WEATHER, WATER, AND RESEARCH

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This is an extremely broad subject and the field we are canvassing is so vast that the best I can hope to do is cut out only a small corner of the problem for inspection. Hence, I will not try to cover all material related to the subject, or answer all objections, or solve all the problems. Rather, I would like to stimulate your interest and thinking in one direction--weather and water as part of watershed research and what can be done to influence them. We have heard a great deal about weather and water, and their importance to the Nation. Weather is a favoriate topic of conversation and is cussed and discussed more than any other subject. To most people, it is either beautiful or lousy. Water, on the other hand, reaches its ultimate as a problem to each citizen when he turns on the tap and no water gushes out. When this occurs, the water supply problem is in his lap. President Kennedy focused attention on the weather and water problems of the Nation in two of his natural resource messages to Congress. The National Center for Atmospheric Research, which has as its objective a concerted attack on a broad range of problems that bear on the development of fundamental and quantitative theory relating to the general circulation and long-term climatic change, has given a tremendous stimulus to weather and its various problems. The Kerr Committee report forcibly spelled out the national water problems, and Senator Anderson has introduced legislation into the Congress, based on the Kerr Report, which would greatly expand water research. Testimony presented in support of this legislation emphasizes the urgent need for all kinds of water research. The research field of water and weather is now serious business. It calls for our very best thinking, best planning, and perhaps above all, ultimate coordination of the various kinds of water research activities.

WEATHER

One of the greatest upsetters and interrupters of human plans and activities is weather. It must constantly be taken into account in the calculations of most individuals. Like the Postal Service, the Weather Service is used by many people with little thought of how it operates. Very few hours of the day go by without some report on the radio or television about the weather. This demand has given present day weather information a new stimulus and place in our lives.

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The scientific approach to weather has to provide the basis for the reports we like in one or two words--clear, fair, cloudy, rain, snow. Those reports that are wrong are the ones that remain in our minds rather than those that are correct from day-to-day. Nowhere in this Nation has weather influenced the patterns of settlement and culture more definitely than here in the Southwest. However, it has given rise to certain basic problems where man has adapted specialized techniques and disciplines to make his settlement a success. Anyone familiar with the dry streambeds of this area can rightly assume we are losing a lot of precipitation somewhere. It is generally recognized the portion of the total precipitation that returns directly to the air is highly variable both in time and space. Per unit volume, its contribution to our requirements is far less than the fraction that runs off or sinks into the ground, because a considerable portion of this latter fraction can be controlled and distributed in accordance with our needs.

In the Colorado River basin, for example, less than 6 percent of the precipitation appears as streamflow. Ninety-four percent of the precipitation is retained where it falls. Part of this retained precipitation is used by vegetation or percolates into the underground aquifers. The major portion soaks into the dry, thirsty desertlands, however, and is later evaporated into the air. Here in New Mexico over 90 million acre-feet of water fall annually on the State. This comes in the form of rain and snow. Only about 2.5 million acre-feet appears as streamflow. Here, again, the major portion soaks into the dry watersheds.

The ability to control weather and climate even to a small degree would be of the greatest importance to everyone. Whether a measure of control can be obtained will remain uncertain until we understand the natural processes in the atmosphere much better than we do now.

WATER

Now let us look at the water picture. Much has been written about the possible water shortages that may appear. These shortages are not supported on a national basis. Of the country's 30 inches of average annual precipitation, about 9 inches or 1,160 billion gallons per day appears as streamflow. Approximately one-third of this amount that appears as streamflow is withdrawn and consumed in use. Twenty-one inches is consumed by evapotranspiration. By the year 2000, about 900 billion gallons per day, or three-fourths of the amount of streamflow will be required and withdrawn for use. Unfortunately, regional needs and problems do not correspond to the national averages. In the 17 Western States water waste amounts to 2.5 times the amount used for public supplies in the United States. This waste amounts to approximately 43 million acre-feet per year. Water problems are vital to this region now and many of the existing problems will become more acute before they are solved.

When good water is plentiful and cheap it is taken for granted; when it is poor in quality, costly or scarce, everyone is concerned. Water can never be a permanent part of any man's property, even though he may catch and store it; when it serves a use some or all of it will get away through the air or down the river. No water supply problem ever arose that was not brought on by use. Wherever research leads to a more efficient use, it leads also to a mitigation of the supply problem. We may influence water supply by modifying the climate, by reducing sea water to fresh water, or by changing or modifying the water yield from watersheds. Each of these topics presents spectacular possibilities of great interest to most of us, and the potential developments could have a major impact on the water supplies of a region.

The amount of water we may have for our needs and how we use it depends on nature's gigantic water-gathering mechanisms, our watersheds. The good or bad management of these watersheds is a personal matter and a paramount public responsibility. The rate small watersheds feed precipitation into larger streams determines the difference between a maintained flow over a long period or a flood crest downstream. Many of the same factors determine the quality of water in the lower areas and the degree and type of use which can be made of that water at any point in transit.

The water problem then becomes not one but many, the people who are affected are not many but everybody. Hence, the need for many approaches. If we could increase our total available water supply in the West alone through the reduction of evapotranspiration or other management practices, we would solve many of the local problems. Water is the life blood of agriculture, industry, commerce, of life itself. It cuts across every segment of our society, our economy, our daily lives.

Early peoples in the Southwest used the same resources available to us today. Obviously, there are more people now and more uses for these water resources, but the difference between our use and theirs is far more than merely more intensive development. The great difference is the tools available to modern man. We can wreak changes in the landscape which, even in geologic time, are nearly irreversible. We do more than use our water resources intensively--we start chain reactions in the environment, the end results of which we cannot visualize and certainly cannot see. The development and management of land, forests, and water have multiple and interlocking effects on this environment. The management techniques of the future, founded on sound water research programs, must be based on a knowledge of these effects. Otherwise, we cannot hope to reduce adverse uses to a minimum.

It is encouraging that we are now coming to recognize generally the difficulties we face in managing our water resources. Our problems are already acute in many local situations. If our population continues to explode as experts predict, we could be overwhelmed with problems unless we take action now.

RESEARCH

Research offers the major opportunity to extend existing water supplies over our increased demands. Successful accomplishment of research goals can have a significant effect upon future adequacy of our water resources. What we haven't recognized so far is this: First, research can keep us from getting into trouble, and second, research can provide us greater opportunities in using our water resources. The lack of research data is a serious limiting factor to more efficient action programs and water resource development. Agencies have frequently been forced to move ahead on a minimum of research data and, in many cases, a research basis for the solution of a critical problem is completely lacking.

Let me illustrate the kind of problem in multiple use of land and water that we face in the Forest Service by citing some research work we have underway, and the objectives of the Beaver Creek Project in central Arizona.

The basic purpose of the Beaver Creek Project is to determine the effects of forest treatments on streamflow from watersheds of 10,000 to 15,000 acres, and to evaluate the technical and economic feasibility of increasing water yields by modifying the vegetal cover through various land treatments. This research is set up to try to provide action programs with answers to the following major questions:

1. What is the amount of additional water that may be realized by land treatment measures?

2. What are the optimum uses and benefits from large flood flows?

3. What are the costs of producing and making available the additional water, and the sacrifices or gains in income from other uses?

4. What is the best multiple-use management of the watershed for water, timber, range forage, recreation, and wildlife?

You will recognize that competing and complementary land uses must be evaluated in terms of the best management of each resource and the most beneficial use of the resulting products. Otherwise, we would not have a fair comparison of the relative benefits from each of the many combinations of land uses in this area.

In this research we must determine the additional benefits that would accrue from increased water yields, if such can be achieved by land management adjustments, together with the costs of land treatment and water delivery and the gains or losses in income from timber and other associated uses. You can see this is a typical problem of marginal costs and benefits, and may bear little resemblance to average costs or benefits associated with the present uses of water.

Values of increased water yields can only be estimated equitably if water is put to optimum uses in complete watershed development programs. The evaluation problems faced in this Arizona project are by no means unique. They occur, in some degree, wherever protection and management of forest lands have a measurable effect on the quality and amount of water supplies. Water development must not only be multipurpose, it involves people, agencies, and the use of multiple skills of scientists, engineers, economists, and politicians, as well as land administrators.

Research programs must not only show the way to increasing water supplies by such means as vegetation management, as on the Beaver Creek Project; it must also determine the relations between ground- and surface-water supplies and the best use of available water with a minimum waste of that water. Successful accomplishment of research goals in these fields can have a very significant effect on the future adequancy of our water resources. While many of the research fields are very promising from the scientific standpoint, successful accomplishment of research goals is by no means assured.

Many of the difficulties in understanding the role and status of water in soils and plants, stem from the dynamic behavior of water in living plants and plant parts. Within the last two decades advances in scientific theory of instrumentation have made it possible to develop a more fundamental approach to the study of plant-water relations. For example, a new instrument to measure moisture flow in stems, called a heat pulse meter, is being evaluated. A pulse of heat is inserted into a stem, and the difference in rate of movement of the heat pulse upstem and downstem is computed to measure sap velocity. This information will be useful in understanding movement of water into and through the plant. Research in this area is seriously hampered, however, by lack of measurement techniques for determining the free-energy status and flow characteristics of water in living plants under field conditions, or experimentally induced environmental conditions. Control over the process of water movement from the soil through the plant to the atmosphere would be an important step in developing methods for improving water yield by vegetation management on watersheds, and in improving other techniques of water conservation.

Atmospheric phenomena of water present many challenging fronts. Water travelling through the hydrologic cycle is subject to many atmospheric forces and processes which tend to affect its movements to and from the land. Some of these are temperature, solar energy, wind, humidity, and evaporation. Evaporation is one of the most important factors in water supply and water consumption, and is largely controlled by air temperature, humidity, wind, and solar radiation. Because basic data are very limited, an improved understanding of their characteristics is essential so that water losses from evaporation can be more readily controlled on mountain watersheds and storage reservoirs.

Closely allied with evaporation are the processes of deposition, sublimation, and melting of snow, which are not well understood. Yet, they are major considerations in many of our critical water supplies.

Detailed studies of snow physics at Fraser Experimental Forest in the Colorado Rockies are revealing how some of these complex processes operate.

In the Rocky Mountain area, the winter snow cover is relatively fluffy and dry, allowing extensive air movement. These movements generally occur in response to the unstable temperature gradients found in the snowpack. Warm moist air from the layers near the soil surface rises to be replaced by colder air from upper atmospheric layers. This causes water vapor loss to take place throughout the snowpack, not just the surface layers. Snow crystals change their shape and arrangement continuously. Each new snowfall forms a distinct layer that develops unique properties which depend on its location in the pack. Moisture migrates from layer to layer under strong temperature gradients. These changes in the snowpack have a strong influence on melt rate, evaporation, and how much water is available for streamflow.

Alpine snow research has also shown that alpine snowfields are significant contributors to late summer streamflow. As spring advances the snow disappears progressively from the lower elevations to the higher. When one-half of the snow has disappeared, the spring peak in streamflow is generally approached; when 80 percent of the snow is melted streamflow is declining.

At present, there is little concentrated research on the hydraulics of water movement over the land surfaces of watersheds. Overland flow and small channel flow are basic to an understanding of the refinement and design criteria for mechanical structures to prevent erosion damage and reduce flood peaks. Accurate streamflow measurements from mountain watersheds are extremely difficult and expensive to install because of steep gradients, sediment or trash-laden flows, or inaccessible gaging sites. New telementry devices and flow meters for streamflow measurements are badly needed.

Full understanding of fundamental erosion and sedimentation processes is a prerequisite for planning and execution of successful programs for water resource development and utilization. Basic research, directed to isolating and evaluating soil characteristics that govern the erodibility and the effects of rainfall, snow topography, and vegetal cover on the rates of erosion and sediment yield from watershed lands, have not been clearly defined. The processes creating streambank and gully erosion and soil piping, and the mechanics of sediment entrainment and transportation from rangelands require reliable refined procedures for estimating and evaluating the effects on water quality and quantity. The application and capabilities of electronic computers, radioisotopes, and ultrasonics are being considered for this type of research.

On the forested upstream watersheds, better understanding of the hydrologic and site production effects of different management practices is urgently needed to provide the best integration of timber, forage, and mechanical structures for minimum sediment damage. New information, new patterns, and systems of timber harvesting on steep, unstable slopes must be developed if we are to control sediment movement from these areas.

The limited research already done shows possibilities of higher water yields through improved vegetation management. Harvesting timber by alternate clear-cut strips running across the contours on the Fool Creek watershed in Colorado has increased streamflow by an average of 2.9 inches yearly for the 7 post-treatment years. On the North Fork of Workman Creek in Arizona, clear-cutting all moist-site timber (one-third of the total area) and planting to perennial grass, has increased streamflow by 50 percent during the 4 years since treatment. Further research is needed to develop principles, methods, and techniques for improving the amount, rate, timing, and quality of water yielded from watersheds.

The opportunities for increasing water yields under different conditions of soils, climate, topography, and plant cover, cannot be assessed until more research is done, but it appears that possibilities are greatest in those areas of highest precipitation. Research in the dryer zones could have great economic significance, however, because even a small water yield increase may mean a considerable percentage difference in total yield. On a 76-acre chaparral watershed in central Arizona, sprayed yearly for shrub control since 1960, the average increase in water yield over the water yield expected from an untreated adjacent watershed has exceeded 3 inches during the past 2 water years.

Practices that may improve or increase water yields are (1) converting to more efficient vegetation covers, (2) reducing the density of forest or brush cover to permit more precipitation to reach the ground and to reduce the number of plants using water, (3) cutting forests in snowpack areas to develop special patterns to increase snow accumulation and control melt, and (4) influencing the drifting of snow by artificial means in high-elevation areas to develop more uniform streamflow. In short, research must find out how to use vegetation to increase water yields and control sediment from watershed lands, rather than how to use water to produce more vegetation.

The recharging of ground-water supplies in watersheds is less direct and often more difficult to measure and to trace, but has great possibilities. We need to know more about the path taken by absorbed water from watersheds. Tracing and timing of underground-water movement from mountain watersheds is needed to determine whether water becomes available for use elsewhere and how it reappears. Methods for conducting such research are yet to be developed. Problems to be investigated include (1) methods for handling sediments to improve infiltration, (2) streambed percolation rates, (3) tools and techniques for characterizing recharge sites, (4) effects of prolonged pumping and recharge, (5) effects high mountain bog meadows have on ground-water flow and stabilization, and (6) techniques for using floodwaters to recharge ground-water aquifers and the use of aquifers to store water supplies. These are only a few of the problems requiring research.

No blanket answers can be given to problems of watershed management. No two catchment basins are exactly alike. Each ground surface and all the soil and rock materials underlying the surface affect the way water will begin its travels down the slopes of a watershed. The amount of precipitation and the climatic factors determine the kinds of vegetation and plant types that affect the runoff. These and many other factors combine to affect the way water is delivered from our small watersheds to our major streams. We cannot modify the major phases of the hydrologic cycle. Neither can we greatly change the amount of precipitation we receive. Clouds can be forced to drop their moisture loads by "seeding," but the main pattern of climate, the gross precipitation, is beyond our present control.

Therefore, through our research efforts we are constantly seeking to effectively modify those factors which influence our supplies and make it possible to meet our spiraling water uses. History records the stories of many civilizations that have fallen by the wayside because they did not manage their soil and water resources wisely.

In the Southwest the handwriting is on the wall. As Secretary Udall stated when he presented the Southwest water plan, "The Pacific Southwest is the Nation's fastest growing and driest region. In the next 40 years its population will triple. The region's supply of water is now inadequate to sustain development, and cannot provide adequately for future growth. Ground-water supplies are being overdrafted at an alarming rate. Unless additional water is made available, the economy of this region will decline--with serious consequences to the area and the Nation."