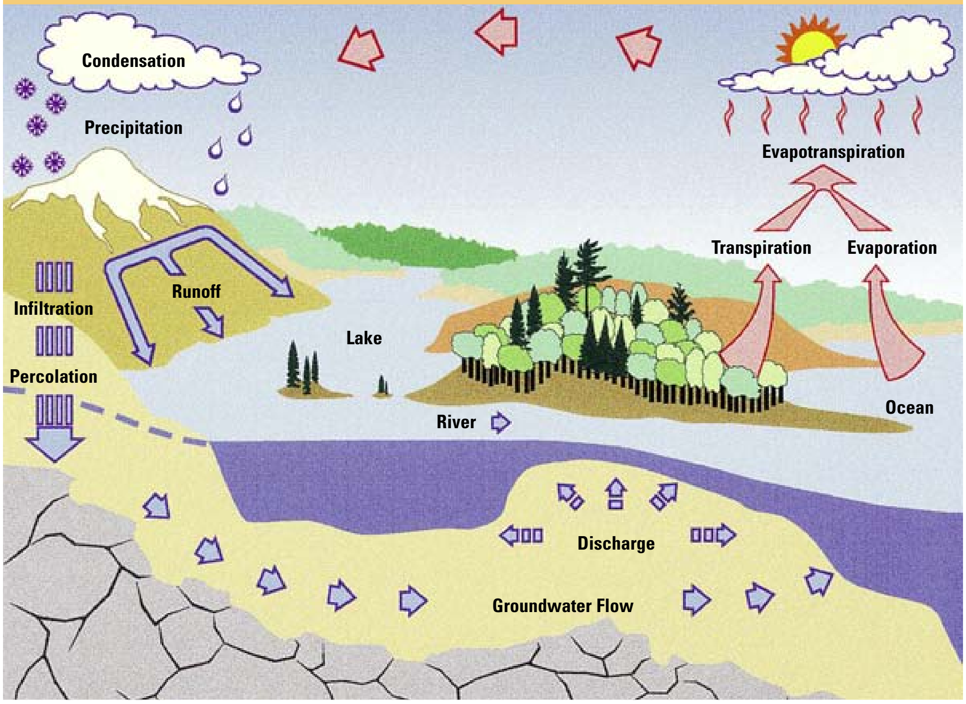
GROUNDWATER BASICS

WATER IN THE EARTH

THE WATER CYCLE



All water on and beneath Earth's surface and in the air is part of the water cycle. As rain hits Earth's surface, it can take several paths. (This is also true for melting snow.) It can run off into streams, lakes or rivers. It can seep into (infiltrate) the ground to be used directly by plants or to recharge groundwater. It can evaporate and return to the atmosphere. The cycle is complete when water in the atmosphere returns to Earth as rain or snow.

In this section, we look at:

- **where water occurs and how it moves in the earth**
- **the quantity of groundwater in aquifers and wells**
- **the quality of groundwater, and the importance of preventing its contamination**
- **types of water wells and pumps.**

Water is in constant motion, continually recycling through the environment in a series of pathways called the water cycle. Understanding the cycle is key to responsible water management. Every drop of water used on your farm – whether for drinking, livestock, laundry, or mixing with pesticides – has been used by other people, plants and wildlife before you. Likewise, when it leaves your operation – through evaporation, infiltration to groundwater, or runoff to surface water – it will be reused. We all have a role in keeping this shared resource as clean and abundant as possible.

Groundwater can move up or down or laterally. When groundwater flows naturally to surface water, it is called baseflow.

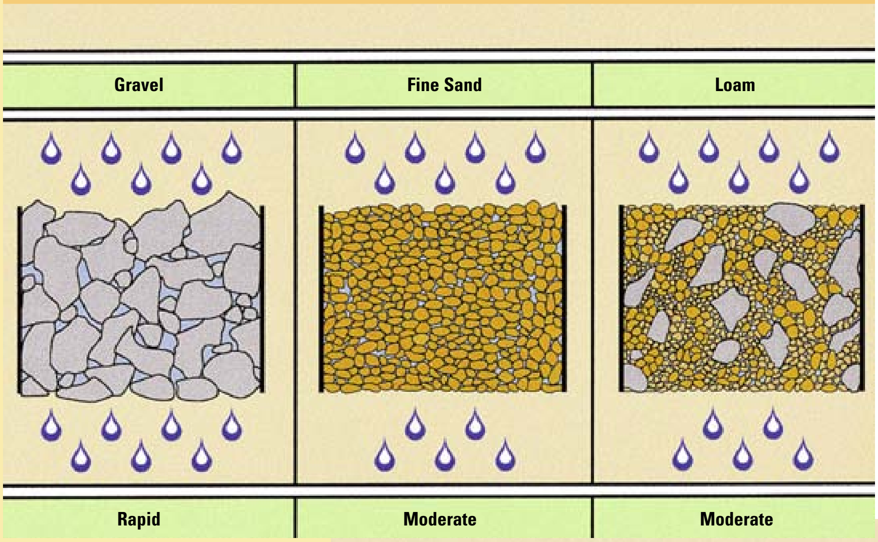
GROUNDWATER BASICS

WATER IN OVERBURDEN AND BEDROCK

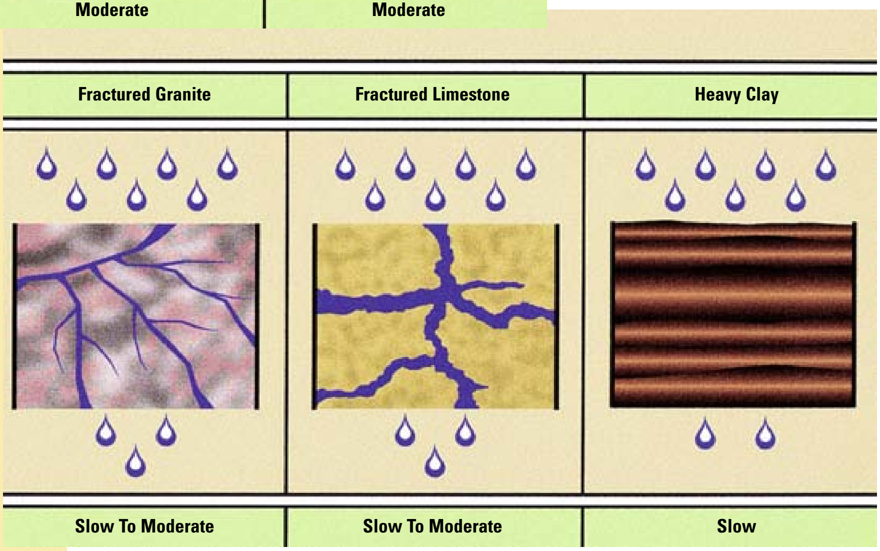
Granite, sandstone, limestone, shale and other types of rock make up the hard crust of the earth, known as bedrock. In many areas, the bedrock is covered with deposits of clay, silt, sand or gravel. These overburden deposits were laid down by the action of glacial ice, water and wind. Well contractors and geologists call the earth's bedrock and overburden deposits "formations".

All formations contain pores or small openings filled with air or water. In some bedrock formations, oil or natural gas fills the pores. The percentage of pore space in a formation is its porosity.

HOW WATER MOVES THROUGH FORMATIONS



Water moves more quickly through formations that have many large pores or continuous cracks, such as gravel. Conversely, water moves slowly through formations with small pores or discontinuous cracks, such as clay.



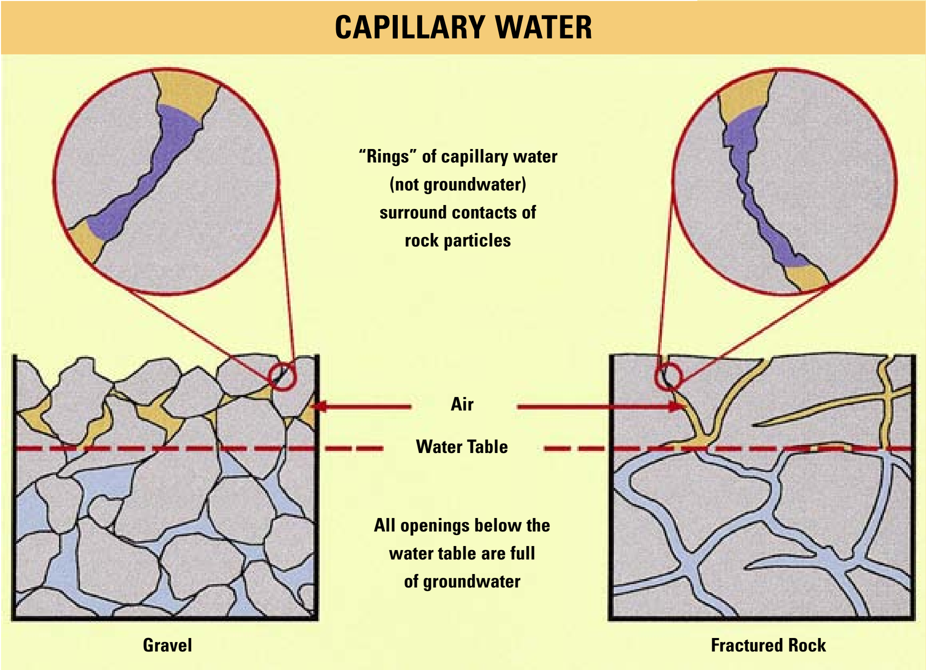
GROUNDWATER BASICS

Sand can contain 25 to 50 percent pore space between the soil grains. Mixed sand and gravel formations can be 10 to 30 percent porous. These pores are large and connected to each other, so water moves easily through sand and gravel.

Clay contains 40 to 70 percent pore space, but water doesn't move easily through clay because the pores are small and poorly connected.

Pores containing air or a mixture of air and water are unsaturated. Pores filled with water are saturated. The depth at which all the pores are saturated, i.e., where the pressure is equal to atmospheric pressure, is the water table. In sand, groundwater will quickly fill a hole dug below the water table. In a tight clay deposit, however, groundwater seepage could take hours or days.

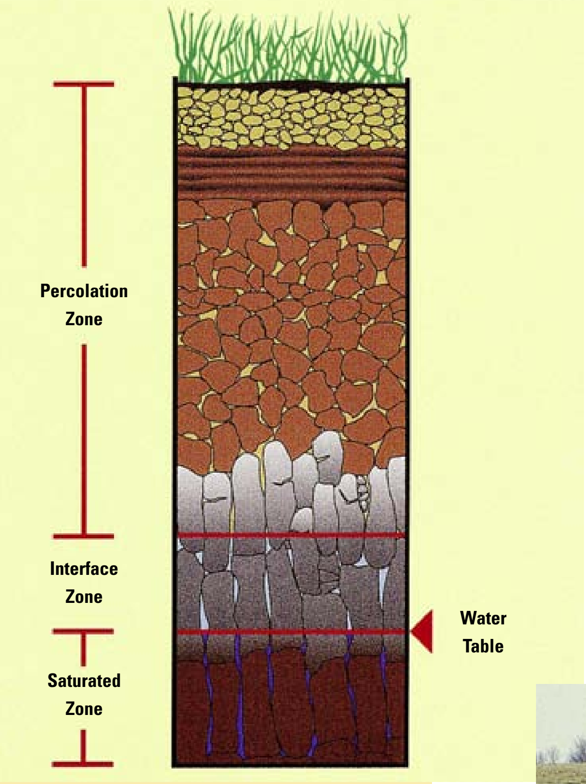
Above the water table, groundwater is drawn upward into the capillary zone, where fine soil pores act like a wick. In clay, for example, the soil may be saturated up to 1.5 metres (5 ft.) above the true water table because of capillary action. Water in this zone cannot be removed by pumping, so it cannot be used for drinking or irrigation. It represents, however, a significant pathway for contaminants to migrate down to drinking water supplies below.



Above the water table, water is held in pore spaces or cracks by capillary forces. The pressure in this water is negative, or less than atmospheric pressure.

GROUNDWATER BASICS

SURFACE WATER TABLE ZONES



In a typical loamy soil profile, water moves downward through the percolation zone to the saturated zone. Water is held by suction in the capillary zone.

Bedding planes are breaks or discontinuities between relatively homogeneous layers of sediment. Sediments are laid down by wind or water and a bedding plane results when a major climatic change occurs.

Formations that allow the rapid movement of water are called highly permeable. Sand and gravel deposits are highly permeable. Water flows easily and quickly through these materials.

Clay and silt are much less permeable. Some clay deposits may be fractured, which increases their permeability.

The permeability of bedrock depends on the number and size of fractures, bedding planes and solution channels, and how well they are connected.

In some areas, water moving through fractures in limestone has dissolved the rock, enlarging fractures and creating caverns. These are known as Karst formations. At the ground surface, this can result in sinkholes and "disappearing streams". Some places in the southern United States (Florida) and Europe have significant Karst areas. The large fractures and caverns associated with Karst formations can result in very rapid groundwater movement. In Ontario, this type of geology occurs in areas of Grey and Bruce counties along the top of the Niagara Escarpment, and in the Kingston area.

The number and size of cracks in the bedrock, and how well they are connected, help determine how fast groundwater will move.

GROUNDWATER BASICS

Although deep aquitards and thick aquitards (see sidebar) help to protect groundwater quality, all geological materials are permeable to some extent. That's why best management practices that protect groundwater from contamination are so important.

Most groundwater occurs in pores or fractures spread through the formation. What we look for when exploring for groundwater is a medium to highly permeable, saturated formation that would yield water easily to wells.

An aquifer is a saturated, permeable formation that can yield useful amounts of water for water supplies.

Common examples include saturated sand and gravel deposits.

An aquitard is a geological formation that prevents the significant flow of water. Common examples include clay layers or tight deposits of shale.

AQUIFERS: GROUNDWATER YOU CAN USE

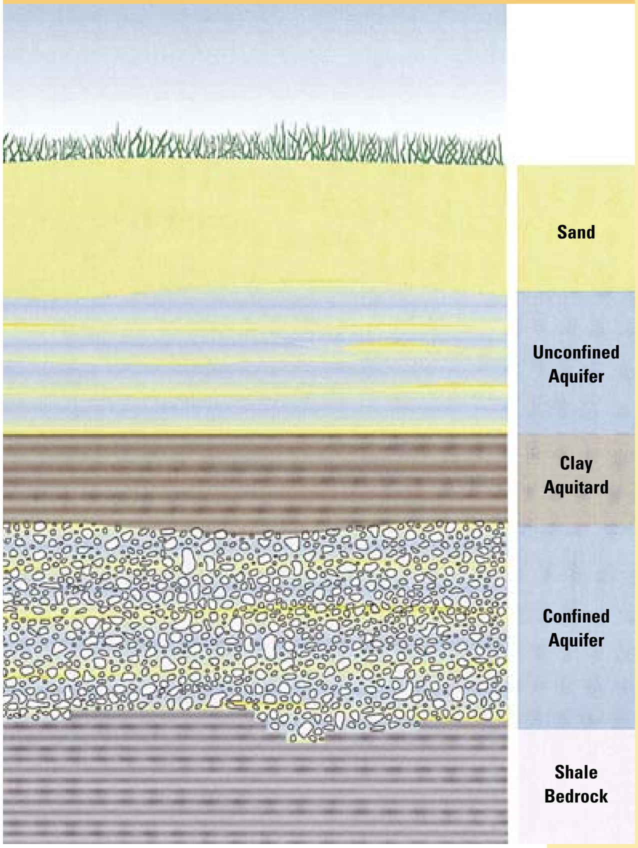
There are three kinds of aquifers.

Unconfined or **water table aquifers** are usually the most shallow. The top of an unconfined aquifer is the water table. In eastern North America, water table aquifers are often encountered between 2.5 and 14 metres (5 and 50 feet).

Confined or **artesian aquifers** are covered by an aquitard, a confining layer of lower permeability soil such as clay. Pressure in a confined aquifer can cause the water level in a well to rise above the top of the aquifer. If the pressure is high enough, the water can rise above the ground surface and flow out of the well. Special steps have to be taken when constructing wells in areas where flowing artesian wells occur. ***Caution:*** some contractors have not properly stopped the flow of water from some flowing wells. Be clear about who is responsible for stopping a flowing water well. In Ontario, a flowing well must be constructed so that all flow can be stopped.

When an aquitard is sufficiently permeable to allow some water to leak downward into the underlying aquifer, that aquifer is described as **leaky** or **semi-confined.** Drilling through an aquitard to the underlying groundwater is another common cause of "leakiness". This is one of the many reasons that water well contractors are licensed.

TYPES OF AQUIFERS



Most unconfined aquifers are shallow. Confined aquifers are usually found at greater depths beneath an aquitard. The pressure from the weight of the aquitard and other overburden materials may cause the water to rise to ground level.

Pressure in a confined aquifer can cause the water level in a well to flow out with force at ground surface.

GROUNDWATER BASICS

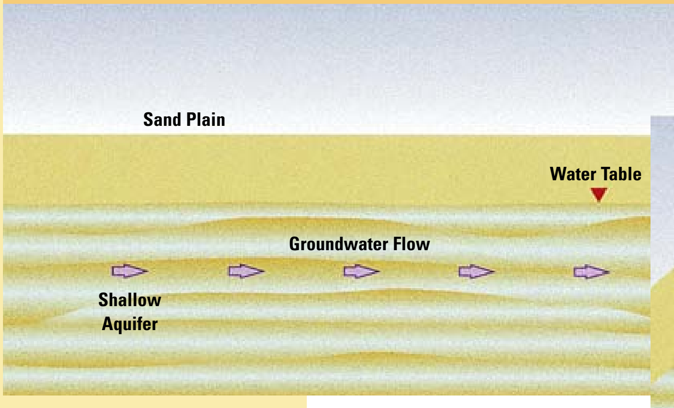
HOW DOES GROUNDWATER MOVE?

Groundwater moves (or flows) from areas of higher energy potential (higher elevation and/or pressure) to areas of lower energy potential (lower elevation and/or pressure). The diagram below shows that groundwater can flow horizontally or vertically upward or downward. Within an aquifer, groundwater naturally flows in one predominant direction, i.e., mainly horizontal or vertical, up or down. Locally, this natural flow direction can be affected or changed by pumping a well.

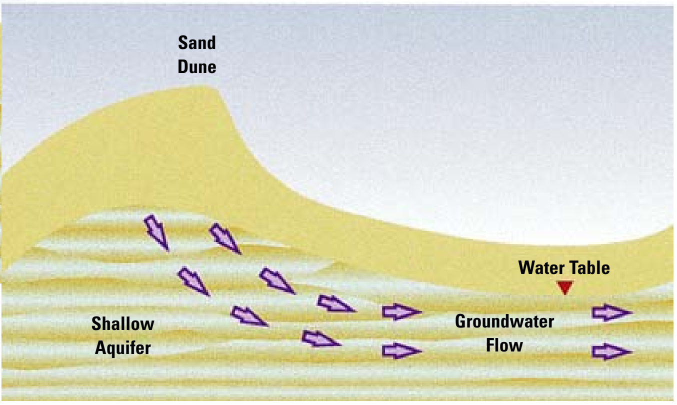
How fast groundwater moves depends on permeability and on the slope or gradient of the groundwater surface. Groundwater moves quickly through very permeable bedrock or overburden, and slowly through clay or silt. There is a great range in groundwater velocities.

Quick water movement is about 30 centimetres (1 ft.) per day, except in Karst topography. In some clay formations, it moves as slowly as a few centimetres a year. Groundwater drawn from a deep well may have been in the ground for hundreds or thousands of years. In a shallow aquifer, the age of the water may be only a few weeks or years.

GROUNDWATER MOVEMENT



LOW GRADIENT. In a shallow, sandy aquifer, where there is very little change in elevation, water moves slowly in a lateral direction from high pressure areas to low pressure ones.



HIGH GRADIENT. Water in hilly, sandy aquifers will move quickly from high elevation areas to areas of low elevation (or pressure). Note: the shape of the water table generally follows surface features.

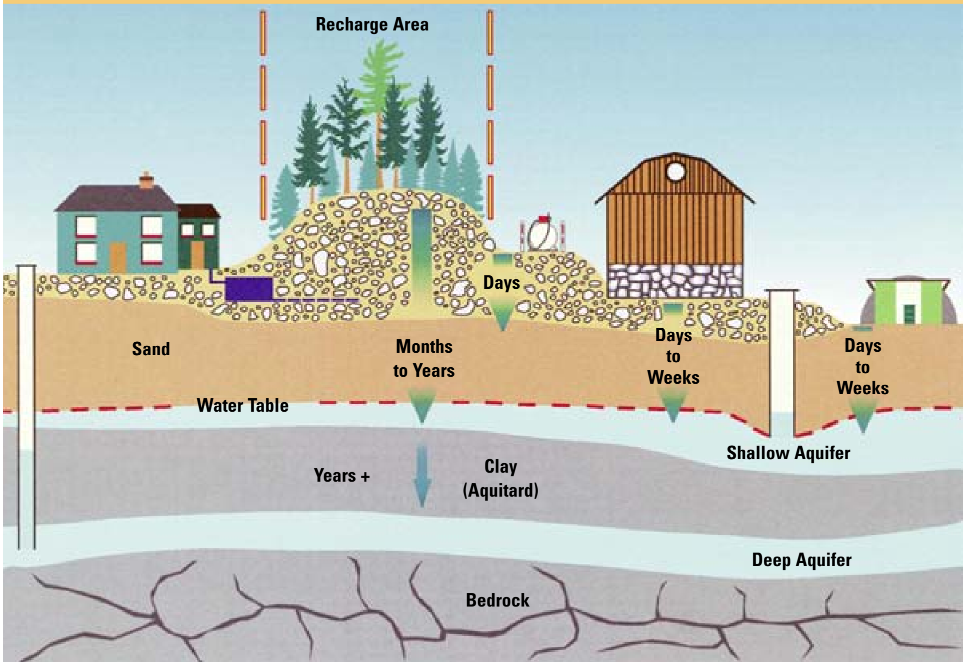
GROUNDWATER BASICS

GETTING WATER OUT OF THE GROUND: WELLS AND SPRINGS

For thousands of years, people have used wells to tap the abundant supply of fresh water in the earth. A water well is a hole drilled, dug or bored into an aquifer from which groundwater can be drawn.

Groundwater can flow to the surface naturally. When the water reappears above the ground surface, the water can discharge as a spring. Sometimes springs are used for water supplies. Groundwater discharge also feeds lakes, rivers and wetlands.

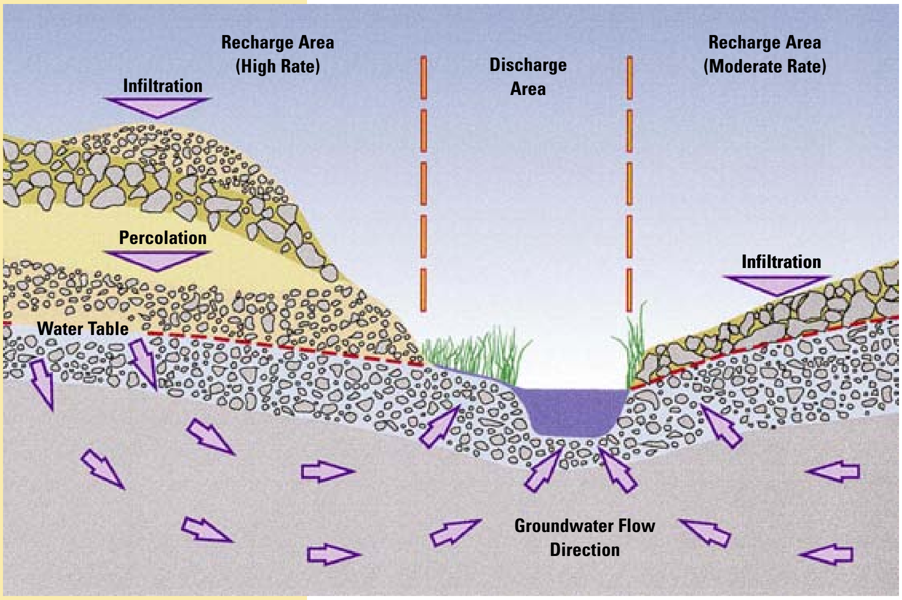
TYPES OF AQUIFERS AND PATHWAYS OF RECHARGE



Shallow aquifers are recharged rapidly when surface materials are highly permeable, as sand and gravel are. Recharge may take days to weeks. Less permeable materials like clays will act as aquitards. Deeper, confined aquifers can be found between aquitards and some permeable materials such as fractured limestone bedrock. Recharge through aquitards to deep aquifers can take decades. Recharge to deep aquifers may be more rapid, however, where the aquifer sediments intersect a shallower aquifer or the ground surface, usually at considerably higher elevation.

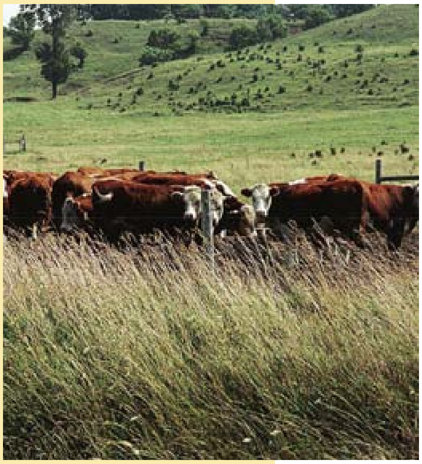
GROUNDWATER BASICS

RECHARGE: HOW AQUIFERS ARE REPLENISHED



In the water cycle, the portion of infiltrating water that isn't taken up by plants will move downward through the unsaturated zone. When infiltrating water reaches the water table, it becomes groundwater recharge. Recharge replenishes water in aquifers, or is discharged in springs, streams, lakes or wetlands.

On a larger, regional scale, recharge from shallow to deeper aquifers also takes place. It's possible to take the path of recharge to a deeper aquifer back up to the geographic areas of entry in the surface landscape. These are known as recharge areas. They are defined by a measurable downward driving force beneath the water table, or a vertically downward gradient. Spills anywhere within a recharge area can contaminate aquifers. Some recharge areas, such as hilly land with coarse-textured soils, are of particular importance because of their high permeability. The Oak Ridges Moraine in southern Ontario is a prime example of a large and important recharge area.



End moraines are good examples of important groundwater recharge areas.

How much recharge gets to the aquifer? In Ontario, the amount of recharge in an area of only one square kilometre (0.4 sq. mi.) ranges from 150,000 to 800,000 litres (30,000 to 180,000 gal.) a day, or 7 to 40 percent of the total precipitation. That's enough water to supply from 400 to 2,300 people daily. The lowest recharge rates occur in areas of fine-grained, low permeability soils, such as clay plains. More permeable soils such as sand and gravel allow higher recharge rates. The recharge rate is also influenced by climate, topography and vegetation cover.

The total groundwater pumped from all wells in an aquifer should be less than the amount of recharge to that aquifer. If not, the water level in the aquifer is gradually lowered, depleting the reserve of groundwater. This is called groundwater mining.

GROUNDWATER BASICS

FINDING GROUNDWATER

There are good sources of information on groundwater in your area and for wells on your property, including:

- Water Well Records on file with provincial agencies – there is more about Water Well Records throughout this book
- maps and reports on groundwater published by provincial agencies and in some cases municipalities have information on groundwater availability and quality, depth to aquifers, and susceptibility of aquifers to contamination
- local licensed water well contractors who understand local groundwater conditions
- hydrogeologists, scientists and engineers who study groundwater.

Find out if a record exists for wells on your property. Call 1-888-396-9355 (WELL).

Before purchasing rural property, it's a good idea to check Water Well Records and ask for water quality results.

TYPICAL INFORMATION IN A WATER WELL RECORD

- date completed
- location
  - lot, concession, municipality
  - mailing address
  - location map
- the original well owner's name
- geologic log listing type of overburden and bedrock
- depths and kind of water found
- casing(s): material, diameters and depths
- annular space, sealing/grouting details
- screen type, slot size, diameter, length, depth in well
- pumping test conducted upon completion
  - static water level
  - pumping level or recovery level(s)
  - pumping rate
  - length of time pumped
  - pump intake depth
  - recommended pump type, depth, rate
- final status of well
- type of water use
- construction method
- well plugging and sealing details
- contractor
  - name, address, license number
  - technician name, license number

GROUNDWATER BASICS

For generations, dowsers have claimed to be able to find groundwater by using a forked branch, rod or pendulum.

PHOTO CREDIT: Burnett, W. and T. Besterman. ***The Divining Rod: An Experimental and Psychological Investigation*** (London: Methuen & Co., 1926).

Some people claim to find groundwater by water witching or dowsing, using a forked stick, rod or pendulum. Although water witching has some popular appeal, there is no scientific evidence that it works better than chance alone. We know that groundwater occurs mainly in pores in geologic formations. An aquifer has to extend under a large area to provide enough groundwater to wells. In much of Ontario, because there is enough rainfall and the right geologic conditions, it is hard not to find groundwater.

GROUNDWATER QUANTITY

HOW MUCH WATER DO YOU NEED?

The amount of water you use depends on:

- family size
- family lifestyle (water-using appliances)
- type of farm (livestock, cash crop, greenhouse)
- number and type of livestock
- irrigation requirements
- lawn or garden watering
- water conservation practices.

All water use can be reduced by practising water conservation.

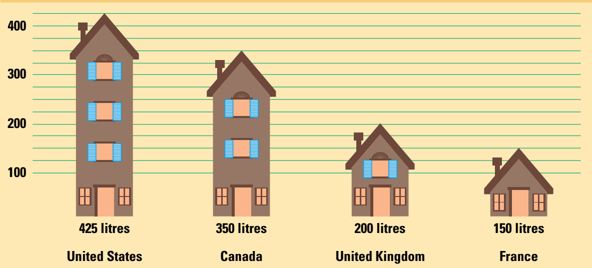
HUMAN WATER REQUIREMENTS

The average Canadian person uses 350 litres (about 80 gal.) a day, but this can vary from 270 to 450 litres (60 to 100 gal.) a day. To ensure an adequate supply, well contractors may base their calculations on 450 litres a day per person.

LIVESTOCK WATERING

Use the chart on the following page to estimate your livestock watering needs.

AVERAGE DAILY HOUSEHOLD WATER USE (PER CAPITA)



The average Canadian uses over twice as much household water per day as a European.

GROUNDWATER BASICS

ANIMAL	QUANTITY – litres (gallons) a day
Milking cow	90 to 135 (20 to 30)
Dry cow, beef cow, horse	40 to 45 (9 to 10)
Steers and heifers	30 (7)
Sow	21 (5)
Boar, dry sow	13 (3)
Feeder hogs	9 (2)
Sheep	7 (2)
Chicken	0.36 (0.08)
Turkey	0.45 (0.1)

PEAK WATER DEMAND

The amount of water a farm uses varies over the day. For example, the peak demand for a dairy operation that milks and feeds two times a day could occur for one hour in the morning and one hour in the evening. If equipment washing, feeding, and major household uses coincide, up to two-thirds of the daily water would be used during these peak hours.

Let's say that the total daily requirement (daily demand) of a family of five with a 50-cow dairy herd pipeline operation is 8,000 to 9,000 litres (1,750 to 1,800 gal.). If used evenly over the 24-hour period, the rate of use would be 6 litres (1.3 gal.) per minute. The rate of water use during the two hours of peak demand is 50 litres (11 gal.) a minute. If the water well can't supply the peak demand, water-using activities have to be changed or storage tanks added to provide water during high use periods. A water meter can be used to determine your daily and peak water demand.

On a dairy farm, the peak demand for groundwater often occurs for one-hour periods in mornings and evenings.

GROUNDWATER BASICS

HOW MUCH WATER CAN YOU GET?

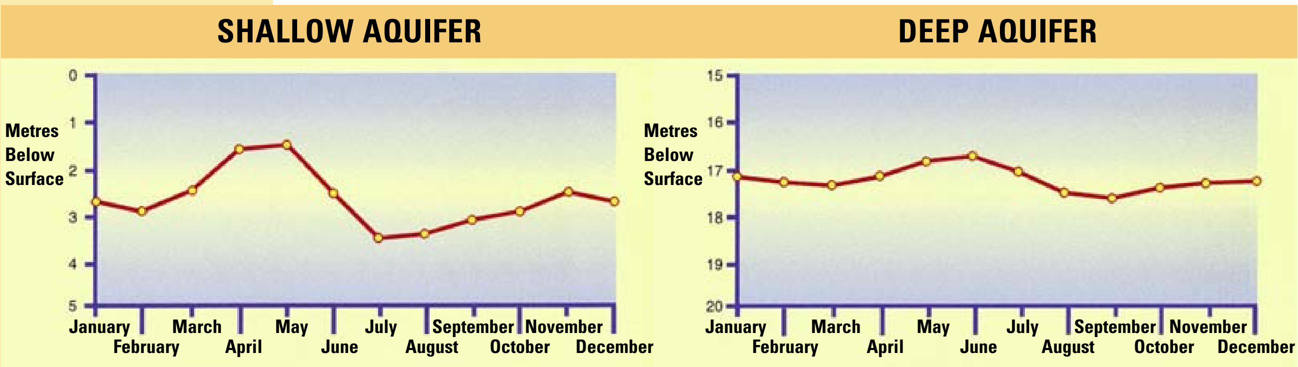
Groundwater yield from aquifers is affected by the characteristics of the aquifer and the amount of recharge getting to the aquifer. For example:

- ▸ thick sand and gravel or permeable bedrock formations extending over a large area can support high-capacity wells, with yields of millions of litres a day
- ▸ thin formations extending over only a small area may yield only a few hundred or thousand litres a day to wells – similarly, fine-textured deposits or bedrock aquifers with poorly developed fractures may supply only limited quantities of groundwater
- ▸ most aquifers in Ontario yield enough water for domestic or agricultural purposes
- ▸ major aquifers can support large-capacity municipal or irrigation supplies.

SHALLOW VERSUS DEEP WELLS

Generally, deeper wells have more available draw-down than shallow wells and are less affected by seasonal changes in water levels. (The illustration on page 70 shows what is meant by drawdown.)

There is no standard definition of shallow or deep wells. The three characteristics that might be used to classify a well as shallow or deep are: depth of intake (e.g., screen depth), depth of static water level, and depth of pump. A 6-metre (20-ft.) dug well with a shallow lift pump would universally be called a shallow well. A 75-metre (250-ft.) deep drilled well with a submersible pump at the 30-metre (100-ft.) level would be called deep. Is a 75-metre (250-ft.) drilled well with a 2-metre (5-ft.) water level and a shallow lift pump a deep or shallow well? For the purpose of this book, we assign the definition according to the bottom depth of the well, and use a cutoff point of 7 metres (25 ft.) – the maximum depth to which a shallow lift pump is effective.



Water levels in aquifers generally follow yearly precipitation patterns, with peaks in the spring and drops in late summer. This is more pronounced in shallow aquifers, and explains why some shallow wells run dry in the summer.

GROUNDWATER BASICS

Groundwater yields from wells are affected by the design of the well.

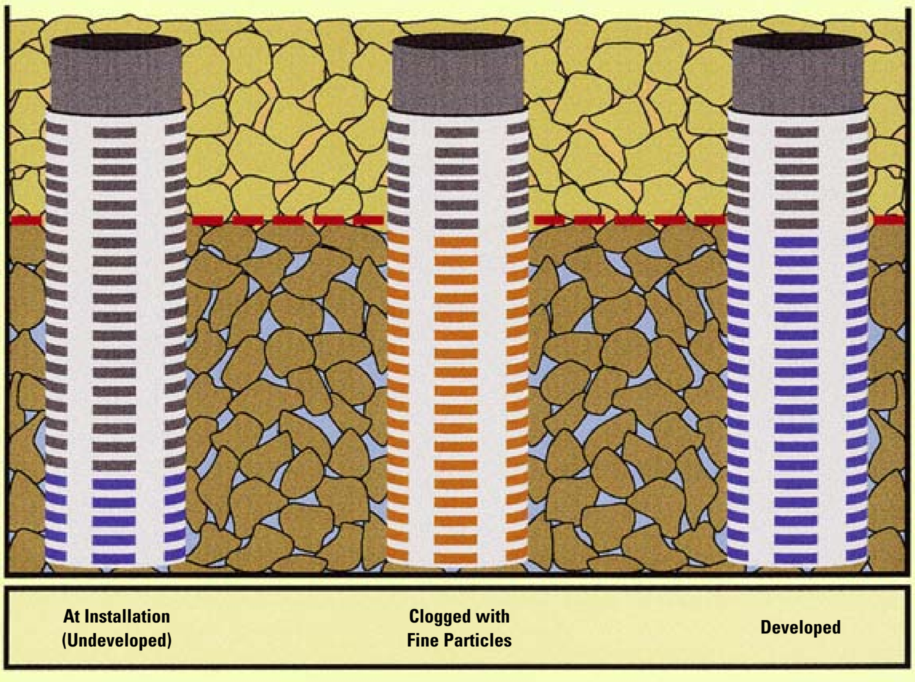
Seasonal changes in the level of the water table can affect the yield from shallow wells. Usually, the water table is highest in spring and fall, and lowest in summer and winter.

Proper selection of well screens and well development increase the efficiency and yield of wells in overburden aquifers. These construction methods are explained later in this book, starting on page 33.

A well owner's perception of how good a well is depends on the water demand. A well that only produces 5 litres (1 gal.) a minute will be a good well if little water is needed, or if extra water storage is provided to meet peak demands. An owner with a very high water demand will regard a 50-litre- (10-gal.-) a-minute well as poor.

Rule of thumb: a large-diameter well is usually shallow and a small-diameter well is deep.

DEVELOPING A WELL



All wells need to be developed at time of installation – or have the well screen flushed to maximize efficiency and yield. Some older drilled wells may also need to be developed to flush accumulated fine particles out of the well screen.

GROUNDWATER BASICS

Not all bacteria found in groundwater are disease-causing. Nuisance organisms clog wells and pipes, and cause well yield to decline.

GROUNDWATER QUALITY

Both natural processes and human activity can impact groundwater. The difference is that natural processes can either improve groundwater quality or degrade its aesthetic qualities. Human activity, for the most part, contaminates groundwater. With care, the impact of human activities can be reduced.

As groundwater percolates downward through formations above the aquifer, water quality may be affected in the following ways:

- the water dissolves minerals from the geologic materials it passes through, e.g., calcium carbonate in limestone can make recharge water hard
- organisms such as bacteria or protozoa may die off or be filtered out
- some substances in the recharge water, e.g., metals and phosphorus, may be removed by charged soil particles – thus improving the groundwater.

The following characteristics refer most often to shallow aquifers:

- the age of the groundwater determines its contact time with geologic materials, which affects its mineral content, e.g., the longer groundwater is in contact with limestone, the higher its calcium level
- bacteria may chemically alter nitrate or sulphur – this process will change the quality of groundwater, for better or worse
- groundwater temperature is affected by the depth of the aquifer
- bacteria may die off or be filtered out or remain dormant.

Water well quality may change due to the seasonal effects of snowmelt and rainfall, or if the depth of the well's aquifer changes.

GROUNDWATER BASICS

NATURAL INFLUENCES ON GROUNDWATER QUALITY

MATERIAL	SOURCE	IMPACT
CALCIUM AND MAGNESIUM	• areas where calcium-rich bedrock is found close to the surface • glaciated regions of Ontario near limestone bedrock formations	• water becomes hard: ○ lime scale becomes attached to fixtures and dishes and can clog plumbing, water heaters and dishwashers ○ soap scum, excess soap consumption • dirty and stained laundry
IRON AND MANGANESE	• most bedrock and soil materials • most acute in areas with iron-rich crystalline (igneous and metamorphic) rocks and reddish shale rocks • acidic groundwater (as pH lowers, levels increase)	• stains plumbing fixtures, cooking utensils and clothing • red and black particles in water • unpleasant tastes and colours • reduced well yield • nuisance organisms
ARSENIC	• some limestone bedrock formations	• long-term health hazard, including increased risk of cancer
URANIUM	• very rare and localized in Canadian Shield	• toxic
CHLORIDE	• salt bedrock (halite) • marine environments	• salty taste • corroded plumbing
SULPHATE	• sulphur-rich bedrocks • gypsum	• water has laxative effects, may taste bitter • combines with calcium to form an adherent scale
SULPHIDE	• sulphur-rich geological material • aquifers with buried organic deposits (swamps)	• hydrogen sulphide or "rotten egg" smell • tarnished copper • corroded plumbing • nuisance organisms
PETROLIFEROUS	• oil-rich deposits	• some fossil-fuel chemical components (e.g., benzene, toluene) are known carcinogens
BACTERIA, PROTOZOA, VIRUSES	• wildlife: populations, waste materials and mortality	• gastrointestinal diseases and parasites

GROUNDWATER BASICS

THE ONTARIO FARM GROUNDWATER QUALITY SURVEY

About 1,300 domestic farm wells located throughout the province were tested in 1992 for nitrate, faecal coliform bacteria, and several common herbicides. The findings may or may not reflect the quality of the aquifer. These are a few of the findings:

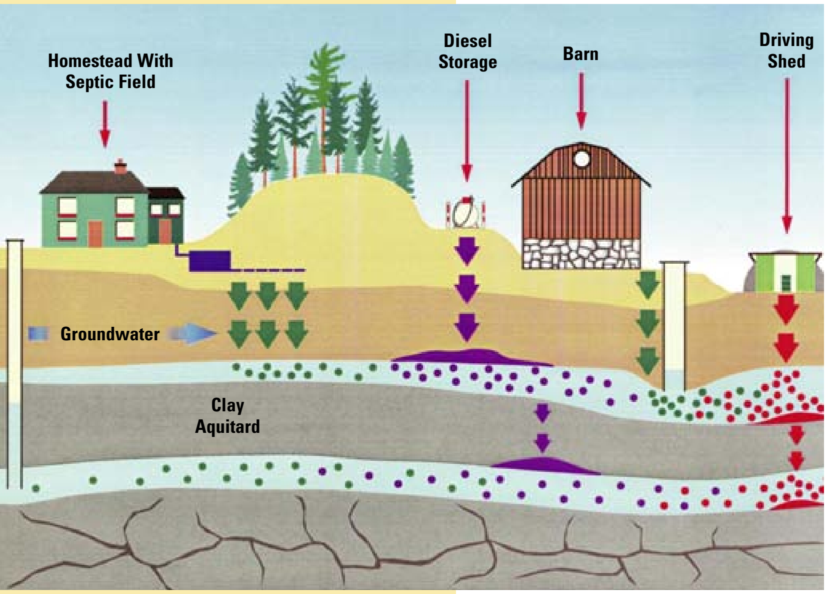
- 40 percent of wells tested contained levels of one or more of the target contaminants above the provincial drinking water objectives
- dug or bored wells and driven sandpoints were the most frequently contaminated well types, regardless of depth
- the frequency of contamination was higher in older wells and in shallower wells
- wells contaminated with nitrate tended to be in areas classified by Ontario Ministry of the Environment as having a high susceptibility to groundwater contamination.

GROUNDWATER CONTAMINATION

PATHWAYS OF CONTAMINATION

Groundwater can become contaminated in several ways:

- spills on the ground, e.g., fuel and pesticide spills
- injection into the ground, e.g., septic leaching beds, disposal of waste in wells, contaminated surface water running into poorly constructed wells, poorly maintained wells, improperly plugged wells and back-siphoning from spray tanks into wells
- improper handling of industrial solvents and chemicals, e.g., varsol and wood preservatives
- leakage from wastes, e.g., manure storages, wastewater, septic tanks and landfills
- leaking underground and aboveground fuel storage tanks
- movement of groundwater between contaminated and clean aquifers
- overapplication of soil amendments such as manure, commercial fertilizers or pesticides.



In aquifers, contaminants and recharge waters can follow similar pathways. This is the case for nitrates from household septic systems, livestock wastes and excess fertilizer application. Some contaminants, like diesel fuel, are less dense than water and will stay mostly near the top of the aquifer. Other contaminants that are more dense than water and do not dissolve readily will tend to accumulate at the bottom of an aquifer. Such contaminants are referred to as dense, non-aqueous phase liquids or D-NAPLs.

GROUNDWATER BASICS

Geologic formations may remove some contaminants. For example, metals like lead and mercury can become attached to soil particles. Nitrate levels can be reduced in the aquifer through denitrification. The likelihood that groundwater could become contaminated depends on:

- the size or strength of the contamination source
- the ease with which the contaminant can move into or travel through the soil.

Septic systems must be located a safe distance from drinking-water wells. They should be maintained regularly to reduce the risk of bacteria and nitrate contamination.

Contaminants move most easily through coarse-textured soils (sand and gravel) and fractured bedrock. But even clay soils can have fractures that allow the movement of contaminants. Once contaminants have reached an aquifer, they are difficult and expensive to remove. High levels of a contaminant in an aquifer can make the water unfit and unsafe to use.

To learn more about where to locate and how to construct a well to reduce the chance of contaminating wells and aquifers, see the section that starts on page 33. The illustration on page 33 shows some of the potential sources of groundwater contamination commonly found on a farm.

TYPES OF CONTAMINANTS

CONTAMINANTS THAT DISSOLVE

Some substances, like common table salt, dissolve easily in water. Examples of substances that can affect groundwater quality include:

- nitrate from septic systems, manure, synthetic and mineral fertilizer, and legume plowdown crops
- water-soluble pesticides
- road salt.

Once contaminants of this type reach an aquifer, they move in the direction of groundwater flow. The zone occupied by the contaminant in the aquifer is often called a plume. The size and shape of a plume depends on the strength and type of the contaminant source and the chemical and physical properties of the aquifer. The strength or level of the contaminant generally decreases the farther it gets from its source. Plumes may exist, however, over several kilometres.

Nitrate is a more common contaminant than pesticides in rural groundwater supplies.

Researchers have found that plowing down nitrogen-fixing forages can result in a "pulse" of nitrogen leaching into the groundwater.

GROUNDWATER BASICS

Some contaminants do not dissolve or flow with groundwater, making them difficult to clean up. These are sometimes known as NAPLs, which stands for non-aqueous phase liquids. Light-NAPLs or L-NAPLs such as gasoline are lighter than water and, for the most part, will remain at or near the surface of a contaminated aquifer. D-NAPLs or dense non-aqueous phase liquids such as perchloroethylene (a common degreasing agent) are heavier than water and will gravitate to the bottom of an aquifer.

CONTAMINANTS THAT DON'T DISSOLVE

Substances like oil don't mix with water, although small amounts may dissolve in water. Even the small amounts that do dissolve may exceed safe drinking water levels. Some liquids like diesel fuel, gasoline, and paint thinner are lighter than water and float on the water table surface. Others, including some common degreasers, are heavier than water and sink to the bottom of an aquifer.

If gasoline, for example, is spilled on the ground, it can travel down through the soil until it reaches the water table. Most of the gasoline floats on the water table where it can get into nearby shallow wells. A small amount dissolves and moves with the groundwater flow where it can affect deeper wells farther away. It only takes a litre of gasoline to make a million litres of water undrinkable because of the toxic chemicals contained in gasoline.

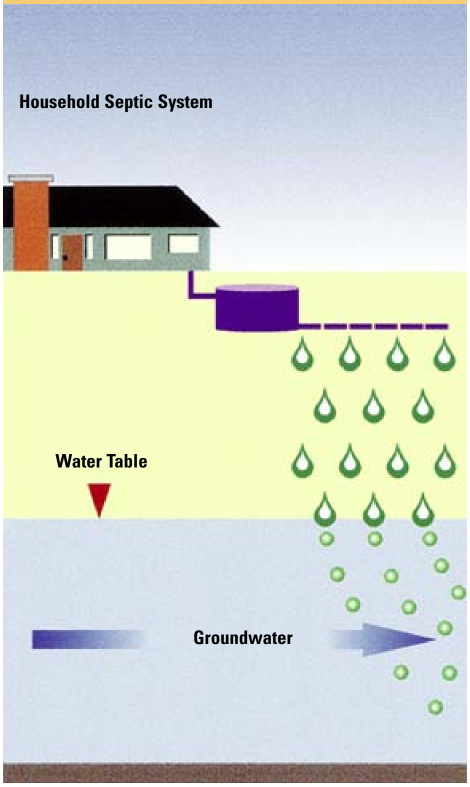
THE COST OF CLEANING UP

Near one small rural community, gasoline leaked from a fuel storage tank into the bedrock aquifer. The water in about 20 wells was contaminated and no longer fit to use. These wells had supplied water for farms, rural residences and livestock. Some wells that weren't too badly contaminated had expensive treatment systems installed to make the water drinkable. Other users had to be supplied with water piped in from a town about 10 kilometres (6 miles) away. The contamination had spread so far in the fractured bedrock that the aquifer could not be cleaned up. Several million dollars was spent in supplying water and cleanup efforts.

With recent changes to fuel regulations, many older installations are no longer acceptable. The 300-gallon fuel tank shown here has been placed in a rectangular containment to offer protection in case of a spill.

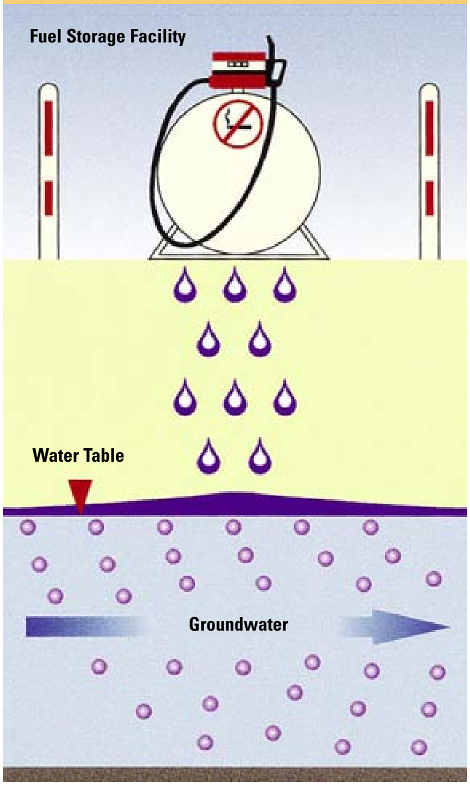
GROUNDWATER BASICS

HOUSEHOLD SEPTIC SYSTEM



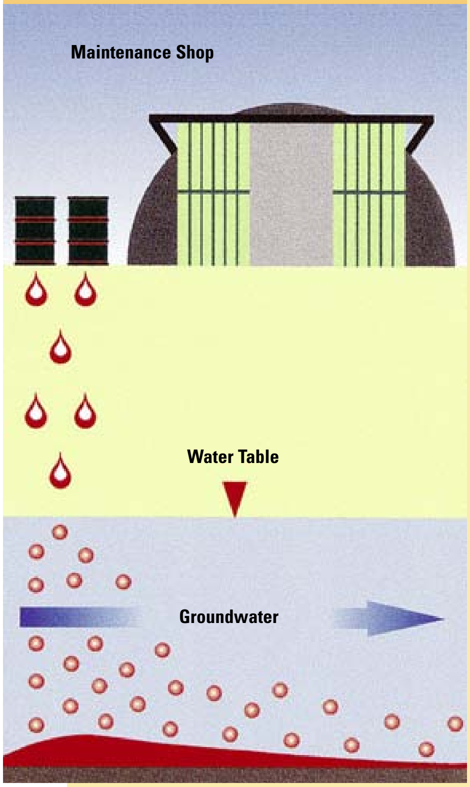
Septic systems are designed to treat human wastes, not hazardous household materials such as solvents and oil products. Substances that dissolve in groundwater such as fertilizers, road salts, water soluble pesticides and septic-based nitrates will move with recharge water to the aquifer. Once they reach the aquifer, they move in the direction of groundwater flow.

FUEL STORAGE FACILITY



Generally, oil products and water don't mix, although some of this material does "dissolve" in the water. If spills or leaks occur, small amounts may make an entire aquifer unfit to drink. Such materials are lighter than water and will remain near the top of the aquifer.

MAINTENANCE SHOP



Perchloroethylene, a common degreaser, is heavier than water. If spills or leaks occur, most of this material will gravitate and remain at the bottom of the aquifer. This characteristic makes it nearly impossible to clean up.

GROUNDWATER BASICS

Do not assume your well water is biologically safe. Have it tested regularly. See the sidebar on page 77 for more information on interpreting results.

BIOLOGICAL CONTAMINANTS

Bacteria, viruses, protozoa, and other disease-causing organisms can also contaminate groundwater. Faecal coliform bacteria found in the excrement of humans and warm-blooded animals can survive a long time in groundwater. Water samples are often taken to test for bacteria, but viruses are very difficult to detect. They are not likely to be transported from the ground surface to the water table and through the aquifer by natural flow. Rather, they are usually conveyed directly to groundwater down improperly sealed wells, via unused wells, and through other direct means such as septic systems.

The survival of disease-causing organisms decreases with: extremely hot temperatures; sunlight exposure; predation; pH extremes; depth to groundwater; lower moisture content and organic matter content in the soil; and smaller grain size.

There are microorganisms that are much more hazardous to humans than common faecal bacteria. Examples are *cryptosporidium,* a parasitic protozoa, and verotoxigenic bacteria, such as *E. coli* O157:H7*,* also known as the hamburger disease. Such organisms are common in animal and human waste, and can inflict serious illness in people.

It is increasingly important that groundwater supplies (aquifers) be protected from surface water by ensuring proper construction and maintenance of active wells and proper plugging and sealing of unused wells. The existence of these contaminants in water results from poor sanitation, improper handling of human and animal wastes, and poor well construction or maintenance.

It's important to assess the potential risk of management practices on the land and in the home to ensure the quality of surface water and groundwater.

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