# Groundwater

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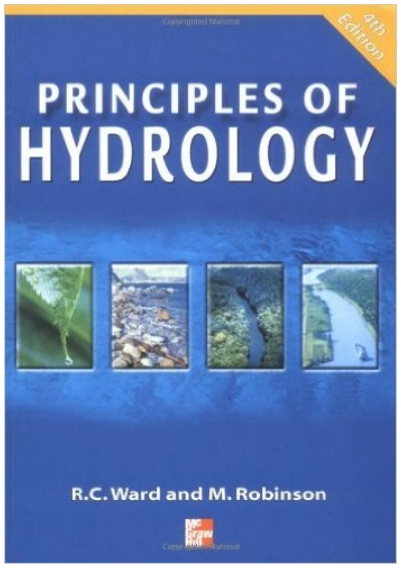
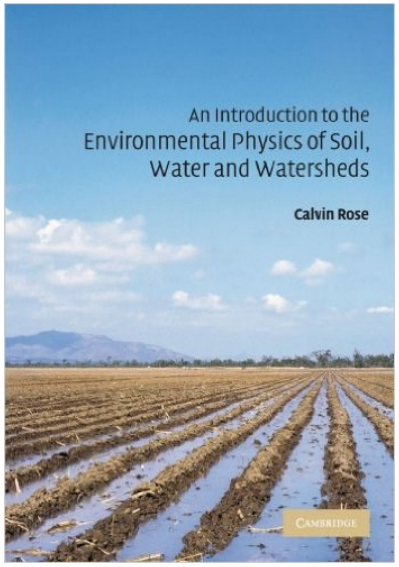
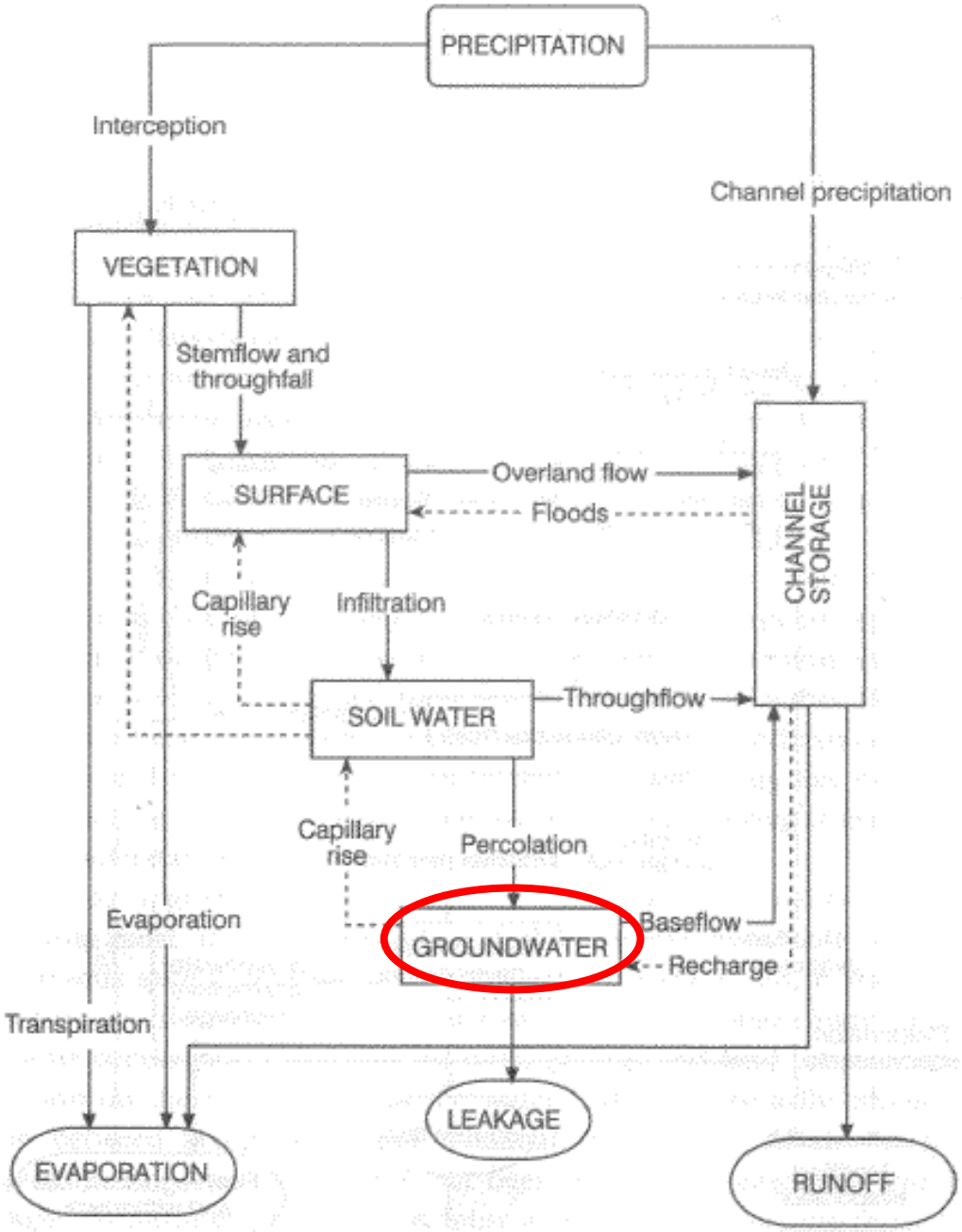
Soil, Water & Atmospheric Processes




Ward & Robinson –
Groundwater chapter




Rose –
Chapter 10




(Ward & Robinson, 2000)

# Introduction

- Groundwater part of the catchment hydrological cycle, but often overlooked
- Definition: "*subsurface water beneath the water table in rocks and soils*"

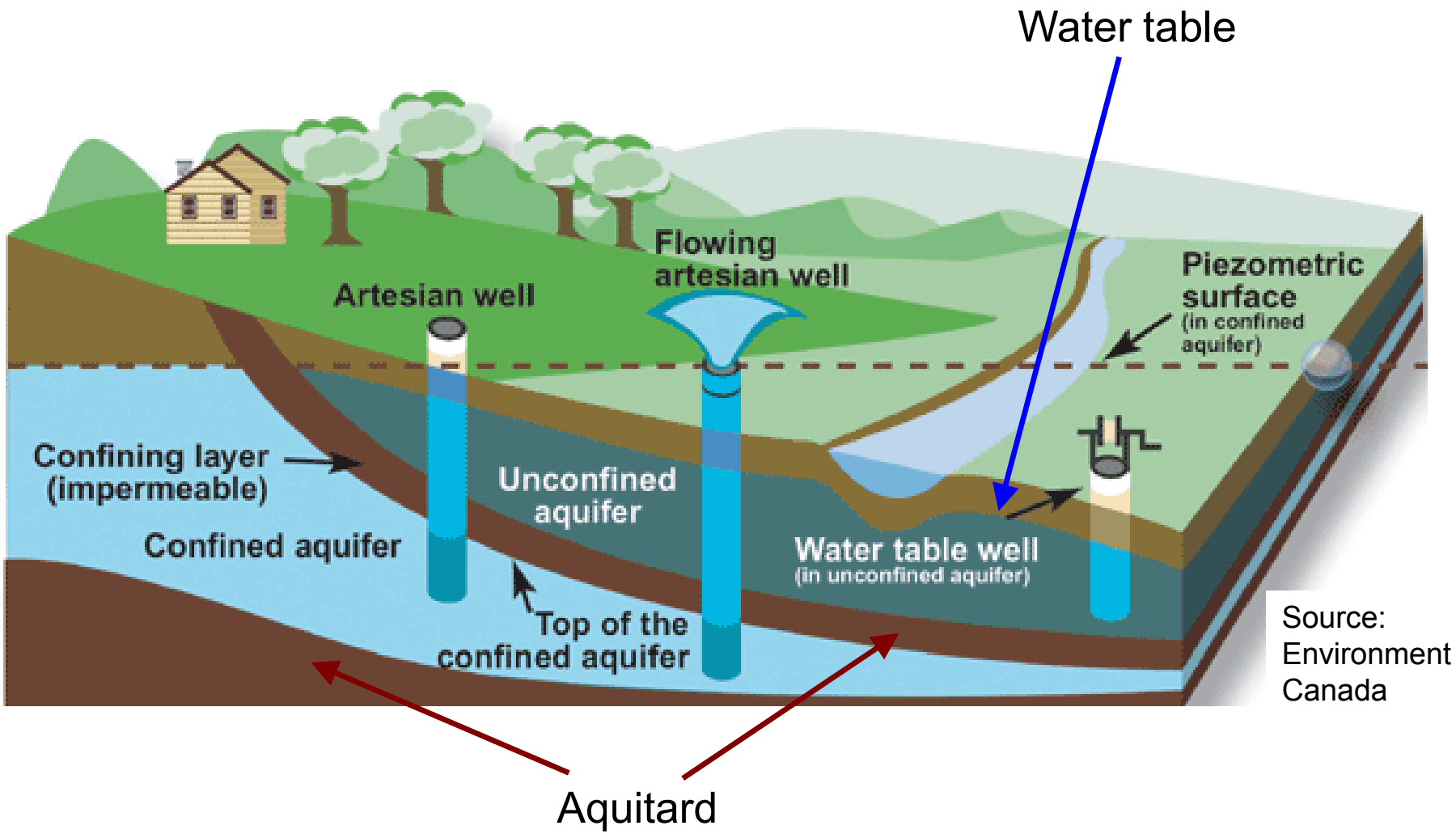
- Lecture structure:
  - Why interested in groundwater?
  - Nature of groundwater store
  - Groundwater movement
  - Groundwater balance
  - Groundwater management and development

# Why interested in groundwater?

1) Catchment runoff
   - Maintains river flows and wetlands when no precipitation
   - Can be an important source of storm runoff

2) Water resources
   - Accounts for 94% of global freshwater
   - Good quality drinking water
   - 35% of public water supply in England & Wales from groundwater

# Nature of the groundwater store




Source: Environment Canada

# Water storage in aquifers (1)

- Water-holding capacity depends on rock characteristics and geological setting
- Three important measures of suitability of rock as an aquifer:

1. Porosity: availability of spaces between rock grains to hold water

$$\textbf{Porosity (\%)} = \frac{\mathbf{V_v}}{\mathbf{V_t}} \times \mathbf{100}$$

$V_V$ = volume of void space

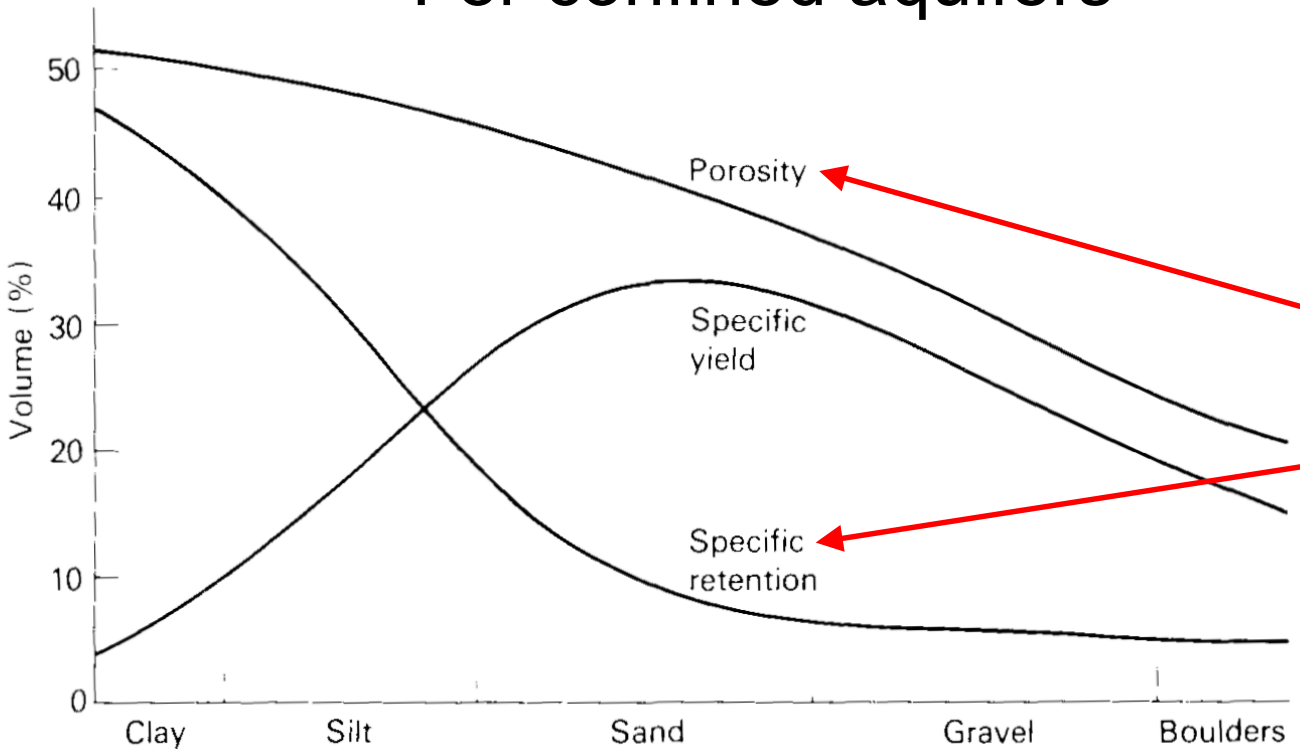
$V_t$ = total volume of rock

| *Material* | *Porosity (%)* |
|---|---|
| Fine sandy alluvium | 45-52 |
| Gravel | 25-40 |
| Shale rock | 5-15 |
| Crystalline limestone | 1-10 |
| Chalk and oolitic limestone | 5-30 |
| Slate | <1-5 |
| Granite | <1-10 |

# Water storage in aquifers (2)

2. Permeability: measure of interconnectivity of pore spaces

For confined aquifers




(Ward & Robinson, 1999)

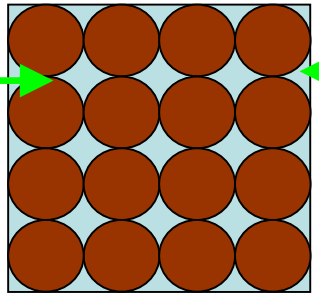
Aquifer yield trade-off between retention forces and porosity

# Water storage in aquifers (3)

3. In confined aquifers the compressibility and elasticity of the aquifer as measured by the Coefficient of storage/storativity: volume of water released or taken into storage, per unit surface area of aquifer per unit change in pressure head

Undisturbed

Intergranular pressures from points of contact of rock grains



Porewater pressures due to weight of contained pore water

**Total stress =**

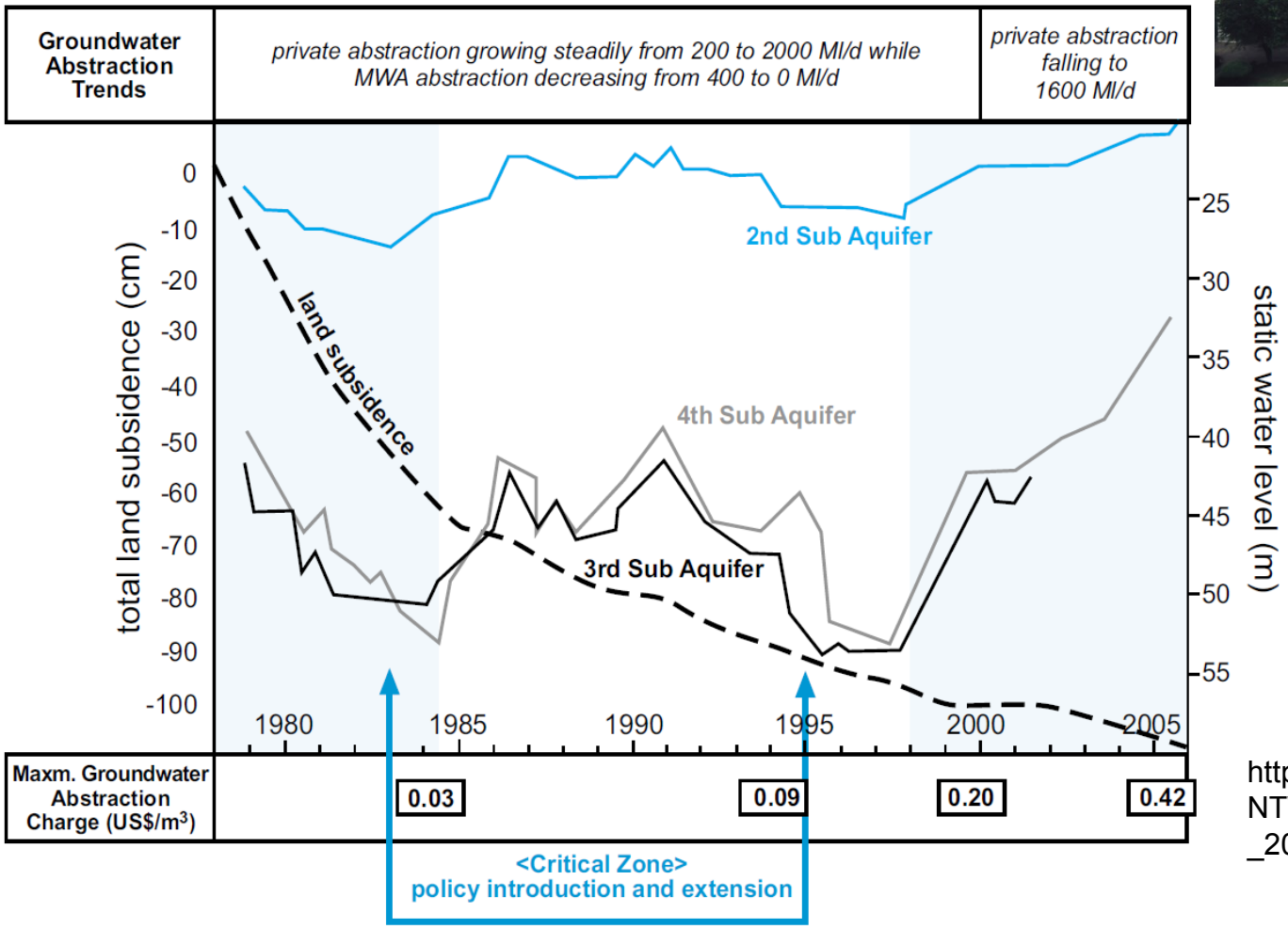
Intergranular pressures + Porewater pressures

Water withdrawn

- Water expands => decrease porewater pressure
- Conservation of fluid mass => total stress unchanged so intergranular pressures increase
- **Result = compression of aquifer rock**

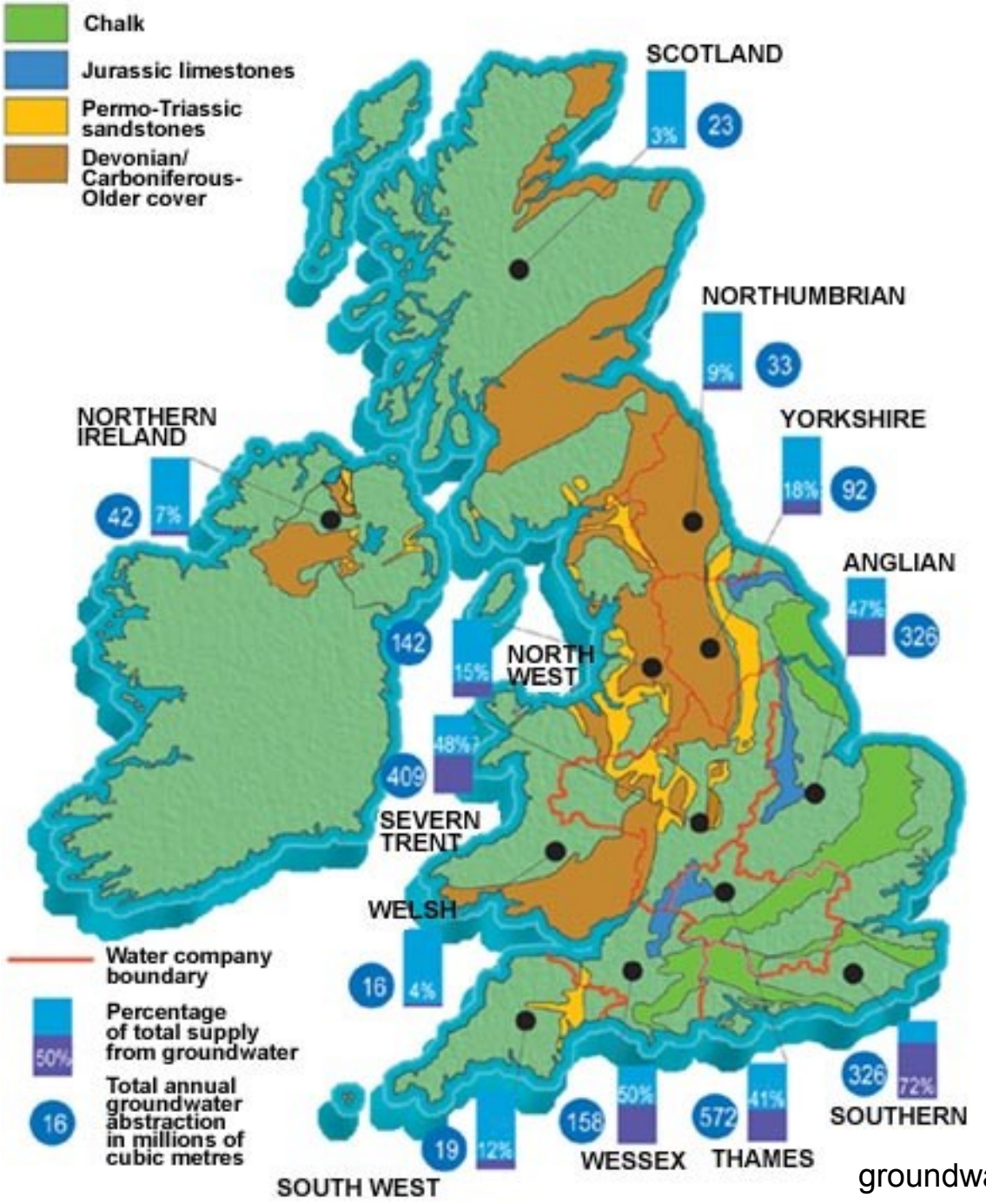
# Subsidence of ground surface

- E.g. Bangkok: subsidence, buildings & roads sinking, salinisation of aquifer
- Solution = increase groundwater abstraction charges




MWA = Metropolitan Waterworks Authority

http://siteresources.worldbank.org/INTWAT/Resources/GWMATE_CP_20_Bangkok.pdf

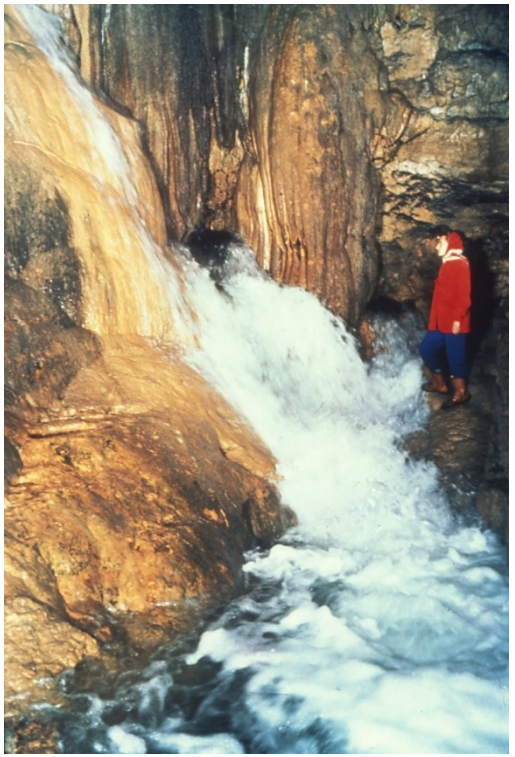



# UK - groundwater areas and usage

groundwateruk.org

# Groundwater movement

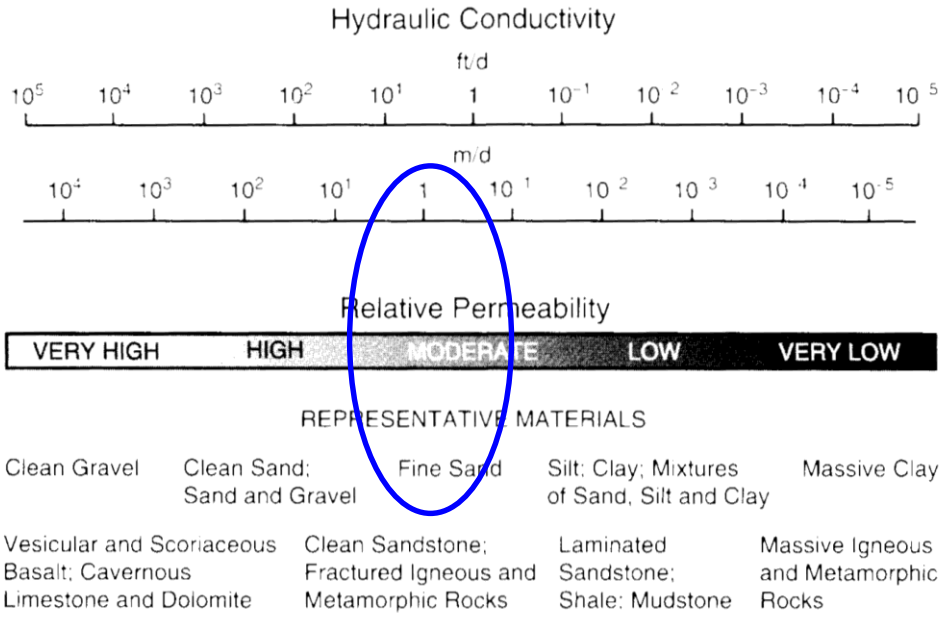
- Darcy's Law: Q = KIA
- Flow from areas of high pressure head to areas of low pressure head
- Slow flow rates
  - Typically < 1 m $day^{-1}$
  - < 1 mm to 5.5 km $day^{-1}$



# Calculation

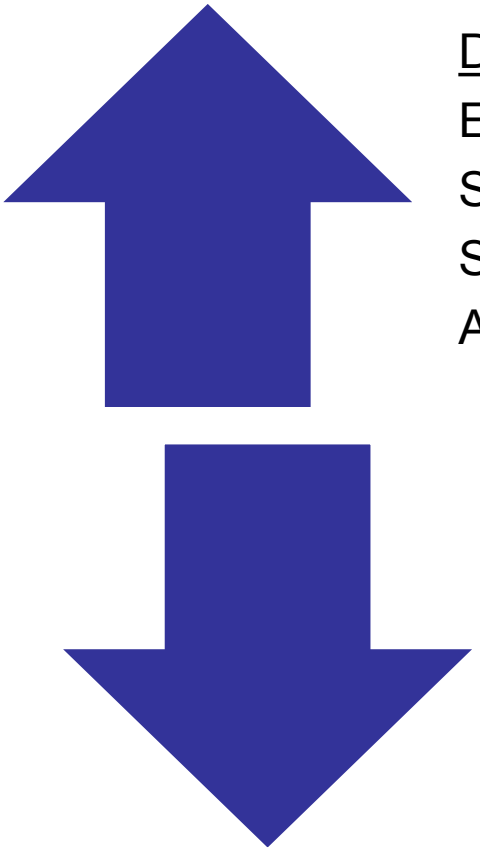
(Ward & Trimble, 2004)

What is rate of water flow (in $m^3$ $day^{-1}$) through a fine sandstone aquifer of cross-sectional dimensions 50 m x 1000 m and with a hydraulic gradient of 0.001 m $m^{-1}$?




- <u>Darcy's Law, Q = KIA</u>
- K = 1 m $day^{-1}$, I = 0.001 m $m^{-1}$, A = 50 m x 1000 m = 50,000 $m^2$
- Q = 1 x 0.001 x 50000 = 50 $m^3$ $day^{-1}$

# Groundwater balance: discharge and recharge



Discharge

Evapotranspiration

Seepage to surface water

Seepage to adjacent aquifers

Abstraction

Recharge

Precipitation

Seepage from surface water

Seepage from adjacent aquifers

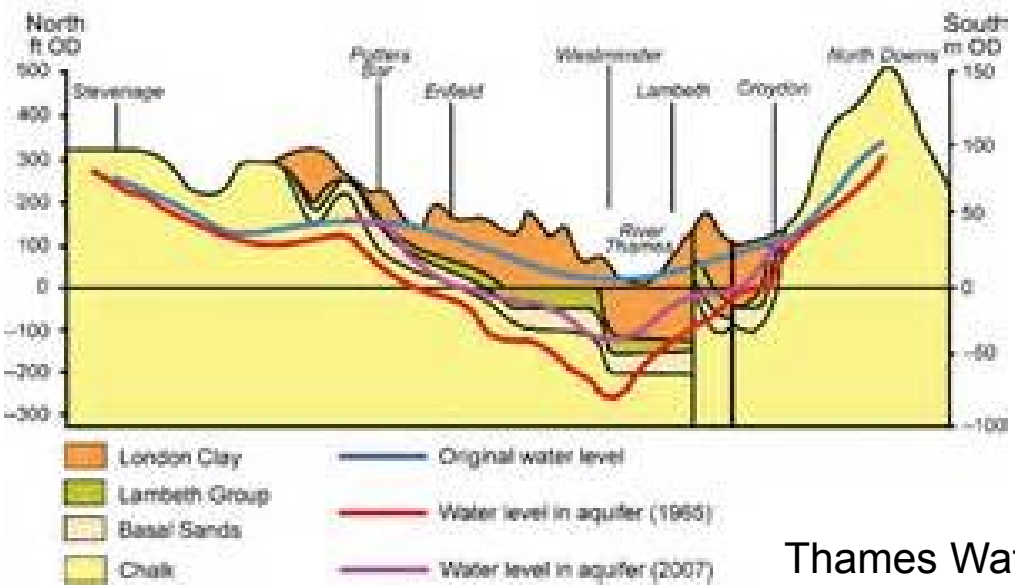
Human recharge (artificial recharge, accidental - mains water pipes, irrigation leakage)

# Problems of groundwater overabstraction (1)

## Groundwater rebound in urban areas

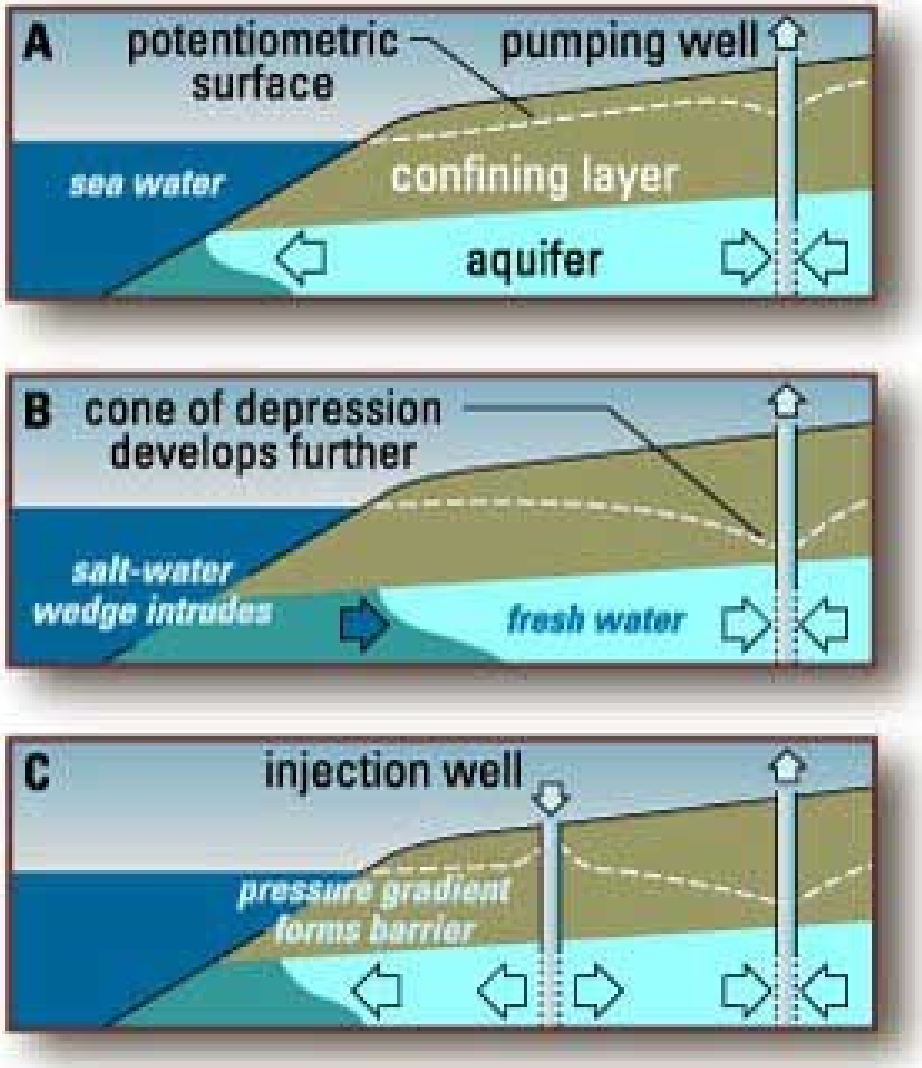

Abstraction increased from chalk aquifer by 50 million litres $day^{-1}$ to relieve groundwater flooding in London

Subsidence




Thames Water 2007

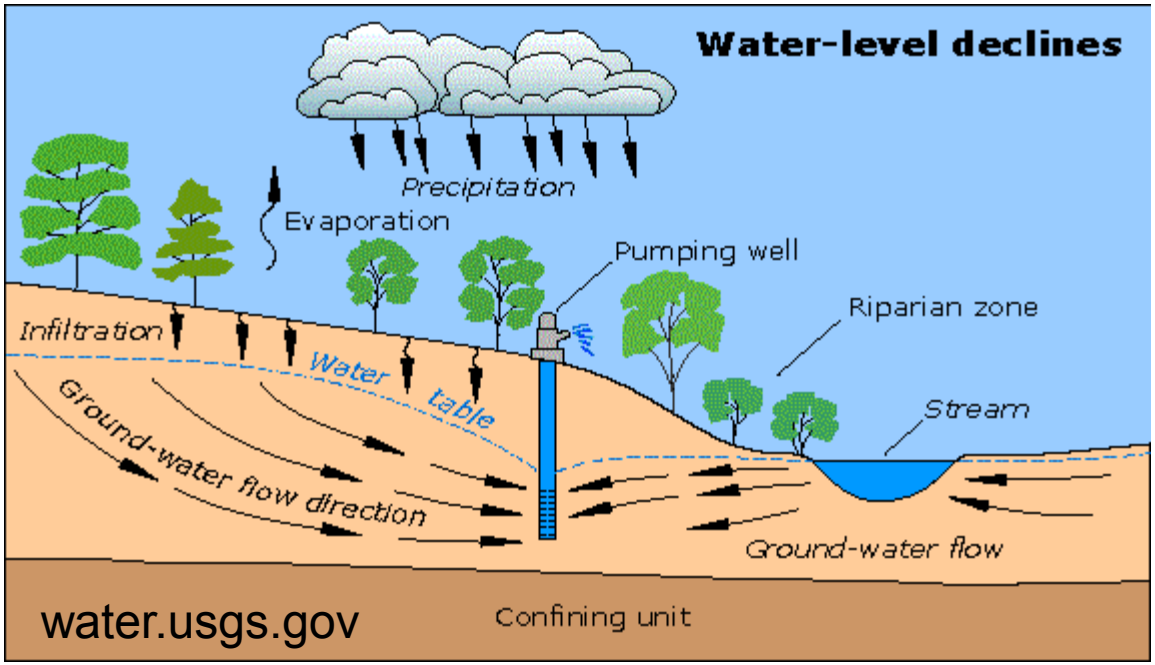
# Problems of groundwater overabstraction (2)




Saline intrusion

# Groundwater management in the UK

- England & Wales
  - 1963 Water Act: abstraction licensing introduced
  - BUT over-generous licences => low flows
  - 2003 Water Act: licences can be removed/varied without compensation
- Scotland
  - Abstraction licensing introduced as part of EU Water Framework Directive for abstractions > 50 $m^3$ $day^{-1}$




Effects of groundwater overabstraction on river flows

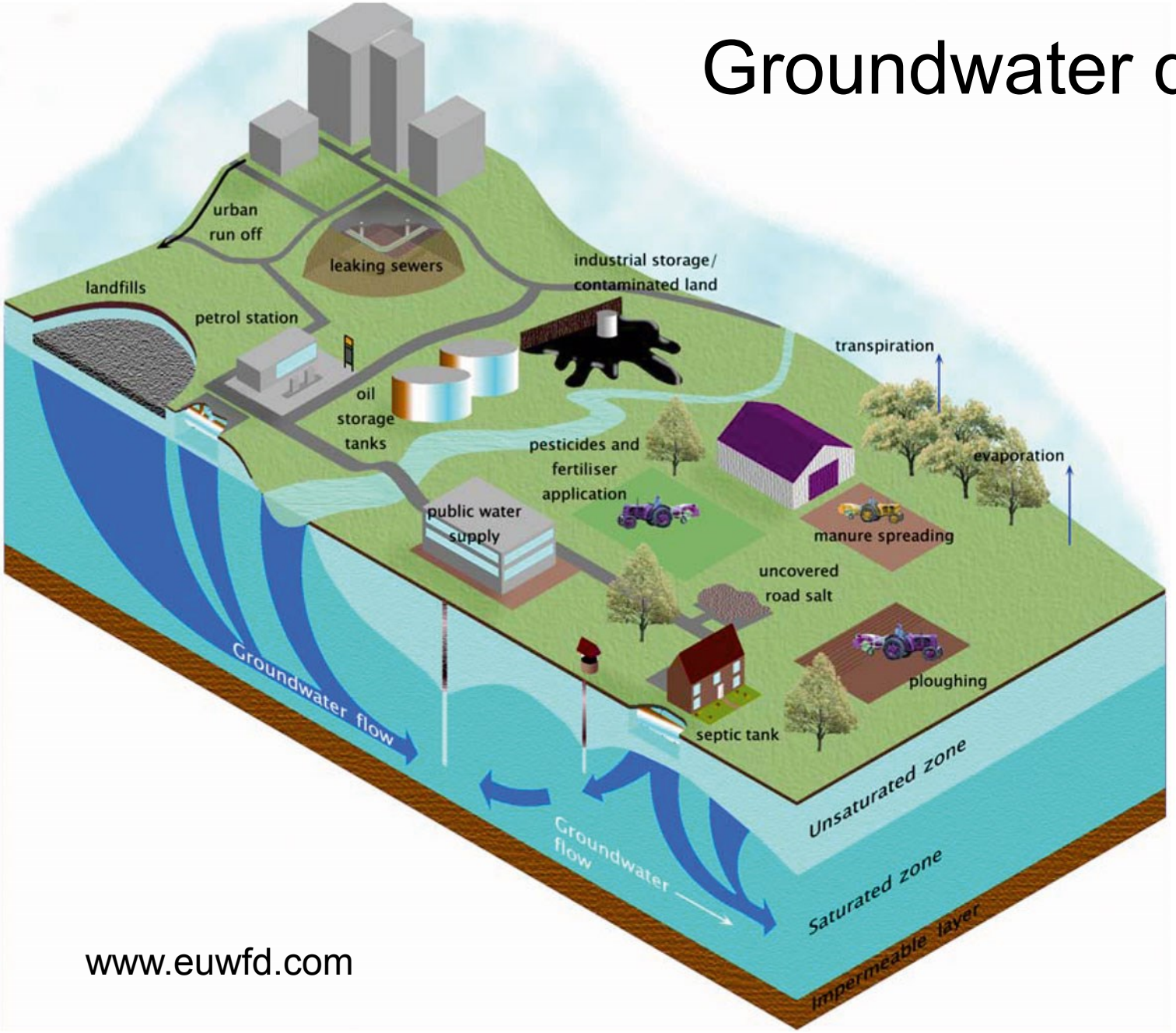
# Low flow case-study: Misbourne, Buckinghamshire

- From 1962, 65% of available water abstracted for public supply
- By 1997, 22.5/27 km dry and inadequate flow to dilute sewage effluent
- Flow alleviation: reduce groundwater abstraction by 15 million litres per day
- Flow returned to river in 1998 and recovery of aquatic life started

Misbourne – no flow

Misbourne – flowing

# Groundwater quality




www.euwfd.com

# Groundwater Protection Policy for Scotland v3

November 2009

Environmental Policy Number 19


SEPA
Scottish Environment Protection Agency