Chapter 8
Climate Change, Adaptive Capacity, and Governance for Drinking Water in Canada

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8.1 Introduction

Water managers have always had to deal with daily, seasonal, and annual changes in precipitation, stream flows, lake levels, and other characteristics of the water cycle (McDonald and Kay 1988; Cech 2003). A key factor contributing to their ability to successfully adapt has been the *predictability* of climatic variability (Kabat and van Schaik 2003). To illustrate, although individual flooding events could not be accurately predicted, the frequency and expected magnitude of floods was knowable based on the observed record of past flood events. Knowing how often floods of a certain magnitude can be expected in a particular area allows – in theory at least – for the design of appropriate responses to the flood risk.

The tendency of natural systems to fluctuate within a predictable envelope of variability is known as *stationarity*. Unfortunately, as Milly et al. (2008) have noted, the assumption of stationarity in the context of climate change is no longer valid. Anthropogenic climate change has already produced measurable changes in patterns of precipitation, evaporation, and runoff. Anticipated future changes in these variables are highly likely to fall outside of the observed range of variability. Even aggressive mitigation of CO_2 and other greenhouse gas emissions will only slow the rate of climate warming (Intergovernmental Panel on Climate Change (IPCC) 2007). This means that a new "predictable envelope of variability" is

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unlikely to emerge (Bergkamp et al. 2003; Bates et al. 2008; Milly et al. 2008). Milly et al. (2008) refer to this situation as the "death of stationarity".

The implications of the death of stationarity for water management are profound. Simply put, past capacity to adapt to the observed climatic variability should not provide confidence in future adaptive capacity. Water managers may have to find ways to deal with much greater complexity and uncertainty than has previously been experienced. How do we cope in this new environment? Milly et al. (2008) suggest that the answer is to improve the sophistication of modeling. They argue that "We need to find ways to identify nonstationary probabilistic models of relevant environmental variables and to use those models to optimize water systems" (Milly et al. 2008, p. 573). Improvements to modeling capabilities certainly will be an important part of any strategy to adapt to the impacts of climate change on water resources and human societies (Kundzewicz et al. 2007). However, in an environment where water management increasingly takes place through collaborative governance involving a shifting mix of state and nonstate actors (de Loë and Kreutzwiser 2006), technological innovation cannot be the only focus for adaptation. Instead, it is also essential to strengthen the capacity of organizations, communities, and societies to adapt to the climate change (Ivey et al. 2004), and to address pressing concerns relating to governance.

Canada provides an ideal context for exploring these concerns. The water management challenges being faced in different parts of the country are extremely diverse, and capacity for addressing those challenges is highly variable. Climate change is expected to have profound impacts on Canada's water resources, with attendant threats to socio-ecological systems (Lemmen et al. 2008). And, importantly, water governance in Canada is in flux, with the roles and responsibilities of state and nonstate actors shifting and changing as new, more collaborative and distributed approaches to governance are adopted (Plummer et al. 2005; de Loë and Kreutzwiser 2006). Hence, Canada's experiences offer insights pertinent to many parts of the world.

In this chapter, we explore challenges associated with adapting to climate change in Canada in the context of drinking water. We adopt the integrative perspective promoted in the introduction to the book. Hence, in the next section, we draw on literature pertaining to climate change adaptation, complex systems, and water governance to identify key concerns that emerge through synthesizing insights from these areas. These concerns are then explored in the context of drinking water supply in two very different settings: urban water supply in small and large centers; and drinking water quality in Aboriginal communities. Exploring the complexity of climate change adaptation from the perspective outlined in the next section permits for nuanced insights into the challenges faced, and highlights the significance of governance.

8.2 Adaptation and Adaptive Capacity

In climate change research and policy making, a distinction normally is drawn between *mitigation* and *adaptation*. The former involves efforts to reduce the greenhouse gas emissions that produce climate change. The latter refers, in the language of the IPCC, to "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Parry et al. 2007, p. 869). Adaptation involves countless actions by governments, individuals, firms, and nongovernment organizations. These can be grouped according to intent, timing, and scope (Smit et al. 1999; Lemmen et al. 2008). In the context of the water sector, numerous adaptation options have been identified. For example, in reference to the challenge of providing water for human uses, adaptation options on the supply side could include expanding storage, desalinizing sea water, capturing rainwater, and prospecting for groundwater. On the demand side, options could include recycling water, expanding water markets, implementing agricultural water management measures, and increasing use of water efficient fixtures (de Loë et al. 2001; Kundzewicz et al. 2007).

In many respects, climate change "adaptation options" such as these are tools that have long been part of the water management toolkit. For example, dams and reservoirs have been used for millennia to capture water when it is relatively abundant so that it can be used when it would be scarce under natural flow conditions (McDonald and Kay 1988). Addressing water shortages in urban, agricultural, and industrial settings by influencing demand is a recent approach when compared with millennia-old supply-focused approaches. Nonetheless, adaptation to water scarcity through demand management techniques has been part of contemporary water management for several decades (Vickers 2001).

From historical perspective, water managers have made considerable progress in addressing problems relating to sanitation, water supply, water quality contamination, flood plain management, and, more recently, the effects of human development on ecological systems. Perhaps the best example in support of this claim can be found in the history of drinking water supply, where improvements in treatment technologies and practices have led to tremendous improvements in the quality of life (e.g., Melosi 2000). Unfortunately, a recent report of the United Nations World Water Assessment Program (UNWWAP) (2006) reinforces the fact that significant water-related problems persist in all parts of the world. More seriously, as noted earlier, the impacts of climate change on all aspects of the water cycle will be so pronounced in most regions and in most contexts that techniques and practices used with some success to date will not guarantee successful adaptation in future (Kabat and van Schaik 2003; Kundzewicz et al. 2007). The death of stationarity is a significant contributing factor. However, the problem is much more fundamental. Simply put, climate change is expected to overwhelm the *capacity* of those involved in water management to adapt (Bergkamp et al. 2003).

In the climate change field, the concept of adaptive capacity is conventionally defined as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2007, p. 21). Importantly, in IPCC literature relating to water, adaptive capacity is commonly treated in an insular and relatively narrow fashion. For example, the IPCC's Fourth Assessment Report is a review of the international state of the art relating to mitigation and adaptation. To their credit, the authors of the water chapter (Kundzewicz et al. 2007) identify key constraints on adaptive capacity, including the following: the nature of the water resource itself; minimum societal needs; insufficient financial resources; political or social constraints; and a set of system-related capacity-limiting factors including ineffective governance, lack of coordination among agencies, and interjurisdictional tensions. However, these critical concerns are dealt with in a cursory fashion. Instead, the adaptation challenge is framed predominantly in terms of the need to improve models and techniques for dealing with risk and uncertainty (Kundzewicz et al. 2007; Bates et al. 2008).

A broader, more integrative perspective on the challenges of adapting to the impacts of climate change in the water sector is clearly needed. We suggest that resilience, flexibility, and adaptability are preconditions for making robust decisions that can respond to changed conditions. This is a position that the authors of the IPCC's Fourth Assessment Report water chapter themselves have briefly acknowledged (Kundzewicz et al. 2007).The complex systems perspective promoted in this volume can provide insights that complement the climate change adaptation literature. The challenge is to find a way to bridge the different literatures effectively.

Fortunately, the water management literature can provide that bridge. For example, there is a long tradition in the water field of considering the factors that shape the capacity of countries, organizations, and communities to provide water services and to protect water resources (e.g., Cromwell et al. 1992; Biswas 1996; Franks 1999; de Loë et al. 2002). This literature is directly pertinent to understanding adaptive capacity relative to climate change. At the same time, authors in the water field have been concerned specifically with questions of adaptability and resilience for over a decade. For example, in the 1990s, a small number of water researchers were drawing on the concept of Adaptive Environmental Assessment and Management (AEAM) to conceptualize new ways of dealing with problems relating to water quality (Grayson et al. 1994) and flooding (Sendzimir et al. 1999).

The impact of AEAM thinking on the mainstream water literature in the 1990s was quite modest. However, concern for complexity and uncertainty, and recognition of the importance of adaptability as a precondition for effective water management, also developed on a separate path that is having a more enduring impact. For example, Geldof (1995a, b) is among the earliest proponents of a nonequilibrium approach to water management. He argued that integrated water management (IWM) displays all the characteristics of a complex adaptive system (i.e., networks of agents acting in parallel, many levels and scales of organization, characterized by perpetual novelty). Instead of the static perspective prevailing in IWM, Geldof argued that *adaptive* water management, which embraced complexity and uncertainty, was needed.

This perspective is becoming more prominent in the water literature (Pahl-Wostl and Sendzimir 2005; Pahl-Wostl 2007). The Global Water Systems Project, for instance, defines the global water system as encompassing human, physical, and biological components and their interactions (Pahl-Wostl 2007). Impacts of climate change on water have prompted concerns about the robustness of water systems to perturbations and their ability to recover (e.g., Fowler et al. 2003). Attention is increasingly directed toward social–ecological resilience, which is concerned with the amount of disturbance a system can absorb and remain in relatively the same state, the extent to which the system is able to self-organize, and the degree to which the system can build capacity for learning and adaptation (Folke et al. 2002; Folke 2003).

Research conceptualizing the water system in terms of complexity and uncertainty provides a conceptual foundation for enhancing understanding of adaptation evident in the mainstream climate change literature. Hence, synthesizing insights from the IPCC-oriented climate change and the complex systems literatures is worthwhile. Other recent efforts in this direction include a 2003 study by the IUCN-The World Conservation Union (2003). In considering the challenge of climate change adaptation, these authors emphasized the importance of building the capacity of people and institutions, maintaining and increasing social capital, and adopting adaptive management styles that involve social learning. These themes also are prominent in the complex systems literature, which stresses the importance of multi-scale networks, cross-scale interactions, and multiple knowledge systems (Folke et al. 2003; Armitage 2005; Gunderson et al. 2006; Armitage et al. 2009).

Framing the challenge of adaptation to climate change in the water sector in terms of complexity and uncertainty has additional benefits. At the outset of this chapter, we argued that contemporary water *management* occurs in an environment where collaboration among a shifting mix of state and nonstate actors has become the norm. In this environment, *governance* – the ways in which societies make decisions – has shifted away from the traditional top-down, technocratic model of past decades. In considering how climate change has affected water resources, Kabat and Van Schaik (2003) argued that climate change has changed the *water* rules. Concomitantly, a transition to distributed and collaborative governance – typically marked by a shift from single centers of power to multiple, distributed centers of power (Plummer et al. 2005) – is changing the *water management* rules. New actors bring new values and capabilities, and new ways of making decisions about water lead to shifts in the distribution of power within society (de Loë and Kreutzwiser 2006). This simply reflects the fact that water governance is and has always been a highly political activity (Swatuk 2005). From this perspective, optimizing water systems through developing probabilistic models of relevant environmental variables – the way forward for water managers confronting the death of stationarity identified by researchers such as Milly et al. (2008) – may not be as important as the need to build adaptive capacity and strengthen governance.

8.3 Case Studies

Canada is perceived to be a water rich nation – a fact reinforced by country statistics on fresh water availability. For instance, the World Resources Institute (2009) places Canada's freshwater supply as third in the world, behind Brazil and Russia.

What is less well understood is the fact that Canada is a vast land with a population concentrated in major cities, most of which are located in the southern part of the country. This means that most of the water resources for which the country is famous are not readily accessible to the majority of its population (Kreutzwiser and de Loë 2004). Hence, despite a persistent myth of abundance (Sprague 2006), Canada does face significant challenges to adapting to climate change (Lemmen et al. 2008).

In this section, we explore the challenge of adapting to the impacts of climate change on a critical system: drinking water supply. Two examples are presented that illustrate the impacts of climate change, the multiple scales at which responses are required, and the challenges of adapting in the Canadian water resource context. These are urban drinking water supply in large and small centers, and drinking water provision in Canada's Aboriginal communities. Each example introduces the specific water management challenge, describes how solutions to climate change will require increased adaptive capacity, and highlights the importance of governance. The cases speak to a series of key questions that emerge from the broad, integrative perspective outlined in the previous section:

- *What is the context of the water system under investigation?* The water system can be defined according to one or more scales (e.g., spatial, temporal, jurisdictional) and described in terms of its human, physical, and biological components as well as their interactions.
- *How is current and projected climate change going to impact the water system and what are the anticipated outcomes of those impacts?* Modeling techniques and climate change scenarios can assist in understanding the influences of climate change on the components of the water system and highlight potential vulnerabilities. However, as noted earlier, more sophisticated modeling alone will not permit successful adaptation to climate change in the water sector.
- *What is the capability of the water system's management arrangements and practices to address the current and future impacts from climate change?* Insights into the degree to which adjustments are possible and adaptation options are feasible come from examination of supply and demand strategies, structural and nonstructural approaches, elements of institutional arrangements and components of capacity. In turn, these insights speak to the extent to which the water system can absorb disturbances and remain in the relatively same state, self-organize, and build capacity for learning and adaptation.

8.3.1 Urban Water Supply

Approximately 90.6% of Canada's population receives its drinking water supply from a water supply system (Environment Canada 2005). These range in size from small communal systems serving a handful of households, to large systems such as the one that provides water to residents of the City of Toronto through a network of four water treatment plants, 18 pumping stations, 10 underground storage reservoirs and 510 km of water mains (City of Toronto 2009).

Canadian drinking water treatment and distribution systems are operated by municipalities, public utilities, and, in a few cases, private companies (Bakker and Cameron 2005). Sources of water for these systems are diverse, and include groundwater, lakes, and rivers – with surface water sources comprising 89% of the water supplied by municipalities in 2001 (Environment Canada 2005). The importance of groundwater as a source of supply is closely associated with population. In 2001, systems in smaller communities (those with populations ranging from 2,000 to 5,000 people) took 42.7% of the water they provided from aquifers. Systems in larger communities (those with populations of more than 500,000) only drew 0.4% of the water they supplied from aquifers (Environment Canada 2005). Exceptions to this rule exist, including the Regional Municipality of Waterloo in southern Ontario, current population of approximately 507,000 (Regional Municipality of Waterloo 2009), which draws approximately 80% of the water its system supplies from groundwater sources.

Globally, climate change is emerging as a serious problem for the operators of drinking water treatment and distribution systems. Concerns relate to the impacts of climate change on both water quality and quantity (Bates et al. 2008). In Canada, climate change is expected to affect the ability of drinking water treatment and distribution systems to provide adequate supplies of safe drinking water in a host of ways. For example, in the Great Lakes Basin, the following concerns pertinent to drinking water systems have been identified based on predictions of likely impacts of climate change on the hydrologic cycle in this critical region (de Loë and Berg 2006):

- An increased frequency of extreme rainfall events is expected to contribute to a greater frequency of waterborne diseases and increased transportation of contaminants from the land's surface to water bodies. For many systems this will necessitate additional efforts to protect drinking water sources from contamination, and to treat water of potentially lower quality.
- Decreases in runoff will contribute to reduced water quality as less water becomes available for dilution of sewage treatment plant effluents and runoff from agricultural and urban land. In turn, this will contribute to increased treatment costs. Decreased runoff will also increase competition for scarce water resources during periods of low flow.
- Decreases in groundwater recharge will increase competition for scarce water resources, for instance, as users formerly reliant on surface water switch to groundwater. This may have implications for surface water resources dependent on groundwater for baseflow.
- Increases in water temperature may lead to reduced source water quality because of greater biological activity (e.g., algae production), and a greater frequency of taste and odor problems in drinking water supplies. As a result, an increased risk of disease may be expected, alongside increased customer dissatisfaction.

Climate change clearly has serious implications for Canada's drinking water treatment and distribution systems. However, these are far from the only challenges faced by these systems (Box 8.1). Thus, in considering how to respond to the challenge of climate change, it is essential that the threats it poses be viewed in a larger context. Specifically, it must be recognized that the impacts of climate change will be layered on top of a host of *existing* concerns and challenges faced by the operators of drinking water treatment and distribution systems. These concerns and challenges are diverse, and include (but are by no means limited to) the following:

Box 8.1: Drinking Water Supply in the Capital Region District

The capital region district (CRD) provides water to approximately 320,000 people living in southern Vancouver Island, making it the second largest system in British Columbia. CRD Water Services wholesales water within the Greater Victoria Drinking Water System (GVDWS), and retails it to customers in the Western Communities. Additionally, it provides system-wide services relating to water conservation and water quality protection. Water for this region is provided by a series of surface water reservoirs. The GVDWS is governed by three water supply commissions, with representatives from area municipalities. Community input into drinking water system planning and operation is provided through the Regional Water Supply, Protection and Conservation Advisory Committee.

The drinking water system faces challenges common to many systems in Canada, including pressure to meet customer demands, compliance with new regulatory requirements imposed by the provincial government, and ongoing infrastructure maintenance and upgrades. Climate change also is emerging as a related concern. Demand for water has increased in the region, and drought-like conditions have been experienced. Following the 2001 drought, reservoir capacity dropped to 73%, prompting the development and implementation of a water conservation and demand management strategy. Forecasts of population and climate indicate that existing infrastructure may be insufficient relative to demands, even with aggressive water conservation. Whether or not the system can meet this challenge depends in part on its ability to address a series of potential vulnerabilities linked to climate change. Many of these are typical of most large water systems, e.g., effects of changes in water temperature on water quality, and finding and repairing leaks in the distribution system. However, some are distinctive to the GVDWS, for instance, dependence on reservoirs that are too small, impacts of forest fires in the source catchments, an inability to control land uses and activities in source catchments, the need to account for downstream fishery needs, and uncertainty regarding Aboriginal title. The last two considerations fall within federal jurisdiction, and thus are beyond the ability of the CRD to control.

Sources: (Cameron 1998; Kolisnek and de Loë 2005; Capital Regional District 2009).

- *Serious concerns about drinking water safety in small communities*. Contamination incidents in Walkerton, Ontario (in 2000) and in North Battleford, Saskatchewan (in 2001) highlighted major weaknesses in operating procedures, standards, and regulations (Christensen and Parfitt 2001). Many problems have been addressed, but recent evaluations suggest that considerable room for improvement still exists, especially in smaller communities (Christensen 2006; Hrudey 2008). For example, over 1,700 boil water orders were in effect across Canada in 2008 – many of these being long term, and most occurring in small systems (Eggertson 2008b). Systems serving Aboriginal communities, as explored in the subsequent case, have a disproportionate number of problems (Eggertson 2008a).
- *Aging infrastructure that is in urgent need of repair and replacement*. In a recent assessment, Infrastructure Canada (2004) indicates that much of Canada's water supply and distribution infrastructure is reaching the end of its life and must be replaced. Cost estimates vary widely. The National Round Table on the Environment and Economy (NRTEE) estimated in 1996 that new capital demands for water and wastewater infrastructure would, conservatively, exceed $41 billion by the year 2015 (NRTEE 1996). Infrastructure Canada's (2004) report questions the accuracy of this and similar more recent estimates, but indicates nonetheless that a massive financial outlay is needed for replacement and maintenance of water supply and wastewater treatment infrastructure.
- *Pressure to meet the demands of urban growth*. Canada is an urban country, with approximately 80% of its population living in places with 1,000 or more people (Statistics Canada 2007). Intensifying the trend to urbanization, population growth is occurring almost exclusively in already densely populated areas such as are found in the southern parts of Ontario, Quebec, and British Columbia, and in the Calgary-Red Deer-Edmonton corridor (Statistics Canada 2007). Where this growth is occurring through low density suburban development, extension of infrastructure can be extremely costly (Infrastructure Canada 2004). At the same time, growth compounded by increased demand for water from existing and new customers adds additional stress on drinking water supply and distribution systems.
- *New regulatory requirements that increase costs for system operators*. Following the outbreaks in Walkerton, Ontario, and North Battleford, Saskatchewan, the regulatory burden on operators of drinking water treatment and distribution systems increased as provincial governments sought to improve drinking water safety (Christensen 2006). While stricter regulations are widely recognized as necessary, they do lead to increased costs for inspections, monitoring, and infrastructure upgrades (Infrastructure Canada 2004). In Ontario, for example, the costs of meeting the regulatory requirements imposed on municipalities by the provincial government following the Walkerton incident were estimated to be over $800 million as of 2005 (Water Strategy Expert Panel 2005).
- *Uneven capacity*. With the size of drinking water systems in Canada ranging from communal supplies that provide water to a few households up to large

> systems serving millions of people, it should not be surprising that capacity is highly variable. The United States Environmental Protection Agency (1998) characterized the capacity of drinking water systems to provide safe water in terms of technical, financial, and managerial considerations. Systems that lack trained staff and necessary equipment have weak or inadequate administrative procedures, and are not revenue self-sufficient struggle to provide clean, safe drinking water (Kreutzwiser and de Loë 2002; Brown et al. 2005). These systems tend to be smaller, and, as noted earlier, the consumers they supply with water are disproportionately exposed to risks.

From this broader perspective, two conclusions may be drawn that are directly pertinent to the themes in this chapter. First, in the context of municipal drinking water supply and treatment systems, adaptation to climate change clearly must be undertaken in concert with responses to other considerations (and vice-versa). For example, as noted in the introduction to this chapter, efforts to upgrade or replace water treatment and distribution system infrastructure must take account of the fact that future water supply availability can no longer be predicted based on the historical hydrological record. At the same time, estimates of the number of people who can be served by the system should take account of changes in demand related to anticipated shifts in temperature, precipitation, and evaporation. In relation to capacity challenges, it is important to recognize that the ability to design effective adaptive responses to climate change will be linked to broader considerations. Thus, operators of small systems who are struggling to meet new regulations relating to drinking water safety cannot be expected to have the expertise needed to develop models that permit integrating the impacts of climate change into demand forecasts. Therefore, initiatives to build capacity to adapt to climate change clearly must be framed in terms of larger capacity concerns. And, respecting the fact that the people who manage the systems already are overburdened with concerns (Kabat and van Schaik 2003), every effort must be made to *mainstream* climate change adaptation, in other words, to build it into existing planning and decision making processes (de Loë and Berg 2006).

Second, the case of drinking water treatment and distribution systems reinforces the fact that efforts to enhance the adaptive capacity of water systems must consider a broad range of technical/engineering approaches *and* socio-economic considerations relating to their resilience, including governance. To illustrate, demand management is commonly identified as a way in which water systems can adapt to climate change (e.g., de Loë et al. 2001). This approach involves technological measures (e.g., leak detection and repair, water efficient fixtures), economic instruments (e.g., pricing, financial incentives), social measures (e.g., public education and outreach), and regulatory measures (e.g., summer water use restrictions) (Vickers 2001). Demand management is a relatively uncontroversial illustration of the way in which technological and socio-economic tools and approaches can be combined. Shifting the focus to the system level raises more divisive issues, and further clarifies the importance of governance.

For instance, in response to the Walkerton tragedy in 2000, the Province of Ontario struck an expert panel with the mandate to inquire into Ontario's drinking water system as a whole (Water Strategy Expert Panel 2005). The Panel identified a series of reforms it considered necessary to address the problems it identified in the system. Several of these related directly to governance:

- Increase the scale and capacity of systems by joining them together into regional networks that permit sharing of resources, economies of scale, and a greater capacity to manage risks.
- Improve governance of systems through forming them into larger, municipally-owned corporations that own assets, and whose finances are separated from the municipal owners.
- Permit greater flexibility through permitting systems to contract out key functions to private companies.

These are issues of governance because they speak directly to who is involved in decision making and how decisions will be made. As such, they are inherently political. The fact that these recommendations have not been pursued by the provincial government reflects their – in Ontario at least – controversial nature. Strong endorsement by the Panel of private sector involvement in what is often considered a "public" realm by many in Ontario led to immediate negative criticism of its report (e.g., Nadarajah and Miller 2005; Canadian Union of Public Employees 2006). As a result, the governance issues raised by the Panel – which could have formed the basis for a broader dialog about the robustness and resilience of drinking water treatment and distribution systems in Ontario – remain largely unaddressed.

8.3.2 Water Quality and Health in Aboriginal Communities

According to the 2006 Canadian Census, 1,172,785 people in Canada (3.75% of the Canadian population) are of "Aboriginal" identity, i.e., Indians (First Nations), Métis, and Inuit (Statistics Canada 2006). There is enormous diversity within the Aboriginal population – culturally, economically, and socially. One key distinction that is important in the context of drinking water and climate change adaptation is the fact that there are 612 recognized Indian bands, and 2,675 reservations designated under the *Indian Act;* these reservations comprise a land area of 2,685 km^2 (Statistics Canada 2006). In contrast, Inuit peoples have not historically been located on reservations. Rather, they have occupied vast traditional territories primarily in northern Canada. Nunavut – Canada's newest territory – was created to reflect this fact. Because of the heterogeneity of Aboriginal people, it should not be surprising that drinking water provision in Canada's Aboriginal communities takes place in an extremely complicated institutional and geographic context.

Access and rights to resources are paramount issues for Aboriginal peoples in Canada. Their traditional institutions to control access and use of the natural environment were destroyed through European settlement, and thereafter access has been a function of contested Aboriginal rights and Aboriginal title (Booth and Skelton 2004). Walkelm (2006, p. 304) observes that "historically, (the Government of) Canada has simply denied that any indigenous territorial rights (including water) exist" and that increasingly access to, and protection of, water has come about through "reserve water rights and Aboriginal title, Aboriginal rights, and treaty rights".

Although a review of Canadian law pertaining to Aboriginal rights and title is well beyond the scope of this chapter, it is important to recognize four key realities that influence Aboriginal water governance and shape the context for adaptation to climate change in Canada's Aboriginal communities (Booth and Skelton 2004; Walkem 2006). First, the Constitutional Act of 1982 (s. 35) protects Aboriginal title and rights and recognizes the fiduciary responsibilities of the Government of Canada. Second, modern treaties (land claims) contribute certain rights and autonomy as established via cooperative arrangements and self-government. Third, water and other "resources" hold different and broader meanings for Aboriginal people than the ones defined in Canadian law. Fourth, gaining rights does not necessarily mean gaining access.

The fourth consideration is particularly significant in this case study. Through a variety of recent Supreme Court decisions, Aboriginal people have secured certain rights that previously were not acknowledged. However, these rights have not translated into access. For instance, in 1995 Indian and Northern Affairs Canada (INAC) estimated that one in four First Nation water systems posed "significant risks to human health," and noted that despite substantial investments in system upgrades between 1995 and 2001 (approximately $560 million dollars plus operation and maintenance at $100–125 million annually) the situation still deteriorated (INAC 2007). The National Aboriginal Health Organization (2002) offered an informative critique of the national level data used in the 1995 and 2001 assessments, noting that these assessments exclusively addressed First Nations and were not representative of Aboriginal peoples; defined a community water system in such a way that provided few details about individual households and/or the 235 communities without any services; and were limited because the categories addressed appear to be arbitrarily selected and lacking explicit operational measures.

In 2003, INAC conducted a national assessment of water systems servicing five or more homes in First Nation communities in Canada (INAC 2003). Disturbingly, 29% of the 740 community water systems assessed were found to pose a "potential high risk that could negatively impact water quality" and an additional 46% were found to pose "potential medium water quality risks". Consequently, INAC and Health Canada launched a First Nations Water Management Strategy and allocated an additional $600 million dollars in funding over the next 5 years.

While these measures are laudable, their effectiveness is questionable. The Report of the Commissioner of the Environment and Sustainable Development in 2005 found that despite efforts to improve drinking water, "residents of First Nations communities do not benefit from a level of protection comparable to that of people who live off reserves" (Office of the Auditor General 2005, p. 1). Responding to this charge, INAC and the National Chief of the Assembly of First Nations in 2006 announced a Plan of Action for Drinking Water in First Nations that examined the multi-barrier approach of the First Nations Water Strategy, emphasized reducing the risk rankings of water systems, and addressed the Commissioner's recommendations (INAC 2008). Perhaps most visible among these accomplishments is the formation of the Expert Panel on Safe Drinking Water for First Nations, which considered the options for a regulatory framework to ensure water quality for First Nations communities (Swain et al. 2006). The most recent progress report on the Plan of Action highlights reductions in the number of high-risk drinking water systems, removal of two thirds of the communities identified as priorities, and several other accomplishments (INAC 2008). Nonetheless, as of November 30th, 2008, 103 First Nation communities in Canada were under a drinking water advisory (Health Canada 2008), and a recent report concluded that "unsatisfactory access to safe drinking water persists for many First Nations people..." (Harden and Levalliant 2008, p. 7).

Clearly enormous challenges exist in relation to drinking water in Canada's Aboriginal communities. Unfortunately, these challenges will be magnified by climate change. As noted earlier, the impacts of climate change will be significant and pervasive in all regions of Canada (Lemmen et al. 2008). Aboriginal people are particularly vulnerable because of their exposure and sensitivity to climatic changes. This is most evident in northern Canada (defined as lands located north of 60° latitude). In the past 50 years, the Arctic region of Canada has experienced change at an unprecedented rate; projections consistently anticipate continued increases in temperature and precipitation and significant alterations in the cryosphere, which will create abrupt changes and variations in freshwater (Bates et al. 2008; Furgal and Prowse 2008). Aboriginal peoples constitute more than half of the population of northern Canada. Additionally, a majority of the more than 100 communities in northern Canada are small (<500 residents) and located along coastlines. Most are places where traditional livelihood activities are incorporated into daily routines (Furgal and Prowse 2008). This close connection with land and water, especially in isolated communities where subsistence livelihoods strategies are employed, increases sensitivity to climate change as current and projected impacts cut across physical, social, and cultural dimensions (Center for Indigenous Environmental Resources 2006a, b). Implications for health are a particularly important concern because of the potential for reduced nutritional contributions from country foods, greater frequency, and magnitude of accidents due to changes in ice, and changes in infective agents (waterborne and foodborne) that lead to real and perceived declines in water quality (Furgal and Seguin 2006).

The impacts of climate change will not only be experienced by Aboriginal people living in northern Canada. Aboriginal people in southern Canada also are vulnerable, but sometimes in different ways. For example, in a recent study the Center for Indigenous Environmental Resources (CIER) draws attention to the impacts of changes in water quality and quantity due to climate change on First Nations people living south of 60° latitude (CIER 2008). These impacts vary enormously by ecoregion (e.g., boreal forest, Carolinian/Great Lakes, taiga/tundra). For example, in the boreal forest ecoregion, the study suggests that overall drier conditions will be experienced, while in the taiga/tundra ecoregion, decreased water quality due to melting permafrost is a particular concern. Thus, in considering the challenge of adaptation to climate change by Aboriginal people in Canada, it is important to recognize that their vulnerability is a function of the different ways in which they are exposed to the impacts of climate change. At the same time, it must not be forgotten that their vulnerability is exacerbated by persistent poverty, disadvantage, and marginalization (Royal Commission On Aboriginal Peoples 1996; Reading et al. 2007). For example, as noted earlier, drinking water quality already is a serious concern in many Aboriginal communities; declining source water quality due to climate change will worsen this problem unless the capacity of community members to provide safe drinking water is greatly enhanced.

The ability of water system managers in many Aboriginal communities to address current and future impacts from climate change is in doubt. Indeed, enhancing capacity for drinking water management in Aboriginal communities has been identified for well over a decade. Most recently, the Summative Evaluation of the First Nations Water Management Strategy (INAC 2007), as well as the most recent progress report on the Plan of Action for Drinking Water in First Nation Communities (INAC 2008), drew attention to the need for a series of capacity enhancement measures. These included development of a protocol on water standards; support for the Circuit Rider Training Program, which trains water operators; provision of technical advice and oversight; and the rectification of key problems relating to the protection of sources of water, system design, operating procedures, and training. These measures have decreased the number of high-risk systems and priority communities from 224 to 116 in a 2-year period (Indian and Northern Affairs Canada 2008). However, as was noted earlier, serious problems exist in almost all Aboriginal communities – even those that have demonstrated both capacity and resolve to address their drinking water safety challenges (Box 8.2).

Box 8.2: Drinking Water and Source Water Protection on Six Nations of the Grand River

Six Nations of the Grand River is the most populous reservation in Canada. From 1972 to 2005, the on-reserve population increased from 4,907 to 11,297, with the future population projected to reach 19,244 in 20 years. There are 2,674 housing units on the reservation, with 85% of those units being classified as rural. The present communal water treatment plant was constructed in 1989 and takes water from the Grand River. It is operated by the Six Nations Public Works Department and primarily services the town of Ohsweken (approximately 450 residential and nonresidential units), also providing a source of water to the 522 houses with cisterns (holding tanks). The community has developed considerable capacity (human, technical, financial) for the community water system. A committee has been formed to address concerns about water quality and quantity and a source water protection plan has been developed. Recognizing the importance of water management beyond the boundaries of the community has prompted several

(continued)

formal and informal mechanisms for information sharing and collaboration with organizations and governments involved in source water protection and watershed management.

Six Nations of the Grand River illustrates the importance of a broad approach to source water protection and recognition that safe drinking water extends beyond water treatment plants. In their alarming report, *Boiling Point*, Harden and Levalliant (2008) observe that water wells are considered the individual responsibility of homeowners and therefore do not factor into the assessment of a community's risk. In Six Nations of the Grand River, approximately 1,735 housing units are serviced by individual wells. Testing of 312 wells in 2005 revealed 86% had some level of fecal coliform contamination and 30% were seriously contaminated with *Escherichia coli* (Neegan Burnside Engineering and Environmental Ltd 2005). Identifying this issue was an important first step for the Source Water Protection Committee in Six Nations of the Grand River. Enhancing well stewardship through awareness and education is an important part of implementing the source water protection plan.

Sources: (Ontario Clean Water Agency 2002; Six Nations of the Grand River 2009; Six Nations of the Grand River Environmental Office 2009).

From a national perspective, Aboriginal communities clearly face systemic problems at individual, organizational, and community-wide levels (Graham 2003). The current form of water governance in Canada is a contributing factor – and will strongly influence the ability of Aboriginal communities to adapt to climate change. For example, Walkem (2006) questions the assumptions and beliefs that underpin water resource management in Canada and calls for fundamental changes that take account of indigenous laws and traditions. Despite the entrenched rights of Aboriginal peoples and the potential of climate change to impact those rights, decisions about climate change have been made without the involvement of Aboriginal peoples. At the same time, climate change itself has not been clearly recognized as an important concern in strategies designed to address drinking water safety. In the absence of a commitment from the various governments to fully and appropriately engage Aboriginal people in water governance, their ability to respond effectively to climate change clearly is limited (Center for Indigenous Environmental Resources 2006a).

Explorations of resilience and adaptive capacity of Arctic communities to climate change have occurred in place-specific case studies and have emphasized short-term responses or coping mechanisms and adaptations such as traditional knowledge and relationship networks that enhance the capacity for learning and self-organizing across levels (Berkes and Jolly 2002; Chapin III et al. 2004). Although Arctic communities have demonstrated considerable adaptability and can continue to draw upon these reservoirs of resilience, researchers who have studied these communities are concerned that future changes in conditions may exceed conventional coping capacities (Ford and Smit 2004; Furgal and Prowse

2008). In a southern Canadian context, capacity to adapt to climate change also is a concern. However, there is recognition of the potential for multiple knowledge systems, including Aboriginal traditional knowledge, to enhance the ability of First Nations communities to undertake source water protection (Chiefs of Ontario 2007). Thus, where Arctic communities already are experiencing and adapting to the impacts of climate change, First Nations peoples in southern latitudes may be able to anticipate adaptation strategies that increase resilience and reduce risks (CIER 2008).

8.4 Discussion and Conclusions

A key tool in the water management toolkit has been the ability to construct a predictable envelope of variability from the observed hydrological record. Climate change is putting this tool out of reach. Not only are future climatic conditions expected to fall outside of the observed range of variability, but also it may be that a new predictable envelope of variability cannot be created. Climate scientists such as Milly et al. (2008) would address this challenge by developing new models that do not depend on stationarity. We argue that while nonstationary probabilistic models may be necessary in adapting to climate change, they will not be sufficient. Instead, we suggest that attention must be directed to building capacity to adapt to climate change, and this, in turn, demands a broad perspective on the system whose capacity is to be developed.

The broad, integrative perspective advanced in this book provides an appropriate lens for understanding the magnitude of the climate change adaptation challenge related to water. This was illustrated in the chapter through examining two very different contexts in which drinking water provision occurs: urban centers and Aboriginal communities. Three questions focused the discussion:

- What is the context of the water system under investigation?
- How is current and projected climate change going to impact the water system and what are the anticipated outcomes of those impacts?
- What is the capability of the water system management to address the current and future impacts from climate change?

Through addressing questions such as these, a more nuanced understanding of the challenges associated with adapting to climate change can be developed, and appropriate strategies can be revealed. This is illustrated in the following synthesis of insights from the two case studies considered in this chapter.

Drinking water systems in Canada are enormously heterogeneous. They draw on different kinds of sources, face varying pressures from development, and must deal with different kinds of infrastructure-related concerns. Furthermore, their vulnerability to climate change varies widely. Thus, it should not be surprising that the impacts of climate change will be experienced differently among systems. Some urban systems already are experiencing pressures from growth, and face constraints on their ability to secure additional water resources; in many parts of Canada, climate change is expected to worsen their circumstances. In contrast, Aboriginal communities in northern Canada that are served by systems drawing from relatively abundant water sources such as large lakes and rivers may feel the effects of climate change on water quality more than on water quantity.

These facts alone reinforce the importance of taking account of contextual circumstances in any effort to create broad-scale adaptation strategies. However, varying sensitivity to climate change is not the only consideration. In Canada, drinking water provision occurs in an extremely complex social and institutional milieu. Systems vary in size from those serving a few households to those serving millions of people. Not surprisingly, their technical, financial, and managerial capacity varies enormously. Capacity challenges are particularly pronounced in systems serving Aboriginal communities. However, small systems across the country typically have less financial, technical, and managerial capacity than their larger counterparts. Adding to basic capacity challenges is the fact that municipalities in Canada are subservient to provincial jurisdiction, while Aboriginal communities located on reserves are under federal jurisdiction. Thus, in both cases the systems that will experience the impacts of climate change lack the legal and policy tools needed to address a threat that, in most respects, originates outside of their boundaries.

Finally, both cases reveal ways in which adaptive capacity is shaped by larger circumstances. In Aboriginal communities, there is little reason to be confident that drinking water systems can absorb shocks originating from climate change, and independently build capacity for learning and adaptation. This reflects the severe challenges that many Aboriginal communities in Canada face, including poverty, unemployment, loss of traditional cultures, substandard education systems, and inadequate health care. The situation of drinking water systems in large urban municipalities unquestionably is better. However, complacency is not warranted given that these systems face profound challenges relating to meeting new regulatory requirements, coping with pressures from growth and development, and renewing crumbling infrastructure. In both cases, therefore, the challenges associated with building capacity to adapt to climate change and making drinking water systems more resilient are inextricable linked to the larger contexts in which those systems are embedded.

The discussion so far has emphasized challenges. Importantly, however, the two cases also provide insights into the most appropriate strategies for addressing these challenges. Simply recognizing that in the context of drinking water systems, climate change adaptation is not just a technical challenge but is a critical first step. It certainly should not be assumed that producing more sophisticated climate models will automatically increase the adaptive capacity of drinking water systems. In systems where the capacity exists to use them, these models can play a critical role in identifying likely alternative futures. However, this capacity should not be assumed in small systems that are challenged to undertake basic maintenance. More fundamentally, sustained attention must be directed to the factors that shape capacity to provide clean drinking water and to adapt to climate change, including those associated with the systems themselves (staff resources, financial stability), but also the larger social, institutional, and biophysical circumstances in which those systems exist.

In light of these facts, we argue that climate change adaptation must be addressed in *concert with* other concerns. Presenting climate change adaptation as a distinct concern that will be added to the existing load borne by the operators of drinking water systems, the communities in which these systems exist, and the various agencies involved, simply is untenable. Indeed, relative to the jurisdictional issues noted above, this position makes it easy for people involved in drinking water provision to argue that responding to climate change simply is not within their mandate. Instead, we argue that climate change must be *mainstreamed* into existing and future planning and decision making processes that fall within the core mandate of those concerned with drinking water provision. Three straightforward examples include the following:

- Operators of large drinking water systems already undertake demand forecasting. Thus, it is not unreasonable to ask that likely future scenarios of climatic conditions should be integrated with demand forecasts.
- Communities across Canada are engaged in processes designed to identify threats and vulnerabilities to source waters. Climate change can readily be integrated into water budgeting exercises, vulnerability assessments, long range planning efforts, and other activities associated with source water protection (e.g., de Loë and Berg 2006).
- All stakeholders involved in drinking water provision in Aboriginal communities have recognized the need to build community capacity to maintain and operate systems and to protect drinking water sources. Capacity building initiatives must be holistic and address a broad range of concerns, and the impacts of climate change can be included as one of those considerations.

Posing the kinds of questions considered in this chapter highlights the complexity of climate change adaptation in the context of drinking water systems. However, it also reveals a host of additional ways in which climate change can be mainstreamed and integrated with other concerns. In that respect, the broader perspective adopted here is essential to respond effectively to climate change.

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