The science of snow surveying

By
Mark McLaughlin
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Feb. 29 survey at Phillips Station, west of Lake Tahoe along Highway 50. | California Department of Water Resources Fred Greaves / California Department of Water Resources

The snowpack from the Sierra Nevada provides crucial water for California and western Nevada each year as the snow melts. Skiers and boarders get fired up about the quality and depth of the snow. Hydrologists and anyone who relies on Sierra snowmelt are more concerned with how much water is in the snowpack — it's called the SWE (snow water equivalent).

Many people are familiar with the media coverage of monthly snow surveys carried out each winter by California Natural Resources Agency and Nevada's Natural Resources Conservation Service, where teams of surveyors manually force a hollow aluminum pipe deep into the snowpack to measure its all-important water content.

The Sierra Nevada snowpack is California's most valuable natural resource and not because of the popularity of winter sports. When all that frozen precipitation melts it supplies more than half of the Golden State's total water supply. The Sierra range occupies only 12 percent of the state's land area, but nearly 70 percent of the state's population relies on its runoff. The Sierra snowpack is a key asset that sustains one of the largest economies in the world by providing high-quality water to millions of people, as well as to industry, recreation, fisheries, ranchers and farmers.

The father of snow surveying
The earliest studies of our regional mountain snowpack began with James E. Church, Ph.D., a Michigan native who was hired in 1892 by the University of Nevada, Reno to teach Latin and Greek. Ironically, Church nearly turned around after he stepped off the train in Reno and watched a man shot in a saloon gunfight die at his feet. Lucky for us, he gazed up at Mount Rose, which towers impressively above the city, and decided to stay.

Known as the father of snow surveying, Church was a pioneer in the field during the early 20th Century. In 1905, he established the first Sierra weather observatory atop 10,776-foot-high Mount Rose (southwest of Reno) and later developed procedures for measuring the depth of snow and its water equivalent. He learned that snow is an elastic substance and its depth does not indicate the amount of water in it.

Watch how the snowpack is measured at the Central Sierra Snow Lab on Donner Summit.

Church got into the streamflow forecasting business by accident. His original research about the logging industry investigated forest influences on mountain snowpacks. That led him to design the Mount Rose Snow Sampler, a hollow metal tube that hydrologists thrust deeply into the snowpack to extract a core of snow. The sample core is then weighed on a specially calibrated, portable scale to determine its water content — a simple but effective system that is still used today.

The measurement of the snow–water equivalent provides vital information for predicting the volume of spring snowmelt and water runoff from elevated mountain terrain during the West's dry seasons.

Managing water levels in massive reservoirs is a complicated business. Especially in California where atmospheric rivers can overwhelm flood control systems, while severe drought can make storage goals impossible. In the 1960s and 70s, Western water managers would consider their work successful if they hit a reservoir storage level within 15 feet of their target. Today, as the science of snow surveying has advanced, it's usually a matter of inches. Lake Tahoe is a reservoir managed for Truckee Meadows Water Authority in western Nevada. Tahoe's springtime water–level rise is usually controlled and accurately predicted to within an inch or less.

When Church started his research in the early 1900s, he established the first snow course at Tahoe City meadows – now Tahoe City Golf Course. A snow course is a permanent line of set measurement probe sites that indicate the average SWE for a section of watershed. It's more accurate than a solitary sample in a random location. Church was focused on Lake Tahoe and its flow into the Truckee River because his initial goal was to protect Reno, Nev., from catastrophic floods.

Snowpack
107% as of March 17, 2024
cssl.berkeley.edu

The Truckee River is one of the most volatile in the United States, averaging a damaging flood every nine years. In the 1930s, snow surveys were expanded throughout the Sierra Range, the Great Basin, Rocky Mountains and Pacific Northwest. The importance of snow in the nation's hydrologic systems cannot be overstated. In the Western United States, 85 percent of freshwater runoff originates as snowmelt. East of the Rockies, nine of the most significant floods in the 20th Century were directly related to snowmelt.

Central Sierra Snow Lab

A major advance for scientific research in Sierra Nevada snow came in 1945 when U.S. Weather Bureau physicist Robert W. Gerdel, Ph.D., was directed to build the Central Sierra Snow Lab at Soda Springs. The first remote data streaming of snow-water equivalent began at the Central Sierra Snow Lab in 1948 when Gerdel and project director B. Lyle Hansen developed the first nuclear snow gage, which used radioactive material to measure the water content of the snowpack.

Gerdel and Hansen took a small capsule of radioactive cobalt–60 to a remote location where the material was placed at ground level and a Geiger counter suspended by a cross arm 15 feet above. As the emitted gamma rays passed through the winter snowpack, collisions with water molecules lowered their energy level, which indicated the amount of water in the snow. The Geiger counters were rigged with radio-transmitters so that their measurements could be relayed in real time to the snow lab, but with the idea that ultimately off-site hydrologists in Sacramento or San Francisco could also receive the signals.

Snowfall telemetry

Beginning in the 70s, steel-mesh pillows were installed in western mountain ranges to try to eliminate manual sampling. Snow pillows are filled with liquid anti-freeze and placed over a weight sensor that is powered by electricity produced from solar panels. As the snowpack increases over a winter season, its weight pushes down on the pillow and the sensor underneath. The weight is calculated into snow-water equivalent. Today, almost 900 of these inert pillows produce near real-time data that is relayed by signal antennae to Western Regional Climate Center. This snowfall telemetry system is called SNOTEL.

Lidar employed

In 2017, NASA started a program called SnowEx that employed airborne gamma–ray detection and Light Detection and Ranging technology (lidar) to develop systems that can effectively survey vast expanses of remote mountain snowpacks. Lidar is a remote–sensing method that combines features of radar (radio-wave navigation used by ships and planes) and sonar (underwater detection using sound for submarines). The lidar apparatus spins rapidly, firing invisible laser beams in all directions. It measures distance and creates a virtual 3-D map with GPS coordinates of everything it can see. For aerial snow surveying, the lidar is mounted beneath an airplane and flown over the sample zone. The results are compared with a previously acquired lidar map of the area bare of snow (snow-off and snow-on).

Snow-depth height and high-resolution horizontal snowpack profiles provide hydrologists with key snow-water equivalent data needed for forecasting runoff.

Mark McLaughlin **snow surveying science**