A PRELIMINARY SURVEY OF THE INFLUENCES OF CONTROLLED LOGGING ON A TROUT STREAM IN THE H. J. ANDREWS EXPERIMENTAL FOREST, OREGON

by

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INTRODUCTION

This report presents the results of a preliminary field investigation conducted to determine the effects of the early stages of an experimental, sustained-yield logging program upon stream conditions, with special reference to trout environment. The location was on the Lookout Creek drainage of the H. J. Andrews Experimental Forest, Lane County, Oregon, which is under the jurisdiction of the United States Forest Service. The periods of field inquiry were from June 25 to October 10, 1951, and from June 20 to September 18, 1952. Since no precedent for conducting this type of study had been established by previous work, much of the investigating was carried on at an observational level and many of the methods employed were arbitrarily chosen.

The experimental forest, established in 1948, comprises a 15,000 acre portion of the Willamette National Forest in which the personnel of the Pacific Northwest Forest and Range Experiment Station are conducting research to determine improved methods for managing old-growth Douglas-fir forests. Since the logging operations in this particular area were controlled, and since the location was on a headwater tributary of the McKenzie River, an important trout stream of Western Oregon, it was deemed advisable by both the Oregon Cooperative Wildlife Research Unit[1] and the Forest Experiment Station[2] that a study be conducted to determine the effects of logging on stream conditions. This report constitutes the preliminary phases of such a study.

The ultimate goal is to secure knowledge which can be used to develop improved stream management practices in conjunction with logging operations. As the result of the decrease in private timber holdings in recent years, and other factors, the United States Forest Service presently writes timber sale contracts for a substantial amount of the total timber being cut in the Pacific Northwest. This trend places the Forest Service in an increasingly favorable position for instituting forest management policies. At the present time many Forest Service employees, and others, are advocating the need for information upon which to build an enlightened stream management program around forestry practices. The rapidity with which the remaining virgin forests are being cut has made the need for research of this type urgent.

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1. United States Fish and Wildlife Service, Oregon State Game Commission, Wildlife Management Institute, Agricultural Research Foundation, cooperating.

2. Pacific Northwest Forest and Range Experiment Station.

The literature was not consulted by the writer until the first summer of field work had been completed. Several references regarding the probable effects of denuding forest land and certain reports showing altered stream conditions as the aftermath of logging were read. Although an exhaustive search was not made, no reports were found of actual observations recorded while a logging operation was in progress. Information from books by Needham, Welch and Geiger (8, 18 and 4) was helpful in interpreting data gathered.

METHODS AND MATERIALS

Physical Description of the Study Area

The H. J. Andrews Experimental Forest comprises approximately 15,000 acres of heavily-timbered, mountainous terrain situated on the western slope of the Cascade Mountain Range in Lane County, Oregon. The boundaries lie along the crests of the ridges which delimit the Lookout Creek drainage. Lookout Creek joins Blue River at a point three miles above the confluence of that stream and the McKenzie River. The study was confined to that part of the forest extending along the south slope of Lookout Creek from its mouth to the junction of Mack Creek. Approximately six miles of Lookout Creek were included, along with the adjacent south slope, which rises to a 2000-foot ridge approximately one mile distant. The area described is roughly one mile wide and five miles long. Several small tributaries, originating at various elevations on this slope, flow into the main stream. Lookout Creek drops from an elevation of about 2750 feet at the eastern edge of the study area to about 1500 feet at its mouth, a vertical distance of roughly 1250 feet. Benches of varying width parallel Lookout Creek and are intersected by the ravines formed by the smaller tributaries. Sedimentary outcrops occur at different elevations throughout the area, and, in some places, form waterfalls.

Cover Description

A description taken from field notes written in September, 1951, states the following: The north-facing slope of the study area receives very little direct sunshine throughout much of the year. As a result, conditions are moist, particularly at the lower elevations, where a 350-year-old association of climax Douglas-fir, Pseudotsuga taxifolia (Poir) Britt., and western red cedar, Thuja plicata D. Don, towers 200 feet above a dense undergrowth of vine maple, Acer circinatum Pursh., and western hemlock, Tsuga heterophylla (Rafn) Sarg. Bigleaf maple, Acer macrophylum Pursh., red alder, Alnus rubra Bong., and

California hazel, *Corylus californica* K. Koch., are common along the main stream, while vine maple and devil's club, *Oplopanax horridum* (Sm.) Miquel., form the common cover over the small tributaries. Western hemlock seedlings abound on the carpet of lesser vegetation that covers the numerous decaying logs and other prominences. There is a heavy litter of organic debris covering a deep layer of soil.

Higher on the slope, drier conditions prevail and a younger stand of Douglas-fir is interspersed with western hemlocks and an occasional sugar pine, *Pinus lambertiana* Dougl. Where there is sufficient sunlight, the understory is often composed of thickets of Pacific rhododendron, *Rhododendron macrophyllum* D. Don.

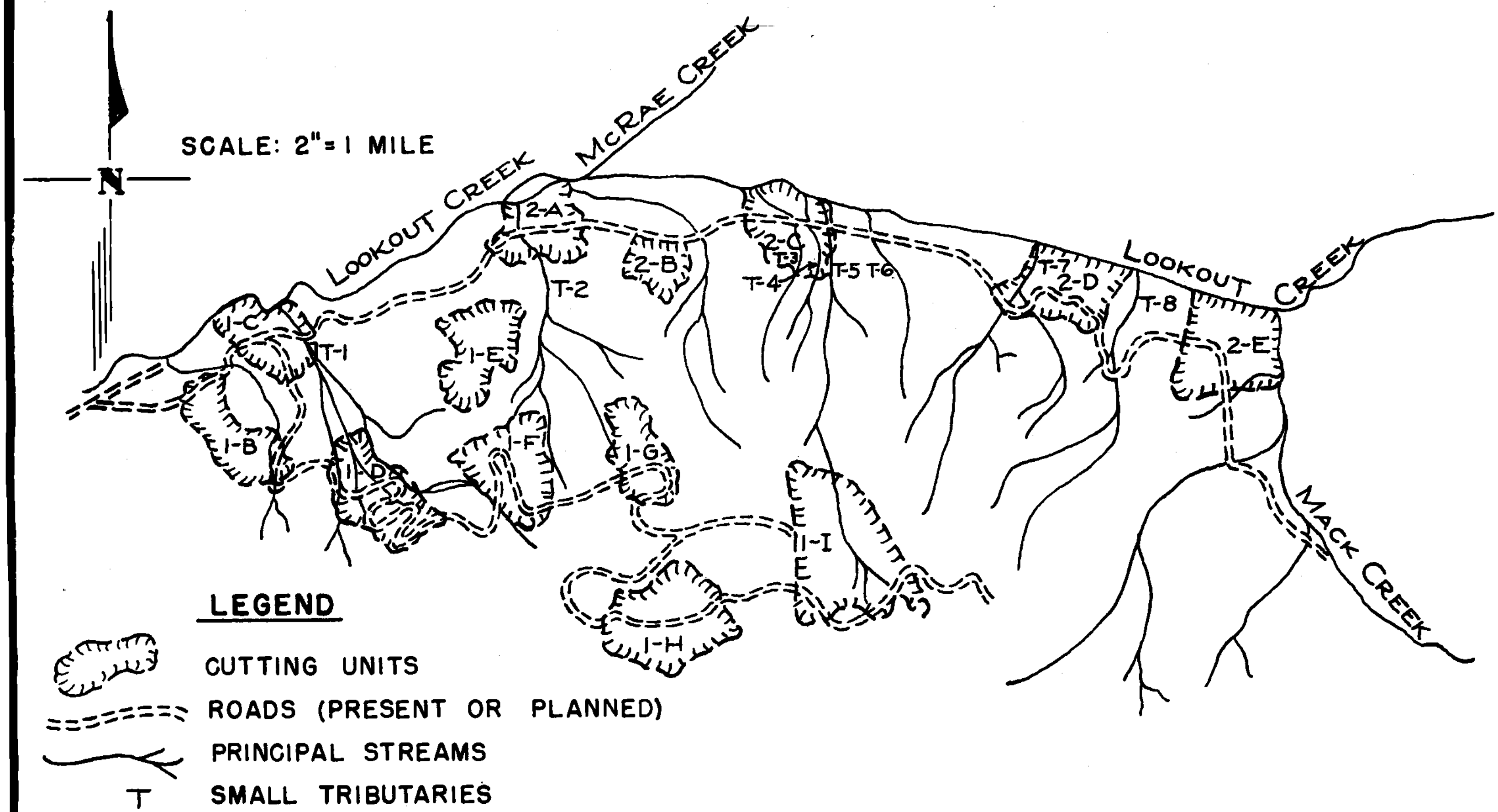
Description of the Study Streams

The volume of Lookout Creek, similar to other streams of the area, fluctuates widely. In 1950, a maximum flow of 1050 cubic feet per second was recorded on January 22, and a minimum flow of 12 cubic feet per second was recorded on September 13 at the United States Geological Survey stream gauge located near the mouth of the creek. The minimum volumes of surface flow at the mouths of the tributaries numbered 5, 6, 7 and 8 were 0.04, 0.01, 0.03 and 0.16 cubic feet per second respectively on September 15, 1951. For locations of these tributaries, see figure 1. The volumes of flow of tributaries 1 and 2 were each estimated to be 0.15 cubic feet per second at this time. These six streams comprise all the major tributaries to Lookout Creek within the study area.

Two species of trout were present in the study streams. Coastal cutthroat trout, *Salmo clarkii clarkii* Richardson, were abundant throughout all the major streams in the area. Resident rainbow trout, *Salmo gairdnerii* Richardson, were found principally in the lower reaches of Lookout Creek. Angling records show that 66 trout were caught within two miles of the mouth of Lookout Creek during the 1951 study period, of which 33 were cutthroats and the remaining half were rainbows. The cutthroats ranged in fork length from 14.0 to 21.2 cm. and the average fork length was 16.4 cm. The rainbows ranged in fork length from 12.9 to 23.3 cm., the average fork length being 15.8 cm. Seining operations were conducted at a point approximately three miles above the mouth of Lookout Creek by Ross Newcomb, Assistant Leader of Fisheries Research, Oregon Cooperative Wildlife Research Unit. In one seine haul made on August 7, 1952, 295 trout were caught, of which 292 were cutthroats and only 3 were rainbows. This indicated that there was a great disparity between the numbers of rainbow trout present in the two areas of Lookout Creek from which the above measurements were taken. Trout observed in the small

FIGURE 1

STUDY AREA IN H. J. ANDREWS EXPERIMENTAL FOREST, LANE COUNTY, OREGON



tributaries were all cutthroat, indicating that very few rainbows, if any, were present during most of the summer. Cutthroat trout were seen in nearly all portions of the small tributaries that were accessible to them. The Lookout Creek trout population was very high, as illustrated by the seining operation, which indicated that more than one thousand fish in excess of one year of age were present in a hole estimated to be 120 feet long and 30 feet wide. Individuals of the current year class were not included in the estimate.

Two sculpins, *Cottus gulosus* Girard, were taken from the pool in which seining operations were conducted. Other information concerning species of fish present in the study streams is lacking. It is recommended that future studies be conducted in the Lookout Creek drainage to determine some of the facts concerning fish species, distributions, growth rates and reproductive habits. At the present time, little is known about the fish populations with which this study will be concerned in the future.

Description of the Experimental Logging Program

The staggered-setting system of logging is used by the Forest Experiment Station in the H. J. Andrews Experimental Forest. This method involves the complete removal of cover from scattered blocks of ground. These "units" of logged area are separated by strips of timber from

700 to 2000 feet wide, and contain approximately 30 acres each, so that no extensive, single area is ever denuded at one time. The procedures involved in the logging program are outlined briefly. The mapping, locating of logging roads and landings, establishing of cutting boundaries, and sale of the timber are all carried out by U. S. Forest Service personnel. The timber is cruised after the unit boundaries have been established.

The purchaser is a private operator who begins logging according to the specifications of the timber-sale contract which gives procedures for cutting, utilization standards, and outlines parts of the experimental work he is required to do as the area is logged. The private operator constructs the roads, the specifications of which are drawn up by a Forest Service engineer. The cost of the road construction is deducted from the price of the timber purchased.

The use of the "high-lead" is specified in the timber sale contract. At the same time that road construction begins, the falling of the trees in the units is also started. In this type of logging, the trees are limbed and bucked where they fall into logs of suitable length. The "yarding" of the logs to the landing, where they are loaded on trucks, is done through the use of spar-poles made from the trunks of tall trees left standing at strategic locations in the units. In "yarding" the logs are dragged to the landing by a cable operated through a large pulley at the top of the spar-pole. Power is supplied by "donkeys" which usually are diesel engines mounted on heavy sleds. Spar-pole locations are chosen, wherever possible, to avoid the dragging of the logs across streams.

Bulldozers are used in constructing roads, landings and fire trails. They are not used in any manner which otherwise requires them to leave the roadways, unless such use is specified in the timber-sale contract.

A large amount of dead organic material in the form of brush, tree trimmings, rejected logs and duff is left in the units after the logs have been removed. This "slash" constitutes an extreme fire hazard in dry season. It is burned at the first opportunity, which is usually after the first fall rains within one season following logging. Natural reseeding on the units is effected by the wind-borne seeds from trees surrounding the units.

The yearly timber cut of the McKenzie working circle, of which the H. J. Andrews Experimental Forest is only a part, is limited to about the productive capacity of the land. The 20 million board feet annual cut in the Experimental Forest will be maintained until most of the road system is complete. The cut will then be shifted to other drainages in the upper McKenzie River. The old growth stands will be harvested on such a schedule in the next 40 years. After that, younger stands will be cut for the remainder of a 120 year rotation period, at which time the stands cut now would be ready for a second harvest.

The second season of logging was in progress at the time this study was begun. Units 1B, 1C and 1D[1] had been cleared of logs and yarding was in progress in Unit 1F. The slash in Unit 1C and the portion of Unit 1D below the road system was burned in the fall of 1951, near the end of the first summer's study period. Logging on the five units of the second sale was begun in the fall of 1951. When the second half of the study was begun in June, 1952, the yarding in Unit 2A had been completed and was in progress in Unit 2B. By the close of the second summer's field work in September, 1952, all logs had been removed from Units 2B and 2C and falling was in progress in 2E.

GENERAL PROCEDURE

The approach to the study was observational and exploratory in character. As might be expected, since the initial work was intended to determine the needs for following investigations, one of the difficulties encountered was in maintaining scope of the inquiry within

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1. Each unit is designated by a number and a letter, as shown in Figure 1. The number refers to the chronological sequence of timber sales, and the letter serves to distinguish between units included in a particular sale.

manageable limits. Much time and effort were directed toward collecting temperature data in Lookout Creek and its tributaries in such a manner as to permit comparisons of the degree of warm-up in streams which had become exposed as a result of logging with streams whose cover remained undisturbed.

Portions of the information gathered have proven to be of limited importance to phases of the work which will be discussed here. These same data, however, may be of considerable value to subsequent observers as bases for future study and comparison. An attempt has been made to present the significant information obtained under logical headings, each of which includes the procedures involved. A summary list of tentative conclusions and recommendations for future study are presented at the end of the report.

When the term tributary is used in the report it refers to one of the small tributaries designated numerically in figure 1. All temperatures appearing are in degrees Fahrenheit.

SEDIMENTATION AND STREAM-BED SCOURING DUE TO LOGGING

During the early phase of the study, the probable importance of sedimentation was pointed out by Roy Silen, Forester in Charge of the Experimental Forest. He ventured the opinion that the amount of sediment which entered the Lookout Creek drainage in its natural state was extremely small compared to the amounts that were introduced incidental to the carrying-out of the experimental logging program. He further stated that the silt introductions originated almost wholly from localized sources resulting from specific phases of the operation. His observations indicated that the building and use of logging roads constituted the major sources of sediment.

Every available opportunity was utilized to observe all phases of the logging operation which normally might be expected to result in the introduction of sediment. The information gathered has borne out the validity of the opinions voiced by Mr. Silen.

Observational surveys were conducted which covered nearly all portions of the study area. Several of the streams were first inspected in their natural state and then frequently revisited during and after the period in which they were logged. Other tributaries which remained untouched during the entire period of study served as observational control streams.

This portion of the study resulted in the accumulation of notes which chronologically described the changes that occurred. Lookout Creek was protected from the direct disturbances of the logging operation to a much greater degree than the tributaries. As a result, many data were collected from the tributaries which were of limited value in predicting what the effects might have been in the main stream had it been subjected to similar treatment. The H. J. Andrews experimental logging program is exemplary, and the stream disturbances observed represent the absolute minimum which could be expected to occur under a less-controlled operation. Examples from the data are presented here in an attempt to convey to the reader some concept of the nature of the changes that were observed.

Sediment Sources

The methods used in determining the relative amounts and effects of sediment entering the drainage consisted of noting the extent and degree to which normally clear flows were colored by the presence of suspended sediments, observing and comparing the amount of sedimentation which occurred in the stream beds, as well as locating and determining the extent of introductions which were known to have occurred.

The opinion that relatively small amounts of sediment enter the drainage from unlogged areas is based upon the few observations of active erosion where natural conditions prevailed. Instances of stream bank cutting were seldom found in undisturbed stream beds. All but the smallest tributaries were free of silt.

The first period of heavy precipitation to occur in the fall of 1951, consisting of approximately seven inches of rainfall in seven days, raised the level of Lookout Creek near its mouth nearly two feet. During this time, extensive visual comparisons were made between the amounts of suspended sediment present in logged and unlogged tributaries. The most important indication of these comparisons was that the discoloration of the flows stemming from unlogged sources in no way approached the striking discoloration of the flows which were in some way affected by road building or logging. It was also noted that the major portion of the discoloration, contrary to what might be expected, originated largely as silt from the road drainages, and not in the surface run-off from the more extensive logged areas. The small rivulets which drained the open, logged areas during rainfall appeared to be quite clear, indicating that a comparatively small amount of silt was being introduced from these areas. Repeated observations strongly indicated that the normal surface run-off from logged hillsides was a small contributing factor to the total amount of siltation caused by this type of logging. This is believed to be due to the scarification of the soil and the presence of an accumulation of organic debris, which retards the surface run-off.

The importance of roads as major agents of sedimentation has been indicated. Multiple sources of sediment were created when roads were constructed into the study area. Several of these sources merit individual discussion.

Culvert Installation

The installation of culverts in tributaries was responsible for a large portion of the sediment introduced during road construction. The culverts consisted of metal pipes of varying diameters. The phase of the installing operation responsible for the sediment was the method used in forming the level bed in the bottom of the stream in which the pipe was placed. Caterpillar tractors were used in a manner which usually left large amounts of soil where the stream would eventually wash much of it downstream. An example of this type of culvert installation is shown in figure 2. This culvert was installed in Unit 1D on June 25, 1951. The outlet of the culvert may be seen protruding at the bottom of the road fill in the background. The pile of debris which was introduced into the streambed when the culvert was installed can be observed in the foreground. The flow of the tributary can be seen emerging from the debris at the lower left edge of the photograph.

Road Drainages

The snowfall in the Experimental Forest is normally not great enough to prevent logging at the lower elevations.

Figure 2. Road Culvert in Unit 1D Showing Outlet and Debris.

Figure 3. Road Drainage Entering Tributary in Unit 1D.

As a result the roads are commonly used during the rainy season. It was observed that the use of logging roads during periods of actual rainfall led to the introduction of large quantities of fine silt, which originated on the roads and reached the streams through the road drainages.

During periods of rainfall there was a continual run-off from the roads. It was standard practice to construct the drainage ditches so that they emptied into the nearest downstream tributary crossed by the road. An example of a road drainage entering a tributary is shown in figure 3. The run-off from unused roads was clear. When logging traffic and rainfall occurred at the same time however, the resulting run-off contained much fine silt.

During the period from September 28 to October 3, 1951, the entire three mile portion of Lookout Creek below the mouth of tributary 1 in Unit 1C was frequently heavily discolored with fine silt. The major source of this suspended sediment was traced to the mouth of tributary 1 in Unit 1C and ultimately to the road drainages which entered its branches in Unit 1D.

Direct Introductions of Sediment into Lookout Creek

The sediment sources thus far mentioned have greatly altered the beds of the tributaries. The materials carried by the tributaries into Lookout Creek were evidently transported through that stream, for only slight silting of the bottom was ever observed there.

The few specific silt introductions of considerable magnitude were observed to have occurred directly into Lookout Creek. The first two of these disturbances to be mentioned occurred during the construction of the access road which parallels the lower portion of Lookout Creek. Information gained in conversation with Roy Silen and personal observations made it possible to provide the following descriptions of conditions transpiring to bring about the observed aftermath.

At a point roughly 1.5 miles above the mouth, a section of rock cliff was blasted into Lookout Creek. The resulting accumulation of large boulders and logs in the stream bed caused a pool to be formed. Figure 4 shows the lower portion of the pool as it appeared in September, 1952. The original bottom of this section of stream was largely bedrock. Shortly following the formation of this pool a miscalculation was made by a bulldozer operator operating on the installation of a large culvert in the mouth of a tributary to Lookout Creek located about one mile above the pool. The "error", which consisted of having accumulated several tons too much earth fill at this point, was corrected by shoving the unneeded dirt and rock into Lookout Creek. Some comprehension of the volume of material involved can be achieved when it is realized that a fan of earth was formed across Lookout Creek which momentarily completely blocked the flow. Roy Silen stated that the coarse-sand bottom, which is depicted in figure 4, was first formed following the aforementioned large introduction of sediment. The formation of this pool was the only example found where any small particles of sediment from the logging operation were lodged permanently in Lookout Creek.

Two major introductions of sediment into Lookout Creek occurred after the study was begun. A section of dirt road in a precipitous portion of Unit 1C slid into Lookout Creek during the winter of 1951-52. The photograph presented in figure 5 was taken in September, 1952, and shows the area of Lookout Creek which was blocked off by the slide. The stream cut a channel through the slide material, leaving a portion of the slide on the far bank of the stream.

A culvert was completely washed out of tributary 1 in Unit 1C during the winter of 1952-53. The cause was believed to have been a poor job of installation plus the occurrence of what amounted to flood conditions in the area. Reference to figures 7 and 8 will give some concept of the amount of material introduced when the culvert was lost. Virtually all of the missing fill was transported at least as far as Lookout Creek, a short distance below. The bed of the tributary below the washout was extremely scoured, possibly due, in part, to the release of a large

Figure 4. Artificial Pool in Lookout Creek Resulting from Road Construction.

Figure 5. Landslide into Lookout Creek from Road in Unit 1C.

Figure 6. Unburned Slash Cover in Tributary 2, Unit 1D.

Figure 7. Road Culvert in Tributary 1 in Unit 1C.

Figure 8. Same area as Figure 7 showing Extensive Flood Damage to road culvert.

volume of water when the culvert gave way. The two introductions of sediment just mentioned resulted in the accumulation of quantities of large rubble and boulders in Lookout Creek.

Stream-bed Scouring

Another type of stream disturbance was found to have occurred in tributary 2 in Unit 2A. A seventy yard portion of this stream below the upstream boundary of the unit was logged with the use of a caterpillar tractor, instead of a spar-pole. In this type of logging the tractor was taken off the roads into the area and the logs were dragged behind it to the landings. One month following the completion of this operation, observations were made which clearly indicated that the amount of stream disturbance which occurred in this area was much greater than the amount which occurred in the lower portion of the same tributary, which was logged with a spar-pole. At this time the "cat"-logged section was completely disrupted. The stream-bed in the high-lead-logged section was less disrupted, but was found to contain a large quantity of fine sediment, which undoubtedly washed down from the section above. The quantity of slash covering the stream was much greater in the lower section where the tractor was not used.

A high-water period followed the fall slash burning in tributary 2 in December, 1952. In February, 1952, the stream was revisited and the following changes were noted. Very little slash was left anywhere in the stream. The stream-beds in both sections were badly scoured and fresh stream bank cutting was evident. The unlogged portion of tributary 2 immediately above Unit 2D appeared very little disturbed by the high water.

The Effects of Slash upon Sedimentation and Scouring

Prior to the burning of the slash, extensive portions of all the tributaries flowing through logged units were covered with a heavy accumulation of limbs and logs. An example of a complete slash-cover over a stream is shown in figure 6, which is a photograph of the lower portion of tributary 2 in Unit 2D. In many areas the amount of slash exceeded an estimated 100 tons to the acre.

Following the burning of the slash the streams were much more exposed to direct sunlight and rainfall, but still contained many unburned slash particles. The photograph presented in figure 9 was taken in Unit 1D approximately 11 months after the slash had been burned, and shows a typical condition in small flows after the slash was burned. A series of terraced, silt-bottomed pools were formed through the combined introduction of particles of unburned slash and silt. In the lower reaches of the tributaries containing larger flows the formation of these terraced pools was less pronounced. It may be mentioned that very little slash was introduced into Lookout Creek.

Foresters from other areas in Oregon have mentioned experiencing severe stream-bed scouring caused by the sudden release of large volumes of water dammed up by accumulations of slash. No instances of this were observed in the study streams.

Factors Related to Stream-bed Disturbances

A more thorough investigation of the physical effects of the sedimentary sources and stream disturbances was not made. Many technical aspects would have been involved that were beyond the scope of this study.

Some of the more apparent principles involved may be mentioned. The volume and velocity of flow determine the sediment-carrying capacity of streams. The transporting and eroding capacities vary with the sixth power of the velocity. This means that water flowing at two miles per hour has 64 times the carrying and scouring capacities of water flowing at one mile per hour. This relationship undoubtedly accounts for the extreme differences in the erosive capacities of streams at various flow stages, and between flows of different volumes and gradients in different areas.

Figure 9. Example of Slash Refuse and Silting in Tributary 1, Unit 1D.

Large disturbances to a stream-bed may occur months after the actual logging is completed, as was the case in tributary 2, where high water scoured the logged section almost one year after the area was logged.

When foreign materials are introduced into a stream one of three things may occur. The particles may be transported downstream in suspension, they may be carried along the bottom as bed-load, or they may remain permanently where they were introduced. Which of these takes place is dependent, of course, upon the transporting capacity of the stream and the nature of the introduced particles. The complex nature of the action exerted by the forces of the current upon the stream-bed materials may be understood when it is realized that the stream velocity is continually changing from point to point, and from time to time.

The introduction of new materials, such as slash into the small tributaries or boulders into Lookout Creek, changes the overall velocity and pattern of turbulence, which in turn causes changes in the transporting capacity at all points affected. Merely changing the position of a rock in the stream-bed results in a decrease in velocity at one point near the stream-bed which must be compensated for by an increase in velocity at a point nearby. Such a change in the intricate pattern of turbulence near the stream-bed is believed to have been a prime factor which caused the scouring described in tributary 2.

CHANGES NOTED IN AQUATIC INSECT POPULATIONS

Frequent observations of aquatic insect populations were made at many locations during the study. These observations consisted of simple descriptions of the orders of insects present and their relative abundance. Time and equipment were not available to conduct a more detailed inquiry involving exact enumerations. However, the information recorded seemed of sufficient value and interest to merit brief presentation.

The following method was arbitrarily devised as a quick means of comparing insect populations present in different areas. Rocks were gently lifted from the stream beds and all macroscopic organisms present were collected on a sheet of white paper. Each sample consisted of the first 100 aquatic organisms collected in this manner. The orders of insects represented in the samples and the relative sizes and abundances of the specimens were noted. An attempt was made to choose rocks of fairly uniform size from comparable stream locations, and a record was kept of the numbers of rocks inspected in collecting each sample.

Comparisons between collections from three different areas were made during the first week in August, 1952. The differences between the insect population sampled were large enough to be detected with the quick-sampling method used. Three types of stream conditions were sampled. They were an undisturbed, unlogged tributary; a tributary which had been "Cat" logged 2 months earlier; and a tributary which had been logged with a "high-lead" approximately 24 months earlier. The contents of collections made from these three areas are presented in table 1.

TABLE 1.

NUMBERS OF INSECTS OF THREE ORDERS PRESENT IN THREE 100 SPECIMEN SAMPLES COLLECTED AUGUST 1, 1952.

Sampling Area	Caddis Larvae	Stonefly Naiads	Mayfly Naiads	No. rocks inspected
Unlogged	64	3	32	10
2 months after "Cat" logging	0	0	0	20
24 months after High-lead logging	5	0	95	7

The sample collected in the unlogged tributary contained a high percentage of caddis larvae (Trichoptera). The remainder of the sample was composed of mayfly naiads (Ephemeroptera) and a few stonefly naiads (Plecoptera). Immature insects up to one inch long were not uncommon.

The section of stream that had been recently "cat" logged was located just downstream from the unlogged section. During the summer of 1951 before this section was logged, it was found to contain a population of insects comparable to that in the unlogged area. After logging it was found to contain virtually no aquatic insects or plant life. Twice as many rocks were inspected in this area as was necessary to collect the sample from in the unlogged area, and only two flat worms (Platyhelminthes) were found.

The section of stream that had been logged about 24 months earlier contained an abundant population of aquatic insects, nearly all of which were mayfly naiads under 3 millimeters in length. A very low number of caddis larvae were present, and no stonefly naiads could be found. The number of immature insects over 3 millimeters in length was much lower in this area than in the unlogged area. Fewer rocks were washed to find 100 organisms than was the case in the unlogged area. The indication was that a new insect population was being regenerated in this section of stream.

The results of the sampling were in agreement with general impressions gained from observations made throughout the study area. The general indications were that the insect populations definitely were adversely affected by the disruption of the stream bed, and that regeneration of the populations began within the first two seasons following logging. The case building caddis larvae and stonefly naiads may have been slower to reestablish themselves than the mayflies. The areas which were changed from a stone bottom to a mud bottom were found to support a different group of organisms. These impressions were based upon such fragmentary data that they are mentioned only as possibilities which should be considered for future study.

In many cases where stream conditions were not too disrupted by logging, a portion of the original insect population was observed to survive the period of logging. The ultimate fate of these organisms was not learned. It was observed, however, that the gills of the surviving immatures often were heavily coated with flocculent silt, as were the nets of the net-building caddis larvae (Hydropsychidae).

The evaluation of the effects of the fine suspended sediment on the aquatic insects will do much to clarify the future direction of investigations needed in ascertaining effects of logging operations on trout streams.

THE ELIMINATION OF TROUT POPULATIONS FROM THREE TRIBUTARIES

All the tributaries in the study area were repeatedly inspected for trout during 1951. Cutthroat trout were found in tributaries 2, 5, 7 and 8. Fry of the current year's hatch were found in tributaries 2 and 8, indicating successful spawning in these streams.

During the spring and summer of 1952, logging was conducted in the portions of tributaries 2, 5 and 7 lying within Units 2A, 2C and 2D, respectively. After each tributary had been logged it was again examined repeatedly for trout. No trout were ever seen in the logged portions of these tributaries.

Tributary 2 was logged in May, 1952, and by September, four months later, there were still no trout to be found in the logged section. The re-entrance of fish from the main stream was blocked at the mouth. Fish were still living in the unlogged section of the stream immediately above the logged unit. It was strikingly apparent that, during the first few months following logging, the upper boundary of Unit 2D marked the downstream limit of the fish population in tributary 2.

Tributary 8 was crossed by a road, but was not logged-over. Much fine silt was introduced into this tributary when the culvert was installed, which frequently discolored the flow and formed thin beds of silt in the quiet water areas. The trout present did not appear to leave this tributary as the result of this disturbance, which indicated that they may endure, for a short time at least, the presence of some fine silt.

THE EFFECT OF SLASH BURNING UPON THE MAXIMUM TEMPERATURE OF TRIBUTARY ONE

Procedure

An attempt was made to determine the effect of the burning of the slash in Units 1C and 1D upon the maximum temperatures of tributary 1 during the warmest portion of the first summer following the operation. The method arbitrarily devised involved the comparison of stream temperature data recorded before and after the burning of the slash.

Stream temperatures were recorded at regular intervals at 17 stations in tributary 1 during a 60 day period preceding the slash burning and during a similar period following the burning. The two periods of stream temperature measurement included all of July and August in 1951 and 1952, respectively. Units 1C and 1D were logged during the summer before the study was begun, and the slash was burned following the first summer's period of temperature measurement.

The locations of the stream temperature recording stations in Units 1C and 1D are shown in figure 10. Recordings were made with a pocket thermometer on three alternate days each week between the hours of 3:30 and 5:30 P.M. Supplementary data collected with the use of a maximum-minimum thermometer has shown that, on most days, temperatures collected during these hours could be considered close approximations of the maximum daily stream temperatures. Twenty-six temperature recordings were made at each station during each period of temperature measurement on such a schedule.

Results

Examples of the stream temperature data collected are presented in table 2. The table contains a list of the temperatures recorded on the two days during each study period when the maximum daily stream temperatures were found to be the highest and lowest. The highest maximum stream temperatures of each season were recorded on July 27, 1951, and July 28, 1952, respectively, and are presented in the first two columns of table 2. Columns three and four of this table contain data gathered on the days during each study period when the lowest daily maximum temperatures were measured. The last two columns contain the calculated averages of all the temperatures recorded at each station.

The data indicate that the maximum temperatures attained in tributary 1 at its mouth were increased roughly three degrees following slash burning. An estimate of three degrees was reached by comparing the data recorded at stations 1 and 2. Station 1 was located in Lookout Creek just above tributary 1, and station 2 was located in the mouth of tributary 1. During 1951 the maximum temperatures recorded at the mouth of tributary 1 were consistently the same as, or slightly less than, the temperature of Lookout Creek at station 1. A similar comparison of the data recorded in 1952 revealed that the maximum temperatures measured at station 2 were consistently about two degrees higher than those recorded at station 1. The consistency with which this difference in temperature was measured strongly indicated that an actual difference in the temperature of tributary 1 was measured.

The portion of the indicated increase in temperature which was due to the slash burning could not be clearly determined, since no attempt was made to measure the effect of other variables such as possible seasonal differences in volumes of flow. When the magnitude of the measured temperature increase and the relative volumes of flow of the tributary and the main stream are considered, it does not appear likely that the increased temperatures resulting in Lookout Creek would be significant.

General observation indicated that any increase in stream temperatures which occurred in tributary 1 was probably due to a combination of factors, rather than the removal of the cover of slash alone. The greatest increases in temperatures were indicated at the stations located in the upper reaches of the smallest branches of

FIGURE 10

DIAGRAMMATIC SKETCH OF TRIBUTARY I SHOWING STREAM TEMPERATURE RECORDING STATIONS

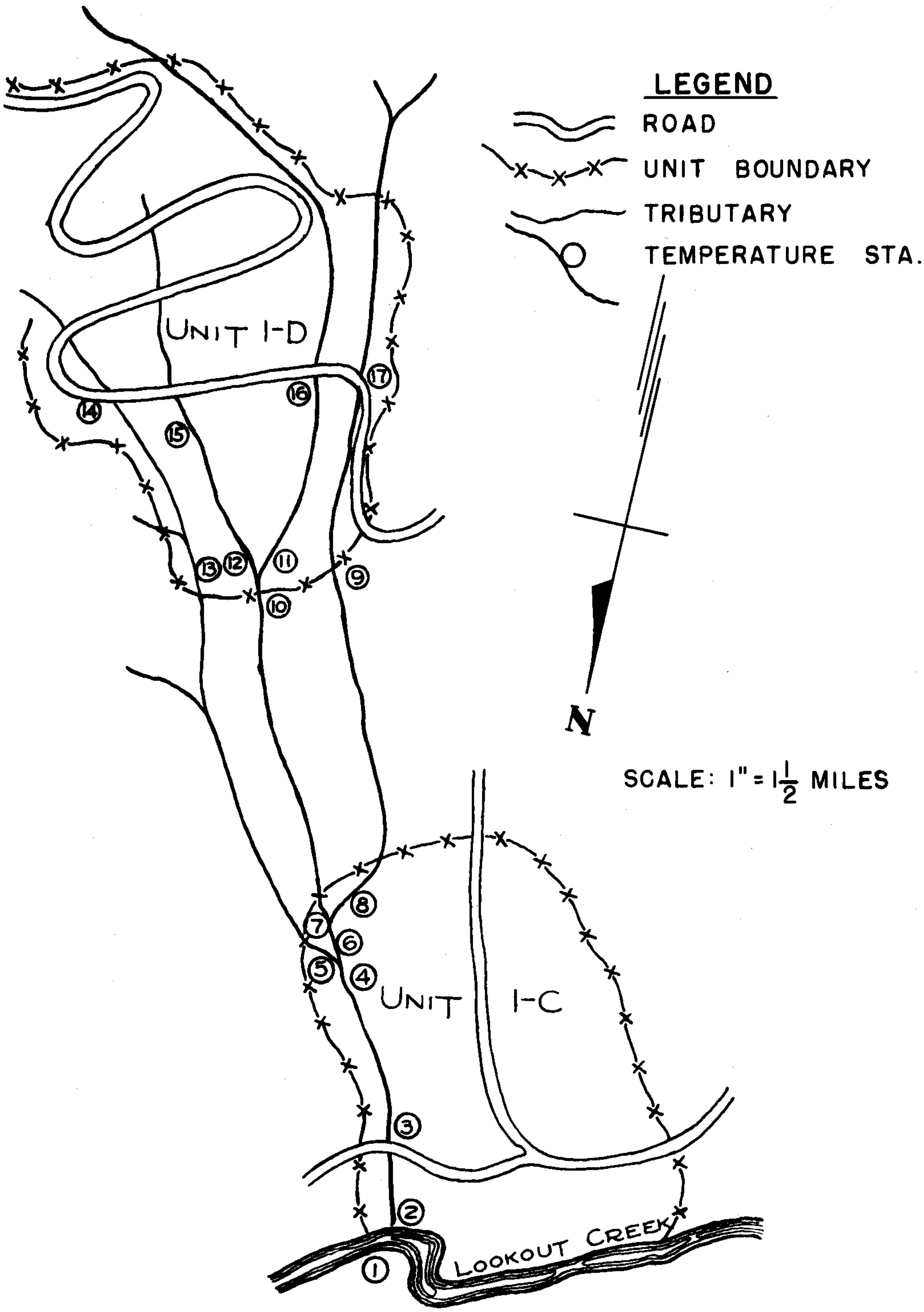


TABLE 2

STREAM TEMPERATURES RECORDED IN UNITS 1C AND 1D BEFORE AND AFTER SLASH BURNING (°F.)

Station	July 27 1951	July 28 1952	August 28 1951	August 25 1952	Average 1951	Average 1952
1	60	62	52	54	58	59.5
2	60	64	51	57	57	62
3	58	63	50	56	56.5	60.5
4	57	60	50	55	55	58
5	60	62	50	56	57	60
6	56	58	50	54	54	57
7	56	59	50	54	54	57
8	53	56	48	52	52	54.5
9	51	56	51	55	50.5	55
10	55	59	50	54	54	57
11	54	58	50	54	53	56.5
12	58	62	49	54	56	60
13	60	64	52	58	58	61.5
14	61	68	52	58	61	64.5
15	62	73	52	60	61	67.5
16	51	54	48	51	50	52.5
17	55	57	50	54	53.5	56

tributary 1. The combined effect of silt and unburned slash particles in these small flows resulted in the formation of a series of terraced pools. It would appear logical to assume that the increased surface area and decreased velocity of the flow which accompanied the formation of these pools may have been responsible for a significant portion of the increase in temperature recorded.

If future study should indicate that increased stream temperatures due to logging are going to be large enough to necessitate control measures in the small tributaries, the factors mentioned should be investigated to determine their relative importance. At present it appears likely that proper control of cover along the main stream will be effective in preventing increased stream temperatures in Lookout Creek due to logging operations of this type. Final judgment should be reserved, however, until the temperature data can be collected which will indicate the effects of the stages of logging before slash burning on the temperatures of small tributaries.

FACTORS AFFECTING THE DAILY TEMPERATURE VARIATION OF WATER

Procedure

The leaving of narrow strips of uncut timber along the banks of Lookout Creek was considered as a means of preventing increased stream temperatures due to logging. Since a narrow corridor of trees could be expected to provide shade, but not necessarily to give protection from increased temperatures which develop in and near the ground in logged areas, an attempt was made to determine the relative importance of air, ground, and the direct rays of the sun as agents of heat-entry into small bodies of water.

The materials used consisted of three "Brown", 24-hour thermographs, three 25-gallon metal tubs, a bag of expanded mica insulation, some tar paper, and a sheet of plywood.

The three metal tubs were buried level with the surface of the ground in an exposed location in Unit 1C. Two of the tubs were buried with their walls in direct contact with the surrounding soil. The third tub was insulated from the soil with a two-inch layer of expanded mica insulation. The insulation was prevented from absorbing moisture from the soil by a layer of tar paper. One of the two uninsulated tubs was shaded from the direct rays of the sun with a sheet of plywood in a manner which allowed the free circulation of air over the tub. Twenty-five gallons of clear water from a nearby stream were poured into each tub. The thermographs were then used to record a continuous temperature record of the water in each tub for a period of 10 days, August 21 to August 31, 1952. A continuous air temperature record was also recorded during this period. Views of the apparatus ready for operation are shown in figures 11 and 12.

Results

The daily temperature variation of the water in the exposed, insulated tub was greater than that in either the exposed, uninsulated tub or the shaded tub. The temperature variations in the shaded tub were very small compared to those in the other two tubs. A typical example of the daily temperature variations recorded is presented in figure 13. There were a few scattered clouds in the sky during the recording period of 6 P.M., August 21 to 6 P.M., August 22, 1952. The maximum air temperature was 87 degrees. During this time the temperature increase was 11 degrees in the exposed, uninsulated tub, 16 degrees in the exposed, insulated tub, and 2 degrees in the shaded, uninsulated tub.

Discussion

The larger temperature variation in the insulated tub indicated that the direction of heat transfer in the uninsulated tubs was from the water to the soil in the daytime, and from the soil to the water at night. The major importance of the direct rays of the sun as a source of heat was clearly illustrated. Although the experimental conditions surrounding the water in the tubs differed from stream conditions in several obvious ways, it was believed that there was sufficient evidence to indicate the possible successful use of narrow stream-side corridors in retarding increased stream temperatures which accompany logging.

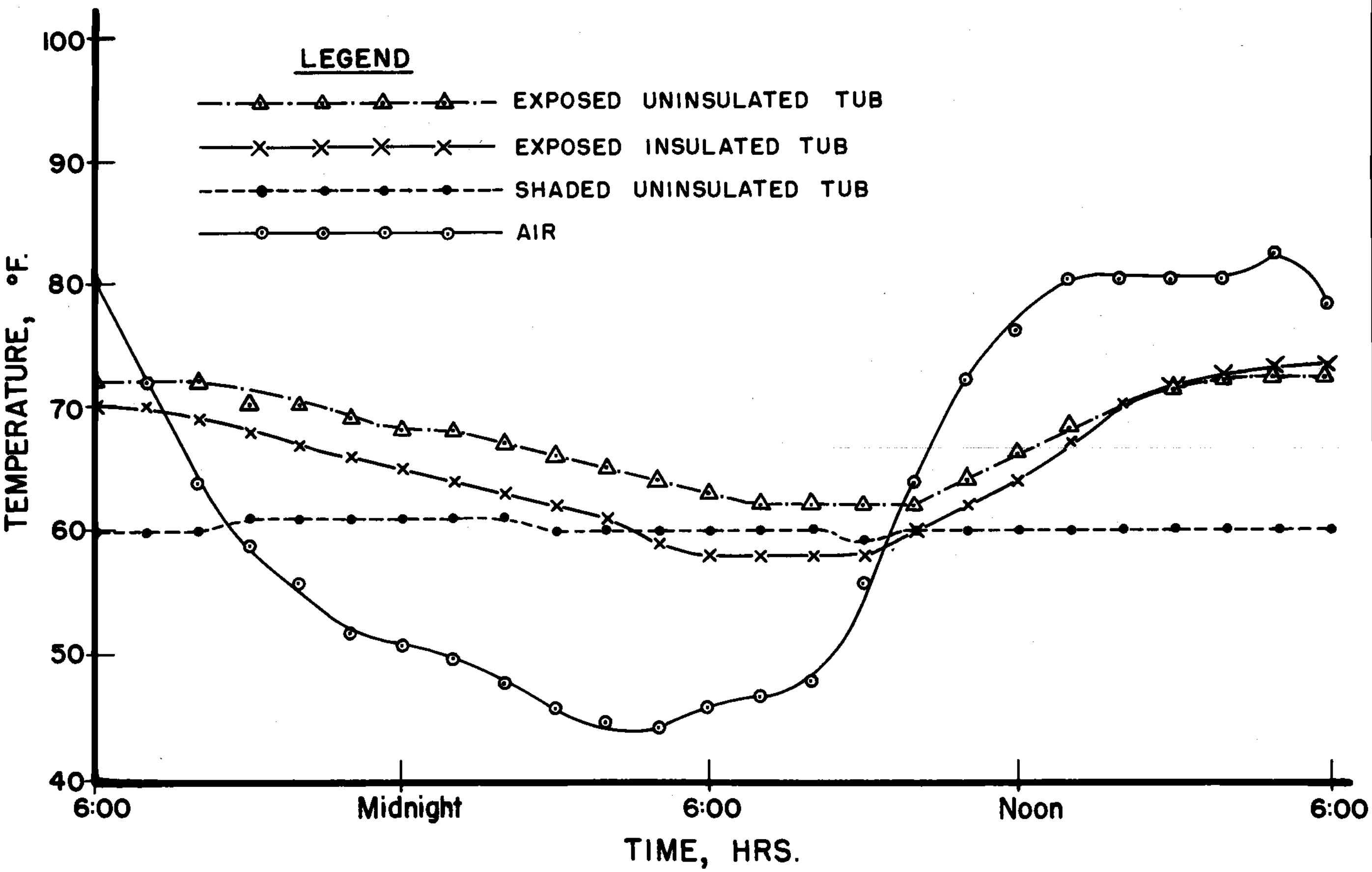
Figure 11. View of Experimental Temperature Apparatus.

Figure 12. Close-up View of Experimental Temperature Apparatus Showing Insulated and Shaded Tubs.

FIGURE 13

TEMPERATURE VARIATIONS OF AIR, AND WATER IN BURIED TUBS

6:00 P. M., AUGUST 21, TO 6:00 P. M. AUGUST 22, 1952



SUMMARY AND CONCLUSIONS

1. An observational study was conducted in the H. J. Andrews Experimental Forest, Lane County, Oregon, to obtain information which would serve as a guide for the future study of the effects of the staggered-setting system of logging in mature Douglas fir upon trout environments.

2. The amounts of sediment entering Lookout Creek drainage were observed to be increased greatly by the experimental logging operation.

3. The major sources of sediment created by the logging operation were observed to be localized and largely associated with the construction, use and maintenance of logging roads.

4. The amounts of sediment entering the drainage as a result of erosion from the open logged areas did not appear to be pronounced.

5. The sediment introduced into Lookout Creek through the tributaries was primarily fine silt, which was transported through Lookout Creek.

6. Several direct introductions of large amounts of sediment into Lookout Creek resulted in the accumulation of large amounts of coarse mineral material in the stream bed.

7. Due to the greater protection given the main stream from the logging operation and the greater transporting

capacity of the flow present, the bed of Lookout Creek remained comparatively undisturbed in comparison to those of the logged tributaries.

8. The greatest amounts of sedimentation occurred in the upper reaches of the small tributaries, which, due to the small volumes of flow present, were unable to transport the large quantities of slash-particles and silt introduced into them.

9. Methods of eliminating a large amount of the sediment now being introduced directly into Lookout Creek could probably be devised without undue cost.

10. Protection of the small tributaries from logging disturbances similar to that exercised on the main stream does not seem possible, since they are too numerous to make the complete avoidance of disturbances practical. However, if future study indicates that some protective measures are warranted, new methods might be devised which would eliminate the introduction of silt during culvert installation and from road drainages, as well as eliminate or minimize other harmful disturbances.

11. The amount of disruption occurring in a stream bed during logging when caterpillar tractors were used was observed to be greated than the amount which occurred when a "high-lead" was used.

12. A logged section of one of the larger tributaries was

severly scoured during a period of high water, while an unlogged adjacent section of the same stream remained relatively undisturbed.

13. Populations of cutthroat trout were eliminated from three small tributaries as a result of the logging operation.

14. Aquatic insect populations were found to be adversely affected for at least one year by stream bed disturbances accompanying logging. Observations on a section of stream that had recently been "cat" logged, revealed that virtually a complete elimination of aquatic insect life had occurred.

15. A controlled experiment was conducted which indicated that the use of narrow stream-side corridors might reduce increased water temperatures resulting from logging practices.

16. Temperature data were gathered which indicated that the effect of slash-burning upon the temperature of a small tributary was too small to be accurately detected with the method used. The data gathered indicated that the increase in maximum stream temperature of tributary 1 at its mouth following slash-burning was not greater than approximately three degrees Fahrenheit.

RECOMMENDATIONS FOR FUTURE STUDY

Methods of eliminating a large amount of the sediment now being introduced into Lookout Creek could be devised by the Pacific Northwest Forest and Range Experiment Station. Before an attempt can be made to do this, there is need to determine to what degree and in what way the sedimentation is affecting the productivity of Lookout Creek. Since Lookout Creek is the only stream in the study area of angling size, the inimical effects of logging on the small tributaries are important in so far as they are transmitted to Lookout Creek. The elimination of large, direct introductions of materials into Lookout Creek could be effected through proper selection of road sites and due care in construction. However, the elimination of silt introduced into Lookout Creek through the small tributaries, and the maintenance of natural conditions in them, would be a more difficult task. Therefore, it is recommended that specific answers to the following general questions be sought:

1. What is the biological role of small tributaries in relation to Lookout Creek?
2. What is the effect upon the productivity of Lookout Creek of the large quantities of suspended silt introduced through the small tributaries?
3. How important to the productivity of Lookout Creek

are the faunal contributions of the minor tributaries?

4. What is the effect of the direct introduction of large quantities of earth and rock into Lookout Creek?
5. Are the tentative conclusions of this study regarding sediment sources borne out by actual measurement?

More basic biological knowledge concerning the environmental requirements of the fishes, aquatic insects, and lesser organisms present in the drainage is needed in order that the above questions may be answered. There is a splendid opportunity available in this area to conduct detailed studies which would show specifically what type of protection from logging disturbances the streams need. To a certain extent, through cooperating with the Forest Experiment Station, the logging disturbances could be controlled to meet experimental needs. The results of such studies would be invaluable as a guide to the forester for developing improved stream management policies.

Since the temperature data collected so far do not indicate that a large increase in stream temperatures occurs with the present system of logging, it is believed that the relative amount of time spent on this phase of the study might be reduced and better utilized on other phases of the study outlined above.

If, however, the increases in stream temperatures due to the present system of logging are to be accurately measured, a more precise method of measurement needs to be developed. The stream temperature data gathered in this study indicate that there is a consistent correlation between the maximum stream temperatures attained at various points which is not altered until the stream conditions are changed. It is recommended that study be conducted to determine the feasibility of applying a statistical method to measure this indicated apparent correlation. If such a method can be successfully applied it is believed that changes in stream temperatures due to logging could be more reliably measured with less time and effort than was expended in the present investigations.

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