



Caspar Creek: Discovering How Watersheds Respond to Logging

Based on the research of Dr. Raymond M. Rice

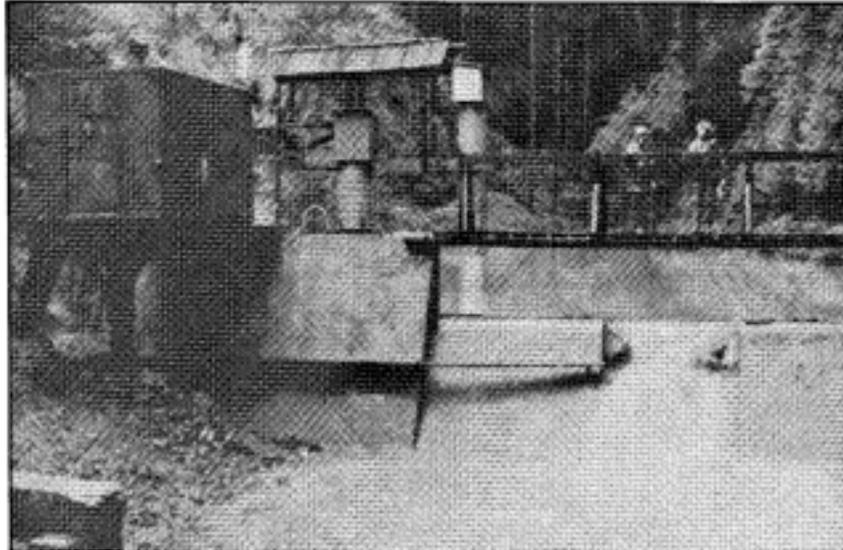
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Caspar Creek: discovering how watersheds respond to logging

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For the past two decades, researchers from the Pacific Southwest Station, in cooperation with the California Department of Forestry (CDF), have been studying the effects of logging on the integrity of northern California watersheds. Their findings have greatly illuminated the extent and nature of the hydrologic impact, erosion, and stream sedimentation for a northern California basin undergoing a "typical" logging operation.

But forest practices change, and along with them, the definition of what effects need to be measured when judging the impact of activities such as logging. That's why researchers at the Redwood Sciences Laboratory in Arcata, California and the California Department of Forestry, Jackson Demonstration State Forest near Fort Bragg, have launched a second study, this time using current logging practices and a design that should enable them to monitor cumulative, not just isolated, effects. It is hoped that, together, the two long-term investigations will give forest managers, public policy makers, and

Data recorded at weirs in the Caspar Creek drainage in northern California are showing effects of logging and roadbuilding on stream flow and water quality.

private enterprise an empirical basis on which to formulate sound logging practices.

Caspar Creek 1962-1976

Based on data from 1962 to 1976, researchers recorded changes in streamflow and sedimentation following roadbuilding and logging at Caspar Creek, located some five miles southeast of Fort Bragg.

Cooperation between CDF and the Station dates from 1962. It has been a fruitful division of labors, with CDF supervising the construction of research facilities, the collection of data, and the logging of experimental watersheds, and the Station designing the experiments and analyzing the data. Together, they have jointly decided upon which studies to undertake and have co-authored several research reports.

Calibrating and treating the watershed

"We started in 1962 with a typical watershed experiment," recalled Project Scientist Raymond M. Rice, during a recent interview. "It was what we call a 'paired watershed' experiment. In this kind of study, you install stream gaging stations in two drainages that are roughly comparable, and monitor both sediment and flow."

The two streams studied were the South and North Forks of Caspar Creek. Both watersheds support growths of redwoods, Douglas-fir, Grand-fir, and hemlock, and had been logged before in the late 19th century.

In the first study, the South Fork was logged using selective cutting procedures typical for that time. The North Fork served as a control.

After a five-year calibration period, logging roads were built into the South Fork area in 1967. The effects of roadbuilding were measured as local on-sight erosion, suspended sediment loads in the stream, and sediment deposited in debris basins. Logging commenced in 1971 and ended in 1973 with the same parameters measured throughout. In all, 60 percent of the timber volume of the South Fork watershed was logged.

Except for a major landslide in the North Fork and an earthen dam break during roadbuilding in the South Fork, Rice, who is a principal hydrologist with the Station, considers the results a paradigm for logging's effects on any Northern California watershed having similar climate, soil, and logging history.



(The winters in Caspar Creek are mild and wet. In the summer, coastal fog often clings to the watershed until late morning. Annual rainfall is 1190 mm (47 in) with 90 percent falling from October to April. Soil in the area is derived from hard, coarse-grained sandstone and shale, which has been deeply shattered and moderately weathered.)

Effects of roadbuilding and logging on sedimentation

Adjusting the data to account for the landslide and dam break, Rice and co-workers Forest B. Tilley (CDF) and Patricia A. Datzman (PSW) found that stream sediment increased 80 percent with roadbuilding and 275 percent with logging (USDA FS Research Paper PSW-146, 1979).

The entire South Fork watershed was tractor yarded between 1971 and 1973.

The researchers observed that most sediment was carried during relatively short periods of high flow. In fact, 81 percent of suspended sediment was transported by flows exceeding 1.23 m³/s (45 ft³/s). Flows of this magnitude or greater occur only 1 percent of the time. Recognition of this sediment transport to flow relationship led Rice to concoct the variable SQ_{25} as an index of the stream's ability to transport sediment; SQ_{25} is the mean rate of sediment discharge in ft³/s/mi² that is associated with the top 25 percent of flow volume.

"Most small, steep watersheds are supply dependent," Rice explained, "the water flowing out has enough energy to carry much more sediment than is available for transport. But logging and allied activities stir up the ground and make more sediment available for transport," he said.

Rice suspected that an undisturbed watershed would show only slight increases in suspended sediment loads as stream power increased, and a plot of the sediment/stream power relationship for the north fork of Caspar Creek during the years 1967-76 confirmed this, showing a slow-to-rise curve (Figure 1 a).

But when sediment enters the stream because of ground disturbance by road building or logging, sediment discharge increases rapidly with stream power (Figure 1 b "disturbance years"). In effect, Rice's data suggest that sediment discharge switches from being mostly "supply dependent" during undisturbed years to being more "stream power dependent" during disturbance years. With more sediment available for transport, sediment discharge becomes more strongly dependent on the ability of the stream to carry sediment.

The bottomline, of course, is that logging and, to a lesser extent, roadbuilding delivered more sediment to the Caspar Creek stream channels than was predicted on the basis of the calibration years.

Extrapolating from stream sediment rates, Rice estimated that if Caspar Creek were logged every 50 years or so, soil in the area would be totally exhausted in 33,900 years.

"That's a planning horizon much beyond what a forest manager needs to consider," quipped Rice. "However," he added in a serious tone, "there is certainly going to be some erosion price to pay when one goes into natural landscapes to take trees; its' just that the price should be prudent and weighed against the commercial benefits."

Effects on stormflows

Another possible consequence of roadbuilding or logging is destabilization of the stream channel because of more or bigger floods. Roadbuilding, even on a moderate scale, might be expected to increase peak stormflow by compacting road surfaces, which would reduce water infiltration, or by channeling water directly into the stream.

However, after reviewing 11 years of Caspar Creek flow data, Researcher Robert R. Ziemer found no change in any of several storm flow parameters measured following the period of roadbuilding in the South Fork. The absence of flow effects in Ziemer's data may be explained by the fact that roads occupied only 5 percent of the area. Selective timber cutting and tractor yarding were, however, also found to have no major hydrologic consequences.

Selective timber putting and tractor yarding were likewise found to have no major hydrologic consequences. By the conclusion of logging, about 15 percent of the watershed had been compacted by roads, landings, or skid trails. Streamflow peaks early in the winter increased three-fold after logging in the South Fork, but were small in magnitude. Storms occurring later in the season-even large ones-were not associated with any change in peak stream flow above the predicted levels. The flood peaks were the same height and the flood volumes comparable between the North and South Forks.

The study suggests that not only was logging relatively innocuous in terms of increasing flow, but further, that the building of skid trails and landings probably did not play a role in increasing even modest run-offs for, if they had, they should have measurably increased flow peaks throughout the year, not just in the fall.

Why did logging affect only Fall storms? Ziemer theorizes that the forested watersheds are initially drier than logged watersheds (trees use more water than no trees) and, therefore, have a greater capacity to absorb moisture. But as soon as soil in the unlogged watershed becomes as wet as that in the logged area, the two perform identically from then on.

In a separate review of the data from Caspar Creek, Rice and co-workers Karen H. Sendek and Robert B. Thomas, found that hydrographs (plots of run-off with time) were shifted forward in time after the area was logged. They found that although peak flows did not change much throughout the year, the logged watershed did respond more quickly to rainfall. "This finding agrees with published engineering studies of agricultural and urban watersheds," Rice said.

Average lag times from storm peak to flow peak decreased by 1.5 hours. Lag times associated with larger storms shortened by as much as 3 hours. The only storms to show an increase in lag time were those occurring early in the season. Since Ziemer had shown these Fall run-off volumes to be high in logged zones, Rice believes it is likely that it was the larger, broader hydrographs that yielded the longer lag times.



Logging roads will be built mid-slope, with cable yarding on the steeper lower slopes and tractor yarding on the gentler upper slopes.

"By creating skid trails, roads and other packed surfaces impervious to water, logging, overall, increases the rate of run-off," Rice said. He added, however, that since the hydrographs were moved forward in time but were unchanged in shape, logging "didn't seem to have an adverse effect on the watershed."

Rice acknowledged, however, that an unwanted impact might be occurring downstream where, for example, tributaries from logged and untouched watersheds join but whose peak flows are normally unsynchronized. After logging, flow at the junction of the two streams could become synchronized with flow effects summing. He noted that the opposite scenario is also a possibility: that synchronized effects downstream could become uncoupled and have some kind of a beneficial effect on lower reaches of the basin.

It's just such complicated interactions between different watersheds and logging activities that Rice and his colleagues are addressing in the second Caspar Creek study.

Caspar Creek: 1985-1994

For the second study the roles of the two watersheds have been switched. The now-stabilized South Fork will be used as a control while, in the North Fork, separate catchments will be clearcut, clearcut and burned, or left unlogged. As in the first study on the South Fork, 60 percent of the trees will be removed.

"The move to clearcutting reflects a change in silviculture practices," says Rice. "Foresters weren't getting the growth rates and regeneration they expected with partial cutting," he said.

Another difference will be the predominant use of skyline yarding to harvest trees. Less than 30 percent of the timber volume will be removed using tractors, and then only on gentler slopes. This change should lead to much less ground disturbance and soil compaction than occurred when the South Fork was logged.

As in the first study, researchers will be monitoring storm sediment discharge and stream flow parameters before, during, and after roadbuilding and logging. However, their study methods and equipment have been improved since the 1967-76 experiment. For one thing, statistician for the group, Robert Thomas, has been able to develop a new sediment sampling technique that yields very accurate estimates of sediment discharge.

"Past analyses of stream suspended sediment yields underestimated actual values by as much as 50 percent," Rice said.

Other improvements include the addition of 13 stream gaging stations, each under microprocessor control (waterlevel recorders provide back-up should the microprocessor fail or be damaged).

Just as logging practices and measurement techniques have changed since the sixties, so too have definitions of effects which are of interest to the public and the subject of regulations.

"This time," notes Rice, "The Caspar Creek study will be designed differently, owing to a number of legislative initiatives. Forest practice rules have changed substantially," he said.

The new requirements were placed on forestry by the National Environmental Policy Act (NEPA), and the Clean Water Act (PL92-500). The latter Act, passed in 1972, mandates the development of plans to reduce non-point source pollution from activities such as timber harvesting. NEPA directs governmental agencies to consider cumulative effects of pollution when assessing environmental impacts.

Cumulative effects

"A cumulative effect," explained Rice, "is when one acceptable activity interacts with another acceptable activity and produces something unacceptable."

As an example, Rice gives the hypothetical case of a factory that discharges organic pollutants into a stream at acceptable concentrations but when the compounds are taken into a water treatment plant downstream, they are converted into harmful chlorinated compounds in concentrations that exceed water-quality guidelines.

"It is conceivable that cumulative effects may occur in a watershed basin subsequent to activities like freeway construction, farming, or logging," Rice said.

In spite of sediment dilution over distance, Rice sees the possibility for adverse scenarios. For instance, it's possible that small, high-gradient watersheds subjected to logging might transport sediment to another stream with less power, where the sediment settles out, possibly lessening the quality of habitat for spawning fish.

In the new study, Rice and colleagues will be measuring sediment in watersheds where no activity is taking place, watersheds where a portion is being clearcut, and those with parts clearcut and burned.

"We will be testing the hypothesis that if there are cumulative effects, disturbance of a given proportion of an upstream watershed will have less impact than will the same proportion of disturbance to a larger downstream watershed," Rice said. "If the sediment delivery from one area is interacting with the sediment delivery from another and the effects are picked up downstream as a joint effect that's greater than would have been expected from analysis of a similar smaller watershed, then cumulative effects will have been demonstrated," he explained.

In addition to sediment changes after roadbuilding and logging, scientists will be looking for changes in the timing of storm run-off as well as possible effects on fish habitat and populations.

"We got our first year's data last winter. We'll get more calibration data in '87, '88, and '89 and then we will log the area and run the experiment for another four years or so to see how it's performing," Rice said.

Planned studies on fisheries

Concurrent to the cumulative effects studies, Fishery Biologist Lynn M. Decker will be studying the effects of logging on fish habitat and survival.

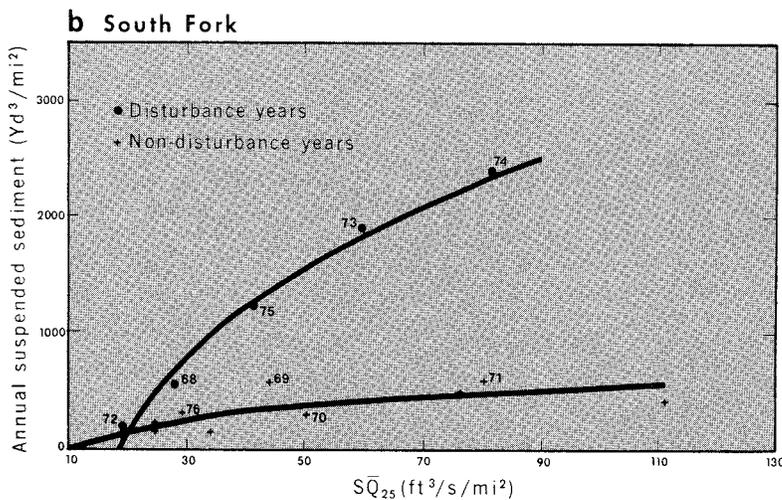
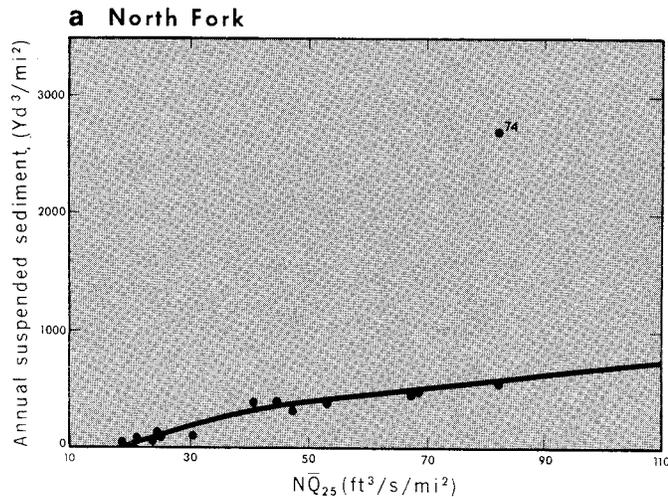
"The impact of logging on steelhead and salmon is an important issue and always has been," says Decker.

However, it's difficult to link directly the effects of watershed processes to fish survival because of the multitude of indirect physical and biological factors that can affect the number of fish produced and whether or not fish will reach the smolt stage. "How does one account for bad years in the ocean, or fishing pressure on what we see on-site in the stream?" Decker asks.

In an effort to answer this question Decker has introduced fish in equal numbers into both forks of Casper Creek and will watch how they respond to the habitat area and volume available to them before, during, and after logging.

"We are assuming that the fish at Casper Creek will stay or leave, depending on the quality of the habitat," Decker said.

One way logging could reduce habitat is by introducing large amounts of sediment into a stream. Pools could fill, reducing habitat volume. Alternatively, sediment could alter the quality of the stream bottom. "I've learned from some of my earlier work that coho salmon tend not to spend as much time in sandy bottom pools as they do in ones with coarser substrates," Decker said.



Annual sediment discharge of the forks as related to stream power as indexed by \bar{Q}_{25} (the mean discharge for the top 25 percent of the flow volume).

The effects of logging on fish survival may not be all detrimental, however.

"One of the direct effects of logging may be that trees get knocked into the stream channel and streamflow scours even more good habitats," Decker observed.

To follow the movement of fish in and out of Caspar Creek's two forks on a day-to-day basis, Decker has installed wire box traps to monitor upstream and downstream movements of fish in the study sections.

"At any point in time I will know the total number of fish in each of the creek's sections," she said. Fish numbers and survival will be correlated with sedimentation, hydraulic, and habitat data before, during, and several years after logging.

By the end of the Caspar Creek study in the middle of the next decade, there should be a sizeable quantity of data from which conclusions can be made regarding the short- and long-term effects that modern logging practices have on fish habitat availability and quality. Along with the findings on sediment discharge and flow effects, the research project promises to provide valuable new insights into the multifaceted, and often surprising, effects of man's removal of timber from forests. The most important of these may be findings related to cumulative watershed effects.

More details are available in *A Watershed's Response to Logging and Roads: South Fork of Caspar Creek, California, 1967-1976*, Research Paper PSW-146. Copies are available from the Pacific Southwest Station.