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701

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Myths and Misconceptions about Forest Hydrologic Systems and Cumulative Effects[1]

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Abstract: Review of forest planning documents and contact with watershed specialists and other forest land managers in the Pacific Northwest has revealed several myths or misconceptions about forest watershed management. These are partly the result of pressures created by the level of planning required by legislation and by the quest for simple procedures to predict cumulative effects of management activities on soil and water resources. Myths and misconceptions discussed include these: (1) simplicity can be willed on the forest hydrologic system, (2) soil compaction of 12 percent of total watershed area constitutes a threshold for detrimental changes in streamflow, (3) desynchronization of flows by logging-induced diversity of snowmelt conditions will always be beneficial to soil and water resources, and (4) wet-mantle runoff is not affected by clearcutting.

Among the various documents that have affected the management of Federal forest lands, perhaps the two most important from the standpoint of forest planning are the National Forest Management Act of 1976 (NFMA) (USDA Forest Service 1979) and the National Environmental Policy Act of 1970 (NEPA) (Council on Environmental Quality 1978). NFMA details how USDA Forest Service is to plan its forest management activities, while NEPA requires environmental assessments or environmental impact statements for planned activities. The current concern over cumulative effects of logging activities can be traced directly to the regulations for implementing NEPA.

Watershed specialists on interdisciplinary planning teams have been directed to formulate guidelines, determine thresholds, and construct methodologies that can be used to address cumulative effects of proposed activities on soil and water resources. Specialists from USDA Forest Service and USDI Bureau of Land Management in western Oregon, western Washington, and northern California have been contacting me, and probably other research hydrologists, in search of the elusive thresholds. In my efforts to provide assistance, I have become aware of a number of myths and misconceptions that are circulating freely among watershed specialists and others concerned with forest management as they look for simple, predictive tools. The object of this paper is to discuss several of the myths and misconceptions as I see them.

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I will not cite specific planning documents or conversations to illustrate where the myths and misconceptions have surfaced. Such instances are irrelevant and would only embarrass well-meaning individuals, many of whom have been given impossible tasks. I can assure you that these myths and misconceptions do exist.

SIMPLICITY OF THE HYDROLOGIC SYSTEM

Perhaps the most basic of the erroneous beliefs is the idea that simplicity can be willed on the forest hydrologic system. This belief encourages the implementation of simplistic guidelines, the adoption of arbitrary thresholds of concern, and the search for all-encompassing methodologies to predict consequences of forest activities on water resources. These actions occur sometimes with the blessings of hydrologists or soil scientists but other times over their objections. The belief in simplicity has been nurtured by the rapid increase in the use of computer simulation models in forest planning and the desire to accept the output from such models. Another reason for pursuit of simplicity is the current emphasis on planning called for by NFMA; such planning is often conducted under strict time and budgetary constraints.

I must point out that, on the average, the simplistic methodologies may have resulted in fairly prudent forest management. But rather than being viewed as merely a first attempt at solving a problem, they often seem to inhibit further investigation and development. Also, they tend to lead forest managers and some specialists to believe that hydrologic systems really do function in the manner described by the simplistic methodologies.

Forest hydrologic systems are more complex than one would believe after reading some of the methodologies and procedures that have been proposed to predict cumulative effects of logging on water resources. For example, many of these procedures state that a threshold of harvest activity or intensity will be determined, without specifying how it will be determined or whether it really exists or can be measured. Similarly, implementing a methodology for estimating cumulative effects of harvest operations on water resources does not mean that such cumulative effects either exist or can be measured.

Watershed management research has discovered general hydrologic principles and basic similarities among various hydrologic systems, but it has also discovered differences among these same systems. The same research results that seem to form the basis for fairly simple views of hydrologic systems also indicate how local site characteristics can interact with basic processes to determine a particular watershed's signature, that is, how it expresses itself in terms of outflows of water, sediment, and nutrients or in terms of landslides, channel morphology, and characteristics of the riparian zone. These different signatures can give insight into how a given set of forest management activities might affect soil and water resources in a given watershed or along a particularly critical reach of stream. But in our desire to simplify, to create a methodology that will predict consequences of harvest activities everywhere or in the average situation, we usually expend considerable energy creating a methodology that predicts reasonably accurately virtually nowhere. We may implement procedures without providing for testing or monitoring the results to see whether the procedures are, in fact, working. In the process, we may even develop a false sense of security that our methodology can really protect soil and water resources.

THE TWELVE PERCENT COMPACTION THRESHOLD

Numerous plans, guidelines, and environmental impact statements have related the predicted amount of soil compaction to a defined threshold of compaction totalling 12 percent of watershed area. Procedures have been developed to summarize compaction from all activities for the entire watershed, including the proposed activity. These procedures commonly contain a recovery function so that changes in soil compaction over time can be considered more realistically. If the proposed activity does not raise the total area of watershed compaction above 12 percent, the proposed activity is deemed acceptable. The myth or misconception here is that soil compaction covering 12 percent of watershed area is a threshold for detrimental changes in streamflow.

What is this 12 percent figure and how did it achieve its mythical threshold status? Some of the cumulative compaction methodologies cite several of my published papers in referring to the scientific basis for the 12 percent figure, while others refer to undocumented studies. I can critically examine the 12 percent figure attributed to my papers, but I can't say anything about the undocumented studies.

In 1979 I prepared a handout for the Harvest Scheduling Workshop held in Portland, Oregon. I used results of three Oregon studies: the Alsea watershed study in the Coast Range (Harr and others 1975), the Coyote Creek study in the South Umpqua drainage of southwestern Oregon (Harr and others 1979), and the Fox Creek study in the Bull Run watershed near Mount Hood (Harr 1980) to illustrate the magnitude of changes in size of peak flows that are possible after certain logging activities. Earlier, Rothacher (1973) had shown that sizes of peak flows were mostly unchanged after clearcutting without roads or ground-based yarding. Size of peak flows may be increased when logging causes soil disturbance.

I plotted the increase in size of peak flow over percent of watershed compacted for eight watersheds, seven of which I used to develop a relationship between flow increase and amount of compaction (fig. 1). Amount of compaction ranged from less than 5 percent to nearly 15 percent of total watershed area, and corresponding flow increases ranged from less than 10 percent to nearly 50 percent. In some watersheds, compaction was determined from postlogging surveys, but in others, compaction was taken as the area in roads (including cut and fill surfaces), landings, and skid trails. To determine flow increases, I compared prelogging and postlogging regressions at a flow of 10.9 liters/(sec)(ha) or 100 $ft^3/(sec)(mi^2)$ at the unlogged watershed. This flow rate was selected arbitrarily, but with a return period of 8 to 15 years among the study

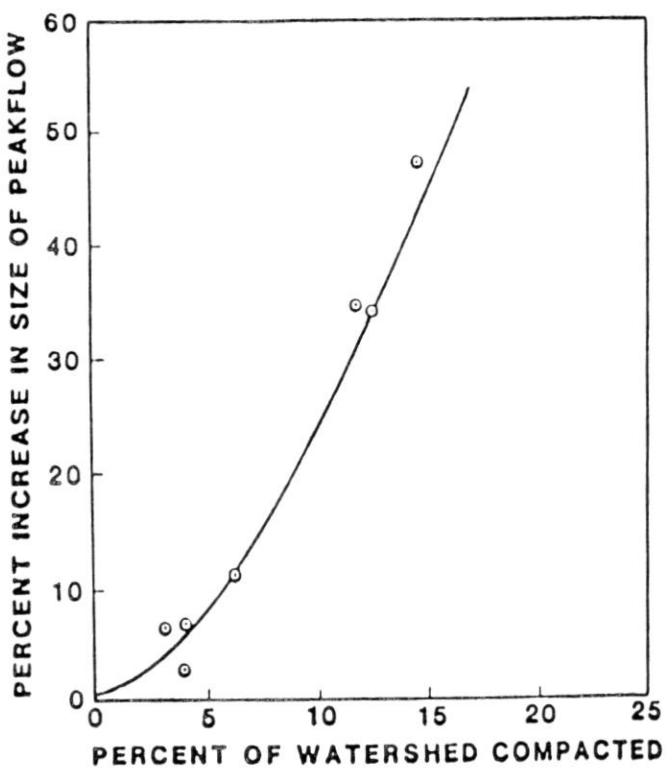

Figure 1--Relation between amount of soil compaction associated with logging and increase in size of peak flow at flow of 10.9 liters(sec)(ha) at unlogged watershed) for seven small watersheds in western Oregon.

areas, it represents a runoff event capable of moving significant amounts of bed materials. Both the Coyote Creek and Alsea watershed studies were hampered by not having relatively large peak flows in both the prelogging and postlogging periods.

There are two major problems with viewing the 12 percent figure as a threshold. First, the relationship shown in figure 1 does not indicate a threshold. Instead, a curvilinear relation between amount of compaction and increased flow is shown. A second and related problem is that the 12 percent figure is arbitrary. Flow changes at lesser amounts of compaction may also cause adverse impacts. According to the simple relationship shown in figure 1, 12 percent compaction corresponds to a 32 percent increase in size of peak flow at the flow of 10.9 liters/(sec)(ha) described above. Are we ready to believe streams can accommodate a 32 percent increase in size of an 8- to 15-year event without adverse effects on the channel? Undoubtedly many streams can, but what about those streams that would be adversely affected by flows that were only 10 to 25 percent higher after logging, flows that correspond to only 5 to 10 percent compaction? Without reference to the stream channels in question, we cannot arbitrarily say nothing will happen until the mythical 12 percent figure is surpassed.

If a threshold is to be used, it must be based on the physical characteristics of the stream in question. Furthermore, the allowable percentage of compaction should be the end product of any methodology to assess cumulative effects of harvest activities on streamflow. A methodology more defensible than one based on an arbitrary compaction threshold should start with the slope, critical particle size, and channel morphology, and based on established hydraulic principles, should determine what percentage of a watershed can be compacted without increasing the erosive power of the stream in the reach of interest. This methodology would still require a relation between logging and flow increase but would not arbitrarily fix amount of compaction at the same level for all streams. Some extremely stable stream systems can accommodate much higher flows without any degradation of the stream channel, and to restrict harvest operations in such watersheds to the same degree as in watersheds where some channel reaches are unstable makes little sense. Another paper at this conference develops such a methodology further (Grant 1987).

DESYNCHRONIZING FLOWS

Another strange belief is that the <u>desynchronization of flows, caused by logging-induced diversity of snowmelt conditions, will be beneficial to soil and water resources</u>. Numerous research results over the past 30 years illustrate how logging can change both snow accumulation and the energy balance of melting snow where net shortwave radiation is the major source of energy for melt (e.g., Halverson and Smith 1974; Troendle 1985). Recently, research has shown differences in snow accumulation and subsequent rate of melt during rainfall when convective transfer of sensible and latent heats are the major source of energy for melt (Harr 1981; Berris 1984).

Although timber removal by logging may desynchronize flows and cause lower peak flows in the parent watershed, it may also synchronize previously unsynchronized flows. Furthermore, whether the resultant desynchronizing or synchronizing is beneficial or detrimental depends on how flows from various source areas originally combined to produce streamflow in the parent watershed. (Here, flow changes are considered beneficial if the resultant peak flow is lowered or its duration is decreased and detrimental if the resultant peak flow is raised or its duration is increased.)

In figure 2A, streamflows 1 and 2 combine to become streamflow 3 at the mouth of the parent watershed. An analysis of channel conditions and bed materials at the confluence indicates a critical flow at which bed materials start to move. Figure 2B shows what could happen if outflow from subwatershed 1 were to occur earlier as a result of logging-induced changes in that watershed's hydrologic system. Peak streamflow below the confluence (hydrograph 3) would be reduced 8 percent, and flow would no longer reach the critical level. According to the definition given above, such a desynchronization of flows 1 and 2 would be beneficial to stream channel 3 below the confluence. But if logging speeded up runoff from subwatershed 2 rather than subwatershed 1, peak streamflow below the confluence would be increased 14 percent, and duration of flow above the critical flow rate would be increased 35 percent (fig. 2C). These changes would be detrimental according to the definition given earlier.

Both scenarios are plausible, but what I've found puzzling is why, without knowing how flows combine under undisturbed conditions, some people believe that logging will desynchronize flows and such desynchronizing will be beneficial to stream channels. These two simplified examples would seem to illustrate clearly that logging may either synchronize or desynchronize flows and that such effects may be beneficial or detrimental to streams. In other cases, changes in volume and timing could offset one another, and the resultant flow from the parent watershed could be unchanged. In large watersheds in western Oregon, analyses of flow changes that coincided with abrupt changes in rates of logging suggest that flows can be increased 22 to 56 percent in large parent watersheds (Christner and Harr 1982). It should be clear that whatever changes do occur as a result of logging cannot automatically be termed beneficial to the stream system any more than they can be automatically considered detrimental. Moreover, because stable stream systems can sometimes accommodate increased peak flows without

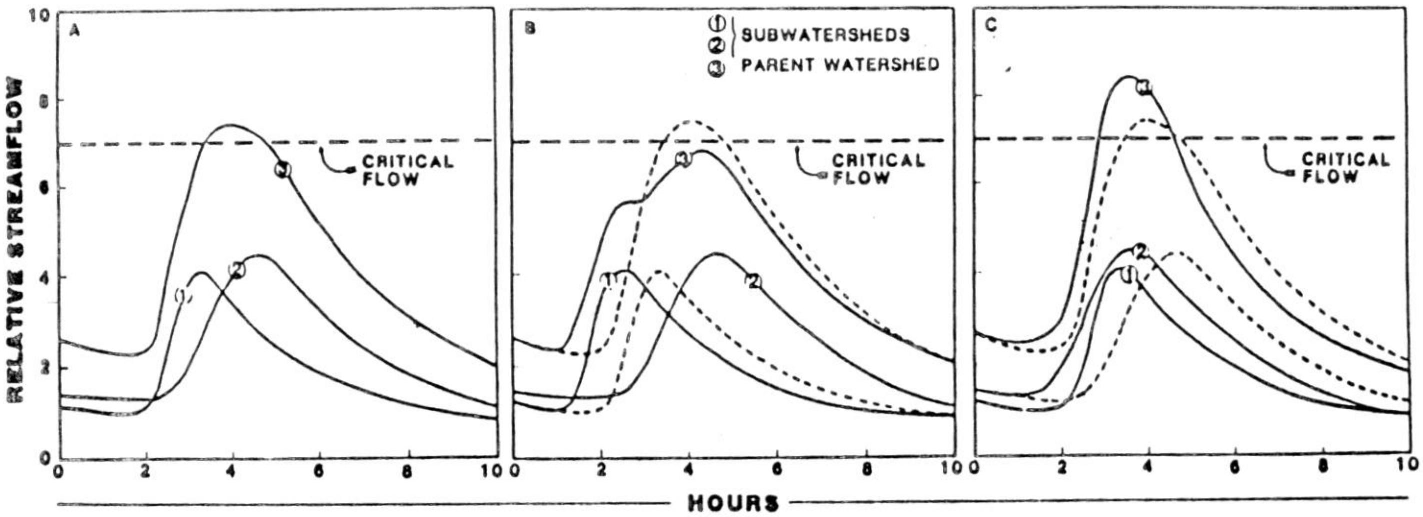

Figure 2--Effects of flow changes due to logging. A, Hypothetical flow at parent watershed 3, comprised of flows from subwatersheds 1 and 2. B, Hypothetical flow at parent watershed 3 if flow in subwatershed 1 occurs sooner following timber harvest. Peak flow in watershed 3 is reduced 8 percent and does not reach critical level. Dashed lines are the original hydrographs shown in A. C, Hypothetical flow at parent watershed 3 if flow in subwatershed 2 occurs sooner following timber harvest. Peak flow in watershed 3 is 14 percent higher, and duration of flow above the critical level is 35 percent longer than before timber harvest in subwatershed 2. Dashed lines are the original hydrographs shown in A.

channel changes, even higher flows considered detrimental in our simplistic analysis here will not always be detrimental in the real world.

WET-MANTLE RUNOFF AFTER CLEARCUTTING

In the 1970's, several published papers described the changes in size of peak flows that could follow harvest activities. It has become common knowledge among hydrologists that early autumn peak flows will be higher after logging. Wetter soils that result from drastically reduced evapotranspiration allow watersheds to be more responsive to early fall rains. Because less rainfall is required to recharge soil water storage, more can be translated into streamflow, and this results in more storm runoff and higher peak flows. But fall peaks are characteristically small compared to winter peaks flows that transport most bed materials and reshape channels. Thus, whether or not fall peak flows are higher after logging is considered to be of little geomorphic significance.

A study by Rothacher (1973) showed that winter flows after soil water recharge were relatively unaffected in a clearcut watershed without roads, and a general belief originated that wet-mantle runoff is not affected by clearcutting. Results of the Alsea (Harr and others 1975) and Coyote Creek (Harr and others 1979) studies tended to support this belief; higher winter peak streamflows in those studies appeared to be related instead to amount of watershed compaction.

The belief that wet-mantle runoff is not affected by clearcutting is not entirely erroneous; it may be true in watersheds at lower elevations where snow rarely occurs. Rothacher (1973) seemed to know he had looked at only part of the puzzle when he concluded "...harvesting of timber will result in appreciably increased peak runoff only under unusual circumstances..." such as "...a rain-on-snow event in which large quantities of precipitation coincide with melt of a larger accumulation of snow in logged areas." However, even with that statement, Rothacher still was not seeing the entire picture. Not only did he consider rain-on-snow unusual (which it isn't), he also didn't recognize what removing forest vegetation might do to rate of snowmelt during rainfall.

Recent rain-on-snow research has shown that changes in both snow accumulation in the transient snow zone and rate of snowmelt during rainfall can combine to cause more water to enter soil in logged areas than in forests. Often, snow intercepted by the forest canopy melts in the canopy and reaches the forest floor as meltwater or as clumps of wet snow. Where trees have been removed, snow accumulates on the ground where it melts much more slowly and is more likely to be available to melt later during rainfall. Because the convective transfer of latent and sensible heats is commonly greater in logged areas where windspeeds are higher, more energy is available to melt snow in many logged areas. During one accumulation-melt sequence in a plot study in the Oregon Cascades (Berris 1984), snow water equivalent in a clearcut was twice that in the forest. And during rainfall, energy to melt snow during rainfall in the clearcut was 40 percent greater than that in the forest.

SUMMARY

The myths or misconceptions about forest hydrologic systems described above are only four of those I have encountered while working with forest hydrologists and other forest land managers over the past few years. As conflicts among forest resource uses and among forest interest groups intensify, more procedures and methodologies designed to assist the planning process or to regulate harvesting activities will probably be technically scrutinized more closely. Technical soundness of the procedures and methodologies will become more critical and will depend in part on how free they are from misconceptions and myth. I hope this discussion has helped dispel some misunderstandings about forest hydrologic systems and the cumulative effects of harvest activities.

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