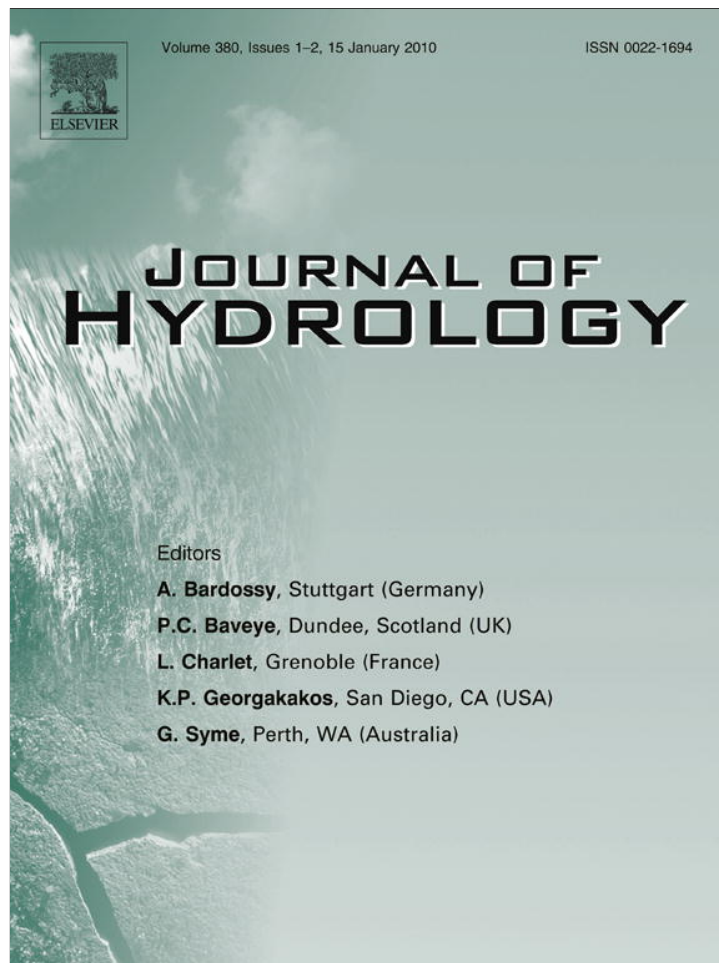


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Goals, gaps and governance: The holy grail in preserving Canada's hidden liquid gold

One of the most pressing issues in hydrology has become the management of increasingly scarce water resources. Scarcity may be defined by decreased rainfall, water quality that has become insufficient for its preferred use, or in relation to burgeoning demand from urban, industrial or irrigation developments. These problems are common to both developed and developing countries. Many hydrologists and water managers then become involved with the conflict of endeavouring to re-allocate water or improve its quality. Such activities are surrounded by disputes in terms of hydrological, economic or political contexts. Often sustainable water management is approached rather than achieved and reflective analyses incorporating all the components of sustainability are simply not attempted.

A refreshing exception to this circumstance may be possible in Canada where the thresholds of sustainable management have not been reached in many circumstances. There is still the opportunity for integrated strategic planning and the delivery of long-term sustainable outcomes. In doing so there may be many lessons and innovations created relevant internationally to achieving sustainable water management. The following describes one important Canadian initiative, undertaken by the Council of Canadian Academies, that attempts to meet such a challenge.

Background

Canada is known for its abundant natural resources, its oil reserves alone are second only to Saudi Arabia; however, Canada's abundance of freshwater is arguably its most precious, and perhaps under-appreciated, gift of nature. Canada has less than 1% of the world's population but its rivers discharge over 9% of the world's freshwater and approximately 8.9% of the country's surface is covered by water. The apparent abundance of water makes Canada vulnerable to the perception of unlimited supply. This makes Canadians less mindful of the dangers of poor stewardship and the need for sustainable management.

Groundwater represents a significant percentage of Canada's freshwater supply for domestic, industrial and agricultural use; for example, almost 10 million Canadians rely on groundwater for drinking water and it also plays an important role in the maintenance of ecosystem health and viability. While our dependence on groundwater is critical, our knowledge of it remains extremely fragmented. Given the inextricably interrelated connection between groundwater and surface water within the hydrological cycle, this information gap represents a significant threat to our ability to sustainably manage Canada's water resources and to secure our water supply for future generations. Furthermore, a lack

of consolidated knowledge to define Canada's groundwater endowment and supply, coupled with a limited understanding of groundwater economics, represents a significant impediment to informed policy-making and long-term sustainable, resource planning. Groundwater extractions are subject to a diverse spectrum of potential demands and challenges, including those related to ecosystem support, urban development, agriculture, industry, mining, and population growth. Developing sustainable management strategies requires that decision-makers have a comprehensive understanding of these demands and challenges, and a detailed awareness of the economic and political instruments at their disposal.

Although Canada has not yet experienced widespread over-usage of groundwater, there have been a number of cases where severe local or regional problems have arisen. Canada is in the enviable position of being able to proactively implement policies and management practices that can prevent the kind of groundwater crises experienced in many other parts of the world. In recognition of this "window of opportunity", the Minister of Natural Resources Canada (NRCan) asked the Council of Canadian Academies (a recently created Canadian analogue of the National Research Council in the US) to address the question '*what is needed to sustainably manage groundwater in Canada, from a science perspective?*'

The Council released the report of the Expert Panel on Groundwater in May 2009; the report can be accessed, and downloaded for free, from the Council's website: <http://www.sciencenadvice.ca>. The 15-member panel – comprised of leaders in the science of groundwater, as well as experts in the social, economic, and legal fields relevant to sustainable groundwater management – concluded that a Canada-wide sustainability framework, applied at all levels of government, is required to improve the management and understanding of Canada's groundwater. Without such a framework, Canada's groundwater is at risk of contamination and depletion and its contribution to freshwater ecosystems remains under threat.

The report addresses three broad themes – goals, gaps, and governance – that identify the key issues and challenges that scientists and decision-makers must face in order to achieve sustainable management.

Goals

The report benefited tremendously from the diversity of views that were represented among panel members, responses to a call for evidence, and insights from 18 independent reviewers. The re-

port is a unique and comprehensive assessment of what sustainable management of Canada's groundwater would look like and the steps that need to be taken to achieve it. This starts with the panel's definition of sustainability, expressed through the interaction of five interrelated goals; three of which lie in the domain of physical sciences and engineering, two of which are essentially socio-economic in nature. These goals define a framework upon which, a systems-based approach to sustainable groundwater management can be developed. Each of the five goals is necessary, and no one by itself is sufficient; true sustainability will require a careful analysis and balancing of the five goals.

The first goal states that, to be sustainable, groundwater management must seek to prevent continuous, long-term declines in regional groundwater levels. The impacts of declining water levels are potentially multi-faceted and include reduced capacity to sustain municipal and agricultural use during droughts, increased costs for pumping and treatment, and reduced discharge to streams and surface water ecosystems. In order to meet this goal, a comprehensive understanding of large-scale groundwater flow dynamics is needed. To this end, the development of a common framework for aquifer categorization would allow the integration of data from local studies into broader regional and national assessments.

The second sustainability goal requires that groundwater quality must not be compromised by a significant degradation of its chemical or biological character. Reduced groundwater quality can significantly impact both human health and ecosystem health, and the economic impact of remediating contaminated groundwater can be immense. Sustainable groundwater management must seek to both prevent groundwater contamination in the first place, and to remediate and restore already-contaminated groundwater. Groundwater residence times far exceed those of surface water. Whereas water that occurs in surface systems typically exhibits residence times on the order of weeks to months; groundwater often resides within an aquifer system for thousands of years. As a result, the impacts of unsustainable groundwater use may take years or decades to appear; once observed, repair may be impossible within our lifetimes and those of many generations to come. This unique aspect of groundwater necessitates management techniques that are quite different to those used for surface water.

As a third goal, a sustainable management plan must balance the human benefits of groundwater extraction against the ecosystem benefits realized by maintaining adequate stream base-flow, and wetland, river, and lake habitats. The role of groundwater in the maintenance of ecosystem viability cannot be underplayed; groundwater discharge plays an integral role in the maintenance of ecologically rich wetland habitats, for example, the dependence of western salmon populations on groundwater seepage into streams. The metrics against which human benefits can be measured are readily available and well understood; however, mechanisms to assign value to the ecosystem benefits derived from groundwater are poorly understood and incomplete. In order to equitably balance ecosystem and socio-economic needs, comparable procedures are necessary in both domains to quantify the value of water.

The fourth goal relates to the achievement of economic and social well-being. The economic benefits of sustainable management policies are multi-faceted; these benefits should be considered in the context, not just of direct economic impacts but also in contribution to Canada's environment and society. In order to promote efficient water usage, end-users should be aware of the full costs and benefits of their water consumption. The use of economic instruments, including market-based incentives, in other jurisdictions has clearly demonstrated their utility in promoting sustainable water use by end-users; for example, there is a strong correlation between water price and consumption in industrialized

countries. The principal challenge in this regard includes the lack of experience of governments in Canada with these policy instruments; a lack of understanding regarding the economic characteristics of users' groundwater demands; and the need to coordinate the introduction of market-based instruments with existing regulatory frameworks.

The fifth goal emphasizes the need for good water governance. Water governance can be defined as the range of political, organizational and administrative processes that are used to articulate interests, receive input, make and implement decisions, and hold decision-makers accountable. Governance is distinct from the on-the-ground, operational activities that define water management. Strong scientific knowledge is necessary but not sufficient for good governance since good water governance must take into consideration a multitude of factors, including participation, inclusivity, transparency, predictability, accountability, and the rule of law. In Canada, major responsibility for water management resides with provincial and local authorities; however, groundwater and surface water systems that transcend provincial borders or international boundaries pose additional governance challenges that must be addressed appropriately. Good governance must ultimately include the means to achieve balance among the other four sustainability goals – for example, failure to do so means that groundwater management decisions will likely favour socio-economic interests over ecosystem and environmental interests, leading to situations that are inherently unsustainable.

Gaps

In order to manage groundwater in a sustainable manner, it is necessary to fill the gaps in our understanding of the behaviour of each hydrogeological system of interest, including its response to human-induced and natural perturbations. To this end, the panel advocated the development of a four-component framework approach to flow-system analysis: (i) understanding the geological and hydrogeological context of groundwater occurrence, (ii) the strategic use of groundwater models, (iii) the collection and integration of groundwater data, and (iv) building and maintaining the necessary capacity in human resources, computer facilities, and field instrumentation capabilities.

Decision-makers require models that can predict the behaviour of the hydrological system, taking into consideration the potential impacts of land-use, climate, and abstraction changes on the entire groundwater flow system. Models provide simulated results rather than unequivocal answers; therefore transparent documentation of the model, outlining its strengths and weaknesses, is a pre-requisite to effective (and credible) use. As modelling technologies improve, and new monitoring data are obtained, models should be continually updated. These "living models" will potentially facilitate more accurate delineation and protection of recharge areas and regulation of withdrawal volumes. As data and experience accumulate, prediction uncertainty decreases; the corollary to this is that models can then be used to set data collection priorities for subsequent monitoring initiatives.

Models are only as good as the data used to construct them; therefore a sound understanding of the subsurface geology and hydrogeological regime are crucial to reducing prediction uncertainty. The lack of a coordinated data-management effort results in loss of considerable amounts of groundwater data from studies conducted by consulting firms, universities, and non-governmental agencies. The panel advocates strongly for a structure and set of best practices to facilitate data sharing among various stakeholder groups throughout Canada, highlighting the need to further develop a platform for sharing data, perhaps via the Groundwater Information Network (GIN) that is hosted by NRCAN.

Furthermore, the development of accurate models requires modellers to have a sound appreciation for the interdisciplinary nature of groundwater science. This will necessitate the development of training programs that emphasize an interdisciplinary and collaborative approach to water management, producing experts who are well-versed in integrated hydrological sciences, ecosystem sustainability, watershed management, water resource economics, and water law.

Governance

New stresses, as well as intensification of existing ones, will raise challenges for the sustainable management of groundwater. These challenges will not disappear and should thus be considered as integral to the decision-making process.

Population growth and urbanization might reasonably be expected to result in both increased demand for groundwater and reduced recharge and thus diminished ability to sustain stream flow during low-flow periods. Growing urban populations also increase the risk of groundwater contamination from urban wastewater, contaminated surface water, industrial activity, and waste management facilities such as landfills. Coordinated action from provincial and local governments will be needed to protect recharge zones and to minimize the adverse effects of potentially harmful land uses.

Growing populations lead to increased agricultural intensity, which itself poses a threat to groundwater quality. Contamination of groundwater by nitrates and microbial pathogens, as a result of agricultural activity, is a serious concern. Stronger enforcement and regulatory regimes, coupled with information and incentive programs, may be needed to protect groundwater integrity in at-risk areas.

Although the quality of municipal drinking water in Canada is generally high, 20–40% of private wells – serving approximately 1.0–1.5 million Canadians – report nitrate or coliform levels that exceed Canadian Drinking Water Guidelines. The lack of uniformity in provincial monitoring requirements makes data interpretation difficult, and may result in erroneous perceptions of geographic variability. Given the prohibitive cost of detailed monitoring initiatives, targeted local-level water-quality monitoring programs, coordinated with efforts on a regional and national level, are necessary in order to identify larger-scale trends affecting groundwater quality.

Operations to exploit Canada's energy-related natural resources will continue to expand. This places tremendous pressure on groundwater and surface water supplies, and also results in the production of large volumes of extraction-related waste. In order to facilitate sustainable groundwater usage in these projects, clear groundwater allocation and quality objectives must be defined prior to the approval of any new energy extraction initiative.

Climate change represents an emerging threat to hydrological systems. Although the impacts of climate change on groundwater systems remain unclear, it is reasonable to expect that changes in recharge, increased withdrawals, decreased synchronicity of recharge and withdrawal events, and increased variability of recharge and withdrawal will ultimately have a profound effect on surface water, groundwater, and the populations and ecosystems that depend on them. Transparent models that seek to integrate and examine these variables will be essential tools for decision-makers in the coming years.

Conclusions

Canada is well positioned to be a world-leader in the development of sustainable management practices to protect and preserve groundwater supplies; however to do so, Canada must take action now.

The interjurisdictional nature of groundwater necessitates the development of a cooperative approach, uniting municipal, provincial, and federal government agencies in the development of scientific programs and policies that will ensure Canada's groundwater resources are managed sustainably. Such cooperation will be necessary in order to meet the five sustainability goals outlined earlier, and is imperative if Canada is to avoid the kinds of catastrophic over-usage or contamination issues experienced by other countries.

Regular reporting to the public by decision-makers on progress towards sustainability targets will be essential in facilitating sustainable resource management. Techniques for acquiring and applying sustainability indicators need further development. The panel recommends that the federal government, in cooperation with the provinces, should be encouraged to report on the current state of groundwater quantity and quality in Canada and on progress towards sustainable management. Such a report should be updated at regular intervals, possibly every 5 years.

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¹ *About the Council of Canadian Academies:* The primary mission of the Council is to manage the conduct of assessments of science that is relevant to key public policy issues, via independent expert panels. The Council addresses the broad spectrum of knowledge – encompassing the natural, social and health sciences, engineering, and the humanities. The primary objective of the Council is to provide for Canada an independent and authoritative, and therefore credible, way to build public confidence that policy and regulatory decisions are being based on broadly accepted scientific knowledge and evidence. The Council also provides a focal point for dealing with academics and related bodies from around the world regarding scientific assessments and related matters.