

**CANADA'S FRESH WATER RESOURCES: TOWARD A NATIONAL STRATEGY  
FOR FRESHWATER MANAGEMENT**

Discussion paper prepared for

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## INTRODUCTION

Freshwater is of vital importance to Canada's environment, economy and populations. Historically it has been an important component to our culture, our early transportation systems and resource development. Fresh water continues to be a source for drinking water, industrial manufacturing, power generation and agricultural irrigation. With recent drinking water contamination in Walkerton, Ontario and North Battleford, Saskatchewan, many regions of Canada are becoming increasingly aware of the disregard for and poor protection of this resource. In 2001, the Auditor General of Canada's report criticized the federal and provincial governments for their inaction on high priority issues of water protection and the implementation of a national freshwater policy (CESD 2001). Given the concern over trans-boundary water management in the Great Lakes, pressures upon surface and groundwater quality and quantity in urban and rural areas, threats to public health in many areas of Canada and the international demand for clean water, the time is right for the consideration of progressive policy initiatives to sustain this vital resource.

Canada is fortunate in regard to water having about nine percent of the world's annual freshwater run-off and one percent of its population. Despite various media claims of water abundance and an imperative to sell water (Macdonald 2001, Scoffield 1998), sixty percent of the freshwater in Canada drains north and ninety percent of the population lives within three hundred kilometers of the southern border. The apparent abundance of water is in reality spatially and temporally distributed away from human population concentrations, with ninety percent of the population having access to only forty percent of the fresh water. This has resulted in various developments including the highest volume of interbasin transfers in the world. Irrigation demands in southern Alberta, southern Saskatchewan and the Okanagan valley of British Columbia have resulted in water scarcity and water rationing in these regions for some time. The construction of water supply pipelines (e.g. from London to Lake Huron or from Regina to the Qu'Appelle River) and the diversion of rivers to generate hydro-electricity (e.g. Nechako, Churchill-Nelson and La Grande river systems) disrupt existing aquatic ecosystems and ignore important surface-groundwater cycles. Given its geography, population distribution and industrial development, Canada is not lavishly endowed with a unending supply of fresh water, and as stated in the 1987 Federal Water Policy, "we have just about our fair share...and must manage water like any other valuable resource – with care" (Environment Canada 1987).

Fresh water is the cornerstone for much economic activity. Thermal power generation accounts for roughly sixty percent of the total freshwater withdrawals in Canada, by far the largest user. The majority of this water is returned to source although at much higher temperatures. Manufacturing industries account for roughly fifteen percent of total withdrawals and many commercial goods require large amounts of freshwater for their production (e.g. one car requires 250,000 litres of water, one computer requires over 33,000 litres). Municipal facilities and agricultural sectors each extract ten percent of the total freshwater withdrawals in Canada (Environment Canada 2001). All of the household water used in Canada is of drinking water quality and municipal infrastructure does little to differentiate uses. Canadians use, on average, 326 litres of water per day and the average household uses half a million litres per year (Environment Canada 2001). This is almost double that of most European nations and many times that of water-stressed countries. Of water used in agriculture, eighty-five percent is used for irrigation with little incentive in place to encourage conservation or improve irrigation technologies. Although agriculture is not Canada's largest user of water, it is its largest consumer, removing a great deal of water from the landscape, tying it up in agricultural products and with evapotranspiration, rather than returning it to surface and groundwater sources.

Additionally, the lower Fraser River in British Columbia, the St. Lawrence River in Quebec, the Mackenzie River in the Northwest Territories, and the Great Lakes of Ontario are important transportation corridors.

Freshwater is one of the most important components of environmental security and environmental health in Canada. Dr. David Schindler states, “water will become Canada’s foremost ecological crisis early in this century” (Schindler 2001). The Auditor General of Canada has also stated that the availability and the management of freshwater are becoming one of the greatest environmental, social, and political challenges of the 21<sup>st</sup> century (CESD 2001). The Royal Society of Canada has proposed that the concept of environmental security should guide Canada’s involvement in bilateral and overseas water issues. This concept has two dimensions: first, the Federal Government should ensure that Canada’s freshwater ecosystems are protected from transboundary threats such as air-borne and water-borne contaminants in addition to global threats such as ozone depletion and climate change; second, to assist in the resolution of water-related disputes before they become armed conflicts and/or threats to public health (Mitchell and Shrubsole 1994).

Freshwater systems are disproportionately rich and imperiled. Although freshwater makes up roughly less than three percent of the earth’s total water resources (with the majority of that existing as groundwater) it has the highest proportion of species compared to any other environment – ten percent more than on land and 150 percent more than in the oceans. Twelve percent of all animal species, including forty-one percent of all fish species, live in freshwater ecosystems. It is estimated that thirty-five percent of all freshwater fish species have already become extinct and freshwater animals are five times more likely to be at risk of extinction than those that live predominantly on land (Barlow and Clarke 2002). The majority of Canadians rely on these same freshwater ecosystems for drinking water, for industry and manufacturing, and for agricultural production; the pressures on this resource are immense and the many threats will challenge federal and provincial regulators to protect it for future generations.

This discussion paper is predicated upon the important need to consider both freshwater quality and quantity issues in Canada. A review of the health of freshwater ecosystems, with the various impacts and effects, provides the background for a consideration of the current management regimes. Finally, and building upon the calls for change from many stakeholders, strategies for sustainable development of Canada’s freshwater resources are presented.

The *Water and the Future of Life on Earth* workshop and think tank at Simon Fraser University, May 22-24, 2002, will bring together key researchers and thinkers in the areas of freshwater policy, management and science. One key objective of the event, and this discussion paper, is to stimulate and focus discussion on priorities for managing Canada’s freshwater resource, including examining the reasons for the poor implementation and enforcement of legislation in the past, and potential solutions. The sustainability of Canada’s freshwater depends upon the development of a renewed national water policy, appropriate resource management policies and continued research on high priority areas. Many of the issues with respect to freshwater health are presented in this document.

## THE HEALTH OF CANADA'S FRESHWATER SYSTEMS

### Introduction: surface and groundwater connections

Canada's freshwater is composed of both surface water and groundwater. Some estimates (Sampat 2000) show that up to ninety-seven percent of freshwater in North America is circulating groundwater, meteoric water that is present and can travel in the void spaces in sediments and rocks known as aquifers (Peilou 1998). It is important to recognize that surface water and groundwater resources are interconnected through the hydrological cycle. Freshwater is *renewable* only by rainfall and the extensive withdrawal from both aquifers and river systems depletes finite water sources.

Over one quarter of Canadian residents use groundwater for their domestic uses, and use varies widely across the country. Twenty percent of Quebec residents depend on groundwater, while sixty percent of those living in New Brunswick and almost one hundred percent of those in Prince Edward Island rely on it for their drinking water needs (Kidd 2002). Domestic household use of groundwater (43% of total) also rivals agricultural use (43%) in importance. Eighty-nine percent of Canadian farms depend on groundwater for drinking and irrigation.

Groundwater-surface water interactions are complex and highly variable and are inextricably linked. Groundwater is nearly always moving, except perhaps at great depths, although this movement is relatively slow (typically thirty meters per year). The permeability of the ground and the hydraulic head (or pressure upon groundwater) are the two main factors determining the rate of groundwater flow (Pielou 1998). An aquifer is a body of rock or sediment that holds water in useful amounts and serves as natural underground reservoir and the water in any aquifer circulates as part of the water cycle. The most important source of new water to recharge unconfined aquifers is falling rain or melting snow. Groundwater is also recharged to some extent from surface water – rivers, lakes and wetlands. Wetlands, such as prairie sloughs, which exist on higher ground typically recharge the groundwater below them. Those that exist at lower levels (compared to the surrounding land formations), such as freshwater marshes, typically receive most of their water from groundwater sources. The contribution of groundwater to surface water sources varies according to surficial geology and other factors. In some areas of Ontario where silt and clay soils predominate, groundwater flow contributes less than twenty percent to stream flow, while it can contribute up to sixty percent where sandy soils dominate, such as in many interior regions of British Columbia (Kidd 2002).

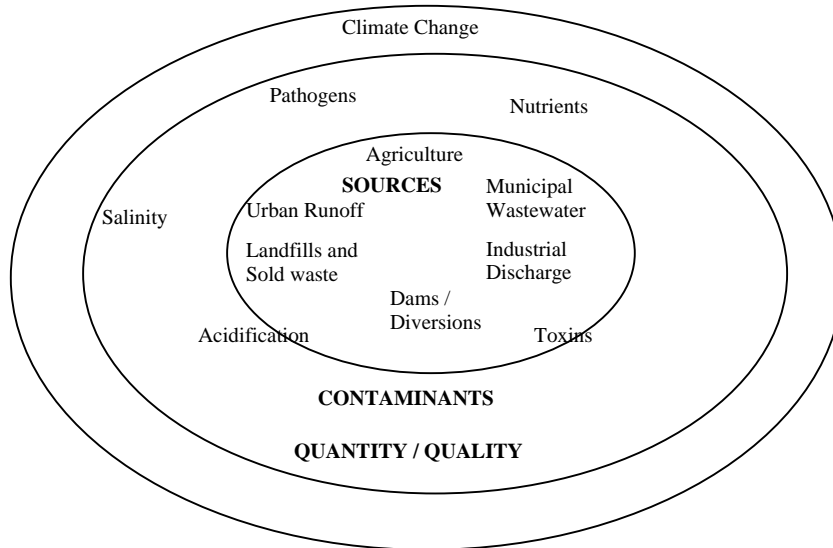
Groundwater discharge is a key determinant of the biological variability of surface water streams. In undisturbed areas, groundwater flows arrive to surface sources at fairly consistent temperatures and water chemistry. Water in the vadose zone (the unsaturated zone below the ground but above groundwater levels) is also a key determinant of biological diversity in surface sources. The degree of infiltration after heavy rainstorms or snow melts and the degree of seepage into surface and groundwater sources depends on soil type and the huge diversity of soil microorganisms and plant species present. Thus, disturbances to the surficial geology and biology surrounding surface water sources can negatively impact upon the quality and quantity of both surface and groundwater recharge. Similarly, changes in groundwater levels can have a major impact on critical habitats, such as riparian vegetation, and on the wildlife that is sustained by those habitats because level changes alter the natural water flux.

With the recognition of these important linkages between different components of the water cycle, the health of Canada's freshwater can be examined. Substantive issues involve those aspects of water that need to be addressed to meet basic human needs, and the needs of freshwater

ecosystems. This discussion paper briefly reviews ten specific threats to freshwater quality and quantity in Canada. Figure 1 displays these threats in a nested hierarchy.

**Figure 1: Threats to Freshwater**

Source: (Environment Canada 2001a)



**Waterborne Pathogens**

Waterborne pathogens pose threats to drinking water supplies, recreational users, agricultural operators and aquaculture operations as well as to aquatic ecosystems. The National Water Research Institute (Environment Canada 2001a) states that there were over 200 outbreaks of infectious disease associated with drinking water in Canada between 1974 and 1996. There were 8,000 confirmed cases linked to these outbreaks (these figures do not include outbreaks in the last five years). Depending on the severity of symptoms, the actual number of affected individuals is estimated to be ten to 1,000 times the number of reported cases. Public attention has recently focused on a variety of drinking water threats from bacteria (*E.coli* O157:H7 in Walkerton, Ontario where seven people died and 2,500 became ill) to protozoa (*Toxoplasma gondii* in Victoria, B.C. in 1995, and *Cryptosporidium parvum* in North Battleford, Saskatchewan where three people died) and viruses (Hepatitis A in Ile d’Orleans, Quebec, in 1995). This list is only a sample of the many instances of contamination and boil-water advisories in Canada. *Giardia* is one of the most prevalent freshwater pathogens and a common contaminant in small lakes and streams and in drinking water in Canadian municipalities. Severe cases can lead to giardiasis. There are also a large number of outbreaks caused by unknown agents currently being investigated by Health Canada (Environment Canada 2001a).

In 1996, Health Canada published the sixth edition of its *Guidelines for Canadian Drinking Water*. The guidelines are based on ‘indicator organisms’ that, if present in water, may indicate contamination by bacteria, protozoa or viruses. While these guidelines are not legally enforceable, they do describe how sources can be protected to guard against contamination, and set relatively stringent limits on the amount of coliforms allowed in drinking water supplies. *E.coli* and *Cryptosporidium* are much more prevalent in the environment than most consumers

would believe. They are transported quite easily and rapidly from agricultural areas to nearby groundwater and surface water and are not effectively killed by chlorination, the conventional water treatment method (SLDF 2001).

Waterborne pathogens also pose threats to many recreational users of freshwater, resulting in everything from illness to economic impacts on local communities. From 1992 to 1995 there were 2,839 beach closures in the Great Lakes region alone (Health Canada 1998) and the contamination of water in many public places throughout Canada necessitates showering after swimming or diving. The National Water Research Institute reports a study by Health Canada and the University of Lethbridge that has identified fecal coliform concentrations exceeding the Guidelines for Canadian Recreational Water Quality (GCRWQ) in Alberta's Park Lake Provincial Park and the Oldman River basin in half and all monitoring sites, respectively. In many cases the coliform counts exceeded the GCRWQ by a factor of five or more (Environment Canada 2001a). This area of southern Alberta includes an extensive network of irrigation canals and intensive livestock operations.

The emergence and spread of waterborne pathogens is likely to become increasingly frequent in Canada and will require new methods of treatment in the near future. Increasingly dense urban populations, and a corresponding growth in urban-fringe agricultural areas, pose significant human and animal waste management challenges. The fate of virulent and antibiotic resistant genes is of increasing concern, as genes resistant to tetracycline have been found in groundwater bacteria downstream from swine facilities (ACFA 2001). The use of antibiotics and growth promoters in livestock has the potential for spreading resistance back into the food chain of animals and people through soil and groundwater bacteria. Together, these sources of pathogens will place greater demands on aging municipal infrastructure and require much better management and protection of freshwater sources.

At present there are only limited surveillance data and knowledge of waterborne pathogens in Canada. Much of the concern to date has arisen from a human health and agricultural perspective; relatively little is known about the significant impact of these pathogens in aquatic ecosystems. For example, newly emerging fungal and viral pathogens have been linked to a significant decline of tiger salamanders in Saskatchewan and outbreaks of botulism caused by *Clostridium botulinum* are believed to have caused substantial waterfowl mortality across Canada (Environment Canada 2001a). Water management programs in Canada will need to take a preventative approach to pathogen pollution and develop better indicators to assess the presence of protozoan and viral pathogens. In addition, more research from an ecosystem perspective will help to understand the epidemiological factors associated with pathogen outbreaks. From a human health perspective, the current patchwork system of monitoring and reporting will have to be improved (i.e. national monitoring programs) and enforced.

## **Toxic Contaminants**

### *Algal toxins*

Toxic contaminants in freshwater ecosystems come from a number of natural and anthropogenic sources: algal toxins, pesticides, heavy metals, and many types of organic pollutants. Algal toxins are produced by cyanobacteria and toxic blooms generally occur in ponds, lakes, reservoirs and slow moving streams or rivers (usually in disturbed or artificial areas). Cyanotoxins are naturally produced poisons stored within cyanobacteria which in humans can attack the liver and the nervous system and irritate the skin. In addition to cyanotoxins, hepatic microcystins are also associated with cyanobacteria and have been identified in drinking water (e.g. Winnipeg, Regina, central Alberta), recreational water and water used to irrigate crops. These are known to be tumour promoters, although their exact role in cancer development is not well understood.

Generally, algal blooms occur in warmer weather and high nutrient loads will promote their growth. They are a particular problem in eutrophic water such as rural ponds, sloughs, dugouts and lagoons. Cyanotoxins have been found in the Great Lakes region and often prompt beach closures throughout Canada. Taste and odour problems from these biological sources occur regularly in the British Columbia interior, Edmonton, Calgary, Lethbridge, Regina, Winnipeg, the lower Great Lakes, Muskoka Lakes and Quebec City (Environment Canada 2001a).

There is relatively little known about the role and impact of algal toxins in freshwater beyond their immediate effects. With the need for more basic data on the different cyanotoxins and microcystins, standards for human health are a long way off. The World Health Organization has developed a standard of 1.0µg/L and the proposed guideline for Canada is 1.5µg/L, but this guideline is not specific to the different toxins and their specific impacts (Environment Canada 2001a). Algal toxins may also be stressful for species in freshwater ecosystems that are not adapted to disturbed or artificial areas. More research on environmental triggers and ecological shifts causing blooms and a better understanding of the food chain transfer of these toxins is needed. In addition, prospective climate change will impact upon the temperature, turbidity, and levels of many slow-moving freshwater bodies (Schindler 2001), potentially augmenting the effect of algal toxins.

#### *Pesticides*

Pesticides pose a threat to water quality and aquatic ecosystems because of their widespread use and the continuing evolution in their chemistries. In Canada, we currently lack a systematic, coordinated, and interjurisdictional system for monitoring pesticides in aquatic systems. There has been an evolution in pesticide use from organochlorines to organophosphates, carbamates, pyrethroids, and beyond (Environment Canada 2001a). In general, this evolution has meant decreased persistence in the soil and more specificity, although the toxicity is often quite high. There are roughly 550 pesticide active ingredients registered under the Pesticide Control Products Act and the Pest Management Regulatory Agency registers 10-15 new actives each year. Roughly eighty percent of the pesticides used in Canada are used for agricultural purposes. Very few of these active ingredients have been evaluated or re-evaluated for their harmful effects and generally this is done on an evidence-first basis. Available data indicate that there are a number of problematic current use pesticides that are persistent, mobile and toxic (e.g. lindane, endosulfan and others).

Groundwater and surface water contamination by pesticides will likely continue and intensify because of changing land use practices and consequent aquifer contamination that often takes years to be detected. The lack of monitoring data on pesticide use essentially eliminates the ability for scientists and regulators to predict areas that may be threatened. In part, the lack of data is due to the lack of coordination between federal and provincial authorities (Environment Canada 2001a). More research on the role of pesticides in both water and sediments (which can act as sinks and sources of toxins) is needed to understand the persistence, desorption, resuspension, and effect on benthic organisms. There is research in other areas on bioconcentration and bioaccumulation that could be applied to freshwater quality standards in Canada.

#### *Persistent Organic Pollutants*

Persistent organic pollutants (POPs) comprise a group of chemicals that degrade very slowly and bioaccumulate in organisms. Many are semi-volatile, can be transported on a global scale and persist in air, water, soil and vegetation. Canada has substantial reservoirs of these chemicals because of their historical use as pesticides. Organochlorine pesticides were used in many agricultural regions of Canada and were sprayed on northern lakes to control mosquitos.

Polychlorinated biphenyls (PCBs), with heavy industrial use in the mid-20<sup>th</sup> century, persist in both urban and rural soils, landfills and industrial sites although their levels have been decreasing since they were banned. On the other hand, the level of mercury concentration in fish-eating birds and mammals has been on the rise. Because of the long-range transport of these chemicals, many are concentrated in the northern parts of Canada, disproportionately affecting the people and the environment of these regions.

The bioaccumulation properties of these toxins means that they are found in many top predators in both aquatic and terrestrial food chains. Environment Canada (1995) has set an interim guideline for PCBs of 0.32 ng TEQ/g ww, which is designed to protect wildlife that consume fish and shellfish. However, this level is routinely exceeded in both predator and forage fish in many areas. The associated disruptive effects on mammalian endocrine systems and reproductive parameters cause neurobehavioural and developmental defects in offspring. Research and monitoring programs with a national focus are needed to ensure that information on current levels and time trends of old and emerging POPs are available in all regions of the country (Environment Canada 2001a).

### **Nutrient Loads**

Anthropogenic nutrient loading of freshwater sources magnifies the natural competition in aquatic ecosystems for nitrogen (N) and phosphorus (P). Without human interference, the most abundant source of nitrogen is nitrogen gas and is only made available through nitrogen-fixing bacteria, algae or plants. Similarly, phosphorus is made available only through mineral weathering. Thus, these limiting nutrients are key stabilizers of aquatic ecosystems and the contamination of water sources by the use of fertilizer, burning of fossil fuels, development of large urban populations and the clearing and deforestation of land disrupts natural nutrient cycles.

Household sewage is the largest *point source* of N and P to the Canadian environment; in 1996 an estimated 5.6 thousand tonnes of total P and 80 thousand tonnes of total N were released into lakes, rivers and coastal waters from municipal sewage treatment plants in Canada (Environment Canada 2001a). Discharge of industrial wastewater is another major source of N and P to the environment. Many industries are not monitored and there are no national figures for losses due to leaching from landfills and other waste disposal sites. Agricultural activities are the largest *non-point source* of nutrient loading to Canada's freshwater ecosystems. Over fifty thousand tonnes of P and over 300 tonnes of N are residual after crop harvesting across Canada. Much of this residual transports into surface and groundwater and many agricultural regions have seepage water with concentrations exceeding 14 mg N/L (drinking water limit) including seventeen percent of Ontario farmland, six percent of Quebec farmland, three percent of Atlantic farmland, and seventy percent of the Lower Mainland agricultural region of British Columbia. The Abbotsford-Sumas aquifer in southern British Columbia has received public attention because of high and increasing N loads that are likely to continue due to slow transport of leachates from surrounding farm and industrial lands. High levels of nutrients in water ecosystems contribute to algal blooms and toxin production as seen in many regions of Canada, most notably the Great Lakes during the 1960s, 1970s and 1980s.

Nutrient loading of freshwater is a persistent but manageable problem that can be eliminated by adopting improved farm management practices and practices of wastewater elimination and treatment. There are many areas that require further research (Environment Canada 2001a), generally on ecosystem interactions between heavy nutrient loads and aquatic food chains. In addition, there are very few monitoring data; 2,130 industries in Canada have discharge permits and monitoring data are only available for ten percent of these. There is no national database. Agricultural loading to surface and groundwater has been studied on small-scale plots but no

quantitative efforts have been made at watershed or regional scales. Water well survey programs are patchy across the country and many of those that are tested are found to have nitrate levels close to the maximum guideline levels. In addition, industrial and agricultural spillages of nutrient-related compounds are only reported on a voluntary basis in many jurisdictions.

### **Acidification**

There has been significant research in Canada on the acidification of freshwater systems (Schindler 1988)(SOE 1999). A scientific consensus on aquatic effects obtained during the late 1970s and early 1980s played a significant role in justifying sulfur dioxide (SO<sub>2</sub>) and nitrous oxides (NO<sub>x</sub>) emission controls both in Canada and internationally. A domestic *Acid Rain Control Program* was established in 1985 that required a 40% reduction in SO<sub>2</sub> emissions by 1994 in the seven eastern-most provinces. In 1998, a *Canada-wide Acid Rain Strategy for post-2000* was signed by federal, provincial and territorial governments with the long-term goal of reducing acidifying emissions to meet critical loads. The strategy also calls for periodic assessments, starting in 2004.

Canada has significantly reduced SO<sub>2</sub> emissions, while NO<sub>x</sub> emissions have changed very little, over the past 25 years. The southeastern part of Canada is the area of most concern because of its elevated acidic deposition (pH<5.6) and acid-sensitive geology (Environment Canada 2001a). This area contains approximately 800,000 water bodies and only a small percentage of these have been surveyed. In general, most of the areas monitored exist near heavy industrial areas in Ontario (e.g. Sudbury) and southern Quebec, and the local industries have been targeted with emission reduction controls. Thus, the more dispersed aquatic ecosystems in Ontario, Quebec and Atlantic Canada may not show the same level of improvement in acidity status because of spatial variables. There has also been recent concern for water bodies in southern British Columbia, northern Alberta and Saskatchewan.

Although important research has been conducted, and there is a wide understanding of the processes of acidification and its impact upon aquatic ecosystems, several important areas deserve attention. There is evidence that the cumulative effects of nutrient loading, specifically nitrogen deposition, may mitigate the degree of SO<sub>2</sub> reduction seen in many regions. Monitoring and studying the connections between these two stressors will be important in the future. Information on the status of the soil base-cation pool and its replenishment rate is of increasing concern due to the erosion of the cation base in Canadian Shield soils over many decades. The mobilization and oxidation of sulfur and nitrogen stored in freshwater ecosystems, under drought conditions, may delay recovery from acidification and the implications of this with respect to climate change require further clarification. The snowmelt 'shock' in many regions of Canada can result in a large flux in pH balances; this may be augmented by climate change and changing precipitation levels. The importance of dissolved organic carbon (DOC) is recognized and changes in DOC inputs from lake and river drainage basins (due to changing land use factors) may also mitigate recovery from acidification, the processes of which require further study. Finally, the interaction of acidification with other stressors such as climate change, toxic contaminants, changes in nutrient loads, and geologic chemistry all have major implications for the chemical and biological status and recovery of aquatic ecosystems from acid deposition.

### **Municipal Wastewater Effluents**

Municipal wastewater is an increasing concern for freshwater quality in Canada. It represents the largest source of effluent discharge to Canadian waters, totaling nearly 4.3 billion cubic metres in 1991 (Environment Canada 2001a). Municipal wastewater treatment plants are designed to remove settleable solids (primary treatment) and oxygen-consuming material (secondary treatment) and nitrogen and/or phosphorus (tertiary treatment). Along with these constituents,

tertiary treatment plants remove some heavy metals and organic chemicals. Only 33% of Canadian municipalities are served by tertiary treatment and there are over ninety Canadian municipalities and cities, including Victoria, Halifax, and St. John's that still discharge raw, untreated sewage into water bodies. Less than half of Atlantic Canada's population is served by sewage treatment. Even in cities with sewage treatment, design flaws cause "wastewater bypass during heaving rainfalls, combining with storm water in sewer outflows" (SOE 1996). Many municipalities face problems related to aging infrastructure and population growth, challenging them to not only maintain existing levels of treatment, but also meet higher levels that would reduce effluent discharge.

Wastewater effluent from municipalities frequently violates the *Fisheries Act* by depositing deleterious substances directly into fish-bearing waters. In 1996 and 1997, there were nearly 100 violations by municipal sewage treatment facilities in Ontario and 76 violations in British Columbia. Although regulations exist, no charges have been laid with respect to municipal discharges and the incentives for municipalities to upgrade are minimal.

Effluent, if not disinfected, contains bacteria and pathogens and many urban beaches receive regular closures because of treatment plant overflows. Oxygen depletion in receiving water (because of the high biological oxygen demand (BOD) loads associated with effluent) and the eutrophication of receiving waters, primarily with nitrogen and phosphorous, have serious ecosystem impacts. Municipal effluents are also a source of endocrine disrupting substances that may adversely affect reproduction and development in animals. The extent to which these chemicals are present in effluent varies and more study is needed to determine the exact impacts upon aquatic ecosystems. In addition, pharmaceuticals and personal care products (antibiotics, blood lipid regulators, analgesics, anti-inflammatory drugs, beta-blockers, fragrances, skin care products, disinfectants and antiseptics) have been detected in municipal effluents and associated surface water (Daughton and Ternes 1999). The implications of exposure to these constituents remain poorly understood and additional research and preventative measures are needed.

On October 12, 1999 the Federation of Canadian Municipalities (FCM) submitted a report detailing its concerns and future needs with respect to municipal water infrastructure programs, including water treatment, water distribution and sewage treatment. Canada is one of the most urbanized countries in the world and the combined effect of population growth presents an enormous challenge for Canadian municipalities. The FCM estimates that an investment of approximately \$13 billion annually over the next ten years is required to address the deficit in Canada's municipal water infrastructure (SLDF 2001). Of this total, \$36.8 billion in improvements to wastewater facilities are needed to bring wastewater effluent up to a high quality standard across the country. Provincial governments have exacerbated funding shortfalls by downloading service delivery and maintenance responsibilities onto municipal governments.

### **Industrial Point-sources**

Industrial point-sources of pollution continue to be a major contributor to effluent discharges across the country. The pulp and paper, mining and petrochemical industries are the three main sectors which contribute to freshwater pollution. While both regulatory and voluntary programs have been implemented over the past decade, end-of-the-pipe treatment has many limitations and pollution prevention programs appear to be the best method to reduce emissions. As the concentration of effluent is often the target of regulation, increased water consumption has resulted in a dilution of toxicity, but with little concern for total pollutant loads into receiving waters. Despite the installation of secondary effluent treatment plants in 99% of the pulp and paper mills in Canada, the majority of these mills still report effects on benthic invertebrates and fish (Environment Canada 2001a). Discharges of dioxins and furans in pulp and paper effluent

have decreased by 99% since 1988, total suspended solid by 80%, and BOD by 95% (Environment Canada 1998). These improvements are directly related to regulations under the *Canadian Environmental Protection Act*, the federal *Fisheries Act* and various provincial regulations. Despite this progress, however, the pulp and paper industry still discharges two million kilograms of toxic chemicals into Canadian waters every year. The failure to prosecute pollution offences hampers efforts by concerned groups and well-meaning industry to improve water quality.

A recent review of government regulations concerning the impact of mining on the environment (AQUAMIN 1996) demonstrated significant impacts of this industry on water quality, sediment quality and on fish and benthic invertebrate communities. With ongoing stakeholder discussions, the *Metal Mining Liquid Effluent Regulations* were amended in July, 2001 and included more stringent monitoring, prevention and discharge measures. However, recent expansions of mining activities in the high Arctic, the development of new large mineral deposits in Voisey's Bay, and the expansion of the oil sands in northern Alberta continue to pose threats to freshwater in those regions. The use of freshwater in mining exploration (e.g. separation of oil from tar sands) is already diminishing stream and river flows in northern Alberta, using nine barrels of water for every barrel of oil extracted (Barlow and Clarke 2002). Additionally, abandoned mines continue to pose a threat to water quality as a result of the failure of tailings dams or acid mine drainage (e.g. Britannia Beach, British Columbia).

The petrochemical industry in Canada continues to be a threat to aquatic ecosystems, especially with the recent expansion of oil sand exploration in northern regions. The cumulative effects of rapid oil sands development and onshore drilling within confined geographic regions are relatively unknown (Environment Canada 2001a). Northern aquatic ecosystems are more vulnerable to degradation, meaning longer persistence of toxic compounds and disturbance effects. In addition, only individual projects are evaluated and monitored for environmental risk and the regional impacts, beyond those identified in individual environmental assessments, are unknown. An integrated approach to management of industrial discharges beyond site-specific assessments is required for cumulative effects assessment and management of multiple effluent discharges.

The development of policy in which federally legislated Environmental Effects Monitoring programs are required across industrial sectors would address many knowledge gaps and help to prevent the cumulative effects of effluent discharge at the ecosystem level. There is also a need for a national monitoring plan and database of industrial point-source effluent discharges. Linkages between different Environment Canada branches and between different levels of government would improve management in this regard (Environment Canada 2001a).

### **Urban Runoff**

In terms of discharge volume and solid load, urban runoff significantly exceeds that associated with municipal wastewater (Chambers et al. 1997). Urban runoff consists of both stormwater and combined sewer overflows, and its composition is often comparable to that of untreated sewage. In Canada, the Great Lakes region, Vancouver, Edmonton, Winnipeg, Windsor, Hamilton, Toronto, Ottawa, Montreal, Quebec City and Halifax all cause serious freshwater pollution problems from urban runoff on a regular basis. Each year, Canadians dump the equivalent of seven Exxon Valdez tankers of used motor oil into Canadian waterways, much of this coming from urban runoff. In the Great Lakes region alone, urban runoff discharges annually in the order of  $10^5$  tonnes of suspended solids,  $10^4$  tonnes of chloride,  $10^3$  tonnes of oil and grease, and  $10^2$  tonnes of trace metals (Environment Canada 2001a).

It should be recognized that the urban quality of runoff, and its impacts are linked to other water quality issues. Overlapping with some municipal sewage and pollution from industrial sources, the impacts obviously include contributions from several sources. Impacts on water quality are exerted by combinations of physical, chemical and microbiological factors, similar to those of other threats to freshwater ecosystems. Physical factors include flow, sediment, thermal energy and densimetric stratification near urban areas. Chemical factors include biodegradable organics and nutrients, trace metals, chloride, and pesticides (mainly lawn and household pesticides). Microbiological pathogens include a range of bacteria, viruses and protozoa.

There are three main knowledge requirements in order to better manage or prevent urban runoff in Canada (Environment Canada 2001a). First, is a better understanding of the processes of urban runoff including: the sources, regional diversity, effectiveness of current control measures, and secondary and cumulative effects on aquatic ecosystems. The second requirement is a need for research on the integrated management of urban water runoff, including best practices research drawing upon approaches in other urban areas of the world. Finally, infrastructure renewal can only be accomplished through the development of national standards for environmentally and economically efficient design and operation of urban runoff control systems and the assessment of alternative modes of infrastructure ownership and operation.

### **Landfills and Solid Waste Disposal**

Solid waste management in Canada has left a series of water quality problems, many of which are just beginning to be understood. Municipal solid waste, agricultural wastes, mining waste and industrial solid waste contribute to leachate contamination of both surface and groundwater. Many of the contaminants of the future currently exist, and have existed, in water for years and have just begun to be discovered. The immediate tasks at hand are the predication of contaminant releases into various aquatic environments and the formulation of an effective regulatory framework that ensures effective management.

As urban populations, especially in the southern regions of Canada, grow so does the amount of municipal waste. Many municipalities (e.g. Toronto, Vancouver) have begun to ship their municipal waste to other regions as local landfills begin to fill up. The use of abandoned mines and other areas that can potentially contain leachate has been the focus of these efforts. The city of Toronto has begun shipping its municipal waste 600 kilometers north to the Adams Mines near Kirkland Lake and the Greater Vancouver Regional District is currently trucking municipal waste to the Cache Creek landfill located in the Ashcroft area, 300 kilometers north of the Lower Mainland. Regulations on the siting, design and operation of these landfills vary across the country; the process is often more political than environmentally sound (i.e. Which community is willing to accept a landfill in their vicinity?). Inevitably, the leachate from municipal landfills requires expensive remedial systems, often ineffective with respect to groundwater.

There has been a trend toward larger mining operations that produce larger volumes of solid waste over the past decade. The potential release of heavy metals and oxyanions from subaqueous disposed mine waste, as well as geochemical reactions at the surface water-groundwater interface, are emerging issues that have long-term effects and for which there are also no monitoring data.

Industrial solid waste has been the focus of regulation and reduction measures for some time in Canada (CCME 1991). The most critical issues center on the harmonization of regulations and guidelines between jurisdictions as well as the importation of hazardous waste from other countries such as the United States, and from other regions of Canada (e.g. a disposal site in the community of Swan Hills, Alberta). Between 1998 and 1999, over 650,000 tonnes of hazardous

waste were imported into Canada from the United States for disposal and storage (Environment Canada 2001a). The reactivity of many fairly benign chemicals can produce extremely toxic leachates and issues of transport within various geologic media are not well known. The contamination of groundwater in Lambdon County, Ontario and the St. Clair River in the 1960s and 1970s, by hazardous waste injected into disposal wells, is a well-known example of water quality damage resulting from a lack of knowledge of these processes.

Additional research into the long-term processes and reactions of solid waste are needed. The construction of adequate liners, covers and leachate collection systems requires improvements in technology and an understanding of the degradation process. Currently management of landfills and solidwaste is done only through guidelines; new regulations, accompanied by enforcement, are needed to adequately protect freshwater systems and to focus on prevention and protection rather than remediation.

### **Agricultural Impacts**

Agricultural use of freshwater in Canada threatens aquatic ecosystems in many ways. Some of the specific stresses have been mentioned in preceding sections of this paper including: the introduction of pathogens, nutrient loading, water quantity stress, solid waste leachates and contamination with toxic chemicals. Agricultural impacts on water resources are caused by the need for additional water, the use of additional nutrients, the use of pesticides, alterations in soil chemistry, the draining of wetlands and modification of streams.

Irrigation, drainage and the rechanneling of water courses puts pressure on the amount of available freshwater and draws water out of existing water cycles, often removing it permanently (Coote and Gregorich 2000). This also provides more water to leach agrochemicals and bacteria into groundwater. The addition of fertilizers, both natural and synthetic, and crop residue left on fields, contribute to nutrient loading of nearby water sources. The different approaches to soil management and the different soil types also have considerable influences on water quality in surrounding surface and groundwater sources. Some crops allow higher rates of erosion resulting in higher losses of sediment into surface water. Pesticide evapotranspiration can result in deposition on surface water, augmenting contamination of groundwater and by seepage. Soil degradation can also hinder the infiltration rates for rainwater, and sedimentation of streams reduces the flow capacity, increases turbidity, impedes respiration and feeding of aquatic organisms, and degrades spawning habitat for fish. Impacts upon aquatic ecosystems are quite significant and this is immediately evident in the surface water of most agricultural areas of Canada. These impacts can be augmented by severe droughts that often affect western Canada (at least 40 times in the past 200 years (Environment Canada 2001a)) and the pressure upon irrigation sources in these periods is critical.

The storage and degradation of animal wastes is becoming another large problem, concurrent with the increased number of feedlots, often concentrated regionally (e.g., feedlot alley in southern Alberta, the hog farming region of southern Manitoba, dairy and poultry operations in the Fraser Valley of British Columbia). The associated occurrence of endocrine disrupting substances and animal pharmaceuticals in the ground and surface water of rural areas is a significant issue for which there are very little available data.

Many provinces have developed guidelines for the management of manure and the application of fertilizers in order to better control nutrient loading into water sources. While new techniques for pest control are currently being developed, with the potential to reduce pesticide application levels, trends of pesticide and herbicide use are generally increasing across agricultural sectors in Canada. The use of pesticides (including their active ingredients, their application rates, and tank

mixing) is currently unregulated on private agricultural land. In short, there is very little in the form of regulation to control and prevent water contamination from agricultural practices. Most policy exists in the form of guidelines and enforcement is minimal.

### **Dams and Diversions**

Canada is the world leader in water diversion with more than six hundred dams and sixty large inter-basin transfers. More than eighty percent of these dams are used for hydroelectric power generation, flooding more than 20,000 square kilometers of land and diverting more than four percent of Canada's total annual water flow (SOE 1996), compared to less than two percent for all other water uses combined. Water is never actually withdrawn from the river system, but the construction and operation of power generating facilities dramatically alters aquatic ecosystems.

Hydroelectric facilities modify water quantity and quality parameters both within the reservoir and downstream. Major effects are thermal stratification within the reservoir, eutrophication, the promotion of anoxic conditions in hypolimnetic water and related changes in metal concentrations in outflow, increased methylation of mercury, sediment retention, and changes in turbidity and nutrient cycling (Environment Canada 2001a). Variations in climate are also capable of producing major changes in water quality and quantity in reservoirs and downstream ecosystems, due to the changes in freshwater renewal and temperature regimes. With the flooding of large amounts of vegetation during the construction of hydroelectric reservoirs, there is the potential for subsequent greenhouse gas emissions during the decay of this material.

Flow diversions can also produce major changes in water quality. The dramatic shifts result from mixing of waters from disparate ecological systems (e.g. freshwater to estuarine environments), resulting in changing chemistry, temperature and sedimentation. The transfer of fish, parasites and pathogens often accompanies such inter-basin transfers, seriously comprising aquatic ecosystems.

### **Climate Change**

The effects of climate change on Canadian freshwater ecosystems will be varied in both magnitude, timing and complexity (Schindler 2001). Global change will affect water quantity, water quality, aquatic biota and groundwater sources in synergistic and cumulative ways. The primary, secondary and tertiary effects of climate change are difficult to predict and very widespread. An appropriate metaphor may be that of 'shifting the rug under the card table'; as Figure 1 indicates, climate change is a key threat whose impact will be felt by, and contribute to, every other stressor of freshwater health.

While long-term data sets that allow predications for climate change impacts are rare, many trends are evident through the use of historical data (e.g. ice cores, lake sediment cores), models, and inference from ecosystem interactions. Most climate change models do not predict large precipitation changes overall for Canada; however, the rates of evaporation are predicted to increase as temperature increases. Increased evapotranspiration rates will have effects on water availability and the efficiency with which water is used in many applications (e.g. irrigation). Projected changes in the precipitation/evaporation ratio will affect the water levels of ponds, lakes and wetlands. Declines in water levels will lead to altered water chemistry, particularly increased salinization. In addition, indirect effects on drinking water and aquatic ecosystem quality will include increased toxins and taste and odour problems related to algal blooms. Decreased water levels in the Great Lakes of Ontario and many northern lakes will cause detrimental effects to surrounding wetlands.

Climate change predictions include an increase in the frequency and magnitude of extreme precipitation, runoff and snowmelt events. This will compromise most current contaminant storage, processing and transportation infrastructures. Similarly, urban runoff and nutrient loading from industrial and agricultural sources will increase during such events.

The interactions between changes in hydrologic regimes and toxic contaminants will be complex and vary by region. In areas that have decreased water inputs, the transport of leachates or seepage of agricultural pesticides is expected to decrease, while their retention in soil sediment and still water is expected to increase. Increases in temperature will enhance the decomposition rates of PCBs and other volatile organics in the southern regions of Canada, while the melting in northern regions may enhance the mixing processes to the point where northern freshwater sources may become new contaminant sinks (Schindler 2001).

Climate change is expected to have significant effects on the biogeochemical processes within aquatic ecosystems. Reduced precipitation and runoff results in lower water tables in catchments and wetlands, in turn changing redox processes that alter stream and lake chemistries, slowing recovery periods for water sources affected by acidification. Nutrient loadings and their cyclings will also be altered. Changes in DOC can affect the physical and chemical quality of aquatic ecosystems, including increased penetration of harmful ultraviolet radiation (UV). There is evidence (Environment Canada 2001a) that reductions in runoff result in DOC decreases in lakes, and that DOC levels can be controlled by incident UV radiation. In addition, the acidification of lakes can alter DOC concentrations. These synergistic (or antagonistic) relationships are very complex and the mechanisms of change are not widely studied or understood.

Changes in local runoff and water balance may also cause many first-order streams to become ephemeral or absent and disconnections between ponds, wetlands and lakes and their associated drainage systems may occur. Warmer thermal regimes will create conditions conducive to the invasion of warm-water fish and aquatic species and the competitive replacement of many native species. Furthermore, the reduced range for cold-water species may drastically alter their life cycles. Projected increases in water demand and use (mainly anthropogenic) will enhance the need for interbasin transfers or diversions, contributing to habitat alteration and the potential introduction of exotic species and new diseases.

Schindler (Schindler 2001) notes that all of these unknown processes and complex interactions of freshwater stressors, under the rubric of climate change, require increased attention and research by Canadian institutions and regulators. Research on the northern great lakes is currently very limited and these freshwater sources are vital for Canadian environmental security. In addition, there is an urgent need for a national water strategy in order to coordinate monitoring and evaluative systems, national databases of emissions, and cooperative regulatory and enforcement efforts. In order to adapt to and manage the unavoidable climate change impacts on freshwater in Canada, preventative measures must be taken to protect surface water and groundwater. This involves increased research funding on the ecosystem processes at work and pro-active management strategies (Schindler 2001).

## **THE MANAGEMENT OF CANADA'S FRESHWATER RESOURCE**

The preceding discussion of threats to Canada's freshwater ecosystem provides an indication of the complexity and challenges present in managing freshwater. The connections, through the hydrological cycle, between surface water and groundwater are only understood at a basic level and there are many more factors that require further research. There are also many surface water sources that cross provincial, territorial and national boundaries and that overlap, to varying

degrees, with associated groundwater sources. These important ecosystem components of freshwater challenge regulatory authorities to manage water use and misuse in a comprehensive, inclusive and enforceable manner. The following section provides a brief outline of the regulatory regime across Canada, including jurisdictional issues, water protection issues and drinking water standards.

### **Roles of the Canadian Federal Government**

There are few federal laws directly addressing water issues as this is mainly an area of provincial jurisdiction under *Canada's Constitution Act* of 1982. There are, however, at least nine pieces of federal legislation and six federal departments that play an active role in freshwater protection in Canada. Environment Canada is the lead organization and the most active, along with Fisheries and Oceans, Health Canada, Natural Resources Canada, Agriculture and Agri-Food Canada and Foreign Affairs and International Trade. However, the federal interest and capacity for dealing with water issues has been significantly reduced over the past fifteen years, as outlined below. There is an apparent contradiction between the growing awareness about the importance of freshwater and the reshaping of federal capacity to deal with water (Bruce and Mitchell 1995). This paradox is partly the result of a desire to restructure federal agencies to work more cross-sectorally while eliminating costly redundancies in bureaucracy. However, the spirit and intent of the reduction in federal responsibility can be interpreted in a number of ways.

The *Canada Water Act* is administered by Environment Canada and has been a primary instrument for federal-provincial collaboration since its inception in 1970. In 1987, the federal government published its *Federal Water Policy*, based on the 1985 *Report of the Inquiry on Federal Water Policy* (Pearse Inquiry); its commitment to protect and enhance the freshwater resource. Reflecting the government's view that Canadians undervalued their water resource and therefore overused and abused it, the policy set out five broad strategies: water pricing, science leadership, integrated planning, legislative changes, and improving public awareness. With concerns emerging in Canada, and internationally, about the demand, availability, and use of water, these were and are important strategies.

The five strategies developed in the 1987 *Federal Water Policy* were directed at the overall goal of "encouraging the use of freshwater in an efficient and equitable manner consistent with the social, economic and environmental needs of present and future generations" (Environment Canada 1987). The strategies and associated twenty-five policy statements provide a comprehensive approach to water management in Canada and, for the purposes of this discussion paper, provide an existing framework which can be revisited, despite their lack of implementation to date.

The Commissioner of the Environment and Sustainable Development (CESD 2001) and other agencies (BCWRA 2002)(Kidd 2002) have reported on the federal government failure to implement its 1987 *Federal Water Policy*. Several federal departments share responsibility for a number of the issues that the policy covers, but they have never been allocated any responsibility or funds to carry out the actions set out in the policy. The Interdepartmental Committee on Water, created to coordinate federal water activities and chaired by Environment Canada, was to be the focal point for administration of the *Federal Water Policy*. It was also to produce an annual report on the overall implementation of the policy. The Committee has tabled only two progress reports, in 1990 and 1994, and has since become inactive. In 1993, the Auditor General criticized the Committee for not playing a stronger role and no new forums for coordination are currently in place.

Environment Canada intended to carry out many of the actions in the *Federal Water Policy* through its Inland Waters Directorate, but this was disbanded in the fall of 1993 and its large staff dispersed among the remaining services of the Environment Canada, effectively removing any focus on water. The following year, the department carried out an internal review to determine whether, and where, it was meeting its various responsibilities for water. It concluded that water quality activities were regionally variable across the country and there was no focus or coordinating activity nationally. There was also no national focal point for international matters related to freshwater. Groundwater programs were operating in British Columbia and the Atlantic provinces, but there was no national leadership or co-ordination of their activities and no effort to develop or implement national strategies or guidelines for groundwater management. Finally, research on groundwater contaminants was transferred to two research institutes that were losing staff and funding and whose core expertise in groundwater was eroding.

In 1997, the inactive Interdepartmental Committee on Water began formal discussions to clarify federal roles and responsibilities for freshwater. In 1998, Environment Canada completed a draft discussion document, *Towards a Federal Freshwater Strategy*, which was intended to be an update of the 1987 *Federal Water Policy*. It was the subject of extensive consultations between the federal government and the provinces and in the end the 1987 policy was not updated. In 2000, a second draft discussion document was prepared, *Fresh Water – A federal discussion document*, which again updated the 1987 *Federal Water Policy* and set out twenty-five new or revised policy statements. This discussion paper describes potential federal priorities and commitment, although these largely restate and confirm current activities. The paper also does not offer new direction or priorities for the federal government and does not recommend any changes in funding levels. Throughout the fifteen-year life of the *Federal Water Policy*, the government has never formally identified its top priorities or decided how it would put them into effect in Canada's freshwater bodies. It has not reported on any progress toward the implementation of freshwater management measures since 1992.

The federal government has the ability to exert influence of freshwater management through the *Fisheries Act*, and the *Canadian Environmental Assessment Act*, and through its jurisdiction over boundary waters. Under the *Fisheries Act*, the federal government has the power to order dam operators to ensure adequate fish protection. This power is seldom used, however, and lawsuits have ensued in the rare cases where it has been applied. Industrial projects affecting fisheries or navigation may trigger an environmental assessment process, depending on various contingent factors; there are many jurisdictional conflicts between federal and provincial agencies and there have been few instances of federal intervention (e.g. Alberta's Oldman dam, Saskatchewan's Rafferty-Alameda dam and Quebec's proposed Great Whale project). Canada's role in boundary water management is regulated by 1909 *International Boundary Waters Treaty* and the 1972 *Great Lakes Water Quality Agreement*. The *Boundary Waters Treaty* also established the International Joint Commission with equal representation from Canada and the United States to undertake reference studies as requested by the governments, to oversee the implementation of specific agreements, and to approve various uses and diversions of boundary waters. Concerns about water uses and withdrawals from the Great Lakes were the subject of a special study by the International Joint Commission in 2000, leading the federal government to introduce changes to the *International Boundary Waters Treaty* which would prohibit large scale transfers or diversions.

The federal government, specifically Indian and Northern Affairs Canada (INAC), has the overall responsibility for the management of water resources in the North of Canada (Environment Canada 2002). Through land claims agreements, First Nations and the Inuit, and the territorial governments share in this management through participation on joint resource management

boards. Aboriginal governments have certain limited authorities as defined in self-government agreements. The *Northwest Territories Water Act*, the *Yukon Waters Act* and the proposed *Nunavut Water Act* provide a unique framework for managing water resources. They establish a water board in each territory that is responsible for conservation, development, and use of water resources. Indian and Northern Affairs Canada is responsible for enforcing the legislation and for resource planning, collecting data, and supplying information to territorial water boards and the public. The department is also involved in water quality issues and the effect of contaminated water on the health of northerners. Under its Northern Affairs Program, INAC's Water Resources Division shares responsibility with Environment Canada's Water Survey of Canada for the hydrometric network that monitors flows on major water-courses and shares responsibility with Environment Canada for collecting water quality data.

### **Provincial and territorial government roles**

The majority of the responsibility for freshwater management rests with the ten provinces and three territories of Canada. Provinces are the primary regulators of freshwater and have authority over water use and quality because of their legislative powers regarding local works and undertakings, property and civil rights and municipal institutions (CEC 2001).

All provinces have enacted their own statutes over the protection of water. Provincial legislation generally includes prohibition of discharges into water sources and the adoption of regulations specifying standards of quality for drinkable and other water supplies, industrial and sewage waste effluents, and ambient water quality in receiving bodies. Although it is beyond the scope of this discussion document, more detail on the statutes in each province with respect to water management is available on-line ([http://www.ec.gc.ca/water/en/policy/prov/e\\_prov.htm](http://www.ec.gc.ca/water/en/policy/prov/e_prov.htm)). Because of the recent events in Walkerton, Ontario, there have been efforts on the part of most provinces to review their drinking water quality standards and examine freshwater management regulations. British Columbia, Saskatchewan, Alberta and Ontario are either in the process of, or finished, these reviews. In addition there are efforts to review groundwater regulation and management both within Environment Canada and by other agencies.

There are many disparities between provincial regulatory regimes across Canada. With the concentration on drinking water quality in last several months, this example is presented to illustrate the degree of difference and highlight the small role of federal regulation in ensuring water quality. The Canadian Council for Environment Ministers has adopted *Guidelines for Canadian Drinking Water Quality* that provide benchmark quality levels across Canada. There is, however, no provincial or territorial legislation that requires that all parameters of these guidelines be analyzed or enforced as part of the permitting or approval process. Currently, the territorial governments consistently test for the highest number of contaminants, while many jurisdictions require water quality analysis on a case-by-case basis.

Drinking water protections may be created through laws (enacted by legislature), regulations (created by the agency and approved by cabinet), permit or approval requirements, or guidelines (created by the agency). Laws, regulations and permit standards may create legally binding and enforceable standards for water quality, while guidelines are not legally binding. Table 1 below compares the jurisdictional statutes and standard/testing requirements for drinking water across Canada, as of January 2001 (SLDF 2001). Note: British Columbia passed the *Drinking Water Protection Act* in April 2001 that requires province-wide tap-water standards, essentially bringing it on par with Alberta, Ontario, Quebec and Nova Scotia).

**Table 1: A jurisdictional comparison of drinking water standards – (SLDF 2001)**

<b>Jurisdiction</b>	<b>Standards and Testing Requirements</b>
Alberta: <i>Environmental Protection and Enhancement Act; Potable Water Regulation</i>	Water quality must meet the microbiological, chemical and radiological characteristics of the Canadian guidelines. The director of Alberta Environment determines the parameters that must be analyzed for each municipality. Surface waters are monitored twice per year and groundwater monitored once per year
British Columbia: <i>Health Act; Safe Drinking Water Regulation</i>	Water quality must meet a coliform standard. Other standards may be imposed on a case-by-case basis. The frequency of sampling is discretionary.
Manitoba: <i>Health Act; Water Supplies Regulation; Water Works Regulation; Protection of Drinking Water Supplies Regulation</i>	Testing for chlorine residuals and microbiological sampling is required and the frequency is mandated; all other testing is discretionary.
Newfoundland: <i>Environment Act; Health Act; Sanitation Regulation</i>	No testing required. The provincial government may undertake some testing.
New Brunswick: <i>Clean Water Act; Health Act; Potable Water Regulation; Water Quality Regulation; Water Well Regulation</i>	Water quality standards and sampling frequency is discretionary. Public water suppliers must have an approved sampling plan.
Northwest Territories: <i>Health Act; Public Water Supplies Regulation</i>	Operators are required to ensure tests are performed monthly for coliforms and annually for 25 chemical and physical parameters.
Nova Scotia: <i>Environment Act; Water and Wastewater Facility Regulations; Guidelines for Monitoring Public Drinking Water Supplies</i>	Disinfection, residual testing, turbidity sampling, fluoride level sampling is required daily. Microbiological sampling must meet Canadian Guidelines. Thirty chemical and physical parameters must be sampled, once a year for surface water and once every two years for groundwater. Water providers have an obligation to provide water that meets the Canadian Guidelines.
Nunavut: uses N.W.T. regulation;	Operators are required to ensure tests are performed monthly for coliforms and annually for 25 chemical and physical parameters.
Ontario (post-Walkerton, effective 2002): <i>Ontario Water Resources Act; Water Works Regulation; Drinking Water Protection Regulation; Ontario Drinking Water Standards; Ontario Water Quality Objectives</i>	Binding testing requirements are in effect (as opposed to pre-2002 where testing was only discretionary) for microbiological characteristics, chlorine residuals, volatile organic compounds, inorganic chemicals, nitrates and pesticides. The frequency of testing varies by contaminant type but is the most rigorous in Canada.
PEI: <i>Environmental Protection Act; Health Act</i>	Sampling is not required
Quebec: <i>Reglement sur l'eau potable</i>	There is mandatory testing for 46 contaminant standards with varied frequency of testing. (Proposed legislation will raise the number of contaminant standards to 77 and implement mandatory controls for turbidity, trihalomethanes and <i>E.coli</i> .)
Saskatchewan: <i>Environmental Management and Protection Act; Water Pollution Control and Waterworks Regulation</i>	Bacteriological testing after water system construction or alteration. Daily chlorine residual testing is required. All other testing is discretionary.
Yukon: <i>Public Health and Safety Act; Yukon Water Act</i>	Coliform testing required and frequency is based on population. Chlorine residual testing is required. Some monitoring of physical characteristics is required. Chemical and radiological testing is discretionary.

## **MOVING TOWARD SUSTAINABILITY**

The remainder of this discussion paper moves beyond the overview of the key issues facing freshwater in Canada toward suggestions for a more sustainable water policy framework in Canada. Many authors (Schindler 2001, Kidd 2002, Environment Canada 2001a, CESD 2001, BCWRA 2002, Kidd 2002, Mitchell and Shrubsole 1994, Blatter and Ingram 2001, Karvinen and McAllister 1994, Pomeroy 1995, Bender and Simonovic 2000, Donahue 1999), from Canadian governmental agencies, non-governmental interest groups and independent researchers, have written on the failings of Canadian water policy and its implication in compromising the health of Canadian freshwater ecosystems. Additionally, there have been calls for increased research, education and cooperation among different stakeholders in the protection of freshwater resources. The inclusion of better groundwater protection is a priority, along with the need to manage at an ecosystem scale. The inclusion of First Nations interests, and those of rural and northern regions has been neglected and must be addressed. Finally, the use of economic tools has rarely been thoroughly applied to any aspect of freshwater management in Canada. These different aspects can direct the development of a *national* freshwater policy, which would be more than the sum of individual federal and provincial policies, providing for the protection and management of Canada's freshwater resource.

The 1987 *Federal Water Policy*, and the revision documents for both surface and ground water, provides a good starting point to build a national water strategy. This initiative requires the coordination of both provincial and federal authorities as there is no national jurisdiction for water in Canada. Jurisdictional issues are a key stumbling block for more integrated and collaborative management, especially with respect to transboundary water courses and groundwater reservoirs. The time is perhaps most appropriate now, spearheaded by the increased attention on drinking water quality, to develop national regulations, monitoring plans and enforcement measures for a variety of freshwater issues.

### **Adoption of an ecosystem approach**

Nearly all governments have recognized the importance of planning, managing and developing water in the context of ecosystems covering both aquatic and terrestrial resources, as does the *Federal Water Strategy*. Bruce and Mitchell (1995) promote the 'nested' basin approach, whereby the context, guidelines (standards), and framework for management are developed for large inter-jurisdictional basins. This is followed by ecosystem planning and management for a range of progressively smaller provincial and community-based basins.

A basis for this approach currently exists; for example, the federal responsibility in connection with large inter-jurisdictional basins such as the Prairie Provinces Water Board, the Mackenzie River Basin Board, the Poplar River Bilateral Monitoring Committee and the Great Lakes-St. Lawrence initiatives all provide examples of inter-agency cooperation and management. However, in approaching ecosystem management by the geographical unit of the river basin, it must be recognized that this unit will not encompass all important interactions. Groundwater aquifers may well have different boundaries and their contribution to water supply, river flow and water chemistry must be taken into account. Likewise, pollutants transported over long distances must be factored in as inputs to the basin ecosystem. In coastal regions, it may be appropriate to include coastal ecosystems in freshwater management strategies as river discharges and delta regions are intricately connected.

### **Increased attention to groundwater management**

The current management of Canada's groundwater resources is not adequate to protect it from land use changes and contamination. Both the recharge areas and underground aquifers must be protected and managed in order to sustain groundwater sources. As an essential component of the hydrological cycle, groundwater is dependent on surface water and vice-versa. The adoption of an ecosystem approach is the best method to address and prevent contamination and over-withdrawal. This in turn will rely upon additional research across Canada; mapping groundwater resources in all regions because of the spatially variable nature of groundwater-surface water interactions is necessary for improved management.

An inherent difficulty in managing groundwater is that the law has traditionally divided water into separate legal class depending on its place in the hydrological cycle. The unnatural division between groundwater and surface water and the application of different laws to the ownership and use of different 'classes' of water makes integrated management difficult (Kidd 2002). The *Federal Water Policy* does provide initiative for the development of codes of practice concerning groundwater management with the provision for more research. Coordinating land-use planning to protect groundwater recharge areas, especially near large urban centers, poses an especially large challenge.

Karvinen and McAllister (1994) identified emerging groundwater policy trends in Canada which continue to be relevant almost a decade later: the lack of inter-jurisdictional coordination between levels of government (local, First Nation, provincial, national, international) and between local governments; the lack of public and political awareness; and, the lack of an adequate mandate to document and monitor groundwater quality and quantity. Many of the largest aquifers, upon which Canada depends, are shared with the United States because of the geographic locations. The transboundary mechanisms of groundwater management and regulation must be harmonized in order to protect the resource. The recently formed National Ad Hoc Committee on Groundwater has begun to outline strategic directions for an inter-agency *Canadian Framework for Collaboration on Groundwater* (Rivera et al 2002). Through a process of national workshops and discussion papers, this committee has taken the initiative to provide the mandate for groundwater management in Canada.

### **Bilateral Issues**

The majority of Canadians live in boundary or transboundary river and lake basins shared with the United States. and are profoundly affected by the results of negotiations and management in these basins (Bruce and Mitchell 1995). The Canadian government has generally relegated much of its authority in these negotiations to the provinces while the American government maintains strong centralized control of its water planning. Each decision can also set precedents, and implications for other parts of the border on the other side of the continent. With respect to groundwater and surface water management, it is important that the Canadian federal government be technically and legally prepared to protect the interests of Canadians by drawing on the expertise at federal and provincial levels, in universities, the private sector, and First Nations and the public. Transboundary aquifers are not well-monitored or studied and the lack of coordinated legislation has resulted in the application of different regulations on either side of the border, meaning that the least stringent regulations protect the groundwater resource. There are examples of this on both the Canadian-US border and the US-Mexico border.

Similarly, the Canadian federal government has a number of obligations under international conventions to protect freshwater at an international scale. These include *The Convention on Biological Diversity*, *The Convention Framework on Climate Change*, *The Convention to Combat*

*Desertification*, and *The ECE Convention on Long Range Transboundary Air Pollutants*. In addition, the implications of the *Kyoto Protocol to the UN Framework on Climate Change* for freshwater management are demanding in both regulation and enforcement and if Canada chooses to ratify the *Kyoto Protocol* it will have additional regulatory responsibilities at the national level.

### **Water export**

The 1987 Federal Water Policy states that the federal government will take all possible measures to prohibit the export of Canadian water by inter-basin diversion, following recommendations by the Pearse Inquiry in 1985. There have been subsequent efforts to introduce legislation banning water exports and to exempt it from the NAFTA trade agreement. However, legislation banning water exports has run into jurisdiction problems between the federal and provincial governments. The federal government has had a longstanding tradition of denying that it has the constitutional ability to address environmental issues (largely because provincial governments reject federal interference in most natural resource management issues), while the provinces claim that laws governing water export remains in the federal domain.

Despite the jurisdictional hurdles, the federal and provincial governments have worked to prevent bulk-water exports. The International Joint Commission has recommended a moratorium on exports of water from the Great Lakes and the federal government has amended the *International Boundary Water Treaty Act* to prohibit large-scale exports of diversions along Canada's international borders. Each of the provinces, with the exception of New Brunswick, have laws prohibiting bulk water exports.

Although bulk water exports receive much of the attention, for some time there has been ongoing export of water in small containers in Canada. Under NAFTA, bottled water is considered a good and is subject to trade rules. Several bottled water companies in British Columbia and Quebec, which currently export billions of litres of bottled water every year, have sued their respective provincial governments under the NAFTA rules because of their legislative action to ban water exports.

Canada's freshwater supply is not unlimited and is not 'wasted by flowing into the oceans' (Macdonald 2001) and policy efforts to date have indicated that there is a desire to prevent bulk-water exports. The demand for freshwater will increase dramatically in the immediate future, especially from the southern and western United States, and the federal and provincial governments must coordinate a national strategy to deal with this issue. This issue is also complicated by NAFTA and WTO rules on barriers to trade and the classification of goods.

### **Partnerships and stakeholders**

Federal and provincial governments have stated for some time that there is a need to forge new partnership arrangements for water management. Examples of this are currently in place between governments (e.g. Prairie Provinces Water Board, the Mackenzie River Basin Board, the Fraser Basin Council), between farmers and governments (e.g. the Regional Municipality of Waterloo, Ontario) and between various individuals, NGOs and government agencies (e.g. the Oldman River Basin Water Quality Group, the GIRB – groupe d'intervention pour la restauration de la Boyer). These examples show that subsidiarity can improve efficiency and be more responsive to local concerns.

It is still not clear how governments with legal mandates and responsibilities for resource and environmental management can share responsibility or authority in an effective manner. In British Columbia, the Commission on Resources and Environment (CORE) and the Land Resource Management Plan (LRMP) efforts have had varied success, but provide one model to

promote stakeholder participation and acknowledge public expectations. The development of a national water strategy may preclude some of this vested authority thereby delegating regional stakeholders to specific implementation and monitoring efforts.

### **Water pricing and demand management practices**

The Organization for Economic Co-operation and Development (OECD) has recommended that water use in Canada "...be metered to a greater extent; that the polluter pays principle be applied more systematically through, for example, a greater use of economic instruments; and that more cost-benefit analysis in setting and implementing objectives ...should be undertaken and published" (OECD 2000). A critical element of Canadian water policy, and which contributes to over-consumption, involves the price of water. Prices are set either provincially or regionally for industrial and agricultural users of surface water. Municipal governments set the rates charged to municipal water users in those municipalities that do charge for water use. Canadian water is the cheapest in the OECD and current strategies of flat rates or declining block rates means that there is no incentive to use less water.

Governments have been moving in the direction of demand management strategies, but there is often considerable debate and controversy over full-cost pricing and other user-pay regimes. Demand management provides the user with incentives (economic or otherwise) that make it worthwhile to conserve water and protect freshwater sources. Water treatment and water conservation are also important aspects of demand management.

The current under-pricing of municipal water in Canada has contributed to crumbling infrastructure and places considerable pressures on surface and groundwater sources that supply drinking water. High levels of water use also create high volumes of municipal wastewater. With increasing population and land use pressures in the most urban areas of Canada, municipalities are going to have no choice but to implement more appropriate economic incentives to encourage water conservation. Finally, groundwater is free for most users and this has contributed to extensive draw-down of aquifers throughout Canada, especially in areas with heavy irrigation demands.

### **Rural and northern regions**

Governments are often anxious to address rural economic issues by proposing the expansion of various developments, from agriculture, industrial, to residential. The post-productivist rural landscape promises to be more diverse than ever. The limitation of water availability may become an important factor in the very near future, however. Water users are already exploiting most available water in the areas that are targeted for development. Data and information are also lacking for most rural areas of Canada especially in relation to groundwater resources, disproportionately more so than those in urban or semi-urban regions. Further intensification of agriculture and the movement of city-dwellers to the rural regions of Canada will place additional demands on water quality and quantity. Rural development is now, and will continue to be, limited by a wide variety of freshwater issues.

Research on Canada's northern lakes is very limited. Great Slave Lake, Great Bear Lake and other large northern lakes are the most unstudied freshwaters of the world (Schindler 2001). Some of these lakes were last studied in the 1950s and 1960s and many have never been comprehensively studied. The impact of climate change and long-range contaminant transport to northern regions means that many of these freshwater sources can be impacted heavily by industry despite their isolation. The expansion of current mining activities in the north puts an additional pollution pressure on these ecosystems.

## CONCLUSION

The preceding discussion of the threats to Canada's freshwater health and of the regime of management at the federal and provincial levels outlines many of the key areas for future research and policy reform. From a human health perspective, the current patchwork system of monitoring and reporting will have to be improved (i.e. national monitoring programs) and enforced. There are very few monitoring data for industrial discharge; 2,130 industries in Canada have discharge permits and monitoring data are only available for ten percent of these and there is no national database. The incidence of water-borne pathogens has been on the rise as evidenced by recent drinking water contamination incidents. The use of water by agricultural industries for irrigation and livestock watering comprises water quantity in a number of regions in Canada, while manure storage issues contribute to severe water quality degradation in many regions. Finally, the urbanization of Canada, and the growth in economic activity, challenge water policies and management plans to keep up; efficiency gains may be mitigated by this growth and the overwhelming scale of economic activity.

The under-pricing of municipal water in Canada has contributed to crumbling infrastructure and places considerable pressures on surface and groundwater sources that supply drinking water. The Federation of Canadian Municipalities estimates that an investment of approximately \$13 billion annually over the next ten years is required to address the deficit in Canada's municipal water infrastructure (SLDF 2001). Of this total, \$36.8 billion in improvements to wastewater facilities are needed to bring wastewater effluent up to a high quality standard across the country. Infrastructure renewal can only be accomplished through the development of national standards for environmentally and economically efficient design and operation of urban runoff control systems and the assessment of alternative modes of infrastructure ownership and operation.

Environment Canada intended to carry out many of the actions in the *Federal Water Policy* through its Inland Waters Directorate, but this was disbanded in the fall of 1993 and its large staff dispersed among the remaining services of the department, thereby effectively removing any focus on water. Jurisdictional issues are a key stumbling block for more integrated and collaborative management, especially with respect to transboundary water courses and groundwater reservoirs. An inherent difficulty in the management of groundwater is that the law has traditionally divided water into separate legal classes depending on its place in the hydrological cycle.

There is a need for a national water strategy in order to coordinate monitoring and evaluative systems, national databases of emissions, and cooperative regulatory and enforcement efforts. In order to adapt to and manage the unavoidable climate change impacts on freshwater in Canada, preventative measures must be taken to protect surface water and groundwater. This involves increased research funding on the ecosystem processes at work and pro-active management strategies. There are a number of impediments and bottlenecks to action on these items, providing a good basis for discussion during the *Water and the Future of Life on Earth* workshop and think tank. Additionally, the questions of political will (policy) and scientific knowledge (research and monitoring priorities) will be important points of discussion under the larger concern of freshwater sustainability globally.

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