# ACCURACY OF SNOW MEASUREMENTS 1/

By

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## Introduction

As the application of automatic snow sensor data in water supply forecasting techniques expands, knowing the reliability of the sensor data becomes increasingly important. Considerable work has been done in evaluating and perfecting snow sensor design and installation methods (1) (2), and a high degree of operational success in obtaining automatic snow data by this means is being achieved throughout the West. However, water supply forecasters have been concerned about apparent errors between telemetered sensor data and occasional control samples taken at sensor sites. To define the causes of differences between on-site and sensor data the California Department of Water Resources has made detailed investigations at the Alpha Instrument Evaluation Site.

Although it is generally known that manual snow samples taken with a standard (Federal) snow sampling tube tend to overmeasure water content by as much as 12 percent (3) (4) (5), the degree of error under various snow conditions had not previously been defined and so specific error levels could not be assigned to each control sample. Pioneers in this field therefore used a constant sample tube correction factor in their sensor accuracy studies (6). Independent checks by the authors revealed a diverging error bias was introduced when a constant factor was used. Results of this current study on snow measurement errors both substantiated the earlier work of others and added a new dimension to previous concepts by introducing a variable correction factor to be applied to each control sample depending on snow density at the time of the measurement.

## Accuracy of Standard Snow Sample Tubes

Following the tube accuracy study conducted in 1964 by the U.S. Soil Conservation Service, in cooperation with the U.S. Cold Regions Research and Engineering Laboratory, a similar test program was begun the same year at the Alpha Test Site in California. The object of the Alpha study was to investigate sample tube errors under the snow conditions peculiar to the California Sierras, a "warm" mountain range. It was quickly discovered that sampling tube errors obtained over several test dates were erratic and that additional investigation was needed to define error levels under a greater variety of snow conditions. Subsequent tests were deliberately scheduled to encounter a wide variation in snow depth and density.

Procedure - The tube accuracy checks were accomplished by comparison of water content values obtained with sample tubes and the absolute water content obtained by weighing a known volume of snow. First, a series of 20 tube measurements were taken within the area of a 5-foot-by-6-foot (1.5 by 1.8 m) steel template laid on the snow surface, in an area where the ground surface had been groomed to avoid obstructions (Photo 1). Tube water contents were recorded and averaged and the cores retained and weighed. The template was then driven slowly to the ground surface, carefully removing and weighing the snow within its area as it was driven down (Photo 2). The absolute volumetric water content of the snow extracted, including the tube cores, was then computed and compared with the water content indicated by snow tube measurements. The difference was sample tube error.

Throughout these tests sample tube cutter diameters were checked by a mandrel, and accuracy of the scales was checked periodically against known weights.

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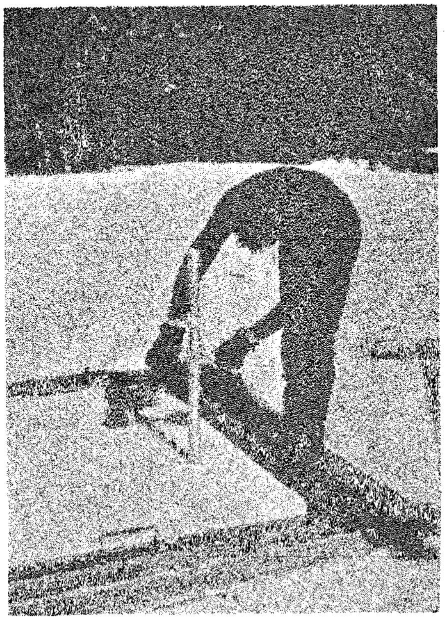


Photo 1. Start of tube accuracy test. Measurements from 20 samples are averaged.

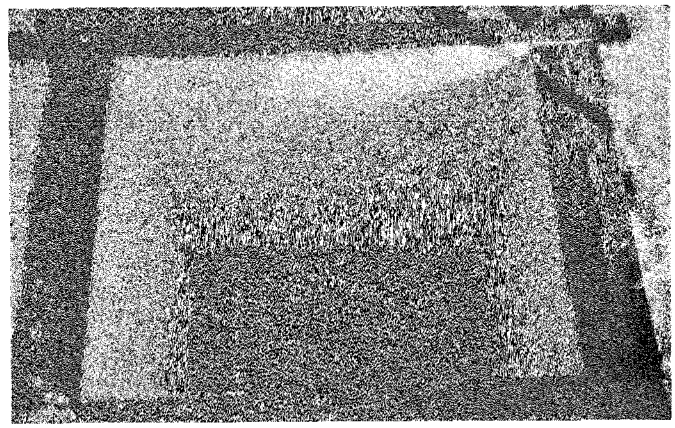


Photo 2. End of volumetric check of sample tube error. Template has been driven to ground surface and snow volume computed and weighed.

Results - Volumetric tests have been conducted in snow depths ranging from 30 to 105 inches (76 to 267 cm), densities varying from 23 to 53 percent, and with water contents of 12 to 48 inches (30 to 122 cm). All tests substantiated that the standard (Federal) 16-tooth sample tube overmeasures snow water content. The significant discovery was that tube error increases as snow density increases, above the 25 percent density condition.

A formulation of these data to illustrate the relationship of error to density is presented on a semi-logarithmic scale in Figure 1 "Control Sample Correction Curve", using the least squares method ($y = bx \pm a$), where y is measured density, x is measurement error established in volumetric tests, and a defines data intercept of the density values. The correlation coefficient of the data was 0.92.

Application of Control Samples to Sensor Data

To test the validity of the "Control Sample Correction Curve", nine years of control sample data were used. Snow tube water contents were corrected for 64 control sample sets obtained adjacent to a 12-foot-diameter (3.7 m) pillow (Alpha #1), from which a continuous record of water content has been obtained on a Stevens A-35 strip chart recorder.

Two curves were then constructed to illustrate the degree of correction that results from application of the Control Sample Correction Curve. One curve was plotted using the uncorrected control sample data, the other using the corrected data. These data, plotted by the least squares method against recorded water content on the pillow, are represented in Figure 2, "Reliability of Corrected Control Samples". Notice again that the light density snowpacks need additional investigation to better define errors in the lower region.

Operational Applications - The information gained in this study is being applied in the California Cooperative Snow Surveys Program in both continuing snow sensor experimental studies at Alpha as well as in evaluating the reliability of operational snow sensor data from the 43 sites now instrumented in the field.

Starting this season, 1974-75, it is now standard practice to obtain manual snow samples adjacent to operational automatic snow sensors on a regularly scheduled basis. The schedule, worked out with the cooperating agencies performing the regular snow surveys, coincides with the regular snow course measurement schedule in most instances. This will provide water supply forecasters with one-per-month checks on the daily sensor data being received by telemetry.

The procedure for setting up this program involved mapping all operational snow sensor sites, placing control pipes at most sensors to enable snow surveyors to obtain the control samples close to, but not on, the sensing device, and publication of the "Sensor Control Sample Schedule" in the program's annual "Index and Measurement Schedule". In most cases four samples are taken adjacent to the snow sensor. The results are recorded on a regular "snow note" and the original note is transmitted to the Department of Water Resources, Snow Surveys office for interpretation, application of the data in adjusting sensor data for use in forecasting procedures, and then filed so as to be available for future use by the Department or program cooperators.

The program of scheduled control samples at all operational snow sensor sites is not considered a rigid, permanent procedure. The decision to initiate control samples and to evaluate this usefulness to water supply forecasters was based on several factors. The 47 snow sensors operated in California since 1965 have yielded 255 data-years, of which 78 data-years, or one-third, have very limited or no record, due primarily to equipment malfunction. In addition to these known data losses, control samples at some sensor sites occasionally have revealed significant errors in sensor data which was being used to update short-term runoff forecasts. Of the 255 data-years, it is estimated that only 37, or 14 percent, yielded perfect data for an entire season. As more snow sensors are installed and become operational, their use will increase. It is anticipated that the performance of snow sensors and related instrumentation will continue to improve and that the data will, therefore, become more reliable. At that time, the control sample program at operational sensor sites will be reevaluated and either scaled down or eliminated.

To illustrate the operational application of sample tube error corrections to sensor controls, the samples obtained last winter at a U.S. Corps of Engineers sensor in the Kern River Basin were plotted in Figure 3, "Operational Application of Control Data". Comparison of corrected control sample data to that received through the Corps telemetry system revealed that the telemetered data was valid and could be used with confidence in runoff forecasting procedures. It is expected that similar treatment at the other operational snow sensor sites in California will also clearly define the reliability of telemetered data. This will increase the water supply forecaster's ability to select the most valid data and, conversely, to reject or adjust questionable data before applying it in his forecasting procedures.

## Conclusions

The information gained in this continuing snow measurement accuracy study will provide snow hydrologists with insights into sensor performance that should lead to increased reliability of operational sensor data and improved water supply forecasts, especially where some of the updated forecasts are based exclusively on sensor data. Continued work on both refinement of the snow tube correction factors and experimental design and placement methods for new configurations of snow sensors is expected to yield improved operational benefits as our knowledge increases. Additional investigation of sample tube overmeasurement in shallow, low density snow is needed to reveal the boundary conditions of error in this range. Also, additional analysis of application of correction factors to sensor data would prove beneficial, especially for data from other types of sensors, i.e., pressure tank combinations, different sized pressure pillows, radioactive gages, etc. It is also important that snow hydrologists recognize the possible limitations of this control sample correction method as it pertains to geographic areas of use. Since the data used was all obtained in the Central Sierra of California, application of this curve in areas where shallow, cold snowpacks, or depth hoar are present, may be subject to influences that do not exist in the Sierra. Therefore, the present configuration of the "Control Sample Correction Curve" is considered preliminary.

FIGURE 1

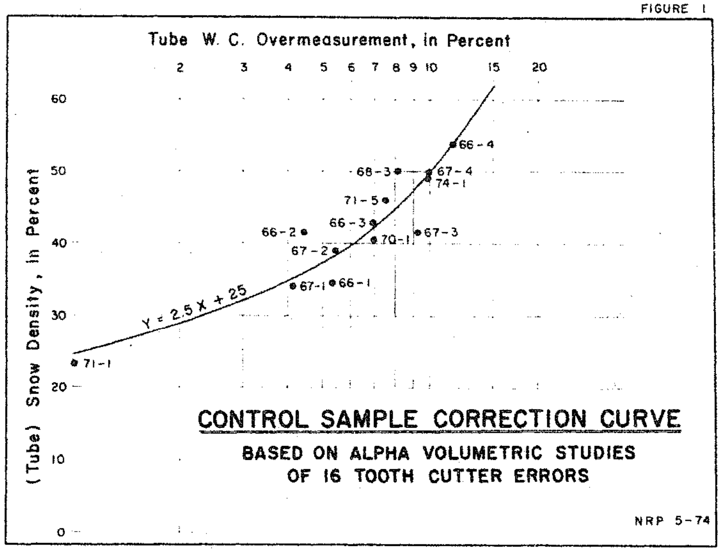



FIGURE 2

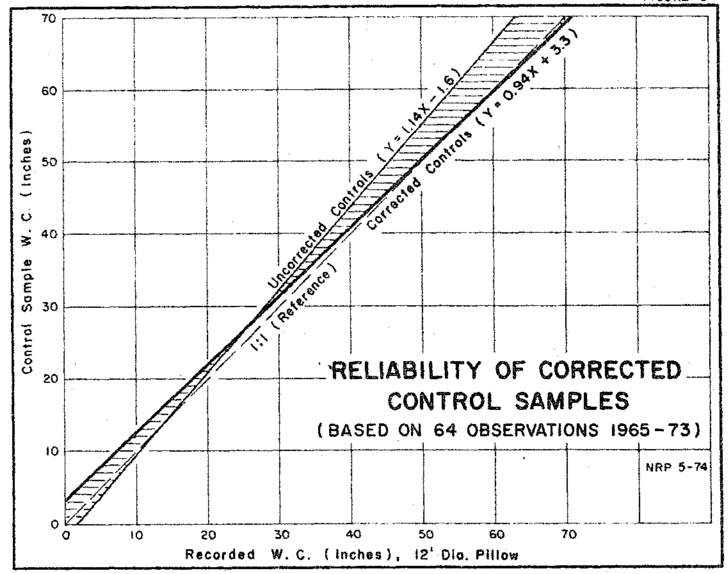



FIGURE 3

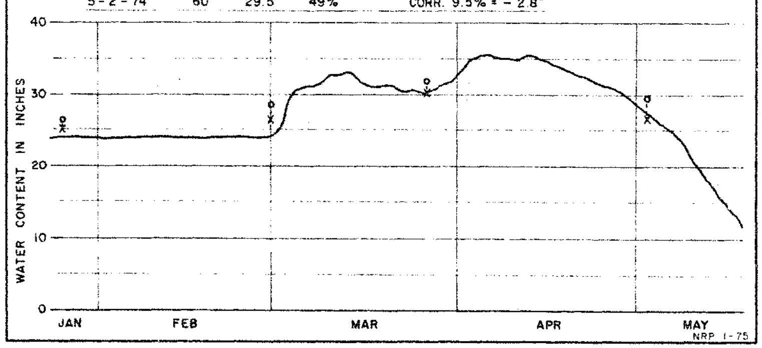
OPERATIONAL APPLICATION OF CONTROL DATA

U.S. CORPS OF ENGINEERS – PASCOE #569
TELEMETERED WATER CONTENT DATA
KERN RIVER BASIN
1974

MANUAL CONTROLS / U.S. FOREST SERVICE

| DATE | DEPTH | WATER | DENSITY | FROM CORR. CURVE |
|---|---|---|---|---|
| 1-25-74 | 75" | 26.3" | 35% | CORR. 4.0% = -1.2" |
| 2-28-74 | 69" | 28.5" | 41% | CORR. 6.5% = -1.9" |
| 3-26-74 | 78" | 31.8" | 41% | CORR. 6.5% = -2.1" |
| 5-2-74 | 60" | 29.5" | 49% | CORR. 9.5% = -2.8" |

LEGEND
o RAW CONTROL
x CORRECTED CONTROL



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