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ACKNOWLEDGMENT

The author wishes to acknowledge the assistance and encouragement from the following, who aided materially through discussions, correspondence and in preparation of this manuscript: R. B. Branstead, Head, Visual Information Section, SCS, Washington, D. C.; R. S. Beeler, Sales Service Division, Eastman Kodak Company, Rochester, N. Y.; Paul A. Ingebo, University of Arizona, Tempe, Arizona; Henry W. Anderson, California Forest & Range Experiment Station, Berkeley, California; Paul E. Lemmon, SCS, Washington, D. C.; Richard E. Wegner and Harlan Wilhelm, Montana State College students, Bozeman, Montana.

SNOW MELT CURVE

by

H. B. Richards 1/

Since the first efforts toward forecasting stream flow from snow surveys the major problem has been to evaluate the data furnished by the snow surveys into terms of stream flow. Various methods were used and are still being used for this purpose.

The factors that influence snow melt and stream flow cannot yet be anticipated. A method that attempts to evaluate these in a regression calculation by considering these factors as variables or constants is difficult and of questionable value. It requires a continuing calculation as any of these factors deviate from empirical normals or averages.

Attempting to evaluate snow survey data for any year, compared with any other year is not satisfactory. Fifty years of stream flow records in this area show that no two years are alike as to snow melt or stream flow. The same records do not show that there is any definite trend or cycle in this period. Stream flows in the Great Basin can vary between extremely wide limits, within short periods of time.

Any methods of evaluating snow surveys based on efforts to classify by tabulation or comparison, or attempting to determine arbitrary yard-sticks for comparison does not seem desirable where climate and weather are involved.

1/ Watermaster-Hydrographer For Truckee-Carson Irrigation District, Reno, Nevada.

It seemed that a method that would eliminate a tendency toward classification and comparison inherent in statistical methods of evaluation would be desirable.

The human mind is geared so that methods of analysis tend toward comparisons, to obtain an answer in terms of this comparison. There are so many elements in precipitation and snow melt, that as yet cannot be evaluated, that a method of stream forecasting based on comparison did not seem to be the proper approach. This method of analysis leads to continuing and increasing complications. The study of precipitation records in this area, extending back about one hundred years, did not provide a satisfactory correlation. The time of the year and the manner in which the precipitation occurs, whether snow or rain, and the total of any given storm all effect the snow runoff period. Yearly precipitation totals or averages of years or of any period of years are of no value for comparison.

Under the method I have developed, each years forecast is based on the data furnished by the snow surveys for that year, without regard to any assumed normals and without comparison to any other year. Any idea of normals does not appear in the method at all.

In an attempt to find another method of evaluating snow surveys in terms of stream flow, it appeared possible that the tabulated records of snow courses that extended back for 40 to 45 years could be utilized. In view of the long period of record, it did not seem to be necessary to attempt any analysis of the area with regard to area elevation, forest conditions, or ground cover. These early snow courses on the Truckee and Carson Rivers have the longest period of continuous record of any snow survey courses in the United States.

The historic records show actual stream flow and snow survey data for this long period of time. Using any method of regression analysis did not appear to be desirable. These methods of analysis have been developed for a different type of sampling and did not seem to be of much value in attempting to analyze the uncertainties of weather conditions and stream flow.

The first work on Snow Surveys was started in the Truckee-Carson drainage basins about 1910 by Dr. Church. The first effort to evaluate these surveys in terms of stream flow was done by taking certain years or groups of years as an average and making each year's forecast in terms of percentage of this average. The first normals used by Dr. Church were derived, by analogy, from Weather Bureau precipitation records. This method inevitably leads to zoning and weighting. In the light of present knowledge where long range weather forecasts are not possible the effort to establish normals or averages is purely empirical.

A study of the historical records seems to show that this method leads to over-forecasting on low years and under-forecasting on high years.

As the records accumulated over the years the weights were adjusted from time to time in an effort to give better results. This method is objectionable because the average used depends upon the period of years for which the average is taken and the method of weighting and zoning and the idea of zoning is not based upon sound reasoning.

The next effort in evaluating the data gathered from snow surveys was by the methods of regression. Regression formulas were calculated for each separate course and then a zoned and weighted regression formula was calculated.

This method of regression analysis requires that the groups of years taken for the analysis include those years or groups of years that deviate only small amounts from the mean. This eliminates the very high or very low years from the calculation. The difficulty of establishing parameters or fiducial quantities, and of fitting variables into this calculation is at once apparent. This calculation often leads to skewness which is not desirable.

Methods of analysis that use parameters, variables or coefficients are objectionable because the quantities used of necessity have to be based on some conception of averages or normals.

The difficulty of fitting variable coefficients into a regression calculation is further complicated by the fact that the sampling from which the variable is derived is already subject to an error in the basic sampling. It is extremely difficult to establish tolerance ranges for sampling both for temperature and precipitation.

In establishing the basic postulates for the proposed method of evaluating stream run-off I did not consider it important to the accuracy of the method, to attempt to determine tolerance limits or the probability of error in the historic records. The standard deviation calculations were based on the actual records without regard to any calculation of the probability of error in the historic sampling. It was assumed that these errors were compensating.

The problem of stream forecasting on the Truckee River is largely a question of estimating the rise in Lake Tahoe. It is required to store all the water possible in Lake Tahoe but not to exceed the high of 6229.1 in any case. This requires the April 1st forecast to be as accurate as possible. The present outlet gates at Lake Tahoe will only discharge 1800 c.f.s.. This in effect reduces the lake .03 of a foot in 24 hours. During peak run-off periods there often is flooding of valuable farm lands in the Reno-Sparks area. This makes it necessary that the releases from Lake Tahoe be regulated as far as possible so that no water is being released during these periods of flooding.

The problem on the Carson River is somewhat similar. The entire flow of the Carson River must be stored and handled through Lahontan Reservoir. Due to the condition of the channel of the Carson River below Lahontan Reservoir the maximum amount of discharge must be kept at or below 2000 c.f.s.. Lahontan cannot be permitted to fill and spill during periods of maximum run-off. This requires that the April 1st forecast be accurate and that Lahontan be kept below the crest during periods of maximum run-off flows and then be permitted to fill when the crest is past.

The total quantity of water in this drainage basin is small compared to the larger stream drainage basins in the United States, but the conditions of storages and flow require that the forecast be accurate and dependable and a forecast greatly in error could cause extensive damage on both stream systems.

The area of the combined drainage basins is about 3000 square miles.

In an attempt to set up another method of evaluating snow melt in terms of stream flow or Lake Tahoe rises certain basic postulates were set up.

1. It is assumed that although individual storms may vary in intensity over the drainage basins, that the yearly snow pattern any year will present a constant ratio of snow fall over the entire area with regard to elevation.
2. The mathematical odds are equal, that any year will fall above or below the mean.
3. Snow melt any year must vary between zero and infinity. This immediately suggests that the snow melt curve is hyperbolic in form. The observed stream flows come within a segment of this hyperbolic curve.
4. The four factors that effect snow melt are:
   A. Temperature
   B. Ground Water
   C. Wind Movement-Evaporation
   D. Precipitation

   A study of the historic records indicate that these may be treated as constants and not as variables.
5. Assuming the curve to be hyperbolic in form, at some point on the curve the effect of these four factors would entirely disappear in terms of stream flow. This was observed to be the case in the big snow year of 1952. In assuming that these four factors can be considered as constants, a scatter diagram made of the historic records should evaluate these.

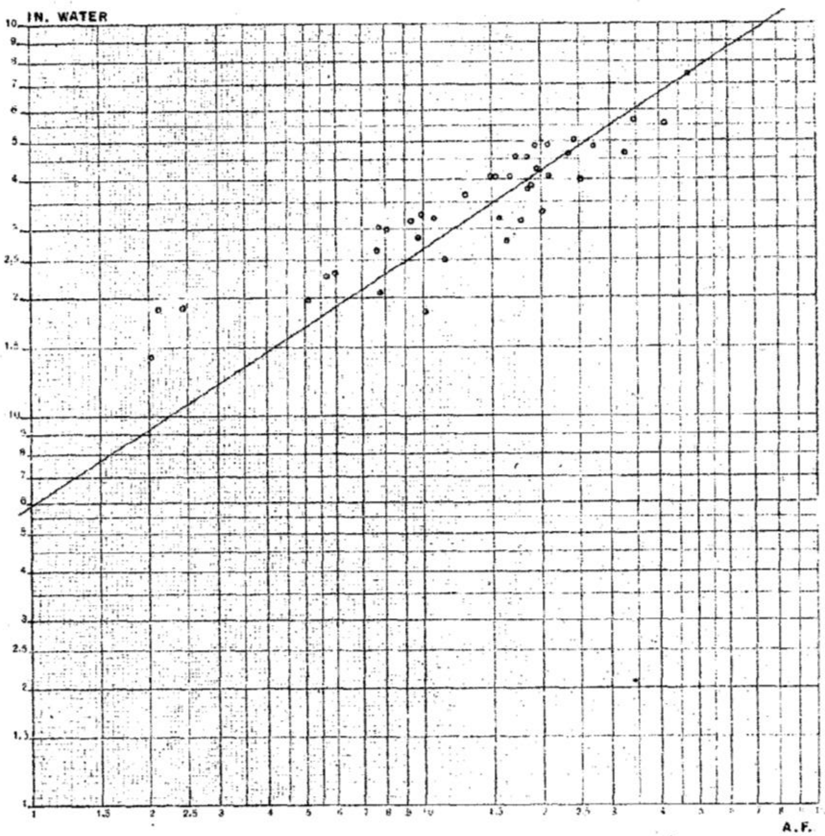
The scatter diagram shows, for each year, the result of the effect of these four factors and the diagram tends to evaluate these factors in regard to the position of the median line.

The snow courses taken as an example in this paper has a continuous record of 40 years. Some of the courses used in forecasting in this area are somewhat older.

The first question in all snow surveys is; what is the correlationship between water content in any given snow course and the resulting stream flow. Correlation coefficients were calculated for all of the snow courses being used. All of the courses that did not give a correlation coefficient on the order of .90 were discarded. Most of the courses below an elevation of 7,000 feet fell in this category and were discarded. The snow courses used at the present are all within elevations 6500 to 8500.

This was noted in an article "Graphical Method of Determination of Area-Elevation Weighting of Snow Course Data" by J. D. Hannaford, C. G. Wolfe, and R. W. Miller published in the proceedings of the 26th annual meeting of the Western Snow Conference.

BLUE LAKES —— EL. 8,000 FT.

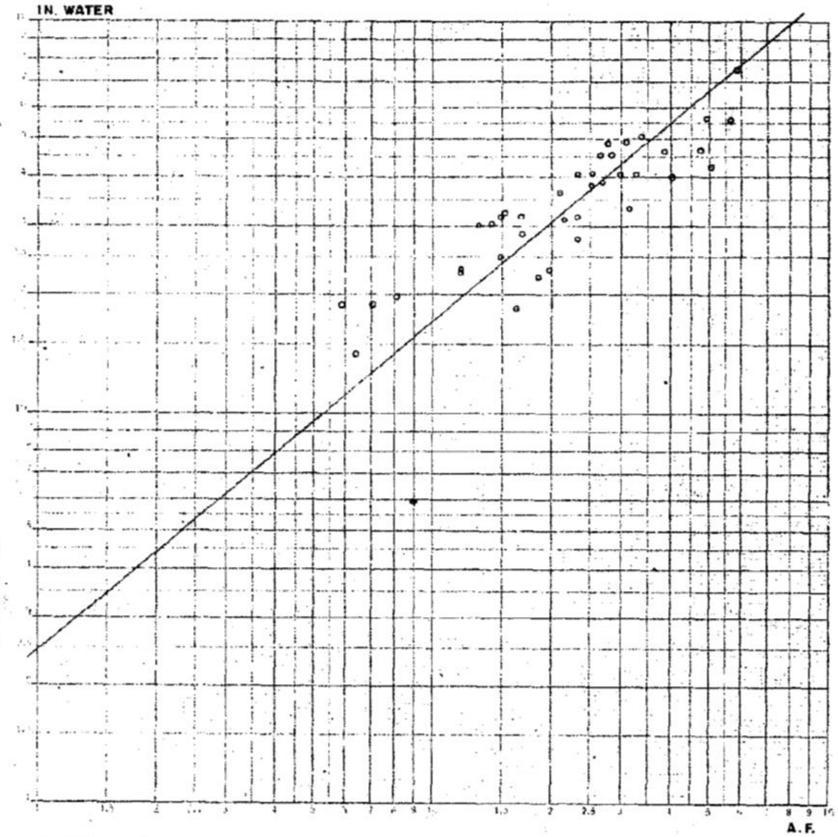


CARSON RIVER NEAR FORT CHURCHILL
APRIL 1ST TO END OF RUNOFF

C.C. = .9192 — 40 YR'S.
S.D. = 30,500
P.E. = 20,600

PLATE 'A'

BLUE LAKES —— EL. 8,000 FT.



CARSON RIVER NEAR FORT CHURCHILL
CALANDER YEAR, TOTAL ACRE-FEET

C.C. = .9192 — 40 YR'S.
S.D. = 30,500
P.E. = 20,600

PLATE 'B'

To utilize these postulates it was determined that a scatter diagram with a median line might provide the best method of using the historical records in terms of each years forecast. The difficulty of fitting a curve of hyperbolic form to a scatter diagram on rectangular paper was apparent. Therefore, the scatter diagram was made on logarithmic paper where the median line becomes a straight line rather than a curve. Statisticians may object to this method as being strictly subjective, but this method has been in use for 10 years and forecasts of the snow melt run-off period made by this method have fallen within very narrow limits of error. Standard deviations and probable error were calculated for all the snow courses used.

When the April 1st snow survey data is assembled all the courses used fall within these limits of error. Snow surveys made at any other time than April 1st are projected into April 1st conditions for forecasting.

Plate A: is a scatter diagram of one of the snow courses used.

Plate B: is the data from the same course plotted in terms of the total yearly run-off of the Carson River. This graph shows that, in this area, the April 1st snow survey has a definite relationship to the total stream run-off. This shows also, on the basic hyperbolic postulate, where the records for each year has included the basic flow, that a reliable forecast of the total stream flow for any year can be made from April 1st snow survey data.

Due to the fact that the stream flow from April 1st to the end of the snow melt period is made up largely of melting snow no effort was made to determine a basic hydrological formula or residual stream flows.

CONCLUSIONS

All snow courses should be carefully analyzed as to their correlation and those courses which do not give a high coefficient should be discarded or relocated.

This method of forecasting obviates the necessity of attempting to establish hypothetical normals or percentages of these normals. Each years forecast is made on the basis of the data furnished for the current year without regard to any other year within the period of record.

Using the historical records it is possible each year to forecast with good accuracy the time in which the maximum flows will occur and the magnitude of these flows.

This method could be used on larger river basins by breaking the basins up into their larger tributaries and by making forecasts on each tributary by this method, and then combining the forecasts for the main river forecast.

Once the basic calculations involved, correlation coefficients standard deviations, and probable errors are made and a decision made as to the snow courses to be used; no further calculations are involved and the method provides a rapid and accurate way of evaluating each years snow survey data in terms of forecast.

It is possible that as the period of record extends over the years it may be expedient to extend two more lines on this scatter diagram. One to be used when the water content falls below a certain point and the other to be used when the water content falls above a certain point. This has not been found necessary in snow courses with a record up to 45 years.

Any type of sampling cannot provide an exact quantity only by coincidence. The snow courses that give the highest correlation coefficient give also, smaller probable errors. Each years forecast has to be made within these limits but the deviations are small enough that the storage reservoirs involved can be operated on the basis of this forecast. It will be noted from the scatter diagram that very few years fall on the median line, but the tabulated results, with few exceptions, fall within the calculated limits of error.

The accuracy of the forecast made by this method over the past ten years, of which several presented extremely adverse water conditions, would indicate that the basic assumptions for this method and the idea that the snow melt curve is hyperbolic in form are correct. Ten years of use have not shown any fallacies in the method.

Basically, regression analysis is used to evaluate random sampling, where parameters or fiducial quantities can be pre-determined in terms of the information to be determined from the analysis of the random samples. Sampling long established snow courses is not random sampling. Attempting to analyze the results of Grid Sampling by combining regression and correlation analysis, over-complicates the analysis and leaves variables that have to be fitted into the calculation as assumed factors or coefficients. Correlation analysis in this area has provided an accurate forecast with the minimum of expense. Standard deviation and probable errors were calculated for each course only as a check against the correlation analysis.

PRELIMINARY REPORT ON EVALUATING THE UTILITY OF WATER SUPPLY FORECASTS

by

Max A. Kohler 1/

INTRODUCTION

At last year's meeting of the Western Snow Conference in Bozeman, Mr. R. A. Work presented a paper[1] entitled "Basic Data Characteristics in Relation to Runoff Forecast Accuracy." In essence, that paper constitutes a comparative verification of the Soil Conservation Service and Weather Bureau water supply forecasts for the period 1944-57. The results of the verification were no surprise to us, but we feel Mr. Work's interpretation of the results was not entirely realistic.

The Weather Bureau also verifies the forecasts of both agencies, year by year, as the streamflow data become available. Verifying all 1947-57 common forecasts, we find that the overall average errors of the Soil Conservation Service and Weather Bureau April 1st forecasts are 27 and 29 percent, respectively, when computed in the manner described by Mr. Work. These figures, 27 and 29, are to be compared with the values 24 and 27 cited in the Work-Beaumont paper. Our analysis covers a period beginning 3 years later; it contains more 1956 and 1957 data; and we have excluded those cases where our forecast period terminated prior to the end of the water year. We do not believe, however, that these or Mr. Work's results substantiate the implied or stated conclusions in the referenced paper to the effect that:

1. Snow surveys constitute "... a more precise method of sampling the greatest factor in streamflow production..."
2. The Soil Conservation Service forecast service is of more value to the water user.
3. Forecasts of river flows should be based on "... data secured as nearly as possible at the water sources..."

It seems obvious that the index value of precipitation observations would increase as the location of the gages approaches the source areas, and snow surveys certainly must be made at elevations where snow accumulates. But even these logical contentions cannot be proven by unrestricted verification of published forecasts.

VERIFICATION METHODS

The method of verification selected by Work and Beaumont utilizes errors of individual forecasts expressed as percent of the observed flow. As pointed out by Work and Beaumont in their paper, this becomes an unrealistic measure of forecast value in extremely dry years. To illustrate this point, consider the Weather Bureau forecast of April 1, 1950, for Embudo Creek at Dixon, New Mexico. The error in our water-year forecast was 960 percent of the April-September flow (incorrectly given as 1033 percent in the Work-Beaumont paper). There are about 6,000 acres of irrigated land above the station and largely because of the less-than-record minimum summer precipitation the April-September flow was only 3,050 acre-feet. A little arithmetic will show that a decrease of six inches in the irrigation diversions would have decreased our error to 430 percent. More important, however, is the fact that an increased diversion of just over six inches would have resulted in sheer calamity — with zero observed flow, the over-all average error of all Weather Bureau and Soil Conservation Service forecasts for all time to come would have been infinite.

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