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Preserving the Quality of Canada's Inland Waters*

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Abstract: *Contrary to general international perception, Canada does not have an unlimited supply of freshwater. However, because Canada has a small population, it does have a generous water allocation on a per capita basis. Nor is Canada immune from water quality problems: its cold continental climate, urbanization and industrial activities all contribute to water quality concerns and deterioration. Generally, the authority to manage water in Canada is held by the country's provincial governments. The Great Lakes basin is the world's largest freshwater ecosystem and is located in Canada's industrial heartland. Water issues, starting with phosphorus in the 1960's, created international headlines. In the 1970's toxics became the predominant issue and this led to the Great Lakes Water Quality Agreement which established the ecosystem approach to water quality management. This approach is now the standard approach to water quality management and has been successfully applied to a number of other lake and river ecosystems in Canada. While there have been improvements in the water quality of the Great Lakes much remains to be done on toxic elimination and the large contaminant stores in the sediments. Atmospheric deposition has become a significant source of chemicals from outside the basin The Canadian prairies, the agricultural heartland of Canada, is one major ecozone that has not been selected to have current and potential water quality problems examined by a federal government program. Both the quantity and quality of water in this region are potentially significant factors limiting economic diversification and sustainable development in this vast and ecologically disturbed region.*
Keywords: *water quality, inland waters, Canada*

1. Introduction

Internationally, the general perception is that Canada has virtually an unlimited supply of fresh water. About 8 % of the Canadian landmass, the largest in the world after Russia, is covered by lakes and another 2 % by perennial snow and ice (Ommanney, 1989). Based on river discharge, which is a good analogue for water availability, Canadian rivers contain about 9 % of the world's

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renewable water supply. This is not inconsistent with Canada having about 7 % of the world's landmass (Pearce *et al.*, 1985). On a per capita basis, however, it is a generous allocation as Canada has only 30 million people (Halliday, 1997).

Although Canada has a bountiful supply of water, like many other countries, it is not immune from having water quality problems. There are several reasons for this.

First, the prevailing climate is cold continental. With the exception of the moist Pacific and Atlantic coasts, precipitation is low and much of that precipitation comes as winter snowfall. Streamflow, and hence water availability, is highly variable both within years and between years. In semi-arid prairie Canada, peak streamflows can vary by orders of magnitude from year to year. Water available for waste assimilation is therefore highly variable.

Second, Canada is a very urban country with almost 80% of its inhabitants living in urban areas and 60% of those living in centres of 500 000 or more people. Also, most of these urban Canadians live within a few hundred kilometres of the United States boundary (Government of Canada, 1996) yet most Canadian rivers flow north to the Arctic Ocean. Thus, Canadians are no strangers to urban water quality issues.

Third, Canada is a major agricultural and forestry producer and a significant portion of the Canadian landscape has been disturbed for agriculture production and forest harvesting. These types of landscape disturbance can also lead to water quality problems, including eutrophication, contamination by pesticides and increased sedimentation. As noted by Gauthier and Henry (1989), the prairies have become one of the most disturbed, ecologically simplified and overexploited regions in the world.

Fourth, Canada is a significant producer of hydroelectric power and Canadian rivers have been dammed and diverted for that purpose. In fact, if one adds up the interbasin diversions in Canada, the total flow would be exceeded only by the flow in the St. Lawrence and Mackenzie rivers (Day and Quinn, 1987). The water quality effects of diversions on donor and receiving basins can be significant. As well, flow regulation whether for hydroelectric or other purposes affects water quality upstream and downstream of reservoirs.

Fifth, Canada and the United States share the Great Lakes basin and 90 significant transboundary streams. Developments in one country have the potential to affect water quality in the other. About 80% of Canadians live in river basins shared with the United States.

In this paper we briefly outline the administration of waters and highlight major water quality issues in Canada. We then present examples of two programs which were used to assess basin water quality and indicate the significance of these programs in preserving water quality in Canada. In addition, these examples will show how Canada has developed and employed the ecosystem approach to protecting and, where necessary, applying remedial actions for its inland waters.

2. Canadian Water Administration

The Canadian constitution does not directly define responsibilities for water management in

Canada. Instead, a number of laws and regulations that affect water management are divided between the federal and provincial governments. In general, the provinces have clear authority to manage natural resources and public lands, hence water.

Federal authority over water is clearest in Canada's two northern territories (Yukon and Northwest Territories) and for other federal lands. Federal government land holdings in the provinces are small, consisting largely of national parks and Indian reserves. The federal government also has constitutional authority over navigation and fisheries and a shared responsibility for agriculture.

From a water quality perspective, the most significant authority for the federal government is that over fisheries. The courts have defined that authority, narrowly restricting it to the protection of fish rather than allowing it to be used by the federal government to protect or enhance water quality (Saunders, 1988).

The federal government also has a largely undefined responsibility with respect to interprovincial waters and a more clearly defined responsibility with regard to Canada-USA waters. The Prairie Provinces Water Board and the recently established Mackenzie River Basin Board, as well as a host of other federal-provincial arrangements, have been used to deal with interprovincial complexities.

In the mid-1980s the Canadian government carried out an inquiry into federal water policy. The ensuing report (Pearse *et al.*, 1985) made 55 recommendations aimed at all aspects of water management. An underlying message was that water has value and should no longer be treated as a free good. Unfortunately, a decade later water is still "cheaper than dirt" (Tate, 1996).

A Federal Water Policy was promulgated by the Canadian government in 1987 with the objectives of protecting and enhancing the quality of the water resource and promoting the wise and efficient management and use of water (Environment Canada, 1987). It identified five strategies and 25 specific policy statements dealing with federal areas.

The results of that Policy have been mixed. Some initiatives have been dropped while others have been subsumed by the current focus on sustainable development and ecosystem approaches (Mitchell and Shrubsole, 1994; Bruce and Mitchell, 1995a; Pearse and Quinn, 1996).

Canada's most significant environmental protection law, the Canadian Environmental Protection Act (CEPA), came into force in 1988. This Act replaced, in whole or in part, many other pieces of environmental legislation and also updated and strengthened that legislation.

The main objective of CEPA was to protect the environment and human health through management of toxic substances, regulation of federal activities, law enforcement, and promotion of intergovernmental co-operation.

CEPA regulated the export of toxic substances from Canada and the introduction of new substances. The 23 000 substances in use in Canada were listed in a Domestic Substances List and a start made on assessing their toxicity. Several years later, however, fewer than 50 substances or substance groups have been assessed. A more timely and effective process is clearly required.

That said, CEPA has had some notable successes. These include the elimination of lead from gasoline for on-road vehicles, reduction of dioxins and furans fróm pulp mill effluents and reductions in ozone-depleting substances.

A parliamentary review of CEPA (Standing Committee, 1995) led to the introduction of new legislation. The new Act, when passed, will shift the focus from pollution control to pollution prevention. That is from a reactive to an anticipatory mode of operation. The Act will seek the virtual elimination of substances that are persistent, bioaccumulative and toxic from the Canadian environment. Toxic anthropogenic substances would be eliminated while the presence of naturally occurring substances would be reduced to background levels (Niemela, 1997).

The new Act also provides for improved control of pollutants and wastes, including transboundary pollution. It will regulate products of biotechnology, provide new enforcement tools and improve public participation (Niemela, 1997). In a recent landmark decision the Supreme Court of Canada (Sept. 18, 1997) clarified the constitutional basis for federal jurisdiction to control toxic substances.

3. Water Quality Issues

Canadians place a high priority on protecting the environment and human health and on having regulations in place aimed at pollution prevention. Almost 50 % of Canadians believe that the most significant threats to the environment originate in Canada while over a quarter of the population identify the United States as the source of such threats (Insight Canada, 1996). There are over 30 000 commercial chemicals used in Canada and new ones are being introduced at the rate of 100 - 200 per year.

About 25 % of Canadians depend on ground water for domestic supplies. Although data are fragmentary, studies have shown that nitrate and coliform bacteria concentrations in rural wells exceed drinking water guidelines in 20 % to 40 % of tests. Pesticide concentrations exceed guidelines only in 0.1 % of rural wells. Industrial chemicals are detected in urban supplies in about 10 % of tests but almost always below safe drinking water levels (van der Kamp, 1997).

There are a number of point and non-point pollution sources of Canadian aquatic ecosystems. By far the largest quantity of effluent is from some 2 800 municipal wastewater treatment plants which serve about 80% of the population. Generally, discharges to coastal waters receive primary or no treatment; discharges to freshwater receive secondary or tertiary treatment. Chlorine is the usual disinfectant (Chambers *et al.*, 1997).

These treatment plants introduce conventional pollutants such as oxygen demanding substances, suspended solids, nutrients and microorganisms to the environment. Effluents also contain toxic substances, some such as ammonia which can be diluted to safe levels in the receiving waters; others such as organic compounds are persistent and may bioaccumulate if they are not broken down by microorganisms in the receiving waters. Canada does not have national effluent quality guidelines. Effluent quality is gauged against Canadian Water Quality

Guidelines for Aquatic Life (CCREM, 1987). The Guidelines identify concentrations in receiving water and are aimed at protecting specified water uses.

An additional source of pollutants from urban centres is runoff from stormwater drains and, in older areas, combined sewer overflows. Roughly 30 to 50% of rainfall is converted to runoff in urban areas (Chambers *et al.*, 1997). A particular problem in Canada is the shock loading of road salt and other contaminants with spring snow melt.

In general, the effect of municipal effluent and storm water runoff on humans is small. There are occasional instances of microbial contamination in rural areas or resulting from malfunctioning water treatment plants. Beach closures following storm events are not uncommon.

The effects of municipal effluent on receiving systems have been well documented. Habitat and community structure are degraded by elevated ammonia and residual chlorine levels and by oxygen depletion. Increased nutrients have lead to algal blooms and weed growth. Altered flow regimes and stream morphology have affected breeding success of important fish species (Chambers *et al.*, 1997). There have been few studies of the effects of estrogens in Canadian municipal effluents, or other hydrophilic substances, on human or animal populations. This is clearly an area requiring investigation.

Although municipal effluents contain some industrial wastes, major industrial sources are treated separately. National concern over toxic substances has led to considerable improvement in the quality of industrial effluents in the last few decades. This has partially come about through public opinion inducing legislators to promulgate new regulations as well as an increased corporate awareness of the environment. Substances such as pulp mill effluents, liquid mining effluent and specific manufactured substances, such as PCBs, are regulated under federal and provincial laws.

3.1 Great Lakes Water Quality

Canada and the United States share a 8 900 km-long boundary (including Yukon-Alaska) and not surprisingly water-related disputes have arisen between the two countries. The need to establish principles for managing and resolving water-related disputes between the two countries led to the signing of the Boundary Waters Treaty and the creation of the International Joint Commission (IJC) in 1909 to implement the Treaty (IJC, 1990).

The Great Lakes basin is the world's largest fresh water ecosystem and is located in Canada 's industrial heartland. The basin contains 8.5 million Canadians, over one-quarter of Canada's population, and an even larger percentage of the country's economic activity. There are also about 25 million American residents which generate an important part of the US economy (Allardice and Thorp, 1995). Unquestionably human activity on this scale leads to water quality problems.

Most pollution questions between Canada and the USA can be put in an upstream-downstream context with remedial action based on implementing upstream measures and measuring results at the international boundary (Halliday, 1997). This is a consequence of the fact that of the 90 significant transboundary streams, roughly half flow from Canada to the USA or *vice versa* making each country similarly vulnerable to actions by the other. Water quality of the Great Lakes, however, is a common pool problem with both countries adding pollutants and withdrawing water from the pool. Another complicating factor is that the lakes surface areas make up almost one-third of the basin's area. Atmospheric processes thus become very important.

The IJC has examined pollution in the Great Lakes a number of times in its history. Work in the 1960's focused on nutrient problems in Lakes Erie and Ontario. The "death" of Lake Erie became a media issue. The principle cause of the problem was phosphorus and the negotiated response on both sides of the international boundary was to improve sewage treatment, to remove phosphate from laundry detergents and to reduce phosphate loadings from agriculture. The two countries signed a Water Quality Agreement in 1972 that identified water quality objectives in the Great Lakes and specified remedial actions aimed mainly at nutrient issues.

Twenty-five years later eutrophication is no longer a problem in the Great Lakes except for localized algal growth. However, decreased nutrient loading to Lake Erie may be leading to the decline of some fish species (Governments of USA-Canada, 1995). Non-point sources are now the largest single source of phosphorus to the lakes.

In the 1970s toxic substances were identified as a significant water quality issue. Indicators of problems included birth deformities and reproductive failures in fish and wildlife, and the collapse of the sport and commercial fisheries. This led to the 1978 Great Lakes Water Quality Agreement which established an ecosystem approach to water quality management which now forms the basis for all water basin studies in Canada. This type of approach recognizes that all components of a system are interconnected. The links of concern with this approach are those that connect human well-being with the quality of the environment (Dinar *et al.*, 1995).

A key feature in implementing the 1978 Agreement was the establishment in the 1980's of 42 Areas of Concern, or areas with particularly high concentrations of toxic substances. The American and Canadian governments enacted a policy of virtual elimination of persistent toxins and pledged to eliminate the discharge of these at toxic concentrations. Remedial Action Plans, to define the scope and cause of the problem and provide remediation and monitoring plans, were developed for each area (Duda, 1990). Through this process, new legislation and enforcement, and voluntary programs by industry, loadings of many persistent toxic chemicals have declined. It forges links to other local planning processes and encourages meaningful public involvement. Contaminant levels in fish and wildlife are decreasing and some populations are recovering (Governments of USA and Canada, 1995).

A good example of this process is the Hamilton Harbour Remedial Action Plan. Hamiltion Harbour, located on the shore of Lake Ontario, supports and serves a large iron and steel industry as well as other uses, such as recreational boating. It receives many industrial and municipal waste discharges and consequently has numerous environmental problems (Dinar *et al.*, 1995).

Although Hamilton Harbour is one of the most severely dergraded areas in the Great Lakes, Dinar *et al.* have noted that there are signs that the degradation is being reversed. Since 1970, reduced pollution loads from industrial and municipal sources have resulted in gradual improvements in water and sediment quality, improved abundance of benthic organisms and >40 species of fish now frequent the harbour (Dinar *et al.*, 1995).

Despite these generally positive trends much remains to be done to achieve the goal of virtual elimination of toxic chemicals from the Great Lakes. In recent years the rate of improvement has slowed and some increases in levels of contaminants at some locations have been noted. Although point sources of toxic substances have been reduced or eliminated, there remains a vast reservoir of chemicals in the water and sediments that will be redistributed for generations to come. Also, as point sources are eliminated, the atmosphere itself becomes a significant source of chemicals from outside the Basin.

The long-range transport of some air pollutants, especially toxics and acidic substances, is not only a problem for the Great Lakes but for many water bodies in eastern Canada generally. This is the situation for PCBs, toxaphene, DDT, mercury and lead in Lake Superior, and northward to lakes in the Arctic (Bruce and Mitchell, 1995b). The problem has been recognized in the Great Lakes since the mid-1970s and is referred to in the Great Lakes Water Quality Agreement. The 1991 Canada-USA Air Quality Agreement addressed part of the problem, particularly sulphur dioxide emissions which cause acid rain problems in Quebec and Ontario on the Canadian Shield. However, as Bruce and Mitchell have noted, the 1994 Progress Report of this agreement indicated that SO_2 emissions declined more slowly than originally hoped and problems of acidified rain and snow in Canada, mainly from USA sources continue. The agreement does not currently deal with the long-range transport of toxic chemicals which affect thousands of aquatic ecosystems and is a major contributor to human health threats in the Great Lakes Basin and the Arctic (Bruce and Mitchell, 1995b). Bruce and Mitchell concluded that if water quality and ecosytems in eastern Canada are to be protected, stronger action may be needed to reduce transboundary airborne toxics, possibly through the Air Quality Agreement, and attempts are required to accelerate reductions in USA acid-causing emissions.

3.2 Northern River Basins Study (NRBS)

The five-year Northern River Basins Study began in 1991 as a result of a joint agreement between the governments of Canada, Alberta and the Northwest Territories. A major objective of the study was to obtain an understanding of how developments within the Peace, Athabasca and Slave river basins have had cumulative impacts on the mainstem and main tributary aquatic systems (Wrona *et al.*, 1996). The study was also designed to provide the necessary knowledge-base and tools required to assess potential consequences of future developments. To achieve these objectives, the study was divided into eight research components which gathered, analyzed and interpreted data on water quality; contaminant distribution, fate and effects; benthos; fish and fish habitat; riparian vegetation and wildlife; hydrology and hydraulics;

drinking water quality; nutrients; dissolved oxygen; traditional (aboriginal) knowledge; and the use of aquatic resources within the region.

Developments in the basin study area included pulp and paper, saw mills, urban centres, oil sands production, and agriculture among others. Instead of attempting to investigate all the potential stressors, the study initially established a number of research priorities: flow regulation, contaminants (particularly pulp mill effluents), and their effects on the mainstem rivers and major tributaries of the basins (Wrona *et al.*, 1996).

Over the 20's years prior to the genesis of NRBS public concern and awareness of environmental issues associated with development in the basin steadily increased. As a result, the NRBS developed out of a general public perception that the ecosystem was increasingly threatened by anthropogenic activity. As noted by Wrona *et al.* (1996), this perception crystallized in the late 1980's with a proposal to construct a pulp mill in the town of Athabasca. In order to fulfill its mandate, the NRBS had to overcome the problem that there was only limited information available on key ecosystem components and processes. An additional complication was that this information was held by a variety of government agencies, universities and industries. A major challenge for the NRBS, therefore, was assemble and integrate this information and use it to design research activities (Wrona *et al.*, 1996).

The NRBS research program was based on 16 questions which provided scope and focus (Wrona *et al.*, 1996). The research program was designed to address information deficiencies and to build upon existing knowledge for the river basins. Fundamental to this process was the adoption of an ecosystem approach, successfully used in the Great Lakes study of the 1980's (see above), and to use a cumulative effects concept in the research design and interpretation. The study identified and quantified the multiple and diverse stressors of the three rivers basins and assessed the ecological consequences of exposure to those stressors. Human health implications were not investigated but the study provided information to the appropriate authorities for their consideration and use (Wrona *et al.*, 1996). Another major feature of the study was the recognition that various ecosystem components are strongly linked and inter-dependent and that it would be difficult to assess and predict the effects of multiple stressors operating simultaneously on an ecosystem. Wrona *et al.* pointed out that this was further complicated by the synergistic and antagonistic effects of multiple stressors and by the effects occurring at a variety of spatial, temporal and organizational (e.g., individual, population, ecosystem) scales. While each research component of the NRBS focused on specific issues, the components were designed to integrate information across ecosystem components. The overall integration of these components was achieved by a synthesis and modelling component.

Two components of the NRBS were traditional knowledge and other uses. These provided important sociologically-based information to the other research components, particularly in identifying issues and geographic areas of concern for human populations in these basins (Wrona *et al.*, 1996).

Despite their ecological importance, our understanding of how large rivers function and respond to human activities is limited (Wrona *et al.*, 1996). Relative to lakes and small streams, few studies have been undertaken for large rivers, in part due to the logistics of sampling such systems. Historically the Athabasca, Peace and Slave rivers systems served as important food and water sources and transportation routes for people living in the basins. Increasing development has placed greater and often conflicting demands on the use of these important aquatic resources. As noted by Wrona *et al.*, for example, the rivers are used as sinks and conduits for waste products while being regarded as ecosystems of aesthetic, cultural and spiritual value.

Stemming from the 146 project reports generated by the NRBS, and a series of 13 synthesis reports summarizing these, the Study Board produced 24 recommendations for future management of the basins to the government ministers of Canada, Alberta and the Northwest Territiories (Northern River Basins Study Board (Canada), 1996). The Study Board concluded that there is sufficient time through good management and planning to preserve and protect the northern rivers while supporting wise and sustainable development. Specific reaches of the rivers where remedial action is needed were identified and underline the importance of action. As highlighted in the Study Board's report, the timeliness of the study, its value as a benchmark, the importance of technological improvements and scientific understanding, and public concerns indicate the need for action on the Board's recommendations as soon as possible. This is the responsibility of the three governments who have stewardship of the basins natural resources. There is strong confidence that continued use and prudent development can occur in balance with protection of the natural ecosystems and preservation of the culture and evolving lifestyles of the traditional residents.

3.3 Future Needs - the Canadian Prairies

Lakes and wetlands across the prairies are regularly interspersed among cultivated fields where both fertilizers and pesticides are commonly used. Herbicides and fertilizers make their way into water bodies through processes of runoff, groundwater flow, spray drift or aeolian deposition (Robarts and Waiser, 1998). Moreover, on the prairies where a high level of soil fertility is maintained by fertilizing, nutrient enrichment of surface waters may be considerable, especially at certain times of the year. Although the potential effects of these chemicals (and nutrients) on prairie surface waters are largely unknown, it has been hypothesized that pesticides might adversely affect primary production thus negatively affecting zooplankton and avian production (Robarts and Waiser, 1998). These surface waters are the foundation for biodiversity in the region and many are also used for drinking water supplies. Further, due to their geographical location, prairie surface waters will be subjected to the interacting effects of climatic warming (which will probably result in a warmer and more arid climate), ozone depletion (increased UV-radiation) as well as agricultural activities (Robarts and Waiser, 1998). Also, while historically agriculture has formed the major economic foundation for the prairies, economic diversification has become a reality for the future. This may present additional environmental concerns for surface and subsurface water quality.

Considering the economic, as well as the ecological, significance of the Canadian prairies it is surprising that no government sponsored programs to look at actual or potential problems related to water quality in this vast region have been undertaken or are currently foreseen. Clearly, there is an urgent need for an ecosystem study, similar in scope and objectives to those of the Great Lakes and the Northern River Basins, of the major surface and subsurface water systems in the prairie ecozone. For example, eutrophication, while no longer considered to be a major water quality problem in eastern Canada, remains a significant problem not only in the prairies but also in the Arctic.

Cities, rural communities and individual farmers in the prairies are faced with the challenge of producing drinking water. In Saskatchewan, surface waters are characterized by high dissolved organic carbon concentrations (>15 $mg \cdot l^{-1}$) and are located on agricultural land where evaporation exceeds precipitation. Saskatchewan subsurface waters are highly mineralized since they often occur in geological formations originating from an inland sea. Conventional water treatment processes currently used in Saskatchewan's offer low possibilities for sustainable, cost-effective production of drinking water. Because of the chemical features of these prairie waters, it may be necessary to design a treatment system that requires physical, chemical and biological processes. There is a strong necessity for the development of suitable methods to provide potable water to communities and individuals on the Canadian prairies if a sustainable future based on economic diversity is to be realized.

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