Restoring Floods to Floodplains: Riparian and Floodplain Restoration at the Cosumnes River Preserve

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ABSTRACT. Riparian and floodplain ecosystems are shaped and sustained by the river's hydrologic processes, such as flooding. The Cosumnes River Preserve is a multi-partner effort to protect and restore natural habitats within the floodplain of the Cosumnes River. This landscape-scale project protects over 40,000 acres of riparian forest, wetlands, and vernal pool grasslands. Early restoration efforts relied on active measures, such as hand planting of oaks and willows. This method, however, was expensive and labor intensive, and sometimes plantings failed. In the last several years we have focused on restoring natural processes that sustain and create habitat, such as flooding. Natural process restoration is now an integral part of the restoration program and central to our planning for property acquisition. Intentional levee breaches have restored the hydrologic connection between the lower Cosumnes River and its floodplain. Floods passing through levee breaches created in 1995 and 1997 have deposited sediment, seeds and plant cuttings on former farm fields, and stimulated natural recruitment of cottonwood and willow riparian forests. This method also provided valuable habitat for chinook salmon and Sacramento splittail. Creating seasonally flooded habitat rather than permanent ponds benefits native fishes more than non-native fishes. Monitoring by the Cosumnes Research Group and others is providing feedback for adaptive management.

INTRODUCTION

California's riparian and floodplain ecosystems have been greatly modified and impaired. Historically, rivers would overtop their banks in the winter and spring to create extensive flooded plains. Many of the fishes native to the Central Valley, including chinook salmon and Sacramento splittail, evolved to take advantage of these productive seasonally-flooded shallow water habitats. Riparian forests were once the predominant floodplain vegetation in the Sacramento Valley prior to extensive settlement (Hunter et al., 1999). Currently on most rivers, however, the natural hydrologic regime has been drastically altered by dams and levees that impound runoff, straitjacket stream channels, and alter the timing and magnitude of flows (Mount 1995). Floodwaters cannot spread across the floodplain to deposit sediment, distribute plant seeds and cuttings, or seep into the ground to recharge groundwater aquifers. Valley oaks grew best in the deep alluvial soils preferred by early farmers, who cleared the forests for agriculture (Reiner 1986). By the late 1980s less than four percent of the floodplain remained covered by forest (Hunter et al., 1999).

Floodplain restoration will require restoring the flooding process. The Cosumnes River is the only unregulated Sierran river in the Central Valley and, as such, it retains much of its natural hydrology. This represents a major opportunity to restore a functional ecosystem by providing the river access to its floodplain. Successful experiments with breaching and removing levees on the preserve have made the Cosumnes a natural laboratory for restoring riparian forests and native fishes, as well as developing non-structural flood management. In this paper we review the planning, implementation and outcomes of levee breaches at the Preserve, and discuss future directions for natural process restoration. An overview of the extensive research being carried out here by the Cosumnes Research Group (U.C. Davis) is provided in Mount et al. (this volume).

Cosumnes River Watershed. The Cosumnes River is the last free-flowing river in the Central Valley, draining the western slope of the Sierra Nevada (ESA, 1991). No large dams have been constructed on the river. A small reservoir, Sly Park Reservoir, is located on a tributary with a capacity of 40,000 acre-ft, or 10% of the average annual yield. The watershed (1,265 square miles) reaches over 7,600 feet elevation in the Sierra Nevada. Little snow accumulates because of the watershed's low elevation. Thus, the river's flow is derived principally from winter rain instead of spring snowmelt.

The Cosumnes River historically wandered back and forth across the valley floor and occupied several channels. Tidal fluctuation is observed in the lower river up to Twin Cities Road (river mile 5). During the summer, streamflow is intermittent upstream of Twin Cities Road. The lower Cosumnes River is extensively leveed (Philip Williams and Associates, 1997). This has contributed to incision of the channel upstream of Highway 99. Surface water diversion rights exceed the river's average monthly flow in some months. Groundwater pumping for agriculture and urban development has created a dramatic decline of ground water levels, up to 60 feet near Highway 99 (Montgomery Watson 1995). Increased water use has delayed streamflow in the fall, which adversely affects chinook salmon attempting to migrate upstream to spawn.

The Cosumnes River supports a variety of natural communities (ESA, 1991): coniferous forests in the upper watershed, oak woodlands in the foothills, and vernal pool grasslands and riparian forests on the valley floor. Bottomland riparian forests consist of cottonwood, willow, valley oak and Oregon ash, which support many species of migratory birds (PRBO, 2000; Estep, 1989). In the lower watershed and east Delta, seasonal marshes and agricultural fields provide habitat for waterfowl and sandhill cranes (Littlefield and Ivey, 2000). Badger Creek provides wetland habitat for giant garter snakes.

The upper Cosumnes River hosts native rainbow trout, as well as non-native brown and brook trout. The middle reaches of the river were historically dominated by native minnows such as hardhead and roach, but are now invaded by redeye bass and smallmouth bass (Moyle et al. manuscript). The lower reaches contain native fishes, such as chinook salmon, Sacramento splittail, and Sacramento suckers, as well as many non-native species, such as largemouth bass, carp, and silversides (Harris, 1986; Moyle, Crain and Whitener, unpublished data). Chinook salmon migrate through the lower reaches to spawn along the middle reaches of the river below a natural passage barrier at Latrobe Falls, 41.5 miles upstream from the confluence with the Mokelumne River.

Cosumnes River Preserve. In 1984, the Nature Conservancy acquired a large valley oak grove on the Cosumnes River. The Cosumnes River Preserve was established in 1987 and currently protects over 40,000 acres of riparian forest, wetlands, vernal pool grasslands and agriculture. The Preserve is a showcase for the Conservancy's strategies of public and private conservation partnerships, habitat restoration, development and demonstration of wildlife-friendly land management methods, community involvement, and compatible economic activities. The Cosumnes River is also a flagship project of the California Riparian Habitat Joint Venture.

The Preserve is managed under an cooperative agreement among The Nature Conservancy, U.S. Bureau of Land Management, California Department of Fish and Game, California Department of Water Resources, Ducks Unlimited, and Sacramento County. About 2,400 acres are private lands that are protected with conservation easements that restrict development and intensive agricultural practices that are incompatible with wildlife, such as vineyards and orchards. Almost 90 percent of the Preserve is maintained in active agricultural production, including annual crops, grazing, and a 1,000-acre organic rice farm managed by Living Farms.

Restoration Projects At The Cosumnes River Preserve

Active Restoration

Early efforts to enhance and restore habitats along the lower Cosumnes focused on active measures, such as wetlands construction and hand planting of trees (Eaton, 1998). Approximately 725 acres of ponds are managed for waterfowl and sandhill cranes. In 1988, the Preserve initiated the first large-scale replanting of a valley oak forest (Griggs, 1991; Reiner, 1996). Since then, a total of 500 acres have been planted with oaks, willows and other trees by volunteers and school children. Planting remains an integral part of the Preserve's education program. However, a 1994 study found that hand planting was expensive and some plantings failed or grew slowly (Reiner 1996). Furthermore, natural regeneration of oaks was occurring in many areas, particularly where natural flooding and sediment deposition still occurred. The Nature Conservancy reoriented the forest restoration program in 1995 to identify areas where natural regeneration could be encouraged by reestablishing natural flooding (Reiner 1996).

Restoration of Natural Flooding Processes

Alteration or removal of levees, such as breaching or creation of setback levees, provides the opportunity to reconnect the river to its floodplain.

A Lesson From Nature: The Accidental Forest. In early 1985, a levee protecting a farm field adjacent to the Preserve failed, and much of the river's flow was diverted through a gap in the levee for a brief period. The floodwaters dropped a substantial amount of sand on about 15 acres. The farmer repaired the levee, but left the deposited sediment and farmed the remainder of the field.

Cottonwood and willows rapidly colonized the depositional area, and by late 1985 the "accidental forest" was well established (Figure 2). Within a few years the area contained a thick mosaic of 15- to 20-foot high cottonwood trees, Oregon ash, and willow thickets. Sixteen years later, many of the cottonwoods are over 40 feet tall and the "accidental forest" provides habitat for songbirds, raptors, deer, beaver, and otter. Researchers from the Point Reyes Bird Observatory have found a variety of migratory songbirds nesting in the forest (PRBO 2000). PRBO has ranked the site well above other areas they have studied in the Central Valley. In the understory of the forest and on its edges, naturally regenerated valley oak trees have taken hold (Tu 2000). As the shorter-lived softwood trees die or fall victim to beavers, the oaks will fill in the forest canopy and ultimately succeed the cottonwoods and willows (Tu 2000).

This farm property was acquired by the Nature Conservancy in 1987. The rapidly growing "accidental forest" inspired us to explore how natural flooding processes could be enlisted to expand the riparian corridor.

1995 Intentional Levee Breach. In 1994, a hydrologic assessment was conducted of the lower preserve, with funding from the US EPA. The goal was to determine whether levees could be intentionally breached without creating flooding problems for the Preserve's neighbors. The HEC-2 modeling demonstrated that water surface elevations in the river would be reduced upstream of a levee breach because waters would spread out on the expanded floodplain (Swanson and Hart, 1994). Thus, a levee breach would reduce flood levels elsewhere on the river.

In October 1995, a 50-foot gap in the levee was created and a shallow channel was cut through the field (Figure 2). This reopened about 200 acres of bottomland to natural flooding. The project cost approximately $10,000-$15,000. In December, the rising river flooded the field for the first time. By March, high flows had scoured the channel and deposited sand in bars parallel to the channel, along with natural "cuttings" of willow and cottonwood. In May, receding floodwaters exposed mudflats, where cottonwood seeds settled. By early fall 1996, the cottonwood trees were about three feet tall (Tu 2000). A three-year study found that cottonwood trees that grew from cuttings were much taller and survived better than those that grew from seed (Tu 2000). Beavers have browsed many trees, but the trees have often resprouted. By late 2000, some trees were over 10-12 feet tall. The success of the 1995 breach has attracted much attention from resource and regulatory agencies.

1997 Levee Breach and Floodproofing. The massive floods of January 1997 caused many levee breaks along the Cosumnes River. Given the success of the 1995 project, the Preserve and local farmers reached an agreement on an "un-leveeing" project and convinced the Army Corps of Engineers to fund a non-structural flood management project in lieu of traditional levee repairs. The project cost approximately $1.55 million, with $900,000 from the Corps (nonstructural flood control program) and $650,000 from a developer (mitigation grant to create wetlands).

The project site was upstream of the "accidental forest" and the 1995 levee breach (Figure 2). A major component of the project involved breaching and abandoning 5.5 miles of levees. The main levee along the Cosumnes was breached to let the river flow onto the floodplain. An internal levee to the south was also breached to allow the floodwaters to drain south into the "accidental forest" and adjacent floodplain. A waterfowl pond was excavated as part of the wetlands mitigation. To protect adjacent farm fields, a low setback levee was constructed. Irrigation pumps were either elevated or replaced with submersible pumps. Construction started in the fall of 1997 with the levee breaches and setback levee. This added about 100 acres to the floodway. Floodproofing of infrastructure was completed by winter 1998-1999.

Floodwaters again created a large sand splay on this restored floodplain, and willows and cottonwoods quickly established (Mount et al., this volume). After 2-1/2 years, these trees were about 6-7 feet tall (W. Trowbridge, UC Davis, unpublished data).

Reconnecting the river with its floodplain did more than just start forest recruitment: it created valuable habitat for native fishes. Significant numbers of juvenile chinook salmon and Sacramento splittail use the seasonal wetlands (Whitener and Kennedy, 1999; Kennedy and Whitener, 2000). The warm, shallow waters produce enormous blooms of algae and invertebrates (Mount et al., this volume), which provide food for fishes (Sommer et al. 2001).

Habitat quality for native fish is influenced by timing and depth of inundation, and habitat complexity (P.B. Moyle, P. Crain, and K. Whitener, unpublished data). Native fishes have adapted to spawn early in the spring, when floods inundate the floodplain and water temperatures are colder. In contrast, the majority of non-native fishes that dominate the Cosumnes spawn later in the season, when water temperatures are warmer. Thus, inundation of the floodplain by the rising river provides shallow water habitat that corresponds with the life histories of native fishes. Late in the spring, river flows decline, waters start draining from the floodplain, water temperatures rise, and the connection between the river and floodplain is severed, thereby eliminating habitat for non-native fishes.

Depth of water within the floodplain is also a critical element. Preliminary data suggests that native minnows such as Sacramento splittail adults spawn on the submerged vegetation at about 4-6 feet deep, while juvenile chinook salmon and splittail feed in shallow waters about 1-3 feet deep. Areas deeper than six feet do not appear to be as productive, possibly because it is too deep for photosynthesis to occur. These deep waters may also harbor more predators. Finally, habitat complexity is important. A mosaic of microhabitat types, with various flows, depths and vegetation will ensure habitat for different life stages of fishes and invertebrates.

DISCUSSION

The Cosumnes River Preserve is a proving ground for innovative approaches to restoring riparian forest and floodplain habitats. Its history mirrors changes in restoration practices and reflects the growing sophistication of conservation biology (Reiner, 1996; Poiani et al., 2000). The preserve has evolved from opportunistic acquisition of the best remaining groves of riparian valley oak forest in the Central Valley, to active restoration via hand-planting of trees, and finally to restoration of natural processes that encourage natural forest regeneration. Current scientific theory emphasizes conserving biodiversity at multiple scales within an ecosystem or landscape context, along with the ecological processes that sustain it (Poiani et al., 2000).

The levee breach projects are a living laboratory for investigating floodplain dynamics and restoration ecology. The Cosumnes Research Group, a coalition of more than 30 university and agency researchers, has been monitoring patterns and processes of the physical and biological environments, including surface and groundwater hydrology, geomorphology, primary productivity, aquatic invertebrates, fish, and vegetation (Mount et al., this volume). This interdisciplinary effort is providing information for further restoration and adaptive management in the lower Cosumnes River and other stream systems.

Altering or removing levees has several consequences for ecosystem restoration as well as flood management and groundwater recharge. These two projects have added about 300 acres to the active floodway, and about 1,200 acres overall to the Cosumnes floodplain. Floodwaters have deposited fresh sediment, seeds and other plant materials on the floodplain, resulting in natural recruitment of cottonwood and willows, which will lead to the establishment of riparian valley oak forest (Tu 2000). Sediment deposition has created diverse topography on the floodplain, thereby increasing habitat diversity. The inundated floodplain provides valuable habitat for wintering waterfowl and sandhill cranes, as well as for native fishes, such as Sacramento splittail and juvenile chinook salmon, that are adapted to take advantage of these seasonally flooded areas. From a farm management perspective, future levee maintenance and emergency repair costs have been reduced. From a flood management perspective, the floodplain's holding capacity has been increased. This attenuates the flood peak and reduces flow velocity in the river, thereby decreasing the risk of flooding to surrounding areas (Philip Williams and Associates, 1997). Finally, groundwater recharge is enhanced when floodwaters have a longer residence time on the floodplain. The regional groundwater table has declined dramatically since 1940, resulting in reduced or absent flows in the Cosumnes River during the fall when chinook salmon attempt to migrate upstream to spawn (Phil Williams and Associates, 1997).

Monitoring is providing valuable information for adaptive management. A few of the lessons learned and possible applications are discussed below.

Multiple breaches could foster increased forest recruitment – Regeneration of cottonwoods and willows was most successful on the freshly deposited sand splay that formed immediately inside the levee breach (Mount et al., this volume). In order to foster more extensive riparian restoration in a field, it may be worth considering filling old breaches once recruitment has occurred, and creating new breaches to get more sand and plant materials spread across the field at a new location (J. Mount and J. Florsheim, unpublished data).

Seasonal spring flooding creates habitat for native fishes –The timing of flooding can have a large effect on fish use of the floodplain, depending on the species' life history (P.B. Moyle, P. Crain and K Whitener unpublished data). Inundation that corresponds to the historic natural hydrograph will allow native species to utilize the habitat while excluding many of the non-native species. Ponds and ditches that hold water year-round tend to favor non-native fishes. Therefore, creation of seasonally flooded habitat will enhance conditions for native fishes.

Floodplain topography can affect fish stranding– Stranding of fishes can be a potential problem. Preliminary data suggests that the decreasing flows and rising temperatures cue the native species to leave the floodplain and avoid stranding. The project design should consider drainage patterns from the floodplain, with an eye toward creating exit points for fish. Stranding seems to be associated with man-made structures such as roads, fences, ponds, ditches and levees. Removal or adjustment of such structures will alleviate potential stranding. For example, a waterfowl pond excavated as part of the 1997 project may be a stranding site for fish. It is worth noting, however, that overall production of fishes on the inundated floodplain is greater than in the river channel alone, even with some stranding.

Placement of breaches and setback levees- Consider carefully the placement of the levee breach and the resulting flow of water. If you're going to breach a river levee and put in a setback levee, leave enough room for flows to work the new floodplain. In some cases, the river could abandon its channel in favor of a new channel through the restoration site. At the Preserve, one end of the low setback levee was constructed too close the levee breach, in order to maximize farmed acres. High flood flows overtop this low levee, resulting in some erosion of the levee and sand deposition in the adjacent farm field, which has required ongoing maintenance.

Floodproof farm infrastructure in the floodplain –Incorporate floodproofing of farm infrastructure in the restoration project if you want to continue farming on adjacent lands. Remove or replace equipment that cannot withstand inundation, raise and improve necessary roads so they can withstand some wave action from temporary floodwaters.

So what does the future hold for natural process restoration of riparian habitat along the Cosumnes River? We are looking for other opportunities to allow the river to inundate its floodplain. Areas that receive regular flooding (i.e. 2-5 year recurrence interval) would be the highest priority for land acquisition and restoration. A hydrologic study indicated that the best opportunities for restoring a functional floodplain exist downstream of Highway 99 (11 miles above the confluence of the Cosumnes and Mokelumne Rivers) (Philip Williams and Associates 1997). Upstream of Highway 99, the channel is incised and consequently the river is isolated from its floodplain. As the channel deepens and increases its capacity, larger flows are required to overtop the banks, resulting in less frequent floodplain inundation. Restoring functional floodplains will not only benefit riparian ecosystems, it can also minimize flood damages and improve groundwater conditions.

The Nature Conservancy is discussing initiating a feasibility study with the Army Corps of Engineers along the lower Cosumnes and Mokelumne Rivers. The objective is to identify and evaluate ecosystem restoration projects that will also reduce flood damages via non-structural measures. The study would include hydrologic and hydraulic modeling of the rivers and measures such as controlled levee breaches, setback levees, and flood bypasses. The Corps process also presents the opportunity for leveraging federal funds for implementation, and provides a vehicle for engineering and environmental review of such projects. We hope this partnership will be a model for innovative riparian restoration and flood management, both in the Cosumnes River basin and beyond.

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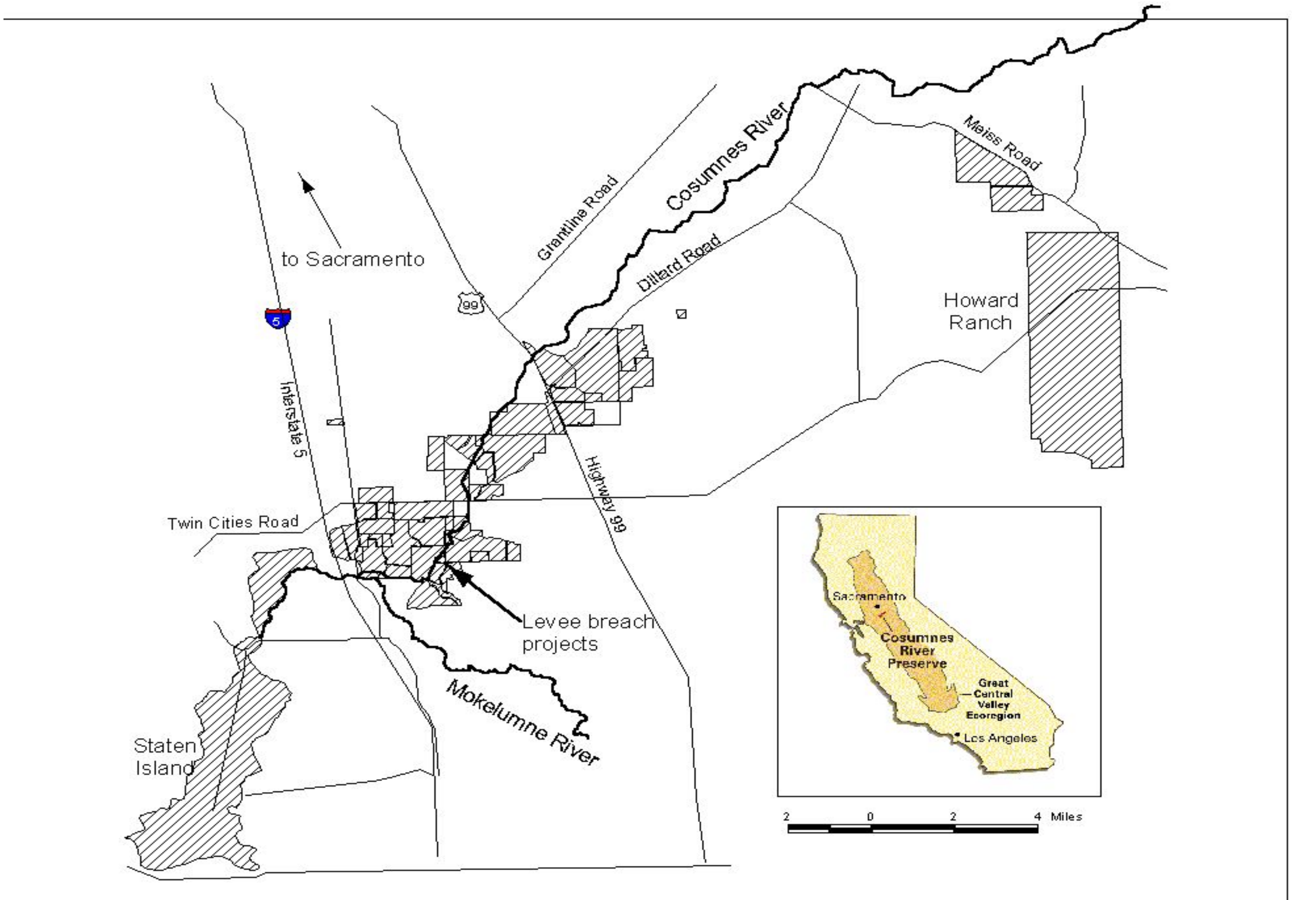

FIGURE 1. Cosumnes River Preserve.

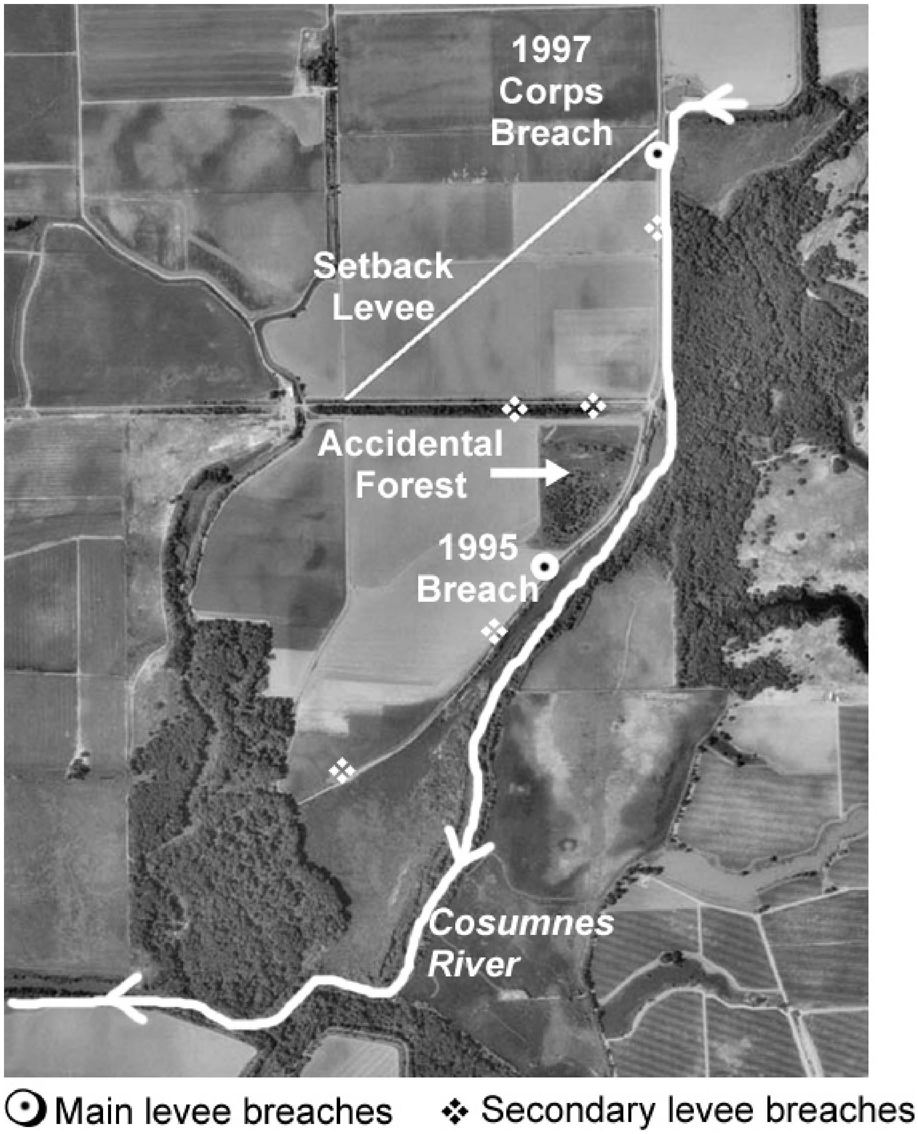

FIGURE 2. Location of levee breaches on the Cosumnes River Preserve.