GROUNDWATER SUPPLY AND QUALITY

HOW DO WE GET GROUNDWATER FROM WELLS?

Groundwater is **abstracted** by sinking a borehole down into an aquifer. If the aquifer is confined then there is **enough hydrostatic pressure** to from a **favourable hydraulic gradient** for water to flow up to the surface.

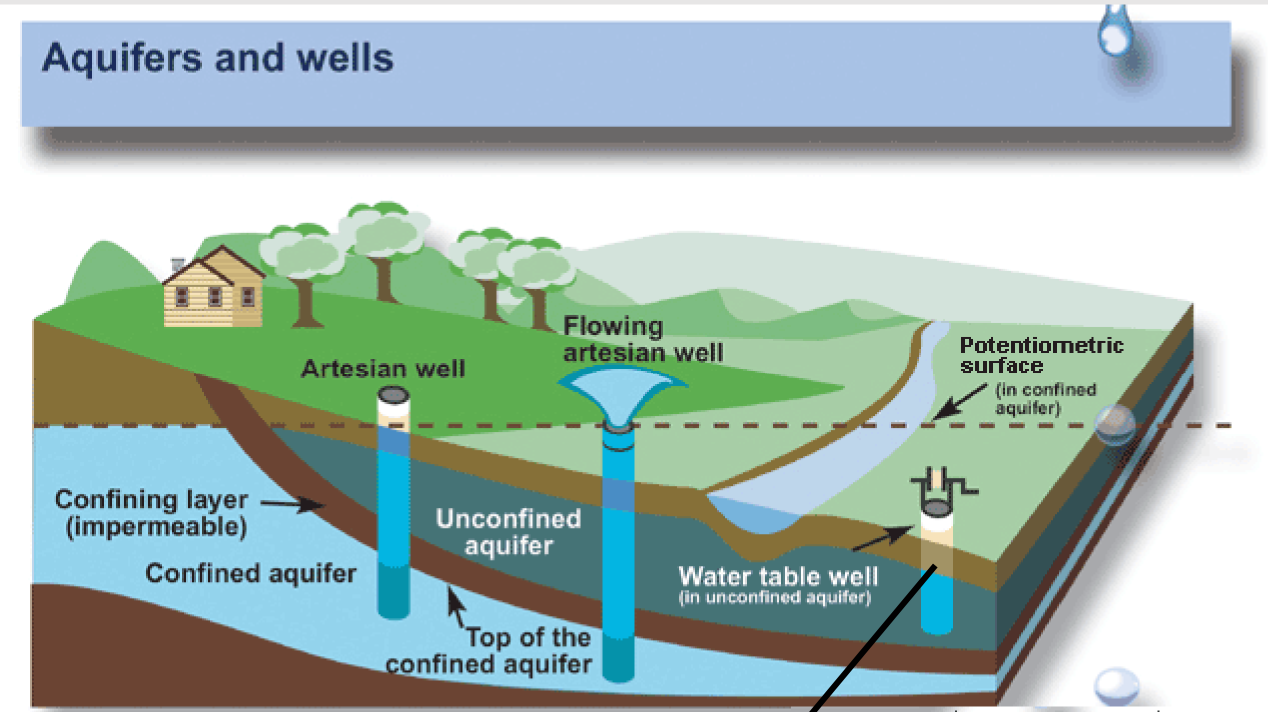
If the **aquifer is unconfined** then there is a **lack of hydrostatic pressure** as the water is held under **atmospheric pressure.** The hydraulic gradient is not favourable so **pumping is required**.

As the water is pumped out the ground from a well, the level of water table falls around the well, leading to a **cone of depression**.

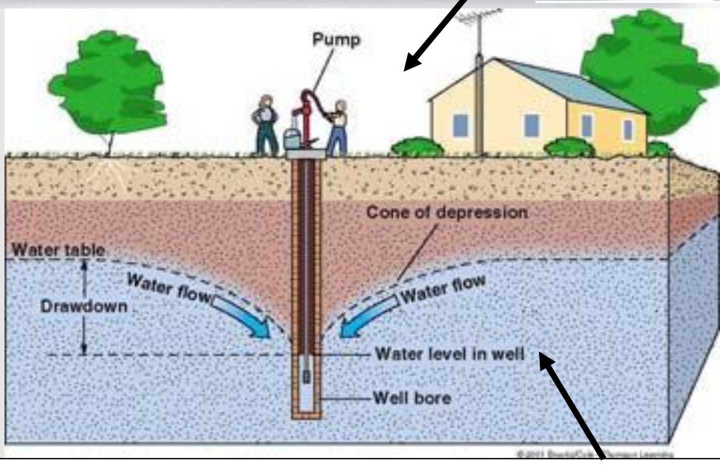
#Drawdown = The height difference between the water table and the level of water level induced in the well

As water is pumped from the well, **hydrostatic pressure** within the aquifer **reduces** so the **hydraulic gradient** being **set up** means that **groundwater flows towards the well**.

- If the borehole is sunk into an artesian basin, the water will rise up under hydrostatic pressure to from an artesian well (no pumping is needed if the well is below the potentiometric surface). The **greatest pressure** will be in the part of the aquifer with the **highest hydrostatic head**. This will **save on pumping costs**.



Source: Environment Canada, USGS



The point of the cone of depression = water height in the well.

Perched aquifer abstraction:

Water stored in a perched aquifer is above the regional water table and so its supply is very limited. Any well sunk into the perched aquifer will quickly become exhausted. The water level in the well will be the same as the perched water table as both experiences the same hydrostatic pressure (equal to the atmospheric pressure).

Unconfined aquifer abstraction:

All the water is under atmospheric pressure and so the lack of hydrostatic pressure means that any well sunk into the water aquifer will need vast amounts of pumping. The water in the well will be equal to the water table height unlike a perched aquifer.

Confined aquifer abstraction:

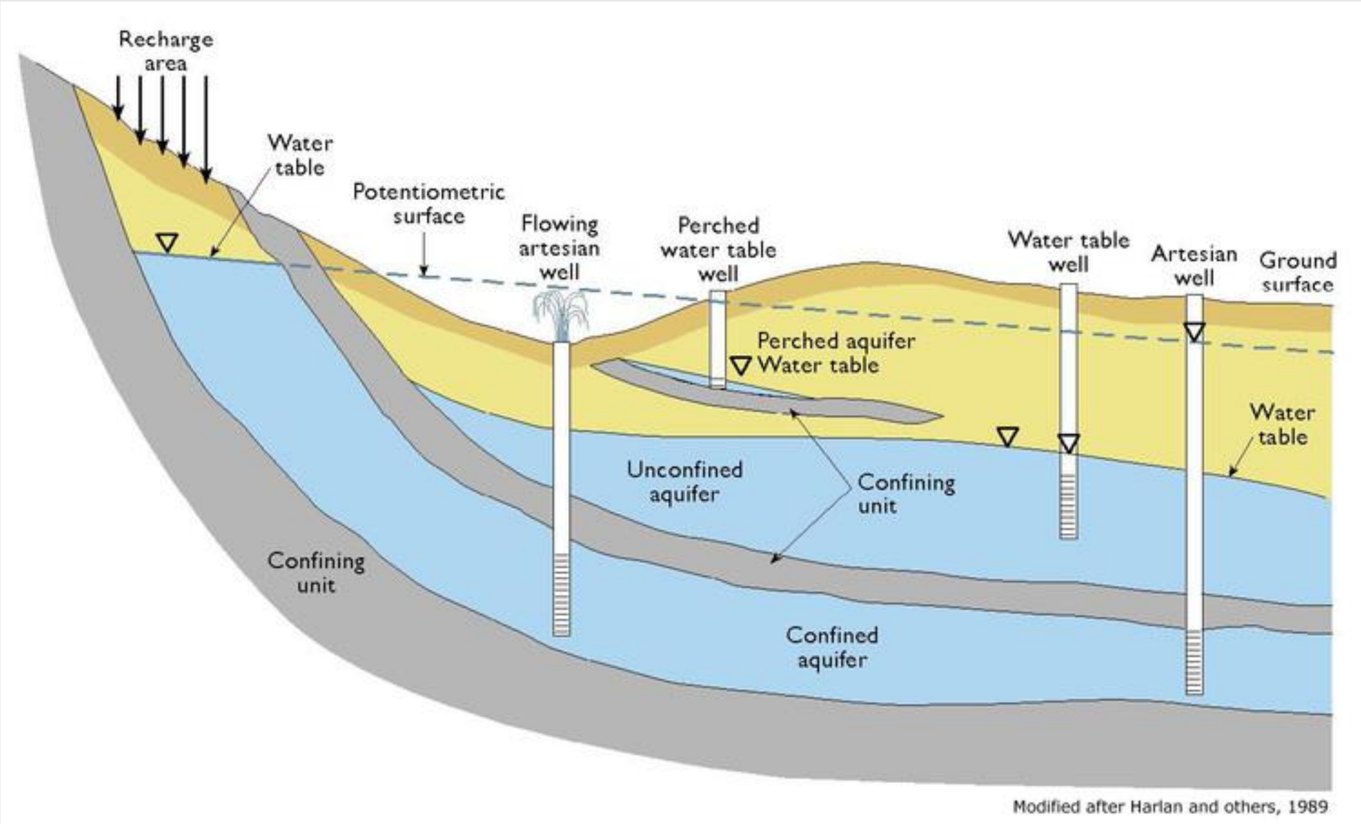
The water level in a well sunk into a confined aquifer will be determined by the hydrostatic pressure in the aquifer. A well sustained by hydrostatic pressure is an artesian well. The level of the potentiometric surface is very important. This is the level to which the water will rise under hydrostatic pressure, and is equivalent to the regional water table’s level.

If the aquifer is confined then the water may well rise up the well (along the hydraulic gradient) to the potentiometric surface or below.

However, the water table falls over time and eventually the water table will have fallen below an appreciable height so the hydrostatic pressure is insufficient to allow the water to rise to the surface. The well will then require a pump.

The following table summarizes the scenarios in the image below

Well name	Position relative to potentiometric surface	Pump required?	Cost
Flowing Artesian Well	Below	No	Low
Perched water table well	Above	Yes	Low (little pumping distance)
Water table well	Above	Yes	High (water does nto rise as it is under atm pressure)
Artesian well	Above	Yes	Medium (water srises to potentiometric surface but not well surface)



PROBLEMS CAUSED BY GROUNDWATER ABSTRACTION

1. **The lowering of the water table**: **Shallow wells become dry** and have to be **sunk further.** This is particularly a problem when more water is drawn than can be replenished by **lateral flow** and when there are **too many wells situated close** to each other. If the well is then deepened, so is the cone of depression. The cone of depression becomes larger and may intersect with **neighbouring wells, running them dry**. There is a **lowering of the whole water** table as a whole (reducing hydrostatic pressure and **increasing pumping costs**).

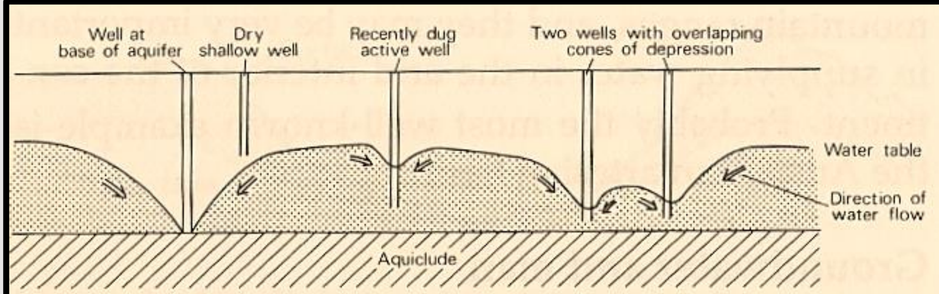
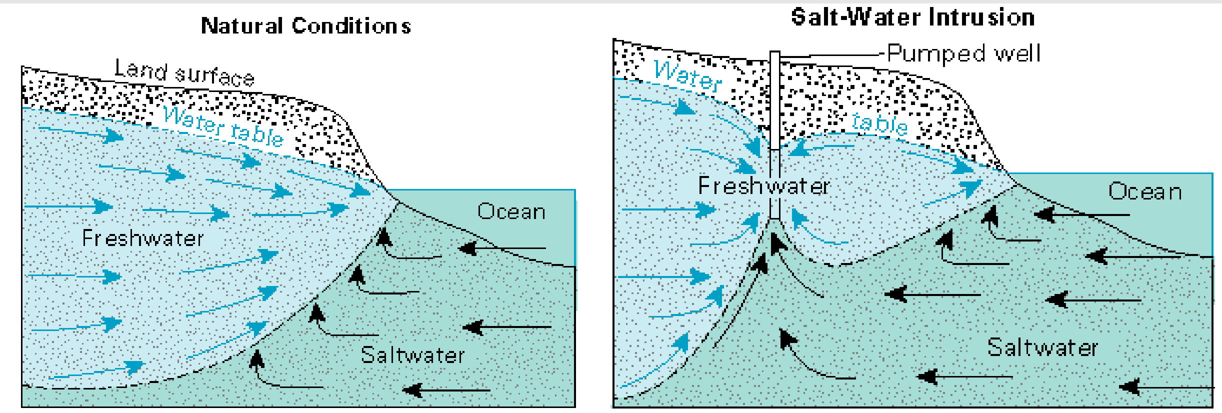


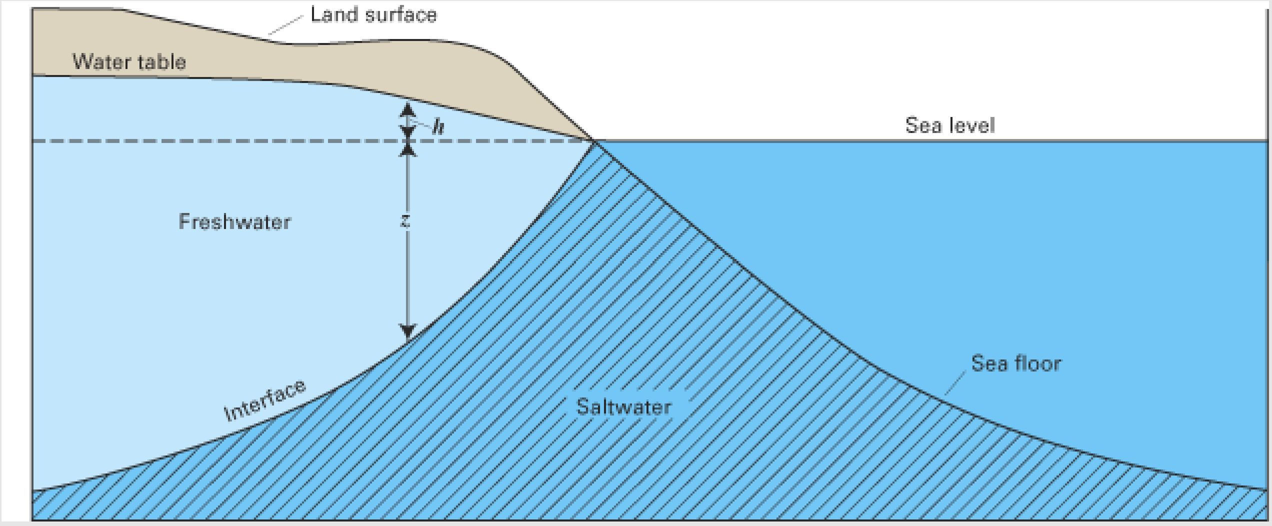
Figure 14.20 Cones of depression developed around wells. Water extraction in the London area has resulted in serious drawdown in this way over the last century. More recently, however, a decline in the rate of water usage has caused the reverse problem – a rise in the water table and a flood risk to subsurface structures such as the Underground

If the rocks are **highly porous and permeable**, **flow is rapid** so **replenishment of a well is efficient** and the cone of depression at any given time is small.
A **deep cone of depression** forms if the **rocks are relatively impermeable** and/or have a **lower porosity** so replenishment is much less efficient.

2. **Subsidence at the surface** resulting from the **removal of water** from **pore spaces** of the rocks. Rocks overlying the aquifer **collapse downwards** creating depressions at the surface which can be several meters in diameter. In turn, compaction results **in permanently reduced water storage capacity**.

3. **Saltwater encroachment**. At coastal aquifers, the **less dense fresh water floats** above the **denser salt water**, forming a **lens floating on top of the saline water**.
Over-pumping disturbs the **freshwater-saline** water i**nterface**. This allows sea water to enter the aquifer, **contaminating** the freshwater supply so it is unfit for drinking. The groundwater is said to become saline **(brackish).**





THREATS TO SUPPLY

1. **Over pumping** – if too much groundwater is extracted then there may not be enough left to provide a reliable public water supply.

2. **Pollution –** groundwater is vulnerable to contamination from a variety of sources and once polluted it is difficult to cleanse**. Unconfined aquifers are more at risk** from pollution than confined aquifers.

   If anything was to leak or spill into the soil directly above an unconfined aquifer, it will seep into and contaminate the water.
   There is greater exposure to contamination from external sources, such as rain, streams and rivers.

   On the other hand, a confined aquifer is `sealed' by an impermeable aquiclude from any contaminates above. Confined aquifers **can still be contaminated** by activities around the well.

- **Direct contamination** of a well and an aquifer can result from spills beside wells, improperly sealed well casings or abandoned wells, flooded well pits or back-siphoning from pesticide mixing tanks.
- **Indirect contamination** results when ground water and rain infiltrating soil contains contaminants or dissolves contaminants before entering the aquifer.

Indirect contamination can come from leaking sewage systems, fertiliser or manure spreading and pesticide spraying. Since nitrate-nitrogen is very mobile in soil, leaking septic systems or spreading manure or fertilisers, at rates that exceed crop uptake of nitrogen can result in groundwater contamination over time.

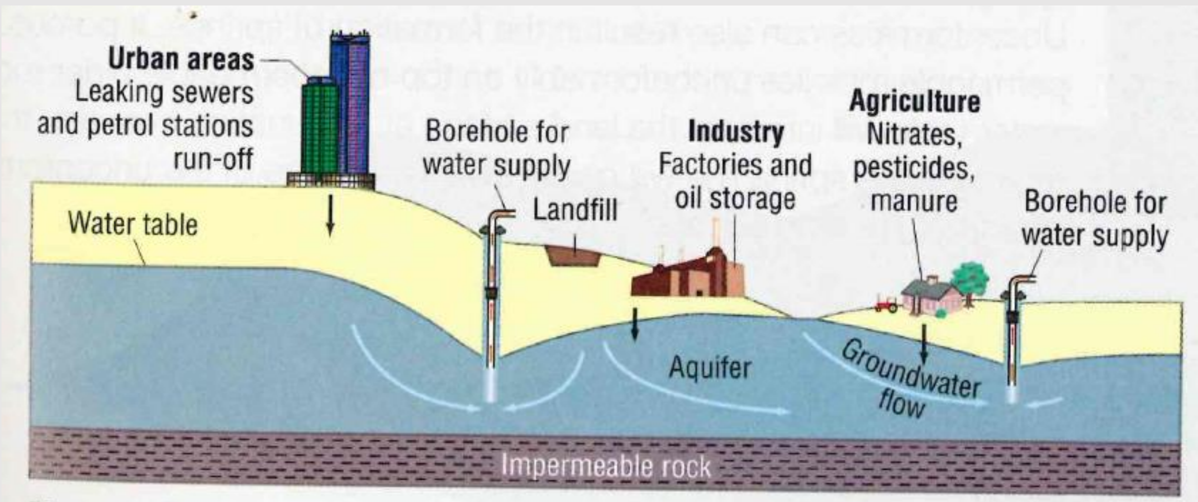


Figure 4 Sources of groundwater pollution

GROUNDWATER QUALITY

Rocks act as natural filters, removing impurities as water percolates through them.
This is so effective that it can **even remove bacteria, viruses and chemical impurities** (not just solids). For this reason, not all water sources require harsh treatments such as chlorination to make it fit for drinking.

Many people prefer to drink fresh, **naturally filtered water** as it is considered to be **healthier** (like organic foods). Moreover, they are full of **soluble minerals** needed for a healthy lifestyle.

As the water passes through rock it will dissolve soluble minerals which are taken into solution. Many of these minerals are beneficial to our health and **taste good** but **some are harmful** or may make the water **taste unpleasant.** The mineral ions present are dependent on the rocks that the water has passed as it percolates downward.

Hard groundwater contains dissolved **calcium (Ca^2+) and magnesium (Mg^2+) ions**. Hard water is harmless to drink but leaves l**imescale** in kettles, boilers and **scum in sinks/baths** and can be **difficult to lather** when you add soap.

Some groundwater contains naturally dissolved **fluoride ions (F^-).** Fluoride in drinking water has been proved to **reduce tooth decay**, but too much **(> 4 ppm**) has been linked to **dental fluorosis** (deposits of excess fluoride causing **teeth to become discolored and pitted**). It has also been known to lead to more serious health problems such as **joint pain, liver and kidney disease**.

Unfortunately, some places, including parts of India and **Bangladesh**, have high concentrations of natural **arsenic** in their groundwater, making it **unfit for human consumption.**

GROUNDWATER POLLUTION

Groundwater is often under the threat from pollution. This can be from a point source such as a factory which is relatively easy to pinpoint or from a more widespread, diffuse source which is much harder to track and prevent. Sources of groundwater pollution include:

Once the groundwater of an aquifer has been contaminated it is very difficult to purify, and the contaminants have a **long residence time of thousands of years**. They are virtually impossible to remove.

Cause	Pollutant
Agricultural run-off / Sewage leakage	Nitrates, pesticides (herbicides, fungicides and insecticides) and microbes
Petrol stations / chemical & manufacturing industry	Hydrocarbons and organic solvents
Landfill sites	Toxic fluids (leachate plumes from rainwater infiltrating and dissolving soluble chemicals and microbes)
Acid mine drainage water contains toxic metals such as lead and cadmium from abandoned coal and metal mines. Toxic metals are also left in soil through smelting.	Acids with lead, arsenic, cadmium and mercury