Groundwater and Surface Water Interactions

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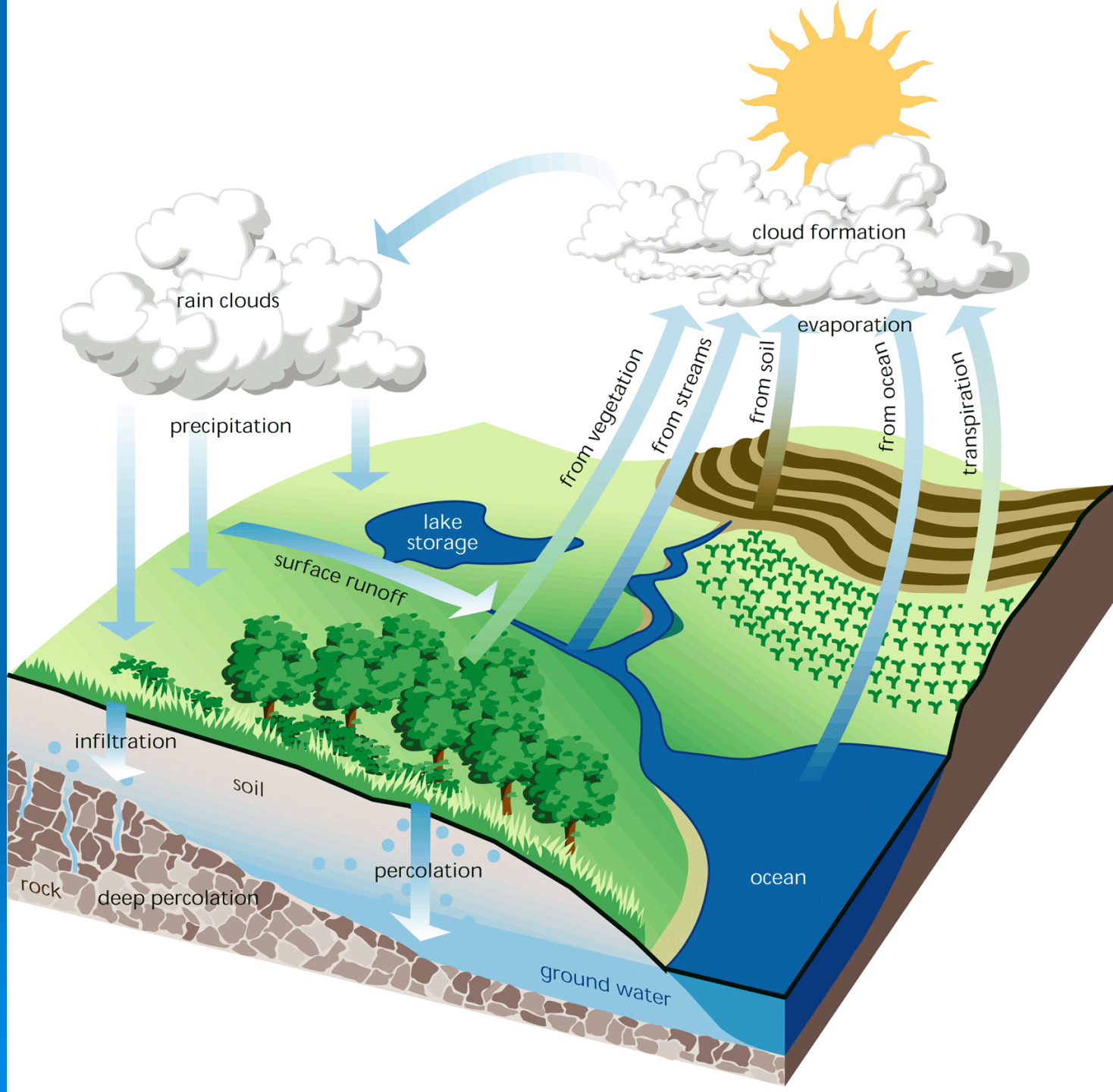
Thanks to Dr David Reynolds for some of his slides

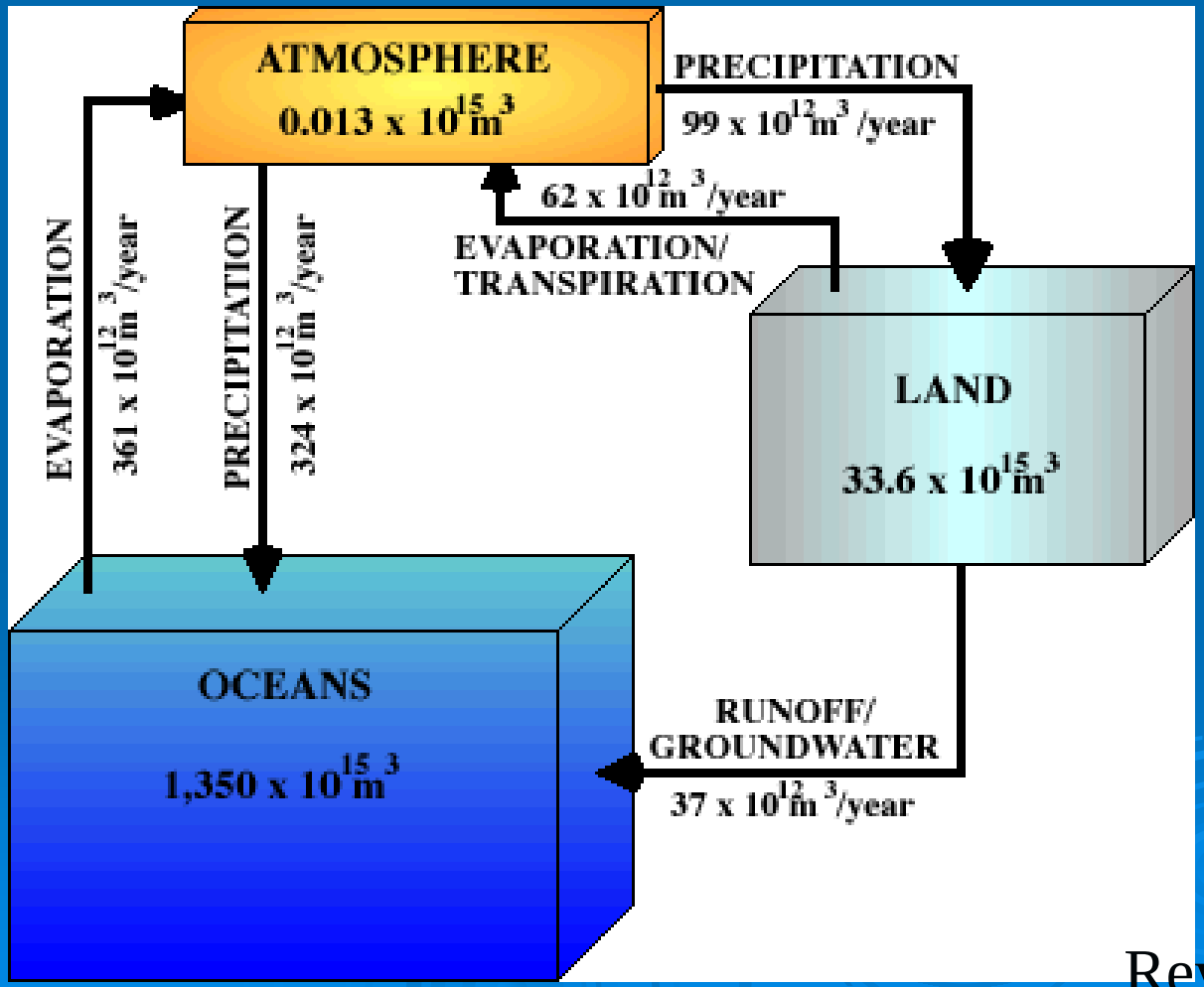
Outline

- Hydrologic Cycle
- Global water budgets and balances
- Interactions
  - Hillslope
  - Lakes
  - Streams
  - Sub-regional scale
- Water balances
- Management and policy implications

It's true, the water we use today has been around for hundreds of millions of years, and the amount available probably hasn't changed very much. Water moves around the world, changes forms, is taken in by plants and animals, but never really disappears. It "travels" in a large, continuous cycle. We call this the Hydrologic Cycle.

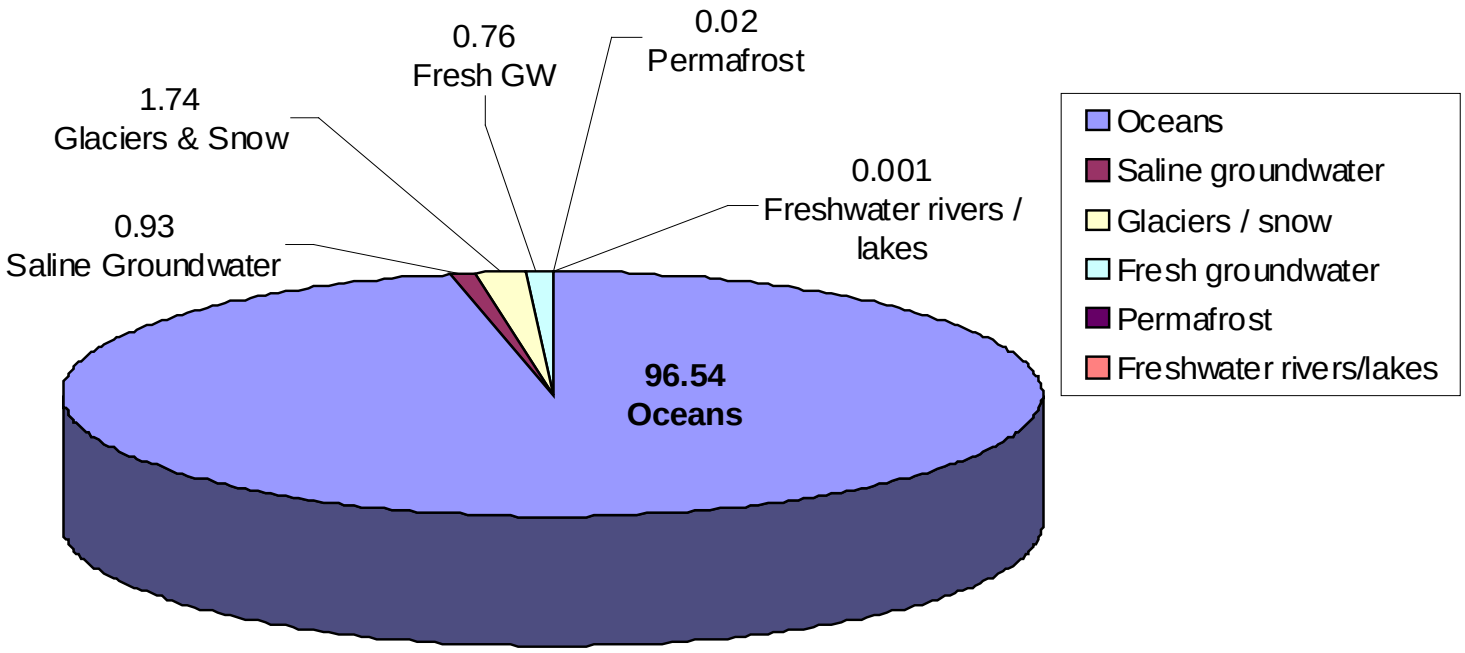


A Global Flux and Storage Budget

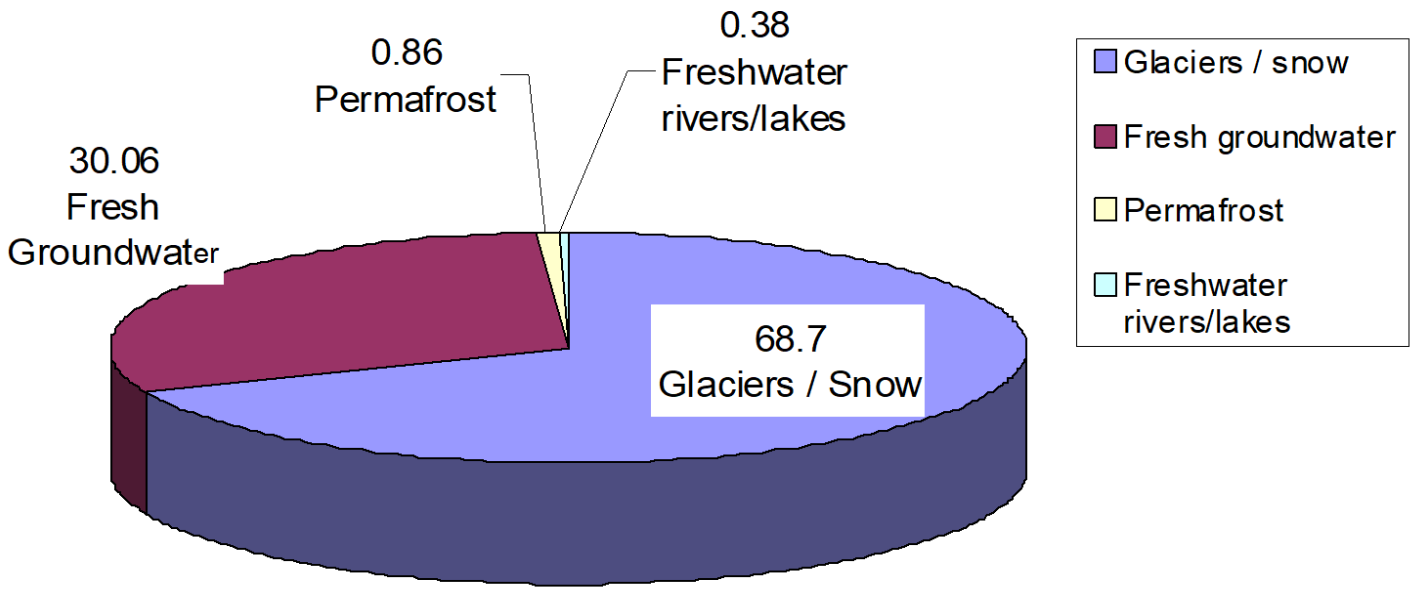


Reynolds, 1998

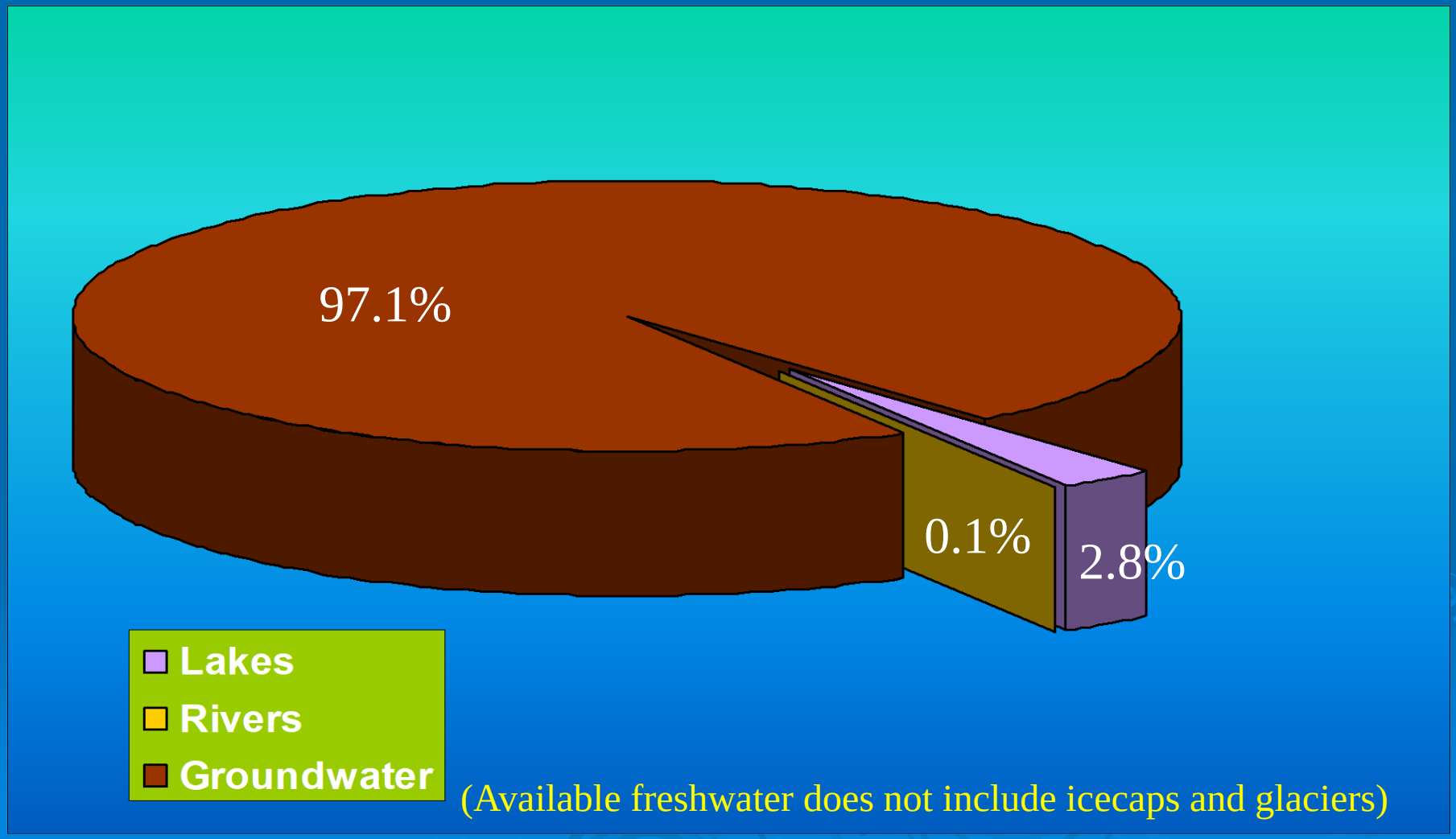
Distribution of Water



Distribution of Freshwater

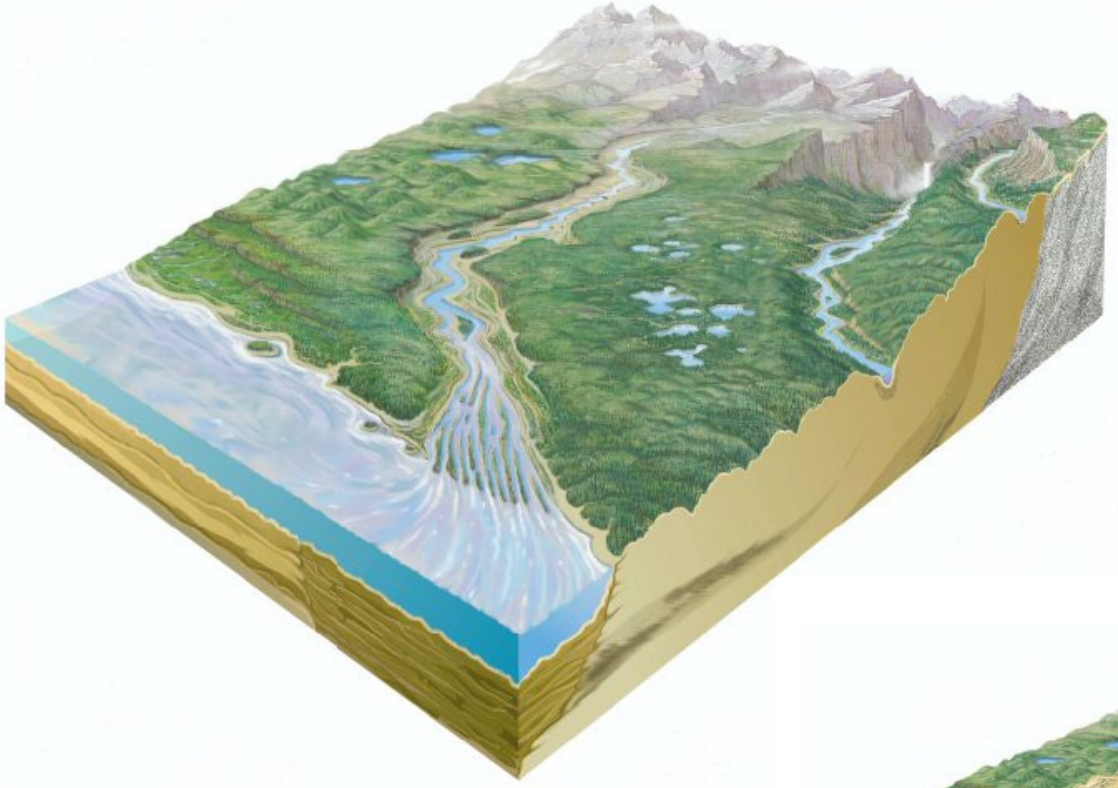


Distribution of Available Fresh Water

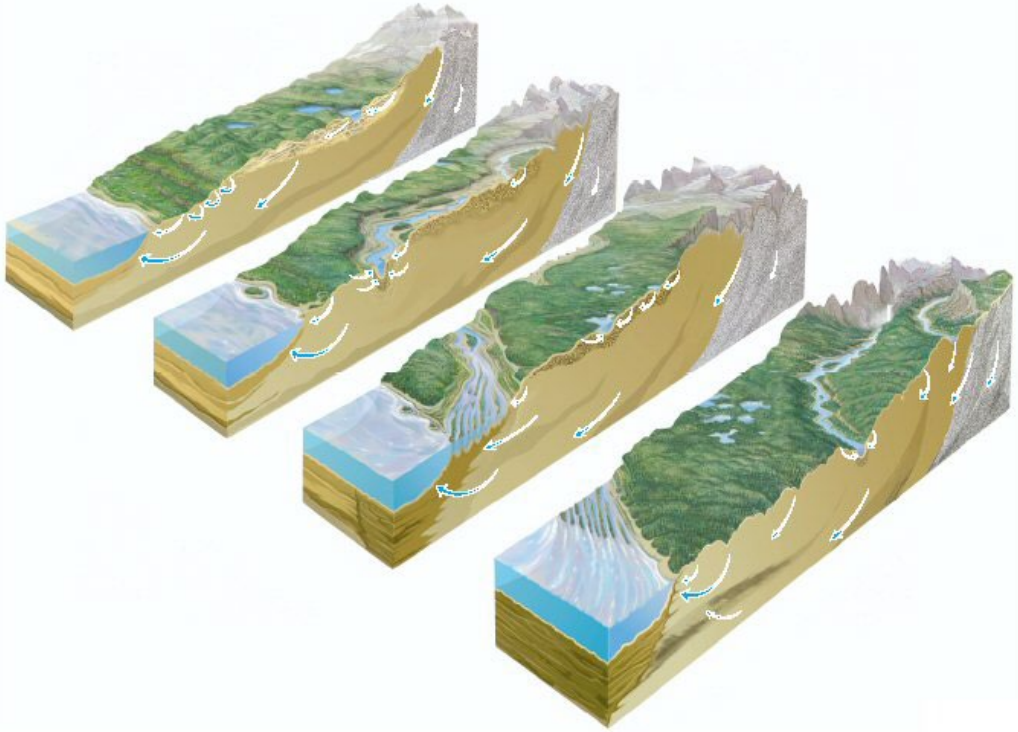


(Available freshwater does not include icecaps and glaciers)

Interactions



Different Interactions Occur in different landscapes



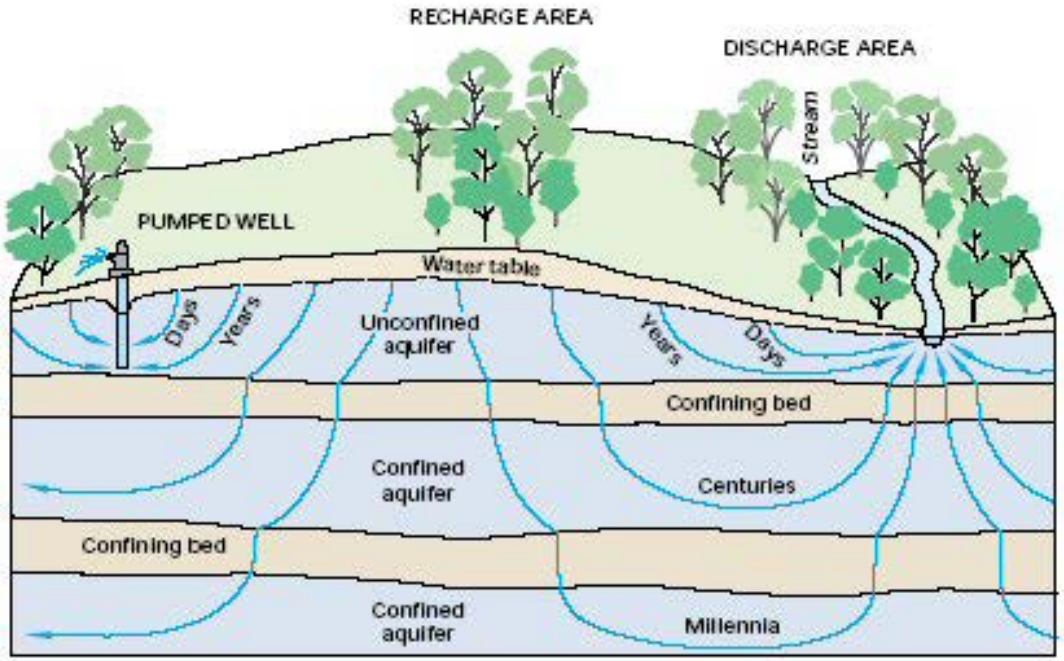


Figure 3. Ground-water flow paths vary greatly in length, depth, and traveltime from points of recharge to points of discharge in the ground-water system.

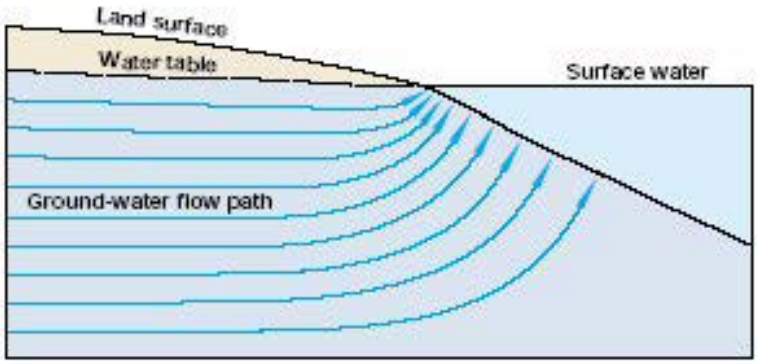


Figure 4. Ground-water seepage into surface water usually is greatest near shore. In flow diagrams such as that shown here, the quantity of discharge is equal between any two flow lines; therefore, the closer flow lines indicate greater discharge per unit of bottom area.

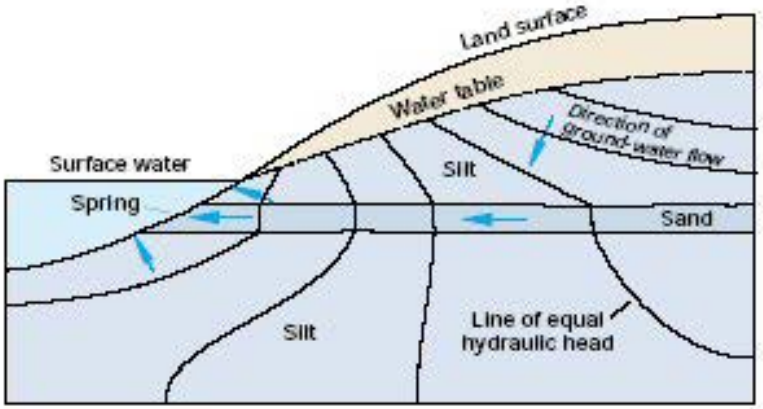
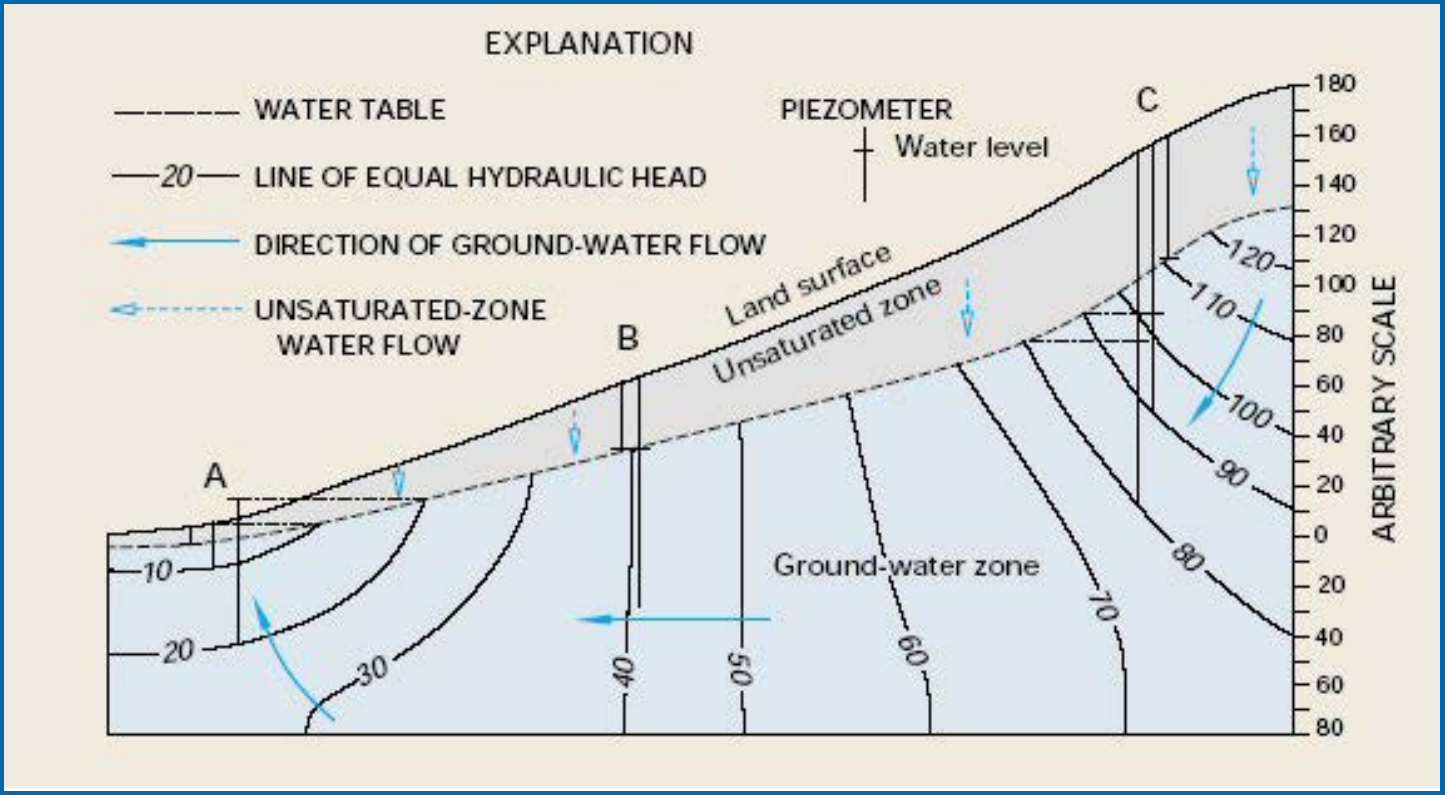


Figure 5. Subaqueous springs can result from preferred paths of ground-water flow through highly permeable sediments.

Winters 1998



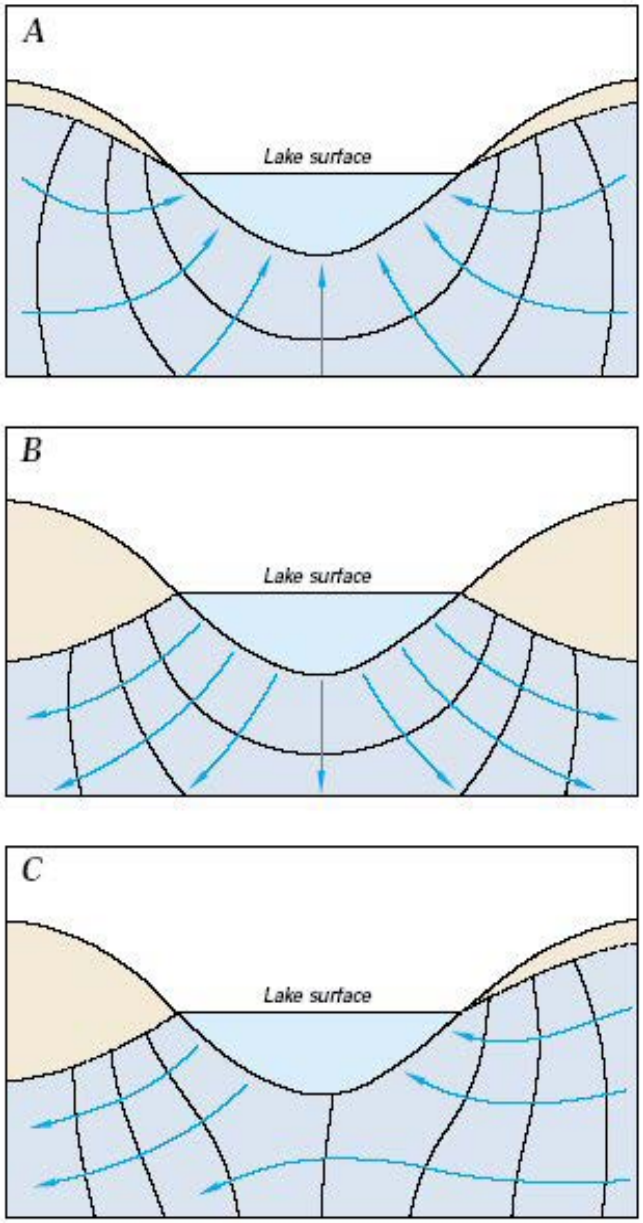
Hillslope Interactions are controlled by:

a) Topography
b) Geology
c) Recharge
d) Discharge

Winters 1998

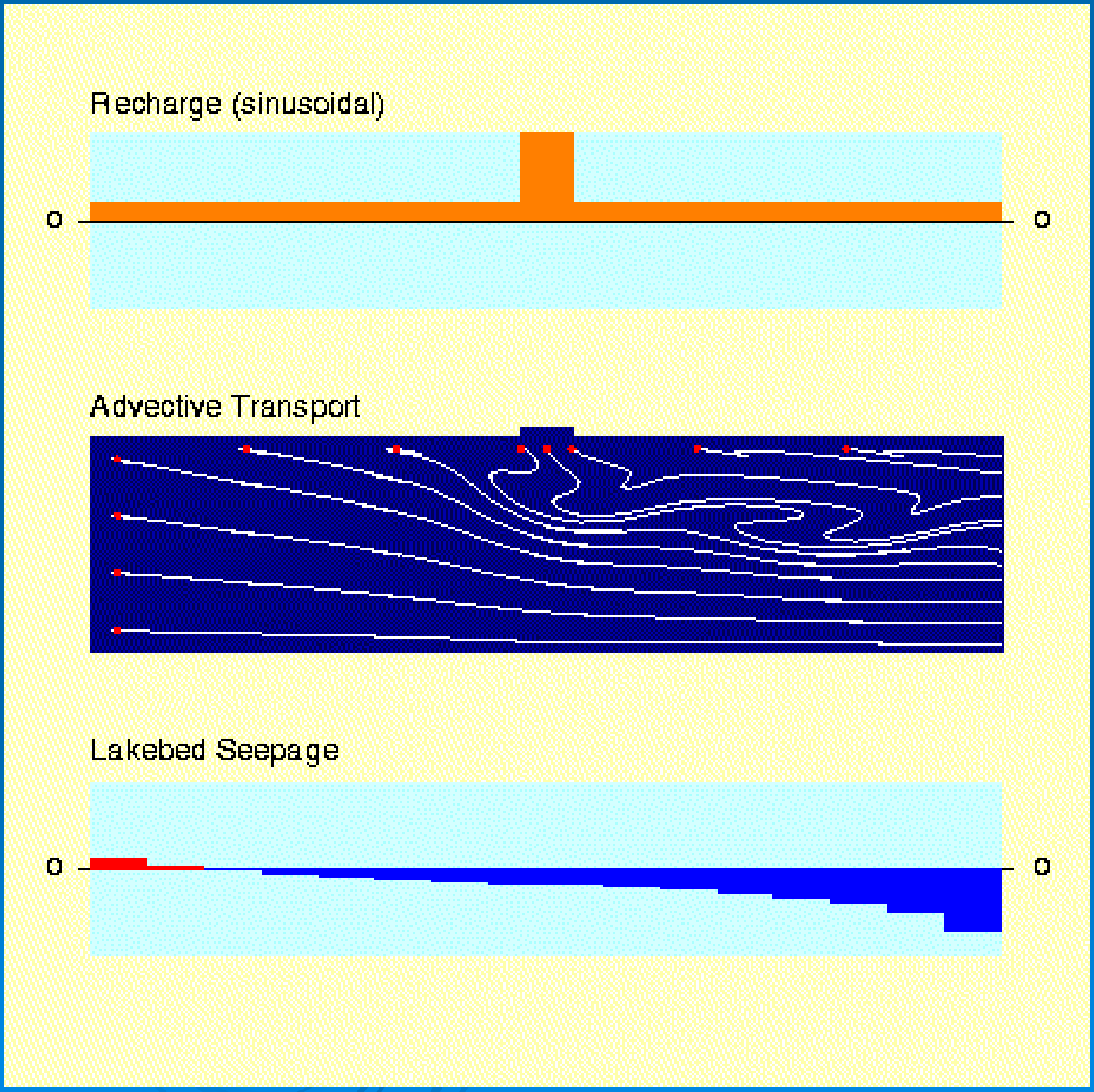
Interactions With Surface Bodies

- Groundwater interacts with static surface water bodies in three primary ways:
  - A) Discharge body
  - B) Recharge body
  - C) Flow-thru body



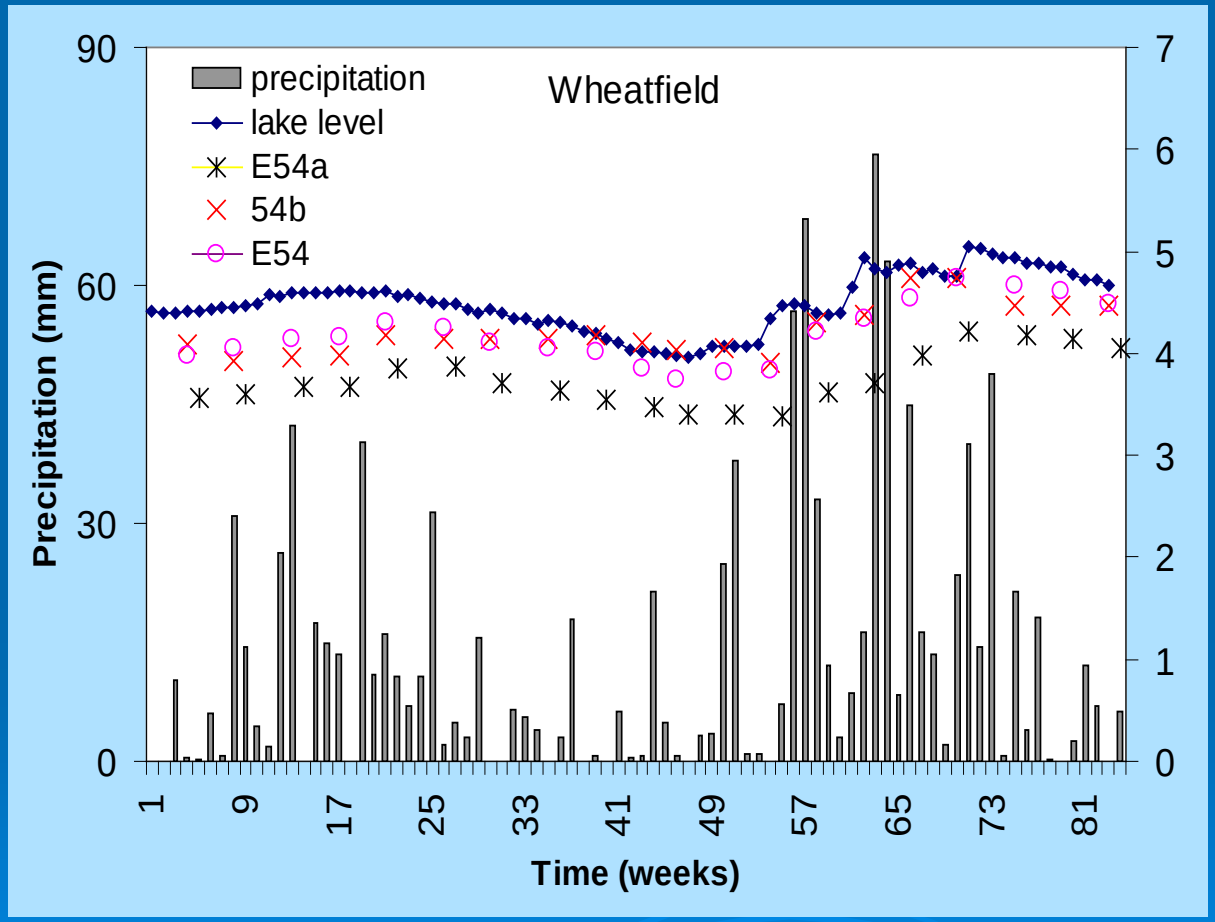
Winters 1998

- Recharge is supplied through rainfall on the ground surface and infiltration from the lake bed
- GW flow is left to right, with the lines representing flowlines
- Blue is positive to the aquifer



Townley, 2005

Lake Wheatfield - Esperance



Temporal variations in the local groundwater flow system

Lake level is generally higher and reversal occurs in summer

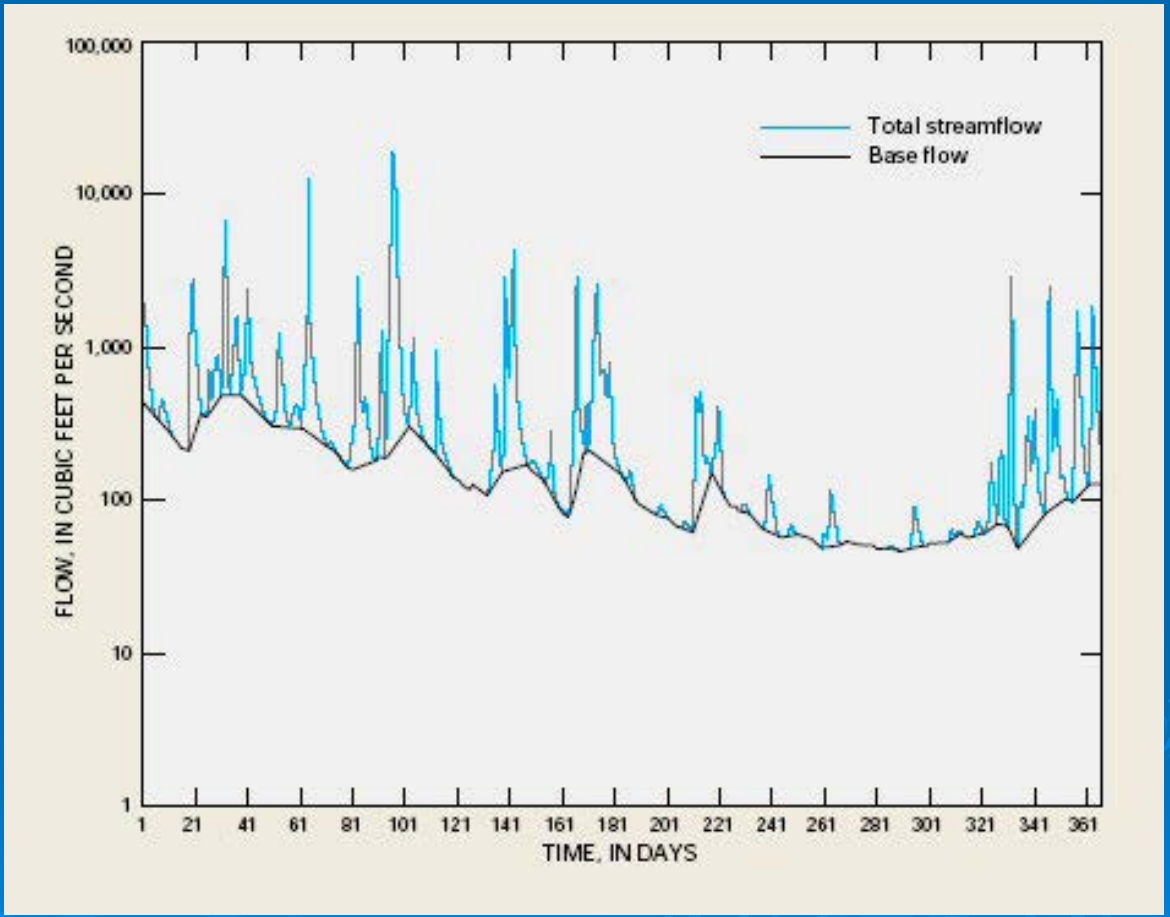
Reynolds, 1998

Interactions With Streams

- One of the best understood SW – GW interactions pertains to streams
- Baseflow of a stream is the component of the total flow that is due to groundwater
- Baseflow often maintains streamflow when the surface of the landscape is completely dry

River Streamflow and Baseflow

- Baseflow remains relatively constant
- Total flow is an expression of surface runoff
- Will usually correlate to rainfall events, may lag due to catchment concentration time



Reynolds, 1998

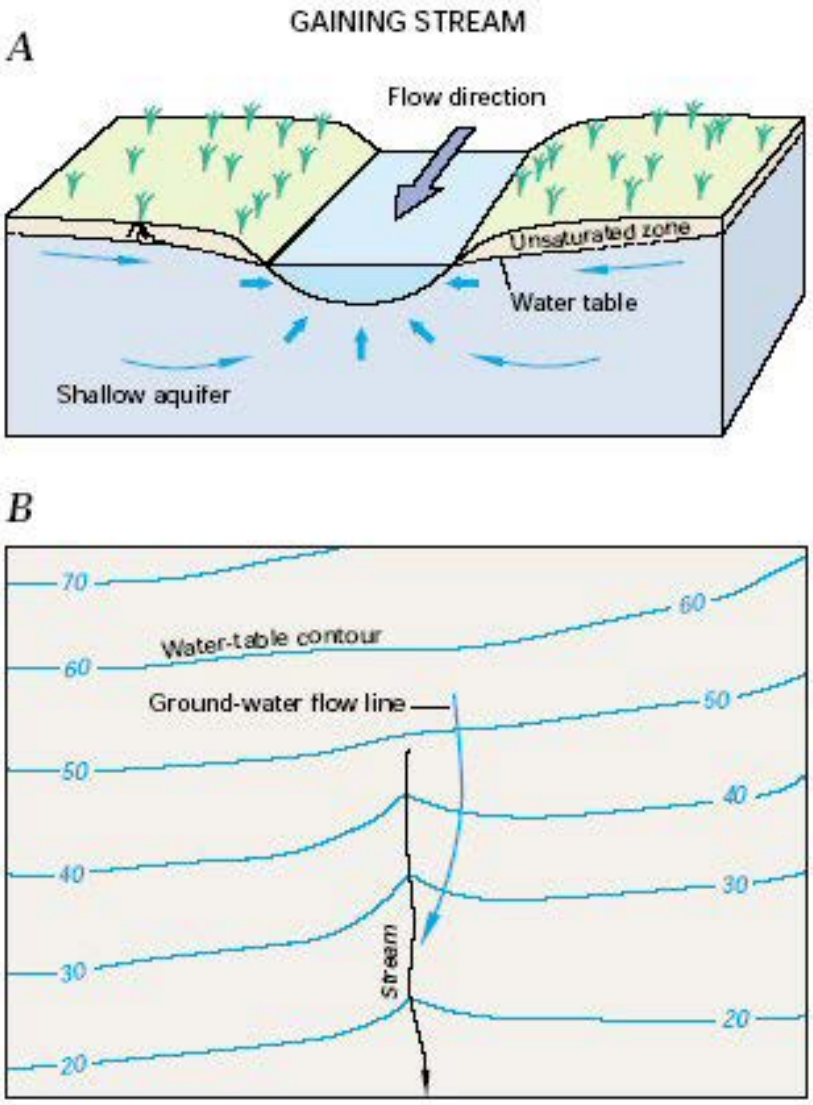


Figure 8. Gaining streams receive water from the ground-water system (A). This can be determined from water-table contour maps because the contour lines point in the upstream direction where they cross the stream (B).

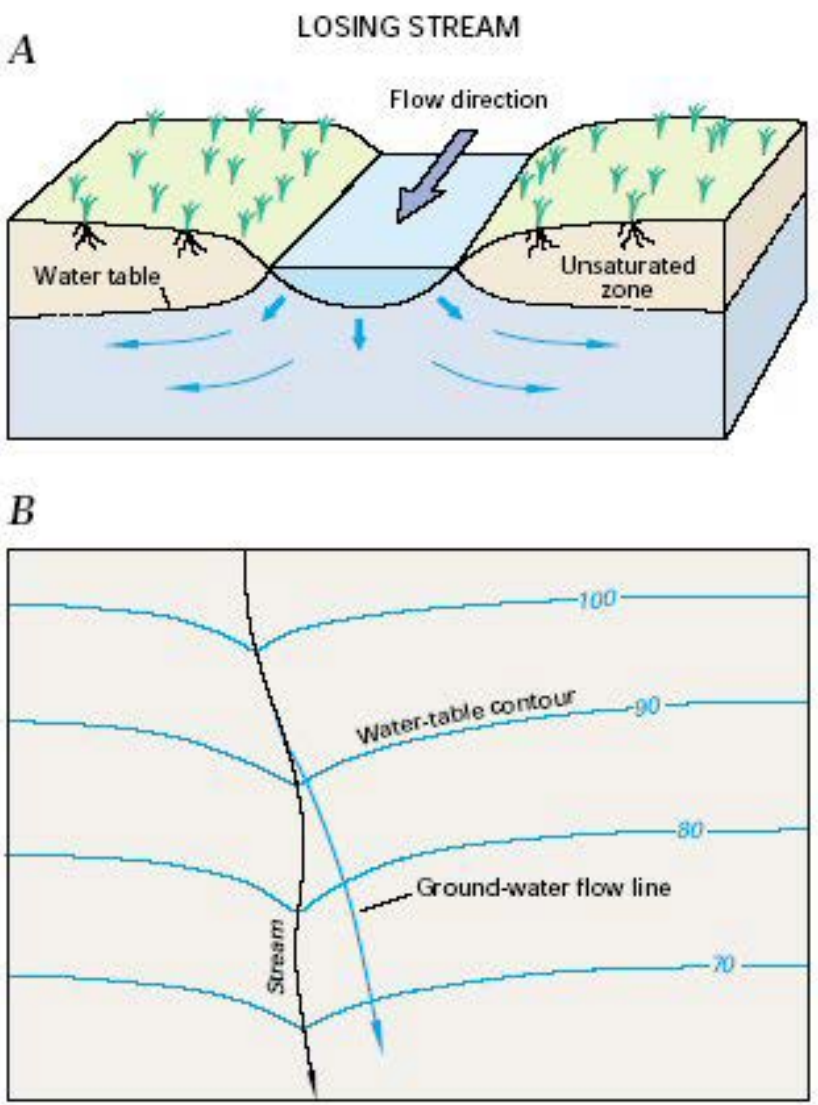


Figure 9. Losing streams lose water to the ground-water system (A). This can be determined from water-table contour maps because the contour lines point in the downstream direction where they cross the stream (B).

Winters, 1998

Annual Cycles

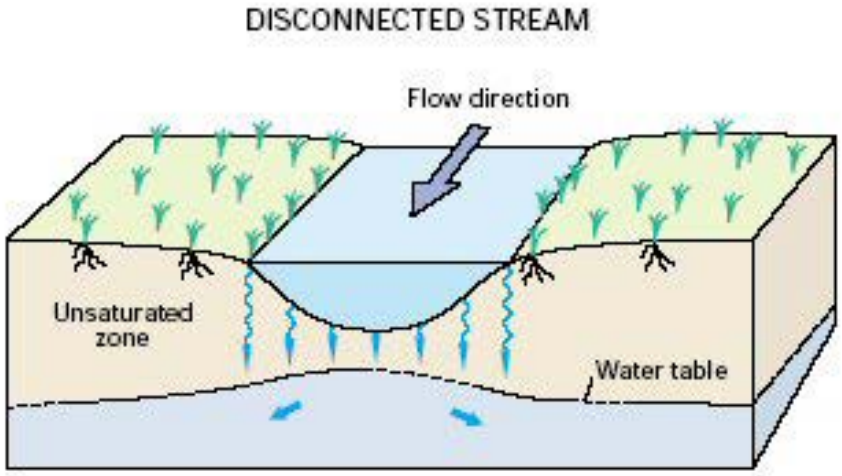


Figure 10. Disconnected streams are separated from the ground-water system by an unsaturated zone.

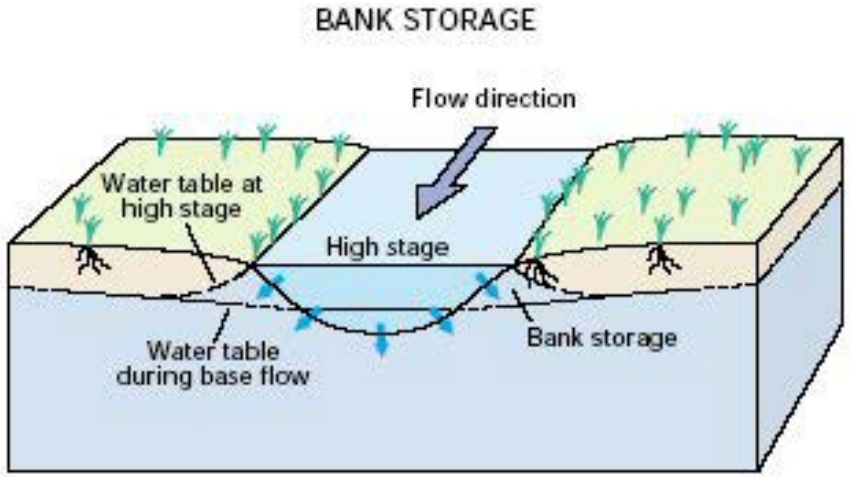
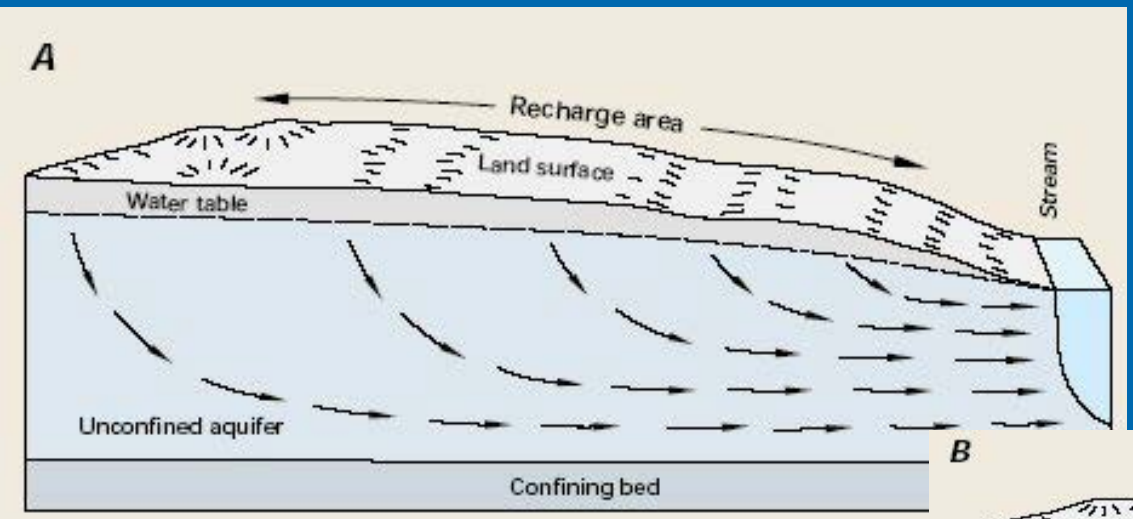
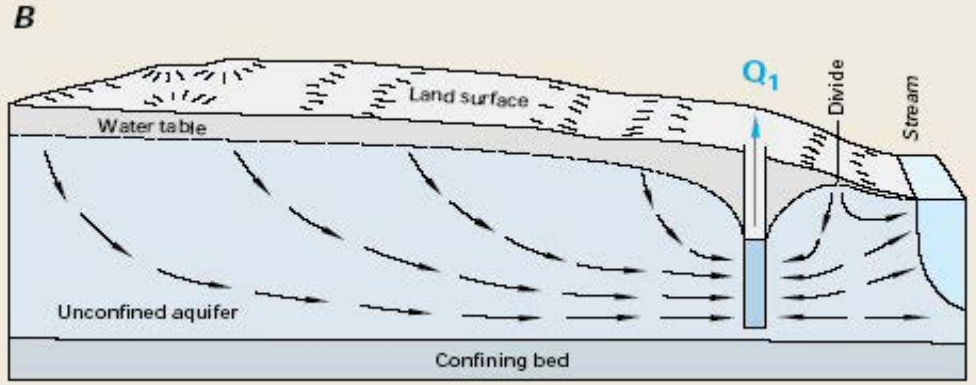


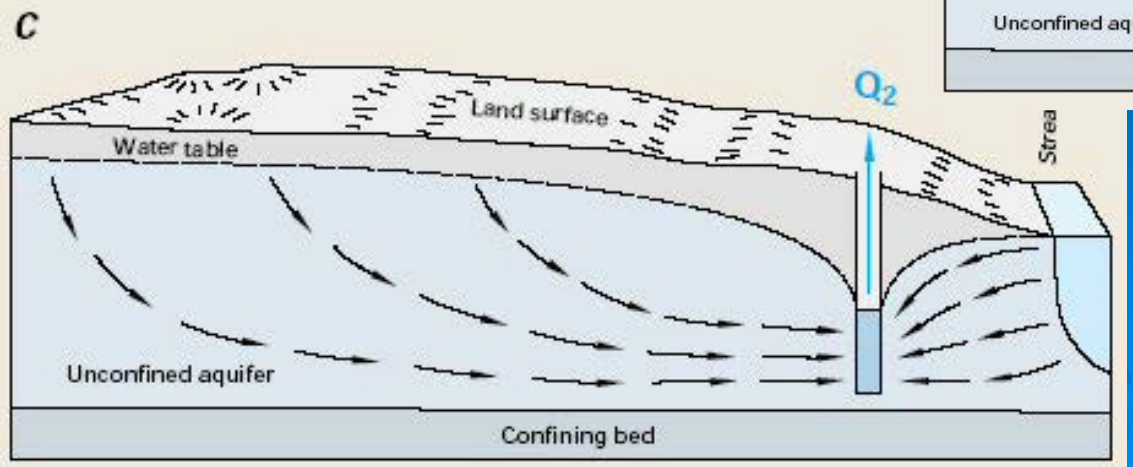
Figure 11. If stream levels rise higher than adjacent ground-water levels, stream water moves into the streambanks as bank storage.

Winters, 1998

Effects of GW Withdrawls

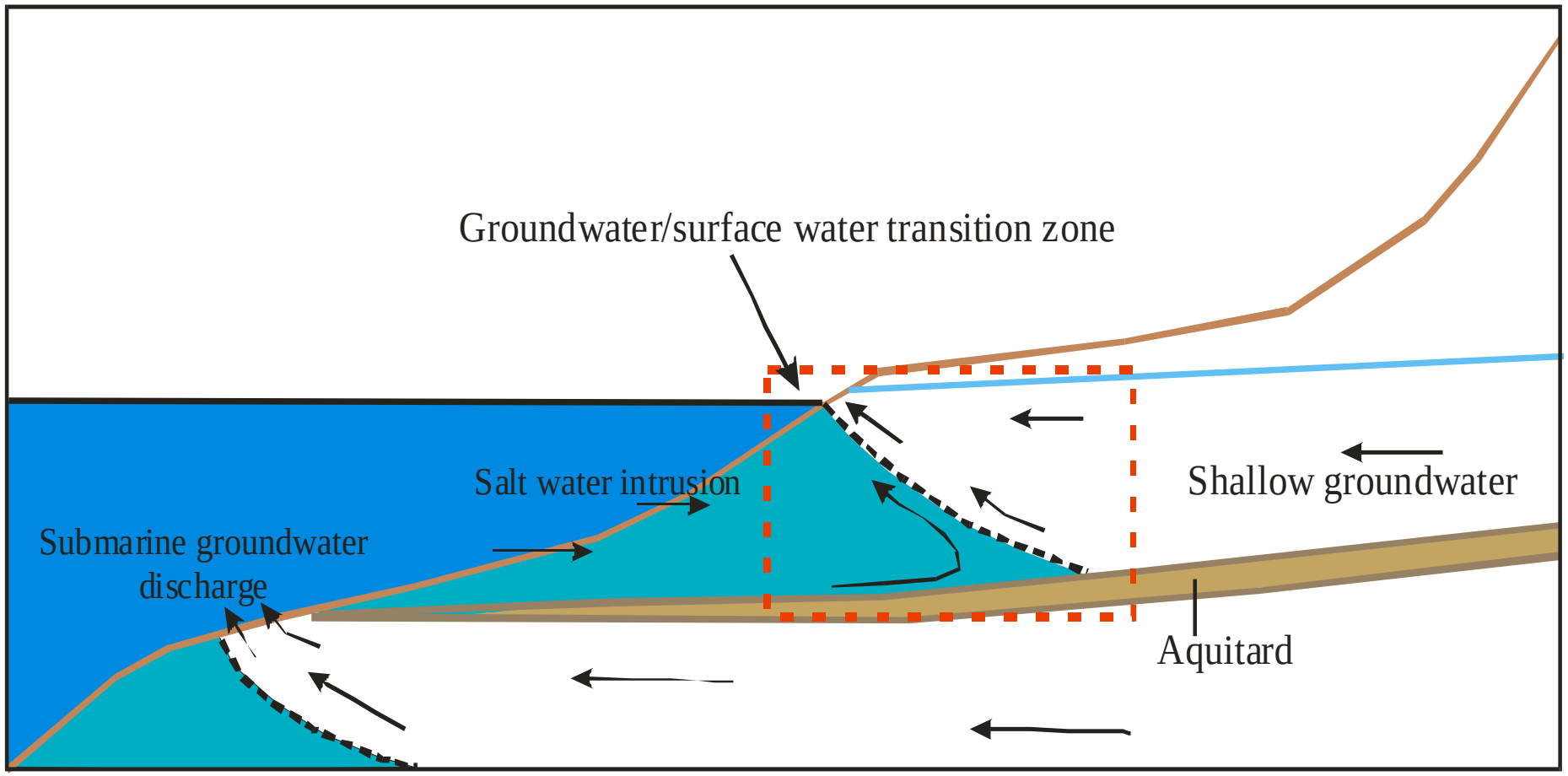




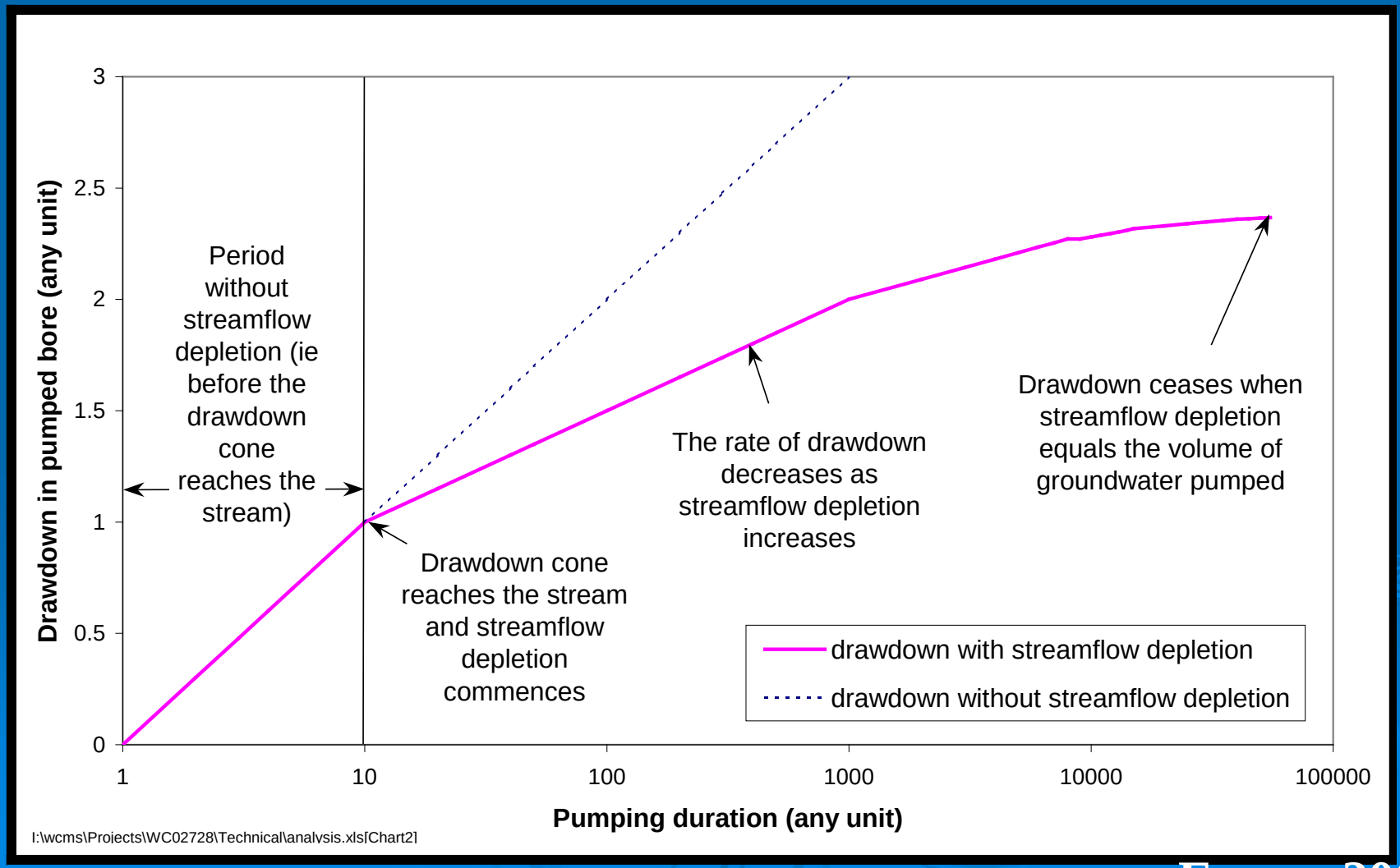


Winters, 1998

Over pumping can lead to salt water intrusion



Influence on Bore Drawdown



Evans, 2005

Water/Solute Balances

- Given that all the inputs and outputs from a closed system can be defined:

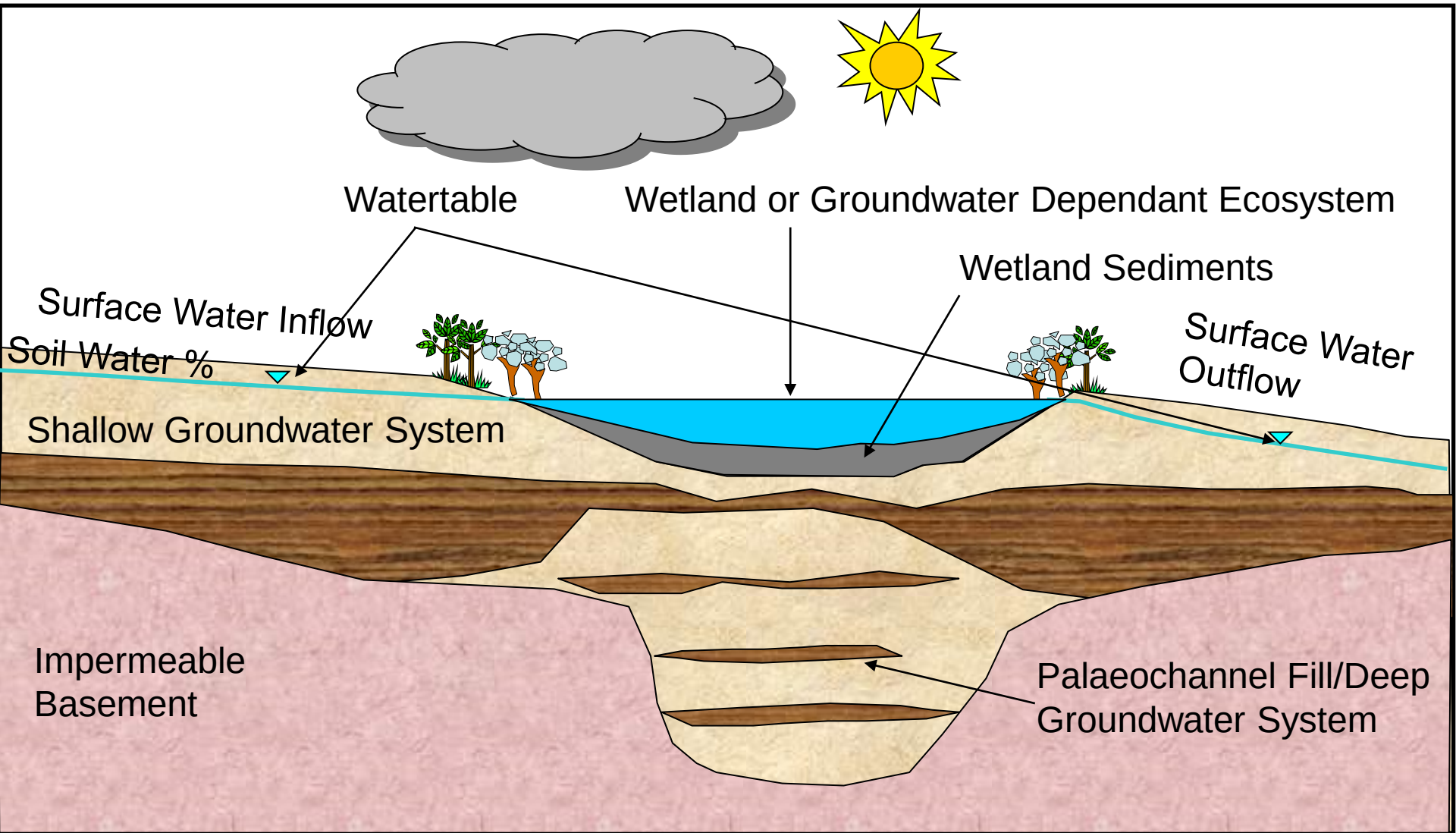
$$\frac{dV}{dt} = G(t)_i + P(t) + S_i(t) - G_o(t) - S_o(t) - E_o(t)$$

Gi and Si - groundwater and surface inflow
Go and So-groundwater and surface outflow
P and E - precipitation and evaporation
V - volume of lake
t - time

- If the values can be quantified, simple balances can be used for managerial decision, future forecasting, etc.

Key areas of understanding for definition of wetland function

Description of the following figures.

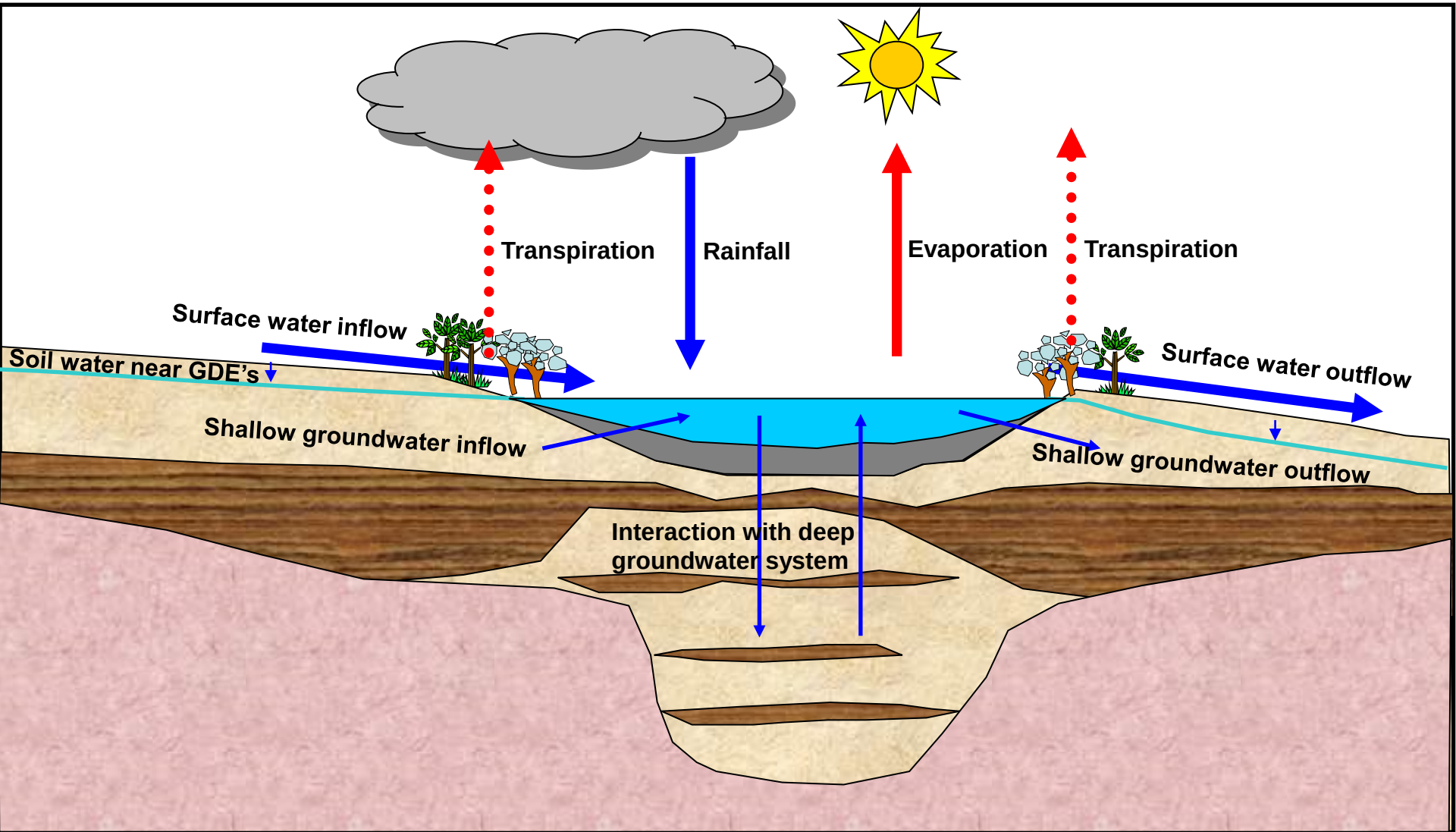


For all of the pathways shown below we need to understand;

A – the movement of water.

B – the movement of salt with that water.

C – the movement and interaction of other water constituents (N, P, SO_4, Cl acidity/alkalinity etc).



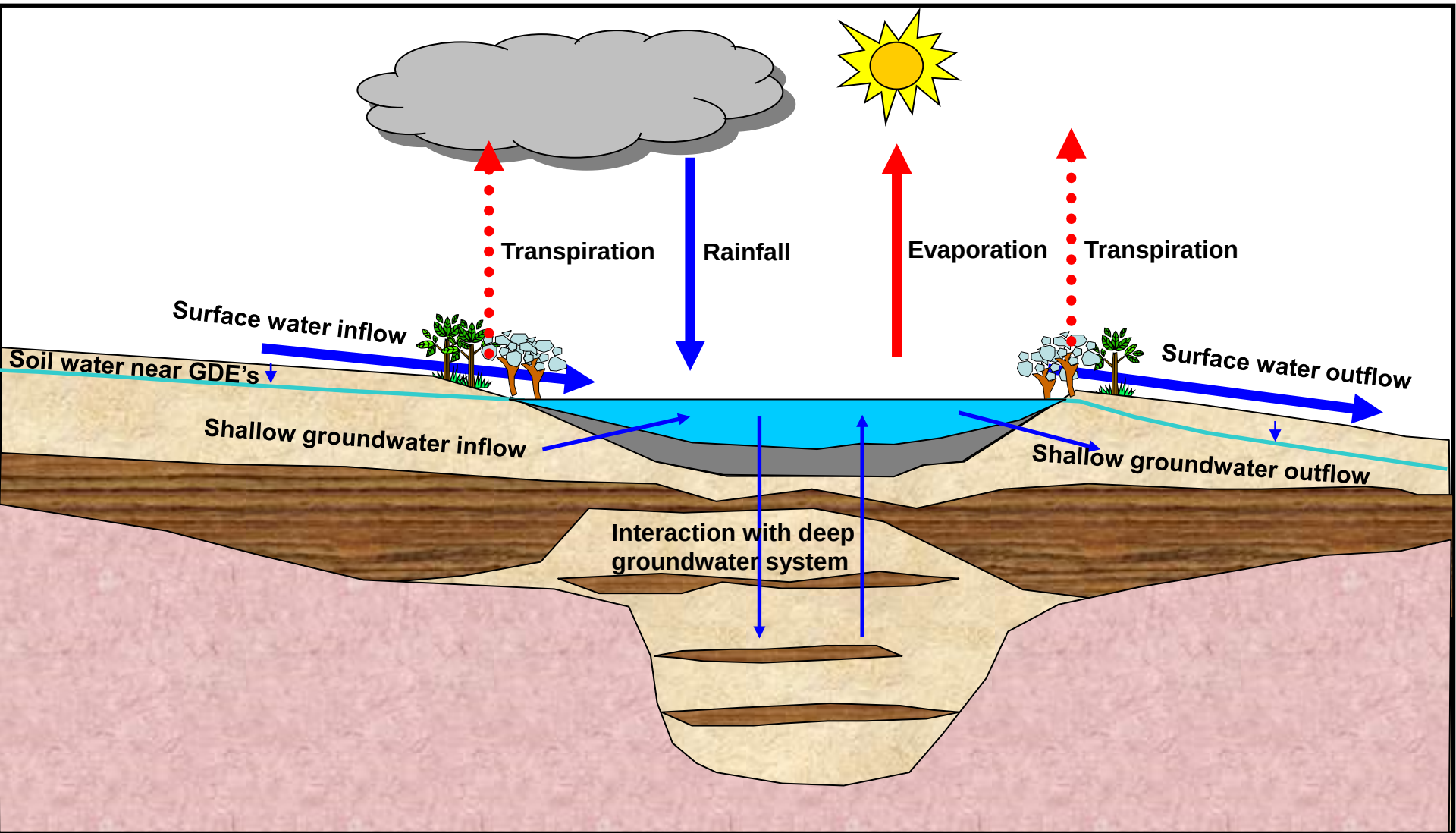
But also how the movement of that water will react with sediments including;

A – precipitation and dissolution.

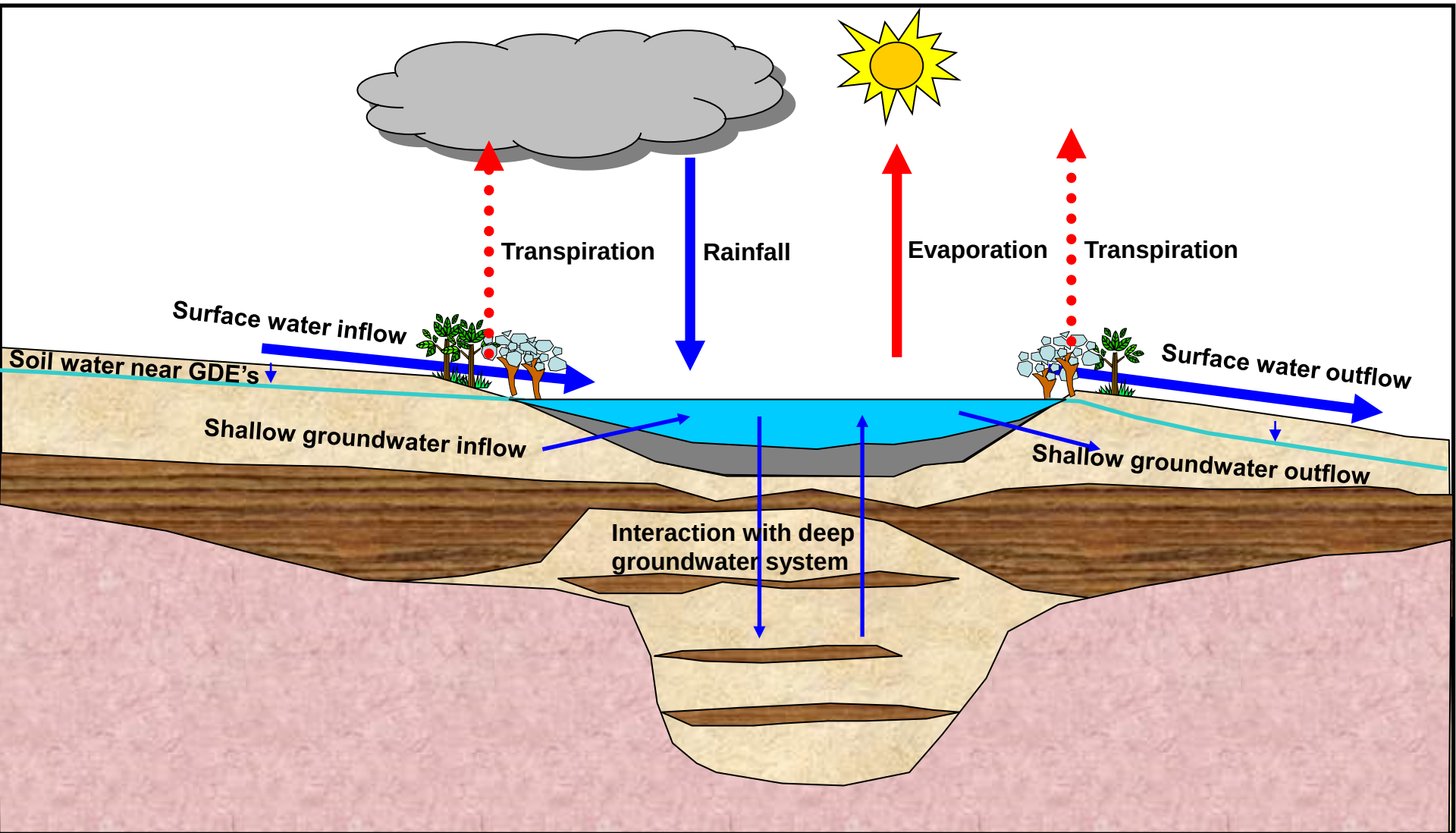
B – erosion and deposition.

C – acid sulphate soil oxidation due to drainage.

D – adsorption, desorption and eutrophication.



This will allow us to develop models (conceptual and numerical) which, when combined with a detailed understanding of the biosphere, will allow us to predict the level of impact or mitigation of various management regimes, i.e. drains, pumping, other engineering solutions, recharge decreases due to re-vegetation etc.



Policy and Management

- Regulations are lagging behind need
- Recent events have shown that even groundwater sustainability is not understood, let alone the complexities of the coupled system

General Principles for Policy

1. We understand that groundwater and surface water are usually interconnected and interchangeable
   - GW becomes SW, and SW becomes GW
2. Not recognised
   - results in double accounting and double allocation
3. Not recognised because of long time lag
   - commonly decades
4. Major growth of GW uses in 1980s and 1990s not yet felt
5. In many parts of Australia we have capped SW, but can still drill a bore on the banks of a river and call it GW and get it licensed

Evans, 2005

General Principles (cont)

6. As distance between bore and river increases, the time delay is proportional to d^2
   ie 10 X increase in distance = 100 X time delay
7. Depending upon hydrogeological features, it may be argued that all groundwater use in a catchment results in reduced stream flow, ie 100% impact, except:
   - discharge to ET
   - discharge to oceans
   - flow to another groundwater system
   - disconnected streams
   - recharge to deep system

Evans, 2005

Summary

1. Freshwater is rare and precious and should not be squandered
2. Numerous types SW/GW interactions exist, generally some site specific information is required to understand the interactions in any detail
3. SW/GW interactions change through time and space. Get a few years worth of data before making any real management decisions
4. Water balances are a good preliminary tool for assessing management feasibility
5. Lack of understanding of groundwater surface water interaction has led to potentially large scale “double allocation” in Australia

References

Evans, R. 2005. *Double Accounting of Surface Water and Groundwater Resources*
The Tyranny of the Time Lag, SKM.

Winter, T.C. et al. 1998*. Groundwater and Surface Water, A Single Resource, USGS Circular 1139.*