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TIMBER PRODUCTION AND WATER QUALITY -- PROGRESS IN PLANNING FOR THE BULL RUN, PORTLAND, OREGON'S MUNICIPAL WATERSHED

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INTRODUCTION

The National Forests were established and are managed to meet a variety of the nation's needs. The increasing demand for wood products has placed greater emphasis on intensive management of these lands for the growth of timber. Soil is the basic resource for forest production because it is the site of biological processes that supply nutrients to tree roots. Forest growth is closely associated with these soil processes. Intensive management may cause soil damage from compaction, erosion, and leaching of nutrients into streams. The loss of soil and nutrients from the forest reduces the quality of water in streams and may also reduce future timber growth. Increased nutrient loading of reservoirs may lead to elevated algae content of reservoir water, and algae control may be required if this growth degrades water quality. Progressive management on National Forests recognizes that today's management determines tomorrow's growth and that future penalties on forest production or water quality must be avoided even if higher log costs are incurred.

Land use planning is a means of arriving at management direction necessary to meet resource goals. For the Bull Run Municipal Watershed where high-quality water is the principal goal of management, we will discuss information from resource inventories, review knowledge about land processes from research, and describe the planning process used to match land capabilities to land use. Finally, we will illustrate the land use planning process through two examples.

The clarity and dependability of flow of the Bull Run River was recognized by early settlers. The Bull Run Forest Reserve was created from public domain by presidential proclamation in 1892. Water from the Bull Run first reached Portland in 1895. The watershed currently serves nearly 700,000 Oregon residents. The area remained primitive until the mid-1950's when concern arose about the risk of uncontrolled wildfire in the decadent 500-year-old Douglas-fir stands. Road construction began in 1955 for fire access and timber harvest. Timber harvesting was carefully controlled and moderately paced to prevent adverse effects on water quality (USDA Forest Service 1970). In 1958 an experimental watershed study was begun on Fox Creek--a tributary of the Bull Run River--to determine the effects of timber harvesting, forest roads, and methods of logging residue disposal on streamflow and water quality. The Fox Creek study is just one of six watershed studies in western Oregon representing a range of soil, vegetation, and climatic conditions.

The characteristics of the Bull Run Watershed, a 119-square-mile (308-square kilometer) watershed, are ideal for a municipal water supply. Annual precipitation ranges from 85 to 170 inches (216-432 centimeters), and streamflow has averaged 98 inches (249 centimeters). Minimum summer flow, augmented by better than 20 billion gallons (76 million cubic meters) of storage in reservoirs, is adequate to meet maximum summer demand projected to the year 2000. Bedrock, composed mainly of porous and fractured overlapping flows of andesite and basalt, stores snowmelt water. Water released from this source maintains a relatively high and steady streamflow during the dry summer months. Springs feed the river at about the temperature of melting snow. Soils with forest vegetation on this glaciated terrain are generally stable and contribute little turbidity to water from erosion. Human entry to the watershed is restricted to minimize the risk of bacterial contamination of the water. The water is chlorinated at the headworks where it enters the conduits for transport to the city. Deep-seated landslides have occurred, but they remained dormant for many years until torrent flow in 1972 activated a formerly stable landslide zone. This erosion episode, not associated with timber harvesting, spread turbid water throughout the Portland water system. Elevated stream turbidity remains the most probable risk of water quality degradation from timber harvesting.

THE LAND USE PLANNING PROCESS

Land use planning is being used throughout the nation to solve the increasingly complex management situations regarding the use of land. The purpose of such planning is to match the uses to the ability of the land to sustain those uses without environmental degradation.

Through planning, the manager seeks to develop a set of goals for products that are compatible with land potentials. On the National Forests, goals are expressed for the quantity and quality of resources, including air, water, soil, timber, wildlife, recreation, and minerals. The goals are met by applying specified management activities and practices to the planning unit.

A distinction must be made between land use planning and project planning. Land use planning is used to determine management direction for a relatively large area of land corresponding to an administrative unit. This management direction prescribes the type, level, and location of the management activity available to the manager. Project planning involves the design of a specific management activity such as a timber sale and identifies all of the actions to be taken in its implementation. Project planning is undertaken in response to decisions reached through land use planning.

Planning is often thought of as a terminal process in which once a plan is produced, planning work is terminated. In reality, the process should be considered as continuous. After preparation of a plan, only through execution and evaluation can the planning process be viable. Planning should be viewed as cyclic, with plans produced periodically and based upon preceding execution and evaluation experience. In the case of the Bull Run, the cycle is expected to be repeated in about a decade.

The planning process overall involves establishing the land's ability to produce, determining public needs, listing a range of alternative courses of action, technically and publicly assessing these courses of action, and finally reaching a decision on management direction to guide the land manager for a decade or more. Input to the planning process from research results reported in the following section will primarily be used to determine the land's ability to produce timber, water, wildlife, and recreation and to make technical assessments of the consequences of proposed management alternatives.

In the Bull Run Watershed, a cooperative land use planning effort between the city of Portland and the Mount Hood National Forest was undertaken in 1973. The objectives of the effort are:

1. Produce a management plan which will maintain or improve the quality of untreated water produced.
2. Determine what forms of use the area can sustain, while maintaining or improving a high quality of water.
3. Define more clearly how the watershed will be managed, while meeting the intent of the congressional acts.
4. Consolidate existing information and provide additional data to determine capabilities and limitations of management.
5. Summarize legislative directives for the management of the watershed.

The study is expected to be completed in 1975.

To reach management decisions, analytical or quantitative techniques and public involvement are being used, along with more traditional approaches, to arrive at an assessment of the probable consequences of any proposed alternative. This approach must be responsive to requirements of the National Environmental Policy Act of 1969, the Multiple Use-Sustained Yield Act of 1960, and other acts regarding the management of the National Forests. To establish the land's intrinsic suitability and evaluate the consequences of alternative courses of action, an analytical procedure termed "linear programing" is being used. Intrinsic suitability is defined as the physical and biological capability of a relatively homogeneous area to support specific uses without serious environmental degradation. The linear programing model requires quantitative data about the physical, biological, and social features of the planning area.

RESEARCH BASIS FOR WATER QUALITY ASSESSMENT IN LAND USE PLANNING

To meet water quality goals through planned management requires knowledge about physical and biological processes that supply materials and energy to streams, how the rates of these processes vary over the planning area, and how methods of management for timber production may affect the rates of these processes. Turbidity, nutrient enrichment, temperature, and microbial content of streams are important water quality parameters that we consider here. This review is based on the results of research and is included to provide a perspective of information which can contribute to sound land use decisions.

Turbidity

Turbidity in forest streams usually consists of suspended soil particles caused by soil erosion. The growth of algae and diatoms in reservoirs may also affect the clarity of water. Soil erosion includes surface, stream bank, and landslide processes.

Erosion of surface soils and stream banks is the result of soil detachment and transport by running water--most often noted on soils disturbed or compacted by construction of truck roads or by tractor logging. But erosion from landslides rather than by running water is the principal process transporting soil to streams in western Oregon. The potential for landsliding increases with the angle of slope. Forest vegetation is important for stabilization of soil on steep slopes.

Roots of trees and shrubs add strength to the soil mantle and may anchor it to bedrock--thus preventing or retarding the downslope movement by the force of gravity.

In a recent review of soil erosion processes on forest land, Swanston and Dyrness (1973) describe three types of soil mass movements commonly found on forest land.

1. Debris avalanches and debris flows produced by instantaneous failure of shallow soils overlying an impermeable surface. These soils are usually of coarse texture and low clay content.
2. Creep, slumps, and earth flows resulting from quasiviscous flow and progressive failure of deeply weathered materials. Speed of movement ranges from a barely perceptible creep to high-velocity slumps and earthflows.
3. Dry ravel, dry creep, and sliding involving downslope movement of single particles and thin sheets of coarse, cohesionless material on steep, sparsely vegetated slopes.

Soil and parent material properties indicate potential for soil erodibility. Whether failures occur only within the soil or in both the soil and the parent material depends upon the strength of these materials. Basalt and andesite parent materials, occupying 96.5 percent of the Bull Run Watershed (table 1), are competent to support their own weight; failure would be expected in the soil mantle by debris avalanches over the bedrock surface. However, failures within deeply weathered volcanic breccias occupying only 1.5 percent of the area (table 1) can be expected to encompass both the soil and geologic parent material.

Table 1. Soil erosion risk from land types in the Bull Run Watershed.[1/]

LAND TYPES AND RISK	SLOPE	AREA
	Percent	
Pliocene basalt and andesite		
low risk	0-10	7.7
low risk	10-25	26.7
moderate risk	25-50	50.2
high risk	>50	11.9
Deeply weathered volcanic breccias		
high risk	10-50	1.5
Lakes and reservoirs	0	2.0

[1/] As developed from Beaulieu (1974).

Recognition of unstable land is a key feature of the inventory stage of land use planning. This can be illustrated with data from the H. J. Andrews Experimental Forest (Dyrness 1967). Landslide occurrence increased with landslope, particularly from unstable soils on slopes steeper than 50 percent (fig. 1). Note that less than 10 percent of the drainage area is occupied by land sloping at greater than 50 percent--suggesting that unstable soils causing most of the turbidity problems occupy only a small percentage of the drainage area. The fact that nearly 60 percent of the soil loss came from areas disturbed by roads on these unstable slopes further emphasizes the importance of recognizing unstable land. A relationship such as this, developed for each major parent material within a planning unit, will indicate major differences in erosion potential and the area of unstable soils.

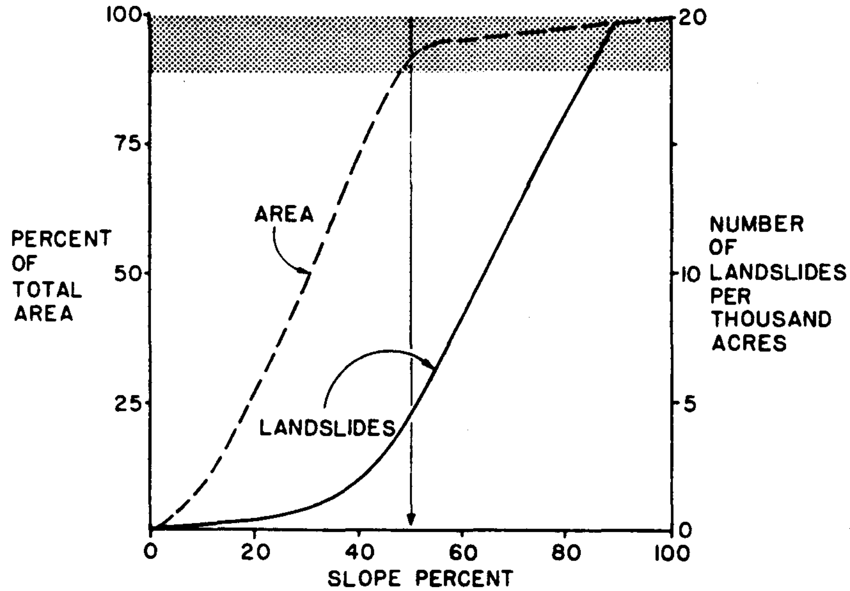

Figure 1. Landslide frequency increases directly with landslopes greater than 50 percent. These steep, actively eroding lands occupy less than 10 percent (shaded area) of the H. J. Andrews Experimental Forest, Oregon. (From Dyrness 1967.)

Soil erosion occurs repeatedly on steep slopes following timber harvesting, and the time duration of active erosion is often determined by the rate of revegetation. At the H. J. Andrews Experimental Forest following two catastrophic storms during 1964-65, soil erosion from roads on steep topography caused the loss of 680 cubic yards of soil per acre (1,285 cubic meters per hectare). Soil erosion in clearcut areas was equal to the erosion observed on undisturbed areas--11 cubic yards per acre (21 cubic meters per hectare) (Dyrness 1967). The minor amount of surface soil disturbance caused by cable yarding and slash burning on clearcut areas appeared to have little effect on these well-aggregated soils (Fredriksen 1970). The soil on stream banks was most susceptible to sliding. Sliding, observed on all slopes, was most pronounced where forest roads crossed stream channels on steep drainage headwalls. Erosion on the steepest sites at the H. J. Andrews Experimental Forest has remained active for 12 years, whereas on more gently sloping ground at the Alsea Study in the Oregon Coast Ranges, active erosion subsided after 4 years (Brown and Krygier 1971). The soil erosion rate on basalt and andesite at the Bull Run Watershed is expected to be approximately an order of magnitude less than the rates observed at the H. J. Andrews Experimental Forest.

Turbidity increase in streams will depend upon the risk that soil erosion will occur, the volume of soil displaced, its textural composition, and the site and velocity of soil movement in relation to distance from streams. The risk of occurrence can be estimated from the angle of slope and the composition and depth of porous material. Land forms indicative of past landsliding often are susceptible to continued landsliding when these areas are disturbed. Actively creeping soils are indicated by leaning and misshapen tree trunks. Larger soil volumes move from deep soil areas than from areas of shallow soil, mainly because of the difference in soil mass. Erosion of heavy-textured soils of silt and clay composition cause higher peak turbidities, and the turbidity may last longer compared to sandy or loamy textured soils that contain a high proportion of coarse fragments. High velocity landslides often deliver a large volume of soil to streams in a matter of minutes, while delivery by mantle creep supplies smaller amounts of material over a longer period.

The shape of hillsides and the position of landslide source areas in relation to streams often determine how much soil enters streams. Old river terraces beside streams will often retain a large proportion of the soil should erosion occur from source areas on steep slopes above. On concave slopes, soil from steep headwalls is often partially retained on more gentle toe slopes. Conversely, streams will receive all of the soil eroded from the lower third of convex slopes; the risk of erosion from these slopes is also high.

Slope steepness and logging treatments on these slopes have caused differing levels of stream sedimentation by soil erosion in experimental watersheds in western Oregon (fig. 2). The greatest sedimentation levels were observed at the H. J. Andrews Experimental Forest where average slopes range from 53 to 63 percent. There, the highest sedimentation rate (320 ppm)[1/] was due to the construction of truck roads across steep drainage headwalls and first-order stream channels. Clearcutting alone contributed much less sediment (48 ppm) (Fredriksen 1970). The spread among sedimentation levels was less at the Alsea Study (35- to 40-percent slope) because of more gentle slopes and roads located on ridgetops away from stream channels (Brown and Krygier 1971). No increase in stream sedimentation was noted at Fox Creek in the Bull Run Watershed from clearcutting and with forest roads in gently sloping topography (7- to 12-percent slopes).[2/] Note that the sediment concentration of streams from undisturbed watersheds increased 9 times over this range of slopes. Though mean annual concentration data are used in figure 2 for illustration purposes, the maximum sediment concentration and the reoccurrence interval of these peaks may be more useful information for planning purposes.

A major portion of the land within the Bull Run Watershed contains relatively stable soils formed from basalt and andesite parent materials unlike the relatively weak and deeply weathered parent materials in the Oregon Coast Ranges and farther south in the Cascade Range at the H. J. Andrews Experimental Forest (Stephens 1966). A recent survey of the Bull Run Watershed (fig. 3) found Columbia River basalt flows and more recent andesite flows the predominant parent materials there (Beaulieu 1974). Actively eroding soils of silt and clay composition are found in the upper layers of volcanic breccia sandwiched between the lava flows. These actively eroding areas are shown in figure 3. Although these unstable soils occupy only 1.5 percent of the area (table 1), they constitute the greatest hazard for increased turbidity because they are positioned adjacent to stream channels often forming the stream banks. Both the North and South Forks of the Bull Run River have cut through these unstable geologic materials, and the turbidity of these streams is noticeably greater than the other streams whose channels are formed in

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1/ *ppm = milligrams per liter.*

2/ *Fredriksen, R. L., and Rothacher, J. Water quality and streamflow following patch-cutting of an old-growth forest system in the Bull Run Watershed, Oregon. Paper submitted to Water Resources Research.*

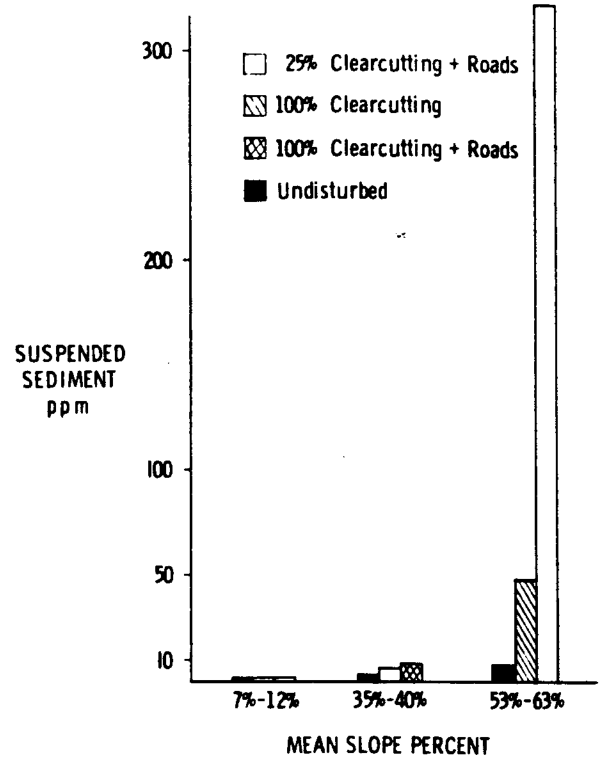

Figure 2. Effects of land slope and attendant soil instability on the mean annual suspended sediment concentrations of streams from varying levels of timber harvest and forest road densities at Fox Creek (7- to 12-percent slope), Alsea Study (35- to 40-percent slope), and H. J. Andrews Experimental Forest (53- to 63-percent slope).

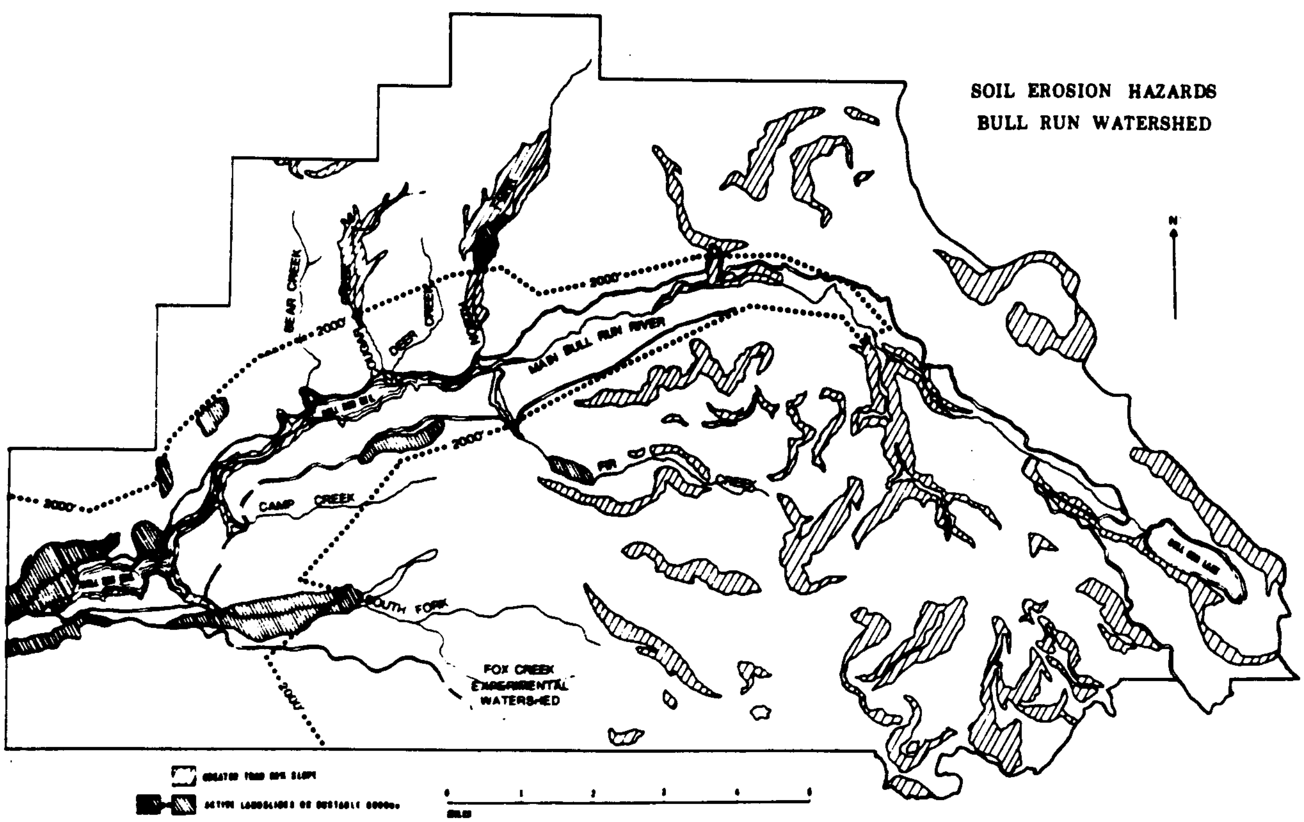

Figure 3. Areas of unstable land subject to (1) active erosion by slumping and earthflows and (2) soil and rock avalanches on slopes steeper than 50 percent and with shallow soils. Turbidity was sampled from the indicated streams representing typical land types within the Bull Run Watershed. Forests below the 2,000-foot (610-meter) elevation generally have better developed shrub layers than those at higher elevations.

harder rock (table 2). These sensitive areas require protection from disturbance. If signs of increased movement are noted, a thorough engineering analysis may indicate the need for special measures such as drainage or relieving the load on slopes.

Table 2. Turbidity of Bull Run streams differs depending upon the rate of natural geologic erosion. Actively eroding soils maintain higher natural turbidities in the North and South Forks compared to stable soils in the other stream drainages.

STREAM	% GREATER THAN 2 JTU[1/]	MAXIMUM MEASURED JTU[1/]
South Fork	3	20
North Fork	4	19
Fox Creek	1	7
Cougar Creek	< 1	6
Bear Creek	1	5
Fir Creek	< 1	4
Deer Creek	< 1	4
Camp Creek	0	2
Main Bull Run River	0	1

1/ Jackson Turbidity Units.

Soils on steep slopes in quaternary andesites and basalts constitute another potential source of soil erosion and increased stream turbidity. Slopes steeper than 50 percent in this terrain occupy nearly 12 percent of the Bull Run drainage (table 1). Soils on these slopes, of medium to coarse texture and of highly variable stone content, normally remain stable when covered by forests. The roots of vegetation strengthen the soil mantle and often reach into cracks and fissures in the bedrock. Observations from studies in other areas have identified several factors that accelerate soil erosion on these steep slopes after timber harvest. Soil is lost from the steepest parts of these slopes by debris avalanches resulting from disturbance of surface soil by log skidding and soil strength lost as roots rot. Burning of slash often destroys much of the remaining vegetation and would tend to further increase soil erosion. The experience we have had with this type of land suggests that timber harvesting on slopes steeper than 50 percent can lead to accelerated soil loss and increased turbidity of streams. Specialized and intensive investigations on steep slopes are necessary prior to road construction or timber harvest.

Dry ravel and creep occur from sparsely vegetated soil banks by wetting and drying during the summer season. Frost heaving by freeze and thaw activity may also loosen soil from these slopes. Unvegetated road cut banks, fill slopes, and stream banks constitute the main source of this type of soil erosion in the Bull Run Watershed. Soil material collects in road drainage ditches, and the silt and clay fractions often enter streams in road drainage water. Prompt revegetation will virtually stop erosion from these slopes. Treatment to revegetate road banks commonly includes grass seeding, mulching, and fertilization (Dyrness 1970). Refertilization is often necessary to maintain this cover.

Nutrient Enrichment

Timber harvesting affects the conservation of nutrients in four ways: uptake of nutrients is stopped, living nonmerchantable tree tissue is converted into decomposable slash, the decomposition rate of the residues and dead roots is increased by a warmed and moistened environment, and soil erosion is increased. The amount of slash left on the ground will depend on the age of the preexisting forest, its productivity, the quality of the timber, and utilization standards. A recent survey found that forest residues on clearcuts in the Douglas-fir region ranged from 32 to 227 tons per acre (72-508 metric tons per hectare) (Dell and Ward 1971). The quantity of nutrients that reaches the stream from the slash may depend on whether the slash is rapidly oxidized by burning or whether a slow oxidation is allowed to occur by microbial or fungal means. But in either case, nutrients are mineralized in quantities in excess of the requirements by vegetation and the ability of soils to store these nutrients (Fredriksen 1971). Increased nutrient losses in streamflow can be expected until the uptake of nutrients in vegetation is again in balance with the mineralization of nutrients by decomposition.

The dissolved chemical load in streams arising from predominantly basalt and andesite terrain in the Bull Run Watershed is very low. The Fox Creek Experimental Watershed streams contain from 7 to 22 ppm of dissolved solids accounting for the very soft water characteristic of the entire watershed (see footnote 2). About 98 percent of the solids are made up of relatively inert substances such as sodium, potassium, calcium, magnesium, and silica. The most interest is in nitrogen, phosphorus, and dissolved organic matter that make up 2 percent of the dissolved load. Nitrogen and phosphorus are often in short supply in Douglas-fir forests; therefore losses may cause reductions in growth of succeeding forests. Welch (1974) has recently reviewed research on lakes in Sweden and in western Washington which shows a direct relationship between nutrient loading and the production of algae and diatoms.

Nitrate concentration in streams normally increases to a maximum one season after clearcutting and coincides with the rapid decomposition of fine fractions of logging slash including needles, twigs, and roots. Uptake of nutrients is particularly slow at this time because there is little residual vegetation remaining from the previous stand (fig. 4). Burning may accentuate the nitrate

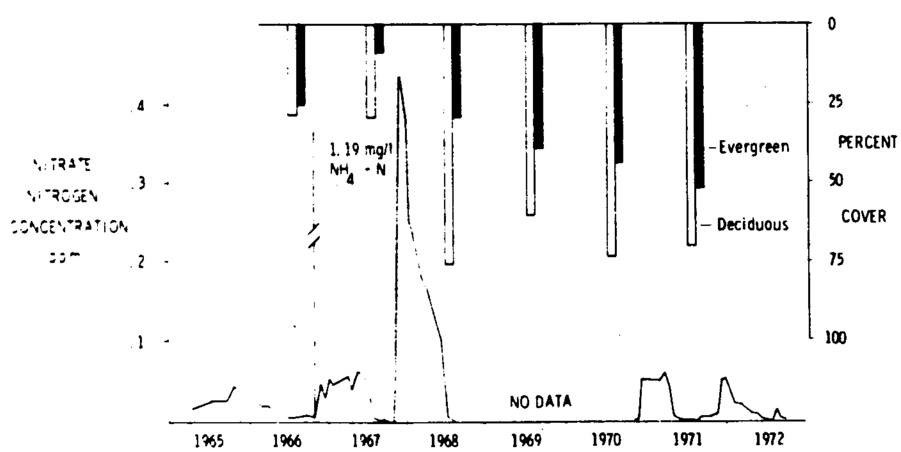

Figure 4. Mean biweekly nitrate and ammonia concentration in streamflow and percent vegetation cover following clearcutting and slash burning at the H. J. Andrews Experimental Forest, Blue River, Oregon.

outflow by destruction of shrubs, and the release of bases may improve the soil acidity for nitrate-producing bacteria. We attribute the rapid decline in nitrate concentration to the dwindling supply of rapidly decomposable organic matter and the reestablishment of herb and shrub vegetation (fig. 4). Evergreen shrubs may be more effective in immobilizing nutrients than deciduous vegetation, because they have the potential for uptaking nutrients (nitrogen and phosphorus) when environmental conditions allow photosynthesis to occur. The concentration observed in streams is undoubtedly increased where there is rapid mineralization in soils; the concentration is reduced by dilution in high rainfall areas.

Nitrate production is also apparently greater from cutting at elevations above 2,000 feet (610 meters) where shrub cover is greatly reduced by winter snowpacks in the Bull Run Watershed (fig. 3). The nitrate outflow at Fox Creek in the Bull Run Watershed, where there was no shrub and little herbaceous vegetation the first 3 years after cutting, was more than double the concentration noted at the H. J. Andrews Experimental Forest where a large shrub cover survived from the previous stand (fig. 5). Where nutrient cycles are closed in mature Douglas-fir forests, little nitrate is lost.

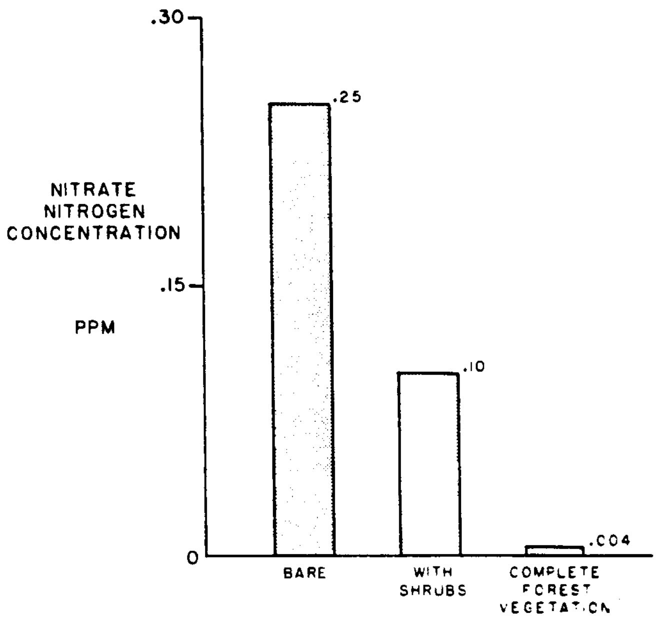

Figure 5. Annual nitrate nitrogen concentration in relation to vegetation cover at Fox Creek in the Bull Run Watershed (bare and complete forest) and H. J. Andrews Experimental Forest (with shrubs).

Nitrogen is most likely to have an impact on water quality, but toxicity of heavy metals is cause for concern if mobilized by management practices. Excess nitrate and ammonia in municipal water supplies may be harmful (Federal Water Pollution Control Administration 1970), but toxic levels have seldom been found in forest streams in the Pacific Northwest. In only one case, toxic concentrations of ammonia and manganese (a heavy metal) were observed, for a period of 12 days following the burning of heavy slash accumulations in one stream channel under study (Fredriksen 1971). Nitrate is present at very low levels (0.001-0.010 ppm) in streamflow from undisturbed conifer forests, and ammonium is seldom present in measurable amounts.

Increased concentration of nitrogen and other nutrients will diminish downstream from clearcut areas by drainage from forested areas that characteristically contain smaller concentrations of nutrients in streamflow.

Increased temperature of stream water frequently results from timber harvesting that removes streambank shade causing increase in direct solar radiation (Brown and Krygier 1970). The effect of this heating on water temperature at the Bull Run intake will also be influenced by dilution from cooler water entering the stream from unlogged areas, the storage time in streams and reservoirs, and the temperature stratification in reservoirs. Since cold water is more desirable for human consumption because it suppresses tastes and odors and is less reactive with metal pipes, provision for water temperature control is often necessary in timber harvesting plans.

The temperature rise (ΔT) that can be expected from harvest operations can be predicted from the stream surface area (A) receiving a solar heat load (H), and the stream discharge (D). Brown (1971) gives the details and methods for estimating equation parameters for ungaged streams--$\Delta T = AH/D$. The general relationships depicted by the equation indicate that water temperature will increase in proportion to the area exposed and the heat load received on that area and that the increase will be inversely proportional to stream discharge. On a municipal watershed, the maximum water temperature may be more important than the increase. Where ground water temperatures are cool and near the temperatures of melting snow, a temperature rise of 10° F (5.6° C) would be less important than in rainfall-fed streams in areas of nonporous bedrock which often have higher ground water temperatures. Also, topographic shade will vary in drainage basins according to steepness, length, and shape (concave vs. convex) of slopes, and the orientation and steepness of stream channels. It follows that streams on north-facing slopes with well-entrenched stream channels sloping at 10 percent will sustain a lower temperature increase than streams facing southward, with a lower gradient. Characteristics of streams can be used to classify stream potential for water temperature increase in land use planning.

The importance of shade over streams is indicated by studies of timber harvesting effects on experimental streams. An increase of 25° F (14° C) to a maximum stream temperature of 85° F (30° C) resulted from clearcutting and slash burning an entire southfacing, slow-flowing stream at the Alsea Study (Brown and Krygier 1970). In another watershed study at the H. J. Andrews Experimental Forest, shade was complete enough that no increase was noted where 29 percent of the channel length was in clearcut areas (Levno and Rothacher 1967). Later, water temperature on the same stream increased 12° F (6.7° C) after logging debris and peripheral shade were removed by a torrent flow resulting from a landslide. In another, nearby stream flowing through an entirely clearcut drainage, residual vegetation and logging debris kept the water temperature increase to 4° F (2.2° C) (Levno and Rothacher 1969). The maximum water temperature increased 14° F (7.8° C) in this same stream after logging debris was destroyed by slash burning and channel clearance. Maximum water temperatures were in the range of 72° to 79° F (22° to 25° C) in these streams.

The duration of the increases rather than the instantaneous maximum observed may be more important in municipal watersheds, where the temperature at the water intake is most important. In one study, the temperature exceeded the maximum before clearcutting (65° F) (18° C) for 30 percent of the time during the summer months (Levno and Rothacher 1969). Though minimum daily water temperature dipped below 65° F every night, temperatures greater than 65° F persisted for 17 hours during several days in July.

Maximum water temperatures decline as clearcut areas revegetate. Environmental conditions are conducive for rapid revegetation in the maritime climate west of the Cascade Range in Oregon and Washington. At the Alsea Study, a mean monthly temperature increase of 14° F (7.8° C) declined to 6° F (3.3° C) 2 years later, after regrowth of vegetation over the stream channel (Brown and Krygier 1970).

Bacteriological Quality

Disease organisms ordinarily come from animal or human excrement in the watershed. Because soils are very porous, runoff from the low intensity precipitation characteristic of western Oregon, flows through the soil. The soil acts as a filter and immobilizes materials carried in water. This phenomenon may explain the low fecal coliform counts observed in these waters. But human residency could cause a greater risk than transient use resulting from logging operations. A study conducted in the Cedar, Green, and Clackamas Rivers, where use ranged from complete protection to permanent human residency and recreation, showed no effect of these occupancy levels on enteric coliform bacteria organisms (U.S. Department of Health, Education, and Welfare 1969). Because of restricted human entry to the Bull Run Watershed and restricted winter range for elk and deer, the hazard from bacterial disease organisms in the Bull Run streams is low. Fecal coliform counts per hundred milliliters of Bull Run water averaged 3 and ranged from 0 to 11 in the 1971-74 period.[3/]

LAND USE PLANNING FOR QUALITY WATER PRODUCTION IN THE BULL RUN WATERSHED

We have talked about the land use planning process and the specific planning objectives for the Bull Run Watershed. In this section, we suggest procedures for interpreting resource data, making technical assessments of these data, and incorporating these data into the planning system. Prediction of the outcome of a proposed action is a requirement of land use planning. Better land use decisions can be made if the risks of alternative courses of action are known--for example, the risk of water quality degradation from any of several logging systems.

Planning units are often large and heterogeneous areas. Inventories of soils, vegetation, rock types, precipitation, and runoff are necessary to describe the intrinsic properties of basic units of land. The basic units of land in the Bull Run are called "response units," with each having a set of relatively homogeneous properties different from other response units (Corliss 1974). About 30 types of response units have been identified in the Bull Run. These response units correspond to the boundaries of soil mapping units. In some cases, individual soil mapping units are identified as response units; in other cases where adjoining soils are similar, response units encompass several soil mapping units. With the response units delineated on a map, resource elements (soil, vegetation, rock type, slope class, precipitation, runoff, and snow retention) are coded to the response units. Six key interpretations are made for each resource element. Considering the number of units, elements, and interpretations, the number of possible combinations may approach 400 on the Bull Run--a number not too unwieldy for allocating management to planning units.

Each of the resource elements of response units has a companion set of interpretations which are used to predict the yield potential of resources within the planning area and the beneficial or detrimental impacts of management activities necessary to utilize these resources. In the prediction of risk associated with a response unit, consideration must be given to the risk associated with the

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3/ *Personal communication from Earl Paulsen and Arthur Smith, Portland Water Bureau.*

basic characteristics of each response unit (intrinsic suitability) and the risk associated with proposed management activities on that response unit. For example, information from figure 1 indicates a strong slope dependence of soil erosion risk, and information from figure 2 shows that there is a greater risk of soil erosion from logging activities which would require a high road density to reach the logs on unstable terrain.

Technical Assessments

Because more is known about physical and biological processes causing turbidity, more definite assessments are possible for turbidity impacts of management activities than can be made for nutrient enrichment, water temperature, and bacteriological quality.

Turbidity.--Because quantitative predictions of turbidity cannot be made for each type of land found on response units, a relative index ranking system is being used. For turbidity risk on response units, consideration is given to the strength of soils, the strength of the rocks underlying the soil, and land slope; a turbidity risk index is computed from an empirical equation. Similarly, activities such as logging methods, roading densities, and slash treatments are given index rankings based upon experience or quantitative data where data exist. Combining turbidity risk with activity risk results in an overall numerical turbidity-hazard ranking for the response units. A numerical ranking is selected for each response unit which will maintain an acceptable stream turbidity level. The index computed for each response unit will be tested against the actual turbidity observed over a range of activities on these response units.

Nutrient Enrichment.--Precise management guidelines for regulation of nutrient enrichment cannot be given at this time. Although the basis for prediction of algae production from nutrient loading of lakes has been established (Welch 1974), the present nutrient loading of the reservoirs in the Bull Run Watershed is still to be measured. Information is not presently available to determine the impact of nutrient loss resulting from timber harvest on future timber production. However, management can minimize the loss of nitrogen and phosphorus after timber harvest through emphasis on conditions that minimize the decomposition rate of organic matter. Rapid revegetation of logged areas will reduce the loss of nitrogen and phosphorus, since uptake of nutrients immobilizes nutrients released by decomposition. Measures which minimize the destruction of the shrub layer by log skidding or burning should maximize retention of nutrients. Shade from the surrounding forest will reduce the soil temperature on logged areas. Small clearcuts narrow in the north-south direction or shelterwood cuttings should reduce the rate of nutrient mineralization and also encourage the early establishment and growth of vegetation and tree seedlings. These modified cutting practices may be especially important at higher elevations where revegetation is slower and shrub vegetation is poorly developed or absent. However, these cultural practices may raise stream turbidity and remove a larger area from forest production if a greater road density is required to harvest timber.

Water Temperature.--A management strategy for water temperature control would be most useful if the stream reaches could be identified that are most susceptible to water temperature increase from removal of peripheral shade. By reasoning given in the preceding research section, this procedure would include information on stream discharge, direction of flow, and the topographic shade received by each stream reach for the summer months when the solar heating potential is greatest. Stream reaches with relatively low discharge, flowing in the southern quadrant, and with no topographic shade should experience the greatest temperature increase. Temperature increases will be most critical in streams with high ground-water temperatures. A temperature increase of 5° F (2.8° C) where ground-water temperatures are already near 50° F (10° C) should be viewed with more concern than a situation where ground-water temperatures are about 40° F (5° C). The temperature increase of streams entering reservoirs will be determined by the harvesting rate, rate of vegetation regrowth over streams in cut areas, and special management practices specifically for water temperature control. Temperature at the intake will be determined by the reservoir effects and the temperature of streams entering the reservoirs. Some reservoir effects include the volume of storage in relation to the daily streamflow entering the reservoir (replacement time), and the depth of temperature stratification in relation to the depth of the water intake.

Bacteriological Quality.--Activity and occurrence of mammals can be predicted for response units and a relative index developed, based upon factors of forage and soil drainage. Logging activities that change the porosity of soils can be expected to cause overland flow. Animal excrement carried to streams in this flow will deliver more bacterial organisms to streams.

Water Quality Suitability Classification

A systematic means is needed to compare the results of utilizing the wood production potential of the land and the water quality that results from management activities. McHarg (1969) has suggested the use of overlays for visual comparison of, for instance, timber production and the potential and risk of water quality degradation. The suitability of land to sustain management activities without impacts on water turbidity is being determined from characteristics of soil, slope, and bedrock at the Bull Run Watershed. Table 3 indicates that deep, coarse-textured soils with a well developed granular structure and high permeability are stable and highly suitable for timber production with little or no increased stream turbidity. Suitability of response units decreases according to the component of gravitational forces acting on slopes of increasing steepness. Permeability and strength of underlying rocks are also considered in suitability rankings. Obviously, the stability of soils is the result of many compensating factors. To account for these synergistic effects on the suitability rating of each response unit, each characteristic of the unit will be ranked independently. Therefore, a deep, permeable, coarse-textured, and well-structured soil over permeable, stable bedrock on slopes near 50 percent could be given the same suitability ranking as a fine-textured, poorly drained soil on more gentle slopes overlying impermeable and unstable bedrock. Ranking response units is presently being done by a linear computer program, and the rankings will be compared to actual field measurements and observations. Predictability of the program will be improved by trial and error adjustment of weightings given suitability characteristics on table 3. A similar procedure is now being developed to assess the risk of turbidity increase from management activities. Suitability rankings for stream nutrient enrichment, temperature, and bacteriological quality will come later.

Example 1--Fox Creek Experimental Watershed Study

Results of a watershed experiment on Fox Creek (fig. 3) have shown that land with slopes between 0 to 25 percent, underlain by stable basalt and andesite parent materials, can be intensively managed for timber production with little or no impact on water quality (see footnote 2). This land type occupies about 34 percent of the Bull Run Watershed (table 1). The watershed area is represented by two response units dependent upon land slope. Streams having steep banks and a moderate erosion risk along portions of the stream channels form one response unit. The upstream portions of the watersheds, stable and gently sloping, form the other response unit. Shrub densities are low in this area of winter snow packs. Game populations are low because of the restricted winter range.

Table 3. Criteria for developing suitability rankings for discrete land units (response units) based on soil, slope, and geology.

RESPONSE UNIT CHARACTERISTICS	SUITABILITY RANKING		
	HIGH	MODERATE	LOW
Soil:			
Depth (inches)[1]	>40	20-40	<20
Texture	coarse	moderate to fine	fine
Structure	granular	granular	platy or massive
Permeability (inches per hour)[1]	>5	0.20-5	<0.20
Slope (percent)	<25	25-50	>50
Bedrock:			
Rock type	highly permeable	moderately permeable	impermeable
Rock stability	highly stable	stable	unstable

[1] 1 inch = 2.54 centimeters.

The Fox Creek study is composed of three small drainage basins. Streamflow and water quality were measured for several years while all were undisturbed. Subsequently, one-quarter of the drainage area of two watersheds was clearcut and the logging residue was burned on one drainage; residue was allowed to decompose on the other (fig. 6). Baseline water quality was monitored from a third watershed, which remained undisturbed. Individual clearcut areas range in size from 8 to 22 acres (3 to 9 hectares) and occur within the gently sloping response unit. Logs were skidded to landings by overhead (high lead) cable except for one small tractor-logged area well away from streams. Because the streams flow generally west and solar heating of stream water was expected from removal of timber to the south, every effort was made to preserve the shade of natural vegetation over and adjacent to the streams.

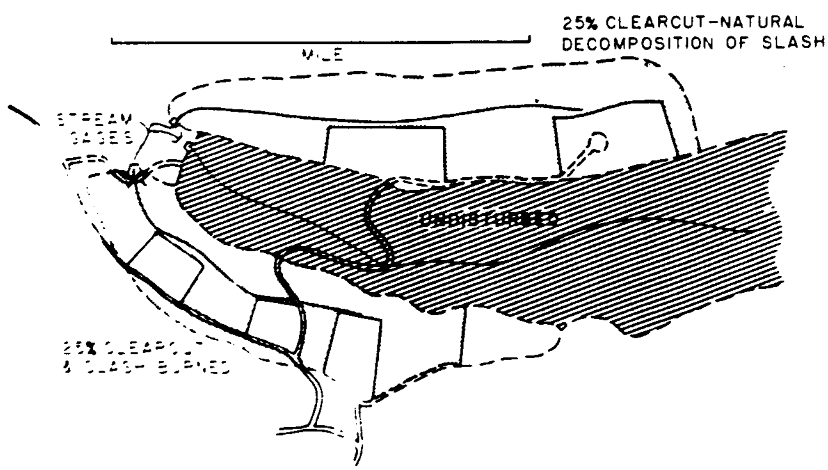

Figure 6. Fox Creek Experimental Watersheds compare effects of logging residue disposal on water quality.

Water quality has been affected in only a very minor way by the timber harvesting. The concentration of suspended matter in these streams was very low before harvesting, although occasional samples contained up to 7 ppm, apparently due to shifting logs of naturally fallen trees in the streambed. Neither the mean nor the maximum turbidity has increased since clearcutting in either drainage (fig. 7). Water temperatures ranged from freezing to the low 40's (4° to 6° C) during the winter and rose to the middle or high 50's (13° to 15° C) during the summer months. No temperature increase was detected. Dissolved chemical load increased slightly. The largest stream nutrient concentration increase from cutting was observed for nitrate nitrogen; the mean annual concentration was 0.046 ppm 3 years after clearcutting and residue burning, compared with 0.005 ppm in the stream from the undisturbed watershed. Although no toxic effects are expected, the effects of nutrient enrichment from this and other similar clearcuttings in the Bull Run drainage are poorly understood.

Water quality degradation from headwater streams such as Fox Creek can be expected to have only a minimal effect at the water intake because of dilution by drainage from undisturbed and older cut areas which characteristically produce cleaner water than freshly cut areas.

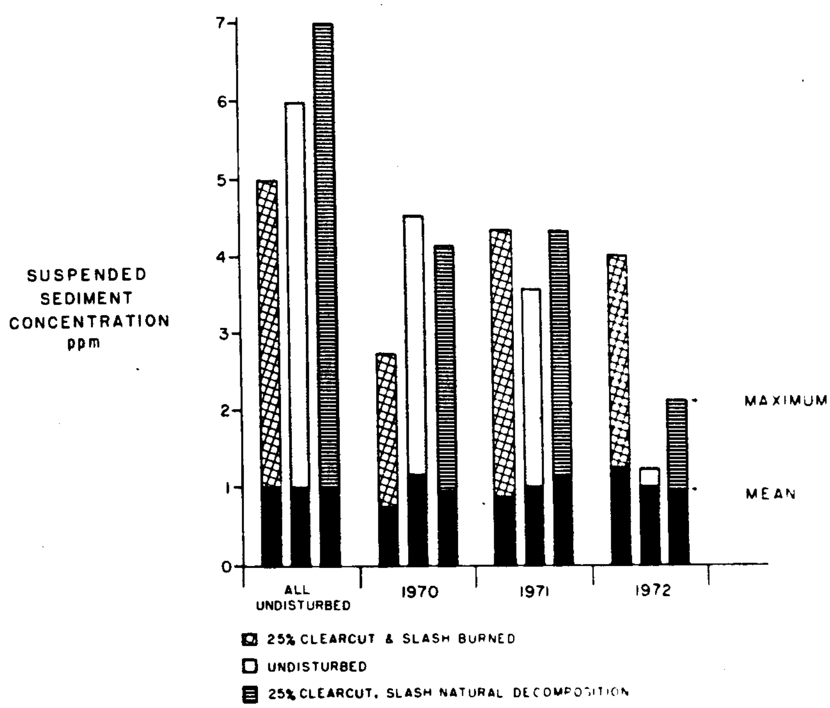

Figure 7. Annual mean and maximum concentrations of suspended sediment from Fox Creek watershed streams while all 3 were undisturbed and after clearcutting of one-quarter of the area of two watersheds. Slash was broadcast burned on one watershed and left to decompose naturally on the other.

Example 2--North Fork, Bull Run River

The North Fork undoubtedly has the greatest turbidity hazard of any drainage within this municipal watershed. This risk is mainly associated with soil erosion from two response units shown in figure 8 represented by an actively moving landslide area and steep topography subject to debris avalanching.

In the active landslide zone, the slow deformation of this deep, fine-textured mass is gradually moving the stream banks toward the stream channel. Drainage from the steep topography immediately above lubricates this mass and further contributes to its instability. Landsliding was reactivated in this response unit by a torrent caused by the sudden release of water from a small upstream reservoir in 1972. When depth, texture, structure, and factors of permeability are considered in relation to impermeable bedrock, an overall low suitability rating (table 3) was assigned to this response unit. Because of this rating, the timber will remain on this response unit and the land will be withdrawn from the area available for timber production.

When slopes steeper than 50 percent are subject to timber harvesting, they constitute another soil erosion hazard. Increased soil movement is often caused by a combination of factors, including the disturbance of surface soils and lost root strength. The steep topography immediately upstream of the active landslide zone forms a second response unit of this type. Again, a combination of soil, slope, and geological factors from table 3 place this unit into a low suitability classification.

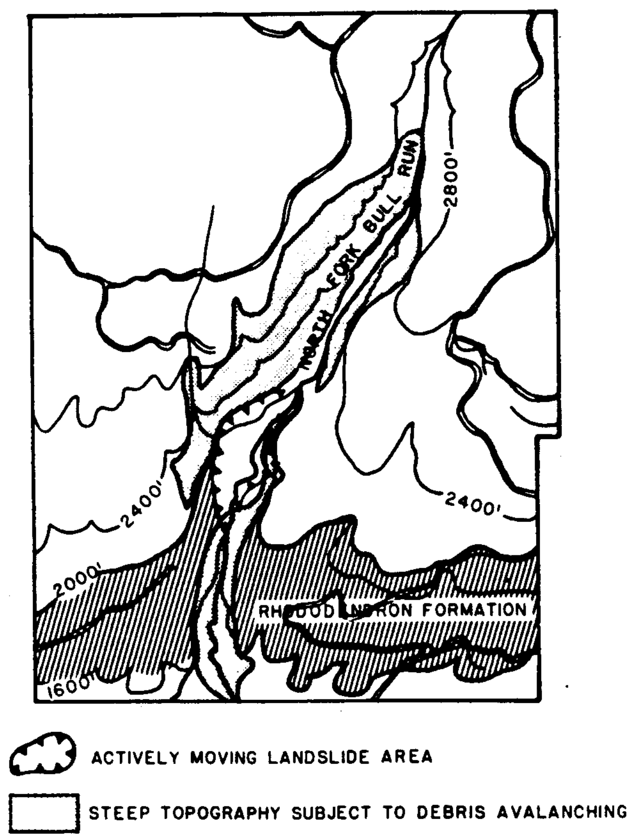

Figure 8. The North Fork of the Bull Run River presents difficult soil management problems because of (1) a deep, fine-textured deposit undergoing active creep and slumping, and (2) shallow soils on steep slopes often subject to accelerated soil erosion after timber harvest.

Nutrient enrichment risk in the North Fork is expected to be variable, depending upon density of the shrub layer beneath the stands and the warmth and moistness of soils after timber harvest. The generalized boundary of shrub density along the 2,000-foot (610-meter) contour shown in figure 3 divides the drainage into two zones. Harvesting on shaded slopes and where shrub cover exists should produce less nitrate and phosphorus than warm, moist habitats without shrub cover.

Increased water temperature can be expected from timber harvesting because of the southerly direction of the channel. Although the ridges on either side provide morning and evening shade, 6 to 8 hours of direct sunlight can be expected to reach the stream in June and July. Buffer strips of vegetation would be necessary where natural shade was lacking. The reaches of the North Fork requiring special consideration are the half-mile section immediately above the reservoir and the headwaters section. Neither of these stream segments would receive topographic shade should the surrounding vegetation be removed.

A greater impact can be expected from natural or management-induced water quality changes depending upon the distance of the streams from the water intake. Turbidity from the torrent-induced channel disturbance in 1972 had an immediate effect upon the turbidity of Portland's water. Travel time to the water intake is another consideration in planning developed for subbasins within the Bull Run Watershed.

SUMMARY AND CONCLUSIONS

In this paper we have discussed the land use planning process and demonstrated how available research information can be used in land use planning, using the Bull Run Watershed as an example. The detail given in this paper is only a portion of the extensive data used in arriving at an overall management direction for this important watershed. Little has been said about the variable water quality related to the type of road and logging systems employed. Surface water features of the watershed must be dealt with differently than the land units. As live streams are linear, they do not lend themselves to area representation on a map or in the computer. A separate but compatible system of representation must be employed.

The planning process we have described is new and evolving and must be viewed as continuing. It is being tested along with other approaches in use throughout the country. Evaluation and refinement of the plan must be done. Learning from results of executing a plan will be valuable in arriving at an updated plan. Research will continue to provide better information for developing management prescriptions. Nutrient enrichment, bacteriological quality, and the effect of reservoirs as a source or a sink in planning are areas needing further study.

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