# Cumulative Silvicultural Impacts on Watersheds: A Hydrologic and Regulatory Dilemma

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ABSTRACT / Because of the nature of watersheds, the hydrologic and erosional impacts of logging and related road-building activities may move offsite, affecting areas downslope and downstream from the operation. The degree to which this occurs depends on the interaction of many variables, including soils, bedrock geology, vegetation, the timing and size of storm events, logging technology, and operator performance. In pans of northwestern California, these variables combine to produce significant water quality degradation, with resulting damage to anadromous fish habitat.

Examination of recent aerial photographs, combined with a review of public records, shows that many timber harvest operations were concentrated in a single 83 km $^2$ watershed in the lower Klamath River Basin within the past decade. The resulting soil disturbance in this case seems likely to result in cumulative off-site water quality degradation in the lower portion of the Basin.

In California, both state and federal laws require consideration of possible cumulative effects of multiple timber harvest operations. In spite of recent reforms that have given the state a larger role in regulating forest practices on private land, each timber harvest plan is still evaluated in isolation from other plans in the same watershed. A process of collaborative state-private watershed planning with increased input of geologic Information offers the best long-term approach to the problem of assessing cumulative effects of multiple timber harvest operations. Such a reform could ultimately emerge from the ongoing water quality planning process under Section 208 of the amended Federal Water Pollution Control Act.

The public regulation of private logging in California has undergone major changes in the past decade. The State Board of Forestry is no longer dominated by the timber industry. A landowner who wishes to harvest timber must file with the California Department of Forestry a Timber Harvest Plan (THP) prepared by a Registered Professional Forester. California is presently the only state requiring plan preparation by licensed professionals. Logging must be carried out in conformance with regulations and standards established by the State Board of Forestry, and criminal penalties are provided for violations.

In spite of the recent reforms, each THP filed with the state is considered as a separate problem. The hydrologic and erosional impacts of the various logging operations in a given watershed, however, may move downslope and downstream, where they may have a cumulative effect on water quality and fisheries resources. Thus, there are strong arguments for evaluating THPs on a watershed rather than an individual basis. To do this, however, would raise some complex physical, legal, and political problems, among them: 1) estimating the probable physical impacts of various activities; 2) accounting for the various objectives and interests of different landowners; 3) establishing a methodology and institutional mechanism to undertake and implement necessary watershed planning; and, 4) financing the costs of the work. The purpose of this paper is to review the physical evidence of cumulative offsite effects of logging and related road construction, to outline briefly the present regulatory scheme and legal basis for considering cumulative effects, and to suggest some possible alternative approaches for handling the problem.

Most of our examples and information are drawn from northwestern California and western Oregon. Problems exist in other parts of the Pacific states, but they are most acute in the Coast Ranges because of climate, geology. and the value of both timber and fisheries resources.

KEY WORDS: Watershed effects, Timber Harvest Plans, Stormflow peaks, Redwood National Park, Turwar Creek, California Environmental Quality Act

## The Physical Problem

The possible cumulative watershed effects of timber harvest include impacts on streamflow regimes and impacts on erosion and sedimentation. Although these impacts are related and may interact, it is useful to discuss them separately.

### Streamflow Effects

It is well known that timber harvest, by reducing evapotranspiration, increases annual streamflow (Hibbert 1967). The important question in this context is the degree to which timber harvest activities increase


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stormflow peaks of a size sufficient to cause downstream channel and bank erosion. The usual method for answering this question is to "calibrate" one or more treatment watersheds against a control watershed for several years, and then compare the post-logging relationship with the pre-logging relationship. Results from several careful studies on the Pacific Coast are now available (Harris 1973, Harr 1976, Harr and others 1979, Rice and others 1979). These studies all found increases in small stormflow peaks (less than the mean annual flood) associated with a reduction in evapotranspiration. The effect is most pronounced in the autumn, when the differences in soil moisture between cut and uncut areas are great. The stormflow peaks affected by the reduced evapotranspiration, however, are generally considered too small to be of much significance to downstream erosion and sediment transport (Harr and others 1979, Rice and others 1979).

Where timber harvest activities result in extensive soil disturbance and compaction, however, there is evidence that large as well as small stormflow peaks may be increased. Results from the Alsea Experimental Watershed (Harr and others 1975) and Coyote Creek (Harr and others 1979) suggest that 12 to 15 percent surface area compaction is sufficient to significantly increase large stormflow peaks. Frequency analysis suggested, in the latter case, that a nine-year flood could be increased in magnitude by 40 percent and a 30-inch diameter culvert would become necessary where formerly an 18-inch diameter culvert would have sufficed.

A similar study at Caspar Creek in Mendocino County, California, however, failed to detect a significant increase in large stormflow peaks, even with 15 percent of the surface area disturbed by heavy equipment (Ziemer 1979). This discrepancy may result from the use of a more conservative statistical test or from real differences in hydrologic response. Clear conclusions from all of the above-mentioned studies, however, are hampered by the fact that a relatively low number of large floods occurred during the sampling periods.

In areas where winter precipitation falls as both rain and snow, the hydrologic effects of tree canopy removal are complex. If winter storms typically begin as snow and then turn to rain, the creation of openings in the forest may actually decrease stormflow peaks by retarding snowmelt (Harr and McCorison 1979). The magnitude of the effect depends on the size of the openings as well as on the precipitation pattern. In areas of considerable snowfall, manipulation of the canopy presents opportunities to alter streamflow characteristics in beneficial ways.

The recent controlled forest hydrology experiments in the Pacific Northwest probably represent a lower limit of hydrologic effects of timber harvest in this region. The studies were all carried out on public lands utilizing "state-of-the-art" logging technology. There are no controlled studies of the hydrologic effects of old-growth removal in the Redwood Region in California. Logging of old-growth redwood may entail considerable soil disturbance and hydrologic impacts, since "layouts" are often dug into the earth to prevent the trees from breaking on impact, and logs are often skidded downhill, resulting in a dendritic pattern of skid trails that concentrates rather than disperses runoff. Fig. 1 shows the relative degree of disturbance resulting from two different systems of yarding during harvest of old-growth trees.

In 1973, the U.S. Geological Survev undertook a study in and around Redwood National Park to determine the impact of logging-related erosion, runoff, and sedimentation on Park resources. Three separate lines of evidence from this work indicate that logging in Redwood Creek Basin has increased large stormflow peaks. 1) A computer model for synthesizing daily runoff was used to compare runoff for periods before and after intensive timber harvest in the Basin. Parameters associated both with soil moisture and with runoff' under saturated conditions changed as a result of logging; total runoff increased by about 20 percent (Lee and others 1975). 2) Synoptic sampling of nine storm events showed that recently harvested catchments in Redwood Creek Basin produced several times more runoff and had higher runoff to precipitation ratios than unlogged catchments (Janda 1977). 3) A significant dilution of soluble streamwater constituents occurs at the discharge peak in streams draining heavily logged catchments, but not in streams from unlogged catchments. This is attributed to increased overland flow associated with soil disturbance (Bradford and Iwatsubo 1978).

## Erosion and Sedimentation Effects

If' the problem of cumulative effects only involved streamilow regimes, it would seem relatively simple. Such, unfortunately, is not the case. The effects of'timber harvest activities on erosion and sedimentation tar outweigh the effects on streamflow, both in complexity and importance. Any attempt to account for potential

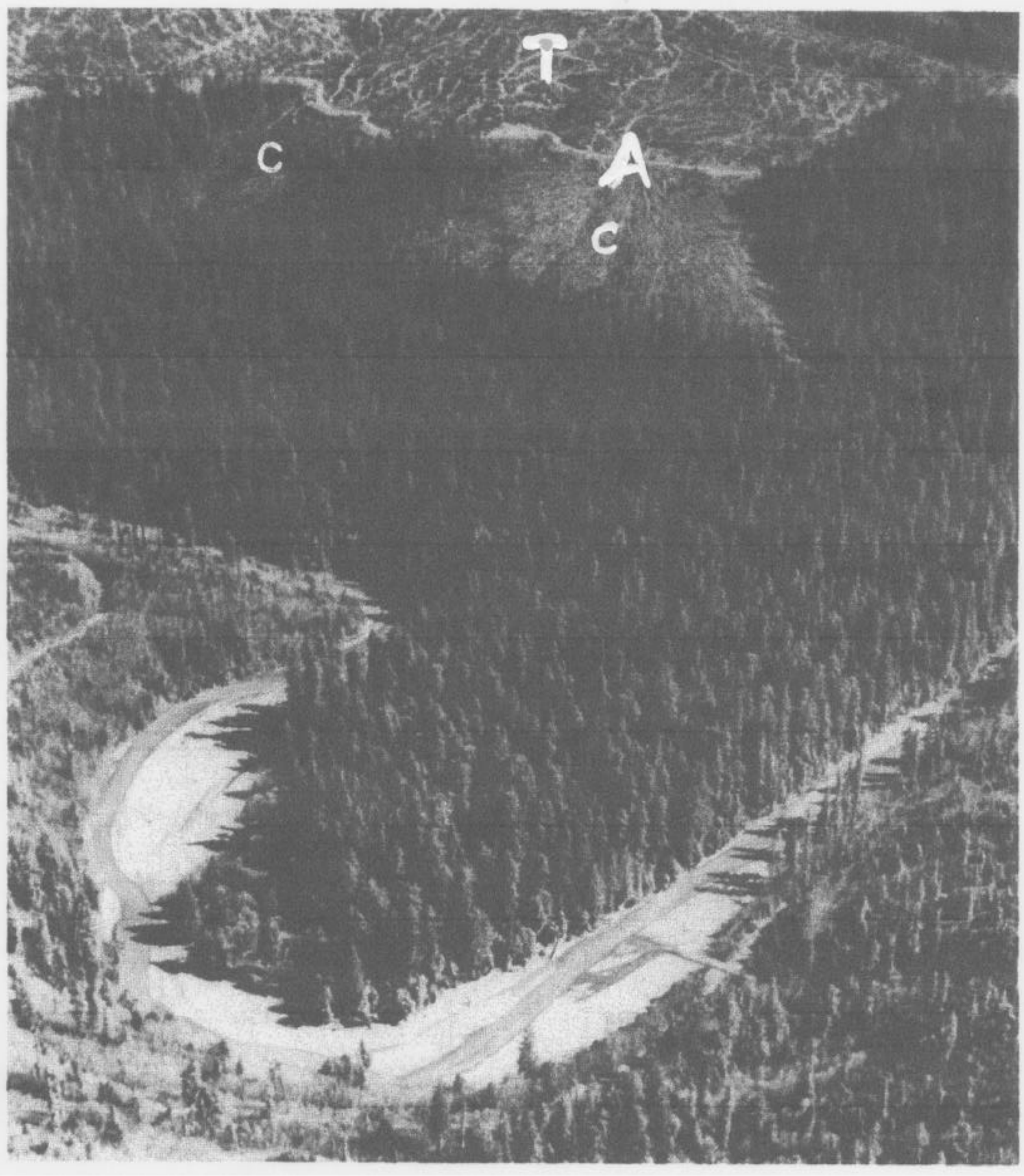


**Figure 1. Clear-cut harvest areas near Redwood Creek, Redwood National Park, California. The cable yarding method was used in area C to haul logs up to main haul road (A). Tractor yarding was** used in **the** areas **(T) above the** road. **Note that tractor skid trails converge downward, whereas the cable skidding paths converge upward. The cutover areas shown were recently added to the National Park. Photo by California Department of Forestry.**

cumulative effects of multiple timber harvest operations must be based on an appreciation of this complexity.

Fig. 2 shows some of the ways in which timber harvest activities may affect hydrologic and erosional processes in a watershed. The (+) or (-) indicates whether the effect of the activity or event is positive or negative on either the frequency or the magnitude of an event downslope or downstream. Numbers refer to the accompanying references. Rather than attempting to review this rather extensive literature, we will briefly discuss some of the **areas of agreement and controversy.**

Virtually every study dealing with the erosional consequences of timber harvest activities has emphasized the importance of local variations in climate, terrain, geomorphology, vegetation, and operator performance. No simple formula or upper limit on the allowable rate of timber harvest in a watershed will provide a solution to the problem of cumulative effects, since each watershed

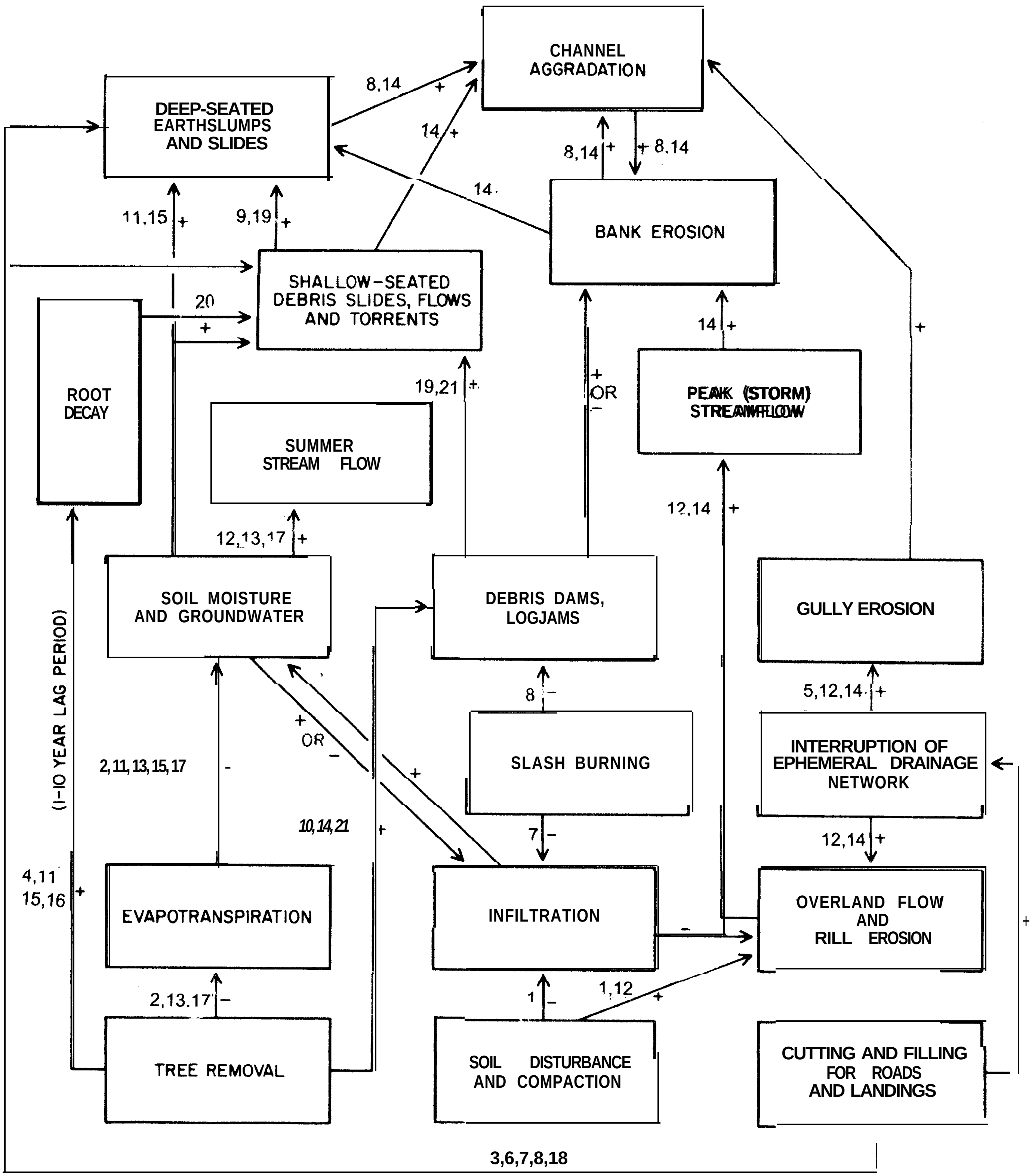


**Figure 2.** The influence of timber harvest activities on hydrologic and erosional processes in a watershed. The (+) or (-) indicates whether an event or activity has a positive or negative effect on the frequency or magnitude of an event downslope or downstream. The numbers refer to the accompanying references. *References Cited:* [1] Anderson, 1962. [2] Bethlahmy, 1962. [3] Brown and Krygier, 1971. [4] Burroughs and Thomas, 1977. [5] Dodge *et* al., 1976. [6] Dyrness, 1967a. [7] Dyrness, 1967b. [8] Farrington and iavina, 1977. [9] Fredriksen, 1970. [10] Froehlich, 1973. [11] Gray, 1970. [12] Hart-, *et* al., 1975. [13] Hibbert, 1976. [14] Janda, *et al.*, 1975. [15] Rice and Krammes, 1970. [16] Rice, *et* al., 1972. [17] Rothacher, 1970. [18] Swanson and Dyrness, 1975. [19] Swanson, *et al.*, 1976. [20] Swanston and Swanson, 1976. [21] Swanston, 1971.

presents a different combination ot' variables. An appraisal of these variables in a given watershed, however, may provide a basis for determining the extent and timing of timber harvest activities that can be undertaken without unacceptable impacts. A good example of an intensive appraisal of geologic and hydrologic variables is the Fox Unit Study in the Six Rivers National Forest, California. This study was undertaken by the Forest Service pursuant to settlement of a suit with the Sierra Club on the adequacy of the final Environmental Impact Statement (Sierra Club vs. Butz, No. C-742421 SAW (N.D. CAL. 1975)). This study mapped geology and geomorphology in existing and planned timber harvest units and attempted to predict fluvial erosion and mass movement on the basis of previous experience in the watershed (Seidelman and others 1977). Existing and predicted slides were followed downslope and downstream (Farrington and Savina 1977), and the effects of increased runoff and erosion on channel stability and sediment transport were evaluated (LaVen and Lehre 1977). The findings of the Fox Unit Study led the Forest Service to prescribe mitigating measures for timber harvest on unstable slopes and to remove certain areas from the plan altogether.

There is general agreement in the literature on erosion and timber harvest that the location of roads. landings, and skid trails in relation to unstable or erosive slopes is a key variable. There are situations, however, where tree removal alone, in the absence of soil disturbance, is sufficient to accelerate shallow debris slides. Such situations exist on the steep inner gorge slopes of deeply-incised streams in northwestern California. Accelerated erosion is more likely to occur if such slopes are vegetated with Douglas-fir *(Pseudotsugu menziesii* (Mirb.) Franco) rather than redwood *(Sequoia sempervirens* (D. Don) Endl.), since redwood root systems remain viable, while Douglas-fir roots decay and lose their capacity to contribute to slope stability (Burroughs and Thomas 1977, Gray 1970). Possibly the only way to protect such slopes will be to designate them "protection forests" and to curtail all timber harvest activities there.

A major difficulty and source of controversy in assessing the erosional impacts of timber harvest concerns the relative importance of infrequent but extreme events. The flood of 1964 has become almost legendary among hydrologists. In the H. J. Andrews Experimental Forest in Oregon, a patch-cut watershed yielded 97.7 percent of its total nine-year sediment yield during this brief' storm period as a result of landslides and debris torrents (Fredriksen 1970). The Eel River in northwestern California (at Scotia) carried 25 percent more suspended sediment in one three-day period during he. 1964 flood than it had carried in the previous eight years (Brown and Ritter 1971). It is important, however. to view these rare extreme events in a long-term context. The long-term sediment transport work done in a watershed by floods of a given size (or return period) is a function of the product of frequency and magnitude. Wolman and Miller ( 1960) analyzed sediment yield and streamflow records and concluded that, tor large rivers. floods with a return period of'about 1.5 years do most of the work in the long run. They suggested that for small tributaries, the relatively rare extreme events are more important.

Failure to understand these relationships has led to serious misinterpretations of data. Recent sampling during moderate storms in Redwood Creek Basin (near Redwood National Park) has shown that the main stem or Redwood Creek carries up to 50 times more suspended sediment per km$^2$ of watershed than do the tributary streams, including those recently logged and heavily disturbed (Janda and others 1975a). This has bee:! interpreted bv consultants for the timber industry. (Ficklin and others 1977) to indicate that the main channel of Redwood Creek, rather than recent logging in the vicinity of Redwood National Park, is the main source of sediment in the Basin. Janda ( 1977), however, plotted the relationship between suspended sediment vield and stream discharge (per unit area) and found that the sediment transport curves for the main stem and tributaries of Redwood Creek tend to converge and cross at high per unit area discharges. This suggests that during years of moderate storm events, sediment is stored in tributary channels, and the main channel degrades. During large events, the tributaries are "sluiced out," and the main channel aggrades. This general view is supported by suspended sediment records for other North Coast river basins (Brown and Ritter 1971, Brown 1973, Kelsey 1977) and is consisten: with the hypothesis of Wolman and Miller ( 1960).

The off-site erosional impacts of timber harvest are, II: some cases, exacerbated by positive feedback mechanisms that translocate erosional processes downstream. Fluvial erosion on a hillslope may result in channel aggradation in a V-shaped inner gorge downstream. The resulting increased width-to-depth ratio, over-bank flooding, and lateral migration of the stream channel lead to increased bank erosion and near-stream land-sliding, which in turn result in further aggradation downstream (Janda 1975b, Farrington and Savina 1977 | Large woody debris often plays a complex role in these processes, in some cases accelerating bank erosion and III other cases armoring the channel and retarding erosion (Swanson and others 1976). Any attempt to regulate cumulative effects should include some procedure for identifying situations where these positive feedback mechanisms are likely to occur.

### Water Quality Considerations

The possible cumulative watershed effects of logging are of interest not just for theoretical reasons but for their impact on beneficial uses of water. In the North Coast region of California, water resources are relatively undeveloped, although the sediment yield of rivers in the region may ultimately become an issue in the controversy surrounding future development. The value of main concern at present is the fishery resource, both anadromous and resident. Fig. 3 shows the three-year running averages for king (chinook) salmon *(Oncorhynchus tshawytscha),* silver (coho) salmon (0. *kisutch)* and steelhead trout *(Salmo guirdneri guirdneri)* at a counting station on the South Fork of the Eel River (Humboldt County) in California. It is especially significant that the decline of steelhead mirrors the decline of' silver and king salmon, since there is no commercial steelhead fishery, and the catch to escapement ratio for steelhead is about one tenth that of salmon (Smith 1978). The decline is thus probably attributable to habitat degradation, which in the South Fork Eel River Basin includes overgrazing, road and highway construction, and gravel operations, as well as poor logging practices during the 1950s and early 1960s (Calhoun 1963, Denton 1974). There are unfortunately no large undisturbed river basins in north coastal Calif'ornia chat might serve as a "control," and population data for other rivers are either spotty or nonexistent.

The processes of fish habitat destruction are, like the processes of erosion itself, complex. Suspended sediment cements spawning gravels, thus impeding the construction of redds by spawning adults and reducing the flow of oxygen-rich water to eggs and alevins (Cordone and Kelley 196 1, Moring and Lantz 1975). Aggradation may fill pools and thereby reduce the available shelter (Denton 1974, Barnes 1977). Destruction of' riparian vegetation results in higher water temperatures, which reduce the dissolved oxygen concentrations and increase the metabolic demands. Organic debris in streams may deplete dissolved oxygen and block fish migration. The establishment of "buffer strips" along streams, tnandated by the 1973 California Forest Practice Act, has provided significant protection for tish habitat and eliminated some of the former damaging practices.

An economic analysis of tishery values may provide some basis for determining the trade-off' between logging costs and fish production. Valuation of fisheries is usually based on the market value ofcommercial fish and on estimates by sports fishermen of the value of their experience (Smith 1978). Estimates of fishery values in the Siskiyou National Forest in Oregon suggest that, if just eight pairs of steelhead and two pairs of king salmon spawn above a road crossing, then an investment of $8,200 for a bridge is justified over spending $4,500 for a culvert that would impede upward migration (Everest 1978).

### Turwar Creek: A Site of Potential Cumulative Effects

Much information relating to the cumulative watershed effects of timber harvest in California is based on logging that occurred prior to the passage of the Z'berg-Nejedly Forest Practice Act in 1973. The Act resulted in a number of significant changes that have reduced the water qualitv impacts of'timber harvest. Among these are the use of stream protection zones or "buffer strips," the exclusion of tractor yarding from steep and highly erosive slopes, and restriction on the size of clear-cuts. It is possible, however, that timber harvest activities are concentrated enough in some watersheds to have significant impacts. Although a detailed field study was beyond the scope of our project, we selected the 83 km2 watershed of Turwar Creek in the lower Klamath River Basin for evaluation and used aerial photographs and Department of Forestry records. A combination of youthful geology, erosive metamorphic rocks, and high precipitation makes Turwar Creek a likely site for erosional impacts of timber harvest activities.

The Turwar Creek watershed was included in a recently completed study on the effects of timber harvest activities on erosional landform activity and fish habitat in the lower Klamath River Basin (Earth Sciences Associates 1980). This study, completed subsequently to our own, mapped the activity of debris slides, avalanches and torrents, earthflows, surficial erosion, and timber harvest from aerial photographs dated 1936, 1962-63, 1 966-69, and 1975. The maps show a dramatic increase in frequency and activity of mass movement associated with progressive timber harvest. In most cases the largest increases in erosional activity did not occur immediately after logging, but showed up in subsequent photographs. The maps indicate logging in the lower part of the Turwar Creek Basin prior to 1962-63, with increased debris slide activity up to 1975. Prior to 1975, the upper basin was relatively undisturbed.

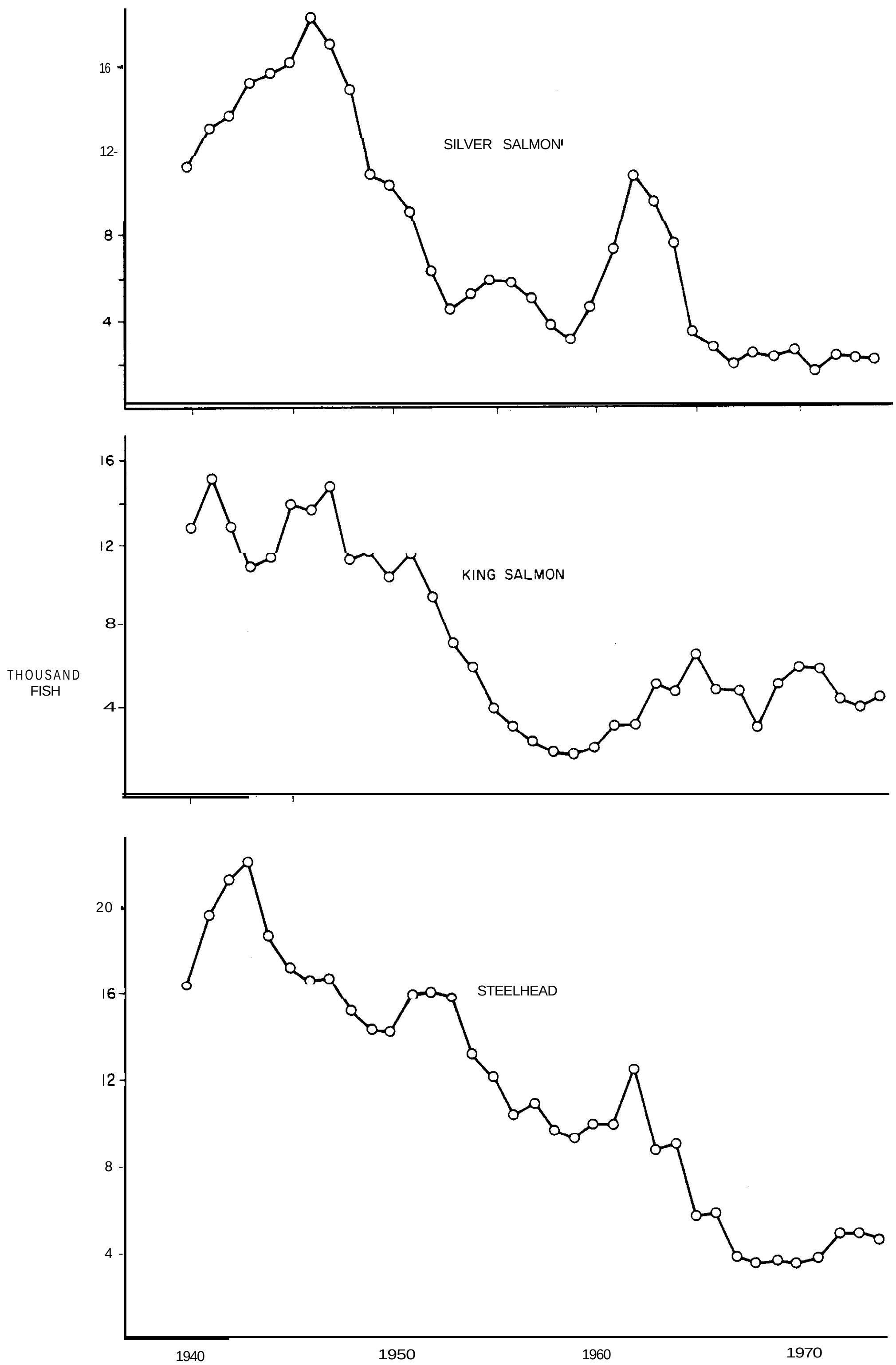


**Figure 3.** Three-vex running averages of three species ofanadromous tish counted on the South Fork Eel River, Humboldt Count\ California. Data from the California Department of Fish and Game.

Using state records and color aerial photographs ( 1: 12,000 and 1:24,000) from 1977, we plotted the timber harvest plans in Turwar Creek through 1978, distinguishing between tractor and cable-yarded units. We then plotted the road system (main haul and most spur roads) and sampled the widths of the road prisms on the 1: 12,000 photographs.

The total area clear-cut in the 83 $km^2$ watershed between 1970 and 1978 was 27 km', or 32.5 percent of the watershed. Of this area, 13 $km^2$ were tractor-yarded and 14 $km^2$ were cable-yarded. In the 21 $km^2$ East Branch tributary, 28.8 percent of the area was tractor-logged, and 6.6 percent cable-logged. We estimated a total road length of 159 km and an average width (including cuts and fills) of 18.8 meters (n = 104). On the basis of these figures, about 3.9 percent of the watershed has been disturbed by roads and landings.

Combining our estimates of the aerial extent of tractor logging in Turwar Creek with "ground truth" estimates from the California Department of Forestry's Soil Erosion Study (Hauge and others 1979a) suggests that a total of 8.7 percent of the soil surface in the watershed is occupied by roads, skid trails, layouts, and landings. The comparable figure for the east branch of the watershed is 12.2 percent. These estimates do not count the soil disturbance in cable units, which is visually significant on the photographs but difficult to estimate without "ground truth."

Soil disturbance in Turwar Creek is approaching a level ( 12 percent) that proved sufficient to increase large storm-flow peaks in experimental watershed studies in Oregon (Harr and others 1979). It is not valid, however, to apply the results from a catchment of 0.4 $km^2$ to a watershed of 83 $km^2$, because of uncertainties about the arrival time of floods from different tributaries. Also, the frequency of a runoff event of a given magnitude is inversely related to watershed size. The evidence suggests, however, that some tributaries of Turwar Creek have been disrupted enough to increase stormflow peaks in those tributaries, with implications for bank erosion and aggradation downstream.

Examination of the aerial photographs of Tut-war Creek revealed several large rotational-translational slides associated with cutblocks, as well as shallow debris slides associated with road cuts and fills. Several dead conifers adjacent to a braided channel suggest recent aggradation in the lower basin. As we noted earlier, the occurrence of mass movement is highly event-related. The water years 1976 and 1977 were exceptionally dry, and water year 1978 was about average in total precipitation, but lacking in large and intense storm events on the North Coast. Thus, much of the timber harvest activities in Turwar Creek have not yet been "tested" by a large storm event.

Given the extent of recent soil disruption in Turwar Creek, the probability of continued timber harvest activities and the documented impacts in watersheds of comparable climate and geology, it appears that the stage has been set for significant accretion of sediment from hillslopes to tributaries and to the main channel of Turwar Creek. The timing of such impacts, however, depends to a large extent on the timing of future storm events.

An examination of Turwar Creek from aerial photographs does not, of course, "prove" that the basin is a site of cumulative hydrologic effects. A more thorough study would include field evaluation of both hillslopes and stream channels. We believe, however, that the record in Turwar Creek makes a strong case for the formal evaluation of potential cumulative effects during the Timber Harvest Plan review process.

## The Regulatory Process

The present system for regulation of private logging in California was established by the Z'berg-Nejedly Forest Practice Act of 1973 (Calif. Public Resources Code Secs. 45 11 et seq.). The Act gave a majority position to public rather than industry appointees on the Board of Forestry, the rule-making body, and established for the first time a harvest permit system (termed "Timber Harvest Plans" or "THPs") applicable to timber cutting on private forest lands in California. Timber harvest on private land is carried out under regulations promulgated by the State Board of Forestry for each of three districts in California. The rules are designed to deal with specific problems of erosion, regeneration, fire control and certain special problems, including protection of archeological sites, rare and endangered species, and coastal resources. Each district uses a system for evaluation of erosion hazards. For any commercial timber harvest operation, a THP must be prepared and submitted by a licensed Registered Professional Forester. The Department of Forestry must review each Plan submitted, and find it in conformance with the Board's regulations prior to the commencement of logging. The law provides for three on-site inspections (before, during, and after logging), although shortage of funds and manpower in the Department of Forestry sometimes results in preharvest inspections being sacrificed.

Following a court finding in 1975 that the TH P process was not in compliance with the California Environmental Quality Act ("CEQA") (Natural Resources Defense Council v. Arcata National Corp., No. 542 12, Humboldt Co., 1975), a revised administrative procedure for review of THPs was developed. This procedure involves representatives from the Regional Water Quality Control Boards and the Department of Fish and Game in the review and inspection of THPs. In addition, two geologists are available to participate in review of plans in the Coast District (northwestern California), but they are able to inspect only a fraction of the plans that need geologic review (Huffman 1977). Representatives of the Regional Water Quality Control Board and the Department of Fish and Game may file a "non-concurrence" with a plan, but have no power of appeal.

Under Section 208 of the amended Federal Water Pollution Control Act, the Board of Forestry contracted with the State Water Resources Control Board in 1978 to develop "Best Management Practices" for control of non-point source pollution from silvicultural activities. Since the water quality degradation associated with silvicultural activities is highly event-related and difficult to monitor, an approach aimed at improving land management practices is more appropriate than specifying and enforcing water quality discharge standards.

To carry out the required "208" tasks, the Board of Forestry in turn contracted with the State Department of Forestry to prepare a report evaluating the adequacy of the present regulatory *system,* and appointed a "Best Management Practices Silvicultural Advisory Committee" to provide industry, public, and scientific input to the Department's report (Hauge and others 1979b). Although this group reached a fair degree of consensus on many of the issues, parts of the Department's report were strongly opposed by industry at the State Board of Forestry hearings. Rather than rewrite the Department's report, the Board then prepared its *own* report. The Board's report, adopted in June, 1980, recognized that "the existing system of forest practice regulation falls short of that needed to provide a system of Best Management Practices . . . in a number of specific respects" and that "current rules do not explicitly provide for the full protection of water quality necessary to achieve water quality goals."

Among the problems recognized by the Board's report are:

1. The present rules pertain only to timber harvest activities; potential water pollution associated with activities such as regeneration, application o chemicals, and stand improvement is not addressed in the rules;
2. Standards for the design of roads and landings are not specified in the rules;
3. Long-term maintenance of erosion control structures (water bars and culverts) is not required;
4. The Department of Fish and Game and Regional Water Quality Control Boards have no power to appeal the approval of a THP;
5. Present enforcement procedures are weak anti would be enhanced by the use of stop work orders and civil penalties rather than just criminal penalties.

In order to remedy these deficiencies, the Board developed a timetable for rule changes and, where necessary, the preparation of a legislative package.

With regard to cumulative effects, the Board's report recognized the geomorphic and hydrologic processes that cause cumulative downstream water quality degradation in some river basins undergoing rapid and extensive timber harvest. The report recommends that explicit consideration be given to possible cumulative effects, but acknowledged the lack of existing procedures and information. As a first step, the report suggested a review of the existing data, mapping techniques, and ongoing programs, as well as a consideration of possible institutional mechanisms and interim rules or guideline> for dealing with the problem (California State Board of Forestry 1980).

It is appropriate that the problem of cumulative effects be considered in the "208 process," since Section 208 or the amended Federal Water Pollution Control Act requires plans to cover "silviculturally related nonpoinr sources of pollution . . . *and their cumulative effects"* and "to set forth procedures and methods (including land use requirements) to control to the extent feasible such sources" (emphasis added).

In the California Forest Practice Act, there is no explicit directive either to consider cumulative effects or to confine THP review to the immediate effects of each plan taken alone. However, the Act's broad policy language and rule-making mandates given the Department and Board clearly provide room, if not explicit instructions, to consider cumulative effects. The policy sections of the Act (sections 45 12 and 45 13) speak of a "comprehensive system of regulation" that includes "watershed protection." And section 455 1.5 of the Act. which lists the matters to be covered in the Board's rules, separately references "watershed control" and "flood control," in addition to soil erosion and water quality, arguably implying the need for some sort of regional impact analysis.

The provisions of CEQA are less vague with respect to cumulative effects. Section 21083 contains a listing of several factors that require a finding that a project may have a "significant effect on the environment." One of the conditions listed is one in which:

> (b) The possible effects of a project are individually limited but cumulatively considerable. As used in this subdivision, 'cumulatively considerable' means that the incremental effects of an individual project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.

CEQA was held to apply to regulation under the Forest Practice Act in *Natural Resources Defense Council v. Arcata National Corporation,* 59 Cal. Ap. 3d (1976). The Court stated that "Since under the rules of interpretation we are to harmonize the two statutes, the provisions of CEQA are deemed to be a part of the Forest Practice Act as well." Two particular "provisions" of CEQA should be noted, in addition to section 2 1083:

1. Section 21002 states that:

> The Legislature finds and declares that it is the policy of the state that public agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen *the significant environmental effects,* of such projects.. . (emphasis added).

2. Section 21080.5 (d) (2) contains very similar language:

> The rules and regulations adopted by the administering agency shall:
>
> (i) Require that an activity will not be approved or adopted as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen any *significant adverse impact which the activity may have on the environment* (emphasis added).

The latter section applies to environmental regulatory programs which have received certification from the California Secretary for Resources under section 2 1080.5. This section establishes the so-called "functional equivalency" procedure exempting certified programs from CEQA Environmental Impact Report requirements (though not from CEQA's policy directives). The Forest Practice Act was certified in January, 1976.

In sum, CEQA includes cumulative effects among the significant environmental effects that, under both the general policy and the functional equivalency sections, the administering agency is required to avoid or mitigate to the degree feasible.

The Board has attempted to provide guidance for Registered Professional Foresters and the Department with respect to the duties imposed by CEQA through the Board's "feasibility analysis" regulations ( 14 Calif. Administrative Code sections 898-898.2). "Feasible" is defined as:

> .. capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social and technical factors. With regard to economic feasibility, the issue shall be whether the plan as revised could be conducted on a commercial basis within 3 years of the submission of the plan and not solely on the basis of whether extra cost is required to carry out the alternatives (section 895.1).

For each Timber Harvesting Plan, the Registered Professional Forester is to carry out an examination, which need not be in writing, to determine if the plan as proposed would result in a "significant adverse change" in a number of listed resource values. including soil and water quality, fisheries and, again listed separately, "watershed." The analvsis is then to consider whether there are alternative operating methods and procedures that would lessen the impacts and whether such alternatives are "feasible," as defined. The THP is to "incorporate the results" of a feasibility analysis and the Director is to disapprove plans that "do not reflect the results of a feasibility analysis.. ." by including alternatives that substantially lessen significant adverse impacts.

Cumulative effects, as noted earlier, are a category of significant effects on the environment under CEQA and thus should be considered in the course of the feasibility analysis, if the directives of sections 2 1002 and 2 1080.5 (d) are to be met.

## Some Possible Responses to the Problem

It is one thing to establish that cumulative effects should be addressed and quite something else to decide what to do about the problem. Four alternative approaches have been identified. These alternatives are not mutually exclusive, but could, in some instances, be used concurrently. Other approaches may also be appropriate. The first two alternatives were recommended by the California Department of Forestry to the State Board of Forestry for its consideration in December, 1976.

A first (and minimal) step would be to authorize or direct the Department of Forestry explicitly to take cumulative impacts into account in the analysis of THP's.

This step would bring the review of THPs closer to conformance with CEQA, Section 208 and the Forest Practice Act itself and give review team members the latitude to review THPs more critically where several plans are known to be concentrated in the same watershed.

It would also provide a new incentive for landowners to take an interest in the degree to which timber harvest on neighboring lands in the same watershed might add to cumulative effects. A drawback of this approach is that, in the absence of specific instructions from the State Board regarding methodology and scope of cumulative effects assessment, it might be applied unevenly. If this approach were adopted, the Board should also adopt general guidelines with respect to the geographic scope of the inquiry and activities of concern.

A second step would be to require that a submitter of a THP include notification of future THPs in the same watershed. This would require a clear definition of a "watershed" and the future time period. The size limits mentioned in the Department's 1976 proposal were 320 to 30,000 acres and a period of three years, although a longer time period would be hydrologically advantageous. This approach would allow the Department to develop a watershed file over a period of years, which would ultimately facilitate a review of cumulative effects.

The CEQA definition of "cumulatively considerable" effects quoted earlier includes "the effects of probable future projects" (PRC sec. 2 1083). Even apart from the statutory requirement, acting only on the basis of past THPs may have some practical drawbacks. Theoretically, when the overall effect of all past and current plans is deemed to be excessive, the "last in line"-that is, the next to be proposed, could be denied or conditioned. This approach, however, amounts to a "brinksmanship" strategy which limits options open to both the submitter of subsequent plans and the Department. When the "last" plan comes along, the choice may be to either deny the plan or to approve it and accept additional impacts. If the "last" and subsequent plans were planned for and evaluated earlier, conditions imposed upon earlier plans might permit the spreading out of effects sufficiently to enable continued approval of plans. Perhaps more likely, pressures for continued timber supplies might lead to approval of plans beyond the point where cumulative effects are considered excessive. In view of these unhappy choices, the alternative of attempting to obtain information concerning future plans appears worthy of further analysis.

A third alternative would be to consolidate multiple THPs of a landowner in a single watershed into one plan spanning a time period of' five to ten years. The review of the plan could then take into account more geologic and hydrologic information than is presently considered in the review of a single plan. A separate THP review scheme would probably be required, with longer time frames for review and more regional data concerning soil, water, and wildlife conditions. Legislation would probably be necessary for such an approach to be adopted. It would have maximum utility, of course, in watersheds in which timber operations are conducted by a relatively small number of large owners. In such cases, several long-term plans might together provide a watershed planning mechanism. The approach would be least helpful in urbanizing watersheds with numerous small ownerships. Care should be taken that a one-stop comprehensive environmental review not overlook site-specific issues on each proposed operation that would otherwise be addressed in individual THP reviews under the present system. This option might reduce the paperwork and uncertainty of the plan-by-plan review. but would have to be designed to retain enough flexibility to allow harvest levels to fluctuate with market conditions.

A fourth alternative would entail the development of "watershed information systems," including information on geologic and hydrologic variables and past and future timber harvest plans and other land management activities. Such information could be organized along watershed lines and then be available as a reference tool for individual THP reviews. Considerable information is probably available in county and Regional Water Quality Control Board offices, and could be made accessible for THP reviews. This approach could be taken further by acquiring necessary additional data to enable a more systematic overview of the impact of timber harvesting and other activities within a watershed. Watershed information systems could be developed on a selective basis to first address areas where cumulative effect risks are greatest or where non-timber resources are particularly valuable. The information systems might make use of the rapidly developing techniques for computer processing of geographic data, some of which are already being used by the U.S. Forest Service (Nagy and Wagle 1979). Watershed studies might also be combined with the longer-term multiple THP proposal noted above. That is, longer-term THPs might only be available in watersheds for which a watershed information system has been completed.

The benefit of this approach is, of course, that it provides the best and most usable information upon which to evaluate impacts of timber harvesting, both with respect to on-site effects and cumulative off'-site effects. The drawback is the expense of doing the work and the time required to complete it. Also, several practical problems are likely to emerge. These include obtaining landowner cooperation, allowing for changes in landowner plans in response to changing market conditions, and taking into account changes in urban areas included within a watershed.

## Summary and Conclusions

In this paper, we have concentrated on the cumulative hydrologic and water quality effects of timber harvest activities in watersheds. We chose to do this because of the existence of a single agency with responsibility for dealing with these impacts. The actual impacts in many watersheds, however, include not only the impacts of timber harvest activities, but also the impacts of highway construction, second home subdivisions, grazing, agriculture, water diversions, and mining. No regulatory mechanism or authority exists for taking into account all of the multiple activities on private lands in a watershed, some of which may far outweigh timber harvest activities in their hydrologic impacts. Some of these activities are regulated at the county level, some at the state level, and some not at all. Extending the evaluation of cumulative effects beyond silvicultural activities would be highly desirable. The information requirements for approving or disapproving a given proposal include the same basic information on resource values, geology, hydrology, soils and vegetation, as well as a record of past and planned activities in the same basin. Watershed information systems developed to improve regulation of timber harvesting could be readily adapted to the needs of local government and water quality regulatory agencies.

A major unanswered question concerning the cumulative watershed effects of silvicultural activities concerns the persistence of the associated erosion, sedimentation, and fish habitat destruction. Examples may be found in the literature of both short-term recovery of normal sediment yield (within three to six years after harvest) and persistence for decades or possibly centuries. There are no quantitative models for estimating the recovery time. If the impacts are relatively short-lived, then it makes sense to mitigate them by dispersing timber harvest through space and time. If they are relatively long-term, then emphasis should be placed on preventing them in the first place. Both the magnitude and persistence of'the impacts are affected by the timing of' future storm events. Since the frequency distribution of storm size is usually unknown, the regulation of forest practices for water quality and erosion control must proceed in the face of considerable uncertainty.

Cumulative off-site effects of silvicultural activities are a problem in some watersheds, and present law in California requires that they be considered in the evaluation of timber harvest plans. Because of the extreme variability in watershed characteristics, the best approach in the long run appears to be some form of collaborative state-private planning, based on a detailed assessment of geologic and hydrologic variables in specific watersheds. Whether or not such a reform will result from present water quality planning programs remains an open question.

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