PARAMETER ESTIMATION FOR THE PRECIPITATION RUNOFF MODELING SYSTEM USING SNOW TELEMETRY SYSTEM DATA

by

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INTRODUCTION

The Water Supply Forecasting Staff (WSFS) of the U.S. Soil Conservation Service (SCS) is responsible for assembling snow, precipitation, temperature, streamflow, and other hydrometeorological data to forecast seasonal irrigation water supplies in the Western United States. Approximately 70 percent of the region's annual surface runoff is generated by snowmelt (Program Evaluation Division, 1977). The data collected by the WSFS are used to provide forecasts at over 600 streamflow gauging points (Shafer, 1984).

As demands on water for agricultural and municipal use increase, the need for efficient management grows as well. The SCS has undertaken an intensive effort to develop and improve its forecasting capabilities in response to these needs. This study constitutes a portion of that effort in which the Precipitation Runoff Modeling System (PRMS) (Leavesley et al., 1983) is tested with some specific uses of snow course, SNOTEL, and aerial marker data to study hydrologic problems on the East Fork of the Carson River, Nevada.

Availability of data is often a limiting factor in making real-time forecasts using computer simulation models. The relatively recent appearance of the SNOTEL system provides a new, well-distributed data network that can be incorporated into forecast procedures (Barton, 1975). The measurement of precipitation on a given watershed, especially mountainous watersheds, is an inexact undertaking at best (U.S. Army Corps of Engineers, 1956). By using the entire network of snow courses, aerial markers, and precipitation stations and determining adjustments to precipitation based on this network, the variability of precipitation over a watershed may be defined more accurately, resulting in improved model simulations. In addition, the ability to provide accurate short-term forecasts requires that the data be representative of the watershed, descriptive of variability, and readily available.

The East Fork of the Carson River watershed is located on the eastern slope of the Sierra Nevada Range in California and has a total drainage area of 92,209 hectares covering a wide range of ecological and climatological regions. The elevation of the East Fork ranges from a low elevation of 1,500 meters to a high of 3,536 meters. Precipitation ranges from a low of 190 millimeters in the valley bottom near Gardnerville, Nevada, to a high of 1,264 millimeters as measured at Twin Lakes National Weather Station located approximately 24 kilometers west of the Sierra crest. Runoff in the East Fork of the Carson is dominated by the snow component, melting snow contributing 80 percent of the average annual runoff.

DSCOR ESTIMATION

In PRMS, as well as in other models, initial parameter values must be estimated bearing in mind three things: (1) the parameters must be sufficiently close to the actual value to minimize the amount of parameter adjustment necessary to produce an accurate calibration for use in forecasting; (2) parameter values must be sufficiently accurate so that simulation over time will be stable; and (3) parameter values must, if possible, be derived from physical measurements so that they represent what's actually observable. Stability, in this case, is defined as a sufficiently representative calibration to guarantee that the value of objective functions remains approximately the same no matter what simulation period is selected, i.e., calibration and verification period differences are acceptable.

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The two parameters, Daily Rain Correlation (DRCOR) and Daily Snow Correlation (DSCOR), extrapolate the index precipitation station measurements to the hydrologic response unit. The estimation procedures discussed in the following sections were limited to only those techniques that use data readily available in an operational time frame to forecasters.

The graphical procedure for estimation of DSCOR uses snow course, aerial marker, and precipitation station data to provide estimates for DSCOR. National Weather Service monthly precipitation data for Woodfords, California; Topaz Lake, Nevada; and Twin Lakes, California; were averaged for the 14 years. Average monthly values were accumulated for November through March to coincide with the snow accumulation period at those sites. These sites, along with snow measurement sites located in the East Fork of the Carson River, were then divided into groups with similar microclimate, exposure, and aspect. Accumulated precipitation data were then graphed and a line was fitted by eye through each of the groupings. Figure 1, shows the results of the fitting procedure on April 1. Estimates of April 1 mean water content were then made for each of the 27 hydrologic response units. Estimated values for all other daily mode parameters were made using the PRMS Users Manual (Leavesley et al., 1983), and previous runs included in administrative reports provided by Leavesley and Saindon (Personnel Communications, 1984 and 1985).

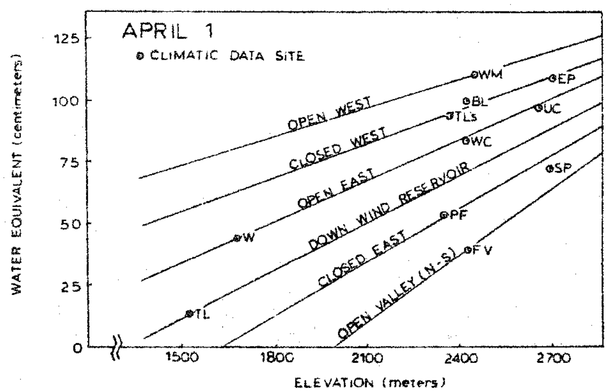

Figure 1. Mean SWE Estimation for HRU

TECHNIQUE	SLOPE b.	CONFIDENCE INTERVAL AT 0.95		CALCULATED t VALUE FOR b_1	ACCEPT OR REJECT
		Upper	Lower		
NWS					
Graphical (DSCOR-DRCOR)	0.791683	1.044	0.534	0.913	$b^1 = 1.0000$
Form Data (input)	1.007733	1.327	0.688	0.0239	$b^1 = 1.0000$
Graphical & Form	0.708172	1.0186	0.397	1.187	$b^1 = 1.0000$
SNOTEL					
Graphical (DSCOR-DRCOR)	0.610543	0.9657	0.2554	1.654	$b^1 \neq 1.0000$
Form Data (input)	0.497528	0.8416	0.1534	2.4096	$b^1 \neq 1.0000$
Graphical & Form	0.50776	0.7229	0.2926	2.3728	$b^1 \neq 1.0000$

Table 1. Statistical Test Results

FORM IDENTIFICATION PROCEDURE DESCRIPTION

The East Slope of the Sierra is affected by a more continental climate than the west slope (Sulahria, 1972). Warm storms often reach the Sierra crest at Twin Lakes, bringing a strong maritime influence to the upper air temperature station but not into the watershed. When this situation occurs, temperature values distributed by a mean daily lapse rate using Twin Lakes and Woodfords, lead to poor simulations. The form procedure was developed to improve the simulations.

PRMS defines precipitation form either by user specification or a temperature based algorithm. The form switch permits a user to overide the temperature based algorithm and assign precipitation as rain or snow.

If precipitation occurred on a given day, identified by a SNOTEL measured precipitation increase, snow pillow data are reviewed. If an increase in snow water equivalent is observed on the same day or the following day with the increase equal to or greater than the precipitation measurement, the precipitation form is snow. If the SNOTEL precipitation measurement is greater than the increase in snow water equivalent, then the precipitation is a mix and the form aassignment is left to PRMS algorithms. If the precipitation received is not accompanied by an increase in snow water equivalent, the precipitation is assumed to be rain.

CALIBRATION AND OPTIMIZATION

The first step in achieving an operational calibration of PRMS is to attempt to match the volume of flow for a selected period to the observed flow for the period. Correctly simulated volume flows are mainly a result of accurate estimates for the parameters DRCOR and DSCOR. Simulations were executed from 1981 through 1983. The DRCOR and DSCOR values were then adjusted until the flow volume for the water years was approximately 20 percent of the observed volume. These estimated values then formed the basic parameter set estimates on which all tests were based. These simulations were repeated using a parameter set for

NWS data and the NWS data set and then a parameter set for SNOTEL data and the SNOTEL data set.

Following manual adjustment an optimization of the manually adjusted DRCOR and DSCOR values associated with SNOTEL and NWS sites was done. Flows were then simulated using these optimized values for the period from October 1, 1980, through September 30, 1983. Optimization is accomplished with the Rosenbrock Optimization procedure (Rosenbrock, 1960) found in PRMS. Upon examination of initial DRCOR and DSCOR optimization simulations, it was interpreted that the resulting DRCOR and DSCOR values were actually compensating for other inadequacies, such as poor estimation of radiation.

The DRCOR DSCOR parameters were not optimized independently. They were optimized with the parameters (BST, SETCON, and base flow parameters) because they all act together in determining the total watershed response. It was hoped that realistic parameter values would result by optimizing with parameters grouped in this manner and that distributed precipitation would be balanced with observed streamflow.

Form data was included and DSCOR, DRCOR, and BST were optimized. The form index temperature BST assumed values as high as 7.2 degrees centigrade during optimization. BST adjusted upward in these simulations improves the accuracy of calibration but not the physical rationality of the parameter. It appears that runoff for those days on which the form is not specifically identified was subject to extreme interpretation because of the unrealistic value of BST. Only one optimization was attempted with the form data in place. When BST began losing physical rationality, the decision to no longer optimize was made.

DATA SOURCE TEST RESULTS

An evaluation of each procedure, graphical DSCOR and Form Data, was made by comparing normalized simulated to normalized observed values for the five key forecast types, volume, peak, peak date, date of 14.15 cms (recession only), and the date of 5.66 cms (recession only). It was not the intention of this study to compare anything more than the five standard forecasts.

The null hypothesis was then the simulated and observed values are equal and because they are equal, the slope of the comparison equation, observed to predicted, is equal to one, with an intercept of zero. Table 1 summarizes the results of these tests. Of the two types of statistical error, type I and II, the type II statistical error is the more important in this study. An alpha level of .2 was selected to minimize type II.

April-July volume forecasts were high by 16% using NWS stations 50% using SNOTEL sites. The remaining forecasts retained the same general relations as in the previous simulations with noticeably closer estimation of the 14.15 cms flow date when using SNOTEL data and closer estimation of the 5.66 cms flow date when using NWS data sites.

GRAPHICAL PROCEDURE RESULTS

The graphical procedure with NWS data was not rejected at the .2 alpha levels (table 1). SNOTEL precipitation data does not appear to provide adequate information for simulation purposes (table 1). The graphically estimated DSCOR values overestimated observed runoff with either data set, but only the simulations procedure using graphically determined DSCOR values used with SNOTEL data was rejected at the .2 level (table 1).

FORM PROCEDURE RESULTS

Including form data following the manual parameter adjustment improved simulation results using NWS data. Table 1 shows the results of addition of form data. Simulated peak flow values were increased in comparison to previous simulations. The remaining forecast values for low flow dates were closely simulated using either data set with errors of less than 20 days.

EXTENDED FORECAST PROBABILITY

To use PRMS as a forecast tool, the model must be able to run for an initialization period to tune it to current conditions and then run from the current date through the end of the forecast period using all available historical data in order to develop a range of possible runoff conditions which can be analyzed using various probability distributions. PRMS can currently initialize, store current watershed conditions, and stop at a designated date usually the beginning of the forecast period. Code modifications were then made to retrieve meteorological data from the historical data base starting at the beginning of the forecast period and ending on the final days of the forecast period.

This procedure was then repeated for all years to be used in the frequency analysis, thus producing multiple hydrograph traces. These runs are then evaluated by forecast type and stored in a file for frequency analysis. A log normal, Log Pearson Type III, or any other distribution can then be run against each forecast type to determine most probable (50% probability of exceedance), the reasonable maximum (10% probability of exceedance), and the reasonable minimum (90% probability of exceedance).

SUMMARY AND CONCLUSIONS

The graphical procedure described earlier has been applied several times (administrative reports to SCS by Leavesley and Saindon, 1984 and 1985). This procedure appears sound because of the acceptable performance of the NWS data and graphically derived DSCOR values.

SNOTEL data on the other hand did not perform well overestimating volumes by as much as 50%. The major factor contributing to this over estimation is the location of SNOTEL sites. They are installed to measure the snow resource at a carefully chosen point, but may not necessarily represent the mean areal distribution on the watershed.

An average over simulation was calculated by taking the predicted volume minus the observed volume divided by the observed volume for each of the three years simulated and then calculating an average error. This error, 30%, was then used to adjust the DRCOR and DSCOR values. With this adjustment, simulation was improved from .65 R value to .87 R. This small test demonstrates that a procedure to make good use of SNOTEL data is possible, and further investigation into the proper use of SNOTEL data on this watershed will be necessary.

To reduce the effects of poor temperature extrapolation on the watershed, the form identification technique was developed and tested. Form data applied on the East Fork drainage provided an acceptable technique when used with National Weather Service data but was unacceptable when used with SNOTEL data.

The graphical estimation procedure and the form identification procedure seem to provide the first steps in the formulation of a process to enable the quick estimation of parameters to calibrate with and result in parameters stable enough to use in forecasting. In addition, the probability algorithm demonstrated that PRMS can be used as a forecasting tool, and further development of its capabilities will be continued.

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