AN ANALYSIS OF THE BUFFERS AND THE WATERSHED MANAGEMENT REQUIRED TO PRESERVE THE REDWOOD FOREST AND ASSOCIATED STREAMS IN THE REDWOOD NATIONAL PARK

Prepared for the
United States National Park Service by

Edward C. Stone, Rudolf F. Grah and Paul J. Zinke

Stone and Associates
Vegetation Management Consultants
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INTRODUCTION

The Problem

In October, 1968, Congress passed Public Law 90-545, authorizing the establishment of a 58,000 acre Redwood National Park. This action culminated a prolonged, emotionally charged, consideration of the need for such a Park and a lengthy, acrimonious, hearing on the effect on the local economy of the withdrawal of additional lands from timber production in Del Norte and Humboldt counties. Final justification revolved around the expected public inspiration and enjoyment this Park would provide and the need to hold for scientific study a unique vegetation complex that might otherwise be destroyed. Preservation was clearly the objective: Preservation of significant examples of primeval coastal redwood forests, preservation of the streams within these forests and preservation of the seashore adjacent to these forests was specifically directed.

One way to achieve these objectives would have been to restrict the Park ownerships to whole watersheds so that boundaries could be established along the upper limits of each watershed, and at the same time keep the total size of the Park within the 58,000 acre limitation. Under such circumstances Park personnel could be used to carry out the management required and danger to the Park from outside forces would have been reduced to a minimum.

Congress ruled out this approach, however, when it included parts of several watersheds in the Park -- less than 50 percent of the watersheds of Lost-Man Creek and Mill Creek and less than 10 percent of the watershed drained by Redwood Creek. By this action the fate of critical portions of the Park was placed in the hands of private land owners in the watersheds tributary to the Park. Consequently, if the preservation objectives set forth by Congress are to be achieved, a cooperative management effort will have to be developed with these owners -- many of whom had earlier viewed the establishment of the Park as a threat to the economic operation of their lands within these watersheds.

To pave the way for this cooperative effort, Congress has provided the Secretary of the Interior with the authority to enter into contracts and cooperative agreements with these owners for the establishment of buffers and watershed management practices that can protect the Park from hazardous inputs generated outside the Park.

With this action a new and radical approach to park preservation and a precedent for cooperation between the National Park Service and private land owners was initiated. It is significant that the buffers and the watersheds tributary to the Park are to be held and operated by the owners thereof except where the cost of establishing and operating the buffers and protecting the watersheds involved exceeds the cost of fee title to the land. It is also significant that the authorization for buffer establishment and watershed protection is not to be used to increase the size of the Park.

The success of this cooperative approach is highly important to this Park; special efforts will be needed to assure its success. Contrary to a widely accepted public attitude that the Park Service and the industrial forest owners surrounding the Park have unresolvable, conflicting interests, many areas of common interests exist, which, if expanded and developed, can serve to protect the Park and enhance its values.

It is clear from current trends that most of the remaining old-growth timber outside the Park will be converted to young-growth stands over the next two decades. In fact a majority of the forest properties on the Park boundary are already cut-over and in various stages of this conversion. For those who visualized a larger Park this conversion period will be a traumatic one. Yet it provides the opportunity to create the kinds of buffers around the Park which will be most important to its protection and preservation over the long run.

It behooves both the National Park Service and the surrounding owners to make every effort to establish effective buffers as quickly as possible. This will require a major cooperative effort and strong leadership on the part of the Park.

The Assignment

Our assignment was to define those problems requiring solution of the situation envisioned in the House of Representative Report No. 1630, dated July 3, 1968.

Their report pointed out ". . . that damage may be caused to the margins of every park, however large or small it may be, by acts performed on land outside those boundaries and that the streams within a park, whatever its boundaries, may likewise be damaged if the land on the watershed above them is permitted to erode. The trees along the margin, for instance, may be subject to blowdown if clear cutting occurs right up to the property line, and the streams within the park may be heavily silted if proper soil conservation practices are not maintained upstream." The Committee apparently visualized restricted selective logging along the Park boundaries and in the watersheds tributary to the Park as a possible solution. This is further suggested in the authorization they granted ". . . the Secretary of the Interior to negotiate agreements with the owners of adjacent lands and of lands on watersheds tributary to the park and, if necessary, to acquire interests in their lands which, while allowing selective logging, for instance, to go forward will require the land owner to follow practices that will, as far as possible, protect the trees, soil and streams within the park."

The Approach

We began our assignment by examining the mosaic of ecosystems that constitute the redwood forest, reviewing the successional processes involved and defining the relationship between the "present" uncut redwood forest in the Park and the "primeval" redwood forest.

Then, in light of the dynamic character of the redwood forest and the successional stages represented in the Park today, we considered the kind of management required to preserve significant examples of the primeval redwood forest and associated streams.

According to our contract with the National Park Service, our principal concern was a management prescription for lands surrounding the Park that would minimize any deleterious effects they might have on park resources. We quickly found, however, that we could not evaluate potentially destructive inputs into the Park without characterizing the biological structure to be preserved, i.e., the primeval redwood forest, and the kind of management that is needed to assure its preservation.

Fortunately, this characterization was simplified by the fact that wilderness values had not been interjected by Congress into the preservation requirements. Thus we were able to focus our concern on the ecological aspects of the preservation involved. Much of the ecological background for preserving the redwood forest had previously been developed in connection with a series of reports we prepared for the State Department of Parks and Recreation on the preservation of the alluvial-flat redwoods along the Eel River.

Of major concern was the need for replacement ecosystems over the next 500 years and how these could be obtained without radically altering ecosystems in the Park now supporting redwoods. Consequently, the possibility of developing these replacement ecosystems on the cutover lands included in the Park was carefully examined.

Next we characterized the potentially destructive inputs into the Park and considered the several types of buffers and watershed management practices needed to reduce these inputs. In particular, we were concerned with the relative effectiveness of buffers managed under the selective and even-aged silvicultural management systems.

Following this evaluation we reviewed the potentially destructive inputs from land adjacent and from watersheds tributary to the Park.

And finally we examined Park boundaries and watersheds tributary to the Park in terms of the specific buffers and management required to protect the Park. Cost elements were considered, but a full study of them did not fall within the scope of our assignment.

The Ecosystems Involved

Ecosystems can be of any size or level of organization. How they are viewed depends on the objectives at hand, thus making the scope of the term very elastic. The level of organization with which we are concerned in this study is that of the plant community and it is for this reason that we have viewed the redwood forest as a mosaic of ecosystems each identifiable by the species present and the successional stage represented.

For convenience, when considering specific ecosystems within the mosaic of ecosystems that make up the natural redwood forest, we have viewed each as having fixed geographical limits. In this way the adjacent and/or surrounding ecosystems can be treated in terms of their potential inputs, e.g., fire, waterborne materials and wind. The areas involved in these ecosystems are thus important only in how they relate to the magnitude of the input they supply. Where we have focused on a watershed and the alluvial flats at its mouth, we have drawn the boundaries of the ecosystem along the drainage limits of the watershed and have included the alluvial flats within the boundaries. All streams, originating within the watershed have been treated as part of the ecosystem. Streams that originate outside this watershed but which impinge upon the alluvial flats we have viewed only as a source of potential inputs into the ecosystem. Where we have focused specifically on the alluvial flats, we have drawn the boundaries of the ecosystem around the flats only. The slopes behind the flats and all streams impinging upon the flats, regardless of their source, are viewed as potential inputs into the ecosystem.

THE PRIMEVAL REDWOOD FOREST

The Forest

Simply stated, the primeval redwood forest was a mosaic of ecosystem supporting redwood that existed prior to the arrival of modern man. Today this mosaic is not precisely the same as then because growth, death and successional change -- all normal ecosystem processes -- have occurred throughout the mosaic. The significant point is that change is an important dimension of the ecosystem. Changes, however, except where logging and clearing have occurred, probably do not differ greatly from those that would have occurred had modern man been absent from the scene. The major impact of his presence has been the vigorous suppression of fire over the last 50 years. This has not yet, however, resulted in any significant successional changes. Therefore for all practical purposes we can view the uncut portions of the Redwood National Park as primeval and typical of the kind of redwood forest Congress has ordered preserved. Briefly let us take a look at the characteristics of this mosaic of ecosystems in the Park.

Not all ecosystems in the mosaic support redwood at any given point in time. Some ecosystems are part of successional sequences that do not include redwood. Others are part of successional sequences that have or will ultimately include redwood, but in which redwood is now absent, either because it is too early in the sequence, as where fire induced grasslands are in the process of being re-converted to redwood forest, or because it is too late in the sequence and redwood has been replaced by species such as hemlock, which appear later in the sequence.

Historically, the successional relationship of redwood in this mosaic has been confused. Even today, in spite of increasing evidence to the contrary, the mosaic is often viewed as if each and every ecosystem in it is moving successionally toward a redwood dominated cover. This view largely reflects a failure to fully appreciate the limitations imposed when techniques successfully employed by the ecologist in characterizing successional sequences involving short-lived species are used in attempts to characterize successional sequences involving long-lived species.

In brief, plant succession is the ecological process through which the plant cover changes with time. This change is brought about by the replacement of one species by another in response to plant or other induced changes in the environment.

A sequence of changes, each involving one or more stages, can often be identified: There is a short period during which colonization takes place, followed by a much longer period during which the environment undergoes repeated modification and finally an equilibrium or steady-state is reached. The particular sequence of stages in each period will depend on the climate, the soil parent material and the relative capacity of species with access to the area to: (1) grow in different environments, (2) modify their environments, (3) produce and distribute their seeds, (4) escape or tolerate browsing and grazing by herbivores, (5) escape or tolerate insect attack and (6) tolerate fire.

As succession progresses, an environment is eventually developed within which only a few of the species native to the region are capable of completing their life cycles. This is the point at which the steady-state or equilibrium is reached. The duration of this steady-state depends on how long the factors controlling the environment, at the time the steady-state was reached, remain unchanged.

Vegetational steady-states are referred to as climaxes or subclimaxes depending on the terminology employed. Clements, an early American ecologist, referred to the steady-state as the climax only when climate was the controlling factor. All other steady-states were treated as subclimaxes. He contended that each steady-state could persist only as long as the controlling factor did not change and that all other controlling factors changed faster than climate. Thus the climax, once reached, would not change as long as climate retained its controlling role and did not in itself change. The steady-state reached when soil parent material was the controlling factor was treated as an edaphic-subclimax which could be expected to persist until soil development masked any direct effect that the soil parent material might have on plant growth. The steady-state reached when fire was the controlling factor was treated as a fire-subclimax which could persist only as long as succession was regularly interrupted by fire.

Some ecologists now prefer to follow Tansley's lead. Tansley, a British contemporary of Clements, referred to all vegetational steady-states as climaxes, and assigned them prefixes according to the controlling factor involved, e.g., climatic-climax, edaphic-climax and fire-climax. It really makes little difference which terminology is used, provided it is used consistently. We prefer to treat the climate-induced steady-state as the climax and the other steady-states as subclimaxes because the regional vegetation is then separated from successional vegetation which is normally subject to change long before the climate is.

Plant succession can be evaluated in a number of ways.

Permanent plots or photo-stations can be employed and change over a period of time can be accurately documented. This approach is largely restricted to situations where succession is rapid following the removal or the introduction of an interruptive factor -- otherwise most researchers could not afford to wait for the record. In the redwood forest mosaic permanent plots are rare and have been used largely for interpreting growth. Short term succession following fire, flooding and logging has been studied with the use of temporary plots.[(1)]

The most widely used approach to study succession has been to substitute area for time by inference. Two basic assumptions are made. First, it is assumed that the successional changes, through which many of the ecosystems in the mosaic pass, are the same. Second, it is assumed that different successional stages can be found in the mosaic at any point in time because succession is proceeding at different rates in response to soil parent material, topographical position, the availability of seed and the frequency and intensity of interruptive factors such as fire. Accordingly, all the investigator needs to do in this approach is to identify the different successional stages represented in the mosaic and to arrange them in the proper time sequence. Obviously, the success of this method requires that succession still be underway in the area under study and that it proceed at different rates at different points within the mosaic. It is also necessary that enough be known about the physiological potential of the plants involved to allow the placement of the successional stages represented in the mosaic in their proper position in the successional sequence.

For many years this approach has been employed effectively by the range manager to follow short term successional changes involving short-lived grass and shrub species. It has been used to characterize successional changes following the removal of interruptive factors such as grazing on the coastal grasslands and fire in the Sierra Nevada. And recently it has been used to characterize sand dune succession on the Monterey Peninsula, where succession is rapid and the stages are well marked.

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(1) Superscripts in parenthesis refer to elaboration or citations requested by the Office of Natural Science Study in Washington, D.C., following a review of the preliminary draft of this study. These are presented in Appendix C.

In the uncut redwood forest, however, this approach has limited effectiveness and must be applied with caution. The longevity of the species, its ability to sprout -- a characteristic through which it is able to maintain itself in environments in which it can not reproduce by seed -- and the limited areas in which redwood trees originating from seed can be found to be invading stands dominated by other species, complicates such an analysis.[(2)] Field estimation of the physiological capacity of these species to respond to the sequence of environments made available as succession proceeds, is difficult and consequently must remain suspect. Some laboratory characterization is required and few researchers are equipped to handle this aspect of the analysis.

Fire has been an integral part of the redwood forest environment for a long time, possible since the redwood forest flora segregated out along the coast of California more than a million years ago.[(3)] That fire has been a part of the environment for the last thousand years is certain. Radiocarbon dating of charcoal layers in a 30 foot alluvial deposit, uncovered along Bull Creek during the 1955 flood, established this fact. Since then a 10,000 year old alluvial deposit containing Douglas-fir logs has been uncovered further up the drainage, along Cuneo Creek. We expect to be able to show charcoal of a similar age in this deposit.

The source of these fires is not particularly relevant. Some were undoubtedly started by Indians and others by lightning. The important point is that prior to organized fire suppression, every ecosystem in the redwood forest reflected the interruptive effect of fire. In reality the primeval redwood forest was a mosaic of fire subclimaxes. Species composition differed in these subclimaxes because soil development, availability of seed, and frequency and intensity of burning have been different in each ecosystem in the mosaic, and succession has been interrupted at different stages in the successional modification of the environment.[(4)]

The Streams

Streams in the Park, except for Redwood Creek, have not changed greatly since modern man arrived. Even in Redwood Creek there undoubtedly were periods in the recent past when the gravel loads contributed by upstream erosion were comparable to what they are today.

These streams owe their characteristics to the geology, the resulting soils and the hydrology of the area. Generally, the structural grain of the country extends from southeast to northwest along fault and shear zones which determine the direction of flow of the major streams. This directional alignment is illustrated by Redwood Creek along the major part of its length. During the uplift of the area, cutting by the bigger streams such as the Klamath River and Smith River kept pace with the uplift and are now entrenched in deep canyons. The smaller streams such as Redwood Creek, Mill Creek, and Prairie Creek have in a sense ridden upon the uplift and are now only barely entrenched except at their lower reaches. Frequently, the creeks and rivers show old mouths to the sea, such as that of the Klamath River west of Yurok, and the old Skunk Cabbage Creek mouth of Redwood Creek west of Orick.

The concentration of precipitation in the winter time results in seasonal peak flows which occasionally results in large floods. In dry periods the streams dwindle until there is barely enough flow to link the pools in their channels.

Streams such as Redwood Creek carry heavy loads of sediment during these peak flows because of the instability of the shear zones in the rocks into which they have cut. Characteristically, these streams have a steely gray color because of the suspended clays they carry. During floods the load of eroded material is carried both as suspended sediment and as a bedload of rolling rocks and gravels. When the stream is able to spread out onto the adjacent lower lying alluvial flats, the water velocity is lessened and the load of suspended sediment is dropped to form a layer of silt loam soil. Floods of this type can be expected to take place at thirty to fifty year intervals and are responsible for alluvial flats such as the one on Redwood Creek which supports the Tall Trees Grove.

In addition to the immediate effect of bank cutting and the widening of the channel, the accelerated movement of gravels, and the raising of the height of the downstream bed these large floods reactivate old slides that have come to rest on the edges of the stream. When the base of these slides are cut away by such floods -- two since 1955 -- these slides begin to move and do not come to rest again until their footing on the edge of the stream channel is once again firmly established and the mass of the sliding material above has reached stability on the slope.

In Redwood Creek a large number of old slides, readily recognized by their Atwell soil, their young vegetative cover and the preponderance of hardwood species, are now actively moving. If left on their own -- which may be the only real choice the park manager has -- they will require years to stabilize. In the meantime they will continue to dump large amounts of medium and fine gravels into the creek.

Streams in the Park support large runs of salmon, steelhead and cut-throat trout which use the coarse bedload materials for spawning beds. Prior to the arrival of the white man, Indian populations had built up around this resource. In Redwood Creek, for example, sizable fishing villages were located at its mouth and midway upstream in Redwood Valley.

The greatest obstacle to complete fish utilization of the streams in the Park is the extreme seasonal fluctuation in the natural flow. Largely, it is the low summer flow that limits the year around habitat. Turbidity of the water due to heavy suspended sediment loads and clogging of the spawning riffles with fine sediments could also seriously impair spawning habitats in the Park. A major source of such material is the Atwell soil that dots the slip-zone along upper Redwood Creek.

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MANAGEMENT IN THE PARK

The destructiveness of inputs from adjacent lands and watersheds depend to a considerable degree on the Park's management objectives and how they are to be accomplished. Preservation of significant examples of the primeval redwood forest and its streams has been clearly stated as the objective in the case of the Redwood National Park. This forest is a mosaic of ecosystems each developing and changing at its own rate. How and at what point in their development are they to be preserved? Will each be held as long as possible at some particular successional stage by the employment of interruptive factors or will they all be completely protected and succession allowed to run its course to the climax?

In considering the action required to minimize deleterious inputs we have assumed that preservation means the retention of the mosaic of ecosystems that were present in the primeval redwood forest and that roughly the same proportion of the various successional stages then present will be maintained. This is a big job. Let us briefly review what it entails.

The Need to Control Natural Forces

The more than 2,000,000 acres of redwood forest that extended along the California coast from San Luis Obispo county to the Oregon border was an expression of succession that had taken place in the mosaic of ecosystems involved up to that point in time. Fire, winds, rains, and floods had all played critical roles in its development. The major changes that have taken place within these areas over the last thousand years of unrestricted ecological development would have continued had modern man not interfered when he did and as he did. This is a fact rarely recognized by the active conservationist, many of whom look upon old-growth redwood stands as unchanging monuments. Too often preservation has been viewed as if the vegetative cover to be preserved was inanimate and not the living, dynamic, changing ecological complex that in fact it is. Had history been such that unfettered ecological development had continued for another 1000 years, many of the ecosystems that have been specifically included in the Park today, because of their advanced successional development -- stands of the biggest, oldest redwoods -- would have already advanced to the point that they would no longer be superlative and would no longer be of park quality. To have found such ecosystems we would have had to go elsewhere -- outside the present Park boundaries -- to where succession had advanced just far enough to meet our aesthetic taste for the primeval.

In terms of park management this simply means that the natural forces that created the primeval redwood forest would in time, if uncontrolled, destroy it. Only if the Redwood National Park were many times its present size -- a million acres or more -- could these forces be allowed free reign. Only then could the park manager presume that significant examples of the primeval redwood forest were automatically being perpetuated by letting nature do its best and its worst.

Successional Status of the Uncut Portion of the Park

According to our assessment of the overall successional state of the uncut portions of the Redwood National Park, the climax has not yet been reached in many of the slope and alluvial flat ecosystems. What is largely represented in the Park and what the park manager is charged with preserving, are fire induced subclimaxes on the slopes and fire-flood induced subclimaxes on the alluvial flats. This is because redwood has a unique capacity to take advantage of fire and flood interrupted environment and because fire on the slopes and fire and floods on the alluvial flats have been highly important factors in the primeval redwood forest environment.

Redwood is favored over other species in the presence of fire by its thick, essentially fireproof bark, by its capacity to sprout along its stem and replace its branches when killed by fire, by its capacity to sprout from its root-crown following destruction of the rest of the tree, by its resistance to insects and killing pathogens and, oddly enough, by its susceptibility to heart-rot following fire-injury. Redwood can only sprout when its root crown is left in the ground. Anything that increases the percentage of root crowns left in the ground when the redwood falls, thus increases the number of trees that can replace themselves by sprouting. Heart-rot does just this, because most of the heavily infected trees break off above the ground when they fall and fail to pull up their root-crowns in the process.

Redwood is favored over other species in the presence of flooding by its capacity to tolerate prolonged inundation. It has a unique capacity to send new roots vertically upward into newly deposited silt as well as to develop new root systems at successively higher levels up the trunk as it is gradually buried under successive deposits of silt.

Other species are favored over redwood by the exclusion of fire. Redwood seedlings -- unlike western hemlock and associated species -- cannot establish themselves on the undisturbed forest floor. Furthermore, because the incidence of heart-rot will drop off sharply in the absence of fire, most of the old redwoods will not break off and when they fall will pull their root crowns out of the ground in the process. Consequently they will be unable to replace themselves by sprouting.

The net result is that, in the absence of fire, an understory of shade-tolerant trees becomes established beneath the redwoods -- completing several life cycles while the redwood is completing but one -- always present and ready to occupy the space vacated in the forest canopy any time an old redwood loses its foothold and crashes to the ground. How many, if any, redwood seedlings in stands with this structure and in this shaded environment can become established on the mounds of mineral soil -- referred to as cradle mounds -- thrown up by the root-crown as it is ripped loose by the falling tree, will depend upon the availability of redwood seed relative to that of other species present and the micro-environment prevailing at the time. We expect some re-establishment of redwood to occur on these exposed areas of mineral soil and occasionally on slide areas as well. But with the completion of each succeeding life cycle, we expect redwood to decrease in the forest and eventually to entirely disappear. In terms of park management, this means that with complete protection the redwood in the various ecosystems that now support them, could be expected to decrease in number over time and eventually disappear unless fire on the slopes and fire and floods on the alluvial flats are allowed to operate again as interruptive factors much as they have in the past. This of course is obviously not a practical solution. Controlled-fire or some other form of interruptive input must be substituted.

It is not clear at this time, what successional stages the various ecosystems in the redwood forest mosaic will pass through if fire is permanently excluded, or alternatively, if the best protection the fire fighting agencies can supply, only lengthen the intervals between fires. By reducing the frequency of fire we can expect succession to progress further during the fire-free intervals than it ever has in the past. Fuels available on the ground will differ with the result that the burning pattern will differ and widespread fires will only occur when the burning potential in the forest is at its highest. We have at this time no reliable estimate of the length of time required following the exclusion of fire, before changes in the species composition of the redwood forest in the Park become significant in a preservation sense. We can be certain, however, that it will vary widely from one ecosystem to the next.

The climax can be predicted with considerable confidence, however, from an evaluation of the relative growth of the several tree species now present, in the environments that will become available, following the exclusion of fire, and the relative capacity of these species to further modify these environments. Of course, the relative response of these species to herbivores, insects and pathogens must also be considered.

Should fire be successfully kept out of the Park and no suitable substitute interruptive factor be introduced, succession over the next one-hundred years would certainly result in some change, particularly on the alluvial flats. Succession over the next five-hundred years would result in the predominance of hardwoods, Douglas fir, Sitka spruce, lowland white fir, hemlock and western red cedar. Succession over the next two-thousand years could result in the disappearance of redwoods from the Park.

Development of a Preservation Plan

The first step required to preserve significant examples of the primeval redwood forest in the Park is to develop a landscape plan of the Park. Ideally this should be completed by a Master Plan Team before the preservation responsibility is handed over to the Park administrator. Such a plan involves stratifying the Park into a number of landscape units based on species composition, appearance of the vegetative cover, its topographical position and any other parameters that are judged to be significant.

Once these landscape units are outlined, the ecosystems included within each landscape unit must be characterized according to its successional potential and the rate of successional change expected. Along with this characterization some readjustment of the landscape units may be required so as not to split ecosystems between two or more units.

With this information available, a decision should then be made as to how each landscape unit is to be maintained. Should succession be allowed to proceed unchecked? Certainly, some unchecked succession should be allowed for purposes of scientific study, if for no other reason. If succession is to be allowed, to what extent? Or should succession be regularly interrupted and held at some particular intermediate or subclimax stage? Obviously, very early in arriving at these decisions, another decision must be made as to the relative amounts of each type of landscape unit that is to be maintained in the Park in perpetuity.

Finally, methods to achieve these objectives must be adopted. Interruptive factors already accepted as being compatible with Park management are fire, herbicides and planting. Others are available and more can be developed.

The development of the preservation plan as well as putting it into operation must be handled with great sensitivity and accompanied by a careful program of public education. The basic plan for preservation as well as its subsequent application in the Park must be widely understood. This is of particular importance with respect to conservation groups which have shown construction concern over Park establishment, but are not always well-informed on vegetation dynamics and the necessity of managerial manipulation for preservation purposes. Unless these groups are reached with effective educational programs, constructive concern could change to destructive distrust. These same conservationists could become an effective force in blocking the preservation of the primeval redwood forest for which they have worked so hard. This would be a national tragedy if it were allowed to happen. The danger of this happening can be greatly reduced if the National Park Service accepts a management philosophy of keeping redwood in all the ecosystems in the Park in which it now occurs, as long as possible. In addition this philosophy must be clearly stated and explained.

Development of Replacement Ecosystems on Cutover Lands in the Park

In a successional sense ecosystems dominated by younger age classes are needed to replace those with older age classes as the redwood trees finally die. The situation can be likened to a pipe filled with ecosystems supporting redwood of decreasing age. Today, at this particular point in time, only a trickle of ecosystems supporting old age classes of redwood are running out at the bottom end of the pipe; but as the redwoods grow older and the trickle increases to a steady flow, ecosystems supporting redwoods of younger age classes must be fed into the other end of the pipe or it will eventually run dry and the Redwood National Park will no longer be a redwood park.

Ecosystems supporting younger age classes can be readily developed on the cut-over areas now included in the Park. In this sense these areas become a highly important asset. They can be managed so that 500 years from now, when many of the ecosystems in the Park will begin to lose their redwood dominated vegetative cover, there will be ecosystems available, supporting 500, 400, 300, 200 and 100 year old redwoods, and a combination of age classes.

We do not visualize any insurmountable public-relations problems arising during the first 100 years of operations of a simple ecosystem replacement plan involving the cutover lands. We can, however, clearly see a major problem 100 years from now, when 4/5 of the revegetated cutover areas will need to be manipulated if the plan to establish a flow of age classes -- to keep the pipe filled -- is followed.[5] It is imperative that a public education program go hand in hand with the revegetation of these cutover lands and that the public be fully informed of the objectives and the plans for future manipulation.

Preservation and the Wilderness Syndrome

The most troublesome public attitude that must be overcome initially, in getting a preservation management program underway, will be that of the dedicated conservationists who were instrumental in getting the Redwood National Park established but who visualized in it, not the preservation of a significant example of the primeval redwood forest and its associated streams, but another wilderness. The focus of this group can be expected to continue to be on the uncut nature of the redwood forest. To this group preservation of the primeval redwood forest <u>per se</u>, and the mosaic of ecosystems it entails, will be of only secondary importance. They want a forest of redwood, established long before modern man's activities became an input into its various ecosystems and from which his inputs can now be excluded.

Had Congress drawn the Park boundaries differently so as to include in the Park a much larger portion of the Redwood Creek watershed, it might have been possible to meet this need in part. With the boundaries as they now stand, no such wilderness potential exists in the Park. The most that can be done to meet the need of this group, is to designate certain blocks of landscape units located back and away from the roads and main trails and to treat these units as wilderness units with a minimum of manipulation therein. Ideally, these units should be buffered against fire both from within and from without.

Critical Management Areas in the Park

The most critical area in the Park from a management viewpoint is the upper end of the Redwood Creek corridor beginning about a half-mile downstream from the mouth of Bridge Creek. Over this distance most of the Park falls largely within a highly active land slip-zone which extends up both slopes for distances of up to a half-mile.

In this area, landslides are a natural feature of the landscape and sliding has been going on intermittently for thousands of years. Here Redwood Creek follows a major schist-sandstone contact zone and in many places the schist has been finely fractured by the shearing action that has taken place along the contact. Where seepage water is present, this finely fractured material is deeply weathered and has produced the Atwell soil which is high in clay content. Where the creek has cut into these materials, compound slides have been activated. Until a few years ago, many of these slides were relatively stable with their bases resting some distance back from the creek channel. Since 1955, a large number of slides have been reactivated by the undercutting of their bases by the flood peak-flows in 1955 and 1964. This undercutting may still be underway since it appears that the streambed has been raised by sediments allowing the streams to spread out during normal peak-flows and eat away at the bases of the slides.

The upper edge of the slip-zone, along with the soils mapped as Atwell by the Soil Vegetation Survey, is shown in Figure 1.[6] A more detailed examination of the soils in the slip-zone would probably show more areas with Atwell soil and a considerable amount of Atwell parent material hidden beneath colluvial-creep from further up the slope, on which Melbourne and other soils have developed.

On our reconnaissance of this portion of the Redwood Creek corridor, we crossed several large compound slides involving Atwell soils that extended up slope to near or beyond the Park boundary -- three on the north bank (the Arcata National side) and five on the south bank (the Georgia-Pacific side) -- and many smaller compound slides near the creek. Our impression is that there are many more active slides on the south bank than on the north bank.

The vegetative cover on the two sides of the creek differs significantly. On the south side, stand density is greater, the percentage of redwood in the stands is higher, and the average age of the trees is older.

On the north side there are relatively few windfall trees on the ground. In contrast, on the south side there are several places where 20 percent or more are down. Many of these trees are clearly associated with active slides. but with some, the relationship is not clear. In general, the direction of fall has been downhill on both sides of the creek. How many of the trees on the ground are a result of wind-throw or slide activation we were unable to judge, but in many cases it must involve a combination of both factors. The floods and heavy rains in 1955, undoubtedly activated many slides and by 1962 the trees on this loose footing would have been a poor match for the winds of hurricane force that struck at that time. Since then, slides, which were further activated by undercutting during the 1964 flood-peak flows, have been responsible for much of the tree fall. The final force that pushed-over several trees this last winter was probably the strong southerly winter winds, which would explain why most of the trees fell in a downhill direction on the south side of the creek. Where sliding is actively going on, however, trees fall even on a calm day when associated with

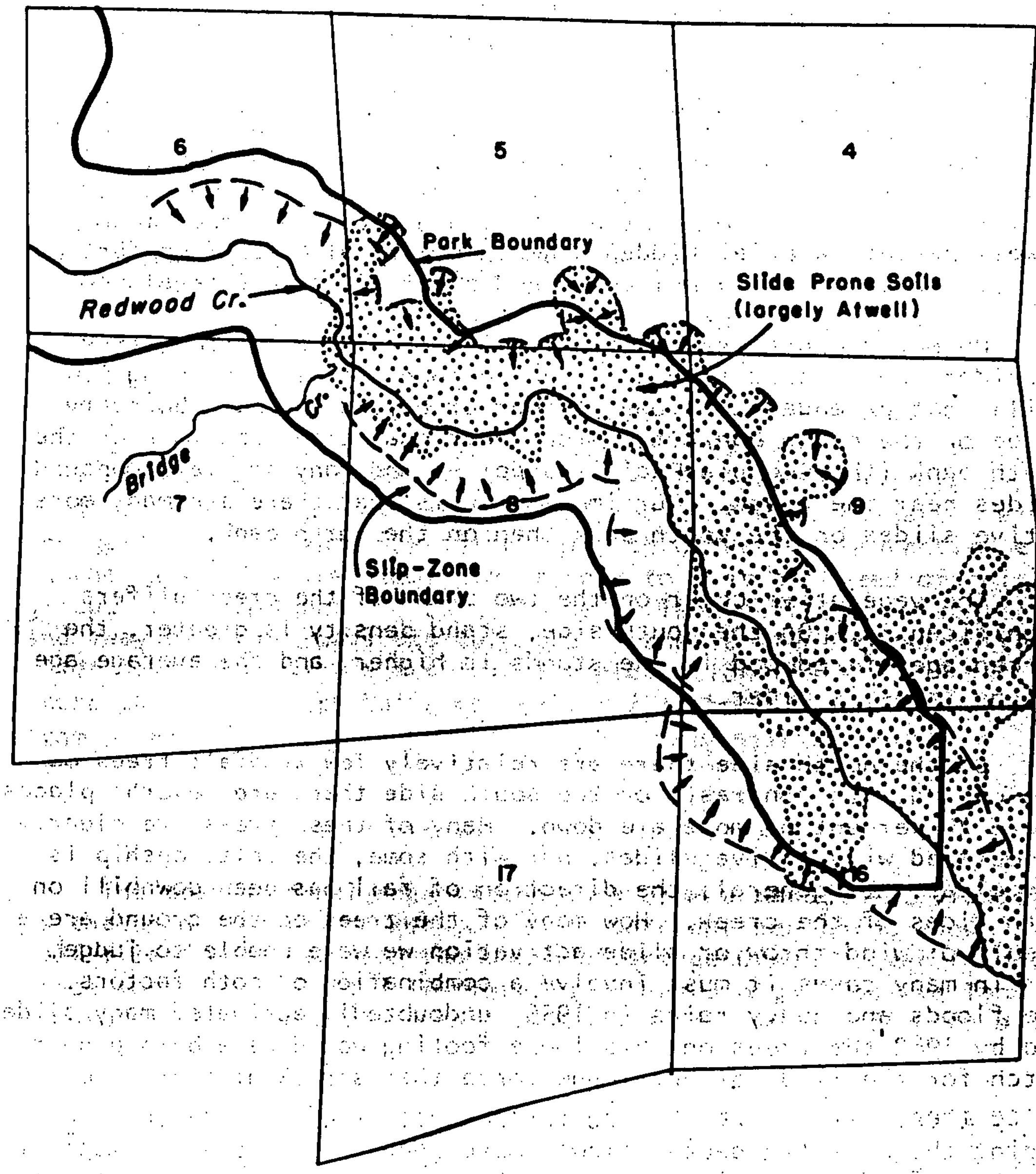


Figure 1. Slip-zone boundary and slide-prone soils -- largely Atwell -- in the upper end of the Redwood Creek corridor.

rotation slides -- as did one tree that fell for our edification while we were in the area.

Two major problems will face the preservation manager in dealing with this slip area. First, he will need to decide whether he can do anything about stabilizing the slides. He probably could do a great deal, but it will be costly. It will involve diverting water off these slides, removing trees from and adjacent to many of the slides, reshaping the surface around the edge of these slides and planting. Second, he will have to decide what to do about the large number of trees now lying on the ground and those that are certain to fall during the next several years regardless of what he does. These fallen trees constitute a major concentration of heavy fuels in the Park. Should he leave them on the ground or should he remove them? Also, not the least of his worries will be the tough public relations problem he will face, whatever he does in this area. This slip-zone has been widely publicized as the "Emerald Mile;" not a word has come out about the dynamic forces at play and the preservation problems they have created.

Although far less critical in a management sense, the Tall Tree alluvial flat must also be classified as a highly critical area in the Park. At all cost it must be preserved -- the public expects it! Two problems must be considered. First, the health of the trees on the flat must be assured, which could become a problem should periodic flooding be eliminated. Second, the flat must be prevented from being washed away. Technically, neither problem should be difficult to solve. A modest research effort should be able to develop methods for maintaining the health of trees on the flat in the absence of flooding. To keep the flats from washing away is a straight forward engineering job. The stream must be kept from being deflected against the bank of the flat. During the last few years the Arcata National Corporation was faced with this problem. They found it necessary to excavate gravels from the bed of Redwood Creek in order to retard the development of a delta at the mouth of McDonald Creek which was beginning to turn the force of Redwood Creek against the flat. Rip-rapping with heavy boulders, properly hidden by willows and alders, may also have to be used eventually to protect the upstream side of the flat.

POTENTIALLY DESTRUCTIVE INPUTS INTO THE PARK

There are a number of potential inputs into the Park that could interfere seriously with the preservation of the primeval redwood forest and its associated streams. Wild-fire is an input that can be expected to alter most ecosystems supporting redwood but not to destroy them. As an input into other ecosystems in the Park, however, wild-fire can be expected to destroy many if not all of them. Wind, soil -- moving either along the surface or in the form of slides, and water -- moving down the slopes or in streams eroding away the alluvial flats during peak flows, are inputs capable of destroying some or all forest ecosystems in the Park. Increased peak flows, sediment loads carried both in suspension and moved along the streambeds as gravels and rocks and organic debris are inputs capable of changing the character of the various stream ecosystems in the Park.

Fire as an Input

The potential effect of wild-fires on ecosystems in the Park depends on the quantity and quality of fuels on the ground, air temperatures, relative humidity, wind, whether the fire burns up or downslope, and whether the fire stays on the ground or moves up into the tree crowns. Generally speaking, we can expect a well-fueled wild-fire, during a period of low humidity and high winds, to kill all but the sprouting species. This, of course, means that redwood will remain, some to sprout from root-crowns, and others to sprout from the trunk where the bark is thick enough to protect the cambium. All Douglas fir -- some bigger than 6 feet in diameter -- Sitka spruce, lowland white fir and hemlock can be destroyed. Thus even though redwood could be expected to continue to occupy most of the ecosystems it occupied prior to the fire, aesthetic values if not totally destroyed, would be greatly reduced over the next 50-100 years. In addition erosion and water runoff characteristics that could be expected to contribute directly to the deterioration of the streams in the area would probably result. Wild-fires, however, should not be confused with the use of controlled-fires as an interruptive factor in the management of particular ecosystems in the primeval redwood forest.(7) Fire may have a role to play as a tool in redwood preservation but if so, only when under close control and where the possibility of wild-fire from escaped controlled-fire has been eliminated by prior cultural operations. The determining factor in the use of fire as a preservation tool in the Park will depend upon its cost as compared with the use of other interruptive factors.

Recent wild-fire history in and around the Park is characterized by a large number of fire starts but with an inordinately small number of fires that reach a size of 100 acres or more. Fire starts are related principally to man's activities and only secondarily to lightning; the area burned per fire start is related to fuels, weather and availability and access to fire control forces.(8) The latter two factors are responsible in a major way for the small number of large recent fires in the Park area. Fuel accumulations remain high, however, in the uncut redwood ecosystems and on many of the cutover areas. The mix of dense understory vegetation, heavy accumulation of large, down-logs and the presence of overmature tall trees with dead tops -- highly susceptible to lightning strike but more important when fires start they tend to throw burning embers far ahead of the fire -- constitute a highly hazardous situation in the uncut redwood ecosystems. With the exception of local accumulation of heavy fuels around old landings and in gullies, recently cutover lands are less hazardous primarily because less fuel is available and better access for fire control forces is available on the logging road-net.

The cool-moist climate which prevails from November to late August is characteristic of the area in and around the Park. It is responsible for the much lower fire hazard conditions that are experienced in this area during this period of the year than in other wildland areas of California. The late August to late October period, however, is frequently the occasion for a reversal of prevailing conditions with the intrusion of warm dry air coming in from the north. These intrusions are often accompanied by high winds predominantly from the north and northeast. Relative humidities drop, temperatures increase and high winds may blow for several days at a time.(10) By late August, dead fuel moisture contents are lowest, live vegetation is under its greatest moisture stress and new fuels have been created by the season's logging. During this period the frequency of fire starts -- particularly man-caused starts -- increases sharply and in the past it has been during this period that most large wildfires have occurred. Thus, it is in early fall that the hazard from wildfire will be the greatest. The likelihood of destructive fires entering the Park will be the highest at this time.

Wind as an Input

In the redwood forest, wind damage consists largely of windfall and stem and branch breakage. Close to the coast, however, foliage is often burned by wind-borne salt. Windfall results from a failure in the root system either due to damaged roots or the inability of the soil and its parent material to provide root anchorage sufficient to offset wind forces developed high in the crowns. Involved is a shear failure of a rotating surface in a clay soil or the parting of a pre-existing shear-zone underlying the root-zone (Figure 2) which

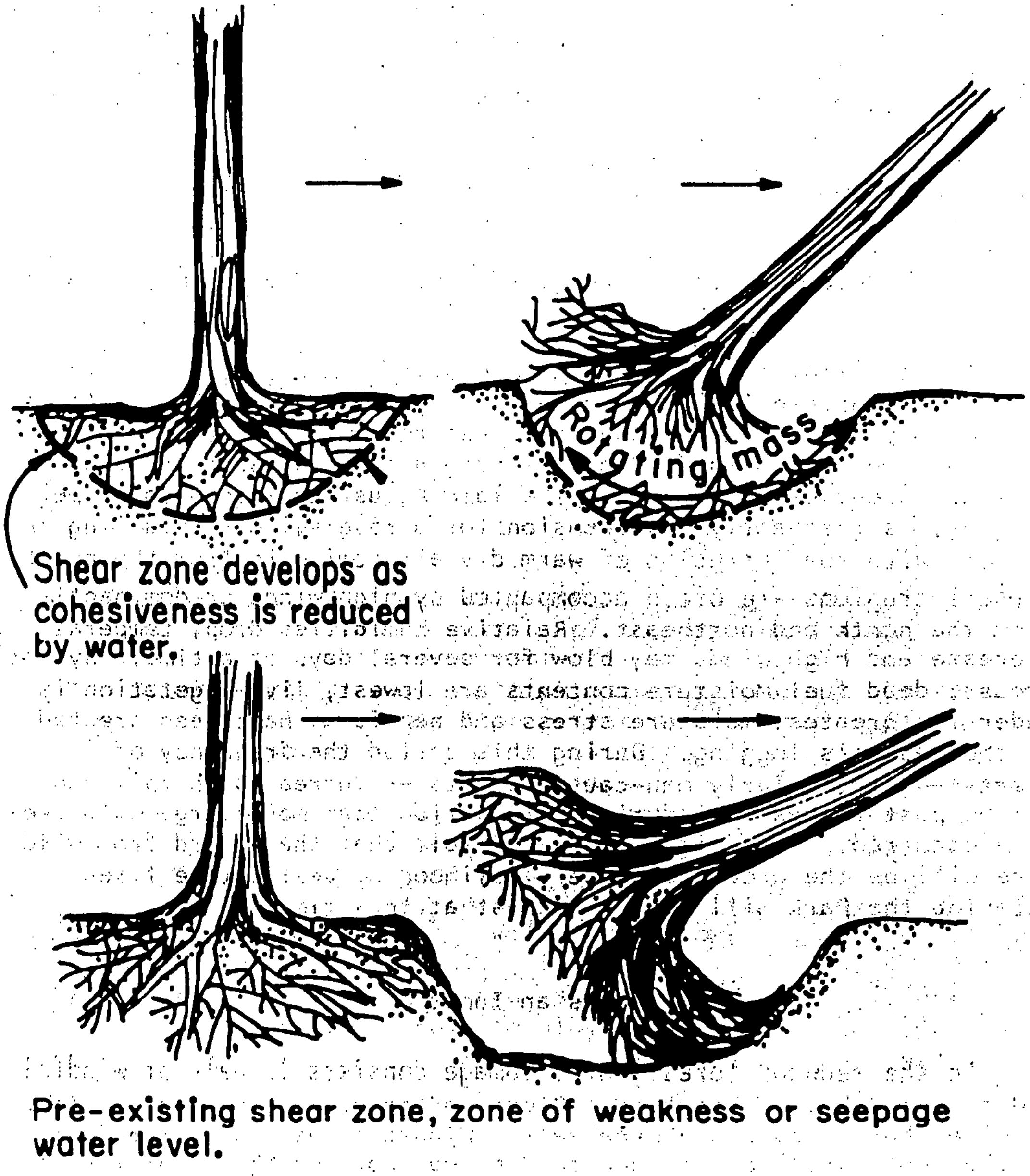


Figure 2. Windthrow showing two types of shear failure in cohesive soils.

results in a pit and mound combination called a cradle-mound (Figure 3). Stem breakage usually occurs at some point of weakness in the stem caused by decay and fire scars.

It is readily evident from fallen trees on the ground and cradle-mounds in undisturbed stands that windfall and windbreakage are natural forces in ecosystems in the Park that support redwood. The series of unusually heavy storms which occurred in 1955, 1962 and 1964, for example, have caused an acceleration in windthrow in the Park unrelated to man's activities. The 1962 Columbus Day storm accompanied by winds of hurricane force was particularly devastating as evidenced by the large number of fallen trees dating to that storm.

Man's activities can, however, greatly increase the amount of windfall and stem breakage. Chief among these is harvesting, where formerly protected trees are suddenly exposed to wind forces previously not experienced. Figure 4 depicts the wind flow patterns that can be expected over a forest adjacent to a clearcut area.[9] A zone of turbulence and accelerated wind velocities will occur at the canopy level at the edge of the uncut forest. This will result in severe oscillations of the crowns in the zone and subject the trees to increased stem breakage and windfall. Trees along a front exposed by clear cutting, for example, are particularly susceptible to windfall and breakage immediately following exposure. In time, these newly exposed trees adjust to the new windforces by shifting the point of new wood deposition on the stem and on the roots put under stress by the thrust of the wind.

In the area in and around the Park wind damage is largely associated with winter winds from the southeast, accompanying the major wet storms during the October to April period.

Topography can reinforce these wind flows and increase turbulence in certain situations (Figure 5).[9] On major ridges, winds are normally accelerated and turbulence accentuated on the immediate lee side, the middle slopes of the lee side -- where vortices form during high windflow -- and the middle slopes of the windward side. Windflows are also often accentuated in narrow valley situations and on the windward middle slopes and two thirds up the lee slopes on secondary ridges.

Soil and Water as Inputs

Soils in and around the Park derive their characteristics from the geology and the length of time that they have weathered from the rock types involved. They progress through a sequence of colors on

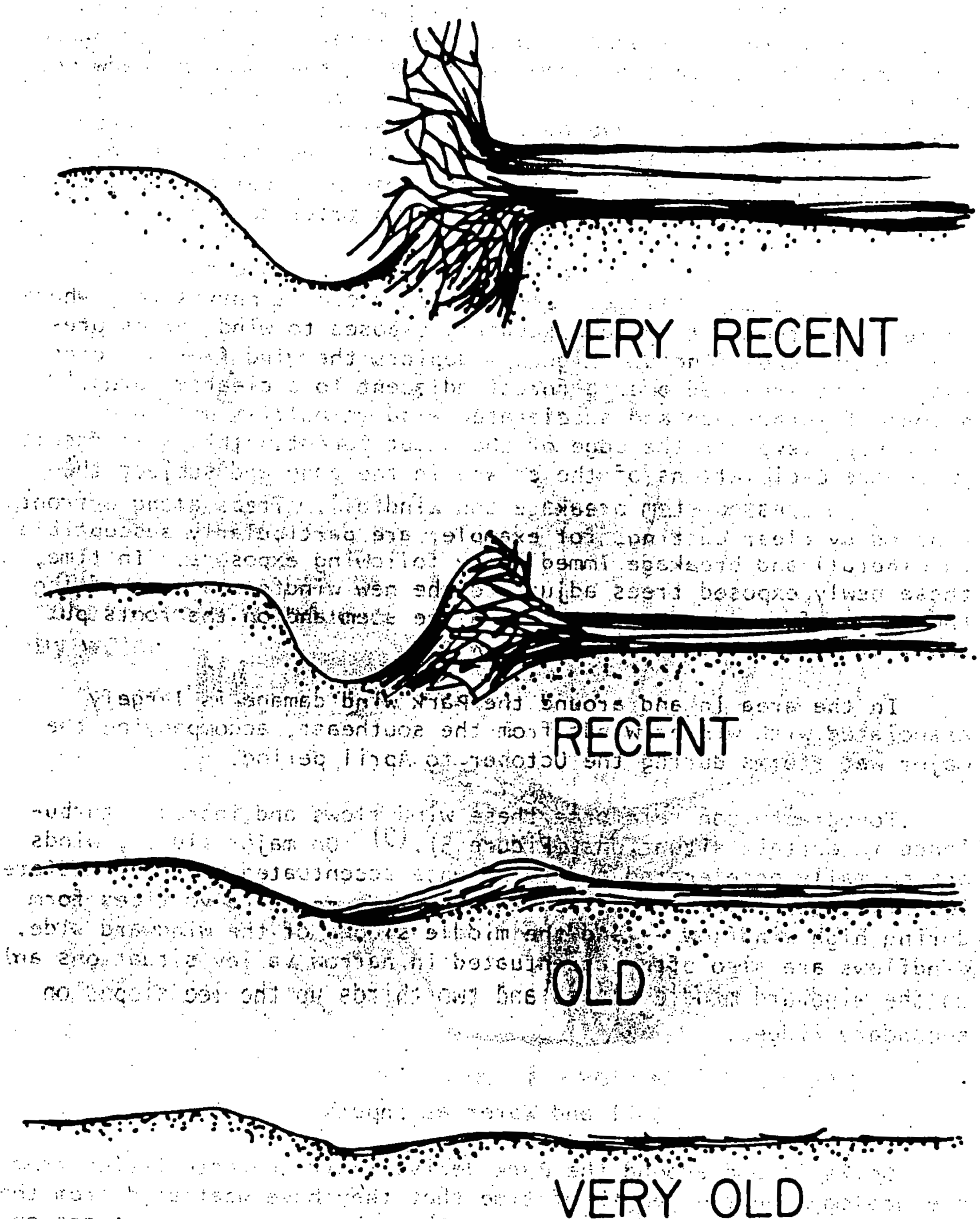


Figure 3. The development of cradle-mounds from windthrown trees.

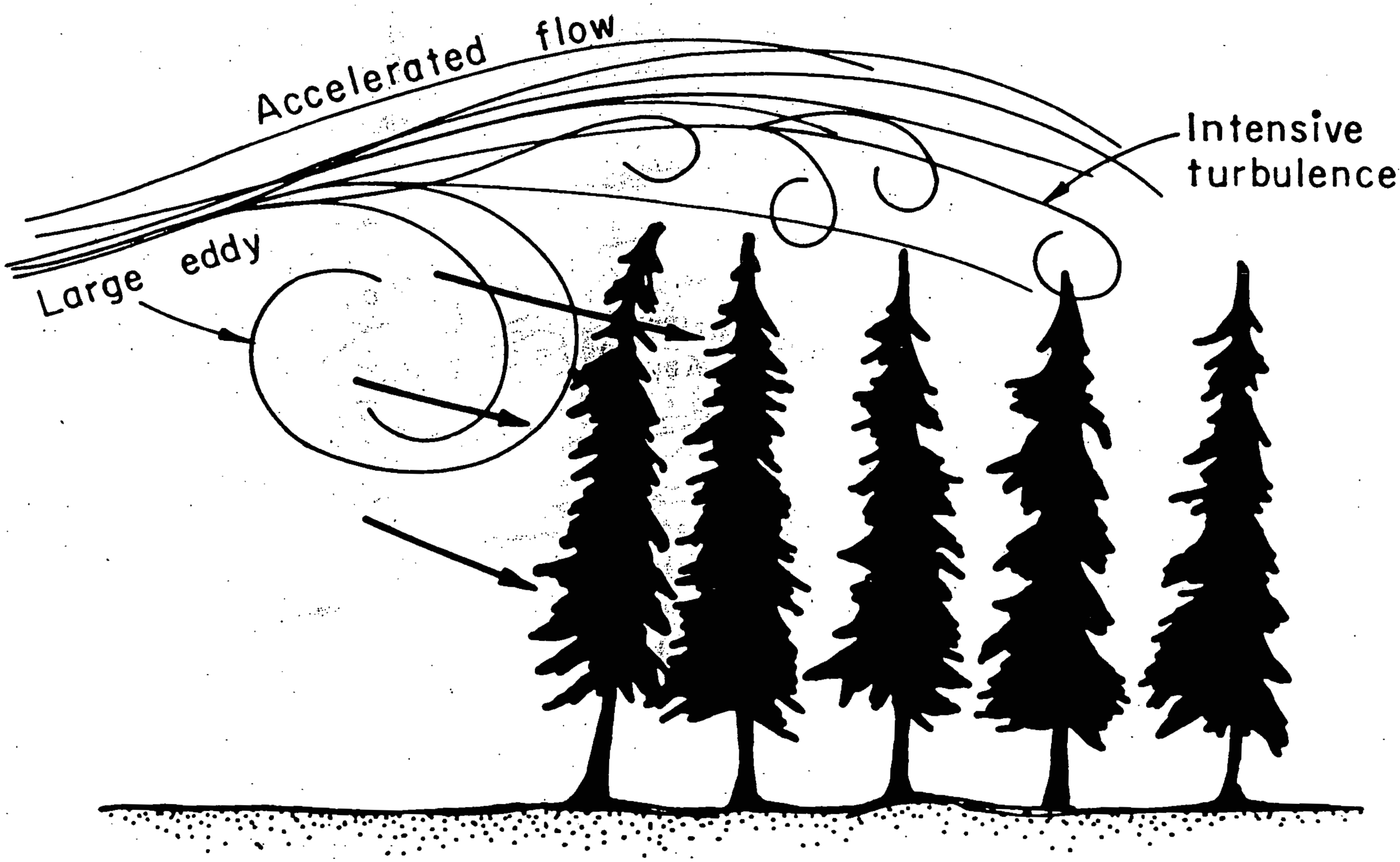


Figure 4. Generalized wind-flow pattern over a clear-cut forest boundary.

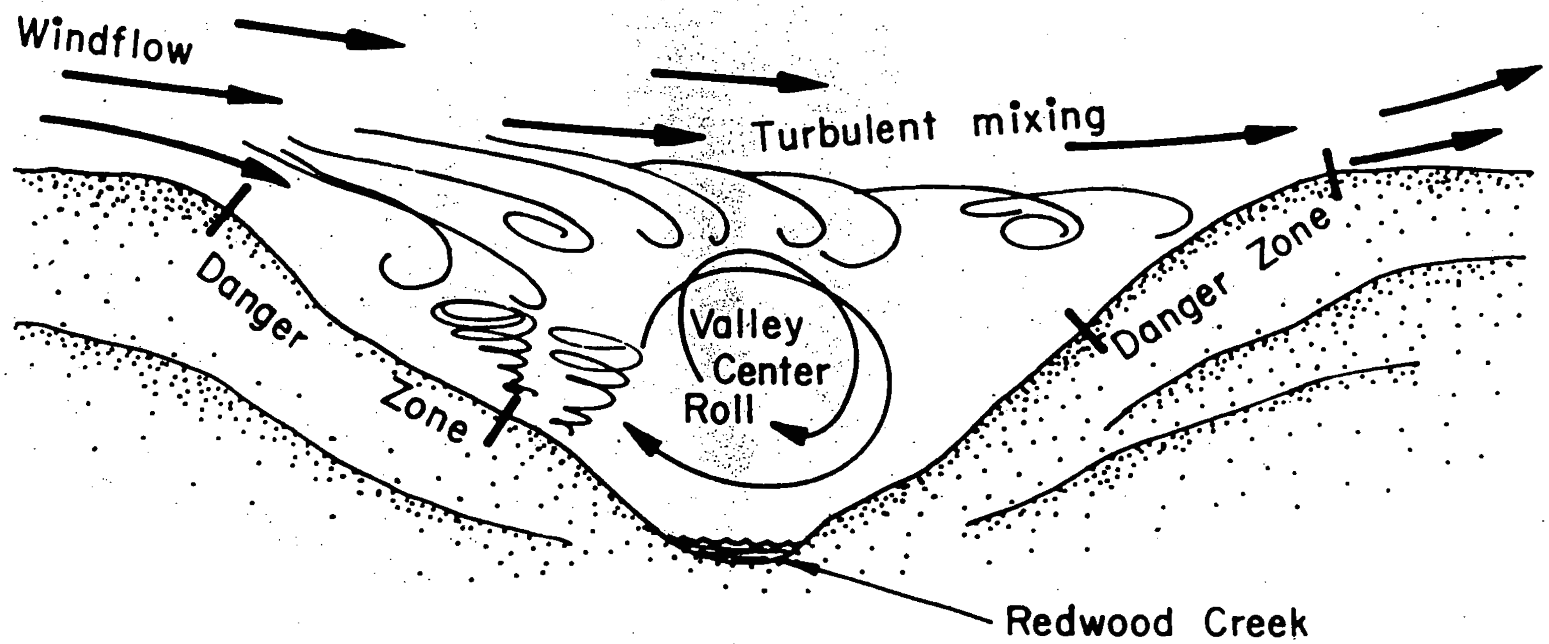


Figure 5. Generalized wind-flow pattern over Redwood Creek.

a given rock type from grey to brown to reddish brown and finally to red at maturity. Soil series names have been given to each of these stages on the major rock types by the Soil Vegetative Survey.(6) Generally, on the steep slopes where "natural" erosion is relatively rapid, the soils will not have developed beyond the brown or light reddish brown stage. On the gentle slopes where "natural" erosion is relatively slow and the surfaces as a result are older, the soils will have developed to the reddish brown or red stage. The major soil types in and around the Park are moderately erosive. The most erosive are the stony phases of the Hugo, Josephine, Melbourne and Orick soil series as they occur on slopes of 50 - 70 percent or more.

Slope and disturbance are the most critical factors contributing to the erosiveness of these soils. Clear cutting with tractor logging for example, on slopes of over 40 percent on Melbourne, Hugo and Josephine soils is highly hazardous in terms of potential erosion. Tractors operate most efficiently in a downslope direction with the result that the general pattern of flow is downhill toward landings where the trucks are loaded. A series of fan shaped patterns of skid trails each converging toward a downhill landing is created with each trail becoming a potential ditch for collecting water and concentrating it at the landing. It is these concentrations of water that cause the serious erosion on steep slopes.

Cable logging systems applied on these same slopes tend to minimize the concentration of water on the slope. These systems are most efficient operating in an uphill direction and the pattern of flow is one of convergence toward the top of the slope. Any overland flow of water tends to be dispersed along the skid trails rather than concentrated. Furthermore, on these steep slopes, cable systems do not generally disturb the soil to the same extent as tractors.

Logging roads are another major source of soil disturbance and thus an erosion hazard on steep ground. Heavy cuts and fills are a major source of erosion unless quickly and satisfactorily re-vegetated after construction. Size of cuts and fills are a function of topography and road width; the steeper the topography, the wider the road, the larger the cuts and fills. This means road widths should be reduced to a minimum in steep land and where possible a one-way road system should be established. Road drainage also critically affects erosion. Normally, logging roads are constructed with a slight inslope toward the bank, necessitating a drainage ditch on the bank side. These ditches are cross-drained at intervals by metal culverts installed in the road bed structure. Since ditches and culvert-openings are on the bank side of the road, bank-sloughing can fill them during periods of heavy rain and when this happens high concentrations of water are dumped on to fill slopes with heavy erosion resulting. Consequently a high level of road design, construction and maintenance is desirable in steep lands in an upslope position from the Park.

There still remains around the Park about 15 to 20 years of cutting in old-growth timber and thus thousands of acres are yet to be converted to young-growth management. It is during this conversion period that the threat to the Park in the form of accelerated erosion will largely exist. Many miles of new roads must be built, especially in the lower portions of the Redwood Creek watershed. Old stands will be clear-cut and large, soil-disturbing equipment will be employed in their logging. Potential inputs into the Park of soil and water from new roads and skid trails will be high during this period unless care is taken in planning, constructing and maintaining new roads, and in planning and conducting logging upslope from the Park. The technical knowledge is available to reduce these destructive inputs, the incentive must be provided to employ this knowledge over the critical 20-year period that lies ahead.

Land Slippage as an Input

Massive soil and rock slides occur commonly along Redwood Creek and occasionally elsewhere in the Park. Relatively few lie on slopes above the Park. As inputs, these slides largely affect the stream ecosystems in the Park.

Several types of earth movements are involved and can be categorized according to the materials involved and the type of movement taking place. When the materials are non-cohesive, consisting of loose soil, sand or rock resting at or near the angle of repose, and the movement is sliding, rolling or falling, it is a colluvial slide. These slides are composed of individual particles of soil and rock material and are usually activated by undercutting (Figure 6).

When the material is cohesive, consisting of masses of clay-rich soil and interbedded rock, occurring on a wide range of slope angles, and the movement of the sliding mass is rotational relative to a concave shearing surface, it is a rotational slide. These slides are composed of large blocks of soil and rock materials, with concentric cracking, back-tilted surfaces and with trees at the upper end of the slide leaning and then falling uphill (Figure 7).

Where the material is cohesive, consisting of large blocks of soil and the movement is that of a block moving along a zone of slope weakness it is a translatory block slide. These slides are composed of large blocks of soil and rock material. Trees on these slides often remain in their original upright position or may lean slightly downhill (Figure 8).

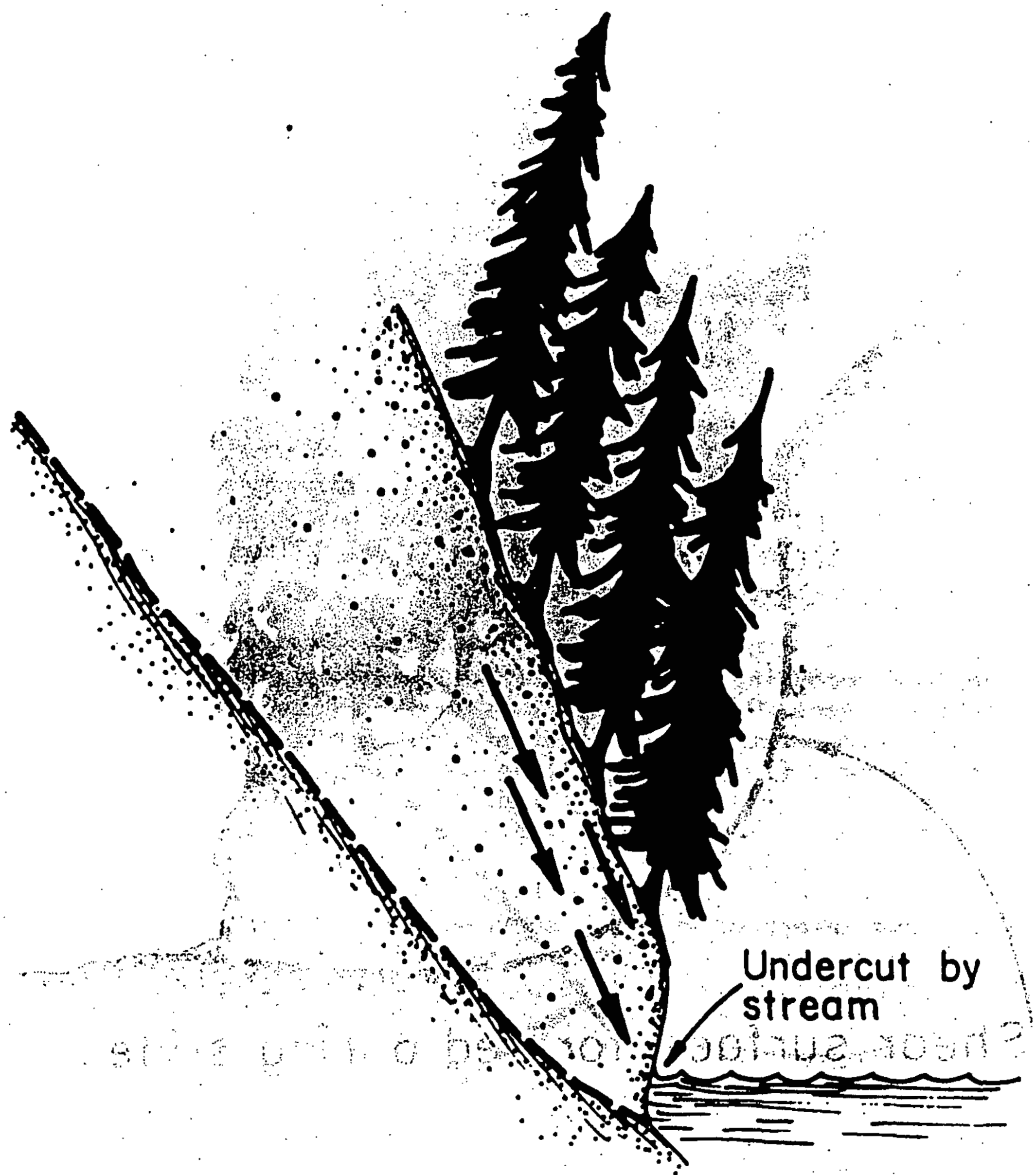


Figure 6. Colluvial or debris slide.

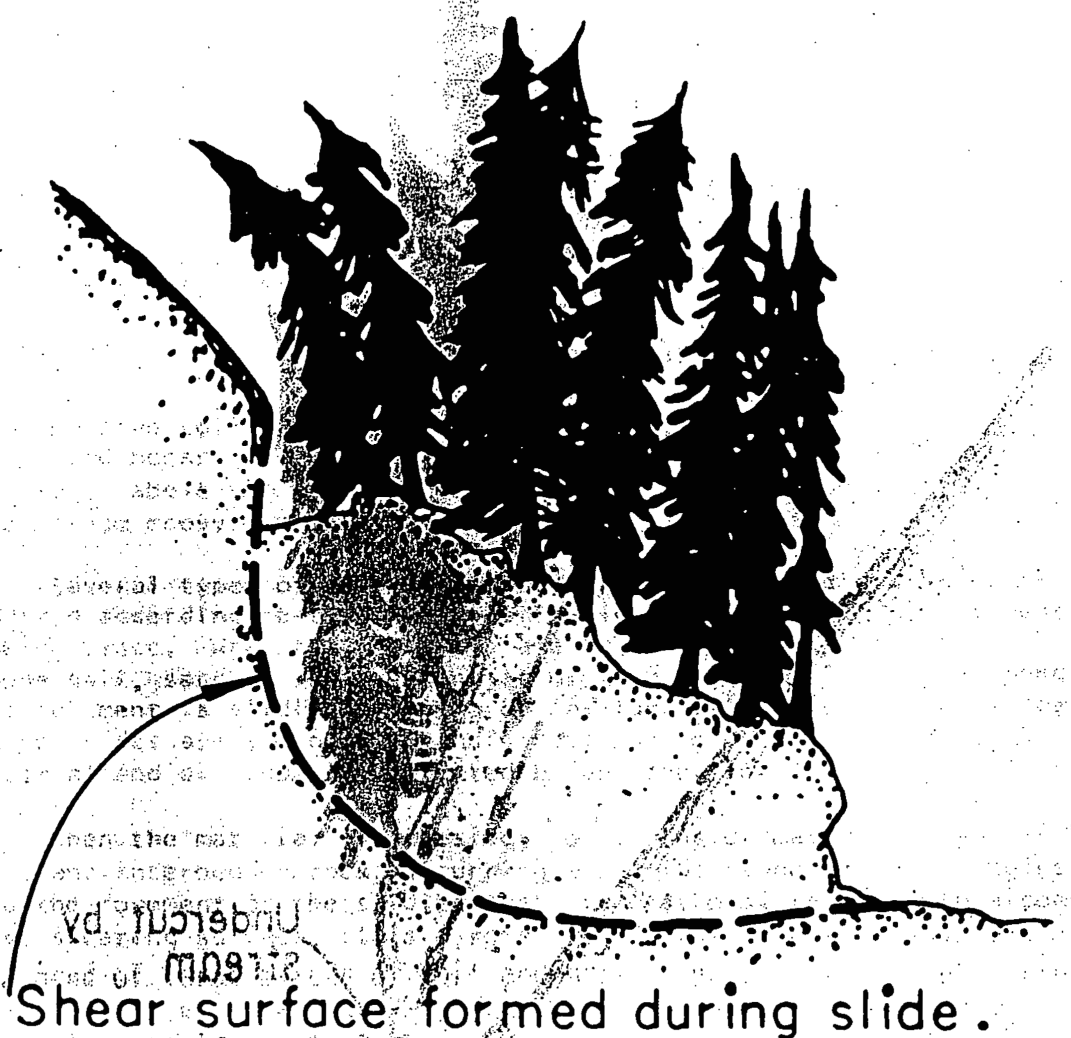


Figure 7. Rotational slide.

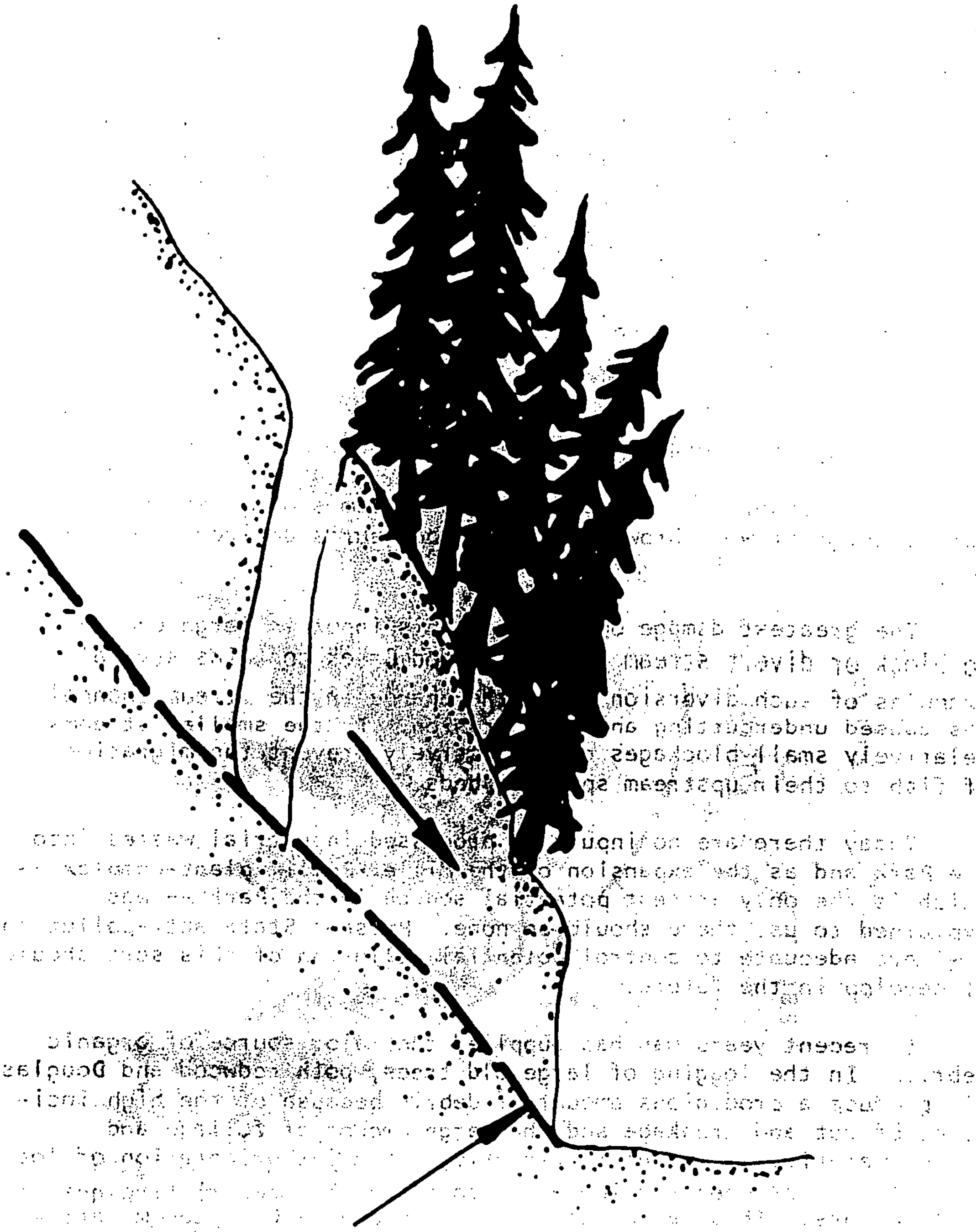


Figure 8. Block slide.

When the material is cohesive and the movement is a compound motion composed of a train of rotational slides that have activated moving blocks with additional rotational slides developing at major changes in the slope, it is a compound slide and is occasionally referred to as a land glacier. These slides consist of soil and rock materials occurring on a wide range of slope angles, often with the lower portions able to move on almost horizontal slopes because of the lateral pressure of moving materials behind it. Trees on these slides may be erect, tilted backward, or tilted forward, falling upslope at the beginning of the rotational portions of the slide and falling downslope along the translatory portions of the slide (Figure 9).

Water content is a complicating factor in these cohesive type slides because shear strength of the soil is reduced by wetting.

Organic Matter as an Input

Inputs of organic matter into the stream ecosystems in the Park consist of windthrown trees or wood debris derived from logging.

The greatest damage occurs when this input is large enough to block or divert stream flow. Redwood Creek contains several examples of such diversion where the change in the stream channel has caused undercutting and bank erosion. In the smaller streams relatively small blockages can effectively prevent the migration of fish to their upstream spawning beds.

Today there are no inputs of processed industrial wastes into the Park and as the expansion of the Miller-Rellim plant-complex -- which is the only present potential source in the Park -- was explained to us, there should be none. Present State anti-pollution laws are adequate to control potential pollution of this sort should it develop in the future.

In recent years man has supplied the major source of organic debris. In the logging of large old trees, both redwood and Douglas fir produce a prodigious amount of debris because of the high incidence of rot and breakage and the large amount of foliage and branch material. Also until recently, the major orientation of log utilization has been for lumber which has highly restrictive quality requirements. Thus large quantities of broken and rotten material was left in the woods. Some of it ended up in the streams. The prospective costs of removing this debris, as legally required, from streams used by migrating game fish, has encouraged careful practice on the part of responsible operators in their logging of

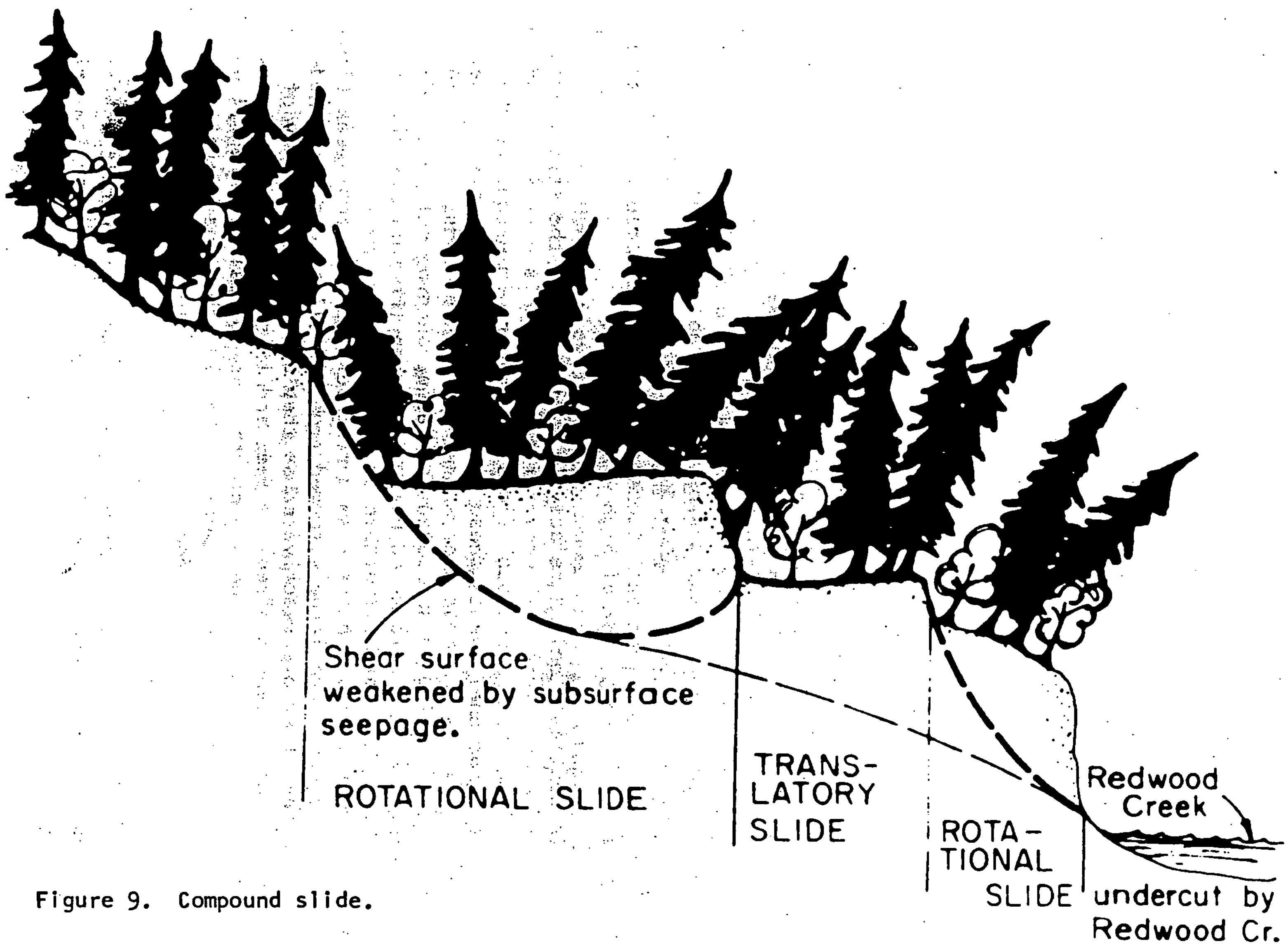


Figure 9. Compound slide.

stream-side timber, but has not solved the problem completely.

Diversified production facilities and expanding wood markets for products such as paper and particle boards has increased utilization of low grade logs. As a result, today, many cut-over lands are being re-logged in order to pick up logs and pieces of logs which earlier were left on the ground as cull material. This will reduce the amount of material left in the woods.

Once old-growth stands have been converted to intensively managed young-growth stands, which will be characterized by smaller logs, less breakage and better utilization, logging debris should be a minor source of organic matter input into the streams in the Park. Windthrow inputs will largely be from within the Park and will need to be handled accordingly.

Flood-Peak Flows as Inputs

Most of the alluvial flat soil and parent material in the Park is removed during the relatively few occasions -- perhaps two or three times during a century -- that flood-peaks are reached in the adjacent streams. The exception is when a shift in the normal channel directs the stream against a vulnerable part of the flat, such as the sharp bend in Redwood Creek behind which the Tall Tree flats developed. Then each succeeding year large amounts of materials are removed by normal high winter flows.

In contrast, only a relatively small part of the stream bank soil and parent material removed from the Park is carried out of the Park during these flood-peak flows. Much more important is the chain of erosional events these flood-peak flows initiate on the adjacent slopes. Almost everywhere along the streams, banks are undercut resulting in subsequent collapse, sending soil and rock crashing into the stream-bed below even when the soil and parent rock are of a relatively stable structure. These materials are then gradually moved downstream during periods of normal-peak flows. Where the banks are largely formed from old slides, as along Redwood Creek, they are reactivated as they are undercut. Many of these slides extend hundreds of feet and in some cases even thousands of feet up the slope and do not come to rest again until cutting of the base by the stream ceases and the upper portions of the sliding mass have reached a delicate equilibrium on the slope.

It is important that the preservation-manager protect against flood-peaks to the greatest extent possible. This is particularly important where he has alluvial flats as along Redwood Creek and the mouth of Mill Creek and in areas of highly unstable redwood-covered stream bank slopes -- as along the Redwood Creek corridor. His job will be a difficult one and whatever success he achieves, will depend upon a knowledge of the hydrologic characteristics of the watersheds within and tributary to the Park.

For the Redwood Creek watershed these hydrologic characteristics are best explained in terms of a yearly water balance for the watershed upstream from the gauging station at Orick. This water balance is summarized in Table 1. The total watersheds drained at this point cover about 180,000 acres (278 square miles) to which Prairie Creek contributes roughly 19,000 acres (30 square miles). From 1956 to 1965 the maximum annual yield varied from 1,174,000 to 533,200 acre feet which is equivalent to an average depth of yield over the watershed of between 79 and 36 inches. The average depth of rainfall for the period varied between 102 and 59 inches. The differences between water yield and rainfall are attributable to evapo-transpiration and interception losses which, of course, are related to vegetative cover. In this particular case this difference amounts to about 23 inches. Without vegetation, interception and transpiration losses would disappear and evaporation would increase. Studies in other areas indicate that vegetation will use about 20 percent in interception and transpiration. Thus some guide is available to the impact of vegetation on water yields.

The immediate effect of timber harvest on the Redwood Creek watershed is to increase water yield. This increase in yield, however, can be expected to decline once the current period of accelerated cutting of old-growth is completed. Lands will revegetate and evaporation and interception losses will increase. On the well-managed working forest only about one or two percent of its total area is cutover each year, thus the increase in yield due to harvesting will be expected to decline in the years ahead. Ultimately yield should stabilize at a point slightly above that on the watershed before cutting began.

During the short time the gauging station has been in operation at Orick, the maximum flow of Redwood Creek at flood stage has been 50,000 cubic feet per second. Presumably flows of this magnitude can be expected about once in every hundred years. Whether or not logging in the watershed would increase flood-peak flows at critical points along Redwood Creek in the Park is not certain. The distribution of logged areas relative to the location of these critical points could easily nullify the increase in surface run-off that can be expected to result from logging. It is not unreasonable to expect, for example, that increased surface run-off from watershed

Table 1. Estimated Water Balance for Redwood Creek for a wet year and a dry year based upon streamflow recorded at the Orick gauging station (1956-1964).

HYDROLOGIC COMPONENT	WET YEAR	DRY YEAR
Water Yield	79"	36"
Estimated Losses (Evapo-transpiration and Interception)	23"	23"
Estimated Precipitation (Average over the Watershed)	102"	59"
Recorded Precipitation		
Prairie Creek	97.8"	46.3"
Forest Glen	102.5"	36.6"

points near the Park would get water off the land more quickly and past critical points in the Park before flood waters from further upstream arrived.

Low-flows as well as high-flows which occur seasonally are an outstanding feature of the hydrology of the Redwood Creek watershed. Eighty percent of the yearly precipitation occurs between November 1 and April 30 and most of the stream-flow is concentrated in the winter and spring months. Thereafter, the flow drops off sharply. By late summer it may be as low as 10 cubic feet per second.

For the Mill Creek watershed there are not enough data available for developing a yearly water balance. Speaking in general terms, however, it should be similar to that described for Redwood Creek, but with less of a tendency toward low flows. In wet years precipitation should average around 100 inches over the watershed; evapo-transpiration and interception losses should be around 20 inches, and water yield as stream-flow should be around 80 inches. In dry years the precipitation should average around 50 inches and since evapo-transpiration and interception losses will be about the same as in wet years, water yield as stream-flow should be around 30 inches. Dry years we can assume will be less severe on Mill Creek than on Redwood Creek because of its proximity to the coast.

Mill Creek because of its deeply incised channel in the Park should be able to handle flood-peak flows with less difficulty than Redwood Creek. Except for the upper one-half mile of low alluvial soils in the Park along the creek, the deep channel between High Terrace soils should make the Park relatively immune from damage when flood-peak flows develop from the Mill Creek drainage.

A stream gauging-station should be installed on Mill Creek just above the Stout Grove in order that information that may be needed in the future, in making management decisions regarding this watershed and its performance, will be available.

Stream Carried Sediments as Inputs

Clays, silts, sands, gravels, rocks and boulders constitute the stream carried sediment input. These materials are carried either in suspension or are rolled or bounced along the stream bed by the force generated by the flowing water. Except for the finely suspended clays and silts, these materials are largely moved into and/or through the Park during periods of high winter flows. The amount of suspended material is particularly important because it increases the buoyancy of the heavier materials carried by the stream and the rate at which they can be moved. As the density of suspended material is increased, even big boulders can be readily moved along the stream bed. As stream flow subsides, these sediments are deposited. Small deposits have little impact on the stream ecosystems. Large deposits can change the direction of the channel but probably more important, they can raise the bed of the streams, thus exposing unstable slopes -- previously safely out of reach of the winter peak flows -- to extensive undercutting and the erosional chain of events described in the last section.

The amount of sediment entering the Park from bank-cutting and land slippage is related to the type of soils found in the watershed and their relative amounts. The general pattern of land slippage along Redwood Creek is one of compound slides of the type shown in Figure 9, involving Atwell and associated soils. The Atwell soils form on deeply weathered metamorphic and sedimentary rocks -- generally finely fractured. Rock weathering takes place under reducing conditions with large amounts of seepage water present and the soil that develops is high in clay content. Redwood Creek has cut deeply into these materials and by this action has activated slides. usually the Atwell soils are closely associated with the shearing action that has taken place in the fault zone, along which Redwood Creek runs for most of its length. Consequently they are found bordering immediately upon the creek, often extending up the slope for a quarter to a half-mile. Occasionally large compound slides involve Atwell parent materials -- not visible on the surface -- that extend under more stable soil types causing them to also slide. Consequently not all areas with high sediment input potential can be identified by a simple review of the Soil Vegetation Survey maps.(6) Nevertheless, to obtain some estimate of the magnitude of these potential sediment inputs from the Redwood Creek watershed upstream from the Park, we used these maps to determine the relative amounts of Atwell and Atwell-Masterson-Hugo complex, Yorkville, High Terrace, Masterson, Hugo and Low Terrace soils along a 42.5 mile section of the creek channel between the upstream limits of the Park and where it leaves the Six Rivers National Forest in the Snow Camp area below Board Camp Lookout. We tallied the soil types present on Soil Vegetation Survey Quadrangels 11C2, 11C3, 26B1, 26B4, 26A3, and 26D2 on both sides of the stream channel at approximately quarter-mile intervals.(6) The results of this tally are tabulated in Table 2.

Based on this survey, there are 28 miles of bank-length capable of actively feeding material into the creek from compound-slides. These materials will come from the blue-grey Atwell and Yorkville soils -- the soils that give the characteristic grey color to Redwood Creek. Mainly, their contribution will be to the suspended sediment load. Some rocks in the sliding mass may be solid enough, however, to add to the bed load. There are 12 miles of bank-length

Table 2. Soil Types along 42.5 miles of Redwood Creek from the Redwood National Park boundary to the Six Rivers National Forest in the Snow Camp Area.

SOIL TYPE	POTENTIAL SEDIMENT INPUT	MILES[1/] OF BANK	PERCENT OF DISTANCE
Atwell (823) or Atwell complex with Masterson or Hugo	Very high (compound	28.0	33.0
Yorkville (752)	Very high (compound landslides)	0.8	0.9
High Terrace (400)	Moderate (debris slides and bank cutting)	12.0	14.1
Masterson (821)	Moderate to low (block slides if dip of schist is downslope toward creek)	33.8	39.7
Hugo (812)	Low to moderate (debris slides if slope is steep or vegetation is removed)	8.5	10.0
Recent Alluvium Low Terrace (200)	Low (unless bank cutting occurs)	2.0	2.3

1/ Each mile of creek was considered to have two miles of bank.

of High Terrace soils capable of contributing to the bed load where any undercutting of the bank occurs. These terraces are made up of cobble and rock from old creek-borne deposits left stranded well above the current grade of the creek. There are 42.3 miles of moderately stable bank-length where Masterson and Hugo soils line the creek. However, about half of these soils rest on slopes greater than 50 percent and are thus potential sources of increased sediment inputs if poor land management is practiced. Where they are allowed to erode, their contribution will be mostly to the bed load. There are 2 miles of stable bank-length composed of recent alluvial deposits; where they erode, they will also contribute largely to the bed load.

Thus on Redwood Creek, in that part of the watershed lying upstream from the Park, 34 percent of the bank distance consists of highly erosive soils which are the major source of the sediment load carried by the creek today. Fifty-two percent of the bank distance consists of moderately stable soils under natural conditions but which could become areas of accelerated erosion if the land surface is disturbed: Poor road location and faulty diversion of surface runoff waters could supply this disturbance. Fourteen percent of the bank distance consists of moderately stable soils, provided the grade of the creek is not drastically altered and bank cutting is held to a minimum. Only 2 percent of the bank distance can be considered stable but even there bank cutting is a potential source of sediment input.

Mill Creek differs markedly from Redwood Creek in the composition of the soils found along its banks upstream from the Park. Unlike the banks of Redwood Creek which are actively adding sediment over much of their length, through the action of compound landslides, the banks of Mill Creek are relatively stable.

In order to obtain a measure of potential sediment inputs from the Mill Creek watershed upstream from the Park, we tallied at quarter mile intervals, soils along a 14 mile stretch of Mill Creek that appeared on Soil Vegetation Survey Quadrangles 9D1, 9D2, 9A3 and 9A4. The results of this tally are tabulated in Table 3. Based on this survey approximately 60 percent of the bank-length consists of low lying gently sloping alluvial soils which have a low potential sediment input except where bank cutting occurs. Another 14 percent of the bank-length offer moderate to low potential sediment input. Only 2 percent of the bank-length is actively feeding material into the creek from compound slides but 24 percent of the bank-length consist of soil lying on very steep slopes -- at or above the angle of repose -- that have a high potential sediment input if disturbed.

Table 3. Soil Types along 14 miles of Mill Creek upstream from the Jedediah Smith Park boundaries.

SOIL TYPE	POTENTIAL SEDIMENT INPUT	MILES[1/] OF BANK	PERCENT OF DISTANCE
Recent Alluvium Low Terrace (200)	Low (unless bank cutting occurs)	17.0	60.6
Hugo soils, on steep slopes (812)	High (due to steep slopes in this watershed which if undercut will produce debris slides)	6.7	24.2
Josephine Soils (815)	Low	2.5	8.9
Melbourne Soil (814)	Low to moderate	.8	2.7
Atwell (823)	Very high (compound landslides)	.5	1.8
Orick Soil (813)	Moderate to low	.5	1.8

1/ Each mile of creek was considered to have two miles of bank.

In addition to determining the percentage of each soil along Mill Creek, we examined the distribution of soils in the watershed by running transects at mile intervals across Soil Vegetation Quadrangles 9D1, 9D2, 9A3 and 9A4 and tallying the soil intersected along each transect at quarter mile intervals.(6) The results of this tally are tabulated in Table 4. Based on this survey about 73 percent of the watershed is covered by soils with moderate or low potential sediment input. The remaining 23 percent of the watershed is covered with soils with a high potential sediment input.

Sediment inputs into Prairie Creek could seriously damage the spawning riffles that now handle most of the Chinook salmon and Cut-throat trout spawning in the Redwood Creek drainage. Potential sediment inputs can come from Lost Man Creek and Skunk Cabbage Creek. Lost Man Creek has its own watershed -- part of which is in the Park -- and near its mouth is joined by May Creek and Little Lost Man Creek -- which lies entirely within the Park.

Potential sediment inputs into Lost Man Creek from May Creek is low. Over the western third of its area the May Creek watershed is dominated by Empire soils developed from deep sandy marine and old dune deposits. Over the eastern two-thirds of its area, in the headwaters of the creek, Melbourne soils prevail with slopes ranging from 30-70 percent. Both of these soils offer low to moderate potential sediment inputs. The steep slopes immediately along the eastern ridge of the watershed can be expected to furnish the greatest potential sediment input. The future problems in this watershed in terms of its potential sediment input will be those associated with the new freeway, which in all probability will be routed up May Creek and across its northern headwaters. This freeway could have a very high potential sediment input.

Potential sediment inputs into Lost Man Creek from its own watershed is fairly high. The lower western two-thirds of its watershed is not steep and is covered mainly with Melbourne soils with a moderate potential sediment input. The upper eastern third of the watershed is steep and is largely covered with a Hugo-Melbourne soil complex with a high potential sediment input. The north fork of Lost Man Creek also traverses a considerable area of gently sloping Empire soil before heading up in a steep slope covered with Hely soils which also has a high potential sediment input. These Hely soils are developed on the soft sand and gravel deposits of an old river bed which was left perched on ridge tops following the Coast Range uplift. Generally the deep beds of the material on which this soil forms are permeable to water and surface runoff, unless concentrated by roads or skid trails. Deep seated slumps in the steep sandy deposits may occur, however, where clay seams form zones of weakness.

Table 4. Distribution of Soils in the Mill Creek Watershed

SOIL TYPE	POTENTIAL SEDIMENT INPUT	PERCENT OF WATERSHED
Deep Melbourne, Hugo and Josephine soils on moderately steep slopes (30-50%).	Moderate to slight (unless surface runoff is concentrated; then is subject to deep gullying)	43.1
Deep Melbourne and Josephine soils on gentle slopes (less than 30%).	Slight	13.7
Soils on recent alluvial flats (nearly flat).	Slight	8.0
Deep Empire soil on gentle slopes (less than 30%).	Slight (unless surface runoff is concentrated; then is subject to deep gullying)	8.0
Moderately deep, stony Melbourne, Hugo, Josephine and Orick soils on steep slopes (50-70%).	High (when cover is severely disturbed, and surface runoff is concentrated)	22.7
Shallow, very stony Hugo soils on very steep slopes (greater than 70%).	High (subject to loose debris slides, and severe gullying in skid trails)	4.5

In order to obtain a measure of the potential sediment input into Lost Man Creek -- a large part of which will come from within the Park -- we tallied at quarter mile intervals, along a $6\frac{1}{2}$ mile stretch of the creek, starting at its juncture with Prairie Creek, the relative amounts of Low Terrace, Empire, Melbourne and Hugo soils that appeared on Soil Vegetation Survey Quadrangles 10A4 and 11B3. The results of this tally are tabulated in Table 5. Based on this survey, there are 10 miles of bank-length along which potential sediment input is low and 3 miles of bank-length along which potential sediment input is very high. A large proportion of the bank-length of Lost Man Creek is along gently sloping alluvial flats involving the western two-thirds of the Creek. Presumably, in this distance, sediment originating from the steep Hugo soils, may be trapped before reaching Prairie Creek.

In summary the potential sediment input into Prairie Creek from Lost Man Creek is low but could be high if proper steps to control it are not taken during and following freeway construction.

Potential sediment inputs from Skunk Cabbage Creek which drains into Prairie Creek from the west is low. The valley of this creek is unusual in that it was probably an old outlet to the sea for Redwood Creek. Skunk Cabbage Creek now flows in a reverse direction to the east with very little gradient. If there is any significant amount of sediment input into this creek, it will probably remain largely in the creek channel and will not move into Prairie Creek except over a long period of time.

Table 5. Soil Types along 6.5 miles of Lost Man Creek and Tributaries.

SOIL TYPE	EROSION SOURCE POTENTIAL	MILES[1/] OF BANK	PERCENT OF DISTANCE
Recent Alluvium Low Terrace (200)	Low (except where bank cutting occurs)	3.5	26.9
Empire (920)	Moderate (subject to bank caving and deep gullying)	3.5	26.9
Melbourne and Hugo (30-50% slopes)	Low to moderate	3	23.1
Steep stony Hugo soils (50-80% slopes)	Very high (occurs mainly southeastern headwaters of Lost Man Creek. Under cutting of base by roads or stream can cause severe debris slides into creek)	3	23.1

1/ Each mile of creek was considered to have two miles of bank.

MANAGEMENT PRACTICES ON ADJACENT LANDS AFFECTING THE MAGNITUDE OF POTENTIALLY DESTRUCTIVE INPUTS

The magnitude of destructive inputs reaching the Park is in part related to the management practiced on the surrounding lands. These practices in turn are influenced by the characteristics of the individual ownerships.

Industrial Forest Ownerships

The lands surrounding the Park are dominated by four major industrial owners -- Arcata National Corporation, Georgia-Pacific Corporation, Rellim Redwood Company and Simpson Timber Company. This group occupies 80 percent of the total lineal boundary of the Park, while the remainder is divided between the United States Forest Service and miscellaneous small owners. The location and general significance of these owners are described below.

Arcata National Corporation is the smallest of the owners in terms of total acreage. Its lands and their management, however are highly critical from the viewpoint of preservation of the southern portion of the Park. It shares slightly less than 25 percent of the Park boundary, which is next to the largest amoung of common boundary held by any of the owners. Even more significant, it owns major portions of the watershed of May Creek and Lost Man Creek as well as the east slope of Redwood Creek north of Counts Hill Prairie.

Much of this corporation's ownership is in an upslope position relative to Park lands and highly important because of the potential inputs it can generate. The largest portion of its remaining old growth stands are concentrated in the Redwood Creek watershed west of the Bald Hills Road and north of Counts Hill Prairie. The company has plans to cut-over these stands during the next 14 year period.

Georgia-Pacific Corporation is the second largest owner in terms of total acreage. It shares about 13 percent of the Park boundary. Its lands border on the southwest of the Park and include major portions of the watersheds of McArthur, Elam, Bond, Forty-four, McDonald and Bridge Creeks as well as the west slope of Redwood Creek above the Park. With the exception of several fingers of uncut or partially cut timber which remain in the steeper portions of McArthur, Bond, Forty-four and McDonald Creek, stands northwest of Bridge Creek have been cut and substantial progress has been made in converting them to thrifty young-growth stands.[10]

The largest block of old-growth this corporation has in the vicinity of the Park -- about 2500 acres -- lies in the Bridge Creek area.

Rellim Redwood Company is next to the smallest owner in terms of total acreage. It shares about 15 percent of the Park boundary. Its lands border the east boundary of the Del Norte unit and the south boundary of the Jedediah Smith unit. It owns nearly all the upstream portions of Mill Creek and thus the policies and practices of management on these lands directly affect the character and behavior of this important stream.

This company has around 4,000 acres of uncut old-growth timber most of which lies on the south boundary of Jedediah Smith State Park and to the north of the main east-west drainage of Mill Creek.

Simpson Timber Company is the largest of the owners in terms of total acreage. It shares over 25 percent of the Park boundary. Its lands border much of the east side of the Park but it has no large areas of uncut old-growth in the vicinity of the Park. From the viewpoint of Park management the most critical of these lands are those in upper Redwood Creek south of the Park. In this area this company's land management practices will have a direct influence on the sediment load of the creek.

To the north, this company borders the Park on virtually the entire east boundary of the Del Norte and Prairie Creek units from the headwaters of Wilson Creek south to the north headwaters of Lost Man Creek. The Wilson Creek drainage is essentially wholly contained in its ownership but the creek itself impinges only at the Park's narrowest point near False Klamath Cove. For the most part company lands are in a downslope position relative to the larger Park units.

Agricultural Ownerships

Agriculture owners occupy a minor portion of the lands in the vicinity of the Park. The principal farm and ranch ownerships are located on the natural, high prairies on the eastern ranges of the upper Redwood Creek watersheds. They affect the Park only through sediment inputs into Redwood Creek. Most of these ranch and farm holdings include both natural grasslands and forests. The principal long term crop is forage which is marketed as meat or wool. Timber has been handled mainly as a one-time crop where once the merchantable trees have been cut an attempt is made to convert the land to grass or browse production. To achieve this conversion is both difficult and expensive and the forage and product output values have not justified the full investment required to fully achieve the conversion. Consequently many of these converted lands are now in an erosive condition.

Government Ownership

The Six Rivers National Forest is the only significant government ownership adjacent to the Park. Approximately five miles of boundary are shared along the southeastern corner of the Jedediah Smith unit. This land is nearly all in a downslope position relative to the Park. Consequently, erosion and other water borne inputs are not a problem. The area has a fairly high fire potential, however, because much of it is covered with soils of low fertility and in places support fairly dense stands of brush. The fire problem is intensified by the fact that the land is currently managed primarily for watershed and wildlife, which are extensive uses from the viewpoint of the Forest Service, and land on which a high level of fire protection normally cannot be justified.

Also included in the boundaries of the Six Rivers National Forest are portions of the far upstream reaches of the Redwood Creek watershed. There are potential sediment inputs from these lands but we have not attempted to evaluate them in this study.

Ownership Characteristics Which Affect Land Management Policies

There are some basic and common characteristics of landowners which affect their management practices and thus the character and magnitude of potential inputs into the Park.

Our concern here with ownership on the Park boundaries is the need for stable ownership with strong economic and ethical interests in keeping the land productive with tree crops and protected from fire and erosion. Forest land intensively managed for tree production will generally be protected land in the sense that a vegetative cover will be maintained, which will minimize erosion, and intensive fire protection will be provided to protect the investment.

Stability of ownership is one of several factors which affect the care with which the land and its vegetative cover is managed. In general large corporate ownerships tend to be more stable and to apply better land management practices than do small individual ownerships. The investment of the larger industrial owners in land and timber generally exceed their investment in the manufacturing facilities; and this investment yields most and maintains its value best when growing well-stocked stands of trees. Forest tree crops are characterized by the long period required to establish and grow them to a state of economic maturity. Few other businesses deal with products or crops that take decades to grow. Thus both planning and ownership must be stable and take a long term view in order to protect and nurture the investments in land and growing stock and to realize return in the form of harvestable tree crops.

Intensity and tenure of management is related to size and productivity of the property. The ownership must be large enough to operate as an economic unit on a long term sustained yield basis for it is only under this situation that old stands will be conscientiously replaced with young ones and that continuous profitable production is feasible. Numerous examples exist of small ownerships where the objective was to harvest and process old-growth stands only. Manufacturing facilities associated with these ownerships were designed, financed and depreciated with a lifetime determined by the period over which the old-growth timber could be processed and marketed. Long-term management of these properties was not contemplated nor was it feasible because the sustained yield production potential of the land area involved was not sufficient. In order to sustain production over the long run there must be a sufficient amount of land of high enough production capacity so that the total growth on the property each year is sufficient to meet the desired raw material needs. A property of 20,000 acres, for example can provide an annual liquidation cut of 50 million board feet for about a 20 year period. On the other hand to sustain the same cut on a long term basis where the property is organized so that cut is equal to growth each year, approximately twice as much land would be needed. The larger the forest area and the higher its productive capacity the greater the feasibility of balancing the cut of old-growth stands with the growth of newly established young stands and thus to create the balance of age classes necessary for sustained production.

There are some estimates that a minimum of 25,000 acres of high quality forest land are needed in a single ownership to allow the development of an economically profitable, fully regulated forest. Such a forest will need to support a normal distribution of age classes, ranging from one-year-old to harvest age and will need to be properly balanced by area so as to provide a continuous flow of products and income sufficient to cover the costs of maintaining a competent management staff, taxes and reasonable profit. In such a forest every acre will be vegetated and growing wood at the economic optimum; losses from fire, pest and windthrow will be at a minimum. Such a forest will be least susceptible to erosion and other destructive outputs which might affect its neighbors.

Large, widely-held corporate ownerships generally have stability of direction and the continuity necessary to plan and undertake long-term intensive management. Closely-held corporate or family held ownerships on the other hand are not likely to be as stable over the long planning periods necessary for sustained forest production. The inevitable shift in ownership brought about by death or departure of a major owner in a closely held corporation or individual ownership is frequently accompanied by a change in objectives and in land management practices.

Private ownership is profit-motivated and profit motivation in the management of forest land on the boundaries of the Park may or may not lead to practices which affect Park preservation. Land management practices on private holdings are closely related to rates of return expected on capital invested in them. A private owner is not likely to invest in regenerating cutover land, salvaging windthrown trees or cull logs, engaging in special cutting practices or even in improvement of fire protection facilities unless the prospective return on the investment is 6 percent or more. Of course, prospective rates of return cannot be clearly predicted in all investment activities. Consequently, many investments, such as in the reduction of fire hazard, in extra erosion control measures or in the foregoing the cutting of certain stands, are made on faith. The owner hopes they will yield or enable the yield of 6 percent or more in terms of sustained productivity, public relations or freedom from hazards. The point we want to stress here, is that an identifiable return is expected from each activity (investment) in land management; and that practices which are above the normal, such as the application of extra erosion control measures, departure from normal cutting practices and the use of extraordinary care in preventing silting of streams -- the kinds of practices which may be desired on the buffer areas -- will not be undertaken voluntarily and without compensation.

From the viewpoint of the Park the desired management of neighboring lands is that which maintains full vegetative cover, allows the least soil disturbance and provides the lowest incidence of fire. On privately owned lands, these conditions are most likely to be met where the objective of management is long term sustained yield directed toward the highest economic yield from tree crops. Most of the large industrial forest ownerships on the boundaries of the Park have publicly stated this objective. In some individual cases due to the small size of their property and its productive capacity, or to other limitations, this objective may not be obtainable. When this is the case the practices may be such that full vegetative cover, minimum erosion and low fire hazard conditions may not be achieved.

Markets for most products of the redwood forest have expanded greatly which, from the viewpoint of land management, has increased the variety and the amount of raw material utilized. These increased markets have also increased the rate of cutting and have supported the cutting of species and forest stands formerly considered unmerchantable. A case in point is the market which developed after 1945 for Douglas-fir. A constantly increasing price for this species was responsible for the cutting of large areas of farm and ranch ownership such as in the headwaters of Redwood Creek. In general farm owners were pleased to have this timber removed because it provided an opportunity to clear the land for grazing purposes. Consequently this cutting was largely opportunistic and was carried on without major regard to soil erosion and sustained production of wood.

Market expansion continues and is responsible for the development of more widely integrated utilization facilities marked by the installation of particle board plants and paper mills. These mills are subsisting mainly on sawmill residues but have created markets for low quality logs and cull materials which were formerly left in the woods. Export markets have also developed for small logs which has increased greatly the opportunity to thin and harvest young growth stands.

Thus, in the short run, expanded markets have accelerated the cutting of old-growth redwood and Douglas-fir which in many aspects is detrimental to the Park environment. On the other hand, these markets have supported the utilization of wood formerly wasted as cull and which provides an opprotunity for better clean-up of the land following logging and a reduction in fire-hazard. Most significant, however, is the opportunity these markets have created for more intensive management of young-growth stands. Better marketability of young-growth material provides the economic incentive for more rapid establishment of new stands after old-growth is cut and for more intensive care than has been possible under the limited markets of a few years ago.

Cooperation Between the Park and Adjacent Ownerships

The propensity of owners to cooperate with the Park on matters of common interest and the characteristics of land management practices which affect potential inputs into the Park are related -- as we have already discussed -- to tenure of ownership, size of property, objective of management, criteria for investment and availability of markets.

<u>Arcata National Corporation</u>. This corporation was most deeply affected by the creation of the Park and in turn is likely to have the greatest affect on the management of the Park. While it is now smallest in size relative to the other industrial holdings around

the Park, it occupies the largest portion of critical Park boundary.

Emphasis in the handling of this corporation's lands has been on the liquidation of old-growth timber. The original cutting method applied was characteristic of that widely applied in the region and a form of economic selection wherein 70 percent or more of the original stand was removed in the initial cut. This qualified the land to be classified as "cut-over" which meant that the residual stand was not subject to county ad valorum tax. These residual stands, however, suffered heavily from windfall and because of the high losses, this particular form of cutting was abandoned in favor of even-aged silvicultural management involving the removal of all the merchantable volume in one cut.

This corporation was the first to apply the clear cut system on a planned basis to redwood and to make a conscientious effort to obtain adequate restocking of cut-over lands. The corporation has invested substantial sums in aerial reseeding which has been relatively successful. The practice, however, quickly aroused great indignation on the part of some conservationists who interpreted this action as an abandonment of responsibility for the productivity of the land. Productivity was not really the issue. Largely, it was a question of aesthetics in relation to the visual incongruities imposed on the landscape. From the viewpoint of managing the forest for successive tree crops, the even-aged silvicultural management system combined with immediate stand regeneration following cutting has much in its favor -- as we will discuss later -- and as a consequence is most widely used in the management of the high-yield forests of the world.

The rate of liquidation of old-growth in relation to the total acreage in the present ownership and the capacity of this acreage to grow wood are not in balance. Less than 10,000 acres remain of the original holding which is considered insufficient land on which to develop a viable, fully regulated forest. Some additional land will be forthcoming from the Northern Purchase Unit but will not greatly change the situation. At the present rate of cutting, all old-growth stands will be cut long before a balanced distribution of younger age classes is established. Consequently long term sustained yield at the present level of cut is not possible. In order to establish an economically tenable sustained yield operation other land will have to be acquired with advanced young-growth stands in the 30-50 year old age classes. But most of the land, with the particular age classes needed and in the amounts required to provide the productive capacity necessary for long-term sustained yield management, is either in Park or other industrial ownerships. Thus the corporation will have to either buy stumpage (standing timber) from other owners, or obtain a larger than its proportionate share of the Northern Purchase Unit, to continue to operate or it will have to merge with some other company. This latter event, of course, need not necessarily occur within the next few years, but the effect of this outlook will have an overwhelming impact on the corporation's long term land management plans. Any change in ownership will probably require a reorientation of the basic transportation net. This could start a new cycle of road development and land disturbance.

The corporation has just recently submitted an Alternate Plan to the State Board of Forestry calling for the clearcutting of its remaining old-growth stands on the eastern portion of Redwood Creek, upslope from the Park corridor. The Plan encompasses a 5,160-acre area on which cutting is to be completed over the next 14-year period. This infers that stands will be cut at the average rate of something over 360-acres per year.

The Alternate Plan is a means of legally substituting a particular forest practice for practices specified under the State Forest Practice Rules. These Rules as applied to the Redwood Region call for the leaving of seed trees -- the number depending on size of the tree to be left. This seed-tree system is considered to be the minimum practice that will assure regeneration of cutover land. Regeneration of the seed-tree system in the redwood forest tends to be very slow and uncertain. Furthermore it does not provide the land manager with the opportunity to obtain the kind of reproduction he wants when he wants it, and in the quantity he wants. Thus, increasingly, companies in the Redwood Region are filing alternate plans whereby clear-cutting followed by aerial reseeding or planting is substituted for the seed-tree system.

The Alternate Plan is to be in effect until 1990 at which time the corporation expects to have all lands regenerated and in full production. Reseeding or planting will, however, be completed on each parcel within two years after each parcel is cut. It is expected that restocking thus obtained will exceed that required by the Forest Practice Rules.

The Alternate Plan is of important concern to the Park because these lands are among the last of the remaining privately-owned old-growth stands adjacent to the Park. Furthermore, a portion of the Plan encompasses the highly critical landslip-prone area in Sections 4, 5 and 9 in the Redwood Creek area (Figure 1). Particular attention must be given to the development of road systems in this area so as to avoid the Atwell soils and cutting should be confined to small blocks along this portion of the Park Boundary.

<u>Georgia-Pacific Corporation</u>. This corporation owns over 90,000 acres of high quality wood producing land near the Park and has a large and well-integrated utilization facility enabling it to process logs of any grade and owns operating forest lands in nearly

all major timber producing areas of the United States. It is a widely-held stock company whose major business is growing, processing and marketing forest products. Through its management practices it is moving rapidly toward the development of a well-balanced distribution of young age classes and the beginning of a fully regulated, sustained-yield forest.

Its lands in the vicinity of the Park have an unusual background of management. The immediate predecessor of the present owner, Hammond Lumber Company, demonstrated some of the earliest interest in progressive sustained-yield management. It was among the first companies to have a professional forestry staff whose responsibility included planning for long term land management as well as the supervision of scheduled cutting of old-growth. These management policies have persisted and to an extent have been strengthened through changes in ownership. One important result of this planning has been the consistent development of young age classes on cut-over areas and thus the company is in an excellent position to shift smoothly from its dependence on old-growth harvesting to young-growth management and harvesting once the old-growth is removed. The sustained future yield of young-growth on the lands involved should ultimately reach 150 to 200 million board feet per year with a cash flow value large enough to justify an intensive and progressive land management policy.

As in the case of the Arcata National Corporation, the Georgia-Pacific Corporation has shifted its silvicultural management system from a modified economic-selection to even-aged with clear-cutting. The change was made in response to poor growth and windthrow in the residual stands. The overall system as planned involves clear-cutting of old-growth in blocks followed by immediate regeneration from natural seed fall and redwood sprouts, supplemented where necessary to achieve adequate stocking with aerial seeding. Stands will be grown on a 50-70 year rotation age at which time they are expected to be economically mature and ready for harvest.

Logging of old-growth is done principally by tractor in a downslope direction with an 800-1000 foot maximum yarding distance. The transportation net is thus located on the lower sides of logging blocks and roads are spaced roughly at 800-1000 foot intervals. This results in a road density of 5-6 miles of road per square mile of land. While high density road systems present high erosion hazards, the roads have been designed so as to reduce this hazard. The road engineering staff has demonstrated a sensitivity to erosion and land slip hazards and has developed an imaginative approach to preventing land-slips along their road locations. The only major exception is the road on the southwest bank of Redwood Creek near the mouth of Bridge Creek. When the Park was established this road had to be abandoned by the corporation before it could be completed and properly drained.

The corporation has shown a willingness to invest money in a study of thinning in advanced young-growth stands and as a result now has the data on which to base a large-scale, commercial thinning program to start in 1969. Thinning is an important part of the evan-aged silvicultural management system since it provides the opportunity to control the growth characteristics of young stands, to capture a larger portion of the total wood produced, by utilizing trees that would ordinarily die due to overcrowding, and to provide income throughout the production period.

From the viewpoint of potential destructive inputs into the Park from this corporation's land, the next decade or so will probably be most critical. During this period old-growth stands in the Redwood Creek area will be cut and converted to young-growth. Because of the large size of the timber, heavy logging equipment will be required and the maximum amount of soil will be disturbed. A substantial amount of debris will be generated and even though markets today allow good utilization of the trees cut, debris will nevertheless accumulate. The greatest hazard, however, will be associated with the development of the road net against the Park boundary on the lower slopes of Redwood Creek just upstream from Bridge Creek. In several places these slopes are dominated by slip-prone Atwell soils.

Rellim Redwood Company. This company now owns about 19,000 acres and is being offered approximately 1,300 acres from the U.S. Forest Service Northern Purchase Unit as part compensation for lands lost in the establishment of the Park. The property taken as a whole is close to the minimum size necessary for the establishment and maintenance of a sustained yield unit. The lands are of high quality and a 20-year supply of old-growth timber remains. This is backed with a good representation of intermediate age classes 40-50 years old. Overall age class balance, however, is lacking at present because of a shortage of stands in the 10-40 year age classes.

It is anticipated that under intensive management the property is capable of yielding between 25 and 30 million board feet per year on a sustained yield basis. This appears to be insufficient to meet the ultimate capacity of the projected manufacturing facility which includes a chip-board plant in addition to its present sawmill and veneer plant. The company has, however, strategic access to timber sales on the nearby Six Rivers National Forest. A combination of logs from its own land plus stumpage purchased from the U.S. Forest Service could make long term sustained yield management of the company-owned lands tenable.

The company is largely controlled by one family which also has interests in forest operations in Oregon. It is somewhat vulnerable to change in ownership because of the limited number of owners. If ownership changes, management policies can also change. This should be taken into account in arranging agreements with this company for the management of buffer areas.

Until about 10 years ago, the company managed their lands on an economic selection system removing at least 70 percent of the volume on the original cut. They now operate on a clear-cut even-aged silvicultural system. They make good use of both tractor and cable logging systems. Access roads are located between 500 and 800 feet above the subdrainages, and little if any cut or fill materials are sidecast into the creeks during road construction. Timber is harvested and yarded uphill and away from the creeks to these roads. Unless there are large areas next to major subdrainages the slopes immediately above the streams are logged by a cable system.

While functioning as a high-yield wood producer the company has demonstrated its intent and ability to practice good watershed management. For example they have had an extensive stream clearance project on the west branch of Mill Creek which in its natural state as a virgin forest became nearly blocked by windfalls and debris. After the timber harvest, this stream was cleared of its natural as well as logging debris and has been cited by personnel of the California Division of Fish and Game as a good example of stream maintenance.

A problem exists over road access to Highway 101 which may affect future relations with the Park. The companies present main road now crosses Park land at the entrance to Highway 101. This road is highly important to the company's flow of traffic in and out of its manufacturing facilities. The company will be particularly sensitive to this situation, unless resolved, when the time comes for negotiating for the establishment of buffers to protect the Park.

Simpson Timber Company. The properties held by this company in Humboldt and Del Norte Counties are the largest of the industrial holdings in the vicinity of the Park and is only one of the company's several holdings on the west coast. It is a closely held stock company which has been both aggressive and progressive in land acquisition and management. It was among the first companies to commit its lands in Shelton, Washington to a cooperative sustained yield unit under Public Law 273, the Cooperative Sustained Yield Act. Under the Act the company and the Forest Service committed roughly equal amounts of lands in Washington under a long term agreement for intensive management for the purpose of assuring a permanent supply of wood for the industrial complex developed at Shelton. The basic objective was to stabilize and develop the community. It was the first major attempt of joint action of this sort between the forest industry and the Federal government.

Their lands which now amount to more than 150,000 acres in the vicinity of the Park, were acquired during the post-World War II period from several timber operating firms. Their total purchases made them the largest single owner of high quality old-growth redwood which aroused fears that through these purchases the company had achieved a degree of price control over the old-growth redwood lumber market. Consequently, the Federal Trade Commission brought anti-trust action against the company. Subsequently, an agreement was reached under which the company agreed to sell on the open market, each year a portion of its old-growth stumpage (standing trees). This has forced the company to liquidate some of its old-growth timber at a faster rate than perhaps desired. It has not, however, significantly affected the company's land management policies with respect to regeneration of young-growth stands or its ability to develop a fully sustained, permanent, tree growing operation.

The company is progressive with high quality lands and a forestry staff capable of applying careful management practices to the land. Until about five years ago, the company operated most of their lands on an economic selection basis. Today all its timber growing activities are organized under an even-aged silvicultural management system. Their cutting blocks, however, are characteristically larger than those of other companies in the area. For example, blocks of up to 4,000 acres are scheduled for cutting over a 5-year period -- 800 acres per year. Aerial seeding is planned and the resulting young-growth species mix will vary. The amount of redwood will be controlled largely by the sprouting of the redwood initially in the area. The resulting large blocks will be treated in future management as single age classes.

Efforts at regenerating cutover areas by artificial seeding have been fairly successful. Young seedling growth on some soil types, however, has been retarded and the company has carried on a substantial research effort in an attempt to find out why. We have no reason to believe at this time that a successful solution to this problem will not soon be forthcoming.

Logging by this company involves heavy equipment and large cutting areas. Tractors are used principally in yarding operations with the direction of wood flow downhill to the truck loading area. The maximum yarding distance is around 800 feet. Overall road density is 6-7 miles of road per square mile of land. The quality of their road system is highly variable. Much of it is well designed but in the Redwood Creek watershed -- where as already discussed the potential for natural land-slip is extremely high -- serious erosion has resulted from poor design and maintenance. On the southeast corner of the Park for example, roads have been cut through areas of erosive Atwell soils and a serious drainage problem along with an attendant high land-slip potential has been created.

The company has a well-integrated manufacturing complex in the Arcata-Eureka area which provides opportunity for utilization of logs of all qualities. Last year, for example, they salvaged approximately 75 million board feet of cull material from their cutover lands. This ability to utilize a wide variety of raw materials allows a large measure of versatility in timber management which favors careful attention to husbanding of perharvest age stands including thinning and intensive fire protection.

Agricultural Ownerships. Agriculture occupies a minor portion of lands in the vicinity of the Park. The land management practices on these lands however, have an important impact on the Park, particularly in the upper Redwood Creek watershed. The principal farm or ranch ownerships include both natural grassland and forest. The forested portions of these properties have been subjected to land clearing in order to enlarge the grass and browse producing areas. In more recent times they have also been used to produce timber incomes. The basic crop is forage which is ultimately marketed in the form of meat or wool.

Prices for these commodities have been relatively depressed in the last several years and smaller holdings have become unprofitable as operating farms. Owners, in order to maintain a way of life which many of them cherish and cling to, have been forced to sell parts of their properties, their timber, or seek outside employment.

Low livestock prices have been somewhat offset by increasing timber values on these properties. Consequently, in the last twenty years income from stumpage sales has been an important support for the farm enterprise in this area. Because of the relatively small size of properties, however, few of these farms can operate profitably as long term timber selling enterprises. As a result timber cutting has been a one-time affair with little hope of working toward sustained forest production and most of these forest lands have been poorly managed because of the low economic incentive. There are some important exceptions to this generality, of course.

Some of the large ownerships will undoubtedly remain profitable as multiple-product enterprises combining livestock, timber and the leasing of hunting rights. These ownerships should remain essentially intact with reasonably good land management practices. The smaller ownerships, however, will be under strong pressure to subdivide their most desirable sites for summer home use. Summer home development is among the most undesirable uses of adjacent lands from the viewpoint of the Park. Proximity to the Park in several areas of Redwood Creek watershed could create fire and pollution problems as well as visual incongruities of serious proportions.

Area of Common Interest and Conflict Between the Park and Private Landowners

It is evident that the well-being of the Park and its freedom from destructive inputs from neighboring lands is highly dependent on the attitudes, policies and cooperation of its neighbors. There has been a traditional schism between public and industrial forest owners in the United States and in many aspects this schism was widened in the rancor that surrounded the establishment of the Redwood National Park. There are clearly many areas of common interest between the Park and the neighboring owners, however, which suggest that the schism can be narrowed if not entirely eliminated.

Both groups of owners deal with similar kinds of lands and a common forest type. The objectives of management are different, but both deal with products or services which are outputs from the redwood forest and thus both are concerned with its preservation. The industrial forest owners have large investments in land and growing stock and thus share full concern for the havoc of fire. It is thus necessary that both cooperate closely in the development of mutual protection through a contractual fire control agency such as the California Division of Forestry. Cooperation on fire control, however, is but part of the overall fire control picture. Fire prevention is a major issue which cannot be simply contracted out to a neutral agency. The forest industries have for long periods campaigned among their employees and the public about the dangers of fires and the prevention of its causes. Of course, there have been publicly supported efforts as well, but the industry's efforts, through the Redwood Region Conservation Council and the Keep California Green organizations, have been both vigorous and effective in this particular area. An additional aspect of fire prevention is the removal of fire hazards, and the maintenance and interconnection of fire roads. Accumulations of hazardous fuels are most obvious on the industrial lands, but they also exist in abundance on the Park lands in the form of standing snags, dead-top old-growth trees and windthrown trees. In the area of the buffer the removal of these materials can be accomplished most effectively by a cooperative effort.

A well-designed and maintained fire road system is highly important and in parts of the Park, fire control access will depend largely on private roads on adjoining property. The creation of new roads for fire protection will not be desirable along the Redwood Creek corridor because of the unstable nature of the area and the aesthetic values that will be reduced. Thus this problem is one which clearly involves mutual interest.

Some common interests exist in the prevention of erosion. The Park's interest is mainly that of preventing the entry of slides and water-borne sediments onto lands in the Park and into the streams that run through it. The industrial forest owners' interest is to prevent the deterioration of the productive capacity of their lands through soil loss by erosion and slides. The harm to the Park in this case is likely to be greater than the loss of productive capacity on the private lands. The private owners are nevertheless sensitive to the problem. An effort on the part of the Park to show a cooperative interest in developing practical erosion control measures for private lands upslope from the Park and on tirbutary watershed could be a major key in developing this common interest.

Common interests potentially exist in the interpretive-educational aspects of land management. The National Park Service has set a superb standard of interpretation of natural and historical features of the landscape. It is not so well known for its efforts in land management. Industry, particularly in the Redwood Region, has demonstrated a beginning effort in such interpretation. Granted that these efforts have been defensively motivated to meet adverse criticism of cutting methods, nevertheless, the effort now has momentum which, if encouraged, could carry it beyond pure defense and into a positive program which could contribute to the public's understanding of forest land management for both the production of wood crops as well as the preservation of the primeval redwood forest.

An opportunity exists to coordinate Park and industrial interests in interpreting the total landscape -- that being preserved as well as that dedicated to the growing of forest crops. Leadership is needed to activate this area of potential common interest which would be the first of its kind. The Park Service could provide this leadership.

Areas of possible conflict are legion and obvious. However a major potential problem from the viewpoint of the Park is the development of residential and summer home sites on the immediate periphery of the Park. The problem already exists on the west face of the Jedediah Smith unit and in the Orick area. The potential exists for proliferation of these developments on most boundaries of the Park. Private land owners, whether large industrial owners or individuals, will shift land uses to those which yield highest rates of return within limits of consistency with overall objectives. The boundaries of the Park contain highly desirable sites for such use and rates of return for sales or leases are high as demonstrated, for example, by Southern Pacific Land Company, Fibreboard Corporation and Pacific Gas and Electric Company, all large forest land owners in the central Sierra. There is little doubt that similar potential exists in the Park area.

The principal problems with such developments relate to high fire hazard, danger of pollution, legal responsibility for physical hazards such as falling trees from neighboring lands, and the visual and environmental incongruities thrust upon the landscape. The problems, of course, relate to industrial lands as well as Park lands, but the industrial lands are the only ones on which such developments can take place.

CONTROL OF INPUTS WITH BUFFERS

Up to this point in our analysis we have been concerned with the nature of the resource to be preserved, the inputs into the Park that can be expected, the potential destructiveness of these inputs and how ownership and management on the adjacent lands and watersheds tributary to the Park can modify these inputs. Now, we want to examine the feasibility of establishing buffers around the Park that can control or reduce these inputs.

The problem is twofold. First, there is the question as to what type of management should be applied on the lands adjacent to the Park in order to filter out the destructive inputs generated on lands beyond the buffer and at the same time prevent the generation of destructive inputs from within the buffer. This is the question we will consider in this section. Second, there is the question of how the National Park Service can get this management applied. This question was briefly discussed earlier and will be considered again in relation to costs.

We assume that the buffers will be on private land with the exception, of course, of the small amount of National Forest land bordering on the Park on its northeast corner. To put the buffers on Park land would be to reduce significantly the size of the primeval redwood forest we are trying to preserve.

The most effective buffer we could hope to achieve would be management of land adjacent to the Park that would accomplish the following:

1. Reduce windthrow loss on ecosystems in the Park supporting redwood.

2. Concentrate on lands outside the Park, any accelerated windthrow resulting from the opening of newly exposed cutting fronts.

3. Maintain fire hazard at a minimum level by removing and utilizing all dead and snag-topped trees as well as all debris resulting from timber harvesting.

4. Convert old-growth stands in a rapid but orderly fashion to young-growth redwood stands.

5. Provide roads necessary for fire control access to all parts of Park boundaries.

6. Restrict commercial, residential or summer home developments outside designated or already established areas in order to minimize the fire hazard from this source.

7. Prevent acceleration of land slippage by locating roads and tractor trails so as to cross the minimum amount of highly erosive soils and where roads must necessarily be built on these soils, design them so that land slippage will not be a problem.

8. Minimize the amount of water-borne sediments entering Park lands and streams by developing a road and tractor trail net designed to disperse overland water-flow and by revegetating harvested lands by the most effective and rapid means.

9. Minimize visual incongruities resulting from harvesting and manipulation of forest cover by keeping cutting units scattered and as small as possible.

Land adjacent to the Park is not now managed to furnish the Park with this buffer. For the most part, the practices necessary to achieve this kind of buffer are not excessive yet even the best of practices on adjacent industrial forest lands do not accomplish all that is needed. Practices, however, are changing rapidly. For example, there is now great concern by most industrial forest owners in obtaining rapid regeneration and revegetation of cutover lands. Not many years ago lands were simply allowed to remain bare until they regenerated naturally which was frequently a slow process. Road nets were designed for one-time use only -- that of removing the old-growth timber -- and these roads were constructed with little concern for proper drainage and land stability. And only a few years ago, up to thirty percent of the wood volume cut in old-growth stands was left on the ground as cull material to create dangerous fuel and debris conditions. These practices have not completely disappeared, but are much rarer than they were. Today, practices typical of a frontier industry and society are being replaced with those that reflect the husbanding of resources necessary in today's modern industrial society.

To obtain the practices that will furnish the Park with an effective buffer will require incentives in the form of payment, legal action and mutual cooperation. The nature and amount of incentive necessary will depend on what the normal management practices are at the time. Let us briefly examine, therefore, the normal practices we can expect to develop during the next twenty years.

The remaining old-growth timber will be cut-over in about twenty years with essentially the same logging practices that prevail now. Harvesting will be accomplished principally with large track-laying or rubber-tired tractors. Eighty percent or more of the ground area logged by these methods will be disturbed. Cable systems will be used only on very steep ground. Average maximum yarding distance will be 800 to 1000 feet, requiring six to seven miles of road per square mile of land.

Companies will apply and emphasize those practices which yield 6 to 10 percent on the capital invested in the practice. Lands which yield returns substantially lower than this will not receive intensive management or protection and will be subject to low intensity management, sale, exchange or diversion to other uses.

An even-aged silvicultural-management system will be applied to all high quality lands. This will involve clear cutting in blocks varying from 40 to 4,000 acres in size depending on the size of ownership, the wood market and company customs. Regeneration of these lands will depend largely on artificial methods -- aerial reseeding or planting. Artificial seeding and planting will emphasize Douglas-fir as the most desired species. Fertilization will be applied wherever added output from fertilization will yield high rates of return and animal control measures will be applied where excessive browsing or other damage poses a threat to young, regenerating stands.

Stands will be grown to 40-80 years of age, harvested, and then regenerated to continue the cycle. Trees harvested at these rotation ages will be principally in the 18-24 inch diameter classes -- much smaller and more uniform than those now harvested in old-growth stands. Smaller equipment will be used and the soil will be less disturbed. These stands will receive one or two commercial thinnings before final harvest which will provide income at intermediate periods in the rotation, reduce mortality and provide control over the financial growth rate of stands.

This is a move to intensive, high-yield forest management of the type now being applied to industrial forest lands in the Pacific Northwest and in the Southeastern States. While lands will not lose their wildland character under this management, they will be substantially altered and will resemble the intensively managed stands of Western Europe, Scandinavia, New Zealand, and Australia.

The pattern of management of a large portion of lands that will need to be included in any effective buffer around the Park has been set to a degree by the type of cutting that has taken place up to now. About 90 percent of the total Park boundary has been cutover in some form or other and thus these lands are well on their way toward fitting into an even-aged management scheme. The remaining ten percent are in old-growth stands scheduled by their company owners to be converted to young-growth in the next ten or twenty years. This conversion of course will not be aesthetically pleasing to the unsophisticated viewer. The trauma he experiences, however, will depend in part on how the conversion is accomplished.

Silvicultural Systems Applicable to Buffers

Much has been said in the discussions leading up to the creation of the Park and specific mention is made in the House of Representatives Report No. 1630, that selective logging should be applied to lands bordering on the Park. It is clear, however, that if normal practices are followed on these lands, selective logging, or more directly stated the application of the selection-system of silviculture management to these lands will not be the generally applied system. The selection-system no longer has the status it once had as the salvation of management of redwood stands. Although the system has only been applied in a few localities with all of the technical detail necessary to achieve its presumed benefits, the high costs in relation to the benefits obtained appear to justify its wide disfavor in this forest type.

In the mind of the public the advantage of the selection-system is that once properly installed, it maintains nearly a full vegetative cover and is thus aesthetically pleasing at all times. There is, however, a long and difficult conversion process involved in changing natural, old-growth redwood stands to fully-regulated, well-balanced selection stands with the full representation of diameter classes necessary for successful operation. To achieve the desired balance, old-growth trees must be removed one by one to release space for new, young trees of the desired size and vigor classes. This conversion may take 20 to 50 years and during the period large, old trees are highly susceptible to windthrow with consequent massive damage to developing understory trees. The same problem of damage to understory applies to the selective cutting and harvesting of large trees in such stands. Furthermore the selection-system is organized around a cutting cycle which is of 5 to 10 years, thus requiring the frequent entry of necessarily large tractor equipment which is highly damaging to the understory trees and which subjects the soil to regular disturbance.

Also, current <u>ad valorum</u> taxing practices strongly disfavor the application of the selection-system. Section 12.75 of the California State Constitution allows the exemption from taxation of stands of trees remaining on lands where 70 percent of the original stand volume has been removed by cutting. Under the selection-system properly applied, 70 percent of the original volume would not be removed for many years, thus constituting a tax burden avoidable under other silvicultural management systems. Past attempts to apply the selective-system to redwood and still take advantage of this characteristic of the tax law led, of course, to the removal of the required 70 percent of original volume which resulted in excessive opening of stands and consequent intolerable windthrow and breakage of high-value, old-growth trees. This is one of the major reasons for rejection of the selection-system by private owners in recent times.

The selection-system also requires a higher level of investment in growing stock. A well-balanced selectively managed stand of redwood should probably have at least 50,000 board feet per acre of standing trees at all times. The rate of return on this capital on the better growing sites is less than five percent per year which is a low rate compared to other investments and thus the system is not favored from a private investment viewpoint.

The even-aged silvicultural management system will predominate on the lands surrounding the Park. Already 90 percent of the lands on the Park boundaries have been cut over and are under or moving toward this system. It has some distinct financial advantages -- lower ad valorum tax costs, lower levels of capital tied up in growing stock (standing trees) and a higher rate of return on growing stock capital -- but more important, it has several silvicultural advantages in terms of the buffer it creates. Even-aged stands do not require the frequent tending which is necessary in selective stands and thus soil disturbance is less. Thinnings, of course, are required, but these are usually not applied with the frequency that cyclical cuts are applied in selectively managed stands. Furthermore since this can be done with smaller, lighter equipment there is less disturbance of the soil.

Young, even-aged stands tend to more fully occupy the site than do mixed old-growth stands, which means that once these stands are well-established, the soil will receive good protection from erosion. These stands will be more windfirm since individual trees do not have the great height, massive crowns and high proportion of decayed and weakened stems.

Fire hazard is lower in that there are fewer snags and dead-topped trees and a lower accumulation of heavy fuels in the form of windfalls and rotten logs. Also since thinnings are required in order to obtain highest performance from young stands a road system is kept open and maintained -- as with the selection system -- which assures access to all parts of the properties for fire control.

The major disadvantage of even-aged management in terms of buffer establishment is that the conversion process from old to young growth is normally carried out in one cut which removes all standing timber. Neighboring uncut stands -- such as those that will be left inside the Park boundary -- if, because of their topographical position are subject to strong winds, will be left unprotected until the young stands gain sufficient height to again provide this protection. This may require 30 or more years. The heavy equipment necessary to move large logs disturbs the soil, increasing erosion hazard. Three or more years may be required for seedlings, sprouts and understory species to again provide vegetative cover.

Species Preference

One of the alternatives that must be considered in establishing buffers is the tree species to be favored. Much of the redwood forest is a mixture of redwood and Douglas-fir, which includes various amounts of white fir, Sitka spruce and western hemlock. All of these species have commercial value and can be grown under the silvicultural management systems considered here. Douglas-fir, however, has been considered the most versatile and marketable. Consequently seed mixes used in helicopter reseeding invariably contain a high proportion of Douglas-fir. Sprouting of old stumps and natural seed fall from surrounding stands have been the source of redwood in essentially all the second-growth stands.

In the buffer, we believe redwood should be the favored species. Versatility and marketability are not the major concern -- although redwood's marketability relative to Douglas-fir continues to improve. A species is needed that combines the greatest protection characteristics; if it has high growth rate and commercial value so much the better. Redwood best meets these specifications. Its growth rate is comparable or greater than its associated species and its wood is usable for a wide variety of products from lumber to paper. But its most important characteristic is its ability to sprout vigorously from its cut stump. Once fully-stocked stands of redwood with 70-90 stumps per acre are established, they can be managed for several generations on a coppice basis. This assures the most rapid regeneration after harvest of any system that can be applied and minimizes the period in which soil is unprotected. Instead of facing the sometimes difficult and expensive task of regenerating stands by aerial reseeding these stands can be regenerated one rotation after another by sprouting. Vegetative control of the site is always well in hand even after a fire because of this sprouting potential.

Harvesting Techniques Applicable on Buffers

Management practices that will affect the amount of water and soil moving downslope into the Park will be those relating to harvesting -- road building, road maintenance and log yarding. Practices designed to prevent erosion will vary with the soil, topography, the stand structure, and the management objectives. The details of desirable practice are legion but some general principles apply where the Park lies downhill from the buffer. These can be used as a guide for specifying the practices to be used in the buffer.

Roads. Roads established within the buffer should be located so that sidecast from their construction does not approach closer than within 75 feet of the boundary. Root systems from trees in the Park can be expected to extend this distance into the buffer zone.

Slip-prone areas should be avoided. Where this is not feasible, an upslope grade should be incorporated in the road as it enters into the slip area and a downslope grade when leaving it. Road width should be held to a minimum in these areas with ditches on the upslope side. Ditches should be drained only onto stable ground and designed to remove the maximum amount of water from the slip area.

On all roads the gradient should be kept below 6-9 percent with distance between cross drains of 200-300 feet. Fill slopes of greater than three foot depth should be compacted.

Temporary or infrequently used roads should be closed after use and all fills and culverts in major drainages removed.

Yarding. As discussed earlier, skidding logs from the felled trees to the truck loading area can be performed by tractors dragging logs downhill or by cable systems hauling logs uphill. From the viewpoint of preventing erosion the cable system is preferable, since it does not require the use of heavy track-laying tractors that stir up and compact the soil. Furthermore the cable system tends to create a water dispersal pattern of skid trails rather than a concentrating pattern typical of the tractor.

The cable system, however, is not as flexible over a wide variety of topographical conditions as is the tractor and tends to be slightly more costly. It is not well adapted to silvicultural systems other than clear-cutting and it cannot be used safely for pulling logs in a downhill direction. Under normal practice its use is limited to uphill upIls on slopes greater than 40 percent. It is, however, an important tool and its use should be expanded where timber size and topography are suitable. Specific recommendations for its use will be made in connection with specific buffers.

Tractor yarding is by far the most common practice around the Park. Much of this land is susceptible to erosion, and is particularly critical when tractors are used on slopes of over 40 percent.

Consequently, within the buffer, cable yarding systems should be used wherever the slope exceeds 40-50 percent and soils are even moderately erosive. Where tractors are used, skid trails should be developed with moderate grades not to exceed 30 percent. These trails should be kept out of stream channels and when logging is completed tractor trails should be closed off by water breaks or cross ditches spaced at 30-100 foot intervals depending on the slope and erosive nature of the soil.

Fire Control Techniques Applicable to Buffers

An important part of management on the buffer is to reduce losses from fire to a minimum. Fire has been a part of the environment throughout the history of the redwood forest. Now, however, we have placed values on the landscape which must be protected from fire.

Fire protection on the buffers begins with the recognition that the Park is a part of a larger whole in which there is common interest in the prevention and control of fire. The owners of surrounding lands have made a major effort in educating the public in the causes, dangers and prevention of fire. They have worked closely with the California Division of Forestry in the development of a highly effective fire control organization which now has the major responsibility for private lands. A cooperatively supported aerial fire patrol has been organized which covers the area north of Eureka during critical fire periods. These are all general efforts which contribute to fire safety and will be highly important to the Park. The Park will need to support and aid these activities in every way possible.

Road access to all parts of the Park will be important from the viewpoint of controlling fire. Thus a careful study should be made of road systems and conditions in both the Park and the buffers. Previous studies and plans already exist and are currently used by the California Division of Forestry and the private companies. However, the changes in ownership brought about by the purchase of the Park may require substantial revision and development of new cooperative agreements with respect to road systems, their use and the deployment of personnel during fire emergencies. This matter should be given high priority in the development of administrative procedures and organization of the Park.

Heavy accumulations of dead and down fuels now exist in the

Park and the surrounding areas in which buffers will be established. A portion of this fuel is on cutover areas now included in the Park, in the form of logs, windfalls, snags and chunks left after logging. Accumulations of fuels of this nature are particularly dangerous because they are dry and, once they start burning, they provide the means for rapid fire spread and are most difficult to extinguish. These fuels should be removed from the buffer. It will also be to the Park's advantage to remove these accumulations from their cut-over areas. Much of this material is usable; a portion of it is involved in land sale agreements with previous owners and thus some complexities are involved in its removal. It is also complicated by the need to develop replacement redwood dominated ecosystems on these cut-over lands -- as we have already discussed -- and in many cases fuel removal should be tied directly to this operation.

Every precaution possible should be taken to prevent the entry of fire on surrounding lands from entering the Park. In a relatively few locations this should involve the development of fuel breaks. The kind of fuel break envisaged here is that prescribed by the U.S. Forest Service and the California Division of Forestry for critical locations. All large dead fuels on or near the ground for a width of 200 to 300 feet and running at right angles to the direction of predicted fire spread are removed. Live, healthy standing trees are thinned so crowns do not touch and lower branches which might serve to conduct fire from the ground to the crowns are removed. These fuel breaks will be part of the buffer but the ground treatment should be extended for at least one tree length into the Park. Specific prescriptions for fuel breaks will be given for each buffer area in the following section.

CONTROL OF INPUTS WITH WATERSHED MANAGEMENT

The principal destructive input from watersheds outside the Park is stream sediments originating from landslips into the streambeds, and erosion from newly exposed soils on road construction and logged areas. A major portion of this occurs during the conversion period from old-growth to young-growth stands and the lack of careful soil management practices that is often associated with old-growth harvesting. The problem here is to promote the application of practices which maintain the protective function of the forest.

The key to the problem of maintaining the protective function of the forest at harvest time is quick reestablishment of the forest cover and the planning of roads and skid trails so as to avoid undercutting unstable slopes, diverting drainage onto erosive soils, and the dumping of debris into the stream channels. All of these are integral practices in the maintenance of the land for continuous forest crops, and will in time be practiced by all companies planning to stay in the timber growing business.

Roads have been a major source of sediment material in streams particularly in the last 15 years during which time the north-coast area has experienced three or four storms which have caused major flooding. It is virtually impossible to design roads to meet such conditions, as was illustrated by the loss of major state highway bridges and fills during these storms. Forest roads suffered similar damage, but they also contribute large amounts of sediment during normal years, mainly because of poor road design and maintenance. Good road design features are fairly common knowledge among forest road engineers, but this knowledge is not always applied. Perhaps this is another aspect of the frontier-society attitude still evident among woods workers of the region. The designs and techniques to prevent erosion on roads are known and for industrial owners they are not excessively expensive to apply. The problem appears to be one of providing proper incentive.

A similar situation exists with respect to the yarding of logs. It is the yarding of old-growth timber with large, track-laying tractors that create extensive soil disturbance and yield patterns of tractor roads which concentrate water in skid trails. As has been discussed, these practices are particularly productive of erosion and stream sediments when conducted on slopes of 40 percent or more and on shallow, stony and sandy soils.

Details of road building and logging practices designed to reduce erosion have been covered in the previous section.

RECOMMENDED BUFFERS AND MANAGEMENT ON WATERSHEDS TRIBUTARY TO THE PARK

Buffer Specifications

To meet the specific protection required on each section of the Park twelve different types of buffers are needed. Each type reflects a specific objective, stand and ground conditions present, and topographical position. These types we have grouped into four categories and are described as follows:

Category I. Fuelbreaks.

All types in this category will be treated as follows: All snags will be felled; all dead fuels larger than 2 inches in diameter will be removed; dead limbs will be pruned from live trees up to a height of 16 feet; sapling stands will be thinned to a minimum of 15 by 15 spacing.

Type IA. Forest lands in a downslope position relative to the Park. The fuelbreak will be 300 feet wide.

Type IB. Forest lands in an upslope or cross-slope position relative to the Park. The fuelbreak will be 100 feet wide.

Type IC. Brush lands in downslope position relative to the Park. In addition to receiving the treatment common for all fuelbreaks, all vegetation except trees over 20 feet tall and herbaceous ground cover will be removed. The fuelbreak will be 300 feet wide.

Type ID. Brush land or farm land in downslope position relative to the Park. Treatment will be the same as in IC but the adjacent lands will be zoned for agriculture or forestry use.

Category II. Young-growth redwood coppice management to be established on cutover lands.

The buffer will be 800 feet wide, outside and adjacent to the Park boundary. All snags and merchantable down material will be removed on the buffer on a strip 200 feet wide and adjacent to the boundary. The buffer will be managed so as to develop 70 -90 well-distributed redwood stems per acre at harvest time. Thereafter these stems will be managed as coppice.

All new roads will be located far enough out from the boundary so as not to have any impact on the root systems of trees within the Park. This will require that sidecast from road construction be kept at least 75 feet away from the Park boundary. All existing roads that do not meet these specifications will be abandoned unless they are a critical part of the established operating road net and where their impact on the adjacent developing forest will not be great, such as along a ridge top or where their length along the boundary is short and relocation would involve the undercutting of unstable slopes. Abandoned roads will have all culverts removed, adequate drainage channels reopened, where fills are involved, and water check-bars established where necessary to prevent water from running down the road surface for a distance of more than 50 feet. All operating roads will be maintained at least twice a year. Specifications for roads have been discussed under an earlier section.

<u>Type IIA.</u> Lands in a downslope or cross slope position relative to the Park. Yarding can be either with tractor or cable.

<u>Type IIB.</u> Lands in an upslope position relative to the Park. On slopes 40-50 percent or greater, depending on the overall topography, yarding will be uphill and by cable.

<u>Type IIC.</u> Lands in an upslope or downslope position relative to the Park. Treatment will be the same as in IIA or IIB above but the adjacent land will be zoned for forestry use.

<u>Category III.</u> Young-growth redwood coppice management to be established during conversion from old-growth stands.

The buffer will be 800 feet wide outside and adjacent to the Park boundary. Conversion will be accomplished by clear cutting in staggered blocks of 30 acres or less so as to achieve 70 - 90 well-distributed redwood stems per acre at harvest time. Uncut areas adjacent to cut blocks will not be cut until full stocking is achieved with trees at least 3 feet tall on the cut block.

All roads will be located far enough out from the boundary so as not to have any impact on the root system of trees within the Park. This will require that sidecast from road construction be kept at least 75 feet away from the Park boundary. All roads will be of permanent construction and will be maintained at least twice a year. Specifications for roads have been discussed under an earlier section

<u>Type IIIA.</u> Lands in a downslope or cross-slope position relative to the Park. Yarding can be either with tractor or cable.

<u>Type IIIB.</u> Lands in upslope position relative to the Park. On slopes of 40 - 50 percent or greater, depending on the overall topography, yarding will be uphill by cable.

<u>Type IIIC.</u> Lands in an upslope position relative to the Park where the landslip hazard is high. Treatment will be the same as in IIIB above, but wherever engineeringly feasible roads will be built to avoid slip-prone soils and rock types, i.e. Atwell soil and finely fractured schists buried by colluvium on which other soils, i.e., other than Atwell, have developed. Where these areas can not be avoided in road construction and are cut, water must be kept out of

them with drains designed to take off the water above the cut. In addition, utmost care will be needed in draining skid trails and spur roads.

Category IV. Young-growth redwood coppice management to be established during conversion from old-growth while giving the trees along the Park boundary sufficient time in which to become windfirm. Only one type of Buffer falls in this category and it has been designed to deal with the conditions found on the west slope (Georgia-Pacific side) of the Redwood Creek corridor upstream from Bridge Creek.

Type IV. Forest land in an uphill position relative to the Park where the combined hazard from landslip and windthrow is high. The buffer will be 800 feet wide outside and adjacent to the Park boundary. Conversion to young-growth redwood coppice management will be accomplished so as to achieve 70 - 90 well-distributed redwood stems per acre at harvest time. Prior to any cutting along this boundary the area must be carefully surveyed so as to locate all Atwell soils and Atwell parent materials, i.e., finely fractures schists, buried beneath colluvium derived from the upper slopes, on which Melbourne and other stable soil types have developed. The type of cutting system to be applied, the type of yarding and the location of roads in this buffer will be based on the distribution of these unstable soils and rock types.

Complete conversion along portions of the boundary where unstable soil and rock types prevail can be expected to take 25 years or longer and will need to be skillfully handled. Cost of establishing this buffer will be higher than for any of the other buffers.

In general a shelterwood system in which 30 percent or less of the stand is removed in the initial cut will be followed but in some areas, where the soils and supporting rock masses are stable, clear cutting in staggered blocks of 30 acres or less will be used. Where the shelterwood system is applied overstory trees will be selected for wind firmness with redwood given preference.

Windthrow and breakage can be expected to occur and may even be high at times within the buffer during the conversion process. Windthrown trees will be removed only in conjunction with planned cuts in the shelterwood or when areas are scheduled for clear cutting.

Specific Buffers by Area

Jedediah Smith Unit: West Boundary. Starting at the north tip of this unit in the northwest corner of Section 36 and running south and west through the section, the area outside the boundary is in young growth stands and lies mainly in a cross-slope position with respect to the Park. Property ownerships are small and are susceptible to diversion to residential or summer home developments. The area 800 to 900 feet back from the boundary should be zoned for forestry purposes and managed according to Buffer Type IIC. If residential use is made of lands behind this buffer, a fuelbreak specified as Buffer Type IB should be installed.

The principal west boundary, running south from Section 36 to the top of Section 26 in the next Township south, constitutes a topographic front which is in an upslope position relative to adjacent private lands. Young-growth stands are scattered with a high alder component. This front is already being used for scattered residential dwellings. The principal consideration here should be fire protection and this section of the boundary should be managed according to Buffer Type ID.

The remaining portion of the west boundary running through Sections 25 and 36 is also a topographic front which is in an upslope position relative to adjacent private lands. Stands have been cutover and are of miscellaneous character with good potential for forest production. This section of the boundary should be zoned against residential use and managed under Buffer Types IIC and ID.

Jedediah Smith Unit: East Boundary. The northernmost portion of this section is river front and needs no special buffer. However, the boundary running south from the top of Section 4 to the north of Section 16 stands next to a fairly well-developed, but scattered residential area. This boundary should be managed according to Buffer Type IB.

From the above point south and around the eastern-most projection of the Park to about the midpoint of Section 26, lies some of the most fire hazardous area of the whole Park. This is an area of low productivity and the vegetative cover has a high component of brush providing an abundance of fine fuels. Most of the land is downslope relative to the Park and along a portion of its base runs the heavily traveled highway into the Stout Grove. Man-caused fires starting from either the homes along the road or by travelers could quickly run uphill into the Park. This part of the boundary should be managed according to Buffer Type IC.

Jedediah Smith Unit: South Boundary. This section of the boundary which first runs west and then south finally turning east on the north boundary of the Del Norte Unit to the line between Sections 5 and 8, Township 15 north, is all shared with the Rellim Redwood Company. Most, but not all, land on the company's side of the boundary is cut over and well on its way toward even-aged young-growth management. With the exception of the small part where Mill Creek enters the Park, the Park lands are in an upslope position. Cutover along this boundary should be managed according to Buffer Types IIA and IIB and old-growth according to Buffer Type IIIA and IIIB depending on the topography.

Del Norte Unit: East Boundary. A small part of the northern portion of the boundary is shared with the Rellim Redwood Company; the southern major portion is shared with the Simpson Timber Company. All lands outside the Park with the exception of two small areas of old-growth near the Rellim-Simpson boundary have been cutover. Most of the boundary is in a downslope position relative to the Park. This boundary south to the mouth of Wilson Creek is principally high quality forest land and should be managed according to Buffer Types IIA and IIB depending on the topography.

Wilson Creek to the Klamath River. Lands along this section of the boundary are highly miscellaneous in vegetation cover, ownership and use. Much of it is dominated by Highway 101 and the scattered residential and business development around it. The principal threat to the Park from this area is fire and the boundary should be managed according to Buffer Type IA.

Klamath River South to North Boundary of Prairie Creek Unit. This section of the boundary encloses Flint Ridge as well as a narrow coastal strip extending south to the northern boundary of the Prairie Creek Unit. Flint Ridge stands as a unique topographic unit covered by a mixture of old-growth and cut-over land which extends east to the new Highway 101. The north portion of Flint Ridge rises steeply out of the Klamath River mouth. A road lies between the flatlands of the mouth and the forest stands on Flint Ridge. This will serve to isolate the Ridge from fire on the flatlands, so no special buffer is needed here.

The east boundary of the Park in the Flint Ridge area lies just to the east of old Highway 101 and although the private lands are in an upslope position relative to the Park, their principal influence is isolated from the Ridge by the highway. Old-growth stands on this section of the boundary should be managed according to Buffer Type IIIA and the young-growth stands according to Buffer Type IIA.

The boundary south from Flint Ridge to the Prairie Creek north boundary is in cutover land with a high alder content. Park lands lie primarily in an upslope position relative to adjacent private lands. This portion of the boundary should be managed according to Buffer Type IIA.

Prairie Creek Unit: East Boundary--South to Boyes Creek. This entire eastern section of the boundary south to the quarter corner between Section 31 and 36 is in an upslope position relative to adjacent private lands. Essentially all of these lands have been cutover and the Simpson Timber Company is the principal owner. Substantial volumes of standing and down timber remain on some of these lands and the fire potential is fairly high. The area is well roaded and access for both salvage of down timber and fire control is good.

Stands in this area are being slowly converted to even-aged management, but full conversion will probably not be accomplished for another 15-20 years. Regeneration on these lands is good, but contains a very high component of Douglas fir. Special effort will be required to increase the redwood component. This portion of the boundary should be managed according to Buffer Type IIA.

Boyes Creek South to Lost Man Creek. Lands adjacent to this section of the boundary are largely owned by the Arcata National Corporation and most of them have been cut over on an economic-selection basis. Roughly 30 percent of the original stand volume remains as scattered standing trees. As with many partially cut stands, windthrow of isolated trees has caused major losses and has contributed to a relatively high fire hazard. The land is re-vegetating along the boundary but in many areas has a high brush component. Stump sprouting by redwood will not be sufficient to provide the desired redwood component in the young-growth stand now developing as an understory. The cut-over areas are mainly in large blocks of 160 acres or more. This portion of the boundary should be managed according to Buffer Types IIA and IIB, depending on the topography.

Lost Man Creek to Arcata Mill B. This section of the boundary is part of the narrow corridor dominated by Highway 101 between Arcata Mill B and the Fish Hatchery. We have not prescribed a buffer for this section of the boundary because the question of relocation of highway through this area is still unresolved.

Arcata Mill B West to Gold Bluff. This section of the boundary is marked by the road leading to Gold Bluffs. Lands on both sides of the boundary have been cut over and should be managed according to Buffer Types IIA and IIB depending on the topography.

Gold Bluff South to Dry Lagoon State Park. This is beach property primarily. No special buffer management is required.

Redwood Creek Unit: West Boundary--Fish Hatchery to Redwood Creek. This section of the boundary is one of the most critical from the viewpoint of aesthetics as well as fire. For the major portion of this section the Park is in an upslope position relative to adjacent private lands. The corridor through Orick will constitite the first view of the Park for visitors entering from the south. Lands in Section 23 have been clear-cut in recent years and while there appears to be adequate regeneration to provide cover over the next twenty years, the revegetation process should be speeded perhaps even by the application of fertilizers.

We have not prescribed a buffer for this section of the boundary at this time because of the question of the highway location through this area is still unresolved. At this time efforts should be made to get as much of the lands as possible zoned for forest use in order to prevent further urbanization.

Redwood Creek Unit: West Boundary--South to McArthur Creek. This section of the boundary is principally a ridge top location with private lands sloping away to the west into the urban area around Orick. Old-growth forest stands predominate the boundary on both sides. Fire and windfall are the primary hazards to the Park. With respect to fire, most of the area is within ready surveillance of the townspeople and fire control forces exist which reduce the hazard of fire from the residential fringes. With respect to wind the trees growing on the ridge top boundary have developed with full exposure to westerly winds and demonstrate a high degree of windfirmness. This section of the boundary should be managed according to Buffer Type IIIA.

Redwood Creek Unit: West Boundary--South from McArthur Creek to Bridge Creek. This boundary area runs mainly up and down slope crossing several minor drainages including McArthur, Elam, Bond, Forty-Four, and McDonald Creeks. Adjacent private land to the west belongs to the Georgia-Pacific Corporation. Most of the ridges and some of the upper slopes are cut over. Many of the creek bottoms are largely uncut and still contain old-growth timber. These watersheds appear to be in good condition with no major erosion evident. Cutover lands on this section ofthe boundary should be managed according to Buffer Type IIA and IIB and old-growth stands should be managed according to Buffer Types IIIA and IIIB depending on the topography.

Redwood Creek Unit: Bridge Creek to South Boundary. This section of the boundary is one of the most critical in the Park. The land on both sides of the boundary is in old growth timber, essentially undisturbed by logging, yet it is the most unstable area we encountered in the entire Park. Old slides on Atwell soils extend upslope beyond the Park boundary onto adjacent private land and many of these slides are active. Soil instability has resulted in major windthrow along the boundary.

When this land is reached in the Georgia Pacific Corporation's harvesting plans, it must be treated with a very high level of technical skill. This section of the boundary should be managed according to Buffer Type IV

Redwood Creek Unit: East Boundary--North to the Bald Hills Road. This section of the boundary has many of the characteristics of the west boundary with the exceptions that wind and/or slip thrown trees are not as evident. The schist-sandstone contact zone moves away from the creek a short distance downstream from the mouth of Bridge Creek, with a consequent reduction in landslide hazard. The entire boundary except for one cut-over area downstream from the Tall Tree flat is in old-growth timber and has yet to be roaded. Limited access for fire control purposes is available from the Bald Hills road and there is a tractor trail from this road to the Tall Tree flat.

All of the land outside the boundary is owned by the Arcata

National Corporation with the exception of the lower ends of several large prairies which are in farm ownership. This land is now the heart of this corporation's remaining old-growth timber and the company will soon need to concentrate its logging here.

The section of boundary running from the south end of the Park to a point a short distance downstream from where the schist-sandstone contact zone moves upslope and away from Redwood Creek should be managed according to Buffer Type IIIC. The rest of this boundary should be managed according to Buffer Type IIIB.

Redwood Creek Unit: East Boundary--Bald Hills Road to Section 19. This section of the boundary is principally a ridge top (Holter Ridge) situation with lands lying to the east and north owned by the Simpson Timber Company. Both sides of the boundary have been cut over. Some of these lands have been partially cut and, in common with other lands of this nature on the Park boundary, may have accumulations of heavy fuels from windthrown trees and cull logs left following the first cut. Generally speaking, these lands have good regeneration which has begun to form a significant understory which should be favored when cull logs and large standing trees are removed. This section of the boundary should be managed according to Buffer IIA.

Redwood Creek Unit: North Boundary--Section 19 to Fish Hatchery. The boundary along this section of the Park is mainly in old growth timber with the adjacent private lands belonging to the Arcata National Corporation. The topographic position of the Park relative to these adjacent lands is highly variable since the boundary crosses two major forks of Lost Man Creek. Management of private lands along this boundary is likely to be somewhat awkward since the line is highly irregular creating some difficult corners and access for harvesting. There are also several areas of highly erosive soils along this boundary. Careful logging of these areas is highly important, otherwise it will contribute sediments directly into Lost Man Creek and thence into Prairie Creek. Cable yarding should be used on these steep erosive areas instead of tractor yarding. The old-growth stands on this section of the boundary should be managed according to Buffer Type IIIB and the young-growth stands according to Buffer Type IIB.

Buffer Costs

Investment in the Park is massive but the values it yields are even greater. This, of course, is a statement of faith since no highly reliable means are available to clearly analyze this relationship in terms of cost-benefit ratios. The same situation applies to making decisions with respect to investment in buffer management, except in this case both costs and benefits are difficult to quantify. For example, full information on costs ascribable to installing a shelterwood system instead of a clear cutting system are not known, nor can the precise benefits from reduced windthrow or prevented landslides be identified. Thus the matter of investing in various forms of buffer management will remain a judgment decision. Further studies are obviously needed.

In general, costs associated with buffer management can be placed in three categories. First are those related to the construction of fuelbreaks. Second are the extra logging costs associated with special treatments such as cutting in small blocks or harvesting under a shelterwood-system. Third are so-called management costs which relate to special regeneration costs, extra timber marking costs or opportunity costs of holding extra timber on the ground as in the case of the shelterwood-wood system.

Fuelbreak Costs. The involvement here is with two types of fuelbreaks. The first requires the felling of all snags, removing all fuels larger than 2 inches in diameter, pruning dead limbs and thinning dense stands. Cost functions are fairly well known for snag felling and general estimates are available for fuel removal, pruning and thinning. Some guide to the latter is available, for example, from studies at the University of California's Whitaker Forest located in the Sierra Nevada which show costs ranging from $50 to $150 per acre. None of these are directly applicable, however, because of varying conditions and particularly where redwood snags and large material on the ground is merchantable. Salvage of this merchantable material could, in some cases, cover the costs of fuelbreak preparation.

The second type of fuelbreak is installed in grass, brush or in timber where no merchantable material is present. Guides to these costs are available from the U. S. Forest Service and the California Division of Forestry from their fuelbreak construction programs. Here again, however, most of these studies apply to the Sierra Nevada region and local studies must be made to determine local costs.

Logging Costs. The key to these costs is the differential in costs of the prescribed practice relative to "normal" costs. The main issues are differentials due to the application of cable systems in locations where owners would normally apply tractor systems, logging in small-block versus logging in large-blocks, the use of uphill roads versus the use of down hill roads, the use of logging spurs versus no logging spurs, the use of extra drainage structures on roads and skid trails, and the advanced roading required in shelterwood management.

With respect to logging with cable systems rather than with tractors there is a question whether a real differential exists at all, since both systems are used in the Douglas fir Region which is comparable in many ways. Use of cable systems tends to be concentrated on steep ground where an advantageous uphill pull can be gained, but in recent years cable systems with portable towers and other adaptations are being used over a wide range of topographic situations in preference to tractors. In the region of the Park, however, the tractor logging is favored in most situations over cable logging. In old-growth stands the argument is made that a tractor must be on hand on cable settings to make beds for felling large redwoods, thus why not use tractors for all aspects of logging? This argument is clearly not tenable in young-growth stands. Perhaps in many cases the real reason for limited use of new cable systems is simply unfamiliarity and a resistance to change. Thus the issue of extra cost for the use of cable systems is a negotiable matter.

Small-block versus large-block management refers to the size of clear-cut or other treatment areas to be used. As was indicated in other sections of this report, some of the neighboring companies prefer to plan their cutting in blocks up to 4,000 acres or more, while we recommend cutting on the buffer to be limited to no more than 30 acres. The question is: are higher costs associated with smaller blocks? Here again there is no straight-forward answer available. At least one company adjacent to the Park uses the small-block approach as a matter of choice and at no apparent cost disadvantage. Small-block management, however, has some theoretical extra costs associated with it which should be mentioned. Administrative and record keeping costs probably are higher since roads must be extended through untreated areas to reach advanced locations that are presumably not necessary with larger block management. Interest on the cost of these roads is a real cost in such a case.

The issue of extra cost of uphill roads is related to the requirement of using cable logging. Extra road is necessary to reach the upslope position. This, of course, is a matter which will vary with local situations and the total orientation of the transportation net.

The cost of drainage structures that are needed under the Buffer Types discussed are not excessive and should be part of normal good practice. There is a question whether any financial incentive should be given for following good practices which many companies follow as a matter of course on some parts of their properties. The principal issue here is to extend these practices to those parts that affect the Park and to apply them with particular care on erosive soils in the buffer area. Educational campaigns and group pressure--as might be exerted by a joint Industry-Park land management committee--may be more effective than offering financial incentives.

<u>Managememt Costs.</u> Identifiable management costs are those associated with favoring redwood over other species, opportunity costs of holding extra timber and timber marking costs.

The issue of favoring redwood on the buffer areas to enable coppice management has some identifiable cost aspects. Where aerial seeding is the normal practice, a substitution of redwood for Douglas-fir or other species is involved. Redwood seed is not commonly available on the seed market and thus a collection cost may be involved. It is also conceivable that direct seeding of redwood will not work and redwood will have to be introduced by planting, particularly if the percentage of redwood in the surrounding stands is low. This would be an identifiable cost under such circumstances. A general issue also exists as to the productivity of redwood versus Douglas-fir on certain sites, and as to the relative values of wood substance from redwood and Douglas-fir. At present young-growth redwood is not as valuable as young-growth Douglas fir; however, productivity of the two species is roughly similar.

A counter argument exists with respect to the extra costs of establishing redwood. Once stands of the desired density of redwood are established, regeneration costs associated with future rotations would be greatly reduced, since no or very low reseeding costs would be incurred in future rotations. This possible cost saving can be expressed in present net worth terms and compared with current costs of establishment.

A special case of costs arises on the Type IV buffer which calls for shelterwood management. The careful application of shelterwood requires consideration of a large amount of technical detail in establishing and applying tree selection criteria. Tree marking of this nature is clearly an extra cost and attributable directly to buffer management, since no special cost for tree marking is associated with the normal clear-cutting. Another associated cost of shelterwood management is that of holding extra timber. The volume and its value associated with the shelterwood overstory may be held for many years depending on protection needs. This is an income foregone over the period and thus interest should be charged on the value. The interest cost, however, may be partially offset by growth of the overstory trees, thus interests costs would be diminished by the value of this growth.

The problem of taxes also arise in connection with holding overstory trees. As discussed previously, forest stands from which 70 percent of the original standing volume is removed, qualify as "cutover" stands and are taken off the county tax rolls. Shelterwood management will call for removal of less than 70 percent in the initial cut thus the remaining stand will be taxed and this cost will be directly attributable to buffer management.

The existence or not of a particular extra cost associated with a prescribed buffer practice is largely dependent on local conditions and what is "normal" for a particular situation. The establishment of compensatory costs for certain management or logging practices must be a matter for study and negotiation at a level where each company's situation and conditions can be carefully considered. To accomplish this we recommend that a committee be set up consisting of equal membership of government and industrial representatives with one neutral member to explore the possibility of setting equitable costs for the prescribed practices by study and discussion rather than by litigation. While this proposal may appear naive, it is made in recognition of the great need to foster and develop cooperative approaches to many management problems between the Park and its neighbors.

Water shed Management

The tributary watersheds with which the Park is concerned are those drained by Mill Creek, May Creek, Lost Man Creek and Redwood Creek. Each is currently affected by logging and road building activities associated with the conversion of old-growth or partially cut stands to young-growth. The Redwood Creek watershed is also affected by ranching activities.

Mill Creek. We recommend that the Rellim Redwood Company--who controls the Mill Creek watershed outside the Park--continue to manage their lands as they have been doing. On steep slopes this means using an uphill road system with a cable yarding system. On gentle slopes it means the use of either tractor or cable logging. On both steep and gentle slopes it means clear cutting in staggered blocks of 40-80 acres and paying careful attention to road and skid trail drainage.

Mill Creek in relation to other watersheds in the north-coast area is relatively stable and can support intensive tree cropping without significant erosion if proper logging practices are followed. The situation in this watershed over which the old-growth is being systematically converted to young-growth, is considerably different than that which prevailed in the Bull Creek watershed in Humboldt County at the time it was being logged. We bring up this point because the extensive erosion that has occurred in the Bull Creek drainage is frequently pointed to as that which can be expected from logging.

The erosion in the Bull Creek watershed is well documented and is a good example of what can result from heavy tractor logging on steep unstable soils. The watershed was heavily logged during the 1950's without concern for the erosion potential of the soils involved. Sediments that came off the logged areas following the heavy rains in 1955 and 1964, were sufficient to seriously endanger the famous Rockefeller Grove downstream. The overall problem was so serious that the State Division of Beaches and Parks (now the State Division of Parks and Recreation) found it necessary to purchase the upper watershed in order to gain control of it and begin its stabilization.

The difference between the two watersheds lies largely in the difference in the geology and the soils. The Bull Creek watershed is unstable geologically. The soil parent materials are interbedded shales and sandstones lying at a dip angle roughly parallel to the slope. As a result, over 85 percent of the Bull Creek watershed, while less than 15 percent of the Mill Creek watershed are covered with Hugo soils. These soils have very low cohesiveness and are potentially highly erosive on steep slopes. Only a small amount of slope undercutting will start them moving. Also the creek grade is closer to the level of the soils of the principal old-growth groves in Bull Creek. Most of the groves along Bull Creek are on recent alluvial soils. On Mill Creek all but a few are on elevated terraces well above the creek. And finally the percentage of steep slopes is greater in the Bull Creek watershed. This relationship is shown in Table 6.

May Creek. The soils in this watershed are largely Empire soils developed from deep sandy marine and old dune deposits and Melbourne soils developed on relatively soft sedimentaries. Both of these soils offer low to moderate potential sediment inputs. The only part of the watershed that offers any serious erosion potential is the steep slope immediately along the eastern ridge of the watershed. Ideally, these steep slopes should be yarded uphill with a cable system but the road net is already designed and partially established which will not permit this unless radically modified. Being realistic about the situation careful skidding on these steep slopes and proper drainage of the skid trails is the best we can hope for; and we believe it will be sufficient.

Continued maintenance of the permanent part of the road net and putting the area "to bed" following logging will be the most important aspects of managing this watershed. This will involve closing the temporary roads after use and removing all fills and culverts in the major drainage channels. The skid trails will need to be closed off by water breaks or cross ditches space at 30-100 foot intervals depending on the slope.

There could be a major erosion problem in this watershed if the new freeway is routed up May Creek and across its northern headwaters. If this does develop an active program to stabilize the cuts and fills will be required.

Lost Man Creek. Only the steep eastern edge of this watershed offers any serious management problems. This steep area is covered with a Hugo-Melbourne soil complex which can be highly erosive if undercut by roads and tractor trails. The north fork of Lost Man Creek also heads up in a steep slope covered with Hely soils. These soils can also be highly erosive if improperly handled.

Logging is also going to be complicated on these steep slopes by the Park boundary. Its location has created some corners that

Table 6. A comparison of Slope Classes in the Mill Creek and Bull Creek Watersheds.

WATERSHED	PERCENTAGE OF LAND BY SLOPE CLASS		
	Slight (5-30%)	Moderate (30-50%)	Steep (50+%)
Mill Creek	23	47	30
Bull Creek	6	54	40

will be difficult to get to without access through Park land. The best care of these slopes during logging can be achieved by yarding uphill with a cable system to one or more high level roads crossing the north boundary at one or more points.

As in the May Creek watershed, the Lost Man Creek watershed should be "put to bed" following logging and this applies also to the cut-over portion of this watershed that lies in the Park. The temporary roads should be closed and all fills and culverts in the major drainage channels removed. The skid trails should be closed with water breaks or cross ditches spaced at 30-100 foot intervals depending on the slope.

Redwood Creek. That part of the watershed upslope from the Park and the recommended buffer zone on the South side of the Redwood Creek corridor should offer no major management problems if the logging practices now being followed by the Georgia-Pacific Corporation are continued. Care, however, will need to be taken not to activate slides in the Atwell soils that extend above the recommended buffer zone in the Bridge Creek area. The road net is well maintained and close attention has been paid to drainage where required.

The watershed upslope from the Park and the recommended buffer zone on the north side of the corridor could offer serious management problems if the road net is not laid out to avoid the Atwell soils. It will also be necessary to maintain the main road system once established and to put each area "to bed" following logging.

Management of the watershed upstream from the Park is a more difficult matter. The major problem will be to stabilize the soils now actively slipping and to prevent any further activiation of land-slips along the creek. This will require keeping the roads above the slip-zone, which can be easily recognized by the type of soil as well as the presence of old slides, and stabilizing slides already activated by the floods of 1955 and 1964, and by logging. It will also be necessary to locate roads so that gully and surface erosion is limited and block slides on Masterson soils and debris-slides on Hugo soils are not initiated on the steep slopes higher up in the watershed.

The cost of stabilizing the upper Redwood Creek watershed will be considerable and will be complicated by the many ownerships involved. At this time, we see no feasible means of directly influencing land management practices in this watershed through legal or financial means. We suggest, therefore, that a voluntary Redwood Creek Land Management Association be organized with membership to include all segments of ownership in the watershed. Then let this group see what it can do with the problem. Road maintenance, for example, in the slip-zone is costly and voluntary action to restrict road building in this zone might be reasonable even in terms of direct financial return. Similar volunteer land management committees have worked well in establishing a cooperative approach to fire protection. We recognized, of course, that a stronger common interest exists in preventing wild fire than in reducing sediment input into Redwood Creek.

SUMMARY

1. A large proportion of the ecosystems that constitute the uncut redwood forests in the Park are primeval in a successional sense. Almost all of these ecosystems reflect the relatively recent exclusion of fire.

2. Preservation of significant examples of the primeval redwood forest in the Park is feasible. It will depend largely on the proper management of land within the Park. Replacement ecosystems will be needed to provide a continuing display of old-growth redwood in the Park and can be developed from cutover stands now included in the Park.

3. Preservation of streams within the Park depends largely on the proper management of watersheds outside the Park.

4. There are a number of potentially destructive inputs from land adjacent to the Park and from watersheds tributary to the Park. The inputs which affect the preservation of the redwood forest within the Park are fire, wind, water moving downslope into the Park, soil moving downslope into the Park--either along the surface or in the form of slides--and band cutting during peak-flows. The inputs which can affect the preservation of the streams are peak-flows and sediment-loads moved along the streambeds as gravel and rocks or carried in suspension as silts and clays. The magnitude of these potential inputs are closely tied to the management practices and can be increased or reduced by modifying these practices.

5. Watershed management plans can be developed to minimize potentially destructive inputs from watersheds tributary to streams in the Park. To achieve this a cooperative approach must be developed with landowners in the watersheds. The major watershed management problem will be in the Redwood Creek drainage, upstream from the Park.

6. Buffers must be established around all perimeters of the Park where redwood ecosystems are to protected. The basic design for these buffers around most of the Park is the establishment of young-growth redwood coppice stands, 800 feet wide on all forested perimeters. Elsewhere the construction of fuelbreaks on all upslope perimeters of the Park will be required.

7. Buffers can be designed to minimize potentially destructive inputs from lands immediately adjacent to the Park.

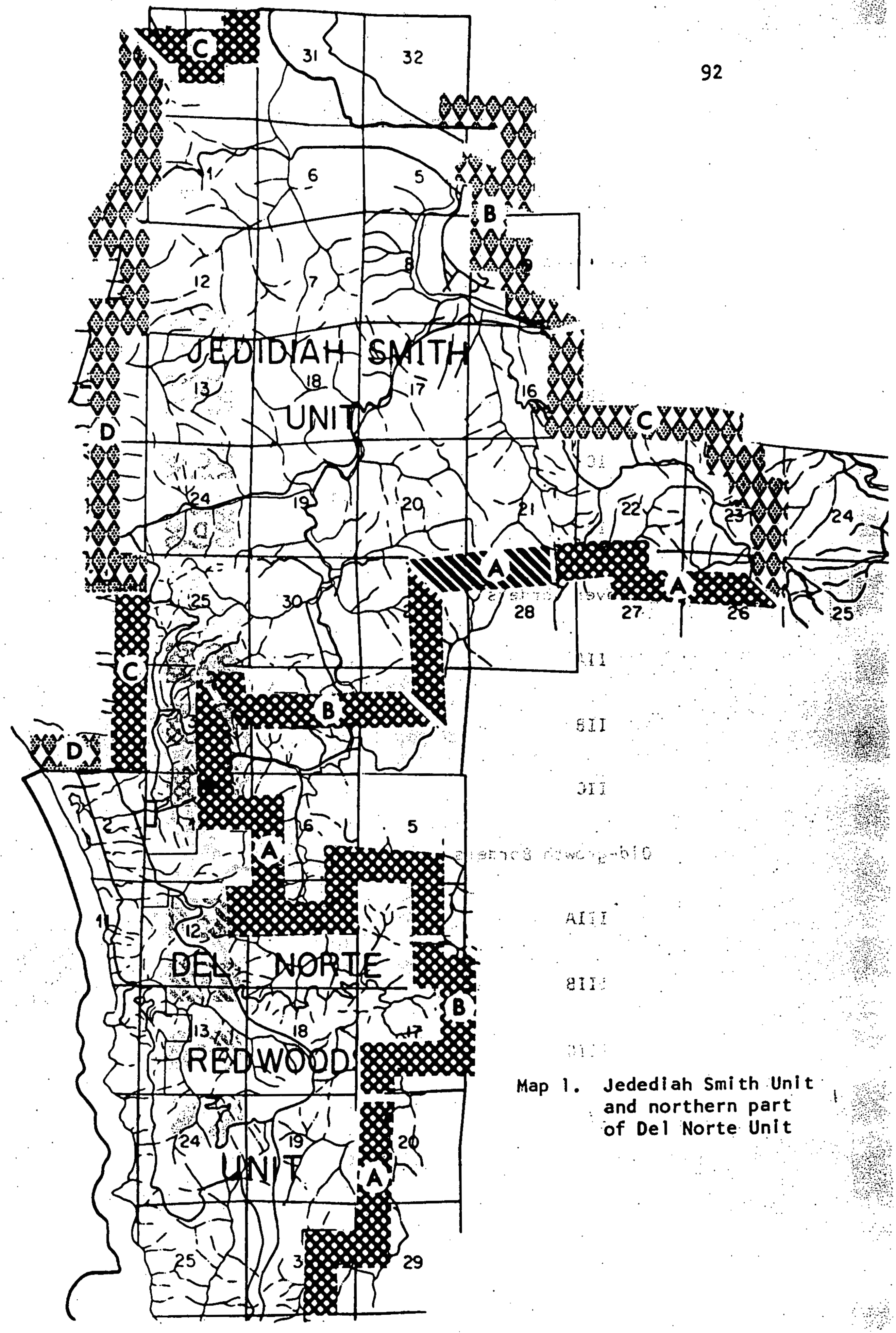
8. Basic buffer design and management, however, must be adapted and modified according to soil, topography and timber stand situations in order to control specific potential inputs.

9. Costs of installing and managing specific buffers will vary. In developing fuel breaks there will be the cost of construction and of removing dead fuels. In shelterwood and small block management there will be extra logging and management costs. In establishing redwood coppice there will be planting costs. And where old-growth trees will have to be retained for sometime as in the shelterwood stands there will be taxes and interest charges.

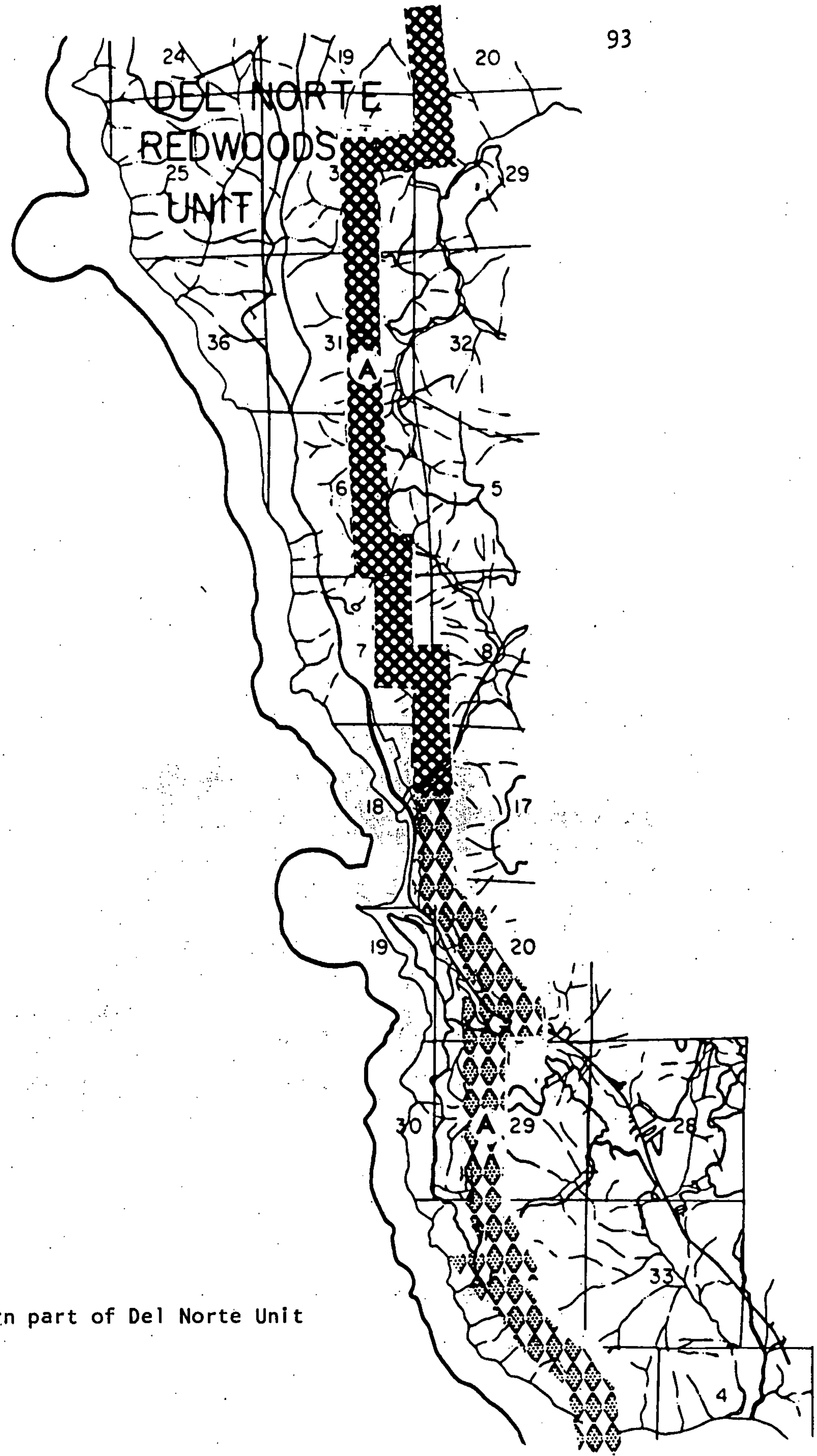
APPENDIX A

MAP LEGEND OF BUFFER TYPES

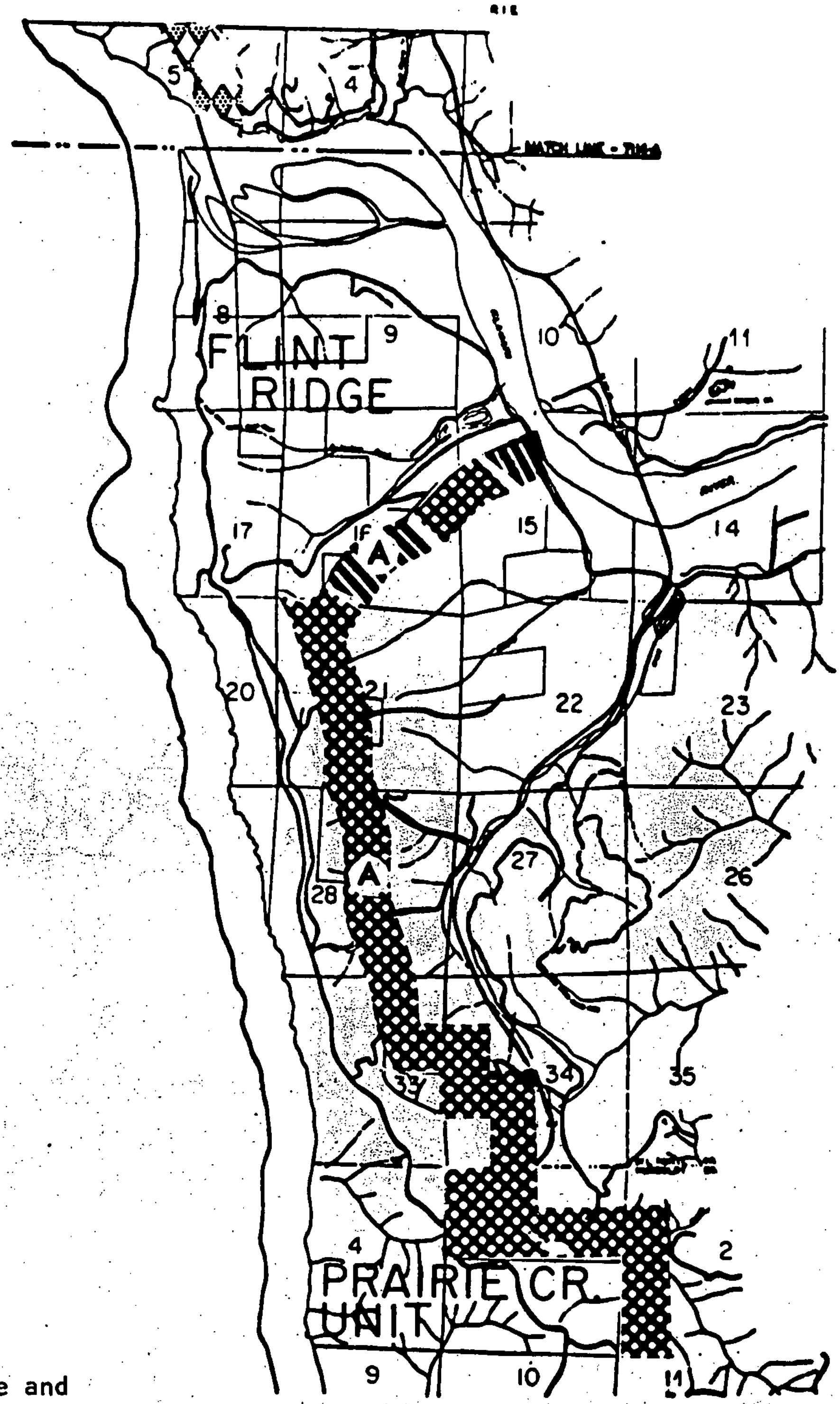
BUFFER TYPE	MAP SYMBOL
Fuelbreaks	
IA	
IB	
IC	
ID	
Cutover Borders	
IIA	
IIB	
IIC	
Old-growth Borders	
IIIA	
IIIB	
IIIC	
IV	



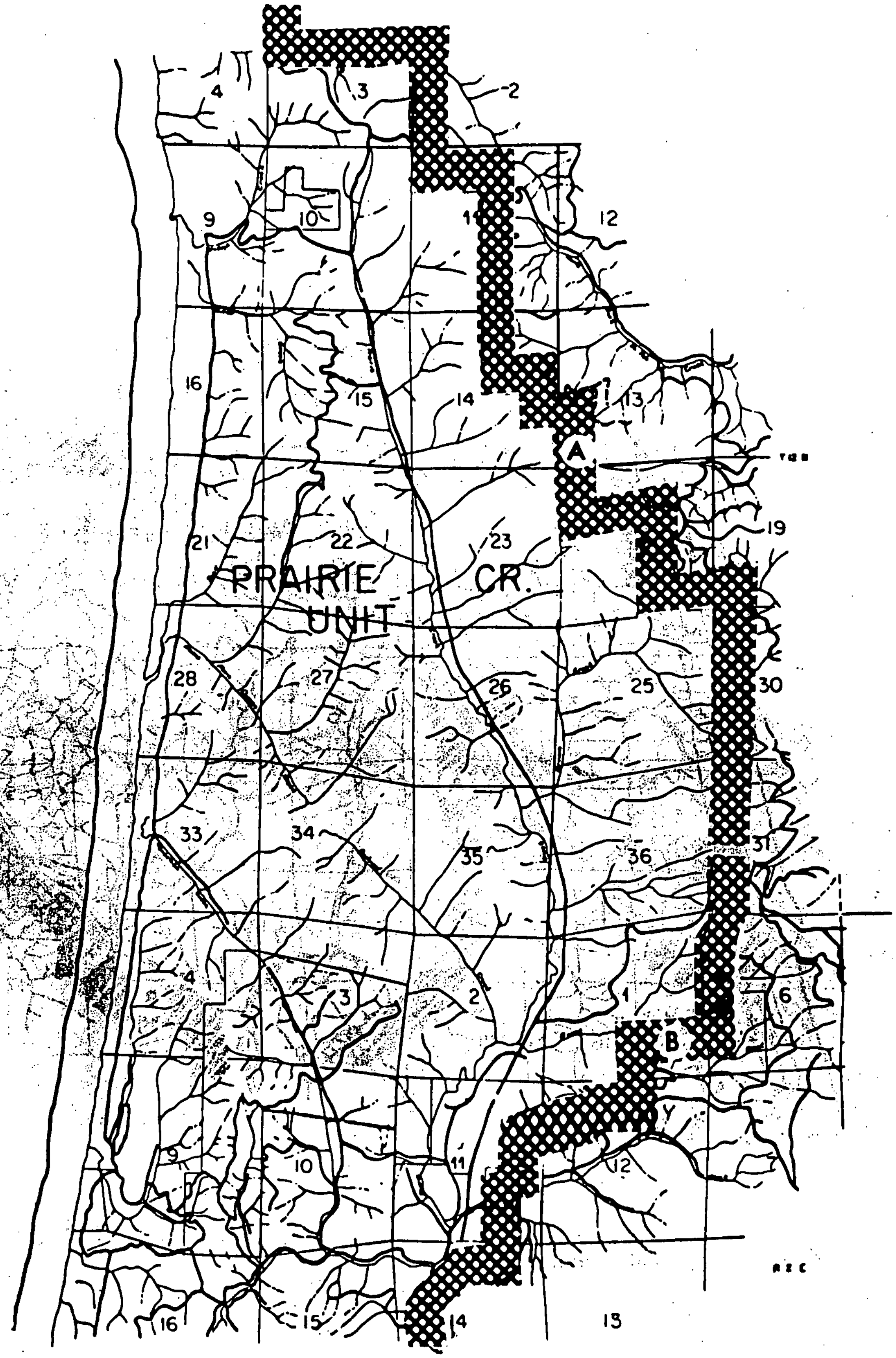
Map 1. Jedediah Smith Unit and northern part of Del Norte Unit



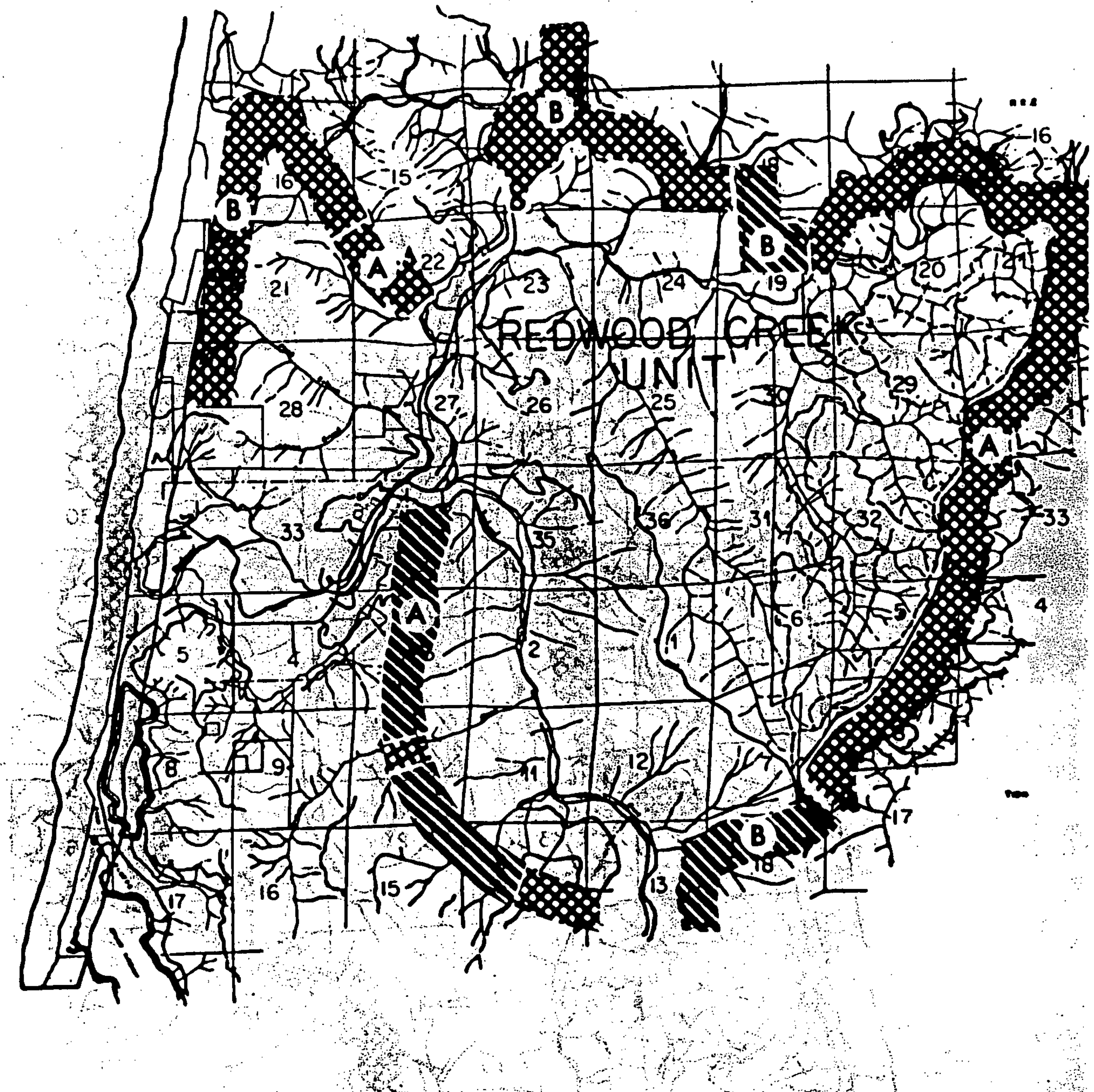
Map 2. Southern part of Del Norte Unit



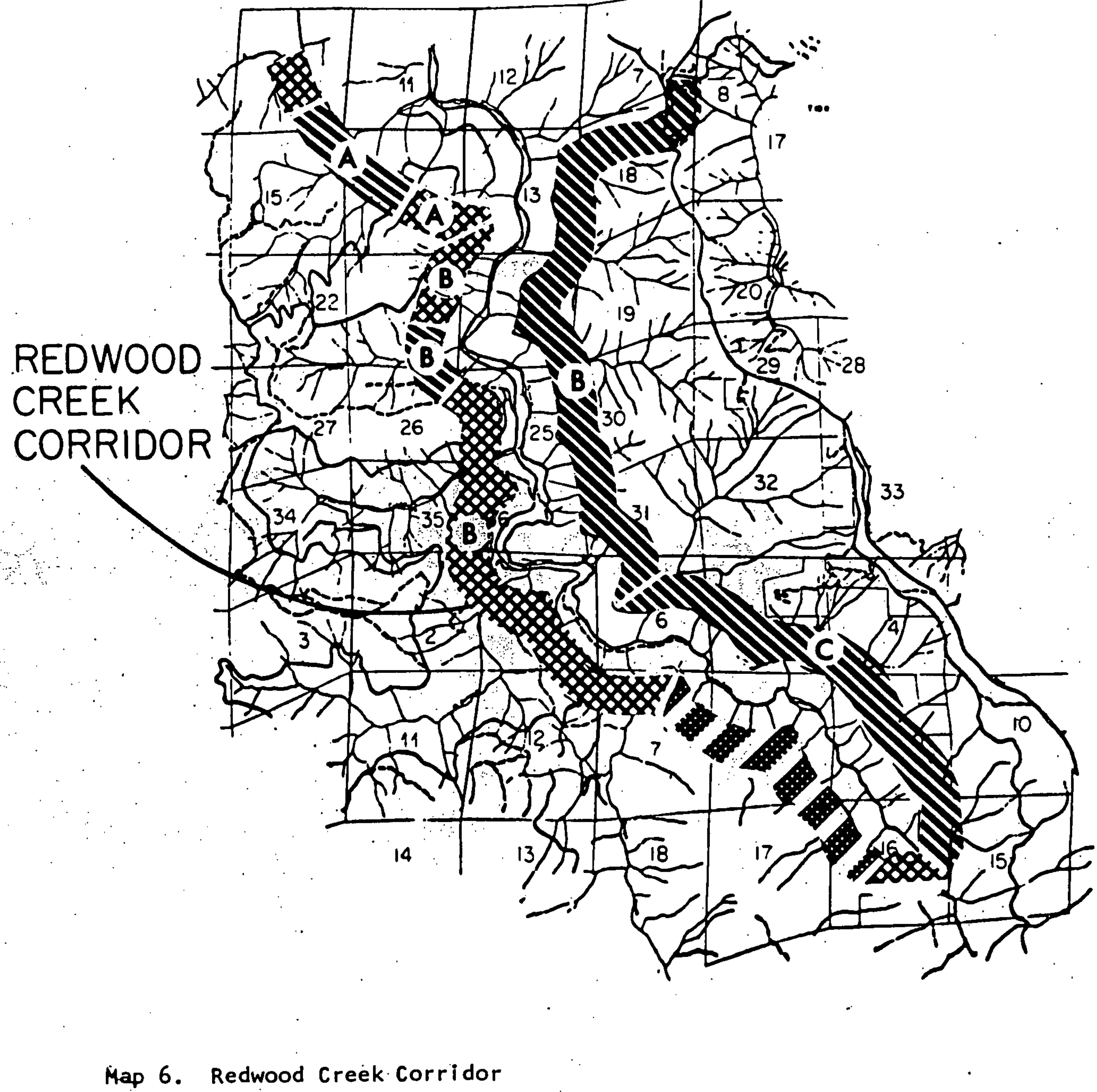
Map 3. Flint Ridge and northern part of Prairie Creek Unit



Map 4. Prairie Creek Unit



Map 5. Redwood Creek Unit



Map 6. Redwood Creek Corridor

APPENDIX B

LIST OF FIGURES

APPENDIX C

ELABORATION AND CITATIONS REQUESTED BY OFFICE OF NATURAL SCIENCE STUDIES AFTER THEIR REVIEW OF A PRELIMINARY DRAFT OF THE REPORT

(1): Pg. 7. Data from most of the observation plots that have been established in the Redwood Region have not and probably will not be published. Studies of the redwood forest by researchers with scientific backgrounds has been sketchy. The research that has been carried out has been concerned largely with the timber producing potential of this species. The first major ecological study of redwood was undertaken by the Wildland Research Center, University of California, Berkeley, at the request of the California State Division of Beaches and Parks. The results of this study are covered in six Annual Reports. Below is a brief list of publications which cover the range of data obtained from temporary and permanent plots involving redwood:

a. Boe, K.N. 1961.
Redwood seed dispersion in old-growth cutovers. Pac. S.W. For. Range Exper. Stat., U.S. Forest Serv., Res. Note 177, 7 pp.

b. Boe, K.N. 1965.
Windfall after experimental cutting in old-growth redwood. Proceed. Soc. Amer. Foresters, pp. 59-63.

c. Cooper, D.W. 1961.
Influence of soil type on reforestation in Humboldt County, Calif. Agric. 15:4-5.

d. Fritz, E. 1938.
Growth of redwood trees left after selective logging. Timberman 39:14-16:53-55.

e. Fritz, E. 1950.
Spotwise direct seeding of redwoods. J. Forestry 48:334-338.

f. Fritz, E. and J.A. Reydelius. 1966.
Rewood reforestation problems. Found. Amer. Resource Management, 130 pp.

g. Lindquist, J.A. and M.N. Palley. 1963.
Empirical yield tables for young-growth redwood. Univ. of Calif. Agric. Exper. Sta. Bull. 796, 47 pp.

h. Muelder, D.W. and Hansen, J.H. 1961.
Biotic factors in natural regeneration of Sequoia sempervirens. Proc. 13th Congr. Inter. Union For. Res. Organ., Vienna.

i. Muelder, D.W. and Hansen, J.H. 1961.
Observations on cone bearing of Sequoia sempervirens. Calif. Forest and Forest Prod: 26, University of Calif., Berk., 6 pp.

j. Pierce, H.L. 1901.
Studies on the coast redwood. Proc. Calif. Acad. Sci. Ser. III 2:83-105.

k. Pearson, H.L. 1942.
Increment of residual redwoods. J. Forestry 40:926-929.

l. Pearson, H.L. and W. Hallin. 1942.
Natural restocking of redwood cutover lands. J. Forestry 40:683-688.

m. Redwood Ecology. 1960, 1961, 1962, 1963, 1964, 1966 and 1967. Wildland Res. Center, Univ. of Calif., Berk.

n. Stone, E.C. 1966.
Ecology of the watershed. Proc. Sympos. on Management for Park Preservation. pp. 65-80. Sch. of Forestry, Univ. of Calif., Berk.

o. Stone, E.C. and R.B. Vasey. 1967.
Preservation of coast redwoods on alluvial flats. Science 159:157-161.

p. Waring, R.H. 1963.
Vegetation of the California coast redwood region in relation to gradients of moisture, nutrients, light and temperature. Univ. of Calif., Berk., Ph.D. thesis, 142 pp.

q. Weber, A. 1926.
Redwood cutover lands. Univ. of Calif., Berk., M.S. thesis, 64 pp.

(2): Pg. 8. The point we wish to stress with this statement is that redwood, through its sprouting capability, can dominate long after the successional stages involving its reproduction by seed has disappeared. Redwood cannot regenerate by seed in the environments that now prevail along much of its eastern and southern limits. In these areas redwood was established under earlier favorable environments and is now a relic and exists only because of its ability to sprout. Elsewhere in its range redwood can regenerate by seed and is not a relic of earlier environments. But everywhere successional stages involving seedling regeneration are almost totally lacking. There are few citations alluding directly to these points. Some background information on longevity, sprout regenerating capacity, seed regenerating capacity and successional potential can be found in the following publications:

a. Fritz, E. 1929.
Redwood, the extraordinary. Timberman 30:38-39, 77.

b. Fritz, E. 1929.
Some popular fallacies concerning California redwood. Madrono 1:221-223.

c. Fritz, E. 1945.
Twenty years' growth on a redwood sample plot. J. Forestry 43:30-36.

d. Fritz, E. 1957.
The life habits of redwood the extraordinary. West. Conser. Jour. 14:4-7, 38.

e. Jepson, W.L. 1910.
The silva of California. Univ. of Calif. Mem. 2, 480 pp. Univ. Calif. Press, Berk.

f. Jepson, W.L. 1923.
The trees of California. 2nd ed.; 240 pp.; Sather Gate Bookshop, Berk., Calif.

g. Metcalf, W. 1924.
Artificial reproduction of redwood (Sequoia sempervirens) J. Forestry 22. 873-893.

h. Muelder, D.W. and J.H. Hansen. 1961.
Biotic factors in natural regeneration of Sequoia sempervirens. Proc. 13th Congr. Inter. Union For. Res. Organ., Vienna.

i. Redwood Ecology. 1966.
Annual report. Wildland Res. Center, Univ. of Calif., Berk.

j. Redwood Ecology. 1967.
Annual report. Wildland Res. Center, Univ. of Calif., Berk.

k. Stone, E.C. 1966.
Ecology of the watershed. Proc. Sympos. on Management for Park Preservation, pp. 65-80. Sch. of Forestry, Univ. of Calif., Berk.

l. U.S. Forest Service. 1908.
Redwood. U.S.D.A. For. Serv. Silv. Leaflet 18, 5 pp.

(3): Pg. 8. Direct evidence of fire in the redwood region prior to the arrival of the white man is confined to buried charcoal deposits in the alluvial flats. In one of these deposits we uncovered charcoal that was around 1200 years old according to the standard carbon dating technique employed. Also, we have found Douglas fir logs in a nearby alluvial flat that are around 10,000 years old according to carbon dating and we expect to find charcoal of a similar age in this deposit. The point we believe should be kept in mind, is that fire was common in the primeval forest prior to the arrival of the white man.

(4): Pg. 8. Except for buried charcoal, as already discussed, we have no way of tracing the occurrence of fire in the primeval redwood forest back into time. We can be reasonably confident, however, that fires ran through the primeval redwood forest every 50-75 years or the forest that greeted the white man on his arrival would not have been what it was. The only researcher who has examined this question in any detail concluded that three or more serious fires occurred per century. An estimate of the frequency of large fires in the past in the Park could be determined, if the cost was acceptable, by a series of stand age analysis at key locations.

a. Fritz, E. 1932.
The role of fire in the redwood region. Univ. Calif. Agr. Exper. Sta. Cir. 323, 23 pp.

b. Fritz, E. 1957.
The life habits of redwood the extraordinary. West. Conser. Jour. 14:4-7, 38.

(5): Pg. 15. If a regular program of controlled burning could be instituted, subsequent recutting of the cutover lands once regenerated would not be necessary. Fires would need to be intense enough, however, to destroy redwood trees in the regenerated stands, otherwise the desired future "flow of age classes" would not be achieved. The cost would probably be prohibitive. Thinning by fire following re-establishment of redwood on the cutover lands would be possible but would be very complicated and costly. Thinning will probably be desirable because when properly applied trees up to 4 feet in diameter and 200 feet tall can be produced in 100 years or less on good sites.

(6): Pg. 17. Soil Vegetation Survey Maps are maps prepared by the California Cooperative Soil-Vegetation Survey carried out by the U.S. Forest Service. Not all of the forested part of the state has been mapped but all of the Park has been mapped. These maps can be obtained from the U.S. Forest Service, San Francisco, California.

(7): Pg. 20. Fires in the primeval redwood forest prior to the arrival of the white man were undoubtedly wildfires. Controlled fires are fires initiated by man kept under his control once started. Prior site preparation is required and burning must be conducted at a time when it can be restricted to the prescribed area. As State and Federal fire fighting organizations can readily testify, there is a long history of controlled fires which started out under control, but which later became uncontrolled and turned into wildfires. Prior to the arrival of the white man, Indians may have started fires so as to clear out the underbrush or drive out game, but once these fires were started the Indians certainly had no way of controlling them. Many of these fires could have readily become wildfires in the true sense of the word.

(8): Pg. 21. Thunder storms with accompanying lightning strikes occur essentially every year in the Redwood region, often during the highly fire-hazardous fall months. According to the local foresters, rarely does a year pass when one or more dead-topped redwood trees are not struck by lightning and caught on fire. During the past 25 years, however, these lightning started fires have been quickly brought under control and the acreage burned as a result of lightning strikes has been insignificant. The important point to keep in mind is that in the past, in the absence of fire control, these lightning started fires -- which can burn for weeks in dead tops and snags -- could have been responsible for many of the extensive wildfires that burned through the primeval redwood forest prior to the arrival of the white man. Indians may have been important in starting fires in the primeval redwood forest but their presence was not essential.

(9): Pgs. 24 and 25. Wind patterns generalized in Figures 4 and 5 are described in more detail in:

a. Boe, K.N. 1965.
Windfall after experimental cutting in old-growth redwood. Proceed. Soc. Amer. Foresters, pp. 59-63.

b. Caborn, J.M. 1957.
Shelterbelts and microclimates. Forestry Comm. Bul. 29, 135 pp.

c. Caborn, J.M. 1965.
Shelterbelts and windbreaks. Faber and Faber, London, 288 pp.

d. Hutte, P. 1968.
Experiments on windflow and wind damage in Germany. Suppl. to "Forestry." Soc. of Foresters of Gr. Britain, pp. 20-25.

(10): Pg. 46. The species make-up of these young-growth stands varies with the slope position. Towards the bottom of the slope redwood dominates. Higher up the slope Douglas fir becomes an important element in the stands and dominates as the ridge top is approached.