SNOW SENSORS IN CALIFORNIA - A PROGRESS REPORT 1/

By

Ned R. Peterson 2/

Introduction

The half-century-old science of snow surveying and water supply forecasting has felt the effects of automation during the last several years. The development of automatic snow sensors for obtaining snow water content data from remote areas has grown from initial experimental attempts, at the University of Idaho and at Mt. Hood, Oregon, to the present network of well over 50 instrumented sites throughout the West. Efforts to improve the pressure pillow and associated sensing, recording, and data transmission instrumentation have been vigorous. In addition, new configurations and materials for the basic sensing untis are being fabricated to meet the demands for a more compact instrument complex for remote sites.

The network of snow sensor sites in the California Cooperative Snow Survey program has grown rapidly during the last three years. There are now 20 sites in Sierra watersheds where operational and experimental snow sensors are providing oncall snow data or are testing the performance of promising new or modified components.

Summary of Snow Sensor Progress

During the early 1960's interest in the use of pressure pillows to monitor snow water content was growing rapidly. Extensive evaluation studies had been carried out by the U. S. Soil Conservation Service at Mt. Hood during the winters of 1961 through 1963 (1). In July 1964, they convened an inservice seminar on remote snow sensors in Portland, Oregon. Several Department representatives were invited to attend this session which included an inspection of the Mt. Hood test site.

The successful operation of pressure pillows at Mt. Hood resulted in their subsequent installation at numerous sites throughout the West. In California, three snow sensor sites were activated during the winter of 1965-66. A 12-foot-diameter pillow was installed at the Independence Camp snow course in the Truckee River Basin by the U. S. Soil Conservation Service. The Department and the U. S. Weather Bureau activated two cooperative sites in the American River Basin. These two sites were developed for both operational use and for snow sensor evaluation purposes. One was located at the Alpha site where a snow course had been established the previous winter to monitor snow cover conditions prior to committing the site to extended use as an instrument evaluation site. The other site was developed near Twin Lakes where a hydrographer of the Pacific Gas and Electric Company was available throughout the year to service recorders and obtain control samples in the pillow area during the snow season.

During the winter of 1966-67, eight more sites in California were equipped with snow sensors for operational use. Also, considerable expansion of the test installation was accomplished at the Alpha instrument Evaluation site and a new test site was established near Cisco by the U. S. Weather Bureau.

Current Operational Sites

This year, automatic snow sensors are in operation from the Kern River Basin in the southern Sierra to the Yuba River Basin in the north. (Table 1 lists pertinent details. Relative locations are indicated on Figure 1.)

Current sensor installations operated by the U. S. Soil Conservation Service and the U. S. Weather Bureau have been described in other presentations to this Conference. Work by the U. S. Forest Service, California Cooperative Snow Research Project, in developing a radio isotope snow gage also has been well documented (2).

1/ Presented at the Western Snow Conference, Lake Tahoe, Nevada, April 16 - 18, 1968

2/ Chief, Program Coordination and Service Unit, Snow Surveys and Water Supply Forecasting Section, California Department of Water Resources.

TABLE 1

California Snow Sensor Installations, 1967-68

River Basin and Site	Elevation	*Associated Snow Course or Aerial Marker	Principal Agency
Kern River			
Wet Meadow	9,000	518-AM	USCE
Round Meadow	9,000	258	USCE
Tyndal Creek	10,650	255	USCE
Kings River			
Wishon Dam	6,500	-	AWRR
Upper Woodchuck	9,100	341	USCE
State Lakes	10,200	545-AM	USCE
Mitchell Meadows	9,900	511-AM	USCE
Carson River			
Wet Meadow Lake	8,100	561-AM	SCS
Walker River			
Virginia Lakes	9,500	150	SCS
Sonora Pass	8,800	152	SCS
American River			
Twin Lakes	8,000	107	USWB
Alpha	7,600	365	DWR
Yuba River			
Cisco	5,900	-	USWB
Blue Canyon	5,000	-	USWB
Lake Tahoe Basin			
Hagens Meadow	8,000	98	SCS
Ward Creek	7,000	101	SCS
Marlette Lake (Nev.)	8,000	332	SCS
Fallen Leaf Lake	6,300	-	USFS
Truckee River			
Independence Camp	7,000	88	SCS

* Assigned California Snow Course Number. AM = Aerial marker location.

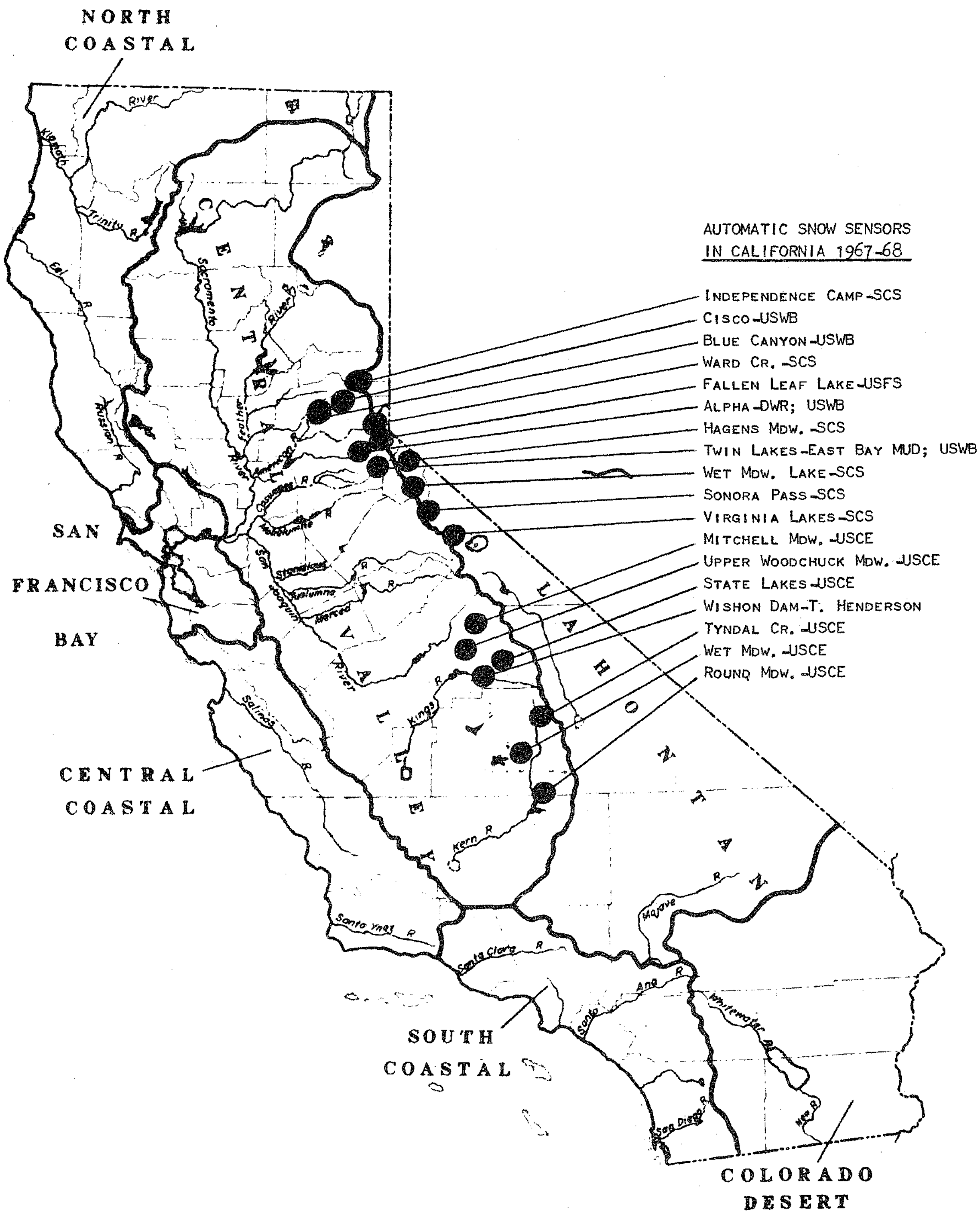

NORTH COASTAL
SAN FRANCISCO BAY
CENTRAL COASTAL
SOUTH COASTAL
COLORADO DESERT
CENTRAL VALLEY
LAHONTAN
AUTOMATIC SNOW SENSORS
IN CALIFORNIA 1967-68
INDEPENDENCE CAMP-SCS
CISCO-USWB
BLUE CANYON-USWB
WARD CR.-SCS
FALLEN LEAF LAKE-USFS
ALPHA-DWR; USWB
HAGENS MDW.-SCS
TWIN LAKES-EAST BAY MUD; USWB
WET MDW. LAKE-SCS
SONORA PASS-SCS
VIRGINIA LAKES-SCS
MITCHELL MDW.-USCE
UPPER WOODCHUCK MDW.-USCE
STATE LAKES-USCE
WISHON DAM-T. HENDERSON
TYNDAL CR.-USCE
WET MDW.-USCE
ROUND MDW.-USCE

Figure 1

In addition to continuing work at the Central Sierra Snow Lab, the U. S. Forest Service has installed a 12-foot pressure pillow in an experimental watershed at Fallen Leaf Lake. The continuous record of snowpack accumulation and melt from the associated A-35 recorder will be used to assist in defining storage and release factors for fishery enhancement.

At Wishon Dam the Atmospheric Water Resources Research Program, Fresno State College, operates a data gathering installation in cooperation with Atmospherics Inc. Precipitation data, snow data from a 12-foot pillow, and temperatures are transmitted to Fresno.

One of the most significant operational snow sensor networks in the Sierra has been activated in the Kern and Kings River watersheds by the U. S. Army, Corps of Engineers (3). Six 12-foot pillows have been installed by the Corps with the assistance of the Department and the Kings River Water Association. The snow data from Mitchell Meadows, State Lakes, and Upper Woodchuck Meadows are telemetered to Pine Flat Dam along with precipitation and temperature data from instruments operated by the Atmospheric Water Resources Research Program. Snow data from Tyndal Creek, Round Meadow, and Wet Meadow are transmitted to Isabella Dam. The sensor components at these installations have been standardized.

The unique feature of these snow sensors is the standpipe assembly which consists of an 8-inch-diameter, 10-foot aluminum riser pipe for the float well, topped by a compact shelter housing for a Telemark. This unit is light, easily transported by helicopter, and allows the entire pillow-standpipe-antenna package to be conveniently installed by two men in two days time. The pillows are of two layer butyl rubber connected to the float well by armoured hose. The radio and battery housing is installed on a ground pad at the base of a sectional antenna tower that is assembled at the site. The nickel cadmium batteries are kept at a fairly constant temperature level after initial snowfall and charged by solar cells mounted on the antenna tower. Normal operation consists of one-a-day interrogation, with more frequent calls being made when conditions warrant. The sensors have been very successful in providing data on a timely basis in order to update water supply forecasts. During their first season of operation, their use during periods of snowmelt was of considerable aid in reaching water regulating decisions during the rapid melt period of late June and early July of 1967.

Snow Sensor Evaluation Studies

Since the fall of 1964, the Department has been engaged in analyzing snow sensor performance and accuracy at the Alpha instrument Evaluation site. Preliminary snow measurement accuracy studies have been rewarding and a detailed report of new findings will be presented to this Conference at a future meeting.

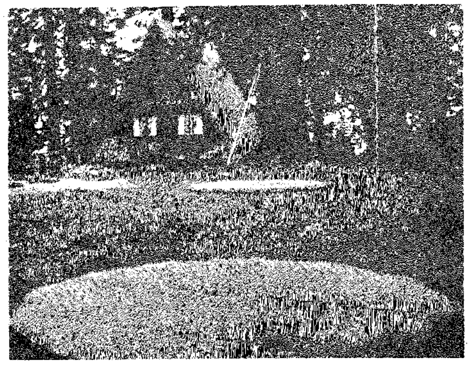
The Alpha site is located in open timber at elevation 7,600 feet in the American River watershed. It was one of several sites selected by aerial reconnaissance in 1964, and was chosen for the instrument evaluation site after close observation of snow cover behavior during 1964-65 when a snow course was established and added to the helicopter snow survey circuit in this area. Figure 2 illustrates site characteristics. Figure 3 shows the current site configuration.

Alpha 1, a 12-foot-diameter, single layer butyl rubber pillow, was installed and operated during the 1965-66 winter, with snow water content indicated on an A-35 strip chart recorder. The instrument was placed in a shelter installed on top of a 36-inch corregated pipe containing a 6-inch float well. In the fall of 1966, a Motorola FM transmitter and a Leupold-Stevens telemark were added to a separate 6-inch well installed in the instrument compartment of a newly constructed, A-frame shelter cabin. Data from this pillow are transmitted to Sacramento and used operationally in forecasting American River runoff. This system is being left undisturbed from season to season to determine its effective life and required frequency of maintenance.

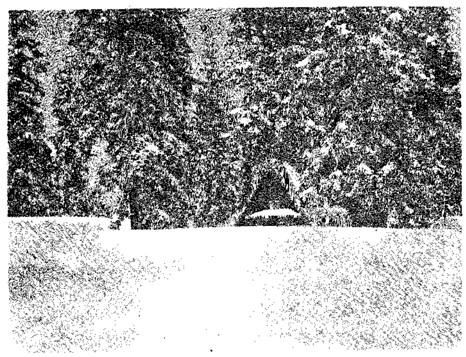
Other existing installations include both missile type and Castle precipitation gages. The Castle gage is equipped with a Telemark which also reports, in sequence, to Sacramento. This season, a bank of Ni-Cad batteries have been installed for the telemetering system and a trickle charge from solar panels is being utilized to maintain a constant power source. A strip chart recorder is also operated on the Castle gage to obtain a continuous record of precipitation.

FIGURE 2

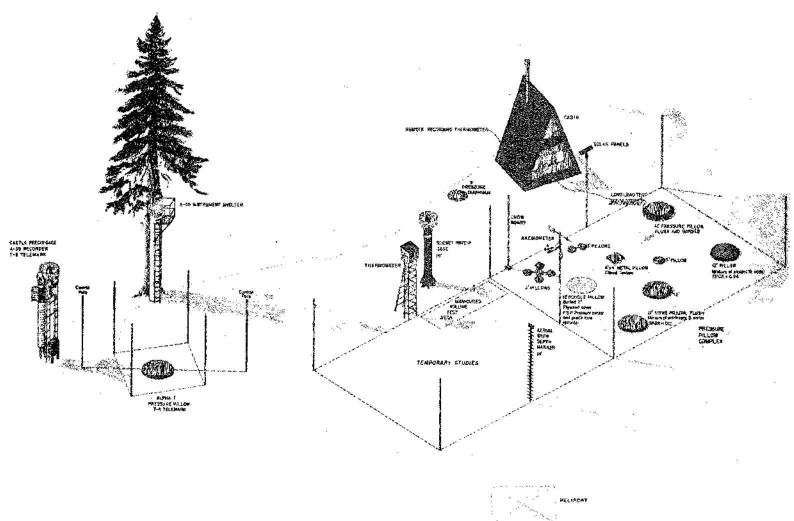
ALPHA INSTRUMENT EVALUATION SITE



COMPLETED INSTRUMENT SHELTER CABIN
AND PORTION OF TEST AREA



WINTER SNOW COVER AT ALPHA



California Cooperative Snow Survey Program
Alpha Instrumentation Evaluation Site–Forni Ridge

COOPERATING AGENCIES

DEPARTMENT OF WATER RESOURCES — SACRAMENTO MUNICIPAL UTILITY DISTRICT
U.S. WEATHER BUREAU — U.S. FOREST SERVICE
U.S. CORPS OF ENGINEERS

Figure 3

A continuous record of wind run, direction, and velocity is obtained from two instruments. The first one installed has a permanent magnet generator and eight wiper points to record wind speed and direction on an analog event recorder. The spring wound chart drive operates unattended for up to 10 days. To insure uninterrupted wind data, Mr. Tom Henderson of Atmospherics Inc. provided and installed the second instrument, an automatic weather station that will operate unattended for 30-day periods.

Snow sensors now being evaluated are:

(1) Alpha #3, a 12-foot pillow which activates two recorders. One has a long-lead hose with a 2.5:1 length ratio to the shorter lead (115 feet and 46 feet respectively). This configuration was used to determine if delayed recorder registration, caused by line lag, was a problem. The snow data obtained on the two recorders shows that no additional lag is caused by the extra length of lead-in hose. Operational installations where the sensor is placed at some distance from radio equipment are, therefore, acceptable.

This pressure pillow was installed flush to the ground and a rim of metal flashing was placed snugly around the perimeter to investigate edge load effect during a dig-out study. Further investigation of edge loading was prompted by witnessing of a load surge on recorders during dig-outs of surface mounted pillows last winter.

(2) Alpha #2 and #7 are groups of two and five 3-foot-diameter pillows, each group connected by a common lead to their respective A-35 strip chart recorders. Overmeasurement is well pronounced this winter. Group configuration has no effect on reducing the overmeasurement of small sized, surface mounted, pillows.

(3) Alpha #4 is a surface mounted 5-foot-diameter pillow, also currently overmeasuring the snow load. Investigation of a possible correlation between this sensor, the 3-foot pillow groups, and other sensors and control samples, will be made after the melt season ends.

(4) Alpha #10 is a 12-foot pillow filled with a mixture of 90 gallons of alcohol and 240 gallons of water (Sp. Gr. 0.94 at 0° F.). This is one of a series of tests on the stability of various solutions under operational conditions to develop criteria for field use in remote areas where transporting large amounts of alcohol can be a logistics problem. No noticeable density variation has occured in this system thus far.

(5) Alpha #14 is a 12-foot surface mounted pillow. This pillow was dug out last winter as part of an accuracy test. It has been left undisturbed so that a comparative test can be performed again this winter under different snow conditions. (In the first test this pillow was found to be overmeasuring 7.2 percent as compared with control samples.)

(6) Alpha #5, a flush mounted 12-foot pillow, contains 72 gallons of glycerin base antifreeze and 292 gallons of water (Sp. Gr. 1.04 at 16° F.). The solution under not too severe conditions, thus far, has not resulted in any change in consistency which is characteristic of some antifreeze solutions at low temperatures, and no separation has been observed.

(7) Alpha #6 is a 12-foot double layered butyl rubber pillow, filled with 400 gallons of alcohol, covered with a plywood cover and buried under 2 inches of soil. In addition to continuous recordation of load by an A-35 recorder, this pillow also energizes two pressure transducers. One is a Fischer and Porter bimetal pressure transducer which activates the standard punch tape ADR. The taped data, at 15 minute intervals, is converted to punched cards and printed out on IBM data processing equipment at headquarters. The other is a Statham unbonded strain gage pressure transducer (PG 132 TC-5-350). This transducer activates a Rustrak adjustable gain amplifier and the signal is recorded by the stylus of a moving coil galvanometer on pressure sensitive paper. Calibration of this system affords a direct recording of 0 to 80 inches of snow water content.

This pillow installation was designed to cross-check the performance of the two types of pressure transducer systems with the A-35 recorder trace and standard snow tube control samples which can be obtained directly over the pressure pillow. Both types of transducers are currently operating satisfactorily.

(8) Alpha #8 is the latest Department design for an experimental snow sensor, consisting of a 6-foot-diameter metal base plate with a rubber top held in place by pressure rings. Clearance, between base plate and top, ranges from one-fourth inch at the edges to about 6 inches in the center. The "Diaphragm Gage" is filled with 42 gallons of alcohol and activates an A-35 recorder connected to a 4-inch float well. The design was selected to eliminate the edge load experienced with surface mounted rubber pillows. With this factor eliminated, small sized pillows may provide a reliable snow water index.

(9) Alpha #15 is a 4 x 4 foot metal tank, 6 inches deep, filled with alcohol under positive pressure, and connected to a visual manometer located in the shelter cabin. This sensor appears to be very sensitive to both pressure and temperature changes within the snowpack. The erratic behavior thus far indicates a new design and possibly a flush installation will be needed to secure more stable conditions.

Temperature data are obtained from a 30-day, battery operated, Weksler gage with four sensors on 25-foot leads. One sensor provides air temperature, another the soil temperature 6 inches below the ground. The remaining two are used to obtain snowpack temperatures at ground level and at 24 inches above the ground. A maximum-minimum thermometer is used as a check and an air temperature trace is also obtained from the automatic weather station mentioned earlier. This information will be valuable when analysis of recorded snow and precipitation data are made and characteristics of snowmelt are described.

Summary

Continued work is needed in evaluating sensor design and pressure transferring devices. This will lead to the development of an economical, compact, easily installed, accurate, and relatively maintenance free instrument complex for remote data gathering sites. But already the existing cooperative snow sensor network in California has provided a new and valuable tool to water supply and flood flow forecasters. The operational network will be continually expanded until representative snow data will be available from several elevation zones in all major snowfed river basins. Forecasting techniques are being improved as a result of the availability of oncall data and the subsequent benefits to public safety and the water economy will be appreciable.

LIST OF FIGURES

REFERENCES

(1) Beaumont, R. T. Mt. Hood Pressure Pillow Snow Gage. Western Snow Conf., Proc. 1965, 29-35

(2) Smith, James L. and Donald Willen. Gamma Transmission Profiling Radiosotope Snow Density and Depth Gage. Western Snow Conf., Proc. 1966, 69-77

(3) Castle, Glenn H. Operational Experience with Snow Pillows in the Sierra Nevada. American Society of Civil Engineers, Irrigation Sec. Nov. 1968, Sacramento