Oct 1984 1202

Removal of Woody Debris May Affect Stream Channel Stability

Robert E. Bilby

ABSTRACT-Sevveral western states mandate the removal of logging debris from streams in order to prevent accumulations impassable to anadromous fish. Monitoring a small western Washington stream revealed large changes in channel structure during the first high flow after cleaning. Nearly 60 percent of the monitored pieces of debris moved during this stormchannel crosssections were substantially altered by movement of stored sediment, and the number, area, and volume of pools decreased. The degree of channel rearrangement was greater than in a comparable undisturbed stream. Subsequent storms caused much less debrismovement and channel change than the first high flow, even though some of the later flows were of greater magnitude. An interim guide to stream cleaning is precribed.

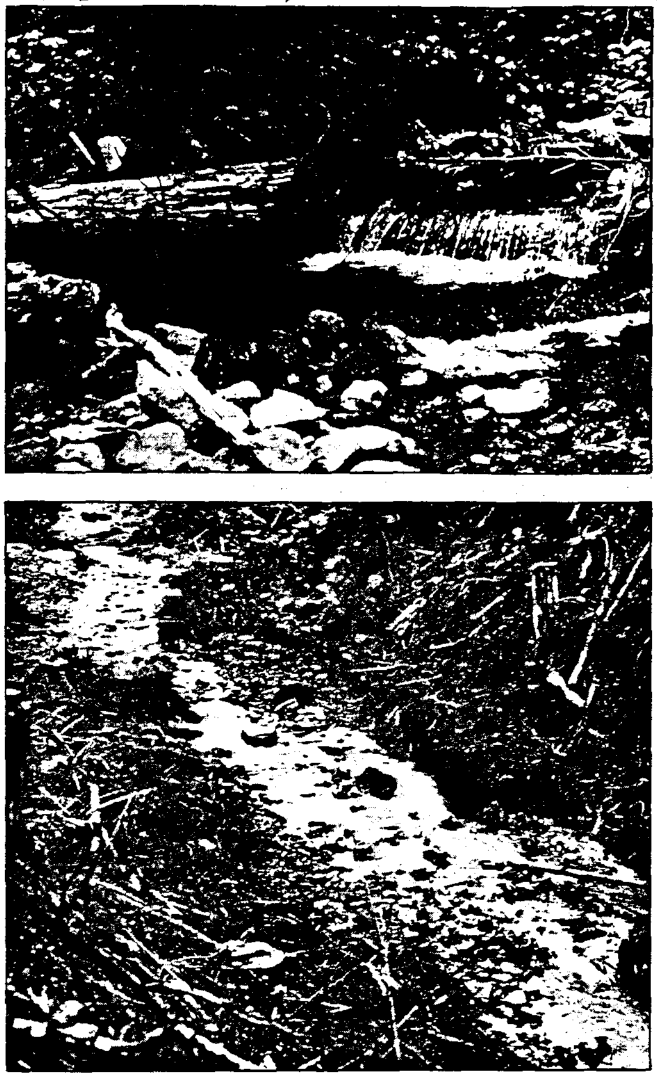

Figure 1. Top - Salmon Creek before logging. Bottom - A stretch of the creek after channel cleaning.

Large woody debris in the channel influences both the physical and biological processes occurring within a stream. The influence on channel morphology and the routing of sediment has been amply demonstrated. Woody debris also traps organic matter, such as leaves and needles, which often forms a substantial portion of the energy base of a stream (Fisher and Likens 1973). In first-order streams in central New Hampshire, for example, 75 percent of the organic matter larger than 1 mm in size was associated with accumulations of woody debris (Bilby and Likens 1980). This value decreased to 58 percent in second-order streams and 20 percent in third-order streams as the frequency of debris accumulations declined.

Debris forms an important component of cover for fish (Lewis 1969). In an Alaskan stream, the population of Dolly Varden char decreased 80 percent after debris removal, presumably because of the loss of suitable cover (Elliott 1979). Anadromous fish may also be influenced by debris when it blocks access to spawning and rearing habitat.

In undisturbed ecosystems, woody debris enters streams ina random fashion, usually as a result of windthrow. Pieces which have recently entered may deflect water, causing localized destabilization of banks or bed (Zimmerman et al.1967). Debris entry ordinarily is rare, and thus the channel changes are of limited extent. In some instances, however; such as catastrophic blowdown, a long reach of stream channel may be affected.

Since logging may increase the amount of woody debris in channels, regulatory agencies in Washington and Oregon currently mandate stream cleaning during or after timber harvesting. Justasnew debris can destabilize a channel, so can the removal of old debris around which the channel has equilibrated (Bilby 1981). While the guidelines in both states stipulate that such older debris be left in the stream, identification of this material is sometimes difficult and often some of it is removed. Even if an old piece is left, it is very often altered by bucking or notching for fish passage.

This article describes changes in channel morphology and the movement of woody debris after logging and subsequent channel cleaning in a stream in western Washington. In addition, the characteristics of those pieces which remained stable after cleaning were determined.

Instream Measurements

The stream was Salmon Creek (fig. 1), a fourth-order tributary to the Chehalis River in the Coast Range of Washington; Salmon Creek drains a watershed of approximately 900 ha. Some of the headwater areas were harvested about 25 years ago, but the lower watershed, including the 600m section studied as the basis for this article, was unlogged prior to 1980. Salmon Creek contains native cutthroat-trout (*Salmo clarki*) and sculpins (*Cottus* spp.) as well as occasional steelhead (*Salmo gardneri*) and coho salmon (*Oncorhynchus kisutch*) in the lower reaches. The section studied has an average bankful channel width of 11.5 m and an average gradient of 1.5 percent.

The section bordering the study reach was logged during the late winter and early spring of 1980. During the summer, the channel was cleaned in accordance with the state forest practice regulations (Washington State Forest Practice Board 1976). Debris was bucked into pieces small enough to be moved by hand and piled along the bank. Many of the large pieces left in the channel were notched or bucked, or had gaps cut in them, to facilitate the upstream movement of fish. Seventy-four remaining pieces were tagged and monitored throughout the winter of 1980–81. Approximately equal numbers of pieces were tagged in each of four length and four diameter classes.

Data on each tagged piece included the diameter and length, degree of anchoring or burial (including keying of the ends of the log into the banks and the extent of burial of the upstream face of the log), and distance to established stream bank reference markers.

After each high flow during the winter of 1980-81 the tagged pieces were relocated and their positions remeasured. Since high flow carried some out of the study section, 500 m of stream below the study reach were examined on each relocation date. Approximately 20 percent of the tagged pieces of debris were lost over the winter, being either carried out of the monitored area or buried somewhere on the study reach.

Changes in channel configuration were monitored over the winter by two independent methods. Ten channel cross sections were installed during June 1980. These were remeasured in November 1980, after the first high flow following the channel cleaning and again in January 1981, after very high flow during late December 1980. In addition, detailed maps of channel configuration were drawn for a 225m stretch of the study section in July 1980, mid-December 1980, and January 1981 (Bisson et al. 1982). These maps indicated the frequency, area, and volume of pools and riffles and differentiated between pools formed by woody debris and those associated with other channel features.

The degree of channel rearrangement occurring on Salmon Creek during this period was compared with that on a 260m undisturbed headwater section of Fall River, another coastal stream approximately 30 km north of Salmon Creek. This section of Fall River is similar in size and morphology to Salmon Creek, draining approximately 1,400 ha. Channel width averaged 7.6 m and gradient 1.6 percent. Nine cross sections were measured in fall 1980 and again in spring 1981. The stream was mapped in summer 1980 and again in December 1980.

To monitor streamflow on Salmon Creek, a gaging station was constructed just upstream from its mouth. A water level recorder provided a continuous record of discharge. Peak flows, which were of primary importance in this study, were quantified and the resultant debris movement or channel changes interpreted in relation to their magnitude.

Movement of Residual Debris

The most extensive debris movement observed in Salmon Creek during the winter coincided with the first period of high flow after cleaning, when nearly 60 percent of the tagged pieces moved (*fig. 2*). This storm was not particularly severe, its discharge peaking at 6.76 m^3/s. In contrast, storms producing flows of similar magnitude in late November 1980 and mid-February 1981 induced movement of 10 percent or less of the tagged pieces. A large storm of

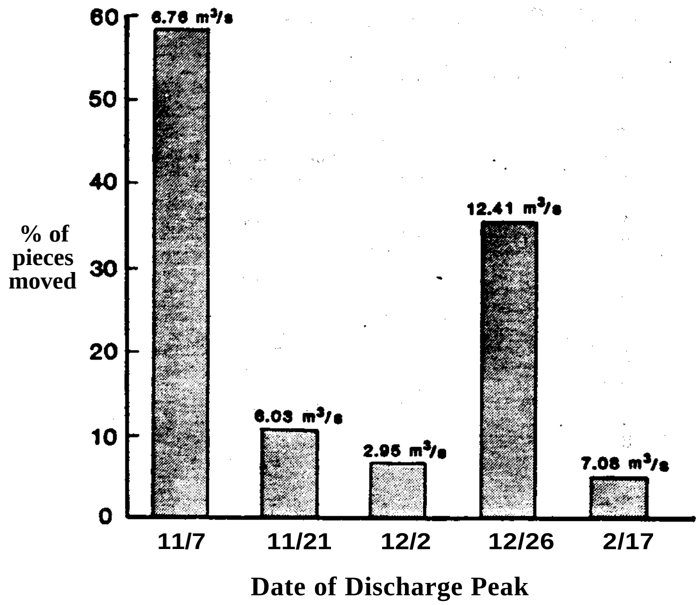

Figure 2. Percent of marked pieces of woodydebris which moved during each high flow period on Salmon Creek during winter 1980-81.

December 26, 1980, resulted in the highest peak flow of the winter. The discharge on this date was 84 percent higher than the initial period of high discharge on November 7, and had a calculated return interval of about 7 years. About 35 percent of tagged pieces moved as a result of this storm.

The debris movement during the November 7 storm was in large part caused by the cleaning. Movement of pieces, or modification of their influence by bucking or notching, altered flow patterns and in turn moved other debris that previously was in stable locations.

Debris moved downstream until it was deposited in a stable location, generally either on the streambank or against some channel obstruction such as a bedrock outcrop, boulders, or other debris. Pieces thus deposited remained in place through lesser discharges of November 21 and December 12.

The flow on December 26 was considerably higher than that on November 7 and some debris that had been stable at lesser flows was moved again. The deposition during this storm was presumably in locations resistant to movement' at lesser flows. Indeed, the high flow during mid-February 1981 had very little influence on the debris.

Changes in Channel Form

The first high flow during winter 1980-81 also modified the channel by triggering scour and fill. During the large December storm substantial additional scour took place as sediments released by the channel cleaning began to move. Reaches downstream from the study section probably experienced a cycle of fill and scour as the wave of material migrated.

The net changes in the channel cross sections on Salnion Creek over the winter of 1980-81 are shown in *table 1*. The general pattern is a scouring and lowering of the bed, probably due to the removal or alteration of debris that was retaining .sediment. By comparison to Fall River, the difference in bed elevation change over winter 1980-81 is striking- Beds changed an average of 25.4 cm per cross section in Salmon Creek but only 3.3 cm in Fall River None ofthe Fall River cross sections changed more than 9

Table 1. Cross-section changes 1980-81. Negative numbers indicate scour, positive numbers indicate fill.

	SALMON CREEK			FALL RIVER	
	CHANGE IN BED ELEVATION				
Cross section	June-Nov. 14, 1980	Nov. 15, 1980-Jan. 11, 1981	Net 1980-81	Cross section	Change in bed elevation, 1980-81
	Cm				Cm
1	11.11	-7.41	3.70	1	0.0
2	.0	-13.61	-13.61	2	-8.19
3	-20.50	17.46	-3.04	3	2.37
4	29.38	-4.90	24.48	4	-8.67
5	37.50	-14.20	23.30	5	.0
6	-8.73	-16.21	-24.93	6	1.67
7	-11.11	-24.44	-35.55	7	-1.36
8	-14.20	-65.99	-80.19	8	6.11
9	.0	2.74	2.74	9	-1.15
10	1.16	-27.91	-26.75		
Average[a] elevation change per cross section	14.19	19.43	25.41		3.28

[a]*Average elevation change values include both scour and fill numbers as positive values.*

Table 2. Changes in channel morphology during winter 1980-81, as determined from maps made on the indicated dates.

	SALMON CREEK			FALL RIVER	
Item	7/17/80	12/12/80	1/6/81	6/24/80	12/19/80
Number of pools	29	17	19	22	24
Pools eliminated since last mapping	—	17	3	—	2
Pools formed since last mapping	—	5	5	—	4
Percent of pools formed by debris	86	77	79	73	71
Percent of stream area in pools	50	32	39	70	74
Percent of stream volume in pools	72	46	63	85	87
Number of riffles	33	26	31	16	14
Riffles eliminated since last mapping	—	12	10	—	6
Riffles formed since last mapping	—	5	15	—	4
Percent of stream area in riffles	50	68	61	30	26
Percent of stream volume in riffles	28	54	37	15	13

cm over the winter, while Salmon Creek showed changes in excess of this on 8 of 11 cross sections and exhibited 80 cm of scour on one cross section.

Comparison of the July 1980, December 1980, and January 1981 channel maps of Salmon Creek also showed major changes over the winter of 1980-81 (*table 2*). The initial high flow reduced the number, area, and volume of pools. Seventeen pools were eliminated, either by filling or rerouting of the stream channel, and five new pools were formed. Of the 22 pools affected by this storm, 20 were associated with large woody debris. Concurrent with the reduction in pool number, area, and volume was a corresponding increase in riffle area and volume. Number of riffles decreased largely because pool elimination joined two or more previously separated riffles into one continuous riffle.

The intense storm of December 26 caused lesser channel changes than those observed during the initial high flow (*table 2*). Five pools were formed and 3 were eliminated. Of these 8 pools, 4 were associated with debris. The increase in number of pools was not sufficient to offset the changes caused by the initial high flow.

The importance of large pieces of wood in forming pools was apparent on this stretch of Salmon Creek. In July 1980, immediately after stream cleaning, 86 percent of the pools were associated with woody debris. Even after rearrangement of the channel by the winter storms, in excess of 75 percent of the pools were debris-related as were 24 of the 30 pools that were formed or eliminated over the winter.

Woody debris was also important on Fall River, forming or significantly influencing more than 70 percent of the pools on the study stretch. This debris was generally stable, with 2 pools eliminated and 4 formed (as compared with 17 pools eliminated and 5 formed on Salmon Creek during the early fall period of high flow). Riffles were less stable than pools on Fall River; during the initial period of high flow 10 were formed or eliminated as compared with 15 on Salmon Creek.

The major change seen on Salmon Creek as a result of channel cleaning and high flow was a reduction in the frequency of pools formed by woody debris. The alteration or removal of debris during the stream cleaning and the subsequent movement of the debris and sediment during the initial high flow after the cleaning eliminated many of the pools. Once the debris was deposited in stable locations and again began to function in control of flow, pools began to reform, as seen by the increase in pool frequency and area following the high flow of December 26. Additional periods of high flow may cause a further increase in pool frequency as the stream equilibrates with the remaining debris. However, the overall reduction in the amount of large woody debris in this stream section may preclude complete reestablishment of the pool and riffle composition that existed before the cleaning.

Characteristics of Stable Woody Debris

The immediate effects of debris alteration or removal on channel stability could be reduced by minimizing changes to pieces that are determining channel morphology. Unstable debris, such as tree tops or branches which enter during logging, should be removed to lessen its accumulation in barriers that cannot be surmounted by anadromous fish. In

THE AUTHOR-Robert E. Bilby is an aquatic ecologist at the Weyerhauser Company's Forestry Research Center, Centralia, WA 98531.

defining what constitutes stable debris, this study indicates that size and degree of anchoring are the most important. The propensity of a piece to move during high flow was closely related to its length (*fig. 3A*). Pieces less than 2.5m long-moved readily while those longer than 10.0 m rarely moved. The long pieces were usually stabilized at several points along their length by stream banks or channel obstructions. Diameter of a piece also influenced the probability of its moving (*fig. 3B*). Pieces more than 50 cm in diameter moved much less frequently than smaller pieces, since deeper water was needed to float them.

Length of debris was inversely related to the distance traveled by those pieces which moved. Average distance moved was 129 m for pieces in the 0-2.5m class, 99 m for pieces from 2.6-5.0 m, 54 m for pieces from 5.1–10.0 m, and 11 m for pieces longer than 10 m. This relationship is likely caused by the increased chance a longer piece has for encountering an obstruction that will hold it in place. The diameter classes, however, showed no relationship to distance traveled. Movement averaged 110 m for pieces from 15-25 cm, 113 m for 25-50cm pieces, 106 m for 50–75cm pieces, and 106 m for pieces larger than 75 cm. Generally, the large-diameter debris that moved during the winter had been cut into short chunks.

The relative degree of anchoring or burial alsb influences the stability of debris (*fig. 4*). Pieces not anchored in the bed or banks were apt to move during high flows. Anchoring one end or the face of the log greatly reduced the probability of movement. Pieces having both ends and their upstream face buried in the stream banks and bed did not move.

Stream Debris Management Guidelines

This study demonstrated that indiscriminant removal of large woody debris has major short-term influences on channel stability. Loss in stability may have adverse effects on fish populations. To preserve channel integrity and maintain stream productivity, pieces influencing channel morphology should be left in place during cleaning. The study further identified features that contribute to debris stability in the stream channel. Knowledge of the size and other features common to stable debris in streams of various sizes and characteristics might provide the basis for managementguidelines designed to protect stream productivity better than do current procedures. As an interim measure, here are cleaning guidelines based on this study. It must be stressed that they are applicable only to streams similar to Salmon Creek. They refer to all debris impinging in any way on the channel, regardless of the proportion of the piece extending out of the stream.

Remove all slash (branches and tops) from bankful stream channel.

Do not remove pieces of debris conforming to the specifications in the key below.

Do not buck, notch, or move any pieces that will be left in the stream,

Debris Stability Key

(use as a dichotomous key starting with couplet 1):

1) a) Debris anchored or buried in the streambed or bank at one or both ends or along the upstream face--LEAVE.
   b) Debris not anchored--2.

2) a) Debris longer than 10.0 m--LEAVE.
   b) Debris shorter than 10.0 m--3.

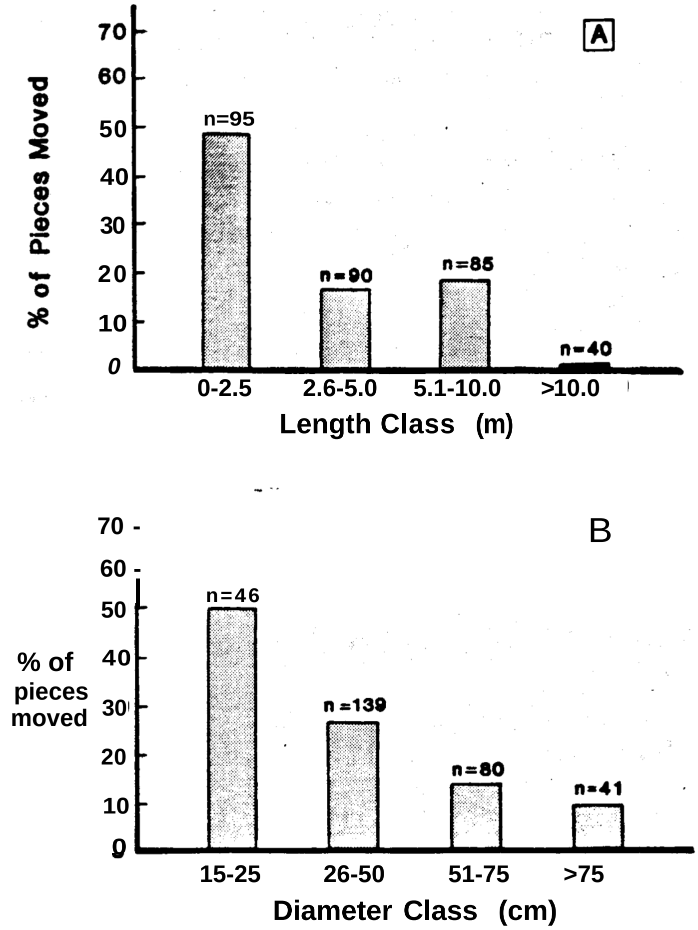

Figure 3A. Percent of the tagged pieces of debris which moved during winter 1980-81 on Salmon Creek as related to length of the debris. The number of observations made in each class over the winter is listed at the top of the bars. 3B. Percent of the tagged pieces of debris which moved during winter 1980-81 on Salmon Creek as related to diameter of the debris. The number of observations made in each class over the winter is listed at the top of the bars.

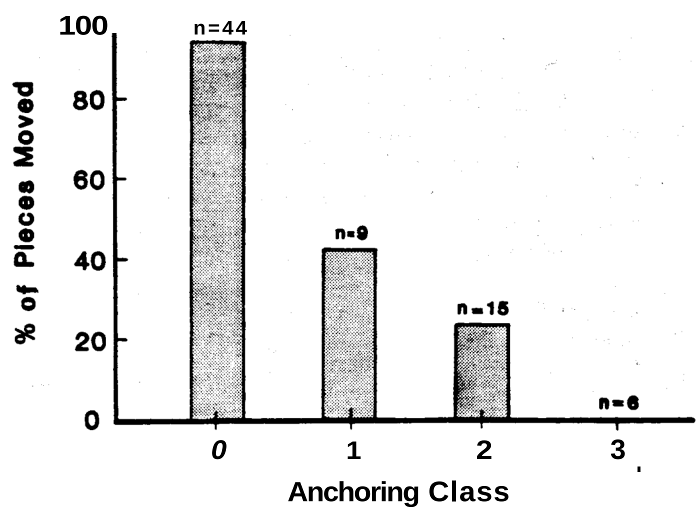

Figure 4. Percent of the tagged pieces of debris which moved during winter 1980-81 on Salmon Creek as related to anchoring of the debris. Anchoring classes were determined asfollows: (0) no burial; (1) one end or faceof debris buried: (2) both ends or one end and face buried; (3) both ends and face buried. The number of observations made in each size class over the winter is listed at the top of the bars.

3) a) Debris greater than 50 cm in diameter--4.
   b) Debris less than 50 cm in diamter--5.
4) a) Debris longer than 5.0 m--LEAVE.
   b) Debris shorter than 5.0 m--5.
5) a) Debris braced on downstream side by boulders, bedrock outcrops, or stable pieces of debris--LEAVE.
   b) Debris not braced on downstream side--REMOVE. ■

Literature Cited

BILBY, R.E. 1981. Role of organic debris dams in regulating the export of dissolved and particulate matter from a forested watershed. Ecology 62:1234-1243.

BILBY, R.E., and G.E. LIKENS. 1980. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology 61:1107-1113.

BISSON, P.A., J.L. NIELSEN, R.A. PALMASON, and L.E. GROVE. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during law streamflow. P. 62-73 in N.B. Armantrout, ed., Acquisition and Utilization of Aquatic Habitat Inventory Information. Western Div., Am. Fish. Soc.

ELLIOTT, S.T. 1979. Ecology of rearing fish. Annual Performance Rep. Alaska Dep. Fish and Game, vol. 19, study 01B, p. 39-52.

FISHER, S.C., and G.E. LIKENS. 1973. Energy flow in Bear Brook, New Hampshire: an integrative approach to ecosystem metabolism. Ecol. Monogr. 43:421-439.

LEWIS, S.L. 1969. Physical factors influencing fish populations in pools of a trout stream. Trans. Am. Fish. Soc. 98:14-19.

WASHINGTON FOREST PRACTICE BOARD. 1976. Washington forest practice rules and regulations. Olympia, WA. 54 D.

ZIMMERMAN, R.C., J.C. GOODLET, G.H. COMER.1967. The influences of vegetation on channel form of small streams. P. 255-275in Proc. Symp. River Morphology. Int. Assoc. Sci. Hydrol., Publ. 75.