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# Debris Removal and Its Effects on Sedimentation in an Oregon Coast Range Stream

## Abstract

The removal of large organic debris obstructing anadromous fish passage in a Coast Range stream in Oregon accelerated downcutting of previously stored sediments. As a result, turbidity and suspended sediment levels increased during several storms after debris removal. Streamflow eroded more than 5,000 m$^3$ of sediment along a 250 m reach the first winter after debris removal. Therefore, fisheries managers who want to remove debris jams from streams must consider the stored sediments that will be scoured from the stream beds and deposited downstream.

8 YD$^3$/FT

3RD ORDER
2800 AC
7% GRAD.

## Introduction

In small forest streams, large organic debris—capable of deflecting or locally reducing streamflow velocities—significantly affects physical characteristics such as channel form and local stream gradients. This observation is particularly true in the Pacific Northwest where headwater streams draining forest ecosystems often have debris loadings of 0.3 to 7.4 metric tons (t) per 10 m of channel length (Froehlich, 1973).

Large debris can markedly influence a stream's ecosystem. Frequently, large stable debris provides diverse habitats for fish and other organisms. It may also slow the routing of fine organics through the stream system, thus increasing the opportunity for biological degradation. However, in other instances debris creates a physical barrier that prevents anadromous fish from passing to upstream spawning gravels (Swanson *et al.*, 1976).

Spatial distribution as well as total quantity of debris significantly affects channel characteristics. Debris accumulations reduce streamflow in a channel and can thereby reduce the rate at which a stream dissipates energy. Consequently, the sediment-transporting capabilities of individual stream reaches also are affected. For example, stored sediment can be readily seen upstream from debris in a channel system while pools form directly downstream.

Debris can accumulate from a variety of natural processes including active earthflows, soil creep, and blowdown. Slope failures may result in debris avalanches that cascade debris and sediment down a hill to be deposited within a channel system. As streams undercut their banks, sediment and streamside vegetation enter the channel. These processes also may be accelerated by forest operations, particularly clearcutting on steep, shallow soils and road construction in unstable terrain (Swanston and Swanson, 1976). In addition, forest operations often directly add debris to streams.

Fishery managers planning to remove instream debris dams face a difficult decision. They must consider not only how this action will benefit fish passage, but also how debris removal will change channels and the load of suspended sediments. Although rates of sediment transport can be expected to change after debris removal, the magnitude and rate of change often are unpredictable. The variability in amount and distribution of debris, channel characteristics, expected flow levels, particle size distributions, amount of stored sediments, and methods of debris removal all influence the final outcome.

In recent years, debris removal from headwater streams has become a tool used increasingly for meeting streamside management objectives. Yet the effects of debris removal seldom are documented. Consequently, this study (1) assessed the effects of debris removal on stream turbidity and sediment loads and (2) evaluated changes in channel geometry after debris removal.

### Study Area

In the early 1960s, roadbuilding and logging began in the Mill Creek drainage approximately 3 km northwest of Alsea, Oregon. During the flooding that occurred throughout much of western Oregon and Washington in 1964-65, several debris accumulations became established in Mill Creek. Logging subsequently continued in the Mill Creek drainage. Road construction and logging immediately adjacent to the stream increased the chances for organic debris to enter the channel. As a result, debris continued to accumulate from 1965 through 1974. By 1975, several large debris accumulations (Fig. 1) had formed along Mill Creek, blocking upstream migration of anadromous fish.

During the summer of 1975, these large debris dams were removed in conjunction with a timber sale in the Mill Creek drainage. Cable yarding was used to remove some debris, and other sections were cleared by tractors and hand crews.

The section of Mill Creek with the debris accumulations (Fig. 1)— characterized

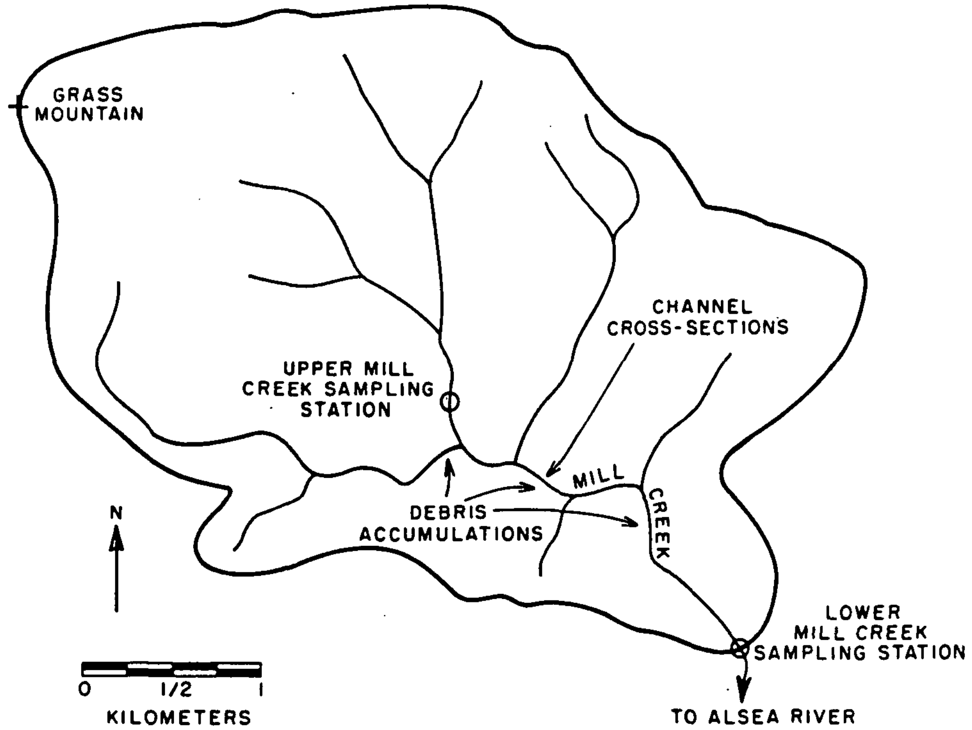

Figure 1. The Mill Creek drainage northeast of Alsea, Oregon.

as a third-order stream (Strahler, 1957)—has an average gradient of approximately 7 percent. The first- and second-order tributaries in this drainage have average gradients of 31 and 12 percent. Hill slopes adjacent to Mill Creek are steep and frequently exceed 75 percent. Elevations range from 150 m along the lower portion of Mill Creek to more than 1070 m on Grass Mountain.

## Methods

The movement of sediment in Oregon's Coast Range streams depends on periods of storm activity and high flows. Although streamflow was not measured in Mill Creek, flow measurements for the North Fork of the Alsea River—draining 163 km$^2$ of watershed immediately north and east of Mill Creek—were used to index flow activity in the Mill Creek drainage.

Turbidity and suspended sediment concentrations were monitored above and below the debris removal sites (Fig. 1). The drainage areas above the upper and lower sampling station were 4.5 km$^2$ and 11.5 km$^2$, respectively. Sampler intakes, suspended in midstream at each location by cables anchored to the creek's banks, led to automatic pumps that collected one sample bottle every six hours. Each bottle contained a composite of four subsamples collected at 1.5-hour intervals. Sample bottles were collected weekly from 5 November 1975 to 24 March 1976 except for several periods when equipment malfunctioned. Turbidity, expressed as nephelometric turbidity units (ntu), was determined for all samples according to *Standard Methods* (American Public Health Association, 1971). Samples were filtered to measure the concentration of suspended sediments, expressed as milligrams per liter (mg $l^{-1}$).

2800 ac

To assess changes in channel characteristics, ten cross-sectional profiles were measured along a 100-m section of Mill Creek (Fig. 1) that had been cleaned by tractor operations. This section of Mill Creek was characterized by gravel-size sediments (approximately 2-64 mm in diameter) that had accumulated behind the debris obstructions. Cross-sectional profiles were first measured in September of 1975 after the debris removal operations of that summer. The transects were remeasured in July of 1976 after the 1975-76 winter runoff period.

## Results and Discussion

From November 1975 through March 1976, daily stream flows on the North Fork (Fig. 2) approximated the average flow for the preceding 15 years (1962-76). Daily flows averaged 0.097 m$^3$sec$^{-1}$km$^{-2}$ or about 93 percent of the 15-year average for the November through March runoff period. A frequency analysis (partial duration series) of peak flows for the 15-year period indicated that the mean annual flood, with a recurrence interval of approximately 2.3 years, was 1.07 m$^3$sec$^{-1}$km$^{-2}$. During the 1975-76 winter runoff, discharge peaked at 1.02 m$^3$sec$^{-1}$km$^{-2}$ on 4 December 1975. Further comparison of flow duration curves indicated that the distribution of stream discharges during the five months resembled the average winter-flow distribution for the 15-year period. Thus, winter streamflow patterns, from November 1975 through March 1976, on the adjacent Mill Creek drainage probably typified nearly average conditions.

Upstream from the debris obstructions, substantial amounts of sediments had collected during the last 15 years. Removal of the large organic debris triggered localized scouring of sediment deposits. During summer and early fall of 1975, such channel changes were relatively minor. However, immediately downstream from the original debris obstructions, several pools began to fill in with silt and sand-sized particles.

In general, most channel erosion was associated with the high runoff in mid-November and early December (Fig. 2). Downcutting continued until large rocks and cobbles were exposed. The effect of this channel scour and downcutting was apparent in the sediment loads measured at the two sampling stations (Fig. 3). Between 12-15 November and 3-5 December, turbidities at the upper station never exceeded 30 ntu, whereas turbidities at the lower station exceeded 100 ntu. This increase was caused by scouring of the sediment previously stored in the channel. Crews continued to remove organic debris by hand from Mill Creek throughout November and December.

Most of the channel downcutting had occurred by 1 January 1976. However, during the mid-January storms, turbidity increased at both the upper and lower sampling stations. Although both locations had turbidities far exceeding 100 ntu, turbidities at the upper station generally were double those of the lower station. This figure indicated that these sediments came from above the upper station and that the turbidity was diluted as the sediments continued downstream. For example, grab samples taken on 14 January 1976 indicated that several tributaries had turbidities of only 5 ntu, while the upper sampling station had turbidities exceeding 200 ntu. The mixing of turbid water from above the upper station (drainage area of 4.5 km$^2$) with relatively clear tributary waters between the two sampling stations (another 7.0 km$^2$ of drainage area) would

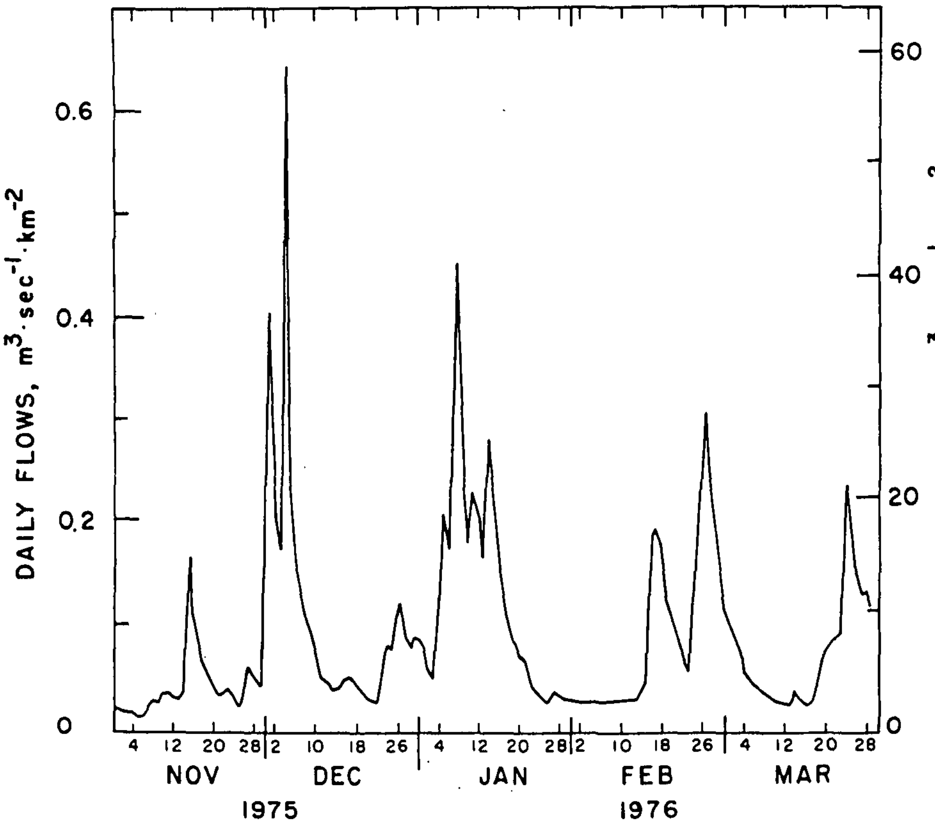

Figure 2. Streamflow for the North Fork of the Alsea River near Alsea, Oregon.

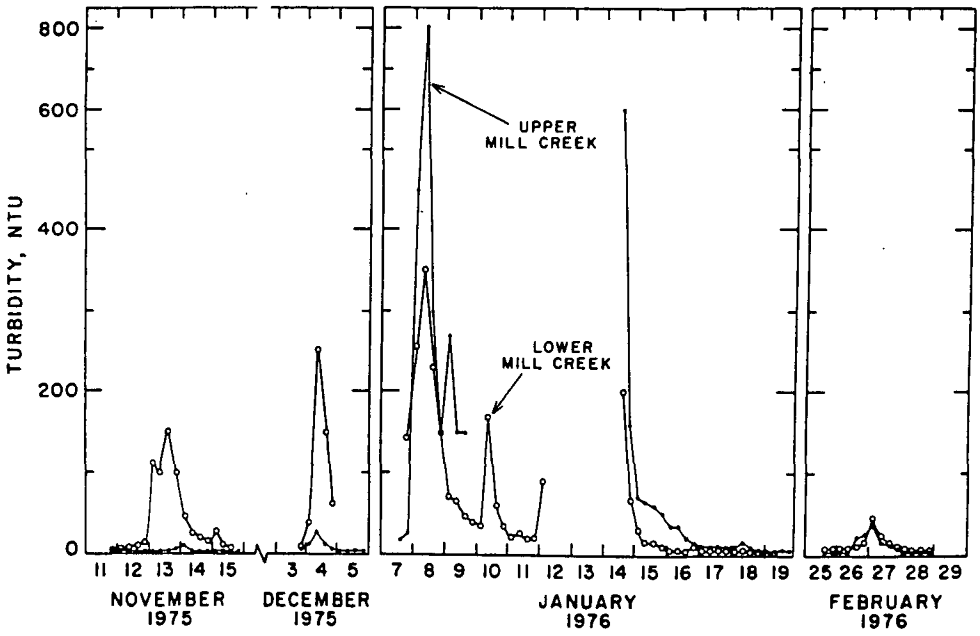

Figure 3. Stream turbidities in Mill Creek during periods of high runoff.

reduce downstream turbidities even though the total suspended sediment load remained relatively unchanged. Apparently that happened from 7-20 January 1976. Even if additional downcutting and scouring of sediments deposited behind the debris had occurred, the high turbidities originating above the upper station would have masked the effect on stream turbidities.

Following the high flows of mid-January, turbidity levels at both the upper and lower sampling stations responded similarly to subsequent storms and generally remained lower than those measured in mid-January. For example, although turbidities exceeded 200 ntu in the first half of January, subsequent turbidities at both the upper and lower sampling stations were always less than 200 ntu. During runoff from 25-29 February, turbidities at the upper and lower stations did not exceed 50 ntu (Fig. 3), indicating that the channel system had again started to stabilize. Throughout the winter, turbidity between periods of high flow generally remained below 10 ntu at both sampling stations.

Simple linear-regression analyses showed significant relationships ($P=0.90$) between turbidity and suspended sediment concentrations for both the upper and lower sampling stations. Because the two regressions did not differ significantly (Draper and Smith, 1966), the data from both stations were combined. The relationship between suspended sediment concentration (SSC) and turbidity (ntu) for Mill Creek is:

$$SSC=(2)(ntu)+55 \qquad r^2=0.77$$

Thus, changes in turbidity associated with periods of storm-generated streamflow and debris removal also reflected changes in the suspended sediment loads of Mill Creek.

Cross-sectional profiles confirmed that substantial channel scouring had occurred during the 1975-76 winter (Fig. 4). Along the 100 m reach where profiles were

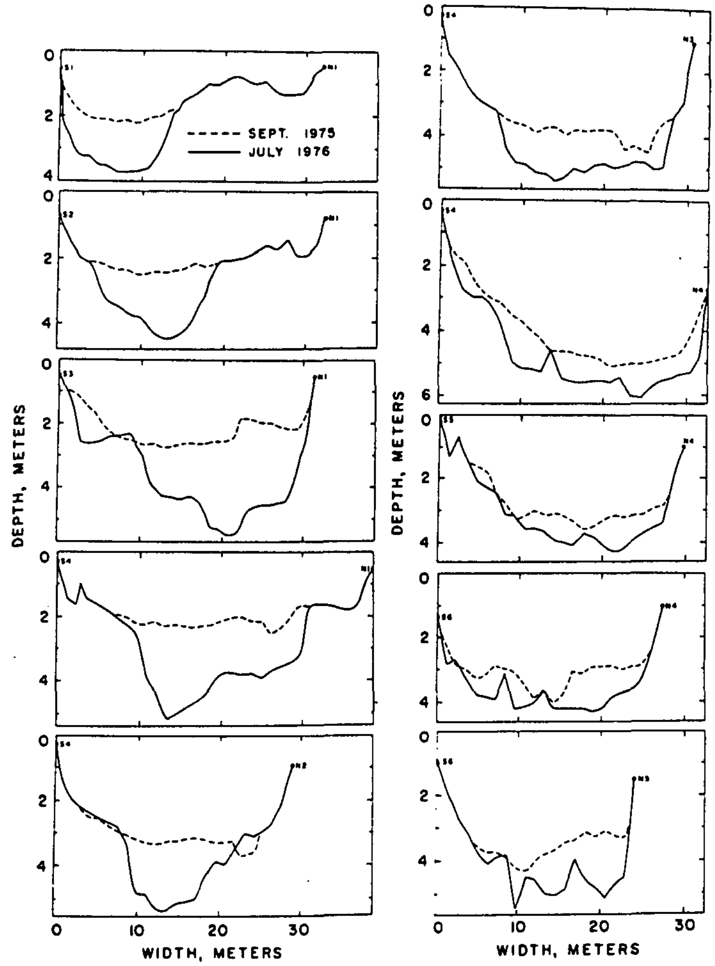

Figure 4. Cross-sectional profiles along a 100-m reach of Mill Creek stream channel. Cross-sections were spaced approximately 10 meters apart.

measured, Mill Creek underwent rapid downcutting. As a result, an average of 21 $m^3$ of sediment was removed for each meter of channel length. The depth of scour averaged 0.9 m, although maximum scour depths exceeded 2 m for one-half of the profiles. Assuming an average density of 1.8 t $m^{-3}$ (Gottschalk, 1964) for water-deposited sediments, stream action removed nearly 3800 t of sediment along 100 m of channel. These values typified an additional 150 m of channel directly upstream from the cross-sections.

The bottom of the stream channel is now characterized by relatively coarse sediments (e.g., cobbles and boulders). Further downcutting probably will not occur, although lateral cutting from unstable banks on Mill Creek may cause additional sediment loading into the stream.

## Summary and Conclusion

This study to quantify effects of debris removal on (A) stream turbidity and suspended sediment concentrations and (B) changes in channel geometry showed that:

(1) Turbidity provided an index of suspended sediment concentrations in Mill Creek;

(2) The greatest measurable increase in turbidity after debris removal occurred during the first several fall and winter storms;

(3) High flows in January were accompanied by high turbidities from upstream sources, thus masking any increases associated with the removal of debris;

(4) Relatively low turbidities occurred during late winter and spring storms, both above and below the debris removal section, possibly indicating that fines were quickly flushed from the watershed; and

(5) Downstream impacts should be considered in assessing trade-offs associated with debris removal and increased sedimentation. High flows during the 1975-76 winter significantly degraded sediments that had previously accumulated behind several of the debris dams. An estimated 5250 $m^3$ of sediment eroded from 250 m of channel, and the fate of this material is unknown.

A relatively large volume of sediment that had accumulated behind several debris dams during the previous 10 years was quickly eroded by fluvial action after the removal of large organic debris. Although the results represent a case study of one stream during one year, they nevertheless suggest what might be expected under similar conditions in other drainages of Oregon's Coast Range.

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