DEVELOPING NRCS SNOTEL AND SCAN SOIL MOISTURE PARAMETERS FOR WATER SUPPLY FORECASTING APPLICATIONS

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ABSTRACT:

Soil moisture is an important component in determining watershed hydrologic condition, and as a contribution to streamflow. Most hydrologic models use precipitation and soil climate information as surrogates for soil water holding capacity and water flow through the soil. The Natural Resources Conservation Service (NRCS) Snow Survey and Water Supply Forecasting Program has a network of installed soil moisture and soil temperature sensors in their Soil Climate Analysis Network (SCAN) and at some SNOwpack TELemetry (SNOTEL) stations throughout the U.S. The data is collected hourly at 4 to 5 soil depths at each location. Some sites have now more than 10 years of data. Soil moisture data is statistically analyzed in conjunction with other parameters in water supply forecasting. An index has been developed and tested that calculates soil moisture for a pedon using specific detailed soil and site characteristics. This method may prove to be a more comprehensive measure of soil moisture that would be applicable to a soil specific geographic area. (KEYWORDS: soil moisture, SNOTEL, SCAN, water supply, forecasting)

INTRODUCTION

Water supply forecasting in the western U.S. is primarily based on the snow water equivalent measure of the snowpack. This provides current data for the water that will be available for spring and summer runoff. While this data is key to water supply forecasting, other data parameters are also important to the contribution of the current year's runoff conditions. The antecedent climate of the last several years has an effect on the condition of the watershed hydrology. The groundwater and soil moisture existing during the snow season creates conditions that will determine the efficiency of the runoff. With wet conditions in the soil, the melting snow will more efficiently runoff and provide a good runoff. Dry soil conditions will require some of the snowmelt to replenish the soil moisture needs before being available to streamflow. Thus, the amount of soil moisture has an impact during the melt and runoff season. The soil profile moisture content will have varying effects on the water supply based on the soil characteristics. Our goal is to use the soil moisture data to improve the accuracy of the water supply forecasts. The current network of stations has enough data to be used in the monthly statistical forecast equations.

METHODOLOGY

The SNOTEL system collects soil moisture data from the station location and provides hourly data. This data can be used in a monthly snapshot that coincides with the water supply forecast. The sensors record data at different depths of 2, 4 8, and 20 inches. Using the data from the different depths as parameters in the statistical water supply forecast for that basin provides an insight to the importance of the data for forecasting. Our premise is that the soil moisture in the shallow 2- and 4-inch depth is more transitory and will provide information on recent rainstorms and snowmelt. The 8- and 20-inch depths will provide longer term water storage information and perhaps provide a synopsis of the past year's climate conditions.

Soil water content was measured with the hydra-probe sensor (Stevens Water Monitoring Systems, Portland, Oregon). The hydra-probe sends a 50 MHz electromagnetic signal into the soil and the reflected wave is associated with the dielectric permittivity of the soil, which is then related to the soil water content and

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Figure 1. Soil Moisture sensor placement at NRCS SNOTEL sites.

conductivity. Output from the hydra-probe consists of four voltages that are converted to volumetric water content using one of four calibration curves provided by the manufacturer. For these sites, the curve associated with the loam texture was used. The probes temperature range is from -10˚C to +65˚C, and can only measure water in the liquid state. Therefore, only water content values corresponding to soil temperatures > 0˚C were used in this study.

There are several stations that have 9 to 13 years of data. Three of the stations were in the Boise River Basin, and one was near a small Owyhee River headwater basin. These were selected to have the best statistical robustness as a parameter for use in predicting runoff volumes. These data were ingested into the NRCS statistical forecast environment and were analyzed as any equation parameter. Each station depth was optimized individually. The data analysis showed that the correlation to streamflow volume varied by depth and station location.

Soil pits were dug at each site. The soil morphology on one of the pit faces was described and horizons sampled for physical characterization at the Soil Survey Laboratory in Lincoln, Nebraska. Soil samples were air-dried (30-35˚C) and sieved (< 2 mm). The > 2 mm fragments were sieved to determine the 2-5 mm and 5-20 mm fractions. Properties determined on the < 2 mm fraction were percent sand, silt, and clay (pipette method); and water content at -1500 kPa tensions (pressure-membrane extraction using sieved samples). Bulk density at field capacity (-33 kPa tension) was measured on whole soil clods. All of the above methods are described in Burt (2004).

RESULTS

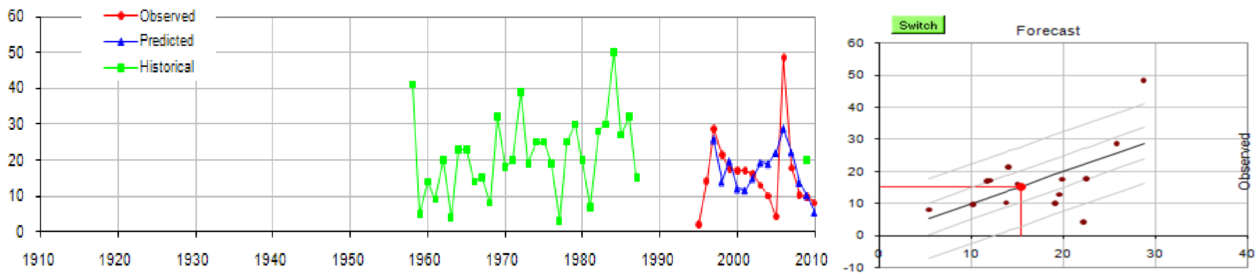
Owyhee basin

The Sheldon SNOTEL site has one of the longest soil moisture records in the data network (14 years). When comparing this station to the nearby streamflow at SF Owyhee R the following results are found.

Table 1. Sheldon soil moisture correlation to future SF Owyhee R streamflow (April- July).

SNOTEL Soil Moisture Depth (inches)	Current Year Month(s) Selected	Current Year SF Owyhee R Single Correlation	Last Year Month(s) Selected	Last Year SF Owyhee R Single Correlation
Sheldon				
2 inch	Mar 1	-0.364	Sept	0.003 (n/a)
4 inch	May 1	0.361	Mar – Jun	0.398
8 inch	Jan 1	0.476	Feb - May	0.363
20 inch	Jan 1	0.645	Apr-Aug	0.622

Figure 2. Forecast equation results compared to observed streamflow



Only using soil moisture from the 4 sensors at one SNOTEL site, the combined correlation (r value) to future streamflow is 0.595.

The forecast for the SF Owyhee River using soil moisture, with the current year's forecast in red. The forecast for the April – July Streamflow is 15.35 (61% of average). The error bars on the forecast are wide, with the standard error of 9.15. The Official published forecast for April 1, was 132% for the April to July volume.

Boise Basin

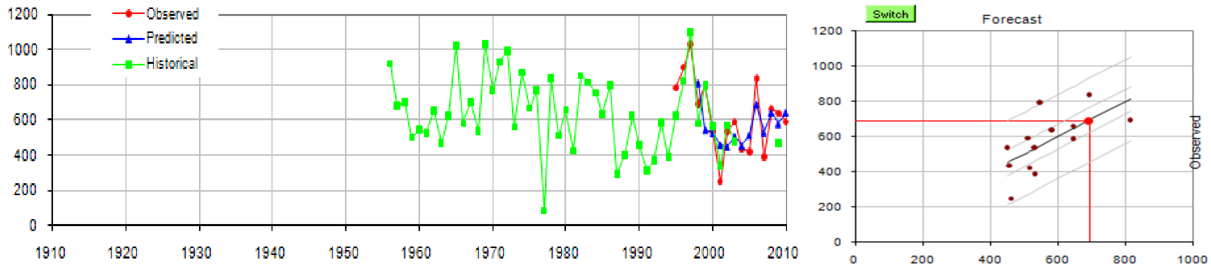
The Boise Basin in South Central Idaho, contains some research instrumentation including soil moisture sensors that have long term record. These SNOTEL stations have a good correlation to the basin streamflow at Boise at Twin Springs USGS gage. Some of the soil moisture sensor depths have fewer years of data than others. The 8- and 20-inch deep sensors, along with the 4-inch sensor at Jackson Peak, have the longest record of 12 years for each sensor location. The other sensor depths have a range from 4 to 6 years and the correlation suggests that this would be useful in the future, but has limited use with a short period of record. Some of the soil moisture data had no correlation (less than 0.300) with the subsequent streamflow, so was shown as "none" below.

Table 2. Soil moisture at SNOTEL stations in the Boise Basin correlated to future Boise R streamflow (Apr- Jul).

SNOTEL Soil Moisture Depth (inches)	Current Year Month(s) Selected	Current Year Boise R Single Correlation	Last Year Month(s) Selected	Last Year Boise R Single Correlation
Bogus Basin				
2 inch	--	none	Jul - Nov	0.593
4 inch	--	none*	Jul - Nov	-0.669*
8 inch	--	none	Apr - Aug	0.410
20 inch	Jan - Mar	0.603	Jul - Aug	0.687
Atlanta Summit				
2 inch	Jan - Mar	0.814	Mar - Mar	-0.770
4 inch	Nov – Mar	-0.470	Mar - Jun	-0.505
8 inch	--	none	Jul - Jul	0.377
20 inch	--	none	Jul - Aug	0.476
Jackson Peak				
2 inch	Jan - Mar	0.322*	Mar - May	0.947*
4 inch	--	none	Feb - Sep	0.387
8 inch	--	none	Mar - Aug	0.471
20 inch	--	none	--	none

*less than 5 years data.

Figure 3. Boise River forecast equation results compared to observed streamflow data using 3 stations.



The forecast equation that is developed using the soil moisture data has an r^2 of 0.412 and a standard error of 132.74. For this year, the statistical model is predicting the streamflow at Boise R near Twin Springs will be 109% of average for the April to July period. The NRCS official published forecast for April 1 was 106%.

Water retentions at -33kPa and -1500kPa were similar between the three stations in the Boise Basin. Therefore, they could have similar runoff potentials. However, the soils from these sites many not representative of all soils in the basin, and thus may not be able to predict its runoff potential very well.

CONCLUSIONS

As more stations increase the soil moisture data, statistical models will be able to incorporate stations in many water supply forecasts. The sensor data from the different depths provides a long term stable dataset that is a valuable tool for improving water supply forecasts. The data that best correlated with the streamflow ranged from positive single correlations of .3 to .8. Several of the soil moisture depths had a negative correlation, which was especially true for many of the last year data at shallow depths to current year streamflow.

The water supply forecast was compared to the official published forecasts for both the SF Owyhee River and the Boise River near Twin Springs. The SF Owyhee River forecast was not a good comparison to the current forecast. This could be for several reasons. The soil moisture station is not in the Owyhee basin itself, but is located in a nearby watershed. Therefore, soil moisture from the two stations may not represent the basin very well in many ways. In the Boise Basin, the three stations produced a statistical water supply forecast that was similar to the one produced using the snow and precipitation in the basin, and was very close to the official published forecast. To get the best forecast, each station and soil moisture depth should be analyzed in the forecast to determine its relevance. A spatial evaluation of soil representation of the basin may assist in a weighting system for using the soil moisture data.

By using soil moisture measurements, we were able to get an overall picture of the recent past and current climate based conditions in the watershed. Using an integrated approach of soil moisture for the whole soil column may improve the correlation to stream flow. Additional years of data and additional testing will provide a way to better use this data in water supply forecasting.

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