

CHAPTER FIVE

THE GENIE IS OUT OF THE BOTTLE

Hydrological Stability Has Been Lost and There Are Consequences

As we have seen, the Canadian Foundation for Climate and Atmospheric Sciences funded three research networks that specifically examined matters related to water and climate security in Canada. These included the Western Canadian Cryospheric Network, or WC²N, which examined climate effects over time on the depth and extent of glaciers in the western mountain ranges of Canada and in the Arctic. The second, the Drought Research Initiative, investigated the consequences of major drought on the Canadian prairies between 1999 and 2005, with the aim of characterizing future risks to our agricultural economy from climate change. The third network, called IP3, undertook research into the fundamental processes that function at the very heart of hydrology, with the aim of understanding how warming temperatures may be affecting the countless interactions within and between water in the myriad processes that together make life possible on this planet.

These research networks did not operate independently. A co-operative information and data-sharing arrangement was created so that what was learned through the micro-scale research by the IP3 network could inform the larger macro-scale hydrological analyses of both the glacier research network and the Drought Research Initiative. As a result of this collaboration it was discovered that Canada's hydrology is in fact on the move and that the established conventions by which our society typically characterizes these processes are no longer adequate where warming is changing both

micro and macro relationships between land, life, water, weather and climate.

IP3 stands for Improved Processes and Parameterization for Prediction in Cold Regions. As the name implies, the research network devoted its efforts to examining what is happening at the most fundamental levels where water interacts in the environment to create the world as we know it. These interactions are known as hydrological parameters. They include, for example, the behaviour of atmospheric, surface and groundwater at various temperatures and in different types of terrain at various altitudes and latitudes during different seasons of the year in Canada. Parameters also include differences in the way water acts in various types of ecosystems, under different kinds of human influence and under a variety of solar and other conditions. In this context, researchers in the IP3 network examined subtle interactions such as those that determine how much snow gets stored on a given landscape; how it is distributed; its patterns of melt and rates of infiltration of the melt-water into frozen ground; how water that infiltrates into thick organic soils may act over time; and how all of these factors might influence streamflow and therefore affect water security.

IP3 also investigated parameters the average person maybe doesn't think much about, including the extent to which surfaces at various temperatures slow or accelerate evaporation; how seasonal differences in energy inputs from the sun affect the behaviour of both liquid and frozen water; and the biogeochemical effects of the length of time rivers and lakes are frozen in winter.

As well as being a lead investigator on his own projects, Dr. John Pomeroy was chair of IP3 and co-chair of its sister network the Drought Research Initiative. Because the hydrology of Canada is dominated by what happens to water in winter, Pomeroy explains, it is impossible to get an accurate picture of future water and security without a clear understanding of the extent of current water supply based on the weather systems that operate in cold regions at high altitudes and high latitudes. For this reason IP3 research was undertaken in nine river basins that represented the widest range of hydrological circumstances in the cold regions of the country. Work undertaken in these basins includes research

into snowpack, snowcover and redistribution at Marmot Creek in Alberta's Kananaskis Country; analysis of how snowpack patterns affected the long-term presence of glacier ice on Peyto Glacier in Banff National Park; and research into subsurface water movement at the Lake O'Hara basin in Yoho National Park. The work also included ongoing studies of streamflow and other hydrological dynamics in the Wolf Creek basin in the Yukon and in the Havipak Creek, Trail Valley Creek, Baker Creek and Scotty Creek basins, all of which are located in the Northwest Territories. Additional hydro-meteorological research was also conducted under the auspices of IP3 at Polar Bear Pass in Nunavut and in the Reynolds Creek basin in Idaho.

While by definition IP3 focused principally on the Rockies and the western Arctic, the outcomes of its research were of great interest in other parts of the country, if only because there is no place in Canada where cold doesn't somehow matter in terms of weather and climate. There was another factor as well, which made IP3's research useful not just in Canada but in many other cold countries: IP3 aimed to contribute to better prediction of regional and local weather, climate and water resources in cold regions, including river basins in which streamflow is not presently gauged. Because of our relatively sparse population, there are many places in Canada where streamflow gauges either don't exist or once were present but have been decommissioned due to government budget cuts. Such research will be particularly valuable in other expansive and sometimes sparsely populated countries such as Russia, Australia and large parts of South America.

UNDERSTANDING THE WORLD BY MODELLING ITS BEHAVIOUR

The overarching goal of IP3, which ran from 2006 until its federal funding was discontinued in 2010, was to bridge the gap between what we know happens in the real world and what we can simulate through modelling. The difference between observation and simulation is held to be one of the critical issues in contemporary science, especially in the domains of water security and climate change prediction. Until we successfully resolve this, we will not

be able to translate what we are observing through direct monitoring in the field into reliable forecasts and useful predictions of what might happen in critical hydrological scenarios as a consequence of a changing climate in the future. If we are unable to accurately simulate what we see happening right in front of us, using models that accurately represent what natural systems actually do over time, the predictions science makes about the future will not create a solid enough foundation upon which to base sound public policy on such matters as water security, infrastructure design and climate adaptation.

John Pomeroy maintains that the challenge is to choose a model that is consistent with the assumptions upon which you may wish to build. This means careful selection of the factors that influence the hydrological processes you want to simulate, so that resulting predictions mirror what is actually happening in nature. In cold regions this means modelling parameters must at a minimum include snow-melt dynamics, the influence of permafrost, how much snow is intercepted by forest canopies, and differential patterns of evaporation from bodies of cold water, frozen ground or glaciated drainage basins. These variables, Pomeroy insists, must be considered in addition to all the other fundamental hydro-meteorological parameters such as precipitation, runoff, evaporation, cloud formation, atmospheric advection and dozens of other energy and thermodynamic factors.

One does not have to be around scientists like John Pomeroy long to begin to understand just how complex nature really is. In learning which parameters are important it becomes clear that hydroclimatologists view the world differently. For them, nothing stays put and nothing can be contained in any kind of disciplinary box. Even the names of things change as the things themselves transform. Circumstance is nested within circumstance, reality within reality, with water performing different facilitating functions at each level.

The world we behold each day is not as solid as we think. It is in fact not so much a material thing as it is a complexly variable interplay of parameters great and small that only create the illusion of substance. Imagine a mirage. Reality is perfused with water and life

made possible by all the ways in which water reacts with nearly every element in the physical world. Change a few parameters in that mirage and you change the world you see outside your window.

Even the best models available today can only reveal a glimpse of the extent to which water plays a role in every aspect of the construction and maintenance of our Earthly reality over time. Some parameters, however, have huge influence over the nature and function of any given hydro-climatic circumstance. The changing of a single main parameter – temperature, for example – changes all the others. It is as if temperature and its influence on water lie at the heart of our reality. If our global temperature changes, an entire new geometry is created around that change. Alter the temperature enough and a new world will create itself around that geometry. The biggest discovery of all is that this is exactly what is happening right in front of us. Rising temperatures have begun to change a vast array of visible and invisible parameters that define the very foundation of the world as we have come to know it. And it is happening here in Canada now.

Though the value of their work has yet to be fully realized by the public, Canadian researchers participating in the linked IP3 and WC²N initiatives have collectively made astounding observations that have revolutionized our understanding of climate change in two crucial ways. The first observation is that new hydro-climatic parameters are emerging as a result of climate warming and that they are creating a new and different world. These parameters have to be understood if we are going to have any hope of determining the kinds of hydro-climatic conditions Canadians are going to have to adapt to in the coming decades. This means that entirely new mathematical descriptions of our cold regions have been developed if we are to be able to accurately predict the effects of climate change on our built environments or on the natural systems upon which those built environments depend for their stability and sustainability.

The second indisputable fact collectively observed by researchers funded under CFCAS is that hydrological systems everywhere in Canada are *already* changing. Climate change is no longer theoretical. Its effects are already being observed and clearly measured.

While hydrological circumstances have changed only slightly in some areas, these changes are highly pronounced in the cold regions of Canada. The evidence is now incontrovertible.

By examining the parameters which define the dynamics of hydrological processes, researchers have made a profound discovery. We simply do not understand all of the hydrological variables that are operative in natural systems. What's more, many of the parameters we thought we had nailed down well enough to employ in models are no longer accurate, because natural system dynamics are being altered by rising temperatures. In other words, we are basing our models on what we know about a world that no longer exists.

Something has suddenly changed in our relationship to the world as we once knew it. What IPCC and WCN researchers are collectively telling us is that the principal concern related to climate warming is not temperature itself, but the effect of rising temperatures on water in its various forms. Unfortunately, this is not a message that is getting out. One of the reasons why is that social sciences have been at war with the physical sciences for nearly forty years over what constitutes the legitimacy of science. We have to change that.

THE WAR BETWEEN SOCIAL THEORY AND THE PHYSICAL SCIENCES OVER WHAT TRUTH IS

One could readily argue that the social sciences have undermined the physical sciences on the matter of climate change in at least three significant ways. The first major assault was mounted under the auspices of deconstructionist social theory, which holds that all human knowing is in essence relative and that there are few solid facts that cannot be subjected to questioning or made the object of differences in interpretation.

The principles of deconstruction were and continue to be employed to question the legitimacy of the outcomes of hard science in ways that lead, through a range of rhetorical tricks, to the questioning of the legitimacy of science itself. The deconstructionist outcome is that no one person's opinion – no matter how qualified the person may be – is ultimately worth any more than the opinion of any other. When applied to the climate change debate this means

that opposing views continue to be held to have equal weight even if they are based solely on opinion that has no foundation whatsoever in observed fact. This has allowed our entire North American society to debate climate change as though it were an article of faith like religion rather than a fact that can actually be physically observed and measured. To the utter astonishment of the scientific community, the whole notion of even the thermometer has been deconstructed and found wanting. We are being told that whatever a thermometer might tell us bears only a contingent relation to truth. Its measurements can mean whatever you want them to mean. As a consequence, wishful thinking is permitted to carry the same weight as incontrovertible fact.

The second assault that social theory mounted on the Earth sciences was made possible through orchestration of techniques and tactics that fall generally in the domain of applied psychology. With deconstruction as a foundation, well-funded energy interests that wish to deny negative human influence on our planet's atmosphere have effectively employed the behavioural sciences to neutralize public discourse on climate change through sophisticated advertising and targeted public relations manipulation. The desired effect of this misuse of psychology was to create suspicion concerning the legitimacy of science as a means of accurately knowing the world, and to cast doubt on any consensus that may have appeared to exist within the physical sciences community regarding the causes and potential impacts of climate change.

Social theory's third attack on the physical sciences has been in the name of wealth. The vigorous misuse of psychology in the climate debate is made legitimate by the overwhelming contemporary influence of yet another social science in which all values are held to be arbitrary and relative: economics. In this field there are blistering debates on the comparative economic benefits of acting on climate change threats now as opposed to waiting to deal with the problem twenty or thirty years hence when the total wealth in the world will be greater and the hardship of action somehow reduced. While the field of economics continues to fail utterly to account accurately for the real, long-term environmental costs of today's prosperity, our society accepts its confident pronouncement that the wisest course

we can take today is to discount the value of the lives of future generations relative to our own. Furthermore, economists tell us, we don't have to worry much about the global environment or about climate change, because market pressures and human ingenuity will carry the day. So vocal, ever present and powerful are the social sciences on such matters that the moment doubt is expressed about our planet's climate future, they suck all the air out of the room with their arguments. Starved of oxygen in the absence of any new fresh air, collective societal brain function is reduced, which serves perfectly to maintain the status quo.

The global thermometer, however, is as indifferent to the psychological tricks of advertising and unrelenting public relations as it is to economic theory. The temperature readings keep coming in, but no matter how many times we check them, the picture that is forming of our circumstances and our future doesn't change. If you are actually observing the world directly rather than indirectly through what others say they think is relatively true about it, the picture doesn't look good. Our world is warming up, and at the moment at least, it looks like it is going to warm up a lot more, with consequences for everything that is important, no matter where or how we live today.

Those who have manipulated social theory in their own interest and those who have based their perceptions and livelihoods on the picture of the world created through the misapplication of psychology and the misdirection of economics may well ask how anyone can say with any confidence that the world is warming. What I can now say in response to that question is that I appreciate the scientific method more than ever and trust its outcomes more confidently on matters related to climate change as a result of five full years of carefully examining the research outcomes funded by the Canadian Foundation for Climate and Atmospheric Science.

As discussed in chapter four, what I observed was that every time another scientist challenges any aspect of contemporary climate science – and this happens continually – researchers are compelled by the long-established conventions of the scientific method to take that challenge seriously. They must re-examine all the knowledge

about climate that has been collected and validated to date so as to test the legitimacy of any given counterclaim.

Perhaps the best source of information regarding the implicate process by which science has come to consensus on matters related to global warming is Paul Edwards's book *A Vast Machine: Computer Models, Climate Data and the Politics of Global Warming*. Though it demands much of the reader, this book explains in great detail how the knowledge infrastructure related to climate science emerged from the field of weather prediction and how each challenge to what we know about our global climate system gets tested against that infrastructure. Edwards describes clearly how centuries of accumulated scientific knowledge are brought to bear on questions related to climate change and how with each challenge the entire existing knowledge infrastructure is "inverted" and recalibrated so as to ensure that no possible connection or implication is ignored in our efforts to truly understand the potential extent of warming and the impact it may have on our future.

The title of Edwards's book comes from a reference made nearly two centuries ago regarding the need for a global Earth-observing system that would allow us to accurately measure large- and small-scale changes in climate. In 1839, Edwards explains, a young British art and cultural critic named John Ruskin dreamed of "a vast machine ... systems of methodical and simultaneous observations ... omnipresent over the globe, so that [meteorology] may be able to know, at any given instant, the state of the atmosphere on every point on the Earth's surface." Today, Edwards points out, that "vast machine" is largely complete, constructed from components – satellites, computers, instantaneous telecommunications systems – that did not exist and could scarcely have been imagined in Ruskin's time.

Weather knowledge works, says Edwards, because its "vast machine" has been around a long time and has matured in its function through countless revisions of practices, countless generations of technological improvement and the endless efforts of forecasters to improve the consistency of data and the reliability of computations. Over time, the vast machine's many moving parts were lubricated with international standards, the introduction of new institutions

such as the World Meteorological Organization, the development of computers and the emergence of digital media. Edwards points out that while much “friction” remains as to the reliability of data and the accuracy of computations, the predictive capacity of current weather forecasting has improved by many orders of magnitude since the days of 19th century telegraphy.

Our current climate knowledge infrastructure, Edwards notes, is built around and on top of weather information systems. But unlike the global weather forecasting system, which is now accepted as a reliable and trusted aid to transportation, public safety and increasingly to agriculture, the way we gather and interpret climate knowledge has not receded quietly into the background of our society’s functioning. Quite the opposite, in fact. As Edwards points out, climate controversies continue to lead very publicly right down into the guts of the climate knowledge infrastructure where debates are revived again and again about the origins of particular data and how they are interpreted.

Edwards explains that there are a number of factors at play here. Beyond obvious partisan motives for stoking controversy, beyond disinformation and what Edwards believes is a very real “war on science,” debates over climate science continue for a more fundamental reason. Weather and climate are very different. Weather is what is happening now or in the next five days. Standards exist for the collection of all data related to today’s weather. Climate begins with patterns of weather that emerge over at least thirty years. In climate science, as Edwards notes, you are stuck with the data you already have, which includes numbers collected decades or even centuries ago. The people who gathered these numbers are no longer alive, so you can’t ask them under what conditions they collected their data. Climate researchers are not only faced with “data friction,” which can be defined as the struggle to assemble records that are scattered across the world. They are also confronted with “metadata friction,” or the problem of recovering the context of the data’s creation, which is to say restoring the memory of how those numbers came into existence, so as to determine their accuracy. Because climate knowledge today is subject to such high friction for both data and metadata, the contemporary climate knowledge

infrastructure never disappears into the background. It is always in view because, as briefly mentioned earlier, it is constantly undergoing what Edwards calls knowledge infrastructure “inversion”: continual self-interrogation, an endless examining and re-examining of its own past. For this reason the black box of climate history never stays closed. Scientists are continually reopening it and rummaging around for yet more information on how old numbers came into existence. This constant re-examination of how data was collected in the past results in new metadata, which in turn results in new data models and ever-changing interpretations of the past. This is why, Edwards explains, climate data is not crisp and perfect but oscillates around identifiable trends. As he puts it, this is why climate data “shimmer” rather than stand out in clear relief. This is also why differences of opinion proliferate even within a general scientific consensus on climate change.

Edwards’s point is that if you understand why climate data shimmer, and always will, then you will understand why climate predictions too will always shimmer. Once that is obvious, it becomes possible to understand and accept the proliferation of slightly different views amid general consensus in the climate research community. Edwards argues that what is preventing us from accepting the fact that different views can in fact coexist within the general consensus is the outmoded Enlightenment ideal of knowledge as possessing or leading to perfect certainty. Another reason why we as a society don’t understand how the climate knowledge system is being true to itself by not only tolerating but encouraging differences of opinion within the general consensus over climate matters is that our society is presently being influenced by a philosophical argument that has become fashionable in the past fifty years that promotes a widespread relativism that elevates virtually any skeptical view to the same status as expert judgment.

Edwards observes that in the 1960s and 1970s scholars in the emerging discipline of science and technology studies attacked what they perceived as “a technocratic elitism that elevated science above other ways of knowing and seemed to place scientists beyond the reach of moral values and democratic ideals.” Edwards admits to being part of this movement, which sought to overthrow what he

describes as “an internalist historiography of science that ignored larger contexts and questions of power.” The object of this movement, Edwards explains, was to emphasize the fact that science was a human invention subject to what these theorists called the “social construction of knowledge.”

Edwards points out that early on in this movement these notions appeared to serve a useful critical purpose. In his estimation, social constructivism correctly asserted that, whatever the explanatory power of scientific methods, scientific knowledge also depends on norms, values and aesthetic principles and on mechanisms of persuasion, challenge, agreement and evidentiary standards. Scientific knowledge therefore could not be reduced to mechanically applied methods or technical apparatus. Such methods are in essence inherently and deeply social. To understand how social values function in science, as in any other human endeavour, deconstructionist theorists argued that it was necessary to employ historical, sociological and ethnological approaches in addition to the scientific method.

It was at this point, Edwards explains, that things got a little scary. As practitioners of science and technology studies pushed these ideas further, Edwards reports, the notion that social processes are *necessary* to knowledge production sometimes blurred into the far more dubious claim that social agreement is *sufficient* for knowledge production. “Socially constructed” stopped meaning “built by people from natural materials” and started meaning something more like “negotiated collectively by social groups,” full stop. Edwards explains that it was if people thought society could stop bothering with steel or glass and gypsum and just make skyscrapers directly from blueprints, mortgages and contracts. At an extreme, this view regards physical reality as unknowable and unimportant, and the history of science as purely contingent, or dependent upon something else for its relevance. Science became little more than ideology or groupthink within which any belief at all might come to count as “knowledge.” As a result, Edwards began to observe, science and technology scholars all too often characterized all sides in a scientific argument as equally plausible, and began to see knowledge simply as the outcome of struggles for dominance

among social groups. Any outcome, any knowledge – in their view – could always, one day, be overturned.

As Edwards notes, however, this strange social theory of knowledge soon began to weaken under the weight of its own internal contradiction. As Edwards puts it, it began to commit epistemological suicide. By depicting physical reality as inaccessible and insignificant even while taking social realities – people’s views and their ways of influencing each other – as transparently and directly knowable, not to mention all-powerful, it began to rub the non-academic world the wrong way. Its relativism has come to be viewed as utterly useless for purposes of practical analysis, if not entirely incoherent. It appears that sometimes we can be too smart for our own good.

Unfortunately, however, a lot of damage was done before the deconstructionist fad began to wane and the terrible weaknesses in this kind of thinking were exposed as a dead end. Among the lingering, highly damaging results of the brief rise of social theory as it relates to science is that a corrosive suspicion of scientific knowledge still permeates our society.

It wasn’t just science that was damaged by this kind of misguided ivory-tower abstraction. It is interesting to note that the author Wallace Stegner was dismissive of deconstructionists for many of the same reasons as scientists were. In a speech he gave near the end of his life, he lashed out at deconstruction and deconstructionist criticism as it affected contemporary literature. Biographer Philip Fradkin quoted Stegner in full on this matter in his *Wallace Stegner and the American West*:

And one kind of critics, the deconstructionist magi of Yale and its colonies, have declared themselves superior to fiction, and to literature in general. It is a joke. Both it and its makers are themselves fictions, mosaics of culturally constructed myths, fragments of previous texts and stereotyped values, phatic verbiage, reverberations of old delusions, echoes of echoes. The delight of these critics is to show what shopworn stuff literature is made of and what shoddy tricks it employs.

They destroy their own justification for being, and before long, like the snake that took hold of its own tail and swallowed itself, they will vanish like all the other over-subtle and scholastic aberrations of history. Perhaps once we have had them, we will be immune, as we are after having had the measles.

In the closing pages of *A Vast Machine*, Paul Edwards notes that there have been signs recently of a return to sanity in the social sciences. Even some once ardent proponents of radical constructivism, Edwards observes, have reconsidered its wisdom. Harry Collins is a professor at Cardiff University in Wales, where he developed the Bath School approach to the sociology of science. Collins has traced the search for gravitational waves, and has shown how scientific data can be subject to interpretative flexibility and how social or “non-scientific” means can sometimes be used to close scientific controversies. Edwards reports that Collins recently proposed in an article in *Nature* that “the prospect of a society that entirely rejects the values of science and expertise is too awful to contemplate. What is needed is a third wave of science studies to counter the skepticism that threatens to swamp us all.” Collins’s “third wave” would recognize and respect the value of scientific evidence, the tacit knowledge gained from disciplinary experience, and the wisdom of expert communities. At the same time, this “third wave” would require of scientists that they “teach fallibility, not absolute truth” – recognizing the provisional character of all knowledge. This, it should be noted, is completely consistent with the ideals of the scientific method and with the notion of the proliferation of interpretations of knowledge within the general consensus regarding climate change put forward by Edwards in *A Vast Machine*.

The climate knowledge infrastructure, Edwards argues, “not only accepts the provisional character of knowledge but constructs its most basic practices around that principle.” This is the meaning of infrastructure inversion with respect to the past and of model intercomparisons as they relate to the future. Edwards notes that the Intergovernmental Panel on Climate Change has already explicitly recognized the provisional nature of climate knowledge

by accepting *controversy within consensus*, and by articulating the climate's past and its future as ranges and likelihoods, not firm black lines. He notes that since the mid-1990s the IPCC has reduced its use of quantitative expressions of uncertainty ("a 25 per cent chance" etc.) in favour of qualitative language ("likely," "very likely," "with high confidence" and so on), especially in its synthesis reports intended for a largely non-scientific audience. Such language, Edwards offers, communicates appropriate levels of trust rather than measurable "uncertainties" – which he considers a massively overused term that naturally invites a negative evaluation of knowledge quality.

Despite these improvements, however, Edwards is not optimistic about how long it might take for science to recover from the relativist attack of the social theorists. He does not see an end to the public relations onslaught that marks the undeclared "war on science" that is still very much in progress, particularly, though not exclusively, in North America. He questions the real value of social media in today's debate over global warming. While Edwards notes that blogs and citizen science do at least initially appear to increase the transparency of climate knowledge, they are not what they seem. On the surface, Edward observes, they look like another mode of infrastructure inversion in that they do extend "ownership" of the knowledge-production process, which can broaden consensus. But on closer examination, he notes, their effects are, so far, decidedly mixed. Some have contributed new insight, but at least as often such media promote confusion, suspicion and false information.

Edwards is clearly worried about the way public perception of climate change has been hijacked by self-interested public relations manoeuvres. He concedes there is a possibility that the global models contain some error of understanding, as yet undetected, that will account for the warming they all predict. Maybe, he says, their warming forecasts are just groupthink, with scientists influencing one another to parameterize and tune their models in similar but unrealistic ways. Perhaps, he admits, systematic errors in the data make global warming only apparent and not real. Maybe ClimateAudit.org, SurfaceStations.org or some successor project

will one day prove that so many monitoring-station records were skewed by so much artificial heating that really there is no warming at all, or at least none outside the range of natural variability. And couldn't it be possible too, he speculates, that the IPCC is just an elite club, just another interest group, representing a scientific establishment bent on defending its well-funded research empire? Could be, he concedes, but not likely. From his perspective such claims don't carry enough weight to be worthy of being taken seriously. There are just too many models, too many controls on the raw data, too much scrutiny of every possibility and too much integrity in the IPCC process for any of these conjectures to be even remotely likely. Edwards accepts that while knowledge once meant absolute certainty, science gave up on that standard long ago. Probabilities are all we have, he notes, and the probability that the skeptics' claims are true is vanishingly small. The facts of global warming are unequivocally supported by the climate knowledge infrastructure.

Does this mean we should pay no attention to alternative explanations, he asks, or stop checking the data? As a matter of science, he answers, no. If you are doing real science, you keep on testing every new possibility; in climate science, you keep on inverting the infrastructure. As a matter of policy, however, the answer is *yes*. In his mind the response is to bring the controversy within the consensus. You get the best knowledge you can, he advises, and then you move, or try to move, against the enormous momentum of the fossil-energy infrastructure on which the world depends. Not an easy task.

What I learned from Edwards's book is that engineering is a social science, subject to all the distortions and self-justifications that direct application to human situations causes in all applied sciences. If engineers are sociologists, then climate scientists are historians. Their work is never done. Their discipline compels every generation of climate scientists to continue to revisit the same data to correct previous misinterpretations or find some new way to deduce the story behind the numbers. Just as with human history, we will never have a single, unshakable narrative of the global climate's past. Instead we get *versions* of the atmosphere, a shimmering cloud of proliferating data images, convergent but never identical.

Edwards asks some important questions. Do we really need to know more than we know now about how much the Earth will warm? *Can we know more?* From about 275 ppm in the pre-industrial era, Edwards notes, the carbon dioxide concentration reached 387 ppm in 2008 – its highest in 650,000 years. Moreover, the *rate* of CO₂ increase is also rising, from about 1.5 ppm per year between 1970 and 2000, to over 2.1 ppm per year since 2004. At the time of this writing, in April 2015, the carbon dioxide concentration in Earth's atmosphere stood at 401.52 parts per million and was continuing to rise steeply. It is now virtually certain that CO₂ concentrations will reach the doubling point of 550 ppm sometime in the middle of this century. By 2100, concentrations could be as high as triple or even quadruple pre-industrial levels, even under optimistic emissions scenarios. Then, on the last page of his book, Edwards wrote the most troubling thing I have ever read about climate impacts on the future I hope to leave for my children.

THE MOST TROUBLING THING YOU MAY EVER READ

Paul Edwards reports that www.climateprediction.net has run thousands of “perturbed physics” simulations, varying model parameters to find the full range of possible climate futures that models predict. From the results of these large ensembles, he notes, the leaders of that project have concluded that the actual climate sensitivity might be considerably higher than IPCC estimates – perhaps greater than 6°C. And that’s just for starters, since the planet will almost certainly overshoot CO₂ doubling.

Even more important, Edwards points out that “these scientists speculate that *we will probably never get a more exact estimate of potential future climate change effects than we already have*, because all of today’s analyses are based on the climate we have experienced in historical time.” Edwards quotes Myles Allen and David Frame: “Once the world has warmed by 4°C, conditions will be so different than anything we can observe today (and still more different from the last ice age) that it is inherently hard to say when the warming will stop.” If that is true, Edwards writes, the search for more precise knowledge has little hope of success. Even more troubling is the realization that implicit in this quest for precision is

the notion that there is some “safe” level of greenhouse gases that would “stabilize” the climate. As Edwards notes, Allen and Frame’s point is that we do not know this, we cannot at the moment find out whether it is true, and now there is ample evidence to suspect it is *not* true. In other words, there is no point at which stabilization of our climate will somehow miraculously occur. One might logically expect that this would be true also of projections of global population stabilization. Such projections rely on a great many assumptions that remain untested.

Edwards makes the case that our stakes in history can be high indeed. “From family, ethnicity and nation to holocaust, apartheid, slavery and war,” he writes, “the facts of the past matter a very great deal. So it is with the history of climate, and the stakes have never been higher. Our climate knowledge is provisional and imperfect. Yet it is real, and it is strong, because it is supported by a global infrastructure ... Its large expert community long ago reached a stable consensus of the climate’s sensitivity to greenhouse-gas emissions and on the reality of the global warming trend. That consensus has survived many rounds of intensive reviews from every imaginable quarter. We have few good reasons to doubt these facts and many reasons to trust their validity.”

The climate’s past and its future shimmer before us, Edwards explains, but neither one is a mirage. When the doubts of skeptics and climate deniers are sent down time after time through the inverted knowledge infrastructure of climate science, the system of knowledge testing regenerates the same conclusions time and again. Within a small range of disagreement there is consensus about what is happening to our global climate. The climate is warming and will continue to do so for some time. How much it will warm and how quickly we can’t say and may never be able to say, until it actually happens. This is the best knowledge we are going to get, Paul Edwards concludes, so we had better get busy putting it to work.

TAKING CLIMATE CHANGE SERIOUSLY

Scientists have been telling us for some time that human activity is changing the composition of the atmosphere. Because we have

never affected the atmosphere on such a scale before, even the best scientists can't tell exactly what is going to happen. But the fact that their predictions are coming true suggests we should be paying attention to the science. Interestingly enough, we find now that almost all of these changes have something to do with water.

What scientists have been saying for nearly ten years is that the hydro-climatic conditions that are emerging in response to warming are increasingly outside the established range of what Canadians have demonstrated an ability to adapt to over the last century. We are already beginning to experience increasingly frequent, deeper and more persistent droughts. Simultaneously – and somewhat counterintuitively – we are also beginning to experience the same intense rainfall and flooding that are becoming more common elsewhere in the world.

This increasing variability is likely to become even greater in the future, which will result in extensive and very costly ongoing damage, not just to public infrastructure such as roads, bridges, dams and water treatment plants but to our entire built and natural environment. The costs of adapting our infrastructure to these changes are presently incalculable.

The fear is that the cost of this continuing damage may in time be substantial enough to make it difficult to sustain prosperity as we know it today and still keep our cities, towns, national transportation systems and other crucial infrastructure in functional repair. Take Toronto, for example. It has endured three 1 in 100 year and six 1 in 50 year storms in the last 25 years. One of these storms caused nearly a billion dollars of damage in only two hours. The same thing is happening in other cities in Canada and around the world. It is here – with the immediate prospect of more intense floods and drought, rainfalls and snowstorms – that our climate woes could really begin.

NON-STATIONARITY

Whether we like it or not, climate warming is changing the way water moves through the hydrological cycle in many parts of Canada. To understand why climate change is such a threat to established stability it is important to understand the central role water plays

in our planet's weather and climate system. The fundamental threat posed by climate change relates to what hydrologists call stationarity.

While few outside the specialized fields of hydrology and climatology presently understand the meaning of stationarity, it won't be long before the term enters public consciousness and the everyday vocabulary of people around the world. Why? Because the loss of hydrological stationarity means our world is changing, in some places faster than anyone expected and in ways that many will not desire.

Stationarity is the notion that seasonal weather and long-term climate conditions fluctuate predictably within established and predictable averages. This perceived stability permits 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. It suggests to us, for example, that winters will be only so cold and summers only so hot. Stationarity induces us to believe that melt from winter snowpacks will always contribute roughly the same amount of water to our rivers each year and that rivers will rise only so high in spring and fall only so low in autumn. Because we know the range of what to expect, stationarity implies we only have to build storm sewers to a certain size, because we know from history that rainstorms only last so long and only result in so much runoff. Because of stationarity we can estimate how much water will reliably be available for hydropower generation or mining or hydraulic fracturing or other water-intensive energy projects such as oil sands.

Stationarity reassures us that sea levels will change only very slowly; that hurricanes will be of predictable intensity and duration and follow established tracks; and that tornadoes will only form in the most extreme conditions of the weather we have come to know and expect. This signals to us that we only have to build our structures to withstand winds of a known velocity, that our roofs will stay on if they comply with established building codes and that the cost of construction will be limited to what is required by those codes.

Stationarity also suggests that lightning will strike only so

frequently and that water's symbolic and diametric opposite, fire, will burn only so much of our forests each year and will do it at times and at temperatures we can predict. From this we can infer how close to surrounding forests it is safe to build houses and that insurance policies can be arranged to cover those instances when the threat of fire exceeds known and predictable norms. In short, a reliance on stationarity statistics keeps the costs of disasters within limits we can predict and afford.

What is happening now, however, is that increased temperatures are altering the patterns of movement of water through the global hydrological cycle. This means that the statistics from the past as to how surface, subsurface and atmospheric water will act under a variety of circumstances are no longer reliable, which means we can no longer be sure that the volumes of water that were available to us in the past will be where and when we want them to be in the future. What IP3 researchers discovered, moreover, is that these statistics haven't in fact been reliable for some time.

Hydrologists observe that, in actual fact, stationarity in global hydrological conditions has likely never really existed, in that the climate is always changing, and that what we have actually done is established our own idea of the range of natural climate variability we think exists. We then constructed our society and all the infrastructure that supports it – including the risk assessments associated with maintaining that infrastructure – to fit within that range. Over time, this mistake in itself was bound to make us vulnerable, but now accelerated climate change is compounding that vulnerability and multiplying our risks.

The claim that we ought not to be concerned about this, because Earth's climate clearly has warmed to a similar or even greater extent in the past, is irrelevant in this context. The problem is that while our climate has changed in the past, it has not done so as quickly as it is changing now – at least not while there were seven billion people relying on out of date or poorly maintained infrastructure and living in stationary cities that were designed for climatic norms that no longer exist. Nor have humans experienced such changes at a time when the civilization they lived in was at the very limits of agricultural productivity and water supply globally.

By warming our climate we have torn open the fixed envelope of certainty within which we anticipated natural phenomena to fluctuate. In a very real sense the genie is out of the bottle, causing droughts, storms, floods and widespread pandemonium. As a society we have wasted four decades listening to arguments that these things wouldn't happen and that if they did we could easily adapt to them. And now we find ourselves almost completely unprepared for what is in fact happening.

The problem we face is that we do not as yet have an adequate replacement for stationarity statistics. In a rapidly changing climate such statistics become a moving target. 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. These risks, we discover, start small but quickly grow in terms of both potential impact and cost. Let us consider an example. How many culverts do we have in Canada? No one knows for sure, but they number in the millions. Under even the most moderate climate change scenario, how many might we have to replace? How about bridges? Roads? What will all this cost – and who will pay?

It is surprising, given these circumstances, that throughout Canada we are still thinking linearly about climate change. We still think the effects of it will be local, minor and cumulative, when in fact it will not be long before climate change will be affecting everyone everywhere simultaneously, compounding every regional economic, social and political disparity all at once. What we have collectively done over time is that we have quite accidentally – unwittingly, in fact – created a hydro-climatic time bomb. It is a bomb we have to defuse.

While the policy implications of this discovery suggest dark clouds forming in the direction of our future, this does not have to end up being an unhappy story. The implications of the IP3 realization that we have entered a period of non-stationarity do not by any means mark the end of the world. They only mean the world is changing.

If we are not able to contain the rate of change, the loss of hydrological stationarity will over time have serious consequences in many parts of Canada. The premise of this book is that we should be

dealing seriously with emerging problems related to this loss of stability now, while time and prosperity are on our side, so that as our population grows and our climate changes, our social and economic future will not be limited by water quality and availability problems we could have and should have addressed in better times. What this discovery suggests is that it is time Canadians changed their attitude toward water.

The loss of relative hydrological stationarity means that more than ever we need baseline information, not just about the state of our water supplies themselves but of the basic eco-hydro-meteorological conditions that comprise the hydrological cycle as it functions in Canada. Over time there has been a serious decline in surface and groundwater monitoring as well as water research. While Canada used to be a world leader in these areas, cuts to government funding have resulted not just in a loss of leadership in these important domains but a great reduction in our own capacity to acquire and share water data and other information necessary to support climate change adaptation, especially in relation to our groundwater sources, of which less than 20 per cent are currently mapped. Commenting on this issue a decade ago, the Standing Senate Committee on Energy, the Environment and Natural Resources stated: “Clearly we cannot manage and protect that which we do not properly understand. When it comes to water, there are still too many questions to which we do not yet have satisfactory answers ... This information gap is more than regrettable; it is unacceptable. This stems in large part from the Government of Canada’s retreat from water management issues and from funding relevant research.”

More recently, the fall 2010 report of the federal Commissioner of the Environment and Sustainable Development echoed the Senate committee’s stance: “... [Environment Canada] is not monitoring water quality on the majority of federal lands ... and does not know whether other federal departments may be monitoring water quality or quantity [there] ... The Fresh Water Quality Monitoring program does not validate the quality of the data it disseminates ... [thus the program] cannot assure that the monitoring data ... is fit for its intended uses ...”

Given the clear evidence that Canada's hydrological system is no longer stationary, the fact that we are now cutting rather than enhancing baseline monitoring capacity would appear to be nothing less than irresponsible. While there have been some improvements in various regions after recent flood disasters, the need for adequate monitoring still demands a great deal of attention.

We are not alone in facing these kinds of problems. Our neighbours to the south are facing challenges too, many of the same ones we will encounter as Canada's population continues to grow.

STOP POLLUTING THE WATER WE HAVE

In his 2011 book *The Ripple Effect*, Alex Prud'homme observes that the Clean Water Act in the United States was violated some 506,000 times between 2004 and 2009, but that less than 3 per cent of the violations resulted in any form of punishment. During the same period, the quality of drinking water in every state deteriorated as a result of violations of the Safe Drinking Water Act. One study revealed that the tap water in 45 states and the District of Columbia was contaminated by no fewer than 316 different pollutants, including the gasoline additive MTBE, the rocket fuel component perchlorate and industrial plasticizers called phthalates. Some 49 of these substances were found to be in excess of safe drinking water standards, meaning 53 million Americans had unsafe drinking water. Bottled water apparently did little better. One study demonstrated that bottled water purchased in nine states and the District of Columbia contained traces of 38 pollutants including fertilizers, bacteria, industrial chemicals, Tylenol and potential carcinogens. The point Prud'homme makes is that while industry associations may argue that such findings are exaggerated, we do not as yet know what cumulative effect water-borne compounds containing such diverse substances as sewage, plastics, pharmaceuticals, cocaine and Viagra will have on aquatic ecosystem health. All this is happening at a time when global demand for water will outstrip supply by 2030. Little, if anything, has changed in the years since these findings were published.

Prud'homme notes that the US Congress overrode President Nixon's veto to pass the Clean Water Act in 1972. This law limits

pollution, sets water quality standards and penalizes violators. Right-wing political interests in the United States have been trying to reduce the CWA's power or eliminate it completely ever since it was passed. Prud'homme points out, however, that the biggest threat to water in the US is not huge oil spills such as occurred in 2010 in the Gulf of Mexico, but rather the myriad tiny leaks from cars, trucks, motorcycles, lawnmowers, boats, planes and other machines that rainwater routinely washes into sewers to end up in rivers, lakes and oceans. Prud'homme cites a 2003 National Research Council study that indicated that North Americans dump more than 300 million gallons of oil into their waters every decade, nearly double the highest estimate of BP's Deepwater Horizon spill in the Gulf of Mexico in 2010, which has been characterized as the worst environmental disaster in American history. The NRC report estimated that some 4 billion gallons, or about 15 billion litres, of oil leaks into the world's oceans every decade, more than 25 times the volume of the BP spill. As a litre of oil can easily contaminate as much as 5000 litres of water, this is not a small problem. As Prud'homme puts it, "the really big spill" is happening every day – all around us.

Neither cities nor bottled water companies, Prud'homme reports, test for pharmaceuticals. The Associated Press has estimated that the healthcare industry alone sends 250 million pounds of pharmaceuticals down the drain each year. The fear here is not just that hospital waste carries more antibiotics and germs than domestic waste. Researchers are also worried that the dumping of drugs into water systems could lead to genetic mutations that create antibiotic-resistant pathogens. This, Prud'homme reports, is not just dystopian paranoia. He cites research done in France at the University of Rouen Medical Centre which found that of 38 wastewater samples, 31 contained chemical compositions capable of mutating genes. Prud'homme also cites an Italian study that concluded that even trace elements of pharmaceuticals in drinking water – a few parts per trillion – "can significantly inhibit embryonic cell growth in vitro." Research in Germany confirmed the conclusions of the Italian work, as did later studies in the United States which also demonstrated that recycled water contains small amounts of pharmaceuticals and steroids – antibiotics, birth-control hormones,

anticholesterol drugs, Valium and Viagra, among other things. It has been shown that some of these substances are resistant to even our most advanced three-stage water treatment processes, which has called into question the safety of using the recycled “grey water” that is increasingly mixed with natural supplies. One study of treated drinking water discovered high concentrations of a drug associated with the production of cocaine. Another in the United States found high concentrations of toxic substances associated with the illegal production of methamphetamines. In California, Prud’homme reports, poisonous chemical discharges from meth manufacturing have killed livestock, polluted streams and destroyed forests.

Prud’homme points out that while scientists have largely concluded that trace amounts of pharmaceuticals may not present a health hazard to human beings, little is known about the cocktail effect of many such drugs on aquatic ecosystem dynamics and on individual species, such as frogs that ingest Prozac, mosquitoes exposed to anti-seizure drugs or fish swimming amid what to them are physiology-altering concentrations of synthetic estrogen.

Studies in both North America and Europe have revealed that estrogen and other endocrine-altering substances exist in high enough concentrations to result in egg formation where the testes should be in male fish. In 2005 a United States Geological Survey researcher, Dr. Vicki Blazer, discovered that over 80 per cent of the male smallmouth bass she examined in the Potomac and other rivers in and around the District of Columbia were affected by endocrine-induced intersex characteristics. Since then, “feminized” male fish have appeared every year in the watercourses under study. A later, broader study that examined 16 fish species at 111 sites found that intersex affected a third of all male smallmouth bass and a fifth of all male largemouth bass. Research conducted by Leland Jackson at the University of Calgary showed similar effects on long-nosed dace. More and more evidence suggests that the principal cause of the intersex characteristic was synthetic estrogen from pharmaceuticals such as birth control pills, agricultural runoff loaded with pesticides and industrial drainage heavy with plastics.

Prud’homme cites a Canadian study undertaken in 2007 in the

Experimental Lakes Area in Ontario where the renowned eco-toxicologist Dr. Karen Kidd added a small amount of ethinyl estradiol, one of the active ingredients in birth control pills, under controlled circumstances to a small lake. The introduction caused the feminization of most of the fathead minnows in the contaminated ecosystem. As a consequence, the minnows were unable to reproduce properly and the population was nearly wiped out.

The research conducted by Blazer in Maryland, Jackson in Alberta and Kidd in Ontario point to the same conclusions. If these substances are affecting the endocrine systems of fish, which are similar to that of humans, are we not now or could we not in the future face the same kinds of negative health effects as these fish?

Prud'homme points to additional work that suggests that manufactured chemicals released into our water and air may in fact be the cause of a surge in serious health issues such as breast cancer, leukemia, asthma, neurodevelopment disorders and physiological changes. He also notes well-documented findings that Western women, on average, are beginning puberty five years earlier than they did two centuries ago and are entering menopause later.

Prud'homme goes on to cite the work of Dr. Robert Hirsch, chief hydrologist of the US Geological Survey, who is of the opinion that a river is like a urinary tract. Just as physicians examine a patient's urine to determine what is happening physiologically in their body, analysis of river water – its chemistry, sediments and pollution – makes it possible to assess the health of a river's entire basin. That, Hirsch pointed out, makes hydrologists the nation's urologists. At a time of changing hydrological stationarity, this may prove to be very true – or at least it should be. Unfortunately, that is not turning out to be the case.

Environment Canada and the US Environmental Protection Agency share a common history. Both flourished in the 1970s, soon after they were formed. Since the late 1980s, however, both have suffered long, slow decline. Underfunded, overly politicized and widely dismissed as either toothless or irrelevant, each of the two environmental agencies suffered huge staffing cuts and became increasingly ineffective during right-wing administrations in the early twenty-first century. The EPA lost of great deal of its

power and credibility during the two terms of George W. Bush, and Environment Canada lost similar ground while Stephen Harper formed successive minority governments followed by a majority in 2011. Both agencies today face the same limitations of jurisdiction and capacity in important areas related to water.

THE STATE OF OUR WATER INFRASTRUCTURE

The most pressing global water governance issue is infrastructure development, operation, maintenance and replacement. If we count the world's unserved – that is to say those who do not have reliable access to high-quality drinking water and sanitation – we are facing a multi-trillion-dollar water infrastructure deficit globally. In early 2015 the United Nations reported it would take investment of between \$1.9- and \$2.1-trillion a year for the next 20 years to supply clean water and sanitation to the billions of people presently without these services. This amount, it should be noted, is roughly equivalent to the subsidies provided to the oil and gas sector globally.

While we know that conservation is no longer an option, we have yet to satisfactorily define the water pricing and conservation measures that need to be put in place so as to free more water to be generally available for minimum human use and other purposes now and in the future.

The institutional mechanisms we have in place in Canada to pay for the orderly operation, maintenance and replacement of our crucial drinking water and sewage treatment infrastructure are inconsistent and won't hold up over the long term, especially as the hydrology of the country continues to change.

It would not be unreasonable to suggest that we have a three-tier system in Canada, each with a different set of rules. The first tier is the system that provides water to First Nations. That system is not working.

The second tier is the one that provides grants for infrastructure development in small communities and rural municipalities. Unfortunately there is no assurance that infrastructure grants will actually be directed toward crucial water infrastructure. Neither is there is any real incentive to manage such systems efficiently and

sustainably. Success at this tier, therefore, is hit or miss. In this observer's estimation, operating this way is a recipe for growing infrastructure deficits. Because of the increasing presence of endocrine-altering substances and other new chemicals in our water, treatment standards are on the rise. Either you keep up or sooner or later you will face the political and legal-liability consequences of non-compliance.

Only at the third tier – where municipalities have priced water to ensure conservation gains and have instituted full-cost recovery and comprehensive asset management strategies – do we find the foundation for sustainability. But even in the domain of large municipalities there are problems.

Alex Prud'homme explores these big-city infrastructure issues at some depth in *The Ripple Effect*. Urban runoff, he argues, is even more daunting a problem than the pesticide and nutrient runoff facing rural communities. Because there is so much cement and pavement in cities, precipitation is not well captured. Moreover, the water-related infrastructure in many municipalities is old and leaky, and sewers designed for an earlier, more stable climate are easily overwhelmed by intense cloudbursts or prolonged rainfall. While cities do a better job than rural areas in separating human and industrial effluent, sewage treatment requires a great deal of energy, which adds to climate warming, which leads in a vicious circle to ever more intense storms. Most of North America's sewer network, Prud'homme points out, was built in the 19th or 20th century and is in poor condition. Contemporary urban water infrastructure here, Prud'homme notes, has been compared to a ruptured appendix – an overburdened system that is struggling to keep functioning and remain clean.

Not only are many urban water systems in desperate need of repair, many are also under assault from changing weather patterns. The sewer system for the City of New York, for example, is designed to accommodate a once-in-five-year storm – that is to say a rain-storm of an intensity that in the past was only expected to occur twice a decade. But weather patterns and storm tracks are changing. In 2007 alone, New York experienced three once-in-25-year storms – storms so intense they are expected to occur only once

in a quarter of a century. The problem goes far beyond visible surface flooding, which obviously can cause tremendous harm in itself. Heavier than normal rainfalls also damage expensive infrastructure that you can't see because it is below ground. Such high-velocity flows can literally erode away whole sewer systems, as was demonstrated in Toronto in 2008 when a single heavy rain caused some \$550-million worth of infrastructure damage in less than two hours. In such events, water treatment plants must be shut down or they fail. And when that happens, the combined outflows of domestic sewage, together with all the contaminants picked up by floodwaters and carried through the sewer system, get discharged untreated into downstream watercourses, producing both pollution and public health risks that persist long after the flood recedes.

Municipal water managers have discovered that even with expensive improvements to sewage systems, there is no way to stop the effects of combined sewer outflows in extreme weather. The replacement of combined systems with "two pipe" systems that separate domestic sewage from stormwater outflows is astronomically expensive and often publicly unacceptable because such improvements, as again clearly demonstrated in Toronto, often require tearing up entire neighbourhoods. Prud'homme notes that the US Government Accountability Office has estimated it would cost \$400-billion just to bring the nation's sewer systems back into fully effective function. No one knows what it would cost to upgrade those systems so they can respond to the new conditions created by changing weather patterns and more intense rainstorms. This means that for the foreseeable future at least, cities and the people who live in them are sitting ducks when it comes to extreme weather events which are expected to occur more frequently as our hydrological circumstances continue to change.

SAVING OURSELVES BY SAVING WATER

It could be said there is a silver lining in the discovery of non-stationarity in our hydrological cycles. We have taken water for granted for so long that we no longer think about how much we use or waste. We are among the world's worse water wasters. Under changing

hydrological conditions we can no longer afford this luxury. Good can come out of this, however, if it stimulates water conservation.

One of the most startling revelations during the two years I spent travelling across the country examining and comparing water policy is how touchy Canadians are in defence of our culture of utter water waste. No one appears to be in any hurry to change, and today's political leaders by and large do not want to force anyone to do so. That is why reliance on engineering solutions to water issues is so popular. Even if such measures don't solve the real problem, they appear to make everyone happy. And that is what we want.

What has happened as a result is that we have accepted and encouraged wasteful water use as a social norm. We have, at enormous cost, overbuilt water infrastructure to support this wasteful norm. Now we find we cannot afford to maintain and replace all the overbuilt infrastructure that supports that waste, which increases the risk of public health disasters such as occurred at Walkerton, Ontario, in 2000. We have also discovered that we waste enormous amounts of energy treating and moving water. The cost of this energy is now rising and we are discovering we can't afford to spend up to 60 per cent of municipal energy budgets to keep doing this. In addition, we have realized that the energy we are wasting by wasting water is also accelerating climate change, which in turn is starting to pound the hell out of the infrastructure we can't afford to maintain and replace.

The situation must be seen for what it really is: an obvious vicious circle that is simultaneously bankrupting us while compounding climate change effects. This cycle will accelerate until we stop wasting both water and the energy it takes to treat the water and move it to the places where we waste it.

One of the biggest obstacles to change is that we have come to believe our own public relations spin. All across this country we have been telling ourselves for decades that our management of water is world class. Simply saying this, however, doesn't make it so. Strategic planning goals are just goals until you actually achieve them. One of the reasons we have been able to make exaggerated claims of our own success is that we largely compare ourselves only to ourselves.

At the time of this writing, average municipal water use in Canada was about 329 litres per person per day. Most of the countries in the European Union are at about 140 litres. Singapore is at about 125. The world champion right now, however, is Munich, at 100 litres per person per day. My question is this: Are we not deceiving ourselves just a little in claiming we are leaders when even our best average municipal water consumption is still three times that of the real leaders, who live in climates similar to ours in countries just as prosperous as ours and with a standard of living just as high?

The rest of the developed world has begun to act on the realization that municipal conservation is central to water and energy security, and that appropriate pricing is the most reliable means of achieving conservation of both. Recent statistics suggest we are now pulling ahead the US as the greatest water guzzlers in the world. In the middle of our continent is a vast semi-arid interior that most climate models say will likely get drier over time. Given our vulnerable circumstances, shouldn't we set our water conservation targets higher? Just the energy savings alone would be worth it.

The other thing we like to do in Canada is compare ourselves provincially to the rest of the country. Sure, any province can call itself a leader in water management in Canada, but what does that actually mean from water's perspective? Let's compare some of the provinces. British Columbia has existed as a jurisdiction for nearly 150 years, but it is only now introducing groundwater legislation. Saskatchewan has destroyed so many of its natural wetlands that it can no longer protect itself from flooding. Manitoba is now home each summer to algal blooms on Lake Winnipeg of up to 15,000 square kilometres, creating one of the largest freshwater dead zones in the world. Let's go to Ontario. After passing progressive legislation and spending billions to clean up industrial pollution, the province is now seeing the Great Lakes becoming contaminated again by agricultural runoff and urban stormwater pollution. Let's go to Quebec and talk water infrastructure. Montreal loses 50 per cent of its treated water to leaks. Its dilapidated water infrastructure puts it in the same category as cities in the developing world. Think of the energy waste. The Atlantic provinces too have these same problems to various degrees, plus one other: in Nova Scotia, New Brunswick

and Prince Edward Island, sea level rise is an additional threat to water supply and infrastructure security.

Speaking here on behalf of water, one might ask if anyone in authority would wish to comment honestly and objectively on the state and fate of our country's aging pipelines? Let's look at ground-water across the country. In some places, contamination is so widespread that we are poisoning aquifers we share with the United States. But pointing fingers is not our purpose here. The goal is to understand that we are not doing as well as we think. Just saying we can do better is not enough. We have to *do* better, and there are sound economic and environmental reasons for that.

By conserving water, we can make more of it available for nature and for future generations of people. By conserving water we can reduce the size and cost of our water infrastructure and free up resources that will allow us to catch up on the maintenance of worn-out infrastructure. By conserving water we can save a fortune in energy costs presently borne by the public to move water to where we waste it. By saving energy costs in wasting less water we reduce our greenhouse emissions, thereby slowing the very climate effects that are altering the hydrological cycle at the same time they are hammering our infrastructure. In this way a virtuous circle can be created in which we save water, save money, save energy and moderate climate change all at the same time. In so doing we also increase our capacity to adapt effectively to the changing hydrological conditions that are now emerging. This is simply too good an idea to ignore. In the end this could be a very happy story. Head-turning economic savings can accrue to governments and the public by way of water conservation. Breaking the combined water and energy waste cycle will save Canadians billions of dollars in direct infrastructure costs in the future while at the same time moderating climate effects on the vulnerable infrastructure that exists today. Saving money by conserving water may be one of the most intelligent adaptations we can make to the climate-related loss of our nation's hydrological stationarity.

