# A METHOD FOR INTEGRATING SNOW SURVEY AND PRECIPITATION DATA 1/

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By

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## Introduction

During the past 2 years the Soil Conservation Service and U. S. Weather Bureau have been conducting joint studies in the West relating to the development of single "best" forecast procedures for forecast points and periods of mutual interest. These studies are still in the preliminary stage and much more work is needed before final agency decisions as to policy and procedure can be made. However, these studies have resulted in developing techniques to determine whether the combination of snow course and winter precipitation measurements into a single "winter index" provides a better variable than either alone.

Combining precipitation and snow survey data in water supply forecasting has been described in a number of Western Snow Conference papers. One of the earliest of these was by Polos (1953). A recent and detailed study was published by the Water Management Subcommittee of the Columbia Basin Interagency Committee (1964).

This paper proposes no radically new methods of forecasting. Rather, it describes a systemetized application of present knowledge which uses current "state of the art" computer techniques. An operational approach has been pursued throughout. The object is to clarify the relationship between variables while using methods convenient for the practicing forecaster.

The primary purpose of this paper is to describe the formulation and testing of the "winter index". Combining snow course and winter precipitation measurements into a winter index was based on the following assumptions:

1. The procedure should use all important variables affecting runoff, whether or not they are known at time of forecast. These are spring precipitation, winter snow-water equivalent and precipitation, and fall precipitation or some other antecedent condition index.

2. In general, the snow variables now used by SCS and the precipitation variables used by the Weather Bureau were assumed adequate for formulating the winter index.

3. Past practice has been to use "weighted" precipitation station and snow course indexes. Even though a snow-water equivalent index may be composed of the simple sum of two or more snow course measurements, it is inherently weighted in favor of the course having the greater variance in snow-water equivalent. Since "weighting" is common, the most meaningful and useful set of weights or station coefficients were selected.

## Procedures

### Precipitation station weights

Relative station weights were determined in the customary manner. Generally, Weather Bureau practice has been to adjust station weights to total 1.0; thereby yielding some arbitrary level of monthly precipitation. These weights could just as easily be adjusted to yield an estimate of basin precipitation; a more meaningful value. Table 1 illustrates this method of adjustment.

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TABLE 1

EXAMPLE OF STATION WEIGHT COMPUTATION

Computation of Precipitation Station Weights
(Basin normal annual precipitation (NAP) = 60 Inches)

| Precipitation Station | Station NAP | Basin NAP ÷ Stat. NAP (A) | Relative Weight (B) | Station Weight (A)x(B) |
|---|---|---|---|---|
| M | 40 | 1.5 | 0.4 | 0.60 |
| N | 50 | 1.2 | 0.6 | 0.72 |
| | | | 1.0 | |

Computation of Basin Normal Winter Precipitation (NWP)

| Precipitation Station | Station Weight (A) | Station NWP (B) | (A)x(B) |
|---|---|---|---|
| M | 0.60 | 27 | 16 |
| N | 0.72 | 33 | 24 |
| | | Basin NWP = | 40 inches |

Computation of Snow Course Weights

| Snow Course | Course Ave. W.E. | Basin NWP ÷ Course Ave. (A) | Relative Weight (B) | Course Weight (A)x(B) |
|---|---|---|---|---|
| X | 50 | 0.8 | 0.67 | 0.53 |
| Y | 25 | 1.6 | 0.33 | 0.53 |
| | | | 1.0 | |

Precipitation monthly weights

If the total index is to approach true effective basin precipitation, then winter months (most effective) should have an average weight of 1.0 and early fall and late spring months a fractional weight. It is difficult to justify other than uniform weights for the snow accumulation months, usually November through March in the Columbia Basin. However, there should be no objection to slight variation from uniform weighting.

Snow course weights

Relative snow course weights using April 1 or maximum snow-water equivalent data were determined in the customary manner. In application these weights yield an arbitrary level of water equivalent which is readily adjusted to yield an estimate of basin winter precipitation. This is accomplished by adjusting the weights so that the period of record average water equivalent equaled the same period average winter precipitation. Table 1 also illustrates this computation.

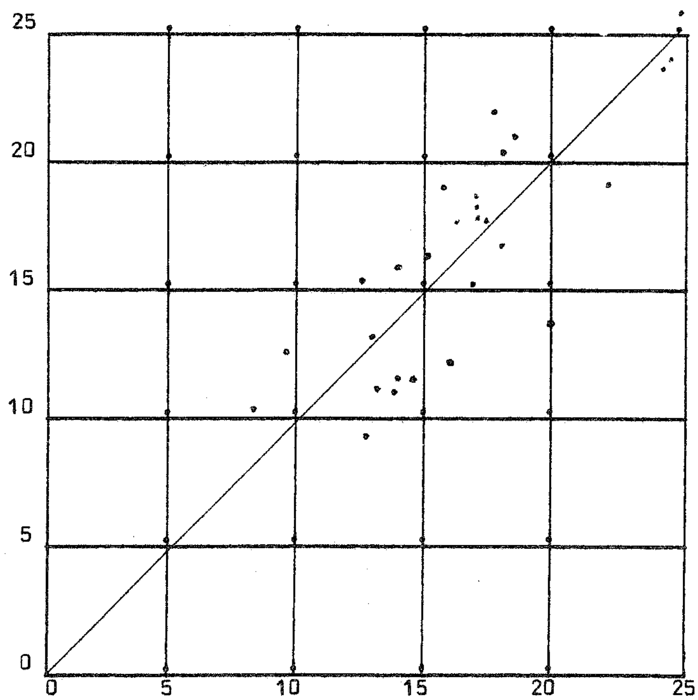
Comparison of snow and winter precipitation indexes

The snow-water equivalent index and the winter precipitation index can be compared at a glance in tabular or graphical form. The comparison is facilitated by having previously "normalized" the indexes to a common basin value. The plotted values scatter about the line of 1:1 slope, as in the example of Figure 1. This kind of chart provided a quick method of evaluating the usefulness of adding winter precipitation or snow-water equivalent to the existing procedure. Comparison of the positions of the points in Figure 1 and in the single winter variable forecast charts gave indications as to the possibility of improvement.

FIGURE 1

SALMON RIVER AT WHITEBIRD, IDAHO

WINTER INDEX COMPARISON




November-March Precipitation Index, Inches

## Multiple regression methods

A more objective evaluation and determination of weightings for converting the two indexes into a single winter index can be made by multiple regression methods. Numerous computer runs were made with predetermined combinations of variables.

Fundamental to the study was holding the fall and spring variables constant while testing various combinations of the winter indexes. Likewise, after determining the best winter index, it was held constant with the spring or fall indexes while various fall or spring indexes were tested. Thus only one runoff producing variable was varied in each study set. This then provided a sound basis for testing significance in that all runoff elements were included in each equation.

The same procedure was used in the selection of individual snow courses and precipitation stations.

In the three test basin examples which follow emphasis is placed on the determination of the best winter index. Statistical details regarding the selection of the best fall and spring variables are not given except for the Salmon River at Whitebird, Idaho.

## Forecast Relation Results

Three test basins were selected to illustrate a cross-section of the results. These basins vary in climate from practically pure snow-fed to predominantly rain-fed.

1. Salmon River at Whitebird, Idaho

This is one of the largest Columbia River tributaries and perhaps the most sparsely inhabited. Almost all precipitation stations are on the periphery of the basin, but there are several well-located snow courses. Most of the runoff comes from the higher elevations with very little winter runoff above base flow.

October-December runoff was determined to be a better antecedent condition index than fall precipitation. The spring precipitation index was that used by the Weather Bureau. These two variables were "locked in" the regression while the winter indexes were tested. Table 2 shows the results.

Note that snow-water equivalent is a far better index than winter precipitation, and that only slight improvement is gained by incorporating the latter index.

TABLE 2

SALMON RIVER AT WHITEBIRD, IDAHO
MULTIPLE REGRESSION RESULTS

Average April-September Runoff (1938-65) 6,770,000 acre feet

| Variables Used | | | | | | Std. | |
|---|---|---|---|---|---|---|---|
| Fall Precip. | Fall Runoff | Winter Precip. | Snow A | Snow R | Spring Precip. | Error 1000 A.F. | $R^2$ |
| X | | X | | | X | 837 | 0.727 |
| X | | | X | | X | 507 | 0.900 |
| X | | | | X | X | 550 | 0.882 |
| | X | | X | | X | 437 | 0.926 |
| | X | | | X | X | 511 | 0.898 |
| | X | X | X | | X | 409 | 0.935 |
| | X | X | | X | X | 482 | 0.910 |

2. Middle Fork John Day River at Ritter, Oregon

This 515 square mile basin is on the west slope of the Blue Mountains in northeastern Oregon. Late winter (January-March) runoff is fairly substantial, averaging 50,000 acre-feet compared with an average April-September runoff of 122,000 acre-feet.

Analysis methods were the same as previously described. Table 3 shows the pertinent results.

In this basin snow-water equivalent and winter precipitation are more nearly equally effective, but the 50/50 combination is significantly better than either.

3. Lewis River at Ariel, Washington

This basin on the west side of the Cascade Range has a large winter runoff, as indicated by the average runoff values in Table 4. The basin has been rather fully developed by Pacific Power and Light Company.

TABLE 3

MIDDLE FORK JOHN DAY RIVER AT RITTER, OREGON
WINTER INDEX COMPARISON

(Fall and spring indexes locked in)

Average April-September Runoff (1939-65) 122,000 acre feet

| | Winter Index | Std. Error 1000 A.F. | $R^2$ |
|---|---|---|---|
| 1. | Snow alone | 22.6 | 0.759 |
| 2. | Winter precipitation alone | 24.5 | 0.716 |
| 3. | 50% snow + 50% precip. | 18.3 | 0.842 |

TABLE 4

LEWIS RIVER AT ARIEL, WASHINGTON
WINTER INDEX COMPARISON

(Fall and spring indexes locked in)

Average April-September Runoff (1944-65) 1,410,000 Acre Feet

| | Winter Index | Std. Error 1000 A.F. | $R^2$ |
|---|---|---|---|
| 1. | Snow alone | 166 | 0.691 |
| 2. | Winter precipitation alone | 236 | 0.379 |
| 3. | 85% snow + 15% precip. | 165 | 0.697 |

Average January-September Runoff (1944-65) 2,670,000 Acre Feet

| | Winter Index | Std. Error 1000 A.F. | $R^2$ |
|---|---|---|---|
| 1. | Snow alone | 334 | 0.560 |
| 2. | Winter precipitation alone | 153 | 0.913 |
| 3. | 30% snow + 70% precip. | 119 | 0.950 |

Table 4 shows that the desired forecast period (April-September) is not the best accounting period. Note that winter precipitation is of no help in the April-September forecast, but alone produces a better January-September forecast. The best procedure uses both snow and precipitation in a 30/70 ratio to produce a January-September forecast, from which measured January-March runoff can be subtracted to yield an April-September forecast.

## Summary

This study indicates that, in the Pacific Northwest, a combination of snow-water equivalent and winter precipitation, coupled with fall and spring precipitation indexes, appears to yield better forecasts than either index alone. The proportion of snow-water equivalent and winter precipitation in each forecast relation varies with the basin involved. The proportion appears to range from 70-90 percent snow-water equivalent plus 10 to 25 percent winter precipitation in practically pure snow-fed streams to 25 percent snow-water equivalent plus 75 percent winter precipitation in predominantly rain-fed streams.

The weighting methods retain the simplicity of the "index" method of water supply forecasting while permitting easy comparison and combination of the two winter indexes.

Each stream must be studied in detail in order to determine the proportion of snow-water equivalent and winter precipitation. "Locking in" all variables except the one being tested aids in this determination, particularly when analysis time is reduced to a minimum by computer techniques.

## REFERENCES

Polos, A. J., The Use of Precipitation and Snow Survey Data in Water Supply Forecasting, Western Snow Conference Proceedings, 1953.

Water Management Subcommittee, Columbia Basin Interagency Committee, Derivation of Procedure for Forecasting Inflow to Hungry Horse Reservoir, Montana, 1964.