# A SEARCH FOR THE LEAST COMMON DENOMINATOR OF RUNOFF FORECASTING

By

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The first snow survey and runoff forecast undoubtedly was made by ancient man looking at the snowdrifts on the mountainside and forecasting the flooding of the stream by which he lived. Today we are still trying to put together the fractional parts of known and unknown information concerning runoff forecasting and combine them with a least common denominator in such a manner that we may be able to make better runoff predictions.

The first snow surveys and runoff forecasts, as we know them today, were begun shortly after the turn of the century by Dr. Church near Reno, Nevada. There, on Mt. Rose, he measured snow depths and recorded temperatures in an effort to forecast the level of Lake Tahoe. His initial successes inspired many to follow in the field of forecasting. However, today there are many facets of runoff forecasting that are unknowns.

The purpose of this paper is to point out some of these facets with the hope that, by so doing, it may lead to methods of discovering and making better use of these unknowns.

Presently, we operate a highly complex system of storage reservoirs and diversions on our rivers. These reservoirs, for the most part, are multipurpose units. In order to realize the greatest use of all their intended features, a highly accurate system of forecasting needs to be developed because, by our present procedures, forecast errors are often greater than the amount of reservoir space to be controlled.

Our snow surveyors do an excellent job of regularly taking snow measurements on the many snow courses. By sampling a very minute part of the watershed snowpack, a seemingly accurate index of area conditions results. In the past, one of the main considerations in locating snow courses has been the accessibility of these courses in the wintertime. With aircraft transportation becoming more practical for travel to and from snow courses and the development of a system of aerial markers that can be read from the air with a high degree of accuracy having been realized, the accessibility problem is not as important as it was thirty years ago. Since freedom to locate snow courses as desired has been attained, a more scientific approach to locating snow courses needs to be undertaken. Of course, attention should be given to selecting courses or combinations of courses that correlate as closely as possible with a given runoff. It should now be possible to include with remote and high elevation courses, that were previously impractical, a suitable combination of low and middle elevation courses if significant value in forecasting exists in these courses.

Another parameter that should be examined is the extent or area of snow cover on a watershed. Although some work has already been done in this region, the results to date are more qualitative than quantitative. With present methods of aerial photography, it would seem probable that a method of photomapping snow fields and incorporating information thus collected into forecasting procedures could improve their accuracy.

The importance of temperature above the snow cannot be minimized. Some of Dr. Church's early work was done with temperature; yet today we have little temperature data that are useful in predicting the nature of the runoff. Here, as with snow courses, some method of evaluation and locating temperature sensing devices is needed.

Evaporation from the snowpack takes place and the importance of this factor cannot be disregarded. Yet, little of practical value is known concerning the utilization and interpretation of this factor, and methods of its measurement are still in the exploratory stages. Such factors as wind directions and temperature may have some bearing.

The Weather Bureau and its cooperative observers record the precipitation and temperature wherever they happen to be located. Yet there are many square miles of

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area on our watersheds where no such measurements exist. Perhaps the establishment of such stations at strategically located points would enable us to increase the accuracy of our forecasts. Again, some method of evaluating the location of these points needs to be devised to make certain that we get the best information to use in making our forecasts. Once the value of one of these stations is determined, a continuing record should be kept for a long period of time under as near unchanging conditions as are reasonably possible.

Perhaps one of the most vital keys to successful forecasting is the long range, high accuracy weather forecast. When we can predict, with accuracy, the weather for at least ninety days in advance, we can then predict most of our unknowns such as the rate of snowmelt, evaporation, soil moisture, irrigation diversions, and return flows.

Measurement of soil moisture and soil temperature is a relatively new innovation in forecasting. As yet, our records are from such scattered locations and of such a short period of time that their values are still largely unknown and difficult to interpret. The instruments that are being used to determine these factors are relatively new. Continuous records, the establishment of additional stations at significant places, together with additional research and engineering on improved instrumentation may be helpful.

At this time much is being done in an effort to develop a system of instrumentation so that remote conditions can be telemetered to desired locations. When these systems are developed to a point where remote station conditions can be determined at will, a new tool will be available to the forecaster. With this information available, research, will need to be undertaken to find the best means of using it.

As our technology in forecasting improves, the problem of forecasting becomes increasingly more difficult to solve. Our rivers no longer resemble the way nature left them. Man has learned to build larger and higher dams; he has made diversions from the river to irrigate land; he has captured the return flow and rediverted it to irrigate additional land; and he has pumped water from the ground to irrigate many thousands of acres. Having done all this, he then tried to forecast the flow of the river below all these operations.

When a storage reservoir is filled, some unexpected events may occur. How much water does it take to fill a reservoir of a given size? Some additional water is required to fill and saturate the banks of a reservoir. Conversely, when a reservoir is drafted what percentage of the water stored is recoverable? Reservoir evaporation and leakage are two additional factors that have to be considered. There is more evaporation loss on a large reservoir surface than there was from the original river channel. Interpretation of existing data, along with additional field studies, should be made to support evaporation loss calculations used at the present time. Reservoir leakage factors cannot be ignored. Records show that some reservoirs have a history of high leakage, even to the extent that it has been impossible to fill some of them. Underground flows, as a result of reservoir leakage, have been known to reappear many miles from some of these dams. The length of time it takes the water to travel and the amount of water in transit are both unknowns.

The use of irrigation water is a function of the weather. When we can more accurately forecast the weather during the snowmelt period, we will be able to make better forecasts of diversions. It is generally accepted that long dry periods will greatly increase diversions while long wet periods will reduce them to a minimum. Another factor influencing diversions is water management--the tendency of some localities to over irrigate when water is plentiful and only to irrigate the better land in short water years.

Little is known regarding the relationship between snowmelt, the recharge of the underground water supply, the effect of ground-water pumping for irrigation, and the effect these have on the runoff. Much of the ground-water pumping utilizes sprinkler irrigation. This type of irrigation has a high consumptive use factor as a result of greater evaporation, which is somewhat compensated by the fact that a given amount of water will irrigate a greater number of acres than will surface irrigation.

The relationship existing between irrigation and return flow needs to be discovered. This return flow is an important part of streamflow that is available to the downstream water user. At this time, little seems to be known about these functions. It stands to reason that, regardless of our ability to forecast other parts of the runoff, if we cannot successfully forecast our irrigation requirements and our return flow amounts, the overall forecast will suffer in accuracy.

With the building of more dams to utilize the head from the natural fall of our rivers to produce power and supply irrigation water, our rivers are rapidly becoming a series of slack water ponds. These present a problem to those who are charged with the responsibility of collecting the accurate flow data on which we need to build our forecasts. Further endeavor must be made to increase the accuracy of stream gaging under all conditions.

Finally, a suggestion might be made that all the collectors of data should take inventory of the use that is being made of the information they collect. If it is found to be of little value or of no use at all, the particular item should be abandoned and the effort placed on collecting the best, most useful information to be used by and for the benefit of the greatest number of people.

Possibly, when we have been successful in evaluating enough of the above-mentioned unknowns, we will be able, in general, to make better forecasts than we are now able to produce. Presently, on some rivers, these unknowns for the most part have been discovered and accuracies of a high degree are realized in their forecasts. On others we remain much in the same position as our ancient ancestors, who looked up at the snowdrift on the mountain and made a guess. The fact remains that we are not equipped to make forecasts on these complex rivers with a degree of accuracy required for our present-day operations.