Infrastructure Canada

Water Infrastructure:

Research for Policy & Program Development

January 2004

RESEARCH AND ANALYSIS
INFRASTRUCTURE CANADA

Canada

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1. Introduction

Canada's infrastructure is among the best in the world: it was ranked fifth out of 22 developed countries in the early 1990s.[1] Since the time of Confederation, the federal government has played a significant role in the development of our infrastructure, and it continues today with initiatives such as the Infrastructure Canada Program, the Canada Strategic Infrastructure Fund, and the new Municipal-Rural Infrastructure Fund. All of these programs fund, among other infrastructure areas, water infrastructure. Water infrastructure – the reservoirs, towers, pipes, pumps, sewers, treatment plants and drainage systems that we rely on every day to store, transport and treat our water – is a vital requirement for public health and economic growth.

Provincial and territorial governments have primary jurisdiction over most operational aspects of water management and protection, and they delegate many of these responsibilities to municipal governments. The federal government's role in water infrastructure is a more strategic one and involves activities such as funding water infrastructure projects and research and policy development to ensure that Canada meets its modern infrastructure needs.

Infrastructure Canada (INFC) is leading the development and implementation of Canada's long-term infrastructure strategy, and as part of this process the department is conducting research on various infrastructure areas, including water infrastructure, to inform future funding and policy decisions. Recently, the INFC Research and Analysis Division reviewed current research on water infrastructure – primarily drinking water and wastewater infrastructure – consulting numerous and diverse sources, ranging from academic publications to organization-funded reports (see Appendix B for the full list), and found common themes related to water infrastructure and future research needs. A large volume of research already exists on water infrastructure, much of which is technical in nature and focused on issues such as optimal pipe design and pressure flow; however, research does exist in non-technical areas including evaluation, financing, water and demand management, partnerships, state and needs, and protection of source water. These non-technical themes are the focus of this report, which is a culmination of the analysis of the research findings.

This report has four main objectives:

- To improve knowledge and understanding around water infrastructure;
- To present preliminary key research findings;
- To identify priorities for future research; and
- To contribute to advancing the department's research strategy through strengthening the knowledge base for evidence-based policy- and decision-making.

1 According to the World Economic Forum/Institute for Management and Development, the top five countries were Norway, Switzerland, Sweden, Denmark and Canada. Federation of Canadian Municipalities and McGill University, *Report on the State of Municipal Infrastructure in Canada*. (Ottawa, Ontario: FCM, 1996), p.4; National Roundtable on Environment and Economy, *State of the Debate on the Environment and the Economy: Water and Wastewater Services in Canada*, (Ottawa, Ontario: NRTEE,1996), p.7. http://www.nrtee-trnee.ca/publications/pdf/sod_water_E.pdf

The report is divided into four sections. Section 1 serves as an introduction and identifies the objectives of the report. Section 2 provides background information on water infrastructure including its definition. In Section 3, the main research findings are presented. The final section identifies some of the key research questions that have emerged from an analysis of the literature. Appendix A consists of an annotated bibliography of several sources of particular interest and relevance to water infrastructure. In Appendix B, the sources consulted for this report are listed by thematic areas.

2. The Nature of Water Infrastructure

Canada has 9% of the world's renewable water[2] and only 0.5% of its population; however, the abundance of this natural resource does not exempt Canada from water-related problems. In Canada, water treatment and distribution are under-priced, and water infrastructure is under-funded. Although we are more dependent on this natural resource, and its necessary infrastructure, than any other type of infrastructure, we frequently forget about it and its significance to our health and our economy – until something goes wrong. This section defines water infrastructure, provides background information on water infrastructure, and describes the properties that make it unique compared to other types of infrastructure.

Definitions of water infrastructure vary from one organization to the next. They generally include any or all of the following:

- Water treatment plants;
- Water distribution systems, including pipes and pumps;
- Urban drainage, including separate storm and sanitary sewers, as well as combined sewers with overflows;
- Wastewater collection systems (such as reservoirs and towers); and
- Wastewater treatment plants.

For example, in its definition of "water infrastructure," Environment Canada includes water treatment plants, water mains, water towers and reservoirs, sewer pipes, and sewage treatment plants.[3] The Ontario Municipal Economic Infrastructure Financing Authority refers to water works as: "any works for the collection, production, treatment, storage, supply and distribution of water, or any part of such works, but does not include plumbing."[4] And in the United States, water infrastructure is commonly divided into drinking water infrastructure and wastewater infrastructure.[5]

Despite differing definitions, the literature agrees that water, and consequently, water infrastructure, is a key determinant of public health and of quality of life. A reliable supply of clean, non-contaminated water is essential in ensuring the health of a community, as is the proper treatment and disposal of wastewater. Water is also an essential component of all sectors of the economy, be it for irrigation, transportation, recreation, or as a product ingredient.

2 Environment Canada, "1987 Canadian Federal Water Policy." http://www.ec.gc.ca/water/en/info/pubs/fedpol/e_fedpol.htm

3 Environment Canada. Freshwater Website. http://www.ec.gc.ca/water/en/manage/effic/e_sustin.htm

4 Ontario Municipal Economic Infrastructure Financing Authority, "2003 Loan Eligibility Criteria and Definitions of Eligible Infrastructure Investments."

5 For example, federal funding in the form of the State Revolving Funds separates water infrastructure along these two categories, as does a US General Accounting Office (GAO) report, which explains that drinking water infrastructure "includes treatment and storage facilities and distribution systems (pipes and conduits), while wastewater infrastructure includes sewage collection systems and treatment works." United States General Accounting Office. Report to Congressional Requesters. "Water Infrastructure: Information on Federal and State Financial Assistance." November 2001. http://yosemite.epa.gov/R10/ecocomm.nsf/0/7b68c420b668ada5882569ab00720988/$FILE/GAO-water%20funding.pdf

Several studies point to the relationship between all types of infrastructure and economic growth[6] While a lack of adequate infrastructure can hamper growth, the research suggests that investment in infrastructure can stimulate economic growth, "the existing literature suggests strongly that public spending on infrastructure generates growth in the private sector. Infrastructure renewal is necessary for maintaining and enhancing prosperity."[7] Public investment in infrastructure is critical, since it encourages productivity growth, competitiveness and trade, and promotes regional economic growth.[8]

The benefits of water infrastructure are clear; however, its expense can deter sufficient investment. Water is the most capital-intensive of all utilities. The ratio of infrastructure investment to revenues is almost 5:1 in water and wastewater, whereas it is only 3:1 in electricity and telephone and 2.5:1 in gas. This means that a significantly higher amount of investment is required to fund water infrastructure, yet it generates fewer revenues than other utilities.[9] Further, about 70-80% of water and wastewater assets are underground. Such infrastructure is therefore often "out of sight, out of mind."[10] There is a tendency to under-invest in maintenance of infrastructure that cannot be seen, especially when financial resources are limited. Consequently, many people do not think about water infrastructure until problems arise, such as leaks or bursts. Once these problems surface, repairing the infrastructure can be a costly endeavour.[11] The 1987 Federal Water Policy recognized water as a scarce commodity that "is, at present, Canada's most undervalued and neglected natural resource."[12]

Water infrastructure, in comparison to other types of infrastructure such as transportation, energy, dams, waste management, recreation, leisure and border infrastructure, is dependent on a limited, vulnerable source. Water infrastructure not only transports and supplies a limited resource; it must protect that supply and ensure its purity for human consumption. In contrast, other types of infrastructure, such as energy infrastructure, do not depend on a natural and scarce resource but instead can be produced using various man-made or natural products and resources. Water infrastructure is a unique type of infrastructure: we rely upon it every day, it is critical to our health and to economic development, and it is dependent on, and responsible for supplying, a vulnerable and limited resource that is under increasing pressure.

6 Two such studies are A. S. Rakhra, *Reinvesting in Infrastructure for Economic Growth.* (Ottawa, ON: Industry, Science and Technology Canada, 1992) and FCM & McGill.

7 FCM and McGill, p.1.

8 Canada Mortgage and Housing Corporation (CMHC), *Alternative Methods of Financing Municipal Infrastructure*, (Ottawa ON: CMHC, 1999a).

9 Ontario SuperBuild Corporation (OSBC), *Organization of Municipal Water and Wastewater Systems in Ontario.* (Toronto ON: OSBC, 2002b).

10 OSBC 2002b, p.73.

11 OSBC 2002b; FCM & McGill.

12 Environment Canada, "1987 Canadian Federal Water Policy." http://www.ec.gc.ca/water/en/info/pubs/fedpol/e_fedpol.htm.

3. Main Research Findings

The 21st century poses new challenges for water infrastructure. Water infrastructure, to be effective, must be studied and evaluated within the particular confines of today's challenges. This section first describes the pressures facing water infrastructure today and then provides a summary of the research findings related to the state of water, the management of water infrastructure assets, and infrastructure financing and innovation.

New Challenges Facing Water Infrastructure in the 21st Century

Water infrastructure faces many challenges, including scarcity of funding and deterioration of old infrastructure; however, there are also some new pressures that have changed the context in which water infrastructure decisions are now made. These pressures compound the existing challenges.[13] This section examines some of these key challenges including the new face of Canadian urbanisation, climate change, and increasingly stringent standards.

Over the years, high population growth focused on large metropolitan centres has dramatically increased the need for expanded and upgraded infrastructure in these areas.[14] In the 1970s, low-density suburban housing mushroomed. These sprawling developments placed a large demand on existing infrastructure, and necessitated the expansion of existing networks.[15] In fact, much of the type of development seen in Canadian cities over the last 40 years is characterized as sprawl. Canada now has 27 census metropolitan areas (CMAs), which make up approximately two-thirds of the nation's total population.[16] A CMA is a very large urban area that possesses a minimum of 100,000 inhabitants and is adjacent to regions with a high degree of social and economic integration with the urban core. Approximately two-thirds of the Canadian population lives in CMAs, and the seven largest CMAs account for about 45% of the national population. CMAs are not traditional urban areas; instead, they are developing into city-region states with unprecedented infrastructure challenges.

As Canada's CMAs grow, residents and businesses tend to move to the suburbs, demanding new infrastructure and leaving a shrinking tax base to support the city core and its infrastructure. Property taxes, commercial taxes, land prices, housing prices, zoning restrictions, and other costs are lower in suburban areas than in the city cores. The flight out of cities causes downtown property taxes to increase further, which creates a vicious circle.[17] Extension of this infrastructure occurs at a significant cost. Furthermore, in the case of sprawl, as opposed to compact developments, the cost of water and sewer infrastructure is much higher. For example, one study showed that low-density developments in the Greater Toronto Area would cost billions more than re-urbanization

13 NRTEE.

14 C. G. Vander Ploeg, *Big City Revenues - A Canada-US Comparison of Municipal Tax Tools and Revenue Levers.* (Calgary, AB: Canada West Foundation, 2002).

15 Rakhra ; FCM & McGill; M.S. Mirza and M. Haider, *The State of Infrastructure in Canada:Implications for Infrastructure Planning and Policy.* (Montréal, QC: McGill University, 2003).

16 TD Economics Special Report, "A Choice Between Investing in Canada's Cities or Disinvesting in Canada's Future." TD Bank Financial Group. 2002.

17 Ibid.

or brown-field developments.[18] In addition, existing infrastructure in urban areas today is in need of maintenance and repair, but these needs are often deferred in favour of infrastructure expansion into new communities on the fringe.[19]

Exacerbating this problem is the inadequate funding and status of Canadian municipalities. Municipalities are creations of the provinces, and provincial legislation limits their ability to spend and raise revenues.[20] These restrictions have serious consequences: between 1995 and 2002, local government revenues increased only 14% compared to federal government revenue increases of 38% and provincial revenues of 30%. Amidst these challenges, municipalities are also facing the increased responsibilities that the federal and provincial governments have downloaded to municipal and regional governments in recent years.

A second key challenge is climate change. Pressures on water sources are increasing, and models are predicting a drier future in many parts of Canada. Climate change is projected to affect river flows, lake levels, groundwater levels and quality, and water temperatures in most of southern Canada, with implications for water infrastructure due to reduced water supplies and waste assimilation, increased pollution concentrations, and increased storm sewer overflows from high intensity rainfalls.[21]

A third challenge is new standards, including stricter environmental and health regulations, which have increased the need for upgraded water and wastewater infrastructure. Increasingly, water systems must meet new seismic, safety and security standards, and legislative and regulatory demands are increasing the need for more complex treatment systems. This can represent a substantial cost for municipalities. Some municipalities may simply not have the money to either upgrade their infrastructure or pay for the effective regulation and maintenance of quality standards.[22]

3.1 The State of Water Infrastructure

Experts agree that Canada's water infrastructure is inadequate and in need of substantial investment. In a 1995/1996 survey of 167 Canadian municipalities, 59% noted that water distribution infrastructure was in need of repair and 43% said that the condition of their water supply was unacceptable. With respect to wastewater infrastructure, 68% described their sanitary and combined sewers as being in need of repair, 58% said that their sewage treatment was unacceptable, and 53% noted that storm sewers were in need of upgrading. Finally, with an estimated average age of 42 years in 1995, the sanitary and combined sewers are the oldest type of infrastructure in the survey, which also included transportation infrastructure, waste management, public buildings and recreational facilities.[23]

18 Mirza and Haider.

19 Ibid.

20 TD.

21 Global Change Strategies International and the Meteorological Service of Canada, "Water Sector: Vulnerability and Adaptation to Climate Change," 2000. www.gcsi.ca/publications/watereport.html.

22 Canadian Council of Environment Ministers. "National Action Plan to Encourage Municipal Water Use Efficiency." 2001. Prepared by The CCME Water Use Efficiency Task Group. http://www.ec.gc.ca/water/en/info/pubs/action/e_action.htm

23 Mirza and Haider.

Aging Infrastructure

Much of the older infrastructure in Canada is approaching the end of its lifespan and needs to be replaced.[24] Water infrastructure construction materials and practices have changed from cast iron pipe with leaded joints in the 1950s to asbestos cement pipe and ductile iron pipe to plastic, which is used today. The old materials and practices cannot accommodate today's environmental and health standards or the application of advanced treatment technology, and bringing older treatment plants and pipes to today's standards requires substantial and ongoing investments.[25] Due to changes in construction materials, pipes created since World War II have shorter life spans than older pipes. Subsequently, pipes installed at the end of the 19th century and newer pipes installed after World War II are nearing the end of their lifespan simultaneously. This is creating a bulge in demand for new water infrastructure.[26]

Aging infrastructure also needs replacement due to a lack of maintenance. Several studies point to the deteriorating conditions of infrastructure facilities.[27] Water infrastructure was well maintained in Canada until the 1970s due to good economic conditions, but also because the majority of the facilities were built after World War II and were still relatively new. Since then, however, all parts of these systems have been deteriorating. Only 20% of expenditures on all types of infrastructure contribute to repairs, while the remaining 80% supports new construction.[28] As Mirza and Haider (2003) discuss, deterioration is mainly due to deferred maintenance and repair of existing facilities. Once deterioration sets in, the costs of repairing infrastructure compound exponentially, which makes maintenance an even bigger task.[29] There is therefore a need for continuous preventative maintenance and reinvestment in water and sewage systems. This type of maintenance will reduce the need to fund the construction of new plants and massive overhauls of existing ones due to crumbling infrastructure.[30]

Favouring construction over maintenance or repair of infrastructure is politically more appealing. A joint study by the FCM and McGill (1996) argues that government priorities frequently prefer the construction of new infrastructure facilities. This approach is much more politically popular than simply repairing existing infrastructure, especially since most water infrastructure is underground, and is therefore "out of sight, out of mind."[31] The public is not fully aware of the infrastructure problem, and thus would rather support other initiatives and developments.[32]

Canada's situation is not unique among other industrialized countries. Many countries belonging to the Organization for Economic Cooperation and Development (OECD) have neglected their public capital. Since 1975, the ratio of investment for all types of public infrastructure to gross domestic product has been declining in most OECD countries, and virtually all of the OECD countries are experiencing needs similar to those of Canada with respect to the provision of water infrastructure.[33] According to Mirza and Haider, "the state of infrastructure around the world has declined steadily at least over the past three decades and several of these existing infrastructure facilities are inadequate to meet

24 FCM & McGill.

25 Canada Mortgage and Housing Corporation (CMHC). *Provision ofMunicipal Infrastructure Through Demand Management.* (Ottawa, ON: CMHC, 1999b).

26 Bob Walker, "Sustainable Infrastructure: It's Our Responsibility." *PVC News.* Volume 24(2). 2001. (Dallas TX: Uni-Bell PVC Pipe Association).

27 Rakhra; FCM & McGill; NRTEE; Mirza and Haider.

28 FCM & McGill; Mirza and Haider.

29 Mirza and Haider; FCM & McGill.

30 Mirza and Haider.

31 OSBC 2002b, p.73.

32 FCM & McGill.

33 Organization for Economic Cooperation and Development (OECD). *Infrastructure Policies for the 1990s.* (Paris, France: OECD,1993).

the present population requirements and the projected future growth and development. Infrastructure everywhere is in serious need of repair and upgrading."[34]

For example, deteriorating water infrastructure is a significant problem in the United States. Deferred maintenance has caused the deterioration of many water and wastewater systems to the point that they are either unsafe or unreliable. The U.S. Environmental Protection Agency estimates that the U.S. will need to spend about one trillion dollars on capital, maintenance and operations of water and wastewater systems between 2010 and 2020. Much of this spending is for the replacement of current systems that were not maintained.[35]

Several organizations have studied the effects of deteriorating infrastructure in Canada. For example, the Ontario Sewer and Watermain Contractors Association (OSWCA) contends that Ontario's water mains experience 25 breaks per 100km per year, which costs $40 million in repairs, and a loss of 40% of purified water. The OSWCA estimates that 25% of the water system must be replaced and 50% must be restored over the next 60 years.[36] The Federation of Canadian Municipalities (FCM) also notes that many systems are currently unable to meet purity standards, and suffer from source contamination, deteriorating storage systems and limited water supplies.[37] Finally, the National Round Table on the Environment and the Economy (NRTEE) estimates that poorly maintained piping systems and sewers lose up to 25% of the water they carry. This means that effluent may discharge into land mass and groundwater rather than being treated in wastewater plants.[38]

Estimates of Needs and Replacement Costs

One of the leading areas of research concerns the quantification of the state of water infrastructure in Canada – be it an estimation of the replacement value of the current stock, or the amount of money required to bring current infrastructure to acceptable levels. The research identified a lack of consistency in assessing both the state of water infrastructure in Canada and current infrastructure financing needs. There are different types of costs associated with infrastructure including maintenance of existing infrastructure, rehabilitation and replacement of existing stock, and new construction. While some studies attempt to estimate the cost of maintaining water infrastructure, others measure the need for new or upgraded infrastructure; therefore, it is very difficult to compare the cost estimates of water infrastructure needs.

The figures presented in the literature are not particularly persuasive, nor are they all comparable. Estimates range from $38-$39 billion for maintaining existing capital stocks and services[39] to $88.4 billion for new and upgraded water and wastewater infrastructure over a fifteen year period[40] to $80 to $90 billion over a ten year period.[41] Evidently, there are several differing estimates regarding water infrastructure needs in Canada, but there is a consensus among all

34 Mirza and Haider, p.3.

35 Walker.

36 Canada Mortgage and Housing Corporation (CMHC), *Urban Infrastructure in Canada.* (Ottawa ON: CMHC, 1992).

37 FCM & McGill.

38 NRTEE.

39 Ibid.

40 According to a 1997 study by the CWWA, the need for new and upgraded water and wastewater infrastructure in Canada is estimated at $88.4 billion over the period 1997-2012. (Canadian Water and Wastewater Association (CWWA). *Municipal Water and Wastewater Infrastructure – Estimated Investment Needs 1997-2012.* (Ottawa ON: CWWA, 1997.)

41 FCM & McGill.

studies that water infrastructure urgently needs billions of dollars of investment. In the 1990s, estimates for necessary water infrastructure expenditures ranged from $9 to $19 billion per year; therefore, in 2003 the total is probably more than $10 billion per year.[42]

These estimates have several problems including their reliance on insufficient data, their static context and their difference in methods and definitions. Data collection on infrastructure is often inadequate. According to Mirza and Haider "several municipalities in Canada do not have an inventory of the infrastructure in their jurisdiction. Moreover, many of the municipalities that do have a partial or more complete inventory of their infrastructure, do not have a detailed description and history of the condition of the various infrastructure facilities."[43] Complete inventories and detailed condition assessments of water infrastructure facilities is crucial for estimating costs and for ensuring optimal repair and rehabilitation strategies. Furthermore, infrastructure cost estimates are often one-time assessments – not longitudinal studies, which makes it difficult to assess a change in need over time. Different studies also employ different methods of data collection and analysis, so their results are somewhat varied.

Each study employs a different definition of "water infrastructure," and as a result, attempts to measure different things. This leads to differing estimates of need. It also makes it difficult, if not impossible, to compare findings between studies. There is a clear need for consistency in the approaches used to estimate the need for water infrastructure. Establishing common methods will enable accurate and comparable assessments of the specific need for water infrastructure – both between regions and for Canada as a whole.

3.2 The Management of Water Infrastructure Assets

Accurate inventories and assessments of infrastructure are required for municipalities to implement asset management practices. The United States Federal Highway Administration (US FHWA) defines asset management as "a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making."[44]

It is often described as a lifecycle management method for infrastructure because it takes into consideration expenditures from construction through maintenance during the entire life of an asset.[45] Data management is central to asset management planning and spans all dimensions of the process, yet is inadequate in many municipalities. As a result, these municipalities lack the expertise and the information needed to monitor infrastructure, and to assess the need for new or upgraded water infrastructure. Without a system of data collection and monitoring, it is almost impossible to make an informed decision on whether to repair, expand or upgrade infrastructure.

Asset management is useful because it focuses on how a system is performing overall, rather than specific indicators such as how much money has been spent. The system is also viewed in its entirety, rather than component-by-component, which requires taking into account the effect that a change in one part of the system can have on another.[46] The research noted that many Canadian municipalities, particularly smaller ones, do not have an asset management

42 A joint study by FCM and McGill in 1996 estimated the need for water infrastructure totaled between $80 and $90 billion over 10 years, which is approximately $19 billion annually. (FCM and McGill). A study by Peat Marwick (1994) has estimated that an additional $41 billion will be required by the year 2015 for new capital demands for water and wastewater infrastructure. (Peat Marwick, "Introduction to Public-Private Partnerships." *Proceedings of the 23rd Annual Technical Symposium and Exhibition of the Water Environment Association of Ontario.* (Toronto ON: Peat Marwick, 1994); CMHC 1999b, p.5.)

43 Mirza and Haider, p.41.

44 United States Federal Highway Administration (US FHWA), "Asset Management." http://www.fhwa.dot.gov/infrastructure/asstmgmt/assetman.htm. 2003.

45 US FHWA. 2003.

46 D. Geiger, "Asset Management: Resources for Maximizing Your Transportation Investment." *APWA Reporter*. Volume 70(7): 23. 2003.

program.[47] This is a concern that impacts water infrastructure in particular, as well as other forms of infrastructure. Research into effective and efficient ways of implementing asset management programs in all municipalities is therefore required.[48] The establishment of such a system in a municipality would leverage several public benefits – it would improve regulation of infrastructure assets and ensure that municipalities show evidenced-based need for water infrastructure. Such a system would ultimately lead to an improvement in the management of public funds.

3.3 Financing Water Infrastructure

Financing water infrastructure can be a major challenge for municipalities and communities. Trends in the last 30 years indicate that the proportion of the national pie devoted to public infrastructure has been declining. Not only has public investment been on the decline, but also investment requirements to maintain, upgrade and expand infrastructure have been on the rise.[49] Thus, a gap has developed between what is needed to bring public infrastructure to satisfactory levels and current expenditures on this infrastructure. A 1984 study by the Federation of Canadian Municipalities estimated that this gap was 25% of annual investment in urban infrastructure.[50]

Lack of Funds

According to the literature, one of the main problems with investing in infrastructure is the lack of funding available for such investment, given the high cost of servicing water infrastructure. Canada had a strong cost-sharing program for infrastructure among all levels of government until 1984, when the federal government terminated all direct assistance for municipal infrastructure. The elimination or reduction of provincial/territorial and federal grants reduced the funds available for maintenance, repair and replacement of water and wastewater infrastructure.[51] There has recently been a renewed commitment from the federal government to assist in financing infrastructure. However, these programs alone are not enough to meet Canada's infrastructure needs.

The municipal revenue structure contributes to the lack of funds for infrastructure. As creatures of the province, municipalities are constrained in the ways in which they can raise revenue. Their main source of revenue comes from property taxes; however, the province regulates property tax increases. Because of this regulation, municipal revenues have not increased in proportion to population and inflation increases. Between 1995 and 2001, local government revenues increased 14%, but federal revenues increased 38% and provincial revenues increased 30%.[52] In many respects, the stagnant growth in revenue is a function of the lack of elasticity in the property tax, the primary tax used by most Canadian cities. Compounding the lack of buoyancy in city tax revenues is the fact that operating and capital grants have not kept pace either. As a result, municipalities are more cash-strapped than before.[53]

Municipalities are also dealing with urban social challenges, such as homelessness, poverty and illegal drug use. As a result, municipalities have tended to focus on the more visible and politically sensitive priorities, while infrastructure spending has been pushed aside. Cities are finding it difficult to keep up with the demand for traditional services, let alone addressing a whole new set of problems.[54] The recent downgrading of responsibilities to municipalities in many provinces has further constrained budgets. Cities are being

47 FCM & McGill.

48 OSBC 2002b; FCM & McGill.

49 Mirza & Haider.

50 Rakhra.

51 FCM & McGill.

52 Mirza and Haider, p.29.

53 Vander Ploeg.

54 Ibid.

confronted with an expanded list of responsibilities due to both federal and provincial downloading, including responsibility for the provision of affordable housing and a larger role in community and social services.

Under-Pricing of Water

One of the major problems with respect to water infrastructure in Canada is that water itself is under-priced. In most countries, there is an inverse relationship between the price of water and the amount of water consumed. This is true for Canada: the price of water is one of lowest in the developed world,[55] and per-capita consumption levels are one of the highest in the world, second only to the United States. On average, Canadians use 343 litres of water per person per day.[56] In countries where water is expensive, such as Sweden and France, per capita water consumption is much lower than in Canada. Further, in these countries, revenues more than cover the costs of providing the service.[57]

In Canada, many municipalities under-charge the real cost of providing and maintaining the service, often through a flat rate, a constant rate, or declining block rates.[58] Flat rates are unrelated to the volume of water used – customers pay the same amount each billing period – and provide no incentive for limiting water usage. In contrast, rate structures that depend on the volume of water used are referred to as "volume-based pricing" and require the use of water meters. Metering, when used with an effective pricing system, is an effective water conservation measure. Metered households in Canada use substantially less water than unmetered households; however, in 1999, only 56% of Canadian households served by municipal water systems were metered.[59]

A constant rate is the simplest type of volume-based rates: users pay a constant rate per unit. Declining block rates (DBR) and increasing block rates are also examples of volume-based pricing. With DBRs, the unit cost of successive volumes (or blocks) decreases as consumption increases. In contrast, with increasing block rates the unit cost increases as consumption increases. DBRs function like a flat rate when customers are charged a minimum fee for a certain volume of water that is greater than the normal amount that residential customers use. The number of customers who paid this type of DBR plus those paying a flat rate totalled 50 % of Canadian households in 1999. This is a serious issue, since residential water users who pay a flat rate used 457 litres/person/day in 1999, which is 70% more water than Canadians charged a volume-based rate.[60]

The under-pricing of water means that municipalities do not recover all of the costs associated with providing the service; therefore, funds for the maintenance and upgrade of water infrastructure must be obtained from general municipal revenues, which are already quite constrained. Subsequently, water infrastructure is under-funded.[61] Furthermore, under-pricing leads to over consumption, which increases overall demand.[62] Under-pricing water depletes the available supply of drinking water and increases the amount of wastewater that must be treated. Ultimately, this leads to an increasing strain on water infrastructure. New infrastructure, in addition to more frequent repairs to the existing stock, becomes necessary.[63] In conclusion, Canada could more effectively use water pricing – especially volume-based pricing – to decrease water consumption, decrease the burden on infrastructure, and increase revenues for infrastructure.

55 Klas Ringskog, "International Trends in Water Pricing and Use." World Bank, 2000. http://lnweb18.worldbank.org/mna/mena.nsf/0/2421f467c2c026268525695100660e9/$FILE/Riyadh-Final.ppt

56 Environment Canada (EC), "Municipal Water Pricing, 1991-1999." 2001. http://www.ec.gc.ca/water/en/info/pubs/sss/Pricing91-99.pdf

57 NRTEE; Klas Ringskog.

58 CMHC 1999b.

59 EC 2001.

60 Ibid.

61 NRTEE; FCM & McGill.

62 NRTEE; CMHC 1999b; OSBC 2002b.

63 CMHC 1999b; NRTEE.

Full Cost Pricing as a Financing Option

Several studies in the literature highlight the need to move toward a full cost, user-pay system with respect to water and wastewater infrastructure.[64] User fees are a good way to finance water and wastewater services, since the people who directly benefit from a service pay for it. They are appropriate in cases where people use facilities to varying degrees and can be used to control use during peak periods. For example, the City of Los Angeles uses peak load pricing with higher charges for water during the dry season, in order to reduce consumption during these periods.[65]

Full cost pricing ensures that resources are allocated efficiently because the users pay the full cost of providing water and wastewater services.[66] Therefore, people must pay more to consume additional water services, and this acts to discourage over consumption. Full cost pricing reduces the need for water subsidization, and more revenue is generated for maintenance and upgrading of infrastructure.[67]

With increasing block rates, in contrast to declining block rates (mentioned earlier), the charge per unit of water increases with use. This approach is efficient, since charges reflect marginal cost. It is also equitable because those who incur higher costs pay more, and thus, the system encourages resource conservation.[68]

Full cost pricing must be used with caution because it can result in equity problems when members of a community cannot afford to pay the full cost of maintaining infrastructure.[69] Such a system must maintain the affordability of water and wastewater services for low-income people,[70] which could be accomplished through subsidies and assistance for low-income people.

The financing of storm water infrastructure can be achieved in part through user pay systems, as well. However, the costs associated with storm water are often large and associated with the clean-up of environmental effects. For example, clean-up costs of storm water impacts at Ontario's 16 Remedial Action Plan sites were estimated to be $2.5 billion, and local storm water management programs can have annual costs in excess of 5 million dollars. Currently, Regina, Saskatchewan is the only city in Canada that levies user fees for storm water infrastructure.[71]

In addition to the advantages discussed, full cost pricing can leverage several other benefits. If full cost pricing reflects the environmental impact of water use such as water table depletion, water pollution, and conservation and replenishment measures, it can promote the conservation of resources and the adoption of sustainable practices. It can also encourage the development of eco-efficient environmental technologies and promote economic development through infrastructure renewal and development. Over the long term, homebuilders and homeowners could change elements of building design, for example, to include plumbing systems that re-use water.[72] This would result in reduced infrastructure requirements. If water prices rise by 100% over

64 CMHC 1999b; American Water Works Association (AWWA), *Manual of Water Supply Practices: Water Utility Capital Financing, Second Edition.* (Denver CO: AWWA, 1998); American Water Works Association (AWWA), *Manual of Water Supply Practices: Principles of Water Rates, Fees and Charges, Fifth Edition.* (Denver CO: AWWA, 2000); NRTEE; FCM & McGill; KPMG, *Analysis of Business Models and Their Applicability to Ontario.* (Toronto ON: KPMG, 2002).

65 CMHC 1999a.

66 Ibid.

67 CMHC 1999b; AWWA 2000; OSBC 2002b.

68 CMHC1999a; AWWA 2000; Vander Ploeg.

69 CMHC 1999a.

70 KPMG; CMHC 1999a.

71 Canadian Water and Wastewater Association (CWWA). *Members' Briefing Book.* (Ottawa ON: CWWA, 2003).

72 NRTEE.

time, for example, water usage and a related percentage of wastewater generated decline by approximately 30%, so the actual amount of infrastructure financing required is an over-estimate, and could probably be reduced by 10-16%.[73] Full cost pricing is a significant and fundamental starting point for water infrastructure financing, but several other financing options may also be used.

Public-Private Partnerships

Public-private partnerships are an increasingly popular method for financing infrastructure, including water infrastructure, in Canada. According to the Canadian Mortgage and Housing Corporation, "public-private partnerships (PPP), or 'privatization' is a growth industry in Canada."[74] These partnerships range in the degree to which private firms are involved in the building or operating of water infrastructure. They can help governments control expenditures while expanding infrastructure and can create new revenue streams, accelerate project completion times, and reduce financial risks for governments. Further, the establishment of partnerships gives governments the opportunity to take advantage of the expertise that private firms can offer in the area of water infrastructure. For example, private sector partnerships can help expose the government to sophisticated methods of planning and financing infrastructure, to more creativity, and to expertise and technology in the financing and delivery of public services.[75]

Such partnerships, however, bring their own potential risks such as a loss of control, confused lines of accountability, increased user costs, loss of public sector jobs, limited competition, limited control over public policy, perception of bias in the selection process, transfer of assets, and leaking of confidential information.[76] Moreover, the private sector may not be as concerned with social responsibility, environmental issues, local knowledge, and job generation as the public sector. When successfully implemented, however, partnerships are an innovative approach to enabling governments to carry out projects unlikely to proceed without private assistance, and are a useful tool to assist in working towards meeting infrastructure needs.

Development Charges, Special Districts, Funds, and Bonds

In addition to full cost pricing and public-private partnerships, the literature discusses tools such as development charges, special districts, funds, and bonds. Development charges are often used instead of property tax increases when funding new infrastructure. With these charges new residents – the principal beneficiaries of the infrastructure – incur the costs of the service. However, they often fail to capture the large increase in operating costs associated with maintaining these new systems. As a result, municipalities must find other sources of revenue simply to maintain this new infrastructure, let alone improve and expand other existing systems.[77]

73 Ibid.

74 Canada Mortgage and Housing Corporation (CMHC). *Public-Private Partnerships in Municipal Infrastructure.* (Ottawa ON: CMHC, 1999c), p.1.

75 Société de partenariat et de coopération (SPC), *Le partenariat public-privé et le programme d'infrastructures stratégiques : une approche.* (Montréal, QC : SPC, 2002); National Audit Office (UKNAO). (2003) *Private Finance Initiative: Construction Performance. A Report By the Comptroller and Auditor General.* (London UK: UKNAO, 2003); Peat Marwick.

76 CMHC 1999c.

77 CMHC 1999a.

Special district financing, which is very common in the United States, is another method used to finance new water infrastructure that will benefit the homeowners who will live in the area serviced by the new infrastructure. It is often used in combination with development charges. A designated urban district, usually referred to as a local improvement area, is created as an entity with the sole purpose of financing new infrastructure. Homeowners can influence the method of financing, which includes a fee or tax. For example, some states have used incremental property tax increases to finance infrastructure improvements in a new development. The advantage of special district financing is that the district can finance the new infrastructure at better rates and over its useful life, resulting in less impact on housing affordability. [78]

Funds, including trust funds and revolving loan funds, are another method that can be used to raise revenue for infrastructure. Trust funds are usually set up to hold and funnel tax revenues when a government uses earmarked taxation. A special tax is an example of earmarked taxation when a percentage of the tax revenue is used to finance a specific investment area. For example, a gasoline tax can be earmarked and used for transportation infrastructure. In contrast, revolving loan funds consist of an initial grant or a low interest loan from a higher or central level of government designed to provide funds for particular infrastructure projects. Lower jurisdictions oversee the administration of the fund. Water and sewage treatment plants are especially well suited to this type of financing.[79] Revolving funds are a reliable source of financing for municipalities and are an effective way of building specific types of infrastructure.[80]

Revolving funds are a popular method of financing water infrastructure in the United States. The most significant water and wastewater infrastructure program in the United States is the State Revolving Fund Program, which includes the Drinking Water State Revolving Fund and the Clean Water Revolving Fund. Most federal assistance for water and wastewater infrastructure is provided through this program.[81] Under the program, the U.S. Environmental Protection Agency (USEPA) provides grants to states, which then use the funds to make loans to communities, individuals, and others for high priority water quality activities. As recipients pay back the loans to the revolving funds, states make new loans to other recipients.[82]

Bonds are also an effective method for financing infrastructure. For example, a municipality may issue bonds to finance a new sewage treatment plant. A bond is a type of loan where the borrower (e.g. the government) provides a written promise to repay the borrowed amount at an agreed interest rate over a specified period. Although all three levels of government in Canada can issue and sell bonds, very few bonds are considered municipal bonds. Even when Municipal Finance Authorities issue bonds, in most cases those bonds are fully guaranteed by the province and are considered provincial rather than municipal bonds.

3.4 Sustainable Innovations in Water Infrastructure

Several techniques and technologies can be used to reduce the amount of water used or wasted, and consequently, the need for new water infrastructure and the demands placed on existing infrastructure. Reducing water consumption can reduce the cost of maintenance and rehabilitation. With the advent of the concept of sustainable development, new practices to reduce the demand for water infrastructure have evolved including demand management, sustainable practices, and technical best practices.

78 Ibid.

79 CMHC 1999a.

80 Vander Ploeg; CMHC 1999a.

81 United States House of Representatives (USHOR), "Water Quality Financing Act of 2002." http://www.house.gov/transportation.

82 United States Environmental Protection Agency, "Wastewater Primer." 1998. http://www.epa.gov/owm/primer.pdf.

Demand Management

Traditional water infrastructure management focused on expanding the supply of water. Instead, demand management seeks to understand and reduce the demand for water or wastewater flow. This approach may include reducing overall water consumption, minimizing peaking of water demand and sewage flow, reducing the loss or waste of water, and increasing the recycling of water so that the supply is conserved. Some examples of demand management practices include the use of water metering, public education, home conservation kits, water recycling, and leakage repair.[83] By reducing the demand for water, the conservation of water is enhanced, the output of wastewater decreases, and the need for new and expanded water infrastructure is reduced.[84] Subsequently, the need for new or upgraded wastewater facilities with higher capacities is reduced. According to the Canadian Council of Ministers of the Environment (CCME) Water Use Efficiency Task Group, "Canada is behind other countries in providing consistent codes, guidelines, regulations and policies affecting water use efficiency."[85]

Sustainable Practices

Several developed countries are pursuing and promoting sustainable practices in water infrastructure to address issues such as urban-sprawl, over-consumption, and scarce financing. For example, roof top gardens, rainwater gardens, and wetland preservation assist with drainage systems and storm water management. With respect to urban sprawl, land use planning can focus on creating more compact, higher-density communities. This reduces the need to extend new water and wastewater infrastructure further away from existing urban areas, and at low densities, and smaller lots reduce water use for lawn irrigation.[86] Ultimately, this means that more money is available for maintaining existing infrastructure.[87] Therefore, sustainable practices can assist in reducing the demand for water and water infrastructure.

Technical Best Practices

Several technical innovations and best practices have been developed in order to reduce the amount of water used, and a large body of literature exists on this topic (*see Appendix B*). Technical best practices include water metering, leak detection and repair, pressure reduction, regulation through by-laws and the plumbing code, audits, plumbing retrofits, and landscaping measures. Technical innovations are increasing water efficiency with efficient pipes and drains, low flow showerheads, low flush toilets, double piping systems for homes and office buildings, and process technologies that use less water and generate less waste in production.[88] Water recovery and wastewater reuse technologies, such as rain barrels and membrane technologies, are being improved, and there is ongoing research into the establishment of high-tech, automatic water meters.

83 CMHC 1999b.

84 KPMG.

85 CCME Water Use Efficiency Task Group.

86 CMHC 1999b.

87 CMHC 2000b.

88 NRTEE; FCM 2003: "Water Use and Loss in Water Distribution Systems."

Water recycling programs that minimize first use water are receiving increasing attention. This is followed by the reuse of grey water – wastewater that has not come into contact with human waste – for secondary uses such as toilets and lawn care. This approach reduces both the demand for water and the amount of wastewater generated.[89] The reuse of water is now being incorporated into urban building and landscape design, including plumbing systems that reuse grey water. Use of these technical innovations can reduce the amount of water used, ensure the conservation of water resources, and ultimately, reduce the costs associated with the provision of water infrastructure.

3.5 Overall Assessment of the Available Literature

Based on a survey of the literature, it is clear that a wealth of information exists on issues such as water pricing, metering and technical best practices. However, many other key issues related to water infrastructure are not well analyzed or studied in the literature. Several gaps have been identified, for example, in the areas of asset management, the state of infrastructure, and the effects of public involvement on infrastructure decisions. More research is needed in these and the areas identified in Section 4.

Further, much of the available research on water infrastructure is not peer-reviewed. Many studies are organization-specific, and are produced by interest groups or associations of some kind, as opposed to being published in an academic journal. As such, they often are not reviewed by other experts in the field, and are thus more prone to bias and methodological errors. In some cases, the methods used are not even explained in any detail. This often leads to variations and inconsistencies in the methodologies used in the studies, which in turn, hampers the accuracy and the comparability of the findings.

Another concern with the available research is that it does not always effectively informing policy- and decision-making. For example, water pricing is one of the most extensively studied areas in water infrastructure research, yet best practices in water metering and pricing are being applied in only a handful of regions in Canada. Clearly, work needs to be done to bridge the gap between research and policy- and decision-making processes.

89 CMHC 2000b; AWWA 1980; NRTEE.

4. Questions for Future Research

The findings presented in Section 3 raise a number of key research questions. The questions below are intended to serve as a starting point for future research on water infrastructure.

Urban Infrastructure Demand

Given the shape of urban development in Canada over the last decade and the size and influence of Canada's largest census metropolitan areas, how can the federal and provincial/territorial governments better assist municipalities as they adapt to rapid urban change? What changes should provincial/territorial governments make to infrastructure-related legislation, the ability of provincial/territorial governments to leverage taxes and increase their revenues, and infrastructure priorities and funding decisions?

State of Water Infrastructure

What is the "need" for water infrastructure across the country? What is the best method for assessing the state of Canada's water infrastructure? What is necessary for improving infrastructure inventories? How can a framework for this purpose be developed? Once the proper framework for determining the state of infrastructure is created, the next step is to actually apply the framework, in order to estimate the need for water infrastructure in Canada today.

Management of Water Infrastructure Assets

What is the best way to implement an effective asset management system? It is clear that asset management is an important factor in ensuring the responsible use of resources and the effective management of water infrastructure. Research is now needed regarding the best methods of implementing assess management programs across municipalities with different sizes and needs.

What are the public benefits of an asset management system? Infrastructure investments, including asset management, have the potential to leverage several other benefits to Canadians. Research is needed in order to determine what these benefits could be, and how to realize them.

Financing Water Infrastructure

A discussion of the pros and cons of the different methods of financing water infrastructure, and how they relate to potential application in various Canadian municipalities, is required. Although some literature examines the pros and cons of various methods of financing infrastructure, much of it is not specifically related to Canada or to water infrastructure in particular.

Innovation in Water Infrastructure

What are the limiting factors in the implementation or success of innovation? Much in the literature discusses the benefits, which are well known. In documentation as far back as the 1987 Federal Water Policy, the federal government noted the importance of water pricing, "the billions of dollars required for the development or rehabilitation of water and wastewater systems cannot be met from existing funding mechanisms. Water pricing is, therefore, a solution."[90] The government also encouraged technological innovation for reducing water demand, "sound management of Canada's water resources requires a comprehensive information base and the development and application of new and improved technology to reduce increasing water demands."[91] What is hindering implementation? What legislative, policy or funding changes are required to ensure that we practice what we already know?

90 Environment Canada. http://www.ec.gc.ca/water/en/info/pubs/fedpol/e_fedpol.htm#7.23

91 Ibid

Appendix A – Annotated Bibliography

The following is an annotated bibliography of several key pieces of literature on water infrastructure.

Canada Mortgage and Housing Corporation (CMHC). (1999a) **Alternative Methods of Financing Municipal Infrastructure**. Ottawa ON: CMHC.

This report highlights the need for maintenance and repair of the existing infrastructure in urban areas, which is often deferred in favour of infrastructure expansion into new communities on the fringe. An overview of financing mechanisms for generating revenue to pay for infrastructure is presented, including development charges, special district financing, user fees, funds and privatization.

Canada Mortgage and Housing Corporation (CMHC). (1999b) **Provision ofMunicipal Infrastructure Through Demand Management**. Ottawa ON: CMHC.

Demand management works to reduce the *need* for new infrastructure, and therefore the costs associated with funding it, while promoting *sustainability*. Demand for water and wastewater flow, for example, can be reduced through water and sewer rates, surcharges and other market-based incentives. Communities charging the full costs of water generally have the money to invest in upgrades and expansions, while those that under-price water cannot make the investments required to maintain and improve their systems.

Canada Mortgage and Housing Corporation (CMHC). (1999c) **Public-PrivatePartnerships in Municipal Infrastructure**. Ottawa ON: CMHC.

The large costs associated with improving infrastructure in Canada necessitate the co-operation between levels of government and within the private sector. However, partnerships also increase government exposure to more sophisticated methods of planning and financing infrastructure, more creativity, and expertise and technology in the financing and delivery of public services. Public-private partnerships also assist with the identification of projects unlikely to succeed without private assistance, and allow the government to assume the role of "steering" rather than "rowing."

Federation of Canadian Municipalities and McGill University (FCM & McGill).(1996) **Report on the State of Municipal Infrastructure in Canada**. Ottawa ON: FCM.

Since the 1970s, infrastructure in Canada has been deteriorating. Repair costs for infrastructure are escalating. There is a lack of continuous maintenance, which has led to the deterioration of infrastructure. Once deterioration sets in, repair costs compound exponentially. In 1985, it was estimated that $12 billion was required to upgrade all water infrastructure facilities to acceptable levels. By 1992, this cost had risen to $20 billion. Causes of decline include funding inadequacies, government priorities, and a lack of information and public involvement.

Mirza, M.S. and M. Haider. (2003) **The State of Infrastructure in Canada**: Implications for Infrastructure Planning and Policy. Montréal QC: McGill University.

The state of infrastructure in Canada has been declining since the 1970s, due to several factors, including the economic recession of the 1980s, some infrastructure reaching the end of its service life, rapid inflation in the late 1970s, competing demands for various types of infrastructure, increased public involvement in decision-making, and the reduction of funds available for the maintenance of infrastructure. Using a review of 1985 and 1995/1996 results from a survey of Canadian municipalities, the report estimates the total infrastructure deficit in Canada to be $125 billion. With respect to water distribution and water supply infrastructure, the survey noted that overall, 59% of systems are in need of some repair. For sewage treatment systems, 58% were identified as in unacceptable condition. This figure was 53% for storm sewers, and 68% for sanitary and combined sewers. The results are based on 1995 data.

National Round Table on the Environment and the Economy (NRTEE). (1996) **State of the Debate: Water and Wastewater Services in Canada. Ottawa ON**: NRTEE. http://www.nrtee-trnee.ca/Publications/PDF/SOD_Water_E.pdf

Canada has the second highest per capita consumption of water in the world, at 343 litres per person per day. In 1991, 10 million households in Canada received unmetered water services. This system encourages over consumption, and is not sustainable in the long-term. This report stresses the need for a comprehensive, user-pay system across Canada for the provision of water. A full cost, user-pay system would reduce the demand for water, and encourage resource conservation. It would also increase the amount of money available for maintenance and expansion of water infrastructure. Such a system would increase the demand for eco-efficient technologies, and promote economic development. Finally, it would open up a major export market for Canadian environmental firms.

Rakhra, A.S. (1992) **Reinvesting in Infrastructure for Economic Growth**. OttawaON: Industry, Science and Technology Canada.

Trends in the last 30 years indicate that the proportion of the national pie devoted to public infrastructure has been declining. Public investment outlays have not grown since the 1970s, when they reached their peak levels. In contrast, investment requirements to maintain, upgrade and expand infrastructure have been on the rise. Thus, a gap has developed between what is needed to bring the public infrastructures to satisfactory levels and the actual expenditures on them. A 1984 study by the Federation of Canadian Municipalities estimated that this gap was 25% of annual investment in urban infrastructure. The study also estimated that Canada needed to spend an additional $12 billion in 1984 dollars on urban infrastructure to bring this infrastructure to satisfactory levels.

Société de partenariat et de coopération (SPC). (2002) **Le partenariat public-privé et le programme d'infrastructures stratégiques : une approche**. Montréal QC : SPC.

Public-private partnerships can elicit many benefits for governments. With respect to water infrastructure, conditions that must be respected in such a partnership are the recognition of the high value of water to the public, a sharing of the risk associated with the project and, most importantly, a realization that in the end, the public still retains control of the infrastructure.

Appendix B – Themed Bibliography

The following is a selected bibliography on water infrastructure, organized by the following themes: evaluation, financing, water and demand management, partnerships, state and needs, technical aspects, and protection of source water.

Evaluation

Fougères, D. and M. Trépanier. (1997) **Le programme de travaux d'infrastructures Canada-Québec. Étude du processus décisionnel et évaluation de certains impacts à partir d'études de cas**. Saint-Paul-de-Châteauguay QC : INRS-Urbanisation; chapitre 4.

Institute for Catastrophic Loss Reduction (ICLR). (2003) **An Assessment of Flood Risk Management in Canada**. Toronto ON: ICLR.

Kulshreshtha, S. and Charles Grant. (2003) "Economic Impact Assessment ofIrrigation Development and Related Activities in Manitoba." **Canadian Water Resources Journal**. Volume 28(1): 53-68.

McLaren, R.A. and S.P. Simonovic. (1999) "Evaluating Sustainability Criteria for Water Resource Decision Making: A Case Study From the Assiniboine Delta Aquifer Region." **Canadian Water Resources Journal**. Volume 24(2): 147-163.

Financing

American Water Works Association (AWWA). (1998) **Manual of Water Supply Practices: Water Utility Capital Financing, Second Edition**. Denver CO: AWWA.

American Water Works Association (AWWA). (2000) **Manual of Water Supply Practices: Principles of Water Rates, Fees and Charges, Fifth Edition**. Denver CO: AWWA.

Canada Mortgage and Housing Corporation (CMHC). (1999a) **Alternative Methods of Financing Municipal Infrastructure**. Ottawa ON: CMHC.

Canada Mortgage and Housing Corporation (CMHC). (2000a) **Assessing the Full Costs of Water, Liquid Waste, Energy and Solid Waste Infrastructure in the Fraser Valley Regiona**l District. Ottawa ON: CMHC.

Coalition pour le renouvellement des infrastructures du Québec (CRIQ). (2002) **Les infrastructures municipales au Québec: Pour un financement durable et une structure de mise en œuvre performante**. Montréal QC: CRIQ.

Environment Canada. (2001) "Municipal Water Pricing, 1991-1999." http://www.ec.gc.ca/water/en/info/pubs/sss/Pricing91-99.pdf.

GeoEconomics Associates Inc. (2002) "Economic Principles and Concepts as applied to Municipal Water Utilities: Final Report." http://www.pir.gov.on.ca/userfiles/HTML/cma_2_25116_1.html.

Kulshreshtha, S., Pearson, G., Brown, G., Roy, S. and W. Thompson. (2001) "Cost Recovery Criteria Under Multiple Goods Production: A Case of Public and Private Goods in Southwest Saskatchewan Water Supply Systems." **Canadian Water Resources Journal**. Volume 26(3): 283-306.

OECD, Environment Directorate. (2000) "Global Trends in Urban Water Supply and Waste Water Financing and Management: changing roles for the public and private sectors." Paris: OECD.

PriceWaterhouseCoopers (PWC). (2002) **Portrait financier de la gestion publique de l'eau – Ville de Montréal**. Montréal QC: PWC.

Rollins, K., Frehs, J., Tate, D. and O. Zachariah. (1997) “Resource Valuation and Public Policy: Consumers’ Willingness to Pay for Improving Water Servicing Infrastructure.” **Canadian Water Resources Journal**. Volume 22(2): 185-195.

Schaefer, K.A. and J.M. Hurst. (1997) “Municipal Water Use and Pricing in Ontario, 1983-1994.” **Canadian Water Resources Journal**. Volume 22(4): 417-431.

Tate, D.M. and D.M. Lacelle. (1991) “Municipal Water Rates in Canada: Current Practices and Prices.” **Social Science Series**. Number 30. Ottawa ON: Environment Canada, Water and Habitat Conservation Branch, Canadian Wildlife Service.

United States Environmental Protection Agency. (1998) “Wastewater Primer.” Online. Internet. http://www.epa.gov/owm/primer.pdf.

United States House of Representatives (USHOR). (2002) “Water QualityFinancing Act of 2002.” http://www.house.gov/transportation.

Vander Ploeg, C.G. (2002) **Big City Revenues - A Canada-US Comparison of Municipal Tax Tools and Revenue Levers**. Calgary AB: Canada West Foundation.

Partnerships

Berdahl, L. (2002) **Structuring Federal Urban Engagement - A Principled Approach**. Calgary AB: Canada West Foundation.

Brubaker, E. (1999) “Privatizing Water Supply and Sewage Treatment: How Far Should We Go?” **Fraser Forum**. April Issue: 11-15.

Canada Mortgage and Housing Corporation (CMHC). (1999c) **Public-Private Partnerships in Municipal Infrastructure**. Ottawa ON: CMHC.

Canadian Council for Public Private Partnerships (CCPPP). (2001) **Benefits of Water Service Public-Private Partnerships**. Toronto ON: CCPPP.

Centre francophone d’informatisation des organisations (CEFRIO). (*n.d.*) **Nouveaux modèles de collaboration**. Québec QC : CEFRIO.

Industry Canada (IC). (2003) “Canada-Ontario Infrastructure Program.” http://www.ic.gc.ca/coip-pico/coip-pico.nsf/publication?openpage&count=10000.

KPMG. (2002) **Analysis of Business Models and Their Applicability to Ontario**.Toronto ON: KPMG.

Mahboobi, L. (2000) “Recent Privatization Trends.” **Financial Market Trends**. No. 76.

National Audit Office (UKNAO). (2003) **Private Finance Initiative: Construction Performance. A Report By the Comptroller and Auditor General**. London UK: NAO.

Peat Marwick. (1994) “Introduction to Public-Private Partnerships.” **Proceedings of the 23rd Annual Technical Symposium and Exhibition of the Water Environment Association of Ontario**. Toronto ON: Peat Marwick.

Seidle, F.L. (2002) **The Federal Role in Canada’s Cities – Overview of Issues andProposed Actions**. Ottawa ON: Canadian Policy Research Networks.

Société de partenariat et de coopération (SPC). (2002) **Le partenariat public-privé et le programme d’infrastructures stratégiques : une approche**. Montréal QC : SPC.

Protection of Source Water

Boulos, P.F. (2003) **The World’s Drinking Water Problems: Our Infrastructure**

Challenges of Tomorrow. Saint John NB: MWH Soft, Inc.

Canadian Union of Public Employees, Local 287 (CUPE 287). (2002) **The North Battleford Water Inquiry: Written Submission**. Regina SK: Mitchell Law Firm, Barristers And Solicitors.

Elwell, C. (2001). **NAFTA Effects on Water: Testing for NAFTA Effects in the Great Lakes Basin**. Ottawa ON: Sierra Club of Canada. http://www.sierraclub.ca/national/programs/sustainable-economy/trade-environment/nafta-great-lakes.pdf.

Environment Canada (EC). (1998) "Freshwater: Summary of Issues and Policy Directions." **Water News**. Volume 17(3).

Geddes, J. (1999) "Hot Water: Ottawa and the Provinces Grapple with the Question Of Selling a Precious Resource." **MacLean's**. Volume 112(20): 26-8.

International Joint Commission (IJC). (2000). **Protection of the Waters of the Great Lakes: Final Report to the Governments of Canada and the United States**. Ottawa ON and Washington DC: IJC. http://www.ijc.org/php/publications/html/finalreport.html.

Murray, D. (2002) **Drinking Water Protection in British Columbia: Work in Progress**? Vancouver BC: Kerr Woods Leider Associates Inc.

Ontario Ministry of the Environment (OME). (2003) "Media Backgrounder: Taking Action to Protect Ontario's Drinking Water at Source." http://www.ene.gov.on.ca/envision/news/2003/042101mb2.htm.

Ontario Ministry of the Environment (OME). (2003) "Media Backgrounder: Protecting Ontario's Drinking Water – Toward a Watershed-Based Source Protection Planning Framework." http://www.ene.gov.on.ca/envision/news/2003/042101mb3.htm.

Ontario Office of the Premier. (2003). "Media Backgrounder: Eves Government Takes Action on Source Water Protection."

Water Infrastructure Network (WIN). (2001) **Water Infrastructure Now: Recommendations for Clean and Safe Water in the 21st Century**. Washington DC: WIN.

State & Needs

Canada Mortgage and Housing Corporation (CMHC). (2000b) **Practices For Sustainable Communities**. Ottawa ON: CMHC.

Canada Mortgage and Housing Corporation (CMHC). (1992) **Urban Infrastructure in Canada**. Ottawa ON: CMHC.

Canadian Society for Civil Engineering (CSCE). (2002) "Critical Condition: Canada's Infrastructure at the Crossroads." http://www.csce.ca/PDF/TRM%20Minister%20Brief.pdf.

Canadian Water and Wastewater Association (CWWA). (1997) **Municipal Water and Wastewater Infrastructure – Estimated Investment Needs 1997-2012**. Ottawa ON: CWWA.

Canadian Water and Wastewater Association (CWWA). (2003) **Members' Briefing Book. Ottawa** ON: CWWA.

Coalition pour le renouvellement des infrastructures du Québec (CRIQ). (2001) "Les Infrastructures du Québec en danger." **Vecteur Environnement**. Volume 34(1): 18-27.

Dore, M. (2003) **Canadian Water Network: Infrastructure Theme**. Waterloo ON: Canadian Water Network.

Environment Canada (EC). (1994) "Urban Water: Environmental Indicator Bulletin." **SOE Bulletin** No. 94-1: 4.

Federation of Canadian Municipalities and McGill University (FCM & McGill).(1996) **Report on the State of Municipal Infrastructure in Canada**. Ottawa ON: FCM.

Fougères, D., Gaudreau, M., Hamel, P.J., Poitras, C., Sénécal, G., Trépanier, M. and R. Veillette. (1998) **Évaluation des besoins des municipalités québécoises en réfection et construction d'infrastructures d'eaux**. Montréal QC : INRS-Urbanisation, GRIEU.

Letendre, S., Proulx, R., Desmarais, P., Brown, H. and N. Periche. (2002) **Étude comportant la collecte d'informations et le portrait technique des infrastructures de la gestion publique de l'eau**. Montréal QC : Ville de Montréal.

Mirza, M.S. and M. Haider. (2003) **The State of Infrastructure in Canada: Implications for Infrastructure Planning and Policy**. Montréal QC: McGill University.

National Round Table on the Environment and the Economy (NRTEE). (1996) **State of the Debate: Water and Wastewater Services in Canada**. Ottawa ON: NRTEE. http://www.nrtee-trnee.ca/Publications/PDF/SOD_Water_E.pdf.

Ontario SuperBuild Corporation (OSBC). (2002a) **Organization of Municipal Water and Wastewater Systems in Ontario**. Toronto ON: OSBC.

Organization for Economic Cooperation and Development (OECD). (1993) **Infrastructure Policies for the 1990s**. Paris, France: OECD.

Rakhra, A.S. (1992) **Reinvesting in Infrastructure for Economic Growth**. Ottawa ON: Industry, Science and Technology Canada.

Robertshaw, R. (2001) **Canadian Experience In Public Sector Benchmarking**. Philadelphia PA: American Public Works Association International Public Works Congress.

Siddiqui, S. (1997) **Infrastructure, Sustainable Development and Society**. Montréal QC : McGill University.

Trépanier, M., Fougères, D., Gaudreau, M., Hamel, P.J., Poitras, C., Sénécal, G.,Vachon, N., and R. Veillette. (1998) « L'état des infrastructures d'eau du Québec. » **Symposium sur la gestion de l'eau au Québec**. Villeneuve, J.-P., Rousseau, A. and S. Duchesne, Eds. Recueil de textes des conférenciers, INRS-Eau : 445-462.

Trépanier, M., Hamel, P.J., Sénécal, G., Gaudreau, M., Fougères, D., Poitras, C. and R. Veillette. (1997) **Étude sur l'état des infrastructures d'eau de la région métropolitaine**. Montréal QC : INRS-Urbanisation.

Trépanier, M. (1996) « L'eau, la technique et l'urbain : l'ingénieur n'est jamais seul dans l'univers des infrastuctures urbaines. », **L'eau, l'hygiène publique et les infrastructures**. L. Potheir, Ed. Groupe PGV: 65-83.

Trépanier, Michel. (1998) « Les infrastructures d'eau dans les municipalities québécoises : évaluation de leur état et des coûts de réfection. » **Symposium sur la gestion de l'eau au Québec. Recueil de textes des conférenciers**. Villeneuve, J.-P., Rousseau, A. and S. Duchesne, Eds. Sainte-Foy QC : INRS-Eau; 209-232.

University of Western Ontario (UWO). (2003) "Expert Commentary 2003: Safe Water Will Save Lives."

Villeneuve, J.-P., Duchesne, S., Mailhot, A., Musso, E., Pelletier, G., Fougères, D.,

Gaudreau, M., Hamel, P.J., Poitras, C., Sénécal, G., Trépanier, M., Vachon, N., and R. Veillette. (1998) **Synthèse des rapports INRS-Urbanisation et INRS-Eau sur les besoins des municipalités québécoises en réfection et construction d'infrastructures d'eaux**. Sainte-Foy QC : INRS-Eau and INRD-Urbanisation.

Walker, Bob. (2001) "Sustainable Infrastructure: It's Our Responsibility." **PVC News**. Volume 24(2). Dallas TX: Uni-Bell PVC Pipe Association.

Technical Aspects

American Water Works Association (AWWA). (1980) **Manual of Water Supply Practices: Water Utility Management**. Denver CO: AWWA.

Bouchard, C., Périn, G, Rahni, M., Painchaud, J., Tremblay, H., Ellis, D., Lebrun, R. and G. Lantagne. (2003) "Évaluation des impacts de la nouvelle réglementation sur la production d'eau potable au Québec." **Vecteur Environnement**. Volume 36(2) : 70-89.

Elnaboulsi, J. and O. Alexandre. (1997) “Détermination de la Date Optimale de Renouvellement des Réseaux Urbains d’Eau Potable.” **Canadian Water Resources Journal**. Volume 22(3): 327-351.

Ezell, B.C., Farr, J.V. and I. Wiese. (2000) “Infrastructure Risk Analysis of Municipal Water Distribution System.” **Journal of Infrastructure Systems**. Volume 6(3): 118-122.

Federation of Canadian Municipalities (FCM). (2002) **Deterioration and Inspection of Water Distribution Systems**. Ottawa ON: FCM.

Federation of Canadian Municipalities (FCM). (2003). **Best-Practices for Utility – Based Data**. Ottawa ON: FCM.

Federation of Canadian Municipalities (FCM). (2003). **Infiltration/Inflow Control/Reduction For Wastewater Collection Systems**. Ottawa ON: FCM.

Federation of Canadian Municipalities (FCM). (2003). **Selection of Technologies for the Rehabilitation or Replacement of Sections of a Water Distribution System**. Ottawa ON: FCM.

Federation of Canadian Municipalities (FCM). (2003). **Selection Of Technologies For Sewer Rehabilitation And Replacement** . Ottawa ON: FCM.

Federation of Canadian Municipalities (FCM). (2003). **Source And On-Site**

Controls For Municipal Drainage Systems. Ottawa ON: FCM.

Federation of Canadian Municipalities (FCM). (2003). **Wastewater Source Contro**l. Ottawa ON: FCM.

Federation of Canadian Municipalities (FCM). (2003). **Water Use and Loss in Water Distribution Systems**. Ottawa ON: FCM.

Kleiner, Y. (2001) “Scheduling Inspection and Renewal of Large Infrastructure Assets.” **Journal of Infrastructure Systems**. Vol. 7(4): 136-143.

Medearis, Dale and Brian Swett. “International Best Practices and Innovation – Strategically Harvesting Environmental Lessons from Abroad.” US EPA.

McMartin, D.W., J.V. Headley and J.A. Gillies. (1999) “Perspectives on Potable Groundwater Quality Monitoring in Rural Alberta.” **Canadian Water Resources Journal**. Volume 24(3): 253-261.

n.a. (2000) “Irrigating Planning: From H_2O to Water.” Plan Canada. Volume 40(5):10-37.

Pelletier, G., Mailhot, A. and J.-P. Villeneuve. (2003) “Modeling Water Pipe Breaks – Three Case Studies.” **Journal of Water Resources Planning and Management**. Vol. 129(2): 115-123.

Saffran, K.A. (1999) “Development and Use of Water Quality Indices - The Alberta Experience.” **Water News**. Volume 18(4).

For additional technical references, please see the bibliographies of the FCM Best Practices Guides.

Water, Demand & Asset Management

Boyer, M., Patry, M. and P.J. Tremblay. (2000) “La gestion de l’eau au Québec: à qui doit-on render les comptes?” **Vecteur Environnement**. Volume 33(5): 55-57.

Canadian Council of Ministers of the Environment (CCME). “National Action Plan to Encourage Municipal Water Use Efficiency.” 2001. Prepared by The CCME Water Use Efficiency Task Group. http://www.ec.gc.ca/water/en/info/pubs/action/e_action.htm

Canada Mortgage and Housing Corporation (CMHC). (1999b) **Provision of Municipal Infrastructure Through Demand Management**. Ottawa ON: CMHC.

Forget, D. (2002) “Future politique québécoise sur la gestion de l’eau: Les attentes de RÉSEAU environnement.” **Vecteur Environnement**. Volume 35(6) :13-16.

Fowler, E.P. and D. Siegel, Eds. (2002) Urban Policy Issues: Canadian Perspectives, Second Edition. Don Mills ON: Oxford University Press.

Geiger, D. (2003) "Asset Management: Resources for Maximizing Your Transportation Investment." **APWA Reporter**. Volume 70(7): 23.

Gentes, P. (2003) **Québec Water Policy**. Québec QC: Ministère de l'Environnement.

Heath, K. and B. Mitchell. (2002) "Education for Water Efficiency Initiatives in the Regional Municipality of Waterloo, Ontario: Measuring Current Effectiveness to Improve Future Success." **Canadian Water Resources Journal**. Volume 27(3): 317-334.

Henderson, J.D. and R.D. Revel. (2000) "A Community Approach to Water Management on a Small West Coast Island." **Canadian Water Resources Journal**. Volume 25(3): 271-278.

Karney, B. (2003) **Water Infrastructure: Long-Term Supply and Demand Management, and Planning**. Waterloo ON: Canadian Water Network.

Kreutzwiser, R.D. and R.C. de Loe. (2002) "Municipal Capacity to Manage Water Problems and Conflicts: The Ontario Experience." **Canadian Water Resources Journal**. Volume 27(1): 63-83.

Leadlay, H.J. and R.D. Kreutzwiser. (1999) "Rural Water Supply in Canada: An Evaluation of Current Policy and Practice." **Canadian Water Resources Journal**. Volume 24 (1): 1-23.

Mitchell, B. and D. Shrubsole. (1994) **Canadian Water Management: Visions for Sustainability**. Lethbridge AB: Canadian Water Resources Association.

Ontario SuperBuild Corporation (OSBC). (2002b) **A Study of Best Practices in the Water and Wastewater Sector**. Toronto ON: OSBC.

Pacin, Sonia. (2003) **The Effects of Agriculture on Water Quality in Canada: A Policy Perspective**. Ottawa ON: Carleton University.

Painchaud, J., Guay, I. and Y. Maranda. (2002) "L'action du ministère de l'environnement en vue de la gestion durable de l'eau au Québec." **Vecteur Environnement**. Volume 35(6): 38-41.

Pearse, P.H. and F. Quinn. (1996) "Recent Developments in Federal Water Policy: One Step Forward, Two Steps Back." **Canadian Water Resources Journal**. Volume 21(4): 329-340.

Plummer, R. and C. Stacey. (2000) "A Multiple Case Study of Community-Based Water Management Initiatives in New Brunswick." **Canadian Water Resources Journal**. Volume 25(3): 293-307.

Sasseville, J.-L. and Y. Maranda. (2000) "L'administration publique de l'eau par basin versant." **Vecteur Environnement**. Volume 33(5): 32-41.

United States Environmental Protection Agency (USEPA). (1993) "Water Infrastructure and Economic Growth." **Clean Air, Water and the American Economy**. Washington DC: USEPA.

United States Federal Highway Administration (USFHWA). (2003) "Asset Management." http://www.fhwa.dot.gov/infrastructure/asstmgmt/assetman.htm.

Vandierendonck, M. and B. Mitchell. (1997) "Water Use Information for Sustainable Water Management: Building Blocks and the Ontario Situation." **Canadian Water Resources Journal**. Volume 22(4): 395-415.

Waller, DH., Scott, R.S., Gates, C. and D.B. Moore. (1997) **Canadian Municipal Water Conservation Initiatives**. Toronto ON: ICURR Press.