THE REDWOOD NATIONAL PARK WATERSHED REHABILITATION PROGRAM:

A PROGRESS REPORT

AND

PLAN FOR THE FUTURE

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RECOMMENDATIONS

From 1979 to 1983, about 40 percent of the watershed rehabilitation program scheduled in the 1981 watershed rehabilitation plan was completed. Based on the past accomplishment and projected needs, a series of recommended actions has been developed. These recommended actions are expected to yield both immediate benefits in terms of improved program efficiency and long term results with respect to information needed by park management to undertake creditable stewardship of a dynamic, rapidly healing ecosystem.

Scientifically sound stewardship which anticipates, detects and remedies resource problems before crisis situations develop, will remain of paramount importance until ecosystem recovery has attained relative stability. Here relative stability means plant and animal communities have achieved self regulation and self perpetuation, modified only by responses to natural environmental conditions. It is presumed the National Park Service will have obtained the information necessary to regulate perturbations, other than those of natural origin, which could adversely affect park resources. Recommendations formulated were the following:

All basic resource information, raw data, maps, reports, observations, photographs and artifacts associated with watershed rehabilitation work must be properly identified, stored, cataloged, computerized and inventoried. Information inventories must be made available for use by all park staff to enable them to locate and utilize information. Duplicates must be used so original data will not be lost or modified.

The park will undertake the systematic acquisition of basic resource information which has not been collected. Such a plan must assure long term stream and erosion studies, fish and wildlife investigations, and in particular, vegetation research. This work is required to assure park resource preservation, effective and timely resources management actions and accurate resource interpretation. The aspect of most interest and value, however, could result from documenting natural successional changes during ecosystem recovery processes. This would be of particular value in view of the influence, either positive or negative, of various aspects of the watershed rehabilitation program. One effective way to help ensure such a program is to establish it in concert with the Man and the Biosphere program. Redwood recently became an element of a California Coastal Ranges Biosphere Reserve. The park will, with Regional and Washington assistance, fully exploit the advantages which accrue from such a designation.

Timely management actions will be undertaken regarding program staffing to consolidate similar organizational functions. These actions should result in greater efficiency and cost savings by eliminating overlapping, parallel and duplicated functions.

Increased efforts will be directed toward determining the value, benefits and effectiveness of erosion control activities applied by the watershed rehabilitation program.

Park management will undertake rigorous review of the design and degree to which rehabilitation prescriptions are applied. Attention will be focused on identifying and treating areas to control erosion. Methods for dealing with areas posing less erosion potential will be identified. Work which accomplishes little erosion control, or is otherwise unnecessary, will be eliminated.

A final rehabilitation program report for general public consumption will be developed. Appropriate, high quality photographs, records and information for use in such a document will be set aside for potential use. This stored material should be progressively synthesized to avoid an overwhelming task at the conclusion of the rehabilitation program.

PREFACE

Redwood National Park was established October 2, 1968 following a long and bitter conservation battle. Its purpose is to preserve significant examples of the primeval coastal (Sequoia sempervirens) forests and the streams and seashores with which they are associated for purposes of public inspiration, enjoyment and scientific study. The 58,000 acre park consisted of three redwood state parks (Prairie Creek, Jedediah Smith, and Del Norte Coast [27,500 acres]), a 5,600 acre northern unit including a section of the Mill Creek watershed and a southern unit comprising 22,500 acres in lower Redwood Creek. A one-half mile wide corridor extended up Redwood Creek to include a grove of the world's tallest trees.

As timber harvests continued in the Redwood Creek watershed, and specifically on lands above the one-half mile corridor, erosion and sedimentation problems beset the newly established park. These problems led to another battle between private timber companies and conservationists over protection of park resources. The result was expansion of the park in 1978 in order to protect existing irreplaceable park resources from damaging upslope and upstream land uses.

On March 27, 1978 President Carter signed into law the Act (Public Law 95-250) expanding Redwood National Park. Section 101(a)(6) of this Act authorized the Secretary of the Interior to initiate, provide funds, equipment, and personnel for the development and implementation of a program for the rehabilitation of areas within and upstream from the park contributing significant sedimentation because of past logging disturbances and road conditions, and, to the extent feasible, to reduce risk of damage to streamside areas adjacent to Redwood Creek. Effective October 1, 1978 an appropriation of $33 million was authorized to carry out the rehabilitation provisions of the Act.

This program for restoration of cutover lands in Redwood National Park has no precedent in the history of the National Park Service. The only possible equivalent program for comparison benefitted many parks. Those which come to mind include the Civilian Conservation Corps established by President Franklin Roosevelt in the 1930's, and Mission 66, the brain child of National Park Service Director Conrad Wirth during the Eisenhower presidency (see Everhart, 1983).

At Redwood, not only were huge financial committments made for acquiring private timberlands, but the Congress, by conceiving the idea and then passing the Act authorizing the watershed rehabilitation program, placed a great burden of trust on the National Park Service to develop and implement an effective program to keep hillslopes in place within one of the most highly erosive watersheds on the North American continent. From the outset, the park recognized nature's healing processes would achieve the desired end result in 500 to 1,000 years, or less, without human intervention. The challenge was then to identify meaningful achievements which could be accomplished during a 10 year watershed rehabilitation program. A secondary objective, which was also viewed as an obligation, was to document program benefits.

This latter objective had several elements. The first involved periodic program progress reports. Such reports necessarily incorporate an evaluation of the efficiency and cost effectiveness of various restoration techniques of erosion control and revegetation. Such information is of value to others involved in erosion control activities. Second, upon completion of the program, especially considering its cost, the park will have engendered a heavy obligation to report in detail on program accomplishments and how these accomplishments have benefitted the American public. In addition, a long term view should be taken to see if in 50 to 100 years the watershed rehabilitation program accomplished its short term as well as longer term objectives. In particular, was it worth the large investment?

At the close of the 1983 work season, the park's watershed rehabilitation program concluded its fifth year. The purposes of this document include a review of accomplishments achieved by the program and proposed work which is required to bring the program to a successful conclusion. In addition, plans are proposed for required resource management actions and resource information following termination of the watershed rehabilitation program in 1991. The park will need an active resources management program to deal with the various fish, wildlife and vegetation problems as they occur while rehabilitated lands heal and develop toward mature forests and associated ecosystems. Resource studies will be required to identify the progressive healing steps, to educe which restoration techniques were most effective and to identify resource problems which threaten the integrity of irreplaceable park resources.

To develop and implement the rehabilitation program, the park augmented an existing research and resources management program. Staff possessing specialized skills were hired to carry out not only the site specific rehabilitation projects and erosion and sedimentation studies specifically cited by the Act, but also staff to provide environmental and archaeological compliance, revegetation studies, fish and wildlife studies and evaluation and documentation of site specific watershed rehabilitation projects. Other required duties of specialized nature included the review of timber harvest plans within the Park Protection Zone, final settlement for lands acquired in the park expansion and revision of the legislatively established park boundaries. Accordingly, the staff acquired to carry out provisions of the park expansion Act with regard to rehabilitation and erosion and sedimentation studies, also undertook associated resource management, research and general park management responsibilities.

It was members of this staff which collectively contributed to the development of this document. The work which they reported includes aspects of site specific watershed rehabilitation and erosion and sedimentation studies as well as associated vegetation management studies, fish and wildlife studies, environmental policy and compliance activities, archaeological clearance actions, watershed rehabilitation evaluation and monitoring, timber harvest plan reviews and basic redwood forest ecology research. Their contributions were compiled and edited in a manner which preserved some semblance of the authors originality. Having identified project accomplishments, authors were then asked to identify work which remained and was necessary to the accomplishment of program objectives. Furthermore, program staff were to anticipate to the best of their ability, additional work which would be required following successful conclusion of the rehabilitation program in 1991 and staff functions needed to continue with required work.

This document then represents their combined efforts to report work accomplished, to identify what remains to be done before the rehabilitation program terminates and to list what work will remain following successful conclusion of the Redwood National Park watershed rehabilitation program.

ACCOMPLISHMENTS

1977 - 1983

I. INTRODUCTION

A. History of the Program

During 1977 park staff anticipated Congressional action to expand the park and to authorize a program to restore cutover lands. Accordingly they initiated four pilot projects designed to test the effectiveness and feasibility of various restoration techniques. These projects were accomplished by three different contractors, employing several erosion control techniques. The effectiveness of these initial four projects was studied.

The first appropriated funds were made available for fiscal year 1979. There were, however, $3 million appropriated previously for the park to initiate restoration work, to hire staff, to acquire logistical support and to undertake early park developments. This funding permitted park staff to undertake during the 1978 summer work season, five pilot rehabilitation projects on recently tractor-logged lands within the newly expanded park.

When the park was expanded, the division of Natural Resources consisted of a division chief, secretary, five professional staff, seven technicians and a labor crew of six. During the summer of 1978, a new management team was assigned to Redwood. A renewed emphasis was placed upon the planning and development of the watershed rehabilitation program. A preliminary May 1978 rehabilitation plan was amended and reissued in November 1978.

The rainy season of 1978-79 was devoted to planning, staffing, developing the summer 1979 erosion control projects, locating a field operations center in Orick, California and procuring equipment, supplies and logistics support to carry out a full-scale watershed restoration program. In addition, several tasks required by law were initiated. These included timber harvest plan reviews in the watershed upstream from the park, endangered species compliance, archaeological clearances and environmental compliance.

Studies of the legislation and legislative history revealed a number of additional tasks to be accomplished. These included the erosion and sedimentation studies directed by Section 101(a)(6), provisions regarding Redwoods United, Inc., the 101 by-pass highway, revestment of personal property and down timber, a west-side access road and the development of timber harvest guidelines. Clearly, the first and largest order of business was getting the erosion control program fully operational.

Early in the program, we recognized two distinct functional entities were required to most effectively conduct the program. A Resource Management Division was required to carry out watershed rehabilitation projects. A Technical Services Division was envisioned to fulfill associated responsibilities such as environmental law and policy compliance, archaeological clearances, the erosion studies, timber harvest plan reviews, rehabilitation technique development and evaluation (both physical and biological) and environmental monitoring for rehabilitation program support and for park resource protection.

The developing team was split into two separate park divisions during October 1979. Staffing of the Technical Services Division was completed during 1979 and 1980. With the hiring of a fish and wildlife ecologist in 1980, and the initiation of corresponding studies, the program was considered fully operational. Staffing of the Resource Management Division was also completed during 1980.

During 1979, preparation of a more thorough rehabilitation plan was initiated in cooperation with the Denver Service Center. It was completed and approved in March 1981. This plan, with seasonal amendments to the erosion control project priority list, has guided the program since. The Resources Management Plan, issued in February 1982, discussed elements of the Watershed Rehabilitation Plan as well as other resource management, research and monitoring programs.

Entering the 1981 work season, the program was fully staffed and equipped. Erosion control techniques had by this time become standardized. Park staff had assumed an even greater portion of the water resources data collection program conducted in cooperation with the U.S. Geological Survey. A west side access road was developed which permitted access to park lands west of Redwood Creek. An experimental rehabilitation training program was undertaken under the aegis of a cooperative agreement with the Redwood Community Development Council, Inc.

Several organizational consolidations were initiated in 1981 following an operations evaluation. The roads engineer, roads maintenance funding ($75,000) and equipment were moved from Resources Management into the Maintenance Division. In addition, the revegetation program located in Technical Services was consolidated with a parallel function within the Resources Management Division. The Research Biologist position and funding ($74,500) were transferred to the Regional Cooperative Park Studies Unit Program.

Progress made in implementing the watershed rehabilitation program, erosion and sedimentation studies and the implementation of other sections of P.L. 95-250 were communicated in annual reports to the Congress, in the Superintendent's annual report, in technical reports, in symposium presentations, journal papers and in regular, periodic briefing papers or memoranda (see bibliography). For two years monthly and/or alternate monthly reports were submitted to the National Park Service headquarters.

During early FY-83, a new Superintendent was assigned to Redwood. Technical Services and Resources Management were consolidated under a new Assistant Superintendent.

B. Staffing/Funding

With the 1978 park expansion, there was a $2,459,700 increase to the park's annual base funding to administer, protect and rehabilitate lands acquired.

Watershed rehabilitation expenditures by fiscal year are presented in Table 1. Total annual expenditures, including all auxilliary staff support and logistic costs, have been about $2 million. Fiscal year 1983 program funding is shown in Table 2.

The approved organization chart for Resources Management has 43 positions, five permanent full time, eight permanent less than full time, 16 term and 14 temporary/seasonals. Technical Services has 30 positions, four permanent full time, ten permanent less than full time, three term, two temporary/seasonal and 11 student positions. The number of temporary/seasonal and students fluctuates annually.

A number of management/administrative positions and a research scientist (the latter assigned to Western Regional Office) manage and assist the rehabilitation team. The Assistant Superintendent, Research Scientist, Secretary, Administrative Technician and a student aid are stationed in the Arcata Office. The Administrative Division has two permanent full time, three permanent less than full time and three student aids stationed in Arcata to provide contracting services, procurement and clerical assistance. In all, there are 87 positions of various types directly associated with the 1978 park expansion and the watershed rehabilitation program.

TABLE 1

Watershed Rehabilitation Expenditures

	1979	1980	1981	1982	1983	TOTALS
PAYROLL	$480,895	$784,765	$1,077,248	$1,100,884	$1,167,898	$4,611,690
HVY EQUIP	365,002	757,155	284,386	503,024	345,647	2,255,214
CONTRACTS	300,585	303,298	240,344	136,657	266,489	1,247,373
SM PURCH	350,580	355,503	246,396	119,244	127,483	1,199,206
USGS	114,500	154,680	136,510	69,450	72,000	719,140
MTR POOL	Not Avail	Not Avail	48,092	92,528	86,588	227,208
TVL/PER DIEM	14,351	10,690	8,249	12,818	11,677	57,785
FEDSTRIPS	17,540	9,760	6,158	1,116	915	35,489
IMPREST	3,370	5,426	5,626	5,423	6,161	26,006
MISC TRANS	Not Avail	2,790	3,674	200	2,688	9,352
TRAINING	Not Avail	Not Avail	480	960	4,467	5,907
TOTALS	$1,646,823	$2,384,067	$2,057,163	$2,042,304	$2,092,013	$10,394,370
INIT BUDGET	$2,102,900	$2,617,900	$1,989,500	$1,920,500	$1,980,000	$10,610,800

TABLE 2

Fiscal Year '83 Program Funding

Technical Services	$	
Administration		121,700
Fish and Wildlife		144,700
Geologic Services		148,700
Environmental Policy		48,000
Geomorphology		156,300
Cultural Resources		57,500
	$	676,900
Resources Management	$	
Administration		148,900
Vegetation		182,500
R.M. Support		223,600
Site Specific Rehabilitation		669,500
R.M. General		57,800
		$1,282,300

II. THE WATERSHED REHABILITATION PROGRAM

The rehabilitation program was designed to meet the following objectives: (1) to reduce the amount of sediment delivered to stream channels from areas disturbed by logging, including removal of 200 - 250 miles of logging roads; (2) to encourage the return of a natural pattern of vegetation on prairies and logged timberlands, and; (3) to encourage erosion control on private timberlands located upstream from the park.

A. Site Specific Watershed Rehabilitation

1. Role and Function

Erosion control has been accomplished through the use of primary and secondary treatments which incorporate heavy equipment and/or labor-intensive techniques. Primary erosion control treatments provide an immediate reduction in land use-related sediment yield. These treatments include logging road outsloping, ripping, construction of cross-road drains and waterbars, removal of soil and debris from stream channels, landslide stabilization and stream channel rediversions. Secondary erosion control treatments consist of labor-intensive and heavy equipment work designed to control erosion from areas disturbed during primary treatment. Secondary treatments commonly include: Checkdam construction, channel armoring and mulching, wattling, planting and seeding bare soil areas. A companion program which addresses revegetation of bare soil areas, including those disturbed during erosion control work, is presented in a section titled Vegetation Management.

2. Summary

Watershed rehabilitation at Redwood National Park has grown from small pilot projects through an extensive experimental phase, with five to six personnel responsible for four or five sites per year, to an organization of twenty to twenty-five people directing and evaluating erosion control and revegetation activities on several large areas each work season (Figure 1). To date, over 11,500 acres of cutover land within the park's boundaries have been treated. Additionally, nearly 72 miles of logging road have been removed (Table 3). Evaluation of data from previous years began to directly influence restoration procedures beginning in 1980 by emphasizing the most cost-effective treatments (see accompanying section on Rehabilitation Monitoring and Evaluation).

Within the boundaries of the expanded Redwood National Park, there were approximately 200 miles of former logging road to remove and 36,000 - 40,000 acres of cutover and roaded land to treat. As shown in Figures 2 and 3, approximately 34 percent of the most erosive cutover land was treated and 37 percent of the total road system was obliterated through 1983. Once treated, these areas were eliminated

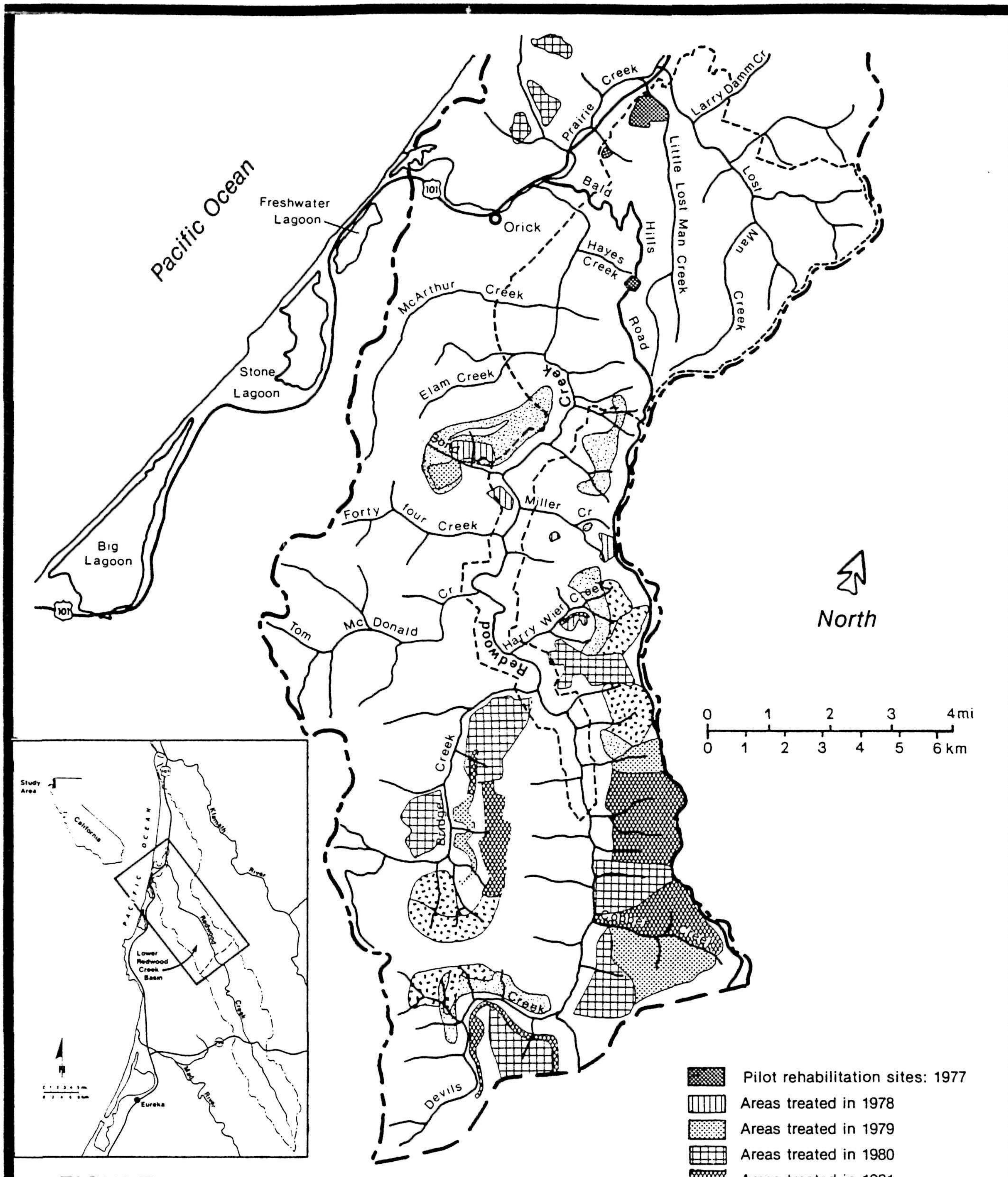

FIGURE 1:
WATERSHED REHABILITATION PROJECTS IN REDWOOD NATIONAL PARK

National Park Service/United States Department of the Interior

TABLE 3

Summary of Erosion Control Activites

In Redwood National Park 1977 - 1983

	1977	1978	1979	1980	1981	1982[1]	1983[2]	Total[2]
Acres of cutover land "treated"	273	271	970	3,119	2,414	2,838	1,630	11,515
Miles of road treated	0.6	1.6	10.4	16.2	19.1	13.6	10.1	71.6
Haul road stream crossings excavated	0	7	64	93	90	67	48	369
Skid trail stream crossings excavated	0	16	57	75	34	21	57	260
Volume of material excavated from stream crossings (yds^3)	?	2,500	22,500	42,000	40,000	52,500	64,500	2,240,000
Excavated stream crossings protected with check dams	0	10	7	24	0	1	0	42
Excavated stream crossings protected with rock armor	0	3	48	104	30	20	23	228

1 Does not include estuary rehabilitation

2 Does not include estuary rehabilitation or several erosion control projects started after 9/1/83

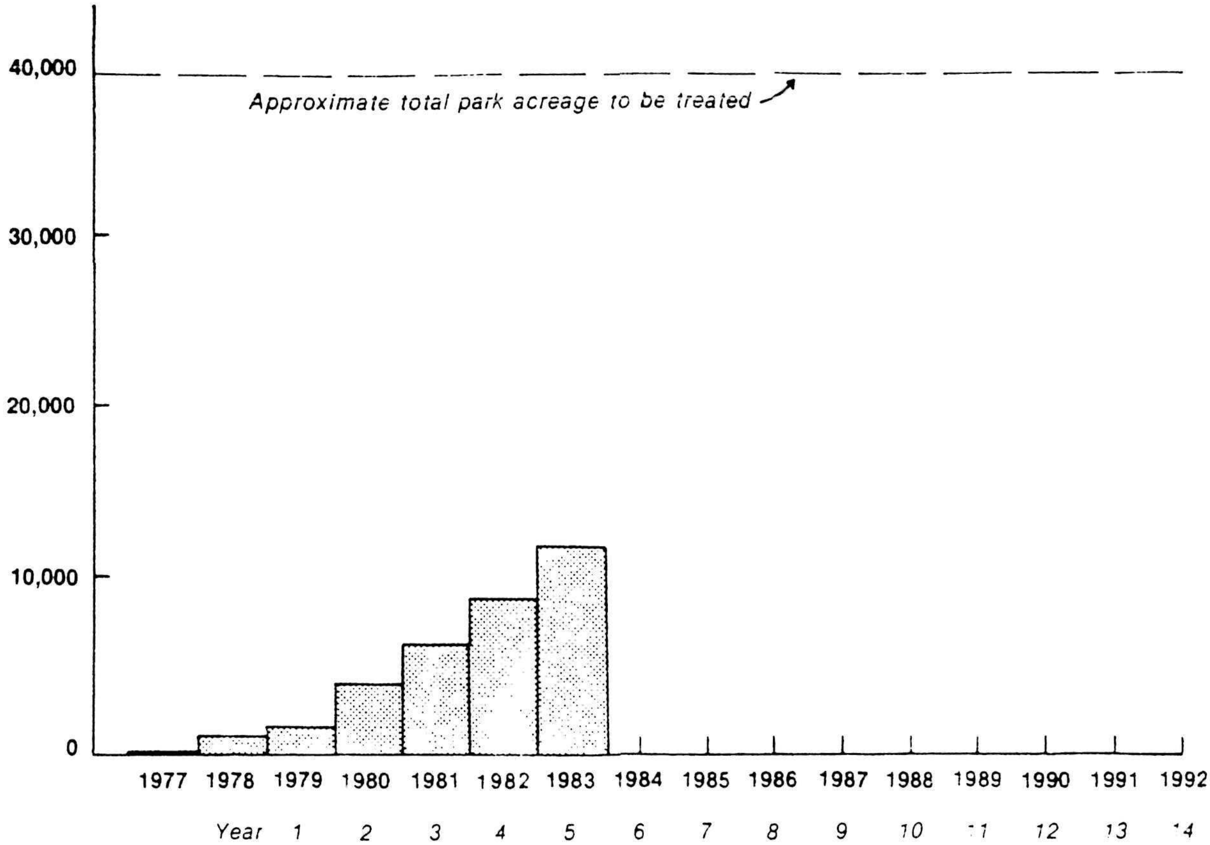

Figure 2 Acres of Cutover Land Rehabilitated

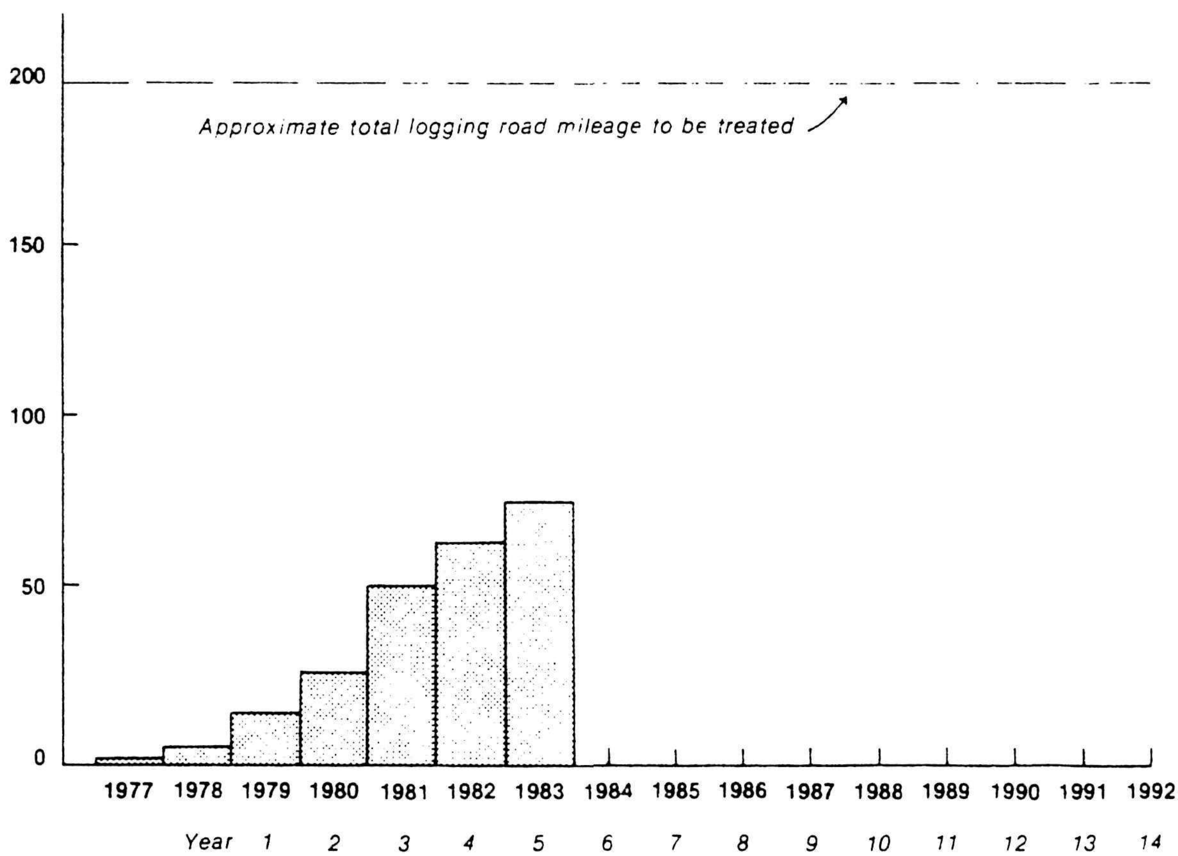

Figure 3 Miles of Logging Road Rehabilitated

from any future rehabilitation work. Only isolated problems, which can be dealt with by hand labor techniques together with the maintenance of existing erosion control facilities, are handled on treated lands. Between 1977 and 1983 nearly 10,000 yd^3 were removed from active landslides. Over 700 checkdams and nearly 10,000 yd^3 of rock armor were placed in newly excavated channels to protect bare soils from future erosion. Hundreds of acres of land were seeded (188 acres) or planted (470 acres) and covered with a layer of straw mulch (299 acres) to prevent soil erosion. Over 65,000 ft^2 of the most highly erosive soils were completely covered with organic erosion control fabric. This work prevented soil and debris from entering Redwood Creek and adversely impacting downstream aquatic and riparian resources.

These figures do not represent the total benefits of the program. Erosion control work reduces erosion and prevents future erosion sources from developing. Progressive revegetation of rehabilitated sites will further reduce erosion rates during the next 10 to 15 years.

3. Accomplishments

The following discussion reviews changes in approach and techniques for erosion control during the first seven years of the watershed rehabilitation program (including experimentation in 1978 - 1979) at Redwood National Park as well as the overall progress and accomplishments of restoration work.

1977: Three pilot projects totalling 273 acres were initiated during the summer of 1977 to study individual erosion control and revegetation techniques and to investigate the feasibility of implementing a large-scale rehabilitation program (Figure 1). A secondary emphasis was to examine the feasibility of using heavy equipment for logging road obliteration. Table 3 shows work performed during 1977 rehabilitation, while overall costs are shown in Figure 4. Prospective test sites were chosen by park staff. Local contractors were requested to submit proposals for erosion control. Under Request for Proposal (RFP) procedures, bidding parties were responsible for proposing specific rehabilitation treatments. Following negotiations, contracts were awarded on the basis of prescribed treatments and bid prices.

Despite its limitations, the 1977 program was important because it revealed specific heavy equipment and labor-intensive techniques which would be useful and necessary for future rehabilitation work. In addition the 1977 program demonstrated some of the advantages of heavy equipment, revealed limitations of performing certain tasks with manual labor, educated park staff in certain contracting procedures, revealed the need for documentating work accomplishments, unit costs, and task effectiveness and pointed to the importance of the proper design, construction and maintenance of erosion control works.

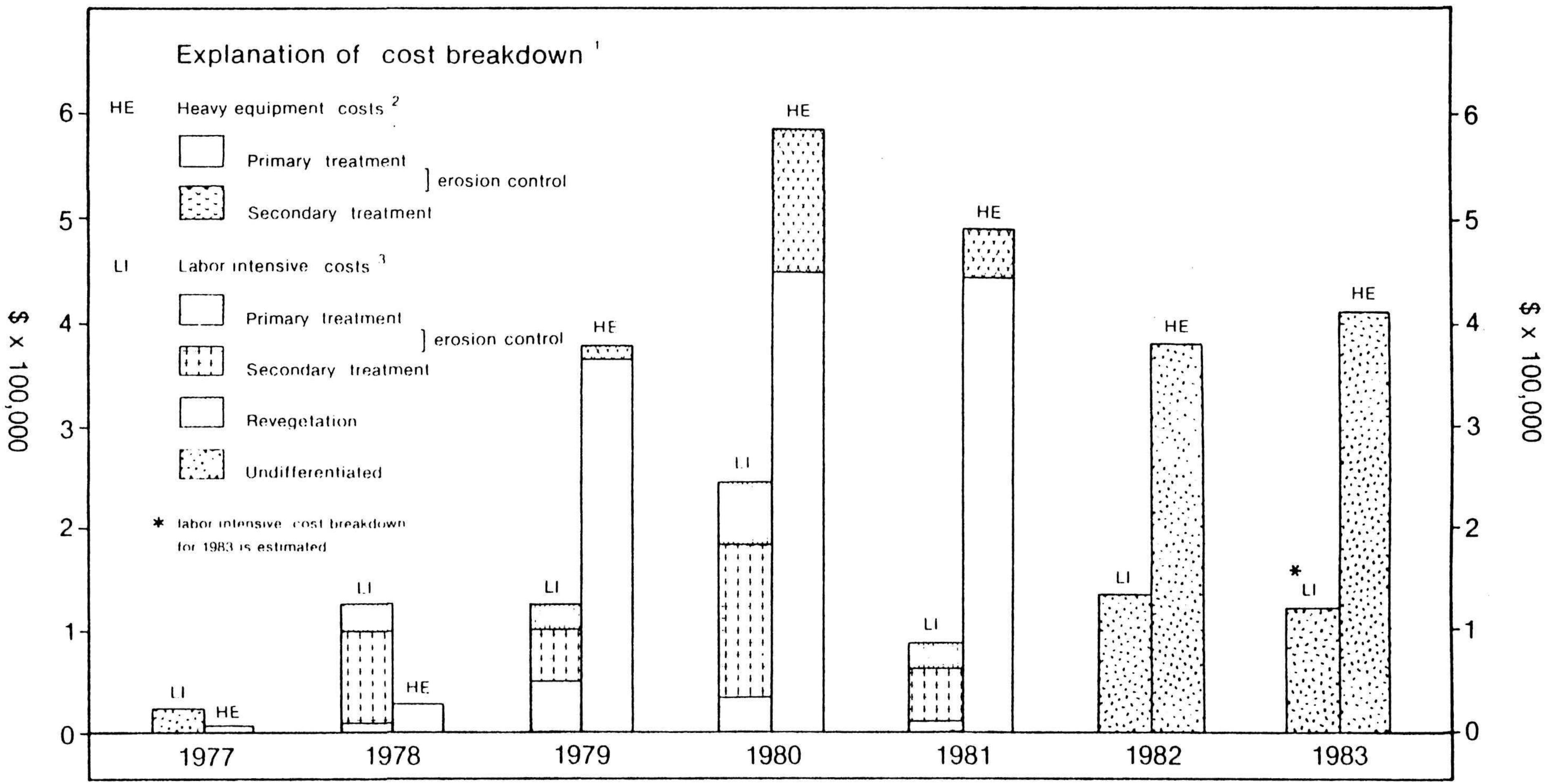

Figure 4. Annual Rehabilitation Cost by Type of Treatment

1978: The five sites treated in 1978 (Figure 1) incorporated a variety of rehabilitation techniques. Heavy equipment was used to remove roads (primarily by outsloping), reshape landings and excavate fill material from road and skid-trail stream crossings. Primarily, effort and money spent during 1978 involved the application of secondary, labor-intensive treatments to protect areas from surface erosion, to prevent downcutting or widening of excavated stream crossings and to promote revegetation on lands disturbed by heavy equipment during rehabilitation treatment. Labor-intensive contracts differed from the previous year in that contract bid items were defined by the park staff rather than by contractors.

Perhaps the most important contributions of the 1978 program were not those specifically associated with controlling erosion. Rather, the experience, methodologies and philosophies of erosion-control rehabilitation gained by the staff in 1978 were the most important contribution of the year's work. For example, items which have proven invaluable in subsequent years include: The experience gained in labor contracting; the need for accurate prescriptions for the use of specific treatments; the formulation of unit-costs for erosion control practices; and the development of a methodology for approaching watershed rehabilitation.

1979: In contrast with previous years, work in 1979 included ample lead time for park staff to inventory erosion features and complete work prescriptions on three sites during winter and spring months. Larger and more complex rehabilitation sites were planned (Figure 1). One work area incorporated over 600 acres, contained more than 100 major work locations and required approximately $250,000 to treat. Rehabilitation work on a fourth site was completed by a Request for Proposal (RFP) contract.

In 1979 a small labor crew was added to the park staff. The time required by formal government contracting made a park labor force an appealing and valuable addition to the rehabilitation effort. The use of in-house labor crews permitted application of mulches and installation of erosion control devices immediately following heavy equipment operations in advance of winter rains. This was not always possible during previous years. Furthermore, a plant ecologist assumed full-time responsibility for prescribing revegetation treatments and evaluating all revegetation treatments applied.

Work in 1979 emphasized experimentation with a variety of equipment used for different tasks, including machinery to excavate and shape soil and debris removed from stream channels and road benches (backhoes, bulldozers, cranes and hydraulic excavators). In addition, different types of equipment were used for similar work tasks, and individual work tasks were performed to varying degrees. For example, landing treatments ranged from a minimum of decompaction and draining with ditches, through mild outsloping, to almost complete removal of the landing fill material. In 1977 and 1978, heavy equipment use was restricted to primary erosion control treatments. In 1979, secondary treatments accounted for three percent of the total heavy equipment expense.

1980: By spring of 1980, full staffing of the Resources Management organization responsible for site specific rehabilitation had occurred. Twenty full-time personnel (compared to six positions in 1975 and five positions in 1978) were responsible for coordinating and supervising erosion control and revegetation activities on six rehabilitation sites in 1980 (Figure 1). Five of these sites were supervised by park staff, the sixth site was treated by a contractor under a negotiated, fixed-price RFP contract. Altogether, the 1980 rehabilitation projects treated 3,119 acres of cutover land, removed 16.2 miles of road, and excavated 93 haul road stream crossings. A noncritical seventh site, located west of Prairie Creek (Figure 1), was treated as part of a training program conducted by the Redwood Community Development Council, Inc.

Heavy equipment treatments in 1980 were partially experimental, but reflected standardized approaches developed over the previous 3 years. Experimental use of heavy earth-moving equipment consisted of prairie restoration (gully and road obliteration), treatment of large land slides, the creation of new stream channels and rock armoring of excavated stream channels. Secondary treatments (predominantly rock armoring) accounted for 26 percent of the total heavy equipment cost in 1980 as opposed to only 3 percent for the previous year (Figure 4).

Most labor-intensive work during 1980 was accomplished by the park labor force. While two projects were completed by IFB (Invitation For Bid) and RFP contracts a significant portion of the remaining labor-intensive work was provided by a nonprofit community organization for the handicapped (Redwoods United, Inc.) through a cooperative agreement. The major advantage of having most of the labor-intensive work performed by park and Redwoods United labor forces was that nearly all erosion control treatments could be applied before winter storms.

Labor-intensive treatments in 1980 focused on the prevention of stream channel erosion in areas disturbed by heavy equipment. Checkdams were used primarily. Previously checkdams had been constructed on stream channels draining between 10 and 40 acres. In 1980, they were installed on streams draining up to 70 acres, permitting comparisons of checkdams with machine-placed rock armor for similar sized streams.

1981: Twelve personnel were responsible for erosion control activities on six projects. Five projects were supervised by park staff and the sixth was treated under a firm, fixed-price contract. In all, 2,414 acres of cutover land were treated, 19.1 miles of road were removed and 90 stream crossings were excavated. Expenditures on rehabilitation work began to decline in 1981. The contract for rehabilitation work on 4.3 miles of road involved new methods for developing erosion control specifications.

Work in 1981 was designed to standardize, as much as possible, the approaches and techniques used for watershed rehabilitation. Prior to 1981, work prescriptions received varied amounts of review based on subjective evaluations regarding the severity of existing or potential sediment sources. In some cases, this resulted in comparatively high unit costs for the amount of erosion prevented (that is, dollars spent per cubic yard of soil saved). In 1981, prescriptions were determined by quantifying the potential for future erosion from each prospective work site and subjecting work plans to detailed peer review. Decisions to perform individual work items were then based upon the size (volume) of the potential sediment source, the amount of damage which heavy equipment would do to the existing vegetation and the estimated unit cost for the amount of erosion prevented ($\$/yd^3$). Additionally, treatments in stream channels were designed by calculating the expected 20-year return-period discharge at each work site. As a result the decision to treat a work site within any one of the rehabilitation units became less dependent on judgment.

Rehabilitation work in 1981 was designed to reduce the use of costly, ineffective secondary erosion control treatments. Instead, more emphasis was placed on completing the more cost-effective primary treatments. Equipment used for rehabilitation was standardized, and as a result more work was accomplished by efficient earth moving machinery, namely bulldozers and hydraulic excavators.

<u>1982</u>: Ten personnel were responsible for five projects. A total of 2,838 acres of cutover land was treated, 13.6 miles of road removed and 67 haul road stream crossings excavated. Expenditures on rehabilitation work continued to decline slightly in 1982.

No rehabilitation projects were completed by contract in 1982. Quality control concerns arose from dissatisfaction with the work completed under the 1981 contract. More time was needed to refine the procedures employed to generate contract specifications. New procedures were developed in 1982 and tested with rental equipment work to evaluate their potential for use in future contracts.

<u>1983</u>: Six rehabilitation projects treated 1,873 acres; 12.4 miles of roads were removed, and 57 haul road stream crossings were excavated. One project included the removal of 15 skid trails and extensive hillslope work. Five projects were supervised by park staff. One project was completed using a contract with specifications developed in 1982.

Large crawler tractors were used extensively for most work. Hydraulic excavators remained dominant for final stream crossing and skid trail excavations. Most other primary heavy equipment treatments remained unchanged. Heavy equipment secondary treatments were kept to a minimum. Labor intensive work was limited to secondary treatments, largely straw mulch application.

The restoration work initiated in 1982 and completed in 1983, at the mouth of Redwood Creek, entailed the removal of large quantities of wave-washed sand from the necks of both the north and south sloughs, and the excavation of mill slash and other waste material from former wetlands south of the Redwood Creek levees. This work was undertaken to restore aquatic habitat beneficial to fishery resources of Redwood Creek. About 2.5 acres of wetlands were created with about 12,000 cubic yards of fill removed.

B. <u>Revegetation</u>

1. Role and Function

Vegetation management staff prescribe revegetation treatments and direct planting on watershed rehabilitation work sites and other park areas being restored. Vegetation management staff are responsible for identifying and providing protection for all threatened and endangered plant species under review for Federal listing. Park activities which could potentially affect vegetation are reviewed and field surveyed to insure that no identified species are adversely affected.

2. Summary

Nearly one-half million trees and shrubs have been planted on rehabilitation sites and understocked lands. Studies undertaken on plant survival, revegetation and cost-effectiveness have resulted in refined revegetation prescriptions. Studies included soils work, greenhouse tests, mycorrhizal inoculations, fertilizer and mulch field tests and seeding experiments. Table 4 lists project accomplishments.

A monitoring program was initiated in 1979 to evaluate plant survival and revegetation technique cost-effectiveness. The results have been useful in developing more effective revegetation prescriptions. Examples of the changes made in revegetation techniques include the discontinuance of wattling and a major reduction in stem cuttings and grass seeding (the latter for surface erosion in forest habitats). Where grass seed is used, the seed mix has been limited to those species which have proven most successful. Large-scale propagation of native shrubs by private nurseries allowed economical, dense planting, which reestablished vegetative cover more rapidly. Experiments undertaken in 1979 developed techniques for large-scale propagation and identified species which could be economically grown. Studies and discussions with timber companies revealed two-year-old bare root conifer seedlings had much higher survival under conditions typical of park rehabilitation sites. As a result, the park switched to using two-year-old stock to the extent supplies permitted.

TABLE 4

Revegetation Project Accomplishments

Project Title/Objective	Year Initiated	Status
Effects of grass-seeding, fertilizer and mulches on natural revegetation of a rehabilitated site.	1979, 1980	Monitoring has been done yearly. Results published in Proceedings of NPS Research Conference, 1982. Follow-up monitoring will be done in 1985. Management recommendations for continued mulching prepared.
Outplanting of native shrub rooted cuttings and seedlings.	1980	Field work completed. Report is being prepared.
Mycorrhizal inoculation and outplanting of nursery stock; comparison of nodulated and unnodulated seedling success; identification of symbiotic organisms on revegetation species.	1980, 1982	Field work completed. Results reported in paper prepared for NPS Research Conference, 1982. Greenhouse studies continuing.
Effectiveness of vexar tubes to reduce deer and elk predation on conifer seedlings.	1980, 1982	Monitoring continues.
Effect of compost and slow release fertilizer on Whipplea modesta grown in surface and subsurface soils (greenhouse).	1980	Project completed and findings published in Proceedings of NPS Research Conference, 1982.
Conifer seedling survival and growth in grass seeded or straw mulched areas.	1980	Field work completed. Data analysis in progress. Results to be reported in management report.
Effect of slow-release fertilizer pellets on planted conifer and shrub seedlings.	1980, 1981, 1982	Field work completed. Data analysis in progress. Results to be reported in management report.
Effects of alder planted with chlorotic Douglas-fir on road cuts.	1981	Field work to be completed in 1984. Results to be reported in management report and erosion control symposium.
Inventory of buried seed in the forest floor under five forest types (to determine potential for natural revegetation) (greenhouse).	1981, 1982	Final inventory in progress. Data to be published in Soil Survey Report.
Effect of nitrogen, phosphorus, calcium sulfate and potassium and compost on Douglas-fir growth in to surface and subsurface soil types (greenhouse).	1981	Project completed. Findings reported in management memorandum.
Effect of compost, phosphorus, nitrogen and potassium on alder grown in two surface and subsurface soil types.	1982	Project completed. Findings reported in management memorandum.
Effect of fertilizer, commercially prepared compost and compost generated by RNP's composting facility on Redwood.	1983	Preliminary field trial initiated using commercially prepared compost. Full scale experiment will begin in summer, 1984.

C. Rehabilitation monitoring, documentation and evaluation

1. Role and Function

Staff geologists develop and test the effectiveness and cost-effectiveness of watershed rehabilitation techniques. Erosion and sedimentation rates from cutover lands are compared with rates on restored sites. Knowledge and technology acquired from these studies are applied to erosion control technique improvements as well as to further describe erosion causes.

2. Summary

As the watershed rehabilitation program progressed, the need to evaluate employed techniques and either discontinue, amend for improvement or adopt new and more innovative methods was recognized. Also recognized was an obligation to account for accomplishments, to effectively expend public funding and to contribute information valuable to professionals in the fields of erosion control and ecosystems restoration.

Although initial evaluations were made of restoration projects begun in 1977, it was not possible to undertake a scientifically designed, systematic studies approach until 1979. Thereafter, studies to evaluate methods for surface erosion control, for landslide stabilization and for preventing post-excavation, stream channel erosion were made. Furthermore, analyses were conducted to evaluate cost-effectiveness as well as the effectiveness in controlling post rehabilitation erosion.

Early studies showed sediment yield from bare soils areas was a minor component of post rehabilitation erosion. Large soil losses were occurring at excavated stream channels, however. A subsequent comparison of labor intensive practices, as opposed to heavy equipment work, revealed heavy equipment was both more effective and most cost-effective in achieving rehabilitation work. Various devices were evaluated for controlling erosion within excavated stream channels. It was determined either rock armor or complete excavation of fill material from stream crossings to the original stream configuration were the best measures.

Landslides were also shown to be a major sediment source. Studies were undertaken to identify forces and features which initiate landslides and to identify alternative means of treating areas which might develop landslides.

3. Accomplishments

During 1978 and 1979 a program was initiated to photograph and survey site conditions before, during and after treatment, together with detailed cost accounting of individual work items. A data base was established to determine the cost and effectiveness of various rehabilitation treatments.

In 1979 a variety of rehabilitation work analyses and geologic studies were completed which resulted in greater erosion control effectiveness and cost savings. Three studies measured surface erosion from bare soil areas exposed by restoration activities. In both 1977 and 1978, 90 percent of rehabilitation expenditures were directed toward handwork to control this perceived sediment source. By spring of 1980, monitoring studies indicated that erosion from bare soil areas on 1978 - 1979 work sites represented only a minor fraction of the total post-rehabilitation soil loss. Most erosion resulted from channel downcutting and widening. These findings supported the trend toward reducing the emphasis placed on controlling surface erosion. Labor intensive techniques were not only too costly but sometimes caused erosion problems more serious than those they were designed to control. The more expensive surface erosion treatments such as wattling, wooden terraces and ravel catchers were abandoned in favor of the more effective and cost-effective application of straw mulch. Beginning in 1980, a 2 to 4 ton-per-acre application of straw mulch was adopted as the most cost-effective method for controlling surface erosion. The most expensive applications, jute netting or excelsior blankets and other fabrics, were reserved for use on exceptionally steep, unstable slopes, judged highly probable to yield large quantities of sediment directly into a watercourse. As a result, experimentation was focused on stabilizing excavated stream channel reaches and promoting revegetation.

Studies on the costs and relative effectiveness of checkdams and channel armor for controlling stream erosion resulted in substantial changes in rehabilitation prescriptions. While effective, checkdams were too expensive and required continual maintenance. Rock armor, while sometimes nearly as expensive, proved to be more effective and required no maintenance. More than 200 monumented cross sections and surveyed profiles were established on 80 separate stream crossings to document post-rehabilitation channel erosion where checkdams, rock armor or no protective measures were applied. These sites were remeasured to verify short-term and long-term effectiveness. In 1977 and 1978, heavy equipment was restricted to primary erosion control treatments. Beginning in 1979, however, heavy equipment was employed for secondary treatments and accounted for three percent of the total heavy equipment expense. Experimentation with heavy equipment in 1979 resulted in a comparatively high cost for total work accomplished (Figure 4), however, these tests resulted in significantly improved cost-effectiveness for rehabilitation work undertaken during 1980 and 1981.

Observations of unprotected stream crossing excavations showed subsequent erosion was dependent on the character and completeness of the heavy equipment rehabilitation work. Basic prescriptions were formulated for the excavation of stream crossings to reduce erosion while at the same time eliminating the need to apply expensive rock armor for channel protection. This substantially reduced stream restoration costs with little noticeable decrease in effectiveness. Overall erosion control costs in 1980 were the highest to date for the rehabilitation program (Figure 4). This was attributed to the amount spent for labor-intensive and heavy equipment secondary erosion control treatments. In many cases, secondary treatments were reduced or eliminated when a high quality primary treatment was applied. This concept became a design criterion for much of the 1981 rehabilitation work and resulted in substantial savings with little noticeable decrease in restoration effectiveness.

Accordingly, 1980 became a year of transition wherein the approach to erosion control shifted from an experimental phase to a more systematic process with considerable peer review. Project planning

included efforts to quantify potential sediment sources and the benefits to be obtained by treatment. Additionally, various design criteria were adopted to standardize and improve specific treatments. Sediment source studies throughout the 280 square mile Redwood Creek watershed identified landsliding as one of the major erosion processes which threaten downstream park resources. Until recently, however, no systematic procedure had been formulated to quantify the magnitude of the problem on park lands or to develop a rigorous procedure for landslide rehabilitation. In 1980, a study was initiated on a large forested landslide located just upstream from the Tall Trees Grove. Preliminary results revealed the stabilizing effects of load removal accomplished by rehabilitation work, the overriding importance of groundwater and increased winter soil-water pore-pressures, the rapid response of forested landslides to rainfall and the apparent beneficial effects of removing surface and subsurface water. Since then, monitoring personnel completed a detailed inventory of active debris flows which originated during the 1981 - 1982 winter. These studies revealed the close association of landslides with logging roads, steep slopes, certain soil types and high soil moisture conditions. This information was used to predict potentially unstable areas on rehabilitation sites and to then treat these areas before they failed.

A primary emphasis of 1981 rehabilitation was to reduce the application of costly and/or ineffective secondary erosion control treatments. At the same time, more emphasis was placed on thoroughly completing the more cost-effective primary treatments. This resulted in a measurable reduction (compared to the previous year) of heavy equipment expenditures (Figure 4).

Stabilization of a large, active landslide near Emerald Creek at a site treated in 1978 (Figure 1) was undertaken in 1981. Smaller, less active landslides had been treated in previous years, but such work represented only single elements of large rehabilitation units. The cost for the Emerald Creek landslide represented approximately 18 percent of the total heavy equipment expenditure for primary erosion control treatments in 1981. This landslide had the potential, however, for contributing at least as much sediment to Redwood Creek as the combined total of all other sediment sources identified and treated during 1981.

Labor-intensive costs in 1981 were the lowest in four years and resulted from a concerted effort to control the application of less cost-effective, secondary, erosion control treatments, especially checkdams.

During 1982 and 1983, emphasis shifted from treatment of rapidly eroding freshly clearcut areas, which are quickly revegetating, to areas where erosion was equally intense but more localized along logging roads constructed on unstable terrain. Specifically, more emphasis was placed on the treatment of landslides and shallow slope failures which frequently occur during the winter months. Utilizing large crawler tractors to a greater degree than before, entire road prisms were removed where sufficient evidence of instability existed.

As a result of the more efficient use of large tractors for road outsloping and excavating stream channel crossings, unit costs dropped to about two dollars per cubic yard of material excavated. While more crossings were left unprotected (no channel armor or checkdams were considered necessary), there was less erosion. Secondary treatments to protect stream channels were used where watercourse adjustments were anticipated. In 1982 and 1983, less than twenty percent of excavated stream channel crossings were protected with channel armoring. These measures resulted in no significant increase in post rehabilitation erosion rates, but did increase the cost-effectiveness of rehabilitation work. Similarly, the only labor-intensive erosion control practice used on a regular basis involved the application of straw mulch to selected bare soil areas near stream channels.

D. Timber Harvest Plan Reviews

1. Role and Function

Staff geologists conduct timber harvest plan reviews in cooperation with timberland owners and the California Department of Forestry and recommend practices which control erosion and sedimentation. The program includes land use investigations in watersheds tributary to the park, development of logging and road building guidelines necessary to protect park resources from upstream erosion and sedimentation and evaluation of the effectiveness of these efforts in accomplishing erosion and sedimentation control objectives.

2. Summary

From 1978 through 1982 park staff participated in the field inspection and review of 107 of 143 Timber Harvest Plans (THPs) submitted for

III. TECHNICAL SERVICES

A. Geomorphology

1. Role and Function

In response to legislative mandates articulated by Public Law 95-250, scientific studies were undertaken to measure erosion, sedimentation and sediment transport in the entire Redwood Creek basin and to differentiate the causes of increased soil losses.

The program includes three phases: An inventory of sediment sources in the Redwood Creek drainage, a determination of the amount of sediment stored in stream channels and a calculation of sediment transport rates throughout the basin. The sediment source inventory includes mapping and measuring all landslides on the mainstem of Redwood Creek and its major tributaries, measuring all gullies on prairie lands, sampling forested hillslopes with gullies and inventorying erosion problems on logging roads. Sediment storage is being evaluated by measuring the volume of material in Redwood Creek and its tributaries and by determining the age and stability of stored sediment and how these changed through time. Sediment transport rates are based on measurements of streamflow, suspended sediment and bedload movement under various conditions. Study results will be used to predict future sedimentation effects on park aquatic and riparian resources. Sediment budget data supplement other study programs and help in the development of management alternatives for the restoration and preservation of park resources.

2. Summary

Since the beginning of the erosion and sedimentation study in 1979, the entire Redwood Creek watershed has been inventoried to locate major sediment sources, the distribution of sediment stored in stream channels and the factors effecting sediment transport rates through the basin. Erosion problems in tributary basins and along the mainstem of Redwood Creek were classified according to their cause, size, location and timing of development. Sediment storage was measured in tributaries and the mainstem of Redwood Creek. Sediment transport (output) was analyzed at seven different stations. The sediment budget is the culmination of several different studies conducted over a number of years. Accordingly, it is presented topically rather than chronologically. See Table 7 for a description of project status.

3. Accomplishments

Sediment stored in Redwood Creek increased almost 1.5 times normal after the 1964 flood. Excess sediment deposited by the flood killed trees along Redwood Creek. Most storm derived sediment was deposited upstream from the park. In subsequent years, however, some of this sediment was transported downstream, aggrading park reaches. According, however, to the sediment budget model, much of this excess sediment could be flushed from park reaches during the next 20 years, provided erosion does not increase upstream and sediment transport follows the pattern of the last decade.

Sediment Monitoring: How long sediment problems remain in park streams depends on how much sediment is transported out of the park each year. A cooperative monitoring program between the Geological Survey and Redwood National Park measures sediment transport in Redwood Creek and its major tributaries. These sediment data indicate: More sediment has been transported into the park each year than is removed; the upper third of Redwood Creek transported more sediment per unit drainage area than any other reach of Redwood Creek; most sediment moves during large floods rather than during smaller floods; and lower Redwood Creek continued to receive surplus sediment.

Cross Section Surveys: Cross section surveys document channel changes due to sedimentation, such as where pools filled or were scoured, where and how much bank erosion occurred, and where and how much the streambed either aggraded or degraded. Surveys showed a wave of aggradation five miles upstream of the Tall Trees Grove in 1975, which by 1982, was located downstream from the grove. It is anticipated some aggradation damage could occur within the lower four miles of Redwood Creek as this sediment wave continues to move downstream. As sediment waves move farther downstream, however, stream channels should begin to recover, as is evident in upper Redwood Creek. Predictions on recovery time and processes remain unknown.

Sediment Routing: Landslide debris delivered to tributaries during the years 1954 - 1980 was 2,415,500 m^3. This represented 38% of the total landslide volume measured in the entire Redwood Creek basin, the remainder being along the main channel. Tributaries were significant sediment sources, but sediment was not stored long in their channels. Sediment eroded by gullying and landsliding was flushed quickly through tributaries to the main stem of Redwood Creek. The 1972 and 1975 storms, with a recurrence interval of about 10 years, were the size of storm which accomplished flushing. Most eroded sediment was stored in the main stem.

Sediment data also showed which tributaries contributed the most sediment to Redwood Creek. For example, Panther Creek, in the Park Protection Zone (PPZ), produced 100-400 tons/mi^2/yr. Lacks Creek, another PPZ tributary, produced 2,000 tons/mi^2/yr. These figures were much higher than sediment transport rates for a pristine basin, Little Lost Man Creek.

Climatic Effects: Research revealed the past century included two significantly different climates. From about 1890 to 1950, the climate was unusually mild with no major storms. Beginning in 1950, the climate became stormier and wetter. Data indicate this latter climate was typical of the climate which characterized the past 3,000 years. Therefore, major storms typical of the period 1950-1975 should occur more frequently during the next few years than would be predicted based upon the climate of the last decade. For example, (using a long term climatological perspective) the major storm of December 1964 probably has a recurrence interval of 45-50 years. Similarly the storms of 1955, 1972, and 1975 have recurrence intervals of 30,10 and 10 years respectively.

Fluvial Erosion: Gully erosion was assessed on 32 study plots located in cutover lands in the Redwood Creek watershed. These surveys showed virtually all gully erosion was associated with roads, and the largest roads were the greatest sediment source. Stream diversions were the most important single cause of erosion. The most important gully erosion preventive measure was careful construction practices used on major logging haul roads. Oak-woodland and grassland soils were found to be more susceptible than forest soils to gully erosion from road caused stream diversion.

Landsliding: Total landslide contribution to the Redwood Creek basin between 1954 and 1980 was 6,415,600 m^3, of which 82 percent occurred either during or before the December 1964 flood. Aerial photo interpretation showed most of this landsliding occurred during this storm. There were two high landslide volume reaches along the 100 km length of Redwood Creek. One was located along the uppermost 30 km, the other extended from the downstream end of Redwood Valley to Bridge Creek. Low landslide occurrence reaches became areas of maximum sediment storage due to their lower gradient and greater valley width. Sandstone slopes were more prone to large landslides than schist slopes.

B. Fish and Wildlife

1. Role and Function

Fish and wildlife staff study the nature, function, and dynamics of aquatic and terrestrial ecosystems and determine man's influence upon these systems and their biologic components. Studies and monitoring of fish and wildlife communities, populations and the park environment are undertaken to provide basic resource information needed to effectively manage and protect the park's fish and wildlife. Information is provided for park management and other division staff to foster understanding and appreciation of park fish and wildlife to guide park developments, to avoid harm to park visitors and to provide for restoration and protection of park resources. Staff prepare management plans to provide for a balanced, diverse, naturally functioning and self-perpetuating biological park community which provides adequate protection for threatened or endangered species and their habitat.

2. Summary

Research begun during 1980 within the Redwood Creek estuary revealed the value of the estuary for downstream migrating juvenile salmonid fish and the adverse effects of channelization and construction of flood control levees on the function of the embayment. Short term management was implemented following public review and an assessment of various short and long term alternatives. Water levels were maintained high enough to provide suitable habitat for downstream fish migrants, but low enough to prevent flooding of adjacent pastures.

Tracking of black bears within the park yielded valuable information on bear behavior, home range, selective utilization of cutover and old growth forests, seasonal physical condition, reproduction, and bear population age and sex composition.

Aquatic invertebrates of the Redwood Creek watershed were studied to assess the impacts of watershed restoration activities within small streams on downstream aquatic biological resources.

Other studies included: Cold pool formation and use by fish as sanctuaries during warm summer months; elk management planning; fishery impacts of the proposed 101 bypass highway; fish habitat management planning; Redwood Creek salmonid nursery area surveys and river otter research. See Table 8 for the status of fish and wildlife projects.

3. Accomplishments

Aquatic Invertebrate Surveys: Aquatic invertebrates represent the major source of food for juvenile anadromous fish and have been used as indicators of stream quality. Species identification and abundance were measured to observe stream changes over time. Surveys were initiated to determine aquatic invertebrate species distribution and abundance in streams of the Redwood Creek watershed.

The first objective of the aquatic invertebrate study was a qualitative survey of larger park streams in the Redwood Creek basin. Bridge Creek, Devils Creek, Tom McDonald and Emerald Creeks were sampled April through October 1980. The survey duplicated objectives of the USGS efforts during their 1973-1975 survey, except improved sampling techniques were employed. The survey resulted in an aquatic invertebrate species list and a description of their relative abundance. These examples will be used to describe baseline stream conditions for comparison with the results from future samplings. In order to use aquatic invertebrate monitoring as a resource management tool, a quantitative technique was developed to sample small streams. A small artificial substrate basket was designed which could sample streams as shallow as 5 cm. without disturbing the substrate (many conventional sampling devices require the substrate to be disturbed as part of the collection process). The sampler collected a lower number

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IN REPLY REFER TO:

November 10, 1975

REPORT TO THE STATE OF CALIFORNIA CONCERNING SEDIMENTATION PROBLEMS IN THE REDWOOD CREEK WATERSHED, AND THEIR IMPACT ON PARK RESOURCES

The National Park Service administers several thousand acres in the lower portion of the Redwood Creek watershed. This southern tip of Redwood National Park includes a narrow, eight-mile long corridor along the creek that contains several of the world's tallest known trees. The purpose of the park is to preserve significant examples of the primeval coastal redwood forests and the streams and seashores with which they are associated for public inspiration, enjoyment, and scientific study. The act that created the park (Public Law 90-545) recognized that land uses adjacent to the park might adversely affect the timber, soil, and streams within the park. We are before the State Board of Forestry to encourage further regulation of forest practices that will minimize such adverse impacts.

The Secretary of the Interior was authorized by section 3(e) of Public Law 90-545 to acquire interests in land from, and to enter into contracts and cooperative agreements with, the owners of land on the periphery of the park, in order to protect the park. This Federal decisionmaking process is now in progress, and we have described four options and their environmental impacts in the Environmental Assessment, Management Options for Redwood Creek, Redwood National Park. This assessment is currently available for public review, and comments are solicited until December 5, 1975. The information and recommendations contained herein concern the option of State regulation. Vigorous enforcement of forest practice regulations on lands adjacent to the park is an element in the current Federal decisionmaking process.

There is damage now occurring to the resources of Redwood National Park in Redwood Creek from past and present land use practices, primarily logging and roadbuilding. Certain processes have been set in motion that are causing current adverse impacts, and through forest practice regulation, some of these impacts can be mitigated. Detailed specific descriptions of the sources of erosion, the location of erosion prone areas, and the physical and biological damage in the park are contained in the U.S. Geological Survey open-file report, "Watershed Conditions in the Drainage Basin of Redwood

Creek, Humboldt County, California, as of 1973," and "Recent Man-Induced Modifications of the Physical Resources of the Redwood Creek Unit of Redwood National Park, California, and the Processes Responsible for Those Modifications." The description of damage presented here is intended to supplement and summarize the material in these reports.

Modification of park resources occurs when damaging inputs enter the park at various locations. Such inputs can enter the park along the main channel of Redwood Creek at the southern park boundary, along tributary streams that enter the park upslope from the main channel, and along hillslopes well away from the stream channels. To date, the damage along the main channel and tributaries has far exceeded that along the hillslopes.

The resource problems associated with Redwood Creek and its tributaries relate to increased intensity and frequency of bedload transport, channel aggradation, and a decrease in bed-material particle size. Fish-rearing pools have been filled, and along most of the main channel, significant aggradation has occurred in recent years. Outside of the park, recent fill since 1952 has locally exceeded 15 feet, and near the Tall Trees flat, fill over the same period is at least 5 feet. The channel aggradation has caused shifting of the water channel, or thalweg, and the frequent shifting of the stream-bed material tends to destroy benthic organisms, fish eggs, and alevins. Fine sediment on stream bottoms has the effect of reducing intragravel oxygen that can result in mortality of aquatic organisms. The magnitude of recent channel modifications is somewhat less along the tributaries than along the main channel of Redwood Creek; significant changes have nonetheless taken place.

Some bank erosion has occurred in the park, and riparian environments have also been altered by deposition of massive berms of sandy gravel. These deposits have killed riparian trees, including redwoods. Coarse organic debris transported by Redwood Creek also affects riparian environments, battering and sometimes toppling riparian trees. Much of this debris consists of logs with sawed ends or cable scars. Occasionally, tires, battered culverts, and cables protrude from alluvial deposits along parkland reaches of Redwood Creek.

Timber harvesting directly adjacent to the park boundary has caused less damage than is present in park tributaries and the main channel of Redwood Creek. Damage has largely been confined to minor penetrations of accelerated erosion and deposition along small ephemeral streams. However, other principal causes of concern associated with future harvesting up to the park boundary include fire, slope wash, windfall, and microclimatic "edge effects." In addition, the critical factor of "summation of minor impacts" can be expected to exert itself as logging activity continues around the park.

The harvest operations up to the park boundary have occurred under interim harvesting guidelines developed between the companies and the park staff. Such harvesting represents several practices in excess of current State regulation, including cable yarding, absence of roads, a small vegetal strip, and small patch cuts. However, as discussed later, even these improved practices need further refinement to provide adequate protection to the park boundary. Away from the so-called "buffer zone", the massive use of tractor yarding over wide areas has caused sediment and water concentration which eventually result in downstream damage.

The park protection problems reflect the cumulative sum of many small problems associated with timber harvest activity, much of which occurs at some distance from the park boundary. Many of the erosion problems involve fluvial and fluvial-induced mass movement processes along pre-existing stream channels, as well as along skid trails, at landings, along roadside ditches, and at fill and culvert stream crossings. The bulk of these problems begin with obliteration of the finer details of the natural drainage pattern, and the concentration of runoff in a limited number of pre-existing channels. Increased peak storm discharges and storm runoff volumes above levels on undisturbed slopes also help to initiate processes that result in downstream damage.

Protection of the resources of Redwood National Park depends on adequate regulation of forest practices, not only at the park boundary, but in all watersheds that drain into the park. The present forest practice rules for the Coast Forest District, effective September 24, 1975, represent a major improvement over the practices of the last 25 years. Notwithstanding this, however, in and of themselves they are clearly inadequate to provide sufficient protection to park resources. The probable impacts on the park from enforcement of the current forest practice rules are discussed in detail in the Environmental Assessment, Management Options for the Redwood Creek Corridor, Redwood National Park. Rather than devote more space to our concern for the adequacy of the present rules, which are fully discussed in the assessment, we feel it is more productive to outline concepts and practices that would improve State regulation as an additional tool to be used to protect the resources of Redwood National Park.

The application of the Z'Berg-Nejedly Forest Practice Act of 1973 is generally done through the preparation, review, and approval of individual Timber Harvesting Plans. These plans should be reviewed not only for what they propose on a specific site, but how they interact with other cutting units in the watershed. The review should include an analysis of the cumulative impacts of several Timber Harvesting Plans in the same watershed, with the recognition that certain areas of the watershed should be allowed to recover before other areas are cut. As a general rule, we would suggest that not more than 30 percent of any tributary watershed draining into Redwood Creek be harvested in any given decade. In application to the Redwood Creek watershed, this would defer cutting in several tributary watersheds around the park, including Wier Creek, Miller Creek, Cloquet Creek, and in the near future, Bridge Creek, in order to allow partial recovery before further cutting is allowed.

The review process for Timber Harvesting Plans is presently conducted by a review team consisting of representatives of the Division of Forestry, Department of Fish and Game, and the Regional Water Quality Control Board. In several instances (THP's 345 and 980, among these) the Department of Fish and Game and the Regional Water Quality Control Board representatives have voted against approval, yet the plan was approved. Apparently their input is advisory only and has no definite authority in the review process. We suggest that review of the timber harvesting process involves multi-disciplinary input, and to have that input effectively applied to the land, a share of the decisionmaking process should be delegated to the Department of Fish and Game and the North Coast Regional Water Quality Board. We suggest that a representative from the Division of Mines and Geology with geological expertise be added to the review team. We further suggest that a representative of the National Park Service be added as a member of the timber harvest review team for all plans being considered in the Redwood Creek watershed. These people would provide further multidisciplinary input into the review of Timber Harvesting Plans. Many of our concerns associated with degradation of park resources would be more effectively addressed if specific harvesting and mitigation measures suggested by related State agencies and the National Park Service were incorporated into the Timber Harvesting Plans.

The most critical concept that must be addressed in an improved set of forest practice rules is the realization that in certain limited areas timber harvesting should not be allowed. While the extent of such no cutting zones might not be widespread, there is no feasible alternative in some streamside zones and special treatment areas (as defined by the forest practice rules at 912.22). Effective mitigation of park boundary inputs such as concentrations of runoff and associated sediment in ephemeral streams, slope wash, and windfall is best achieved by an uncut buffer. Along streams, uncut streamside zones can absorb upslope impacts and prevent significant increases in stream bedload, which in turn prevents increased downstream slides. The width of these zones should vary depending on land slope and geology. These factors are considered in Erosion Hazard Ratings, and as a general rule, the width of the uncut zone should increase as the Erosion Hazard Rating increases.

Our recommendation for improved forest practices are divided into two categories: those for the boundary zone of 800 feet around the park corridor, and those for the tributary watersheds draining into Redwood Creek south to and including Lacks Creek and Panther Creek. Recommendations for areas further upstream recognize the largely cutover nature of this portion of the watershed, and are limited to a strict enforcement of present regulations coupled with rehabilitation work discussed under our concluding remarks.

Boundary recommendations are applicable to the first 800 feet upslope from the park boundary, and include:

1. A 150 foot wide buffer zone of no cutting, in order to absorb overland inputs of soil and water, potential mass movement, and prevent windthrow in the park.

2. Within a 100 foot wide zone upslope from the no cutting buffer zone, tractors shall be prohibited. Layouts and tractor-built firebreaks shall be prohibited, and no slash burning shall be allowed. Some slash shall be left to absorb surface erosion, and only commercial coniferous vegetation shall be extracted. Excess concentrations of slash shall be yarded upslope for possible disposal out of this zone.

3. Patch-cuts shall generally be limited to 15 acres maximum within the 800 foot zone, recognizing the total cutting unit may be larger when the yarding distance to the first road is considered, when the lay of the land would allow a slightly larger unit, or to accommodate the harvesting of presently isolated blocks that are 20-25 acres in size.

4. Adjacent (sideslope, downslope or upslope) areas to present or planned patch cuts shall not be harvested within 7 to 10 years (adjacent is defined as within 300 feet).

5. All harvesting shall be restricted to cable yarding with the exception of the areas presently marked acceptable for tractor yarding on maps accompanying the present cooperative agreements negotiated between the companies and the park staff.

6. All cableways (and all tractor skid trails in the few allowable tractor yarded areas) shall be intensively waterbarred at 50 to 100 feet intervals. Maintenance shall occur each fall and, if needed, several times per winter for a minimum of 5 years after the end of disturbance.

7. Residual debris in draws shall sometimes be left to trap sediment. The decision should be specifically justified for each draw in the Timber Harvesting Plan.

Recommendations for tributary watersheds include those for streamside zones and those for hillslope areas outside of streamside zones:

1. Streamside zones - The newly revised cutting and logging methods in the Stream and Lake Protection Zone provide protection against water temperature increases and will reduce sediment input. However, to additionally reduce sediment and especially bedload additions, the following practices should be employed:

   (a) Along each side of all streams, as defined by current regulations, and commencing at the Stream and Lake Transition Line, an uncut buffer shall be left, the width of which shall be defined by the Erosion Hazard Rating:

Erosion Hazard Rating	Buffer Width
Less than 100	75
101 - 200	100
More than 200	125

Where an area of active mass movement is present and borders the Stream and Lake Transition Line, the uncut buffer shall begin around the crown of the mass movement zones.

(b) Adjacent to the uncut buffer, a 75 foot zone of modified harvesting practices shall be established, wherein:

(1) no tractor-built layouts or firebreaks are allowed,
(2) no slash burning is done,
(3) commercial conifers only to be removed.

(c) The last yarding level, and in no case less than 400 feet slope distance adjacent to a stream, shall be cable yarded.

2. Roads

(a) Roads shall be located at least 75 feet slope distance away from stream banks except at stream crossing.

(b) If a slide zone must be traversed, engineering standards designed to minimize the impact ofsuch roads on the land will be followed. Such practices shall include but are not limited to narrow road widths, extra drainage structures, the use of riprap or retaining walls, reshaping slide crown areas and angling gradient of the road up into and down out of the zone.

(c) Road surfaces on grades steeper than 6 percent shall be rocked.

(d) All raw slopes shall be revegetated.

(e) No woody material shall be incorporated into fill slopes and landings.

(f) Place at least a 24 inch culvert in all natural drainages. Place at least one 24 inch culvert per 800 feet of roadway as a minimum standard to cope with the high intensity storms prevalent in the area.

(g) Road design shall include culvert placement to prevent an area increase of more than 40 percent in any drainage.

(h) Culverts shall be designed to accommodate a 50 year flood capacity. In drainages more than 30 percent logged within the last ten years, increase culvert size one or two sizes above the calculated size.

(i) Culverts shall be placed in the natural stream channel and/or installed with a securely fastened elbow with transition at the lower end to carry water below the toe of fill to a non-erodible base. Riprap or energy dissipators shall be installed where necessary to prevent downslope erosion.

(j) Trash racks shall be installed to insure against culvert failure, and where past culvert plugging has occurred or is reasonably likely to occur, additional structures shall be placed upstream to catch debris.

(k) Temporary roads and skid trails (planned use for one dry season only) shall be closed out annually by the effective installation of control devices that will minimize road surface and downstream, downslope erosion. This will include but not be limited to water bars, cross drains and the prompt removal of drainage structures or temporary obstructions to drainage channels.

(l) Winterization shall be completed annually by October 1 for permanent roads and for all others will be commenced annually by a date so that it is reasonably expected to be completed before winter rains reach a level that further road work would result in any significant damage.

(m) On steep slopes, excess dirt should be endhauled rather than deposited as sidecast. In general, this shall apply where roads are built on slopes exceeding 40 percent or crossing streams.

3. Clearcut size shall be limited to a 40 acre maximum, with a limit of 25 acres in the first yarding distance away from a streamside buffer, and 15 acres in areas with extreme erosion hazard or identified as "critical" or "special" zones in the present form of the cooperative agreements developed between the companies and the park staff.

4. Adjacent areas (sideslope, downslope, or upslope) to present or planned patch cuts shall not be harvested until 7 to 10 years following slash disposal. (adjacent is defined as within 300 feet).

5. Cable systems shall be employed on all slopes steeper than 30 percent.

6. Where tractor logging occurs, all skid roads shall be pre-built, with post-logging drainage incorporated into the design.

All specific harvesting recommendations are subject to the application of the condition that no Timber Harvesting Plan be considered in any tributary watershed that has been harvested in excess of 30 percent in the previous 10 years. The specific rules are not objectives unto themselves. Rather, they define practices which will prevent damage to the park boundary, and to tributary streams where excessive sediment and water inputs would cause downstream damage in the park.

The National Park Service requested a voluntary 18 month moratorium on further timber cutting in certain areas of the Redwood Creek watershed from the three companies operating on lands in the vicinity of the park. The moratorium was designed to address our concerns with the current rate of harvesting on lands surrounding the park in view of our responsibility to report to the Congress on available management options. In our judgment further cutting (1) adjacent to the park boundary, (2) in critical areas jointly defined by the companies and the park staff, (3) in some areas of high and extreme erosion hazard, and (4) in tributary watersheds recently harvested in excess of 30 percent would preclude other actions that could mitigate impacts in the drainage.

The moratorium has been expressly requested of the companies on a voluntary basis, and we have not received responses from all three companies. It was requested as an interim measure leading to that time when other practices could be implemented. The suggested improvements in State regulation are one means of achieving these practices.

The concept of a rehabilitation program in the Redwood Creek watershed is sound, and was proposed in August 1975, by the State of California's multidisciplinary study team in a report, "Rehabilitating the Redwood Creek Watershed." The recommendations for channel clearance, roads, landslides, and disturbed areas should be implemented under the guidance of a Land Management Committee. The National Park Service will assume responsibility for rehabilitation on park lands. In this regard, we would like to expand upon the rehabilitation efforts we have implemented in the park.

The study team report recommended two specific actions to protect the Tall Trees Grove: (1) removal of the old M-line bridge at the mouth of Tom McDonald Creek across from the grove, and (2) installation of riprap along upstream and downstream sections of the Tall Trees alluvial flat. The staff of Redwood National Park, with the help of Louisiana-Pacific Corporation, removed the M-line bridge during September 1975, and eliminated this man-induced problem near the Tall Trees flat. We have recommended against the use of riprap at the Tall Trees flat for several reasons. Riprap offers little or no protection against aggradation problems, which most significantly threaten the grove. Experience with revetments of active channels, although a widespread practice, causes deposition or erosion downstream that cannot be forecast. Riprap may increase erosion problems between the riprapped areas as well as downstream. Further man-induced erosion problems could cause installation of more riprap, and might eventually require channelization for miles downstream, a very costly and esthetically displeasing action. If the stream got behind the riprap, it would increase bank erosion from prevent levels, and completely negate the use of artificial bank protection. Present bank erosion, incidentally, is confined only to the downstream edge of the grove.

The study team organized by the State of California was itself divided on the issue of bank protection, recommending it as a majority position in contract to the unanimous suggestion for removal of the M-line bridge. The questionable effectiveness of riprap and the additional perturbations it will introduce into the system are the reasons why the National Park Service has recommended against its use at the Tall Trees Grove.

The leadership for rehabilitation efforts on private lands should come from the California Resources Agency, and we would be willing to provide representation from the National Park Service if desired. Our position regarding remedial measures on private lands was first stated in the 1973 report by the Department of the Interior, "Resource Management Actions Affecting Redwood Creek Corridor--Options Paper," and remains that such measures are the responsibility of those State agencies charged with regulating forest practices and maintaining water quality standards. The means by which such measures are carried out are in the domain of the State of California.

The National Park Service appreciates the opportunity to outline for the State Board of Forestry concepts and practices that will improve the option of State regulation in the protection of the resources of Redwood National Park.