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AN ANNOTATED BIBLIOGRAPHY OF THE EFFECTS OF LOGGING ON FISH OF THE WESTERN UNITED STATES AND CANADA

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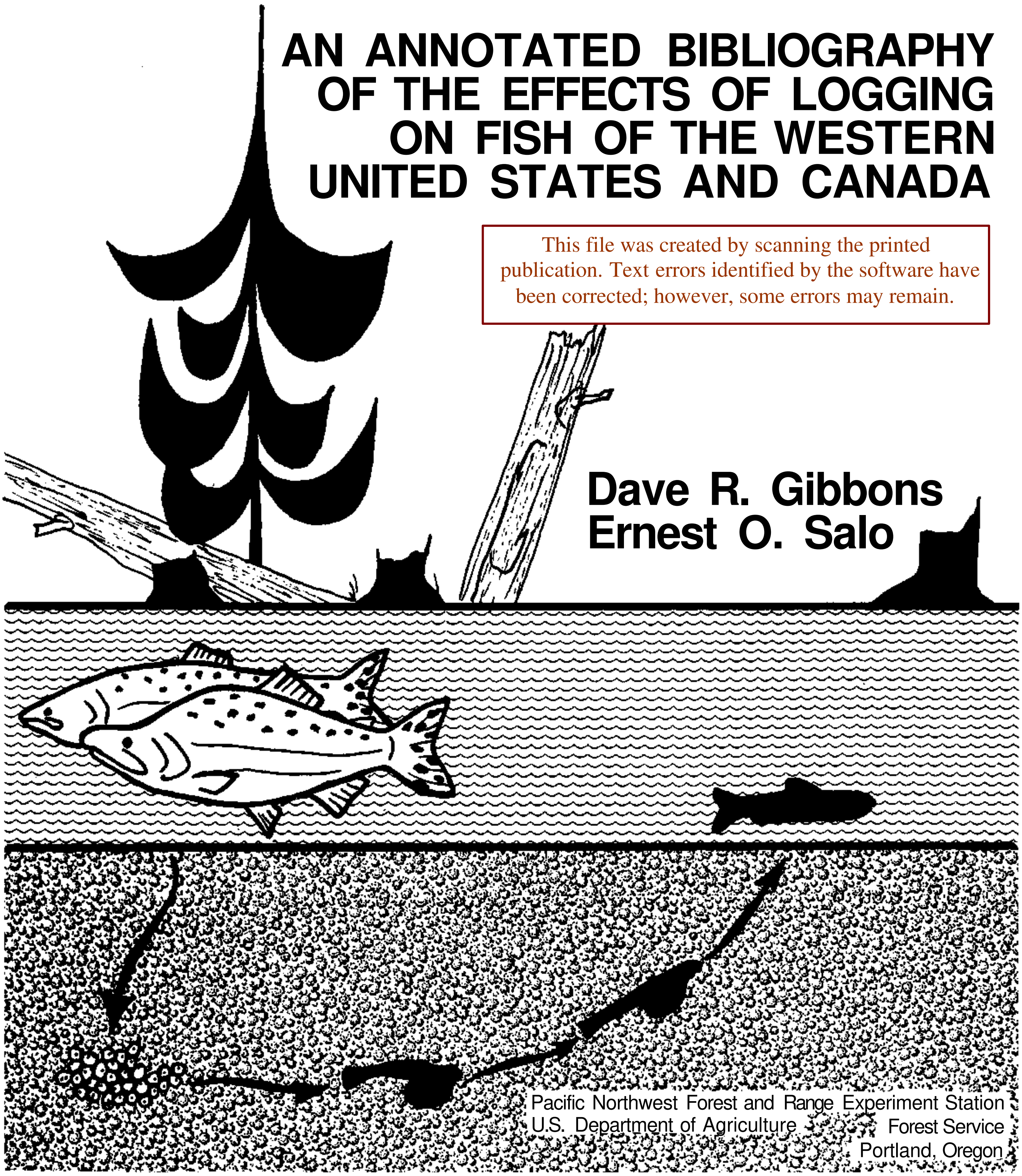

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ABSTRACT

This bibliography is an annotation of the scientific and nonscientific literature published on the effects of logging on fish and aquatic habitat of the Western United States and Canada. It includes 278 annotations and 317 total references. Subject areas include erosion and sedimentation, water quality, related influences upon salmonids, multiple logging effects, alteration of streamflow, stream protection, multiple-use management, streamside vegetation, stream improvement, and descriptions of studies on effects of logging. A review of the literature, a narrative on the state of the art, and a list of research needs determined by questionnaires are included.

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A REVIEW OF THE LITERATURE ON LOGGING AND FISHERIES--
A STATEMENT ON THE STATE OF THE ART

This narrative on the "state of the art" of the effects of logging on fish of the Western United States and Canada consists of two parts; the first is a review of the literature; the second, an analysis of a workshop on logging and fisheries held at the University of Washington, November 20-21, 1972. The numbers in parentheses indicate references in the annotated bibliography developed from the literature.

INTRODUCTION

There is no question that, historically, certain logging and associated land-use practices have had deleterious effects upon freshwater and anadromous fish populations. It is evident that some of these detrimental practices are continuing, although many others have been discontinued. A tremendous amount of progress has been made. Man's activities, coupled with naturally occurring events such as forest fires, floods, and slides, generate complexities that are difficult not only to assess but to control. Obviously, continuous assessment of potential environmental impacts is the concern of the land-user as well as of the resource manager. On the other hand, the ability of the management biologist sometimes is limited by ignorance of the requirements and status of fish stocks inhabiting the waters in question. This ignorance may range from the lack of knowledge of the peculiarities of the life histories of the endemic fishes in the streams and of the basic productivity of streams to the role of nonlogging factors such as fishing. In the absence of precise information, the biologist is inclined to recommend conservative regulations as a safety factor to protect the fish resources. Multiple uses of resources such as by fisheries and forest harvesters have, in the past, been conflicting; however, recently, the two groups have attempted to enter into coordinated research and management.

REVIEW OF THE LITERATURE

Sporadic research was conducted on the effects of logging and related use on the ecology of streams from 1900 to the 1950's. Since that time, extensive research has been conducted by many agencies. As productive as the research has been, it is still not possible to generalize on the effects of logging because of the varied land and aquatic habitats found in the Western United States and Canada. The hazards of logging to fish and water resources of the Pacific coast have seldom been quantitatively defined; in most cases, the potential harm was only inferred. Definite problems have been recognized in the literature. The harmful effects on fish which can result from logging and poor silvicultural methods used on the Pacific coast include:

1. Introduction of sediments
    a. Bedload sediments
        (1) reduced dissolved oxygen caused by reduced inter- and intragravel waterflow
        (2) physical barrier to the emergence of alevins
        (3) lowered production of aquatic plants and invertebrates
        (4) damage to eggs by adhesion to the chorion
        (5) reduced catchability of sport fish
    b. Suspended sediments
        (1) erosion of gill membranes
        (2) degradation of rearing habitat
        (3) lowered production of aquatic plants and invertebrates
2. Altered streamflow regimes
3. Introduction of logging debris
    a. Barriers to movement by juveniles and spawning adults
    b. Reduced dissolved oxygen as a result of high biological oxygen demand
4. Degradation of rearing habitat through streambank erosion
5. Altered temperature regimes
    a. Increased summer temperatures
    b. Decreased winter temperatures
6. Alterations in stream energy resources
7. Indiscriminate use of pesticides and herbicides
8. Altered chemical water quality regimes by the exposure of mineral soils and indiscriminate use of fertilizers.

The sources and effects of erosion and sedimentation have received the greatest research emphasis (fig. 1); however, the general topics of water quality, alteration of streamflow, stream protection and improvement, and the environmental requirements of salmonids have also received considerable discussion and documentation within North America. The research conducted before and after 1960 has shown similar emphases but with increased emphasis on water quality after 1960 (fig. 1).

Sources of Literature

The majority of the research results have been published in symposia or by academic institutions; however, considerable quantities can also be found in biological and forestry journals and in publications by the U.S. Forest Service and State agencies (table 1).

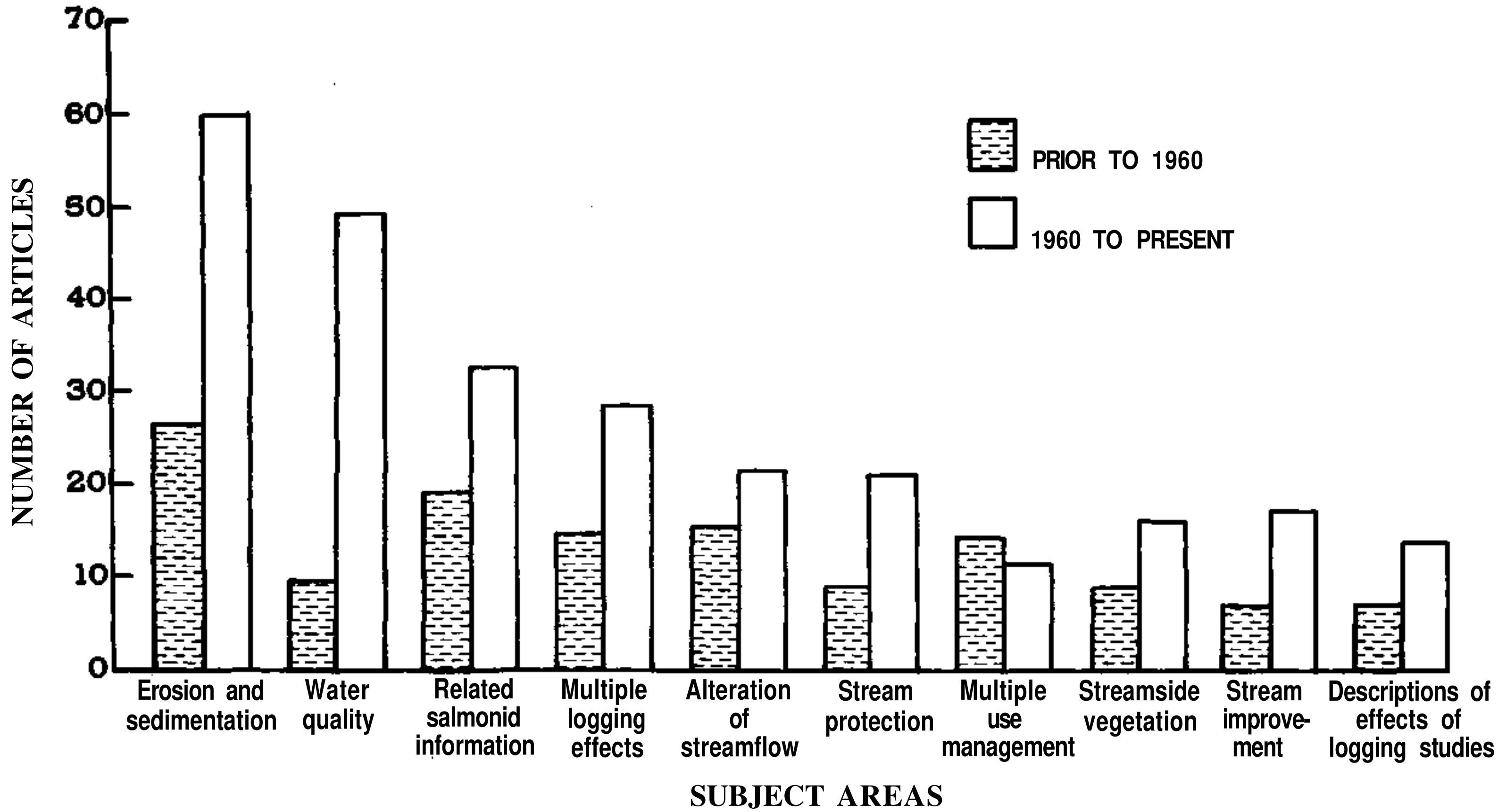

Figure 1.—*Research conducted on the effects of logging in the Western United States and Canada.*

Table 1.--Literature concerning the effects of logging on fish, 1928-73

Categories	Number
Symposia and academic institutions	83
Biological journals	60
Forestry journals	60
U.S. Forest Service publications	59
State agencies	49

Analysis of Literature

An analysis of the literature shows that although some critical analyses of the detrimental effects of logging are in the scientific literature, most blanket condemnations of logging are found in the popular, nonscientific journals. Actual quantitative, documented evidence on detrimental effects of logging on fish populations is limited to seven articles (56, 61, 252, 153, 275, 277, 211).

Many unpublished data are present in the files of fisheries management agencies. The results of many research summaries can be classified only as inconclusive. Table 2 is an attempt to categorize the conclusions of articles which appraise logging and silvicultural practices; 118 articles were not included as they do not fit the classifications chosen. Recent publications on the effects of logging have been less critical than in the past, perhaps as the complexity of the problem has become better understood. There seems to be a recent change in attitude favoring prevention instead of rehabilitation and an increase in collection of data for integration into watershed models.

Table 2.--Categorization of articles which appraise logging practices as described in the literature

Rank	Category	Number of articles	Percentage
1	Data collection on the effects of logging leading to inconclusive results	63	33
2	Description of adverse logging practices	58	30
3	Prevention of adverse logging practices	37	19

Table 2.--Categorization of articles which appraise logging practices as described in the literature—continued

Rank	Category	Number of articles	Percentage
4	Undetermined as to the effects of logging	10	5
5	Reviews of literature	8	4
6	Quantitative evidence of the detrimental effects	7	4
7	Condemnation of logging	5	2.5
8	Beneficial results of logging	5	2.5
	TOTAL	193	100

LITERATURE SUMMARY

Sedimentation

Most articles on sedimentation of streams have been purely descriptive, and sometimes dramatic, in their portrayal of an adverse effect on the environment. A lesser number of articles have reported qualitative effects of sedimentation. Quantitative studies of sedimentation, although few in number, have provided the real basis for present knowledge and can be divided into two categories: its sources and its effects on stream environments.

Sources of Sediment

Erosion, landslides, and the occurrence of sediments in our waters are natural phenomena and vary with the inherent erodibility of soils, geology, climate, and vegetation. Man's activities can, and usually do, accelerate these natural processes. The summation of approximately 25 articles documenting the effects of logging and logging roads on sediment production indicates: (a) logging roads are the greatest source of man-caused stream sediments; (b) sediments from clearcuts occur infrequently and are primarily a result of bared mineral soils and reduced surface-soil permeability due to compaction; and (c) severe burning of logging slash is often followed by increased rates of surface soil erosion, due primarily to the removal of stabilizing vegetation and litter.

The diverse characteristics of watersheds prevent extrapolation of results over wide geographical areas. Stephens (*50*) stated that "because of the striking differences in watershed characteristics, most of the published research results on the effects of logging on streams from other areas cannot be extrapolated directly to Southeast Alaska." Recently, however, some researchers through quantitative measurements of soil characteristics, meteorology, topography, and land-use conditions, have provided a basis for predicting differences in sediment production (*2*, 5, *51*).

Continuous research needs to be conducted on the development of new or redesigned logging methods that require fewer roads and produce less soil disturbance.

Effects of Sediment *on* Aquatic Environments

Fluctuations in the characteristics of aquatic environments, including the numbers and diversity of organisms, are natural phenomena. Through time, organisms have become selectively adapted to life within a set of environmental parameters. Changes which exceed the natural tolerance of these organisms will drastically change the population. The severity of stresses imposed by man upon the adaptability of these organisms will determine the degree of change.

Suspended sediment--The summation of six available articles dealing with the direct effects of suspended sediment or turbidity on fish, mostly salmonids, demonstrates several mechanisms of damage, including: (a) the adhesion of silt particles to the chorion of salmonid ova (29) and (b) the abrasion, thickening, and fusion of gills as a result of increased silt concentration (*295*). In addition to direct mortality of fish, suspended sediment also blocks or decreases light penetration and thereby limits the production of phytoplankton and other aquatic plants. It may also cause alterations in stream temperature-change rates and precipitation of organic particles which produce high stream BOD (Biological Oxygen Demands). Another concern is the loss of sport fishing time as a result of increased turbidities. It has been stated that fishing success declines with increasing turbidity above 25 ppm *(43).*

The literature demonstrates a large variation in results, making it impossible to define precisely what levels are lethal. Generally, prolonged exposures to concentrations from 200 to 300 ppm are lethal to fish. Shorter exposure times to concentrations of 90 to 810 ppm may reduce survival through synergistic effects with other stresses (i.e., increased temperature and decreased dissolved oxygen) in the environment (*16*, *295*). This research on the direct effects of suspended sediment on fish has been conducted in the laboratory and bears questionable applicability to field situations.

Future research should emphasize: (a) more detailed laboratory studies of the mechanisms of damage to fish from suspended sediments, (b) quantitatively documented studies in actual field situations, and (c) studies of the adaptability of salmonids in glaciated streams vs. natural streams subjected to increased suspended sediment concentrations.

Bedload sediments--Of all the factors affecting aquatic life, bedload sediments cause the most damage. The smothering effect and instability of sediment reduce invertebrate diversity and populations (55, 56, 298, *199*), reduce available living space for fish (29, *43*), and reduce early survival of fish (*184*, 295, *211*).

A summation of the findings from 50 articles dealing with bedload sediments shows: (a) sediment fills gravel interstices, thereby reducing inter- and intragravel waterflow, reducing dissolved oxygen to incubating salmonid ova; (b) deposited sediment can physically prevent emergence of fry (fig. 2); and (c) sediment reduces food resources by filling gravel interstices and promoting unstable substrates for aquatic invertebrates and periphyton communities.

Research has indicated that the lethal effects of sediment are most pronounced during the developmental stages of fish while in the gravel, and that once hatching occurs, physical environmental factors become less important and food availability becomes more important. Research on the effects of sediment has been quite extensive, as shown by the literature reviews of Cordone and Kelley (*15*), Gebhardt (*289*), Hollis et al. (*29*), and Koski (*32*). In spite of the fine work that has been completed, there still exist serious gaps in data documenting the quantities of sediment altering stream productivity related to fry quality and survival.

Organic sediments--Organic fines introduced by logging are important in stream environments where they decrease dissolved oxygen concentrations and intergravel flows and increase salmonid ova and alevin mortalities through the promotion of the growth of *Sphaerotilis* (bacteria which attack fish gills, resulting in suffocation). Suspended conifer fibers have been shown to lower the survival of rainbow and brown trout fry by inhibiting gill functions (*95*).

Water Quality

The watersheds of the Western United States and Canada harbor some of the most productive salmonid populations in the world. In the past, forest management has focused primarily upon the production of timber with little regard for maintaining stream quality; and consequently, water quality in many streams has been degraded. Logging and silvicultural practices have resulted in changes in the physical and chemical characteristics of water, e.g., increased water temperatures and the addition of silvicultural chemicals.

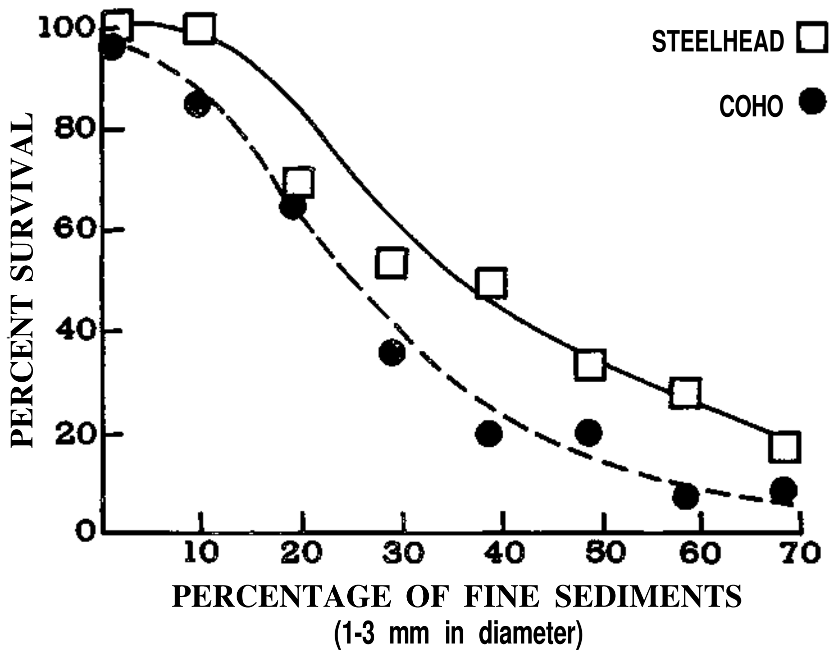

Figure 2.—*The relation between amount of fine particles in an artificial gravel bed and the ability of coho salmon and steelhead trout fry to emerge through the gravel* (211).

Water Temperature

Water temperature is a parameter that has received considerable attention recently in reference to land-use studies. Water temperature has been proven to be a major determinant in the suitability for salmonid production, with small forested streams being the most susceptible to a temperature change (78, 80, 90). As well as inducing direct mortality of organisms, adverse water temperature influences the level of dissolved oxygen and nutrients; controls algal blooms which may impart taste, odor, color, and ecological changes; and affects growth, condition, and behavior of fish. Warm water is also conducive to the growth of bacterial species which may constitute health problems to humans and fish. Finally, prolonged alteration in the temperature regime may eventually alter the species composition of streams.

A summation of 22 articles concerned with the effects of logging on stream temperature indicates: (a) removal of streamside vegetation increases maximum water temperatures by exposing streams to increased direct solar radiation; (b) stream temperature (Δt in °F) is directly proportional to surface area exposure (A in ft^2), the solar energy input (H in B.t.u./ft^2/minute) and inversely proportional to the flow (D in c.f.s.):

$$\Delta t = \frac{A \times H}{D} \; 0.000267 \qquad (77);$$

(c) warmed water reaching shade does not normally cool unless there is an inflow of cool water; and (d) winter minimum water temperatures can be lowered through removal of streamside vegetation (84).

Any change in the temperature regime of small streams may be deemed detrimental by some, but moderate increases in temperatures have been suggested by others as a means of improving salmonid habitat. However, care must be taken to prevent eutrophication and the destruction of salmonid habitats.

Future research should determine: (a) the effects of streamside vegetation removal on winter stream temperatures in the Western United States, and (b) the different effects of various cutting practices on water temperature.

Chemical and Physical Properties

The chemical and physical properties of stream water under natural conditions vary with the geology of the watershed through which it flows. Degradation of water quality can occur naturally due to leaching of mineral elements and humic acid compounds but often is induced by man's activities. Water quality can be affected by logging through accelerated leaching of nutrients from soil and wood and through the introduction of silvicultural chemicals.

Nutrients--Aquatic organisms require organic and inorganic nutrients which originate primarily from the terrestrial forest system. It has been shown that there is relatively little elemental loss from undisturbed forest soils in the temperate regions. Timber harvesting and silviculture can, however, increase the leaching rates. A summary of 15 relevant articles discloses: (a) increased loss of chemical nutrients from the soil follows logging and slash burning; however, these nutrient additions to the streams are only temporary and dissipate with stream dilution, flushing, and removal by aquatic organisms; (b) leaching rates of nutrients can be affected by topographic and meteorological features of the watersheds, by soil textures, and by the degree of clearcutting; (c) leachates from stored logs vary with the volume and flushing rate of the storage site, number, species, and age of logs stored, and can produce fish mortalities; and (d) the levels of nutrients observed in streams after timber is harvested appear to be below the toxic thresholds for aquatic organisms.

Some researchers have advanced the idea that the addition of nutrients to a stream may be beneficial, especially to relatively sterile streams by supporting additional plant and animal life, but such results are difficult to predict and may result in eutrophication.

Research needs include: (a) the acute and chronic effects of nutrient leaching on aquatic organisms, (b) the absorption or adhesion of nutrients to stream sediments, and (c) the quantification effects of documented nutrient addition.

Forest chemicals--Intensified forest management practices may include the utilization of a large number of chemicals including fertilizers, herbicides, and insecticides. A summary of 16 articles dealing with the use of chemicals indicates: (a) direct aerial application to surface waters is the major source of forest chemical pollution; (b) unless application is made directly to the water, the major potential for contamination is heavy rain resulting in overland flow and sedimentation; (c) insecticides are the most dangerous and have adversely affected aquatic communities; and (d) herbicides and fertilizers generally can be used safely if not applied adjacent to or in streams or lakes.

Further research should include: (a) the acute and chronic effects of specific forest chemicals on aquatic organisms and (b) the reactions on aquatic organisms of solvents, carriers, or other additives introduced with the forest chemicals.

Streamflow

Streamflows in coastal areas of the Western United States and Canada are primarily affected by precipitation patterns and somewhat less by evapotranspiration losses (*138*). The removal of vegetation by timber harvesting increases streamflows, since the reduction in evapotranspiration losses is much greater than the possible evaporation from increased soil exposure.

A summary of 26 articles relating to streamflow shows: (a) streamflows increase after clearcut logging, especially if followed by slashburning; (b) for every 1 percent of watershed cut, an average increase of 0.2 inch in water runoff can be expected the first year after cutting (*126*); (c) minimum flows are increased, although major flood flows are not significantly increased; and (d) changes in streamflow resulting from vegetation removal are, in most cases, less than natural climatic-caused variations (*138*).

The effects of altered streamflows may be either detrimental or beneficial to aquatic stream organisms. Increased flows cause egg and alevin displacement and mortality as a result of gravel shift and reduce benthic algae and insects by gravel grinding actions and displacement. Increased flows will expand the available living space for fish and insects and thus increase the carrying capacity. Increased summer flows will also lessen the adverse effects of increased solar radiation on stream temperatures due to vegetation removal.

Environmental Requirements of Salmonids Related to Logging

Pacific salmon and trout comprise the major constituents of the upper trophic levels in stream systems of the Western United States and Canada.

Due to the breadthof theinformation on the environmental factors affecting these salmonids, no attempt will be made to summarize this information. There are, however, excellent reviews including articles by McNeil (*182*), Neave and Wickett (*187*), and Wickett (*195*).

Early studies attempted to evaluate the effects of logging on stream environments by comparing the numbers of adult salmon returning to logged watersheds. These studies were not capable of discerning causes and effects because they were masked by a fluctuating saltwater survival, and freshwater mortality caused by sedimentation, floods, droughts, and temperature changes. For example, it has been reported that changes in an adult salmonid population of less than 50 percent due to any one cause would be difficult to detect within the large natural variations (262). Recently, it has been suggested that cutthroat trout be considered as an indicator species, due to their sensitivity to small changes (personal communication, Richard L. Lantz), There is still a lack of information and understanding of population dynamics and inventories of fish stocks. The problem is immense but must be made tangible and applicable to timber harvesting and silvicultural practices.

Future research should include: (a) case-history-type studies that contribute to more general models of land use, (b) *in situ* studies of tolerances and effects of water temperature on salmonids and resident fishes, and (c) accumulation of basic data on the inventories and carrying capacities of streams.

Ecological Effects

Trophic relationships of stream systems are complex but, as in all ecosystems, depend primarily on sunlight. Light energy reaching the stream and its borders is fixed by terrestrial vegetation and algae. The algae and terrestrial plant detritus dropping into the stream are eaten by aquatic organisms, primarily insects; and in turn, the latter are eaten by fish. Timber harvesting has been shown to disrupt this system.

A summary of 11 articles dealing with general ecological effects indicates:. (a) removal of streamside vegetation 'can shift the populations of insects from detrital feeders to algal feeders; (b) the beneficial effects of increased solar radiation upon algal production may be offset by the loss of terrestrial plant detritus; (c) terrestrial insects as a food resource can increase as a result of clearcut logging; and (d) shifts in stream algal flora can occur as a result of clearcut logging.

Future research should examine how biotic and abiotic changes affect stream communities. This implies longer and more detailed biological monitoring.

Streamside Vegetation

Research has shown that clearcut logging can significantly affect salmonid streams, particularly the small ones. These effects can, in some cases, be prevented if a protective strip of vegetation (buffer strip) is left along the stream.

A summation of 16 articles dealing with buffer strips indicates that they: (a) provide shade, preventing adverse water temperature fluctuations; (b) prevent logging-debris from entering streams; (c) provide streambank stability; (d) maintain natural water quality; and (e) provide food resources [organic detritus and insects] to the stream organisms. The role of tree canopy becomes less important with increasing volume of water and with channel width.

Most recent Federal and State timber sales require buffer strips along streams where fish and water quality are considerations. Buffer strip designs vary with specific situations according to timber species, soil type, terrain, rainfall, and strength and direction of prevailing winds. It is not necessarily essential for commercial timber to be left in a buffer strip if adequate shade can be provided by shrubs and other species of trees, and if the commercial timber can be removed without destroying the needed shade and streambank stability. The width of the buffer strip required will depend upon the shading ability of the streamside vegetation, A method for determining the optimal width for buffer strips has been developed utilizing an angular canopy densiometer to measure maximum shading ability (canopy density) (62). This method considers only width as a means of temperature control; protection from other disrupting factors may require modifications in the buffer strip boundaries.

Needs for future research include: (a) evaluation of factors involving windthrow in buffer strips and development of preventive designs, (b) comparison of deciduous vs. coniferous trees in buffer strips, and (c) rate of deposition and role of coniferous needle decomposition in stream ecosystems.

Watershed Management and Stream Protection

Soil and water are the two most important resources of the United States and can be beneficially or detrimentally affected by watershed management. The soil conditions and productivity that logged'watersheds currently possess are more the result of chance than proper watershed management, However, this situation is changing since earlier preoccupation with "forest management" is being transformed into "watershed management."

A summary of 36 articles dealing with watershed management and stream protection indicates that logging and related activities can be compatible with fertile, stable soils and salmon-producing streams if adequate consideration is given during both planning and operational stages. There have been many management guidelines recommended by Federal and State agencies for resource protection. The most important management requirements are: (a) a detailed plan of the best methods of harvesting, considering all resources; (b) coordination with all other resource users; (c) budgeting manpower and money wisely, since the best management methods may not be the cheapest; and (d) surveillance and supervision of the timber harvesting and silvicultural operation as it progresses.

Biologists and other interested groups must help to determine the type of protection required, and managers must plan the harvesting procedure so that all necessary protection is afforded if effective watershed management can be attained.

Stream Improvement

Stream rehabilitation and improvement must be considered in the same light as most of the other factors discussed; i.e., each stream should be treated as an individual case, based on its specific characteristics. Most of the stream rehabilitation or improvement presently conducted is in conjunction with, or a result of, timber harvesting and is concerned with the removal of natural or man-caused log jams and logging debris.

A summary of 16 articles concerning stream improvement discloses that logging debris and jams can adversely affect: (a) fish passage, (b) stream gravel stability, (c) intergravel and intragravel dissolved oxygen and waterflow, (d) chemical water quality [tannins and lignins], and (e) stream productivity.

The first concern should be to keep logging debris out of streams; however, this problem is not as great as it used to be. Watershed management should now be concerned with the removal of logs in relation to fish spawning and rearing, chemical and physical water quality, stream productivity, and recreational and esthetic values. Research is needed to determine the best ways to conduct stream improvement in conjunction with logging operations.

Summary of Research Needs as Determined from the Literature Survey

I. Sedimentation

A. Sources

1. Development of new or redesigned logging roads

B. Effects on aquatic environments

1. Suspended sediment

a. More detailed laboratory studies of the mechanisms of damage to fish
b. Quantitatively documented studies in actual field situations
c. Studies of the adaptability of salmonids in glaciated streams vs. natural streams subjected to increased suspended sediment

2. Bedload sediments

a. More studies filling the gaps in the data documenting the quantities of sediment altering stream productivity related to fry quality and survival

II. Water Quality

A. Temperature

1. The effects of streamside vegetation removal on winter temperatures
2. The different effects of various cutting practices on water temperature

B. Chemical and physical properties

1. Nutrients

a. Further studies on the acute and chronic effects of nutrient leaching on aquatic organisms
b. Absorption or adhesion of introduced nutrients to stream sediments

2. Forest chemicals

a. The acute and chronic effects of specific chemicals on aquatic organisms
b. Reactions of solvents, carriers, or other additives introduced with forest chemicals on aquatic organisms

III. Environmental Requirements of Salmonids Related to Logging

a. Case-history-type studies that contribute to more general land-use models
b. *In situ* studies of tolerances and effects of water temperature on salmonids
c. Accumulation of basic data on the inventories and carrying capacity of streams

IV. Ecological Effects

a. A more thorough and detailed analysis of the biotic and abiotic changes of streams as a result of logging

V. Streamside Vegetation

a. Evaluation of factors involving windthrow in buffer strips and development of preventive designs
b. Comparison of deciduous vs. coniferous trees in buffer strips
c. Studies on the rate of deposition and rate of coniferous needle decomposition in stream systems

VI. Stream Improvement

a. The determination of the extent of stream clearance in relation to the stream and the aquatic organisms
b. The development of methods to conduct stream improvement in conjunction with harvesting procedures

ANALYSIS OF THE WORKSHOP OF NOVEMBER 1972

A workshop of interested scientists and resource managers was assembled to attempt to define the major problem areas and research deficiencies in the analysis of the effects of logging. Although neither the discussion nor a written survey disclosed either a unanimity of opinion or any definite mandates, several needs became evident, although their priorities did not.

Abstracts of Presentations and Discussions Presented in Order of Appearance

Quentin Stober (Fisheries Research Institute, University of Washington)

Dr. Stober discussed the work of the International Biological Program (IBP) in watershed and ecosystem modeling and management.

Milo Bell (College of Fisheries, University of Washington)

Professor Bell's book, entitled "Fisheries Handbook of Engineering Requirements and Biological Criteria," and written for people involved in river management and structural factors, was discussed. The book was published by the U.S. Army Corps of Engineers in Portland, Oregon, in February 1973 but is very difficult to obtain.

Brian Allee (Quinault Resource Development Program, Taholah, Washington)

An outline of the work on the effects of logging on the Quinault Indian Reservation and some aspects of a preliminary low resolution land-use model were presented. The model is intended to: (a) elucidate the interactionary areas of forest harvesting and fisheries resources, (b) depict short-term vs. long-term strategies in land planning, and (c) estimate the recovery rates of aquatic populations as functions of land use,

James Burns (California Department of Fish and Game)

The Department of Fish and Game has conducted little logging research in California since 1969. However, they are presently working on legislative acts which are a result of an appeals court ruling on September 16, 1971, which declared the forest practices acts unconstitutional. In the 'areas of research, Mr. Burns feels that quick field monitoring methods and a stream classification system are necessary in California for proper stream protection.

Gene Deschamps (Washington State Department of Fisheries)

Mr. Deschamps provided a review of the State of Washington's hydraulic code which gives the Fisheries Department power to control activities in or near streams. A hydraulic permit is required for all activities involving streams which must, in turn, be reviewed and approved by the Departments of Fisheries and Game. Mr. Deschamps also stated that little basic or applied research is presently being conducted. However, some inventory work on the streams in the State is in progress.

Don Lee Fraser (Washington State Department of Natural Resources)

Mr. Fraser presented the idea that there must be a balance between stream protection and log production in the State of Washington. The State should apply a cost/benefit analysis to obtain the maximum benefit from our resources, In addition, legislation is needed to define and standardize rules and procedures for the timber harvester. He emphasized the need for more "basic" research to determine the actual impacts of present-day logging methods.

Richard Lantz (Oregon State Game Commission)

Mr. Lantz reviewed the work conducted on the Alsea watershed and a broader monitoring program for 12 coastal streams. With the completion of these studies in October 1973, the Oregon State Game Commission will analyze the results and incorporate them into a new Forest Practices Act.

Gene Haydu (Weyerhaeuser Company, Longview, Washington)

Dr. Haydu presented a quick overview of his present and past research including a literature survey on the effects of logging on water quality. In conducting the survey, he encountered few studies which dealt with the impact of timber harvesting and land management on water quality and as a result such research is presently underway. Dr. Haydu's summary of research needs emphasized the meaningfulness of present water quality criteria. In essence, he felt there is a need for more factual data to establish a "realistic" set of water quality criteria.

Joseph Krammes (U.S. Forest Service, Arcata, California)

Mr. Krammes reviewed the present work being conducted by the U.S. Forest Service on fish habitat inprovement in California, This work primarily deals with the installation of culverts to rehabilitate stream sections lost as a result of past road construction. Life history studies on anadromous fish present are also being conducted with results indicating the importance of ephemeral streams to fish production. Mr. Krammes also suggested a need for research to quantify the effects of timber harvesting, such as the conditions under which sediment or increased water temperature is a pollutant.

William Meehan (U.S. Forest Service, Juneau, Alaska)

Dr. Meehan summarized the research previously conducted, including: (a) the effects of logging on stream temperature, (b) methods by which sediment reaches streams, (c) effects of forest chemicals on aquatic organisms.

Leon Murphy (U.S. Forest Service, Portland, Oregon)

Mr. Murphy is concerned with the management of forest resources and their values as being directly proportional to its applicability to on-the-ground management objectives. He suggested that we examine and improve methods of communication and transfer of data among researchers, managers, and technicians (loggers). He also felt there should be an application of existing data and a pooling of professional knowledge to establish management directions. The solutions to effects of logging problems will not be provided by researchers or managers separately; there must be cooperation before optimum management of our resources can be achieved.

Thomas Chamberlain (Canadian Fisheries Service, Department of Environment)

Dr. Chamberlain discussed the probable use of a modeling system to integrate past research conducted in other areas with present research findings from the Carnation Creek study (located on Vancouver Island) to provide a management scheme suitable for the forest resources of British Columbia.

David Narver (Canadian Fisheries Service, Pacific Biological Station)

Dr. Narver reviewed the research presently in progress in British Columbia at Carnation Creek on Vancouver Island. The research was initiated to: (a) evaluate the guidelines presently in use in British Columbia: (b) attempt to understand a west coast overmature rain forest-salmon-trout ecosystem and how this system can be affected by logging and silvicultural practices; and (c) recommend forest management practices to optimize the watershed resources of fish, timber, and water. The study is designed as a long-term project with road construction scheduled for winter 1974-75 and timber harvesting to commence in 1975 and continue for the next five years.

Jack Rothacher (U.S. Forest Service, Corvallis, Oregon)

Mr. Rothacher presented a brief summary of his work in Oregon on effects of logging on streamflow and water quality; chemical changes in water quality after burning, logging, slash treatment, and forest chemical applications ; and the development of new logging techniques. He also mentioned his present work with IBP and Dr. George Brown's study on the effects of finely divided logging debris on small coastal streams, including some work on its toxicity to fish.

William Sheridan (U.S. Forest Service, Juneau, Alaska)

Mr. Sheridan discussed three major problem areas confronting managers: need for more research, application of existing information, and dissemination of information. He also considered the need for studies in Alaska on the effects of logging on wildlife, especially rare and endangered species. Mr. Sheridan also discussed the use of interdisciplinary teams to achieve optimum land use and management, an idea he feels is a major breakthrough in land planning.

Bruce Pease (Fisheries Research Institute, University of Washington)

Mr. Pease described his research on the effects of log dumping and rafting in Southeast Alaska, including examination of present and past log dumping and rafting sites. His laboratory work with the comparative analysis of the leaching rates of the four major species of timber of Southeast Alaska and his present work with the acute toxicity analysis of these leachates to pink salmon were also discussed. The results of these studies are now available.

K V. Koski (Fisheries Research Institute, University of Washington; presently with U.S. Forest Service, Juneau, Alaska)

Mr. Koski described and discussed the work conducted at the Big Beef Creek chum salmon spawning channel located on Hood Canal at Seabeck, Washington. The channel provides for controlled experiments concerning the effects of gravel composition on mortality and condition of emerging fry. Generally, there is a decreasing percentage of survival of chum salmon fry with an increasing percentage of fines of less than 3.0 mm. He believes the results from these studies can be used as a predicting tool for the effects of sediment depositions in natural streams.

Richard Tyler (Fisheries Research Institute, University of Washington)

Mr. Tyler reviewed the preliminary results of a summer field study conducted in Southeast Alaska in 1972 on small logged and unlogged salmon-producing streams. Results showed that water temperatures increased more rapidly in logged than in unlogged streams; temperatures reached as high as 24.2°C for short periods of time; juvenile coho salmon and Dolly Varden char populations were apparently unharmed by the temperature peaks; a 50-percent reduction in streamflow due to drought resulted in a fourfold increase in time of net water transport; and aquatic insect diversity appeared to be unaffected by logging.

Summary of the Workshop

A preliminary questionnaire distributed to those attending was used to rank needs for research, general considerations, and management. Under research, basic stream ecology (including fish census data and data for classifying streams) received highest priority. From the resulting discussions as well as the questionnaire, one can assume we just don't know enough about our fish populations, especially those in logged watersheds. The most frequent question was: "How can changes in populations be measured if the effects are subtle and our knowledge of dynamics is deficient?" Life history research which is directly applicable to land-use problems is definitely needed.

Under general considerations, the need for more short-term studies (less than five years) was emphasized, rather than several isolated long-term studies, The need for a long-term plan (regional rather than by watershed) was brought out, possibly with a readily modifiable model which would be supplied by "case history studies" to answer specific questions.

The last area of consideration was management. A need for improved communications between management agencies and timber harvesters received the highest rating. Several other priorities were also quite evident, the first being the application of existing data. This includes two major aspects: (a) making existing data available to any and all agencies or researchers and (b) preserving the availability of the data. It was suggested that perhaps a small system or model for the exchange of information and continuity of research be developed.

Another priority was the need for a stream classification system to enable resource planners and managers to make the proper decisions regarding stream management. Possible classifications include: (a) stream productivity, (b) sensitivity to disturbance, (c) watershed geology and composition, or (d) fish producing capabilities and present standing stock,

A second questionnaire sent after the workshop to those who had attended produced similar results.

The exceptions in the similarities between the two questionnaires were in the category of research, with an increased emphasis on buffer strips and the effects of sediment on aquatic organisms. A combination of priority and feasibility values was used to determine needs, with feasibility implying a combination of available knowledge and realistic cost values, and priority implying a need for research. Categories receiving a high priority but a low feasibility rating indicate a research need but perhaps a lack of funds or knowledge to fulfill the need.

Prevention of logging mishaps instead of rehabilitation was a common concern throughout the workshop. The needs listed are all necessary considerations for the establishment of guidelines for "optimum watershed management," The ultimate goal of watershed management and protection should be to maximize social benefit from our watershed resources; and without adequate information, land planners and managers cannot accomplish this goal.

SUMMARY

Increasing emphasis is being placed on meeting the requirements of Forest Practices Acts (California, Oregon, and Washington, in particular), and in the future, more environmental impact statements of the Environmental Protection Agency-type will be required. Judging from published research, adequate impact statements obviously will be difficult to formulate. Consequently, regulations will continue to be conservative, with an increasing amount of field supervision required to monitor whatever environmental impacts are predicted.

Research is at a point of requiring precise information on population dynamics of fishes and continued research on physical measurements of the environment. This will lead to more case history research which will ultimately lead to more precise and meaningful guidelines for management,

Meanwhile, general survey-type research such as that of Calhoun (201), Calhoun and Seeley (202), and Fisk et al. (208) of California streams, has had its day; and the logger, the researcher, and the management agencies must realize that there are no finite answers, no finite guidelines, and perhaps never will be. This, however, should intensify research and concern rather than relax it, for the formulation and application of theory or scientific laws that are open-ended are sometimes difficult but necessary. This is particularly difficult for the land user to accept, but it is a fact of life and a state-of-the-art for some time to come. On the other hand, the fisheries resource manager has difficulty accepting that which is becoming obvious--i.e., logging (even clearcutting) can be performed without radical damage, in fact, the changes can be so subtle as to defy measurement and at times may, indeed, be beneficial. An obvious area of needed research is the degree to which a stream should be cleared, manipulated, or even altered for improvement. In conclusion, there will never by a "once-and-for-all" answer to land use-fisheries problems, but we must continue answering questions to provide for optimal watershed management.

ANNOTATED BIBLIOGRAPHY

INTRODUCTION

The following annotated bibliography documents publications on effects of logging on fish of the Western United States and Canada, with a few other selected references also included. Whenever possible, the abstract or summary written by the author was used for the annotation.

The titles are arranged alphabetically by authors and chronologically under each author's name. Author and subject indexes are included.

EROSION AND SEDIMENTATION

(1) Aitken, W. W.
1936. The relation of soil erosion to stream improvement and fish life. J. For. 34(12):1059-1061.

The author notes that gradual changes in stream environment caused by erosion can bring about corresponding changes in fish fauna. Without erosion control, stream improvement devices are of little value since they cannot eliminate turbidity, siltation, and other conditions resulting from erosion that are deleterious to fish life.

(2) Anderson, H. W.
1957. Relating sediment yield to watershed variables. Trans. Am. Geophys. Union 38(6):921-924.

"The yield of sediment from watersheds depends upon three sets of variables: (1) inherent watershed characteristics such as geology and topography; (2) land use, condition of vegetation, and management and protective measures; and (3) nature of storms and streamflow which produce and transport sediment. Measured quantities of yield also depend on the sediment measuring device and on which fraction of total sediment yield is measured. The sources of variation in sediment yield between and within watersheds can be evaluated by study of the yield from many watersheds which have wide differences in variables affecting sediment yields. Such studies are useful to determine and evaluate the principal sources of sediment, to evaluate the probable effects of conservation programs on yield, and to provide criteria for design of reservoirs and channels. This paper summarizes some recent studies in which multiple regression analysis was used in relating sediment yield to watershed variables. The studies are discussed in the light of methods of selecting watersheds, data, variables, and functions; and the effects of neglected variables, errors in variables, and exclusion of nonsignificant variables."

(3) Anderson, Henry W.
1954. Suspended sediment discharge as related to streamflow, topography, soil and land use. Trans. Am. Geophys. Union 35(2):268-281.

"The results of suspended-sediment sampling were used to obtain average annual suspended sediment discharge from 29 watersheds of western Oregon by relating sediment-sampling results to streanflow and by using streamflow frequencies. The values of average suspended sediment thus obtained were related by regression analysis to average watershed values of two streamflow variables, two topographic variables, two soil variables, and one channel bank variable. The soil variables were functions of particle size and aggregation determined by analyzing samples of the surface soil taken at standardized locations in the major geologic types. The other variables were functions of data published in maps and other secondary sources. The regression results were used (1) to construct a map of

the sediment producing potential of lands in western Oregon under average land use conditions; (2) to estimate how the actual production of sediment would differ from the potential with deviation of land use from average; and (3) to distribute present sediment production to the three major source areas: forest land, agricultural land, and channel banks of the main river."

(4) Anderson, Henry W.
1962. Current research on sedimentation and erosion in California wildlands. Rep. Publ., Assoc. Int. Hydrol. Sci., Gentbrugge 59:173-182.

The effects of fire and logging on erosion and sedimentation were studied in the Sierra Nevada Coast Range and San Gabriel Mountains. No study of buffer zones was made, nor was their relation to logging discussed.

(5) Anderson, Henry W.
1971. Relative contributions of sediment from source areas, and transport processes. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 55-63. Oreg. State Univ., Corvallis.

"The paper reports new findings, offers a reanalysis of older studies, and summarizes pertinent results in the literature. Past land use, forest fires, road building, 'poor logging,' and conversion of steep lands to grass have increased sediment discharge by factors ranging from 1.24 to more than 4. Projected future use is expected to increase sediment production by a factor of 4, with 80 percent associated with roads and 20 percent with logging.' Major floods have increased subsequent turbidity of streamflow by a factor of 2. The increases were greater in logged areas of watersheds where roads were next to streams and landings were in draws than in undisturbed watersheds. Most landslides were associated with road development, next most with logged areas, and least with undisturbed forest area. The number of turbid days in streamflow varied by a factor of 2.34 with differences in silt plus clay content of soils, by 8.55 with differences in erodibility, and by 4.3 with the percent of gravel. Further, these soil characteristics were predictable from geologic rock types. In a sample calculation, 89 percent of channel bedload became suspended load enroute downstream. Soil creep contributed 15 percent to total sediment discharge from watersheds; channel bank erosion contributed 54 to 55 percent."

(6) Anderson, Henry W., and James R. Wallis
1963. Some interpretations of sediment sources and causes, Pacific coast basins in Oregon and California. U.S. Dep. Agric. Misc. Publ. 970:22-30.

Sediment discharges associated with specific measures of meteorological potential, topographic potential, soil erodibility, and land use and condition from studies of sedimentation in coast basins of western Oregon and California were compared. Results obtained by combining the

effects of all the various sediment potentials can be used to delineate areas where caution in management may be needed and to measure the effectiveness of certain types of land management.

(7) Bachman, Roger Werner
1958. The ecology of four northern Idaho trout streams with reference to the influence of forest road construction. 97 p. M.S. thesis, Univ. Idaho, Moscow.

Physicochemical and biological measurements of four trout streams, one of which was being logged, were studied. Turbidity was found to increase during rapid runoff from storms or snowmelt. Sedimentation increased in both riffles and pools. Water temperatures, volume of flow, and water chemistry showed no change from the previous year. The relocation of stream channels away from road fills appeared to reduce the amount of eroded material entering the stream.

(8) Bishop, Daniel M., and Mervin E. Stevens
1964. Landslides on logged areas in southeastern Alaska. USDA For. Serv. Res. Pap. NOR-1, 18 p. North. For. Exp. Stn., Juneau, Alaska.

"Recent large-scale clearcut logging of timber in southeast Alaska has accelerated debris avalanches and flows on steep slopes during heavy rainfall. Characteristics and possible mechanisms for these disturbances include:

"1. Flows are more frequent within the V-notch side-drainages than on the smoother glacial valley walls. This may be attributed to V-notch channel downcutting producing oversteepened slopes.

"2. Flows or avalanches usually slide on relatively smooth, wet planes oriented parallel to the slope when this plane is composed of such materials as glacial till, iron-organic layered material, metamorphosed sediments, or diorite. Such planes are resistant to downward water passage; hence, moisture builds up immediately above this layer.

"3. Limited evidence leads to the assumption that southeast Alaskan flow-prone soils are usually cohesionless. If this is true, then soil pore pressure phenomena may not reasonably be expected.

"4. A greater addition of water weight to the soil mantle through rainfall is not a likely stimulus for increased flows after logging. Research in other areas indicates that water infiltration rate into the soil is reduced by clear-cut logging, and that loss of soil organic matter as a result of logging reduces water-holding capacity. If these findings are applicable to southeast Alaska, then less weight from soil water might be expected.

"5. Weight loss by timber removal probably has no direct net effect on the likelihood of shearing since decrease of shear stress with unloading is equal to shear strength reduction.

"6. Loss of timber weight may reduce shear strength in soil immediately under the tree root systems. This action might result from 'decompaction' of zones of soil earlier compacted by the weight of the tree.

"7. Loss of root systems as a strength builder-maintainer in the soil mantle may be an important factor in accelerating flows after logging. This may reflect the destruction of inter-connected root systems by high-lead skid-roads. It may also reflect death and gradual deterioration of root systems after clear cutting. The time lag in slide activity after logging supports this view.

"8. Debris in the bottoms of steep ravines aggravates stability conditions. Logs and stumps on side slopes contribute to such instability by rolling or sliding into the channel. The process follows a pattern--debris accumulates in the ravine bottoms and this is followed periodically by sweeping torrent-flows.

"9. Slopes of 34° (67 percent) or more are highly susceptible to failure when conventional downhill high-lead logging is used."

(9) Brown, George W., and James T. Krygier
1971. Clear-cut logging and sediment production in the Oregon Coast Range. Water Resour. Res. 7(5):1189-1198.

"The impact of road construction, two patterns of clear-cut logging, and controlled slash burning on the suspended sediment yield and concentration from three small watersheds in the Oregon Coast Range was studied for 11 years. Sediment production was doubled after road construction but before logging in one watershed and was tripled after burning and clear-cutting of another watershed. Felling and yarding did not produce statistically significant changes in sediment concentration. Variation in the relation between sediment concentration and water discharge on small undisturbed streams was large. Conclusions about the significance of all but very large changes in sediment concentration are limited because of annual variation for a given watershed, variation between watersheds, and variation with stage at a given point."

(10) Bullard, W. E., Jr.
1965. Role of watershed management in the maintenance of suitable environments for aquatic life. *In* Clarence M. Tarzwell [ed.], Transactions 3rd seminar on biological problems in water pollution. U.S. Public Health Serv. Publ. 999-WP-25, p. 265-269. Robert A. Taft Sanit. Eng. Cent., Cincinnati, Ohio.

"Increased sedimentation of streams seems to be the most obvious effect of land use practices on the aquatic habitat. The addition of finer particles on the bottom gravels reduces the niches where many benthic organisms live. Perhaps the direct effects on eggs are among the most important. There is a smothering effect from silt coatings and a decreased permeability of the bottom gravels reducing the flow of water over the eggs. The turbidity resulting from the increase in suspended particles also reduces the light penetration and photosynthetic rate.

"Not all sedimentation is a result of obvious operations such as mining and cultivation. Instances are on record in which the activity of ducks has reduced fish egg survival. Perhaps the trampling of stream banks by cattle may be far more important than is commonly recognized. Changes in the stream bank brought about by cattle or man-made channel changes may produce a cycle of changes which may be carried clear to the mouth of the stream. Usually, these changes are not desirable.

"The feeling among the discussants seemed to be that, ideally for fish production, partial tree cover of the banks, something less than complete bank stabilization, and an increase in rainfall infiltration of the soil are all desirable goals along with reduction in siltation and turbidity. However, the attainment of such goals may affect the stream flow patterns and reduce the total amount of water reaching the stream. In more arid areas, grasses are more desirable than trees because they achieve stabilization of soil but do not lose as much water through transpiration.

"In any case, the optimum conditions for fish production will have to be sacrificed in many instances for multiple uses of the surface waters. However, the general feeling was that many improvements could be made that would improve the waters for fish production and still incorporate multiple use."

(11) Bullard, William
1959. Watershed management-grazing, deforestation and road building. *In* E. F. Eldridge and J. N. Wilson [eds.], Proceedings 5th symposium— Pacific Northwest on siltation--its source and effects on aquatic environment, p. 27-31. U.S. Dep. Health, Educ. & Welfare, Portland, Oreg.

Sources of siltation and methods to control and correct it are discussed. An outline of factors to consider in watershed management for the control of erosion and subsequent siltation of streams is presented.

(12) Burns, James W.
1970. Spawning bed sedimentation studies in northern California streams. Calif. Fish & Game 56(4):253-270.

"Changes in the size composition of spawning bed materials in six coastal streams were monitored for 3 years to determine the effects of logging on the habitat of silver salmon *(Oncorhynchus kisutch)* and trout (*Salmo gairdnerii gairdnerii* and *S. clarkii clarkii*). Four test streams were sampled before, during and after logging. Two streams in unlogged watersheds and the undisturbed upstream section of one test stream served as controls. A variety of stream types in second-growth and old-growth forests was selected for observation.

"Spawning bed composition in the four test streams changed after logging, roughly in proportion to the amount of streambank disturbance. The heaviest sedimentation occurred when bulldozers operated in narrow stream channels having pebble bottoms. In a larger stream with a cobble and boulder bottom, bulldozer operations in the channel did not increase sedimentation greatly. Sustained logging and road construction kept sediment levels high in one stream for several years. Sedimentation was greatest during periods of road construction near streams and removal of debris from streams, confirming the need for special measures to minimize erosion during such operations. Control streams changed little in spawning bed composition during the 3 years."

(13) California Resource Agency
1970. Task force findings and recommendations on sediment problems in the Trinity River near Lewiston and a summary of the watershed investigation. A Report to the Secretary for Resources, 32 p. Sacramento, Calif.

Estimated amounts of sediment and transport capacities show that before logging and dam construction the Trinity River was capable of transporting bedload sediment. After logging, the river's transport capacity and sediment discharge were approximately equal; hence, the river was still able to flush the added sediment from logging operations. After dam construction, the sediment transport capacity of the river was reduced to such an extent that sediment in the channel quickly built up. The result has been the deterioration of adequate spawning grounds.

(14) Cooper, A. C.
1965. The effect of transported stream sediments on the survival of sockeye and pink salmon eggs and alevin. Int. Pac. Salmon Fish. Comm. Bull. 18, 71 p.

"Results are presented of studies made to assess quantitatively the effects of sediment deposition upon and within salmon spawning beds on the survival of salmon eggs and alevin. Methods of determining the size of bed load materials that may be expected on a given portion of a stream bed are presented. Spawning gravel permeability is defined in terms of particle size grading, particle shape and gravel porosity. The velocity of fluid flow through the gravel is quantitatively related to the gravel permeability and the hydraulic gradient. Deposition of sediment either on the gravel surface or within the gravel is shown to reduce gravel permeability with consequent reduction in fluid flow and reduction in rate of survival of salmon eggs and alevin deposited in the gravel.

Formulae are developed which relate time and silt size and concentration to the effect on gravel permeability, and examples of the consequent effect on survival of salmon eggs and alevin are presented. The results of the studies show the importance of preventing deposition of sediments on or within a salmon spawning bed."

(15) Cordone, Almo J., and Don W. Kelley
1961. The influences of inorganic sediment on the aquatic life of streams. Calif. Fish & Game 47(2):189-228.

The effects of inorganic sediment on aquatic life in streams were discussed. The report covered the following subjects: direct effect of sediment upon fishes; influence of sediment upon eggs, alevins, bottom organisms, aquatic plants, chemical and physical characteristics of aquatic life, and fish habitat and population; and sediment standards and research.

(16) Cordone, Almo J., and Steve Pennoyer
1960. Notes on silt pollution in the Truckee River drainage, Nevada and Placer Counties. Calif. Fish & Game, Reg. 2, Inland Fish. Admin. Rep. 60-14, 25 p. [Processed.]

Silt from a gravel washing plant drastically reduced the populations of bottom organisms immediately below the outfall and as far as 10 miles downstream at Cold Creek and Truckee River, California.

(17) Dellberg, Robert A., and John N. Taylor
1962. Erosion control on timberland at harvest. J. Soil & Water Conserv. 17(4):177-178.

Methods of erosion control were studied in a limited logging operation in Mendocino County, California.

(18) Dyrness, C. T.
1966. Erodibility and erosion potential of forest watersheds. *In* William E. Sopper and Howard W. Lull [eds.], Forest hyrology, p. 599-611. Proc. Natl. Sci. Found. Adv. Sci. New York: Pergamon Press.

"This paper reviews a portion of the literature dealing with forest soil erosion and erodibility. Two main aspects to forest soil erodibility are generally stressed--resistance of soil particles to detachment and transport, and soil infiltration rate. Resistance to detachment and transport is controlled to a large extent by amounts of water-stable aggregation. Several erodibility indices, utilizing different measurements of surface soil aggregation, have been developed. Factors strongly influencing these erodibility indices include soil parent material, organic matter content, climatic conditions, and soil chemical properties. Many studies have shown that infiltration rate decreases considerably when plant and litter cover is removed, thus exposing the mineral soil surface to the destructive action of rain.

"Some accelerated erosion is generally a necessary consequence of road construction and logging in forest watersheds. Primary causes are reported to be exposure of bare mineral soil and surface soil compaction. Both controlled burning and wildfires in forested areas are often followed by increased rates of surface erosion. Although severe burning may cause increased erodibility, light burning apparently has little effect on soil properties. A change of primary importance caused by fire is removal of protective vegetation and litter.

"Research needs in this field include development of methods for quantitatively estimating forest soil erosion potential and establishment of erosion tolerances for individual forest watersheds."

(19) Dyrness, C. T.
1967. Mass soil movements in the H. J. Andrews Experimental Forest. USDA For. Serv. Res. Pap. PNW-42, 12 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"Analyzes 47 mass movement events resulting from severe storms during the winter of 1964-65. Earthflow and channel scouring events were the most common. About 72 percent of the mass movements occurred in connection with roads and 17 percent in logged areas. Over 94 percent of the events occurred in areas of tuff and/or breccia bedrock which occupy only 37 percent of the total area."

(20) Dyrness, C. T.
1967. Soil surface conditions following skyline logging. USDA For. Serv. Res. Note PNW-55, 8 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

There was very little difference in yarding-caused disturbance when skyline and high-lead logging were compared. It was therefore concluded that the main advantage of skyline logging is that it requires less road construction. Skyline logging was previously proven by V. W. Binkley to require one-third as many road requirements as high-lead logging. This reduction is extremely important in reducing stream source sediments which are a proven major source of sediment in streams. Thus, the use of skyline logging in steep, mountainous areas to reduce stream sedimentation deserves serious consideration.

(21) Dyrness, C. T.
1970. Stabilization of newly constructed road backslopes by mulch and grass-legume treatments. USDA For. Serv. Res. Note PW-123, 5 p. Pac. Northwest For. & Range Exp. Stn.', Portland, Oreg.

"Amounts of soil loss from an unprotected newly constructed backslope were two to four times greater than loss from a comparable slope 5 years after construction. Of six roadside treatments studied, the two showing consistently large amounts of soil loss during the first critical rainy period were the only ones without a straw mulch covering."

(22) Dyrness, C. T., C. T. Youngberg, and Robert H. Ruth
1957. Some effects of logging and slash burning on physical soil properties in the Corvallis watershed. USDA For. Serv. Pac. Northwest For. & Range Exp. Stn. Res. Pap. 19, 15 p. Portland, Oreg.

"Physical soil properties measured in this study did not differ significantly among 4 of the 5 surface conditions sampled. Only in the severely burned condition was there found a consistent and significant departure, indicating that intense heat altered the character of the surface soil. Physical properties of soil in undisturbed, disturbed-unburned, and lightly burned portions of the clearcuts remained closely similar to those under adjacent timber stands.

"This study can be considered only a partial evaluation of the effects of logging and slash burning on soils in the Douglas-fir region. Soil tests were not intended to be a complete investigation of the soil changes which occur. Furthermore, only three types of soil were examined. These are known to occur throughout the Coast and Cascade Ranges in Oregon and Washington, so, while limited in scope, results of this study are applicable over a substantial part of the Douglas-fir region. Still, to assess fully the effect of logging and slash burning, other soils associated with the Douglas-fir type will need to be sampled and subjected to comprehensive tests."

(23) Ellis, M. M.
1936. Erosion silt as a factor in aquatic environments. Ecology 17:29-42.

Effects of silt on the aquatic environment are discussed. Erosion silt alters the environment by (1) screening out light, (2) changing heat radiation, (3) covering the stream bottom, and (4) retaining organic material.

(24) Fredricksen [Fredriksen], R. L.
1965. Sedimentation after logging road construction in a small western Oregon watershed. U.S. Dep. Agric. Misc. Publ. 970: 56-59, illus.

"During the summer of 1959, 1.65 miles of logging road were constructed in a 250-acre forested watershed that rises 2,000 feet in a distance of 1 mile. This study evaluates the change in sedimentation subsequent to road construction. Runoff from undisturbed watersheds in this area remains clear during the summer low-flow months and reaches concentrations of 100 parts per million during winter storm peaks. Runoff from the first rainstorms after road construction carried 250 times the concentration carried in an adjacent undisturbed watershed. Two months after construction, sediment had diminished to levels slightly above those measured before construction. Sediment concentrations for the subsequent 2-year period were significantly different from preroad levels. In about 10 percent of the samples, sediment concentrations were far in excess of predicted values, indicating a streambank failure or mass soil movement. Annual bedload volume the first year after construction was significantly greater than the expected yield, but the actual increase was small. A trend toward normalcy was evident the second year."

(25) Fredriksen, R. L.
1970. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds. USDA For. Serv. Res. Pap. PNW-104, 15 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"In two steep headwater drainages, landslides were the predominant source of increased sedimentation of streams following timber harvest. Patchcut logging with forest roads increased sedimentation compared with a control by more than 100 times over a 9-year period. Landslide erosion was greatest where roads crossed high gradient stream channels. In an adjacent clearcut watershed with no roads, sedimentation increased three times that of the control."

(26) Gangmark, Harold A., and Richard G. Bakkala
1960. A comparative study of unstable and stable (artificial channel) spawning streams for incubating king salmon at Mill Creek. Calif. Fish & Game 46:151-164.

"With the knowledge that fast stream run-off was significant in the mortality of spawn, effort was directed toward finding exactly how severe runoff caused these losses. It was determined that mortalities were caused by both direct and indirect factors. Direct losses of spawn was due primarily to erosion of the streambed by high velocities of water. Information as to the fate of spawn washed out is not available, but it is reasonable to assume that once the eggs are washed from the protecting gravel bed out into the stream of violent water flow and shifting gravel, their chance of survival is low. Indirect losses of spawn occurred from a series of events of diverse and complex nature involving loss of spawning gravel and erosion of soil. Another series of events causing indirect loss of salmon spawn starts with soil erosion that clogs the redd. This blockage leads to: inadequate oxygen and poor delivery of oxygen to the eggs and poor cleansing of metabolic waste products.

(27) Hansen, Edward A.
1971. Sediment in a Michigan trout stream, its source, movement, and some effects on fish habitat. USDA For. Serv. Res. Pap. NC-59, 14 p. North Cent. For. Exp. Stn., St. Paul, Minn.

"A sediment budget was constructed from 3-years of measurements on a pool and riffle stream. Total sediment load increased five times along a 26-mile length of stream; most sediment came from 204 eroding banks. Three-fourths of the total sediment load was sand size. The area of streambed covered with sand decreased downstream, indicating that the transporting capacity of the stream exceeded sediment supply. Complete streambank stabilization would reduce the sediment load by about half and probably result in streambed composition changes beneficial to trout."

(28) Haupt, Harold F., and W. Joe Kidd, Jr.
1965. Good logging practices reduce sedimentation in central Idaho. J. For. 63(9):664-670.

"From the inception of a study of cutting ponderosa pine on 16 small watersheds in the Boise Basin Experimental. Forest, sedimentation was checked reasonably well because of careful advance planning, close supervision of logging, and application of intensive measures for controlling erosion promptly after harvest. Sediment that reached the stream channels originated primarily on haul roads. Proximity of a road to a stream affected the frequency with which sediment flows reached that stream. Sediment reached channel bottoms through undisturbed buffer strips averaging 8 feet wide, but did not reach them if the strips were more than 30 feet wide. After 3 years, movement of sediment 'en route' had almost halted."

(29) Hollis, Edgar H., Joseph G. Boone, Charles R. De Rose, and George J. Murphy. 1964. A literature review of the effects of turbidity and siltation on aquatic life. 26 p. Staff Rep., Dep. Chesapeake Bay Aff. Annapolis, Md

The detrimental effects of turbidity and siltation upon aquatic life are reviewed. The report contains a fairly extensive bibliography.

(30) Hornbeck, J. W., and K. G. Reinhart
1964. Water quality and soil erosion as affected by logging in steep terrain. J. Soil & Water Conserv. 19(1):23-27.

"The influence of different forestry practices on streamflow has been investigated since 1951 on 5 forested watersheds, 38 to 96 acres in area, on the Fernow Experimental Forest in the mountains of West Virginia. The effects of cutting and logging practices on water quality are reported in this article.

"Practices ranged from a commercial clearcutting without regard to water values or the future value of the property to an intensive selection cutting with useful planning and careful logging. The experiment demonstrated that excessive damage to water quality can be avoided even when logging on steep terrain. Measured maximum turbidities of streams were 56,000 ppm on the commercial clearcut area and only 25 ppm on the intensive selection cut watershed. Most of the damage to water quality occurred during and immediately after logging.

"Recommended forestry practices discussed include: planning of the logging operation; proper lccation, drainage, and grade of skidroads; and timely completion of the operation in any specific area. In most respects, practices recommended for watershed protection also contribute to the overall efficiency of the logging operation."

(31) Kelley, Don
1962. Sedimentation helps destroy trout streams. Outdoor Calif. 23(3):4, 5, 10-11.

The effects of sediment on the basic needs of a trout population--its food, shelter, and a place to reproduce--are discussed.

(32) Koski, K V.
1972. Effects of sediment on fish resources. Presentation--Wash. State Dep. Nat. Resour. Manage. Semin., April 18-20, 1972, 36 p. [Mimeogr.]

The effects of sediment on aquatic organisms are discussed. Specific areas of discussion are: (1) freshwater requirements of salmonids, (2) general effects of sediment on fish, (3) effects of sediment on the reproduction of salmonids, (4) the harmful threshold of sediment, (5) effects of sediment on natural populations of fish, and (6) effects of logging on sediment production. An extensive bibliography is included.

(33) Larse, Robert W.
1971. Prevention and control of erosion and stream sedimentation from forest roads. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 76-83. Oreg. State Univ., Corvallis.

"To minimize erosion and resultant stream sedimentation, prevention and control measures must be given consideration in every aspect of road planning, design, construction and maintenance. In mountainous terrain the forest land manager must establish specific objectives and prescriptions to guide road network construction and utilize the combined professional skills of the forester, engineer, geologist, biologist, and others to set standards for the protection of watershed values, identify alternatives, and offer solutions to specific problems.

"The decision to road an area should only be made after the resource-serving benefits have been carefully weighed against the cost and effect of roading on the watershed. The decision not-to-road and to accept other alternatives for land-use management must be strongly considered when the probability of lasting damage to soil, water, and other ecological values is recognized."

(34) Lull, Howard W., and K. G. Reinhart
1965. Logging and erosion on rough terrain in the east. U.S. Dep. Agric. Misc. Publ. 970:43-47.

"Most of the erosion from logging roads occurred during the logging operation. This suggests:

"1. That the operation in any one area should not be prolonged, but should be completed as soon as possible.

"2. That more attention should be paid to preventing erosion during the operation. It is not enough to limit erosion control measures to after-logging care. Perhaps the most practical measure is to cut and maintain broad-based outsloped drainage dips across skid-roads. This is not always easy, and the idea will often be resisted by loggers.

"This study points up again the fact that erosion from only a fraction of the logging area can pollute a lot of water. Hoover... has pointed out that a short stretch of logging road can produce much more sediment than occasional patches of steep land in cultivated crops. The forester who might not permit clearing a piece of forested municipal watershed for a row crop because of the erosion hazard should feel just as much concern over the location of logging roads.

"Finally, observations in many areas indicate that continuously used permanent road systems in the forest can create serious water-quality problems. Standards for constructing and maintaining such roads should be even higher than for logging roads that are used for only short periods of time."

(35) McCrimmon, H. R.
1954. Stream studies on planted Atlantic salmon. J. Fish. Res. Board Can. 11(4):362-403. [Taken from Cordone (148).]

"This is an evaluation of the survival and distribution of Atlantic salmon fry planted in a small stream tributary to Lake Ontario. Included is an examination of some of the factors affecting the survival of these fry. The influence of sedimentation on survival was studied in detail.

"When the correlation of salmon survival with brook trout predation was analyzed further, it was found that the amount of available shelter which the stream offered the fry was most important in determining the survival or death of the planted fish.

"It has been shown in a previous section that the shelter offered by shallow gravelly riffle area was the only satisfactory habitat for the survival of planted fry in all streams. In the general description of the relative extent of sedimentation over the stream system, the criterion employed was the degree to which these gravelly riffle areas had become sedimented. Areas typed as 'unsedimented' were those in which the spaces around the gravel and rubble were not filled in by sediment and hence offered the shelter required by the planted fry. The degree of bottom sedimentation played an important part in influencing the survival and distribution of the planted salmon.

. . . .

"It was shown that the survival of the small fry in the pools was low, largely because the absence of suitable shelter for the young salmon resulted in predation by certain species of fish. This lack of shelter was directly caused by the deposition of sediment in the pools sufficiently great to cover generally the gravel and rubble, and fill the spaces around stones, boulders, logs and the like, to an extent that they could not be utilized by the fry.

"Survival studies showed an average percentage survival for underyearling salmon. . .of 23.4 percent in comparison to a survival of only 2.2 percent in an area in which riffle sedimentation was the heaviest observed in the part of the stream system planted with salmon."

(36) McRorey, R. P., N. F. Meadowcroft, and C. J. Kraebel
1954. A guide to erosion reduction on National Forest timber sale areas. USDA For, Serv. Calif. Reg. For. & Range Exp. Stn., 78 p. Berkeley, Calif,

Over one-half the manual concerns the construction and maintenance of logging roads.

Leaving an uncut, protective strip along streams is recommended; however, no minimum width is mentioned.

(37) Marcuson, Pat
1968, Stream sediment investigation, Mont. Dep. Fish & Game, South Cent. Mont. Fish. Study. Job Completion Rep. Proj. F-20-R-13, 10 p.

"This report...compares current data with data collected before completion of three stream habitat improvement projects on Bluewater Creek. Maximum and minimum water temperatures, mean monthly discharge and mean sediment data are tabled and discussed for the report period.

"Mean monthly sediment concentrations and loads were lowest at Station 1 and progressively increased downstream. Average suspended sediment load'has been reduced by 1.9 tons/day or 32% at Station 2, 14.0 tons/day or 52% at Station 3 and 10.5 tons/day or 44% at Station 4 following the three streambank improvement projects located near Station 2.

"Trout composition at all stations on Bluewater Creek represented 37% of the fish sampled in 1968 compared to 13% in 1963 prior to habitat improvement. Trout:rough fish ratios were not appreciably altered following a 32% reduction in sediment load at Station 2. Corresponding with a 52% reduction in sediment load at Station 3, there has been a change in weight ratios of trout:rough fish from 39:61 in 1963 to 63:37 in 1967 and 78:22 in 1968. At Station 4 the trout:rough fish weight ratio has changed from 12:88 in 1963 to 34:66 in 1967 to 51:49 in 1968."

(38) Megahan, W. F., and W. J. Kidd
1972. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. J. For. 70(3): 136-141.

"Erosion plots and sediment dams were used to evaluate the effects of jammer and skyline logging systems on erosion and sedimentation in steep, ephemeral drainages in the Idaho Batholith of central Idaho. Five-year plot data indicated that no difference in erosion resulted from the two skidding systems as applied in the study. Sediment dam data obtained concurrently showed that the logging operations alone (excluding roads) increased sediment production by a factor of about 0.6 over the natural sedimentation rate. Roads associated with the jammer logging system increased sediment production an average of about 750 times over the natural rate for the six-year period following construction."

(39) Miner, Norman H.
1968. Natural filtering of suspended soil by a stream at low flow. USDA For. Serv. Res. Note PNW-88, 4 p. illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"During road construction, soil that is added to a stream by tractors crossing during low flow is temporarily 'filtered' out before it travels far. Five-gallon samples were taken at 150, 300, 600, and 1,200 feet downstream from a road crossing, with sodium fluorescein dye used as a tracer. Suspended particle concentration was reduced from 1,055 p.p.m. at 150 feet below the road to 108 p.p.m. at 1,200 feet. The The 'filtering' action is a combination of settling of larger particles and dilution of sediment-laden water. This filtration is temporary, and deposited soil will tend to be flushed downstream during high flows and may cause channel erosion or other damage."

(40) Packer, Paul E., and George F. Christensen
[n.d.] Guides for controlling sediment from secondary logging roads. USDA For. Serv. Intermt. For. & Range Exp. Stn. and North. Reg., 42 p. Missoula, Mont.

"Measurements and observations indicate that as much as 90 percent of the sediment produced by erosion on timber sale! areas is from roads. Research and experience show that damage to soil and water can be largely prevented by conscientious application of specific guides for design, location, construction, and maintenance of forest roads.

"This handbook contains guides to help in location and design of secondary logging roads and installation of water control structures that will reduce erosion and prevent sediment from entering streams."

(41) Patric, J. H., and D. N. Swanston
1968. Hydrology of a slide-prone glacial till soil in southeast Alaska. J. For. 66(1):62-66.

"Heavy irrigation caused no surface runoff, erosion, or debris avalanches on well-drained Karta soil, a tentative series producing much of the commercial timber in southeast Alaska. Interpreting measured rainfall, streamflow, and piezometric head in terms of Darcy's equation showed how this slide-prone soil accommodates large amounts of water. About 2/3 of the water applied drained laterally through permeable surface layers to a stream adjacent to the study area. The remaining 1/3 presumably drained deeply into highly fractured bedrock. Less permeable soil, less fractured bedrock, or longer irrigated slopes probably would have caused saturated soil under heavy watering. It appears that Karta soil must be saturated to cause debris avalanches, a condition which may occur naturally when much larger areas are wetted by much smaller rainfall."

(42) Peters, John C.
1965. The effects of stream sedimentation on trout embryo survival. *In* Clarence M. Tarzwell [ed.], Transactions 3rd seminar on biological problems in water pollution. U.S. Public Health Serv. Publ. 999-WP-25, p. 275-279. Robert A. Taft Sanit. Eng. Cent., Cincinnati, Ohio.

"Bluewater Creek, during the study period, was characterized as a stream with little fluctuation in discharge. There was a progressive downstream increase in sediment concentrations at the five sampling areas in the stream. Man-made redds filled with 3/8-inch gravel chips were placed in the vicinity of each sediment-sampling station. Each redd, at the start of the study, had almost identically large intragravel dissolved-oxygen concentrations and intragravel apparent velocities. The intragravel dissolved-oxygen concentration rate and apparent velocity decreased progressively downstream in relation to the progressive downstream increase in sediment concentration. Accompanying the progressive downstream decrease in intragravel dissolved-oxygen concentrations and intragravel apparent velocities was a progressive increase in trout embryo mortality.

"Sediment passing a given area of a stream can greatly affect trout embryo survival. Small sediment concentrations with small fluctuations in discharge in a stable streambed environment indicate a stream area with a potential for good trout embryo survival."

(43) Phillips, Robert W.
1971. Effects of sediment on the gravel environment and fish production. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 64-74. Oreg. State Univ., Corvallis.

"Research in the field is summarized. Sediment influences fish in several ways. In suspension, (1) it blocks the transmission of light, reducing algae production, and (2) it damages the gill membranes, causing death where concentrations are high and exposure is prolonged. When sediment settles on the gravel beds, it is harmful in the following ways: (1) It fills the interstices reducing interchange between surface waters and waters within the gravel bed. This reduces the supply of dissolved oxygen to the egg, and interferes with the removal of metabolites (carbon dioxide and ammonia). (2) Sediment also forms a barrier to fry emergence by blocking the route of egress. (3) Low dissolved oxygen and the physical barrier effect of sediment appear to be additive in reducing survival. (4) Survival after fry emergence is impaired because of a loss of escape cover and a reduction of aquatic organisms that are food for fish. Examples are cited showing that pink and chum salmon survival is inversely related to the amount of sediment in gravel beds."

(44) Platts, William S.
1970. The effects of logging and road construction on the aquatic habitat of the South Fork Salmon River, Idaho. [Abstract.] USDA For. Serv., Zone Fish. Biol., 4 p.

The harvest and resulting road construction of 325 million board feet of timber removed from 7 percent of the South Fork Salmon River caused aquatic habitat degradation. To determine the aquatic habitat conditions, data were collected from 325 randomly located stream transects, 670 streambank points, 90 additional stream transects in spawning areas, 155 streambed core samples, and 80 additional streambed core samples in major spawning areas. Results showed the South Fork Salmon River to be a heavily sedimented stream, especially in the salmonid spawning areas. The studies showed that both streambed surface and depth sediment content were very high. The salmon redds contained slightly less fine materials than the overall spawning areas but were not capable of eliminating required amounts of sediment from egg incubation, areas which would result in good permeability.

A debris basin was effective in improving the aquatic habitat in the stream immediately below the basin during low and normal waterflows, but it was detrimental to downstream habitat during its initial construction and early existence.

(45) Rice, R. M., and J. R. Wallis
1962. How a logging operation can affect streamflow. For. Ind. 89(11):38-40.

Effects of logging on streamflow and sedimentation in Castle Creek, a high Sierra watershed,, were studied. The results pinpoint the fact that even though the total disturbance of the Castle Creek watershed was not great, roads and landings created a large source of sediment.

(46) Saunders, J. W., and M. W. Smith
1965. Changes in a stream population of trout associated with increased silt. J. Fish. Res. Board. Can. 22(2):395-404.

"Low standing crops of brook trout, *Salvelinus fontinalis*, were closely associated with silting in Ellerslie Brook, Prince Edward Island, and appeared to result from the destruction of hiding places. Spawning was also curtailed by silting. Following scouring, trout stocks soon increased. The remarkable adaptability of trout to silting, in a habitat with favourable flow and water temperature, was illustrated."

(47) Shapley, S. Philip, and Daniel M. Bishop
1965. Sedimentation in a salmon stream. J. Fish, Res, Board Can. 22(4):919-928.

"Sediment was artificially added to a small southeastern Alaskan salmon stream. Observations in sediment and control riffles indicate that the amount of sediment settling to the stream bottom decreases exponentially with distance downstream. The dissolved oxygen content of intragravel stream water remained high in sedimented riffles. The added sediment was removed from streambed gravels by fall freshets and floods."

(48) Sheridan, William L.
1968. Land use and sediment. *In* Richard T. Myren [ed.], Logging and salmon, p. 62-79. Proc. Forum Am. Inst. Fish. Res. Biol., Alaska Dist., Juneau, Alaska.

"Of the characteristics that logging and road construction could influence, sediment levels in spawning gravels may be one of the most important. It has been established that sediment decreases permeability of spawning gravels, interferes with interchange of water between the gravels and the surface stream, decreases the velocity of water bathing salmon embryos, and when abundant, prevents alevins from emerging.

"Although there is little doubt that logging and road construction contribute some sediment to salmon streams, there is no evidence to show that these activities, when conducted according to protective clauses included in all timber sale contracts, have damaged the salmon resource in southeastern Alaska.

"We know something of the mechanics and dynamics of sedimentation, but regarding some phases we still have much to learn. We know, for example, that some sediment is carried into streams in almost every instance where roads are built in the watersheds. Through watershed studies, we are attaining a better understanding of the way in which sediment reaches the mainstream as a result of road construction and logging activities (chiefly by way of the, lateral tributaries)."

(49) Sheridan, William L., and William J. McNeil
1968. Some effects of logging on two salmon streams in Alaska. J. For. 66(2):128-133.

"Sedimentation of spawning beds and density of pink salmon (O. *gorbuscha*) were observed before and after logging in two streams in southeastern Alaska. The study lasted seven years (1958-1964). Although the amount of fine particles in spawning beds increased temporarily, the amount in 1964 (five years after logging began) was not significantly greater than in 1959. Densities of salmon spawners and fry increased in the sampling areas during the period of this study. The increases were probably due to the abolition in 1959 of salmon traps (formerly the primary means of catching salmon)."

(50) Stephens, F. R.
1966. Soil and watershed characteristics of southeast Alaska and some western Oregon drainages. USDA For. Serv. Alaska Reg., 16 p. Juneau, Alaska.

Stephens states that the results of any study on the effects of land management on streams cannot be universally applied to all streams unless the land characteristics of each area are known and are comparable. To illustrate the variability of land characteristics which influence the hazards of sedimentation, four areas are compared: the South Umpqua, Alsea, and Bull Run drainages in Oregon, and southeast Alaska.

(51) Swanston, D. N.
1971. Principal mass movement processes influenced by logging, road building, and fire. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 29-40. Oreg. State Univ., Corvallis.

"Dominant natural soil mass movement processes active on watersheds of the western United States include 1) debris avalanches, debris flows and debris torrents; 2) slumps and earth flows; 3) deep-seated soil creep; and 4) *dry* creep and sliding. A dominant characteristic of each is steep slope occurrence, frequently in excess of the angle of stability of the soil. All but *dry* creep and sliding occur under high soil moisture conditions and usually develop or are accelerated during periods of abnormally high rainfall. Further, all are encouraged or accelerated by destruction of natural mechanical support on the slopes. Logging, road building, and fire play an important part in initiation and acceleration of these soil mass movements. Road building stands out at the present time as the most damaging activity, with soil failures resulting largely from slope loading, back-slope cutting, and inadequate slope drainage. Logging and fire affect stability primarily through destruction of natural mechanical support for the soils, removal of surface cover, and obstruction of main drainage channels by debris."

(52) Swanston, Douglas N.
1967. Debris avalanching in thin soils derived from bedrock. USDA For. Serv. Res. Note PNW-64, 7 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"On slopes steeper than the internal angle of friction and in the absence of a well-developed, cohesive soil, landslides must be considered a natural erosion process responding to the basic laws of physics.

They are an inevitable result of any occurrence which tends to reduce the resistance of a slope to sliding.

"Many of these slopes remain stable for years despite the action of external forces tending to reduce their resistance to sliding. The slope soils, therefore, must possess a slide resistance which is not directly related to the physical properties of the soil. Present indications are that this force is produced by tree rooting through the soil and into cracks in the underlying bedrock. Destruction of this rooting system would greatly increase susceptibility of the slope soil to slides."

(53) Swanston, Douglas N.
1969. Mass wasting in coastal Alaska. USDA For. Serv. Res. Pap. PNW-83, 15 p., illus. Pac. Northwest For. & Range Exp. Stn., Inst. North. For., Juneau, Alaska.

"This paper summarizes and interprets the accumulated data and knowledge about slope erosion in southeast Alaska, particularly in relation to recently logged areas, with general suggestions and guidelines for prediction and control."

(54) Swanston, Douglas N.
1970. Mechanics of debris avalanching in shallow till soils of southeast Alaska. USDA For. Serv. Res. Pap. PNW-103, 17 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"Studies in the Maybeso valley show that the majority of debris avalanches and flows develop on slopes greater than 34° and are especially frequent around a critical angle of 37°. On an isosinal contour map of Maybeso valley ... this angle is represented by the critical contour 0.6, the sine of 37°. Above this critical contour, sliding is imminent with the destruction or disruption of any cohesive forces acting to hold the soil in place. Below the critical contour is a zone of decreasing instability. The zone of instability thus defined is located principally in the deeper stream notches and in a narrow band near the 1,200-foot contour. The narrow band in the vicinity of maximum slide activity corresponds to the steep face of a till shoulder marking the upper limit of younger till.

"By construction of an isosine map, or more simply mapping of slope angles, areas of general slope instability within a watershed can be located and the feasibility of applying preventive or control measures determined. If the area of instability is a bedrock cliff, no additional consideration need be given. If the area lies within some of the best timber stands, serious thought should be given to harvesting techniques and road construction in the critical area."

(55) Tebo, L. B., Jr.
1955. Effects of siltation, resulting from improper logging on the bottom fauna of a small trout stream in the southern Appalachians. Progr. Fish-Cult. 17(2):64-70.

Logging influenced the bottom fauna of a small trout stream in the Coweeta Experimental Forest. Bottom fauna were selected to measure the effects of siltation on a stream community. Logging practices were those used commonly in the southeastern States. Results indicated that poorly planned road systems and skid trails result in a high rate of erosion and siltation in stream channels. Properly constructed roads will benefit the logger by reducing road maintenance.

(56) Tebo, L. B., Jr.
1957. Effects of siltation on trout streams. Soc. Am. For. Proc. 1956:198-202.

A study of the Coweeta Experimental Forest in western North Carolina showed that soil erosion and siltation reduced and, in severe cases, even destroyed the trout fishery by (1) inhibiting spawning success, (2) reducing the available food supply, and (3) changing the physical characteristics of the habitat so as to make it unsuitable for trout.

(57) Ursic, S. J.
1965. Sediment yields from small watersheds under various land uses and forest covers. U.S. Dep. Agric. Misc. Publ. 970: 47-52.

"Data from small watersheds in the hilly uplands of northern Mississippi show large variations in annual runoff and sediment production attributable to land use and cover types. Runoff decreased in the order: corn and pasture > abandoned fields and depleted hardwoods > pine plantations. Annual sediment yields and average concentrations of sediment per unit of runoff decreased in the order: corn > pasture > abandoned fields and depleted hardwoods > pine plantations and mature pine-hardwoods. These progressions represent discrete populations of erosion potential.

"Runoff was greater from watersheds with loessial soils than from those with both loess and Coastal Plain soils, but the effect of soil on sediment yields was not consistent for all covers.

"Extremes in annual sediment production ranged from 43 tons per acre from a cultivated watershed to a few pounds per acre from pine plantations. Sediment yields from abandoned fields with a dense cover of native grass and from forest covers did not exceed 0.5 ton per acre annually. By contrast, yields from gullies in the same locality have been reported as 84 to 400 tons per acre.

"The studies are yielding data that should eventually allow prediction of sediment production and permanent covers. They suggest opportunities for reducing runoff and sediment by changing land use and cover types.

"Establishing pine on actively eroding abandoned fields has in two decades reduced sedimentation to amounts probably not in excess of the geologic norm for undisturbed climax forests in this area."

(58) Wallis, James R.
1963. Logging for water quality in northern California. USDA For. Serv. Res. Note PSW-N23, 7 p. Pac. Southwest For. & Range Exp. Stn., Berkeley, Calif.

"Eleven 'do's' and 'don'ts' of logging for preserving water quality are listed and tips for recognizing the more erodible sites are given."

(59) Wickett, W. P.
1959. Effects of siltation on success of fish spawning. *In* E. F. Eldridge and John N. Wilson [eds.], Proceedings 5th symposium--Pacific Northwest on siltation--its source and effects on aquatic environment, p. 16-17. U.S. Dep. Health, Educ. & Welfare, Portland, Oreg.

Effects of siltation on salmon are discussed.

(60) Wilson, John N.
1960. Effects of turbidity and silt on aquatic life. *In* Clarence M. Tarzwell [ed.], Transactions 195.9 seminar on biological problems in water pollution. U.S. Public Health Serv. Tech. Rep. W60-3:235-239. Robert A. Taft Sanit. Eng. Cent., Columbus, Ohio.

Effects of turbidity and silt on aquatic life and a consideration of the establishment of water quality criteria for silt and turbidity in natural waters are discussed.

(61) Wustenberg, Donald W.
1954. A preliminary survey of the influences of controlled logging on a trout stream in the H. J. Andrews Experimental Forest, Oregon. 51 p. M.S. thesis, Oreg. State Coll., Corvallis.

The staggered-setting system of logging in mature Douglas-fir stands affects trout environments. 'Findings included: (1) an increase in localized sediment entering the stream associated with maintenance and use of logging roads, (2) a lack of pronounced increases in sediment concentrations as a result of logging, (3) a fine silt consistency for most sediments, (4) a preponderance of sediment concentrations in the upper parts of small tributaries, (5) a greater disruption of streambeds from

tractor logging than from high-lead logging, (6) severe scouring in logged streams during high flows in comparison with relatively undisturbed conditions in unlogged sections of the same streams, (7) the elimination of cutthroat trout populations in logged streams and adverse effects on aquatic insects for at least one year, and (8) the possibility of reduction in water temperatures through the use of streamside buffer strips.

STREAMSIDE VEGETATION

(62) Brazier, Jon R., and George W. Brown
1972. Buffer strips for stream temperature control. Oreg. State Univ. Res. Pap. No. 15, 12 p.

"The purposes of this research bulletin are to show which buffer strip characteristics are important in regulating the temperature of small streams and to describe a method of designing buffer strips that will insure no temperature change and at the same time minimize the amount of commercial timber left in the strip to provide the necessary shade."

(63) Burns, J. E.
1970. The importance of streamside vegetation to trout and salmon in British Columbia. Dep. Recreation & Conserv., Vancouver Island Reg., Fish & Wildl. Branch, Fish. Tech. Circ. 1, 10 p. Nanaimo, B.C., Can.

"Salmonids are adapted to cool, well oxygenated streams that have traditionally been relatively free of sediment and have been provided with energy sources and cover from streamside vegetation. Environmental disturbances such as the removal of the streamside canopy, erosion, sedimentation, debris deposition and spraying of toxins have resulted in the loss of much productive stream habitat for trout and salmon in Northwestern North America. The magnitude of this loss could have been reduced significantly by treating the stream as an integral part of the total forest environment and leaving streamside vegetation, a small part of the environment, relatively undisturbed."

(64) Cormack, R. G. H.
1949. A study of trout streamside cover in logged-over and undisturbed virgin spruce woods. Can. J. Res. 27(3):78-95. [Taken from Cordone (148).]

"The purpose of the survey was to obtain information concerning the vegetation of undisturbed and disturbed forest areas, to analyze the information and to relate it to the problems of soil erosion, water conservation, and trout stream management.

"From evidence obtained in the present survey one measure of stream protection that seems most desirable would be the prohibition of all cutting along wide strips on both sides of the stream. There is considerable precedent for advising a policy of this kind, as multiple use forestry admits non-cutting in certain areas, if it is genuinely needed. The width of the strips to be left uncut will undoubtedly vary with the individual stream and with the type of forest cover. Taking conditions in the Carbondale River Valley as more or less general for this part of the watershed the writer suggests as a beginning point a strip of at least 60 feet on each side of the stream. Certainly the uncut areas should be wide enough to provide the maximum of shade and protection to both stream and streamside cover and to preserve the natural attractiveness of the stream. Also they should be extensive enough to include the stream's source, springs, and small feeder tributaries."

(65) DeWitt, John W.
1968. Streamside vegetation and small coastal salmon streams. *In* Richard T. Myren [ed.], Forum on the relation between logging and salmon, p. 38-47. Proc. Forum Am. Inst. Fish. Res. Biol., Alaska Dist., Juneau, Alaska.

"The main purpose of this talk is to review some general considerations of the influence of streamside vegetation, especially its stream canopy aspects as affected by canopy removal, on the conditions and ecology of small coastal salmon streams. Some of the direct effects that I shall ascribe to changes in streamside vegetation can also be the result of changes in vegetation on slopes and ridges well away from the stream. The streams I am referring to are those of minimum flow of only a few cubic feet per second. In areas of virgin and recovered forest, these streams tend to have well-vegetated banks and to be well shaded."

(66) Green, Geoffrey E.
1950. Land use and trout streams. J. Soil & Water Conserv. 5(3):125-126.

A study in the Coweeta Experimental Forest of North Carolina compared stream temperatures of two streams--an agricultural stream and an undisturbed forest stream. As was expected, shading was the key to control of stream temperatures. The agricultural stream with little shade ranged from 9°-20° F higher than the forest stream.

(67) Johnson, Fred W.
1953. Forests and trout. J. For. 51(8):551-554.

The author states that:

"...Stream-bank vegetation helps to maintain such [deep-water] areas through the reduction of lateral erosion. Strips of timber left along stream banks...provide this needed protection against lateral erosion. Moreover, they also serve as buffers that arrest silt flows from skid trails and logging roads. During summer rainstorms, the writer has observed that silt flows fan out within 20 or 30 feet after entering the undisturbed mat of pine needles and other forest litter."

The article discusses trout-forest relationships in general but probably refers to the Rocky Mountain area.

(68) McMynn, R. G.
1970. "Green belts" or "leave strips" to protect fish! Why? Dep. Recreation & Conserv., Commer. Fish. Branch, 36 p. Victoria, B.C., Can.

Papers concerning logging practices in relation to water management and fish production are reviewed; first, to outline how logging practices can affect a watershed, and second, to explain how "leave strips" or "green belts" can be important in offsetting some of the detrimental effects of logging.

(69) McMynn, Robert
1970. Strips of trees could protect fish from loggers. West. Fish. 80(6):20-24.

Benefits of "leave strips" or "green belts" along streams are discussed. Author states that such strips or belts would provide the most valuable means of protecting streams from harmful effects of logging on fish.

(70) Sadler, Ronald R.
1970. Buffer strips--a possible application of decision theory. Bur, Land Manage. Tech. Note, 11 p. U.S. Dep. Inter. Portland, Oreg.

The economic values of leaving buffer strips for stream protection are discussed. The article includes various formulas to determine economic value of the fishery as compared with the value of the timber in the buffer strips.

(71) Streeby, Larry
1971. Buffer strips--some considerations in the decision to leave. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 194-198. Oreg. State Univ., Corvallis.

"Buffer strips have been receiving a great deal of attention as a method of protecting streams and the stream environment. But they are not equally useful in all places. The desirability of applying buffer strips is dependent on three classes of factors--physical-biotic factors, outside cultural factors, and management objectives. Some potential costs and benefits associated with buffer strips are identified, but all these costs'and benefits should not be expressed in dollar terms. Rather, all costs and benefits associated with each management objective should be explicitly recognized in their own natural measure of contribution to goals, and decisions should be made on the basis of this information."

WATER QUALITY

(72) Allen, E. J.
1960. Water supply watershed problems - Seattle watershed. *In* E. F. Eldridge [ed.], Proceedings 7th symposium water pollution research, p. 15-17. U.S. Public Health Serv., Reg. IX, Portland, Oreg.

Watershed activities which have a deleterious effect upon the quality or quantity of water are discussed. The author suggests that the solution is multiple use management.

(73) Atkinson, Sheridan William
1971. BOD and toxicity of log leachates. 96 p. M.S. thesis, Oreg. State Univ., Corvallis.

"A series of log storage experiments was conducted to determine whether leachates derived from water storage of logs are acutely toxic to fish. Log segments approximately 18 inches long and 16 inches in diameter were stored in tanks and held submerged for a period of 7 days. The holding water containing leached materials was made toxic with mercury to retard biological decomposition of the leached substances. Mercury was selectively removed from leachate samples by chelation prior to biochemical oxygen demand (BOD) and bioassay testing.

"Trout and salmon fry were subjected to the leachate water in short term acute bioassay tests. Results are reported as a median tolerance limit, (TLm), i.e., the concentration of leachate at which 50 percent of the test fish died for any given exposure time. Leachates were also tested for BOD_5, BOD k-rate, chemical oxygen demand (COD), wood sugar and Pearl Benson Index (PBI).

"Test results show that leachates from Douglas fir stored in fresh water exert a slight acute toxicity to fish. A TLm_{96} of 20 percent leachate by volume, for a 50 year old Douglas fir log, was the most toxic leachate observed. Leachates from ponderosa pine, hemlock and older fir log stored under identical conditions produced no measurable acute toxicity. Leachates contained a significant quantity of BOD and PBI exerting substances. The highest BOD_5, (1.36 g/ft^2 of submerged surface area) was exerted by leachate from a ponderosa pine log segment stored with bark removed. The highest PBI value (12.5 g/ft^2), was observed for leachate from a young Douglas fir log segment. BOD:COD ratios and BOD k-rate ranged widely for the various leachates, but were relatively low which indicated a significant fraction of non-biodegradable substances. Hoffbuhr...also observed a high non-biodegradable fraction in samples taken from log storage ponds. Wood sugars were found to account for a large part of the degradable portion of leachates. Leachates from ponderosa pine log with bark intact exerted a high BOD and also contained the highest concentration of wood sugar observed, 0.84 g/ft^2."

(74) Bormann, F. H., G. E. Likens, D. W. Fisher, and R. S. Pierce
1968. Nutrient loss accelerated by clear cutting of a forest ecosystem. Science 159:882-884.

"The forest of a small watershed-ecosystem was cut in order to determine the effects of removal of vegetation on nutrient cycles. Relative to undisturbed ecosystems, the cut ecosystem exhibited accelerated loss of nutrients: nitrogen lost during the first year after cutting was equivalent to the amount annually turned over in an undisturbed system, and losses of cations were 3 to 20 times greater than from comparable undisturbed systems. Possible causes of the pattern of nutrient loss from the cut ecosystem are discussed."

(75) Bridges, W. R.
1965. Some effects on fish of chemical control of forest insects. Soc. Am. For. Proc. 1964:192-194.

"This paper deals primarily with some of the effects on fish caused by DDT aerial sprays conducted for forest insect control. Some aspects associated with the use of other less toxic chemicals are also considered."

(76) Brown, George W.
1969. Predicting temperatures of small streams. Water Resour. Res. 5(1):68-75.

"Hourly temperatures of small streams can be accurately predicted using an energy balance. Micrometeorological measurements are required to assess the environment of the small stream accurately. The temperature-prediction technique was tested on three streams 'in Oregon. On unshaded stretches, net all-wave radiation is the predominant energy source during the day; evaporation and convection account for less than 10% of the total energy exchange. Conduction of heat into the stream bottom is an important energy balance component on shallow streams having a bedrock bottom. Up to 25% of the energy absorbed by such a stream may be transferred into the bed. Hourly temperature changes of 0-16° F were predicted to within 1° F more than 90% of the time. This technique permits foresters to control water temperature through manipulation of stream-side vegetation."

(77) Brown, George W.
1970. Predicting the effect of clearcutting on stream temperature. J. Soil & Water Conserv. 25(1):11-13.

"The temperature change that occurs between two points on a stream is directly proportional to the surface area of the stream and the heat load applied between these points. It is inversely proportional to the flow. Good estimates of the heat load can be made with solar radiation data if the stream is uniformly exposed to sunlight. Foresters can use this technique to predict the effect of clearcutting on stream temperature."

(78) Brown, George W.
1971. Water temperature in small streams as influenced by environmental factors and logging. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 175-181. Oreg. State Univ., Corvallis.

"Clearcut logging can produce large changes in the temperature of small streams. The principal source of heat affected by clearcutting is direct solar radiation. Shade removal may increase radiation loads by six to seven times. Temperature control can best be achieved by providing shade between the boundary of the clearcut and the stream. Adequate shade may be provided by brush species if streams are very small. The impact, both at the site and downstream, of exposing given amounts of stream surface to direct solar radiation is predictable."

(79) Brown, George W.
1972. An improved temperature prediction model for small streams. Water Resour. Res. Inst., Rep. WRRI-16, 20 p. Oreg. State Univ., Corvallis.

"A model for predicting the maximum change in temperature from completely exposing a reach of stream to solar radiation was developed during earlier research. This model, which assumes that net solar radiation is the sole source of energy to the stream, worked well on most streams. In a few cases it worked very poorly. These streams contained either a large proportion of pools or bed rock in the stream bottom. We found that only the flowing portion of the pools should be included in the heat exchange process. We also found that the bed rock stream bottoms can conduct about 20% of the incident solar radiation away from the stream. Reducing our estimates of stream surface area and net heat load according to pool configuration and bed condition provided good estimates of temperature change using the original model."

(80) Brown, George W., and James T. Krygier
1967. Changing water temperatures in small mountain streams. J. Soil & Water Conserv. 22(6):242-244.

The results from two studies show that clearcutting influences summer temperatures in small Oregon coastal streams. The integrated effect of numerous clearcuttings on small tributary streams may be a significant source of thermal pollution.

(81) Brown, George W., and James T. Krygier
1970. Effects of clear-cutting on stream temperature. Water Resour. Res. 6(4):1133-1139.

"The principal source of energy for warming streams is the sun. The amount of sunlight reaching the stream may be increased after clear-cut logging. Average monthly maximum temperatures increased by

14° F and annual maximum temperatures increased from 57° to 85° F one year after clear-cut logging on a small watershed in Oregon's coast range. In a nearby watershed where strips of brush and trees separated logging units from the stream, no changes in temperature were observed that could be attributed to clear-cutting."

(82) Brown, George W., Gerald W. Swank, and Jack Rothacher
1971. Water temperature in the Steamboat drainage. USDA For. Serv. Res. Pap. PNW-119, 17 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"Stream temperatures were studied in a drainage in which logging operations were typical of much of the commercial forests on the west slopes of the Cascade Range. Changes in water temperature of tributary streams influenced by various degrees of exposure from logging were measured, and a simplified prediction equation was tested."

(83) Bullard, William
1963. Water quality problems originating on wild lands. *In* Symposium on forest watershed management, p. 313-319. Oreg. State Univ., Corvallis.

The water quality problems originating on wild lands and some possible solutions to these problems are discussed.

(84) Eschner, Arthur R., and Jack Larmoyeux
1963. Logging and trout: four experimental forest practices and their effect on water quality. Progr. Fish-Cult. 25(2):59-67.

Results of studies conducted in West Virginia are discussed:

"Experimental logging of watersheds caused significant changes in quantity and quality of streamflow.

"Poorly located and constructed skidroads resulted in continuous, very high stream turbidities during logging. This effect diminished with time after logging disturbance ended. Carefully planned and constructed skidroads contributed negligible amounts of turbidity.

"Clearcutting resulted in significantly higher maximum stream temperatures in the growing season, lower minimum temperatures in the dormant season. Maximum stream temperatures above those generally tolerated by brook trout were noted often in the summer of 1959. Moderate cutting did not produce water-quality changes that might be harmful to trout.

"Increases in pH, alkalinity, and specific conductance were noted in the stream flowing from the clearcut watershed.

"Streamflow was increased by the treatments in proportion to the amount of timber cut and killed. Most of the increases came late in summer and early in fall, the periods of high evapotranspiration and soil moisture recharge, when flow in many trout streams is dangerously low.

"Changes in stream pH, alkalinity, and temperature are persisting; but treatment effects on quantity of flow and turbidity are diminishing as time passes."

(85) Fredriksen, R. L.
1971. Comparative chemical water quality - natural and disturbed streams following logging and slash burning. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 125-137. Oreg. State Univ., Corvallis.

"The loss of nutrients from an old-growth Douglas-fir forest was measured in the streams of experimental watersheds. Following timber harvest and slash burning, loss of nutrients cations increased 1.6 to 3.0 times the loss from the undisturbed watershed. A surge of nutrients that followed broadcast burning contained concentrations of ammonia and manganese that exceeded Federal water quality standards for a period of 12 days. Annual nitrogen loss following burning averaged 4.6 pounds per acre; 53 percent of this was organic nitrogen contained in sediment. Inorganic nitrogen, dissolved in the stream, made up the remaining part. Annual loss of nitrogen from the undisturbed forest was very small--.16 pound per acre."

(86) Gibson, H. R., and D. W. Chapman
1972. Effects of Zectran insecticide on aquatic organisms in Bear Valley Creek, Idaho. Trans. Am. Fish. Soc. 101(2):330-344.

"We assessed effects of the experimental insecticide Zectran® on aquatic organisms in Bear Valley Creek, Idaho in 1966. Hayden Creek drainage, nearby and not sprayed, served as a control. We found no significant fish mortality, and no effect on growth rate and condition of age 0+, 1+, 2+, and 3+ dolly varden (*Salvelinus malma*). Insecticide applications did not increase emigration and intrastream movement of fish. We noted no effects on benthic aquatic insect numbers, but observed that more insects drifted downstream for several hours beginning about 3 hours after spraying on July 7, 1966. Adult terrestrial insects, immature Heptageneidae and Rhyacophilidae, adult Chloroperlidae, and immature and adult Phryganeidae, Limnephilidae, and Blephariceridae increased in drift samples after spraying. We concluded that the Zectran insecticide damaged aquatic organisms very little."

(87) Goldman, Charles R.
1967. Effects of pesticides in California watersheds. *In* Man's effect on California watersheds, p. 211-217. Part III, 1965-1967. Sacramento, California.

The effects of pesticides on both the aquatic and terrestrial habitats are discussed. A list of needed research and legislation in California is also included.

(88) Gordon, Robert, and Dennis Martens
1969. Sockeye eggs killed by bark on spawning gravel. West Fish., Sept., p. 41-43.

"Dangers of log-driving on salmon spawning streams are being studied by the Salmon Commission. Two biologists outline their findings, which conclude that concentrations of bark over four percent of the gravel surface are detrimental. Resumption of the Stellako log drive, they say, would be 'ill-advised.'"

(89) Graham, John LeRoy
1970. Pollutants leached from selected species of wood in log storage waters. 46 p. M.S. thesis, Oreg. State Univ., Corvallis.

"A study was conducted to determine the quantity and character of substances leached from logs floating in water, and the rate of leaching of these substances. The species of wood studied were Douglas fir and ponderosa pine. The research was carried out in a controlled laboratory environment with log sections 14-inches in diameter by 20-inches long. The study included log sections submerged in both tap water and saline water. The holding water was chemically poisoned to prevent biological degradation of the leached materials.

"The analyses performed on samples of the holding water taken at specified intervals during 40 day leaching periods included chemical oxygen demand (COD), Pearl-Benson Index (PBI), total solids (TS), total volatile solids (TVS) and total organic carbon (TOC).

"The data showed that ponderosa pine logs contributed measurably greater quantities of soluble organic materials and color-producing substances than Douglas fir logs. The following COD and PBI values were measured after a leaching period of 20 days: ponderosa pine - 4.3 g COD/ft^2, 15 g PBI/ft^2; Douglas fir - 3.2 g COD/ft^2, 11 g PBI/ft^2.

"Leaching rate appeared to be affected by the concentration of soluble organic materials in the stagnant holding water; however, experiments showed that, in flowing water, the leaching rate was nearly constant.

"Extrapolation of the laboratory test data to field conditions resulted in an estimate of nearly 800 pounds of COD per day contributed by approximately 8 million board feet of floating logs to a typical log storage water."

(90) Gray, J. R. A., and J. M. Edington
1969. Effect of woodland clearance on stream temperature. J. Fish. Res. Board Can. 26:399-403.

"A study was made of the temperature characteristics of a stream which flowed first through open fields and then through woodland. When the woodland was felled, that section of the stream showed a marked rise in summer temperature. It is argued that the presence or absence of tree shading can be the decisive factor in determining the temperature of small streams."

(91) Griffin, L. E.
1938. Experiments on tolerance of young trout and salmon for suspended sediment in water. Oreg. State Dep. Geol. Miner. Ind. Bull. No. 10, Append. B., p. 28-31. Portland, Oreg.

The preliminary examination of data from a study on the tolerance of young trout and salmon to suspended sediment indicated that young trout and salmon are not directly injured by heavily silted water.

(92) Grondal, Bror L.
1945. Relation of runoff and water quality to land and forest use in Cedar River watershed. J. Am. Water Works Assoc. 37(1): 15-20.

A study commission formed with the primary objective of deciding the future policies in the Cedar River watershed with respect to logging recommended a continuation of logging in the watershed on a controlled sustained-yield basis.

(93) Klock, G. O.
1971. Streamflow nitrogen loss following forest erosion control fertilization. USDA For. Serv. Res. Note PNW-169, 9 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"Three gaged watersheds, approximately 500 hectares in size, in north central Washington were severely burned in 1970 by wildfire. In an experimental erosion control seeding program, two watersheds were fertilized, one with urea and the other with ammonium sulfate. The third watershed was retained as an unrehabilitated control. For a 60-day period during and following fertilization, 1.37 kilograms of urea-N and 2.90 kilograms of nitrate-N were estimated to have been carried by streamflow from the watershed fertilized with 27.5 metric tons of elemental nitrogen as urea. On the watershed fertilized with 33.16 metric tons of elemental nitrogen as ammonium sulfate, 1.45 kilograms of nitrate-N was estimated to have been transported from the watershed by streamflow."

(94) Kopperdahl, Fredric R., James W. Burns, and Gary E. Smith
1971. Water quality of some logged and unlogged California streams. Calif. Fish & Game, Inland Admin. Rep. 71-12, 19 p.

"Water quality was monitored in 1968 and 1969 in six coastal streams in northern California, four of which were subjected to logging and/or road building (Bummer Lake Creek, South Fork Yager Creek, Little North Fork Noyo River, and South Fork Caspar Creek), while the others remained undisturbed (Godwood Creek and North Fork Caspar Creek). The purposes of this study were to characterize the water quality of the streams, to determine if the logging and road construction drastically altered water quality, and to collect water quality data which could be tested for predicting stream carrying capacities for salmonids.

"Conditions were generally suitable for salmonids during and after the logging. No abnormal concentrations of dissolved oxygen, alkalinity, hardness, dissolved solids, phosphate, chloride, sulfate, nitrate, tannin and lignin, or pH were detected. Carbon dioxide was low in most streams, except in South Fork Caspar Creek when it reached 8 ppm during decomposition of logging debris in the summer of 1968. Turbidity was highest in areas where bulldozers were working in the streams. Temperatures of most streams increased after the logging, but seldom exceeded 70° F because of the cool climate in the coastal fog belt. Alternating cut and uncut blocks on one stream, and retaining a buffer strip along another, kept temperatures low in two streams."

(95) Kramer, Robert H., and Lloyd L. Smith, Jr.
1965. Effects of suspended wood fiber on brown and rainbow trout eggs and alevins. Trans. Am. Fish. Soc. 94:252-258.

"Brown and rainbow trout (*Salmo trutta* and *S. gairdneri*) eggs were held in continuous-flow suspensions of 0-, 60-, 125-, and 250-ppm conifer groundwood fiber 6 to 8 days before hatching. Resulting alevins were held in the same fiber concentrations until swimup (14 to 16 days), then removed and maintained in clean water for up to 91 days. Suspended fiber had no effect upon egg survival, respiration rate of embryos, or growth rates of alevins and juveniles from eggs incubated in fiber but hatched and grown in clean water. When alevins were held in wood-fiber suspensions, survival was reduced from 98 to 100 per cent in controls to 0 to 72 per cent in 250-ppm fiber; respiration rate from 336.6 mm^3/g per hour in controls to 146.3 in 125-ppm fiber; breathing rate from 1.39 to 1.92 respiratory movements per second in controls to 0.52 to 0.97 in 250-ppm fiber; heart rate from 1.50 to 1.60 beats per second in controls to 0.67 to 1.33 in 250-ppm fiber; and instantaneous growth rate (g) from .0213 to .0345 in controls to .0061 to .0062 in 250-ppm fiber. Growth rate of rainbow trout juveniles in clean water after exposure to fiber during the alevin stage was significantly reduced only in the 250-ppm-fiber group. Concurrent tests indicated that observed effects were due to the fiber and not to residues of a mercuric slimicide added to the fiber at the paper mill."

(96) Lantz, Richard L.
1971. Influence of water temperature on fish survival, growth and behavior. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 182-193. Oreg. State Univ., Corvallis.

"Water temperature can control the functions and activities of freshwater fishes since their body temperature is similar to the temperature of their environment. The removal of streamside vegetation during logging operations can increase water temperatures. Such temperature increases would be most significant on small streams, which are essential to the production of salmon and trout in the Pacific Northwest. A general technical review of the effects of temperature on fish survival, growth, and behavior is presented. Concepts regarding the thermal requirements of fishes are summarized. Buffer strips of vegetation along streams are suggested as an important land management tool. In addition to eliminating or minimizing water temperature increases, buffer strips serve other purposes and provide for true multiple-use of the resources of our watersheds."

(97) Levno, Al, and Jack Rothacher
1967. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. USDA For. Serv. Res. Note PNW-65, 12 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"...In this study, mean monthly temperature increases of 7° to 12° F. persisted from April through August, following direct exposure of the stream channel by scouring during the 1964 flood...

"Under the pattern of patch clearcuts commonly used in the Douglas-fir region, little or no increase in maximum stream temperatures would be expected unless a large proportion of the streambed was directly exposed to solar radiation. Protection of any streamside vegetation which provides some shade to the stream will apparently help prevent excessive increases in maximum water temperatures."

(98) Levno, Al, and Jack Rothacher
1969. Increases in maximum stream temperatures after slash burning in a small experimental watershed. USDA For. Serv. Res. Note PNW-110, 7 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"The first year after slash was burned on a 237-acre clearcut watershed in the Cascade Range of Oregon, average maximum water temperatures increased 13°, 14°, and 12° F. during June, July, and August. A maximum stream temperature of 75° F. persisted for 3 hours on a day in July."

(99) Likens, Gene E., F. Herbert Bormann, Noye M. Johnson, and others 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecol. Monogr. 40(1):23-47.

"All vegetation on Watershed 2 of the Hubbard Brook Experimental Forest was cut during November and December of 1968, and vegetation regrowth was inhibited for two years by periodic application of herbicides. Annual stream-flow was increased 33 cm or 39% the first year and 27 cm or 28% the second year above the values expected if the watershed were not deforested.

"Large increases in streamwater concentrations were observed for all major ions, except NH_4+, SO_4= and HCO_3-, approximately five months after the deforestation. Nitrate concentrations were 41-fold higher than the undisturbed condition the first year and 56-fold higher the second.... Sulfate was the only major ion in stream water that decreased in concentration after deforestation.., . Average streamwater concentrations increased by 417% for Ca++, 408% for Mg++, 1558% for K+ and 177% for Nat during the two years subsequent to deforestation. Budgetary net losses from Watershed 2 in kg/ha-yr were about 142 for NO_3-N, 90 for Ca++, 36 for K+, 32 for SiO_2-Si, 24 for Al+++, 18 for Mg+++, 17 for Na+, 4 for Cl-, and 0 for SO_4-S during 1967-68; whereas for an adjacent, undisturbed watershed (W6) net losses were 9.2 for Ca++, 1.6 for K+, 17 for SiO_2-Si, 3.1 for Al+++, 2.6 for Mg++, 7.0 for Na+, 0.1 for Cl-, and 3.3 for SO_4-S. Input of nitrate-nitrogen in precipitation normally exceeds the output in drainage water in the undisturbed ecosystems, and ammonium-nitrogen likewise accumulates in both the undisturbed and deforested ecosystems, Total gross export of dissolved solids, exclusive of organic matter, was about 75 metric tons/km^2 in 1966-67, and 97 metric tons/km^2 in 1967-68, or about 6 to 8 times greater than would be expected for an undisturbed watershed.

"The greatly increased export of dissolved nutrients from the deforested ecosystem was due to an alteration of the nitrogen cycle within the ecosystem.

"The drainage streams tributary to Hubbard Brook are normally acid, and as a result of deforestation the hydrogen ion content increased by 5-fold (from pH 5.1 to 4.3).

"Streamwater temperatures after deforestation were higher than the undisturbed condition during both summer and winter, Also in contrast to the relatively constant temperature in the undisturbed streams, streamwater temperature after deforestation fluctuated 3-4°C during the day in summer.

"Electrical conductivity increased about 6-fold in the stream water after deforestation and was much more variable.

"Increased streamwater turbidity as a result of the deforestation was negligible, however the particulate matter output was increased about 4-fold. Whereas the particulate matter is normally 50% inorganic materials, after deforestation preliminary estimates indicate that the proportion of inorganic materials increased to 76% of the total particulates."

(100) McCall, Merley
1970. The effects of aerial forest fertilization on water quality for two streams in the Capitol forest. Wash. State Dep. Ecol., 14 p. Olympia.

"The studies of two streams in the fall and winter of 1969/1970 indicated that aerial application of a urea fertilizer to the forested areas in the watersheds resulted in a rapid increase in urea concentration in the water. This was likely due to the direct application to feeder streams. Further sampling shows the urea concentration to fall to background levels within one month. After a month the nitrogen lost is apparently in the form of nitrate only. The overall effect on the water quality was to significantly change the nitrogen levels, although the change was of short duration."

(101) McNeil, William J.
1962. Variations in the dissolved oxygen content of intragravel water in four spawning streams in southeastern Alaska. U.S. Fish & Wildl. Serv. Spec. Sci. Rep., Fish. 402, 15 p.

"Inexpensive equipment for sampling intragravel water for dissolved oxygen is described. Water samples were withdrawn from plastic standpipes driven into the streambed. Dissolved oxygen values representative of points sampled were obtained from 30-ml. samples of water taken about 24 hours after standpipes were placed.

"Fourfold seasonal and yearly changes in dissolved oxygen levels were observed. Spatial differences in dissolved oxygen levels were greatest when discharge was low and temperature was high.

"For routine measurement of dissolved oxygen level random sampling was tried and found to be satisfactory."

(102) Meehan, William R.
1968. Relationship of shade cover to stream temperature in southeast Alaska. *In* Richard T. Myren [ed.], Logging and salmon, p. 115-131. Proc. Forum Am. Inst. Fish. Res. Biol., Alaska Dist., Juneau, Alaska.

"Temperature measurements in several streams in upper southeastern Alaska indicate that shade-producing streamside cover is important in maintaining cool water. Stream temperatures increase rapidly in unshaded reaches on clear, warm days and likewise cool quite quickly when the water passes through shaded reaches. On overcast days, the temperature increases as the water flows downstream, but to a much lesser extent than on clear days in open areas. Average temperature differences per 20 yards of stream channel exposed to solar radiation on warm, clear days were significantly different between streams in the Juneau-Haines area and in the Petersburg-Wrangell area. Such was not the case in shaded reaches and on overcast days."

(103) Meehan, William R.
1970. Some effects of shade cover on stream temperature in southeast Alaska. USDA For. Serv. Res. Note PNW-113, 9 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"Water temperatures were recorded in several southeast Alaska streams with a portable thermometer accurate to 0.01° C. Measurements were made at 20-yard intervals in shaded and unshaded reaches and on cloudy and clear days. Results indicate that (1) the effects of streamside cover on stream temperatures can be evaluated by this technique, and (2) shade-producing streamside cover is important in maintaining cool water."

(104) Morris, Logan A.
1968. Stream contamination by herbicides after fall rains on forest land. West. Soc. Weed Sci. Res. Prog. Rep., p. 33-34.

Based on previous studies and on a study of two Oregon streams, it was concluded that fall rains will not result in appreciable contamination of streams flowing through forest areas treated with phenoxy or amitrole herbicides. Unless heavy application is made directly into the stream, the major contribution of herbicides is overland movement of water and soil.

(105) Morris, Logan A., and Duane G. Moore
1971. The entry and fate of forest chemicals in streams. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 138-158. Oreg. State Univ., Corvallis.

"Initial distribution of aerially applied forest chemicals, mechanisms of their entry into, and their fate in the aquatic environment are considered. Research findings and long history of use have established that most forest chemicals offer minimum potential for pollution of the aquatic environment when they are used properly."

(106) Pacific Northwest Pollution Control Council
1971. Log storage and rafting in public waters. Task Force Rep. 56 p.

"Available research findings show that log debris, bark, and wood leachates resulting from log handling in public waters can adversely affect water quality. The range of effects varies from mild to gross depending upon the specific characteristics of both the involved water body and log handling practices. In most instances where logs depreciate water quality, there are a number of practicable changes that can be made to improve conditions.

"This report sets forth a number of recommendations for implementing improved log handling practices that will benefit water quality:

"1. Log storage and handling should be restricted in or eliminated from public waters where water quality standards cannot be met at all times or where these activities are a hindrance to other beneficial water uses such as small craft navigation.

"2. The free-fall, violent dumping of logs into water should be prohibited since this is the major cause and point *source* of loose bark and other log debris.

"3. Easy let-down devices should be employed for placing logs in the water, thereby reducing bark separation and the generation of other wood debris.

"4. Positive bark and wood debris controls, collection, and disposal methods should be employed at log dumps, raft building areas, and millside handling zones. This would be required for both floating and sinking particles.

"5. Log dumps should not be located in rapidly flowing waters or other water zones where positive bark and debris controls cannot be made effective.

"6. Accumulations of bark and other debris on the land and docks around dump sites should be kept out of the water.

"7. Whenever possible, logs should not be dumped, stored, or rafted where grounding will occur.

"8. Where water depths will permit the floating of bundled logs, they should be secured in bundles on land before being placed in the water. Bundles should not be broken again except on land or at millside.

"9. The inventory of logs in public waters for any purpose should be kept to the lowest possible number for the shortest possible time.

"10. Industry should provide and periodically update an accurate quantification of its use of public waters for log handling activities."

(107) Packer, Paul E.
1967. Forest treatment effects on water quality, *In* William E. Sopper and Howard W. Lull [eds.], Forest hydrology, p. 687-699. Oxford: Pergamon Press.

A review of information to determine the effects of forest treatments associated with timber harvesting has shown that: (1) undisturbed forests produce small amounts of sediment; (2) timber cutting does not adversely affect water quality except for increases in streamflow peaks, streamflow temperatures, and streambank erosion caused by increased discharge; (3) skidding of logs and logging can increase sedimentation considerably; and (4) roads that are inadequately drained or located too close to streams are the main cause of deterioration of water quality in forests.

(108) Packer, Paul E., and Harold F. Haupt
1966. The influence of roads on water quality characteristics. Soc. Am. For. Proc. 1965:112-115.

This paper discusses the impact of timber harvest roads and attempts to answer three questions: (1) How much sediment comes from forest roads and logging operations? (2) What are the harmful effects on stream biology? And, (3) What are some criteria for road location and drainage that will assure better water quality?

(109) Schaumburg, Frank D.
1970. Influence of log handling practices on water quality. *In* Water studies in Oregon, p. 1-9. Semin. Water Resour. Res. Inst., Oreg. State Univ., Corvallis.

The influence of log handling practices on water quality was evaluated in a study initiated in 1968. The results to date indicate that logging and log handling practices do contribute measurably to the pollution of natural waters. The effects of logging practices must be evaluated at each location to determine their real significance.

(110) Schaumburg, Frank D.
1970. The influence of log rafting on water quality. Annu. Rep. Res. Proj. WP-01320-01, 68 p. Oreg. State Univ., Corvallis.

Research activities on the influence of log rafting on water quality are summarized. The major portion of the report describes various projects including methods and apparatus used, experimental results, and a discussion of the pertinent findings. Four technical publications are also included: (1) Pollutants leached from selected species of wood in log storage waters, (2) The quantity and distribution of bark debris resulting from water storage of logs, (3) Pollution associated with the water storage of logs - Part I: Bark debris; Part II: Leachates.

(111) Sears, Howard S., and William R. Meehan
1969. Short-term effects of 2,4-D on aquatic organisms in the Nakwasina River watershed, southeastern Alaska. Pestic. Monit. J. 5(2):213-217.

Preliminary results and analysis of data on the effects of aerial spraying of 2,4-D on aquatic organisms are presented. Results showed that 2,4-D caused no apparent significant immediate mortality on aquatic organisms.

(112) Servizi, J. A., D. W. Martens, and R. W. Gordon
1970. Effects of decaying bark on incubating salmon eggs. Int. Pac. Salmon Fish. Com., Progr. Rep. 24, 28 p.

"The effect of bark contamination on salmon spawning grounds was assessed in laboratory tests on sockeye salmon (*Oncorhynchus nerka*) eggs and alevins. Bioassays showed that chemical toxicity of materials leached from bark of Douglas fir, Lodgepole pine, Englemann spruce and Alpine fir was not a factor influencing survival under the conditions tested. However, abundant growths of *Sphaerotilus* occurred on bark during initial stages of decay, causing severe mortalities among sockeye eggs and alevins owing to suffocation. In gravel-filled incubation boxes, contamination of gravel with bark caused significant reductions in survival from egg to fry at bark concentrations of 10% by volume, but 1% bark concentrations did not influence survival. Mortalities were attributed to blockage of intragravel water flow by bark particles. The oxygen demand of decaying bark was found to be relatively constant with time during the 683-day study. Calculations based on oxygen demand of bark indicated the amount of oxygen which would remain for egg incubation in natural redds at various temperatures and levels of bark contamination. Possible effects of various oxygen concentrations on size and emergence timing of fry were discussed and limiting amounts of bark recommended."

(113) Swift, Lloyd W., Jr., and James B. Messer
1971. Forest cuttings raise temperatures of small streams in the southern Appalachians. J. Soil & Water Conserv. 26(3): 111-116.

"Stream temperatures were measured during six forest-cutting treatments on small (23- to 70-acre) watershed in the southern Appalachian Mountains. Where forest trees and all understory vegetation were completely cut, maximum stream temperatures in summer increased from the normal 66° F to 73° or more. Some extreme treatments raised temperatures

more than 12° above normal. Where streambank vegetation was uncut or had regrown, summer maximums remained unchanged or declined from temperatures measured under uncut mature hardwood forest. Increases in stream temperature were judged to degrade water quality and constitute thermal pollution because, after each clearcut, water temperatures exceeded optimum levels for trout habitat."

(114) Tarrant, Robert F.
1967. Pesticides in forest waters—symptom of a growing problem. Soc. Am. For. Proc. 1966:159-163.

The water pollution problems associated with the application of forest chemicals are discussed.

(115) Thut, Rudolph N., and Eugene P. Haydu
1971. Effects of forest chemicals on aquatic life. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 159-171. Oreg. State Univ., Corvallis.

"Results of pesticide bioassays are not readily applicable to the conditions found after forest spray operations. They do have some value in determining the relative toxicities of the more widely used pesticides. The insecticides, particularly chlorinated hydrocarbons, are more toxic than most herbicides to aquatic life. There have been instances where insecticides applied to forests, particularly DDT, were directly toxic to stream life; such has not been demonstrated with herbicides applied to forests. Field studies conducted to date indicate that the concentrations of urea fertilizer and its breakdown are well below toxic thresholds for aquatic life. An increase in the rate of eutrophication of some lakes remains a possibility."

(116) Titcomb, John W.
1926. Forests in relation to fresh water fishes. Trans. Am. Fish. Soc. 56:122-129.

Titcomb states that where streamside vegetation is eliminated, water temperatures rise and that deforestation may cause silt to be carried into streams.

(117) USDA Forest Service
[n.d.] Guides for protecting water quality. Pac. Northwest Reg. 27 p. Portland, Oreg.

The purpose of this publication is "(1) to familiarize the user with some of the factors and influences that should be considered in making an on-the-ground decision on a case-by-case basis and (2) to provide a means for predicting temperature changes."

ALTERATION OF STREAMFLOW

(118) Anderson, Henry W., and C. H. Gleason
1960. Effects of logging and brush removal on snow water runoff. Hannoversch-Münden, Int. Assoc. Sci. Hydrol. 51:478-489.

The effects of snow accumulation, snowmelt, summer soil moisture losses, interception, and estimated water yields are documented. Snow melt was affected by logging slash disposal. The area in which the slash was piled and burned had 3-1/2 inches more runoff water in the late spring than did the area of untreated slash. Duration and quantity of water yield from snow zone runoff may be influenced by methods of logging and brush removal.

(119) Anderson, Henry W., and Robert L. Hobba
1959. Forests and floods in the Northwestern United States. Hannoversch-Münden, Int. Assoc. Sci. Hydrol. 48:30-39.

A regression model was used to isolate meteorologic, topographic, and geologic causes of floods; covariance analysis was used to determine forest effects, variation in forest effects with respect to watershed size, storm size, and geology. Results showed that clearcutting and forest fires have increased floods from watersheds in the Northwestern United States.

(120) Berndt, H. W.
1971. Early effects of forest fire on streamflow characteristics. USDA For. Serv. Res. Note PNW-148, 9 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"A comparison of streamflow records from three small mountain streams in north-central Washington before, during, and after a severe forest fire showed three immediate effects of destructive burning. These were:

"Flow rate was greatly reduced while the fire was actively burning.

"Destruction of vegetation in the riparian zone reduced diurnal oscillation of flow rates.

"Flow rates quickly increased to points above protracted normal depletion rates but to varying degrees.

"No drastic immediate change in stream temperatures was noted."

(121) Berndt, H. W., and G. W. Swank
1970. Forest land use and streamflow in central Oregon. USDA For. Serv. Res. Pap. PNW-93, 15 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

"In this case study, the hydrologic performance of a 295-square-mile drainage in central Oregon was compared with the land use history for the period 1921-65. Two distinct changes in streamflow regimen were identified. The first, beginning about water year 1942, was an increase of 2.21 inches in average annual yield. The timing of this increase is approximately coincident with the onset of timber harvesting activity in the basin. The second change was a decrease of 1.18 inches in average water yield beginning about 1958. This change could possibly be related to the full stocking of cutover lands by dense, second-growth stands and a general reduction of timber harvest activity.

"Though more sensitive, refined tests of the influence of timber harvest on water yield are needed for stands east of the Cascade Range, the analyses in this report show that accepted management practices for vegetative types found on Ochoco Creek have favored water yields."

(122) Dunford, Earl G.
1960. Logging methods in relation to streamflow and erosion. 5th World For, Congr. Proc. Vol. 3, Sec. VII, p. 1703-1708. Seattle, Wash,

Various steps in logging operations and their effects on streams and soil are discussed, An "undisturbed" strip of land between a stream and parallel logging roads is recommended.

(123) Ferrell, W. K.
1960. The control of stream flow and water quality through timber harvesting. *In* E, F. Eldridge [ed.], Water problems of the Pacific Northwest. 7th Symp. Water Pollut. Res. Proc., p. 45-47. U.S. Public Health Serv., Reg. IX, Portland, Oreg.

The effects of timber harvesting on stream flow and water quality are discussed. The author also discusses the idea that forest harvesting practices of various kinds can be compatible with watershed management if these practices are carefully planned and controlled.

(124) Gangmark, Harold A., and Richard G. Bakkala
1958. Plastic standpipe for sampling streambed environment of salmon spawn. U.S. Fish & Wildl. Serv. Spec. Sci. Rep., Fish. 261, 21 p.

"Knowledge of prevailing conditions of streams for spawning salmon can lead to improved management of these streams and improved production of salmon. All-important to the salmon is the condition of the streambed, based both as the characteristics of seepage rate and on the availability of oxygen at spawn depth. At Hill Creek, California, the most feasible method for procuring this information is by using the standpipe system. This paper describes the design of the Hill Creek standpipe and its method of operation, discusses the mechanics of seepage, and compares the data obtained with data on survival of king salmon spawn."

(125) Harper, Warren Charles
1969, Changes in storm hydrographs due to clearcut logging of coastal watersheds, 116 p. M.S. thesis, Oreg, State Univ,, Corvallis.

"The purpose of this study was to determine the effect of clearcut logging on stormflow by analysis of characteristic parameters of individual storm hydrographs. Parameters considered included height-of-rise, peak discharge, volume and time-to-peak. The hydrologic data were derived from experimental watersheds of the Alsea Study located in the Oregon Coast Range.

"Three clearcut watersheds were selected for study; Deer Creek IV (39 acres) was clearcut, and Needle Branch (175 acres) was clearcut and burned. Both watersheds were compared to Flynn Creek (502 acres), and untreated control, before and after treatment.

"Change in hydrologic parameters was determined from differences between pre- and post-logging linear regressions. Statistical techniques were utilized to test for difference in slope or vertical position.

"Significant increases were found in peak discharge from both Needle Branch and Deer Creek IV following clearcut logging. Larger increases were noted during the fall period than during the winter period. Volume parameters of quick flow, delayed flow, and total flow were increased for Needle Branch. Volume of flow was not shown to increase from Deer Creek IV, This may have been due to a lack of usable storm events for analysis from this watershed. Time-to-peak was not altered in Needle Branch but was decreased for low flows and increased for high flows on Deer Creek IV, The height-of-rise parameter did not prove to be of value for detecting change in this study. Comparison of the burned watershed (Needle Branch) to the unburned watershed (Deer Creek IV) did not produce a noticeable difference in any of the parameters.

"The observed changes in stormflow were related to clearcut logging and the effect of vegetative removal on watershed response."

(126) Hibbert, Alden R.
1967. Forest treatment effects on water yield. *In* William E. Sopper and Howard W. Lull [eds.], Forest hydrology, p. 527-543. Oxford: Pergamon Press,

"Results are reported for thirty-nine studies on the effects of altering forest cover on water yield. The studies reveal that forest reduction increases water yield, and that reforestation decreases water yield, A practical upper limit of yield increase appears to be about 4.5 mm/year for each percent reduction in forest cover, but most treatments produce less than half this amount. There is strong evidence that in well-watered regions, streamflow response is proportional to reduction in forest cover. Streamflow response to treatment is variable; response in streamflow may be almost immediate or considerably delayed, depending upon climate, soils, topography, and other factors."

(127) Hoover, Marvin D.
1952. Water and timber management. J. Soil & Water Conserv. 7(2):75-78.

Research on the relationship between forest cover and streamflow reveals that streamflow is significantly increased by removing trees growing along streams.

(128) Hoyt, W. G., and H. C. Troxell
1932. Forests and streamflow. Am. Soc. Civ. Eng. Proc. 56:1039-1066.

Two adjacent tracts in the Wagon Wheel Gap area, Colorado, were studied for eight years in the forested state and seven years following the deforestation of one tract. Some of the results are:

"1. The total runoff increased an average of 15% in the deforested area.

"2. About 52% of this increase occurred in nonflood periods.

"3. The maximum daily discharges increased an average of 48% in the deforested tract.

"4. The summer runoff showed an average annual increase of 12% in the deforested area. The average minimum flow increased 12%.

"5. Deforestation produced no appreciable change in minimum winter flows.

"6. Erosion increased about eightfold in the deforested area, although always remained slight.

"7. The mean annual temperature of the deforested area increased 1.3° F."

(129) Hsieh, Frederic Shu-Kong
1970. Storm runoff response from roadbuilding and logging on small watersheds in the Oregon Coast Range. 149 p. M.S. thesis, Oreg. State Univ., Corvallis.

"The effects of roadbuilding, logging and burning upon stream runoff responses to individual storms are evaluated for the Alsea experimental watersheds, located in the Oregon Coast Range. The parameters analyzed are peak discharge, induced peak discharge, time-to-peak, and storm-runoff volume. The volume parameter is further sub-divided into total, quick, delayed, rising limb and falling limb flows. The control-watershed approach and linear regression method are utilized in this study.

"Calibration of the main stations at Flynn Creek (502 acres) and Deer Creek (750 acres) started in 1958. That for subwatershed DC II (138 acres) and DC III (100 acres) started in 1962. Watershed treatments included differing amounts of roadbuilding in the summer of 1965 and logging in 1966. The percentages of each watershed area subject to roadbuilding and to logging, respectively, were: Deer Creek main station, 3.7% and 26% of area in roads and logging, respectively, DC 11, 3.1% and 20%, and DC 111, 12.1% and 72%. One small portion on the main watershed also received burning treatment in 1967. Flynn Creek was preserved in its natural state as a control. Data were analyzed through 1968.

"The storm-runoff responses of the treated watershed were found to relate to the type of treatment applied and percent of area treated. Roadbuilding resulted in significant increases in peak and induced peak discharges on DC 111, which was subjected to the most intensive treatment. Logging generally demonstrated a more pronounced effect on runoff than did roadbuilding, since more vegetation was removed. Although highly significant augmentations in peak and induced peak discharges were detected after logging on subwatershed 111, only minor changes were observed at the main Deer Creek outlet.

"The time-to-peak parameter was generally not affected by the land manipulations in this study.

"Separation of the annual data into the assumed recharging and recharged periods, based on antecedent soil moisture conditions, was selected for seasonal comparison over the use of an arbitrary cutoff date.

"Changes in flow volume parameters due to roadbuilding were insignificant. Rising limb flow on DC III as well as at the Deer Creek main station was moderately increased after logging. Although an increase in delayed flow and a decrease in quick flow occurred at the main station, these are considered to be compensating errors.

"Effects on design floods after treatments were indicated by the sharp increases in peak discharges, based upon flood frequency and statistical analyses."

(130) Jeffrey, W. W.
1968. Forest harvesting and water management. For. Chron. 44(6):5-12.

"Forest harvesting affects water management. Total water yield, flow regime and water quality are affected. Usually, in Western Canada, these effects -- whether for good or ill -- are accidental and are not taken into consideration in management. This is at least partly due to resource management people being resource oriented (technocentric) rather than society oriented (democentric) in their attitudes. Forest harvesting-water management interactions represent a technical problem of ultimate social importance. To cope with this problem requires coordination of resource uses, improved communication and administrative organization, more democentricity, expanded research into socio-economic factors, more attention to long-term environmental goals, examination of land tenure systems, more land use planning, re-orientation of resource management education, a broadening of social conceptual awareness, and increased professional staffing."

(131) Kovner, Jacob L.
1957. Evapotranspiration and water yields following forest cutting and natural regrowth. Soc. Am. For. Proc. 1956: 106-110.

"The experiment has shown that in the high-rainfall belt of the southern Appalachians cutting down all vegetation on a well-forested watershed produced very large increases in streamflow. These increases accompanying regrowth of the forest stand following clear-cutting were remarkably well defined and showed dynamic relationship between vegetation and streamflow, which could be expressed as a linear function of the logarithm of the time variable. Practically all the increase in streamflow came from the base flow or groundwater.

"The results obtained using paired watersheds were verified by use of the water-balance equation for the treated watershed. The increase in streamflow each year was due to a corresponding real decrease in the amount of evapotranspiration. Annual losses to the atmosphere are quite constant for the Coweeta watersheds because of the high rainfall. This accounts for the fact that the increases in streamflow were statistically independent of the annual precipitation for the range experienced--from 56 to 89 inches. It should be noted in this connection that the rainfall was not low for a series of years.

"Heavy sprout and herbaceous growth sprang up and re-covered the area with surprising speed. Tests show that in the 13th year total annual foliage production, by oven-dry weight was not significantly different from that of the control watershed. At the end of the 12th year the basal area per acre was 51.6 square feet, or approximately 50 percent of the projected normal stand. The original relatively all-aged stand was replaced by an even-aged stand with essentially a 6-inch diameter limit."

(132) McGuinness, J. L., and L. L. Harrold
1971. Reforestation influences on small watershed streamflow. Water Resour. Res. 7(4):845-852.

"Analysis of flow duration curves showed that reforestation of a 44-acre watershed near Coshocton, Ohio, reduced flow in the low flow tail of the curve but did not significantly reduce flows above 0.25 inch per day. Other analyses showed that reductions also occurred in the maximum annual flow volumes for all periods of flow durations of 1 day or longer. The onset of dormant season flow was significantly delayed."

(133) Martin, Iury L., and E. Roy Tinney
1962, Logging in west coast watershed shows no effect on area's water yield. Timberman 63(5):46-48.

The data from the study of the Nasselle River watershed show that logging has had a negligible influence on the area's water yield and base flow,

(134) Pollard, R. A.
1955. Measuring seepage through salmon spawning gravel. J. Fish. Res. Board Can. 12(5):706-741.

"The rate of oxygen supply to salmon eggs incubating in a streambed depends on the oxygen concentration in the ground water [intragravel water] and the rate of seepage through the redd. Wickett... devised a simple field method of both sampling the ground water for the determination of its dissolved oxygen content and measuring the seepage rate, using one tool, a standpipe. The theory of seepage is outlined to show the factors governing the velocity of flow through a redd. Alternative ways of measuring this velocity were examined; the best one is a modification of Wickett's procedure using a similar standpipe. A new field procedure for measuring the oxygen concentration and ground water seepage rate in a streambed is recommended."

(135) Reinhart, K. G., and A. R. Eschner
1962, Effect on streamflow of four different forest practices in the Allegheny Mountains. J. Geophys. Res. 67(6):2433-2445.

"After a 6-year calibration, four watersheds in the Fernow experimental forest in West Virginia were logged during 1957-1958. Practices ranged from a commercial clearcutting with "logger's choice" skid roads to a light selection cutting with planned skid roads on moderate grades. For the most part, the treatments did not seriously disturb the forest floor. Annual flow increased up to 5 area-inches on the clearcut watershed the year after treatment. Increases fell into a logical pattern with volume cut, Most of the increase came in the growing season; from May to October 1959, increases were 3.0, 1.8, 1.4, and 0.3 area-inches for per-acre cuts of 8.5, 4.2, 3.7, and 1.7 thousand board feet, respectively. Low flows were augmented, especially for the two heavily cut watersheds. Effect on high flows was variable; on the clearcut watershed some storm-period flows in the growing season were more than doubled, whereas some snow-melt flows were less than expected. Care in the logging operation was clearly reflected in water quality; maximum turbidities ranged from 56,000 ppm on the watershed having unplanned skid roads and no provision for drainage to 25 ppm on the watershed having carefully planned skid roads. Effects of treatment are diminishing with passage of time."

(136) Rothacher, Jack
1965. Streamflow from small watersheds on the western slope of the Cascade Range of Oregon. Water Resour. Res. 1(1):125-134.

"Streamflow from small watersheds on the western slopes of the Oregon Cascade Range is strongly influenced by a maritime climate (wet winters and dry summers). Although annual precipitation is high (94 inches in the study area), overland flow is almost unknown. Peak flows result largely from subsurface flow and under conditions in which both retention and detention reservoirs are almost filled during extended periods of low-intensity rainfall. Under these conditions, vegetation appears to exert a minimum influence on high streamflow. Lowest streamflow occurs from late August to mid-November and may follow a 60- to 100-day period with little or no rain. The dense vegetation of this part of the Douglas-fir region appears to exert its major influence at such times. Removal of vegetation from only 30% of a 250-acre watershed has caused a 12-28% increase in minimum streamflow. On a 237-acre watershed on which 80% of the trees were cut, the increase in low flow was 85%."

(137) Rothacher, Jack
1970. Increases in water yield following clear-cut logging in the Pacific Northwest. Water Resour. Res. 6(2):653-658.

"Increases in water yield following timber harvest roughly conform to the proportion of the area cleared. In high precipitation areas of the Oregon Cascades, clear-cut logging can increase annual water yield 18 inches. Approximately 80% of the increase occurs during the October to March season."

(138) Rothacher, Jack
1971. Regimes of streamflow and their modification by logging. *In* James Morris [ed.], Proceedings of a Symposium--Forest land uses and stream environment, p. 40-54. Oreg. State Univ., Corvallis.

"Streamflow in the Pacific Northwest is most strongly influenced by the precipitation pattern, somewhat less by evapotranspiration losses. Evaporation and transpiration are strongly influenced by logging. Logging and burning old-growth Douglas-fir forests on an experimental watershed increased annual yields of streamwater by 18 inches or more. Most of the increase occurred in fall and winter months. We can't positively attribute any great increase in major 'wet mantle' flood flows to logging in west slope forests. Logging which removes transpiring vegetation increases lowest summer streamflow. Such increases may be short lived as vegetation rapidly invades the cutover areas."

(139) Rowe, P. B.
1963. Streamflow increases after removing woodland-riparian vegetation from a southern California watershed. J. For. 61(5):365-370.

"A test of applied watershed management on the San Dimas Experimental Forest in southern California has shown that streamflow yields can be appreciably increased. This was accomplished by clearing the deep-rooted woodland-riparian vegetation from selected canyon bottom reaches of Monroe Canyon, a typical southern California mountain watershed. The increases in flow were especially important because they occurred primarily in summer and in the initial period of soil wetting during succeeding rainy seasons, when streamflow was lowest and water most needed. During the one rainy season of heavy precipitation and continuously wet soils the removal of the woodland-riparian vegetation had no appreciable effect on streamflow, peak discharge, or erosion rates. However, during wetting periods and during the one rainy season of light precipitation, streamflow yields, particularly during storms, were considerably increased, Streamflow was inadequate to produce sediment movement in either the treated or control watersheds during these wetting periods. Removal of the tree-brush cover shading the stream course resulted in an increase in the algae content of the late spring and summer flows but had no other detectable effect on water quality. These first results show that, while streamflow can be increased by removal of the canyon bottom vegetation, this kind of treatment, to be most successful, should be limited to carefully selected areas with conditions of climate, vegetation, soil, and water capable of yielding the desired increases. That is, to areas in which (1) the water supply is adequate to exceed evapo-transpiration losses after treatment, (2) the water table or zone of saturation is within reach of the heavy water using woodland-riparian vegetation, and (3) the canyon bottom soils overlaying the water table are of sufficient extent and depth to permit reduction in evapo-transpiration if the deep-rooted vegetation is eliminated."

(140) Sartz, Richard S.
1951, An objective look at the vegetation-stream flow relationship. J. For. 49(12):871-875.

The important factors involved in the precipitation-vegetation-soils streamflow relationships are discussed.

(141) Terhune, L. D. B,
1958. The MARK VI groundwater standpipe for measuring seepage through salmon spawning gravel. J. Fish. Res. Board Can. 15(5):1027-1063.

Procedures of the MARK VI standpipe method for measuring gravel permeabilities and velocities are described. This method incorporates new procedures to the Pollard (134) method of measuring permeabilities and increases the range of permeability measurements from 100 to 100,000 cm/hr and velocity measurements from 5 to 200 cm/hr with less than 10 percent error. Complete details of design, construction, and procedure for use in salmon spawning gravels are given.

(142) Vaux, Walter G.
1962. Interchange of stream and intragravel water in a salmon spawning riffle. U.S. Fish & Wildl. Serv. Spec. Sci. Rep., Fish. 405, **11 p.**

"Dissolved oxygen is supplied to intragravel water in a salmon spawning riffle through (1) interchange of water from the stream into streambed gravel, and (2) ground-water flow. The primary variables that control interchange are gradient in the stream profile, permeability of the gravel bed, and dimensions of the bed.

"The delivery of dissolved oxygen to intragravel water and the way in which rate of delivery is affected by stream profile, permeability, and dimensions of the bed are explained.

"The dissolution of oxygen through the air-water interface in turbulent stream water is rapid. This is shown by the near-saturation oxygen level in surface water of unpolluted streams."

(143) Zach, L. W.
1950. Effect of rainfall on stream flow in southeast Alaska. USDA For. Serv. Tech Note 4, 3 p. Alaska For. Res. Cent., Juneau, Alaska.

The study has shown that southeastern Alaska salmon streams are characterized by marked fluctuations in flow and recurring fall floods. In the fall rainy season, violent floods move log jams and gravel bars and produce minor changes in the stream channels.

DESCRIPTIONS OF EFFECTS OF LOGGING STUDIES

(144) Bureau of Commercial Fisheries
1963. Review of research on effects of logging on pink salmon streams in Alaska. Fish 4 Wildl. Serv., 18 p. U.S. Dep. Inter. Bur. Comm. Fish. Biol. Lab., Auke Bay, Alaska.

The long-term study of the effects of logging on Alaskan pink salmon spawning streams is reviewed. The research objectives, methods of research, and achievements of the study and the specific problems which should be investigated in future studies are covered.

(145) Calhoun, Alex
1962. A long look at logging. Outdoor Calif., Nov. p. 7-10.

Poor logging practices in California and some of the efforts to correct these problems are discussed. The article states that there are two major problems: (1) log jams, which block migrating salmonids, and (2) sedimentation, which smothers stream gravels, thus producing less food and fewer young fish by hatching fewer eggs and producing fewer places for small fish to hide.

(146) Campbell, Homer J.
1970. Fish, forests and water. Oreg. Game Comm. Bull., July, p. 3-6.

The problems of resource managers and the results of improper logging are discussed. Briefly described are some of the studies the State of Oregon has conducted and some of the results.

(147) Chapman, D. W.
1962. Effects of logging upon fish resources of the west coast. J. For. 60(8):533-537.

The author reviews the effects of logging on fish. It was found that after logging:

"1) stream runoff was increased and as a result of heavy runoff gravel shifting occurred;

"2) summer temperatures increased and winter temperatures decreased;

"3) chemical quality of water deteriorated;

"4) sediment increased;

"5) stream energy source was disrupted; and

"6) barriers to fish migration were left."

A good bibliography is included.

(148) Cordone, Almo J.
1956. Effects of logging on fish production. Calif. Fish & Game, Inland Fish. Adm. Rep. 56-7, 98 p. [Mimeogr.]

"The material examined consisted of published and mimeographed literature, regulations and policies, and correspondence. No attempt was made to compile a complete bibliography. However, it is believed that the more important published and mimeographed literature was reviewed. The subject of pollution from sawdust and sulfite liquor wastes was not covered. The physical influences of logging on the environment were stressed, i.e., soil erosion, turbidity, sedimentation, fluctuating stream flows, etc. Material on direct effects of logging on fish life was rare, but papers concerning the foregoing factors were common. That these factors are interrelated with fish production is universally accepted.

"The report is divided into three parts: (1) review of literature, (2) review of regulations and policies, and (3) list of literature not examined. The first part is presented in the form of an annotated bibliography. Direct quotes are employed as annotations whenever feasible. This eliminates some subjective interpretations. A brief summary of the surveyed material is presented at the end of the report."

(149) Fisheries Research Institute
1959. Logging and salmon. Fish. Res. Inst. Circ. 105, 12 p., Univ. Wash., Seattle.

A booklet to acquaint the reader with some of the techniques and results of studies by the Fisheries Research Institute at Hollis, southeast Alaska.

(150) Hall, James D.
1967. Alsea watershed study. Oreg. State Univ., Dep. Fish. & Wildl. Pam., 11 p. Corvallis.

The pamphlet is a guide to the Alsea study area and an outline of the research underway to determine the effects of logging on aquatic resources. Areas of research include: (1) hydrologic studies; (2) soil-vegetation survey; (3) streamflow, sediment, and water temperature; (4) chemical and bacteriological water quality; and (5) fishery studies. The pamphlet presents some initial results from the study.

(151) Harris, A. S.
1961. The physical effect of logging on salmon streams in southeast Alaska. [Abstract.] 11th Alaskan Sci. Conf. Proc. 1960:143-144.

The physical effects of logging on salmon streams are discussed. Results show that more basic research is needed on the physiological requirements of salmon eggs and alevins before man can evaluate the physical effects or changes of logging on salmon.

(152) Lantz, Richard L.
1967. An ecological study of the effects of logging on salmonids. 47th Annu. Conf. West. Assoc. State Game Fish Corn. Proc. 1967: 323-335.

The Alsea watershed study and some of its findings concerning the effects of logging on fish populations are outlined. The objective of the study was to evaluate and compare the effects of two patterns of timber harvesting. The study included an examination of fish population, stream environment, intragravel environment on salmonid survival to emergence, streamflow, stream temperature, and suspended sediment.

(153) Lantz, Richard L.
1970. Effects of logging on aquatic resources. *In* H. J. Rayner, H. J. Campbell, and W. C. Lightfoot [eds.], Progress in game and sport fishery research...1963-1970, p. 13-16. Rep. Res. Div. Corvallis: Oreg. State Univ.

The work carried out by Oregon State University on the Alsea watershed in Oregon is summarized. Primary changes observed on the aquatic environment due to logging were (1) an increase in stream temperature, (2) a decrease in dissolved oxygen levels in surface waters during summer when logging debris was present, (3) a decrease in intragravel dissolved oxygen levels and in the permeability of the intragravel environment when salmon embryos were present in the stream, (4) an increase in suspended sediments, and (5) a decrease in the cutthroat trout populations.

(154) Narver, David W.
1971. Carnation Creek watershed study. Fish. Res. Board Can. Biol. Stn., 7 p. Nanaimo, B. C., Can. [Mimeogr.]

"There is little scientific information about the impact of current logging and reforestation methods on the productive capacity of salmon and trout streams in British Columbia. Long-term watershed studies, including years before, during and after logging, are required. An unknown but presumably large portion of the coho salmon production in British Columbia is from small streams. The rate of deforestation (usually meaning clear-cutting and burning to the stream margin) is accelerating, and probably the small streams are most susceptible to damage. Small salmon nursery streams without lakes in the watershed to provide some flow control, are common along the British Columbia coast. Thus the study being implemented on Carnation Creek should have rather broad application on much of Vancouver Island and the coastal mainland.

"The purpose of this document is to provide information to government, university and industry personnel about the Carnation Creek watershed study that is being conducted cooperatively by certain agencies of the new Federal Department of the Environment and MacMillan Bloedel Ltd. The possibility of participation by other organizations is emphasized."

(155) Phillips, Robert W.
1963. Effect of logging on aquatic resources. Oreg. State Game Corn., Res. Div. Rep., p. 105-122. Portland.

The study conducted in the Alsea watershed was primarily concerned with measuring the effect of logging on the production and yield of silver salmon and steelhead. The aim of the investigation was to determine (1) the effect of a gravel environment on survival and (2) the effect of logging on the environment. This preliminary report covers the effect of the environment on survival and includes a discussion of (1) dissolved oxygen and apparent velocity versus emergence, (2) dissolved oxygen versus emergence, (3) gravel size versus emergence, (4) dissolved oxygen content of intragravel water, and (5) gravel permeability.

(156) Phillips, Robert W., Homer J. Campbell, Wayne L. Hug, and Errol W. Claire
1966. A study of the effects of logging on aquatic resources, 1960-1966. Oreg. State Game Corn., Res. Div. Prog. Memo. Fish. 3, 28 p. Corvallis: Oreg. State Univ.

The scope, methods, and techniques of a logging study are outlined; and some of the initial effects and specific problem areas encountered are presented.

(157) Sheridan, William L., and William J. McNeil
1960. Effects of logging on the productivity of pink salmon streams in Alaska. *In* Ted S. Y. Koo [ed.], Research in Fisheries, 1959. Coll. Fish. Contrib. 77:16-17. Univ. Wash., Seattle.

The broad plan of the work carried out at Hollis, southeast Alaska, was to define normal patterns before logging so that the changes might be measured as logging progressed. Changes studied were year-to-year escapements of adult spawners, the abundance of downstream migrants, survival rates of eggs and alevins in gravel, distribution and intensity of spawning, and the quality of the environment.

RELATED SALMONID INFORMATION

(158) Au, David Wah Kwai

1972. Population dynamics of coho salmon and its response to logging in three coastal streams. 258 p. Ph.D. thesis, Oreg. State Univ., Corvallis.

"This study examines the ecology and dynamics of coho salmon (*Oncorhynchus kisutch*) in environments experimentally altered by logging. The objective was to evaluate processes that stabilize or regulate the populations.

"Two small watersheds in Oregon's Coast Range were logged in 1966, one clear-cut, the other patch-cut. A third adjacent watershed was left uncut as a control. The influence of these treatments on the biology of the coho was assessed. Attention was concentrated on populations of the six year classes 1963 to 1968.

"The natural variability of streamflow-related conditions influencing both the magnitude and pattern of coho recruitment each year was increased in the logged watersheds. Peak flow during storms increased; intragravel dissolved oxygen levels decreased in the stream draining the clear-cut watershed. These changes, however, were apparently within the range of variation that the coho naturally experience. Increased stream temperatures and mortalities, due to the logging effects, altered the post-recruitment life conditions of the coho in that stream but did not significantly affect the final smolt yield.

. . . . . .

"Adjustments in coho population size were largely accomplished by fall, resulting in stable and characteristic population levels in each stream. A stable smolt yield was a further result. These adjustments are accomplished through high mortality during the months of the first spring and summer. This mortality is likely density dependent and related to the territorial and agonistic behavior of the fish.

"Growth, biomass, and net production varied greatly during each year. Seasonal changes in growth rate resulted in seasonal variations in biomass that were in contrast to the stabilized trends of population number. The pattern of net production rate was also largely determined by the seasonal growth pattern, and like biomass, did not show a tendency to stabilize with time. It averaged 5 g/m^2 among the three streams for the period June 1 to April 15.

. . . . . .

"This study has shown that coho streams normally produce characteristic levels of smolt yield in spite of large natural variations in fry input and conditions for growth. The range of environmental variation for which this result holds may include short-term changes due to logging, However a normal population response to such a severe alteration as occurred on Needle Branch is very likely conditional upon a program that at least includes vigorous stream clearance, the restriction of additional mortality to early summer, when population adjustments are far from complete, and the encouragement of streamside revegetation. A streamside buffer strip of trees is an effective way of protecting aquatic resources."

(159) Bakkala, Richard
1964. Abernathy spawning channel proves effective for reproduction of chum salmon. Comm. Fish. Rev. 26(12):20-21.

"With one exception, the environment created in the Abernathy channel has been adequate for the successful incubation of chum salmon eggs. Deposition of sediment from the water supply as it moved through the channel has made it difficult to maintain the original permeable condition of the streambed gravel. Removing and screening the gravel in the channel provided a temporary solution to this problem. A more permanent solution will be attained with a settling basin which will remove silt and sand from the water supply before it enters the channel."

(160) Bjornn, T. C.
1968. Survival and emergence of trout and salmon fry in various gravel-sand mixtures. *In* Richard T. Myren [ed.], Logging and salmon, p. 80-88. Proc. Forum Am. Inst. Fish. Res. Biol., Alaska Dist., Juneau, Alaska.

"The survival and emergence of steelhead trout and chinook salmon were tested in various mixtures of gravel and sand in troughs with flow and gradient control. The emergence of swim-up steelhead trout fry placed in the troughs was reduced by large percentages of sand. Swim-up chinook salmon fry appeared to be more impeded by sand than were steelhead trout, but these results need to be verified because some sick fish were unknowingly included in the test samples. The survival from green egg to emergence of chinook salmon was relatively high (70-77 percent) in gravel with little or no sand but much reduced in gravel with 18 percent or more sand."

(161) Burgner, Robert L.
1960. Spawning and growth of fish. *In* E. F. Eldridge [ed.], Proceedings of 7th symposium on water pollution research, p. 33-39. U.S. Dep. Health, Educ. & Welfare, Reg. IX, Portland, Oreg.

The aquatic environment and its effect on the development and survival of eggs and larvae of pink and chum salmon are discussed with respect to the logging studies conducted by the Fisheries Research Institute in southeast Alaska.

(162) Burns, James W.
1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish & Game 57(1):44-57.

"Standing crops of juvenile coho (silver) salmon (*Oncorhynchus kisutch*), steelhead rainbow trout (*Salmo gairdneri*), and coast cutthroat trout (*Salmo clarki*) were examined in seven coastal streams to define the natural carrying capacity of these streams, and to develop methods of population comparison and prediction which could be used to determine the effects of road construction and logging on salmon and trout production.

"Biomass per unit of surface area was the best method of expressing carrying capacity, because biomass was better correlated with stream surface area than with other parameters tested. Volume of streambed sediments, total dissolved solids, alkalinity, and total phosphate in six streams were not satisfactory predictors of carrying capacity. Only living-space variables correlated significantly with biomass. Not all streams reached carrying capacity in the summer and salmonid biomass was highly variable. Even with 3 years of prelogging study, it would be difficult to attribute a change in carrying capacity under 50% to anything but natural variation."

(163) Chapman, D. W.
1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Am. Fish. Soc. 94(1):40-52.

"Net production of juvenile coho salmon was estimated in three small streams in Oregon for 4 consecutive years. Annual net production of coho was greatly different in the 4 years, but production per unit area was similar among streams, averaging about 9 g/m^2 per year. No significant differences were found among streams in production per unit area for 14 months from emergence of fry one spring through seaward migration the next spring. For 4 years biomass averaged 5-12 g/m^2 shortly after emergence of fry, declining to 2-3 g/m^2 by July and remaining at about 2-4 g/m^2 until emigration of smolts in the following spring. In all years, mean production declined from 1.9-2.8 g/m^2 per month after emergence to 0.2-0.3 g/m^2 per month in winter, then increased to 0.5-0.6 g/m^2 per month prior to emigration. Monthly instantaneous growth rates were highest shortly after emergence of fry, declining until late winter, then increasing just before smolt emigration. The mean monthly instantaneous growth rate was about 0.19 for all streams and years. Yield of smolts as seaward emigrants ranged from 18 to 67 per 100 m^2. Net production was 1.5 to 3.0 times greater than yield as biomass of smolts. Net production of all fish in one stream containing coho, steelhead and cutthroat trout, and cottids was estimated to be 16 g/m^2 per year and compared with data from other waters. Relatively large freshets appeared to cause large downstream movements of juvenile coho. Downstream drift of postemergence fry and emigration of yearlings tended to bias estimates of growth and net production in the residual populations."

(164) Coble, Daniel W.
1960. The influence of environmental conditions in redds on the survival of salmonid embryos. 37 p. M.S. thesis, Oreg. State Univ., Corvallis.

Movement of gravel 10 inches below the surface of a streambed was indicated in areas where no logging disturbance was apparent. The survival of salmonid embryos in the gravel was related to the apparent velocity and dissolved oxygen content of subsurface water.

(165) Cooper, A. C.
1959. Discussion of the effects of silt on survival of salmon eggs and larvae. *In* E. F. Eldridge and J. N. Wilson [eds.], Proceedings 5th symposium--Pacific Northwest on siltation--its source and effects on aquatic environment, p. 18-22. U.S. Dep. Health, Educ. & Welfare, Portland, Oreg.

Surface flow over a smooth bed with a constant gradient showed intragravel flow lines nearly parallel with some interchange near the surface. Interchange in the top 1 foot of stratum was increased with the addition of large rocks, and downward interchange occurred when a pile of gravel was formed by a female salmon digging a redd.

(166) Dill, L. M., and T. G. Northcote
1970. Effects of gravel size, egg depth, and egg density on intragravel movement and emergence of coho salmon *(Oncorhynchus kisutch)* alevins. J. Fish. Res. Board Can. 27(7):1191-1199.

"In experimental aquaria with large gravel (3.2-6.3 cm), vertical and lateral movements of coho salmon *(Oncorhynchus kisutch)* alevins were more extensive and area utilized per alevin was greater than in small gravel (1.9-3.2 cm). At low density (50 per aquarium) the alevins moved farther towards the inlet, but the mean area occupied per alevin was the same as that at high density (100 per aquarium). Burial depths tested (20 and 30 cm) had no significant effect on vertical or lateral movements or on area utilized per alevin. Alevin orientation in the gravel, survival to emergence, and timing of emergence were not affected by any of the environmental variables examined."

(167) Dill, Lawrence M.
1969. The sub-gravel behaviour of Pacific salmon larvae. *In* T. G. Northcote [ed.], Proceedings of symposium--Salmon and trout in streams, p. 89-99. Univ. B. C., Vancouver, B.C., Can.

"Results of a study of the sub-gravel behaviour of the coho salmon *(Oncorhynchus kisutch)* are compared with studies of other salmonid larvae. The present results were obtained through observation of the larvae or alevins in specially designed aquaria. The alevins moved about within the gravel prior to emergence, apparently as a result of phototaxes and rheotaxes, the directions of which varied with the age of the fish. For example, the response to light was initially negative, but changed to positive as the time of emergence approached. Lateral movements were similarly influenced by the current direction.

"There was evidence that the alevins were spacing themselves out within the gravel, and that some interaction was taking place between them. The effects upon behaviour of changes in burial density, burial depth, and gravel size were also explored. Several studies are suggested as logical and productive continuations of the present work, and their implications are discussed from both practical and theoretical standpoints."

(168) Fisheries Research Institute
1960. Observations in Hollis area study streams, fall 1959. Fish. Res. Inst. Circ. 117, 6 p. Univ. Wash., Seattle.

"Our evidence indicates that in the fall of 1959 suspended sediment increased in tributaries to the Harris River and that during the same period streambed sediment increased in the upstream sampling area. Loss of, nor death to, salmon eggs in the intertidal study area as a result of a number of large trees sweeping downriver on high water was not detected."

(169) Gangmark, Harold A.
1963. A view of the present status of spawning channels. Report to 2d Governors' Conference on Pacific Salmon, Convened by Governor Albert D. Rosellini at Washington Hyatt House, Seattle.

"Advantages of improved production (salmon) areas usually include: stabilized stream flow, reduced silt loads, clean gravel, gravel sizes that preclude washout of eggs, and predetermined hydraulic gradients. They can also include temperature regulation of the stream flow below impoundments.

"Disadvantages may include construction and maintenance costs and confinement that might limit the carrying capacity and, in one way, favor predators.

"On a management scale the cost benefit of controlled flow may make such areas of controlled flow for salmon alone prohibitive. When tied in with other benefits, however, it can become feasible. For example, the water conservation and flood control programs that involve practically every stream in California can provide many acres of such control flow for the benefit of salmon."

(170) Gangmark, Harold A.
1962. The mill creek channel study. Presented West. Div. Am. Fish. Soc., Seattle, Washington.

"To learn how we might achieve the conditions desired in our spawning channel, we studied, among other places, the Sacramento River near Red Bluff. In test plants similar to the ones made in Mill Creek, (salmon) egg samples were eroded out of the streambed and lost in four out of five seasons. In the one successful year, in which we were able to measure ow results, only 1.7% fry were produced.

"In the fall of 1961, we moved the location of our river studies 40 miles upstream to a riffle near Redding where the tributaries entering the river, do so, below the Redding area.

"Actual survival was 53.6% of the eggs planted or 74.4% of eggs that survived the initial handling and planting operation. As a result of comparing the differences between the Redding and Red Bluff stream sections we found the former had only 1/3 the fines. The streamflow at Redding was stabilized and heat storage in Shasta Reservoir was responsible for moderating and tempering water temperatures."

(171) Gangmark, Harold A., and Robert D. Broad
1955. Experimental hatching of king salmon in Mill Creek, a tributary of the Sacramento River. Calif. Fish. & Game 41:233-242.

"The upper Sacramento River system continued to flood during the last stage of the experiment. The water gauge used by the California State Division of Water Resources was torn from its position by the flood. Records received from the Water Resources Branch of the United States Geological Survey show the Mill Creek rose to 5,240 c.f.s. or approximately 100 times the flow recorded at the time the eggs were planted. The result was that all but six sacks of eggs (salmon) disappeared from the stream bed. Examination of the sacks that could be found revealed that' none of the embryos had survived the floods. The shifting of the channel and the eroding and smothering action of silt and sand apparently caused a complete kill of the developing young salmon."

(172) Gangmark, Harold A., and Robert D. Broad
1956. An experiment with Vibert boxes. Prog. Fish. Cult. 18(3):143-144.

"Stream erosion and silting were mentioned as products of flooding which caused damage to (salmon) eggs in nature. In 1954, to explore this subject further, Vibert boxes...were used along with the usual plastic mesh sacks, for incubating eggs. The boxes were to serve as a research tool rather than to prove or disprove the Vibert system.

As Vibert boxes are made from extremely rigid plastic, the writers felt that damage to eggs by stream erosion could be eliminated.

"It had been supposed that use of the rigid boxes, rather than plastic sacks, would eliminate the grinding, wearing factor of stream erosion; but except for three samples washed downstream, results favored the sacks."

(173) Gangmark, Harold A., and Robert D. Broad
1956. Further observations on stream survival of king salmon spawn. Calif. Fish & Game 42:37-49.

The authors present evidence of a relationship between the occurrence of floods and the reduced survival of salmon eggs.

(174) Gangmark, Harold A., and F. Bruce Sanford
1963. Theory on development of mounds near Red Bluff, California. U.S. Fish & Wildl. Serv., Fish Bull. 63(1):213-220.

"Although the subject of mounds is not directly a part of fishery studies, the agents that we think lead to the formation of mounds - namely, flooding of the stream and erosion of soil materials - also kill salmon by scouring the stream gravel or depositing silt in the streambed. This action destroys incubating spawn by removing gravel and washing out eggs and by depositing silt and subsequently smothering the eggs. Similarly, larvae and other aquatic forms that the salmon fry eat are either washed out or the habitat of these forms is destroyed by deposition of silt, and the food supply for the young salmon is greatly diminished."

(175) Graves, David S., and James W. Burns
1970. Comparison of the yields of downstream migrant salmonids before and after logging road construction on the South Fork Caspar Creek, Mendocino County. Calif. Fish & Game, Inland Fish. Adm. Rep. 70-3, 11 p.

"Yields of juvenile steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) and silver salmon (*Oncorhynchus kisutch*) emigrants were compared in South Fork Caspar Creek, a small coastal stream in Mendocino County, California, before and after construction of a logging road along the stream in the summer of 1967. Numbers, lengths, and age class structures were compared.

"There were 138% more steelhead smolts and 41% fewer silver salmon smolts in 1968 (first spring following road construction) than there had been in 1964 (preroad construction). Increased emigration of steelhead smolts in 1968 was probably caused by a decrease in favorable living space. The decrease in salmon smolts accompanied high mortalities during road construction. Eighty-three percent of the total salmon population and 86% of the total steelhead population died or emigrated from the affected area during the road construction from June to October 1967. The combined populations of steelhead and salmon smolts decreased 20%. This combined decrease is within the range of natural fluctuation reported from other California streams; however, there is no doubt that road construction contributed to the decrease in Caspar Creek.

"Steelhead and salmon fry were more numerous in 1968 than in 1964. No steelhead fry were trapped in 1964, while 72% of the migrants trapped in 1968 were fry. The age composition of the salmon also shifted markedly from 1964; fry comprised 5% of the total in 1964 and 81% in 1968. This increase in numbers of emigrating fry in 1968 could have resulted from poor environmental conditions.

"Steelhead smolts were smaller in 1968 than in 1964, while salmon smolts were larger. Salmon fry were smaller in 1968. Steelhead fry cannot be compared as none was trapped in 1964. The increase in length of the salmon smolts may have resulted from a decrease in competition due to higher mortality in 1967. The fry may have been smaller due to unfavorable intragravel conditions during incubation. Comparison of steelhead smolts is difficult because of the emigration of more than one year class. The decrease in average length, however, supports the hypothesis of premature emigration due to unfavorable habitat."

(176) Hanzel, Delano A.
1961. Inventory of the waters of the project area. Northwest Mont. Fish. Stud. Mont. Fish & Game, Fish. Div. Fed. Aid in Fish Restoration, Job Completion Rep., Proj. F-7-R-10, 9 p. Helena, Mont.

"Seven lakes and four of the principal tributaries in the Stillwater River Drainage were surveyed. Netting series on the lakes indicated a predominance of pumpkinseeds, largescale suckers, northern squawfish, and redside shiners. Electrical censusing of the tributaries show a predominance of cutthroat trout, brook trout and Dolly Varden. Physical barriers block fish movement up the major tributaries.

"Surveys of five lakes in the South Fork of the Flathead River Drainage were conducted during the report period. Data is presented as a record of present fish populations and composition in a remote wilderness area. The majority of cutthroat trout collected and checked in creels from the South Fork River and tributaries were in the III and IV age groups (ave. 9.4 inches). Fish measured on the Middle Fork River and tributaries averaged 1.3 inches smaller than those taken in the South Fork Drainage. Estimated 1960 use of the Bob Marshall Wilderness Area (including both South and Middle Fork Drainages), west of the Continental

Divide, was 3,990 people (Summer - 2,190; Fall - 1,800). There is a total of 80 established camp sites in the wilderness area. Summer use is primarily (64 percent) non-guided parties.

"A survey of the fish populations and physical stream characteristics were continued on Pinkham Creek in order to establish the effects of logging on a fish population. Timber has now been cut on 30 percent of the 39,300 acres within the drainage. Three of the eight sections previously censused were electrically fished, A total of 250 brook trout weighing 9.55 pounds and 170 rainbow trout weighing 10.63 pounds were collected. The number and weight of all fish in 1960 was greater than taken from these three sections in any previous year (1951-56)."

(177) International Pacific Salmon Fisheries Commission
1966. Effects of log driving on the salmon and trout populations in the Stellako River. Int. Pac. Salmon Fish. Corn. Prog. Rep. 14, 88 p.

"Field and laboratory investigation of effects of log driving on the fish populations of Stellako River were carried out during 1965. Field studies showed that log jams caused damage to approximately eight per cent of sockeye spawning grounds by erosion of gravel and bark deposition, That the damage was real was verified through analysis of subsequent spawning distribution which showed that spawners tended to avoid the damaged areas. Laboratory results indicated that moderate gravel disturbance due to erosion and gouging by individual logs could also have killed incubating trout eggs in Stellako River, but that vertical impact on the gravel surface would have caused only occasional mortality."

(178) Johnson, B. W., E. M. Miller, and C. H. Ellis
1952. A report on steelhead egg and fry survival experiments on the North Fork of Stillaguamish River with relation to the North Fork earth slide. Unpubl. rep., Wash. State Fish, Dep., Olympia.

"The silting of the slide in the Stillaguamish River has a very definite effect on development of eggs and fry for a limited distance of less than one mile below the slide and in that area causes 50% to 100% loss of eggs and fry.

"From one mile to five miles below the slide no significant difference could be observed in loss of eggs and fry from silting effects [a 33.5% survival].

"Comparing survivals from a distance of one mile or more below the slide and survivals above the slide a very maximum of 10% loss to eggs and fry could be assessed to silting of the river. [Authors buried steelhead eggs in plastic sacks in gravel.]"

(179) Kabel, C. S., and E. R. German
1967. Caspar Creek study completion report. Calif. Fish & Game Mar. Res. Admin. Rep. 67-4, 27 p.

This study included the effects of logging on Caspar Creek and its population of silver salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdnerii*). The information on both species includes behavior of adults and young population, counts, length frequencies, and length-weight and length-fecundity relationships. The report recommends that similar experiments be made on two tributary streams entering the ocean rather than on two forks of a single stream. It also suggests that these tributaries be larger than the individual forks of Caspar Creek.

(180) McKernan, Donald L., Donald R. Johnson, and John I. Hodges
1950. Some factors influencing the trends of salmon populations in Oregon. Trans. North Am. Wildl. Conf. 15:427-449.

"Three factors were found to be significantly correlated with the fluctuations and trends in silver salmon production in Oregon.

"(1) Logging was found to adversely affect the runs of salmon in later years. A significant negative correlation was found between the trend of logging in one coastal watershed studied and the abundance of silver salmon (as measured by the catch) in the river two cycles or six years later.

"(2) Exceptional winter floods and low summer water flows seem to produce poor runs.

"(3) The intensity of fishing was also found to affect the subsequent productivity of the fisheries.

"Other factors studied did not bear on significant relationship to the fluctuations or trends of productivity of silver salmon."

(181) McNeil, William J.
1964. Environmental factors affecting survival of young salmon in spawning beds and their possible relation to logging. U.S. Fish & Wildl. Serv., Bur. Corn. Fish. Manuscr. Rep. 64-1, 25 p. Auke Bay Biol. Lab., Auke Bay, Alaska.

"In this report, an attempt has been made to review some of the factors influencing survival of salmon embryos and alevins which conceivably may be influenced by logging. The review has not been exhaustive, but an attempt has been made to include the more pertinent recent work which has come to the author's attention. It is possible to make some conclusions on the basis of this review.

"Results of field studies have revealed that extrinsic environmental factors have an important bearing on the survival of young salmon in spawning beds. The data indicate that increased mortality may occur during periods of minimum and maximum flow of streams, when debris shifts position in stream channels and when permeability of spawning beds is reduced by the presence of fine particulate matter. It is conceivable that logging could exert both harmful and beneficial influence on young salmon in spawning beds. Harmful effects might include increased maximum flows of streams, more debris in stream channels, and more settleable solids transported into spawning streams. A beneficial effect might result should logging cause the minimum flows of streams in Southeastern Alaska to increase. It is apparent that the addition of silt and debris to streams should be avoided and the stability of stream banks should be preserved whenever possible.

"Solution of the salmon-logging problem lies ultimately in the economic development of watersheds and streams for the benefit of both resources. In this regard, some initial efforts have been made on improvement of natural spawning beds in Alaska...and more work is planned or underway. But even in the area of spawning bed improvement there is a great need to obtain a more detailed understanding of the biological and physical factors that control fry production from spawning beds. Hence, the natural processes that control fry production from salmon spawning beds must be well understood before a satisfactory evaluation or solution of the salmon-logging problem can be achieved."

(182) McNeil, William J.
1966. Effect of the spawning bed environment on reproduction of pink and chum salmon. U.S. Fish & Wildl. Serv., Fish. Bull. 65(2):495-523.

"Mortality of 5 brood years of pink salmon, *Oncorhynchus gorbuscha*, and chum salmon, O. *keta*, in spawning beds of three Southeastern Alaska streams was studied. Eggs and larvae were sampled periodically, and mortality was associated with certain environmental factors: The supply of dissolved oxygen, the stability of spawning beds, and freezing.

"Total mortality between spawning and fry emergence typically varied between 75 and 99 percent in the study areas. High mortality occurred during low and high stream discharge and freezing air temperatures. Mortalities ranging from 60 to 90 percent of deposited eggs occurred in association with low dissolved oxygen levels during and after the spawning period. Movement of gravel in certain instances was associated with the removal of 50 to 90 percent of eggs and larvae present in spawning beds. Freezing caused up to 65 percent mortality of eggs and larvae in one stream.

"Low dissolved oxygen levels occurred once in 5 years. This occurrence was associated with unusually low water during spawning in late summer. Mortality during periods of heavy precipitation was highly variable. In one instance, a 90-percent mortality occurred where wood debris was deposited within the high water channel. Wood debris floating over spawning beds was not damaging to eggs and larvae. There were several instances where mortality estimated at almost 50 percent occurred with no evidence that deposited wood debris shifted position. High mortality from freezing occurred only in the stream having the lowest minimum discharge."

(183) McNeil, William J.
1968. Effect of streamflow on survival of pink and chum salmon in spawning beds. *In* Richard T. Myren [ed.], Logging and salmon, p. 96-114. Proc. Forum Am. Inst. Fish. Res. Biol., Alaska Dist., Juneau, Alaska.

Studies conducted in southeast Alaska revealed the following:

"1. Low streamflow in summer causes low levels of dissolved oxygen in intragravel water and high mortality of pink and chum salmon spawn.

"2. Freezing can cause high mortality of pink and chum salmon spawn where streamflow fluctuates drastically. Spawn in streams with relatively stable streamflow which varied less than 100-fold between average daily minimum and maximum discharge experienced low mortality in cold winters.

"3. Eggs and alevins of pink and chum salmon are highly vulnerable to dislodgment from spawning beds during high streamflow. The stranding of debris on spawning beds increases gravel movement and mortality.

"4. Increased high streamflow and addition of debris to stream channels from logging would be harmful to pink and chum salmon. Increased low streamflow would be beneficial."

(184) McNeil, William J., and W. H. Ahnell
1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Fish & Wildl. Serv, Spec. Sci. Rep., Fish. 469, 15 p.

"The potential of a salmon spawning bed to produce fry is directly related to its permeability. The relationship between the coefficient of permeability and the fraction of bottom materials consisting of fine particles is inverse,

"Field methods for measuring size composition of bottom materials in salmon spawning beds are described, and an empirical relationship between the fraction (by volume) of solids less than 0.833 mm. minimum dimension and coefficient of permeability of stream bottom materials

is given. Size of bottom materials in streams utilized for spawning by pink salmon (*Oncorhynchus gorbuscha*) varied considerably. The more productive spawning streams had the more permeable spawning beds. Adult pink salmon caused the removal of finer particles from bottom materials during spawning. The evidence indicates that the fine particles removed consist largely of organic matter. Logging caused fine sands and silts to accrue to spawning beds. Flooding caused the removal of fine particles from spawning beds."

(185) McNeil, William J., Philip Shapley, and Donald E. Bevan
1962. Effects of logging on pink salmon and spawning-bed improvement. *In* Ted S. Y. Koo [ed.], Research in Fisheries. Coll. Fish. Contrib. 139:15-18. Univ. Wash., Seattle.

A 6-year study on factors causing egg and larval mortality in three southeastern coastal salmon streams was conducted. The summary includes a discussion on the interrelationships among spawners, quality of intragravel water, quality of spawning bed, and the effect of these factors on egg and larval mortality. Spawning bed improvement studies on two of the salmon streams were alsc conducted.

(186) Neave, Ferris, and R. F. Foerster
1955. Problems of Pacific salmon management. Trans. North Am. Wildl. Conf. 20:426-439.

Past and present Pacific salmon management problems are discussed. The authors state that present research efforts are aimed toward increasing salmon production by decreasing freshwater mortality. Deforestation looms as the major problem of freshwater mortality.

(187) Neave, Ferris, and W. P. Wickett
1949. Factors affecting the freshwater development of Pacific salmon in British Columbia. 7th Pac. Sci. Congr. Proc. 4:548-556.

The ecology of the freshwater phases of Pacific salmon is discussed including the chemical, physical, and biological factors causing mortality in freshwater. The importance of freshwater factors as measured by adult populations is reviewed. The report also correlates adult populations with streamflow.

(188) Phillips, Robert W., and Homer J. Campbell
1962. The embryonic survival of coho salmon and steelhead trout as influenced by some environmental conditions in gravel beds. Pac. Mar. Fish. Comm. Annu. Rep. 14:60-73.

The results of two studies designed to determine the effect of three environmental factors on embryonic survival of steelhead trout and

coho salmon are reported. The three environmental factors considered are: (1) dissolved oxygen concentration of the intragravel water, (2) seepage rate of intragravel water, and (3) permeability of the gravel. Also included in the report is a literature review of the effect of dissolved oxygen on embryonic survival.

(189) Phillips, Robert W., and K V. Koski
1969. A fry trap method for estimating salmonid survival from egg deposition to fry emergence. J. Fish Res. Board Can. 26:133-141.

"The method involves a trap of nylon netting placed over an individual redd with the trap's edges buried 15-20 cm in the gravel just outside the periphery of the redd. It has been used successfully on more than 70 coho salmon (*Oncorhynchus kisutch*) redds over the past 5 years, with as many as 2061 fry being captured from a single redd. The trap is relatively stable because it is flexible and conforms to the surface of the streambed, causing debris to float or roll over the surface. It can be used on individual redds; thus, emergent survival for separate parental combinations can be estimated. Field tests showed the efficiency of the trap approached 100%. Installation and presence of the trap had no significant effect on intragravel dissolved oxygen and gravel permeability. Mortality of fry in the traps averaged less than 1.5% when fry were removed at least three times a week. We concluded that the trap provides a more accurate estimate of survival from egg deposition through fry emergence than four other methods."

(190) Shapovalov, Leo, and Alan C. Taft
1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*), with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Fish & Game, Fish Bull. 98, 375 p.

The report describes the life history of the steelhead rainbow trout and the silver salmon. The authors discuss: (1) the correlation between number of eggs and size of fish, (2) the relationship between hatching time and temperature, (3) the effects of silting on the duration of survival, (4) factors influencing growth, timing and size of migration, and (5) the improvement of the biological and physical habitat.

(191) Sheridan, W. L., and S. T. Olson
1970. Timber harvest and the salmon and trout fisheries of southeast Alaska. Presented to West. Div. Am. Fish. Soc., 10 p. Victoria, B.C., Can.

"The purpose of this paper is to (1) summarize the progress of timber harvest on National Forest lands in Alaska; (2) outline the status of some of the fisheries that could be affected; (3) discuss past and present studies aimed at evaluating the effects of logging; (4) review progress of the opportunities for habitat improvement; and (5) point out the most pertinent problems needing attention."

(192) Sheridan, William L.
1962. Waterflow through a salmon spawning riffle in southeastern Alaska. U.S. Fish & Wildl. Serv. Spec. Sci. Rep., Fish. 407, 20 p.

"The following characteristics were studied in a small salmon stream in Southeastern Alaska from 1956 through 1959: (1) dissolved oxygen content of ground water, (2) variation of dissolved oxygen with depth in streambed, (3) temperature of ground water, (4) extent of ground-water seepage, (5) interchange of flowing stream water and water of streambed gravels, and (6) flow of water in the gravel of streambank and gravel bar.

"Ground water was generally low in dissolved oxygen content, and dissolved oxygen levels decreased with depth in streambed. Because of these and other points discussed in this paper, I conclude that the main source of intragravel water of high oxygen content is the flowing stream."

(193) Wells, Ralph A., and William J. McNeil
1970. Effect of quality of the spawning bed on growth and development of pink salmon embryos and alevins. U.S. Fish & Wildl. Serv. Spec. Sci. Rep., Fish. 616, 6 p.

"Among three segments of the spawning ground in Sashin Creek, southeastern Alaska, the largest and fastest developing embryos and alevins of pink salmon, *Oncorhynchus gorbuscha*, came from spawning gravels characterized by high levels of dissolved oxygen in intragravel water. The high oxygen levels occurred in a stream segment which has a relatively steep grade and coarse materials in the bed. No differences in water temperature were observed among the three segments."

(194) Wendler, Henry O., and Gene Deschamps
1955. Logging dams on coastal Washington streams. Wash. Dep. Fish., Fish. Res. Pap. 1(3):27-38.

The types and operations of log dams, their effects on fish life, early fisheries rehabilitation efforts, and rehabilitation efforts are discussed.

(195) Wickett, W. P.
1958. Review of certain environmental factors affecting the production of pink and chum salmon. J. Fish. Res. Board Can. 15(5):1103-1126.

"The relation between stock and numbers of spawners is obscured by annual environmental changes. Stream discharge at the time the spawners are migrating upstream, at the time when the eggs are in the early stages of incubation, and extreme discharge during the period eggs and alevins are in the gravel can impose an eightfold variation in the stock resulting from a given number of spawners in one area. Ocean conditions soon after the fry enter the sea have been observed to increase or decrease survival by a factor of 3. The density of spawners that produces the greatest numbers of fry is related to the average permeability of the stream bottom. Preliminary data indicate that more spawners could be used to advantage in most areas of the coast."

(196) Wolf, P. H.
1950. American problems and practice, I. Salmon which disappeared. Salmon Trout Mag. 130:201-212.

The author states that among the many factors contributing to the elimination of salmon runs around Lake Ontario, siltings from erosion after extensive land cultivation and deforestation are the major contributors. Salmon fry disappear from silted areas of a river, whereas a good yield is found from less spoiled regions.

(197) Ziebell, Charles D.
1960. Problems associated with spawning and growth of salmonids in Northwest watersheds. *In* E. F. Eldridge [ed.], Proceedings of 7th symposium on water pollution research, p. 28-32. U.S. Dep. Health, Educ. & Welfare, Reg. IX, Portland, Oreg.

Our watershed problems fall into two basic categories, natural and manmade, which the author discusses with respect to spawning, incubation, and affiliated problems, as well as to fish growth problems emphasizing the need for more research and better control over logging operations.

MULTIPLE LOGGING EFFECTS

(198) Brode, John M., James W. Burns, and Gary E. Smith
1973. Effects of logging road construction on invertebrates in a small coastal stream. Calif. Fish & Game, Inland Fish. Adm. Rep. 73-1, 47 p.

"Benthos density, invertebrate drift rates, and salmonid diets were compared on two forks of Caspar Creek, Mendocino County, California, before and after the construction of a logging road on the South Fork. Road construction was immediately detrimental to most aquatic invertebrates in the South Fork, although conditions created favored Diptera and Plecoptera. The increases in these two insect orders offset losses of other invertebrates, causing the South Fork's benthos to increase about 122%, from 286.02 to 634.41 mg/m^2, immediately after the road construction. The impact of the road construction, however, was partially obscured by the fertilization of the South Fork's disturbed areas with 817 kg urea immediately after the road was completed. The urea probably enriched the stream's food base for insects. In addition, a comparable increase in benthos density occurred simultaneously in the undisturbed North Fork, indicating that the South Fork's immediate increase was not necessarily caused by the road construction and fertilization. Recolonization of the South Fork by other invertebrates was rapid and, within 2 years, the benthos was 1,347.54 mg/m^2, 371% greater than it had been prior to the road construction. The North Fork's benthos increased only 65% during the same period. Drift rates were highly variable in both streams, ranging from 0.43 to 3.57 mg/hr/net in the North Fork and from 1.07 to 3.89 in the South Fork. This variability was probably due to the low sampling effort and precluded any statistical comparisons of drift rates before and after the road construction. In both streams, Trichoptera and Coleoptera made up the greatest biomass of insect orders in the drift. Salmonid diets generally changed in response to changes in the availability of food items, with juvenile steelhead trout (*Salmo gairdneri*) and coho (silver) salmon (*Oncorhynchus kisutch*) consuming relatively more Diptera in the South Fork after the road construction."

(199) Burns, James W.
1972. Some effects of logging and associated road construction on northern California streams. Trans. Am. Fish. Soc. 101(1):1-17.

"The effects of logging and associated road construction on four California trout and salmon streams were investigated from 1966 through 1969. This study included measurements of streambed sedimentation, water quality, fish food abundance, and stream nursery capacity. Logging was found to be compatible with anadromous fish production when adequate attention was given to stream protection and channel clearance. The carrying capacities for juvenile salmonids of some stream sections were increased when high temperatures, low dissolved oxygen concentrations, and adverse sedimentation did not accompany the logging. Extensive use of bulldozers on steep slopes for road building and in stream channels during debris removal caused excessive streambed sedimentation in narrow streams. Sustained logging prolonged adverse conditions in one stream and delayed stream recovery. Other aspects of logging on anadromous fish production on the Pacific Coast are discussed."

(200) Calhoun, Alex
1966. Bulldozer delinquents. Outdoor Calif. 27(8):10, 11, 19.

Watershed and stream damage in California and regulations needed to control logging damage are discussed.

(201) Calhoun, Alex
1967. Stream damage. *In* Man's effect on California watersheds, p. 363-380. Part 111, 1965-1967. State Calif., Sacramento.

Stream damage on California watersheds by logging operations, dam construction, earth-moving activities, overgrazing, and placer mining is discussed. The main emphasis is concern with logging operations; and the author recommends that loggers should leave buffer strips, practice more effective erosion control on roads and skid trails, and stop using streambeds as working areas, roads, and skid trails.

(202) Calhoun, Alex, and Charles Seeley
1963. Logging damage to California streams in 1962. Calif. Fish & Game, Inland Fish. Admin. Rep. 63-2, 15 p.

"Careless logging operations continue to damage priceless watersheds and to degrade important salmon and trout streams in California. Destructive practices include use of streambeds as roadways, operation of heavy equipment in streams, tractor logging on steep slopes, and removal of streamside vegetation. Accelerated erosion compounds the damage. Valuable forest soils erode off the slopes and deposit in streams, smothering eggs, fish, and fish food. Organic logging debris may also pollute the streams.

"During 1962, 33 streams were damaged by logging operations, mostly in north coast counties. All are on private land.

"Careful timber harvesting on some private lands and in National Forests, has shown that such damage can be largely prevented.

"Model timber sales contracts requiring good practices to protect soils, streams, and timber would help inexperienced owners of timberlands to minimize damage by contract loggers.

"The increasingly serious problem of erosion control involves many agencies. It is beyond the power of the Department of Fish and Game to solve alone. Nevertheless, we hope to hasten corrective action by calling attention to resulting stream damage. More research is needed to define this problem."

(203) Campbell, C. J.
1963. Fish management problems associated with timber harvesting. *In* Symposium--Forest watershed management, p. 331-337. Oreg. State Univ., Corvallis.

The article is a general discussion of fishery problems associated with timber management and harvesting.

(204) Chapman, D. W.
1963. Physical and biological effects of forest practices upon stream ecology. *In* Symposium--Forest watershed management, p. 321-330. Oreg. State Univ,, Corvallis.

Changes induced by land treatments on the aquatic ecosystem and their effects on stream ecology are reviewed and discussed.

(205) DeWitt, John W.
1964. The fish and fish habitats of the coast redwood region in Mendocino, Humboldt, and Del Norte Counties in California, Final Rep., Coast Redwood Study. U.S. Natl. Park Serv., Proj. NPS-WASO-11-64-(4), 31 p. [Mimeogr.]

"The purpose of this report partly is to identify the common fishes and to describe their distributions, general abundance, and importance, and ecological status in the redwood forest region in Mendocino, Humboldt, and Del Norte Counties. It is also for the purpose of describing the general nature, extent, and condition of fish producing waters in this region.

"A discussion of the main fish and stream protection problems of the present and the future is presented. Special emphasis is given to the problem of protecting fish species peculiar to the redwood region and their habitats."

(206) Edgington, John R.
1969. The impact of logging on the ecology of two trout streams in north Idaho. 73 p. M.S. thesis, Univ. Idaho, Moscow.

"The effects of logging on two study locations, with a test and control stream, were studied for 11 years in northern Idaho. Clear and selective logging was carried out in varied percentages on the two locations. An impact on the stream ecology was noted early in the study due mainly to road construction. A decline then a gradual increase to previous levels was noted for four orders of stream insects with the exception of the order Plecoptera which showed a decline in abundance due to siltation. There was no apparent effect on trout populations. The timing and methods of timber harvesting are credited for the moderate effects to the stream ecology."

(207) Ellis, Robert J., and William A. Smoker
1970. Report on a study of effects of log rafting and dumping on marine fauna in southeast Alaska, June 6-9, 1970. U.S. Fish & Wildl. Serv. Interdep. Rep., 11 p. Auke Bay Biol. Lab., Auke Bay, Alaska.

A reconnaissance survey was made of log dumping sites and their effects upon the marine fauna in the vicinity. The results showed a localized accumulation of bark and wood debris which eliminated plants and many animals in the immediate area.

(208) Fisk, Leonard, Eric Gerstung, Richard Hansen, and John Thomas
1966. Stream damage surveys--1966. Calif. Fish & Game, Inland Fish Adm. Rep. 66-10, 9 p.

"Four stream drainages were surveyed during July 1966 to determine the extent of damage from past logging and other activities. The streams are the Garcia River, Mendocino County; Redwood Creek, Humboldt County; North Fork of Battle Creek, Shasta County; and Middle Fork of Mokelumne River, Calaveras County.

"A total of 328 miles was surveyed. Of this, 108 miles (33%) were severely damaged, 27 miles (8%) more moderately damaged, 127.5 miles (39%) were lightly damaged, and 65.5 miles (20%) were undamaged.

"The most severe damage occurred in Redwood Creek and the Garcia River, both in the redwood forests of the Coast Range.

"In the North Fork of Battle Creek and in Forest Creek, tributary to the Middle Fork of Mokelumne River, there was five times the poundage of trout per unit area in undamaged control sections as in severely damaged areas.

"In Forest Creek, water temperatures increased about 0.5°F. per mile in well-shaded areas, compared to 1.5 to 2.0° F. per mile in unshaded areas."

(209) Froehlich, Henry A.
1971. Logging debris - managing a problem. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 112-117. Oreg. State Univ., Corvallis.

"Floatable debris in forested watersheds is produced by both natural and human action. The natural accumulation of organic debris and its subsequent flushing by periodic flood events are discussed. The frequency of major flood events since 1861 was examined and found to occur at an average of only eight-year intervals. Flood damage studies show that one of the major contributors to storm damage is nonmanufactured debris. Studies were reviewed which show that logging debris adds significantly to the natural debris and often aggravates the flood damage. The impact of this debris movement on the forest road system was examined and a number of management techniques were discussed. A plan for reducing road and culvert damages is recommended."

(210) Fullerton, E. C.
1972. Fish, wildlife, and logging practices in the Sierra. Presented to Assem. Comm. Nat. Resour. & Conserv. 7 p. Sugar Pine Point State Park, Lake Tahoe, Nev.

This article presents a discussion of some of the effects which logging has on wildlife and its habitat in the Sierra. The discussion includes: (1) streamside vegetation, (2) logging debris disposal problems, (3) landslides, and (4) siltation and logging benefits to wildlife.

(211) Hall, James D., and Richard L. Lantz
1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. *In* T. G. Northcote [ed.], Proceedings of a symposium--Salmon and trout in streams, p. 355-375. Univ. B. C., Vancouver, B. C., Can.

"The effects of two patterns of Douglas-fir logging on water quality and fish populations have been studied in three coastal headwater streams. Clearcut logging of an entire watershed of 71 hectares (175 acres) is being compared to clearcutting in patches on a larger watershed of 304 hectares (750 acres), where about 30 percent of the area has been harvested and a strip of timber left along the stream. The third watershed of 203 hectares (500 acres) will remain unlogged as a control. Prelogging studies began in 1958, access roads were constructed in 1965, and logging took place in 1966.

"Substantial changes in temperature and dissolved oxygen content of stream water followed logging in the entirely clearcut watershed. A maximum temperature of 30°C and a maximum diurnal fluctuation of 16° were recorded. Comparable pre-logging maximums were 16° and 1.5°, respectively. Dissolved oxygen levels of surface and intragravel water dropped below 2 mg/l during logging operations. Survival of coho salmon and cutthroat trout in the clearcut watershed has been affected by logging, but the significance of the effect cannot yet be fully evaluated.

"No significant changes in the fish population or its habitat have been noted in the patch-cut watershed. Studies will continue for several years to evaluate long-term effects of logging on the stream and to determine the period of recovery."

(212) Hess, Lloyd J.

1969. The effects of logging road construction on insect drop into a small coastal stream. 58 p. M.S. thesis, Humboldt State Coll., Arcata, Calif.

"Because stream fisheries are so closely associated with forested watersheds, it is necessary that the streams and forests be managed jointly under a system of multiple use. This requires a knowledge of the interrelationships between these resources to yield maximum returns from both. It is the purpose of this paper to relate logging practices to fish management by ascertaining the effect of logging-road construction on the drop of insects into a stream.

"On the South Fork of Caspar Creek the insects falling into the stream were greatly increased after a logging road was built. A twofold increase in number and weight of insects occurred over the entire stream. In 'Disturbed' areas, where the road paralleled the stream, drop insects increased three and one half times by number and one and one half times by weight over the 'Insect-Control' area. In the 'Highly Disturbed' areas, where the road crossed the stream, insect numbers increased by five and one half times and a threefold increase by weight over the 'Insect-Control' area was noted.

"A more than proportionate amount of the increase occurred in those adult insects having aquatic immature stages. One such family, Chironomidae, had a greater occurrence after road construction than all insects combined before construction. This family showed the most significant change of the families studied."

(213) James, G. A.

1956. The physical effect of logging on salmon streams of southeast Alaska. USDA For. Serv. Stn. Pap. No. 5, 49 p. Alaska For. Res. Cent., Juneau, Alaska.

A 5-year study made on three streams concerning logging effects on streamflow, temperature, channel change, and sedimentation is summarized.

(214) James, G. A.

1957. The effect of logging on discharge, temperature and sedimentation of a salmon stream. USDA For. Serv. Tech. Note 39, 2 p. Alaska For. Res. Cent., Juneau, Alaska.

The effect of logging on streamflow, stream temperature, and sedimentation is analyzed. Increase in streamflow was found to be small; however, it occurred during the dry weather months and may prove to be beneficial to coho salmon fry and late migrating pink and chum fry. It may also help early spawning escapement upstream. Logging did not change stream temperature and sedimentation in the logged stream.

(215) Larkin, P. A., and graduate students
1959. The effects on fresh water fisheries of man-made activities in British Columbia. Can. Fish-Cult. 25:1-33.

"There can be no question that historically, extensive clear cut logging has had deleterious effects on populations of freshwater and anadromous fish, particularly in coastal areas. However, the recent trend to sustained yield management of forest resources together with the inclusion of practices in logging which are designed to protect fisheries resources, will no doubt greatly mitigate these effects in the future.

"At the same time, other trends in modern forestry practices are causing substantial concern to fisheries agencies. The indiscriminate spraying of large areas of forest for insect control is known to have disastrous effects on fish in streams. If forest spraying is to be carried on in the future on a large scale--and there are indications that it may be--fisheries agencies will require a greatly increased knowledge in this field upon which to base sound conservation measures."

(216) Lehman, Carl
1970. Effects of log storage on the Dungeness crab fishery in southeastern Alaska. Alaska Fish & Game. Corn. Fish. Res. & Dev. Act, Job Completion Rep., Proj. 5-10-R and 5-21-R, p. 39-43. Juneau, Alaska.

"The scanty observations made during this preliminary study have shown that the physical presence of bark and associated debris on the substrate mechanically reduces the suitability of the habitat for Dungeness crab. This mechanical effect is greatest in the immediate log-rafting area, and in the absence of strong current. When strong currents are present log-rafting debris is swept away and therefore has little effect upon the crab population in the immediate vicinity. What happens in the area where such debris is eventually deposited, or to the marine animals in such an area, is not within the scope of this study."

(217) Meehan, W. R., W. A. Farr, D. M. Bishop, and J. H. Patric
1969. Some effects of clearcutting on salmon habitat of two southeast Alaska streams. USDA For. Serv. Res. Pap. PNW-82, 45 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

The effects of clearcutting on streamflow, suspended sediment, stream temperature, log-debris jams, and indirectly on salmon populations of two watersheds were evaluated and compared with an uncut watershed in southeast Alaska. Although some effects were observed, the timber harvesting as practiced on these watersheds did not appear harmful to salmon habitat or populations.

(218) Narver, David W.
1971. Effects of logging debris on fish production. *In* James Morris [ed.], Proceedings of a Symposium--Forest land uses and stream environment, p. 100-111. Oreg. State Univ., Corvallis.

"Stream salmonids (8 species of Pacific salmon, trout, and char) are discussed in relation to their environmental requirements and the possible impact of logging debris on their production. The emphasis is on small streams because of their great importance as nursery and spawning areas for certain species and because they may be more susceptible to damage than larger streams or rivers. Extensive use is made of pertinent literature. It is concluded that accumulations of logging debris in small streams can have serious consequences on the production of salmonid fishes."

(219) Narver, David W.
1972. A survey of some possible effects of logging on two eastern Vancouver Island streams. Fish. Res. Board Can., Tech. Rep. 323, 55 p.

"The lack of British Columbia studies relating logging practices to salmon and trout production was the basic reason for a 1970 survey of sections of two streams on the east coast of Vancouver Island. The objective was to compare fish populations, invertebrate drift, stream temperatures and stream channel widths in recently clearcut and burned stream sections and adjacent upstream sections in standing timber.

"Late summer standing stock estimates of the trout population in Jump Creek was considerably greater in the timbered (2226 fish/acre and 38.8 lbs/acre) than the logged section (1420 fish/acre and 3.9 lbs/acre). The standing stock of juvenile coho salmon and steelhead in Wolf Creek ranged from 6722 fish/acre (27.9 lbs/acre) to 10,206 fish/acre (49.8 lbs/acre) with the highest density (mainly steelhead) in the logged sections. Stock estimates for these two streams are similar or higher in comparison to other stream salmonid populations reported in the literature.

"Other possible effects of logging revealed in this survey was fish size, stream temperature and stream channel width. A larger average size of each age group of trout in the logged section of Jump Creek compared to the timbered section may have been related to higher stream temperatures in June and July leading to faster development of pre-emergent fry and earlier emergence. Stream temperature in the logged sections were higher than in upstream timbered sections. In Jump Creek maximum temperature was 21.1° C (70.0° F) in the logged section and 15.1° C (59.2° F) in the timbered section; temperatures over 20° C (68° F) lasted only a few hours each day. The channel of both streams in the logged sections appeared badly eroded with cutbanks and wide gravel bars, but only in Wolf Creek was the channel significantly wider in the logged than the timbered sections."

(220) Reinhart, Kenneth G.
1972. Effects of clearcutting upon soil/water relations. *In* R. D. Nyland [ed.], A perspective on clearcutting in a changing world. Appl. For. Res. Inst. Misc. Rep. 4, p. 67-74. Syracuse, M.Y.

The effects of timber harvesting are discussed, including tree cutting and removal of products on (1) streamflow, (2) water yield, (3) storm flows, (4) sediment, (5) nutrients, and (6) aquatic plants and animals. The author states that the cornerstones of a good job from a soil and water standpoint are: "(1) restricting the size of clearcuts and scattering their location; and, (2) following the highest standards of road location, construction, and maintenance."

(221) Rich, Lowell R., H. G. Reynolds, and J. A. West
1961. The Workman Creek experimental watersheds. USDA For. Serv. Rocky Mt. For. E Range Exp. Stn., Stn. Pap. 65, 18 p. Fort Collins, Colo.

A study of the effects of logging on water quality and quantity is discussed.

It was also found that selective cutting in a central Arizona watershed did not greatly affect the rate of sedimentation'in adjacent streams if made under carefully controlled conditions.

(222) Ringler, Neil Harrison
1969. Effects of logging on the spawning bed environment in .two Oregon coastal streams. M.S. thesis, Oreg. State Univ., Corvallis.

"The effects of two patterns of logging on the intragravel environment were studied in three Oregon coastal streams between June 1968 and June 1969. The watershed of one stream (Needle Branch) had been clearcut, and that of a second stream (Deer Creek) cut in staggered settings in 1966. A third watershed (Flynn Creek) served as an unlogged control. The dissolved oxygen content, biochemical oxygen demand, and temperature of the intragravel water were determined, as well as the size composition and organic content of the gravel. Changes were evaluated in terms of their effects on the survival of salmonid eggs and alevins.

. . . . . .

"Dissolved oxygen in redds of Needle Branch averaged 7.15 mg/l, whereas that in Deer Creek averaged 8.91 mg/l during 1969. Oxygen levels in Needle Branch redds in 1969 were 37.4 percent lower than those reported in 1964. Oxygen in Deer Creek redds dropped 12.7 percent in the same @eriod. Dissolved oxygen at permanent standpipe locations was significantly lower than that in redds and showed greater variability. Oxygen levels were positively correlated with streamflow and negatively correlated with temperature.

"Organic content of the gravel ranged from 0.33 to 7.52 percent by weight: less than 3 percent of the organic material was larger than 6.35 mm. The quantity of organic material was directly related to the amount of fine sediment in the sample. Recent redds in Needle Branch contained significantly less organic debris than did former redds. However, the organic content of redds in Needle Branch did not differ statistically from that in Deer and Flynn Creeks. The biochemical oxygen demand of the intragravel water averaged 1.95 mg/l for the three streams; differences among streams were not statistically significant.

"Stratification of fine sediment was evident in many redds, but a definite pattern of stratification could not be detected. Gravel size composition in Needle Branch did not differ statistically from that of the other streams. Recent redds in Needle Branch contained significantly less sediment than did former redds.

"Intragravel water temperature lagged from 2 to 6 hours behind surface temperature in attaining the diurnal maximum. Water temperature decreased with depth in the gravel in Needle Branch and Deer Creek on clear days, but the intragravel water was almost isothermal in Flynn Creek. Fluctuation in intragravel water temperature occurred as early as March, and maxima as great as 19.7°C were recorded prior to complete emergence of coho salmon. Surface and intragravel temperatures reflected the amount of shade over the stream surface. Survival to emergence of coho salmon appeared to be little affected by the observed changes in the intragravel environment."

(223) Salo, Ernest O.
1967. Study of the effects of logging on pink salmon in Alaska. Soc. Am. For. Proc. 1966:59-62.

The effects of logging on the pink salmon of the Harris River and Twelvemile Creek are discussed. A temporary increase in fine sediments in the the salmon spawning gravels was found. The survival rate of eggs and fry decreased during the study period (1959-64), but the actual number of fry produced increased due to an increase in numbers of eggs deposited.

(224) Sheridan, W. L.
1949. Effects of deforestation and logging operations on watersheds with special reference to the effects on fish life in the streams. Fish. Res. Inst., Circ. 2, 15 p. Univ. Wash., Seattle.

"1. There is a direct relation of forest and streamflow according to most writers in the field. Denudation of timberland, depending on the extent to which it is carried on, may have the following effects on streams:

"a. Fluctuations in streamflow may be altered to such an extent that a deleterious effect on young fish and spawn would ensue.

"b. Temperatures of the water might be increased above the optimum level necessary for fish-life in the streams.

"c. The occurrence of erosion and silting may be so aggravated by removal of forest cover that an adverse effect on aquatic organisms and spawning beds would result.

"2. Accentuated runoff due to deforestation may scour stream bottoms, deposit sand bars and destroy aquatic organisms.

"3. Logging practices, depending on which methods of logging are used, may create a harmful environmental change for fish in the following manner:

"a. The unwise construction of dams might possibly block salmon migration and fishways would have to be built. Artificial regulation of this type may also prove detrimental to both spawning adults and eggs and young in the gravel.

"b. The use of streams as roadbeds down which logs would be dragged to tidewater could change the physical characteristics of the stream with a possible harmful effect on spawning fish, spawn, and also exert a diminishing effect on spawning areas.

"c. The accumulation of chips, sawdust, etc., in streams could create a biochemical oxygen demand possibly high enough to lower the dissolved oxygen level of the water to an extent that fish could not live.

"d. The construction of logging roads through forests might possibly increase erosion with a consequent heavier silting of the streams.

"5. The conclusions in any study of the influences of deforestation or logging in a new region due to the institution of pulp or paper mills in that region must be based on assumptions and data drawn from other areas in which similar work has been done."

(225) Sheridan, W. L., J. F. Weisgerber, and C. N. Wilson
1965. The effect of logging on twelve salmon streams in southeast Alaska. USDA For. Serv., 59 p. Alaska Reg., Juneau, Alaska. [Mimeogr.]

"The authors were accompanied at each of the streams by a representative of the local Forest Service office and, on eight streams, by a member of the Alaska Department of Fish and Game. For each stream observations or measurements of the following items were recorded: (1) present vegetation in the cutting area; (2) evidence of any erosion; (3) stream characteristics, including configuration, gradient, particle size, evidence of bedload movement, pool-riffle relationship, water quality, approximate discharge and water stage, bank stability, and apparent spawning potential; (4) number of salmon in the stream; (5) log jams in the stream; and (6) overall changes since the 1950 examination. In addition, areas photographed in 1950 were relocated (where possible) and comparison photos taken."

(226) Stefanich, Frank
1956. The effects of logging on Pinkham Creek's fish population. Mont. Fish & Game. Fed. Aid in Fish Restoration, Job Completion Rep., Proj. F-7-R-6, 10 p.

"Eight randomly selected stations were sampled and a total of 401 eastern brook trout and 218 rainbow trout taken. The total weight and average condition factor C for the brook trout was 17.42 pounds and 36.1, respectively. For the rainbow trout, figures of 13.29 pounds and 25.3 were obtained for the total weight and average condition factor C. The total number of fish caught was higher than in 1955.

"Approximately 1,350 acres of timber were logged on Forest Service land, producing 13,587.26 MBM and 181,090 linear feet of poles. An estimated 1,000 MBM of timber was cut on private lands. To date, a total of 61,087 MBM of timber has been removed from the Pinkham Creek drainage."

(227) Stefanich, Frank
1957. The effects of logging on Pinkham Creek's fish population. Mont. Fish & Game. Fed. Aid in Fish Restoration, Job Completion Rep., Proj. F-7-R-6, 10 p.

"Eight randomly selected stations, each 300 feet long were sampled and 345 eastern brook trout and 226 rainbow trout were captured. The condition factor (C) of the eastern brook trout averaged 26.4 and the rainbow trout 32.2. Logging operations have continued and 1,180 acres of land were cut from a 5 to 95 percent cut. There was a slight increase of both total number and total weight of all trout captured."

(228) Stefanich, Frank A.
1955. The effects of logging on Pinkham Creek's fish population. Mont. State Dep. Fish & Game. Fed. Aid in Fish Restoration, Job Completion Rep., Proj. F-7-R-4, 5 p.

"Nine randomly selected sections, each 300 feet long were sampled and 388 eastern brook trout and 200 rainbow trout were captured.

The eastern brook trout comprised 66 percent of the population. The condition factor of the brook trout averaged 37.4 and the rainbow trout 38.9. Logging operations have continued and 1,250 acres have had some timber removed during the current year. Ninety percent of the logging was selective cut pine, fir and larch and the remainder was clear cut spruce. The rainbow trout were found to be more numerous in the lower sections than in the upper. There was a decrease in both numbers and weights of fish from that of the previous years. The rainbow trout suffered the greatest reduction. Some new erosion of the stream banks was observed in the portion of the stream in which the lower three stations are located."

(229) Steinbrenner, E. C.
1966. Logging on watersheds: what type, where, what disturbance? *In* Proceedings of a Symposium--Practical aspects of watershed management, p. 109-115. Oreg. State Univ., Corvallis.

"It appears that although we do have the scars on the landscape from past logging, once the problem was brought to light, improvements began to take shape. The development of new and better logging equipment has been encouraged and this equipment utilized to minimize disturbances to the watershed, thus maintaining the productivity of the forest lands.

"The forest industry moved into tree farming 25 years ago and is moving toward more intensive forestry. Among other things, the importance of maintaining the productivity of the land is recognized. Maintenance of improvement of site quality is a worthy objective in managing land for timber or water, or both."

(230) Wooldridge, David D.
1960. Watershed disturbance from tractor and skyline crane logging. J. For. 58(5):369-372.

"In a comparative study of logging methods, soil disturbance caused by a Wyssen Skyline Crane was only a quarter of that caused by a standard crawler tractor operation. Soil disturbance on the Skyline Crane area was found on fewer transects, less damage was evident in the residual stand, and less road construction was needed. These advantages suggest the possibility of using skyline logging systems for harvesting timber in municipal watersheds and other areas previously closed to logging because of erosive soil conditions or steep, broken terrain."

(231) Zach, L. W.
1951. Past logging affects little of watersheds. USDA For. Serv. Tech. Notes 8, p. 1. Alaska For. Res. Cent., Juneau, Alaska.

"Past logging near salmon streams in Southeast Alaska has disturbed the watersheds very little. A compilation of watershed areas compared to areas cut on 24 Forest Service timber sales adjoining streams showed the following:

"1. Southeast Alaska watersheds are small. On the 24 sales they ranged from 342 acres to 20,000 acres.

"2. Areas logged are small. They ranged from 18 acres to 178 acres.

"3. Average proportion of watershed cut over was only 1.3 percent. Individual sales ranged from 0.28 percent to 15.5 percent.

"4. Cutting is nearly always confined to the lower part of the watershed. In no case did cutting proceed more than two miles up a drainage.

"5. Southeast Alaska forest stands are so broken up and intermingled with nonmerchantable types that no great unbroken clear-cuttings or denuded watersheds can be expected."

STREAM PROTECTION

(232) Burwell, Dave
1971. Prevention of debris accumulation in streams by uphill felling. *In* James Morris [ed.], Proceedings of a symposium --Forest land uses and stream environment, p. 118-120. Oreg. State Univ., Corvallis.

"Felling trees uphill using a truck-mounted donkey and climber to attach the line, prevents breakage and distributes limbs and tops on slopes instead of in stream bottoms. Costs are two to three times those of comparable conventional cutting. Savings include the intangible of increased safety, lessened breakage, reduction of slash to eliminate burning and enable quicker regeneration, and reduction of expensive creek cleaning. These may more than offset additional costs."

(233) Evans, W. A., and F. B. Johnston
1973. Fish migration and fish passage--a practical guide to solving fish passage problems. USDA For. Serv., Reg. 5, 41 p.

"This report is prepared as a working guide for forest biologists and engineers who are confronted with the practical problems of providing fish passage through or over both natural and artificial structures in streams. Useful material has been selected from the various reference sources and combined to form a simplified source of information for the California Region."

(234) Federal Water Pollution Control Administration
1970. Industrial waste guide on logging practices. U.S. Dep. Inter., 40 p. Portland, Oreg.

Some of the problems involved in improper or poorly planned logging operations are described, and guidelines are prescribed which should be used to prevent such operations.

(235) Jones and Stokes Associates, Inc. and J. B. Gilbert Associates
1972. A study to develop administrative and regulatory practices to prevent water quality degradation resulting from logging and construction operations in the north coast of California. Prog. Rep., Stand. Agreement No. 1-5-018, 72 p. State Water Resour. Control Board, Sacramento, Calif.

This progress report is a summary of the studies conducted to date along with a prospectus of future work. The first of three sections contains a summary review of literature regarding the adverse effects of logging operations on water quality. The second section deals with a format for evaluating the potential impact of a proposed logging operation. The final section surveys the administrative and regulatory practices of other States, the Federal Government, and other State agencies in California.

(236) Lantz, Richard L.
1971. Guidelines for stream protection in logging operations. Oreg. State Game Corn., Rep. Res. Div., 29 p. Portland, Oreg.

Practical guidelines for the management of a coastal watershed in Oregon are presented. The aims of management are to maintain production of timber, fish, and high-quality water. By protecting streamside vegetation and minimizing sources of sedimentation, a watershed can be managed to benefit man. The report's main premise is that forestry and fishery management need not conflict but rather should work together for optimum success.

(237) Lawler, Thomas A.
1971. Resource protection possibilities and alternatives in logging. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 84-85. Oreg. State Univ., Corvallis.

"Forest land resources may be protected during logging through the use of many logging alternatives. Three forest management concepts are discussed relative to using various alternatives including equipment now available and available in the future. 1) Any extra costs incurred by using a logging method other than the most economical must be balanced by a benefit of at least equal value. 2) Forest lands should be inventoried to determine specific future logging standards or requirements which will be compatible with anticipated resource protection needs. This will give direction to equipment development and acquisition. 3) The public ultimately pays for and benefits from resource protection. Work must be done to determine how much protection the public is willing to pay for and how the costs should be borne."

(238) Oregon State Game Commission
1963. Precautions for stream and fish protection in road construction and logging operations. *In* Symposium--Forest watershed management, p. 338-340. Oreg. State Univ., Corvallis.

Recommended practices for fish and stream protection are listed. The report states that the most common causes of fish problems in forest lands are removal of bank cover, improperly laid culverts, siltation, and logging debris.

(239) Reid, Kenneth A.
1955. For better trout fishing. Pa. Angler 24(10):4, 5, 23.

In a study of trout production made in streams in the Adirondacks, more careful and well-planned logging practices are said to be needed to protect trout environments.

(240) Rothacher, Jack
1960. How much debris down the drainage? *In* Proceedings, Cooperative watershed management short course, p. 13-1 to 13-4. Oreg. State Coll., Corvallis.

The author points out problems associated with the question of where logging debris should be removed from streams. He suggests that if a stream *is* fed by a watershed larger than 40 acres, logs and chunks should be withheld from the stream or removed before the winter flows.

(241) Rothwell, R. L.
1971. Watershed management guidelines for logging and road construction. Can. For. Serv, Inform. Rep. A-X-42, 78 p. For. Res. Lab., Edmonton, Alberta, Can.

"This report presents a set of guidelines for logging and road construction to minimize erosion, sedimentation, and detericration of water quality. In the absence of local research and information, the guidelines are based on an extensive literature survey of research results and practices in North America and on a broad reconnaissance of forest conditions in Alberta."

(242) Schneider, P. W.
1956. The effects of logging old-growth timber on fish management. Soc. Am. For. Proc. 1955:121-123.

Effects of logging virgin timber and the best way to avoid excessive damage to fishery resources are discussed, Two approaches suggested are research on the responses of stream to various timber harvest practices and the integration of fishery considerations with timber harvest operations.

(243) Sheridan, William, Theodore Hoffman, and Sigurd Olson
1965. A technique for monitoring effects of land use on salmon streams in Alaska, 45th Annu. Conf. West. Assoc. Fish E Game Comm. Proc. 1965:155-159.

"Because of possible effects on salmon spawning environment in Alaska, a monitoring technique has been developed by the Forest Service in cooperation with the Alaska Department of Fish and Game. The general objective of the monitoring system is to detect changes in the spawning environment that adversely affect salmon production. Characteristics being monitored in one stream (soon to be followed by two others) are as follows:

"1. Composition of streambed spawning areas

"2. Streamflow and water temperature

"3. Stream channel configuration and amount and kind of debris in stream channel

"4. Soil types in the watershed

"5. Production of salmon fry

"6. Adult salmon escapement

"If changes in the salmon spawning environment, thought to be harmful, do occur, remedial measures can be undertaken. On the other hand, practices which may enhance the habitat can be expanded."

(244) Smedley, Stephen C.
1968. Progress report of joint stream monitoring by the Alaska Department of Fish and Game and U.S. Forest Service. *In* Richard T. Myren [ed.], Logging and salmon, p. 48-61. Proc. Forum Am. Inst. Fish. Res. Biol., Alaska Dist., Juneau, Alaska.

The monitoring system of three salmon streams in southeastern Alaska is discussed. The six characteristics monitored were: streambed gravel composition, yearly spawning escapement, preemergent pink salmon fry, streamflow, temperature, and incidence and movement of logs or debris in stream channels.

(245) Society of American Foresters, Columbia River Section, Water Management Committee
1959. Recommended logging practices for watershed protection in western Oregon. J. For. 57(6):460-465.

Recommended practices for watershed protection are. outlined in the order in which problems occur in logging operations.

(246) Society of American Foresters, Columbia River Section, Water Management Committee
1961. Watershed protection. A manual for forest landowners. Oreg. State Coll., 16 p. Corvallis, Oreg.; Coll. Press.

The manual serves as a nontechnical guide for logging and multiple-use management by private landowners and the general public. The report states that to provide' shade and protection from erosion the streambank should be protected from the wind whenever possible.

(247) USDA Forest Service, Alaska Department of Fish and Game, and Alaska Department of Natural Resources
[n.d.] Logging and fish habitat. 22 p. Juneau, Alaska.

"This pamphlet, directed mainly to timber sale administrators and loggers, describes some of the major habitat requirements of trout and salmon and lists some basic practices that will help to protect the habitat."

(248) Wilson, Robert L.
1960. Reducing erosion in the construction of logging roads, *In* Proceedings, Cooperative watershed management short course, p. 17-1 to 17-4. Oreg. State Coll., Corvallis.

"Erosion on logging roads can be minimized by increasing the angle to the back slope, hence reducing the area of slope subject to erosion, and by proper construction methods such as keying in all fill material and by compacting the subgrade."

STREAM IMPROVEMENT

(249) Bishop, Daniel M., and S. Philip Shapley
1963. Effects of log-debris jams on southeast Alaska salmon streams. [Abstract.] 13th Alaskan Sci. Conf. Proc. 1962:90.

"Log debris jams which were constructed on Maybeso Creek, Prince of Wales Island, induced streambed scouring under and around the jams and downstream migration and deposition of bedload. Fall floods which washed out the jams, removed fine material in the gravel which was accompanied by significant increase in dissolved oxygen in one of the jam areas.

"Log jams created unstable streambeds by maintaining readily changeable conditions and concentrating high flows in the vicinity of the construction.

"Salmon eggs deposited near the log jams may be washed out or buried thus gravel movement above a certain degree may offset the advantages of improved quality of inter-gravel water."

(250) Boussu, Marvin F.
1954. Relationship between trout populations and cover on a small stream. J. Wildl. Manage. 18(2):229-239.

"The study showed that trout populations in Trout Creek, Gallatin County, Montana, can be directly correlated with natural cover, application of artificial cover, and removal of natural cover on the stream."

(251) Broad, Robert D., and Harold A. Gangmark
1956, Establishment of a controlled flow area and construction of king salmon spawning pens at Mill Creek, California. Prog. Fish-Cult. 18(3):131-134,

"An isolated channel that leads independently from Mill Creek to the Sacramento River was selected for conducting experimental spawning and incubation studies. Spawning pens and a water-control dam were built as essential counterparts of the experimental area. Brush, silt, sand, and gravel were bulldozed from its entrance to reestablish flow into the channel. A length of corrugated metal pipe was laid in the channel and covered with earth to create a dam extending 8 feet above the pipe. A headgate (Calco Model 101) was mounted at the upstream end of the pipe for flow regulation.

"Stream improvement work was done in the old channel for approximately 1,000 feet below the dam. This involved removing large rocks, loosening gravel, and freeing it of silt and sand. The channel was made a uniform width, and the slopes of each riffle were made constant. Two additional settling ponds were excavated below the dam."

(252) Helmers, A. E.
1966. Some effects of log jams and flooding in a salmon spawning stream. USDA For. Serv. Res. Note NOR-14, 4 p. North. For. Exp. Stn., Juneau, Alaska.

"Streambed scouring and deposition occurred in the areas of two constructed log-debris jams. Gravel shifting associated with jams and flood flows reduced the fine material content of the streambed gravel and may have been responsible for the increased dissolved oxygen concentration.

"Log-debris jams intensify streambed instability, especially during floods. They may reduce salmon production in otherwise favorable areas. Gravel movement presumably reduces egg and larvae survival. On the other hand, loss of fine material because of gravel movement should benefit the salmon development environment by improving intragravel waterflow, thus increasing dissolved oxygen availability and making possible more effective removal of metabolic wastes. The effect of log-debris jams on salmon production remains undetermined. From a conservative viewpoint, however, temporary or unstable jams are judged to be detrimental."

(253) Holman, Gerald, and Willis A. Evans
1964. Stream clearance project-completion report Noyo River, Mendocino County. Calif. Fish & Game, Inland Fish. Adm. Rep. 64-10, 13 p.

"This report covers one of the first major stream clearance projects to be conducted in the State. Activities are described from the initial surveys to post project inspections.

"A total of 36 miles of spawning and nursery areas of the Noyo River drainage were improved at a cost of slightly over $19,000. Clearance work was conducted by use of Conservation Camp personnel.

"The project was deemed beneficial, although no satisfactory method was devised to evaluate results. Contrary to popular belief, the principal benefit of log jam removal is not removal of impassable barriers. It is improvement of habitat by permitting scouring winter flows to remove silt and gravel deposited behind log jams. It is believed that both spawning conditions and food production are thus removed for anadromous fishes."

(254) Meehan, William R.
1971. Effects of gravel cleaning on bottom organisms in three southeast Alaska streams. Prog. Fish-Cult. 33(2):107-111.

"The cleaning of gravel in three streams by the gravel shifter initially reduced the bottom fauna populations in each of these streams, but within 1 year these populations apparently returned to the pretreatment levels in each of the streams."

(255) Merrell, T. R.
1951. Stream improvement as conducted in Oregon on the Clatskanie River and tributaries. Fish, Com. Oreg., Res. Briefs 3:41-47.

"All evidence seems to point to the fact that drastic clearance of logs and debris from salmon streams increases accessibility and at least does not damage productivity. Although the stream bottom was greatly disturbed, in less than a year natural conditions had largely restored themselves. About 15 additional miles of stream were made readily available to spawning salmonoids.

"It is believed that due to improvements made the Clatskanie and its tributaries are at present capable of providing spawning and rearing facilities for large numbers of silver salmon and steelhead trout."

(256) Nobel, E. L., and L. J. Lundeen
1971. Analysis of rehabilitation treatment alternatives for sediment control. *In* James Morris [ed.], Proceedings of a symposium--Forest land uses and stream environment, p. 86-96. Oreg. State Univ., Corvallis.

"The aquatic environment of the South Fork Salmon River has been severely damaged in recent years by excessive rates of sediment production. A special study was conducted to determine the source and extent of the damage, and measures required to reduce future sediment production to a 'tolerable' level. Linear programming was used as an aid to select from 190 possible treatment alternatives and minimize treatment costs at various levels of sediment reduction, The desired level of sediment could be reached at a cost of $5 million. Debris basins to trap sediment moving in the channel proved to be the most effective and economical type of treatment while control of sediment production from roads and timber harvest on steep, fragile lands would have a very high cost."

(257) Richard, James A.
1963, Log stream improvement devices and their effects upon the fish population, south fork Mokelumne River, Calaveras County. Calif. Fish & Game, Inland Fish. Admin. Rep. 63-7, 12 p.

Richard states that due to severe bank erosion at the ends of the dams the construction of log dams proved ineffective for increasing fish populations or improving trout stream habitat. Log stream improvement devices are recommended only for controlled streamflows.

(258) Sheridan, W. L.
1969. Benefit/cost aspects of salmon habitat improvement in the Alaska Region. USDA For. Serv., 47 p. Branch Wildl. Manage., Reg. 10, Juneau, Alaska.

"...the purpose of this report is to:

"1. Present a method of benefit/cost analysis of habitat improvement projects whereby funds can be allotted to obtain the highest dollar return on the investment.

"2. Using a completed project, demonstrate how the method works in terms of project costs, benefits actually realized to date, and future returns.

"3. Present benefit/cost analyses for a series of proposed representative fish habitat improvements projects not yet funded."

(259) Sheridan, W. L.
1969. Effects of log debris jams on salmon spawning riffles in Saginaw Creek.... USDA For. Serv., 12 p. Juneau, Alaska.

"A preliminary study of the effect of log debris jams on salmon spawning habitat was made in Saginaw Creek on Kuiu Island in June, 1968. This study showed that about 27 percent of the area in one lineal mile of this stream had been eliminated as spawning area by log jams. Recommendations are made for judicial removal of jams and leaning trees, especially while a logging operator is in the watershed. Discounted benefit cost ratio is 34:1 for removal of a log jam and 342:1 for removal of leaning trees."

(260) Sheridan, W. L., Richard W. Wilke, and S. T. Olson
1968. The gravel cleaner ("Riffle Sifter"). USDA For. Serv. Prog. Rep., 1967, 8 p. Alaska Reg., Juneau, Alaska.

"Research in fisheries and engineering has shown that egg to fry survival of salmon embryos is higher in sediment free gravels. For this reason, the Forest Service is developing equipment to remove sediment from spawning gravels. A prototype model was developed by Forest Service engineers in 1964, and a working model was developed by the Clark Equipment Company in 1966. The equipment was tested in Alaska in 1966 and 1967. Although mechanical failures precluded thorough testing in Alaska, it was demonstrated that the equipment would remove large quantities of sediment from streambed gravels and that the principle of jetting the fines to the surface where they can be sucked up and disposed of is sound. The history of development and the results of testing of the "Riffle Sifter" are given in this progress report. It is not anticipated that a production (working) model will be available for use in Alaska prior to 1969."

MULTIPLE-USE MANAGEMENT

(261) Andersen, Harold E., and George A. James
1957. Watershed management and research on salmon streams of southeast Alaska. J. For. 55(1):14-17.

General problems associated with logging on salmon streams are discussed; i.e., sedimentation, temperature increases, and log jams. Restrictions in timber sale contracts are also reviewed.

(262) Borovicka, Robert L.
1968. Consideration of aquatic resources with forest practices in western Oregon. Presented to Oreg. State For. Dep., For.-Fish. Habitat Semin., 9 p. 'Tillamook, Oreg.

The Multiple-Use Act is discussed; defining its multiple uses to fisheries and forestry. The importance of the fishery resource affected by forestry practices in Oregon is pointed out, as well as forest practices which have helped fisheries.

(263) Bullard, W. E.
1950. Some references on watershed management. USDA For. Serv. Pac. Northwest For. & Range Exp. Stn., Res. Note 63, 26 p. Portland, Oreg.

The relationship of forest vegetation to climate, soil, erosion, runoff, and streamflow and the effects of logging on each are summarized.

(264) Bureau of Land Management
1970. An allowable cut plan for western Oregon. 90 p. U.S. Dep. Inter., Portland, Oreg.

"The purpose of this report is to present the results of the application of the BLM proposed allowable cut policies and procedures to the recent re-inventory of BLM's western Oregon forest lands. It identifies the highest level of sustained timber production that can be economically achieved under environmentally sound management. A further objective is to develop a program indicating the manpower, funding and the size and timing of investments needed to implement timber production, multiple use, and environmental protection."

(265) Cosens, Richard D.
1958. Reducing logging damage. USDA For. Serv. Calif. For. & Range Exp. Stn. Res. Note 82, 9 p. Berkeley.

Preventing logging damage will be made easier by

"1. Preparing and carrying out a detailed logging plan aimed at reduction of damage.

"2. Properly training and supervising logging crews; and

"3. Focusing engineering and logging ingenuity on designing equipment that will lessen damage to the advance growth as well as increase efficiency of yarding logs."

(266) Croft, A. R., and Marvin D. Hoover
1951. The relation of forests to our water supply. J. For. 49(4):245-249.

Several practices to reduce the deleterious effects of logging in the northern Rocky Mountains are suggested including selective cutting in a 200-400-ft strip along streams. The problem of erosion as related to water quality is briefly discussed.

(267) Gleason, Clark H.
1958. Watershed management--An annotated bibliography of erosion, streamflow, and water yield publications by the California Forest and Range Experiment Station. USDA For. Serv. Calif. For. & Range Exp. Stn. Tech. Pap. 23, 79 p. Berkeley.

"Bibliography has two purposes (1) to list and describe publications of the California Forest and Range Expt. Station and (2) to cite a few important early articles by other workers that helped set the stage for the station's work. Subjects covered include: (1) analytical methods, (2) climate, (3) floods and flood control, (4) geology, (5) instrumentation, (6) watershed management, (7) plant relations, (8) research programs and (9) soil relations and water relations."

(268) Greene, A. F. C.
1967, The relationship of aquatic wildlife habitats to forest management. Soc. Am. For. Proc. 1966:62-65.

Need for multiple-use management to protect and preserve our aquatic wildlife habitat is discussed.

(269) Hagenstein, W. D.
1953. The tree farm program--an asset to fish and game management. J. For. 51(9):620-623.

Hagenstein states that the controlled logging programs in Douglas-fir forests benefit the hunter and fisherman because ground cover is seldom lacking more than 6 months during the year due to natural plant selection. Water courses can be protected through the use of streamside strips and forest rotation.

(270) Neale, Alfred T.
1953. Watershed problems and their relation to water quality. Wash. Pollut. Control Com., Tech. Bull. 15, 16 p. Olympia.

Several methods of operations are suggested for use in commercial and recreational activities in forested watersheds with streams which support anadromous fish runs. Author suggests leaving a buffer strip at least 30 feet wide, except "in special cases where stream banks are subject to undercutting."

(271) Needham, Paul R., and Fred W. Johnson
1949. Forests and fish. *In* A. Stefferud [ed.], Trees, the yearbook of agriculture, p. 581-585. Washington, D.C.: U.S. Gov. Print. Off.

Importance of multiple-use management in relation to factors affecting fish populations is discussed.

(272) Packer, Paul E.
1957. Management of forest watersheds and improvement of fish habitat. Trans. Am. Fish. Soc. 87:392-397.

"Management of forest watersheds in the western United States for protection against floods and sediment and to improve water yields can also be very beneficial in fishery management. Some of the important hydrologic processes that operate on watersheds are discussed. The principal kinds of watershed protection and water yield improvement problems are outlined and discussed in relation to maintenance of desirable fish habitat. Need for research to determine quantitative hydrologic relationships on watersheds and develop methods of forest management for better regulated and higher quality streamflow is emphasized."

(273) Schlapfer, T. A.
1972. Title 2100-multiple use management. USDA For. Serv., For. Serv. Man., Reg. 6, Suppl. 11, Code 2121.33, p. 27-34. Portland, Oreg.

The Manual:

"...Provides new policy and guidelines for protecting water quality through establishment of 'streamside management units' (SMU). Stream classification is determined by use made of water and each class has certain water quality objectives and criteria to be met in the conduct of land management activities."

(274) Smith, Allen C.
1963. Tractor roads and trails planning, use and post treatment. *In* Symposium--Forest watershed management, p. 283-289. Oreg. State Univ., Corvallis.

"In logging a watershed with tractors it should always be remembered that a tractor is very versatile; and weather, soil, slope, and other conditions should regulate plans and policies rather than pre-set rules. It should be possible to protect the watershed and still keep costs to a minimum so that a maximum return from the timber can be realized. Fire protection is of high importance because when fire destroys the timber the watershed may be ruined. Most areas are safer for fire control with skid trails distributed throughout.

"Protection of watershed areas should be easy with tractor logging if the logger realizes that this protection is part of his job."

(275) Tanner, Howard A.
1954. Place of game and fish in multiple use of watersheds. Trans. Am. Fish. Soc. 87:386-391.

"Fish and wildlife in the near future will often have to be fitted into multiple use programs for watersheds. This involves compromise between various desired uses of land and water; uses which may be compatible, conflicting or independent. If fish and wildlife are to receive proper consideration in the multiple use program, it is essential that there be more factual information on relationships of wildlife to habitat and on wildlife values. Public support must be won through the use of these facts."

(276) Toney, Robert D.
1961. Multiple-use management and its effect on logging practices. 11th Alaskan Sci. Conf. Proc. 1961:156-161.

"This paper has attempted to point out some of the ways in which other uses of the national forests affect timber harvesting and logging practices. There are, however, still areas where the only logging criteria are good forestry practices, but as the population increases and more and more people move into an area other uses for the land gain in importance and cannot be, and are not, ignored. Fisheries, water, and recreation are all gaining in importance, and it may be that someday the other uses for the national forests will become so important and widespread that standard logging practices will be obsolete."

(277) University of Washington
1971. Clear-cutting, impacts - options - trade-offs. Inst. For. Prod. Proc., Coll. For. Contemp. For. Ser. No. 1, 44 p. Seattle.

Discussions about the natural resources, including plants, soils, and water, the economics and politics of clearcutting, and land use decisions are included. The conference was not designed to provide answers but to raise questions, to attempt to sort these questions as to their relevancy, and to provide information that might help those making policy decisions to arrive at useful answers.

(278) Willington, R. P.
1971. Forests, fish, and water. Symp. Cent. Contin. Educ. & Fac. For. 4 p. Univ. B. C., Vancouver, B.C., Can.

The purpose of the symposium was to identify some of the major problems in forest-fish-water resources, with the objective of reaching a consensus of opinion. Although conclusive unity of opinion was not achieved, some valuable generalizations were developed, including: (1) a need for more advanced planning in forestry operations, (2) operator supervision of operational plans, (3) research aimed at the operational level rather than at the academic or basic level, and (4) retraining or refresher education courses for all levels of research personnel.

ADDITIONAL REFERENCES NOT ANNOTATED

(279) Allen, K. Radway
1960. Effect of land development on stream bottom faunas. N. Z. Ecol. Soc. Proc. 7:20-21.

(280) Barney, Charles W., and Robert E. Dils
1972. Bibliography of clearcutting in western forests. Coll. For. & Nat. Resour. 65 p. Colo. State Univ., Fort Collins.

(281) Bethlahmy, Nedavia
1960. Surface runoff and erosion--related problems of timber harvesting. J. Soil & Water Conserv. 15(4):158-161.

(282) Bureau of Land Management
1968. 6760-Stream preservation and improvement. U.S. Dep. Inter. BLM Man.

(283) Bureau of Land Management
1969. 5110-Stream protection. U.S. Dep. Inter. BLM Man. Suppl. Oreg. State Off., Portland.

(284) Bureau of Land Management
1969. 6512-Wildlife--forest management. U.S. Dep. Inter. BLM Man.

(285) Chutter, F. M.
1969. The effects of silt and sand on the invertebrate fauna of streams and rivers. Hydrobiologia 34(1):57-76.

(286) Copeland, Otis L., Jr.
1965. Land use and ecological factors in relation to sediment yields. U.S. Dep. Agric. Misc. Publ. 970:72-84.

(287) Dyrness, C. T.
1967. Grass-legume mixtures for roadside soil stabilization. USDA For. Serv. Res. Note PNW-71, 19 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

(288) Evans, Willis A.
1960. The effect of current west coast logging practices upon fisheries resources. Soc. Am. For. Proc. 1959:106-108.

(289) Everts, Curtiss M., Jr.
1957. Water quality depends on good forest management. Soc. Am. For. Proc. 1956:199-201.

(290) Gebhardt, Gary A.
1970. The influence of stream disturbance activity on aquatic organisms--a review. U.S. Dep. Inter. Bur. Land Manage., 43 p., Salem, Oreg.

(291) Hall, James D.
1968, Effects of logging on fish resources. Loggers Handb. 28(Sect. II):24-28.

(292) Hall, James D., and James T. Krygier
1967. Studies on effects of watershed practices on fish. Fed. Water Pollut. Control Admin. Res. Grant WP 423, Prog. Rep., 95 p. Oreg. State Univ., Corvallis.

(293) Hall, James D., and Thomas G. Scott
1969. Recreational and esthetic values of wildlife in relation to forest management. *In* Hugh C. Black [ed.], Proceedings of a Symposium, wildlife and reforestation in the Pacific Northwest, p. 22-25. Oreg. State Univ., Corvallis.

(294) Hansmann, Eugene W.
1973. Effects of logging on periphyton in coastal streams of Oregon. Ecology 54(1):194-199.

(295) Herbert, D. W. M., and J. C. Merkens
1961. The effect of suspended mineral solids on the survival of trout. Int. J. Air & Water Pollut. 5(1):46-55.

(296) Hewlett, John D., and Alden R. Hibbert
1961. Increases in water yield after several types of forest cutting. Int. Assoc. Sci. Hydrol. Bull. 6:5-17.

(297) Jeffrey, W. W., and B. C. Goodell
1970. Land management in municipal watersheds. J. Am. Water Works Assoc. 62:380-385.

(298) Juntunen, Erland T., and Logan A. Norris
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