

CHAPTER TEN

KNOWLEDGE IS POWER

Building a Better Bridge between Science and Public Policy

While it existed the Canadian Foundation for Climate and Atmospheric Sciences served as a bridge between the research community and the users of new knowledge in government and in the private sector. It was the main funding body for targeted, university-based research on extreme weather, air quality, climate and marine prediction. It offered a key advantage: its ability to stimulate intersectoral partnerships, particularly between universities and government. The interactions it fostered among government, academic and private sector scientists and managers were all directed toward the development of targeted solutions, but by their nature they also served to enhance Canada's international reputation. When the federal government ceased to fund it, the CFCAS reorganized under the name Canadian Climate Forum.

At the time of this writing the Canadian Climate Forum still exists. It remains a non-governmental agency dedicated to improving understanding of weather and climate in the Earth system. Its mission is to collaborate with partner agencies and individuals to accelerate the uptake and use of weather and climate knowledge to serve the needs of society and the economy.

A SYMPOSIUM ON EXTREME WEATHER

In April 2014 the Canadian Climate Forum held a symposium in Ottawa to examine the incidence and impact of severe weather, the challenges it raises and how to prepare for or adapt to it in order to minimize its often devastating effects. On the evening before the

formal symposium opened, an information session open to the public and the media was held at the University of Ottawa. The topics of discussion were the outcomes of the recently released report by Working Group II of the United Nations Intergovernmental Panel on Climate Change Fifth Assessment Report, which outlined the latest research findings related to climate change impacts, vulnerability and adaptation. Discussions also included comments on the IPCC Working Group III report on climate change mitigation. The October 2013 report on the science of climate change was also discussed.

The information session outlined advancements in our understanding of contemporary climate change issues and demonstrated even greater consensus as to the risks associated with failure to adapt to these changes. Over and over again participants in the discussion made the case that climate change is clearly a matter that needs to be addressed far more seriously at the federal level in Canada, and that more harmonization is required between federal, provincial, territorial and municipal governments to accurately assess vulnerability so that meaningful adaptation strategies can be developed that will protect people and their property, critical infrastructure, economic vitality and social and political stability.

The formal proceedings, on April 23 and 24, brought together scientists, agency executives and policy- and decision-makers from the public and private sectors. Presentations and discussions provided insights into extreme events and addressed the economic, infrastructural and health challenges they raise. Participants also discussed measures to develop resilience and to safeguard people and businesses.

In his opening remarks, symposium chair Gordon McBean reiterated that extreme weather events don't just damage property but disrupt lives and alter and stress ecosystems. Extreme events therefore have environmental, health and insurance impacts. McBean noted that we are likely to see 2° to 5°C warming during the current century, and that North America will not be immune. Adaptation and mitigation are therefore necessary. We need leadership, new programs and best practices, McBean said. To highlight these was the goal of the symposium.

After his opening remarks, McBean introduced a former federal

commissioner for environment and sustainable development, Scott Vaughan, who gave the symposium's opening keynote. Vaughan began by outlining the contents of the most recent IPCC reports in the context of the 2012 UN report on extreme weather events. The latter report, he said, was important in that it overlaid climate change effects on top of existing vulnerability, something which leaders in the insurance industry had understood for years.

THE KEYNOTE ADDRESS

Mr. Vaughan delivered a powerful and comprehensive assessment of world conditions. There were three main warnings from the recent Fifth Assessment Report. Sea level rise is expected to affect hundreds of millions of people. Higher carbon dioxide concentrations are altering the chemistry of oceans a million times faster than what occurs naturally. Over time this will cut tropical fisheries yields in half, which will have huge impacts on global food security. Vaughan noted that for each 1°C temperature increase there will be a 20 per cent decrease in the amount of freshwater available to a significant part of the global population. This, in addition to growing populations, will demand a 70 per cent increase in food production during this century. Innovative adaptation is beginning but serious challenges remain, particularly in developing countries.

Citing the World Resources Institute, Mr. Vaughan noted that each of the past 36 years has exceeded global average temperatures. The frequency, intensity and duration of extreme weather events are increasing. Heavy rainfalls and droughts are occurring more frequently. Reported claims for flood damages alone have risen from an average of \$7-billion a year globally in the 1980s to over \$24-billion in 2011. Incremental, linear approaches to adaptation are not enough now and will not be enough in the future.

Risks are clearly rising in Canada, Vaughan said, but we are not moving as quickly as we should to deal with climate change effects. The need to replace much of our aging and inadequate infrastructure must be seen as an opportunity to adapt. Vaughan urged Canadians to look to federal leadership beyond the work presently being done by Environment Canada, Public Safety Canada, Health Canada and Natural Resources Canada in efforts to make the badly

needed linkage between risk assessment and risk management. There is a need to mainstream meaningful adaptation approaches in all federal government departments. There is also a need for better understanding of cumulative risks, and more work needs to be done to make these risks known in established engineering practice.

Vaughan noted that there are climate tipping points beyond which sustainable development will no longer be possible for some. We need national leadership and coordination on disaster risk reduction, adaptation and mitigation, he said. We need deep cuts in carbon dioxide emissions. This was not a question of science, he asserted, but of arithmetic, and if we withdraw the subsidies to the fossil fuel industry, the arithmetic will change. Vaughan also commented obliquely on Canada's role in addressing climate risks. If we do not work with the international community to reduce climate effects, we will face a much larger adaptation challenge in the future. "We have got to get moving," Mr. Vaughan concluded.

SESSION ONE: IMPACTS

The Impacts session was opened by the author of the present book, examining the math and aftermath of the catastrophic flooding in Calgary and southern Alberta in June of 2013 and in Toronto less than three weeks later. This presentation drew the attention of participants to the contents of a report prepared by Dr. John Pomeroy for Environment Canada 18 years before, in 1996, which warned of changes in hydrology that would likely increase the potential for flooding, particularly on the Canadian prairies. In that report Dr. Pomeroy had observed that fresh water is both a mediator and a transmitter of climate change effects. Water, he wrote, should be viewed not just as a substance but as a flow of mass, energy and biochemical constituents through and between ecosystems and between the land surface and the atmosphere. Liquid water, water vapour, snow and ice, wrote Pomeroy, transmit climate change impacts across the country and across ecological and political boundaries. This, it appears, is exactly what seems to be happening.

The author's Session One presentation continued with an hour by hour synopsis of hydrologic events during the Alberta flood and compared it to similar disasters that occurred the following July

in Toronto, August in Russia and September in Colorado. Focusing back on Alberta, the author pointed out that the flood was not the once in several centuries event many claimed; rather, it was well within what had been experienced in the recent past. This demonstrated that Alberta was not even prepared for the hydro-climatic variability that exists today, he said, let alone what might be projected in the future as the Earth's atmosphere transports more and more water vapour to fuel ever larger floods. The conclusion was that Canada's hydrology appears to be changing. We can expect flood events to be increasingly expensive socially, economically and politically.

The author then offered five lessons that might be learned from the 2013 flood:

1. The loss of hydrologic stationarity could very well be a societal game-changer. What this means is that simply managing water in ways that are useful to us at a local scale will no longer be enough. We have to be alert to changes locally of course, but we now also have to keep an eye on changes in the larger, global hydrological cycle and where possible try to manage and adapt to them. This is a huge new concept, this game changing, and it is going to take time to get our heads around it not just environmentally but economically.
2. What we have seen is what we are going to get. Predicted rises in temperature of between 2° and 6°C would result in further amplification of the hydrological cycle by 15 per cent to 40 per cent or more. This game change is not going to go away. Because of our country's fur trade and colonial history, many Canadian towns and cities are located on flood plains in river valleys. According to a recent survey, some 20 per cent of Canadians believe they live on or near what they describe as a flood plain. Defending or evacuating these areas will be very expensive.
3. The new normal is that there is no new normal. Unless we want our future to continue to be a moving target, sooner or later we will have to confront the fact that we are rapidly altering the composition of our planet's atmosphere, with

significant effects on hydrology – a subject not many political leaders want to talk about in meaningful terms, even after the disastrous flooding of 2013.

4. Structural engineering solutions are going to be necessary, but they are not going to be enough. We cannot ignore the local value of natural ecosystem processes. In order to retain even partial rein over the hydrological cycle we have to enlist all the help nature can provide us. We gain that help by protecting and restoring critical aquatic ecosystem function locally by and reversing land and soil degradation wherever we can.
5. The watershed basin is the minimum scale at which water must managed. This should be perceived as good news. There is much power in realizing that we can do a great deal for our way of life and perhaps sustain our prosperity by taking care of our watersheds. This suggests that it is at the local level – where we live – that we have the most power to effect change and to act most effectively in service of the common good, now and in the future.

In conclusion the author pointed out that this was not the time to throw up our hands in helpless despair. The sky is not falling. The world is not coming to an end. But we do owe it to those who have suffered so much from the 2013 flooding to start getting it right for the next time – for there *will be* a next time – and a time after that. The problems hydro-climatic change is bringing in its wake are not going to go away. Public awareness of water issues is on the rise. There is room to move, he said, and we should get moving while that room still exists.

Dr. John Pomeroy of the University of Saskatchewan was then invited to describe the basin in which the Alberta flooding occurred. High streamflows, he began, are natural in mountain headwaters, and in this context the notion of flooding is a human construct. Pomeroy laid out the synoptic meteorology associated with the storm that brought on the flood. He then showed the weather prediction reanalysis, which demonstrated that it wasn't a wrong weather forecast that affected flood prediction. Rainfall

measurements, Pomeroy pointed out, are only part of flood prediction, and in circumstances such as those that created the Alberta flood, only part of the total precipitation is rainfall. Another component in this case was snow, and a great deal of the runoff was caused by warm rain melting the remaining winter snowpack.

Pomeroy observed that snowpacks in the Alberta Rockies were below normal in early May that year. This changed, however, with snowfalls at high altitudes later in the month. Rapid snowmelt contributed significantly to streamflow, which overwhelmed the capacity of already saturated soils to absorb more water.

Dr. Pomeroy went on to describe the research he and his team were undertaking at Marmot Creek in the Kananaskis region of the Alberta foothills, which happened to be epicentre of the storm that started the catastrophic flooding downstream in Calgary. He then graphically illustrated how stream gauges were overwhelmed and then washed away by the torrents created by persistent rainfall and rapid snowmelt on already saturated mountain soils. The potential loss of instrumentation, he explained, is one of the reasons models are so important.

Pomeroy reported that his research had shown that return periods for flood events of the magnitude that occurred in Alberta in June 2013 were about 1 in 32 years at Banff and 1 in 45 years at Calgary. He noted, however, that the floods of record in the past were not caused by the same kinds of storms. Climate change has made the circumstances in which such storms occur different in this place. Pomeroy demonstrated that the region is experiencing warmer winters, with less snow at low elevations and a greater percentage of total precipitation falling as rain. We now have a warmer, drier system throughout the region in which these big storms occur. This, Pomeroy concluded, is why we are witnessing floods and droughts in the same basin in the same year.

Drought is another expression of extreme weather. Ronald Stewart talked about coping with dryness in the context of Manitoba and the Canadian Prairies. After defining drought, Dr. Stewart illustrated its devastating historical impact on the economy of Canada over time. He showed the many factors that influence the occurrence, depth and persistence of drought, and the way wet and dry

periods have historically oscillated in Manitoba. This, Stewart explained, was reflected in crop insurance. There were farms in Manitoba, he said, that qualified for crop insurance for both flood relief and drought damage in the same basin in the same year. Stewart then identified drought indicators and various parameters of drought preparedness. He showed how different regions have different susceptibility to drought, and introduced the basic principles behind the proposed surface water management strategy for Manitoba. He also explained how changes in Manitoba Hydro's operations can help mitigate drought impacts in the province.

Stewart then demonstrated drought effects on specific crops. Longer-term droughts, he warned, have to be seen as possible. He went on to describe the challenges associated with predicting where and when droughts will occur, and concluded by noting once again that drought is of great concern in a changing climate, especially as it relates to food security.

Over lunch, renowned Environment Canada meteorologist David Phillips regaled symposium participants with stories of how he chooses his highly celebrated and publicized Canadian Weather Events of the Year. Phillips explained that he bases this wildly popular annual summary of weather disasters in Canada on three criteria: where the event occurred, what happened and how the public responded. Phillips explained that the world has changed over the 20 years he has been offering this annual summary. There are more of us and we're more prosperous, he said, and that is making extreme events more costly. Our landscapes have been re-engineered and there is greater urbanization. Even without climate change, said Phillips, these factors make us more vulnerable to extreme weather events.

Alberta, Phillips said, has been particularly hard hit, qualifying as having experienced the first-, fourth- and fifth-most severe weather events on his long-term list. Alberta is not the only region affected, however. Disasters with insured losses of over \$1-billion have occurred every year for the past five years in Canada. Governments and CEOs should be concerned, Phillips pointed out, as extreme events will continue to affect many important social and economic performance measures.

He also noted that extreme weather events appear to cluster together in time and place. We are not experiencing new weather, he said – there are still tornadoes, hailstorms and hurricanes – but the events appear to be statistically larger, more frequent and more intense. In addition to more frequent heavy rainfall, there also appears to be a clear trend toward higher winds. Extreme weather events also cover larger areas and persist longer, making recovery slower and costlier.

Phillips explained that storms that would have been top stories 20 years ago barely rank today, in part because the duration of extreme weather events is lengthening. We are not just breaking weather records, he quipped, we are clobbering them. And it is not the weather we see when we look out the window that is necessarily changing, he said, but the antecedent conditions such as the rainfall or snowfall intensity and soil saturation that may intensify that weather.

Perhaps the biggest weather-related change, Phillips observed, is the concentration of the full effect of extreme weather events on major urban areas. The loss of green spaces in cities, he noted, is clearly contributing to the intensity of such events. The variability of weather over the course of a year is plainly increasing, he said, but so is variability in any given season. “We are experiencing the best times and the worst times all at once,” Phillips said. We are witnessing the wettest and driest conditions in the same region in the same season.

In conclusion, Phillips noted that weather disasters are in a growth phase. Changes in these conditions have not slowed; things can clearly get worse; you cannot logically argue it is not happening. If you change the weather, you change the climate, he said, and these trends are not going to go away. “We need to reduce the threat of disaster by preparing for it.”

SESSION TWO: EFFECTS ON HUMAN HEALTH

The first afternoon session explored the health impacts of extreme events. Iqbal Kalsi led off, addressing the issue of urban versus rural consequences of extreme weather events as they relate to public health. Kalsi reminded the audience that climate change is the

biggest public health threat of the 21st century. Canadians, he noted, should expect greater health impacts as a result of heat waves, with significant associated economic costs. With a projected warming of 2° to 5° C we should expect mortalities to rise.

Kalsi then focused on extreme weather events in the Middlesex-London (Ontario) Health Unit, where he is responsible for the health hazards prevention and management section, which includes climate change effects. In his health unit's district, Kalsi explained, winters are warming and summers are hotter. The frequency of 1 in 100 year, 1 in 200 year and 1 in 500 year floods is increasing, with commensurate public health impacts. There has also been a dramatic increase in tornadoes. The urban heat island effect too is becoming a public health issue in the jurisdiction, and a trend toward higher nighttime temperatures has been observed. Kalsi then demonstrated how these effects will become more pronounced right across Canada.

Groups that will be vulnerable include older adults, infants and young children, farmers and other outdoor workers, the physically active and those with chronic illnesses. Kalsi said his health unit is working with local municipalities to expand the area covered by tree canopy to reduce this effect, but obviously such projects take time.

Constraints to implement programs to reduce the health effects of climate change are many, Kalsi noted, but they all begin with financial resources. The next steps for his health unit, he said, will be to collaborate with stakeholders and current and potential public and private sector partners to create sustainable, healthy communities.

Up next was Dr. Emmanuelle Cadot, to speak about what Canadians might learn from the heat waves that occurred in Europe between 2003 and 2006. Cadot noted that 2003 was the hottest year ever recorded in Europe. It is estimated that in France alone there were 14,802 excess deaths, of which 1254 were in Paris, a 190 per cent increase compared to the reference years of 2000 to 2002. Dr. Cadot went on to demonstrate individual risk factors associated with age, sex, marital status, level of physical activity, state of health and ethnicity. She outlined the Paris program called Chalex (for "chaleur extrême," extreme heat), part of the French government's strategy

for information dissemination, prevention and mobilization against elevated-temperature-related climate risks, which includes a national alert system for heat waves that clearly outlines health risks.

Peter Berry of Health Canada's Climate Change and Health office talked about current climate-related impacts on public health in Canada and the preparations that were required to prepare for further changes. Dr. Berry began by drawing attention to a number of heat and other extreme weather events around the world and outlining the human health hazards they posed. These included heat waves, wildfires, undernutrition due to decreases in food production, food and water shortages, vector-borne diseases and mental-health and violence concerns. Berry then spoke about increases in the transmission of Lyme disease in Canada and health impacts associated with the Toronto ice storm of 2013.

Citing what has been done elsewhere, Berry outlined what we can do to prepare for climate change effects on public health in Canada. National public health plans with respect to climate change, he noted, exist in other countries. After demonstrating how preparedness had dramatically reduced mortality from floods in Bangladesh, Berry explained how emergency measures can be aided by clear adaptation strategies in Canada.

Berry outlined a number of specific concerns, including warming impacts on northern Canadians, climate-related spread of infectious diseases, and health impacts associated with extreme heat. Steps forward include heat and health messaging to support increases in personal adaptation; filling knowledge gaps in health-related climate science; identifying factors that increase individual and societal vulnerability; and the development of alert protocols similar to those instituted in France, which will be made available to communities across Canada. In conclusion Berry noted that health-care facility resiliency tools have been developed that include facilitator presentations, resiliency checklists and best practices.

Because of scheduling challenges the final presentation in the health session of the symposium was made on the morning of the second day. Speaking via Skype, Pulitzer Prize winning journalist Sheri Fink described the desperate situation at a hospital in New Orleans in the wake of Hurricane Katrina. In introducing her book

Five Days at Memorial, Fink asked participants of the symposium to give consideration to the impacts of extreme weather events on the most vulnerable in our society and on the people who are entrusted to serve them. Fink invited the audience to think about whether or not, in such extreme circumstances as Katrina, it is even possible to adhere to established moral values or if certain extreme weather made it necessary to abandon such values.

In the aftermath of Katrina, sections of New Orleans were uninhabitable for weeks. The hospital where Fink worked was an island in the middle of the flood zone. When the power went out in the city, the hospital's backup generators could not keep the air conditioning working and still keep the lights on. The vulnerability of those in the hospital increased as hot summer temperatures returned after the storm passed. Helicopters could only take one or two at a time of the 2000 people that needed to be evacuated. The ethical question became the classic dilemma of triage: whom to evacuate first. Do you take the young first because they have a long life ahead of them, or those who because of fragility or age need immediate help without which they will die? When boats finally started to arrive at the hospital's emergency ramp, same hard question: Who first? Another ethical question arose when people arrived at the hospital hoping for medical help or refuge. There were also issues with medical staff who had their own health problems. What do you do when needs outstrip resources? How do you prioritize who lives and who dies? Hurricane Katrina made it clear, Fink explained, that such ethical issues need to be considered in advance.

The situation at Memorial Hospital deteriorated even further when, as feared, the backup generators failed and the lights went out altogether. The question then became whether some patients should be put out of their misery. While that issue was being considered, patients began dying. In the aftermath some doctors and nurses were charged with murder. Ethics and legality, however, rely on intention, and in the case of Memorial Hospital, health workers were not intentionally hastening death but providing comfort. They were found not guilty.

The moral jeopardy that arises in the aftermath of extreme weather events, Fink explained, is similar to what happens in

combat zones. As in times of war there are examples of great heroism. In New Orleans during Katrina local volunteers arrived in airboats to evacuate patients. Health workers carried premature babies under their shirts because incubators wouldn't fit aboard helicopters. As in war, Fink concluded, we can't know what we should have done, only know what we would have liked to do.

Better triage, fuller disaster plans and more adaptive preparations are necessary if we are to be able to deal with more frequent, increasingly destructive extreme weather. In concluding her powerful presentation, Sheri Fink pointed to a critical need for political will in recognizing that we are all fragile and vulnerable to the increasing threat of extreme weather events.

SESSION THREE: THE SCIENCE

This segment of the symposium examined specific aspects of science behind our understanding of extreme weather events. Jennifer Francis broadened the scope of the discussion by connecting climate changes in the Arctic with their potential impact on extreme weather events at mid-latitudes. Francis began her presentation with a smorgasbord of wacky weather events from all over the world and asked whether these episodes had anything in common. All of them were related to persistent weather events. The question this raises, said Francis, is whether human-caused climate change is playing a role. She answered by explaining that we have put ourselves in a serious predicament by increasing the concentration of carbon dioxide in the atmosphere. March 2014, she noted, represented the 349th consecutive month with above-average temperatures. She said this meant that if you are presently 29 years old or younger, you live in a climate regime different from the one experienced by people older than you. A warmer atmosphere, Francis explained, is going to provide more moisture to energize and fuel extreme weather events. This will make wet places wetter while increasing evaporation generally, which will make dry places drier.

Arctic sea ice, Francis continued, is now a mere shadow of its former self. There has been a 75 per cent decrease in volume in the past 35 years, and much of what remains is "rotten," or slushy. The year 2012 marked a spectacular loss of Arctic sea ice, which resulted in

additional warming of the Arctic Ocean, which in turn melted still more ice. This feedback, Francis explained, causes more and more ice to melt, which is why the Arctic is warming two to three times faster than the rest of the world. This loss of Arctic sea ice is also combining with the diminishing extent and duration of snowcover in the northern hemisphere to result in lessening the temperature difference between the pole and the tropics. Francis believes this has begun to affect the behaviour of the jet stream in the northern hemisphere.

The influence of warmer Arctic air causes the west winds created by the jet stream to become weaker. It is the waviness of the jet stream that creates weather at mid-latitudes. As the jet stream slows and its deviations become wider, weather patterns persist longer and do things we don't expect. When we look at extreme events such as heat waves, heavy snowfalls and long rainfalls we are seeing the result of very large jet stream waves. Are these really getting bigger and/or more frequent? Yes, Francis answered. And this appears to be particularly evident in the North Atlantic in October and December.

She then showed the jet stream patterns for a number of extreme weather events, including extended droughts in parts of the US and the bitter winter experienced in eastern Canada in 2013–2014. Each could be seen to be caused by large waves in the jet stream. Francis concluded by noting that this understanding presents yet another opportunity to demonstrate how human activity is in fact impacting weather patterns in the northern hemisphere

Francis Zwiers of the Pacific Climate Impacts Consortium then weighed in on the question of whether precipitation events have in fact become demonstrably more extreme. He noted there was strong evidence supporting warming temperatures but less clear evidence of changes in precipitation patterns. Zwiers drew attention to the locations of some 8376 weather stations around the world that had been collecting data for 20 years or more. Of these, some 8.5 per cent showed significant measurable increases in rainfall, while 2.2 per cent showed significant decreases. About 64 per cent of these locations did show a correlation between mean temperature and precipitation, however, in accordance with the Clausius–Clapeyron

relation, which, as mentioned earlier, describes mathematically how the atmosphere will hold 7 per cent more or less water vapour for every degree Celsius of warming or cooling.

Zwiers went on to demonstrate how computations of potential increases or decreases in precipitation are made in climate modelling. The results of such modelling to date suggest precipitation is intensifying in Canada. What were previously once in 20 year rainfall events now appear to be occurring every 15 years. Zwiers noted that, in his estimation, there is a 25 per cent probability that such events may be attributable to human influence. He went on to cautiously predict that what are now one in 20 year rainfall events could become one in six year events by the end of the century. Zwiers concluded by saying that data limitations continue to hinder clear detection of the climate signal with respect to changes in precipitation. Observed changes, however, do fall within the expectations of the Clausius–Clapeyron relation.

SESSION FOUR: ADAPTATION

In this segment the focus of the symposium turned toward strategies for adapting to extreme weather events in Canada. In the first presentation, Paul Kovacs of the Institute for Catastrophic Loss Reduction talked about adapting Canadian homes to prevent damage from intense rainfall and severe winds. Our houses, he said, are our most valuable asset, and we build good ones in Canada. How, he asked, can we sustain that success?

Kovacs noted that innovative builders are testing and sharing new ideas and slowly enshrining them in building codes and standards. When attempting to bring new approaches to protecting existing houses, however, Kovacs had met considerable resistance. Many Canadian homes, Kovacs noted, are vulnerable to floods and severe winds. Based on insurance claims, it is clear also that severe weather is becoming more common. Insurance claims related to wind and flooding are now greater than claims for damage by fire. As a result, Kovacs said, insurance companies are finding themselves in a new business.

Several factors are increasing risk. These include population growth in areas at risk; aging infrastructure in many parts of the

country; and an increase in lavishly finished basements which may be subject to flooding. Precipitation is also increasing. Kovacs's institute put these arguments before builders, and this led to a program that empowers homeowners to consider their particular circumstances through the use of a risk-assessment tool and readily available risk reduction advice, particularly with respect to basement flooding.

The ICLR has also created its own research lab and storm simulator. Research conducted with this simulator has led to adaptation strategies that cost pennies but can save thousands of dollars in damage in the event of high winds or potential flooding. The Institute has also partnered with local governments and the media, through which it celebrates municipal leadership by recognizing progressive jurisdictions and telling their stories.

Kovacs concluded by observing again that we build solid houses in Canada but many of them are vulnerable. The increase in insurance payouts he said, is as much a result of greater vulnerability as it is to more frequent storms. We can build more resilient homes, Kovacs asserted, if we use science as a foundation for action. Progress, however, remains slow.

Deborah Harford of Simon Fraser University's Adaptation to Climate Change Team began her presentation by summarizing the climate change impacts urban areas need to adapt to. She went on to describe the effects of the loss of relative hydrologic stationarity on health, insurance and other important sectors of the Canadian economy. Adaptation, she pointed out, is complicated by urbanization and by the aging of critical infrastructure. Sea level rise is an additional problem for coastal cities such as metropolitan Vancouver. Harford then spoke of the Coastal Cities at Risk Project and its five research themes. These include social vulnerability, health risks, economic exposure, physical hazards and organizational and governance challenges.

Cities, Harford pointed out, are undertaking adaptation projects on their own without provincial support. This has to change, she said. Regional co-operation will ultimately be required to ensure that one jurisdiction isn't undertaking action at the expense of neighbours. The next steps in realizing meaningful adaptation

strategies in coastal cities like Vancouver include intergovernmental collaboration; stakeholder engagement, especially with professionals in planning and engineering; continuous assessment of current and future risk; strategic action; and the mainstreaming of adaptive behaviours. Harford concluded with a summary of adaptation needs, goals and barriers. She stressed the importance of updated plans, maps and zoning and of support for municipal adaptation efforts and central leadership.

The next speaker in this session was Don Lemmen of Natural Resources Canada, who talked about adaptation planning in Canada. Lemmen explained why planning mattered and asked rhetorically if extreme weather events shouldn't be used as a wake-up call for advancing adaptation. Noting that risks will affect all economic sectors, Lemmen pointed out the need to more completely link climate adaptation to disaster risk management. These risks, he observed, include immediate effects such as flooding, heat waves, wildfires and droughts but also include slow-onset changes such as sea level rise, glacier retreat, permafrost thaw, ocean acidification and ecosystem changes.

Lemmen pointed out that adaptation is occurring in Canada and that examples of progress abound. Most progress, he noted, has been at the municipal level, which suggests a need for engagement and support from higher levels of government. He went on to describe current and emerging drivers of adaptation, which include concerns about national reputation, access to international markets and matters of regulatory compliance. Lemmen outlined challenges and key regional risks to which extreme events contribute and demonstrated how adaptation can reduce these risks. Increasing exposure of people and assets has been the major cause of increase in disaster risk.

We need to be prepared, he said, and co-operation is necessary, if not critical. Barriers to co-operation have to be identified in advance so they can be overcome when extreme weather events become disasters. We need to ask what practical steps can be taken now, he said, to strengthen the linkages between the climate change adaptation and the disaster risk reduction communities. Lemmen concluded by suggesting that immediately after a natural disaster is a good time to advance adaptation strategies.

Session Four continued with a presentation by Jacinthe Clavet-Gaumont, of the Montreal-based climate research group Ouranos, on the influence of climate change on extremes affecting the hydroelectric sector in Quebec. Clavet-Gaumont began by explaining that 97 per cent of the electricity in Quebec is generated by hydro, which makes reliable distribution highly vulnerable to extreme events. As examples of adaptation, she pointed to the aftermaths of the Saguenay flood of 1996 and the Great Ice Storm of 1998. A process was put into place to identify vulnerabilities and opportunities, develop scenarios and analyze impacts of climate change on targeted activities, with the goal of developing and implementing adaptation strategies.

The development of climate scenarios required downscaling of global models to regional levels and on down to local hydrological models. These models project a 10 per cent increase in the volume of spring flooding in Quebec. They also anticipate that the maximum flood in the most severe of probable meteorological conditions is expected to increase by 28 per cent by 2080.

In summary, Clavet-Gaumont offered three conclusions of note: Hydro-Québec operations are vulnerable to hydro-climatic extremes; hydro power generation and distribution systems are vulnerable to climate change; and therefore adaptation is required.

The final presentation in the adaptation segment was offered by Michel Girard of the Standards Council of Canada, who spoke about the use of standards as vital tools for adaptation. Girard began by introducing participants in the symposium to the Joint Declaration on Conservation of 1908, which more than a century ago concerned itself with many of the environmental issues we face today. In the same way as the Joint Declaration functioned in the early decades of the 20th century, the Standards Council of Canada works today to mainstream adaptation through appropriate standards and verify competence in the achievement of those standards.

Girard pointed out that standards and codes are now being developed through the Northern Infrastructure Standardization Initiative to increase adaptation capacity in order to reduce climate change impacts and disaster risks. For infrastructure these standards include those for design, installation and maintenance of

thermo-siphons to keep permafrost from melting; changing standards for snow loads on roofs; management of effects of permafrost degradation on existing buildings; and drainage plans in northern communities that account for the possibility of more-extreme weather events. Girard also described joint US–Canada initiatives on standards for such technologies as balloon-type, ball-shaped back-water valves to reduce basement flooding. He concluded by inventorying various international standardization initiatives and outlining next steps in the exploration of areas of adaptation interest.

SESSION FIVE: IMPACTS AND ADAPTATION IN THE INSURANCE SECTOR

The fifth segment of the symposium dealt with the challenges that extreme events pose to the insurance industry. The first presentation was by Chris White of the Insurance Bureau of Canada, who talked about the financial impacts of extreme weather events on the property and casualty sector.

After noting that the sector was strong and competitive, White outlined the economic contribution of the insurance industry. He cautioned, however, that more-extreme weather events posed a challenge to the entire sector, giving the example that the average basement flood claim in Canada is \$50,000. The devastation in Calgary in 2013 was not just dramatic but traumatic, White said. He expressed the concern that another major flood could unbalance the federal budget as it currently stood, possibly impacting the outcome of the next election.

In response to the growing risk associated with extreme weather events, White said, the Insurance Bureau has developed a municipal risk assessment tool which it is piloting in Coquitlam, BC; Fredericton, NB; and Hamilton, Ontario.

The bureau has also done a study on earthquake vulnerability, White added. Canada is the only country in the world that is vulnerable on two coasts, he said, noting that the Insurance Bureau's report had observed that Canadians are not aware or financially prepared for an earthquake of any significant magnitude.

White pointed out that the total economic costs of a major earthquake on the heavily populated west coast were projected to be over

\$74-billion, including direct damage to buildings and their contents, business interruption costs and indirect impacts on the economy. This is equivalent to about 4 per cent of Canada's GDP and over 35 per cent of BC's, White observed. Putting this amount in perspective, he said the estimate is also roughly equivalent to the combined output of BC's agriculture, forestry, mining, construction, manufacturing, retail, scientific services and transportation sectors. Insured losses would be much less, he said, totalling \$20-billion, and would be largely concentrated in the commercial sector, which could afford and had the foresight to buy earthquake insurance.

For Quebec, White reported, total economic costs of a major earthquake were projected to be over \$60-billion, equivalent to 3 per cent of Canada's GDP and almost 17 per cent of Quebec's. Putting this amount too into perspective, White said it would be roughly equivalent to the combined output of Quebec's construction and manufacturing sectors. Insured losses were projected to cover only \$12-billion and would be almost entirely in the commercial and industrial sectors, as would be expected given that only 4 per cent of Quebec residents have earthquake insurance.

In conclusion White said individuals have to do more to protect themselves and their property from extreme weather events. Businesses too have to do more, and so do governments. He reiterated his belief that issues of extreme weather events and disaster liability were likely to figure prominently in the next federal election and many elections thereafter.

SESSION SIX: EMERGENCY MANAGEMENT AND PREPAREDNESS

How well prepared are Canada and its communities for extreme weather events? The first presenter on this topic was Ernest MacGillivray, executive director of emergency services for New Brunswick. As he was at that moment dealing with a real-time flooding disaster where he lived and could not leave, Mr. MacGillivray was Skyped into the symposium.

His presentation dealt with where governments currently stood with respect to extreme weather crises. He noted that in a real emergency, disaster service agencies are often seen as independent from

government. Emergency services, MacGillivray pointed out, were becoming ever more important in the face of more frequent extreme events. He observed that greater attention needed to be paid to regions where people find themselves repeatedly in harm's way. Risks could be reduced, he said, by better disclosure, by discouragement of development and activities that increase risk, and by appropriate sharing of risks among jurisdictions and governments. This will require a rebalancing of public and private risk, he noted.

MacGillivray described a roadmap for reducing the risk posed by extreme weather events. The roadmap included investments in assessment; fuller disclosure; better public education; and enhanced management of risk that would lead to better control of the outcomes of weather-related disasters. The reason Canadians were not following this roadmap, in MacGillivray's estimation, was largely a consequence of public denial of climate issues. Governments, he said, don't generally lead; they follow. He pointed out that costs associated with disaster relief are already factored into government budgets, and evidence is required to change government direction. Such evidence has to clearly prove that societal and government risks are increasing as a result of more frequent and intense extreme weather events. The federal government, MacGillivray noted, had recently budgeted \$200-million over five years, starting in 2015, for a national disaster mitigation program that will be administered by Public Safety Canada. MacGillivray left it to the participants in the symposium to determine for themselves whether this level of funding was adequate.

He then explained how flood disaster mitigation is advancing in New Brunswick. He pointed to a new flood monitoring and alert system and a damage assessment program aimed at helping flood victims almost immediately after an event. But governments can't do what is necessary on their own, he said. What was needed now was an alignment of the work that needed to be done. This alignment includes the implementation of a disaster risk reduction strategy with regular reporting to the provincial government. MacGillivray also noted that there was a need for a new focus on community resilience and sustainability. Greater adaptive capacity also has to be developed at local and regional levels. Building codes have to be altered,

land-use plans improved and professional engineering and architectural practice informed by new emergency measures standards.

In conclusion Mr. MacGillivray offered that what we all need to do now is understand the risks, learn from each other, and work to educate government officials and the public so as to better inform policy and practice related to the growing public safety risk of extreme weather events.

The next presentation in Session Six was by Barney Owens, director of response in Ontario's Office of the Fire Marshal and Emergency Management. Owens began by talking about the December 2013 ice storm and showing its effects, noting that at its peak a million people were without power. In such circumstances, he explained, co-ordination of public communication is central to ensuring public safety.

Owens noted that hydro utilities throughout the affected region immediately shared deployable field resources. As in the case of Hurricane Katrina, however, hospital backup generators proved to be inadequate and had to be augmented with additional units. Small communities proved more resilient during the disaster, Owens said, especially in terms of people helping one another.

He also commented that public expectations range from "it won't affect me" to "the government will immediately come to my aid." One can't count on either of those to be true, and thus personal preparedness is important. As an example, Owens noted that when the power is out, bank machines do not work; in forest fires, cell phone towers burn. He emphasized the importance of working with the media for frequent, accurate communications, as social media can contribute to a loss of control of messaging.

Owens observed that the ice storm affirmed the realization in Ontario that a new emergency measures operations regime is going to be necessary to deal with a changed climate. Ontario learned what constituted vulnerable populations and where they lived. The government also learned that warming centres were critical in such events and that problems with demographics and language can become serious issues in a disaster. The realization also presented itself that there will never be enough money to do the necessary planning. Planning must span multiple jurisdictions and cover both immediate

response and the recovery period. Key elements in managing emergencies include promoting personal preparedness; sticking to the plan; applying past recommendations; promoting public/private partnerships; education and awareness; and having sufficient generating capacity where needed.

SESSION SEVEN: THE GLOBAL IMPLICATIONS OF EXTREME WEATHER EVENTS

The final section of the symposium focused on the bigger picture. David Greenall, who leads Deloitte's global climate adaptation and resilience practice, began his presentation by talking about private sector resilience to extreme weather events. He noted there were real risks to business from such events and that these risks may impact enterprise value. Heat waves, for example, may affect cash flow because of lost sales, compromised competitiveness, degradation of critical infrastructure that impacts supply chain reliability, and increased insurance costs.

Greenall then talked about how different responses to extreme weather events can make a difference to both reputation and the bottom line. He gave the example of Hurricane Sandy in October 2012, a storm that knocked out power to over 8.5 million people and caused an estimated \$65-billion in damage. Greenall compared the operation of New Jersey Transit with that of the MTA (New York's Metropolitan Transportation Authority) during the storm. In the one case, trains were vulnerable and became unusable, but in the other, a risk assessment had led to operational changes that saw fleet vehicles get moved out of harm's way so that service recovery was fast and financial losses were limited. Similarly, Greenall illustrated what happened in Thailand in 2011, when floods interrupted global supply chains, and in Toronto during the flooding in July 2013.

Greenall explained that Deloitte helps businesses view their profitability through the lens of climate risks, which in this context are modelled using large data sets. Deloitte has encountered some resistance to such assessments, however. Many businesses argue that extreme weather is nothing new or that assessments are unnecessary because such analyses can be done in-house by the company's

own engineers. Companies are also wary of committing funds to extreme weather preparedness, as such investments will be lost if threats don't materialize. Greenall explained that businesses need climate and hydrological projections at high resolution. They need to understand direct and indirect impacts and the need for adaptation plans.

Greenall went on to quote a 2013 statement by the American Meteorological Society which predicted that in an increasingly competitive global environment, nations that invest most effectively in clarifying weather and climate risks will have an important competitive advantage. He also quoted Christine Lagarde, the head of the International Monetary Fund, who said in 2013 that "unless we take action on climate change, future generations will be roasted, toasted, fried and grilled."

Greenall concluded his presentation by citing a report by International Finance Corporation called *Enabling Environment for Private Sector Adaptation*, which reviewed actions that have significant potential for enabling private sector adaptation and the promotion of climate resilient development.

SUMMING UP THE COMING STORM

So what, in summary, did we learn from this national conference about where we stand in Canada with respect to extreme weather in the context of climate change? We learned that extreme weather doesn't just damage property. It disrupts lives, impacts economies and alters and stresses ecosystems. Extreme events also have health, insurance and liability impacts. We are likely to see 2° to 5°C of warming over this century, and North America will not be immune. Adaptation and mitigation are therefore necessary.

The recently published Intergovernmental Panel on Climate Change Fifth Assessment Report offers a number of warnings. Sea level rise is expected to affect hundreds of millions of people. Higher carbon dioxide concentrations are altering the chemistry of oceans a million times faster than what occurs naturally, which, in combination with overfishing, will reduce fish stocks. This, in addition to growing populations, will demand a 70 per cent increase in food

production during this century. Innovative adaptation is beginning but serious challenges remain, particularly in developing countries.

There will also be significant impacts on water. For each 1°C temperature increase there will be a 20 per cent decrease in the amount of fresh water available to a significant part of the global population. Warming will also cause the hydrological cycle to intensify. The frequency, intensity and duration of extreme weather events are already increasing. Reported insurance claims for flood damage alone have risen from an average of \$7-billion a year globally to over \$24-billion in 2011. Under these circumstances, incremental, linear approaches to adaptation are not enough now and will not be enough in the future. A storm is coming. We have to get moving.

EXTREME WEATHER EVENTS WILL IMPACT US ALL

Fresh water is both a mediator and a transmitter of climate change effects. Liquid water, water vapour, snow and ice transmit climate change impacts across the country and across ecological and political boundaries. We have to be alert to changes locally of course, but we now also have to keep an eye on changes in the larger, global hydrological cycle and where possible try to manage and adapt to them. This is a huge new concept. "This changes everything," as author Naomi Klein put it.

Floods and droughts represent different sides of the same hydrologic coin, and we have begun to see both occurring in the same basin in the same year. Drought represents a great concern in a changing climate, especially as it relates to food security. Long-term education is needed to encourage drought-proofing and better water management.

There are more of us now and we are more urban, which is making extreme weather more costly. Disasters with insured losses of over \$1-billion have occurred every year for the past five years in Canada. In addition to more frequent heavy rainfall, there appears to be a clear trend toward higher winds. Extreme weather events also cover larger areas and are persisting longer, making recovery slower and most costly. These trends are not going away. We need to reduce the threat of disaster by preparing for it.

Climate change has been identified as the single greatest threat

to human health of the 21st century. With projected warming of 2° to 5°C we should expect mortalities to rise. The urban heat island effect has already become a major public health issue, even in Canada. Groups that will be vulnerable to these effects include older adults, infants and young children, farmers and other outdoor workers, the physically active and those with chronic illnesses. A model worth emulating has been developed in France for information dissemination, prevention and mobilization against temperature-related climate risks. Included is a national alert system for heat waves that clearly outlines health risks and shows people how to cope.

Having alert systems in place is one thing; actually dealing with extreme situations is another. In disasters such as occurred in New Orleans, it was clearly apparent that it is not always possible to adhere to established moral values. The moral jeopardy that arises in the aftermath of extreme weather is similar to what happens in combat zones. There were examples of great heroism. But also as in war, sometimes it's not possible to know what we should have done, only what we would have liked to do. In such prolonged emergencies, ethical questions revolve around who gets rescued first. When needs outstrip resources you may be forced to prioritize who lives and who dies. Hurricane Katrina made it clear that such ethical issues need to be considered in advance. Better triage, fuller disaster plans and greater adaptive preparation are necessary if we are to be able to deal with more frequent, increasingly powerful extreme weather events.

THE SCIENCE IS CLEAR

March 2014 represented the 349th consecutive month with above-average temperatures. This suggests that if you were 29 years old or younger in 2014, you live in a climate regime different from the one experienced by people older than you. A warmer atmosphere provides more moisture to energize and fuel extreme weather events. This will make wet places wetter while increasing evaporation generally, which will make dry places drier.

Arctic sea ice is disappearing. There has been a 75 per cent decrease in volume in the past 35 years. This loss allows heat to warm the Arctic Ocean, which in turn melts more ice. This feedback causes

more and more ice to melt, which is why the Arctic is warming two to three times faster than the rest of the world. The loss of Arctic sea ice and the reduction of the extent and duration of snowcover in the northern hemisphere are reducing the temperature gradient between the pole, the mid-latitudes and the tropics. This diminution of the temperature difference between the pole and mid-latitudes has begun to affect the behaviour of the jet stream in the northern hemisphere. It is the jet stream that creates weather at mid-latitudes. As the jet stream slows and its waves become wider, weather patterns persist longer and do things we don't expect.

EXPECT EMERGENCIES

More attention needs to be paid in Canada to areas where people find themselves repeatedly in harm's way. Risks can be reduced by better disclosure; by discouraging development and activities that increase risk; and by appropriate sharing of risks among jurisdictions and governments. Planning must span multiple jurisdictions and cover both immediate response and the recovery period. Key elements in managing emergencies include promoting personal preparedness; sticking to emergency plans; applying past recommendations; promoting public/private partnerships; education and public awareness; and having sufficient electricity generating capacity where needed.

There needs to be a renewed focus on community resilience and sustainability. Greater adaptive capacity also has to be developed at local and regional levels. Building codes have to be altered, land-use plans improved and professional engineering and architectural practice informed by new emergency measures standards.

ADAPTATION

We can build more resilient homes if we use science as a foundation for action. Progress, however, remains slow. Adaptation is complicated by urbanization and the aging of critical infrastructure. Sea level rise is an additional problem for coastal cities.

The next steps in realizing meaningful adaptation strategies include intergovernmental collaboration; stakeholder engagement, especially with professionals in planning and engineering; ongoing

assessment of current and future risk; strategic action; and the mainstreaming of adaptive behaviours. Of critical importance are updated plans, more accurate flood maps tied to better zoning, funding support for municipal adaptation efforts and stronger central leadership.

Climate change related risks will affect all economic sectors. There is a need to strengthen the linkages, including institutional connections, between climate change adaptation and disaster risk management. Individuals have to do more to protect themselves and their property from extreme weather events. Businesses have to do more, and so do governments. Issues of extreme weather events and disaster liability are such that they are likely to figure in future elections.

EXTREME WEATHER EVENTS ARE ALREADY IMPACTING BUSINESS

The risks to business globally that are associated with extreme weather events are real and can directly affect reputation, bottom line and enterprise value. The business case for investing in climate resilience is evident. Such investment reduces unwanted exposure and the likelihood of adverse risks with catastrophic consequences; improves business efficiency and effectiveness; proactively addresses growing concerns of regulators, investors, analysts and rating agencies; and creates decision-support frameworks and processes to better equip management to make more informed decisions.

In an increasingly competitive global environment, nations that invest most effectively in clarifying weather and climate risks will have an important competitive advantage.

WHAT DO WE DO NOW?

The problems associated with extreme weather are expected to multiply. The effects of more frequent, intense and longer-duration events such as floods and droughts will have increasing impacts on personal safety, property damage, infrastructure renewal, the reliability of transportation and energy distribution, the cost of insurance, public and private liability, mental and physical health and well-being, economic productivity and social and political stability.

We will all have to adapt. Individuals will need to focus on personal preparedness; communities on resilience and sustainability; and regions on planning and adaptation. Governments at all levels will have to bear down on public education, communication, disaster mitigation, better links to emerging scientific research outcomes, and proactive support for adaptation measures. Professions such as engineering, architecture and urban planning will have to incorporate different parameters into the design and function of our built environment. New levels of emergency preparedness and management will have to be conceived.

Organizations like the Federation of Canadian Municipalities have the opportunity to work with the professional community and with scientists to lead the country's towns and cities in the direction of meaningful adaptation.

Businesses will have to incorporate investments in climate resilience into strategic planning frameworks. The national government will have to invest in both adaptation and mitigation to retain competitive advantage in a world that is about to become very different from the one we knew before our climate changed.

PREPARE FOR THE STORM

In crossing and recrossing this country dealing with water policy matters over the past decade I've discovered a growing sense of unease among informed people that something is brewing out there in the world that is bigger even than the global economic crisis. The sense also is that whatever it is, it is coming at us fast and it has something to do with water. Anybody who is paying attention has already sensed that our basic hydrology is on the move. We don't know what it means yet, but the deep collective sense is that it is not going to be anything good.

A storm is coming and we need to prepare for it. If we do not, then what we will face will be not just any storm but a perfect storm. All perfect storms have one thing in common: when conditions are just right, circumstances can align to create a serial combination of vulnerabilities that lead straight to disaster. We know all about the elements converging in our time to create this tempest. We are fully aware of the global environmental impacts caused by unrestrained

growth of human populations and material desire. The converging trade-offs of food security, industrial development, habitat and biodiversity loss and destruction of ocean ecosystems have been expertly described and explained. We have been bickering and prevaricating over what to do about these issues for fifty years, until at last that which many feared most is now upon us.

What is new about climate change is that in synergistic combination with other wide-ranging impacts, warming temperatures threaten to exacerbate already serious problems. Climate change is poised to absorb into itself the hurricane we have already created through population explosion, landscape change and global water scarcity. At the moment, climate change also appears poised to overwhelm institutional structures designed for an earlier, more climatically stable era of human existence. Poverty, deteriorating environmental conditions, jealously protected private property rights, short-sighted economic and market imperatives, self-centred social preferences, unconscionable waste, the increasingly atomized and toxic nature of public discourse, and the reduced capacity of contemporary political frameworks to function in a timely manner in addressing urgent issues are all lining up globally in just the right way to create a hurricane of their own just waiting to be absorbed into the perfect storm of global warming.

If we want to avoid the worst of this storm we need to create a new water ethic. Under the aegis of that ethic we need to ensure formal representation for the environment itself and ways to advocate for nature's own needs for water so as to perpetuate the bio-diverse ecosystem productivity that is central to the hydrological conditions favourable to human populations. If we can balance the water availability and water quality needs of nature, agriculture and our cities, many other things we need to do, including achieving sustainability, may very well fall into line. But most importantly, we may be able to avoid turning climate change into a storm many of us might not survive.