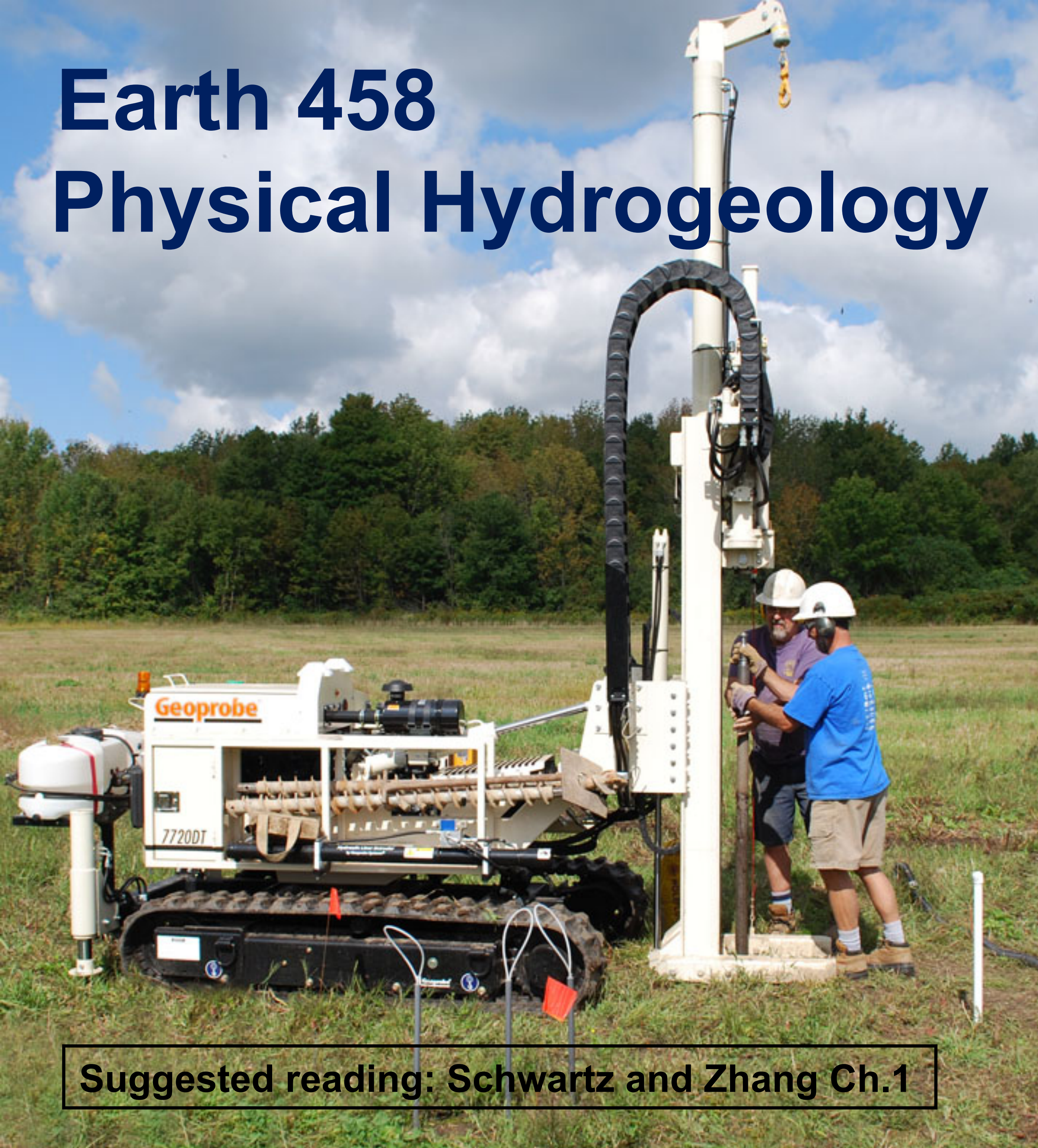
Earth 458
Physical Hydrogeology



Suggested reading: Schwartz and Zhang Ch.1

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Maxime Salman

University of Waterloo

the water INSTITUTE University of Waterloo

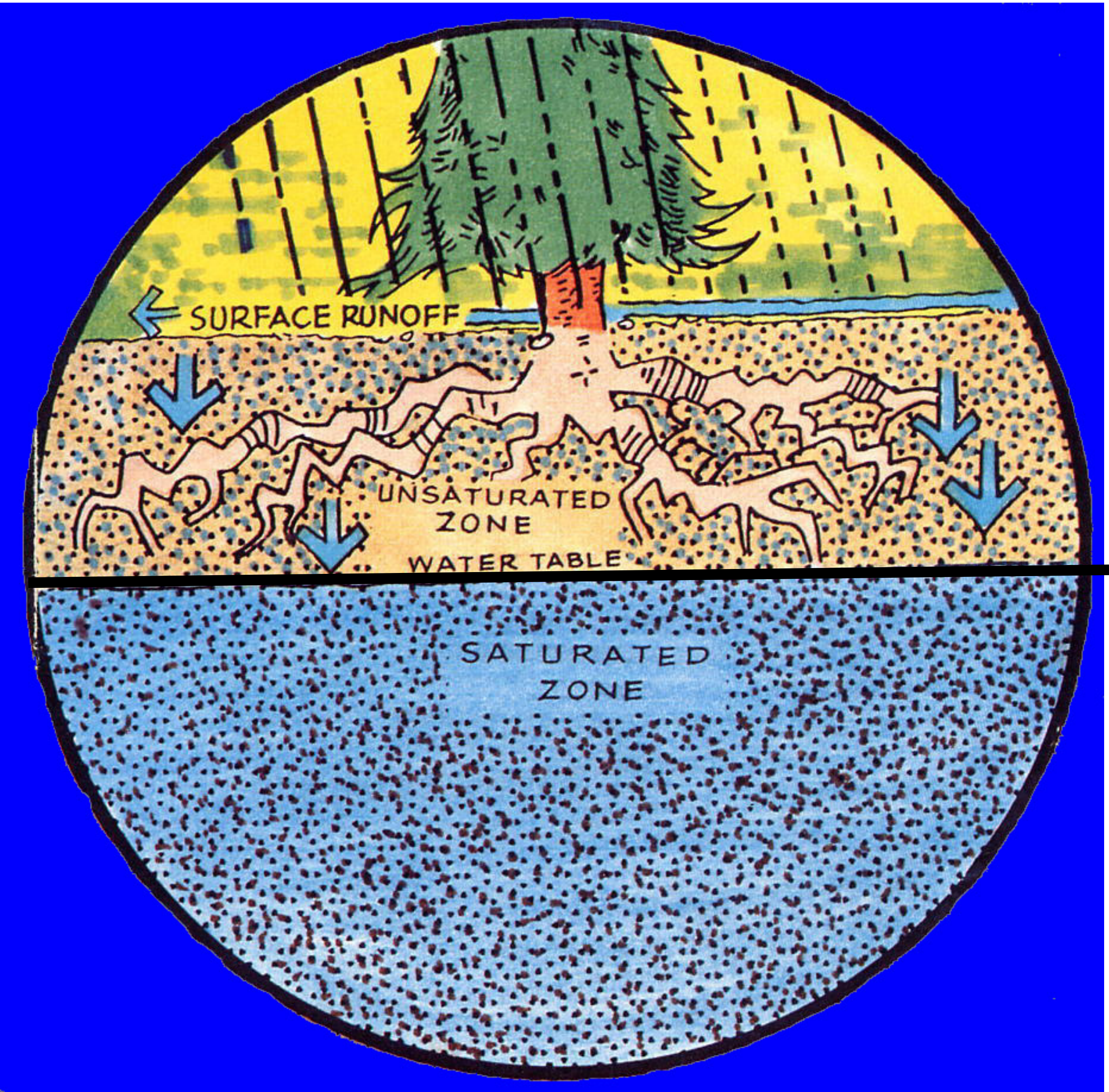
Hydrogeology

- **Definition**

  “The study of the interrelationships of geologic materials and processes with water – especially groundwater”

Fetter (2001)

Groundwater

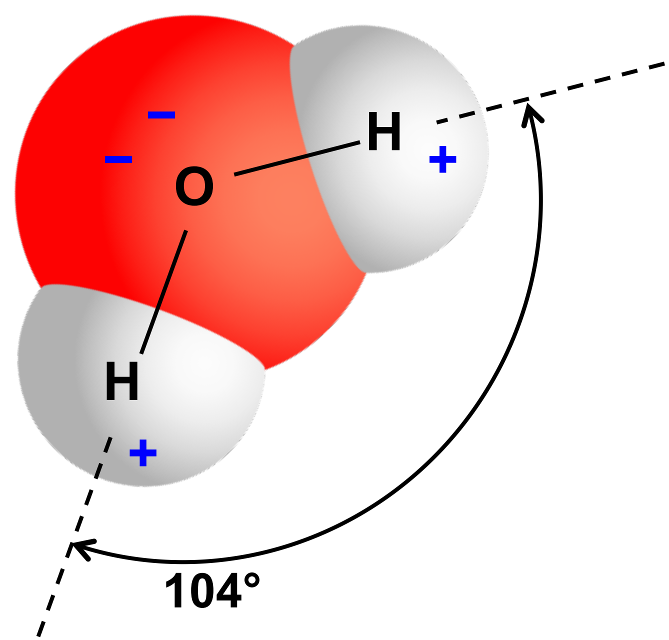


Water Table

Water - The Miracle Substance

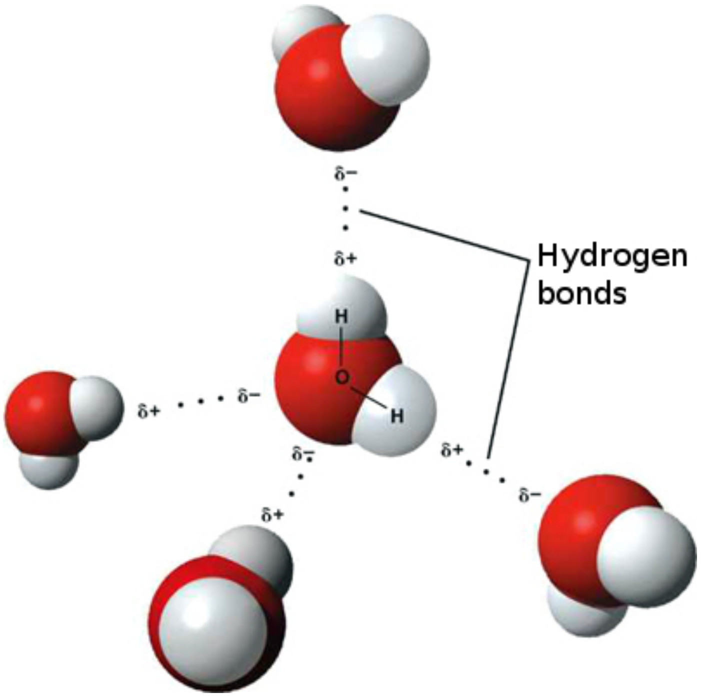
- Hydrogen and oxygen atoms
- Most abundant molecule on earth's surface
- Only substance to naturally appear in all 3 states
    - Solid
    - Liquid
    - Gas

Molecule shape and atom electronegativity create a polar molecule.

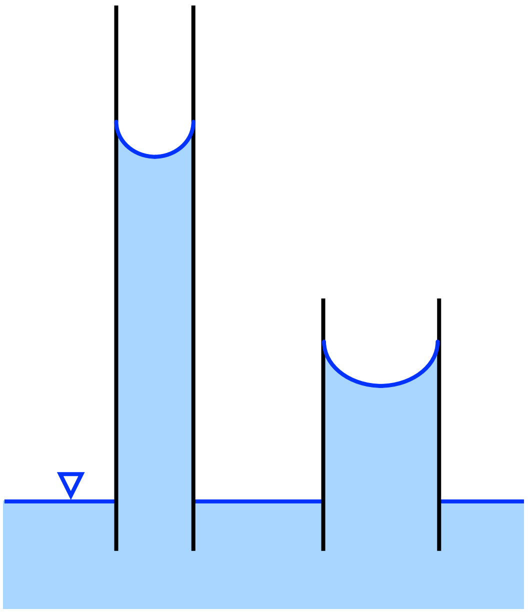


Polarity causes water molecules to form hydrogen bonds, which have a dramatic affect on the physical and chemical properties of water.

- **High surface (or interfacial) tension**
  - **molecules are attracted to one another (cohesion)**
  - **water "sticks" to water**
- **Adhesion**
  - **dipole forces also promote attraction to other molecules (adhesion)**
  - **water "sticks" to charged surfaces**

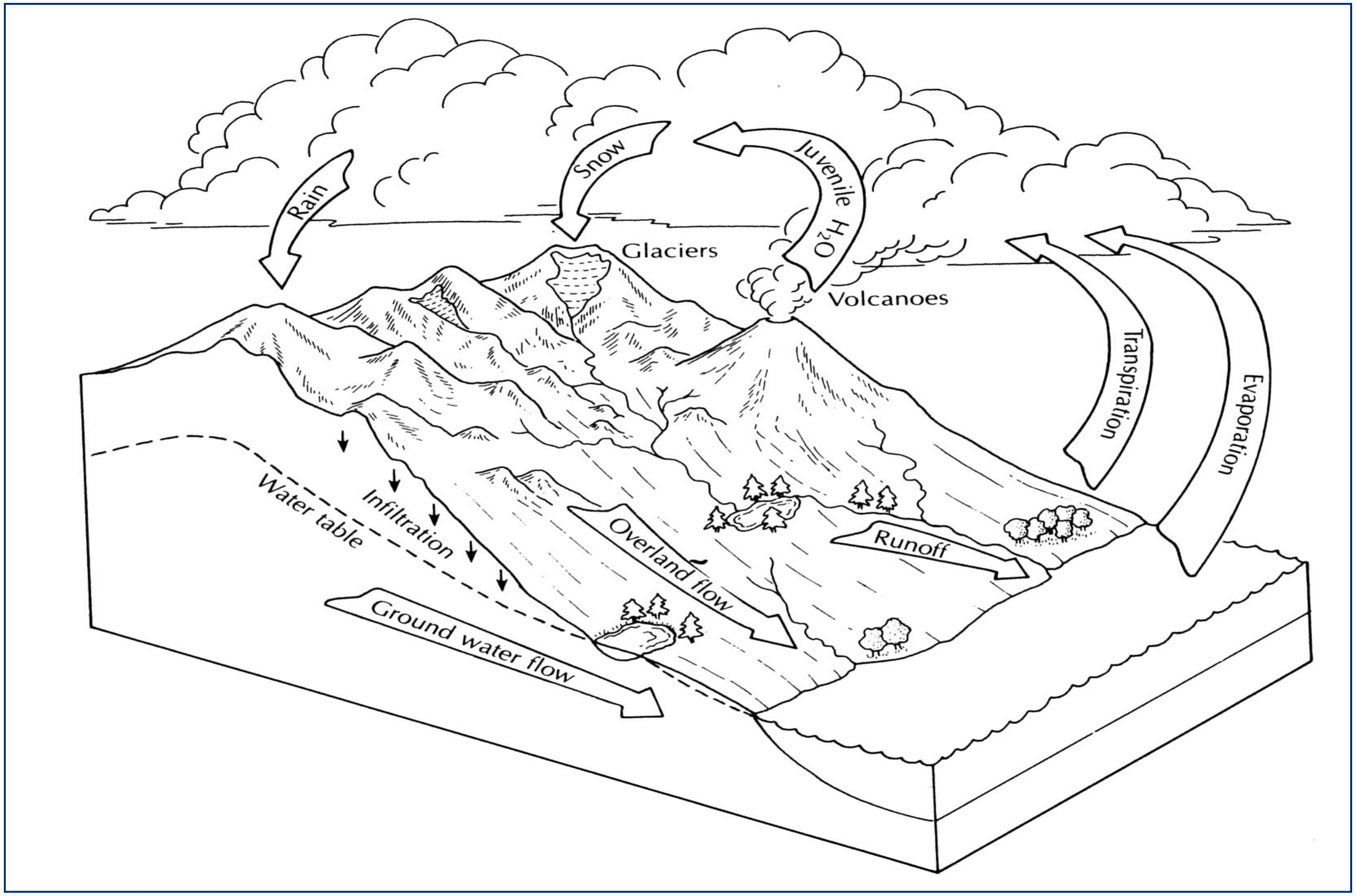


- **Capillarity**
  - **water's cohesion and adhesion together cause capillary action**
  - **water rises against gravity in a capillary tube**
  - **controls water in vadose (unsaturated) zone**



- **"Universal" solvent**
  - **many substances dissolve readily in water**
    - **e.g., salts, acids, sugars, oxygen, CO_2**
  - **very important for groundwater chemistry, chemical dissolution, nutrient and mineral migration, etc.**

The Hydrologic Cycle



Forms the basic framework for understanding freshwater resources and their response to climate change and human activities.

Entire water cycle represents a single resource!

From:Fetter (2001)

Groundwater as a Resource

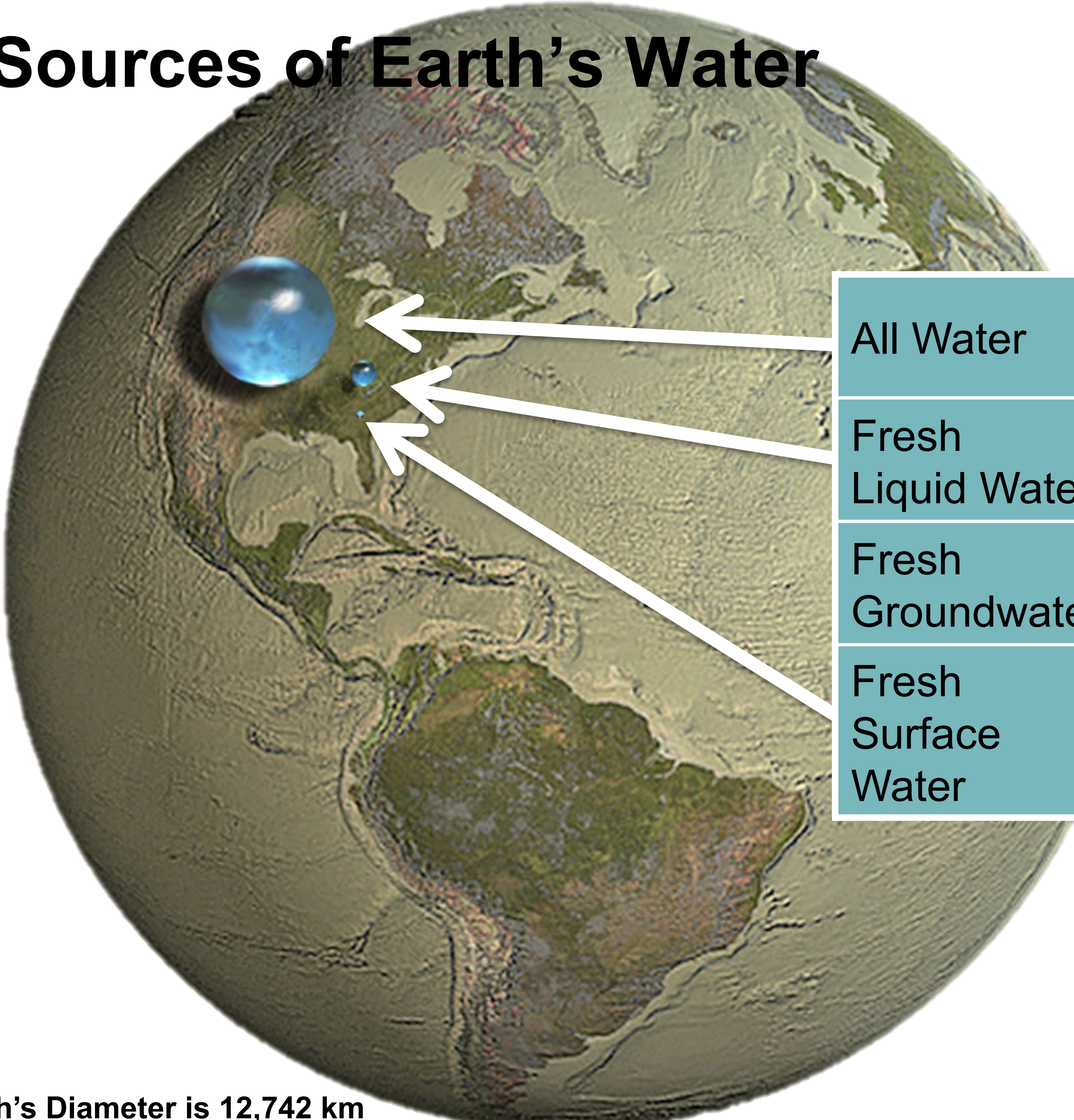
Groundwater is by far the largest source of available fresh water on the planet.

Global Water Distribution

Water Source	% of Total Water	% of Fresh Water
Oceans and seas (saline)	96.5	---
Ice caps and glaciers	1.74	68.7
Groundwater	0.76	30.1
Surface water	<0.01	0.3
Other (soil moisture, permafrost, atmospheric, biologic)	<0.03	0.9

(Gleick, P. H., 1996: Water resources. In: Encyclopedia of Climate and Weather, ed. by S. H. Schneider, vol. 2, pp.817-823.)

Sources of Earth's Water



	Diameter
All Water	1385 km
Fresh Liquid Water	272.8 km
Fresh Groundwater	271.7 km
Fresh Surface Water	56.2 km

Earth's Diameter is 12,742 km

Source: Howard Perlman, USGS; globe illustration by Jack Cook, Woods Hole

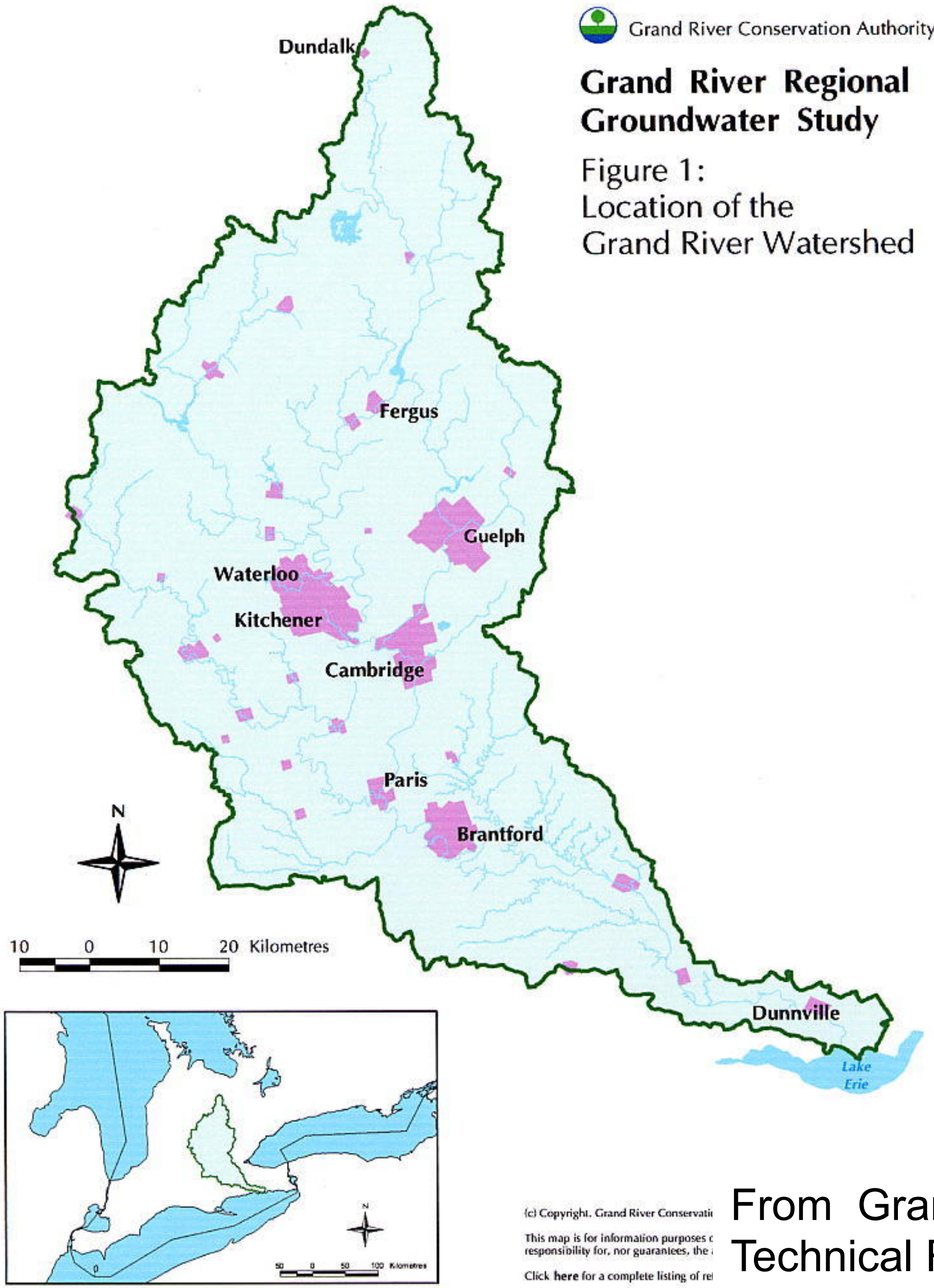
Groundwater (GW)

- Importance
  - Largest reservoir of fresh water readily available to humans
  - Provides water for rivers, lakes, & wetlands

Watersheds

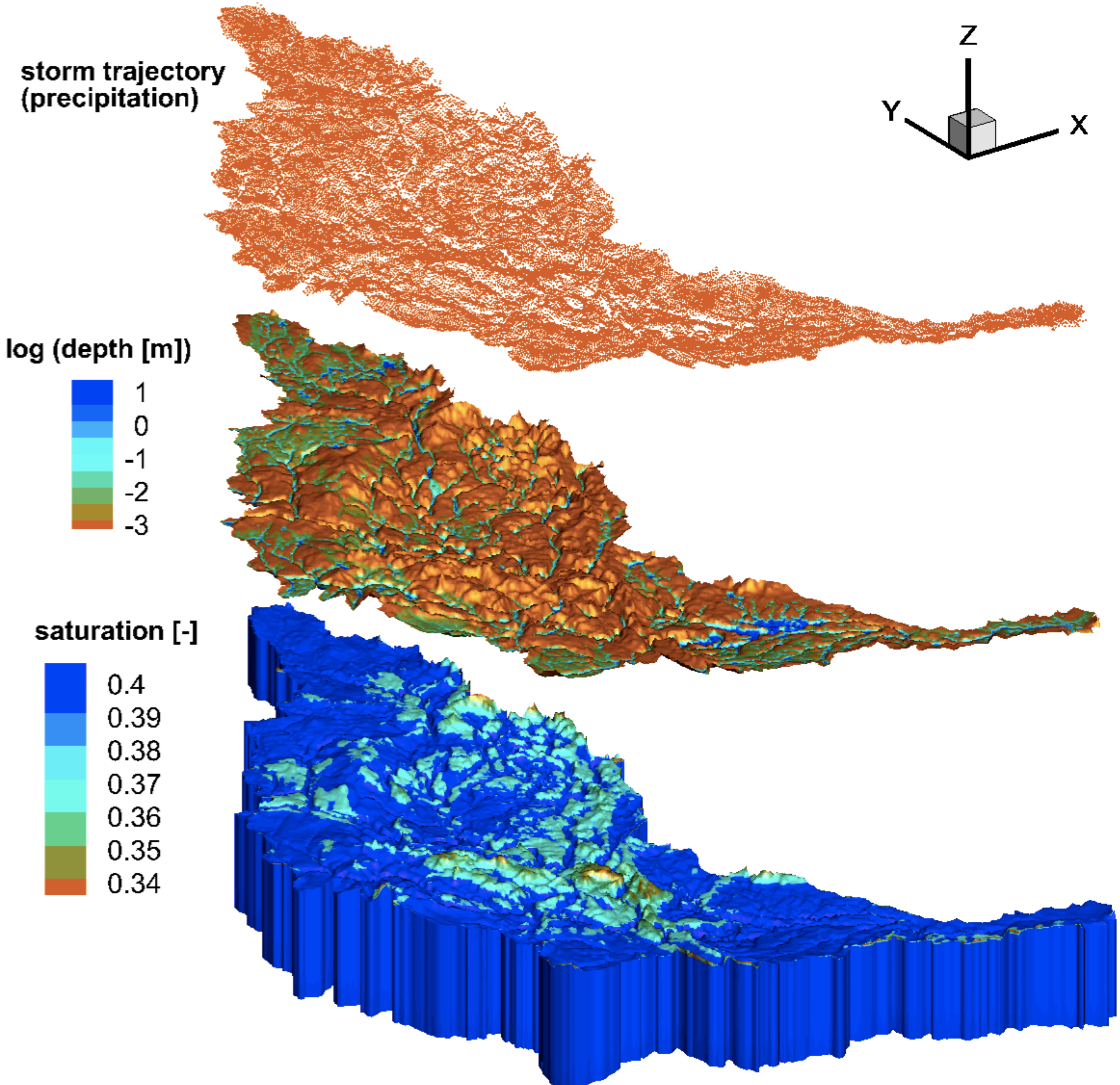
Watershed, catchment, and drainage basin mean the same thing - an area over which water falling on the surface will drain into a river or lake. A surface water designation only.

Grand River Basin



- Drains an area of 7,000 km^2
- Grand River is approximately 300 km in length
- Average flow 55 m^3/ sec
  - 1800 m^3/sec maximum
  - 6m^3/sec minimum

From Grand River Regional Groundwater Study, Technical Report GRCA (2001)



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m^3/

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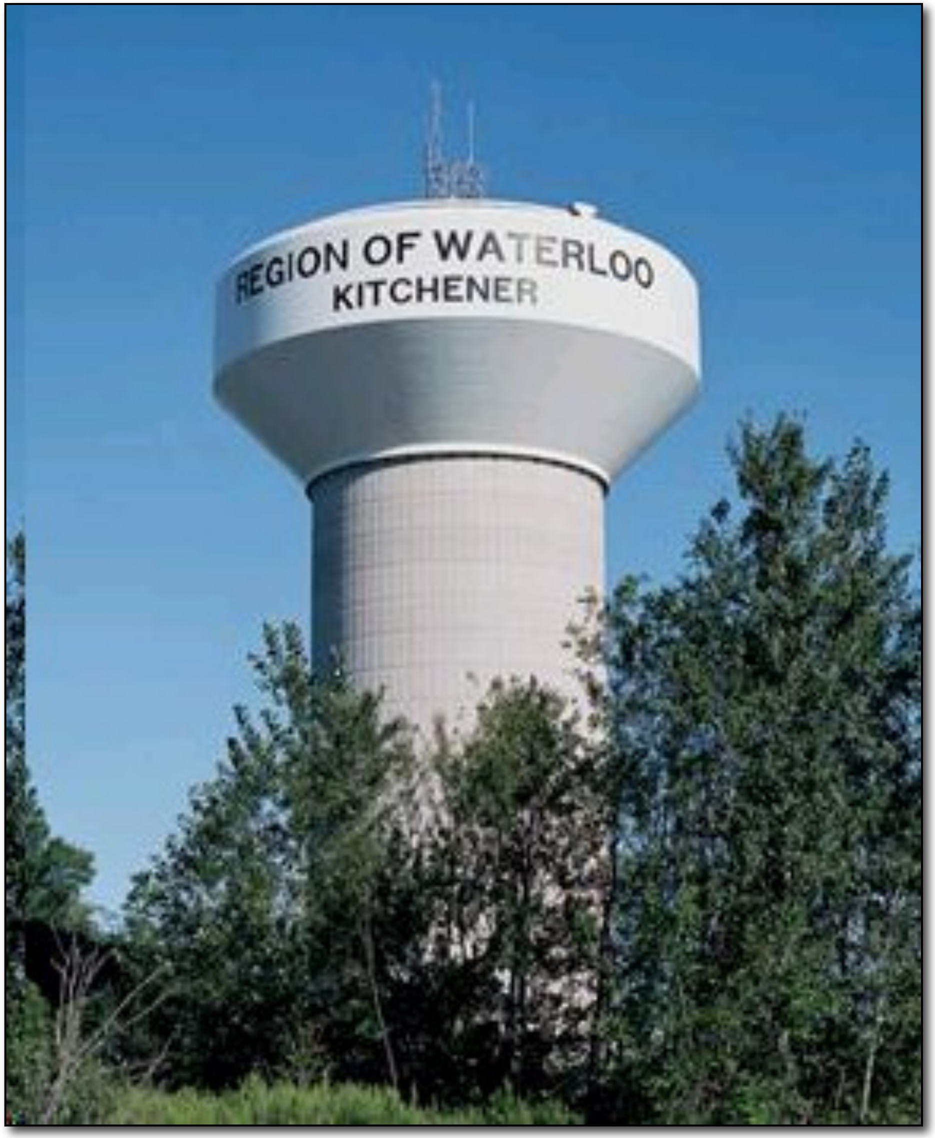
Study,

Kitchener-Waterloo

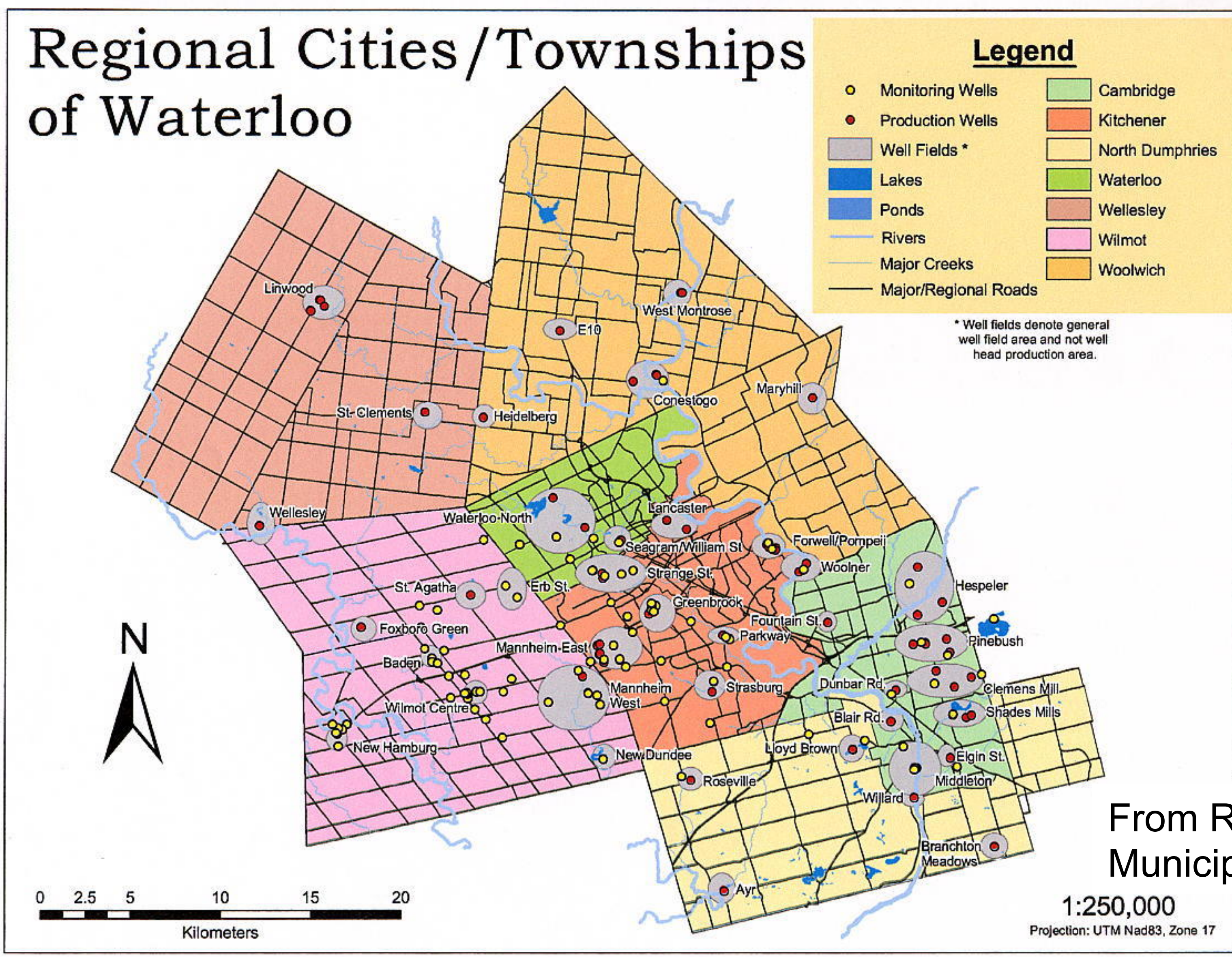
Depends almost entirely on groundwater

126 wells produce approximately 40 MGD ($150{,}000\ m^3$/day)



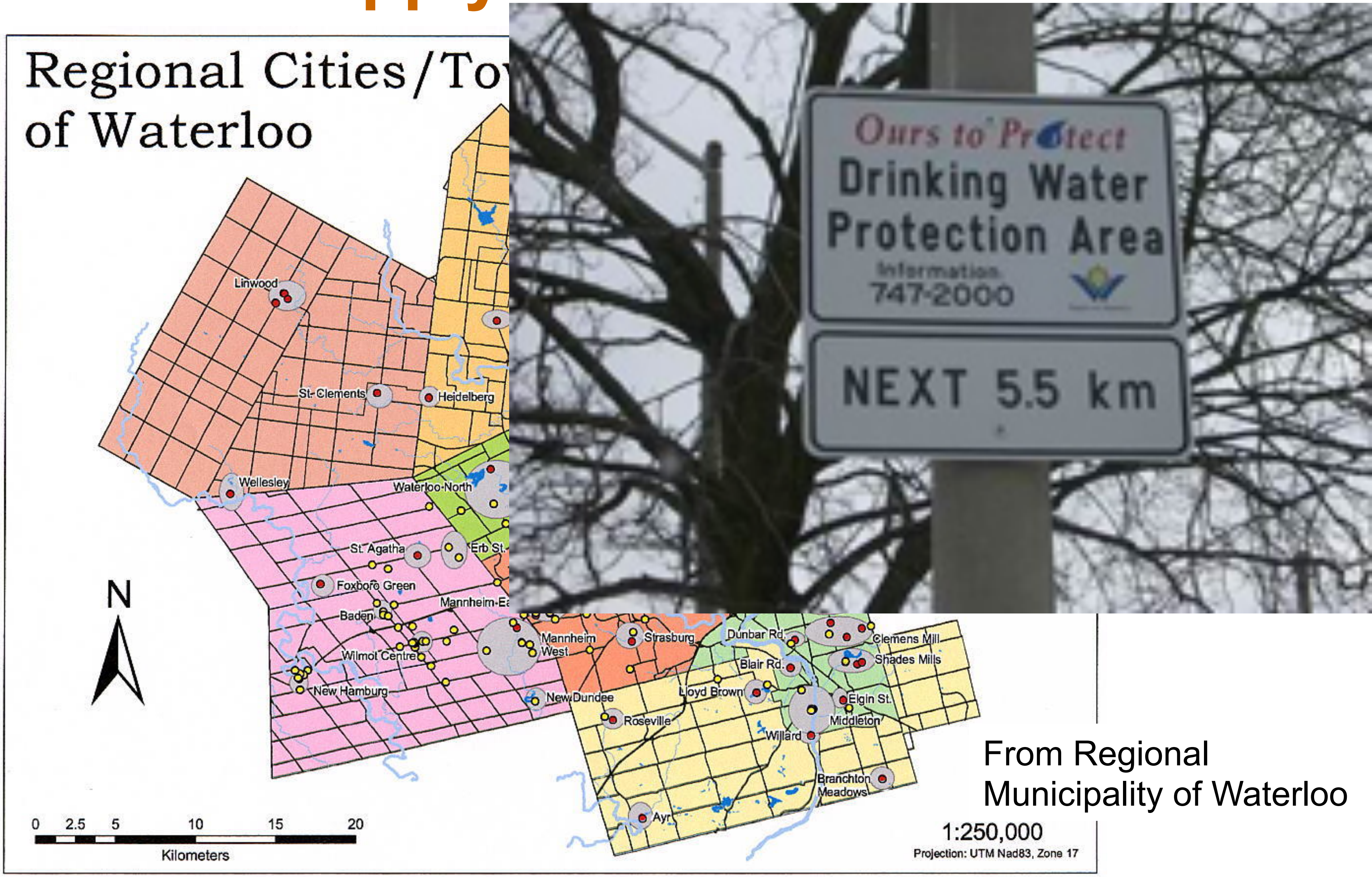
http://www.region.waterloo.on.ca/

Location of Well Fields & Municipal Water Supply Wells



From Regional Municipality of Waterloo

Location of Well Fields & Municipal Water Supply Wells



From Regional Municipality of Waterloo

Role of Groundwater

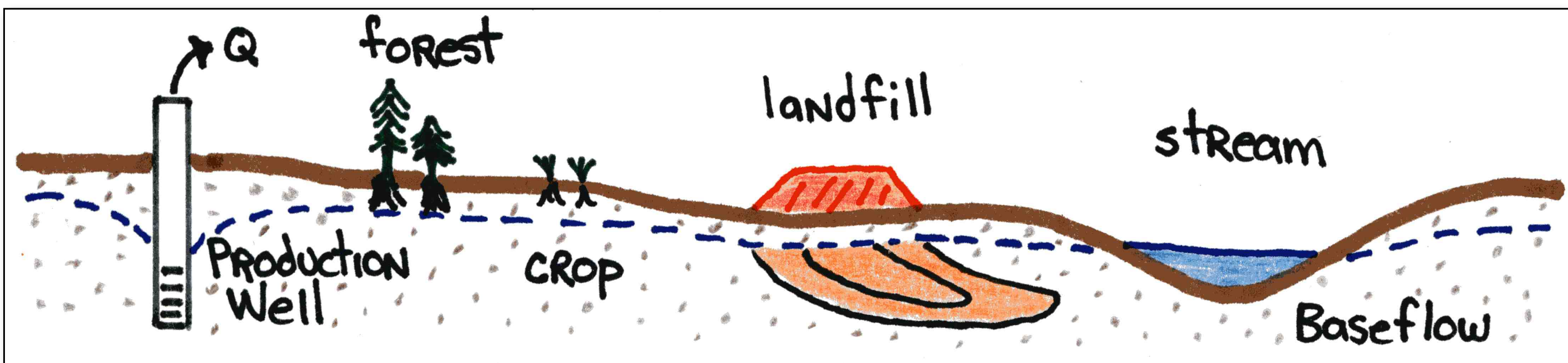
a) Provides moisture to support cultivated crops and forests

b) Used as major source of drinking water

c) Maintains stream flow (flood control)

d) Alters chemistry of infiltrating precipitation

- Susceptible to contamination (eg. Landfills)



Water Resource Development

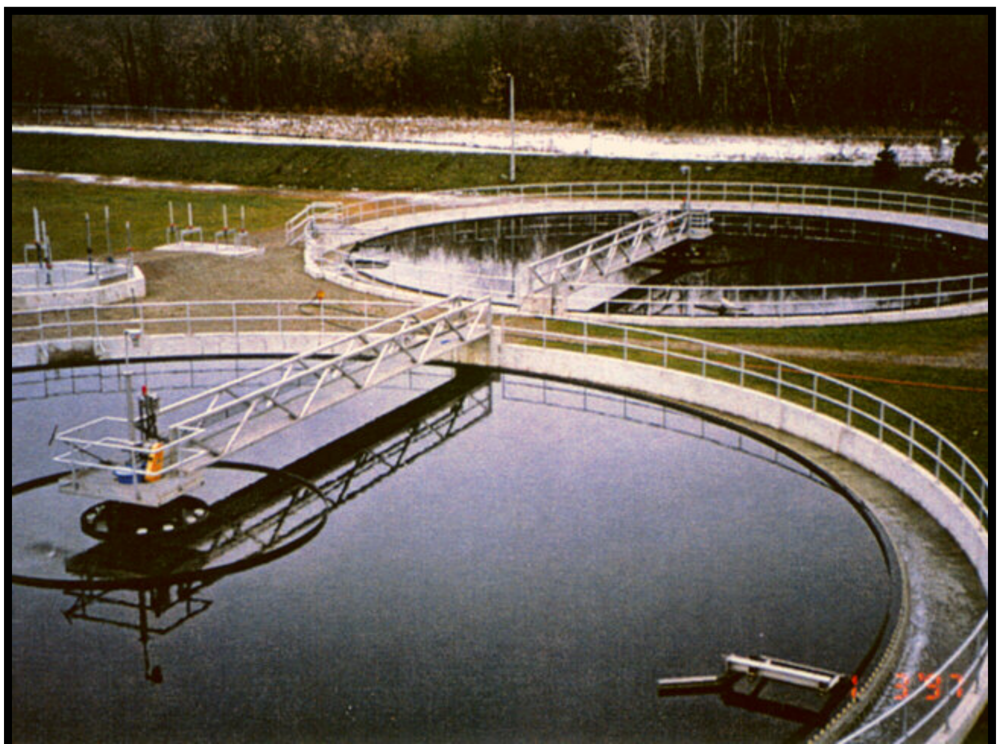
Groundwater Domestic Use

30% of Canadians and 50% of Americans

Water Resource Development

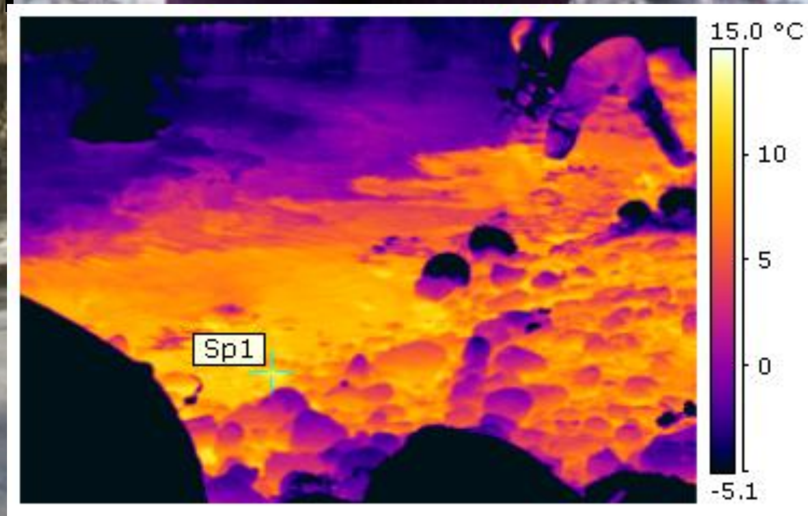
Geotechnical and Engineering

Contamination Issues



Groundwater and Fish Habitat

- Identify & protect
  - spawning areas
  - thermal refuges
  - critical habitat



Geological Erosion Agent

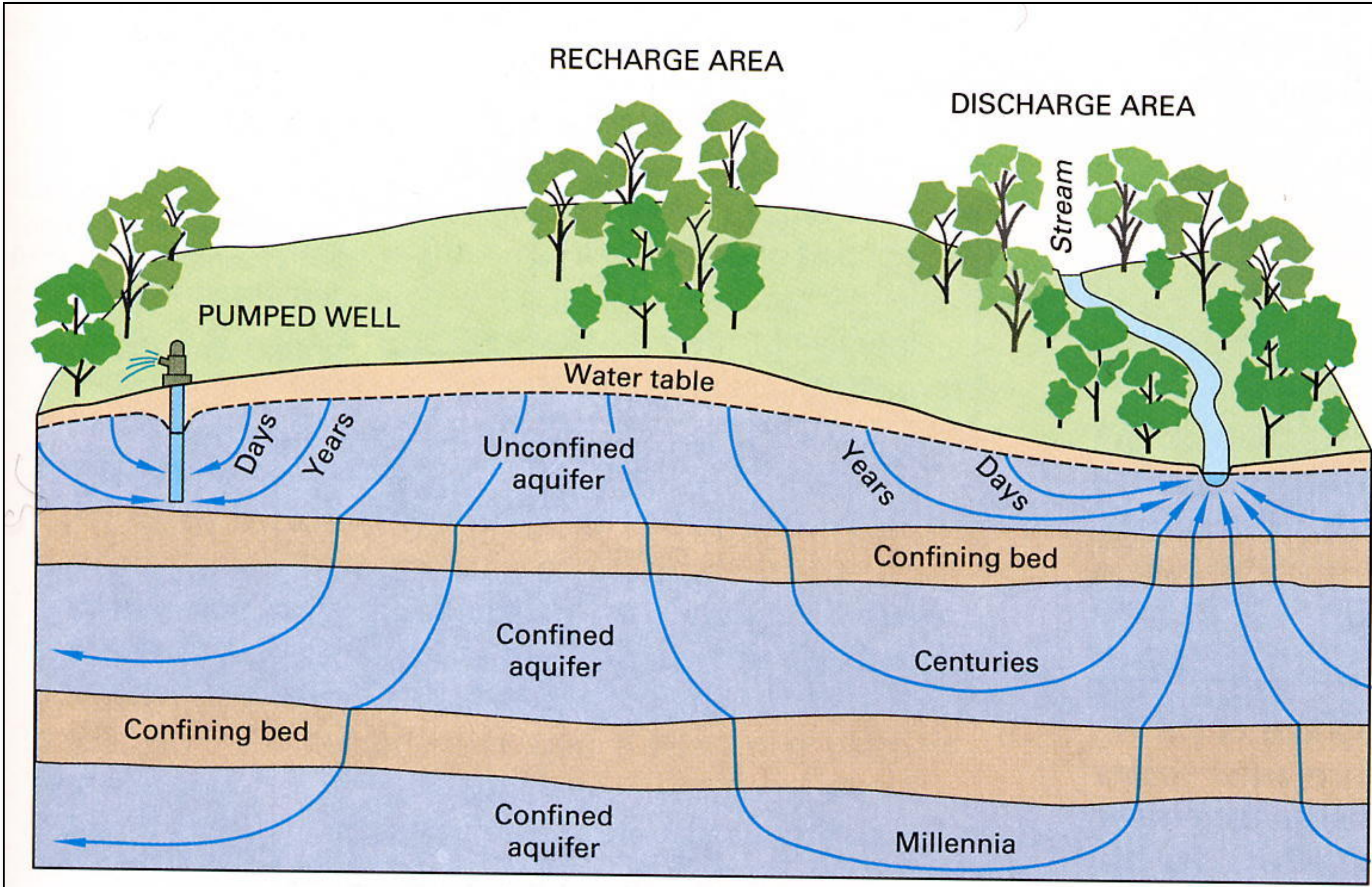
Sinkhole – Winter Park, Florida

Thompson and Turk, 1994

Goals

- Understand principles of physical hydrogeology
- Ability to properly conceptualize problems
- Acknowledge complexity and limitations
- Develop quantitative expertise on problem solving.
- Develop an appreciation for the subject

Groundwater Flow Paths and Travel Times



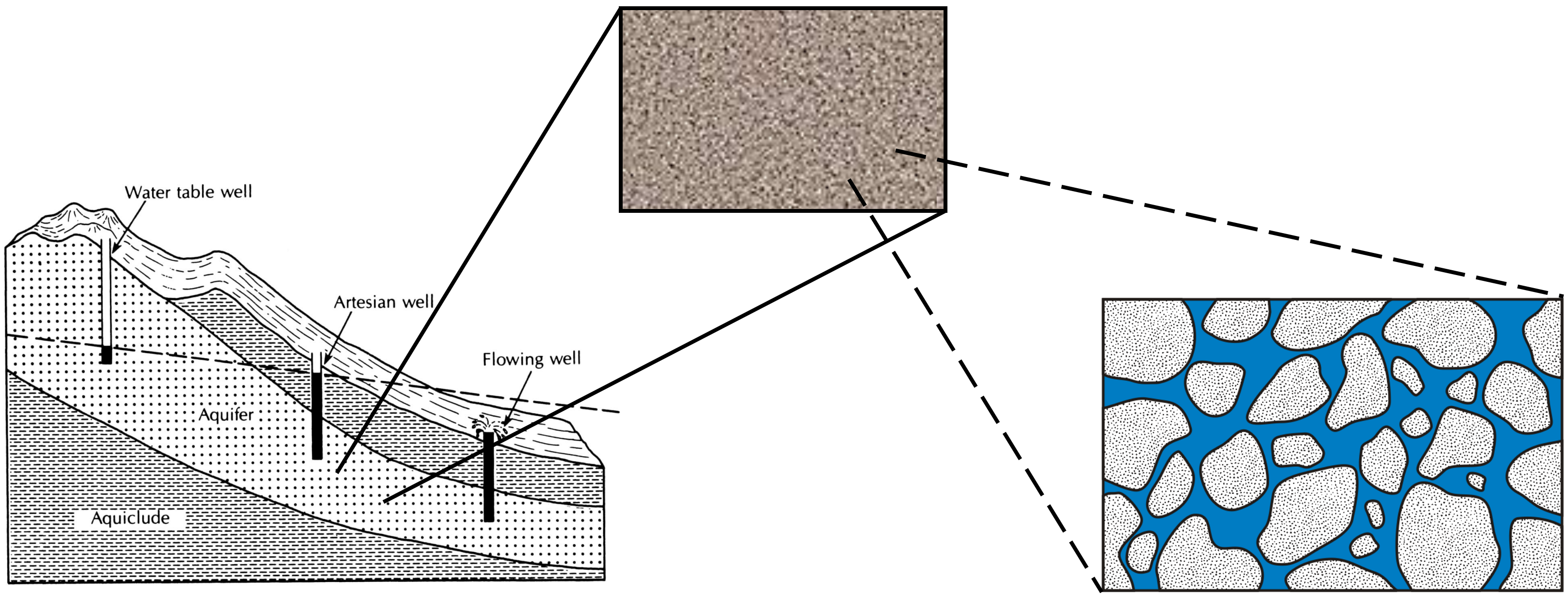
USGS Circular 1139 (1998)

Classic Definition

Subsurface water that occurs *below the water table* in the pores of fully saturated soils and geologic formations

Hydrologic Definition

Water that exists *below ground surface* in the unsaturated and saturated zones (including soil moisture)



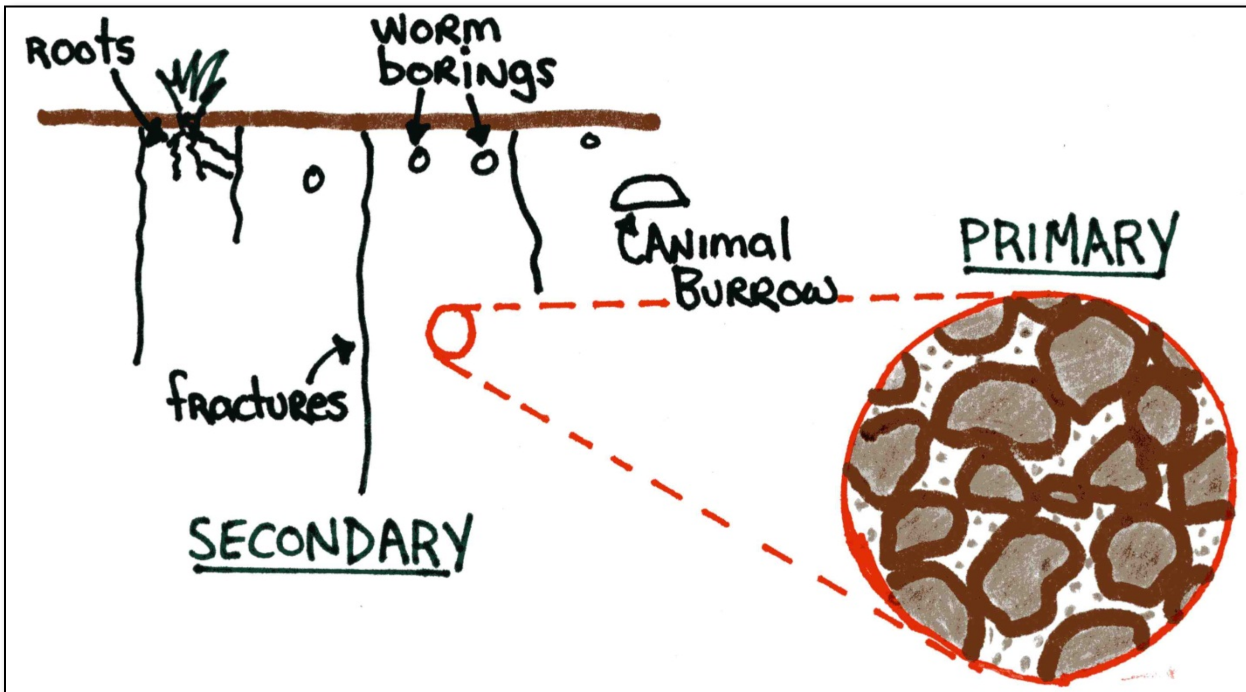
Physical Concept of Porosity

Porosity
(Soils and unconsolidated materials)

$$\frac{V_v}{V_T} = n$$

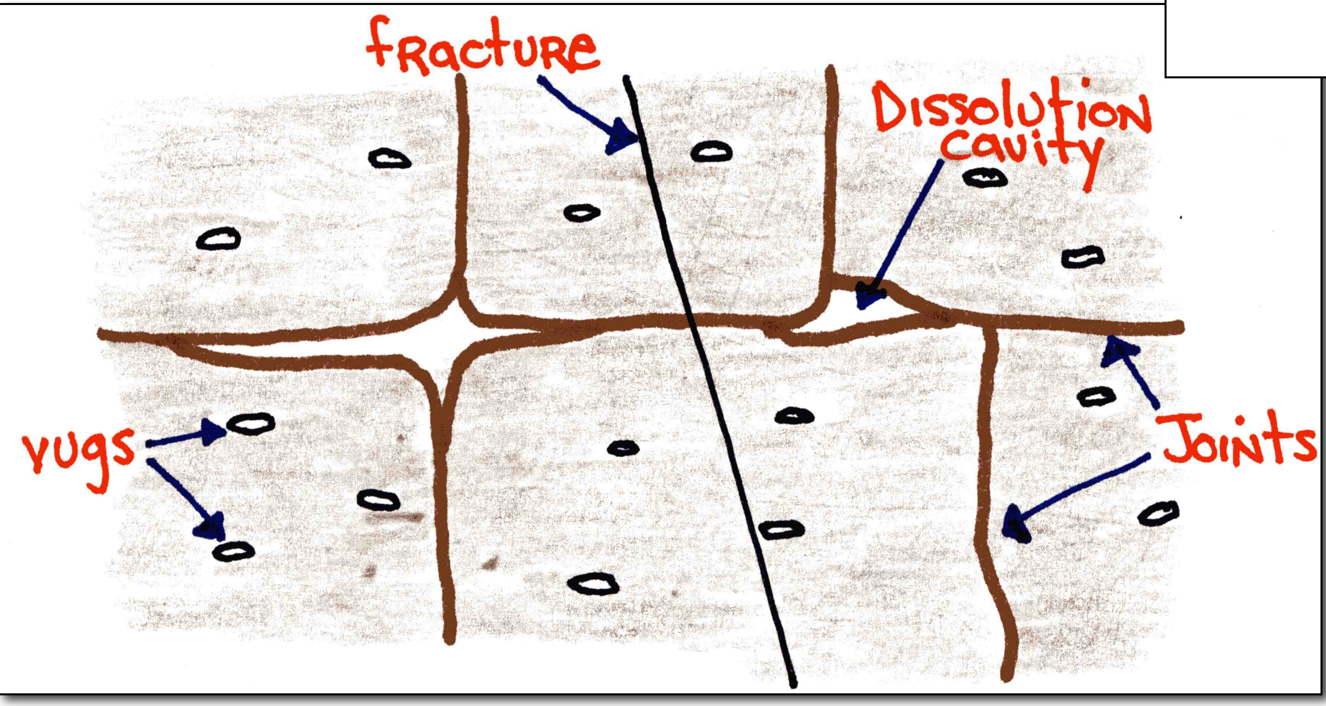
Primary
- Intergranular
- Dependent on grain size, alignment and shape

Secondary
- Fracturing
- Root holes
- Burrow holes



Porosity (Rock)

$$n = \frac{volume\ of\ voids}{total\ volume}$$



Note:
Flow primarily occurs in secondary porosity for rocks

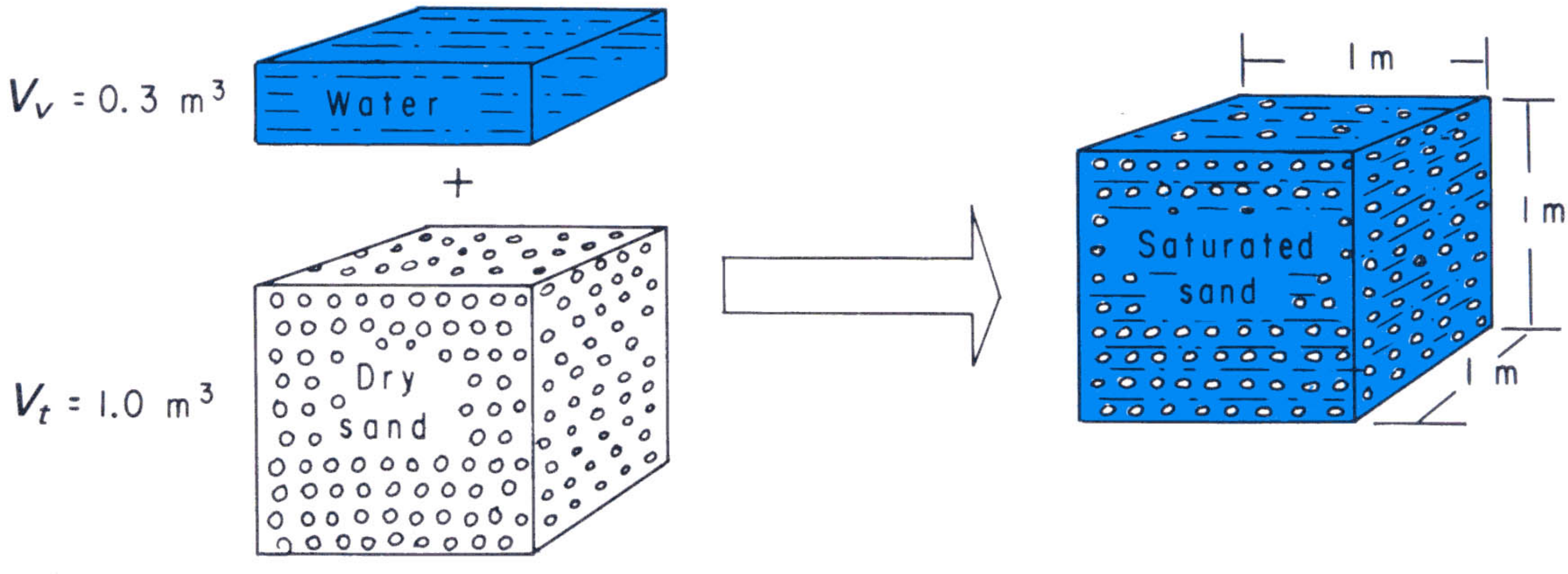
Primary

- Vugs (carbonates)
- Vesicules (volcanics)
- Pore Space (sedimentary)

Secondary

- Fracturing & Shear Zones
- Jointing
- Dissolution
- Cementation

Porosity con't



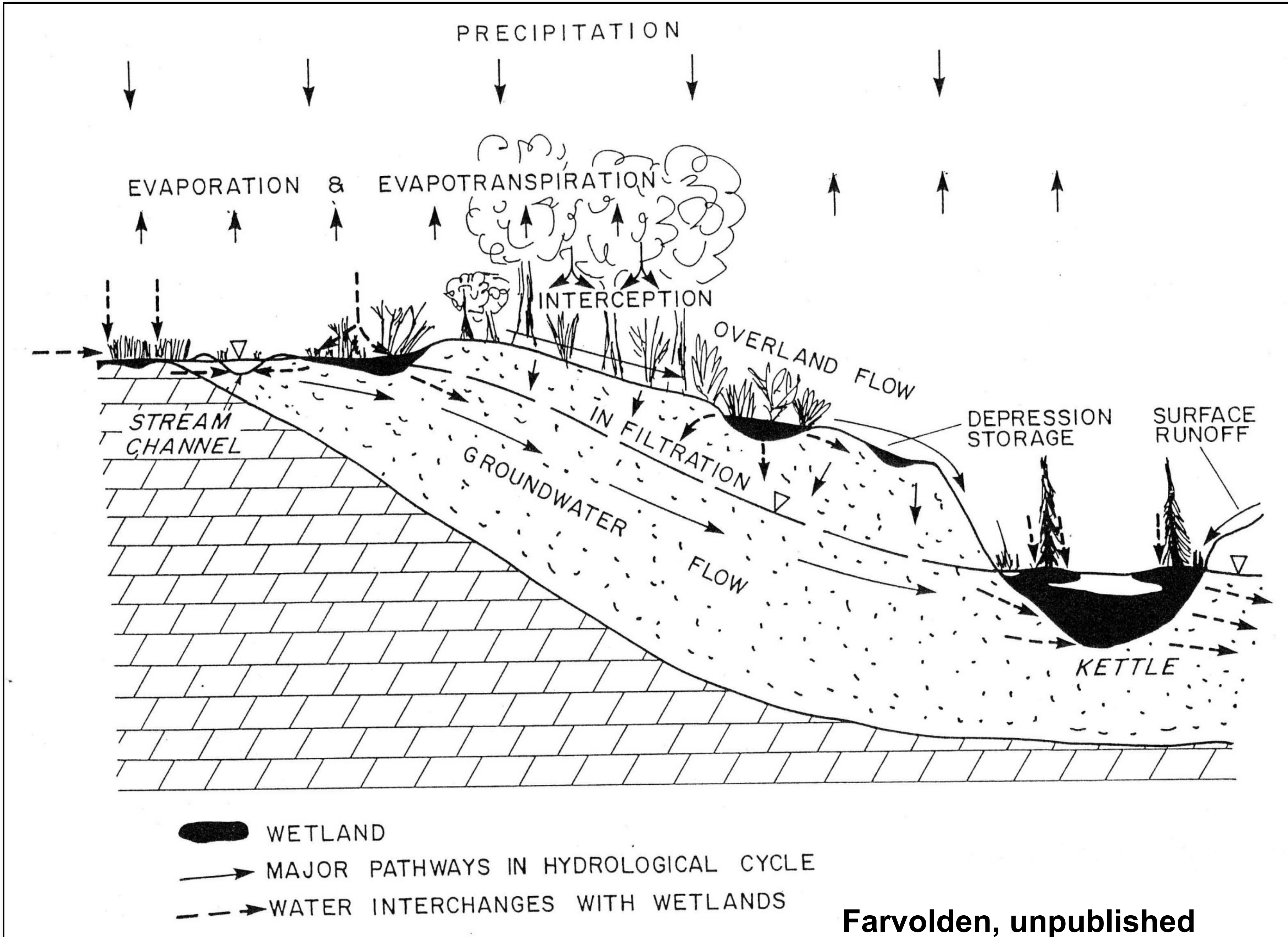
$$\text{Porosity } (n) = \frac{\text{Volume of voids } (V_v)}{\text{Total volume } (V_t)} = \frac{0.3\ m^3}{1.0\ m^3} = 0.30$$

Example of Porosities:

- **sand or gravel 25-50%**
- **clay 40-70%**
- **glacial till 10-20%**

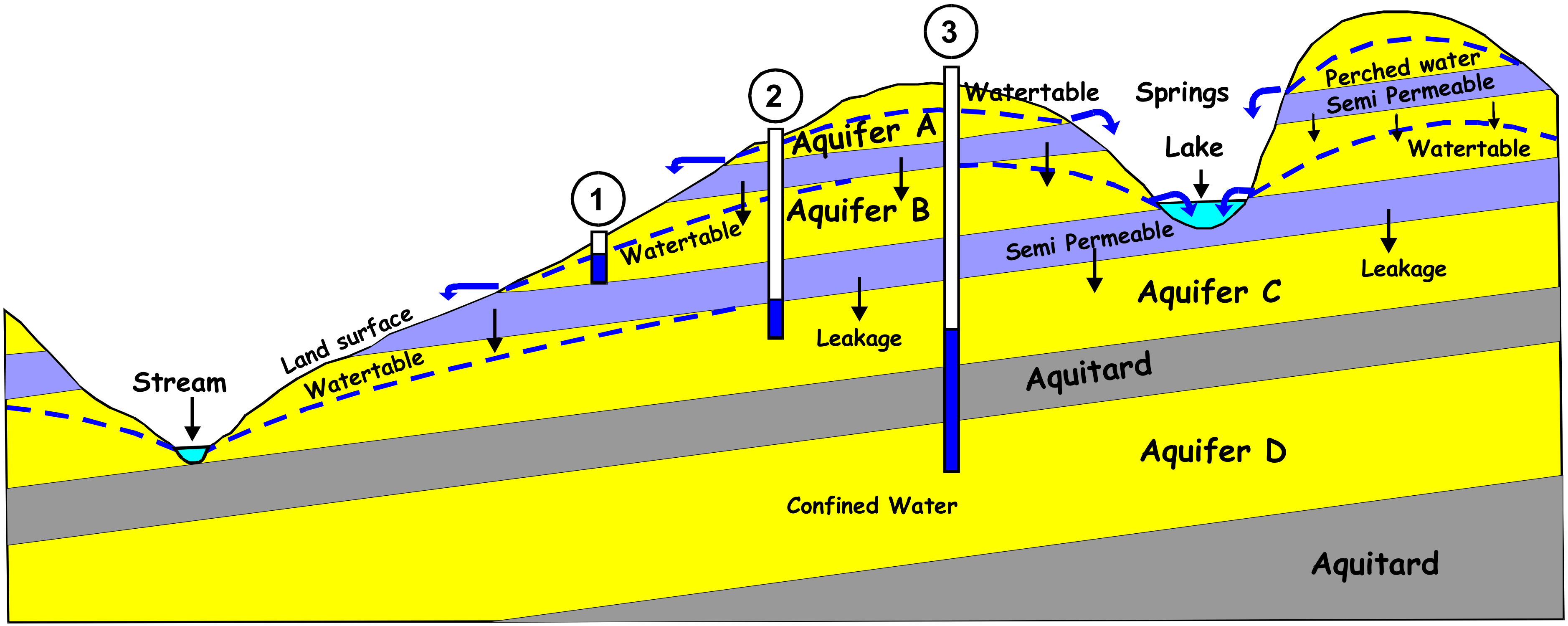
USGS Water Supply Paper 2220 (1987)

Groundwater in the Hydrologic Cycle



Farvolden, unpublished

Aquifers and Aquitards



Confined, unconfined and perched aquifers in sequence of shale and sandstone deposits

- Modified from Ward (1967)

Aquifers & Recharge and Leakage

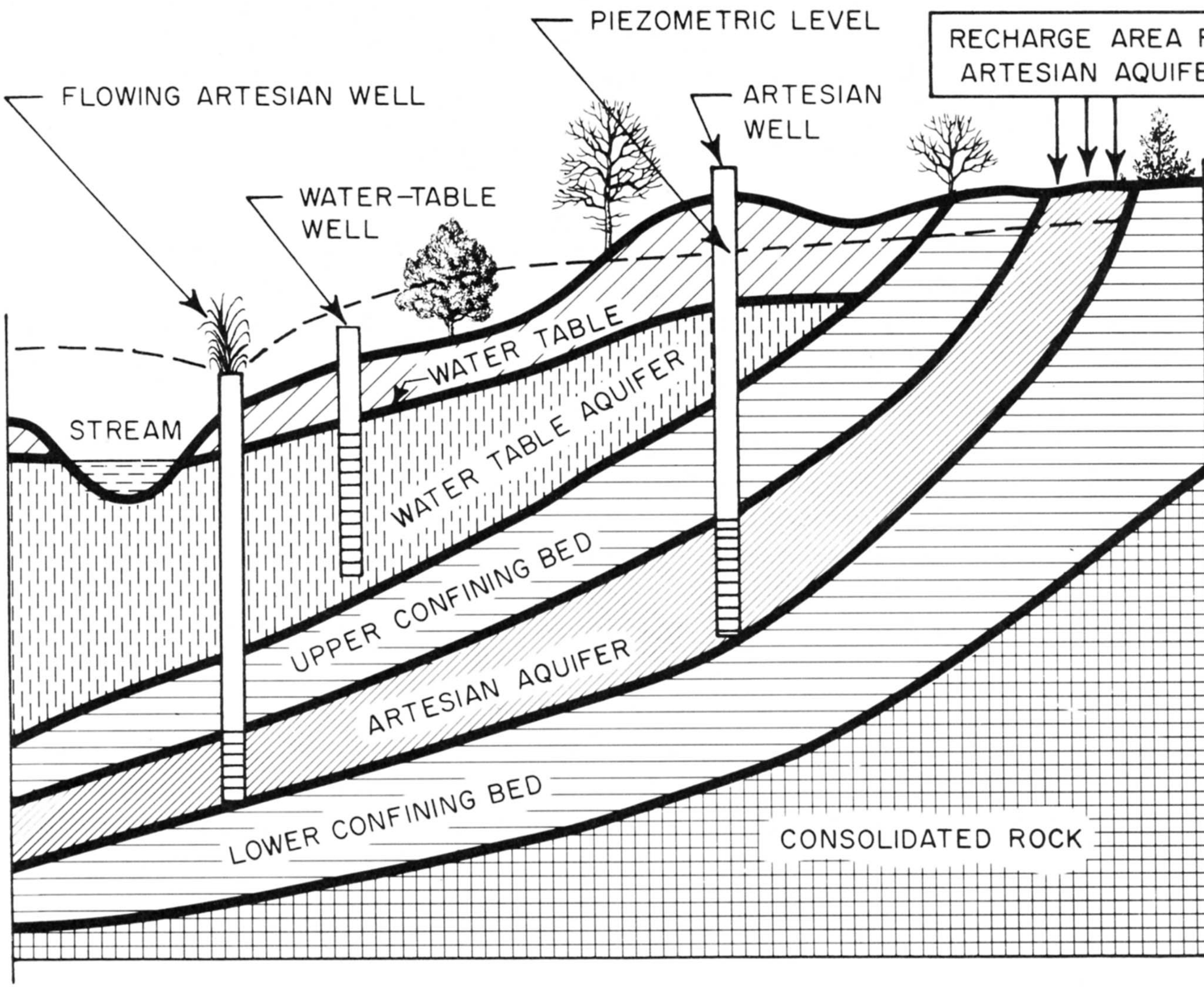


Fig. VI. 12 Classical Confined and Water-Table Aquifers (Johnson, 1966a)

Gray (1970)

Hydrogeologic Strata

"Aquifer"

- **Geologic formations of permeable material (sand, gravel, porous limestone, sandstone or highly fractured rock) that can transmit <u>or</u> yield groundwater at a reasonable or economic rate**

Aquitards (Aquiclude)

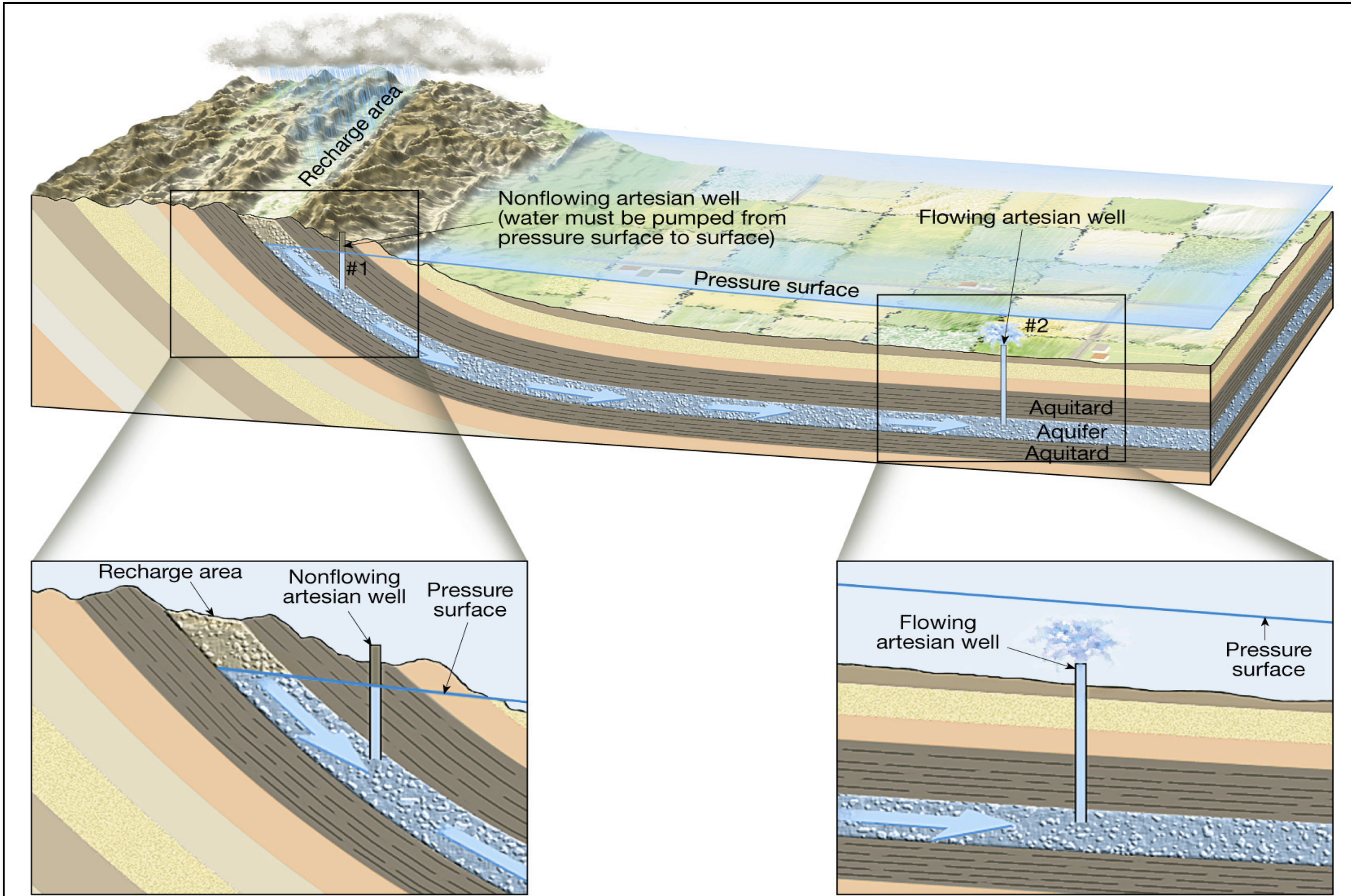
- **Geologic formations composed of relatively low-permeability material (silt, clay, till or shale), that *do not transmit* significant amounts of groundwater (economical)**
  - ***water wells cannot be completed in these units***

e.g.

Lacustrine clay ☞ Mexico City

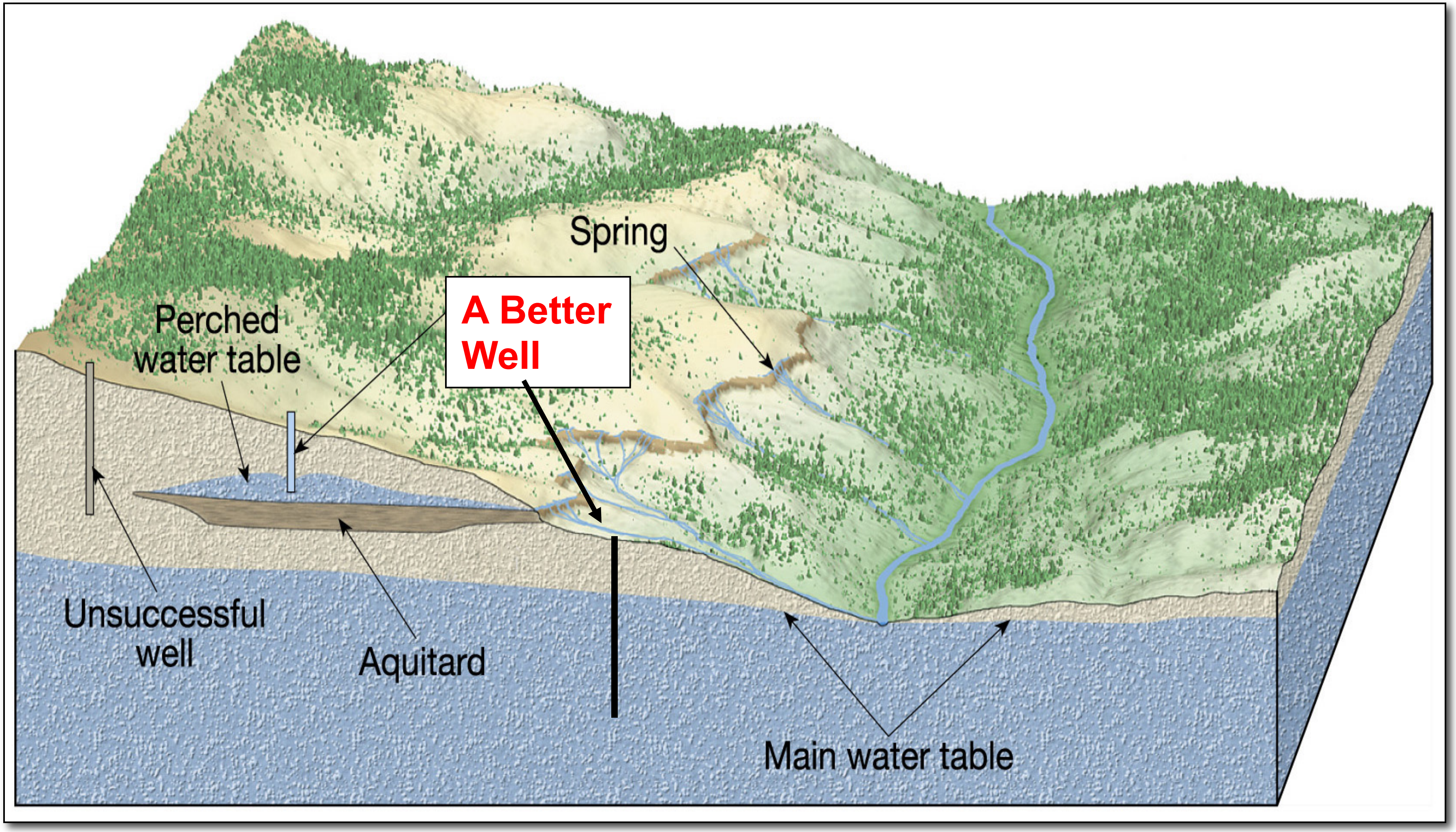
Glacial till ☞ K-W region

Artesian Wells



From Tarbuck and Lutgens (2002)

Springs and Perched Water Table



Tarbuck and Lutgens (2002)

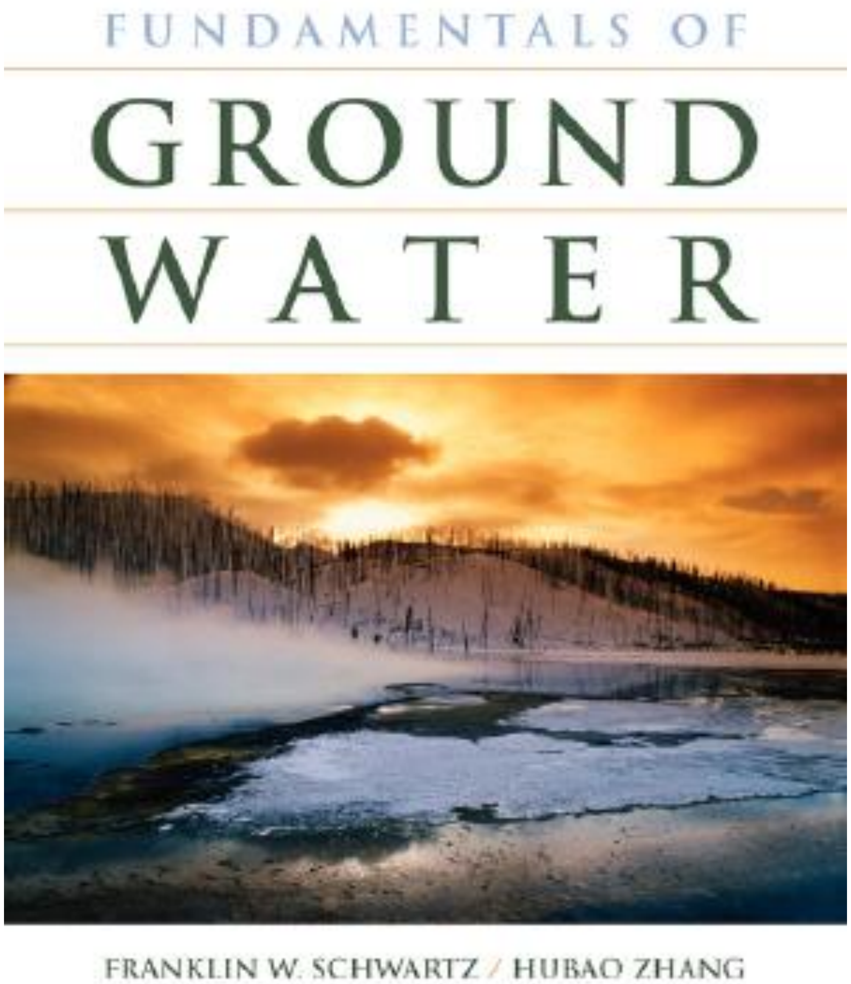
Typical Aquifers

1) Glacial outwash sands and gravels
   - Kames (moraines – K-W Region and Oak Ridges)
   - Eskers (K-W region)
   - Deltas and outwash fans
2) Carbonate sedimentary rock
   - Fractured limestone (Winnipeg/ Cambridge)
   - Karstic limestone (Florida)

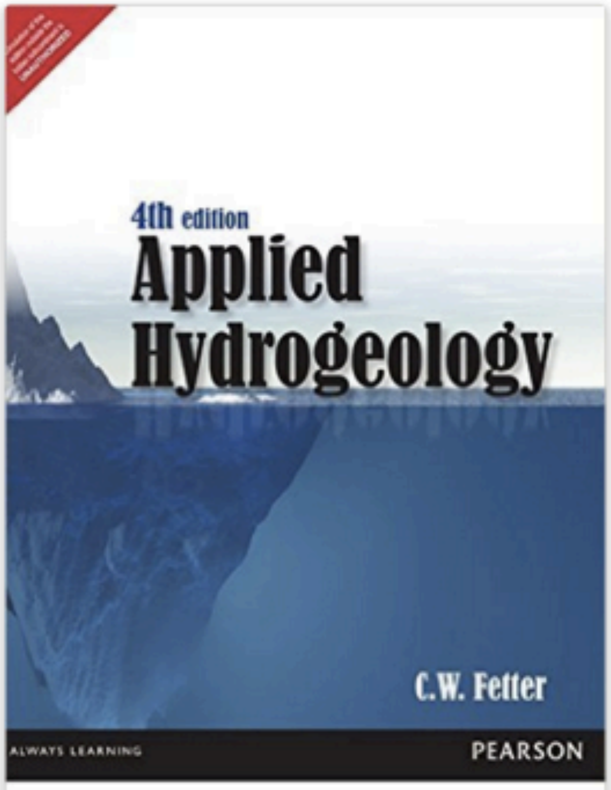
Other Typical Aquifers

3) Lithified sandstone (Texas)
4) Buried river channels (Saskatchewan)
5) Alluvial and fluvial deposits (Mexico City; Lima, Peru)

Main Textbook



https://www.amazon.ca/Applied-Hydrogeology-4Th-Fetter-C-W/dp/9332535116/



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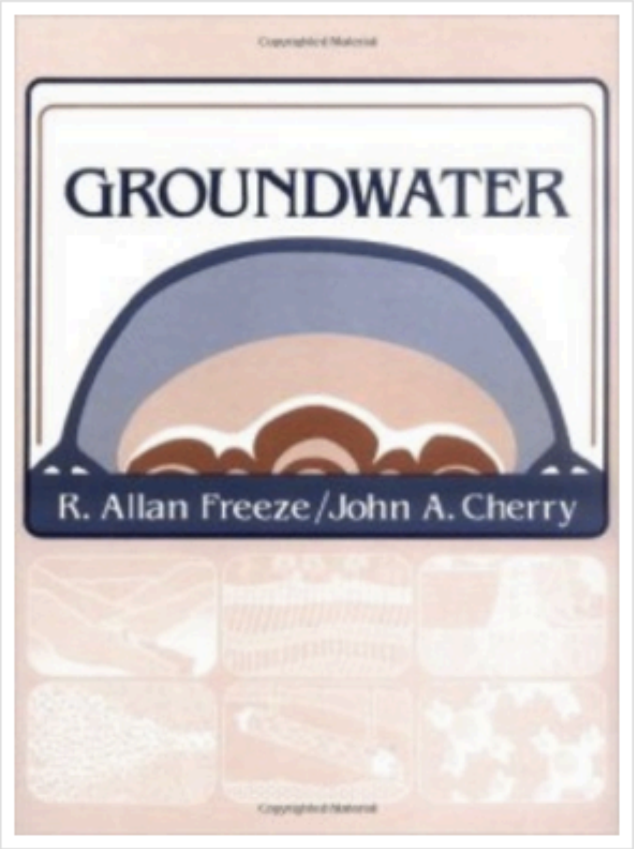
http://hydrogeologistswithoutborders.org/wordpress/textbook-project/

GW2.0 Text Project

Original Groundwater by Freeze and Cherry, (1979) now available online!!

We are grateful to Pearson Publishing, Alan Freeze and John Cherry for allowing HWB to post this textbook free of charge on our website.



Click on the following chapter links for the pdf version of the original Groundwater (by Freeze and Cherry, 1979):

Intro-Freeze-and-Cherry-1979

Chap-1-Freeze-and-Cherry-1979-Introduction

Chap-2-Freeze-and-Cherry-1979-PhysicalPropertiesPrinciples

Chap-3-Freeze-and-Cherry-1979-ChemicalPropertiesPrinciples

Office Hours Preference

5% of assignment #1 based on completing worksheet

http://doodle.com/poll/ns87zqaxa763vw9f

Doodle

Table view

	May 2016 Mon 2								Tue 3					
1 participant	10:00 AM – 11:00 AM	11:00 AM – 12:00 AM+1	12:00 PM – 1:00 PM	1:00 PM – 2:00 PM	2:00 PM – 3:00 PM	3:00 PM – 4:00 PM	4:00 PM – 5:00 PM	5:00 PM – 6:00 PM	10:00 AM – 11:00 AM	11:00 AM – 12:00 AM+1	12:00 PM – 1:00 PM	1:00 PM – 2:00 PM	2:00 PM – 3:00 PM	3:00 PM – 4:00 PM
Jason Davison	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Your name	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
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