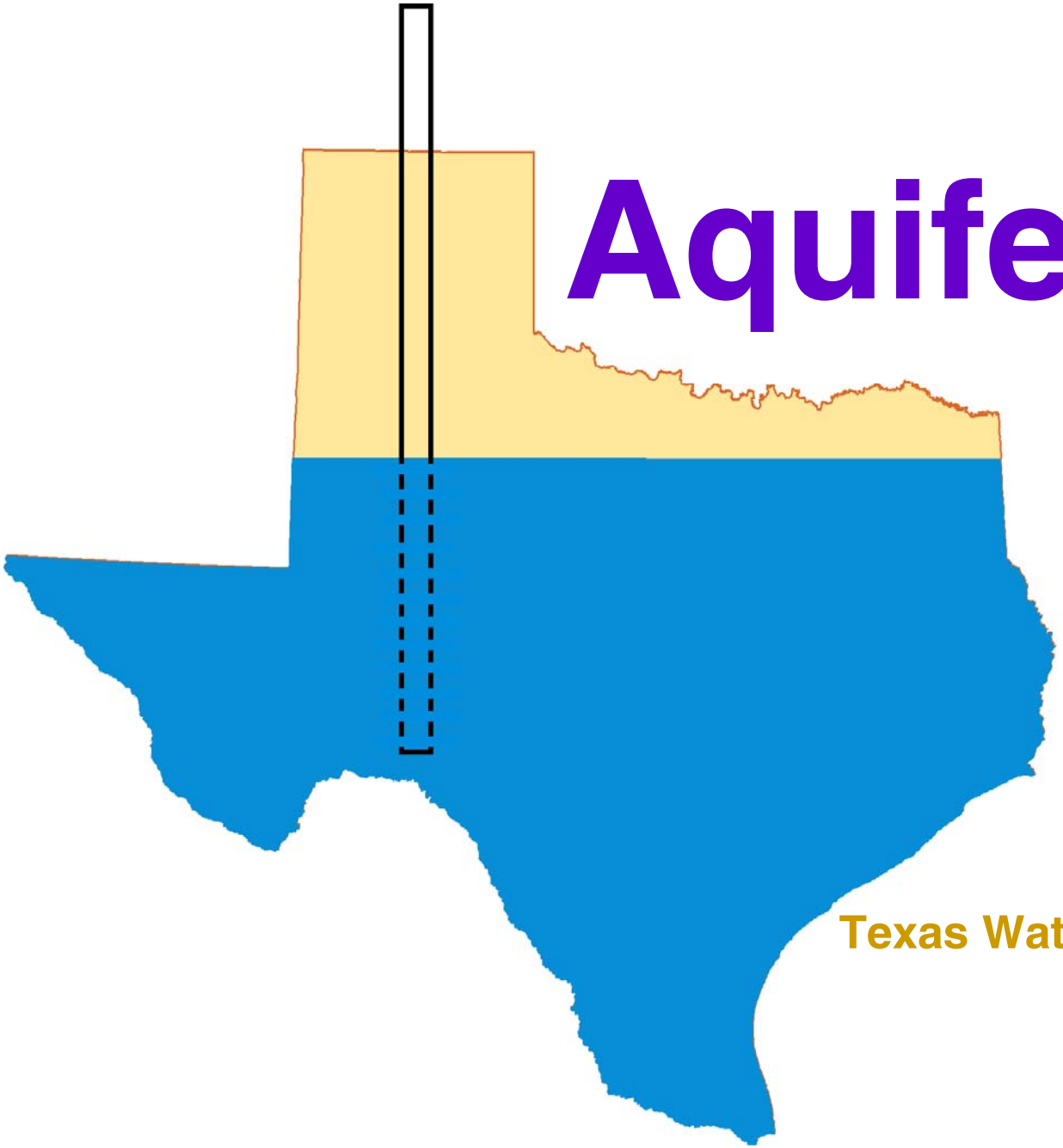
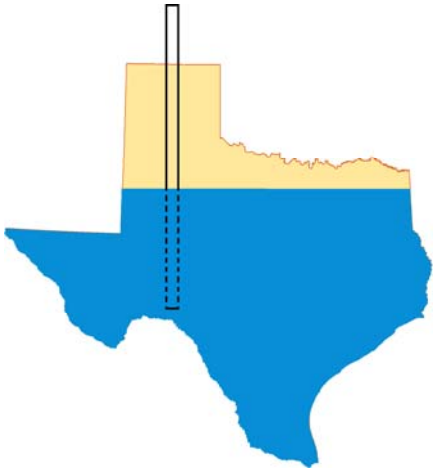


Aquifers 101

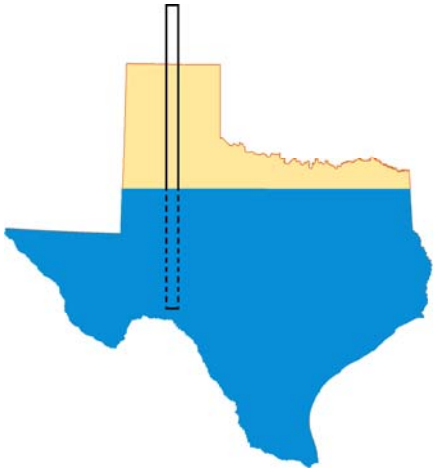
Robert E. Mace
Texas Water Development Board

Groundwater 101
August 12, 2015
Groundwater Summit
Caldwell, Texas



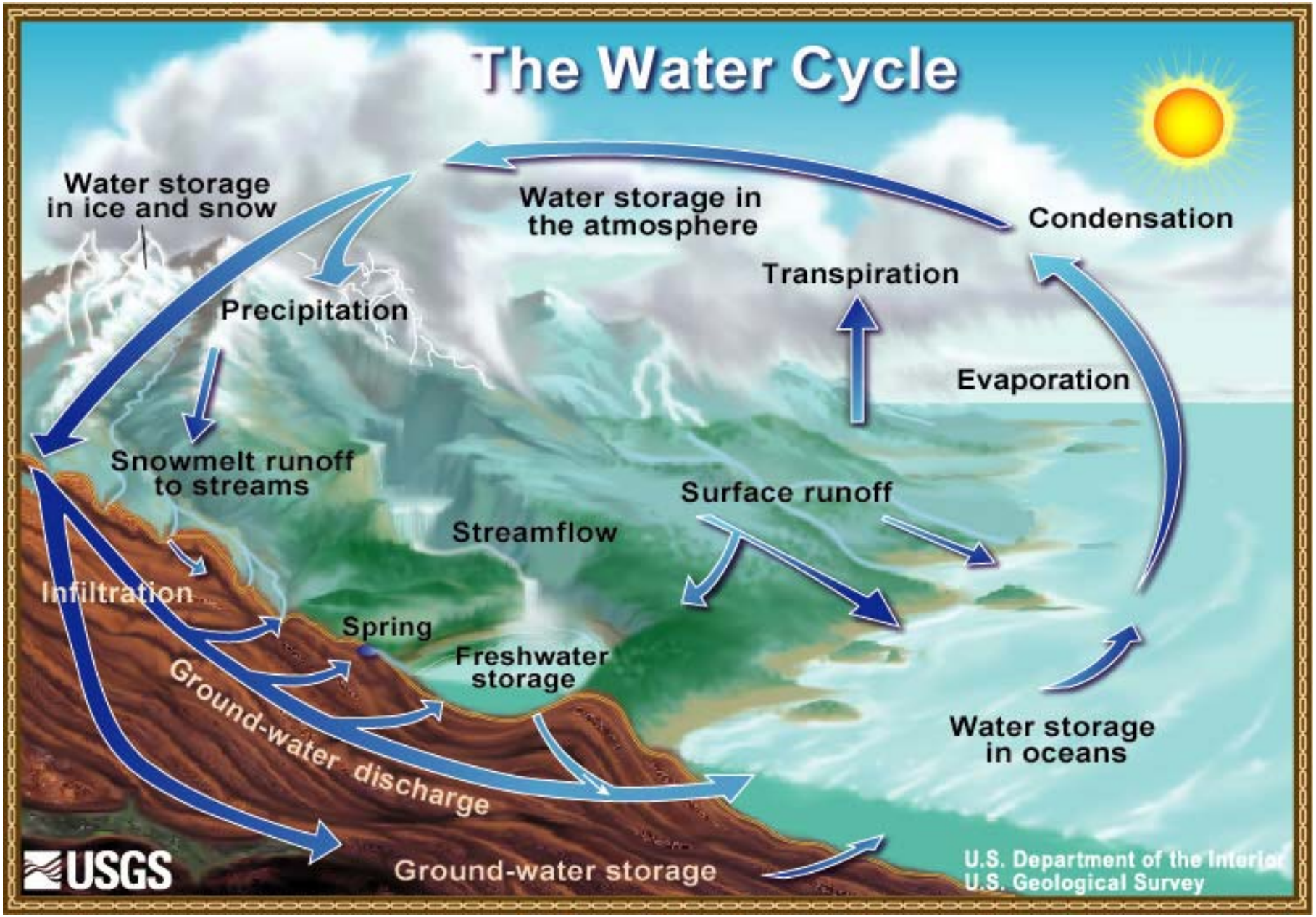
Outline

- Yay for aquifers!
- Definitions
- Flow through an aquifer
- Pumping an aquifer

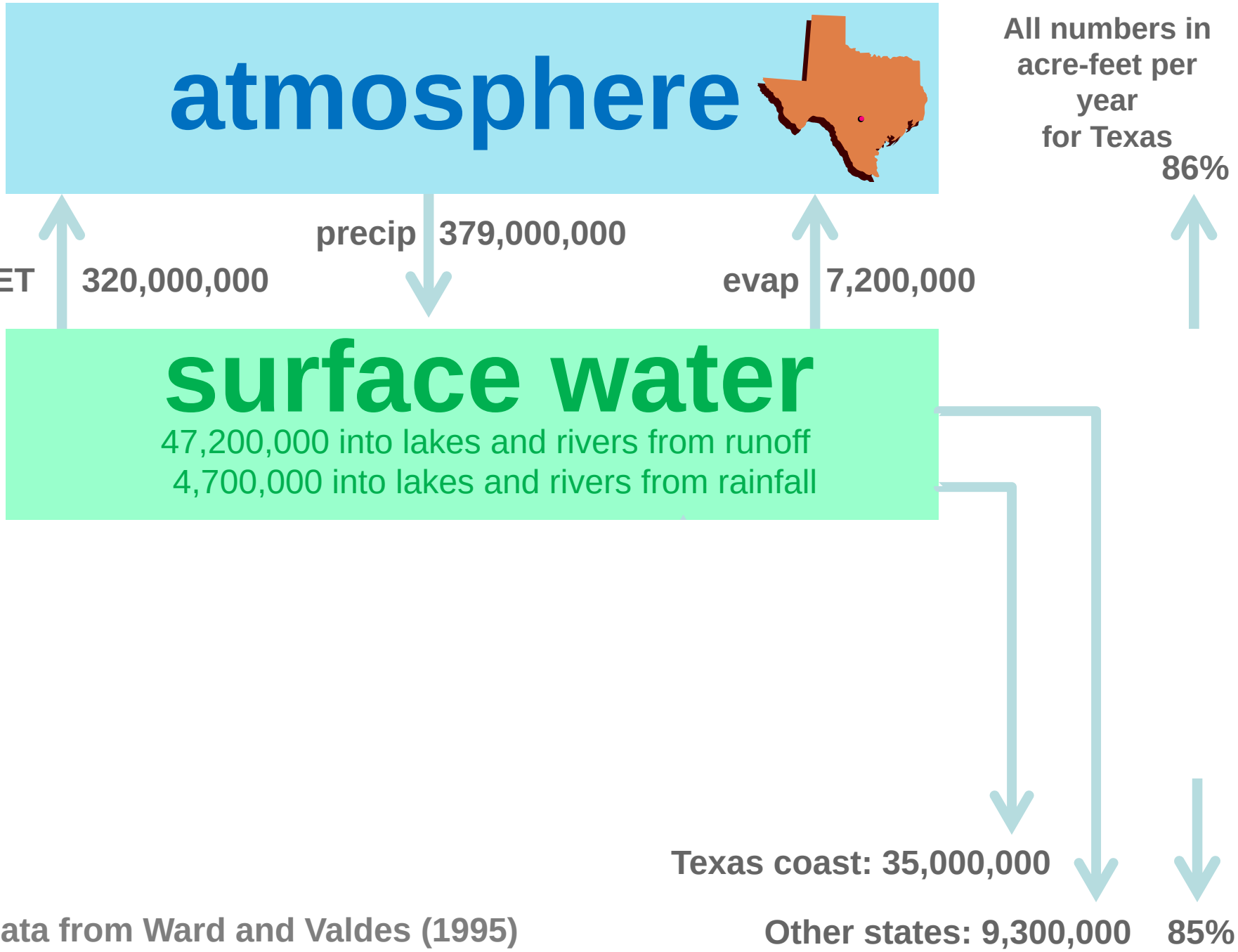


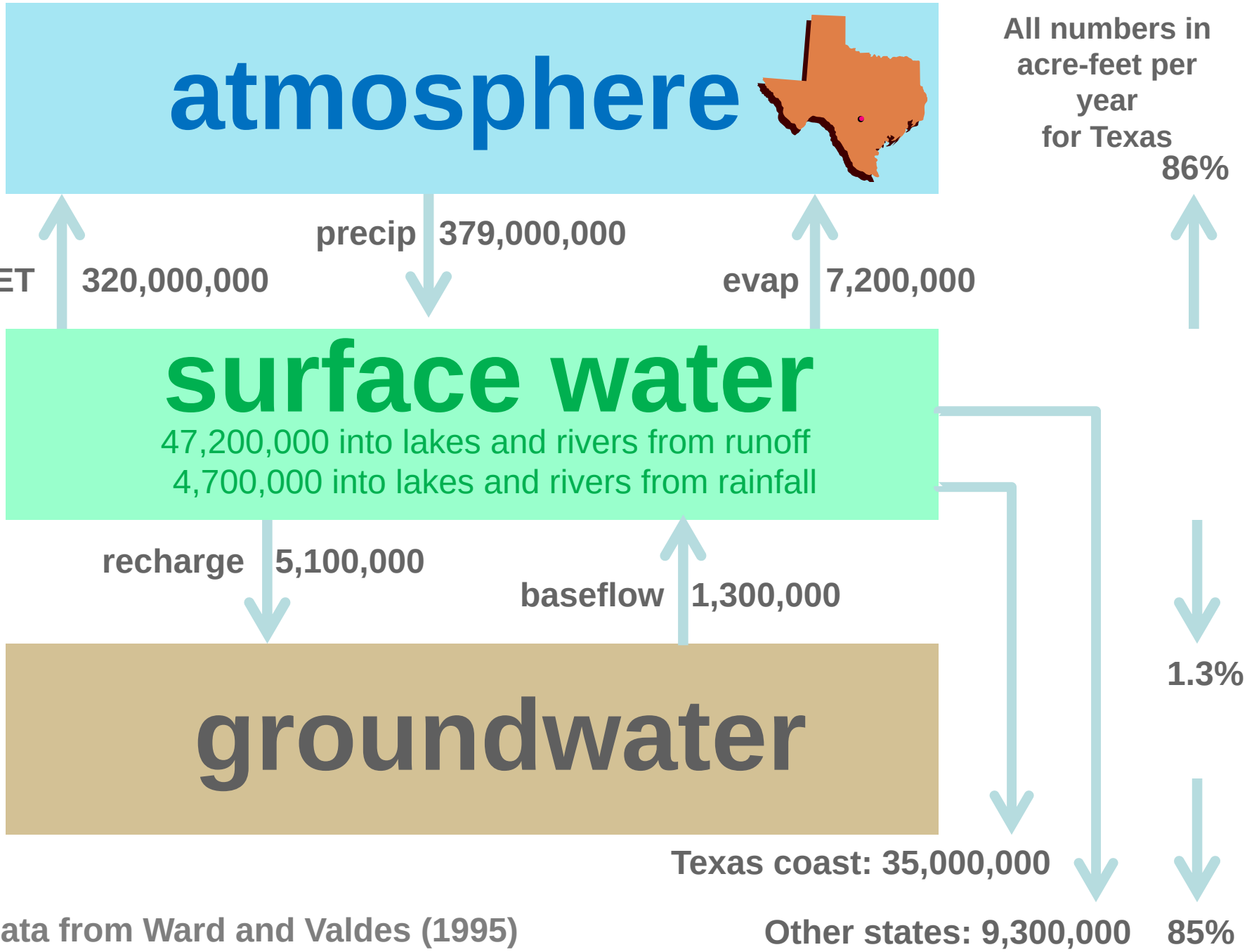
Outline

- **Yay for aquifers!**
- **Definitions**
- **Flow through an aquifer**
- **Pumping an aquifer**


The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Transpiration
Precipitation
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Infiltration
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
USGS
Ground-water storage
U.S. Department of the Interior
U.S. Geological Survey


atmosphere
All numbers in acre-feet per year for Texas
86%
precip 379,000,000
ET 320,000,000
evap 7,200,000


atmosphere
All numbers in acre-feet per year for Texas
86%
precip 379,000,000
ET 320,000,000
evap 7,200,000
surface water
47,200,000 into lakes and rivers from runoff
4,700,000 into lakes and rivers from rainfall
Texas coast: 35,000,000
Other states: 9,300,000
85%
data from Ward and Valdes (1995)


atmosphere
All numbers in acre-feet per year for Texas
86%
precip 379,000,000
ET 320,000,000
evap 7,200,000
surface water
47,200,000 into lakes and rivers from runoff
4,700,000 into lakes and rivers from rainfall
recharge 5,100,000
baseflow 1,300,000
1.3%
groundwater
Texas coast: 35,000,000
Other states: 9,300,000
85%
data from Ward and Valdes (1995)

World Water Balance

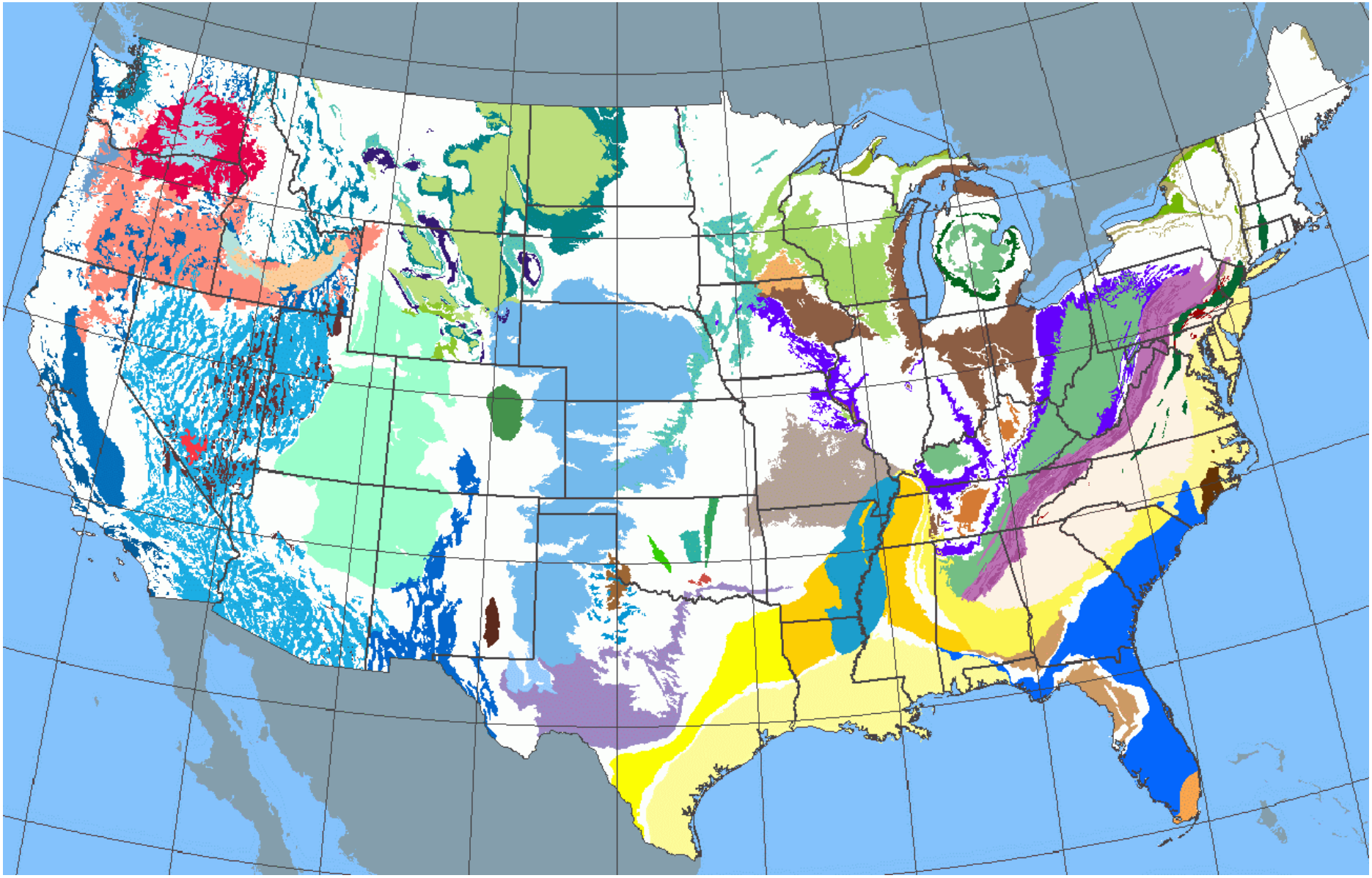
Table 1.1 Estimate of the Water Balance of the World

Parameter	Surface area (km^2) $\times 10^6$	Volume (km^3) $\times 10^6$	Volume (%)	Equivalent depth (m)*	Residence time
Oceans and seas	361	1370	94	2500	~4000 years
Lakes and reservoirs	1.55	0.13	<0.01	0.25	~10 years
Swamps	<0.1	<0.01	<0.01	0.007	1–10 years
River channels	<0.1	<0.01	<0.01	0.003	~2 weeks
Soil moisture	130	0.07	<0.01	0.13	2 weeks–1 year
Groundwater	130	60	4	120	2 weeks–10,000 years
Icecaps and glaciers	17.8	30	2	60	10–1000 years
Atmospheric water	504	0.01	<0.01	0.025	~10 days
Biospheric water	<0.1	<0.01	<0.01	0.001	~1 week

SOURCE: Nace, 1971.

*Computed as though storage were uniformly distributed over the entire surface of the earth.

From Freeze and Cherry (1979)



groundwater and Texas

- ~60 percent of the 16.6 million acre-feet of water used
- ~80 percent of groundwater is used for irrigation
- groundwater provides 39 percent of water to cities
- tastes good when yer thirsty

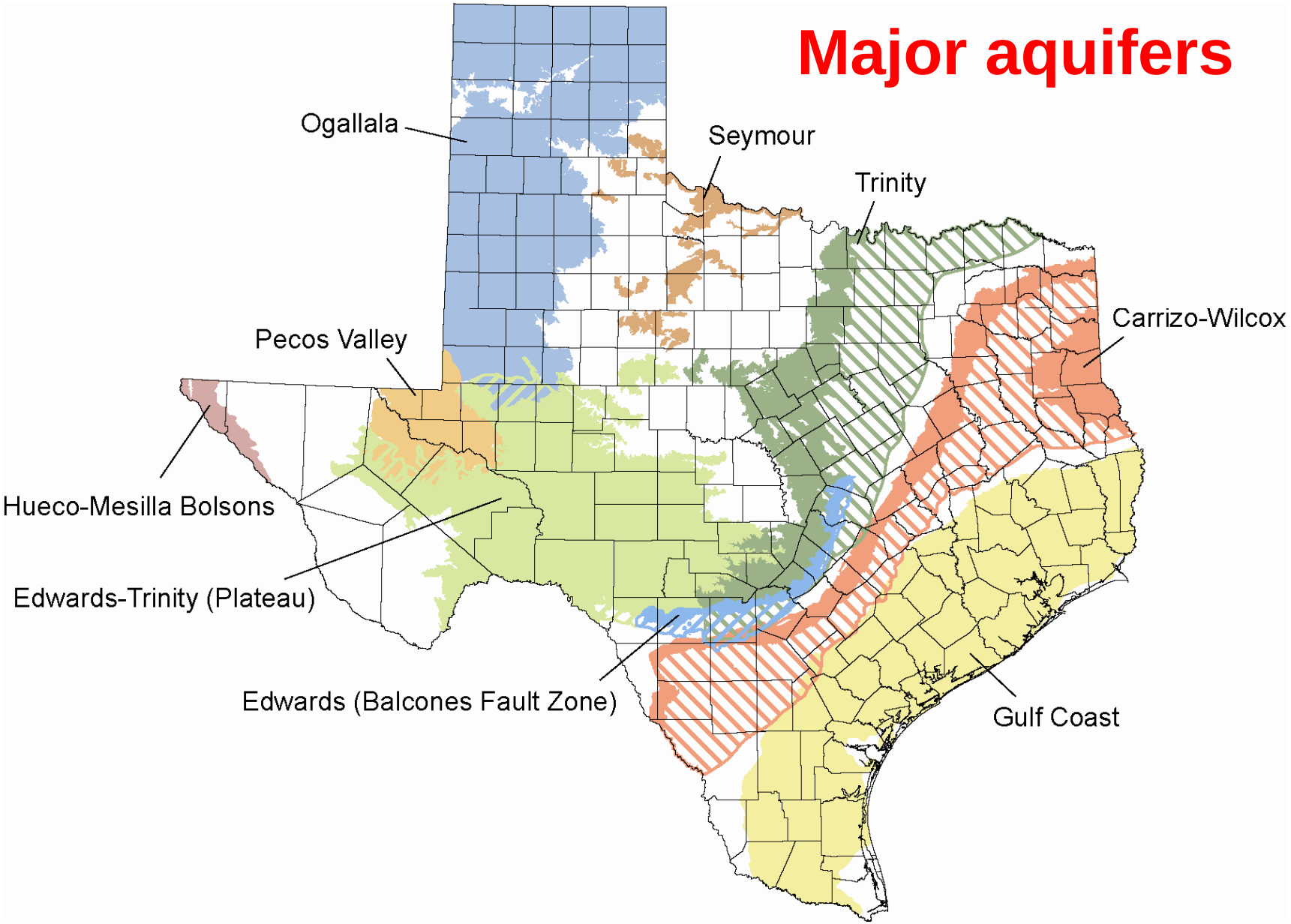
austin chalk

catfish farm well
Edwards aquifer

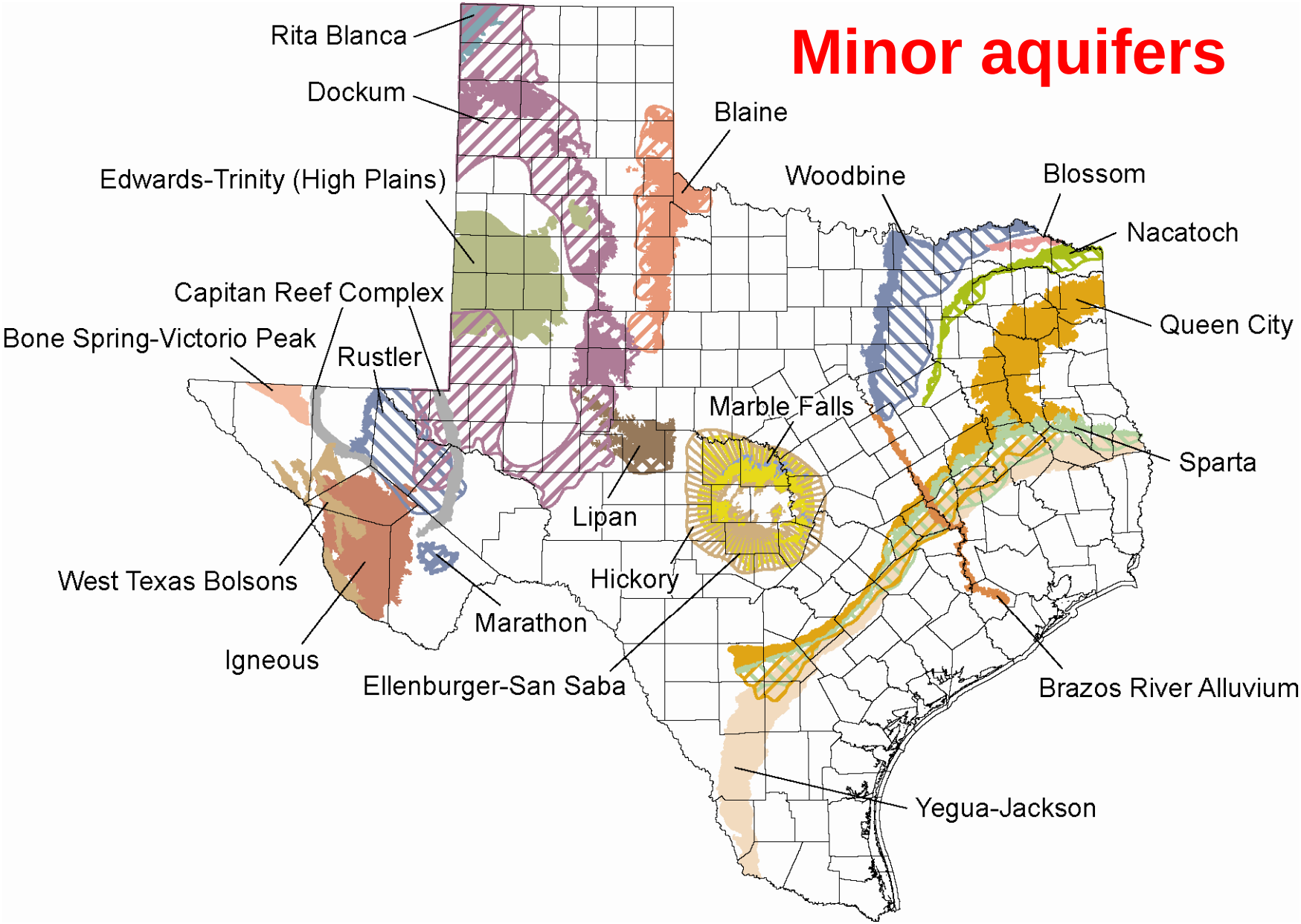
- **flowing well at 40,000 gpm**
- **1/4 of San Antonio's use**
- **9% of Annual Recharge**
- **world's largest artesian well**

National Geographic (1993)

Major aquifers



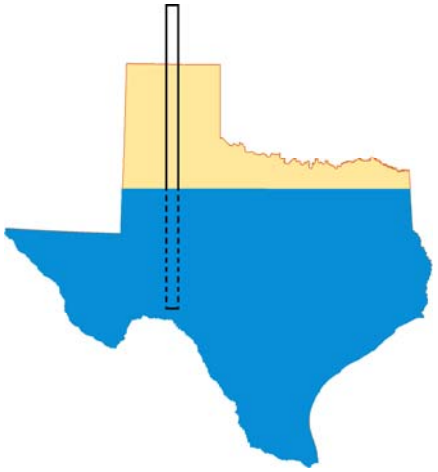
Minor aquifers



Hickory Aquifer, sandstone

Edwards-Trinity (Plateau) Aquifer, limestone

Ogallala Aquifer, sand and gravel



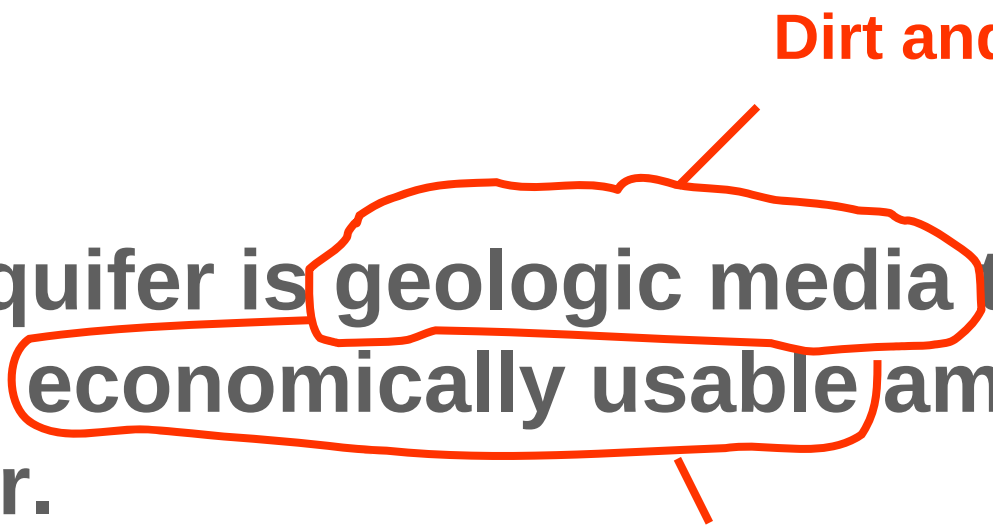
Outline

- Yay for Groundwater!
- Definitions
- Flow through an aquifer
- Pumping an aquifer

Definitions

- Aquifer
- Aquitard/confining layer
- Vadose zone/unsaturated zone
- Water table
- Recharge
- Water level
- Unconfined aquifer
- Confined aquifer

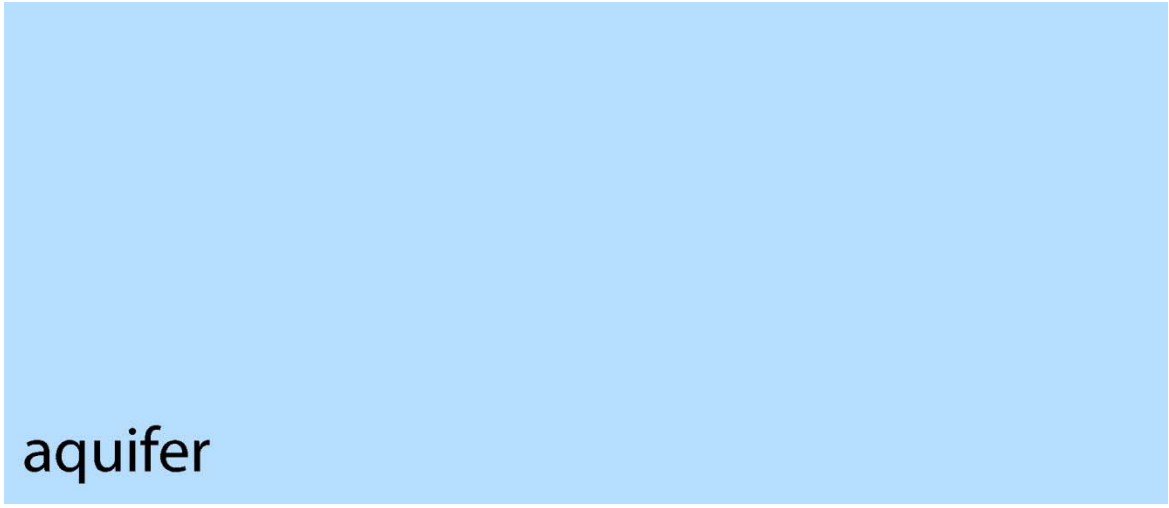
what is an **aquifer**?



- **an aquifer is geologic media that can yield economically usable amounts of water.**

what is an **aquifer**?

Limestone (especially karstified), sandstone, sand, gravel, fractured rocks



what is an **aquitard**?

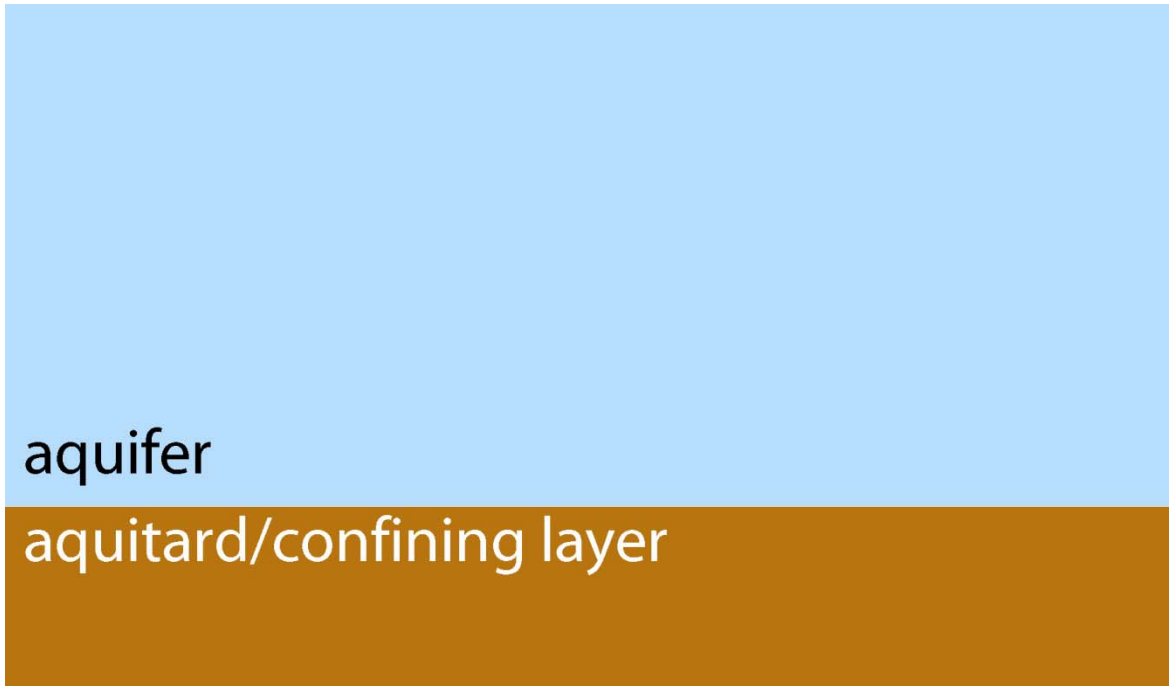
- **an aquitard is geologic media that can not yield economically usable amounts of water.**

what is an **aquitard**?

- **clay, shale, unfractured dense rocks**
- **Note: can still transmit water, but *s l o w l y***

what is a **confining layer**?

- **A confining layer is an aquitard that bounds an aquifer.**

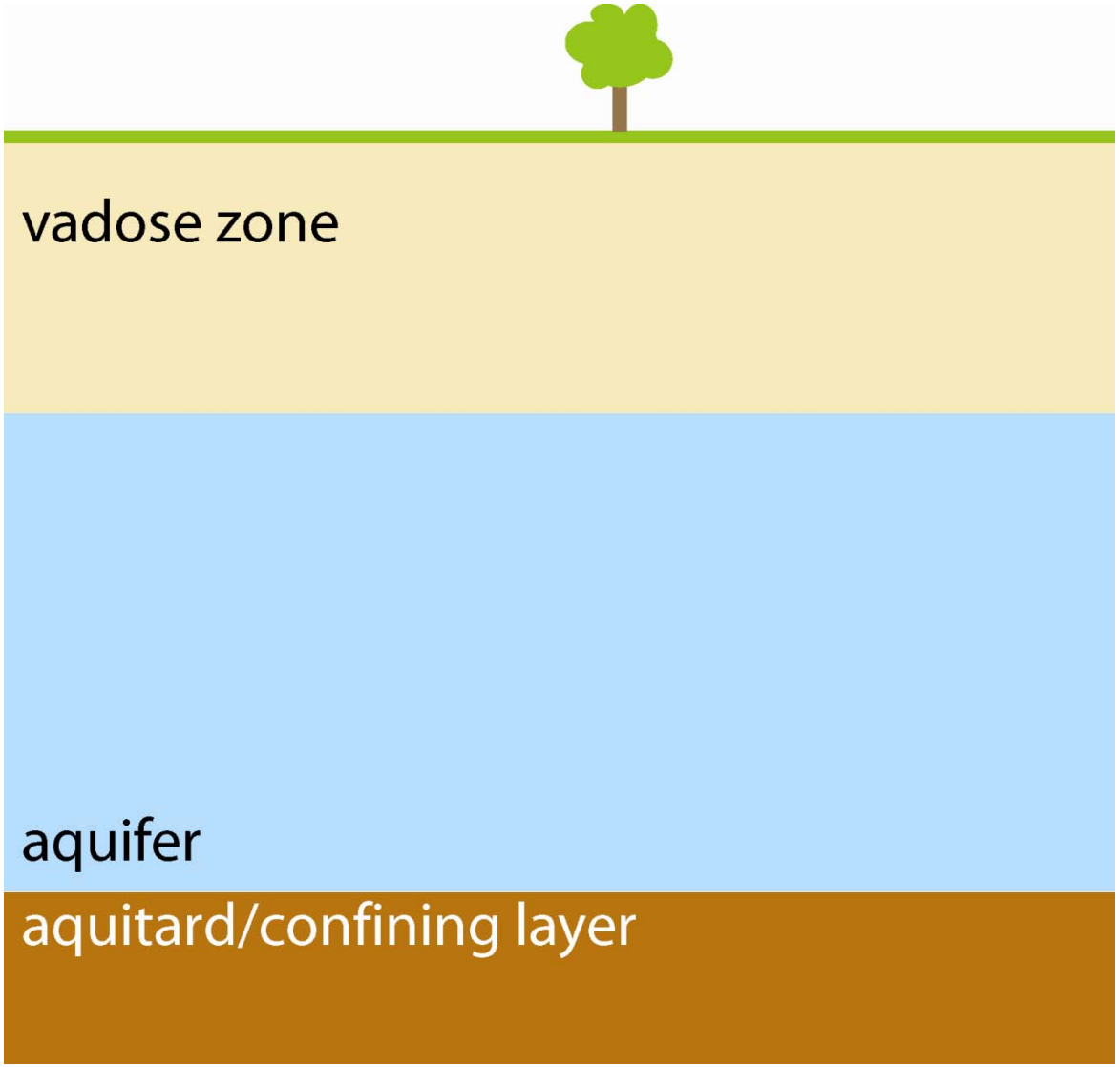


what is a **vadose zone**?

- **The vadose zone is the unsaturated geologic media between the water table and the land surface.**

- Scientific side note: There is a saturated capillary zone between the vadose zone and the water table.

the vadose zone

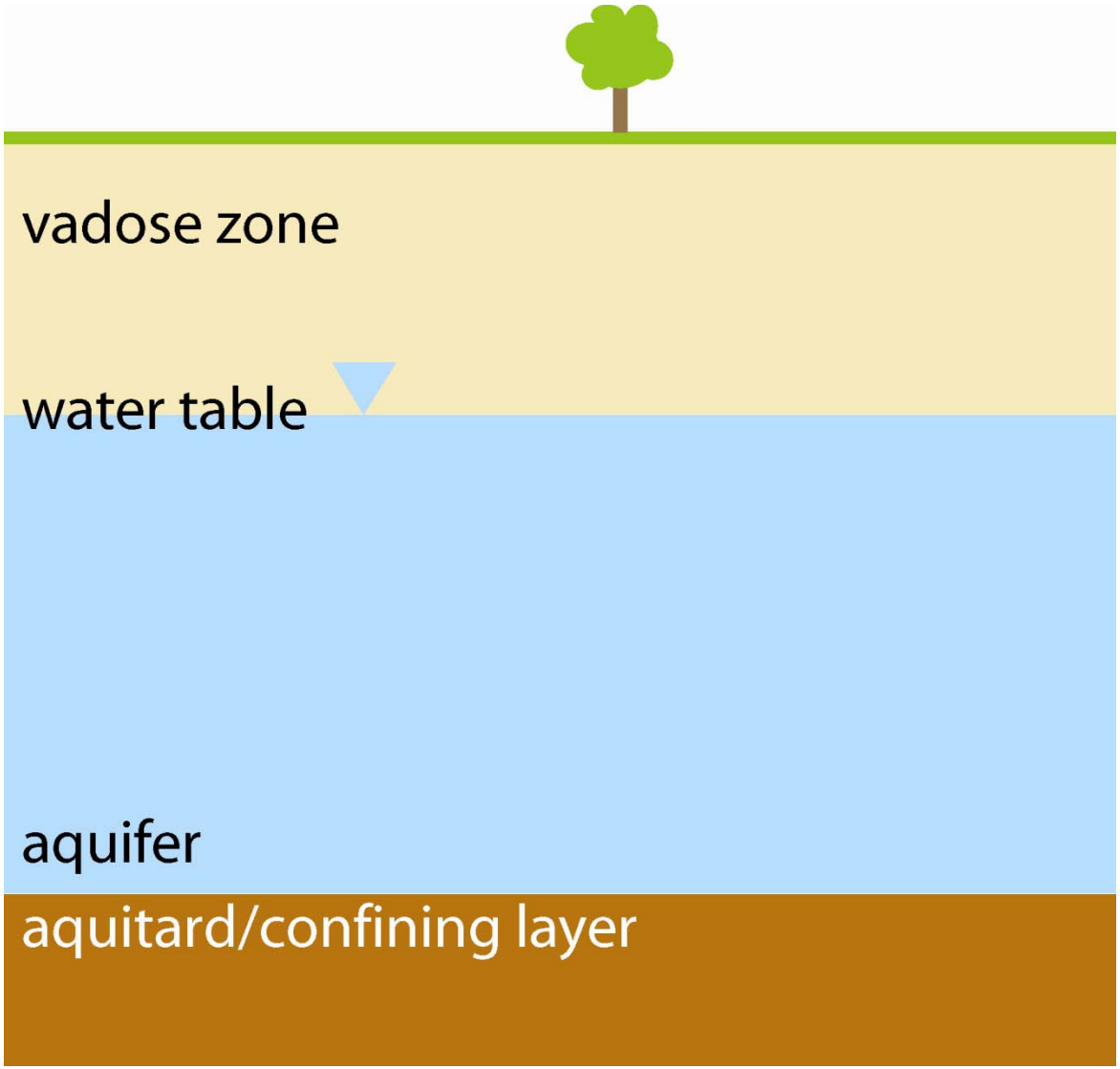


what is a **water table**?

- **A water table is where the aquifer meets the vadose (unsaturated) zone.**

- Scientific definition: surface on which the fluid pressure in the pores of a porous medium is exactly atmospheric.

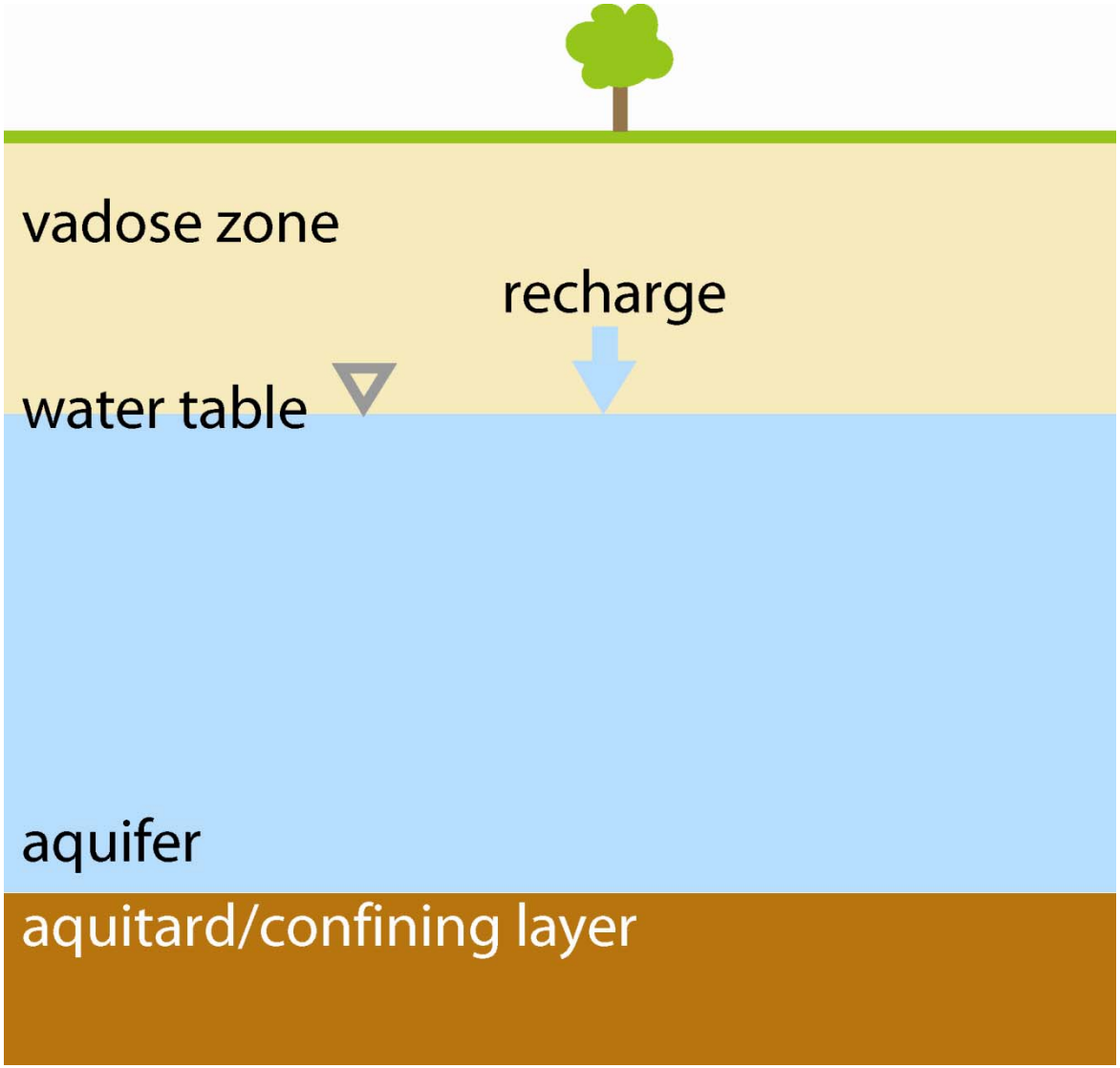
the water table



what is **recharge**?

- **Recharge is water that infiltrates to the water table of an aquifer.**

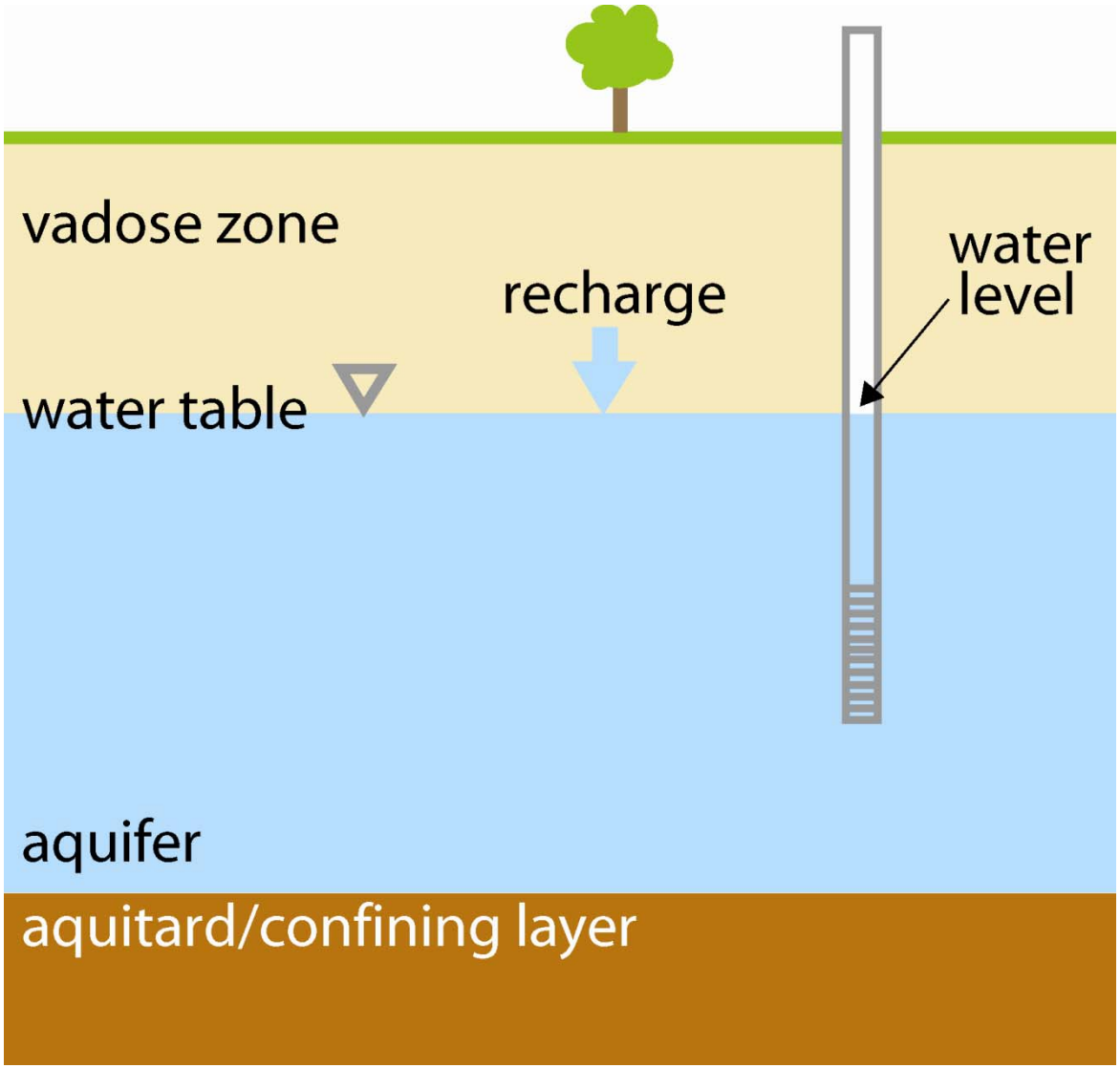
recharge


vadose zone
recharge
water table
aquifer
aquitard/confining layer

what is a **water level**?

- **A water level is the level at which water rests (or would rest) in a well.**

the water level

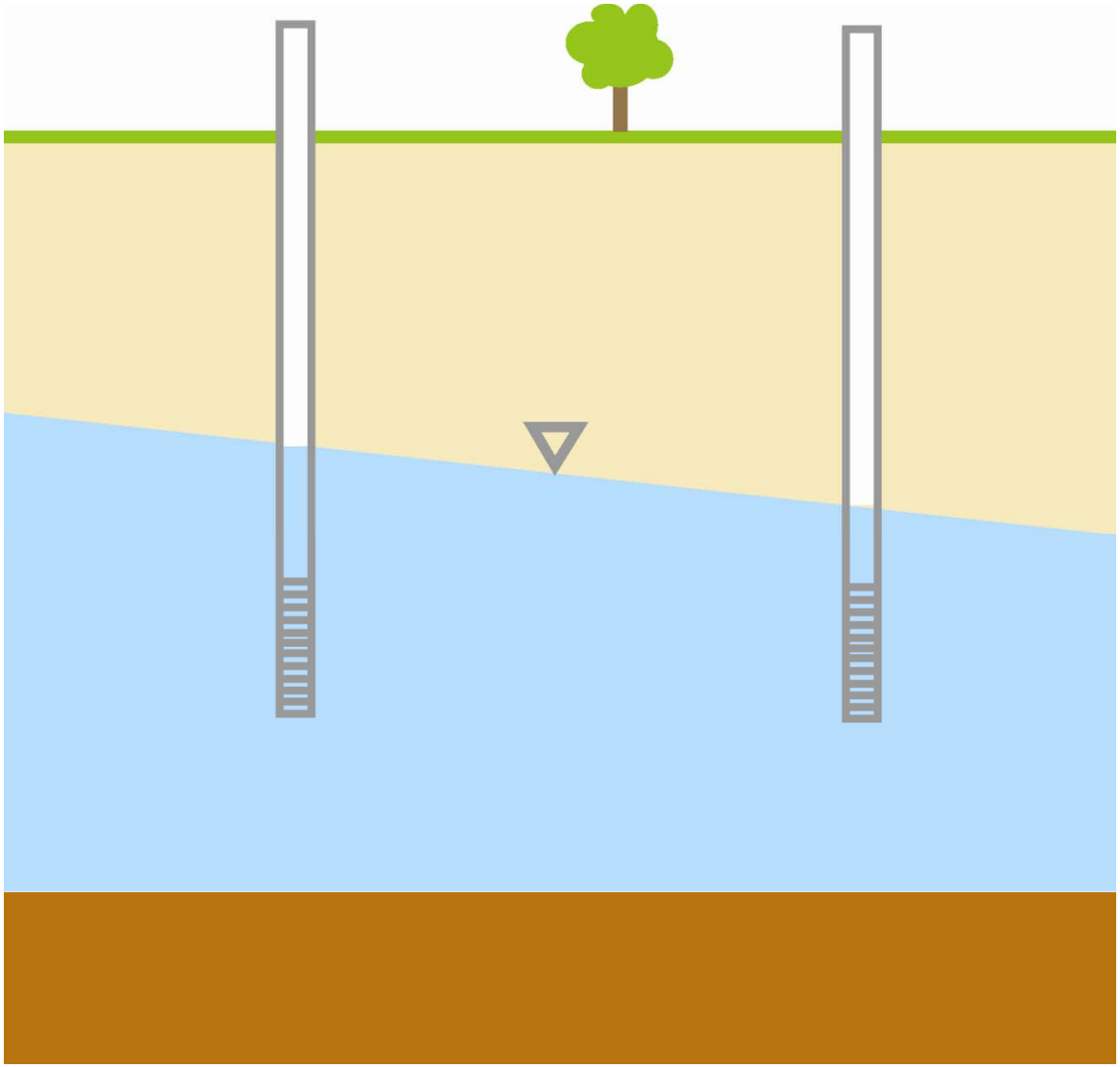


2 rules of groundwater **flow**

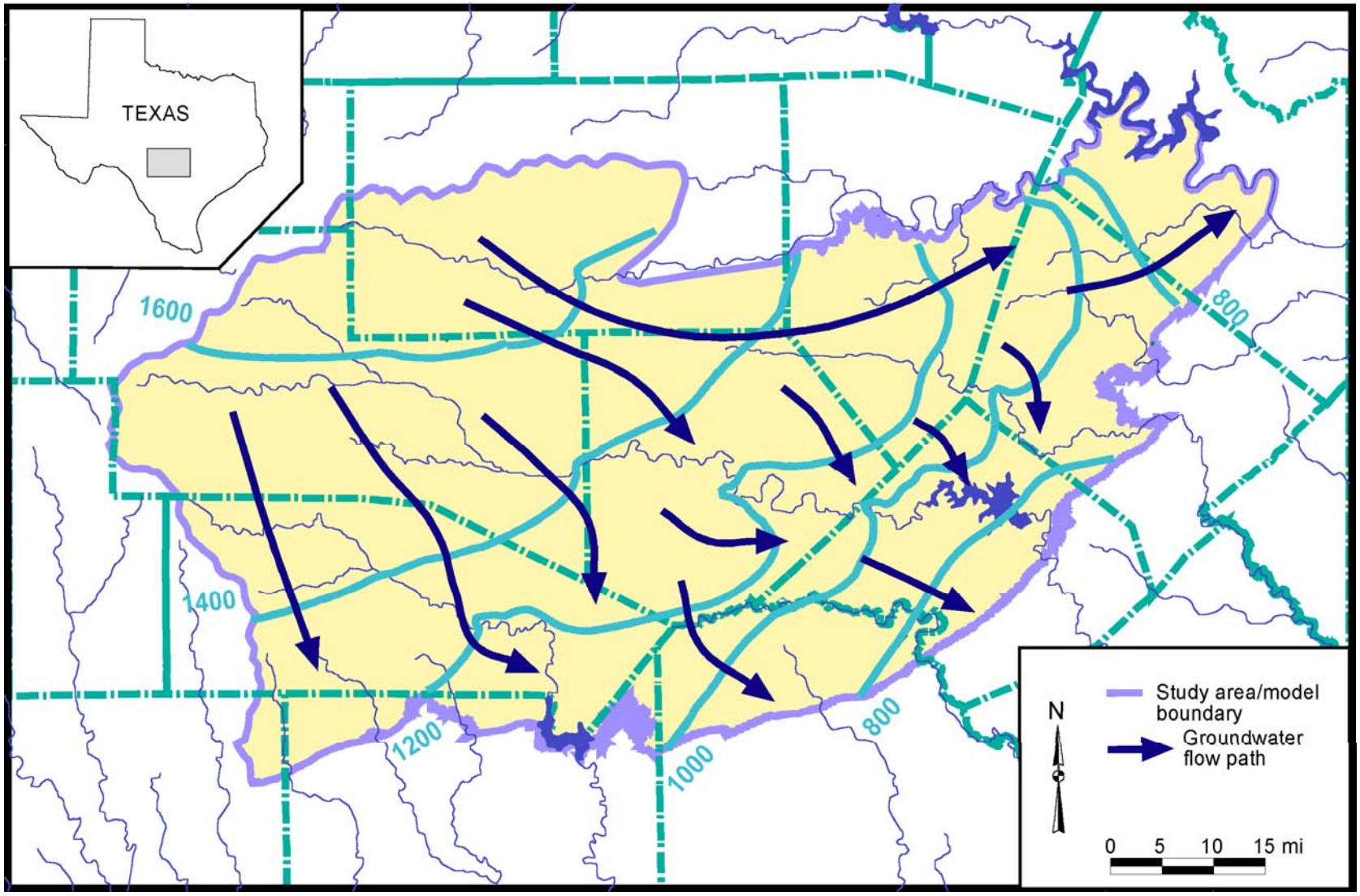
- **water flows downhill (**  **to lower potential energy)**

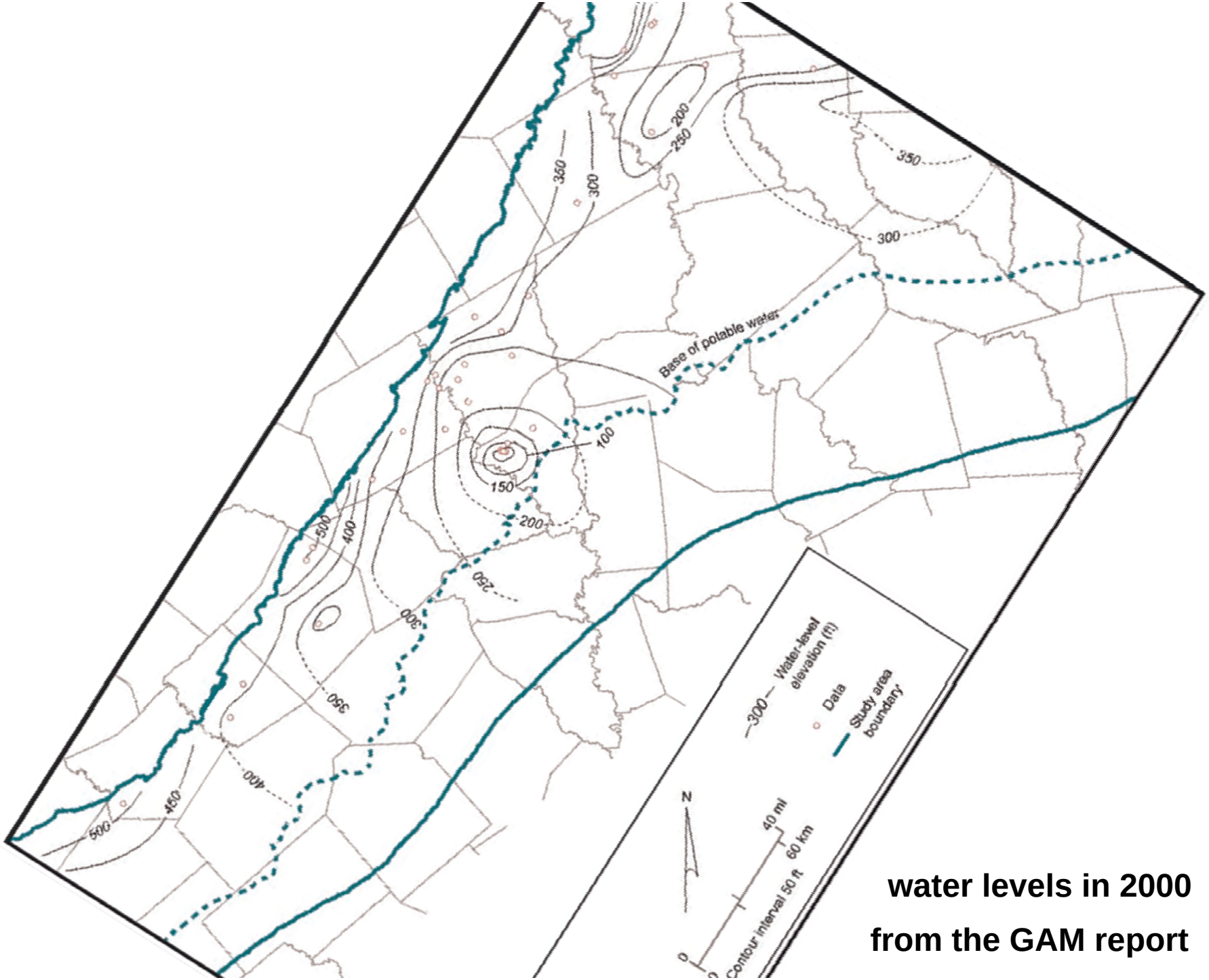
- **water flows uphill to money**

water flows downhill (to lower potential energy)



Groundwater Flowpaths





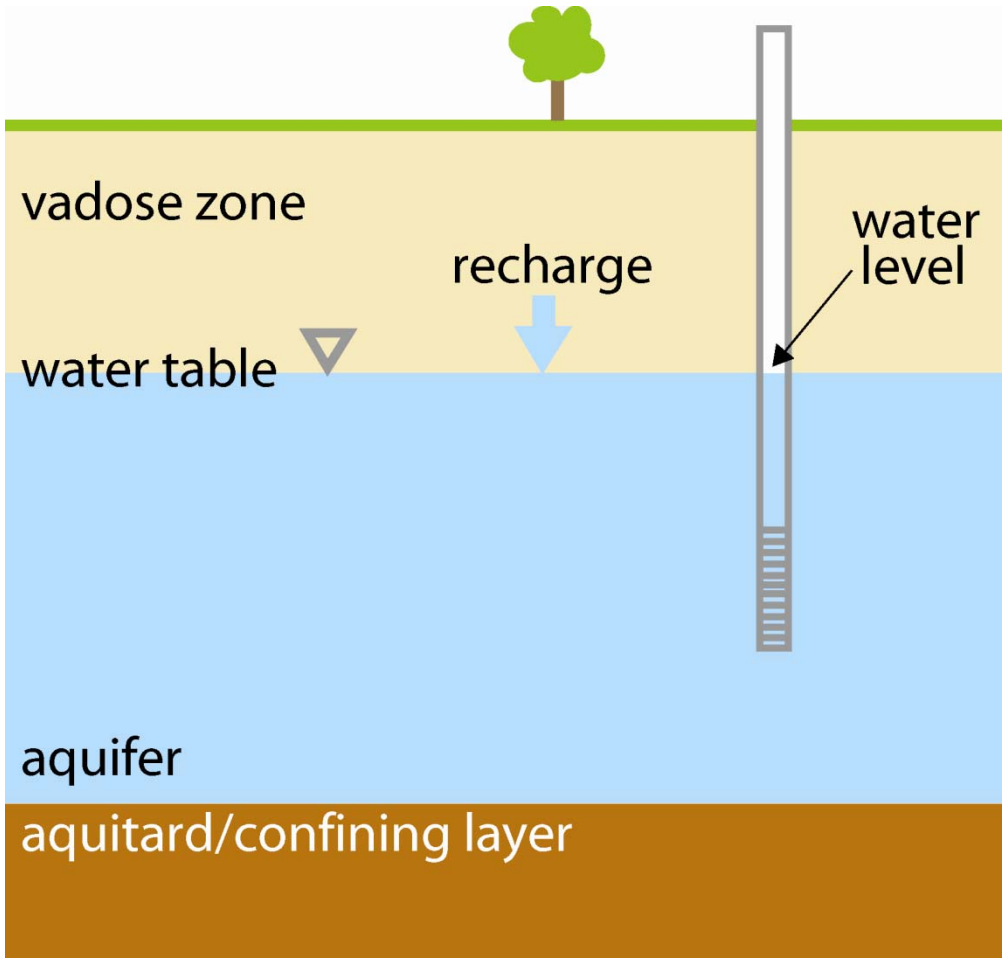
water levels in 2000

from the GAM report

what is an **unconfined aquifer**?

- **An unconfined aquifer is an aquifer that is bounded by a confining layer at its bottom but not at its top.**

an unconfined aquifer

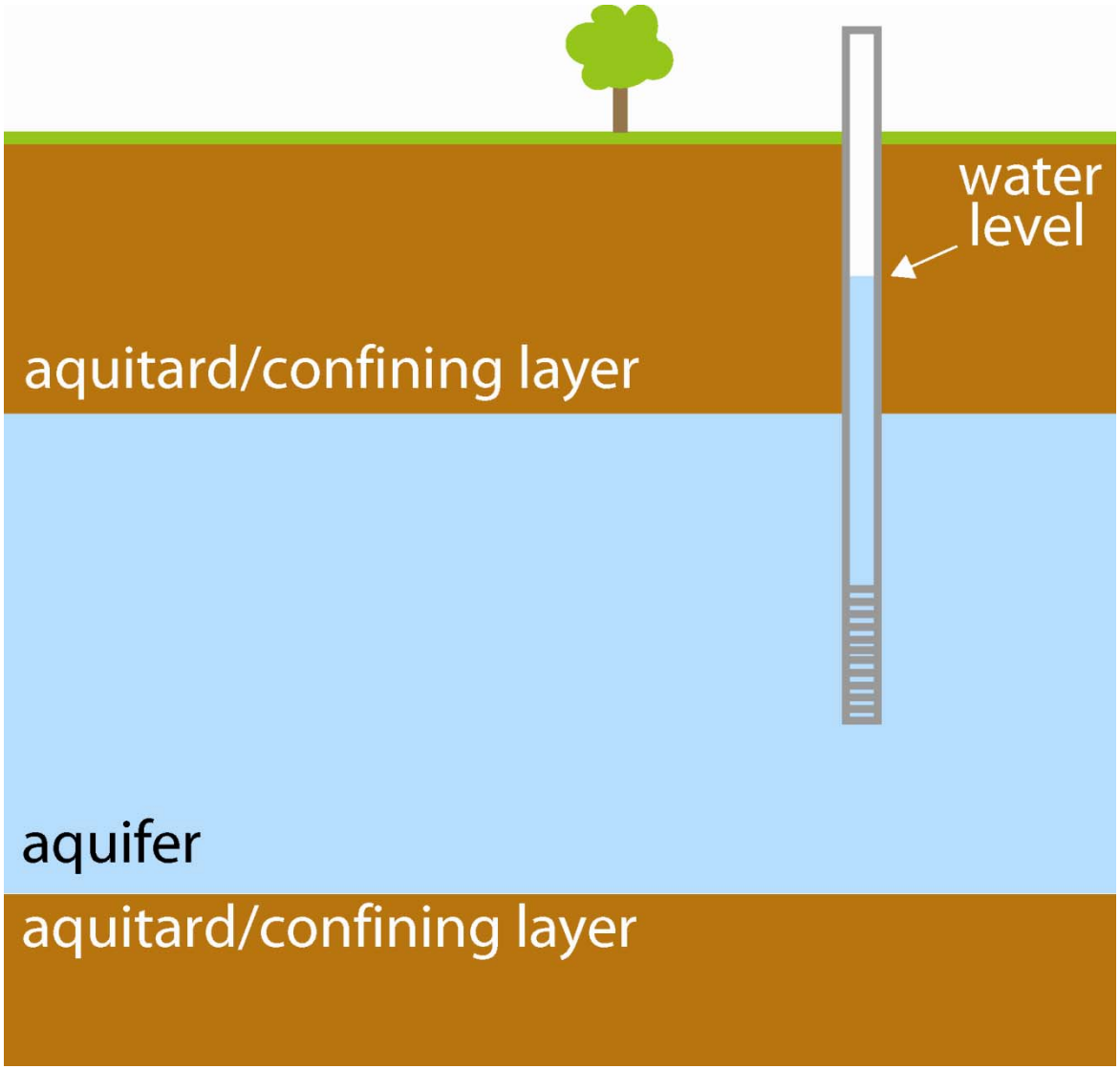


what is a **confined aquifer**?

- **A confined aquifer is an aquifer that is bounded by confining layers at its bottom and top and where the water level rises above the top of the aquifer.**

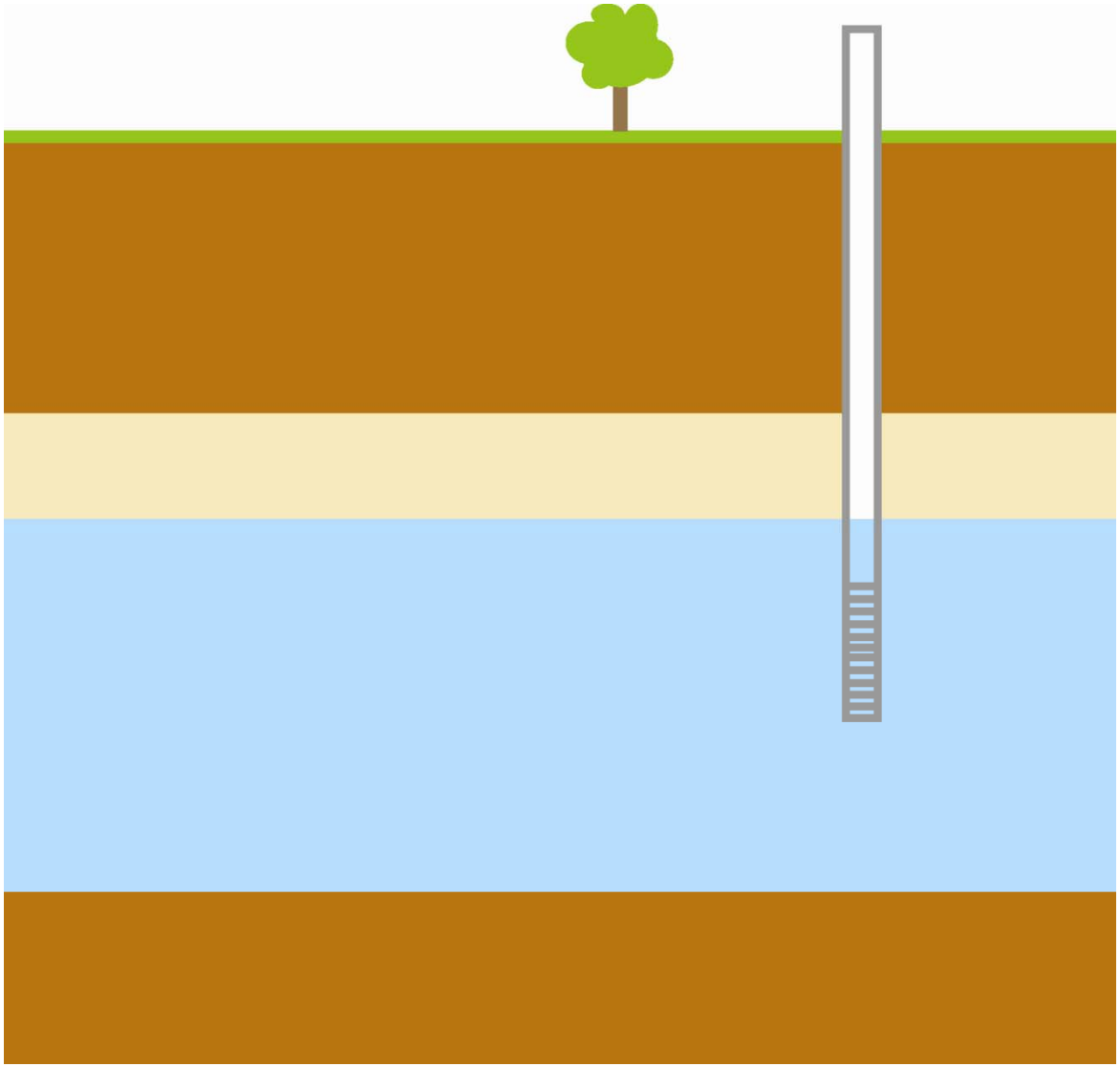
- **Scientific side note: This is also an artesian aquifer. "Artesian" does not require water to flow at land surface.**

a confined aquifer

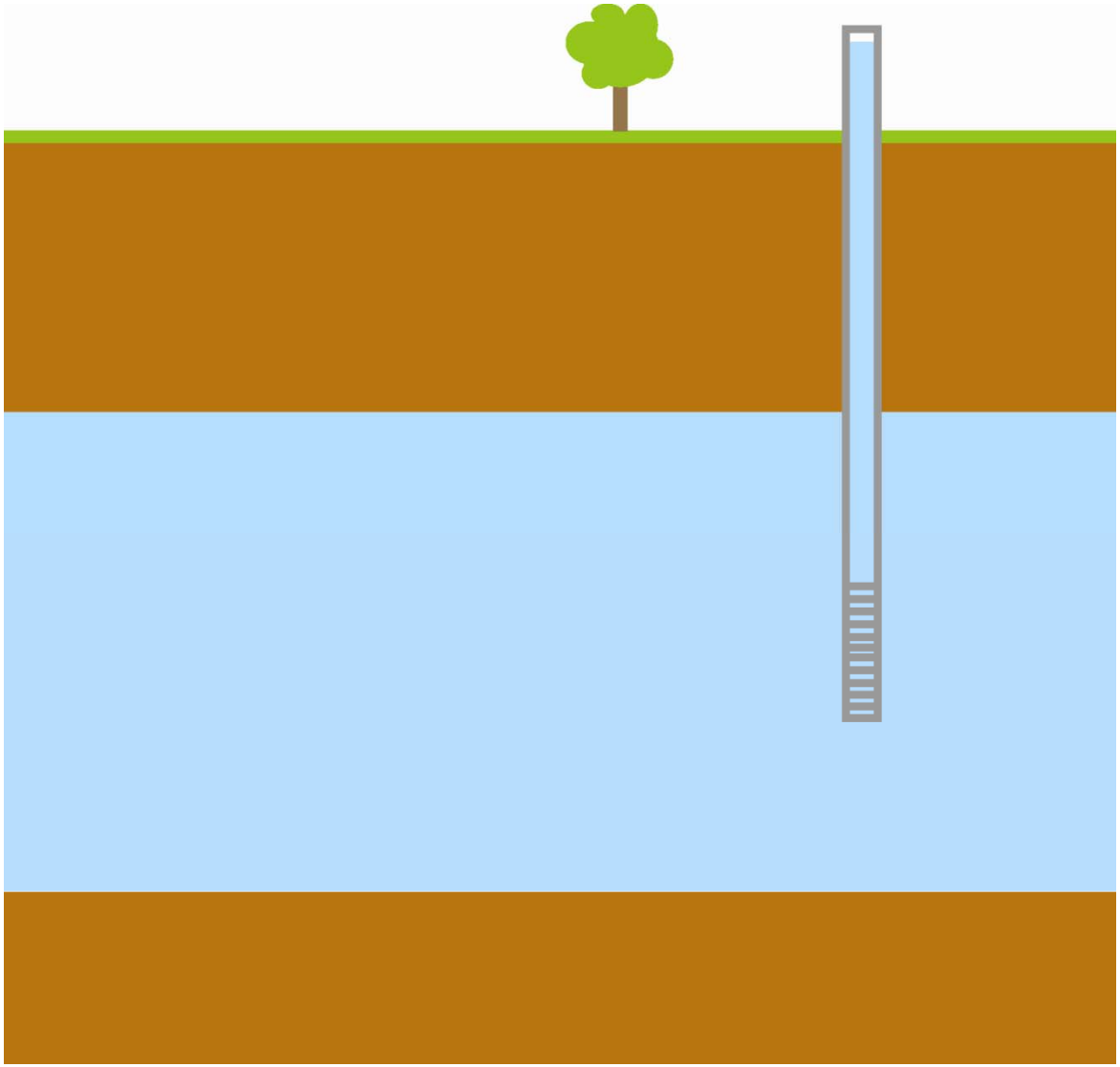


POP QUIZ!!!

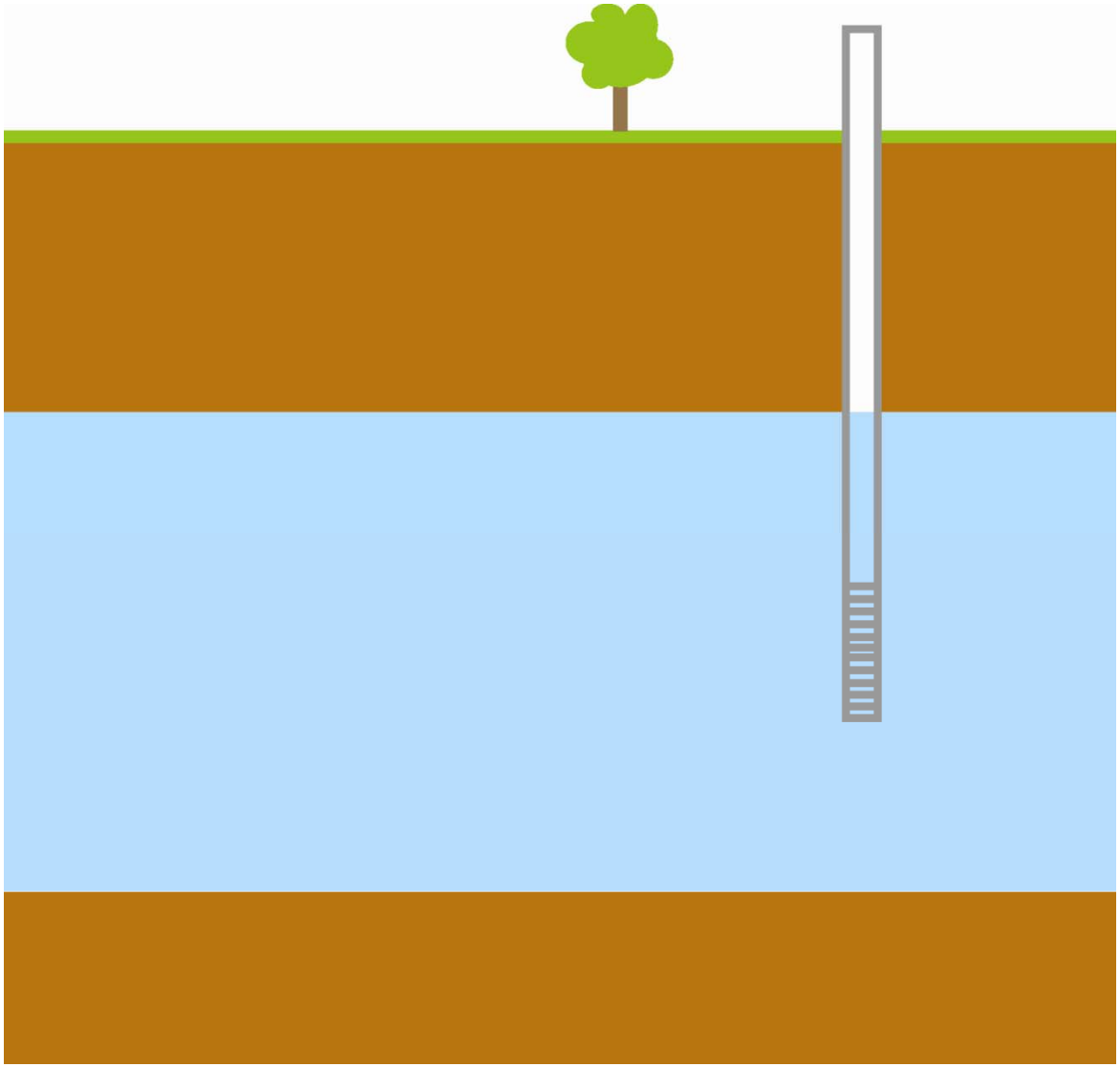
confined or unconfined?



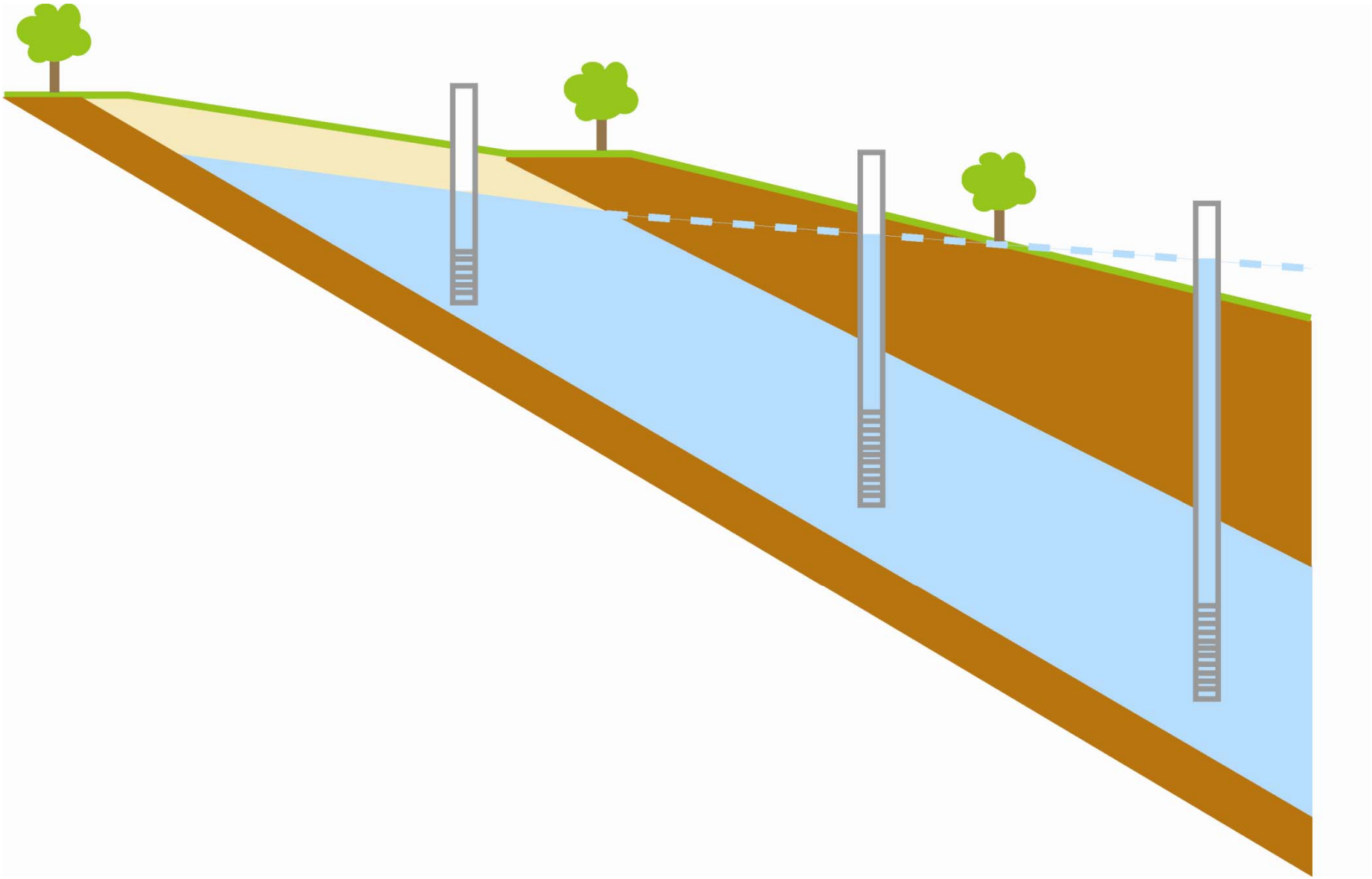
confined or unconfined?



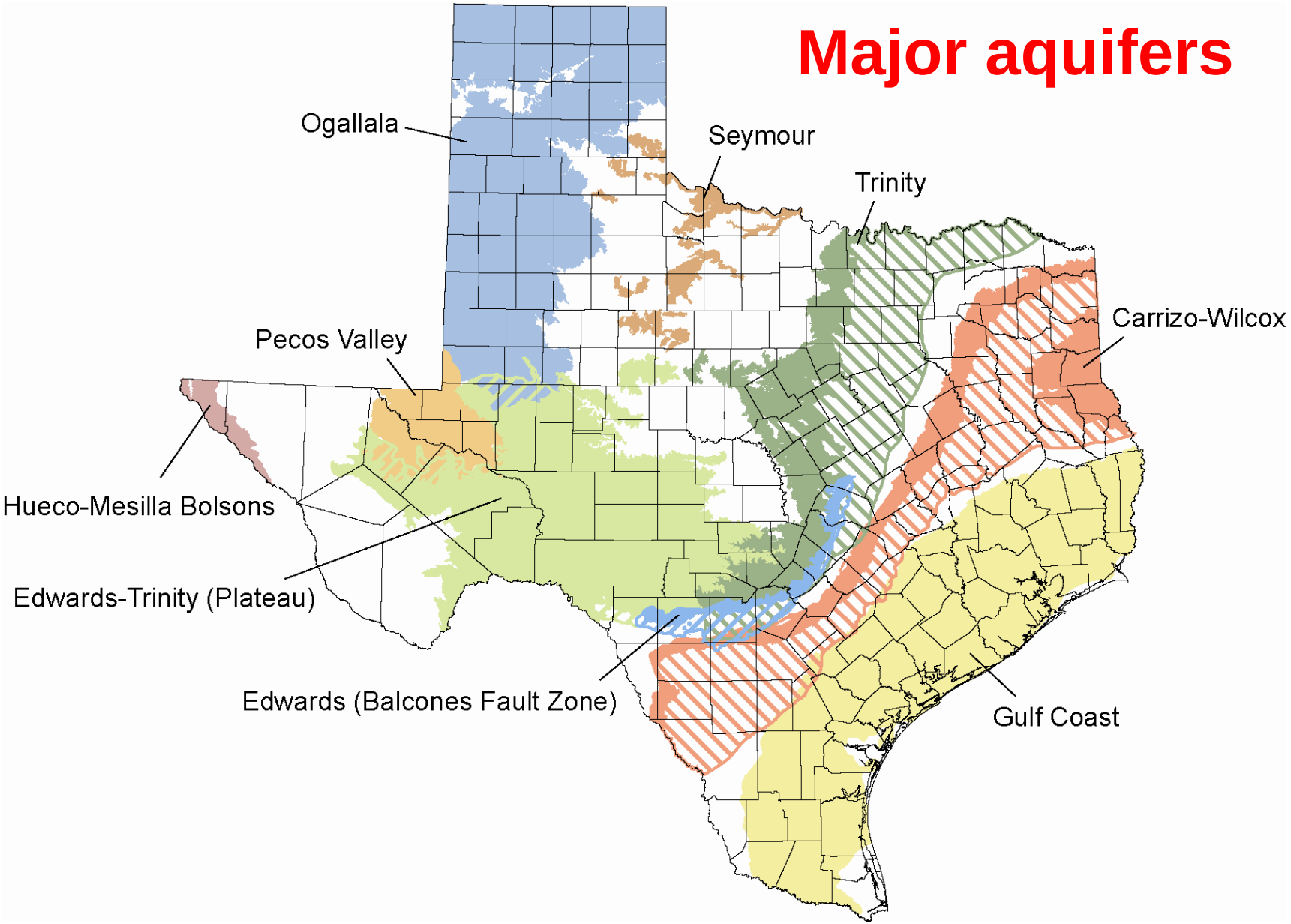
confined or unconfined?

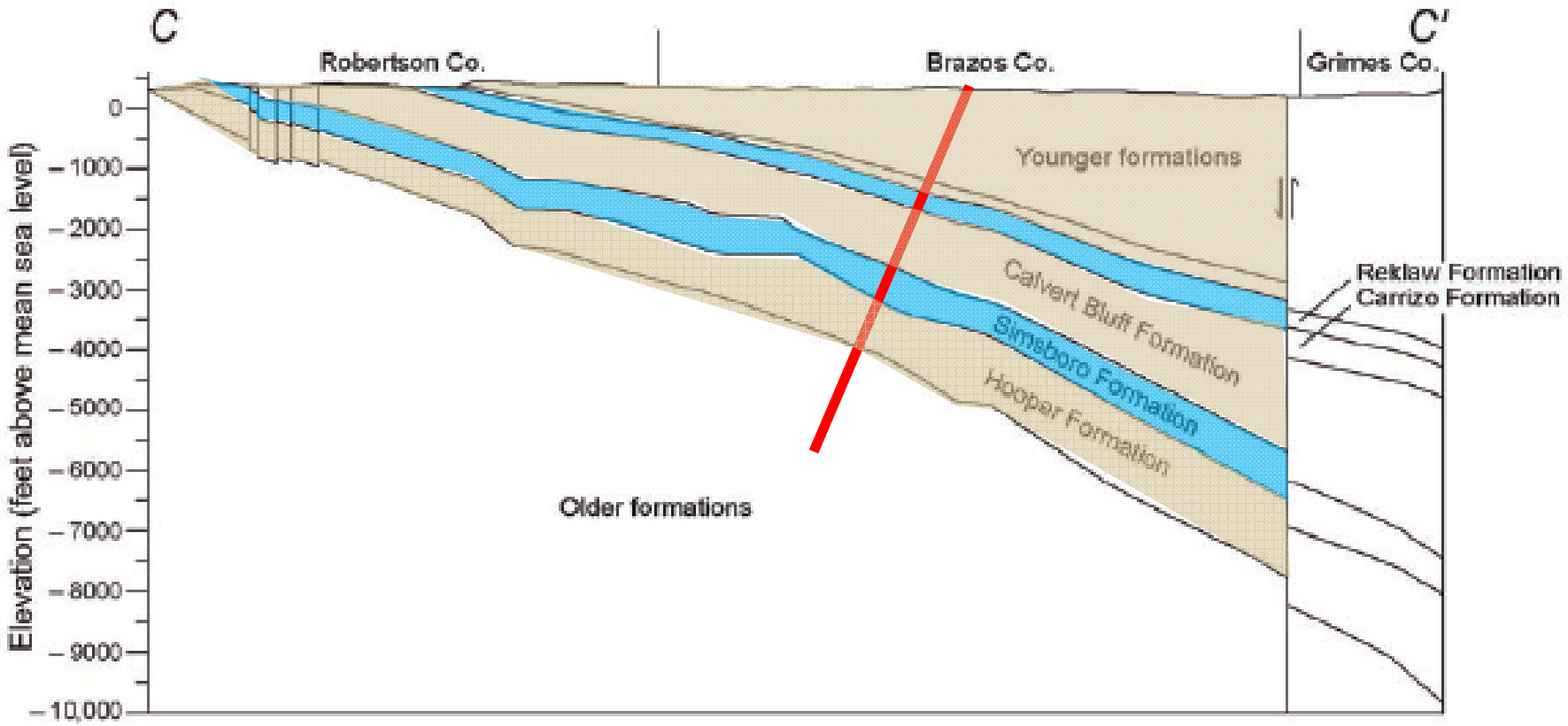


same aquifer: **unconfined and confined**

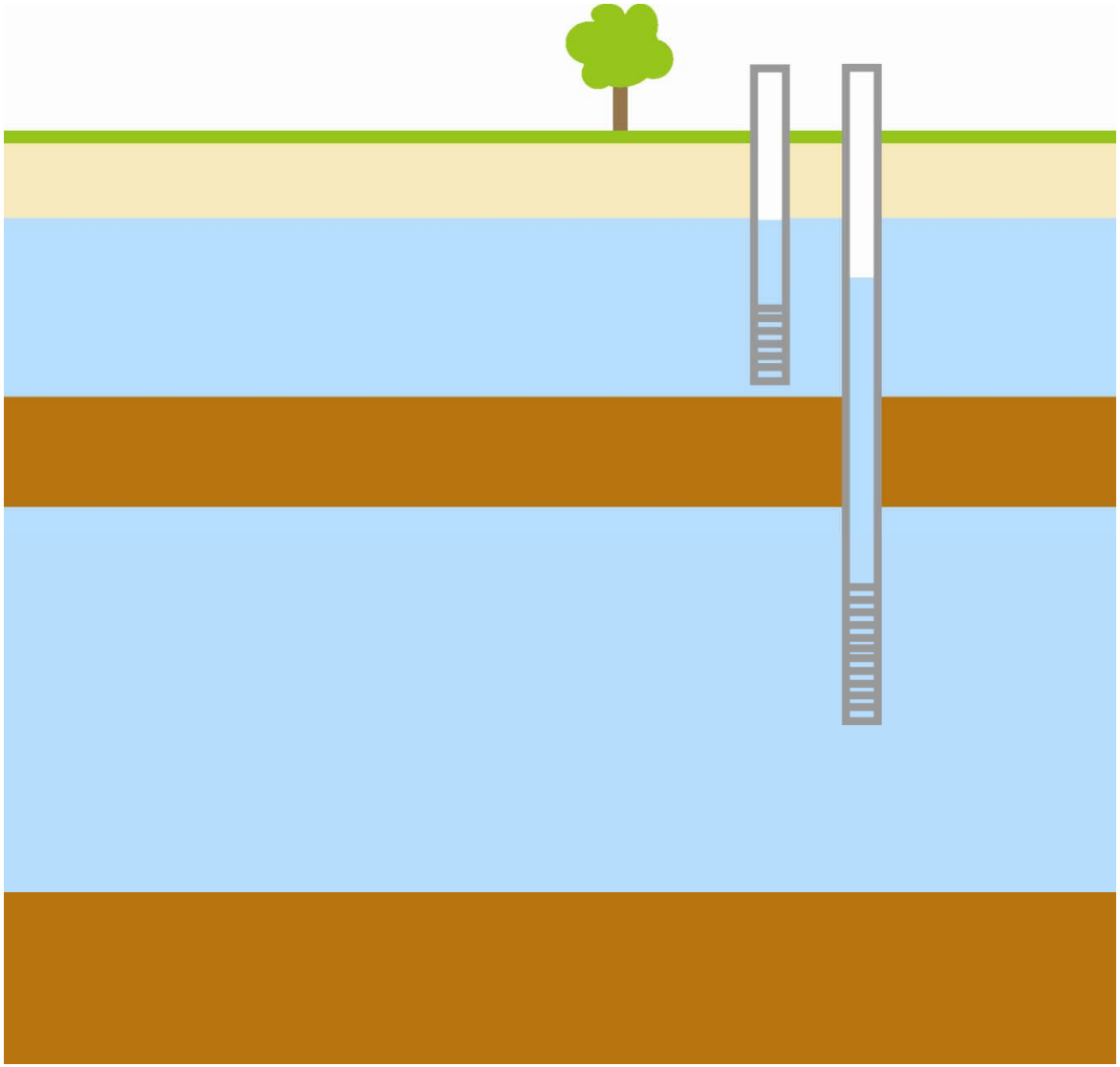


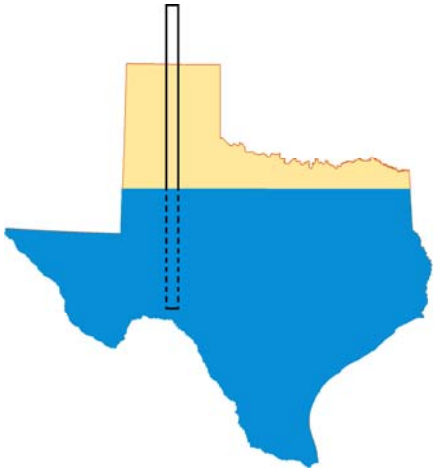
Major aquifers




C
C′
Robertson Co.
Brazos Co.
Grimes Co.
Elevation (feet above mean sea level)
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
−8000
−9000
−10,000
Younger formations
Calvert Bluff Formation
Simsboro Formation
Hooper Formation
Older formations
Reklaw Formation
Carrizo Formation

same location: **confined and unconfined aquifers**





Outline

- Yay for aquifers!
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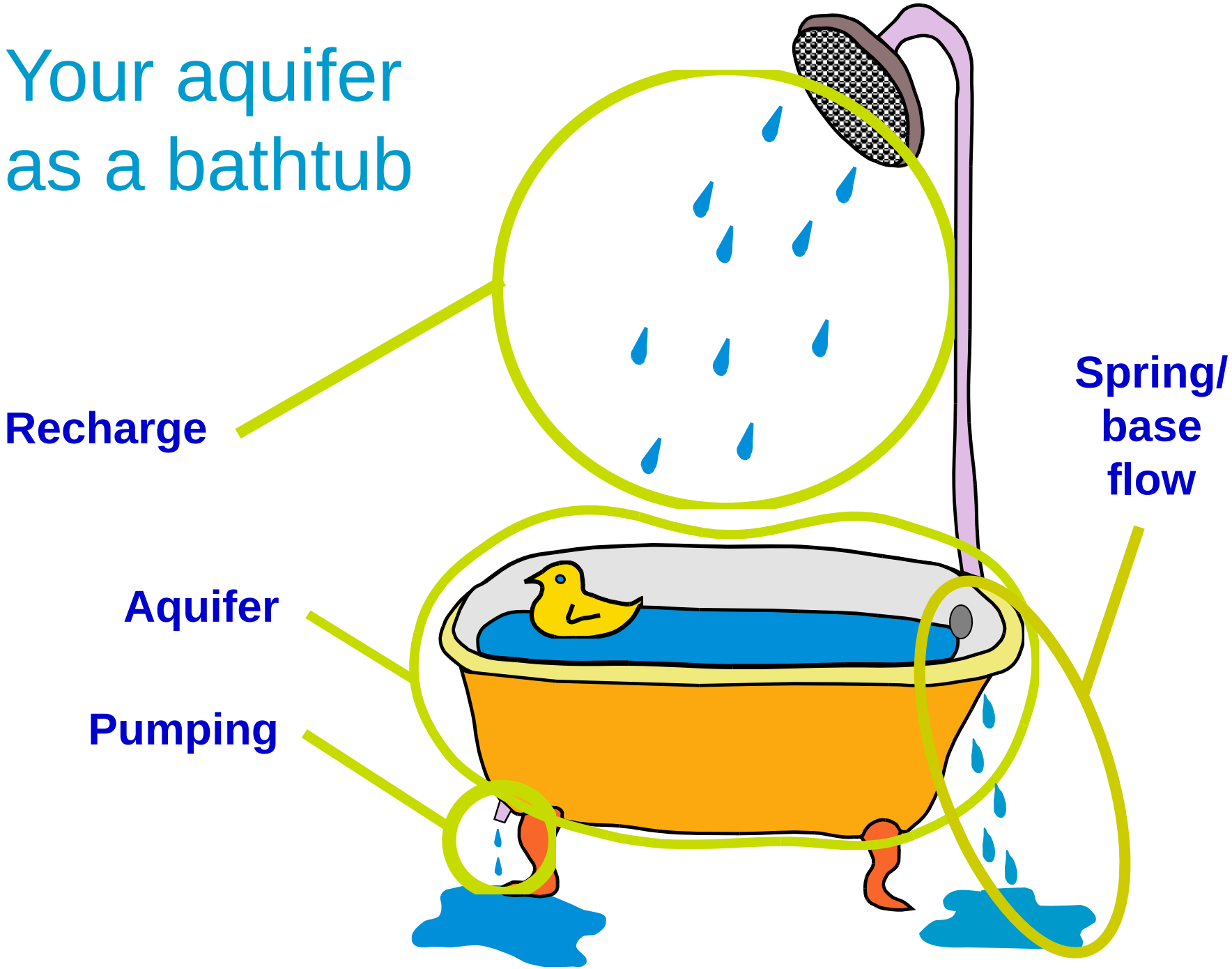
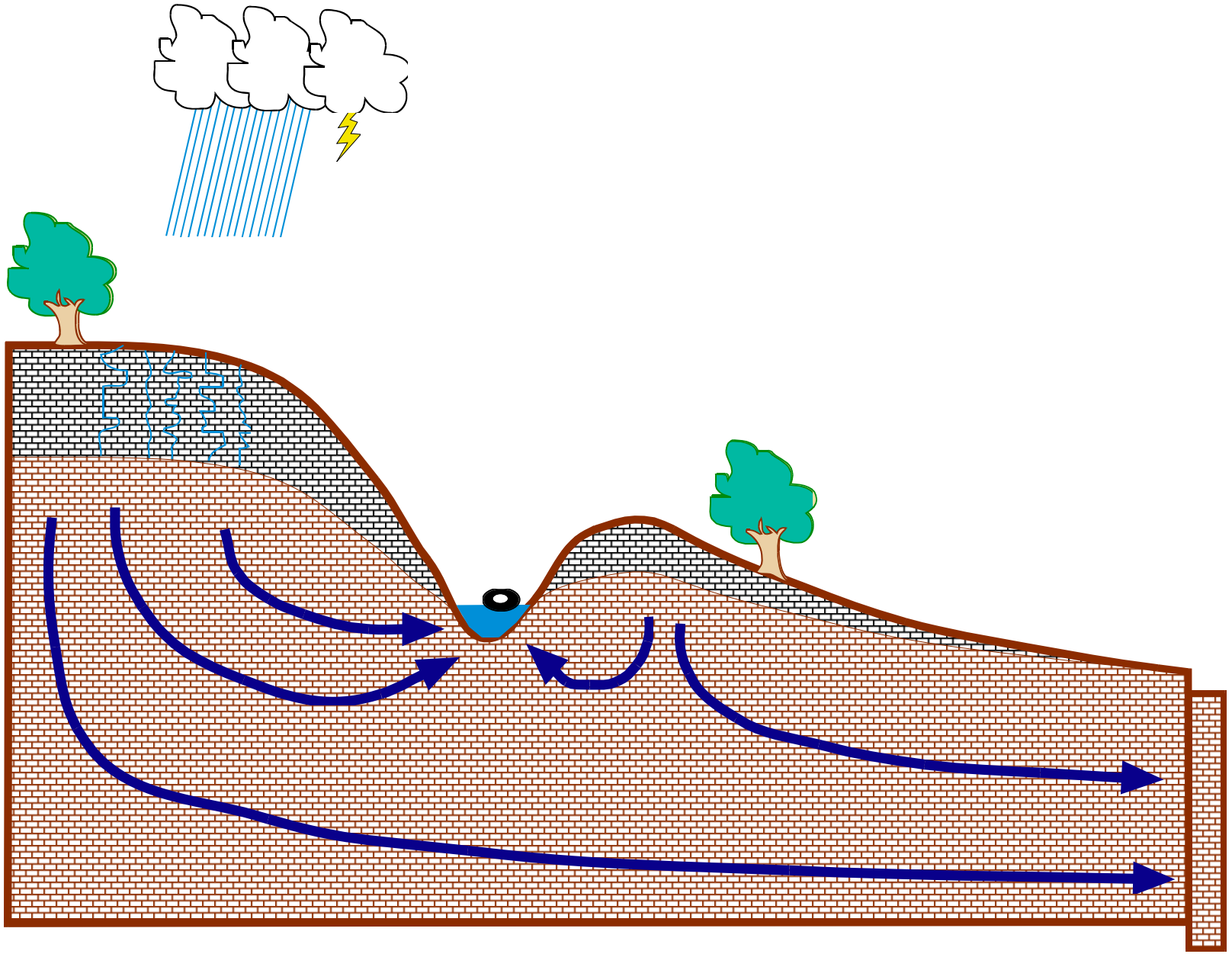
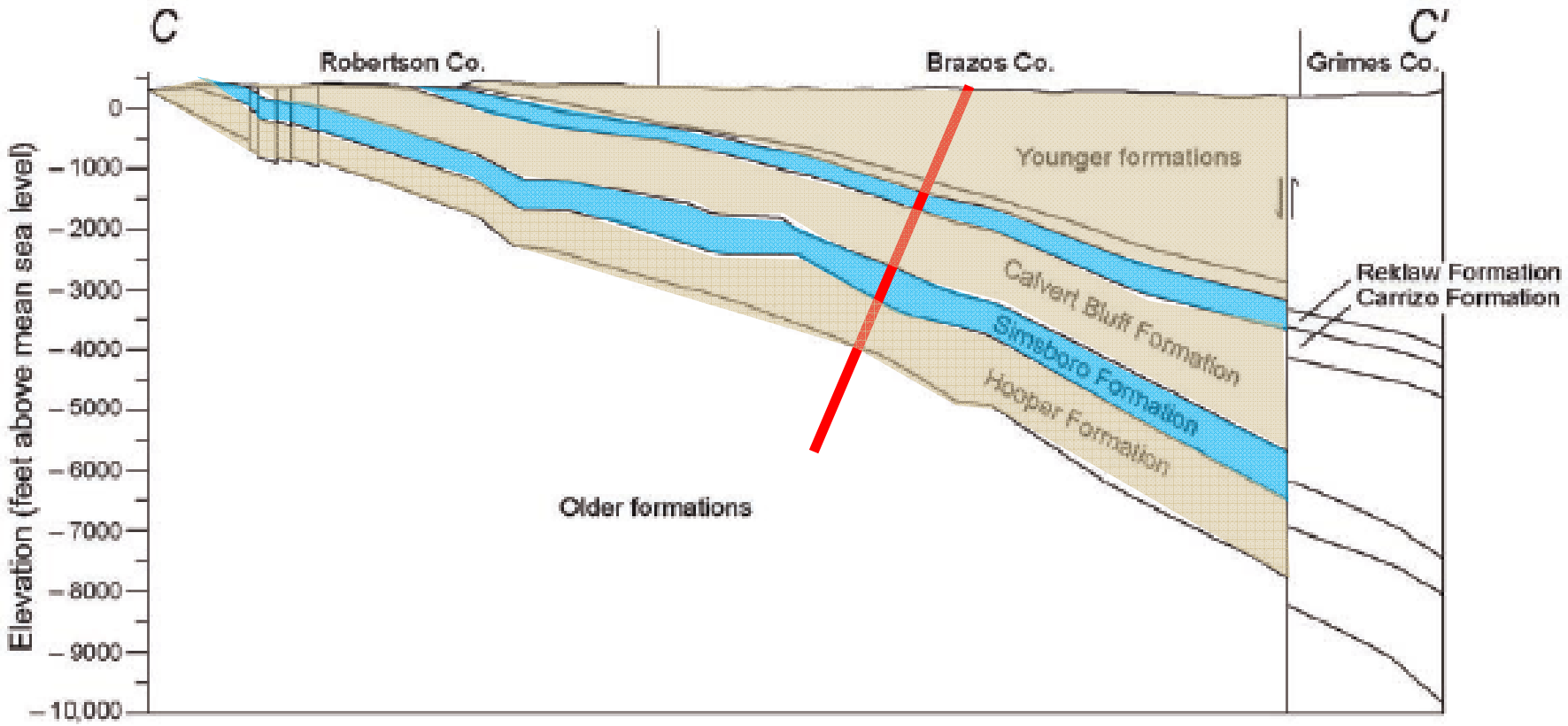
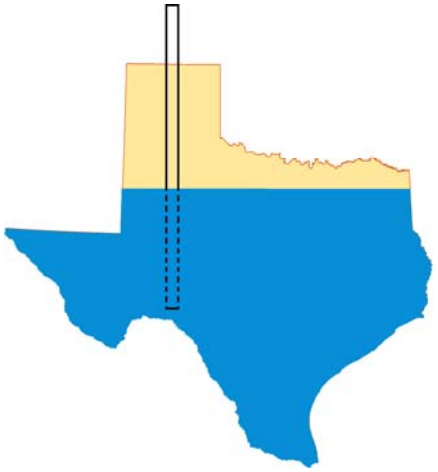
Your aquifer as a bathtub






C
C′
Robertson Co.
Brazos Co.
Grimes Co.
Younger formations
Calvert Bluff Formation
Simsboro Formation
Hooper Formation
Older formations
Reklaw Formation
Carrizo Formation
Elevation (feet above mean sea level)
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
−8000
−9000
−10,000



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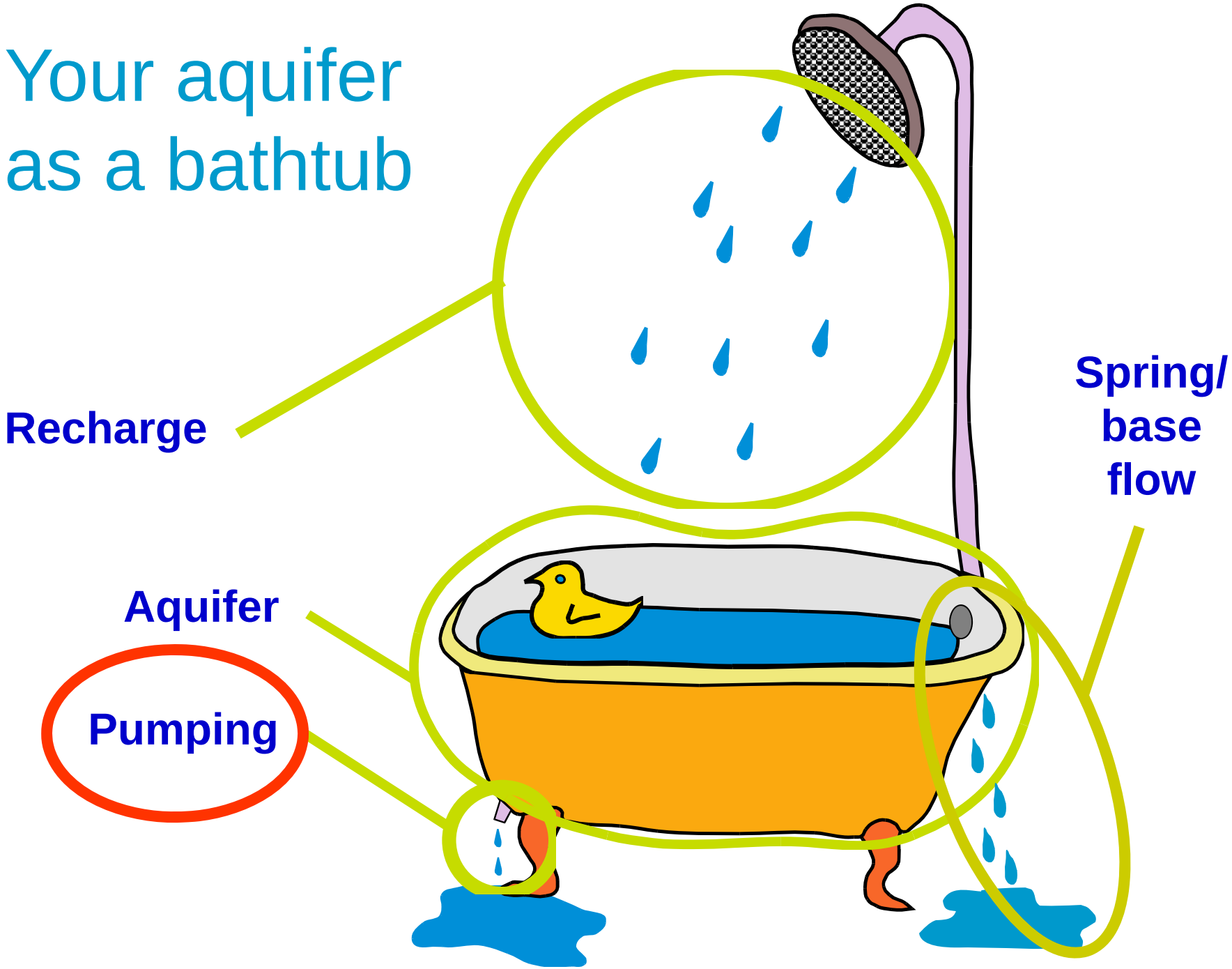
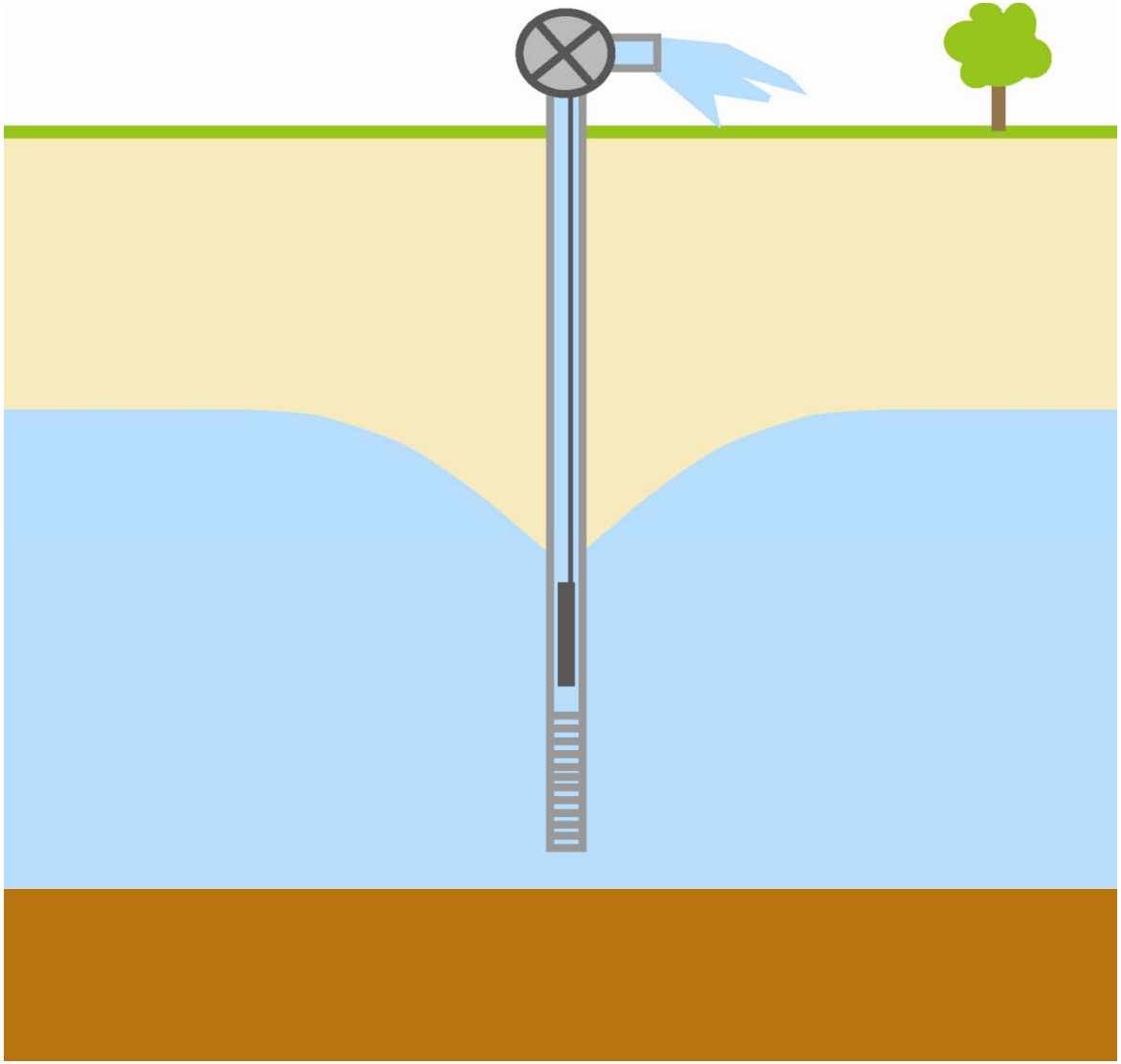


McDonald Irrigation Well, 1200 Gallons per Minute, Hereford, Texas.

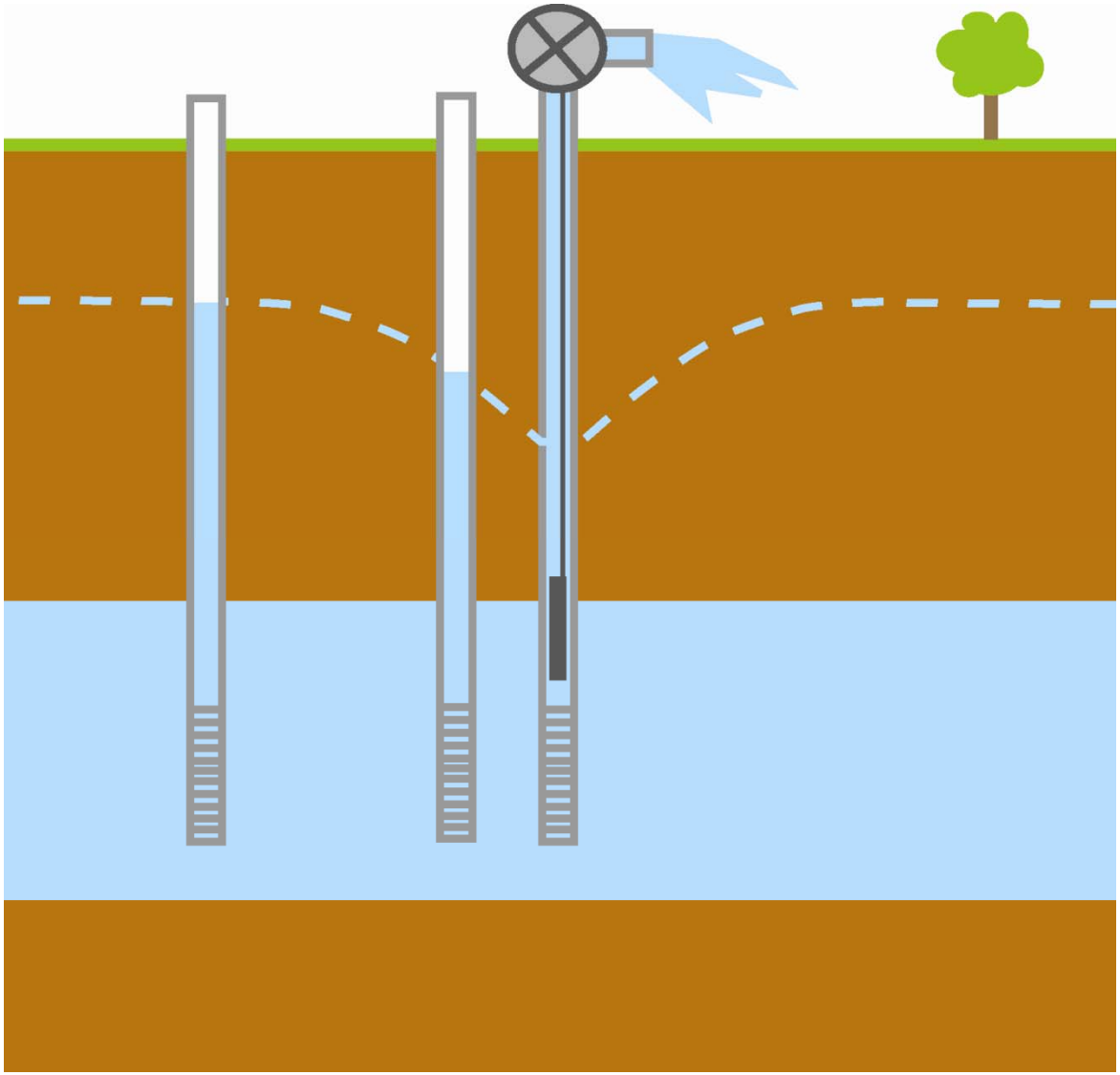
2 rules of groundwater **flow**

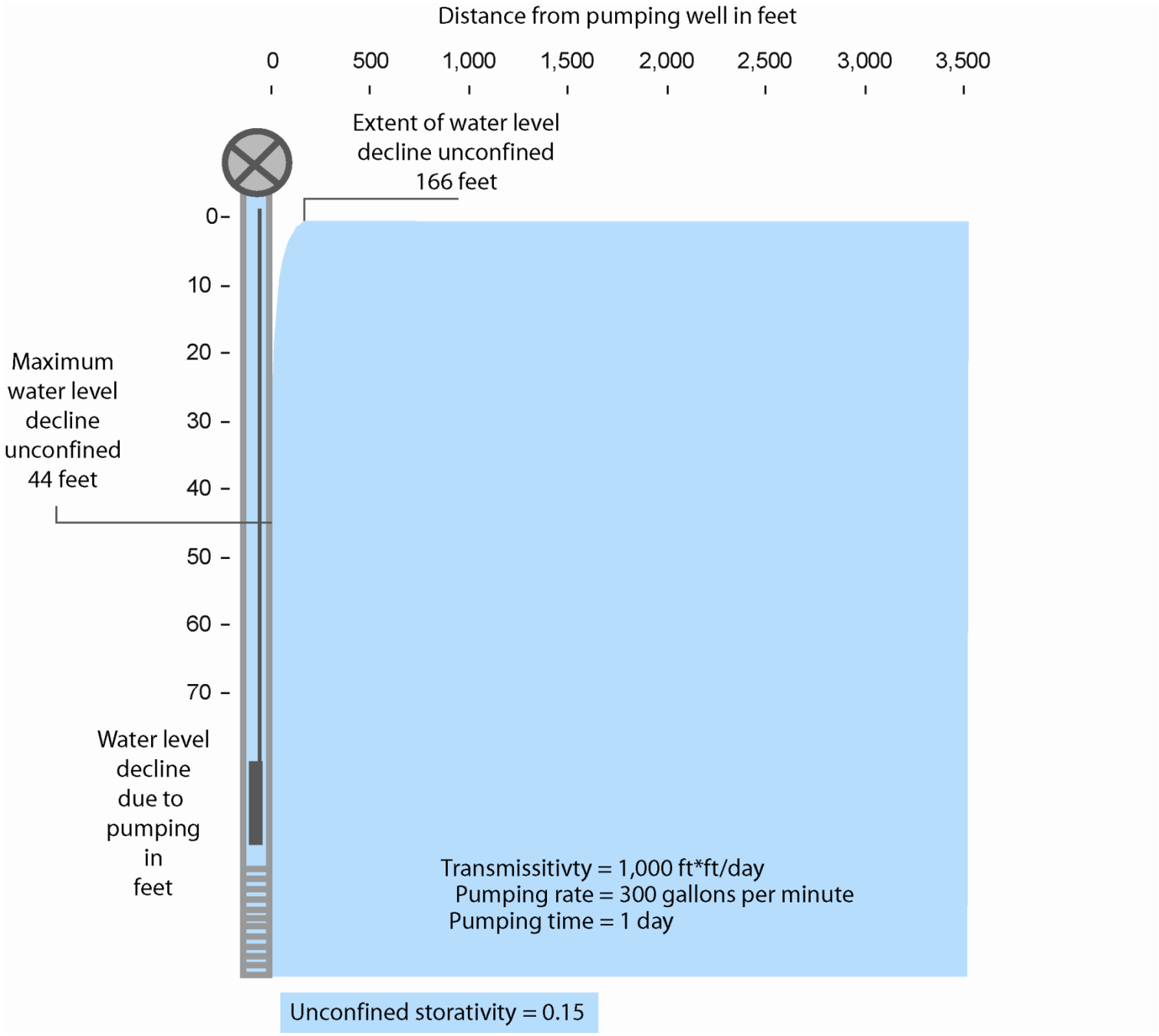
- **water flows downhill (to lower potential energy)**
- **water flows uphill to money**

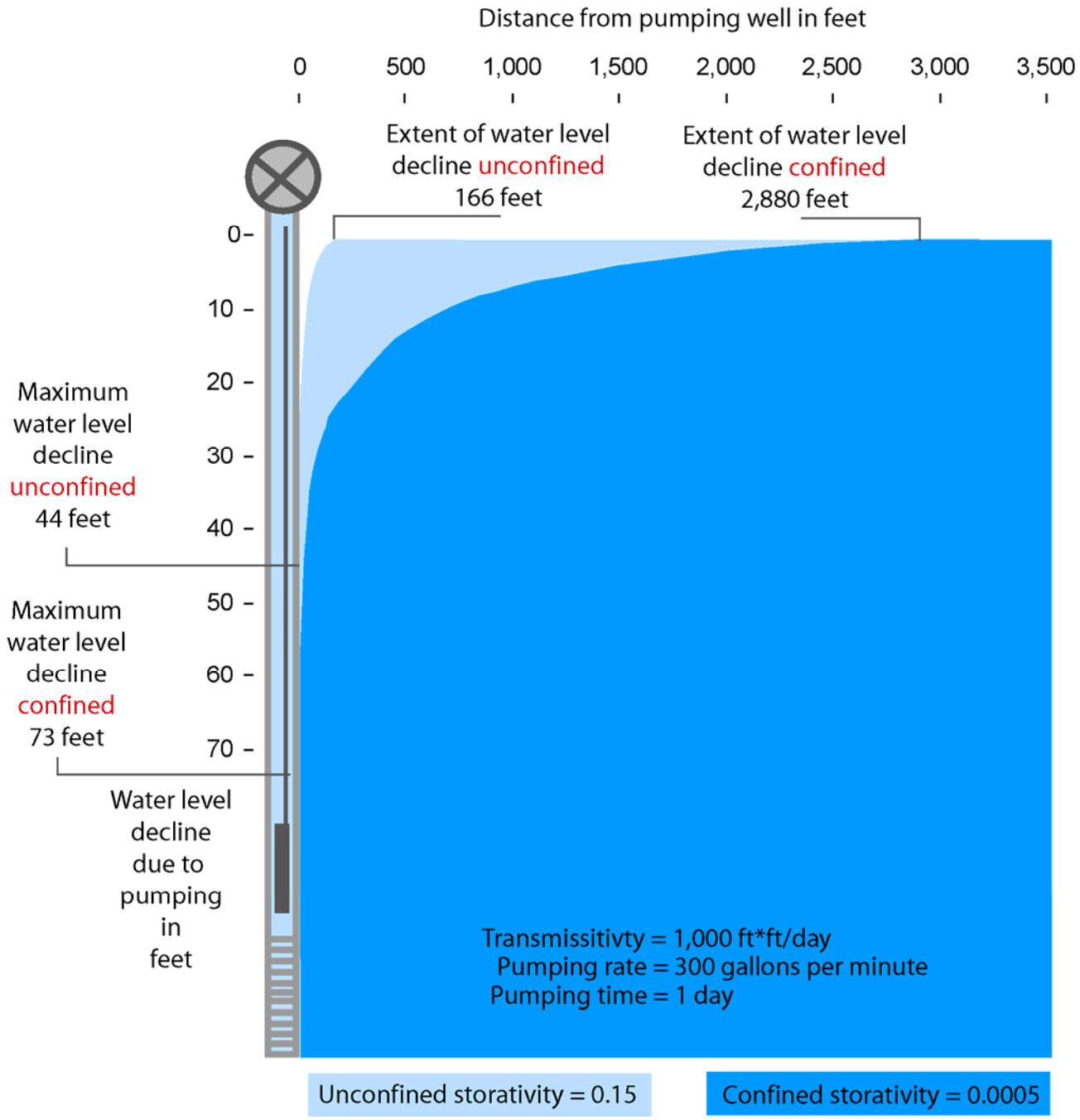
pumping a well: unconfined



pumping a well: confined




Distance from pumping well in feet
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Extent of water level decline unconfined 166 feet
0
10
20
30
40
50
60
70
Maximum water level decline unconfined 44 feet
Water level decline due to pumping in feet
Transmissitivty = 1,000 ft*ft/day
Pumping rate = 300 gallons per minute
Pumping time = 1 day
Unconfined storativity = 0.15


Distance from pumping well in feet
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Extent of water level decline unconfined 166 feet
Extent of water level decline confined 2,880 feet
0
10
20
30
40
50
60
70
Maximum water level decline unconfined 44 feet
Maximum water level decline confined 73 feet
Water level decline due to pumping in feet
Transmissitivty = 1,000 ft*ft/day
Pumping rate = 300 gallons per minute
Pumping time = 1 day
Unconfined storativity = 0.15
Confined storativity = 0.0005

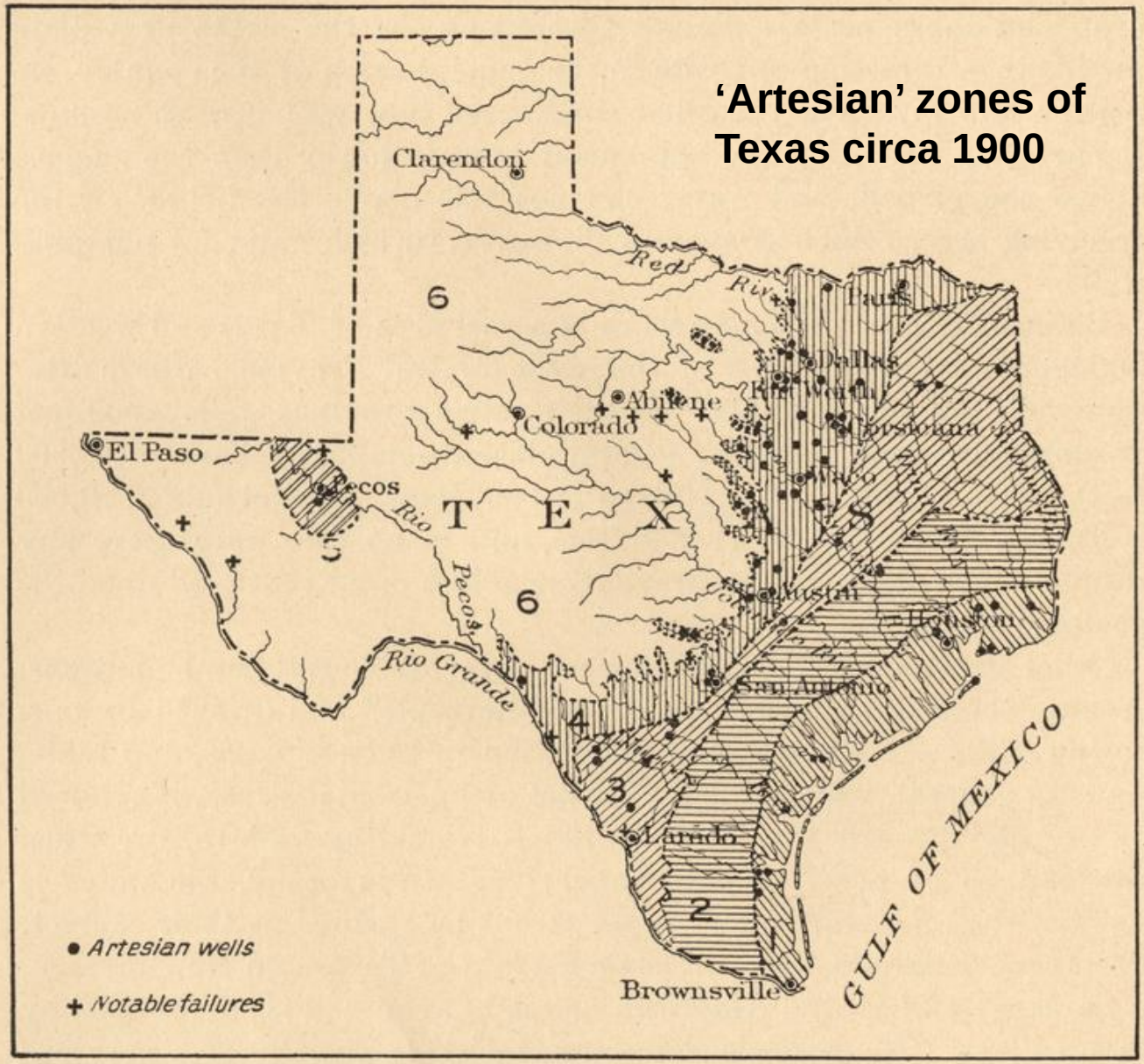
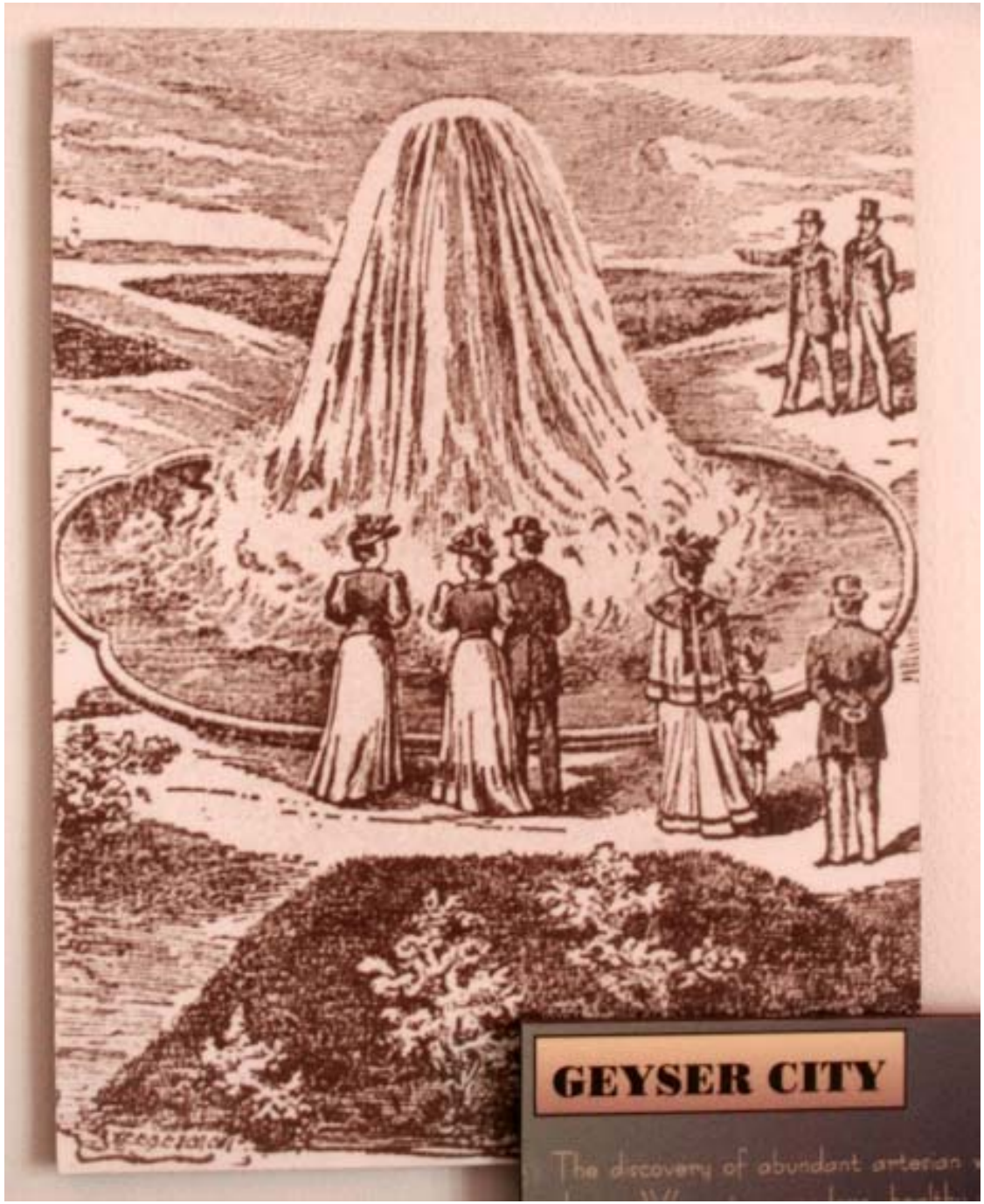


FIG. 44.—Map showing artesian districts of Texas. (from R.T. Hill, 1901)

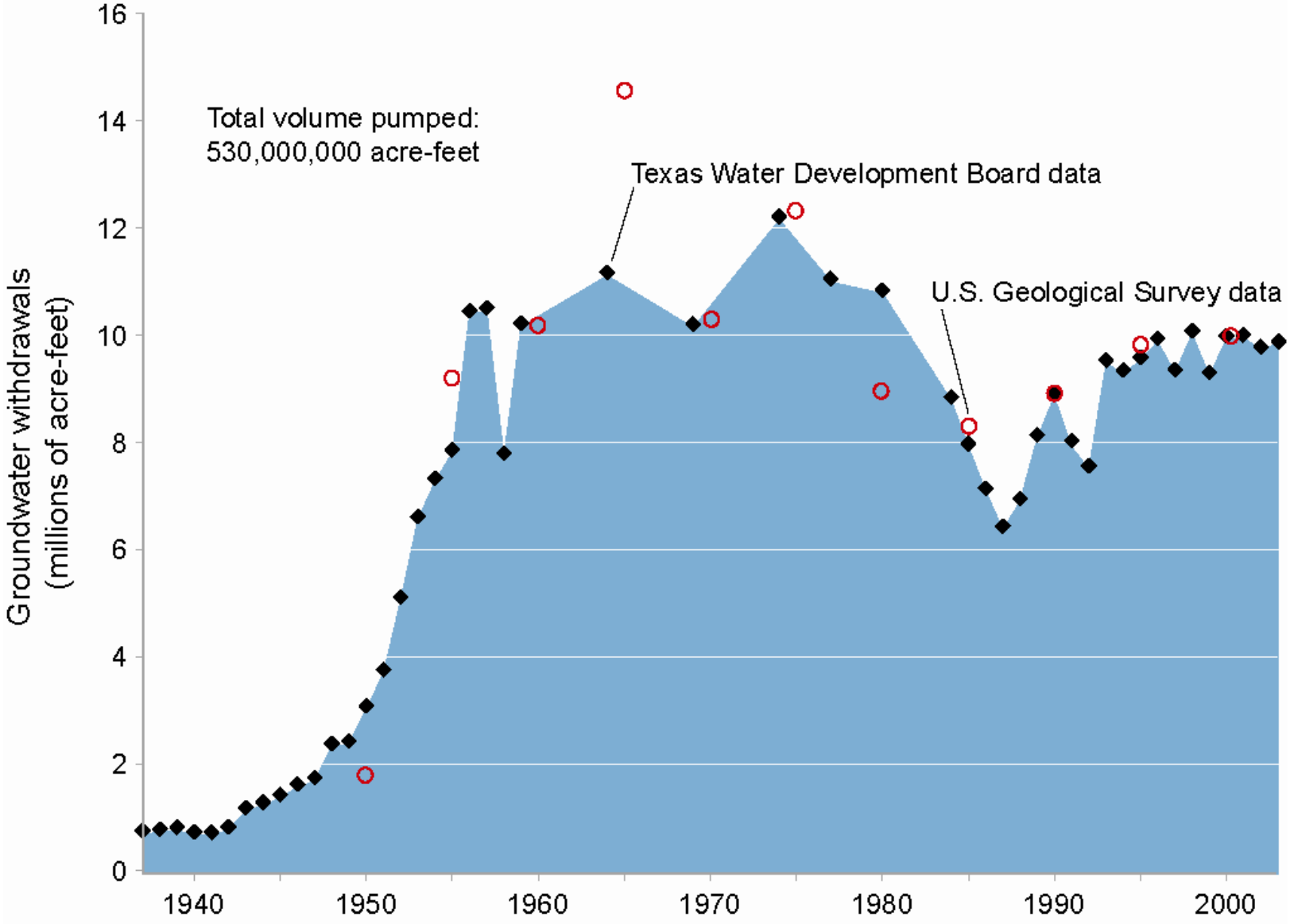
1, Coast Prairie system; 2, Hallettsville system; 3, Carrizo system; 4, Black and Grand prairies system; 5, Trans-Pecos Basin system; 6, Stevens County and Jack County systems.


GEYSER CITY
The discovery of abundant arterian

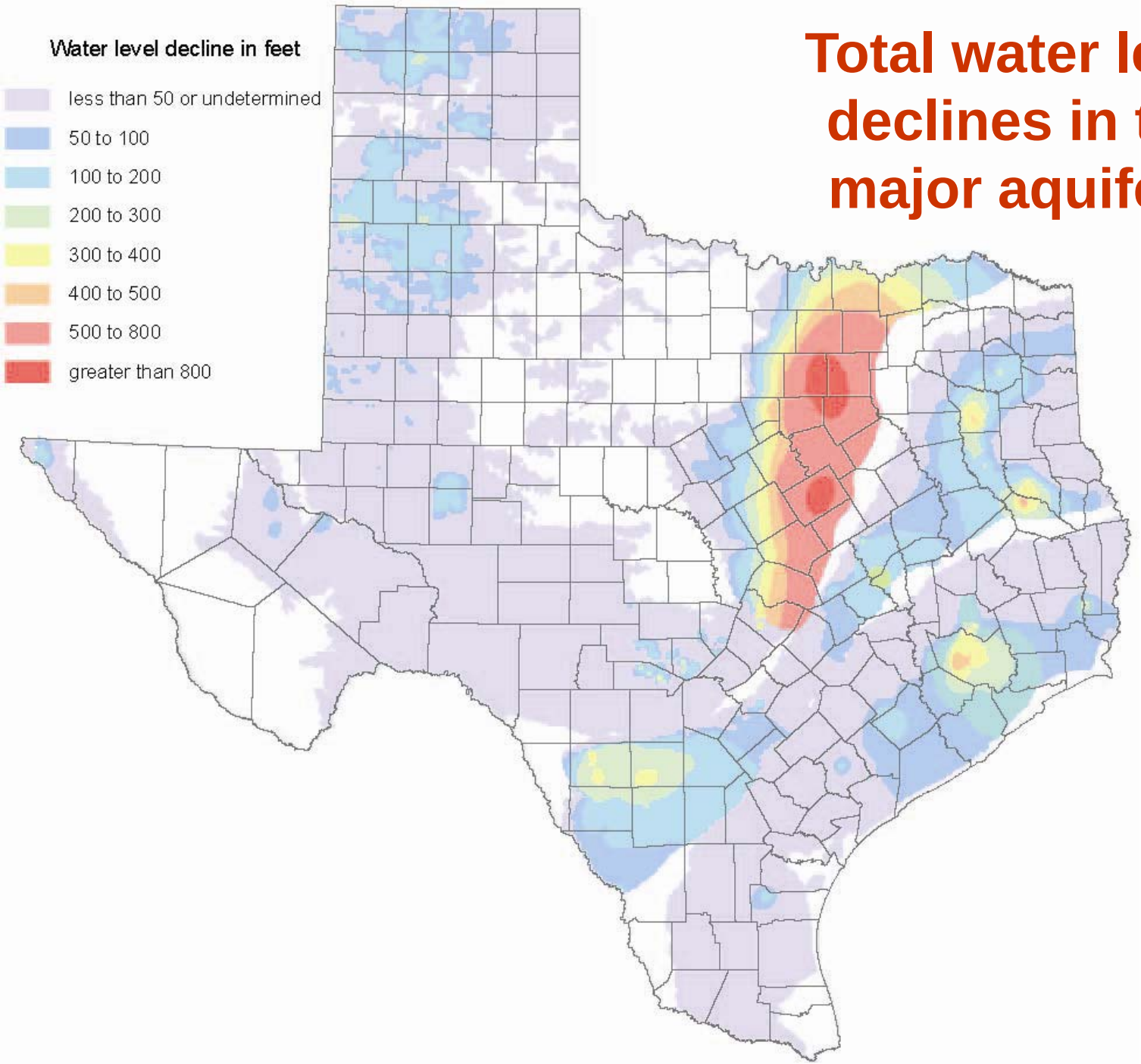
ARTESIAN WELLS AT CITY WATERWORKS, SAN ANTONIO.

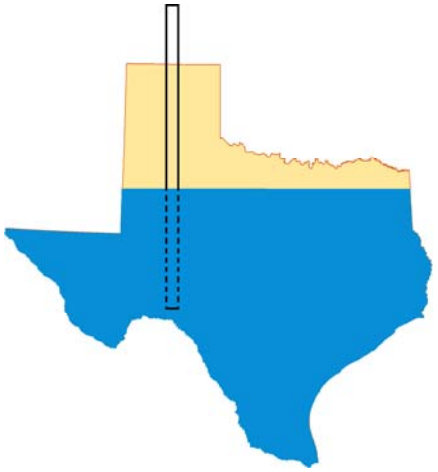

Flowing Artesian Well,
Houston, Texas
211.882 J.V.

groundwater use in Texas (1937 to 2003)



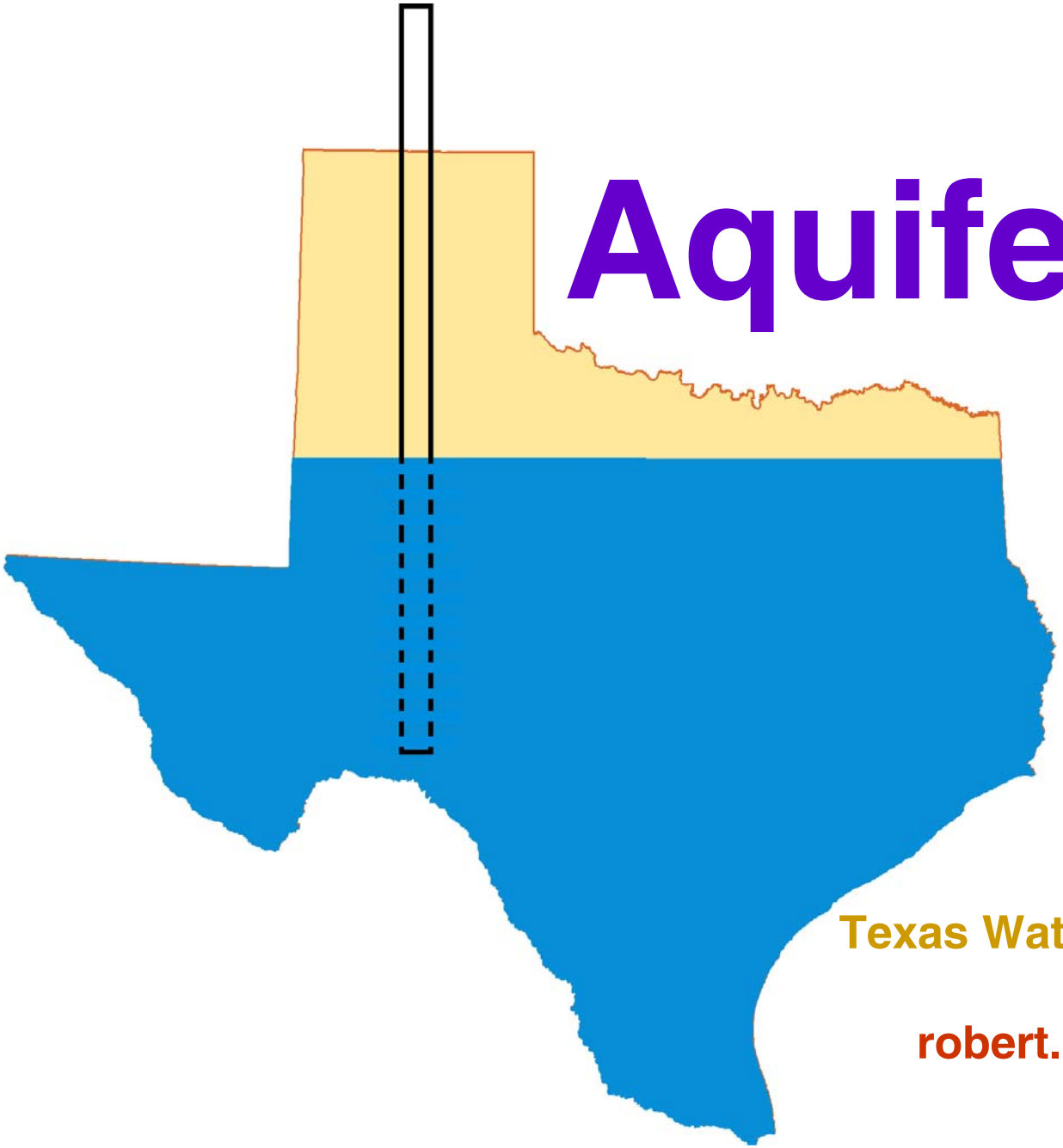
Total water level declines in the major aquifers





Outline

- Yay for aquifers!
- Definitions
- Flow through an aquifer
- Pumping an aquifer



Aquifers 101

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