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GEOMORPHIC AND BIOLOGICAL EFFECTS OF ACCUMULATED

DEBRIS IN STREAMS OF THE WESTERN CASCADES

by

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A THESIS

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# INTRODUCTION

## The Stream System

Traditionally, the stream has been viewed as a pipe or conduit transporting particulate, suspended, and dissolved material (both organic and inorganic) from the terrestrial environment to the sea. Little thought was given to the processes that occur within the stream environment. Recently, however, interest and study in the stream ecosystem have increased, and the chemical, physical and biological processes of the stream are better understood. The importance of the stream ecosystem to the entire forest environment should not be underestimated.

Geomorphic theory has also recently undergone some conceptual reevaluation. The idea of "dynamic equilibrium" or a balance between geomorphic processes has replaced the more traditional descriptive classification of landforms (Hack, 1960; Chorley, 1962). Schumm and Lichty (1965) clarified the problem by showing that on differing temporal and spatial scales, dynamic equilibrium has differing importance. The narrower the limits of time and space, the more valid the concept for the components of the stream, but not the entire system.

The stream ecosystem may also be viewed in terms of variable temporal and spatial scales. Many individual studies concern only a pool or short reach of stream and results may have little bearing on other stream reaches. On the other hand, large scale operations such as dams, highways, or land use planning may consider only major rivers in the plans and neglect the effect of the disruption on the smaller streams. A stream must be considered as part of a large system; a continuously varying ecosystem that gradually changes in chemical, physical and biological character from the headwaters to the sea (Vannote, 1975).

The processes that occur in any given reach of stream are a function of the input of material from the terrestrial ecosystem and from the aquatic ecosystem immediately upstream and the output of material to the reach immediately downstream. Any change that may occur in a stream reach may have consequences both downstream and upstream.

When describing or comparing processes occurring in a stream channel, some description or classification of the stream in terms of size is useful. Horton (1945) devised a stream order classification, which was later modified by Strahler (1957). Accoring to this scheme, streams without tributaries are termed first order streams. When two first order streams meet they become a second order stream. A third order stream is not reached until two second order streams converge and so on. A map of the Lookout Creek watershed in the H. J. Andrews Experimental Forest near Blue River, Oregon (Fig. 1) illustrates this classification.

## Debris in Streams

The study under consideration in this paper is part of a much larger study of accumulated stream debris. Field work was done in the summer of 1975. The main thrust of the work was to catalogue the various

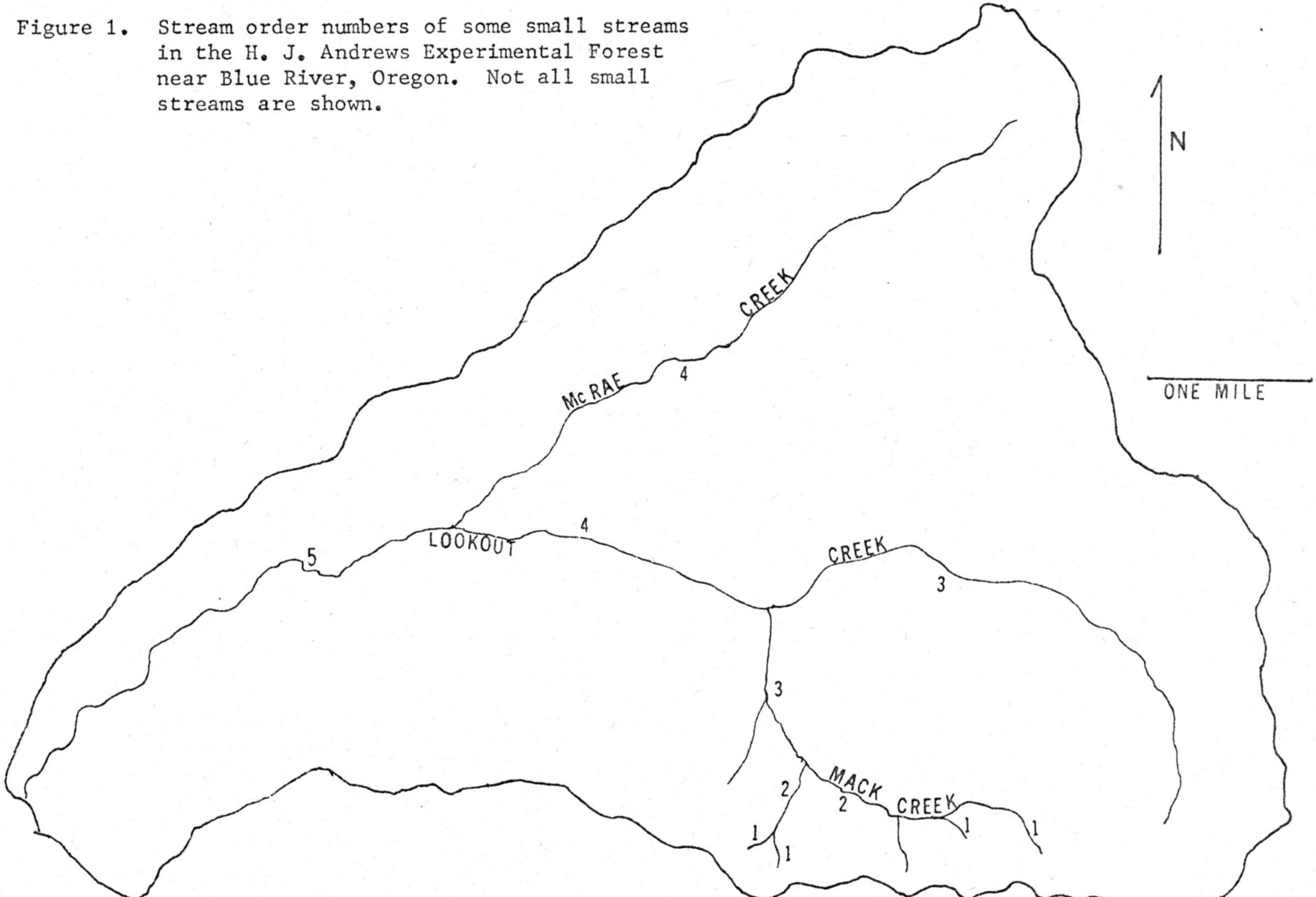



Figure 1. Stream order numbers of some small streams in the H. J. Andrews Experimental Forest near Blue River, Oregon. Not all small streams are shown.

types and functions of debris accumulations present in Pacific Northwest streams. To that end, approximately 10,000 feet of stream channel were mapped in streams in the Cascades and Coast Range.

On nearly every stream in the western Cascades, there are reaches that are choked with large organic debris. This material ranges in size from needles to whole trees and includes branches, twigs, bark, cones, trunks, and even root wads. Input processes randomly deliver debris to the stream channel, which is then moved downstream until it reaches an obstruction. Obstructions include rocks, narrow stream banks, live trees, or other stream debris. As material stacks up behind an obstruction, an accumulation of organic debris is formed.

Debris accumulations of the western Cascades are noteworthy for their variability. Few generalizations can be made about the form or geometry of accumulated stream debris, but the manner in which debris physically affects stream flow can be described broadly in two ways: material that affects only a portion of the stream width and deflects the stream flow; and material that affects the entire stream width and may potentially dam stream flow. Most accumulations contain both deflectors and debris dams.

## Previous Work

While interest in the question of debris in streams has been increasing during the past ten years, few studies have been made concerning the input or history of debris in streams. H. A. Froehlich and his students (Froehlich, 1971, 1973, 1975; Froehlich and others, 1972;

Lammel, 1972) have surveyed selected Pacific Northwest streams to determine the amount of organic material, both coarse and fine, present in the streams flowing through stands of various types and ages. They monitored debris before and after falling, and after yarding, in a variety of cutting units where several different methods of tree harvest were being used. Quantities of debris in undisturbed streams were large and variable. Measured concentrations range from 0.9 tons/100 feet of channel to 26 tons/100 feet.

Bishop (1968) and Swanson and Lienkaemper (1975) have determined some factors pertaining to the origins and movement of debris in streams. They have found windthrow and stream bank undercutting to be important sources of organic stream debris. Examples in studies by Colman (1973) and Swanson and James (1975b) illustrate that relationships among input processes are extensive. In both studies an earthflow was encroaching on a stream, constricting flow and tilting trees, making them highly susceptible to windthrow. High stream flow, undermining the toe of the earthflow as well as the opposite stream bank, resulted in slumps and slides in the bank which carried whole trees into the stream channel.

The importance of debris torrents in transporting stream debris through a small channel has been mentioned by several authors (Fredrikson, 1963, 1965; Rothacher and Glazebrook, 1968; Morrison, 1975; Swanson and Lienkaemper, 1975). Debris torrents are generated by hillslope or roadfill failure in steep gradient headwater streams or by a sudden washout of a debris accumulation. Material released in a debris torrent (inorganic, as well as organic) hurtles down the stream channel, picking up sediment and debris lying in the channel, and scouring vegetation and the soil mantle from the stream banks. Decreased stream gradient or an obstruction in the stream channel can stop the torrent, which usually deposits a substantial amount of material where it stops (Swanson and Lienkaemper, 1975).

Leopold and others (1964) have considered the effects of the interruption of stream flow in terms of energy dissipation. They conclude that internal distortion resistance to stream flow (horizontal diversion) dissipates energy proportional to the square of the flow velocity. On the other hand, spill resistance (falls) dissipates energy proportional to flow velocity to powers higher than the square. This suggests that large organic debris has an important function dissipating stream energy (Heede, 1972).

# STUDY SITES

## Factors Influencing Debris Accumulation

Jenny (1961) set forth a list of variables which together make up the ecological setting of a given area. These variables are climate, soil parent material, the organisms that inhabit the area, topography, and time. The variability of debris accumulations indicates that their formation and maintenance is probably a function of several varying parameters. These parameters may be dependent on or independent of one another, according to the time scale on which they are viewed. Although there are many variables contributing to the accumulation of debris, lithology, regional climate, stream size, stand age and vegetational characteristics appear to be most important.

When viewed in terms of Jenny's scheme, lithology and regional climate appear to be independent variables on the time scale of plant succession. These variables are unlikely to change in such a time span. Lithology and regional climate, along with topography, directly influence the size and location of drainage systems and the amount of discharge carried through them. Stream size, therefore, can be counted as a dependent variable.

The capacity of the stream to float material that has entered the channel appears to be an important influence on the existence of discrete debris accumulations. Small headwater streams are able to move only the smaller fraction of organic debris (needles, twigs, and cones) and are often, literally, one long accumulation of debris. Conversely, larger streams, which may be able to float large pieces of organic debris for some distance, tend to have large more distinct debris accumulations.

Lithology, regional climate and topography are all instrumental in determining the type and amount of vegetation that is available to the stream as input of organic debris. However, the mechanism which resets a plant community to a new successional sequence in the western Cascades is wildfire. Stand age is directly dependent on fire history, which is, in turn, dependent on factors of lithology, regional climate, topography and stand type.

The age of a stand through which a stream is flowing has various effects on debris accumulation. One would expect to find material in the stream that reflects the size of the trees growing in the surrounding stand; i.e., small debris from youthful stands and large diameter debris from old growth stands. At various times in their history stands tend to go through periods of extensive mortality as less viable trees lose out in competition. During these high mortality periods an increased input of organic debris into the stream system should be expected.

## Selection of Study Sites

The streams of this study were chosen on the basis of an array of two dimensions; stream size and stand age. Lithology, regional climate, and stand type can be thought of as being constant. The lithology of the four study sites is virtually identical, andesitic and basaltic flows overlain by glacial deposits (Swanson and James, 1975a). Climatically, all four streams are located in the orographic precipitation area of the Cascade Range and annually receive approximately 110 inches of precipitation.

All study sites lie within the *Tsuga heterophylla* zone delineated by Franklin and Dyrness (1973). The major tree species comprising the forest canopy in this zone are *Psuedotsuga menziesii* (Mirb.) Franco. (Douglas fir), *Tsuga heterophylla* (Raf.) Sarg. (western hemlock), and *Thuja plicata* D. Don. (western red cedar).

Reaches of stream were chosen to show little disturbance by forest management. The debris accumulations described in these streams are the type that occur naturally and often in undisturbed settings. Huge catastrophic "log-jams" were not considered in this study. In addition, reaches were selected that showed no evidence of debris torrents during the history of accumulation of debris. The general stream and vegetational characteristics of individual streams are summarized in Table 1.

Table 1. Selected Physical and Vegetational Characteristics of Several Streams of the Western Cascades

| Stream | Order[1/] | Drainage[2/] Area (Acres) | Stand Age[1/] (Years) | Average[1/] Gradient (Percent) |
|---|---|---|---|---|
| Creek A | 2 | 17 | 75 | 12 |
| Creek B | 2 | 33 | 125 | 10 |
| Zog Creek | 2 | 160 | 400+ | 36 |
| Mack Creek | 3 | 1,500 | 400+ | 10 |
| McKenzie River | 7 | 130,000 | Mixed | 10 |

[1/] in mapped reach

[2/] above mapped reach

Creeks A and B and Zog Creek are all headwater streams that drain undisturbed stands of variable age. Zog Creek and Mack Creek vary in size, but both drain stands dominated by old growth forest. Each stream is represented in this study by a map of a 200-foot section of channel typical of the stream. A 400-foot section of Mack Creek is represented because of the interesting features of this area, and a photograph of the McKenzie River is included for comparison. Few data were collected for the McKenzie and it was not mapped, but observations were made almost daily. Locations of the study sites are shown in the reference map in Figure 2.

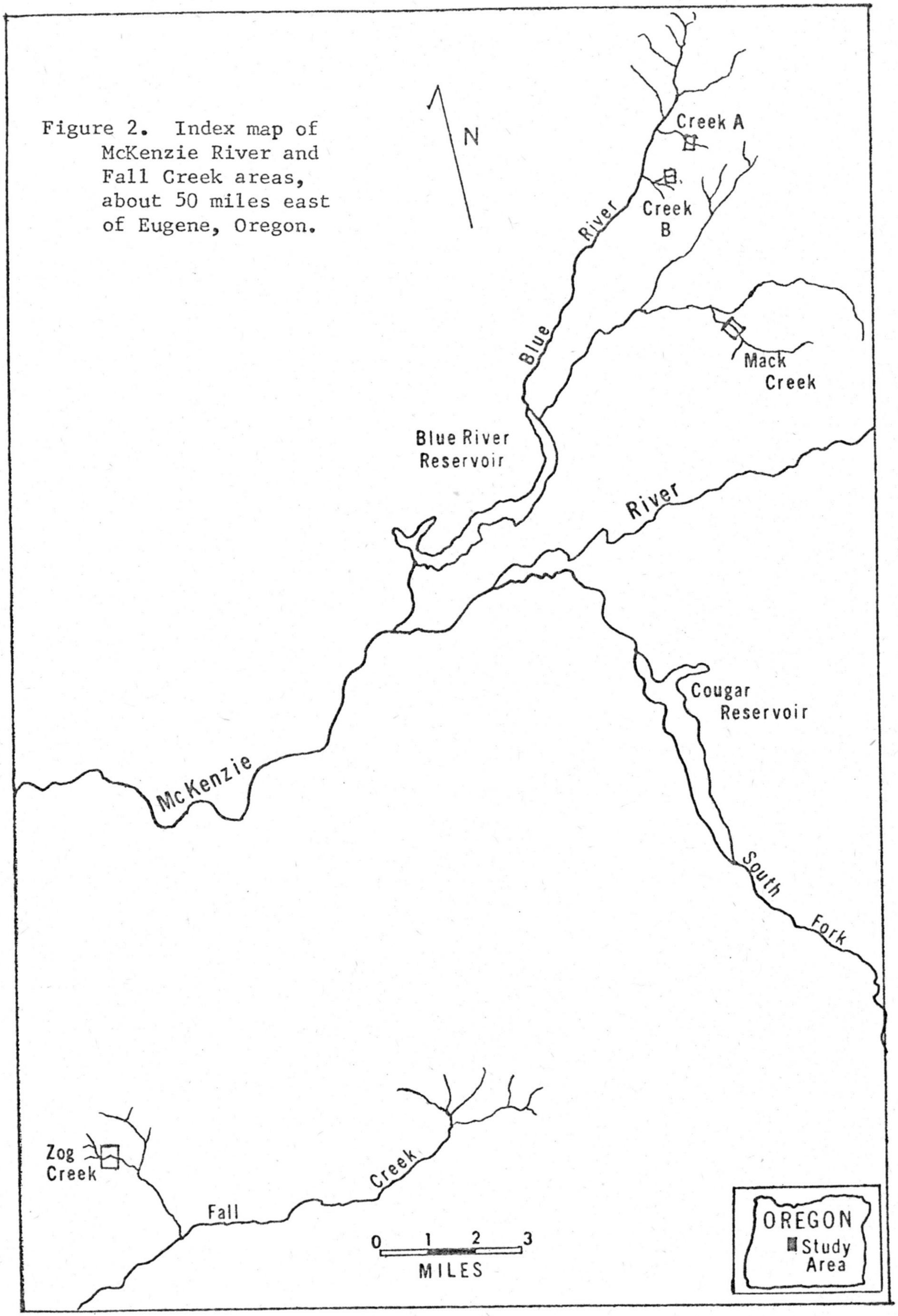



Figure 2. Index map of McKenzie River and Fall Creek areas, about 50 miles east of Eugene, Oregon.

# FIELD METHODS

Mapping was done on a scale of 1 inch to 10 feet. Wooden stakes were driven into the stream bank or a piece of debris in the stream channel, marking survey stations at either end of a 100-foot tape. A bearing and percent gradient were measured for each 100-foot section. The lower size limits of debris pieces to be mapped were determined as pieces that would not be floated by the smallest stream in the study at annual peak flow conditions. This critical size was estimated to be 6 inches in diameter and 4 feet in length.

## Small Streams

In streams less than 50 feet wide, the following method was used. The 100-foot tape was used to measure the distance up or down channel and a 30-foot telescoping measuring rod was used for cross channel measurements. The apparent high water level was determined by noting the appearance of flotsam or a line on streamside rocks below which mosses had failed to establish themselves. The high water level was measured at 5-foot intervals along the stream by holding the rod horizontally and perpendicular to the tape (see Figure 3). The margins of the stream channel were then drawn in on the map sheet. Every piece of debris that lay within the high water shore lines was measured and drawn on the map. Diameters of all pieces were measured to the nearest half foot. To simplify measurements and drafting, most debris pieces were

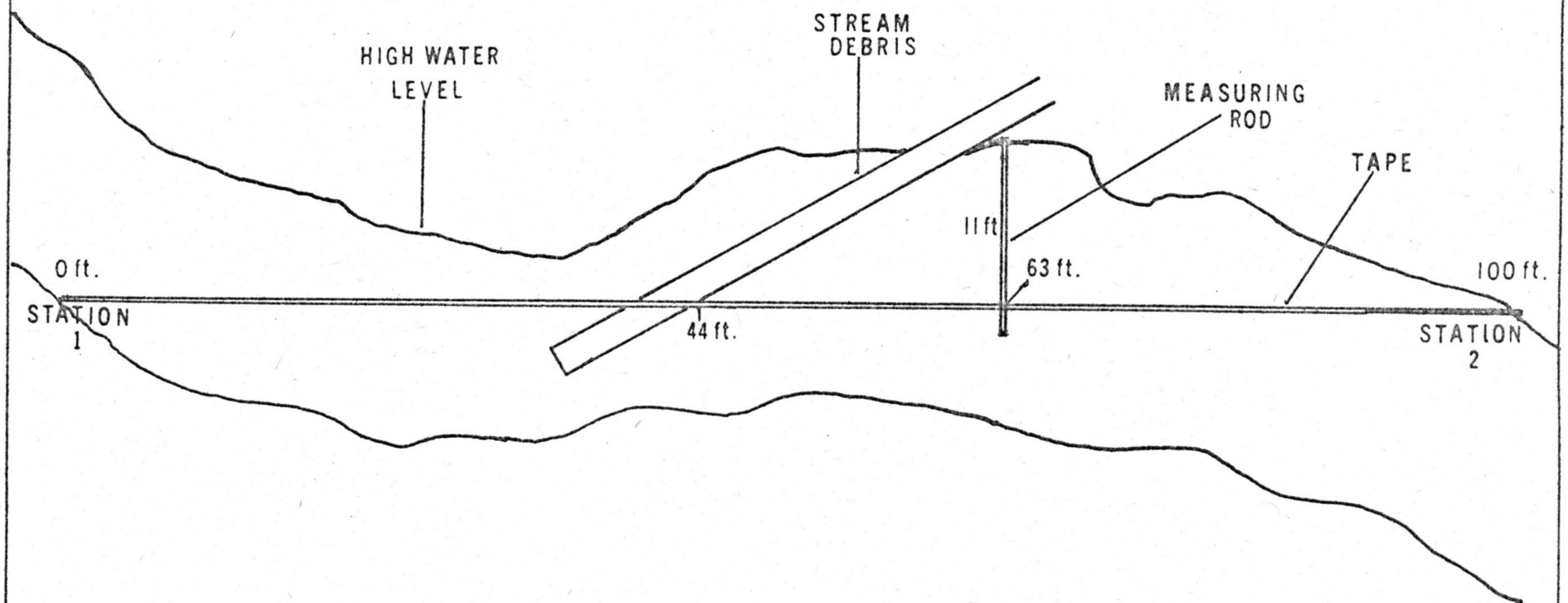



Figure 3. Diagram showing positions of tape and measuring rod for measurements of stream banks and debris pieces.

mapped as having a constant diameter and flat ends. Sawed ends were noted on field maps.

## Large Streams

Methods used in streams where the channel was too wide for accurate measurements with the telescoping rod or where the strong current precluded wading up the stream, were similar to those used in small streams, except that cross channel measurements were made with a range finder. On large accumulations, pacing was used in addition to direct measurements of lengths and diameters.

## Dendrochronology

Dendrochronology was used to determine residence times of debris and the history of debris accumulation. Two methods were found to be useful.

Upon entry into the stream channel, a dead or dying tree is immediately subject to bacterial and fungal attack. As the tree is decomposed it develops into a potential substrate for the germination of seeds being shed by surrounding trees. This "nurse log" phenomenon is often observed in the forest and on logs in debris accumulations. By sampling one of the nursed trees (usually the largest) and counting the annual growth rings, a minimum date for residence of the piece of debris serving as the substrate could be determined.

There were, of course, problems with this method. There is no way to determine the length of time that elapses between the entrance of material into an accumulation and the point at which it becomes a suitable substrate for seed germination and seedling development. From advice offered by other field workers and observations of pieces of debris with known residence times, an approximation of five years was made for this time span. However, this figure is probably a minimum estimate and was not included in dates reported in this paper. Trees that were nursed near a root wad were not used for estimating dates because of the possibility that these trees were growing before the tree fell and were using the soil, not the tree, as a substrate.

Another method of dating utilized the ability of an injured tree to grow datable scar tissue over a wound. This tissue grows in annual rings and from field observations, seldom lags behind the injury by more than two years. Many trees which blow down into a stream and remain in place as part of an accumulation show signs of having scarred neighboring trees. By drilling through the scars with an increment borer or sawing out a wedge of the scar tissue, a date for the occurence of the injury could be determined. This, of course, gave a date for the entry of the material into the stream channel.

## Other Methods

Other information about the characteristics of debris accumulations was observed and noted. In large streams where debris was distributed into distinct accumulations, a debris accumulation data sheet was used. Information was collected on the volume and stability of the accumulation, its effect on the stream, the amount of material trapped (both organic and inorganic) and a general description of the area. A sketch map of the debris accumulation was also included. In smaller streams, where debris was not distributed into distinct accumulations, much of the above information was noted directly on the field maps. Photographs were also made of many accumulations in order to have a pictorial record available.

Each of the survey stations was located with respect to large stable objects on the stream bank to allow further work on the area, even if the survey stations were removed by high water or other stream processes.

# RESULTS AND INTERPRETATIONS

## Zog Creek

Zog Creek is a second order stream that is part of the Fall Creek drainage system, a tributary of the Willamette River (Fig. 4). The mapped section of the stream flows through a decadent old growth stand composed chiefly of Douglas fir, western hemlock and western red cedar. Zog Creek drains about 160 acres at the area of mapping and carries surface flow all year.

Material has accumulated in Zog Creek chiefly as a consequence of windthrow. Root systems of old or diseased trees have been weakened enough so that a strong wind is able to topple them. Evidence of windthrow can be seen where root systems, pulled from the ground, have left a noticeable pit where they once grew. The root wads are seldom far from these pits. At several places along Zog Creek scars were noted on trees that had been struck by falling trees. Many of the fallen trees were still in place and extended into the stream. Stream bank undercutting may play a role in weakening root systems in this stream, but windthrow appears to be the major contributing process. The jack-straw nature of the large pieces of debris in Figure 4 is typical of a windthrow area.

In small headwater streams the volume of discharge is seldom great enough to move any but the smallest fraction of stream debris (needles, twigs, and small branches). Therefore, any large piece of organic

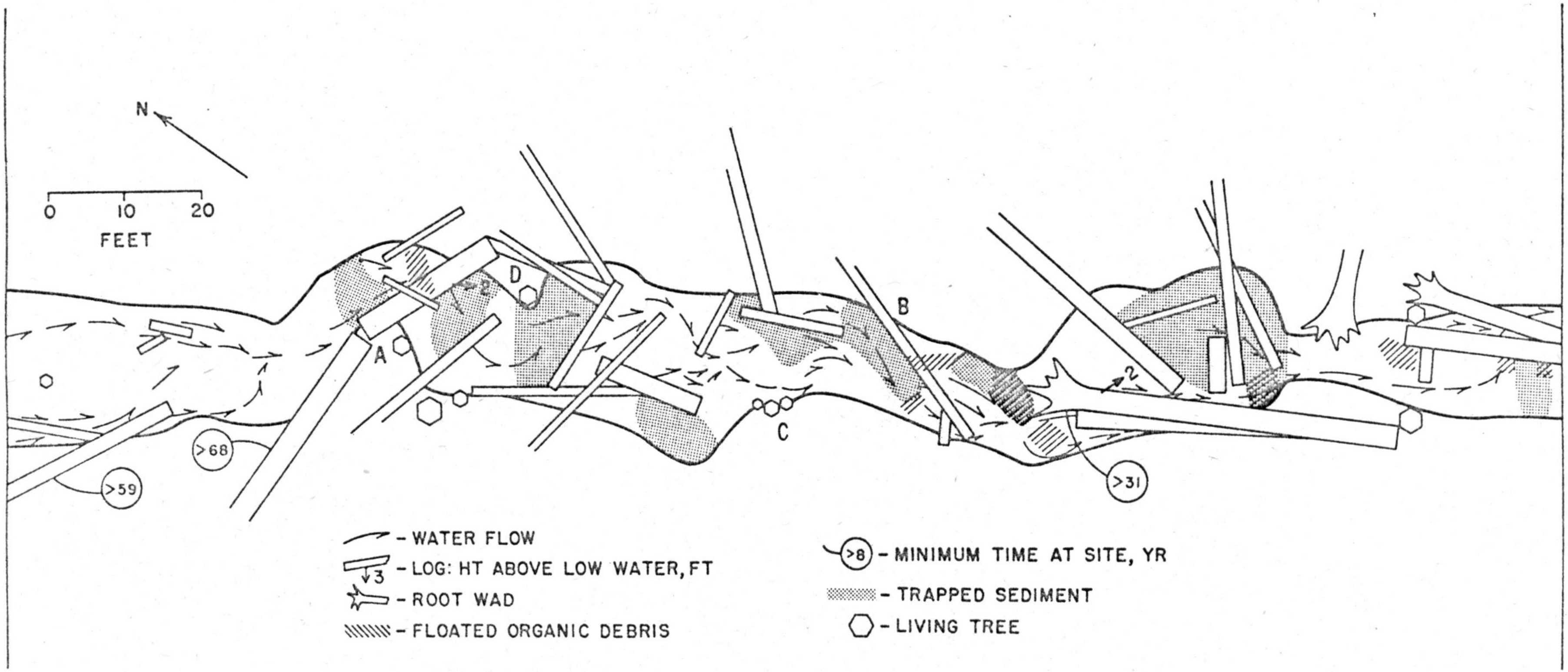



Figure 4. Map of large organic debris and other material in a 200-foot section of Zog Creek, flowing through an old growth stand.

debris that enters the stream channel is likely to remain in place until it has decomposed to a point where channel processes can begin to break it up into small pieces, which can be carried downstream. For this reason the time of residence of such a debris accumulation is a function of the rate of decomposition of the large debris. In the moist temperate forests of the Pacific Northwest a typical log, two feet in diameter, may retain its integrity for over 150 years, as will be shown by other data. As a consequence, a small stream in an old growth forest becomes literally clogged with debris (Fig. 4). Minimum dates for accumulations on Zog Creek reflect the longevity and stability of large pieces in the stream bed (Fig. 4).

Zog Creek flows over bedrock in most of the study reach. Therefore, the form and direction of the channel are dependent on the resistance of the bedrock to erosion. However, organic debris also plays an important role in shaping the channel. Figure 4 illustrates the diversion of the stream as a consequence of large organic debris at points A and B. Living trees (at points C and D), because of their root systems, also tend to influence the shape of the stream channel. Since the stream carries small volumes of water, seedlings have a chance to root and grow on suitable debris pieces or stream banks without being washed away. Once established, the root system adds strength to the debris on which it is growing or the stream bank.

Organic debris plays an important role in the trapping of sediment in small headwater streams. In the 200-foot section shown in Figure 4, stream debris accounts for the trapping of approximately 25 cubic yards of inorganic sediment and 6 cubic yards of floated organic material. At this time the rate at which these sediment traps fill is not known, but they do impound significant amounts of material.

## Mack Creek

Mack Creek is a third order stream in the Blue River drainage system, a tributary of the McKenzie River. Maps of a 400-foot section of Mack Creek are included in this paper (Figs. 5 and 6) because the debris accumulations are scattered far enough apart that more than 200 feet is needed to characterize the diversity of structures of stream debris accumulation found in this area. The stream flows through a decadent old growth stand of Douglas fir, western hemlock and western red cedar. Mack Creek drains about 1500 acres in the area of mapping and is a fast moving stream throughout the year.

The old growth forest contributes much organic debris to Mack Creek in the form of windthrown trees. The major logs in almost every accumulation on Mack Creek entered as diseased or old trees blown into the stream channel. These logs can be followed right up to the root wad on the hillside, where the roots have left a sizeable pit upon being pulled from the earth. Often a little detective work can lead to the discovery of the origin of a treetop in the stream channel, as a snag that has been decapitated in a windstorm. Many pieces of large organic debris, entering Mack Creek as a result of wind, scarred standing trees as they fell and thereafter remained in place or nearby.

Mack Creek is a stream large enough to rework its floodplain and in doing so undercuts its banks. This process is a contributor to the accumulation of organic debris in the channel. In Figure 5 the

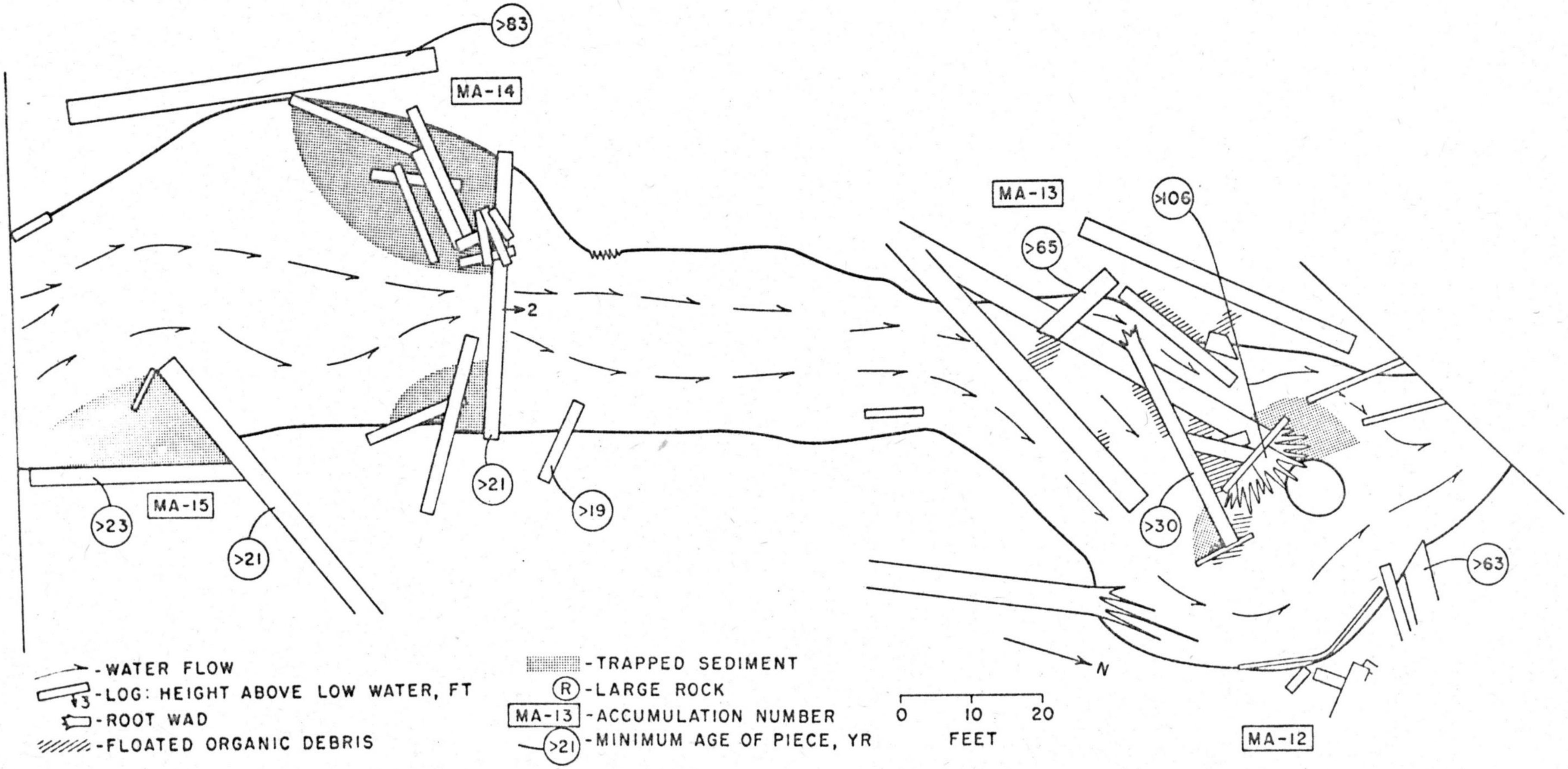



Figure 5. Map of large organic debris and other material in a 200-foot section of Mack Creek, flowing through an old growth stand. This section is immediately downstream from the section in Fig. 6.

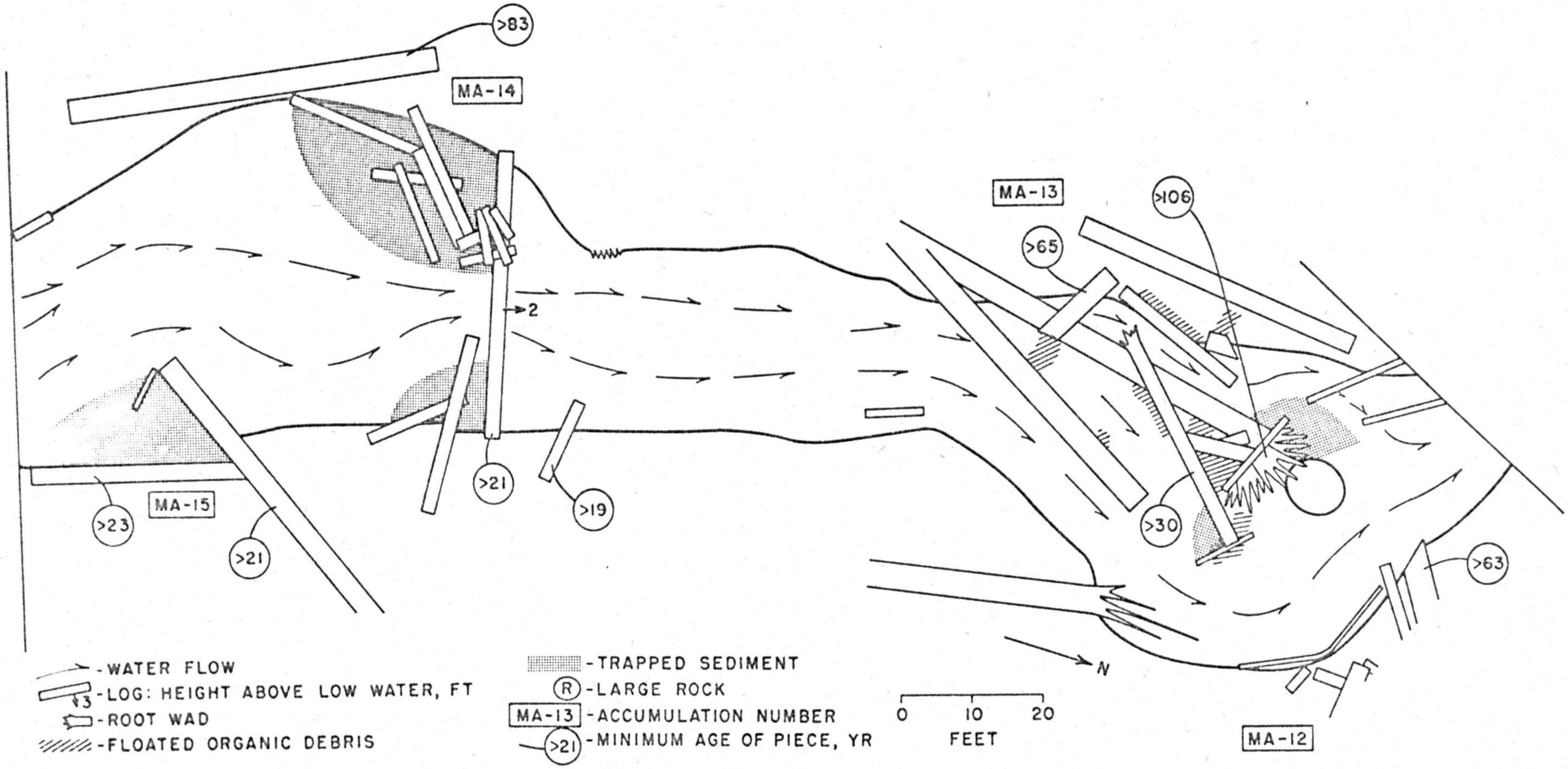



Figure 5. Map of large organic debris and other material in a 200-foot section of Mack Creek, flowing through an old growth stand. This section is immediately downstream from the section in Fig. 6.

accumulation MA-13 illustrates this process. From dating methods it has been determined that more than 100 years ago Mack Creek flowed closer to the west bank at MA-13. A large tree (whose roots are labeled > 106) was undercut and fell across the stream. That tree and the organic debris and sediments which accumulated upstream from it, diverted the stream to the east bank, where the major flow is now located. However, the bank at MA-12 is now being undercut and several large trees above the bank may eventually be added to the material in the stream.

While not observed in the Mack Creek area, organic material may be added to a third order channel by a debris torrent in one of its tributaries, which delivers large amounts of material to the stream channel and may redistribute pre-existing pieces of debris into new accumulations.

The debris accumulations in Mack Creek show remarkable stability. Flows during the winter storms of 1964 and 1965 were quite large in the Blue River drainage system (Fredrikson, 1965; Rothacher and Glazebrook, 1968) and structures were expected to reflect this by being relatively new to the stream. However, this was not the case. Accumulations in Figures 5 and 6 have extremely variable minimum ages, but all are 10 years or older (Table 2).

The volume of discharge in Mack Creek is apparently great enough at peak flows to float some pieces of organic debris. However, the stream width in this area averages about 30 feet and it is unlikely that a piece will travel very far downstream. The ability to float larger material leads to a distinct distribution of accumulated debris (Figs. 5 and 6).

Table 2. Data on Debris Accumulation of a 400-Foot Section of Mack Creek

| Debris Accumulation Number | Debris Influenced Stream Drop (ft.) | Volume Trapped Sediment (cu. yds.) | Percent Channel Width Affected | Percent Floated Debris | Age of Core of Accumulation (yrs.) |
|---|---|---|---|---|---|
| MA-12 | 0 | 15 | 30 | 60 | 63+ |
| MA-13 | 3 | 45 | 60 | 10 | 106+ |
| MA-14 | 0 | 40 | 100 | 50 | 21+ |
| MA-15 | 0 | 5 | 30 | 10 | 21+ |
| MA-16 | 8 | 120 | 100 | 25 | 30+ |
| MA-17 | 5 | 50 | 75 | 50 | 10 (?) |
| MA-18 | 4 | 30 | 80 | 40 | 9-10 |

In third order streams in the western Cascades the residence time of accumulated stream debris continues to be determined by the rate of decomposition of the foundation pieces. Accumulation MA-14 in Figure 5 is an example. The foundation of the accumulation withstood the high flows of 1964 and 1965 and probably trapped much of the material that makes up the bulk of the accumulation at the present time. The part of the log labeled > 21 on the east bank has rotted further and has now cracked under the weight of the accumulation. A large piece of debris floated by a peak flow could break this foundation piece and wash out MA-14.

Geomorphologically, Mack Creek is perhaps the most interesting of the streams studied. The structures in Figures 5 and 6 function in a variety of ways to modify channel geometry. In Figure 5, MA-12 serves as protection for the stream bank downstream. The diversion of the stream flow by MA-13 has been mentioned above. MA-14 constricts stream flow, creating a high energy chute and an accompanying downstream plunge pool. MA-15 protects the bank downstream, while accumulating sediment

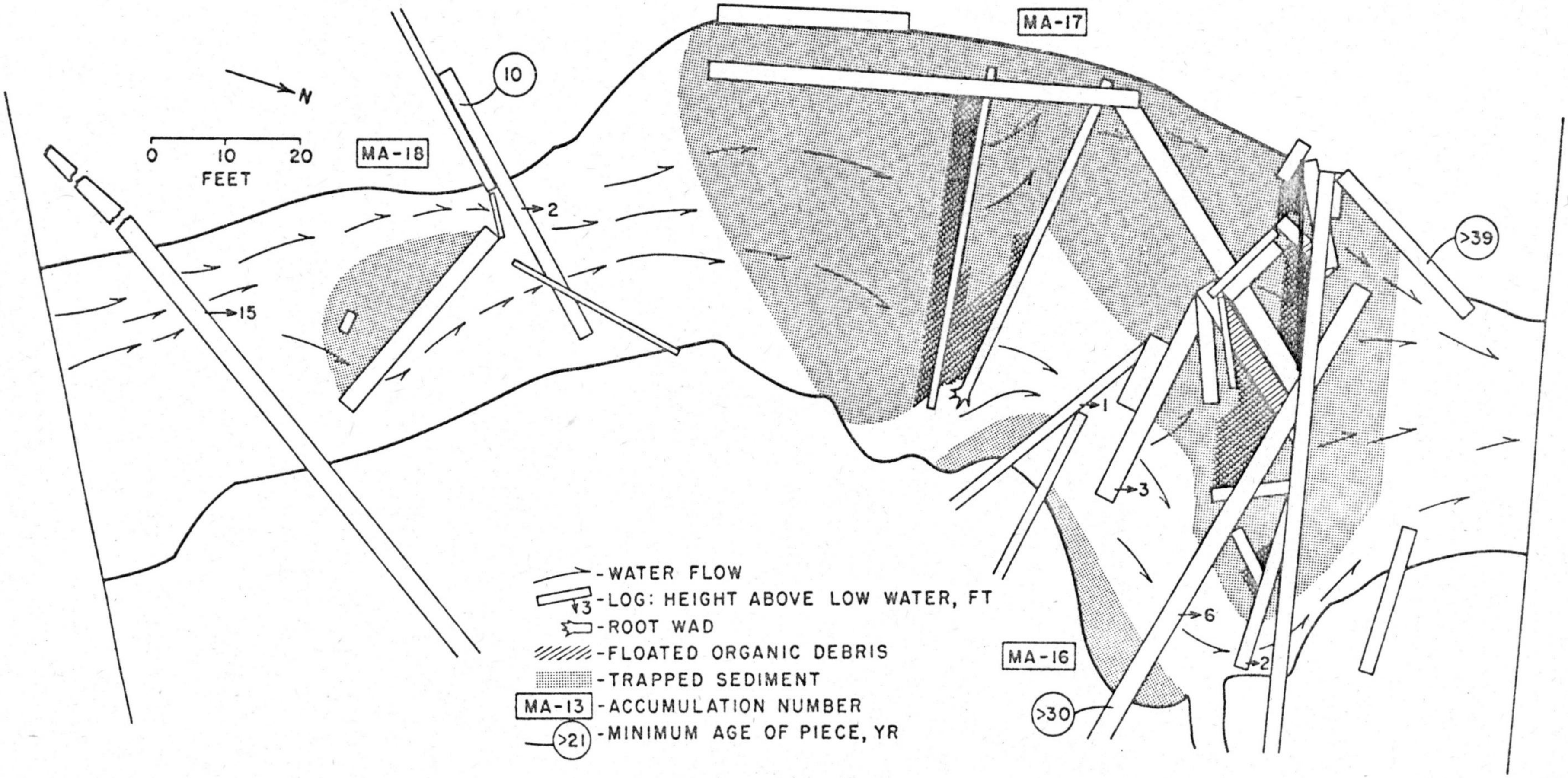



Figure 6. Map of large organic debris and other material in a 200-foot section of Mack Creek, flowing through an old growth stand. This section is immediately upstream from the section in Fig. 5.

and partially deflecting the stream.

In Figure 6, MA-16 has partially dammed the stream, diverting flow toward the east bank and significantly widening the entire stream bed. MA-17 is apparently one of the youngest accumulations in this section (Table 2) and is in the process of stabilizing itself. The upstream of the two pieces that lie across the stream probably entered the channel first, created an efficient obstruction in the stream, and diverted the stream flow toward the east bank. The downstream piece, standing at the time, was undermined and entered the stream channel when it fell. At peak flows in recent years the flow of the stream has been almost entirely diverted to the new channel being cut around the eastern end of the accumulation (Sedell, 1975, personal commun.). At the time of this study, however, the upstream crosspiece appeared to have been cracked and the accumulation breached. Channel geometry may change again during the next peak flow.

Mack Creek flows on bedrock in some reaches and a boulder pavement in others. The principal sediment size trapped in the study reach was course gravel. Debris accumulations in this area have impounded large volumes of sediment and floated material (Table 2). The filling and scouring of several sediment traps (MA-14, MA-17, MA-18) is probably a function of stream energy, but a study of this aspect has not yet been completed.

## McKenzie River

The McKenzie River has been included in this discussion as a basis for comparison. Debris accumulated in the McKenzie River is primarily a function of the amount of material that has been floated in from its tributaries. Input processes such as windthrow and stream bank undercutting do operate along the McKenzie, but the size of the channel and the drainage system make those processes much less important.

Debris accumulations in the McKenzie River rarely form in mid-stream or even within the limits of low water flow, but appear at the stream margins and are implaced by peak flow (Plate 1). Consequently, the residence time of accumulations in the McKenzie River is a function of the return frequency of peak flows that can refloat the material once it is in place.

The ability of the river to float most peices of organic material that enter the channel, reduces the importance of the influence of stream debris on channel geometry. However, at high flows, accumulated debris may play a larger role by deflecting stream flow, creating eddies, and contributing pieces that may float further downstream.

PLATE 1

Plate 1. Debris accumulation on an island in the McKenzie River. The accumulation is above the influence of stream flow for most of the year.

## Creek "A"

Creek A is an unnamed second order channel flowing into Blue River and draining about 17 acres on the north side of Carpenter Mountain (Fig. 7). Near the turn of the century, the area was burned by wildfire. The existing stand is approximately 75 years old and consists of Douglas fir, western hemlock, western red cedar, and some true fir (*Abies spp.*). In the summer of 1975 only a sub-surface flow through a thick gravel bed moved through the channel, however, steep channel margins and sediments obviously deposited by running water indicated that during seasons of higher runoff, Creek A carries a surface flow.

As in most headwater streams in the western Cascades windthrow is the most important process contributing debris to the stream channel. Many trees in the stand around Creek A are standing dead or dying as a consequence of canopy closure. Many pieces are bridged across the channel and are kept off the stream bed. The finely divided material that can float through the stream system may move along the channel and tends to accumulate behind large pieces of organic debris that pre-date the wildfire in the area. These large pre-fire pieces show little sign of having been burned and were probably in the stream bed at the time of the fire. Many are quite rotten, but are still providing a foundation for the accumulation of debris from the existing stand.

Although now filled with gravel, the channel form of Creek A appears to have originally been a function of the resistance of bedrock to erosion. Large pieces of organic debris play an important role in shaping channel form by damming and diverting the stream during periods

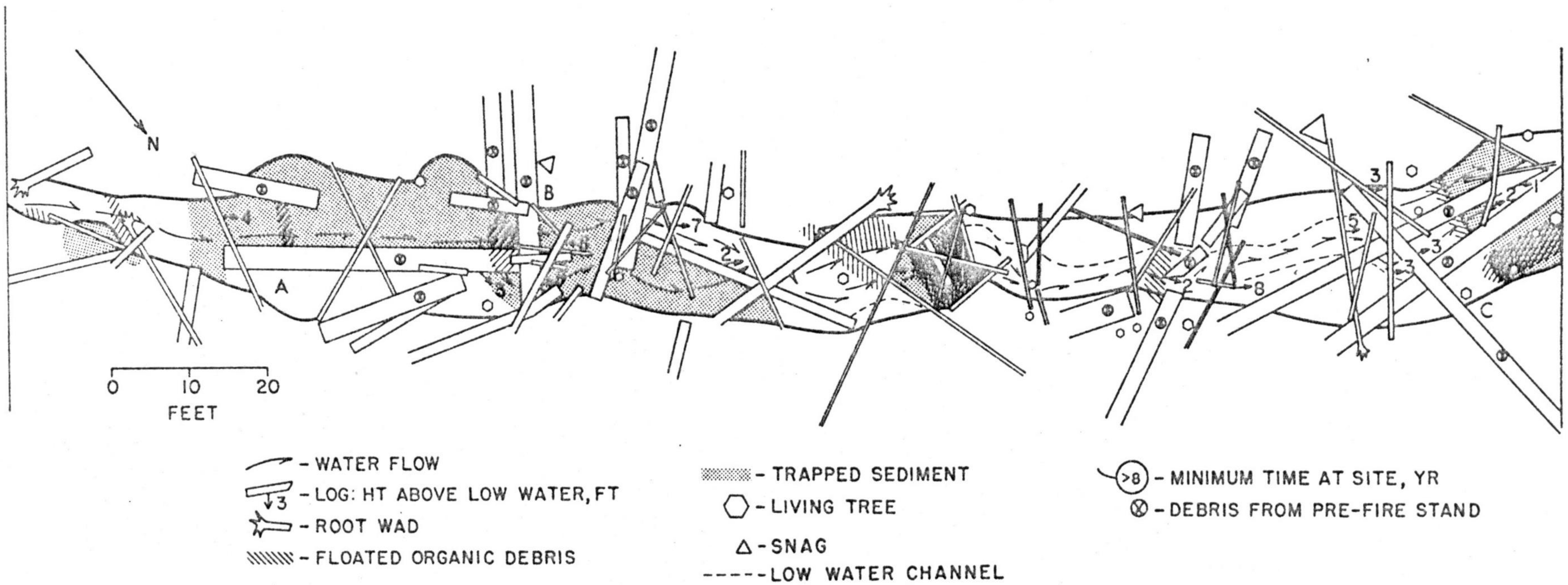



Figure 7. Map of large organic debris and other material in a 200-foot section of an unnamed stream (Creek A), flowing through a 75 year old stand.

of high flow (Fig. 7, points A, B, and C). Trees standing in the stream channel or near the bank are small and have little influence on channel geometry.

Considerable amounts of sediment have been trapped by debris accumulations in Creek A (Table 3). Large pre-fire pieces appear to have trapped the bulk of the sediment. If these pieces were in place at the time of the wildfire, they probably had considerable influence in retaining material eroded from the slopes following the fire. In this manner, the old stand contributed to the trapping of soil after the stand's destruction.

Table 3. Geomorphological Data on Selected Streams of the Western Cascades*

| Stream | Average Number of Pieces on Stream Bed | Percentage of Pieces of Pre-Wildfire Age | Volume Trapped Sediment (cu. yds.) | Percentage of Stream Drop Influenced by Debris |
|---|---|---|---|---|
| Creek A | 35 | 38 | 30 | 46 |
| Creek B | 52 | 13 | 25 | 50 |
| Zog Creek | 28 | X | 25 | 32 |
| Mack Creek | 30 | 0 | 150 | 50 |

*Data reported is for a 200-foot reach.

XFire history of Zog Creek is unclear.

## Creek "B"

Creek B is an unnamed second order tributary of Blue River, draining approximately 33 acres (Fig. 8). This area was burned by wildfire circa 1850 and now supports a 125 year old stand of Douglas fir, western

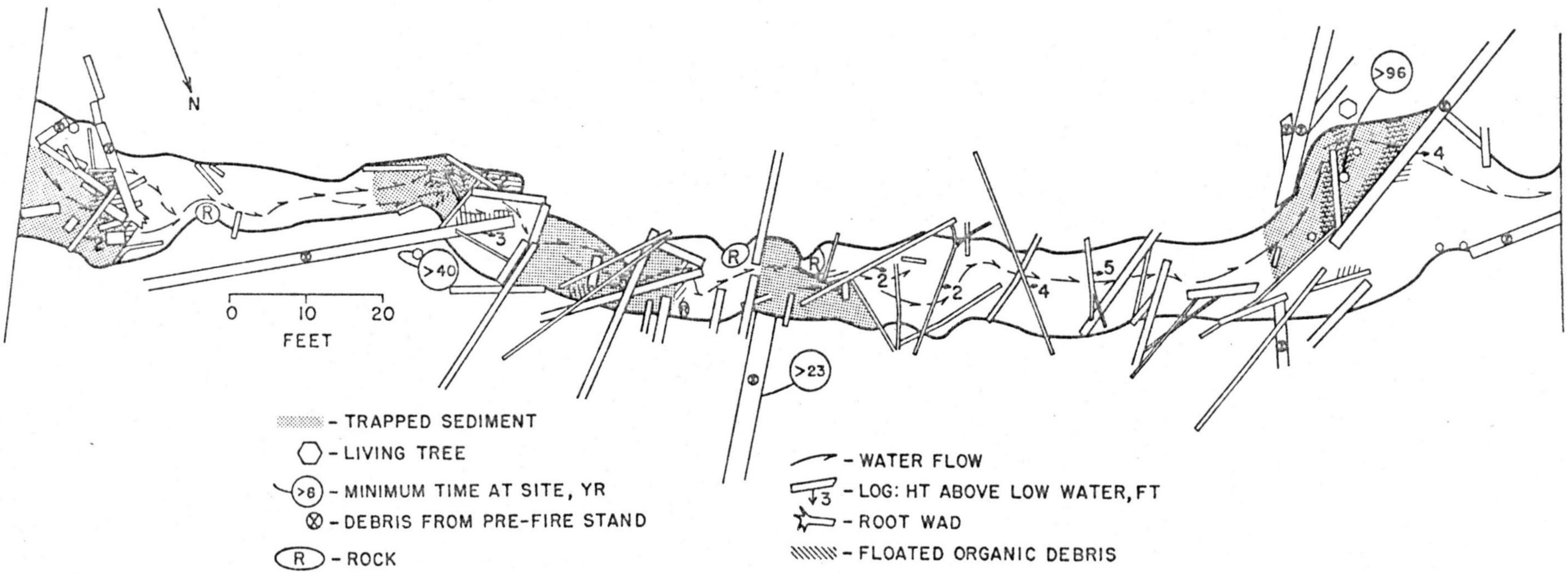



Figure 8. Map of large organic debris and other material in a 200-foot section of an unnamed stream (Creek B), flowing through a 125 year old stand.

hemlock, and western red cedar. Creek B is a perennial stream.

The entry of debris into Creek B is primarily by windthrow. There appears to be less intense competition among trees, probably because of high mortality at an earlier time, but many dead or dying trees in this stand have been susceptible to strong winds. This material either bridges the narrow stream channel, falls directly into the channel, or rolls in; or is shattered on impact and enters the channel as pieces. Large pre-fire pieces of debris in the stream channel, although badly decomposed and beginning to wash away, are also important in this age stand, because they form the foundation for new debris accumulations of material derived from the existing stand.

The role of debris of stand age in trapping sediment is increasingly important in stands of 125 years or greater. This material can reside in the channel long enough to trap large amounts of sediment. The large pieces of pre-fire age are important in trapping sediment, but since they are beginning to decompose and are becoming less abundant in the stream (Fig. 9) their significance as sediment traps is decreasing.

# DISCUSSION

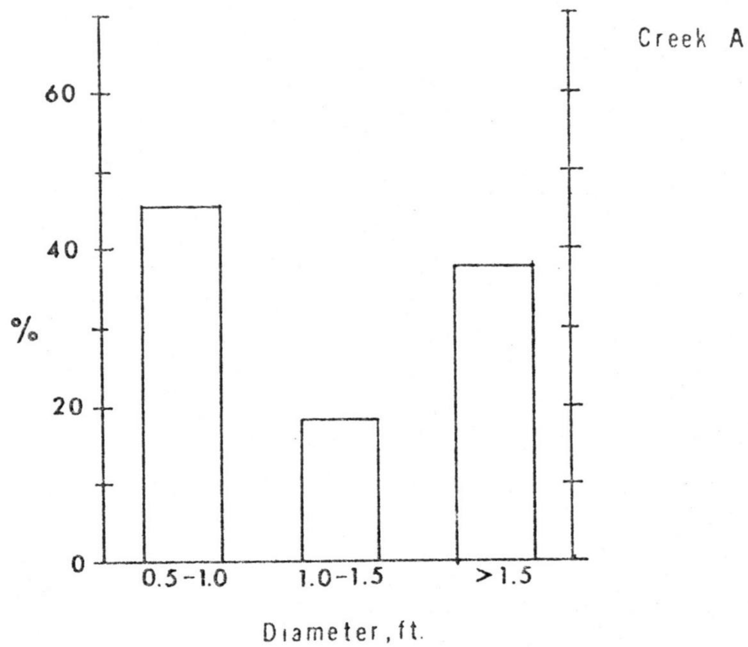
Investigations of stream debris accumulation in the western Cascade Range have revealed some rather important features of their stability and residence and the effect of stand age and stream size on these features. Small streams, while receiving a rather steady input of material from windthrow, are unable to float large material away and are choked with debris. Here residence is a function of the decomposition rates both of foundation pieces and material from the existing stand. Larger streams, with a flow great enough to float some large pieces, tend to have debris distributed into distinct accumulations, but decomposition rates still appear to be the factor controlling the residence time of material. In streams of river size the residence time is a function of the return frequency of a peak flow high enough to refloat stranded material.

In small streams the role of material in the stream bed that predates the age of the existing stand appears to be significant. The pre-wildfire material in the stream beds of Creeks A and B showed little evidence of being burned and was assumed to have been in place at the time of the wildfire. In Creek A (75 year old stand) about 38 percent of the material resting on the stream bed in a 200-foot reach was of pre-wildfire origin. In the 125 year old stand, Creek B had only 12 percent pre-fire pieces in the stream bed and Mack Creek had no pieces in the stream bed that exceeded the age of the stand (Table 3 and Figure 9).

The relative decrease of pre-fire pieces in the stream bed with increasing stand age must play an important part in the accumulation of stream debris. In young stands small material (needles, twigs, etc.) is delivered to the stream channel at a more or less constant rate and this material is trapped by the large pre-fire pieces in the stream bed. Large debris pieces from the existing stand entering the stream channel (1 to 1.5-foot pieces in Figure 9) are held off the stream bed by pre-fire pieces and trap very little floated debris. In older stands there are fewer pre-fire pieces in the stream bed and the larger size material contributed by the existing stand may reside on the stream bed and begin to accumulate floated material. In old growth stands material of pre-wildfire age has probably all rotted away, but large material from the existing old growth stand is setting up in the stream bed as pre-fire material in another successional sequence.

The role of pre-wildfire pieces in trapping sediment cannot be overlooked. Values in Table 3 indicate that small streams trap similar amounts of sediment, regardless of stand age. Pre-wildfire pieces in streams draining young and medium age stands are playing a major role in trapping sediment. Immediately after wildfire the pieces in the stream could provide a good trap for sediment released by accelerated erosion from the burned area. As these pre-fire pieces slowly decompose, they may gradually release the sediment they have trapped, regulating release of material to downstream reaches.

Debris accumulations which retard stream flow are important in streams of all sizes as energy dissipators. Any piece of debris or debris accumulation which diverts or deflects stream flow laterally,



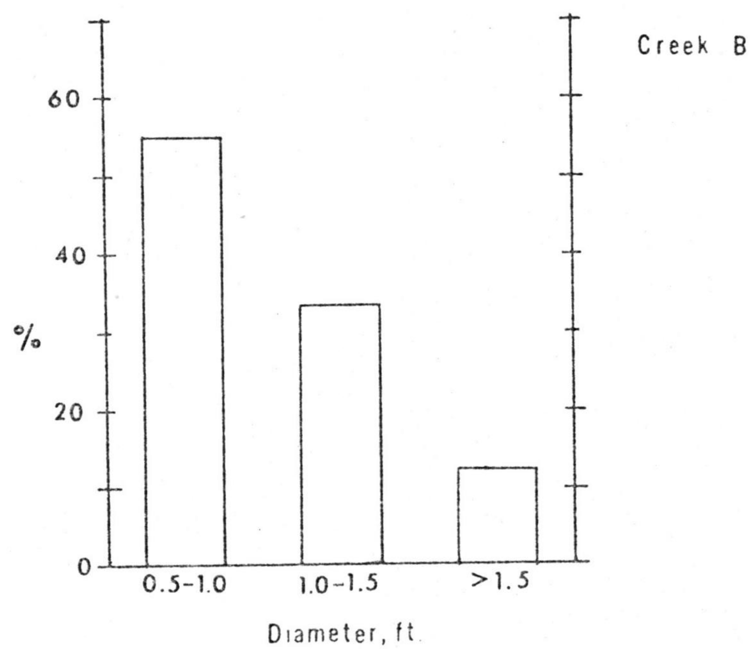




Figure 9. Histograms of the percentage of size/age class pieces (0.5-1.0 ft. = background level; 1.0-1.5 ft. = existing stand material; 1.5 ft. = pre-wildfire material) resting on the stream bed in stands of different ages. Creek A (75 years) and Creek B (125 years).

contributes to energy dissipation. However, the greatly increased potential for energy dissipation by spill resistance makes vertical displacement a much more important feature. The values for stream drop influenced by debris in Table 3 indicate that in the western Cascades debris is an important agent of stream energy dissipation.

# BIOLOGICAL EFFECT OF ACCUMULATED STREAM DEBRIS

## Litter Processing

In considering the biological consequences of accumulated stream debris the interaction of the terrestrial and lotic environments must be investigated. By comparing the respiration of a stream community to the photosynthesis of that community, a ratio can be determined that describes the dominant process. If the ratio of photosynthesis to respiration exceeds one, the community is described as autotrophic; if the ratio is less than one, the community is termed heterotrophic. The ratio may change with stream order or over diel or seasonal cycles (Cummins, 1974).

Investigations of many streams have concluded that small shaded woodland streams are heterotrophic. Nelson and Scott (1962) found that 66 percent of the energy utilized by consumers in a rock-outcrop stream community came from allochthonous sources (outside the stream system). Hynes (1963), Minshall (1967) and Coffman and others (1971) also reported that allochothonous detritus was the base of the food web in small woodland streams in England, Kentucky, and Pennsylvania. In similar streams in New Hampshire (Fisher and Likens, 1972) and Oregon (Sedell and others, 1974) investigators reported that almost 99 percent of the energy entering the stream system was allochthonous.

Allochthonous material in the form of small organic debris can enter a stream directly as litter fall or by lateral movement down a steep slope. Needles and broad leaves usually enter as litter fall, but cones, twigs, branches, bark, and small wood pieces generally enter by lateral movement. One small Cascade stream has been found to receive 170-200 pounds of small organic debris/100 feet of stream channel per year. Of that total, the litter fall consisted of approximately 30 percent cones, twigs, bark, and wood; 10 percent broad leaves, and 60 percent conifer needles. Material moving laterally into the stream consisted of approximately 67 percent cones and woody material, 14 percent conifer needles and 11 percent broad leaves (Triska and Sedell, 1975).

As soon as organic material enters the stream channel, the soluble organic fraction is leached out (Cummins, 1971, 1974). Experiments have indicated that the most dramatic litter weight loss is in the first 24 hours (Peterson and Cummins, 1974). Depending on the species of leaves, from 5 to 30 percent total weight may be lost in the first day (Cummins and others, 1972 ; Peterson and Cummins, 1974). Triska and Sedell (1975) have found that in Pacific Northwest streams leaves of alder, big leaf maple, and vine maple and Douglas fir needles lose up to 20 percent of their dry weight in four days through leaching. Stream microbes may utilize the leachate and rapidly increase the biological oxygen demand (Ponce, 1974; Triska and Sedell, 1975). However, material that has senesced causes a much smaller increase than does green material (Triska and Sedell, 1975). The microbial processing converts the leachate to biomass and carbon dioxide (Wetzel and Manny, 1972).

Soon after the leaching process begins, the residue is colonized by fungi and bacteria (Cummins, 1971, 1974; Triska, 1970; Triska and

Sedell, 1975). Spores of terrestrial fungi may enter the stream system with the litter, but aquatic hyphomycetes residing in the stream account for most of the fungal activity (Triska, 1970). Bacterial colonization occurs during and after fungal colonization (Cummins, 1974). After leaching, the litter represents a good carbon source, but a poor nitrogen substrate (Cummins, 1971). Kauschik and Hynes (1968) have found an increase in protein in leached leaves due to the fungal colonization.

After microbial conditioning the leaf material is consumed by large particle detritivores or shredders (Vannote, 1969; Cummins, 1971, 1973, 1974; Cummins and others, 1973; Peterson and Cummins, 1974). Several workers have found that the microbial life on the leaf, not the leaf itself, is the material being fed upon by the shredders (Cummins and others, 1973; Mackay and Kalff, 1973; Bärlocher and Kendrick, 1973). Cummins (1974) compares the microbial tissue to "peanut butter" on a leafy "cracker." The "crackers" are consumed by shredders only if there is "peanut butter" on it because the nutrient content of the "peanut butter" is much greater than the "cracker." The shredders process the detrital material by physically grinding it up and passing it through the digestive tract (Cummins, 1974). Welch (1968) determined that only 40 percent of the material ingested was fixed in shredder tissue or respired; the remainder being egested as feces. Physical grinding by the stream and chewing and digestion by shredder organisms reduce the leaf material to small particles (Cummins, 1974).

The fine particulate organic matter is then collected by another detritivore group, the collectors. These organisms weave fine nets to catch particles suspended in the water or may collect detritus on the bottom. Apparently collectors choose material to be ingested only on the basis of particle size, not by palatability, and further reduce particle size by digestion (Cummins, 1973).

In western Cascade streams accumulations of large organic debris play an important role in the processing of small organic debris. Vannote (1969) and Triska and Sedell (1975) contend that the efficiency of litter processing depends on the residence time of the material in the stream system. Douglas fir needles, an abundant nutrient in small western Oregon streams, take up to 150 days to be properly conditioned by fungi and bacteria. The needles are then palatable to stream shredders (Sedell and others, 1974). Accumulations of large debris provide retention devices that slow the movement of fine organic detritus and allow this conditioning to occur (Triska and Sedell, 1975).

## Effect of Debris on Fish

Hall and Baker (1975) have pointed out that debris accumulations may have both positive and negative effects on fish populations. The detrimental factors appear to be closely related to anadromous (migrating) fish and are less applicable to resident trout populations in small streams. Meehan (1974) has reported that green organic material creates a biological oxygen demand as it is decomposed and supports a slime bacteria that smothers developing eggs. Fine organic material may form a barrier on the gravel surface and reduce circulation between the surface and intergravel water. In addition, organic debris in the stream channel may impound water in ponds long enough so that insolation increases water temperature. All of the above are fatal to developing eggs and young fry (Meehan, 1974).

Bishop and Shapley (undated) have found that a man-made log-debris jam reduced the spawning area of salmon. Sheridan (1969) reported that on Saginaw Creek in southeast Alaska, more than one quarter of the salmon spawning area was unavailable for spawning because of accumulated debris.

There seems to be little agreement that debris accumulations present obstacles to the migration of anadromous fish. James (1956) and Meehan (1974) mention blocked passage as an adverse effect of debris in streams, but Bishop and Shapley (undated) conclude that blockage is rare.

Perhaps the most beneficial effect of debris accumulation is the cover provided to fish. Butler and Hawthorne (1968) and Lewis (1969) have found that overhead cover provided by logs and streamside vegetation is the critical factor in the distribution of trout in a stream reach. Boussu (1954) found that by providing artificial overhead cover to pools in Trout Creek, Montana, the population of trout in the pools was increased. The removal of the cover reduced the size of trout populations.

Reproduction of salmon and steelhead may be enhanced by debris in streams. James (1956) and Sheridan (1969) have found that pools created by debris are used for resting places for salmon and steelhead waiting to spawn. In addition, Sheridan (1969) has found pools associated with debris to be rearing areas for fry.

Salmonids and trout display a winter hiding behavior. Hartman (1965) and Bustard and Narver (1975) have found that young steelhead, coho salmon, and trout hide during the winter months under logs and root wads for protection from injury during freshets and from predation.

# CONCLUSION

Fisheries are probably of greatest concern when considering the biological consequences of debris accumulation. The damage incurred by fisheries from fry mortality and migration blockage, attributable to organic debris, is probably offset by the protective habitat provided by debris. However, large numbers of debris accumulations do occur naturally at the present time, and presumably have throughout the development of the forest ecosystem. Fish abound in the natural setting so stream debris must be an important feature of the natural forest ecosystem.

The role of allochthonous debris as the major source of energy in the stream environment is the critical aspect of the question of debris in streams. The finer material furnishes the base of the detrital food web and the larger material provides a habitat suitable for further processing of the detritus by numerous detritivores. The fish in the stream, finding a well protected habitat in and around debris accumulations, will also find an abundant source of nutrition in the form of litter processing invertebrates. Clearly, debris accumulations are an integral part of the stream and forest ecosystems.

# EDUCATIONAL BENEFITS OF STREAM FIELD STUDIES

Field studies provide a valuable experience for a practicing or prospective science teacher. One experiences lab and field techniques and procedures first hand, instead of observing or reading about them. The value of a mastery of lab and field manipulations is apparent to any teacher who has endured the results of a poorly performed experiment or demonstration.

Good field studies are closely tied to a familiarity with classic and current literature pertaining to the question of interest. Knowing of the failures and successes of other scientific field investigations is an easy way to avoid repeating those mistakes and also instructs students in the difference between good and bad experimental design.

Field investigations, if properly conducted, provide both teachers and students with an appreciation of the delicacy or tenacity of the various systems under study. A teacher with such an appreciation should be convincing during presentations pertaining to natural systems.

The stream provides an excellent outdoor laboratory for innumerable studies of natural ecosystems. No stream is completely without life and every stream is subject to biologic and geomorphic modification, both natural and man-caused. Even studies of heavily polluted streams can yield interesting and important results.

In Oregon few schools are very far from a stream. Weekly or after-school visits to a study site would not be difficult or expensive to arrange. In cities where small streams may be diverted underground, major rivers or their backwaters could provide an aquatic laboratory.

Many different types of courses can be designed around a stream study. Most obviously, a stream ecology class could be developed that incorporates biological principles into the real-world situation of the stream environment. With careful planning an entire general biology study is possible using the stream as a reference point that ties each phase of study together. Processes of biology, chemistry, physics and geology are operating on and within the stream environment. This combination makes the stream a natural and relatively easily accessible subject of study for general or physical science courses. In addition, fluvial processes segments of earth science classes are based on streams and first hand observations give such processes increased meaning.

The outdoor lab may provide students with an enjoyable means of studying science. The chance to get out of the classroom and participate in scientific investigations can provide an opportunity to sharpen observational skills, improve experimental technique, and develop an awareness of the sensitivity of natural systems to disturbance. In short, the student may become more in tune with the outdoors, while experiencing a pleasurable and interesting method for scientific investigation.

Stream field studies are a valuable tool for science teaching in that they provide the teacher with technical knowledge necessary for effective teaching. Streams are easily studied and readily accessible in nearly every part of Oregon and studies of streams can be adapted to a wide range of scientific disciplines. Finally, field work, in general, is more enjoyable than classroom work and therefore more instructive for students and teachers.

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