Erosion on Logging Roads in Northwestern California: How Much Is Avoidable?

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ABSTRACT-A study was made on 344 miles of logging roads *in northwestern California to assess sources of erosion and the extent to which road-related erosion is avoidable. At most, about 24 percent of the erosion measured on the logging roads could have been prevented by conventional engineering methods. The remaining 76 percent was caused by site conditions and choice of alignment. On 30,300 acres of commercial timberland, an estimated 40 percent of the total erosion associated with management of the area was found to have been derived from the road system.*

Although studies have dealt with various aspects of road-related erosion, few provide an overall view of site conditions and management decisions that affect the degree and significance of the problem (Anderson 1954, Rice et al. 1972). Also rare in the literature is recognition that not all road-related erosion is preventable. As Fredriksen (1963) points out, "Even a fully benched road inevitably upsets the balance of forces within the soil mantle. A decision to build a road in an area of unstable topography constitutes a calculated risk no matter how well the road is designed and constructed to minimize damage."

In 1976, we inventoried 344 miles of logging roads in northwestern California. We looked at the effects of site variables on erosion, erosion on various standards of roads, and the extent to which road-related erosion is preventable. We also investigated about 30,300 acres of commercial timberland to gain a perspective on the sources and amount of erosion coming from a harvest area as compared with erosion on road rights-of-way.

Road Inventory

The inventory included 344 miles of roads in Del Norte, Humboldt, Siskiyou, and Trinity counties. Portions of the Coast and the Klamath mountain ranges were sampled. Both ranges are geologically young, with shallow soils and extensive fracturing in the underlying rocks. Characteristically rugged and steep, average slopes are about 44 percent. Study sites ranged in elevation from near sea level to 6,000 feet.

We divided each 1-mile road segment into fifths. At each 0.2-mile point we recorded slope, grade, aspect, cut-and-fill heights, and other site descriptions. Each major erosional event (one that had displaced more than 20 cubic yards of soil) on each 1-mile segment was recorded along with volume of soil displaced, possible causes, and other information similar to that which described the entire road segment. Smaller erosional events were measured on a randomly chosen 0.2-mile part of each 1-mile segment. The smallest event measured had a depth of at least 0.1 foot and a cross section larger than about 0.05 square foot. Soil samples from the random stretches were used to represent the soil conditions for the entire road.

Three road standards were considered. *Seasonal roads* are permanent or temporary, for use in the dry season only. They consist of a single lane, 10 to 14 feet wide, with turnouts and a surface of natural or thinly rocked soil. Some have drainage to accommodate the severe storm that hits the area about every 25 years. *All-weather secondary roads* are permanent and suitable for year-round use, of 12 to 16 feet drivable width, gravel or crushed rock of moderate depth, and drainage enough for the 25-year storm. *Main-haul roads* are permanent, all-weather roads, used as main collectors of traffic, with a drivable surface of about 30 feet. They receive regular maintenance, are heavily rocked or oiled, and have drainage to accommodate the 25-year storm. This class includes some low-standard county roads as well as those built by owners of timberlands. In Forest Service parlance, such roads are called "temporary," "local," and "collector."

We classified the cause of each major erosional event by one of three ways. *Naturally derived erosion* affected our measured road segment, but was not caused by the road itself (logging-caused erosion may have inadvertently been included in this class). *Unavoidable road-related erosion* could not have been prevented by normal engineering practices or by relocation of the right-of-way within the 1-mile road segment. *Avoidable road-related erosion* could have been avoided by better design or by modifications of alignment within the 1-mile segment. Whether an example of erosion was considered unavoidable or avoidable often depended on the road standard, because more elaborate engineering could be justified on higher standard roads. Also, because consideration of realignment was restricted to the 1-mile segment being studied, major events that could be avoided in actual practice by rerouting a longer section of road were classified as unavoidable when, in reality, they were avoidable.

Erosion

Slides accounted for more than 80 percent of the natural, and about 44 percent of the total, erosion measured (*table 1*). If some portion of the surface

Table 1. Average frequency and volume of erosion on 344 1-mile road segments in northwestern California. All values are per mile.

Type of erosion[a]	Road-related erosion		Naturally derived erosion		Total erosion	
	Events	*Yd^3*	*Events*	*Yd^3*	*Events*	*Yd^3*
Slide	0.179	82	0.032	201	0.211	283
Slump	.229	108	.015	12	.243	120
Debris flow	.006	7	0	0	.006	7
Earth flow	.009	8	.003	34	.012	42
Rock fall	.006	1	0	0	.006	1
Gully[b]	.015	16	.003	1	.018	17
Rills	---	4	0	0	---	4
Surface sloughing[c]	---	169	---	---	---	169
Total	.444	395	.053	248	496	643

[a]*Mass wasting types of erosional mechanisms are as defined by Varnes (1958).*
[b]*About one-half the gully erosion was not tallied as individual events.*
[c]*Surface sloughing is the almost planar retreat of cut-and-fill slopes because of dry ravel, minor rills, and small mass movements.*

sloughing were also considered mass wasting, the predominance of mass erosion over surface erosion would be even greater. As tabulated, minor — erosion-surface sloughing, rills, and gullies smaller than 20 cubic yards — contributed 28 percent of the total; large gullies, 12 percent; and mass wasting, the rest.

The overwhelming influence of a few large events was evident. Three mass movements contributed 85 percent of all the natural erosion and about 33 percent of the total erosion measured. That a few large events are responsible for so much erosion seems to be typical in northwestern California. In another study of erosion associated with timber harvest, Datzman's (1978) data were affected similarly by a few catastrophes:

Amount of road-related erosion increased with the slope traversed by the road (*fig. 1*). Fifty-one percent of the erosion measured was on roads that cross slopes of sixty percent or more. Such roads made up only 19 percent of the total amount of road studied.

We studied all of the major geologic types in northwestern California (*fig. 2*). Most erosive of all rock types were the hard sedimentary formations. The Franciscan, ultramafic, and soft sedimentary formations, often considered to be unstable, had relatively low erosion rates. The granitics ranked in the middle, probably because the sample was on a well-weathered batholith. Granitic soils in the intermediate stages of weathering are the most erosive and become more stable as clay minerals develop (Durgin 1977). The low erosion of the soft sedimentary rocks may have resulted from our inability to find roads on steep slopes in this rock type. The high erosion rate on hard sediments may be the result of a correlation between slopes and this rock type. Hard sediments have been found to have relatively high rates of erosion in logged areas (Dodge et al. 1976).

Heavily fractured areas were 2.7 times as erosive as those that were lightly fractured and yielded 3.8 times as much erosion as areas where no fracturing was observed in the parent rock (*fig. 3*).

The position of the road on a valley slope affected the amount of erosion (*fig. 4*). The variation in erosion rates probably resulted from the generally convex shape of watershed slopes in the study area. Steeper slopes and deeper soils are both likely to be found in the lower two-thirds of the drainage.

As soil displaced by road construction increased, erosion associated with the road tended to increase, especially where construction displaced more than 35,000 cubic yards per mile (*fig. 5*). All-weather secondary roads had the least erosion per mile of right-of-way (*table* 2). Differences in erosion related to road standard were, however, statistically significant only at the 8-percent level. Apparently, all-weather secondary roads represent a good compromise between design and construction costs and reduced erosion. Such roads have drainage structures comparable to main-haul roads, rock surfacing that seems adequate for their traffic volume, and an alignment that more closely conforms to the terrain than main-haul roads. All-weather secondary roads are also about half as wide as main-haul roads.

Seasonal and main-haul roads had about the same erosion rates per acre, but because of the main-haul roads greater size, they produced about 56 percent more erosion per mile (*table* 2). A higher erosion rate for the main-haul roads is to be expected because more soil is displaced in their construction, and their cuts and fills tend to be higher than those of lower. standard roads. That seasonal roads have the same erosion rate per acre as main-haul roads suggests' that seasonal roads are not actually being "put to bed"; rather, they are being abandoned and are eroding at a substantial rate.

We had little confidence in our information relating to the age of the road segments, but. we recorded the best information available. Roads in the 11-to-15 age group had by far the greatest erosion (*fig. 6*). This greater erosion may result from slides caused by the decay of stumps and other large woody material that were buried during road construction, or by construction practices

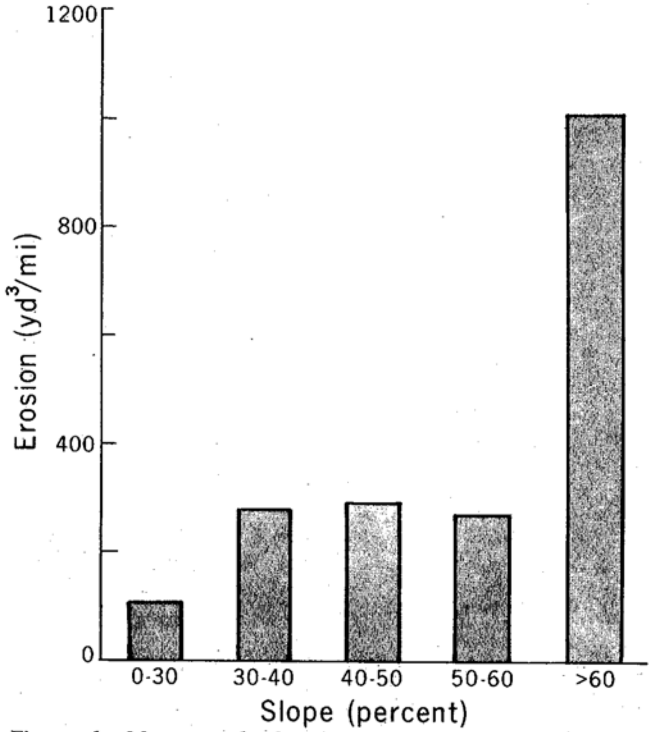

Figure 1. Mean road-related erosion in five terrain slope classes. Here and in figures 2 through 6 differences are significant at P<0.01.

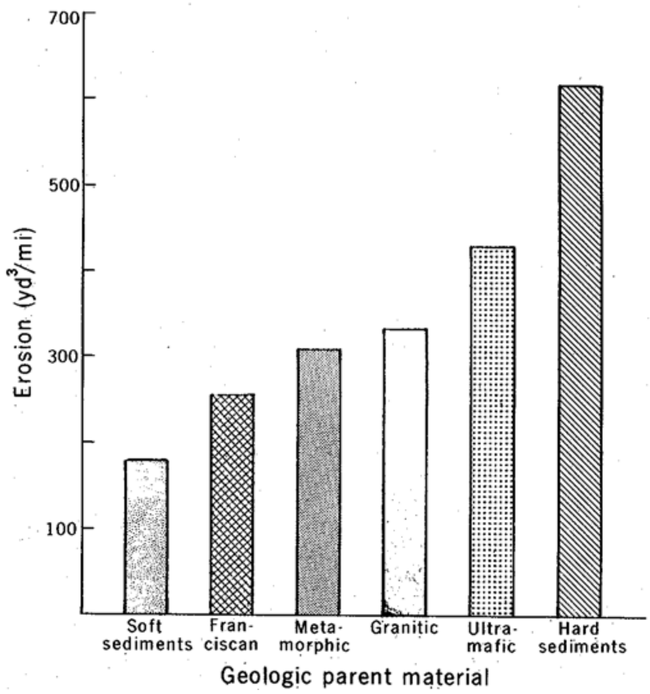

Figure 2. Mean road-related erosion from roads constructed on six geologic types.

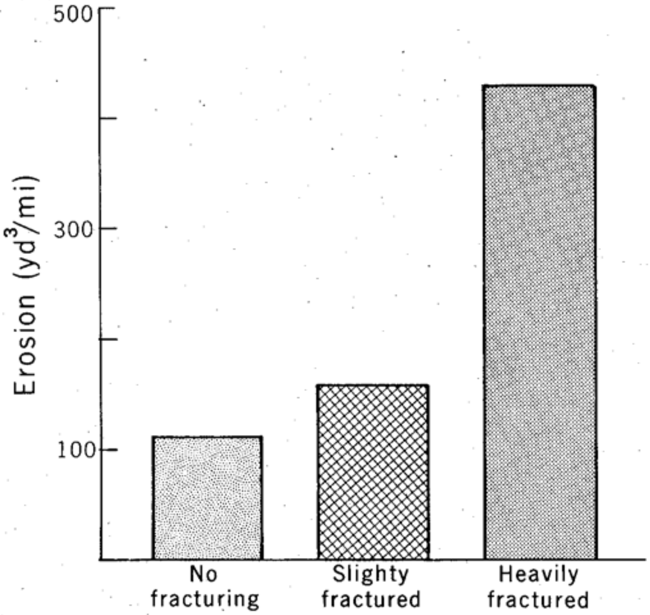

Figure 3. Mean road-related erosion as related to fracturing of geologic parent material.

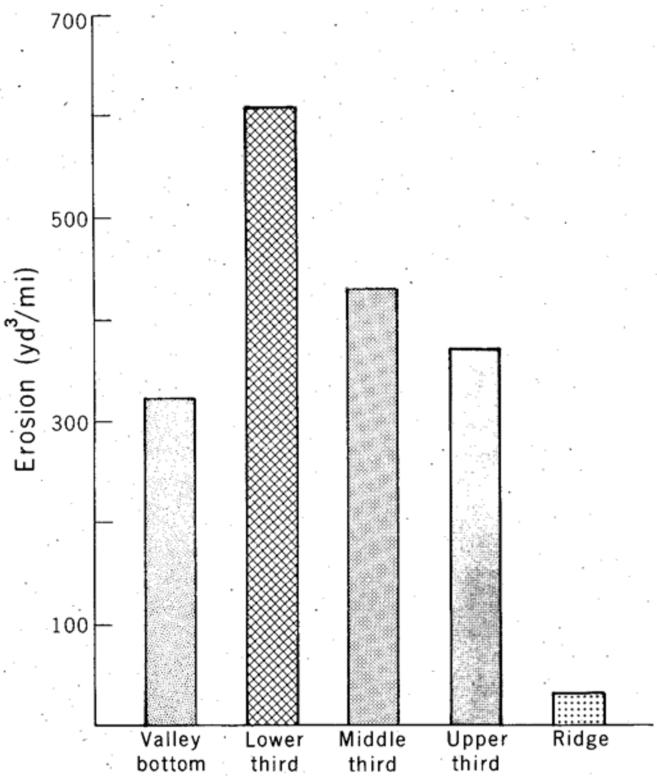

Figure 4. Topographic position of the road on a valley slope affected the amount of road-related erosion that occurred.

Table 2. Sources of erosion on an area of the Six Rivers National Forest, California.

Source erosion	Extent	Disturbance areas		Erosion rate	Erosion
	Miles	Acres	Yd^3/acre	Yd^3/mile	Yd^3
Logged area	0.0	29,115	2.82	0.0	82,104
Road system					
Main haul	33.7	208	73.2	455.2	15,339
Secondary	197.8	959	40.4	196.0	38,769
Seasonal	5.5	18	89.1	291.6	1,604
Total roads	237	1,185			55,712
Total		30,300			137,816

prevalent during the late 1950s, or by effects of the large flood in 1964.

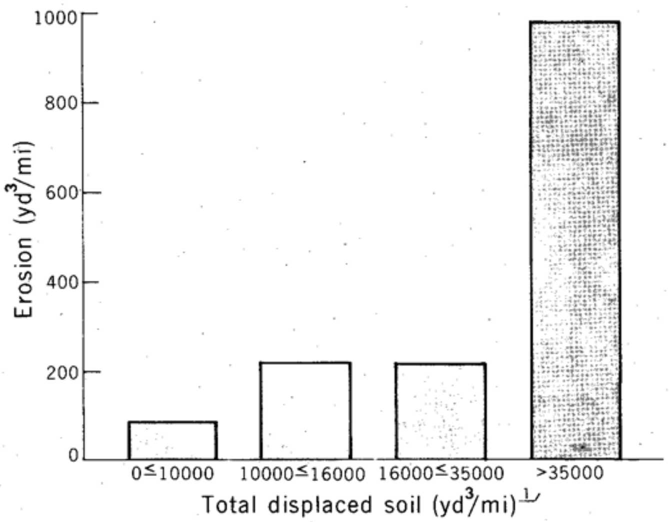

Figure 5. Mean road-related erosion associated with amount of soil displaced during construction. If construction were perfectly balanced, this figure would be twice the total excavation.

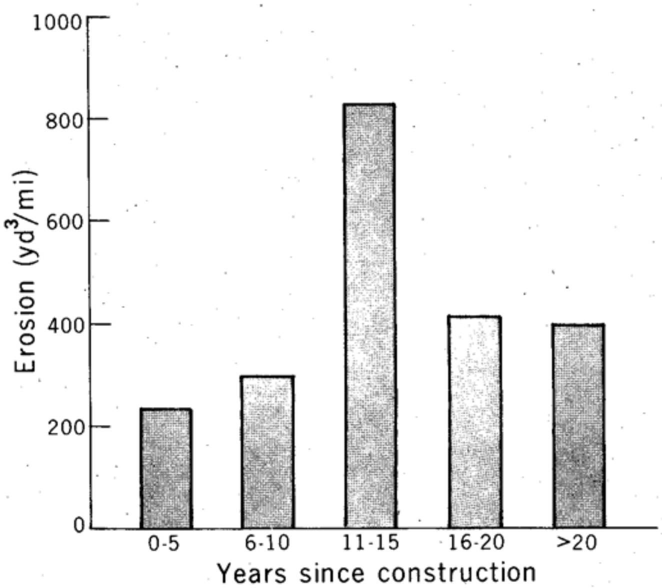

Figure 6. Erosion on roads of various ages in northwestern California.

Of 171 major erosional events, only 19 were not caused by roads. But those 19 yielded almost 40 percent of the erosion measured. Sixty-one percent of the remaining erosion was related to roads; fifty percent of the total was considered unavoidable, and eleven percent avoidable: The proportion of the road-related erosion considered unavoidable hinges, in good measure, on whether surface sloughing is felt to be unavoidable. We chose to consider it so because it was nearly ubiquitous in the roads we investigated. It is just this type of erosion, however, that is supposed to be prevented by conventional stabilization of cut-and-fill slopes. If surface sloughing were considered avoidable, the 61 percent road-related erosion would be apportioned as 24 percent avoidable and 37 percent unavoidable.

Sources of Erosion from a Harvest Area

About 30,300 acres of. commercial timberland in the Six Rivers National Forest were used to obtain a perspective on the proportion of erosion coming from harvest areas as compared with that from road rights-of-way. Sale areas with nearly complete road systems and representative topographic features were selected. A complete road system was compiled on orthophoto contour maps by adding the roads needed to harvest the remaining timber. Acreages of commercial timber were obtained by using a polar planimeter; road lengths were obtained with a map measurer.

The mapped road network was 237 miles long and occupied less than 4 percent of the total harvest area (*table* 2). Fourteen percent of the road mileage (eighteen percent of the road area) was in main-haul roads. All-weather secondary roads comprised 84 percent of the road mileage and 81 percent of the road area. Seasonal roads accounted for only 2 percent of the mileage and 1 percent of the area. From the road inventory we were able to estimate the amount of road-related erosion for each of the road standards. By using similar measuring techniques, Datzman (1978) found that 182 acres on 17 harvest areas in the Six Rivers National Forest yielded an average of about 2.8 cubic yards of erosion per acre.

Total erosion for the 30,300-acre area was about 137,800 cubic yards, or about 4.5 cubic yards per acre. Average erosion on the road rights-of-way was 47 cubic yards per acre, or about 17 times the average erosion in the timber harvest areas. Forty percent of the total erosion came from the road network, sixty percent came from the logged area. These percentages are remarkably similar to those estimated for the H. J. Andrews Experimental Forest (Swanson and Dyrness 1975).

To be comparable to each other, measurements of erosion on roads and logged sites should span a full cutting cycle. Our data, however, were from relatively new roads and harvest areas. On both roads and logged sites most of the erosion related to the disturbing activities probably occurred before the studies. Nonetheless, roads probably recover more slowly from initial construction than do timber harvest areas from initial cutting. The timber harvest areas will receive additional disturbances (and erosion) each time they are entered for intermediate cuttings. The proportion of harvest-caused erosion to that caused by roads would therefore be likely to increase in subsequent cutting cycles.

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