry has developed in California, supplementing the great numbers of people who own their own equipment and head for white water most every weekend. In 1989, the American White water Affiliation classified 2,256.3 miles of water, in 60 rivers and streams in California, as suitable for white water fun. Some of the more popular stretches are the South and Middle forks of the American, portions of the Cosumnes, Kings, Kern, Stanislaus, Klamath, Mokelumne, Trinity and South Yuba rivers, and the Truckee River from Alpine Meadows. Over 237 separate outfitters filed for commercial permits on the upper Klamath River, the lower Klamath River, the Salmon River and the South Fork American River in 1982 alone. This is a 2000 percent increase since 1970 (DWR, 1982).

The American River is the most popular of the rafting rivers in the state. Figures for white water rafters on the three forks of the American river, including both commercial and private trips, show a general increase even during the recent drought cycle. The approximate number of commercial raft trips on the South Fork of the American river have been kept for over 18 years (1975 -1992). The numbers average 59,882 raft trips per year. Even during the recent drought, the number of rafting trips on the American river increased.

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Table 1. American River Commercial Raft Trips.

	South Fork	North Fork	Middle Fork	Total
1990	76,716	112	1,218	78,046
1991	63,308	184	1,253	64,745
1992	77,025	32	2,004	79,061

Under certain conditions other stretches of rivers become popular. The last period of drought (1987-1993) made portions of the Feather River, usually under Lake Oroville, a favored destination. Weekend water releases from Hetch Hetchy Reservoir create recreational rafting conditions on the Tuolumne (Sunset, 1991)

During this same three-year period, private rafters have gone down the South Fork of the Feather River in increasing numbers. During the most popular months of May through September the number of trips have been counted at 34,400 (1990), 33,746 (1991) and 37,100 (1992). This averages over 100,000 rafting trips each year. Rafting figures for the Tuolumne are counted as passengers. The numbers for 1986, including both commercial and private passengers, are 7,200. In 1991 that number had dropped to 5,100 commercial and non-commercial passengers.

It is reported by local commercial canoe operators that canoe trips on the Russian River have declined over the last three years (1990-92) primarily because of the effects of the drought, and in part because of other recreational activities in the area and pollution (the 1985 sewage spill apparently still concerns some boaters).

The smooth water enthusiasts generally have larger boats (though many canoers and kayakers like smoother water as well) or even houseboats. They often keep their boats in marinas, rather than using trailers to transport their boats from place to place. Most of these people use the Sacramento and San Joaquin rivers and the Delta for their trips. All types of boats, but especially houseboats, can be rented all over the Delta for leisurely cruising the quiet backwaters.

The Department of Motor Vehicles maintains registration records for boats as well as cars, including commercial boats. In September of 1992, their records showed Californians owning 811,740 boats, and that 97.8 percent of those were pleasure craft. Five years earlier, in 1987, the count was 696,513.

Recreational Swimming

Swimming in California rivers is as varied as everything else about the state. There is the challenge of cold Sierra fed water, rough Kings Canyon flows, the warmer and more relaxing Russian River and the awesome Colorado River. To swim in rivers can be a challenge because of currents, submerged rocks and fallen trees. Another

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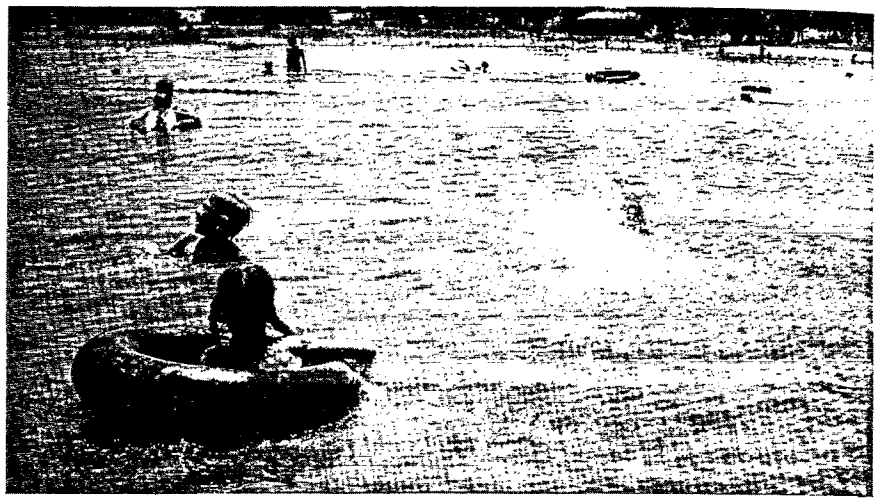
challenge is river access. Although interest in swimming is high—a 1987 statewide telephone survey by the Department of Parks and Recreation gleaned that 59 percent of the state's population swam in rivers, lakes or ocean—there is no swimming access guide to California rivers.

Figure 22. Swimmers and Water Play.



Courtesy of U.S. Soil Conservation Service.

Nature Study

The most direct way to learn is by experience. People learn about trees, birds and flowers by exploring them in their natural environment. No matter how much one reads about the "force of nature," better understanding of this force comes by observing the dramatic changes of a river bed after a major storm. The concept of nature's rejuvenating ability is understood when one observes the young willows sprouting by the newly created riverbank. People learn to associate nature with change and rebirth by walking along the river.

Thus riparian habitat zones attract more than plants and animals, they also attract those who want to study and appreciate this wildlife. And in California, it is the riparian habitats that are among the richest of the ecological treasures that people seek. The value of education as the key for fostering a stewardship ethic in Americans is recognized by the California Association of Resource Conservation Districts (CARCD). CARCD's resource staff promote a statewide program for an Adopt-a-Watershed curriculum beginning at the primary grades and extending through high school.

Surveys conducted by the U.S. Fish and Wildlife Service document that one of the most popular types of recreation in California is simply viewing wildlife. Surveys by the Department of Fish and Game report that the natural beauty of a location is as much, or

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even more, of a draw to a specific spot for people fishing than is the number of fish caught. Tour buses, obviously not carrying hikers or fishers, regularly conduct millions of Californians and non-Californian tourists to Yosemite, through the Redwoods, along the coast and into the Mother Lode country. These people travel simply to take in the inherent beauty that is California's legacy. Even in major urban centers, such as Sacramento, the hundreds of thousands of users coming to the American River Parkway attest to the need people have to visit the splendor of rivers.

Figure 23. Bird Watchers.

The River as a Destination

> *Down through the middle of the Valley flows the crystal Merced, River of Mercy, peacefully quiet, reflecting lilies and trees and the onlooking rocks; things frail and fleeting and types of endurance meeting here and blending in countless forms, as if into this one mountain mansion Nature had gathered her choicest treasures, to draw her lovers into close and confiding communion with her.* — John Muir, *The Yosemite*, 1874.

> *I had walked from Redding, sauntering leisurely, better to see the rocks and plants, birds and people, by the way, tracing the rushing Sacramento to its fountains around icy Shasta.* — John Muir, 1874.

The sight of a river cascading through granite and exploding into mist on the rocks is a sight that lures many hikers and campers out of California's cities and suburbs and into the hills. The state's rivers are destinations for picnickers, day hikers, backpackers and recreational vehicles every day of the year. Some come to fish or swim, or they bring their boats on trailers, but many come just to see and hear the river flow.

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Table 2: State Park System Units on California Rivers, 1992-1993.

	Miles of River
Klamath/North Coast Region:	
Castle Crags State Park	3.1
Admiral William Standley State Recreation Area	.6
Grizzly Creek Redwoods State Park	3.4
Humboldt Redwoods State Park	56.5
Reynolds Wayside Campground	1.1
Richardson Grove State Park	2.4
Smithe Redwoods State Reserve	.8
Standish-Hickey State Recreation Area	5.4
Jedediah Smith Redwoods State Park	8.7
Hendy Woods State Park	3.3
Montgomery Woods State Reserve	.2
Paul Demmick Wayside Campground & Navarro River Project	17.3
Modoc/Cascade Region:	
Ahjumawi Lava Springs State Park	6.7
McArthur-Burney Falls Memorial State Park	5.0
Sacramento Valley Region:	
William B. Ide Adobe State Historic Park	.2
Colusa-Sacramento River State Recreation Area	.8
Bidwell Sacramento River State Park	1.7
Irvine Finch River Access (Unclassified)	.1
Woodson Bridge State Recreation Area	3.5
John Marsh Home (Unclassified)	.2
Calaveras Big Trees State Park	5.0
Brannan Island State Recreation Area	3.0
Delta Meadows River Park (Unclassified	.6
Frank's Tract State Recreation Area	.1
Caswell Memorial State Park	4.6
Fremont Ford State Recreation Area	1.7
George J. Hatfield State Recreation Area	1.4
McConnell State Recreation Area	1.1
Great Valley Grassland State Park	1.5
Marshall Gold Discovery State Historic Park	1.1
South Yuba River (Unclassified)	23.5
Old Sacramento State Historic Park	.2
East Side/Great Basin Region:	
Lake Valley State Recreation Area	.5
Washoe Meadows State Park	.7
Central Coast Region:	
Pfeiffer Big Sur State Park	6.2
Carmel River State Beach	2.0
Castle Rock State Park	.5
Henry Cowell Redwood State Park	7.9
South Coast Region:	0
Desert Region:	
Picacho State Recreation Area	9.7

Scenic appreciation has been noted in various studies. Scenic beauty is regarded as a resource to be protected because it is intrinsic to recreational and cultural experiences on rivers. It may be that the public subconsciously evaluates quality of life or the state of our resources in an integrative way and scenery may be a prime indicator of that evaluation (NPS, 1990).

Camping along rivers is often a recreational activity of Californians. The State Park system (Table 2), includes 170 miles of rivers

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and streams associated with parks, reserves, recreation areas and unclassified units. The 170 miles is approximately 22 percent of river units under California Department of Parks and Recreation administration. (Other units are on the ocean and lakes). Attendance figures for day use and camping facilities have been increasing steadily for all state-run units.

Another segment recreationists often overlooked includes the people who own larger boats and keep them at marinas on the river. Studies have shown that many such people never, or very infrequently, actually take the boats out on the river. They come down for the weekend to "get away" or to socialize without ever leaving their mooring (State Lands Commission, 1986).

Wild and Scenic Rivers Act

In 1968, the United States Congress established a policy of protecting some free flowing rivers and their outstanding values to balance the nation's existing policy of developing other rivers for their water, power and other consumptive resources. Rivers in the National Wild & Scenic Rivers System are designated "wild" (undeveloped and accessible only by trail), "scenic" (essentially wild but occasionally accessible by road) or "recreational" (accessible by road with some development allowed). All classifications prohibit new dams and major diversions, as well as guide the management of public lands within an average of one-quarter mile on each side of the river. The federal law does not prohibit development on private land along designated rivers, but allows for the acquisition of this land to protect wild and scenic values.

The passage of the 1968 federal act included the Middle Fork Feather River. In 1978, the North Fork American River was included in the system. Other state protected rivers (see Figure 24) were added to the federal system in 1981, garnering federal protection for the Smith, Klamath, Salmon, Scott, Trinity, Eel, Van Duzen and lower American rivers. In 1984, the Tuolumne was added to the federal system, followed by the Merced, Kings and Kern rivers in 1987. Sespe Creek, Sisquoc River, Big Sur River and the lower Merced were granted federal protection in 1992 (Figure 24).

In 1972, the California legislature passed a similar law to protect anadromous fisheries and exclude the North Coast's free flowing rivers from major water development. Except to observe local needs, this law prohibits the construction of dams and diversion structures, although this prohibition may not apply to federal projects. In addition, state protection is limited to the river bed up to the first line of riparian vegetation.

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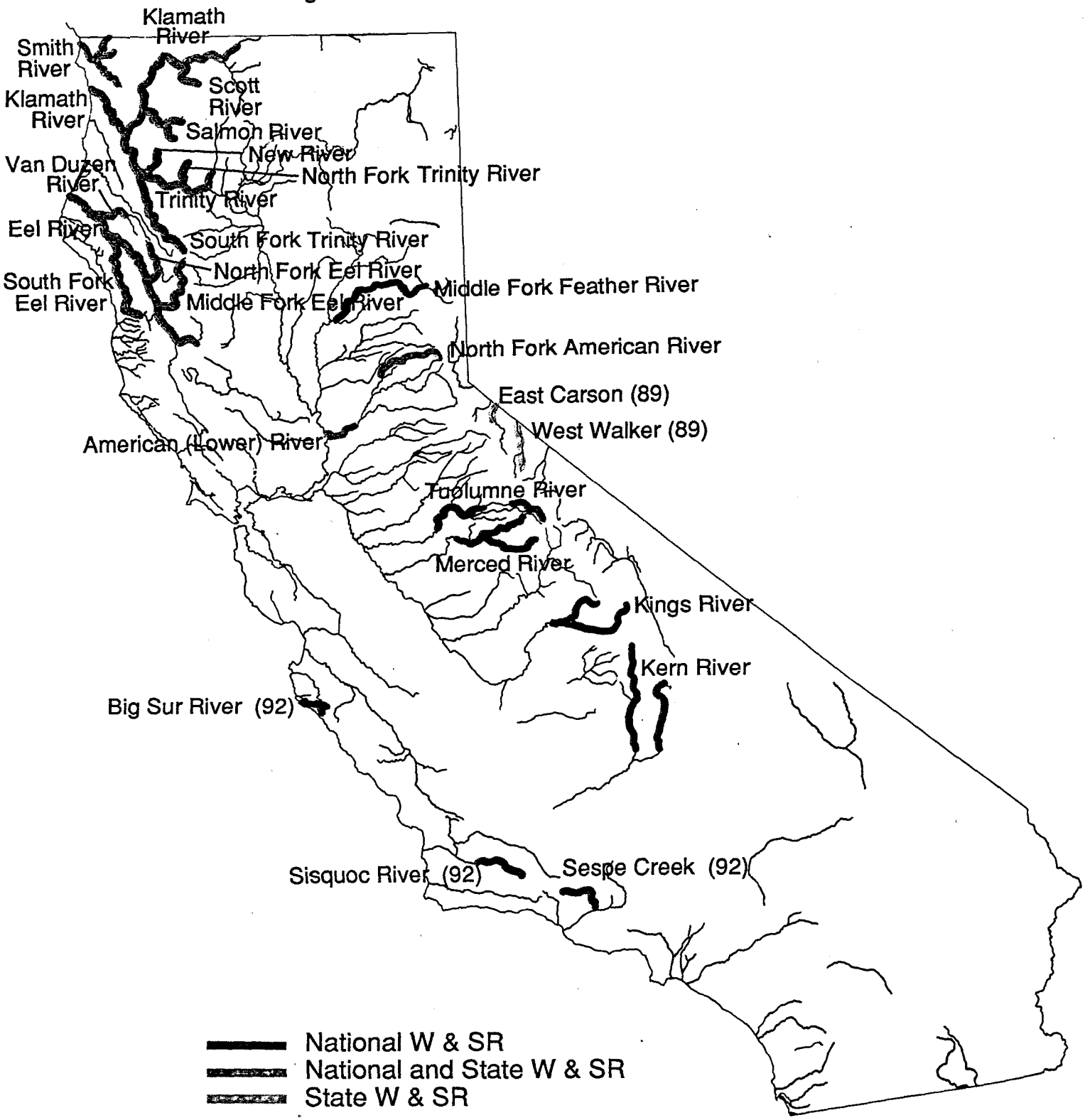
Figure 24. California Wild and Scenic Rivers.



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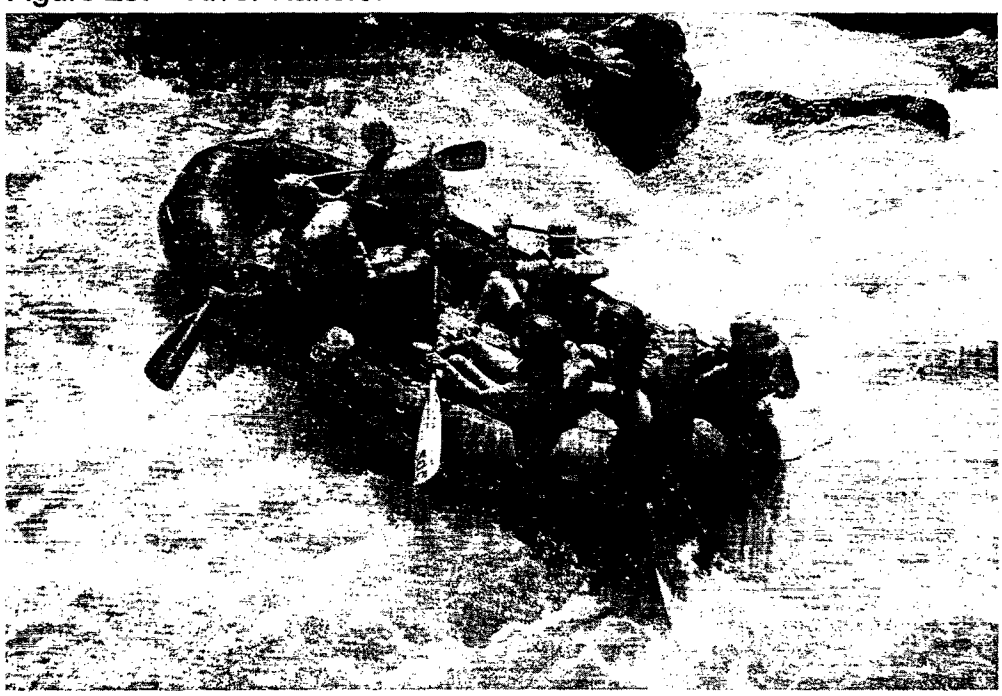
The state Wild & Scenic Rivers System includes the entire Smith River and sections of the Klamath, Scott, Salmon, Trinity, Eel, Van Duzen and American rivers. In 1978, the North Fork American was added to the federal system, followed by the rest of the state rivers in 1981. The East Carson and West Walker rivers were added to the state system in 1989.

More than 1,900 miles of California rivers, or about 7 percent of all rivers in the state, are under wild and scenic protection. In addition, federal agencies have identified more than 200 river segments totaling more than 2,200 miles as eligible for federal wild and scenic designation. Of these, 35 segments totaling more than 550 miles have already been recommended for protection.

The Smith River is California's only major undammed water shed. Rising from its source in the Syskiyou Wilderness in the North Coast county of Del Norte, the Smith is considered the "Crown Jewel" of California's state and federal wild and scenic rivers. In recognition of this unique watershed, the 305,000-acre Smith River National Recreation Area (NRA) was established by Congress in 1990. Recognizing the nationally significant values of the North and Middle Forks of the American River near Sacramento, the federal Bureau of Land Management determined 48,000 acres encompassing the upper American river canyons to be suitable for NRA status in 1991, although Congress has not yet acted on this recommendation.

Figure 25. River Rafters.



Courtesy of Friends of the River.

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California Rivers: Effects and Consequences

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Here in the U.S. we turn our rivers and streams into sewers and dumping grounds, we pollute the air, we destroy forest, and exterminate fishes, birds, and mammals—not to speak of vulgarizing charming landscapes with hideous advertisements. But at last it looks as if our people were awakening. Many leading men, Americans and Canadians are doing all they can for the Conservation movement.—Theodore Roosevelt, *Our Vanishing Wildlife: Literary Essays* (Works of T.R. nat. ed., Vol. 12, originally appeared in *The Outlook*, Jan. 25, 1913).

There may be a relationship between the amount of landscape that rivers occupy and the importance with which people regard rivers. This may be especially true in the West where rivers do not always flow. This ephemeral quality belies their importance as environmental systems and resources for human use. As discussed in the previous chapter, rivers are major recreational attractions for Californians: sport fishing, swimming and boating are immensely popular.

Rivers are also used by humans for commercial purposes, including fishing, transportation, irrigation, sand and gravel mining, industrial and agricultural water supplies, and receiving waters for wastewater effluent. Apart from these important uses, rivers have intrinsic ecological and environmental values. Notwithstanding their importance in every aspect of human endeavor, rivers have been harmed in every way imaginable.

Agriculture and urban growth in California have demanded water for development and flood control. Water development generally has been through the impoundment of water behind dams or the diversion of rivers and tributaries to aqueducts conveying the water directly to farms and cities. Some dams also serve flood control needs, as do other measures, such as levees. Agricultural land use also results in the loss of riparian corridors and is a source of pollutants released to rivers. Urban land use is often traumatic to entire watersheds not only because of the construction of dams and flood control

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projects, but also because of massive landform changes which alter runoff patterns and drainage networks. These and other insults interrupt springs, affect ground water tables, reduce riparian corridors and threaten the very existence of rivers.

Forestry and range management are major land uses in the 85 percent of the state which is not intensely developed. Like urbanization and agriculture, these activities have many significant effects on river systems, including watershed damage and pollution. In addition, mining in wildland watersheds and in river channels and flood plains has degraded myriad streams and rivers. Unfortunately both the legacy of past mining practices and current operations pose significant problems.

Before this century's human activities, the few potentially harmful substances that entered the water bodies came from Native American settlements along the shoreline, or from natural sources such as the weathering of rocks. Gold mining between 1853 and 1884 introduced the first major anthropogenic pollutant: an estimated 3,500 tons of highly toxic mercury used to extract gold. Mercury was followed by untreated industrial and sewage wastes from towns and cities. Implementation of the state Porter-Cologne Water Quality Act of 1969 and the federal Clean Water Act of 1972 led to rapid improvements in the quality of municipal and industrial effluent. Urban runoff contributes much larger quantities of many kinds of pollutants than do municipal and industrial sources. Pesticides are one of the most important components of agricultural runoff. It is estimated that agricultural drainage contributes more than 20 percent of the total time-averaged flow in the San Joaquin River, and most of its flow during the summer (DWR, 1986; Nichols et al., 1986).

Over the course of the 20th century, California's rivers have been put under great stress. This stress began almost immediately

Figure 26. Kern River Oil Fields.

Bryant Sturgess Collection.

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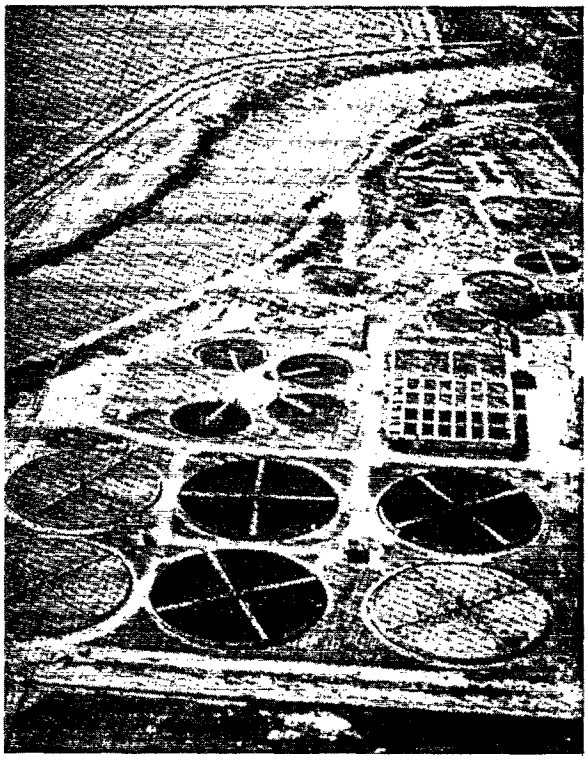
with European/American use because of hydraulic mining for gold, navigation needs, the transport of logs, and water diversion for urban, industrial and agricultural development at a time of exceedingly rapid growth. Indeed, during the 20th century California saw the most rapid population increase of any developed area in the world, coupled with phenomenal rates of economic expansion and revolutionary agricultural practices.

This chapter identifies the principal human activities that have affected the ecological health of rivers' and streams' ecosystems in the 20th century. In this chapter we will discuss the factors of water pollution that affect the chemical, physical and biological characteristics essential for aquatic living resources and the status of these resources.

Water Pollution

> *Something will have gone out of us as a people if we ever let the remaining wilderness be destroyed. . . if we pollute the last clean air and dirty the last clean streams.*—Wallace Stegner.

Figure 27. Sewage Treatment Plant.



The ecological health of an aquatic ecosystem is defined by its combined chemical, physical and biological characteristics—the concentrations of chemical constituents in its water, sediments and organisms; the condition of its physical habitat (e.g. streambed, banks, riparian vegetative cover and streamflow); and the health, variety and nature of the plants and animals that live around and within it (USEPA, 1988).

Water pollution is a broad term. It refers to the alteration of aquatic ecosystems so that aquatic life may be impaired or destroyed, or the fouling of water so that recreation and aesthetic enjoyment are diminished or no longer possible. These changes may occur from substances such as chemicals, sediments and excess nutrients

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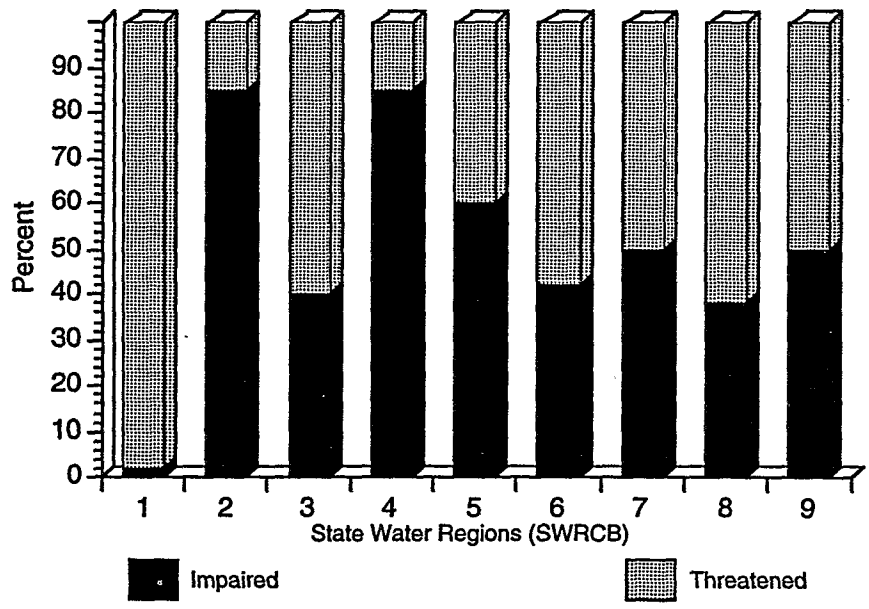
which are introduced into the water. However, water pollution also includes other actions that alter aquatic ecosystems, such as dredging or changing flows (SF Bay RWQCB, 1992).

All waters of California are required by federal law to be designated for "beneficial uses" that must then be protected. Such waters may be classified for support of aquatic life and contact recreation, and should be usable for fishing and swimming. The state is responsible for establishing criteria necessary to protect those uses. If these criteria are not met, the uses they are protecting may be "impaired" or "threatened" (SWRCB, 1991a). In general, impaired means the beneficial uses of water such as aquatic life or drinking water supply have been harmed and reduced. Threatened means the beneficial uses may be fully supported at this time but activities could impair these uses if not controlled (SWRCB, 1991a) (Figure 28).

Figure 28. Ratio of Impaired vs. Threatened Rivers by Water Region.



Most Regions are close to evenly split on impaired and threatened water bodies except Region 1 which is almost entirely threatened and is responsible for the heavy influence on forest practices. Regions 2 and 4 are predominantly represented as impaired.

Note: Habitat modification, which includes diversions and channelization, is a major effect on beneficial uses although it does not fit generally as a water quality problem.

Source: SWRCB, 1991.

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Most of California rivers meet state water quality standards and satisfy most goals set by the federal Clean Water Act (SWRCB, 1992a). The primary cause of water quality degradation in impaired water bodies in California is nonpoint source pollution. Nonpoint sources include agricultural, forestry and urban runoff (Charbonneau and Kondolf, 1991). Urban areas produce primarily point-source pollutants including storm drains in lower amounts than nonpoint agricultural sources, but they may cause locally severe effects, especially with high amounts of industrial discharge. Table 3 describes major water quality impacts in California (Adapted from Charbonneau and Kondolf, 1991).

Table 3. Major Water Quality Impacts in California.

Source	Impact
***Agricultural practices** (Includes livestock and grazing)*	
Pesticide and fertilizer application, irrigation return flows	Toxics contamination, eutrophication, salinity
Animal confinement areas	Pathogenic bacterial contamination, eutrophication, ammonia toxicity, BOD/oxygen depletion, turbidity/ siltation
Cultivation, soil disturbance, overgrazing	Turbidity/siltation
Forestry Practices	
Timber Harvest	Turbidity/siltation, BOD/oxygen depletion
Access road construction, site preparation	Turbidity/siltation
Pesticide application	Toxics contamination
Urban Development	
Urban Runoff, including pesticides and fertilizers in landscaping and drainage and spills from transportation corridors	Toxics contamination, eutrophication
Waste discharge (municipal & industrial outfalls, septic system leachate)	Toxics contamination, eutrophication, pathogenic microbial contamination, BOD/oxygen depletion
Air pollution	Toxics contamination, acidification
Mining	
Hard rock mineral mining	Toxics contaminants (e.g. heavy metals, acidification
Instream and terrace aggregate mining	Turbidity/siltation

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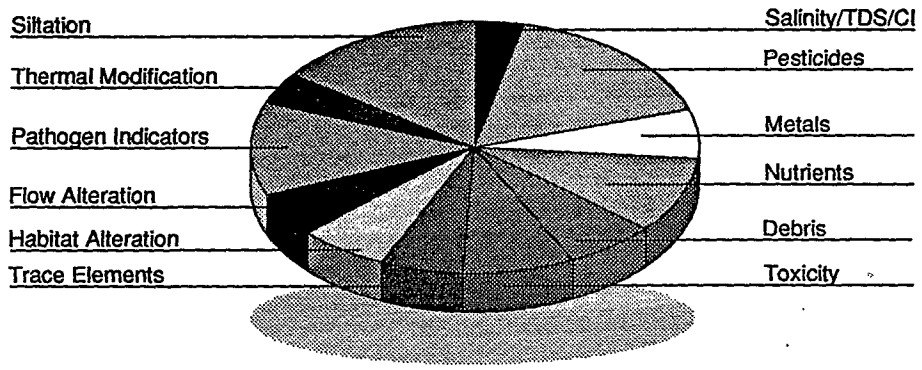
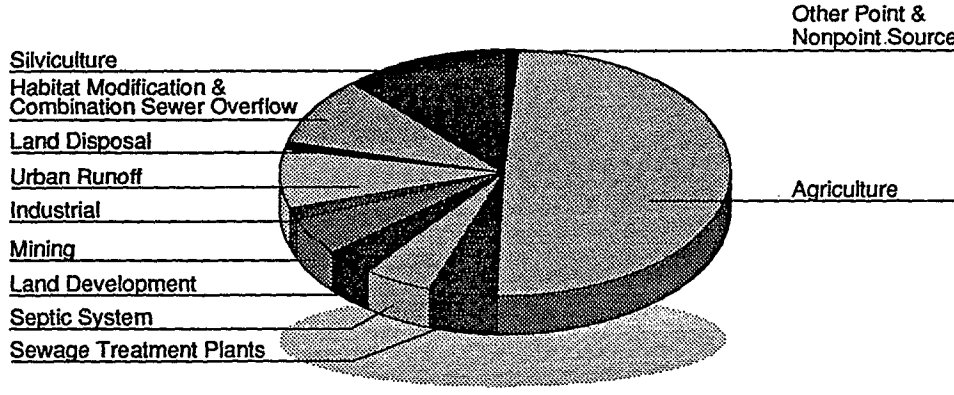
The most extensive source of water pollution impairing and threatening the state's rivers and streams is agriculture, primarily from excess nutrients, pesticides, herbicides, sediments and habitat modification (Figure 29) (SWRCB, 1991b). Other types of river pollution include elevated water temperature and toxic chemicals. Sources of these contaminants include municipal sewage and storm water runoff; resource extracts, such as mining; and silviculture (including timber harvest) (SWRCB, 1991a). Hydrologic habitat modification is caused by water diversions, flood control and urbanization.

Figure 29. Relative Percentage of Pollutants and Their Sources.



Pollutants



Sources

- The above pie diagrams depict the sum of Impaired and Threatened classifications of sources and pollutants for assessed rivers and streams of the state.

- The sources and pollutants shown above are heavily influenced by Region 5 with 41% of the State's assessed rivers.

Source: SWRCB, 1991.

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Pollutants

Pollutants are substances or actions that adversely affect the physical, chemical or biological properties of the environment. The State Water Code (§13050[1]) defines "pollution" as "an alteration of the quality of the waters of the state by waste to a degree which unreasonably affects either. . . 1) the waters for beneficial uses [or] 2) facilities which serve such beneficial uses." Additionally, the impairment of water quality by contamination is defined as pollution that creates a hazard to public health.

Pollutants are measured in terms of concentration (the quantity of a pollutant in a given amount of water), sediment or animal tissue. The units of measurement for describing pollutant concentrations are low because the occurrence of pollutants in the environment and biota are comparatively low. These units of measurement are commonly expressed as parts per thousand (ppt), parts per million (ppm), and parts per billion (ppb). Even parts per billion are significant to certain flora or fauna, causing death, deformity or mutations. Water's ability to ionize and dissolve substances and assimilate wastes is a major reason why aquatic ecosystems are on the one hand productive but on the other quite susceptible to pollution (Moyle and Leidy, 1992).

Discussed below are the principal types of pollution effects on aquatic biota and habitats: altered temperatures (usually elevated); depletion of dissolved oxygen; acute and chronic toxicity by inorganic chemicals, natural and synthetic organic chemicals, biological contaminants and suspended sediments; the smothering of bottom substrates by siltation; and habitat modification. Excessive pesticides, siltation, pathogens and nutrients chiefly from agricultural uses are the primary threat or impairment of rivers and streams (SWRCB, 1991b).

Altered Temperatures

Temperature pollution can occur with the discharge of industrial cooling water, agricultural drainage, the passage of river water through warm water ponds created by gravel mining pits, or surface reservoir releases. As an example, the Colusa Drain on the Sacramento River discharges irrigation runoff in flows up 2,000 cubic feet per second (cfs) at temperatures over 80°F, which is highly detrimental to salmonid smolts (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, 1989). Decreases in flow also can result in increased water temperature. The removal of tree canopy by logging, grazing or other clearing near the channels of streams and small rivers also results in higher water temperatures.

Elevated temperature directly affects aquatic biota, especially those organisms adapted for cold water habitats. Organisms may be

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killed outright or, more likely, subjected to chronic stress which predisposes them to premature mortality. Salmonid fishes are particularly vulnerable to high water temperatures (see discussion under fishes—Chapter 1). Temperature changes can also affect migration and spawning behavior (Dunne and Leopold, 1978).

Depletion of Oxygen

Dissolved oxygen problems arise with the addition of biodegradable organic material, which is then worked upon by decomposing microbes. Sources of organic-matter pollution in rivers include agricultural runoff, wastes from food processing plants, human or animal waste discharges, and plant debris from crops or logging. Decomposition of organic matter requires a certain amount of oxygen, measured by an index called the Biological Oxygen Demand (BOD). If oxygen becomes completely depleted, anaerobic bacteria increase in activity, often producing noxious gases such as methane.

The addition of dissolved nutrients, for example from fertilizer run-off or sewage discharge, stimulates a bloom of algal growth. This over stimulation of the growth of aquatic plants and algae also cuts off light in deeper waters. This seriously affects the respiration of fish and aquatic invertebrates, leads to a decrease in animal and plant diversity, and affects the use of the water for fishing, swimming and boating. When algae dies it decomposes, adding enormously to the BOD. The phenomenon of artificial nutrient enrichment, rampant algal growth and subsequent oxygen depletion in a body of water is referred to as cultural eutrophication.

Toxicity

Important river pollutants which are toxic to organisms include herbicides and other pesticides, heavy metals, chlorine, surfactants and ammonia. Changes in salinity and acidity also directly and indirectly affect river biota. Rainfall and irrigation can wash pesticides and herbicides used on agricultural lands into surface waters. These contaminants are generally very persistent in the environment and may accumulate in the tissues of fish and wildlife.

Inorganic Contaminants

Sources of toxic substances include runoff and leachate from mines, e.g. the Penn Mine on the Mokelumne River and Iron Mountain Mine on Spring Creek, tributary to the Sacramento River; chemical wastes from pulp mills and refineries; chemicals used in agriculture or contained in agricultural waste; or drainage water (e.g. selenium and sulfate ions, Saiki et al., 1992). All take their toll on living resources and habitats. Toxic inorganic substances including metals

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(such as mercury, lead, selenium and cadmium) can cause death or reproductive failure in fish, shellfish and wildlife.

Organic Contaminants

Organic compounds include natural and synthetic chemicals. Many synthetic compounds are resistant to decomposition and are toxic to living organisms. Compounds containing chlorine or bromine, members of a group of elements known as halogens, are among the most persistent and toxic of organic chemicals. Familiar halogenated compounds include polychlorinated biphenyls (PCBs) and pesticides such as dichlorodiphenyltrichloroethane (DDT), and polynuclear aromatic hydrocarbons (PAHs) from combustion (vehicles), oil and petroleum products (benzene, xylene, toluene) whose detrimental effects may continue for decades once introduced into the environment.

Disease

Biological pollutants, such as bacteria and viruses which cause cholera, hepatitis, salmonella and typhoid can enter water bodies from septic systems, untreated municipal sewage, recreational boat discharges, water contact in recreation (swimming) areas and in runoff from farms, feedlots and urban areas.

Habitat Modification

Loss of habitat occurs when streams and rivers are modified by activities such as grazing, farming, channelization, construction of dams, dredging, gravel mining and interwatershed disturbance that leads to changes in channel morphology. Typical examples of habitat modification include loss of streamside vegetation, siltation, smothering of bottom dwelling organisms and increased water temperatures.

Sediments

When it rains, silt and other suspended solids wash off plowed fields, construction and logging sites, urban areas and mined land. These suspended solids and sediments can have damaging physical effects. Increased turbidity decreases photosynthesis of aquatic plants, and can clog the respiratory surfaces and feeding mechanisms of aquatic animals. Sedimentation can smother benthic communities and alter habitat. Salmonids, which need clean gravel for successful spawning and early rearing, are particularly vulnerable to impacts from sedimentation.

Sediments constitute nearly half of the materials introduced into rivers from nonpoint sources (USEPA, 1988). Fine silt, part of the

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overall sediment transported in rivers, remains suspended for long periods of time, producing extended areas of turbidity. Turbidity causes light to be scattered and absorbed, reducing light penetration and thus diminishing or even eliminating aquatic plant growth.

When plants die, their roots no longer act as anchors for soil in the bottom of the river bed, causing increasing turbidity. It has been demonstrated that the loss of aquatic plant life leads to the loss of associated snails and aquatic insects that depend on the plants and serve as a food source for young fish. Predatory fish depend on clear water for finding food. Thus, turbidity generally reduces the feeding of fish even if there is an abundance of food in the water. Many species of fish have complex reproductive and social behaviors that depend on visual signals which may be obscured in the turbid waters. Although living resources tolerate high levels of sediment in water for days or weeks, continued turbidity can result in a population finally succumbing to starvation, reproductive failure or cumulative stress.

State Water Resources Control Board and Regional Water Quality Control Boards

To gain an appreciation of the state of California rivers, one should understand the context of water quality assessment. The beneficial uses of rivers are varied and thus the health of the rivers consists of more than a drinking water quality standard. The process for assessing and monitoring river water quality is central to any restoration strategy. Because there is a need for this basic understanding of how river water quality is determined and the state of such determination in order to evaluate the status of rivers, the following discussion is provided.

The State Water Resources Control Board (SWRCB) has authority and responsibility under the Porter-Cologne Act for protection of the quality and beneficial uses of water. Nine Regional Water Quality Control Boards are individually responsible for developing Regional Water Quality Control Plans, (or Basin Plans) and ensuring compliance with the act. The status of California rivers' water quality is reported by the SWRCB in the *Water Quality Assessment* inventory (SWRCB, 1992b) that includes information about their characteristics and conditions. It is prepared by the regional boards and varies widely in what is measured and in consistency (John Norton, SWRCB, pers. comm. 1/1993). The prioritization step of the state's Clean Water Strategy (SWRCB, 1991a) involves the preparation of water body fact sheets, determination of resource value and water body condition. Resource value and condition ratings are prepared for higher priority waters, as determined by the regional boards, and for those waters that are water-quality limited (SWRCB, 1992b).

The SWRCB assesses river water quality to determine if the river can strongly support its uses, such as aquatic life and wildlife

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and recreation. Those rivers which do not fully support these and other purposes are judged to be impaired. The regional boards' assessments have determined optimal strategies for achieving water quality and distribution of assimilative capacity for each major river basin. Assimilative capacity is a measure of a water body's ability to meet standards or provide "beneficial uses" under increasing "loads" of individual pollutants. The Total Maximum Daily Load (TMDL) for a few pollutants and some hydrologic units has been determined—for instance, San Francisco Bay, Morro Bay, Central Valley and North Coast/Klamath regions and Santa Ana and Truckee rivers. However, the SWRCB has recently initiated an alternative "watershed" approach, rather than determining assimilative capacity for each major pollutant. These "watersheds"—not water basins—are defined in area by pollutants, beneficial uses and land use change regimes (John Norton, SWRCB, pers. comm., 1/1993). This area definition allows water quality standards to be achieved in a system rather than at isolated treatment facilities. For instance, if a wastewater treatment facility charged by law to meet a water discharge standard can identify upstream sources of the pollution which are outside its jurisdiction, then a multi-jurisdictional collaborative effort could achieve the required water quality standard. For impaired streams, the SWRCB and the Regional Water Quality Control Boards adopt water quality standards to mandate enforcement authority or to encourage practices to improve the water quality.

Testing the effects of pesticides and herbicides on aquatic life is an ongoing effort. The Regional Water Quality Control Boards must identify which components in the stream or river's chemical makeup are toxic. Toxicity is determined by stream water survival and the reproduction of certain test animals. Toxic levels may be too low to kill, but they can inhibit reproduction and eliminate the food supply. Once the toxic level is determined to be caused by a pollutant, the source of that pollutant must be identified.

Annual reports on the state's river water quality only document the impairment and suggest its source; they do not provide remedies or implementations. For example, the state does not have requirements for integrated pest management (IPM) to reduce the application of pesticides or herbicides; nor does the state have a comprehensive Best Management Practices program to require vegetation buffers between crop fields and streambanks. Such buffers would delay or block the chemicals from entering surface waters or "treat" them through plant uptake and, in many instances, substantially reduce their toxicity. These buffers would also trap sediment which is the principle carrier of pollutants.

Currently the state does not have a complete description of each river basin that would be adequate for an environmental assessment. There is no comprehensive list of environmental problems in the river basins. These existing partially descriptive basin

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plans are being updated. Fact sheets on 250 water bodies, including rivers, briefly describe the beneficial uses, pollutants and causes of impairment. However, there is no single document with these descriptions. Reports and assessments that do exist are based on different protocol for water quality evaluation. Although there are standard laboratory procedures set by USEPA, and state regulations for environmental indicator testing, it is difficult to compare data from different regions and different water conditions due to regions' subjective determinations based on "Best Professional Judgement." Thus, there is no consistent method by which watersheds are characterized nor are there consistent criteria to measure the ecological condition of aquatic, wetland or riparian systems to evaluate either the need for remedial action or the effectiveness of management actions on beneficial uses.

The first large scale attempt to create a coordinated voluntary watershed resource management plan based upon needs of landowners and citizens is the Napa River Resource Management Plan of 1992. A $61,000 grant was awarded by the State Water Resources Control Board to the Napa County Resource Conservation District to help develop the plan. Recommendations to landowners and public agencies about ways to enhance and protect the natural resources of the watershed will be made. The stated objectives are to: encourage development of practices that will increase biological diversity; increase the long-term health of agriculture and open space lands; enhance and protect fisheries; public education programs to avoid urban pollution; integration and enhancement of wildlife habitat throughout the watershed.

The program will consider the entire watershed from Mt. St. Helena through the Napa Marsh State Wildlife Area. Several local and state agencies are providing technical assistance. The program could be a model for other water region areas seeking long-term methods of protecting and enhancing natural resources under pressure from increasing population and development. The plan is intended to demonstrate the integration of resource conservation principles in land management planning as a method of water quality protection (Napa RCD, 1992).

Effects of Mining

Instream and Terrace Aggregate Mining

Sand and gravel are used for a large variety of construction activities including roads and highways (base material and asphalt), pipelines (bedding), septic systems (drain rock in leach fields), and concrete (aggregate mix) for highways and buildings. Since the end of World War II rapid population growth and the consequent construction boom in California, the demand for aggregate has been strong. In

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1986, the production of sand and gravel in California, primarily derived from river channels and their flood plains, was estimated at 128.5 million tons with an estimated value of nearly $500 million (Sandecki, 1989), nearly double the estimated production of 65 million tons in 1955. Aggregate mining is the largest mining industry in California.

Aggregate is derived principally from pits in active flood plains, pits in inactive river terrace deposits or directly from the active channel. Other sources include hard rock quarries and mining from deposits within reservoirs. Although no figures are available to specify the proportion of total production derived from various sources, it is clear that the great majority of aggregate is derived from active channels and adjacent alluvial deposits.

Figure 30. Russian River Aggregate Mining.

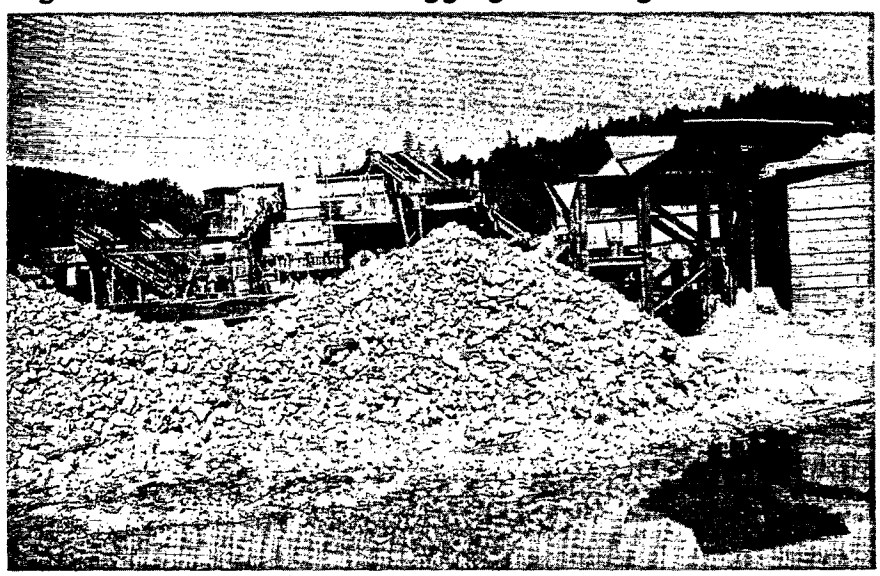

Figure 31 shows where aggregate mining in and adjacent to California's rivers is occurring. This information was derived from databases maintained by the State Lands Commission and the Department of Conservation, Office of Mine Reporting and Reclamation Compliance. The Department of Fish and Game is also responsible for issuing "streambed alteration agreements" which are prepared at the regional level; thereby making collection of complete information difficult. Local governments may also issue permits for some mining activities. The completeness of the information on instream aggregate mining is therefore problematic due the variety of federal, state and local agencies with regulatory authority.

Extraction sites present a problem for regulators for a variety of reasons. Those reasons include water quality, public access and navigation, loss of riparian vegetation and anadromous fisheries habitat, downstream replenishment, site reclamation responsibilities, structure damage (bridge and highway crossings) and the extent of aggregate supplies.

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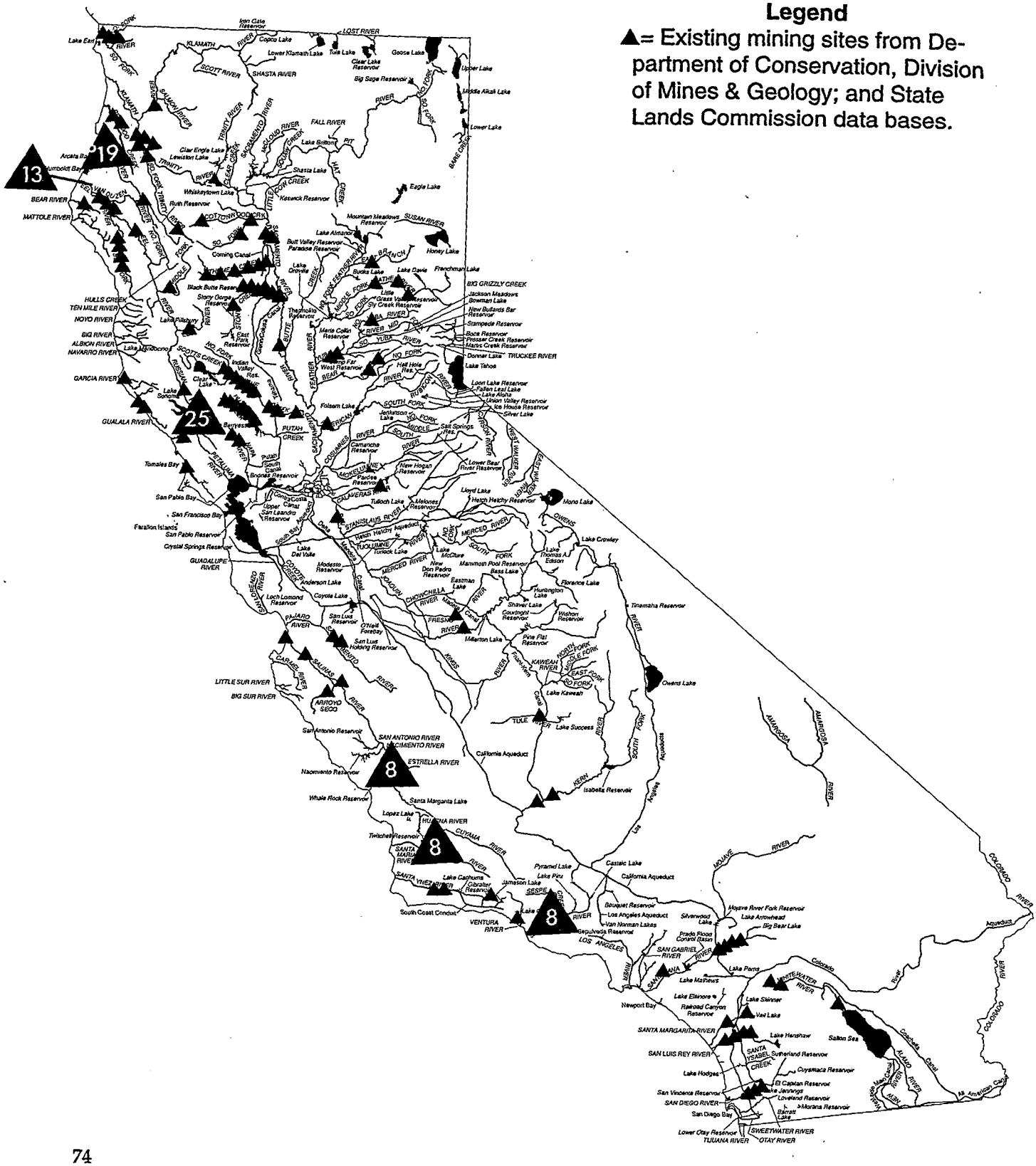
Figure 31. Map of Instream Aggregate Mining Sites.

Legend

▲= Existing mining sites from Department of Conservation, Division of Mines & Geology; and State Lands Commission data bases.



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There are currently two major efforts, including both public and private organizations, aimed at coordinating efforts and sharing information on the extent of gravel extraction in the state. First, the Instream Gravel Committee was established at the state level in 1993 to provide a coordinated effort to manage gravel extraction activities by identifying impacts and providing a streamlined process for review of these activities. Thirteen state agencies and the U.S. Army Corps of Engineers participate. The second effort is the Mad River Memorandum of Agreement (MOA). It was developed to address gravel extraction activities on the Mad River in Humboldt County. The MOA is one of the few concerted effort among industry and local, state and federal agencies and public interest groups to identify and address potential impacts of gravel extraction for a specific region while providing for an agreed level of extraction. The State Lands Commission participates in both of these efforts.

Aggregate derived from active riverbeds is especially desirable because it typically requires little processing or transportation. Natural river processes eliminate weak materials by abrasion and attrition, so the resulting deposits are durable, rounded, well-sorted, and relatively free of interstitial fine sediment. Suitable deposits are often located near the markets for the product, which reduces transportation costs. This is especially important to this industry, where a general guideline is that the cost of the product doubles with each 25 miles of transport (Randy Sater, Teichert Construction Company, Sacramento, pers. comm., 1991).

Until recently (and still in many areas) the environmental costs of instream gravel extraction have not been factored into production costs, making instream sources more attractive than alternatives such as dry terrace mines (in which interstitial fine sediment content is often greater, requiring additional processing), quarries (from which rock must be crushed, washed, and sorted), or distant sources, such as reservoir deltas, involving greater transportation costs.

As described in Chapter 4, the sediment in the bed of a river is a dynamic feature, in transit through the system during floods. The flux of bed sediment depends on the supply of coarse sediment from the watershed and the transporting power of the river. In addition, transport rates vary over space and time. If the sediment flux is altered, the river channel is likely to adjust to the changed conditions. Instream gravel mining, by removing this sediment continuum, disrupts the preexisting balance between sediment supply and transporting power.

The concept of replenishment rate is commonly applied to instream gravel mining to specify acceptable levels of sustained yield. The notion is that if the harvest rate does not exceed the rate at which coarse sediment is delivered from upstream, the harvesting can be sustained without impact on the channel system. However, when viewed in the larger context, this extraction site can be seen as

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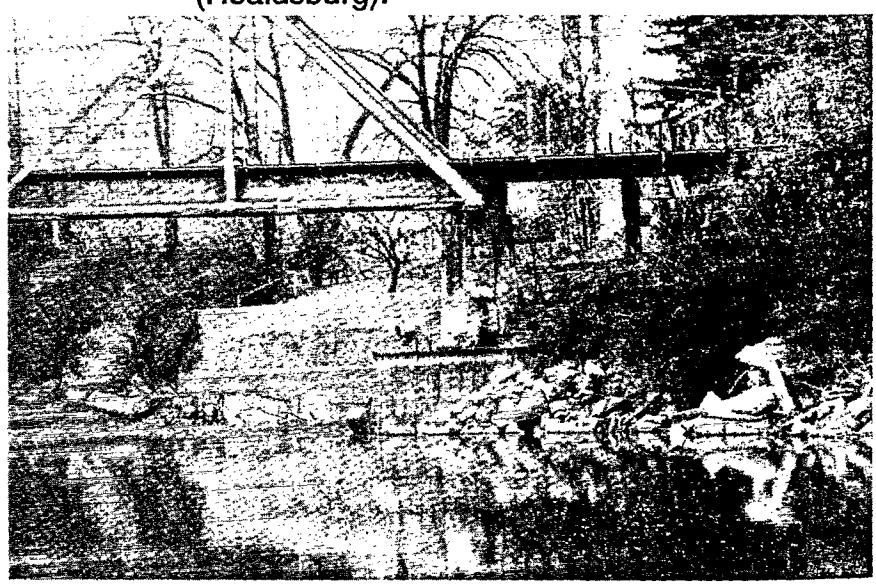
the "upstream" from which downstream reaches derive their coarse sediment supply. If the sediment in transit through the system is rerouted out of the channel into gravel trucks, the flow of gravel is interrupted and downstream reaches are deprived of their sediment load. One effect of this is essentially the creation of "hungry water" downstream of extraction sites. When this happens, the river will typically expend its excess stream power by eroding bed and banks. Thus, channel incision and instability may result downstream of extraction sites even if the extraction rate does not exceed the "replenishment rate."

The most dramatic effects of instream mining occur when pit mining is conducted within the active channel. By excavating large pits, whether shallow or deep, the equilibrium profile of the stream bed is altered and the channel must adjust to the locally steeper gradient upon entering the pit. This steeper gradient creates a stream power excess which is generally capable of eroding the bed, causing incision, often both upstream and downstream of the pits. As the streambed degrades, the material remaining on the surface will coarsen as the finer material is transported away. This leaves a coarse lag and an armor layer similar to that seen downstream of dams. In severe cases, the degradation will continue until bedrock or older substrates under the recent alluvium are uncovered.

Incision has many direct effects, notably the undermining of bridge piers and other structures, such as has occurred under the Highway 299 Bridge over the Mad River and bridges over the Russian River (Figure 32). The cost of such damage to bridges through 1984 in California probably exceeded $12 million (Kondolf and Matthews, 1993). Degradation can induce channel instability and

Figure 32. Exposed Pilings of Bridge on Russian River (Healdsburg).



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trigger bank erosion and channel migration in formerly stable reaches. The physical alteration of the stream channel may result in the destruction of existing riparian vegetation and the reduction of available area for seedling establishment. Loss of vegetation impacts riparian and aquatic habitat by causing a loss of the temperature-moderating effects of shade and cover, and habitat diversity. As noted above, bed coarsening results in loss of spawning gravels for salmonids. Extensive degradation may induce a decline in the alluvial water table, as the banks are effectively drained to a lowered level, affecting riparian vegetation and water supply wells (Woodward-Clyde Consultants, 1976).

By altering the natural channel configuration, even low-volume gravel bar skimming operations can reduce habitat diversity by producing a wide, shallow channel lacking in the pools and cover needed by fish, and potentially increased water temperatures. In addition, the cumulative effects of skimming approach those of instream pit mining, i.e. bed degradation.

Because of environmental impacts related to mining in the active channel, more and more aggregate is being mined from river terraces. Terraces are made up of flood plain deposits, but are somewhat isolated from the current river due, for example, to bed degradation or flood control. In terrace mining, huge pits are excavated alongside the channel, leaving a small strip of unmined bank to act as a levee between the active river channel and the pits. Because the pits are dug much deeper than the groundwater elevation (and deeper than the original river bed) the pits become giant ponds after mining.

Terrace pit mining can cause many adverse environmental effects. If the river should meander and "capture" the terrace pits, the flowing river habitats would be subsumed into a system of warm-water lake habitats. For example, flood waters breached a levee on the lower Merced River in 1986 and changed the course of the river to flow into a terrace mining pit. The low Merced salmon population was further stressed by these new migration impediments and increased exposure of the juveniles to predation. DFG's 1993 proposal to rebuild the levee and restore the river to its channel is under review. In addition, terrace mining replaces land, which may be useful for agriculture or riparian habitat, with ponds. Terrace pit lakes can provide wetland habitats, but the side slopes are usually left so steep after mining that extensive reclamation is necessary to gain any environmental benefits.

Suction-dredge Gold Mining

California rivers and streams are still mined for gold, by both recreationists and commercial enterprises. All the larger operations, both commercial and recreational, use similar methods. A suction dredge is floated in the stream and a four to ten inch hose is guided

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over the bottom, sucking up water, sediment, small rocks and, it is hoped, gold nuggets. This flow is passed over riffle boards or "rockers" to separate the gold. The separator may be on shore, or floating attached to the dredge. In either case, the fully mixed flow is returned to the stream. In smaller streams, this flow may be a significant percentage of the total stream flow. There are no changes to the temperature or additions of chemicals in these operations. Other than the increased turbidity, the major damage to the stream is to the bottom environment, which is effectively "vacuumed" clean. Most aquatic organisms, sediment and gravel are removed from the site of the dredge operation and deposited downstream in a pattern determined by flow and channel characteristics. In coastal rivers, dredger holes excavated in the bottom can prove hazardous to wading anglers fishing for steelhead or salmon. Considerable damage does occur by illegal activities such as excavation into stream banks, which can wash out large amounts of soil.

Impacts of dredging are influenced by the dredge size and density, stream size, the fineness of the sediments and flow regime. For example, observations on the North Fork of the Feather River and the North Fork of the Yuba River indicated that the dredging activities effects were limited to the site. This is contrasted with observations at a tributary of Butte Creek which was completely channelized and riffles were transformed into exposed gravel bars by the operation of one dredge (Harvey, 1986). In general, fish and invertebrates apparently were not highly sensitive to dredging. The fluctuations in flow, turbidity and sediment source can greatly reduce the long-term impact of dredging. Studies indicate that suction dredging effects can be short-lived on streams under the right conditions and appropriate operations (Harvey, 1986).

Figure 33. Minerals Leaching from Abandoned Mine.

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Mining Pollution

Thousands of inactive California mines pocket the state. (Figure 33). Many have gaping holes and fractures spilling toxic substances into streams and rivers. Past hydraulic and explosive mining exposed rock to weathering conditions. Now, air and water act on these exposed interiors to corrode and leach pollutants from the mine ores.

Mine discharge into surface waters is a near-statewide problem (Rick Humphries, SWRCB, pers. comm., 4/1993). Ninety-four mines have been studied for their threats to water quality. The magnitude of toxic discharge from the other thousands of mines is unknown. This state of affairs is partly due to the fact that current law holds anyone attempting cleanup liable for their actions in the remediation effort; thus the cleanup of abandoned mines usually is dependent on public financing.

Acid drainage causes more damage than any other known mine pollutant (Paul Helliker, Cal EPA pers. comm., 1993). When pyrite ore is exposed to the environment, the actions of water, oxygen and bacteria change pyrite to an acid solution as corrosive as battery acid, capable of dissolving metals.

Mining wastes which threaten aquatic life also include cadmium, mercury and asbestos. Ninety percent of the copper, zinc and cadmium measured in the Sacramento River originate from inactive mines (Paul Helliker, Cal EPA, pers. comm. 1993). Other wastes are chromium, lead and nickel. These metals accumulate in fish with traumatic effects to the fishes' reproduction and, in some cases, lives.

Acid and Heavy Metals

Mine remediation is sensitive to liability issues. For instance, a bill was proposed in 1992 by the SWRCB staff to plug abandoned or inactive mines leaking acid wastes into the state's water. It also contained authority to develop, demonstrate and evaluate treatment and reclamation techniques for abandoned mines. The proposed bill was not approved by the SWRCB for submission to the legislative process due to concern about possible state liability if projects failed to achieve success.

Iron Mountain Mine near Keswick and Shasta dams discharges more metals to rivers and streams than any other source in the nation. Approximately one ton of copper and zinc are released daily. This is equal to one-fourth of the discharge from all industrial and municipal sewage treatment plants in the country. It is also the largest source of copper, cadmium and zinc in the Sacramento River watershed (USEPA, 1993).

Mine pollution cleanup strategies include treatment plants to extract copper and neutralize acidity with limestone, revegetation

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and creating artificial wetlands. Plants are used to absorb water and prevent moisture from seeping into mines; downstream wetlands "treat" the toxic drainwater.

Effects of River Navigation

When California's road system was paved, and motor vehicles became affordable and reliable, the era of the river boat was over. Commercial traffic shifted, for the most part, to the roads, and the steamboats were left to fall apart on the mud flats up and down the rivers. Major shipping still came to the river mouth towns that had become seaports, and to the inland sea that was the San Francisco-San Pablo Bay system, but the only true river ports were Sacramento and Stockton.

Both Sacramento and Stockton now have artificial channels leading to their port facilities. Stockton's is the oldest (1950), and consists mostly of cuts that straightened out the main channel of the San Joaquin river. When Sacramento's turn came, a completely artificial river, the Sacramento Deep Water Channel, was carved out of the valley soil (1963). The cargo which passes through these ports is largely related to agriculture and forest products (Figures 34 and 35).

Figure 34. Port of Sacramento Total Cargo Tonnage, 1989.

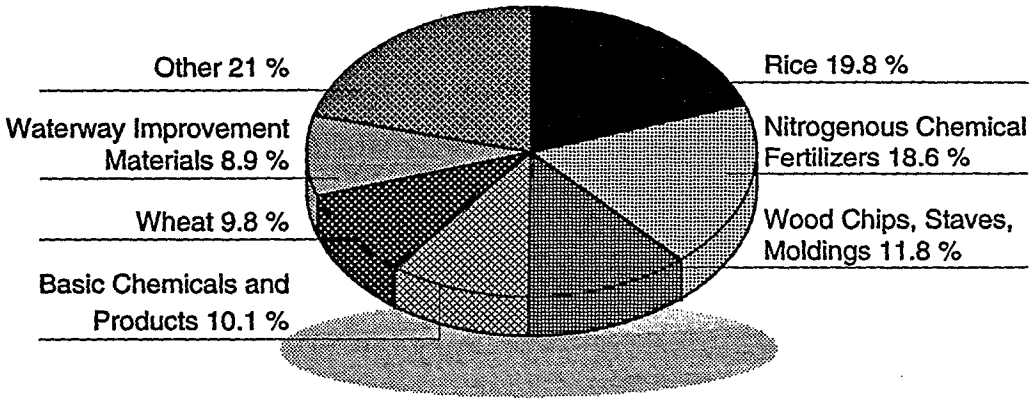
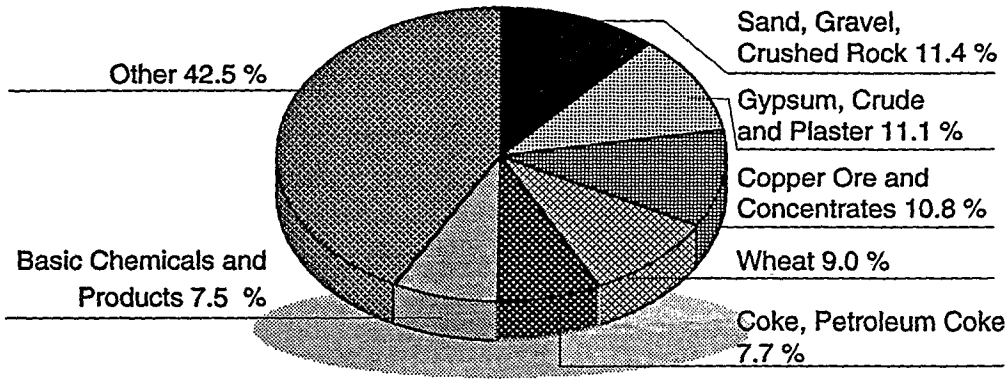


Figure 35. Port of Stockton Total Cargo Tonnage, 1989.



Source for Figures 57 and 58: U.S. Army COE, Waterborne Commerce of U.S.

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It was the river traffic that first brought engineers to California. As the boats got larger, and the water shallower (see Chapter 1), the engineers were called upon to "keep the rivers open" for commercial navigation. This meant both clearing debris from the river and "improving" the channels, and as dredge technology improved, they straightened them. Commercial navigation included barges, deep draft ships and other boats.

Dredging and Clearing

As noted, one kind of channelization is the creation and maintenance of clear waterways for navigation. Former commercial river boat traffic was much more important than it is presently, but shipping still exists on the Sacramento and San Joaquin rivers. Recreational boating, including commercial fishing guide services and touring, are increasingly important activities on many California rivers.

Prior to the great floods of 1865 and 1878 there was little need to do any real "navigation improvements" on the channels used by the steamship companies. The upper San Joaquin, the Mokelumne and some of the smaller rivers outside the Delta needed work, but it was more brush clearing than channel cutting (MacMullen, 1944). The boat owners did most of the work on their own, often as part of the job of getting wood to keep the boats going.

As discussed elsewhere in this report, hydraulic mining changed the depth of rivers and sloughs so that navigation either ceased or depended on dredging. Many of the channels in the present Delta have been deepened, created or widened. Some modifications were done for navigation, and some were done for drainage and reclamation.

Ambitious dreams of connecting Stockton and Sacramento directly to the sea for modern deep draft vessels have been around since the turn of the century. The Venice and Mandeville Cuts on the San Joaquin were the beginnings of the Stockton Deep Water Channel. Its final path was a straightened and deepened San Joaquin River (Bauer et al., 1983).

The Port of Stockton was formally established in 1933. Currently the port can accommodate ten ocean going vessels at one time. The Port of Sacramento began construction on the bypass of the Sacramento River through its Deep Water Channel in 1949. The artificial channel was cut from Cache Slough up to the City of Sacramento, connecting with the Sacramento River by a barge lock. Five ocean going ships may be accommodated at once. The port is in the process of deepening its channel by five feet to accommodate ships with up to 36 feet of draft.

Keeping navigational channels open and clear has been the U.S. Army Corps of Engineers' (Corps) chief responsibility since it was established in the Department of Defense. In California, with the exception of dredging in the major harbors, this has meant work on the San Joaquin and Sacramento rivers. By 1917 the Corps had removed 24

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million cubic yards of dredged material from the Sacramento, up to the junction with Cache Creek. By the end of the 1930s, the Stockton channel was dredged to a 30-foot depth, over a width of 100 feet.

Completing the two deep water channels to Stockton and Sacramento, the Corps ceased its general navigation dredging of the other channels of the Sacramento River, the Delta and the San Joaquin River. Now, the only dredging outside of the two main channels is an occasional removal of "hazards" to navigational boating. Other rivers maintained by the Corps are Petaluma and Napa.

Local efforts by public officials, commercial ship crews, and recreational boaters supplemented Corps activities by clearing fallen logs for safe and easy navigation (Sedell et al., 1988). The State Lands Commission sponsored a snag removal project in the Delta and on the Sacramento River to remove hazards to navigation during the low flows of the 1977-1978 drought.

Navigation improvements on some of California's smaller rivers are carried out by the Corps as a "mitigation" for lost recreational use as the result of the Corps dams. This work involves the removal of boulders, tree stumps and some gravel bars on the downstream side of dams. For example, a variety of capital-intensive, recreational improvements to the reservoir behind New Melones Dam as well as to the lower Stanislaus River below the dam were promised to mitigate the destruction of the Stanislaus River's white water resources. Those improvements, for the most part, never were provided.

Maintenance dredging affects water quality by increasing turbidity and possibly releasing toxic substances from bottom sediments. The deepening of shipping channels requires more frequent dredging: The deeper a channel is dredged, the slower the water moves within it, allowing more sediment deposition. Another concern with water quality on the lower San Joaquin and Sacramento rivers is that the deepened and widened channels may allow increased salt water intrusion into the Delta (San Francisco Estuary Project, 1992a). Dredging and dredged materials disposal may cause direct impacts to marshland, aquatic and riparian habitats. There is an emerging interest in reusing the dredged material for tidal wetlands restoration and replenishing organic material in subsided tidal lands and Delta tract lands (if the dredged material is without toxic levels of pollutants, such as heavy metals). Also considered for the reuse of dredged materials are Delta levee stabilization or repair. The salinity of the dredged material from the Bay may limit its use.

The removal of snags and other large debris from waterways eliminates underwater structures that are biologically significant. These "structures" and other channel irregularities create back eddies which collect organic debris, provide cover, and are surfaces for algae and invertebrates to colonize. The increasing awareness of the value of snags and submerged elements creates a

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conflict of priorities between those responsible for river navigation—both commercial and recreational—and those protecting the rivers' ecology.

Effects of Timber Harvest and Grazing

Timber Production

Ninety percent of the state's annual runoff originates from forest and rangelands (DFFAP, 1988). Therefore, forest and range management activities can have significant influences on our river systems. Forest management for the production of wood products is the primary land use in the North Coast and Sierran regions of the state.

Timber Operations

The management of land for timber production involves many activities which can affect watersheds and river systems, including the construction of access roads and logging operation areas, tree removal, the preparation of the site for reforestation, and the control of competing vegetation, disease, insect and animal pests.

After deciding upon the harvest strategy, the first step necessary in timber production is the layout and construction of access roads for the transport of logging equipment into and logs out of a harvest area. Paved highways and county roads are used as far as they go, but often additional dirt roads are needed to extend truck access into an area. Along with a road network, skid trails and with cleared areas for equipment and log storage, called "landings" or "yards," must also be built in strategic locations throughout a logging site.

Figure 36. Clear-cutting.

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Logging may be carried out under three general categories of forest management: 1) clear-cutting—systems which cause wholesale conversion of a forest stand, by cutting down all or nearly all of the trees (Figure 36), 2) selection cutting—systems which harvest only a portion of an area's timber at a time, or 3) thinning—removing the smaller trees in the stands to promote growth of desired trees. In either 1) or 2), it is the largest trees, suitable for lumber production, which comprise the primary harvest.

After the trees are felled, the trunks are cleared of limbs and cut apart into logs to be removed from the area. Gathering and moving logs, or yarding them, requires heavy equipment and experienced workers as the logs are dragged, pushed, pulled and hoisted uphill or down to log landings. In California, most log moving on slopes less than 30 percent is done by large tractors driven over the harvest site, causing considerable soil disturbance. Removing logs from steeper slopes by a cable system or even by helicopters causes less damage to the land; however, both are more expensive than tractors and so are less frequently employed when tractor logging is feasible.

Site preparation following logging involves disposing of the branch and leaf debris left behind (the slash), usually by burning it. After this, tree regeneration by natural or artificial seeding or planting occurs.

As young trees of the desired commercial species begin to grow, so often do noncommercial trees and shrubs which may compete with the harvest crop for water, light or growing room. If this happens, herbicide spraying may be carried out on the cut-over lands. Any spraying on any timber lands is usually met with public outcry.

Past and Current Efforts

Although California is characteristically Mediterranean in climate, with a wet season and a dry season, the North Coast receives an exceptional amount of rain. Here, where most of California's timber production occurs, there are steep and unstable slopes. This and the amount of rain cause high rates of erosion and mass wasting (landslides) generating significant quantities of sediment. Through these processes river beds and riparian habitat may be buried or scoured, and flood and landslide debris may be deposited by lower flood flows. In addition to these natural processes, human activities affect the fragile soils as well.

Timber harvest and associated activities like road and landing construction have a number of effects on rivers, primarily by altering their watersheds. Such effects may include increased flood peaks from a basin, decreased summer base flows, increased upland ero-

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sion rates, and subsequent increased delivery of fine sediment to stream channels. Such activities can also damage or destroy riparian habitat and adversely affect water quality.

In the past, timber harvests virtually devastated some watersheds and rivers, choking small drainages with debris, ruining spawning gravels and other habitats with siltation, altering natural runoff patterns, and destroying riparian vegetation. Today, state and federal enforcement of forest practices regulations can mitigate these problems. However, many rivers and streams are still in a degraded condition from past impacts and imperfect current practices.

A marked increase in the extent of clear-cut timber harvest over the past two decades, especially on National Forest lands and privately-owned parcels within them, has drawn attention to the cumulative effects of many individual timber sales within a drainage basin over a period of years. These cumulative watershed effects (CWEs) are manifest in erosion of gullies (especially below landings and logging roads), delivery of fine sediment to stream channels (with deleterious effects on aquatic life), increased flood peaks for a given storm or snow melt (resulting in erosion of channel bed and banks as the channel adjusts to the higher peak flows), and decreased summer base flows (resulting in a reduction in aquatic habitat and increased summer temperatures).

Timber harvest itself is one of the most visible (though not major) culprits in producing CWEs. Tree canopy or cover over the land plays an important role in watersheds by intercepting precipitation and slowing runoff, which results in more precipitation infiltrating into the ground (from which it can emerge slowly into the stream over the summer months) and less immediate runoff during winter storms. In addition to tree cover, a duff layer (organic mulch) on top of the soil aids in water absorption. Heavy logging eliminates these important functions. Tree roots also impart considerable strength to hill slopes and stream banks. Usually, ten years after trees are cut, their roots have rotted enough that they no longer stabilize the hill slope, and landslides may ensue. Stump sprouting of redwood and black oak are exceptions to this trunk decay.

The tracks left by equipment in the course of removing cut trees can also serve to concentrate flow, resulting in the development of gullies. This is especially true in tractor yarding, in which tractors are used to carry trees from an upper hill slope to a lower landing, because these tracks tend to converge to a point in a down slope direction. Cable yarding, in which logs are dragged up the hill slope to an uphill landing, results in tracks that radiate outward down slope, and thus tend to disperse runoff. The operation of heavy equipment across the land surface also compacts the soil, resulting in less infiltration and more runoff and erosion. This is one reason why cable and helicopter logging have fewer impacts.

The construction of logging roads and landings produces the greatest hydrologic effects, and in some forest areas contributes the

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single largest source of excessive sedimentation, because all precipitation runs off bare, compacted surfaces. The roads also alter the natural drainage pattern, intercepting small drainages and diverting them to others, resulting in increased flow down fewer channels. Seemingly subtle alterations of the drainage network can result in large gullies down slope. The effect of roads is persistent, because unless roads are physically removed (which is rarely done), their hydrologic effects continue, although erosion rates from the roads themselves can be expected to decline if they are not heavily used (Reid and Dunne, 1978).

Increased erosion from logging and road building results in elevated suspended and bedload sediment loading in streams and rivers down slope and downstream of the activity, adversely affecting aquatic biota (Everest et al., 1987; Newcombe and MacDonald, 1991). This is especially true for sites with steep slopes, fine-textured erodible soils and high rainfall, or where shallow soils overlay impervious soils or substrata. A direct effect of heavy siltation is the smothering of incubating salmonid eggs or emerging alevins in spawning gravels. Long-term degradation of gravels and other habitat features also occurs until excess sediments are washed through, if ever. Silt-laden waters also reduce the abundance and diversity of other aquatic organisms.

Unless an undisturbed buffer strip of forest and riparian vegetation between the stream and the logged areas is maintained, large amounts of logging debris may end up in the waterways of a logged area. This material robs the aquatic ecosystem of its oxygen supply as the material decomposes. Such conditions are particularly damaging to aquatic life during the summer, especially under low flows and with temperatures in the upper tolerance range and when salmon, steelhead and trout eggs are developing and hatching in the gravels.

Another effect of logging on riparian habitats is increased water temperatures. Tree canopies greatly moderate the daily temperatures and reduce summer maximum temperatures on the forest floor and its streams. Water temperatures in headwater streams are a major determinant of the temperature of downstream, midsize streams and rivers. The cumulative effects of temperature increases in tributaries could cause adverse changes in the environment of downstream reaches, which are often important salmonid rearing habitats. Buffer zones, if wide enough, can significantly ameliorate potential temperature effects of logging (Beschta et al., 1987).

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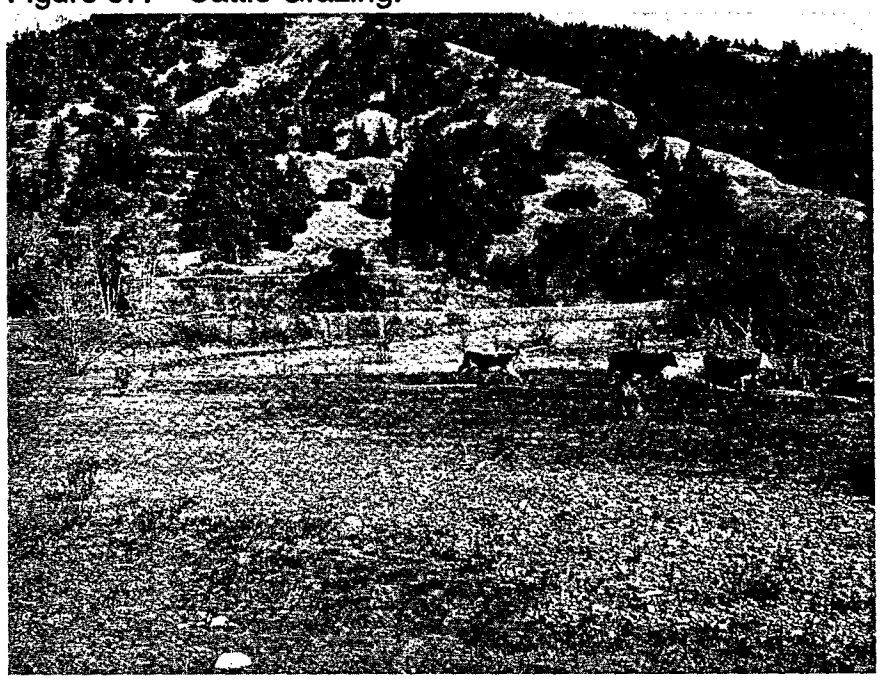
Grazing

Livestock grazing by sheep and cattle occurs on half of all the undeveloped land in California, but is mainly concentrated in the Central Coast region, the San Joaquin Valley, and the foothills. The most valuable rangeland in this state is grassland, but shrub and woodlands are also used for domestic livestock. Although some pastures are irrigated, seeded or fertilized artificially, most rangeland is not actively manipulated. The primary method of range management is controlling when and where the livestock is grazed.

Cattle prefer grasses while sheep prefer broad-leaf herbaceous (nonwoody) species, but both will browse on trees and shrubs within reach if other forage is unavailable. In most parts of the state, the dominant European grasses which replaced the native bunch grasses dry up in the autumn, leaving trees and shrubs, especially the younger plants, the only green feed around. Grazing may be year-round or seasonal on any particular area, depending on the climate and vegetation of an area, as well as the market. Livestock grazing, depending upon stocking rates and timing, can have significant effects on the plant growth of the grazed area, and can even determine whether tree and shrub regeneration occurs.

Livestock grazing is increasingly recognized as a major cause of increased erosion rates and degradation of water quality (Armour et al., 1991, Chaney et al., 1990). Livestock eat tree seedlings and trample vegetation along stream banks, resulting in a decline in riparian vegetation and the loss of the vegetation's functions of bank

Figure 37. Cattle Grazing.



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stabilization, shading and filtering fine sediment from runoff. Loss of vegetation also reduces food sources both through leaf litter and insects for aquatic animals. Livestock chisel banks with their hooves, breaking down the banks and introducing sediment directly to the stream. To a certain degree, livestock waste can directly impair water quality by introducing pathogens and excess nutrients into the surface water.

Completely fencing off riparian areas from livestock has been successfully used as a basic first step in encouraging natural recovery of degraded stream channels (Elmore, 1989). In some instances, grazing can be allowed in riparian areas without significant harm to stream banks and riparian trees and shrubs, but the timing and intensity of the grazing must be carefully monitored and managed.

Effects of Water Diversion, Flood Control and Channelization

Dams and Diversions

The profound changes on California rivers caused by dams are exemplified by Shasta and Friant dams in splitting the Sacramento and San Joaquin river systems in half. In vernacular usage there are two "Upper Sacramento Rivers," one above Shasta Dam, and one from Keswick (Shasta) Dam to the mouth of the Feather River. Similarly there are two "Upper San Joaquin Rivers," one above Friant Dam and one from Friant Dam to Mendota Pool.

Dams in California are built and operated primarily for flood control, water supply, the production of hydroelectric power or a combination of these uses. Recreation, fish and wildlife are also sometimes additional stated purposes for dam/reservoir projects, albeit subservient to flood control, human water supply and power. Smaller dams may be built for purely recreational uses. These are often installed seasonally. The patterns of flow releases out of a dam— its operations— depend upon the project's purpose(s) and the weather.

The Feather River

The Pacific Gas and Electric's (PG&E) moniker of the "Stairway of Power" belongs to the Feather River. In the 1880s civil engineers noted the region's natural advantages of underground storage of water in the porous volcanic rock formation. Beginning in 1913 ten PG&E powerhouses were built utilizing the river (PG&E, 1987).

The future governor of California, Spanish Captain Luis Arguello, exploring the river in 1817, named it El

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Rio de las Plumas (the River of the Feathers) because of the myriad "feathers" of wild fowl floating on the water (the feathers may have been willow pollen).

On the North Fork of the Feather River, a major branch of the Feather River which, in turn, is a major tributary of the Sacramento River, are two large hydroelectric facilities—Rock Creek and Cresta—which have shackled the power of the river to generate electricity. In the process they also have seriously damaged what was once one of the state's finest trout fisheries.

In the early 20th century, the North Fork of the Feather River was an outdoor paradise. Its sparkling waters, magnificent and breathtaking scenery and trout-rich pools drew fishers from around the world (*Sacramento Bee*, Oct. 11, 1991). Decades of logging, livestock grazing and road building upstream have flushed mountains of silt and sediment into the watershed. These problems, coupled with hydroelectric dams on the river which diverted river flow through tunnels and penstocks and effectively eliminated the former extreme spring floods and summer low flows, have led to low wild trout populations. In the upper reach of the river spared the development activity, it has been demonstrated that a substantial population of wild rainbow trout can maintain themselves and large populations of nongame fish when environmental conditions are favorable for trout growth and survival (Moyle et al., 1983).

A recent agreement between PG&E and the Department of Fish and Game promulgates repair of the watershed by increasing stream flows, reducing the impacts of cattle grazing in Humbug Valley, drawing cooler water out of Lake Almanor to reduce downstream water temperatures during the summer, improving fish habitat in important tributaries and providing for scientific monitoring.

The ecological damage on this river is so severe that conservationist and fisheries interests are skeptical about the future for this once prolific aquatic ecosystem.

Characteristic operations of most water supply and flood control dams include a decrease in high natural flows when runoff peaks from winter rains and/or spring snow melt are stored behind dams. Flood control reservoirs can contain larger floods than reservoirs operated solely for water supply, and the larger the

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reservoir capacity relative to river flow, the greater the reduction in peak floods. Sometimes reservoirs are not able to store the most extreme flood peaks, either because of their size or because they were previously filled to capacity, and spill releases result.

Water that is stored in reservoirs is later released downstream over the dry season. In California, agriculture uses 85 percent of developed water sources; thus releases usually coincide with crop demand. Rivers which normally would be quite low in flow in summer may have their flows augmented. Their once natural channels are used as canals for water transfer to downstream users.

Some rivers have flow augmentation because of water transferred from other drainages. The Upper Owens River near Mammoth Lakes has experienced increased flow since 1941, when water was first transferred from the Mono Lake Basin via the Mono Craters Tunnel. The Sacramento River below Shasta and Keswick dams has received about 70 to 90 percent of the runoff of the Trinity River at Lewiston since 1963 through the elaborate system of dams, reservoirs and other works of the federal Central Valley Project.

Direct Effects on Living Resources

The most obvious effects on river systems from dams are the loss of free-flowing waterways and the loss of river aquatic, riparian and upland habitats inundated by reservoirs. Dams frequently completely block passage by fish, other biota and human users. Anadro-

Figure 38. Stranded Fish.

"A True Fish Story" Edited version of postcard text, dated 1899.

Scene on Kelsey Creek, seven miles from Lakeport, one mile from Kelseyville Every spring the fish run up the Creek to spawn, sometimes in such quantities that the high water subsiding quickly often leaves them stranded.

Bryant Sturgess Collection.

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mous fish are particularly affected by the physical barriers of large dams. Over 95 percent of the historic salmon and steelhead spawning habitat in Central Valley river systems has been eliminated, primarily by the construction of large dams on every major river (California Advisory Committee on Salmon and Steelhead Trout, 1988).

Other direct effects of large dams on fish and other aquatic biota are inappropriate increases and decreases in flows, and changes in water temperature. Rivers can be defined partly on the basis of a more or less predictable and lengthy flood pulse, as opposed to the brief and unpredictable floods of smaller streams (National Research Council, 1992). Native aquatic biota evolved and survived under certain environmental conditions, and artificial changes to their environments usually have detrimental effects. Sudden flow decreases may dry up gravel spawning sites or strand fish in backwater pools. Sudden increases can scour away spawning beds or the algal and invertebrate communities growing on bottom surfaces. Other unnatural flow reductions can prevent fish from receiving appropriate migratory cues. Flows also affect water depth and temperatures, influencing the amount and quality of aquatic habitat, and the passage of fish over instream obstacles such as shallow riffles. Generally, the higher the flows, the cooler the instream water temperature.

A New Era

In 1902, Congress enacted the Reclamation Act and created a Reclamation Service to implement it. The purpose of the act was to open new lands in the West for settlement through irrigation.

The Central Valley Project Improvement Act (Public Law 102-575, Article 34 [Miller-Bradley Act]), enacted in 1992, is said by many to be the most important water reform in California in the last three decades. For the first time, natural habitat protection must be seriously considered when decisions are made about California's water resources under federal control. In addition, specific set-asides have been established for fish and wildlife protection.

This landmark legislation will likely result in enormous changes in California water policy by increasing allocations for environmental protection, reforming water contract policy and pricing, and permitting water transfers (water marketing) that will allow contract water purchasers to transfer water at a profit.

The act adds important new purposes to the Central Valley Project (CVP). They are: to protect, restore and enhance fish, wildlife and associated habi-

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tats in the Central Valley and Trinity River Basins of California; to address impacts of the CVP on fish, wildlife and associated habitats; to improve the operational flexibility of the CVP; to increase water-related benefits provided by the CVP through expanded use of voluntary water transfers and improved water conservation; to contribute to California's interim and long-term efforts to protect the San Francisco Bay and Sacramento-San Joaquin Delta Estuary; and to achieve a reasonable balance among competing demands for use of CVP water, including requirements of fish and wildlife, agriculture, municipal and industrial, and power contractors.

The act makes "mitigation, protection, and restoration of fish and wildlife" new purposes of the CVP, presumably on equal footing with preexisting project purposes such as water supply, flood control and power.

Within three years the Secretary of Interior must develop "a program which makes all reasonable efforts to insure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long term basis, at levels not less than twice the average levels attained during the period of 1967-1991." There are also provisions that authorize and direct the secretary to "dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing fish, wildlife and habitat restoration purposes and measures."

The act establishes a restoration fund created to provide up to $50 million annually for the restoration of fish, wildlife and habitat. The money for this fund comes from the new payments imposed on CVP water contractors and transferees of CVP water. (These payments are to be at the maximum rate of $6 per acre-foot for agricultural water, $12 per acre-foot for municipal and industrial water, and $25 per acre-foot for any water sold or transferred to an entity which has not previously been a CVP customer. It is argued that this additional fee may make CVP water too expensive for non-CVP agricultural users to purchase in a transfer).

The secretary must develop plans within three years for "improvements in, modifications of, or additions to the facilities and operation of the project, con-

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servation, transfers, conjunctive use, purchase of water, purchase and idling of agricultural land and direct purchase of water rights" in developing the additional yield. A new era in water management has begun with the above agenda to guide the direction of water reform.

The most dramatic example of the impacts of dams on salmon is Friant Dam on the San Joaquin River. The dam's construction resulted in the extinction of the largest spring-run chinook population in the state. The dam blocked upstream spawning grounds. Downstream of the dam, San Joaquin River flows in spring, summer and fall are minimal, and the riverbed completely dries up every year in the reach upstream of the Mendota Pool in Fresno County.

Larger reservoirs develop stratified water temperatures, with warm water on the surface and cool water at lower depths. Reservoir releases which come from the surface can raise temperatures adversely downstream. On the other hand, if dam releases tap from the cold pool, water temperatures below the dam can be significantly lowered.

Due to this cold pool effect, Shasta Dam for a time mitigated partially for some of its detrimental effects on salmon: The dam closed off access by salmon to historic cool water in the McCloud, Pit and Upper Sacramento rivers, but cold water releases increased spawning below the dam over what it was naturally. Winter-run chinook numbers in particular rose dramatically from cold water releases (Fry, 1979). However, during drought times, the cold pool in the reservoir decreases with decreasing water level. Under the recent drought (1987-1993), the Bureau of Reclamation had to operate Shasta Dam by choosing between cold water releases for fish, power production through turbines which tap into warmer reservoir layers, and storing and delivering water supplies for customers of the Central Valley Project. Recent declines of salmon runs and the size of the cold pool necessary to support them have been so severe that in September of 1992, nine fishing and conservation groups filed suit to force the Bureau to give the disappearing salmon stocks first priority over other uses. The suit was dropped in December, 1992, at least for the time being.

Smaller dams are not without problems. Red Bluff Diversion Dam on the Sacramento River, Daguerra Point Dam on the Yuba River, Woodbridge Diversion Dam on the Mokelumne River, and Benbow Dam on the South Fork Eel River are examples of smaller size dams which have affected anadromous fish. Poorly designed fish ladders, inadequate releases for upstream attraction flows or out-migration flows can delay or block salmon and steelhead runs and block American shad and striped bass runs.

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Seasonal recreation dams can also be very damaging to salmon and trout. Out-migration of juveniles may be totally blocked, water releases are usually minimal, and temperature of the impounded water increases, thereby reducing the habitat values of both the impounded and released water.

Single-purpose hydroelectric dams affect aquatic and riparian habitats and biota by upstream inundation, large and rapid flow alterations, and sometimes the complete dewatering of downstream reaches if the flow is diverted through long penstocks.

Water diversions can affect aquatic life when organisms are sucked directly into intake pipes. Some diversions have screens which are meant to prevent fish from being entrained, but these are often ineffective, especially for eggs, larvae and juveniles of salmonids and other anadromous fishes. Most individual diversions are unscreened, numbering in the hundreds in Central Valley rivers. Up to 10 million juvenile salmonids are estimated to be lost to unscreened diversions on the Sacramento River alone (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, 1989).

Effects On Stream Processes

Some of the most significant impacts dams and diversions have on the character and functioning of rivers in California are through changes of geomorphic processes. To understand the nature of these changes, it is helpful to view them in terms of the independent variables that control alluvial channel geometry: flow regime and sediment load. Changes in these variables will produce adjustments in alluvial channels—the nature of which will depend upon the precise nature of the flow regime and sediment load, and how they are changed. Some general trends are outlined below.

Dams disrupt the longitudinal continuity of the river system, interrupting the action of the "conveyor belt" of sediment transport. Upstream of the dam, all bedload sediment and most suspended load is deposited in the quiet water of the reservoir, while downstream, water released from the dam possesses the energy to move sediment, but has no sediment load. Clear water released from the dam is known as hungry water, because the excess energy is typically expended on erosion of the channel bed and banks for some years following dam closure. For example, on Stony Creek (a tributary to the Sacramento River), since the closure of Black Butte Dam in 1963, the channel downstream has undercut and migrated laterally, annually eroding enough bedload sediment to compensate for about 20 percent of the bedload now trapped annually by the dam (Kondolf and Swanson, 1993).

Channel erosion below dams is frequently accompanied by a change in particle size on the bed, as gravels are transported downstream, leaving a coarse lag deposit of cobbles, known as an armor

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layer. Development of the cobble-bed is an adjustment by the river to changed conditions because the larger particles are less easily entrained by the hungry water flows below the dam. However, this change in particle size can be detrimental to salmon populations, which require gravel for spawning. This problem has been observed on many rivers in the state, including the American River below Folsom and Nimbus dams, the Sacramento River below Shasta and Keswick dams, the Mokelumne River below Camanche Dam, and the Carmel River below Los Padres and San Clemente. In these (and other) cases, gravels suitable for spawning have been artificially placed in the channel in an attempt to restore the lost spawning habitat.

Downstream of a reservoir, the river may respond to the reduction in flood scour by narrowing its channel with encroachment of riparian vegetation into parts of the active channel from which vegetation formerly was scoured annually, and by depositing sediment along channel margins. Vegetative encroachment synergistically feeds the process of armoring and channelization by increasing sediment stability (Williams and Wolman, 1984). Once thick vegetation becomes established, flows which previously might have scoured the channel no longer are as effective.

If dams impede natural geomorphic processes to a significant degree, riparian vegetation regeneration over the flood plain will be affected. On the Colorado River, dams almost completely prevent overbank flooding and meander, and have so severely depleted base flows that the regeneration of native riparian vegetation has been essentially eliminated (Ohmart et al., 1977).

Vegetative encroachment has been observed below a number of dams in California—such as on the lower Stanislaus, Tuolumne and Merced rivers (Pelzman, 1973). Pelzman suggested that vegetative encroachment may be exacerbated by summertime flow augmentation. He observed that there was little extra plant growth below a dam on the Yuba River, which at that time had releases which were similar to the pre-project flow regime, i.e., a more natural decline in summer flows.

Channel narrowing has been greatest below reservoirs that are large enough to swallow the river's largest floods, such as on the Trinity River (Figure 80, Chapter 4) and Anderson Reservoir on Coyote Creek. Coyote Creek, which flows through the urbanized San Jose area, was dammed for water supply in 1936 and 1950. Its channel has since narrowed to less than 50 percent of its pre-dam width, and a riparian forest has encroached upon the surface of the formerly active channel (Kondolf and Matthews, 1990).

In some cases, fine sediment delivered to the river channel by tributaries accumulates in spawning gravels because there are no more natural floods to flush the river bed clean. The Trinity River below Trinity Dam is probably the best known example of this in California, with accumulation of sand in the riverbed and consequent

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destruction of the invertebrate community and salmonid spawning habitat (Fredericksen and Kamine, 1980). Experimental, controlled releases are now being conducted to determine the flows required to flush the sand from the gravels in the Trinity River (Kondolf and Wilcock, 1993).

Flows, primarily during the drier seasons, can also be affected by direct diversions from a stream or river or by groundwater pumping from interdependent aquifers in the flood plain. Extensive groundwater pumping in the flood plain of the Carmel River in the 1960s and early 1970s resulted in the death of large amounts of riparian vegetation. This in turn contributed to channel instability so that relatively low magnitude storm floods in 1978 and 1980 resulted in huge amounts of erosion and channel widening (Kondolf and Curry, 1986).

The Owens Valley Perspective

The export of water from Owens Valley to Los Angeles has had dramatic effects on the environment, economy and way of life of this valley. Owens Valley is approximately 100 miles long and varies in width from 6 to 15 miles. It is situated between the Sierra Nevada and the Inyo/White mountains approximately 250 miles north of the City of Los Angeles. The high mountain peaks (10,000 to more than 14,000 feet) block precipitation, creating a rain shadow in the valley. Although the valley receives an average annual precipitation of only four to six inches, runoff from the Sierra Nevada snowpack in streams that flow through the valley into the Owens River creates riparian and wetland environments.

Historically, the Owens River, originating in Long Valley in Mono County and terminating at Owens Dry Lake, supported riparian habitat and fisheries and provided recharge to the Owens Valley groundwater basins. Meadows, springs and marshes in the valley supported wetland plant and animal species (See Chapter 3).

Surveys made in 1885 showed that it would be feasible to construct a gravity flow aqueduct from the Owens River to Los Angeles and began a history of land deals, betrayal, wasted land, violence and litigation (Reisner, 1986). Los Angeles' diversion activities over the last 80 years from over 50 miles of the Owens River and portions of its tributary streams

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caused the destruction of the associated riparian vegetation, fisheries and wildlife habitats. These diversions also led to the drying up of the 100-square-mile Owens Lake. Groundwater pumping has dried up an extensive spring and marsh system, destroyed associated vegetation and wildlife habitats, caused the reduction of diversity and density of groundwater-dependent vegetation over large areas, and lowered water levels in privately owned domestic and irrigation wells.

When a Memorandum of Understanding was adopted by Inyo County and Los Angeles in 1982, the first step was taken to cooperatively study the relationship between groundwater pumping and its impact on native vegetation. Efforts for a long-term management plan include a management goal of avoiding changes and decreases in areas of riparian vegetation dependent on springs and flowing wells, stands of willow trees and cottonwoods, and in rare or endangered species.

The management agreement also provides for the implementation or construction of certain projects. These projects include rewatering 53 miles of the dry channel of the Lower Owens River, including the establishment of off-stream ponds and wetlands; releases of Los Angeles-owned lands for public and private use; permanent transfers of the Owens Valley water systems from Los Angeles to local entities; control of an invasive plant called salt cedar; and other environmentally oriented projects. In addition to some question about the ethics of this agreement, there have been legal challenges.

When one views the Owens Valley in the context of urban growth in other areas of California, it becomes apparent that despite environmental problems caused by water export from the Owens River by the Los Angeles Department of Water and Power, the Owens Valley remains one of the most choice and beautiful areas in the state. This is a direct result of land management and ownership policies of the City of Los Angeles which have discouraged extensive urban development and, by so doing, have spared the Owens Valley the myriad problems plaguing developed (and developing) urban areas.

The long-term economic future of the Owens Valley lies in its enormous and unmatched recreation potential. The value of the east slope recreation resource is only

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beginning to be realized. Already the Inyo National Forest alone supports more recreation use than Yellowstone, Grand Canyon and Glacier national parks combined—more than 7 million visitor days in 1983—and use increases annually. Urban development would ruin this special area. One 40-year resident of Bishop summed up this concept as follows: "In the long run, the one thing that would be far more damaging to the Owens Valley than having the City of Los Angeles here would be **NOT** having them here!" (Phil Pister, pers. comm., 1993).

Effects of Flood Control and Channelization

Complete channelization converts an irregular, typically meandering, natural channel into a straight, geometrically simple canal. More often the case in large rivers, meander bends are maintained, but the banks are engineered to a given slope (e.g. 2:1), and armored with rock revetment, also called riprap. Such bank protection attempts to stabilize the active channel and prevent bank erosion. Other purposes of channelization include increasing the efficiency with which water can be conveyed through the channel for flood control or irrigation, draining lands bordering the channel, and improving navigation. Channelized reaches typically have an active channel wider and deeper than the natural channel, with smooth banks devoid of vegetation or irregularities (at least upon construction). Where channelized reaches are not protected by concrete beds and banks, the artificial channel dimensions are frequently unstable, and the channel undergoes adjustments both within the modified reach and in adjacent reaches (Brookes, 1988).

Channelization produces a suite of negative ecological effects, mostly related to the loss of habitat diversity created by bends, pool/riffle sequences, sunken woody debris and other irregularities (Figure 39). The rectangular or trapezoidal engineered channel lacks the cover, food sources, instream nutrient detention and protection from high velocities afforded by the natural channel. Often fish migration is hindered by uniformly high velocities across the channel. Commonly the channelized reach is devoid of bank vegetation to reduce hydraulic roughness (resistance to flow) and for easier maintenance. As a result, riparian habitat is lost, and the shading and food production provided by overhanging vegetation is lost to the aquatic community. Perhaps the most adverse effect of channel stabilization is its impact on riparian plant community succession. One of the most important river processes determining riparian succession is the erosion and deposition which naturally occur as the river migrates over its flood plain. Anything which interferes with the

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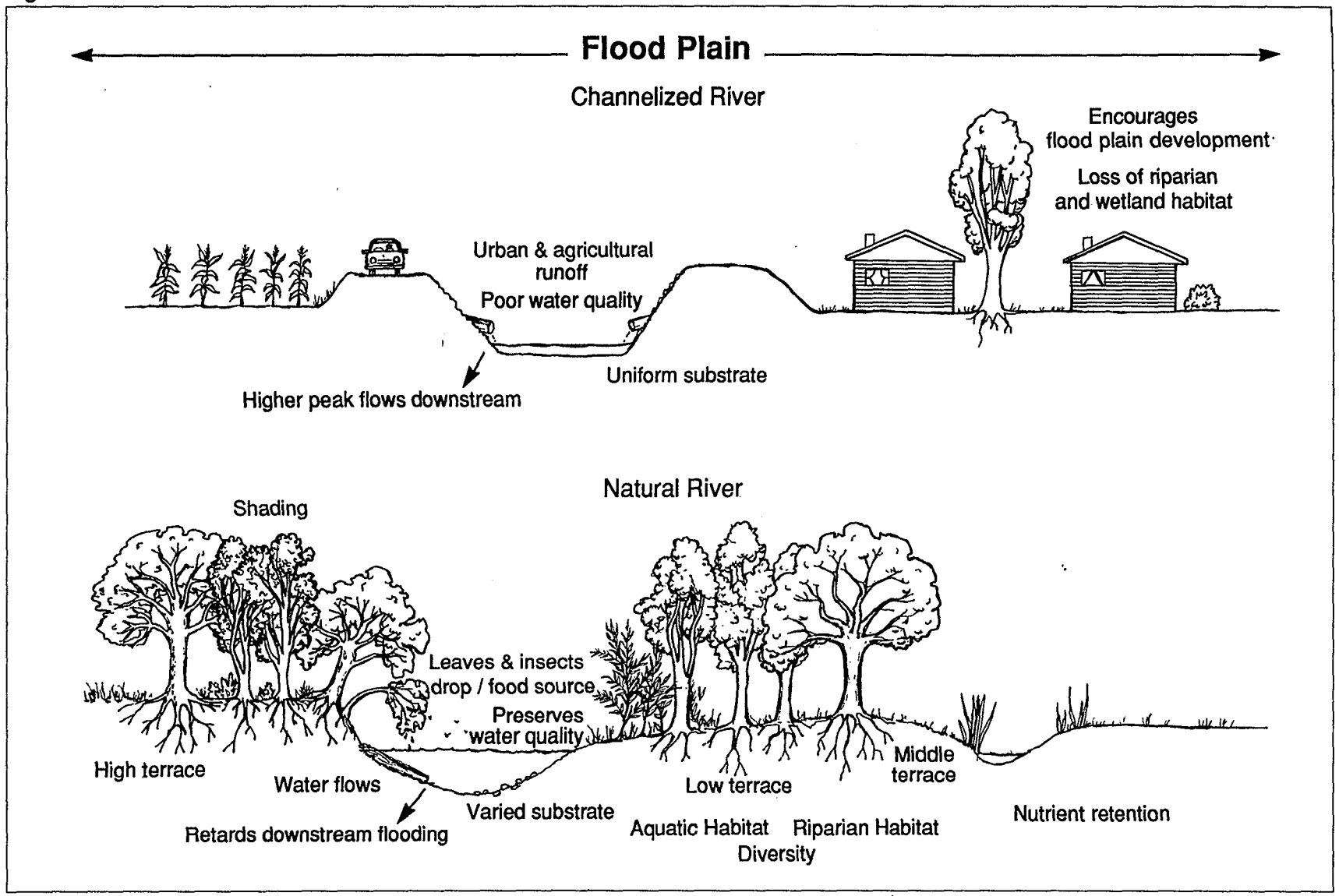
Figure 39. Natural vs. Channelized River.



Adapted from Stream Renovation Committee Guidelines, 1983.

establishment of new sand and gravel bars, and overbank depositions of sediment, will also interfere with the establishment and subsequent development of the various plant communities that make up riparian habitat.

Under various Army Corps of Engineers flood control projects, the Sacramento River has been subjected to enormous changes by the levee system and by efforts aimed at stabilizing the river channel using rock or other types of bank protection. These include the Chico Landing to Red Bluff Project, the Sacramento River Flood Control Project and the Sacramento River Bank Protection Project. Such programs have reduced or eliminated the ability of the riparian vegetation to regenerate itself and eliminated shaded riverine aquatic habitat. Bank stabilization is the primary threat to the survival and recovery of the Bank Swallow, a state-listed Threatened species, which nests in eroding banks.

The use of straightened, often concrete-lined, channels to achieve flood control has been the mainstay of what has been referred to as "single-objective flood control": to convey floodwater as efficiently as possible and to leave as much land as possible for development. This approach left little room for aquatic or riparian habitats and their needs. Some spectacular recent failures—such as the San Lorenzo River in the City of Santa Cruz (Williams and Swanson, 1989) and cases where channelization has caused dramatic channel instability (Simons and Hupp 1986)—cast doubt on the effectiveness of traditional channelization projects in achieving their single objective.

Conventional engineering approaches have relied on hydraulic design criteria developed in artificial, controlled situations, but these methods have resulted in a number of problems. Commonly, designers of flood control projects have underestimated a number of critical factors, including channel roughness (resistance to flow), effects of sediment and debris, and channel bed erosion and deposition during floods. In addition, requirements for expensive channel maintenance, such as clearing sediment or vegetation, are not realistically considered. Channels are designed to carry a certain amount of water at a certain velocity under the assumption the channel bed and walls are smooth, or have low roughness. However, floods often convey large amounts of bedload sediment into the design channels, increasing roughness so much that water does not flow as planned and can even overtop channel banks. Similar effects occur when flood-carried debris blocks flows, causing water to back up and flood out of the channel. In channels with unlined bottoms, scour and/or deposition can occur, and sometimes straightened channels attempt to reestablish natural meanders. Such changes in channel morphology also lead to project failures (Williams and Swanson, 1989).

An accurate evaluation of the true costs and benefits of conventional designs would likely cast a more favorable light on multipurpose

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stream and river management schemes which incorporate environmental values such as natural flood plains and aquatic habitats, but which heretofore had been considered too expensive.

Effects of Agriculture

California is the national leader in agricultural production, has been for more than 40 years. The state's $18.5 billion a year agricultural industry (Department of Food and Agriculture, 1992) is noted not only for its high value, but for its great diversity of products. California leads in over 60 different crop and livestock commodities, which fall under all major categories: livestock, fruits, nuts, vegetables, field crops (including cotton), nursery products and flowers. Farming and ranching occupy 30.6 percent of the state's land (Bailey, 1993).

Crops and the cultural practices used to grow and harvest them vary greatly. Some crops are annual, and live only one growing season, while others are perennial, such as vines, shrubs and trees. Annual crops are generally harvested and tilled under by the end of the summer growing season and not replanted until spring. This leaves the ground bare or nearly bare during the rainy season. Perennial crops stay rooted, but the ground under or around the plants is also usually tilled for fruit harvest and weed control.

Agricultural crops are a monoculture of species developed primarily for commodity production, rather than any kind of hardiness, and are thus vulnerable to attack by disease, insects and other pests. Common agricultural practices in California apply pesticides to combat plant disease and pests, although "organic" farming is growing in popularity.

Most crops in the state require irrigation during California's rainless growing season. Over 8.5 million irrigated acres use 85 percent of the state's developed water. This water is captured and delivered by systems of dams, aqueducts and canals. In addition, in many parts of the state, agriculture relies on groundwater pumping for water, either used alone or in conjunction with developed surface water (American Farmland Trust, 1986).

Harvest of Agriculture

California farms and ranches contribute more than food and fiber. Practices associated with farming not only increase the introduction of pollutants into streams, but also alter the physical structure and function of river-riparian ecosystems. Over 163 million pounds of pesticides and herbicides were used in 1990 by California growers (SWRCB, 1990). This is nearly one-third of all pesticide application in the entire United States. Also, agriculture changes the landscape from natural vegetation to croplands. The reduction of this natural vegetation results in more pollutants being released to the rivers.

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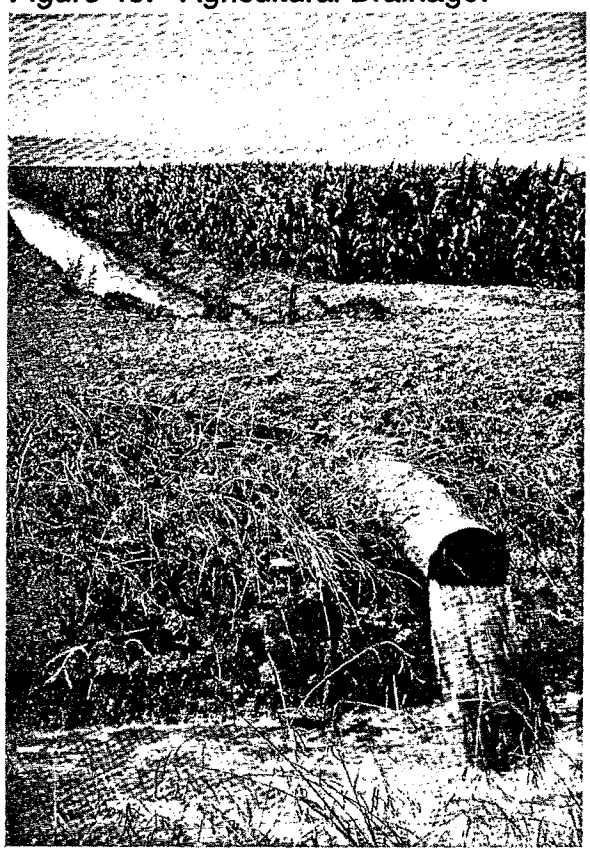
Figure 40. Agricultural Drainage.



U.S. Soil Conservation Service.

Pollutants include sediment, animal waste, nutrients and pesticides. The SWRCB identified agriculture as contributing to over 58 percent of the pollution statewide to California's rivers (SWRCB, 1991) (Figure 29).

Examples of physical and chemical changes induced by large-scale agricultural practices are found in the rice-growing areas of the Sacramento Valley where agricultural drain water is one-third of the Sacramento River flow during peak rice irrigation in early summer. Two events in the cultivation of rice had catastrophic effects. First, short stature rice was developed at University of California at Davis for use in California rice fields in the early 1980s. The shorter height of the rice yielded ideal growing conditions for weeds. The rice growers turned to herbicides to control the weeds. Over a three-year period, herbicides from the rice fields killed fish. The striped bass population decline accelerated, apparently because the fish were spawning at the time that the herbicides were being released on the rice fields. The histology of larval striped bass showed seriously deformed livers (Bailey, 1993). State and regional water quality people and local growers sought a solution. The solution adopted by the growers was to hold water longer in the fields and allow the herbicide to chemically breakdown, thus reducing by 95 percent the herbicide pollution in the Sacramento River from these rice fields. The second catastrophic event in the 1980s was a 30,000 carp kill which was traced to the herbicide molinate to which the carp are exceptionally vulnerable.

A number of toxic substances (herbicides and pesticides) are absorbed on soil particles moved into the stream from soil leaching. Metals known to accumulate in sediment include copper, zinc and lead.

Pesticides are also assimilated by living resources in the river. Improvement in newer pesticides provides for greater and more rapid degradation; however, degradation products can be harmful. These products and other factors such as agricultural land with persistent pesticides can cause fish kills (USEPA, 1979).

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Effects of Urbanization

General Effects

When watersheds are urbanized, problems may result simply because structures are placed in the path of natural processes, or because the urbanization itself has induced changes in the hydrologic regime, which in turn impact structures.

The simplest case involves settlement on a flood plain or on an alluvial fan downstream from an undisturbed watershed. The flood plain settlements are vulnerable to large floods that may occur once every 50 to 100 years. The interval between floods is too long for the average home buyer to recognize or believe the danger, unless the event has just occurred. Even then, the home buyer may treat it as a random "Act of God" or a piece of bad luck, rather than a recurring natural event, predictable in its frequency over the long term. The distribution of large floods over time reflects the precipitation and runoff region of the watershed, and large floods are natural and necessary for the drainage of the watershed and maintenance of the river channel. Urbanization of the upstream watershed itself produces fundamental changes in watershed hydrology. Infiltration is reduced by the creation of extensive roof area and pavement, and runoff moves more quickly from uplands to streams through storm sewers. As a result, runoff from the watershed is flashier, with increased flood hazard (Leopold, 1968). Flood control and land drainage schemes may increase the flood risk downstream by concentrating runoff. Urbanization can also produce large changes in erosion and the delivery of sediment to the stream channel. As outlined by Wolman (1967), high sediment yields of the construction phase are followed by reduced yields once the area is fully built and sewered. Water quality can actually be improved by the conversion of agricultural land to urban use (Charbonneau and Kondolf, 1991).

Figure 41. City of Sacramento During Flood of 1862.

Sacramento Archives and Museum Collection Center.

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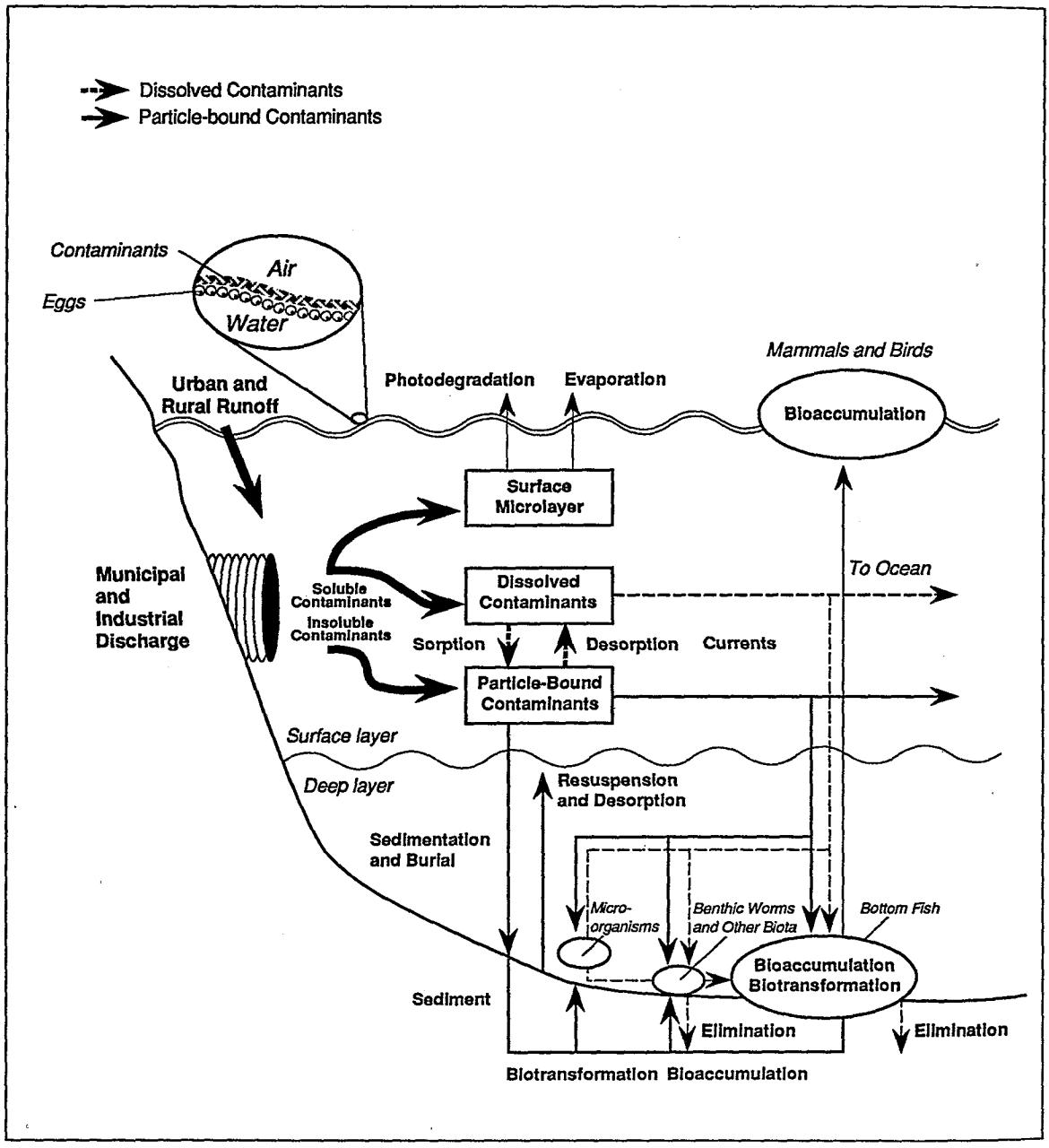
The dimensions and geometry of stream channels reflect the runoff and sediment load they carry (Leopold et al., 1964); urbanization-related changes in these variables typically induce channel widening and downcutting.

Urban Runoff

At almost every point that urban activity touches the watershed, nonpoint source pollution (NPS) is created. Sediments washed

Figure 42. Diagram of Transport and Fate of Pollutants in Water.



Source: *State of the Estuary*,1992. U.S. E.P.A. and the Association of Bay Area Governments

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from the urbanscape and deposited in river waters include trace metals such as cadmium, copper, lead and zinc. The SWRCB identified PAHs from vehicular gasoline and oil that leaks onto roads and parking lots as a significant source of pollutants (SWRCB, 1991a). These, together with pesticides, herbicides and fertilizers, contaminate drainage waters. Urban activity also yields sediments transported to rivers which cause turbidity, concentrate toxic pollutants and destroy fisheries. (Figure 42).

Urban, agricultural and wildland runoff contribute much more significantly to river pollution than point sources such as municipal and industrial discharges. Using the Bay-Delta Estuary as an indicator, the California watershed at the urban interface appears to be under considerable stress from pollution loads. The Water Quality Assessment Summary Report published by the SWRCB in 1991, indicates that NPS pollution is the cause of 50 to 80 percent of impairment to water bodies. Earlier reports by SWRCB indicated similar finding regarding NPS.

Dunsmuir Spill

I think what we all want is the river to come back like it was with a healthy native trout fishery. Leonard Everson, Dunsmuir Cafe Owner, *S.F. Chronicle*, Wednesday, June 10, 1992.

Railroad workers founded the town of Dunsmuir in 1884. It is halfway between Portland, Oregon and Sacramento on the Southern Pacific Shasta route through the Siskiyou Mountains. In the past 20 years, tourism has been the main business, replacing the dominance of the railroad. Anglers, from California and around the nation, have contributed to the town's prosperity.

A train "mishap" in July of 1991 spilled a tanker carload of the potent soil fumigant metam sodium into the river, killing every fish along the 42-mile stretch from Cantara Loop to Shasta Lake. Also killed outright were amphibians, aquatic insects and the primary foundation of the food chain—algae and moss. The magnitude of this spill can be compared to the Mill Creek acid spill disaster, the 150-mile Tennessee Roanoke River ethyl benzene spill and acute pH stresses on the Clinch River (all in the 1970s).

The town's economic health is inextricably

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linked to the ecological health of the river. Since the catastrophe, Dunsmuir and other communities along the Upper Sacramento have suffered a substantial loss in tourism, particularly due to a ban on fishing in the river that could last until 1994. To date, the scientists, government and non-government people working on the remediation and restoration seem to have replaced the tourists. Nearly half of the $12 million paid out by the railroad company has gone to affected businesses and residents.

Loss of wildlife is expected to be in the tens of millions. Estimations of the recovery time from the spill ranges from two to greater than ten years, depending on many factors. Favorable factors include high water levels for good dilution and the breeding season so that young fish are available for repopulation. Relatively long recovery times are believed to be due to the persistence of petroleum products (Yount & Niemi, 1990). The railroad payments have not addressed the damage caused by the spill in a comprehensive manner. Meanwhile, the state is directing the river's recovery under the Department of Fish and Game. The overall strategy is to allow "wild fish" to repopulate the river before introducing hatchery fish. Not only was the river's ecology poisoned, but some claim that the very existence of this riverside town has been threatened. People in Dunsmuir know and understand sustainable resources, both economic and environmental.

Effects of Recreation

Because there are so many different recreational uses and users on our rivers, conflicts are inevitable. The person who wishes to anchor over a favorite fishing spot and the high speed water skier do not coexist well. The family out for a quiet picnic on the banks of a secluded river will be frustrated and possibly angered by jet skiers speeding up and down the river. The scuba divers with the gold suction dredge will muddy the waters for the swimmers downstream. Each group wants the river for a specific purpose, and resents others using the river in a way that diminishes their own enjoyment.

Basic recreation data—describing the number of users, activity participation, seasons of use and residential location of users (local, state or country)—are needed to assess the importance of the recreation resource and the effects of recreational activities on rivers. A river assessment describing stream conditions is needed: Issues of

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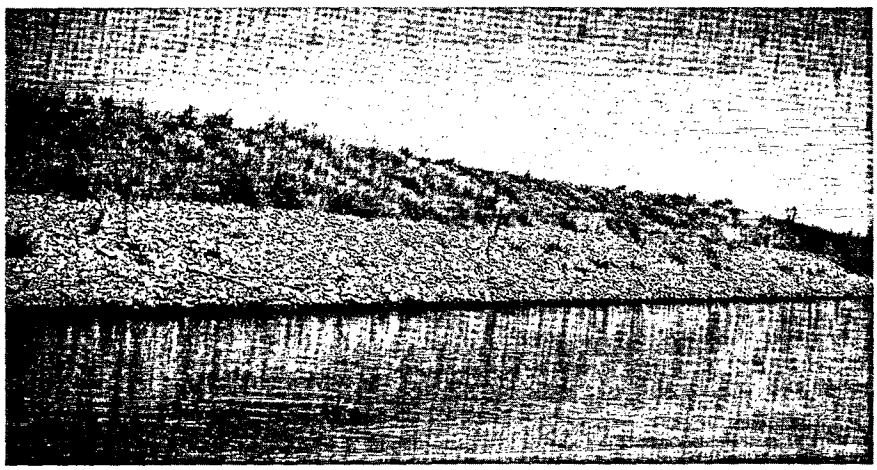
controlled public access, resource management and stream restoration need to be addressed. Several benefits would be realized from a such an assessment, including the gathering of data on use and the conditions of streams. This information is essential to the development of a river access guide describing the facilities and opportunities available. Public awareness must be heightened regarding the legal access to streams, a recreational ethic to balance the use of streams with other resource needs, ranching needs and possible harm to ongoing ranching activities if hikers leave gates open or allow dogs to run "free", public health hazards and other law enforcement issues. And finally, a river assessment should estimate monetary values to stream resource recreation uses, particularly the benefits to the local economy.

Impacts of Development on Recreational Opportunities

As discussed previously, the development of dams for water diversion and flood control has altered many river systems so that some uses have been eliminated while others are reminders of what once was. Until recently, the most successful arguments made by the Bureau of Reclamation and the Corps of Engineers during the dam building era were that rivers that actually reached the sea "wasted" water, and that lakes provided better recreational experiences than did running water. Again and again in the documents that supported yet another dam, the economic value of the existing river was shown as nonexistent, while the value of the fishing and boating to take place in the new lake was shown as very high. In the same way, the proponents of the river alteration schemes downplayed or even ignored the high recreational values of riparian habitats for recreation.

Figure 43. Riprapped River Bank.



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The Naked River—Levees Without Trees

Glen Martin, a *San Francisco Chronicle* reporter, kayaked the Sacramento River from its headwaters to San Francisco Bay in July 1992 and told his story in a week-long series, "River: A Reporter's Journey." This remarkable journey chronicled the nature and character of the largest of California's rivers, some 375 miles long, fed by the major tributaries of the McCloud, Pit, Feather, Yuba, Bear and American rivers. Martin wrote of the striking differences between the upstream river-natural and meandering, and the "strait-jacketed" engineered, downstream reaches.

> Drifting past thick stands of woodland and the mouths of creeks and slough, I contemplate the wild creatures that surround me in abundance. For the most part, they remain unseen, but their presence is palpable.
>
> I regret leaving this lovely place, with its bankside jungles and silences pierced only by bird song. Twenty miles south, "the Ditch" awaits me. It is a bleak stretch of river from Colusa to the delta, its banks largely riprapped and stripped of vegetation (Martin, 1992).

Over 150 miles of the river's banks are lined with riprap, an armor layer of rocks placed on river banks or levees to control erosion (Figure 43). Prior to placing the rock, a slope is typically stripped bare of any vegetation and graded smooth. Nowadays, jagged quarry rock is the usual choice for riprap, although concrete rubble and smooth river cobbles have been used. The end result is a barren rock wall, extending from the top of the bank down under the water, nearly devoid of wildlife, aquatic or fishery habitat value.

Historically, riprapping has been done to maintain a navigational channel, keep the Sacramento from meandering and prevent flooding. By far most of the riprap on the Sacramento River has been placed by the U.S. Army Corps of Engineers and the State Reclamation Board, as part of the Sacramento River Flood Control Project. The flood control system, which mainly

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controls the lower 200 miles of river, was begun in 1914 and was essentially in place by the 1940s. The design of the flood control system for the Sacramento River depends upon a system of levees to keep flood waters off developed land, in combination with artificial bypass channels to receive redirected flood flows.

Since the 1960s, riprap bank protection in this area has been a primary component of the state and federal flood control program. Seventy percent of the banks on the river below Sacramento, and almost 30 percent of the river from Sacramento upstream to Red Bluff, is rocked.

The guiding idea behind flood control programs has been to straighten channels to provide fast drainage. The effect has been a constrained river with great energy capable of severe stream bank erosion. The engineering dilemma is to cope with the increased velocity in the artificial river channel. The Corps depends on riprap as the least costly solution. To compound the effects of the riprap, current Corps mandates require levee riprap to be clear of trees and shrubs.

As Glen Martin discovered, people responsible for flood control have always believed that trees weaken levees. However, environmental concerns over habitat loss for endangered species is directing the Corps and Reclamation Board (and its staff from the Department of Water Resources) to evaluate other approaches. For example, in other countries such as Germany, where flood control expertise is world reknowned, trees are part of the levee landscape. The trees stabilize the levees by sending roots directly down to the water table rather than throughout the levee substructure.

> Because the levees will be around for the foreseeable future, it seems that revegetation of the rocked banks would be the best way to compensate for the loss of wildlife habitat. I had seen some examples of this on riprapped banks west of Chico, where the Department of Water Resources has established some experiments.
>
> It looked good. While levee revegetation does nothing to restore gravel for spawning salmon, trees planted in the riprap can ultimately consti-

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tute a new riparian forest, providing shade and food for a variety of wild animals (Martin, 1992).

Marinas: A Question of Carrying Capacity

Marinas on rivers in California are varied as to the kinds of vessels they accommodate. From a residential or clubhouse pier with tie-ups to facilities with more than a 100 covered berths and transient tie-ups, these facilities are relatively permanent structures within rivers. They account for a large portion of the boating traffic on the waterways. In this context, marinas include private nonprofit (yacht clubs) and commercial berthing, docks and launch facilities. The majority of marinas on California's rivers are concentrated in the Sacramento/San Joaquin River Delta. Other river marinas are located on the Klamath in the north and on the Colorado River in the south. Figure 45 shows the approximate number of marinas and yacht clubs in the Delta. As in many instances when looking for information on California's rivers, there is no one source of information regarding the number of and statistics on all marinas within the state. Not all marinas on California's rivers require leases from the SLC; all new facilities are reviewed for public trust consistency.

Marina development creates several problems: Too many marinas within a river reach generates a "tunnel effect," where marinas reach out from both banks of the river. These marina rows are visually unattractive and often are a visual barrier on the river. Residential piers, although individually less intensively used than

Figure 44. Marina on the San Joaquin River.

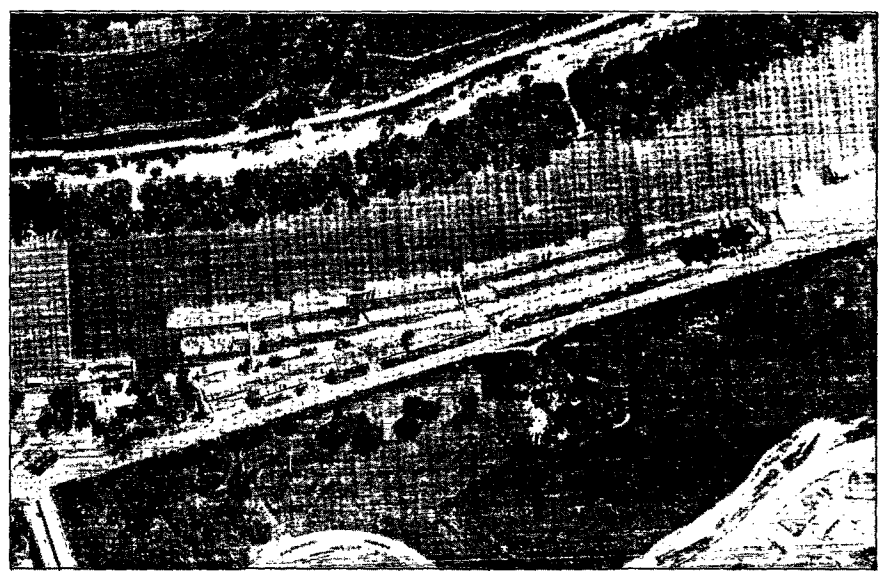

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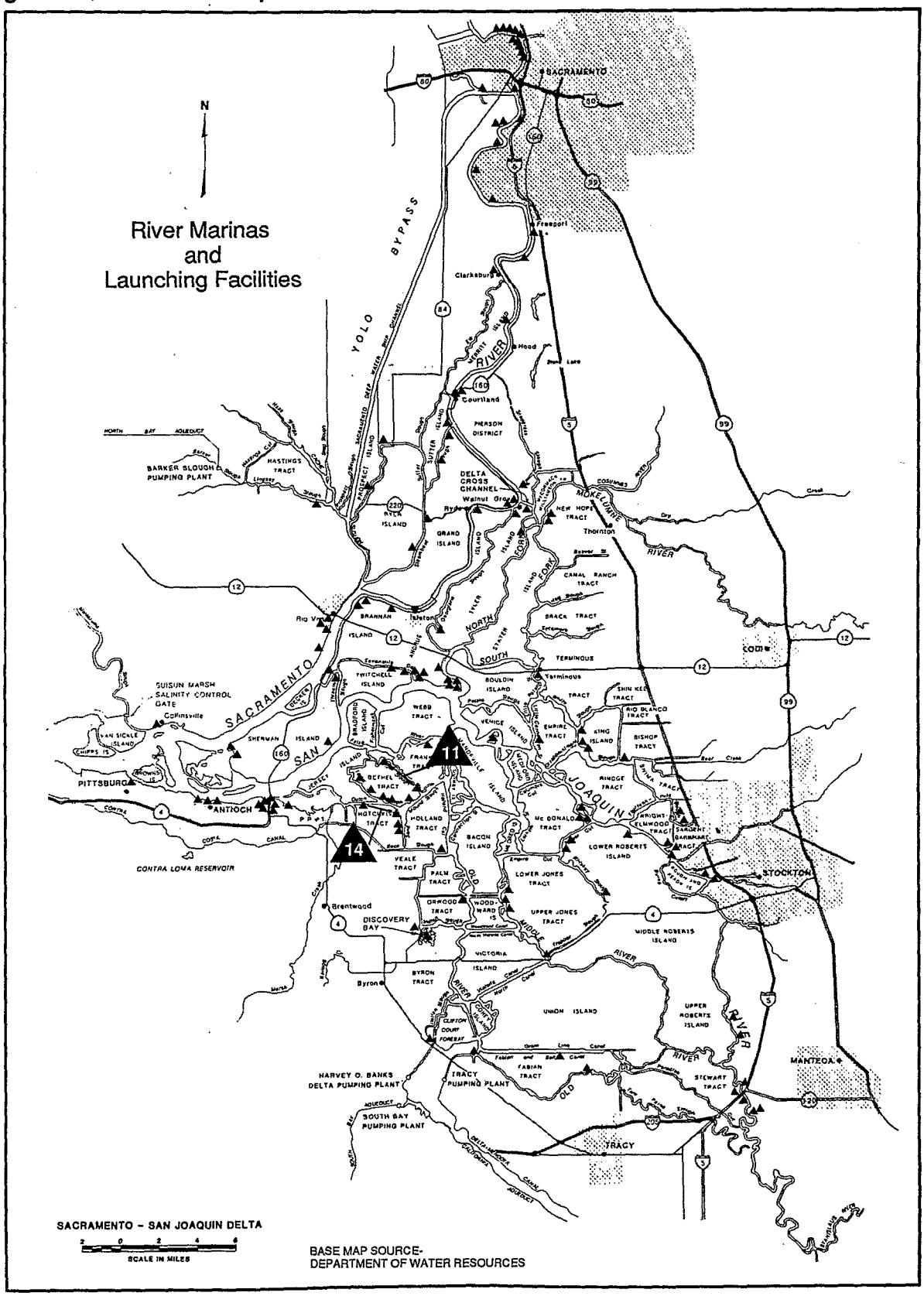
Figure 45. Location Map of River Marinas.



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riverine environment. (SLC, 1986). Power boats must keep their speed down to five miles per hour to avoid causing wakes that could damage the marinas or moored boats. Marinas add to the boat traffic on rivers, which at times resembles urban traffic congestion. This boat traffic conflicts with the needs of, and sometimes endangers, people fishing. And lastly, marina development may require the removal of riparian vegetation and dredging both for construction and maintenance—both of which may destroy fisheries.

Pollution

Marinas and boats can be a significant source of pollution. Although boats are required to have proper sewage disposal, few marinas use proper handling methods or are equipped with pumpout facilities. Sewage is often disposed of directly into the rivers, an action that is now illegal but not effectively enforced. Fueling accidents, leaky tanks and lines and carelessness allow spilled oil, diesel and gasoline into marinas and the rivers themselves. Paint and toxic antifouling chemicals contaminate many marinas, and spread from there into the rivers, often in significant concentrations. California has prohibited the use of antifouling paint since 1988 (Title 3 CCR §6488).

Nonpoint pollution from marina-based and recreational boating activities may also result in detectable adverse environmental effects to the nearby water column and benthic resources. These impacts can be caused by physical and chemical disturbances: toxicity in the water column related to decreased levels of dissolved oxygen and elevated levels of metals and petroleum; increased levels of metals and organic chemicals in the tissues of organisms; levels of pathogen indicators that result in fishing or swimming area closure; disruption of the bottom during dredging and positioning of pilings which may destroy habitat, resuspend bottom sediment, and increase turbidity which affects the photosynthetic activity of algae and estuarine vegetation; and shoaling, shoreline and shallow area erosion due to bulkheading, motorboat wake or changes in circulation.

Marina construction; marina and boat operation, repair and maintenance; and dredging and dredge disposal are the three source categories of marina and boating operations that may cause nonpoint pollution. Maintaining water quality within a marina basin depends primarily on how readily the marina renews its waters, a process aptly known as "flushing." If a marina is not properly flushed, pollutants will concentrate to unacceptable levels and result in impacts to biological resources.

Trash and litter are also problems in and around California's rivers. Boaters are only part of the problem, although the restricted space on most boats tempts many into "overboarding" paper and plastic. Hikers, anglers and picnickers are also guilty, and the "pack

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it in, pack it out" ethic is still a long way from universally being adopted. Trash collection facilities are often long distances apart and, in eras of tight budgets, are often not emptied frequently enough.

Riverside Development

Riverside development for commercial or residential use detracts from all forms of recreation. This development may restrict public access to the river, notwithstanding Article IV, and the Subdivision Map Act (see Chapter 5). Boaters' recreational experience may be more memorable for the urbanscape view that has replaced the riparian forest.

Today, even with at least 80-90 percent of riparian habitat in most Western states eliminated (Faber and Holland, 1988), the remaining pieces are still being threatened by development. While cutting for fuelwood is now minimal, and agricultural clearing is probably no longer occurring to a great extent, urbanization poses a serious threat. Riversides are desirable places to site a home or business, and development along rivers and in the flood plain also brings with it the need for flood control, which results in more vegetation removal.

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California Rivers: Regional Perspectives

3

Each ecosystem has intrinsic value. Just as a country treasures its finite historical episodes, classic books, works of art, and other measures of national greatness, it should learn to treasure its unique and finite ecosystems, resonant to a sense of time and place. E.O. Wilson. *The Diversity of Life,* 1992.

Introduction

Within California's borders are lands and waters which encompass an enormous variety of environments—including a broad range of climates, soils, topography and oceanographic features. In this chapter, the incredible natural diversity within California—from the desert Mojave and Amargosa rivers, almost entirely dry, to the constantly cold, spring-fed Pit and McCloud Rivers above Shasta Dam—is explored regionally to illustrate the continuity and public trust-related elements of rivers. California's climate, and her rivers' complex geologic and biological histories, are exceptional in natural diversity.

In order to ensure the permanent sustainability and productivity of terrestrial, aquatic and wetland resources, California's natural diversity, especially our biological diversity, must be protected. The "bioregional" and "watershed council" movement in grass roots organizations and in government indicates a growing realization that a regional approach in protecting and enhancing California's natural resources is the most rational course to take. (See Andruss et al., 1990, and California's Coordinated Regional Strategy to Conserve Biological Diversity, 1991.)

Rivers integrate living resources (biotic) and the non-living (abiotic) environment over an entire watershed. A single drainage basin can cover large regions, as in the case of the Sacramento/San Joaquin River drainage which encompasses one-third of the state's land area. It is especially appropriate that river management, including ecosystem restoration, is done using a regional approach, which recognizes both the interrelationships between watershed and

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river and the significant differences between different ecoregions (National Research Council, 1992).

For the primarily descriptive purposes of this report, the state has been divided into seven river regions (Figure 46), based on a combination of geomorphic or physiographic province (Jenkins, 1938), major hydrologic basin or drainage unit, distribution of fish (Moyle, 1976) and composition of riparian woodlands (Roberts et al., 1977). There are about 7,800 miles of rivers in California (SLC GIS analysis based on 1:1,000,000 USGS Hydrography map). The distribution of rivers and size of each region discussed in this report are summarized in Table 4.

Each region is characterized and a "case study" is provided for the public trust resource issues: wildlife habitat, water pollution affecting aquatic resources, public access, recreation, and watershed management for restoration and sustainability. Table 13 is a list of common riparian plants of California, followed by Table 14—common animals of California. These lists are found at the end of this chapter.

Table 4. Distribution of Major Rivers by Region.

Region	Length of Major Rivers		
	Miles	Rel.%	Acreage (mill.)
North Coast/Klamath	1381	18	13.5
Central Valley	3863	49	33.5
Modoc/Cascade	399	5	4.5
Central Coast	611	8	9.1
Eastside/Great Basin	369	5	6.6
South Coast	571	7	6.9
Desert	606	8	27.2
TOTAL	7800	100	101.3

Kreissman, 1991.

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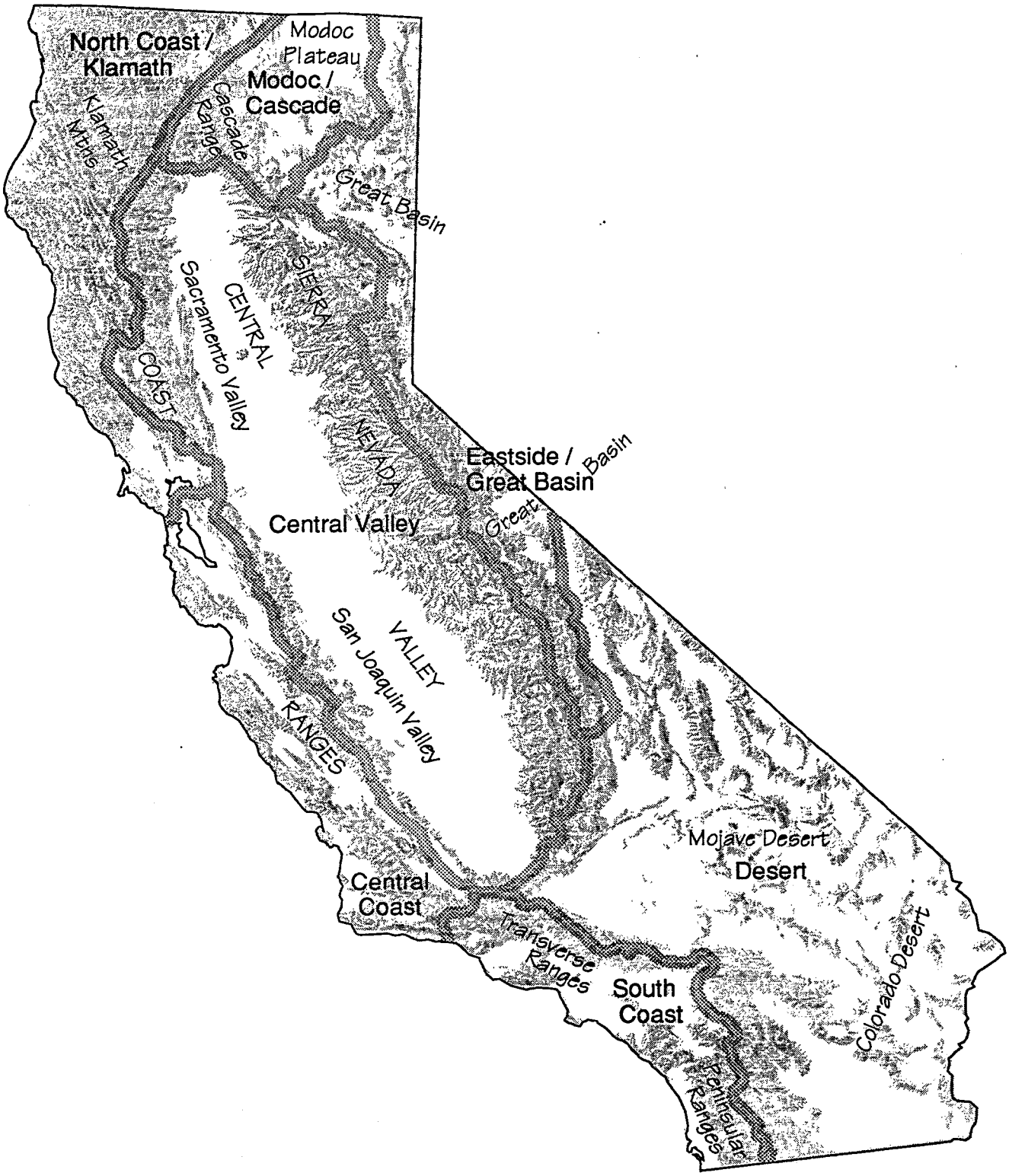

Figure 46. River Regions of California.

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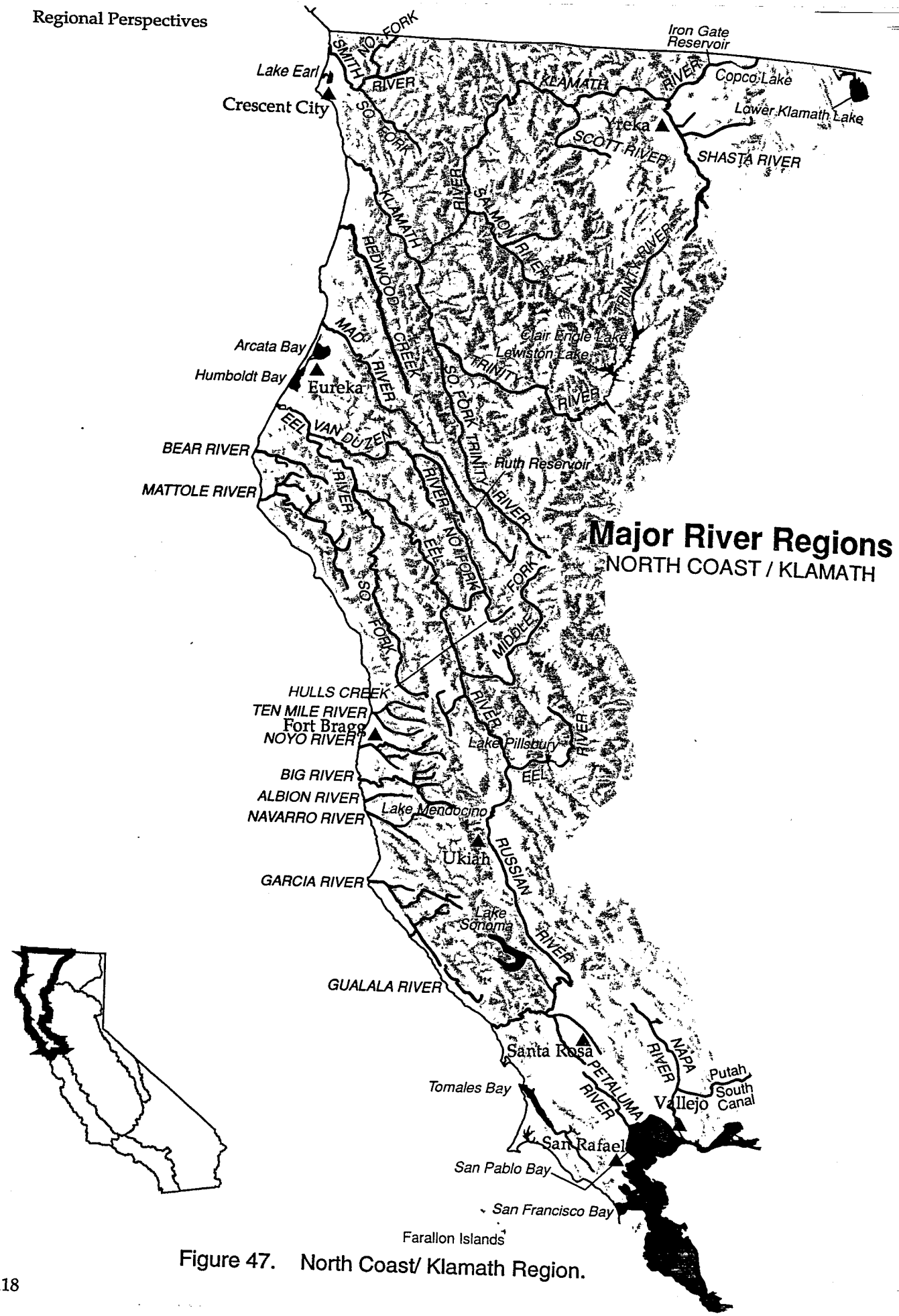

Figure 47. North Coast/ Klamath Region.

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North Coast/Klamath Region

The North Coast/Klamath region is typified by some of the most rugged mountains in the state, heavily forested with coniferous trees. Most of this land is wild and sparsely populated. The entire region has fewer people than the City of San Jose. The economy is dependent on enterprises associated with its natural resources: timber production, fishing, recreation and ranching. With its high rainfall, the region contains many large rivers—the Smith, Klamath, Trinity and Eel—and includes most of California's Wild and Scenic River segments. This entire region extends from the San Francisco Bay northward to the Oregon border and encompasses the North Coast and the north San Francisco Bay hydrologic basins.

Some find the setting, especially along the Sonoma and Mendocino coasts, suggestive of the Scottish Highlands with its sheep and its windswept bleakness. But it is the Redwood and Douglas-fir forests and seeming unending expanse of trees that make up most of this region. The North Coast/Klamath region is riddled with active faults and is undergoing rapid tectonic uplift. As a result, most rivers draining this region have high gradients, flow through steep-sided, confined gorges, and carry exceptionally large sediment loads. The area's geomorphology, and thus its river systems, varies between two subregions: the Coast Ranges in the south and the Klamath Mountains in the north.

The Coast Ranges subregion, from the Eel River southward, is underlain by easily eroded sedimentary rocks of the Franciscan Formation. The Eel River carries the highest average annual sediment load in the contiguous United States, over 15 times the yield of the Mississippi (Brown and Ritter, 1971), and its watershed is among the most erosive in the world (Beaumont, 1975). The longer rivers that drain the Coast Ranges—the Eel, Russian, Napa and Petaluma rivers—follow the northwest alignment of the mountains and faults.

The Klamath Mountains subregion is dominated by the large Klamath River system, with a drainage area of 12,000 square miles, This system includes several major tributaries—the Trinity, South Fork Trinity, Salmon, Scott and Shasta rivers. The Klamath has cut its gorge across the entire width of the Klamath Mountains.

The Klamath Mountains watersheds are generally less erodible than the Coast Ranges. For example, the Smith River near the Oregon border, now included within a National Recreation Area, drains a watershed of highly resistant rocks and is famous for the speed with which it clears after major storms. A notable muddy exception in the Klamath Mountains is a portion of the Trinity River watershed that contains decomposed granite soils, which are extremely vulnerable to erosion. Logging in the 1940s and 1950s resulted in extensive watershed damage, leading to severe sediment problems for salmonid habitats on the Trinity River (Bramhall, 1989).

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Figure 48. Klamath River Gorge.

The North Coast/Klamath region overall has the highest rainfall in California, but its distribution is strongly controlled by location, especially relative to topography. San Rafael on San Francisco Bay and Fort Bragg on the coast both receive about 38 inches of rain annually. Areas in the steep King Mountain Range of the Mattole River drainage average more than double that, with 80-90 inches annually. In the unusual water year of 1982-1983, sites in the Mattole headwaters area just inland and north of Shelter Cove were drenched by an almost inconceivable 240 inches of rain.

Over the whole North Coast/Klamath region, precipitation (nearly all rain) is concentrated in the winter months. Runoff follows this seasonal pattern, with massive winter floods in response to intense rainfall, followed by a gradual decline in spring to summer base flow which can be no more than a trickle in late summer. This pattern is true even for large rivers on the North Coast. Also visible are the extremely rapid rises in river stage, such as the increase from 60,000 cubic feet per second (cfs) to 230,000 cfs in three days.

There are three general patterns of riparian vegetation found along the rivers of the region: 1) the Klamath Mountains; 2) the alluvial valleys of the Coast Range; and 3) the foggy coastal strip. In the Klamath Mountains, most rivers are confined for much of their lengths, and riparian vegetation zones are typically narrow. The high winter rainfall and resultant high flood peaks subject riparian zones to frequent scouring, erosion and deposition.

Along the low-gradient flood plain reaches of big rivers, the riparian habitat is more extensive, approaching in appearance the great river forests of the Central Valley. Large cottonwoods are often present along North Coast valley rivers.

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Near the immediate coast, the distinction between riparian and upland vegetation is often blurred on the small rivers of the area, for example along the Gualala and Navarro rivers. Because of the mesic (moist) local climate, tree species which are limited to riparian habitats in drier parts of the state often extend into upland areas in this region, e.g., Big-leaf Maple, and upland conifers grow in the riparian zone. Redwood attains its maximum growth on coastal river flood plains.

The Eel, Smith and other large rivers and streams of the northwest created alluvial plains and deltas at their ocean mouths. At one time these delta plains were sites of thick black cottonwood, willow and red alder forests, often mixed with Sitka spruce and redwood (Ray et al., 1984). All the thickest and most productive forests which formerly existed in the North Coast/Klamath region were cleared for agriculture and urbanization, and in the coastal plains of Humboldt and Del Norte counties, extensive areas of redwood and Sitka spruce were logged for timber. The flood plains of the Russian and Napa rivers are renowned for their vineyards, now growing where riparian woodlands once stood. Along rivers flowing through narrow and frequently scoured channels, riparian habitat remains substantially in its natural state, except for localized impacts due to logging, mining, grazing and other development activities.

The North Coast/Klamath region is known for its salmon and steelhead—resources long important to humans in the region. As narrated in Chapter 1, much Native American culture centered around rivers and their fish, with salmon the most important harvest. There are no reliable estimates for historic fish abundance, but from all descriptions it was enormous. The region's major salmonid species include chinook and coho salmon, steelhead and coastal cutthroat trout, and resident trout in headwater areas. The rivers of northwestern California support about one-third of the state's chinook, almost all of the coho and steelhead, and all of the coastal cutthroat.

Coniferous forests are predominant over the area, and timber harvest is the main land use. As a consequence of logging, massive surface erosion and landsliding have occurred, drastically increasing sediment delivery to downstream channels. Although most existing impacts were due to past, unregulated forest practices, there is still a significant threat from modern logging due to cumulative watershed effects.

During the 1800s, the plentiful fisheries resource of this region attracted Americans from the East and European immigrants. After the start of the Gold Rush, salmon were exploited at unsustainable rates by in river netting. Such early commercial harvest, coupled with habitat destruction by logging, nearly destroyed the salmon fisheries of the North Coast. With the advent of fishing regulations, populations were able to stabilize, and even

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recover, to a large degree (See Chapter 1). However, much of the habitat damage from the earliest logging remains.

Because of the steep terrain, human settlements and roads are concentrated in river valleys, and are thus subject to frequent flood damage. The great floods of 1956 and 1964, exacerbated by huge amounts of logging debris and sediment, wiped out many small villages and significantly altered river ecosystems of the area.

Anadromous fish once ran all the way up the Klamath River system into Oregon. With the construction of Iron Gate Dam (1917-1922) a drainage area of about 4,300 square miles was no longer available to runs of chinook salmon and steelhead trout. Dams and diversions on the upper Klamath, Scott and Shasta rivers have resulted in decreased flows and increased water temperatures. Agricultural drainage returns in these areas today cause additional water quality problems. The Trinity River main stem was dammed in 1963 by Lewiston Dam, blocking significant upstream spawning areas. More dramatic was the dam's ultimate effect of allowing the diversion of up to 90 percent of the flow of the river out of the basin for transfer to the Central Valley Project via the Sacramento River. The anadromous fisheries declined by 90 percent soon thereafter. Hatcheries for mitigation exist at Iron Gate and Lewiston dams, but cannot make up for the loss of wild production.

Instream gravel mining is increasing in the region, and its effects on geomorphology and biological resources only recently are being documented. On the Mad and Russian rivers, aggregate extraction has resulted in extensive degradation (downcutting) of the river channels, which has damaged aquatic habitat and riparian vegetation, undermined bridges and impaired water supply availability. The counties of Humboldt and Sonoma are beginning to address the cumulative impacts of sand and gravel mining on these rivers.

Even though the northwest is still famous for its fishery resource, the area has experienced at least 80 percent declines in salmon and steelhead since the 1950s (California Advisory Committee on Salmon and Steelhead Trout, 1988). Many native salmonid stocks are considered at risk of extinction (Figure 49). Historically, the Klamath River Basin chinook runs were in the hundreds of thousands; in 1990 and 1991 the in river population was just over 30,000, a 90 percent decline. The Shasta River is the most important chinook spawning tributary in the upper Klamath River system. Its chinook run has declined from recent averages of 30,000 (a historic high was over 60,000) to a count of 700 in 1991 (PFMC, 1992).

The coho, steelhead and coastal cutthroat have also suffered population declines. The coho, summer-run race of steelhead and coastal cutthroat are all California Fish Species of Special Concern (Moyle et al., 1989).

The Klamath River supports California's largest spawning run of eulachon (candlefish), a native anadromous smelt. Eulachon (from its Indian name, pronounced "oolak-on") are an important prey fish

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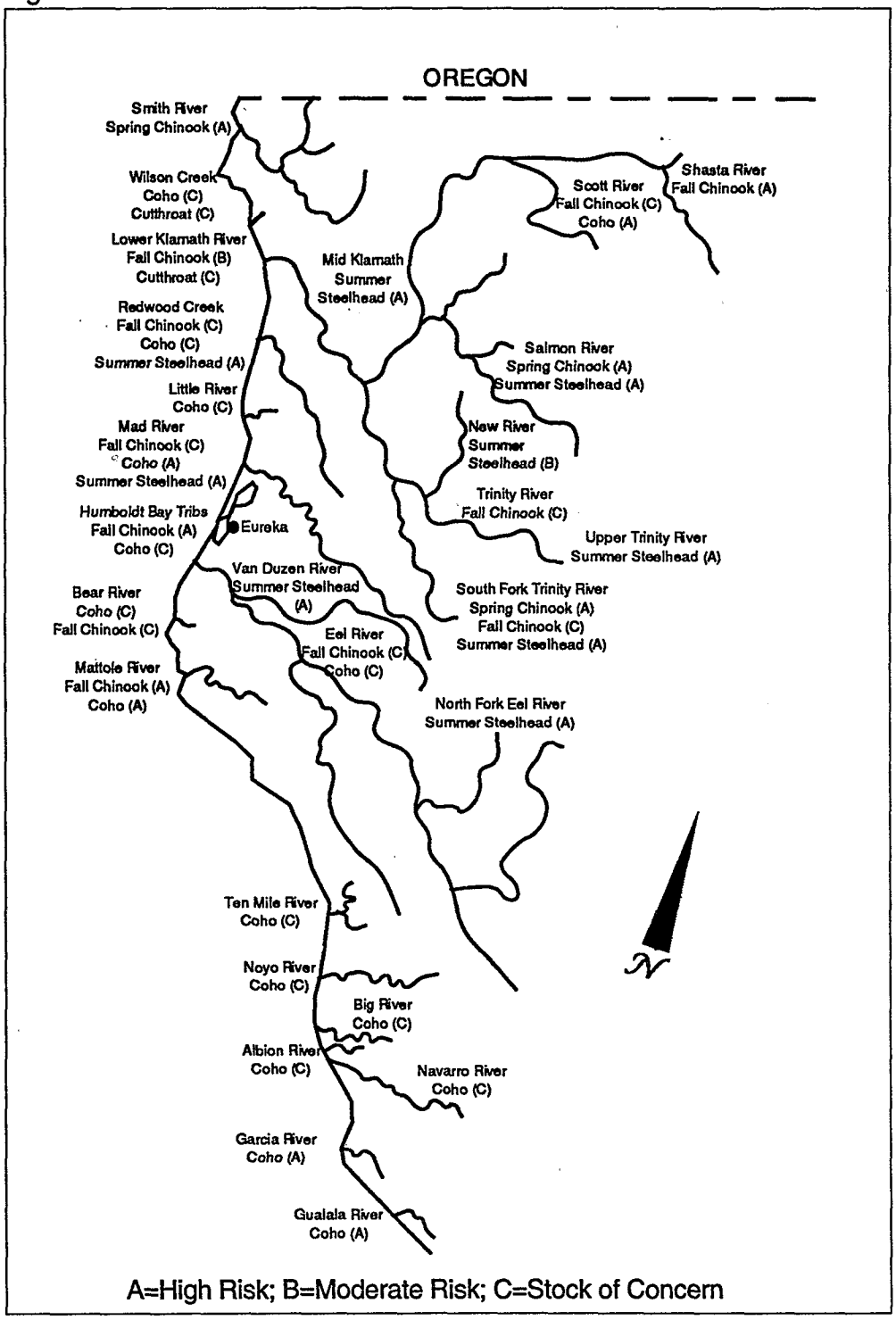
for ocean, estuarine and river birds, mammals and fish. Eulachon are quite oily and when dried were used as candles by northwest Indians. They were an important food fish as well (Moyle, 1976).

Figure 49. Anadromous Salmonid Stocks at Risk in Northern California.



Source: Humboldt Chapter, American Fisheries Society (Higgins, 1992)

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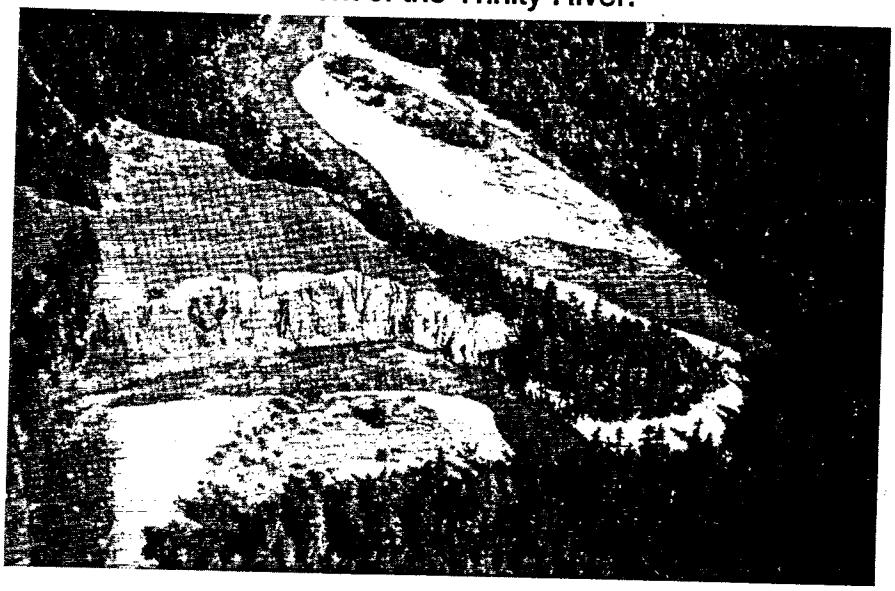
Figure 50. South Fork of the Trinity River.



Case Study: South Fork of the Trinity River

The longest free-flowing wild river in California is the South Fork of the Trinity River, flowing 90 miles from its headwaters in the Yolla Bolly Wilderness to the confluence with the Trinity River. The lower 53 miles of the South Fork is designated as a segment of the state and federal Wild and Scenic River Systems.

The primary basis for inclusion in the Wild and Scenic system was the anadromous fisheries resource. Seven different species or stocks are known to use the South Fork, including summer steelhead, winter-run steelhead, spring-run chinook salmon, fall-run chinook, coho salmon, chum salmon and Pacific lamprey (U.S. Forest Service, 1992). Spring and fall chinook and summer steelhead on the South Fork are currently considered to be at high risk of extinction (Higgins et al., 1992). Chum salmon are a widely distributed and abundant Pacific salmon species, but are quite rare in California. The South Fork Trinity is one of the three rivers which still have chum spawners (Moyle and Yosiyama, 1992).

Much of the South Fork Trinity watershed lies over geologic formations which produce soils and terrain that are highly unstable, and are susceptible to surface erosion and large landslides (U.S. Forest Service, 1992). In the late

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1950s and early 1960s, much of the watershed was logged, with little regard for the effects of altering the drainage network or removing vegetative cover. In 1964, a massive flood event wreaked havoc with the South Fork watershed (as it did in much of the North Coast region). Huge amounts of sediment and debris washed downslope, filling tributaries as well as the South Fork's main channel.

Historically, the South Fork contained many large, deep pools. These provided excellent habitat for holding summer steelhead and spring chinook over the dry season until fall and winter spawning (Higgins et al., 1992). In the 1964 floods, millions of cubic yards of sediment eroded into the river, filling pools, destroying riparian vegetation and otherwise damaging river habitats. In some areas, up to 25 feet of channel aggradation occurred. Today, some of the sediment has washed out of the system, which is slowly recovering. However, the devastating effects of 1964 still plague the fishery.

Lightning caused fires in 1987 burned thousands of acres in the South Fork Trinity watershed. Following the fires, the U.S. Forest Service proposed to carry out sanitation-salvage logging on the burned lands, under the South Fork Fire Recovery Salvage Project. The USEPA and the North Coast Regional Water Quality Control Board both objected to the logging on the basis that timber harvest and road building would cause significant adverse impacts on an already stressed system. The Forest Service ignored these objections. A coalition of environmental and fishing groups, including the Wilderness Society, Sierra Club, Pacific Coast Federation of Fisherman's Associations, Inc., and California Trout, Inc., brought suit against the Forest Service to halt the logging under provisions of the federal Wild and Scenic Rivers Act. The winning bidder for the proposed sale, Sierra Pacific Industries, Inc., intervened on the side of the Forest Service.

A temporary restraining order was imposed in the fall of 1988 which halted the timber sale and logging, followed by a preliminary injunction several months later. After various legal appeals and orders, several years passed, still with no logging having occurred and the preliminary injunction in place.

One of the most important issues to be considered in granting a preliminary injunction is

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whether "irreparable injury" could result if the action in question is allowed to proceed. Both sides of the dispute produced expert testimony which offered differing interpretations of the facts about the impacts of the proposed logging on river resources. In February of 1992, the court finally appointed its own expert to sift through the scientific testimony which had been presented by both sides. Dr. R. Dennis Harr, an employee of the Forest Service from Seattle, concluded that the logging would produce a limited amount of sediment to the river, which by itself would not be expected to irreparably harm salmonid resources of the river. However, Dr. Harr also concluded that sedimentation from the salvage logging taken *cumulatively* with the amounts that would occur from the watershed in general, and the amounts already present in the river system, would indeed cause significant and irreparable harm to steelhead and salmon populations in the South Fork Trinity.

In the spring of 1992, the U. S. District Court denied motions to dismiss the preliminary injunction, citing in part the findings by the court's expert on cumulative impacts. In the fall of 1992, the notice of appeal of the court's decision was dismissed, and the timber sale was withdrawn.

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Table 5. Major Rivers in the Klamath/North Coast Region.

River	Length (mi.)	Watershed Area (sq. mi.)
Albion	14	65
Bear	25	120
Big	40	180
Black Butte	25	130
Eel	200	3,120
Elk	17	80
Garcia	32	110
Gualala	35	290
Klamath	210	12,100
Little	17	40
Mad	90	490
Mattole	56	340
Napa	55	426
Navarro	19	300
New	25	220
Noyo	35	130
Petaluma	25	140
Russian	105	1,480
Salmon	46	750
Salt	8	20
Scott	68	650
Shasta	52	790
Smith	50	630
Ten Mile	10	110
Trinity	170	2,860
Van Duzen	63	275

Kreissman, 1991.

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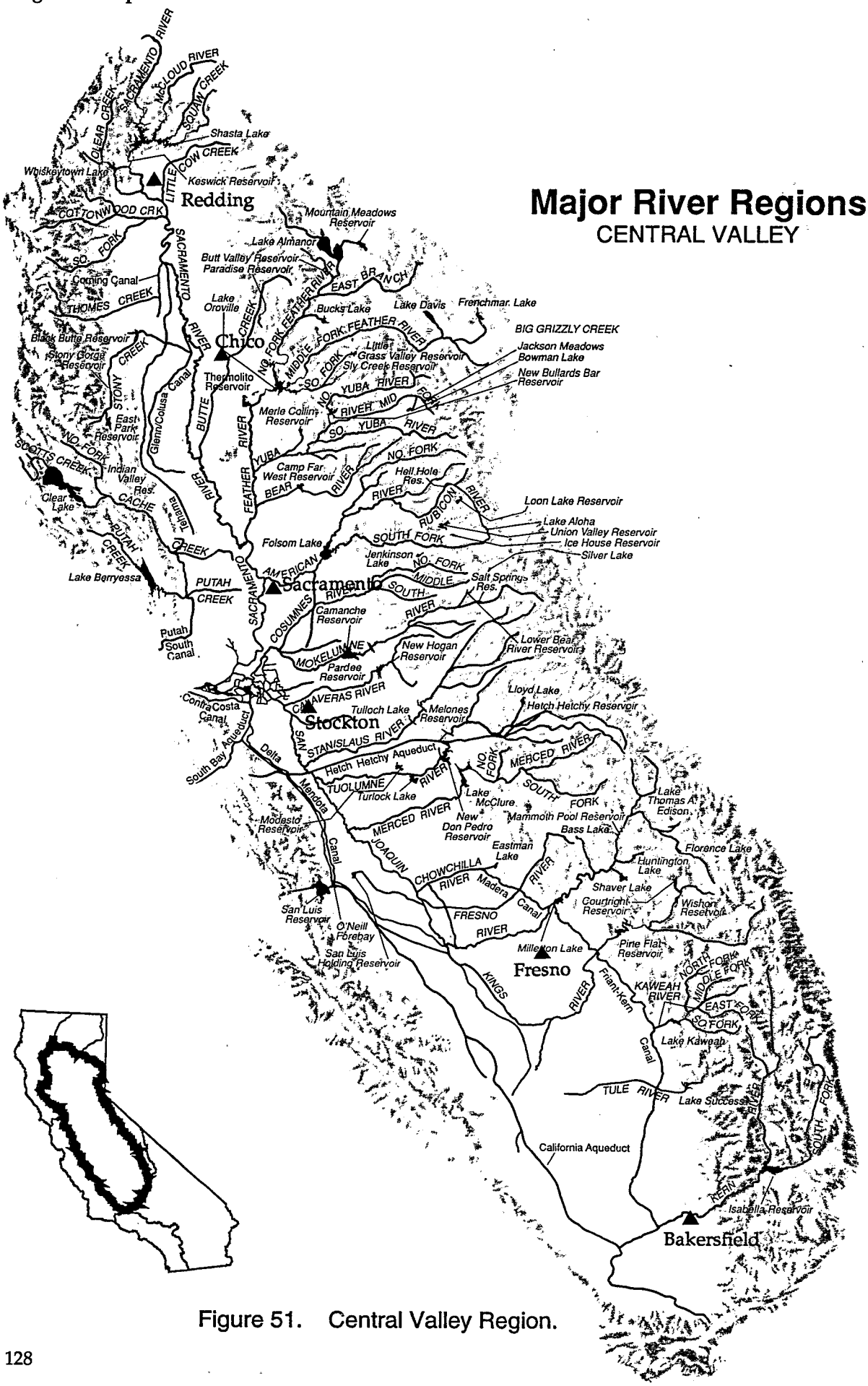

Figure 51. Central Valley Region.

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Central Valley Region

The Central Valley region includes the drainage area of the Sacramento River (to Shasta Dam) and San Joaquin River systems, and the rivers which flow into the Tulare Basin in the southern San Joaquin Valley. Rivers which are part of the natural Sacramento River watershed but are now cut off by Shasta Lake are discussed in the Modoc/Cascade region section (e.g. Pit, McCloud).

The Central Valley is dominated by the Sacramento and San Joaquin rivers, which join together in the Delta to flow into San Francisco Bay and eventually into the Pacific Ocean. These are the state's largest rivers with historically the most extensive riparian systems and greatest fish resources. The southernmost rivers in the San Joaquin Valley (the Kern, Tule, Kaweah and Kings) do not actually flow into the San Joaquin River, but flow into two closed basins at the south end of the valley; their flows are heavily diverted to support agriculture.

The rivers in the region flow from the Sierra Nevada mountains, traverse the range in high gradient channels cut into steep canyons, pass through the foothills, and emerge onto the valley floor. With the decrease in channel gradient, the rivers adjust to a more sinuous, meandering pattern, flanked by broad flood plains which formerly supported extensive riparian forests. Thus, the same rivers display very different characteristics along their length. Runoff is derived almost exclusively from the higher elevations, and seasonal runoff patterns reflect both snowmelt and rainfall runoff peaks.

The headwaters of the Sacramento and San Joaquin rivers (and their tributaries) receive 60-80 inches of precipitation annually, but the valley floor itself is quite dry, increasingly so to the southern end. Red Bluff receives 24 inches of rain, Stockton receives 13 inches of rain annually, and Bakersfield receives only six.

Mature riparian forests of the Central Valley are California's version of a rain forest jungle. Lush growths of riparian trees and shrubs contribute a high amount of standing biomass and primary productivity. Measurements of biomass (basal area) for the Central Valley riparian forests (Conard et al., 1977 and Strahan, 1984) are comparable to amounts indicated for a variety of flood plain and swamp forests of the eastern United States (see data compiled by Brinson et al.,1981, p 29; Holstein, 1984). It is likely that California lowland flood plain riparian forests—with optimal conditions of high sunlight, water and regular infusions of nutrients—have ecosystem productivities even higher than tropical rain forests (Major, 1977).

Katibah (1984) has estimated that the Central Valley floor historically contained about 922,000 acres of riparian vegetation, including growth along the Sacramento and San Joaquin rivers, their tributaries, and the rivers and streams of the southern San Joaquin Valley such as the Kern, Kings and Kaweah. Warner (1985) estimated

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riparian vegetation covered a total of 1.6 million acres for the Central Valley, suggesting that the amounts given by Katibah for the area from the Kings River south were too low. As of the early 1980s, about 102,000 acres in the valley remained, with about one-half that in a highly degraded condition (Katibah, 1984), a decline of 90 percent or more.

The largest salmon runs in the state were from the Sacramento/ San Joaquin river systems, estimated at up to 1 million fish in peak years, with average yearly runs at 600,000 (DFG, 1991a). Historically, of the four races of chinook salmon in the Central Valley (winter, spring, fall and late-fall runs), the spring-run was the most abundant. Before the recent drought, chinook river populations in the Central Valley averaged about 272,000; over 85 percent of this consisted of fall-run from the Sacramento River (Reynolds et al., 1990).

With the exception of the Cosumnes River, all Central Valley rivers of any size have been dammed in the foothills. Some of these dams were constructed by local irrigation or municipal water districts, but the biggest structures were erected either as part of the CVP of the U.S. Bureau of Reclamation in the 1940s or the SWP of the Department of Water Resources in the 1960s. In addition to these large foothills reservoirs, most basins have a network of smaller dams and diversion canals for hydroelectric generation in their upper watersheds.

The construction of dams in the foothills has effectively prevented anadromous salmonids from reaching natal spawning grounds upstream. Before water development, there were about 6,000 miles of anadromous fish spawning habitat in the Central Valley. In a steady progression of water project developments, valley rivers were picked off one at a time and their waters dammed and diverted for flood control, power generation and water supply. Less than 300 miles of spawning area remain—just five percent of the historic amount (California Advisory Committee on Salmon and Steelhead Trout, 1988). Also, irrigation siphons, intake pipes and high-capacity diversion pumps along valley waterways, including the Delta, directly kill millions of salmon eggs, larvae and young, and other fish resources every year. There are an estimated 300 intakes on the Sacramento River and 1,800 in the Delta. Only a handful are screened, and those still cause significant mortality of fisheries (Reynolds et al.,1990).

Sacramento River

The Sacramento River drains 24,000 square miles, and is so large that it is in a class by itself among California rivers. Along its length, the river geomorphology varies. From Redding to Red Bluff (River Mile 302-243), the river channel is naturally constrained by resistant geologic formations on both banks. From Red Bluff to Hamilton City (RM 243-194), the channel freely meanders, flanked by a wide flood plain. From Hamilton City to Colusa (RM 194-143). The river once naturally meandered between natural levees built up

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Figure 52. Sacramento River Between Levees.

during overbank floods, but now is somewhat constrained by set-back levees and bank protection. Downstream of Colusa (RM 143-0), the river flows through a completely channelized reach, narrowly constrained by artificial levees built for flood control (Figure 52).

At the time of statehood, there were an estimated 500,000 acres of riparian vegetation bordering the Sacramento River main stem (Upper Sacramento River Advisory Council, 1989; Katibah 1984). Diaries and notes from observers at the time described these riparian forests as luxuriantly green and dense, dominated by stately oaks, sycamores and cottonwoods. In just a few decades after 1850 most of the riparian forests were decimated by fuelwood cutting. From the turn of the century on, agricultural clearing and flood control projects added to the losses (Thompson, 1961).

By 1979, woody riparian habitat along the Sacramento had decreased to 11,000-12,000 acres, about two percent of historic levels (McGill, 1979). Interestingly, from 1982 to 1987, riparian vegetation incrementally increased to about 16,000 acres, including an addition of several thousand acres into high terrace climax vegetation (McGill, 1987). This recent increase probably reflects the combination of a decline in agricultural economies and natural riparian plant succession.

The Sacramento River's main flow is regulated by Shasta Dam and by water transfers from the Trinity River, both part of the federal CVP, which have increased summer base flow (to supply agricultural diverters) and reduced winter and spring peak flows. The Feather and Yuba rivers, two major tributaries to the lower Sacramento, are also controlled by dams.

Shasta Dam (constructed 1938-1944) blocked the entire upper Sacramento, McCloud and Pit river systems, which were the principal spawning grounds for chinook salmon and steelhead. The remnant salmon population of the Sacramento system must spawn in

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the main stem below Shasta Dam, in the remaining undammed tributaries (such as Battle and Cottonwood creeks), and below dams on major tributaries. However, spawning in the main stem is severely limited by a lack of suitable spawning gravel. The lack of gravel has several causes. Shasta Dam traps all gravel that would normally travel downstream from the watershed, so flood flows scour gravel away without bringing in a fresh supply. Another cause is the extensive mining of gravel from the bed of the main stem and from its principal tributaries, which formerly supplied fresh gravel to the main stem. An additional source of gravel to the channel is erosion of gravel from river banks as the channel naturally migrates across its flood plain. Further bank protection works threaten to eliminate this important source of gravel.

The Feather River system was formerly a world class fishery; earlier in this century, fishing resorts along the North Fork Feather attracted European nobility and other enthusiasts to fish for its remarkable runs of spring and fall-run salmon. Water development on the North Fork Feather started in about 1913, and today it is stair-stepped with dams and reservoirs built by the Pacific Gas & Electric Company. Fish ladders were either not effective or nonexistent. Since the construction of Oroville Dam in 1968, good fishing is now restricted to the reach below the dam, mainly supported by a hatchery. In addition to inadequate spawning gravels, this reach suffers from episodic pulses of flow released from the dam.

The Yuba River is the Feather's main tributary. Although the Yuba is blocked about 25 miles upstream by an impassable dam, there have been sufficiently good channel and flow conditions downstream of the dam in many of the years to support spawning runs of salmon and steelhead. With the latest climatological dry cycle, as in other dry years, flows in the spring are far less than optimal for salmonid survival and migration (Reynolds et al., 1990). Gold dredging has severely altered the Yuba flood plain. Today the Yuba is still worked by miners, who divert river flows into a vast area of dredger tailings and ponds, compounding impacts to fish.

In the Sacramento River system every life history stage of chinook salmon is present every month of the year, a unique feature among California river systems. The Sacramento fall-run is now the most numerous race in the Central Valley, but its numbers have been trending downward since accurate records have been kept, and have declined severely under the latest dry cycle.

The spring-run has only about 1,000 spawners and is at high risk of extinction (Nehlsen et al., 1991). This race is listed as a Species of Concern by the California Department of Fish and Game. In 1991 winter-run was estimated at less than 200 fish, and just over 1,000 fish were counted in 1992. It is listed as Threatened under the federal Endangered Species Act and as Endangered under the state act. This race may have numbered about 200,000 before the construction of

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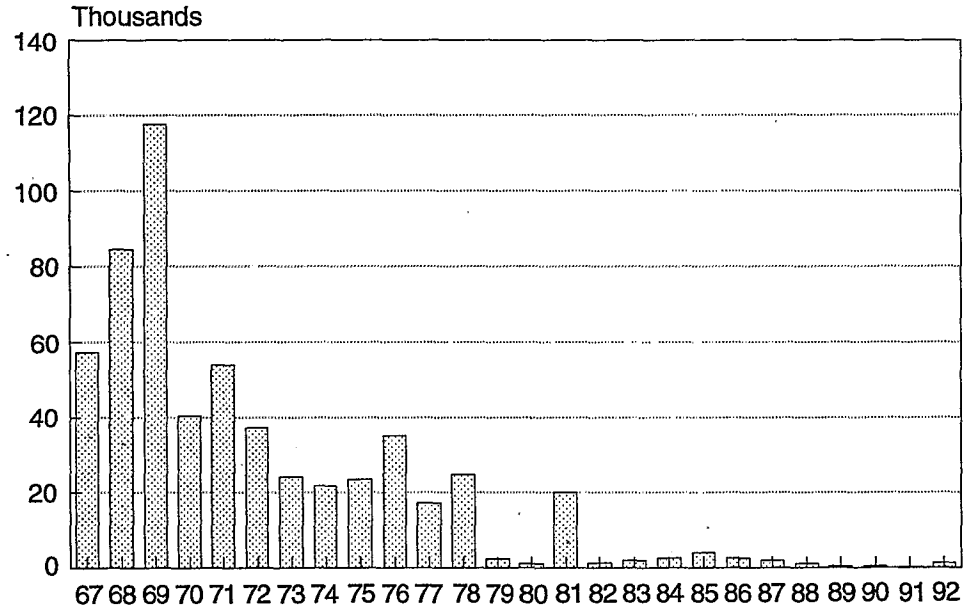
Figure 53. 25 Years of Winter-run Salmon Counts on the Sacramento River at Red Bluff Diversion Dam.



Shasta Dam (Harry Rectenwald, DFG, cited in NMFS, 1991). Since the construction and operation of Shasta Dam, the highest population was estimated at 117,808 in 1969, a year before the construction of Red Bluff Diversion Dam, but has declined since that time to its present status (Figure 53).

The effect of this listing has impacted the California ocean troll and recreation fisheries and is expected to continue until the species has recovered (PMFC, 1992). This listing has only marginally impacted the amount of water diverted from the Sacramento-San Joaquin Delta by the SWP or the CVP. During the spring of 1992, significant winter-run smolts were lost (estimated at about 10,000 juvenile winter-run; Deborah McGee, DFG, pers. comm.) with the majority lost at the SWP's Banks Pumping Plant.

San Joaquin River

The San Joaquin main stem has been dammed since 1949 by Friant Dam, part of the CVP. Construction began in 1939 and the dam was fully operational by 1949. The San Joaquin has virtually dried up below Friant, resulting in devastation of the fishery. Flow in tributary rivers—the Stanislaus, Merced, and Tuolumne—has also been regulated and reduced, primarily by diversion for agriculture. For example, the Merced River's natural seasonal flow pattern has been altered, with high snowmelt peaks reduced and flows augmented over the summer irrigation season. In most years, and certainly during the latest dry cycle, flows have been inadequate in

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the three tributaries for the spawning, rearing and emigration of salmonids.

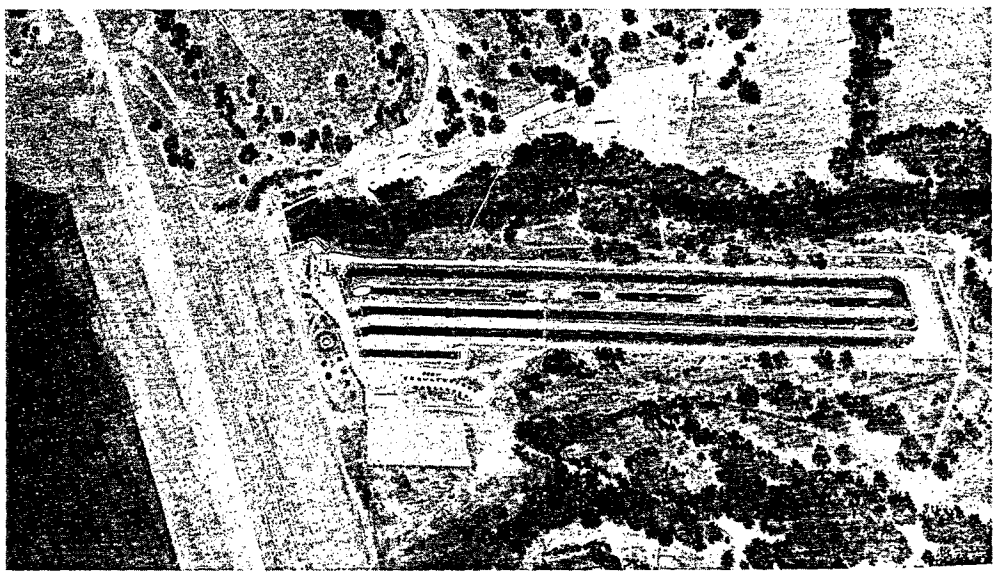
The San Joaquin main stem and major tributaries have been important sources of commercial aggregate for the region. Gravels have been largely stripped from the active channel, and are now being removed from adjacent flood plains and terraces. The removal of gravel from the river channels has adversely affected spawning habitat in the river channels below the lowest dams, the only spawning grounds available to the remnant salmon runs in the San Joaquin system.

The San Joaquin River drainage once supported fall and spring-runs of chinook salmon. Escapement was estimated at from 100,000 to 300,000 fish annually, with the spring-run the dominant run. With the construction of dams and diversions on every major waterway, the San Joaquin spring-run salmon was extirpated. The system now supports only fall-run on the three main tributary rivers.

The combined fall-runs of chinook salmon to the Merced, Tuolumne and Stanislaus Rivers declined from an average escape-ment of 72,000 in the 1940s to 10,700 fish in the 1970s, rebounding slightly to 32,000 for the 1980s (Reynolds et al., 1990). With the latest dry cycle (1987-1992), San Joaquin Valley chinook numbers are only in the hundreds and are at severe risk of extinction. The runs for the San Joaquin basin were down to about 600 naturally spawning fish during 1991 (PFMC, 1992).

It should be noted that during the years 1981 through 1986 the San Joaquin system spawning runs of chinook salmon were in excess of 30,000 fish with a high of 70,000 fish in 1985. The high returns of 1983-1985 are believed to be the result of fortuitous high spring run-off and Delta outflow conditions during the previous two years (Reynolds et al., 1990).

Figure 54. The Mokelumne River.



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Case Study: Mokelumne River–Toxic Mine Drainage

The Mokelumne River, along with the Cosumnes and Calaveras rivers, is directly tributary to the eastern Delta, without joining the Sacramento or San Joaquin rivers. The Mokelumne drains from the western slope of the Sierra Nevada and runoff is primarily from snowpack in the upper watershed.

The Mokelumne once supported a large spring-run salmon population, as well as fall-run chinook and steelhead. In 1929, the East Bay Municipal Utility District (EBMUD) constructed Pardee Dam in the Sierra foothills, allowing the diversion and pipeline transport of water to the EBMUD service area. The dam blocked access to the cooler upstream spawning waters necessary for the spring-run, and this stock was extirpated. There was no mitigation for fish losses due to Pardee. In 1963, EBMUD constructed Camanche Dam and reservoir downstream of Pardee to enable the district to better meet downstream riparian water rights. This dam and reservoir ruined much of the remaining spawning grounds for the fall-run chinook and steelhead stocks which had survived after Pardee Dam. This time, a hatchery was built for fishery mitigation, situated below Camanche Dam.

EBMUD derives 95 percent of its water supply from the Mokelumne River, a source famous for its outstanding quality. The district's current water right entitles it to one-half of the average annual runoff from the river system, although its current average annual diversion is about one-third. Instream flows for fish are currently only required for the hatchery below Camanche, in an amount of one to two percent of the total runoff. Fishery resources have plummeted since Pardee and Camanche dams went in and the hatchery has not been successful at mitigating losses. The disparity in the flows fish get and what they need is illustrated in part by the draft management plan released by California Department of Fish and Game which calls for up to 28 percent of runoff to be dedicated to fish.

Lawsuits have been filed by environmental organizations, and several different government bodies have begun various hearings and investigations into

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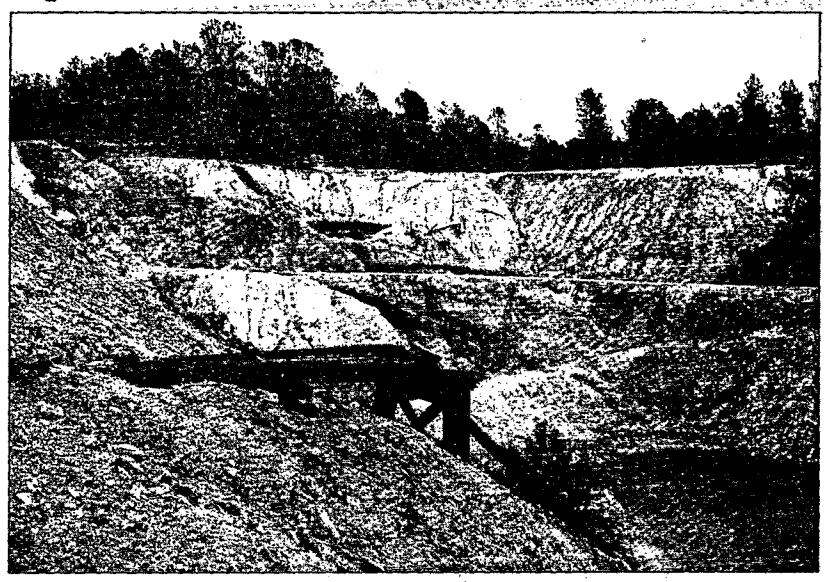
EBMUD's water rights and project operations to look at whether improvements are necessary in managing Mokelumne flows for environmental protection.

There are many troublesome issues to contend with on the Mokelumne, including: water allocation among competing users; the protection of the public trust resources in the river; possibly changing the point of EBMUD's diversion to the Delta; and providing high-quality drinking water to the district's customers. However, all of these water supply questions are made extraordinarily more difficult by the presence of another, seemingly unsolvable problem—toxic runoff from the abandoned Penn Mine. The environmental problems have been accompanied by charges from environmental groups, notably the Committee to Save the Mokelumne, that government agencies have mismanaged the situation.

Figure 55. Penn Mine on the Mokelumne River.



Penn Mine is an old copper and zinc mine located in Calaveras County between the present site of Pardee and Camanche dams, on slopes which drain to the Mokelumne (Figure 55). The mine was opened in 1861 and operated steadily until 1919, and then intermittently until the 1950s. Copper and zinc ore were mined from underground shafts through the mountains, and more than 55,000 linear feet of shafts still honeycomb the hills. Rainwater

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reacts with sulfides in the ores exposed by mining to produce sulfuric acid at battery acid or worse levels. This strong acid in turn dissolves heavy metals such as cadmium, zinc and copper, which are highly toxic to aquatic life and to humans.

Before the construction of Pardee, toxic mine leachate ran straight into the river, affecting aquatic biota, but unimpaired flows diluted and flushed toxic substances downstream. When the river was dammed and flows were diverted, dilution and flushing were decreased. In 1937, following a flushing of some of the mine shafts, the first recorded fish kill occurred, sterilizing the river for 60 miles downstream. Other fish kills have happened through the years.

In 1964 Camanche Dam was completed, creating in effect a storage trap for toxics, but fish kills and sublethal toxic effects still continued with regularity on the river below Camanche Reservoir. In 1977, after a drought period, the water levels in Camanche had dropped substantially. This exposed a mud flat loaded with high concentrations of toxic heavy metals. EBMUD released a sudden flush of water from Pardee, which stirred the toxics into solution, wiping out fish life in the reservoir, the river and the hatchery. EBMUD, which owned much of the property at the Penn Mine site and operated the two reservoirs, was ordered by authorities to clean up the toxic problem (Figure 56).

Following many negotiations, enforcement action was dropped against EBMUD, and the district and the Central Valley Regional Water Quality Control Board (CVRWQCB) cooperatively built what was thought to be a solution to the problem. However, the system of holding ponds and other facilities installed at the mine site has, allegedly, never performed adequately. Experts hired by environmental groups contend that the problem was even exacerbated by the remediation project. The environmental groups further allege that information on the supposed remediation action was suppressed by government agencies and they have filed a number of lawsuits.

Currently there are actions pending in court and in various government agency hearing and permit processes, looking at water allocation and toxic remediation.

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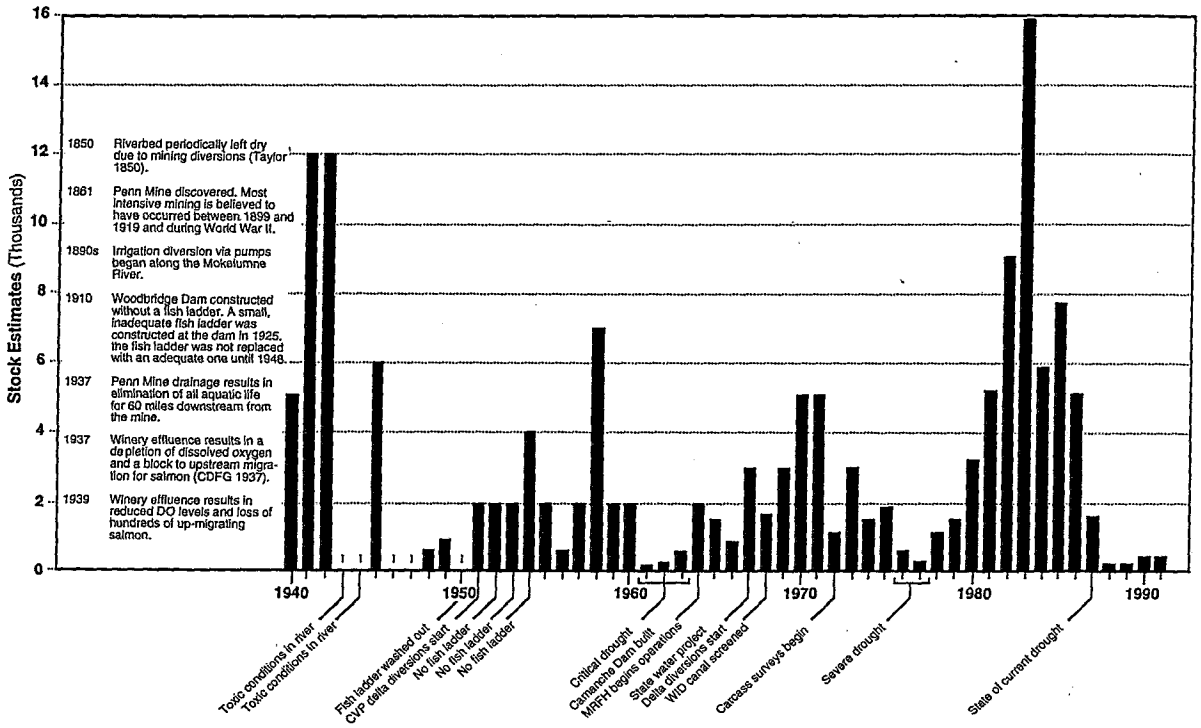
Figure 56. Mokelumne River Salmon Stock Estimates and Important Environmental Events, 1850-1991.



Note: 1 No official estimates

Source: BioSystems Analysis, Inc./ EBMUD-EIR

In March 1993, a U.S. District Court judge ruled that EBMUD and the CVRWQCB were in violation of the federal Clean Water Act due to the toxic discharges from the "remediation" facility. EBMUD has steadfastly maintained that it is not culpable for problems dealing with the fishery resource, and is fighting attempts to significantly alter water rights and other permits for their activities on the Mokelumne.

The above information was taken from papers prepared by the Committee to Save the Mokelumne, articles in the December 2, 1991 *Sacramento Bee*, and articles in the September 28 and 29, 1992 *San Francisco Daily Journal*.

Table 6. Major Rivers in the Central Valley Region.

River	Length (mi.)	Watershed Area (sq. mi.)
American	265	2,000
Bear (Feather)	77	295
Bear (Mokelumne)	20	60
Calaveras	80	365
Chowchilla	65	250
Clavey	35	170
Cosumnes	80	725
Downie	20	40
Fall (Feather)	25	40
Feather	175	4,580
Fresno	75	240
Kaweah	77	720
Kern	164	2,400
Kings	133	1,745
Merced	135	1,275
Middle	30	—
Mokelumne	160	660
Old	48	—
Rising	5	—
Roaring	17	80
Rubicon	65	315
Sacramento*	327	24,000
Saint Johns	25	—
San Joaquin	330	13,540
Stanislaus	161	1,100
Tule	91	395
Tule-Little Tule	149	1,900
White	55	850
Yuba	96	1,350

*Includes above and below Shasta Dam.

Kreissman, 1991.

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Major River Regions
MODOC / CASCADE

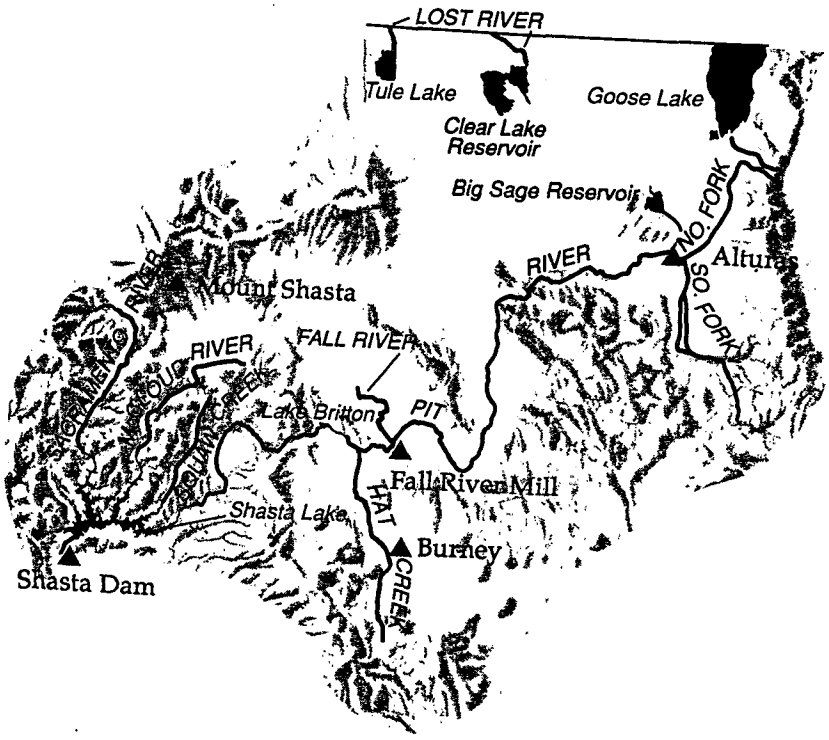

Figure 57. Modoc/Cascade Region.

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Modoc/Cascade Region

The Modoc Plateau/Cascade Range region, a rugged and isolated part of the state, is drained by the Pit, McCloud and Upper Sacramento rivers, tributaries to the Sacramento River. The upper reaches of the Sacramento system now end in Shasta Lake, the reservoir created by the CVP's Shasta Dam.

This region is underlain by volcanic rocks and its two principal rivers, the McCloud and Pit, are notable for their cold, steady flows fed by prolific springs which issue from the slopes of volcanic mountains. The rivers are typically incised into steep-sided canyons within the volcanic uplands, and riparian habitat is limited. The steady base flows are augmented by snowmelt runoff in early summer, although the seasonal variability is much less than that displayed by rivers in other regions of the state. Precipitation is generally low, except on the high volcanic mountains, notably Lassen and Shasta. The Pit River as it passes through the mountains gets an average annual precipitation of 75 inches, but Alturas receives only 13 inches annually. Most of the snowfall on the mountains infiltrates into the permeable volcanic rocks and reemerges as spring flow.

Prior to the construction of Shasta Dam, the Upper Sacramento, McCloud and Pit rivers supported vast runs of anadromous salmonid. The clear, cold, steady spring flows provided ideal spawning and rearing habitat for salmon, and supported runs of hundreds of thousands of fish, primarily spring-run (Reynolds et al., 1990). The McCloud was the historic spawning grounds for the now-endangered winter-run Chinook. With construction of Shasta Dam in 1940, sea-run fish could no longer reach these sites, and entire races adapted to the specific conditions of particular rivers dis-appeared. Shasta Dam eliminated one-half of the natural spawning and rearing habitat for salmon and steelhead in the Sacramento River system (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, 1989). Ironically, the first fish hatchery in California was built in 1872 on the McCloud River for chinook salmon; the site was later flooded by Shasta Lake reservoir (Hedgpeth, 1991; Higgins, 1991) (See "The Wintu Fishery" box).

The resident fisheries of the Upper Sacramento River and its tributaries (the Pit, McCloud and Fall rivers) are of still tremendous importance, since rainbow and the introduced brown trout are still much sought-after as game fish.

The lower Pit River is now heavily developed for hydroelectric power production, and much of its course is a staircase of hydroelectric power plants, impoundments and diversion canals. Aquatic habitats have been drastically altered.

The upper Pit River and its tributary, the Fall River, flow through the relatively flat Modoc Plateau country. Here watercourses are bordered by marshy and wet meadow areas, with relatively small

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amounts of woody riparian vegetation. Several rare fish are found in the Pit system, including two species of sculpin and a state and federally listed Endangered invertebrate, the Shasta Crayfish. Grazing is a major cause of adverse impacts on riparian and aquatic habitats in this area.

At the extreme northern end of the state, the Lost River system lives up to its name in more ways than one. It originates in Clear Lake Reservoir, flows out of California into Oregon, then returns back to California ending in Tule Lake. The Lost River drainage supports a unique fish fauna, including the state and federally endangered Lost River Sucker and Shortnose Sucker. Habitat alterations by agriculture, water diversions and grazing have severely threatened these and other native aquatic species in the far northern part of the state.

Figure 58. Fishing the Fall River.

Source: California Trout, Inc.

Case Study: Fall River

The Fall River, in northeastern Shasta County, is only 25 miles long but is of statewide importance as the site of an often cited court decision involving the public's rights to use navigable waterways.

The Fall River originates from an area called Thousand Springs, near the small town of Dana. These

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headwater springs produce a relatively high and constant flow in the Fall River, with a summertime average of about 450 cfs (Rode and Weidlein, 1986). Winter high water does not peak at very high rates; the 10-year flood event flow is about 4,000 cfs (Jones and Stokes, 1992). (Compare this with the Eel River, with an August average flow of only 150 cfs and 10-year flood events of over 340,000 cfs (Jones and Stokes, 1981).

The Fall River follows an extremely sinuous path as it meanders through the Fall River valley to its confluence with the Pit River near the town of Fall River Mills. The valley is primarily wet meadows and grassy fields used for pasture and hay production. Woody riparian vegetation along the river occurs in minor amounts. Almost all of the valley, including the river shore zone, is in private ownership.

The river's stable flows and water temperatures support a fish fauna renowned for both sport fishing and for biodiversity. Native rainbow trout are abundant and are managed as a game fishery under the California Department of Fish and Game Wild Trout program. The Fall River also supports the Rough Sculpin, the Bigeye Marbled Sculpin and the Shasta Crayfish, all special-status species.

The Fall River is nationally famous among anglers for its wild trout fishery. Essentially all fishing is done from boats on the river, due to the private ownership on the shore. Additionally, the meadows and wetlands of the Fall River valley attract migratory waterfowl and hunting is popular. About 20 percent of the hunters hunt from boats on the river. Public access to the river is limited to only a few launch areas. Boats large enough to require trailering can only put in at one location, the boat ramp at Big Lake, which is upstream on the Tule River, a tributary to the lower Fall River. There are also a handful of private access points at resort lodges which charge a fee (Rode and Weidlein, 1986).

A low-clearance county bridge on Island Road on the lower third of the river effectively keeps large power boats from the upper river, but small boats can freely pass under. Despite the lack of access points, the Fall River is currently used heavily by the boating public for fishing, hunting, nature observing, water-skiing and cruising (Jones and Stokes, 1992).

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Free use of the Fall River was not always available. Prior to 1950, fishing and boating were generally allowed along the river. Then, in the early 1950s, private landowners along the river erected booms, fences and low bridges across the river and fences along the river to prevent access to and over the waterway. In 1964, the state, represented by Shasta County District Attorney Robert Baker, sued for an injunction to prevent private owners from interfering with public use of the river. The trial court found the segment of the river in question to be navigable in fact, and issued the injunction. The defendant private property owners appealed, and the Court of Appeal affirmed the original decision. The appellate decision, *People ex rel. Baker v. Mack* (1971) 19 Cal. App. 3d 1040, is an important reaffirmation of the public's rights to boating, fishing, hunting and related activities upon navigable waterways. Equally important, or perhaps more so, was the finding that a waterway is navigable for purposes of public use if it is capable only of pleasure boating. Commercial navigation is not necessary in order for the public's rights to apply. The court further held that ownership of title to the bed of the Fall River was irrelevant to the question of whether or not public navigation rights existed. Those rights exist on bodies of water which are navigable in fact irrespective of ownership of the underlying land, as long as access to the waterway can be gained legally.

Recently an interesting situation has arisen on the Fall River which must employ the principles set forth in *Baker v. Mack*. In 1945, the Island Road Bridge, mentioned above, was constructed midway on the Fall River. By the late 1980s, this wooden structure had deteriorated to the point that it needed to be replaced. (Background information on the Island Road Bridge project in the following was taken from Jones and Stokes Associates, Inc., 1992).

Shasta County Department of Public Works and the Federal Highway Administration circulated a draft Initial Study/Environmental Assessment for the bridge replacement which compared three alternatives for bridge reconstruction; one with 3.5 feet clearance underneath, which was the same elevation above normal summer flow levels as the original; one with 6.5 feet clearance; and one with 14 feet of clearance. The proposed alternative ended

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up being the smallest of the choices, replacement at the same height as the existing bridge.

One citizen, represented by counsel, commented to Shasta County's environmental document that the original Island Road Bridge, by preventing larger boats from passing, was a "public nuisance" (citing *Baker v. Mack*, among other cases). The commentator noted that the other alternatives for increased bridge height, albeit more expensive, would reduce or eliminate this "nuisance." The county disagreed, responding that Civil Code § 3479 defines a nuisance as "Anything which . . . unlawfully obstructs the free passage or use, in the customary manner, of any navigable lake, or river, bay, stream, canal, or basin." The selected alternative would result in the same type of usage as the current situation which the County deemed to be the customary situation.

Interestingly, the California Department of Fish and Game also supported the alternative of the lowest height, on the basis of protecting the fishery resource, both for the Wild Trout Management program and the special status aquatic species. The County has proceeded to file a Notice of Determination approving the replacement of the bridge at its original height.

Table 7. Major Rivers in the Modoc/Cascade Region.

River	Length (mi.)	Watershed Area (sq. mi.)
Fall (Pit)	25	—
Lost	26	—
McCloud	60	600
Pit	200	5,000
Sacramento*	327	24,000

*Includes above and below Shasta Dam.

Kreissman, 1991.

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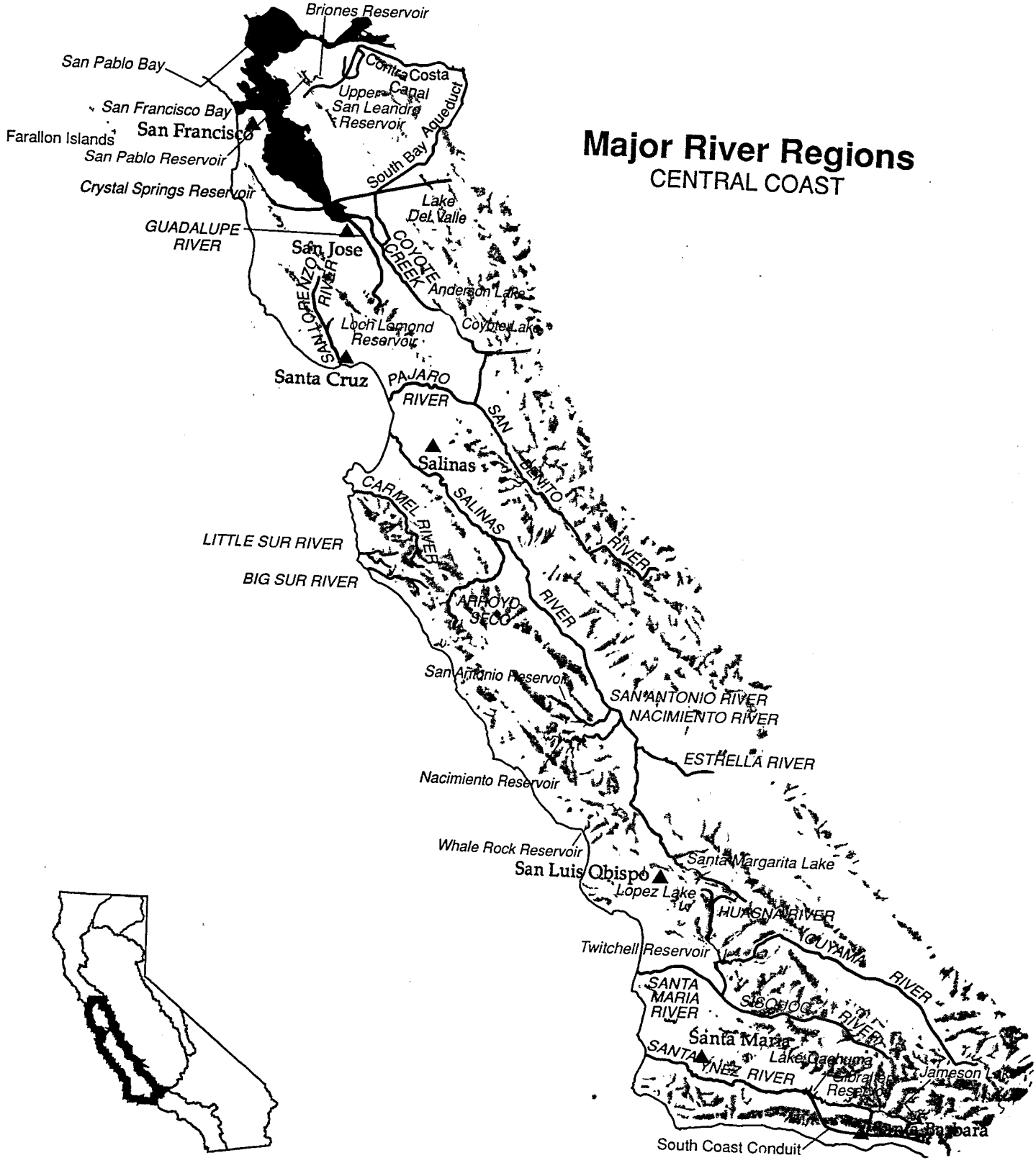

Figure 59. Central Coast Region.

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Central Coast Region

The Central Coast region lies within the southern Coast Ranges, from San Francisco Bay south to the Santa Ynez River in Santa Barbara County. It includes the Central Coast Basin and southern portion of the San Francisco Bay Area Hydrologic Basin. In this region, mountain ranges alternate with elongated alluvial valleys, such as the Pajaro, Salinas, Santa Maria and Santa Ynez river plains.

Mountains and foothills of the Central Coast are wooded or chaparral-covered, while the large alluvial valleys (e.g., Salinas, Santa Maria) are mainly agricultural. The Central Coast is one of the state's leading areas of range and pasture livestock production (California Department of Forestry and Fire Protection, 1988) and agriculture.

Rainfall is generally low in the valleys. For example, Salinas has an average annual rainfall of only 14 inches. The higher mountains receive considerably more, such as the Santa Cruz Mountains above the city of Santa Cruz, with over 60 inches of annual precipitation. Rainfall and runoff are highly seasonal, with nearly all rainfall between November and April, 60 percent falling in December, January and February. River flows show comparable variability, with high winter flows (in direct response to intense rainstorms) and low summer base flow.

Central Coast rivers maintain a base flow in their mountainous reaches. Under natural historic conditions, base flow was sustained over the length of their alluvial valleys through all but the longest of droughts (and maintained high alluvial water tables throughout). However, valley base flows have been reduced (or eliminated in most years) by human extraction of underflow (which is shallow ground-water recharged by the river). Along the Carmel River, municipal supply wells dropped the water table below the rooting depth of willows, resulting in an extensive die-off of willows, loss of bank protection afforded by the vegetation, and locally massive erosion (Kondolf and Curry, 1986). Along the Salinas River, base flow is maintained by releases from San Antonio and Nacimiento reservoirs, designed to recharge the alluvial water table from which local farms draw their water.

Groundwater levels have also dropped in the alluvial flat adjacent to the Sisquoc River, caused by instream gravel mining which lowered the river bed 40 feet in places.

Riparian vegetation in the Santa Cruz and Santa Lucia mountains is limited to narrow stream borders, and is similar to that on the forested coastal rivers of the North Coast region. Redwood is often present, such as along the San Lorenzo River. By contrast, valley areas in the Central Coast once supported large flood plain forests of deciduous riparian trees and shrubs, dominated by sycamore, willows, and Fremont and black cottonwood. Because of the long-time use of the area for grazing and agriculture, such valley riparian habitat is now scarce. Water regulation by upstream dams

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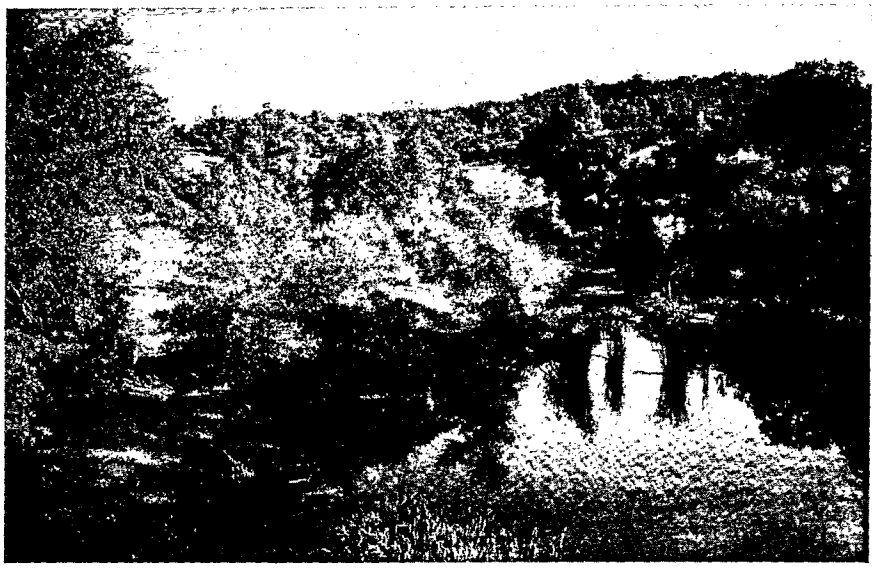
and ground water pumping also have impacted these riparian communities. Remaining patches of riparian habitat on the Salinas River and a few other localities in the Central Coast are important as some of the last known breeding areas of the Least Bell's Vireo, a state and federally listed endangered bird species (DFG, 1992a).

There are two types of natural fish fauna in the Central Coast. The larger Salinas/Pajaro River systems have species characteristic of the lowland habitats of the Sacramento-San Joaquin systems—such as Sacramento squawfish, Sacramento sucker and hitch—and a coastal fish community of anadromous species. Smaller rivers mostly have only anadromous species which can take advantage of seasonal high flows. Steelhead and Pacific lamprey are the most common anadromous fish on all the region's rivers, but have drastically diminished in numbers during the past decades.

Figure 60. Salinas River.



Case Study: Salinas River—
An Agricultural River

A few miles south of Soledad, the Salinas River drops in close to the hillside bank and runs deep and green. The water is warm too, for it has slipped twinkling over the yellow sands in the sunlight before reaching the narrow pool. On one side of the river the golden foothill slopes curve up to the strong and rocky Gabilan mountains, but on the valley side the water is lined with trees-willows fresh and green with every spring, carrying in their lower leaf junctures the debris of the

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winter's flooding; and sycamores with mottled, white, recumbent limbs and branches that arch over the pool. On the sandy bank under the trees the leaves lie deep and so crisp that a lizard makes a great skittering if he runs among them. Rabbits come out of the brush to sit on the sand in the evening, and the damp flats are covered with the night tracks of 'coons, and with the spread pads of dogs from the ranches, and with the split-wedge tracks of deer that come to drink in the dark. (John Steinbeck, *Of Mice and Men*, 1937.)

The Salinas River is the Central Coast region's largest river, flowing through the longest intermountain valley in the state. It originates in the mountains to the east of City of San Luis Obispo and flows 170 miles northward to Monterey Bay, largely paralleling U.S. Highway 101.

The Salinas has been called the "upside-down river" because it flows north and, for much of its length, underground (Fisher, 1945, referenced in U.S. National Park Service, 1992). It is one of the largest "submerged" rivers in the U.S. (California Coastal Commission, 1987), flowing through extremely porous substrates underlying the bed and flood plain.

Headwaters of the Salinas are dammed at Santa Margarita Reservoir to provide water for the City of San Luis Obispo. Coming out of the hills, the river meanders through valley lands around Atascadero and Paso Robles in San Luis Obispo County. In Monterey County, for the final half of its length, the river main stem passes through the Salinas Valley, one of the state's richest farming regions.

Near the county line, the Salinas receives waters from major tributary rivers, the Nacimiento and San Antonio, which are also dammed. The dams on the Nacimiento and San Antonio rivers were built and are operated by Monterey County water supply interests. They are used primarily for recharging groundwater in the Salinas Valley, where wells are the source of water for farms and urban use in the city of Salinas. Stored water is released from the dams to flow down the river for percolation into the ground.

The Salinas Valley in Monterey County is faced with a number of water problems including: widespread groundwater overdraft and inadequate

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water supply for recharge; seawater intrusion into aquifers near the coast caused by groundwater depletion; surface and ground water quality problems from nutrient enrichment and pesticides; and flooding. The Monterey County Water Resources Agency (MCWRA; formerly the Monterey County Flood Control and Water Conservation District) has embarked on a major planning effort to solve problems related to flood control, water supply and environmental protection. This program, the Salinas River Basin Water Resources Management Plan Study, involves the inventory of natural and socio-economic conditions; review of watershed, river and groundwater management; and study of water supply and demand (Source: various editions of the *Water Resources Quarterly*, Newsletter for the Salinas River Basin Water Resources Management Planning Project).

Although pesticides are widely used on farms in the Salinas Valley, current practices are not as significant a water quality problem as is residue from pesticides used in the past. Poisons which are now banned, such as Dieldrin and DDT, still persist in high concentrations in the soil and can enter the Salinas River through the natural processes of runoff and drainage, and through agricultural land practices. The Association of Monterey Bay Area Governments, with partial funding by USEPA, has undertaken a pilot project to assess the problem and recommend Best Management Practices to reduce pesticide migration from soil to river (Kleinfelder, Inc., 1992).

At the ocean, the Salinas River historically was blocked, except at unusually high flows, by a strip of coastal dunes and turned north to flow past Moss Landing into Elkhorn Slough. The extensive salt marshes in the area gave the Salinas River its name. Around the turn of the century, land near the coast was diked and drained for agriculture and a new mouth was created straight through the barrier dune system, leaving a only a narrow channel to Moss Landing called the Old Salinas River. However, the new "mouth" of the Salinas River is still frequently blocked at the dunes at low flows, creating a lagoon.

The Salinas Lagoon area is rich in fish and wildlife values including wetlands, dunes, riparian

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vegetation and estuarine aquatic habitats. The California Department of Parks and Recreation and the U.S. Fish and Wildlife Service both have land holdings in the lagoon and beach area. With high flows in winter, the dunes are breached, which opens the river mouth and drains the lagoon. Under certain conditions flows are high enough to cause the lagoon to back up and flood adjacent farm lands but not high enough to open the mouth.

The MCWRA has assembled the Salinas River Lagoon Task Force to address the special problems of lagoon water management for flood control and habitat protection and restoration. The group is made up of federal, state and local agencies, and other private parties and organizations. In 1993, the Salinas River Management and Enhancement Plan (prepared for the task force by a team of consultants) was released which recommends measures to address flooding and biotic resources.

In San Luis Obispo County, the upriver end of the Salinas River has long been used as a source of water for agriculture and pasture, and as an unofficial recreation site for hiking, horseback riding, and wildlife enjoyment. In recent years, the area's population has increased, leading to heavier and heavier use of the river. Trespass and vandalism problems are rampant, and local people are concerned about damage to habitats and property, and degradation of water supply and quality with increased development. Citizens have initiated a planning and problem-solving program, using the model of the Coordinated Resource Management and Planning (CRMP) process. Government agencies such as the County Parks Department and the Rivers and Trails Conservation Assistance Program of the National Park Service are assisting the effort (U.S. National Park Service, 1992). Comprehensive river planning in a community in transition from rural to more populated will be difficult, but it is important for all competing interests along the river.

Thus, the long Salinas River is finally the focus of comprehensive management in both counties through which it flows. In the future, the river will no longer be treated merely as a water supply or a flood threat, but as a renewable resource which needs to be

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managed for protection in perpetuity. Values of the river other than water supply—such as fish and wildlife habitat and public recreation—will be part of long-term management goals.

Table 8. Major Rivers in the Central Coast Region.

River	Length (mi.)	Watershed Area (sq. mi.)
Arroyo Seco	40	385
Big Sur	21	70
Carmel	35	250
Cuyama	91	1,130
Estrella	55	800
Guadalupe	12	150
Huasna	25	115
Little Sur	12	45
Nacimiento	65	325
Pajaro	40	1,190
Salinas	180	4,160
San Antonio	60	310
San Benito	80	540
San Lorenzo	25	137
Santa Maria	20	1,740
Santa Ynez	70	845
Sisquoc	45	445

Kreissman, 1991.

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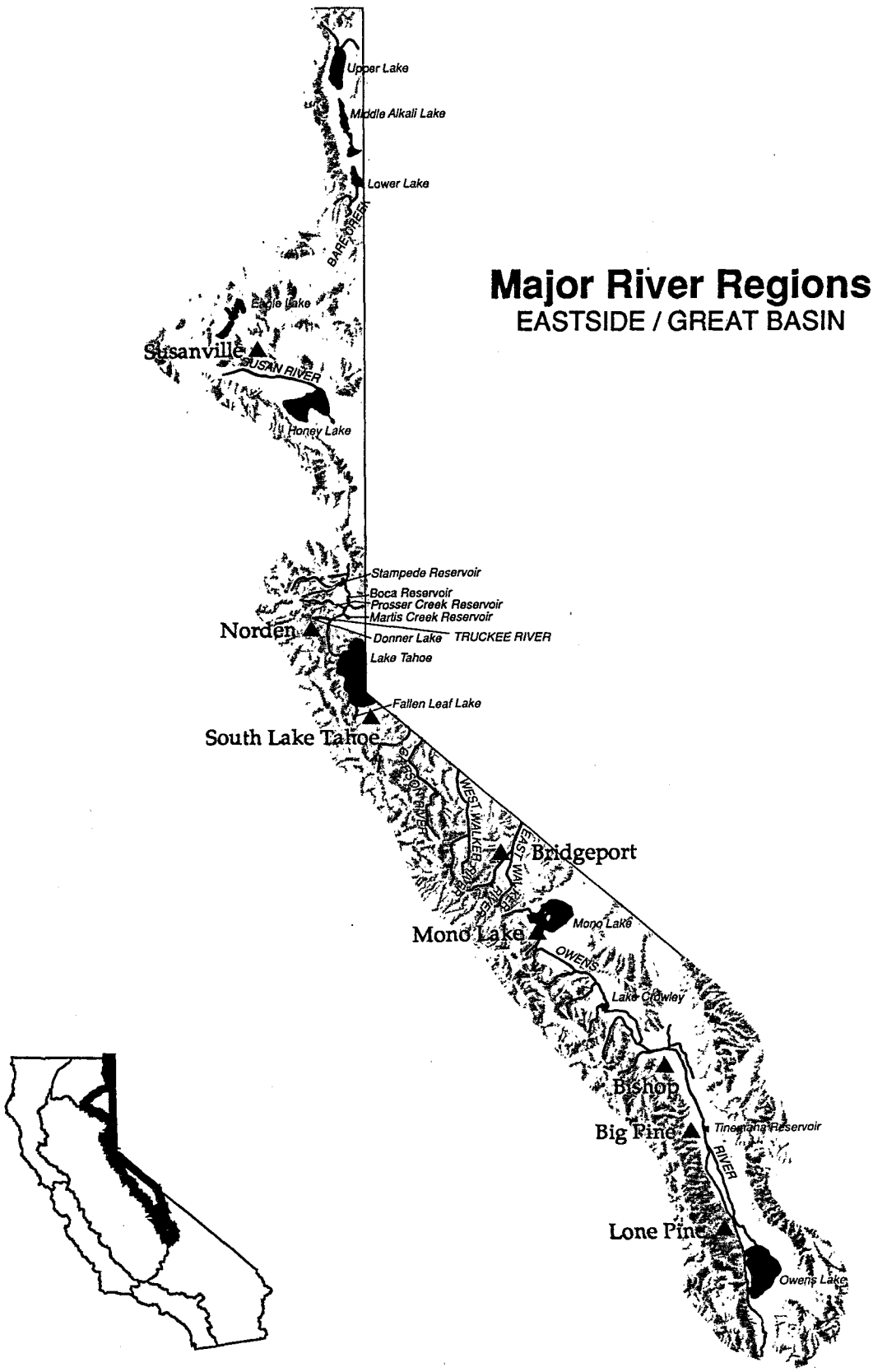

Figure 61. Eastside/Great Basin Region.

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Eastside/Great Basin Region

The Eastside/Great Basin region includes most of the California extent of the Great Basin (also called Basin and Range) Province, exclusive of the Mojave Desert. No waterways in this area drain to the sea; all dead-end in lakes or dry sinks.

During the Pleistocene epoch the Great Basin region of the United States was covered by lakes so vast they were more like inland seas. In the western part of the Great Basin, Lake Lahontan covered over 8,000 square miles. As the climate gradually dried into the modern regime, Lake Lahontan shrank, leaving a series of smaller lakes behind, including Honey Lake in California and Pyramid and Walker lakes in Nevada. These lakes are fed by rivers originating in the California mountains to the west (Minshall et al., 1989), such as the Truckee and Walker.

This region lies in the rain shadow of the Sierra-Cascade ranges and receives very little precipitation compared to the mountains to the west. The Sierra Nevada is an asymmetrical range, with a broad western slope and steep eastern slope, so rivers draining the eastern side have smaller drainage basins, relatively low flows and steep gradients. Eastside rivers are fed by high elevation snowmelt, originating in the steep eastern front of the mountains and flowing through the semiarid plateau and valley regions below. Runoff is greatest during snowmelt in May and June. Despite high precipitation on the range crest (e.g. 60 inches annually near Soda Springs), Susanville receives only 16 inches and Bishop only six inches.

Riparian tree and shrub vegetation is limited to narrow corridors along rivers in this harsh region. Even the oasis-like lower Owens River (below its gorge) in the Owens Valley, by most accounts, historically had relatively little riparian woodland and forest, but was primarily an area of extensive wet meadows and wetlands (Brothers, 1984).

The native fish fauna in this region, dominated by endemics, has been severely altered by habitat degradation and introductions of nonnative species and strains. The Lahontan Cutthroat trout was formerly wide-spread throughout much of the region, primarily inhabiting the Great Basin lakes and spawning up their tributary rivers including the Truckee, Carson and Walker. These fish were once so abundant they supported a commercial fishery in the area (Minshall et al., 1989). Because of dams, diversions and the introduction of other trout species, the Lahontan Cutthroat is now exceedingly rare and is a federal threatened species.

The Owens River has been isolated since Pleistocene time and unique fish species evolved, adapted to the difficult conditions of aquatic life in the arid environment. Native Owens Valley fish include the state and federal endangered Owens Tui Chub and

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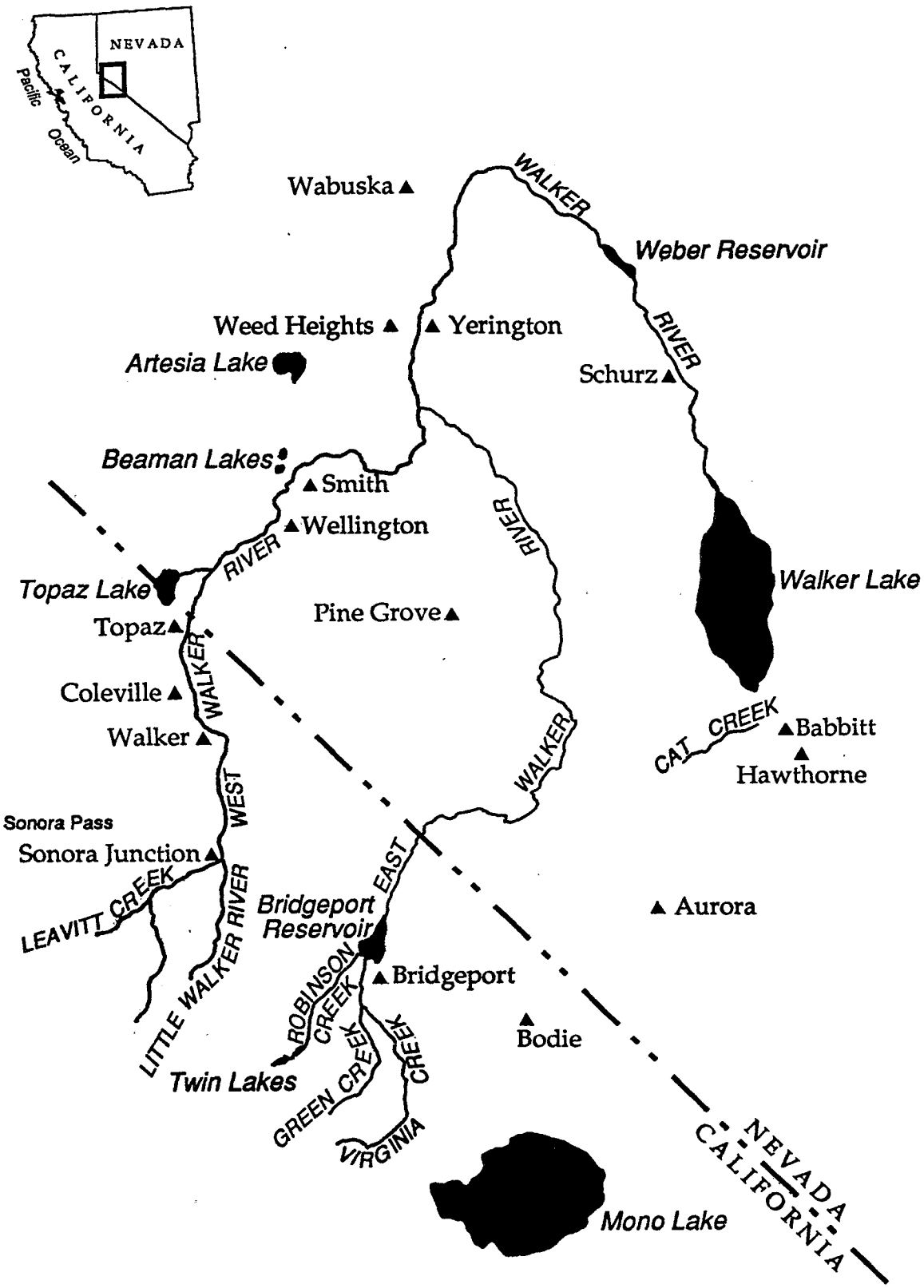

Figure 62. Walker River Watershed.

Owens Pupfish, and two California Species of Special Concern, the Owens Sucker and Owens Speckled Dace.

All of the rivers in this region have been dammed and diverted for agricultural or municipal water supply. The Truckee River, regulated by Lake Tahoe, is an important water source for Reno, Nevada and for agricultural interests in the region. As a result of diversions, its inflow into Pyramid Lake has been reduced and the lake level has fallen as evaporation has exceeded inflow.

The Owens River is probably the best known river in this region, because of the controversy over water use by the City of Los Angeles. In the gorge, the river had been diverted into penstocks which effectively dewatered the channel through the gorge, formerly a superb trout fishery. Although water eventually rejoined the channel for a short length in the upper valley, another diversion point diverts the flow again into an aqueduct for export to the City of Los Angeles (Figures 63 and 64). Below this diversion point, the river is essentially dry. The Owens River ends in Owens Lake. When Los Angeles diverted the river into its aqueduct, this once huge saline lake dried up, which is its current condition, except in wet years.

Figure 63. Owens River above Los Angeles Aqueduct.

Figure 64. Owens River below Los Angeles Aqueduct.

Such alterations in river flow, along with grazing and farming in the Owens Valley, have threatened the unique fish fauna and degraded riparian and wetland valley habitats. In addition to the direct diversion of the river, the groundwater is pumped within the valley for use in and out of the basin, which also degrades aquatic habitats. Currently, after long legal battles, the gorge fishery is being restored and plans are being formulated to restore the lower Owens River.

Case Study: Walker River

The Walker River has its headwaters in the crest of the Sierra Nevada. It runs clear and cold in the mountains down to flatter valleys to the east, ending in

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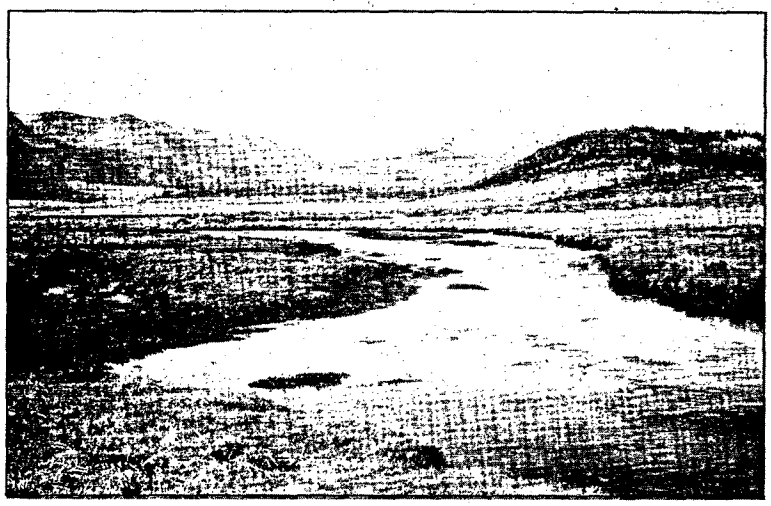
Walker Lake in Nevada. In the lowlands it becomes slower, meandering, and heavily laden with dissolved and suspended solids. The Walker is actually two forks, joining together far down its length inside Nevada. Within California, the Walker remains separate in the East Walker and West Walker rivers.

Figure 65: Walker River.



When European-American settlers first came to the area in the 1700s, the Walker River system (as well as the Carson, Truckee and other eastside rivers), supported huge spawning runs of Lahontan cutthroat trout. Up to the early 1800s a thriving commercial fishery existed in the region. With the mining boom in the area after 1850, dams and diversions begin to severely reduce cutthroat populations. On the Walker, spawning runs still survived into the 1920s and 1930s in the Antelope Valley on the West Walker and in Bridgeport Valley on the East Walker (Minshall et al., 1989).

The West Walker is larger than the East Walker, but neither is very large in total runoff. They are similar in size to most rivers in the South Coast region of California, but flow peaks are in May and June, rather than winter or early spring. Despite the small size of the Walker system, it has been the subject of many legal battles for rights to its water in this arid region. The following historical review is from the *Walker River Atlas* (DWR, 1992).

When farmers and ranchers settled the Walker River valleys in eastern California and western Nevada,

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they turned to the only decent source of water around, the river itself. At first farmers and ranchers settled close to the river for a riparian water supply. As agriculture expanded, primitive irrigation systems were developed including small seasonal dams and ditch systems. With water in short supply, a number of conflicts soon arose over water rights on the Walker, in large part between ranchers in California and Nevada. Litigation led to a federal court decree in 1919 specifying water rights in the area. In response to the litigation and decree, farmers in Nevada established the Walker River Irrigation District, to insure an adequate water supply for themselves. The Nevada based district went into California and built two reservoirs in the early 1920s, one at Topaz Reservoir on the West Walker, and one at Bridgeport on the East Walker. Shortly thereafter another lawsuit led to a new federal decree (Decree C-125) on water rights in California and Nevada, which is in existence today.

After World War II, interest grew in further developing the Walker system for additional supply. New reservoir sites were studied, including two areas on the West Walker near Sonora Junction. These were not constructed due to cost.

In recent decades, other uses of the Walker have gained importance, namely recreation and environmental protection. Fishing is quite popular on the two branches of the Walker in California, especially in the canyon paralleling Highway 395 in the West Walker and below Bridgeport Reservoir on the East Walker. Although the native Lahontan Cutthroat is no longer present, the California Department of Fish and Game actively manages both rivers for hatchery raised rainbow, brook and brown trout. In 1989 part of the West Walker was included in the California Wild and Scenic River system, precluding building the once-proposed additional reservoirs.

Today, the major conflict is not between ranchers over water rights, but between California fisheries and Nevada irrigators. In the late 1980s, the Walker River Irrigation District drained Bridgeport Reservoir to supply its Nevada farms and ranches. The fish in the reservoir died, and the release of an enormous amount of mud as the stream cut into the lake bottom resulted in a massive fish kill in the East Walker below the dam.

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Both areas had been popular for fishing. In 1988 California Trout, Inc., a fishing and environmental organization, filed a complaint with the State Water Resources Control Board. After an attempt at negotiation between the district and the California Department of Fish and Game, the SWRCB went ahead with a full investigation and water rights hearing.

Meanwhile, Mono County achieved convictions on criminal misdemeanor charges against the district for violation of California Fish and Game Code violations. Later, in 1990, the SWRCB completed its hearing process and amended the district's water right permit to protect the fishery in the reservoir pool and the river downstream. The district has now filed suit against the SWRCB, challenging its authority, on the basis that the federal Decree C-125 had already determined water rights on the river.

Within the state of Nevada, the diversion of Walker River water has its own environmental conflict. Flow reductions in the Walker have been depriving Walker Lake of its inflow, resulting in the lowering of the lake's water elevation and an increase in salinity. The Lahontan Cutthroat, now maintained by hatchery propagation, is at extreme risk of survival in the lake's salty waters. This is, of course, another example of a pervasive environmental problem occurring throughout the eastside region; Pyramid Lake, Mono Lake and Owens Lake are also drying up or have dried up due to upstream diversions.

Table 9. Major Rivers in the Eastside/Great Basin Region.

River	Length (mi.)	Watershed Area (sq. mi.)
Carson	46	280
Owens	120	1,965
Susan	59	185
Truckee	60	930
Walker	47	360

Kreissman, 1991.

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Figure 66. South Coast Region.

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South Coast Region

The South Coast region includes the watersheds of coastal streams from the Ventura River south to the Tijuana River estuary near the Mexican border. This region juxtaposes short but rugged mountain ranges with intensely developed plains and valleys. Urbanization and agricultural land use on what used to be river flood plains has led to widespread damming and channelization of the region's natural waterways.

In the north part of the region, the Transverse Ranges run east-west, as does one of the principle drainages, the long Santa Clara River, which enters the ocean between Ventura and Oxnard. Further south and east lies the urbanized Los Angeles plain which is crossed by the highly regulated Los Angeles, San Gabriel and Santa Ana rivers. Old photographs show that these rivers were already channelized by the late 1920s (Faber et al., 1989). In San Diego County, the north-south trending Peninsular Ranges are drained by a series of short rivers, including the San Luis Rey, Santa Margarita and San Diego rivers. These rivers cut into a broad mesa, or coastal terrace, as they flow to the sea.

Precipitation is low overall in the region, with 14 inches at Santa Barbara and 10 inches at San Diego. However, rain usually falls in intense cyclonic storms or local convective storms. As a result, the rivers have highly seasonal flow and enormous year-to-year variations. These rivers can be dry (or nearly so) most of the year, except for huge floods that can cause sudden rises in river stage. Most South Coast rivers are perennial in their mountainous headwaters, but intermittent or ephemeral, that is, they flow only in direct response to intense rainfall and usually dry up within days or weeks, downstream in the alluvial basins and coastal terraces. This is especially true now because of extensive groundwater withdrawals from the alluvial basins.

The broad natural channels of sand and gravel characteristic of these rivers reflect not only the extreme variation in discharge, but also their high sediment loads, especially the load of sand and gravel. Debris flows are frequent occurrences in the mountainous headwaters of these river systems, posing a chronic risk and management problem to the heavily urbanized canyons and foothills of Los Angeles. Sediment transport is now highly regulated by reservoirs, debris basins and flood control channels. Because of the trapping of the natural sediment load, the natural delivery of sand to beaches has been reduced, with the result that most of the region's beaches are now experiencing erosion problems.

The impact of development on southern region rivers has been substantial. Clearing for urbanization and agriculture destroyed and degraded riparian and aquatic habitats as did the flood control and water supply projects which accompanied such development. Table 10 illus-

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trates the degree to which controls have been placed on seven major river systems in the South Coast area.

Table 10. Major Southern California River Systems Controlled by Dams and Channelization, as of Early 1980s.

River System	% of Basin Controlled By Dams	Miles Inventoried	Channel Condition % Natural	Channel Condition %Channelized
Ventura	42	90	70	30
Santa Clara	37	320	49	41
Los Angeles	40	235	12	89
San Gabriel	84	106	42	59
Santa Ana	90	278	36	64
San Luis Rey	37	141	60	39
San Diego	61	141	69	31

* Includes main river channel and major tributaries.

Faber et al., 1989

Other current threats to river corridors in the South Coast include sand and gravel mining, off-highway vehicle damage, illegal dumping, pollution, and introduced plant and animal species. Rivers that are not completely channelized still remain and offer good potential for restoration, such as the San Luis Rey and Santa Margarita rivers in San Diego County (Faber et al., 1989).

Natural riparian vegetation along river flood plains in the South Coast is dominated by many species common to river valleys throughout the state, including Fremont and black cottonwood, willows, sycamore and white alder. Historically such vegetation was found along many rivers and streams of the area, but was probably less extensive than in other parts of the state due to the more arid conditions. Currently, less than five percent of the natural riparian vegetation remains in the south coast (Faber et al., 1989).

In southern California mountain canyons, several tree species which are found normally upland in the northern part of the state, become restricted to riparian environments—including coast live oak, canyon live oak and California bay, which grow together with the more typically riparian white alder, cottonwoods and sycamore. Canyons are subject to less urban and agricultural development than valley flood plains, and thus have more natural riparian vegetation remaining. However, such areas are often subject to heavy recreational use.

Alluvial outwash fans on rivers and streams flowing out of the San Gabriel, San Bernardino and San Jacinto mountains support a unique type of scrubby vegetation (Hanes et al., 1989). Alluvial fan scrub is composed of species adapted for the extreme conditions of

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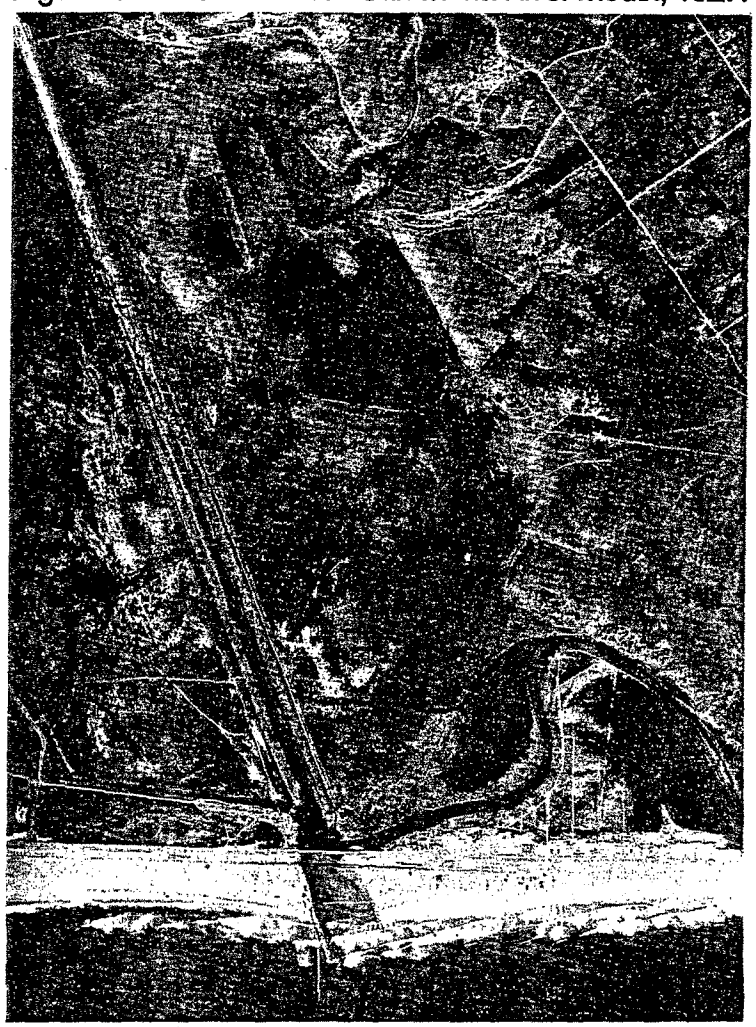
mostly dry sandy and gravelly soils subject to infrequent but intense floods. Scale-broom, California buckwheat and mulefat are some of the common species. Such alluvial fan scrub once covered much of the Los Angeles Basin (Faber et al., 1989). Flood plain development and other impacts have almost completely eliminated this plant community (Hanes et al., 1989). Two alluvial fan scrub plants are state and federally listed endangered species—the Santa Ana River Woolly-star and the Slender-horned Spineflower.

Figure 67. Channelized Santa Ana River Mouth, 1927.



Source: Whittier College Geology Department Fairchild Collection, photo date 1927.

Where they met the ocean, many rivers and streams in the South Coast area formed large estuarine ecosystems. Flood control projects and shore zone development have now drastically reduced and fragmented most southern California estuarine systems.

The Least Bell's Vireo, a state and federally endangered bird species, is dependent upon willow-dominated riparian vegetation for suitable nesting sites. This bird has declined more drastically than other passerine (perching songbird) species in California (US Fish and Wildlife Service, 1986.) Habitat loss throughout the state has limited the species to a few nesting areas, with southern California rivers some of the few remaining important sites. Continuing habitat loss and nest predation by the Brown-headed Cowbird critically threaten the Least Bell's Vireo.

The native fish fauna was never very diverse in the South Coast region, but all species have suffered significant declines. Most native species are so limited they are now species of concern, includ-

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ing the Santa Ana Sucker, the Santa Ana Speckled Dace, and the Arroyo Chub. The Unarmored Threespine Stickleback, a state and federally endangered fish species, is restricted to the upper Santa Clara River system and one other isolated transplanted population in San Diego County.

Remarkably, numerous South Coastal rivers and streams, all the way through to San Diego County, once supported steelhead runs of 5,000 to 20,000 adults. Now, all runs are lost except remnant populations in the Ventura and Santa Clara river systems and Malibu Creek in the Santa Monica Mountains (Nehlsen et al., 1991). Sespe Creek, a tributary of the Santa Clara River, contains almost all of the suitable steelhead spawning habitat left in the system (Keep the Sespe Wild Committee, 1992). Efforts are underway by public interest environmental groups and government agencies to restore the steelhead populations in southern California.

Case Study: Santa Ana River—
Flood plain Development

The Santa Ana River basin is the largest in the South Coast region, with a watershed of 2,400 square miles. The Santa Ana River is the principal drainage of the San Bernardino Mountains. The large watershed size and high elevation of its headwaters region caused the Santa Ana River in its natural state to flood with tremendous force, albeit infrequently. In the flood of record in 1938, the Santa Ana River carried over 40,000 cfs as it emerged from the San Bernardino Mountains.

In the San Bernardino Mountains, the Santa Ana River and tributaries support typical riparian plant communities of cottonwood, willows, white alder and sycamore (Faber et al., 1989). Where the river system comes out of the mountains northeast of Redlands, it forms a wide flood plain wash, with unique alluvial fan scrub vegetation. Flowing westward over the plain past the City of Riverside, the river goes through the Prado Basin, the Santa Ana River Canyon in the Santa Ana Mountains, and then to the sea. Lowland riparian forests and woodlands still remain along the Santa Ana River where it has not yet been channelized (Hanes, 1984). Where the river historically met the ocean, in a location in present-day Orange County, it once flowed through a marsh thousands of acres in size, winding south into lower Newport Bay. Now the lower river

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runs straight into the ocean in a concrete channel, with only fragments of marshland left in the area (California Coastal Commission, 1987). The lower 23 miles of the Santa Ana River was channelized to the Pacific by 1927 (Faber et al., 1989) . Prado Dam was constructed on the river in the Santa Ana Mountains in 1941, flooding the Prado Basin with a flood control reservoir.

Urbanization, of course, is widespread in the area, including within the natural flood plain of the Santa Ana River. The flood protection intended by Prado Dam and previous channelization is now judged by the Army Corps of Engineers to be inadequate to protect the coastal plain of Orange County. In part, this was due to increased run-off in the watershed due to urbanization, and to the silting in of Prado Reservoir, which decreased its flood storage capacity. In addition, the now-developed areas of Riverside and San Bernardino counties in the river flood plain above the Prado Basin are also considered vulnerable to flood hazard. The Corps estimates that billions of dollars of property values and millions of people are at risk, stating "[t]he Santa Ana River is currently the worst flood threat west of the Mississippi River" (U.S. Army Corps of Engineers, 1989).

While the Santa Ana River may pose a serious flood threat to humans, the flood control works the Corps has planned to constrain the river and its tributaries are an equally serious threat to ecological values in the area. New upstream dams and levees east of Redlands will destroy aquatic and riparian habitats, including alluvial fan scrub.

Currently the Prado Basin contains the largest riparian woodland in southern California (Faber et al., 1989). When Prado Dam was built, it resulted in the destruction of significant amounts of riparian habitat. However, new riparian habitat has become established in the basin due to the reservoir, and it is possible that there is actually more habitat now then there was historically in the Prado Basin (U.S. Fish and Wildlife Service, 1986). However, it should be noted that channelization below the dam resulted in the loss of extensive amounts of riparian habitat.

The endangered Least Bell's Vireo is found in the Santa Ana River system, including the Prado Basin and below the dam. Part of the Corps' proposed flood control retrofit is to enlarge Prado Dam, which could

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endanger the Vireo, as well as other wildlife.

Ironically, as the pressure to control the river grows, so has an appreciation of the natural values of the river. The Santa Ana River Trail is a multiagency project to create a continuous trail from the San Bernardino National Forest to the Pacific Ocean. (Figure 68).

Figure 68. Santa Ana River, Restored Segment.

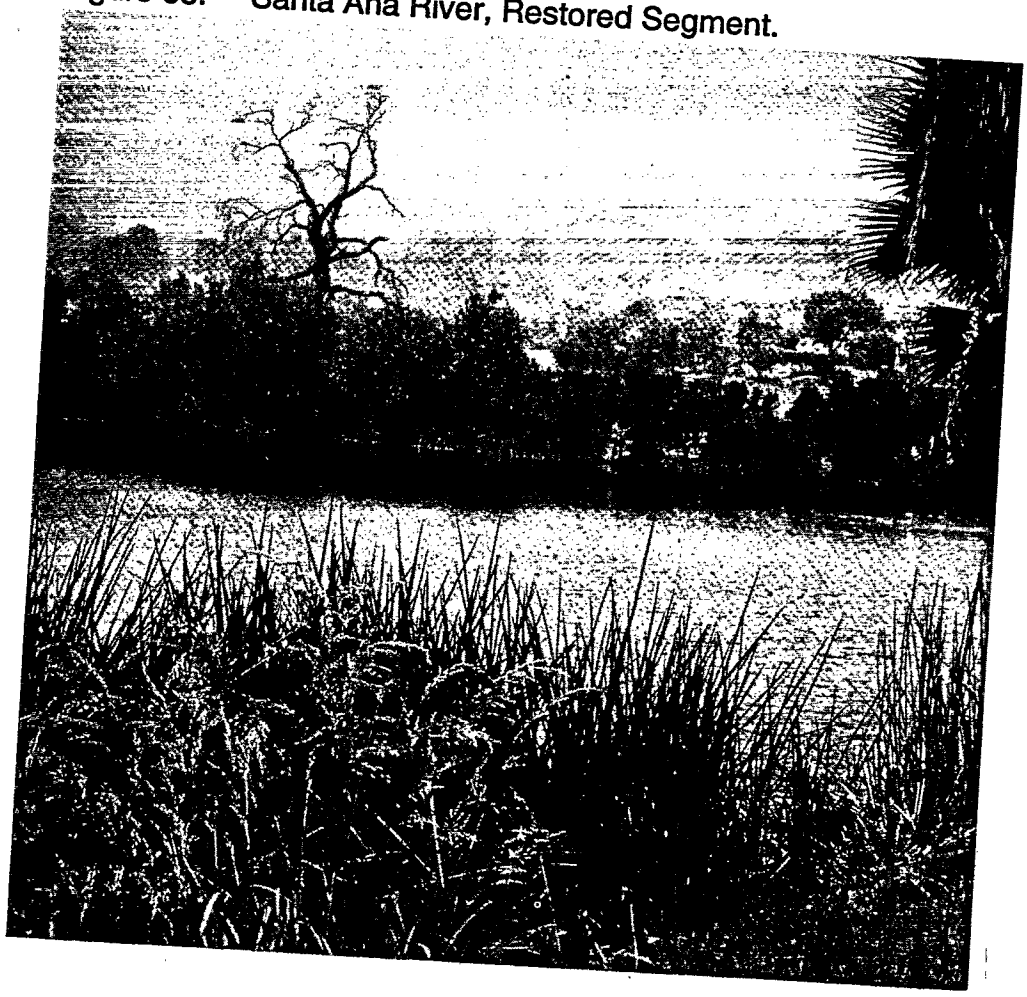

Table 11. Major Rivers in the South Coast Region.

River	Length (mi.)	Watershed Area (sq. mi.)
Los Angeles	97	830
Otay	25	135
Rio Hondo	20	125
San Diego	45	439
San Dieguito	11?	300
San Gabriel	59	350
San Jacinto	38	725
San Luis Rey	51	575
Santa Ana	93	1,700
Santa Clara	75	1,616
Santa Margarita	11?	740
Sweetwater	11?	190
Ventura	33	190

Kreissman, 1991.

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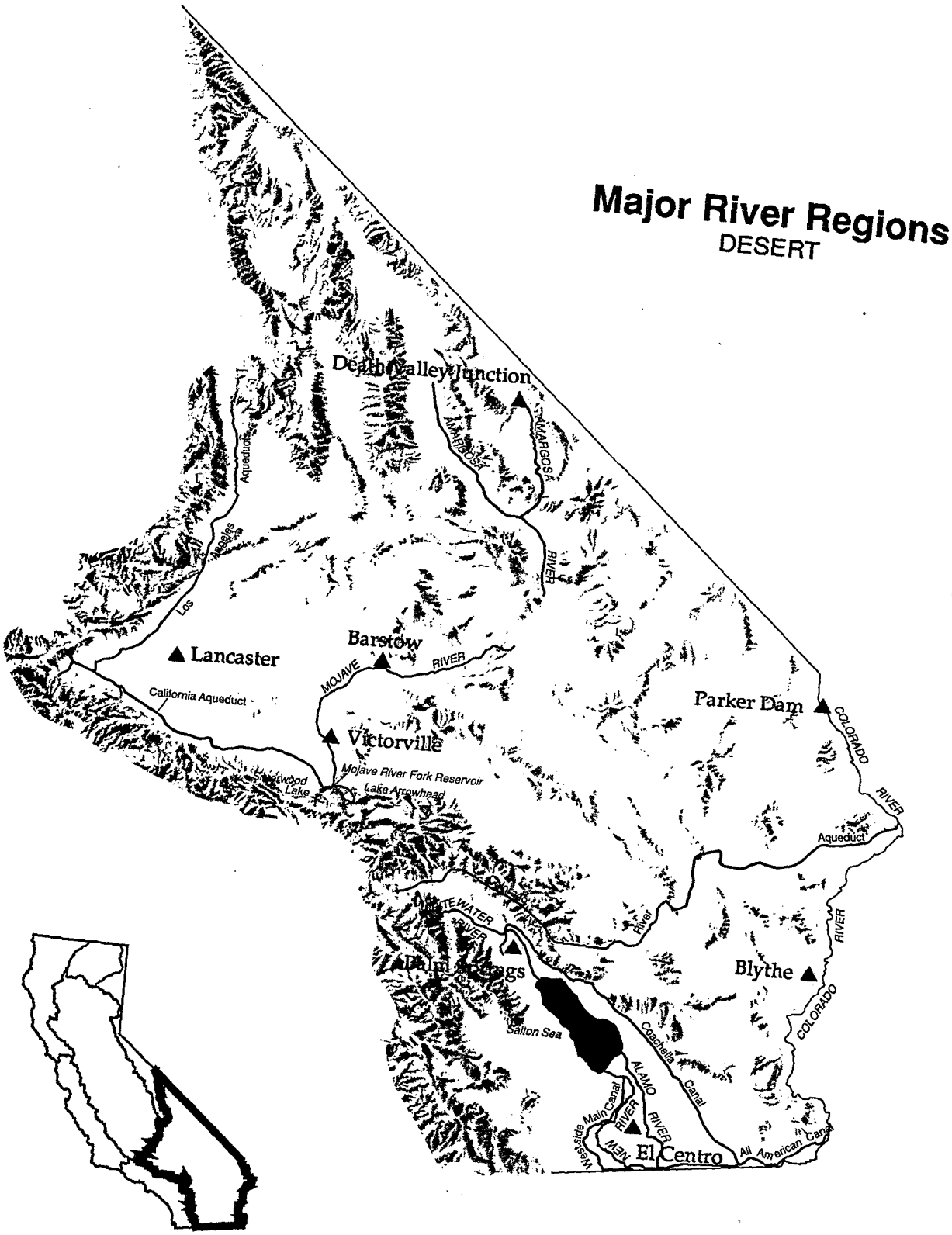

Figure 69. Desert Region.

Desert Region

The Desert region of California encompasses the Mojave and Colorado (Sonoran) desert areas. This combines the southern part of the Lahontan hydrologic basin with the Colorado River basin.

Rainfall in the desert is low and evaporation high. Barstow receives just over four inches annually. Natural rivers in this region are few and are mostly ephemeral. The Amargosa and Mojave rivers are the two purely "desert" rivers within the state. Their channel flood plains are dry washes, except for points where high ground water tables bring water to the surface and support distinctive riparian and aquatic communities.

The Amargosa River arises in mountains in Nevada, flows south into California, then loops north to Death Valley, although surface water rarely reaches all the way to this end point. The Amargosa River is dry for most of the year, except for isolated flash floods.

The few places with surface water, fed by springs, along the Amargosa are "ecological islands" and support uncommon flora and fauna, such as in the Amargosa Canyon in San Bernardino County (Williams, J. et al., 1984). At the California-Nevada border, the Amargosa River passes through Ash Meadows, an area of spring-fed wetlands which has more endemic plant and animal species than any other area in the United States (Williams, C., 1984). Amargosa River aquatic and wetland biotic resources are threatened by the invasion of nonnative competitors and predators, and by declines in surface water quantity and quality from human activities.

Case Study: Colorado River

The most exceptional river in the desert region is the Colorado River, which drains 242,000 square miles of the Rocky Mountains and Colorado Plateau. Seven states share the length of the river's 1,700 miles as it falls nearly two vertical miles. The Colorado River passes California, forming the state's border with Arizona, then flows into Mexico and the Sea of Cortez (Gulf of California).

With an unimpaired average annual flow of 15 million acre-feet, the Colorado River in its natural state is between the Klamath and Sacramento rivers in size. The Colorado once carried immense silt loads, at concentrations ten times greater than the Nile (California Water Atlas, 1979). Natural flows varied widely between years, including occasional massive spring and summer

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floods with heavy sediment deposition.

The lower Colorado River (below Hoover Dam) was formerly an actively meandering river system, bordered by extensive riparian forests and wetlands. It flowed into the Sea of Cortez through its enormous migrating delta system below Yuma. The river naturally flooded its bottomlands with large silt-laden flood pulses. The New and Alamo rivers in the Imperial Valley were in fact old flood channels of the Colorado River conveying overflow northward into the Salton Sink from Mexico. At the turn of the century, an attempt was made at diverting irrigation water from the Colorado River to the Imperial Valley via the Alamo River and various canals. Massive spring floods in 1905 broke through canal levees, sending the whole Colorado River north for a while, forming what is now the Salton Sea (California Water Atlas, 1979).

The lower Colorado ecosystem was a rich and diverse area of river channels, sloughs and small back channels, marshes, arrowweed and willow scrub lands, cottonwood and willow flood plain forests, and mesquite bosques. There were at least 5,000 acres of cottonwood communities along the lower Colorado in the 1600s (Ohmart et al., 1977). The fish fauna was small but unique, including Bonytail, Colorado Squaw-fish and Razorback Sucker, which were all probably quite abundant (Minckley and Brown, 1982). In addition, Desert Pupfish were found in pools and marsh channels in the backwaters of the river (Moyle, 1976).

Today, it is hard to imagine a river with more alterations to its natural system and more conflict over its waters than the Colorado. Its silt-laden floods are now almost completely tamed by a sequence of massive reservoirs upstream, including Lake Mead (Hoover Dam) and Lake Powell (Glen Canyon Dam). The lower river is nearly completely artificial, with channel cuts, levees, and over a half dozen smaller impoundments from Needles to Yuma. Essentially all of the flow of the Colorado is appropriated for consumption, divided among seven states and Mexico under the Colorado River Compact. California takes by far the largest share of water from the Colorado, which supplies more than one-half the water used in Southern California.

Spanish explorers and later Anglo-American

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explorers and settlers to the lower Colorado began a process of impacts to the riparian and other habitats which has resulted in the near extirpation of native communities on the river. First, riparian forests were cut for fuelwood, and land cleared for agriculture. The modern dams and channelization works for flood control followed settlement, as did water diversions for irrigation and eventually for water supply for southern California. Tamarisk, or salt cedar, was introduced shortly after turn of the century and has spread vigorously throughout the bottomlands. The drastic changes in annual flow patterns following the closure of Hoover Dam has permitted Tamarisk to compete successfully for remaining groundwater in the former flood plain. Tamarisk provides little habitat for the local wildlife species, and is somewhat more water-using than indigenous vegetation.

The formerly extensive riparian habitat of this system has been reduced to a fragment of its original size. Because flow no longer varies in a natural way, riparian vegetation succession has been arrested, precluding natural reestablishment of riparian forests and woodlands. By the 1970s only a little over one-half the cottonwood-willow riparian forest remained (Ohmart et al., 1977). High water in 1983 and 1986 has all but eliminated most cottonwood-willow habitat (Laymon and Halterman, 1989). Today only a few isolated, mostly degraded willow and cottonwood stands can be found.

With such a severe loss of riparian, marsh and aquatic habitats, it is no surprise that the fish and wildlife species dependent upon them also have declined. The Colorado River has more species unique to it that are at critical risk of extinction than any other river in California. For example, along the entire lower Colorado, recent surveys have observed only a few successful breeding pairs of the Western Yellow-billed Cuckoo (Laymon and Halterman, 1989) and Gila Woodpecker (DFG, 1992). The Desert Pupfish and Colorado Squawfish no longer exist naturally in the lower Colorado and the Bonytail and Razorback Sucker are on the verge of extirpation.

These environmental problems are being addressed by several federal and state agencies with

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jurisdiction and interests in the Colorado river. According to a 1986 Bureau of Land Management jurisdiction map, of the 529 miles from Davis dam down to Yuma, there are only about 40 river miles of private riparian land on the California side, and 35 river miles of private land on both sides. Indian reservations, National Wildlife Refuges, Bureau of Reclamation (BOR) land and BLM and Arizona state lands include or at least abut the Colorado. The following identifies agencies' efforts to coordinate river management:

- The BOR, in concert with US Fish and Wildlife Service (USFWS), has inventoried environmental problems along the Lower Colorado and is beginning to revegetate a few places. Some modest adjustments of its water-diversion and -regulation functions have been made or agreed to. However, the old water contracts were based on wetter than normal years, so flows have seldom exceeded the amounts committed. Thus, there is not much hope for renegotiating the contracts with the seven states and Mexico to decrease their water entitlements for the benefit of the fishery or habitat uses.
- The USFWS operates the Lake Havasu, Cibola and Imperial National Wildlife refuges on the Lower Colorado. Their primary concerns in this area are to manage the refuges, to identify and map wetlands, and to ameliorate recreation's impact on wetlands and endangered species.
- The Fort Mojave, Chemehuevi, Colorado River and Fort Yuma Indian reservations in general operate as independent "nations." They have their own interests to pursue, including the concessioning of recreational development proposals. The tribes need not do environmental reporting for such projects, and are subject only to a limited range of regulatory requirements such as Section 404 of the Clean Water Act, Section 106 of the National Historic Preservation Act (re Cultural Resources), and the Endangered Species Act.
- BLM riparian lands in this desert terrain are managed primarily for recreational use. The primary users are southern Californians from Orange and Los Angeles counties. By agreement with the California State BLM Office, the Yuma

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District office also manages California BLM lands in the river valley. Providing river access facilities (launching ramps, day use and overnight camps, and marina concessions operating on BLM land) forms a major policy component of the district's responsibilities. However, user statistics have been only casually collected until recently. BLM is currently seeking a more active role in river habitat maintenance and improvement.

- Arizona State Lands Department lands along the river are managed in a similar manner as BLM for enabling and enhancing public (primarily recreational) use, and maintaining environmental values where these are not mutually incompatible.
- The Arizona State Parks Department has begun planning (in cooperation with Arizona Game and Fish and U.S. Fish & Wildlife Service) for enhancement of Arizona wetlands, the Colorado River included. Its statewide Rivers, Streams and Wetlands Study (1989) resulted in creation of a Governor's Riparian Habitat Task Force to define, classify and identify riparian areas' quality and needs. This program has resulted in a major Wetlands Inventory Database. State legislation also ensued, creating the Arizona Heritage Fund, in which $20 million a year from lottery receipts are designated for parks, trails, natural area acquisition, historic and archaeological preservation, and education. In addition, by a Governor's Executive Order, Arizona state government now has an official Riparian Protection Policy statement to guide its decisions and actions affecting wetlands.
- The California Department of Fish and Game and the Arizona Game and Fish Department have similar missions and methods, except the absence of a comparable environmental review process (CEQA) in Arizona for private projects. The National Environmental Policy Act (NEPA) and Clean Water Act Section 404 allow review and comment on federal projects on the Arizona side, however, and most of the riparian land there is federally owned.
- The California State Lands Commission's (SLCs) interest in the Colorado has been primarily to identify its last natural bed and to lease or exchange

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these lands to adjacent owners (principally farmers) for purposes of the Kapiloff Land Bank. The land bank process is invoked to benefit the trust for commerce, navigation and fisheries which characterizes the natural navigable waterways of California. Through the land bank process, the commission receives land which can be used for riparian habitat, recreational, use or access, or other environmental value, in exchange for releasing all of its title to the original bed of the river. These transactions usually occur where oxbows or berm areas are left high and dry by past diking or rechanneling of the river. Thus, they usually take place in sediment-deposit areas of flat valleys, rather than in steeper sediment-cutting river reaches. On the Colorado, that means generally from the Palo Verde Valley around Blythe, California downstream to its mouth at the Gulf of Mexico.

These programs demonstrate success in effective coordination. Agencies and private groups with interests in restoring resources of the river are agreeing to do so in "bite-sized" pilot or demonstration project.

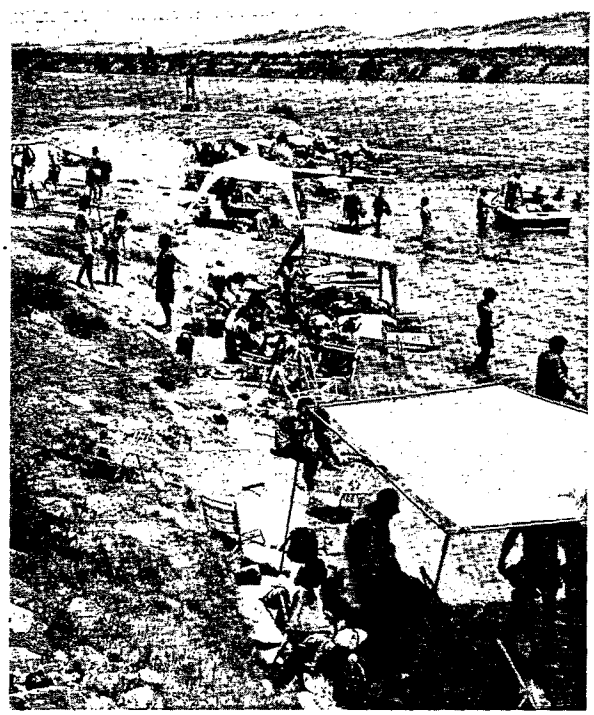

Figure 70. Recreation on the Colorado River.

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Table 12. Major Rivers in the Desert Region.

River	Length (mi.)	Watershed Area (sq. mi.)
Alamo	52	695
Amargosa	198	3,090
Colorado	230	3,950
Mojave	100	2,120
New	60	1,000
San Gregorio	30	155
Whitewater	25	1,500

Kreissman, 1991.

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Table 13. Common or Indicator Riparian Plants of California.

Scientific name	Common name
Abies grandis	Grand Fir
Acer circinatum	Vine Maple
Acer macrophyllum	Big-leaf Maple
Acer negundo var. californicum	Box Elder
Aesculus californica	Buckeye
Ailanthus altissima (Intro.)	Tree-of-heaven
Alnus rhombifolia	White Alder
Alnus rubra	Red Alder
Alnus incana ssp. *tenuifolia*	Mountain Alder
Artemisia douglasiana	Mugwort
Aristolochia californica	Dutchman's Pipevine
Arundo donax (Intro.)	False-bamboo
Baccharis salicifolia	Mule Fat, Seep-willow
Betula occidentalis	Water Birch
Cephalanthus occidentalis var. *californicus*	Buttonbush, Button-willow
Clematis ligustifolia	Virgin's Bower
Cornus glabrata	Brown Dogwood
Cornus sericea ssp.	American Dogwood
Cortaderia jubata	Jubata (Pampas) Grass
Eichornia crassipes (Intro.)	Water Hyacinth
Equisetum spp.	Horsetail
Eriogonum fasciculatum var.	California buckwheat
Ficus carica (Intro.)	Common Fig
Fraxinus latifolia	Oregon Ash
Fraxinus velutina	Velvet Ash
Juglans californica var. *hindsii*	Northern California Black Walnut
Juglans nigra (Intro.)	Eastern Black Walnut
Lepidospartum squamatum	Scale-broom
Leymus triticoides	Creeping Wildrye
Phragmites australis	Common Reed
Picea sitchensis	Sitka Spruce
Pinus contorta ssp. *murrayana*	Lodgepole Pine
Platanus racemosa	Western Sycamore
Pluchea sericea	Arrow Weed
Populus fremontii	Fremont Cottonwood
Populus balsamifera ssp. *trichocarpa*	Black Cottonwood
Populus tremuloides	Aspen
Prosopis glandulosa var. *torreyana*	Honey Mesquite
Prosopis pubescens	Screw-bean Mesquite
Quercus agrifolia	Coast Live Oak
Quercus chrysolepis	Canyon Live Oak
Quercus kellogii	Black Oak
Quercus lobata	Valley Oak
Quercus wislizenii var. *wislizenii*	Interior Live Oak
Rubus procerus (Intro.); *R. ursinus*	Blackberries
Salix exigua	Sandbar Willow; Narrowleaf Willow
Salix geyeriana	Geyer's Willow
Salix goodingii	Gooding's Black Willow
Salix hookeriana	Coastal Willow
Salix laevigata	Red Willow
Salix lasiolepis	Arroyo Willow
Salix lucida ssp. *lasiandra*	Yellow Tree Willow
Salix lutea	Yellow Willow
Salix scouleriana	Scouler's Willow
Sambucus mexicana	Blue Elderberry
Sambucus racemosa var. *racemosa*	Red Elderberry
Sequoia sempervirens	Coast Redwood
Shepherdia argentea	Buffalo Berry
Tamarix parviflora; T. ramosissima	Salt Cedar, Tamarisk
Toxicodendron diversilobum	Poison Oak
Typha spp.	Cattails
Umbellularia californica	California Bay
Vitis californica	Wild Grape
Vitis girdiana	Desert Wild Grape

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Table 14. Common or Indicator Animals of California.

	Distribution by Region +
Amphibians	
Northwestern Salamander *Ambystoma gracile*	NC
Western Toad *Bufo boreas*	NC,CV,Mo,CC,ES,SC
Pacific Giant Salamander *Dicamptodon ensatus*	NC
California Treefrog *Hyla cadaverina*	NC
Pacific Treefrog *Hyla regilla*	NC,CV,Mo,CC,ES,SC
Bullfrog *Rana catesbeiana*	NC,CV,Mo,CC,ES,SC,D
Rough-skinned Newt *Taricha granulosa*	Mo
California Newt *Taricha torosa**	CV,Mo
Reptiles	
Rubber Boa *Charina bottae*	NC,CV,Mo,CC
Common Kingsnake *Lampropeltis getulus*	
NC,CV,Mo,CC,ES,SC,D	
Western Aquatic Garter Snake *Thamnophis couchi*	NC,VC,Mo,CC,SC
Western Terrestrial Garter Snake *Thamnophis elegans*	NC,CV,CC
Common Garter Snake *Thamnophis sirtalis*	NC,CV,Mo,CC,SC
Birds	
Spotted Sandpiper *Actitis macularia*	NC,CV,Mo,CC,ES,SC,D
Red-winged Blackbird *Agelaius phoeniceus*	NC,CV,Mo,CC,ES,SC,D
Wood Duck *Aix sponsa*	NC,CV,CC,SC
Scrub Jay *Aphelocoma coerulescens*	NC,CV,Mo,CC,ES,SC
Black-chinned Hummingbird *Archilochus alexandri*	CV,Mo,CC,ES,SC,D
Cedar Waxwing *Bombycilla cedrorum*	NC,CV,Mo,CC,ES,SC,D
American Bittern *Botaurus lentiginosus*	NC,CV,Mo,CC,ES,SC,D
Great Horned Owl *Bubo virginianus*	NC,CV,Mo,CC,ES,SC,D
Red-tailed Hawk *Buteo jamaicensis*	NC,CV,Mo,CC,ES,SC,D
Rough-legged Hawk *Buteo lagopus*	NC,CV,Mo,CC,ES,SC,D
Red-shouldered Hawk *Buteo lineatus*	NC,CV,CC,SC
Green-backed Heron *Butoroides striatus*	NC,CV,CC,SC,D
California Quail *Callipepla californica*	NC,CV,Mo,CC,ES,SC,D
Lesser Goldfinch *Carduelis psaltria*	NC,CV,Mo,CC,ES,SC,D
American Goldfinch *Carduelis tristis*	NC,CV,Mo,CC,ES,SC,D
House Finch *Carpodacus mexicanus*	NC,CV,Mo,CC,ES,SC,D
Purple Finch *Carpodacus purpureus*	NC,CV,Mo,CC,ES,SC
Swainson's Thrush *Catharus ustulatus*	NC,CV,Mo,CC,ES,SC
Belted Kingfisher *Ceryle alcyon*	NC,CV,Mo,CC,ES,SC,D
Killdeer *Charadrius vociferus*	NC,CV,Mo,CC,ES,SC,D
American Dipper *Cinclus mexicanus*	NC,CV,Mo,CC,ES,SC
Northern Flicker *Colaptes auratus**	NC,CV,Mo,CC,ES,SC,D
Western Wood-Peewee *Contopus sordidulus*	NC,CV,Mo,CC,ES,SC
American Crow *Corvus brachyrhynchos*	NC,CV,Mo,CC,ES,SC,D
Common Raven *Corvus corax*	NC,CV,Mo,CC,ES,SC,D
Stellar's Jay *Cyanocitta stelleri*	NC,CV,Mo,CC,ES,SC
Pacific-slope Flycatcher *Empidonax difficilis*	NC,CV,CC,SC
Brewer's Blackbird *Euphagus cyanocephalus*	NC,CV,Mo,CC,ES,SC,D
American Kestrel *Falco sparverius*	NC,CV,Mo,CC,ES,SC,D
Common Yellowthroat *Geothlypis trichas*	NC,CV,Mo,CC,ES,SC,D

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Table 14. Continued.

	Distribution by Region +
Northern Pigmy Owl *Glaucidium gnoma*	NC,CV
Blue Grosbeak *Guiraca caerulea*	CV,CC,ES,SC,D
Cliff Swallow *Hirundo pyrrhonota*	NC,CV,Mo,CC,ES,SC,D
Hooded Oriole *Icterus cucullatus*	NC,CV,CC,ES,SC,D
Northern Oriole *Icterus galbula*	NC,CV,Mo,CC,ES,SC,D
Dark-eyed Junco *Junco hyemalis*	NC,CV,Mo,CC,ES,SC,D
Hooded Merganser *Lophodytes cucullatus*	NC,CV,Mo,CC,SC,D
Acorn Woodpecker *Melanerpes formicivorus*	NC,CV,Mo,CC,SC
Song Sparrow *Melospiza melodia*	NC,CV,Mo,CC,ES,SC,D
Lincoln's Sparrow *Melospiza lincolnii*	NC,CV,Mo,CC,ES,SC,D
Common Merganser *Mergus merganser*	NC,CV,Mo,CC,ES,SC,D
Northern Mockingbird *Mimus polyglottos*	NC,CV,Mo,CC,ES,SC,D
Brownheaded Cowbird *Molothrus ater*	NC,CV,Mo,CC,ES,SC,D
Ash-throated Flycatcher *Myiarchus cinerascens*	NC,CV,Mo,CC,ES,SC,D
Brown-crested Flycatcher *Myiarchus tyrannulus*	D
Western Screech-owl *Otus kennicottii*	NC,CV,Mo,CC,ES,SC,D
Plain Titmouse *Parus inornatus*	NC,CV,Mo,CC,ES,SC,D
Fox Sparrow *Passerella iliaca*	NC,CV,Mo,CC,ES,SC
Lazuli Bunting *Passerina amoena*	NC,CV,Mo,CC,ES,SC
Yellow-billed Magpie *Pica nuttalli*	CV,CC
Black-billed Magpie *Pica pica*	Mo,ES
Nuttall's Woodpecker *Picoides nuttallii*	NC,CV,Mo,CC,SC
Downy Woodpecker *Picoides pubescens*	NC,CV,Mo,CC,SC
Hairy Woodpecker *Picoides villosus*	NC,CV,CC,ES,SC
Pine Grosbeak *Pinicola enucleator*	CV
Albert's Towhee *Pipilo alberti*	D
California (Brown) Towhee *Pipilo crissalis*	NC,CV,CC,SC
Rufous-sided Towhee *Pipilo erythrophthalmus*	NC,CV,Mo,CC,ES,SC,D
Bushtit *Psaltriparus minimus*	NC,CV,Mo,CC,ES,SC,D
Great-tailed Grackle *Quiscalus mexicanus*	D
Black Phoebe *Sayornis nigricans*	NC,CV,CC,SC,D
Rufous Hummingbird *Selasphorus rufus*	NC
Allen's Humminbird *Selasphorus sasin*	NC,CC,SC
White-breasted Nuthatch *Sitta carolinensis*	NC,CV,Mo,CC,ES,SC
Red-breasted Sapsucker *Sphyrapicus ruber*	NC,CV,Mo,CC,ES,SC
Northern Rough-winged Swallow *Stelgidopteryx serripennis*	NC,CV,Mo,CC,ES,SC,D
Calliope Hummingbird *Stellula calliope*	NC,CV,Mo
Tree Swallow *Tachyncineta bicolor*	NC,CV,Mo,CC,ES,SC,D
Bewick's Wren *Thyromanes bewickii*	NC,CV,Mo,CC,ES,SC,D
House Wren *Troglodytes aedon*	NC,CV,Mo,CC,ES,SC,D
American Robin *Turdus migratorius*	NC,CV,Mo,CC,ES,SC,D
Common Barn Owl *Tyto alba*	NC,CV,Mo,CC,ES,SC,D
Warbling Vireo *Vireo gilvus*	NC,CV,Mo,CC,ES,SC
Hutton's Vireo *Vireo huttoni*	NC,CV,CC,ES,SC
Wilson's Warbler *Wilsonia pusilla*	NC,CV,Mo,CC,ES,SC
Mourning Dove *Zenaida macroura*	NC,CV,Mo,CC,ES,SC,D
Golden-crowned Sparrow *Zonotrichia atricapilla*	NC,CV,Mo,CC,ES,SC
White-crowned Sparrow *Zonotrichia leucophrys*	NC,CV,Mo,CC,ES,SC,D

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Table 14. Continued.

	Distribution by Region + Mammals
Mountain Beaver *Aplodontia rufa* *	K,CV,Mo
Ringtail *Bassariscus astutus*	NC,CV,Mo,CC,ES,SC,D
Beaver *Castor canadensis*	NC,CV,Mo,CC,ES,SC,D
Virginia Opposum *Didelphis virginiana* I	NC,CV,Mo,CC,SC
Mountain Lion *Felis concolor**	NC,CV,Mo,CC,ES,SC,D
Bobcat *Felis rufus*	NC,CV,Mo,CC,ES,SC,D
River Otter *Lutra canadensis*	NC,CV,Mo
Striped Skunk *Mephistis mephistis*	NC,CV,Mo,CC,ES,SC,D
Yuma Myotis *Myotis yumanensis*	NC,CV,Mo,CC,ES,SC,D
Mink *Mustela vison*	NC,CV,Mo,ES
Dusky-footed Woodrat *Neotoma fuscipes* *	NC,CV,Mo,CC,SC
California Mule Deer *Odocoileus hemionus californicus*	NC,CV,Mo,ES,D
Black-tailed Deer *Odocoileus hemionus columbianus*	NC,CV,Mo,CC,SC
Muskrat *Ondratra zibethicus*	NC,CV,Mo,CC,ES,D
Harbor Seal (in tidal reaches) *Phoca vitulina*	NC
Raccoon *Procyon lotor*	NC,CV,Mo,CC,ES,SC,D
Western Gray Squirrel *Sciurus griseus*	NC,CV,Mo,CC,SC
Ornate Shrew *Sorex ornatus**	CV,CC,SC
Pacific Shrew *Sorex pacificus*	NC
Water Shrew *Sorex palustris*	NC,CV,Mo,ES
Vagrant Shrew *Sorex vagrans*	NC,CV,Mo
Western Spotted Skunk *Spilogale gracilis*	NC,CV,Mo,CC,ES,SC,D
Brush Rabbit *Sylvilagus bachmani**	NC,CV,CC,SC
Gray Fox *Urocyon cinereoargenteus*	NC,CV,Mo,CC,ES,SC,D
Black Bear *Ursus americanus*	NC,CV,Mo
Western Jumping Mouse *Zapus princeps*	CV
Pacific Jumping Mouse *Zapus trinotatus*	NC

+ Regions (see Map of Regions, Figure)
NC = North Coast/Klamath
CV = Central Valley
Mo = Modoc/Cascade
CC = Central Coast
ES = Eastside/Great Basin
SC = South Coast
D = Desert (Mainly represents Colorado River)

* Certain subspecies found along California rivers are rare

Sources: Brode and Bury (1984), DFG (1992a), Laudenslayer et al.(1991), Miller et al. (1989), Remsen (1978), Stebbins (1966), Williams (1986), Williams and Kilburn (1984), Williams et al (1989), Zeiner et al (1988, 1990a, 1990b); CNDDB Special Animals List, December 1992; CNDDB list of Habitat Associations, 1/31/92.

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Figure 71. Rivers as Systems (Eel River).

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California Rivers: Their Nature, Function and Restoration

4

A river seems a magic thing. A magic, moving, living part of the very earth itself—for it is from the soil, both from its depth and from its surface, that a river has its beginning.
Laura Gilpin, *The Rio Grande.*

Introduction

A river is more than a large stream of flowing water. Rivers collect and concentrate water and materials yielded by the land they drain. Rivers transport water, materials, organisms and people and their goods. Rivers bring water to otherwise dry environments. A river is a major influence on the landscape through which it flows, carving and sculpting the land and connecting land and water. At the same time a river is at the mercy of the land, passively receiving whatever runs into it—water, soil, rocks, nutrients, debris and pollutants.

Thus, a river is more than a channel of water. To manage rivers and to sustain them it is necessary to understand their functions as ecosystems. Ecosystems are systems incorporating the physical/chemical environment, biological organisms and processes, and the close interactions between and among them. In river ecosystems, the most important physical and chemical components are: 1) geomorphology, the landscape and land-forming processes; 2) hydrology, the flow and occurrence of water over time and space; and 3) water quality, the chemical and related properties of water as a liquid.

River ecosystems include both aquatic and riparian living resources, or biota. The aquatic biota are found submerged in the water, while the riparian biota are the more terrestrial, yet water-influenced, natural communities found on the banks and flood plains of a river. Important living resources of California river systems include the fishes of the aquatic environment and the woody plants (trees and shrubs) and associated wildlife of the riparian environment.

Within a river ecosystem the riparian vegetation, the aquatic biota and the environment are closely interrelated. For example,

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cottonwood trees growing on river banks produce an abundant biomass of woody branches, trunks and roots. This plant growth casts shade over the water to cool it and supports insects which fall into the water and are eaten by the fish. Tree roots or fallen trees, exposed by water erosion, provide hiding places for fish in their aquatic world.

This chapter describes the ecology of California's larger stream resources—those named and mapped as rivers by modern geographers—with an emphasis on those rivers considered navigable. There is no definition of how large a stream must be to be called a "river"; a look at the variation within California shows this is a very relative term. We use the term "rivers" to describe the most economically or socially important streams of an area, and to describe the relatively larger streams which are more controlling over the landscape and biota.

A river ecosystem must be recognized as continuous from its source to its ultimate destination, whether ocean, lake or underground basin. To focus on the public trust resources of rivers, we recognize the upstream connection, but concentrate on their downstream reaches, rather than headwater regions.

Geomorphology and Hydrology

The dynamic nature of river channel features, commonly lost to the casual observer, is of enormous importance in understanding the effects of human activities on river channel stability. A river is composed of three closely linked elements: the drainage basin or watershed, the channel and flood plain, and the water (Keller, 1977). Rivers can be examined by their physical components as integrated channel-flood plain systems; or by their biological components as riverine-riparian ecosystems (Jensen and Platts, 1989). Physically, in rivers subject to annual flow variation, the active channel includes the permanently submerged bed, often called the low flow channel, and a near zone of seasonally exposed substrate (sand and gravel bars) which is frequently modified by floods. Ecologically, the "active channel" is also the riverine zone, and contains aquatic habitats (Cowardin et al., 1979; National Research Council, 1992). The flood plain encompasses the entire landscape subject to river geomorphic and hydrologic processes. However, this word is frequently used in reference to the less-often flooded, more terrestrial zone above the active channel, such as a flat valley adjacent to the channel. The flood plain is essentially synonymous with the biological riparian zone (Figure 72).

This section describes the processes of geomorphology and hydrology which link watersheds and water into integrated channel and flood plain river systems.

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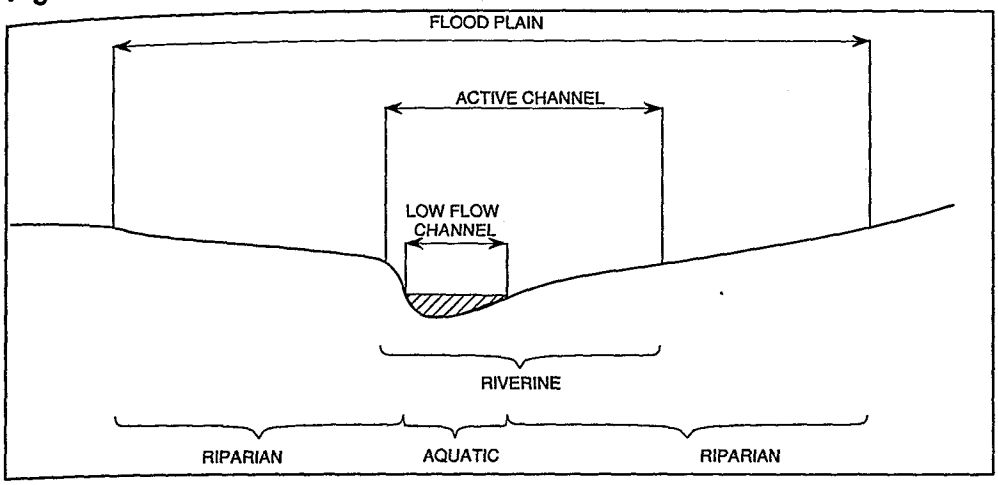
Figure 72. Channel Cross-section and Ecological Zones.



River Basins

The runoff of water from higher elevations toward sea level produces the complexity of natural drainage networks, the variety of stream channel forms, and in part, the form of the landscape. This runoff is due to a fundamental imbalance in precipitation between land and sea. More water evaporates from the ocean surface than falls on it as precipitation, while more water falls on the continents than evaporates from their surface. Of the precipitation that falls on land, most is lost to evaporation or transpiration by plants. The remainder (typically less than half) runs off, draining via networks of stream channels to larger rivers and thence to inland lakes, sinks or oceans. The land area drained by a given river is termed its drainage basin or watershed, and is separated from adjacent watersheds by topographic high points termed drainage divides (Figure 73). Drainage basins can be defined on many scales, from large rivers such as the Sacramento River at Sacramento with a drainage basin of 23,500 square miles, to its tributary Cottonwood Creek, with a drainage basin of 922 square miles (Figure 74).

The basin is actually drained by the drainage network (Gregory et al., 1991), the system of branching waterways which combine into larger and larger streams, eventually forming rivers. Individual segments or reaches of the same river system can be very different because of local bedrock, topography, other geomorphic features and climate. Many rivers display characteristic changes along a gradient from headwaters to mouth.

Confined reaches occur mainly in mountainous, steep-gradient areas and have relatively straight, well-defined channels with narrow flood plains. Unconfined reaches are typical of low-gradient reaches in downstream parts of the basin; they typically have broad valley floors with wide flood plain and riparian zones (Gregory et al., 1991).

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Figure 73. A River Watershed.

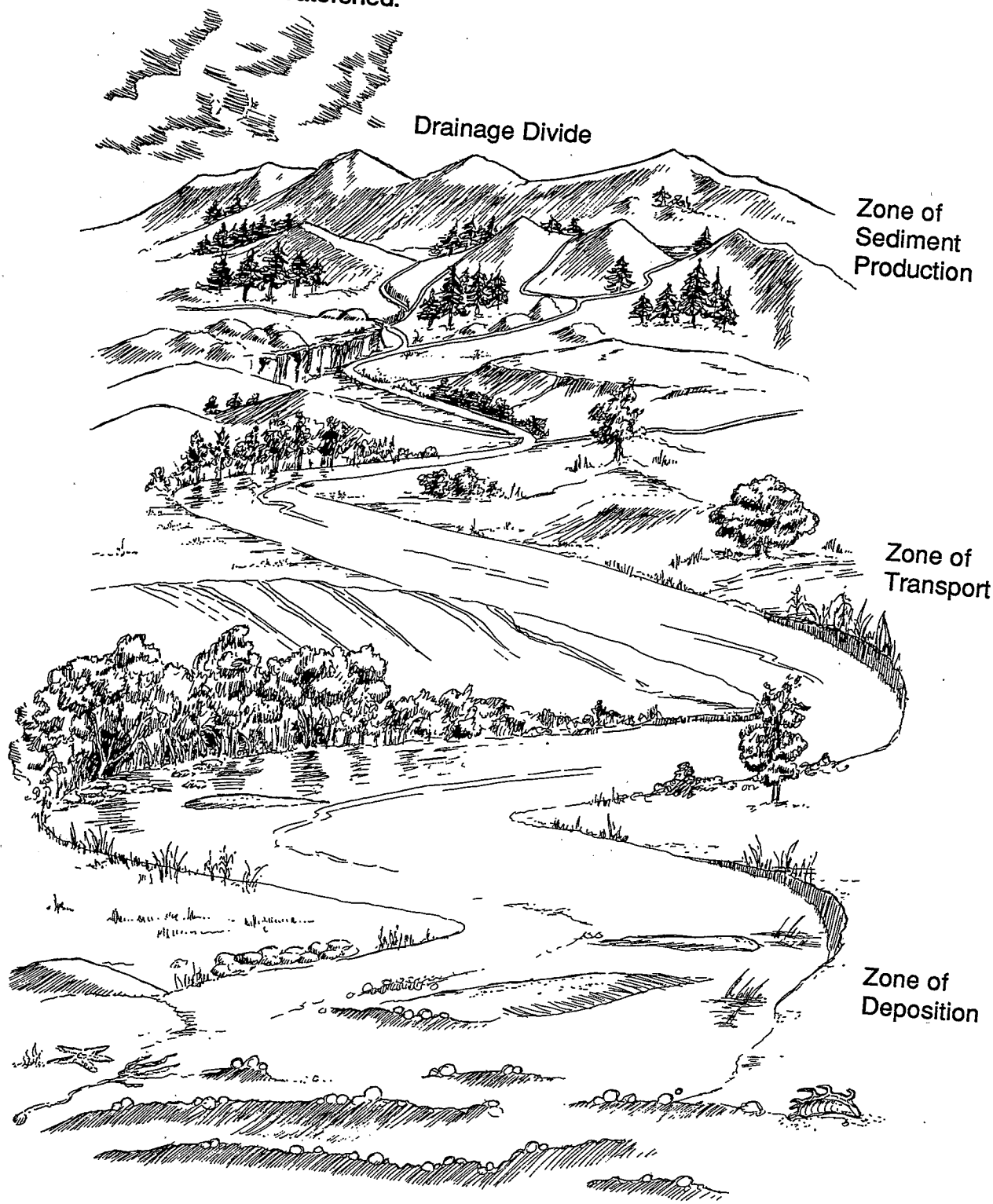
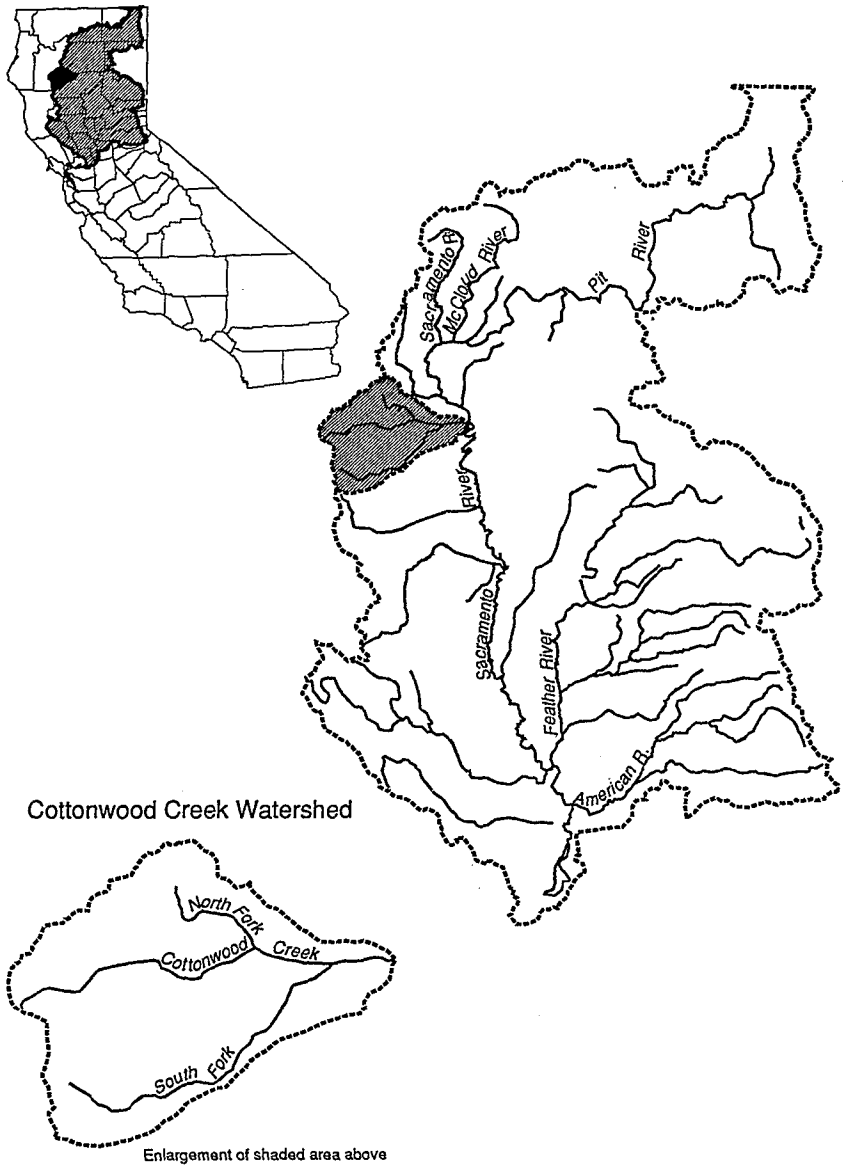


Figure 74. Sacramento River Watershed.



Watersheds are viewed as the fundamental landscape units because processes occurring upstream can affect downstream reaches, and to a lesser extent vice-versa. For example, clear-cutting of forests and construction of roads in the upper drainage basin can increase rates of erosion and sediment delivery to stream channels, overwhelming downstream channels with sediment and causing the channel to aggrade (build up its bed with sediment). This has occurred in the North Coast region, notably in Redwood Creek in Redwood National Park, where timber harvest in the upper watershed caused the downstream channel to aggrade, threatening the integrity of the tall trees grove (Kelsey et al., 1981).

If the level of the sea or a lake drops, tributary channels may incise (erode their beds downward to adjust their profiles). Tectonic uplift in the Coast Ranges has caused many streams to readjust by

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cutting deeper, as has occurred on the Mattole River watershed in Humboldt County (Mattole Restoration Council, 1989). Active incision, coupled with a highly erodible geology common to the Coast Ranges, often results in increased landslides as slopes are eroded away at their bases (Jones and Stokes, 1981b). Channel incision commonly propagates upstream until it hits resistant bedrock or other grade control.

Differences in topography, underlying geology, and the soil and vegetation cover within watersheds influence the amount and rate of runoff from a particular part of the landscape. Some watersheds produce storm discharges with very pronounced peaks over a short time interval (Beaumont, 1975). Such watersheds are called "flashy," and can be naturally occurring in areas of steep terrain, hard bedrock, or thin soils and sparse vegetation. Urbanization of a watershed, with large amounts of impervious surface, can induce the same phenomenon artificially (Leopold, 1991). By contrast, well-vegetated watersheds will be slower to respond to storms and have less pronounced runoff peaks spread over a longer period.

John Wesley Powell and the Watershed as Landscape Unit

Drainage basin boundaries and political boundaries, while frequently coincident in part, usually differ. Actions in the upper basin may result in substantial physical impacts to lower reaches of the river but because these areas are typically in separate counties, states or countries, coherent management of the entire river system does not occur. These problems were anticipated by an early director of the United States Geological Survey (USGS), a remarkable man whose sensible proposals to avoid jurisdictional conflicts were largely ignored.

John Wesley Powell, the first person of European ancestry to navigate the Colorado River through the Grand Canyon, epitomized the public servant of the Jeffersonian school. Powell is responsible for innumerable insights into the science of geology and hydrology, but his most important accomplishments were establishing the highly respected USGS; conceiving and promoting the topographic mapping program we now take for granted; standardizing symbols used on topographic and geologic maps; and founding the field of Native American ethnology.

Powell recognized the critical importance of water in western North America, and argued forcefully that water resources be managed by watershed, with political bound-

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aries drawn along drainage divides, so that watersheds would be managed by the same public agencies that managed water use downstream. Such coherent management would encourage land use policies designed to protect water supplies and encourage distribution of water (essential for agriculture in the semi-arid west) in an equitable and efficient fashion. Powell's public-spirited ideas conflicted with the frontier, extraction oriented politics of the time. After achieving many of his objectives, his reform proposals ran afoul of conservative politicians and he was driven from directorship of the USGS in 1894, after which he devoted most of his efforts to his ethnologic studies.

Source: Stegner, 1953.

Energy Dissipation and Sediment Transport

As water flows from the upper reaches of the watershed downward through the drainage network, some of the potential energy of its elevation is converted into energy of motion. The remaining energy is expended on transporting sediment and is dissipated in turbulence from rough, irregular beds and banks, and through energy losses at bends.

Energy of Motion

The steeper the channel, the more rapid the rate of energy dissipation (conversion of energy from potential to other forms). Steep streams typically have large rocks on the bed (with greater flow resistance and stability) with most energy losses concentrated in localized drops. These drops may be bedrock or boulder steps, step-pool reaches, or gravel-cobble riffles in pool/riffle reaches.

California's rivers possess energy in excess of that required to move water to sea level. Many Sierra Nevada rivers are high in the potential for hydroelectric power generation because of their steep reaches. Many hydroelectric power projects are run-of-the-river: They involve no large storage reservoirs, but simply divert flows from the channel into smooth canals or tunnels that convey the water at a gentle grade along the mountainside above the river. The river falls more steeply than the canal until the canal is 100-200 feet above river level, at which point the water is dropped abruptly through reinforced pipes (penstocks) driving turbines in the power plant.

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Sediment Transport

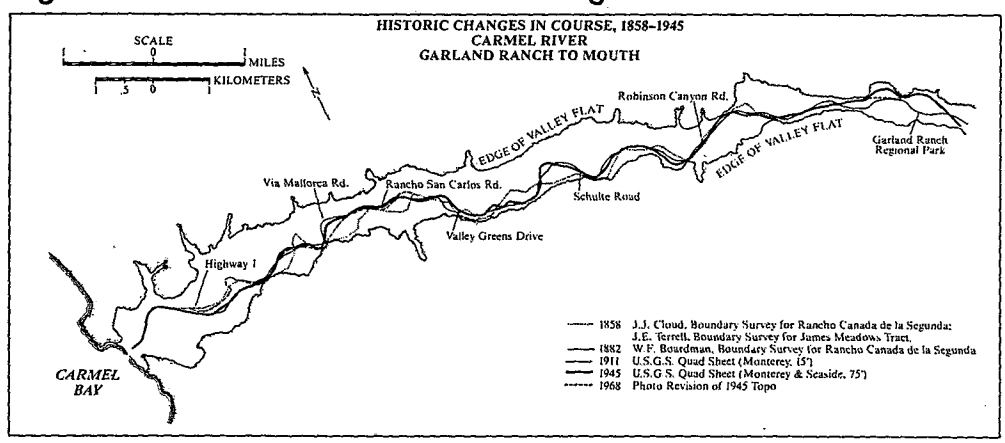
Much of a river's excess energy is used to move sediment, the soil and rock fragments eroded from the watershed. Sediment is transported in three ways. Dissolved load consists of weathering products in solution, suspended load consists of clays, silts, and sometimes sand that are held in suspension by turbulence in the water column, and bedload consists of larger, heavier grains of sand and gravel, sometimes up to boulder size, that move along the bed by rolling, sliding and bouncing.

The size of movable sediment grains depends on the water velocity (which depends upon water depth and channel gradient) of the flow and turbulence. The total amount of sediment moved in a river also increases with flow velocity. Since flow velocity increases with increasing flow, both the particle size and total amount of sediment movable by a river increases with flow. The rate of sediment transport typically increases as a power function of flow, that is, a doubling of flow typically produces more than a doubling in sediment transport. Because the rate of sediment transport is so much greater in higher flows, most sediment transport occurs during floods.

Viewed over a long time period, runoff erodes the land surface and the river network carries the sediment away. The upper watershed can be viewed as a sediment "factory," and the river channel as a "conveyor belt," which transports the products downstream to the ultimate depositional sites below sea level (See Figure 73). Along the length of the river system, the size of sediment changes from coarse gravel-boulder in steep upper reaches to dissolved materials, sands and silts in low gradient reaches.

Along this "conveyor belt," sediment in the river channel may appear stable in the short term but probably moves frequently (Leopold et al., 1964). A gravel bar in the Eel River may look much the same from year to year, but the gravel particles in it may be largely replaced each year (or every two years, or less frequently), as sediment moved downstream from an upper reach replaces sediment carried away.

Figure 75. Carmel River: Historic Changes in River Channel.



Source: G. Mathias Kondolf

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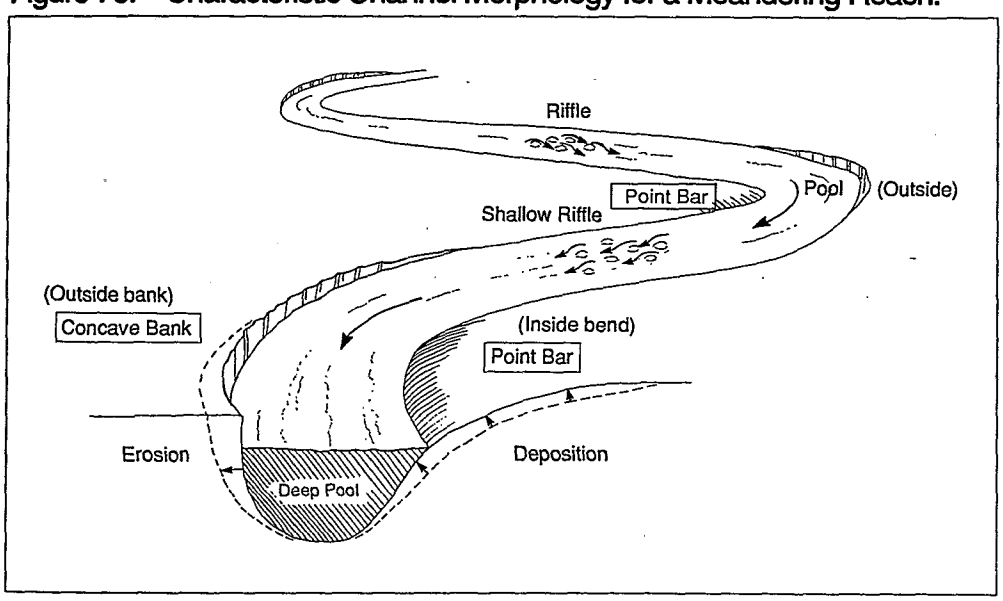
While the sediments on the bed of the channel are mobile on a time scale of years, the sediments that make up a large river flood plain are mobile on a time scale of decades or centuries. The flood plain acts as a storage reservoir for sediments transported in the channel, alternately storing sediments (by deposition) and releasing sediment to the channel (by bank erosion). Figure 75 depicts migrations of the channel of the Carmel River since the first surveys in 1857. The river channel migrated over a quarter of a mile in places, with most channel shifts occurring during two large floods, in 1862 and 1911. The 1911 flood left behind a wide terrace of freshly deposited channel sediments. By 1960, the channel had cut 12 feet below this terrace surface, and the terrace had been subdivided for low density housing, despite the recent origin of the land.

Dynamic Geomorphology

Natural rivers tend to develop complex beds with alternating deep and shallow areas, called pools and riffles, often with sand or gravel point bars deposited on the inside (convex) bank. Unconfined rivers typically have a sinuous form, illustrating the river's own formation and movement of bends as it meanders or migrates across its flood plain (Figure 76).

Figure 76. Characteristic Channel Morphology for a Meandering Reach.



Large lowland rivers, such as the Sacramento River below Red Bluff, often shape their channels and flood plains by large-scale meandering. Over centuries, the Sacramento River has moved laterally over its flood plain, creating a mosaic of land forms (Scott and Marquiss, 1984; Thompson, 1961). Rivers create meander loops by eroding to one side and depositing point bars on the other. As the

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river erodes, it enlarges the loop, building the older sections of the point bar higher as the river continues to move sideways. Eventually the river may cut off the loop in a short straight chute, and then begin eroding another bank to form a new loop. Old loops may become quite isolated from the river channel, creating oxbow lakes (Figure 77).

Another geomorphic phenomenon on many meandering rivers is the formation of natural levees, which are zones of higher ground adjacent to the channel. Natural levees form as floodwaters

Figure 77. River Meanders and Oxbow Lakes (Sacramento River).

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just leave the channel, and the coarse sediments deposit first along the channel margins. The natural levees of the middle Sacramento River are up to 10-15 feet high and several miles wide in places (Scott and Marquiss, 1984; Thompson, 1961).

Thus, the flood plain is a dynamic feature closely related to the channel. In fact, the channel and the flood plain are best viewed as a single unit hydrologically and geomorphically, just as the watershed is a single landscape unit. Unfortunately, the natural functions of the flood plain have frequently been ignored, with disastrous effects.

Flood Frequency and Channel Form

Flow in California rivers is exceedingly variable, except in unusual cases below large springs (such as the Fall River near Burney in northeastern Shasta County). This is due to the highly seasonal precipitation and intensity of the state's winter storms. Within the year, flows range from seasonal lows (in late summer in the Coast Ranges; in winter in higher elevation Sierra Nevada streams; non-existent in desert) to high flows (during winter storms along the coast; during spring snowmelt at higher elevations; shortly after a large rainstorm in desert). Flows also vary from year to year, depending on the abundance and intensity of precipitation for the year. The typical pattern of high flows is of particular importance in shaping a stream channel. This is especially true for rivers flowing through sediments, less so for rivers flowing through bedrock canyons. The history of floods on a given river can be analyzed to determine the probability of a certain sized flood occurring in a year. The flood that occurs, on average, once in every two years is the "two-year flood" or "Q_2"; the flood that occurs once in every ten years is the "Q_{10}." The probability that these flood levels will be exceeded in any given year is 50 percent and 10 percent, respectively. It is a common misconception that if a river experiences a 100-year flood one year, the probability of a similar sized flood the following year will be less. In fact, the probability of another 100-year flood the next year remains unchanged at one percent.

It is apparent that rivers with larger flows possess larger channels to convey the larger quantities of water. But how much larger must the channels be? More to the point, is there a flow to which the channel adjusts its geometry? During summer low flows most rivers do not fill their banks, but flow at reduced level, exposing gravel bars and other such features. At extreme floods, the river flows out of its banks and spreads across its flood plain. In many streams, the point at which flow just begins to exceed the capacity of the banks occurs at about the $Q_{1.5}$ to Q_2, designated as bankfull flow (Leopold et al., 1964). This implies that many channels are adjusted to these frequent small, high flows rather than to larger, but less frequent floods.

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Figure 78. Trinity River Flow Changes With Dam.

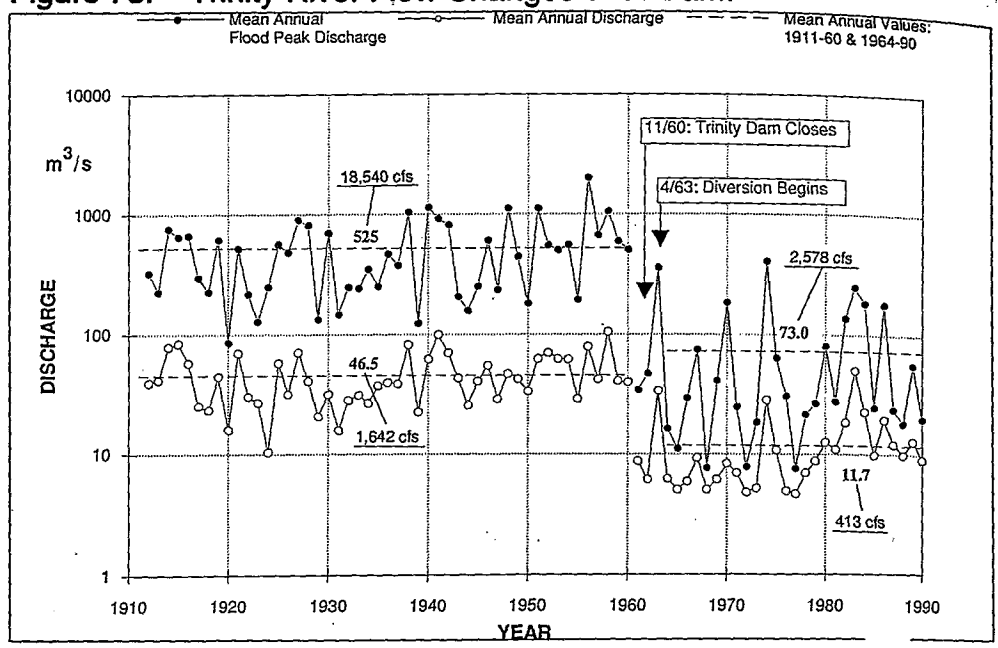

Figure 79. Trinity River Channel Before Dam.

Figure 80. Trinity River Channel After Dam.

Source for Figures 78, 79 and 80: G. Mathias Kondolf.

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Given this apparent relation between flood frequency and channel form, it should be possible to estimate the bankfull flow of a river from measurement of its channel dimensions and slope alone. It also raises the question of how the channel may respond if bankfull flow is artificially increased or decreased. An example of a decreased bankfull flow is provided by the Trinity River after construction of Trinity Dam in 1960. Results of the flood frequency analysis show that prior to dam construction, the mean annual flood peak discharge was about 18,500 cfs and after dam construction only 1,600 cfs. The mean annual discharge was reduced from 2,500 cfs to 400 cfs (Figure 78). Given such a dramatic change in flood frequency, we might expect to see the dimensions of the channel decrease over the three decades since construction of the dam, and indeed, that has been the case (Figures 79 and 80).

Change Versus Stability

River landforms are a result of the interaction of the watershed (its topography, bedrock, and soil-vegetation mantle) with the system's hydrologic regime (low and high flow amounts and occurrence). At any point in time, most streams in a natural condition seem to tend toward a dynamic equilibrium condition balancing the amounts of sediment entering and transported through the system to maintain what appears to be a stable channel and flood plain form. To put it simply: Erosion in one place or time is balanced by deposition in another place or time.

"Stability" of rivers is only relative, however, and must be considered in the context of temporal and spatial scales (National Research Council, 1992). In short reaches, over a few months or years, individual depositional bars may be scoured and redeposited frequently, but overall channel and flood plain appearance may not change significantly. Over long time periods, rare flood events coupled with meandering may cause large changes in landform, such as the large channel movements of reaches of the Sacramento River over the last century. Over large spatial scales, a single long reach of a meandering river will have a kind of constancy in the amounts and kinds of landforms—the number of bends, point bars and meander tracings—although individual locations will change. Over geologic time and over the entire regional landscape of a watershed, major environmental alterations such as those caused by tectonic movements and climatological changes can produce irreversible major changes in rivers.

The different geomorphic structures of a river system—its deep pools, shallow riffles, eroding banks, freshly deposited point bars and flood plain surfaces of various elevations—all create a diverse complex of river habitats for living organisms. Living resources respond not only to spatial variation, but to changes over

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time as well. As will be discussed in later sections, natural river systems support diverse and abundant biotic communities, including riparian gallery forests, hundreds of wildlife species and rich aquatic life, most of which not only can endure the dynamic nature of rivers but require it for best survival and development.

Figure 81. River Habitat Diversity.

Water Quality

Truly aquatic biota, from fish down to the simplest bacteria and fungi, are closely dependent upon the physical and chemical nature of the water they inhabit. Aquatic organisms must derive gases and nutrients necessary for survival from the watery environment immediately surrounding them, and must similarly excrete waste products back into the same milieu. Because they cannot internally regulate temperatures and often cannot distinguish between substances necessary for survival and those which are toxic, or move toward or flee from them, they are particularly sensitive to environmental conditions posed by the water around them. River and stream organisms must additionally contend with life in moving waters.

What makes a river a river is its unidirectional flow of water. Flow in rivers and streams can be quantified in terms of discharge, which is the total volume of water moved over time, and current or velocity, the distance moved over time. Discharge is largely a function of watershed size and character and amount and distribution of precipitation. As noted, rain and snow patterns in California result in highly variable discharges between seasons and years. Velocity is a function of discharge and the channel's physical configuration. For a given discharge, velocity will be faster if forced through a smaller cross-sectional area than it will in a larger bed.

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Geomorphology Dynamics

Most river and stream flow in nature is not smooth and straight but is subject to varying degrees of turbulence (Reid and Wood, 1976). Water flowing over irregular beds and around curves of natural rivers shows uneven velocity distributions and develops many eddies and circular currents. Some generalities are possible: for curved reaches, currents are fastest at outside bends; for straight reaches, the fastest current is often in the middle; in areas of flow obstructions and steep gradient changes such as at sharp bends, over riffles, or near boulders and logs, turbulent mixing occurs. Patterns of currents within channels are usually quite different at low flow than at flood stage.

Turbidity

The velocity and amount of turbulence determine the amounts of sediments put into and retained in suspension. Turbidity is the relative opaqueness of water, dependent primarily on the amount of suspended particulate matter present. Turbidity increases with higher discharge as the suspended load increases, due to the higher velocities and turbulence in the channel as well as usually increased sediment inputs from upland and bank erosion (Beaumont, 1975).

Sunlight is necessary for plant photosynthesis, the source of much primary productivity in rivers. The clarity of water and hence its ability to transmit sunlight to lower depths is an important determinant of the amounts and kinds of plant life which can thrive underwater, including algae attached to submerged surfaces, floating phytoplankton and rooted higher plants.

Most small stream reaches at low flow are relatively clear (Hynes, 1970). Lowland reaches of rivers, as they become larger, receive cumulatively more inputs of solids from the land as well as nutrients, and thus support more one-celled plants. They are thus usually more turbid than upstream reaches (Reid and Wood, 1976).

Water color in California rivers, as opposed to clarity, is primarily dependent on suspended substances during high flows and the presence of plankton during low discharge. The greenish hue of most lowland rivers in California during the warmer months of the year is due to plankton growth and, rarely, the presence of dissolved organic substances such as humic acids which can turn river waters dark.

Temperature

Sunlight is important in rivers, not only for photosynthetic production, but as the major determinant of water temperature (Reid and Wood, 1976). The amount of solar radiation received by the waters of a river varies with angle of exposure, amounts of shade cast by riparian

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vegetation or landforms, and water depth, flow and clarity. Light is quickly attenuated by water and even more so when dissolved or suspended substances are present. Water temperature is also quite dependent on outside air temperature. In rare cases, river temperature is a function of cold (or warm) springs which feed it, such as the constantly cool lower McCloud River in northern California.

Temperature is important because of its direct influences on rates of metabolic processes; all organisms have optimal temperature ranges for their reproduction, survival and growth. Many aquatic life-forms have different temperature tolerances at different life stages, and many can acclimate to a certain degree to new temperature ranges. Temperature is also important indirectly in its effects on other qualities of water such as solubility of gases.

There are usually quite dramatic temperature differences between seasons and, depending on stream size, over a day or diurnally. Upstream river segments and smaller streams show much wider seasonal and diurnal variations in temperature than do larger streams and rivers (Goldman and Horne, 1983). The higher amount of suspended solids in the water in downstream reaches tends to increase absorption of heat, and so increases temperature (Reid and Wood, 1976).

Dissolved Gases

Natural scientists know water as the "universal solvent" because of its ability to dissolve and ionize substances. No pure water exists in nature. River waters contain large amounts of dissolved inorganic and organic substances, including dissolved gases and nutrients necessary for life.

The most important gases in river waters are oxygen (O_2) and carbon dioxide (CO_2). External oxygen is required for metabolic processes (primarily cellular respiration) by all organisms but a few types of anaerobic microbes. Carbon dioxide is a waste product from most metabolic reactions, but is required by plants for photosynthesis.

Oxygen enters river and stream water through diffusion from the atmosphere and as a chemical by-product of photosynthesis. The amount of oxygen which dissolves into rivers is influenced by temperature and the degree of mixing or turbulence (Reid and Wood, 1976). Oxygen has decreased solubility in water with increased temperature. Typically, upstream reaches with a higher gradient, more turbulent flow and cooler temperatures have higher oxygen content than lowland reaches. Downstream river segments are not only warmer but have fewer riffles and rapids to physically aerate the water.

Carbon dioxide has a major role to play in the buffering of acidity of natural waters. Normal precipitation is somewhat acidic but most unpolluted natural streams are neutral to alkaline. Complex chemical reactions—involving carbon dioxide, calcium and magnesium

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ions, and calcium carbonate and bicarbonate, all in various balances—determine the pH or relative acidity of water (Hynes, 1970). The calcium and magnesium constituents come originally from rocks and soils of the watershed. Carbon dioxide in running waters is rarely in short supply. It normally comes from diffusion from the air and from buffering reactions involving carbonates.

Carbon dioxide is the reverse of oxygen in life processes; photosynthesis uses it up and metabolic processes produce it. Where there are high amounts of organic matter to be decomposed by biological activity, oxygen can be decreased, at the same time as there are high levels of carbon dioxide. This condition is eventually harmful to higher organisms such as invertebrates and fish. Downstream river reaches tend to experience decreased oxygen and increased carbon dioxide, due partly to higher turbidity, which decreases photosynthetic oxygen production, and also due to higher accumulations of organic matter to be decomposed.

In flooded soils, the oxygen/carbon dioxide balance is also critical for root survival of riparian plants. Diffusion of oxygen into air-filled soil pores is 10,000 times faster than when pores are filled with water. Within hours after flooding, soil microorganisms can exhaust available oxygen and produce a buildup of carbon dioxide. If flood waters stagnate over a period of time, root death may occur. However, in turbulent flood waters oxygen can diffuse into soil water (Kozlowski et al., 1991).

Dissolved Inorganics

Water also contains large amounts of dissolved solids. Inorganic substances come primarily from land sources, collected as runoff passes over and through rocks and soils. Major dissolved minerals in natural rivers which are important to aquatic life include magnesium, calcium, sulfur, iron, sodium, potassium and silica. Phosphorous is necessary only in small amounts, but in its usual forms in nature it is unavailable for plant uptake. Phosphorous is often limiting to plant growth in aquatic environments, as evidenced by algal blooms when runoff containing phosphate detergents or fertilizers pollutes a waterway.

Nitrogen is a major constituent of proteins, and is needed by all organisms in large amounts. Nitrogen is a major component of the atmosphere, but cannot be used by most organisms until captured into ionic forms, chiefly nitrates, by microbes. Much nitrogen is recycled over and over through feeding, decay and plant uptake, mediated by microorganisms. Nitrates can also enter streams from the land (Goldman and Horne, 1983). Available nitrogen may be added to rivers and streams by the presence of alder trees, which have nitrogen-fixing capabilities in their roots similar to members of the legume family (Gregory et al., 1991).

There are a number of other elements which are necessary in minor amounts for life, many of which are heavy metals. Some, such

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as copper and zinc, usually become toxic to organisms in higher concentrations in the environment (Haslam, 1990).

Dissolved Organics

All rivers contain high amounts of dissolved and particulate organic matter (Hynes, 1970). Stream ecologists distinguish between Dissolved Organic Matter (DOM) and Particulate Organic Matter (POM) (Cummins, 1974). As will be discussed later, river food chains and webs are highly dependent upon the instream processing of organic matter. Much organic matter in streams, especially smaller ones, comes from adjacent terrestrial environments. Leaves and twigs of riparian vegetation are primary sources. Insects and microorganisms break down raw plant materials into smaller pieces, which are cycled through feeding and decomposition networks. Bacteria and fungi also play important roles in stream and river nutrient and energy cycles.

Very dilute dissolved organic substances in rivers are also important for the homing ability of salmonids to return to natal streams (Goldman and Horne, 1983).

The amount of total dissolved solids (TDS), both inorganic and organic, is often used as an indicator of water quality, especially its suitability for human consumption, irrigation or industrial use. Salinity refers to the concentration of those substances which are in ionic form, a subset of TDS. The electrical conductivity (EC) of water is a commonly measured index of salinity. Salinity is normally not high in California rivers except near the ocean, where rivers meet the sea in estuaries. However, agricultural runoff has increased the salt concentrations of certain rivers, notably the lower San Joaquin River, to levels which seriously impair water quality for human use and sensitive river biota.

Living Resources: Organisms and Communities

Overview of Biological Concepts

Within ecosystems, living organisms each have a particular function, which is a combination of what they do—niche—and where they live—habitat. The niche of an organism refers to its role in a variety of interactions and processes, such as its place in trophic or food-related relationships, or in other direct interactions such as competition or parasitism. An organism's habitat is the particular place which provides environments suitable for survival.

Organisms can also interact directly or indirectly through habitat relations; organisms can modify the habitat of others or even be habitat themselves (Jones and Stokes, 1981a). For example, riparian tree and shrub vegetation is important habitat for many birds, mammals and other fauna, so much so that frequently the term "riparian habitat" is

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used synonymously with "riparian vegetation."

The assemblage of organisms in a particular geographic location or type of place is often referred to as a community. The term community (or natural community) denotes a close and predictable relationship between the kinds and numbers of organisms and the environment of a place.

Figure 82. Typical Riparian Habitat.

Ecosystems are defined in large part by the relative closeness of organism interrelationships. For example, in river ecosystems, trees on flood plain lands and fish underwater may be closely linked through trophic and habitat relationships. Cottonwood trees, perhaps California's most important riparian plants, live in a mostly terrestrial habitat, but one with a high water table and which is subject to occasional major flood events. Fish require a water covered habitat of suitable temperatures and quality, and a plentiful food supply. Many native fish species require underwater structures such as boulders or large woody debris for cover and feeding. Cottonwood trees support high insect populations which can fall into the water of adjacent channels and provide food for fish. Branches and roots which extend over or under water and even whole fallen trees provide cover and shade for fish.

An important function of an individual or population within a river ecosystem is its place in the transfer of energy and matter in trophic relationships. The base of food chains or webs consist primarily of green plants which can capture the energy of sunlight in photosynthesis and use it to produce biomass. This primary production is carried out by riparian trees and shrubs, attached algae, and free-floating phytoplankton. Watershed vegetation further removed from riparian zones can also be important sources of primary production in smaller streams. Riparian and aquatic animals in turn consume the plant material and each other. Organisms which eat plant biomass are called primary consumers. Animals which consume other animals are called predators, and are also considered secondary or even

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tertiary consumers. A special type of consumer is the decomposers, organisms (primarily microbes) which break down dead plant and animal material, returning nutrients to the environment or to be used again by plants.

The following is an introduction to the different types of organisms found in California river systems. It is not exhaustive, but is intended to provide a background for understanding rivers as systems and an appreciation of river natural history and its diversity across the state.

Some types of organisms live their entire lives in terrestrial habitats of the riparian environment, some exist exclusively under water, and some require both aquatic and riparian habitat elements for survival and reproduction. These differences in habitats cut across most taxonomic groups, so this discussion avoids divisions made along the more traditional lines of aquatic biology (limnology) versus terrestrial ecology.

Organisms

Microorganisms

The smallest organisms of ecosystems—bacteria, fungi and protozoans—are frequently overlooked in ecosystem descriptions, but play some of the most critical roles in energy and matter processing and cycling. Microorganisms are also significant to humans as pathogens (Fjerdingstad, 1975).

Bacteria and fungi, especially in aquatic environments, are important decomposers of organic material (Goldman and Horne, 1983). Microbes break down large pieces of animal and plant tissue into fine or dissolved organic materials which can feed zooplankton, insects or other invertebrates. While bacteria can break down cellulose, only fungi can break down lignin, the skeletal material of leaves and wood (Goldman and Horne, 1983). Decomposition by bacteria and fungi is an important step, transforming the input of leaves and woody debris from riparian vegetation into energy and nutrients available for aquatic food chains and webs (Cummins, 1974). Decomposer bacteria and fungi together with plant and animal debris and the organisms which feed on this material form the detrital community on stream and river bottoms.

Bacteria as a class have diverse functions (Goldman and Horne, 1983). They are important in ecosystem cycles of nitrogen, sulfur and iron, and some bacteria produce methane gas in low-oxygen environments such as dense muds. Bacteria can also break down polluting substances such as pesticides (Fjerdingstad, 1975) and oil (Goldman and Horne, 1983).

The presence of certain masses of bacteria and fungi are often indicators of organic matter pollution. A particular community of

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microorganism growth has been called "sewage fungus," a growth of bacteria, fungus, protozoans and some algae which encrust underwater surfaces in rivers subject to organic matter pollution (Haslam, 1990). In addition, the presence of coliform bacteria, normally found only in animal digestive tracts, in water is a likely indicator of sewage pollution (Goldman and Horne, 1983).

Plants

In river systems, the most important groups of green plants are aquatic algae and riparian trees and shrubs. Rivers as a rule do not support much growth of aquatic macrophytes (large plants) such as pondweeds (Goldman and Horne, 1983). One reason is that smaller rivers and headwater regions have currents too swift, especially in winter floods, for these type of plants to survive. In larger lowland rivers, the current disturbance of the substrate might be less, but the water is usually too deep and turbid to allow light penetration to the bottom.

Algae

Rivers have two types of algae. Benthic algae are species which are attached to the bottom and other surfaces; and phytoplankton are species which are free-floating in the water column. Generally, in small rivers and upstream reaches attached algae is common but plankton is rare. In downstream large river reaches, the increased turbidity and depth limits the growth of attached algae, but the increased nutrient concentration allows for an abundant phytoplankton community.

Benthic algae along with the other organisms that feed upon it, including many herbivorous invertebrates, is called the periphyton community in rivers and streams. Diatoms, green algae and blue-green algae are the most common groups of attached algae in streams and rivers (Goldman and Horne, 1983). The distribution of attached algae is related to substrate type, water temperature, current, sunlight and nutrient availability (Hynes, 1970). Many of these environmental factors vary with season, causing seasonal changes in algal growth.

In upstream areas, periphyton growth often detaches and enters the water column food web, but there is no almost no true plankton. Downstream, a phytoplankton community can develop, dominated primarily by diatoms (Hynes, 1970). This community is quite unstable with regard to species composition and abundance. Like attached algae, temperature, light and nutrients are important community determinants. For example, in the Sacramento River, large nutrient influxes after spring floods coupled with warming temperatures result in phytoplankton blooms in April, May and June (Greenberg, 1964 cited by Hynes, 1970).

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Riparian Plants

Riparian zones owe a major part of their character to their vegetation, which in relatively arid climates such as California, is usually very different from nearby upland areas. Broad-leaved, winter-deciduous trees and shrubs dominate riparian vegetation, especially in unconfined, meandering river systems. Lush and green in the summer and bare in the winter, riparian corridors can easily be recognized from a distance. In California, the most ubiquitous species are cottonwoods, willows, alders, sycamore and valley oak, although there is considerable variation in species composition of the vegetation throughout the state. The most common or indicative riparian plant species in California are listed in Table 13, Chapter 3 and special species are listed in Table 17 at the end of this chapter.

Riparian tree and shrub species share a unique set of ecological characteristics, most of which explain why they are limited to or highly successful in river environments: They are broad-leaved and winter-deciduous; fast-growing and often short-lived; require high soil moisture due to high transpiration (water loss) rates; able to produce suckers, sprouts, and new root systems; and tolerate seasonal flooding.

The large surface area of broadleaf winter-deciduous leaves provides maximum light capture, enabling extremely fast growth rates and high biomass production. The broad-leaf deciduous growth habitat of riparian species generally provides the ability to grow very fast, especially when young. On the other hand, the fastest growers, the willow and cottonwoods, have relative short life spans.

Large, thin deciduous leaves are a liability for water loss due to transpiration, unless soil moisture is plentiful enough such as along a river or stream. Riparian plant species are sometimes called phreatophytes ("well plants"), plants which have roots tapping moisture from the soil water table. Such plants have the ability to grow roots rapidly down to the water table and can readily absorb and conduct water efficiently through the plant, thus compensating for the rapid transpiration losses through thin succulent leaves. Riparian species, notably willows and cottonwoods, are limited almost exclusively to riparian environments largely because of their high water demand.

The broadleaf deciduous forest types of California riparian areas are similar to the most common kind of forests in the eastern third of the United States, Europe and parts of Asia. In the arid West, such forests are mostly limited to riparian environments. Two other adaptive characteristics of riparian trees and shrubs relate to the environmental stresses caused by river flooding. Most riparian woody species have an ability to sprout and sucker after mechanical damage, partial burial or bending (Figure 83). Well established trees can usually grow a new platform of roots in response to burial by river deposited sediments, even several

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feet thick. Riparian species also show a high degree of tolerance to the low-oxygen root environment in saturated soils. There are significant differences among species' ability to tolerate flooding, which causes them to segregate out over different flood plain and riverbed land elevations.

Figure 83. Willow Sprouting After Physical Damage.

Because river systems have frequent major disturbances such as flooding, erosion and deposition, and because many dominant riparian plant species have short life spans, the ability of riparian species to replace themselves by seed reproduction is important in maintaining the mosaic of riparian shrublands, forests and woodlands found in a natural flood plain. Many common riparian species produce abundant seed crops every year, ensuring dispersal whenever suitable habitat becomes available.

In the late spring, willows and cottonwoods disperse abundant small seeds. The "cotton" flying in the air in spring along many rivers and streams is their light seeds with fine hairs enabling wind dispersal. The small seeds can travel far, but have little stored energy for young plants. For these species to have successful seedling reproduction, they require sites of high sunlight and wet soils. Such conditions are met on substrates recently deposited and exposed from river physical processes such as new sand and gravel deposits still wet from receding flood waters. However, as water levels continue to drop over the summer, seedlings must be able to grow roots rapidly to maintain connection with moisture (McBride and Strahan 1984; Pelzman, 1973).

Riparian vegetation at any point in time and space is a result of the interactions between geomorphic and hydrologic processes, the environments they create, and the plants' responses. Riparian vegetation

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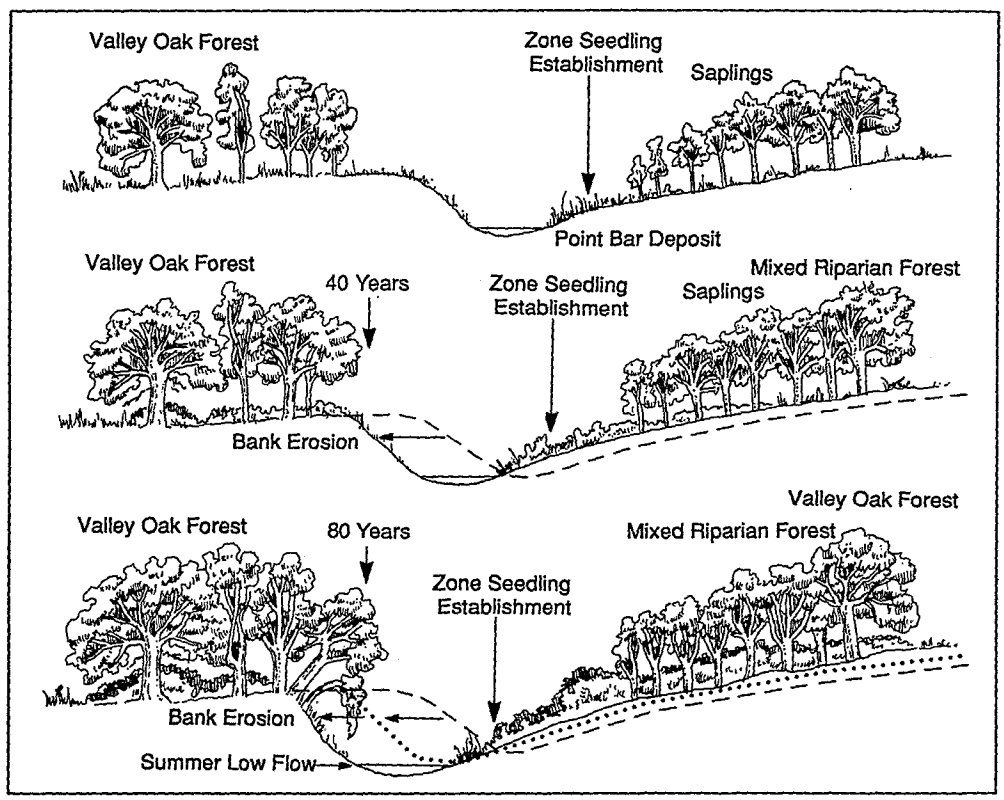
is comprised of species which can tolerate, and to some degree require, the high water and physical buffeting of the river environment.

In meandering river systems, flood plain riparian vegetation includes many different types such as gravelbar willow scrub, mid-terrace mixed forest and high terrace mature forest. These different communities occur in slightly different environments, depending on substrate type (e.g., sand vs. gravel), height relative to water elevations, distance from river, etc. Many of these communities are related to each other successionally, which means one community evolves into another over time, and so on, in a predictable sequence.

Plant succession is the change in composition of the dominant species over time. Studies on the Sacramento River illustrate the relationship between vegetation, plant successional processes and river geomorphic and hydrological processes (Conard et al., 1977; Strahan, 1984) (Figure 84).

Figure 84. Riparian Vegetation Succession along the Sacramento River.



As the river meanders, high banks are eroded on one side and low point bars are developed on the other. Willows and cottonwoods pioneer onto these newly deposited substrates, with seed dispersal and germination in spring timed to coincide with snowmelt flows receding in May and June. New seedlings grow very fast, developing into a willow-cottonwood thicket. Depending on the subsequent year's floods, the river channel may continue to erode high terrace

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land, but deposit on the other side. Established willow and cottonwoods may further deposition by impeding current flows over the low terraces. With the passage of time, the former point bar becomes higher and more stable, with new bars forming outward. Species not able to colonize at first are now able to seed on the developing terraces and become established under the shade of the willows and cottonwoods, which become tall trees. Eventually, terraces build up high enough so that species which are somewhat less tolerant of flooding but more tolerant of shade, such as valley oak, become established.

The later stages of riparian forest are often called climax or gallery forests. Typically, they are dominated by towering, aged cottonwoods and tree willows, or in the oldest stands, by spreading valley oaks, sycamore and black walnut. These forests have a well-developed understory of many other smaller tree species, shrubs and vines. The structural diversity of riparian gallery forests is unmatched in any other vegetation type in the state.

Cottonwoods and willows are not able to regenerate by seed in the mature forests of higher terraces, and when they die they are replaced by the more drought and shade tolerant species. Without river meandering, and its erosion and deposition, it is impossible for new large stands of cottonwood and willow to become established. Point bar deposition somewhere along the river, with receding flows in spring, are essential in order to replace older groves as they die naturally.

Fluvial processes also cause additional landform changes. For example, sudden river cutoffs create oxbow lakes, or meander scrolls, visible on aerial photographs. Overbank flooding can cause the deposition of natural levees, areas of high ground reachable only by the largest floods, in contrast to point bar deposition. Plant successional processes respond to all landforms and hydrologic environments created by the river. The result is a mosaic of plant communities over the flood plain, dependent upon a dynamic river system.

These patterns and relationships hold true for the Central Valley, most other large, meandering rivers of the Coast Ranges (e.g. the Russian and Salinas rivers) and, to a certain extent, the Colorado River. It should be noted there is considerable variation in riparian vegetation around the state, influenced in part by differences in regional flora and in part by differences in the physical/chemical environment. For example, in northwestern California, redwood and Sitka spruce (two evergreen conifers) are common components of riparian vegetation, and Colorado River riparian vegetation contains mesquite "bosques," or woodlands. In confined river systems, such as along parts of the Klamath, vegetation does not often develop into later mature stages; the constant fluvial actions keep vegetation in a state of "perpetual succession" (Campbell and Green, 1968).

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Animals

The fauna, or animal life, of rivers includes diverse forms representing all major taxonomic groups on earth. Of particular interest to resource managers is the traditional grouping of fish, reptiles, amphibians, birds and mammals which is usually meant by the term "fish and wildlife." However, invertebrates, including zooplankton, worms, molluscs, crustaceans and insects are equally important components of river ecosystems.

Invertebrates

In abundance and diversity, insects are among the most successful and dominant animal forms on earth, and their significant role in river ecosystems is unquestionable. Insects important to river and stream ecosystems include some species which are purely terrestrial, some which are purely aquatic, and many which live a portion of their lives in both aquatic and terrestrial environments. The later two types are both commonly called "aquatic" insects. Aquatic insects are the most important group of primary consumers in stream and river food chains and webs linking plants to fish (Goldman and Horne, 1983). Many aquatic insects emerge from the water environment in their mature stage, living as adults in the riparian zone, where they are major components in the diets of riparian bird and bat species (see review by Jackson and Resh, 1989).

About 2,000 species in California are considered aquatic or semiaquatic, occupying water for at least part of life (DWR, 1982). Major groups are mayflies (*Ephemeroptera*), dragonflies (*Odonata*), stoneflies (*Plecoptera*), caddisflies (*Trichoptera*), dobsonflies and alderflies (*Megaloptera*) (Erman, 1984; Goldman and Horne, 1983). Members of the fly and mosquito order (*Diptera*), including midges, blackflies, craneflies and mosquitos, are also important insects of river systems as food for fish and riparian birds and as pests to humans and other animals (Faber et al., 1989; Goldman and Horne, 1983).

Aquatic insects, including the aquatic larval and nymph forms of flying species, have evolved remarkable and diverse adaptations for life in running water (Hynes, 1970). Many of these adaptations deal with the problem of staying in one place in a moving environment, including flattening and other streamlining of the body, claspers, suckers, hooks and sticky substances. Despite such adaptations, benthic (bottom dwelling) insects frequently become detached, floating downstream in the current.

Benthic insects which have released or otherwise detached, together with terrestrial insects which fall into the water and detached algae, form an important source of food for aquatic organisms called drift. Drift may be the predominant food source for fish in environments otherwise too deep and swift to have benthic community development (McGinnis, 1984).

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In recognition of the importance of function, aquatic fauna, primarily insects, have been classified and described by their method of feeding, rather than by taxonomic grouping (Cummins, 1974).

Table 15. Feeding Methods of Aquatic Fauna.

Functional Group	Food source
Predators	Motile food
Scrapers (grazers)	Attached algae
Collector-filterers	Drifting plant and animal fragments, wastes, microorganisms
Collector-gatherers	Sunken plant and animal fragments and wastes
Shredders	Large plant parts: leaves, bark, twigs, logs, seeds, cones, etc.

Other aquatic invertebrates include molluscs (e.g. clams and snails), crustaceans (e.g. crayfish) and several groups of worms. The fauna of stony bottom and fast current environments of upstream reaches is typified by stoneflies, caddisflies, mayflies and dobsonflies, while worms tend to be more prevalent in softer sediments found in lowland rivers. Tubificid worms and midge larvae are tolerant of lower oxygen and higher nutrient environments characteristic of lowland river bottoms and thus can also be indicators of river pollution (Haslam, 1990; Hynes, 1970; Reid and Wood, 1976).

Terrestrial insects in the riparian zone have many of the same functions as aquatic forms. As noted above, they are food items for fish and are very important for riparian bird species, as well as other vertebrates and invertebrates. Some insects themselves are predators, feeding on other insects and invertebrates. Others are important herbivores that feed on succulent riparian plant growth, have a role in the breakdown and decomposition of dead plant and animal matter, and are major pollinators (Faber et al., 1989).

Three species of invertebrates associated with California rivers have been listed as threatened or endangered by the state or federal government: the Valley Elderberry Longhorn Beetle, California Freshwater Shrimp and the Shasta Crayfish. The small number of listed invertebrates does not mean that many more are not at risk, but probably indicates instead a lack of adequate information (Eng, 1984).

The riparian Valley Elderberry Longhorn Beetle, a federal Threatened Species, is found only in the Central Valley, and requires elderberry plants as host plants for both immature and mature stages (Eng, 1984). Two aquatic crustaceans, California Freshwater Shrimp and Shasta Crayfish are both state and federal Endangered Species.

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The California Freshwater Shrimp is limited to lowland streams in Marin, Sonoma and Napa counties. The Shasta Crayfish is found in Shasta County in the Pit River system, including the Fall River Drainage (CDFG, 1992).

Fishes

The California native fish fauna is extremely varied—from the once abundant runs of salmon and steelhead swimming the waters from mountain streams to the Pacific Ocean, to tiny species of the most limited distribution and numbers in desert oases. About half of all native fish species and subspecies are found only in California (Moyle et al.,1989).

Fish are perhaps the most important indicator of aquatic biodiversity. Not only are fish the best studied of all aquatic organisms, they are excellent indicators of environmental conditions and have major influences over other aquatic life (Moyle and Leidy, 1992). Over two-thirds of the 116 native California fishes have already declined to the extent they are considered species of concern, including a number which are extinct entirely or extirpated from their native ranges within this state (Moyle and Williams, 1990).

The decline of native fish fauna is indicative both of habitat degradation and the introduction of nonnative fish species (Moyle, 1986). In California at least 48 nonnative species have become established (McGinnis, 1984). The Western United States have fish fauna comprised of 30 to 60 percent introduced species, compared to about 10 percent for the East (Moyle, 1986). Moyle suggests the high number of introduced species in the West is partly because native fish diversity in any one drainage was naturally low to begin with, and partly due to severe environmental degradation which created habitats more favorable for the nonnative species.

River and stream fishes are often divided into two major groups: resident and anadromous. Resident fish live their entire lives in freshwater, usually in a limited reach of river or stream. Anadromous fish spawn in freshwater, the young migrate to the sea to mature, then adults return again to freshwater.

The principal fishes of California rivers are shown in Table 16. More thorough lists and descriptions of individual species' ecology can be found in McGinnis (1984), Moyle (1976), and Moyle et al. (1989).

Fish assemblages are often described as either cold water communities or warm water communities (DWR, 1982). In general, cold water fish require aquatic habitats with temperatures below 68°F, high oxygen content, good water clarity, high turbulence and stony beds. Warm water fish can survive conditions of higher temperature, doing well at 80°F, lower oxygen, high turbidity and mud bottoms. River habitats actually are more variable than the two general types outlined above.

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Table 16. Common Fishes of California Rivers.

	Distribution by Region +
White Sturgeon *Acipenser transmontanus* A	NC,CV,CC
American shad *Alosa sapidissima* IA	NC,CV,CC
Sacramento sucker *Catostomus occidentalis occidentalis*	NC,CV,Mo,CC
Klamath smallscale sucker *Catostomus snyderi*	NC
Tahoe sucker *Catostomus tahoensis*	ES
Prickly sculpin *Cottus asper*	NC,CV,CC,SC
Paiute sculpin *Cottus beldingi*	ES
Riffle sculpin *Cottus gulosus*	NC,CV,C
Pit sculpin *Cottus pitensis*	Mo
Upper Klamath marbled sculpin *Cottus klamathensis klamathensis*	NC
Lower Klamath marbled sculpin *Cottus klamathensis polyporus*	NC
Coastrange sculpin *Cottus aleuticus*	NC,CC
Red shiner *Cyprinella lutrensis* I	D
Common carp *Cyprinus carpio* I	NC,CV,Mo,CC,ES,Sc,D
Threadfin shad *Dorosoma petenense* I	CV,SC,D
Western mosquitofish *Gambusia affinis* I	NC,CV,Mo,CC,ES,SC,D
Fully plated threespine stickleback *Gasterosteus aculeatus aculeatus* A	NC,CV,CC,SC
Partially plated threespine stickleback *Gasterosteus aculeatus microcephalus*	NC,CV,CC,SC
Lahontan creek tui chub *Gila bicolor obesa*	ES
Klamath River tui chub *Gila bicolor bicolor*	NC
Pit River tui chub *Gila bicolor* subsp.	Mo
Blue chub *Gila coerulea*	NC,Mo
Wakasagi *Hypomesus nipponensis*	NC,CV
Sacramento tule perch *Hysterocarpus traski traski*	CV,Mo
White catfish *Ictalurus catus* I	CV,CC,SC
Black bullhead *Ictalurus melas* I	CV,Mo,CC,ES,SC,D
Brown bullhead *Ictalurus nebulosus* I	NC,CV,Mo,CC,ES,SC,D
Channel catfish *Ictalurus punctatus* I	CV,Mo,ES,SC
Pit-Klamath brook lamprey *Lampetra lethophaga*	Mo
Pacific brook lamprey *Lampetra pacifica*	NC,CV,CC
Sea-run Pacific lamprey *Lampetra tridentata tridentata* A	NC,CV,CC,SC
Sacramento hitch *Lavinia exilicauda exilicauda*	CV
Monterey hitch *Lavinia exilicauda harengus*	CC
Sacramento roach *Lavinia symmetricus symmetricus*	CV
Green sunfish *Lepomis cyanellus* I	NC,CV,Mo,CC,ES,SC,D
Warmouth *Lepomis gulosus* I	CV,D
Bluegill *Lepomis macrochirus* I	NC,CV,Mo,CC,ES,SC,D
Redear sunfish *Lepomis microlophus* I	CV,Mo,CC,ES,SC,D
Inland silverside *Menidia beryllina* I	CV
Smallmouth bass *Micropterus dolomieui* I	CV,Mo,CC,ES,SC,D
Largemouth bass *Micropterus salmoides* I	NC,CV,Mo,CC,ES,SC,D
Striped bass *Morone saxatilis* IA	NC,CV,D
Golden shiner *Notemigonus crysoleucas* I	NC,CV,CC,SC,D
Fall run chinook salmon *Oncorhynchus tshawytscha* A	NC,CV
Late-fall run chinook salmon *Oncorhynchus tshawytscha* A	CV
Winter run chinook salmon *Oncorhynchus tshawytscha* A *	CV

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Table 16. Continued from page 209.

Spring run chinook salmon *Oncorhynchus tshawytscha* A *	NC,CV
Coho salmon *Oncorhynchus kisutch* A *	NC,CC
Resident rainbow trout *Oncorhynchus mykiss gairdneri*	NC,CV,Mo,CC,ES,SC
Fall/Winter run steelhead *Oncorhynchus mykiss gairdneri* A	NC,CV,CC,SC
Spring/Summer run steelhead *Oncorhynchus mykiss gairdneri* A *	NC
Sacramento blackfish *Orthodon microlepidotus*	CV,CC
Yellow perch *Perca flavescens* I	NC
Bigscale logperch *Percina macrolepida* I	CV
Fathead minnow *Pimephales promelas* I	CV,D
White crappie *Pomoxis annularis* I	CV,Mo,SC,D
Black crappie *Pomoxis nigromaculatus* I	NC,CV,Mo,CC,SC,D
Mountain whitefish *Prosopium williamsoni*	ES
Sacramento squawfish *Ptychocheilus grandis*	NC,CV,Mo,CC
Flathead catfish *Pylodictus olivaris* I	D
Klamath speckled dace *Rhinichthys osculus klamathensis*	NC
Lahontan speckled dace *Rhinichthys osculus robustus*	ES
Sacramento speckled dace *Rhinichthys osculus* subsp.	CV,Mo
Lahontan redside *Richardsonius egregius*	ES
Brown trout *Salmo trutta* I	NC,CV,MO,ES,SC,D
Brook trout *Salvelinus fontinalis* I	NC,CV,MO,ES,SC,D
Eulachon *Thaleichthys pacificus* A	NC

I = Introduced; A = Anadromous

+ **Regions** (see Map of Regions, Figure 69)
NC = North Coast/Klamath
CV = Central Valley
Mo = Modoc/Cascade
CC = Central Coast
ES = Eastside/Great Basin
SC = South Coast
D = Desert (Mainly represents Colorado River)

* Winter and spring run chinook, coho, and spring/summer steelhead are now rare

Sources: McGinnis (1984), Moyle (1976), Moyle and Yoshiyama (1992), Moyle et al. (1989), Robins et al. (1991).

There is variation at many levels—between different drainage systems, along longitudinal gradients, between pools and riffles within one reach, and between years and seasons in the same reach.

Trout are the archetypical cold water fish, not only in California, but in the rest of North America and Europe as well (Moyle, 1986). They are often joined by sculpins, speckled dace, and suckers. Warm water downstream river habitats commonly support "deep bodied" fish such as the Sacramento perch or tule perch. In their natural state, California lowland rivers were dominated by these native perches, and native minnows such as hitch, squawfish, Sacramento blackfish and Sacramento splittail (Moyle, 1976). Today, such habitats are dominated by introduced species from the sunfish and catfish families, and a few others. The native species have been eliminated or severely reduced in range and numbers.

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A number of fish groups are distributed over many habitats. Suckers, roach and squawfish are widespread, and are especially common in environments transitional between cold and warm water habitats such as in the Sierran foothills or many coastal rivers (Moyle, 1976).

Anadromous fish must live in many different habitats, migrating upriver or downriver depending on the stage in their life cycle. Most anadromous species in California are important fishery resources, including members of the Salmon family, sturgeon and the introduced American shad and striped bass. The Pacific salmon, more than any other fish, is vitally important to human culture in western North America. Knowledge of their life history is critical to some of most significant issues of river management in California.

Pacific Salmon

The Salmon family (Salmonidae) includes both anadromous and freshwater forms. The major native salmonids found in California rivers are all closely related, belonging to the same genus, *Oncorhynchus* (Smith and Stearly, 1989). They are the chinook (king) salmon, coho (silver) salmon, and several forms of steelhead/rainbow trout and cutthroat trout. Salmon, steelhead and sea-run coastal cutthroat are anadromous, while the rainbow trout and other types of cutthroat trout are resident species.

Anadromous salmonids have a remarkable life cycle. They begin life as eggs spawned in freshwater rivers and streams, then, as tiny young fish, rear in the streams where they were hatched. After a period of growth, sometimes months but up to a year or more in some species, the developing young fish migrate downstream to the sea. Their major growth occurs as they roam the ocean pasture for several years, covering thousands of miles. In one of the animal kingdom's most extraordinary feats of migration, adult salmon return to reproduce in the same rivers that spawned them, often to the exact same reach or tributary.

Salmonids separate into distinct populations among different locations, and may segregate populations in one place further by migrating at different times. Runs at different times within a single species or subspecies are called races. California chinook are generally fall or spring run, although the Sacramento River is unique in having four different races—the fall, late fall, winter and spring runs. The fall-run is the most numerous chinook race in the state today. Steelhead are considered to have two races, the more prevalent fall/winter run, and the spring/summer run. Separate races have not been identified for coastal cutthroat and coho salmon.

With such a high degree of reproductive isolation among different river systems and among different races, Pacific salmon species are considered to be made up of distinctive stocks (See

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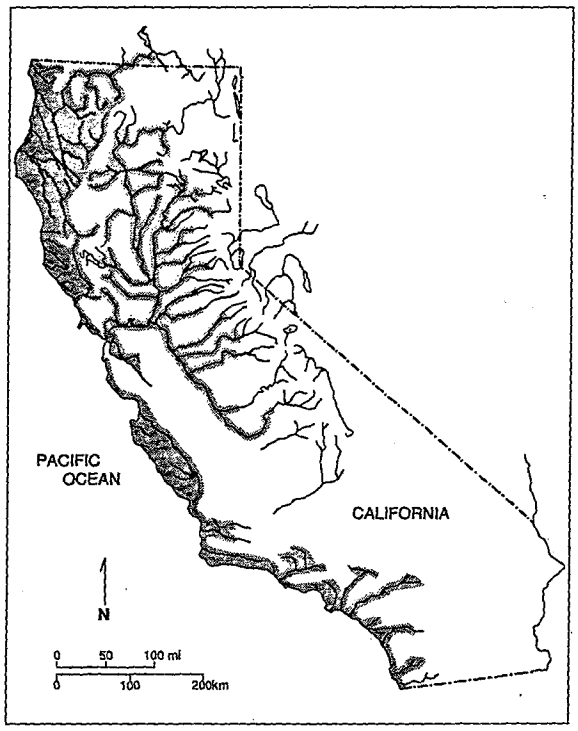
Figure 85. California Steelhead Distribution, 1900s.



review by Nehlsen et al., 1991). Stocks are identified by taxonomic grouping (species or subspecies), river or stream system, and migratory season. A stock of Pacific salmon judged to be an evolutionary significant unit (ESU) of a species is itself considered a "species" under the federal Endangered Species Act (National Marine Fisheries Service, 1991). An example of the stock concept is the listing of the Sacramento River Winter-run Chinook as a federal Threatened and state Endangered species.

Historically, anadromous salmonids were found throughout the Central Valley drainages and in coastal streams and rivers the entire length of the state. The chinook is the largest Pacific salmon and its distribution in California is correlated with the state's biggest rivers. The largest runs of the chinook are in the Sacramento-San Joaquin systems of the Central Valley, with other major populations on the Klamath, Smith and Eel rivers of the North Coast (Fry, 1979). Coho typically spawn in smaller coastal streams and tributaries

Figure 86. California Steelhead Distribution, 1980s.

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from Monterey Bay north (Moyle, 1976). Coastal cutthroat are fish of the Pacific Northwest rainforest belt extending south in California only down to Humboldt Bay (Trotter, 1989).

Steelhead once migrated up all significant streams of the state which had a connection to the ocean, including most southern California rivers. Of all the major California salmonids, steelhead have suffered the most dramatic decline in distribution. They currently occur mainly in northern California rivers and streams, having been all but eliminated from the Central Valley and South Coast (DFG, 1991c) (Figures 85 and 86).

Life History of the Salmon Family

The ecological requirements of salmon, steelhead and sea-run cutthroat trout are similar. They must have free access to the ocean and back to the spawning grounds. To survive and reproduce at their maximum levels they need cool or cold water, with a reasonably stable flow regimen and good quality, including high oxygen content, especially in spawning areas. Optimal and tolerated water temperatures vary between different species of salmonids, different life stages within a species, and between locally acclimated populations. Most Pacific salmonids prefer temperatures somewhere between 40° and 60°F (Allen and Hassler, 1986; Barnhart, 1986; Bjornn and Reiser, 1991). If water temperatures change out of the preferred range, such as with normal seasonal variation, salmonids will often move to other areas, if available, to avoid suboptimal temperatures (Bjornn and Reiser, 1991).

Also essential for maintaining healthy salmonid populations is habitat with proper current velocity, water depth, a varied and abundant food supply, and adequate space for spawning and for growth of eggs, young and juveniles. Salmonids are closely dependent on the physical nature of the water course (spawning gravels, cover, pools, riffles, etc.).

The chinook salmon life cycle is a good example of the exacting requirements of these fish. (See Allen and Hassler, 1986; Moyle, 1976). Adult fall-run chinook salmon, after spending from one to five years in the ocean, return to their natal stream to spawn during August through December. Fish may travel hundreds of miles upstream (over 1,000 miles in the Yukon River, Alaska). Female chinook salmon select spawning sites, preferring areas of swift current, porous gravels and cool temperatures. The females construct redds, or groups of nests, in the gravel by vigorous wriggling on their sides. Salmon spawn at depths ranging from 5 to 6 inches to 3.5 feet (Reynolds et al., 1990). Females lay thousands of eggs, fertilized by the males as they are deposited, over a one to two week period. The adult salmon usually die two to four weeks after spawning, leaving the eggs and young to fend for themselves.

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The eggs, in the gravel and nurtured by clean water, incubate for a period of 40 to 60 days depending on water temperature. It is essential that the gravels remain porous and clear of fine sediment so water can bring adequate supplies of oxygen to the incubating eggs and remove waste materials. The incubation stage is the period of greatest mortality. The eggs are particularly vulnerable to shock injury which can result from bottom scouring, superimposed spawning activity, low dissolved oxygen, toxic metals or chemicals, dewatering, high water temperatures, rapid or abrupt temperature changes or sedimentation. Under poor conditions egg mortality may be as high as 95 percent while under optimum conditions egg mortality may be as low as 10 percent (Reynolds et al., 1990).

At the end of the incubation period the eggs hatch and become alevins. They spend another 20 to 40 days in the gravel during which time the egg sack is absorbed and they emerge from the gravel as fry. These inch-long chinook salmon are free swimming, but seek out low-velocity back eddies and slack water areas where they feed heavily on zooplankton and small insects. Growth is usually rapid as they become fingerlings. At 2 to 3 inches long, they move downstream to the estuary or to the Pacific Ocean during spring freshets or snowmelt runoff (Allen and Hassler, 1986; Reynolds et al., 1990).

Most juvenile salmon migrate quickly to the ocean during March through June, reaching the sea at two to four months of age. Some individuals may stay many months in the downstream estuary. The San Francisco Bay/Delta Estuary is an important rearing area for Central Valley salmonids, although the extent and significance of estuarine use on the North Coast is not well-understood (DFG, 1991b). Salmon spend from one to five years in the ocean, feeding on fish and crustaceans, before migrating to their natal stream to spawn and repeat the cycle.

The fall-run chinook starts entering the various rivers usually in August and spawn in October through December. The late fall-run enters freshwater from mid-October through mid-April and spawn January through April. The winter-run migrates from mid-December through mid-July and spawn from mid-April to mid-July. Before the construction of Shasta Dam, the winter-run chinook migrated up the Pit and McCloud rivers to spawn in their cold, spring-fed waters. The spring-run was historically the most numerous in the Central Valley, with annual runs of .5 million to 1 million fish (Moyle and Yoshiyama, 1992). This run would move up the valley rivers on the spring runoff from melting snow in March through July, migrating far upstream to cooler waters where they would summer over and spawn from mid-August to mid-October. Dams have eliminated both access to upstream spawning grounds and spring flows from snowmelt runoff. Only small populations of the winter and spring runs now remain.

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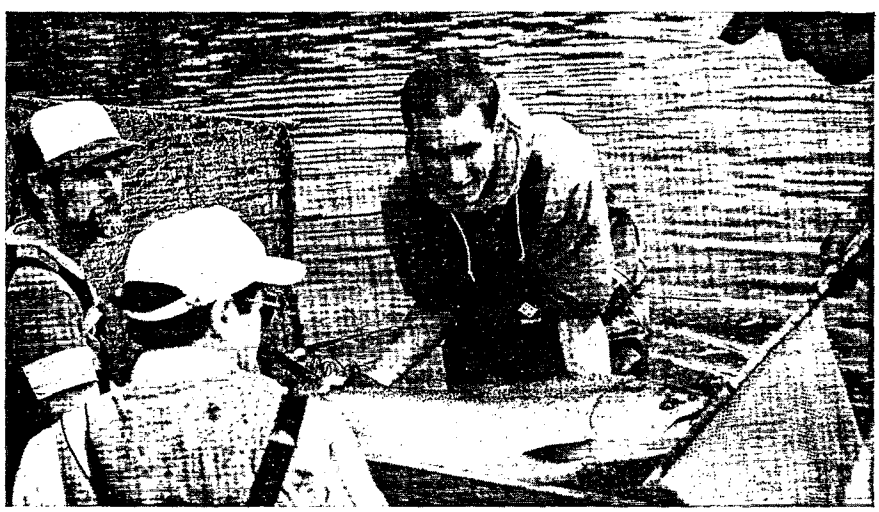
Unlike most chinook, steelhead and coho salmon may stay one to three years in freshwater. Juveniles require good habitat and water quality conditions throughout the year. Coho are quite sensitive to warm temperatures and typically spawn in mid-size coastal rivers and tributaries (Bell, 1985; Hassler, 1987; Shapovalov and Taft, 1954). Steelhead usually spawn in the smaller tributaries to a river or stream, and even commonly use intermittent streams. Unlike salmon, steelhead do not die after spawning and a small portion of the population may return to spawn again. (Bell, 1986; Barnhart, 1986; Shapovalov and Taft, 1954).

Native populations of anadromous salmon, steelhead and coastal cutthroat (*Oncorhynchus* spp.) are in serious decline in the Western United States—Washington, Oregon, Idaho and California. The American Fisheries Society Endangered Species Committee (Nehlsen et al., 1991) has identified 214 naturally spawning Pacific salmonid stocks threatened with extinction, of which 39 are in California. At least another 106 major populations, 21 in California, have already been lost. (See list of salmonid stocks at risk, Table 18).

The most economically important runs in the state are the Sacramento and Klamath Rivers fall-run chinook. The Klamath system chinook are also highly valued culturally by native peoples. These stocks in the last two years are not meeting the spawning escapement goals of fisheries management authorities. (Escapement is the total river run size which "escaped" ocean harvest, and is a commonly used estimator of population size. The total production = ocean catch + escapement. In any one year, escapement may be one-third to one-half total production. Spawning escapement is that portion of the river run or total escapement which is not caught inriver and is available for reproduction).

Figure 87. Fishery Biologists Monitoring Chinook.



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In 1991 the total river population of the Sacramento fall-run chinook was about 110,000 fish (PFMC, 1992), compared to a peak of 403,000 in 1953, observed shortly after counts began in the river (Reynolds et al., 1990). The Klamath fall run in 1991 had a total escapement of about 31,000, only 15 percent of a recent high of 204,000 in 1987 (PFMC, 1992). Tragically, estimates of run numbers are continually becoming outdated as populations continue to collapse. The present regulatory situation is that commercial ocean harvest of chinook has been almost completely curtailed, and severe restrictions have been placed on recreational ocean and all inriver fishing, including native tribal harvest.

Birds

Without question, high bird species diversity and abundances are a major characteristic of California riparian habitats. The aquatic and riparian habitats of rivers are used by a broad variety of species, but river avifaunas are typically dominated by passerine species (smaller perching birds) such as flycatchers, warblers and swallows. Herons and egrets are also common along rivers, utilizing tall trees of riparian forests for rookeries, and feeding on fish and other aquatic organisms in the channel. On salmon spawning rivers in northern California, Ospreys and Bald Eagles take advantage of abundant fish for food.

Riparian woodland and forests have been noted to support a greater number of bird species than any other habitat type of the state (Miller, 1951). The importance of river riparian habitats to bird life holds true for all regions of the state, e.g. the Central Valley (Gaines, 1977; Hehnke and Stone, 1978); the South Coast (Faber et al., 1989); the Truckee and Carson rivers on the east side of the Sierra (Ridgeway, 1877, cited by Klebenow and Oakleaf, 1984), and the North Coast (Ray et al., 1984). Riparian vegetation is valuable as suitable or optimal spring/summer breeding habitat for over 120 bird species in California (CDFFP, 1988). In addition, its importance for migratory bird populations cannot be overemphasized. Fall and winter densities of migrant bird species are often two to three times greater than breeding species densities in the same riparian habitat (Michny et al., 1975; Motroni, 1984), and over ten times greater than adjacent nonriparian cover types (Stevens et al., 1977).

Many bird species, including a number at extreme risk of extinction or extirpation, have declined in response to losses of up to 95 percent of riparian vegetation in the Western U.S. In a national review of imperiled and extinct birds of the United States and Canada, Ehrlich et al., (1992) state:

> Habitat loss and degradation pose the greatest threat to North American birds. From forests to wetlands, avian

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habitats are everywhere endangered. Riparian areas (corridors of water-loving vegetation along streams and rivers) are especially vulnerable and of critical importance.

Currently, at least 40 bird species on California rivers are considered to warrant special concern (see Table 17). Examples of riparian species in California which are most endangered include the Least Bell's Vireo and Western Yellow-billed Cuckoo. The following summaries are from the California Department of Fish and Game (1992).

The Least Bell's Vireo is listed both state and federally as Endangered. Once widespread in riparian forests and thickets of the Central Valley, the desert, and the Central and South Coast, it is now limited to around 300 pairs mainly in coastal southern California. It is threatened by habitat loss and nest parasitism by the Brown-headed Cowbird.

The Western Yellow-billed Cuckoo is a state Endangered species. The U.S. Fish and Wildlife Service thus far does not consider this a valid taxon for protection under the federal Endangered Species Act. This species once bred all over the state except the high Sierra, utilizing the larger stands of willow and cottonwood which it prefers. With extensive habitat loss and fragmentation of riparian habitat, by 1977 there were only an estimated 122-163 breeding pairs in California. The last census in 1986 and 1987 found only 31-42 pairs.

Other Vertebrates

While many mammal species are not limited to stream and river ecosystems, riparian forests and woodlands provide habitat for significant concentrations of species diversity. As examples, out of 181 mammal species (excluding whales and porpoises) found in the state, Central Valley riparian communities are habitat for 55 species (Trapp et al., 1984), and in southern California, riparian habitats support 44 different mammal species (Faber et al., 1989).

The most widespread river or stream dependent mammals are river otter, beaver, mink and muskrat (Mayer and Laudenslayer, 1988). Other species with a strong dependency or preference for riparian habitats include many furbearers, such as ringtail, raccoon, mink, grey fox, red fox, coyote and skunks (Brinson et al., 1981; Stone, 1976b).

Riparian environments found on California rivers provide suitable habitat for about one-half the amphibians and one-third the reptiles found in the state (from information in Brode and Bury, 1984; and Zeiner et al., 1988, 1990a & b).

The California Red-legged Frog, once widespread in Central Valley rivers and marshes, was decimated by intensive market hunting (for the frog leg trade) in the late 1800s. The remaining limited populations are threatened by habitat loss and competition from other species. The Foothill Yellow-legged Frog has also

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declined in response to loss and degradation of rocky-bottom stream and river habitats, which it prefers, and interspecific competition. (See review in San Francisco Estuary Project, 1992b). Both are California Species of Concern.

See Chapter 3 for lists of common or indicative amphibians, reptiles, birds and mammals on California river systems.

River Habitat and Community Classification

An important tool for understanding and managing rivers and streams is their classification. Classifying rivers, as well as other natural systems, is essential for making comparisons and thus inferences about them, and for communication between researchers and managers familiar with different areas and different disciplines. Most river and stream classification systems which have been developed thus far come from two different orientations: ecology vs. geomorphology, emphasizing living organisms or the physical environment, respectively. The major river classification systems which have been applied to California rivers are described below; however, no comprehensive inventory of the entire state has yet been done.

Ecological River Classification Systems

For natural areas which contain significant amounts of vegetation, the dominant types of plants are commonly used as the indicator of both the environmental conditions and of the diversity and amounts of living things found there. For example, the presence of a large cottonwood dominated mixed riparian forest in the Central Valley would suggest that the environment is within the flood plain of a river or large stream, has high groundwater, and likely supports over 200 different kinds of vertebrate wildlife species in high numbers.

In scientific literature and in natural resource management there are many ways that the natural world has been described and classified, depending upon the scale and ecological characteristics of the study region, the purpose, and even the academic background and traditions of the person doing the classification. Riparian vegetation is included in numerous terrestrial vegetation classification systems at regional, state, national and even international scales. The U.S. Fish and Wildlife Service includes riparian vegetation types in a nationwide system of wetland classification (Cowardin et al., 1979), which is one of the few systems to include aquatic habitats.

Different classification schemes use different ecosystem units, different names and different decision paths. For example, a particular grouping of riparian plants might be referred to as a habitat type, natural community, vegetation type, ecosystem type, plant community, association, biotic community or cover type.

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Often, a specific example or stand of vegetation will be called a habitat or community, while the class of all similar areas will be called a habitat "type" or a community "type."

Unfortunately, there is no consensus on how best to describe and classify natural systems. Resource managers and scientists must be aware of differences in looking at the world and in terminology. Explanatory "crosswalks" which list and compare classification schemes are valuable, such as the de Becker and Sweet (1988) system prepared for California vegetation types. There are at present two major trends in California for classifying habitat types.

In one program, the California Natural Diversity Data Base (CNDDB) in the Department of Fish and Game catalogues and monitors biological diversity in the state. The CNDDB currently uses a classification system of "Natural Communities" (Holland, 1986) which identifies and describes 273 upland and wetland vegetation types—86 of which are tracked as rare—including many kinds of riparian forests, woodlands and shrublands. This community classification system is undergoing a major revision by an interagency group, including staff of the CNDDB, representatives of California Native Plant Society and other vegetation scientists. With regard to aquatic habitats, the CNDDB has not yet devoted much effort at habitat identification and rare community monitoring due to limited funding. A working scheme was developed which identified freshwater, estuarine and marine community types (Ellison, 1984). Recently, Moyle and Ellison (1991), presented a new classification system for California inland freshwater habitats, based on "ichthyological provinces" (fish species distribution). This classification system has been designed to provide the basis for creating a statewide system of Aquatic Diversity Management Areas (ADMAs).

Another effort in California has focussed on classification of mainly terrestrial vegetation cover types with the primary purpose of predicting vertebrate wildlife habitat relationships. The Wildlife Habitat Relationship (WHR) System (Mayer and Laudenslayer, 1988) distinguishes only about 50 different habitat types, but these are proving useful for broadscale assessments of wildlife habitat trends as well as other forest and rangeland resources (e.g. CDFFP, 1988). Only a handful of riparian and aquatic habitat types are differentiated under the WHR system.

Another way of studying ecosystems is by taxonomic inventories. The taxonomy of living things is how they are divided into different species and other levels of phylogenetic (evolutionary) classification. Knowledge of the identity of organisms is basic to any ecological research or application. For example, if the function of a species is well-known, its presence or absence in an ecosystem can be used as an indicator of environmental conditions.

An individual species' function in an ecosystem can probably never be known completely, and for many species, it is barely known

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at all. Sadly, many applied environmental studies are limited to simple taxonomic inventories, rather than more involved studies of function. Such inventories are however, a critical first step. For ecosystems to survive, the assumption made by scientists today is that it is imperative "to keep all the pieces." This is the basis of the concern for preserving biological diversity. California has never comprehensively inventoried aquatic invertebrates, despite their extreme importance in aquatic food webs and as indicators of environmental quality (Erman, 1991).

Geomorphic River Classification

When river and stream channels are a focus of study or management, as for restoration of fisheries or bank stabilization, geomorphic classification systems may prove useful. Classifications are useful for inventories over broad regions and for initial assessment of ecological potential or restoration needs. However, classification alone may be misleading and is insufficient alone as a basis for designing channel works (Kondolf, in prep).

Rosgen (1985) developed a classification system based on channel attributes of gradient, sinuosity, width/depth ratio, bed material size and degree of confinement. His system, currently under revision, is increasingly being used in the West. For example, the California Department of Fish and Game has incorporated Rosgen's system as a basic part of the approach for fish habitat restoration presented in their *California Salmonid Stream Habitat Restoration Manual* (Flosi and Reynolds, 1991).

Rivers as Ecosystems—Systems of Interacting Environments and Organisms

To understand, sustain and manage natural systems it is useful to describe and categorize them as ecosystem—communities of organisms and their environments which are closely linked. Depending on purpose, ecosystem boundaries can enclose areas vastly different in size and function. For example the community of algae, microbes and insects living in a single submerged rock could be regarded as an ecosystem, as could the ten-mile stretch of river in which it is found. Even the entire biosphere of the earth can be considered an ecosystem. A new national priority is emerging for the restoration and protection of rivers as ecosystems (National Research Council, 1992).

A river ecosystem extends laterally over its entire flood plain and longitudinally from headwaters to the sea, lake or sink. A river ecosystem may even extend far beyond the flood plain to hydrologically connected aquifers. Most California river ecosystems are characterized by extreme variation over the three dimensions of space and over time.

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The dynamism of rivers includes seasonal high and low flows, changes in channel and flood plain forms, and drought and flood events. Floods considered catastrophic to humans are not "disturbances" to river ecosytems. Most river biotic communities recover quickly from denudation or other mortality, and in fact large floods are beneficial for many species (National Research Council, 1992).

Rivers are considered open ecosystems; a large proportion of organic matter and nutrients comes from outside the system, especially in headwater rivers. Once in the river system, materials are continually transported downstream in a one-way flow of water. The implications of this tendency to lose materials from a particular site along a river are several: There must be a constant influx, either from terrestrial or upstream sources, of new material; there needs to be a certain amount of retention of materials at a site so that river organisms can take advantage of them; recolonization of disturbed aquatic habitats is generally from upstream; and materials tend to accumulate in downstream reaches.

Figure 88. Riparian and Aquatic Habitats.

Traditionally, stream and river biological studies make a major distinction between riparian "systems" and aquatic "systems. " While from an organismal point of view it is frequently convenient to separate riparian from aquatic habitats, they should not be regarded as separate ecosystems. Riparian zones are sometimes even demoted to being called "transitional" areas or "ecotones" (boundary habitats) between upland and water. Riparian environments and biota are more than merely the edge separating dry land and water, they are integral parts of a river ecosystem. One should avoid concepts that deemphasize or ignore the tight linkages between river geomorphic and hydrologic processes, habitats, and riparian and aquatic biota.

To better appreciate the importance of the linkages between

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riparian vegetation, aquatic biota, and the physical/chemical environment, it is necessary to have an understanding of ecosystem functions pertaining to energy and nutrient processing in the aquatic environment. For any section of stream or river, the balance between production and consumption, and import and export, will be major determinants of the character of the aquatic community.

Energy and Nutrient Budgets

A basic concept in river and stream ecology is classifying the sources of organic matter, nutrients, sediments or even pollutants entering the aquatic environment. For a particular river or stream aquatic habitat, materials which come from outside the system are termed allochthonous, and any material created or derived from inside the system is termed autochthonous. Leaves, twigs and insects from riparian vegetation which fall into the water are examples of allochthonous materials (Figure 89); benthic algal growth is an example of autochthonous production.

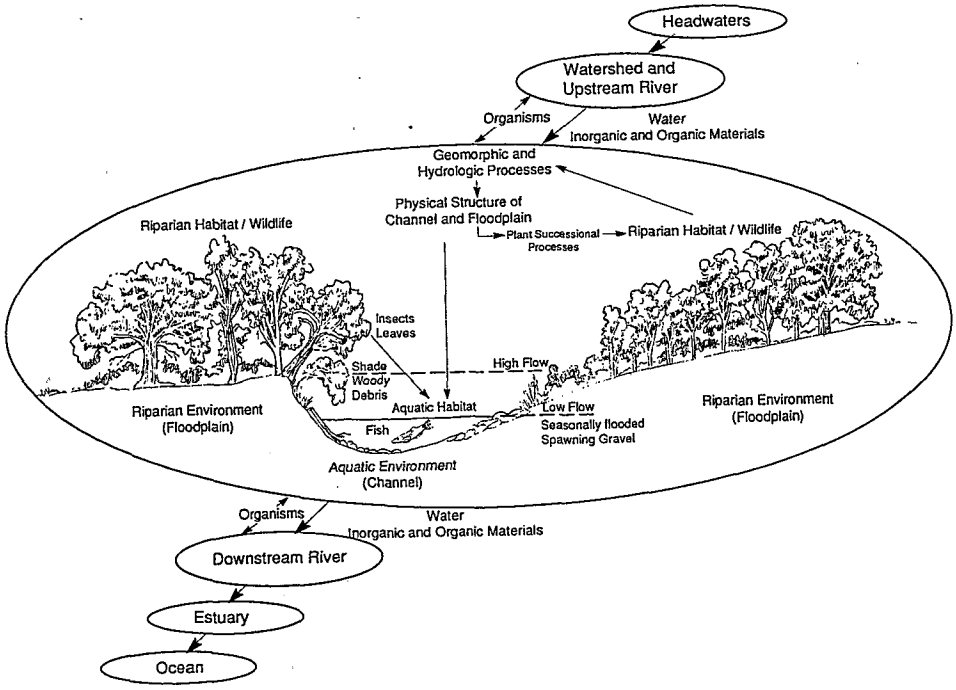
Figure 89. Leaves As Energy/Nutrient Source.

Another functional classification of aquatic habitats pertains specifically to the primary source of organic matter for use by consumers and decomposers. A river or section of river which derives most of its organic matter energy sources from primary production within the system is said to be autotrophic. A segment which is dependent upon organic material input from outside sources is said to be heterotrophic. An example of an autotrophic situation would be a reach in a medium-sized river with minimal shading and clear water, which allows for high benthic algal production. A lowland river with deep water and high amounts of turbidity limiting phytoplankton or benthic algal production would be heterotrophic (Vannote et al., 1980).

Ecosystem Linkages

Discussed below are the most important linkages in river ecosystems: fluvial geomorphic processes and riparian vegetation; riparian vegetation and vertebrate animals; and riparian vegetation and aquatic habitats and food supply. Also discussed are the relationships among river ecosystems and upland/watersheds, estuarine and ocean systems and upstream-downstream variations (Figure 90).

Figure 90. Model of a River Ecosystem.



Relationship of Fluvial Geomorphology/Hydrology and Riparian Vegetation

No other aspect of California river ecosystems is so critical yet at the same time has been so ignored in river management as the interdependence of riparian habitat and fluvial geomorphology and hydrology. The distinctiveness of riparian forests and woodlands and their high value for fish and wildlife habitat is largely due to the physical environments created by natural river processes.

Flood plain landforms present subtle but important variation in topography and substrate texture. The height, shape and soil characteristics of river landforms combine with groundwater and surface water regimes to create unique plant environments. Species will predictably segregate in space over these different environments, and therefore riparian vegetation patterns can be used as indicators of hydrogeomorphic conditions (Hupp and Osterkamp, 1985).

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For alluvial or meandering rivers, variation of river landforms over time is as significant to riparian vegetation as spatial variation. As described in the previous section on plants, riparian vegetation successional processes must proceed in order to perpetuate the mosaic of riparian habitats. Without flooding, erosion and deposition, the large forests of riparian vegetation along valley rivers cannot be maintained naturally.

For constrained reaches, for example in narrow mountain valleys, riparian vegetation is less dependent in a positive way upon physical river processes, and is generally in a battle just to survive the frequently scoured environment.

Once a geomorphic feature is stable enough to be successfully colonized by vegetation, the vegetation tends to enhance stability of the site. Roots enhance tensile strength of soil and therefore can reduce bank erosion, at least up to a certain magnitude of shear stress. In addition, above-ground plant parts can act to slow flood currents, which in turn may cause sediments to deposit.

The important role of riparian vegetation as a source of large woody debris within the active channel has only recently been explored. Sedell et al. (1988) reviewed the many functions of fallen logs in Pacific Northwest rivers. Coarse woody debris increases the complexity of aquatic habitats by physically obstructing and diverting flow, which in turn creates backwater areas, pools and other depth variability. Woody debris also increases retention of sediment and organic material and is itself a substrate for organisms to colonize. During floods, logs can protect live vegetation, adding stability to a channel, or act as battering rams on banks and vegetation. After extreme large floods or landslides, channel equilibrium is restored faster with the stabilizing effects of woody debris. In rivers originating in heavily timbered and mountainous watersheds, it is not uncommon for instream coarse, woody debris to come from upland as well as streamside forests.

Relationship of Riparian Habitat and Vertebrate Wildlife

Riparian vegetation is of extreme value as habitat for vertebrate wildlife species. Throughout the United States, riparian habitat has been shown to support a greater diversity and abundance of wildlife than practically any other cover type (see extensive review of previous studies by Brinson et al., 1981). Riparian habitats are characterized especially by a rich bird life.

Attributes of riparian vegetation which relate to its importance as wildlife habitat include (from Brinson et al. 1981): predominance of woody plant communities (trees and shrubs); presence of surface water and soil moisture; diversity and interspersion of habitat features; and role as corridors for dispersal and migration.

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For California, a major distinguishing feature of riparian vegetation is the dominance by mesic deciduous species. Their copious transpiration, succulent leaves and high productivity create a virtual greenhouse environment (Roberts et al. 1977) in contrast with adjacent upland areas.

Riparian habitat in California is best developed along larger meandering rivers. As described previously, the geomorphic processes of erosion, deposition and meander influence plant succession processes. Areas on higher flood plain terraces which grow into mature gallery forests represent the most productive habitat in the state. Such riparian forests have a highly complex structure, with a high tree top canopy, many understory layers, often a thick ground layer, and a profusion of vines hanging in lianas from the uppermost forest strata to the ground. This dense and diverse vegetation provides a large variety and quantity of animal living requirements including nesting and perching opportunities; food from seeds, fruits, and insects; and a shady, cool and moist microclimate. Riparian habitat supports many smaller birds, mammals, reptiles and amphibians which in turn are prey to larger vertebrates.

Often, different successional stages of riparian vegetation are important to different wildlife species. For example, the Willow Flycatcher prefers willow thickets, an early stage in riparian vegetation succession. Cavity nesters such as woodpeckers require large trees with broken canopies such as might be found in older sycamores or oaks.

While vegetation is the most important feature determining the value of riparian zones for vertebrate wildlife habitat, it is not the only one. For certain species, the physical characteristics of the substrate textures and land forms are critical components of their habitat. For example, most of California's remaining population of the Threatened Bank Swallow nest on eroding sandy banks of the Sacramento River and tributaries. Without the continuing meander of the river, survival of this species is in doubt (DFG, 1992). Killdeer are ground-nesting and -feeding birds which are common along river shores. Killdeer rely on camouflage for protection of adults as well as nests, and river gravel bars provide excellent concealment.

Relationship of Riparian Vegetation and Aquatic Communities

Riparian vegetation is a major influence on aquatic communities in streams and rivers by physically altering the habitat, by affecting inputs of dissolved and particulate organic and inorganic substances, and by providing terrestrial habitat for prey and predators of aquatic organisms. The close interrelationship of riparian vegetation and aquatic habitats has been reviewed by many, e.g. Baltz and Moyle (1984); Gregory et al. (1991); Knight and Bottorf (1984); and Meehan et al. (1977). Their description of ecosystem functions, both conceptual and quantified, are summarized on the next page.

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Riparian vegetation, through influences on channel and flood plain geomorphology (as described above) often plays a major role in shaping the structure of the underwater habitat. Submerged roots, branches and trunks usually enhance the productivity of a stream or river reach, particularly for fish.

Riparian vegetation can alter instream temperatures by shading water from solar radiation. The presence of vegetation, especially a thick tree canopy, can also reduce daily temperature fluctuations compared to an open stream. The temperature-moderating effects of riparian vegetation are strongest with smaller streams. On very large rivers, such as the Sacramento River, the effect of adjacent riparian habitat on overall water temperature becomes minimal.

Riparian vegetation is a major source of primary production for streams. In headwater areas, the input of allochthonous plant material provides most of the base of the aquatic food chain. Coarse leaf and twig material is broken down in the stream by insects and microbes into fine and dissolved organic matter which is consumed onsite or transported downstream.

In lowland reaches, primary production is a combination of phytoplankton growth and the input of fine and dissolved substances which originated upstream. In downstream reaches, the riparian vegetation immediately adjacent is less important for the energy balance of the whole river than for headwater areas.

The input of dissolve inorganic substances draining from upland sources into the water is controlled to a large extent by intervening riparian vegetation. Riparian trees and shrubs take up large quantities of nutrients and thus can alter the amount reaching the aquatic environment.

Along the Sacramento River system, the specific importance of riparian vegetation lining the banks has recently been observed and evaluated by the U.S. Fish and Wildlife Service (DeHaven, 1989). Shaded Riverine Aquatic Cover (SRA) is the habitat formed by the interface

Figure 91. Shaded Riverine Aquatic Cover.

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between woody riparian vegetation and the water. Overhanging branches, submerged roots and irregular crevices and surfaces of natural banks provide shade, cover and food supply to the immediate nearshore environment of large rivers.

SRA cover along the Sacramento River benefits numerous wildlife and fish species, including river otter, beavers, herons, egrets, kingfisher and salmonids. The extreme value of SRA cover has been demonstrated in studies and observations on juvenile salmonids. Higher densities of juveniles occur along natural banks than along those which are riprapped (armored with rock) and lacking SRA cover (DeHaven, 1989). The shaded environment created along the banks by SRA cover is considered critically important in the lower river, where water temperatures can heat to over 70°F. As of July 1992, 70 percent of the banks have been riprapped in the lower 60 miles of the Sacramento River and adjacent sloughs (Storfer, 1992). Because of the extremely high habitat value, scarcity and threatened future of SRA cover, this has recently been determined to be Resource Category 1, i.e. unique and irreplaceable, by the Regional Office of the Fish and Wildlife Service (Memorandum signed by Marvin Plenart, Regional Director, Portland; September 21, 1992).

Relationship of Rivers to Upland/Watershed

The influence of watershed condition and rivers and streams is readily observable when watersheds are artificially disturbed (Debano and Schmidt, 1989). Timber harvest, grazing and urbanization can significantly alter downstream waterways. The removal of vegetation, the construction of roads and alterations of the drainage network can lead to increased runoff and higher flood peaks, significant land erosion and reduced water retention for later release. Stream and river channels are subjected to flashier, sediment-laden flows during storms and decreased base flows in the dry season. Channels become unstable, with increased bank erosion, and riparian and aquatic habitats are destroyed or damaged, with almost no potential of easy recovery.

As noted above, the amount and character of dissolved nutrients draining from the land into the water is influenced by riparian vegetation. Riparian forests can remove dissolved nutrients such as nitrates and phosphates and particulate organic matter from upland surface and ground water before they drain to river waters. This filtering by riparian vegetation is potentially significant in reducing nonpoint source pollution from agricultural sources (Peterjohn and Correll, 1984).

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Relationship of Rivers to Estuaries and the Ocean

Estuaries are enclosed bodies of water where fresh water from land meets salt water from the sea. Estuaries are among the most productive ecosystems in the world, supporting abundant shellfish, fish and bird life. Healthy estuarine ecosystems result in large part from the unique circulation patterns created by the mixing of salt and freshwater, and from large influxes of nutrients from streams and rivers. River and stream flow amounts and timing are thus critical determinants of the character of estuaries.

Because estuaries are at the receiving end of whatever is transported by their tributary waterways, they are vulnerable to significant impacts caused by upstream alterations to rivers and streams. The most severe problems in California estuaries include decreases in freshwater input or changes in flow timing, excess sedimentation and chemical pollutants.

An overview of California's estuaries can be found in the *California Comprehensive Offshore Resource Study (Draft)* by the State Lands Commission (1991). Reports on the status and trends of the San Francisco Bay/Delta Estuary, the largest estuarine ecosystem on the West Coast, include *The State of the Estuary (1992), Status and Trends Report on Aquatic Resources in the San Francisco Estuary (1992), Status and Trends on Wetlands and Related Habitats of the San Francisco Estuary (1991), Status and Trends Report on the Wildlife of the San Francisco Estuary (1922)*, by the San Francisco Estuary Project; *Ecology of the Sacramento-San Joaquin Delta: A Community Profile* (Herbold and Moyle, 1989); and *Delta-Estuary: California's Inland Coast*, by the State Lands Commission (1991).

Materials transported by rivers also affect the ocean, the ultimate sink for most of California's natural waterways. As with estuarine systems, chemical pollutants from river runoff are a major problem for nearshore ocean environments. One of the most notorious examples of runoff effects on marine resources is the near extinction of the California Brown Pelican from eggshell thinning caused by DDT, a once commonly used pesticide (now banned).

Sediment transported by rivers and streams in California is the major source of sand for most of the state's ocean beaches (Griggs et al., 1992). Human activities on coastal rivers which interrupt natural geomorphic and hydrologic processes, such as upstream dams, settling basins and flood control projects, have reduced natural sand replenishment to eroding beaches (California State Lands Commission, 1991).

A major linkage between rivers and estuaries and the ocean is through anadromous fish. Pacific salmon and steelhead connect headwater areas, valley rivers, estuaries, and the high seas of the Pacific Ocean. Habitat damage and overharvest can equally affect fish populations. In the past, uncontrolled in river fishing, and then

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later ocean fishing, seriously depleted salmon stocks which led ultimately to tight regulations. Early mining and logging also took their toll, but populations could usually rebound once fishing pressure was reduced. Today, diversions and other habitat impacts are so severe that recovery from the recent dry cycle seems problematic. In response to the desperate prognosis for California anadromous salmonids, the Pacific Fishery Management Council (PFMC) and California Department of Fish and Game have all but eliminated ocean fishing and, in some places, in river fishing as well.

Upstream-Downstream Variation

A river changes as it flows from headwaters to mouth. Environmental factors—flows, channel form, substrate texture, temperature and other parameters of water quality —vary along its course. The distribution of river organisms responds to these gradients in the environment, often resulting in recognizable zones. Aquatic species in particular have been studied world-wide to attempt to classify river reaches or zones (See Hawkes, 1975; Hynes, 1970).

Moyle (1976) identified zones for California rivers and streams based on fish species distribution. For example, in the Central Valley, five zones were recognized (in up-to downstream order): 1) Rainbow Trout Zone; 2) California Roach Zone; 3) Squawfish-sucker-hardhead Zone; 4) Deepbodied Fishes Zone; and 5) Estuarine Fishes Zone. The trout zone is in the high mountains (much extended as a result of planting), the roach and squawfish zones are in the foothills, and the deep-bodied fish zone is in the valley flat portions of rivers. Moyle, with Ellison, (1991) has since expanded and refined his description of fish zones, in the new classification system for inland waters discussed elsewhere in this chapter.

Rivers are difficult to classify for the purposes of study and management because of their differences. However, it is instructive to consider rivers in two major zones, upstream and downstream, as first identified by Illies (various papers; refer to Hawkes, 1975, p. 366; Hynes, 1970, p. 392). A large number of the differences between upstream and downstream reaches are similar for most California rivers as well as many temperate-region rivers world-wide, shown in Figure 92.

Despite the ease and convenience of classifying and studying rivers by zone, it is closer to reality to recognize that environmental factors and biotic responses change over upstream-downstream gradients. Stream and river ecology in the last few decades has attempted to explain changes in the ecosystem functions of the aquatic community along these gradients. The River Continuum Concept (Vannote et al. 1980) holds that there is a more or less predictable gradient of environmental factors—flow regime, water temperature, solar radiation and others—from headwaters to downstream large river reaches. Aquatic energy and nutrient processing

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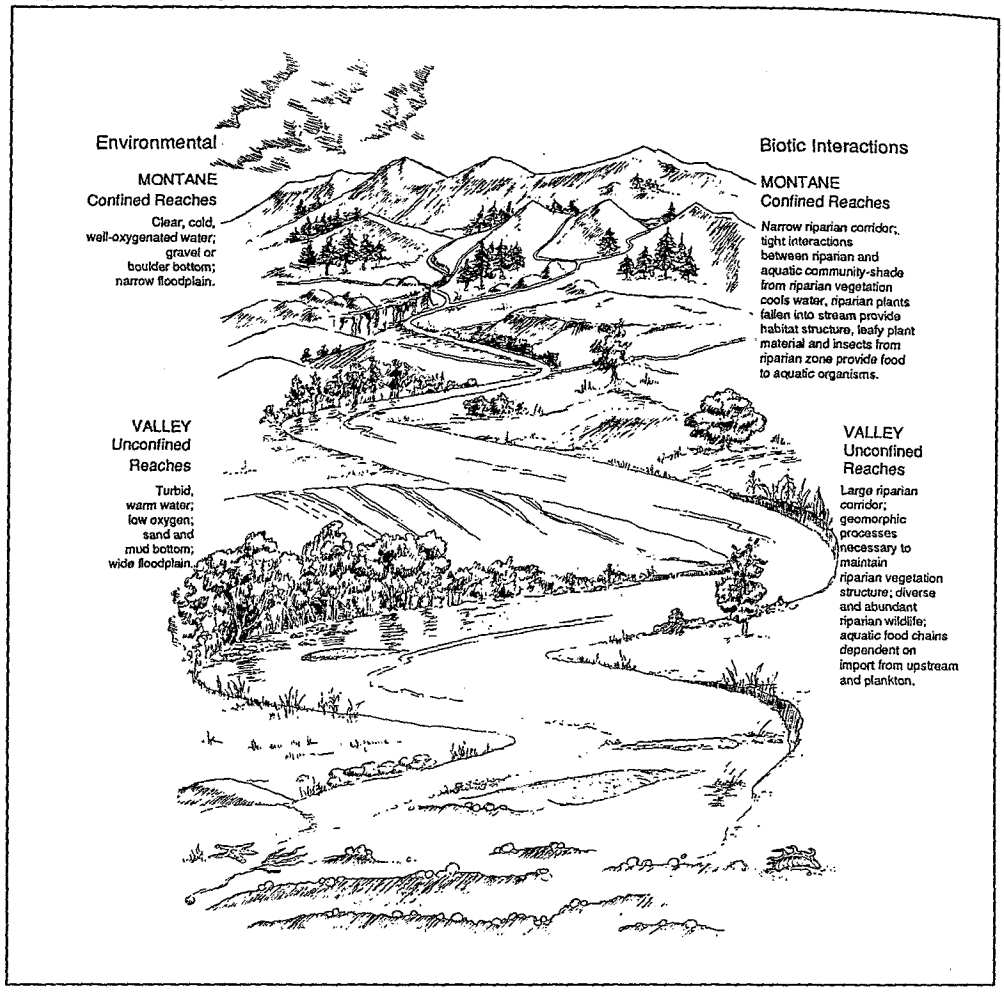
Figure 92. Upstream/Downstream Variation in Rivers.



also vary in a predictable way in response to environmental gradients as proposed in the concept.

For example, this concept generalizes that smaller headwater reaches are highly dependent upon allochthonous sources of coarse organic matter, which decreases downstream in importance. The aquatic biota in headwater areas is predicted to be dominated by shredders and collectors such as caddisflies, with little algal growth.

Such predictions have been shown to be true for many streams, generally those originating in heavily forested regions. However, the pattern of change in ecosystem functions along river continua is not the same for all streams. In contrast to forested areas, headwater desert streams may have high instream primary productivity and less reliance on allochthonous material (Minshall, 1978; and Minshall et al., 1989). Upstream-downstream gradients are rarely smooth; the environments and living resources vary between short patches, such as pool/riffle sequences (Schlosser, 1982).

These advances in ecological concepts are being refined and tested in field research, which will improve predictive abilities. This

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type of knowledge should be applied to solving difficult problems of river management, but as yet is not (Karr, 1991).

River Biodiversity

What All This Means

This California landscape, lying over a broad range of climates, soils and topography, yields an exceptional diversity of terrestrial, freshwater and estuarine plants, animals and natural communities, including species dependent upon river habitats. The survival of these diverse and interdependent systems is threatened by human population growth, land and water development and environmental deterioration of water and air quality. Protection of biological diversity, or biodiversity, is the key to survival for all ecosystems.

Biodiversity is the variation in living resources at all levels of organization, including genes, species, communities and landscapes. Species diversity, which is all the different kinds of plants and animals in an area, is relatively easy to conceptualize. Equally important, although harder to study and understand, are the smaller and larger scales of variation in the gene pools of populations or species, and variation in habitats and ecosystems over extensive landscape regions.

Michael Barbour, a U.C. Davis botanist, wrote in *California's Changing Landscapes* . . . "of the world's ten major soils, California has all 10. As many as 375 distinctive natural communities have been recognized in the state." More than 5,000 kinds of native ferns, conifers and flowering plants have been identified. Japan, which is similar in area to California, has far fewer species; nor does Alaska match California's plant diversity. "Moreover, about 30 percent of California's native plants are found nowhere else in the world."

Status of Biodiversity

The significant loss of natural diversity in California in the last 150 years is alarming. These losses are partly caused by direct commercial exploitation of certain species and partly by the effects of human population growth and modern technology. In the last 200 years, numerous plants and animals have become extinct or have been eliminated from the state, including the thicktail chub, once one of the most common fishes of the Central Valley lowland rivers and Delta, and the grizzly bear, California's state mammal.

In California, freshwater-based natural systems are the most damaged of all ecosystems (Jensen et al., 1990; Mooney et al., 1986). The state's rivers have been distressed more than any other aquatic resource. No pristine rivers are left. This is dramatically indicated by the long lists of declining and threatened species associated with rivers seen in Table 17 at the end of this chapter.

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Internationally, aquatic ecosystems are experiencing significant problems of biodiversity loss and threats, as evidenced by freshwater fish fauna, the best studied of aquatic biota. A conservative estimate is that 20 percent of freshwater fish worldwide are extinct or are seriously threatened (Moyle and Leidy, 1992).

Biodiversity of California rivers is threatened by a battery of impacts: vegetation clearing; altered hydrology, sedimentation and erosion processes; channelization; watershed land use practices; flood plain development; pollution; native species overharvest; and exotic species introductions. (For discussion of many of these impacts see Chapters 1 and 2.)

These impacts of human activity have degraded (or eliminated) ecosystem *parts*—species populations and habitats; and interrupted natural ecosystem *processes*—flooding, erosion, and plant succession. Natural communities have become increasingly fragmented, with the result that species and habitats may no longer be self-sustaining within a region. This is especially true for riparian communities, which have been shrunken into narrow corridors and broken up along the lengths of river reaches.

Such fragmentation of riparian communities adversely affects river dependent species and has major impacts on other species by destroying corridors between habitat areas. In many parts of the state, so much natural area is gone that the remaining small pieces of habitat left can only function if they can be connected to other small pieces through corridors for migration, recolonization and other movements of living resources. Continued exchange of genetic information is a major benefit of such connections. Riparian areas offer probably the single best opportunity for creating and maintaining habitat corridors (Harris and Gallagher, 1989).

Another significant threat to biodiversity is the introduction of nonnative species. California's flora and fauna have been drastically altered over the last two centuries by the establishment of exotic plant and animal species. Although the ecology of invasion varies by individual species and environments, generally those ecosystem types which have suffered the greatest artificial disturbance are the most susceptible to successful invasions of plants and animals (Mooney et al., 1986). Rivers are among the most altered ecosystems in the state and most riparian and aquatic communities have been damaged by species introductions.

Major nonnative plant species which threaten riparian communities include Jubata (Pampas) grass, tree-of-heaven, fig, false-bamboo and salt cedar (tamarisk). These plants are capable of spreading quickly over large areas to the exclusion of native riparian plant species. The habitat values provided by these species is generally lower than that for the natural vegetation, and these weedy species often cause problems for other aspects of river and stream management such as flood channel maintenance.

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Introductions of exotic fish species are often accompanied by declines and disappearances of native species. It may be that native species cannot compete or cannot escape predation. Introductions usually accompany other environmental changes so that it is difficult to tell the cause of native species declines (Moyle, 1986). Introduced species into California rivers include the striped bass and American shad, two popular anadromous game fishes, and many warm water species such as catfish, sunfishes and basses.

The African clawed frog on the South Coast and bull frogs throughout the state threaten native amphibians, as well as invertebrates and fish (Faber et al., 1989; Moyle, 1973).

Brown-headed cowbirds, parasitic in other bird species' nests, formerly were found only in the far eastern part of the state. With the development of extensive agriculture and other intensive land uses they have dramatically extended their range and numbers. This species is having devastating effects on many bird species, including the Endangered Least Bell's Vireo (Zeiner et al., 1990).

Trends in Protection of Biodiversity

Preserving areas in their natural states is the most effective way to maintain biological diversity (U.S. Congress, Office of Technology Assessment, 1987). Numerous areas in California have been given official protection to preserve natural ecosystems, provide habitat for rare or endangered species, safeguard scenic areas, maintain open space or provide recreation in undeveloped areas. However, the protection of aquatic habitats in reserves has not been done on any significant scale.

Aquatic community preservation presents a difficult challenge. Activities on surrounding watersheds or in upstream reaches of water bodies have as much to do with the condition of a river, lake or estuary as uses onsite. Furthermore, larger waterways have traditionally been important for navigation and other commercial uses. For example, although the larger North Coast rivers have been placed under protection in the state and federal Wild and Scenic River systems, many reaches of these rivers have been significantly affected by logging, mining and other development activities.

Aquatic Diversity Management Areas

A scheme for protecting aquatic diversity in California has been proposed by Peter Moyle (Moyle and Ellison, 1991; Moyle and Yosiyama, 1992). The proposed framework is based upon inventory and classification of aquatic habitats and organisms in order to establish a system of protected Aquatic Diversity Management Areas (ADMAs). At present, taxonomic and genetic data is lacking for

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many species, and cataloging of aquatic habitats has just begun. The CNDDB in the Department of Fish and Game is incorporating diversity data using the community classification system developed by Moyle and Ellison.

Restoration

Unfortunately, the preservation of remaining natural areas is in itself not enough to ensure biological diversity, due to the scarcity and fragmentation of relatively pristine systems. Species and community restoration of damaged ecosystems is also necessary for long-term protection of biodiversity, especially for aquatic ecosystems. The National Research Council (1992) has recommended that a national strategy for the restoration of rivers and other aquatic ecosystems be developed, with a target of restoring at least 400,000 miles of river ecosystems within the next 20 years.

In California, many riparian restoration projects have been implemented, but most are on a relatively small scale, rather than for whole systems (See Chapter 5). Riparian and stream restoration projects are undertaken for a variety of reasons, including streambank stabilization, fisheries improvement, recreation or project mitigation. They may be carried out by local cities or counties, public interest groups, government agencies or private developers. Projects in southern California have been mostly for development mitigation purposes, while the projects in the central and northern counties are undertaken for streambank stabilization and fisheries enhancement.

A large number and variety of projects to help return fish populations to historic levels in California have been attempted. Both habitat restoration projects and the artificial propagation of fish, primarily through hatcheries, are used. Habitat restoration projects involve modifications to disturbed areas in an attempt to return them to a more natural and useable state. These modifications include placing structures in streams (rootwads, trees, etc.) to increase fish habitat and cover, removing migration barriers such as log jams, revegetation and stabilizing landslides.

Small-scale artificial propagation of native stocks is often utilized with good success to boost natural populations. Several American Indian tribes rear salmon on a small scale for the enhancement of local populations, as do a number of private fishing and conservation groups and some school programs. These grass-roots efforts are probably quite valuable in keeping small individual stocks healthy, thus helping to maintain genetic diversity.

While large hatcheries are often used to produce fish, especially for water project mitigation, they are not nearly as significant as natural spawning. Hatchery fish account for only 11 percent of all the fall-run chinook salmon in the Central Valley and 19 percent of the Klamath run. In addition, fishery biologists are

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seriously concerned with the effect of hatcheries on the genetic diversity of natural populations (Higgins, 1991). In the long run, hatcheries may weaken the genetic make-up of wild stocks so that they can no longer survive the extreme variability of environmental conditions found in the natural world. Many of the over 200 Pacific salmonid stocks found at risk for survival, including a number from California, are threatened in part by genetic contamination from artificial propagation (Nehlsen et al., 1991). Other problems with hatcheries include the potential for intraspecific competition and disease which can harm the wild stocks, as well as the possibility for human error.

While site-specific restoration programs for fisheries and riparian habitat are important as stopgap measures, the key to truly effective aquatic ecosystem restoration is through integrated restoration of whole landscape units (National Research Council, 1992). With river systems, in most cases restoration will need to be based on watersheds.

In California, as well as in other states, there is a growing movement toward cooperative watershed associations. These watershed associations (often called watershed councils or alliances) may involve private landowners, government, resource users and citizens' groups. The point of such associations is to bring together all parties with a stake in restoring and managing watersheds and waterways to find solutions to problems through consensus.

Figure 93. Living Resources of the River.

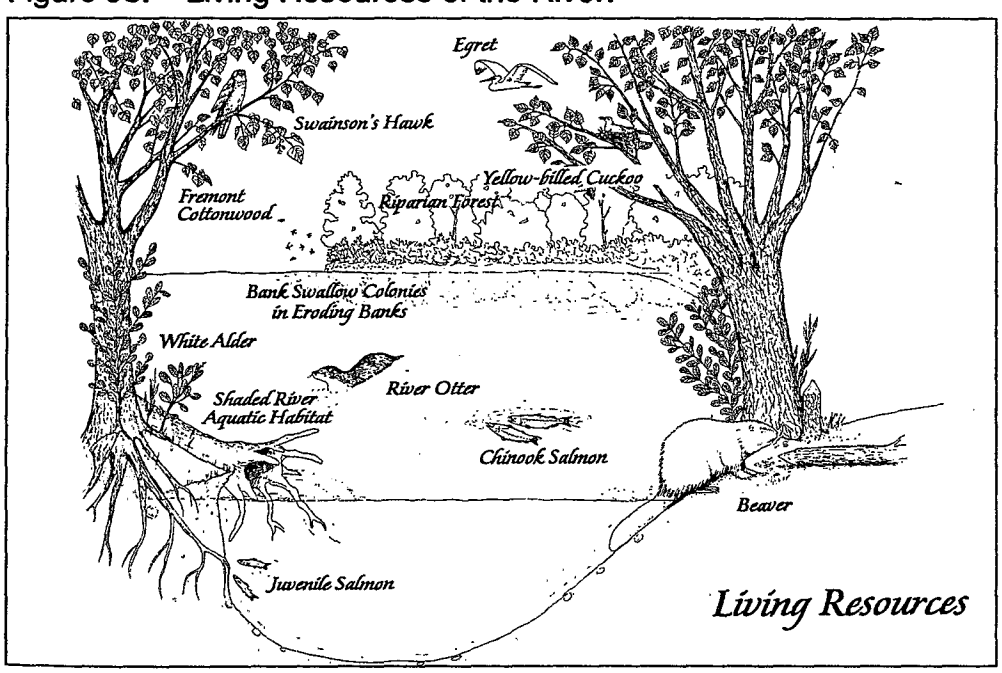

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Table 17. Special Species of California's Rivers.

SPECIAL PLANTS OF CALIFORNIA'S RIVERS

	Status	Distribution by Region+
Suisun Marsh Aster *Aster chilenseis lentus*	FC	NC,CV
Spring-loving Centaury *Centaurum namophilum namophilum**	FT	D
Slough Thistle *Cirsium crassicaule*	FC	CV
Suisun Thistle *Cirsium hydrophilum hydrophilum*	FC	NC
La Graciosa Thistle *Cirsium loncholepis*	ST,FC	CC
Flaming Trumpet *Collomia rawsoniana*	FC	CV
Soft Bird's Beak *Cordylanthus mollis mollis*	SR,FC	NC,CV
Slender-horned Spineflower *Dodecahema leptoceras*	SE,FE	SC
Santa Ana River Woolly Star *Eriastrum densifolium sanctorum*	SE,FE	SC
Delta Button Celery *Eryngium racemosum*	SE,FC	CV
Ash Meadows Gumplant *Grindelia fraxino-pratensis*	FT	D
Mojave Tarplant *Hemizonia mohavensis*	SE,FC	D
California Hibiscus *Hibiscus californicus*	FC	CV
Delta Tule Pea *Lathyrus jepsonii jepsonii*	FC	NC,CV
Mason's Lilaeopsis *Lilaeopsis masonii*	SR,FC	NC,CV
Northern California Black Walnut *Juglans hindsii hindsii*	FC	CV
Truckee Barberry *Mahonia sonnei**	SE,FE	ES
Abbott's Bushmallow *Malacothamnus abbottii*	CNPS1A,FC	CC
Willowy Monardella *Monardella linoides viminea*	SE,FC	SC
Amargosa Nitrophila *Nitrophila mohavensis*	SE,FE	D
Santa Lucia Mint *Pogogyne clareana*	SE,FC	CC
Narrow-leaved Cottonwood *Populus angustifolia*	CNPS 2	ES,D
Valley Oak *Quercus lobata*	CNPS 4	NC,CV,CC
Parish's Gooseberry *Ribes divaricatum parishii*	FC	SC
Del Norte Willow *Salix delnortnesis*	CNPS 4	NC
Owens Valley Checkerbloom *Sidalcea covillei*	SE,FC	ES

* Taxonomic status in question

+ Regions (see Map of Regions, Figure 69)
NC = North Coast/Klamath
CV = Central Valley
Mo = Modoc/Cascade
CC = Central Coast
ES = Eastside/Great Basin
SC = South Coast
D = Desert (Mainly represents Colorado River)

SR,ST,SE = State listed rare, threatened, or endangered
FT,FE = Federally listed threatened, or endangered
FC = Federal candidate

Above plants are all Calif. Native Plant Society List 1B unless otherwise noted
CNPS Lists: 1A = Presumed extinct; 1B = Rare, threatened, or endangered everywhere; 2 = Rare, threatened, or endangered in California but more common elsewhere; 3 = Review - need more information; 4 = Watch - limited and vulnerable

Sources: DFG (1992a), Jepson Manual (1993), Smith and Berg (1988)
DFG Natural Diversity Data Base Special Plants List, August 1991.

Continued on next page.

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Table 17. Continued.

SPECIAL ANIMALS OF CALIFORNIA'S RIVERS	Status	Distribution by Region +
Invertebrates (Listed species only)		
Valley Elderberry Longhorn Beetle *Desmocerus californicus dimorphus*	FT	CV
Trinity Bristle Snail *Monadenia setosa*	ST,FC	NC
Shasta Crayfish *Pacifastacus fortis*	SE,FE	Mo
California Freshwater Shrimp *Syncaris pacifica*	SE,FE	NC
Amphibians		
Tailed Frog *Ascaphus truei*	CSC	NC,Mo
Colorado River Toad *Bufo alvarius*	CSC	D
Arroyo Southwestern Toad *Bufo microscaphus californicus*	CSC,FC	CC,SC
Arizona Southwestern Toad *Bufo microscaphus microscaphus*	FC	D
Del Norte Salamander *Plethodon elongatus*	CSC,FC	NC
Northern Red-legged Frog *Rana aurora aurora*	CSC,FC	NC,Mo
California Red-legged Frog *Rana aurora draytonii*	CSC,FC	NC,CV,Mo,CC,SC
Foothill Yellow-legged Frog *Rana boylii*	CSC,FC	NC,CV,Mo,CC,SC
Mountain Yellow-legged Frog *Rana muscosa*	CSC,FC	CV,SC
Leopard Frog *Rana pipiens*	CSC	ES,D
Olympic Salamander *Rhyacotriton olympicus*	CSC	NC
Couch Spadefoot *Scaphiopus couchii*	CSC	D
Coastrange Newt *Taricha torosa torosa*	CSC	NC,CC,SC
Reptiles		
Northwestern Pond Turtle *Clemmys marmorata marmorata*	CSC,FC	NC,CV,Mo
Southwestern Pond Turtle *Clemmys marmorata pallida*	CSC,FC	CV,CC,SC
Sonoran Mud Turtle *Kinosternon sonoriense* **EXTINCT?**	CSC	D
Alameda Whipsnake *Masticophis lateralis euryxanthus*	ST,FC	CC
Giant Garter Snake *Thamnophis gigas*	ST,FPE	CV
Birds		
Cooper's Hawk *Accipiter cooperi*	CSC	NC,CV,Mo,CC,ES,SC,D
Northern Goshawk *Accipiter gentilis*	CSC,FC	NC,CV,Mo,ES
Sharp-shinned Hawk *Accipiter striatus*	CSC	NC,CV,Mo,CC,ES,SC,D
Tricolored Blackbird *Agelaius tricolor*	CSC,FC	CV,Mo,CC,SC
Great Blue Heron *Aredea herodias*	SpA	NC,CV,Mo,CC,ES,SC,D
Long-eared Owl *Asio otus*	CSC	NC,CV,Mo,CC,ES,SC,D
Aleutian Canada Goose *Branta canadensis leucopareia*	FT	NC,CV
Ruffed Grouse *Bonasa umbellus*	CSC	NC
Barrow's Goldeneye *Bucephala islandica*	CSC	NC,CV,CC
Swainson's Hawk *Buteo swainsoni*	ST	CV,MO,(CC),ES,(SC)
Northern Cardinal *Cardinalis cardinalis*	CSC	D
Great Egret *Casmerodius albus*	SpA	NC,CV,Mo,CC,SC,D
Western Yellow-billed Cuckoo *Coccyzus americanus occidentalis*	SE	(NC),CV,Mo,CC,SC,D
Gilded Northern Flicker *Colaptes auratus chrysoides*	SE	D
California Yellow Warbler *Dendroica petechia brewsteri*	CSC	NC,CV,Mo,CC,ES,SC,D
Sonora Yellow Warbler *Dendroica petechia sonorana*	CSC	D
Reddish Egret *Egretta rufescens*	FC	SC
Snowy Egret *Egretta thula*	SpA	NC,CV,Mo,CC,ES,SC,D

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Table 17. Continued.

Birds, continued	Status	Distribution by Region +
Willow Flycatcher *Empidomax traillii*	SE	(NC),(Mo),CV,(CC),SC
Southwestern Flycatcher *Empidomax traillii extimus*	SE,FC	SC
American Peregrine Falcon *Falco peregrinus anatum*	SE,FE	NC,CV,Mo,CC,ES,SC,D
Bald Eagle *Haliaeetus leucocephalus*	SE,FE	NC,CV,Mo,CC,ES,SC,D
Harlequin Duck *Histrionicus histrionicus*	CSC,FC	CV and along coast
Yellow-breasted Chat *Icteria virens*	CSC	NC,CV,Mo,CC,ES,SC,D
Western Least Bittern *Ixobrychus exilis hesperis*	CSC,FC	CV,Mo,ES,SC,D
California Black Rail *Laterallus jamaicensis coturniculus*	ST,FC	CV,D
Gila Woodpecker *Melanerpes uropygialis*	SE	D
Elf Owl *Micrathene whitneyi*	SE	D
Brown-crested Flycatcher *Myiarchus tyrannulus*	CSC	D
Black-crowned Night Heron *Nycticorax nycticorax*	SpA	NC,CV,Mo,CC,ES,SC,D
Osprey *Pandion haliaetus*	CSC	NC,CV,Mo,CC,ES,SC,D
Black-capped Chickadee *Parus atricapillus*	CSC	NC
Double-crested Cormorant *Phalacrocorax auritus*	CSC	NC,CV,Mo,CC,SC
Summer Tanager *Piranga rubra*	CSC	D
Purple Martin *Progne subis*	CSC	NC,CV,Mo,CC,ES,SC
Vermilion Flycatcher *Pyrocephalus rubinus*	CSC	
Yuma Clapper Rail *Rallus longirostris yumanensis*	ST,FE	D
Bank Swallow *Riparia riparia*	ST	NC,CV,Mo,CC,ES,(SC)
Crissal Thrasher *Toxostoma dorsale*	CSC	D
Arizona Least Bell's Vireo *Vireo bellii arizonae*	SE	D
Least Bell's Vireo *Vireo bellii pusillus*	SE,FE	(CV),CC,SC
Mammals		
Sierra Nevada Mountain Beaver *Aplodontia rufa californica*	CSC	CV
White-footed Vole *Arborimus albipes*	CSC,FC	NC
Mexican Long-tongued Bat *Choeronycteris mexicana*	CSC,FC	SC
Spotted Bat *Euderma maculatum*	CSC,FC	ES,SC,D
Yuma Mountain Lion *Felis concolor browni*	CSC,FC	D
California Wolverine *Gulo gulo luteus*	ST, FC	NC,CV,Mo,ES
Oregon Snowshoe Hare *Lepus americanus klamathensis*	CSC	NC,Mo
Sierra Nevada Snowshoe Hare *Lepus americanus tahoensis*	CSC	CV
Southwestern River Otter *Lutra canadensis sonorae*	CSC,FC	D
California Leaf-nosed Bat *Macrotus californicus*	CSC,FC	D
Pacific Fisher *Martes pennanti pacifica*	CSC,FC	NC,CV,Mo
Mohave Vole *Microtus californicus mohavensis*	CSC,FC	D
Amargosa Vole *Microtus californicus scirpensis*	SE,FE	D
Owens Valley Vole *Microtus californicus vallicola*	CSC,FC	ES
Arizona Myotis *Myotis lucifugus occultus*	CSC,FC	D
Cave Myotis *Myotis velifer brevis*	CSC,FC	D
Riparian Woodrat *Neotoma fuscipes riparia*	CSC,FC	CV
Pocketed Free-tailed Bat *Nyctinomops femorosaccus*	CSC	D
Pacific Pocket Mouse *Perognathus longimebris pacificus*	CSC,FC	SC
Pale Big-eared Bat *Plecotus townsendii pallescens*	CSC	NC,CV,Mo,CC,ES,SC,D
Townsend's Big-eared Bat *Plecotus townsendii townsendii*	CSC,FC	NC,CC
Colorado River Cotton Rat *Sigmodon arizonae plenus*	CSC,FC	D
Yuma Cotton Rat *Sigmodon hispidus eremicus*	CSC,FC	D
Buena Vista Lake Shrew *Sorex ornatus relictus*	CSC,FC	CV

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Table 17. Continued.

Mammals, continued	**Status**	**Distribution by Region +**
Monterey Ornate Shrew *Sorex ornatus salarius*	CSC,FC CC	
Riparian Brush Rabbit *Sylvilagus bachmani riparius*	SC,FC	CV
Amargosa Pocket Gopher *Thomomys bottae amargosae*	CSC,FC	D

ST,SE = State listed threatened, or endangered
CSC = California DFG Species of Special Concern
SC = State candidate
SpA = CNDDB Special Animal; declining and/or rare enough to warrent attention
FT,FE = Federally listed threatened, or endangered
FPE = Federally proposed endangered
FC = Federal candidate

Sources: Brode and Bury (1984), DFG (1992a), Laudenslayer et al.(1991), Miller et al. (1989), Remsen (1978), Stebbins (1966), Williams (1986), Williams and Kilburn (1984), Williams et al (1989), Zeiner et al (1988, 1990a, 1990b); CNDDB Special Animals List, December 1992; CNDDB list of Habitat Associations, 1/31/92

Fishes	**Status**	**Distribution by Region +**
Green Sturgeon *Acipenser medirostris*	M&Y	NC,CV
Sacramento Perch *Archoplites interruptus* **EXTIRPATED**	CSC,FC	(CV,CC)
Owens Sucker *Catostomus fumeiventris*	CSC	ES
Modoc Sucker *Catostomus microps*	SE,FE	Mo
Mountain Sucker *Catostomus platyrhyncus*	CSC	ES
Santa Ana Sucker *Catostomus santaanae*	CSC,FC	SC
Klamath Largescale Sucker *Catostomus snyderi*	CSC,FC	NC
Shortnose Sucker *Chasmistes brevirostris*	SE,FE	NC
Rough Sculpin *Cottus asperrimus*	ST,FC	Mo
Bigeye Marbled Sculpin *Cottus klamanthensis macrops*	CSC	Mo
Desert Pupfish *Cyprinodon macularius*	SE,FE	D
Amargosa Pupfish *Cyprinodon nevadensis amargosae*	CSC	D
Owens Pupfish *Cyprinodon radiosus*	SE,FE	ES
Lost River Sucker *Deltistes luxatus*	SE,FE	NC
Tidewater Goby *Eucyclogobius newberryi*	CSC,FT	NC,CC,SC
Unarmored Threespine Stickleback *Gasterosteus aculeatus williamsoni*	SE,FE	SC
Santa Ana Threespine Stickleback *Gasterosteus aculeatus santannae*	CSC,FC	SC
Mohave Tui Chub *Gila bicolor mohavensis*	SE,FE	D
Owens Tui Chub *Gila bicolor snyderi*	SE,FE	ES
Thicktail Chub *Gila crassicauda*	**EXTINCT**	(CV)
Bonytail *Gila elegans*	SE,FE	D
Arroyo Chub *Gila orcutti*	CSC	SC
Delta Smelt *Hypomesus transpacificus*	ST,FT	CV
Russian River Tule Perch *Hysterocarpus traski pomo*	CSC,FC	NC
River Lamprey *Lampetra ayresi*	CSC	NC,CV
Modoc Brook Lamprey *Lampetra folletti*	CSC	NC
Kern Brook Lamprey *Lampetra hubbsi*	CSC,FC	CV
Klamath River Lamprey *Lampetra similis*	CSC	NC
Pit Roach *Lavinia symmetricus mitulus*	CSC,FC	Mo
Navarro Roach *Lavinia symmetricus navarroensis*	CSC	NC

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Table 17. Continued.

Fishes, continued	**Status**	**Distribution by Region +**
Gualala Roach *Lavinia symmetricus parvipinnis*	CSC,FC	NC
Monterey Roach *Lavinia symmetricus subditus*	CSC	CC
San Joaquin Roach *Lavinia symmetricus* ssp.	CSC	CV
Tomales Roach *Lavinia symmetricus* ssp.	CSC	NC
Hardhead *Mylopharadon conocephalus*	CSC	NC,CV,Mo
Coastal Cutthroat Trout *Oncorhynchus clarki clarki*	CSC	NC
Lahontan Cutthroat Trout *Oncorhynchus clarki henshawi*	FT	ES
Paiute Cutthroat Trout *Oncorhynchus clarki seleniris*	FT	ES
Pink Salmon *Oncorhynchus gorbuscha*	CSC	NC,CV,CC
Chum Salmon *Oncorhynchus keta*	M&Y	NC,(CV)
Coho Salmon *Oncorhynchus kisutch*	CSC	NC,CV,CC
Volcano Creek Golden Trout *Oncorhynchus mykiss aguabonita*	CSC,FC	CV
Summer Steelhead *Oncorhynchus mykiss gairdneri*	CSC	NC
Kern River Rainbow *Oncorhynchus mykiss gilberti*	CSC,FT	CV
Little Kern Golden Trout *Oncorhynchus mykiss whitei*	FT	CV
McCloud River Redband Trout *Oncorhynchus mykiss* ssp.	CSC,FC	Mo
Chinook Salmon, Spring Run *Oncorhynchus tshawytscha*	CSC	NC,CV
Chinook Salmon, Winter Run *Oncorhynchus tshawytscha*	SE,FT	CV
Sacramento Splittail *Pogonichthys macrolepidotus*	CSC,FC	CV
Colorado Squawfish *Ptychochelus lucius* **EXTIRPATED**	SE,FE	Mo
Amargosa Canyon Speckled Dace *Rhinichthys osculus* ssp. 1	CSC,FC	D
Owens Speckled Dace *Rhinichthys osculus* ssp. 2	CSC,FC	ES
Santa Ana Speckled Dace *Rhinichthys osculus* ssp. 3	CSC,FC	SC
Longfin Smelt *Sprinchus thaleichthys*	M&Y	NC,CV
Bull Trout *Salvelinus confluentus* **EXTIRPATED**	SE,FC	(Mo)
Razorback Sucker *Xyrauchen texanus*	SE,FE	D

+ Regions (see Map of Regions, Figure 69)
NC = North Coast/Klamath
CV = Central Valley
Mo = Modoc/Cascade
CC = Central Coast
ES = Eastside/Great Basin
SC = South Coast
D = Desert (Mainly represents Colorado River)

ST,SE = State listed threatened, or endangered
SC = State candidate
CSC = California DFG Species of Special Concern
FT,FE = Federally listed threatened, or endangered
FPE = Federally proposed endangered
FC = Federal candidate
M&Y = Moyle and Yoshiyama potential candidates for listing

Sources: CNDDB Special Animals List, December 1992; CNDDB Listing Dates, January 1993
Moyle (1976), Moyle et al. (1989), Moyle and Yoshiyama (1992).

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Table 18. California Salmonid Stocks Extinct or At Risk.

Chinook Salmon

Winter Run

R Sacramento River *
EX Calaveras River

Spring Run

R Smith River
R Klamath River
R Salmon River
R Trinity River
R South Fork Trinity River
R Sacramento River (incl. tribs.)
R Yuba River
EX San Joaquin River (incl. tribs.)
EX American River
EX McCloud River
EX Pit River

Fall Run

R Smith River
R Shasta River
R Scott River
R South Fork Trinity River
R Lower Klamath tributaries
R Redwood Creek
R Mad River
R Minor Humboldt tributaries
R Lower Eel River
R Bear River
R Mattole River
R Little River
R Russian River
R San Joaquin River
R Cosumnes River

Coho Salmon

R Smith River
R Klamath River
R Lower Klamath tributaries
R Trinity River
R Scott River
R Minor Humboldt tributaries
R Redwood Creek
R Wilson Creek
R Mad River
R Eel River
R Bear River
R Mattole River
R Ten Mile River
R Pudding Creek
R Noyo River
R Big River
R Little River
R Albion River
R Navarro River
R Garcia River
R Gualala River
R Russian River
R Small coastal streams
EX Malibu Creek

Pink Salmon

R Russian River
EX Klamath River
EX Sacramento River

Chum Salmon

EX Klamath River
EX Sacramento River

Steelhead

Fall/Winter Run

R Malibu Creek
R Santa Clara River
R Ventura River
R Santa Ynez River
R Little Sur River
R Big Sur River
R Carmel River
R Salinas River
R Pajaro River
R South San Francisco Bay tribs.
R Sacramento River
R Napa River
EX San Luis Rey River
EX San Mateo Creek
EX Santa Margarita River
EX Rincon Creek
EX Gaviota Creek
EX Maria Ygnacio River
EX Los Angeles River
EX San Gabriel River
EX Santa Ana River
EX San Diego River
EX Sweetwater River

Spring/Summer Run

R Smith River
R Klamath River
R Salmon River
R South and North Forks Trinity River
R Upper Trinity River
R New River
R Mad River
R Redwood Creek
R Middle and North Forks, Eel River
R Van Duzen River

Sea-run Cutthroat trout

R California coastal streams
R Lower Klamath River
R Mad River
R Wilson Creek
R Lower Eel River

R = Stocks at high or moderate risk of extinction, or of special concern
EX = Stocks known to be extinct

* = State listed endangered

Sources: Higgins (1992), Nehlsen et al. (1991).

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California Rivers: Restoration, Tools and Beginnings

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A Paul Bunyan saga tells how he floated many a log down the Round River . . . No one has suspected Paul of speaking in parables, yet in this instance he did. The [restless waters'] current is the stream of energy which flows out of the soil into plants, thence into animals, then back into the soil in a never ending circuit of life.

We of the genus Homo *ride the logs that float down the Round River, and by a little judicious "burling" we have learned to guide their direction and speed. This feat entitles us to a specific appellation* sapiens. *The technique of burling is called economics, the remembering of old routes is called history, the selection of new ones is called statesmanship, the conversation about oncoming riffles and rapids is called politics. Some of the crew aspire to burl not only their own logs, but the whole flotilla as well. This collective bargaining with nature is called national planning.* Aldo Leopold, "The Round River" from *A Sand County Almanac,* 1949.

Introduction

There are a great many public and private organizations that may have an interest in or some influence over a particular waterway. The sheer number of such organizations is often overwhelming. (See Table 19. Managing Entities for California's Wild and Scenic Rivers). Unfortunately, there is no one entity which synthesizes river and stream data, distributes it to all interested parties, arbitrates disputes between competing legitimate demands for the use of scarce river resources, and plans and coordinates watershed or bioregional level management. On any given waterway, those resources may include aggregates, fish and wildlife and their habitats, the consumptive use of water, recreation and aesthetics, flood control, hydroelectric power, water quality and many others.

Typically, each resource that may be provided by a river or stream has its own constituency, and each constituency is served by a specific single-purpose governmental body devoted to regulation

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Table 19. Managing Entities for California's Wild and Scenic Rivers.

	NPS			BLM			Indian Reservation			FS			Other Managing Entity			
River	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	Total
Klamath			1.0			1.5			29.0	12.0	21.0	177.5		3.0	41.0	286.00
Tuolumne	37.0	17.0		3.0						7.0	6.0	13.0				83.00
Merced	53.0	14.0	14.0	3.5						15.0	2.0	12.5				114.00
Kings	49.0		6.5							16.3		9.0				80.80
Kern	27.0									96.1	20.9	7.0				151.00
Smith										78.0	30.5	187.85		.5	28.5	325.35
Trinity						17.0		6.0	8.0	42.0	22.0	71.0	2.0	11.0	24.0	203.00
Eel				21.0	4.5	6.5	5.0	1.0	16.0	31.0			36.0	22.5	205.0	394.00
Middle Fork American										32.9	9.7	35.0				77.60
South Fork American										26.3						26.30
North Fork American	12.0															12.00
Lower American															23.0	23.00
Total	178.0	31.0	21.5	27.5	4.5	25.0	5.0	7.0	53.0	356.6	112.1	512.85	38.0	37.0	367.0	1776.05

W = Wild River Miles; S = Scenic River Miles; R = Recreational River Miles
NPS = National Parks Service; BLM = Bureau of Land Management; Indian Reservation = Hoopa Valley Reservation; FS = Forest Service.

Source: Bureau of Land Management, May 1992.

and/or advocacy of the development of rivers and streams for that particular constituency's needs. The net result of this narrowly focused regulatory and management activity is far too often the destruction of those natural values which made the river system valuable in the first place.

The development of economic analyses for proposed projects that will alter natural river systems in some way is another important subject related to the diversity of single-purpose entities involved in such projects. Economic analyses performed to justify single-purpose projects often ignore significant project costs which are more difficult to estimate than the capital outlay costs for the proposed project. A clear picture of damage to ecosystems and particular resources might often make an otherwise attractive project economically infeasible. It is therefore not necessarily in the best interest of the project proponent to evaluate *all* of a project's potential costs. Even though the task of estimating the economic value of resource damage is difficult, the cost of making alternative uses, especially extractive uses, of public trust lands should reflect the real economic and environmental cost of pursuing those uses, so that fully informed and balanced decisions are possible.

As demonstrated elsewhere in this report, when rivers and streams are "loved" for one single purpose, they are often "loved to death" for all competing purposes. There is a powerful need to develop mechanisms to harmonize competing uses where possible, and to decide between uses when harmony is not possible. That is the essential responsibility of the state as public trustee.

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It is neither necessary nor desirable to determine that one and only one use of a watershed shall dominate over all others. However, it is desirable that no one activity be allowed to destroy the very essence of the natural system, especially where the long-term costs to the public are unknown, and where the broader public has had little or no input into management decisions. The law of public trust suggests that legitimate needs for resources which *only* river systems can provide should take precedence over those needs which could be served by some other means. Where two uses are contemplated, one a trust and the other a nontrust use, the nontrust use should be allowed only to the degree that to do so is consistent with trust needs.

The following discussion of governmental and nongovernmental involvement in decision making and project implementation processes which affect rivers and streams illustrates just how diverse the various interested entities are and, as a corollary, how complicated the task of coordinating those entities may be. It should be noted that the nongovernmental list is not intended to be comprehensive but rather a sampling of the extent and breadth of such organizations. The number of nongovernmental organizations suggests that local interest in conserving and restoring rivers is increasing.

State Lands Commission Jurisdiction and Public Trust Responsibility

Introduction

The State of California owns and administers several different types of interests in rivers and streams within the state's borders by virtue of being the sovereign representative of the people. These rights are the property of the state, and the state's powers with respect to these property rights are similar in certain ways to the rights of private property owners, but are governed by the law of public trust. These rights are grounded in English common law, as interpreted and applied by the federal and state court systems of the United States. The state is the guardian of those rights which fall under the protection of the ancient "Public Trust Doctrine," which in England governed certain rights and responsibilities which were entrusted to the King. As a result, these rights and lands collectively often are referred to as "sovereign" rights, or "sovereign lands."

In California, sovereign rights and responsibilities of the state which are traditionally associated with real property ownership have been delegated to the State Lands Commission (SLC). The Public Trust Doctrine, as it affects these rights, is designed to protect the rights of the public to use watercourses for commerce, navigation, fisheries, recreation, open space, preservation of ecological units in

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their natural state, and similar uses for which those lands are uniquely suited.

Types of Jurisdiction and Interest

Public Trust—Sovereign Fee Ownership

The state owns, as trustee for the public, the beds of *tidal* navigable rivers and streams up to Ordinary High Water Mark (under natural conditions, that elevation reached by the average of all high tides over an 18.6 year period). In the case of *nontidal* navigable rivers and streams, if the adjacent uplands have been conveyed into private ownership, the state in most circumstances holds sovereign title, in trust, up to the Ordinary Low Water Mark. (The term "ordinary" in each of the above statements is a legal term of art which refers to property boundaries, which may be sometimes, but not necessarily always, visible on the ground.) Where the state owns the fee interest in the underlying land, its ownership has some of the same characteristics of private property ownership, but is subject to the constraints of the public trust doctrine. For example, the state can and does require compensation to the public for any private use of its property, including both surface use and the extraction of resources from the land. However, the state does not have the unfettered right to alienate its trust property.

Public Trust—Easement

Along navigable nontidal waterways, the state also owns a right often termed the "public trust easement" in the area between Ordinary Low Water Mark and Ordinary High Water Mark. The state has both the right and the obligation to balance competing land uses in the easement area. In general, the title of a private owner of the fee underlying the state's easement is subservient to the easement, although the fee owner may use the lands in any way "not inconsistent with public trust needs." It should also be noted that in some instances the state has retained a fee interest in the area between the Ordinary Low Water Mark and Ordinary High Water Mark. A title search is generally needed to verify the status of the state's interests vis-a-vis those of the upland owner.

Navigation Rights

In California, members of the public have a right to utilize for boating, fishing and similar water dependent uses any waterway that is susceptible of being navigated by even the smallest recreational craft, where access to the waterway may be legally obtained. Under well established California law, this right to utilize such waterways

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exists even where the bed is privately owned. Any member of the public, or the state acting on behalf of the public, may enjoin any interference with this right.

Right to Abate Nuisance

The state has a right (and, under trust law, an obligation) to seek to abate any nuisance activity, whether on public or private property, which can be demonstrated to have a deleterious effect upon the property, or the rights associated with the property, which is subject to the Public Trust Doctrine. Obstructions to navigation and the pollution of waterways are examples of types of nuisances that can be abated.

Access

The Act for the Admission of California to the Union, and the State Constitution, provide that protection of the public's right to use navigable waters is a paramount responsibility of state government. In addition, several statutory provisions exist (most notably, the Subdivision Map Act) which require that public access to and along waterways be provided. The public does *not*, however, have a right to cross private property to access public waterways unless there is a legally protected express or implied right to do so.

Legal Bases for Jurisdiction and Interest

Act for the Admission of California to the Union

Section 3 of the Admission Act provides, in part:

> . . . that all the navigable waters within the said State shall be common highways, and forever free, as well to the inhabitants of said State as to the citizens of the United States, without any tax, impost, or duty therefor.

California Constitution

The California Constitution, Article 10, Section 1, states:

> The right of eminent domain is hereby declared to exist in the State to all frontages on the navigable waters of this State.

Article 10, Section 4, provides:

> No individual, partnership, or corporation, claiming or possessing the frontage or tidal lands of a harbor, bay,

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> inlet, estuary, or other navigable water in this State, shall be permitted to exclude the right of way to such water whenever it is required for any public purpose, nor to destroy or obstruct the free navigation of such water; and the Legislature shall enact such laws as will give the most liberal construction to this provision, so that access to the navigable waters of this State shall always be attainable for the people thereof.

California Statutes

Division 6 (Public Lands) of the Public Resources Code (PRC), beginning with Section 6001, spells out the varied powers and responsibilities of the State Lands Commission, including those relating to management of rivers and streams. Some of the more important sections of the PRC are cited below.

PRC Section 6301 provides, in part:

> The commission has exclusive jurisdiction over all ungranted tidelands and submerged lands owned by the State, and of the beds of navigable rivers, streams, lakes, bays, estuaries, inlets, and straits, including tidelands and submerged lands or any interest therein, whether within or beyond the boundaries of the State as established by law, which have been or may be acquired by the State (a) by quitclaim, cession, grant, contract, or otherwise from the United States or any agency thereof, or (b) by any other means. All jurisdiction and authority remaining in the State as to tidelands and submerged lands as to which grants have been or may be made is vested in the commission.

PRC Section 6307 authorizes the commission, under limited circumstances, and upon making appropriate findings, to exchange lands, where to do so would result in a net benefit to the public trust.

PRC Section 6357 authorizes the commission to ". . . establish the ordinary high water mark or the ordinary low water mark of any . . . tide, or submerged lands of this State, by agreement, arbitration, or action to quiet title, whenever it is deemed expedient or necessary."

Case Law

There are dozens of cases which deal with state jurisdiction over rivers and streams. There are also several appellate decisions, many of which involved the State Lands Commission as a party,

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which explain the specifics of California's jurisdiction. Some of the more important decisions are listed at the end of this section.

Two important lines of cases have helped to define and refine the role of the state as public trustee for rivers and streams. One series of cases defines the scope of the trust and the duties of the trustee, while the other spells out the geographic extent and the navigation rights associated with that authority and responsibility.

In the first instance, the courts have held that the state, as trustee, is bound by a very stringent standard of conduct in its stewardship of trust resources. A recent example of this principle is the California Supreme Court's language in the *National Audubon* (33 Cal.3d 419 (1983)) decision which states that the state has "an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible." That language is the most clear statement to date that the state is not free to decide when and where it will apply the principles of the Public Trust Doctrine, but must actively seek to protect those properties and values which form the corpus of the trust. On the other hand, the state does have a great deal of discretion to balance, and to choose between, conflicting uses which are themselves consistent with the principles of the doctrine. For example, the state may authorize construction of a port facility even though an effect of that construction may be to prevent fishing within the port boundaries (of course, separate environmental legislation such as CEQA places additional constraints upon state action).

The Public Trust Doctrine seems to be at least as much a *limitation* on the powers of government as it is specific direction to act. It is clear from a reading of cases beginning with *Illinois Central* (146 U.S. 387 (1892)) and extending through *Audubon* (supra) that the Public Trust Doctrine will be invoked by the courts to tell a state government when and where it has gone too far in ignoring its trust responsibilities.

The cases which describe the geographic limits of trust jurisdiction and the public rights that go with the public trust have also been reaffirmed over time, as increasing pressure on river resources has created conflict between prospective users, and between natural systems and users. When population distributions were largely sparse and rural, and travel was more difficult, there was not much competition for use of river resources (with the exception of the water itself). There were seldom conflicts over access or over potential destruction of natural systems, and therefore no need for detailed analyses of jurisdictional limits. However, as population density and urban development increased, and people became more sophisticated and aware of the degradation of their natural surroundings and the impacts of that degradation on the quality of life, increasing and more strident conflict arose. As a consequence, disputes over ownership and jurisdiction over rivers became more frequent. The courts are

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today being asked to resolve conflicts between citizens who want access to and along streams which may have been used by members of the public for generations, but which are now closed off by owners of upland property.

The courts, as a general rule and in keeping with the spirit of the Public Trust Doctrine, have always been protective of the public's right to access to waterways. Courts have carefully examined the elements of navigability which determine state ownership of title to the bed of a river, taking notice of surrounding circumstances and expectations. A careful reading of the decisions leads to the conclusion that the decisions have become increasingly detailed, in order to provide guidance to both public and private parties. The newer decisions provide extensive detail about what constitutes the sort of "commerce" that would support state ownership, or about what circumstances would indicate that a waterway was *susceptible* of supporting commercial navigation.

Management Trends

System Management

The State Lands Commission and its staff have become increasingly concerned and alarmed by the declining state of California's river and stream resources, as demonstrated in this report. At the same time, the commission and the staff have become more sophisticated in their understanding of the bioregional and system wide effects of past uncoordinated management practices. It is clear that the state, as trustee, can no longer allow to continue those patterns of uncoordinated activities which collectively threaten the very health of the system itself. The commission is particularly concerned about land management activities which, while they may occur outside the boundaries of state ownership jurisdiction, nonetheless can be demonstrated to have substantial negative effects on river systems as a whole, and consequently on the commission's jurisdiction. As a result, the commission has initiated a public education program through a series of status and trends reports on the public trust resources; programs to coordinate protection and restoration of riverine ecological systems such as the statewide greenway projects; and collaboration with federal, state and local agencies to support approaches for long-term resource management and planning activities. This report is intended to provide background and guidance to this system management approach.

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Collaborative Planning

The commission seeks to enlist the support of all interested individuals and organizations to carry out its public trust responsibility to ensure the future health and welfare of California's river resources. The SLC also seeks to engage in collaborative planning with public and private entities to ensure that all feasible alternative management policies and practices are considered, that Best Management Practices are adopted for the management of river systems, and that continuous monitoring and evaluation mechanisms are in place. Recent developments, such as the Central Valley Project Improvement Act of 1992 (the Miller-Bradley Act) and the creation of the national Biological Survey (United States Department of Interior, Office of the Secretary, Memorandum March 17, 1993), will affect not only the State Lands Commission, but all of the myriad agencies and private groups with an interest in the ecological health and well-being of rivers and streams.

Water Marketing

Water marketing is an old concept, now being defined in new ways, that will have far-reaching impacts on how public and private entities manage and interact with river and stream resources. The Central Valley Project Improvement Act will lead to water marketing as a way of allocating scarce water resources among competing users. Holders of water rights will be able to (more or less) freely transfer those rights to entities willing and able to pay a market price for use of those rights. It is probable, for example, that the Metropolitan Water District of Southern California will purchase water rights now utilized to farm marginal lands in the Sacramento-San Joaquin River Valley, taking the marginal lands out of production. The water would be transferred to Southern California, largely for domestic and industrial use.

A provision of the Central Valley Project Improvement Act that is critical to the health of river systems provides express protection for various instream uses of water, even when that protection must be at the expense of other beneficial uses of the water. Agricultural and domestic users of water are required by the legislation to share equally in the burdens of water shortages, rather than allocating a disproportionate share of the pain of such shortages to instream uses.

Other Jurisdictions

The role of the State Lands Commission in managing river resources is discussed above. The following additional governmental and nongovernmental organizations each are involved in managing some river-related resource:

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The Federal Role

Department of Agriculture

United States Forest Service (USFS)

The USFS manages approximately 20 million acres of National Forest lands, or about 20 percent of the land in California. By law, National Forest resources are managed for many uses including water supply and watershed protection, timber, range, fishery and wildlife habitat, and recreation. About 50 percent of the water supply in California originates in watersheds within National Forests, and the headwaters of most rivers and streams are found in National Forests. Approximately 1,000 miles of federally designated Wild and Scenic Rivers originate or pass through one or more National Forests.

Management of the riparian and aquatic resources in the National Forests is guided by Standards and Guidelines found in individual Forest Land and Resource Management Plans, as well as national environmental legislation such as the Clean Water Act, the Clean Air Act, and the Endangered Species Act. All National Forests in the Pacific Southwest Region of the USFS are staffed with specialists including hydrologists, fisheries biologists and wildlife biologists to guide the interpretation and implementation of these regulations. All National Forests utilize a special management designation for riparian areas (Streamside Management Zone), and land management activities that affect the riparian area may be modified or curtailed when impacts to riparian resources are anticipated. A portion of the Forest Service budget is directed specifically at restoration of riparian areas.

In many inland areas where underlying land titles have not been settled by litigation or agreement, USFS asserts exclusive control over rivers and streams passing through National Forest land, and thus controls river activities such as camping, boating, off-highway vehicle uses, and access for fishing, hunting, boating and bathing. In addition, USFS has recently begun asserting federal reserved water rights for the benefit of instream, nonconsumptive uses.

In fiscal year 1991, 1.3 billion board feet of timber were harvested from California's National Forests. Private firms do the cutting under contract with the Forest Service, and receipts (totaling $169 million for California in fiscal year 1991) are turned over to the U.S. Treasury.

The service supervises livestock grazing, which is allowed on a fee basis on certain National Forest lands. Wildlife management on the forests is conducted in cooperation with the California Department of Fish and Game.

An important use of the National Forests is recreation: there are some 1,100 developed camp and picnic sites, among other uses;

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and there are about 14,000 miles of mapped trails. Some 3.9 million acres have been set aside as Wilderness under the Wilderness Act of 1964.

U.S. Soil Conservation Service (SCS)

SCS provides guidance in the conservation and sustainable use of California's nonfederal lands through Resource Conservation Districts. Technical assistance is provided to individuals, cities and counties in the inventory, planning and installation of natural resource conservation measures. The assistance also includes soil, water and other resource inventories, and the development of appropriate Best Management Practices to protect the quality and/or the quantity of soil, water, air, vegetation and wildlife resources.

The several programs of the SCS affect, or have the potential to affect, riparian systems. For example, the SCS is participating with other agencies in the development of livestock management systems in riparian zones.

SCS also administers the Water Bank Program, with assistance from the Agricultural Stabilization and Conservation Service and other agencies. The objectives of the program are to preserve, restore and improve habitat in important migratory waterfowl nesting and breeding areas and to benefit other wildlife resources. Landowners with eligible wetlands may enter into agreements to receive annual payments for conserving land as wetlands.

As another example, SCS participates in the implementation of Farm Bills enacted in 1985 and 1990 with the objective to retire farm lands that have identified soil and water problems. Landowners with eligible lands may enter into agreements to receive annual payments.

Department of Commerce

National Oceanic and Atmospheric Administration (NOAA)

NOAA is the federal government's primary source of data and information on problems of the ocean and the atmosphere.

NOAA's activities include providing information on resources of river estuaries; performing assessments, research and synthesis/prediction; monitoring ambient levels of pollutants in the sediment and water column; and researching the effects of pollution on estuary habitats, organisms and subsequently, human health.

NOAA administers the Coastal Zone Management Act (amended 1990) the purposes of which are to enhance the effectiveness of the CZMA of 1972 by increasing understanding of the coastal environment and expanding the ability of state coastal zone management programs to address coastal environmental problems; and controlling land use activities which result in nonpoint

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pollution of coastal waters, and which anticipate sea level rise. It also provides a procedure for state inland coastal boundaries to be modified to extent necessary to control the land and water uses that have a significant impact on coastal waters of the state.

Federally funded projects and projects on federal lands must be consistent with the State Coastal Zone Management Program; Section 404 (Clean Water Act) permit actions must also be consistent with the CZMA programs.

NOAA administers the National Estuarine Research Reserve System (NERRS) which provides estuarine site acquisition for research and education.

National Marine Fisheries Service (NMFS)

NMFS's mission is to conserve, manage and develop living marine resources and to promote the continued utilization of these resources for the nation's benefit. Although NMFS jurisdiction and management activities are primarily confined to the coastal zone and its network of estuaries, the agency also is an advocate of measures to protect the health of anadromous species such as salmon. NMFS, together with eight Regional Fishery Management Councils and the coastal states, manages U.S. fisheries under the authority of the Magnuson Fishery Conservation and Management Act, the Fish and Wildlife Coordination Act, and many other federal statutes. Together with the states and the U.S. Coast Guard, NMFS also operates a stringent program to enforce fisheries and protected species laws.

Each NMFS Regional Office is served by a Science and Research Center that conducts the studies necessary to support management decisions. Research that contributes to this important work is conducted at the 24 NMFS laboratories which collect fisheries statistics, perform resource and environmental surveys, study the biology and population structures of marine species, analyze the ecosystems that control the abundance and distribution of living marine resources, and investigate contaminants of the nation's seafood supply.

NMFS serves as a caretaker for many marine species protected under the Endangered Species Act, including (increasingly) stocks of Pacific salmon, which have declined in abundance so much that their future existence is now in jeopardy. NMFS works to recover these depleted resources, protecting species from activities that threaten their safety and critical habitat.

Magnuson Fishery Conservation and Management Act of 1956: The Act governs fishing in all U.S. waters throughout the U.S. Exclusive Economic Zone. The purpose of the act is to promote conservation and sound management of commercial fishing resources. The act covers all species of marine animals and plants, including anadromous species, except for marine mammals, birds and highly migratory species of tuna.

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Pacific Fishery Management Council

This regional council, authorized by the Magnuson Fishery Conservation and Management Act, makes recommendations for regulation to the Secretary of Commerce; these recommendations are usually adopted with little or no change. The council does not supersede the authority of the California Department of Fish and Game in California waters.

The council is distinguished from the Pacific Marine Fisheries Commission. The commission is an interstate body created in 1947 by interstate compact between California, Oregon and Washington. Its purpose is to promote the better utilization of fisheries and to develop a joint program of protection and prevention of physical waste of fisheries. The commission's authority rests on the states' jurisdiction, rather than the federal government. The commission's actions complement those of the council by dealing with subjects outside the boundary of federal authority.

Department of Defense

United States Army Corps of Engineers (Corps)

The Corps' mission is to develop, control, maintain and conserve the nation's waterways and wetlands. The Corps is the principal federal agency involved in the regulation of wetlands, although, under recent legislation more clearly defining the process, EPA has oversight responsibilities.

The Corps carries on an extensive Civil Works (water resources development) program, including the planning, design, construction and operation of flood control and navigation projects, levee systems and shoreline erosion control works. Much of Corps work with respect to inland waterways during the past half century has been engineered flood control facilities and the creation and maintenance of navigable shipping channels. Until recently, engineered flood control improvements usually consisted of straightened and armored bank channels, the removal of riparian vegetation, leveeing, the construction of bypass facilities to handle peak flows, and similar facilities. The impacts of such measures on the health of natural systems is discussed elsewhere in this report.

The Corps regulates a permit program for structures and operations in navigable waters under Section 10 of the Rivers and Harbor Act of 1899, which essentially deals with any activity which would restrict navigation. Under Section 404 of the Clean Water Act of 1974, the Corps regulates the placement of fill in all waters and wetlands of the United States.

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Department of Energy

Federal Energy Regulatory Commission (FERC)

FERC is the licensing entity for hydroelectric projects on inland waterways and its jurisdiction over such projects has been held by the courts to be preemptive of state jurisdiction for many purposes. FERC operates under the authority of the Federal Power Act, amended by the Electric Consumers Protection Act of 1986. It is required to give equal consideration to and balance, in the public interest, all uses of the waterway on which a project is located. When FERC reviews competing interests, the environment, recreation, fish and wildlife and other nondevelopmental values are to be equally considered with power and other developmental values. FERC independently weighs the economic and environmental trade-offs of the various developmental and nondevelopmental uses of the waterway when determining whether, and under what conditions, it licenses or relicenses a hydropower facility. Its analysis includes consideration of the recommendations of federal and state natural resource agencies.

The nature and extent of FERC jurisdiction has been a source of contention between FERC and natural resource agencies in California and other states.

Department of Health and Human Services

Food and Drug Administration (FDA)

FDA sets and enforces allowable levels of toxics in food, controls fish catches transported between states and monitors catches in federal waters.

Department of the Interior

Bureau of Land Management (BLM)

BLM manages California's "public domain." In this context, public domain includes all of the unsold federal lands within the state which are not withdrawn or reserved for some other federal purpose, e.g., Department of Defense, National Forests, National Parks and Monuments, Strategic Petroleum Reserve, Water Project, etc. BLM is mandated by the 1976 Federal Land Policy & Management Act to manage public lands for multiple uses, including recreation, wilderness, animal and plant species, grazing, mining and alternative energy. While the majority of BLM lands are located in the southern California deserts, public lands exist throughout the

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state. Much of BLM's jurisdictional area encompasses rivers and streams with very substantial recreational and ecological value.

BLM manages the riparian areas along those streams which flow through its jurisdictional area as part of its mandate to provide for multiple use of its resources. Impacts from past practices have been discussed elsewhere in this report. Although current efforts include concerns about riparian areas, a comprehensive management program is not available. For example, BLM has developed specific management plans for Upper Cache Creek as it flows from Clear Lake toward the Capay Valley, and for the Sacramento River south of Red Bluff. Those plans incorporate recreation and the preservation of wildlife habitat. BLM recently completed a Riparian/Wetland Stateside strategy that calls for interdisciplinary planning, on-the-ground improvements of wetland/riparian areas, monitoring, out-reach efforts, and expanding work with partners and volunteers to restore and enhance wetland/riparian areas.

BLM is consolidating public land parcels through land exchanges and Land and Water Conservation Fund purchases in order to improve management of riparian areas along rivers such as the Sacramento, American, and Cosumnes. BLM is also involved in Challenge Cost Share programs with environmental groups, private organizations, and other government agencies. Along the Cosumnes River, BLM is working with Ducks Unlimited, The Nature Conservancy and the Central Valley Joint Venture to restore wetlands necessary to waterfowl in the Sacramento-San Joaquin Delta.

In addition, BLM is developing cooperative agreements with farmers and cattle ranchers to help protect riparian areas. For example, BLM has revised its grazing management plans to reduce overgrazing near sensitive stream and river banks and to increase monitoring. With the help of volunteers, BLM has been fencing riparian areas in order to provide appropriate livestock grazing prescriptions, rehabilitating closed roads, and restoring native plant species along river banks.

BLM takes part in the Coordinated Resource Management Planning (CRMP) process. The CRMP process is a collaborative public-private project planning and implementation process which seeks to involve all interested parties in management and restoration decisions and in project implementation. Many successful projects have been undertaken and completed at the grassroots level. CRMP projects include innovative bank restoration projects and restoration of riparian habitat. BLM is participating in bioregional planning and management efforts including the Cosumnes River Preserve and the Coachella Valley Preserve.

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Bureau of Reclamation (USBR)

The Bureau of Reclamation constructs and maintains federal water development and reclamation projects including those along the Colorado River and the vast Central Valley Project (CVP). It provides water for irrigation, municipal and industrial use, hydroelectric power generation, water quality improvement, wind power, fish and wildlife enhancement, outdoor recreation, river regulation and flood control. The USBR plays a major role on the more significant river systems, and a lesser role on their tributaries. The Central Valley Project Improvement Act requires the USBR to put environmental uses of CVP water on an even footing with urban and agricultural consumptive uses, and also guarantees minimum quantities for fishery protection under specified circumstances.

The USBR controls about 1.1 million acres in California, all of which are related to completed or authorized projects. Activities include the Central Valley Project, including Shasta, Clair Engle, Whiskeytown, New Melones, Folsom, San Luis and Millerton lakes, and major canals and hydroelectric facilities; the All-American Canal system in the Imperial Valley; and the Parker, Davis, Cachuma, Klamath, Orland, San Diego, Solano, Truckee Storage, Ventura River, Santa Maria, and Washoe projects.

The USBR is signatory to the Coordinated Operating Agreement between the Central Valley Project and the State Water Project (1986), which: provides that both the CVP and SWP are subject to water quality standards and export decisions taken from SWRCB Water Rights Decision 1485; provides for CVP/SWP proportional splits of 75/25 responsibility for meeting in-basin use from stored water releases and 55/45 for capture and export of excess flow; requires a commitment of about 2.3 million acre-feet from both projects during a critical water supply period.

The CVP concept and design originated with the California state government, as part of an overall plan for water resource development for the state. Periodically, there have been initiatives to return control over CVP facilities to the state. The concerns of environmental interest groups and the questions of price and payment terms would present formidable obstacles to a transfer of jurisdiction.

The USBR's role on the Colorado River has been varied. It has provided flood control, water supply and hydroelectric power by constructing and operating multiple-use dams and diversion structures, and it has straightened, denuded and bank-armored sections of the river to facilitate flows. Significant degradation of water quality in the southern reaches of the Colorado River has resulted from agricultural water use and drainage patterns.

The USBR also funds and participates in the Interagency Ecological Study Program.

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U.S. Geologic Survey (USGS)

USGS provides geologic, topographic and hydrologic information that contributes to the management of resources. USGS collects data on a routine basis to determine quantity, quality and use of surface and groundwater; conducts water resources appraisals describing the consequences of alternative plans for developing land and water resources; researches hydraulics and hydrology; and coordinates all federal water data acquisition.

U.S. Fish and Wildlife Service (USFWS)

The USFWS is the principal agency through which the federal government carries out its responsibilities to conserve, protect and enhance the nation's fish and wildlife and their habitats for the continuing benefit of the people. The agency's major responsibilities are for migratory birds, candidate species, endangered species, certain marine mammals, and freshwater and anadromous fishes.

USFWS's programs includes fish and wildlife conservation; technical assistance on wildlife management to federal, state and local agencies; migratory birds; the acquisition of areas for management and protection of migratory birds; wetlands conservation; funding for wetlands acquisition; the conservation of estuarine areas under the Estuarine Areas Act (PL 90-454); the National Wetland Inventory and insuring compliance with NEPA.

Fish and Wildlife Coordination Act (1958): The act provides a procedural framework for the consideration of fish and wildlife protection and improvement measures to be incorporated into federal and federally permitted or licensed water development projects. Pursuant to the act, the USFWS investigates and makes recommendations on water projects planned by the Corps of Engineers (Section 10 and Section 404) and licensed by the Federal Energy Regulatory Commission (hydropower projects).

Endangered Species Act (1973): The purposes of the Endangered Species Act are to conserve threatened and endangered species and the ecosystems upon which they depend, and to carry out programs pursuant to international treaties and conventions regarding fish, migratory birds and other wildlife.

The act provides for the establishment of lists of threatened and endangered species. Any inclusions to or deletions from the lists must come after proper notice and, if requested, public hearing. The lists are reviewed every five years to determine if any species should be removed or have its status changed. The Secretary of the Interior may also identify critical habitat and impose regulations governing those areas.

The Secretary of the Interior is also directed to establish programs for the conservation and recovery of listed species,

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including the acquisition of land or other interests affecting habitat. The act directs the secretary to cooperate with state governments to implement these programs.

The Migratory Bird Conservation Act of 1929 (16 U.S.C. 715): Authorizes the USFWS to acquire lands for conservation of migratory waterfowl and the *Fish and Wildlife Act of 1956* authorizes the acquisition of lands for wildlife refuges.

The Emergency Wetland Resources Act of 1986: Authorizes the Secretary of the Interior to acquire wetlands, and the *North American Wetland Conservation Act of 1989* authorizes acquisition of wetlands to implement the North American Waterfowl Management Plan.

The North American Waterfowl Management Plan (1986): Signed by United States and Canada (endorsed by Mexico), provides a broad framework for waterfowl conservation and management in North America through the year 2000. This plan seeks to restore and maintain the diversity, distribution and abundance of waterfowl that occurred from 1970 to 1979 by solving habitat problems with a focus on seven priority habitat areas. The Central Valley, including the Sacramento-San Joaquin Delta, is one of these areas. The Central Valley Habitat Joint Venture (Joint Venture) is a group of private organizations and public agencies which have agreed to pool their resources to solve habitat problems in the Central Valley. Conservation easement and fee title acquisitions in the North Central Valley Wildlife Management Area are proposed as a major USFWS program contributing to the Joint Venture.

Funding for the Migratory Bird Conservation Act comes from the Migratory Bird Conservation Fund, derived primarily from the sale of federal duck stamps. Funding for both the Fish and Wildlife Act and the Emergency Wetland Resources Act come from the Land and Water Conservation Fund, which is from revenues derived primarily from oil and gas leasing. The North American Wetland Conservation Act authorizes appropriations as well as earmarks proceeds from migratory bird fines and accrued interest from Pittman-Robertson funds to implement the management plan.

Refuge Revenue Sharing Act (Public Law 95-469): Under provisions of this act payments are made to counties to offset tax revenue lost as a result of fee title acquisition of private property for refuge establishment.

USFWS manages the Kern National Wildlife Refuge, Klamath Basin National Wildlife Refuge, Modoc National Wildlife Refuge, Sacramento National Wildlife Refuge, Salton Sea National Wildlife Refuge, San Francisco Bay National Refuge and San Luis National Wildlife Refuge.

National Park Service (NPS)

The National Park Service (NPS) in California has jurisdiction of and manages five river segments designated under the National Wild

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and Scenic Rivers System within National Park Units: the Tuolumne River including Lyell and Dana Forks (Yosemite); the Merced and the South Fork Merced rivers (Yosemite); the Middle and South Fork Kings rivers (Sequoia/Kings Canyon National Park); and the North Fork Kern River (Sequoia/Kings Canyon). In addition, other river segments potentially eligible for designation under the National Wild and Scenic Rivers Act §2(a)(ii) flow through National Parks and are managed under existing NPS laws and regulations. Research on and management of these river segments are addressed in each park's general management plan and resources management plan.

The Natural Resources and Research program of the NPS in California has considerable expertise in the management and restoration of riverine and riparian habitats. Redwood National Park is nationally recognized for its watershed restoration program mandated by the park's 1978 Redwood National Park Expansion Act. Other major management efforts currently being implemented include the restoration of natural river channels and riparian habitat of four reaches of the Merced River within Yosemite National Park, and an inventory of aquatic resources of the Middle Fork of the Kaweah River within Sequoia/Kings Canyon.

NPS acts on behalf of the Secretary of the Interior in reviewing impacts on state administered components of the National Wild and Scenic Rivers System when these segments are not under the jurisdiction of any other federal management.

From 1979-81, NPS, in cooperation with state and local agencies, organizations and the public, completed the first nationwide inventory of significant free-flowing rivers potentially eligible for the National Wild and Scenic Rivers System. The inventory established the potential eligibility of over 60 rivers in California.

The Rivers, Trails and Conservation Assistance (RTCA) program of the NPS cooperates with and assists states, local governments and citizen groups to protect and restore river corridors, to establish trail systems and to conserve open space. The goal of this outreach service is to share the expertise and experience of the NPS with groups working to protect their river and trail resources. RTCA, in partnership with the California Resources Agency, is currently undertaking a statewide rivers assessment to enhance the planning and conservation of California's river resources. The goal of the assessment is to create an informational planning and decision making tool that can be used by resource management agencies, river related organizations and decision-makers to design effective river management strategies. RTCA works through the invitation of a local or state group.

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Department of Transportation

U.S. Coast Guard

The U.S. Coast Guard enforces federal fisheries laws; promotes navigation and boating safety; aids vessels in distress; and protects ports, waterways and shoreside facilities. The Coast Guard is the primary enforcement agency for ocean disposal activities and assists the Corps of Engineers in monitoring the activities of disposal barges. The Coast Guard has increasing control over spills of pollutants and requires and enforces contingency cleanup plans for accidental spills.

Other Federal Agencies

Environmental Protection Agency (EPA) (Independent Agency)

EPA was established (1970) to protect, maintain, restore and enhance environmental quality and human health through the regulation of activities that have potentially harmful effects on air, water and land resources. EPA exercises authority through the National Pollution Discharge Elimination System (NPDES), National Pretreatment Program, Ocean Dumping/Dredging and Fill, and has delegated to states the authority to certify that permitted actions are consistent with the state's water quality objectives under the Clean Water Act.

Clean Water Act: The Clean Water Act was originally enacted in 1948, but extensively amended in 1972 and 1977. The act's objective is to restore and maintain the chemical, physical and biological integrity of the nation's waters. While its administration is in the hands of the EPA, management of water pollution control generally is the responsibility of the states. Allocation of water is also expressly left to the states.

Of particular interest is Title III which provides for the establishment of water quality standards and for enforcement. Code section 1311 makes unlawful the discharge of any pollutant of any kind by any person, except in compliance with specific provisions of the act. The same section also provides for the establishment of effluent limitations within a specified time schedule. Title III also contains provisions for establishment of more stringent controls on particular point sources, state establishment of water quality control standards, establishment and publication of water quality criteria, biennial state reporting to EPA, state control of discharge sources, establishment of effluent standards and controls for toxic pollutants, and control of sewage discharges from vessels. When the EPA finds a violation of state standards it notifies the state first and, if the state

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does not act, then orders the violator to comply with the standard or seeks an injunction ordering compliance.

Council on Environmental Quality (CEQ)

The CEQ was established by the National Environmental Protection Act of 1970 with the responsibility to inform and advise the president and Congress on environmental problems and issues. It is a three-member commission whose chairperson and members are nominated by the president and confirmed by the Senate. It is within the Executive Office of the president along with the National Security Council and the National Science Advisor, among others. Among its more notable accomplishments are an annual report on the state of the nation's environment and the *Global 2000 Report*, a status report on the world's environment which contributed significantly to the knowledge of environmental problems and trends.

Federal Emergency Management Agency (FEMA)

FEMA provides flood insurance to jurisdictions that meet the criteria for participation in its program. The program was initiated to encourage better flood plain management and reduce damages in flood-prone areas. To identify flood-prone areas, FEMA requires delineation of a 100-year flood plain, which is then subject to regulation. In developed or developing areas, FEMA also identifies a part of the flood plain called the "floodway" that is subject to extreme limitations on development. In general, structural developments are prohibited in the floodway. The floodway is technically defined as the portion of the flood plain which is required to convey the 100-year peak flow with no more than a one-foot increase in the computed water surface elevation. Development is generally allowed outside of the floodway, although purchase of flood insurance is generally required. The result of this regulatory system is that floodways are left undeveloped, but portions of the flood plain outside of the floodway—termed the "floodway fringe"—continue to be developed, sometimes at a rapid pace.

The State Role

Business and Transportation Agency

Department of Transportation (CALTRANS)

Caltrans' role with respect to rivers is both direct and indirect. Caltrans is responsible for the construction and operation of the state's extensive primary and secondary State Highways system. It

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constructs and maintains bridges over almost every river in the state. In that capacity, Caltrans is very concerned about the effects of riverbed degradation caused by aggregate extraction operations. The lowering of riverbeds in the vicinity of highway bridges is cause for concern to Caltrans both for repair cost and public safety reasons. Bed degradation caused by aggregate operations can also lead to the erosion of engineered fills along waterways. On the other hand, Caltrans is also a major *consumer* of aggregate products. In that capacity, it may occasionally find itself in the somewhat contradictory position of advocating instream extraction as the most cost-effective means of acquiring construction materials, while at the same time expressing concern about the effects of extraction on bridges and highway fills. The resolution of those concerns often means limiting the commercial extraction to those areas far enough removed from bridges that no significant degradation is probable. The timing of extraction can also be significant, as evidenced by the particularly severe streambed degradation which has occurred on some North Coast rivers during the recent drought.

Environmental Protection Agency (Cal-EPA)

Office of the Secretary for Environmental Protection

The Office of the Secretary coordinates functions that cut across the various Cal-EPA programs designed to address pollution in specific media, e.g., air, surface water, groundwater, land disposal, and serves as the primary point of accountability for the management of environmental protection programs. The secretary chairs the Environmental Policy Council, which includes the heads of the constituent boards, departments and offices of the Cal-EPA, and the governor's Office of Planning and Research.

Air Resources Board (ARB)

ARB's mission is to control air pollution and improve air quality throughout California. Its primary responsibility is to control motor vehicle pollution and oversee the activities of 14 local air pollution districts which regulate industrial sources of air pollution.

The ARB establishes air quality standards, researches pollution problems, monitors air quality, inventories major sources of air pollution and regulates agricultural burning.

Integrated Waste Management Board (CIWMB)

The CIWMB was established in 1990 as the state's lead agency for managing solid waste in California. The board's role is to protect the public and the environment from any deleterious effects of solid waste

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management by establishing regulations that meet environmental concerns and provide flexibility to local governments.

State Water Resources Control Board (SWRCB)

SWRCB is responsible for both the allocation of water rights and, through the Regional Water Quality Control Boards, for ensuring compliance with state and federal water quality laws, including the Clean Water Act and the Porter-Cologne Act.

In its capacity as permitter and regulator of appropriative water rights, the SWRCB acts as public trustee of the state's ownership interest in the water. As trustee, the agency must allocate water equitably among potential consumptive uses, while guaranteeing that instream public trust resources receive enough residual flow so that they are not impaired.

The SWRCB develops control strategies for pollution sources and management plans. Assessment reports identify categories of pollution, identify surface water bodies that would not attain water quality standards without pollution source controls, describe the development of "Best Management Practices" (BMP) for control of pollution sources, and review existing control programs.

The SWRCB is charged with establishing water quality standards for the Central Valley Project and the State Water Project. The SWRCB reviews applications for the diversion of water from the Delta or its tributaries to determine the effect of the proposal on the quantity and quality of the water, and the resultant effect on other uses of water in the system. The SWRCB recently issued and then withdrew D-1630, a draft decision proposing new interim standards for the flow and operational requirements of the Delta, in an effort to address the decline of Delta fishery and wildlife resources. Environmentalists assert the decision was flawed in several significant ways including the use of "target species"and the apparent abandonment of the goal to return the water quality standards to pre-project (SWP/CVP) standards. Others argue that the D-1630 would require too much water from agriculture uses.

The SWRCB is also chiefly responsible for implementing section 208 of the Clean Water Act, the mandate to control pollution. The SWRCB and Regional Water Quality Control boards review all proposed activities in the waterways that require federal grants, licenses or permits to determine the effect of the proposed action on water quality.

Regional Water Quality Control Boards (RWQCB)

Regional boards act as agents of the State Water Resources Control Board and the Environmental Protection Agency, issuing waste discharge permits.

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Department of Toxic Substances Control (DTSC)

DTSC is responsible for locating, investigating and cataloging toxic waste sites, for identifying the responsible parties, and for supervising remediation of those sites. It is able to expend bond money, where necessary to facilitate cleanup, and to recover its costs through the court system.

Department of Pesticide Regulation (CDPR)

The department oversees pesticide registration and enforces all state and federal pesticide laws governing the agricultural, industrial, domestic or other use of pesticides in California. Under the direction and supervision of the department, the County Agricultural Commissioners carry out pesticide enforcement activities at the local level.

Resources Agency

Office of the Secretary for Resources

The secretary directs the State Resources Agency which functions as an "umbrella" agency, setting major resource policy for the state and overseeing programs of agency departments including the Departments of Water Resources and Fish and Game, and the Coastal Commission. The agency evaluates CEQA documents for consideration of existing state policy, programs and plans, and coordinates all state agency comments on applications for Corps permits.

San Francisco Bay Conservation and Development Commission (BCDC)

BCDC is authorized by the McAteer-Petris Act to analyze, plan and regulate San Francisco Bay and its shoreline. It implements the San Francisco Bay Plan and the Suisun Marsh Protection Plan, and regulates filling and dredging in the Bay, its sloughs and marshes, and certain creeks and tributaries. BCDC jurisdiction is the Bay and inland area within 100 feet of shoreline. The Bay Plan is subject to CZMA consistency review as a component of California's Coastal Plan which is administered by BCDC.

California Coastal Commission (CCC)

The California Coastal Act of 1976 (see Public Resources Code Section 30000 ff.) mandates the CCC to protect marine and coastal resources, promote coastal conservation, regulate coastal development and perform as the principal, designated coastal zone management agency under federal law. The CCC aids local planning efforts concerned with

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land use and water development, public access, natural resources, offshore oil development, agriculture and other issues affecting the coastal zone. The CCC has permitting authority over certain major land use decisions along the California coast, and hears appeals regarding a broader spectrum of coastal permitting decisions that are initially made by local governments. The CCC generally has jurisdiction over the mouth or estuary areas of many rivers and streams.

Delta Protection Commission (DPC)

The Delta Protection Act of 1992 established a 19-member commission designed to protect, maintain and enhance a significant portion of the lands of the Sacramento-San Joaquin Delta for agriculture, wildlife habitat, recreation and other public trust uses. The commission is charged with developing a plan to preserve and restore Delta dependent fisheries, riparian and wetland habitat, water quality, open space and outdoor recreation opportunities, agricultural viability, public access and navigation; protect the Delta from development that results in significant loss of habitat or agricultural land; and promote strategies for voluntary cooperative arrangements between property owners and conservation groups.

Boating and Waterways (B&W)

The Department of Boating and Waterways is responsible at the state level for navigation safety, for constructing and maintaining certain boating and ancillary facilities, and for funding, through low interest loans, certain privately built and operated boating and fishing facilities. B&W has a small staff devoted to studies of coastal sand supply and transport which is, in turn, related to the management of inland stream systems.

State Conservancies

Several conservancies that have river related obligations operate under the aegis of the Resources Agency. These agencies facilitate public and private initiatives to preserve, rehabilitate and protect natural systems through programs of land acquisition and grants. The Coastal Conservancy, the Tahoe Conservancy, the Santa Monica Mountains Conservancy and the newly created San Joaquin River Conservancy are examples.

Colorado River Board of California

The Colorado River Board was established in 1937, Water Code Sections *12500, et seq.*, to protect the interests and rights of California, its agencies and citizens in the water and power resources

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of the Colorado River System. The chairperson, who serves ex officio as the Colorado River Commissioner of California, represents the state on various interstate and federal-state bodies concerned with the river basin. The board reviews and evaluates water requirements and supplies.

Department of Conservation (DOC)

DOC's programs include mining and geology, recycling, land resources protection, and oil and gas. It issues oil, gas and geothermal well permits.

DOC's programs address soil conservation, particularly as it relates to land use. The DOC administers the Williamson Act on agricultural lands and maintains a task force to evaluate the progress of the Act. DOC's Office of Land Conservation administers the Farmland Mapping and Monitoring Program which provides information updates on conversion of these lands to other uses every two years.

DOC oversees the administration by local agencies of the Surface Mining and Reclamation Act (SMARA) which requires reclamation of mined lands to alternate uses such as range and forage. In this latter capacity, DOC plays an important role in ensuring that local governments comply with those provisions of SMARA which are designed in part to guard the health of riparian and aquatic systems. DOC also contracts with the Department of Forestry and Fire Protection to map highly erosive watersheds that may be affected by timber harvesting.

Department of Fish and Game (DFG)

DFG has jurisdiction over, and responsibility for, resident and anadromous fish resources in all rivers and streams of the state, and also for wildlife resources which use adjacent riparian habitat. DFG conducts wide-ranging programs including research on fish and wildlife propagation, habitat requirements, fishing and hunting licensing, hatchery management, fish planting, stream alteration permitting, natural heritage database management and related programs. It is responsible for the administration of the provisions of the state Endangered Species Act, and for operating the California Natural Diversity Database. DFG Stream or Lake Alteration Agreements are required for activities that result in changes to natural conditions in streams, lakes channels or crossings.

DFG conducts an aggressive and wide-ranging stream and watershed planning and restoration program to maintain and rehabilitate aquatic and riparian habitats. The program stresses public participation and interagency cooperation. Approximately 1,500 projects have been completed over the past 10 years.

DFG acts as trustee, on behalf of the state, of California's fish

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and wildlife resources, and is governed by the principles of the public trust with respect to them. As trustee, DFG plays an active role in all those management activities of other agencies and individuals which may affect the resources within its jurisdiction.

Inland Fisheries Division: Established to protect, maintain and enhance populations and habitats of resident inland fish, amphibians, reptiles, invertebrates and anadromous fish. The division conducts a hatchery program for the production and planting of some 60 million fish each year, carries out habitat restoration projects, and conducts surveys and research.

Natural Heritage Division: Focuses on the protection, management, restoration and recovery of endangered and rare plants and animals.

Wildlife Conservation Board (WCB)

This board acquires land, develops recreation facilities and public access to natural sites, and investigates areas to determine suitability for wildlife production, preservation and recreation. The WCB works closely with the Department of Fish and Game to coordinate spending Water, Parks and Wildlife Bond (Prop. 70) money.

California Fish and Game Commission

The California Fish and Game Commission, with advice from the Department of Fish and Game, sets ocean fishing regulations within the three-mile zone of state waters, consistent with fishery plans developed by the Pacific Fishery Management Council. The Commission also regulates inland fishing, except for Indian fishing within a reservation, which is controlled by the U.S. Bureau of Indian Affairs.

Department of Parks and Recreation (DPR)

The Department of Parks and Recreation's mission is to provide for the health, inspiration and education of the people of California by acquiring and protecting the state's most valued natural and cultural resources and by providing opportunities for high quality recreational experience. The department has an important role in the management of the state's rivers because many river corridors with ecological values of statewide significance are within existing State Park units and can provide important public recreational opportunities.

DPR manages over 250 State Park System units encompassing over 1.5 million acres. Many of these units include significant portions of important rivers and streams. Resource management by the department includes native plant reintroduction, exotic plant removal, prescribed fire management and restoration of stream channels, banks and associated riparian vegetation.

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DPR is responsible for the disbursement of state bond funds and federal Land and Water Conservation Funds and other grants to local government park and recreation agencies which contribute to the resource management of rivers and streams.

Department of Water Resources (DWR)

DWR is responsible for formulating coordinated statewide plans for the control, conservation, protection, enhancement and use of state water resources. DWR's mission is to evaluate current and projected needs for water and development programs; to direct the use of the resource; to protect the public through water quality improvement, flood control and dam safety programs; and to assist local water agencies with funds, expertise and technical support to improve their water delivery systems. DWR issues permits for activities involving dams or reservoirs.

DWR is responsible for maintaining specified portions of the Sacramento River Flood Control Project, which includes the ". . . channels and overflow channels of the Sacramento River and its tributaries. . . ."

DWR is responsible for constructing and operating the State Water Project which delivers water to 30 agencies throughout the state. DWR coordinates the operation of the SWP with the U.S. Bureau of Reclamation's operation of the federal Central Valley Project and other projects to meet legal requirements for water quality standards.

DWR is a bulk electrical utility, producing, selling, purchasing and exchanging energy to meet the project's needs. Principal energy sources are hydroelectric, coal and geothermal, and exchanges and sales with other utilities.

The Division of Flood Management is responsible for the statewide flood protection, the assessment of department's flood control needs with consideration to flood plain management, and the more traditional structural works.

State Reclamation Board (Rec. Board)

Staffed by DWR, this board exercises responsibilities for flood management on the Sacramento and San Joaquin rivers and their tributaries, and participates with the federal government in the planning, design, construction, operation and maintenance of federally authorized flood control projects. The board may designate floodways in order to control encroachments and thus preserve the flow regimes of the floodways.

The board subsidizes the maintenance of local reclamation and local flood control district levees in the Sacramento-San Joaquin Delta through the Delta Subvention Program (SB 34). The board

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regulates encroachments into the Sacramento and San Joaquin flood control projects.

Energy Commission (EC)

Established by the Warren-Alquist State Energy Resources Conservation and Development Act of 1974 to address the energy challenges facing the state, the commission is the state's principal energy planning organization. It has five major areas of responsibility: forecasting future statewide electricity needs; licensing power plants sufficient to meet those needs; promoting energy conservation; developing renewable energy resources and alternative energy generating technologies; and planning for and directing state response to energy emergencies. The EC ensures that needed energy facilities are sited in an expeditious and environmentally acceptable manner.

California Department of Forestry and Fire Protection (CDF)

CDF has jurisdiction to review and approve timber harvest plans (THPs) prepared in connection with logging proposed on both the State and privately-owned lands. Preparation of THPs and subsequent enforcement of the terms of an approved THP can have a dramatic impact on overall watershed management, both in the immediate vicinity of a cut and far downstream. Watershed, riparian habitat and fisheries protection are important elements to be considered in the preparation of each THP.

Health and Welfare Agency

Department of Health Services (DHS)

DHS finds and prevents pollution of public water supplies and promotes other environmental health issues.

Governor's Office

State Historic Preservation Office (SHPO)

The National Historic Preservation Act (NHPA) 1966 established the National Register of Historic Places, Advisory Councils on Historic Preservation, State Historic Preservation Offices and Grants-in-Aid programs. Section 106 requires that all federal agencies consult with the Advisory Council prior to undertaking any action that would affect a property on or eligible for the National Register. It established regulations that encourage coordination of agency cultural resource compliance.

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The American Indian Religious Freedom Act recognizes that Native American religious practices, sacred sites and objects have not been properly protected under other statutes. It establishes as national policy that such traditional practices and beliefs, sites, including right of access, and the use of sacred objects, shall be protected and preserved.

The intent of the Archaeological Resources Protection Act (ARP) of 1979 is to enhance the preservation and protection of archaeological resources on public and Indian lands. Its primary emphasis is on a federal permitting process to control the disturbance and investigation of archaeological sites on these lands. Many of these sites are in riparian areas.

Office of Planning and Research (OPR)

OPR has no regulatory authority, but has substantial influence in guiding administration environmental and planning policy and in providing guidance to local governments. This includes the formulation of a statewide growth management strategy. OPR administers the State Clearing House for CEQA documents and is responsible for preparing planning reports to the governor.

The California Environmental Quality Act (CEQA) (1970), patterned after federal environmental legislation (NEPA), sets the state's basic charter for protecting the environment. Its policies include preventing the elimination of fish and wildlife populations. The Sacramento-San Joaquin Delta is listed as having regional and statewide significance; wetlands and riparian lands are also defined as significant. Environmental impacts must be mitigated to a level of insignificance (or a Statement of Overriding Considerations adopted) and there must be a mitigation monitoring plan to ensure effective mitigation measures.

Office of Emergency Services (OES)

OES assists local governments in preparing for and responding to disasters, such as flooding.

Local Government

Decisions by local governments, may have a profound impact on the health of river systems which pass through county jurisdiction. In addition to their normal planning responsibilities, local governments are delegated lead agency responsibility for ensuring that aggregate producers comply with the Surface Mining and Reclamation Act (SMARA) (Public Resources Code Section 2710, et seq.) That responsibility includes the permitting process itself, and follow up on approved reclamation plans. Since instream and/or

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near-stream aggregate mining can have such significant impacts on the character of both upstream and downstream reaches of a stream system (see Chapters 2 and 4) the local role may be pivotal for the continued well-being of the system as a whole. Local government bodies which play a particular role in the SMARA process may include city and county planning commissions and elected governing boards or councils.

Other local government bodies which play a role in stream management are flood control districts, parks departments, water districts, community service districts, resource conservation districts and, in some cases, special districts or commissions set up specifically for stream management. The City of Redding, for example, has a Sacramento River Commission which advises the city on river corridor management issues.

Local Jurisdictional Planning Authority

Local governments (counties and cities) are required (Government Code, Section 65000 et seq.) to have a general plan with mandated elements including open space/conservation, safety, land use and circulation. There are very few regional requirements for plan consistency between the counties and cities.

The general plan land use element delineates the general distribution, location and extent of local development patterns and land use.

The conservation element addresses the "conservation, development, and utilization of natural resources, including water and its hydraulic force, forests, soils, rivers, and other waters, harbors, fisheries, wildlife, minerals, and other natural resources."

The open space element defines provisions for open space, for the preservation of natural resources, the management of resources, outdoor recreation, and public health and safety.

Zoning Ordinances

State law requires that the adopted zoning ordinance and map must be consistent with the general plan. In general, there has not been a mechanism to assure consistency between or among general plans at the regional level. For example, until the enactment of the Delta Protection Act (Public Resources Code Section 29700 et seq.), there were no comprehensive local governmental zoning tools in the Delta area that could be applied effectively against the alteration of significant resource areas. The Delta Protection Act was designed to remedy that situation.

Subdivision Ordinance Controls

The Subdivision Map Act (Section 64478 et seq.) requires that a subdivision map be reviewed and approved by the appropriate local

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government for all projects creating five or more parcels of land or condominiums. Maps may be denied if a finding is made that the subdivision and proposed improvements are likely to cause substantial environmental damage. In general, local governments must incorporate adequate criteria or habitat descriptions into their subdivision ordinances to implement the state law. The act (Section 66478.1) requires that reasonable public access to rivers be provided as part of the subdivision process.

Local Agency Formation Commission (LAFCO)

LAFCOs coordinate and approve changes in local government boundaries by authority of the Knox-Cortese Act; LAFCOs have authority over all cities and special districts requesting changes in geographic or public service boundaries, and establish "spheres of influence" for cities and districts. Government Code Section 56108 provides that no tidelands or submerged lands which are owned by the state or by its grantees may be incorporated into, or annexed to, a city without the approval of the State Lands Commission.

Special Districts

Resource Conservation Districts are authorized by Division 9 of the California Public Resources Code to assist the state in conserving soil and water resources on farm, range, urban and timber lands. The districts provide assistance to landowners and government agencies to prevent soil erosion, control runoff, stabilize soils and protect water quality. Districts receive technical assistance from the USDA Soil Conservation Service. Each district prepares a long-range plan for lands within its boundaries.

Open Space and Park Districts acquire and preserve open space lands, and manage wildlife, recreation and stock animals.

Reclamation Districts were the first special districts established by law. There are 108 reclamation districts which are responsible for levee maintenance. These special districts are formed and supported by the landowners of the area protected by the levees. Except for the maintenance of Corps project and direct agreement levees, they are subject to limited state and federal flood maintenance and environmental requirements and virtually no local planning regulations. However, in many cases Reclamation District projects are subject to the jurisdiction of the State Lands Commission. When state subsidy funds are used, or if construction activities on private levees require a permit from the Corps of Engineers or the State Lands Commission, environmental conditions can be imposed.

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Utilities

Public utilities have developed both domestic water supply and power generation facilities on most major California watersheds. Pipelines often are operated by utilities. Insofar as river management is affected, it probably makes little difference whether the utility in question is public or privately owned and operated. Because privately held utilities are regulated by the Public Utilities Commission, they tend collectively to act somewhat like quasi-public agencies.

In Southern California, the activities of the giant Los Angeles Department of Water and Power (DWP) in the Mono Lake area and in the Owens Valley are well documented. Other major utilities with active operations in the area include Southern California Edison, the San Diego Gas and Electric Company, and the Metropolitan Water District of Southern California (MWD).

In Northern California, the collective impact of utility operations on rivers and streams is even more far-reaching. The Sacramento Municipal Utility District (SMUD) constructed and operates several dams and associated power generation facilities on the American River system. The East Bay Municipal Utilities District (EBMUD) operates facilities on the Mokelumne River watershed and also has access to American River water above Sacramento. The City and County of San Francisco divert Tuolumne River water at Hetch Hetchy Reservoir near Yosemite. For sheer numbers of facilities, the Pacific Gas and Electric Company (PG&E) is the unquestioned leader. PG&E operates 19 power plants on the Feather and the Pit/McCloud river systems, for example.

Irrigation Districts

Local and regional irrigation districts (often called simply "water districts") construct, operate and maintain diversion and drainage works to support agricultural use of water. Typically, such districts buy water from a wholesaler such as the CVP or the SWP, but some districts also possess riparian rights to divert significant quantities of water. In either case, the diversions themselves are subject to the permitting requirements of the SWRCB. Since agriculture is the single largest user of water resources in California, the operating procedures and facilities utilized to supply that water can be expected to, and do, dramatically affect the quality of instream and riparian resources. Fisheries, in particular, are sensitive to agricultural diversion practices. The drainage of runoff water from agricultural use may also play a significant role in fisheries and wildlife management within river systems.

Sanitation Districts

Local and regional sanitation districts treat and dispose of industrial and domestic sewage, most often by discharge into local

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rivers and streams. Many districts are now capable of tertiary treatment, although many others are only capable of secondary treatment.

Flood Control Districts

Flood control districts are responsible for developing facilities for the conveyance, containment, storage and distribution of flood flows, so that domestic and agricultural lands are not unnecessarily flooded. Flood management facilities may consist of modified natural channels, lined channels, dams, catch basins, diversion and energy dissipation structures, bypass, detention and storage facilities, and similar engineered flood responses. Degradation of aquatic and riparian habitats typically results when natural channels are managed primarily for flood control. The presence of flood control structures often regulates water flows to the detriment of downstream channels.

Private Organizations

American River Coalition

The American River Coalition came together in 1989 as a group of 27 different recreation, business and environmental organizations all dedicated to preserving the American River. Coalition efforts center around attaining river protection designations such as federal Wild and Scenic and National Recreation Area status, as well as full-time efforts to prevent the Auburn Dam and help resolve flood control issues for the Sacramento area. The coalition is a Friends of the River-funded project.

California Salmon, Steelhead and Trout Restoration Federation (CSSTRF)

The CSSTRF holds an annual California salmon, steelhead and trout conference in different areas of the state with significant salmonid fisheries. The conferences typically focus on restoration problems of special concern in the area where the conference is held, such as gravel extraction and timber harvest for the North Coast. The federation also provides educational, referral and liaison services to the organizations, businesses and individuals actively engaged in restoring the state's salmonid populations. Beginning in the summer of 1993, the federation will be operating a fish restoration technical school in Quincy (Plumas County) that is open to the public.

California Trout, Inc. (CalTrout)

Since its formation in the 1960s, CalTrout has worked to preserve, protect and restore wild trout, native steelhead and their

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waters in California. CalTrout led the efforts in 1969 to block the proposed construction of Dos Rios Dam on the Middle Fork of the Eel River. CalTrout also played a major role in the passage of the California Wild and Scenic Rivers Act of 1972, and was instrumental in getting the North Coast Rivers (and the American River) enrolled on the federal Wild and Scenic list in the final hours of the Carter Administration.

CalTrout devotes the majority of its energies to the protection of rivers, streams and riparian habitats through administrative proceedings (SWRCB, FERC, etc.), litigation (*CalTrout v. SWRCB* [real party in interest, Los Angeles Dept. of Water and Power]), legislation, follow up with responsible agencies and hands-on restoration (for example, Yellow Creek in Plumas County).

Central Sierra Watershed Coalition

The coalition's purposes are to preserve the integrity of the watershed, advocate stewardship of the ecosystem and present alternate value analysis of sustainable low-impact recreation use. The coalition covers the geographic range from Merced to Mokelumne. Its goals are to assist local, state and federal agencies in developing alternative operations for the New Melones reservoir which would provide additional Stanislaus River flows for downstream and Delta fisheries, while restoring riparian vegetation and providing for white water recreation upstream. Coalition objectives include coordinating with Central Valley Project and state water political movements including water banking and "fair share" negotiations, restoring the main stem Stanislaus as a river of national significance and stopping the Clavey River Project.

Committee to Save the Mokelumne River

The committee has been a leading proponent of providing higher instream flows in the lower Mokelumne River downstream of existing water supply dams and diversions in order to restore the river's anadromous fisheries and mitigate pollution problems.

Desert Fishes Council

Organized in 1969, the Desert Fishes Council is an interdisciplinary group of more than 500 university research scientists and agency resource managers concerned with maintaining the biological integrity of desert aquatic ecosystems and their related floras and faunas. The council is involved with problems relating to the Colorado River and other desert streams.

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Ducks Unlimited, Inc.

Ducks Unlimited works to protect and enhance North American wetland ecosystems with special emphasis on those habitats of greatest value to waterfowl; it has projects affecting nearly 500,000 acres in all 50 states.

Friends of the Garcia (FrOG)

The Garcia is a relatively short river in Mendocino County which has been affected by past timber harvest, ranching and aggregate extraction practices. As a result, the local fishery has been severely degraded. FrOG is working with a local resource conservation district to promote voluntary rehabilitation programs to restore the stream to its former productivity, and to promote public access while protecting the rights of private property owners.

Friends of the Los Angeles River

Friends of the Los Angeles River is working to restore riparian habitat and establish parkways along portions of the Los Angles River.

Friends of the River

Organized in 1972 to save the Stanislaus River, Friends of the River expanded to become the largest statewide river conservation organization in the nation, with more than 10,000 members dedicated to the preservation and restoration of free-flowing rivers, streams and watersheds. Current conservation programs include encouraging Wild & Scenic designation of free-flowing rivers, stopping needless and destructive dam projects while developing environmentally benign flood control, water supply and energy alternatives, and providing individual activists and watershed organizations the necessary training and skills to be effective river advocates.

Friends of the Santa Margarita River

Friends of the Santa Margarita River is working with a number of local, state and federal agencies to develop a cooperative management plan to preserve the outstanding scenic, wildlife and ecological values of the Santa Margarita River.

Keep the Sespe Wild Committee

Keep the Sespe Wild was formed to preserve, rehabilitate and protect one of the last relatively undeveloped watersheds in southern California. The Sespe has supported an anadromous fish population,

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and a major goal of Keep the Sespe Wild is the rehabilitation and preservation of that resource.

Klamath Forest Alliance

The alliance works to protect streamside riparian areas and to restrict logging in Klamath River watersheds and tributaries deemed critical for anadromous fisheries. The alliance is also organizing cooperative federal efforts to maintain optimum flows in the river for several endangered fish species.

Mattole Restoration Council

The Mattole Restoration Council is a community-based non-profit organization working to retain and restore natural systems within the Mattole River watershed to historic levels of health and productivity, especially in regard to forests, fisheries, soils, and native plant and animal communities. The council is made up of individual landowners and residents, as well as over a dozen smaller organizations in the watershed formed for specific purposes, such as the restoration of a particular tributary, community education, land trusts and salmon restoration.

Mattole Watershed Alliance

The Mattole Watershed Alliance was formed to address Mattole River watershed concerns through communication, education and cooperation. The alliance includes representation from all user groups, including ranchers, timber companies, large and small landowners, fishers and environmental restoration groups. One of their first projects was the adoption of new, more protective, sport fishing regulations by the Fish and Game Commission.

The Nature Conservancy

The Nature Conservancy has established several preserves which are centered around or include riparian habitat within California. The conservancy is a private, nonprofit conservation organization whose resources are entirely devoted to the acquisition and management of ecologically significant land, including:

Cosumnes River Preserve

The Cosumnes Preserve is located in Sacramento County on the eastern edge of the Sacramento-San Joaquin Delta between Highway 99 and Interstate 5. The nearest town is Walnut Grove. The preserve is jointly owned by the conservancy, the Department of Fish and Game, the Bureau of Land Management and Ducks Unlimited.

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The conservancy, in partnership with Ducks Unlimited, Inc., has launched an ambitious management and restoration project in the preserve, one of the first of its kind between the two conservation organizations. The conservancy is restoring the riparian forests and Ducks Unlimited is restoring the wetlands.

Kern River Preserve

The Nature Conservancy started the Kern River Preserve in 1980 to protect plants, animals and natural communities which rely on this habitat for survival. The preserve is located along the South Fork Kern River, 60 miles northeast of Bakersfield along State Highway 178 near Weldon. There are 1,133 acres of riparian forest currently in the preserve. The preserve contains the largest continuous stand of riparian forest habitat in the state and 25 percent of the total Great Valley Cottonwood Riparian Forest found in California. Over 245 acres of the preserve are under restoration to reestablish a defined, native, historic ecosystem. The goal of this process is to replicate the structure, function, diversity and dynamism of that particular ecosystem.

The Sacramento River Project

The Sacramento River Project is perhaps the most geographically extensive undertaking by any conservation organization. The project encompasses 100 miles of river between Red Bluff and Colusa, and seeks to protect 50,000 acres of riparian forest and associated wetlands through the acquisition of fee-title and conservation easements. The Sacramento River National Wildlife Refuge, managed by the U.S. Fish & Wildlife Service, will be the main result of the project. The USFWS, the Wildlife Conservation Board (DFG) and the State Reclamation Board are acquiring riparian lands. The Nature Conservancy manages the forest on about 14,000 acres in scattered blocks of habitat. An equal acreage of flood-prone agricultural lands will be restored to riparian forest, with the goal of expanding existing forested blocks and connecting them with habitat corridors. Agricultural lease revenues will fund the habitat restoration. Restoration technologies are currently being developed in concert with local farmers and private land owners.

Putah Creek Council

The council is working with the U.S. Fish and Wildlife Service and the University of California, Davis to develop a management plan and to restore riparian vegetation along Putah Creek. In addition, the council is working to increase stream flows from Monticello Dam.

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Sacramento River Preservation Trust

Organized to stop destructive bank protection projects along the Sacramento River, the trust has been instrumental in focusing the efforts of state and federal agencies on the acquisition of riparian habitat along the river. The trust also supports the recovery of the river's many endangered species, including the winter-run chinook salmon.

San Joaquin River Committee

The San Joaquin River Committee is working to establish the San Joaquin River Parkway along the river, oppose unwise development in the flood plain and restore riparian habitat along the river.

San Joaquin River Parkway and Conservation Trust (SJRPCT)

The SJRPCT is a nonprofit public benefit corporation, organized for charitable and educational purposes. The trust's mission is to preserve and restore San Joaquin River lands of ecological, scenic or historic significance, to educate the public on the need for stewardship, to research issues affecting the river, and to promote educational and recreational uses of the river bottom consistent with protection of its environment.

Save the American River Association (SARA)

Save the American River Association is a citizen-volunteer group which advocates protection of the natural resources and recreational opportunities of the American River. Organized initially to combat development of subdivisions along the American River Parkway, in recent years SARA has been involved in issues dealing with American River water supply allocation, including instream uses and flood control.

Sierra Club

The Sierra Club has been very active, primarily through the grass-roots efforts of its local chapters, in monitoring issues which affect rivers and streams. The club actively promotes conservation activities, and takes a particular interest in the environmental effects of activities such as gravel extraction on natural systems. The Sierra Club is by far the largest environmental organization in the state. It was founded in 1892 by John Muir.

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South Yuba River Citizens League (SYRCL)

SYRCL was originally formed in 1983 to oppose proposed hydroelectric projects on the South Yuba River. Since that time, while continuing its fight against hydro proposals, the organization has expanded its activities to include leasing land to hold for future park acquisition, monitoring the activities of the Yuba County Water Agency and promoting Wild and Scenic River designation for the river.

Tuolumne River Preservation Trust

The trust was formed in 1981 to protect the Tuolumne River from a proposed dam at Wards Ferry on the Clavey River. Through bi-partisan efforts the river was designated Wild and Scenic by Congress, thus averting the development of the dam. Currently, the organization is interested in watershed resource management practices for the river and its tributaries. Efforts are focused on maintaining the Clavey River in its free-flowing state in the face of proposed development of a hydroelectric dam. The organization uses education, legal and political means to achieve its goals.

United Anglers of California

United Anglers of California is the state's largest fishery conservation organization working to restore and protect California's fisheries and their habitat. The organization's membership includes anglers, sport fishers and affiliated fishing groups. It works with agencies and elected bodies to attain sound fishery management and to obtain funding to support such management. A tax deductible subsidiary foundation, the Fishery Foundation of California, seeks funding for and conducts projects to enhance fishery production and restore fishery habitat. Projects range from the restoration of several watersheds in the Eel River drainage to the creation of habitat for warm water fisheries in reservoirs. The foundation is pen rearing wild striped bass in the Delta and growing artificially produced white sea bass in pens along the Southern California Coast.

Urban Creeks Council

The council is a California nonprofit group formed to encourage the protection, preservation, and restoration of urban creeks. The council advocates land use planning to preserve creeks and decrease potential flood damage from creeks; promotes alternative flood control designs and alternative streambank stabilization techniques; provides assistance to grassroots neighborhood and community groups; conducts special projects; holds meetings, workshops and

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conferences to promote the aesthetic, ecological and recreational value of urban creeks; and develops educational materials.

Regional Initiatives

The past decade has brought an increasing awareness at all levels of government and in the public of the signal importance of riparian systems to the overall health and welfare of the environment. Many significant regional initiatives have arisen, sometimes through the actions of government, but quite often at the instigation of private interest groups concerned with the continued well-being of areas which they have historically used for recreational and aesthetic refuge. These efforts are widely varied in goals, available resources, and ultimate potential for success.

Blue Bird Mine Riparian Rehabilitation and Enhancement Project

This $32,300 initiative of the Shasta-Trinity National Forest will result in the restoration and enhancement of a closed mine which was not fully reclaimed. Activities will include an ecological inventory of the proposed project area, soil and ground cover enhancement measures, and enhancement of various anadromous fish and wildlife habitat characteristics of the area. Work will be accomplished through existing cooperative agreements between BLM, USFS and the multi-agency Trinity River Restoration Program. Portions of the work will be completed by local interest groups such as the Garden Club, Trinity County Mining Alliance, California Native Plant Society, Burnt Ranch 4-H Club and elementary school students.

Klamath River Fishery Restoration Program

This program is guided by the Klamath Fishery Task Force, which in 1991 consisted of representatives of the California commercial salmon fishing industry, the in river sport fishing community, the California Department of Fish and Game, the Hoopa Valley Tribe, the Department of the Interior, the National Marine Fisheries Service, the Department of Agriculture, the Oregon Department of Fish & Wildlife, Del Norte, Siskiyou, Humboldt and Trinity counties, the Karuk Tribe and the Yurok Tribe. Projects are primarily funded through the Klamath Basin Fisheries Resources Restoration Act (P.L. 99-552), with matching nonfederal contributions. The principal objective is the restoration of the once-great fishery resources of the basin through habitat protection, management and restoration, fish population protection and restoration, education and communication, and program administration.

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Napa River Coordinated Resource Management and Planning Process (CRMP)

The Napa River CRMP is a joint effort of the San Francisco Bay Region (Region 11) Water Quality Control Board and the Napa County Resource Conservation District (NCRCD). The plan will recommend a series of cooperative land management strategies to maintain a healthy, sustainable watershed. Preliminary planning work is being funded by a grant from the State Water Resources Control Board.

Sacramento River Greenway

The Greenway Plan was initiated in 1990 by the State Lands Commission through a Memorandum of Understanding. A Cooperative Management Agreement (CMA) with the counties of Sacramento and Yolo and the City of Sacramento and the City of West Sacramento has been adopted (1993). A Greenway is proposed for a 31-mile corridor along both sides of the Sacramento River from the Sacramento/ Sutter county line south through the cities of Sacramento and West Sacramento to Freeport. The goals of the plan are to accommodate public access and enhance riparian vegetation.

Salinas River Basin Water Resource Management Plan

The Salinas River Basin Water Resource Management Plan study is composed of a series of related elements designed to improve and protect water supplies for public and agricultural use in Monterey County. It includes development of a Basin Management Plan, which in turn includes development of a complete database and comprehensive plans for watershed, river channel, reservoir and groundwater management including saltwater intrusion issues. The program utilizes the expertise of both public and private sources, and is designed to foster public participation in the decision-making process.

Salinas River Coordinated Resource Management and Planning Process (CRMP)

In San Luis Obispo County local citizens, aided by staff from the county government and the Rivers and Trails Conservation Assistance Program of the National Park Service, have initiated a planning and problem-solving program for the upper Salinas River. Issues being addressed include trespass, access, water supply and water quality.

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San Joaquin River Management Program Advisory Council (SJRAC)

The council is charged by the legislature (AB3603, Costa, Water Code §12260) to develop the San Joaquin River Management Program, as prescribed, to identify actions which can be taken to benefit legitimate uses of the San Joaquin River system. The program objectives are to develop compatible solutions to water supply, water quality, flood protection, fisheries, wildlife habitat and recreation needs. The study area covers the river from Friant Dam downstream through the Sough Delta Water Agency. DWR acts as staff to the council whose members represent federal, state and local agencies and nongovernmental organizations.

Trinity River Basin Fish and Wildlife Restoration Program

This project of the U.S. Fish and Wildlife Service will, when fully implemented, result in the construction of anadromous fish habitat improvement measures in a 40-mile section of the Trinity River. Already completed pilot projects in this ten-year program (1986-1996)—including gravel placement, pool dredging, and the construction of side-channels and bank feathering site—have provided information sufficient to prepare an overall plan for the approximately 40 miles of river from Lewiston Dam to the North Fork of the Trinity River. The overall project is funded for $57 million.

Important Statutes

Federal

Watershed Protection and Flood Protection Act, 16 USCA § 1001, et seq.
Rivers and Harbors Act of 1899, 33 USCA § 401, et seq.
Clean Water Act, 33 USCA § 1251, et seq.
Bridges Over Navigable Waters, 33 USCA § 491, et seq.
River and Harbor Improvements Act, 33 USCA § 540, et seq.
Flood Control Act, 33 USCA § 701, et seq.
Wild and Scenic Rivers Act, 16 USCA § 1271, et seq.
Water Resources Development Act 33 USCA § 2201, et seq.
Endangered Species Act, 16 USCA § 1531, et seq.
Fishery Conservation Act, 16 USCA § 1801, et seq.
Soil and Water Resources Conservation Act, 16 USCA § 2001, et seq.
Small Hydroelectric Powerplant Projects Act, 16 USCA § 2701, et seq.
Fish and Wildlife Conservation Act, 16 USCA § 2901, et seq.
Toxic Substances Control Act, 15 USCA § 2601, et seq.
National Environmental Policy Act of 1969, 42 USCA § 4321, et seq.
Central Valley Project Improvement Act, 102 P.L. 575, 106 Stat. 4600

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State

Porter-Cologne Water Quality Act, Water Code § 13000, et seq.
Hazardous Waste Control Law, Health and Safety Code § 25100, et seq.
Safe Drinking Water and Toxic Enforcement Act, Health and Safety Code § 25249.5, et seq.
California Environmental Quality Act, Public Resources Code § 21000, et seq.
California Endangered Species Act of 1973, Fish & Game Code § 2050, et seq.
Native Species Conservation and Enhancement Act of 1974, Fish & Game Code § 1750, et seq.
Wetlands Preservation Act of 1976, Pub. Res. Code § 5810, et seq.
Fish & Wildlife Habitat Enhancement Act of 1984, Fish & Game Code § 2600, et seq.
Davis-Dolwig Act of 1961, Water Code § 11900, et seq.
Land Conservation (Williamson) Act of 1965, Gov. Code § 51200, et seq.
Underground Storage Tank Act, Health & Safety Code § 25280, et seq.
Petroleum Underground Storage Tank Cleanup Act, Health & Safety Code § 25299.1, et seq.
Toxic Pits Cleanup Act, Health & Safety Code § 25208, et seq.
Hazardous Materials Release Response Plans & Inventory Act, Health & Safety Code § 25500, et seq.
Levee Maintenance Fund Act of 1973, Water Code § 12980, et seq.
Subdivision Map Act of 1975, Gov. Code § 66410
Coastal Act of 1976, Pub. Res. Code § 30000, et seq.
Salmon and Steelhead Spawning Areas, Pub. Res. Code § 6378
Surface Mining and Reclamation Act (SMARA), Pub. Res. Code § 2710, et seq.
McAteer-Petris Act, Gov. Code § 66600, et seq.
Fish and Game Code Provisions
- Fish and Wildlife Protection and Conservation, § 1600,et seq.
- Native Plant Protection, § 1900, et seq.
- Natural Communities Conservation Planning, §2080
- Water Pollution, § 5650, et seq.
- Water releases for downstream fisheries, § 5937

Important Cases

Federal

Woodruff v. North Bloomfield Mining Co., 18 F. 753 (1884)
Illinois Central Ry. v. Illinois, 146 U.S. 387 (1892)
United States v. Utah, 283 U.S. 64 (1931)
State of Alaska v. Ahtna, Inc., 891 F.2d 1401 (9th Cir. 1989)

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State

People v. Gold Run Ditch and Mining Co., 66 Cal. 138 (1884)
Wright v. Seymour, 69 Cal. 122 (1886)
People v. Truckee Lumber, 116 Cal. 397 (1897)
People v. Russ, 132 Cal. 102 (1901)
Forestier v. Johnson, 164 Cal. 24 (1912)
People v. California Fish, 166 Cal. 576 (1913)
Bohn v. Albertson, 107 Cal.App.2d 738 (1951)
Marks v. Whitney, 6 Cal.3d 251 (1970)
People ex rel. Baker v. Mack, 19 Cal.App.3d 1040 (1971)
Hitchings v. Del Rio Woods, 55 Cal.App.3d 560 (1976)
People v.Sweetser, 72 Cal.App.3d 278 (1977)
People ex rel. Younger v. El Dorado Co., 96 Cal.App.3d 403 (1979)
State v. Superior Court (Lyon), 29 Cal.3d 210 (1981)
State v. Superior Court (Fogerty), 29 Cal.3d 240 (1981)
National Audubon Society v. Superior Court, 33 Cal.3d 419 (1983)
Kern River Public Access v. Bakersfield, 170 Cal.App.3d 1205 (1985)
CalTrout v. State Water Resources Control Board, 207 Cal.App.3d 585 (1989)
CalTrout v. Superior Court, 218 Cal.App.3d 187 (1990)
Bess v. County of Humboldt, 3 Cal.App.4th 1544 (1992)

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Glossary

Abiotic - non-living components of an environment.

Active channel - as used in ecology, the active channel is the physical environment of the permanently submerged bed, together with the frequently disturbed adjacent substrates. In ephemeral or intermittent streams, it is the zone of the most disturbed substrates. The active channel is usually characterized by having little or no permanent vegetation.

Aggrade - to build up a river bed and flood plain with deposited sediment.

Alevins - hatchling salmon larvae with the egg sack still attached.

Algal blooms - sudden growth of algae in an aquatic ecosystem; naturally due to photosynthetic production exceeding consumption by aquatic herbivores, or induced by nutrient enrichment of water due to pollution; a symptom of eutrophication.

Alienate - to convey or transfer property rights by a specific act rather than by the due course of law.

Allochthonous - derived from outside a system, such as leaves of terrestrial plants that fall into a stream (opposite of autochthonous).

Alluvial fan - a mass of sediment deposited at a sharp decrease in gradient, such as between a mountain range and a plain; the land-bound equivalent of a river delta formation.

Alluvial water table - the level of saturated soil in unconsolidated alluvium in riparian zones.

Alluvial deposits - sand, silt and clay deposited by moving water as it slows down.

Anadromous - (of fish) moving from the sea to fresh water for reproduction.

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Anaerobic - (of organisms) occurring, living or growing in the absence of free oxygen (O_2).

Appropriative water rights - legal rights to the use of water resources developed by "beneficial" use. The first appropriator in time may perfect a right as against all subsequent appropriators. California utilizes a complex mixture of appropriative water rights and riparian water rights.

Aquatic biota - organisms spending the major portion of their life cycles submerged in the water.

Armor layer - layer of lag, or course particles such as gravel or cobble, on a stream bed, which is highly resistant to erosion (see lag); also, artificial bank protection such as rock riprap.

Assimilative capacity - a measure of a water body's ability to meet standards or provide beneficial uses under increasing loads of individual pollutants.

Autochthonous - created or derived within a system such as organic matter in a stream resulting from photosynthesis by aquatic plants (opposite of allochthonous).

Autotrophic - deriving most of its organic matter energy sources from primary photosynthetic production within a system.

Avifauna - birds.

Bankfull flow - the flow or discharge as used in hydrology and geomorphology, at which the water level begins to exceed the height of the most pronounced banks.

Base flow - sustained summer low river or stream flow, free of overland flows and storm runoff, and derived from natural groundwater sources.

Bedload - larger, heavier particles of sediment, such as sand and gravel, sometimes up to boulder size, that move along the bed by rolling, sliding, and bouncing.

Benthic algae - submerged algae growing on the bottom and other surfaces.

Best Management Practices - techniques in various land use activities to mitigate or prevent harm to or inhibition of natural attributes or processes (e.g., forestry).

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Bight (e.g., Southern California b.) - a wide bay formed by a long bend or curve in the shoreline.

Biological diversity ("biodiversity") - variation in living things in a particular area or region, at the level of genes, species, communities, ecosystems or landscapes.

Biological Oxygen Demand (BOD) - the amount of molecular oxygen taken up by microbial decomposition of organic matter.

Biomass - total weight of living matter in a region, habitat or other defined area or volume.

Biotic - pertaining to living organisms.

Bosques - woodlands (Spanish); applied to southwestern mesquite or cottonwood-mesquite woodlands.

Buffer strip - a strip of undisturbed land and vegetation on each side of a stream left to protect it from the effects of adjacent land use or development (e.g., logging).

Channelization - the straightening and smoothing of river channels, primarily for flood control, often accompanied by paving or bank armoring .

Clear-cutting - removal of the entire standing crop of trees from an area.

Climax or Gallery forests - (as used in this report) the later stages in riparian plant succession, dominated by towering trees.

Climaxes - areas where the Native Americans were particularly culturally innovative and were promulgating customs throughout the region (primarily in California).

Cold pool - the colder water at the deepest part of a reservoir.

Community - the assemblage of organisms living in a particular environment or geographic location.

Confined reaches - stream or river segments which have relatively constrained, well-defined channels, with narrow flood plains; often mountainous and steep-gradient.

Cultural eutrophication - nutrient enrichment, rampant algal growth and subsequent oxygen depletion in a body of water caused or accelerated by human activities.

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Cumulative watershed effects (CWE's) - erosion of gullies, delivery of fine sediment to stream channels, increased flood peaks and decreased summer base flows.

Debris plain - a jumble of rocks, gravel, soil, plant fragments and other organic matter deposited by fast moving or sudden flood waters, avalanche or landslide, e.g. from hydraulic mining.

Degradation - a lowering of the elevation of streambeds and flood plains by erosional removal of alluvium; may be caused when upstream sources of sediment are blocked as by dams or by excavation of sand or gravels. See incision, scour, aggrade.

Denudation rate - the rate at which the landscape is lowered by erosion.

Detrital - characterized by organisms feeding on and decomposing organic litter.

Dissolved load - the part of the total sediment load carried by a river that is carried in solution.

Diurnally - daily, as in the characteristic rise and fall of temperature or light over a 24-hour period.

Discharge - volume of water flowing past a reference point per unit of time (eg. cubic feet per second, cfs).

Drainage basin - land area drained by a given river or stream; watershed (also catchment).

Drainage network - the system of converging waterways which combine into larger and larger streams, eventually forming rivers.

Drainage divides - topographic high points between adjacent watersheds.

Dredge - a machine that scoops up mud, sand or gravel, usually from beneath a water surface.

Dredging - excavating unconsolidated alluvial deposits from beneath standing water or from saturated soils adjacent to watercourses.

Drift - benthic insects which have become detached, together with terrestrial insects which fall into the water, and detached algae which float downstream in currents, forming an important source of food for aquatic organisms.

Duff layer - the matted, partially decomposed organic surface layer of forest soils.

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Dynamic equilibrium - a condition in which the amounts of sediment entering and transported through a river system maintain what appears to be a stable channel and flood plain form.

Ecosystems - systems incorporating physical, chemical and biological organisms and processes, and the close interactions between and among them.

Ecotones - narrow and fairly sharply defined transition zones between two or more different vegetation types or environments.

Effluent - water or solution which drains out, e.g. complex fluid waste material such as sewage or industrial refuse that is released into the environment.

Emigration - migration away from a place; e.g. juvenile salmon migrating out to sea from fresh water.

Eminent domain - a right of a government, as a representative of the people and in case of necessity, to take and control private property for public use; subject to the requirements of the constitution.

Endemics - species or other taxonomic group native and restricted to a region.

Enjoin - to require a person or entity, by injunction, to perform or to abstain or desist from some act or acts.

Ephemeral - rivers or streams that flow only a short time (days or weeks) in direct response to rain storms.

Equilibrium profile - the grade or slope of the reach of a river where a balance of erosion and deposition over many years is maintained. A dynamic, not a static balance is the usual case; see incision, degradation, dynamic equilibrium.

Escapement - the incoming river run portion of a salmonid population which has escaped ocean harvest or other mortality.

Estuaries - usually tidal, semi-enclosed coastal bodies of water connected to the sea, where fresh water derived from streams draining the land is mixed with seawater.

Fee interest - part of the "bundle of rights" which constitute real property ownership; the most fundamental interest in property available under American law; generally the right to possess and control property, subject to easements and licenses, and subject to the police and eminent domain powers of government.

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Fingerlings - young fish one to three inches long.

Fish ladders - an ascending series of pools so arranged as to permit fish to leap or swim upward from level to level and thus bypass dams and waterfalls.

Fish screens - Screens installed in a waterway or intake pipe to prevent passage of fish.

Flashy - a characteristic of watersheds having high runoff rates, due to relative imperviousness; produces storm discharges with pronounced peaks over a short time interval.

Flood plain - the entire landscape subject to river geomorphic and hydrologic processes; in particular the frequently flooded, more terrestrial zone of unconsolidated river-borne sediment above and equal to the bankfull channel or the flat valley adjacent to the bankfull channel.

Fluvial - pertaining to, or produced by, stream action.

Fry - young fish about an inch long, just emerged from their gravel beds, their egg sacks having been absorbed.

Fyke traps - a fish net in the form of a long bag reinforced with hoops.

Gene pool - the collection of genes, or the amount of genetic information, in all the reproductive members of an interbreeding population.

Geomorphology - the landscape and land-forming processes.

Gill nets - a net set upright in the water to catch fish by entangling their gills in its meshes.

Gravel bar skimming - method of aggregate mining in stream and river channels which scrapes materials off large areas in layers.

Groundwater overdraft - removal of groundwater by pumps and wells more rapidly over time than it is naturally replenished; groundwater "mining".

Habitat - the particular living place which provides an environment suitable for survival of an organism, a species or a community.

Hearths - areas where the Native Americans were particularly culturally innovative and were promulgating customs throughout the region; equivalent to climaxes.

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Heterotrophic - dependent upon complex organic material input as its main or sole source of carbon, as opposed to depending upon CO_2 from the air captured in photosynthesis.

Humic acids - mixture of dark brown soil organic substances dissolved in water.

Hungry water - clear water released from an impoundment into the river channel possessing "excess" energy which is expended on erosion, incision and increased movement of bedload.

Hydraulic mining - form of mining that directs a jet of highly pressurized water onto an exposed placer deposit and runs the sediment through sluices to remove the gold or other heavy metals.

Hydrographs - graphic representation of river flows over time, produced from instrument data at water gauging stations.

Hydrologic basins - large geographic areas drained by one or more similar river systems defined for management and study; may contain more than one watershed.

Hydrological habitat modification - modification of an aquatic or riparian habitat by water insufficiency, excess or energy.

Hydrology - the flow, occurrence and circulation of water in the environment.

Ichthyological provinces - geographical region defined by fish species distribution.

Incision - extensive degradation or down-cutting of a stream or river bed.

Indicator - a plant or animal species sensitive to one or more environmental factors, the presence of which indicates a particular environmental condition.

Intermittent - streams or rivers which flow only part of a year.

Ionize - the production of positively or negatively charged substances (ions) as by dissolving.

Lag - deposit of gravel or cobbles remaining in place after finer particles have been eroded away (see armor layer).

Leachate - substances in suspension or solution removed from rock, soil or organic matter by water.

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Lianas - wiry or woody free-hanging, climbing plants.

Low flow channel - the river channel containing the lowest or the residual flow, reached in any given year; also called the wetted channel.

Macrophytes - large plants.

Mass wasting - soil mass movement or landslide.

Meander loops - sinuous, regular river channel formed in lower, flatter reaches of a river by erosion on one side and deposition on the other.

Mesic - an environment that is neither extremely wet (hydric) nor extremely dry (xeric).

Metabolic - pertaining to internal physical and chemical processes of living organisms which produce, maintain, and break down substances, and the release of energy from food for these life processes.

Midden - a deposit marking a former aboriginal habitation site and containing materials such as discarded artifacts, bone and shell, food refuse, human remains, structural remnants, etc.

Motile - exhibiting, or capable of movement.

Natural levees - zones of non-man-made higher ground resulting from sediment deposition adjacent to the river channel.

Niche - a species' role or position in the variety of interactions and processes within an ecosystem.

Nonpoint Source (NPS) pollution - pollution from sources not defined as discrete points: e.g. runoff from farmland, logged areas, or urban areas.

Ocean Trollers - commercial salmon fishing in the ocean.

Out-migration flows - releases of water to assist young anadromous fish in migrating downstream from their spawning beds.

Oxbow - section of a former meander loop that no longer carries the main river flow, cut off by a lateral channel shift.

Passerine species - largest order of birds, which includes smaller perching song birds such as flycatchers, warblers, and swallows.

PCBs - polychlorinated biphenyls; a family of industrial compounds noted primarily as environmental pollutants that accumulate in animal

tissue, with resultant pathogenic (disease-causing) or teratogenic (embryo or fetus malformation-causing) effects.

Penstocks - steep gradient pipes or channels for gravity acceleration of water for driving electric generators in hydroelectric plants.

Periphyton - benthic algae and organisms which feed upon it.

Phreatophytes - plants needing to have their roots at or near the water table.

Phylogenetic - evolutionary.

Phytoplankton - microscopic plants which are free-floating in the water; important primary producers in many aquatic systems.

Pit mining - excavation of large pits for extraction of aggregates or ore.

Point source pollution - pollution emanating from a defined point, such as a pipe, ditch, tunnel, well or floating craft.

Point bars - sediment bars deposited by water slowing along the concave (inside) bank of a meandering stream.

Pollutants - substances that enter the environment or become concentrated within it, and that have or may have a detrimental biological effect, whether by natural causes or resulting from human activity.

Primary Productivity - production of organic matter from inorganic substances by plant photosynthesis (or less commonly by chemosynthesis).

Public domain - all unsold federal lands within the state which are not withdrawn or reserved for some other federal purpose.

Public trustee - a public agency to whom property is legally committed, to be administered for the benefit of the public (or: one occupying a position of trust and performing functions comparable to those of a trustee).

Races - in salmonids, distinct runs within a population which migrate at different times.

Reaches - sections of a stream or river between two specified points or possessing some common characteristic(s).

Reclamation - "reclaiming" land from a condition unsuitable for certain human uses by civil engineering works (levee building, draining wet areas, etc.).

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Recreational river - designated under the Wild and Scenic Rivers Act as accessible by road with some development allowed. This designation prohibits new dams and major diversions and certain other human uses.

Redds - fish spawning nest or group of nests dug in a gravel bed.

Replenishment rate - the rate at which a stream, in equilibrium condition, moves its bedload, particularly of gravel, downstream.

Revetment - a facing, as with cement or rock, to support an embankment and prevent its erosion; see riprap.

Rill - a small (few inches deep) watercourse.

Riparian - pertaining to the environment of river and stream banks and flood plains (sometimes term is used more broadly for wet, mostly terrestrial, environment around any fresh water body (including seeps or springs).

Riprap - rock revetment placed to armor banks, usually at a given slope, e.g. 2:1.

River terrace deposits - aggregate deposits in the flood plain.

Riverine zone - the zone of habitats in the active channel of a stream or river, essentially ending at the riparian zone; includes the permanently submerged bed and adjacent exposed sand and gravel bars.

Riverine - riparian ecosystems - ecosystems encompassing both instream and adjacent riparian zones, especially their biological components.

Salinity - the concentration of dissolved solids in ionic form in water.

Scenic river - designated under the Wild and Scenic Rivers Act as essentially wild, but occasionally accessible by road. This designation prohibits new dams and major diversions and certain other human uses.

Scour - localized erosion by flowing water.

Seawater intrusion - penetration of saline water into rivers, sloughs or groundwater aquifers normally containing fresh water flowing seaward, due to water diversion or low flows, or groundwater overdraft up-flow from the normal zone of salt-fresh water contact.

Sediment yield - the amount of sediment transported from a river basin which can be used to compute the average rate at which the basin landscape is lowered by erosion.

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Seine - a large fishing net with floats along the top edge and weights along the bottom.

Shaded Riverine Aquatic Cover (SRA) - the habitat formed at the interface of woody riparian vegetation and water.

Silviculture - management of forests, including harvest and regeneration.

Skid roads (skid trails) - access roads in a logging operation to permit removal of cut logs to a transfer area.

Smolts - juvenile salmonids one or more years old which have undergone physical changes to cope with a marine environment; the seaward migrant stage.

Sovereign lands - the lands and rights in lands held by the state as sovereign, in trust for the benefit of its people.

Spawning escapement - the portion of the total river run salmon population which has escaped river fishing and is available for reproduction.

Stocks - in salmonids, identification of subsets of a species or subspecies by taxonomic grouping, river or stream system, and migratory race. Pacific salmon species are considered to be made up of distinctive stocks.

Striped Bass Index - a measure of young bass present in the Bay-Delta estuary, used as an indicator.

Substrate - any object or material upon which an organism grows or is attached; the underlying layer or substance.

Succession (plant) - change in species composition of vegetation over time, due to environmental change and the intrinsic properties of the plants themselves.

Suction dredge - a floating dredge using a pump with a flexible hose four to ten inches in diameter guided by an operator in the water to suck up sediments from the streambed likely to contain gold.

Surfactant - a surface-active substance.

Suspended load - clays, silts, and sometimes sand that are held in suspension by turbulence in river water.

Swales - low, usually damp, areas of land.

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Tailings - portions of washed or milled ore regarded as too poor to be treated further; often left as tailings piles after mining.

Taxonomy - the classification of living organisms into different species and other levels of phylogenetic (evolutionary) groups (e.g., phylum, order, family, genus, species).

Tectonic - brought about by the formation or movement of the earth's crust.

Terrace - in common usage (especially California) the flood plain of a river or stream; in some technical usages, an abandoned flood plain now higher than the current flood plain.

Terrace mining - excavating alluvial deposits from alongside a river, in the river flood plain terrace, usually by pit mining.

Trace elements - essential chemical elements required in small or minute amounts for successful growth and development of an organism, usually the metals.

Transpiration - evaporation of water from plants, principally from leaves.

Trophic - relating to feeding relationships between living things.

Turbidity - relative opaqueness or cloudiness of water due to suspended or dissolved particles, blocking light penetration.

Unconfined reaches - low-gradient, meandering segments of rivers in broad valley floors with wide flood plain and riparian zones.

Underflow - the shallow groundwater under the river channel recharged by the river; subject to extraction as with non-riverine groundwater.

Water quality - the chemical, physical and biological properties of water as they affect the uses of it by man and nature.

Watershed - the land area drained by a given river; synonymous with drainage basin (also catchment).

Weir - a barrier built in a stream to divert fish or water, or to raise water lever; or a notch or depression in a dam through which the flow of water is measured or regulated.

Wild river - designated as undeveloped and accessible only by trail under Public Resources code section 5093.54– the Wild and Scenic Rivers Act. This designation prohibits new dams and major diversions.

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