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GROUNDWATER JURISDICTION: A CANADIAN PERSPECTIVE

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Abstract: Recent Canadian studies confirm that certain aspects of urban growth pose a serious threat to the quality and quantity of groundwater. While Federal, Provincial and Municipal laws exist that may limit impacts, this legislation is complex, limited in extent, and rarely acknowledges either the wide range of potential urban contaminants or the temporal dynamics of groundwater flow. For much of Canada, a perceived abundance of fresh water resources has led to widespread complacency with few Canadians regarding groundwater protection as a priority issue. In recent months, this view has apparently changed, in southern Ontario at least, with local residents visibly angered by proposals to build housing on the Oak Ridges Moraine aquifer. The ensuing campaign to "Save the Moraine", championed by citizens' groups and fuelled by the media is highly politicised and scorns scientific evidence showing potential impacts can be ameliorated. The battle has served, however, to highlight the archaic state of existing legislation for groundwater protection in the province. Indeed, Canada as a whole, sorely needs a broad, and scientifically based policy that will adequately protect all ground and surface water. Research and experience suggest that such a policy should be based on a standards of performance approach, and be policed at the provincial level. Standards would designate limits for the degree to which a change in land use would be allowed to degrade water quality, and may also require that total recharge remain unaltered on a sub-watershed basis. This type of approach would show respect for local hydrogeological conditions and encourage planning innovation. The approach would also encumber the proponent of land use change with the responsibility to perform appropriate sub-surface investigations and provide designs, monitoring programs and contingency plans that would enable environmental standards to be met for all time.

CANADIAN GROUNDWATER RESOURCES - A NEGLECTED RESOURCE

Canada is endowed with copious volumes of fresh water. Average annual precipitation is about 600mm across almost 10 million km^2 of territory (equivalent to 7% of the global land mass). Allowing for evaporation and transpiration losses, the national input of fresh water exceeds 3,000 cubic kilometres annually (Hare, 1984), a quantity that is 9% of the world's renewable fresh water supply. To complete the hydrologic cycle all this water ultimately enters the Pacific, Arctic and Atlantic Oceans at a mean rate close to 100,000 m^3 every second. Even recognising that Canadians are the world's second largest per capita users of water (360 litres per person for household use alone) it is readily estimated that only 2% of the nation's renewable input is withdrawn to meet human and industrial needs.

In many regards, it is the perceived abundance of fresh water in Canada that has caused the many water problems we face today. A noticeably lax attitude to water resource management and protection has allowed many rivers and lakes to become contaminated by industrial plant effluents, runoff from agriculture, urban and industrial areas and forestry, landfill leachates, inadequately treated sewage, and long-range transport of airborne contaminants (Government of Canada, 1991). There is also increasing evidence of groundwater contamination, a particular concern given that groundwater residence times are large and regularly exceed several hundred years. If it is assumed that the total volume of water in storage at any time (groundwater, surface water and ice) probably exceeds a staggering 300,000 km^3, mean residence time for all fresh water in Canada averages 100 years.

It is estimated that 90% of Canada's fresh water is stored as groundwater - primarily contained in clastic sedimentary rocks, limestones/dolomites (including karst), fractured crystalline rocks of the Canadian Shield, and glacial sediments. This fraction compares with approximately 4% stored in the nation's 100,000

glaciers and about 3 % stored, at any one time, in its numerous rivers and lakes. To help put these figures in perspective, it has been suggested that the lakes and rivers, which cover nearly 8% of the country, contain enough water to flood the entire nation to a depth of 2m (Science Council of Canada, 1988). If groundwater were described to similar effect, the water depth would approach 50m or more.

The most recent figures suggest that groundwater obtained from aquifers provides a domestic supply for between 25 and 30 % of all Canadians. The value varies regionally from 100% in Prince Edward Island to as little as 1% in the Northwest Territories and Nunavut. Almost 70% of those reliant on groundwater are rural users; in fact, over 80% of the rural population depend on groundwater for domestic use. Industrial use of groundwater is about 1% and partly reflects the large volumes of surface water used by thermal plants (electrical power generation).

In general, and as observed by Vonhof (1985), the attention paid by individual Provinces to the protection of groundwater resources is a function of its relevance as a source of potable water and the availability of alternate surface-water resources. Largely, it is the rural communities that have greatest dependence on groundwater; yet, in many Provinces with abundant surface water supply, it is precisely these stakeholders that have least influence on the decision-making process. Groundwater continues to be a neglected resource in Canada. Few Provinces maintain adequate groundwater monitoring networks (either quality or quality); few attempts have been made to document groundwater resources and the extent to which the potability of these resources is being compromised by pollutant sources. Moreover, while some Provinces argue that they "manage" groundwater resources, the truth is that most do little more than issue permits for water-taking. It is of little surprise that groundwater contamination is becoming a serious issue for concern.

SOUTHERN ONTARIO AND THE OAK RIDGES MORAINE

Until recently, groundwater resources and the threat of contamination would have barely raised an eyebrow for the vast majority of Canadians. In Toronto, for example, Canada's largest urban region, virtually all drinking water is drawn from Lake Ontario, and the risk of land use change to groundwater resources is regarded by many as of little consequence. In the past six months, this attitude has changed rapidly, with proposals by land developers to "sprout" housing along tracts of the Oak Ridges Moraine (Howard et al., 1995) (Figures 1 and 2), one of the Province's larger aquifers and the headwater source of many of the region's streams. "Concerned citizens", fired by activist groups and supported by the local press, began an intense campaign to "Save the Moraine" from urbanisation, an increasingly politically motivated movement that has brought the issue of groundwater protection to the public eye. In many regards, the groundwater science has been lost in the ensuing and highly contentious debate. Few protestors seem to care, for example, that the unusually detailed hydrogeological studies conducted as a prerequisite to development suggest potential problems are readily manageable and that impacts will be negligible. What has been highlighted, however, and brought to centre stage is the archaic state of existing groundwater legislation for much of the Province. In fact, somewhat ironically, the Oak Ridges Moraine is one of few areas in the Province where existing legislation provides groundwater with a significant degree of protection.

For the most part, the legislation is woefully inadequate. Comprising little more than a patchwork of statutes, policies, programs, regulations and guidelines, it clearly lacks the breadth, versatility and conviction to deal with the wide range of potential land-sourced contaminants (Howard, 1997a) and the dynamics of groundwater flow within frequently complex glacial aquifer systems. From a purely practical standpoint, prospective land developers find they are faced with a maze of legislation at virtually all levels of government (Howard, 1997b) while groundwater receives only piecemeal protection. The underlying problem is that there is no single body, either at the Provincial or Federal level, which is willing to take jurisdictional responsibility for the management and protection of groundwater resources.

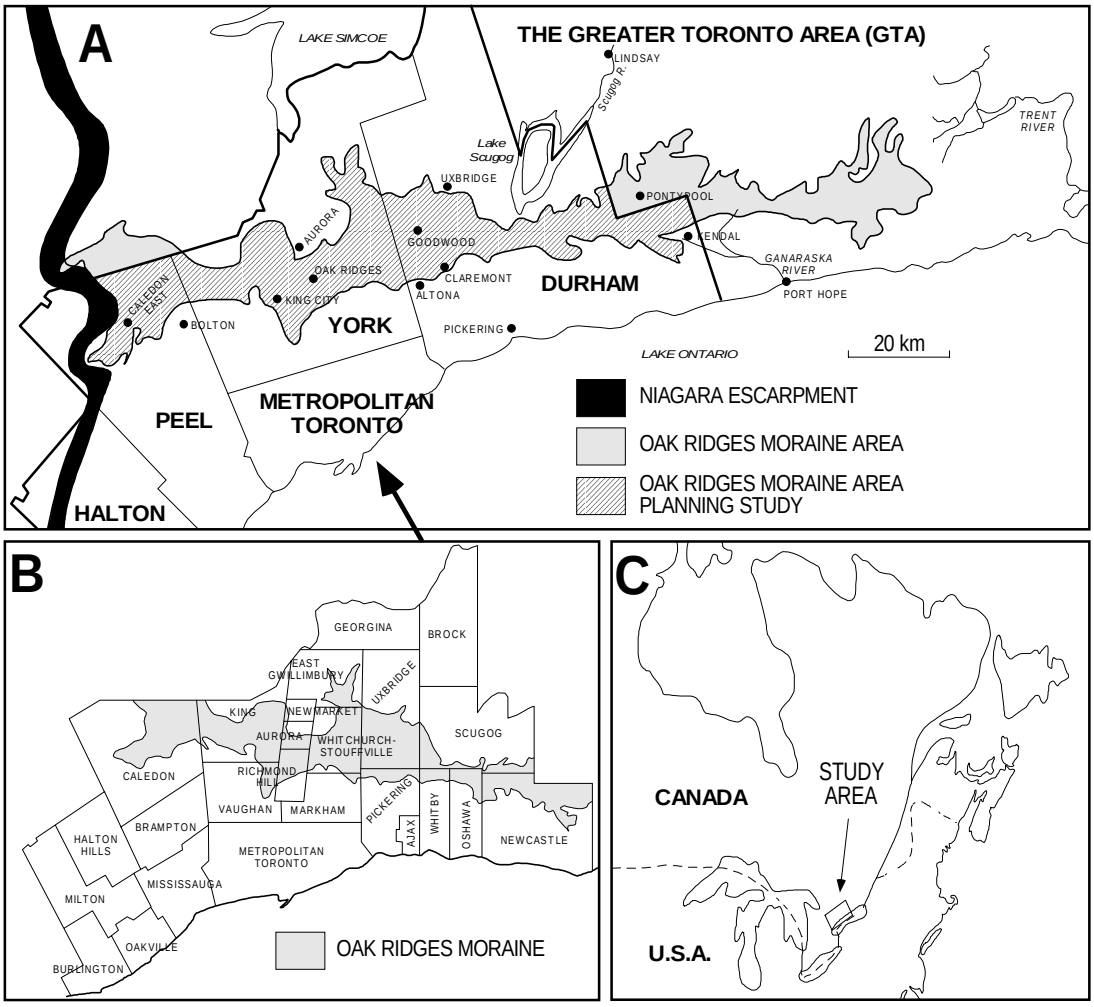

Figure 1. A) Location map showing the Oak Ridges Moraine (ORM) in relation to Metropolitan Toronto and the four Regions that together comprise the Greater Toronto Area (GTA). The Oak Ridges Moraine Planning study area refers to that part of the moraine contained within the GTA; B) Local Townships; and C) Regional location (after Howard et al., 1995).

ONTARIO'S LEGISLATIVE PROCESS

The urban planning process in Ontario, Canada's most populated Province, provides a good illustration of the complex and archaic state of the legislation that is supposed to protect groundwater. The 1995 Ontario Planning Act gives the Ministry of Municipal Affairs (MMA) responsibility for the approval of official plans, official plan amendments (OPAs), subdivisions, consents and zoning order amendments. In practice, approval authority for sub-divisions and, in some cases, OPAs is delegated to regional municipalities at the local level (Counties and Townships). By similar token, the Ontario Water Resources Act, the Environmental Protection Act, and the Environmental Assessment Act, all passed into law by the Provincial government in 1990, vests legislative responsibility for the management and protection of ground and surface water to the Ontario Ministry of Environment (MOE). Increasingly, the Ministry of Environment passes this responsibility on to the regional municipalities, despite the fact that few have either the expertise or the resource base to make informed decisions. Groundwater protection issues become further complicated and

sometimes obscured when other agencies enter the picture. Regional municipalities are responsible for providing services such as water, sewage treatment, waste disposal and roads. Conservation Authorities become involved where land development is likely to affect valley lands and flood plains. The Ministry of Natural Resources (MNR) has no direct interest in water resources, but is responsible for protecting, aquatic habits, and areas designated as environmentally sensitive (ESAs) or determined to be of natural and scientific interest (ANSIs). MNR has also assumed primary responsibility for the protection of "special areas of local or Provincial interest". These areas include large moraine areas and selected watersheds/sub-watersheds, even though such areas receive this designation based largely on water resource issues - issues that should logically fall under the jurisdiction of MOE.

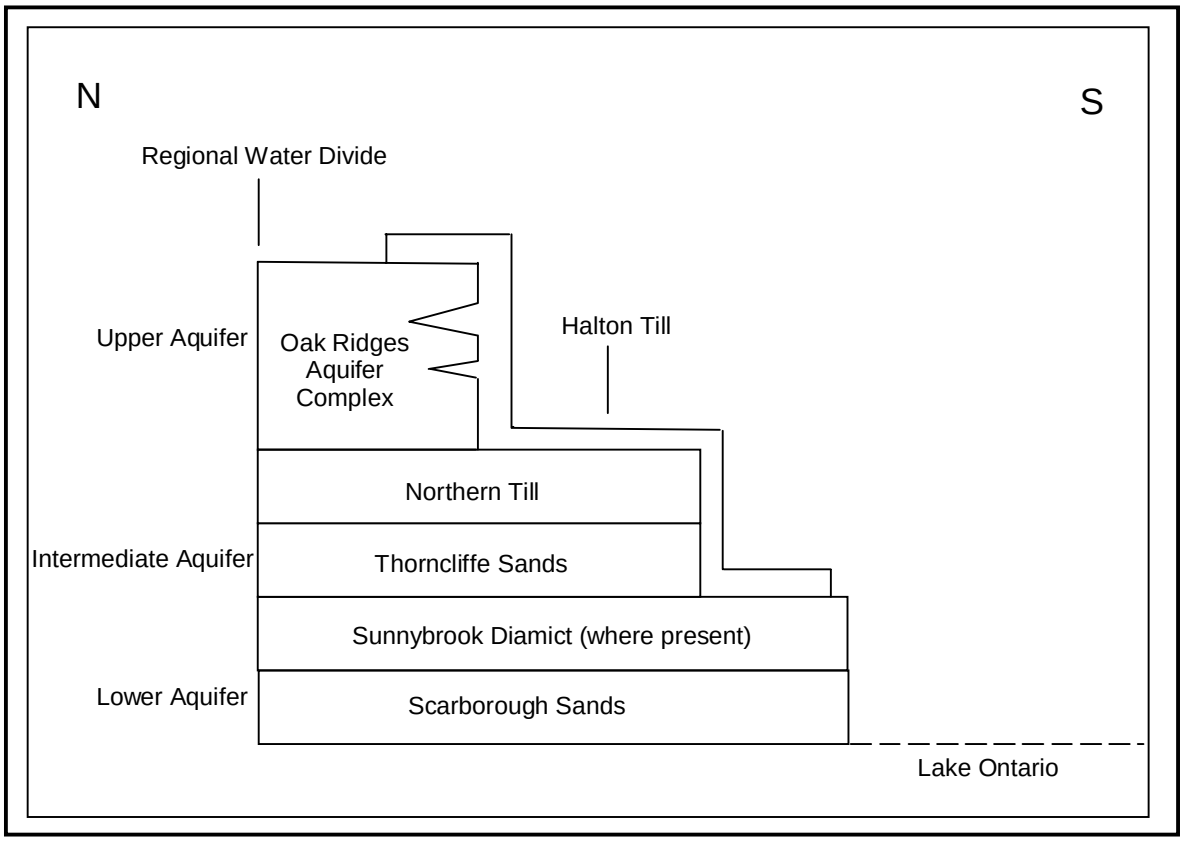

Figure 2. Schematic north-south section showing multi-layer aquifer system capped by the Oak Ridges Moraine aquifer.

Fortunately, some help is available to the prospective land developer in the guise of an unwieldy document published by the Ontario Ministry of Environment (previously the Ontario Ministry of Environment and Energy) (MOEE, 1995). This document was commissioned by the Office of the Provincial Facilitator of the Ministry of Municipal Affairs, and was prepared by external consultants to guide land development applicants (and likely, no doubt, confused government personnel) through those aspects of the planning process that are relevant to groundwater. While the document is clearly useful for steering prospective developers through a veritable minefield of statutes, policies, programs, regulations and guidelines, it also allows the many shortcomings and inconsistencies of the process to be identified. For example, groundwater protection is not explicitly recognised in the urban planning process, and hydrogeological investigations are required only where one or more of the following conditions are met:

i) Groundwater is required for domestic supply (in which case the adequacy of the resource and potential interference problems must be examined);

ii) Sewage systems are proposed that require subsurface disposal of waste via leaching beds or surface disposal using spray irrigation (in which case, impacts must fall within Provincial guidelines);

iii) Soil and/or ground water at the site is known or suspected to be contaminated; or

iv) The site is located on areas that have been designated as hydrogeologically sensitive and therefore of "special" interest to the Province.

In effect, for a major urban expansion comprising fully serviced subdivisions, arterial roads and highways, parks, shopping malls and gas stations, groundwater protection becomes a consideration (and often little more than that) only in areas that have been designated as "hydrogeologically sensitive". Perhaps more seriously, this designation is normally assigned to "recharge areas of major aquifers", in the misguided belief that

a) Recharge to aquifers occurs exclusively in areas where aquifer material is exposed i.e. "outcrops" at the surface; and

b) Areas where recharge to underlying aquifers is highest are the most sensitive and thus most in need of groundwater protection.

Quite to the contrary, many studies including Gerber and Howard (1996,1997) and Howard and Gerber (1997) have shown that with respect to a), significant quantities of recharge can occur through finer-grained aquitard material, including dense till deposits previously regarded as "impervious" to water. Furthermore, while it may be appropriate to protect high recharge areas in some circumstances, there can be many situations where poorly recharged areas deserve greatest protection. For example, high rates of infiltration and/or high aquifer storage volumes provide for greater attenuation of contaminants, and will result in less serious impacts on water quality. By similar reasoning, water levels in unconfined aquifers underlying recharge areas may, by virtue of a high specific yield, be less susceptible to gains or losses in recharge than water levels in semi-confined aquifers. In effect, it is the weaker aquifer with low recharge and low groundwater fluxes that is likely to be the most affected i.e. is most "sensitive" to any sort of land use change. This runs contrary to popular perception.

A PROPOSED SOLUTION

It goes without question that Canada is in serious need of a broad, and scientifically based legislation that will provide for the protection and management of all ground and surface water. The questions to be asked are,

"What type of legislative policy is appropriate?"

"What level of government should enact the legislation?"

"Is there anything to be learnt and possibly salvaged from the piecemeal legislation presently in place?"

Groundwater protection measures that choose to ban or limit certain land use practices in areas that have been designated or classified, as "recharge" zones or areas "vulnerable to pollution", are examples of "standards of practice". Wellhead protection methods (Cleary and Cleary, 1991) e.g. zones of contribution (ZOCs) (USEPA, 1987, 1993), and source protection zones (SPZs) (NRA, 1992) also fall into this category. Methods based on standards of practice are welcomed by planners as they are easy to administer and are

readily incorporated into planning tools such as geographical information systems, thus enabling decisions to be made rapidly with a minimal degree of subjectivity. As groundwater protection measures, they provide no information on the degree of impact anticipated, either in the aquifer or receiving wells, and tend to be effective only in geologically simple, steady state groundwater flow systems where hydrogeological conditions can be clearly and confidently defined. Such conditions are rare, particularly in Canada where the glacial sediments frequently result in geometrically complex, multi-layer aquifer systems (e.g. Martin and Frind, 1998). In most cases, classification schemes represent an over-simplification of the groundwater system at best, and provide a recipe for misinterpretation and abuse at their worst. They are particularly dangerous when used by individuals with limited hydrogeological knowledge and experience.

At the University of Toronto, groundwater protection measures based on "standards of practice" have been rejected in favour of a quantitative "standards of performance" approach to impact assessment. Enforced at the Provincial level of government, performance standards would provide protection for quality and quantity by designating limits to which changes in land use practice are allowed to impact an aquifer. The onus would be put on the proponent of the land use change to perform the necessary sub-surface investigations and provide designs, monitoring programs and contingency plans that would ensure the environmental guidelines will be met for met for all time. Importantly, the "standards of performance" approach must not simply be limited to residential subdivisions, a relatively innocuous component of an urbanised region from the standpoint of water quality and quantity degradation. To be effective, it is essential that the protection measures be invoked for all urban infrastructure, without exception. This includes shopping malls, arterial roads, gasoline stations, parks, and even golf courses.

From a quantity perspective, and in the case of urban development, it is believed that the standard should require total aquifer recharge (direct plus indirect) be maintained on a sub-watershed basis at pre-development levels. Where necessary this may require the use of soakaway pits and rapid infiltration basins (RIBs) to replace lost recharge. From a water quality perspective, it is proposed that the "Reasonable Use Guidelines" (MOE, 1994), presently used in Ontario to regulate the design of domestic landfills be adopted and modified as appropriate. Essentially these guidelines (Howard et al., 1996) recognize that all landfills must ultimately cause some impact on subsurface water quality, and therefore establishes limits of degradation, which must not be exceeded beyond the site boundary for all time. Typically, these limits are set for individual contaminating chemicals at between 25 and 50% of the drinking water quality standard. Where landfills overlie major aquifers, the dilution of leachate by fresh groundwater moving in the underlying aquifer can play a major role in allowing these standards to be met. In the case of urban development, it is considered less appropriate to rely on dilution to attenuate introduced contaminants to the appropriate levels. Instead, it is proposed that the reasonable use guidelines be modified to require that the performance standards be met, not at the site boundary, but in the recharge water as averaged over the site. Under this scenario, the risk of cumulative degradation due to development on adjacent sites is avoided. As an example, for an urban subdivision where groundwater recharge averages 100 mm per year, it would be necessary to limit the annual use of NaCl road de-icing chemicals to approximately 20 tonnes (12.5 tonnes chloride) per km^2 to meet a performance standard of 125 mg/l chloride in the recharge.

CONCLUSION

Metropolitan Toronto faces a problem common to many cities worldwide - rapid urban growth with serious questions being asked as to its environmental sustainability and the potential impacts on the quality and quantity of water resources. Recent studies undertaken at the University of Toronto confirm that while residential sub-divisions are relatively innocuous components of a heavily urbanised region, urban infrastructure including shopping malls, arterial roads, gasoline stations, parks and golf courses can pose a serious threat to the quality and quantity of groundwater. While Federal, Provincial and Municipal laws exist that may limit impacts, this legislation is complex, limited in extent, and rarely acknowledges either the wide range of potential urban contaminants or the temporal dynamics of groundwater flow.

For many Canadians, the perceived abundance of fresh water resources has led to widespread complacency. While there is some awareness for surface water issues, very few Canadians rank groundwater protection as a priority concern. Matters seemed to have changed somewhat in recent months with many

southern Ontario residents enraged by proposals to develop parts of the Oak Ridges Moraine, a major aquifer. The resulting campaign to “Save the Moraine”, spearheaded by citizens’ groups and spurred by the media has become highly political, preferring to ignore scientific evidence showing that responsible sub-division design can negate impacts on water. Nevertheless, the movement has at least served to bring groundwater issues to the public’s attention and highlight the archaic state of existing legislation for groundwater protection in the province.

In the case of urban ground water, existing laws for the protection of urban water resources in Ontario and much of Canada are essentially impotent. For the most part, the Ontario legislation is little more than a patchwork of statutes, policies, programs, regulations and guidelines which lack the breadth, versatility and conviction to deal with the wide range of potential urban contaminants and the dynamics of groundwater flow within frequently complex glacial aquifer systems. A key problem is that there is no department at any level of government, that appears willing or, for that matter, capable of taking responsibility for the management and protection of Canada's groundwater resources.

Ontario, indeed, Canada as a whole, urgently needs a broad, and scientifically based policy that will provide Protection and Management for all ground and surface water. Research and experience suggest that such a policy should be based on standards of performance approach, and be policed at the provincial level. Standards would designate limits for the degree to which a change in land use would be allowed to degrade water quality, and may also require that total recharge remain unaltered on a sub-watershed basis. This type of approach would show respect for local hydrogeological conditions and encourage planning innovation. The approach would also encumber the proponent of land use change with the responsibility to perform appropriate sub-surface investigations and provide designs, monitoring programs and contingency plans that would enable environmental standards to be met for all time.

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