Snow Survey Centennial Celebration
1906-2006

Water Supply Forecasting through the Ages

From 1947-1972, a trade publication called the "Snow Surveyor's Forum" was published, covering a range of topics from tips on the maintenance and field repair of equipment like wooden skis and snow tubes to sharing real-life tales of hijinks and high adventure in the wilderness. Often in the form of cartoons or humorous verse, this forum contained no shortage of roasts and ribbings of the main user of the snow data they were collecting, namely water supply forecasters.

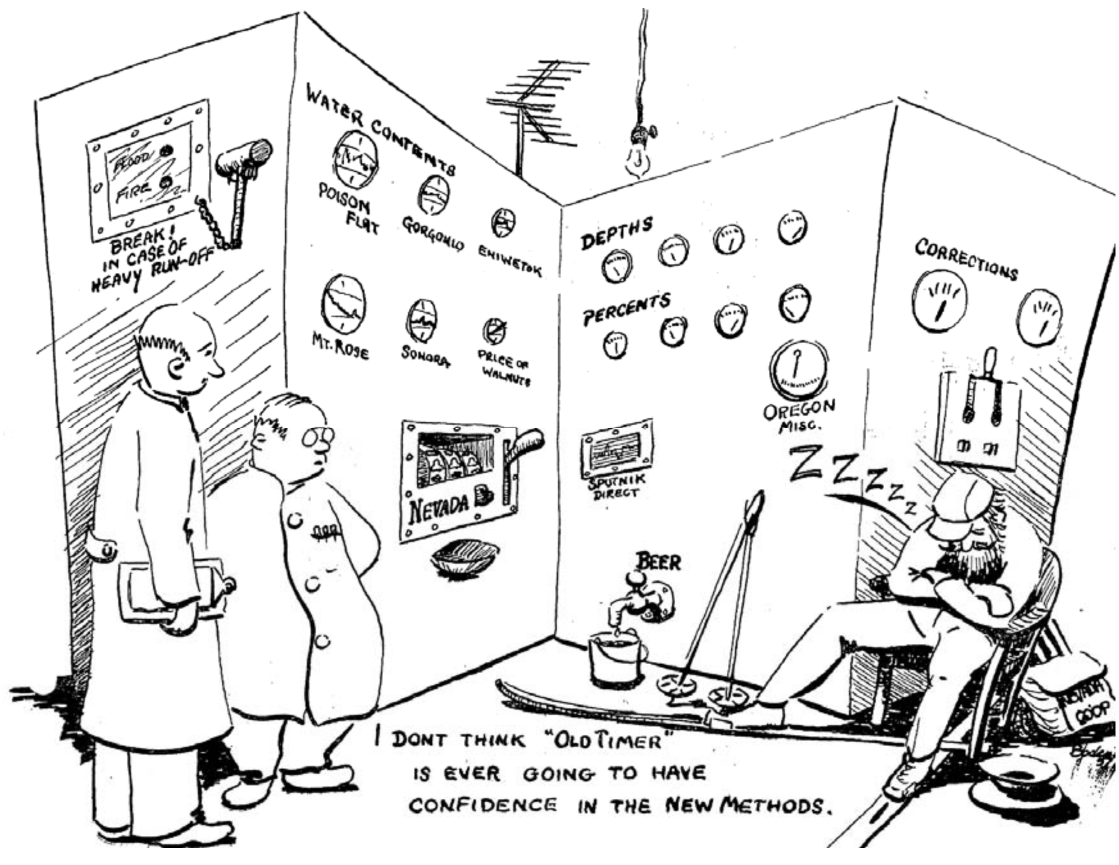

Exhibit A. Graphical depiction of modern forecast technology (Snow Surveyor's Forum, 1957). The Nevada Cooperative Snow Survey program representative (right) seems unimpressed.

One imagines the archetypical hydrologist in a white lab-coat tinkering on his latest data taffy-puller, a cacophonous gonkulator capable of stretching two weekends worth of measurements into a 30-year normal. During data collection time he could be found in a smoking jacket and fez, dozing off in the comfort of a wingback study chair by a crackling fireplace, holiday nog in hand and a golden Labrador napping at his feet. While visions of scatterplots danced in the forecaster's head, hundreds of miles away, shivering in the sleet, the grizzled snow surveyor scrambles up a ponderosa pine to escape the ravenous family of bears circling below.

While fezzes have gone out of style among most hydrologists, a prime directive of the operational community remains finding ways to gain the most accurate assessment of basin moisture conditions in the shortest amount of time, with the least amount of "busy work." Back in the day, developing forecasts and equations must have been tedious with its hundreds of manual calculations, the equivalent of carrying each number up and down the mountain by hand. In the 1950s, it took a hired school teacher an entire summer, day in and day out, to develop nine forecasting equations. Today, a modern hydrologist might have more than 900 equations in his or her roster.

Exhibit B. Montana Snow Survey Supervisor Ashton "Ash" Codd busy water supply forecasting. The model of the rotary pinwheel calculator indicates circa 1915, although carbon dating of the photograph suggests 1952. Original caption observes "No wonder now and then he is a bit short of water with such a short calculator". Mr. Codd also developed and built the first "Sno-Bug", the predecessor of the modern-day snowmobile.

For 100 years now, snow surveyors have repeated a ritual of braving winter conditions to measure high-elevation moisture in rugged terrain. In almost every climate of the Western US, a steady beat of data throughout the season provides a rising signal of things to come. As this sound draws nearer and clearer in spring, it becomes increasingly evident whether it is a song of jubilation or chords of a minor tone. One group of surveyors arrives at a site with bare ground in April for the first time in 75 years and knows that the community must be warned of imminent shortage. However, when the snow tube plunges to an unexpected depth, it could foreshadow bountiful crops or raging torrents. The mission of the hydrologist is to convert these impressions into quantitative guidance on anticipated streamflows.

From the early beginning

As you read in the most recent Centennial newsletter, not five years after the first snow surveys were made around Lake Tahoe, James Church was urged by the Sierra Pacific Power Company to advise about the possibility of high flows in 1911. Horace Boardman, professor of civil engineering at the University of Nevada, developed the forecasting equations relating snowpack and streamflow. The forecasts were well received until 1915-1916: the first "busted" forecast. A near complete absence of spring precipitation caused a divergence between the forecast and observed streamflow of 50%. So too was born the first irate water supply forecast user, who would have seen the entire snow surveying enterprise sold off for scrap were it not for the cooler heads that prevailed.

From 1917-29, six snow survey programs developed across the western US, each region producing its own water supply forecasts. According to a survey in 1934, the most common forecasting method was to relate snowpack to streamflow directly by percent of normal (e.g. "134 percent of normal snowpack on April 1st means 134 percent of normal streamflow this summer"). Some more ambitious hydrologists tried to swiss cheese the watersheds with snow measurements to estimate the total volume of snow (both depth and area), although it is unclear whether it was the low forecast skill or an insurrection on behalf of those that were forced to collect the data that eventually did this technique in.

After snow surveying and forecasting responsibility was put in the hands of the Natural Resources Conservation Service (NRCS - then called the Soil Conservation Service) in the mid-1930s, the merits and ease of regression-based statistical procedures were increasingly appreciated, especially by the 1950s. The National Weather Service (NWS) began forecasting in 1948, using techniques that generally favored low elevation precipitation measurements (instead of snow) and debates raged for close to two decades on which technique was best. Most recently in 1992, NRCS hydrologist David Garen developed a highly advanced statistical technique that has become the water supply forecasting industry standard among both agencies, in Canada and elsewhere around the world.

In 1983, NRCS forecast responsibilities were collected from the states into the National Water and Climate Center (NWCC) in Portland, Oregon. Today, NWCC hydrologists track basin moisture conditions on a daily basis while the snowpack accumulates in the mountains and melts off in the spring. Working with other NWS hydrologists throughout the Western US, water supply outlooks are issued every month from January through June for rivers at the top of the Artic Circle to the deserts of southern Arizona. These volumetric streamflow forecasts are a key to the sustainability of water supplies across a range of sectors, from reservoir management, irrigation, the environment, recreation and others.

Although many things have changed about the production of water supply forecasts, the core principles remain the same. All hydrologists ask "How much snow is on the basin and where? Will dry soils steal away some of the water? Will the rest of the season be wet or dry? How certain am I about what will happen?" Over the years, the speed, ease and reliability of answering these questions has improved with the use of science and technology.

Faster and Faster

An eternity seemed to pass between measurement of the data in the mountains and the final forecast numbers arriving in the hands of the water user. On wooden skis in the 1920's, it would sometimes take two weeks for a group of surveyors to complete a circuit, perhaps longer if they encountered inclement weather. Mechanized over-snow transport revolutionized snow surveying in the 1950s with the advent of the Sno-Cat and personal snow machines. Then, in the 1970s with the formation of the automated SNOw TELemetry (SNOTEL) network, data could appear instantly on the computer screens of the forecasters. In the late 1980s, centralization sped the forecast creation process, but a bureaucratic bottleneck, unusual even for government work, seriously slowed the distribution process, a trend sharply reversed by the Internet in recent years. Now, satellites ring the planet, beaming back reams of high resolution data on everything ranging from snow covered area to soil moisture, plant health and land use.

Although many forecasts were distributed by post or telephone as they are today, the community was often kept informed during the 1930's by extended radio address and commentary. Tune in to the January 16th newsletter in this series for an example. Telemetered data systems allow the water manager to track a quickly evolving rain on snow event as it happens. To compliment increased data availability, the NWCC has developed a prototype system this year that automatically creates a new water supply forecast every day. During water year 2006, 50 basins were calibrated and daily forecasts delivered to users through the Internet. This may be the world's very first "instant basin forecast" system developed by a public agency.

The Role of Humans

It has been said that the factory of the future will have two employees; a human and a dog. The human is there only to feed the dog and the dog is there to bite the human in case he or she tries to touch anything. While the GS (General Service, i.e. federal) employee of today is probably not the German Shepherd of tomorrow, there has always been a running theme of automation versus human intervention throughout all forecasting enterprises.

Today, airplanes can take off, fly and land by themselves using computers. Human pilots remain on board to put the passengers at ease and to take hold of the controls in the event of an emergency. Similarly, developing hydrologic forecasts is both an art and a science, relying on the quantitative output of tools as the foundation, while using human expertise to synthesize the information and sort out strange situations (e.g. furnace hot winds in springtime).

The key, of course, lies in picking the right battles - allow the computers to do the tedium and drudgery to free up the humans to focus on analysis and interpretation. The NRCS especially has made great strides in producing much information with limited personnel. Many people are surprised to learn that only four NWCC hydrologists produce analyses for close to 800 locations in almost half a work-week, making forecasts that are tied to multi-million dollar power and water management decisions. Forecasting progress has recently been accelerated by a new interactive visualization environment developed last year.

But who knows what the future holds? Just as Big Blue defeated Kasparov in chess, weather forecasters are increasingly finding it difficult to be more skillful than some of their objective models. The day may come when developing forecasts is like tending a campfire; despite the temptation to interfere, it may be best sometimes to leave it on its own.

Predictions for the future

Having been born in the 1970s, it is sometimes difficult for me to conceal my disappointment with the lack of hover cars and space colonies in the 21st century. At the same time, it is a challenge to pass up such an opportunity to add my name to the list of those that have tried to cast light into the future of the program. Nonetheless I will try to adhere to this sage advice "Predict a time, place, or magnitude, but never all three at once."

Fundamental understanding of watershed and climate processes will improve. In particular, the NRCS's recent investment in soil moisture measuring technology will mature into quantitative forecasts of runoff efficiency in as few as 10 years. In 20 years it should be fairly obvious who is right or wrong in the climate change debate.

Computing power will greatly accelerate, and in 10 years we will have hand-held computers with 10,000 GB hard drives that use 100 GHz processors to delete torrents of spam from our email inboxes at lightning speed anywhere we go. Transfer times and storage of large data sets will become a trivial matter. Hopefully everyone will adopt a universal language and format for exchanging data. I predict this format will be called "E.S.P.E.R.A.N.T.O." [*Ed: Google it, or do whatever you futurelings call melding with the Global Brain*] and that only NASA could be responsible for such a long and likely nested acronym.

Increased computing power should lead to more "distributed" forecasting systems, i.e. everyone can create their own forecasts anytime from anywhere, even in their pajamas. The Internet will be their database. This means that more university research groups will create more "real-time" models and have much to contribute during the actual creation of the official forecasts.

In 15 to 20 years, along with relying on the help of others, the NWCC will be running a diversity of models and tools for guidance. Someday we will start thinking about ways to automatically and objectively combine these tools, much like a human would. And if that dream becomes a reality, my shaggy new office-mate will be paid in Milk Bones, but I'll still be paid in scraps!

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