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RESTORING THE REDWOOD CREEK ESTUARY

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Abstract

During the mid-1960's, construction of a flood control project drastically altered the lower 5.1 kilometers of Redwood Creek, impairing the physical and biological functioning of the estuary. During late spring and early summer, a sand berm builds at the mouth of the creek, forming an embayment. As the water level rises in the embayment, adjacent private property floods. Draining of the embayment by landowners to prevent flooding destroys fish habitat and can prematurely flush young fish into the ocean. Data collected from research have shown that the estuary is critical to chinook salmon and steelhead trout in Redwood Creek and that natural estuarine function has been severely impacted. From research data, management techniques and restoration options were developed. Estuarine water levels are regulated by "controlled breaching" of the berm to prevent flooding of private lands while protecting aquatic habitat. Redwood National Park has worked with other Federal and State agencies to implement an estuarine restoration project at the mouth of Redwood Creek.

Introduction

Redwood National Park (RNP) was established to protect, preserve, and restore the primeval redwood forests and associated streams and seashores for the use and enjoyment of future generations. Stretching 56 kilometers along the northern California coast, the park is best known for the world's tallest trees which grow along the banks of Redwood Creek. Following park creation, logging and road construction on lands adjacent and upstream to the park continued, posing threats of severe damage to downslope and downstream park resources. In 1978, Congress moved to protect existing parklands through expansion of Redwood National Park by 19,200 hectares. Most of the newly acquired land had been logged and was in various stages of regrowth. Congress addressed the severe erosion problems by including in the expansion legislation (Public Law 95-250) a provision that authorized a watershed rehabilitation program to restore lands damaged by logging. The focus of the restoration work is on minimizing man-induced erosion and encouraging the return of a natural pattern of vegetation (USDI 1981). The long-term goal is to reestablish a naturally-functioning, self-sustaining ecosystem. Today, the park encompasses the lower one-third of the narrow, 80

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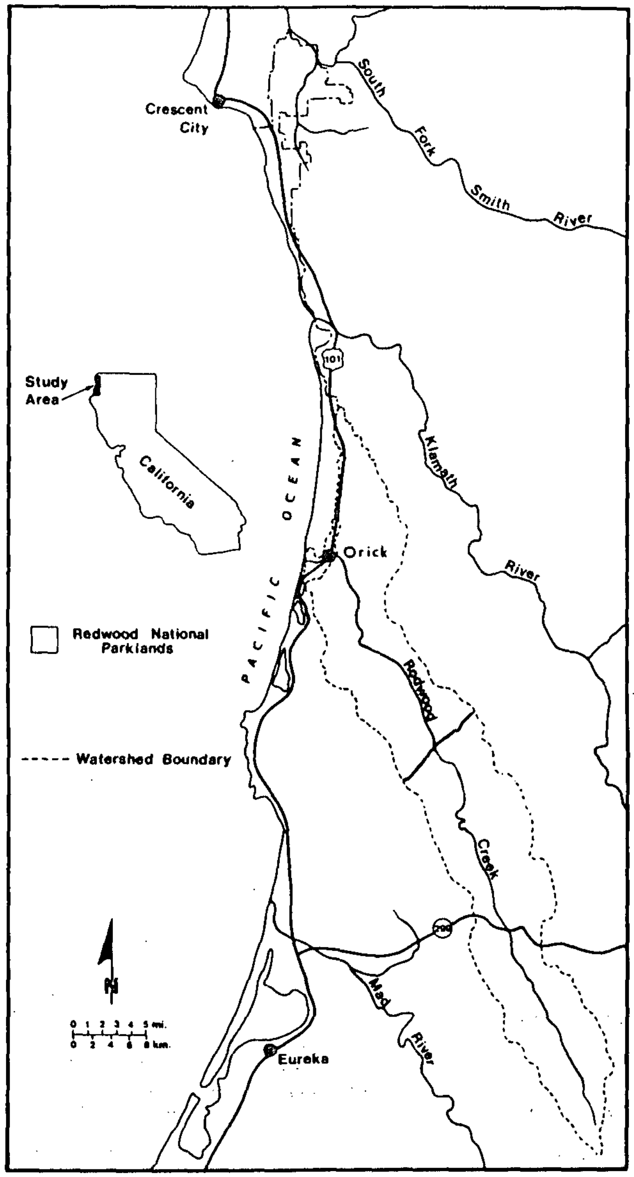


Figure 1. Northern California Location Map

a. September 7, 1948 (Corps photo). A relatively deep, broad embayment would form just landward of the beach before the flood control project was constructed.

b. May 2, 1978 (RNP photo). Ocean sand accumulated rapidly in the lower estuary following construction of the flood control project.

Figure 2. Mouth of Redwood Creek

kilometer long Redwood Creek basin (Figure 1). The town of Orick and adjacent private property are encircled by park lands.

A series of severe storms, resulting in the damaging floods of 1950, 1953, 1955, and 1964, prompted the channelization and construction of flood control levees on the lower 5.1 kilometers of Redwood Creek. Completed in 1968, the levees bypassed the last downstream meander on the creek and directed stream flow straight out into the ocean (Figure 2). Impacts of restructuring the channel included loss of riparian vegetation, accumulation of sediment in areas which were previously viable fish rearing habitat, and isolation of productive side channel areas, now referred to as the north and south sloughs (Figure 3).

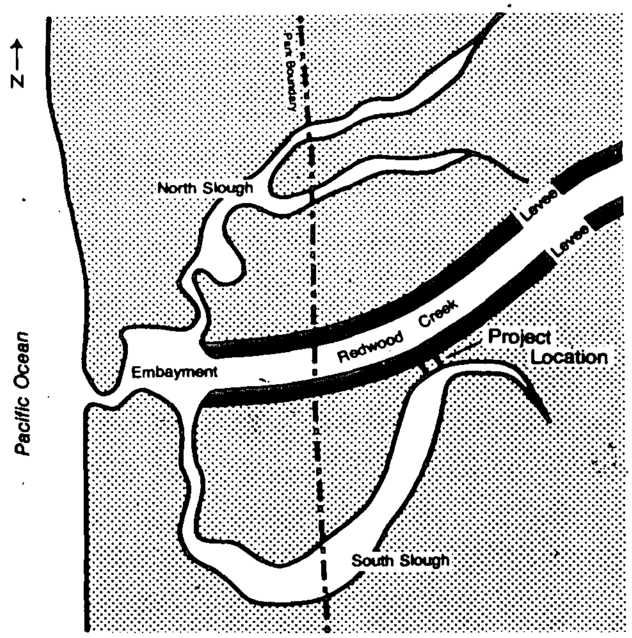


Figure 3. Existing estuarine conditions showing park boundary, sloughs, embayment, levees, and location of proposed restoration project.

Although the mouth of the creek itself is within the legislative park boundary, the estuary is only partially within the park. Upstream portions of the estuary lie outside the boundary. Therefore, other agencies have interests in the area's resources. The California Department of Fish and Game (CDF&G) has jurisdiction over fish and wildlife resources and has authority to approve stream-bed alteration activities. The State of California Lands Commission owns lands

extending from mean high tide to 4.8 kilometers off shore (the park boundary extends 0.4 km off shore). Roughly the lower 3.2 kilometers of the Redwood Creek basin is under the State of California Coastal Commission's purview. The County of Humboldt owns the mouth of Redwood Creek, the flood control project on the Creek, and is responsible for its maintenance. The Corps of Engineers (Corps), which designed and built the flood control project oversees county upkeep and maintains a strong interest in the area. Private individuals own the land adjacent to the upper ends of both sides of the estuary, and use their property for cattle grazing and limited crop production.

During early planning for the watershed rehabilitation program, the park recognized the Redwood Creek embayment as an extremely important and potentially very productive part of the basin. However, it was also recognized that the flood control levees constructed by the Corps had adversely affected the functioning of the estuary. To understand the nature and extent of the problem and to evaluate the feasibility of restoring the estuary, a research program was initiated in 1980.

Research and Results

Investigations were initiated to: compare present patterns of inundation, seasonal morphological changes and sediment sources with historic information; determine seasonal water quality patterns; and, determine abundance, distribution, and seasonal timing of estuary use by fish. Research data indicated that the embayment was critical in the life history of resident chinook salmon and steelhead trout (Hofstra and Harrington 1982). It was in the embayment where major increases in growth of juvenile fish occurred.

The predominant impacts of the flood control project were significant decreases in both estuarine volume and productivity. Comparing Corps topographic/bathymetric surveys from 1966 with RNP's 1981 surveys revealed 47 to 54 percent of the lower estuary (between zero and 1.2 meters above mean sea level) had filled with sediment (Ricks 1985). Confining stream flow between the levees permitted sediment to accumulate in backwater areas at either side of the levees. This resulted in the filling of productive fish rearing areas and isolation of the original last downstream meander (south slough) and north side tributary channel area (north slough).

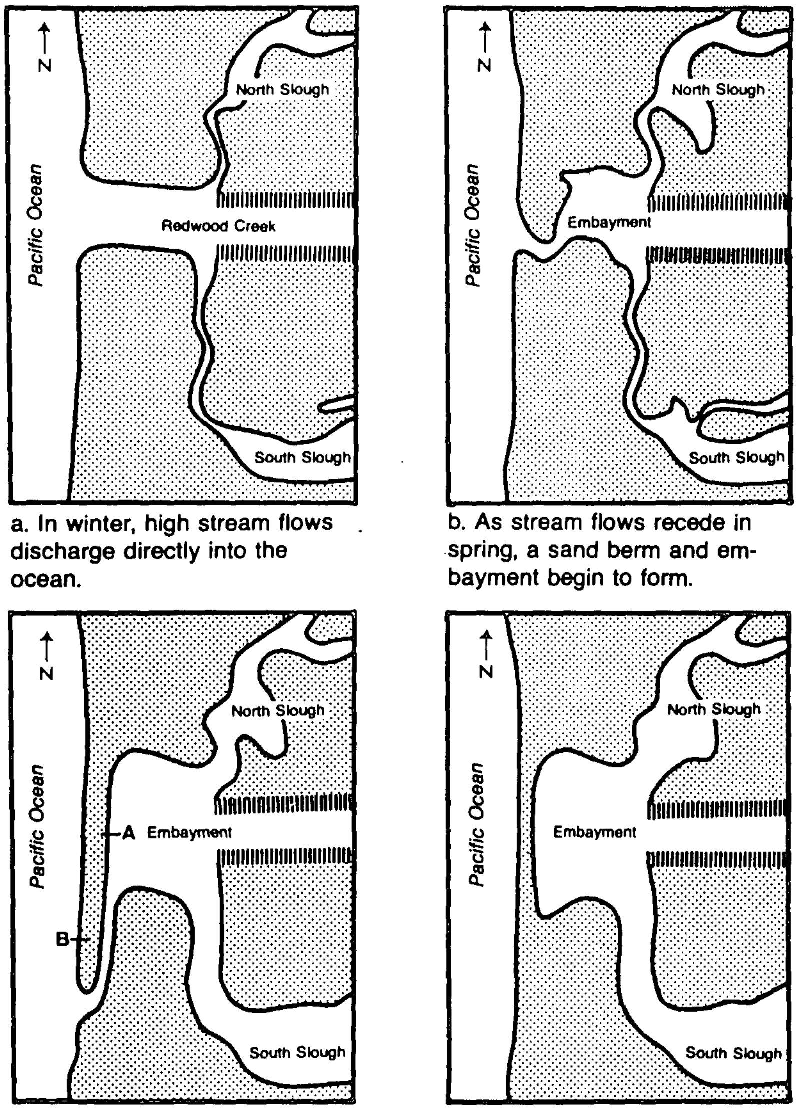
Isolation of the sloughs from the mainstem embayment leads to conditions unique to each. As a result, each functions as a separate entity rather than as a contributing part of a larger system. Invertebrate production is lower in the sediment-filled, levee constricted mainstem than in the sloughs, which support higher invertebrate production throughout the year (Larson et al. 1982). Water quality conditions often exclude fish from the sloughs. For example, dissolved oxygen levels and temperature during summer low flow periods are often below five parts per million, and above 20 degrees Celsius, respectively. Such conditions exceed those acceptable for juvenile salmonids (Reiser and Bjorn 1979). A lens of salt water generally persists on the slough bottoms throughout the summer, thus, only a small portion of the slough volume near the surface and near the slough necks, offers conditions suitable to rearing fish. Therefore, fish use of the sloughs is limited even when high water connects them with the main channel. In contrast, the embayment consistently exhibits temperature and dissolved oxygen levels favorable to rearing salmonids.

As stream discharge decreases through spring months, the straight outflow channel is modified by incoming waves and tidal currents (Figure 4). Prevailing north-northwest winds along with high tides, force the outflow channel to migrate rapidly to the south. As this migration occurs, waves deflect stream flow against the shoreward channel bank, eroding the bank, while at the same time depositing a berm on the seaward side. Should the berm build above mean sea level the mouth is functionally closed.

When an embayment forms, its substrate becomes stable and biomass of the tube-building amphipod, Corophium, increases greatly. This period usually coincides with peak downstream migration of juvenile salmonids, and the fish utilize this expanded food base. However, as the mouth closes, water may rise in the embayment to a level that floods adjacent private properties. Landowners have dealt with flooding problems by digging through (breaching) the berm to drain the embayment and their fields. Embayment draining is destructive to fish and fish habitat. For example, in 1980, peak downstream migration coincided with formation of an embayment and by June, the salmonid population began to rise, indicating extended utilization of the area. In late June, a population estimate revealed approximately 20,000 pre-smolt salmonids in the embayment. A week later, the threat of flooding caused landowners to breach the berm, releasing an estimated 75% of the water in the embayment within six to eight hours. The draining occurred so rapidly that a subsequent population estimate showed nearly all the fish were entrained in the discharge and flushed into the ocean. Breaching the berm before winter rains begin also adversely affects returning adult salmon and steelhead. As the berm is breached and fresh water drains into the ocean, adult salmonids may be induced to enter the creek. Insufficient instream flows prevent adult fish from continuing their upstream migration, trapping them in shallow pools within the levee-constricted creek.

Estuary Management

Serving not only as an area for acclimating from freshwater to saltwater, but also as critical juvenile rearing habitat, the estuary was recognized as being important in the production of fall chinook salmon. In studying the Sixes River in Oregon, a river similar in size and function to Redwood Creek, Reimers (1973) documented the role that estuaries play in fall chinook salmon production. Through scale analysis of spawning fall chinook, he showed the majority of returning adults spent June, July, and August as juveniles within the estuary before completing their seaward migration. Juvenile chinook spending less than three months in the estuary seldom returned to spawn in the natal stream. He concluded these fish did not survive as well as fish that had spent three



a. In winter, high stream flows discharge directly into the ocean.

b. As stream flows recede in spring, a sand berm and embayment begin to form.

c. By summer, the outflow channel has migrated south and the sloughs are connected to the embayment. A controlled breach is accomplished at B, uncontrolled at A.

d. By late summer, the creek mouth usually closes. Heavy equipment is now used for controlled breaching so the new outlet can be closed when water level falls.

Figure 4. Embayment formation.

months in the estuary and had attained a larger size before entering the ocean. Other studies have also documented the importance of estuaries to chinook salmon (Healy 1980, 1982; Kjelson et al. 1982; Myers and Horton 1982; Simenstad et al. 1982).

Our research data indicated, that as an interim management strategy, it might be possible to control water levels in the estuary. This involved lowering embayment water levels so pastures were no longer flooded, while still retaining some portion of the remaining fish habitat. The process is referred to as controlled breaching and is intended to release water at a rate resulting in fewer fish being entrained in the outflow, and to partially maintain an embayment and substrate stability.

As the mouth migrates further south, and the length of the outlet increases, the berm gets higher and embayment water level rises. This southward migration reduces the flow gradient, decreases water velocity and amount of downcutting, and allows the berm to build higher. Conversely, reducing the length of the outlet increases channel gradient and water velocity, and results in downcutting through the berm and a reduction of embayment water levels. A breach of the berm can be controlled if the gradient of the outflow channel is kept low.

In controlled breaching, the outflow channel is shortened by capturing the flow in a new channel dug through the berm. The closer to the embayment the new channel is dug (Figure 4c), the steeper the gradient achieved, and the lower the resultant embayment water level. The park undertook active management of the remnant estuary in 1982. This was a time of experimentation, however, the embayment water level was manipulated a total of 20 times that year and except for three separate events, flooding of adjacent pastures was precluded. Throughout this period, juvenile chinook salmon used the estuary as rearing habitat (Table 1). The estuary has been managed by controlled breaching each year since 1982.

Table 1. Population and growth of juvenile chinook salmon in the Redwood Creek estuary in 1982.

Date	Population Estimate	Total Length (mm)
July 1	17,342	85.1
July 21	17,112	99.9
August 3	8,118	100.1
August 20	12,699	100.9
September 2	11,992	108.6
September 14	---	111.45
September 28	---	114.54

The park monitors juvenile salmonid population size, fish growth, food habits, and water quality in the estuary each summer. Trapping of downstream migrating juvenile salmonids was conducted from 1982 through 1985 (McKeon 1985). Population estimates for juvenile chinook salmon and steelhead trout for the years 1982-1986, reveal large numbers of juvenile fish rearing in the managed estuary. Likewise, growth of these fish was substantial, increasing their survivability upon entering the ocean.

Restoration Alternatives

Management activities implemented thus far have been interim in nature, designed to maintain some of the remnant estuary as summer rearing habitat for juvenile salmonids, but long-term, permanent restoration is the ultimate goal for the area. In keeping with the park's enabling legislation, National Park Service (NPS) Management Policies (USDI 1978), RNP's Resource Management Plan (USDI 1982) and Statement for Management (USDI 1984), the goal of rehabilitation and management actions at the mouth of Redwood Creek is to restore natural processes and the quality of aquatic habitat. This could involve both interim management as well as long-term rehabilitation. The park summarized research, outlined possible interim policies, and long-term restoration alternatives (Hofstra 1983), and has conducted yearly public meetings since 1983 to receive input and guidance on dealing with the problems at the estuary. Interim policies considered included:

No Action - RNP would not undertake management actions at the estuary and water level control would be through existing CDF&G regulations. It is unlikely that water level control would be done except in rare instances due to limited CDF&G resources. Furthermore, when private property is threatened by flooding, CDF&G is required to allow landowners to breach the sand berm and drain the embayment. The result would be annual loss of juvenile salmonids and long-term reduction in numbers of returning adult spawners.

Strict Enforcement of NPS Management Policies - This alternative would preclude water level management and strictly apply NPS Management Policies, which indicate that natural shoreline processes will continue unimpeded unless required by law or legislation. The result would be rising water levels and flooded private property. Protection of fishery resources would be achieved but alienation and economic loss to landowners would also occur. Illegal attempts to open the estuary would likely increase, leading to confrontations between enforcement personnel and landowners. Tort claims and lawsuits would proliferate.

Dredging - The aggraded necks of the north and south sloughs would be dredged on a regular basis to maintain the historic estuary depth. The amount of habitat available for juvenile and adult salmonids would be increased, and a connection between the sloughs and mainstem would exist even during relatively low water levels. However, benefits would be temporary as ocean overwash and sediment accumulation would continue. One large winter storm could quickly fill the dredge sites. The slough necks were dredged in 1983 as an experiment and because of public requests to do so. Subsequent bathymetric surveys reveal that these areas have again filled with sand. Furthermore, slough water quality was poor and limited fish use of the sloughs even though they were connected to the mainstem because of dredging.

Diking Pastures - The pasture lands threatened by flooding would be diked to prevent summer backwater inundation. Water level control would be facilitated by increasing the maximum allowable water level and a larger volume of fish habitat could be maintained throughout the summer. Costs of this alternative would be high and pasture drainage problems during winter rainy periods would be difficult to overcome.

Controlled Breaching - Using either hand tools or heavy equipment, the mouth of the creek would be breached in such a manner as to retain some embayment integrity, lower water levels, and minimize fish losses. Annual costs can be high and difficult to predict depending on the number of times breaching is required. However, this method has been implemented successfully and provides some protection to fish resources and private property.

Temporary Installation of Drainage Structure(s) - Metal pipe culverts would be placed in the sand berm to drain water from the embayment to the ocean. This was tried in 1983 with little success. The drains functioned intermittently for seven days before becoming plugged with sand. The culverts had no effect on reducing the frequency of controlled breaching; however, given a proper anchoring system, such drains if installed beyond the sand deposition zone, may carry flows throughout the summer. It is still unknown whether this would reduce the need for controlled breaching. Installation and maintenance costs are high.

Long-term alternatives would aim towards rehabilitation of the embayment while minimizing long term commitment of resources to carry out management activities. Ideally, the long-term alternatives would result in a self-sustaining, naturally-regulated estuary. The ultimate long-term solution will probably include one or more of the following:

Flood Easements - Landowners would receive compensation for the possibility of their fields being flooded. Normal dairy cattle grazing and crop production would continue, but fields could be flooded at any time. Easements would eliminate the need for embayment water level manipulation almost entirely, except when roadways would be threatened. Easements could alleviate the problems associated with conflicting land uses without the expense and problems of land acquisition. However, local landowners are opposed to easements except as a last resort to land acquisition.

Land Acquisition - The land subject to flooding would be acquired in fee and placed in public ownership. By eliminating the conflicting land uses, the major management consideration would be fisheries and other natural resources. Substantial benefits to wildlife would occur by allowing the acquired properties to become naturally vegetated and inhabited by native wildlife although land acquisition would leave landowners with a reduced land base.

Levee Removal - The lower 0.4 kilometer to 0.8 kilometer of levees would be removed and the area restored to a facsimile of its natural condition. Flows would be restored to the south slough and would provide additional circulation in the north slough. Sand accumulated in the lower estuary during summer would be scoured by winter flows, historic depths would return, summertime water quality would improve, and increased habitat for fish would result. However, the stream now carries increased bedload compared to pre-levee conditions. Consideration must be given to patterns of sedimentation that may occur in the estuary as a result of this increased bedload. Increased flooding of pastures would be expected during winter, benefitting affected areas by depositing nutrient rich silt, but crop and livestock losses could also occur.

Install Controlled Flood Gates - Culverts with manually operated floodgates would be installed through the levees at the points where the north and south sloughs historically connected with the mainstem. Controlled flood gates would allow only regulated flows to circulate through the sloughs and could be closed when desired. Perhaps the greatest benefit would be during the summer low flow period when the gates could be opened to improve circulation and water quality, restoring these areas to productive fish rearing habitat. Fish could pass directly through the culverts from the mainstem and utilize this restored habitat.

Habitat Restoration

Implementation of one of the long-term restoration alternatives, placing controlled flood gates (culvert) through the south levee and into the upper end of the south slough (Figure 3 and Figure 5), became a possibility in late 1983. The California Department of Transportation (Caltrans), with funding by the Federal Highway Administration (FHWA), was completing plans for a freeway bypass to be constructed around a portion of Redwood National Park and in tributary streams of Redwood Creek. During analysis of the potential impacts from highway construction, it was recognized that erosion and sediment from the project would adversely impact downstream fish spawning and rearing habitat. Biologists from the CDF&G, Caltrans, and RNP identified and characterized the pre-project salmonid habitat quality and quantity in affected streams. Using estimates of sediment yield provided by Caltrans project engineers, biologists estimated the fisheries losses that would result from the bypass (Wood et al. 1982). Both fish numbers and their calculated dollar values were used to lay out a multi-part program of mitigation which would respond to short and long term fisheries losses.

In its entirety, the mitigation program includes money to upgrade or continue the operation of existing hatcheries, to place a hatch box and rearing pond in a tributary of the Klamath River (also an affected basin), to restore habitat in a Klamath tributary, to restore habitat at the mouth of Redwood Creek by improving water circulation in the estuary, and to replace in-kind wetland and riparian resources lost by the project. Implementating the culvert alternative required preparing and signing a variety of agreements between involved agencies. A five part agreement was signed by NPS, Humboldt County, Caltrans, U.S. Fish and Wildlife Service, and FHWA describing the entire fisheries, wetland, and riparian mitigation program. This was followed by separate agreements between NPS and the Corps, the County of Humboldt, and Caltrans to outline responsibilities for implementing and maintaining the culvert project. The park was to obtain all necessary permits and maintain and operate the culverts. Caltrans was to obtain rights-of-way from private landowners and the County of Humboldt (who owns the levees). With Caltrans and FHWA funding, the Corps designed, and will oversee the construction contract for the culverts.

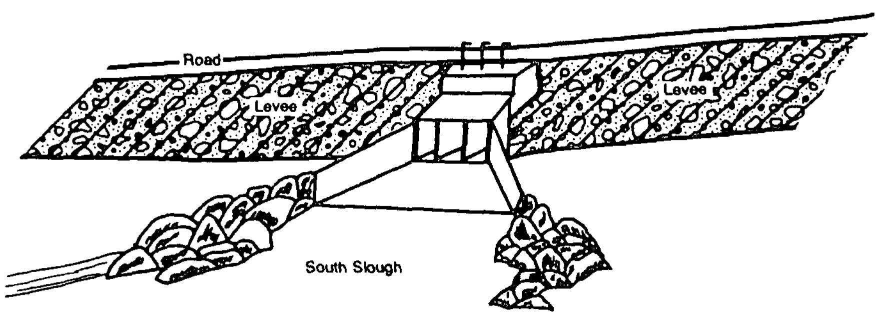


Figure 5. Controlled flood gates will be constructed through the south levee to improve water circulation in the south slough.

The agreement between the park and Humboldt County proved to be the most problematic. Questions arose over responsibility and liability. Humboldt County was reluctant to grant a right-of-access for construction and operation of the culvert because the culvert was viewed as an additional potential liability risk. While the park was willing to operate and maintain the structure in accordance with Corps requirements, the County would still remain ultimately responsible should proper maintenance not occur. This liability is the result of the county being Congressionally designated as responsible for operation and maintenance. Therefore, the Corps could not relieve the County's responsibility regardless of the park's willingness to assume maintenance activities. The County public works department recommended that County Supervisors reject the request for a right-of-way, saying it would place the County at risk of future maintenance expenses and damage claims. County Supervisors, however, voted to allow the project to proceed, and accepted any additional risk as a trade-off for benefits accrued to fisheries by the project, and to avoid impacts to future highway construction if mitigation for this highway project was impeded. The County recommended several changes to the preliminary design plans which were made by the Corps and approved by the park.

Conclusions

Management and restoration of the damaged ecosystem at the mouth of Redwood Creek illustrates the effectiveness of applied research and agency coordination in responding to environmental problems. Benefits will serve as mitigation for fisheries losses expected from an action occurring in another portion of the Redwood Creek basin, and also represent the first step in restoring a previously damaged system.

The Redwood Creek estuary, while relatively small in size, reflects the same ownership, land use, political, and jurisdictional problems that are commonly found in other estuarine areas. These problems compound the difficulty in treating the effects of damaged resources. However, this example also shows that early recognition of potential problems, researching these problems, and innovative management can result in resource protection and restoration.

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