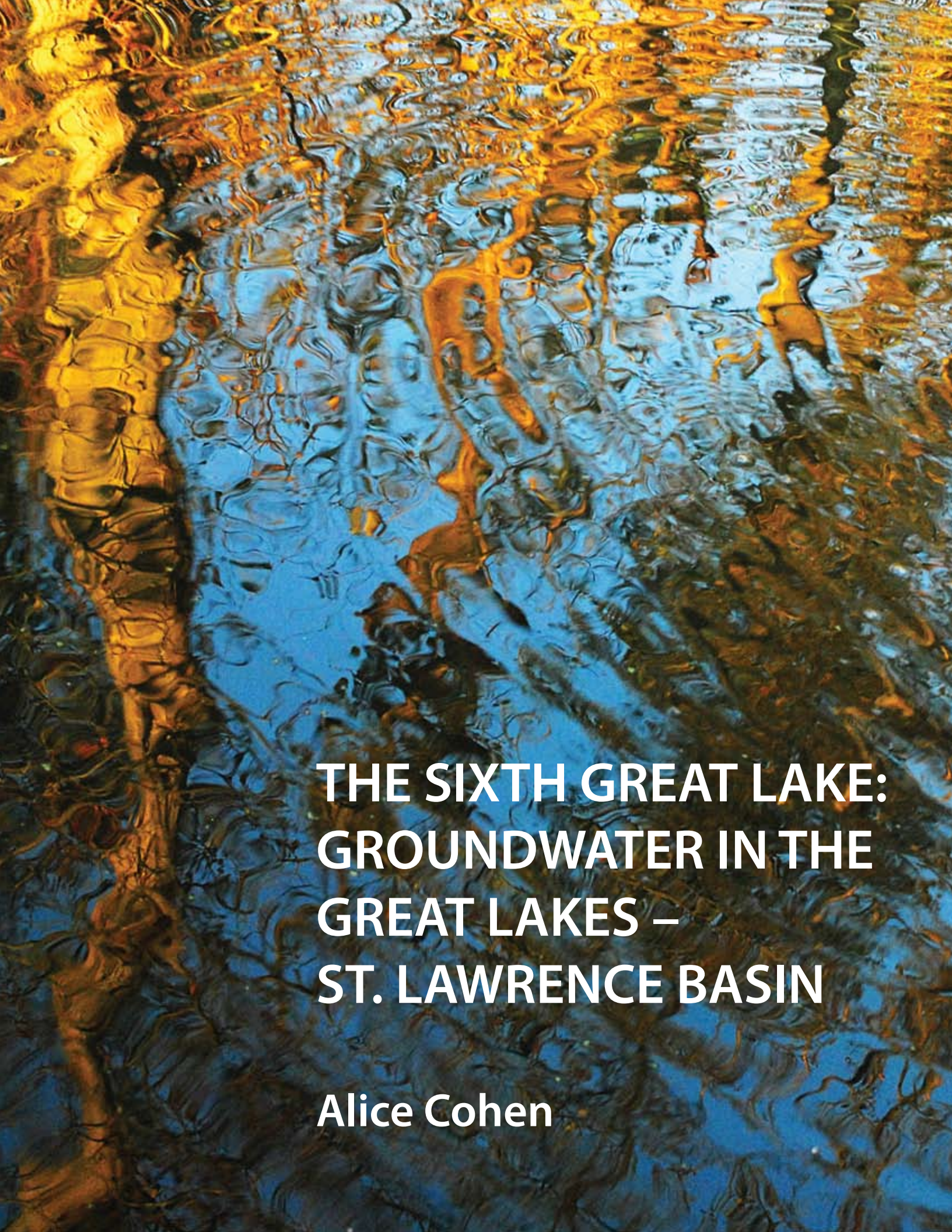

THE SIXTH GREAT LAKE: GROUNDWATER IN THE GREAT LAKES – ST. LAWRENCE BASIN

Alice Cohen

Acknowledgements

The author gratefully acknowledges the financial support through the Water Policy Fellowship program at the Walter and Duncan Gordon foundation, as well as the support of the Sierra Club of Canada, the Program on Water Governance at the University of British Columbia, and the time and expertise of those who were consulted.

About the Author

Alice Cohen is a PhD Student in Resource Management and Environmental Studies at the University of British Columbia.

April 2009

Table of Contents

EXECUTIVE SUMMARY

Background and Current Legislation

This report provides a 'snapshot' of the current state of groundwater management in the Ontario portion of the Great Lakes – St. Lawrence River Basin ('the basin'). It serves as a primer on groundwater in the basin, an introduction to legislative frameworks in the basin, and offers recommendations for future action. Research for this report included consultations with experts at Federal and Provincial government agencies as well as experts outside of government.

Addressing groundwater issues in the basin is critical, as the volume of groundwater in the system is approximately equivalent to Lake Michigan (4168km3) and is a significant contributor to surface water supply in the Great Lakes. Further, groundwater provides drinking water for many communities in the basin, recharges the basin's streams and rivers (many of which flow into the lakes), as well as the lakes themselves, and contributes to fish habitat.

Current legislation and agreements most pertinent to groundwater in the Ontario portion of the basin are explored in this primer. These pieces of legislation are: the Boundary Waters Treaty (1909), the Great Lakes Water Quality Agreement (last amended 1987), the Great Lakes Charter (1985), the Great Lakes Charter Annex Agreement (2005), Ontario's Permit to Take Water regulations (last amended 2005), Ontario's *Clean Water Act* (2006), and the subsequent Source Water Protection Plans.

Each of these pieces of legislation is examined from a groundwater perspective, which is then overlaid onto existing knowledge of the basin's hydrogeology and community needs in order to present an overall picture of the state of groundwater in the basin. This overall picture suggests that the three central challenges to effective groundwater management in the basin are: 1. limited knowledge and understanding of groundwater flows in the basin; 2. population growth and its associated increase in groundwater use in the Ontario portion of the basin, and; 3. lack of coordination between responsible agencies.

Recommendations

Targeted recommendations include:

- The creation of an overall groundwater strategy by the Ontario Ministry of the Environment (MOE) for the province, offering coordination of multiple threads of groundwater legislation in the basin;

- Coordinated groundwater mapping carried out to meet agreed upon criteria, including vulnerability mapping, recharge area mapping, and identification of groundwater outflow areas into critical fish habitat;

- Increased coordination, where needed, between land-use planners, municipal groundwater studies, and provincial agencies;

- Increased transparency by making available existing groundwater data and publicizing existing efforts, and;
- Explicit inclusion of groundwater in the upcoming renegotiation of the Great Lakes Water Quality Agreement.

LIST OF ACRONYMS

BWT – Boundary Waters Treaty (signed 1909)

GLC – Great Lakes Charter (1985)

GLCAA – Great Lakes Charter Annex Agreement (2001, signed by Ontario 2005)

GLFC – Great Lakes Fishery Commission (established 1955)

GLWQA – Great Lakes Water Quality Agreement (1972, revised and updated 1978 and 1987)

IJC – International Joint Commission

NRCan – Natural Resources Canada

PTTW – Permit to take water

SWPP – Source Water Protection Plan

1. Introduction

This document discusses groundwater in the Ontario portion of the Great Lakes-St. Lawrence river basin ('the basin') – one of the most pressing groundwater management challenges in Canada. The volume of groundwater in the system is approximately equivalent to Lake Michigan (4168km3) and is a significant contributor to surface water supply in the Great Lakes.[1] The report focuses on the Canadian side of the basin, and, more specifically, on the Ontario portion of the Canadian side.

The aims of this report are:

1. To provide basic background information on the role of groundwater in the basin;
2. To present a 'snapshot' of the current state of groundwater knowledge and policy in the Canadian (and specifically Ontario) side of the basin;
3. To overlay this 'snapshot' onto the current legislative framework for groundwater in Ontario in order to:
4. To identify challenges and gaps in the management of groundwater in the Ontario portion of the basin, and;
5. To suggest constructive ways to fill these gaps.

In meeting these aims, this report provides background information about groundwater in the Great Lakes, including basic hydrogeology and a list of existing groundwater-relevant legislation in the basin. The subsequent sections of the report are organized from the top down – from the International Joint Commission (IJC) through to the national and provincial levels. The final section of the report explores central challenges in the basin and offers constructive suggestions as to how these challenges could be addressed.

1 Grannemann et. al. 2000

2. Background

A. Basic Hydrogeology in the Basin

Although this report focuses on groundwater in the basin, it is important to emphasize that groundwater and surface water are inextricably linked.

The Great Lakes-St. Lawrence River Basin comprises the largest concentration of unfrozen fresh surface water in the western hemisphere,[2] about 5,500 cubic miles or 23,000 km3 of water – a magnitude that is difficult to comprehend and which is estimated to be between 18-20% of the world's total fresh surface-water supply.[3] No other basin in the world consists of such a continuous chain of large lakes.[4] In addition to the Great Lakes, there are over 80,000 smaller lakes[5], thousands of rivers and streams that flow into the them, and a considerable ground water system, estimated to be roughly the size of Lake Michigan (more than 1,000 mi3 of water).[6]

Groundwater (water that has infiltrated the soil and is located underground) accumulates as a result of rainfall, snowmelt, or runoff. Once underground, the water moves horizontally and vertically through the pores and cracks in the rock in a process that is referred to as "groundwater flow". The rate of groundwater flow depends on a number of factors including temperature, slope, porosity of soil, and whether the aquifer is unconfined (has no impediment preventing direct recharge from waters percolating downwards) or confined (has an impermeable layer of rock or sediment that essentially 'blocks' the path of water that percolates downwards).

2 Grannemann et al. 2000, 1
3 USEPA and Government of Canada 1995
4 Colborn 1990, 1
5 These lakes cover an area about the size of Lake Erie (Ibid, 1).
6 Supra note 2, 1

Groundwater rarely stays stationary in aquifers; it moves along flow paths due to gravity or pressure. As it moves along flow paths, it attempts to find its way to the surface, which then results in a spring or upwelling in streams or lakes. The time between which water percolates down into an aquifer and when it is discharged into a spring, river, or lake can be as short as a few weeks, or as long as hundreds – or in some cases thousands – of years. Or, in the case of 'fossil groundwater' (groundwater in a desert), the aquifer may not recharge at all. Surface water, if it does not evaporate or get taken up by plants, is just as apt to enter the ground water system and percolate downwards as far as gravity, soil and rock conditions will allow. Some water also runs along the earth' surface and into streams, lakes or oceans, this is referred to as 'runoff'. Consequently, it should be recognized that much (perhaps as much as half[7]) of the water within a basin has actually come from the ground. Rather than being treated separately, the terms "ground water" and "surface water" should therefore be regarded as deeply interconnected.

Exactly how groundwater interacts with surface water in the Great Lakes is still under investigation. What we do know, however, is that ground water makes up a significant percentage of inflow to the Great Lakes. Ground water enters the Great Lakes both directly, through the banks and the base of the lakes ("direct ground water discharge"), and also indirectly through streams and rivers that then flow into the Great Lakes ("indirect ground water discharge").[8] For example, one study shows that groundwater accounts for 67% of the stream flow of the rivers and streams running into the great lakes on the US side. The contribution of groundwater to these rivers and streams is particularly important during times of low precipitation or drought, because groundwater can provide water to streams long after surface water inflow (precipitation and runoff) has ceased. [9]

B. Agreements Governing Groundwater in the Basin

A number of agreements, treaties, and programs govern the way in which groundwater is managed in the basin. Listed below are those agreements that explicitly address groundwater in the Ontario portion of the basin.

- The Boundary Waters Treaty (1909) governs waters shared between Canada and the United States. Although the treaty makes no explicit mention of groundwater, the International Joint Commission (the organization created through the treaty) has since stated that it considers groundwater within its mandate.
- The Great Lakes Water Quality Agreement (1972, updated in 1978 and 1987) is focused on monitoring and reducing the flow of contaminated groundwater into the Great Lakes.
- The Great Lakes Charter (1985) limits diversion of over 19 million litres per 30-day period for both surface and ground waters.
- The Great Lakes Charter Annex Agreement (2001, signed by Ontario in 2005) aims to "conserve the levels and flows of the Great Lakes and their tributary and connecting waters" and speaks explicitly to the basin's groundwater.
- Ontario's Permit to Take Water program (last amended 2007), governed under the Ontario Water Resources Act

7 Personal Communication February 2008
8 Grannemann et al. 2000
9 Galloway and Pentland 2005; Hotlschag and Nicholas 1998

and administered through the Ontario Ministry of Environment, governs groundwater allocation throughout Ontario, including in the basin.

- Ontario's *Clean Water Act* (2006) and its associated Source Water Protection Plans (SWPPs) are designed to protect drinking water. Where a community's drinking water is groundwater, it can be protected through this legislation.

3. The Federal Role and Groundwater in the Basin

A. The Boundary Waters Treaty and the International Joint Commission

In 1909, Canada and the United States signed the Boundary Waters Treaty (BWT), which sets out a framework for managing boundary and transboundary waters along and across the Canada-US border. The International Joint Commission (IJC) was created as part of the BWT framework and is the bi-national body responsible for the resolution of boundary and transboundary water disputes. Although IJC dispute resolution recommendations are not binding, the BWT's signatory parties have implemented the overwhelming majority of their recommendations.

Though progressive for its time, the BWT neglected to include groundwater in its mandate; according to the BWT, boundary and transboundary waters are:

> "the waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and the Dominion of Canada passes, including all bays, arms, and inlets thereof, but not including tributary waters which in their natural channels would flow into such lakes, rivers, and waterways, or waters flowing from such lakes, rivers, and waterways, or the waters of rivers flowing across the boundary".[10]

Further, the 1978 version of the Great Lakes Water Quality Agreement (discussed in greater detail below) – written under the authority of the IJC – does not mention groundwater.

However, despite this apparent omission, the IJC has, more recently, indicated its willingness to undertake groundwater activities. For example, the committee's 1997 report "The IJC and the 21st Century" recommends undertaking studies to better understand water supply and demand, suggesting that the study of "the effects of climate change on surface and groundwater and water demand" and "the effects of population growth and urbanization on the demand, use, and quality of surface and groundwater" are critical to determining existing supply and demand scenarios.[11] In another example, a 2004 IJC report recommends that "Governments should immediately take steps to enhance groundwater research in order to better understand the role of groundwater in the Great Lakes Basin".[12]

Thus, the IJC has an important role, as it is a bi-national institution to which both countries can report concerns with respect to shared groundwater resources – which of course includes the Great Lakes. In addition to the IJC, other federal departments and agencies are also involved in water in the Great Lakes, as detailed below.

10 BWT 1909, preliminary article
11 IJC 1997, 33
12 IJC 2004

B. Federal Jurisdiction Over Fish Protection

Another area over which the federal government has jurisdiction, beyond the IJC, is coastal and inland fisheries. The connections between fish and groundwater, as well as how these play out with respect to the legislation, are outlined below.

i) How is groundwater quantity related to fish?

Groundwater quantity plays three significant roles with respect to fish.

First, groundwater is an important source of recharge to the lakes, helping to keep lake levels stable when other sources of recharge (such as precipitation and surface runoff) fluctuate. This groundwater flow into surface waters is referred to as 'baseflow'. Groundwater withdrawals may therefore affect lake levels, which in turn may affect fish. The contributions of groundwater to water levels in the Great Lakes have been documented both historically[13] and more recently[14], suggesting that groundwater contributes between 48% and 79% of total water recharge to the lakes (Lake Erie and Lake Michigan, respectively). Indeed, groundwater not only recharges the lakes directly, but also feeds the streams that flow into the lakes; as Galloway and Pentland note, "during periods of low rainfall, when direct runoff to streams is reduced, groundwater may provide the only natural source of water that keeps streams flowing".[15]

Links between water levels and fish health are well-documented. As many species of fish lay eggs and feed near the shoreline, changes to this area can impact these behaviours and, in turn, species' health and survival. One example of this is the case of Northern Pike, whose Great Lake populations decreased in step with increased fluctuations in the lakes' water levels. Since "High water levels increase nutrient concentrations and primary and secondary production in inundated areas, increasing the amount of available prey for the larval fish, make more spawning habitat accessible, expand the amount of cover, and reduce the potential for predation and cannibalism."[16] More recently, scientists in the basin have observed that "Very low water levels change the areal extent of the available habitats, allowing opportunistic terrestrial plants to invade drained wetlands. Low river levels also affect animals and micro-organisms, oxygen levels in the water and ecosystem diversity. Sport and commercial fishers may find their catches infested with parasites and pathogens. Low water levels and slow currents promote these infections in fish, with sometimes disastrous economic consequences".[17] Low water levels negatively impact on fish by reducing the area available for habitat (including spawning habitat), reducing available nutrients, exposing fish to predators, and increasing risk of exposure to parasites, pathogens and infections because of low currents.

Second, groundwater helps regulate the temperature of rivers and streams flowing into the lakes. Because groundwater is colder than surface water (maintaining a year-round temperature of approximately nine degrees), groundwater inflow into the streams feeding into the lakes helps keep lake temperatures low. These low temperatures are critical to certain species of fish, such as the Lake Superior Coaster Brook Trout and some species of Salmon. One of the first studies of interactions between groundwater and fish, for example, showed

13 Miller et. al. 1998
14 Grannerman et. al. 2000
15 Galloway and Pentland 2005, 739
16 Casselman and Lewis 1996, 162
17 Environment Canada 2008

the critical role of groundwater in providing stream habitat for salmon in British Columbia.[18] In the context of the Great Lakes, a 1997 study suggests that "limited groundwater to maintain suitable stream temperatures and provide spawning habitat" is a stressor for Lake Superior Coaster Brook Trout.[19] Interestingly, this report cites a 1960 study stating "Springs are the life blood of our trout streams".[20]

Finally, groundwater quality plays an important role in fish health. 'Clean' groundwater inflow can help dilute poor-quality surface water, thereby increasing water quality (and subsequently fish health) in the lakes. Conversely, groundwater of poor quality can occasionally flow into the lakes, reducing water quality, and consequently fish health. Indeed, a 2002 report by the IJC states that "Contaminated groundwater is polluting surface water due to direct, ground to surface withdrawals by people and through passage of contaminated water into tributaries to the Great Lakes or directly into the Great Lakes."[21] Research on the Canadian side of the border – and especially in and around Toronto – has shown that urban and agricultural chemicals do leach into the groundwater[22]; it is estimated that 1-2% of the volume of all agricultural fertilizers, road salt, underground storage tanks, and septic systems are released (as runoff) into urban streams and Lake Ontario each year.[23] This is particularly troubling in the case of agricultural areas, as increased nutrient loads can cause eutrophication: the process whereby nutrient input into a body of water causes excessive plant growth, thereby reducing dissolved oxygen and turning the body of water into a swamp or marsh. Eutrophication is problematic for fish health; indeed, one study notes that:

> "The first stages of eutrophication are favourable for many fish species. Proceeding eutrophication interferes so strongly with the environment that fish is brought in a vulnerable position: vegetation, which is a prerequisite for a number of species, disappears; oxygen depletion near the bottom affects fish food organisms; turbidity hampers catchability of preyfish and decomposition of dead phytoplankton or vegetation may especially at the end of the summer result in lethal oxygen contents."[24]

These three important contributions – quantity, temperature, and quality – highlight the importance of groundwater to fish.

ii) The current state of management

Sections 91 and 92 of the Canadian Constitution establish Federal jurisdiction over "seacoast and inland fisheries"; this includes the fisheries in the Great Lakes. A number of initiatives to protect the Great Lakes fisheries have been undertaken in recent years, including the Sea Lamprey program, which examines strategies to prevent and mitigate the effects of the introduction of this invasive species into the basin. The Sea Lamprey program (among others) is carried out under the auspices of the Great Lakes Fishery Commission (GLFC): a bi-national body established in 1955 and consisting of federal, provincial, state, tribal and First Nations representatives.

Responsibility for fisheries lies with the Department of Fisheries and Oceans

18 Douglas 2006
19 Newman and Dubois 1997
20 Heding and Hacker 1960
21 IJC 2002, 64
22 Hodge 1989; Gilham 1978; NRC 1978
23 Howard 2000, fig. 7
24 Willemsen 1980, 12

(DFO).[25] One example of how this responsibility relates to groundwater in the basin is the link between permits for groundwater withdrawals and their impacts on fish habitat. Here, if the Ontario MOE receives a Permit to Take Water (PTTW) application and suspects that it may impact upon fish habitat, it and sends the application to the DFO. Department biologists review the possible impact of the withdrawal on fish habitat, and report back to the Ontario MOE, who in turn will either allow the permit or not. At no point is an assessment of the cumulative impact of all the PTTWs on fish habitat undertaken. This is a central example of the 'cooperation but not coordination' phenomenon described in our conclusions and recommendations.

C. The Great Lakes Water Quality Agreement

As the name suggests, the Great Lakes Water Quality Agreement (GLWQA) deals with issues of water quality rather than water quantity. The 1987 amendments to the GLWQA include the addition of Annex 16: "Pollution from Contaminated Groundwater", which states that parties to the agreement shall

> "identify existing and potential sources of contaminated groundwater affecting the Great Lakes; (ii) map hydrogeological conditions in the vicinity of existing and potential sources of contaminated groundwater; (iii) develop a standard approach and agreed procedures for sampling and analysis of contaminants in groundwater in order to: (1) assess and characterize the degree and extent of contamination; and (2) estimate the loadings of contaminants from groundwater to the Lakes to support the development of Remedial Action Plans and Lake-wide Management Plans pursuant to Annex 2; (iv) control the sources of contamination of groundwater and the contaminated groundwater itself, when the problem has been identified; and (v) report progress on implementing this Annex to the Commission biennially, commencing with a report no later than December 31, 1988"[26]

Although it has laudable goals and intent, a number of reports point to flaws in the design and implementation of Annex 16. For example, a 2002 IJC report confirms the presence of groundwater contamination, discusses increased citizen concern over groundwater resources, and expresses concern over the "extremely limited" availability of mapping data. This same report urges parties to proactively apply the "precautionary principle (err on the side of caution) with respect to removals and use of groundwater in the basin" since so little is know about groundwater-surface water interactions in the basin.[27]

In a similar vein, a 2006 report analyzes each element of Annex 16 and concludes that, to date, achievements under the Annex have fallen short of their intended goals, largely due to unclear responsibilities and lack of mapping data.[28] Finally, a joint 2007 review of the GLWQA stated that Annex 16 "has some problems"[29] in that it is unclear who is responsible for implementing the Annex, reporting is inconsistent, the Annex does not mandate pollution prevention, and groundwater is not adequately integrated into the rest of the GLWQA.[30]

25 This is the case with the entirety of the Fisheries Act with the exception of section 36 (dealing with deleterious substances) which is overseen by Environment Canada.

26 Annex 16 of the GLWQA
27 IJC 2002, 64
28 Granneman and Fleischer 2006
29 Environment Canada and USEPA 2007 :43
30 Ibid

In terms of quality, then, it appears the most relevant piece of groundwater protection – Annex 16 of the GLWQA – is not meeting its intended goals.

D. The Great Lakes Charter and Great Lakes Charter Annex Agreement

The Great Lakes Charter (GLC) (1985) is focused on water quantity rather than water quality. It was signed in 1985, with one if its purposes being to "conserve the levels and flows of the Great Lakes and their tributary and connecting waters".[31] To this end, Principle III of the Charter states that "diversions of Basin water resources will not be allowed if individually or cumulatively they would have any significant adverse impacts on lake levels, in-basin uses, and the Great Lakes Ecosystem".[32] Under the Charter, consultation between signatory parties is required for withdrawals greater than 5,000,000 US Gallons (19 million litres) per 30-day period. However, the GLC makes no distinction between groundwater and surface water withdrawals.[33] The Charter also calls for an inventory of the basin's surface and groundwater resources.

Sixteen years after the introduction of the GLC, an Annex Agreement was introduced; it is known as the Great Lakes Charter Annex Agreement (GLCAA) (2001). The purpose of the GLCAA (2001) remains the same as its predecessor, that is:

> "**to conserve the levels and flows of the Great Lakes and their tributary and connecting waters;** to protect and conserve the environmental balance of the Great Lakes Basin ecosystem; to provide for cooperative programs and management of the water resources of the Great Lakes Basin by the signatory States and Provinces; to make secure and protect present developments within the region; and to provide a secure foundation for future investment and development within the region."[34] (emphasis added)

The 2001 GLCAA explicitly covers the basin's groundwater, as well as lake and stream water. Further, it

- Strongly discourages all bulk water diversions and prohibits all large-scale, long-distance ones (any diversions outside bordering counties)
- Assures that most proposals to withdraw water for local use will, for the first time in most jurisdictions, be scrutinized for potential harm to the basin environment
- Requires the provinces and states to institute water conservation programs
- Provides for states, provinces, and citizens to take a jurisdiction to court for not implementing the agreement or for failing to abide by its terms
- Promises substantial improvement in bi-national collaboration in reviewing diversion proposals
- Requires assessment of accumulated impacts of new water withdrawals and the role of potential climate change impacts at least every five years
- Provides for substantial public participation in water withdrawal approval processes
- Bases the agreements in the governments' "public trust" responsibilities and in their "duty to protect" basin waters
- Affirms the central role of the Boundary Waters Treaty and the International Joint Commission in protecting the

31 GLC 1985
32 GLC 1985; principle III
33 Galloway and Pentland 2005
34 GLCAA 2001, emphasis added

Great Lakes
- Preserves the rights of the individual states and provinces to enact stronger protections as needed.[35]

Thus, the GLCAA provides a framework that allows the parties to the agreement to put in place domestic legislation and regulations that meet the standards set out in the GLCAA. While the subsequent legislation may be legally binding, the GLCAA is not; it is a good-faith agreement and ultimate responsibility for implementation of relevant legislation rests with individual Provinces and States.

The success or failure of the GLCAA on the Canadian side of the border rests very much on the way in which it is implemented on-the-ground in Ontario. The implementing agreement that applies to the Canadian Provinces is the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement. In order to understand the scope of possibilities with respect to implementation in Ontario – especially as the GLCAA relates to groundwater – it is critical to review the legislative framework onto which the new legislation would be placed. It is to this topic that the final section of this report now turns.

4. The Provincial Role and Groundwater in the Basin: Ontario's Legislative Framework for Groundwater

There are two sets of legislation in Ontario relevant to groundwater. The first addresses groundwater quantity and deals with groundwater licensing; the second addresses groundwater quality through source water protection. The province of Ontario also has jurisdiction over its municipalities, which is discussed in part 4(c).

35 Council of Great Lakes Governors

A. Groundwater Quantity: Licensing and Permitting

Groundwater licenses in Ontario are regulated under section 34 of the Water Resources Act (1961), the subsequent "Water Taking and Transfer" regulation, and the "Charges for Industrial and Commercial Water Users" regulation, which regulates water takings for industrial and commercial water uses.[36]

Until 2005, Ontario's permitting system was the subject of widespread criticisms, including:

- Insufficient data on water use and water supply;
- Unclear objectives and water use priorities;
- Failure to protect the environmental uses of groundwater;
- Ignorance of the cumulative effects of pumping;
- Lack of coordination with local municipalities and conservation authorities;
- Limited public participation;
- Poor enforcement due to inadequate funding;
- No link between permitted amount and sustainable use; and
- No follow-up on allowable pumping levels.[37]

Amendments made to Ontario's Permit to Take Water (PTTW) permitting system have taken some remedial steps, including annual reporting of water use and notification of withdrawals. The current regulations stipulate that anyone taking more than 50,000 litres per day (of either ground or surface water) must apply for a

36 Nowlan 2005, ONMR 3007

37 AMO, 2002; ECO, 2000; ECO, 2001; Kreutzwiser et al. 1999; Kreutzwiser et al., 2004; Leadlay & Kreutzwiser, 1999; McCulloch & Muldoon, 1999, O'Connor, 2002; personal communication February 2008

permit to take water (PTTW), and, as of October 2005, applications for PTTWs are to be assessed based on their potential for environmental impacts.[38][39] Further, ecosystem function and water availability are to be taken into account in PTTW application decisions. However, little is currently known about ecosystem needs, making it difficult to plan around them.[40]

B. Groundwater Quality: The Ontario Clean Water Act and Ontario's Source Water Protection Plans

With respect to groundwater quality in the Ontario portion of the basin, the Clean Water Act provides the basis for Ontario's Source Water Protection Plans (SWPPs), which aim to protect communities' drinking water sources. These plans stemmed from the recommendations of the O'Connor Inquiry into the Walkerton tragedy. The Act requires Source Protection Agencies to develop source water protection plans, which are then approved by the Ontario MOE. Once an SWPP is approved, actions undertaken under other relevant legislation (e.g. the issuing of building permits) must be in accordance with the source water protection plan.[41] In effect, thismakes source water protection plans the dominant piece of planning legislation in the province.

38 OMNR 2005

39 Uses exempt from the PTTW process include domestic purposes, livestock when the water is not taken into storage, and firefighting.

40 OMNR 2004

41 For more information on the legislative supremacy of the act, see sections 37 and 38 in part III of the Clean Water Act.

C. Ontario's Municipalities

Finally, the Canadian constitution gives Ontario jurisdiction over the province's municipalities. Municipalities act as the nexus between citizens and their groundwater by:

- Operating the city's water and sewerage systems;
- Coordinating municipal groundwater studies (which focus on the four areas of aquifer characterization, municipal wellhead protection area mapping, contaminant inventories, and water use assessments)[42][43];
- Owning property within a municipality;
- Acting as the lead agencies in planning for community growth, and;
- Working actively with the Conservation Authorities in which they are located.

Thus, Ontario's Municipalities play an integral and essential role in protecting groundwater in the province, including in Ontario's portion of the Basin.

5. Groundwater Challenges in the Basin

The basin faces critical challenges with respect to groundwater. These include limited knowledge about groundwater in the basin and increasing groundwater use. These concerns are explored in this section.

A. Limited Knowledge of Groundwater in the Basin

Significant gaps exist with respect to groundwater knowledge in the basin, particularly on the Canadian side. These gaps were recognized as early as 1985, when the collection of groundwater data

42 Ontario Ministry of the Environment

43 Environmental Commissioner of Ontario 2000

was included as a component of the Great Lakes Charter. In its 2000 report, "Protection of the Waters of the Great Lakes", the International Joint Commission (IJC) states that groundwater consumption and groundwater recharge in the basin are not well understood, and suggests that possible reasons for this include a lack of mapping; a lack of understanding of the role of groundwater in supporting ecosystems; potentially inaccurate figures for consumptive use of groundwater; a lack of recorded changes of land uses over time; and a lack of recharge data.[44] For more detail of scientific gaps see Appendix A (page 3). Ontario's municipal groundwater studies program – initiated in 2001 – has taken steps towards addressing these gaps.[45]

The lack of information on the Canadian side becomes particularly evident when compared to the information available on the U.S. side of the basin. Most notable is a 2005 report by the U.S. Geological Survey (USGS) that documents the relationship between groundwater withdrawals in Wisconsin and groundwater flows to Lake Michigan.[46] It appears that groundwater withdrawals have reversed groundwater flows to the lake. Before pumping began, groundwater flowed towards Lake Michigan and was responsible for 34% of inflow to the lake. Today, instead of water flowing into the lake, water moves from the lake toward pumping centres.[47] NRCan maintains that these studies are "relevant for Canada as the basin in question is the Great Lakes Basin and there are increasingly large withdrawals of groundwater from this Basin on the Canadian side of the border, especially in the Greater Toronto area".[48]

In addition to missing information, a second key problem is lack of access to existing information. Although groundwater mapping data are available from relevant ministries and departments upon request, it is not otherwise available to the general public.[49] This lack of information decreases transparency, slows the work of those using the data as a basis for decision-making, and makes it difficult for citizens and residents of the area to get involved.

In sum, despite some pioneering work undertaken through the USGS and Ontario's groundwater mapping program, serious knowledge gaps remain, particularly on the Canadian side of the basin, and existing data are not always readily available.

B. Population Growth in the Basin

On the Canadian side, growing communities within the basin that are not located near the lakes, such as the Region of Waterloo and the City of Guelph are heavily dependent on groundwater and are experiencing rapid population growth. As these cities grow and reach the limits of local groundwater supplies, large water and wastewater supply pipelines to the Great Lakes become real possibilities. For example, the Region of Waterloo has suggested that by 2035 it will need to construct a 120 kilometre pipeline to either Lake Huron or Lake Erie in order to meet regional water demand, at a cost of between $432 million and $478 million.[50] Increasing urban growth also changes aquifer recharge areas: urbanization often involves the paving of previously permeable surfaces such that groundwater can no longer percolate down into the aquifer, and if it does it usually carries urban contaminants.

44 IJC 2000

45 The Municipal Groundwater Studies program builds on the "Provincial Water Protection Fund" program, initiated in 1998 (de Loë, R., R. Kreutzwiser, and D. Neufeld 2005)

46 USGS 2005

47 USGS 2005; Rivera 2005

48 Rivera 2005: 25

49 Personal communication, November 2008

50 Regional Municipality of Waterloo 2000

Urban growth therefore impacts on groundwater in two ways. First, increased population means that more water is needed to support communities. Second, increased urbanization can reduce the area of permeable surfaces, thereby reducing groundwater recharge into the basin. The Environmental Commissioner of Ontario discusses the relationship between that Province's *Places to Grow Act* and groundwater protection, and concludes that natural features of the landscape – such as large moraines with significant hydrologic functions – "should be used as the starting point to guide local land use planning decisions." Further, the Commissioner's report states that "The current land use planning system gives insufficient weight to environmental concerns, and it does not adequately empower planning authorities to restrict specific forms of development where they are ecologically inappropriate."[51]

C. Cooperation, but Not Coordination

Research – including interviews with key policy makers[52] – indicates that relevant ministries are working together. For example, a handful of Ontario's Conservation Authorities have used some of their financial resources to fund NRCan (Geological Survey of Canada) to carry out groundwater mapping research and regional methods development.

This cooperation is necessary and positive; however, it is one step behind the coordination that would be required in order to have a consistent plan across federal departments and provincial ministries for dealing with groundwater in the basin. Examples of places where better coordination could be implemented include:

- Coordination between land-use decisions and groundwater quantity protection (e.g., guidelines for paving surfaces and protecting critical recharge areas);
- A comprehensive, coordinated groundwater mapping program at nested scales that includes long-term monitoring of the resource.

For example, coordination of land use decisions and groundwater quality protection could take the form of shared GIS mapping data so that areas vulnerable to groundwater quality concerns are quickly and easily identified by land use planners. Similarly, the cumulative water-takings from PTTWs could be stored in a database shared by DFO and the relevant Ontario Ministries. These and other recommendations are discussed in section 6.

51 Environmental Commissioner of Ontario Annual Report 2007-2008 at 141

52 Interviews carried out with representatives from Conservation Ontario, the Ontario Ministry of the Environment, Natural Resources Canada, Fisheries and Oceans Canada, and the United States Geological survey.

6. Recommendations

Challenges and their associated recommendations are listed in the table below.

Table 1. Challenges, Recommendations and Opportunities for Implementation

Challenge	Recommendation	Implementation Opportunities
Limited knowledge of groundwater in the basin	1.Concerted effort towards groundwater mapping in the basin, including recharge area mapping, surface-groundwater links, vulnerability mapping, and identification of groundwater outflow areas into critical fish habitat	Ongoing MOE coordination of Ontario's municipal groundwater studies, and MOE-coordinated groundwater mapping to be carried out to meet agreed upon criteria, including vulnerability mapping, recharge area mapping, and identification of groundwater outflow areas into critical fish habitat
	2. Increased coordination between land-use planners, municipal groundwater studies, and provincial agencies	MOE-coordinated groundwater database shared between agencies
Lack of access to existing information	Increased transparency by making available existing groundwater data and publicizing exiting efforts	Publication and visible cross-posting between the websites of MOE, municipal groundwater mapping programs, and NRCan mapping programs
Lack of coordination	Overall groundwater strategy for the Ontario portion of the basin offering coordination of multiple threads of groundwater legislation	Incorporation of a comprehensive groundwater strategy for the basin into a comprehensive groundwater strategy for the Province.
Upcoming GLWQA renegotiation	Explicit inclusion of groundwater in the upcoming renegotiation of the Great Lakes Water Quality Agreement	Inclusion of groundwater by the Federal governments of Canada and the United States in upcoming negotiations

7. Conclusions

Groundwater is an essential resource in the Great Lakes Basin: it provides drinking water for many of the basin's communities, recharges streams and rivers in the basin (thereby protecting and maintaining fish habitat), and recharges the lakes themselves. Estimates suggest that the volume of groundwater in the entire Great Lakes system is approximately equivalent to Lake Michigan, in effect making groundwater the hidden "sixth great lake". This document has detailed the ways in which groundwater interacts with surface water in the basin, as well as the various pieces of legislation that address groundwater in the Ontario portion of the basin.

Our recommendations are:

- The creation of an overall groundwater strategy by the Ontario Ministry of the Environment (MOE) for the province, offering coordination of multiple threads of groundwater legislation in the basin;
- Coordinated groundwater mapping carried out to meet agreed upon criteria, including vulnerability mapping, recharge area mapping, and identification of groundwater outflow areas into critical fish habitat;
- Increased coordination, where needed, between land-use planners, municipal groundwater studies, and provincial agencies;
- Increased transparency by making available existing groundwater data and publicizing existing efforts, and;
- Explicit inclusion of groundwater in the upcoming renegotiation of the Great Lakes Water Quality Agreement.

These recommendations speak to overall issues of data gathering, coordination, and visibility, all of which were identified as challenges throughout the report. The first recommendation of creating an overall groundwater strategy for the province echoes a similar call from Ontario's Environmental commissioner in 2000, and one that has yet to be realized.

Given the importance of groundwater in the Ontario portion of the basin (as well as in Ontario more generally), effective groundwater management is critical. It is hoped that that the information included in this report will provide decision-makers with the information and tools necessary to move forward towards greater groundwater protection in the basin.

8. SOURCES CITED

AMO (Association of Municipalities of Ontario) (2002). Proposed Improvements to Ontario's Water Taking Permitting Process, Recommendations to the Government of Ontario. Association of Municipalities of Ontario, Water Taking Taskforce, 2002

Casselman, J.M. and C. A. Lewis (1996), "Habitat Requirements of Northern Pike (Esox-Lucius)" *Canadian Journal of Fisheries and Aquatic Sciences* 1: 161-174.

Colborn. T. (1990) "Great Lakes, Great Legacy?" The Conservation Foundation and the Institute for Research on Public Policy.

Council of Great Lakes Governors: http://www.cglg.org/projects/water/index.asp

de Loë, R., R.D. Kreutzwiser, and D. Neufeld (2005) "Local groundwater source protection in Ontario and the Provincial Water Protection Fund", *Canadian Water Resources Journal*. 30(2): 129-144.

Department of Fisheries and Oceans (DFO) *Fact Sheet: Fish habitat & fluctuating water levels on the Great Lakes.* Accessed online at http://www.dfo-mpo.gc.ca/regions/central/pub/fact-fait-on/t2_e.htm. Retrieved March 2008.

Douglas, T. (2006), "Review of groundwater-Salmon interactions in British Columbia", written for 'The Walter and Duncan Gordon Foundation' and 'Watershed Watch Salmon Society'. Available online at http://www.watershed-watch.org/publications/files/Groundwater+Salmon++hi+res+print.pdf

ECO (2000). The protection of Ontario's groundwater and intensive farming. *Special Report to the Legislative Assembly of Ontario*, Environmental Commissioner of Ontario, July, 2000.

ECO (2001). Ontario's permit to take water program and the protection of Ontario's water resources, *Brief to the Walkerton Inquiry.* Environmental Commissioner of Ontario, January 2001.

Environment Canada (EC) *Impacts of Water Level and Flow Fluctuations in the St. Lawrence River* Project Website at http://www.qc.ec.gc.ca/csl/pgr/pgr003_e.html. Retrieved March 2008.

Environment Canada (EC) (2006) "Water – How we share it". Online at http://www.ec.gc.ca/water/en/info/pubs/primer/e_prim07.htm#a9. Retrieved April 2008.

Environment Canada and USEPA (2007) "Great Lakes Water Quality Agreement Review 2007", available online at http://binational.net/glwqa_2007_e.html. Retrieved September 2008.

Environmental Commissioner of Ontario. 2000. "Protecting Ontario's Groundwater." Changing Perspectives, ECO Annual Report, 1999-2000. Toronto: The Queen's Printer for Ontario. 35-42.

Environmental Commissioner of Ontario Annual Report 2007-2008. Available online at http://www.eco.on.ca/eng/index.php/pubs/eco-publications/2007-08-AR.php

Galloway and Pentland (2005), "Securing the Future of Ground Water Resources in the Great Lakes Basin", *Ground Water* 43(5): 737-743.

Gillham, R. W., Cherry, J. A. Hendry, M. J. Sklash, M. G. Frind, E. O. Blackport, R. J. & Pucovsky, M. G. (1978). *Studies of the*

agricultural contribution to nitrate enrichment of groundwater and subsequent loading to surface water (203 p). Final Report. Report prepared for International Joint Commission Pollution from Land Use Activities, Task Group C, Activity 1 Project 14. Windsor, Ont. (PLUARG 78-064).

Glynn, J. K. (2002). Impacts of Agriculture on Water Quantity in the Great Lakes - St. Lawrence Basin: Executive Summary. Institute for Agriculture and Trade Policy, http://www.environmentalobservatory.org/library.cfm.

Grannemann, N.G., R.J. Hunt, J.R. Nicholas, T.E. Reilly, and T.C. Winter (2000) "The Importance of Ground Water in the Great Lakes Region". Water Resources Investigations Report 00 – 4008. Available online at http://water.usgs.gov/ogw/pubs/WRI004008/contents.htm

Granneman, N.G. and F. Fleischer (2006) "Great Lakes Water Quality Agreement. Annex 16: Pollution from Contaminated Groundwater" Review working group H. Final Report. December 15th. Available online at http://www.speakongreatlakes.org/glwqa/RWGH.pdf.

Great Lakes Charter (1985)

Great Lakes Charter Annex (2001)

Great Lakes United (GLU) "Great Lakes Charter Annex Agreements" web site, at: http://www.glu.org/english/annex_2001/summary_background.htm . Last accessed April 2008.

Heding, R. And V. Hacker (1960). "A trout's thermostat; springs" *Wisconsin Conservation Bulletin* 25(5):19-22.

Hodge, R.A. (1989), "Groundwater in the Great Lakes Basin: The natural system, use and abuse, and policy implications", *Chicago-Kent Law Review* 65: 439-463.

Holtschag, J. and J. R. Nicholas (1998) "Indirect Ground-Water Discharge to the Great Lakes" USGS Open-File Report 98-579 at 1.

Howard, K.W.F. (2000), "Transport of urban contaminants into Lake Ontario via sub-surface flow", *Urban Water* 3(2): 183-195.

IEPD: Government of Ontario Integrated Environmental Planning Division, Strategic Government of Ontario, Policy Branch, Ministry of the Environment (2004), *White Paper on Watershed-based Source Protection Planning*.

International Joint Commission (IJC) (2004) *Protection of the Waters in the Great Lakes: Review of the Recommendations in the February 2000 Report*. August 2004.

International Joint Commission (IJC) (2002) "11th Biennial Report on Great Lakes Water Quality: The Challenge to Restore and Protect the Largest Body of Fresh Water in the World". September.

International Joint Commission (IJC) (1999). *Protection of the Waters of the Great Lakes – Interim Report to the Governments of Canada and the United States*. International Joint Commission, http://www.ijc.org/php/publications/pdf/ID1284.pdf

International Joint Commission (IJC) (1997) *The IJC and the 21st Century*.

Kreutzwiser, R.D., de Loë, R.C. & Benninghoff, B. (1999). *Agricultural and Rural Water Allocation in Ontario*. A Report to the Agricultural Adaptation Council under the National Soil and Water Conservation Program

Kreutzwiser, R.D., de Loë, R.C., Durley, J. & Priddle, C. (2004). Water allocation and the permit to take water program in Ontario: challenges and opportunities. *Canadian Water Resources Journal*, 29, 135-146.

Leadlay, H.J. and R.D. Kreutzwiser (1999) Rural water supply allocation in Ontario: an evaluation of current policy and practice, *Canadian Water Resources Journal* 24 (1999) (1), pp. 1–14

McCulloch, P. & Muldoon, P. (1999). *A Sustainable Water Strategy for Ontario*. Canadian Environmental Law Association Publication No. 367.

Miller, B., J.S. Tevesz, and J.S. Carney (1998), "Holocene environmental changes in the Whitefish Dunes Area, Door Peninsula, Northern Lake Michigan Basin, USA", *Journal of Paleolimnology* 19(4): 473-479.

Mackereth, R., S. Moore, J. Imhof, A. Carlson and C. Richards (2004) "Stream Habitat of Lake Superior Coaster Brook Trout: A Multi-Scale Review of Features Critical to Protection and Enhancement." *Great Lakes Fishery Commission 2004 Project Completion Report*, available online at http://www.glfc.org/research/reports/Schreiner.pdf

National Research Council (1978). Nitrates: An environmental assessment environmental studies board, commission on natural resources. US EPA Contract No. 68-01-3253, Washington, DC.

Newman, L.E. and Dubois, R.B. (1997) *Status of Brook Trout in Lake Superior.* Prepared for the Lake Superior Technical Committee by the Brook Trout Subcommittee. Great Lakes Fishery Commission. Ann Arbor.

Nowlan, L, (2005) "Buried Treasure: Groundwater Permitting and Pricing in Canada" a report written for the Walter and Duncan Gordon Foundation.

O'Connor, D. R. (2002), *Report of the Walkerton Inquiry, The Events of May 2000 and Related Issues, Part Two*, Ontario Ministry of the Attorney General, Toronto, Ontario.

Ontario Conservation Authority: http://www.conservation-ontario.on.ca (last accessed April 2008)

Ontario Ministry of the Environment, "Groundwater Studies in Ontario: Mapping a Hidden Treasure" online at http://www.ene.gov.on.ca/programs/4197e01.htm

Ontario Permit to Take Water Website (Retrieved October 2007) at http://www.ene.gov.on.ca/envision/water/pttw.htm .

Ontario Ministry of Natural Resources (OMNR) (2005) "Green Facts: New Classification System for Permit to Take Water (PTTW) Applications"

Ontario Ministry of Natural Resources (OMNR) (2004) "Compendium to the Final Water Taking and Transfer Regulation (Ontario Regulation 387/04). December 2004.

Regional Municipality of Waterloo (2000). *Council Report E-00-027.1 approving the Long Term Water Strategy of the Regional Municipality of Waterloo*, http://www.region.waterloo.on.ca.

Rivera, A. (2005), *How well do we understand Groundwater in Canada? A Science Case Study*, Natural Resources Canada, Earth Sciences Sector, Groundwater Program.

BWT: Treaty Between the United States and Great Britain Relating to Boundary Waters, and Questions Arising Between the United States and Canada, United States and Great Britain, 5 May 1909, entered into force in Canada as the International Boundary Waters Treaty Act R.S., 1985, c. I-17 [Boundary Waters Treaty]

USEPA (United States Environmental Protection Agency) and Government of Canada (1995) "Great Lakes: Environmental Atlas and Resource Book", 3rd edition. Available online at http://www.epa.gov/glnpo/atlas/

Willemsen, J. (1980) "Fishery-Aspects of Eutrophication", *Aquatic Ecology* 14(1-2): 12-21.

LEGISLATION CITED

Canada Water Act R.S., 1985, c. C-11

Clean Water Act, 2006, S.O. 2006, c. 22

Great Lakes Water Quality Agreement (1972), Annex 16 (added 1987)

Ontario Water Resources Act, R.S.O. 1990, c. O.40

The Constitution Act (British North America Act) (1867) 30 & 31 Victoria c.3

Ontario Water Taking and Transfer, O. Reg. 285/99

Ontario Charges for Industrial and Commercial Water Users, O. Reg. 405/07

Appendix A

Gaps in Scientific Understanding of Groundwater in the Great Lakes[53]

a) No consistent mapping of ground water flow systems.

i) There is no consistent mapping of local ground water flow systems. To improve the understanding of shallow unconfined aquifers, new geologic maps need to be produced that show the extent, thickness, and boundaries of these aquifers.

ii) Although some studies have been done on specific regional ground water flow systems, such as the USGS study in southeastern Wisconsin, there is no consistent mapping of regional ground water flow systems including boundary and transboundary hydrogeological units.

b) Lack of knowledge with respect to how much water is withdrawn from aquifers and how much water is lost to the particular aquifer, the watershed or the entire basin.

i) The amount of groundwater being withdrawn from aquifers in the basin needs to be accurately quantified at both local and regional scales.

ii) There is not enough information describing the location of withdrawn groundwater once it has been used. Once groundwater has been withdrawn, is it leaving the recharge area of the aquifer? Is it leaving the sub-watershed, the larger watershed or even the basin? This information is needed to accurately predict the effects of ground water withdrawals at both local and regional scales.

c) No accurate information available on recharge rates.

i) There is no systematic estimation of natural recharge areas. Studies need to be conducted at a local level to determine the rate of recharge to local flow systems.

ii) Although groundwater recharge rates estimated in previous studies have provided an approximate range of recharge in the basin, a comprehensive study is needed to completely determine the importance of ground water in the hydrologic budget of the Great Lakes.

d) No comprehensive description of the role of groundwater in supporting local ecosystems.

i) There is inadequate information on groundwater discharge to surface water bodies and the role that ground water plays in sustaining aquatic ecosystems and the habitats on river banks and lake shorelines.

ii) The understanding of the relation-

53 This list has been compiled from two reports. Many of the regional scale deficiencies are highlighted by the International Joint Commission in their report to the governments of Canada and the United States, International Joint Commission, "Protection of the Waters of the Great Lakes – Final Report to the Governments of Canada and the United States" (February 2000). The need for local scale scientific studies is emphasized to a greater extent by the United States Geological Survey in Norman G. Grannemann et al., "The Importance of Ground Water in the Great Lakes" (2000) USGS Water Resources Investigations.

ship between groundwater and the basin's wetlands is not well known.

e) The relationship between groundwater flow and the Great Lakes is not well understood.

i) Comprehensive estimates of indirect groundwater discharge to the Great Lakes is required.

ii) More work needs to be done to define and quantify the interactions between regional ground water flow and groundwater discharge to the Great Lakes.

f) Estimates are needed of the effects of land-use changes and population growth on groundwater availability and quality.

g) There needs to be more regional and local scale analyses of changes in groundwater quality as a result of groundwater withdrawals. We know little of natural groundwater quality over the various scales in the Great Lakes basin.