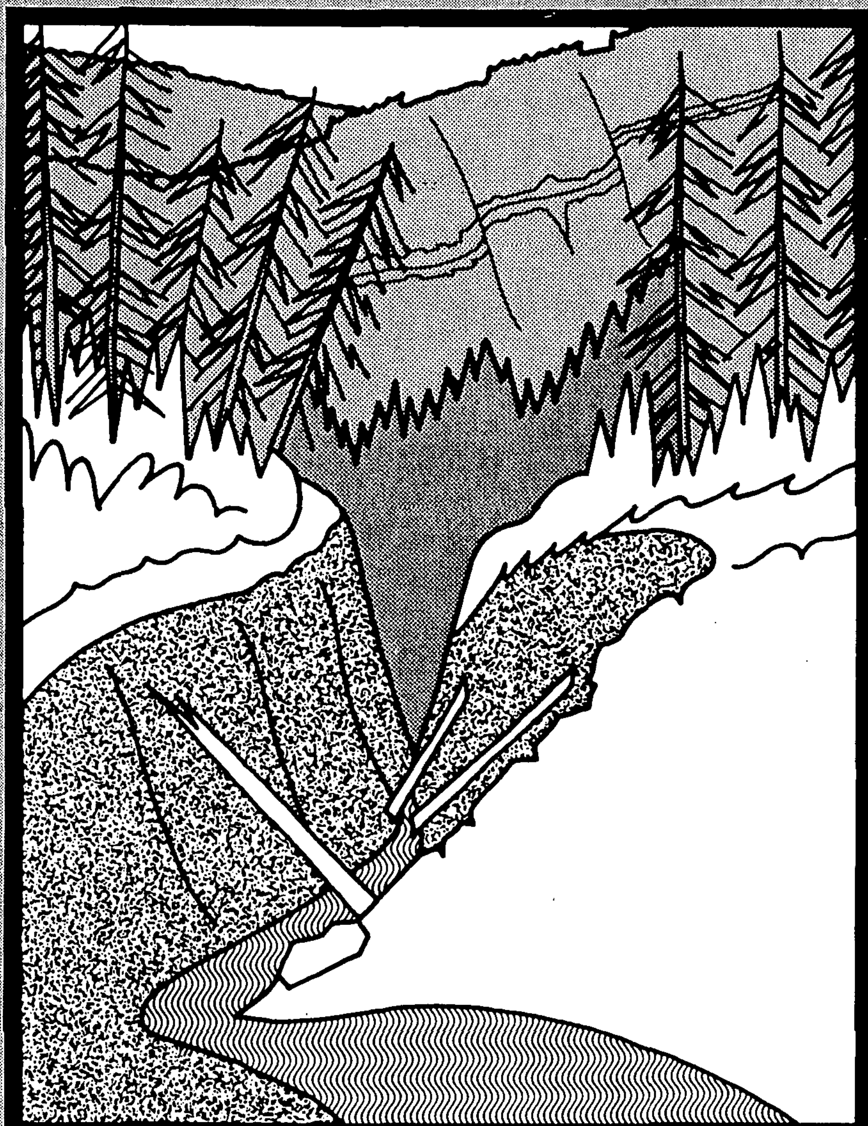
WATERSHED REHABILITATION IN REDWOOD NATIONAL PARK AND OTHER PACIFIC COASTAL AREAS

Proceedings of a symposium held August 24-28, 1981

Edited by R.N. Coats



CENTER FOR NATURAL RESOURCE STUDIES OF JMI, Inc.
and NATIONAL PARK SERVICE

PROCEEDINGS OF A SYMPOSIUM ON WATERSHED REHABILITATION IN REDWOOD NATIONAL PARK AND OTHER PACIFIC COASTAL AREAS

Edited by
Robert N. Coats

THE CENTER FOR NATURAL
RESOURCE STUDIES, JMI, INC.

in cooperation with the

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PREFACE

With the expansion of Redwood National Park in 1978, the National Park Service embarked on an ambitious program to rehabilitate disturbed and cut-over forest lands on steep and highly erodible terrain in the basin of Redwood Creek, Humboldt County, California. Fortuitously, this program has coincided with a period of rapidly growing interest among watershed scientists, land managers and practitioners in the problems, processes and limitations of steep forested lands. In keeping with the National Park Service's long tradition of respect for basic research, the watershed rehabilitation program at Redwood National Park has played an important role in the growth of the professional "watershed community", and has contributed valuable information on both specific rehabilitation techniques and basic watershed processes. The purpose of this volume is to bring into focus both the recent work of the Park's rehabilitation program and other work relevant to the problem of maintaining and restoring watershed values in Pacific coastal areas. It complements the collection of "Readings in Watershed Management and Rehabilitation" which was distributed at the August 1981 Symposium.

The papers in this volume are organized into five sections. These are: 1) Processes and issues relating to watershed rehabilitation; 2) Restoring vegetation for erosion control and natural succession; 3) Hillslope processes and rehabilitation techniques; 4) Stream channel processes and fisheries restoration; and 5) Management alternatives, case studies and cost effectiveness. The flow of papers is meant to follow the flow of both watershed and thought processes that managers go through when grappling with the problem of watershed rehabilitation in steep forested lands.

ACKNOWLEDGEMENTS

Numerous institutions and individuals made the Watershed Rehabilitation Symposium possible and contributed to its success. Funding for the Symposium was provided by the National Park Service, the U.S. Geological Survey, the California Department of Water Resources and the State Water Resources Control Board. The USDA Forest Service Pacific Southwest Region also provided helpful logistic support for the Symposium. We gratefully acknowledge the support of these agencies.

Taylor Miller, Laurel Collins, Joan Florsheim and Patti Kolb of the Center for Natural Resource Studies all contributed to organization and administration of the Symposium and publication of the Proceedings. David Nagler and Sue Breitenbach of J. Lewis Associates and William Israel and the staff of the Jolly Giant Conference Center provided invaluable assistance with Symposium arrangements and facilities.

We extend our sincere appreciation to the National Park Service Western Region and the technical and clerical staff of Redwood National Park for their enthusiastic support of the Symposium and tireless efforts to make it a success. We particularly thank Howard Chapman, Director, John Davis and Gerard Witucki of the National Park Service Western Regional Office and Robert Barbee, Redwood National Park Supervisor for their support and interest, and Lee Purkerson, Bill Weaver, Lisa Babcock, Danny Hagans, and Ron Sonnevil for technical assistance in conducting the Symposium and field trip.

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N. Coats, Editor

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ERRATUM - Acknowledgment

In accordance with Murphy's Law, the California Department of Forestry was inadvertently omitted from the Acknowledgments. The Department of Forestry provided key funding support at the early stage of developing the Symposium. We regret the error and express our appreciation for the Department's support and participation in the Symposium.

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STRATEGY FOR RESTORATION OF CHANNEL STABILITY,

CARMEL RIVER, MONTEREY COUNTY, CALIFORNIA

Robert R. Curry[1] and G. Mathias Kondolf[2]

ABSTRACT

The Carmel River Basin of 670 km^2 was dammed in the 1920's. Prior to that, the lower 24 km alluvial reach had been a high-gradient braided largely-ephemeral arroyo typical of chaparral-dominated central coastal watersheds. Fire suppression, reservoir sedimentation, and a sequence of low-flood magnitude years led to channel incision, narrowing, and growth of a major riparian vegetation community. Loss of riparian vegetation in some sites, coupled with moderate magnitude flood flows caused destabilization of the channel locally and a return to conditions more typical of those prior to 1920. A management plan has been developed to attempt to achieve the conditions of quasi-stability to which the residents had become accustomed by the mid-1960's when riparian vegetation began to die back.

INTRODUCTION

The Carmel River drains a 670 km^2 (255 mi^2) basin. Rising in the rugged Santa Lucia Mountains and passing through the 24 km (15 mi) long, alluviated Carmel Valley, it ultimately discharges into the Pacific near Carmel, Calif. (fig. 1). This alluvial reach is sub-divided by a bedrock constriction and narrowing of the valley (the "Narrows") into a lower 16 km (10 mi) reach (the "Lower Carmel") and a middle 8 km (5 mi) reach (the "Middle Carmel"). The "Upper Carmel" refers to the segment above San Clemente Dam (fig. 2). Average annual rainfall in the mountainous headwaters with elevations to 2133 m (7000 ft) is 1040 mm (41 in) but decreases to 430 mm (17 in) in the lower valley. While the upper river is perennial, the lower river is intermittent, with surface flow typically from December through June. Near the river's mouth, average discharge is 2.7 cms (97 cfs), and the bankfull discharge (here, the 2.4 yr flow) is 79.2 cms (2800 cfs).

Two water supply dams, the Los Padres and San Clemente Dams, together impound about 3000 ac-ft (fig. 1). The Carmel basin supplies most of the water for the Monterey Peninsula cities of Monterey, Pacific Grove, Seaside, and Carmel. As these areas have grown, demand for water has risen substantially. To meet demand, California-American Water Company (Cal-Am), a private utility, has drawn increasingly upon water supply wells in the alluvium along the lower and middle Carmel valley over the past two decades. Of the 13,000 ac-

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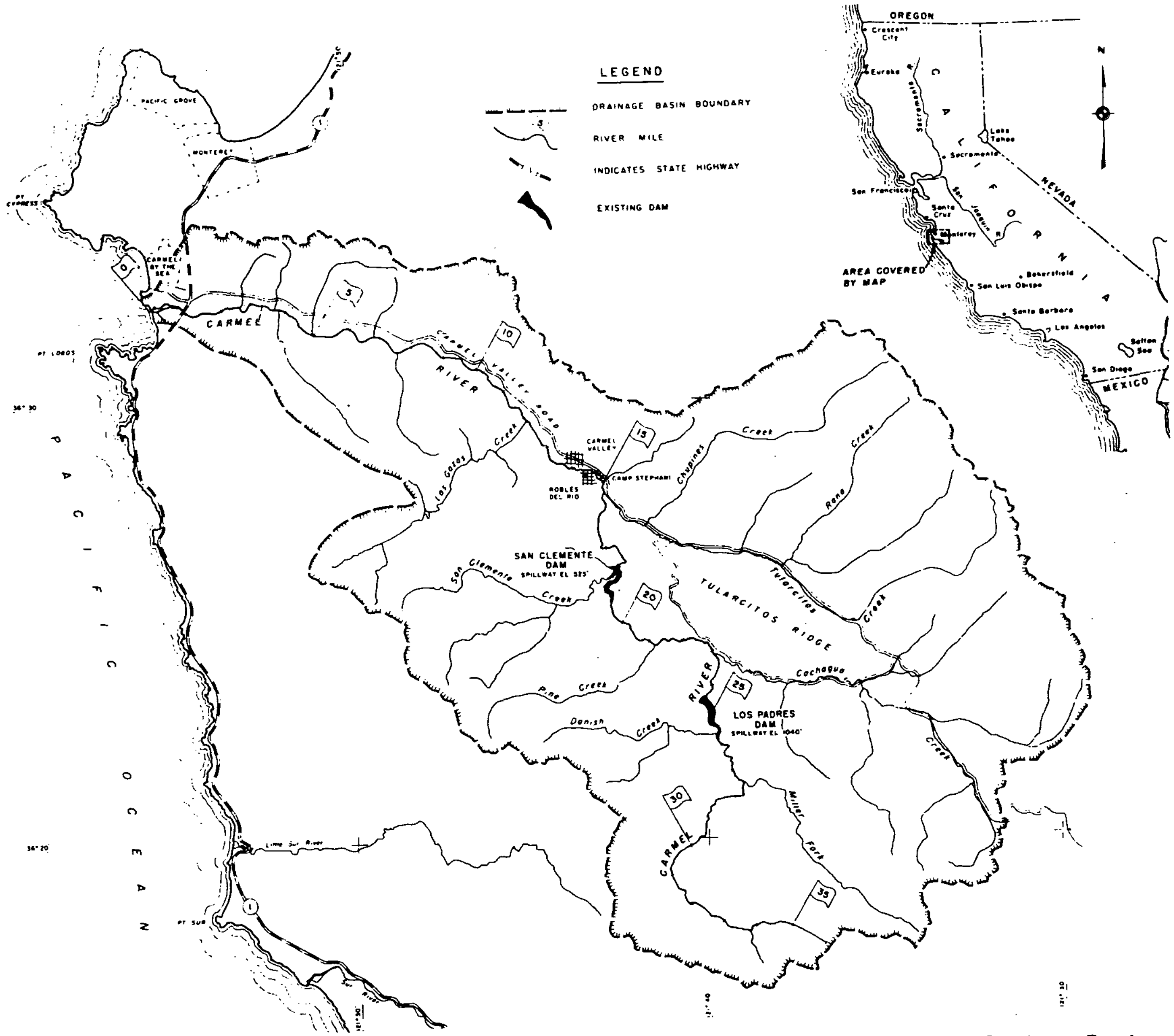

Figure 1a) Vicinity map of the Carmel River Basin.
1b) General map of the Carmel River Basin. (U.S. Army Corps of Engineers, 1967)

ft total exported from the basin in 1980, 9,000 ac-ft was diverted from reservoirs, and 4,100 ac-ft was extracted from streamside wells.

By the late 1960s, residents were complaining that vegetation was dying off near the wells in the "mid-valley" region, in the vicinity of Robinson Canyon Road (fig. 2, also see Lee, 1974). The Carmel Valley Property Owners Association hired a forestry consultant to study the vegetation problem; he concluded that lowered water tables near the wells killed the vegetation (Zinke, 1971). Cal-Am hired another consultant, who acknowledged that lowered water tables near the wells affected vegetation, but observed that the effect was simply an acceleration the "natural succession" of vegetation (Stone, 1971).

The drought of 1976-1977 imposed additional demand on streamside wells. The die-off of phreatophytes was significant in the mid-valley region and above the Narrows - two areas of substantial groundwater withdrawal. The high flows of 1978 and 1980 resulted in severe bank erosion, primarily in areas where bank-stabilizing vegetation had been affected.

HISTORY

River course and pattern changes were documented by comparing maps of the Carmel River from 1858 to 1945 and aerial photos of the river from 1939 to 1980. Extensive channel surveys were conducted in 1965 by the Corps of Engineers and again in 1980-81 by the Monterey Peninsula Water Management District.

CHANGES IN COURSE

Historical changes of the Carmel River from Garland Ranch to the mouth were assessed. The 1858 and 1882 channels were determined from boundary surveys. The 1911 course appears on the USGS Monterey 15′ topographic map of 1913 (based on surveys in 1911-12), and the 1945 course is taken from the USGS Monterey and Seaside 7.5′ quads of 1947 (based on aerial photography in 1945). The 1947 maps were photorevised in 1968, but the only mapped revision in the river′s course was downstream of Garland Ranch, where a northward bend of the river was eliminated by highway construction.

Comparison of these channels reveals nine localities where lateral channel migrations of 250-500 m (820-1640 ft) occurred during the 87 years between 1858 and 1945. Except for the changes in course near Garland Ranch Park, no major shifts of course have occurred since the survey of 1911-12, which was completed after the flood of 1911. While more gradual migration and changes in channel geometry have occurred since, dramatic changes in channel course that would be evident at mapped scales are absent from 1911 to 1945. This is consistent with the observation that most major shifts take place during large floods. No floods comparable to the 1911 event occurred between that year and 1945, nor have they since.

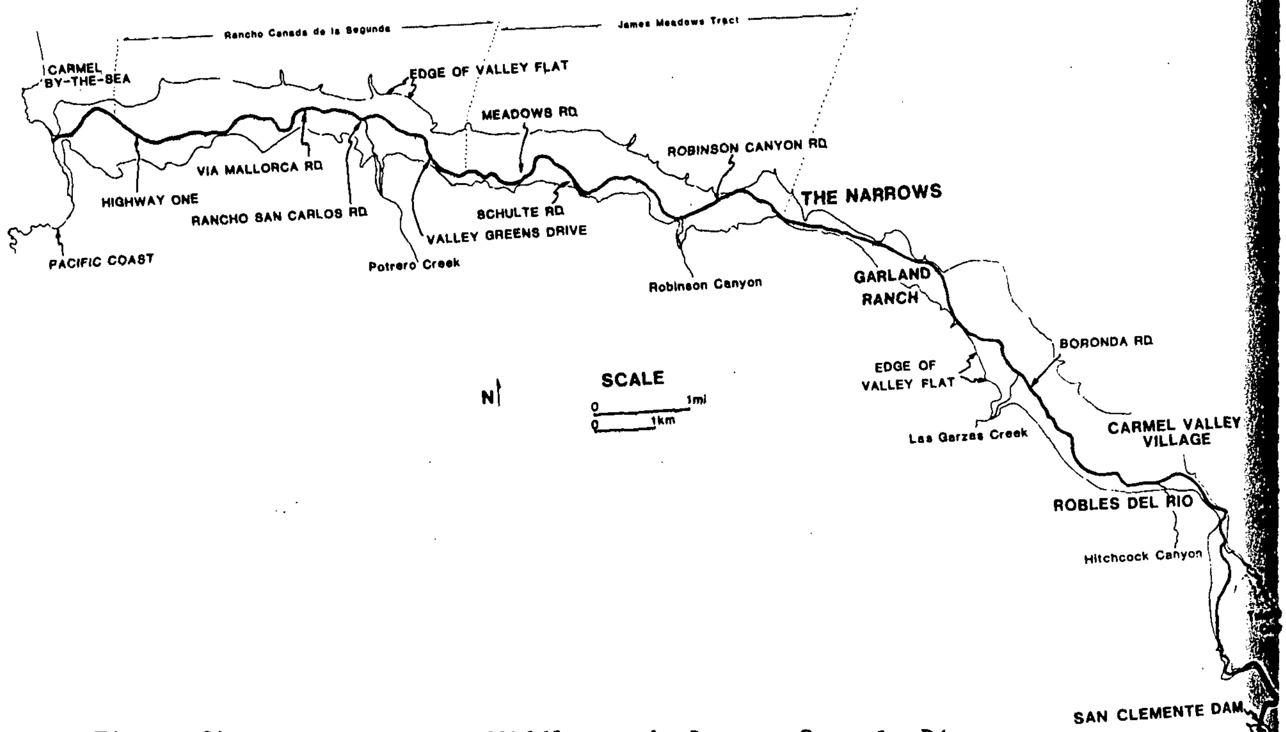

Figure 2) Location map, Middle and Lower Carmel River. (Base from USGS Monterey, Seaside, and Carmel Valley 7.5′ Quadrangles)

FLOOD HISTORY

The earliest flood of record along the Carmel was the great statewide deluge of 1862. While no records exist to document the exact magnitude of this flood, it was severe enough to induce the few valley residents to move to higher ground (Roy Meadows, pers. comm. of family history). Most of the great changes in channel course visible between the 1858 and 1882 channels in Rancho Canada de la Segunda probably occurred during this flood.

The next great flood occurred in 1911. An account in the Monterey Cypress of March 11, 1911, reports that Fannie Meadows and Roy Martin lost ten acres and a pear orchard due to lateral migration of the river. Their adjacent properties extended downstream from the present Schulte to Meadows roads. The flood of 1911 was a large magnitude event. Before it was swept away, a staff gauge at the present site of the San Clemente Dam indicated a discharge of 480 cms(17,000 cfs). In 1914 another major flood occurred, but this one was far less destructive. It is not known whether this flood was significantly lower in magnitude than the 1911 event, or if it simply caused less disruption because it flowed through a channel preadjusted to the large 1911 flow.

No comparable floods occurred in the following decades. The absence of floods, together with the drop in sediment load resulting from construction of the San Clemente Dam on the main channel in 1921, served to permit channel incision, narrowing, and increased sinuosity.

CHANGES IN SINUOSITY AND GRADIENT

Sinuosity, defined as the ratio of stream channel length to valley length, was computed for several sequential channels. From 1911 to 1945, the reach of river from Garland Ranch to the mouth increased in sinuosity from 1.11 to 1.18. The reach from Sleepy Hollow to Las Garzas Creek experienced an overall increase in sinuosity of 1.05 to 1.09 from 1917 to 1954. Slopes computed from the 1911 and 1945 mapped channels from Garland Ranch to the mouth show a decrease from .0034 in 1911 to .0029 in 1945. At sites of local disturbance with increased bank erosion and resulting imposed sediment load, very considerable increases in gradient are noted today. For example, the reach from the Manor Well to Schulte Road increased from a gradient of .0017 in 1965 based upon Corps of Engineers surveys to a gradient of .0059 in 1981 based upon current surveys. The overall increase in sinuosity and decrease in gradient from 1911 to 1965 suggests that the Carmel River stabilized in the aftermath of the 1911 flood.

CHANGES IN CHANNEL PATTERN AND FORM

Channel pattern (pattern in plan view, e.g. meandering, braided) and form (cross sectional shape, e.g. narrow, wide) of the Lower and Middle Carmel River have changed dramatically since the last major flood and dam construction. No doubt, the entire Lower and Middle Carmel was strongly modified by the 1911 and 1914 floods. The resulting channel is probably well represented by the historical photos (ca. 1918) from the Slevin Collection (U.C. Berkeley). These photos (plate 1) of the river, at and downstream of the Narrows, near Robinson Canyon Road, show a wide, sandy channel, reflecting the recent passage of a major flood.

By 1939, the Lower Carmel had developed a narrower, more sinuous channel while the Middle Carmel retained much of its braided character, as

Plate 1) Carmel River channel, 1918, viewed from right bank upstream from location of present Robinson Canyon Road bridge. (Slevin Collection, Bancroft Library, U.C. Berkeley)

demonstrated by aerial photography of 1939.

This change in channel pattern occurred concurrently with the increase in sinuosity and decrease in gradient apparent by 1945. Together, they indicate that the Lower Carmel had adjusted to the absence of major floods and to the cut-off of 60% of its previous sediment load (based on drainage area upstream of San Clemente Dam). These adjustments included channel narrowing with encroaching vegetation, an increase in sinuosity, and reduction of gradient through incision. Similar adjustments have been documented in other rivers in response to the absence of floods or to construction of upstream dams (Leopold, et al., 1964, p.453-458).

Above the Narrows along the Middle Carmel, similar adjustments took place, but they occurred later. The 1939 aerial photos show the scars of numerous anastamosing channels in the Middle Carmel. By 1971, most of these scars no longer appeared on the photos. Accompanying this change in pattern was degradation of the bed. Sequential cross sections show 1.5 m (5 ft) of degradation under the Boronda Rd. bridge from 1946 to 1980.

By the 1960s, most of the Lower and Middle Carmel had developed a narrow, sinuous, well-vegetated course. It bears repeating that these conditions developed only in the absence of major floods and depended upon a cut-off of upstream sediment by the dams. Additionally, before their suppression by European settlers, fires occurred regularly in the upper Carmel watershed. U.S. Forest Service studies in the Santa Lucia mountain headwaters demonstrate an approximate 21-year fire frequency from the record preserved in the oldest fire-scared trees from 1640 to 1907. From 1907 to 1977 there was no fire, and then the Marble Cone Fire burned a major portion of the northern mountain range. The accumulation of sediment in the Los Padres reservoir after the Marble Cone fire of 1977 was dramatic. The capacity of this reservoir decreased from 3200 ac-ft upon closure in 1947 to 2600 ac-ft in 1977, a loss of storage of 600 ac-ft in 20 years. Following the Marble Cone fire and the high flows in the ensuing winter, the reservoir's capacity decreased to 2040 ac-ft by the end of 1978. Thus, in one year the reservoir lost 560 ac-ft of storage (B. Buel, Monterey Penin. Water Mangmt. Dist., pers. comm., 1981). This post fire sedimentation rate was nearly twenty times greater than the pre-fire rate. Prior to dam construction, all this sediment passed through to the Middle and Lower Carmel. It is probable that a wide, steep channel would have developed to transport these high sediment loads. However, it is notable that the sediment contributed by the recent bank erosion has passed through lowermost reaches of the Carmel (Valley Greens Drive downstream) without destabilizing that narrow channel. The stability of this lowermost reach may be due to the stability of vegetation in that unpumped area of consistently high groundwater. Alternatively, it may be in part due to the automobile bodies and rip-rap emplaced within the banks or to the extensive irrigating of stream side golf courses. Without these stabilizing influences, the channel might have widened in response to the higher load. Alternatively, such a narrow channel in its natural state, protected only by bank vegetation, may be able to pass these high loads without disruption of its existing geometry. In this latter case, the observed changes in channel pattern, form, gradient, and sinuosity must be ascribed to recovery from the major floods of 1911 and 1914.

RECENT BANK EROSION

Peak discharges over the winters of 1978 and 1980 were 168 cms (5920 cfs) and 208 cms (7360 cfs) respectively. These flows resulted in massive bank erosion along parts of the Middle and Lower Carmel. Most severly affected was the region upstream of Schulte Road Bridge. Here the channel at bankfull discharge (defined as the flow with a recurrence interval of 2.4 years on an annual maximum series) increased in width from 13 m (43 ft) to 35m (115 ft) in two years. This increased the width/depth ratio from 15 to 113. Aerial photographs show the changing aspect of this reach from 1939 to 1980. In 1939 and 1965, a narrow channel fringed by dense riparian vegetation is visible (plate 2a and 2b). The 1977 photo indicates no obvious change in the channel, but does show a marked thinning of streamside trees (plate 2c). The 1980 photo exhibits a major widening of the channel, most of which occurred during one storm in the winter of 1980 (plate 2d).

Throughout the Middle and Lower Carmel, the river banks are composed of unconsolidated sands and gravels, which lack cohesive strength in the absence of binding vegetation. These banks apparently offered no resistance to lateral erosion. A comparison of surveys and air photos of 1965 and 1980 from Schulte Bridge upstream .6 km (.4 mi) indicates that 100,000 m^3 of bank material was contributed to the river locally, mostly during the winter of 1980. The resulting channel is wide and floored by sand and gravel (plate 2d).

Similar, but less destructive lateral erosion occurred near Robinson Canyon Road. The well vegetated narrow channel of 1939 and 1965 had suffered a loss of riparian trees by 1977 and substantial bank erosion by 1980.

The die-off of bank vegetation and consequent lateral erosion appear to be coincident with lowering of water tables below the root zone of trees in the vicinity of water supply wells. Downstream of Valley Greens Drive, where no producing wells were located, the riparian community remained largely unaffected during the drought. The channel there remained stable during both the 1978 and 1980 winters. A plot of water table elevations for the drought, i.e. drawdown (October 1977), and post-drought, fully-recharged conditions (May 1978) shows far less drawdown in this lowermost reach of the Carmel (fig. 3). This figure shows that along much of the Middle and Lower Carmel the water table was drawn down about 10 meters. This is generally considered to be below the root zone of riparian willows (Zinke, 1971). Most points of figure 3 were chosen to be distant from major producing wells so that regional water table elevations would be shown, but one point (at 8.5 km upstream) fell within the cone of depression of a producing well. The depression of the water table here reflects the widespread drawdown created by wells in the highly permeable alluvium of the Carmel Valley. While the drought of 1976-1977 certainly exacerbated the drawdown problem, the drought alone cannot explain the fact that the vegetation die-off and subsequent bank erosion affected certain areas only.

MANAGEMENT RECOMMENDATIONS

The primary goal of local landowners has been the restoration of the main river channel to the conditions of the early 1960's. These conditions are

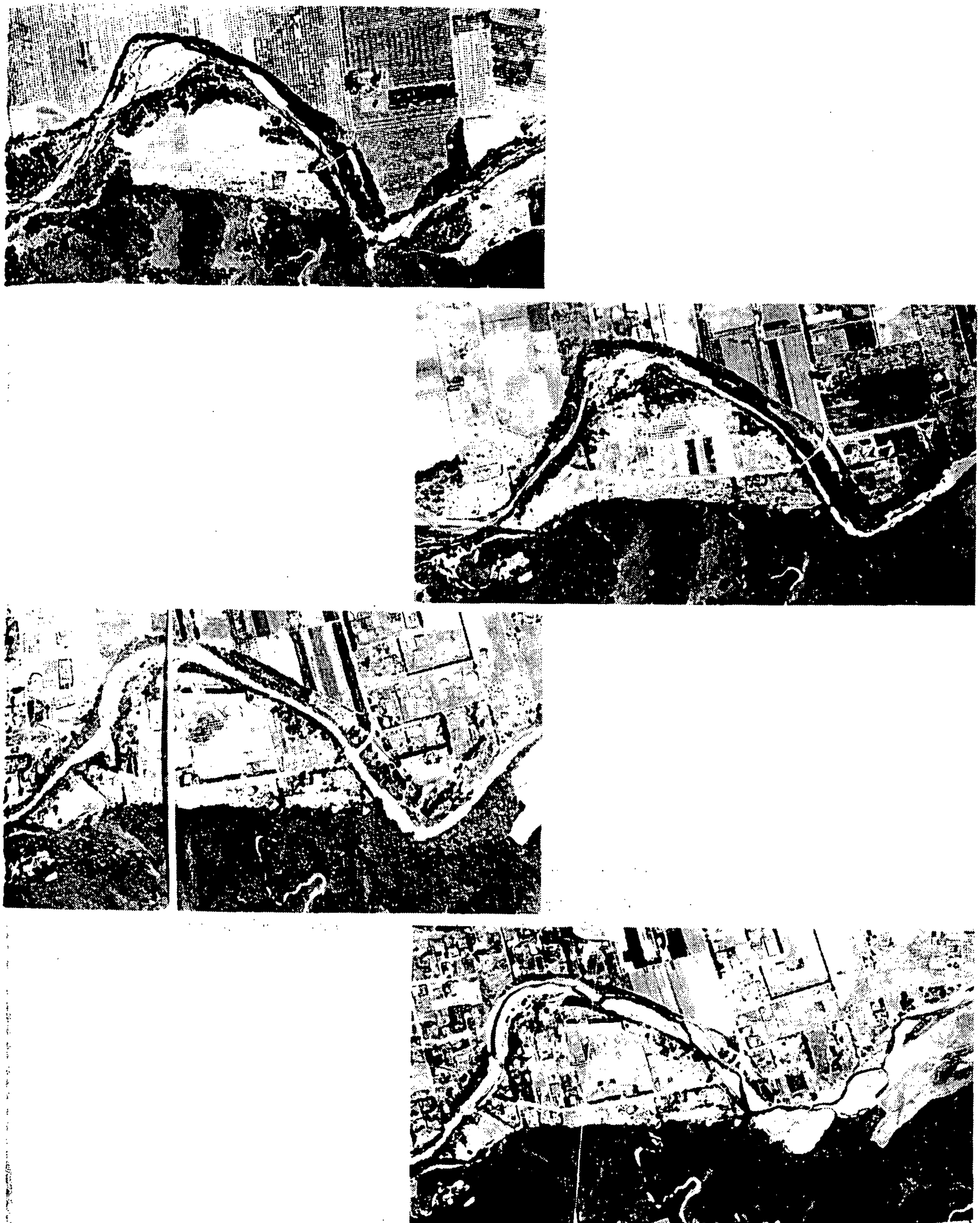

Plate 2) Aerial photographs of the Carmel River near Schulte Road bridge. a) 1939, b) 1965, c) 1977, d)1980. (Air photo collection, Monterey County Flood Control, Salinas)

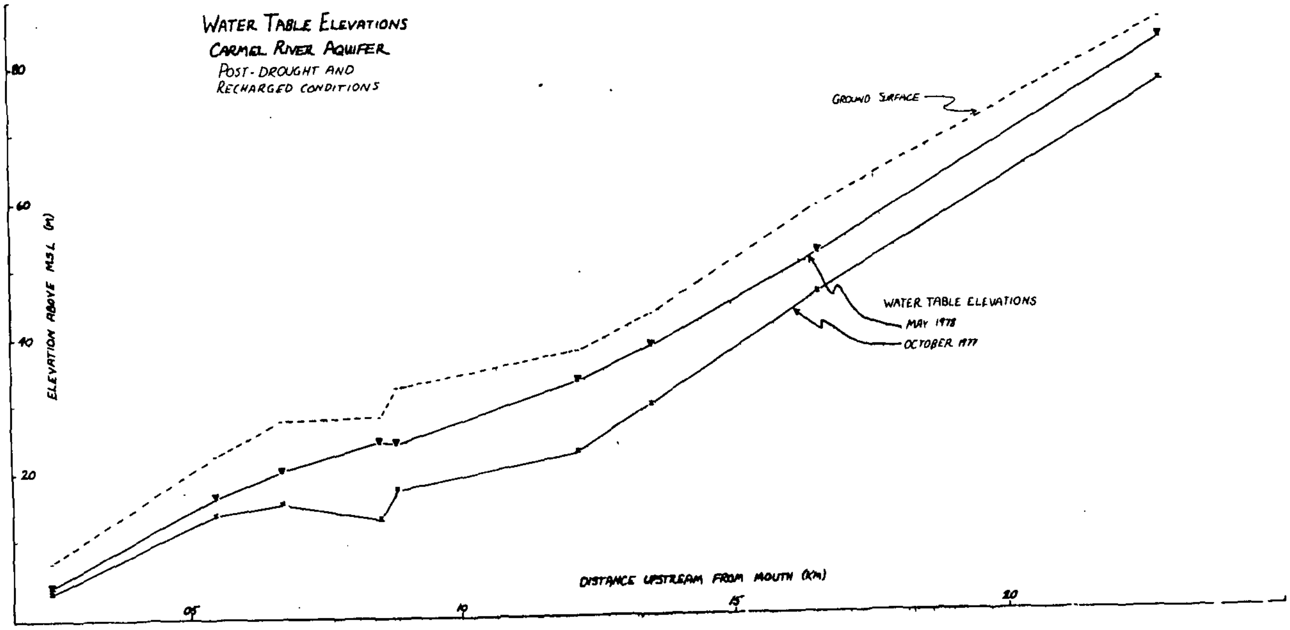

Figure 3) Water table elevations, drought and recharged conditions. (Data from Monterey County Flood Control well level records)

not "natural" in that, although they developed without significant direct human intervention or planning, they did so in response to significantly altered sediment loads. The sediment discharge alterations were not natural in that they resulted from fire suppression, dam construction, and, possibly, from an unusually long period without significant flooding. Thus, management recommendations must be those that reestablish and maintain a quasi-stability. Any such effort must be taken with full knowledge that no such "stabilization" can be permanent.

EROSION MITIGATION

Efforts by individuals to control bank erosion along the Carmel include those with a wide range of cost and effectiveness. Rip-rap has been used with mixed results. Among the materials used for rip-rap on the Carmel are ornamental dolomite, concrete blocks, and rubble from Cannery Row. Gabions and pervious fences with rock fill have been used successfully. Some landowners are attempting to establish willows on their eroding banks, but many of these seedlings are not adequately irrigated and die. One of the most popular revetment strategies is emplacement of automobile bodies in the eroding banks. The individual bank protection efforts thus far are uncoordinated and may have deleterious downstream effects. The government agency charged with managing the area's water resources, the Monterey Peninsula Water Management District, is now considering an integrated management plan for the Carmel River. As part of this effort, experimental work is ongoing in 1982 with various vegetated revetments such as "willow rolls". Some of these will be irrigated and others will be established without irrigation if possible.

Since the primary source of in-channel sediment today is bank erosion, and since severe channel destabilization occurs wherever banks are eroding rapidly, the primary initial goal of erosion mitigation is bank stabilization through revegetation. Where bank recharge or regional groundwater levels remain high enough throughout the year to support stabilizing vegetation, a simple goal of replanting damaged sites is sufficient. Since most such sites are presently well vegetated, no immediate remedial work need be done. Where seasonal groundwater "overdraft" has contributed to loss of bank vegetation and where active ongoing erosion and bed aggradation make revegetation problematic, more effort is needed. Here three basic plans are being considered.

To provide sufficient moisture to maintain bank-stabilizing vegetation through periods of moisture stress, the Monterey Peninsula Water Management District has undertaken research on the physiological ecology of site-adapted suitable vegetation. Studies are now underway to determine the maximum depths from which water may be extracted by plants that help retain channel banks at higher flows, without leading to seasonal die-back or reestablishment of unsuitable rooting patterns.

After this is known for the local species (primarily willows and alder), plans will be made to supplement water needed to maintain bank vegetation. Phreatophytes will be watered, when needed, to maintain a vigorous community for erosion control, maintenance of engineered bank stabilizing structures, and development of suitable riparian wildlife and fisheries habitat. To accomplish this, the Water Management District is investigating 1). direct surface irrigation (now done by drip and sprinkler in one reach), 2). injection irrigation (to depths that maximize bank-stabilizing root development), and 3). flow regulation through controlled releases from the reservoirs to recharge bank storage directly.

Structures designed for channel bank stabilization will be primarily those that utilize vegetation as an integral part of the structures. Such "biotechnical" approaches are desirable primarily because of need to restore fishery habitat as well as bank stability. An excellent review of such vegetative bank stabilization work is presented by Siebert (1968). The papers presented elsewhere in this volume by Gray and by Seidelman provide examples of use of this technology for slope stabilization as well.

RE-DESIGNING AND RE-TRAINING THE OPTIMUM CHANNEL

The "river training" experience of New Zealand engineers provides a possible model for restoring unstable reaches of the Carmel (Nevins, 1967). Their procedure is to determine "design geometries" from stable reaches and to re-engineer unstable reaches to the design geometries. Cross sectional geometry, sinuosity, and gradient of the stable reaches are duplicated as closely as possible in the unstable reaches. Initially, bank protection works are used to stablize the banks and willows are planted. Once fully established, the willows are expected to become the principal bank stabilizing agent. The re-engineered channels in New Zealand have remained stable at all but very high flows. If large discharges disrupt the design channels, these reaches can be re-engineered to design specifications at a lower cost than the initial work (Nevins, 1967).

For the Carmel River, the stable reaches downstream of the disturbed reaches can serve as models for design geometries. In figure 4, cross sections are plotted for an eroded reach upstream of Schulte Road (section 37) and for a stable reach about 1.5 km (1 mile) downstream (section 45). No tributaries enter between these sections, so discharge remains essentially constant. Yet the present-day geometries are vastly different. Surveys by the U.S. Army Corps of Engineers in 1965 indicate that the reach encompassing section 37 was characterized by a geometry closely resembling that of the present-day section 45. Thus, a design stable geometry for section 37 could be drawn largely from the existing geometry at section 45. Certain corrections would have to be made for differences in gradient, sinuosity, and bed material size between these reaches. Fortunately, many of these parameters are well documented for the stable, pre-disturbance Carmel River.

Width-to-depth ratios for vegetated channels that had stabilized following dam construction were, in 1965, on the order of 15-25:1 for a 2.4-year recurrence interval bankfull flow. Design of restabilized channels will emulate these ratios. Vegetated permeable jacks will be used to constrain the channel to these widths. Since aggradation has gone on locally during the recent destabilization, depth and gradient manipulation will have to be accomplished to restore stability. Current plans are to investigate opportunities for "flushing flows" that can be augmented with reservoir releases during periods of seasonal high flow. Preliminary field evidence suggests that flows on the order of magnitude of the mean annual flood are effective for bedload transport and channel incision. Primary goals are to develop sediment transport and sediment routing models that will optimize transport while minimizing bank erosion and local overbank flooding caused by aggradation. Since sequential or long-duration low magnitude flows lead to bed armoring and cessation of further downcutting, management models must accommodate natural or induced flows that will effectively mobilize armor layers.

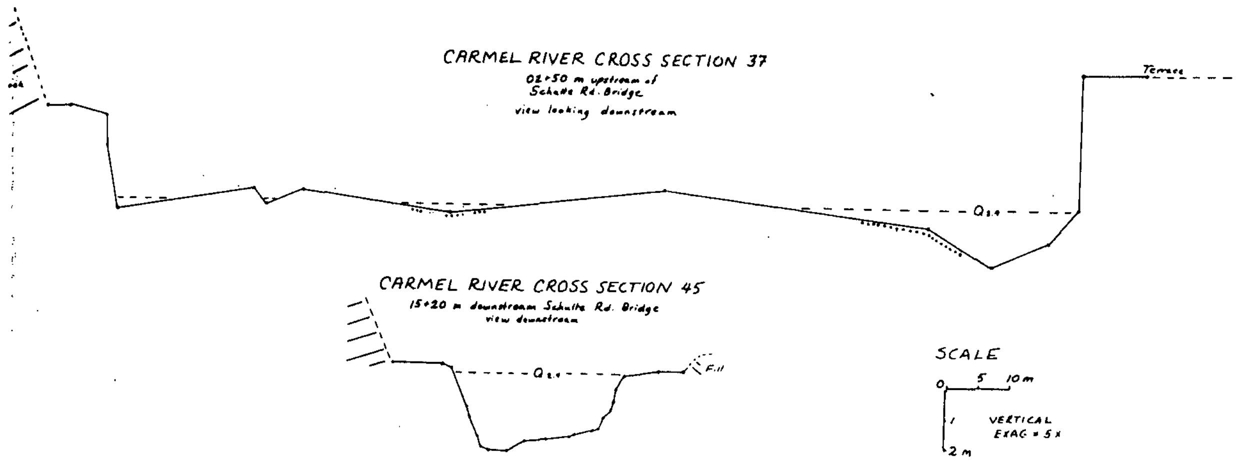

Figure 4) Channel cross sections of the Carmel River near Schulte Road Bridge. Section 37: 250 m (820 ft) upstream of bridge, Section 45: 1520 m (5000 ft) downstream of bridge. Discharge remains essentially unchanged between reaches. (From field surveys by the authors)

This modeling is being done using Modified Einstein and Meyer-Peter and Muller bedload transport functions calibrated with bedload transport measurements and scour observations made during a 200 cms (7000 cfs) discharge event in January, 1982.

The success of a river training program depends, in part, on a favorable flow regime in the years following channel redesign. A major flood (e.g. a 20-30 year event) in the first few years following the redesign may take out the new banks before they have been stabilized by vegetation. A catastrophic flood (e.g. a 75-100 year event) will probably carve a new channel for itself regardless of how well-vegetated the existing banks might be (Nevins, 1967). Applying these concepts to the Carmel, we might expect that a flow comparable to the 1980 event within the first five-to-ten years following channel re-design could damage the design banks. An event comparable to the 1911 flow might take out the design banks whether vegetated or not.

CARMEL RIVER MANAGEMENT PROGRAM

To develop and implement a channel-stabilization program, the Monterey Peninsula Water Management District, in November, 1980, formed the Carmel River Advisory Committee. The express purpose of this body was to "Propose a comprehensive program of activities, institutional arrangements and financing mechanisms to manage and maintain the health of the Carmel River riparian corridor". After 15 meetings and considerable staff work, a program plan has been developed. This plan proposes the following:

1. Formation of a management "Zone" for a 10-year minimum period in which actions take place and through which authority for restorative and preventive work is implemented.

2. Formulation of standards and a structural master plan to guide all streambank and channel modification projects. Guidelines are to set, at minimum, optimum channel width, depth, and bank steepness conditions; establish coordination requirements among adjacent landowners; evaluate cost and effectiveness of alternative bank stabilization approaches; establish preferred approaches; define acceptable circumstances and processes for sediment removal; set general engineering requirements for materials and design; and establish requirements for covering, replanting and maintaining works once completed. This work is to be done by a fluvial geomorphologist/engineer, and standards are to reviewed and revised annually as experience is gained.

3. Annual review is to be made of the full channel by a fluvial geomorphologist and a full flight-line of aerial photos are to be taken each spring to document changes and determine areas that may need protective work before the next season.

4. Snag and tree removal shall be conducted by the management zone annually in summer or fall to remove in-channel debris that can accelerate local erosion or deposition.

5. Technical assistance to landowners shall be provided by the water management district to facilitate state, county, and federal permits needed by landowners for river protection. Additionally, coordination

of efforts among landowners, assistance in design of works, coordination with local government, and assistance with funding shall be provided by the zone.

6. Sponsorship of river protection projects shall be done by the management zone for administration of outside funds where multiple owners are working on a single reach of riverbank. The zone further assumes responsibility for oversight of construction and maintenance efforts.

7. The pre-1967 longitudinal stream profile (post- dam construction) shall be set as a goal for restoration. Erosion of existing bed sediment to that profile shall be facilitated through either natural or controlled-release flows.

8. Maintenance of riparian vegetation shall be a primary goal of a river management program. This is to be accomplished through: a) monitoring the entire riparian corridor annually and sampling for physiological stress at permanent sampling transects, b) planting and revegetation is to be conducted by the zone according to priorities established annually using species that are site-adapted and with costs to be borne partly or fully by the zone, c) providing technical assistance for landowners, d) constructing irrigation systems to be operated and maintained by the zone where necessary, and e) regulating flows to enhance bank storage and groundwater recharge for maintenance of riparian vegetation.

9. Enforcement of standards established by the zone shall be its responsibility, including inspection of flood control works, prevention of removal of desirable vegetation, and prevention of unauthorized grading or bank modification along the channel.

10. Ordinances regulating activities potentially deleterious to riparian systems will require new legislation sponsored by the water management district covering groundwater withdrawal, access, rationing, and river dewatering. These legislative controls will be implemented to regulate the location, timing and amount of groundwater withdrawn for export from the watershed so as to maximize streamflows and minimize drawdowns to maintain and improve the health of riparian vegetation. Groundwater pumping will be regulated to maintain a groundwater table within an effective root zone and to provide instream flows uninterrupted by channel dewatering through overpumping. When water tables are pumped close to the limits of the riparian root zone, rationing may be phased in to minimize negative impacts.

11. Education and research on erosion prevention, vegetation, and grading will be a goal of the management zone.

12. Liability insurance, financial and legal administration, and land trust acquisition of riparian lands and rights-of-way are additionally being considered as responsibilities for the management zone.

Financial implications of such a management plan have yet to be clearly addressed by the water management district. Since taxing powers are vested in the agency and since many costs may be able to be included in the rate base of water users, it is not at all unreasonable to assume that the proposed program can be readily implemented. The proposed riparian management zone authority is to automatically expire after 10 years unless reenacted by the electorate. This 10-year period may well not be sufficiently long to insure retraining and stabilization of the channel, particularly if annual flood events during that time are not optimum for sediment transport without destruction of bank works.

WATERSHED MANAGEMENT

Not yet addressed yet clearly of import for the goals of the water management district is a comprehensive watershed management plan. Sources of sediment can exist in tributaries not protected by dams. Part of the watershed not impeded by dams is underlain by decomposed granitic soils that are subject to massive debris slides when altered through grading or other site changes. Monterey County only recently passed a grading ordinance and it has not yet been tested for adequacy. Large scale development projects involving simultaneous construction of golf courses and multi-unit housing are not uncommon and can contribute to sediment influx and stream-bank alteration.

Natural fire frequencies in the Santa Lucia Range headwaters between 1640 and 1907 averaged one fire every 21 years for any given site (Griffen and Talley, 1981). No fires occurred between 1907 and 1977. Fire suppression in the watershed has set up conditions that led to the disastrous Marble Cone fire of 1977, burning a major portion of the watershed above the dams. If such a fire occurs in the lower watershed, no amount of channel restoration will be effective.

Establishment of a comprehensive watershed management plan, regulating development rates, preventing impairment of permeable areas, protecting critical groundwater recharge zones, reestablishing fire frequencies through controlled burns, and planning experimental reforestation with genetically selected drought-tolerant site-adapted plants are all to be recommended for further consideration.

SUMMARY

The lower 24 km (15 mi) reach of the Carmel River is alluviated, and is divided by a bedrock constriction into a lower 16 km (10 mi) reach and a middle 8 km (5 mi) reach. This alluvial reach of the river has experienced major changes in channel course, pattern, and form over the past 130 years. Major floods in 1862 and 1911 changed the river's course by up to 500 m (1640 ft). After 1914, the absence of severe floods, coupled with dam construction upstream, led to a change from a wide, braided channel to a narrow, more sinuous channel. Accompanying this change was a decrease in overall gradient in the lower reach from .0034 to .0029 between 1911 and 1945.

By 1939, the date of the first coverage by aerial photography, the lower reach had developed a narrow, sinuous channel with well-vegetated banks. The middle reach of the river, however, displayed a predominantly wide, braided pattern. Between 1939 and 1971, this middle reach developed a single thread channel and downcut up to 1.5 m (5 ft).

As groundwater withdrawal from streamside wells increased in the 1960s, residents began complaining that riparian vegetation was dying near the wells. During the 1976-1977 drought, lowered water tables were associated with substantial die-off of riparian vegetation. The death of this bank-stabilizing community is associated with significant lateral erosion that occurred during the winters of 1978 and 1980. Upstream of the Schulte Road bridge, the river's bankfull channel increased in width from 13 m to 35 m, increasing the width/depth ratio from 15 to 113. Downstream, the channel remained stable despite passage of some of the sediment derived from the eroding reaches.

Individual efforts to control bank erosion have included planting of willows and and emplacement of various forms of rip-rap. The mixed success of these efforts demonstrates that a co-ordinated program is needed to manage the river. Most promising as a model for the Carmel is the experience of New Zealand engineers in "river training". Their procedure is to determine design geometries from stable reaches and then re-design disturbed reaches to the design geometry. After initial stabilization using engineering works, riparian vegetation is expected to serve as the primary stabilizing agent.

A river management program, focusing on the riparian zone, has been drafted and is being approved. This effort will emphasize restoration of a design channel, maintenance of riparian vegetation, and restoration of a fishery resource.

ACKNOWLEDGEMENTS

This study was supported by a contract with the Monterey Peninsula Water Management District. Our thanks to the District staff for generous assistance in every phase of the study. We are also grateful for the invaluable cooperation of Monterey County Flood Control, the California Fish and Game office in Monterey, and the Army Corps of Engineers San Francisco District. To the friends who helped with the field work, our thanks. Parts of this paper have been submitted for publication to the University of California, Davis, Riparian Systems Conference proceedings of 1981.

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SPAWNING GRAVEL ENHANCEMENT STUDIES ON SIX NORTHERN CALIFORNIA RIVERS

Koll Buer, Ralph Scott, Dennis Parfitt, Gene Serr, Jan Haney and Lynn Thompson[1/]

ABSTRACT

As part of the Resources Agency's Resource Investment Fund and the Wild and Scenic Rivers Program, the Department of Water Resources (DWR) is studying spawning gravel enhancement techniques and locating potential new spawning areas in six California rivers (Fig. 1). Three studies have been completed. These are the Sacramento River between Keswick Dam and Red Bluff (Parfitt and Buer 1980), the Klamath River between Iron Gate Dam and Humbug Creek, and the Shasta River between Lake Shastina and the mouth (Buer 1981). Construction of these proposed spawning areas would provide for an additional 16,000 salmon pair. Similar studies are in progress for the Feather River and the Wild and Scenic portions of the South Fork Trinity and Middle Fork Eel.

INTRODUCTION

The anadromous fishery has made a substantial contribution to the Northern California economy for many years, augmenting both the sport and commercial fisheries. However, spawning escapement of salmon in many streams has declined dramatically over the last century. There are many reasons for this, including dams, diversions, overfishing, major floods and droughts, gravel extraction, timber harvesting and attendant watershed degradation. Each river system differs in watershed characteristics and the specific causes of its fishery problems.

The upper Klamath River, the upper Sacramento River, and the Shasta River were once primary chinook spawning rivers. Few salmon now spawn in the reach below Iron Gate Dam on the Klamath River, and Shasta and Keswick Dams on the Sacramento River because the riffles are now armored by cobbles too large for salmon to move. This is due to loss of gravel recruitment from areas above the dams, to channel degradation and to scour of spawning gravel below the dams during high flows. Gravel extraction for aggregate has reduced tributary input. There are similar gravel recruitment problems, high water temperatures, and siltation and irrigation diversions, on the Shasta River. The Feather River below Oroville Dam is now being studied to determine what problems exist there.

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Figure 1. Northern California with darkened circles showing the locations of spawning gravel enhancement and stream geomorphology studies by the Department of Water Resources, Northern District Geology Section.

The South Fork Trinity and the Middle Fork Eel are both wild rivers without dams. Both were among the better salmon and steelhead streams in California and among the few streams in Northern California that support spring-run steelhead.

Both rivers were severely damaged during the December 1964-January 1965 flood. The flood, estimated to be a 100 year event, caused extensive bank failures, landsliding, and stream aggradation. In some areas, severe watershed damage was linked to the cumulative effects of areas logged before the flood (Scott, Buer and James 1979). Twenty to thirty feet of channel aggradation was common after the flood. This reduced the number of summer holding pools, degraded summer steelhead habitat, and silted in spawning gravel.

The fish runs on the Middle Fork appear to be returning but runs on the South Fork have not recovered.

METHODOLOGY

Each river system has its unique problems of hydrology, stream geomorphology and fishery. However, these rivers are similar in that a reduction over historic levels of adequate fish habitat has occurred. As a result of these studies, DWR has developed an investigative methodology for evaluating spawning gravel and enhancement techniques. These techniques are applicable to other salmon spawning streams in California. They include:

1. making an aerial photo atlas of the study reach;
2. compiling historic spawning, channel morphology and watershed data;
3. sampling the spawning gravel using bulk and surface sampling techniques;
4. analyzing streamflow data to determine the hydrologic characteristics;
5. identifying and surveying potential enhancement areas;
6. calculating critical discharge for bedload movement and calculating the gravel bedload budget;
7. recommending suitable enhancement sites.

AERIAL PHOTOGRAPHY

Nine by nine inch aerial photo surveys with a scale of 1:24,000 or 1:12,000 are flown along the river. The photos are enlarged to 1:6,000 for the 11 x 17" atlas sheets. River miles, a scale and a north arrow are shown for convenience.

The aerial photo atlas is used in the field to plot stream survey data, stream meandering, suitable spawning areas, and landslides. In addition, bank protection, blockages, riprap and unstable banks are plotted. To evaluate geomorphic changes such as stream meandering and landslide densities, data obtained from historic aerial photos and survey maps are plotted on the atlas. Historic spawning areas are also plotted where these areas have been located.

ENHANCEMENT SITES

Potential enhancement sites are identified by comparing stream gradients, critical flows, stream morphology, and gravel stability characteristics. The recurrence interval of critical flows determines the advisability of placing imported spawning gravel in the stream channel. The ten-year flood is used as a design criterion. If critical flows occur at less than ten-year intervals, retention structures such as rock or gabion weirs, deflectors, groins or dikes are recommended; instream enhancement is generally not advisable in such a case, and side channel development is preferable.

Side channel enhancement site selection is based on stream morphology, access, available spawning gravel near the site, environmental impact, flood flow routing and excavation needs (Photo 1). Instream enhancement sites are selected according to gravel transport equations and accessibility.

Enhancement sites were surveyed using transit, chain and rod. The cross-sections are plotted and a contour map and longitudinal profile of the channel thalweg for each site is drawn.

Design and construction methods differ between instream and side channel enhancement sites. Instream sites may degrade during flood flows, are generally more difficult to get to, and present problems with using equipment in deep or swift water. Construction requires placement of gravel and retention structures (Photo 2). Side channel sites require excavating portions of the channel and importation and placement of graded gravel. For side channel work, a weir may be placed across the upstream portal to control flows during and after construction. Downstream from the weir, gabions or rock weirs may be placed in a series of steps to create a pool-riffle sequence and control the gradient.

During the fall of 1980, DWR, in conjunction with DFG and CCC, constructed three enhancement structures on the Shasta River. These included a rock-filled gabion weir, a buttressed rock weir and a low rock weir. The purpose was to evaluate the effectiveness of different spawning gravel retention structures during high winter flows. Gravel trapped behind the weirs would also be a measure of gravel movement in the Shasta River. Gravel was also placed behind the weirs to see if spawning would occur. Finally, spawning activity on the emplaced gravel was evaluated. Approximately 3 000 ft^2 of new spawning area was created by this project. No salmon spawned at the site before the project, but an estimated 60 redds were counted in the new gravels in the fall of 1980.

HYDROLOGY AND STREAM CHANNEL GRAVEL CHARACTERISTICS

Stream hydrology is used to plan and design fishery enhancement structures and to determine the gravel bedload budget. Data developed from stream gage measurements include annual yields, mean and peak monthly flows, flood flow frequency analyses, and flow duration curves. Stream flow diagrams were developed for each stream and its tributaries, showing average yields for the four seasons.

The annual yields show the dry and wet years on record. The mean and peak monthly discharges are characteristic of a particular watershed. The hydrographs show large variations in flow, both during and between the years, reflecting the precipitation pattern, snowmelt and watershed characteristics. The peak monthly flow is the highest mean daily discharge for the month. This shows the flood events on record. Stream character and salmonid escapement are affected by these floods.

Flood frequency diagrams are used to predict the flood magnitude expected within a given number of years and to rate the floods that have occurred in the basin. The reliability of these predictions depends on the length of record.

Flow duration curves show the percent of time a specified discharge is equalled or exceeded.

The gravel budget is calculated by comparing hydrology to gravel characteristics, surveyed cross-sections, and other stream properties. These data are used in bedload transport formulas to determine the gravel budget. Using the formulas, critical velocities and the stability of emplaced gravel are also estimated.

Many methods have been used for sampling and evaluating spawning gravel. These include surface sampling, bulk sampling, and freeze cores. Bulk sampling and surface sampling were used for these studies, since freeze cores were too expensive and slow for large project areas.

Sieve analyses and the frequency distribution of the gravel sizes are used to determine the size suitability of the gravel for spawning. Statistical parameters useful for describing sediment samples are then calculated. These include the median, geometric mean, standard deviation, skewness and kurtosis.

The gravel budget is estimated using the Schoklitsch and Myer-Peter and Muller (MPM) equations (Vanoni 1975). Critical transport discharges (the flow where spawning-size gravel begins to move) are estimated by comparing flows with gravel movement and integrating to zero transport. Velocities were estimated using the Manning equation, gaging station data and direct measurements. These velocities are then compared to the Hjulstrom (1935) diagram as another estimate of initial movement (Fig. 2).

The Schoklitsch equation (Vanoni 1975) may be expressed as:

$$G_s = \Sigma i \; pi \; \frac{(25.3)\;(95.56)}{\sqrt{dsi}} \; S^{3/2} \left(\frac{Q}{W} - .638 \frac{dsi}{S^{4/7}s}\right) IW$$

where G_s = bedload transport in yd^3/yr
pi = weight fraction of sediment samples of a particular size range
dsi = mean diameter of pi in feet
S = energy slope
Q = discharge in ft^3/sec
W = width in feet
I = interval that a particular Q occurred during a 100 day period

The calculation is repeated for the different combinations of pi and Q.

The MPM equation in the foot-pound-second units is:

$$G_s = 9.67 \left[3.306 \left(\frac{Qs}{Q}\right)\left(\frac{D90}{ns}\right)^{3/2} rS - .627\ D_g\right]^{3/2} IW$$

where n_s = roughness coefficient
r = hydraulic radius
D_{90} = gravel diameter at 90th percentile
D_g = mean gravel diameter
$\frac{Qs}{Q}$ = ratio of critical discharge to discharge

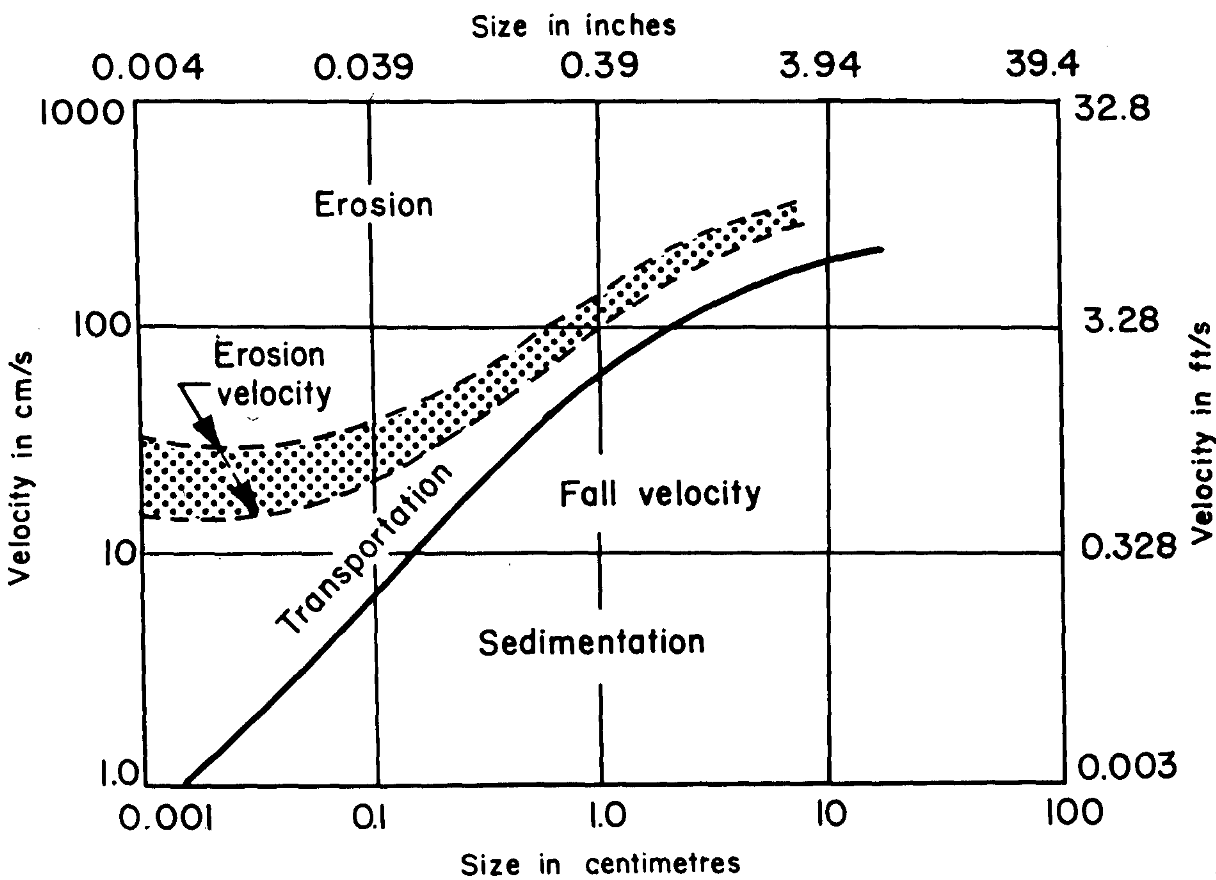

Figure 2. Curves of erosion and deposition for uniform material. Erosion velocity shown as a band. (Redrawn from Hjulstrom 1935)

Photo 1 - Potential side channel enhancement site on the Klamath River. The site is protected from high flows that scour gravel in the main channel.

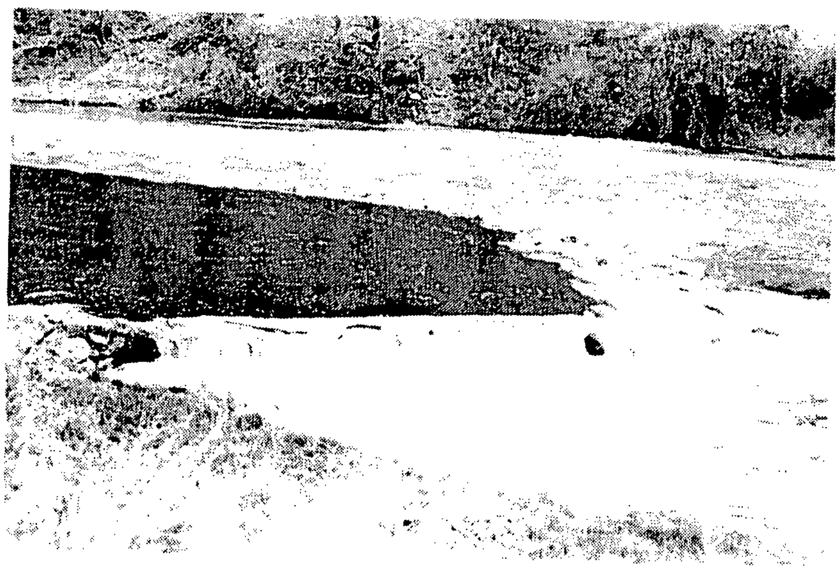

Photo 2 - Salmon Heaven instream enhancement site on the Shasta River. Low gradient and wide channel reduce flow velocities. Gabion was installed to trap gravel and provide additional spawning habitat.

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HISTORIC SEDIMENTATION IN AN ESTUARY: SALT MARSH SUCCESSION AND CHANGE BIG RIVER ESTUARY, MENDOCINO COUNTY, CALIFORNIA

Laurie Marcus and Steve Reneau[1/]

ABSTRACT

The salt marshes bordering Big River Estuary have exhibited rapid vegetative succession in response to an accelerated build-up of levees along the estuary banks. Since the advent of logging in the watershed in 1852, the estuary has experienced major geomorphic changes. The natural progression of river deposits down the estuary has been greatly accelerated in the past 130 years.

Silt-laden flood water, slowed by tidewater flowing into the estuary, deposits sediment to form levees along the channel. These levees act to isolate salt marshes from tidal inflows. As tidal sloughs fill in and saline influence into the marsh diminishes, an unusual vegetative succession begins. Halophytic salt marsh plant species are replaced by riparian and coastal scrub plants. Salt marsh habitat is lost as a direct result of accelerated erosion in the watershed.

Detailed vegetation maps and comparative diagrams illustrate the significant changes these tidal flats have undergone. Comparison of recent infra-red imagery, field surveys, aerial photographs and historic photographs dating from 1860, reveal the time sequence of these vegetative changes.

NTRODUCTION

he estuaries of north coastal California are limited in distribution and, excepting the San Francisco Bay system, generally small in size. They experience broad range of conditions governed by both the tide and flood cycles of their distinctive components: ocean and river. As the confluence of these two components, the estuary receives both river-carried sediment and tide-borne sand Steers 1967). Estuaries are sites of active sedimentation. During flood tages, high tide waters mix with and slow, silt laden river water resulting in he deposition of sediment in the estuary. If river sediment loads are large, eposition in the estuary will also be great. San Francisco Bay provides one xample; the large amounts of sediment produced by hydraulic mining in the ierras were deposited in the Bay, significantly reducing its depth (Gilbert 917). Consequently an examination of the geomorphic patterns found in an stuary can reflect erosional processes occuring in the watershed.

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Big River is amongst the largest watersheds along the Mendocino coastline, draining an area of approximately 165 square miles. As with other north coast rivers, discharge is concentrated during the winter and early spring, and summer outflows are quite low. Tidewater extends up the lower 8 miles and a series of eight salt marsh flats border the lower three miles. Unlike many estuaries, Big River estuary is not lagoonal but instead has a long linear channel. Crescent-shaped tidal flats alternate on either side of the channel corresponding with the alluvial deposits of the river. Redwood and mixed coniferous forest cover the steep slopes which border the channel (Figure 1).

Big River estuary has experienced rapid sedimentation of its channel and salt marshes since the advent of logging in the watershed. Timber harvesting which began in 1852 has been and continues to be the primary land use. These lands have been continuously harvested for 120 years using a variety of methods. The resulting erosion and transport of sediment down the river is evidenced by the historic changes in the estuary. The changes are cumulative and represent the long-term effects of timber harvest operations in the watershed. This paper seeks to document the depositional process occuring in the estuary, describe a relative time scale for these events and present the effects of this process upon the biotic components of the estuary.

METHODS

In order to assess historic changes in the estuary, a survey comparing the estuary's present condition with that in the early logging days was necessary. Therefore we not only documented present conditions through vegetation maps and topographic studies but also researched past information. We were able to contact a local expert on the early logging of Big River (Francis Jackson) and obtain historic photographs of the estuary. Many of the old logging structures remain and their former position in relation to the shoreline (as evidenced in the photographs) could be compared with their present position.

The vegetation maps were produced from a variety of sources. Initially in-depth field checks of each flat were completed producing rough maps outlining slough locations and vegetation distributions. A series of 144 aerial photographs were taken of the flats using both color and infra-red modes. The photographic series was designed for a 60% overlap between slides to assure complete coverage. The slides were photographed from a pre-determined altitude (8,000 ft.) to provide the desired projected scale (1 inch:200 ft.). Another set of color slides of the flats taken from a lower altitude (1,000 ft.) also were made during this flight. The final set of slides was created by photographing 1978 U-2 Nasa infra-red aerial photographs of the Big River Watershed. The slides were projected and an outline of each flat traced. Physiographic characters, slough systems, pans and vegetation forms, (trees, grasses, etc.) were mapped. The low altitude slide series was used to check vegetation lines and identifications. The field sketches were compared with the new maps to retain accuracy. Comparative diagrams of vegetation types were produced from black and white aerial photographs taken in 1952 and 1963. Vegetation types were defined by dominant species and all plant species encountered were collected and identified.

GEOMORPHOLOGY

The deposition of sediment is a natural geologic process in estuaries. However Big River estuary exhibits greatly accelerated sedimentation and an unusual

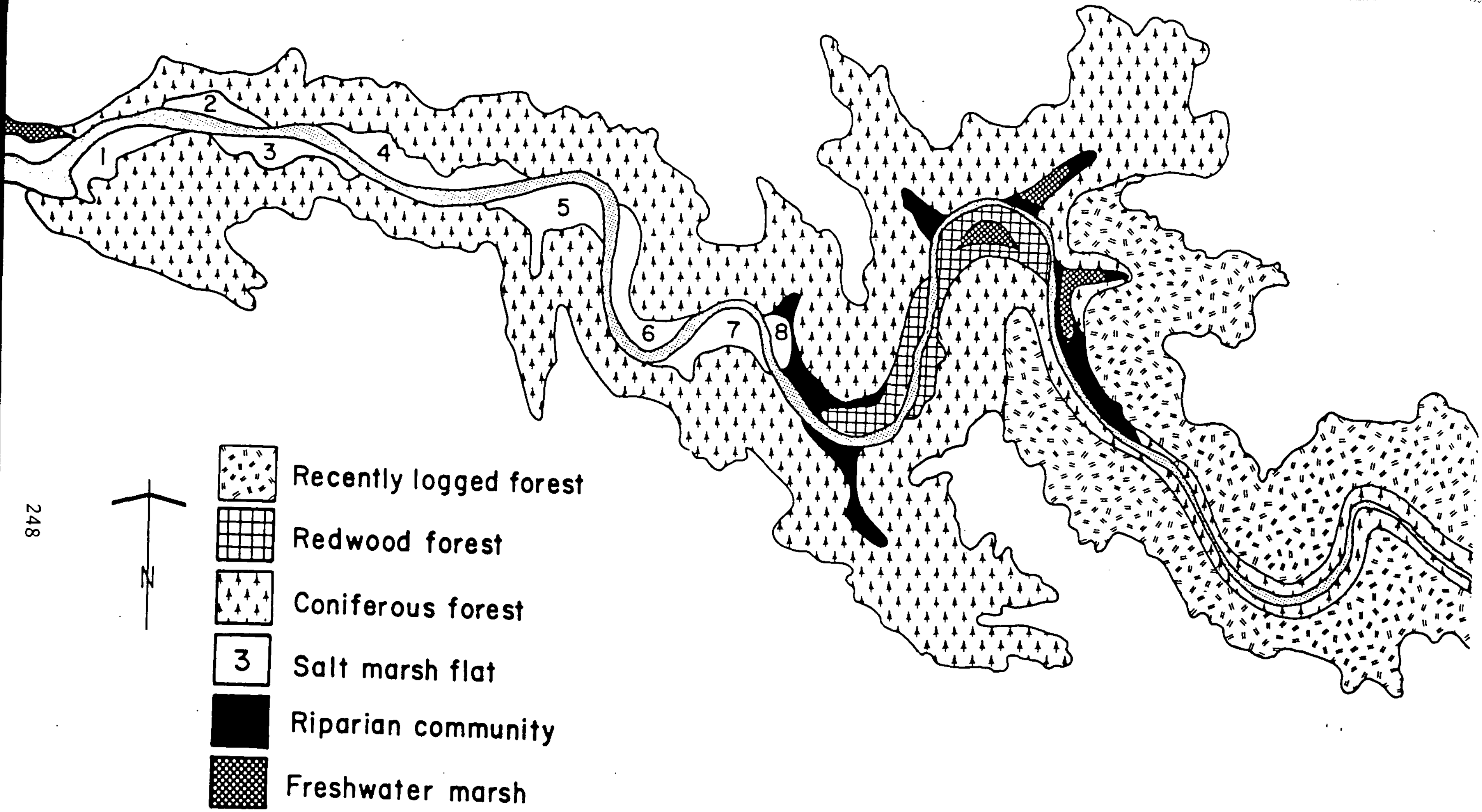

Figure 1. Big River Estuary, reference map of salt marsh flats.

pattern of deposition. The most obvious indicator of this accelerated process is the occurance of levees bordering the estuary channel. These levees extend along the channel down to 1.7 miles above the mouth and display a regular decrease in height. Their size varies from 40 ft. in width in the upper estuary to 10 ft. and less in the lower region. These levees record the transition in the estuary from primarily tidal influences (salt marsh and mudflat) to primarily river influences (floodplains).

These levees are formed as silt laden flood waters are slowed along the edges of the channel (Figure 2). The coarser, heavier sediments settle out forming an embankment along tidal flats and estuary channels. Driftwood and eelgrass beds located along the edges of the channel as well as tidal inflows act to slow down the flood waters and permit the sediment to settle out. Floculation of clay particles in the estuary may also contribute to this process. The increased sediment load resulting from erosion in the watershed cannot be transported out of the system by winter floods. The result is storage of the sediment in levees and on tidal flats.

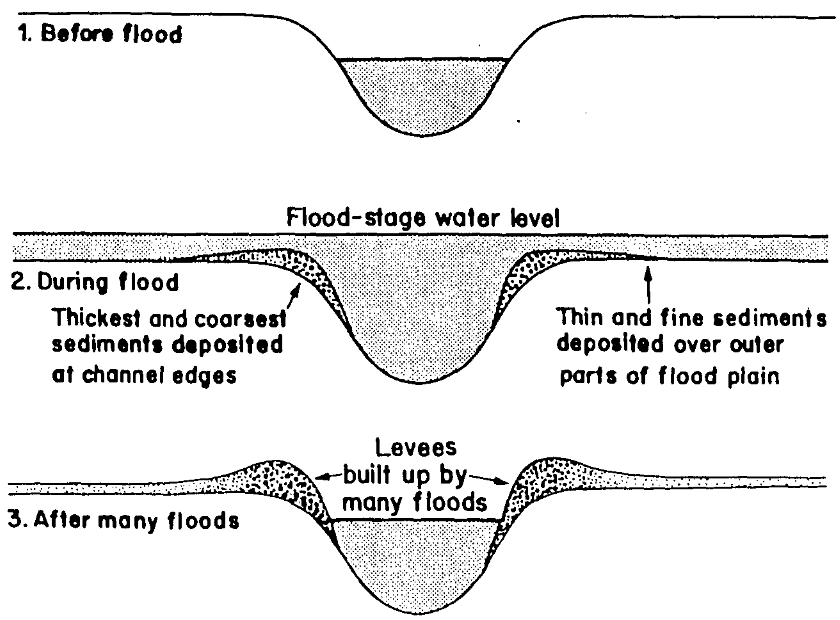

Figure 2. Formation of levees by river floods. As a river in flood stage overflows its banks, it rapidly decreases in velocity away from the channel and so drops most of its sediment, the coarser parts near the channel and the finer parts as a thinner layer of silt and clay over most of the floodplain. Successive floods build up the levees to ridges many meters high.

This sedimentation and levee build-up have taken several forms. The estuary banks have prograded resulting in a narrowing of the channel and an increase in floodplain size at the expense of mudflat and subtidal areas. Blockage or reduction in tidal influence has occured in the upper flats while a filling of sloughs and increase in mudflat height is found in the lower flats.

A few comparisons serve to illustrate these processes and estimate a time scale for their occurance. A railroad system was used to transport logs to the estuary during the early logging. A log dump located 3.8 miles upriver served as a spur of the railroad where logs could be dumped directly into the water. This log dump is shown in a historic photograph taken in the 1920s as standing in open water (Jackson 1975). The border of Flat 8 sloped gently away from the water. Today the pilings of this log dump stand adjacent to Flat 8, bordered by a levee 4 ft. in height. The historic development of this levee records a major change in the hydraulic conditions of the estuary. Winter floods were not able to deposit enough sediment to build levees at the site of the log dump prior to 1900. Since the photograph was taken, levees have developed 2 miles further down the estuary.

Once the logs were dumped into the estuary, they were rafted down to the sawmill at the mouth. To avoid stranding the logs on the tidal flats, rows of pilings were placed at the lower low tide line (Jackson 1975). Chains were stretched between these pilings and acted as a barrier to the floating logs. Presently in Flat 4, two sets of pilings occur, the outer one at approximately low tide line and the inner one trending back into the salt marsh. Two sets of pilings were installed during the logging operations before 1938 indicating that heavy sedimentation had extended the low tide line out into the channel, thus rendering the original set obsolete.

The filling of these tidal sloughs by sediment is demonstrated by the presence of several barges, buried in Flat 4. These barges were used for transport in the estuary. The barges are 42 ft. in width and were moored in the tidal slough, indicating the original slough was at least this wide. Presently the same slough is 7 ft. in width and the barge is buried adjacent to the bank.

SALT MARSH SUCCESSION

Accompanying levee build-up and siltation of slough systems are significant changes in the vegetative composition of the flats. As tidewater inflow to the flats is blocked rapid vegetative succession from salt tolerant or halophytic plant species to non salt-tolerant plants occurs. This successional scheme is unusual for salt marshes and represents a significant loss of wetland habitat in the estuary.

The circulation of salt water throughout the marsh is most important in determining the species distribution of marsh plants. Studies from England, North Carolina, San Francisco Bay and Oregon (Adams 1962; Hinde 1954; Miller 1950; Eilers 1979; Chapman 1938; Atwater 1979) have found tidal inundation to be the strongest determining factor in plant species distribution.

The channel systems found on Big River's flats are dendritic drainage sloughs formed through erosion by ebbing tides (Pestrong 1972). These flats are not completely inundated by tidewater and the slough channels are the only agent for tidewater inflows. Therefore, the distribution of these channel systems and their proportionate area within each flat is a direct measurement of saline influence to each marsh. The channel systems are extensive in the lower three flats becoming reduced to non-functional in the upper flats. Vegetation patterns coincide with the placement and extension of these slough systems.

Salt marsh plants, such as the succulent pickleweed, are specifically adapted for saline soils. They are able to store water in their tissues and thus avoid dessication. When saline inflows are reduced to marsh soils, as in the upper flats at Big River, the halophytes loose their adaptive advantage and are replaced by other species.

TABLE 1

FRESHWATER AND SALT MARSH PLANT ASSOCIATIONS

*--indicates dominant species

Vegetation Type	Species Composition	
pickleweed	Salicornia virginica	PICKLEWEED*
	Triglochin striata	ARROW GRASS*
	Jaumea carnosa	
	Cuscuta salina	PARASITIC DODDER
rushes	Juncus lesueurii	RUSH*
	Distichlis spicata	SALT GRASS
	Gramineae spp.	GRASSES
	Holcus lanatus	VELVET GRASS
	Hierochloe occidentalis	VANILLA GRASS
alders	Alnus rubra	RED ALDER
	Salix lasiolepis	WILLOW
coastal scrub	Baccharis pilularis	COYOTE BRUSH*
	Lupinus rivularis	LUPINE*
	Rubus ursinus	CALIFORNIA BLACKBERRY*
	Anaphalis margaritacea	PEARLY EVERLASTING*
	Senecio jacobaea	RAGWORT
	Foeniculum vulgare	SWEET FENNEL
	Erechtites arguta	FIRE WEED
	Rumex crassus	DOCK
	Carex salinaeformis	SEDGE
	Orthocarpus castillejoides	OWL'S CLOVER
	Pteridium aquilinum	BRACKEN FERN
	Rhus diversiloba	POISON OAK
	Convolvulus occidentalis	MORNING GLORY
	Geranium molle	CRANESBILL
	Gentiana amarella	FELWORT
freshwater or brackish-water marsh species	Typha latifolia	CATTAILS*
	Scirpus robustus	BULRUSH*
	Cicuta douglasii	WATER HEMLOCK
	Torilis arvensis	HEDGE PARSLEY
	Juncus effusus	RUSH
	Scirpus arnuus	BULRUSH
	Carex obnupta	SLOUGH SEDGE
	Plantago hirtella	PLANTAIN
	Potentilla egedei	PACIFIC SILVERWEED

The plant associations in the salt marsh flats are listed in Table 1. Vegetation types are defined by the dominant plant species (e.g. pickleweed, rushes). The coastal scrub assication while being dominated by coyote brush and lupine, contains many plant species from the disturbed ground community.

The various flats along the estuary have distinctly different vegetation. The lower three flats exhibit extensive slough systems and are covered with halophytic plants, pickleweed and rushes. The rushes, being less salt tolerant, occupy the more elevated areas of marsh where soils are less saline (see Figure 3).

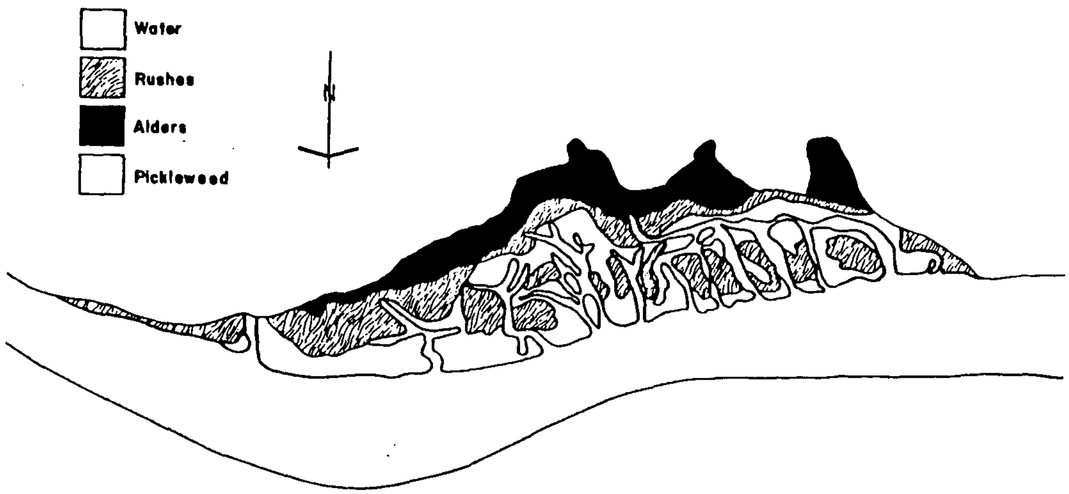

Figure 3. Vegetation map of Flat 3. An extens ve slough system and predominance of halophytic vegetation characterize the lower flats.

The upper flats, however, exhibit a very different plant distribution pattern. Beginning in Flat 4, a levee occurs along the estuary bank blocking tidal inflows to the interior of the flat. The levee is higher than the surrounding marsh and is colonized by non-halophytic plant species of the coastal scrub and alder communities. Several of these plant species are nitrogen-fixing, containing nitrate producing bacteria in their root nodules. Consequently they have an advantage on the newly deposited, non-saline soils of the levees. Inside this levee in the marsh interior are low, depressed areas filled with pickleweed.

In Flats 5-8 a levee encloses the perimeter of much of the marsh, restricting tidewater inflows. Slough systems are greatly reduced or non-existent. Dead pickleweed patches which occur within Flat 7 are enclosed by a thick corridor of alder and scrub plants (see Figure 5). In this flat tidal inflows have been

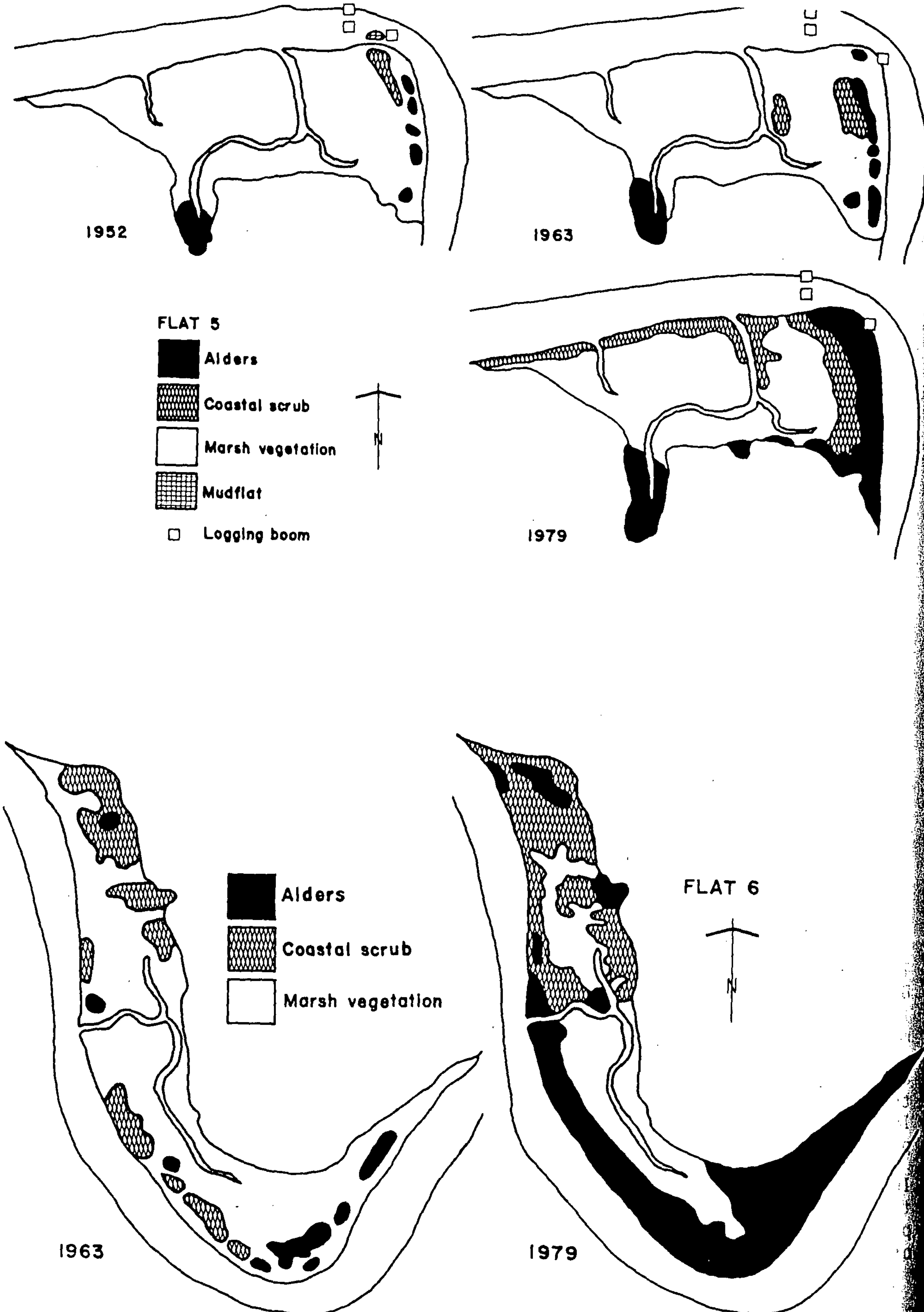

Figure 4. Comparison of vegetation in Flats 5 and 6.

completely blocked; a lower salinity level in the soils allows for the replacement of salt marsh plants.

In Flats 4 and 5 salt pans are found, just inside the levee and indicate the rapid deposition of sediment. These pans form as the marsh changes (Yapp 1917). During rapid sedimentation and halophytic plant colonization of muds, some regions become isolated. Normal submergence is restricted and with no drainage slough connections, the tidewater is trapped in these isolated regions. After this tidewater is caught within these pans, vegetative colonization is restricted. Even after evaporation has occured, the salinity level of the soil is prohibitive to plant growth.

Figures 4 and 5 illustrate the vegetative changes which have occured in the upper flats over the past 30 years. The replacement of marsh vegetation by coastal scrub and eventually alder, indicate a significant loss of salt marsh in the estuary. The enlargement of the levee is also illustrated in Flats 5 and 7.

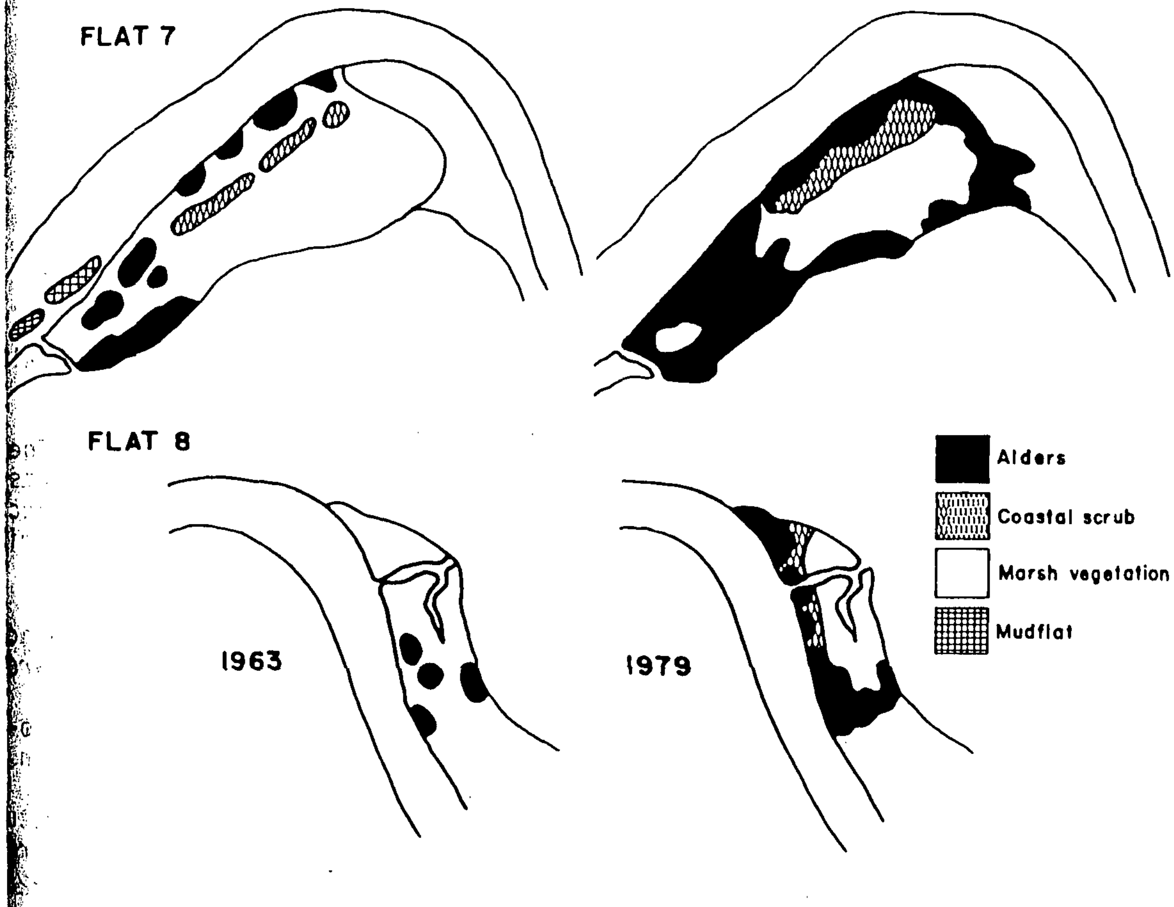

Figure 5. Comparision of vegetation in Flats 7 and 8.

Historic photographs (circa 1900) of Flat 1 reveal a mudflat with no vegetation of any type. Presently about half of this flat is covered with halophytic plants indicating a substantial rise in height of the flat. In addition this flat was across the channel from the logging mill pond. A row of old pilings still crosses its reaches diagonally. These pilings are the remnants of a wingdam, built in 1884 and used to direct the river's current toward the mill to flush sawdust and other debris (Jackson 1975). If the placement of these pilings in 1884 was such as to direct current movements then it may be assumed that they were placed in areas covered by water most of the time. At present, these pilings can have no effect on channel water currents, for they are located in a slough surrounded by islands of vegetation.

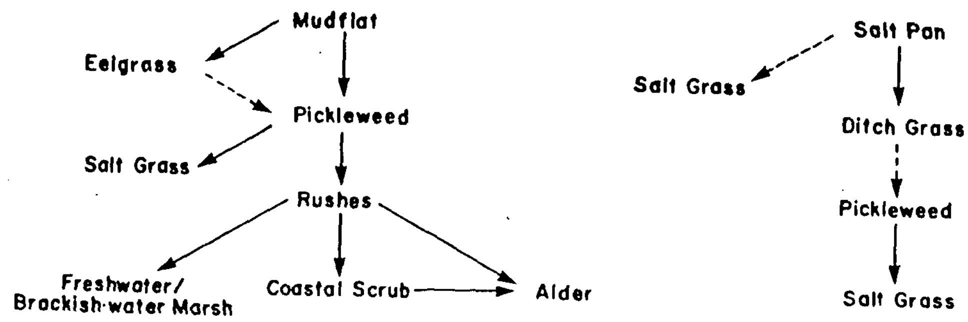

Figure 6. Salt marsh vegetation succession at Big River Estuary. Dotted arrow indicates hypothesized future vegetation succession.

By comparing the changes in the flats over time and between marshes, we have devised a successional scheme (Figure 6). The most unusual change in this salt marsh succession is the direct replacement of rushes by alder and coasta scrub. Other successional patterns (Chapman 1976) for European marshes resul in freshwater marsh ultimately replacing salt marsh. While coastal scrub species are occasionally distributed around the periphery of salt marshes (Wherry 1920) wetland areas are not normally replaced by this community. The direct colonization of newly deposited levees by alder and coastal scrub acts to produce riparian woodlands over former wetlands. In addition sediment acc tion in other salt marshes is commonly a gradual process with sediment distrib uted approximately evenly over the flooded area (Steers 1948).

Once these marshes are isolated from tidal infl ences, their productive capac is lost. Juvenile estuarine fish, benthic invertebrates and algal blooms are common in the backwaters of tidal sloughs. Recent research indicates that tidal sloughs in Pacific salt marshes may be the location of the primary pro- ductive food base for the estuary (Zedler 1978; Eilers 1979). The reduction of slough systems reduces estuarine habitat available and consequently the productivity of the entire system. The long-term effects upon Big River est ary of this sedimentation and loss of salt marsh is undocumented. Further re search is needed to determine the exact consequences.

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Eagles Point Site Restoration

and Revegetation Project

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ABSTRACT

The Golden Gate National Recreation Area began a large labor intensive erosion control project in the Lands End area near 32nd Avenue and El Camino Del Mar in San Francisco in late February 1980. The site known as Eagles Point extends out into the Golden Gate Channel, between China Beach to the east and Deadman's Point to the west. As geographically situated, Eagles Point provides a panoramic view of the Golden Gate and Marin Headlands from the Golden Gate Bridge to Point Reyes. Due to its spectacular vista, scores of sightseers came for reflective recreation. As a result, hillside vegetation was trampled eliminating ground cover, exposing highly erodable Colma formation soils, and exposing tree root systems for twenty-eight Monterey Pines located at the site which resulted in their death.

The Young Adult Conservation Corps and the Youth Conservation Corps installed a network of checkdams, retaining walls, formal trails, steps, waterbars, vista platforms, range fence and nearly 80 tons of sand for fill with 3 tons of woodshavings and horse manure as a mulch cover. The three phased construction work project was completed by the end of July, 1980, with approximately 16 weeks of hard physical labor invested. Project cost was $24,148.24, including salaries, with an additional $4,037.00 in donated materials. The final stage of site rehabilitation involving the actual revegetation of Eagles Point was launched in mid-October, 1980. Irrigation by a hose sprinkler system was implemented using reclaimed water from the City of San Francisco. A winter rye grass was sown over the entire site to establish a ground vegetation. Native coastal shrubs were transplanted from the park's native plants greenhouse to the project site. A weekly maintenance program monitors vegetation spread, erosion of trails and continues native shrub plantings.

Introduction: Statement of the Problem

The spectacular panoramic view of the Golden Gate Channel and Marin Headlands as seen from Eagles Point was the catalyst to the accelerated erosion problem at the vista site. Eagles Point became a victim of its own popularity. Park visitors emerging from under the tree canopy at El Camino Del Mar Drive walked out onto the point's ridge to feel the ocean breeze, smell the Pacific's waters, listen to the surf, and view the ocean environment as it meets the coast.

Through the subtle leisure activities of reflective recreation, thousands of park visitors eventually trampled all but the highest mounds of vegetation on the point. With ground vegetation removed, the weak soils of the Colma formation were now exposed to the severe marine environment of gale winds and driving rains. What had probably started out as a few beaten paths leading down the slope to the cliff edge, eventually branched out into a myriad of finger trails. This led to the formation of a large gully system in the western basin and also on the lower west slope of the point itself just east of the large western basin.

By 1976 ground cover in the west basin was trampled beyond naturally regenerative abilities and erosional processes dominated the landscape. Accelerated erosion removed over five feet of top soil at certain sites. This resulted in exposed root systems of all thirty-two Monterey Pines. Twenty-eight mature trees and ground vegetation were removed. With unrestricted pedestrian traffic increasing, the accelerated erosion transformed a vegetated vista point in the Golden Gate to a textbook example of badland topography with many examples of exposed tree root systems. Once the hard-pan soils became saturated, storm runoff fed into one of three tributary gullies in the western basin's large gully system. Runoff on the east side of the ridge drained down to the lower gully field on the west slope of the point. The lower gully field extended from the cliff edge for 200 feet up the steep slope.

Since these conditions were a direct result of the impact by park visitors, the South District Ranger staff sought means to arrest the erosion problem and revegetate the site. In accordance with the 1972 establishing act of the Golden Gate National Recreation Area, the park lands in San Francisco and Marin were founded "to preserve for public use and enjoyment." The Act continues "...Management...shall utilize the resources in a manner which will provide for recreation and education...consistent with sound principles of land use planning and management...and shall preserve...and protect it from...uses which would destroy the scenic beauty and natural character of the area."

Geographic Sketch of Eagles Point

Located on the north shore of San Francisco in the Golden Gate Channel, Eagles Point protrudes out between Deadman's Point to the west and China Beach to the east. From the Lands End trail head at 32nd Avenue and El Camino Del Mar the point extends out as a narrow ridge, at first sloping down at a 10° gradient. However, 180 feet from the Lands End Trail, the gradient drops steeply to 30° for 160 feet to the cliff edge. The beach is approximately 150 feet below.

The east slope of the Eagles Point Ridge drops off steeply, ranging from 40° to 85° slope closer to the channel. The west slope is an open basin sloping at a 15° gradient with an area of 40,000 square feet. With the exception of a few isolated mounds, over 70% of this basin area was unvegetated. Accelerated erosion dominated the landscape. In the lower end, mass wasting had degraded over 5 feet of top soil, whereas in the upper reaches 1 to 3 feet had been degraded. Sediments were washing into a large gully system that extended 82 feet up from the cliff edge with 45 foot long tributaries. The gully was 6.5 feet deep at its lowest point. During the winter of 1979-80 which was a wet year, the gully advanced 8 feet uphill. Gully width ranged from 12 to 4 feet.

Following the ridge 140 feet north of the Lands End Trail, a separate gully system fed by a small drainage produced extensive examples of badland topography. This gully system was 200 feet long by 25 feet wide. Parallel gullies 6 inches to 2.5 feet deep ran nearly the entire length of the field. The lower gully field and additional area to the west covered over 7000 square feet of unvegetated hillside.

Geology

There are three geologic formations exposed at Eagles Point. All three are associated with the heterogenous group of marine sedimentary and volcanic rocks of eugeosynclinal origin known as the Franciscan formation. The main rock component of Eagles Point is graywacke which forms the ridge and point. A small exposure of radiolarian chert is found on the ridge near the Lands End Trail. The badland topography is attributed to surfical deposits of the Colma formation. The Colma formation is of medium-fine orange quartz-feldspar sand with minor amounts of clay. The sands enclose clay beds 6 inches to 5 feet thick. A deeply gullied badland topography commonly develops on the Colma formation as it is soft and easily eroded. One can easily scratch it with the fingernail, but is consolidated enough in outcrop to stand indefinitely in steep to vertical slopes 5 to 20 feet high. Present evidence indicated that the deposits assigned to the Colma formation are Pleistocene in age, laid down at least 30,000 years ago.

Nearly the entire project site with the exception of the exposed ridge is made of the surfical deposits of the Colma formation. Approximately 60 feet from the cliff edge on the lower gully field, there existed a 12 inch layer of clay sandwiched between the Colma formation and the Franciscan graywacke bedrock.

Vegetation

John McLaren planted thousands of Monterey Pines and Cypresses in the Lands End area around 1924. Only four out of thirty-two trees survive today at Eagles Point from his plantings. Prior to the introduction of McLaren's trees along the Lands End Trail, the area was characteristically known for the wind manicured coastal shrub (see map). *Baccharis*, *Ceanothus*, *Lupinus*, *Salix*, *Elymus mullis*, Pearly Everlasting, Paint brush, Plantain, Beach Strawberry, Live-forever, Seaside Daisy, Yarrow, Wild buckwheat and assorted varieties of annual and perennial grasses (Fescues, ryegrass, vetch and bionegrass) were common plants.

In 1979, due to severe trampling, vegetation was restricted to isolated mounds and cliff edges. Remnant outcrops of the Colma formation that were protected by a topcover of vegetation were being undermined by wind erosion. Accelerated erosion had degraded the soil horizon leaving an armored surface of fragmented chert and graywacke across the main drainage above the gully. Gale force winds, blowing sand and total exposure created unfavorable conditions for natural revegetation to occur.

Until December 1979, the park had allowed the visitor trampling and unrestricted access to continue without plans for restoration. Many park visitors enjoyed the wild setting of exposed roots and gullies. The site as it existed prior to restoration reflected a natural unmanaged landscape which was a dramatic contrast to the neighboring urban park environment.

On February 12, 1980 the park's compliance committee met and formally decided that restoration work should be done to control the erosion and define visitor access. The committee requested designs for the checkdams, gabions, retaining walls and steps. Emphasis was placed on maintaining a natural appearance for the site with a minimum number of structures.

Erosion Control Structures

The Eagles Point rehabilitation project utilized four types of erosion control structures to stabilize soil and divert and distribute water flow. Checkdams, retaining walls, gabions and waterbars. All materials used in the fabrication of the structures was from reverse construction projects from areas throughout the park.

Barrier Fencing

Since the erosion problems and climatic environment were severe, restoration and revegetation of Eagles Point required exclusion of park visitors from the two eroding basins. Eagles Point serves three uses for the park visitors; those that want a view of the Golden Gate Channel and bridge from the main vista area; those that want a cliff side view of Deadman's and Eagles Point Beach and surfing area; and surfers desiring access to the narrow Deadman's Point Trail to the west. It was realized that if any of these traditional uses were halted the barriers would be ignored or vandalized. The final solution was to lay a designated trail that brought visitors down to the cliff edge to see the beaches and have a commanding view of the Golden Gate. Surfers would still have access to the Deadman's Point Trail. A 330 foot fence made of 4x2 galvanized wire, 4 feet high, supported by 4x4 posts encircled the rim of the basin in a horseshoe pattern. The program will maintain the fence until 1984 to prevent public access to the western basin until a ground cover is well established. Once the substantial shrubs like Baccharis, Lupines, and sage have grown to a mature height and regeneration is occurring, the existing fence will be removed. At this time it is recommended that a subtle barrier still be used to discourage access to the basin. Either logs or a low, 3 foot wire strand fence could be installed. Meanwhile, maintenance of the fence and trail system is critical to the success of this project to encourage the visitors to use only the formal paths.

Revegetation

Loss of soil from the project site was reduced by the installation of checkdams at various locations within the gully field. However, establishing a ground cover was the only permanent natural means to arrest erosion and prevent further degredation of the site. This was done in three stages. First, by installing checkdams, jute-rope netting and a mulch cover in critical areas, the soil would be stabilized sufficiently to allow revegetation. Second, seeding a grass cover anywhere that vegetation was not established. This would be the critical factor in halting the wind from blowing sand and establishing a fine root structure that would minimize soil loss. Third, reintroduce native shrubs to enhance the habitat and develop a more protective vegetative cover (Fig 2).

Twenty-five yards of manure were spread over the area, and 1500 yards of jute-rope netting was laid in both drainages. The second phase began in the spring of 1980 and was reinstated in the fall of 1980. Between April through January 1981, 270 pounds of grass seed was sown over the 47,000 square feet of unvegetated hillside found at the point. Below is a list of grass species that were purchased for this project.

Dryland Mix . . . . 207 lbs.

- 13.50% Blando Bromegrass
- 44.88% Tetraploid Annual Rye
- 24.69% Lana Vetch
- 14.99% Rose Clover
- .05% Crops .04 weed

Ryegrass, Linn Perrenial . . . . 56 lbs.

Fescue, chewing . . . . 7 lbs.

Starting in late September, the San Francisco Parks and Recreation Department gave the Ocean District permission to tap the Lincoln Park irrigation system. A 200 foot rubber hose was used 3-4 times a week until late December 1980. This particular winter was a drought year, and rain did not fall regularly until late January. Recycled waste water is pumped to Lincoln Park and used for the irrigation of the golf green. By December grass was covering 85% of the site that was planned for revegetation. The grass grew stronger with better coverage when the woodshavings and horse manure were supplied. The mulch cover retained moisture for the grass seedlings, reduced the impact of rain, and delivered nutrients.

Native Plants

The final phase of the project called for a revegetation program using native coastal shrubs (Fib. 2). By accelerating revegetation with a substantial ground cover two objectives were met. Extensive planting of coastal shrubs added a renewable erosion control resource to the site. This enriched soils with nutrients, delivered a constant supply of leaf litter, strengthened the weak soil structure, and discouraged public use of drainage areas.

Three species of shrubs are being planted in large numbers, along with additional coastal plants for diversity. Baccharis, Bush lupine, and Beach Sagewort are being transplanted from cuttings that have been rooted at the Ocean District Native Plant Nursery. Selected cuttings are clipped from native stock from Fort Funston, Lands End and Fort Scott areas, allowed to root, hardened up, and transplanted at the site about four months later. The nursery began in October 1980 with 318 transplants completed by March, 1981. Transplanting will continue in the fall of 1980. At present the nursery stock is being developed on a rotational basis. The major benefits of this are that selected cuttings of local native plants are used, thereby working with a gene-pool that has evolved especially adapted to this coastal environment. Another advantage is the reduced cost in raising our own stock and eliminating the necessity of purchasing the plants from a commercial nursery which does not have local plants. Below is a list of native plants used in the revegetation project.

1. *Baccharis pilularis*
2. *Lupinus arboreus*
3. *Artemisia pycnacephala*, Beach Sagewort
4. *Fragaria chiloensis*, Beach Strawberry
5. *Erigeron glaucus*, Seaside Daisy
6. Ceanothus (cuttings/seeds)
7. Yarrow (cuttings/seeds)
8. Buckwheat (cuttings)
9. Monterey Cypress and Pine (seeds)

Some cyclical seeding of grass seed will continue in the fall of 1981, however, the main emphasis from now on is transplanting shrubbery.

Construction Logistics

The work project was separated into three phases, listed below are the goals of each phase.

Phase One - February 24 through March 14

- -Build ten checkdams in main western gully
- -Flag trail course for phase two

Phase Two - March 17 through April 29

- -Grade and fill lower gully field
- -Construct six retaining walls
- -Build designated trail and appropriate shoring
- -Construct the east and west vista platforms
- -Install safety railings
- -Lay jute rope and manure and seed

Phase Three - June 23 through July 24

- -Remove hazard snags, tree stumps and dead limbs
- -Construct main vista platform for tree root protection, gabion structure and stair trail.
- -Build designated trail from main vista to lower vista trail
- -Construct gabion for stair trail shoring on east cliff edge
- -Install checkdams in small cliff gullies on east slope
- -Install waterbars in appropriate locations on trail and hillslope
- -Fill main gully and gabions with imported soil
- -Construct range fence around restricted area

Both phase one and phase two were assigned to the park's Young Adult Conservation Corps (YACC). The Crew Leader supervised four enrollees throughout both phases. Phase three, which was very labor intensive was assigned to the Youth Conservation Corps (YCC). The Crew Leader supervised eight to ten enrollees. Both work crews had unskilled enrollees. As a result, the progress was slow; however, the final product was professional and of sound construction.

Man Hours

Phase One 14 days	Hours	Pay	Total Cost
1 Crew Leader	112	8.20	918.40
4 Enrollees	448	3.10	1388.80
1 Park Technician	112	6.49	726.88
Phase Two 33 days			
1 Crew Leader	264	8.20	2197.60
4 Enrollees	1056	3.10	3273.60
1 Park Technician	264	6.49	1713.36
Phase Three 25 days			
1 Crew Leader	200	5.50	1100.00
8 Enrollees	1600	3.10	4960.00
1 Park Technician	200	6.49	1298.00
Maintenance Personnel			
2 WG-5	24	8.09	388.32
2 WG-3	24	7.33	351.88

Continuing Maintenance

1 Park Technician	160	6.49	1038.40

TOTAL SALARY COST 19,355.24

TOTAL MAN HOURS 4,464

Materials

All lumber used at Eagles Point was from reverse construction projects in the park or purchased as recycled material. Approximately 500 board feet of 2x12s were used to build checkdams and retaining walls. The planks all came from Ft. Cronkhite where the YCC had removed buildings in the summer of 1977 and 1978.

The 182 eight foot railroad ties were used to build the stair trail and gabions. Although the YACC had purchased about 50 of these, the remaining 132 ties were donated by the Santa Fe and Belt Railroad and were all recycled.

Rebar, nails, jute rope netting, range fence, and tools were paid for by both the YACC and YCC. Nearly 2950 lineal feet of rebar was used to anchor the railroad ties on the stair trails and gabions. 1500 hards of jute rope netting was staked at the site to stabilize soil and hold down manure and seed.

Approximately 25 yards of wood shavings and horse manure were brought to the site and spread by buckets and wheelbarrows. Material cost came to $8,830.75

Material Expenses

YACC Cost $3966.00
YCC Cost. 730.00
Ocean District Cost 97.75
Donated/Recycled 4037.00
Actual Federal Money Spent. . . . 4793.00

Sand Fill

19 dump-truck loads of clean sand were delivered from Ft. Mason to the site. The San Francisco Park and Recreation Department gave Ocean District staff permission to cross the golf course with the dump trucks to get closer to the site. From the Lands End Trail the sand was then wheelbarrowed by hand down the steep slope and dumped into the main gully. To fill all ten checkdams required 77 tons of sand. The wheelbarrows were then pushed back up a 12 inch wide ramp to the Lands End Trail to minimize the impact on the remaining sparse vegetation. The remaining 38 tons of sand was used to cover the exposed tree roots under the main vista platform. Transporting sand by wheelbarrow was

very laborious and exhausting work but because of the slope gradient of the gully and the 200 foot cliff beneath it, maintenance was reluctant to use heavy equipment in fear that it would go over the cliff edge.

Conclusion

The Ocean District of the Golden Gate National Recreation Area is the sole guardian of the remaining pristine coastal habitat in the San Francisco peninsula. Areas supporting native shrubs, grasses and plants should be protected and enhanced whenever possible. Eagles Point site restoration and revegetation project illustrates the National Park Service's commitment to protecting the natural resources from uses that would destroy the scenic and natural character of the area. Whenever site restoration is attempted in the park, Eagles Point Project should be used as an example in maintaining the appearance of a natural unmanaged landscape, even though structures have been built to control erosion. As the growing seasons pass, ground cover will eventually obscure the low retaining walls, checkdams, and waterbars.

At the same time, whenever the natural resources are being threatened, the park should not hesitate in taking bold measures, such as installing temporary barrier fencing to insure site restoration and protection. The management objectives of this project were to halt accelerated erosion, restore native habitat, and provide public access that was in harmony with the site enhancement. To fulfill these goals, 4,464 man hours were invested. Project expenditures and salaries cost $24,148, with an additional $4,030.00 worth of donated and scavenged materials. By utilizing youth work crews, instead of the park's maintenance division, the government saved $13,130 in salary cost (based on a WG3 salary, $7.33/hr.).

As annual visitor levels approach 12 million people, the impact on park lands in the Ocean District increases each year. There are many other sites in the park that require attention as did Eagles Point. Had this project not been implemented, accelerated erosion would have continued unchecked. The gully field would have degraded further and lengthened after every large storm. Trampling would have continued and the remaining vegetation would have died.

Fortunately, this scenario was discontinued. Eagles Point is slowly recovering. At present, the once barren slope is now a lush grass hillside with native shrubs being planted and others naturally recolonizing. The gullies are filled and the trampling has stopped. This project will not be completed or determined a success until the coastal shrubs are well established and regeneration is occurring. As for now, Eagles Point has been preserved as a land form, as habitat, and with a trail design that the public may use and enjoy with a minimum of impact. This was accomplished by implementing sound principles of land use planning, natural resource management techniques, and hard, physical intensive labor.

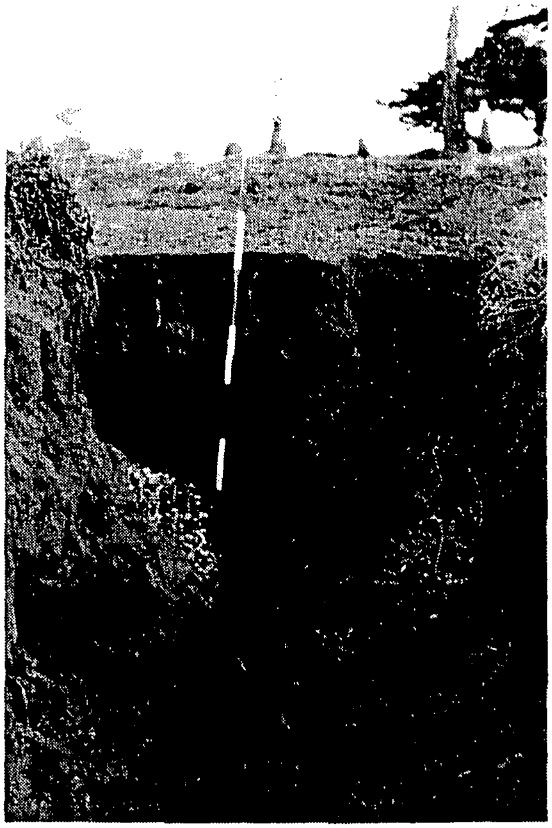

Fig. 1
Headwall to main gully in the upper basin. The gully was 81 feet in length and six feet deep.

Fig. 2
Exposed tree roots as a result of severe trampling

Fig. 3

View looking east across main gully and basin, note bare soil and exposed tree roots.

Fig. 4

Same view as Fig. 3 seven months later with a ground cover established and tree roots buried.

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