CHANGING CURRENTS

WATER SUSTAINABILITY AND THE FUTURE OF CANADA'S NATURAL RESOURCE SECTORS

National Round Table on the Environment and the Economy | Table ronde nationale sur l'environnement et l'économie

Canada

Canada's apparent water abundance masks a looming scarcity challenge

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MESSAGE FROM THE CHAIR

As Chair of the National Round Table on the Environment and the Economy, I am pleased to present *Changing Currents: Water Sustainability and the Future of Canada's Natural Resource Sectors,* the first of two reports examining the future of Canada's water supply.

The world's supply of freshwater is limited and finite. While Canada is blessed with an abundance of freshwater, an expected increase in the development of the natural resource sectors begs the question of whether our country has enough to support economic growth while also maintaining the health of our ecosystems. We need to know whether we are in a position to sustainably manage our water resources for future generations and if we have the capability to deal with issues like an anticipated change in precipitation patterns caused by climate change.

While many of the challenges we found in our work are regional in nature, they risk becoming national problems if we do not move quickly to deal with them. They include issues like water governance, allocation, and access to water-use data. We plan to deal with some of these matters in our next report.

We also believe that governments and industry still have many options available to them to resolve the issues in the most effective and efficient manner, before water availability and ecosystem degradation become country-wide problems.

The NRTEE believes that the opportunity is now to put Canada on a policy path to ensure sustainability of our water and natural resource sectors. There is a clear urgency in proceeding on this task to ensure sufficient clean water for future generations.

Bob Page
NRTEE Chair

MESSAGE FROM THE PRESIDENT AND CEO

Water is essential for the operation and growth of Canada's natural resource sectors.

And as world-wide demand for our country's bounty of minerals, forest products, agricultural goods and energy continues to grow, so will the need for water.

This report, *Changing Currents*, is the first of two reports that will examine the importance of water use by our natural resource sectors. It sets out the NRTEE's findings for further study to protect this important resource and the natural ecosystems it supports.

New stresses and demands are likely to pose a significant challenge to the sustainability of Canada's water resources if action is not taken now.

Water underpins our economy – whether it is used for raising crops, developing the oil sands, or producing the forest products that build our homes. We must ensure that it is protected from overuse. We need to understand the future impacts on water quantity of issues like climate change, energy use and governance.

To ensure that it continues to play these roles, we need to get a better handle on how much water we use, who governs it and manages its allocation, and how much of it will be needed.

Knowing how water is used by our critical national resource sectors and how it is managed across Canada is our first step to ensuring a truly sustainable resource for Canadians.

David McLaughlin
NRTEE President and CEO

NATIONAL ROUND TABLE ON THE ENVIRONMENT AND THE ECONOMY: ABOUT US

Emerging from the famous Brundtland Report, *Our Common Future*, the National Round Table on the Environment and the Economy (NRTEE or Round Table) has become a model for convening diverse and competing interests around one table to create consensus ideas and viable suggestions for sustainable development. The NRTEE focuses on sustaining Canada's prosperity without borrowing resources from future generations or compromising their ability to live securely.

The NRTEE is an independent policy advisory agency that advises the federal government on sustainable development solutions. We raise awareness among Canadians and their governments about the challenges of sustainable development. We advocate for positive change. We strive to promote credible and impartial policy solutions that are in the best interest of all Canadians.

We accomplish that mission by fostering sound, well-researched reports on priority issues and by offering advice to governments on how best to reconcile and integrate the often divergent challenges of economic prosperity and environmental conservation.

The NRTEE brings together a group of distinguished sustainability leaders active in businesses, universities, environmentalism, labour, public policy, and community life from across Canada. Our members are appointed by the federal government for a mandate of up to three years. They meet in a round table format that offers a safe haven for discussion and encourages the unfettered exchange of ideas leading to consensus.

We also reach out to expert organizations, industries, and individuals to assist us in conducting our work on behalf of Canadians.

The *NRTEE Act* underlines the independent nature of the Round Table and its work. The NRTEE reports, at this time, to the Government of Canada and Parliament through the Minister of the Environment. The NRTEE maintains a secretariat, which commissions and analyzes the research required by its members in their work.

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As Canada's largest water user, growth in our natural resource sectors means we must think fresh on how to ensure strong water management so that use of this precious resource is made sustainable for our environment and economy.

EXECUTIVE SUMMARY

Access to clean, sustainable supplies of water is essential for the operation and growth of Canada's major natural resource sectors — energy, mining, forest, and agriculture. The health of our ecosystems is also dependent upon those same clean, sustainable water supplies, creating the potential for competing uses. *With development of the natural resource sectors on the rise, does Canada have enough water to support economic growth while maintaining the health of our country's ecosystems? And are we in a position to sustainably manage our water resources for future generations?* Canada's apparent water abundance masks a looming scarcity challenge for our important natural resource sectors and for certain regions of our country.

The National Round Table on the Environment and the Economy (NRTEE) is conducting a two-year program on Water Sustainability and the Future of Canada's Natural Resource Sectors. The overall goal of the program is to address the above questions while increasing public awareness of how our natural resource sectors use and manage water. Phase I of the program, the findings of which are included here, examined principal water uses by Canada's natural resource sectors and identified the key water issues flowing from these. Phase II of the program will include research into the potential solutions to these critical issues. These efforts will result in recommendations to governments and industry on policies, approaches, and mechanisms through which water can be better managed to foster both ecosystem health and the natural resource sectors economic sustainability.

Changing Currents is the result of over a year of research and engagement involving some of the country's leading experts on water management and policy, and collaboration with key industry representatives and associations. The focus and approach of the program was guided by the NRTEE's Expert Advisory Committee. The NRTEE held seven consultation meetings across the country in 2009-2010, involving over 150 experts and stakeholders. Finally, the findings and conclusions of this report were peer-reviewed by specialists in the different areas of investigation.

SETTING THE SCENE

Canada is blessed with a bounty of forests, minerals, metals, energy sources, and agricultural products, yet its most valuable natural resource is its water. In 2009, just over half of Canadians polled ranked freshwater as the country's most important natural resource, ahead of forests, agriculture, oil, and fisheries.[1] Water is a critical component of the development of the energy, forest, mining, and agricultural products that contribute to Canada's economic wealth and social well-being.

There is a misperception that Canada's water is a plentiful and secure resource. Canada, with one-half of one per cent of the world's population, is fortunate to have 20% of the world's freshwater, but this equates to only seven per cent of the world's renewable supply. While approximately 60% of fresh surface water flows north, 85% of Canada's population and many of our economic activities are present in the south. And so our water resources are not located where they are needed for many of our uses. Water scarcity is not a national problem in Canada, but it is certainly a regional one and this can be of national significance. One need only look to the prairies of Alberta and Saskatchewan and to British Columbia's Okanagan Valley to witness clear examples of regions facing water shortages. Between now and 2050, Canada's population is expected to increase by 25%, the Canadian economy is predicted to grow approximately 55% by 2030, and climate change is anticipated to increase temperatures, change precipitation patterns, and increase the frequency of extreme weather events such as floods and droughts. These stresses will impact Canada's watersheds and create new pressures on the long-term sustainability of our water resources.

The natural resource sectors studied in this report are the greatest water users and consumers across Canada. In 2005, collectively, they accounted for approximately 84% of Canada's *gross* water use — the total volume withdrawn from water bodies. Of all the water *consumed* in Canada, the natural resource sectors accounted for 84% of the total — that is, water that was withdrawn and not returned to a water body after use. The thermal power generating sector was responsible for the greatest gross water use, while agriculture accounted for the majority of national water consumption.

The natural resource sectors make a significant contribution to the Canadian economy. In 2009, these sectors accounted for approximately 12.5% of the country's gross domestic product (GDP). The long-term economic growth of these sectors is anticipated to be substantial with growth forecast to be about 50% to 65% by 2030. This level of development will mean more pressure on our water resources. Overlay this projected growth with already existing pressures on water usage, and one can start to see the potential for future conflicts over water availability.

Further pressures exerted by climate change on water resources are also expected to be felt across the country. There is broad agreement from the scientific community in Canada and internationally, that we are now seeing global changes to the climate and hydrological cycle and that freshwater ecosystems are likely vulnerable.[2] Climate models show that changes in temperature and precipitation are likely to continue affecting the following: run-off and evaporation patterns; the amount of water stored in glaciers, snowpack, lakes, wetlands; soil moisture; and groundwater. The key impact from climate change on water will come in the form of extreme events such as droughts and flooding, seasonal shifts in flow regimes, and reduced winter ice coverage. The impacts of climate change on water resources will vary across the country due to regional differences in hydrological characteristics, water demand, and management practices.[3] The response of water users to climate change, including the implementation of adaptive management approaches, will be critically important to the future sustainability of our water.[4]

Water is a common good and governments have a duty and a responsibility to protect it and manage it for future generations. And so the sustainability of water resources relies on governance. The governance and management of water resources in Canada is complex and multi-jurisdictional involving all levels of government. In many cases, the laws and rules are outdated and in need of renewal. At the policy level, some governments are taking action by developing new approaches and strategies. For its part, industry is taking a lead to improve water management on an operational level, as is exemplified by the implementation of best management practices, technology development and deployment, public-private research, and sustainability reporting. However, at a national level, a concerted, strategic approach to water governance and management has not been undertaken.

FINDINGS

In order to understand the linkage between water sustainability and Canada's natural resource sectors, the NRTEE examined (1) the importance of freshwater to our ecosystems, (2) the governance structures managing water in Canada, and (3) the most important water uses and critical issues within each of the natural resource sectors.

In considering the sustainable development of our natural resources and water requirements, we must first recognize and accept the importance of ecosystem needs with respect to water. Water is essential for all living things. Canada's ecosystems cannot function properly and deliver ecosystem services without adequate, reliable, and clean sources of freshwater. Second, we need to understand the complexity of governance around water in this country, so that we ensure it is managed sustainably. Water is one of the most challenging resources to govern and manage due to the division of power and shared responsibilities for management among all levels of government.

The natural resource sectors all rely heavily on reliable, clean supplies of freshwater. The use of water and the effects on it by the natural resource sectors vary considerably across the country, from a gross and consumptive use perspective. The sectors operate in different regions across this vast land, and this regional distribution directly influences where the pressures on water resources are felt. The complexity of this picture is complicated by the numerous and varied sub-sectors that operate in each region, each having differing uses and impacts on water resources. All things considered, these factors make for a very complex "water story."

WATER USE AND CANADA'S NATURAL RESOURCE SECTORS

	HYDRO POWER	THERMAL POWER	OIL & GAS	AGRICUL-TURE	MINING	FOREST
Percentage of National Gross Water Use	Unknown*	64%	Unknown*	10%	4%	5%
Percentage of National Consumptive Water Use	Unknown*	12%	Unknown*	66%	3%	2%
Regions Most Implicated	BC, AB, MB, ON, QC, Atlantic	Territories, AB, ON, Atlantic	AB, BC, SK	Prairie Provinces	BC, AB, SK, Territories	All provinces
Operations & Sub-sectors Included in This Report	Storage-based; Run-of-river	Fossil fuel plants; Nuclear power plants	Oil sands; Shale gas; Enhanced oil recovery	Primary production; Manufacturing	Metals; Minerals	Forest management; Pulp & paper
Water Quality Issues Noted	In-stream flow needs; Fisheries	Thermal & chemical discharges	Ecosystem impacts; Mine tailings	Non-point source pollution	Ecosystem impacts; Mine tailings	Effluent discharge effects on ecosystems

* These sectors are not included in the Statistics Canada Survey so the national use is unknown. Water use may be known at provincial or facility levels.

In order to understand the complexity of this "water story" the NRTEE has examined the individual sectoral uses and highlighted the most important water issues.

The thermal electrical power generation sector is highly reliant on water availability. In 2005, this sector was responsible for withdrawing 64% of water across Canada, making it the greatest water user in the country. The sector was also the second largest consumer of water. Finally, this sector also has important effects on aquatic ecosystems they are located on, with concerns related to thermal and chemical discharges.

Similarly, the hydroelectric power generation sector is completely reliant on the availability of plentiful sources of water. Unlike the thermal power sector, hydro facilities are not significant consumers of water. But they do have important impacts on ecosystems and downstream users. Given the strong reliance of both hydro and thermal facilities on water availability, future expansions will need to give due consideration to this factor, especially in areas where competing uses for water are anticipated, and where water shortages may be expected.

On a national level, the oil and gas sector uses small overall volumes of water in comparison with the other sectors, leading to water quantity concerns being more localized. As with hydro power, quantitative water use at a national level is unknown, but is more likely understood on a provincial and operational basis. The key water issue for the oil and gas sector centres on the potential impacts on water quality and ecosystem integrity, particularly on a regional and watershed basis. With significant growth anticipated for the sector, particularly in oil sands and shale gas, issues of both water quantity and quality are likely to continue.

Next to the power generation sectors, agriculture is the most important user of water across the country. In 2005, it was responsible for 10% of the gross water use. It is the most significant water consumer in the country, accounting for 66% of water consumption, largely due to crop irrigation. Water availability is currently an issue for farms in water-scarce regions of Canada. As the sector's need for irrigation increases, due to the demand for higher-value crops and efforts to convert dryland operations, the risks associated with water limitations will continue to rise and potentially spread to other regions of the country. The sector may also be at risk from climate change resulting in reduced spring runoff and prolonged cyclical drought. Water availability will continue to be a dominating issue for the sector, and as such, is a key driver for water efficiencies and conservation.

Finally, the mining and forest sectors are relatively small users of water in comparison with the other natural resource sectors. For both sectors, water availability does not appear to be a constraint to future operations. However, both sectors do have the ability to significantly impact water quality in the regions and watersheds where they are located, and this is one of the most important aspects of water management for both. The potential for long-term effects of operations on the health of the surrounding ecosystems is of particular concern, due to contaminants that may be introduced to the environment.

While the issues noted here are currently of a regional and/or sectoral scope, increasing pressures due to population and economic growth and a changing climate could transform them into national issues if not addressed now. Governments and industry still have many options available to them to resolve the problems in the most effective and efficient manner, before water availability and ecosystem degradation become national problems.

CONCLUSIONS

The NRTEE has identified four water sustainability issues that are of national importance, cutting across all natural resource sectors and jurisdictions. These are water governance and management, the impacts of climate change, the water-energy nexus, and the public licence to operate.

The governance and management of water is very complex, within which reside a number of challenges. First and foremost, water governance in Canada is a complicated and fragmented collection of statutes and policies, involving all levels of government. Second, the water allocation approaches in most of the country are outdated and may no longer be appropriate given the pressures and competing interests that now exist. Third, Canada currently uses a limited suite of policy instruments, largely restricted to regulations. Economic instruments could play a larger role, but this has generally not been explored in Canada. Fourth, knowledge of actual water use and access to data held by most of the natural resource sectors is limited. Finally, there is an overall lack of capacity and expertise across the country to effectively manage water resources. This is reflected in the reduction of scientific capacity as well policy expertise within governments.

Climate change is emerging as a key factor expected to transform the way we manage water resources. Impacts of climate change on water resources are likely to affect all regions of the country, but will manifest themselves in different ways. The uncertainty regarding the severity, timing, and frequency of events — and their subsequent impacts — is the main challenge. Having robust and adaptive water management plans will help prepare industry for the uncertainty and risks that lie ahead.

Another important issue for water policy development is the water-energy nexus. From the industrial processing and production side, water is needed to produce energy and energy is needed to produce useable water. Financial savings, gained through energy conservation and efficiency, is a key driver for improving water use for all of the natural resource sectors. Some opportunities, such as conservation practices, simultaneously reduce water and energy use. However water conservation may not always lead to energy savings. Climate change is often linked to discussions about the water-energy nexus due to the greenhouse gas emissions that result from energy production. Therefore, the linkage between future energy requirements and anticipated water uses warrants more analysis in Canada, especially as policies and approaches for reducing greenhouse gas emissions and exploring alternative energy sources are contemplated.

Public pressure to better manage water use is unanimously felt across all the natural resource sectors. Industry must assess various signals such as societal pressure, demands from other sectors in the value chain, future regulatory shifts, or price signals, in order to best integrate water considerations into strategic planning and operations. Responding to societal concerns is very important to businesses, not only from a public relations perspective but also as a means to address customer and shareholder expectations. Financial markets are also starting to examine the way in which companies address water-related risks, adding to this public pressure to sustainably manage natural resources.

NEXT STEPS

The NRTEE believes that the opportunity is now to put Canada on a policy path to ensure sustainability of our water and natural resource sectors. We must ensure that Canada's ecosystem services are protected to ensure the long-term health of our natural environment. At the same time, we need to ensure that our natural resources are developed in a sustainably responsible manner, and do not significantly impact upon our natural environments including our water resources. To do so, Canada needs to put in place a national framework for integrated water governance and management and should do so before water availability is constrained. Governments and water users are currently in a position to consider trade-offs of water use as well as future options.

Of the four national issues identified in our research, the NRTEE has decided to further explore the key challenges surrounding governance and water management. Governance at a national level is not currently positioned to respond to expected increasing pressure on our water resources. This is largely due to jurisdictional complexity, inconsistent approaches across the country, policy fragmentation, a lack of resources, and insufficient technical, scientific, and policy capacity. By addressing these specific challenges, governments will be able to establish more effective governance structures that will enable industry to develop solutions at the regional scales where they operate.

In order to provide advice that will assist in the development of a national water framework, the following key issues related to governance and water management will be explored: water allocation schemes, integrated collaborative governance approaches, collection and management of water data, and policy instruments. In Phase II of the NRTEE's water program, we will undertake to:

- Evaluate current water allocation approaches across the country to determine if they remain effective and appropriate means of managing water, and identify opportunities for improvement to water allocation going forward.

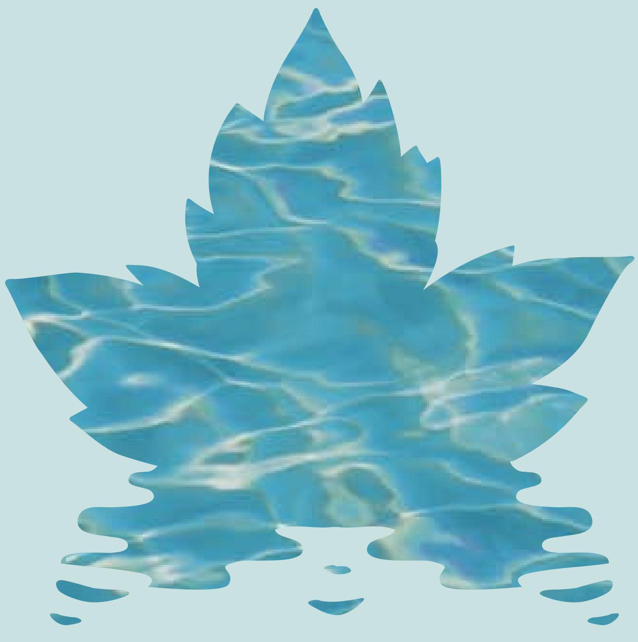
- Explore collaborative governance approaches for integrated water management.

- Investigate strategic approaches to the collection and management of water-use data.

- Evaluate a full suite of policy instruments for water management in Canada, from traditional regulatory and voluntary conservation efforts to pricing and market-based instruments.

CHAPTER ONE

INTRODUCTION AND PURPOSE



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HIGHLIGHTS

Water is essential for the operation and growth of Canada's energy, agriculture, mining, and forest sectors, which account for over 80% of Canada's gross water use.

Water availability is an issue in the interior of British Columbia, the southern regions of Alberta, Saskatchewan, and Manitoba, and to a lesser degree in some areas of Ontario and Southern Québec.

In order to ensure the economic sustainability of the natural resource sectors, water use must be managed with the maintenance of ecosystem integrity as a core principle.

INTRODUCTION AND PURPOSE

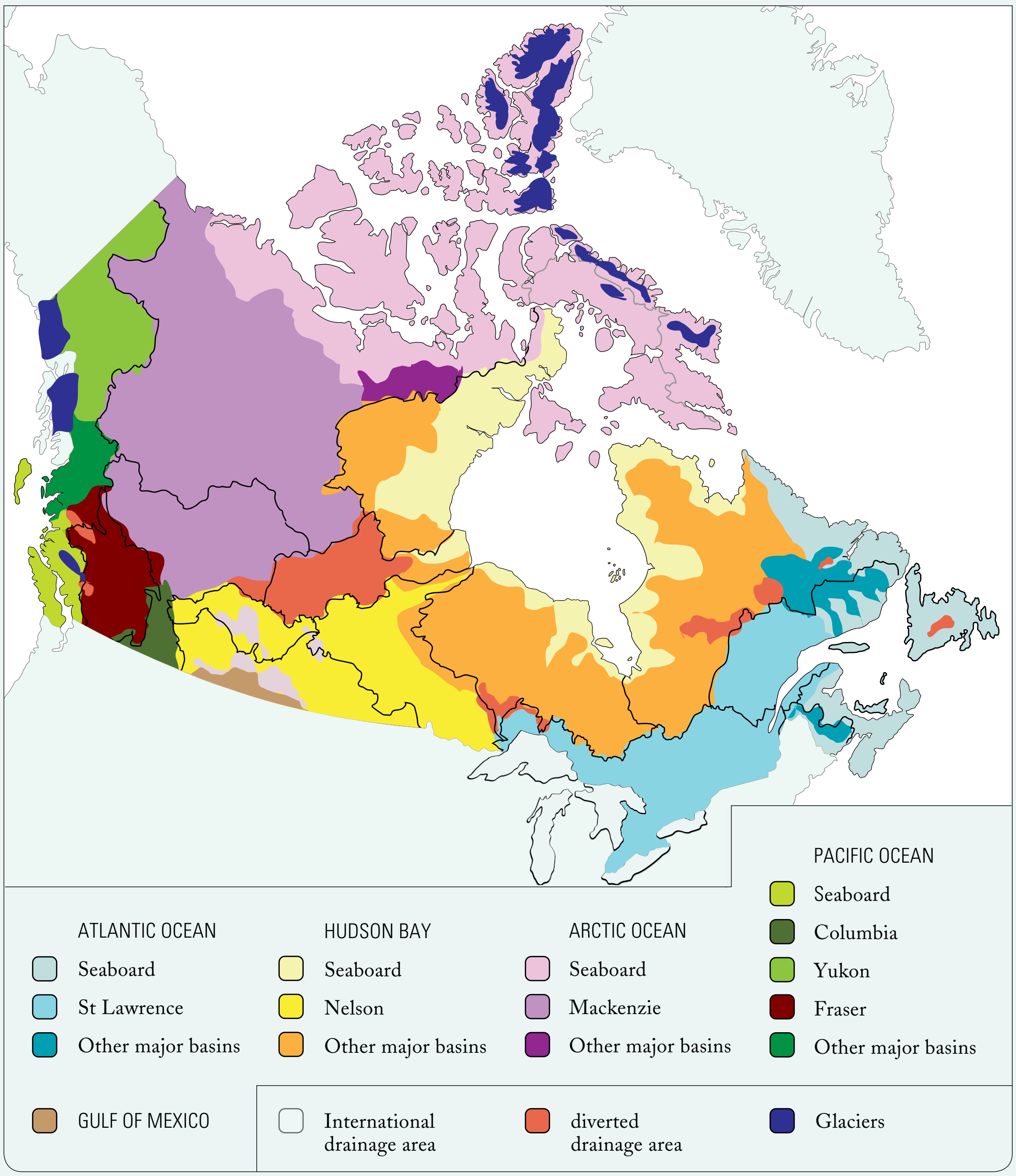
INTRODUCTION

Canada is a country rich in natural resources with its most valuable being water. Freshwater provides many benefits that humans rely upon, some of which are visible, such as drinking water or hydroelectric production, while others are less obvious, such as erosion control and water retention. These services that are imperative to all life on Earth depend upon the health and functionality of ecosystems. Alterations to the timing and volumes of flow, quality, and temperature of freshwater, create incremental effects to both aquatic and terrestrial ecosystems. In order to safeguard water resources for present uses and the future, water use must be managed with maintenance of the integrity of ecosystems as a core principle.

Canada is fortunate to have a significant proportion of the world's freshwater; however its renewable supply is not as abundant as many would believe. Over half our fresh surface water flows to the north, while most of our population and many of our economic activities are located along our southern border (see Figure 1 for Canada's drainage basins). The majority of the water is not located where it is needed most by Canadians.

FIGURE 1

CANADA'S DRAINAGE BASINS

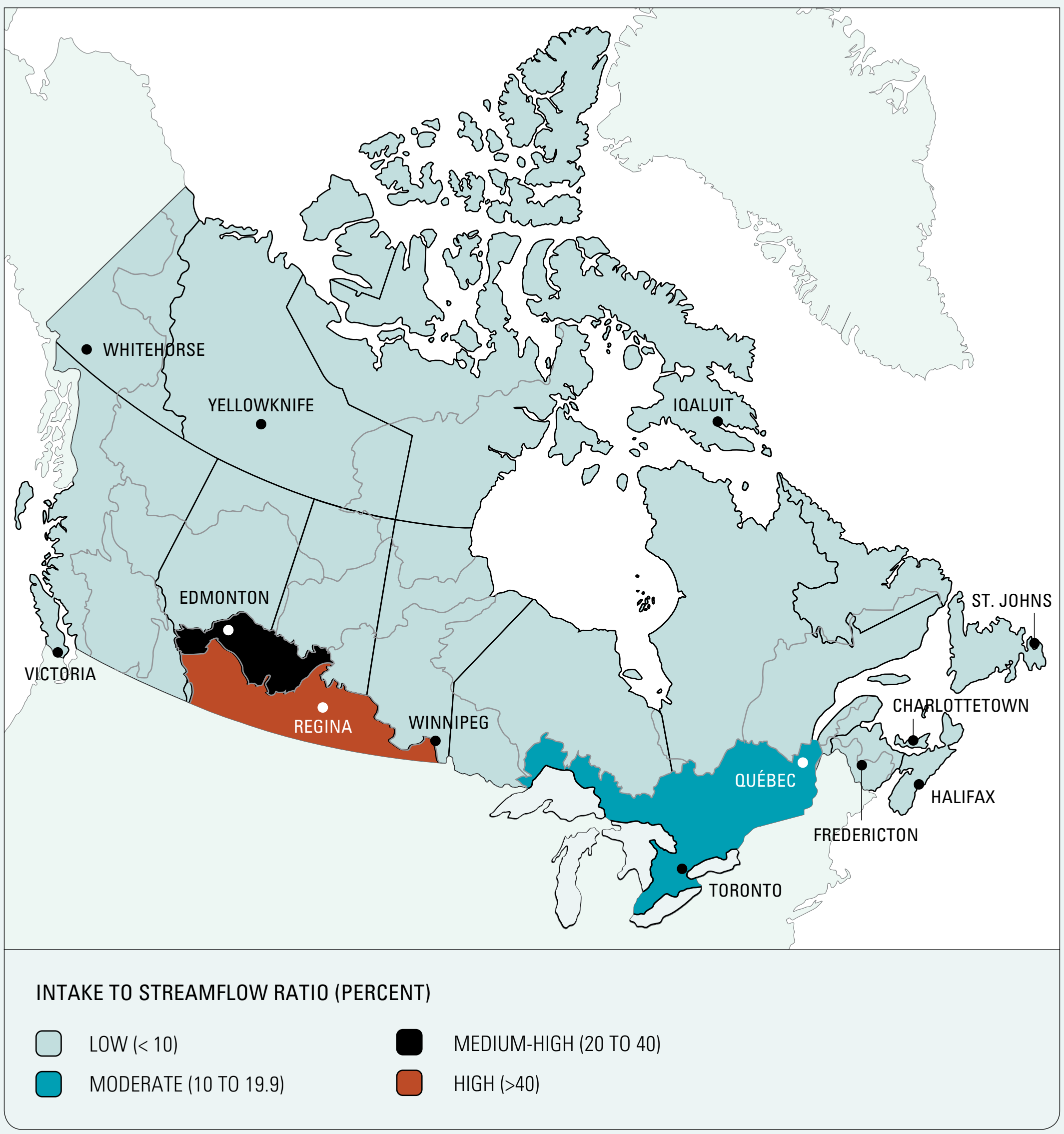


Source: Natural Resources Canada, Atlas of Canada, 2004.[5]

Figure 2 illustrates the proportion of surface freshwater that is used by Canadians within each of Canada's major drainage basins. The river basins in the Prairies, Southern Ontario, and Southwestern Québec are under the greatest stress. That is, the water taken out of the watersheds in these regions is greatest relative to the volume of water flowing into them, with the greatest pressures felt in the prairie regions.

FIGURE 2

WATER USE AND AVAILABLE STREAMFLOW IN CANADA



Source: Statistics Canada, Environment Accounts and Statistics Division, 2009.[6]

WATER USE: DEFINITIONS USED IN THIS REPORT

Water use is often characterized as non-consumptive and consumptive. Non-consumptive use is also referred to as "water intake" or "gross water use" and represents the total amount taken from surface water bodies or aquifers. Consumptive water use represents the amount of water intake that is not returned to the source, and which is generally lost to evaporation or contained within wastewater or products.

Water is essential for the operation and growth of Canada's natural resource sectors — energy, mining, forest, and agriculture — as they all rely on access to clean, sustainable supplies of water to extract or work with raw materials and process goods. In 2005, these sectors together accounted for the greatest *gross water use** across Canada, amounting to 84%. These sectors were also responsible for 84% of the water *consumption* in Canada — which is defined as the amount of water that is taken from a source and not returned. Agricultural irrigation activities alone accounted for almost 66% of national water consumption, with the remaining sectors accounting for approximately 18% of national consumption.

While the withdrawal alone is an important indicator of water pressures, knowledge about the cumulative impacts on water resources, including timing of the withdrawals, return flows, and quality of water returning to the system, is necessary in order to understand the regional effect of water use on the ecosystems. Increasing pressures on water resources due to industrial uses, climate change, population growth, and a general lack of capacity to manage the impacts of industrial developments on a regional basis will all have an impact on Canada's watersheds. These stresses are likely to pose a significant challenge to the sustainability of Canada's water resources if action is not taken now to address the shortfalls of our governance and management systems.

* Withdrawals that are taken from surface and/or groundwater resources.

PURPOSE OF REPORT

In November 2008, the National Round Table on the Environment and the Economy (NRTEE) initiated a research program on Water Sustainability and the Future of Canada's Natural Resource Sectors (agriculture, forest, mining, and energy) to identify what is known about the main uses of water by the natural resource sectors. The program has two high level objectives:

1. To raise the profile of the importance of water management in this country and some of the key water issues relative to Canada's natural resources sectors; and

2. To provide recommendations to governments, industry and water management authorities on policies, approaches and mechanisms through which water can be better managed to foster both ecosystem health and the natural resource sectors' economic sustainability.

The program is divided into two phases. Phase I (2009–2010) sets out to identify key issues related to the sectors' water uses, as well as the barriers, drivers, risks, and opportunities associated with the sustainability of Canada's freshwater as they relate to the natural resource sectors. Phase II (2010–2011) will focus on exploring options and proposing solutions to some of the key issues identified in this Phase I report.

This report sets out to present the most important uses of water by the natural resource sectors, highlight the current and emerging uses that are important for the sustainability of the water resources, and identify critical issues common to one or more of the sectors.

Changing Currents provides a description and overview of the relationship between Canada's natural resource sectors and water, focusing on the current and emerging key water issues facing the sectors. It specifically synthesizes information on the following:

- the sectors' growth and what this means to increased water demand;
- the most important sector activities that use and/or impact water resources;
- the key current or emerging water issues in each sector; and
- potential drivers and opportunities for improvement to water use and efficiency.

The NRTEE set out to explore water uses by the natural resource sectors from a quantity perspective. Through our research, it became apparent that the sectors can also have significant impacts on water quality, and that the linkage between water quantity and quality is important to consider. Therefore, some of the most important water quality issues related to the natural resource sectors are noted in this report, specifically where they interfere with water availability for other usages, including ecosystem needs.

The report is the result of extensive research and consultations with water and governance experts, the natural resource sectors themselves, as well as with the NRTEE's Water Expert Advisory Committee.[*] An initial national expert workshop was held in February, 2009, to help the NRTEE scope out the water program. Based on advice from this meeting, the NRTEE partnered with the natural resource sectors' industry associations,[†] to hold six roundtable meetings in the fall of 2009 to discuss the key water uses and issues pertaining to their sectors. This series of meetings verified the in-house findings of the NRTEE and enhanced the understanding of the key issues from the perspective of the industry stakeholders. The meetings also provided for open, transparent dialogue among small groups of stakeholders on which key water issues required attention. These meetings confirmed for the NRTEE that there is an interest and need for exploring sustainable water use by the natural resource sectors.

The discussion of water use and availability in this report is largely focused on surface waters, rather than groundwater supplies, simply due to the scope of research of the report. However, the NRTEE recognizes the critical importance of the connection between surface flows and groundwater, as many streams receive at least half their total flow from groundwater.[7] The complex linkage between groundwater systems and surface streams in Canada, while recognized, is not well understood and requires further study.[8]

The report also looks at ecosystem needs and services, and highlights the jurisdictional complexity of the governance and management of water resources in Canada and what this means. Finally, the report concludes by identifying the most pressing issues that need to be addressed in the short term, together with policy conclusions on our next steps for research.

There is a need for better information regarding current and potential future water use in this country, so that it can be better managed and so that citizens can understand how and why water is used. This will lead to a more informed debate regarding future water use and allocation in the country, especially in those areas that are now or may soon face water shortages. It is the NRTEE's belief that addressing some of the critical issues now will enable Canada to avoid the challenges other countries are already facing.

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* See Appendix for list of Expert Advisory Committee members.

† Mining Association of Canada; Canadian Nuclear Association; Canadian Association of Petroleum Producers; Canadian Federation of Agriculture; and Forest Products Association of Canada.

CHAPTER TWO

ADDRESSING NATURE'S WATER NEEDS

CONTENTS

HIGHLIGHTS

The health of Canada's ecosystems and the ability to deliver ecosystem services is critically dependent upon clean, sustainable water resources.

Watersheds deliver ecosystem services to society that, when valued economically, often far exceed the value of water allocated for other uses.

Ecosystems are resilient and can cope with degrees of human-induced change, but these changes must be managed with careful monitoring and responsive adaptive management programs.

Water cannot be sustainably managed into the future solely through on-going efforts to improve and increase water supplies. Greater emphasis must also be placed on reducing water demand to avoid problems for future generations.

ADDRESSING NATURE'S WATER NEEDS

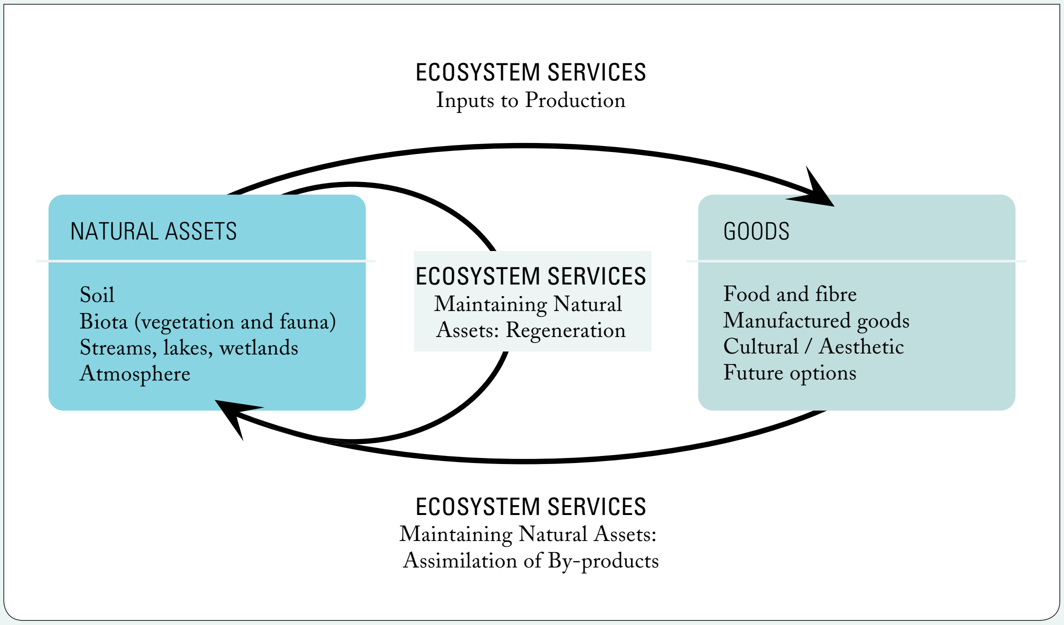
ECOSYSTEM SERVICES

Freshwater is vital to ecosystems, biodiversity, and human well-being. Without water, there is no life. Water is also a critical component of Canada's natural resource sectors. And so the implicit fact is that water must be managed sustainably to ensure the continued economic prosperity of these sectors. International experience has demonstrated that managing water from a supply perspective alone can pose risks to both the environment and society when there is little to no consideration for the needs of the natural environment. The sustainable use of water by the natural resource sectors cannot be achieved in the absence of considerations of the integrity of ecosystems and the *services* they provide.

The concept of *ecosystem services* was created to encourage a dialogue about the human dependence on and value of the natural environment, both socially and economically. Ecosystem services are the benefits provided to people, both directly and indirectly, by ecosystems and biodiversity. Direct economic benefits are those materials gained through the use of natural assets (e.g., water, trees, and crops) that provide inputs to production. Indirect benefits refer to all those natural goods and assets that keep soil intact, assimilate pollutants, pollinate plants, provide oxygen, and lead to regeneration of natural assets (Figure 3). These latter functions are a crucial foundation of the economy and human well-being. Moreover, their absence from the price of goods and services, market value, and policy decisions surrounding market drivers, result in numerous hidden costs to society and industry.

FIGURE 3

A CONCEPTUAL FRAMEWORK FOR ECOSYSTEM SERVICES



Source: Abel et al., 2003.[9]

The UN Millennium Ecosystem Assessment identifies four types of ecosystem services provided by freshwater: provisioning, regulating, cultural, and supporting services (Table 1).

Human alterations to the timing, volumes, quality, and temperature of water can impair ecosystem health and ultimately the services they provide, and the direct economic benefits they bring.[10] Conventional financial markets do not capture the value of these services, yet the value provided to society by freshwater cannot be underestimated. In regions where ecosystems are severely degraded, the economic costs associated with lost ecosystem services and efforts to restore them are considerable and can far outweigh benefits of other water uses. The sustainability of Canada's water resources is directly related to the ecosystem services they provide to society, and should be placed in that context.

TABLE 1

ECOSYSTEM SERVICES PROVIDED BY FRESHWATER

ECOSYSTEM SERVICE	EXAMPLES
Provisioning services	Goods such as drinking water, food, and fibre
Regulating services	In support of those biophysical processes that control natural processes (i.e., erosion and climatic control)
Cultural services	Recreational and spiritual
Supporting services	Those underlying processes that support all life such as photosynthesis and nutrient cycling

DEFINITION OF WATERSHED & INTEGRATED WATER RESOURCE MANAGEMENT

The term watershed (also called a drainage basin or a catchment) is defined as an area of land that intercepts and drains precipitation through a particular river system or group of river systems. All land that is connected by rivers and streams could therefore be considered a watershed.

Integrated Water Resources Management is defined "as a process, which promotes the coordinated development and management of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."[11]

HUMAN ACTIVITIES THAT AFFECT ECOSYSTEM SERVICES

Understanding the nature of water and its movement through the hydrological cycle is necessary to recognize how water can be managed to capitalize on its many uses. Although water is a finite element, its location and availability is constantly shifting. Water circulates from oceans and land to clouds, falls back onto land as rain or snow, absorbs into soils and feeds runoff, with each of these phases playing an important role in supporting ecosystems. It cannot be managed simply as a resource that regenerates in a predictable manner.

Even in watersheds that have been relatively unaltered by human use, freshwater ecosystems are constantly changing. A healthy aquatic ecosystem gains stability from complex interactions of a dynamic series of chemical, biological, and physical fluctuations. In essence, these interactions are the life-support system for all species and maintain a sort of equilibrium. It is the ability of ecosystems to change and adapt that makes them *resilient*.[12] And it is this resiliency that makes them capable of handling changes in flow, temperature, sedimentation, vegetation composition, and other conditions, such as diminished wetlands and contaminant inputs. However, the timing, frequency, and intensity of each of these pressures, separately and cumulatively, determine the degree to which the health of the ecosystem is compromised.[13] Human activities that occur in one part of a watershed can have effects on other parts of the ecosystem and so are not isolated in geography or time.

Clearly, human water uses and land management decisions change the ecosystem services provided by freshwater. Table 2 illustrates some of these impacts. Within limitations, the environment can adapt to pressures, provided that we take measures to minimize impacts and prevent irreversible damage. However the failure to address cumulative effects of fragmenting waterways — reduced variability in natural flows and increased contamination — in concert with the effects of climate change have already put many of Canada's rivers and watersheds under considerable stress. When the health of a freshwater ecosystem is compromised and its productivity is diminished, there is a risk that the ecosystem will no longer be able to provide the full range of ecosystem services to humans. To manage these watersheds into the future, a shift away from supply-management toward an approach that is based on demands, including ecosystem needs, is necessary.

TABLE 2

EXAMPLES OF HUMAN IMPACTS ON ECOSYSTEMS

HUMAN ACTIVITY RELATED TO THE NATURAL RESOURCE SECTORS AND WATER USE	IMPACT ON ECOSYSTEMS	ECOSYSTEM SERVICES AT RISK
Dam location, construction, and operation	Alters the timing and quantity of river flows, water temperature, nutrient and sediment transport, delta replenishment, and blocks fish migration. Flooding of ecosystems (previously upland, wetland or riparian)	Provision of habitat for native species, recreational and commercial fisheries, maintenance of deltas and their economies. Transportation, recreation and tourism
Dike and levee construction	Fragments hydrological connection between river and floodplain habitat	Natural flood control, habitat, sport and commercial fisheries, natural floodplain water variation
Diversions	Diversion takes water from one system and places it in another; therefore one system is depleted, while the receiving system gets more flow Enables invasive species to migrate from one system to another	Habitat, sport and commercial fisheries, recreation, pollution dilution, hydropower, transportation
Draining of wetlands/ Conversion to other land uses	Eliminates key component of aquatic ecosystem	Natural flood control, habitat, recreation, natural water purification
Deforestation/land use	Alters runoff patterns, inhibits natural recharge, fills water bodies with silt, changes water temperatures	Water quality and quantity, fish and wildlife habitat, transportation, flood control
Release of polluted water effluents	Diminishes water quality	Water supply, habitat, commercial fishing, recreation

Adapted from Postel and Richter, 2003.[14]

ECOSYSTEMS MANAGEMENT IN THE CONTEXT OF COMPETING INTERESTS

The challenge in ecosystem management is that ecosystem services do not function in isolation. The services provided by ecosystems are interdependent and often interact in complex ways. Decisions that negatively affect one aspect of an ecosystem will likely negatively affect others; and likewise, those decisions that restore or improve one aspect of the ecosystem will almost certainly have multiple benefits. For example, years of phosphorous pollution from sewage treatment plants and agricultural runoff in Lake Erie caused a biological reaction that lowered levels of dissolved oxygen in the bottom layers of the lake. The low levels of oxygen suffocate many bottom-dwelling species, which provide food for other species. Long-term impacts cause a decline in all lake species, which ultimately impairs the ability of the lake to provide clean water for drinking, fish, and recreational use.[15] Careful monitoring and research of various components of freshwater systems is required in order to recognize when key thresholds of resiliency have been affected and to determine what decisions are required to reverse the changes.

Understanding the quantity and movement of water is a critical component of ecosystem management. Removing or restricting the movement of water from groundwater, lakes, wetlands, or rivers can impact the amount of oxygen in the system, water temperature, and species composition, among other things. Knowing the water requirements to sustain a healthy ecosystem — the "environmental flows" — is critical to water management. To understand requirements for environmental flows, managers must first have a basic knowledge of the ecological functions provided by the watershed.

DEFINITION OF ENVIRONMENTAL FLOWS

As defined in the Brisbane Declaration,* "environmental flows" describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.[16]

* The Brisbane Declaration is a non-binding commitment signed by more than 800 delegates from 57 countries, including Canada, in 2007. It focuses on collaborative work to protect and restore the world's rivers and lakes.

In Canada, governments in many parts of the country are responding to the concept of environmental flows and acknowledge the interactions between water quality and quantity in surface and groundwater at the watershed level.[17] British Columbia is currently reviewing regulatory tools to legislate environmental flow, and Québec's Bill 27 (*An Act to Affirm the Collective Nature of Water Resources and Provide for Increased Water Resource Protection*) provides the legal grounds to restore a water body to its original or a similar state. Yet, no province, to date, has legislated environmental flow protection measures. Canada has yet to develop a widely-acceptable science-based policy framework to define methods for determining environmental flows to be used by provinces and complement the general provisions of the federal *Fisheries Act*. Evidence and experience therefore point to the need for a national strategy to address environmental flows.

Alberta's *Water Act* provides an example of a provincial measure that enables the protection of the aquatic environment in specific watersheds, as witnessed in the Athabasca. The *Act* enables the Crown to develop in-stream flow requirements and withhold up to 10% of flows through the use of a water conservation objective if it is in the public interest. But specifications for in-stream flow requirements are not in themselves legislated.

A key challenge of managing watersheds is addressing not only individual impacts, but cumulative ones as well. This requires current and future assessments of the sectors and other users in consideration of the interdependency of cumulative stream uses, as well as groundwater resources.[18] The Mackenzie River Basin demonstrates this well, as it is affected by the upstream development of oil sands on the Athabasca River and the Bennett Dam on the Peace River, and could be further impacted if proposals for hydroelectric development move forward on the Slave River. Governments of British Columbia, Alberta, Saskatchewan, the Northwest Territories, and Yukon recognized the need to work collaboratively to manage water and ecosystem requirements of the Mackenzie River Basin and have been doing so since the 1970s.

Human use of water causes changes to natural systems, but much can be done to ensure that alterations to freshwater flows don't compromise the resiliency of the ecosystem.[19] Decisions about water allocation, the scale and placement of development, and the location, design, and operation of in-stream infrastructure are all important aspects of sustainable water management. Monitoring and assessment of measurements pertaining to hydrology, physical habitat, water quality, and biological function are needed to inform management decisions and monitor changes in the system.[20] To determine what changes are acceptable requires judgment on the adequate quantity, quality, and timing of flows in rivers required to maintain ecological resilience. As with all quantitative assessments, historical measures based on consistent, reliable data and capacity to assess and communicate results are required to address watershed trends. But ultimately, the determination of ecosystem water requirements will involve societal decisions on the desired condition of the ecosystem and water uses.[21] By making environmental flows a key principle of water policies, stakeholders at the watershed level will have flexibility to make societal judgments about future water uses before those uses are in direct competition with ecosystem needs.

ADDRESSING THE VALUE OF FRESHWATER ECOSYSTEM SERVICES

Economic valuation of freshwater ecosystem services, or natural capital, is one method that builds upon the science of watershed assessments, bringing them into the realm of economic decision making. Economic valuation is useful in informing cost-benefit analyses and scenario analysis for land management, restoration, and development decisions. In Canada, valuation studies of freshwater ecosystem services have been conducted in the boreal forest, the Mackenzie River watershed, Lake Simcoe Basin, and in many settled areas of the country.[22, 23]

Because valuation of ecosystem services attempts to put a price on those things that are not normally valued in the marketplace and may not provide consistent "worth" across different landscapes, this type of assessment has certain limitations. Most of the attempts to date have been site-specific. The challenge is to expand these very local economic evaluations to larger scales in a meaningful fashion. Even at the local scale, barriers such as the lack of data and information about the resource and ability to assess ecosystem services in the context of the entire flow regime exist. Without this information, it is difficult to examine the trade-offs between multiple water uses and to make quantifiable determinations of those services (e.g., assessing the potential value of draining a wetland to expand agricultural land). Even with a service value in hand, the transaction of payments for watershed services is complex, although this is a field quickly developing at the regional level.

Ecosystem valuation is just one way markets can be used to conserve nature. Where markets exist for ecosystem services, the economic value of such services can be reflected in prices. Such markets exist in Canada for wetlands providing waterfowl habitat. Outside of Canada, they are increasingly common for in-stream flows protecting fish. An assessment of such instruments used to preserve water for ecosystem services is an area that requires greater attention in Canada.

EXAMPLE OF VALUATION OF ECOSYSTEM SERVICES IN NEW YORK

To help inform a decision on how best to purify local drinking water, the City of New York conducted a comparative study to determine the costs of restoring the Catskill watersheds versus the cost of developing a water treatment plant. The study showed that the watershed could be restored to levels under which it could continue to provide natural water purification for a $1 to $1.5 billion investment, whereas the water filtration plant would cost an estimated $6 to $8 billion.[24] The ultimate decision to restore the watershed was thus made on an economic basis.

Addressing ecosystem needs is a foundational area of policy research that has not received significant attention in Canada. Much can be learned from regional efforts to improve and incorporate ecosystem needs in watershed planning. Examples such as the proposed changes to the regulation of the Moses Saunders dam on the St. Lawrence River[25] and the process to incorporate "ecosystem base flow" for the Lower Athabasca River demonstrate this well.[26] Canada has yet to broadly incorporate environmental flows into existing policies. Ecosystem services valuation and environmental flow assessments hold promise in supporting Integrated Water Resource Management. But there is a need to better understand the outcomes of such mechanisms, the most effective roles and responsibility for planning and implementation in watershed management, and the information requirements to achieve these ends. There is also a need for improved knowledge about how to address the economic and environmental trade-offs that come with various water uses.

CHAPTER THREE

WATER GOVERNANCE AND MANAGEMENT IN CANADA

CONTENTS

HIGHLIGHTS

Water management in Canada is complex, fragmented and lacks coordination between and within the various levels of government.

Mechanisms in place across Canada do not allow the collection and sharing of reliable information on actual water use by natural resource sectors and other water users.

Current water management rests on a strong regulatory framework across Canada, with limited use of market-based instruments.

The emergence of collaborative governance models provides an opportunity to improve water management in Canada.

WATER GOVERNANCE AND MANAGEMENT IN CANADA

Water governance and management are central to ensuring sustainable water use by Canada's natural resource sectors. Water governance refers to the processes and institutions through which decisions are made about water. This includes the range of political, organizational, and administrative processes used to make and implement decisions, as well as how decision makers are held accountable. Management refers to the operational, on-the-ground activity to regulate the water resource and the conditions of its use.[27] In the past century, formal water governance models have increasingly centred on a top-down approach where governments made all the decisions. There is a movement now toward collaborative governance models where the authority and responsibility for decision making is shared among levels of government, individuals, firms, and non-governmental organizations. This chapter describes the governance and management of water relative to quantitative uses, not qualitative, and largely focuses on water allocation and permitting/licensing roles and responsibilities.

DIVISION OF RESPONSIBILITY FOR WATER MANAGEMENT

The *Constitution Act* does not refer directly to responsibilities pertaining to water resources, although the constitutional authority for water belongs primarily to the provinces as they exercise direct control over the natural resources — including water resources — within their borders. Responsibility for water management is shared between the provinces/territories and the federal government, which retains authority over fisheries, navigation, transboundary issues, federal lands, and Aboriginal matters. The federal government also shares jurisdiction with the provinces/territories on other water-related issues such as agriculture, health, and environmental protection. In some areas of federal jurisdiction, such as fisheries management and fish habitat protection, the federal government has entered into agreements with certain provinces, delegating some of its authority to the provincial governments. This has necessarily led to a very complex legislative and policy water management framework across Canada, with shared and sometimes duplicative authorities.

Aboriginal water rights are increasingly considered in water management in Canada. Aboriginal rights and treaty rights became constitutionally protected in 1982. This means that any rights, including water rights, that have not been extinguished before 1982 cannot be infringed upon by governments. Any activity that could potentially infringe on Aboriginal rights requires consultations with the Aboriginal rights holders, and this includes water management decision-making processes.

In many regions across Canada, First Nations are engaging directly in water governance, working with or encouraging collaboration with other governments and partners through watershed planning, water source protection planning, and water management initiatives. For example, a very successful collaboration has been in place in the Northwest Territories (NWT) since 2006 when Aboriginal peoples formally asserted the need for, and have since been integrally involved in, the development of the NWT government's Water Stewardship Strategy. First Nations and Indigenous knowledge can contribute to our understanding of the health and workings of the watershed, to our approaches for effective collaboration, to identification of values and priorities, and to successful, cooperative implementation of actions and solutions.

FEDERAL JURISDICTION AND RESPONSIBILITIES

The federal government exercises its constitutional authority on water through a number of legislative, regulatory, and policy instruments. At least 20 federal agencies have responsibilities regarding water management, covered under 11 different pieces of federal legislation. Environment Canada is the lead federal department responsible for water. Natural Resources Canada, Fisheries and Oceans Canada, and Indian and Northern Affairs Canada also have central responsibilities.

FEDERAL LAWS INVOLVED IN FRESHWATER MANAGEMENT

The main pieces of federal legislation relevant to freshwater are:

- *Canada Water Act*
- *Fisheries Act*
- *International Boundary Waters Treaty Act*
- *International River Improvements Act*
- *Mackenzie Valley Resource Management Act*
- *Navigable Waters Protection Act*
- *Northwest Territories Water Act*
- *Nunavut Waters and Nunavut Surface Rights Tribunal Act*
- *Canadian Environmental Protection Act*
- *Canadian Environmental Assessment Act*
- *Canada National Parks Act*

One of the key federal documents on water management is the 1987 *Federal Water Policy*. The overall objective of this policy is to encourage the use of freshwater in an efficient and equitable manner consistent with the social, economic, and environmental needs of present and future generations. The policy identifies five strategies to reach its stated objective: water pricing, science leadership, integrated planning, legislation, and public awareness.

A recurring criticism of the federal water strategy is that, while the federal government has expended substantial resources in the past 25 years to define and develop the strategy, few actual policies or actions on the ground have been implemented.[28] It has been suggested that the challenge of coordinating the work of many federal agencies and the lack of political will may be the main reasons for the limited action from the federal government. Some successful initiatives must be noted, however, such as the recent Canada-wide Strategy for the Management of Municipal Wastewater Effluents, which was developed under the leadership of the federal government through the Canadian Council of Ministers of the Environment (CCME).

PROVINCIAL JURISDICTION AND RESPONSIBILITIES

Provinces are mainly responsible for water management in Canada. Three frameworks in Canada define the principles under which water allocations are determined (Figure 4):

1. The **First in Time, First in Right (FIT-FIR) approach** is in effect in British Columbia, Alberta, Saskatchewan, and Manitoba. This approach is based on the principle of prior appropriation, which gives the licensee exclusive rights to use the water in a system of seniority based on the age of the licence. In Yukon, the Northwest Territories, and Nunavut, where a public authority (various Water Boards across the territories) makes the decisions about water, priorities are also established through the FIT-FIR principle.

2. The principles of the **Common Law of Riparian Rights** are the basis of the water-user permit systems in Ontario, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador. Under the common law, which was developed before water rights were legislated, individuals who own or occupy land beside lakes and rivers have the right to the natural flow of the water adjacent or through their property, unchanged in quantity or quality. The provinces have responsibility for administering water and supervising its allocation; their legislative jurisdiction over water is to be exercised in a manner equitable to all.

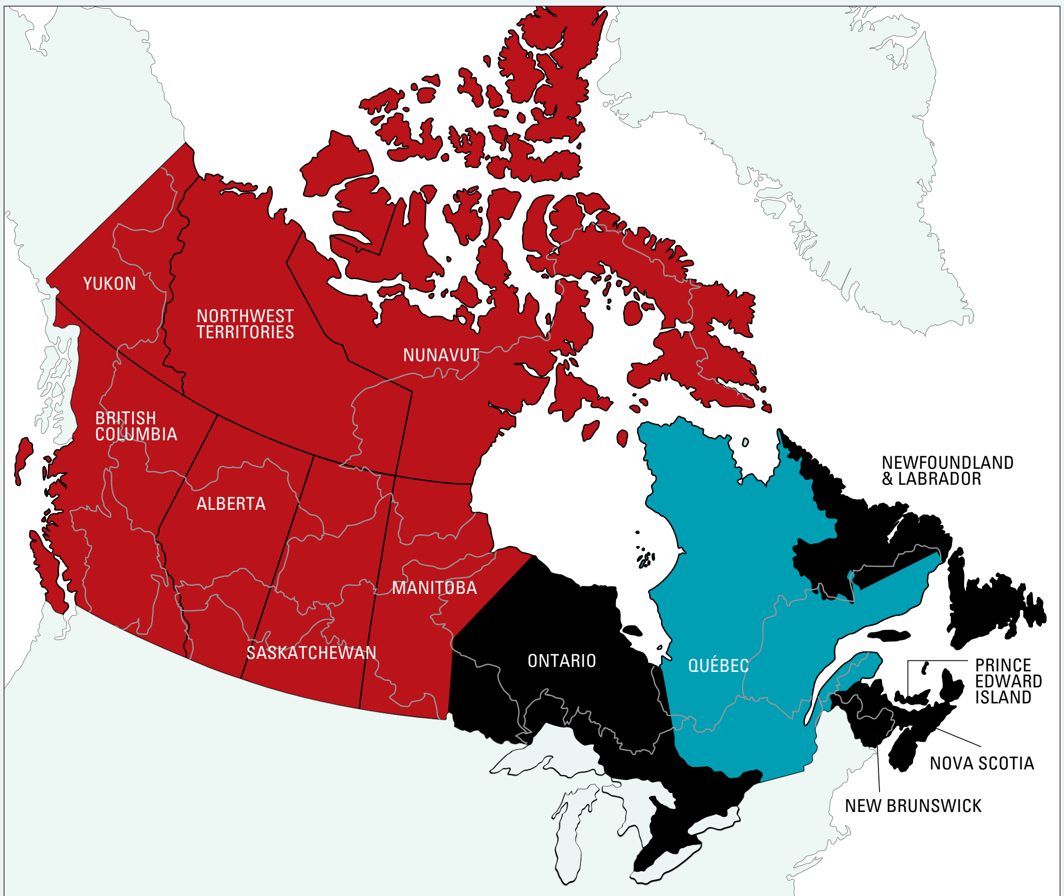
3. In Québec, water use permitting is based on **Civil Law** principles. Québec's civil law states that water is not owned by anyone, but rather its use is common to all. The province therefore has a guardianship role to play to ensure the common good.

All provincial and territorial water allocation systems involve either a licensing or permitting system, for both surface and groundwater in all jurisdictions, except in British Columbia where there are no provisions for groundwater.

Water-use licence fees exist in all provinces and territories but they differ significantly. In most cases, these are one-time fees payable at the time of the application, supplemented with annual fees in certain situations. Some provinces have fixed prices while others have variable fees, depending on the volume of water used and type of use, such as: industrial, power generation, or agriculture. Generally speaking, fees are low, ranging from $20 to a few thousand dollars. In certain cases, such as in Ontario and Saskatchewan, some specific activities including agriculture

FIGURE 4

LEGAL FRAMEWORKS FOR WATER ALLOCATION IN CANADA



- FIRST IN TIME, FIRST IN RIGHT (FIT-FIR)
- CIVIL LAW
- COMMON LAW OF RIPARIAN RIGHTS

are exempted from the fees. Revenues from water-use fees generally go into provincial general revenue funds. One notable exception is in Prince Edward Island, where the revenue from water withdrawal permits is used to offset the costs associated with the administration and implementation of the government's water-monitoring program.

All jurisdictions have the legal framework to require water licensees to report on the amount of water actually used. However, this does not appear to be a common requirement of licences and permits across the country. In reality, water use reporting requirements vary greatly among provinces and territories in terms of the obligation to report and the expectations for the accuracy of reporting. Reporting requirements are specified through legislation and/or regulations (in Ontario, Québec, the Northwest Territories, and Yukon) or as conditions in permits or licences (in the rest of Canada, except in New Brunswick where there are no reporting requirements). Prince Edward Island has reporting requirements only for groundwater. The requirements for accuracy also vary greatly across Canada, making the interpretation and comparison of data quite difficult.

In regions where water allocation is based on prior appropriation, there has been recent progress on developing a water market, or transferrable water rights. Alberta has incorporated water transfers into its water-use legislation and is now exploring an expansion of this system more broadly in the province. In British Columbia, the "transfer of appurtenance" provision, which allows licence holders to change the location of use of their water right, has been interpreted to allow some water transfers. Currently no such water markets are permitted in other provinces; however, both Manitoba and Saskatchewan are considering this option. In the Territories, water licences are transferrable with approval from the Water Boards that issue the licence.

In recent years, a number of provincial governments have invested significant resources in the development of comprehensive water policy frameworks, including the Québec Water Policy (2002); Alberta's Water for Life Strategy (2003); Ontario's *Clean Water Act* (2006), enabling source water protection; British Columbia's Living Water Smart (2008); Northwest Territories' Water Stewardship Strategy (2009); and Nova Scotia's Water Strategy (to be released in 2010). These attempts to revise existing water management differ in the details but they all call for the following principles to be broadly recognized and incorporated into water decision-making processes:

- water management at the watershed scale
- shared authority/collaborative governance models allowing greater stakeholder engagement and accountability

- integration of water management planning with land use planning
- integration of surface water management with groundwater management
- inclusion of environmental water requirements as part of the water allocation schemes

Moving from such broad concepts to specific targeted actions requires a significant amount of human and financial resources, which do not seem to be readily available. In most cases, progress has been slow, as water managers and stakeholders are still struggling to translate those well-intended strategies into concrete action.

Ecosystem needs, or the allocation of water for environmental requirements, are a key feature of modern water management schemes around the world. In Canada, this concept is increasingly embedded in provincial/territorial water management systems. Some provinces, such as British Columbia, Alberta, Manitoba, Ontario, and Québec, have requirements for environmental water allocations in their licensing systems. These requirements sometimes apply only in certain designated areas or watersheds. In most provinces, environmental requirements are not automatically part of the allocation or licensing system, but are secured through other environmental statutes that must be triggered before issuing a new water licence (for example, environmental assessment requirements). Ecosystem needs may also be incorporated into water management systems through general provisions allowing the regulator to take any appropriate action deemed necessary to protect the public interest.

Water allocations in Canada are usually done in isolation of land use planning. Not only do the government agencies involved in both processes differ in most cases, but the geographic scales upon which water management and land use planning are conducted are often dissimilar.

INTER-JURISDICTIONAL WATER MANAGEMENT

All Canadian provinces and territories (with the exception of Prince Edward Island) share freshwater resources with other provinces/territories and sometimes with the United States. In some cases, inter-jurisdictional arrangements have been put in place in Canada, addressing interprovincial or international boundaries.

Provincial boundaries rarely overlap with watershed boundaries. As a result, most major water bodies and hundreds of streams cross jurisdictional boundaries within Canada. This may give rise to disputes over water uses and who decides how water will be allocated. The *Master Agreement on Apportionment,* signed in 1969 by the Prairies provinces and the federal government, is an example of a successful coordination of water management systems involving several provinces. Under this Agreement, Alberta and Saskatchewan may each take up to one-half of the natural flow of water originating within their boundaries and one-half of the flow entering the province. The remainder is left to flow into Manitoba. The Prairie Provinces Water Board manages the agreement. It is composed of one representative each from Alberta, Saskatchewan, and Manitoba, and two representatives from the federal government.

A recent review of contemporary international transboundary water governance showed that while apportionment of transboundary water resources between countries has the potential for conflict, it has, for the most part, been a basis for cooperation.[29] This is also true in the North American context. Canada and the United States have a long and successful history of jointly managing their transboundary water resources under the auspices of the 1909 *Boundary Waters Treaty* and the International Joint Commission (IJC) created by the treaty. In setting limitations on the freedom with which each country can use water, the Treaty provides controls on water levels and flows. Over time, the IJC has evolved into an institution providing sound science available to governments of both countries to support the management of Canada-U.S. transboundary waters and joint decision making.

Despite the existence of these institutions and governance mechanisms, the potential for conflicts still exists. Recent disagreements involving surface water illustrate the variety of issues that might arise, such as: the Devils Lake dispute between Manitoba and North Dakota; the potential transboundary pollution in the Flathead River originating from a proposed coal mine in British Columbia and flowing into Montana; and the continuing pollution and water-level issues in the Great Lakes.[30]

The challenge of managing transboundary water is even more acute when dealing with groundwater. Situations where two or more provinces share groundwater from the same aquifer (sometimes in addition to neighbouring U.S. states) may give rise to water disputes and governance challenges. The case of the Abbotsford-Sumas aquifer on the West Coast is an example of how nitrate contamination migrates from Canada to American wells. Aquifers generally do not follow the same boundaries as surface watersheds. Therefore, watershed-based management, which is increasingly used in order to better address local and regional issues, may not be the best governance tool for groundwater. In recent years, a number of multi-stakeholder working groups have emerged in the interest of coordinated groundwater strategies.[31] However, formal multilateral governance bodies having the authority to make decisions about groundwater do not currently exist in Canada.

The Canadian Council of Ministers of the Environment (CCME) also plays a role in water governance in Canada. In 2009 the CCME adopted a Canada-wide vision for water, entitled *Setting Strategic Directions for Water*. It provides a strategic, forward-looking framework to guide its members in all future actions and activities related to water. In addition, the Council of the Federation, an intergovernmental initiative consisting of all provincial and territorial premiers, agreed to create a Water Stewardship Council in 2009. This initiative is to be based upon the existing Western Water Stewardship Council. Its initial focus is on water efficiency and conservation.

EMERGING ROLE OF COLLABORATIVE GOVERNANCE STRUCTURES

Recent global trends show that governments are moving toward a less centralized approach to water management and governance. New approaches promote flexible policy processes that are open, adaptive, and collaborative. In Canada, several provinces are experimenting with various types of collaborative governance models and enhanced stakeholder engagement. For the natural resource sectors, this shift requires more intense engagement with stakeholders.

Collaborative water governance may be broadly defined as the involvement of both governments and non-government organizations in water management decision making. This frequently implies the delegation of decision making to lower scales of governance stemming from the watershed, municipality, or region.[32] This concept has increased in popularity over the past few years and is now considered an essential component of modern water governance. Collaborative governance structures are often associated with watershed management, as the watershed offers a relevant scale for the involvement of local and regional stakeholders.

In Canada, various collaborative governance models have been or are being put in place. The numerous watershed organizations in Québec, the water source protection committees in Ontario, Alberta's water planning advisory committees, and the Fraser River Basin Council in British Columbia are notable examples. The various Water Boards in the Northwest Territories, Nunavut, and Yukon could also be considered collaborative governance structures.

In February, 2010, an NRTEE workshop* on the evolving role of natural resource sectors in Canadian water governance shed some light on the benefits and challenges of collaborative water governance models in Canada, and highlighted the importance of several key factors to

* Workshop coordinated in collaboration with the Water Policy and Governance Group.

making collaborative models successful. Some of the key factors noted were addressing divergent values and perspectives, ensuring clear roles and responsibilities, creating shared knowledge between stakeholders, ensuring accountability and legitimacy, addressing capacity issues, and overcoming the jurisdictional complexity. Collaborative water governance models will succeed and be seen as legitimate only if a number of conditions are met:

- they focus on a clear scope and clear outcomes;
- the right people are brought together, with the right convener;
- participants agree to fully get engaged and there is real commitment to the process;
- clear roles are identified for participants;
- the processes foster shared ownership and accountability; and
- an ongoing dialogue is built.

Collaborative water governance is a tool that can improve water management in Canada, as it allows a more regional or local planning process, which promotes better-informed place-based decisions and facilitates the involvement of regional stakeholders. It must, however, follow all principles of good governance, be used under appropriate circumstances, and involve the right actors. Any attempt to implement collaborative governance models without putting in place such conditions will only raise expectations, waste precious time and financial resources, and result in a loss of credibility and legitimacy of the government agencies involved.

KEY CHALLENGES, GAPS, AND OPPORTUNITIES

Canada's water management is complex and fragmented, and lacks coordination. Water allocation systems in place across Canada are archaic and have not adapted to more collaborative approaches. In several provinces, water rights are granted based on prior appropriation principles (First in Time, First in Right). While certain provinces and territories have made progress over the past few years to renew their water management schemes, a systematic review of water allocation schemes in Canada is needed. Most of the systems still rest on a strong regulatory framework with limited use of economic incentives and market-based instruments. Another major problem is the lack of a reliable and accurate water-use data collection in most provinces, as well as a comprehensive information management system.

Water management, governed by political boundaries, can be a significant challenge as many issues are of a cross-boundary nature. Upstream and downstream impacts of surface and groundwater cross political jurisdictions, further emphasizing the need for multi-jurisdictional collaboration.

Inter-jurisdictional water management is based on a number of agreements dealing with specific water bodies or regions of the country. The large variations between provincial water management regimes, however, make inter-jurisdictional water management a challenging task. There are no overall direction or principles in Canada that provide guidance to the various water managers in a way that would facilitate the collection and exchange of comparable data throughout the country, or facilitate the integration of interests from all water users.

The emergence of collaborative governance models provides a potential opportunity to improve the way we manage water in Canada and brings the flexibility required for addressing regional and local particularities. It will require, however, strong leadership from governments to create the conditions necessary for these collaborative arrangements to be successful. Lessons learned from governance models in Canada and elsewhere call for effective processes to be put in place, including clear and achievable desired outcomes, clear roles and responsibilities, and the choice of the right convener. Currently, the role of the federal government in water management in Canada is discreet, unclear for most actors involved in water governance and sometimes at odds with stakeholders' expectations. A renewed and more effective water governance model in Canada will require a review of the role of each level of government.

CHAPTER FOUR

NATURAL RESOURCE SECTORS

WATER USE, ISSUES AND OPPORTUNITIES

CONTENTS

HIGHLIGHTS

The natural resource sectors are expected to grow by about 50% to 65% by 2030; their water uses are likely to increase with economic growth.

Water use varies considerably between the sectors, both in terms of their quantitative uses as well as their impacts on water quality and associated aquatic ecosystems.

Water quality issues are of critical importance to the sectors.

NATURAL RESOURCE SECTORS

WATER USE, ISSUES & OPPORTUNITIES

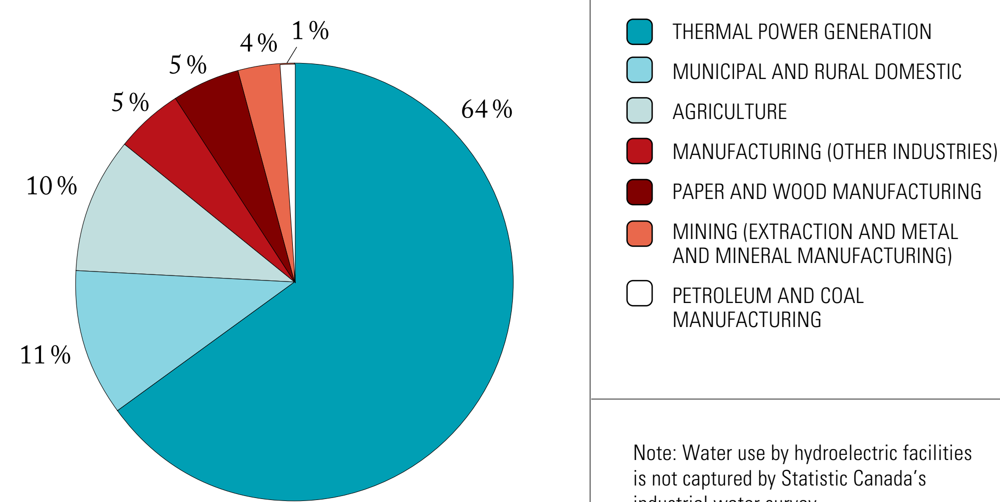
The use of water and the effects upon it by the natural resource sectors vary considerably across the country. The regional distribution of the sectors largely influence where the pressures on the water resources are felt. The complexity of this picture is complicated by the numerous and varied sub-sectors that operate in the regions, making for a very intricate "water story." To understand the complexity of water use and issues we need to disaggregate and understand the individual sectoral uses.

This chapter describes the natural resource sectors' most important water uses, key issues, and possible areas of opportunity for improved water use. The NRTEE analyzed the following sectors: electricity (hydro and thermal power generation), oil and gas, agriculture, mining, and forest.

From a quantitative perspective, the natural resource sectors are the greatest gross water users in the country, accounting for approximately 84% of all water withdrawn in 2005 (Figure 5). The thermal power generation sector is by far the single largest gross water user in Canada. Based on consumptive use — meaning the volume of water that is withdrawn and subsequently not returned to the source — the agriculture sector is the most significant user in Canada (Figure 6).

FIGURE 5

GROSS WATER USE BY MAJOR CANADIAN SECTORS, 2005*



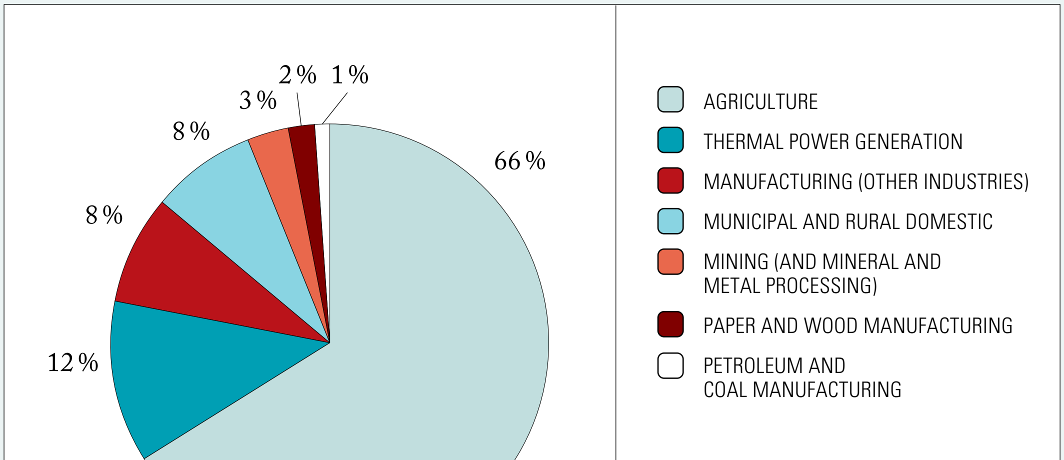
Note: Water use by hydroelectric facilities is not captured by Statistic Canada's industrial water survey.

These numbers provide only a partial understanding of significant water uses. First of all, the figures are estimates, in some cases based on modelled or proxy data. Second, the figures do not include information on water use by the hydroelectric sector, a significant gross water user in Canada. And finally, the figures tell us only part of the overall water-use story. Just as important are the timing of withdrawals and returning water, the quality in which water is returned to the systems, and the consumption of water within the context of the regional or local water situation (i.e., consumption is likely more important in areas where water is scarce or intake to flow is high). The water uses and issues by each of the natural resource sectors are unique; each has a different use and impact on the water resources upon which they rely, and each must be examined on its own.

* All industrial values are from 2005 (Statistics Canada's survey of Industrial Water Use, 2005, available at: http://www.statcan.ca/bsolc/english/bsolc?catno=16-401-X) , Municipal values are from 2006 (Environment Canada's 2006 Municipal Water and Wastewater Survey, available at: http://www.ec.gc.ca/Water-apps/MWWS/en/publications.cfm) and Agricultural values are from 2001 (Statistics Canada's Estimation of Water Use in Canadian Agriculture in 2001, available at: http://www.statcan.ca/bsolc/english/bsolc?catno=21-601-M2007087).

FIGURE 6

CONSUMPTIVE WATER USE BY MAJOR CANADIAN SECTORS, 2005*



Note: Water use by hydroelectric facilities is not captured by Statistic Canada's industrial water survey.

As significant users of water and as drivers of economic growth, the natural resource sectors will likely exert increasing pressure on our water resources into the future. Despite the recession of 2008–09 and projected modest growth in 2010, forecasts predict a period of recovery-paced growth in 2010–13 for the Canadian economy as a whole and for the natural resource sectors. Even though natural resource sectors have been heavily impacted by the recession, very few sectors are expected to contract between the years 2008 to 2013. Based on the projections of forecasting organizations, natural resource sectors are expected to grow about 50% to 65% between now and 2030. It is reasonable to expect their water uses to increase with production levels.

* All industrial values are from 2005 (Statistics Canada's survey of Industrial Water Use, 2005, available at: http://www.statcan.ca/bsolc/english/bsolc?catno=16-401-X) , Municipal values are from 2006 (Environment Canada's 2006 Municipal Water and Wastewater Survey, available at: http://www.ec.gc.ca/Water-apps/MWWS/en/publications.cfm) and Agricultural values are from 2001 (Statistics Canada's Estimation of Water Use in Canadian Agriculture in 2001, available at: http://www.statcan.ca/bsolc/english/bsolc?catno=21-601-M2007087).

HIGHLIGHTS

As the most significant gross water user in Canada, the electricity sector will face choices about Canada's future electrical generation mix that will have implications for the sustainability of water resources.

For fossil and nuclear power generation, water availability is a key consideration, both in terms of constraints at existing facilities and siting of new facilities.

Key issues facing the electricity sector include:

- Managing impacts of climate change -
- Managing impacts on ecosystems -
- Water availability -
- Impacts on water quality -

ELECTRICITY SECTOR

The NRTEE's examination of water use by the electricity sector focuses on hydroelectric and thermal electric including fossil and nuclear. Both have similar water uses and experience similar water management issues.

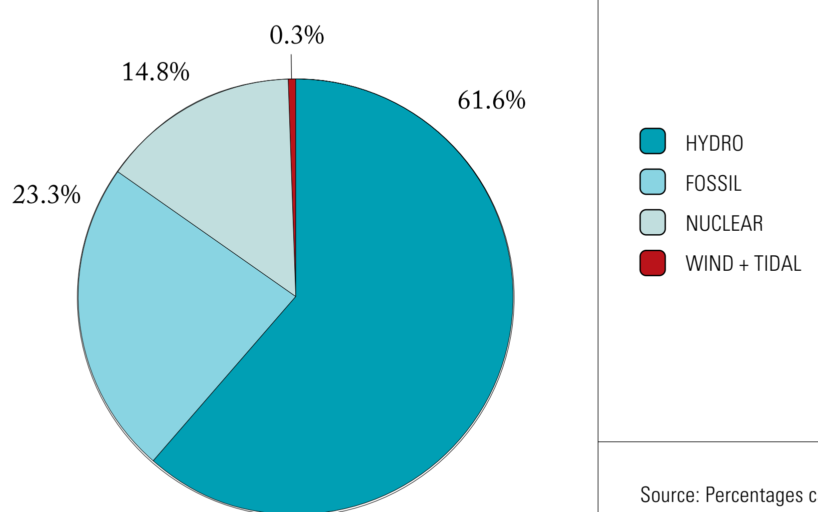
The electricity sector is the most significant water user in the country with thermal electricity alone accounting for 64% of all gross water use. In order to keep up with current and future electricity demand the Canadian electricity system will need significant renewal and new build, and so the generation makeup is likely to change over the next 20 years; therefore the choices that will be made concerning the future generation mix may be very important to the sustainability of our water resources. While changes to the generation mix may not drastically alter national aggregate water use, the establishment of new facilities may substantially impact water resources on a local or regional scale.

ECONOMIC IMPORTANCE OF THE ELECTRICITY SECTOR TO CANADA

The electric power generation (including transmission and distribution) sector contributed $24.5 billion to Canada's GDP in 2009.[33] Canada's electricity supply is a diverse mix of hydro, fossil, nuclear, wind, and tidal power, with hydro (62%), fossil (23%), and nuclear power (15%) being the most significant sources (Figure 7). The generation mix varies across the country with hydro being most significant to British Columbia, Manitoba, Québec, Newfoundland and Labrador, and Ontario (Figure 8); fossil dominates production in Alberta, Saskatchewan, New Brunswick, and Nova Scotia (and also provides just under a quarter of Ontario's energy supply); and nuclear power supplies over half of Ontario's energy (Figure 9).

FIGURE 7

TOTAL ELECTRICITY GENERATION IN CANADA

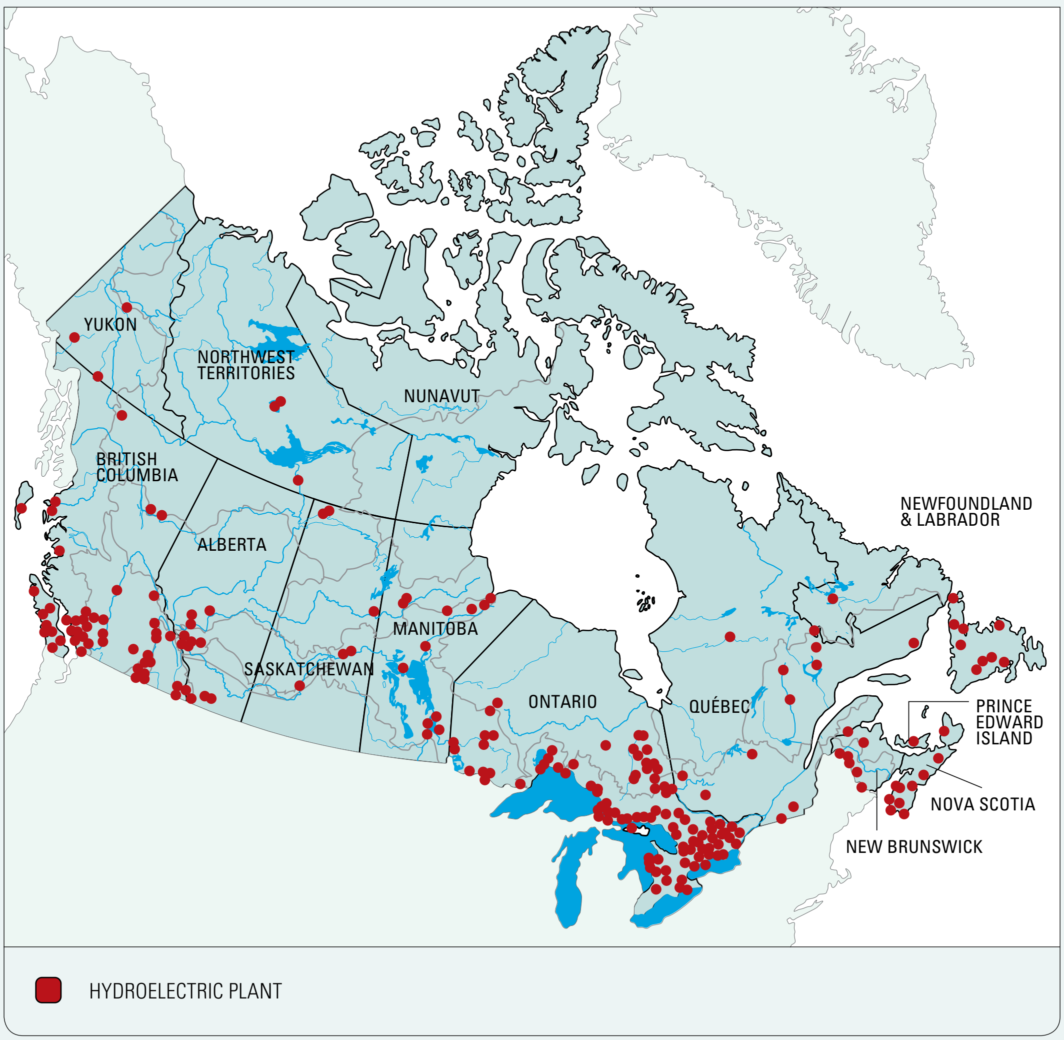


Source: Percentages calculated from data available at Canadian Electricity Association*

* Canadian Electricity Association, "Electricity Generation in Canada by Province and Fuel Type, 2008: Electricity Generation in Terawatt-hours (TWh)". 2008. Available at http://www.electricity.ca/media/data/Electricity%20Generation%20in%20Canada%20by%20Province%20and%20Fuel%20Type%202008_twh.pdf

FIGURE 8

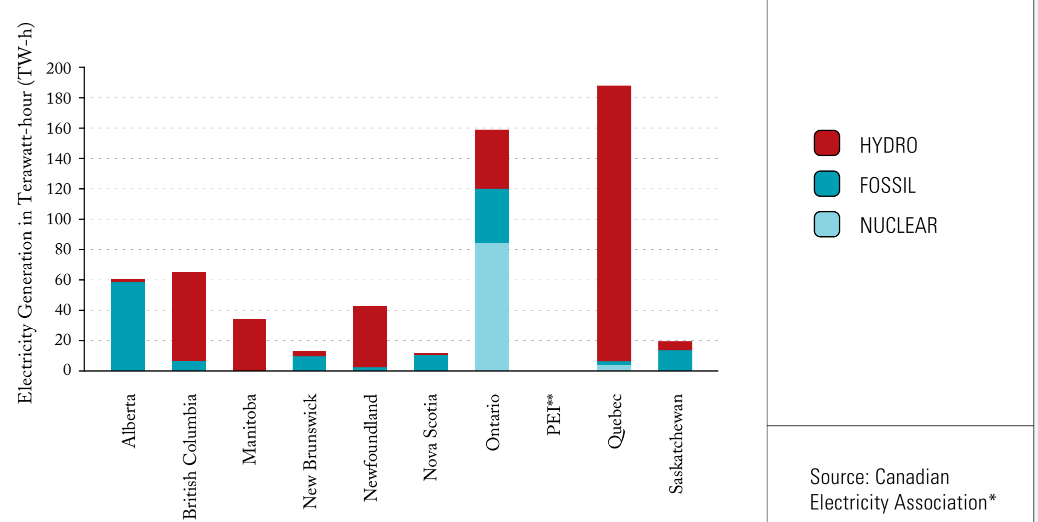
HYDROELECTRIC POWER GENERATION IN CANADA



Source: Canadian Centre for Energy Information, 2009.[34]

FIGURE 9

ELECTRICITY MIX ACROSS CANADA, BY PROVINCE



Source: Canadian Electricity Association*

** Note: total generation for PEI is 0.1 TWh

* Canadian Electricity Association, "Electricity Generation in Canada by Province and Fuel Type, 2008: Electricity Generation in Terawatt-hours (TWh)". 2008. Available at http://www.electricity.ca/media/data/Electricity%20Generation%20in%20Canada%20by%20Province%20and%20Fuel%20Type%202008_twh.pdf

Canada is experiencing growing energy needs and the sector is expected to grow substantially over the medium and long term. The International Energy Agency (IEA) estimates that Canada will need an additional 74 gigiawatts (GW) of capacity by 2030 to meet both system demand growth and plant retirement needs[35] — an addition equal to more than half our existing electricity capacity. The need to lower greenhouse gas emissions may further drive infrastructure renewal in Canada with the potential electrification of other sectors.[36]

This projected demand has prompted Canadian utility companies to consider investing in medium-term projects.[37] Major hydroelectric projects are under construction in the near and medium term for Québec and Newfoundland and Labrador, and for Manitoba over the medium term. Over the longer term, Ontario is anticipated to make significant power generation investments in nuclear and wind power. Investment in fossil power generation is expected to dominate capacity development particularly in British Columbia and Yukon. Prince Edward Island is expected to invest in large-scale wind energy projects, while New Brunswick is currently refurbishing the Point Lepreau nuclear plant and considering a second reactor.

One key consideration that will influence the overall electricity generation mix in the future is the types of electricity generation available to provide *baseload* supply versus *peak* supply. Baseload supply is the minimum amount of electricity constantly demanded at all times, and has historically been provided by hydro, nuclear, and coal-fired facilities. Peak supply is produced to meet peak demand requirements at certain times of the day when electricity demand is high, and is usually provided by oil, single-cycle natural gas, coal, and hydro facilities. Future changes to the generation mix will most likely be made to peak supplies, but in some cases to baseloads as is the case in Ontario as it moves away from coal-fired generation. The change to the generation mix is an important consideration because the development and extraction of the fuel sources (oil, gas, coal) all have different implications for water resources.

Hydroelectricity is expected to continue to dominate future power generation in Canada and presents an opportunity to meet a significant portion of Canada's increasing energy needs with both large scale and small hydro facilities. Canada's hydroelectric expansion potential is estimated to be more than double its current capacity, with potential in all of the provinces and territories.[38] A recently completed inventory of Canadian hydro potential determined that approximately 163,000 MW[39] of additional capacity could be developed across the country.

Hydroelectric Power Generation Sector

This study considers conventional hydropower electricity covering two types of operations:[*]

- *Storage-based hydro*, which requires dams to control water flow or increase the head of a waterfall, and reservoirs to store water.
- *Run-of-river hydro*, which have lower dams than storage-based hydro and either have little or no storage capacity (i.e., water intake roughly equals water outflow).

Although often distinguished as different types of operations, in actuality these exist on a continuum (i.e., some facilities may have a few days' worth of water storage, but are still usually referred to as run-of-river).

* Pumped storage hydro, which pumps and stores water for reuse in periods of high demand, is not considered in this study.

KEY WATER USES

While there are no statistics to draw upon to describe the quantitative use of water by the hydroelectric power sector, it is obvious that the sector relies upon and uses a great deal of water to produce electricity; but the use is largely non-consumptive. While such use does not quantitatively affect rivers and streams, the large storage-based hydroelectric facilities can have a big impact on flow regimes and water levels in the watersheds in which they are located. Careful management is required to balance electricity production with the needs of other users including ecosystem needs.

At storage-based hydroelectric facilities, water is stored in a reservoir that could contain up to years of storage capacity or little more than days. To produce electricity, water from the reservoir enters an intake in the dam, flows through a large pipe (called the penstock), and then spins a turbine to generate electricity before being released back to the river, below the dam. From time to time, excess water may be passed through a dam's spillway, which allows water to be spilled from the upstream side of the dam to the downstream side of the dam. Run-of-river facilities use moving water from rivers or streams to generate electricity by diverting water into turbines that are either placed directly in the river or off to the side of the river. The amount of electricity that can be produced depends on fluctuations in river flow and the capacity of the facility, as water is not stored for strict run-of-river facilities.

Electricity output depends on two factors: 1) the height of the dam head above the turbine, and 2) the volume of water flowing through the turbine. In almost all cases, water use intensity (per unit of energy generation) is higher for hydroelectric facilities than for nuclear and fossil-fuel facilities. Although some very small quantities of water may be consumed at hydroelectric facilities for domestic purposes, all other water uses are considered non-consumptive. In some parts of the world, large storage-based facilities may consume roughly one to two per cent of dam capacity through evaporative loses from reservoirs; however, this is not the case for most facilities in Canada. In Canada, many reservoirs are covered in ice during the winter, and air and water temperatures do not get very high in the summer, so evaporation from reservoirs is negligible.

As large storage-based hydroelectric facilities are built and land is flooded to create reservoirs, the physical layout of watersheds may be drastically altered. Once hydroelectric facilities are operational, they can continue to impact physical characteristics of watersheds by trapping sediment and changing flow regimes, which may affect the structure of natural river composition. In addition, water chemistry may be affected as silt accumulates heavy metals and other pollutants, and water temperature may be affected as a result of storing water in reservoirs.

KEY WATER ISSUES

Main concerns about water availability for the sector include managing impacts of climate change and managing impacts on ecosystems.

MANAGING IMPACTS OF CLIMATE CHANGE

Secure water provision for the hydroelectric power generation sector is a critical issue. The sector sees its greatest vulnerability as any event that threatens long-term water supply. The sector is most interested in how extreme events (e.g., droughts, floods, early freezes, and early thaws) will affect systems in the future. Because hydroelectric facilities are designed to have about a 70–75 year lifespan, an accurate understanding of future conditions is essential for designing new facilities and, as such, the sector has advanced models that try to predict future hydrological conditions. Hydroelectric power generators in some provinces (e.g., Manitoba, Ontario, and Québec) are concerned about the potential impacts of climate change and the uncertainty associated with model predictions.

Some utilities have noticed greater variability in weather patterns and water flows, but are unclear about how to incorporate this knowledge into planning. Others are used to dealing with considerable variability and use extreme events as design targets, but are concerned about whether long-term climate change impacts will pose threats beyond what has been experienced previously. Certain utilities may be more vulnerable to climate change impacts, such as those that operate in a single river basin.

As a result of more frequent or higher intensity extreme events, facilities will need to undertake greater efforts to manage floods and dam safety issues. This might include changing design standards and management practices for dams and reservoirs. The sector is undertaking research to examine impacts of climate change on operations and many companies are undertaking impact and vulnerability assessments with the intention of integrating findings into risk management strategies and existing operations and planning processes. Currently, some utilities may be incorporating some safety factors into the design of new facilities (i.e., by including a bigger margin of safety in design), but for the most part, hydroelectric power generators are simply monitoring climate science.

Despite the potential negative effects that climate change poses to the sector, opportunities exist to leverage changing weather patterns to generate more electricity. Most climate change models predict that average annual precipitation will increase in regions that have significant hydroelectric development (e.g., eastern Canada) or in areas that have development potential (northern Canada). The purpose of reservoirs is to store water in times of low flows, to save it for when it is needed. With increased precipitation and more extreme events, the role of reservoirs may become more important and actually permit greater electricity generation in certain regions.

MANAGING IMPACTS ON ECOSYSTEMS

All types of hydroelectric facilities can block migration of aquatic organisms and impact the health of regional fish populations; however, these impacts can be managed more easily at run-of-river facilities because dams are lower, making it easier to address fish passage. Run-of-river facilities do not create impacts to water resources on the same scale as storage-based facilities; however, they do alter water flows in a river and therefore, on a cumulative basis, have the potential to negatively affect the ecosystems and watersheds within which they are developed. Small run-of-river facilities have the potential to be much greater in number and pose a potential cumulative effect on the broader landscape. Similar to large storage-based facilities, run-of-river facilities undergo multiple regulatory reviews and licensing requirements in order to obtain approval, including a review of potential environmental effects to ensure that potential impacts are identified and mitigated.

Concerns about fisheries and in-stream flow needs are placing increasing pressures on hydroelectric facilities to mitigate impacts and maintain certain water levels. In some provinces, meeting environmental requirements (i.e., in-stream flow) is the main concern. Fisheries considerations are strongly influencing the design of new facilities, resulting in significant financial costs in some cases. Some power generators also believe that commercial fishery interests may be resistant to new hydroelectric facility development in coastal regions.

Ecological requirements are usually described in operating licences and identify maximum and minimum flows. Interested stakeholders usually direct their concerns to regulators during the licensing process; however, as part of the social license to operate, some facilities have been working with a greater number of environmental groups to address concerns. Many measures are implemented to mitigate impacts including regulating flows, and installing fish ladders or diversion nets to facilitate passage. Some operators have also developed, or are in the process of developing, memorandums of understanding (MOUs) with the Department of Fisheries and Oceans (DFO) to establish a risk-based approach to the management of fisheries issues.

It is worth noting that the existence of dams in the Prairie provinces plays an important role in capturing annual spring runoff, controlling flooding and regulating flows throughout the summer. Without this reservoir capacity many of the downstream ecosystems and communities would likely be without sufficient water in dry periods. This type of situation demonstrates the trade-offs that are sometimes necessary when considering the effects existing dams have on ecosystems.

DRIVERS, CHALLENGES AND OPPORTUNITIES

Although hydroelectric facilities in Canada do not consume water, opportunities for improving water use have been driven by finding ways to use water more efficiently. Producing greater electrical capacity from the same flow of water is cost effective, and thus cost savings is a major driver for improved water use. There are many old hydropower facilities in Canada, so several utilities have programs to replace old equipment with newer, efficient equipment including new turbines, control gates, and runners. Hydroelectric power generators have indicated that equipment upgrades can increase overall energy production by 10–20%.

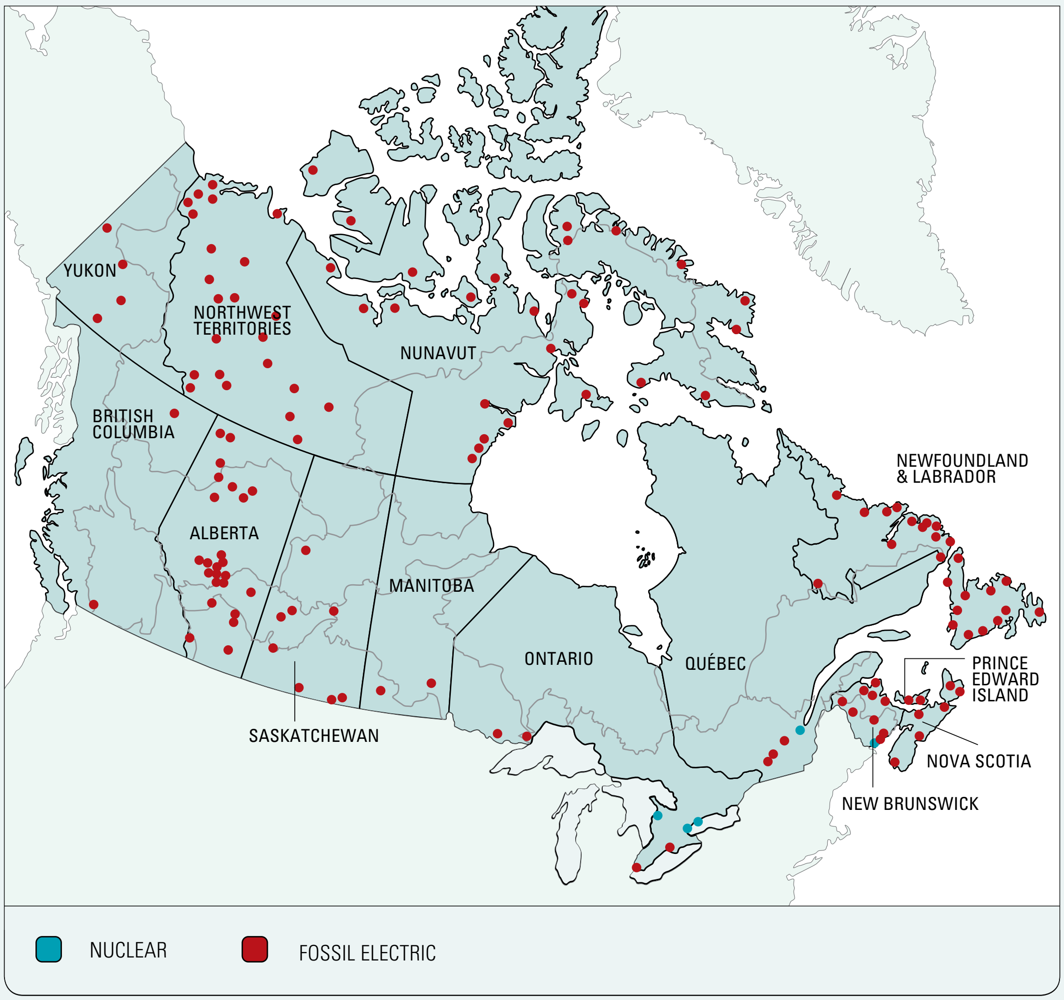
Many utilities have also installed, or are planning to install, technologies to improve monitoring capabilities at facilities. Refining how they look at water management can lead to managing water resources more effectively.

Thermal Power Generation Sector

In thermal power generation, fuels are combusted to either generate heat, which produces steam, or create highly pressurized gases, which rotate turbines to produce electrical energy. Fuel sources that are burned at *fossil electric power* facilities include coal, oil, natural gas, and less common forms of fuel such as biomass, biogas, municipal waste, and industrial by-products. In the case of *nuclear power* generation, nuclear fission — rather than combustion — is used to create heat to generate steam. Uranium is the fuel source used at nuclear power facilities. This report considers thermal power generation at fossil fuel combustion facilities and nuclear facilities, but excludes the discussion of water use at facilities that use alternate fuel sources such as biomass and biogas, which currently make up only a small portion of thermal power generation in Canada. Fossil electric and nuclear power generating stations are found across Canada (Figure 10) with many located close to major rivers and lakes, illustrating their reliance upon large, sustainable supplies of freshwater. Of the electricity produced by fossil fuel facilities in Canada, coal-fired facilities currently generate the most, followed by natural gas-fired facilities (with oil-fired facilities well behind).

FIGURE 10

FOSSIL ELECTRIC AND NUCLEAR POWER GENERATING STATIONS



Sources: Alberta, 2008;[40] Atlantic Energy, 2008;[41] Canadian Centre for Energy Information, 2009;[42] Hydro Québec, 2000;[43] New Brunswick, 2009;[44] SaskPower, 2010.[45]

KEY WATER USES

Relative to the hydroelectric power generation sector, the fossil and nuclear power generation sectors use less water but have greater consumptive use, and greater potential to negatively affect water quality. For both fossil and nuclear power generation, two main uses of water exist:

1. **Generation of steam to drive turbines:** Most fossil power plants and all nuclear power plants generate electricity by converting water into high-pressure steam, which then drives turbines. This steam is then condensed and recycled so that it can be reused in the generation process.

2. **Use of water for cooling:** Water is also used as a coolant at most facilities to condense steam into water. Water is drawn directly from a water body and run through a heat exchanger, and then either released back into the water body (once-through cooling) or pumped to cooling towers and recycled in the plant (closed-loop cooling).

Water use and water consumption at fossil and nuclear electric power facilities, and the associated impacts to water resources, vary considerably depending on the type of fuel, turbine, and cooling system used. Fossil and nuclear power facilities can be categorized according to their primary fuel source and the process used to generate electricity (Table 3).

TABLE 3

FOSSIL AND NUCLEAR POWER WATER USE CHARACTERIZATION

	NUCLEAR	FOSSIL FUEL			
FUEL SOURCE	Uranium	Coal	Heavy oil	Natural gas	
TURBINE	Steam	Steam Future: Integrated Gasification Combined Cycle (combustion & steam)	Steam	Single cycle (combustion) *Can also run on light oil for a limited time	Combined cycle (combustion & steam)

Generally speaking, coal-fired and oil-fired power plants use more water than natural gas-fired plants and potentially have greater negative effects on water quality.* Steam turbines use more water than combined-cycle facilities, which in turn use more than single-cycle combustion turbines. However, many special cases exist in Canada, so water use must be examined on a facility-by-facility basis. Coal-fired and oil-fired facilities may be equipped with wet scrubbers to reduce air emissions, which result in greater water use and greater consumption through the production of wastewater. On the other hand, if wet scrubbers are not installed, diffuse water pollution may occur from long-range transportation and deposition of acidic air pollutants and mercury. In addition to effluent streams from power plants, additional wastewater is produced on-site at coal-fired facilities through coal-pile drainage and stormwater runoff from the plant site and ash landfill. These effluent streams are collected and typically treated at on-site wastewater treatment facilities.

Once-through cooling systems use more water than closed-loop cooling systems, but water consumption is negligible. Cooling water is drawn from a water body and most is returned to that water body at a higher temperature, producing a thermal discharge. In some cases, chlorine may be released into water bodies to control mussel and bacterial growth in warmed cooling water.

Closed-loop systems use less water than once-through cooling systems as a result of recycling cooling water, but consume more water as a result of evaporative losses in cooling towers. Further, due to a salt build-up in cooling towers, some water is used in removing these solids (known as blowdown) and results in the production of wastewater. Dry cooling systems use and consume essentially no water, as air is used for cooling; however, as with closed-loop systems, some water is used for blowdown. Most of Canada's fossil electric power facilities are located next to major lakes or rivers and feature once-through cooling systems; all nuclear power facilities are located near major water bodies due to significant water requirements of the once-through cooling systems. A number of closed-loop fossil electric power plants exist in western Canada. At some facilities, ocean water, rather than freshwater is used for once-through cooling.

KEY WATER ISSUES

As the fossil and nuclear power generation sectors have typically relied on access to large quantities of water, availability — both in terms of constraints at existing facilities and proper

* Some water is produced as a result of burning fossil fuels. This water is released into the atmosphere through evaporation, resulting in a small net increase to surrounding surface water sources, but is not typically accounted for in water use calculations.

siting of new facilities — is a key consideration for the sectors. Some members of the sectors do not appear to be significantly concerned about water scarcity; however, there are some regional and operational concerns due to recent weather conditions. The sectors' primary concern regarding future water management is to ensure a secure electricity supply. Concerns about climate change are less of a focus, but are largely related to responding to the potential cost of emissions and adapting to changing climatic conditions. Effects on water quality from thermal and chemical discharge are also important issues that the sectors manage.

WATER AVAILABILITY

Concerns about water availability prevail in some parts of the country for both existing and new facilities, particularly in central Canada and the Prairie Provinces where fossil or nuclear facilities are used to produce baseloads. Unlike hydroelectric facilities, thermal power facilities are usually located next to big electricity-using centres in densely populated areas. Therefore, in times of drought, maintaining certain water levels that take into account a variety of human and ecological uses can be a challenge. Competing water uses and water availability can be a big issue for large, older facilities because these facilities cannot be retrofitted with closed-loop cooling systems. It has been, and continues to be, more economical to design fossil and nuclear power facilities with access to lots of water so that once-through cooling systems can be used. Facilities that use less water can be designed, and will likely be necessary in water-constrained locations in the future.

IMPACTS ON WATER QUALITY

At facilities where once-through cooling systems are used, large quantities of cooling water are returned to water bodies at warmer temperatures. There is the potential that warmer water could impact fisheries, or could cause eutrophication, changing the chemical composition of water. Utilities must comply with provincial thermal discharge regulations. Monitoring of environmental effects at facilities has demonstrated that discharges have not produced significant adverse effects.

Fossil and nuclear power facilities try to reduce chemical emissions to water; however, the release of toxins is always an issue. One of the main concerns is the release of hydrazine, which is used to prevent scaling and corrosion of pipes at nuclear power facilities; another is the release of chlorine, which is used to control zebra mussels at some thermal discharge sites. Tritium, which is produced at nuclear power facilities, may also be released inadvertently or accidently to water bodies. Substantial detailed reporting is required for discharges, and some facilities are testing different management practices to reduce chemical releases, such as using predatory controls to manage zebra mussel populations in place of using chlorine. Wastewater is produced in a number of ways at fossil and nuclear power generation stations including from blowdown, sewage, coal-pile drainage, and stormwater runoff from the plant and ash landfill sites; however, wastewater is treated and tested before being released back into the environment. Groundwater and surface water sources that may be impacted are typically monitored at facilities on a regular basis.

ADAPTING TO CLIMATE CHANGE

The potential impact of climate change on water availability is an unknown factor for most companies in the fossil and nuclear power sectors at this time, and needs further investigation. As climate change may cause an increase in air and water temperature in some regions where facilities exist, more water may be required for cooling processes. The unknown factor is how much additional water supply will be required and whether this will be available. In some parts of the country, the sectors are used to dealing with huge variability of water and have learned to manage these conditions by designing systems to operate on the lowest flows on record. These operators may be well positioned to deal with fluctuating water levels.

In some cases climate change is not a concern for fossil (gas) plants because they are small facilities used primarily as back-up, or because they will be phased out over time. However, coal-fired facilities are typically designed for a lifespan of about 40 years, natural gas facilities for a lifespan of about 25 years, and nuclear for a lifespan of about 30–40 years. Once built, these facilities have limited flexibility for retrofits to accommodate significant technology changes. Existing facilities will likely be able to accommodate only small changes to operations if water requirements change. In the future, taking climate change into account, companies will need to make crucial decisions in the selection of appropriate cooling technologies and location of new facilities. Some companies are undertaking risk assessments to better understand potential implications for their operations.

DRIVERS, CHALLENGES AND OPPORTUNITIES

To date, physical characteristics of the environment in which facilities have been built have largely influenced technology choices at thermal power facilities. Many thermal power facilities are relatively old and contain once-through cooling systems, which were constructed based on access to a large supply of cooling water. Although cooling technologies that reduce water use exist, retrofitting existing facilities is usually not possible, so these technologies can only be incorporated into new facilities. However, technology that is less water-intensive is often more expensive to build, may be less energy efficient, and may result in greater water consumption (as is the case with closed-loop cooling systems).

Regional water availability and conditions will likely continue to drive cooling water technology choices in the future. For example, provinces regulate thermal discharge from once-through cooling systems, and if the temperature of receiving water bodies increases (as predicted with climate change) this may create challenges for companies complying with regulations. In the U.S., regulations have largely driven greater use of closed-loop cooling technologies. Some industry representatives believe that restrictions on water use or some form of water valuation or pricing might influence how the sector develops and uses water in Canada.

Regional water availability may also drive industry to find alternative water sources. For example, "grey water" (wastewater generated from domestic activities) is currently used in a few fossil-fuel generating facilities in Alberta and Saskatchewan. In anticipation of further uses, Alberta is looking to develop guidelines for grey-water use. More restrictions on water withdrawals may push the industry to look further into using grey water in the future. However the key challenge remains with costs. Clean water is required in thermal power steam generation processes and so the added costs associated with the treatment of grey water to an acceptable quality for use within the plants would have to justify such a shift.

New fuel and clean-air technologies are thought to provide promising opportunities for reducing air pollutants and GHG emissions at thermal power facilities, but these may or may not be accompanied by associated improvements to water use and impacts. Certainly, natural gas combined-cycle facilities use, consume, and produce fewer impacts on water than other fossil-fuel systems and result in fewer GHG emissions. However, the application of certain technologies could result in greater water use and/or the production of wastewater. For example, putting wet scrubbers on coal plants to reduce air emissions would result in greater water use, more wastewater, and the need for treatment. Further, if carbon capture and storage technologies for fossil power facilities are commercialized, water use could potentially increase. One new technology under development, Integrated Gasification Combined Cycle (IGCC), which uses gas produced from coal, results in fewer GHG emissions, but the amount of water needed is uncertain. IGCC may also result in greater impacts to water quality through the release of arsenic, selenium, and cyanide. One last example is found specifically in Ontario with plans to substitute biomass for coal in some of its facilities. Facility-level water needs are unknown, but aggregate water use will likely decrease as a result of running fewer facilities in the province.

IN SUMMARY

Future trends point toward a more diversified electricity sector in Canada, which will include a mix of small and large facilities. Generation from both oil-fired and coal-fired plants is expected to decrease with growth expected from natural gas plants and hydropower. Although nuclear power provides a generation option that is less emissions intensive, growth of the sector may be difficult for economic and/or public acceptance reasons. The use of alternate fuel sources such as biomass or municipal waste is also expected to grow over the next 20 years, but will still remain small compared to conventional thermal power generation. Anticipated water use by the sector will be dependent upon the future generation mix, and as this is currently in the planning and development stages across the country, expected future water use is not known. However, given that the electricity sector is a major water user across the country, pressures on water resources can be expected to grow as a result of this sector's activities. For both thermal and hydroelectric power, existing technologies and approaches hold promise for reducing water use and improving conservation.

HIGHLIGHTS

Even though the oil and gas sector uses relatively small volumes of water on a national scale, the anticipated strong growth for the sector will have important consequences for regional water resources.

The sector's impacts on water quality and ecosystems will continue to be a challenge for the sector to manage.

Key issues facing the oil and gas sector include:
- Water quality with respect to both oil sands and future shale gas developments -
- Water availability -
- Unknown impacts on groundwater sources -

OIL AND GAS SECTOR

The focus of the NRTEE's review of water use by the oil and gas sector is on the upstream industry* with particular attention given to the unconventional development and operations. The main oil and gas activities considered here include oil development using water for enhanced oil recovery (EOR); oil sands development including both mining and in situ methods; and natural gas, focused on the shale gas development.

Water is an essential component of the sector. For example, in 2007, three-quarters of all Alberta's oil production was water-assisted. All types of oil and gas developments use water but vary considerably in the sources, volumes, production uses, recycling and reuse, and treatment. The oil and gas sector uses small volumes of water in comparison to the other natural resource sectors.† In 2005, in Alberta, the oil and gas sector accounted for approximately seven per cent of the province's total allocations, and in many cases companies reportedly used much less than the amount they were allocated.[46] The key difference with the other energy sectors is that much of the water use for oil and gas production could be considered to be consumptive as it is either injected into oil reserves or stored in tailings ponds, and is not returned to the environment.

* The downstream production of the oil and gas sector is an important component of the Canadian economy; however, it was not considered within the scope of this research.

† Oil and gas water use is unknown on a national level as it has not historically been part of Statistics Canada's Industrial Water Survey.

ECONOMIC IMPORTANCE OF THE OIL AND GAS SECTOR TO CANADA

In 2008, the oil and gas extraction sector contributed approximately $40 billion to Canada's GDP. While it is a critical sector for the provinces of British Columbia, Saskatchewan, and Newfoundland and Labrador offshore, Alberta accounts for approximately 75% of the Canadian oil and gas production (Figure 11). Alberta enjoys the second largest oil reserves in the world with its oil sands reserves, containing an estimated 1.7 trillion barrels of (volume-in-place) bitumen of which approximately 11% is recoverable.[47] In absolute terms, according to the Canadian Energy Research Institute (CERI), Canada produced 2.7 million barrels per day (Mbd) of oil in 2008. Of that amount, 2.4 Mbd came from Western Canada and of that, 1.2 Mbd from the oil sands. Oil sands production could grow to 1.7 Mbd in 2015 and 4.5 Mbd in 2030.

The recent global economic recession resulted in decreased demand for oil, and, on average, current oil prices are lower than in recent years. Furthermore, the economic downturn has hindered the ability of companies to acquire investment capital.[48] Closer to home, the recession has slowed the rate of expansion of oil sands with many projects being put on hold. Over the medium term, the oil and gas sector is predicted to see moderate growth, and much larger growth over the longer term. At a provincial level, the growth is concentrated in Alberta, Saskatchewan, and British Columbia.

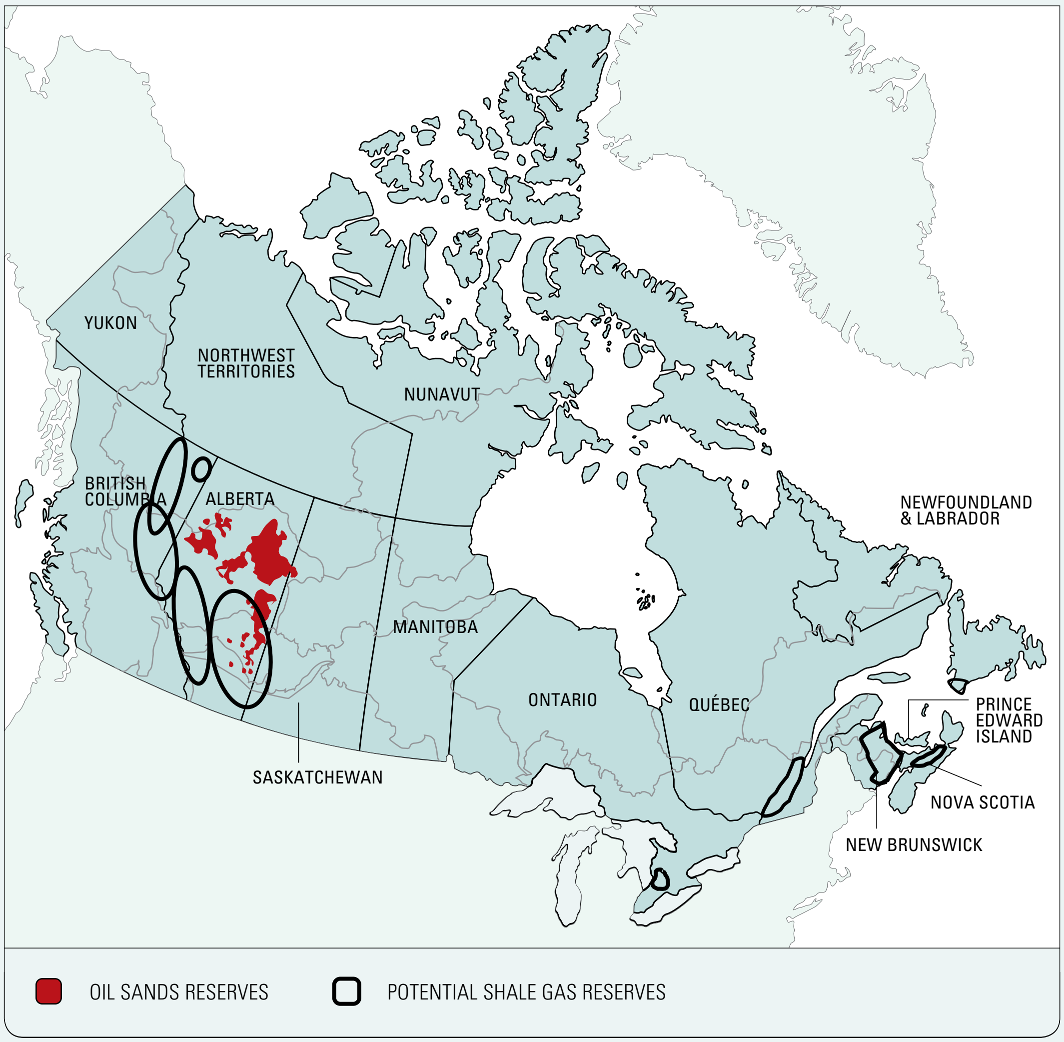
OIL PRODUCTION

Forecasts indicate that Canadian oil production mix will tend increasingly toward non-conventional oil production from the oil sands in the coming years, with conventional oil production expected to decline. Table 4 shows three medium-term oil production forecasts; all forecasts concur that conventional oil production will decrease more than 10% in the next five years and that oil sands will increase by at least 50%.

The National Energy Board predicts oil production growth in Canada to be moderate over the medium term for the reference case, with larger increases over the longer term. The low price scenario sees very little growth over both the medium- and longer-term forecasts, whereas the high price scenario sees larger growth over both time horizons.[49] A provincial analysis indicates that Alberta represents the main driver in the growth of oil production, with a small contribution coming from the Northwest Territories and Atlantic Canada for the longer-term reference case and high price scenarios. Overall these forecasts align with those of the Canadian Association of Petroleum Producers (CAPP).[50]

FIGURE 11

OIL SANDS RESERVES AND PROSPECTIVE SHALE GAS



Sources: Canadian Centre for Energy Information, 2009[51]; CSUG, 2010.[52]

TABLE 4

OIL PRODUCTION GROWTH FOR 2008-2013

FORECAST	OIL SANDS	CONVENTIONAL OIL
National Energy Board	53%	-20%
Conference Board of Canada	71%	-16%
CAPP – Scenario: Growth*	55%	-13%

* CAPP conducted a survey of oil sands producers in early 2009 to determine their plans for production of both bitumen and upgraded crude oil for the period from 2009 to 2025. From this data, CAPP has prepared a "Growth Case" that represents the expected outlook. It assumes the current investment climate will improve over time.

NATURAL GAS PRODUCTION

Conventional natural gas currently supplies two-thirds of the Canadian production but this is expected to decline to only one-third by 2020 due to declining reserves. Increasing demand for natural gas, both domestically and internationally, will likely result in future development of unconventional gas production.[53] Unconventional gases include coal bed methane (natural gas embedded in coal deposits), tight gas (natural gas within low permeability, usually sandstones), and shale gas (natural gas within relatively low permeable organic shale beds). Estimates suggest that shale and tight gas in Canada and the United States could contribute up to one-third of all North American production by 2020. Estimates of shale gas in western Canada vary significantly from 86 trillion cubic feet (Tcf) to over 1000 Tcf.[54] While there is huge potential in British Columbia and some in a few other regions of Canada (Alberta, Saskatchewan, Québec) (Figure 11), shale gas production is in very early stages and commercial development is not likely to occur in the short term due to current market prices and technical challenges.[55]

KEY WATER USES

Water is a component of all oil and gas developments and operations. However the types of water uses, volumes required, and water sources all vary considerably within the sector. The NRTEE research considered the following sub-sectors: oil sands, shale gas, and enhanced oil recovery.

OIL SANDS MINING AND IN SITU PRODUCTION

Oil can be extracted from oil sands using two methods: mining and in situ. Mining techniques are used where the oil sands are close to the surface and in situ techniques are used for deeper deposits. Currently 20% of Alberta's total oil sands recoverable reserves are deemed to be mineable, the remaining 80% must be accessed through in situ techniques. In 2007, Alberta produced approximately 55% of its oil from the mineable oil sands, and 45% from the in situ areas. These proportions are expected to shift as future oil sands production moves to extraction from the deeper deposits using in situ methods.

OIL SANDS MINING

The water use in an oil sands mine is technically complex. In simple terms, water use in oil sands mining is similar to water use in metal mining and can be divided into three categories: mine water and groundwater inflow, process water (includes recycled and make-up water), and tailings pond water. As in other mining operations, mine water and ground water flowing into the mine pits must be managed so as to ensure it does not contaminate surrounding ecosystems. A key difference with oil sands mines is there is a "no discharge" policy in place, which doesn't permit water to be discharged into surface water bodies. Water is either treated and recycled or reused, or it is held in long-term tailings ponds. In some operations, process water is re-injected into deep geological formations as an acceptable means of disposal. The focus of the rest of the discussion is related to the process water and the tailings pond water.

"Process water" is critical to the separation process — it is essential in order to separate bitumen from the sand. The process water is a combination of make-up water, both from surface water or groundwater sources, and recycled water from the tailings ponds. A common misconception is that the water requirements involve only water from surface or groundwater sources. In fact, a substantial amount of process water is recycled. For example, a mature mine can use about 80% recycled water from its tailings ponds for the process water. Surface-mining oil sands production uses from 2.0 to 4.0 barrels of water (net) per barrel of bitumen produced.

The production of bitumen from mining results in significant volumes of fluid tailings that include sand, fine clays, and residual amounts of bitumen mixed with water. They are held in long-term containment ponds called tailings ponds. While a substantial proportion of water from the tailings ponds can be recycled and used in process water, a significant volume of contaminated water remains in the tailings ponds, possibly indefinitely. Tailings management is a critical component of mining operations and is also one of the greatest concerns of the local community and environmental advocacy groups. As such, significant research and efforts by industry and government bodies has been ongoing since the early days of oil sands development to figure out how best to manage the tailings. Over the years, the industry has invested heavily in new tailings technology. It continues to try to achieve "dry tailings" technologies where, essentially, the water in the tailings is minimal and the tailings are solid enough to be incorporated into a sustainable reclaimed landscape. The provincial regulators are cognizant of this issue, and recently initiated a more comprehensive regulatory framework for tailings management with the objective of minimizing and eventually eliminating long-term storage of fluid tailings in the reclamation landscape.

IN SITU OPERATIONS

Most oil sands deposits will need to be developed by drilling wells (in situ) and injecting steam into the reservoir. The two most common thermal in situ production processes are cyclical steam stimulation and steam-assisted gravity drainage, both of which inject steam into the reservoir to liquefy the oil and separate it from the sand so that it can be pumped to the surface. The steam condenses in the reservoir and is pumped back to the surface with the liquid bitumen. This is called "produced water" and is often treated and reused. Three types of water can be used in thermal in situ operations: fresh (from either surface or groundwater sources), brackish or saline groundwater, and produced water.

Estimated water use for in situ oil sands production can vary from 0.4 to 5.5 barrels of water per barrel of bitumen.[56] The average use is about one barrel of water (net) per barrel of bitumen produced.[57] The water use varies between facilities due to technology, use of recycling, and the phase of development. The start up phase of an operation requires more water, however this usually decreases as the project matures. In some in situ operations, saline groundwater replaces some or all of the freshwater requirements for extraction. In the case of those operations located within the Athabasca region, no water is withdrawn from the Athabasca River for in situ production. In situ oil sands projects can recycle more than 90% of water produced. Thus, for freshwater only, the average net value is 0.5 barrels of water per barrel of bitumen produced. All recent in situ projects are required to recycle a minimum of 90% of their produced water.

In Alberta, the Energy Resources Conservation Board (ERCB) and Alberta Environment are taking steps to enhance the conservation and encourage the efficient use of water sources for new in situ schemes.[58] ERCB's new Directive, which builds upon existing water conservation policies in the province,[59] will require in situ operations to limit the sector's use of fresh and brackish water, and maximize the recycling/reuse of produced water. Freshwater use will be limited to a maximum of 10% of total make-up water; brackish groundwater will be no more than 25% of the total make-up water (less if freshwater is used as well). In addition it will also require operators to improve their measurement and reporting of all major water streams at thermal in situ oil sands schemes.

NATURAL GAS

Shale gas merits some attention as a potential unique area of development for the oil and gas sector in Canada, both in terms of potential for expansion and the unique water requirements that are associated with this type of gas production. Shale gas resources in Canada are estimated to be in the order of 1500 Tcf of gas in place, with the most significant known play located in Horn River in Northeastern British Columbia.

Gas from shale requires fracturing of the rock in order to allow the natural gas to flow out — known as hydraulic fracturing (or "fracing") — which involves the injection of fluids into the gas wells at very high pressure. These pressurized fracing fluids are used to crack open the underground formation to allow oil or gas to flow more freely and increase production. While some of the injected fluids are returned to the surface, some remain underground and may eventually seep into the groundwater aquifers. The fracing fluids often contain many additives such as friction reducers, biocides, surfactants, and scale inhibitors.

Shale gas development requires the drilling of multiple horizontal wells for the purpose of fracturing the shale beds to extract the natural gas. Thousands of wells are required for shale gas production to be commercially viable, and this requires significant volumes of water. Much of the water is not returned to source in the short term and so is considered a consumptive use. As the shale gas developments of Northern British Columbia and Québec are in their initial development stage, it is hard to predict how much water will be required, how it will be managed, and what effects it may have on the water resources and the surrounding ecosystems.

WATER FOR ENHANCED OIL RECOVERY (EOR)

Enhanced oil recovery is the process of increasing the amount of oil that can be recovered from a reservoir. EOR is used to increase the productivity from conventional oil wells that would otherwise no longer be in production, and it can employ a number of different methods such as water flooding and thermal methods, involving the injection of either water or steam (with solvents) into the reservoir to force the oil out. Water flooding relies on the availability of freshwater, but it can also use saline, recycled, or treated produced water. Steam injected recovery largely uses freshwater or non-saline sources, including recycled water. In comparison with conventional oil recovery, EOR can increase recovery from approximately 15% to 25–30%. Relatively small volumes of water are used for EOR in comparison with other users. Of the total water allocated in Alberta in 2001, the oil and gas sector actually used less than half of one per cent for EOR processes.* The volume of freshwater being diverted for injection has declined significantly over the past 30 years.[60]

KEY WATER ISSUES

WATER QUALITY

OIL SANDS

One of the most prevalent water issues facing the oil sands industry is its impact on water quality rather than quantity. Water recycling and reuse is high in this industry, the result of intensive research and development over the years, driven more recently by increasingly stringent policy directives.† However, unanswered questions remain regarding the potential for oil sands mining and in situ production to adversely affect water quality in the region. The complexity of these questions is reflected in the significant effort put forward by the industry and governments to find answers. Since the late 1990s the Athabasca oil sands region has been the focus of substantial monitoring and research, much of it led by the Cumulative Environmental Management Association (CEMA). A number of sub-committees exist in this association, such as the Surface Water and Reclamation Working Groups. In addition to this association, there is the Regional Aquatics Monitoring Program (RAMP), a multi-stakeholder monitoring program that assesses the health of rivers and lakes in the region. To date RAMP has concluded that there has been no significant impact from oil sands development on the Athabasca River;‡ however, this is contested by many scientists, stakeholders, and environmental groups. Therefore, the potential impacts of oil sands operations on water quality in the Athabasca region continues to be one of the most important issues for the oil sands industry.

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* For detailed description of water use in enhance oil recovery see *Water Use for Injection Purposes in Alberta*. Geowa Information Technologies Ltd. March, 2003.

† The oil sands regulator, the Alberta Energy Resources Conservation Board (ERCB), must be satisfied with operator's plans for water use and disposal. Provincial regulations require operators to minimize the use of fresh make-up water and the disposal of waste water, as well as to maximize the recycling of produced water.

‡ RAMP's information and technical reports may be reviewed on its website www.ramp-alberta.org/RAMP.aspx.

Related to the water quality effects is the issue of tailings management. The production of oil sands mining results in significant volumes of tailings. While up to 80% of the water from tailings ponds can be recycled and reused in the processing, a substantial volume of contaminated water remains in the tailings ponds. The lifespan and long-term implications of the tailings facilities is the subject of significant research by the industry and governments, and continues to be a focal point of their efforts. A key concern of tailings ponds is related to the risks of contaminated water seeping into the aquatic ecosystems (surface and groundwater), particularly the Athabasca River. The main toxics found in the tailings include naphthenic acids and polycyclic aromatic hydrocarbons (PAHs) and are of high concern for the communities in the region, particularly those downstream of the oil sands operations. Stakeholders continue to engage in an intensive debate regarding the potential effects of the tailings ponds on the ecosystems within the vicinity of the Athabasca oil sands. In July, 2009, Environment Canada indicated it would conduct an independent study of leakage from the tailings ponds.[61]

SHALE GAS

As shale gas developments in Canada are in their infancy, it is difficult to say exactly what water quality issues the industry will face. However there may be some merit in looking south to the United States where shale gas operations are well developed. Their main operational issue is potential groundwater contamination due to fracing fluids and their possible impact on drinking water supplies. This has been of particular concern where fracturing operations have contaminated groundwater due to seepage of the fracing fluids or migration of natural gas into drinking water aquifers. This is not to say the same will happen in Canada, but a cautionary approach to regulating this new industry should include protective measures to address such possibilities. Industry and government should pay special attention to investigating and understanding the potential impacts to groundwater as the industry develops further in our country.

WATER AVAILABILITY

There is a perception that the water use from oil sands activities is high and unsustainable and many call into question the volumes of water that are allowed to be withdrawn under existing licences. While gross volumes taken from the river are substantial, the levels should be viewed with some perspective relative to other river systems in the province. The Athabasca River has one of the smallest water allocations of any river in Alberta and yet one of the largest flows. The total annual allocation of water from the Athabasca River for all uses (municipal, industrial, and oil sands) is less than 3.2% of flow. This is low in comparison with allocations in other rivers in Alberta: 37% for the North Saskatchewan River, 60% for the Oldman River and 65% for the Bow River.[62] All existing and approved oil sands projects will withdraw less than three per cent of the average annual flow of the Athabasca River. During periods of low river flow, water consumption is limited to the equivalent of 1.3% of annual flow.[63] Therefore it does not readily appear that water availability is currently an issue in the northern region of Alberta and particularly for this sector. That said, stakeholders involved in the oil sands region, who have been working together for a number of years under CEMA, have substantial concerns about future water withdrawals and uses. Most recently CEMA undertook a three-year study that resulted in a comprehensive report that addresses many issues associated with oil sands developments including water withdrawals from the Athabasca River. As a result of this study, CEMA's Phase II Water Management Framework recommended to the Alberta government that oil sands operators be allowed to withdraw only 4.4 cubic metres per second during low flow conditions of the river — almost half the current allowable rate of 8 cubic metres per second.[64] Clearly, this recommendation strongly suggests serious concerns with current water allocation in the Athabasca River. The Alberta government is currently reviewing the report and taking its recommendation into consideration. Given the potential substantial growth of the oil sands, future water requirements will need to be considered carefully, and not just project by project, but from a cumulative, watershed basis.

The question of future water use and availability for shale gas developments remains unanswered. The natural gas resource is significant, and under the right economic circumstances (i.e., higher gas prices) supported by further innovation and technology in fracturing, the potential for this resource development seems very plausible. This current situation presents an opportunity for regulators and decision makers to put in place a framework under which the resources can be sustainably developed.

UNKNOWN IMPACTS ON GROUNDWATER SOURCES

A very important unknown cumulative effect of oil sands operations may be that of the impact to groundwater aquifers. The significant groundwater use by in situ operations could potentially affect drawdown of fresh or shallow saline aquifers, change groundwater levels, and allow freshwater to infiltrate voids created by bitumen removal.[65] The aquifers in the regions are currently not accurately mapped and so the potential impact is very uncertain. The provincial and federal governments recognize this information gap and are now mapping some of the most significant aquifers in the region.

DRIVERS, CHALLENGES AND OPPORTUNITIES

PUBLIC ACCEPTANCE

The relatively abundant supply and low cost of water have traditionally supported the development of water-intensive technologies for the oil and gas sector. This is now changing as public pressure and government policies require industry to improve its water efficiency. The most obvious example of this is the Alberta Government's Water for Life Strategy, which sets a target of 30% for improving water efficiency for all industrial activities in the province by 2015.

TECHNOLOGY DEPLOYMENT

There are many technologies that exist, and many more that could be further developed that would improve the sector's water use. The challenge is that there is no one-size-fits-all solution, and so many solutions need to be pursued. Not unlike other natural resource sectors, the capital costs and risks associated with moving from bench-scale technology to pilot-scale — let alone full-scale implementation — present a barrier to full technology deployment. A second challenge is that of competitiveness: a competitive edge that reduces costs is not something that companies necessarily will share openly.

Several technologies exist to reduce water use for in situ recovery. Some technologies involve the use of solvents that are vaporized and injected into the bitumen to liquefy the oil. Other technologies being developed replace traditional steam injection with combustion or gasification, thus reducing water requirements. Further, methods are being pursued that use more recycling of produced water in the recovery process.

EOR is moving toward the use of carbon dioxide instead of water. Notable examples can be found in Weyburn, Saskatchewan, and Joffre, Alberta, where CO_2 is injected into depleting oil formations to increase production and lengthen the life of the fields.

On the tailings management side, current efforts are underway in Alberta to develop dry tailings technologies that use little or no water for extraction. As an example, Natural Resources Canada (CanmetENERGY) is working with oil sands mining companies to develop technology that may reduce the water in tailings ponds, possibly resulting in dry tailings. Research such as this — in combination with other advancements on reclamation approaches for tailings — holds promise for addressing one of the most significant problems facing the oil sands industry.

PRIVATE-PUBLIC APPROACH TO WATER INNOVATION

The Alberta Water Research Institute and General Electric (GE) Water & Process Technologies have combined forces in a multi-million dollar research agreement focusing on technology to improve the treatment and re-use of water in some oil sands operations. The initial investment is cost-shared by GE, The Water Institute, and its research funding partners. Any solutions and learnings from the project will be publicly available. These innovative partnerships are good examples of how public agencies and industry can work together to develop programs that benefit the environment and the economy.

IN SUMMARY

Overall, the oil and gas sector has made significant improvements in water use, particularly over the last 20 years within the oil sands industry, with improved recycling rates and reduced water intensity (consumption per barrel of bitumen). However, the oil sands is one of the world's most important oil resources and therefore the pressure on the use of water will continue to grow. The potential for substantial oil sands and shale gas developments may mean significant water requirement within the provinces of Alberta and British Columbia, and so this potential expansion needs to be taken into account. Governments and industry both have important roles to determine the potential impacts of the withdrawals on the aquifers and surrounding areas, and to establish measures that ensure the effects are not long term or irreversible. Further research is necessary to ensure that not only is the water use sustainable, but that the surrounding ecosystems are not irreparably damaged.

HIGHLIGHTS

Due to irrigation, the agriculture sector consumes more water than any other natural resource sector in Canada.

Anticipated increases in demand for irrigation, meat, consumable crops, and biofuels, coupled with the pressures expected from the effects of climate change, will likely result in increased water demand by the agriculture sector.

Key issues facing the agriculture sector are:
- Climate change adaptation -
- Impacts on water quality and ecosystems -

AGRICULTURE SECTOR

The NRTEE's examination of the Canadian agriculture sector and water use focuses on two areas: primary production and manufacturing. Primary production refers to the traditional definition of agriculture (crops, red meat, dairy). Manufacturing is focused on the processing of biofuels.

Although primary agricultural production accounts for less total water used in Canada than other natural resource sectors (10% of national use),[66] it is the largest consumer of water in Canada, accounting for 66% of national consumption. Most of the water used by the sector is consumed into irrigation practices and is accounted for in plant uptake, deep percolation, and evaporation. However, not all primary production requires irrigation, so water use and consumption depends on the type of farming practices as well as climatic and regional characteristics. Agriculture practices may also impact water quality as they are a significant contributor of non-point source pollution.

ECONOMIC IMPORTANCE OF THE AGRICULTURE SECTOR TO CANADA

The value and contribution of the agriculture sector to both the public and the Canadian economy cannot be separated from the sector's historical, cultural, and economic roots and its place in the Canadian landscape. Although the number of farms in Canada has decreased dramatically over time, the total area of cropland has increased.[67] This trend is in part a result of the economic success of farms that are increasingly large and specialized and is important in the context of agricultural water use. It also has relevance in relation to the "public licence to operate" and competing water interests.

Canadian agricultural producers provide more than 70% of the food bought in Canadian stores (2007).[68] Agricultural production of goods and services contributed $14.9 billion in 2008,[69] about two per cent of GDP, excluding food manufacturing. Its annual contribution is driven by many outside forces that affect the production and market value of its products such as water availability, temperature, humidity and frost, energy prices, and global demand and supply of major farm products, as manifested in their price changes in world markets.[70]

Highly volatile agricultural commodity prices and increased competition from other exporting countries challenge Canada's growth in grain production and exports. Over the long term, the percentage increase in Canadian agricultural output is expected to exceed that of global population growth, with an average annual compounded growth rate of two per cent over 2008–2030. The forecasts demonstrate that increasing global demand for biofuels may drive some crop prices up over the long term.[71] This increased demand is the result of policy changes in the U.S., Canada, and many other developed countries. Current and anticipated growth in the biofuels sector is notable, given the rapid expansion of the sector since 2005. Annual production capacity was more than 1 billion litres for ethanol and 200 million litres for biodiesel in 2008.[72] Projections for annual production capacity are 2.3 billion litres of ethanol and 67 million litres of biodiesel by 2012 (if all plants under construction come into production); however, lower oil prices caused the development of several facilities to be put on hold in early 2009.[73] Ultimately, the growth of the biofuel industry will largely depend on government policies for reducing GHG emissions and resulting market impacts.[74]

KEY WATER USES

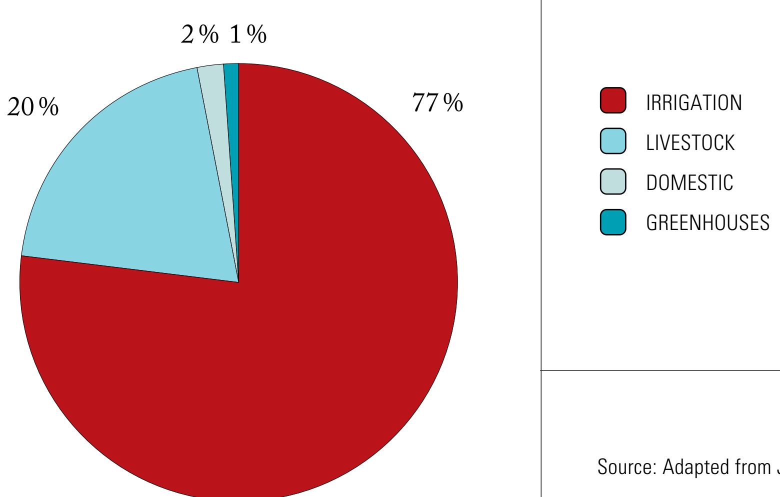
Clean freshwater is vital to the production of fruits, vegetables, and cereal foods consumed by humans, as well as the grains used for human and animal consumption. Water is also crucial to the production of meat and of fuel derived from crops and animal by-products.

It is important to note that the existing data on water use vary in availability and accuracy across the agriculture sector. Livestock operations have a good handle on their water use, as do large-scale irrigation districts common in Alberta. But most irrigation systems used by farmers are not equipped with water meters, so accurate data on water use is unavailable. Statistics Canada continues to refine its Agricultural Water Use Survey.

Water use by the sector varies greatly across Canada, and by agricultural product. Together, British Columbia, Alberta, and Saskatchewan account for 92% of total national agricultural water use.[75] As shown in Figure 12, crop irrigation makes up the majority of water used by the sector, drawing approximately 77%, while livestock farming uses 20%. Although total water used by agricultural greenhouse growers accounted for only one per cent, it is worth noting that this sector increased use by 21% between 2001 and 2006.

FIGURE 12

DISTRIBUTION OF AGRICULTURAL WATER USE



Source: Adapted from J. Walker, 2005[76]

TABLE 5

WATER USE AND LOSS IN AGRICULTURE PRODUCTION

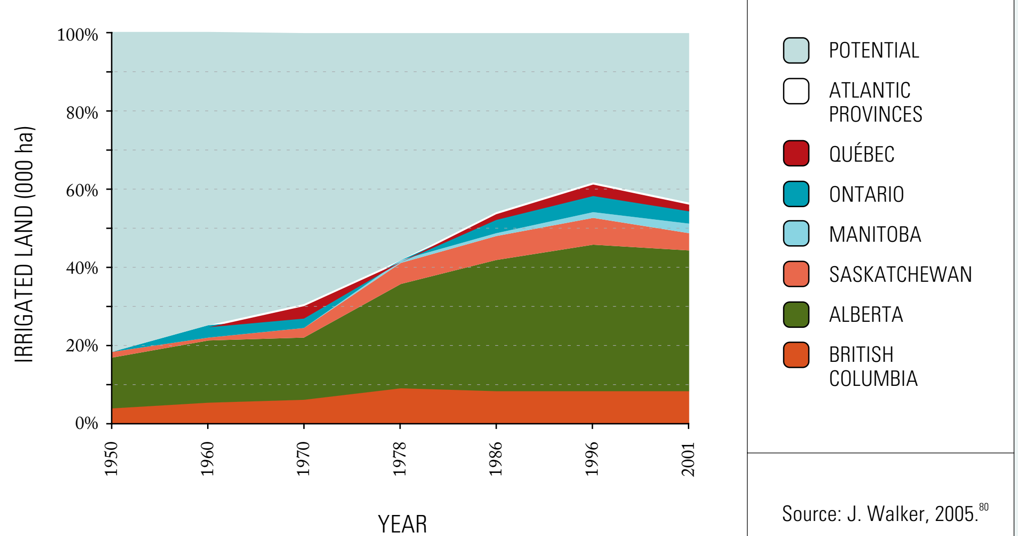
AGRICULTURAL PHASE	TYPICAL ACTIVITIES	WATER USE/ CONSUMPTION/LOSSES
Livestock production	Barn yard cleaning	Water consumption, animal waste, evaporative losses, runoff
Dairy production	Livestock watering and care	Water consumption, animal waste, evaporative losses, runoff
Crop production	Crop frost protection	Evaporative losses, seepage, runoff
Crop production	Tank mixing	Evaporation, plant uptake, seepage
Crop production	Irrigation	Plant uptake, off target, deep percolation, evaporation, surface run-off
Biofuel manufacturing	Converting feedstocks to fuel at biorefineries	Evaporative, wastewater losses

Irrigation is the largest consumptive use of water in Canada.[77] In regions where irrigation is widespread, the ratio of water use to availability is higher than in other regions in Canada. Although the majority of farms in Canada are "dryland farms," meaning that they rely on natural precipitation only, the prevalence of dryland farms is rapidly changing. By virtue of need and availability, irrigation practices vary greatly by region. Demand is driven by the type of crop, soil conditions, and the end use of the crop, in combination with climate and seasonal variations. British Columbia is presently more dependant on irrigation than any other provinces, with 17% of the total cultivated area being irrigated. This is followed by Alberta and Nova Scotia, where 4.6% and 2.9% of the provincial cultivated area is under irrigation.[78] Although water licences are only proxies for actual water use, they demonstrate that irrigation nearly doubled in most provinces (with the exception of British Columbia) between 1950 and 2001 (Figure 13).

Estimates from Agriculture and Agri-Food Canada show that there remain over 3 million hectares of land with "irrigation potential" in Canada as shown in Figure 14, half of which are found in Saskatchewan. Some industry estimates of potential expansion exceed these numbers. For example, a recent report from the Saskatchewan Irrigation Projects Association recommends a tripling of the irrigated areas in Southwestern Saskatchewan (the province's most water-stressed region). While areas of designated irrigation potential may fall into watersheds that are not under stress right now, there is no framework to consider irrigation development in the context of current and future water needs.[79]

FIGURE 13

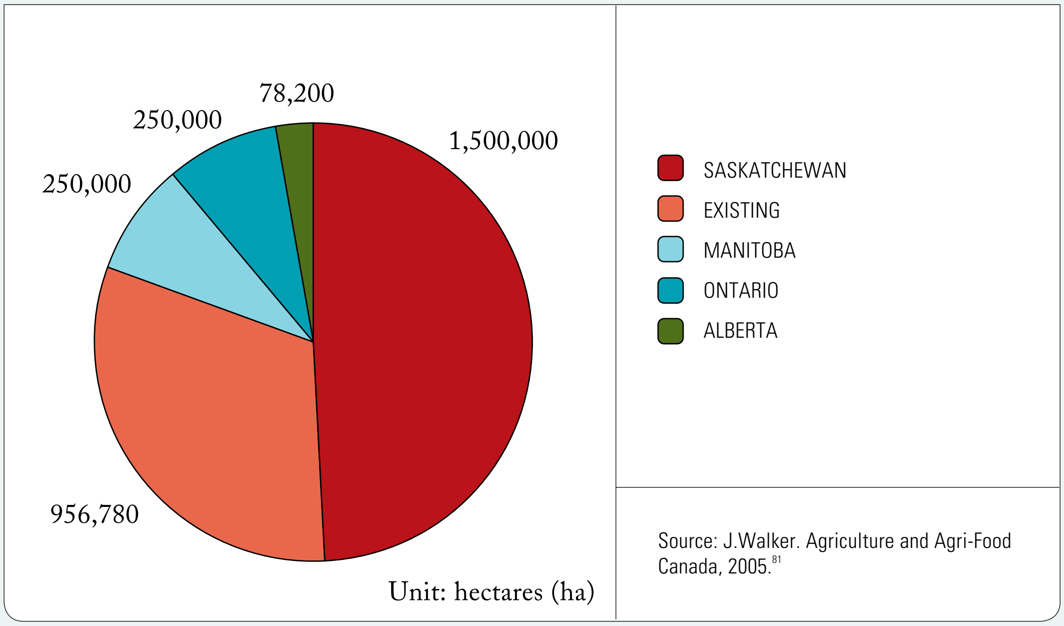
IRRIGATION DEVELOPMENT IN CANADA, 1950-2001



Source: J. Walker, 2005.[80]

FIGURE 14

IRRIGATION POTENTIAL IN CANADA



Source: J.Walker. Agriculture and Agri-Food Canada, 2005.[81]

LIVESTOCK PRODUCTION

Livestock production accounts for much less water use than irrigation, at approximately five per cent.[82] Yet the sector is far more water-intensive than staple crop production, with most of this water drawn from groundwater resources. Livestock production is critically dependant upon a stable supply of high-quality water for animal maintenance (for digestion, absorption of nutrients), to deal with heat stress, as well as for cleaning and maintaining stalls.

The impacts of livestock production on water resources are two-fold. From the perspective of water quality, there are issues around the management of contamination caused by animal wastes, antibiotics, hormones, chemicals from tanners, fertilizers. Water contamination also occurs as a result of pesticides used for feed crops and sediments from eroded pastures.[83] Sound land management practices and containment can be used to control the adverse effects associated with applying manure to lands and livestock grazing. However, there are fewer opportunities for controlling the amount of water required to maintain livestock. This is influenced by the type of livestock, its activity level, local air temperature and humidity, feed composition, and a variety of other factors.[84] If Canada responds to increasing demands for meat products in emerging countries like China and India, demand for water will also increase.

BIOFUEL PRODUCTION

Biofuel production, whether from plant-based feedstocks or animal wastes, requires the same amount of water as the production of crops and livestock for other uses. Examining the full production process, water is also required to convert feedstocks to fuel at biorefineries, although relatively speaking this volume of water is smaller than the water requirements of crop irrigation or livestock production. The issues and impacts of processing biofuels are similar to those at breweries and other industrial processing facilities that require heating and cooling. Consumptive uses of water at ethanol biorefineries are largely due to evaporation losses from cooling towers, evaporation losses from drying-fluid discharge, and wastewater discharge. For biodiesel production, water is added as a catalyst and is consumed through both evaporative loss and discharge.

The biofuel sector has received attention in certain parts of the world, in particular the United States. The increased demand for feedstocks has been held responsible for a spike in food prices, creating what is known as the "food-versus-fuel debate." Questions are also raised about the relative emission reductions of biofuel production, from a life-cycle perspective. It is also frequently pointed out that water demands have traditionally not been considered in policies aimed at expanding the use of biofuels. The local implications of meeting biofuel demands could have significant implications for water availability and potentially for water quality.

Total water use and consumption per unit of fuel produced vary by feedstock, fuel, and production process. Estimates of water use and consumption to convert feedstock to fuel are presented in Table 6. These figures exclude water uses and consumption from growing feedstocks. Estimates for cellulosic ethanol are expected to be refined as these processes become more mainstream. Table 6 is based on U.S. analysis and therefore may not correlate fully to Canadian estimates.[85] At the same time, these numbers highlight the need for further analysis within Canada in order to inform policy decisions for both today and the future. The Canadian government is beginning to examine the cumulative water impacts of future growth of the sector, but much of this information remains unknown today.

TABLE 6

WATER USE AT BIOREFINERIES BY FUEL TYPE

FUEL TYPE	GROSS WATER-USE ESTIMATES (L of water / L of fuel)	CONSUMPTIVE WATER-USE ESTIMATES (L of water / L of fuel)
Corn Ethanol	4–7	4
Biodiesel	3	1
Cellulosic Ethanol: Sugar Fermentation	9.5	2–6
Cellulosic Ethanol: Thermochemical Conversion	2	2–6

Source: National Research Council, 2008.[86]

KEY WATER ISSUES

CLIMATE CHANGE ADAPTATION

Extreme weather events such as drought are predicted to increase as a result of climate change and will vary considerably from one region to another. The need to address drought potential has led the agricultural sector to move forward on a more sophisticated strategy for adaptation to climate change — more so than in other resource sectors. Producers are inclined to address weather and precipitation using the traditional methods of short-term adaptation with which they have always responded. But the relevance of the regional expression of climate change and the implications it will have on regional patterns on climate variability will require a more concerted response.[87]

The risks associated with failure to meet water demands are well known to agriculture in many regions of Canada. The prolonged drought of the 1930s shaped the culture of water risk for Canadians. And again in 2009, competition for scarce water resources forced governments to curtail agricultural use in British Columbia, where farmers on the Nicola River were forced to limit their use in an effort to maintain water levels for salmon spawning.[88] Examples of conflicts over water currently exist in regions such as the Okanagan Valley in British Columbia (between fruit growers and residential users) and Ontario (between different agriculture producers). In the South Saskatchewan River Basin, where water allocations exceed environmental flow requirements in much of the Basin[89] and where agriculture is responsible for approximately 75% of water allocated (2006),[90] water managers may be forced to make some difficult decisions about future water use. In Southwestern Ontario, governance mechanisms such as the Irrigation Advisory Committee have been put in place to avoid and resolve such conflicts.[91]

As farmland becomes progressively more focused on planting higher-value crops, it is likely that water demand will increase and competition for scarce water resources will arise. There is strong evidence that the Prairie Provinces will likely face long periods of drought. Added pressures to water supplies including ecosystem allocations and population growth may cause a crisis in water quantity and quality with far-reaching implications for the sector.[92] In addition to the risks associated with a warmer, drier climate, global climate models are also projecting more climate variability characterized by increased frequency of severe drought and extreme weather-related events such as hail and floods, which will have ramifications for crop success and increased run-off affecting water quality.

In general, an increase in drought conditions could lead to increased irrigation of farmland, which can impact water quantity (surface and groundwater levels) and quality (from increased erosion and runoff of eroded soil). In warmer climates, greater evaporation may also occur depending on the nature of the irrigation technique. Climate change impacts and competing uses in some regions may pose water availability or even scarcity challenges. The implications for the long-term viability of lands and ecosystem integrity are a core challenge in these regions. Increased water use by the sector has historically resulted in direct and indirect wetland depletion, which affects water availability and quality for future generations.[93]

IMPACTS ON WATER QUALITY AND ECOSYSTEMS

In terms of environmental impacts, the challenge of contamination due to sedimentation, pathogens, pesticides, and nutrient loads are pervasive. In some regions of Canada, these impacts have become particularly pronounced, affecting the availability of clean water for other uses. Examples include communities in Prince Edward Island that rely on aquifers for drinking water,[94] or Lake Winnipeg where ecosystem services have been compromised. In response, farmers are increasingly adopting water protection practices, such as growing buffer strips of vegetation around waterways and wetlands.[95]

DRIVERS, CHALLENGES AND OPPORTUNITIES

Water efficiency in the agriculture sector is driven mainly by energy costs associated with transporting water. Water metering is not common across most operations, with irrigation districts being the exception. In 2002–2003, Agriculture and Agri-Food Canada and the National Water Supply Expansion Program completed an extensive survey of water supply and management issues facing Canada's agriculture. The study concluded that Canada's agricultural resources are significantly vulnerable and current water infrastructure is insufficient. The emphasis in this context is often based on expanding irrigation and storage capacity. In many areas of the country, improvements in water-use efficiency through infrastructure, land management, and biotechnology could be employed to reduce vulnerability. The study suggests that deficiencies in current practices are often a result of the limited learning, extension, and technical assistance opportunities provided to producers, pointing to areas of significant opportunity. Further improvements in irrigation technology and scheduling, as well as a shift in where certain crops are grown in respect to local climate conditions, should also be part of the future solution.[96]

In areas where crops are grown strictly for biofuel production, the demand on freshwater could be reduced by irrigating with wastewater or moderately saline water.[97] As cellulosic ethanol technologies are refined and developed commercially, the production and cultivation of less water-intensive feedstocks also offer a promising option for reducing the use of irrigation water. Over time, efficiency gains have been made in ethanol production by improving water recycling efforts and cooling systems.[98] Further opportunities exist to improve the design of cooling towers and boiler-feed operations and to incorporate the use of recycled wastewater in biorefineries.[99]

The improved use of market mechanisms to support both the efficient allocation of water across users (such as water pricing and the water market introduced in Southern Alberta), and improved societal and ecological services in integrated land management have been heralded for their potential to improve water use by the sector. Land management decisions that are beneficial to local water bodies and improve water use have a place in integrated watershed management planning and can be encouraged through market mechanisms. In general, greater emphasis should be put on the role of agriculture in ensuring ecosystem health at the watershed level.[100]

IN SUMMARY

Water-related issues in the agriculture sector are highly localized, but economically significant nationally. As the sector's need for irrigation increases from demands for higher-value crops and efforts to convert dryland operations, the risks associated with water limitations will continue to rise. The sector is at risk because of climate-change effects that result in reduced spring runoff and prolonged cyclical drought. If public scrutiny over irrigation in Canada's water-stressed regions continues to mount, the agriculture sector may be forced to defend its water entitlements in the face of other expanding social and environmental water demands. Water availability issues, as well as regulatory and reputational challenges, will continue to plague the sector until a more proactive approach is taken. There are significant opportunities for agricultural lands to be better utilized to protect and enhance ecosystem services.

HIGHLIGHTS

The mining sector is not a significant user or consumer of water, however mining activities can impact water quality and ecosystems if not managed properly.

Climate change impacts may have important consequences for the management and future design of mines across Canada, particularly in the North.

Key issues facing the mining sector include:
- Water management and quality -
- Climate change adaptation -

MINING SECTOR

Mining activity occurs throughout much of Canada (Figure 15). The metals and minerals sector is largely made up of gold, copper, lead, zinc, iron ore, coal, asbestos, nickel, potash, titanium, aluminum, platinum, diamonds, and uranium.* The NRTEE's study of water use by the mining sector considered mining and mineral processing at the mine site for metallic and non-metallic mining operations. The description of water use and issues generally apply to hard rock mining (metal mining), soft rock mining (coal), uranium mining, and potash mining.

The mining sector is not a significant user or consumer of water and the mining sector does not see water availability as a major constraint or risk to operations in the future. However, as mines have the potential to significantly impact water quality and surrounding ecosystems, water quality is one of the most important management considerations.

* Aggregate mines (e.g., sand and gravel) were not considered in this report.

FIGURE 15

MINING ACTIVITY IN CANADA

Source: Natural Resources Canada, 2009.[101]

ECONOMIC IMPORTANCE OF THE MINING SECTOR TO CANADA*

The mining industry is an important contributor to Canada's economy. In 2008 the industry contributed $40 billion to Canada's GDP which included $9 billion in mineral extraction and $31 billion in mineral processing and manufacturing. Internationally, Canada is one of the world's leading mining countries and ranks among the largest producers of minerals and metals. The industry accounted for 19% of annual Canadian goods exports in 2008.

Over the long term the mining sector is expected to see modest growth, varying among the sub-sectors of coal, metals, non-metallic minerals, and mineral fuels. The medium-term projections see improvements largely due to the unprecedented amount of fiscal and monetary stimulus injected into the global economy. Long-term growth is expected for uranium production, diamond production, and potash. On the other hand, coal mining is predicted to have negative growth over the medium and longer terms, notably due to the anticipated shift to cleaner energy producing technologies.

KEY WATER USES

Mining activities can affect water resources during all phases of mining: exploration, planning, development and commissioning, operations, and closure. Important water considerations for a mine site include management of stormwater, mine water, and groundwater inflow; process water (includes recycled and make-up water); tailings pond overflow; and contact water. Water is used or managed in most aspects of the mining life cycle (Table 7). Mine development and Commissioning, Operations and Closure are the most important phases with respect to water resources.

POTENTIAL IMPACTS TO WATER FROM MINING ACTIVITIES

Mine construction may alter both surface and groundwater flows due to development of access corridors (roads), mine site facilities, and discharges from the mine site into the streams/rivers.

* Information on the economic state of the mining sector was taken from "A Report on the State of the Canadian Mining Industry. Facts and Figures 2009." The Mining Association of Canada. Accessed from http://www.mining.ca/www/media_lib/MAC_Documents/Publications/2009/2009_F_and_F_English.pdf.

TABLE 7

WATER USE BY MINE PHASE AND ACTIVITY

MINE PHASE	TYPICAL ACTIVITIES	WATER USE
Exploration	Subsurface investigations (drilling, exploration pits, adits, or shafts)	Water for exploration drilling
Planning	Feasibility studies including further drilling	Water for drilling, dust control
Development and Commissioning	Construction (mine infrastructure, processing plant, tailings storage, and water treatment facilities)	Geotechnical drilling, dust control
Operations	Mineral extraction, ore transport	Ore body dewatering, drilling, dust control. Water not used for ore transport
	Mineral processing	Process water added during size reduction and used in mineral extraction processes
	Development of waste facilities (waste rock, tailings storage)	Process water for tailings slurry. Some water retained within tailings and is not recycled to process plant
	Product transport	Low, usually transported dry in Canada
Closure	Decommissioning: Dismantling of site infrastructure, site reclamation	Water lost during long-term tailings consolidation

The greatest potential for long-term impact to surface water and groundwater flows occur within the local watersheds and to river systems downstream from the mining operation. All water that comes into contact with ore or waste rock requires some treatment before discharge; the risk is higher with sulphide ore mines. All mining activities, such as site preparation, mining of ore and waste rock, mineral processing, tailings management and transport of mineral products, use water but at different levels of intensity (m^3/tonne of ore).

In most types of mining, relatively little water is used in actual ore excavation/production. Its principal use is for drilling and dust control. A notable exception is potash solution mining found in Saskatchewan.

Most mines process the minerals on site. The mined particle size from typical hard rock mines measures several centimetres up to a metre, thus requiring reduction of particle size so that minerals can be separated from waste and recovered in downstream processing. During particle size reduction in grinding mills, water is added and further mineral recovery is carried out in the aqueous medium. Water is also used for dust control. After the mineral recovery processes the waste (tailings) is usually transported through a pipeline as an aqueous slurry to the tailings storage facility where the solid fraction settles out and as much water as possible is recycled to the processing plant for use as process water.

To the extent possible, mining operations maximize recycling of water in order to minimize both their freshwater make-up requirements from either surface or groundwater sources and water treatment requirements. This is accomplished within constraints imposed by water quality requirements, water availability, and discharge considerations. Surplus water collected from the mine area is discharged (and treated first if necessary) if it is not needed to operate the mine and associated mineral processing systems. During the closure phase, water management is important to ensure no negative long-term impacts result from water coming into contact with potentially acid-generating ore and waste material.

KEY WATER ISSUES

The primary water issue facing the mining industry is the management of water whose quality has been adversely affected by mining operations and the potential release of these waters back into the environment. The key issues for a mine are two-fold: water management and climate change adaptation.

WATER MANAGEMENT

For most mining operations in Canada, the key issue is too much water rather than a scarcity of it (with exception of the Prairies and the North). Therefore, water management and particularly the segregation of clean and “contact” water by upstream diversion of clean runoff is one of the most important issues from an operational perspective.

The "site water balance" is an important tool for water management in mining operations, and refers to the need to account for all water in and out of the site. The challenges of a site water balance include extreme events (the result often being large volumes of water entering the mine site), annual snow melt, and the mine site location, requiring the companies to deal with the associated site hydrology.

While the mining sector's consumptive water use is relatively small, a mine's water management can have a significant effect on a region's water quality if contaminated water is released to the surrounding environment (via surface water runoff or wastewater discharge). This in turn can affect downstream water users and the health of the ecosystem. One significant issue related to water and mining is the use of natural lakes for tailings impoundment areas,[*] an option that is considered by some mines in Canada but rarely allowed by federal regulators.

Water treatment is costly so mines make great efforts to manage the water footprint of a site to both reduce costs of water treatment and to minimize impacts to downstream water quality. As part of this effort, mines segregate clean and used waters in order to reduce the volume of water to be treated.

CLIMATE CHANGE ADAPTATION

Important climate change effects relevant for mining operations include changes in the amount of precipitation, changes in the timing of precipitation, and an increase in the frequency of extreme events. As the NRTEE's *True North* report on adapting infrastructure to climate change in Northern Canada found, melting permafrost will have a serious impact on the stability of engineered structures.[102] This will affect the design of future tailings impoundment facilities to avoid the failure of tailings impoundment dykes, which could result in a release of tailings and impact the environment. In light of potential increased precipitation volatility this issue may become more prevalent in future mining operations. Having a robust and adaptive water management plan will help prepare industry for this uncertainty.

A recent study found that (1) while the effects of climate change are not well understood, the majority of mining operations will be affected by climatic hazards including vulnerabilities in the closure phase, and (2) climate change is a minor concern in this sector and there is limited adaptation planning occurring.[103] However, a number of recent initiatives and/or reports take climate change into consideration for mining practices and guidelines.[†]

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* The use of freshwater lakes in Canada for tailings impoundment areas is allowed under regulation of the federal *Fisheries Act*.

† Environment Canada's 2009 Environmental Code of Practice for Metal Mines; the Canadian Dam Association's Dam Safety Guidelines; the Mining Association of Canada's Guide to the Management of Tailings Facilities.

DRIVERS, CHALLENGES AND OPPORTUNITIES

The main driver for improving water efficiency by the mining sector is energy costs associated largely with water treatment. A secondary driver for improvement comes from the pressure put on the industry to improve its overall environmental management practices as water quality from mine sites can have a significant impact on the surrounding aquatic ecosystems. There appear to be opportunities for further improvements in water efficiencies in the mine processing phase. Many companies are working toward this goal and identifying corporate targets for improved water efficiency. Some companies are participating in the Global Reporting Initiative. On the whole, the industry is trying to improve upon its sustainable practices and gain greater social licence to operate.

IN SUMMARY

Water availability in Canada is not likely a factor that will limit the sustainability of the mining sector because the sector is not a significant water user. The most important issue facing the mining sector is its potential impacts on the watersheds within which the mines are located. Water quality is, and will continue to be, one of the most critical components of the industry's operational and strategic goals. While not a significant user of water on a consumptive basis, the sector is very aware of the amount it does use and continues to strive for improved use through both voluntary means and regulatory requirements. Past experience in this sector has shown that there are benefits to be had in pursuing best management practices and innovative solutions.

HIGHLIGHTS

Pulp and paper manufacturing industries have significantly improved their water use practices and account for approximately five per cent of gross water use in Canada, of which only two per cent is consumptive.

Canada's forests play a crucial role in influencing the quality and quantity of water resources; in light of climate change impacts, more research is needed to better understand forest-water resource interactions.

Key water issues for the forest sector include:

- Pulp and paper mill effects on water quality and aquatic ecosystems -

- Limited knowledge of forest-water resource interactions -

- Public licence to operate -

FOREST SECTOR

The NRTEE's examination of water use by the forest sector focuses on both forest management activities such as harvesting and tree planting, and forest products manufacturing industries. The manufacturing sector largely involves wood and paper manufacturing including pulp and paper mills, softwood lumber, and other wood products. Water use for the production of engineered wood products, softwood lumber, and structural panels is typically extremely low (roughly one per cent of that used in pulp and paper[104]) and is expected to stay low in the future, so this sub-sector is not discussed further in this report.

Both forest management and manufacturing activities affect water resources, but in very different ways. Sustainable forest management has a critical influence on the hydrology and water quality of watersheds. Pulp and paper manufacturing uses water in a similar manner to the mining sector, with substantial gross water use but low consumptive rates. Overall water intake is not viewed as a high priority issue by the sector, given that most of the water withdrawn is returned to surface waters.[105] For most operations, their location on large waterways in regions that are not currently experiencing water shortages diminishes their concern about water availability. However, facilities on smaller waterways, or waterways with seasonal flow changes, are very concerned about effectively controlling water use. Water management, in terms of conservation and wastewater treatment, are important areas of focus for these industrial operations.

ECONOMIC IMPORTANCE OF THE FOREST SECTOR TO CANADA

In 2008, total industry contribution to the GDP was almost two per cent, with wood and paper manufacturing accounting for 11% of the country's manufacturing GDP.[106] The forest products industry is active in 12 of 13 provinces and territories in Canada, with the majority of forest-reliant communities located in British Columbia, Ontario, Québec, and New Brunswick (Figures 16 & 17).

Internationally, Canada is the world's largest exporter of forest products, with exports totalling $30.2 billion in 2008. It is the largest exporter and second-largest producer of softwood lumber and wood pulp, and the world's largest producer and exporter of newsprint. The United States is the largest importer of Canadian forest products, with Asian countries also being major importers.

The industry has been facing economic decline for some time. The pulp and paper industry in particular has faced considerable long-term structural challenges since the mid-1990s. Natural Resources Canada reports that since 2003, over 300 plants (pulp mills, paper machines, sawmills, etc.) have closed, and approximately 33,000 mill jobs have been lost. Job losses accelerated through 2006 and 2007.[107] The recent economic challenges are expected to keep the industry's growth down. These include a continued depressed housing market in the U.S., a continuing decline in demand for newsprint due to online media competition, high energy prices, increasing fibre costs due to saw mill closures, and a continuing strong Canadian dollar affecting exporters.

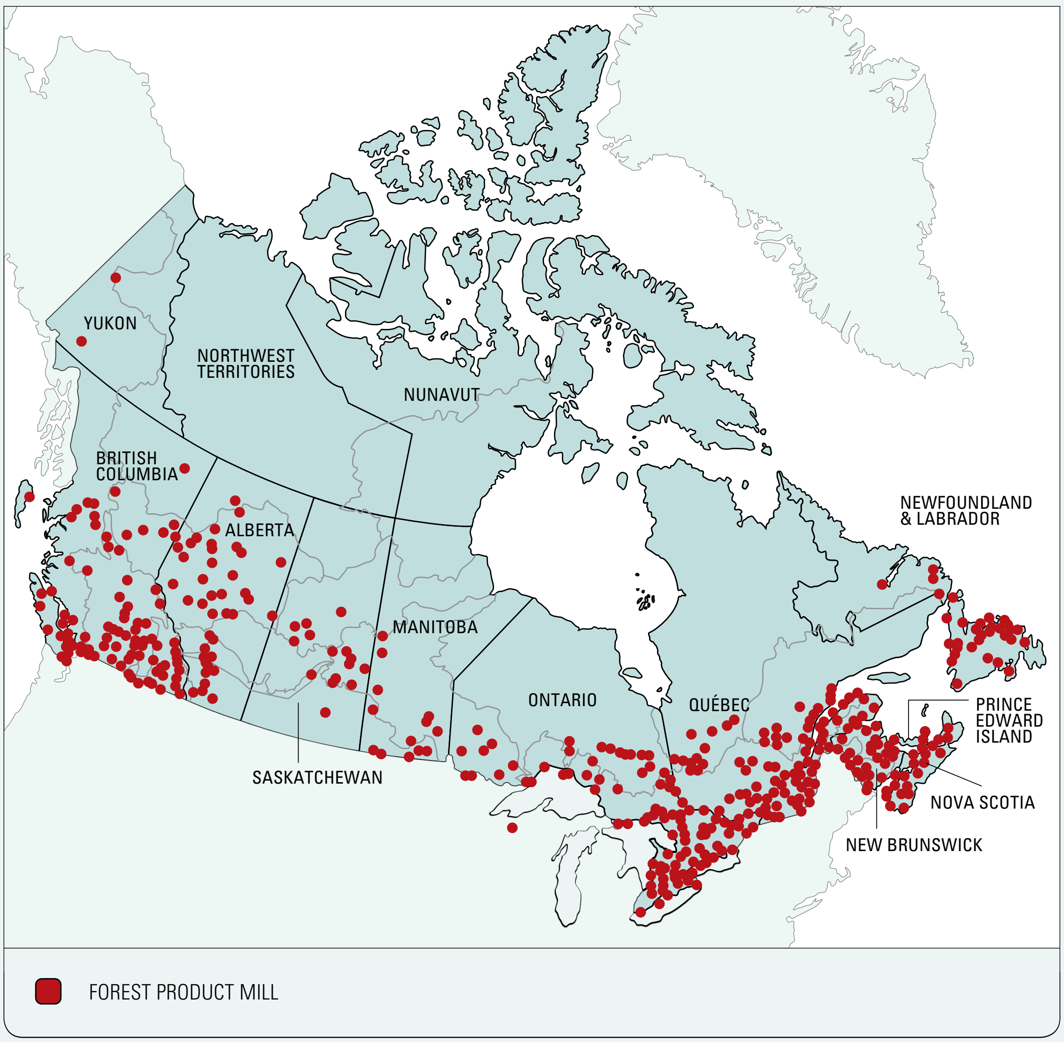
Serious supply and demand constraints are anticipated to restrict the growth of the industry over the medium and long terms. With the recent global economic recession the forest sector does not expect short-term growth; however, the eventual rebound of the forest products sector may be anticipated for the medium to long term.

KEY WATER USES

The key water uses considered in this overview are forest management and pulp and paper manufacturing.

FIGURE 16

FOREST PRODUCT MILLS IN CANADA



Source: Global Forest Watch Canada, 2003.[108]

FOREST MANAGEMENT

Forest land management plays an important role in regulating water quantity and has a critical impact on the timing of surface flows, water quality, groundwater recharge, and floodplain maintenance. At a basic level, forests affect water resources by intercepting precipitation and capturing transpiration of soil moisture. It is estimated that half the precipitation that falls on Canadian forests is intercepted, allowing the rest to enter surface and groundwater.[109] Forests improve soil infiltration and prevent erosion and therefore provide ecological services in relation to water management.

All forested lands provide these ecosystem services, however the boreal forest is a noteworthy example. Canada's boreal forest contains the world's largest area of peatland which is critically important for flood control and water filtration. Recent studies demonstrate that Canada's boreal forests store an estimated 208 billion tons of carbon — more carbon than any other terrestrial ecosystem on Earth.[110] Therefore land management decisions in boreal forests are of national and global significance.

The main forest management activities that can affect water resources include construction of access roads, harvesting, re-planting, and pesticide application. While forest management activities use limited quantities of water, they can and do have a significant effect on the water quality within watersheds. Watersheds across Canada have been extensively developed by forest harvest developments (Figure 17). However, regulations and guidelines exist for these activities and so the negative effects can be minimized if managed responsibly. The structure of the forest, including replanting, has an important influence on the watersheds, and therefore remains an important consideration for sustainable development of forests and ecosystems.

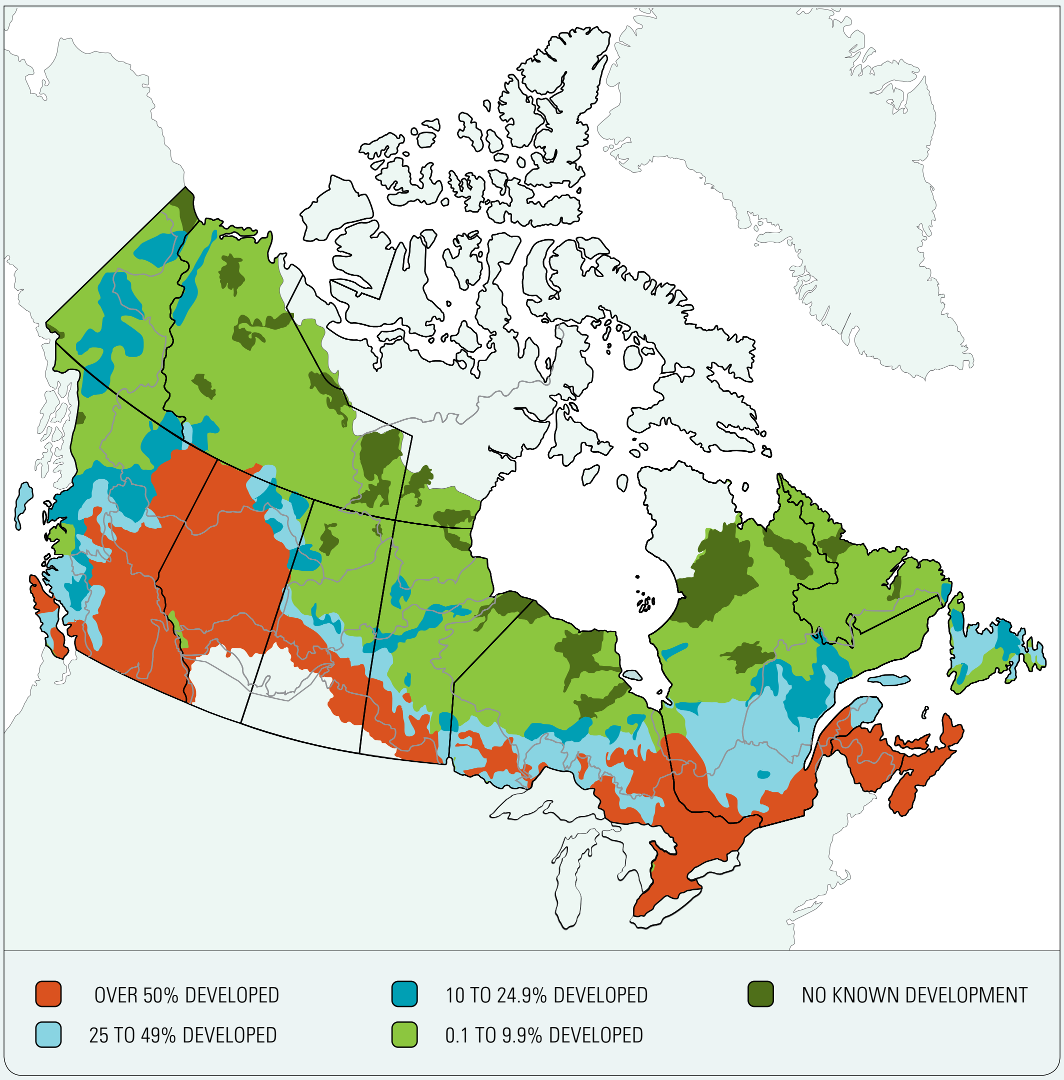
PULP AND PAPER MANUFACTURING

Large volumes of water are used in the pulp and paper manufacturing industry, accounting for five per cent of gross water use in Canada, however the majority of this water use is non-consumptive, and nearly 90% is returned to surface waters after treatment. In addition, water recycling rates within the mills are high. Overall gross water use, water-use intensity (water use per unit of production) and water withdrawals by forest products manufacturing have declined substantially since the 1980s.[111]

In simple terms, pulp production involves chemical and/or mechanical processes to separate and recover cellulose fibres from lignin and other wood constituents; both processes involve large volumes of freshwater. Water serves four main functions in pulp and paper mills — chemicals

FIGURE 17

DEVELOPMENT STATUS OF FORESTED WATERSHEDS



Source: World Resources Institute and Global Forest Watch Canada, 2000.[112]

make-up, transport of material flows throughout the production process, materials separation, and cooling.[113] Water used in processing and cooling represents the most significant demand on quantity. Water that is added through the use of water-containing chemicals compensates for the small amount of water that may be consumed by the production process.* Water conservation is critical in mill operations, with processing and cooling waters segregated as much as possible. In addition to recycling, both efforts reduce the amount of water that has to be treated, and subsequently the energy requirements involved. Wastewater from a mill is a critical component of a facility's water management. It is treated before release in order to comply with the federal Pulp and Paper Effluent Regulations.

KEY WATER ISSUES

PULP AND PAPER MILL EFFECTS ON WATER QUALITY AND AQUATIC ECOSYSTEMS

The key environmental concerns relate to effluent from pulp and paper mills and the need to mitigate any potential negative effects to aquatic organisms and to minimize nutrient enrichment. The effluent entering a water body can contribute biochemical oxygen demand (BOD), total suspended solids (TSS), and chlorinated organics, with possible effects on fish and benthos, and the effects can be negative if released in amounts that cannot be assimilated by the aquatic environment. As a result of the combination of strict regulations and monitoring requirements,† and the industry's response in reducing these releases, the effluent from pulp and paper operations has greatly improved over the last 15 years.‡

LIMITED KNOWLEDGE OF FOREST-WATER RESOURCE INTERACTIONS

It is broadly acknowledged that not enough is known about forest-water resource interactions and that most forest management decisions are based on outdated research. Canadian research on forest hydrology was robust in the 1960s and early 1970s, but has been scaled back significantly since that time. The potential for climate change impacts underpins the need for renewal of this work in Canada. The increasing prevalence of forest fires, insect disturbances, and changes to forest species will have dramatic effects on freshwater resources. There are two challenges to overcome:

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* For a full description of water use in pulp and paper mills see *Water Use Performance and Practices at Low Water Use Mills. Technical Bulletin No. 968*. National Council for Air and Stream Improvement (NCASI). November 2009.

† This aspect of the sector is regulated by the federal government under the Pulp and Paper Effluent Regulations of the *Fisheries Act*, as well as other regulations under various provincial regulations. In addition mills must participate in a federal environmental effects monitoring (EEM) program.

‡ Recognition of these improvements has led the federal government to recently reduce the broad EEM requirements and have more site specific monitoring programs to address specific issues.

- Forest management typically is orchestrated at the stand level, rather than the watershed level and this needs to change.
- Research in this area in Canada is underfunded and there is a deficit of expertise.

The National Council for Air and Stream Improvement recently assessed the effects of forest management on hydrology and water quality, in both Canada and the U.S. It concluded that effects of forest management on hydrology and water quality are highly variable across Canada in both magnitude and duration. Due to this variability the report recommends that watershed studies should be conducted in the ecozones in which the results will be applied for forest management.[114] Continued data collection is needed to better understand the effects of forestry on water resources, and this presents an opportunity for better management resulting from ongoing research efforts.

PUBLIC LICENCE TO OPERATE

The forest sector has a long history of demonstrating significant environmental improvements as a result of public interest. The public concern about water most often focuses on water quality and health issues rather than on concerns about water withdrawal and quantity. Most recently, the sector has been tasked with addressing issues related to water quality and endocrine disruption. In cases where local communities have demonstrated concerns over the volume of water use, the sector has taken efforts to share information on water use and Environmental Effect Monitoring results. Improvements and advancements by the sector have been incorporated into third-party certification, sustainability reporting, and eco-labelling schemes. Some facilities are also now making a voluntary effort to participate in the Alliance for Water Stewardship and to incorporate the World Business Council for Sustainable Development's Global Water Tool to communicate their water use. In order to stay competitive, the Canadian forest sector is looking closely at its water "footprint" and possible requirements to improve its water use, as a direct result of customer demands.

DRIVERS, CHALLENGES AND OPPORTUNITIES

Economic and environmental improvements are the driving forces for water reduction at pulp and paper mills. Reduced water requirements result in lower costs of water treatment and energy use. Strict environmental regulations and standards can also be drivers for improvements to water efficiency.

The key challenge for the sector right now is economics; given the market situation the sector is in, capital investment in research and development for new technologies and innovation is limited. Despite this, multiple opportunities exist for research and development of innovative water-use technologies[115] for pulp and paper mills. These largely involve process water recycling and reuse, or finding innovative effluent processes such as low-effluent mills. However, the sector argues that, given its economic situation, it needs incentives and assistance from government to help the industry pursue these opportunities.

One particular aspect of the effluent quality requirements under the federal *Fisheries Act* is viewed as a barrier by the industry to improvements to its water use efficiency. Current regulations require that effluent from a mill meets certain test requirements involving acute toxicity testing. In order to meet these requirements, the mills must ensure that their effluent meets the regulated levels before discharging it to surface waters. The industry believes that the nature of the toxicity regulatory requirements prevent them from achieving greater water use reductions and advocate for a different approach to determining effluent concentrations.

IN SUMMARY

Due to the recent decline in the industry, and limited growth anticipated in the next few years, particularly for pulp and paper mills, water use by the sector is not expected to increase. However, the sector is likely to rebound over the long term and there is a concern from the sector surrounding the future availability of water resources at that point. Existing or recently closed mills currently have water allocations; the question is whether they will continue to have the right to use their water allocations into the future? Both pressure from the local public and international customers will continue to insist that the sector continue to address water management responsibilities including its water use.

CHAPTER FIVE

NATIONAL WATER ISSUES

CONTENTS

HIGHLIGHTS

The effectiveness of water management in Canada is challenged by the fragmented nature of governance and management across the country.

Climate change effects on water are predicted to pose significant management challenges for sectors.

Water and energy policy are interrelated, requiring integrated policy development in order to avoid conflicting requirements on the natural resource sectors and unintended negative impacts on the natural environment.

Public interest in water is driving innovation and improved water use and management.

NATIONAL WATER ISSUES

Many of the sector-specific water issues identified in Chapter 4 are of a regional nature. Through its investigation of water issues and Canada's natural resource sectors the NRTEE identified a number of critical issues that are of national importance, cutting across sectors and political boundaries. These are:

- governance and management;
- the impacts of climate change on water resources;
- the water-energy nexus; and
- the public licence to operate.

GOVERNANCE AND MANAGEMENT

The governance and management issue is the most complex of the four issues and is defined by:

- complicated and fragmented statutes and policies surrounding water use across the country;
- outdated and possibly inappropriate water allocation systems in some parts of the country;
- limited policy instruments and narrow approaches to manage water resources;

- limited knowledge of actual water use and availability (surface and groundwater); and
- a general lack of capacity and expertise.

STATUTES AND POLICIES

Current water policies and regulations in Canada are burdensome and complex, due to the jurisdictional division of powers between the federal and provincial governments and to the fact that provinces also delegate some of their authority to municipalities. Even within one order of government, responsibilities for water management are usually shared between several agencies. The natural resource sectors, critical water users in Canada, must deal with a multitude of statutory and policy instruments managed by various government and non-government participants, often without adequate coordination.

WATER ALLOCATION SYSTEMS

As explained in Chapter 3, water allocation systems vary across the country. In recent years, there have been numerous calls for a modernization of allocation practices in certain parts of the country. Faced with serious water shortages in the southern part of the province, Alberta has undertaken a review of its water allocation management system. This will allow government, communities, industry, and the public in this province to explore options to better meet future water needs and support regional outcomes. Similar initiatives that assess and improve the existing allocation systems are being contemplated in other provinces such as British Columbia. There is a need to assess current allocation systems across Canada. The time to do so is now, before water shortages become more prevalent in the country and conflicts over allocations arise.

POLICY INSTRUMENTS

Throughout the last century, water management in Canada was increasingly achieved through regulatory and legislative tools. To enable a more flexible and adaptive policy approach that recognizes regional and local particularities, a move toward a broader suite of policy tools for water management is needed. This requires identifying and evaluating economic and fiscal policy instruments in a Canadian context. Canada needs a more complete investigation of regulatory and non-regulatory instruments along with an examination of the potential implications these types of water management instruments might have on the natural resource sectors.

KNOWLEDGE BASE

Good, reliable data and information about the availability of ground and surface water as well as accurate measures of water use are necessary to ensure informed decisions. But a real challenge exists in accessing, understanding, and interpreting water information pertaining to the natural resource sectors' uses.

Overall, most sectors have a good understanding of their operational water uses, which they collect from primary sources such as metres, or proxy sources such as pump data and effluent discharge volume. Through water-use permits and licences, provinces and territories collect a great deal of water-use data, across these sectors, but the nature of that data, consistency of approach, and accuracy vary across the country. What is known about a sector's water use is often based on water permits and licences, which are an indication of water *allocation*, and not the actual water *use*. In some provinces (e.g., British Columbia) water drawn from groundwater sources is exempted from the permit process and therefore not monitored. Actual water use at regional and national levels remains uncertain.

Given the shared nature of water governance, information sharing between jurisdictions merits some attention and consideration. Integrating data on water use, availability, and flow measurements is necessary for informing place-based decisions and integrated watershed management. Furthermore, this kind of integration is necessary to examine the costs and benefits associated with certain decisions that will impact water resources. The movement toward the integration of databases across jurisdictions does not yet exist in Canada but is being contemplated. Creating integrated databases, especially between organizations and even more so across jurisdictions, will be a significant challenge — from the perspective of data quality and control, to resourcing and management.

CAPACITY AND EXPERTISE

There is an increasing recognition that governments do not have the capacity – in terms of human resources, expertise, financial resources, and management systems – to act alone and properly manage water resources. Collaborative governance models, under which the authority over water is shared with water users and other stakeholders within a watershed, are seen as a better approach to developing policies and managing our water resources. Such approaches are increasingly implemented in Canada and other countries, and show promise of being successful. But some experience has demonstrated that delegation to a local authority can fail if not properly resourced with adequate capacity and expertise.

IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES

Climate change is emerging as a key factor expected to change the way in which we must manage water resources. Although water scarcity is not currently a problem across the country, broad agreement from the scientific community in Canada and elsewhere has demonstrated that large-scale hydrological cycles driven by climate change are occurring and are anticipated to continue to change in the future.

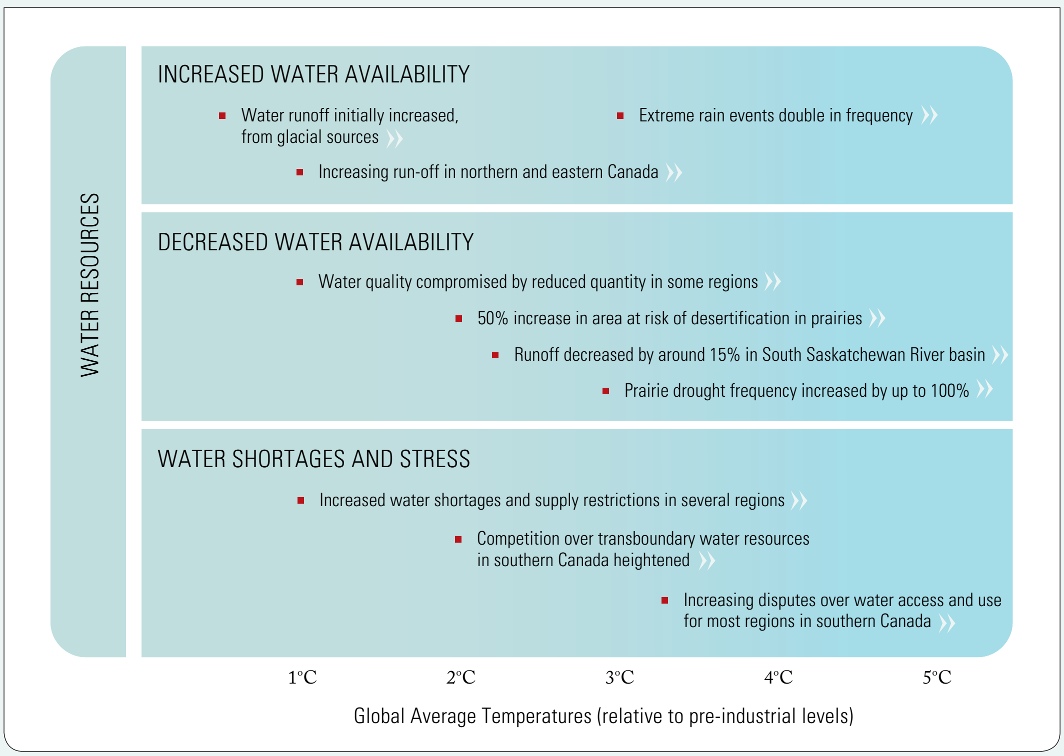
Over the next century, Canada is likely to experience warming at twice the global average, with more northern regions experiencing the greatest increases.[116] Changes in precipitation and evaporation are anticipated as a result of the temperature change,[117] as well as changes in the frequency, extent, and severity of many climatic extreme events including droughts, heat waves, and intense storms. The effects on Canada's water resources will vary across Canada and will be highly localized, given the complex and evolving nature of the natural processes that regulate hydrology. The same forecasts suggest that increasing water shortages (both ground and surface water) will be a key issue in many parts of Canada. Experts have acknowledged that past hydrological experience will be insufficient to provide a good guide to future conditions. For the natural resource sectors the uncertainty and risks associated with these changes is a challenge.

Research on the physical impacts on water resources in Canada highlights potential changes to precipitation events and regional hydrology (Figure 18). Overall precipitation is expected to increase slightly in the north and decrease slightly in the south and west, with less in summer, and more during intense events. Winter warming is expected to reduce snow accumulations in alpine areas[118] and across the Prairies. This will cause declines in annual streamflow and a shift in streamflow timing to earlier in the year, resulting in lower summer water supplies. In addition, Canada is already experiencing the effects of glaciers retreating. In the future, glacier melting will be accompanied by an increase in runoff for a period until the runoff declines as glaciers are depleted.[119] While many western Canadian rivers are currently experiencing an increased flow phase from glacial melt, some are already showing evidence of this decline.[120] The results of this decline in water availability will be significant. British Columbia is expected to face increasing water shortages, particularly during periods of peak demand.[121]

Water shortages will also be exacerbated in the Prairies due to continued glacier retreat and reduced runoff. Lower summer stream flows will be experienced in an already arid Prairie region. By 2020 annual flow of the main rivers is expected to be reduced.[122] Reduced discharge and increasing frequency of dry years will increase both soil water deficits and surface water deficits with implications for all users.[123] As glacier melting increases, the degree of dryness on the Prairies is expected to increase by 50% by 2050. The drought frequency is expected to double and stream flow and soil moisture are expected to decline 30%.[124]

FIGURE 18

IMPACTS ON WATER RESOURCES IN CANADA DUE TO CLIMATE CHANGE



Source: National Round Table on the Environment and the Economy (forthcoming).[125]

In Ontario, ground water recharge will be decreased.[126] The Great Lakes are expected to experience lower net basin supply and an increase in the frequency of low water levels.[127] To the east, the Maritime Provinces are projected to experience increases in both precipitation and temperature.[128] Seasonal and yearly variations in precipitation will combine with higher evapotranspiration to induce drier summer conditions.[129]

Regions with reduced water supplies and increased demands will likely experience competition among users. Water quality in many regions will be compromised by lower water levels, warmer temperatures, and more intense precipitation.[130] Warming will likely compromise water quality through the intensification of thermal stratification, contributing to oxygen depletion.[131]

Overall, the natural resource sectors, with their significant reliance on water, will be affected by reduced water supplies. Presently, some sectors are very concerned about the impacts of climate change on water availability and others less so, but all sectors struggle with incorporating uncertainty of climate change predictions into management practices. In general, it will require a more concerted response from industry to assess potential risks and develop adaptation strategies. As both local and regional hydrology is anticipated to change, water managers will need to consider how to adapt. Thinking about these issues now will permit earlier and more effective adaptation.[132] Governments have a responsibility to better understand the potential changes for water resources and should respond accordingly by changing their water policies. These new polices need to be flexible enough to adapt to the changing physical environment and evolving activities of the natural resources sectors, and robust enough to protect the ecosystem and services upon which communities rely.

THE WATER-ENERGY NEXUS

An important issue for water policy development is the linkage between water and energy (or the "water-energy nexus"). Climate change is often linked to discussions about the water-energy nexus due to the greenhouse gas emissions that result from energy production and the impacts that occur to water resources as a result of climate change. This has been referred to as the water-energy-climate change feedback loop.[133]

From the industrial processing and production side, water is needed to produce energy (i.e., to extract and produce fuel and to generate power) and energy is needed to produce useable water (i.e., to access, treat, and distribute water). Indeed, the electricity sector is the most significant user of water in Canada, and energy requirements to manage and transport water can be a major component of total energy use by natural resource sector operations. Representatives across sectors commonly identify financial savings through energy use reductions as the main driver for improving water use. While some opportunities such as conservation practices simultaneously reduce water and energy use, other opportunities pose trade-offs between water and energy use. For example, closed-loop and dry cooling systems are frequently identified as technologies that use less water, and could be used as alternatives to once-through cooling systems that require large amounts of cooling water. However, closed-loop and dry cooling systems require greater energy use than once-through cooling systems, resulting in decreased plant efficiency and increased greenhouse gas emissions. Therefore, water use, energy use, and associated greenhouse gas emissions objectives may sometimes be in conflict at the production level.

From the policy and regulatory perspective, climate change mitigation, energy security, and sustainable water use are all issues that governments must manage. However, policies are usually developed in isolation and often by different departments. Without integrated policy development, future policies may end up imposing conflicting requirements on the natural resource sectors or creating unintended negative impacts to other resources. For example, as the Canadian government seeks opportunities to reduce greenhouse gas emissions, it has supported the growth of the biofuels industry, but little is known about how this will affect water resources. Another example is the electricity sector: as electricity demand grows in Canada, it is likely that pressures on water resources will increase, possibly creating water supply challenges or leading to degraded water quality.

The linkage between future energy requirements and anticipated water uses warrants further detailed analysis in Canada, especially as policies and approaches for reducing greenhouse gas emissions and exploring alternative energy sources are contemplated. Taking the opportunity now to address the integration of energy, water, and emissions policies could encourage the implementation of complementary objectives in future policies.

PUBLIC LICENCE TO OPERATE

In addition to actual, measurable water issues, the natural resource sectors must also address public perceptions on how they use water. Public pressure can be a powerful driver. More than eight in 10 Canadians currently believe that Canada will have a freshwater shortage problem if conservation measures are not put in place.[134] Despite the rigour most companies demonstrate in meeting regulatory requirements, only 30% of Canadians currently believe that corporations, businesses, and industry are making reasonable efforts to conserve freshwater.[135] For industry, statistics such as these may signal reputational and even future regulatory risks if they are not adequately addressed.

Public pressure to better manage water use is unanimously felt across all the natural resource sectors in Canada. Outside of improvements to lower overhead costs, industry must assess various signals (e.g., societal pressure, demands from other sectors in the value chain, future regulatory shifts or price signals) to integrate water into strategic planning. Such planning may result, in:

- improved measurement, monitoring, and reporting on water use;
- conservation of water by increased recycling and reuse, decreasing contamination, and changing production processes to be more efficient;
- increasing collaboration with government and public groups to improve knowledge exchange;
- coordination with suppliers and purchasers in the value chain to create awareness of future water issues; and
- investing in further research and innovation where needed.[136]

Although not well developed in Canada, financial markets are also starting to examine the way in which companies address water-related risks. In some cases, these are restricted to those risks related to physical limitations to water access, but may also extend into analysis of regulatory compliance and exposure to reputational concerns. In this way, investor groups use their influence to encourage disclosure of water risks and to credit companies that demonstrate progress. The "public licence to operate" in this instance extends into the realm of shareholder approval.

The Canadian resource sectors are responding to public pressure to improve water use and are also investing in water management based on other factors. For example, the forest sector is working to develop quantitative profiles of water uses by forest products in Canadian operations in an act of voluntary transparency. The oil and gas sector has partnered with the Alberta government to invest in furthering shared innovation and in technology for increased water efficiency. The mining sector is developing methods for integrating water use and efficiency in its sustainability reporting standards. In Southwestern Ontario, agricultural producers have mobilized with public authorities to engage the public on allocation decisions during seasonal drought.[137] As issues of water scarcity and quality increase across the country, such actions will be increasingly important for the sectors to demonstrate their corporate responsibility and keep their public licence to operate.

CHAPTER SIX

FINDINGS AND CONCLUSIONS

CONTENTS

HIGHLIGHTS

As significant users of water already, anticipated growth of the sectors will likely result in increasing pressure on our water resources.

The sustainability of the country's water resources remains in question given limited and dated information regarding water availability and actual water use on regional and national scales.

In order to address the issue of water sustainability and the future of the natural resource sectors, Phase II of the NRTEE's water program will examine four key challenges related to governance and water management:

- current water allocation approaches across the country -
- collaborative governance approaches for integrated water management -
- a more strategic approach to water-use data -
- policy instruments for water management in Canada. -

FINDINGS AND CONCLUSIONS

FINDINGS

The natural resource sectors are very important for Canada's economic prosperity and will continue to be a dominant factor in the country's economic profile over the long term. As significant users of water already, anticipated growth of the sectors will likely result in increasing pressure on our water resources. However, specific details regarding where and when these impacts may be felt are lacking. Due to limited, dated information and data regarding water availability (surface and groundwater) and industrial water use on regional and national scales, the sustainability of the country's water resources becomes a question.

SECTOR-SPECIFIC FINDINGS

The water uses of, and issues pertaining to, each of the natural resource sectors are unique. Each has a different use and impact on the water resources on which they rely. The issues are largely local and/or regional rather than national, in comparison with the issues identified in Chapter 5. With increasing pressures due to population and economic growth, and a changing climate, these matters could develop into national issues if they are not addressed now.

HYDROELECTRIC POWER GENERATION

Water is critical for hydroelectric power. Because this sector will be a significant future energy source in Canada (for both internal use and export), and in light of the drive for lower-emission energy sources, it is reasonable to expect water use by the sector to rise substantially over the medium to long term. As this sector's water use is largely non-consumptive, impacts on regional water quantities do not readily appear to be of concern. However, the timing of use is an important consideration for hydroelectric power operations and therefore will continue to be a key issue in watersheds where there are competing uses for the water.

As hydroelectric facilities can have significant effects on flow regimes and water levels within watersheds, these considerations must be carefully managed on a facility and on an individual watershed basis. Prudent management is necessary to balance electricity production with the needs of other users while also considering ecological needs and fisheries requirements. Moving forward, management of hydropower facilities should be considered on a watershed basis, particularly where there are multiple facilities and users on the same river system, to address potential cumulative effects.

FOSSIL AND NUCLEAR ELECTRIC POWER GENERATION

Water availability is also a major requirement for fossil and nuclear electric power. Relative to the hydroelectric power generation sector, the fossil and nuclear electric power generation sectors use less water (intake) but have greater consumptive use, and greater potential to negatively affect water quality. These sectors will continue to count on water availability into the future. Water availability will also remain a key consideration for siting new facilities. The sector does not appear to be significantly concerned about water scarcity overall, but rather is focused on future water management to ensure a secure supply of electricity. The need to refurbish and rebuild the Canadian electricity infrastructure may alter the sector's water use over the medium to long term. How those developments impact water use remains to be seen, and is difficult to predict at this point without knowing the future generation mix, including hydropower. The key challenge of balancing electricity production with the needs of other users, including ecosystem needs, will remain into the future. The effects on water quality from thermal and chemical discharges continue to be an important issue that the sector needs to manage to ensure ecosystems are not adversely affected.

OIL AND GAS

On both a national and regional basis, the oil and gas sector uses small volumes of water in comparison with the other natural resource and energy sectors. As such, the sector does not perceive water availability to be a critical issue. It's impact on water quality and aquatic ecosystems remains the primary issue. This is particularly true for the oil sands sub-sector, which anticipates significant growth. This pace of development will exert increasing pressures on the ecosystems on a regional basis. Similarly the anticipated development of shale gas in Western Canada warrants attention, both because of potential effects on water quality and quantities in the region. A proactive approach to planning for further oil sands expansion and new developments in shale gas in British Columbia is necessary to ensure sustainable management of the water resources in those respective regions.

AGRICULTURE

Water is crucial to the development of products and fuel derived from crops and animal by-products. While not the largest gross water user of the natural resource sectors, agriculture is the largest consumer of water largely due to crop irrigation. Water availability is currently an issue for farms in water-scarce regions of the country. As the sector's need for irrigation increases because of demand for higher-value crops and efforts to convert dryland operations, the risks associated with water limitations will continue to rise. The sector may be at risk from climate change (resulting in reduced spring runoff) and prolonged cyclical drought. Water availability will continue to be a dominating issue for the sector, and as such is a key driver for water efficiencies and conservation.

MINING

Relative to other natural resource sectors, the mining sector is not a significant user of water, gross or consumptive. As such, water availability does not appear to be a constraint or risk to future operations. Mines have the ability to significantly impact water quality in the regions and watersheds where they are located, and therefore water quality is one of the most important aspects of water management for this sector. The potential for long-term effects of mine operations on the health of the surrounding ecosystems is of particular concern due to contaminants that may be introduced to the environment as a result of mining activities.

Mining operations will need to consider the effects of climate change on a mine's water management practices. Particular effects of interest include change in the amount of precipitation, change in the timing of precipitation, and an increase in frequency of extreme events. Having a robust and adaptive water management plan will help in addressing the uncertainty related to such events.

FOREST

Both forest management and manufacturing activities affect water resources, but in very different ways. Forest harvesting activities can have significant impacts on the hydrology and water quality of watersheds; therefore, sustainable forest management strives to protect forest health and build in water protection measures to minimize these impacts. The pulp and paper manufacturing sector uses large volumes of water but with very low consumptive rates. Overall water conservation is not viewed as a high priority issue by the sector, given that most of the water use is non-consumptive and because most operations are located on large waterways in regions that are not currently experiencing water shortages. Similar to mining, the pulp and paper sector's primary water issues pertain to water quality related to discharges and the potential effects on downstream aquatic ecosystems.

The pulp and paper industry is reinventing itself in the wake of the recent economic downturn. The sector's recovery into new markets and product lines is uncertain, and as such its future growth and the potential implications for water resources and impacts on ecosystems remain largely unknown.

OPPORTUNITIES FOR INNOVATION

Significant economic barriers for broad implementation of water-efficient technologies exist for all sectors. However, some important drivers are resulting in advancement of better water conservation and management:

- The sectors are acutely aware that water efficiency is closely tied to energy efficiency. The water-energy nexus is a key driver of water conservation efforts.
- Public pressure in some cases has led to the development and implementation of a number of technologies to improve the way water is used.
- Water quality is more closely regulated, and as such has garnered significant investment for effluent treatment and containment measures.

Still, further opportunities for improving Canadian innovation in water management continue to exist for all sectors. Although there is no one-size-fits-all approach or method for improving water use, a greater emphasis on increased knowledge transfer, research, leveraged funding through private-public partnerships, and economic instruments are examples that could enable industry to reduce its absolute and relative water footprints. This in turn will help ensure that there will be water — in the required quality and quantity — for the environment and future development.

CONCLUSIONS

The natural resource sectors are a vital part of the Canadian economy and are anticipated to grow by as much as 50 to 60 per cent by 2030. As the most significant users of our water resources, these sectors' growth can be expected to put increasing pressure on our water resources. Exactly how much pressure and exactly where it will be exerted is unknown. This is due to a lack of reliable, accurate data on our actual water resources, and data on *actual* water use by the natural resource sectors.

While certain areas of the country are responding to these concerns, governance at a national level is not currently positioned to respond effectively to this problem due to jurisdictional complexity, inconsistent approaches across the country, policy fragmentation, and a lack of resources and technical, scientific, and policy capacity. By addressing these specific challenges, governments will be able to establish more effective governance structures that will enable industry to develop solutions at the regional scales where they operate.

The NRTEE has determined that in order to address the issue of water sustainability and the future of the natural resource sectors, the following four key challenges related to governance and water management will be explored in Phase II of the NRTEE's Water Program:

- **We will evaluate current water allocation approaches across the country to determine if they remain effective and appropriate means to manage water, and we will identify opportunities for improvement to water allocation going forward.**

Most of the water allocation approaches in Canada are based on historical policies. They were developed in response to the division of water resources to encourage settlement and development of this country, created at a time when water was plentiful, with few if any competing uses on any given water body. This is no longer the situation. There are now competing uses for water, the prospect of increased demand and a likely reduction in supply. In light of these changing circumstances, we need to explore other water allocation approaches beyond what we have in Canada today. And specifically we need to understand how such approaches might affect Canada's natural resource sectors.

- **We will further examine collaborative governance approaches for integrated water management.**

Water governance is changing across the country, with varying approaches due to differing regional demands and challenges, as well as differing watershed characteristics. Part of the change involves "collaborative" governance, resulting in the inclusion of more stakeholders in decision making than ever before. While differences exist between regional approaches, many governance issues are common across the country, including access to and understanding of good science, availability of data and information, policy fragmentation, regulatory incoherence, dispute resolution, political engagement, and financial support. Good collaborative governance principles and models exist and can be applied. The challenge is to figure out how to overcome the barriers that are preventing implementation of potential solutions.

- **We will investigate strategic approaches to the collection and management of water-use data.**

The evidence to date suggests that accurate, reliable data and information regarding actual water use by the various resource sectors is quite variable. Each of the sectors appear to have different regulatory requirements pertaining to water use, which differs between sectors and varies across jurisdictions. The reporting requirements also vary significantly. As a result, some sectors have a good understanding of their water use and potential areas for improvement (e.g., pulp and paper sector). Other sectors may not collectively have a solid understanding of their actual water uses, but on an individual operational basis, some proactive operators do understand and appreciate their water use. If Canada is to fully understand water use now and into the future, a comprehensive picture of actual usage across the country is necessary. This in turn must be paired with other monitoring data to ensure ecosystem flows are accounted for. This is not a simple, easy task — it will require resources, time, and commitment. Investigation of a strategic approach on how this may be accomplished is warranted.

- **We will explore a full suite of policy instruments for water management in Canada, from traditional regulatory and voluntary conservation efforts to pricing and market-based instruments, which will be necessary for implementation of effective policies and strategies.**

While conventional regulatory approaches play an important role in water management, market-based instruments could serve a function that to date has largely not been used in Canada. Putting an economic "value" on water may be an important approach to improving the demand-side management of the resource, both to encourage efficiency and to account for the many non-market ecological goods and services provided by water. Water "valuation" can also be used to ensure that costs or benefits associated with changes in the environment are considered. Research suggests this approach may improve conservation efforts and contribute to pollution prevention.

The NRTEE believes that there is an opportunity now to put Canada on a policy path to ensure sustainability of our water and natural resources sectors. Canada needs a national approach to water governance — complemented by effective management systems — while governments are still in a position to consider all possible options and before water availability becomes constrained and turns into a critical national economic and environmental issue.

CHAPTER SEVEN

APPENDICES

CONTENTS

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GLOSSARY

ADAPTIVE MANAGEMENT	The implementation of policies as experiments. A methodological approach to resource management whereby management decisions can be adjusted based on outcomes.
ALLOCATION	The process of determining who is given access to an amount of water from a surface or ground water source, how much that amount is, and when it may be used.
AQUIFER	A subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater.
CONSUMPTIVE WATER USE	The amount of that water intake that is not returned to natural sources, generally lost to evaporation or contained within wastewater or products.
DRAINAGE BASINS	A geographical area that drains all precipitation received as a runoff or base flow (groundwater sources) into a particular river or set of rivers.
EFFLUENT	A liquid, solid, or gaseous emission, such as the discharge or outflow from an industrial process.
ENVIRONMENTAL FLOW	The quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.
ECOSYSTEM RESILIENCE	The capacity of an ecosystem to cope with disturbances, such as storms, fire, and pollution, without shifting into a qualitatively different state. A resilient ecosystem has the capacity to withstand shocks and surprises and, if damaged, to rebuild itself.
ECOSYSTEM SERVICES	The benefits provided to people, both *directly* and *indirectly*, by ecosystems and biodiversity. Direct economic benefits are those materials gained through the use of natural assets (e.g., water, trees, crops) that provide inputs to production. Indirect benefits refer to all those natural goods and assets that keep soil intact, recycle pollutants, pollinate plants, provide oxygen, and lead to regeneration of natural assets.
GROSS WATER USE	The total amount of water taken from a source (ground or surface).
HYDROLOGICAL CYCLE	The cycle in which water evaporates from the oceans and the land surface, is carried over the earth in atmospheric circulation as water vapour, precipitates again as rain or snow, is intercepted by trees and vegetation, provides runoff on the land surface, infiltrates into soils, recharges groundwater, discharges into streams, and ultimately, flows out into the oceans, from which it will eventually evaporate again.
INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)	A process that promotes the coordinated development and management of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

MAKE-UP WATER	Water (not produced water) that is injected into an oil-bearing zone to enhance the operation of an enhanced oil recovery project. Make-up water is new water needed to replace the volume of oil and gas produced in conventional enhanced oil recovery projects, and replace volumes of produced water that are lost in the treatment and steam generation processes for thermal in-situ projects (oil or crude bitumen). In electrical generation, the term is also used to describe the largest volume of water required by an electric generator, which typically will be used in the cooling tower.
PRODUCED WATER	Water that is extracted from the subsurface along with oil, gas, or other hydrocarbons.
PROCESS WATER	Water that is used in the manufacturing process.
RECIRCULATED WATER	Water that is used more than once, often for different processes. Recirculated water can also refer to water that leaves a particular process and then re-enters that same process, including water that is discharged to a cooling pond and is later reused.
RETURN FLOW	Water that is withdrawn but returned to its source or to another body of ground or surface water as opposed to being consumed or lost via evapotranspiration.
SALINE WATER (BRACKISH)	Water that contains a significant concentration of dissolved salts. In Alberta, this refers to groundwater that has >4000 mg/L total dissolved solids.
TAILINGS	Ground rock and process effluents that are generated in a mine processing plant.
TAILINGS IMPOUNDMENT	Structures functionally pertaining to tailings, including (but not limited to) dams, spillways, and decant structures.
WATER ALLOCATION	The quantity of water available to be taken under a water access licence.
WATER BALANCE	An equation used in hydrology to describe the flow of water in and out of a system.
WATER DISCHARGE	Water that is withdrawn, used, and then returned to the natural environment.
WATER EFFICIENCY	The accomplishment of a function, task, process, or result with the minimal amount of water feasible. The term *water efficiency* can also be used as an indicator of the relationship between the amount of water required for a particular purpose and the amount of water used or delivered.
WATER FOOTPRINT	The total volume of freshwater that is used to produce the goods and services consumed by the individual or community (measured in cubic metres per year).
WATER INTAKE OR WITHDRAWAL	The total amount of water extracted for use in an establishment or industry.
WATERSHED	An area of land that intercepts and drains precipitation through a particular river system or group of river systems.

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