PROCEEDINGS

of the

SEVENTH SYMPOSIUM

on

WATER POLLUTION RESEARCH

WATER PROBLEMS IN WATERSHEDS

OF THE NORTHWEST

Assembled by

Edward F. Eldridge

Technical & Research Consultation Project

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE

Public Health Service

Region IX

Portland, Oregon

April, 1960

FOREWORD

In May 1957 the Public Health Service initiated the "Technical and Research Consultation Project" as a means of better reaching and serving those engaged in water pollution research in the Northwest. A series of symposiums have been held as one of the activities of this Project. The purpose of these symposiums is to provide an opportunity for a free and informal exchange of knowledge on subjects related to water pollution. The following is a list of the subjects covered by the seven symposiums held to date:

1. Research Relating to Problems of Water Pollution in the Northwest
2. Financing Water Pollution Research
3. The Slime (Sphaerotilus) Problem
4. Short-term Bio-Assay
5. Siltation - Its Sources and Effects on the Aquatic Environment
6. Oceanography and Related Estuarial Water Problems of the Northwest
7. Status of knowledge of Water Problems of the Northwest

These proceedings are compiled from the prepared papers and discussions of the seventh symposium held in Portland, Oregon on April 12, 1960. The agenda has four main parts each with a panel of persons with special knowledge and experience in the specific subject. These persons presented prepared statements which are included as given. The discussions were recorded and are abstracted in these proceedings.

SEVENTH SYMPOSIUM ON WATER POLLUTION RESEARCH, PACIFIC NORTHWEST

SUBJECT: Status of knowledge of Water Problems in Watersheds of the Northwest

DATE: April 12, 1960

PLACE: Room 104, U. S. Court House Building, S. W. Main & Broadway, Portland, Oregon

THEME: What do we know and what further do we need to know about watersheds as related to water quality.

AGENDA

Introductions

Purpose and scope of symposium, E. F. Eldridge, Public Health Service, Portland, Oregon

Item 1 Factors affecting water production in watersheds, (Types of Watersheds, precipitation, retention and runoff).

Item 2 Water supply watershed problems, (Domestic and industrial supply sanitation, turbidity, etc.)
E. J. Allen Seattle Water Department
H. Kenneth Anderson, Bureau of Water Works, Portland, Ore. (will show new color movie of Bull Run Watershed).

Item 3 Problems of the aquatic environment
1. Primary productivity - light vs cover
Homer Campbell, Oregon Game Commission
John N. Wilson, Public Health Service

2. Spawning and growth of fish
Chuck Ziebell, Washington Pollution Control Commission
R. L. Burgner, College of Fisheries, University of Wash.

Item 4 Correction or Control Through Management
1. Recreation
Wilson Bow, Washington Department of Health
2. Timber (Production, cutting, etc.)
W. K. Ferrell, School of Forestry, Oregon State College
3. Road and Highway Construction
R. L. Wilson, School of Forestry, Oregon State College
4. Mining Operations
Oregon Dept. of Geology and Mineral Industries
R. S. Mason

OPENING REMARKS

E. F. Eldridge

This is the seventh of a series of symposiums which have been held in this area on subjects relating to water pollution. The theme, today, is what do we know or need to know about watersheds and their management as related to the quality of water produced.

The watershed as considered in these discussions is not necessarily synonymous with drainage basin. We are largely concerned with the areas in the upper reaches of streams where a major portion of the water for downstream use originates.

Activities in watersheds, whether they be timber production and harvesting, agricultural, recreational, mining, road construction, or any other major operation, have a most profound influence on both the quality and quantity of the water produced. We cannot cover all of the influences in the time we have available. Consequently, we have selected two major areas for consideration, namely water supply and fisheries. The problems involved with these two uses of water from watersheds will be discussed, after which we will consider methods of correction through management. Since we are as much concerned with what we do not know, as with what we do know, we should not hesitate to point out the limitations in our knowledge. This, perhaps, may stimulate someone to undertake research to enlarge our information in order that we may better understand these problems and their solution.

To further stimulate thinking regarding research on the subject of watersheds, I have prepared a prospectus containing my ideas of the areas of needed study. This will be attached to the proceedings which will be sent to you as soon as possible after this meeting.

ITEM I

FACTORS AFFECTING WATER PRODUCTION IN WATERSHEDS

W. E. Bullard

What is a watershed?

Simply defined, a watershed is an area drained by a stream. A watershed may be any size, any shape, in any location. Today, we are primarily concerned with those watersheds producing water for use by man; - for domestic use, in industry, for irrigated agriculture, for recreation, and for development of hydroelectric power.

Where are the productive watersheds located?

In the Pacific Northwest, the moisture-bearing winds come from the Pacific Ocean on the west. As they are lifted in crossing the coastal mountain ranges, they drop a large part of their moisture load. This precipitation in the Coast Ranges is largely rain, except in the higher elevations of the Siskiyou Mountains on the south and the Olympics on the north. Rivers draining the Coast Ranges have a high yield; but most flow westward to the ocean through areas not yet extensively developed, and their waters are not intensively used.

The Puget Sound - Willamette trough just east of the coast ranges is in a rain shadow and receives much less precipitation than the mountains on either side. It is, however, an area intensively developed for agriculture and industry, and contains the bulk of the population of the Northwest. It is also the source of the greatest demand for and most intensive use of water.

East of this trough lie the high mountains of the Cascades along a north-south axis through Oregon and Washington. The western slopes of the Cascade Range face the moisture-bearing winds from the Pacific, and receive large amounts of precipitation both rain and snow. The westward draining streams have a high water yield and are intensively developed for hydroelectric power, irrigation, flood control, and recreation.

The east side of the Cascade Range receives fairly great precipitation, mostly as snow, on its upper slopes. This snowpack is the principal source of water for irrigation projects on the plateaus and in the valleys to the east.

Since the high Cascade Range collects so much precipitation, there is little left for the plateaus and valleys to the east which consequently are arid and entirely dependent on water from the mountains. Agricultural development is extensive, and the principal water demand is for irrigation.

Beyond the dry central plateau country, the Rocky Mountain chain trending northwest-southeast forms the eastern edge of the area. These again are high mountains, and receive considerable precipitation, mostly snow, though not as much as the Cascades. The vast headwater area of the Columbia River lies in these mountains, and most of the flow at Grand Coulee Dam is derived from the Rocky Mountain snowpacks.

Below the Grand Coulee Dam, the flow of the Columbia is doubled by water received from the much smaller tributary area in the Cascade ranges, and further increased by the Snake River. The greatest development and the heaviest demands for water lie along both sides of the Cascade ranges, and we may therefore consider the Cascade watersheds to be of most concern to us as well as being among the highest in water yield.

Physiography

Watershed size affects water yield. On the western slopes of the Cascades, watersheds as small as half a square mile will have permanent flow; though on the eastern slopes possibly two square miles would be the minimum for permanent flow. Obviously, the larger the watershed, the greater the precipitation catch and the greater the yield. However, there are many other modifying factors.

Shape of the watershed may be significant. A round or fan-shaped watershed with most of the component tributaries about the same length and joining at or near the same point will tend to have more rapid concentration of flow and higher peak flows than along narrow watershed with tributaries well spaced along the main drainageway. This is particularly important in considerations of flood possibilities.

Orientation of a watershed relative to sun, wind, and direction from which precipitation comes can be important. South-facing slopes are warmer than northerly slopes; snow melts sooner and faster, and evaporation and transpiration rates are greater on south slopes. Orientation may also affect runoff concentration times and flood peaks, particularly in long narrow watersheds flowing away from prevailing storm direction.

Topography, elevation, and gradient are also significant factors. Water moves faster from steep slopes than from gentle, and flows faster down steep channel gradients than on the flatter grades. Erosion hazards are greater on steep slopes, whether from soil creep, runoff, landslide or avalanche; and the cutting and carrying power of streams is a power function of channel gradient and velocity of flow. Since the higher elevations generally receive more precipitation, they generally produce more water. At the highest elevations where temperatures are low most of the precipitation is snow and the seasonal distribution of runoff is different.

Geology and soils

Geology may be a major control of topography and the surface movement of water, and of subsurface movement as well. Certain rock formations are porous, with large cracks and tubes through which water can flow underground. Both volcanic and limestone rocks are often of this kind. Other formations may have small cracks and fractures through which water can seep slowly. Still others are firm and practically impermeable. Though scarcely rock formations, the strongly cemented glacial drift of the Puget Sound area and the lake-deposited clays of interior regions are in the impermeable group. Water moves along the surface of such formations, rather than through them.

Covering the geologic structure in most areas is the soil mantle. Soil may be developed in place by weathering processes, or moved in by gravity, water or wind. In eastern Washington there are the wind-deposited soils of the Palouse area; fine-grained, well sorted silts.

In eastern Oregon there are extensive areas of wind-deposited pumice and volcanic ash from explosions of the ancient volcanos of the Cascades. In the lower John Day River drainage in eastern Oregon there are beds of lake-deposited materials with a rich fossil record. Every valley has its accumulation of soil brought down by gravity or water erosion from the slopes above and reworked and sorted by water into alluvial clays, silts, sands, and gravels. Some areas are barren rock, with soil particles carried away as fast as they are developed by weathering; but most of the land surface of the region has a residual soil developed by weathering in place.

Soil characteristics are to a great extent determined by Geology. If the parent rock is coarse-grained, so is the soil developed from it. Diorites and grandoriorites tend to produce sandy soils; shales to produce clay soils. Climate has its effects, too; - volcanic rocks in the wet coastal belt and on the west slope of the Cascades produce permeable loam to shot loam soils, but in the dry climate east of the Cascades produce fine-grained, less permeable clay soils.

Soil type and condition determine how much water will infiltrate, and how fast it will percolate to the water table. Well developed loamy soils with a high percentage of incorporated organic matter maintain a porous structure and can accept water at high infiltration rates and let it move along at a fairly high rate. Tight clay soils absorb some water from the surface, but tend to swell and become impermeable. Abused and degraded soils may become too compacted to permit percolation, and the surface may become puddled and sealed against infiltration. Compact soils freeze easily and to considerable depth; frozen soils is usually impermeable.

<u>Plant Cover</u>

Vegetation on a watershed exercises the greatest control on water movement. Leaves and twigs and branches of the plant crowns form a canopy that breaks the force of falling rain. Plant stems carry much of the intercepted moisture to the ground. Plant roots provide avenues for entrance of moisture into the soil. Litter from fallen leaves and twigs affords a protective barrier that cushions the impact of rain-drops and keeps the soil surface open and porous.

Any type of vegetation - desert shrub, grass, brush, woodland, or forest - has these effects. Strength of the effect will depend on density of the cover, and on the amount of litter deposited on the soil. Forest cover has the greatest effect but grass is also very effective. The tangle of aerial stems and the tight interlacing of the fibrous root system of a dense grass cover provide ample protection against erosion, a cushion against compaction, and insulation against freezing. It also furnishes sufficient organic matter to maintain soil structure, and the root systems keep the soil porous for rapid infiltration and percolation.

Forest cover provides shelter against wind and shade against the sun, permitting snow packs to accumulate and to melt slowly. Any plant cover provides protection against evaporation from the soil, though transpiration by the plants themselves may exceed evaporation losses.

Precipitation

Precipitation is the general term for moisture received from the atmosphere, whether fog drip, dew, rain, snow, sleet, or hail. Precipitation is the source of all water flowing from watersheds. Volcanic waters come to the surface in a few places, or are tapped by deep wells, but they are insignificant in terms of total water supply. Even these may at one time have been derived from precipitation.

Rain and snow are the most abundant forms of precipitation. Dew may occur more frequently, but is of minor quantity and significance in the Northwest. Strictly speaking, both dew and fog drip are directly condensed on vegetation and soil, rather than precipitated. Dew and fog drip may locally be important in providing moisture for plant growth during non-rainy periods, but do not add materially to useable water supply.

West of the Cascades and in the higher elevations to the east, precipitation is plentiful. Along the coast and in the valleys it is mostly rain, varying from 30 to 80 inches average annual fall. In the mountains and high plateaus it is mostly snow. Mountain snowpacks may reach several feet in depth and hold many inches of water, but over most of the region east of the Cascades total precipitation is less than 20 inches per year. Domestic, industrial, and irrigation demands in these drier areas depend on streamflow from water stored in mountain snowpacks.

Seasonal distribution of precipitation is dominated by the movement of storms from the Pacific Ocean. Most of the rainfall and snowfall comes in late fall and winter. Summers are dry, though in eastern parts of the region summer convectional storms provide some moisture. Mountain snowpacks accumulate during the winter, and melt in late spring and summer to maintain streamflow during much of the dry season. Peak streamflow in mountain streams - particularly east of the Cascades - usually occurs in late spring or early summer, well past the season of heaviest precipitation.

Rainfall intensity and snowmelt rates strongly affect runoff and streamflow peaks, though subject to control by soil and cover conditions. West of the Cascades rainfall intensity rarely reaches one inch per hour, and soil and cover conditions are generally adequate to accept and hold storm rainfall. In long-continued storms moisture storage capacity is exceeded and ground-water movement to streamflow is increased, but the soil and cover still exert a braking influence on the rate of movement. East of the Cascades, particularly in spring and summer convectional storms, rainfall rates occasionally exceed two inches per hour and cause local flash floods. Warm rain on snow on frozen ground is another frequent source of flash flooding, severe erosion, and mudflows. Neither type of storm adds much to useable water supply, except perhaps locally in stockwatering ponds and for meadow irrigation.

Wind and temperature

These climatic elements are significant with regard to snow melt rates and to evaporation losses. Warm winds hasten spring snowmelt. Dry winds increase evaporation from water surfaces and from soil, and stimulate high rates of transpiration from vegetation. Evaporation can remove soil moisture to a depth of more than a foot; in shallow soils the moisture held in retention storage against gravity will be lost either by evaporation or by transpiration.

Plants can use tremendous amounts of water if the water is in plentiful supply throughout the warm growing season. Plants along watercourses with their roots directly drawing on the permanent water table, do decrease significantly the water available to support streamflow. But plants on watershed slopes draw mainly on what moisture is in retention storage in the soil, to a lesser degree on water in temporary detention storage. Part of the plant take would be lost by evaporation, and the rest of it is a cheap price to pay for the benefit's afforded by plant cover. These benefits include protection against erosion, maintenance or soil structure for optimum infiltration and percolation, accumulation of snowpacks, and prolongation of the snow-melt season.

It is the protection against wind and temperature that is highly significant in snow zones. Small openings in the forest canopy permit deep snowdrifts to build up. Mechanical interruption of wind and provision of shade by the canopy extends the snowmelt season two to three weeks longer than on exposed areas. Forest is cooler in summer and warmer in winter than corresponding open area.

The Soil reservoir

Depending upon where one chooses to set its boundaries, the Pacific Northwest includes about 200,000,000 acres. Of this total, 65,000,000 is included in the drainage of the Columbia River. Perhaps 30,000,000 acres lie in British Columbia; and nearly 30,000,000 acres more in the Puget Sound and coastal areas of Washington and Oregon.

Over this 200,000,000 acres we may assume the average soil depth to be three feet. We may further assume that this soil averages 40 percent pore space, made up of three-quarters retention storage space, and one quarter detention storage space. The soil of the Northwest then has a moisture storage capacity of 0.4 x 3 x 200,000,000 or 240,000,000 acre-feet. Three-quarters of this is retention, and unavailable to support streamflow though it does have (by subtraction from water made available at the soil surface) a strong regulatory effect. One quarter, or 60,000,000 acre-feet, is detention storage space, from which water slowly percolates out to groundwater, springs and streamflow.

This 60,000,000 acre-feet is sufficient to provide an average flow of more than 80,000 cubic feet of water per second over the period of a year. Comparatively, this equals about four times the average annual flow of the Willamette River, or twice that of the Snake River. The soil detention reservoir is obviously quite important, though according to our assumptions it averages in water equivalent only 3½ inches depth.

At least a brief consideration of the disposal and replenishment of water in the soil reservoir is in order. Retention storage water is removed by evaporation and transpiration; it is in part replenished with each new rain storm, and during the spring snowmelt season. Detention storage operates only after retention storage space is satisfied, and is similarly replenished. If we enter the winter season with dry soil on the watersheds, much of the winter snowpack water content must go to satisfy retention storage deficits before there will be any surplus for streamflow.

Total stream flow in the Northwest is about double what we have estimated from soil detention storage. Since stream channels and lakes represent about one percent of the total area, they receive a certain amount of precipitation directly. During protracted storm periods and at times of rapid snowmelt the soil may be temporarily saturated; at such times there will be considerable surface runoff moving directly to streamflow. We do not know nor can we adequately estimate the amount of this runoff; it is possible, also, that the estimate of soil detention storage used here is too low.

Streamflow

The table below gives information on flow of several major streams of the Northwest.

	AVERAGE ANNUAL YIELD			
River	Drainage Area	Flow	Depth on Watershed	Volume
	sq. miles	cfs	inches	acre-feet
Skagit	2,970	16,200	74	11,700,000
Cowlitz	1,170	5,210	60	3,760,000
Willamette	7,280	22,100	41	15,670,000
Umpqua	3,680	7,066	26	5,106,000
Deschutes	10,500	5,826	8	4,210,000
Grande Ronde	2,555	1,967	10	1,422,000
Upper Snake	35,800	10,530	4	7,654,000
Clearwater	9,570	14,410	20	10,439,000
Kootenai	13,700	14,500	14	10,479,000
Methow	1,810	1,660	13	1,230,000
Yakima	3,560	3,840	15	2,780,000
Spokane	4,350	6,930	22	5,010,000
Columbia (Dalles)	237,000	194,600	11	140,637,000

Variation around these averages from season to season is considerable. Over a long period of record for most streams the low water year yield is about 60 percent of the average, and the high water year yield about 160 percent of the average.

The figures on "depth on watershed, inches" show where the most productive watersheds lie. The Skagit, Cowlitz, and Willamette Rivers all drain the west side of the Cascade Ranges. Streams from the Olympic and Coast Ranges would show similar figures. The Methow, Yakima, and Deschutes Rivers draining the east side of the Cascades show much lower values. The Spokane and Clearwater Rivers draining the western Rockies are a little higher. The Snake River, draining a large area of desert as well as a part of the Rockies, has comparatively low yield.

<u>What can we do to control water production?</u>

Of the various factors we have considered, there are three upon which we can exercise some control. On one of them - the soil - the control is mainly negative or preventative. In its natural condition not subject to use or development by man, most soil is deep and has as good hydrologic characteristics as may be expected for the climate and cover and parent material that produced it. Under use, the plant cover may be removed and the soil eroded so that soil depth is decreased. The soil may be covered by impervious construction, and given no opportunity to absorb water. The soil may be compacted by the trampling feet of many grazing animals, or by the vibration of heavy machines when it is wet and soft, and lose its porosity. Denuded, less porous soil has low acceptance for infiltrating water, and low transmission capacity; shallow eroded soils have less total storage capacity. Proper management avoids soil degradation. Rehabilitation can restore some of the desirable hydrologic characteristics, improving infiltration and percolation and total storage capacity, but the process is slow and expensive. Degradation, however, may be rapid and have severe effects even within a single season.

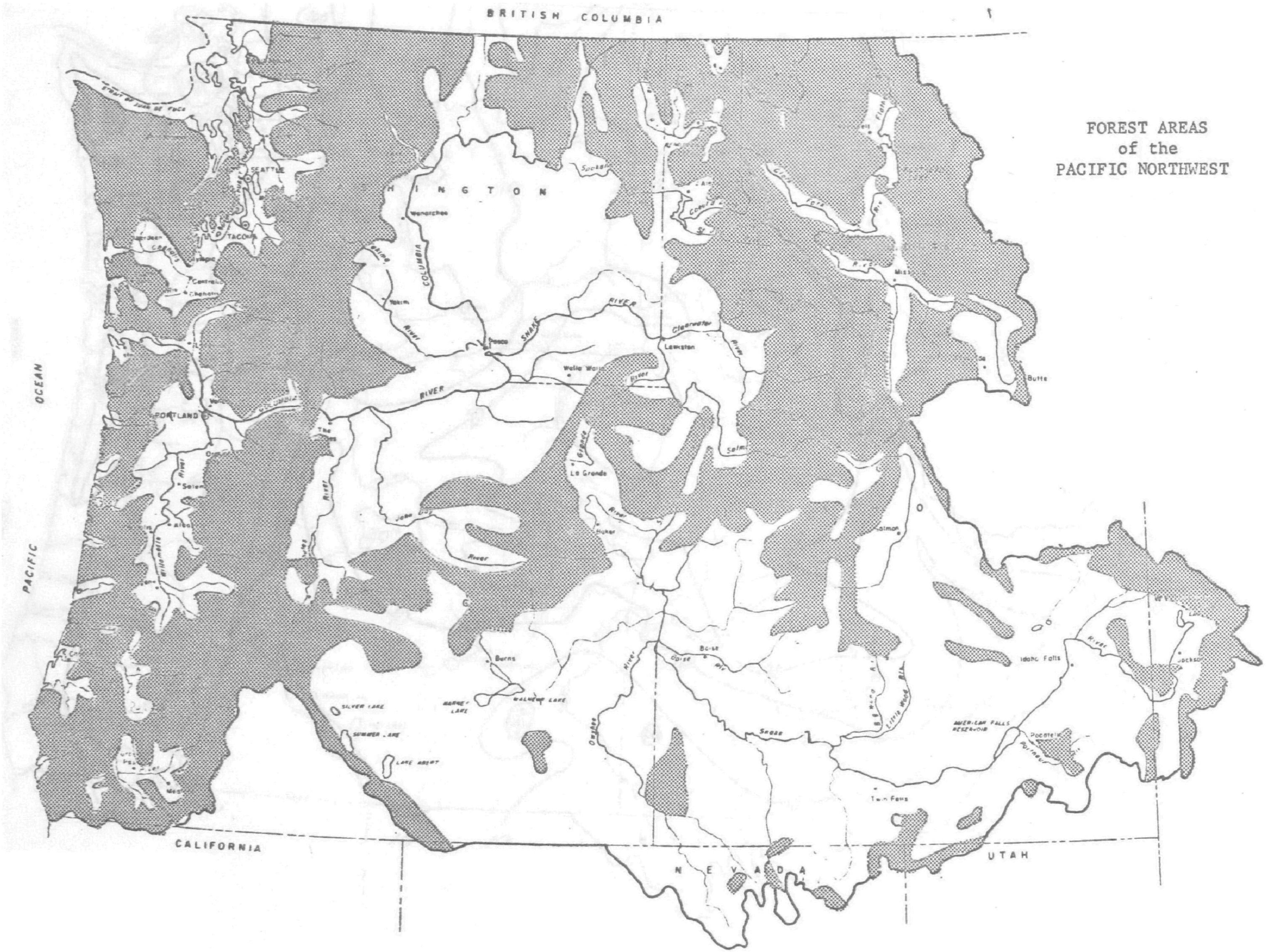
On the positive side, particularly in the timber harvest, it is possible to control the size and shape and location and orientation of openings in the forest. These things strongly affect water yield from snow country. Studies in the Rocky Mountains in Colorado indicate nearly ten percent increase in water yield from forest openings in narrow strips normal to prevailing wind direction. Part of the increase may be attributed to reduced transpiration draft on soil moisture, but much of it came from increased snow catch and shading of the snowpeak that reduced evaporation and sublimation loss. Several studies, both here and in Europe, indicate that the ideal cover for snow catch and retention to improve water yield is forest with numerous small openings of an acre or two in size. In the Douglas-fir region west of the Cascades and in the high-elevation mixed conifer forest elsewhere, the usual patch clearcutting system approaches this idea. A little more planning as to shape and orientation of the clearcut patches, and restriction in size to what can be logged from one setting, and we have accomplished it.

Fire control and pest control help maintain forest cover. We already have and will continue these control programs in the interest of timber supply, but they work equally well in the interest of watershed protection and maintenance of water yield.

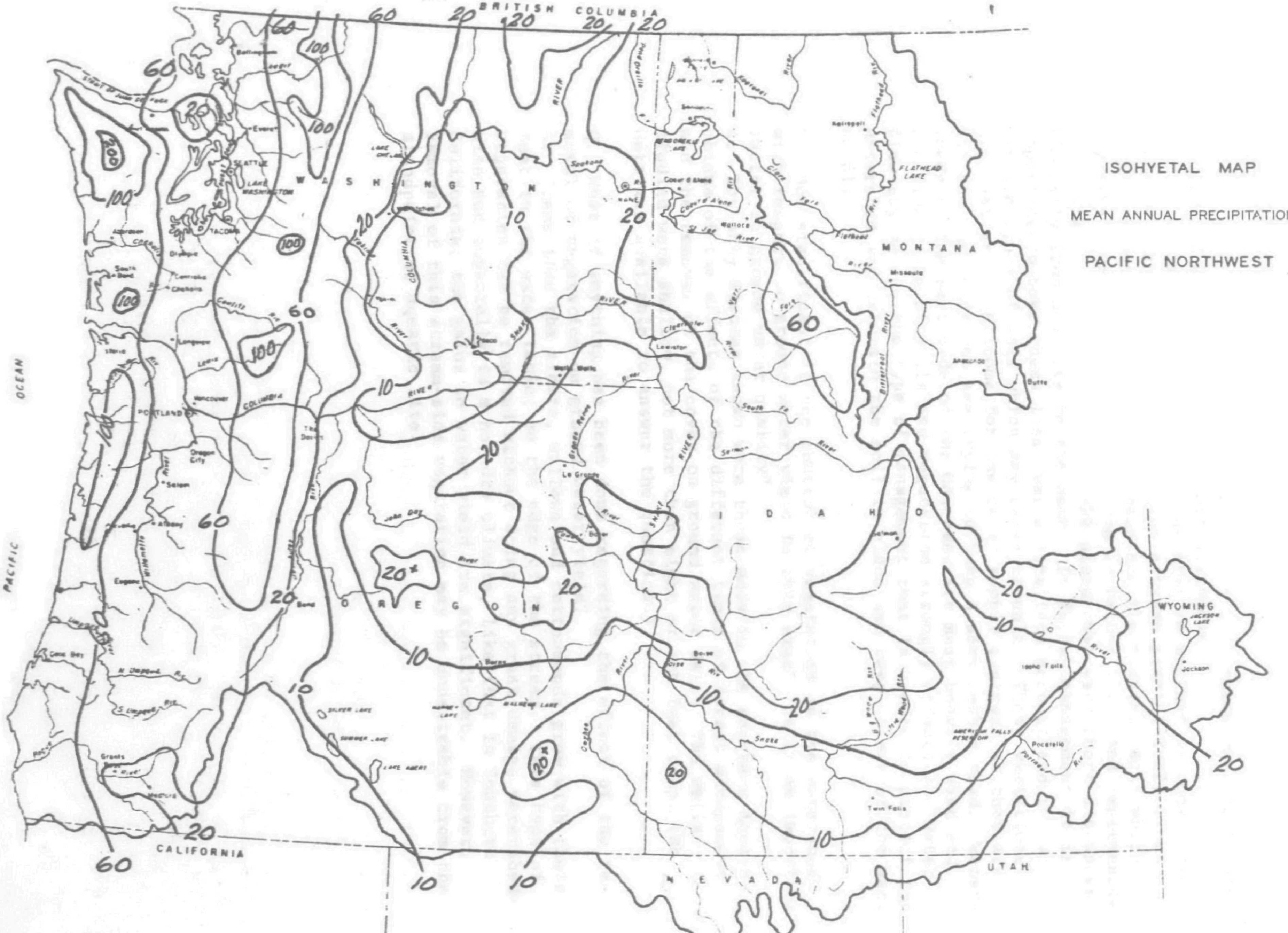
Rehabilitation of areas denuded in the past by fire or grossly degraded by long-continued overgrazing is proceeding, but at a rate too slow to accomplish all the needed work in the near future. This program offers definite benefits in terms of reduction of erosion, control of flash floods and sedimentation, and improvement of water quality. It deserves to be speeded up; the more so because even with the work completed, the development of good cover and the restoration of desirable soil conditions is a gradual process.

The last item of control of water yield factors is more or less in the "possible but not fully proved" category. This is weather modification by means of cloud seeding to produce rain or snow in above-normal amounts. Cloud seeding is currently in use, and undoubtedly will show greater potential as we learn more about it. It is also used to break up electrical storms to reduce hazards of lightning-started forest fires.

The greatest returns, though, still would be those gained through enlightened management of watershed cover and soils.



FOREST AREAS
of the
PACIFIC NORTHWEST


ISOHYETAL MAP
MEAN ANNUAL PRECIPITATION
PACIFIC NORTHWEST
BRITISH COLUMBIA
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
NEVADA
UTAH
CALIFORNIA
PACIFIC OCEAN
SEATTLE
TACOMA
PORTLAND
Spokane
Lewiston
Walla Walla
La Grande
Boise
Missoula
Butte
Idaho Falls
Pocatello
Twin Falls
Jackson
FLATHEAD LAKE
COLUMBIA RIVER
SNAKE RIVER
200
100
60
20
10

DISCUSSION - ITEM I

Q. Would it be of any value to point out the tremendous variations in types of soil, even within short distances?
A. The variations in soils from one area to another is considerable. There is a sharp line of demarcation between glacial drift flows which are quite permeable and porous and the mountain soil which may vary from reasonably coarse loam to rather light and impermeable silty clay. These changes can take place over very short distances, literally from one acre to the next. In forest management it is important to take these local variations into account and to avoid certain types of soil which may cause trouble. These variations are just as troublesome for the water supply engineer as they are for the engineers who are trying to keep a serviceable road. Watersheds on the east side of the Cascades are most heavily used and the wide range of soils and vegetation strongly affects the water flow regime and the type of management that is needed to protect the watershed and maintain the soil in place and keep it out of the water-supply.

Q. How significant is the control of vegetation in the watershed with respect to ground water yield in this area? Is it an important factor in ground water quality?
A. The only studies known were those made in the southern Appalachians of the effects of the different types of forest management and the removal of the cover on ground water data. The wells studied were shallow, not more than eight or ten feet deep. (No data was available to answer the question.)

Q. What if anything has been done regarding the effect of the removal of vegetation on ground water yield?
A. Trees like the alders, willows and cottonwoods grow with their feet in the water table, on the edge of the stream. This type of vegetation can be removed without doing any great damage watershed-wise and especially in a hot dry climate, like that in Southern California; the gains in water yield are significant. However, removal of this stream-side vegetation may be undesirable from the standpoint of aquatic life.

ITEM 2a

WATER SUPPLY WATERSHED PROBLEMS - SEATTLE WATERSHED

E. J. Allen

Suppliers of water for domestic use have the moral responsibility of providing a safe, potable water reasonably cool in temperature, sparkling clear, free from tastes and odors and adequate in quantity to meet not only the average demands, but peak hour requirements as well. Federal and State statutes establish specific bacteriological standards and chemical constituent limitations. Industrial water requirements often impose more restrictive limitations of clarity and chemical constituents.

Surface waters are subject to variations in quality factors. Watershed conditions which cause major variations of water quality are a particularly vexing problem to suppliers of water. Water treatment facilities are engineered to properly treat water within predetermined limits of quality variation based upon the type of water and history of its quality.

Watershed activities which have a deleterious effect upon the quality of water used for domestic or industrial purposes or materially deplete the quantity required, are the source of the watershed problems.

One of the major problems is turbidity, a conditions which can be related to introduction of wastes into streams, presence of microorganisms, disturbance of soil, removal of cover crops and erosion. A turbid water requires more extensive and costly treatment for proper conditioning. Few domestic water supplies in the Pacific Northwest presently require complete treatment and filtration with the accompanying average construction costs of $100,000 per million gallons capacity and $14. to $15 operating and maintenance costs per million gallons of water treated. Removal of soil cover through over grazing of watershed range lands is one of the problems causing turbidity.

Road location and construction pose problems stemming from foundation stability and soil overburden. Excessive cuts and fills, steep gradients, rapid drainage concentrations, improperly sized or located culverts and drain ditches create the potential for increased turbidity.

Logging operations can be responsible for stream turbidity if improperly planned. The layout of cutting boundaries, landings and roads, giving consideration to the topography and soil is essential to avoid turbidity. Tractor logging on steep slopes or across water courses are potential causes of turbidity as are undrained skid trails or leaving abandoned skid trails without water bars.

The burning of slash and forest fires are potential causes of turbidity problems; the resulting destruction of duff and organic matter leaves an unprotected soil, easily eroded by rains and snow run-off. Public highways crossing watersheds also provide the potential for forest fires as well as sanitary problems. That public highways pose a problem is evidenced by the following excerpt from a letter addressed to the Superintendent of the Seattle Water Department by J. A. Kahl, Acting State of Washington Director of Health, "In considering the potential effects on water quality of the proposed highway construction through the Cedar River watershed, the most significant factors will be the sanitary quality and turbidity."

Too often we are inclined to think of watershed sanitary problems only in terms of bacteria. Of course water borne disease producing bacteria are a continuing problem; as recently as November, 1959, Keene, N. H. experienced a typhoid epidemic with resulting deaths, traceable directly to watershed activities. Evidence points to water as the mode of transmission for many diseases both bacterial and virus, such as Infectious Hepatitis.

Recreational use of domestic and industrial water supply--Watersheds pose not only the sanitation and fire problem, but also the problem of legal liability to the property owners. The compatibility of recreational uses and water supply are directly related to the existing water quality. Major treatment problems arise from recreational use of certain watershed areas. Those waters normally requiring full treatment and filtration would be little affected, but those waters of such natural purity as to require only chlorination would require additional treatment as proper safeguards against the effects of pollution.

Public access to domestic supplies offers the potential for communication of waterborne disease. Habitation exists on some watersheds, thus creating the problem of wastes disposal, a constant source of concern to suppliers of water. Similarly the problem of sanitation in watershed work areas requires constant vigilance.

Today man is faced with many new and exotic chemicals of complex organic composition which are being used as cleansing agents, pesticides, insecticides, weedicides and fertilizers. Very little is known concerning the long term build up of these chemicals or the effects. Certainly the use of such complex chemicals should be limited to areas some distance removed from water courses or impoundments. Experience has shown that some of the unsaturated hydrocarbon ring compounds do combine with chlorine, commonly used for water purification, to produce most unpleasant tastes.

Tastes and odors are usually considered as an aesthetic aspect of water quality; our living standards today demand full consideration of the aesthetic values. Most tastes and odor problems of water supply are linked to algae which exist by virtue of adequate food supply and proper environment of light and temperature. Decaying organic material provides the required food supply. Shallow inundated areas created by beaver dams and logging debris in streams are problem areas and locale for taste and odor problems. Deciduous trees adjacent to water courses and impoundments not only through their falling leaves provide the organic material for algae growth with resulting taste and odor problems but alder being subject to caterpillar infestation has created filth problems from the caterpillars.

A little known yet factually documented source of a taste problem has been the burning of alder slash at a time when rain carried the tars and compounds from the smoke into a source of water supply; subsequent application of chlorine to the water produced a strong phenolic taste.

Many of the watershed problems can of course be resolved by suppliers of water through treatment process of various kinds. Such steps create the economic problem of costs and in no way does such treatment resolve the effect of pollution upon the streams, lakes or impoundments. The problem of proper management remains also the problem of securing the greatest total contribution to the public needs.

From the foregoing recitation of water supply watershed problems it becomes apparent that multiple uses of our resources must be managed to prevent conflicts of use and encourage compatible uses. Multiple use has been described by J. Herbert Stone, of the United States Forest Service (proceedings 38th Washington State Forestry Conference 1959) "as a principle rather than a system of management. As a principle it does not have a precise or universal meaning for every area, nor is it applied to small areas." Charles A. Connaughton in his article "Wise Use of Wild Lands" (Proceedings 49th Western Forestry Conference, 1958) states, "Multiple use is a concept of Management, not a system...it presupposes that an area of land from which a series of uses or services can be obtained will be managed to secure the greatest total contribution of this land to the public need."

The moot questions in solving watershed problems are economic and involve proper planning and management.

ITEM 2b

WATER SUPPLY WATERSHED PROBLEMS - PORTLAND WATERSHED

H. Kenneth Anderson

Mr. Anderson showed a recently developed color film entitled "The Bull Run Story" which contained excellent pictures of the watershed which serves the city of Portland, Oregon.

A brochure on "Water Supply, Portland, Oregon" is attached as an addendum to these Proceedings through the courtesy of Mr. Anderson and the Portland Bureau of Water Works.

DISCUSSION - ITEM 2

Q. Was the taste of the water in Vancouver caused by the burning of the alder slash?
A. The slash was burned on the banks above the high water elevations. The smoke from the fire carried over the impoundment and an air inversion probably pushed it down close to the water, with the rain falling. These factors were described as being the source of phenolic tastes and odors. The problem ceased when the burning was limited to times when winds would carry the smoke away from the water impoundment and when there was no rain.

Q. Have other cities in the Tacoma-Seattle area experienced tastes that might have been due to the burning of slash?
A. Slash is not burned in the Seattle watershed. Access is restricted and any access into the area is controlled, therefore, the watershed is not subject to carelessness which causes fires. In the long run it is considered better economics not to burn. Burning destroys the ground cover and in a sense sterilizes the soil and retards future growth of trees. The logging slash is allowed to lie and decay which provides better restoration of the trees.

Q. What is your policy in Portland regarding the burning of slash?
A. Practice in the Portland area is to burn only the smaller diameter items and the debris. No problems of taste have been experienced.

Q. What is the minimum and maximum dosage of chlorine applied?
A. The minimum meets the standards of the States and the Public Health Service. The maximum is the amount which can be applied without too many complaints from the public. The water is soft and non-buffered. Some problems with minor chlorine tastes and odors are experienced, due to the interaction of the chlorine with algae and micro-organisms. A residual of 0.2 ppm is carried in the distribution system.

Q. To what extent is recreational use of watersheds compatible with city water supply?
Q. It depends entirely upon the availability of other recreational areas. In areas where there are ample recreational facilities there is no reason to carry recreational facilities into watershed areas used to supply water for human needs. It is commonly accepted that domestic water supplies for people is the highest use of water and the highest use of the watershed. Logging and timber production is compatible as long as the people and the manner in which they cut timber and develop the watershed is controlled without adverse effect on watersupply. Where complete treatment and filtration is available there probably would be

little ill effect from various types of recreation. In cases where no facilities for filtration or treatment are available the expenditures of considerable sums of money to add those safeguards might not justify opening the watershed to recreation--in areas where ample facilities for recreation are available.

Q. Recently the East Bay area in California has opened their watershed to recreational use. The principal problem is turbidity, primarily arising from the runoff of watersheds into the local storage reservoirs in the East Bay and San Francisco areas. Comment?
A. No doubt the City of San Francisco will ultimately have to provide treatment. On the basis of a recent economic analysis it will cost the City of San Francisco about 10% more to provide treated water, because of the difference in size, it might cost Seattle 30% more.

Q. Is this price worth paying in order to assure water of high quality?
A. It is essential to have water of continuing high quality. Two factors are often controlling, namely pressure groups and politics. Some persons in the East Bay district have definitely been opposed to the utilization of the watersheds for recreation. However, they usually agree that the day will come when the pressures will be so great that it cannot be avoided and it will probably be so in the Pacific Northwest too. It cannot be avoided, but the first consideration is to protect the watersupply.

Q. Is there any danger of fire damage by leaving slash on the ground?
A. There is no danger as far as the slash is concerned. There is always the possibility of lightening starting fires by striking a snag. The greatest hazard in the burning of slash comes from the access of people into the area, the careless handling of trucks, or the use of equipment without proper spark arrestors. These factors are easily controlled.

Q. Is there greater problem about planting of the area, if this slash has been left on the ground?
A. No, planting is usually done by seeding, as opposed to the use of nursery stock, since the seed is now treated to prevent destruction by rodents. You just can't afford to plant by hand except in those areas which will not support seed growth or seed germination.

Q. Isn't it true that numerous times water users, in what they like to consider the highest applicable use, normally go all out to protect their source, but yet have complete disregard for downstream users who also get their domestic water supplies from the same streams.
A. That is right. That is just exactly why there is a need for proper management and why full consideration must be given to

to multiple uses in order not to infringe upon or cause hardship to other people. This matter of opening water supply watersheds to recreation is a real problem for the Forest Service. The Service manages many of the productive watersheds and the problem is becoming acute.

The people who use the watersheds for water supply are the same people who are asking that these watersheds be open for recreation. These are the ones in the long run who will determine what is done. If they want to invade the watersheds then they are going to be faced with the problem of paying for the complete water treatment which may cost about one hundred dollars per person for the initial installation and about ten dollars additional per year thereafter. It is strongly indicated that in the not too distant future these areas will be opened to public recreation.

ITEM 3a

PROBLEMS OF THE AQUATIC ENVIRONMENT PRIMARY PRODUCTIVITY

John N. Wilson

We have noted earlier in this symposium that the characteristics and patterns of usage of watersheds are basic to an understanding of the quantity and quality of the waters in question. To the hydraulic engineer, river forecaster and water supply specialist, the matter of total available quantity of water and seasonal flow characteristics are of paramount importance. The quality of water is of lesser importance except to the water supply specialist who is responsible for supplying a pleasant tasting product to his customers.

But to the fisheries' biologist, the ecologist, the physiologist and water pollution research specialist, this mere quantity-quality consideration is only a part of a much larger concept inherént in all waters: the aquatic environment, or, to quote famed Izaak Walton, "the watery realm."

As water issues from springs it may be devoid of all life, but usually contains some minerals in solution. As water flows toward the seâ more minerals are added by additional springs and from runoff and soon small species of green algae including diatoms appear to start the "web of life" or food chain by using the dissolved minerals. The first step in energy transformation is relatively simple. Radiant energy from a single source - the sun - is fixed by these photosynthetic plants as chemical energy in a variety of organic compounds. This constitutes the primary production of the aquatic ecological system (ecosystem). The net product so formed supports the pyramid of other organisms in the food chain with fish at the top.

There is another important source of energy in Pacific Northwest streams particularly, that contributes to the overall production, bypassing the stage of primary production just described. Organic matter from erosion of top soil, dead leaves, and rotting timber provide food for bacteria, fungi, single-celled animals, stream bottom insects and fish. In streams such as those in the Alsea watershed of western Oregon which are presently under study by Oregon State College and other cooperating agencies, a sizeable portion of the productivity in the headwaters streams is attributed to this so-called allochthonous organic matter - as over against autochthonous organic compounds that originate from the primary producers.

The shading of steep canyon walls and dense foliage creates a virtual "tunnel effect" in many headwaters streams of the Cascade and Coastal ranges. The heavy moss and humus cover, profuse herbaceous shrub and tree growth contributes substantial amounts of organic material. Primary producers are present in the form of diatoms and other thread and plate-like green algae attached to rocks on the stream bottom. True plankters that grow independent of the stream bed are few in number.

Streams such as these in the headwaters of mountain ranges close to the sea serve principally as spawning and nursery areas for anadromous fish, silver salmon and steelhead, and for some resident trout. Owing to the low content of dissolved inorganic salts from the igneous rocks and extensive shading, there is a tendency to low primary productivity. Fish spawned here depend upon more productive waters for completion of their life cycle - the middle and lower reaches of streams, or the ocean itself. Silver salmon in the Pacific Northwest normally complete their sojourn in fresh water in little more than a year.

In Iceland where the streams are poor in nutrients and there are no trees, the Atlantic salmon require up to six years to develop from spawning to time of migration to the sea. In all that time, they grow a scant four to six inches in length and are thin. As soon as they reach the rich waters of the sea, they fairly "explode" - attaining a length of about two - three feet and an an average weight of fifteen pounds in one year!

The aquatic environmental factors that favor the production of fish also influence the capacity of streams for the assimilation of wastes. Thus the water pollution research worker has an interest in primary production and the whole food chain that ensues. In Odum's paper entitled "Primary Production in Flowing Waters,"* there is an excellent discussion of measurement of primary production and the relation of this phenomena to stream pollution. The interplay of photosynthesis and respiration are discussed in connection with downstream succession in polluted and unpolluted streams.

Odum further discusses productivity of streams in comparison with that in lakes and the ocean. The earlier concept of standing crops of fish and intermediate links in the food chain as a parameter of production has been supplanted by measurements of rate of production. This is accomplished by determining the rates of oxygen - versus carbon-dioxide production, i.e. the metabolism of a body of water.

To sum up: the understanding of primary aquatic production is the key to wise multiple use of our waters.

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*Odum, H. T., Limnology and Oceanography - 1 (2): 102 - 117.

ITEM 3b

PRIMARY PRODUCTIVITY

Homer Campbell

From the previous discussion it is apparent that while primary productivity is an important link in the aquatic food chain, those in fisheries managment have given this link very little consideration.

One of the principal uses of water is that of maintaining an adequate commercial and sports fishery. This year, for instance, there will be about 400,000 people buying fishing licenses in the State of Oregon. This situation will be duplicated in other areas of the Northwest and the numbers are expected to increase about five per cent per year. It is the responsibility of fishery agencies to maintain a fishery which will adequately serve this demand and a fish population can be no better than the potential stream productivity.

It is of interest to note that while ecologists and botanists have been concerned with the basic study of productivity, those in fisheries management have been occupied with the writing of a history of the effects of the decline of fish populations without knowing the causes.

The Northwest is in an era of rapid development. This development will affect fisheries largely by changing the basic ecology of habitat. It is not enough to know that salmon and steelhead are on the decline, or holding their own, or that they will perish. It is necessary to know and understand the factors involved in primary biological production in order to better manage and maintain these species.

There are a number of definitions for the term primary productivity, two of which are discussed here.

1. Basic or primary productivity of an ecological system, community or any part thereof, is defined as the rate at which energy is stored by photosynthetic and chemo-synthetic activity of producer organisms (usually green plants) in the form of organic substances, which can be used as food materials. This is the beginning of the food chain in water. The ultimate animal consumer is the fish. Primary productivity can be "gross," which is the total rate of photosynthesis, including the organic matter used up in respiration during the measurement period, or it can be a "net primary productivity" which is the rate of storage of organic matter in plant tissue in excess of the respiratory utilization by the plants. There are a few ecologists and botanists who have studied productivity, but few fisheries people understand the various aspects of basic primary productivity.

2. A definition by Dice is similar, "The ultimate limit of productivity of a given ecosystem is governed by the total effective solar energy falling annually on the area, by the efficiency with which the plants in the ecosystem are able to transform this energy into organic components and by these physical factors of the environment which affect the rate of photosynthesis."

There are very definite differences between primary productivity in the higher watershed streams and in ponds or lakes. In general, these differences revolve around three conditions: (1) the current is much more of a major controlling and limiting factor in streams (2) land-water inter-change is relatively more extensive in streams, resulting in a more open ecosystem, and (3) oxygen tension is generally more uniform in streams and there is little or no thermal or chemical stratification.

(1) Velocity of the current varies greatly in different parts of the same stream (both longitudinally and transversely to the flow) from one time to another. In large streams the current may be so reduced that virtually standing water conditons result. Current as a primary factor, however, makes a big difference between stream and pond life and it governs differences in various parts of a given stream. Where fish are concerned or where the general nature of the stream community over an appreciable stretch is being considered, the surface gradient alone gives a good index of average conditions. Correlations have been developed regarding the species of fish and stream gradients on the basis of their natural and inherent life requirements.

(2) Land-water interchange: Since the depth of water and cross-sectional area of streams is much less than that of lakes, usually the land-water surface junction is relatively great in proportion to size of the stream habitat. Streams, therefore, are more intimately associated with the surrounding land. Studies are underway in the Alsea drainage basin in Oregon to relate fish populations to the physical attributes of the watersheds. The watersheds are short, yet they contain most of the factors involved in larger streams including the light intensity and cover situations as related to productivity. It is already apparent that conditions in the main stream are dependent upon what happens in these very small watersheds.

Most larger streams depend on land area and on the connected ponds or lakes for a large portion of their basic energy supply. Small streams, however, have producers of their own, such as fixed filamentous green algae, diatoms, and aquatic mosses; but these are usually inadequate to supply the large populations of consumers found in streams. Many primary consumers in streams are detritus feeders which depend, at least in part, on organic materials which are swept or dropped from terrestial vegetation.

(3) Oxygen: Because of the smaller depth, larger surface exposed and constant motion, streams generally contain an abundant supply of oxygen, even when there are no green plants. For this reason the stream animals generally have a narrow oxygen tolerance and are especially susceptible to any type of organic pollution which reduces the oxygen supply.

Although surface water in streams may be saturated with oxygen, the interchange between the stream and the subsurface gravel stratum will not necessarily create high oxygen levels beneath the surface of the gravel. Interchange is dependent on the permeability of gravel, the gradient of the stream and configuration of the bottom. The bio-chemical oxygen demand in streams will affect the levels of oxygen beneath the surface. Wide variations in subsurface oxygen content have been recorded in the Alsea watershed where repeated measurements have been made.

One of the objectives of the Alsea watershed study is to be able to predict the effects that might occur in any particular stream when the natural virgin cover is removed by logging. It is important to know what happens in streams in areas that are being stripped of their timber, in relation to water quality, quantity and the ultimate production of fish. It is hoped that future studies will add to the presently limited knowledge regarding the function of primary productivity in the aquatic food cycle.

DISCUSSION ITEMS 3a and 3b

Q. Is there evidence that the changes in primary productivity could be the cause for the decline of fisheries?
A. Such evidence is not clear because of the lack of direct information.

Q. Is there a relationship between primary productivity and yield of fish?
A. Of course, there is a relationship, but again there is no ready answer as to its magnitude. For instance, there is evidence that the production of silver smolt correlates with minimum flows. It is possible also to observe a relationship between any one factor, such as temperature, flow, chemical content, number of aquatic insects and the poundage of fish. One creek under study in British Columbia was found to produce about 100 silver smolt per 100 square yards. In a second creek the production was around 40. Other streams in other parts of the coast produce about 20 smolt per 100 square yards. The latter appears to be a fair average and one from which to start in making comparisons. This figure is about the same as obtained for Atlantic salmon in Scotland and in Eastern Canada.

Q. How is primary production measured?
A. Making such measurements is probably the biggest drawback in approaching this problem. It largely involves a measure of light energy vs production. Oregon State College is developing a photo-chemical actinometer as a means of light energy determinations. Primary production largely involves a measure of organic material produced by photosynthesis. To make such determinations in 150 to 200 places along a test stream is expensive, if proper equipment is used. Further research is needed to develop less expensive equipment and less complicated methods before adequate information can be collected on the subject of primary productivity.

ITEM 3c

PROBLEMS ASSOCIATED WITH SPAWNING AND GROWTH OF SALMONIDS IN NORTHWEST WATERSHEDS

Charles D. Ziebell

1. Introduction

In the past twenty years or so, applied fishery research and improved management techniques have done much to provide more fish to many of our various fisheries. This is general common knowledge among men in the fisheries field. However, even with the utilization of the newest innovations in fisheries science, some fisheries have shown a decline. Some of our anadromous fish fall into this category.

Many opinions have been expressed concerning the cause of the decline of some of our fishes, particularly the Chinook Salmon. These causes may differ from one area to another. Blame is often placed on over-fishing, pollution or some other factor, but too often the watershed with its spawning tributaries is completely overlooked. The assumption is made that conditions are adequate for normal reproduction and sustenance of the fishery. This, however, may not be true and before any premature conclusions are made, spawning and rearing areas for salmon and trout in our watershed streams require investigation. This possibly could be the origin of a problem.

Our problems in watersheds fall into two basic categories, one being that of natural influences and the other of man-made influences. The natural influences such as adverse weather conditions, of course, we are not able to control. On the other hand, the man-made changes that influence spawning and rearing such as poor logging or farming practices, or highway construction can be prevented or controlled so that no deleterious effects are experienced by our fish. Regardless of whether or not the problems are natural or man-made, they are still problems and cannot be overlooked.

2. Spawning, Incubation and Affiliated Problems

Today we are concerned with the problems that exist in the spawning and rearing tributaries of the watershed. Let us delve into these particular areas in more detail. In my discussion, I shall be referring to theSilver Salmon, primarily because this is the species that we have been studying.

The first of the two influences that I mentioned, namely natural, I shall mention briefly because Mr. Burgner will go into more detail in his presentation. Silver Salmon most frequently prefer to spawn in depths of water between one and two feet. Also, they prefer to spawn where water velocities are between 1.2 and 1.8 cubic feet per second. From this you can plainly see how heavy rains could delay or disrupt spawning activities. Another natural phenomenon that must be recognized is that of occasional superimposition of redds. This is normally experienced on desirable spawning beds. The eggs deposited by the initial spawners are relocated or completely extruded from the original redd by the spawning activities of other salmon coming in afterward. Consequently, eggs may be destroyed and high mortalities could result. These aforementioned influences are natural, and actually there is very little that we can do to prevent their taking place, however, they must be recognized and properly evaluated in any watershed research.

Man-made influences on the environment are another situation and certainly must be given due consideration. There are many of man's activities that have an influence on the environment in and surrounding our spawning and rearing streams; namely, logging, dam construction, farming, highway construction, and building of roads for logging operations.

When uncontrolled logging occurs in the upper regions of a stream where our salmon spawn and rear, there are many things that could be harmful to fish spawn or to young fish as they are rearing. Quite often logging commences directly adjacent to the spawning tributaries, and heavy equipment may be run through the stream bed where fish are spawning or have spawned. Stream banks are denuded, slash is thrown into the creeks, and silt and organic debris can be washed into the stream beds when rains occur. These poor logging practices and operations can drastically change a stream's ability to be a good fish producer. The clearning of brush and trees along a stream reduces or eliminates shade, and consequently may increase water temperatures to a point that a problem would result in the late summer. Improperly constructed logging roads usually are subjected to erosion by heavy rains and silt finds its way to the stream bottom. Excessive siltation can destroy good spawning beds, and may also reduce food populations on which young salmon or trout depend for their livelihood during their stay in fresh water. The abnormal deposition of organic detritus and inorganic silt are the two substances with which we are primarily concerned.

After excessive logging or poor logging practices have taken place and heavy rains occur in the fall, the fine silt from the logging roads and the organic debris that is washed into the stream has a tendency to work its way into the gravel. If deposition is heavy enough, it will actually cover the desirable spawning beds. This silt finds the interstitial spaces in the gravel, greater compaction results; and a reduction in permeability is experienced. With this reduction in permeability, the retarded sub-gravel flow influences two of the basic factors that fish spawn need for proper incubation. These are sub-gravel dissolved oxygen and percolation. With the addition of excessive siltation, dissolved oxygen is either limited or reduced to the stage where it is actually detrimental to proper survival of the eggs themselves.

Now one might ask, "What if there is low permeability in the stream? How is that going to affect the dissolved oxygen?" We know that water can be in a quiescent state and still maintain adequate dissolved oxygen. So there must be some influence by which the oxygen must be reduced. The abnormal deposition of organic debris and detritus washed into a stream normally will work its way into the gravel and consequently will become part of the stream bed itself. With the reduced sub-gravel flows caused by excessive siltation and lack of or reduced percolation, this organic material is subject to bacterial decomposition. If there is not enough percolation in the gravel to renew the redd with oxygenated water, then the bio-chemical oxygen demand becomes greater than that of replenishment. The result is plain. Oxygen values are often reduced to levels at which they can be detrimental to salmon spawn survival. With bacterial decomposition occuring in these salmon redds, there may be various other changes that may have some effect on the proper incubation of the eggs. More knowledge needs to be acquired on this specific phase. If the BOD exerted is great enough to completely eliminate dissolved oxygen under the gravel, there are two things that can result. One being the production of hydrogen sulfide, which in itself is a toxic substance, and methane gas also toxic to fish. If these conditions would exist in the redd, it is very likely that there would be little or no survival of the eggs or alevins.

These particular conditions are most apt to occur during the most critical stage of incubation. For example, after a fish has spawned, the gravel is loose and percolation and dissolved oxygen are generally good. As the eggs lay in the gravel incubating, heavy siltation could cause a reduction in permeability and percolation and the bio-chemical oxygen has a chance to exert itself on the organic material, thus reducing the amount of dissolved oxygen available to the eggs. Normal compaction also occurs in the gravel which in turn accounts for some reduction in permeability. At the most critical stage of the incubation period, which is normally just prior to hatching, the greatest amount of oxygen is needed. This is the time at which the detrimental conditions are most likely to show up. So it can be readily seen that abnormal amounts of silt and organic debris are more serious and have their most detrimental effects at the time when the eggs or emergent fry need the best conditions. If this occurs, the survival rate could be greatly reduced and consequently, the normal run of fish is reduced.

3. Fish Growth Problems

The next aspect of our problem is that of growth. Once the fish emerge from the gravel and are living in the stream, we are primarily concerned with their growth and condition. Good growth is mainly dependent upon adequate food and good water quality conditions. Small aquatic insect larvae and nymphs, and phyto and zoo-plankton make up a good portion of the food of these small salmon. Some terrestrial insects are utilized also. In order for these fish to have sufficient food, the normal reproduction cycles of fish food organisms must not be disrupted.

Again, natural influences come into the picture. These must be recognized before conclusions can be made concerning man-made influences. There are certain natural factors that are important to consider when the growth of juvenile fishes is concerned. Heavy populations of salmon in certain streams can account for reduced aquatic insect nymphs and larvae. Other larger species inhabiting the same rearing area can be direct food competitors. Consequently, the numbers of fish present in varying areas of the stream definitely have a bearing on the growth and condition of the fish present.

After completing one year of our study in the Chehalis Basin with Silver Salmon, and after making some preliminary analyses of condition coefficients in relation to the populations in particular streams, there appears to be one important aspect that should be mentioned. In two of the streams, where populations are relatively low, the average condition factor of these groups was found to be 1.54 and 1.68; in two other streams where there were greater fish populations the average condition factor dropped to 1.40 for both streams. This is a natural phenomenon and must be considered as part of the natural cycle and growth of the salmon. If conditions factors are used to measure harmful effects to fish they must be used with caution.

Taking into consideration again, the abnormal deposition of siltation caused by poor logging practices, road building, or dam construction, the siltation is definitely known to be of detrimental nature. I would like to refer a study that I did on the Wynooche River above and below a gravel drag line operation. In this particular study, the siltation influences upon the aquatic insect population were determined. Samples of insect populations were taken in similar areas both above and below the gravel operation. After these samples were analyzed in the laboratory there was a productivity decline of 85% below the gravel operation when compared with that above the gravel operation. Turbidities were also increased tremendously from practically zero to 91. Suspended solids increased from 1 or 2 ppm above the gravel operation to 103 ppm below the gravel operation. As these solids were carried downstream and the water velocities were reduced, settling occurred and siltation of the stream bed was the result. The aforementioned reduction of aquatic insect populations was the consequence.

With the food reduction such as it was, one can readily determine that there was less food for growth of the fish. It is easy to see also, that the fish would either leave the area and go to a more desirable portion of the stream or have their diet cut down considerably.

Good growth and good conditions of the fish are essential to healthy normal populations. If food supplies are adequate, I am sure that nature has provided these fish with the ability to take care of themselves.

4. Conclusions

In conclusion, I would like to reiterate the two types of influences with which we are concerned in our spawning and rearing streams. It is true we are not able to influence the rainfall, which produces adverse conditions in our streams. We also have no way of controlling superimposition of spawning beds. However, when it comes to the man-made influences we definitely can do something about it. Logging operations should be controlled so that abnormal amounts of silt do not get into the streams. We should control the amount of growth left along the stream banks, and prohibit the use of equipment in a stream bed or spawning area.

We have made what we call sizeable strides in working with the Highway Department of our State pertaining to this problem of siltation. We are generally notified of operations that are to commence prior to the actual date when the work begins. We, in turn, try to take necessary precautions so that abnormal siltation is kept out of our streams. This has worked fairly well in the past and we hope that it will continue and get better as time goes on. This is also needed with logging operations. Companies need to be told what is expected of them, and an enforcement program must follow to keep them within their boundaries and limitations. If this could be accomplished the fishery and the stream could be protected.

In our studies on the Chehalis Basin we not only studied populations, condition factors, and food indices, but also we studied the apparent velocity and dissolved oxygen in actual Silver Salmon redds. After completing one year of field work, we have not had the chance to evaluate any of the data other than a few of the figures that I have mentioned pertaining to condition factors of the fish. There are many problems involved in doing research on this sort of program. We are constantly striving to improve the equipment and methods used so that conditions can be made known. In this way preventative measures can be taken so that our watersheds can be kept under control and deleterious effects will not be experienced by our spawning and rearing anadromous fish. I would like to emphasize the fact that more research needs to be done in this field in the future, and that better control be maintained over logging operations in our watersheds.

Item 3d

SPAWNING AND GROWTH OF FISH

Robert L. Burgner

The title of this panel is "Spawning and Growth of Fish." I am going to broaden that slightly to include in my discussion "development and survival." At the same time I am going to restrict my topic essentially to the aquatic environment as it affects development and survival of eggs and larvae of pink and chum salmon. The same general relationships exist with the eggs and larvae of other salmon and trout. With pinks and chums, which migrate almost immediately to sea after emergence, the greatest influence of the watershed is exerted while they reside as eggs and larvae in the gravel of the spawning grounds.

Most of my information on water quality and survival of these two species is based on my studies in Southeast Alaska. In this area pink and chum salmon comprise about 85% of the salmon pack and play a dominant role in the economy of the area. Problems of water pollution in salmon streams of Alaska are becoming much more real than in the past. Large-scale logging was initiated in Southeast Alaska about 1952 with establishment of a pulp mill at Ketchikan. Another has just been completed at Sitka and still others are planned for Southeast Alaska and Prince William Sound. To furnish logs for these mills operating today, logging operations are now conducted on a scale that was unheard of in Alaska 20 years ago. The Forest Service has set up a crop rotation schedule which will see nearly all of the salmon stream watersheds with marketable timber in Southeast Alaska logged over during the next 100 years.

Mining operations have been sporadic over the past few years but we anticipate mineral resources will be exploited on a large scale in the future. Road construction can be expected to increase. Increased multiple use of watersheds in Alaska means an increased likelihood that salmon runs already depleted will be further affected.

A study of the effects of logging on the productivity of pink salmon streams in Southeast Alaska is well under way. This is a cooperative study sponsored by the Forest Service and the Fish and Wildlife Service, and being conducted by the Alaska Forest Research Center and the Fisheries Research Institute.

In our part of the study our first task has been to determine the natural factors which exert most influence on mortality. Logging began in our study stream areas this year. The influence of logging on survival will depend on the direction, extent and timing of changes produced in the aquatic environment by logging practices.

The determinations of embryonic mortality are carried on at various times through the development period in order to detect at what stages mortality occurs and to relate them with routinely measured environmental conditions to determine cause. Mortalities have been highly variable in time and area of occurrence in the streams under study. The major mortalities in our study streams have been the result of either (1) mechanical removal of the embryos from the streambeds by floods or (2) poor water quality associated with low stream flows.

Flooding of study area streams has generally been most severe in late fall. Bill McNeil has found that gravel flow and resultant loss of embryos has varied greatly from year to year depending upon the severity of the flood stages. In 1956 and 1957 no detectable loss of the eggs and larvae resulted from this cause. However, floods in October 1958 caused extensive movement of gravel in Twelve-mile Creek, one of our study streams, and resultant egg mortality was estimated at 95 percent. This flood, however, did not affect nearby Indian Creek which has a more stable streambed and there was no loss detected at that time. In 1959, extreme floods caused still higher egg mortality and even normally stable Indian Creek was seriously affected. Yet, intertidal spawning areas of adjacent Harris River escaped serious scouring in spite of the extreme runoff conditions. I will come back to this matter of stream stability a little later.

Poor water quality associated with low stream flows can result in mortalities both in summer and winter. In the fall of 1957, for example, stream levels were low. Through most of the September of 1957 the oxygen content of water in the gravel of our study areas averaged less than 40 percent of that in stream water over the spawning beds. (Fisheries Research Institute, 1959). This indicated that water from the stream was not circulating properly through the gravel. The mortality to salmon eggs associated with these low oxygen conditions in 1957 exceeded 95 percent in our study areas. We had no measure of the efficiency of yolk conversion and condition of those embryos that did not survive. However, in 1958 and 1959, stream levels were up during summer and dissolved oxygen levels were high in all areas sampled during and after spawning (Sheridan and McNeil, 1960). The higher stream levels in the fall of 1958 and 1959 maintained a favorable interchange of water between the stream and the streambed.

Low streamflow in wintertime has resulted in mortality through freezing. Eggs and larvae in Indian Creek suffered considerable mortality from this cause in the winter of 1959.

From these observations, it is quite apparent to us that stream discharge exerts an important influence on mortality rate of eggs and larvae of pink salmon in Southeast Alaska streams. Logging adjacent to salmon streams can conceivably alter stream runoff pattern. In this connection it will have an effect on salmon, either favorable or unfavorable, depending upon the direction, degree, and timing of change in stream flow.

In studies in Indian Creek and other streams in Southeast Alaska, Bill Sheridan has found that groundwater was generally low in dissolved oxygen, and that dissolved oxygen level decreased with depth in the streambed gravel. His studies corroborate those by Vaux and Sheridan (1960) that the primary source of intragravel water of high oxygen content is the stream itself. Therefore, if the interchange of stream and intragravel water is interfered with, the amount of dissolved oxygen available to salmon eggs will be decreased and the rate of flow past the embryos will be lowered. Siltation of the streambed will, of course, reduce permeability and interchange, as Chuck Ziebell pointed out earlier today.

Last year at the Fifth Symposium, Cooper explained some of the theoretical relationships between suspended sediment concentrations and changes in permeability of gravel with time. We feel that there is still much to learn about the process of streambed siltation. I will illustrate from our experience this past fall. Our personnel observed last fall that the suspended sediment load in the Harris River and its tributaries appeared to be much heavier than in previous years prior to logging and also comparatively heavier than in adjacent Indian Creek, which is not being logged. The silt load was observed to be noticeably heavier in tributaries which drained areas where logging had taken place. In order to detect changes in fines in the gravel, random streambed gravel sampling was conducted in three study areas in the Harris River before and after the period of observed increased suspended silt load. A significant increase in fine materials was found in the study area gravel farthest upstream; however, a reduction in the amount of fines was measured in the lower and middle study areas. Although data indicate that the suspended silt load was above normal in Harris River, there is nothing to suggest accretion to the two study areas farther downstream. On the contrary, fine materials were lost from the lower spawning beds. Upon resampling the upstream area still later in the season, we found that the increased load of fine materials had vanished.

These were preliminary observations but they pointed out the need to know how the settleable solids enter into and disappear from the spawning beds; that is, the mechanics and dynamics of the process. How is the rate of accretion affected by concentration and composition of suspended settleable solids, composition of streambed gravel, and flow velocity? What effect do the spawning activities of salmon and the shift of nonstable beds have on the deposited silt? Some of these factors can be predicted on a theoretical basis. However, tests more closely tied in with field conditions are necessary.

There is also a distinct need for study of the process of siltation in intertidal zones of coastal streams in Alaska. Observations made by Fisheries Research Institute personnel indicate that 70 to 80 percent of all pink salmon in Prince William Sound and 10 to 40 percent of all pink salmon in Southeast Alaska spawn in the intertidal zones of coastal streams. In many streams intertidal zone spawners supply the complete production for the stream. The changes in waterflow and salinity associated with the incoming tides and the possibility of settling out of sediments during slack water periods are considerations that are unique to the intertidal zones.

Finally, I would like to touch on some of the possibilities for improvement of watershed conditions for survival of salmon eggs and larvae. It may be possible to restrict improvement to relatively small areas of the streams. Royce (1959) and Neave and Foerster (1955) have pointed out that small areas of the natural environment can be highly productive. We know fairly well the requirements of salmon eggs and larvae in the gravel. We know that survival will be high in natural unpolluted areas if the eggs remain undisturbed, if there is an adequate flow of oxygenated water past them, and if the temperature cycle is of normal character and provides rate of development that results in proper timing of emergence of the young fish.

Obviously the type of control most needed will depend on the stability of the streambed and the runoff pattern of the stream. It will also depend on the permeability of streambed gravels and the rate of accretion of settleable solids into the streambed. We are finding that these factors vary from stream to stream in southeastern Alaska depending upon watershed characteristics, terrain, and streambed composition. They also vary between intertidal and upstream spawning areas.

One method is, of course, to control stream discharge to avoid periods of excessive flooding and excessively low water levels. Although this is obviously desirable, the cost element is great. A second consideration would be to study methods of increasing streambed stability. It appears that with relatively little cost the stream channels in some of our spawning areas under study could be modified in such a way as to decrease the amount of gravel flow and to provide more dependable low water flows over the spawning areas.

We must also consider increasing streambed permeability. Royce (1959) has pointed out that very large proportions of the eggs and larvae die in the gravel and that most of the mortality is associated with low water flow caused by silting and consolidation of fine materials in the gravel. Tests in Hollis area streams in Southeast Alaska indicate that removal of part of the fine particles from sampled areas is quite feasible. Others are also experimenting with methods to remove the fines from the gravel. We believe it will prove quite feasible to improve survival by this means particularly in the more stable streams.

However, we do not need to know the duration of the increased permeability. It may be necessary to repeat the procedure each year. In our study area streams in Southeast Alaska, the critical period from the standpoint of low oxygen has occurred only during low flow and high temperature, that is, during and shortly after spawning. Cleaning of the gravels shortly before spawning should accomplish this quite satisfactorily since in most instances the heavy siltation is expected during the late fall periods of high water.

In summary, we can expect that there will be a certain conflict between stream management by the biologists and the activities of logging, mining, and road building. However, there is an excellent possibility that production in many natural streams can be greatly improved by controlling stability of the stream and by removing fine materials. If this can be done, it may be possible to log more economically and with less concern about damage to the streams. However, before we proceed, we need some pilot plant operations to test our procedures. The task ahead is actually experimentation in the field where the salmon spawn and die.

Fisheries Research Institute
1959 Logging and salmon. Fish. Res. Inst. College of Fisheries, University of Washington, Seattle. Circular 105, 12 pp.

Neave, Ferris and R. E. Foerster
1955 Problems of Pacific salmon management. No. Amer. Wildl. Conf. Trans. Vol. 200 pp. 426-439.

Royce, William F.
1959 On the possibilities of improving salmon spawning areas. 24th No. Amer. Wildl. Conf. Trans., pp. 356-366.

Sheridan, William L. and William J. McNeil
1960 Effects of logging on the productivity of pink salmon streams in Alaska. In Research in Fisheries, 1959. College of Fisheries. University of Washington, Seattle. Contribution No. 77, pp. 16-17.

Vaux, Walter and William L. Sheridan
1960 Interchange of flowing stream and intragravel water in a salmon spawning riffle. Fish. Res. Inst., College of Fisheries, University of Washington, Seattle, Circular 115, 4 pp.

DISCUSSION Items 3c and 3d

Q. Is it possible or practical to stabilize a stream bed or to make it more permeable?
A. Certain areas of streams seem to escape erosion and scouring while other areas are very unstable. This condition depends considerably upon the configuration of the stream as regards the stream banks and other factors affecting the current pattern. A study of such factors may indicate methods by which some improvement of bed stability can be obtained without a great deal of expense. However, some ideas of stream bed improvement used in the past have been erroneous and have resulted in decreased stability rather than to increase it. Here again is an area requiring further study. If stabilization can be accomplished, it would be of considerable value to the fishery.

Q. How does logging affect the timing and changes of the stream flow patterns?
A. The Forest Service along with the Alaska Forest Research Center, in preliminary studies have found indications that the s summer flows have actually been increased following the logging of a watershed. It would be an advantage from the stream standpoint, if the summer flows were increased. This is one example of how logging could possibly benefit survival. On the other hand, if the run-off pattern as a result of logging of a watershed changes the sharpness of the peak of run-off (increases it) so that the erosion is more severe, then a higher mortality of eggs and larvae in the gravel can be expected.

Q. How far downstream would the effect of drag line operations be evidenced?
A. In studies in Washington an 85% decline in fishery was experienced about 1.7 miles below the operation. However, the distance and magnitude of the effects are dependent upon many factors and will vary with the specific conditions.

Q. Is there information on hand to tentatively, at least, say that there is some correlation between turbidity of water and productivity?
A. The problem is basically one of particle size, light refraction, and the interference with water velocity and bottom permeability. There are so many variations that it is difficult to establish a turbidity-production correlation. However, in the studies in Washington a 75 to 85% decline in fish food organisms (aquatic insects and larva) that normally inhabit the riffles was experienced with turbidities in the order of 26.

Q. Is the effect on aquatic insects a mechanical interference such as the coating of rocks with mud or does the movement of particles in the water interfere with their respiration?

A. Certain types of aquatic insects have different types of gill placement. The ones that are the least tolerant to adverse conditions are the ones in which the gills are located on the ventral side. These in turn are the ones which require the highest amount of oxygen for survival. Silt works into the gravel, choking out insects either mechanically or by reducing the flow of water and reducing the amount of available oxygen.

ITEM 4a

CORRECTION OR CONTROL THROUGH MANAGEMENT - RECREATION

Wilson Bow

Recreation.

The word "recreation" as defined by Webster's Dictionary is "the act of recreating, or state of being recreated; the refreshment of the strength and spirits after toil or diversion." A synonym is the word "play", which could describe the diversion of activities that human beings are likely to be doing in a watershed.

The problems that humans create wherever they go has not changed through the ages. There is still disease. Some diseases are controllable, with a bright future in this direction. There are instances where man's inroads on nature by carelessness, such as fire, erosion, etc., has caused great havoc to whole communities.

Let us look at some of the activities that we class as recreation or play in the great outdoors in the Northwest:

Hunting of wild animals and birds
Fishing
Camping and picnicking
Hiking
Boating
Water skiing
Swimming and bathing
Snow activities - skiing, etc.

This list carries in its scope about every type of outdoor activity in the way of recreation that we will need to deal with in this discussion.

As a basis for this subject in an open-ended discussion, what should we expect of the quality of the water for recreation for man and what will recreational activity of man do to the quality of the water?

To answer these paradoxical problems, we can see that you must start with a definite watershed in mind. Therefore, before such decisions can be made, the following basis should be considered:

1. A study of the hazards associated with the specific use.
2. Ways in which the hazard can be minimized.
3. The willingness of the taxpayer to pay the expenses involved in providing such controls.
4. Additional treatment facilities and operational needs, as the case may dictate, to provide the greatest degree of protection to the water user.

In the first part of this discussion, let us not forget the man in his environment at play. Let us consider those activities of man where he comes in direct contact with water, such as bathing, swimming, or less frequently as boating and water skiing, together with aesthetic enjoyment of recreation.

Water quality for this type of activity must be inoffensive to the senses of smell, sight, feel and taste. It shall not be toxic upon ingestion or irritating to the skin, eyes or nose and shall be reasonably free of pathogenic organisms. There are exceptions in these cases, such as high alkaline lakes; but, applying the general criteria to watersheds, the above considerations are not unreasonable when applied in light of the Water Quality Objectives of the Water Supply and Watershed Protection Bulletin adopted by the Pollution Control Council, Pacific Northwest Area, and published in May of 1952. These criteria will not be repeated in this paper for brevity's sake.

Some of the problems associated with each of the recreational activities are listed below so that a broader view can be had of the whole problem:

Hunting

By the very definition of the word, the "hunter" is free to roam at will in all directions on the land, perhaps on water on occasion, without restraint. No control can be had over his wastes or his actions. That something could be done with special privileges in the way of permits is countered by many, due to the fact that there is no way to be sure of the hunter's actions once he is on his own within a watershed. The chances that the hunter would pollute or contaminate streams with human wastes may be small, but the danger is still there, and when it is multiplied by hundreds of people the chances certainly increase, just as man-made forest fires increase during dry periods of the year.

Is there any way of knowing that the individual hunter will not be a menace once he is allowed to roam at will?

Fishing

Like the hunter, the fisherman is free to roam the streams of a watershed at will, if allowed in the watershed. There is no control over the individual's wastes once he is free in the watershed. There is always the possibility that the fisherman's body wastes will contaminate the waters. Also, like the hunter, he may be told what to do with his wastes, but there is no assurance that he will comply. What assurances does the water consuming public have that the fisherman will comply to even minimum sanitary regulations?

Camping and Picnicking

The development and maintenance of these areas is the responsibility of a number of federal, state, county and private groups. The principal activities which can affect the quality of surface waters are the construction of roads, buildings, parking areas, picnic areas, camp grounds and drainage facilities; disposal of wastes and locating tent camps.

Bacterial contamination and pollution may result from improper maintenance of these grounds, or roads, buildings, parking areas. Garbage, refuse and untreated domestic sewage may be discharged or drained into streams from cabin camp facilities, hotels, picnic areas or camping grounds.

Hiking

The hiker could be classed next to the hunter or fisherman as a free roamer. However, generally speaking, the hiker will stay to trails and usually will be in parties of two or more, but this is not always the rule.

Where trails cross or are close to streams, there is always the hazard of the disposal of human wastes, garbage and litter by the hiker, in addition to damage to the forests by fires.

Boating

The boating problem in lakes, reservoirs and rivers has increased due not only to the type of boats but to the new equipment used to transport boats. In the trailer type outboard cruisers, whole families and groups of people stay out in the water overnight or even for several days at a time. The sanitary facilities are portable type toilets with nothing more than a vessel that is emptied overboard. This operation presents a serious hazard to the water quality, when great numbers of these boats are plying such waters as may be used for domestic purposes.

Water Skiing

This is a sport with direct contact with the water at times. It might be classed as a minor as compared to bathing or swimming activities.

Swimming or Bathing

The practice of bathing or swimming will certainly add some contamination to the quality of the water, because it can be shown that the coliform count will rise in water used by bathers. The amount of contamination is probably directly in relation to how well the bather is cleaned before entering the bathing area. The correlation between bather and disease is extremely difficult to prove, probably due to so many natural barriers and various conditions not understood.

Skiing in Watersheds

The skiing activity in watersheds, with the exception of major ski areas, such as in the vicinity of a tow, probably is minor. The disposal of wastes in the vicinity of tows can be controlled to some extent by approved waste disposal centers, such as toilets, etc., but where skiing is allowed overland, there is no control over the individual, as he may go any direction at will.

We should now look at the total recreation picture which presents the problem, in our opinion, as it relates to watersheds, to see if we can propose some guide lines to correct or control the hazards presented here, through management of the watersheds.

We should all be aware of guides or policies set forth by such organizations as the American Water Works Association, for example: "Recreational Use of Domestic Water Supply Reservoirs", found in the Journal of May, 1958. To briefly comment on this policy, it treats equalizing terminal and upstream reservoirs in accordance with Class A, B. and C. water quality and treatment to be received, and, in summary, states: "The American Water Works Association registers its opposition to legislation permitting or requiring the opening of domestic water supply reservoirs and adjacent lands to recreational uses. Control of water supply reservoirs must remain the prerogative of the water purveyor."

We should be familiar with our Pollution Control Council of the Pacific Northwest Area's own bulletin on water supply and watershed protection. For example, this bulletin states definite policies on swimming, camping, hunting, and fishing. It states such activities should be prohibited in watersheds yielding high quality water where there is no treatment except disinfection.

We should all be aware of our State laws and rules and regulations pertaining to watersheds. The point that should be noted here is that these are different in each state. More could be done by the management of watersheds than all the laws and regulations combined if the real problems and people that cause these problems could be fully understood.

DISCUSSION ITEM 4a

Q. Has any agency conducted studies that would determine the relative concentration of coliforms from human and animal sources?
A. Some studies are being conducted to differentiate between the organisms from various sources, especially those from warm blooded animals. This is one of the problems involved in the use of the coliform tests and the interpretation of the results thereof. For instance, the test is adequate in a captured body of water such as a swimming pool where the source of contamination is established, but it is not adequate for water such as that from a watershed. There are other tests that are better than the coliform test for the latter conditions, but they are not as well adapted to routine testing. (Note: The Taft Engineering Center, Public Health Service, Cincinnati, Ohio has developed a promising method which is now being field-tested.) If a watershed is open to public access it is necessary to assume that any organisms coming from the watershed are of human origin and that the water will require chlorination to be safe. The water purveyor must be sure. He is responsible under law to provide safe water.

No !

A number of surveys have been conducted by the Washington Pollution Control Commission in streams of the Northwest. During all of these surveys there were control stations at the head of all of the streams surveyed. The data collected showed a significant coliform concentration often was as high as 200 per 100 mil. In these areas where there were no significant pasture lands the concentration dropped to a few hundred.

Studies made in the San Francisco watersheds indicate that there is a correlation between rainfall and bacteria count. When the rainfall went up the bacterial count increased. The City of San Francisco has experienced MPNs in its mains as high as 7000.

The Department of Health has made numerous tests of streams in Washington during the summer periods and has found that the background coliform count averages about 50 per 100 mil. Much of this contamination results from animal life along the streams and in watersheds.

ITEM 4b

THE CONTROL OF STREAM FLOW AND WATER QUALITY THROUGH TIMBER HARVESTING

W. K. Ferrell

The effects of timber harvesting on stream flow and water quality have been matters of controversy since the beginnings of forestry practice in this country. Between the extremes of the claims of those believing that the cutting of forests have caused all of the problems of floods and siltation which may exist in the region and those who believe that forest cutting has had no effect on streams and water, is a zone where the truth must lie. The problem is to obtain the facts so that we may learn where the truth is. In the Northwest, we are just beginning to set up research to determine with some precision the effects of cutting on water. Meanwhile, there is research information available from other areas from which we may draw some general conclusions, there is preliminary information available from research in this region, and there is a great deal of observational information from logged areas which helps us to draw some general guidelines.

It might be best to consider the effects of timber cutting from the standpoint of water regimen, quantity, and quality in turn. More is known about the latter than about the first two and we will say more about quality, but we are accumulating more information about all of them.

Extreme cases of the disturbance of regimen are known to occur where the land has been denuded by clearcutting followed by uncontrolled fires. Increased flooding has followed such activity in some instances and the effect on streamflow is to decrease the time to peak flow as well as to increase the peak. Other instances of alteration of the pattern of flow have followed the extreme soil disturbance from certain logging methods. Tractor logging on steep slopes, for example, can result in a pattern of drainage to speed up runoff and in turn disturb the pattern of stream flow. The data for the effects of intermediate amounts of cutting on streamflow are not extensive and here is the area where considerably more research is needed. A recent analysis of the streamflow of two Oregon streamflow records by Anderson, where one stream was progressively logged and the other was not, gives more indication of the increased flow and alteration of peaks one might expect from logging. Many more such studies are needed, and the U. S. Forest Service is initiating such studies.

The problem of the effect of forests on the quantity of water yielded by streams has been of great interest in the past in areas of low rainfall and irrigation agriculture because of the possibility of increasing water yield through forestry practices. From studies in such areas we know that it is possible, through carefully regulated logging, to increase the yield of water from an area without causing appreciable disturbance to the regimen or to the quality. This comes about primarily through decrease of interception of rain and snow, and some control over evaporation from the snow. Just how much we can modify water yield in this region remains to be determined. Increasing yield by this means has a great deal to recommend it but the results to be expected in various forest types in this region remain to be worked out. Another possibility for modification here is to replace one forest type with another, lower H_2O using type.

The effects of forest practices on the quality of water have probably been of the greatest interest in the Pacific Northwest. The fisherman, the municipal water user, and industrial plants all have an interest in maintaining the highest possible water quality. Here is where the first and most obvious effects of timber cutting may be felt. It is clear from work on municipal watersheds such as those in Corvallis, Oregon, and others in the state that it is possible to do considerable logging on a watershed including clearcutting followed by controlled burning, without decreasing the water quality. The emphasis here is on care.

Some soils are much more erodible than others and these must be identified. Poor logging practices can lead to most disastrous results, as common observation indicates. Logging across streams with tractors, logging down excessive slopes with tractors, and similar operations can lead to severe erosion into streams with the consequent damage to many values downstream. The actual falling of trees into streams is another practice which can be avoided and thus prevent later difficulties with debris being carried down the stream from the tops and branches. Similarly logging debris should be removed from a stream after the logging operation so that it will not cause later blocking and subsequent bank erosion.

Perhaps the greatest improvements which might be made in logging methods to improve the quality of water would be to perfect improved yarding systems. At present, there are two so-called sky-line systems being tried out experimentally in this country which show promise. Both of these are systems in which the logs are hauled up off the ground so that they make a minimum of disturbance on the site. Economics will probably dictate whether either of these systems, one American and one European, will be used extensively. The point is that either one can be used where a critical watershed situation exists and improvements will no doubt be made so that these systems will come into common use.

At one time it was thought that burning of any kind was detrimental to water quality. Recent studies by Tarrant of the U. S. Forest Service and Dyrness and Youngberg of Oregon State College have shown that controlled burning can be accomplished without damage to a significant amount of soil and without decreasing the water quality from the burned area. Such results must be checked on various types of soil to determine their general applicability but they illustrate perhaps as well as anything that could be presented the point that forest harvesting practices of many kinds can be made compatible with watershed management if the practices are carefully controlled by the operator and we are willing to give enough thought to them.

ITEM 4c

ROAD AND HIGHWAY CONSTRUCTION

Robert L. Wilson

The problems of watershed management can be compared to the three blind men and the elephant. Each has his own idea of describing the animal. We are fortunate in that it is possible for us to see the overall problems that are involved but there are some, myself included, who feel that certain phases are more important and such problems should be given first priority. I feel that much can be done to remedy many of the problems by proper road location and design.

Perhaps we would not have the problems to deal with such as recreation, timber harvesting and mining that are being discussed by other members of this panel, if we did not have roads to furnish access to the areas which are considered as watersheds. However, many more roads will be constructed and the problems will multiply but the engineer can do his part to minimize them. The first step is to see that the road is located in the proper position in relation to the landscape.

This may appear to be a very easy thing to do but a wide and varied background is needed by those who are to be considered qualified to take the responsibility of this task.

Those responsible for this initial stage of development of our forest resources should have a thorough background and appreciation of geology and geomorphology and the ability to apply this science. The proper location of the road is dependent on the landscape and how it will react after the road is constructed. Closely allied with this is aerial photo interpretation of landforms. Many features of the area are not recognizable when making a reconnaissance on the ground.

The study of soils should be given emphasis because it is closely related to geology. The type and characteristics of soils vary with the geological formation. Recognition of these soils and how they will behave from the viewpoint of erosiveness and bearing capacity is important.

I hope that everyone appreciates the problems of the road engineer. Each of these sciences; geology, soil, and aerial photo interpretation require/a little time in addition to all of the problems and courses relating to forestry.

I feel that the location, design and construction of roads should be predicated to the resources which they are to serve and it is intolerable to exceed these limits. There is much more involved in locating a road than running a grade line, and setting slope stakes.

The next point to consider is the design of the road. There is no place in forestry for a road that is over designed. Why construct a two lane road when a single lane with turn outs will serve the purpose. Not only is the cost unreasonable but the area that is taken out of production is not justified. It is at this point that forest engineers and highway engineers part. In highway design they speak of cutting the backslopes on a 2:1 or 4:1 slope to reduce erosion and to increase stability. The slope stability will be increased but the erosion will not be lessened unless you think of erosion as being only a function of the velocity of water. Low back slopes would, of course, reduce the velocity of water that runs off. Slopes of this sort are impossible in mountainous terrain. It is ironoical that one of the end products of good watershed management is one of the forces which produces erosion. There are two means of eliminating erosion by water. One is to cover the soil and the other is to dike the area so that no water can leave. One of the most serious forms of erosion is splash erosion which is the first in a series of events that leads to more erosion.

What is the source of the sediment that reaches the streams? Does it come from the area that has been logged or does it come from the areas where the soil has been disturbed in the construction of the roads? I do not know. Studies are being conducted on the H. J. Andrews Experimental Forest at the present time on this problem.

Perhaps a step in the right direction to reduce sediment in streams is the correct design of the logging road itself. As I have already indicated accelerated erosion takes place when the soil is exposed.

Assuming that approximately 5 miles of road are required to log a section of land, the area that is taken out of production is about 22 acres per section. This is based on the following: 14 foot road width, 2 foot ditch, fill slopes 1½:1, cut slopes 1:1, 60% ground slope, and half of the road constructed on fill. However, if the backslope were reduced to ½:1, the area taken out of production by the road would be reduced by 35%.

Charles Fogelquist of the Bureau of Land Management computed the differences between backslopes of ½:1, and 1:1 per mile of road on 80% ground slope for a 20 foot road to be 10.1 acres. Thus, by increasing the angle of the cut slope, a considerable saving can be made in excavation and at the same time reducing the area of raw soil that is exposed to erosion. Taking this one step farther, it is not unreasonable to cut the backslope almost vertically if the cut does not exceed 10 feet. Hence, no soil would be exposed. Back slopes which are cut vertically do not have the factor of safety that is often desired and this would be evident by small slumps and failures. Temporarily these failures might be a nuisance but when the road is maintained, this material, if not too great in volume, could be spread on the surface of the road where it would serve as an excellent binder for the surface rock. Where the cut is greater than 10 feet, the back slope might be made steeper than normal but this should be accompanied by bench construction. Studies have shown that the factor of safety on cut banks is increased more per cubic yard of excavation by benching the slope than by reducing the angle of the slope. Precaution must be taken to provide careful drainage of the benches so that the water reaching them is drained away and not permitted to infiltrate into the soil thereby reducing the resistance of the soil to shear which would result in more failures.

If the road has been properly designed, there will not be an excessive amount of waste material. However, the side cast material cannot always be avoided when the road is fully benched. Where the ground slope permits a portion of the road is constructed on fill, the slope should be properly prepared. All of the organic material should be removed from the area involved because if it is not removed, it will only serve as a plane of failure which increases the chances of the road failing by having the fill material slide down the cut.

Since many roads are constructed in clay type soils, the chances of the above types of failures would be decreased if the slope on which the fill is to be constructed is stepped or notched and covered with a granular material before constructing the fill. This will tie the fill material to the slope and it is easily done without an increase in cost by the operator when the road is pioneered and before the cut is started at the upper slope stake.

Clay soils create many problems in road construction, particularly in fills. While clay has a low bearing capacity, this feature can be overcome if the clay soil is covered by adequate material that has more desirable characteristics. In fill sections, the clay soils may be used to within 3 feet of the surface of the subgrade. The fill itself should not be made by end dumping if it is to have a height greater than ten feet but should be built up in lifts of eight or ten inches and properly compacted the full width of the fill.

Compaction is another part of the construction that has not received adequate attention in the construction of logging roads. It is true that optimum moisture conditions are difficult to obtain even to approach them would limit road building to a short period during the summer. Too much road construction takes place when conditions are unfavorable. The type of compaction depends on the soil type. In a sandy soil vibration of the caterpillar will provide compaction but in most soils, operating equipment on the road is not enough to provide proper compaction, and what compaction does take place is concentrated in the two wheel tracks.

The benefits of proper compaction are more than justified by the increase in cost of construction for this operation. Compaction reduces the void ratio of the soil and this retards capillary action. Capillary water can cause a road to fail in spite of the fact that it may have a near impervious surface. Compaction increases the bearing strength of the soil which results in less rock being required for surfacing. This means lower costs and less maintenance to repair failures in the subgrade. A means of compaction which involves no cost is to permit the road to set through one or two winters before using. Time, rain, and gravity will provide the compaction.

Many full bench failures result because of a lack of compaction. Ruts are formed in the road which serve as collecting places for water. The water enters the soil and reduces the resistance of the soil to shear. Compaction should be also applied to roads that are fully benched.

Small intermittent drainages should not be diverted by ditch to a large culvert in a fill to reduce costs. This excess water can cause a fill failure by weakening the subgrade of the fill.

I realize that I have dealt in generalities but in summarizing I would like to emphasize these points again.

1. Be sure that the road is properly located by considering the landscape and stability of the landforms.
2. Do not over-design the road.
3. Reduce to a minimum the area of raw soil exposed in construction.
4. Give more consideration to compaction and construction methods in building fills.

DISCUSSION ITEM 4b and 4c

Q. What increase in yield can be expected by decreasing the interception of rain and snow through the controlled removal of the forest cover?
A. The interception losses result from evaporation of rain and snow intercepted by the forest cover. The evaporation rate is higher than that of the snow pack due to the larger area exposed. Along the Cascades the best figures available indicate a 20% loss due to interception. In the Rocky Mountains the figures are considerably greater, about 40%.

Q. At what elevation do these figures apply?
A. They apply to a 2500 foot elevation and perhaps will be lower above this elevation and higher below it.

Q. Is there evidence of logging reducing run-off?
A. A study of the effect of logging in the Seattle Cedar River watershed, an area of about 143 square miles, showed no indication that there was any reduction in run-off due to logging.

Q. What are the relative merits of stream gravel vs crushed rock for the construction of logging roads?
A. What is practiced and what is preached are two different things. This is an economic problem. The logging companies are inclined to take gravel from the most available area, which sometimes is directly from the stream bed. On Federal forest lands the Forest Service has complete jurisdiction and can demand that a company use crushed gravel. Here the question is whether taking the stream gravel is doing any harm.

The use of rock from the stream is not desirable from the standpoint of the best road because of the rounded smooth surfaces. Even crushed rock from the stream is not desirable as it leaves one rounded side. For best results there should be complete fractures on all sides of the rock.

A major factor in the selection of rock is the stability of the logging operation. In the State of Washington logging is a long term operation since much of the timber is on a sustained yield basis. Higher costs for roads are more justified on a long term operation.

Item 3d

MANAGEMENT OF MINING OPERATION

R. S. Mason

Mining in Oregon began with the discovery of gold at Jacksonville in 1851. That same year gold was also discovered at Griffin Gulch not far from Baker. The next quarter of a century saw a full-fledged gold rush in Oregon. Placer gold, found in the streams and later in the adjacent banks, formed the basis for this tremendous activity which brought thousands of people to the State, provided a wilderness society with an abundance of wealth, and established the first semblance of a legal structure. It is significant that Oregon became a State long before many of her sisters lying far to the east, due in large part to the search for gold.

The abuses perpetrated by the early-day miners are common knowledge. However they were not alone. The farmer, the stockman, the logger--all moved to Oregon because of the land. They left behind wreckage and brought injurious practices with them. The prospect of limitless land and an abundance of natural resources made conservation of any kind uneconomic and unheard of.

Once the easily obtainable stream placers were exhausted, miners turned first to the gold-bearing stream banks and later to the rich veins cropping out on the hillsides. To work banks required capital, and in many cases water for the hydraulic giants. Ditches to supply the water were dug by hand, often in record time, in mountainous, unsurveyed areas. The Auburn Canal, the Rye Valley Ditch, the Sparta Ditch, and the Eldorado Ditch were completed in the 1860's and '70's. The Eldorado Ditch, incidentally, was 100 miles long, an engineering feat which would be of major proportions today even with earth-moving machinery. To mine underground required even more financing and for the first time the large mining companies appeared. The completion of the transcontinental railroad in 1885 signalled the beginning of a period of intensive mining and milling which was to continue, with some fluctuations, until World War II and the ill-advised government order L-208 which permanently closed nearly all of the State's metal mines. Gold dredging in Oregon began in earnest about 30 years ago. In 1938 there were 12 dredges active in eastern Oregon; in 1939 the State had 15 floating dredges and 13 non-floating washing plants. Gold dredging came to an abrupt halt with World War II, and only a few attempts have been made to revive it since.

Of all the mining activity in the State during the past 109 years, none has been subjected to more criticism than gold dredging. Admittedly there were abuses, but the outcry has been largely based on an emotional rather than a factual basis. In 1939, a total of .0015 percent of the State's crop land was dredged. Translated this amounts to only 70 acres. It has been estimated that if all of the potential dredgeable ground should be dredged it would amount to .04 percent of the State's crop land. Land abuse and stream pollution are always related. The relationship is sometimes obvious, as in the case of some dredging where water is muddied and silt introduced into the stream. In other cases the tie between land abuse and stream pollution is not so readily apparent. An over-cropped farm or a hillside stripped of trees will eventually pollute the streams with topsoil and silt. The big difference is that pollution from dredging occurs at the time of the operation, but pollution from poor farming or logging takes place during periods of heavy rain when the muddy water is assumed to be due to "natural" causes. Dredging operations attract the public because they are unique. Farming is conducted on private land often protected by "No Trespassing" signs; and logging is carried out on vast areas of the public domain to which the public is barred by locked gates.

Today the mining industry presents a far different picture from that of 50 years ago. Mining companies have largely replaced the individual operator who was primarily interested in immediate return rather than a long-term investment. Mining has recognized that it must accept its share of community responsibility, just as other manufacturers and logging companies have done. Any well-established business realizes that good public relations are a "must." The high cost of setting up any type of industry today requires a long period for amortization--and the assurance that it will be permitted to stay in business. The mining industry is particularly vulnerable to this situation, with amortization periods ranging from 20 years upwards required for most large-scale operations. Mining companies also have learned that it is good business to police their own ranks rather than to have punitive and restrictive legislation forced upon them. A few examples of present-day mining company pollution-control practices illustrate this point. In the southeastern United States, areas which have been mined for bauxite by ALCOA have been reseeded to trees which are tended every bit as carefully as our own tree farms in the Northwest. Here in Oregon, ALCOA is also in the tree farm business - before they have even started to mine. In Washington and Columbia counties, where this company owns a considerable acreage of land underlain by ferruginous bauxite, a two-fold planting program is underway. Much of the land is cut over, brush covered, nonproductive, and only part of it has minable bauxite. Incidentally, a great deal of this nonproductive area is the result of bad cutting practice by early loggers. On the areas that are not underlain by bauxite, trees are planted in the regular tree-farm way; on the areas which will be mined eventually trees are planted for sale as Christmas trees. Sand and gravel operators in the Middle East have found that unsightly gravel pits can be landscaped and made into housing developments featuring a boat landing for every home. The reclamation work of the Porter Brothers in Bear Valley, Idaho, is well known. Twenty years ago Harms & Larson dredged and then leveled and resoiled 100 acres along Horse Creek in northern California. In this case it is interesting to note that the cost of doing this work was exactly double the original value of the land. With these examples in mind it is difficult to see why there should be any problem. Actually there is one. Over the years, and in many parts of the world, the gold dredging industry has been accused of despoiling the countryside when it could have reclaimed much of it. The plain fact of the matter is that in most cases the landowner did not want his land reclaimed--if he had to pay <u>anything</u> to have it done. The economics are quite clear: An acre of gold-bearing alluvial material containing the least amount of gold that would make it economic to mine would probably return the landowner about $850. A farm containing 100 acres would return $85,000 without one penny of expense. How many farmers would be interested in farming any more if they had that kind of money all in one chunk? The same problem exists for land underlain with sand and gravel, bauxite, or any other mineral product which must be mined from the surface. Most surface-stripped land can be reclaimed and water pollution held to an absolute minimum; the mining industry is willing and eager to do it, but the sad fact remains that all too often the landowner is more interested in immediate gain than in a long-term investment. Clearly something must be done.

The problems as we see them are these: (1) the failure by large segments of the people to recognize that mining is an essential industry, indispensable to our way of life and to our very existence. Since the invention of fire, man's eating habits have Cahnged little. What sets modern man apart from his ancestors is his use of metals, and metals also spell the difference between the free nation and the conquered one. (a) Although mining operations on State and Federal lands can be controlled by existing legislation and present mining practices, there is a real problem when mining is conducted on privately-owned land. The landowner needs to be educated in the value of his land, not just for his own sake but as a community responsibility. The mining industry will cooperate as fully as possible, but cooperation is a two-way street. (3) Mining is not the only industry that has stream pollution problems, and the matter should be viewed in its entirety. Basically, stream pollution and land abuse are the by-products of civilization, and the record dates back 7000 years. (4) Realization that any regulatory measures to control mining activity must be drawn with care lest they destroy the industry. Over the past twenty-five years most of the legislation related to mining has been of a restrictive nature. This is in sharp contrast to the great number of laws passed to help nearly every phase of our economy. It is not necessary to spend large amounts of taxpayers' money on slogans such as "Keep Oregon Mineralized." All that the mining industry wants is the opportunity to "Keep Oregon Mining."

The economic impact of surface mining has been often obscured by a flurry of criticism. The mining industry produces more dollars per gallon of water used than nearly any other industry, and most of the water that is used can either be re-cycled or returned to the stream in good condition. A few comparisons may be informative. In 1957 the average return from an acre of agricultural land in Oregon was $20.18. At this rate it would take 42 years of production to equal the value of the gold royalty paid to a landowner whose land contained the absolute minimum that could be mined economically. Farm land in the Salem Hills area would have to produce crops continuously until the year 2439 to equal the monetary gain from the sale of bauxite lying just below the surface. Over 100 years ago the gold rush leap-frogged Oregon and California into statehood years ahead of some of the less minerally-endowed states. Today the mining industry offers the same springboard opportunity in our race against time. With proper care we can have our minerals our productive land, and clear streams. Mining has learned to live in its community as an active, potent, wealth-producing neighbor.

Attendance at the Seventh Symposium

Allen, E.J.	Water Department	Seattle
Anderson, H. Kenneth	Bureau of Water Works	Portland
Benson, D. J.	Oregon Sanitary Authority	Portland
Bow, Wilson	Wash. Dept. of Health	Seattle
Bowerman, H.	U. S. Forest Service	Portland
Brand, R. E.	Oregon Dept. of Health	Portland
Bullard, W. E.	U. S. Forest Service	Portland
Burgess, F. J.	Oregon State College	Corvallis
Burgner, R. L.	Univ. of Washington	Seattle
Campbell, Homer	Oregon Game Commission	Corvallis
Charlton, David	Charlton Laboratories	Portland
Clapp, Nick	Bureau of Water Works	Portland
Clemetson, Tom	Wash. Pollution Control C.	Olympia
Cuyler, C. E.	Public Health Service	San Francisco
Dunstan, G. H.	Washington State Univ.	Pullman
Eldridge, E. F.	Public Health Service	Portland
Ferrell, W. K.	Oregon State College	Corvallis
Haydu, E. P.	Weyerhaeuser Timber Co.	Longview
Holloway, J. H.	Rayonier Inc.	Shelton
Kari, Earl H.	Public Health Service	Portland
Katz, Max	Public Health Service	Corvallis
Kelly, C. B.	Public Health Service	Purdy
Liggett, Al	Bureau of Water Works	Portland
Livingston, Al	Wash. Pollution Control C.	Olympia
Lucas, L. F.	Crown Zellerbach Corp.	Camas
Madison, Robert	U. S. Geological Survey	Portland
Mason, R. S.	Oregon Dept. Geology	Portland
McHugh, Robert	Oregon Dept. of Health	Portland
Milliken, H. E.	Oregon Dept. of Health	Portland
Minnehan, Robert	Public Health Service	Portland
Northcraft, M. E.	Oregon State College	Corvallis
Norseth, B. Paul	Bureau of Water Works	Portland
Orlob, G. T.	University of California	Berkeley
Ovenell, F. J.	Water Resources Adv.Com.	Mt. Vernon
Pine, R. E.	Washington Pollution C.C.	Olympia
Pintler, H.	California Dept. Fish & Game	Sacramento
Rulifson, R. L.	Oregon Fish Commission	Portland
Stein, Jerry	Rayonier Inc.	Shelton
Tatone, Ron	Bureau of Water Works	Portland
Wagner, R. A.	Wash. Pollution Control C.	Yakima
Wales, J. H.	Oregon State College	Corvallis
Weathersbee, E.J.	Oregon Dept. of Health	Portland
Wickett, W. P.	Canadian Fisheries Res. Br.	Nanaimo
Wilson, R. L.	Oregon State College	Corvallis
Ziebell, Chuck	Washington Pollution C.C.	Olympia