Groundwater studies in Ontario

Mapping a hidden treasure
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of Common Groundwater Terms
Detailed scientific studies, conducted at the local level and supported by the Ministry of the Environment, are being used to better understand and, ultimately, safeguard one of Ontario’s greatest “buried treasures”: our groundwater resources.

For some three million Ontarians, groundwater is the primary source of the water used in their homes and farms, businesses and industries. They depend on the groundwater resource to keep their schools, hospitals, fire services and other institutions operating. Ninety percent of Ontario’s rural residents rely on wells for their water supply.

As part of a province-wide initiative, community-led groundwater studies are being undertaken to promote groundwater source protection in Ontario. This cooperative initiative — involving municipalities and conservation authorities, together with residents, farmers, business leaders and other stakeholders — is providing local decision-makers and water managers with the solid scientific information needed to safeguard groundwater sources.

Understanding the groundwater resources of a community means methodically studying groundwater conditions, defining wellhead protection zones and other sensitive areas, cataloguing the potential threats to water quality, and tracking groundwater usage patterns. These studies comprise the necessary first steps in developing an effective groundwater source protection strategy. This publication describes the groundwater research being conducted by municipalities and conservation authorities across the province, and how this information is being used to ensure that the groundwater resource remains clean and plentiful for generations to come.
In Ontario, some three million residents — living in more than 200 communities, and on the surrounding farms and rural homes — depend on an abundant and clean supply of groundwater. The protection of this vital resource requires reliable and up-to-date scientific knowledge of the groundwater resource and the threats to that resource. Since 1998, the Ministry of the Environment has helped fund up to 85 percent of the cost of these essential groundwater studies across the province. Studies conducted by municipalities, regional governments and conservation authorities are supplying much of the critical information these communities need to effectively manage their groundwater resource.

Studies are being completed in over 95 percent of the groundwater-dependent communities in Ontario, providing those communities with a much better understanding of the groundwater supply, the threats to its future quality, and the issues that should be addressed as part of an integrated source protection strategy.

The studies include four basic components: aquifer characterization, municipal wellhead protection area mapping, contaminant inventories, and water use assessments.

- **Aquifer Characterization** shows us, at a regional scale, where groundwater is distributed, where it is replenished, and where it is discharged to rivers, streams and lakes. This work also includes mapping areas of intrinsic susceptibility, where pollutants released onto the land’s surface could more easily seep down to the groundwater below.

- **Wellhead Protection Area** studies analyze the local geology and groundwater conditions surrounding a community well and then define a series of protection zones based on the length of time it would take a contaminant dissolved in the groundwater to reach the well.

- **Contaminant Inventories** catalogue the potential threats to groundwater quality. Unless stored, handled and used correctly, toxic chemicals and fuels, manure and fertilizers, pesticides and road salt can enter the groundwater environment and pose a threat to public health and safety.

- **Water Use Assessments** reveal the demands on the groundwater resource to meet the needs of residents, farmers, business and industry, schools, hospitals and other local institutions.

Groundwater protection is a partnership initiative. The province is working with municipalities, regional governments, conservation authorities, and other stakeholders to conserve and protect the resource. Collaborative steering committees that are designing, overseeing and conducting the groundwater studies are also providing a solid management structure for implementing future source protection measures.

The study process is an excellent forum for educating communities about the value of groundwater and the steps necessary to conserve and protect it. Programs that draw local and regional stakeholders together have proven the value of focusing attention on source protection. The information produced through the groundwater studies is helping private, public and non-government sectors make informed policy decisions and ensure Ontario’s groundwater remains plentiful and clean.
Gathering information on local conditions is the first step in protecting groundwater.

While the province has contributed funding and technical guidance, groundwater studies are the responsibility of local or regional steering committees of decision-makers, conservation authorities and other stakeholders. Here are the basic steps that committees are taking to develop the source protection strategy that makes sense for their community.

1. Form a community steering committee or planning team that represents local interests, major water users and other key stakeholders, environmental expertise, and residents and non-governmental groups.

2. Collect up-to-date and reliable information on groundwater resources. Characterize the regional aquifers and their intrinsic susceptibility to contamination, identify municipal wellhead protection areas, and assess current groundwater use.

3. Identify any potential threats to the resource, such as underground storage tanks, active and closed waste disposal sites, PCB storage sites and abandoned wells.

4. Put together an action plan that meets the specific needs of the study community, including an overall or guiding strategy, a list of regulatory and non-regulatory measures that might be implemented, monitoring needs, and the outreach and education programs to promote public awareness of groundwater issues and protection opportunities.
The precipitation that falls to earth can travel by a number of pathways on its journey through the hydrologic cycle. Much of the water either evaporates or is transpired through plants back into the atmosphere. Some flows overland through Ontario’s network of rivers, lakes and wetlands. And a small portion of that water seeps downward through the spaces between soil particles and cracks in the bedrock where it collects in underground aquifers. In turn, these layers of sediment, sand and gravel saturated with groundwater feed our private and municipal wells.

The surface area of land where water infiltrates into the ground down to the water table is called the recharge area. The accumulated groundwater feeds the wells that serve local farms, residents and businesses. It also supplies the springs, streams and marshes that support the aquatic ecosystem, and provides moisture to trees and other deep-rooted vegetation during dry periods.

Understanding the demands for groundwater

Groundwater does more than supply water for human needs; it also maintains the baseflow in streams and rivers and supports the natural ecosystem. It is important to assess the current and future pressures on the aquifer in order to implement any needed conservation measures and sustain the ecological functioning of the watershed.

A sustainable groundwater supply is inseparable from a sustainable community. Local planners and water managers need certain information in order to make balanced decisions that will protect their community’s livelihood and the resource they depend on.

Groundwater studies help communities better understand who withdraws water and in what volume, how groundwater gets replenished, and how quickly the aquifer recharges. Some examples of entities that withdraw groundwater include:

- Public and private water suppliers for residential, commercial, industrial, institutional and public use;
- Individual users not connected to a municipal system, that can include residential wells, large and small businesses, schools, hospitals, golf courses, pools and others; and,
- Agricultural operations for watering livestock and irrigating crops.
What’s an aquifer?

An aquifer is a geological formation, such as porous sand and gravel or fractured rock that is able to supply a useable quantity of water.

The way that water — as well as any contaminants it may contain — moves through the ground and into an aquifer depends on a number of characteristics, including the porosity, the permeability and the geological structure of the area.
Regional Aquifer Characterization maps the basic groundwater conditions across a study area. It identifies where the groundwater resource is replenished, where it is distributed and stored, and where it is discharged to lakes, rivers and streams.

This component of the study requires a variety of information from a number of sources. Water well data from the provincial database, municipal records and independent reports provide a wealth of geological and hydrological information. Details on surface water features, land use, surface and bedrock geology, and surface topography are also key ingredients for defining groundwater conditions. Some studies are supplementing existing information sources with additional field work, including constructing and analyzing new boreholes, pump testing existing wells, and sampling stream flow.

From these sources, topographical, geological and hydrological data is collected, compared and consolidated, validated as necessary, standardized, interpreted and mapped. The maps produced from this information and analysis illustrate some of the key characteristics and functions of the local groundwater system, including the water table, flow directions, recharge areas, and discharge areas.

Mapping Groundwater Susceptibility

As part of the regional aquifer characterization, maps are generated that show where groundwater may be more susceptible to any pollutants released on the ground surface. Areas of high, medium and low intrinsic susceptibility are identified, depending on the depth to the water table and how readily the overlying rock and soil could retard the downward migration of contaminants. For example, an aquifer with 20 metres of clay or silt situated above it would
Groundwater can be degraded by a variety of contaminants

- The bacteria and viruses found in sewage sludge, septic tanks and manure are readily absorbed on to clay particles or filtered out in sand. Most die off and are decomposed in about 100 to 250 days. However, they can also be carried a considerable distance through coarse gravel or fractured bedrock in this time period.

- Nitrates from fertilizers and organic waste are highly soluble, stable and capable of migrating considerable distances if they are leached into a groundwater source.

- The chloride in road salt is highly soluble and can readily build up in an aquifer.

- Gasoline, fuel oil and other petroleum products can be harmful in drinking water at only a few parts per billion. While petroleum products seldom travel more than several hundred metres from their source, they can persist in the environment for years.

- Highly toxic chlorinated solvents, such as paint removers, dry cleaning fluids and metal degreasers, are also very persistent and can be highly mobile in groundwater. Heavier than water, they tend to pool at the bottom of an aquifer and can be very difficult to detect or remove.

- While many of the pesticides in use today are biodegradable, they can be toxic at low concentrations. Some of their breakdown products are also dangerous.

Virtually anything spilled or placed on the ground can potentially leach into groundwater. Compounds that are persistent, don't readily degrade, are soluble in groundwater, or are toxic in very small doses pose the greatest threat to groundwater quality and, subsequently, to human health.
Wellhead protection areas are being delineated for municipal wells or wellfields in the study areas. The wellhead protection area identifies the sub-surface area that supplies groundwater to the well. The protection area is comprised of time-of-travel capture zones that are based on the direction and speed of groundwater flow to the well. These zones represent the horizontal distances that water (and any contaminants it carries) is likely to travel through the aquifer towards the well over set periods of time.

The time-of-travel zones are mapped using sophisticated computer models, taking into consideration pumping rates and local groundwater conditions. In most cases, three-dimensional computer models are used to delineate capture zones and produce realistic time-of-travel boundaries. In certain situations, other mathematical formulae may be more appropriate, like the uniform flow method or the calculated fixed radius method.

Different contaminants behave differently in the groundwater environment. Some break down rather quickly or readily adhere to soil particles, while others dissolve in the water or are highly mobile and persistent. Because of this, a minimum of three different zones are being identified.

*Please Note: These definitions have been used for study purposes only and do not constitute a legal definition.

For many communities across the province, groundwater is not just the primary source of water. It is their only source. It is safer, more efficient and economical to prevent groundwater problems than to try to clean up a contaminated aquifer or replace a degraded water supply.
• **Zone 1** is the most sensitive area, surrounding the wellhead. Groundwater in this zone reaches the well intake in less than two years, along with any dissolved contaminants it may carry. It is important to carefully manage all land use activities within this zone to avoid possible risks, including those posed by potential sources of bacteria and viruses, hazardous chemicals and other toxic contaminants.

• **Zone 2** extends further from the wellhead. In this zone, groundwater takes two to 10 years to reach the well. Biological contaminants represent a lesser hazard in this zone, while persistent and hazardous chemicals pose the greater risk.

• **In Zone 3**, groundwater takes 10 to 25 years to reach the well. Attention in this zone is mainly directed towards the control of the most persistent and, in some cases, hazardous contaminants.

In addition, a 50-day time-of-travel zone should be identified within Zone 1 to highlight potential risks from the day-to-day activities of the water utility itself, as well as other potential contaminant risks posed by municipal activities (such as chemical spills and salt storage).
Once a region’s basic hydrogeology has been charted and municipal well capture zones have been identified, the next step is to map and gather information on those facilities, activities and materials that could pose a threat to a community’s drinking water if not managed properly. In completing a contaminant source inventory, study communities identify historic pollution problems, potential sources of future contamination, and possible contaminant shortcuts to the groundwater, such as unused and improperly sealed wells.

**How are potential contaminant sources identified?**

The province and local municipalities have records that show where potential contaminant sources might exist. Information is extracted from city licensing files, planning or zoning records, fire and health department documents, provincial ministry databases and telephone directories. There is a good chance that much of the contaminant data needed has already been recorded somewhere.

Long-time residents, retired municipal staff, chambers of commerce and local historical societies are consulted. These people know what businesses used to operate in the area, where abandoned wells are located, and where people used to dump their trash or empty pesticide drums.

When in doubt, or when faced with conflicting information, researchers are going out into the field. They may visit industrial parks, large farms and commercial operations, or conduct door-to-door surveys in wellhead protection areas. A street-by-street investigation can uncover abandoned gas stations, auto or machine repair sites, and chemical storage areas.

**Using the inventory**

Once a comprehensive contaminant inventory has been assembled, a community is in a position to take preventative action. Contaminant threats within sensitive groundwater areas can be better managed and monitored. It is safer, more practical, and more economical to prevent groundwater contamination than to try to clean up a polluted aquifer.

If contaminants are detected in a monitoring well in trace amounts, investigators will already have a list of the most likely sources. Containment and clean-up efforts are much more effective if a community is prepared to act quickly.

**Tracking “non-point source” pollutants**

The sources of some potential groundwater contaminants are harder to pin down. Pesticides and fertilizers applied to crops, salt and deicing chemicals spread on highways, and oil and other pollutants washed off city streets by the rain are all considered potential non-point source contaminants. To protect groundwater, it is necessary to consider both the identifiable point sources of potential pollution and the human activities that also release contaminants throughout the community.
Groundwater does more than supply water for human needs; it also maintains the baseflow in streams and rivers and supports the natural ecosystem. It is important to assess the current and future pressures on the aquifer in order to implement any needed conservation measures and sustain the ecological functioning of the watershed.

A use assessment estimates the purpose and distribution of groundwater use in the watersheds within the study area. This information is based, in part, on public works and utility records, the Ministry’s Permit to Take Water database, its Water Well Information System, certificates of approval, other available sources of data, and field surveys. The use assessment accounts for the water withdrawn:

- by public and private water suppliers for residential, commercial, industrial, institutional and public use;
- by domestic wells for residential, commercial and institutional users, including hospitals, schools, mobile homes, fire services, amusement parks, pools and other uses not covered by the public supply;
- for irrigating crops, and watering parks and golf courses;
- for watering livestock;
- by large manufacturing, industrial and mining users; and
- by other major users.

Here are some of the potential contaminant sources that are being inventoried and mapped:

- Airports
- Animal feed lots
- Car washes
- Chemical plants
- Dry cleaners
- Food processors
- Fuel storage tanks
- Gas stations and garages
- J unk yards
- Laboratories
- Laundromats
- Manure storage ponds
- Medical and dental offices
- Metal plating companies
- Mine operations
- Oil and gas pipelines
- Paint shops
- Paper mills
- Pesticide storage tanks
- Photo processors
- Rail yards
- Road salt storage areas
- Septic tanks & cesspools
- Sewage lagoons
- Snow dumps
- Stormwater ponds
- Transportation corridors
- Unused wells
- Vehicle service yards
- Waste disposal sites

It can cost up to 200 times more to clean up a seriously contaminated aquifer than it would to implement the proper protective safeguards — including adequate mapping, monitoring and source protection measures — in the first place.
Putting Together an Action Plan: What Can Communities Do To Safeguard Groundwater?

The provincially funded groundwater studies are providing communities with some of the key information needed to build a framework for protecting and conserving their groundwater resources over the long term. There is an array of effective measures a municipality can take to better safeguard its groundwater supply:

- Incorporate protective policies for wellhead protection areas and other sensitive groundwater areas into Official Plans and zoning by-laws.
- Negotiate easements with land owners to protect sensitive areas or acquire land in the most sensitive areas.
- Identify and monitor sources of possible contamination, including industrial, commercial and agricultural operations.
- Develop contingency plans and procedures to be invoked in the event that a spill or accident threatens the groundwater resource.
- Promote pollution prevention activities that encourage and support landowners in implementing practices and programs that protect and preserve groundwater.
- Collect baseline and on-going data on groundwater quality and quantity to better manage the resource and make informed decisions about pressures.
- Coordinate and collaborate groundwater protection efforts by local municipalities, conservation authorities, regional governments, provincial agencies, non-government organizations and other interested groups.
- Incorporate groundwater concerns into watershed and subwatershed plans, nutrient management plans, and other environmental initiatives.

Case Study: Oxford County
Refining and augmenting existing protection efforts

Oxford County, in the centre of Ontario’s agricultural heartland, is completely reliant on groundwater to meet the drinking water needs of its more than 97,000 residents. Over 70 public wells in over 20 municipal systems supply about 70 percent of the population; the remainder is served by approximately 7,000 private wells. The County has long recognized the importance of its resources: groundwater protection policies have been part of the County’s Official Plan since 1996. Groundwater quality throughout Oxford is generally considered to be good, though some shallow wells have shown elevated levels of bacteria, chloride and nitrates. The County is also concerned about the impact of large-scale farming operations and past and present industrial and waste disposal uses on its groundwater supplies, as well as the future water demands of a growing population.

Oxford’s Phase II Groundwater Management Study, completed in March 2001, helped refine wellhead capture zones, recharge areas, and areas susceptible to contamination. It also updated previously collected data and identified potential sources of contamination, including 318 waste generators, 67 waste disposal sites, 350 petroleum wells and 83 livestock operations with nutrient management plans. Since completing the study, the County has acted on a number of its recommendations, including drafting stronger protection measures in its Official Plan. Wellhead protection areas have been delineated, and land uses that could threaten groundwater quality are being identified. The County is building its contaminant database to include both historic and current threats, and is planning to develop a network of sentinel wells. The County has also purchased land specifically to protect the main well field that supplies water to the City of Woodstock and the Village of Sweaburg.

Study steering committees bring together local decision-makers, conservation authorities, major water users, resident groups and other people with an interest in groundwater. In many cases, these groups are staying together to help plot the groundwater source protection strategy.
Case Study: Exeter
Taking the initial steps to address local concerns

Exeter (now part of the Municipality of South Huron) lies about 50 kilometres north of London, close to the southeast shore of Lake Huron. Its population of 4,350 residents is 90 percent dependent on the groundwater supplied by five wells in a municipal field, while farms and rural residents are supplied by a number of private wells. The system is currently operating at its maximum capacity. Water conservation measures have been introduced in recent years to optimize the available supply. There have been reports of high levels of nitrate and iron, some bacteria problems, and complaints about water taste and odours.

Five monitoring wells were drilled and a groundwater flow model developed as part of a Groundwater Management Study that wrapped up in May 2001. In addition, a number of potential contaminant sources, including auto salvage yards, gravel pits and a municipal works yard were identified. Based on this information, an overall groundwater strategy was developed that incorporates, among other measures, basic education programs, the introduction and enforcement of various land use controls, and the acquisition of land in wellhead protection areas. Groundwater protection measures recommended by the study team would also address nitrates, nutrients, pesticides, fuels and other hazardous materials, above and underground storage tanks, septic tanks, road deicers and dust control materials.

Case Study: Larder Lake
How a small Northern community is protecting its groundwater supply

Fewer than 900 people live in the town of Larder Lake, located in the northern District of Temiskaming about 15 kilometres west of the Ontario-Quebec border. Almost all their drinking water comes from a single municipal well, augmented by few private wells. The wells are considered highly sensitive to contamination. A sewage lagoon, several disposal sites, a snow dumping area, a road salt storage yard, fuel tanks, a parking lot and a large septic system are all located either within or near the wellhead area.

As part of the town’s Groundwater Management Study, completed in 2001, the groundwater system and hydrogeology were mapped, a groundwater flow model was constructed, potential contaminant sources were identified, an emergency plan was prepared, and nine monitoring wells were drilled to collect background data. Based on this research, the town has moved to relocate its snow dumping site, worked with Ministry of Transportation to upgrade the salt storage facility, and begun connecting problematic septic tanks to the existing sewage system. It also plans to incorporate policies to protect the wellhead protection area into its Official Plan and is re-evaluating its zoning by-law. The Ontario Clean Water Agency has taken over the municipal water system and has installed testing and monitoring equipment while the town develops a plan updating the system. An overall groundwater strategy will be developed after plans for the new pumping station and water treatment plant have been completed.

An important objective of the groundwater studies is educating the public about how their water supply can be compromised, and what steps can be taken to safeguard their groundwater.

Groundwater studies are providing communities with the vital information they need to prevent potential contamination problems and to promote effective local management strategies to protect the local supply.
Aquifer From the Latin for “water carrier”, a geological formation (typically porous material, such as sand or gravel, or fractured rock) that stores and is capable of transmitting water in sufficient quantities to serve as a source of water supply.

Capture Zone The area surrounding a well that will supply groundwater to that well when pumped at a specified rate for a specified period of time.

Contaminant An undesirable chemical or biological substance that is not normally present in groundwater, or a naturally occurring substance present in unusually high concentrations. Common contaminants include bacteria and viruses, petroleum products, chlorinated substances, pesticides, nitrates and salt.

Groundwater Water located below the water table that fills the pore spaces between sand, gravel and fractures in rock.

Hydraulic Conductivity A measure of the ability of groundwater to flow through the subsurface environment.

Hydrogeology The science dealing with the physical, chemical, and biological properties of groundwater.

Porosity The open spaces or voids that occur between mineral grains or in fractures of bedrock.

Recharge Area Area of land where surface water infiltrates down into an aquifer.

Surface Water Includes water bodies (lakes, wetlands, ponds, etc.), water courses (rivers and streams), infiltration trenches and temporary ponds.

Time of Travel The length of time it takes groundwater to travel a specified horizontal distance.

Wellfield An area containing more than one pumping wells that provides water to a public water supply system or single owner (i.e., municipality).

Wellhead or Wellfield Protection Area The area both above and below ground surrounding a well through which contaminants are reasonably likely to move toward, eventually reaching the water well.

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