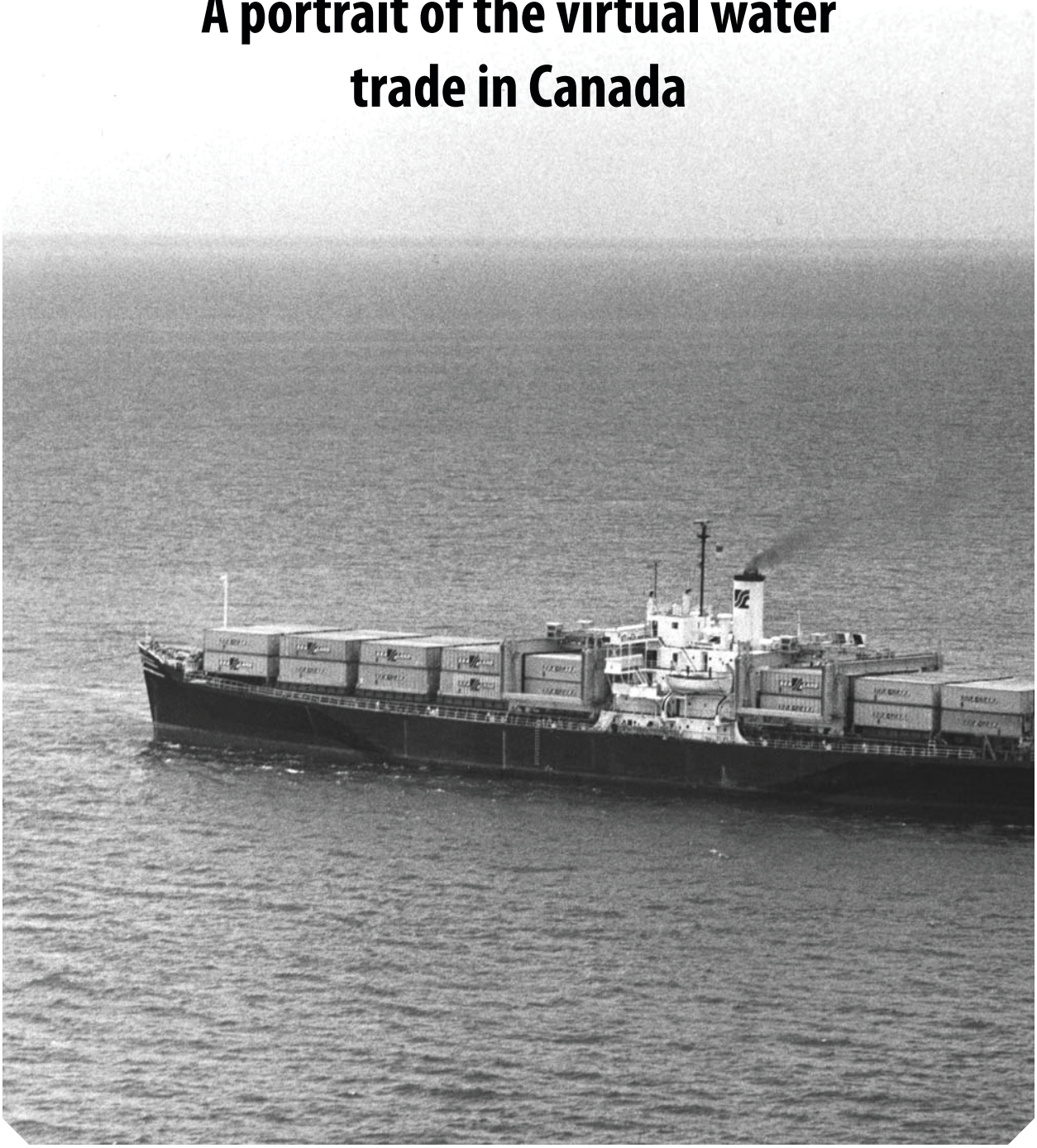
Leaky Exports:

A portrait of the virtual water trade in Canada



THE COUNCIL OF CANADIANS
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“The water wars that the popular media would have us all believe to be inevitable will not be fought on a battlefield between opposing armies, but on the trading floor of the world grain markets between virtual water warriors in the form of commodity traders.”

- Dr. Antony Turton, South African scientist and water expert

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g/m^2	gram per square metre	Bm^3	billion cubic metre
ml	millilitre	Bm^3/yr	billion cubic metre per year
g	gram	$m^3/cap/yr$	cubic metre per capita per year
m^3	cubic metre	l/day	litre per day
m^3/yr	cubic metre per year	km^2	square kilometre
Mm^3	million cubic metres	sq. mi.	square mile
Mm^3/yr	million cubic metres per year	l/US$	litre per U.S. dollar

Acronyms

VW	virtual water
VWC	virtual water content
CUSFTA	Canada-U.S. Free Trade Agreement
NAFTA	North American Free Trade Agreement

EXECUTIVE SUMMARY

This report highlights a little understood practice in Canada: the daily loss of massive amounts of the country's fresh water used to produce commodities, minerals and energy for export. Virtual, or embedded, water is the sum of water used in the production of a good or service. Virtual water trade refers to the embedded water transferred across borders when these goods and services are internationally traded.

The practice is now coming under close scrutiny as some impoverished and water-poor countries are depleting their water supplies in order to maintain export markets, while other, more wealthy countries import most of their "water footprint" (the total volume of water needed to produce the goods and services for their citizens) in order to protect their own limited water resources.

Because Canada has more abundant water supplies than some other countries, successive provincial and federal governments have built their economies on the "myth of abundance" and the assumption that these supplies are unlimited. Most depend to this day on exports that may endanger Canada's fresh water legacy. While Canada is often touted as having 20 per cent of the world's water supplies, in fact it has 6.5 per cent of the world's renewable water. Many parts of Canada are facing some form of water crisis and nowhere is our groundwater properly mapped. Yet the practice of allowing almost unlimited access to our rivers, lakes and aquifers for commodity, energy and mineral production and export continues without public debate or oversight.

Major Findings

1) Agriculture consumes 70 per cent of Canada's fresh water withdrawn.

2) Due to its high volume of agricultural exports, Canada is a major virtual water exporter, second in the world only to the United States.

3) Canada is a major *net* virtual water exporter, second only to Australia. Canada's net annual virtual exports (exports minus imports) amount to just under 60 Bm^3 (billion cubic metres), enough to fill the Rogers Centre in Toronto 37.5 thousand times.

   (Note**:** This figure, the latest available, is a decade old. With the increase in food and energy exports over the last decade, the real figure is likely considerably higher.)

4) Every year, Canada exports an amount of virtual water in wheat, barley, rye and oats equivalent to twice the annual discharge of the Athabasca River.

5) Alberta is particularly at risk from this practice. The province, with just two per cent of the country's water supply, accounts for two-thirds of the country's water used for irrigation, much of it for export.

6) The United States is the destiny of most of Canada's virtual water exports.

   * Over 60 per cent of Canada's total agricultural exports and their embedded water go to the U.S.

   * The U.S. is the destination of almost 99 per cent of Canada's cattle and swine exports.

   * Every year, Canada uses (and destroys) 1 billion, 95 million cubic metres of fresh water in the production – mostly for export to the U.S. – of energy from the tar sands of Alberta.

   * The U.S. is the destination of 58 per cent or 1.1 Bm^3 of virtual water exports annually from Canada's minerals, metals and non-metal commodities, including coal.

7) The increase in virtual water exports to the U.S. is closely related to the Canada-U.S. Free Trade Agreement and NAFTA, due to the post–trade agreements' increase in water-intensive exports to the U.S. and the integration of key parts of the North American agriculture and energy sectors.

   * For instance, two American companies control 95 per cent of Canada's cattle industry.

   * Similarly, American energy companies now control over 50 per cent of the tar sands operations.

Canada is a large net exporter of virtual water. Our fresh water heritage is at risk from the lack of government concern; poor information, mapping and research on our groundwater and surface water supplies; and the almost total absence of policy intervention by any level of government to set conditions on access to fresh water sources for export-driven production.

Most of these virtual water exports go to the United States and represent a huge environmental cost that is not reflected either in the pricing of these commodities or in the calculations of the costs and benefits of free trade. The so-called NAFTA "benefits" claimed by some industries and sectors come at the expense of Canada's fresh water heritage.

There is an immediate need to assess the loss of so much of Canada's fresh water supplies in trade-related economic development if our water heritage is to be preserved for future generations. It is our hope that the findings of this report will spark the debate and research so long overdue in Canada.

Maude Barlow
May 2011

INTRODUCTION

Canada has experienced rapid economic development due to international trade agreements in recent years. However, the benefits to some sectors of trade liberalization have hidden environmental costs that are often neglected. The increase in production of agricultural and industrial commodities is putting a strain on Canada's most valued resource – water. Water not only defines Canada's geography but also quite often dominates political discussions. For nearly half a century, the issue of bulk-water exports from Canada to the U.S. has been a topic of hot debate. Now, this issue is gaining new and urgent life with the information, contained in this report, that we are indeed exporting huge amounts of Canadian water every day embedded in goods and services in virtual form.

Industrial water use is not targeted in policies aimed at water conservation and there is very little analysis of the loss or displacement of water through Canada's export economy.

A 2010 Statistics Canada study examined water loss in the country between 1971 and 2004 and concluded that there had been an annual loss of fresh water the equivalent of 1.4 million Olympic size swimming pools, almost as much water as was supplied to the country's entire residential population in 2005.[1] The report confirmed the findings of other federal government reports including an internal 2007 document titled *A Federal Perspective on Water Quantity Issues*, which warned of a fresh water crisis in Canada for which the federal government is not prepared. The document, which was not publicly released, demonstrated that 60 per cent of Canada's GDP is directly dependent on water. Yet so far, very little attention has been paid to the impacts of industrial water use and trade on water loss in Canada.[2]

Purpose of the Report

The purpose of this report is two-fold. First, it is intended to provide an overview of the virtual water concept and its usefulness in developing policies aimed at protecting freshwater resources. Second, the report will provide an analysis of the current and projected volume of water that is exported out of the country in the form of agricultural and industrial goods. Due to the limitation and scope of data, the virtual water calculations focus on selected agricultural and mining commodities.

What Is Virtual Water?

Water is an essential requirement in the production of goods and services. The amount of water consumed in the production process of a good or service is called the "virtual water" contained in the product.[3] For example, to produce 1 kg of wheat, we need about 1,000 litres of water. For livestock products, we need about five to ten times as much.

The term "virtual water" was introduced in 1993 by J.A. Allan, a geography professor at King's College London, to indicate the amount of water made available in the global system through agricultural commodity trade. In March 2008, he was named the 2008 Stockholm Water Prize Laureate for pioneering a concept that is an essential tool in

understanding and communicating water issues and how they are linked to agriculture, climate change, economics and politics.[4]

Many scientists have tried to put their own spin on the concept. In 2003, A.Y. Hoekstra (a scientist at the University of Twente in the Netherlands) expanded the definition of virtual water as being to denote the water used in the production process of an agricultural or industrial product, "including the water applied in the use and waste stages of the product."[5] He used this definition to calculate the Virtual Water Content (VWC) of various agricultural commodities and later did an extensive estimation of the Virtual Water transfers between nations.

Some definitions

***Virtual Water Content (VWC)*:** The virtual water content of a product (a commodity, good, service) is the volume of fresh water used to produce the product, measured at the place where the product was actually produced. It refers to the sum of the water used in the various steps of the production chain.[6] For example, the virtual water content of a live animal is the total volume of water that is used to grow and process its feed, to provide its drinking water, and to clean its housing and the like from birth to the end of its lifespan.[5] The virtual water content consists of all the different water components – blue, green, brown and gray water. Blue water is the visible water in streams, lakes and run-off; green water is the water in the biological bodies of vegetation; brown water is the water in the soil profiles, and gray water is the water polluted due to the production of the product. Table 1 lists the global average virtual water content of selected products, per unit of the product.

Table 1: The VWC of various products

Product	VWC (litres)
1 sheet of paper (80 g/m^2)	10
1 cup of tea (250 ml)	35
1 orange (100g)	50
1 apple (100g)	70
1 glass of beer (250 ml)	75
1 slice of bread (30 g) with cheese (10g)	90
1 glass of wine (125 ml)	120
1 egg (40g)	140
1 cup of coffee (125 ml)	140
1 glass of milk (200 ml)	200
1 hamburger (150g)	2,400
1 cotton T-shirt (250g)	2,700
1 pair of shoes (animal leather)	8,000

Source: Hoekstra & Chapagain, 2008 [6]

***Virtual Water Trade*:** Virtual water trade between two nations or regions is the volume of virtual water transferred from one place to another because of product trade. If a nation trades water-intensive products, it trades water in virtual form. In this way, some countries use their own water so that other countries can meet their water needs or conserve their own water. Since it is at present physically difficult to trade real quantities of water, countries that are water-scarce can import water-intensive commodities and offset their water demands for the product domestically. (When the term "virtual water trade" was introduced in 2002, it received criticisms from several economists claiming that the term is "misleading," because real things, not virtual things, are traded. Since then, the term "virtual water transfer" is used in some literature.)

***Water Footprint*:** Virtual water can be used in the calculation of "water footprint," which is analogous to the ecological footprint developed by Wackernagel and Rees in 1996. The "water footprint" of an individual or community is defined as the total volume of fresh water that is used to produce the goods and services consumed by the individual or community. The water footprint can be a strong tool to show people their impact on natural resources. Awareness of one's individual water footprint could stimulate a more careful use of water.

Consumptive vs Non-consumptive Water Use: Non-consumptive use (often simply referred to as water use) refers to water that is returned to the watershed. Consumptive use, or water consumption, is the measure of water that is not returned to its original source. Water-intensive production for domestic consumption therefore does not have the same impact as water-intensive production for export, although if it is contaminated with pollutants and returned to the watershed, it can pose a different set of problems. Once exported, water embedded in the product is removed entirely from the watershed.

Why is the concept of virtual water important?

When Allan envisioned the virtual water concept, he perceived it as an instrument to achieve water security through which water-scarce states could conserve domestic water by importing from water-rich states. He also promoted it as an instrument to achieve global water use efficiency[7]: If a water-intensive commodity is traded from an area where it is produced with high water productivity (resulting in products with low VWC) to an area with lower water productivity, there should be an associated global water saving, he suggested.

The reality is not as simple. On the whole, in practice, the virtual trade in water has not been about water-rich regions of the world providing water-intensive goods for water-scarce regions. According to a paper by Vijay Kumar and Sharad Jain in the Indian scientific journal *Current Science*, "analysis of country-level data on freshwater availability and net virtual water trade of 146 nations showed that a country's virtual water trade is not determined by its water situation."[8] In fact Kumar and Jain point out that often, virtual water is exported out of land-rich countries that are not necessarily water-rich. Hence Canada may be targeted not for its water resources but for its landmass.

However, Kumar, Jain, Allan and other analysts have paid little attention to the importance of power relations in international trade. Trade, virtual or real, takes place on an uneven playing field where a country's "success" in trade is often a reflection of its wealth and power. The nature of a country's export industry is more often than not determined by factors other than its ecological reality.

In a world with scarce water resources, the ability to import water-intensive products reflects an invisible source of power for states that are able to conserve domestic water resources by importing water-intensive products. Germany, for example is not a water-scarce country, but it is a net importer of virtual water. It leaves its water footprint in countries like Brazil, the Ivory Coast and India, from which it imports coffee, cotton and other goods.[9] The United Kingdom imports two-thirds of its water footprint. Saudi Arabia and Japan import most of their water footprint. Wealthy countries are able to maintain their water security by relying on countries from the Global South for water-intensive products. They see virtual water as an alternative source of water. Unlike bulk water exports which generally fuel public outrage, virtual water exports are a more covert form of water export that enable national leaders to avoid fuelling political unrest associated with water deficiency. "It prevents water crises from becoming water wars."[10]

Kenya, for example, is a top beneficiary of the United Nations World Food Programme while fertile land in the lake Naivasha region is used for industrial horticulture and floriculture farms which ship more than 88 million tons of cut flowers to European markets.[11] With no legal framework guiding their use of the lake, multinational farms dominate the area, leaving cattle herders and communities with very limited access to a small portion of Lake Naivasha. Massive amounts of water are shipped out of Kenya to European countries through this virtual water trade. As Severino Maitima, director of the Ewaso Ngiro River water authority, puts it: "The flower companies are exporting our water. A flower is 90 per cent water. We are one of the driest regions in the world and we are exporting water to one of the wettest."

The increased risk of environmental impact is significant in many exporting countries. Most recently, the interconnectedness between climate change and virtual water exports has been gaining media attention. As countries use water to grow commodities for export, they are, in effect, removing water from local watersheds, and hence, from the local hydrological cycle. Slovakian hydrologist Michal Kravcik explains that due to the "reduction of volume of soaked rainwater in the soil, and reduction of evaporation, a huge amount of heat accumulates in the atmosphere, overheating it and creating chaos in the atmosphere. As a result, extreme weather increases, bringing about more frequent and more extreme floods, droughts and related risks of water insufficiency, famine and conflicts, while endangering the food safety."[12]

VIRTUAL WATER CALCULATIONS FOR CANADA

The virtual water concept is an emerging field in the Canadian water management arena even though very little has been done to provide quantitative data on virtual water transfers between Canada and its trading partners. The table in Appendix 1 provides a chronological list of quantitative virtual water research work done based on Canadian agricultural data. Some of the highlights of research findings are provided below:

- Global estimates of virtual water flows during the period 1997-2001 amounted to 1,625 Bm^3/yr on average.[6] The major share (61 per cent) of the virtual water flows between countries was related to international trade in crops and crop products; trade in livestock products contributed 17 per cent and trade in industrial products was 22 per cent.
- On average, Canada exports 95.3 Bm^3/yr of virtual water in agricultural and industrial commodities. Imports amount to 35.4 Bm^3/yr. This makes Canada a net exporter of **59.9 Bm^3** of virtual water each year.[6] This amount is enough to fill the Rogers Centre in Toronto that has a volume of 1.6 Mm^3, approximately 37.5 thousand times.
- Canada ranks second after Australia as a net exporter and these exports consist mostly of cereals and livestock products.[6] Table 2 shows the virtual water flows from Canada compared with those of selected countries and the rest of the world. For detailed breakdowns, please see Appendix 2.

Table 2: Virtual Water flows from Canada and selected countries 1997-2001

(The net virtual water import of a country is equal to the gross virtual water import minus the gross virtual water export

Country	Gross VW flows (10^6 m^3/yr)		Net VW import (10^6 m^3/yr)	Per cent of VW lost as a result of trade
	Total export	Total import		
Canada	95,318	35,430	-59,888	62.8%
Australia	72,998	9,007	-63,991	87.7%
USA	229,303	175,811	-53,491	23.3%
World	1,624,319	1,624,319	-	-

Source: Hoekstra, A.Y., and Chapagain, A.K., 2008.

OVERVIEW OF CANADIAN AGRICULTURE

The agri-food system is a significant part of the Canadian economy. Since the 1970s Canadian agriculture and agri-food exports have commanded a three to four per cent share of the world's total food exports.[13] The U.S. is Canada's largest trading partner, accounting for over 60 per cent of Canada's total agriculture and agri-food export sales in 2005 compared with a 40 per cent share in 1990.[13] Much of this increase can be at-

tributed to the implementation of the CUSFTA and NAFTA, which have created a free trade zone between the Canadian-U.S. markets.

Grains and oilseeds are the largest export commodities, accounting for one-third of the total value of agriculture and agri-food exports, followed by livestock and meat products. Consumer products, including tropical fruits and vegetables, as well as coffee, tea and other products unavailable from domestic production, dominate imports.

Nationally, agriculture withdraws relatively small amounts of water (9 per cent) compared with thermal power generation (63 per cent) and manufacturing (16 per cent). However, it consumes almost 70 per cent of the total water withdrawn.[14] According to Statistics Canada, Alberta had the greatest share of irrigation water use, with 2,900 Mm^3, followed by British Columbia and Saskatchewan, in 2001.[15] The three western-most provinces constituted 95.9 per cent of total water used for irrigation.

Table 3: Total irrigation water use by province

Province	Irrigation Water Use (1000 m^3)	
	Total	Per cent
Canada	4,424,600	100.00
Newfoundland and Labrador	200	0.00
Prince Edward Island	1,400	0.03
Nova Scotia	5,400	0.12
New Brunswick	1,600	0.04
Quebec	49,000	1.11
Ontario	92,000	2.08
Manitoba	30,000	0.68
Saskatchewan	500,000	11.30
Alberta	2,900,000	65.54
British Columbia	845,000	19.10

Source: Statistics Canada, 2007b

Virtual Water in crop agriculture

Wheat is Canada's largest crop in terms of both area seeded and production, and is the single biggest export earner of all Canadian agricultural products. Canada is one of the top three high protein-milling wheat exporters on the planet, and a leading exporter of barley, rye and oats. Unfortunately, these grains are also those with the highest virtual water content compared to other crop commodities. Appendix 3a provides a comparative list of virtual water content of various crops in Canada based on studies by H. Schreier et al.[16] (2007) and Chapagain and Hoekstra[17] (2004). Canada was a *net* virtual water exporter after the United States, exporting **55 Bm^3/yr** of virtual water in crop trade alone during the 1995-1999 period, and **32.1 Bm^3/yr** during the 1997-2001 period. The decline in virtual water traded between the two periods was due to unfavourable grow-

ing conditions and a stronger Canadian dollar, and not due to decrease in demand for Canadian commodities.

Tables 4 and 5 show export statistics for the top four grain exports from Canada over the five-year period from 2005 to 2009. The virtual water transfer was calculated by simply multiplying trade volumes (measured in tonnes per year) with the virtual water content (in cubic metres per tonne) in the traded products.

$$VW\ transfer = T\ (tonnes/year) \times VWC\ (m^3/tonne)$$

On average, Canada exports **40.2 Bm^3/yr** of virtual water in wheat (25.6 Bm^3/yr), barley (11.9 Bm^3/yr), rye (2.5 Bm^3/yr) and oats (243.5 Mm^3/yr) alone. This amount is equivalent to twice the amount of discharge in the Athabasca River per year (24.7 Bm^3/yr).

Table 4: Export volume (tonnes) of the top five grains for Canada 2005-2009

	2005	2006	2007	2008	2009
Wheat	15,698,000	19,428,000	15,857,000	17,800,000	16,900,000
Barley	11,700,000	9,600,000	11,000,000	11,800,000	9,200,000
Oats	1,353,617	1,852,883	2,026,194	2,159,171	-
Rye	111,489	158,193	246,383	97,254	-

Source: Agriculture and Agri-food Canada, 2010

Table 5: Virtual Water flow from Canada in top four grain exports

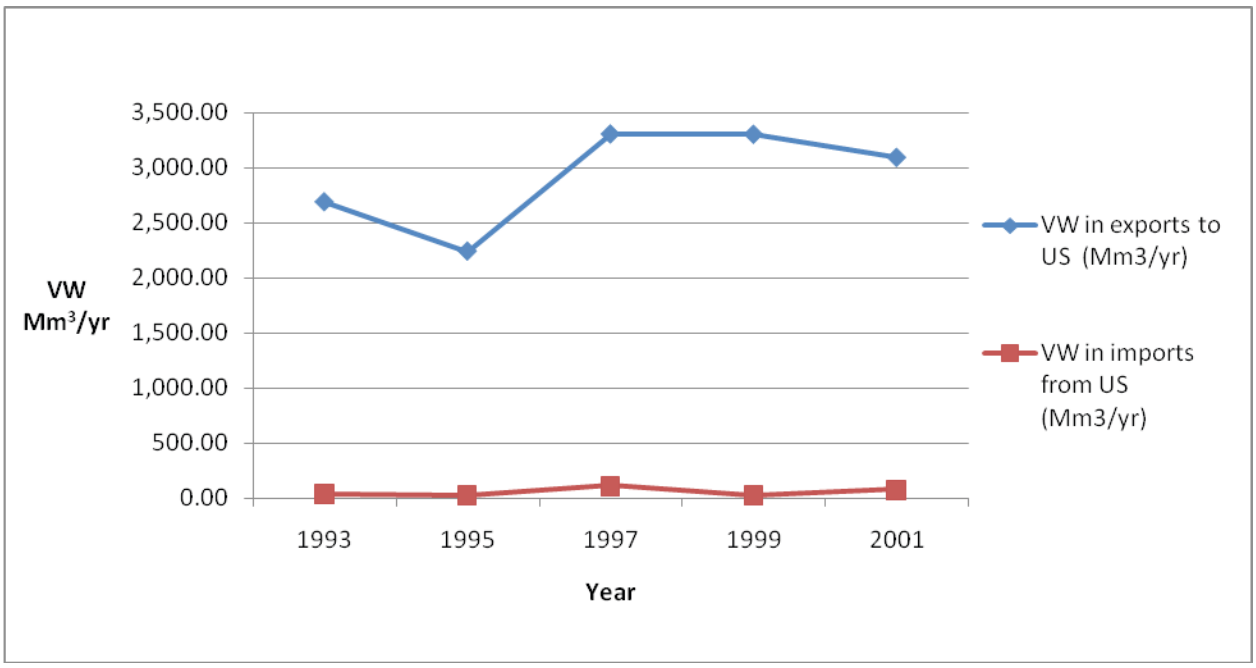
Type of Grain	VW in Exports (Mm^3)*					Total (Mm^3)	Avg.(Mm^3/yr)
	2005	2006	2007	2008	2009		
Wheat	23405.718	28967.148	23642.787	26539.800	25197.900	127753.35	25550.67
Barley	13104.0	10752.0	12320.0	13216.0	10304.0	59696	11939.20
Oats	1823.322	2495.833	2729.283	2908.403	-	9956.84	2489.21
Rye	177.044	251.210	391.256	154.439	-	973.95	243.49
Total						198380.15	40222.57

* Calculations based on Hoekstra, A.Y., and Hung, P.Q. (2002). VWC values for wheat, barley, oats and rye. Appendix 3c

The U.S. is Canada's leading trading partner in crop trade, followed by Japan, Algeria and Indonesia. Based on trade statistics[18], the U.S. receives almost 20 per cent of Canadian virtual water, followed by Japan at 8 per cent.

Comparing the export and import quantities of wheat between Canada and the U.S. from 1993 to 2003, it can be seen that Canada is a net exporter of virtual water. On average, there is a difference of **2.9 Bm^3** per year of virtual water from Canada to the U.S. Appendix 3 contains detailed calculations of the trade differences. Figure 1 shows the virtual water trade in wheat between Canada and the U.S.

Figure 1: Virtual water in trade of wheat between Canada and the U.S.



Virtual Water in animal agriculture

Animal production plays an important role in Canadian agriculture. In 2006, total livestock and poultry receipts amounted to CDN$17.960 billion of the total cash receipts of CDN$37.014 billion derived from agriculture.[13] The major sectors include beef, dairy, swine, sheep and poultry.

In livestock production, water is used for drinking, to clean facilities, sanitize equipment, and dilute manure.[14] From an animal's physiological perspective, water constitutes 50 to 80 per cent of the live weight of an animal and is very important for its growth and maintenance of body tissues, reproduction and lactation. The water intake of an animal depends on the species, physiological conditions and environmental factors. Table 6 highlights the average daily water requirements of various animal categories.

Table 6: Average daily water requirements of various animals

Animal Category	Types of Animal	Average Typical Water Use
Dairy Cattle	Milking cow	115 L/day
Beef Cattle	Feedlot cattle: short keep	41 L/day
Swine	Feeder pig (70-110 kg)	9 L/day
Horses	Medium weight (1000 lb.)	32.5 L/day
Sheep	Gestating meat ewe/ram	5.25 L/day
Chicken	Broiler chicken (winter, spring, fall)	280 L/1000 birds/day
	Broiler chicken (summer)	450 L/1000 birds/day

Adapted from OMAFRA, 2007[19]

To date, there have been *three* studies conducted to estimate the virtual water content of various animal categories for Canada (see Appendix 1 for details). The results from the estimation of virtual water content of various livestock categories are tabulated in Table 7. For a detailed list of virtual water content for various livestock and livestock products, see Appendix 3b.

Table 7: VWC of livestock categories as calculated by various authors

The tables indicate the VWC per animal measured in (i) cubic metres per animal and (ii) cubic metres per tonne of animal.

Livestock	VWC of a Live Animal in Canada (m^3/animal)	
	Chapagain and Hoesktra	Rahman, N.
Beef Cattle	5,252	2,746.4
Dairy Cattle	39,359	17,599.34
Swine	361	92.67
Sheep	276	151.41
Goats	152	-
Fowls/Poultry	5	3.74
Laying Hen	25	-
Horses	2,313	-

Livestock	VWC of a Live Animal (m^3/tonne)		
	Schreier, H. et al.	Chapagain and Hoesktra	
	Canada		Global
Beef Cattle	10,771	9,636	9,678
Dairy Cattle	55,302	86,693	94,642
Swine	3,280	3,276	2,819
Sheep	5,650	5,674	6,049
Goats	-	2,775	5,234
Fowls/Poultry	5,124	1,358	1,498
Laying Hen	-	9,563	9,529
Horses	-	5,567	5,455

Source: Chapagain and Hoekstra (2003);[5] Schreier, H., et al. (2007)[16] and Rahman, N. (2008)[20]

The virtual water content values for dairy cows (in m^3/animal and m^3/tonne) are very high compared to any of the live animal categories. However, a dairy cow has higher water productivity since it produces milk during its productive lifespan and meat after slaughter. Similarly, a laying hen produces eggs while it grows and meat at the end of its productive lifespan. The virtual water content (per tonne) of beef cattle is roughly six to seven times higher than a broiler chicken (poultry). It implies that a diet with white meat from a broiler chicken is more water-efficient than a diet with red meat from a beef cow. Swine is second most water-efficient in terms of water use per tonne of meat production.

According to Hoekstra and Chapagain (2008),[6] Canada exports 17,424 Mm^3/yr of virtual water in livestock and livestock products and imports only 4,952 Mm^3/yr. This makes Canada a net exporter of virtual water, leaving a deficit of **12,472 Mm^3** of virtual water every year. Most of Canada's livestock, however, end up across the border. According to Statistics Canada,[13] the United States receives almost 99 per cent of all of Canada's cattle and swine export share. The average difference in virtual water trade between the two countries has been calculated to be 3.6 Bm^3 per year,[20] with the U.S. being on the receiving end. This is because Canada exports mostly water-intensive commodities like cattle and cattle commodities while importing less water-intensive commodities such as chicken and mutton from the U.S. A comparison of average virtual water export and import values for different livestock categories and primary products between Canada and the U.S. for the period 1993-2006 is shown in Appendix 3d.

If net agricultural water export is taken to be the sum of net crop and livestock virtual water exports, then Canada's total export of virtual water through agriculture is **44.5 Bm^3/yr**.

AN OVERVIEW OF THE CANADIAN MINING INDUSTRY

Canada is one of the world's top producers and exporters of many minerals and mineral products. In 2006, the total value of mineral production (including metallic minerals, non-metallic minerals and coal) was $34 billion (91.6 per cent from non-fuel minerals and the rest from coal).[21] The leading metallic minerals are nickel, copper, iron ore, gold, zinc and uranium. Potash is the leading non-metallic mineral followed by cement, diamond, stone, sand and gravel. The majority of Canada's minerals come from Ontario and Quebec. They account for 46 per cent (ON) and 23 per cent (QC) of total exports in mining and mineral processing products.[22]

Water use in the mining industry

The mining industry is an extremely water-intensive industry and requires large volumes of water for extraction and concentration of metals and non-metal minerals, on-site processing, smelting and refining.[23]

Metal and non-metal mining: There is a lack of industry data on how much water is consumed in the different metal and non-metal sectors. However, the table in Appendix 4 shows Statistics Canada's (2005)[26] estimate of the total amount of water used per year in mineral extraction. Since the water removed from the environment ends up in tailings ponds or is discharged in a polluted state, it is safe to assume that the total amount of water used (gross water use) in the extraction and manufacturing process of minerals is the total amount of virtual water contained within it. Hence, Canada uses **2,516.6 Mm^3** or **2.5 Bm^3** of virtual water in the mining process every year. This figure might be an inflated estimate since most of the water is recycled in the extraction pro-

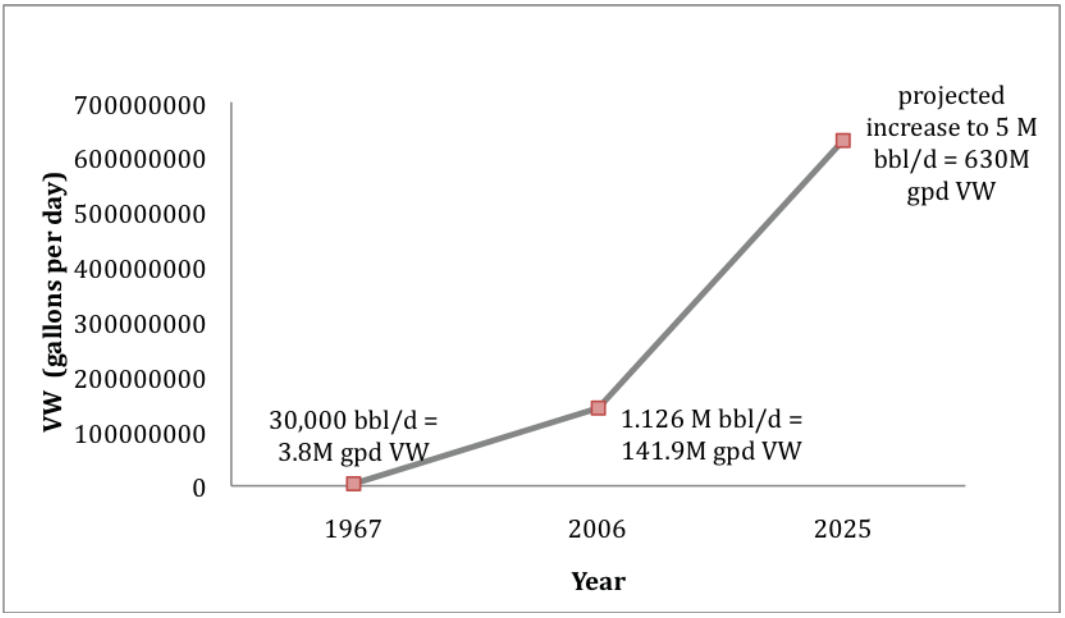
cess – it is nonetheless the best estimate given the discrepancies in discharge data and gaps in industry information.

According to Industry Canada, 74 per cent of all Canadian mineral and metals production is destined for export. This means that, on average, Canada exports 1.85 Bm^3 of virtual water to other countries. In 2008, the U.S. imported 58 per cent of Canadian metal and non-metal commodities including coal[22], or 1.1 Bm^3 of virtual water.

Perhaps the most talked-about extractive industry in Canada is the tar sands extraction operation in northern Alberta. Water is used in the tar sands to recover bitumen from the sand. Bitumen, deemed the world's most water-intensive hydrocarbon, consumes a net average of three barrels of water to produce each barrel of oil.[24, 25] There are two types of oil recovery from the oil sands – *open-pit* and *in situ*. In open-pit mining, large surface areas are excavated to remove dense bitumen mixed with sand, silt and clay. Hot water is then used to separate the oil from the mixture. What remains is a slurry of toxic, contaminated water known as tailings. According to Pembina Institute[26], a Canadian not-for-profit think tank, the industry produces 2,000-2,500 litres of tailings per barrel of bitumen. Given current levels of production, this equates to 1.8 billion litres of tailings every day. For in situ recovery, water is heated and converted to steam, which is then injected into underground reservoirs that contain bitumen. The bitumen is heated by the steam, which enables it to flow to a producing well. The two most common processes are cyclic steam simulation (CSS) and steam-assisted gravity drainage (SAGD). Industry spokespersons claim it takes about one barrel of water to produce four barrels of bitumen through SAGD, but many experts believe that the amount of water used is much higher.

Open-pit mines require 12 barrels of water to make one barrel of bitumen. Around 90 per cent of the water processed in the tar sands ends up as toxic tailings, which, in 2007, covered an area of approximately 50 km^2 (19 sq mi).[27] On average, after recycling of the water, production of one barrel of bitumen requires three barrels of fresh water.[24,25] Canada exports 1 million barrels of bitumen to the U.S. per day,[25,29] which is equal to **3 million barrels** or **478800 m^3** of virtual water per day (1 barrel = 42 gallons; 3 million barrels = 126 million gallons = 478800 m^3/day). By 2025, projected bitumen export quantities are expected to be 5 million barrels per day.[29]

Figure 2: Trend in virtual water use in oil sands industry



VIRTUAL WATER IN INDUSTRIAL PRODUCTS

So far, research has not been done to estimate the virtual water content of various industrial commodities. This is because statistics related to production and consumption of industrial products are hard to find, considering the numerous categories of products and the diverse range of production methods. According to Chapagain & Hoekstra (2008),[6] the global average virtual water content of industrial products is 80 L/USD$. In Canada, industrial products take only **10-15 L/USD$** compared to the U.S. at 100 L/USD$. They also estimated that Canada's virtual water exports of industrial products are approximately **29.6 Bm^3/yr**. Canada imports approximately 14.3 Bm^3/yr in virtual water through industrial products, making our net export 15.3 Bm^3/yr. Canada is therefore a net virtual water exporter in industrial products.

AREAS OF CONCERN

Canada's fresh water resources are grossly mismanaged. Due to neglect by successive governments, many water bodies are now on the verge of ecological disaster. In Quebec, blue-green algae caused by pollution plagues the St. Lawrence River, where the water levels are so low that water had to be pumped in from Lake Ontario in 2008. The Great Lakes Basin faces growing demand from industry, power plants, farms and urban sprawl. Water levels are at historic lows in some of the Great Lakes. On the Prairies, farmers have struggled with severe droughts over the past few decades.

Trade liberalization, facilitated by the two free trade agreements (CUSFTA and NAFTA) with the U.S., has increased production and consumption levels of commodities. This in turn has caused increased pressure on natural resources, especially water. Industrial and agricultural developments are occurring rapidly in areas where water is scarce. Alberta, Saskatchewan and Ontario are some of the areas trapped in an accelerating cycle of economic development placing pressure on water supplies. Unless the water issues are dealt with in these regions, there will very likely be severe water shortages in the future.

Alberta: Agriculture, Alberta's largest economic producer, is very water-intensive. Total irrigation water usage in Alberta amounts to just under 66 per cent of the national water use for irrigation. Seven per cent, or 3.9 Bm^3, is allocated for irrigation alone. In addition to irrigated agriculture, intensive livestock operations (ILOs) have doubled over the last 20 years. ILOs are extremely water-demanding operations and put significant pressure on water resources. According to a water use forecasting assessment by AMEC International[30], livestock populations and water demand will increase annually at rates of between 0.5 per cent and 2.2 per cent per year. In 2025, livestock water use is projected to increase by 46 per cent from 2005.

As well, the rate at which the Athabasca River supplies water for tar sands development in northeastern Alberta is alarming. As mentioned, according to conservative estimates, producing one barrel of bitumen from tar sands takes an average of three barrels of fresh water. The tar sands mines account for more than 76 per cent of the water allocations from the Athabasca River, or 8 per cent (359 Mm^3) of all water licensed in the province.[29] That is enough fresh water to sustain a city of two million people.[29] Current permits allow companies to extract 2.3 billion barrels of fresh water per year. Planned expansions could bring the total to 3.3. billion barrels per year.[25] The Athabasca and Peace Rivers are critical for ecological sustenance of the Peace-Athabasca Delta World Heritage Site at the rivers' confluence, which is home to several thousand aboriginal people.[31] Already summer flows in the river have declined by 30 per cent since 1970 due to climate change.[31] Over the long term, the Athabasca River may not be able to meet the needs of all planned mining operations and maintain adequate environmental flows.[32] Alberta has experienced a sharp population increase due to the rapid expansion in Alberta's tar sands–based petroleum industry. Some communities have grown by 15-40 per cent in the period of 1996-2001. Calgary and Edmonton now have more than 1 million people each.[31]

Saskatchewan: Most of the province's water demands are in the south but water resources are located in the north and southwest. There are concerns of drought, poor water quality and declining water tables. Worst affected is the South Saskatchewan River, where summer flows have been reduced by 84 per cent since the early 20th century.[31] The river's major tributaries (the Oldman, Bow and Red Deer rivers) have been subjected to multiple impoundments and large withdrawals for irrigation, municipal, and industrial use[31] that have caused significant deterioration of the quality and quantity of the water. With increasing demand for wheat and non-metal commodities, water shortages are imminent**.**

Ontario: Ontario has approximately 18 per cent of the total Canadian fresh water area and may seem to have abundant water wealth. However, a closer look reveals that there is enormous variability across the province in terms of quantity, quality and reliability of water. Ontario's rapid urban growth has increased the competition between agriculture and other sectors. Localized droughts have been reported almost every year somewhere in the province since 1960.[33] Run-off and other sources of contamination from agricultural operations often degrade surface and groundwater quality. In a survey done in 1992 on ground water quality, 34 per cent of all wells had high Coliform bacteria counts and 7 per cent contained nitrates and bacteria exceeding the maximum pollution standards.[14,34] As the market grows for Ontario's agricultural and industrial commodities, concerns over access to safe, clean and reliable water grow with it.

EMERGING TRENDS

Emerging trends in federal and provincial economic development strategies suggest that things are only going to get worse. Hydraulic fracturing and the practice of using lakes and rivers as dumpsites for metal mining companies are two examples of new ways in which Canada's water footprint will be further impacted.

Hydraulic fracturing

Hydraulic fracturing (also known as "fracking" or hydro-fracking) is a technique used to release oil and natural gas from conventional and unconventional sources. In order to extract natural gas from underground formations, a fluid made with water, sand and chemicals is injected at high pressure, which cracks open the formation and forces the gas up the well.

Hydraulic fracturing is used to extract shale gas in British Columbia, Saskatchewan and Alberta. The three provinces have promised to lower environmental standards and increase royalties to entice the natural gas industry. Massive shale developments are also being planned for Quebec, Nova Scotia and New Brunswick.

Hydraulic fracturing has a huge water footprint. Large amounts of water are required for hydraulic fracturing, particularly from shale. This water can come from municipal sources, surface or groundwater and often needs to be trucked in from elsewhere. Approximately 2 to 9 million gallons of water are required for a single "fracking" job because much of it becomes so contaminated it does not (or should not) return to the watershed. In some areas like Albuquerque, New Mexico, groundwater depletion from fracking has been so extreme that it has caused the land to collapse.

Lakes as mining dumpsites

Schedule 2 is a loophole in the Metal Mining Effluent Regulation (MMER) of the federal Fisheries Act that allows metal mining corporations to use lakes and rivers as toxic dumpsites. Once added to Schedule 2, healthy freshwater lakes lose all environmental protections.

The Liberal government first introduced Schedule 2 in 2002. At the time, environmental groups were told it was merely an administrative detail aimed at accounting for the lakes and rivers that had historically been used for mining waste. The Liberal government gave assurances that Schedule 2 would not be used for healthy bodies of water.

Then in 2006, under the Harper government, two lakes in Newfoundland and Labrador were approved for destruction using the MMER loophole and a precedent was set that would put the future of all lakes and rivers throughout the country in jeopardy. Since then, Environment Canada has released a list of 13 natural water bodies that mining corporations have applied to use as toxic dumpsites – or what the companies refer to as “tailings impoundment areas.” Five bodies of water have already been approved for destruction. If the trend of destroying entire bodies of water for mining projects continues, the water footprint of metal mining in Canada will grow tremendously.

WHY IS THE U.S. ON THE RECEIVING END OF CANADA’S VIRTUAL WATER?

Free trade agreements with the United States and Mexico (the Canada-U.S. Free Trade Agreement [CUSFTA] and North American Free Trade Agreement [NAFTA]) have substantially increased trade activity between Canada and the United States since their adoption in the late 1980s, and given competitive market forces a dominant role in determining trade flows between the countries. The U.S. remains Canada’s largest trading partner and as a result, receives the majority of Canada’s virtual water. NAFTA has also accelerated the consolidation of certain North American industries, ensuring that water used for production in Canada is guaranteed to the U.S. market in the form of virtual water exports. One example of this is the integration of the meat industry. Two American companies, Tyson and Cargill, control 95 per cent of Canada’s cattle industry and 70

per cent of all Canada's livestock industry; the remainder is controlled by a handful of other transnational companies such as Australian-based Ridley.

A similar consolidation has taken place in the energy sector where foreign companies, mostly American, now control more than 50 per cent of oil and gas production in Canada. As well, NAFTA's proportionality clause guaranteed the U.S. access to Canadian energy resources in perpetuity and required the deregulation of any and all regulations that protected Canadian energy for Canadians. As a result, 69 per cent of Canada's oil and 65 per cent of Canada's natural gas production is now exported to the United States, up from 33 per cent and 25 per cent respectively in 1985.

With these increased exports in livestock, energy and other commodities from Canada to the U.S. comes a dramatic increase in the trade of virtual water, which was never taken into account in the cost/benefit analyses done by government or industry.

Further, NAFTA's Chapter 11, the investor-state clause, lets U.S. and Mexican corporations with access to water resources in Canada sue the Canadian government if a province were to restrict water access to manage shortages. If the Alberta government were to impose limits on the water used by energy corporations in the tar sands, for example, the American companies operating there could sue the Canadian government for billions of dollars in compensation. Recently Chapter 11 was used by an American corporation that voluntarily pulled out of its Canadian operations but which claims rights to the natural resources used when they were in production. In October 2010, the Canadian government set a dangerous precedent by "compensating" U.S. pulp and paper giant AbitibiBowater $130 million after it claimed ownership of the water and timber rights from its now deserted Newfoundland operation. Chapter 11 gives American corporations operating in Canada superior access to Canadian water resources and puts Canada's water supplies in danger.

The NAFTA water debate has been in the public eye since the agreement's inception in 1994. However, most of the debate has centred on bulk water exports and bottled water, not on the less visible issue of virtual water exports. The hidden environmental costs of this increase in commodity trade have not been part of the debate, nor have they been taken into account in the pricing of these commodities. It is clear that a strategy to address unsustainable virtual water exports needs to take into consideration the international trade agreements that set the conditions for these exports.

NAFTA's mandate to expand trade and investment through the removal of all trade barriers between the two countries is encouraging increased virtual water trade. Virtual water trade will also increase trade in commodities if the Canada-EU Comprehensive Economic and Trade Agreement, which is now being negotiated between the two governments, is ratified.

More than a catalyst for increasing demand for Canadian commodities, NAFTA and other free trade agreements have protected the rights of investors and forced a level of production that has undermined the capacity of Canadian governments to protect Canada's water heritage.

CONCLUSION

Over the past few decades, the Canadian government has pursued a trade and development agenda that has put our country's water resources at risk.

Although Canada is home to approximately 6.5 per cent of the world's fresh water, much of it is unevenly distributed across a vast landscape and many watersheds are under great stress. While policymakers have placed much emphasis on household water consumption, attention has not been paid to water-intensive industries that have led to water shortages and contamination.

Large amounts of water are being displaced through the virtual trade in water. While we are not calling for an end to all virtual water trade, a better understanding of how much water is lost through the export of virtual water, and the stress that is placed on watersheds used for export production, will hopefully lead to better water management policies.

In the last few years there has been a growing recognition of water scarcity in Canada, but little analysis of its causes. This preliminary analysis of the virtual water trade sheds some light on one of the contributing factors to this crisis, which has already extensively been documented by environmental NGOs and government departments alike.

Globally, Canada is a net virtual water exporter, which means that it trades more virtual water than it brings into the country. Exports of water-intensive commodities, such as wheat, cattle and bitumen, have resulted in Canada having a deficit of an average of **59.9 Bm^3** of virtual water each year. This amount is enough to fill the Rogers Centre in Toronto, which has a volume of 1.6 Mm^3, approximately 37.5 thousand times. Moreover, most of the virtual water is ending up across the border. The U.S. is able to offset its water requirements by exporting water-intensive commodities from Canada while importing less water-intensive commodities, causing an imbalance of trade.

Limitations of virtual water trade as a policy tool

While being an important tool in demonstrating the impacts of trade on water resources in Canada, virtual water calculations are only one piece of the puzzle when it comes to addressing water shortages in Canada. Their limitations include a failure to account for localized impacts on watersheds. While providing an overview of the quantities of water being traded, the virtual water content does not indicate the environmental impact on a local watershed.

Virtual water calculations also fail to account for water quality issues and social impacts of water consumption, which are important to consider in water policy decisions.

It's time for Canada to put virtual water on the political agenda by:

1. **Completing a comprehensive study on virtual water:** While this paper provides a general overview, a more comprehensive study on virtual water transfers needs to be conducted by the government of Canada to determine the extent of trade impacts on Canada's water resources.

2. **Establishing public trust legislation:** Local ecological needs and public interests must be prioritized in decisions regarding water allocation through public trust legislation. The declaration of surface and groundwater as a public trust will require the government to protect water for the public's reasonable use. Under a public trust doctrine, private water use would be subservient to the public interest. Permission to extract groundwater under the public trust doctrine, for example, might be granted based on the ability to show public benefit for any proposed extraction. It may also lead to the creation of a hierarchy of use requiring that water use be allocated for ecosystems and basic human needs first, and not corporate needs such as large-scale industrial projects such as fracking or by bottled water companies.

3. **Excluding water from NAFTA and all future trade agreements:**
In 2007, a motion was passed in the House of Commons calling on the government to enter into negotiations with other NAFTA parties to have water excluded from the trade agreement. Beyond the threat of bulk water exports, NAFTA protects the rights of foreign investors to consume vast and unsustainable amounts of water to extract bitumen from the tar sands, to bottle ancient glacier water and groundwater, and to dump their waste into lakes. Before the Canadian government can sustainably manage virtual water exports based on the availability of water resources, NAFTA provisions that limit exports or the rights of governments to manage water resources must be re-examined and renegotiated.

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APPENDIX 1

This table provides a chronological list of research on virtual water for Canada including a summary of research findings

Year	Summary of findings
2002	Hoekstra, A.Y. and Hung, P.Q. (2002) 'Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade', Value of Water Research Report Series No. 11, UNESCO-IHE, Delft, the Netherlands. The first global virtual water study was done by Hoekstra and Hung from the UNESCO-IHE Institute for Water Education in Delft, Netherlands. The objective of the study was to quantify the volumes of all virtual water flows between nations in relation to international crop trade (of 38 primary crops) in the period 1995-1999. The study found that Canada was the second net virtual water exporter after the United States, exporting **272.5 Gm^3/yr** of virtual water in crop trade alone.
2003	Chapagain, A.K. and Hoekstra, A.Y. (2003) 'Virtual water flows between nations in relation to trade in livestock and livestock products', Value of Water Research Report Series No. 13, UNESCO-IHE, Delft, the Netherlands. Complementary to the virtual water study done in 2002, Hoekstra and Chapagain developed a methodology to assess the virtual water content of various types of livestock and livestock products and to quantify the virtual water flows related to the international trade in livestock and its products from 1995 to 1999. Detailed calculations of the virtual water content of various livestock and livestock products from the Canadian livestock sector had been the highlight in the study. The study concluded that Canada is the fourth major net virtual water exporter after USA, Australia and New Zealand, exporting **11.8 Bm^3/yr** of virtual water in its livestock and livestock products. Overall, Canada ranks third in the virtual water transfer of agricultural products, after USA and Australia.
2004	Chapagain, A.K. and Hoekstra, A.Y. (2004) 'Water footprints of nations' Value of Water Research Report Series No. 16, vols. 1 and 2, UNESCO-IHE, Delft, the Netherlands. In this report, the authors used their methodologies devised in earlier reports to produce a comprehensive study on international virtual water flows for the period 1997-2001, covering trade in crop, livestock and industrial products. The study found that Canada is the second net exporter of virtual water (**59.9 Bm^3/yr**) after Australia and this export is mostly connected to the export of cereals and livestock products. The report also looked at the water footprint of nations, Canada's being among the top of the list at 2049 m^3/cap/yr. The results of the report was later published in the form of a book titled "Globalization of water: Sharing the planet's freshwater resources"in 2008.

Year	Summary of findings
2007	Schreier, H., L. Lavkulich and S. Brown. 2007. Real and virtual water and water footprints: A comparison between the Lower Fraser Valley and the Okanagan Basin. For Walter and Duncan Gordon Foundation, Toronto, 32 pp. This report, compiled by a group of researchers at the University of British Columbia, contains calculations on the virtual water content of various crops and animals based on regional and local data. The study evaluated the water use and virtual water needs between the driest and wettest watersheds in Canada – Okanagan Basin (OK) and the Lower Fraser Valley (LFV). The study found that there are large differences in VWC between the locally calibrated data and the global and national calculations. They concluded that the VWC calculations are highly sensitive to local conditions, and locally collected data need to be used for any decision-making process.
2008	Rahman, N. (2008). NAFTA and Virtual Water Trade: An estimation of virtual water trade in livestock and livestock products between Canada and the United States. Unpublished M. Envtl. St. thesis, University of Waterloo, Waterloo, Ontario. This is the first study to examine the implications of the North American Free Trade Agreement (NAFTA) on Canadian water resources due to the trade of livestock and livestock products between Canada and the U.S. The results found that Canada is a net exporter of virtual water to the U.S, transferring on average **3.6 Bm^3/yr** of virtual water in water-intensive commodities like cattle and cattle commodities.

APPENDIX 2

Virtual Water flows per country related to international trade in crop, livestock and industrial products for the period of 1997-2001

Country	Gross VW flows (10^6 m^3/yr)								Net VW import (10^6 m^3/yr)			
	Related to trade in crop products		Related to trade in livestock products		Related to trade in industrial products		Total		Related to trade in crop products	Related to trade in livestock products	Related to trade in industrial products	Total
	Export	Import	Export	Import	Export	Import	Export	Import				
Canada	48,321	16,190	17,424	4,952	29,573	14,289	95,318	35,430	-32,132	-12,472	-15,284	-59,888
Australia	46,120	3,864	26,377	745	501	4,399	72,998	9,007	-42,256	-25,633	3,898	-63,991
USA	134,623	73,129	35,484	32,919	59,195	69,763	229,303	175,811	-61,495	-2,564	-10,568	-53,491
World	9,86,259	9,86,259	276,222	276,222	361,838	361,838	1,624,319	1,624,319	0	0	0	0

Source: Hoekstra, A.Y. and Chapagain, A.K. (2008)

APPENDIX 3

Appendix 3a: VWC (m^3/tonne) of selected grains, vegetables and fruits for Canada.

Primary Crop	Lower Fraser Valley	Okanagan Valley	Canada	Global
Grains/Field Crops and Vegetables				
Wheat	1345	1674	1491	1334
Barley	-	1512	1120	1388
Maize	84	105	353	909
Rye	1195	1102	1588	901
Oats	1448	1803	1347	1597
Mixed Grain	1345	1674	826	1105
Potatoes	264	109	106	255
Maize for Forage + Silage	84	105	84	636
Cabbages	221	118	147	211
Asparagus	-	-	1524	1473
Lettuce	427	109	61	133
Spinach	627	424	148	144
Tomatoes	200	282	39	184
Cauliflower	168	648	169	159
Pumpkins, Squash, Gourds	192	151	122	234
Cucumbers and Gherkins	195	284	59	242
Chillies & Peppers, Green	515	678	120	323
Onions, Dry	53	275	72	346
Beans, Green	217	468	319	359
Peas, Green	431	765	532	343
Carrots	106	222	16	131
Green Corn (Maize)	513	593	346	509
Fruits				
Apples	204	310	169	697
Pears	-	308	287	727
Apricots	-	2497	444	1391
Sour Cherries	-	980	476	1343
Cherries	-	1534	602	1543
Peaches and Nectarines	-	1093	288	1194
Plums	-	1300	614	1612
Strawberries	594	379	362	276
Raspberries	982	934	485	713
Blueberries	722	-	456	395
Cranberries	165	-	65	152
Grapes	870	787	287	655

Source: Chapagain, A.K. and Hoekstra, A.Y. (2004) and Schreier, H. *et al.* (2007)

Appendix 3b: VWC (m^3/tonne) of selected livestock and livestock products (1997-2001)

Livestock and Livestock Products	VWC
Horses, live pure-bred breeding	3274
Asses, mules and hinnies, live	3274
Bovine, live pure-bred breeding	6355
Bovine, live except pure-bred breeding	6355
Swine, live pure-bred breeding	4159
Swine, live except pure-bred breeding weighing less than 50 kg	4159
Swine, live except pure-bred breeding weighing 50 kg or more	4159
Sheep, live	2965
Goats, live	1826
Fowls, live domestic weighing not more than 185 g	1835
Poultry, live except domestic fowls, weighing not more than 185 g	1835
Poultry, live except domestic fowls, weighing more than 185 g	1835
Bovine carcasses and half carcasses, fresh or chilled	10069
Bovine cuts bone in, fresh or chilled	10069
Bovine cuts boneless, fresh or chilled	14184
Swine carcasses and half carcasses, fresh or chilled	4441
Hams, shoulders and cuts thereof, of swine bone in, fresh or chilled	5770
Swine cuts, fresh or chilled, nes	6086
Lamb carcasses and half carcasses, fresh or chilled	3254
Sheep carcasses and half carcasses, fresh or chilled	4666
Sheep cuts, bone in, fresh or chilled	4671
Sheep cuts, boneless, fresh or chilled	5845
Milk not concentrated and unsweetened not exceeding 1per cent fat	691
Milk not concentrated & unsweetened exceeding 1per cent not exceeding 6 per cent fat	714
Milk and cream not concentrated and unsweetened exceeding 6 per cent fat	1286
Yogurt concentrated, not sweetened, not flavored or containing fruit or cocoa	804
Cheese, fresh (including whey cheese) unfermented, and curd	2161
Eggs, bird, in shell, fresh, preserved or cooked	1496

Source: Chapagain, A.K. and Hoekstra, A.Y. (2003)

Appendix 3c: VW trade in wheat trade between Canada and the U.S.

	1993	1995	1997	1999	2001	Average
Canada exports to US (tonnes)	1,802,000	1,501,000	2,216,000	2,214,000	2,073,000	
VW in exports to US (Mm^3/yr)	2,686.78	2,237.99	3,304.06	3,301.07	3,090.84	
Canada imports from US (tonnes)	26,000	18,000	75,000	17,000	52,000	
VW in imports from US (Mm^3/yr)	38.77	26.84	111.83	25.35	77.53	
Difference in VW trade (Mm^3/yr)	2,648.02	2,211.15	3,192.23	3,275.73	3,013.31	2,868.09

VWC=1491 m^3/tonne

Sources: Chapagain, A.K. and Hoekstra, A.Y. (2004); Hufbauer, G. C., & Schott, J. J. (2005)

Appendix 3d: Comparison of average (1993-2006) virtual water export and import values for different livestock category and primary products between Canada and U.S.

Livestock Category	Avg. VW Export	Avg. VW Import	Difference	Avg. Ratio of Trade
	m^3	m^3	m^3	
Beef Cattle	2.7 B	30 M	+ 2.5 B	17
Dairy Cattle	610 M	70 M	+ 540 M	26
Swine	440 M	0.3 M	+ 440 M	3400
Sheep and Lamb	6.8 M	1.5 M	+ 5.3 M	40
Broiler Chicken	1.8 M	61.8 M	- 60 M	61
Beef	680 M	150 M	+ 530 M	7
Pork	106 M	13 M	+ 93 M	10
Mutton	129 T	470 T	- 340 T	31
Chicken Meat	14 M	100 M	-86 M	11
Milk	4 M	2.3 M	+ 1.6 M	37

Conclusion: Canada is a net exporter of virtual water to the United States.

Overall, Canada exports more livestock and livestock commodities than it imports from the U.S. The difference in the VW trade is 3.6 billion m^3/year.

Source: Adapted from Rahman, N. (2008)

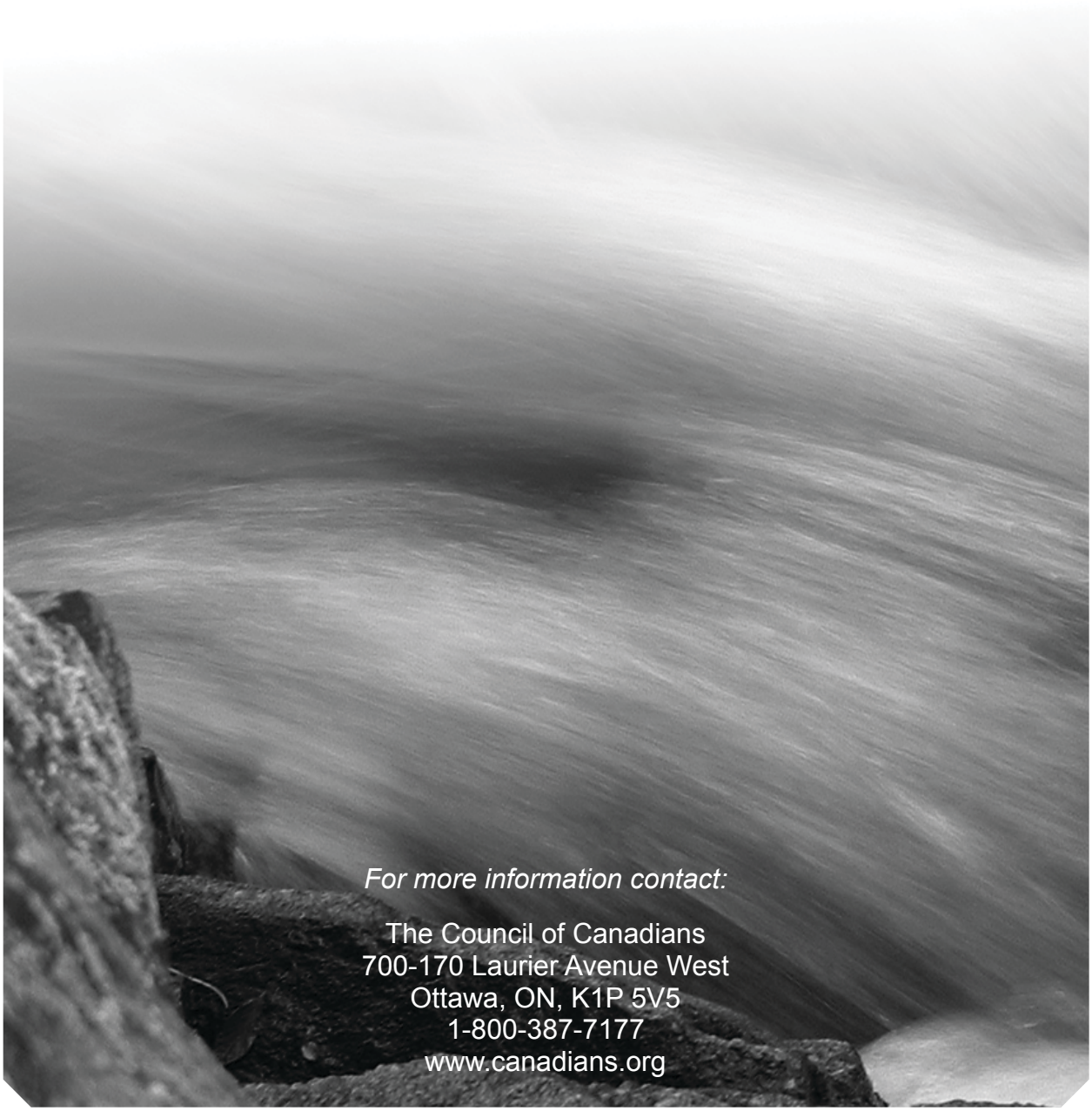
APPENDIX 4

Selected characteristics of water use in mineral extraction industries, by water use parameter and industry group and region, 2005

	Intake		Recycle		Recycle rate[1]	Gross water use[2]		Discharge		Mine water
	millions m^3	%	millions m^3	%		millions m^3	%	millions m^3	%	millions m^3
Industry group										
Metal mines	346.6	75.5	x	x	x	x	x	448.4	71.1	110.0
Non-metal mines [3]	x	x	x	x	185.1	247.8	9.8	148.3	23.5	x
Coal mines	x	x	x	x	50.3	x	x	33.8	5.4	x
Total	**458.9**	**100.0**	**2,057.7**	**100.0**	**448.4**	**2,516.6**	**100.0**	**630.6**	**100.0**	**216.0**
Region										
Atlantic	x	x	x	x	21.9	310.3	12.3	273.9	43.4	62.3
Quebec	24.2	5.3	x	x	x	x	x	105.3	16.7	45.2
Ontario	42.7	9.3	x	x	x	x	x	114.5	18.2	64.1
Prairies	x	x	x	x	148.2	x	x	76.9	12.2	21.3
British Columbia and territories	62.1	13.5	148.2	7.2	238.7	210.3	8.4	60.0	9.5	23.2
Total	**458.9**	**100.0**	**2,057.7**	**100.0**	**448.4**	**2,516.6**	**100.0**	**630.6**	**100.0**	**216.0**

1. Recycle rate = Amount of recycled water as a per cent of intake. The same water can leave a sub-system and re-enter it or is used in another sub-system many times, resulting in a recycle rate > 100 per cent.
2. Gross water use = Intake + Recycle.
3. Excluding sand, gravel, clay, and ceramic and refractory minerals mining and quarrying.

Source: Statistics Canada, Industrial Water Use (2005)



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