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Robert Sandford

Taking water for granted

How our growing inability to predict droughts, floods and storms could bankrupt whole provinces.

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ESSAY

An Unexpected Water Crisis

Canada's changing climate means more droughts, floods and storms—along with less ability to predict them.

ROBERT SANDFORD

WHEREVER I TRAVEL IN THIS COUNTRY, the first question I am invariably asked is if Canada really faces a water crisis. To many, I will have to admit, the very notion is ludicrous. "How, in a land in which there is so much water," they ask, "could such a thing even be possible?" Canada is blessed with more fresh water than any other country on the planet, and if we compute it on a per capita basis, with our sparse population, our water wealth reaches stratospheric proportions.

But abundance, in this case, leads to dangerous complacency. Water experts, as opposed to the general population, have seen the warning signs for years and have attempted, mostly futilely, to catch the country's attention. They talk of population increases and industrial land use that put inexorable pressure on the water supply. They warn that surface water is now fully utilized, leaving us dependent on groundwater in the future, without protections in place to save that groundwater from contamination. They point to our aging water infrastructure—pipelines, canals, reservoirs, pumping stations—and predict public health problems for future generations (remember Walkerton?). They are particularly concerned about industrial-scale agriculture and the degradation of water that it produces. There are new contaminants—pharmaceuticals, hormones and endocrine-disrupting compounds—entering the water system every day and not getting filtered out when the water is recycled for reuse. And looming over all the experts' warnings is the vast and unpredictable canopy of climate change.

If things stay the same, none of the issues I have listed need constitute—by themselves—what could properly be called a national water crisis in Canada. There is one small problem, however. Things are not staying the same. After a century of relative stability, rising atmospheric temperatures have begun to drive changes in the rate and manner in which water is moving through the hydrological cycle. (You remember the hydrological cycle from grade school, right? Evaporation, condensation, precipitation, etc., etc.) Changes in the hydrological cycle, in tandem with our other water problems, might be the only thing that could actually create a bona fide water crisis in Canada. It is with the discovery of evidence supporting this view that my story begins.

Robert Sandford is the EPCOR Chair of the Canadian Partnership Initiative in support of the United Nations Water for Life Decade. In addition to playing other roles related to water policy nationally and internationally, he is also on the Advisory Committee for Living Lakes Canada.

NORTHERN VOICES, NORTHERN WATERS

Over the past decade the people of the Northwest Territories have found themselves confronting hydro-climatic changes they cannot easily adapt to and can no longer ignore. In addition to water-quality concerns related to upstream oil sands development, rapid loss of permafrost and changes in weather, snowpack and snow cover were becoming obvious.

Collaboration to address such issues began in 2005 and resulted in the publication of "Northern Voices, Northern Waters: NWT Water Stewardship Strategy." Water experts from across the country were then asked to comment on the strategy in an 18-city tour sponsored by RBC's Blue Water Project. An utterly unexpected outcome of the national tour was the realization that the same kind of ecological/hydrological/climatic impacts being tracked in the NWT were already affecting many other regions of this country in highly damaging ways that were not being connected with one another or with climate change.

Visiting Manitoba, we unexpectedly discovered there was a region in plain sight in southern Canada that appeared to be changing even more rapidly than the Arctic.

It was not until we were well into the speaking tour and visiting Manitoba that we unexpectedly discovered there was a region in plain sight in southern Canada that appeared to be changing even more rapidly than the Arctic. According to some experts, the region of southern Manitoba, in particular, appeared to be approaching—or perhaps had even passed over an invisible threshold into—a new hydro-climatic state that residents had been unable to cope with, let alone adapt to. At first we thought this region could be defined and confined geographically as the Lake Winnipeg Basin. As I will demonstrate, we later found out that the problem was much more widespread than that.

THE LAKE WINNIPEG BASIN

The Lake Winnipeg Basin covers 1 million square kilometres and extends over four Canadian provinces—Alberta, Saskatchewan, Manitoba and part of Ontario—and four American states—Montana, North Dakota, South Dakota and Minnesota—in the Central Great Plains region of North America. The first evidence of problems in the basin was that algal blooms in Lake Winnipeg began to grow in size over the course of each summer. Algal abundance has increased between 300 percent and 500 percent since 1900.

Algal blooms of up to 15,000 square kilometres have now begun to appear in the lake annually. The presence of such high concentrations of algae prevents light penetration and oxygen absorption, causing a condition called eutrophication. In extreme cases eutrophication can limit the amount of oxygen available for other species, thereby reducing biodiversity in a given aquatic ecosystem. Then came the cyanobacteria, a form of blue-green algae that can produce toxins in such concentrations that they can poison and even kill animals and people. Cyanotoxins can also accumulate in fish and shellfish, which then become poisonous if eaten.

The concentration of cyanobacteria in Lake Winnipeg has increased 1,000 percent since 1990. While smaller lakes everywhere, including many in Canada, have been similarly affected, Lake Winnipeg is now considered the most ecologically compromised of the world's great lakes.

Over the last 20 years, it has been scientifically demonstrated that the increased area of algal blooms and growing presence of toxic cyanobacteria in Lake Winnipeg are a warning of larger eco-hydrological problems, not just in the immediate Lake Winnipeg area but throughout the region. That fact must be combined with the major spring flooding throughout the region, which has been increasing in the past decade, setting new records. The effects in the Lake Winnipeg Basin are proving to be drastic and deadly.

Recent research shows that the spring floods create a wash effect that flushes the nitrogen and phosphorous contained in livestock and wildlife feces and farm field fertilizers from the land surface into Lake Winnipeg. The ultra-high concentrations of these substances form the nutrient supply for the algal blooms. The flooding problem has been made much worse by the draining of up to 90 percent of the natural wetlands throughout the region so as to improve agricultural productivity. These wetlands not only stored water in times of flood but were also sinks in which nitrogen and phosphorous concentrated, performing a natural ecosystem function of purifying runoff before it poured into Lake Winnipeg. Further climatic influences associated with warming are likely to exacerbate all these already existing problems.

THE URGENCY

The increased frequency and intensity of spring floods is becoming a serious problem. The floods of 2011 cost the province of Manitoba a billion dollars. Flood damages in North Dakota and Saskatchewan

were in the same range. The situation in the Central Great Plains region is so serious that it is no longer described simply as an environmental problem. The situation is now seen as a major threat to the economic future of the entire region.

There is growing concern that the cost of persistent ongoing flooding and related damages will, in time, be substantial enough to make it difficult to sustain prosperity in this region as we know it today. The risk economically is that the people of the region will not be able to afford both things: dealing with recurring disasters and addressing their causes. Parts of this region are not going to be habitable and the costs of ongoing flood damage may reach a magnitude that could easily bankrupt Manitoba.

Adaptation in the Central Great Plains is no longer an option but an urgency. How did this occur and what exactly is happening here that constitutes evidence of a potential water crisis in Canada?

The Eco-hydrological Foundations of Climate Change

The deteriorating condition of Lake Winnipeg reminds us that the changing climatic situation to which we must all ultimately adapt is, first and foremost, ecological in origin. We have changed our landscapes, in some instances dramatically. These changes have implications for how water moves on the landscape and how much evaporates back into the air and is available as precipitation elsewhere.

The situation to which we must therefore adapt is also in part hydrological in that by changing the land and withdrawing more water for our purposes, we have altered both surface flows and groundwater recharge. We are leaving less water for natural systems to use. In so doing, we have reduced the amount of water available to nature for its purposes and how much nature can purify and supply for our use.

Finally, our situation is climatic because if the land is altered and its hydrology changed, the climate invariably changes too. Civilizations before ours learned this the hard way long before fossil fuels came into common use. Lingering evidence of this lesson can be seen even today in the cradle of civilization in the Middle East and in the regions of North Africa that were once heavily forested but are now arid. In our time we are learning that if, on top of all these effects, more of certain substances are added to the atmosphere—such as carbon dioxide and methane—this combination of eco-hydro-climate change accelerates, leading to unpredictable and highly unsettling increases in floods, drought, windstorms and other environmentally devastating events. This appears to be what is now happening in the Central Great Plains region of North America.

Big Changes on the Prairies

The province that contains the upper headwater reaches of the Lake Winnipeg Basin is Alberta, where the landscape has been completely altered since the province joined Confederation in 1905. In only four generations of development, total human activity in the province now accounts for 50 million hectares. That area does not seem large given the total size of the province, but almost all that human activity is concentrated in the Central Great Plains region.

This land use is not passive. As cumulative effects researcher Brad Stelfox has pointed out, "Alberta is definitely firing on all land-use cylinders." Each year it produces up to 2 million head of cattle, 3 million head of swine, 120 million kilograms of poultry, 35 million tonnes of field crops and 25 million cubic metres of timber. In addition, Alberta produces 160 million cubic metres of natural gas, 35 million cubic metres of conventional oil, 80 million cubic metres of bitumen, 35 million tonnes of coal, and between 1,200 and 1,500 petajoules of electricity every year.

It will come as no surprise that such massive land-use changes in combination with resource production on this scale are affecting the province's water. Alberta's growing water woes include reduced surface-water flows, particularly in small streams and ponds, and reduced main-stem river flow and aquifer volume. All these concerns are reflected in the deterioration of water quality.

Few Albertans have yet to realize the extent to which their climate has already been affected by global warming in and of itself. That will come as winter and spring temperatures continue to rise. It is, however, becoming very difficult to ignore the combined simultaneous effects of early but rapid, accelerating and, in many cases, irreversible eco-hydro-climatic change.

This three-pronged change is also occurring in Saskatchewan largely as a result of similar large-scale land-use changes and the destruction of natural wetlands. With neighbouring Manitoba as well as Minnesota and North Dakota being no less transformed, these impacts accumulate and multiply as one moves downstream through the basin.

In the Central Great Plains region, the feeding and watering of the global economy have become a locally damaging proposition. These cumulative impacts produce the massive algal blooms in Lake Winnipeg. But something else is now happening. As we move toward the centre of the continent, we should not be surprised to observe that eco-hydro-climatic change is already being compounded by more extreme weather events of the intensity and duration predicted by climate models.

Unfortunately, the Central Great Plains region is unprepared for these shifts. It finds itself in a situation in which it is not moving in the direction of sustainability. Governments have been standing still while the region around them is moving toward irreversible eco-hydro-climatic change. But that, too, by necessity, is changing.

The Loss of Hydrologic Stability

To understand why additional human-caused climate warming is such a threat, it is important to understand the central role that water plays in the planet's weather and climate system. The fundamental threat that climate change poses relates to what hydrologists call stationarity.

Stationarity is the notion that there will always be approximately the same amount of water available in any given place or region as we have come to expect. Stationarity implies that seasonal weather and long-term climate conditions will fluctuate predictably within established limits. The fact that we have determined that natural phenomena fluctuate within a fixed envelope of certainty has permitted us a relatively high degree of certainty when it comes to predicting and managing the effects of weather and climate on our cities and our agriculture.

Unfortunately, that certainty no longer exists. Increased mean atmospheric temperatures are altering the patterns of movement of water through the global hydrological cycle. This means that past statistics related to how surface, subsurface and atmospheric water will act under various circumstances are no longer reliable. The situation, we have recently discovered, is a lot more serious than we first thought.

In late 2011, the National Academy of Sciences in the United States published a report entitled "Global Change and Extreme Hydrology: Testing Conventional Wisdom." It found a consensus on the fact that anthropogenic land-cover changes such as deforestation, wetland destruction, urban expansion and the pervasive impacts of water engineering in the form of impoundment, irrigation and water diversions have significant impact on the duration and intensity of floods and drought. The report observes that predictions related to major hydrological extremes are currently based on stationarity, but observations now demonstrate that notion is no longer a valid assumption. The report states that "continuing to use the assumption of stationarity in designing water management systems is no longer practical or defensible."

It is important to consider what this suggests: the old math and the old methods no longer work. This is one of the reasons forecasters were unable to predict the extent and nature of flooding in Saskatchewan and Manitoba last year. As pointed out in the "Review of Lake Diefenbaker Operations 2010–2011" following last year's flooding in southern Saskatchewan, forecasters were sometimes "overconfident in their predictive capability." They thought they could count on what they knew about the hydrology of the past half century to predict the

future. Unfortunately, the future is no longer perfectly contained in the past.

What happened in Saskatchewan, Manitoba and North Dakota in 2011 could be viewed as evidence that warming atmospheric temperatures have already begun to accelerate the global hydrological cycle that is expected to result in more frequent and severe floods and droughts. The algorithm upon which this assertion rests is one of the few hydrologic parameters that does not seem to be changing in relation to all the others as atmospheric temperatures rise. This algorithm is called the Clausius-Clapeyron Relation.

The Clausius-Clapeyron Relation

Formulated in the mid 19th century by a German physicist named Rudolf Clausius and a French railway engineer named Benoît Clapeyron, the Clausius-Clapeyron relation establishes the water-holding capacity of the Earth's atmosphere at about 7 percent per degree Celsius, or about 4 percent per degree Fahrenheit. For the man, woman or child on the street this means that, as global temperatures rise, there will be a lot more water in the atmosphere in the future and rainstorms are likely to be of greater duration and intensity.

The anticipated changes in precipitation inferred by the relation are reasonably well simulated in global climate models. We are already seeing changes. Between 1948 and 2007, the mean temperature in Canada increased by 1.3°C. Canada is now 12 percent wetter on average than it was in the 1950s. More severe weather events are already a reality. Heavy rainfall events that used to happen once every 40 years are now happening every six years in some regions.

We are not the only ones confronted by such changes and it looks as if we may have a lot more company in the future. Scientific observation has revealed some very interesting phenomena that confirm the Clausius-Clapeyron relationship. Suddenly we are aware of rare phenomena such as the *derecho,* which have always existed but have suddenly leapt into public consciousness because of the damage their intensity and increasing frequency caused this past summer in the eastern United States. These are not ordinary summer thunderstorms. These are widespread, long-lived windstorm events that cause straight-line swaths of damage 400 kilometres across. They can cause the same kind of damage inland that hurricanes cause in coastal areas.

Researchers have also discovered the presence of what are being called atmospheric rivers—monster conduits of water vapour the size of a hundred Mississippis roaming through the sky looking to deposit huge volumes of water, often on the unsuspecting. Atmospheric rivers have likely been around for eternity—but now they are overflowing their cloud banks in ways never witnessed before, producing floods of the magnitude we saw in Australia and Pakistan in 2010 and in parts of the Central Great Plains region of North America in 2011.

The New Normal

We do not yet have an adequate replacement for stationarity statistics. Until we find a new way of substantiating appropriate action in the absence of stationarity, risks will become increasingly difficult to predict or to price, not just in Manitoba, but widely.

We can expect the increasing intensity and duration of storms projected in the future to result in extensive and very costly ongoing damage to public infrastructure such as roads, bridges, dams and water treatment plants—and also to our entire built and natural environments. The costs of adapting our infrastructure to these changes are incalculable.

The Challenge of this Generation

Science cannot speak any more clearly than this. We appear to be in harm's way. Returning to the Central Great Plains example, we need to bring the Lake Winnipeg Basin back under our control before it is no longer possible to do so. The threat is not just to Manitoba. We have to realize that what is happening here could affect the entire West.

The loss of hydrologic stationarity is a societal game changer because our hydrology is on the move and we are not sure where it will stop or even if we will ever be able to expect stability again. For those who live in the Central Great Plains region, adaptation to the loss of hydrologic stationarity will be one of the greatest challenges of this generation. It is not just emissions cuts that we need to achieve to restore climatic stability. Difficult as those cuts may be, they will not be enough. We have to restore at least some elements of our natural ecosystems as well. In order to sustain its economy and provide hope for the future, the Central Great Plains region may have to be re-engineered from a hydrological perspective.

The first thing that must be done is to halt needless wetland drainage. The second thing is to support the renewal of agricultural systems that are more resilient to extreme weather events. Most of all, we have to work together to undo the damage we have already done—so that nature can work for us instead of against us. If we can achieve these goals we can protect the Manitoba economy by securing the globally important agricultural future of the West. In so doing, we might also be able to save Lake Winnipeg along the way.

The scale of such a project, however, should not be underestimated. Highly eutrophied lakes can be restored to their initial health, but it is costly to do so and it takes time. One of the most cited examples of lake restoration is Europe's Lake Constance. Located on the Rhine, the lake borders Germany, Switzerland and Austria within sight of the Alps. After it became eutrophied as a result of contaminated inflows, it became clear that agricultural runoff had to be reduced and communities in the Lake Constance watershed had to improve standards of water treatment. It was neither cheap nor easy to do so. It took €2 billion (some $3 billion) and 40 years to bring the lake back to its original condition. Lake Winnipeg is 45 times the size of Lake Constance.

Where Do We Go from Here?

All this said, the sky is not falling and the world is not coming to an end. There is no need for desperate, paralyzed resignation. With the NWT water stewardship strategy, the government of the Northwest Territories and its aboriginal and federal government partners have demonstrated that there is nothing in the Canadian federal, provincial or territorial political structure that makes it impossible to undertake the kinds of water policy reform necessary to adapt successfully to climate change. With the NWT example before us, it is no longer possible to say that such levels of reform are out of the question because of legislative, legal, policy or political obstacles. We can do it. This should be taken as really good news. Governments need not be limited to playing around at the edges of reform. They can make real change happen. Sustainability, therefore, is not an impossible goal.

The people of the Central Great Plains region are not without means. They know that true adaptation is not just survival but is a commitment to flourishing in a changed world. Some 76 percent of all disasters globally are hydrological. The most effective way to adapt quickly to the growing number of negative consequences and costly feedbacks associated with rapid eco-hydro-climatic change is to manage water more effectively.

We know what to do. Canada has advanced water technology and—for the moment at least—we can afford to employ it. We know how to restore ecosystem function, and cooperation exists at provincial and state levels in the basin to make such restoration possible. Others in Europe and elsewhere have been where we are now and we can learn from them. The time may be coming when citizens have to pay for ecosystem services such as wetland protection that can be shown to slow or moderate climate change effects. When that happens urbanites will pay others such as farmers to generate those services that will be seen to have a value equal to or greater than that of many contemporary crops.

In order to orchestrate the actions of 6.6 million people in four provinces and four states we need to remobilize at a higher and more integrated level. A wide range of interests in the basin appear ready to do just this. And the drivers behind this impetus are not only established environmental organizations but also the Manitoba Chambers of Commerce and the international Red River Basin Commission. For the first time, it is the larger economic community that is bringing this issue before government as an urgent priority—and many others are helping. What is missing is an organizing force that will bring all these interests together and synergize their efforts both on the ground and politically. But that, too, may be coming.

Does Canada Face a Water Crisis? Yes.

Does Canada face a water crisis? Absolutely, but it is not one we might have expected. While supply and quality issues plague many parts of the country, the real water crisis facing Canada is the loss of hydrologic stability that has resulted from wholesale changes in land use and a combination of natural and human-caused climate change. I have used the Central Great Plains region in the centre of this continent as this country's most dramatic example of that loss of stability, but other areas—the Arctic certainly, the northern Boreal, the Great Lakes, coastal regions on all three of Canada's oceans and the mountainous West—could all be facing similar or related problems as rising temperatures further accelerate the global hydrological cycle.

Remarkably, the realization is emerging in both scientific research and in the economic circles with which that research overlaps, that we are now, in fact, looking at what in time could very well become the beginnings of a national climate adaptation emergency.

Under less serious circumstances, adaptation might have required only relatively superficial changes to patterns of our collective behaviour. Unfortunately, the prospect of radical and irreversible eco-hydro-climatic change suggests we likely face extraordinary circumstances that will demand that we re-examine our most fundamental beliefs right down to the level of re-evaluating the relationship between where and how we live in many parts of Canada. That re-evaluation process could and should begin with a thorough reassessment of how we value water in this country—and how we ought to regard and manage the most precious of Canada's liquid assets in the future. LRC