The Riparian Forests of the Sacramento River Ecosystem

The Sacramento River Conservation Area extends along 222 miles of the main stem between Keswick Dam and Verona (Figure 2-1). The river changes character several times as it travels from the erosion-resistant volcanic tablelands in Shasta County to the broad alluvial basins of Colusa, Sutter, and Yolo Counties.

This chapter provides background on the riparian forest system, illustrating the importance of the physical processes of channel movement and flooding in creating and maintaining a diversity of habitat types. These habitat types include the successional stages of the riparian forest, gravel bars and bare cut banks, shady vegetated banks, and sheltered wetlands, such as sloughs, side channels, and oxbow lakes. This diversity is key to the wildlife habitat value of the Sacramento River system. By using the restoration priorities discussed in Chapter 1, the physical processes described in this chapter can be used to create and maintain the richness, diversity, and continuity of the river's riparian forest ecosystem.

There are four distinct reaches of the Sacramento River between Keswick Dam and Verona, each unique in terms of geomorphology, biology, and human impacts. In the Keswick-Red Bluff Reach, much of the river is confined in relatively stable geologic formations and the band of adjacent riparian vegetation is often quite narrow. In the Red Bluff-Chico Landing Reach, the river meanders over a broad alluvial floodplain. In both of these reaches a large system of tributary watersheds connects the river with the surrounding uplands.

In the Chico Landing-Colusa Reach, the topography changes so that only the Stony Creek tributary provides water to the river. Here, "distributaries" or sloughs once relieved the main channel of excess water during high flows, draining to broad basins which extend for miles on either side of the river channel. Today a series of setback levees and weirs has altered the system of sloughs by controlling the release of flood water into the basins through a system of weirs and bypasses. These setback levees allow the river to continue to meander between them, creating extensive tracts of riparian vegetation.

In the Colusa-Verona Reach, most floodwater leaves the main channel through the sloughs and weirs. The main channel itself is tightly leveed, with much of the riparian vegetation existing as linear strips along levees and levee berms.

Historical Extent of Riparian Forests

The historical riparian forests and associated valley oak woodland reflected many physical and biological processes. These included cycles of drought and flooding, fire, the erosion and deposition associated with flooding and channel movement, the impact of herds of large herbivores, and the cycle of riparian forest succession. Today, dams and levees have altered the flooding pattern, the impacts to the riparian forests from fire and large herbivores have changed, and human land uses have altered much of the floodplain. Nevertheless, along much of the Sacramento River the processes of flooding and channel movement continue to sustain a viable riparian ecosystem.

Historically, the Sacramento River was bordered by up to 500,000 acres of riparian forest, with valley oak woodland covering the higher river terraces (Katibah, 1981). The width of the riparian forest corridor was probably greatest in the Red Bluff-Chico and Chico-Colusa Reaches. Upstream, in the Redding-Red Bluff Reach, the riparian corridor was, as it is today, often confined to a narrow strip along the river's edge. Downstream, along the Colusa-Verona Reach, it is thought that riparian forests, including valley oak woodland, occurred along the natural levees on either side of the river. Beyond the forests lay vast seasonal marshlands in the basin areas. Much of this area became dry alkaline sinks in the summer. In all reaches, the main corridor of riparian habitat was connected to habitat corridors along the river's many tributaries and sloughs.

Rapid development of the Sacramento Valley began in the second half of the nineteenth century. By 1868 some noticed a scarcity of woody vegetation. Use of trees for lumber and fuel, particularly cordwood for steamboats, reduced the extent of the riparian forests in the Sacramento Valley. Since then urbanization and agricultural conversion have been the primary factors eliminating riparian habitat. Water development projects, including channelization, dam and levee construction, bank protection, and streamflow regulation have altered the riparian system and contributed to vegetation loss (Katibah, 1981). After the construction of Shasta Dam, for example, a decrease in flooding risk contributed to further decline in riparian forests as more lands were converted to orchards (DWR, 1983). There has been some increase in riparian habitat since 1982 (DWR, 1987) (Appendix D). Data compiled in this Handbook indicates that approximately 23,000 acres of riparian habitat and valley oak woodland remain within the Sacramento River corridor, about eleven percent of the original amount.

THE PHYSICAL ENVIRONMENT

Channel movement, geology, and hydrology are physical factors largely responsible for the development and maintenance of riparian forests along the Sacramento River. In many places along the river it is the preservation and restoration of these physical processes that is key to the successful restoration of its forests. This section describes some of the interconnections between these factors and the biology and ecology of the riparian forests along the Sacramento River.

Channel Movement and River Meander

The meandering portions of the river include the Red Bluff-Chico Landing and Chico Landing-Colusa Reaches, and portions of the Keswick-Red Bluff Reach. In meandering river systems, point bars form on the inside (convex side) of channel bends, on alternating sides of the river. Erosion is generally associated with the outside (concave side) of the bends (Figure 2-2). The combination of erosion of outside bends and deposition on point-bars results in channel migration.

Over time, this process of erosion and deposition creates an alluvial floodplain. Channel movement is often incremental and the river bends gradually move downstream. The channel will often move back and forth along a meandering river, reworking much of the same area. This area is referred to as a meanderbelt. In areas where the river is actively meandering, it is the translocation, or north-south movement, of these river loops that define the minimum width necessary to maintain the continuum of riparian plant communities created by the river over time. When a meander bend becomes tight, a chute cutoff sometimes occurs, temporarily straightening the channel and creating an oxbow lake (Figure 2-3).

The *sinuosity* of a river channel refers to the tightness of its meander loops. A straight reach has a low sinuosity, while a very curved reach has a high sinuosity.

Bank protection is often installed along the outside of river bends to protect existing land uses, including agriculture, as well as buildings, pumping plants, bridges, and levees. These "hard points" may change the rate and pattern of channel movement both upstream and downstream. When the channel migration process is frozen in place at one bend by bank protection, the bend downstream or across the river may erode more rapidly than it would have otherwise. Bank protection has been most successful where it is placed along geologic control or in long straight reaches parallel to the flow direction.

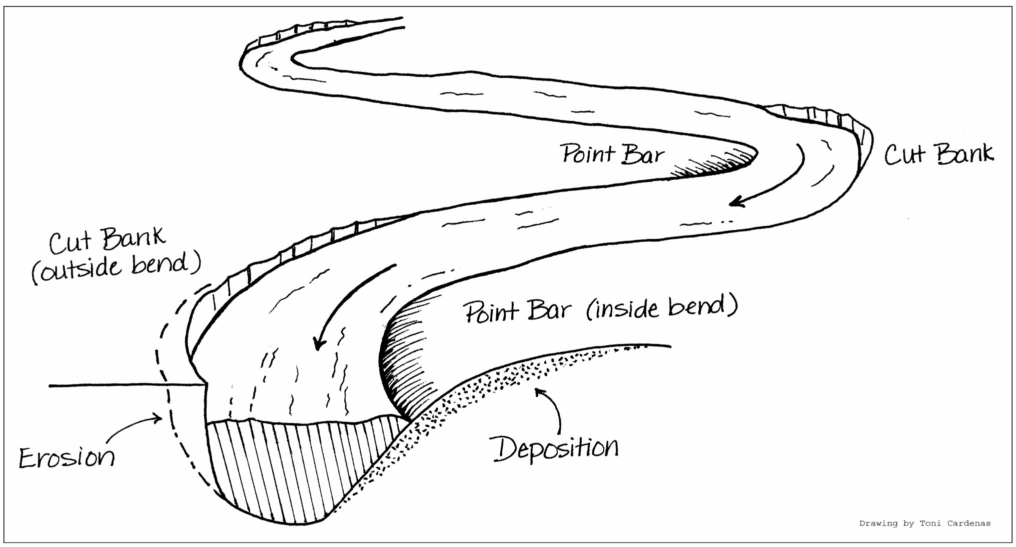

Figure 2-2. Typical bend on a meandering river.

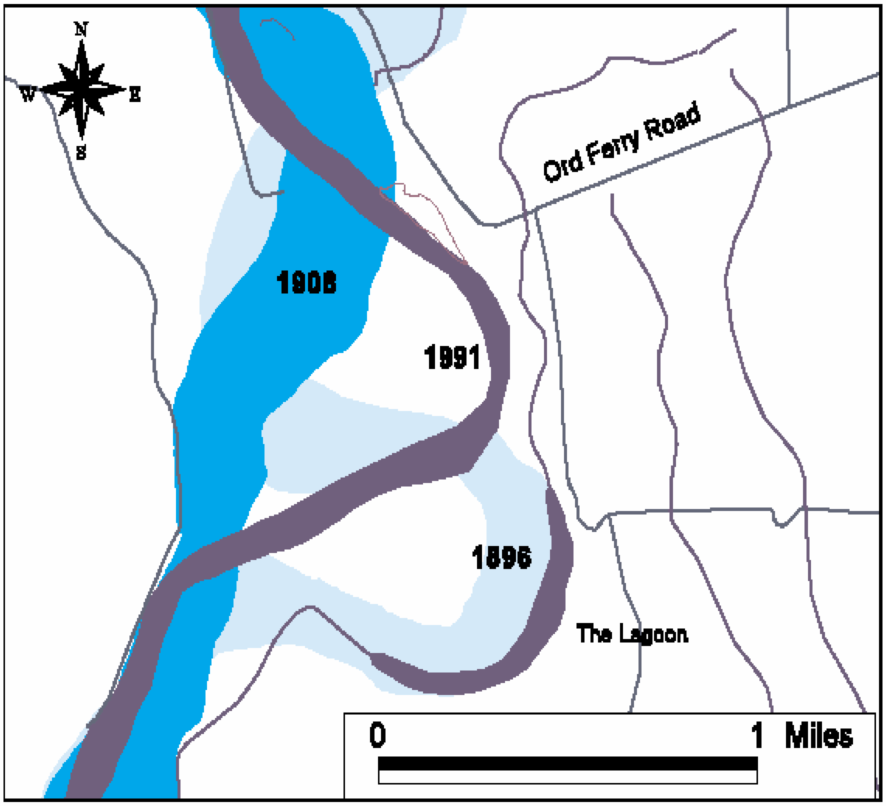

Figure 2-3. Sacramento River channel at River Mile 183, south of Ord Ferry Bridge, in 1896, 1908, and 1991. Chute cutoff prior to 1908 resulted in formation of "The Lagoon", an oxbow lake. Notice development of a new meander bend in the 1991 alignment. NOTE: map indicates channel alignment only. Channel width representation not accurate.

Geology

The geology of the Sacramento River varies considerably among the four reaches. In many areas In the Keswick-Red Bluff Reach, resistant formations confine channel movement, resulting in a very narrow riparian corridor. Between Red Bluff and Chico the meander process is occurring in the alluvium along the river and is constrained by older, more consolidated and erosion-resistant geologic formations. These resistant units, the Modesto, Riverbank, Red Bluff and Tehama Formations, are actually older fluvial fans or floodplains, discussed further in Chapter 6. In the Chico Landing-Colusa and Colusa-Verona Reaches basins flank the river, separated from the main channel by natural levees. The very different cross-sections of the four reaches reflect the differences in geology (Figure 2-4).

Sediment Transport

A river works as a conveyor of sediment, transporting materials eroded from the upper reaches and depositing them in the lower ones. The process of erosion, transportation, and deposition of sediment is closely linked with the patter of riparian forests on both the historical and present-day landscape.

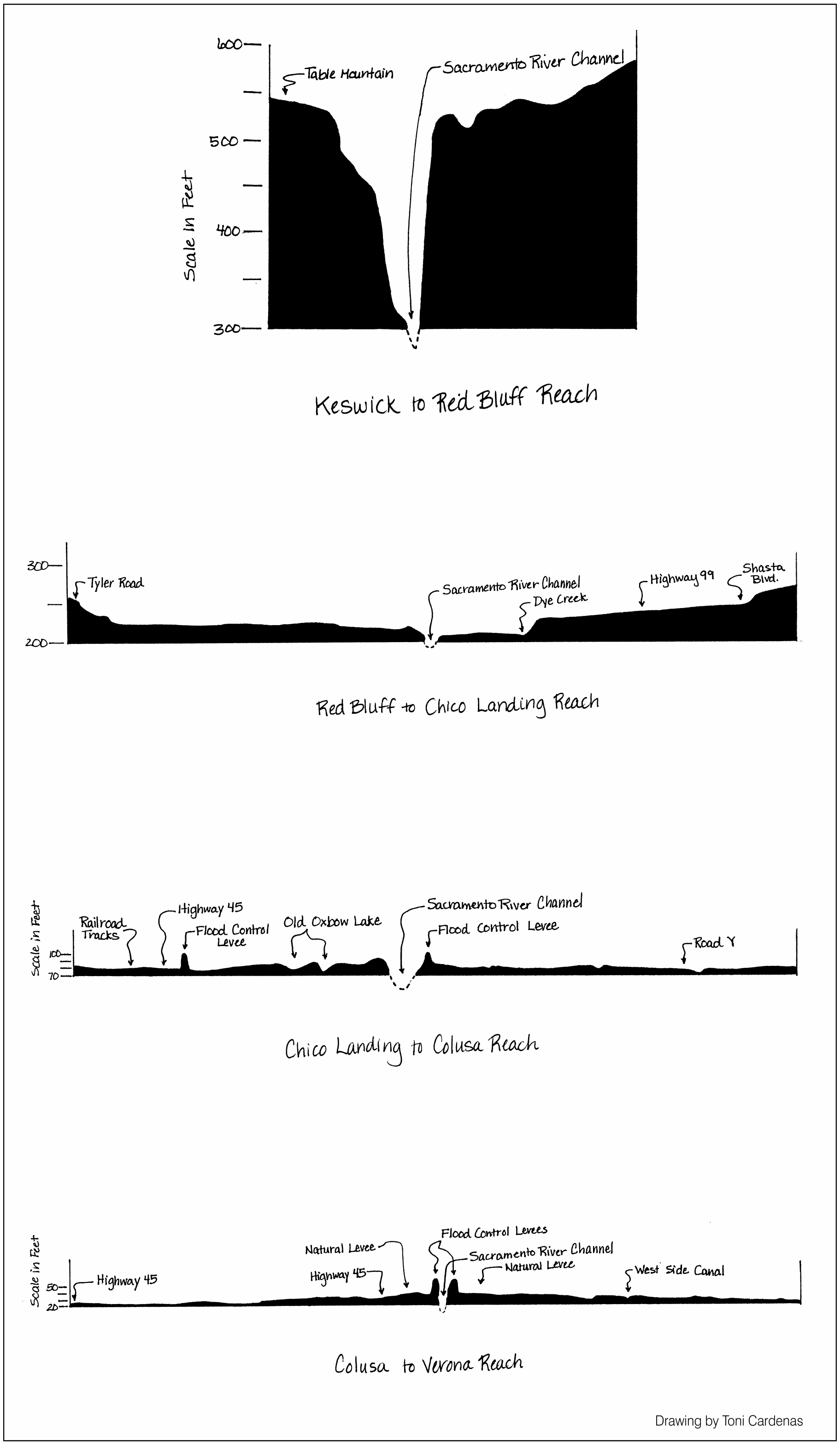

Figure 2-4. Typical cross-sections of the four reaches

River channel *stability* refers to the balance between the amount of sediment available and the amount that the river is capable of transporting. When there is more sediment available than the river can carry, the river bed will *aggrade (*bed elevation increases as sediment is deposited*).* If there is less sediment available than the river is capable of carrying, the river is "starved" and the bed tends to *degrade.*

It is often perceived that because of bank erosion, high-terrace lands are being replaced by low-terrace point bars because Shasta Dam reduces deposition of soils on the flood-plain. Observations made by DWR indicate that this may not be the case.

First, floodplain deposition can still rebuild high-terrace soils at a fairly rapid rate–areas that were river bottom in the 1940s are presently being farmed. Secondly, although the incidence of floodplain deposition has decreased, so has the rate of bank erosion. A study of land use changes in the Sacramento River riparian zone conducted by the California Department of Water Resources in 1983 similarly concluded that there has been no overall loss of high terrace prime soils since Shasta Dam went into operation, suggesting an overall balance between erosion and deposition. High terrace riparian forest has routinely been converted to agricultural land uses. There is little evidence, however, that depositional imbalance has slowed or hindered riparian forest succession.

Hydrology and Flooding

The magnitude of a flood is described by discharge, commonly measured in cubic feet per second (cfs). The relative size of a flood is often described in terms of a *recurrence* interval*.* The recurrence interval, the frequency with which such a flood is likely to recur, is based on historical records. The larger the flood, the less frequently it will occur. For example, a "100-year flood" has a recurrence interval of 100 (or Q100). Such a flood has a 1-in-100 chance of occurring in any given year (even if a 100-year flood just occurred the previous year!). A smaller "3-year flood", on the other hand, has a 3-year recurrence interval (Q3), and a 1-in-3 chance of happening in a given year.

A river is composed of both a channel and a floodplain. When floodwater discharge is greater than the capacity of the channel, portions of the floodplain will become inundated. The "floodplain" is a general term referring to that part of the landscape that shows evidence of sediment deposition from floods of the modern-day river system. It often coincides with the area of reworked alluvium resulting from the meander process. The nature of the floodplain changes considerably along the Sacramento River between Keswick Dam and Colusa. For most of the distance between Keswick and Red Bluff, the floodplain is less than a mile wide, narrowing to less than 500 feet in some places, such as Iron Canyon. Downstream from Red Bluff, the floodplain broadens to between 1.5 to 4 miles wide south of Chico Landing. The pre-reclamation floodplain actually includes the Butte, Sutter Colusa, and Yolo Basins (Figure 2-1).

The area of the floodplain that is inundated depends on the magnitude of the flood. For example, the area inundated by a 100-year flood on the Red Bluff-Chico Landing Reach of the Sacramento River may be 1 to 4 miles wide. On the other hand, a 3-year flood may only inundate an area about 60 ft to 2.5 miles wide.

The Central Valley Project's Shasta Dam has significantly altered the hydrology of the Sacramento River. Water from the upper Sacramento River drainage has been stored in Shasta Lake during the winter and spring months since September 1943, and released during the summer and fall. As a result, winter flows have lessened and summer flows tend to be higher. The reservoir mostly impounds peak flood flows, resulting in smaller floods. A large influx of water into the reservoir during a large storm and/or snowmelt occasionally may necessitate high volume releases. These various changes in hydrology may influence the pattern of riparian habitat along the river. Although releases from Shasta Dam highly regulate the hydrology of the Sacramento River, many tributaries still preserve the winter flooding necessary for riparian forest succession.

In addition to the extensive levee and weir system of the Sacramento River Flood Control Project downstream of River Mile 194, there are a number of discontinuous privately-built levees north of Chico Landing. Levees change the pattern of flooding and sediment deposition along the river. For example, a levee may block floodwaters from a portion of the floodplain, preventing the succession necessary for the natural establishment of riparian habitat. Prevention of flooding and deposition at one site along the river, however, can move these impacts farther downstream.

THE BIOLOGICAL ENVIRONMENT

Each plant community is a successional stage that creates an environment that permits the establishment of the next stage until, finally (barring a disturbance), the vegetation becomes a *climax community.* By definition, a climax community will regenerate itself and continue to exist indefinitely. The establishment of plant communities takes place through the biological process of succession as one plant community replaces another over time. The plant communities in this successional process are known as *seral stages*. Each of these vegetation communities, or seral stages, serves a variety of needs of a different group of wildlife species.

Along the meandering portions of the Sacramento River, succession is tightly linked with the process of deposition on point bars and the gradual accretion of the floodplain. In addition to the various successional stages of the riparian forest, riparian habitat includes shady and bare eroding banks, sloughs, side channels, riparian grasslands, and sand and gravel bars. It also includes the large woody debris and snags in the river itself.

The Ecological Adaptations of Riparian Plants

The plants in the riparian forests of the Sacramento River have many specialized adaptations to life in an environment frequently disturbed by flooding and deposition. The majority of species present along the river are phreatophytes, which must have their roots in contact with a stable water supply. Most of the trees associated with the riparian corridor of the Sacramento River are broad leaved and deciduous during the winter months.

Broad leaves enable the tree to maximize the exposure of the leaf surface to light, thus maximizing growth. Such “early colonizing” species as willows and cottonwood exhibit the rapid growth of foliage and roots necessary for pioneer colonizers to survive the hot, dry summer on a substrate made up of sands or gravels. Table 2-1 lists the most common plant species along the Sacramento River.

Colonizing species are prolific seed producers and most have adaptations for wide-spread distribution. For example, cottonwood seeds are embedded in the cotton-like material floating over wide areas in the spring. Germination will be triggered if the seeds of these species land on a suitable site, such as an open, moist sand bar. The timing of seed dispersal may also be an adaptation to natural hydrologic patterns on the river. For example, cottonwood is adapted to release its seeds in the spring as water levels recede from low terrace riparian areas, providing moist open sites for colonization. Sycamore, which does best on sites with well-aerated soils, releases its seeds in January, just prior to average peak flows; thereby increasing the likelihood of seeds landing on high terrace riparian areas.

Table 2-1. Common Sacramento River riparian forest species.

1. TREES

Scientific Name	Common Name
Acer negundo var. californicum	box elder
**Ailanthus altissima*	tree-of-heaven
Alnus rhombifolia	white alder
**Eucalyptus spp.*	gum tree
**Ficus carica*	edible fig
Fraxinus latifolia	Oregon ash
***Juglans californica var. hindsii*	Northern California black walnut
**Maclura pomifora*	Osage-orange
Plantanus racemosa	California sycamore
Populus fremontii	Fremont cottonwood
Quercus lobata	valley oak
Quercus wislizenii	interior live oak
**Robinia pseudoacacia*	black locust
Salix goodingii	black willow
Salix laevigata	red willow
Salix lucida ssp. Lasiandra	yellow willow

2. SHRUBS

Scientific Name	Common Name
Artemisia douglasiana	mugwort
**Arundo donax*	giant reed
Baccharis douglasii	marsh baccharis
Baccharis pilularis	coyote-brush
Baccharis salicifolia	mule's fat
Calycanthus occidentalis	spice bush
Cephalanthus occidentalis var. californicus	California button-willow
Heteromeles arbutifolia	toyon
Hibiscus lasiocarpus	rose-mallow
Rhamnus tomentella ssp. Tomentella	hoary coffeeberry
Rosa californica	California rose
**Rubus discolor*	Himalayan blackberry
alix exigua	sandbar willow
Rubus ursinus	California blackberry
Salix lasiolepis	arroyo willow
Salix melanopsis	dusky willow
Sambucus mexicana	blue elderberry
**Tamarix parviflora*	tamarisk

Table 2-1(cont). Common Sacramento River riparian forest species.

3. COMMON VINES, PERENNIAL GRASSES AND SEDGES (UNDERSTORY SPECIES)

Scientific Name	Common Name
Aristolochia californica	California pipevine
Carex barbarae	Santa Barbara sedge
Clematis ligusticifolia	virgins-bower
Leymus triticoides	alkali ryegrass
Smilax californica	California greenbrier
Toxicodendron diversilobum	poison oak
Vitis californica	California wild grape

* Exotic species
**Native (versus introduced) status is currently a matter of dispute (Griffin, 1972).

Other adaptations that some riparian species exhibit include:

- seeds which float and are resistant to rotting;
- adventitious roots (roots from the buds along the buried stem) which form after sand and silt is deposited over the plants during flood events;
- the ability to tolerate low levels of oxygen in the soil during flooding events; and
- the ability to form suckers and roots after mechanical damage.

These mechanisms ensure survival in the river zone, which is seasonally inundated. This all but guarantees that the initial colonizers will not be able to replace themselves at the site; instead they will colonize another newly disturbed area and the cycle will repeat.

As silt accumulates under the willow-cottonwood scrub, other trees such as box elder and ash are able to germinate in the spring after flood flows have stopped. Because the existing trees have slowed flood flows the depositional materials in these areas tend to have a higher percentage of fine material such as silt; finer soils are able to retain moisture longer than sandy and gravelly substrates. Species such as box elder and ash can tolerate some deposition, but not to the extent of the early colonizers. Plants found in the most mature riparian forest of the river, the valley oak riparian forest, are unable to survive within areas which have heavy silt deposition.

Other riparian species found in more mature stands are not adapted for frequent flooding; their seeds tend to be heavier and, because of a susceptibility to molding, require a drier site for establishment. These species tend to be shade tolerant and are able to develop under the closed canopy of earlier successional stages.

The Changing Mosaic of Successional Stages

When viewed from the surrounding foothills, the riparian forests of the Sacramento River may appear as a uniform blanket of lush green growth. A closer view, however, reveals distinct bands of vegetation, differentiated by plant species composition, forest structure and wildlife usage. The Sacramento River system is actually composed of a wide variety of habitat types (Table 2-2).

Along the Sacramento River the process of succession is most pronounced in the meandering reaches (Red Bluff–Chico Landing, Chico Landing–Colusa, and parts of the Keswick–Red Bluff Reaches). It also occurs elsewhere, but may be difficult to see because of the narrowness of the riparian corridor, the frequency of disturbance from flooding, or an altered substrate such as rock revetment.

The successional stages of the riparian forests along the Sacramento River can be classified into four plant communities (a fifth habitat type, valley oak woodland, occurs above the high frequency floodzone), although any one species of tree, shrub, or vine could occur in more than one plant community. In other words, there is an intergrading between communities and rarely is there an abrupt edge between them. Figure 2-5 shows the typical succession pattern for these communities in relation to river hydrology and channel movement. Such other plant communities as valley oak woodland, wetland, and nonnative grassland often occur in conjunction with riparian forests. This *Handbook* uses the plant community classification of Robert Holland (1986).

Table 2-2. Typical habitats of the Sacramento River system and examples of wildlife using these habitats.

Habitat Type	Examples of Wildlife Use
Gravel Bars	nesting killdeer, spotted sandpiper and lesser nighthawks; foraging water birds
Cut Banks	nesting bank swallows
Heavily Shaded Banks (SRA)	juvenile salmon burrowing otter and beaver
Willow Scrub	nesting blue grosbeaks
Wetlands	foraging water birds
Sloughs and Side Channels	egret and heron rookeries basking western pond turtles
Great Valley Cottonwood	foraging yellow-billed cuckoos and
Cottonwood-Oak Riparian Forests	nesting eagles, osprey, Swainson’s hawks
Open Grassland	foraging Swainson’s hawks
Valley Oak Woodland	nesting owls, woodpeckers and bluebirds

Figure 2-6 Willow scrub, Sacramento River

Great Valley Willow Scrub

This is the pioneer riparian community found on depositional areas (point bars) near the river's edge. The community will tend to survive along a band that meets the substrate, texture, and moisture requirements of the germinating seeds (Figure 2-6). The young plants prefer a coarse substrate such as sands and gravels. The rapidly growing root systems must reach the groundwater before it recedes to summer levels. If conditions allow, the narrow bands of young cottonwoods in this community will become the riparian forests of the future. (Figure 2-5). The most common willow species identified with this community is sandbar willow, easily identified by its dense gray-green foliage. Also commonly occurring within the stands are other willows (black, red, yellow, arroyo, and dusky willows) as well as young cottonwoods. Young sycamores, box elders, walnuts and Oregon ash may become established as the ground becomes shaded by willows and cottonwoods but, because of the high frequency of flooding, they may be washed out or buried under deposited material.

Openings within willow scrub may be covered by annual and perennial grasses and forbs. As deposition of soil continues (and the river meanders away from the point bar), the length and frequency of flooding decreases and the community develops into a great valley cottonwood riparian forest.

Young, lush cottonwood-willow stands tend to support high concentrations of invertebrates, which provide food for migratory and resident insectivorous bird species. Species such as blue grosbeak also use low dense willow and cottonwood thickets for nest sites.

Great Valley Cottonwood Riparian Forest

As its name indicates, this community is dominated by cottonwoods (sometimes 100 percent of the upper canopy), which have established dominance over the early colonizing willow species (Figure 2-7). A second tall tree, *Salix goodingii* (black willow), is often a significant member of this community. Additionally, many species are able to germinate under the dense canopy cover, including berries, wild grape, poison oak, and many tree species which can develop into a dense understory. All of these tree species require a permanent subsurface water supply.

Yellow-billed cuckoos and other medium to small-bodied land birds are often associated with this plant community during the spring and summer.

Trees such as box elder and ash may become established in the understory, but do not become significant canopy species until flooding becomes less frequent. When this occurs, the community succeeds to a mixed riparian forest.

Figure 2-7. Great Valley cottonwood riparian forest, Sacramento River

Great Valley Mixed Riparian Forest

This community has a diverse, often dense, mixture of tall mature cottonwood and willows, as well as sycamores, box elders, walnuts and alder. Shrubs such as buttonbush, blackberries, and poison oak are often covered by an assortment of vines (clematis, wild grape, and pipevine), which extend up into the overstory trees. Perennial grasses such as creeping rye and the Santa Barbara sedge may form dense pockets in the understory. Openings within this community may also contain elderberry savannas. This community also supports nesting yellow-billed cuckoos and other medium to small-bodied land birds.

The great valley mixed riparian forest may be a fair distance from the active channel, but still experience overbank flooding. This brings additional deposition, but not necessarily damaging flows and subsequent erosion. As the community becomes "drier" (i.e., further above the water table), species such as valley oaks are able to germinate and become established. Over an extensive period of time this species becomes dominant and the community develops into the most mature of the four riparian vegetation types.

Great Valley Oak Riparian Forest

This spectacular plant community was once extensive along the Sacramento River. Valley oaks dominate the closed canopy riparian forest with significant numbers of black walnuts, sycamore, and ash. The understory may be dense with various vines, typical shrub species (and species from drier sites), and very often with stands of perennial grasses and sedges. Also present within this community type between Red Bluff and Colusa are very large, often very old specimens of elderberry.

These areas are still subject to flooding where the hydrologic regime is intact. Good regeneration of valley oak often occurs at sites with little livestock grazing or active agriculture. As a site becomes flooded less frequently and rises further above the water table, it may develop into valley oak woodland or annual grassland.

Valley Oak Woodland

Some consider valley oak woodland to be the climax community for the riparian habitats (Figure 2-8). It occurs on the deep alluvial soils of the higher floodplain terraces, but can also be found in other upland communities (Griffin, 1972). A canopy covering of up to 40 percent valley oaks is typical; non-native grasses dominate the understory. This plant community once covered extensive areas of alluvial soils, forming wide bands alongside the riparian forest. Today, isolated islands of majestic, old valley oaks occur in alluvial soils on the river's historical floodplain. Valley oak woodland occurs in association with river systems, but its regeneration does not depend on flooding and deposition, and will become established in areas of rich, loamy soils with good drainage. In suitable years, in areas with little livestock grazing or active agriculture, the valley oak is often capable of reproducing.

Other Plant Communities

Pockets of different plant communities may occur within or adjacent to the riparian corridor. These include upland communities such as non-native annual grassland, valley wildrye *(Leymus triticoide*s) grassland, and elderberry savanna. Additional communities are associated with areas of standing water either perched alongside the channel, as occurs in the volcanic formations between Red Bluff and Redding, or associated with cut-off meanders such as Murphy Slough. In these areas, typical marsh plants provide a very different habitat type; areas of calm waters support animal species, such as western pond turtles, and various wading birds and waterbirds. Vegetation consists of typical emergent species (tules and cattails) or floating mats of water primrose. Bordering these wetland areas are areas of buttonbush scrub. An unusual ephemeral freshwater marsh type is upstream of the Bend Bridge. Several pools that occur on the volcanic formations were found to support typical vernal pool flora, despite having high water flows over them during the winter months.

Figure 2-8. Valley oak woodland, Sacramento River

Exotic Species

Plant species which have become established within natural ecosystems, but were not native to California prior to European settlement, are often referred to as "exotics". The reasons for importing these species into California include erosion control, food crops and animal fodder, use in gardens, as well as accidental introduction. Table 2-3 lists the exotic plant species found within the Sacramento River system.

Some of these species are extremely invasive and have been able to displace native plant species. Adaptations of "successful" invading species include the production of large amounts of seeds, fast growth, and the ability to reproduce from small pieces of plant. Adding to these advantages is frequently the lack of natural predators, diseases, or competing plants. A plant species with these adaptations can quickly take over a natural ecosystem, and in doing so, may eliminate valuable wildlife habitat. An example of such a species is *Arundo donax* (giant reed), a large bamboo-like plant along the Sacramento River (Bell, 1993) (Table 2-3, Figure 2-9). Giant reed is able to reroot from small pieces of plant. It tolerates a wide variety of soil types, but becomes established primarily in alluvial deposits which, in the Sacramento Valley, often support willow scrub plant communities. It grows at an alarming rate (3-1/2" per day under optimal conditions) and any attempts to remove the plants mechanically simply sends additional pieces downstream to start new colonies. Because of this rapid growth, the ground is quickly covered and species such as cottonwoods and willows are unable to become established. A population of the reed at the top of a small tributary can result in numerous colonies downstream. When dry, the giant reed burns easily and will sprout readily after a fire. Fire in a stand of giant reed may, over time, eliminate any remaining riparian species. Little wildlife value exists in giant reed colonies.

Other exotic species, such as tree of heaven, that appear to "fit" into the riparian habitat are also poor wildlife habitat, either because of a lack of cover value or structure, or because the seeds produced are of low nutritional value. Some plant species have the ability to produce chemicals that inhibit the germination of competing plant species. The edible fig *(Ficus carica*), an exotic species common on the higher riparian terraces, has this ability.

Table 2-3. Exotic plant species within the Sacramento River riparian area.

Arundo donax	Giant reed
Rubus discolor	Himalayan blackberry
Tamarix chinensis	salt cedar
Eucalyptus globules	tasmanian blue gum
Ailanthus altissima	tree of heaven
Ficus carica	edible fig
Robinia pseudoacacia	black locust

Figure 2-9. Giant reed (Arundo donax)

Sensitive Plant Species

Many plant communities associated with the Sacramento River have declined in acreage and are considered rare enough to be included in the CNDDB computerized inventory of the State's sensitive biota (DFG, 1996). Appendix A includes a list of sensitive plant species known to occur within or near the Conservation Area, a brief description of their habitats, and their current legal status.

Of the 16 species, only the rose mallow (California hibiscus) and the silky cryptantha are known to occur within the Conservation Area. Several populations of the rose mallow occur in marshy areas, such as backwaters within oxbows between Knight's Landing and Golden State Island. The silky cryptantha has been found near tributaries within the northern reaches. Populations are known from Battle, Cottonwood, and Frazier Creeks near the Sacramento River.

The remaining species, except the adobe lily, are associated with ephemeral swales, pools, and alkaline areas. Adobe lilies are found on deep heavy clays and are unlikely to be found within the riparian habitat.

Habitat Types at the Water's Edge

In addition to creating a mosaic of riparian forest plant communities, the river system creates many other critical habitats and habitat elements. Erosion, channel movement, flooding, and aggradation create sloughs and side channels, sand and gravel bars, bare cut banks, and shady banks with vegetation and woody debris extending into the water. These forces also contribute (through channel change and aggradation) to the aging of cottonwoods into dead snags, an important habitat element. All of these features play an integral part in the functioning of the riparian ecosystem. Habitats are used by different species for different needs, such as foraging or nesting. Table 2-2 illustrates the importance of these habitats and habitat elements to various wildlife species along the Sacramento River.

Shaded Riverine Aquatic Habitat

Shaded banks are an important component of the Sacramento River ecosystem, created as the river erodes into a bank supporting riparian forests (Figure 2-10). This habitat has an important aquatic component. The U.S. Fish and Wildlife Service has dubbed this type of area "shaded riverine aquatic cover," (known as SRA) an area where "the adjacent bank is composed of natural, eroding substrates supporting riparian vegetation that overhangs or protrudes into the water" (USFWS, 1992). It is also characterized by "variable amounts of woody debris, such as leaves, logs, branches and roots, as well as variable depths, velocities and currents." SRA provides feeding and cover for aquatic species such as salmon, and when less vegetated (see following section on cut banks) provides burrowing substrate for bank swallows.

Cut Banks

Cut banks are another important component of the riparian ecosystem along the Sacramento River. Most often associated with valley oak woodland and high terrace agriculture, cut banks along the Sacramento River also support the majority of California's bank swallow *(Riparia riparia)* colonies. The migratory bank swallow, which winters in Central and South America, nests in the spring, mostly in steep freshly eroded earth banks (Figure 2-11).

Figure 2-10. Shaded Riverine Aquatic Habitat along the Sacramento River.

Figure 2-11. Cut bank with bank swallow burrows, Sacramento River, Chico Landing-Red Bluff Reach

Figure 2-12. Slough along the Sacramento River

Sloughs and Side Channels

Channel movement creates sloughs and side channels that contribute to the richness of the riparian ecosystem (Figure 2-12). Sloughs provide shelter from the fast current of the main channel creating habitat for many wildlife species, such as beavers and pond turtles. Sloughs and side channels often have shaded riverine aquatic habitat along their banks. Most heron rookeries are located in sloughs or oxbow lakes.

Such areas, particularly when surrounded by riparian forests, also offer refuge from human disturbance. The interface between the waters of the river and adjacent land surface is very important for foraging wildlife species. Side channels, sloughs, and oxbows greatly increase the length and amount of this interface. For example, between River Mile 235 and 239 (the vicinity of Todd Island in Tehama County), the length of the water-land interface along the main channel is increased by over 200 percent due to the presence of side channels, sloughs and oxbow lakes.

Riparian Habitat and Wildlife

Anyone walking from a grassland or open field into a riparian area along the Sacramento River during a hot summer day is acutely aware of the abrupt change in habitat. Not only is the area cooler because of a dense closed canopy, but the air is humid due to high transpiration rates of the surrounding trees. Grass and annual species, which dried up weeks or months ago in the adjacent lands, remain green and succulent under the numerous layers of riparian vegetation.

Cottonwood-willow riparian areas support more breeding avian species than any other comparable broad California habitat type (Gaines, 1977). Riparian forests along the Sacramento River have several characteristics that enable them to support such an abundance and diversity of wildlife. *Abundant resources, high structural and habitat diversity,* (maintained over time by flooding and channel movement) and *linear continuity* all contribute to the diversity of wildlife species in riparian habitats (Warner, 1979).

Proximity to water, rich deep soils, and the periodic influx of nutrient-rich sediment from flooding contributes to the abundance of resources in the riparian forest system. This abundance continues throughout the summer and autumn months, in contrast to much of California, which lies dry and dormant. It attracts caterpillars, moths, butterflies, and aquatic insects, which in turn attract many species of birds and fish.

The riparian forest system also has a *diversity of habitat types and high structural diversity,* both providing a variety of roosting, nesting, and foraging opportunities for a wide range of wildlife species. The many plant communities and habitats described earlier contribute to the diversity of habitat types. In addition, there is high structural diversity within the forest itself. Trees with a range of sizes and ages, a diverse understory, thick ground cover (which may include debris brought in by flood waters) and, in mature stands, tall dead snags all contribute.

The dynamic nature of the river system is key to this diversity. As the course of the river changes and as riparian plant communities mature, both the species and the composition of plant and wildlife communities change. For example, an area of willow–cottonwood scrub containing young seedlings and sapling trees may be an ideal site for nesting willow flycatchers. Several decades later, deposition may have raised the site further from the water table. The willows may have died and the cottonwoods matured. Snags will offer nesting habitat for osprey.

Another example is a heavily vegetated bank providing cover for river otter or instream cover for migrating salmon. As the river changes course, erosion may remove this vegetation and cover, but the site then may become ideal for nesting bank swallows.

Despite the unending change in habitat at any particular site on the river, under ideal conditions, the relative proportion of habitat types will remain constant over the years. As willow scrub matures to a mixed riparian forest, for example, bare gravel bars will begin to support willow scrub. As a heavily shaded bank is exposed by erosion, changes in channel alignment will result in another area becoming vegetated, and so forth. Factors which influence the rate of change of these habitat types (and therefore their relative proportions) may include agricultural conversion and other land use changes, hydrologic patterns, flooding patterns, and bank protection.

The *linear continuity* of riparian areas, providing a corridor for wildlife movement, is important for several reasons: food may be seasonal; young need to disperse into their own territories; and it allows for the movement of individuals into and out of areas, thus ensuring a good mix of genetic material into a population. Corridors serve as a connection between large blocks of high quality habitat.

The entire riparian forest is valuable for wildlife, but even a single tree species can support wildlife in a surprisingly wide variety of ways. The life cycle of the valley oak tree provides a good example. As an oak matures, its spreading canopy provides numerous nesting sites; the spring flowers attract many insects, which in turn become food for the nesting birds. Other wildlife are also attracted to the new leaf material as it emerges in the spring. Acorns from oaks and the fruits from understory plants such as coffee berry, wild grape, and poison oak serve as important food sources for many wildlife species. Acorn production decreases as the tree ages, but populations of wood boring insects increase in the decaying wood, and nesting cavities become more common. Cavities provide nesting sites for the acorn woodpecker, owl, western bluebird, American kestrel, and other birds. When the tree dies, the snag will serve as an important perching, roosting, or nesting site, as well as providing insects for food. Dead and downed woody materials provide both forage sites and cover for small mammals, reptiles, and amphibians.

The California Wildlife Habitat Relationships (CWHR) database was used to predict which wildlife species could be found along the Sacramento River (DFG, 1996). More than 250 species of mammals, amphibians, reptiles, and birds were listed (Appendix B).

Fragmentation of Habitat

The historical changes to riparian habitat described earlier have resulted in habitat fragmentation, a condition that occurs when a large, fairly continuous tract of vegetation is converted to other vegetative types such that only scattered fragments of the original habitat type remain. Habitat fragmentation affects riparian wildlife species in several ways, including loss of habitat, increased edge habitat and edge effect, and isolation effects. The species that habitat fragmentation most adversely affects include those with large home range sizes, narrow or very specific habitat requirements, and sedentary species with little ability to disperse.

Each wildlife species requires a specific arrangement of food, water, and cover to meet its biological needs. In addition, each species requires a minimum amount of suitable habitat (space). Western yellow-billed cuckoos require deciduous riparian thickets or forests with dense, low, or understory cover by slow-moving watercourses. This species generally selects these habitats for nesting only if they are present in contiguous stands of at least 25 acres and are 300 feet in width (Gaines, 1974). Smaller or narrower stands of suitable habitat are rarely used. When the minimum home range size is greater than the fragment size the species frequently disappears. So, a consequence of habitat fragmentation is a reduction in species richness and diversity with the greatest effects on the smaller or linear shaped fragments.

Riparian wildlife species may be absent from a fragment of apparently suitable habitat even if the fragment greatly exceeds the minimum home range size due to edge effects. An edge is the area where two habitat types, or seral stages, meet. The edge habitat generally contains species from each of the intersecting habitat types or seral stages and species adapted to the edge habitat itself. This characteristic of edges is known as edge effect. Because edges increase species diversity and many game species are adapted to edges, most historic wildlife habitat improvement projects have attempted to create edge habitats. As habitat fragmentation occurs, however, the amount of edge increases relative to the amount of interior area. This further serves to reduce the quality and amount of habitat for interior species. The qualitative habitat reduction due to edge effects on fragmented habitats has been documented for forest birds and includes increased rates of nest predation, brood parasitism, interspecific competition, as well as reduced pairing and nesting success. These edge effects have been documented to extend 150 feet to 1,800 feet into the interior of the fragmented forest habitats.

Isolation effects lessen a species' ability to move between fragments. The dispersal ability of a species and the characteristics of the habitat between fragments are key factors that determine the relative degree of isolation. Island biogeography theory suggests that isolated fragments may support lower densities and diversities than similar sized fragments with less isolation and that the long-term potential for population survival is less. Avian (birds and bats) species generally have excellent dispersal capabilities, while small mammals and some species of reptiles and amphibians are significantly poorer.

Management of fragmented habitats should be guided by the following principles:

- Larger fragments are better than small fragments.
- Efforts to protect, acquire, or create larger blocks of habitat should be a priority.
- In situations involving equal amounts of habitat, one large fragment is better than several smaller isolated fragments.
- Several fragments located close together is better than equivalent sized fragments with greater relative isolation.
- Interconnected fragments are better than isolated fragments.
- A fragment with a greater ratio of interior area relative to perimeter length is superior to a fragment with a lower ratio of interior area relative to perimeter length (linear shaped habitats are poorer than circular shaped fragments).

Sensitive Wildlife Species

Historically, there have been many sensitive wildlife species within the Sacramento River Conservation Area, including several that have been extirpated (Appendix B). *(Sensitive* refers to state or federally listed threatened or endangered species, or species of special concern). Each of the remaining species depends on different habitat types and components of the riparian ecosystem. Many of these species require broad and unfragmented habitat areas. The least Bell's vireo, considered the most numerous songbird along the river in the 1940s, was completely absent by the early 1960s. This vireo depends upon the willow scrub riparian communities created by river meander. It is thought that willow scrub habitat declined following flood control projects, increasing the vireo's vulnerability to cowbird parasitism and, eventually, causing its removal.

The bank swallow is another example of a species that depends upon the dynamic nature of the river system. Swallows make their spring nests in eroding river banks, precisely where landowners install rock revetment to protect their property from erosion. Consequently, this species, once common throughout California, has disappeared throughout much of its historic range. Today the meandering portions of the Sacramento River above Hamilton City support nesting for the majority of the state's remaining bank swallows.

RIPARIAN FOREST SUCCESSION AND AN INNER RIVER ZONE GUIDELINE

The riparian habitat management policies that the SB1086 Advisory Council developed in the *1989 Plan* include the concept of the "inner river zone." The *1989 Plan* recommends that such a zone be established taking into account "the river's natural geologic controls and effects on erosion, riparian ecosystem dynamics, existing land uses including agriculture, and structures such as buildings, bridges and levees that must be protected from bank erosion. Within the zone, the natural river processes of erosion and deposition would be allowed to occur for the most part unhindered by human intervention" (Resources Agency, 1989). Because participation in Conservation Area programs will be strictly voluntary, the inner river zone will actually include only the properties of those public and private landowners who choose to participate.

The inner river zone guideline combines the past 100-year meanderbelt with projected erosion locations 50 years in the future (Figure 2-13).

1. The 100-year Meanderbelt

The 100-year meanderbelt is the combination of all channel locations between 1896 and 1991. In other words, it is that area along the river that has experienced channel movement in the immediate past.

Interestingly, 100 years also represents the approximate life span of a cottonwood tree. In theory, any area along the Sacramento River that has not been channel bottom since 1896 has had time to grow into a mature riparian forest on its way to becoming high terrace valley oak woodland. The successional stages of riparian forest generally occur within the band represented by the 100-year meanderbelt. Outside of the 100-year meanderbelt, forests will intergrade into valley oak woodland.

2. Erosion Projections

Erosion projections are also used to develop the inner river zone guidelines. Data from the Department of Water Resources (DWR) and the U.S. Army Corps of Engineers (USACE) are used to determine probable channel locations over a 50-year timeline.

DWR developed erosion estimates for two hypothetical scenarios:

1. Erosion is projected under the assumption that all public and private bank stabilization remains in place. This scenario provides a baseline for analysis purposes.
2. Erosion is projected over fifty years (since 1991) in the absence of all existing riprap. Although as unlikely as the first, this scenario provides a picture of the physical potential for channel migration and is used for the inner river zone guideline.

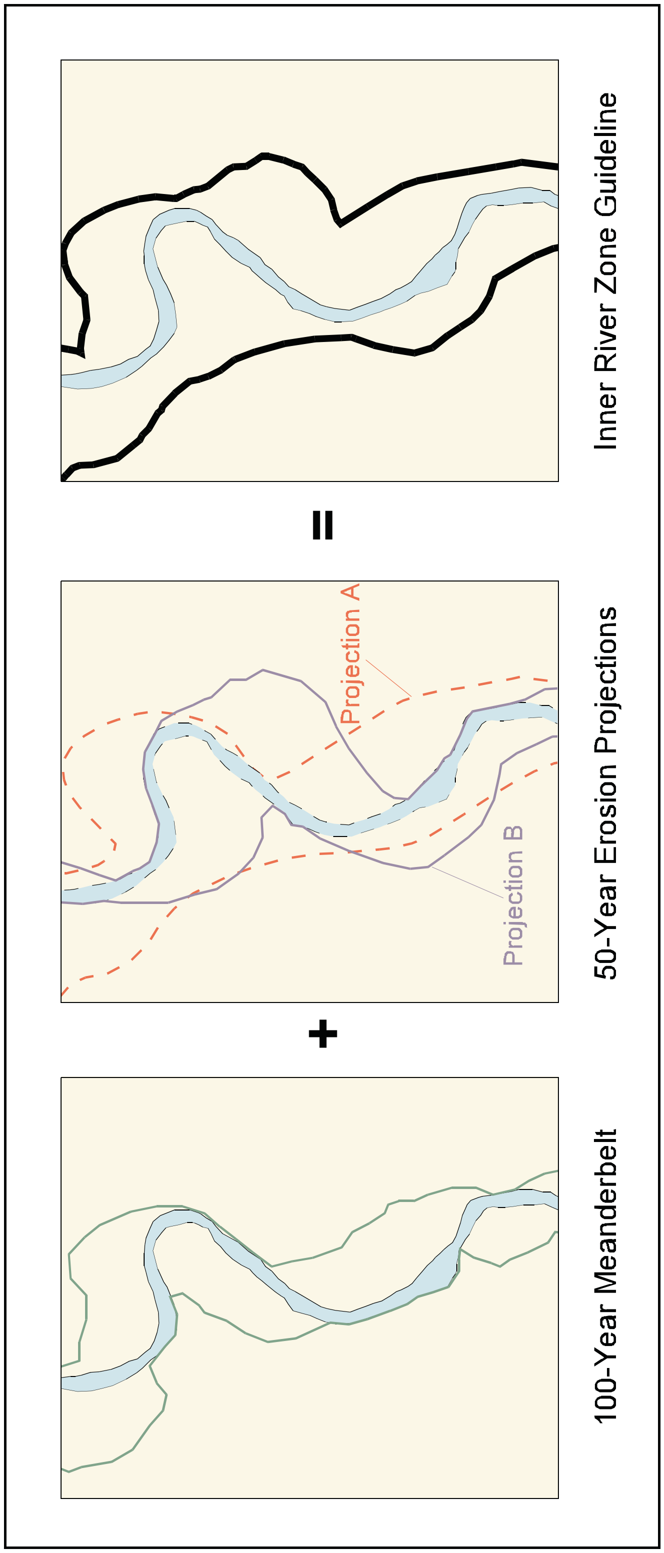

Figure 2-13. The 100-year meanderbelt is combined with 50-year erosion projections developed by U.S. Army Corps of Engineers (Projection A) and California Department of Water Resources (Projection B).

Many possible sources of error can affect the results of an erosion analysis. Erosion rates do not progress linearly, but change as the bank curvature and hydraulic factors change. Rock revetment installed at one site may affect erosion rates and patterns both upstream and downstream. Also, storms may occur that cause major channel realignments through chute cutoffs or other mechanisms (DWR, 1994).

The USACE has made very general projections of channel locations in 50 years (USACE, 1981). An examination of these projections indicates erosion in areas where DWR has not predicted it would occur. This *Handbook* uses the USACE projections along with the DWR projections to define an inner river zone guideline between Chico Landing and Red Bluff and DWR projections to define the guidelines between Colusa and Chico Landing. Because the river channel is closely confined by Sacramento River Flood Control Project Levees from Colusa to Verona and by geologic control from Keswick to Red Bluff, different criteria were used to develop the guidelines for these reaches.

The combined area of the 100-year meanderbelt and 50-year erosion projections is referred to as an inner river zone *guideline* because several factors will influence its actual location:

- Participation in programs; the inner river zone will include only voluntary public and private landowners;
- Unpredicted changes in channel alignment
- Individual decisions to install bank protection

A landowner choosing to participate in riparian habitat conservation programs offered by the nonprofit management entity or others will work with the entity to develop a site-specific management plan (Chapter 9). A technical team of specialists familiar with the area will assist with the development of this plan. Many of the parameters to be used in analyzing the site and developing the plan are mapped and available in the Sacramento River Geographic Information System (Appendix C).

These include:

1. geology
2. channel movement history
3. projected erosion
4. land use
5. roads, bridges
6. water diversions
7. federally installed bank protection
8. soils
9. riparian habitat
10. bank face characteristics

This information will be used to assess the site, develop a site-specific management plan, and assess its merit in terms of the mission of the nonprofit management entity.

THE SACRAMENTO RIVER FLOOD CONTROL PROJECT

All riparian habitat management along the river must be placed in the context of the Sacramento River Flood Control Project, described in the following section. The project affects riparian habitat in different ways in the four broad reaches. The Keswick-Red Bluff and Red Bluff-Chico Landing Reaches lie upstream of the Flood Control Project. The Chico Landing-Colusa Reach includes the upstream end of the project at the Butte Basin Overflow Area (BBOA). The reach is characterized by the setback levees of the project (Chapter 5). Any riparian habitat management within this reach must be coordinated with the Reclamation Board and the U.S. Army Corps of Engineers (USACE). The Colusa-Verona Reach (Chapter 6) lies within the portion of the project that is tightly leveed. As stated earlier, any riparian habitat management in this reach must be coordinated with the flood control agencies.

Many individual flood control elements make up the Sacramento River Flood Control Project (Figure 2-14). Congress authorized the overall project in 1917 and modified it by the various Flood Control or River and Harbor Acts of 1928, 1937, and 1941. Construction began in 1918, and the overall project was completed in 1968.

The major features of the Sacramento River Flood Control Project are:

- the greatly enlarged river channel from Rio Vista to Collinsville
- approximately 1,300 miles of levees along the Sacramento River extending from River Mile (RM) 0 at Collinsville to RM 194 at Chico Landing, distributary sloughs, the lower reaches of the major tributaries (American, Feather, Yuba and Bear Rivers) and additional minor tributaries;
- the Moulton, Colusa, Tisdale, Fremont, and Sacramento Flood Overflow Weirs;
- the Sutter and Yolo Bypasses and Sloughs; and
- the Flood Relief Structures within the Butte Basin Overflow Area.

The flood control project protects about 800,000 acres of agricultural land, as well as the cities of Sacramento, West Sacramento, Yuba City, Marysville, Colusa, Gridley, Live Oak, Courtland, Isleton, Rio Vista, and numerous smaller communities. Several economically significant crops are grown throughout the basin; orchards and field crops such as almonds, pears, peaches, rice, tomatoes, sugar beets, and corn are the most prevalent. Sacramento Valley’s annual agricultural production exceeds $2 billion. Infrastructure within the valley includes irrigation works (diversions, pumping plants, canals, and drains), roads, and bridges. Major transportation routes are Interstate Highways 5 and 80, and State Highways 50, 99, 45, 20 and 160.

During major flood events, upstream reservoirs intercept and store initial surges of runoff and provide a means of regulating floodflow releases to downstream leveed streams, enlarged channels, and bypass floodways. In order to achieve the full benefits of the reservoirs, specific downstream channel capacities must be maintained. Reservoir operation is coordinated not only among various storage projects, but also with downstream channel and floodway carrying capacities.

Shasta Dam is a major structural feature of the basin. This multipurpose dam controls runoff from 6,420 square miles (excluding Goose Lake), and serves agricultural demands by providing 4.5 million acre-feet (maf) of total storage, 1.3 maf of which is allocated to flood control. At Colusa, the drainage area below the dam is 6,180 square miles. The only flow control in the reach from Shasta Dam to Colusa is on Stony Creek where Black Butte Dam creates a 144,000 acre-foot multipurpose reservoir.

The Sacramento River Flood Control Project basically mimics the natural historic flooding patterns with its system of levees, basins, bypasses, and weirs. The project levees begin on the right (west) bank just downstream of the Butte Basin Overflow Area (BBOA). The BBOA, located roughly between RM 174 and 194, includes three flood relief structures (3 B's, Goose Lake, and M&T) that allow for high flows on the river to drain into the Butte Basin, a trough created by subsidence, to the east. The Colusa Basin Drain, a similar trough located to the west of the river, intercepts runoff from west side tributaries.

In addition to the basins and flood relief structures, the flood control system includes several weirs. The Tisdale Weir is the first flood relief structure to spill at 23,000 cubic-feet per second (cfs), which is quite frequent. Colusa Weir is the next structure to spill at 30,000 cfs, and the Moulton at 60,000 cfs. By comparison, the BBOA begins to spill at 90,000 cfs, and if flood flows exceed 300,000 cfs, the Sacramento River would be expected to spill into the Colusa Basin.

Oroville Dam provides 3.5 maf of storage for several purposes; 750,000 af of storage is allocated to flood control to provide roughly a 140-year level of protection downstream.

The north fork of the Yuba River is uncontrolled except for New Bullards Bar, which provides 960,000 af of storage (170,000 af is for flood control). The 50-mile-long by 7-mile-wide Yolo Bypass provides 1.11 maf of flood storage. Prior to hydraulic mining, the Feather River had deep (60-foot) pools that would take months to drain. Now these pools are filled with debris and no longer provide flood flow detention and attenuation.

Sacramento River Bank Protection Project

To ensure that the flood control project continues to provide a design level of flood protection and to reduce the need for emergency levee repair, periodic dredging, and loss of land due to bank erosion, Congress authorized the Sacramento River Bank Protection Project in 1960 in Public Law 86-645, and in subsequent acts of Congress. The Flood Control Act of 1960 authorized construction of the first phase of the project. The second phase of the project was authorized by the 1974 River Basin Monetary Act, the Further Continuing Appropriation Act of 1993 (which extended the authority into the Butte Basin), and the Water Resources Development Act of 1986 (which also authorized environmental mitigation for the first phase of the project). The bank protection project provides a long-range program to protect the flood control system from erosion. The project includes a total of 835,000 linear feet of bank protection in two phases: 430,000 linear feet in the first phase (carried out between 1963 and 1974), and 405,000 linear feet in the second (begun in 1974).

Approximately 86,000 feet of the second phase has not yet been completed. Of this amount, between 16,000 and 31,000 lineal feet (best current estimate of about 26,000 lineal feet) are currently being designed in Design Memorandum Supplements 7 and 8 for sites on the Sacramento and American Rivers.

In the late 1950s, the levees were deteriorating rapidly and the bank protection project was authorized. It is important to note that this project is an "O&M" (operation and maintenance) project authorized in lieu of providing bank protection in the original authorization of the flood control project. In the authorizing documents for the initial phase of the project (HD 103, 86th Congress, 1960), USACE performed a gross economic evaluation. Upon review by the Board of Engineers for Rivers and Harbors (BERH), and confirmed by the Chief of Engineers, it was determined that economic justification was not needed. The following was included as paragraph 12 of the BERH report:

> *The Board considers that the remedial work is clearly justified to preserve the integrity of the existing levee system, the failure of any part of which would endanger lives and cause extensive property damage. The improvements would also reduce the need for emergency expenditures and the costs of maintenance dredging for navigation and flood control channels. The Board considers it impractical to assign a monetary value to the benefits which would result from the removal of threats of eventual levee breaks when there are hundreds of vulnerable locations in various states of deterioration.*

The second phase of the bank protection project was authorized according to HD 93-151 of the 93rd Congress (1973). This report indicated that the views of the BERH on the initial phase of the project also were applicable to the second phase work.

The current phase of the Sacramento River Bank Protection project was authorized in 1973. This authorization was for a total of 405,000 linear feet of protection of which 82,000 linear feet of protection was identified at that time and 323,000 linear feet was expected to be critical in future years (specific sites would be determined later). To date, bank protection has been or is being provided to approximately 335,000 linear feet, leaving only 70,000 linear feet remaining to be designed and built.

Most of the bank protection work placed to date has been either where levees eroded that were constructed adjacent to the channels with no berms, or where berms eroded and active erosion threatened the safety of the levee. To adequately protect the levees in such areas, it has been necessary to clear the waterside levee or berm slope, grade the slope, and face it with stone.

Recreationists and conservationists have objected strongly to the aesthetic and wildlife losses that occur when native vegetation is removed from the river levee or berm slope and the slope is faced with stone. There is strong interest in developing a more comprehensive program of bank protection on the berms and levees that would not only protect the levee system, but could also preserve riparian environmental values. These ideas were expressed as early as 1973 in House Document (HD) 93-151 of the 93rd Congress.

The need for bank protection is a "built-in" design feature of the Sacramento River Flood Control Project. Originally, the project levees for the main stem of the Sacramento River and its major tributaries were set close together to provide for two of the original purposes for the Corps: (1) to maintain summer flows deep enough to accommodate navigation and (2) to keep hydraulic mining debris moving (through scouring of the channel). As a result of the original design, especially now that the mining debris has essentially passed through the system, erosion is a serious problem.

This has long been recognized, causing the state and the USACE to place both riprap and setback levees years before the bank protection project began.

The Sacramento and San Joaquin Rivers Basins Comprehensive Study

The “Comprehensive Study” was authorized in 1997-98 through joint actions of Congress and the California State Legislature. It is a joint study by the California State Reclamation Board and the U.S. Army Corps of Engineers to “develop a system-wide, comprehensive flood management plan for the Central Valley to reduce flood damages and integrate ecosystem restoration”

- Phase I focused on evaluating current conditions, developing hydrologic and hydraulic models, identifying flooding and related environmental problems, formulating preliminary planning objectives, initiating a public involvement program, collecting potential solution measures, and developing a plan of action for Phase II.
- Phase II is concentrating on fully implementing the public involvement program, conducting feasibility-level assessments, developing concept approaches and the Starting Point Plan.

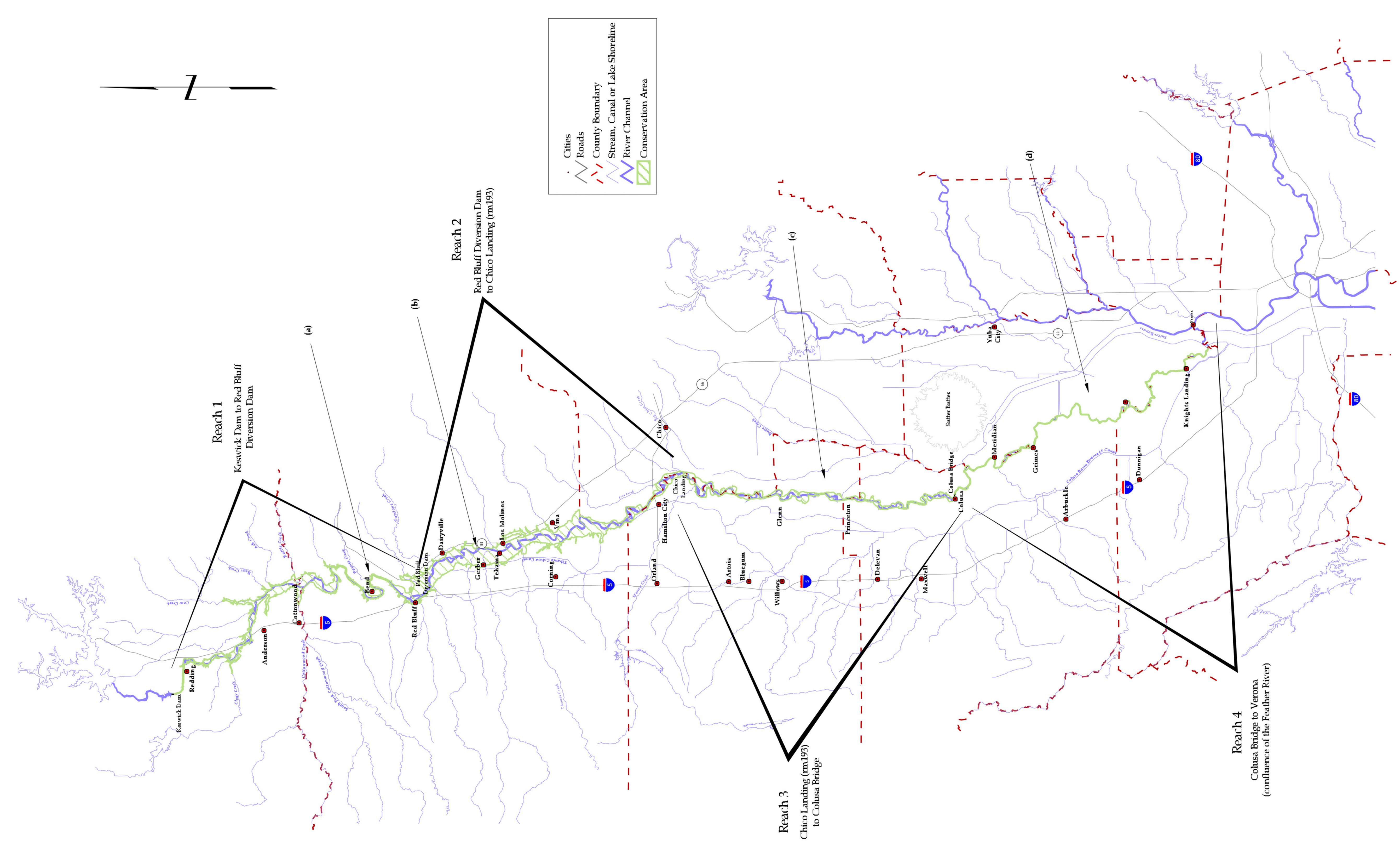

Figure 2-1. The four reaches of the Sacramento River Conservation Area. Letters refer to cross sections shown in Figure 2-4.

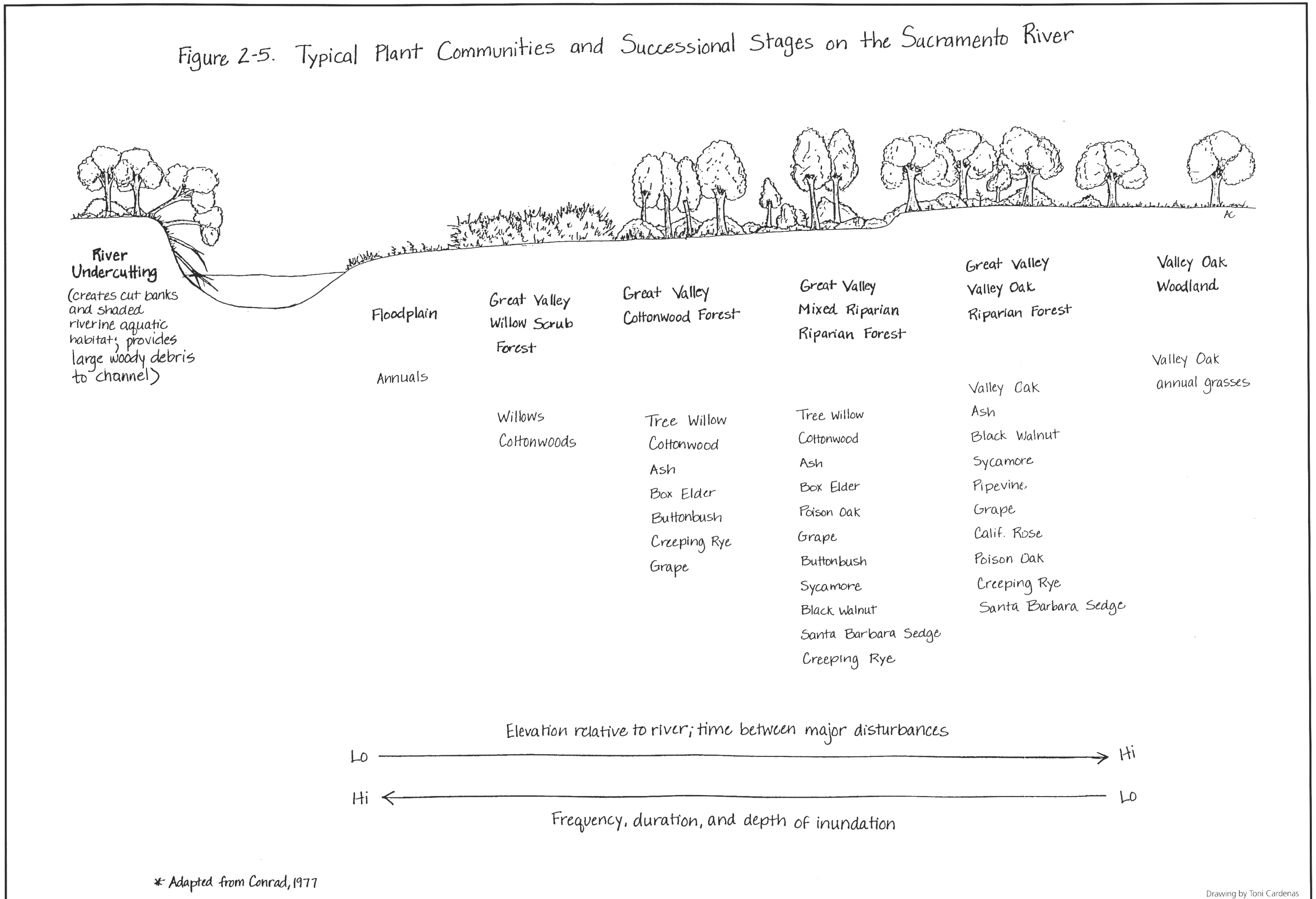

Figure 2-5. Typical plant communities and successional stages on the Sacramento River

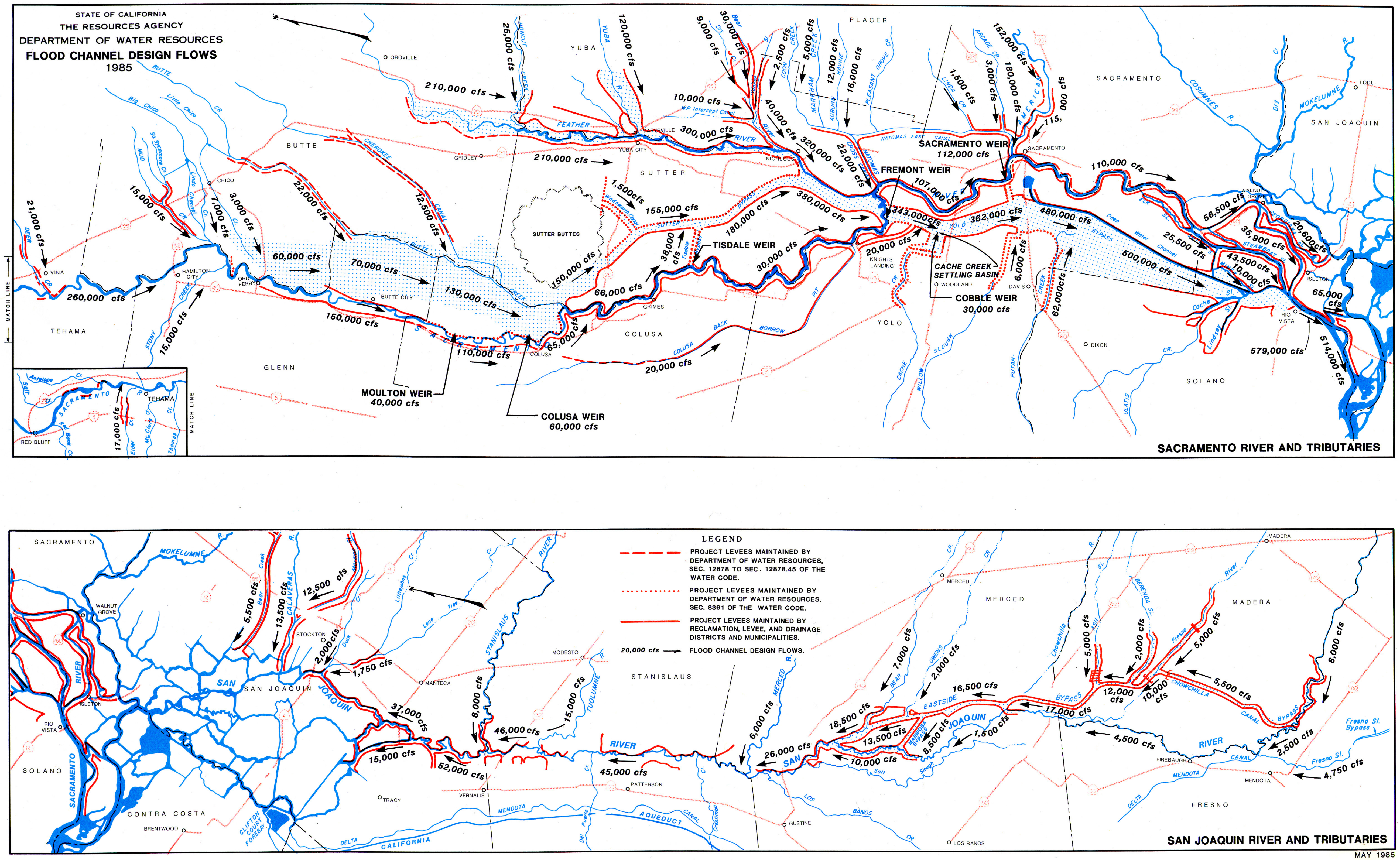

Figure 2-14. Sacramento Valley flood control system