

CHAPTER SIX

CONSIDERING THE STORM

Lessons Learned from the Western Canadian Floods of 2013 and Other Disasters

It had been three years since the Ottawa climate conference described in chapter two. The worst fears expressed at that gathering were realized when a spring flood inundated the town of Canmore, Alberta, in late June of 2013. During the night, a spectacularly swollen pulse of floodwater swept downstream from Canmore into the unprepared city of Calgary. Twenty neighbourhoods had to be evacuated and more than 100,000 people were forced from their homes.

And Calgary wasn't the only municipality in trouble. Twelve southern Alberta communities declared states of emergency, and eight of them besides Calgary were under evacuation orders. The flooding was particularly serious in small towns immediately to the south of the city. Waters at High River, for example, had risen so quickly that residents were trapped in their cars and homes and had to be rescued from their roofs. Two-thirds of the town was inundated and 5000 residents were forced from their homes.

With total damages exceeding \$6-billion and a record \$2-billion in insured losses, the Alberta flood of 2013 quickly became the most costly natural disaster in the history of Canada.

Late the following winter a conference was convened in Canmore to determine what lessons could be learned. But this was no ordinary townhall meeting. It was a high-level, expert analysis at which a great deal of significant scientific information would be exchanged. The conference was opened by the mayor of Canmore,

John Borrowman, who welcomed participants and thanked the organizers for holding this important conference in Canmore.

Introductory remarks by professor Howard Wheeler underscored the importance of a newly established research initiative called the Changing Cold Regions Network (CCRN) in terms of understanding environmental change in the Rocky Mountains. Dr. Wheeler summarized the goals, objectives and geographical reach of CCRN. He stressed the partnership aspect of the network, which would make it possible to establish observatories to provide data to help us better understand and predict regional and large-scale hydro-climatic variability and change. He noted also that the ultimate goal is to share new knowledge with a broader user community.

Professor John Pomeroy added his welcome and showed video of the flood event in the region. He then outlined the purpose of the workshop: to evaluate, analyze and synthesize the flood of June 2013 as a case study of extreme weather and hydrology. He explained the methodology of the workshop, which would be to compile a diagnosis of the floods and synthesize descriptions of the event and its implications, and thereby show how local floods are connected to broader atmospheric, hydro-meteorological and climatic trends. The workshop, Pomeroy explained, aimed for improved science and understanding of extreme-event processes that can be shared widely.

THE CONFERENCE GETS UNDERWAY

Professor Ronald Stewart led off with an atmospheric overview of the flood. His presentation, a prelude to later segments of the workshop, focused on climatology and the hydro-meteorological preconditions that led up to the flooding. Dr. Stewart provided a very detailed foundation for understanding how the 2013 storm formed, why it was so powerful and what was unusual about it. The event itself, he pointed out, was linked with a mid-level, closed low-pressure system to the west of the region and a surface low-pressure centre initially to the south. This configuration brought warm, moist, unstable air into the district, which led to dramatic, organized convection with an enormous amount of lightning in some areas, as well as some hail. Among the unique elements of the storm,

he said, was the amount of lightning in the northern part of the region and the lack of lightning farther south, in Kananaskis Country. Lightning is an indication of strong convection – the lifting air current cools clouds and induces heavy precipitation; and the absence of such lightning in some of the main precipitation areas was notable for this region. Dr. Stewart pointed out that research is now being focused on comparing the devastating 2013 chain of events with other extreme weather to determine whether this storm was a harbinger of things to come.

Dr. Pomeroy followed with a summary of the hydro-meteorology of the storm. He noted that 15 researchers were in the affected area when the rain began to fall. He explained the geography of the area and showed a weather prediction model reanalysis of the precipitation that accompanied the event. Pomeroy noted that the storm was unusual in that precipitation did not increase with altitude in the mountains during the event. He pointed out that precipitation rates were not exceptionally high, but what was distinctive was the duration and areal extent of the rainfall. The effect of rain on snow was also important in generating additional snowmelt contributions to the rainfall runoff. At Dr. Pomeroy's study sites at Marmot Creek in Kananaskis, there had been a 41 per cent decrease in snow-covered area over the two weeks surrounding the flood period, which contributed at least 72 millimetres of snowmelt water to runoff during the flood. The limited capacity of frozen or wet soils to store water also contributed to the flash flooding. Together these factors resulted in the streams becoming torrents carrying heavy sediment loads. Pomeroy compared the 2013 event with episodes known to have happened in this area of the Rockies since 1879. Despite the heavy precipitation and concurrent snowmelt, the 2013 storm was only a 32-year return event at Banff and a 45-year return event at Calgary. For small mountain streams, however, there were no records that could put the flash flooding into historical context, as relevant hydrometric stations were destroyed in this flood and such stations did not yet exist for earlier floods.

Among Pomeroy's conclusions were that snowmelt over frozen ground contributed an additional 30 per cent to precipitation. We were lucky, he said. The Canadian Rockies flood was big but not

extraordinary. It was not likely the flood of century as so many were calling it. Given the return periods of river flows, it was not even the flood of a lifetime.

Flood forecaster Colleen Walford then outlined Alberta Environment's flood forecasting mandate and methodology. She demonstrated how their team's forecast model works and sketched out the operational stages the team progressed through during the 2013 event. Walford concluded by outlining the reviews and projects that were set to be undertaken the following year aimed at improving the province's forecasting capacity for the present and into the future.

Bill Duncan of Saskatchewan's Water Security Agency introduced conference participants to the effects of Alberta's 2013 flood downstream in the neighbouring province. He showed the locations and outlined the storage capacities of dams on the South Saskatchewan River system, explaining how these works functioned to deal with the increased flows generated in Alberta. Duncan noted that despite careful operation of these dams, some flooding of farmlands did take place and unfortunately the Cree Nation at Cumberland House had to be evacuated. Major flooding was avoided at Saskatoon, however.

Continuing in a similar vein for BC, professor Sean Carey observed that the 2013 event also increased flows in the Elk River, which threatened the East Kootenay communities of Elkford, Sparwood, Hosmer and Fernie. With five active open pit coal mines in the area, mobilization of selenium and other contaminants was a concern. It was not possible to monitor the effects of such mobilization, however, because of safety issues during the storm and resulting flooding. Dr. Carey reported that rainfall in Fernie was 25 per cent greater than ever recorded. The good news was that defences constructed after a flood in 1995 proved largely effective.

Next up was professor Masaki Hayashi, who explained the potential roles of groundwater in mitigating or exacerbating the impacts of floods. He began by reminding us of the interactions between ground and surface water. He then cited research in the Himalayas that demonstrated the extent to which mountain aquifers can store water and buffer the effects of flooding. Dr. Hayashi introduced the hydrogeological research he and his students were

conducting at Lake O'Hara in Yoho National Park. He also cited additional research at Marble Mountain, near Sundre, Alberta, where his team was able to employ an isotopic tool to calculate groundwater contribution to surface flows. This research demonstrated that up to 90 per cent of storm flows can originate as groundwater. Dr. Hayashi demonstrated how underground storage can both reduce and further contribute to streamflows during storms by introducing a delay in water flow. He then discussed the active exchange of Bow River surface and groundwater in the alluvial aquifer beneath Canmore. He noted once more that mountain aquifers were natural water detention systems. In conclusion, Dr. Hayashi asked a very interesting question: Can we utilize groundwater detention as a mechanism for flood risk mitigation?

The conference's lunch speaker was Don Cline, chief of the hydrology laboratory at the US National Weather Service, which is part of the National Oceanic and Atmospheric Administration, or NOAA. Dr. Cline's topic was extreme hydrology prediction. He began by noting that the National Weather Service has been providing flood warnings to the United States for 124 years, and that over that period there has been constant improvement in the quantity, frequency and lead time of forecasts. The recent increase in extreme weather events and the growing number of challenges in managing water, he said, have demanded that new tools be developed for prediction. As an example, Dr. Cline pointed out that his organization is moving toward ensemble hydrological models, like those used by climate scientists to predict future conditions, to make more accurate flood forecasts. The National Weather Service, he noted, has now expanded its prediction repertoire to include not only high flows and floods but also low flows and droughts. With its partner agencies, the service is now leveraging national investments in the direction of a nested Earth-system approach to understanding the global water cycle and its effects locally, nationally and globally, and is establishing a new 6000 square metre National Water Center in Alabama to further integrate and enhance US flood prediction. It did not go unnoticed at the conference that despite the heroic efforts of many of the scientists present, in many ways we here in Canada appear to be going

in the opposite direction with respect to science-based flood and drought prediction.

After the lunch session, professor Julie Thériault examined the 2013 Alberta flood from the perspective of climatology, synoptic conditions and precipitation fields. Building on Dr. Stewart's earlier presentation, Dr. Thériault graphically explained the influence of the jet stream, synoptic forcing, accumulated precipitation, terrain, snowpack and snowline on the intensity and severity of the event. Noting that the source of water vapour for the storm was in the Gulf of Mexico, Thériault discussed the impact of increased sea surface temperature on moisture movement from the Gulf to Alberta. She also pointed out where efforts to improve current atmospheric models can be focused.

The next presenter was Logan Fang, who talked about the use of the Cold Regions Hydrological Model (CRHM) to simulate hydrological processes during Rocky Mountain floods. CRHM has been developed to model cold- and warm-season hydrological processes, including snow distribution, sublimation, melt runoff over frozen ground and unfrozen soils, evapotranspiration, subsurface runoff on hill slopes, groundwater movement and streamflows. No direct comparison between simulated and observed streamflow was possible, since, as mentioned earlier, gauging stations were destroyed in the June 2013 flood. However, basin records suggest that modelled peak streamflow lagged actual flows during the event. This suggests that the current model structure and parameterization are prone to previously undetected inadequacies in simulating peak streamflow timing during extremely wet conditions. The model was used to diagnose responses of hydrological processes in the 2013 flood for different environments such as alpine, treeline, montane forest and forest clearings in Marmot Creek in order to better understand flow pathways in such extreme wetness. To examine the model's sensitivity to antecedent conditions, "virtual" flood simulations were conducted using a week of flood meteorology (June 17–24, 2013) superimposed on the meteorology of the same period in other years (2005–2012) as well as in different months of 2013 (May–July). The results show sensitivity to snowpack, soil moisture and forest cover, with the highest runoff response to rainfall from locations in the

basin where there are recently melted or actively melting snow-packs. Fang went on to note that, had the rainfall occurred in previous years at the same time of year, it would have generated a larger flood in most years. Had it occurred earlier in 2013, it would have produced a significantly larger rain-on-snow flood than occurred.

Bruce Davison of Environment Canada then offered a cautionary tale regarding the use of models to predict high-precipitation events. Davison noted that the Canadian Precipitation Analysis model underestimated precipitation at the basin scale, and he observed that model calibration is required to accurately parameterize precipitation, particularly in high-rainfall events. Flood simulations with the empirical WATFLOOD model showed great difficulty in simulating the flood peak on the Bow River without extensive calibration. However, the more physically based MESH model, which is a coupled hydrological land surface scheme that can be run directly coupled to Environment Canada's GEM numerical weather forecasting model, showed accurate simulation of Bow stream-flow and peak flow during the flood. This was a very encouraging example of where better science and improved model physics lead to better prediction, and showed that Environment Canada's MESH coupled to GEM can provide the basis for a sophisticated national flood forecasting tool. Davison's presentation showed that the use of radar as well as rain gauges to provide reanalysis products from weather models can improve forecasting.

Professor Yanping Li then added to Dr. Stewart's and Dr. Thériault's earlier contributions with a presentation on the use of NOAA's weather research and forecasting model to simulate the 2013 Alberta flood. She began by explaining how the model worked and described the processes it could parameterize. She then revisited the synoptic conditions and water vapour sources at the time of the flood. This work, she explained, is being done to see whether model simulations can be used under global warming scenarios to determine whether these kinds of events might happen more frequently in the future.

Don Cline concluded the afternoon presentations with a detailed introduction to the US National Weather Service's Snow Data Assimilation System, or SNODAS. Dr. Cline's agency collects

meteorological, satellite and snow survey data into this model, which estimates snowfall, snow depth, snow water equivalent, snowpack temperature, sublimation and snowmelt on a 1 kilometre grid across the US. He showed that the SNODAS satellite remote sensing program extends well into Canada. This began some time ago with US analysis of the Canadian portion of the Columbia River system. The most recent additions include all of Canada south of the 54th parallel. Dr. Cline explained that the agency did not just use satellite data and models but also relied heavily on field monitoring. It was very interesting to learn how much the current US data assimilation program relies on volunteers to collect such data. Also notable was the fact that the SNODAS website publishes virtually everything the agency knows about snow, much of it in three-dimensional imagery. In conclusion, Cline took conference participants back to June 2013 to demonstrate what the US knew about snow conditions in Alberta at the time of the flooding in the Canmore region. Utilizing remote sensing and the information available to them from field stations in both countries, they could tell snow-water equivalent, snow depth and snow melt in the Canmore-Banff area. From the SNODAS output they could see the potential for a substantial rain-on-snow event that was likely to result in catastrophic flooding.

In the evening, representatives of the Town of Canmore described the challenges the municipality faced during the 2013 flood and outlined their immediate response and short-term mitigation strategies. Before the flood, municipal officials had a limited appreciation of the risk, the size of the coming event or the damage it could cause, as no similar events had occurred in recent memory and flood plain maps were restricted to overflows from the Bow River. Through adaptive management and great effort, much infrastructure and all lives were protected in Canmore. The Town is interested in a risk management approach to mitigation, improved flood forecasting and debris flow prediction, and accordingly promised further consultation among academia, the provincial government, the consulting industry and the local community on possible solutions to the continued flood threat in Canmore.

CONFERENCE DAY 2

Opening the morning session, Dr. Danny Marks introduced participants to the Reynolds Creek experimental watershed in Idaho. Dr. Marks has analyzed the location of the rain-snow transition zone in the major storms that took place in the watershed between 1968 and 2006. In the 1960s, he noted, this area of Idaho had a snow-dominated hydrological regime. Today, rain predominates and this change has occurred in only 40 years. Marks observed that what causes melt in rain-on-snow events is not direct warming from the rain so much as heat flow to the snowpack due to energy released by condensation on the snowpack during rainfall. He went on to demonstrate how changes in snowpack energy can be modelled, noting that in large rain-on-snow events, snowmelt energy is increased by 50 to 100 times. Dr. Marks showed how changes in phase and energy balance affected snowmelt in a storm that occurred in Idaho over the Christmas holidays in 2005. He concluded by noting that if the 2013 Canadian Rockies rain-on-snow event had occurred when there was snow in the valley bottoms instead of just on the peaks, the flooding could have been orders of magnitude worse. For those who are concerned with future flooding in the Canadian Rockies this observation in itself is provocative. Should we expect more rain-on-snow events? With further warming should we also expect them to start happening in winter as well, as is occurring now only a short distance to the south?

Paul Whitfield expanded on Dr. Marks's research themes by describing changes in autumnal streamflow in the broader Rocky Mountain region of North America, looking at a transect from Mexico to the Arctic Ocean. In a warming climate, he said, we should expect earlier snowmelt, lower summer flows, and changes in autumnal climate and hydrology leading to changes in precipitation patterns that could result in more numerous early autumn snowfalls turning into rain and rain-on-snow events. Dr. Whitfield noted that there is a trend toward increasing numbers of autumnal floods throughout the Rockies, something that is now clearly understood in Colorado (see p. 132). Such events, he said, could become more common in this region of the Rockies as well.

Dr. Al Pietroniro then talked about the Water Survey of Canada and its role in basic measurement of water, with a special focus on flooding. He described Canada's national hydrometric system, the federal-provincial cost-sharing that supports it, and the challenges and opportunities of anticipating and responding to flood events in Western Canada. He explained how the Water Survey responded to the 2013 flood and how the course of the floodwaters was tracked through southern Alberta, Saskatchewan and Manitoba. He also showed the damage the flood did to his agency's monitoring station network and explained what is being done to restore the system.

Katrina Bennett spoke about the effects of extreme events on the warm-permafrost boreal forest region of the Alaskan sub-Arctic. She noted there is a trend toward warming in the interior of Alaska. While average annual streamflows are decreasing in response to this warming, winter and spring flows are increasing. Bennett pointed out that the 2013 river ice breakup was one of the latest in the season ever recorded in Alaska. March and April that year were warm in Alaska but May was very cold, delaying snowmelt. This late cold snap was followed by a record-breaking heat wave in June during which temperatures in some parts of Alaska approached 100°F, nearly 40°C. Her conclusions were that streamflow patterns changed in Alaska between 1951 and 2012. Systems dominated by snowmelt are declining in the spring, becoming dominated instead by rainfall. In the future, Bennett observed, Alaskans can expect more days with record-breaking maximum temperatures, with impacts that will cascade through the hydrological cycle.

Rick Janowicz built on Katrina Bennett's presentation with a description of the ice jams and freshet flooding that occurred during the same period of 2013 in neighbouring Yukon. Janowicz noted that the Yukon has a long history of flooding due to early settlement in flood plains along river transportation routes. He pointed out that 2013 was a cold winter and that snowfall in the Yukon that April was up to 250 per cent of normal. This was followed in May by a rapid snowmelt and runoff. Because of the cold winter, river ice was thick, and this combined with the compressed runoff period to cause serious ice jams. Janowicz recalled that flooding the year before had been so extensive it had cut off highway access to the Territorial

capital, Whitehorse, which meant that food and other supplies had had to be airlifted into the city. Janowicz posed the inevitable question: Is this continual flooding connected to climate warming? He answered by noting that summer temperatures in the Yukon have risen on average by 2° to 6°C and that winter temperatures have risen on average from 4° to 6°C in the past century. Greater precipitation, higher temperatures, increased flows and compressed runoff periods all contribute to greater flooding. In concluding, Janowicz drew a knowing chuckle from his conference audience by pointing out that because of breakthroughs in computer technology, concomitant with a wider range of flood timings over the summer, it is now possible and occasionally necessary to forecast floods remotely even while travelling in foreign countries.

Dr. Roy Rasmussen concluded the morning session with a presentation about a major blizzard that took place in Colorado in March of 2003. Dr. Rasmussen and his colleagues modelled this storm in the context of what such a blizzard might be like if it were to occur in some future climate situation. The scenario they used was one in which mean temperatures were on average 2°C warmer with 15 per cent more moisture in the atmosphere than at present. The model showed that under these changed climatic conditions the current 10-year return period for blizzards of the intensity of the one that struck Colorado in 2003 would be cut in half. Rasmussen left the implications of such a change to the imaginations of the conference participants.

Model results showing heavier snowfall at high elevations were countered by ones showing more rainfall at low elevations and therefore a change in the spatial extent of the storm. The model runs also projected that with a 2°C rise in temperature, precipitation in Colorado could increase by as much as 30 to 40 per cent, which is three times more than what would be expected given the Clausius-Clapeyron relation (the principle in atmospheric physics which defines how much water vapour can be transported in a warming or cooling atmosphere). The net effect of more rain, heavier snowfalls at altitude and increased runoff will likely be larger floods. Dr. Rasmussen is now doing a supercomputer model run that could answer one of the most critical questions posed at the workshop: If

future precipitation does increase by 35 per cent in Colorado, could flooding of the magnitude experienced in the front ranges of the Rockies in Alberta and Colorado in 2013 become a more regular occurrence? Stay tuned.

Dr. Rasmussen spoke again that evening, at a public session sponsored by the Town of Canmore, about the Colorado front range flood of 2013 and the lessons it holds for Alberta. He began with visuals showing the extent of the inundation and the damage it caused to homes, roads, bridges and other infrastructure. He noted that 262 homes were destroyed in Boulder County alone and that some 1300 landslides were attributed to the flooding. Dr. Rasmussen commented that it was highly unusual for such a storm to occur in September, and that the cause of the flooding was a low-pressure system that parked over Colorado and continued rotating, all the while bringing up tropical moisture from the south. Rasmussen said the storm was remarkable in how much precipitable water it carried in the form of atmospheric water vapour, more than tripling the former record. The storm also set new records for daily, monthly and annual precipitation, despite the severe drought that had preceded it. The previous Colorado record for rainfall in 24 hours, 4.8 inches, was nearly doubled by the 9.08 inches that fell in 2013.

Dr. Rasmussen went on to point out that the Alberta and Colorado floods were quite similar in a number of ways. Both involved slow-moving upper-level low-pressure systems bounded by high-pressure systems to the north and south. Both low-pressure systems remained nearly stationary for an unusual length of time and worked with nearby atmospheric cells to bring large amounts of water vapour up from the south. And both of the resulting storms were of long duration, delivered heavy rainfall and covered a very large area. The differences were that in the case of the Colorado flood there was no snow on the ground and the lightning events were more numerous. Rasmussen noted one other important difference, which had yet to be determined: the Colorado flood may in fact have been caused by what can be defined as a tropical, as opposed to a temperate-region, in-cloud rainfall formation process.

As for lessons Alberta could learn from the Colorado event, Dr. Rasmussen pointed out that accurately predicting heavy

precipitation is difficult in all of the US National Weather Service climate models. The service had been working on this problem for some time, and the 2013 flood accelerated research efforts to improve ensemble analysis of coupled hydro-meteorological changes in real time. Quantitative weather radar was invaluable in the US and not normally available yet in Canada; the NowCast and Forecast products are part of a new US system that has emerged since the 2013 storm. There is still work to be done, however, to identify sources of error and opportunities for improvement.

WHAT DID WE LEARN? WHAT DO WE DO NEXT?

So what do we do now? With respect to describing floods and their statistical properties, workshop participants proposed the following. We need to go beyond conventional analysis in characterizing the frequency of flood events. We need to look at more than simple examination of annual extremes and include all events in a single year. In these types of analyses we need to think more about flood mechanisms, including, for example, rain on snow and antecedent moisture conditions and their effect on potential flood intensity. Consideration should be given to how the potential for increased flooding is affected by historical and recent changes in land use and vegetation. We should compare historical flooding events in different basins to look at similarities and spatial correlations. As the climate continues to change, we should investigate how large-scale precipitation events are also changing in terms of magnitude, frequency and duration and look into the role of teleconnections and the transport of moisture northward from the Gulf of Mexico. Geomorphological processes and other dynamics of the systems need more consideration. This includes, for example, sediment redistribution on alluvial fans and changes in stream channels, which affect the hydraulic regime and may lead to reductions in future stability and certainty in behaviour. Groundwater and its effects on persistence of high flows should also be considered. It is important that statistical analyses include confidence ranges for the results, as this is useful for planning and operations and for public awareness. Finally, it is also very important to communicate research findings and our uncertainties more effectively and more widely.

In considering challenges and opportunities related to modelling, there was consensus among workshop participants that we need a broader range of better observations, including precipitation and other meteorological measurements. This would improve data assimilation into models. Other suggestions on how best to model floods included continuous flow simulations, physically based modelling, ensemble forecasting, clear understanding of hydrological processes and model parameter limitations, incorporation of human impacts into models, coupled atmospheric–hydrological modelling, and improved ice-jam modelling. Some other points noted included the importance of publicly disseminating model outputs, and that models can be used to help develop indices for conditions related to flash floods, landslides and debris flows.

The western Canadian flood in June 2013 and the Colorado one the following September make good potential case studies for modelling. For the Canadian flood, a legacy dataset should be developed and a special-issue journal publication should emerge. A modelling intercomparison study in connection with the US National Center for Atmospheric Research, incorporating the western Canadian and Colorado front ranges floods, would be a useful exercise that would provide valuable insight.

The group also noted some longer-term issues and opportunities. These included coupled atmospheric–hydrological modelling and ensemble modelling; risk communication; technology transfer of newer models to the provinces and territories; linking drought and flood modelling through continuous simulation; model intercomparison efforts; and climate and weather change modelling studies. A key point for the modelling perspectives was that, once again, researchers heard that they have to be better at public dissemination of model results.

With respect to water management and flood mitigation, workshop participants proposed that we need to translate research outcomes into useful tools for engineers, architects and planners. For engineers, the needs and implications centre around updated storm intensity, duration and frequency analysis and peak discharges for infrastructure design. For municipalities this involves stage and water levels and updated flood maps, while for water managers

this would include reservoir operation. Some challenges for reservoirs were noted. Among these were different philosophies on the purpose and operation of the reservoir as they relate to, for example, drought resilience, water supply, hydro-power generation and flood protection. The current state of water resource systems modelling presents challenges for reservoir operation, where daily and hourly simulation is needed to assess flood management, and flow routing needs to be incorporated into current schemes. Other challenges and important issues canvassed were that uncertainty propagates from observations and models up to the management decision level, making reliable forecasts critical for reservoir management. Scenario assessment and economic and ecological risk and benefit analysis are useful for better evaluation of possible outcomes, and this is something the research community should strive to enhance and to include reservoir operation.

In terms of mitigation, we need enhanced zoning and socio-engineering solutions, improved public awareness and education programs, better risk quantification and communication to the public and to political leaders, and forecasting tools that will help arrive at stricter floodplain zoning. It was also pointed out that floods have important and beneficial environmental functions, such as redistribution of sediments and nutrients, and that these benefits should be considered along with the risks.

After the close of this important Canmore conference, researchers once again came away with great respect for the work that is being done and for the people who are doing it. After the disaster of 2013, they were in even greater awe of the challenges to come. They were also left with the relentless reminder that they have got to get better at sharing, with political leaders and the general public, what they know now and what they will be learning in the future. These are the kinds of promises that are made in the wake of a storm.

