SOIL CONDITION MEASUREMENTS AS A FORECASTING PARAMETER

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Soil moisture measurements have been made for a great variety of purposes. The obvious and probably the most ancient measurements were to determine whether the dry farm crops would grow each season. In relatively recent times, hydrologists have seriously attempted to evaluate the importance of soil moisture conditions as they affect runoff. There is general agreement that soil moisture characteristics, varying with each season, exert a significant influence on the total volume flow and the shape of the hydrograph itself.

Dr. E. A. Colman of the California Forest and Range Experiment Station at Berkeley, California and the University of California devised the fiberglass electrode which carries his name. Dr. Colman's untimely death slowed down the practical use of the units and possibly the development of a better soil moisture and temperature unit.

The Soil Conservation Service, realizing that soil conditions exert an influence on total flow, established a series of field measurement sites located at snow courses throughout the West. The advantage of locating soil moisture measurement sites near snow courses is that we know which snow courses correlate with streamflow and, therefore, feel that soil moisture measurements at these sites have a significant bearing on streamflow.

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The soil moisture stations consist of Colman soil moisture units buried at 1-foot intervals in the soil profile. Wires from the units run up through a standpipe and connect to a terminal block. Readings are monthly throughout the winter months with a meter designed to measure the resistance of the soil moisture unit, which varies with the amount of soil moisture. The readings are correlated to the percent of total water in the soil.

The technical problem in these locations is that there is a great variety of soil conditions. The snowpack, although it is highly variable, is a much more homogeneous mass than soil. At soil moisture sites where the soil is representative of a large part of the drainage basin, we find the data to be significant as a corrective parameter on the snowpack variable in the forecast equations. The technical problems of placement of the unit in the soil and the soil characteristics in each horizon require individual laboratory analyses for each unit placed.

The temperature circuits, which are a part of the Colman units, work very well and have given us significant information on temperature fluctuations in the soil profile.

One thing that is now apparent from our data, which extend over a 14-year period (1954-1967), is that we cannot make up for the lack of good snow-course locations by adding the parameter of soil moisture. The water content of snow is the best single forecast parameter. Since the soil moisture factor is relatively small, its true value maybe lost or hard to identify if other parameters are not accurate or are not included. A watershed made up of high steep mountain ranges having heavy snowfall and shallow soils will not have a soil moisture parameter that is important. The problem in areas of this type is that our basic data are not good enough to make a determination of the value of soil moisture as a single parameter.

The variable that usually represents soil moisture is the August, September, and October precipitation. In the final multiple regression equation, there is high intercorrelation in some cases between the precipitation for this period and soil moisture. However, since the precipitation station is usually not at the soil moisture site, these two variables are often used in the same equation and actually increase the precision of the forecast relationship. The higher elevation of the soil moisture site could explain the superiority of the data. In the Boise and Payette River, the precipitation stations are almost as high in elevation as the soil moisture site.

The soil moisture data appears to have a superior corrective effect on the snowpack data. This can be explained by the fact that it is an integration of consumptive use factors which exert their effect on streamflow. The current soil moisture data may have more of a corrective effect on the forecast than antecedent precipitation data. For instance, in mountainous country, a half inch of rain occurring over a 2-hour period does not change soil moisture status significantly. Therefore, a series of very light rains might indicate as much as 2 inches of water, but the effective soil wetting is negligible.

Another technique of accounting for soil moisture conditions in general is the use of base flow or antecedent flow of the river itself. Where we have these data, soil moisture is often only a duplicating corrective factor. Flow figures in some areas are not available in time for current forecast equations.

The soil moisture data also determine whether or not the soil is frozen. This phenomenon, however, is not important under the area of deep snow. The snow, when more than 2 feet deep in the West, insulates the soil and allows it to thaw out before the snowmelt begins. However, soil moisture and temperature measurements on the periphery of the snowline become extremely important because the soil can freeze deeply when not covered by snow. Under these conditions, subsequent snow can fall and melt before the soil thaws out. Destructive floods may occur because the soil has lost its ability to absorb the snowmelt and rain. This is a forecastable hazard in the West and I suspect in many areas in the East.

The three rivers studied in detail are in Idaho and Nevada. The Boise and Payette Rivers range in elevation from 2,200 ft. to over 10,000 ft. The soils have not been mapped in detail but in general are medium in depth. They were formed under subhumid and humid climate. These soils are classified as Inceptisols, Alfisols, and Mollisols.

The soil moisture site used in the study as the forecasting parameter is called "Bogus Basin". The total water holding capacity of the 4 foot profile is 13.10 inches and the range in data, as measured January 1 of each year, is from a low of 3.68" to a high of 7.5".

Salmon Falls Creek, on the other hand, has great wide areas of soils formed under arid and semiarid climate (Aridisols and Mollisols) with a relatively small area of mountains. The elevation of this drainage basin range from 3,300 ft. to 10,000 ft.

Technicians feel that data could be improved by a soil survey delineating the soil types. This would provide information for weighting the measurements of moisture on each type in the forecast equation.

In this study, correlations were carried out to determine the significant independent variables related to the dependent variable, streamflow for the March or April through September period. Different periods and months were used in determining the independent variables to use. The significant independent variables were combined in a multiple-stepwise linear regression with the following results:

IMPROVEMENT OF COEFFICIENTS AND VARIATION EXPLAINED

DEPENDENT VARIABLE BOISE RIVER AS MEASURED NEAR BOISE, IDAHO (1954-1967)

Independent variables	Multiple coefficient of correlation	% of variation explained
Snow water	.85	73
April & May precipitation	.89	7
Soil moisture, January 1	.93	7
March temperature	.94	2
Antecedent precip. Aug., Sept., Oct.	.95	2

Total variations explained in forecasts from multiple regression equation 81% without soil moisture, 91% with soil moisture.

DEPENDENT VARIABLE PAYETTE RIVER AS MEASURED NEAR HORSESHOE BEND, IDAHO (1954-1967)

Independent variables	Multiple coefficient of correlation	% of variation explained
Snow water	.88	77
April & May precipitation	.93	10
Soil moisture, January 1	.95	4
March temperature	.97	2
Antecedent precip. Aug., Sept., Oct.	.98	2

Total variations explained in forecasts from multiple regression equation 89% without soil moisture, 95% with soil moisture.

DEPENDENT VARIABLE SALMON FALLS CREEK AS MEASURED NEAR SAN JACINTO, NEVADA (1956-1967)

Independent variables	Multiple coefficient of correlation	% of variation explained
Snow water	.78	62
March temperature	.84	7
Antecedent precip. Aug., Sept., Oct.	.86	4
April & May precipitation	.88	4
Soil moisture, January 1	.88	.03

Total variation explained by soil moisture not significant.

Soil moisture data have many other uses other than as corrective factors on the snowpack. Range and cropland conditions, fire hazard, research on soil, soil classification, and flood potential all make use of soil moisture data.

The technical problems of maintaining meters, training personnel, and determining soil characteristics as related to the soil moisture unit in each horizon make these data difficult to obtain. On the other hand, the increasing economic value of water stipulates that in the future every significant forecasting parameter should be measured. Our experience to date indicates that soil moisture is a useful factor under limited conditions. Great care is needed in installation of sites and the cost is high compared to snow data.

The soil moisture data constitute significant corrective forecasting parameters in limited situations. At the present state of knowledge, it is impossible to say whether this forecasting variable will work in all cases or all regions of the country. We are in the same position as snow surveyors were 40 years ago when they attempted to install snow courses. Many of the courses established that long ago have little or no forecasting use. However, they provide excellent data for many other purposes such as recreation, design of snow loads on buildings, survival of game, road plowing problems, and others.