The Global Water Cycle

Introduction

The Cycle

- Fluxes
- Pools

The water cycle in the future

Table 6-3 Reservoir turnover times

Reservoir	Volume (km^3)	Avg. turnover time
Oceans	1.338×10^9	2640 yrs
Cryosphere	24.1×10^6	8900 yrs
Groundwater/permafrost	23.7×10^6	515 yrs
Lakes/rivers	189 990	4.3 yrs
Soil moisture	16 500	52 days
Atmosphere	12 900	8.2 days
Biomass	1120	5.6 days

From: Jacobson, Charlson, Rodhe & Orians 2000. Earth Syst. Sci.

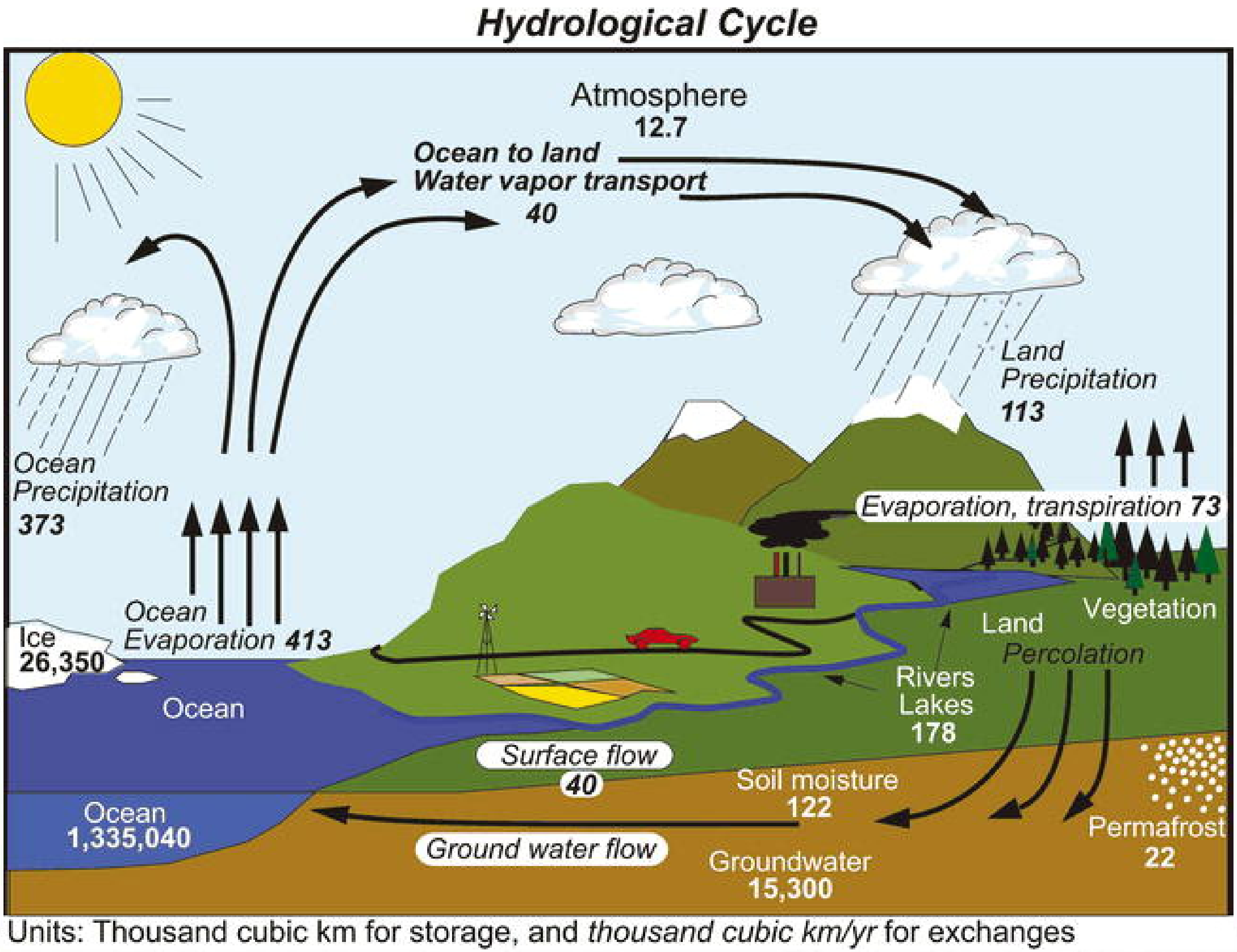


FIGURE 10.1 The global hydrologic cycle, with pools in units of 10^3 km^3 and flux in 10^3 km^3/yr. *Source: Modified from Trenberth (2007). Used with permission of the American Meteorological Society.*


Missouri
River
Mississippi
Illinois R.
Wabash R.
Ohio
River
Cumberland R.
Tennessee R.
Arkansas
River
White R.
Red
River
Mississippi
Delta
550 m3/s
1400 m3/s
2800 m3/s
4250 m3/s
8550 m3/s
0
500km

Fluxes of the Global Water Cycle

Transpiration: the process of evaporation of water from moist plant surfaces (e.g., leaves).

Latent heat of evaporation: the amount of heat required for a unit amount of liquid to evaporate under certain temperature and pressure. For example, it will take approximately 2260 J (590 calories) of heat to evaporate 1 gram of water under 15 degree Celsius at 1 atmospheric pressure.

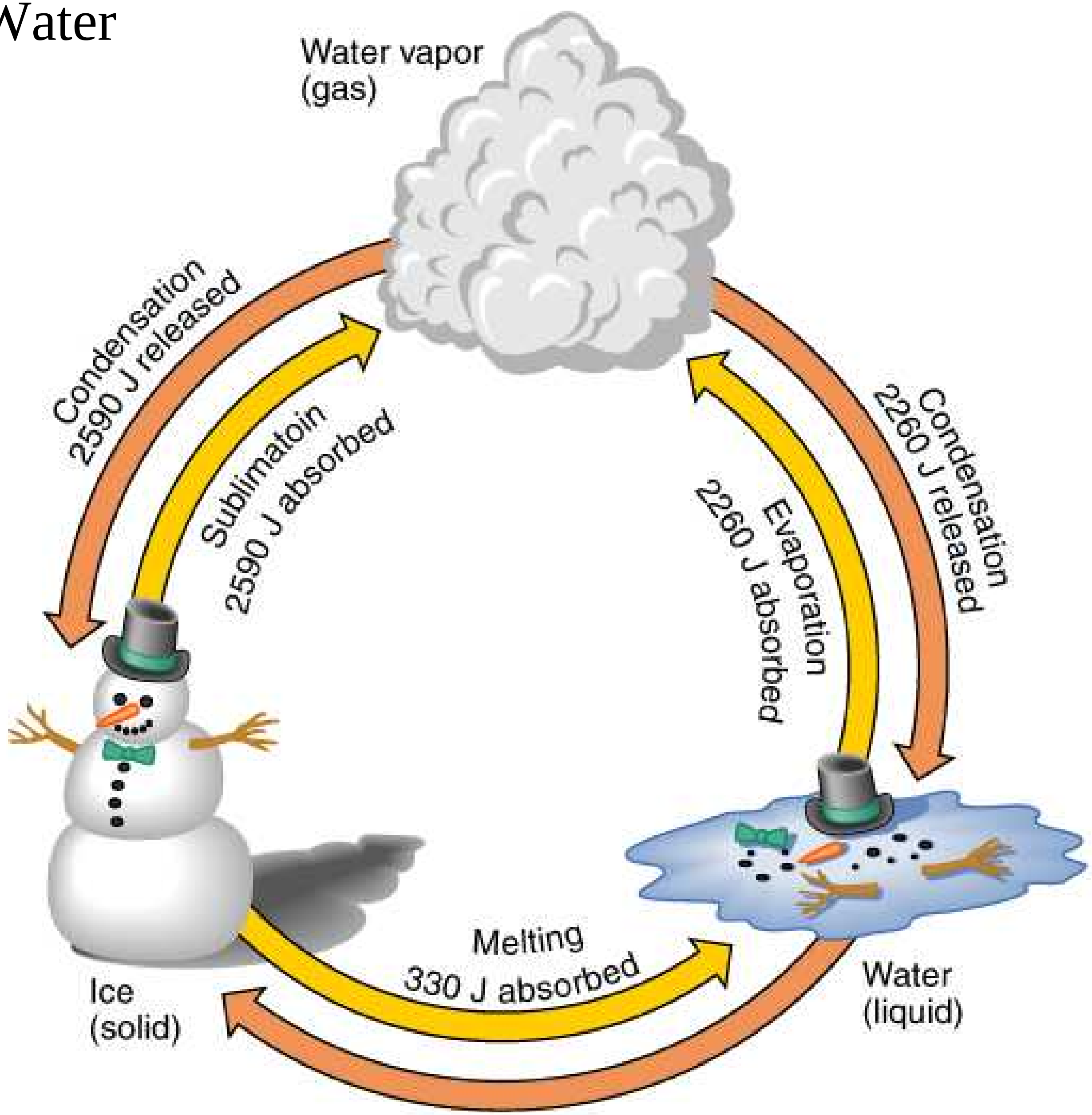
Water **evaporation** is the fastest under warm temperature, dry air, windy, and low pressure. Warm air can hold much more water vapor than cold air because high temperature increase the water vapor holding capacity or the saturation level.

Humidity is a measurement of water vapor content in the air, often expressed as water vapor pressure for absolute humidity. Whereas relative humidity is expressed as a percentage of saturation humidity at a particular temperature and pressure.

Dew Point: the juncture at which any further cooling results in the deposition of water vapor onto convenient surfaces, generally the very small atmospheric particles that serve as condensation nuclei. The small droplets formed by this condensation process grow by further water vapor accretion to form clouds in the air.

Precipitation includes all forms of water falling onto Earth's surface.

Latent Heat of Water



At Hubbard Brook

At Andrews Forest

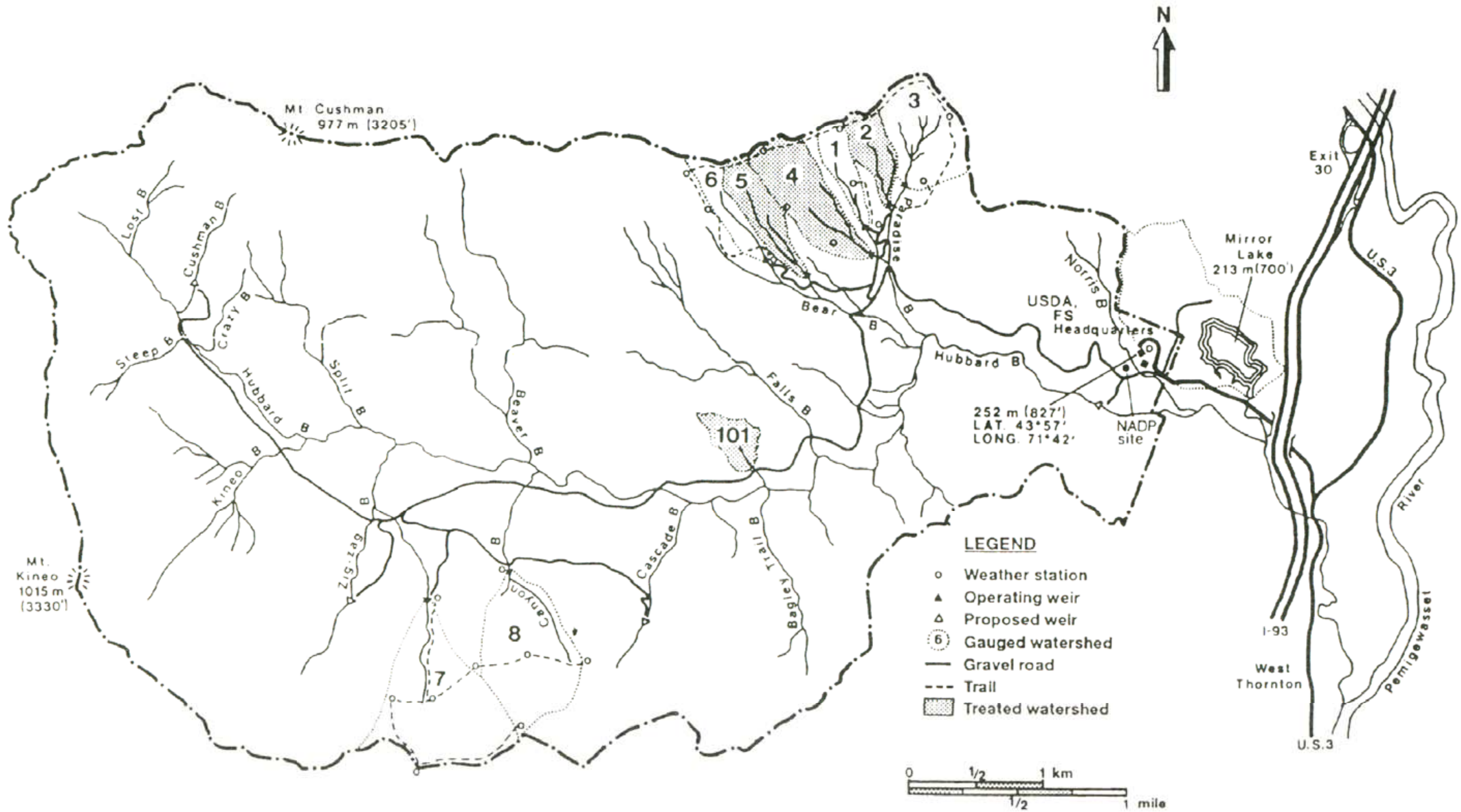


FIGURE 2. Hubbard Brook Experimental Forest, West Thornton, New Hampshire, USA.

Likens & Bormann 1995

Likens & Bormann 1995

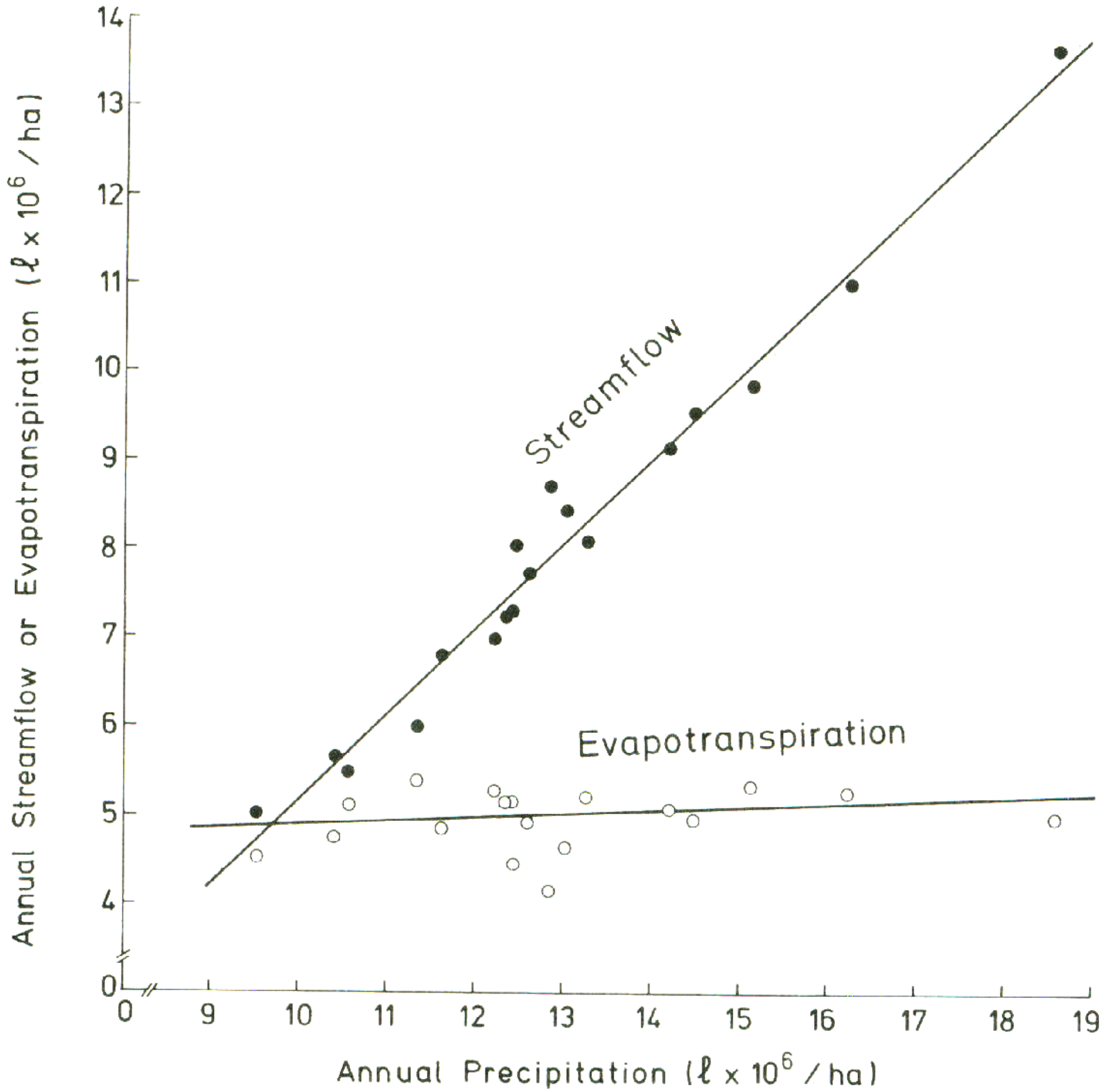


FIGURE 7. Relationship among precipitation, streamflow, and evapotranspiration for the Hubbard Brook Experimental Forest during 1956–1974. The regression lines fitted to these data are $Y = b + ax$, where Y = annual streamflow or evapotranspiration in 10^6 l/ha, b = Y intercept, a = slope, and x = annual

Likens & Bormann 1995

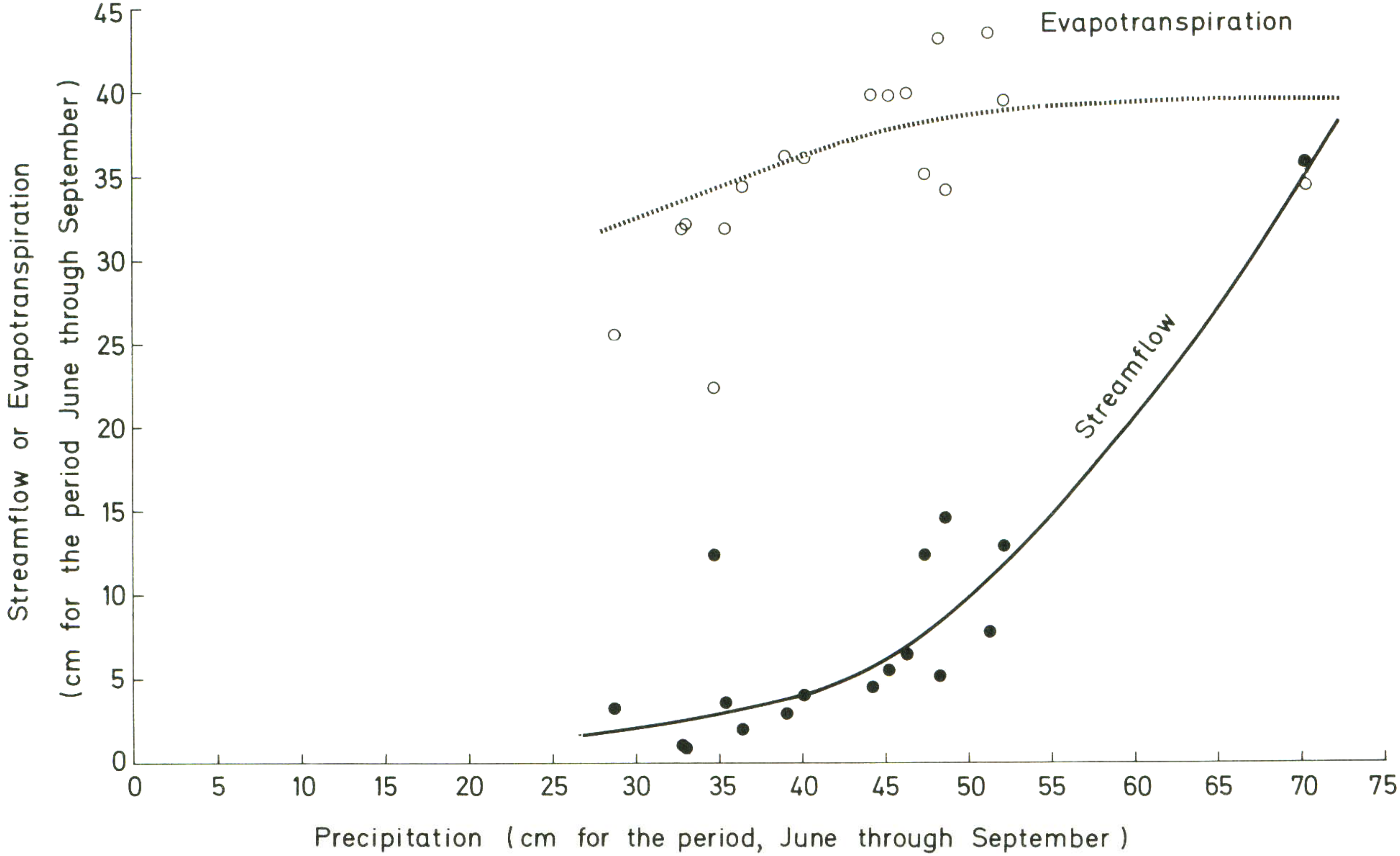


FIGURE 8. Relationship among precipitation, streamflow, and evapotranspiration during the months of June through September for Watershed 3 of the Hubbard Brook Experimental Forest during 1958–1974. Evapotranspiration (open circles) is determined as the difference between the amount of precipitation and streamflow for 1 June to 30 September. The solid line is fitted by eye. The dashed line

The Cryosphere--the world of frozen water in ice, snow and frozen ground, making up approximately 2% of the water on Earth.

The Cryosphere fluctuates through geologic time (glaciation vs. deglaciation).

Glacial ice sheets found in Greenland (can be 3 km in thickness) of the north and Antarctica (3.6 km or more in maximum thickness) of the south currently makes 95% of the total cryosphere.

Glacial ice sheets are the main regulators of global sea level. If all the ice sheets would melt, the sea level would rise up 60 meters.

Polar snow fall and polar temperature are the two most important regulators of glacial ice sheets.

Snow and ice on high mountains are important fresh water resources such as the ones in Sierras.

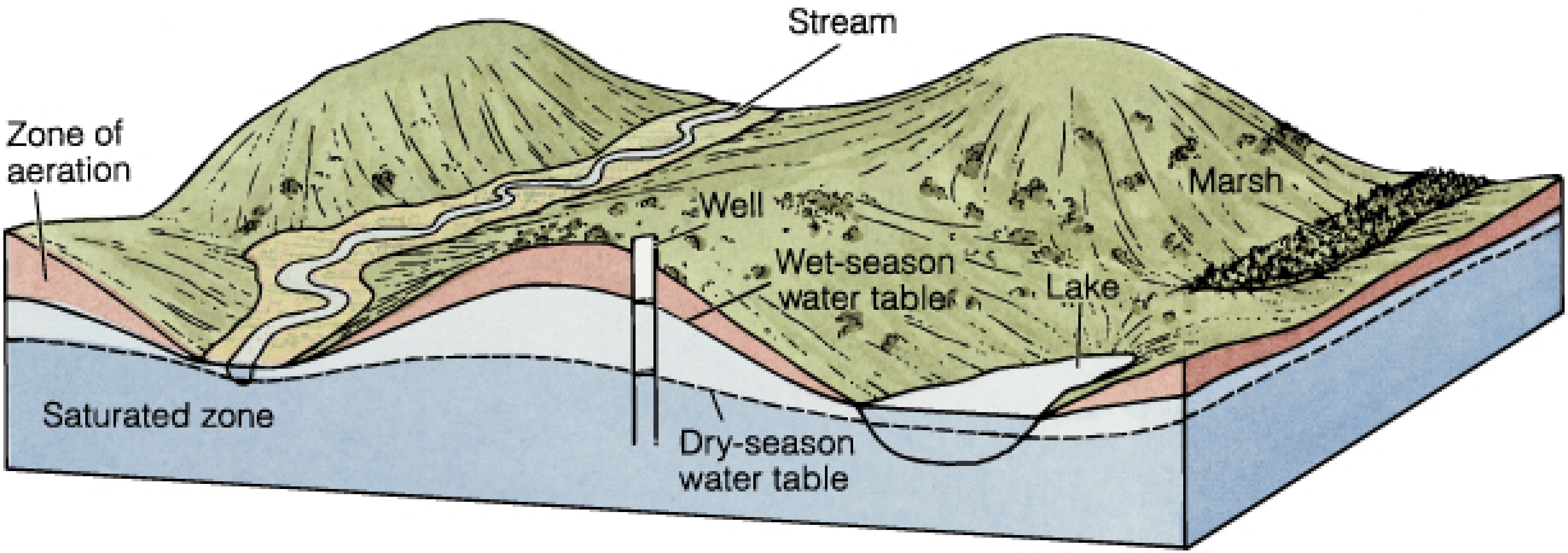
Groundwater

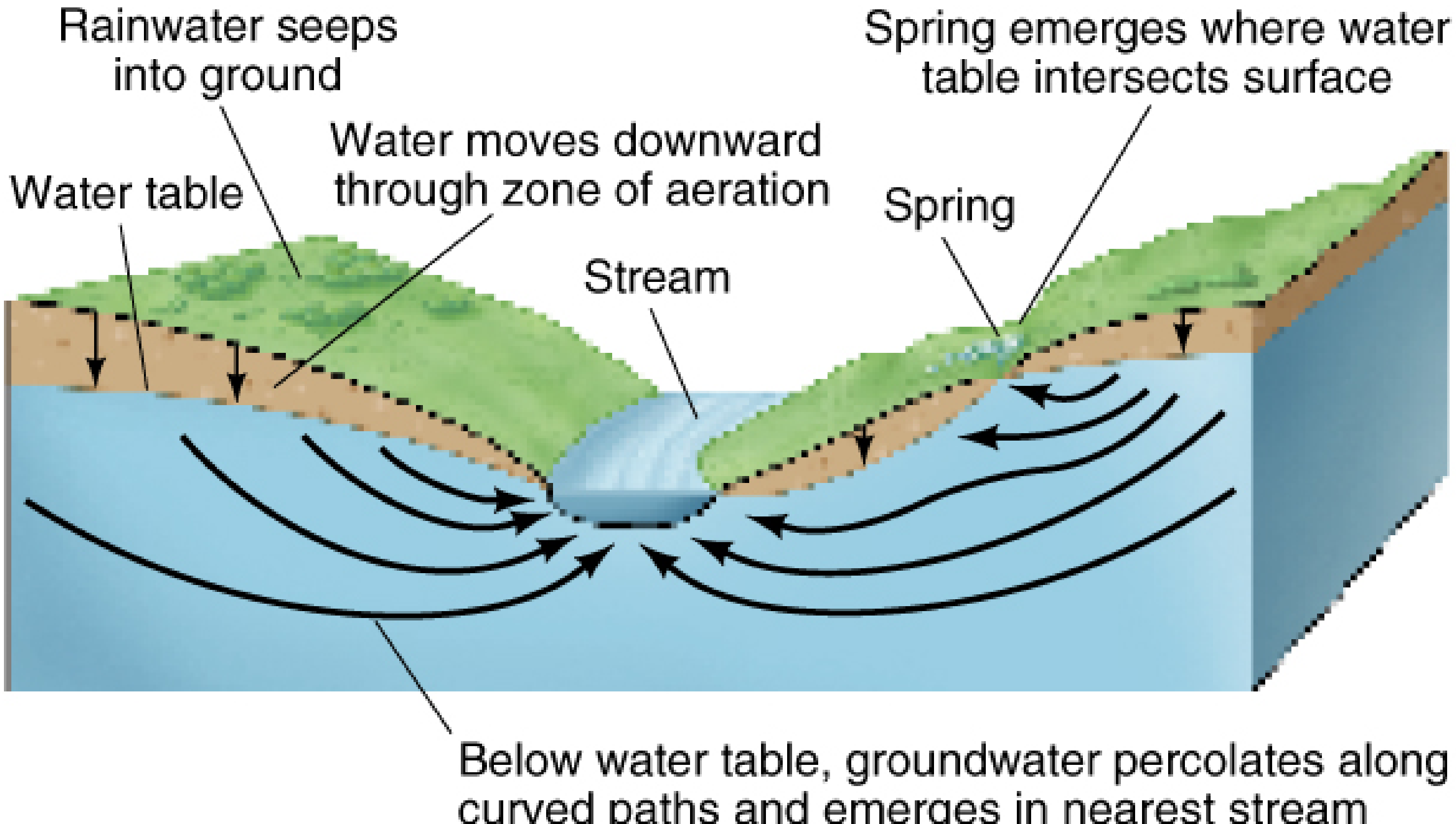
Approximately 0.68% in the hydrosphere is found in groundwater, which has a range of turnover time from 300 years (active) to 5000 years (deep, inactive). Groundwater occurs mostly within 750 meters below land surface.

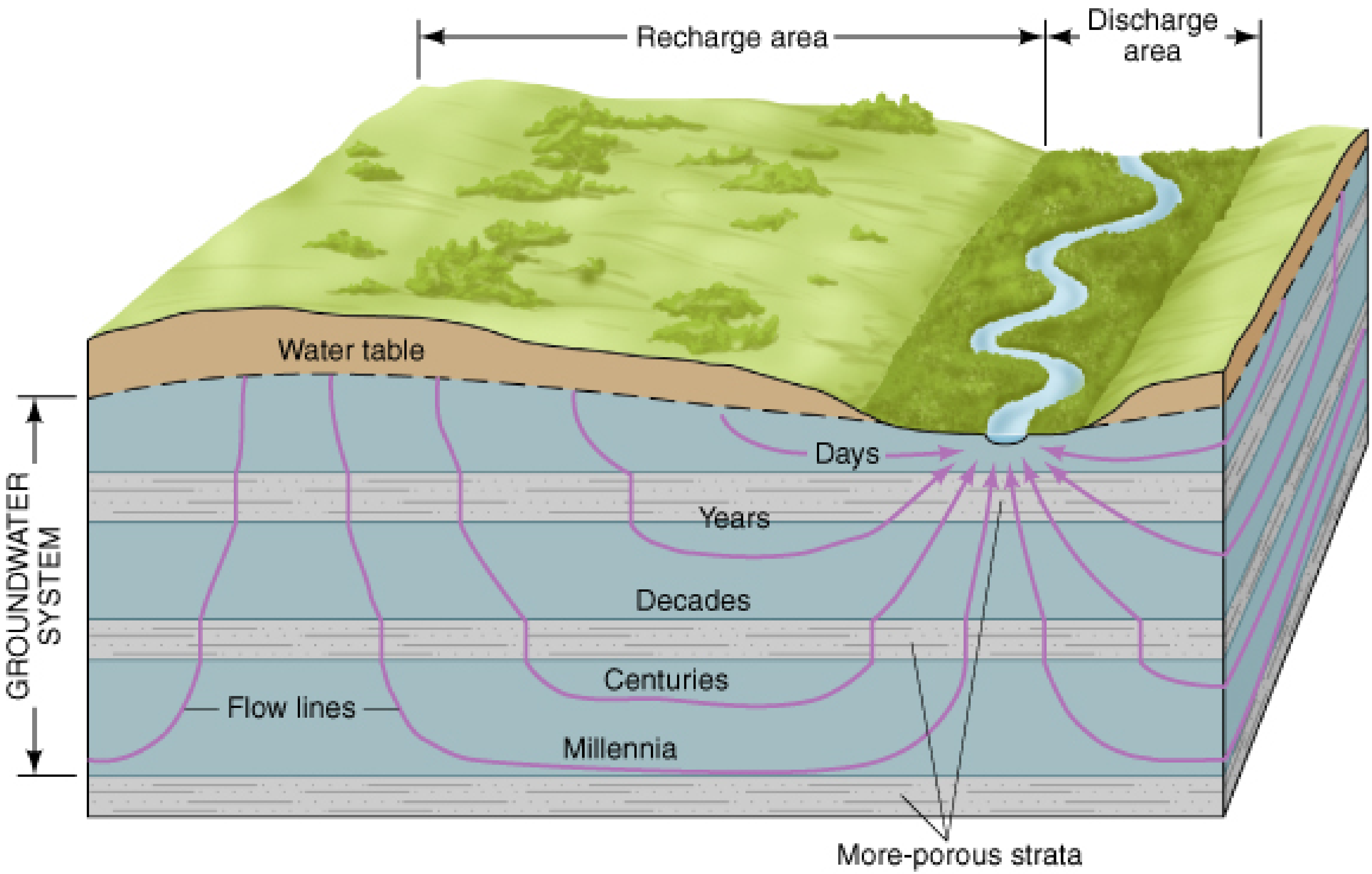
Some basic vocabulary of hydrology:

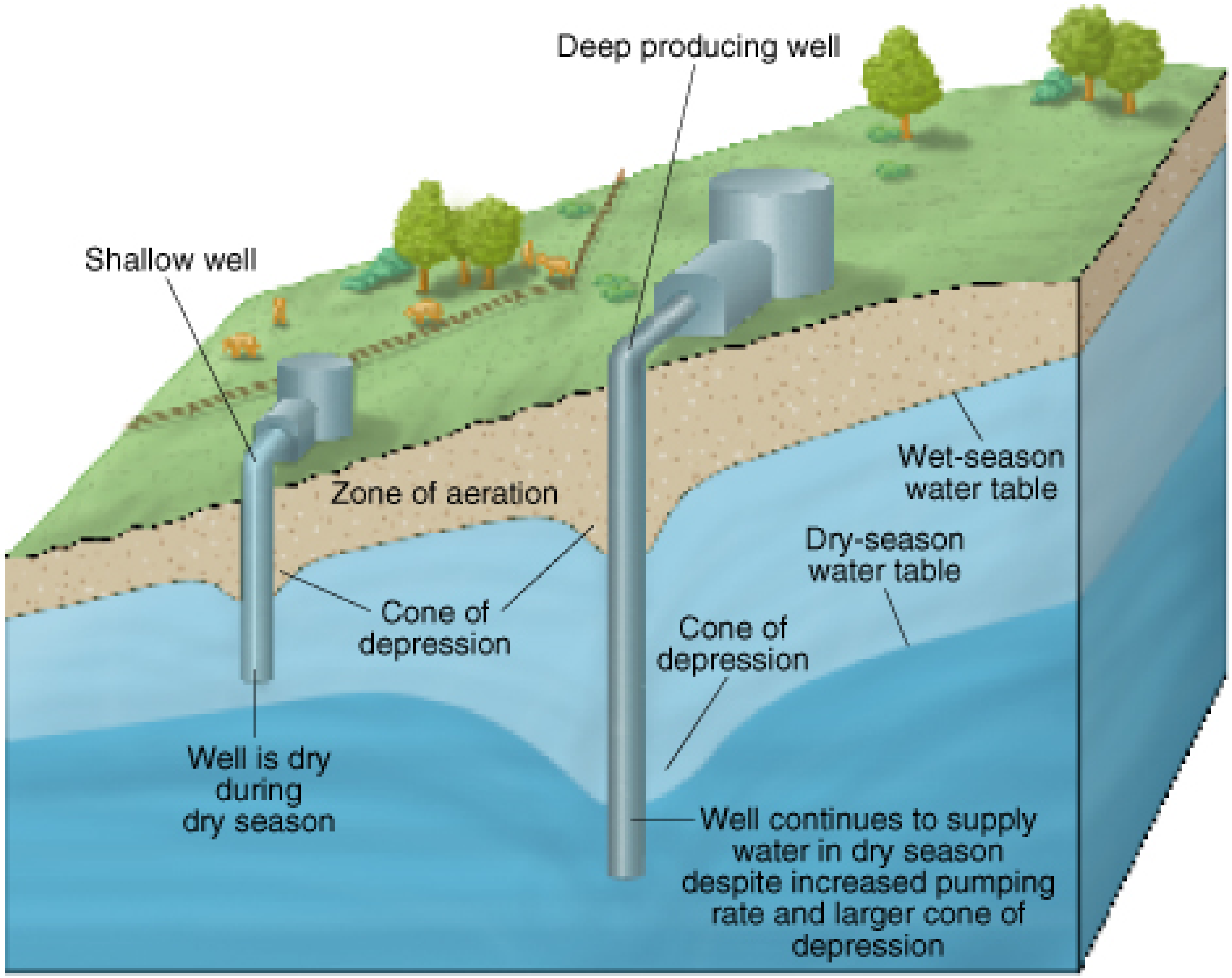
Water table or **phreatic surface** is the upper limit of saturation in an unconfined body of ground water. It separates the **vadose zone** above, which is normally unsaturated, from the saturated **phreatic zone** below. Rocks/regolith holding ground water are called **aquifers**. Rocks that hold and transmit very little water are called **aquicludes**.

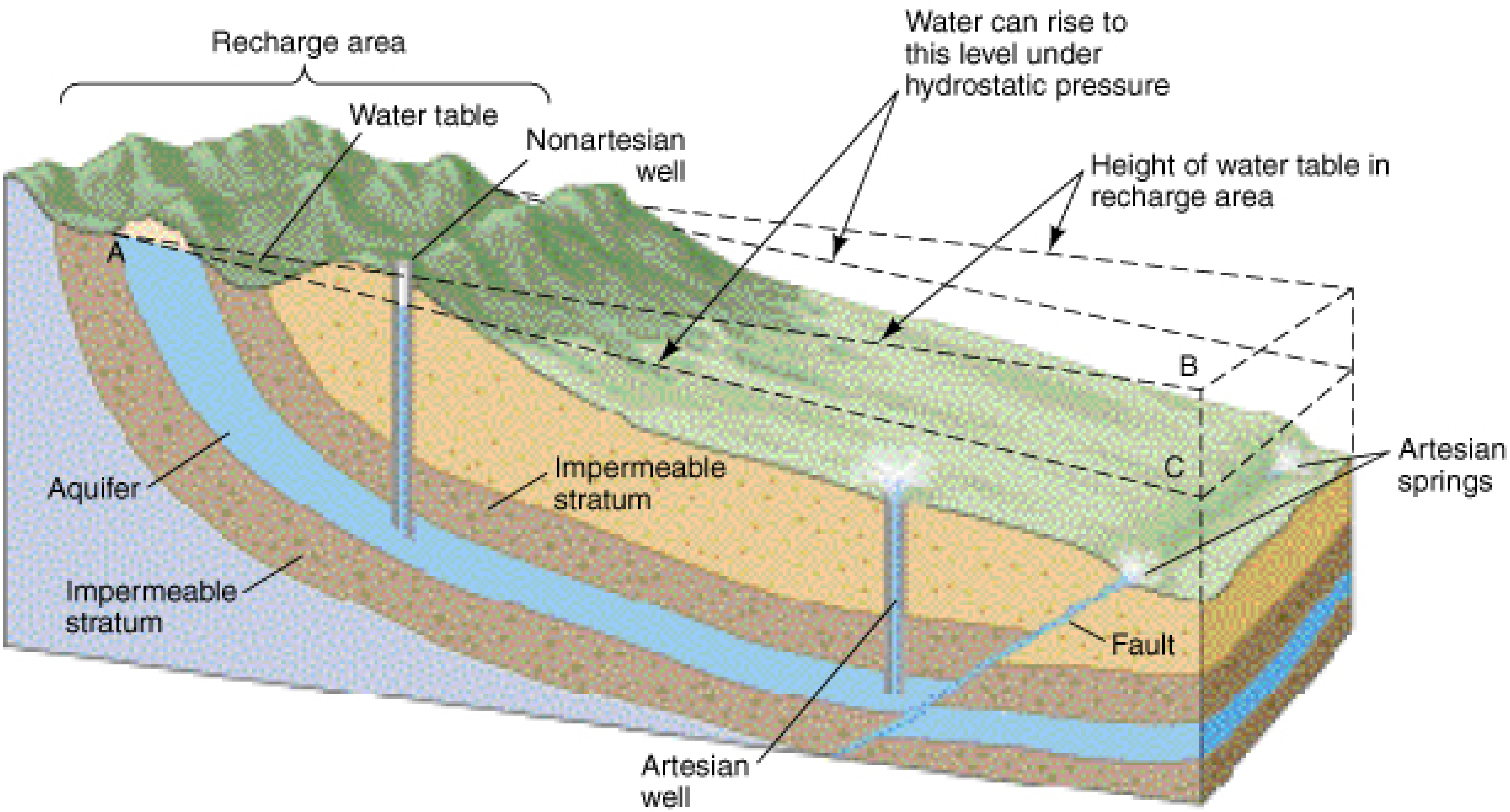
There are many factors involved in groundwater storage. Some of the main ones are: (1) the balance of precipitation and total loss from evapotranspiration; (2) vegetation and surface properties; (3) soil infiltration; (4) topography; (5) geology; and (6) human usage and disturbance.


Stream
Zone of aeration
Well
Marsh
Wet-season water table
Lake
Saturated zone
Dry-season water table


Rainwater seeps into ground
Water table
Water moves downward through zone of aeration
Stream
Spring
Spring emerges where water table intersects surface
Below water table, groundwater percolates along curved paths and emerges in nearest stream


Recharge area
Discharge area
Water table
Days
Years
Decades
Centuries
Millennia
Flow lines
GROUNDWATER SYSTEM
More-porous strata


Deep producing well
Shallow well
Zone of aeration
Wet-season water table
Dry-season water table
Cone of depression
Cone of depression
Well is dry during dry season
Well continues to supply water in dry season despite increased pumping rate and larger cone of depression


Recharge area
Water table
Nonartesian well
Water can rise to this level under hydrostatic pressure
Height of water table in recharge area
A
B
C
Aquifer
Impermeable stratum
Impermeable stratum
Artesian springs
Fault
Artesian well

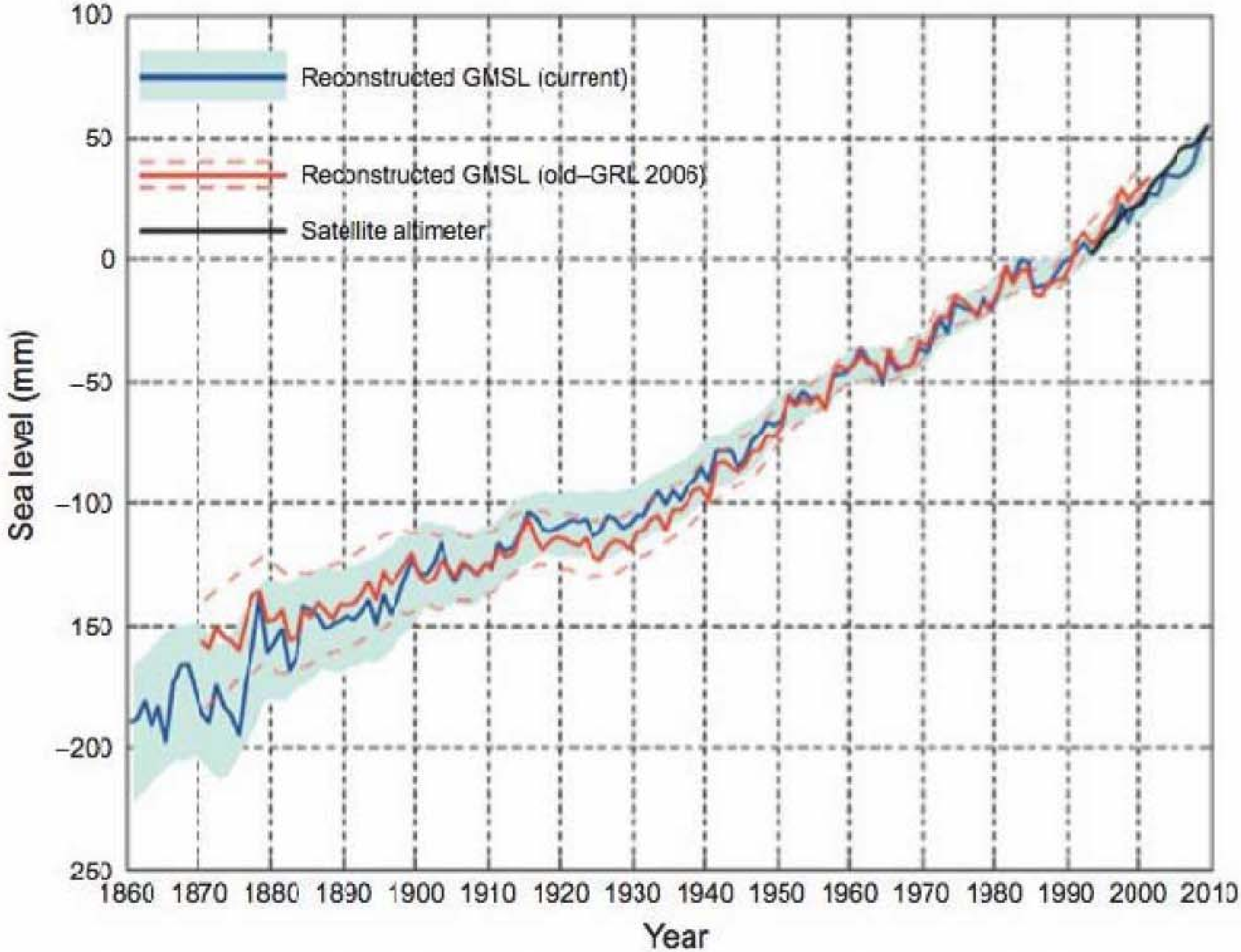


FIGURE 10.7 Global average sea level from 1860 to 2009. *Source: From Church and White (2011). Used with permission of Springer.*

Sea level in the future?

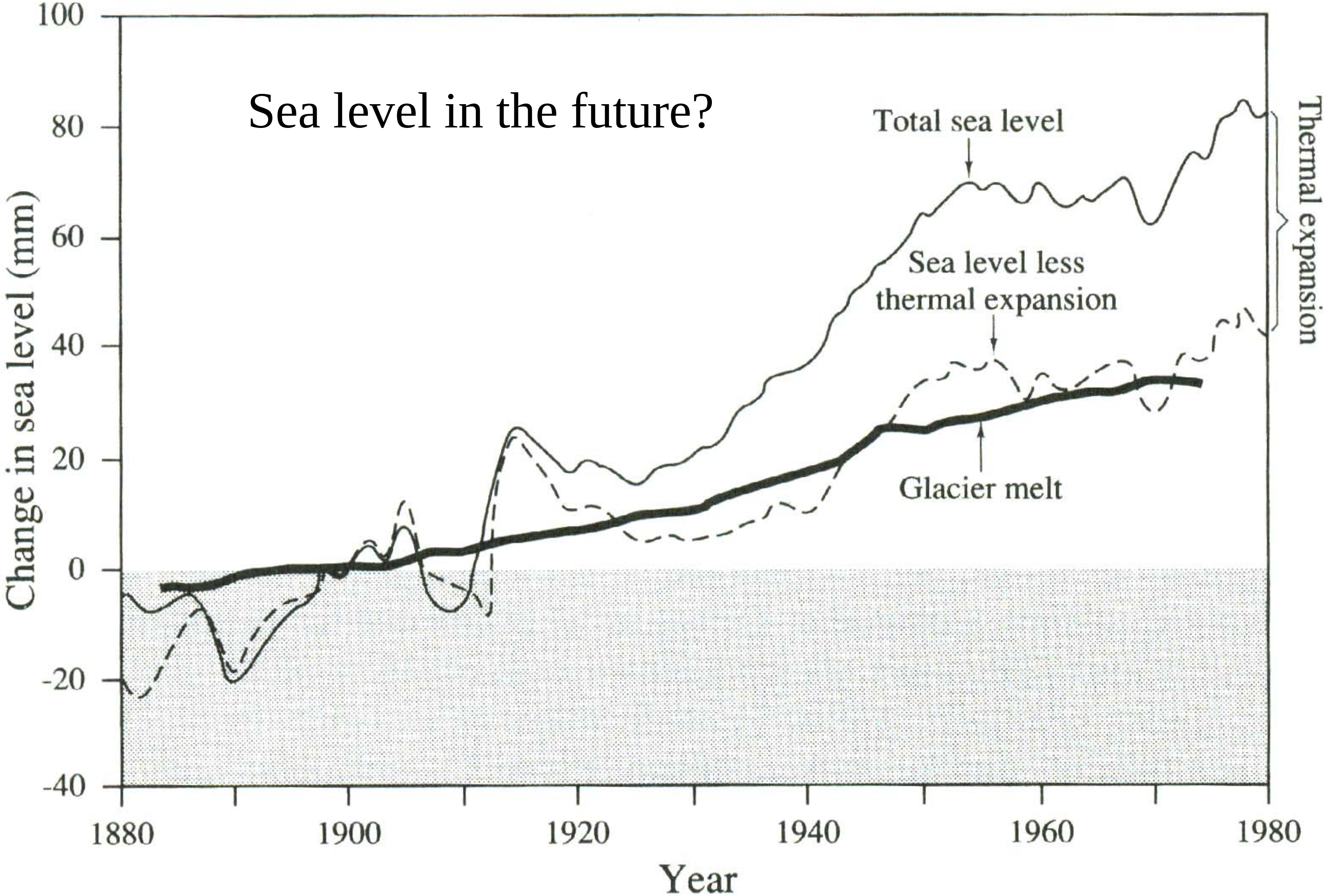


Figure 10.3 Changes in sea level during the last century (Gornitz et al. 1982), indicating the proportion due to thermal expansion of the oceans and that due to melting of glaciers. From Jacobs (1986), after Meier (1984). Copyright 1984 by the AAAS.

From: Schlesinger 1997.