Fifty Years of Research at South Cascade Glacier

Wendell Tangborn

It was a typical day at South Cascade Glacier in October — wet, cold, windy, cloudy and dark. After breakfast we gathered up the equipment we would need for the day (ice axes, current meter, measuring tapes, snow probing rods, rubber hip boots, collapsible wading rod), packed a lunch (a can of sardines, a box of Ry-Krisp and a can of apple sauce), dressed in the most water-proof clothes we could find and headed up glacier. The rain turned to snow as we gained elevation and a brisk wind from the southwest warned us that the day was not going to be pleasant. We read ablation stakes and measured new snow depths as we moved up the east side of the glacier, avoiding the areas we knew were heavily crevassed but now covered with a foot or two of new snow. But a boot would still break through occasionally, leaving a small gaping hole in the new snow and warning us we were getting into dangerous territory.

All of this was a little scary for me, as I had never stepped foot on a glacier until the previous July (1960), after being transferred by the Geological Survey from Minnesota to Washington to work in Mark Meier's glacier project. To say I was naïve would be an understatement as monumental as the peaks that now surrounded us. I was also unsure of my position as Mark's understudy, which was the word used to describe my new job

By noon we reached the head of the glacier. The wind was now at a velocity such that the falling snow moved more horizontally than vertically. Just off the glacier we ate our lunch in a sheltered spot in the lee of a large boulder but the relentless wind and driving snow made eating a chore. We had brought along a thermos of hot water and some packets of a dried cocoa mix, envisioning a steaming mug of cocoa to go with our sardine/Ry-Krisp sandwiches. But when we poured the powder into a cup the wind whipped it out before hot water could be added — so our hope for a hot cup of cocoa was revised to one of tepid water.

We did not dawdle over lunch and quickly began our trek down the west side of the glacier, measuring those stakes that could be found. These data would be used to calculate the glacier's final balance for the year — the difference between total snow accumulation and total ablation (snow and ice melt). One of the vital goals of the project was to measure the glacier's balance and determine if it was gaining or losing mass. Visibility was now down to 10 or 15 feet and just staying on the right course was all we could do. By the time we reached the firn line, the boundary between snow and ice, the snow had turned back to rain and the wind intensity lessened slightly. We spent the afternoon measuring the discharge of some small streams flowing on the glacier and issuing from the cliffs below LeConte Peak. These measurements would be useful later for calculating the glacier's water balance, another task that would help us relate the glacier's health to the climate. One measurement was a little frightening as it was just above a moulin, into which

the glacier stream poured making a thunderous roar as the water fell 200 feet to the glacier bed. It was easy to imagine slipping on the wet ice, falling into the stream and sliding out of control into the moulin (aided by the wet hip-boots and the rubberized rain gear I wore). Mark commented that if I fell in he would see to that I was remembered by naming it the "Tangborn Memorial Moulin".

At the glacier terminus, we had to make a decision quickly, as the rain and wind were picking up. Should we head back up the glacier and pick up our route from this morning, or follow the rocky shore along South Cascade Lake, cross the south fork Cascade River, and climb the bedrock ridge back to a warm and dry hut?

The hut at South Cascade Glacier in 1960. Photo by Mark Meier

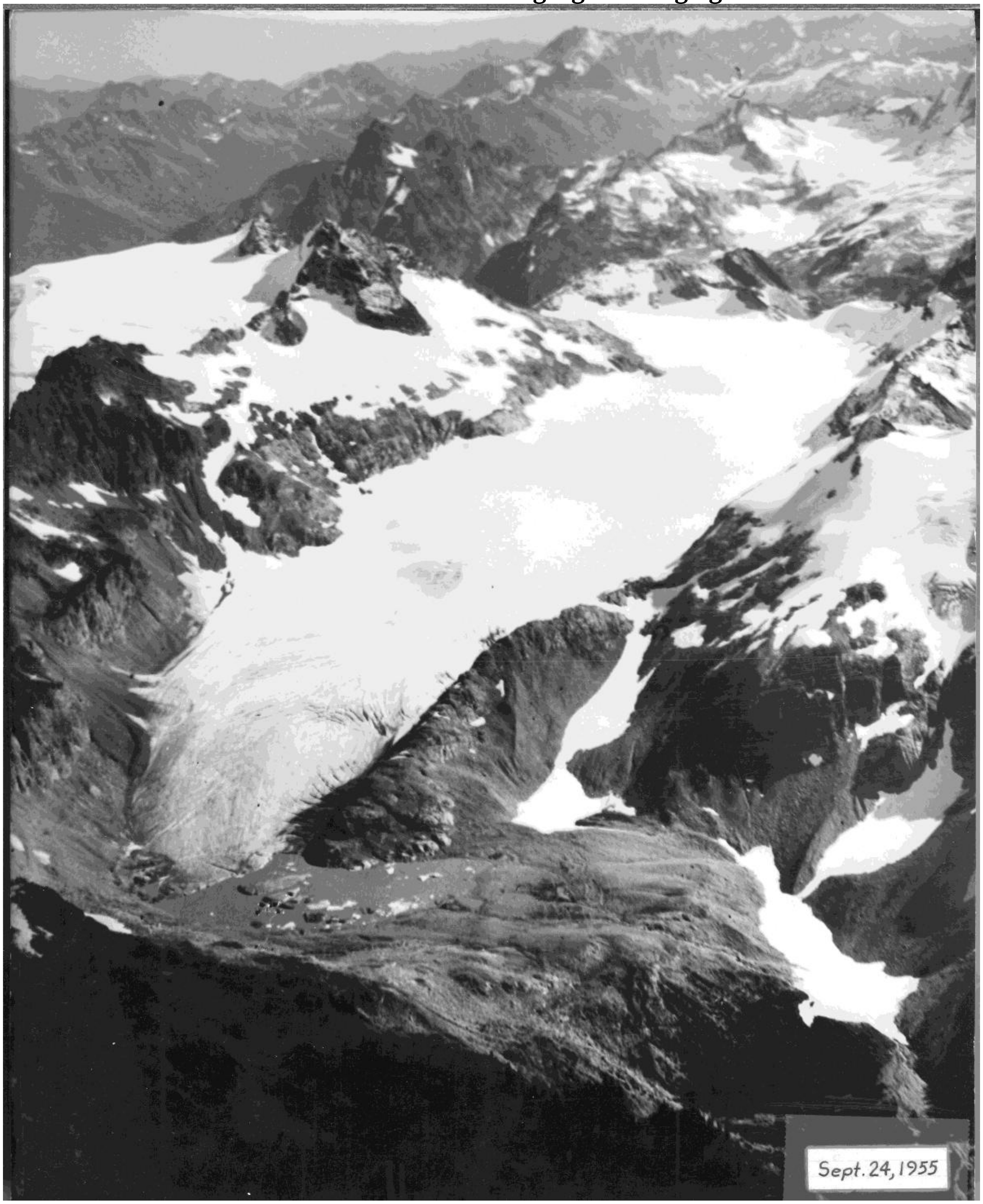
Mark thought the lake route the quickest and least dangerous so we began the traverse immediately, after I changed back from rubber hip boots to hiking shoes. The glacier had occupied this entire lake just 30 years before, when the ground on which we walked was covered with ice a hundred or more feet thick The lateral moraine left by the retreating glacier around the lake was composed of rocks that varied in size from a fist to a small automobile, and because they were only recently deposited on a steep terrain, were extremely unstable. I had not made ten steps when I stepped on a teetering boulder, which turned over, pitching me headlong into a rocky depression. I soon understood that the remaining one-half mile traverse around the lake required utmost caution for each step. By the time we reached the river, darkness was closing in, the rain and wind were sapping our strength and rapidly diminishing our interest in glaciology, for that day at least. I was now beginning to realize that it was this type of work that made glacier study so hazardous.

Research studies at South Cascade Glacier in the North Cascades, were initiated by the Water Resources Division of the US Geological Survey in 1957. One of the primary goals of the USGS mission was to determine how glaciers respond to

climate change. It has long been known that glaciers are sensitive to the climate and the indelible traces left by glaciers on the landscape over much of the Northern Hemisphere portrayed past climates. But the complex interaction of a glacier with its environment needed to be understood with greater precision before past climates could be deciphered from their imprints left on the landscape. The impact of a changing climate was not of as great a concern then as it is now so the foresight shown by the development of this program at that time is remarkable. Luna Leopold, son of the world-renown naturalist, Aldo Leopold, was chief hydrologist of the Water Resources Division from 1957-1966, so it is not surprising that such a strong effort was made to support and fund this research program.

The statement "glaciers are sensitive to the climate" was made countless times in published articles and the presentations we made throughout the 1960s-1970s, but little did we know just how sensitive they were. The now impending demise of many of them suggests glaciers are much more sensitive to the earth's climate than are

humans. We should have heeded their warning signals long ago.



South Cascade Glacier on September 24, 1955. Photo by Austin Post

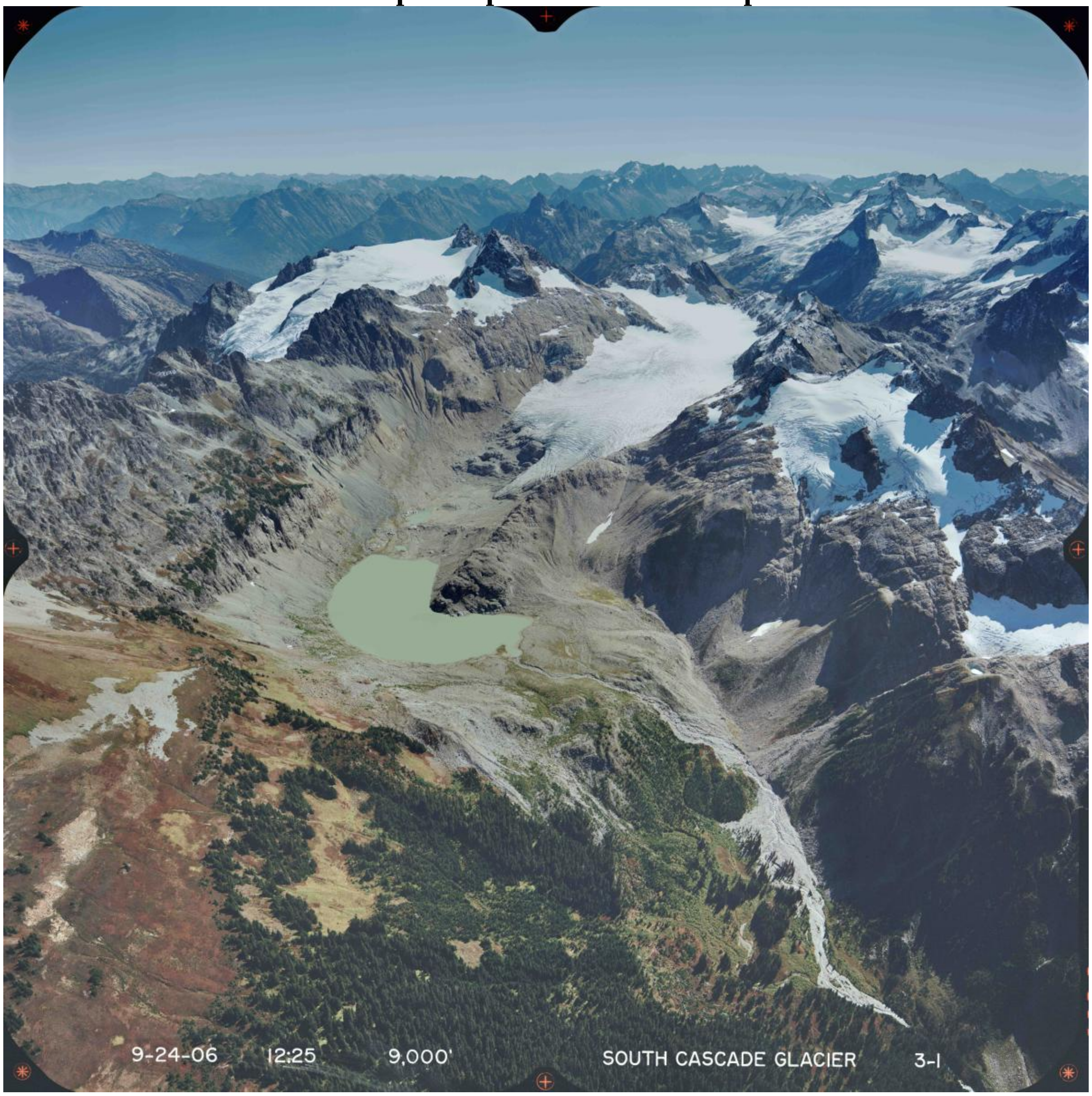
Mark Meier was designated chief of the Glacier Project Office in Tacoma and served in this position until he retired 1985. I transferred from the St. Paul District office of the Water Resources Division in 1960. Austin Post, the imminent glacier photographer and glaciologist joined us in 1966 and Robert Krimmel in 1968, first as a field assistant, then as a hydrologist. Meteorologist William Campbell,

mathematician Lowell Rasmussen and hydrologist Donald Richardson became part of the core staff in the 1960s, and glaciologist Steven Hodge, mathematician William Sikonia, photographer David Hirst , geologist David Frank and mathematician Suzanne Brown in the 1970s. Currently William Bidlake is in charge of the South Cascade Glacier operation for the USGS in Tacoma, Washington.

The snow and ice research at the Glacier Project Office was largely directed toward an improved understanding of how a changing climate would affect water supplies that are derived from melting snow and ice. Over much of the United States and many areas of the world, snow and ice are important sources of runoff. Because changes in the climate would alter both the seasonal snow cover and the size and extent of glaciers, and therefore have a significant effect on water resources, another project goal was an improved understanding of snow and glacier hydrology. In some parts of the world people depend on the water from melting glaciers as their only source of supply during the summer season. The disappearance of mountain glaciers in these remote areas will have severe consequences for them.

South Cascade Glacier was selected as the main study glacier for this project because it was small and could be easily traversed. Also, it had a well-defined basin from which the runoff could be accurately gauged, it had well-defined moraines for historical analysis and was reasonably accessible by trail. It proved to be a good choice, and as it is rapidly disappearing, may be a perfect example to demonstrate

the fate we all face from atmospheric pollution of human-produced carbon dioxide.



South Cascade Glacier on September 24, 2006. Photo by Vern Potts, WDT.

One consequence of our snow hydrology research on the glacier and in the North Cascades was the development of an improved streamflow forecasting model for mountain basins. The model uses only weather observations collected at low altitudes, from established weather stations to simulate the snowpack, therefore does not require expensive and environmentally intrusive helicopters, on-site snow surveys and weather stations installed at remote mountain sites. However, even though the forecast accuracy of this model has proven to be more accurate than snow surveys and other snow measuring techniques, it has never been accepted by the governmental agencies responsible for providing the public with water supply forecasts. We (HyMet•) currently use it to forecast runoff of the Columbia River at the four main hydroelectric dams and distribute weekly runoff and energy forecasts to energy traders, public utilities and investment banks. I was certain that a reliable

runoff forecasting model, which would end intruding into wilderness areas with helicopters and motorized vehicles and at the same time save taxpayers millions of dollars, would be quickly adopted by the National Weather Service and other government agencies, but 30 years later I am still waiting.

The South Cascade Glacier program emphasized both glacier dynamics and the ice and water balance of the glacier. A great effort went into designing and constructing streamflow and precipitation gauges that would operate throughout the year in a harsh environment. Several significant findings resulted from this research. One was to learn that by simultaneously measuring the glacier's cumulative mass balance and its time-varying flow, we could demonstrate a dynamic relationship between them. It was then possible to establish the link between glacier flow and climate change. In addition, for the first time longitudinal profiles of ice discharge and glacier thickness were calculated from only surface measurements. Another noteworthy contribution was the discovery that a glacier internally stores a substantial amount of liquid water during the summer melt season and slowly releases it during the winter. The proposition that there are large reservoirs of sub-glacial water encountered considerable skepticism in the glaciological community, but it has since been confirmed for many glaciers throughout the world. Sub-glacial water is now considered critical for predicting the response of both glaciers and large ice sheets (such as Greenland and the West Antarctic) to climate change. In the late 1980s, Andrew Fountain mapped the basal water levels by drilling holes to the bed of the glacier, revealing new insights regarding the drainage patterns of sub-surface water.

Measuring the mass balance (the total snowfall and ablation of snow and ice) of a glacier requires intensive field operations that are time-consuming and expensive, and also means some environmental damage, regardless how carefully we try to minimize it. Not long after starting work as a glaciologist I started thinking there must be a better way to make these measurements (my thoughts were likely inspired by the necessity of digging snow pits, sometimes as much as 30 feet deep). Although it turned out to be possible to substitute low-elevation precipitation and temperature observations for snow surveys in runoff forecasting, glacier balance calculation requires more detailed measurements. Snow surveys are used to forecast runoff from large drainage areas, often many hundred square miles in area, whereas most glaciers, except in the arctic regions, are on the order of a few square miles (South Cascade glacier is about 1 square mile).


Probing snow depths on South Cascade Glacier, spring 1962. Photo by Mark Meier

It took another twenty years after I retired from the USGS in 1979 to evolve a method to simulate glacier conditions using observations at distant weather stations. An explanatory paper was published in 1999 in Geofiska Annaler, a science journal published in Sweden. As with the attempts to convince governmental forecasters to adopt the HyMet runoff forecasting model, the initial resistance to the glacier balance model by glaciologists was even stronger — most simply felt it was impossible to determine snow accumulation and ablation on a glacier from weather observations at a valley weather station 50-100 miles away. However, the model has been used successfully for several large glaciers in Alaska and for others in Washington and is now accepted as a valid alternative to field measurements of mass balance. Plans are now underway by the Geological Survey to use this model to monitor balance and weather conditions at South Cascade Glacier on a real-time basis at their Tacoma offices.

In developing this model it appears I may have stumbled on to something about glaciers that no one has suspected and is also the reason the mass balance model works as well as it appears to. The PTAA model (precipitation-temperature-area-altitude) as it is called, determines a glacier's balance using weather records collected at low-altitude stations with long historical records, plus the area-altitude distribution of the glacier's surface. The area-altitude distribution (the AA profile) is a rough approximation of the spatial orientation of a multitude of individual

facets that define a glacier's surface (if each facet is assumed to be a 10x10 foot square, South Cascade would have nearly 300,000). Each facet's altitude and inclination is determined by erosion of the underlying bedrock by the sliding glacier and by glacier flow. Glacier bed erosion proceeds over geologic time, on the order of hundreds of thousands or even millions of years for many existing glaciers. The energy (solar radiation and turbulent heat transfer from the surrounding air), and mass (mostly as snow) each facet receives determine the glacier's total mass balance. Therefore each glacier has embedded in it a memory of the past climate and responds to the current climate according to the imprint carved in the bedrock by the erosion at its bed. An artificial intelligence expert may be able to construct a neural network model that would provide a better explanation, and also enhance our understanding of how a glacier responds to climate change.

In 1958, a tree stump was discovered that was just uncovered along the edge of the retreating glacier. A radio-carbon date of the wood revealed an age of 4700 +/-300 years, which meant that the glacier was at one time at least as small as it was in 1958 and in an advancing state about 5000 years ago. The advance sheared off the tree and must have immediately covered the stump with ice as it showed no signs of decay when it was found. Parallel to this finding, a body was found in 1991 adjacent to a receding glacier in the Austrian Alps. The Otzi man, as he is now called, died approximately 5300 years ago and his well-preserved body, like tree stumps in the North Cascades, must have also been immediately covered by ice that kept Otzi more or less intact until he was found. The conclusions based on these two coincidental phenomena is that the climate from 5-6000 years ago appears to have been similar to today's climate, as both were marked by retreating glaciers. However, these two glaciers apparently made rapid advances about 5000 BP and it seems unlikely this will be repeated anytime soon. We do not know if the cause of the retreating glaciers then was due to increasing temperatures, as it is now, or by much lower rates of winter snowfall. Glacier advances 5000 years BP may not have been so unusual in the Northern Hemisphere but evidence is sparse because later advances were greater and obliterated the earlier moraines. There is ample evidence, however, that tidewater glaciers in Alaska advanced 3000 years BP and those in the Southern Hemisphere made significant advances 4400-4600 BP.

The chance visit by Harvey Manning and Dick Brooks during a Labor Day storm in 1961 had a profound influence on my view of how we should treat our environment. Before that I'm afraid I was unaware of how fragile the earth really is and how easily it can be and is being damaged by blundering humans. Listening to Harvey expound his views on a wide variety of subjects for those three snowbound days was one of the best educations anyone could have. I consider myself extremely fortunate that an unseasonably early and severe autumn snowstorm forced these two stalwart mountaineers to seek shelter at the South Cascade Glacier Hut (even though both of them deplored its being there but admitted later they were glad it was). An account of their excursion to the glacier from where they were camped at White Rock Lakes can be found in *The North Cascades National Park, by Harvey Manning and Ira Spring.* If either or both of the two computer models I developed to measure snow

accumulation and ablation using low-elevation observations are ever fully accepted or adopted by others, the resulting reduction of human intrusions into pristine wilderness areas should largely be credited to Harvey Manning.

I also feel fortunate to have survived the hazards of working in the mountains as a glaciologist for nearly 20 years, especially considering my initial naivety and lack of experience. Falling into a glacier crevasse would seem to be the most obvious danger but we seldom roped up while on the glacier (which, in retrospect, seems I must have been horribly dimwitted about safety but also incredibly lucky). There were many other dangers — helicopter or small plane accidents, climbing falls, unexpected illnesses, snow avalanches, hypothermia, severe storms, many potential water hazards — all of which I and others narrowly escaped experiencing at one time or another (I never have learned to swim and nearly was swept over a 300-foot waterfall in Norway when attempting to gauge a glacier stream during a storm). There was one close call in which a co-worker nearly died from an obstructed intestine but was saved by the courage and piloting skill of the late Bob Munro, founder of Kenmore Air Harbor. A dramatic account of this rescue can be found in *Success on the Step, The Story of Kenmore Air Harbor, by Marin Faure.*

There was a trail we used at first from the nearest road to the glacier that followed Downey Creek for eight miles but its total length was 14 miles and required climbing from the hut to 7000 feet before descending to the timberline. After a few years, a new route only nine miles long and following the South Fork Cascade River was opened by Austin Post. There were tremendous advantages to this trail, besides being shorter. It could be used in stormy weather as the shelter of a heavy forest was reached in minutes after leaving the hut, and the hike out to the road could be done in 5 or 6 hours. The Downey Creek route would take up to 14 hours, which meant we often would not reach the road until after dark. I still have a recurring dream (not quite a nightmare) about getting caught on a mountain trail just before nightfall and realizing I will never be able to find the way out in the dark.

At the end of that October day in 1960, we faced another dilemma — a 30-foot-wide, turbulent and fast-flowing river, and only one pair of hip boots. We discussed the options. I could put them on, cross the river, remove them and throw one at a time back to Mark. But the chance of one landing in the stream was too great (a rubber hip-boot does not throw like a baseball). We did what was now the obvious alternative. Without further discussion, I removed my hiking boots, placed them in my pack and put the hip-boots back on. Mark slipped on both his and my backpack, and then hopped onto my back. Grasping the two ice axes, one in each hand, we started crossing the stream. Without the two extra legs provided by the ice axes it would have been impossible because of the swift water and slippery, invisible rocks at the bed of the stream. Also, without a doubt the extra 200 pounds provided better traction. However, half way across I stepped on a large, unusually slippery rock and nearly fell. "Slip and you're fired," came from above and just behind my head. Fortunately, I stayed on my feet and we crossed without mishap.

Despite my initial misgivings about the precarious position I felt I was in working for Mark Meier, I owe him a debt of gratitude for selecting an inexperienced, not too well-educated farm boy to work with him. Looking back now to1959 when he interviewed me, I still am puzzled that I was hired for this job when there were so many other applicants who were more qualified, better educated and had greater familiarity and experience working in the mountains. He also had me promoted four times during my 20-year career as a glaciologist, which each time renewed my enthusiasm for glacier work, not to mention my relief at not being fired.

Wendell Tangborn was born in Sioux City, Iowa in 1927 and grew up on a small farm in Northern Minnesota. He was drafted into the army in 1951 and after being discharged in 1953 attended the University of Minnesota, receiving a BS in Geological Engineering in 1958. After retiring from the US Geological Survey in 1979 he formed a consulting company, HyMet Inc, specializing in forecasting streamflow in western United States and developing glacier balance models in Alaska. Additional information can be found at www.hymet.com or by contacting him at HyMet Inc.,19001 Vashon Hwy. SW, Suite 201, 98070. Phone 206 463 1610, Email hymet01@gmail.com

Thanks to Betty Manning and Andrea Lewis for editing, and to William Sikonia for reviewing the initial manuscript.

Published in The Wild Cascades, the journal of the North Cascades Conservation Council, Winter 2007-2008