GROUNDWATER PRINCIPLES

Dr. MARK KING

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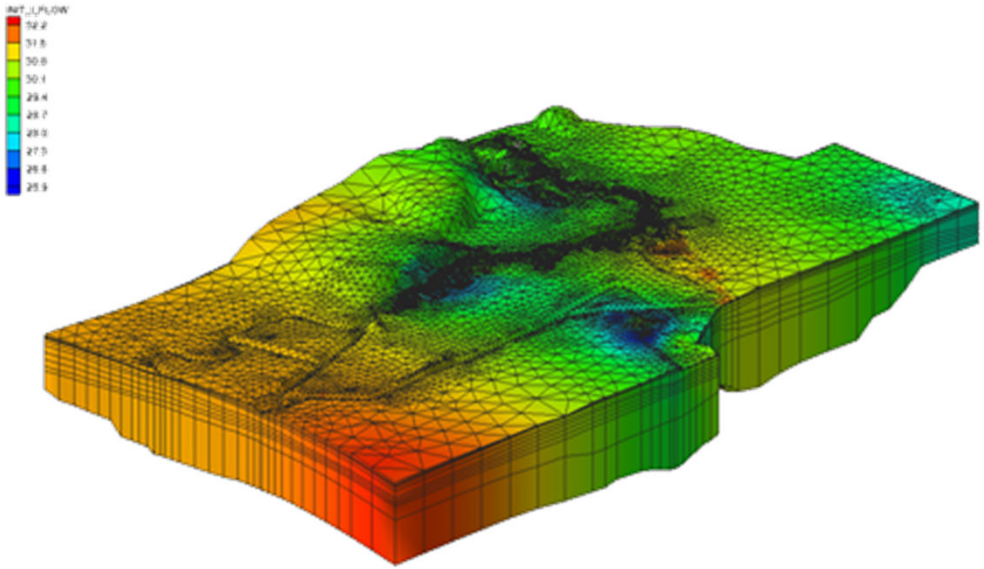
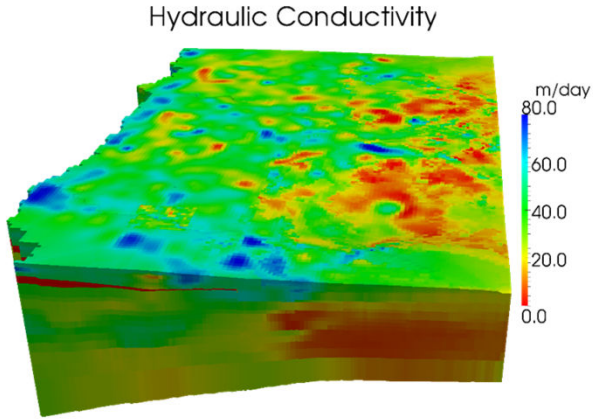
THE VILLAGE DRILL

Basic Groundwater Flow Principles





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GEOLOGY

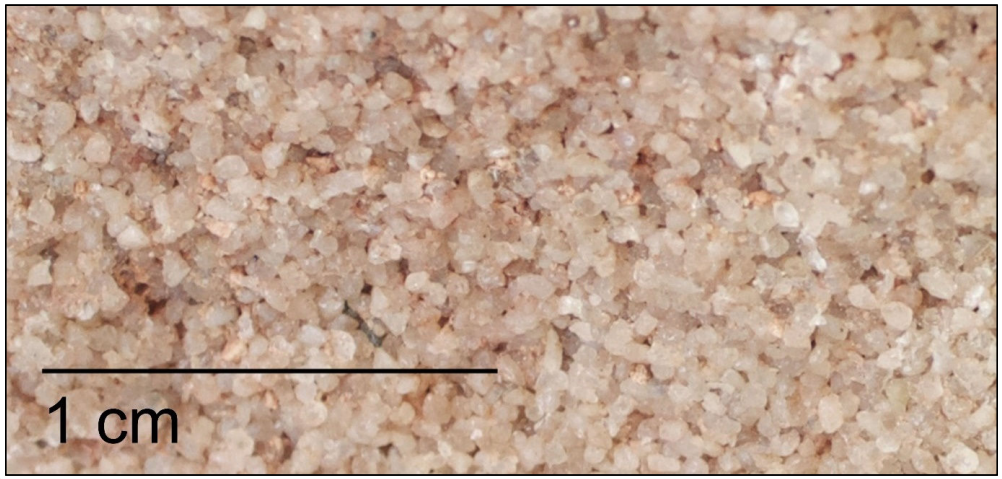
- **Geology** is *the study of the earth.* It describes the origins and formation of the rocks
- The original material or "building blocks" of the earth are the *hard rocks* such as granites and *volcanic formations,* formed when molten material cooled beneath or at the surface of the earth
- These are known as the *igneous rocks* ("made by fire")
- *Sedimentary layers* may form when these igneous rocks are broken up, by a process known as *erosion or weathering*

GEOLOGY

- Sedimentary layers are formed by the *weathering*, transport (by wind or rivers) and *deposition* (sediment) of particles broken down from rocks
- Those particles can range in size from extremely fine (clay particles) through silt-sized to sand, gravel and even boulders
- Sedimentary layers may be *unconsolidated* (loose such as clays and sands) or *consolidated* (cemented together) to form harder rocks such as sandstones

GEOLOGY

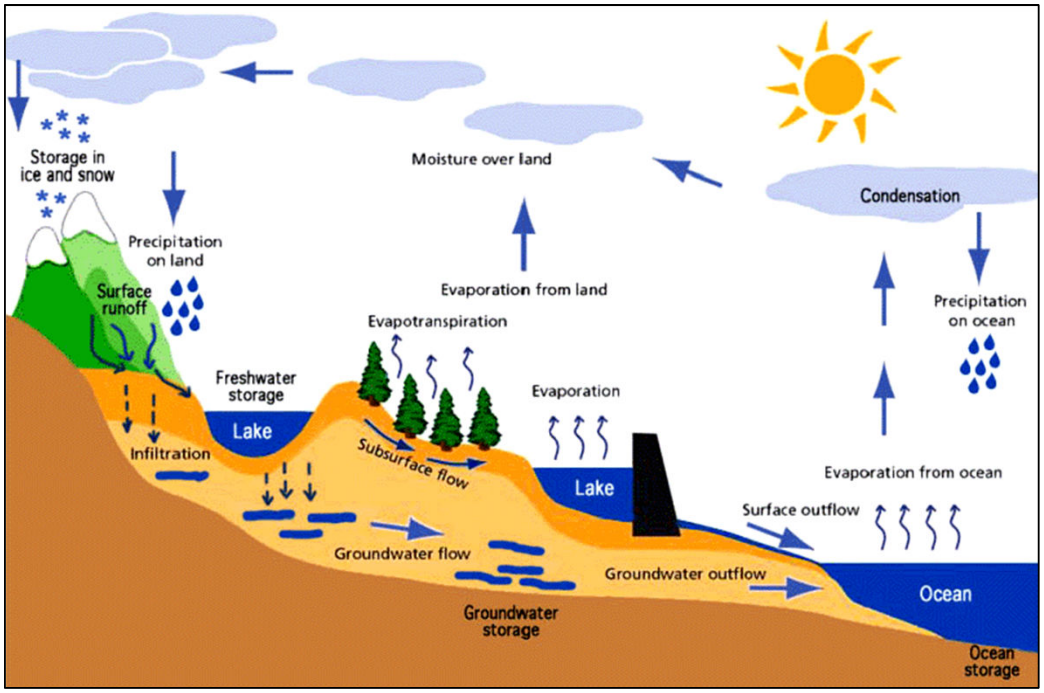
- When a mixture of sand and fine particles has been *compacted* by the weight of layers on top of it and *cemented* by minerals present in the mixture, *sandstone* is formed
- Sandstone is *consolidated sediment* that may be possible to drill, and may have important porosity



GROUNDWATER FLOW

- Hydrology describes the *cycle of water* as it rises from the sea and the earth's surface as evaporated water vapor
- This vapor forms clouds, which fall to the earth as rain
- Part of the water may infiltrate into the ground and become groundwater; part may flow over the land, reaching streams and rivers, then flow to the sea

We are most interested in the part that infiltrates into the ground!



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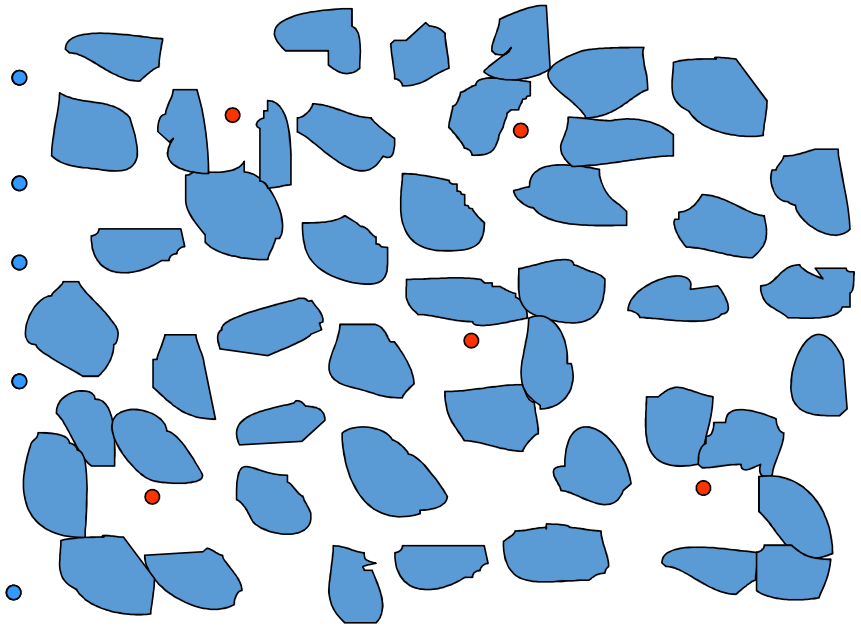
GROUNDWATER FLOW

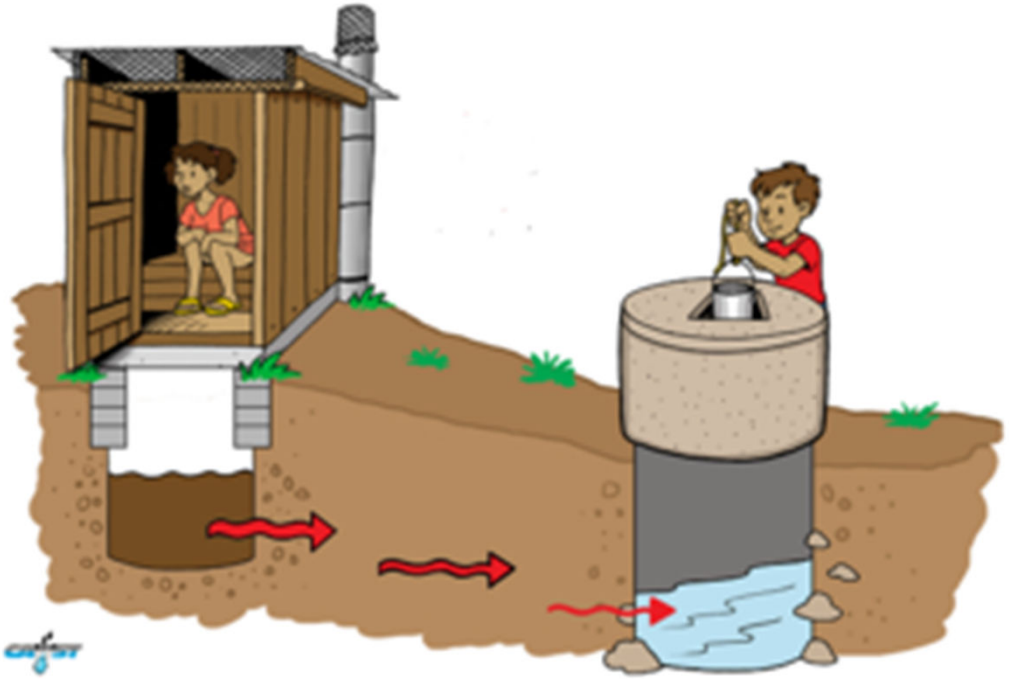


- For drillers it is important to know in particular about the location and movement (flow direction) of groundwater in permeable, water bearing layers (aquifers), and factors affecting the quality of groundwater in those layers.
- Just as surface water moves “downhill” in river and streams, *groundwater flows “downhill”* through the pores and fractures in the rocks and soil
- So, groundwater does not stand still!
- And, it is not always easy to determine the *flow direction* of groundwater.

GROUNDWATER FLOW

- It can be of great importance for the water quality of the well water to know in which direction the groundwater is flowing and where it came from. Imagine a *latrine* close to a well which is to be used for drinking water.

- We do not want *bacteria, viruses* and *parasites (disease-causing micro-organisms called pathogens)*, that originate from latrines, to be carried by flowing groundwater to a well.



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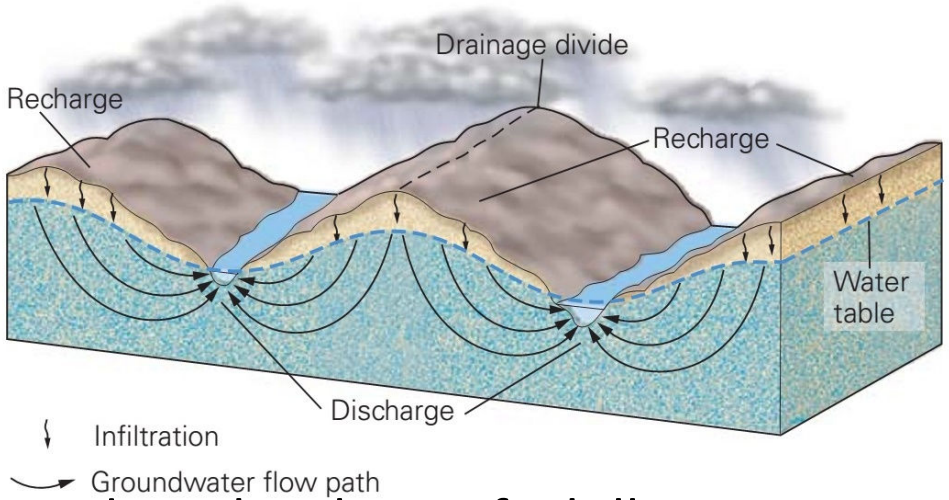
GROUNDWATER FLOW



- Although it can be difficult to detect the flow direction without detailed surveys, in the case of shallow groundwater, examination of the landscape can help.
- For instance, when a latrine is located on the slope of a hill or a mountain, the groundwater (possibly contaminated with bacteria) is likely to flow in the same direction as the slope of the hill.
- In this case it would be inadvisable to place the well immediately down-slope (downstream) of the latrine, but rather on the same level or higher than (up-slope from) the latrine.

SOIL CLASSIFICATION

- An essential skill of a drill team is the ability to recognize and describe different types of soil (formation material) encountered during drilling.
- A basic classification is based on particle size

Particle name	Particle size
Clay	< 0.004 mm
Silt	0.004 – 0.06 mm
Sand (fine, medium, coarse)	0.06 – 2 mm
Gravel and pebbles	2 – 64 mm
Stones and boulders	> 64 mm

SOIL CLASSIFICATION

- For the construction of a good quality well it is essential to recognize the *characteristics* of different soils, due to the influence on the yield (water that could be extracted)
- In other words, it is important to know whether the types of soil drilled are *permeable* or *impermeable*.

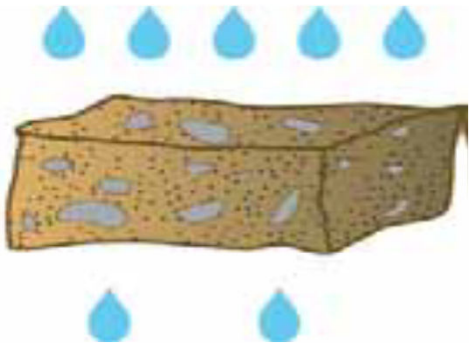
SOIL CLASSIFICATION

- **Permeability** is a measure of the ability of a soil (or formation) type to transmit water

- **Sand** and **Gravel**
- Water flows easily through the pores (open space) between the grains and the material is thus very *permeable*.

- **Clay** and **loam**
- Water does *NOT easily flow through clay*. Clay is therefore described as *low permeability or impermeable*.

- **Mixed** formations
- Water *flows slowly* through mixed soils and they are therefore described as *semi permeable*.



SOIL CLASSIFICATION

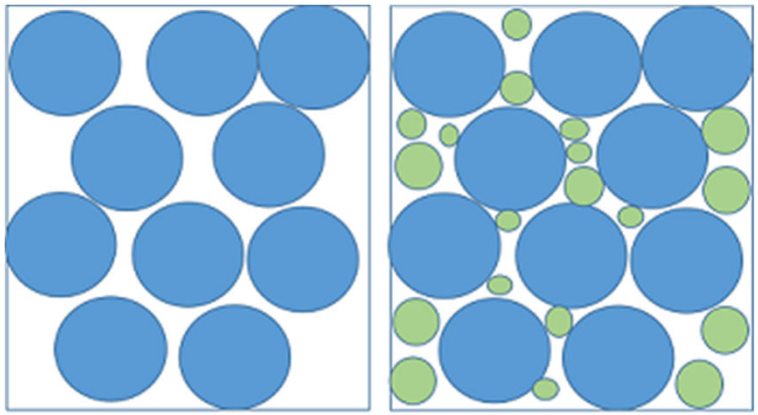
This is a small trick to help you determine the difference between *permeable or impermeable* layers:

- Take a representative sample of the soil and squeeze it into a ball, between your hands. Then drop the ball from a height of one meter above ground level. The ball falls down on the ground.

1. If the ball consists of non-cohesive (non-sticky) particles, the ball totally falls apart. In this case the material is *permeable*. The particles of sand or gravel will be easily visible.
2. If the ball falls apart only partially, the soil contains some silt or clay and sand. The formation will have a *low permeability*.
3. If the ball only deforms and/or remains more or less in shape, it is composed of clay, and is described as *impermeable*.

SOIL CLASSIFICATION

- Sedimentary layers consist of particles such as sand, silt and clay. Between these particles there is still lots of open space called pores
- Porosity is a measure of the percentage of free space in the formation. A porosity of 30% means that 30% of the total volume of the sample is open space while the remaining 70% is occupied by solid particles

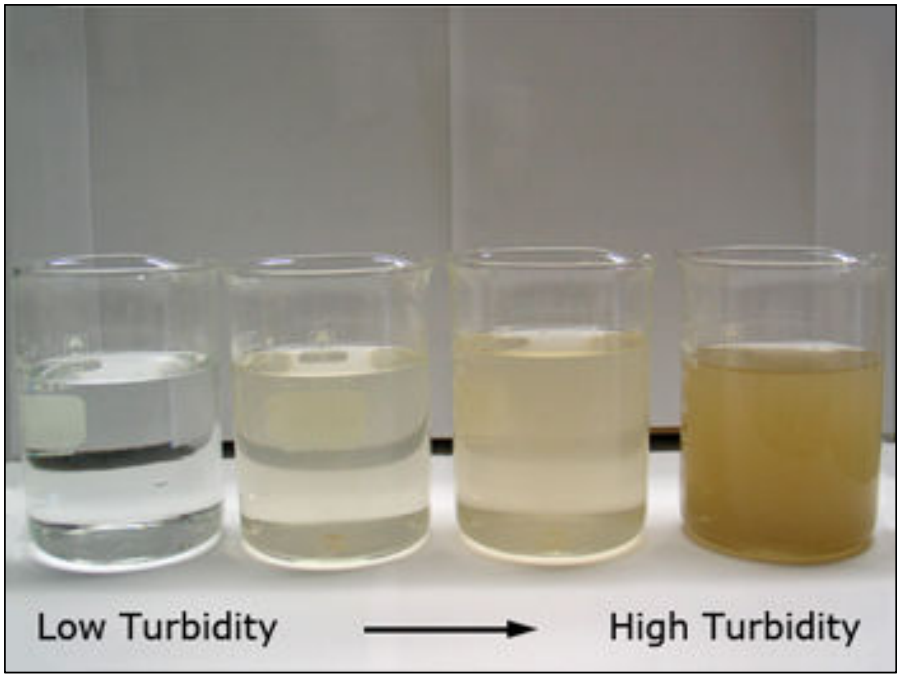


High porosity – large spaces Low porosity – small spaces

- The pores can be filled with air or water. This does not always mean that the water easily flows through the soil. For example, clay has a high *porosity,* but low *permeability.*

GROUNDWATER QUALITY

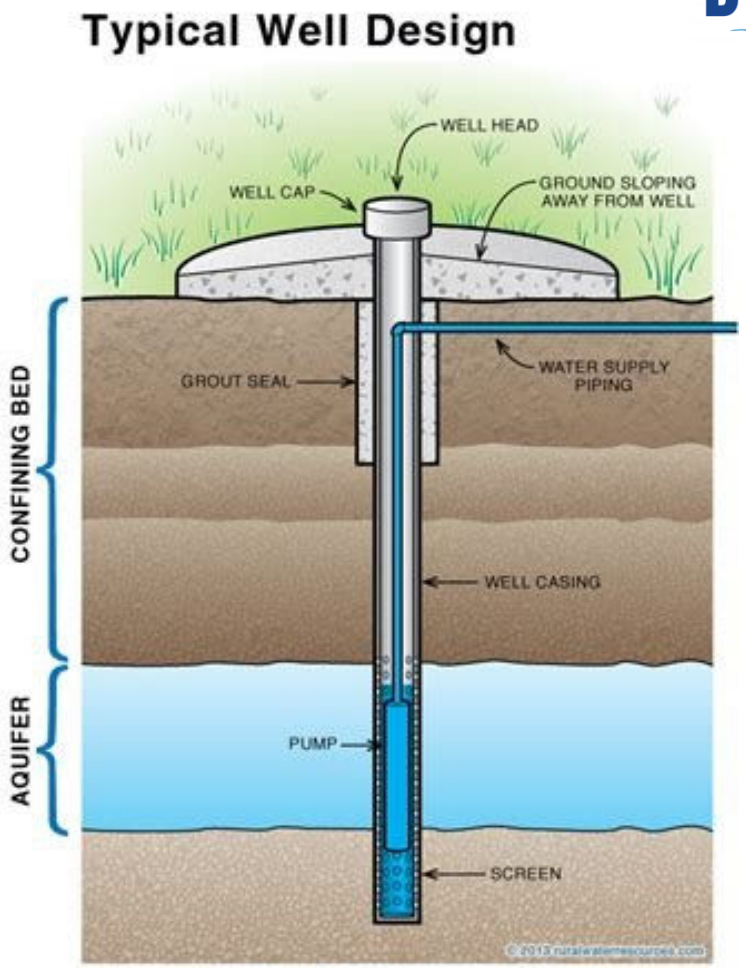
- Turbidity describes the *cloudiness* of water. It is caused by very small particles in the water (called suspended particles), rather like smoke in the air
- Clay and silt-sized particles are very fine, and settle slowly out of the water. When these particles are found in water they cause it to be turbid or cloudy.



- If well water is extracted from a clay or silt layer, some of the fine particles in the formation may be transported by the flow and become suspended (mixed) in the water. As a result the water will look cloudy…..more later

GROUNDWATER QUALITY

- Ideally, we will continue drilling until a *permeable* layer (sand or gravel) is reached, and then install the entire well-screen in this layer
- This layer is known as an AQUIFER
- If the layer is permeable, the water flow to the well will be high (high yield)
- Another benefit of a sandy AQUIFER is that it contains fewer small particles, so the water drawn from the AQUIFER will be clear (not turbid).



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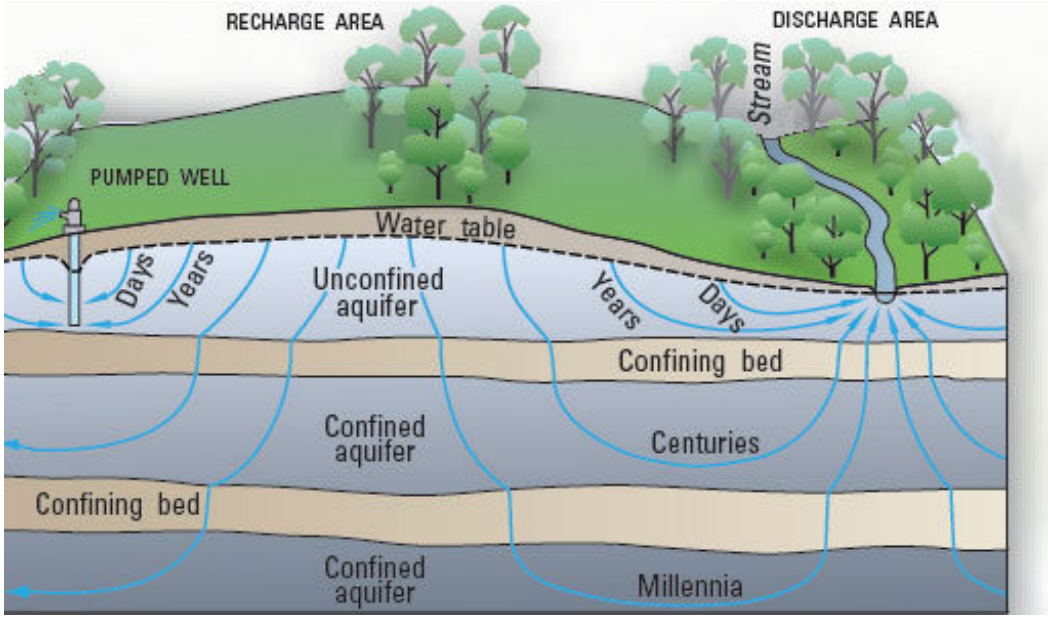
TYPES OF AQUIFERS

- The word *'aquifer'* simply means *'a water bearing layer'.*
- A good aquifer for the installation of a well-screen is a *permeable layer* below the groundwater table.
- During drilling you may come across different aquifers at different depths, separated by *impermeable layers.*



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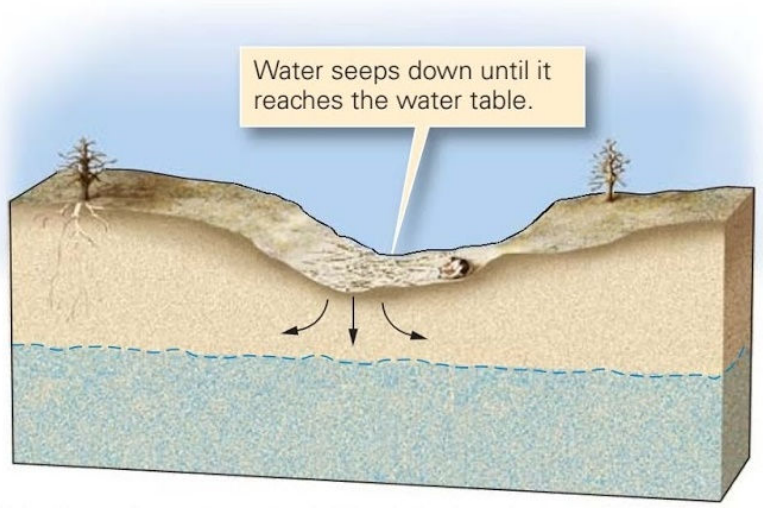
TYPES OF AQUIFERS

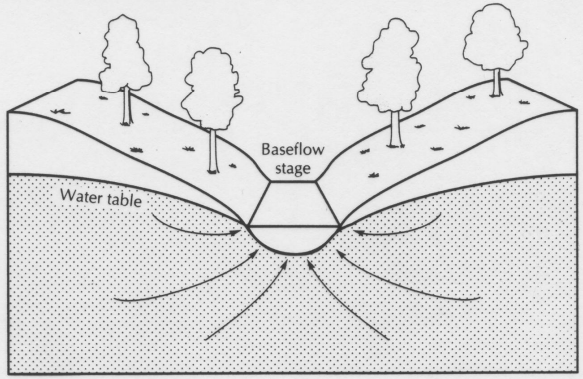
- **Phreatic aquifer or…..the "water table"**
- The *upper* aquifer is called the *'phreatic'* aquifer. Rainwater that infiltrates the soil may be added directly to this aquifer. In that way, this aquifer may be more sensitive to surface contamination, as the rain can take contamination (such as bacteria or pesticides) down into the groundwater.
- In other words, a phreatic aquifer may be sensitive to surface activities. Also, if this phreatic groundwater layer is just a few metres thick, it may dry out during the dry season, leaving your well empty.



Discharge versus recharge

3.2.3 Gaining and Losing Streams

The typical stream of a humid region receives ground-water discharge; therefore, as one goes downstream the baseflow increases, even if no tributaries enter. This is a **gaining,** or **effluent,** stream. The water table slopes toward the stream, so that the hydraulic gradient of the aquifer is toward the stream. Figure 3.10A shows a cross section through a gaining reach of a stream.



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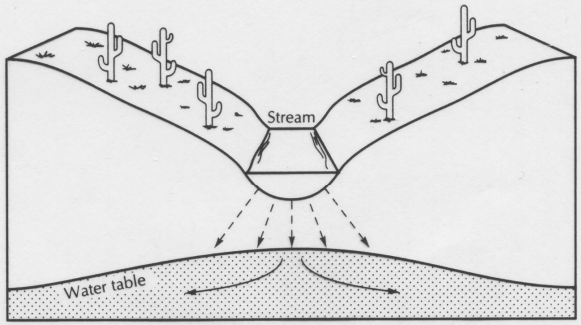


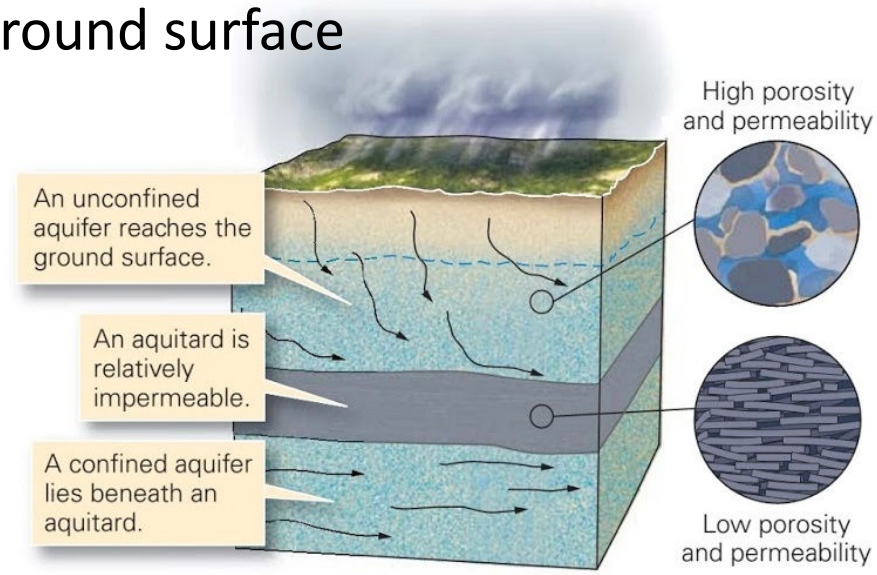
B

FIGURE 3.10 **A.** Cross section of a gaining stream, which is typical of humid regions, where ground water recharges streams. **B.** Cross section of a losing stream, which is typical of arid regions, where streams can recharge ground water.

TYPES OF AQUIFERS

“Confined” aquifer

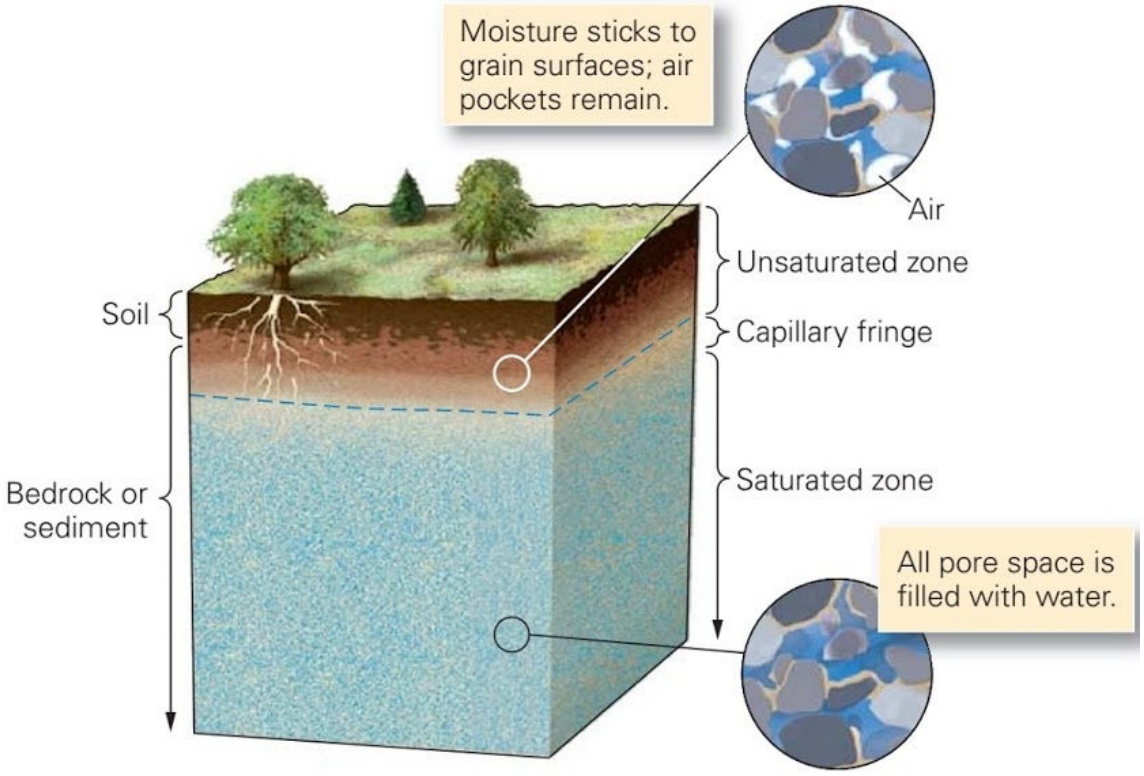
- This type of aquifer is covered by an impermeable layer on top (for example, a clay layer) and so it is called a confined aquifer. The impermeable layer may form a barrier for bacteria and other contaminants that may originate from at or near the ground surface
- If a confined aquifer is penetrated by the drill, it should be a preferred target for building a well
- Multiple confined aquifers may be present, one below the other, separated by impermeable layers



TYPES OF AQUIFERS

Single aquifer

- Sometimes only one aquifer is present (at least within the drilling depth). In this case it is best to drill (and screen) as deep as possible to prevent bacteria and pollution from entering the well. Drilling deep also reduces problems of wells drying up because of seasonal fluctuations (difference between wet and dry season) of the water table.



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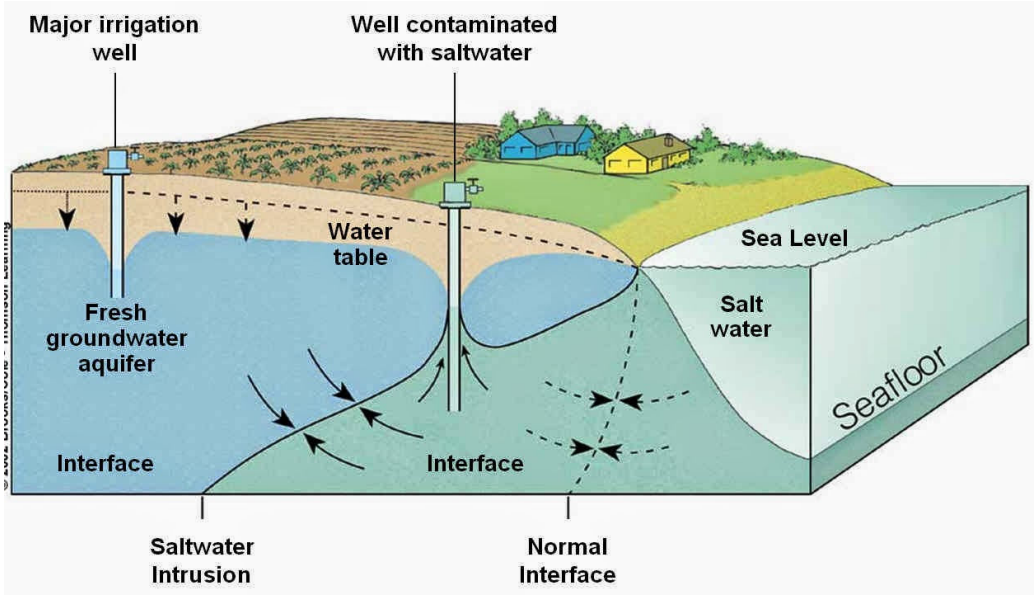
TYPES OF AQUIFER

Sea water intrusion

- In coastal areas, a deeper aquifer could contain salty sea water. Also, during the dry season when the water table is lower, salty sea water could move inland. When this happens it is called *saltwater intrusion*.
- Fresh water tends to float on top of the salt water layer. When a well is drilled in a coastal area where s*altwater intrusion* exists, the salty water may move up, due to the suction of the well. Therefore in coastal areas, *drilling deeper will NOT always be the best option*.



WATER QUALITY

Salt, iron and minerals

- Besides pollution from the surface (bacteria and chemicals) or salt from the sea, water can taste bad or be harmful to health due to *natural minerals* in the aquifer.
- These minerals may be present due to the chemistry of the aquifer solids. Some well-known examples of natural minerals that may occur in groundwater include: Calcium, Chloride, Carbonate, Arsenic, Fluoride and Iron…..and many more

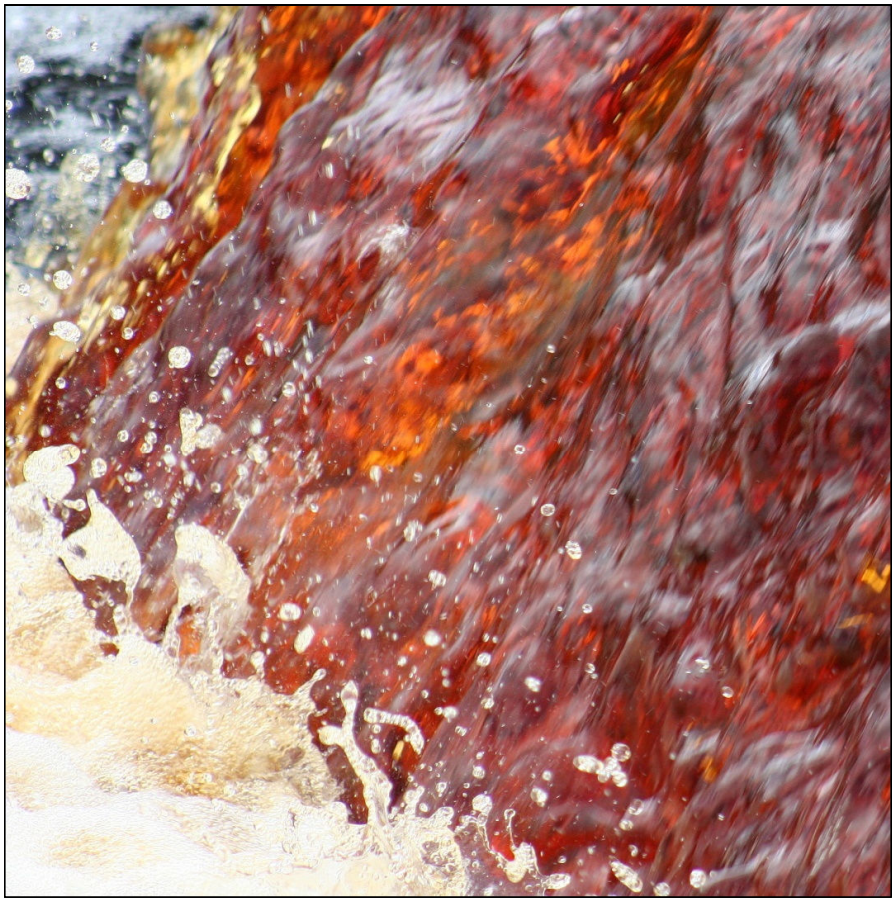
WATER QUALITY

Salt, iron and minerals

- Some natural minerals (for example arsenic) can damage health; therefore a sample of the groundwater should be analyzed to find out if harmful chemicals are present
- Fortunately, in most places, these minerals are minor components, and the water is safe for drinking, but it is necessary to check

WATER QUALITY

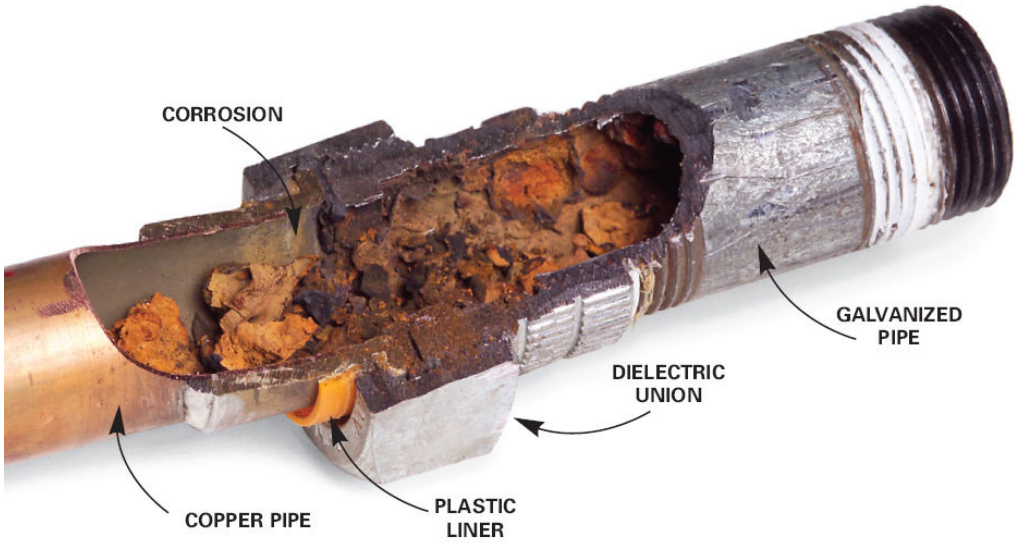
- **Peat / coloured water**
- When remains of old plants (for example, peat) are present in the sub-surface, it is recommended not to install a well-screen in this layer.
- Plant remains below the water table decompose very slowly. They may lead to acidic water that may be brownish in colour and may smell sulphurous.



WATER QUALITY

Acidic groundwater (low pH)

- pH is a measure of the *acidity* of water
- If the pH of the water is low the water is considered acidic
- Acidic groundwater may cause corrosion to steel and iron pump parts
- In such cases a pump made of PVC, plastic or stainless steel may be considered



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WATER QUALITY

Hard water

- Water with high content of the calcium and magnesium is considered “hard”
- Hard water may be occur in limestone or limestone sands
- Hard water is not harmful (may be safe for drinking)
- However, it may cause problems for washing and taste
- Soap may not lather (give foam) in hard water

GROUNDWATER PRINCIPLES

Summary

- As we drill, we must be aware of the materials that we are drilling through
- Permeability will determine where we place our screens and build the well
- In most cases, we cannot know the quality of the water until after the well is complete (and the water is analyzed)
- But we should be aware of the various water quality problems that can arise (often, these will already be well known to the local people)

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