1 Rain on Snow

Climate change steepens the challenge of forecasting floods.

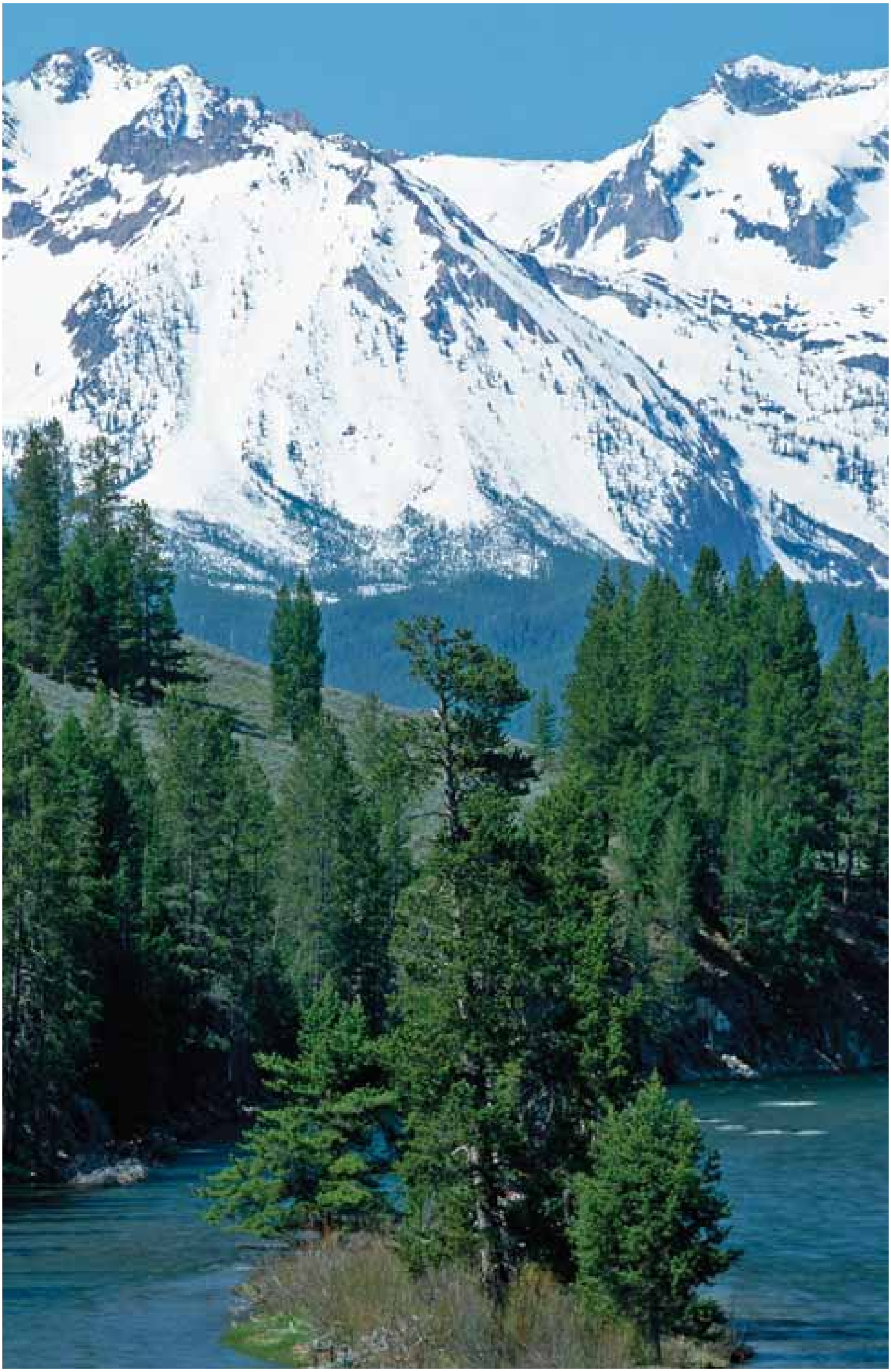
by Roy V. Cuellar

September snow had already fallen in the Northern Rockies. A U.S. Department of Agriculture (USDA) snow surveyor in a four-wheel-drive truck was climbing toward tangled wires, sensors, hoses, antennae, and gauges amid a stand of lodgepole pine. Each piece of equipment at SNOTEL site no. 550, atop Jackson Peak just north of Idaho City, was strategically placed and interconnected. "This is the place," said Alex Rebentisch of Boise.

SNOTEL (short for *SNO*wpack *TEL*emetry) is a western network of data collection stations spread across 12 states. The USDA's Natural Resources Conservation Service uses the sites to collect data on snow accumulation to forecast snowmelt. Rebentisch and other SNOTEL technicians scramble when snow comes out of season. In late September 2014, during an early snowfall, they raced up slopes to pump antifreeze into bladder-like precipitation gauges and check the condition of glycol-filled pressure-sensing snow pillows. The rush to beat winter was on.

Snow data drive the balancing act that keeps the Boise River contained while storing irrigation water. The U.S. Corps of Engineers, a flood agency, strives to empty enough reservoir space to handle a sudden snowmelt. The U.S. Bureau of Reclamation, an agency for the irrigators, hopes to store enough reservoir water to weather a cycle of drought. Both agencies impound and release snowmelt according to complex models based on the SNOTEL forecast, but the calculus is shifting as Idaho temperatures rise. The same climatic forces that are shrinking Montana's iconic glaciers have warmed Boise River Valley by more than 2° F since the Corps of Engineers built Lucky Peak Dam. Increasingly, in the mid elevations, spring thaw has shifted from April to March. Stream temperatures have risen nearly 1° F since the 1990s. Idaho's cold water bull trout have declined 11% to 20%.

Snow is but one of many factors changing the flood equation. Suburbs pave over absorbent marshes. Levees narrow the floodway. Silt fills reservoirs. Erosion degrades infrastructure. In the Boise Valley, where water is politics, geography and engineering



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conspire with climate to transform the flood-irrigation balance. Warm rains and shorter winters make the snowmelt equations more complex than ever before.

A Contrast in Two Idaho Rivers

High in the Sawtooth Range of the Rocky Mountains in central Idaho, the season of two rivers begins with the first snows of autumn. On the east slope of the range the 425-mile-long Salmon River begins, while on the wetter, west slope the 102-mile Boise River rises. Both rivers are tributaries of the greater Columbia Basin, and each contributes to the fabric of Idaho in a completely different way.

The Salmon River's value is in its wildness, which attracts a steady stream of tourist dollars to the state's economy. Over the past century and a half, the United States has built dams,

IDAHO AIRSHIPS, INC.

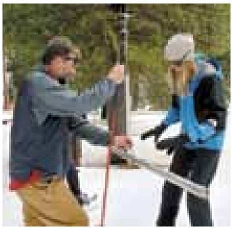
Lucky Peak Dam, completed in 1955

diverted streams, and created reservoirs to provide water where it was needed by farms and settlements. By virtue of its remoteness and surrounding rugged terrain, the Salmon River escaped this human interference. Not without controversy, the dynamics of this free and wild river were recognized and, in 1980, Congress created the Frank Church–River of No Return Wilderness to protect this scenic area.

In contrast to the Salmon, the Boise is a river diverted through dozens of log runs and headgates. Five historic dams—Diversion (1909), Deer Flat (1911), Arrowrock (1915), Anderson Ranch (1950), and Lucky Peak (1957)—serve a metro population of about 600,000. With water from the Payette River, now technically part of the Boise Project, the network reclaims about 400,000 acres. Annually, in dollars, the project's surface value is easy to measure: $581 million in crops, $600 million in livestock, $13 million in hydropower, $30 million in boating and fishing fees and other recreational income, $170 million saved from the damage of seasonal floods. Measuring the cost of those benefits is more problematic. "A series of disappointments, misrepresentations, and blasted hopes" was how the Bureau of Reclamation described the project in the 1920s. In the short term, the project sustains farming in the Boise Valley. Whether those benefits of dams outweigh the longer-term expense of maintaining the systems is a question hotly debated in Idaho's contested West. Although the added values of these structures are hard to measure, one variable must be measured as accurately as possible—snow.

Measuring Snowpack

To effectively measure snow beyond anecdotal amounts is a scientific process. Because of significant scientific advances over the past 100 years, this process has become more precise, allowing crops to grow where none had before, cities to be built along corridors that once flooded unpredictably, and floodways to be terraformed into parks and urban streets. Some cities, like New Orleans, are famous for their floodplain locations. In the 21st century, Idaho's capital city, Boise, is also a product of modern river engineering.



BOISE WEEKLY, MATT FURBER

Taking snow course samples at Mores Creek Summit

Unlike rivers in the eastern half of the continent, the rivers of the American West are dependent on winter snows and a snowpack that lasts into summer. In some areas this snowpack is nil, whereas in the high Cascades snow can accumulate to depths of 30 to 40 feet. In some years, up to 80% of the water that flows in the Boise River began as snow.

The first snow survey courses date back to 1906 when Dr. James Church, a hydrologist with the University of

Nevada, Reno, began to document the relationship between accumulated mountain snowpack and watershed stream flows in the lower elevations. By refining early Russian technology, Church improved the technique by which the amount of water contained in snowpack (referred to by scientists as the *snow water equivalent*) is measured. Soon after Church developed his new technique, the USDA took note and began to develop snow courses of their own across the mountainous West. Today data are collected at more than 1,600 locations in 10 western states. As a result, hydrologists are able to make reliable stream flow predictions that individuals and businesses can plan around.

Not all reaches of the Boise Basin are as remote as the west slope of the Sawtooth Range where the Middle Fork of the Boise River rises. Depending on the snow cover, some locations are easily accessible year round by tracked or wheeled

BOISE WEEKLY, MATT FURBER

A USDA snowpack measurement station above Idaho City

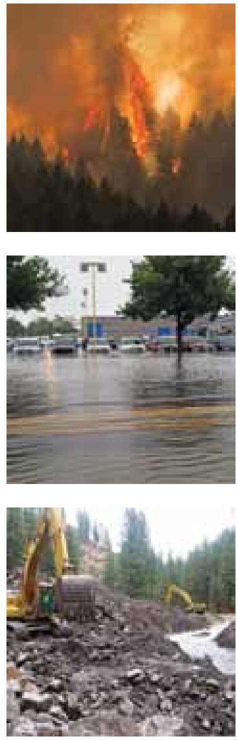
vehicles, offering excellent snowpack data collection points. Some of the sites are manual stations, set out along a course easily accessed by snowmobile and snowshoes, whereas others are electronic.

Beginning in 1977, the Natural Resources Conservation Service of the USDA began converting many locations to SNOTEL sites. The snowpack at these sites is measured electronically by solar-powered instruments that then transmit data by meteor burst telemetry across long distances to two master stations—one in Boise, Idaho, the other in Dugway, Utah. Depending on the weather event or time of year, data may be transmitted hourly in bits and bytes of binary code by a system designed specifically for computers to exchange data in real-time nanosecond bursts, thus conserving the power of the stations' solar-charged batteries during the darker days of winter.

El Niño and La Niña

"If everything was normal, you wouldn't need me," said Ron Abramovich of the Natural Resources Conservation Service. On October 21, 2014, at a professional conference in Boise, Abramovich sought to explain drier winters and warmer springs. Rain-on-snow events, he continued, occur when unseasonably warm temperatures follow mountain snowstorms. Early spring in the Boise Mountains has become increasingly common.

Shifting winds may also be a factor, according to Abramovich. Wet winds hit the mountains from two directions—from Washington-Oregon and from the California Southwest. Westerly systems bring the snow to Bogus Basin. Southwesterly influxes from California are affected by a 3- to 7-year weather cycle called the El Niño Southern Oscillation. El Niño, the warmer phase of the broader climatic cycle, brings moist air over the Pacific Ocean from the equator. La Niña, the colder phase, brings weather extremes of flooding and drought. La Niña often dumps snow in the Northern Rockies. El Niño hits harder in the Sierra Nevadas and the Upper Midwest.



TOP TO BOTTOM: CNN, KMTV (TWIN FALLS), U.S. FOREST SERVICE

The effects of El Niño and La Niña

El Niño's turbulent heat transfer from the winds to the snow surface causes condensation and melting. This process increases the exchange of two kinds of heat: sensible and latent. Both raise the water available for runoff to lower elevations where the ground is thawed. This in turn leads to extensive sediment transport, downstream flooding, and the potential for further mass wasting in the form of land and rock slides. Frozen soil prevents water from being absorbed in the ground and quickens the flow of runoff.

In forested and vegetation-covered areas, natural shade helps to keep temperatures cooler and wind speeds lower. In essence, these areas can be broken down into three vegetation subclasses: the higher canopied conifer forest, the aspen stands, and the sage class, which provides the least shading. These covered locations generate less water available for runoff than adjacent open areas experiencing the same rain-on-snow event.

Climate Change and the Danger of Floods

In 1996-1997, at Reynold's Creek in Owyhee County, USDA hydrologist Danny Marks closely followed the dynamics of rain on snow. The warm December storm brought 3.47 inches of precipitation, most of it rain. The daily flow of Reynold Creek increased 50-fold.

U.S. GEOLOGICAL SURVEY

A U.S. Geological Survey hydrologic technician measuring streamflow

The year 2011 set Idaho records for rain-on-snow runoff flooding. In March, 26 SNOTEL stations reported record-breaking precipitation. Warm rains melted the snow about 2 weeks earlier than SNOTEL forecast. In April, between 6,000 to 8,000 feet in elevation, temperatures reached 70 °F. The heat in the Boise Valley reached 90 °F. Two inches of rain in the last week of April flood the Boise River Greenbelt. "It was easier to be a water manager or farmer back in the '60s and '70s," Abramovich explained. Today in the chaos of unpredictable weather, the old formulas no longer apply.

Monsoon rains, hard to predict, complicate SNOTEL forecasts. A heavy rain in August can be welcome relief near the end of the irrigation season. In 2014, August rains in Boise Basin were heavy enough to rival the moisture of May. For water storage, nevertheless, summer monsoons are inconsequential compared with the importance of snow.

NASA

Bracing for La Niña

Conclusion

As the Boise River rolls downhill from the Sawtooth and Boise Mountains, it shows none of the peril that its snowpack holds. It is a charming river to bike or hike along on the warmest, sunniest days of the season. But upstream, as winter wanes, the impact of falling rain on sodden snow presents far more challenging conditions. How will the agencies deal with water retention systems nearing capacity, reservoirs aging and filling with sediment, uncertain climatic conditions, and close to a million people living downstream when a sudden, voluminous, unseasonal deluge threatens to overtop reservoirs? Who can say, but you might want to keep your tennis shoes under your bed.

ROY V. CUELLAR is a retired pilot and the father of three daughters, all graduates of Boise State University. Cuellar graduated from Boise State University with a bachelor's degree in applied science with a minor in history and a concentration in geoscience.

Todd Shallat and Mike Medberry contributed to this chapter.