Swanson, Frederick J.; Lienkaemper, George W. 1980. Interactions among fluvial processes, forest vegetation, and aquatic ecosystems, South Fork Hoh River, Olympic National Park, Washington. In: Proceedings of the 2d conference on scientific research in the National Parks; 1979 November 26-30; San Francisco, CA. [Place of publication unknown]: [Publisher unknown]: 23-34. Vol. 7. [Also reproduced in 1982 by the USDA Forest Service with page nos. 30-34.]

INTERACTIONS AMONG FLUVIAL PROCESSES, FOREST VEGETATION, AND AQUATIC ECOSYSTEMS, SOUTH FORK HOH RIVER OLYMPIC NATIONAL PARK, WASHINGTON

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ABSTRACT

Interactions among fluvial processes and forest vegetation create a variety of landforms, plant communities, and aquatic habitats in the South Fork Hoh River. We distinguish six geomorphic surfaces based on differences in vegetation and elevation relative to low water level. Relations between high flows and forest vegetation vary from one surface to another. Flood effects include inundation, bank cutting, surface scour, deposition, and transport of large organic matter. Geomorphic processes have created four distinctive aquatic habitats in the valley: main river channel, off-channel areas along the main stem, and valley wall and valley floor tributary streams.

INTRODUCTION

Landforms and geomorphic processes are important factors in development of most terrestrial and aquatic ecosystems. Interactions between physical and biological features and processes are especially well developed along glacier-fed rivers flowing through heavily forested, glacially carved valleys such as the Hoh River. On the broad valley floor of the Hoh River system, fluvial geomorphic processes create landforms that provide sites for terrestrial and aquatic ecosystem development that contrast markedly with valley wall sites. Fluvial processes regulate the development of these ecosystems in areas subject to flooding and sedimentation.

The geomorphology phase of the interdisciplinary South Fork Hoh River study examined these relationships by addressing three specific objectives:

1. Map valley floor geomorphic surfaces and channel features and age associated trees.

2. Examine relations among fluvial processes and vegetation along the main river channel.

3. Define and contrast the general types of stream environments.

Here we briefly report results of each of these phases of the study to provide the physical environmental context in which to view results of terrestrial and aquatic ecosystem studies.

FLUVIAL SURFACES AND CHANNELS OF THE MAIN STEM

At low and moderate flow conditions, the main stem of the South Fork Hoh River meanders within its broad, gravel-floored, flood channel. Within the study reach, about 2.5 km east of the western Olympic National Park boundary, the unvegetated flood channel is about 100 m wide, less than 10 percent of average valley floor width. The steep (60%) valley side slopes, carved by glaciers as recently as the latest Wisconsin advance (Crandell 1965, Heusser 1974), end abruptly at the valley floor. The valley bottom is partially filled with younger outwash gravels which form a complex set of terraces.

The 1000 m long study reach contains six geomorphic surfaces distinguishable on the basis of vegetation and elevation above river level (Figures 1 and 2). Successively higher surfaces up to Surface 5 bear forest communities in progressively more advanced stages of development and greater amounts of large woody debris produced by forests on the surface. Emergent, unvegetated gravel bars of Surface 1 extend to 1 m above the late summer river level at the time of the study (mid September 1978). Surface 2 has alder (Alnus rubra) thickets of trees up to 30 years old. Alder and spruce (Picea sitchensis) trees on Surface 3 are up to more than 100 years in age. Old-growth, open-grown spruce and western hemlock (Tsuga heterophylla) on Surface 4 range in age up to 258 years, based on a sample of about 20 trees (McKee et al. 1980). Individual spruce and hemlock trees on Surface 5 do not appear to be significantly older. McKee et al. (1980) observed a maximum age of 266 years in a sample of about 20 trees). However, unlike Surface 4, many large, down boles in advanced stages of decay litter the forest floor of Surface 5, suggesting that the community may be much older than the oldest, living individuals. This hypothesis is favored by the occasional occurrence of well-rotted Douglas-fir logs on Surfaces 5 and 6 (Lambert 1980). An alternative hypothesis is that greater biomass of down logs on higher surfaces is a consequence of higher stand densities. Forests of Surface 6 are not readily distinguished from those of Surface 5.

Tree ages only roughly bracket the age of geomorphic surfaces. Oldest trees on Surfaces 2 and 3 may well date the time the geomorphic surface was formed as a fresh substrate for vegetation establishment. Old-growth trees on higher surfaces simply provide minimum estimates of surface ages. Estimates of minimum ages of Surface 5 and 6 will be improved with better understanding of stand development and age and decay rate of pieces of dead wood. These data from the South Fork Hoh River provide no basis for accepting Fonda's (1974) suggestion that

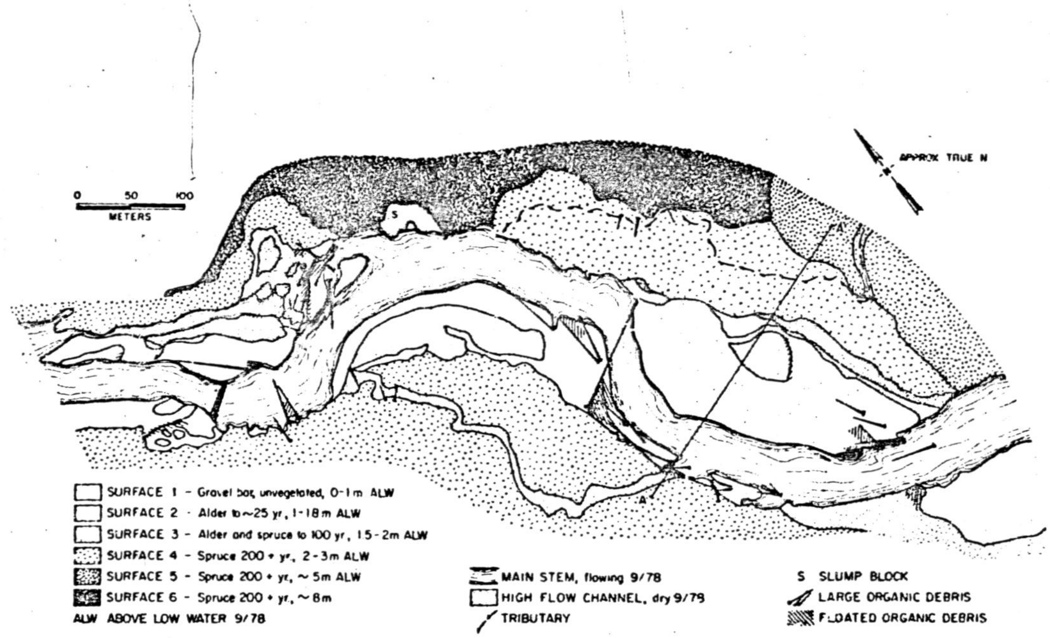

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Fig 1

Figure 1--Map of geomorphic surfaces, channel position, and large organic debris in a section of South Fork Hoh River. Mapped by pace and compass by G. W. Lienkaemper.

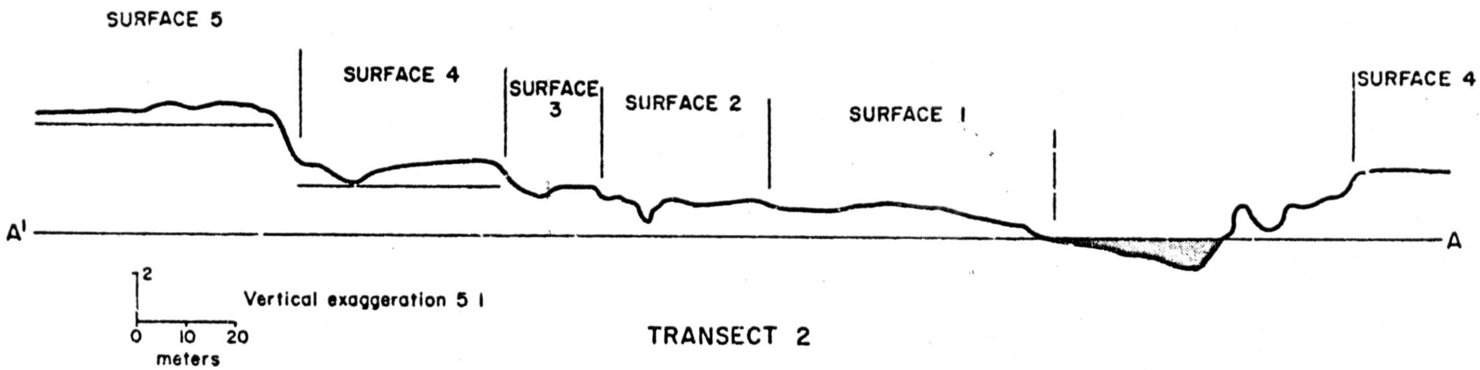

Figure 2--Surveyed cross-section of valley bottom along transect A-A' (Figure 1).

formation of terraces in the Hoh River system corresponded to Neoglacial ice advances.

The mapped reach and adjacent areas examined only in reconnaissance reveal some consistent patterns of backwater channels and zones of addition and accumulation of large organic debris. Whole trees fall into the river where Surface 4 and higher surfaces are undercut on the outside of bends in the river. These trees accumulate at the heads of the downstream gravel bars (Surface 1) which are persistent sites for accumulation of large debris. In many instances, these debris accumulations regulate water movement into high water channels that occur regularly along the back edges of Surfaces 1, 2, and, in some cases, 3 on the inside of bends in the river.

Many small tributary channels flow directly toward the river over Surfaces 5 and 6, but then turn downstream and parallel the river by flowing along the back edge of Surfaces 3 or 4. The tributary stream in the east portion of Figure 1 takes such an indirect route. The net effect is to increase the area of low gradient, valley floor tributary streams. The cause of this channel pattern is not clear. The back edges of many surfaces are wet areas and surveys across the valley floor reveal some tendency for surfaces to slope away from the main channel (Figure 2). This could be a product of a type of levee formation due to preferential accumulation of sediment on the margin of the surface along the river during periods of overbank flow. Low areas at the back edges of Surfaces 3 and 4 might also originate by the same processes that form and maintain high flow channels along the back edges of Surfaces 1 and 2. These types of gravel bars with high centers in the axis of the main channel have been observed in other sediment-laden rivers (R. J. Janda, pers. comm.). In some instances along the South Fork of the Hoh, accumulations of large organic debris on the prows of gravel bars may aid sediment accumulation along the axis of the bar and direct high flows into a channel along the back edge of the bar. As the river continually changes its course. these high water channels may be largely abandoned by the main stem only to be occupied later by a tributary stream.

INTERACTIONS OF FLUVIAL PROCESSES, LANDFORMS, AND VEGETATION

Interactions between high flow events and forest vegetation vary from one geomorphic surface to another (Figure 3). Flooding by the main stem affects Surfaces 1 through 4. This inundation may affect plant community composition. One effect is localized deposition of fine sediment which may provide seed bed for species such as alder which might not become established in the stand otherwise. Surface 3 and higher surfaces are subject to bankcutting while surface scour is the more important erosion process on lower surfaces. Floated large organic debris has both positive and negative effects on live vegetation. Debris carried by flood flow can severely batter living plants on lower surfaces. Stabilized, down, large debris provides protected sites where alder and other pioneering species may become established. Once established, living vegetation itself begins to stabilize geomorphic surfaces by developing root systems and reducing water velocity by the flow resistence of stems.

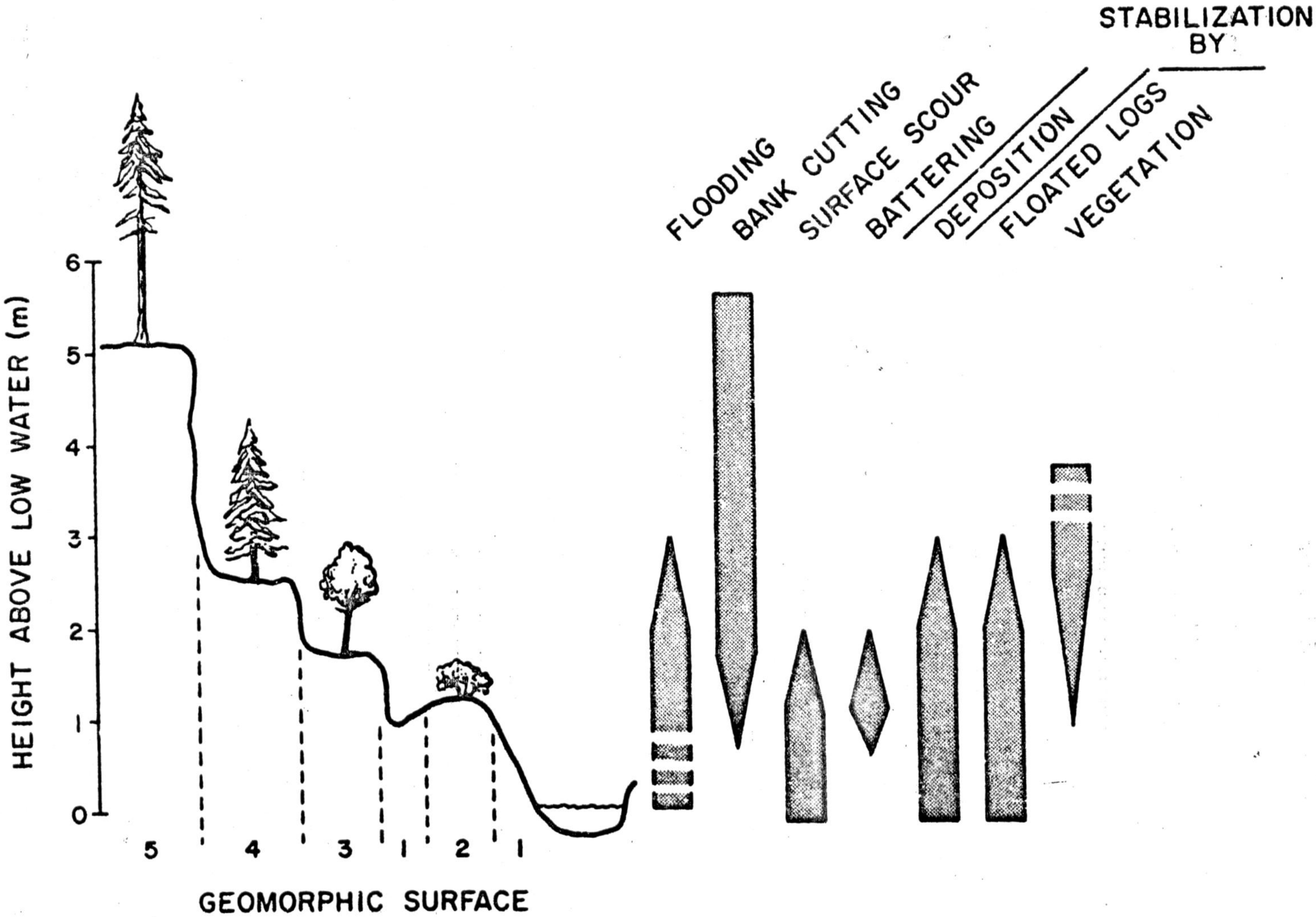

Figure 3--Types of effects of fluvial processes on geomorphic surfaces 1 through 5.

Some of these interactions between fluvial processes and vegetation can be interpreted from analysis of the alder thicket ("camp thicket") on Surface 2 along section A-A' in Figure 1. This thicket appears to have developed after floods in 1962, 1966, and 1968 (Figure 4). Tree ages vary over more than a decade, suggesting occurrence of repeated disturbance and opportunity for establishment. The main body of the stand is protected by several large logs partially buried in sediment (Figure 5). Alder stems in bordering areas not protected by the down logs have been repeatedly and heavily abraded by floating organic debris and moving bedload sediment. The major down logs protecting the thicket and trees in the thicket itself create a localized quiet water environment where fine sediment is deposited during high flows. This process, coupled with litter production by the stand, accelerates soil development and growth of the stand. The large, down debris helps the stand reach a stage of structural development where it can better withstand most floods.

Analysis of ages of sapling and small trees at the camp thicket and other sites in the mapped area provides additional insight into the role of flooding on vegetation establishment (Figure 4). The camp alder thicket appears to post-date the flood of November 1962, but the broad spread of ages indicates that subsequent high flows provided new opportunities for establishment. Some other areas mapped as Surface 2 have trees nearly 30 years old which may have been established after the second highest flow on record in November, 1949. Trees sampled on Surfaces 3 and 4 have a broad range of ages some of which cluster following years with high flows (Figure 4). The group of 23 to 28 year old trees on Surface 4 appears to post-date the high flow of November 1949. The forest floor of this surface is well covered with litter and herbaceous vegetation, suggesting that establishment of these alder trees may have occurred on overbank deposits.

In general, the lower geomorphic surfaces are repeatedly affected over a period of at least several centuries by high flows which damage vegetation and create new opportunities for establishment. Forests on Surface 4, for example, contain trees over 250 years old and these stands are still affected by flooding. Consequently, forests on these surfaces are not simple single-aged stands dating from single floods.

AQUATIC HABITAT

Geomorphic processes have created and maintained four broadly defined classes of aquatic habitat in the valley. The main river channel is characterized by fast, turbid water and shifting channel position. Glaciers at the river's head are a source of abundant silt and clay-sized sediment during the spring, summer, and fall months. Riparian vegetation has only moderate influence over the wide river and overall abundance of large organic debris is low relative to the other three classes of stream environments.

The broad valley floor allows development of a variety of back water and high flow channels we term "off-channel" sites. These sites range from ephemeral high flow channels to secondary river channels that carry

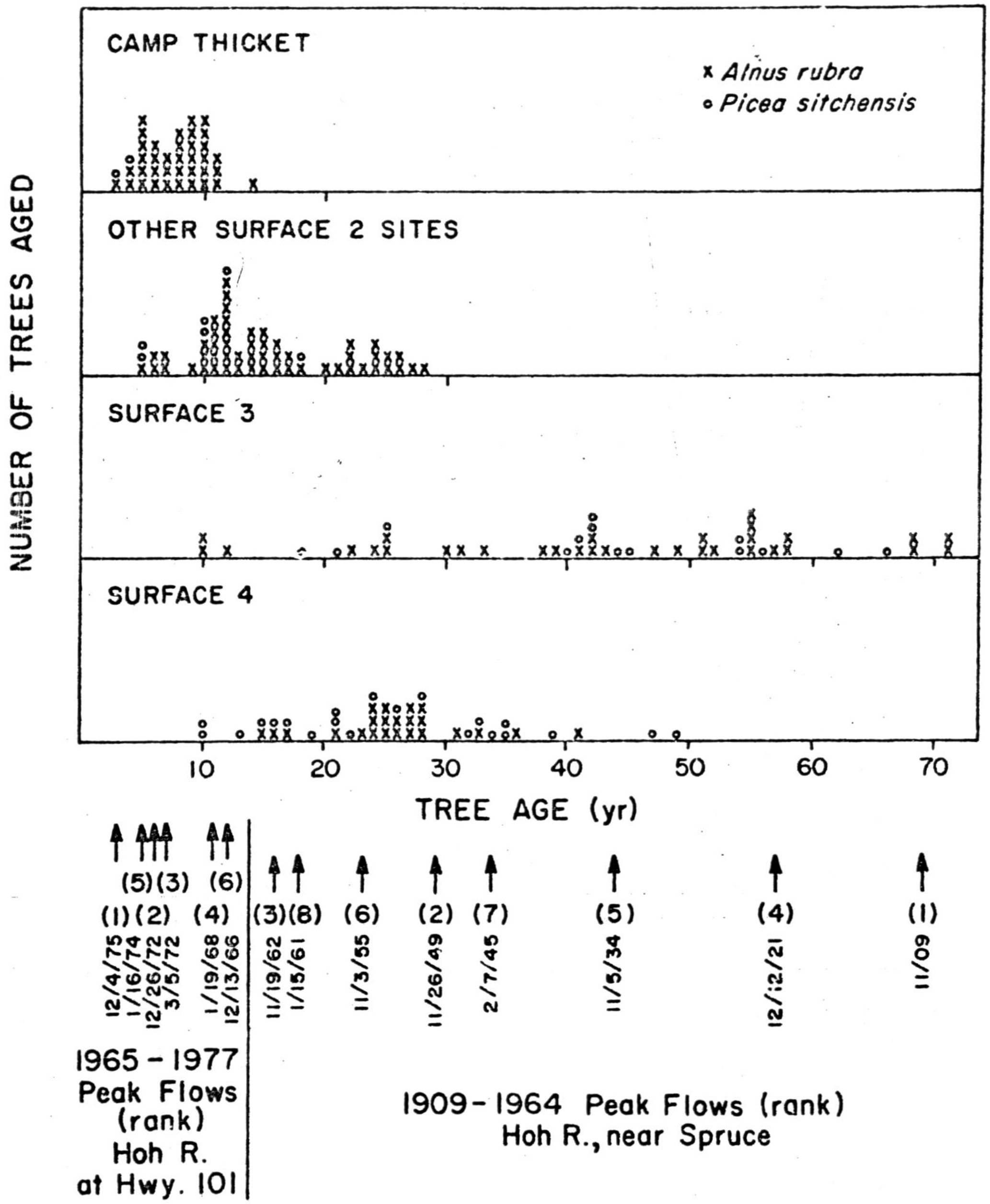

Figure 4--Age distribution of alder and spruce saplings and small trees on Surfaces 1-4 and peak flows since 1909. Peak flow data for 1927-1957 for Hoh River and earlier peaks for Quinault River from Bodhaine and Thomas (1964). More recent data from annual U.S. Geological Survey reports of Surface Water Supply of the United States, Part 12, and Water Resources Data for Washington.

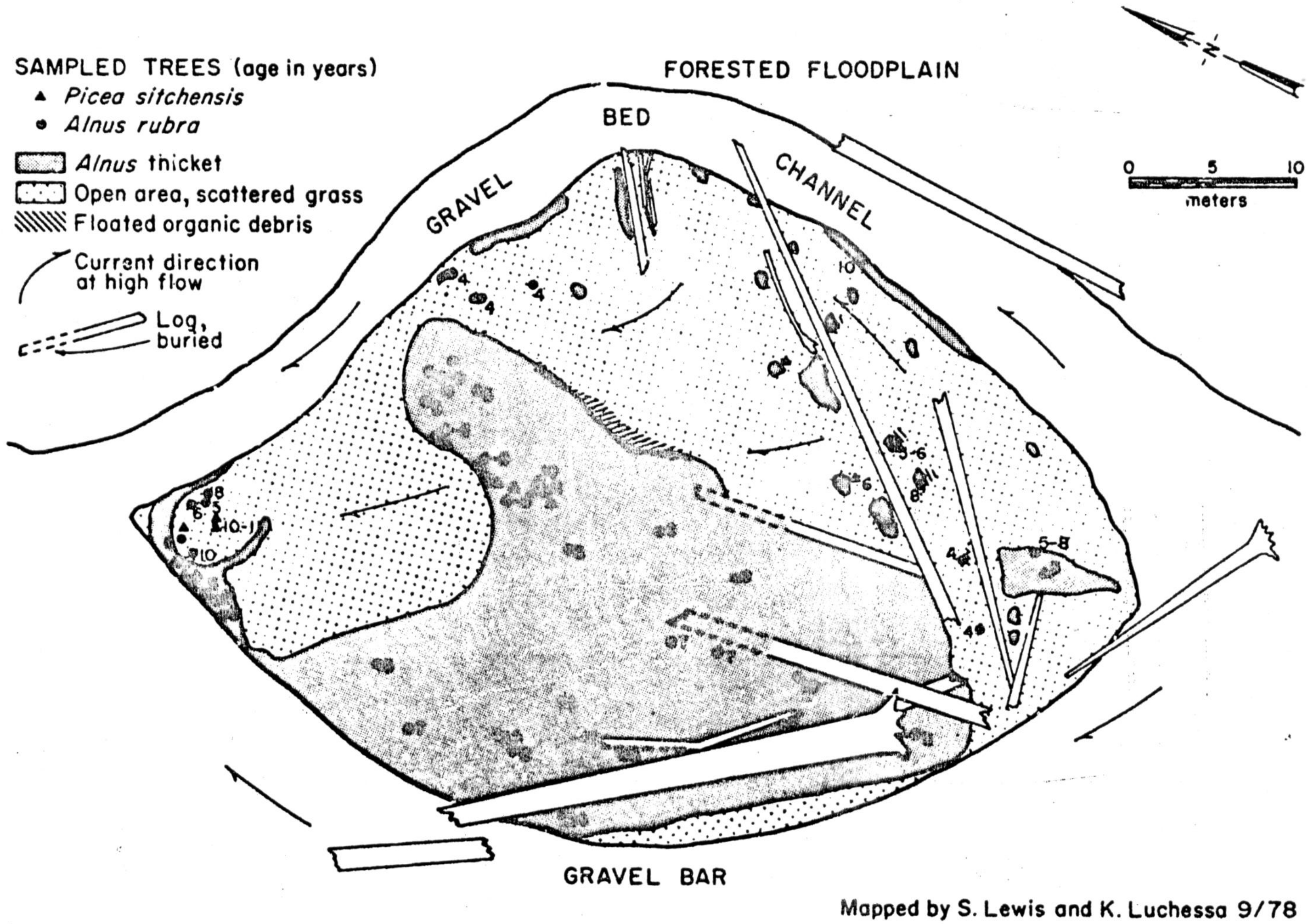

Figure 5--Map of "camp" alder thicket on Surface 2 located on transect A-A', Figure 1.

water much of the year. In some cases, log jams regulate flow into off-channel areas. Compared with the main channel, flow velocity is moderate and large organic debris and riparian vegetation are more important. However, this environment is quite varied with flow conditions ranging from fast and turbid to slow and clear to no flow at all.

Tributary streams originating from springs at the back edges of valley floor surfaces or from streams draining the valley walls are termed "terrace tributaries." These streams are typified by low gradients, quiet, clear water, and strong influence of surrounding forest vegetation.

Valley wall tributaries are rigorous environments with steep gradients and flashy flows. Since these streams are not glacier-fed and heavy forest vegetation on the valley walls minimizes soil erosion, stream water is clear except during periods of high flow. Forest vegetation strongly influences valley wall tributaries, particularly in the case of large organic debris which forms a stair-step profile along streams. Falls and plunge pools formed in this fashion dissipate stream energy, store sediment, slow removal of fine organic detritus which is the food base of the aquatic ecosystems, and shape microhabitats within the stream.

The influences of forest vegetation on aquatic ecosystems and geomorphic forms and processes increase across this range of stream types from main river channel to valley wall tributary. Structure and productivity of aquatic communities vary across these stream types in response to geomorphic factors and degree of forest influence (Sedell et al. 1980, Ward and Cummins, 1980).

CONCLUSIONS

Geomorphic features set the stage for development of terrestrial and aquatic ecosystems of the South Fork Hoh River. Geomorphic processes regulate the types and rates of ecosystem development. Structure, age distribution, abundance of dead wood, and other characteristics of forest communities vary from one geomorphic surface to another in response both to the time period available for forest development and to degrees and types of influences of floods. Successively higher surfaces are less influenced by fluvial processes of the main river. For example, vegetation on Surface 2 is subjected to a variety of destructive and beneficial influences of high flows, while higher surfaces are mainly affected by bankcutting and overbank deposition of sediment. Alder establishment in spruce forests on Surface 4 may have occurred on seedbed provided by deposits of fine overbank sediment deposits. Thus, this surface appears to have been affected by fluvial processes for at least several centuries.

Geomorphic processes have created and maintained four distinctive types of aquatic environments in the valley: (1) the main river channel with fast, turbid water and only moderate influence of forest vegetation; (2) off-channel areas of the main stem with flows that vary from fast to quiet and turbid to clear and may dry up part of the year; (3) terrace

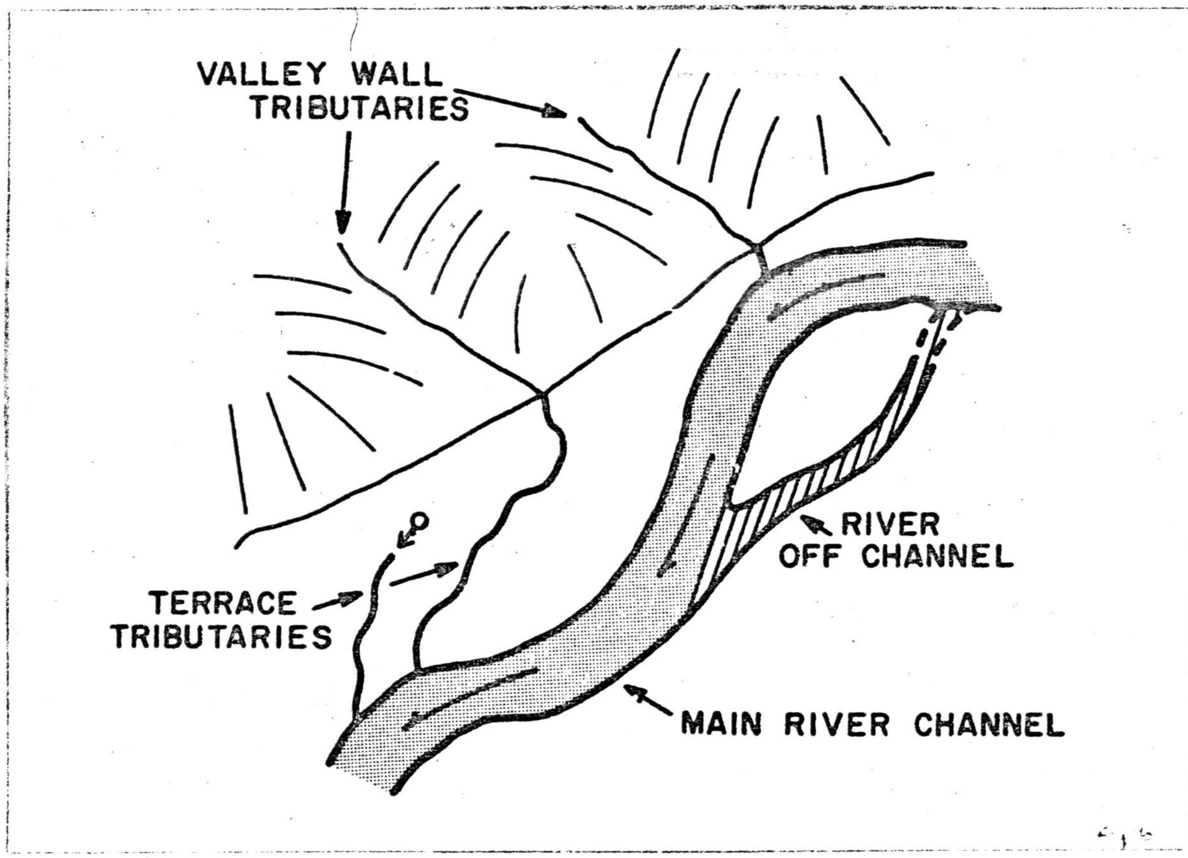

Figure 6--Four types of stream environments.

tributaries characterized by quiet, clear water; and (4) valley wall tributaries which have fast, generally clear water. Forest influences increase across this array of stream types.

Understanding geomorphic setting, both in terms of landforms and processes, is essential to interpreting terrestrial and aquatic ecosystems of the Hoh valley.

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Proceedings of the Second Conference on Scientific Research in the National Parks

VOLUME 7: Ecosystem Studies / Interdisciplinary Approach
Resource Management and Planning
Information Technology

San Francisco, California
November 26-30, 1979

Sponsored by:
National Park Service
and
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