PROSPECTS FOR AFFECTING THE QUANTITY AND TIMING OF WATER YIELD THROUGH SNOWPACK MANAGEMENT IN SOUTHERN ROCKY MOUNTAIN AREA

By

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For this discussion, we have each been asked to describe snowpack, climate, topography and forest and soil conditions in our respective regions; to discuss research, past and present; give a summary of results to date and outline major questions and problems remaining; and finally to suggest possible applications of research results. Because we have been given only 20 minutes to do this, I have chosen to give primary attention to two zones typical of the Colorado high mountains and which illustrate some points I wish to make.

The first is the Alpine Zone. This is the area above timberline and has been estimated to include 5 million acres of Wyoming, Colorado and New Mexico. A quickly noticed characteristic of the alpine is wind. Because of wind, snow cover is not continuous. Snow is swept from exposed areas and piled into protected spots where it may accumulate to great depths. These snowfields persist into late summer or even fall and are obvious sources of late season runoff. In common with the water users, we have looked at these snow patches glistening in the summer sun and asked:

1. Does this snow contribute its fair share to streamflow or is much of it lost to evaporation?
2. If it does contribute to streamflow, how can we cause more snow to pile up on the fields?
3. Can anything be done to control melt rates? Can we slow melting, or can we speed it up to produce runoff when it is most useful?

Results to date give some answers to these questions.

1. Evaporation of alpine snow is minor. In fact during summer, gains from condensation often offset evaporation losses. The alpine is a good place to store snow. Each acre of snow releases almost $1\frac{1}{4}$ acre feet of melt water per week during July and August. The vertical ablation is quite constant at 2 feet per week. In other words, a depth of 16 feet of snow on July 1 means the snow will persist for 8 weeks and release 10 acre feet of water per acre of snow.

   The snow fields are good reservoirs and a little more than 60 percent or so of their total volume is water all set to run downhill.

2. Now how can one put side boards on the fields and cram on some more feet of snow? Here, in spite of some hard work, we begin to do more hoping than knowing. Certainly snow fences of proper density, construction, and effectively sited should do some good. Well, trying to spell out proper density and construction of fence and deciding where to put them turns out to be harder than we thought.

   So far we have tried only ordinary "highway" snow fence of wood slats held by wire. It does a fair job but it looks as if something else should do better. The approximately 50 percent density of the stiff slats probably adds to turbulence in the fence lees during high winds. Also during high winds the lack of give in the fence adds extra stress which contributes to collapse. These difficulties add zest to the investigation because they do not appear impossible to solve. They merely illustrate that solutions are seldom as easy as we hope.

   There are other possible ways to add to the depth of snow in some areas. One is to induce avalanches in selected spots. This might empty the head of the avalanche before new storms arrive, adding to the capacity to trap snow. Reshaping of the terrain by bulldozers to form basins and ridges might also help. But we haven't tested these possibilities.

3. The control of melt rates is appealing. Small scale tests indicate that something might be done. Carbon black application increased melt rates about 10 percent and a layer of sawdust reduced melt rate almost 50 percent. However, so far we've attached more importance to catching snow than to learning how to control melt.

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We expect that the most important result of increasing the volume of alpine snowfields will be more streamflow during the summer. The total amount of annual streamflow may not be changed. It is possible that more effective trapping and retention of snow at high elevations may reduce total evaporation losses. Nevertheless, we believe this effect will be slight compared with the effect on timing of runoff. More flow during normal low water periods is the most pressing need in areas above large storage basins. Alpine snow control appears to be the most certain management tool for meeting that need.

My second example is the Subalpine Forest Zone. In Colorado, this is the Engelmann spruce, subalpine fir, aspen, and lodgepole pine forest. Winter visitors to these forests have observed among other things that: coniferous trees hold snow on their foliage; and snow melts slowest in the dense shade of conifers.

These observations have been confirmed by numerous measurements and this has led to speculation which may be briefly summarized as follows. The less trees on an area the more snow will reach the ground and the greater will be streamflow. But without shade the snow will melt rapidly, therefore, enough trees should be left to prevent excessive melt rate. From these premises, patterns of openings may be planned that provide a maximum of open area with the minimum reduction in shaded area.

The results of such patterns of snow accumulation and snowmelt rates have received some testing. The typical result in Colorado is that cutting all trees on small plots will increase snowpack 20 to 30 percent. Intermediate cuttings increase snowpack in proportion to the amount cut (if clear cutting increases the pack 30% — cutting half the trees increases the pack 15%). Melt rates on cut plots have increased right along with the increased snow. In other words, in spite of greater snow depth, plots where trees have been cut are more exposed and become bare at the same time as the uncut shaded plots.

The plot studies to measure snow interception do not directly prove that more snow is evaporated from dense forest. Snow is measured by snow tubes so that what is actually determined is where snow finally comes to rest. The open plots may actually be trapping snow more effectively rather than snow evaporating more rapidly from tree crowns on uncut plots. What I am trying to point out is that the cut plots are not independent of the surrounding forest. Without the wind protection given by the uncut trees how much snow would actually remain in the openings? How much of the snow in the openings was blown off the foliage of surrounding trees?

The most convincing way to determine whether changing forest cover influences runoff is to make a trial on a watershed. Two such tests in Colorado are familiar to you. The oldest was the Wagon Wheel Gap Experiment. Here clear cutting of a young aspen forest increased runoff about 16 percent. The spring runoff peak was earlier and larger than before cutting. Increased flow was attributed to the elimination of interception and to more rapid melting which decreased the time snow was exposed to evaporation. It isn't easy to accept this explanation today because aspen holds almost no snow on its bare limbs and we've learned that evaporation from snow is minor.

The more recent watershed study on Fool Creek at Fraser Experimental Forest is in an area of higher precipitation than was Wagon Wheel Gap. Here, one half the timber was removed in alternate clear cut and uncut strips. The result is that water yield has been increased 26 percent in the 4 years since cutting. Most of the increased runoff is in the snowmelt period, with only very minor increase in late summer flow. This increase is about twice as much as was obtained from the plot tests of interception in the same area.

By this time it is obvious that I am questioning the conventional emphasis upon interception of snow as an important factor controlling water yield in the Colorado area. It appears that the transpiration use by trees is a more logical explanation for the lower water yield from forested areas at Wagon Wheel Gap. At Fool Creek, reduced transpiration after cutting may be a factor at least as important as reduced interception.

It is fair to ask why we worry about the causes for increased flows so long as they can be obtained by cutting trees. The answer is that we cannot work out efficient land management unless we know the processes we are attempting to control. We must be able to indicate how long flow increases will persist; the areas where changing vegetation will give significant results; and be able to specify what kind of vegetation should be permitted to develop on treated areas. Some form of plant life will occupy the site and we must manage towards the form that best serves our purpose not wage an indiscriminate attack. Enough is known to indicate large differences in water use between kinds of plants and we must learn to capitalize on such differences.

Needless to say, we are working to separate out the different kinds of evapo-transpiration losses. We have found that aspen makes a greater drain on soil moisture during the growing season than does spruce and hat both species withdraw water from greater depths in the soil than does native bunch-grasses. Unanswered, at present, is the amount of winter and early spring transpiration by trees. It does not appear that there can be much transpiration from November through March because soils are ordinarily dry then and evaporative forces are at their minimum. The situation is different in the spring. Temperatures are rising; days are long; soils are wet; and unless conifers have some biologic control to restrain transpiration rates, considerable water should be transpired. So far we do not have a method to measure transpiration losses during the melt season. Soil moisture measurements do not give this information while soils are gaining water content. Methods of measuring water movement directly within the tree stems probably promise the solution and recent developments offer at least a comparative type of measurement.

The application of present watershed research knowledge to Colorado subalpine forest management looks about this way:

1. Clear cutting strips or patches of dense forest should result in increased water yield for several years after cutting.

   For the moment, it appears that if increased water yield is the primary goal, the cutover areas should be seeded to grasses. If continued timber production is a goal, we could not say which of the possible species of trees would produce a timber crop with minimum use of water.

   However, cuttings in the extreme upper edges of the forest zone or clear cutting of isolated patches of trees represent a different condition. Much snow is blown into the trees from the adjacent open areas. Removal of trees from these situations is expected to be detrimental to water yield.

2. Because of the generally thin snowpack in the Colorado forests, no type of management to increase late season streamflow appears particularly promising. As pointed out in discussing the alpine, it takes a really deep snowpack to still be yielding water by late summer.

We have recently had an opportunity to give more attention to the snowpack in northern New Mexico and the Arizona White Mountain area at the head of the Salt and Little Colorado Rivers. For the past two winters, reconnaissance type observations of snow accumulation, soil frost, snow evaporation, and melt rates have been made.

One important difference from Colorado is the large area of frozen soil in the snowpack zone there. This is especially conspicuous in the Arizona area where there is frequent melt throughout the winter. Soils freeze in both open and forest areas and freeze tight enough to reduce water percolation into the soil. In the Sangre de Cristo of New Mexico, soils freeze in open areas and in aspen areas but not in spruce where snow is protected from melt during the winter months.

Another important difference in Arizona is the attitude of water users towards the timing of snow-pack runoff. They have little or no desire to prolong the snow runoff period. Because of the large reservoir capacity downstream, they are interested in having the snow melt rapidly and add to the early spring runoff. Minimum conveyance losses are expected at that time when water can be run on top of other water.

I expect you will be hearing a lot more about our research in snowpack management in the southern Rocky Mountain Region. Obviously we have benefited greatly from the help given us by many of you as individuals and through your organizations. We are grateful and so appreciative that you can expect us to continue to call on you.