HYDROMETEORLOGICAL INSTRUMENTATION AND AUTOMATION - PAST PERFORMANCE, PRESENT UTILIZATION AND FUTURE DIRECTIONS

by

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"A wise man learns from experience,
A wiser man learns from the experience of others"
- - -An Old Chinese Proverb.

The title of this paper might well be paraphrased, "The Advantage of hindsight".

The vantage point of being able to speak to you here in 1984 gives me all of the advantages of the experience gained over the years since Dr. Church developed snow tubes in 1909 and first adapted use of the data obtained to the issuance of water supply forecasts the following year (1). That experience is measured in progressive development of both instrumentation and forecast procedures. The excellent presentation by Harlowe M. Stafford at your 1959 Western Snow Conference meeting in Reno, entitled, "History of Snow Surveying In the West", sets forth in detail much that transpired during the years up to that date.

This paper is for the purpose of updating the record touching upon a number of points that have been made in the past at your annual meetings, offering a few comments in passing and making a few suggestions for the future.

To set the stage, a brief review of the past development and present State of the Art is necessary.

THE SNOW SAMPLER, DEVELOPMENT AND FAULTS:

Development of the successful Mt. Rose snow sampler in 1909 is reason for stating snow surveying began in that year. The Mt. Rose Sampler, made of steel, was replaced over the years by the Utah Snow Sampler developed in the early 1920's by Professor George D. Clyde of Utah Agricultural College (later Governor of the State of Utah). This sampler made of aluminum had a cutter 1.485-inches in diameter. Because a cylinder of water 1.485-inch in diameter, 1-inch high weighs 1 ounce, it was now possible to use commercial scales reading in ounces to determine the water content of the snow in inches. It is important to note, however, that the Mt. Rose Samplers already in use on numerous watersheds were not in all instances immediately replaced with the Utah Snow Sampler when it was introduced in 1932 (2).

With the commencement of the California Cooperative Snow Surveys program in 1930, effort was made to standardize the equipment throughout the Sierra. Unfortunately, the deep snows of the Sierra, particularly when exceeding 200-inches in depth, presents problems for those utilizing aluminum tubes. This was due primarily to the ready transfer of temperatures to the metal. This caused rapid heating of the tubes when exposed to sunlight and air-temperatures above 32 degress and the freezing of the snow to the wall of the tube when inserted into the deep snowpack having temperatures well below freezing. This experience and the effort in the 1950's to improve upon the design of the snow cutter (without success) gave ample cause for appreciating the early work of Dr. Church.

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Sampling errors occur in the measurement of snowwater content due to a number of causes. The problems associated with deep snowpacks as above described, the slow encroachment of vegetation upon the snow course, or the almost overnight change brought about by timber harvesting, fire, avalanche, or disease may all give cause for bias of the measurement data. It has now been found that measurement accuracy may be related to snow density at the time of sampling (3). The lighter density usually associated with early season measurements gives an added increment of water content as compared to the sample normally obtained as of the first of April. Sharpness of the cutter may contribute to sampling error as well (4) and one more admonition, - a poorly trained snow survey team may be cause for inaccurate data.

PERCIPITATION GAGES:

Precipitation stations are subject to measurement bias due to site changes similar to that of a snow course. Precipitation stations normally are located close to habitation. All too frequently the addition of a new building, the cutting of a tree, or the relocation of the gage to a more convenient spot is cause for a change in measurement enviornment. Although every effort is made to document such occurances in the station record, these substantial changes often occur without recordation and is cause for misleading results.

The Photocanopyometer (5) is an invaluable tool for recording change of the enviornment at the snow course or precipitation gage site. An annual update of the site record by use of the photocanopyometer is highly recommended so that the hydrologists of the future can verify either the subtle or sudden change that may otherwise occur without recording.

STREAM GAGES:

The streamflow gaging site is also subject to change. Major changes may occur gradually or overnight due to flooding, change in upstream use, or change in forest cover.

Thus it is difficult to be assured of homogenious records for snowpack, precipitation, or streamflow. The early need for water supply forecasts focused upon use of readily available data. It was quite logical that during the early years of forecast development that the possibility of error was pushed into the background. It is only the luxury of the length of record presently available that now allows question to be raised as to the possiblity of such errors.

AUTOMATION:

The foregoing discussion has over simplified the description of the Snow Sampler and the precipitation gage. A number of progressive improvements have occurred that allows one to "sit in the office" and obtain the field data on a real time and continuous basis. This brings us to the discussion of automation with respect gathering of data. The first instrument for obtaining continuous readout of the snow water content was the development of the radioactive snow gage (6). Although this instrument was installed at a number of sites during the 1950's, the telemetry necessary for carrying the data to the receiving station also required development.

With the development of the snow pillow in the late 1950's and early 60's (7) the age of automatic snow gaging had truly arrived. Progressive improvement of the telemetry and installation of the pillows throughout the snowsheds of the world now allows automatic data acquisition to be a dream realized. With 84 automatic snow reporting stations listed in the April 1st, 1984 California Cooperative Snow Surveys Report, first of the month data was listed for 80 which indicates a 95% reliability factor.

The telemetry available at each of these sites also allows temperature, wind and other hydrometeorlogical data to be obtained convienently and at small additional cost.

A number of developments have come about with the opening of the space age. The aerial reconnaissance of mountain snowfields - - - (8) as reported to you in Reno in 1959 now became possible by use of Satellites (9) as first reported to you in 1962 in Cheyenne. Snow cover, snow surface temperature (10), and other weather data are all available to the hydrologist today, almost on a "real time" basis.

One can quickly gather from the above resume of recent technical advances that today's hydrologist must be specially equipped to process all this data avalanching onto his desk - which brings us to the next part of this paper - automation in the office.

OFFICE PROCESSING:

Water supply forecasting began in 1910 only one year after development of the Mt. Rose snow sampler. The forecast method utilized that year became identified as the percentage method. As more years of data became available, the forecast procedure was changed (in California) to the Direct Method in 1938. Soil moisture correction was introduced into the procedures in the early 1940's. As the years of data increased, adjustment was made for abnormal spring and summer temperatures in 1944. A general revision of forecast methods as practiced in California (11) commenced in the late 1940's and finally evolved into the Multiple-Graphical Correlation (12) method as reported to you at your Penticton meeting in 1956. Although a further refinement "Graphical Method For Determination Of Area-Elevation Weighting Of Snow Course Data" (13) was presented at your Bozeman meeting in 1958, essentially all forecasts made as of this date by the California Cooperative Snow surveys office utilize the graphical procedure as described at the 1956 and 1958 meetings.

The time consuming development of a Multiple-graphical correlation, particularily without the aid of a computer, has led to the use of the Multiple-Linear Regression method by many. In recent years, that same method has been used to create non-linear regressions by transforming some of the data to logarithmic values. It is only a matter of time until a full computer program will become available for developing the multiple-graphical correlation. However, the development of a multiple-graphical correlation is highly dependent upon sufficient data so that the degrees of freedom lost in the development of the correlation does not unduly detract from the statistical strength of the developed correlation. The years of data now available should allow for retention of the required statistical strength.

COMPUTER MODELING OF THE WATER BASIN:

"The Development And Application Of A Hydrologic Model As An Operational Tool" (14) presented as a paper at your 1970 meeting in Victoria detailed the time dependent variables and their resultant influence on the river hydrograph during the runoff season. The model consisted of a computer program that allowed for the numerous calculations necessary to allow synthesizing the hydrograph on a real time basis. This tool is to be recognized as a great help to the river operator who daily must coordinate operations in tune with the vagaries of weather.

Basin modeling allowed recogniation for the first time of the effect of temperature patterns upon the amount of snowmelt runoff that occurs from a given snowpack. This was pointed out in the paper "Directions In Water Supply Forecasting" (15) presented at your meeting in Billings in 1971.

SUMMARY:

Much has been accomplished since snow surveying became a fact in 1909. We have truly seen the art advance by use of snowshoes at first and in recent years by skis, satellites and computers. More advances will be made in the coming years, but snow surveying is an empirical science, and the years of record of the past are necessary for the projections into the future. The snow surveyor, traveling on foot, still is vitally needed in the spaceage!

This paper has briefly touched upon the mileposts of the developments that bring us to the present. In future years many of our present findings or concepts will be brought into question. This is essential to the making of progress. An anomaly continues, past records are known to incorporate errors, many of which cannot be identified, and yet they are used "inflexibly" to test the truth of any later development.

Time has allowed the building of a data base that now allows the opportunity for questioning some of the data of the early years. This questioning is essential for the progress to be made in the future. But with the questioning, caution must also be exercised for each of us must realize that sampling methods does not always allow determination of the true index, nor the precise flow, and that many of the missing answers are presently hidden to us by the random occurance of errors due to whatever cause. Only time will allow progress to be made. The development of the computer hydrologic model, will allow the identification of runoff differences caused by varying patterns of temperature. By applying the model to past years, it may be possible to improve the basic April 1 forecast correlations.

The Western Snow Conference has been the focal point of sharing these developments particularly in the science of snow hydrology as they are reported from year to year. The rapidity of progress in the development of hydrological instrumentation - automation - and utilization requires such meetings if we are to try to maintain a current position in that field of knowledge.

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