



Natural Resources  
Canada

Ressources naturelles  
Canada

## Groundwater Program Newsletter



# Groundwater

### **Groundwater News**

Volume 4, Issue 2

December 2007

Editor: Alfonso Rivera

Layout: Marie-Josée Tremblay

Web site: [ess.nrcan.gc.ca/gm/index\\_e.php](http://ess.nrcan.gc.ca/gm/index_e.php)

### **Editor's Message**

***"Precaution is better than cure."***

Johann Wolfgang von Goethe

I was recently asked several questions: Why is it important to know our groundwater resources now? Why is it important to conduct a national inventory of our groundwater resources? What issues are affecting the inventory? What issues would emerge without that inventory? Why do we care about knowledge gaps?

Those questions appalled me. The short, quick and easy answer to all those questions: to know! As scientists, we tend to do research for the sake of knowing (as with early scientists, such as Aristotle and Socrates). But in today's society, knowledge provides more than our need for scientists' self-esteem. Knowledge has become the backbone of development, of well being, of productivity. Knowledge has become the basis for decision-making processes.

So, because I am pragmatic and act on rational thinking, I wonder why we are suddenly spending lots of time and money to develop decision-making procedures, laws and regulations, yet spending little to acquire knowledge of groundwater!

I often receive requests for groundwater knowledge from ordinary Canadians (Gulf Islands' residents, Alberta's farmers, Ottawa's citizens): Should we expect saltwater intrusion into our wells? Are the oil industries going to dry our aquifers? Is my well going to be affected by my neighbour? I still cannot answer such questions. I am surprised that in this highly industrialized country, we still do not know our groundwater resources. I do know, however, that our disadvantages with respect to other countries are huge! Simply put, we are "ignorant" (pun intended) about groundwater. Let me explore this further, to try to find out why we lack this knowledge.

There is no economic value in groundwater, unless you bottle it and sell it. There is no incentive to preserve groundwater, unless you start running out of it or live in an area of droughts. There is no interest in the natural quality of groundwater, unless your neighbour is taken to the hospital contaminated by E. coli. There is no interest in knowing how groundwater moves underground, unless a nearby oil industry begins using the same aquifer formation. And there is no interest in knowing how much groundwater is available, unless you need to drill deeper and deeper, or wells begin drying rivers.

So we seem to need "drivers" and "motivations" to invest in acquiring knowledge. The problem is that when and if we finally decide to acquire knowledge, it might be too late; in particular, when dealing with groundwater, for groundwater has its own timing. For example, groundwater has a good natural quality almost everywhere. Most causes of poor groundwater quality are due to human activities that modify the aquifer functioning. Over the years, we have learned that anthropic effects may appear slowly and after a long delay. As a result, hydrogeologists are learning that aquifers are potentially vulnerable to contamination. What have we learned from the '70s, '80s and early '90s, when millions to hundreds of millions were spent on cleaning up contaminated aquifers? "Because of turnover time of water in the groundwater is often measured in years to many hundreds of years, it meant that groundwater quality recovery after diffuse or point contamination processes may be very slow; and although some artificial remediation is possible, it is often inefficient and expensive" (Custodio, 2007).

So, to paraphrase one of von Goethe's most famous ideas 200 years ago, why don't we prevent so we don't have to heal?

To me, it is crystal clear: let's invest in acquiring groundwater knowledge. It will pay off in time. Thus the theme of this issue is "knowledge on groundwater." Enjoy the reading.



**Alfonso Rivera**

Chief Hydrogeologist and Program Manager  
Groundwater Mapping Program

Canada

## In this issue:

Editor's Message.....	P.1
Continued Accumulation of Knowledge	
– P.E.I. nitrates study completed.....	P.2
– Evapotranspiration trends in Canada linked to rising temperatures – except in the Prairies.....	P.2
– Two new projects launched: “Impacts of Climate Change and Human Activities on Groundwater Recharge” and “Methodology development and hydrogeological characterizations in support of groundwater resources mapping” ....	P.3
– Groundwater information network: a coordinated approach to disseminating groundwater information.....	P.4
– Groundwater assessment by the Council of Canadian Academies .....	P.4
UNESCO's IHP and the OAS Hold 5 <sup>th</sup> International Workshop of the ISARM Americas Project (Transboundary Aquifers of the Americas) .....	P.4
Advances in Groundwater Research	
– Mapping the variability of groundwater resources over major Canadian water basins from GRACE satellite data .....	P.6
– Mapping groundwater from space .....	P.6
People in the News	
– Canadian governmental hydrogeologists .....	P.7
Poetry in hydrogeology .....	P.8
Suggesting Readings	
– Walter and Duncan Gordon Foundation's “bleu print” for federal action on freshwater .....	P.9
– References .....	P.9

## Continued Accumulation of Knowledge

Summaries of knowledge acquired or in the making, are presented in the following sections. These represent only recent samples; more groundwater knowledge can be found on the Web site of the Groundwater Mapping Program ([http://ess.nrcan.gc.ca/2002\\_2006/gwp](http://ess.nrcan.gc.ca/2002_2006/gwp) and <http://ess.nrcan.gc.ca/gm>), including its newsletter series, which began in April 2003.

### P.E.I. nitrates study completed

(project leader: Martine Savard)

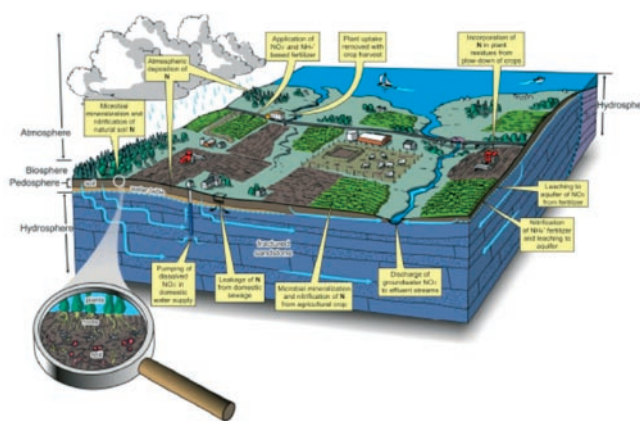
The significant “Study of Prince Edward Island Nitrogen Cycle of Aquifers at Risk” was developed with multi-partnerships at two levels of government (Natural Resources Canada [NRCAN]; Agriculture Canada; PEI Department of Energy, Environment and Forestry) and universities. During this project, they developed new analytical methods and a new approach to quantify the nitrogen cycle in streams and groundwater in Prince Edward Island, which is 100 percent groundwater-dependant. The study

- Characterized the nitrogen cycle in the Wilmot River watershed by quantifying the input of various nitrate sources
- Studied the processes involved for nitrate transport and accumulation in streams and aquifers
- Evaluated the impact of climate change on the quality of groundwater resources at the provincial scale

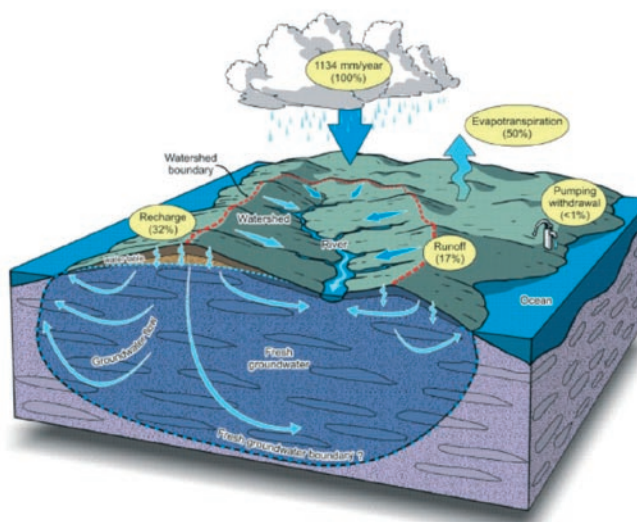
The study revealed some disturbing data. Nitrate concentrations in most regions are significantly higher than normal. One in five wells tested showed nitrate levels above Health Canada regulations. The study also identified the culprit: chemical fertilizers used in farming.

The province's reaction to this is appropriately serious. Agriculture Minister James Bagnall says it's “simply unacceptable that any well in this province should not have water quality that meets Canada's drinking water standards.” Accordingly, the government plans to gather farmers, processors and fertilizer companies in an effort to address

the concern. The province's decision to establish a working group to look at how nitrate levels in our groundwater can be reduced is a welcome one.



Conceptual diagram of the nitrogen cycle adapted to the context of Prince Edward Island and the Wilmot watershed (Savard et al, 2007b)



Schematic representation of the water balance in P.E.I. and conceptual model for the numerical simulation (Savard et al, 2007b)

With this project completed, Martine Savard and her team won NRCAN's Earth Sciences Sector Merit Award. See the report online at [adaptation.nrcan.gc.ca/projdb/pdf/109\\_e.pdf](http://adaptation.nrcan.gc.ca/projdb/pdf/109_e.pdf). A shorter scientific article also appeared in the *Water Resources Research* journal in June 2007 (see Savard et al., 2007a).

### Evapotranspiration trends in Canada linked to rising temperatures – except in the Prairies

(project leader: Richard Fernandes)

A recent paper published in the *Journal of Hydrometeorology* links rising trends in evapotranspiration from 1960 to 2000 to increasing temperatures over southern Canada – except in the Prairies (Fernandes et al, 2007). The authors, from NRCAN and Noetix Research Inc., have ongoing research on evapotranspiration projections over certain regions (the Great Lakes; Annapolis Valley, N.S.; and the Okanagan basin, B.C.). This work was done in collaboration with the Groundwater Mapping Program. Below is the publication's abstract.

“The assessment of annual trends in actual evapotranspiration (AET) and associated meteorological inputs was performed at 101 locations across Canada with available long-term hourly surface climate observations to determine if AET in Canada is increasing in relation to observed increases in air temperature. AET was estimated for the dominant land cover class, with representative soil and leaf area index conditions, within a 50 kmx50 km window around each location for the



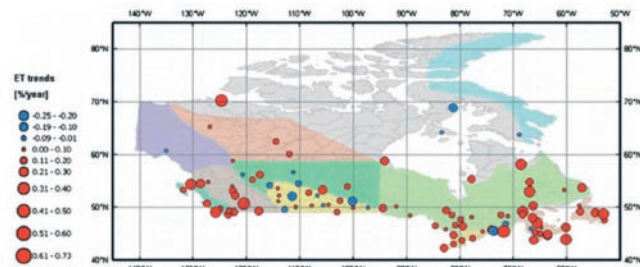
period 1960–2000. The Ecological Assimilation of Land and Climate Observations (EALCO) land surface model, which simulates coupled carbon, energy, and water cycles, was applied to estimate AET on a half-hourly basis at each location using in situ meteorological measurements and ambient atmospheric CO<sub>2</sub> concentrations.

"Increases in annual AET, of up to 0.73% yr<sup>-1</sup>, were identified at 81 locations, and decreases, of up to 0.25% yr<sup>-1</sup>, were found at the remaining 20 stations. Statistically significant increasing trends were detected in 35% of the locations with the majority corresponding to Atlantic and Pacific

Initially, this new project will use historical river flow series (from which the base flow will be estimated), which are long and extensive, and historical water levels in wells series, which are less frequent and generally cover shorter periods of time. Secondly, river flow data will be generated using the CRCM (Canadian Regional Climate Model) for the 1961-1990 (reference period for a statistical comparison with observed data) and 2010-2100 time periods. This study will provide a Canadian picture of groundwater recharge trends (specifically, whether the recharge is reducing, increasing, or remaining stable), and will help to quantify them and make predictions for the 2010-2100 time period.

provincial organizations or private firms, are often too sparse and at a resolution that is too low to map aquifers accurately. Integration of geophysical and geological data combined with accurate flow and transport measurements adapted to the hydrogeological context will contribute significantly to aquifer characterization.

The objective of this approach is to develop a process which will allow three-dimensional characterization of the hydrogeological properties of aquifers from a variety of different sources. This approach will be validated within the specific context of a superficial deposits aquifer in Saint-Lambert-de-Lauzon, Quebec, where there is a contamination problem from a former sanitary landfill site. Also, this project was undertaken in cooperation with INRS-ETE which further examined the issue of natural attenuation of the leaching plume. The proposed approach is mainly based on defining relations in situ between the



*Trends of annual AET between 1960 and 2000 at CWEDS [Canadian Weather for Energy and Engineering Data Sets?] stations, expressed as a percentage of the average annual AET over the same period at the same stations, based on fitting a Kendall–Theil line to EALCO modelled AET*

coastal regions. Increasing trends were generally related to increasing temperature and total downwelling surface radiation trends in eastern Canada and increasing temperature, surface radiation, and precipitation trends in western Canada. In sharp contrast to other studies based on simpler AET models, annual AET trends in the prairie climate zone were mixed in terms of increases and decreases with no locations showing statistically significant trends. Future studies focused on scaling AET model estimates to sub-basins or basins are required both to account for this spatial variability in soil conditions and to permit water budget closure validation."

## Two new projects launched

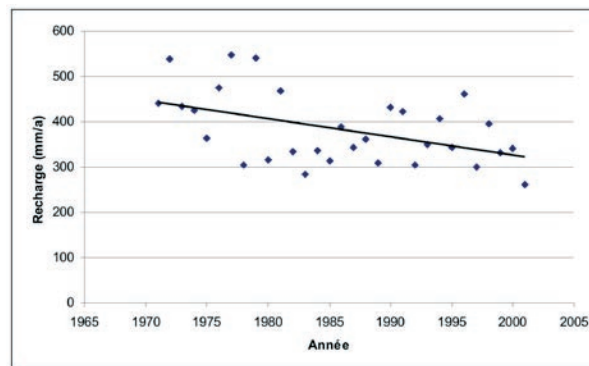
### «Impacts of Climate Change and Human Activities on Groundwater Recharge».

Project Lead: Christine Rivard

Groundwater plays a major role both in regional social and economic development and in population health. However, little is known about the potential impacts of climate change on this resource in Canada. A pilot study of the impacts of climate change on groundwater recharge in three provinces in Eastern Canada (where rainfall is high, Rivard et al, 2003) showed that recharge appears to have reduced over the past 30 years. To further this study and extend it across the country, a new study project began last April. This project will focus on the impacts of climate and human-induced changes on groundwater recharge, using historic data and different climate change scenarios.

The database was developed recently, including river flow, base flow and water levels in wells data. River flows were taken from the HYDAT database, which belongs to Environment Canada (EC). Base flows were all calculated by Andrew Piggott from EC (NWRI). Water levels in wells data was taken from provincial monitoring wells. Only 30-year historical series and longer were retained for this study. Trends

will be calculated with 30-, 40-, and 50-year series using the non-parametric Mann-Kendall test. An example of results for a given river appears in the figure below. This part of the study should be completed by the end of the fiscal year. The second year will be devoted to modeling and generating future river flows.

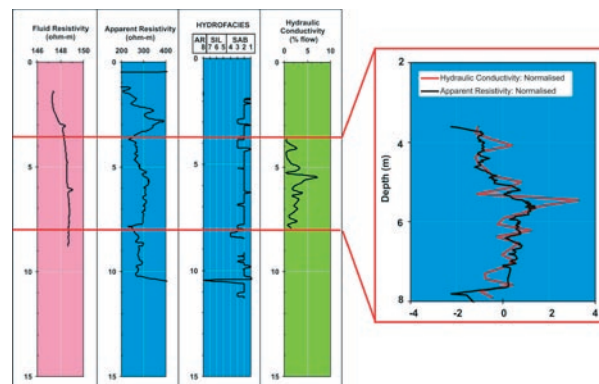


*Trend obtained for recharge estimated using base flows from the Annapolis River, in Nova Scotia. The Mann-Kendall test indicates a significant downward trend of 16.8%. (Recharge (mm/a) = Recharge (mm/y); Année = Year)*

### «Methodology development and hydrogeological characterizations in support of groundwater resources mapping».

Project lead: Daniel Paradis

Accurately characterizing flow, and in some instances solute transport, in regional aquifers is a critical issue and it requires an excellent understanding of the spatial variability of the aquifers' properties. Existing data, generally horizontal hydraulic conductivity measurements, from databases made available by



*Example of correlation between the electrical resistivity obtained during penetrometer testing and hydraulic conductivity obtained using a well flowmeter.*

indirect measurements (ex. electrical resistivity) and direct measurements (ex. hydraulic conductivity) of hydrogeological properties from test wells representative of the overall hydrogeological conditions of the study area. These relations and the indirect measurements, which are generally larger in number, are then used for hydrofacies interpolation. Special attention will also be given to vertical hydraulic conductivity characterization, which is very important in recharge control in aquifer systems. The potential of methods developed in the Saint-Lambert context will then be evaluated to be extended to other hydrogeological contexts.

## Groundwater information network: a coordinated approach to disseminating groundwater information

Groundwater information is increasingly needed to help address pressing societal and scientific concerns. However, although many Canadian government agencies collect, analyse and report groundwater information, it is not always accessible. That's because it is distributed by many geographically disperse agencies, exists in different formats and data structures, is collected for different purposes and is not always available on the Web. Hence there is an increasing need for agencies to work together to improve access to groundwater information (Rivera, et al., 2003, section 7.3). To meet this need, a group of federal, provincial and watershed agencies are working in partnership with the national GeoConnections program to develop a groundwater information network.

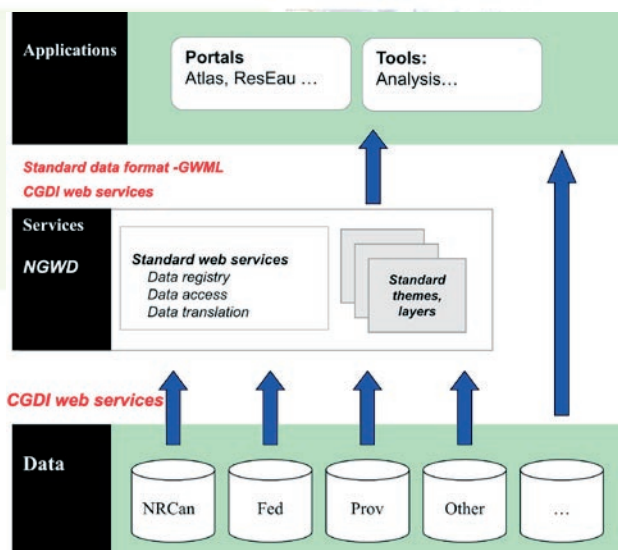
The network will utilize advances in Web-based geospatial standards and technologies as well as the Canadian Geospatial Data Infrastructure (CGDI). It will serve as a national catalogue of groundwater information, as a place on the Web where groundwater information can be accessed using standard technologies and data formats, and as a national-scale Web-mapping portal with enhanced analytical tools. This will enable user groups to improve the management of their water resources and contribute to enhanced decision-support capabilities. It will also permit access to online data by people who are not geographic information systems (GIS) specialists or are in settings where expensive GIS software is not available.

The initiative has three principal aspects:

1. Data provision – Data sources will provide information using CGDI-compliant Web services, without altering their existing databases.
2. Standards – Data providers will register these services with a central registry maintained by NRCAN and provide a translation, so a central broker can dynamically convert data to the standard format.
3. Web applications – A Web application (developed with a commercial partner) will provide tools to cache display and analyse water-well data and watershed information.

In addition, it is anticipated that the network will stimulate further application development among the groundwater community and that existing portals, such as RésEau and the Atlas of Canada, will take advantage of the network, thus providing several channels into groundwater information.

The initiative aligns with the three-tiered CGDI architecture of data, services and applications, as shown in the figure below:



Architecture of the groundwater information network

The establishment of the groundwater information network will make Canadian groundwater information more accessible to scientists, decision-makers and the public. For more information about this project, send an e-mail to Boyan Brodaric at Brodaric@nrcan.gc.ca or David Sharpe at DSharpe@nrcan.gc.ca.

## Groundwater assessment by the Council of Canadian Academies

The Council of Canadian Academies has appointed a panel of experts to identify the scientific knowledge – as well as gaps in our knowledge – that is needed to inform groundwater policymaking and regulation at the local, provincial, territorial and federal levels. The assessment will also better inform Canadians of the value and possible vulnerabilities of the nation's groundwater resources. The panel is composed of the following:

- James P. Bruce (FRSC), Chair, Expert Panel of Groundwater; Environmental Consultant, Climate and Water
- William Cunningham, Assistant Chief, Office of Ground Water, U.S. Geological Survey
- Allan Freeze (FRSC), Former Professor and Director, University of British Columbia
- Robert Gillham (FRSC), Professor and Natural Sciences and Engineering Research Council of Canada (NSERC) Chair, University of Waterloo
- Sue Gordon, Research Hydrogeologist and Leader, Alberta Research Council
- Steve Holysh, Senior Hydrogeologist, Conservation Authorities Moraine Coalition
- Steve Hruddy (FRSC), Professor, University of Alberta
- William Logan, Senior Staff Officer, National Research Council, U.S.
- Kerry MacQuarrie, Professor and Canada Research Chair in Groundwater-Surface Water Interactions, University of New Brunswick
- Paul Muldoon, Vice-Chair, Environmental Review Tribunal
- Linda Nowlan, Faculty Research Associate, University of British Columbia
- John Pomeroy, Canada Research Chair in Water Resources and Climate Change, University of Saskatchewan

- Steven Renzetti, Professor, Brock University
- Barbara Sherwood Lollar (FRSC), Professor and Director, University of Toronto
- René Therrien, Professor, Laval University

The Expert Panel on Groundwater arranged for a Public Call for Evidence on what is needed to achieve sustainable management of Canada's groundwater. Responses were received until November 2, 2007. For details on the Public Call for Evidence, visit [www.scienceadvice.ca/groundwater.html#groundwateranchor1](http://www.scienceadvice.ca/groundwater.html#groundwateranchor1).

This important review may affect government policy on groundwater for years. Groundwater associations (e.g. International Association of Hydrogeologists – Canadian National Chapter [IAH-CNC]), provincial and territorial governments and other groups participate in this review process. The report of the assessment is expected to be completed and made public in spring 2008.

## UNESCO's IHP and the OAS hold 5<sup>th</sup> International Workshop of the ISARM Americas Project

The 5th International Workshop of the ISARM (Internationally Shared Aquifer Resources Management) Americas project (UNESCO/OAS ISARM Americas Programme) was held September 17–20, 2007, in Montréal, Canada. It was coordinated by UNESCO's International Hydrological Programme (IHP) and the Organization of American States (OAS). The workshop brought together national coordinators of the 20 countries participating in the project and international experts from UNESCO, the International Network of Basin Organizations (INBO) and the International Groundwater Resources Assessment Centre. Ambassador Chusei Yamada, Special Rapporteur of the UN's International Law Commission (ILC) for the topic shared natural resources, also participated in the workshop.

Cooperation between neighbouring countries in the Americas led to the identification of 69 transboundary aquifers. These results are published in the book launched at the workshop (see ISARM book series below). The workshop also provided an opportunity to listen to several international presentations, such as those from Jean-François Donzier on INBO and the EU Water Framework Directive and Ambassador Yamada on the draft articles on the law of transboundary aquifers.

The workshop, organized by Alfonso Rivera of the host department, NRCAN, was composed of many events. It was a success, as witnessed by the goals reached and comments made by participants



during and after the workshop. Below are the highlights, a map of the transboundary aquifers of the Americas and photographs of the workshop.

#### • ISARM book series

The ISARM-Americas book series (other ISARM programs include ISARM-Europe, ISARM-Asia) was launched at the workshop. The first book is on the inventory of the transboundary aquifers (TA) of the Americas. It contains the scientific area of the TA aquifers identified in the American Hemisphere. It was published in Spanish only, but given its success, it will be translated into English in 2008.

To complete the ISARM series on TA, UNESCO will publish two other books. The second book will contain information on legal and institutional aspects of each of the countries sharing one or more aquifers. The third book will contain the socio-economical and environmental aspects of the TA aquifers identified in the first book.

To provide data and information on Canada for the books, NRCan's Earth Sciences Sector's Groundwater Mapping Program compiled all aspects of the Canadian side of the U.S.–Canada aquifers, with the help of Foreign Affairs and International Trade Canada (DFAIT), Environment Canada and a few provinces. The U.S. Geological Survey (USGS), meanwhile, compiled information for the U.S. side. This information includes data produced within the ESS Groundwater Mapping Program. Seven transboundary aquifers between Canada and the United States were identified and are inventoried in the book (see figure below).

#### • United Nations Rapporteur

Ambassador Chusei Yamada, Special Rapporteur on shared natural resources of the ILC, presented the status of the codification of law of transboundary aquifers (TA) by the ILC.

In 2002, the UN adopted the new topic of "shared natural resources," which covers three kinds of natural resources: groundwater, oil and natural gas. However, the Special Rapporteur recommended that the UN adopt a step-by-step approach and focus first (and only) on groundwater. Thus the ILC began work on groundwater, completing its first reading of a set of 19 draft articles on the law of TA in 2006. The ILC transmitted these articles to the United Nations General Assembly. The draft articles contained in the Report of the International Law Commission were made available to workshop participants in English, Spanish and French (copies are available upon request; please send your request to the editor of the Newsletter).

The ILC asked for written submission of comments and observations on the draft articles by governments by January 1, 2008, so it can proceed with the second-reading exercise at its session in 2008. Alfonso Rivera will coordinate Canadian comments (if any) from DFAIT, the International Joint Commission, Environment Canada and NRCan.

Ambassador Yamada concluded with a plan to complete the second reading of draft articles next

year and to recommend them to the UN General Assembly for adoption. To complete this task, he pleaded for continued assistance from UNESCO and groundwater experts in the Americas. The final aim is to produce a framework instrument (whether this will be binding is not yet decided) that would serve as a guideline to bilateral or regional agreements on some specific aquifer system to be negotiated by the countries concerned.

#### • A vision for managing TA

The UNESCO/OAS/ISARM initiative will attempt to generate a vision for managing transboundary aquifers based on data, information and experiences in the American countries. (This information will be contained in the three ISARM books mentioned above). The vision will have a "diagnosis analysis" to managing TA and will be ad hoc to the American hemisphere. [i.e., based on characteristics of American countries). However, workshop participants agreed that because of the many similarities in any geographical setting, the American countries' vision could be used as a good example elsewhere (others continents might adopt it).

Some of the main points discussed in Montréal will be included in the vision:

- Multi-stakeholders
- Multicultural aspects involved in the sharing of TA
- The use of the groundwater from different perspectives
- Layers of scientific committees in addition to socio-political groups
- Boundaries' issues
- Standardized operational definitions
- Data-collection integrity
- Making information available for the decision-making process
- Economic impacts

The vision will be designed as a high-level "framework for management." It will attempt to include recommendations from the law of TA by the ILC on shared natural resources. NRCan's Groundwater Mapping Program was invited to help prepare this vision.

#### • The field trip

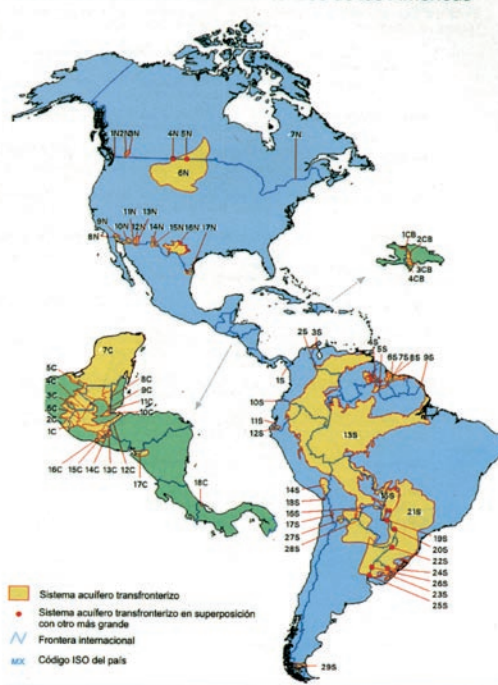
Alfonso Rivera (NRCan), Charles Lamontagne (Quebec's Ministère du Développement durable, de l'Environnement et des Parcs) and John Williams (USGS) organized and led a field trip to the Châteauguay transboundary aquifer. It is shared by the Province of Quebec (Canada) and the State of New York (United States). The trip included 10 stops, nine in Canada and one in New York State, to visit some springs in recharge areas. The participants realized with hindsight what a good transboundary aquifer can be. They noticed no obvious issues between Canada and the United States. They also noticed the high level of cooperation between the Geological Survey of Canada (GSC), USGS, Province of Quebec and universities who assessed this TA.

Copies of the colourful guidelines prepared for the trip are still available upon request (send your request to the editor of the Newsletter.)

#### • The technology workshop

The technology (and scientific) workshop, held at the end of the week, was the highlight of the event. Scientists were instructors for the

Sistemas Acuíferos Transfronterizos de las Américas



Location of the 69 transboundary aquifers of the Americas

technology workshop; of these, six were from the USGS and four were from the GSC. About 45 participants stayed for this workshop, including lawyers, high-level officials from several countries and Ambassador Yamada.

The technology workshop comprised high-level lectures on the advances in aquifer characterization and assessment. The lectures covered approaches to TA diagnosis, geophysics, data and information management, groundwater (GW) modelling, real-time GW monitoring and GW sustainability issues. At the end of the workshop, several countries approached UNESCO, requesting that it coordinate the cooperation between the USGS and the GSC.

In summary, those are the highlights of the international event. A more comprehensive report will be prepared by UNESCO by February 2008. Check the UNESCO-IHP site at: [www.oas.org/dsd/isarm/Documents/English/Documents\\_e.htm](http://www.oas.org/dsd/isarm/Documents/English/Documents_e.htm).

For more information, visit [www.oas.org/dsd/isarm/ISARM\\_index.htm](http://www.oas.org/dsd/isarm/ISARM_index.htm).

## Advances in Groundwater Research

### Mapping the variability of groundwater resources over major Canadian water basins from GRACE satellite data

(project leaders: Jianliang Huang and Calvin Klatt)

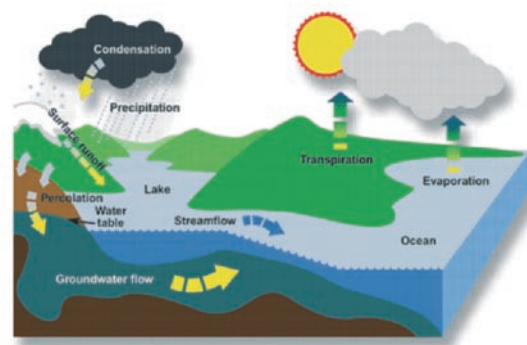
The Gravity Recovery and Climate Experiment (GRACE) satellites were launched on March 17, 2002, and will operate until approximately 2011. A follow-up mission, GRACE-II, is planned. One of the key mission objectives is to monitor terrestrial water storage changes. During the past five years, extensive studies have aimed to extract water-storage change signals from GRACE gravity data at the finest possible resolution in time and space. The latest studies suggest that water thickness equivalent (WTE) solutions from GRACE gravity data have a spatial resolution of about 400 km and an estimated error of 1 cm for 10-day periods.

NRCan's Groundwater Mapping Program has initiated an experimental project to map the temporal variability of groundwater resources in major water basins across Canada, using the GRACE data and auxiliary measurement of snow, ice, surface water and soil moisture, etc. These maps will provide a new, comprehensive, national view of groundwater that complements the targeted in situ data and the microwave remotely sensed data now available. These activities comprise two phases. Phase one (from approximately 2006 to 2008) involves the validation of GRACE data and the development of processing methods. During phase two, from approximately 2008 to 2009, a series of maps will be produced to show the groundwater variability in the major Canadian water basins for 2002 to 2009.

NRCan has joined forces with the Canadian Space Agency (CSA) to implement its Groundwater Mapping Program. Through the Government Related Initiatives Program (GRIP), the CSA fosters the development of Earth observation applications and products that will help fill gaps in current groundwater mapping efforts. With this value-added support, the NRCan-CSA partnership will provide methods, tools and best practices to map surface parameters.

With the GRIP support, the advanced model EALCO (Ecological Assimilation of Land and Climate Observations, see figure) will be further improved to simulate groundwater recharge, groundwater-surface water interactions, and climate change impacts on groundwater resources. Key features of the EALCO model include its capability to directly assimilate Earth Observation (EO) data at various spatial resolutions for groundwater recharge assessment.

Land use and land cover (LULC) mapping, leaf area index (LAI) product and soil properties characterization are basic information required for the estimation of water-balance parameters used in recharge modeling. The use of EO data to extract this information is a practical approach because of their extensive coverage and relatively low purchase and processing costs. NRCan has developed operational approaches that produce validated regional maps of land cover and leaf area index using optical satellite images. Scientists are also working at developing cartographic methods and prototype products using radar and optical medium-low spatial resolution sensors. Synthetic



GRACE and the hydrological circle (from NASA and Environment Canada)

### Mapping groundwater from space

(Project leaders: Stéphane Chalifoux, NRCan; and Paul Briand, Canadian Space Agency)

Water is fundamental to the needs of humans and the environment. Protecting groundwater supplies – aquifers – is a national priority. It is in this context that Natural Resources Canada (NRCan) has undertaken to map key regional-scale aquifers in Canada.



aperture radar imagery can be used to map soil conditions and land surfaces; specific researches have proven the utility of multi-polarization and high spatial resolution radar sensors. Through Canada's RADARSAT and the European Space Agency's ENVISAT satellites, Canada has continuous access to strategic information on our entire territory.

## People in the News

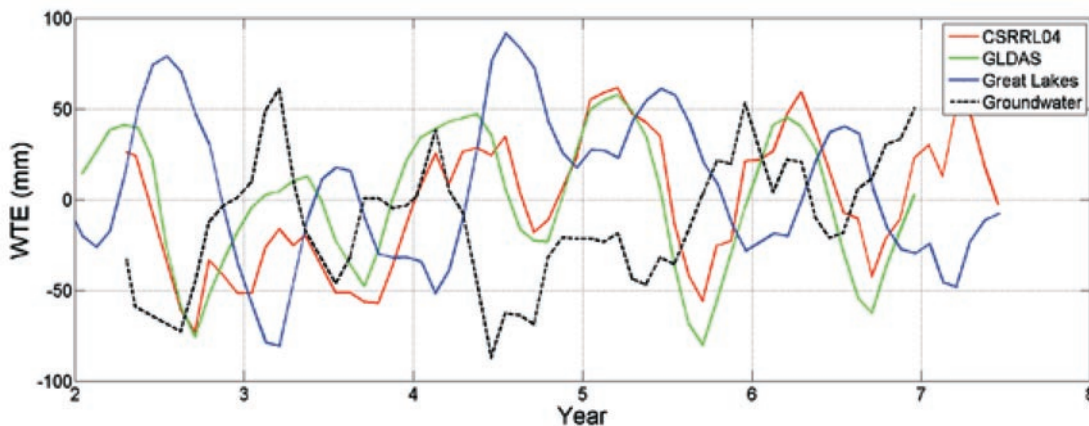
### Canadian governmental hydrogeologists

A meeting of Canadian governmental hydrogeologists, sponsored by the International Association of Hydrogeologists – Canadian National Chapter, was convened on October 25, 2007, in Ottawa,

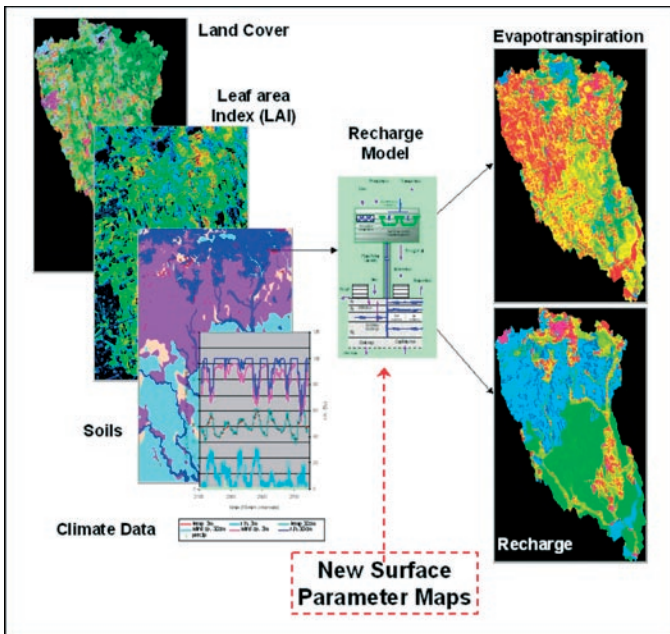
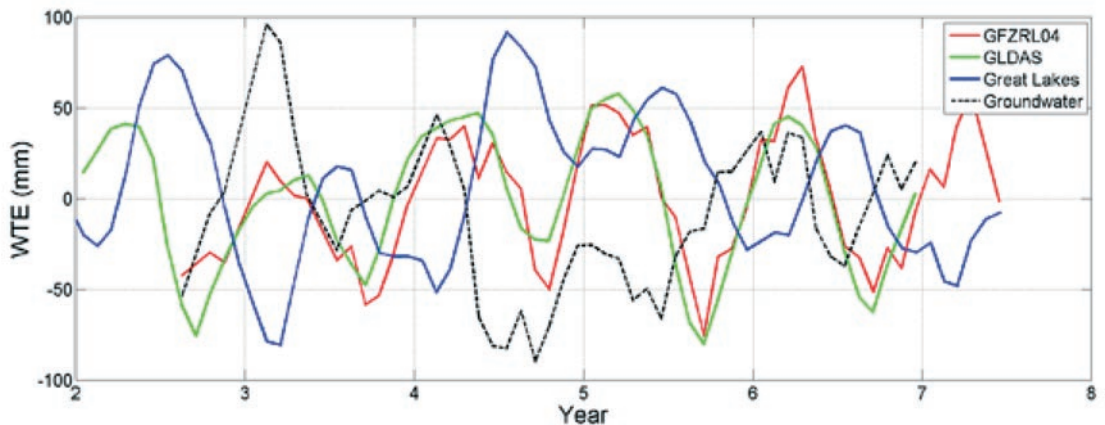
- Encourage the exchange of hydrogeological knowledge on important issues of common interest to governmental hydrogeologists
- Build a strong network between governmental hydrogeologists
- Hold annual meetings following each Joint CGS/IAH-CNC Groundwater Specialty Conference

Each federal organization and province had 20 minutes to present a summary consisting of the following:

- What hydrogeology work they conduct
- Their main provincial/federal hydrogeology issues
- How their organization is structured in relation to hydrogeological issues and activities
- How groundwater is managed and regulated



Estimation of groundwater variation (black dash line) using two different sets of the monthly GRACE gravity models. The water thickness equivalent (WTE) results represent mean values over the entire Great Lakes water basin. The soil moisture and snow models from the Global Land Data Assimilation System (GLDAS) are used to separate the ground water variation from the total terrestrial water storage variation (red line) estimated from GRACE data.



Groundwater Recharge Assessment using EALCO

following the 8th Joint CGS/IAH-CNC Groundwater Specialty Conference. (CGS is the Canadian Geotechnical Society.)

The theme of the meeting was "Canadian Governmental Hydrogeologists: Who are we? What do we do?" This meeting, organized by the IAH-Canadian National Chapter, was designed following similar national workshops on groundwater, organized by the Geological Survey of Canada in 2000, 2001 and 2003.

The purpose of the meeting was to:

- Promote dialogue between interprovincial or federal/provincial governmental hydrogeologists throughout Canada

- What hydrogeological programs they deliver

The presenters included the following:

- John Drage from Nova Scotia
- George Somers from Prince Edward Island
- Charles Lamontagne from Quebec
- Jamie Connolly from Ontario
- Bob Betcher from Manitoba
- Nolan Shaheen from Saskatchewan
- Steve Wallace from Alberta
- Mike Wei from British Columbia
- Garth van der Kamp from Environment Canada
- John Oosterveen from the Prairie Farm Rehabilitation Administration
- Alfonso Rivera from the Geological Survey of Canada

A CD-ROM with the presentations will be produced and will be available through the IAH-CNC Web site.



*Participants of the governmental hydrogeologists meeting, Ottawa, October 25, 2007*

## Poetry in hydrogeology

The fall 2007 edition of The Hydrogeologist, the newsletter of the Geological Society of America's Hydrogeology Division, included "Hydro-Poetry" on page 13 (visit <http://gsahydrodiv.unl.edu/newsletters/fall07.pdf>). With permission kindly granted by Harry E. LeGrand, I reproduced this poem below.

### Listen To the Aquifers

With elegant awe we view piedmont and mountain land  
And its underground counterpart we try to understand.  
The animated hidden ground water has much to say.  
Looking closely, we see how the water game will play.

Beneath all of the slopes of every mountain valley  
And under more Piedmont slopes than we can tally,  
Ground water moves at its preferred pace.  
Never interested in some competitive race.

Under the soil and into rock's winding fractures,  
Always seeking springs and lowland apertures,  
Trickling below elusively for hundreds of weeks,  
Ground water moves steadily toward nearby creeks.

The aquifers are bounded by hilltops and adjacent streams.  
Further limited by deep unfractured rocks, each seems  
Ready to cope with global warming and our water need,  
But our greedy habits don't abide by the aquifers' creed.

In a trough between adjoining aquifers is each river or creek.  
Aquifers nourish and pamper them and try not to let them leak.  
Furnishing water to streams during long periods without rain  
Is a big responsibility that aquifers try to maintain.

A true environmental pulse is each aquifer's water table  
Down in dry weather and up in wet weather is a nice label.  
As each aquifer is small, modest in yield, and not tightly connected  
Over-pumping of ground water regionally is not to be expected.

As the aquifers are sensitive to abuse by us,  
They spitefully fight back and raise a fuss.  
When water is overused or contaminants are in its path,  
An aquifer has several ways to boldly express its wrath.

Not easily adaptable to human regulations,  
Aquifers behave with their own deliberations.  
The aquifers are talking, but do we listen?  
Are there valuable lessons we are missin'?

Our forefathers expected pristine ground water everywhere.  
Now, the hidden sea of ground water is pocked here and there  
With a plume of contaminated ground water from each waste site.  
Spreading and mixing of good and bad water is now a sorry plight.

Local aquifers refuse to cooperate with urban sprawl.  
Dense population creates waste, and aquifers have gall.  
Some aquifers are poisoned each month and can never come back.  
Sustainability of good ground-water supplies is not on track.

In emergencies that may arise with unforeseen disaster  
Places for special pure water we may need to get faster.  
Here and there is a pristine spring in a v-shaped valley  
For us to appreciate and around which we can rally.

Aquifers can maneuver water to level land,  
Where wetlands may be alive and grand.  
Wetlands display some habitats to appreciate  
And are lands on which humans negotiate

Hill and dale, linked mini-aquifers everywhere surround us  
Translations of landscape and geologic thoughts are a plus.  
Topographic maps help us to view aquifers in a splendid way.  
We now see how each aquifer's underground game can play.

The underground landscape offers new scenic views,  
And exploring with aquifers offers a creative cruise.  
To look under ground with art in virtual reality,  
One can see nature's handiwork and its vitality.

Harry E. LeGrand  
July 5, 2007





## **Suggesting Readings**

### **Walter and Duncan Gordon Foundation's "bleu print" for federal action on freshwater**

The Walter and Duncan Gordon Foundation is an independent Canadian grant-making foundation. It is dedicated to the development of sound and innovative public policies. The Foundation has provided financial support to the Gordon Water Group to prepare a blueprint report for federal action on freshwater.

The Gordon Water Group of Concerned Scientists and Citizens – a group of scientists, lawyers, policy experts and former federal government policy advisors – is united by a shared concern for Canada's freshwater future. The Gordon Water Group has established a comprehensive blueprint for federal action on freshwater protection in the recently published report (2007) entitled *Changing the Flow: A Blueprint for Federal Action on Freshwater*. The report may be downloaded as a PDF file at [www.gordonwatergroup.ca/](http://www.gordonwatergroup.ca/).

The blueprint recommends essential steps that would re-ignite the Government of Canada's role in sustaining this most precious resource and help guide our nation to a sustainable freshwater future. *Changing the Flow* builds on mounting calls from a diverse range of groups and sectors for renewed federal action on water. It establishes what they believe is a compelling case for urgent actions to be undertaken by the Government of Canada and provides clear and concise direction through 25 recommended actions organized around seven priority areas:

1. Enhancing national capacity for freshwater protection
2. Responding to the impacts of climate change and energy production
3. Securing safe drinking water for all Canadians
4. Protecting aquatic ecosystems and Aboriginal water rights
5. Promoting a culture of water conservation
6. Preventing inter-jurisdictional conflicts and bulk water exports
7. Developing world-class water science

This blueprint is directed at federal decision-makers and influential policy advisors. Copies of this blueprint have been distributed to every Member of Parliament, all Senators and key decision-makers in provincial, territorial and Aboriginal governments.

In particular, note recommendation action 23, under priority 7 (p. 44): "Create National Water Inventories and Ensure All Major Aquifers Are Mapped." Thus, even though the Groundwater Mapping Program of NRCAN is a modest program relative to the many water initiatives in Canada, its vision and mission seem to have caught the attention of this group, with a recognition implicit in action 23.

### **References**

Custodio, E., 2007. *Groundwater Protection and Contamination*. Published by NGWA Press, Westerville, OH, USA. Special edition based on selected papers of The Global Importance of Groundwater in the 21st Century: Proceedings of the International Symposium on Groundwater Sustainability. Alicante, Spain, January 2006.

Fernandes, R., Korolevych, V. and Wang, S., 2007. Trends in Land Evapotranspiration over Canada for the Period 1960–2000 Based on In Situ Climate Observations and a Land Surface Model. *Journal of Hydrometeorology*, Vol 8, 1016–1030.

Huang, J. and Halpenny, J., 2007. Estimating variation of groundwater storage within the Great Lakes Water Basin from GRACE, soil moisture and lake levels. Joint International GSTM and DFG SPP Symposium, October 15–17, 2007, at GFZ Potsdam, Germany.

Morris, T.J., D.R. Boyd, O.M. Brandes, J.P. Bruce, M. Hudon, B. Lucas, T. Maas, L. Nowlan, R. Pentland, and M. Phare, 2007. *Changing the Flow: A Blueprint for Federal Action on Freshwater*. The Gordon Water Group of Concerned Scientists and Citizens. ISBN: 978-0-9699660-3-6.

Rivard, C., Marion, J., Michaud, Y., Benhammane, S., Morin, A., Lefebvre, R. and Rivera, A., 2003. Étude de l'impact potentiel des changements climatiques sur les ressources en eau souterraine dans l'Est du Canada, Geological Survey of Canada, Open File 1577, 39 pp.

Rivera, A., Crowe, A., Kohut, A., Rudolph, D., Baker, C., Pupek, D., Shaheen, N., Lewis, M., Parks, K., 2003. Canadian Framework for Collaboration on Groundwater. Geological Survey of Canada. Available at: [ess.nrcan.gc.ca/2002\\_2006/gwp/pdf/cadre\\_canadien\\_collaboration\\_eau\\_souterraine\\_e.pdf](http://ess.nrcan.gc.ca/2002_2006/gwp/pdf/cadre_canadien_collaboration_eau_souterraine_e.pdf).

Savard, M. M., D. Paradis, G. Somers, S. Liao, E. van Bochove, 2007a. Winter nitrification contributes to excess NO<sub>3</sub><sup>-</sup> in groundwater of an agricultural region: A dual-isotope study, *Water Resour. Res.*, 43, W06422, doi:10.1029/2006WR005469.

Savard, M.M., et al, 2007b. Consequences of climatic changes on contamination of drinking water by nitrates on Prince Edward Island. Composed of 10 chapters and edited by Martine Savard and George Somers. A joint NRCAN–PEI–AAFC report. Available from GSC Libraries: [adaptation.nrcan.gc.ca/projdb/pdf/109\\_e.pdf](http://adaptation.nrcan.gc.ca/projdb/pdf/109_e.pdf).