

CHAPTER TWO

A STORM IS COMING

Emerging Perspectives on the State and Fate of Canada's Water Supply

The writing was already clearly on the wall in 2010. Canada's hydro-climatic regimes were changing, but that was not news the country wanted to hear. In the midst of blistering record high temperatures in the spring of that year, Ottawa was the venue for the final Canadian Foundation for Climate and Atmospheric Sciences conference on the critical role of science in ensuring Canadian water security. Moderated by Gordon McBean, chair of the board of trustees for CFCAS, as it was known, this conference featured presentations of recent findings related to water security in Canada that had emerged over several years from research projects funded by the foundation. The presentations were offered by some of this country's and the world's most respected climate and water scientists.

Opening remarks were offered by Dan Wicklum, who at that time was director-general for water, science and technology at Environment Canada but later went to work for an oil sands industry group. Dr. Wicklum began with first principles. One of the oldest adages in management in general and environmental management in particular, he said, is "if you can't measure it, you can't manage it." In the past, Wicklum pointed out, Canada had a long history of measuring water quantity and quality. In the specific case of managing water and water security, however, simply measuring was not enough. We need to be able to predict supplies and demand, he said, which can be challenging in circumstances where the climate may be changing.

Wicklum stressed that sound policy is not possible without a

sound knowledge base. Every step in an adaptive management cycle, he said, from the development and implementation of policy to protect public interest to the tracking of the efficacy of policy directions requires knowledge. Knowledge at each of these steps is largely created by research and monitoring, which is to say that sound policy relies heavily on good science. Dr. Wicklum identified the challenge of conducting ongoing environmental monitoring as being one of the central threats to water security in Canada. His message, which he repeated over and over, was that you can't manage what you don't measure.

There was a certain irony in Dr. Wicklum's observations – an irony which pervaded the entire conference. Wicklum presided over the federal agency responsible for much of the monitoring of water quality and climatic conditions in Canada. His department was in the midst of dramatic funding cuts that would clearly make it far more difficult to manage even what was being measured. Though he may not have intended to do so, Wicklum put into relief what many scientists and policy analysts in the room feared most: that the government of the day did not hold scientific research in the domains of water and climate to be central to its mandate and current priorities. This meant it was likely that the ongoing work of CFCAS would not be supported and that the agency would cease to exist when its current funding ran out.

The opening session was chaired by Elizabeth Dowdeswell, president of the Council of Canadian Academies and later Lieutenant Governor of Ontario, who spoke of the urgent need for relevant science. Dr. Dowdeswell wanted every scientist at the conference to understand that if there was ever a time to demonstrate the value of scientific research to decision-makers, it was now. She succinctly listed crucial unanswered questions in science. Is science generating useful knowledge? Is that knowledge relevant to the problems we face? Is it place-based? Does it empower decision-makers? Is it even available to decision-makers? How do we strengthen and widen the bridge between research outcomes and policy action?

Dowdeswell argued that we need to learn how to create models that encourage researchers to work together and do a better job

of bringing social as well as physical science to bear on the central problems of our time. Instead of just organizing more meetings, she urged, science has to generate action.

The keynote address was given by Gordon Young, who at the time was the president of the International Association of Hydrological Sciences. Drawing on decades of international experience, Dr. Young characterized the global freshwater situation and explained why it should concern Canadians. A storm is coming, he said, and we will need all the interdisciplinary science and institutional co-operation we can muster to weather it. Canada, he observed, is not immune to the problems that have created the global water crisis. To avoid crisis, Young maintained, will require a reformed Canadian water ethic.

Dr. Young explained how much fresh water is available to humanity. He illustrated how increases in demand were causing widespread shortages, and in ten minutes he established the clear link between water and food, and water and energy. He observed that while the world was on track to meet the United Nations Millennium Goal of supplying freshwater to the world's unserved, there was little hope of achieving equally important goals with respect to improvements in sanitation. Dr. Young went on to show the direct link between reliable water supply and adequate sanitation and economic and social development.

Dr. Howard Wheeler, who in 2010 was the newly appointed Canada Excellence Research Chair in Water Security at the University of Saskatchewan, responded to Dr. Young's address with complementary observations on the growing world water crisis and what it might mean to Canada. Dr. Wheeler defined water security as "the sustainable use and protection of water resources, safeguarding access to water functions and services for humans and the environment, and protection against water-related hazards (flood and drought)." Wheeler then pointed out that precipitation changes around the world were likely to make water management more difficult in the future. These changes, he said, raise major challenges for science – and for society. He made the point that we need new science, new technologies, new decision support tools and new mechanisms for public engagement to address these challenges.

Dr. Wheeler further noted that water managers and policy makers had the same needs as scientists in the context of the planet's changing hydrology. Improved global and regional climate models were needed, and they will have to recognize the limits of predictability. Wheeler pointed out that climate models must be improved to ensure they can provide accurate predictions at local scales. There is much to be done to improve Earth-system science too, he said, especially at the level of land surface and climate interaction. It is also very important to assimilate data better, so that adaptation solutions can be robust in the face of considerable uncertainty.

In his conclusion, Dr. Wheeler underscored the need to create interdisciplinary collaboration, linking the atmosphere, land and water through integration of natural and engineering sciences with health and social sciences. He added that new science and technologies need to be developed to support integrated water quantity and quality management and to address national and global water security agendas.

In concluding this session, Elizabeth Dowdeswell commented that addressing the global water crisis requires that we harness the intellectual capital and passion of the wider scientific community. We also need to embrace the ethical and moral challenges associated with water issues, and most importantly we need to generate a sense of urgency in addressing water and water-related climate threats.

The rest of the presentations at the conference almost perfectly mirrored not just the content but the urgent tone of the opening session. Hydrologists and atmospheric scientists from across the country offered clear evidence of the fact that Canada's climate is changing and that these changes are being reflected in the timing and type of precipitation and in other factors that could affect water security. Other researchers concentrated on exactly the kinds of measures for addressing these problems that were put forward in the keynote addresses. Not a single speaker denied that our climate is already changing. Each in turn explained why warming temperatures were bound to have a significant influence on the hydrological circumstances of almost every region in the country eventually. Report after report said the same thing. The world our

grandchildren will inherit will be very different from the one that exists today.

RECOGNIZING THE PROBLEMS

Among the scientists demonstrating that a storm was indeed brewing were Dr. Ronald Stewart and Dr. David Sauchyn, who summarized recent findings related to climate change effects on the Canadian prairies, especially as they relate to the disturbing prospect of deeper, more persistent drought, not just in that region but throughout southern Canada.

Dr. Stewart, who coordinated the activities of the CFCAS-funded Drought Research Initiative, summarized his network's findings in the following way. The climate forecast for the Canadian prairies suggests there will probably be more drought and at the same time more frequent heavy precipitation events, all signalling the likelihood of greater climate variability. The reason for this is that climate processes appeared to be moving in the direction of greater extremes. A warmer climate will likely accelerate this motion. Why does this matter? Because increased variability in an already highly variable system could have impacts across all sectors of society, which will have major policy implications for all levels of government.

Dr. Sauchyn presented work undertaken principally through the Prairie Adaptation Research Collaborative at the University of Regina. Sauchyn began by pointing out that of the 18 most economically costly natural disasters that have taken place in Canada, 16 were on the prairies. Of those, 11 were droughts. He offered an example: the 2001–2002 prairie drought caused an estimated \$2.42-billion loss in crop production in Saskatchewan alone and resulted in a \$5.8-billion reduction in the gross domestic product of Canada as a nation.

Quoting from the journal of an early fur trader, Sauchyn observed that major droughts have occurred throughout the historical record and beyond. By carefully analyzing tree rings over a broad area of the Canadian West, Sauchyn and his colleagues have demonstrated that droughts lasting a decade or even longer were not uncommon during the past thousand years. Evidence exists that the

wettest two decades on the prairies in recent history were the 20 years when European settlement occurred.

We could not live in such drought-prone places without adaptation in the form of irrigation. Sauchyn noted, however, that there is now increasing pressure in the region to use water resources for purposes other than agriculture. This pressure is mounting at a time when streamflows originating on the eastern slopes of the Rockies are becoming more uncertain.

Sauchyn then introduced findings that showed a strong correlation between drought on the prairies and the 60-year cycle of an ocean-current phenomenon called the Pacific Decadal Oscillation, or PDO. Sauchyn noted, however, that most of our instrumental records – archives of historical data from thermometers, barometers, rain gauges and the like – cover a period of less than one PDO cycle. Climate modelling undertaken by Sauchyn and his colleagues has demonstrated that warmer temperatures will result in a shift toward more positive PDO conditions in the future, which is likely to result in further decline of river flows and even greater climate variability. Extra water will be available in winter and spring, while summers will be drier. Both drought and unusually wet years could occur with greater frequency and severity. This suggests that both floods and deep and persistent droughts are likely to occur more frequently on the prairies, with huge potential costs to the economy.

Dr. Sauchyn also noted that Canada was losing the advantage of cold winters, in terms of both stored water and evaporation. Cold temperatures also created a barrier to disease pathogens that affect both people and agricultural production. He concluded by reiterating that there will be greater variation in water and climate in the future, which could have significant impact on agriculture and other sectors of the Canadian economy.

Dr. John Pomeroy then presented new research findings confirming that substantial winter warming is already affecting the hydrology of the mountain West, reducing streamflow and shifting the snowmelt season. Evidence suggests that between 1970 and 2004 there has been a one- to two-month decline in the duration of snowcover in the southern Canadian Rockies.

The conclusions of this research, however, have broad implications that will likely affect every sector of the western Canadian economy. The modelled sensitivity of an alpine snow regime to winter warming suggests that warming of up to 4°C will have a number of effects. It will reduce maximum snow accumulation by up to one-half; reduce seasonal snowfall and sublimation of intercepted snow by more than half; move the date of maximum snow accumulation forward by up to a month; first increase and then reduce snowmelt rates by up to two-thirds; first decrease and then extend the duration of snowmelt by up to one-fifth; and move the date of snowcover depletion forward by up to four weeks.

These results of research conducted by the Pomeroy-directed IP3 (Improving Processes and Parameterization for Prediction in Cold Regions) research network show that intact mountain forests have a mitigating effect on some aspects of climate variability and that windswept open environments are highly sensitive to climate warming. Pomeroy also indicated that mountain forests demonstrably mitigate some aspects of climate variability. As snowpack and forests are clearly going to play a huge role in determining future water security in Canada, Pomeroy urged the research community to press for continuation of the Canadian Foundation for Climate and Atmospheric Sciences so that more could be learned about how to manage landscapes in order to generate optimal water supply in the future.

Environment Canada's Paul Whitfield then introduced research findings from the CFCAS-funded Western Canadian Cryospheric Network (wc²N). The object of this work was to document climate variability and glacier extent in the Pacific Northwest region of Canada over the last 400 years and to predict how glaciers will respond to projected climate change over the next 50–150 years. These research outcomes further confirmed that the hydrology of the West is changing in a direction in which water security will be more difficult to assure.

Through the efforts of IP3 and wc²N researchers, we now know it is possible that we lost 300 glaciers in the Canadian Rockies between 1920 and 2005. Some 150 of those likely disappeared in the 65 years between 1920 and 1985. The other 150 likely disappeared into thin

air in the 20 years between 1985 and 2005. This suggests that our losses may be accelerating. The combined findings of the two networks confirmed other studies that had indicated that long before warming reduces the size and output of glaciers in Canada's north and west, it will be changing snowpack and snowcover in ways that could dramatically affect water supply.

Reduced flows in Western rivers, Whitfield noted, will impact power generation and agricultural, industrial and municipal water security throughout western Canada. These flow reductions will also affect interprovincial water sharing arrangements and trans-boundary agreements with the United States such as the Columbia River Treaty.

Hydrologist Garth van der Kamp then shared the results of his recent research on the role groundwater will play in defining water security in Canada. Many in the audience were surprised by his findings. Dr. van der Kamp offered evidence that prairie groundwater is not recharged from the Rocky Mountains as many believed; rather, nearly all the groundwater in Canada is found in small aquifers. This suggests that in the event of need, these aquifers can only supply large amounts of water for short periods. Water security over time will require careful management of groundwater to prevent overdraft.

At present, van der Kamp explained, the security of groundwater is being widely diminished by contamination. The fact that one in four Canadians rely on groundwater for domestic supply and a million people rely on wells that already exceed federal contamination guidelines suggested to van der Kamp the need for co-location of ongoing research in experimental watersheds.

Dr. van der Kamp's research demonstrated that groundwater can provide water security during droughts – provided it is left in reserve and not overexploited. At present, however, we continue to separate groundwater and surface water in our management approaches, ignoring the air-soil-groundwater-surface water interface that is the very essence of how the hydrological cycle works, especially on the Canadian prairies. Monitoring groundwater, van der Kamp concluded, should be a priority, because without clear knowledge of what is happening to it, adaptation to climate change

may become very difficult. “We have to realize the seriousness of the problem,” van der Kamp said quietly, “and then act on it.”

Philip Marsh then moved the focus of the conference to the North and one of the largest features of its kind in the world, the 12,000 square kilometre Mackenzie Delta. Dr. Marsh explained the influence of the flows of the Mackenzie on the 40,000 lakes found in the region and the delta’s influence on the Beaufort Sea and its ecology. Dr. Marsh and his colleagues have discovered that the delta is subsiding, causing water levels to change. This subsidence will affect ecological function as well as actual and projected gas pipeline operation. Marsh argued that an improved knowledge of the effect of the Mackenzie Delta on flows of water, sediment and nutrients is very important to understanding the Beaufort Sea, especially considering the likelihood of future changes in the Beaufort’s ecology.

Marsh observed that over the last 15 years, Canada has made significant investments to improve our science capacity in order to both understand and improve our ability to predict the weather, climate and hydrology of the Mackenzie basin and delta. These programs include the Beaufort and Arctic Storms Experiment; the Mackenzie Global Energy and Water Experiment; the CFCAS-funded IP3 initiative; and Canada’s Northern Energy Studies pertaining to the Mackenzie gas project. These research undertakings were all advanced in one way or another through the International Polar Year, which focused in part on changes in Arctic river deltas.

Dr. Marsh lamented that just when much more can be known as a result of the recent development of coupled climate models, research is ending. He concluded by explaining that what we presently need most is follow-up support to allow the newly created models to use data collected in these research projects to generate policy-relevant outcomes.

The next presenter, Sean Carey, showed results which confirmed that climate change effects are already being dramatically felt by way of widespread landform changes wrought by permafrost melt in the Arctic. Change in the North is now the norm, not the exception. Nowhere on Earth, Carey observed, is the landscape changing more quickly. The rate of change in the Arctic has been much more

rapid to date than all but the most extreme projections, Carey said. And most of the changes involve water.

Carey and his IP3 network colleagues were working to determine how a changing climate and accelerated human activity will affect the northern water cycle. The network, which functioned from 2006 until 2010, was composed of about 40 investigators and collaborators from Canada, the US, the UK and Germany. Carey explained that IP3 was devoted to understanding water supply and weather systems in cold regions at high altitudes and high latitudes, which explains the focus on research in the Rockies and the western Arctic. The network has already contributed to better prediction of regional and local weather, climate and water resources in cold regions, Carey said, including understanding of streamflow in places where there are no gauges. The research has also led to advances in understanding of changes in snow depth and cover and the resulting effects on water supplies and calculation of freshwater inputs to the Arctic Ocean.

Carey went on to point out why the hydrology of the Arctic is so sensitive to upward changes in temperature. Permafrost acts as an aquitard – a formation through which water flows transversally much slower than it does through an aquifer, and which also restricts vertical movement because of the impervious nature of subsurface ice layers. In losing permafrost, the landscape is not only losing the rigidity provided by subsurface ice, but water is moving downward in ways that have not been witnessed before. Everything with respect to hydrology appears to be changing at once.

The Fort Simpson area of the Northwest Territories, Carey indicated, has experienced a 30 per cent decrease in permafrost in the last 53 years. Ponds are shrinking in the Arctic as a result of internal drainage made possible by the degradation of shallow permafrost. Streamflow chemistry and water quality will also be impacted as the movement of water in the subsurface changes. Changing climate also affects the timing and magnitude of floods, breakup and river freezing, which is already causing considerable damage to northern infrastructure such as culverts, dams, bridges and roads. Carey noted that at present we have a poor scientific capacity to predict flow – or floods – in small and medium-sized northern streams.

Carey noted that road and pipeline river crossings in the north routinely fail because we apply insufficient understanding of hydrology, runoff generation and permafrost or frozen ground dynamics in our designs. Carey also indicated that across the northwest of our continent, certain tree species no longer respond to climate signals as they have in the past half-millennium. There is also evidence that ecological thresholds have been reached. Like many of the other researchers at the conference, Sean Carey concluded by underscoring the importance of ongoing research in this area to the building of further adaptive capacity in both northern and southern Canada.

Next, Dr. John Hanesiak of the Storm Studies in the Arctic Research Network shared groundbreaking new results tying higher temperatures to changing precipitation and storm patterns in the Arctic. Storms and their related hazards in this region have profound effects, including loss of life and impacts on industry, transportation, hunting, recreation and even the landscape itself. Such storms also impact sea ice and marine systems. Hanesiak demonstrated that over recent decades the frequency and intensity of storms in the Arctic have been increasing.

In the Arctic, ecosystems and people can be dramatically affected not just by prolonged blizzards but also by windstorms and unusual warming events. In 2006, for example, February temperatures of +5°C, as opposed to the normal seasonal values of around -20°C, brought about by an intense cyclone across southern Baffin Island, caused rain showers, while accompanying 125 kilometre an hour winds caused property damage and made travel impossible. In June of 2008, some 35 millimetres of rain fell in 12 hours at Pangnirtung, Nunavut. Temperatures soared to more than +13°C, with winds of 80 kilometres per hour. Significant snowmelt followed, causing a stream to take a new and deeper course through the community. The town remained physically divided until new bridges could be built.

In combination with permafrost loss, extreme weather events are expected to play havoc with northern development. Unfortunately, however, the lack of observational sites makes it difficult to know exactly what is happening in the Arctic. The surface and

satellite-based research Dr. Hanesiak and his colleagues were undertaking was aimed at improving understanding and prediction of severe Arctic storms and their hazards. The team's models demonstrate that in future there are likely to be more days with precipitation at northern latitudes and more rain days, which will likely result in less ice. The models also projected an 8 per cent increase in freezing precipitation per decade, which could have a significant impact on herd species such as caribou and muskox. This is bad news given the already diminished state of many of the largest caribou herds currently in the Canadian North. The potential effect of more frequent and intense storms on potential hydropower developments and other infrastructure is unknown.

One of Canada's most respected scientists, Jim Bruce, then told the audience that IPCC climate change projections are likely too cautious and that some effects are already occurring faster than expected. Despite this, he said, emissions continue to rise, with the global total in 2010 topping the 1990 level by 41 per cent. As a result, impacts are becoming obvious: glaciers are visibly receding; ice on Canadian lakes and rivers is disappearing; and extreme weather events are becoming more common. Dr. Bruce observed that if the changes that have taken place over the past 40 years continue into the future, Canada should expect to experience significant climate-related impacts on its water supplies. He concluded by pointing out that in the Canadian context, climate security equals water security. Without the one, you don't have the other.

It's not just the Arctic that is changing, either. Research outcomes of projects supported by the CFCAS also demonstrated how climate change was beginning to alter ecosystem function in some of the most heavily populated areas of the country. Linda Mortsch, for example, explored impacts on water and aquatic ecosystems in the Great Lakes region, notably the interconnected effects of lower water on habitat suitability for wetland vegetation, birds and fish. Research at Long Point on Lake Erie demonstrated that a 1.48 metre decline in water level resulted in a 32 per cent decrease of the surface area of the inner bay. The shoreline grew from 200 metres in width to more than 2 kilometres. Mortsch noted that water level variability maintains vegetation, bird and fish habitat, and that changes in

this variability as a result of climate will have implications for biodiversity and ecological services.

Turning attention to the prairies, Dr. Mortsch observed that “prairie potholes” are particularly sensitive to water balance changes. In drought conditions, permanent potholes become ephemeral, altering wetland vegetation and wetland functions and values, with significant effect on waterfowl habitat. Mortsch further observed that during drought such wetlands become vulnerable to being converted into agricultural land.

Her team also identified the effects of warming water temperatures on aquatic ecosystems, with particular reference to changes in water chemistry and the effect of that on algae populations and invasive species. All of this, Dr. Mortsch pointed out, would have important implications for water security in the future.

IDENTIFYING THE SOLUTIONS

While the research outcomes of the physical scientists clearly revealed growing widespread threats to water security as a result of current management policies, which will be exacerbated by climate change, policy analysts who spoke at the conference demonstrated that solutions exist and are still within our means. In fact, important steps forward are already being made. The challenge always is to keep up with the problems we are creating for ourselves under current water governance regimes and under the weak climate change policy formally adopted by the former Harper government.

In order to put into relief how we arrived at where we are in Canada with respect to water and climate security issues, water policy scholar Ralph Pentland tracked and compared the role of science in decision making and policy development over four 20-year periods in the history of Canada-US water relations. His research revealed that the gradual hollowing-out of government itself and the decline of government science over time have eroded the sustainable management of water resources in favour of short-term economic interests. This, Mr. Pentland pointed out, has adversely affected relations between the two countries, as exemplified by the

return of water quality problems in the Great Lakes and growing difficulty with algae blooms in Lake Winnipeg.

Pentland observed that between 1965 and about 1990, there was a dramatic change in conventional wisdom about governance. We suddenly realized, he noted, that one person's effluent was another person's intake, and that the public good did not always coincide with the pursuit of private interest. The high degree of interdependence created by technology suggested the need for a total "systems" approach in the search for optimal societal solutions, especially as they relate to the environment. Pentland observed that as we moved into the most recent period after about 1990, globalism and competitiveness agendas began dominating conventional wisdom and governance. Even though we claimed to be operating under the banner of sustainable development, the agenda had become the so-called virtuous circle – the assumption that global economic growth, the promotion of democratic systems and the encouragement of international trade and investment would automatically produce a self-reinforcing cycle of wealth generation, social advances and eventually ecological protection.

The conventional wisdom about governance will have to change, along with the perceived role of science in decision-making, Pentland predicted, if only because the present system is not sustainable and will be even less so in a world in which the climate is changing. Real ingenuity will be required, he said, as Canada as a nation is forced to work its way back to sustainability. We will have to catch up with our American neighbours in the areas of monitoring and pollution control, Pentland concluded, if we don't want our relations with the US over water resources to deteriorate.

In a similar vein, Ted Yuzyk of the International Joint Commission (IJC) talked about the importance of enhancing Canada's scientific capacity with respect to the joint management of transboundary waters. He explained that all of the IJC's boards relied heavily on sound science, particularly in the form of comprehensive and standardized data. Mr. Yuzyk lamented the absence of long-term standardized monitoring information.

Noting that water covers 43 per cent of Canada's 8900-kilometre border with the United States, Mr. Yuzyk identified a broad

range of transboundary issues that need to be considered jointly by both countries. These included climate change and variability, deterioration of water quality, the appearance of invasive species, water apportionment, and joint response to floods and droughts. Fundamental to addressing these issues, he reiterated, is the need for comprehensive, standardized data. We need to upgrade our models and modelling capacity with respect to changing hydrology, surface and groundwater quality and change in climate, he said.

It was interesting that the remarks of Yuzik, as one of the last speakers in the conference, mirrored those of the very first presenter: if you can't measure, it is hard to manage. Yuzyk also observed, reflecting on what Ralph Pentland had said, that in the 1990s Canada had gone the wrong direction with its water monitoring strategies. Both nations now desperately need sustained, harmonized hydrologic data, Yuzyk said, and without it there would be no assurance of good relations with our American neighbours.

Al Pietroniro of Environment Canada's National Water Survey demonstrated that real progress is in fact being made on water security problems in Canada. He began by illustrating innovative new ways of coupling inputs of research data that could vastly improve the predictive capacity of weather and climate models. Linking Environment Canada's MESH hydrology model with the Canadian Precipitation Analysis model, for example, combines different sources of information on precipitation into a single, nearly real-time analysis. Analysis is then used to improve environmental predictions, which can now include satellite observations of soil moisture.

Pietroniro went on to share progress in modelling and parameterization that had emerged from the CFCAS-funded IP3 research network. He noted that innovation and networking have allowed for measurable advances in Environment Canada's water cycle modelling system. Coupling atmospheric and hydrological systems allows for advances that are of value to the entire water resources management community. A consistent and coherent "community approach" to modelling has resulted in systematic improvements in the modelling framework. These improvements include greater efficiencies in software development and maintenance and growing

rigour in the design and development of models. These innovations can and do make their way directly into the operational systems decision-makers rely on for information, which underscores the value of partnerships between universities and governments in water and climate research. The further development of these models, Pietroniro indicated, would be central to the enhancement of Canadian understanding of – and adaptation to – future climate circumstances. It was clear, however, that the results of these technological innovations need to find their way into the decision-making process more quickly than they do today, which was the subject of the final presentations at the conference.

Slobodan Simonović offered a new way of thinking about water management in an era of climate change in central Canada. He was unequivocal in stating that climate change is real and more serious than expected. Dr. Simonović made the point that water is the delivery mechanism for many of the impacts of climate change, and that water-related feedbacks will likely be a central feature of climate change effects over much of Canada. Global warming, he agreed, will likely enhance both extremes of the water cycle. We should expect more intense droughts, heat waves and wildfires. We should expect heavier rainfall, more floods and stronger storms. Adaptation to these will demand new ways of managing water based on emerging understanding of systems dynamics.

Our current management traditions, Simonović observed, attempt to manage the environment by addressing water, land and air issues separately. Whenever we push at one point in the environment, however, it results in unexpected changes elsewhere. Dr. Simonović pointed out that this was in fact one of the fundamental features of an integrated system. This realization suggests there is a need for a broader, “systems-based” view of management options.

A new way of viewing the problem involves accepting that *interaction* between socio-economic and natural systems causes climate change. Interaction determines the entire system’s evolution. The systems approach establishes the proper order of inquiry and helps in the selection of the best course of action that will accomplish a prescribed goal. By broadening the information base of the decision-maker and providing a better understanding of the system and

the interrelatedness of its component subsystems, systems analysis facilitates prediction of the consequences of several alternative courses of action.

Dr. Simonović proposed putting hydrology at the centre of a new decision-making model where concerns related to water radiate outward to inform the way we function as a society. The creation of such a decision-making model, he concluded, would rely on science's ability to identify the tipping points that will inspire politicians to act. Like all the other speakers, Simonović had only twenty minutes. But the import of what he said radiated throughout the room. What he proposed was nothing less than turning the decision-making world on its head and putting water back into the position it once occupied of being central to who we are as a people and what we mean as a nation.

The next speaker, Dr. Hank Venema, presented findings that linked crisis and vision to future opportunity. He observed that there are presently a number of gaps in water management as it is presently practised in Canada and abroad. The water management sector, he argued, urgently requires new institutional capacity that can merge the natural sciences, the social sciences and public health concerns with engineering and public policy innovation so as to enable us to overcome the jurisdictional fragmentation that currently characterizes water governance. He also noted that the sector requires a much greater use of innovative financial and investment instruments that reinforce the values of integrated water resources management and restore natural capital.

Dr. Venema proposed that one solution would be to recast our current "commingled crises" as an opportunity to integrate climate change concerns, hydrology and water quality issues and nutrient scarcity into new economic possibilities. Venema noted that adaptation will require corporate and community collaboration at the intersection of social and technological innovation, and he illustrated how these ideas could be applied to problems associated with nutrient loading in Lake Winnipeg, currently the most eutrophic large lake in the world.

Extended forms of collaboration, Dr. Venema concluded, will have to become the norm in Canada if we are to address serious and

growing concerns related to water and climate security. We need to respond early to the storm warning, he said, so that we can minimize its impact on our future.

SEEING OUR WAY THROUGH DARK CLOUDS

Five points appeared consistently throughout the broad range of research outcomes and related presentations at this Ottawa conference. The first was that we are already seeing significant changes in the climate and hydrology of the country. The evidence is obvious and visible. Changes have been measured and observed everywhere in Canada. All the research presented suggests this could be a problem for, if not a threat to, water security.

Climate change effects largely relate to water. The problems are already serious in some areas and could have huge consequences economically, socially and politically in the future. Deep and persistent drought could devastate our agricultural sector. Groundwater overdraft will diminish our adaptability to drought. Long before warming has diminished the size of our glaciers, it will begin to reduce snowpack and snowcover, which could dramatically and directly affect water security. The Arctic as we knew it is vanishing right before our eyes. And yet – perhaps because scientists are trained to be objective in such matters – researchers act as though they are resigned to these outcomes. This resignation only serves to preserve the status quo, especially as it relates to political inaction on climate threats to water security.

It became clear through the conference proceedings that we did not have any real idea what we were signing up for when, as a nation, we decided it would be cheaper and less inconvenient to adapt to climate change rather than address it. By choosing adaptation without thinking about the consequences of the climate threat, we have been forced, without even discussing the matter, to agree that we won't mind dealing somehow with hordes of environmental refugees; conflicts locally and abroad over water supplies; the enormous costs of protecting coastal cities from rising sea levels; and huge outlays for repairing damage to our cities caused by more frequent and intense rain, snow and ice storms and floods.

By choosing to adapt rather than act on the climate change problem, we are agreeing that we accept the loss of the Canadian Arctic as we know it and that we will somehow manage through 45°C summer temperatures on the prairies and absorb the enormous economic costs associated with deep and prolonged drought that could lead to food shortages. Because we are choosing to adapt rather than respond, we have accepted that we will live with more frequent wildfire, an increase in invasive plant and animal species, and the likelihood of new diseases, all of which will result in a lower quality of life for ourselves and our children.

The second important realization to emerge from this conference was that just when we are beginning to find out what we really need to know about climate effects on water security in Canada, we are terminating critical scientific projects. The findings from research networks funded by the Canadian Foundation for Climate and Atmospheric Sciences were of national if not global significance. Over the last seven years researchers had planted a spectacular garden and now they were forced to sit by and watch as it got hauled out. The subject of disasters surfaced several times during the conference. The termination of support for the CFCAS was itself a disaster.

Another thread running through these presentations was that there is a great need in this country for more interdisciplinary and interinstitutional co-operation on research related to water. We know what we need to do to create an interdisciplinary domain, but we have to do it. As Slobodan Simonović pointed out, water is the delivery mechanism for many climate change effects. We need to use water science as a vehicle for better land-use planning and more effective management of our water resources. Better understanding of our water resources may be the cheapest, simplest and most direct way to adapt to climate change.

The fourth theme to become apparent from this conference was that there is an urgent and ongoing need for federal institutions like the CFCAS to fund network research. Individual scientists cannot, and may not wish to, concern themselves with linking research outcomes to public policy action. But backed by research networks, they can. If nothing else, presentations at this conference suggested

that more of the budget of any given project has to be committed to making research outcomes intelligible to others. Networks have to be far more directed and forceful in getting their results onto decision-makers' agendas. One wonders if this fact doesn't put into relief the need to create a whole new interdisciplinary field that could build a far more effective and durable bridge between science and public understanding that ultimately, through policy action, would lead to greater water security in Canada.

A related idea emerging from these sessions was that there is also a need to preserve an existing bridge between science, public understanding and public policy action on climate-related threats to Canadian water security. This crucial need to connect research outcomes with public policy choices was affirmed once more in the final keynote presentation. This address was offered by the only sitting politician to accept an invitation to attend the conference.

The Hon. Michael Miltenberger, at the time deputy premier and minister of environment and natural resources of the Northwest Territories, spoke about politics and water. He began by outlining the details of the Northwest Territories' new, jointly developed *Northern Voices, Northern Waters* strategy. He observed that in the context of implementing this groundbreaking water policy, the building up and passing on of knowledge about climate and water issues in the Northwest Territories were of crucial importance to his government. In this, he explained, science was not enough. He noted that politicians could not afford the luxury of the singular intellectual focus enjoyed by scientists. He went on to indicate that politicians like himself needed scientists and vice versa.

Miltenberger urged conference participants to find ways to break down silos in both science and government in Canada so as to arrive at a common vision and set of principles regarding the management of our country's water resources. Everything he had learned as minister, Miltenberger said, had told him that Canada needed a nationwide water strategy and that water security demanded the creation of such a strategy.

In closing it was held that this final Ottawa conference could be a turning point in the history of Canadian science. With the passing

of the Canadian Foundation for Climate and Atmospheric Sciences we may very well ask ourselves the following questions. Are we going to gravitate to the lowest common denominator in our response to climate change effects on our country's water resources or are we going to take charge of the problem? Are we going to be satisfied with doing less with less or are we going to properly support research that will yield answers to questions we desperately need to ask about our future as a nation? And are we going to take those answers seriously?

It may be time to recognize the urgency of these questions. The failure to do so – as was pointed out many times at this important conference – may result in our losing our way as a country and causing the loss of our place in the world. There was not a person present who wasn't dedicated to preventing that from happening.

One might wonder how far south from the Arctic, how far downslope from mountains and how far inland from the seas the effects of climate change are going to have to advance before we get serious about its potential effect on the nation's water security. The hydro-climatic time bomb we have created is now ticking loudest in the Arctic, where the landscapes that people historically held to comprise their country have begun to melt out from under their feet. It is in the Arctic that the story of water and climate security really begins and ultimately may end.

