Understanding Aquifers: in Texas and Especially Milam County

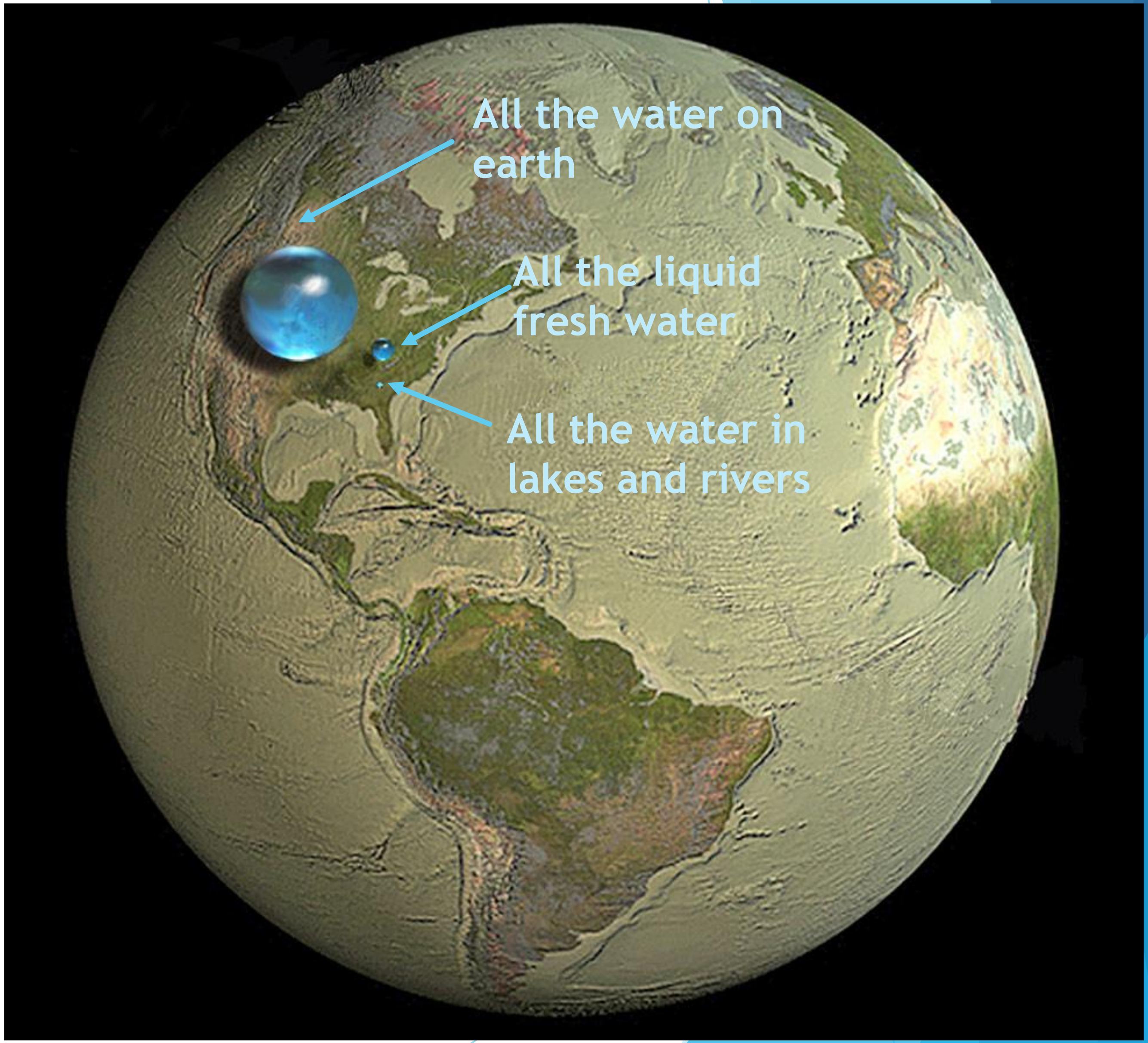
Mike Conner, PhD

Plan

- Context
- Basic Concepts
- Other Important Texas Aquifers
- Carrizo-Wilcox Deep Dive
- Regulatory Situation
- Conclusion: Lots of Unknowns

Water, Water Everywhere and So Little to Drink

- There are about 338 million cubic miles of water on earth
  - This is not changing. Water is not destroyed or created.
- 8.4 million cubic miles of fresh water (about 2.5% of total)
  - This is going down slowly as the ice caps melt and we extract groundwater.
- 2.5 million cubic miles of fresh water available for human use (about 0.8% of total)
- Of the fresh water available for human use, 99.1% is groundwater, the rest is in lakes and rivers.

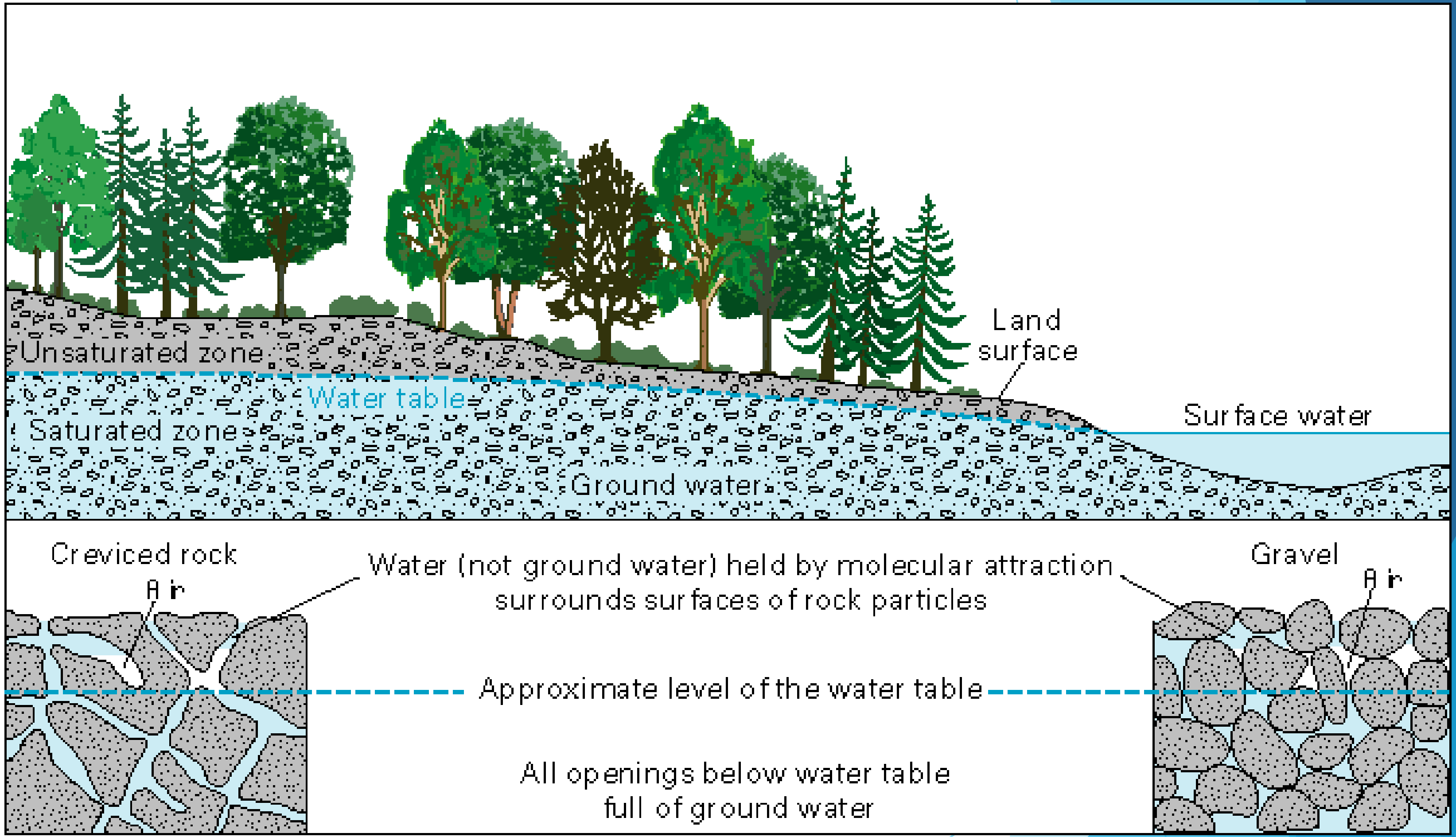


What are Texas' Water Needs and How Can They Be Met?

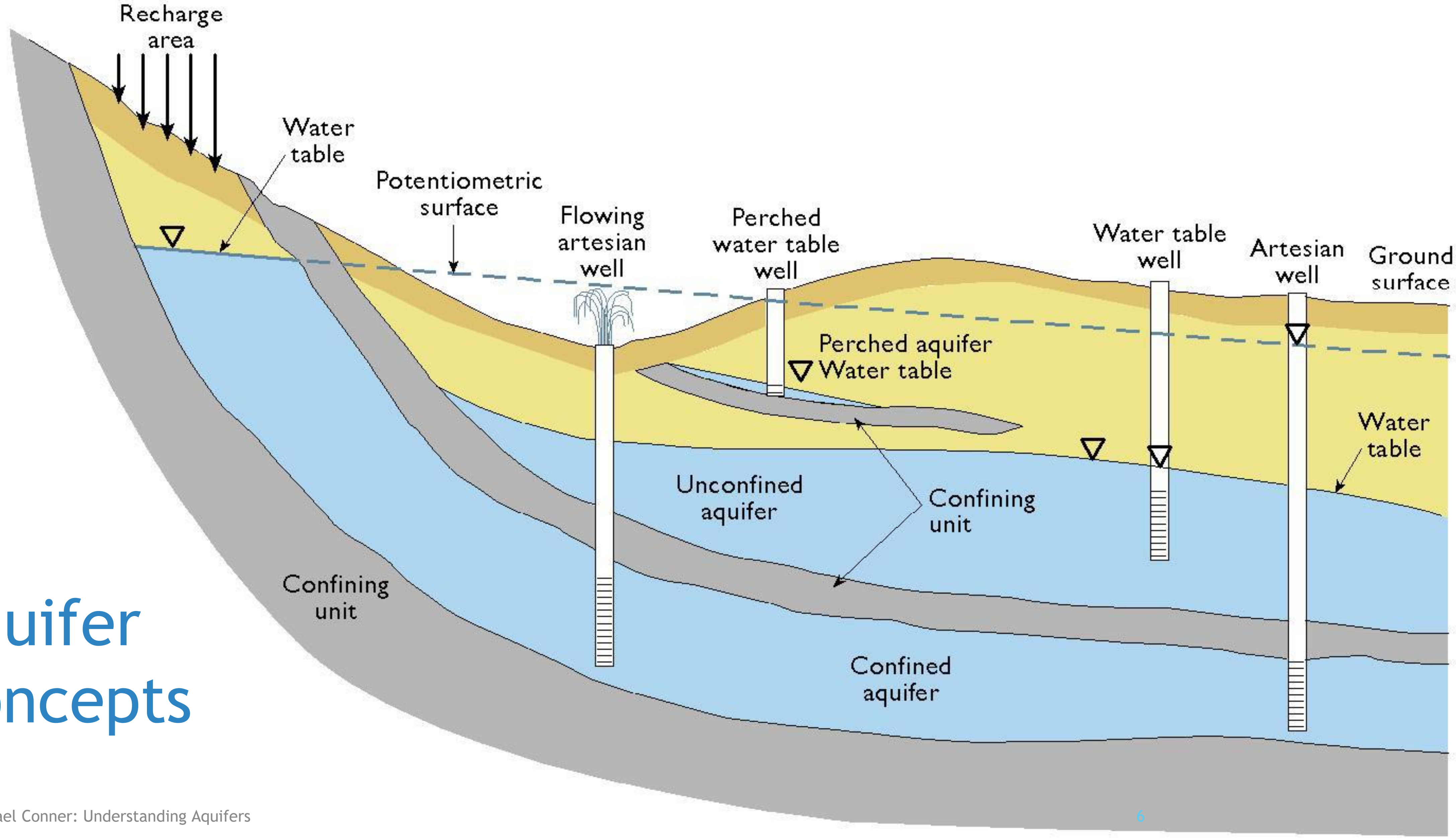
- Texas' surface waters are almost completely utilized.
  - "No more reservoirs"
- Almost all new water demand in Texas comes from population growth.
  - Not industrial, Not agricultural, Not energy generation
- There are only three major sources to meet future water needs:
  1. Conservation and reuse – lowest cost, but requires social change
  2. Desalination of ocean water – Costly (but getting cheaper) and requires expensive and disruptive transportation
  3. Groundwater (fresh, brackish, and saline) - ???

What is an Aquifer?

- Underground water storage – Where groundwater comes from
  - Usually in porous ground formations (sand, gravel)
  - Also in “Karst Formations”: underground caves, fissures, fractured rock
- Only saturated formations can be pumped



Aquifer Concepts



Modified after Harlan and others, 1989

Aquifers are Hard to Analyze

- Aquifers are complex
- Aquifers are not directly observable
- Aquifers are not uniform
- Aquifers are generally very large
- Aquifers can “leak” in very complex ways, some of which cannot be measured
  - Confining layers are never perfect
- Aquifers can contain fresh, brackish, or saline water; or, usually, all three
- There are several types of aquifers with very different characteristics

⇨ All the “science” about aquifers is a simplification, and it is frequently quite controversial.

Dimensions of Aquifers

- Confined/Unconfined
- Recharge rate, recharge area
- Leakage: to springs, to/from streams, to/from other aquifers
- Rate of water movement: conductivity, hydraulic gradient
- Rate and spread of drawdown
- Composition: sand, gravel, silt, fractured rocks, and mixes.
- Quality of water: fresh, brackish, saline (1-1000 mg/l, 1,000-10,000 mg/l, 10,000+ mg/l)

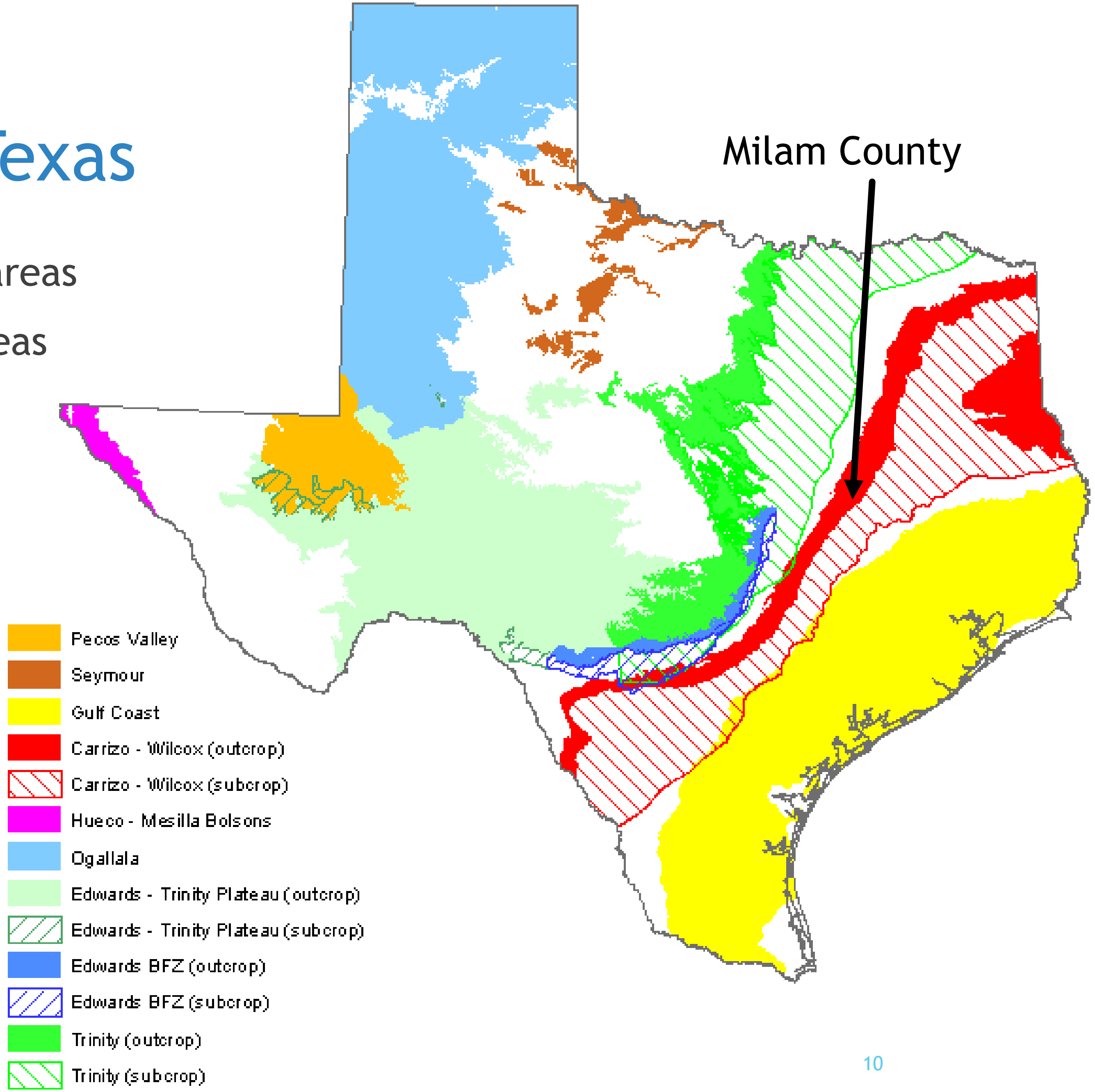
Rate of Flow

Typical hydraulic conductivity of geological units	
Geological unit Hydraulic conductivity (m/d)	**Ratio**
Fine sand 0.02 to 17	850
Coarse sand 0.08 to 520	6,500
Gravel 26 to 2,592	100
Shale 8 x 10 -9 to 2 x 10-4	40,000
Sandstone 3 x 10-5 to 0.5	60,000
Permeable basalt 0.03 to 1,728	57,600
Least to most	324,000,000,000

- The rate that water flows through an aquifer varies based on the composition and sloop of the aquifer.
- Aquifers usually do not have uniform composition
- Hydraulic conductivity can vary over relatively short distances
- ➔ Predicting the rate at which the impact of pumping spreads is very speculative

Major Aquifers of Texas

- Solid colors are the recharge areas
- Hashed colors are confined areas

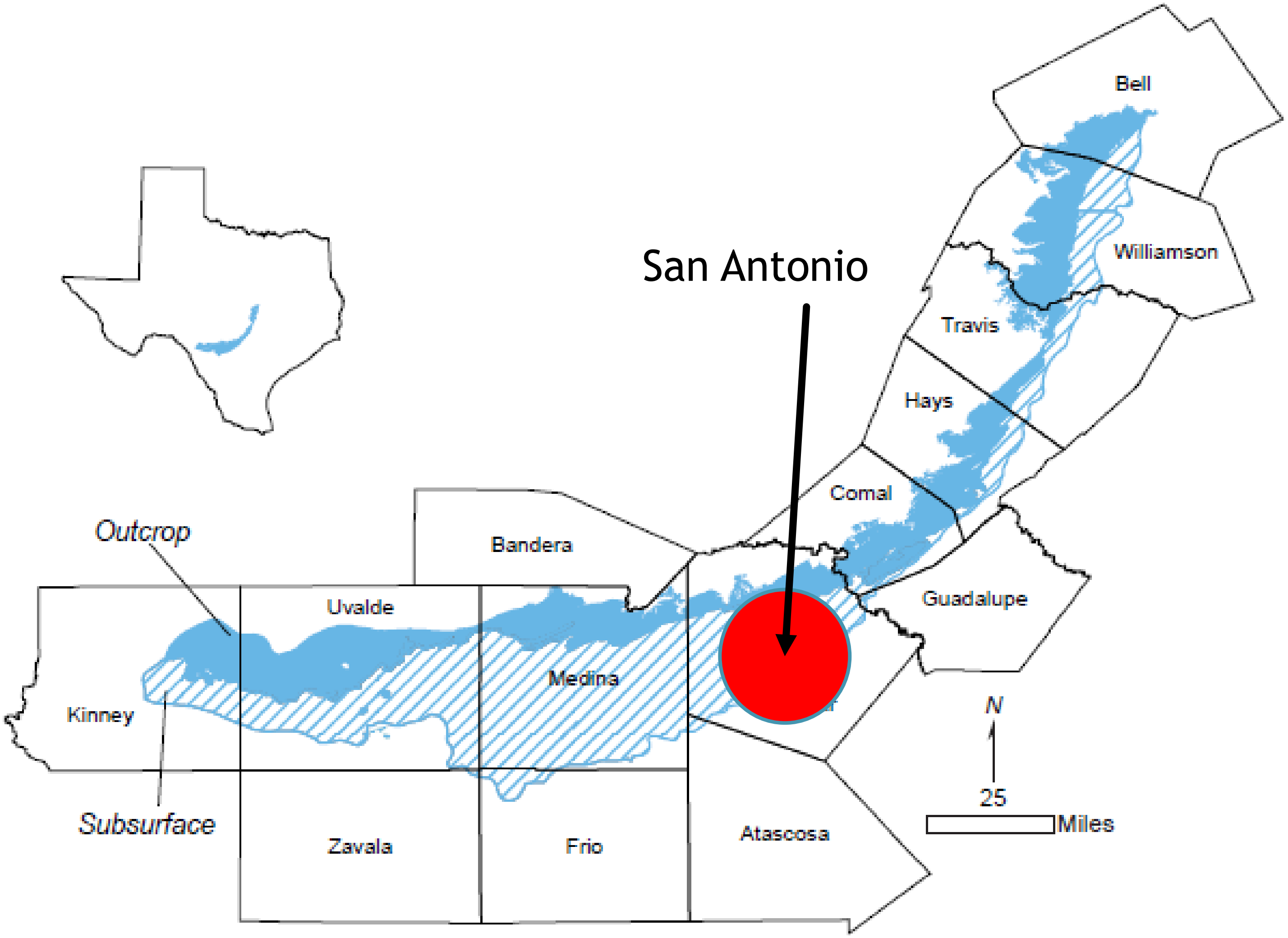


Ogallala Aquifer

- Almost completely unconfined, max 800 ft
- Freshwater saturated thickness averages 95 feet
- Largest aquifer in US
- Most productive aquifer in Texas
- Underlies and supports the US grain belt
- Is being pumped much faster than it is being recharged – 1 ft drawdown vs 1 in recharge
- Some parts have been drawn down to half full
- Water level decline of 300 ft in some areas, but the rate of decline has slowed

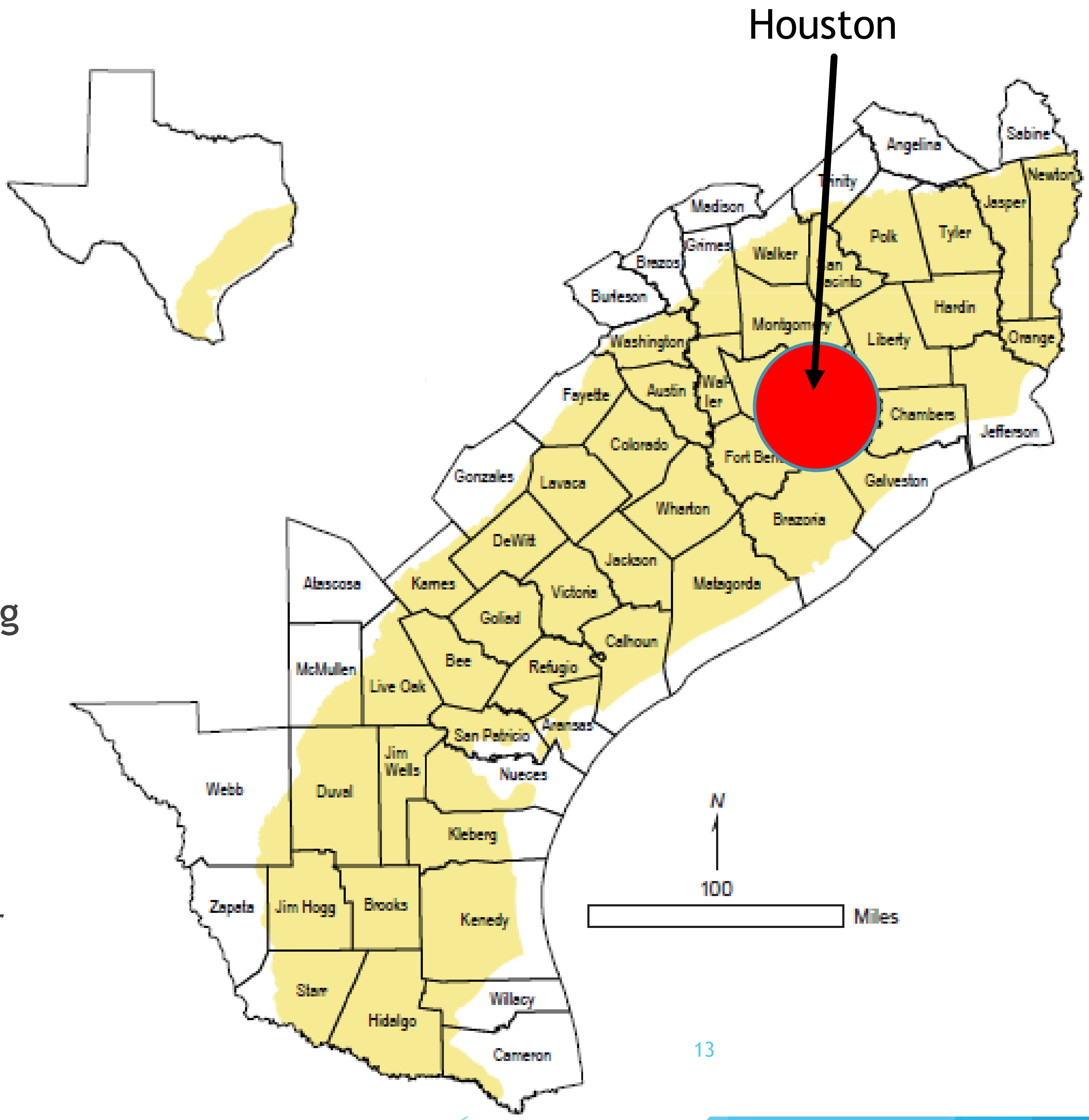
Edwards Aquifer (Balcones Fault Zone)

- Karst Formation – Water flows rapidly through cracks and tunnels
- Recharges directly through cracks in creek beds
- Water levels and spring flows respond quickly to rainfall, drought, and pumping
- Provides almost all of San Antonio's water (However, starting in 2020 they will get 50,000 ac/ft a year from us.)



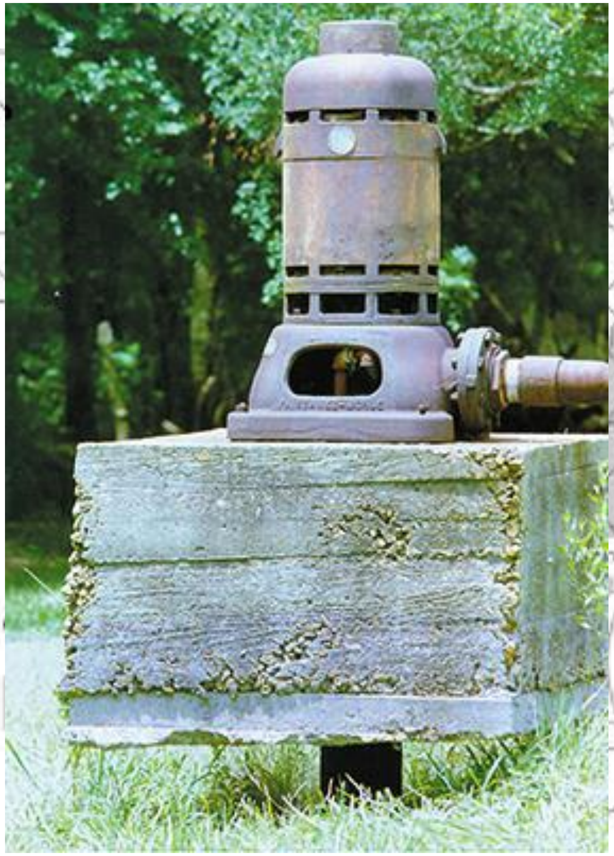
Gulf Coast Aquifer

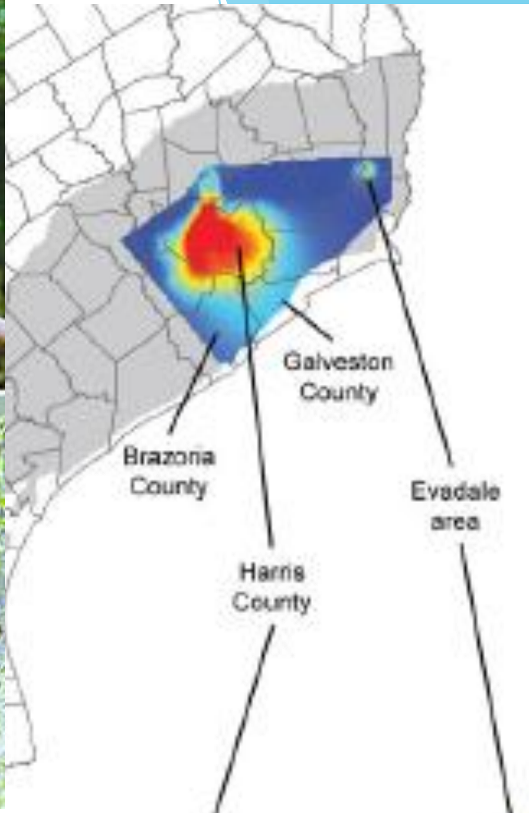
- Average 1,000 ft of freshwater
- Water quality and productivity drop off to the south
- In counties around Houston water level has dropped as much as 350 feet
- Land subsidence is currently the limiting factor
- Trend is to shift to surface water, but Brazos River is fully allocated
  - Off-channel reservoirs
  - Pump our groundwater into Brazos River

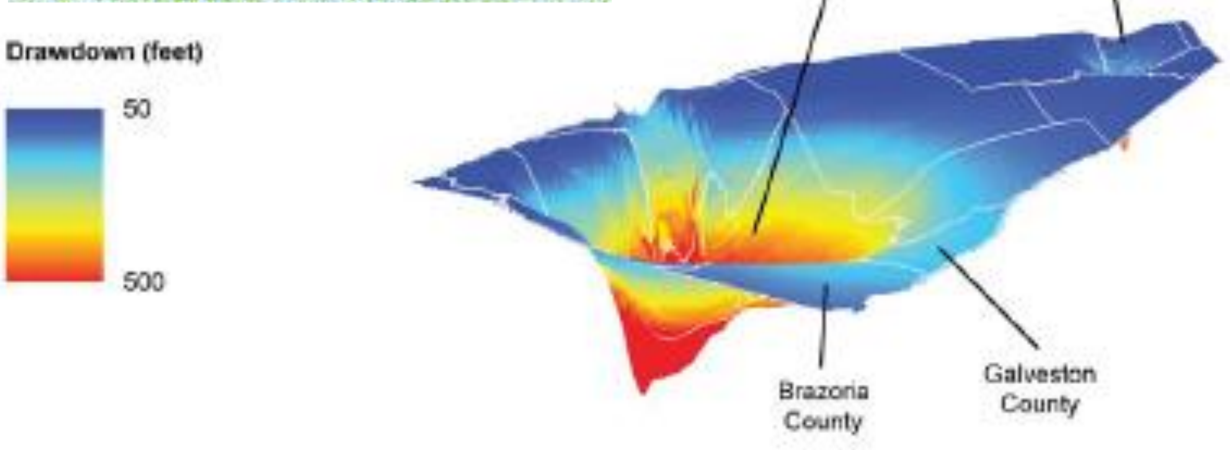


Subsidence

- Reduces the ability to store water in an aquifer
- Partially or completely submerges land
- Collapses water well casings
- Disrupts collector drains and irrigation ditches
- Alters the flow of creeks and bayous which may increase the frequency and severity of flooding
- Damages roadways, bridges, building foundations, and other infrastructure
- Without regulation the main economic sectors of Houston would be flooded by 2030

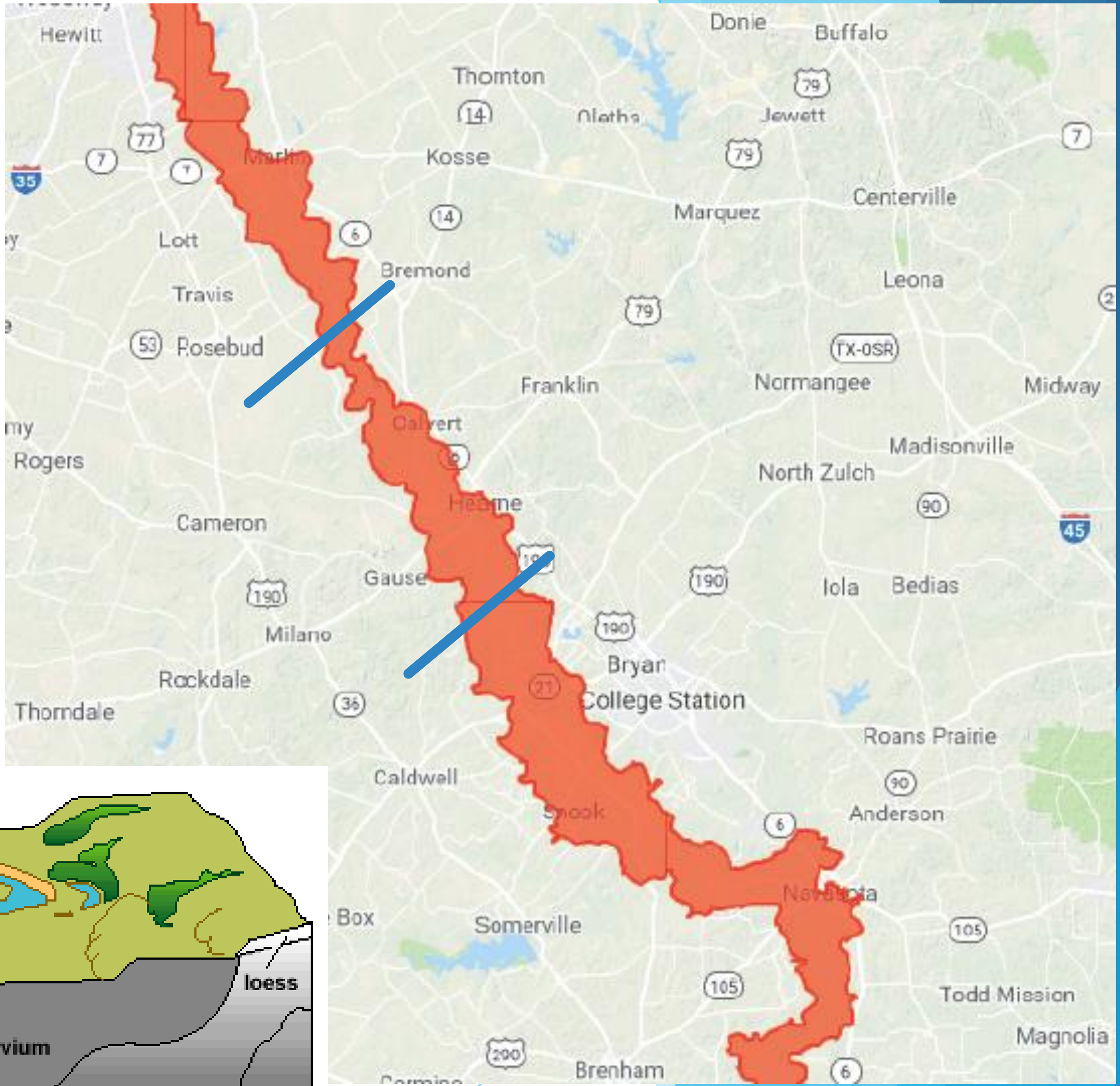


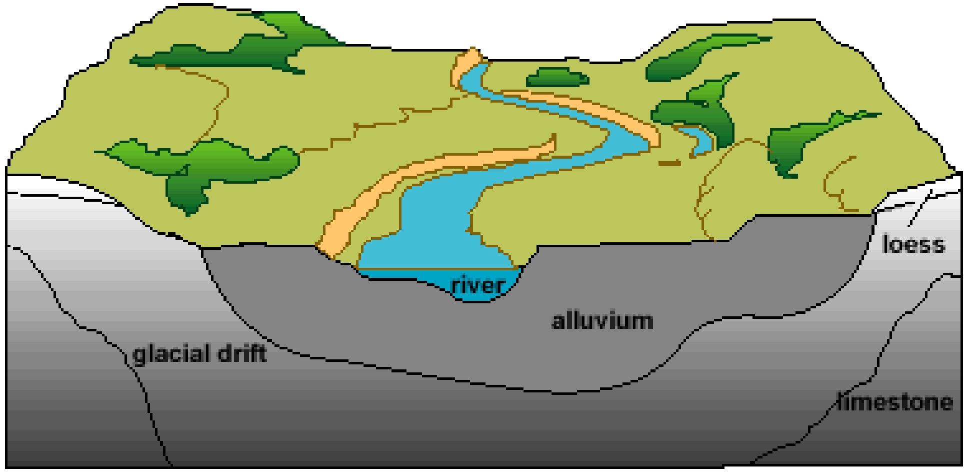




Brazos River Alluvium

- Unconfined, composed of unconsolidated material deposited by water
- Mostly on the Robertson County Side of the Brazos River in Milam County
- Recharged by rain falling in the Brazos River Basin
- Level varies with rainfall and demand but is not falling overall
- Major source for agricultural irrigation in the Brazos Valley





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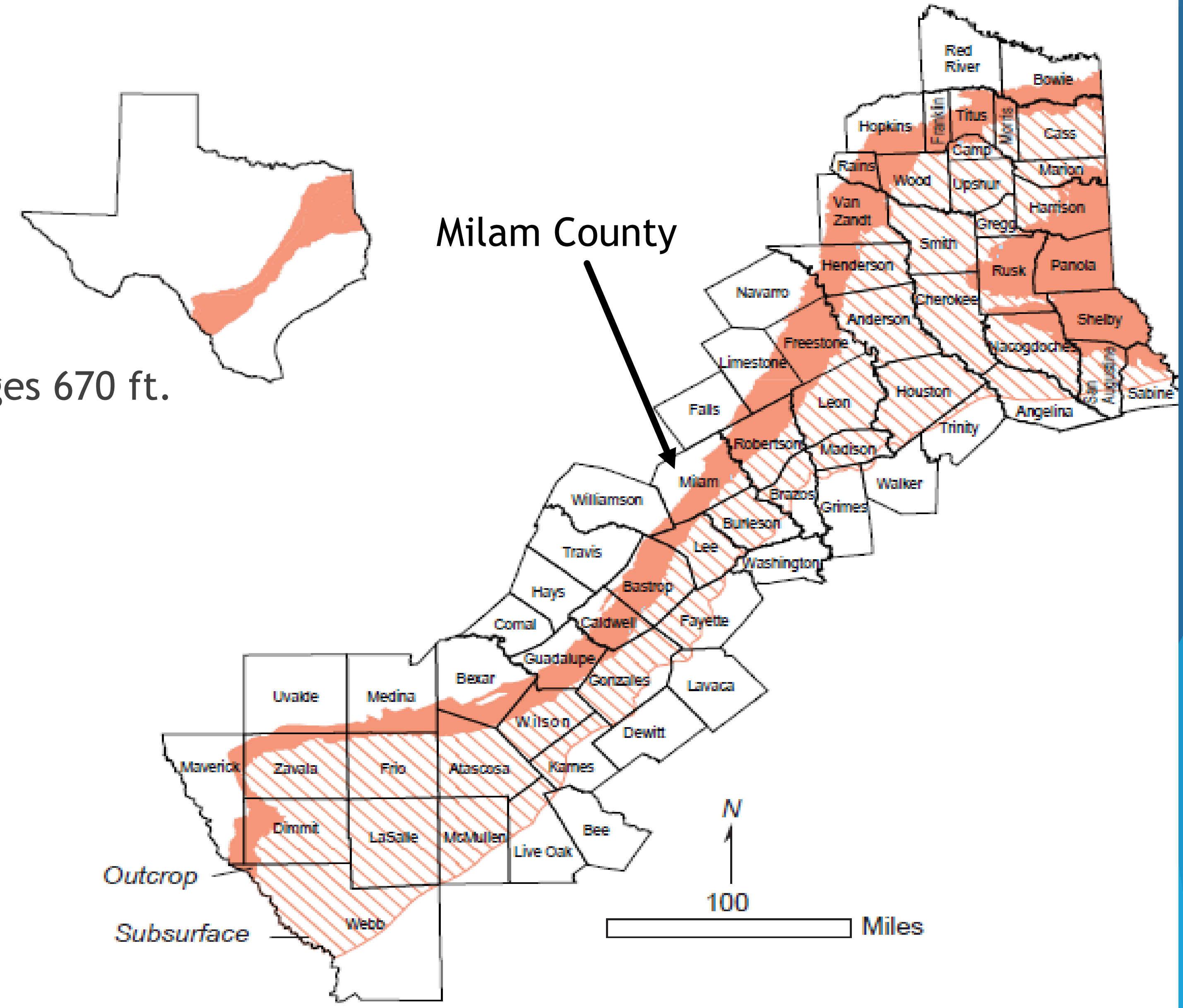
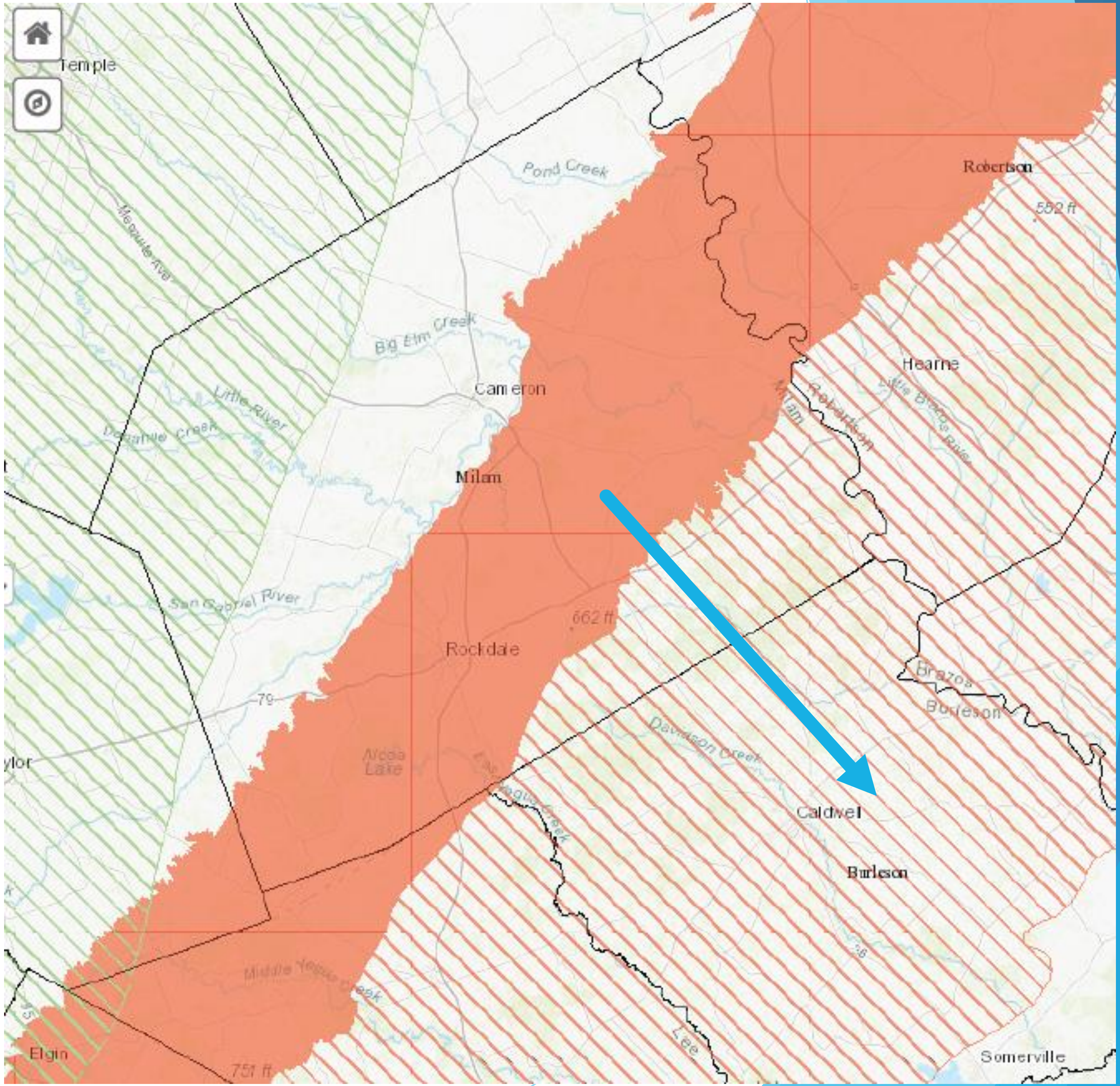
Carrizo-Wilcox Aquifer

- Saturated thickness of up to 3,000 ft.
- Freshwater saturated thickness averages 670 ft.

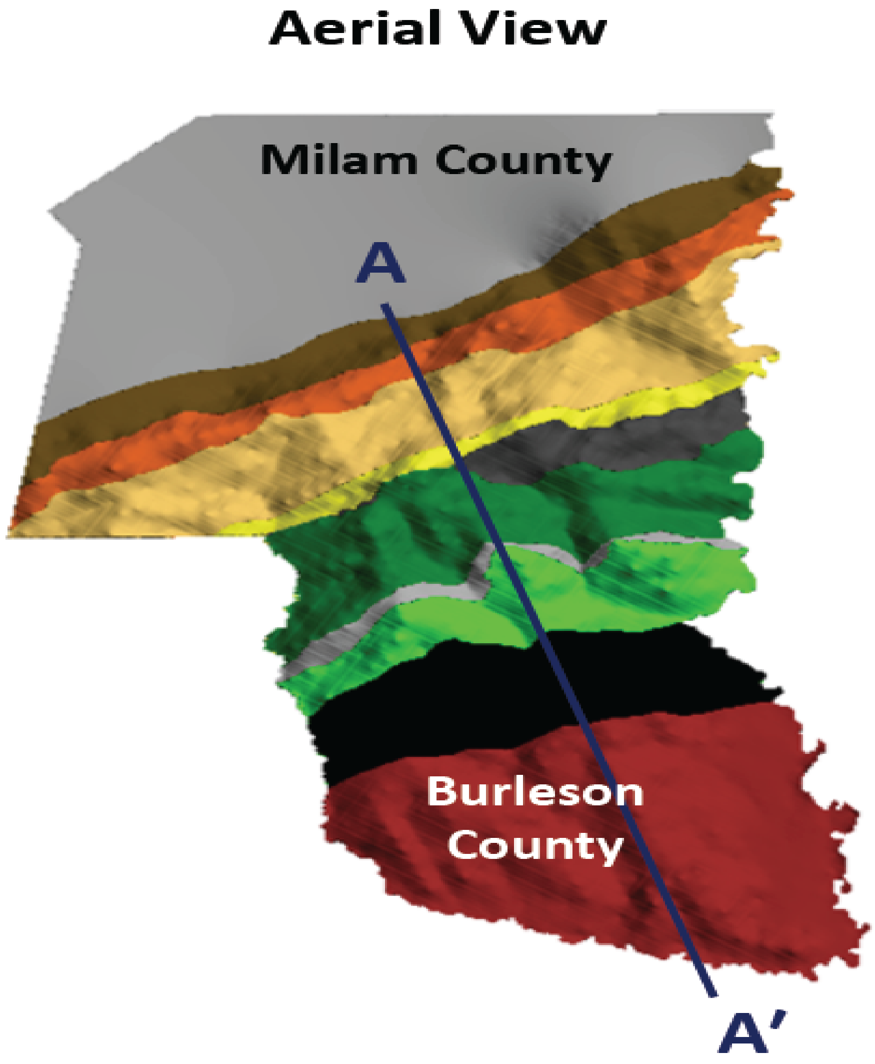


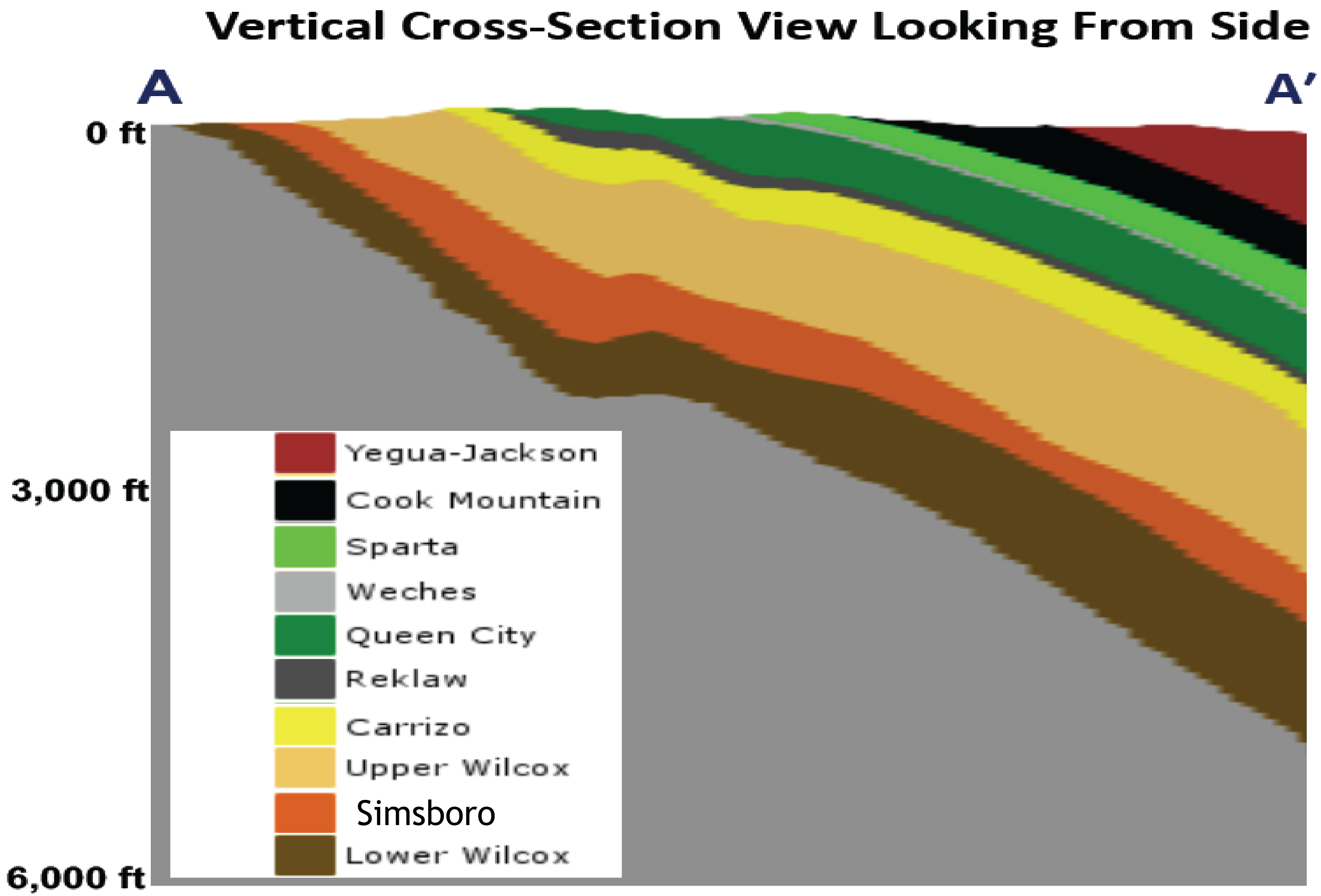
Carrizo-Wilcox In Milam County

- Milam County mostly contains the unconfined part of the aquifer (the recharge zone)
- The Aquifer slopes to the southeast



POSGCD Aquifers/Formations

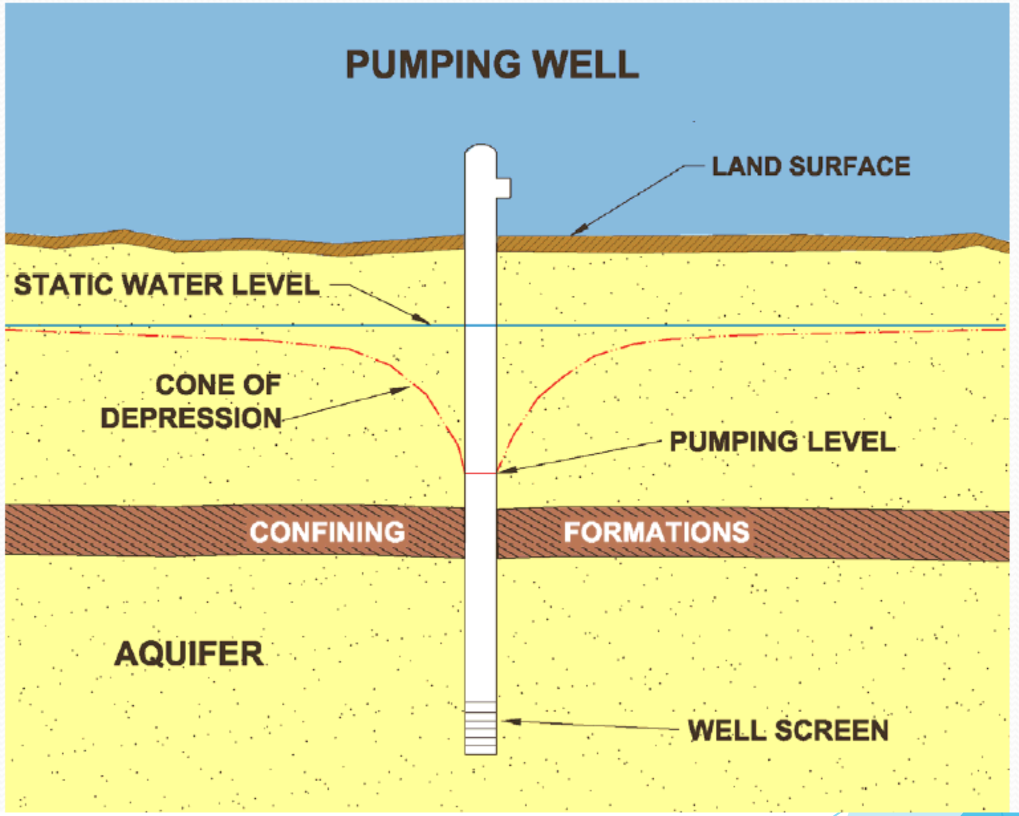




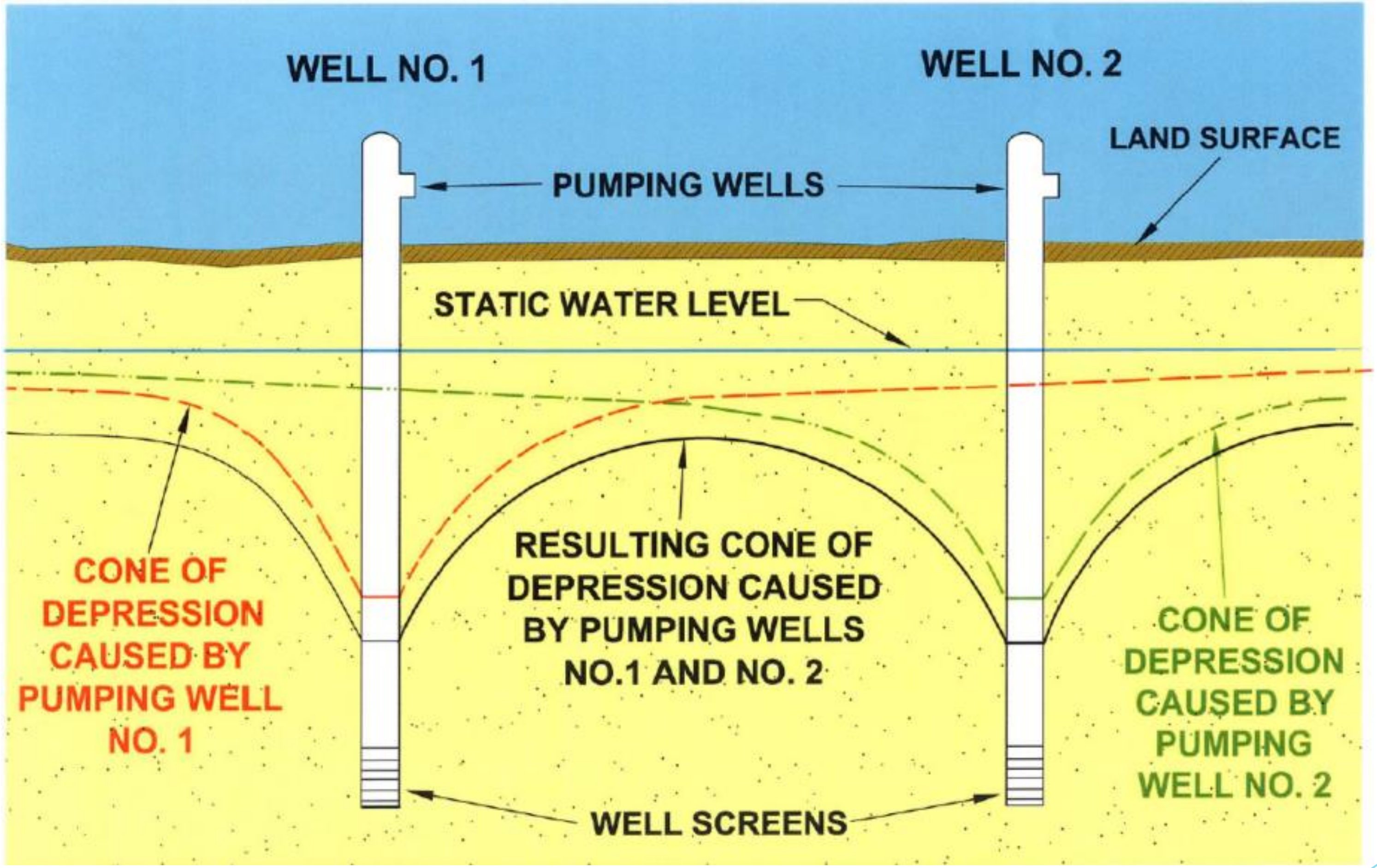
INTERA

Drawdown: Cone of Depression

- Water level does not drop, but pressure level does.
- Rapid (for an aquifer) spread of pressure drop
- What happens when water is removed?
  - Expansion of water?
  - Expansion of substrate?
  - Subsidence of surface?
  - Recharge from unconfined zones?
  - All of the above?



Drawdown: Multiple Wells



Drawdown: The Big Picture

- Water flows downhill
- Pumping from the confined part of an aquifer does not dewater the well, it lowers its head.
  - Slightly increasing the cost of pumping
  - May increase the rate of downdip flow
- If water is pumped from the aquifer faster than it is recharged it will eventually dewater shallow wells
- As water is drained from parts of the recharge zone it may increase recharge rate

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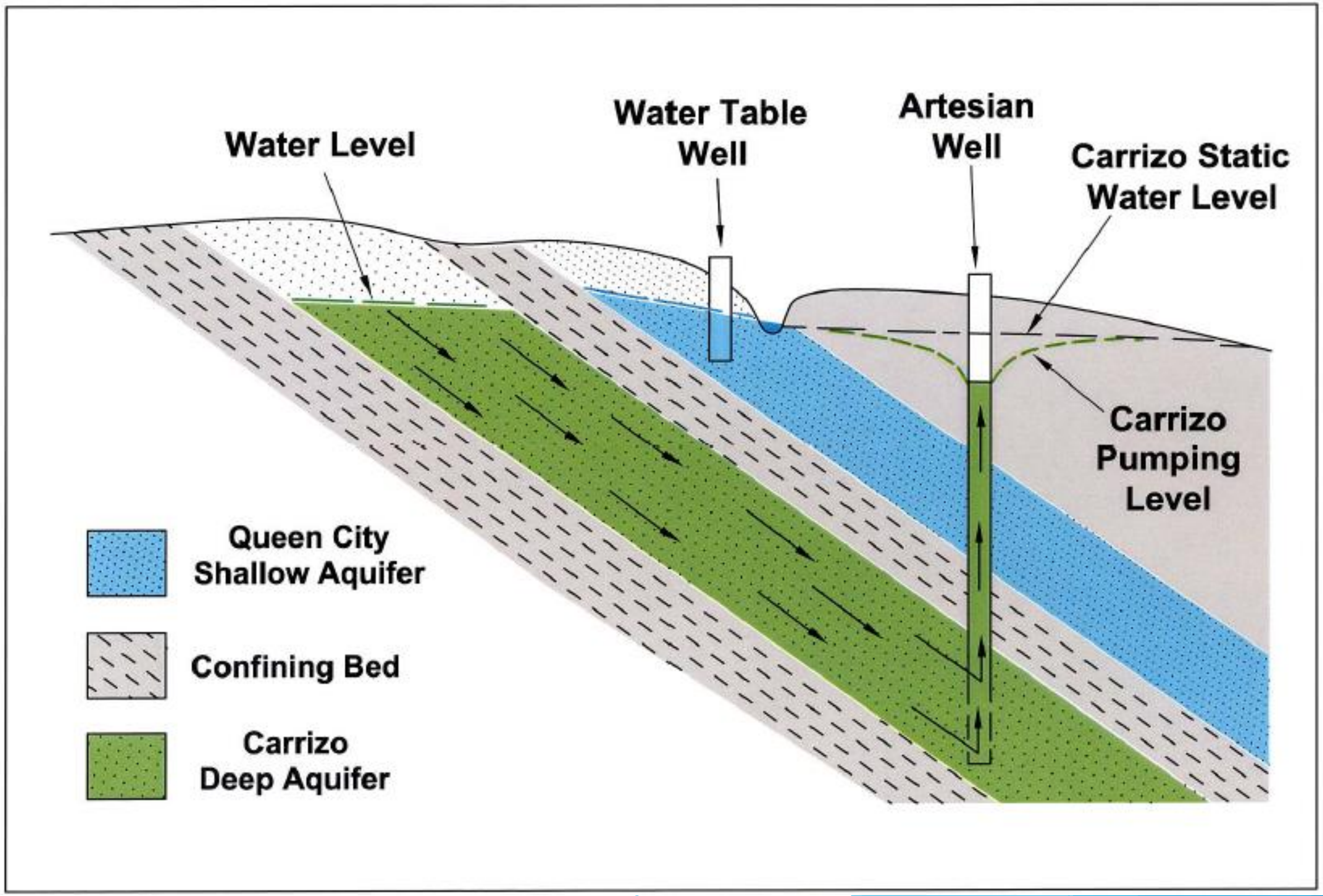
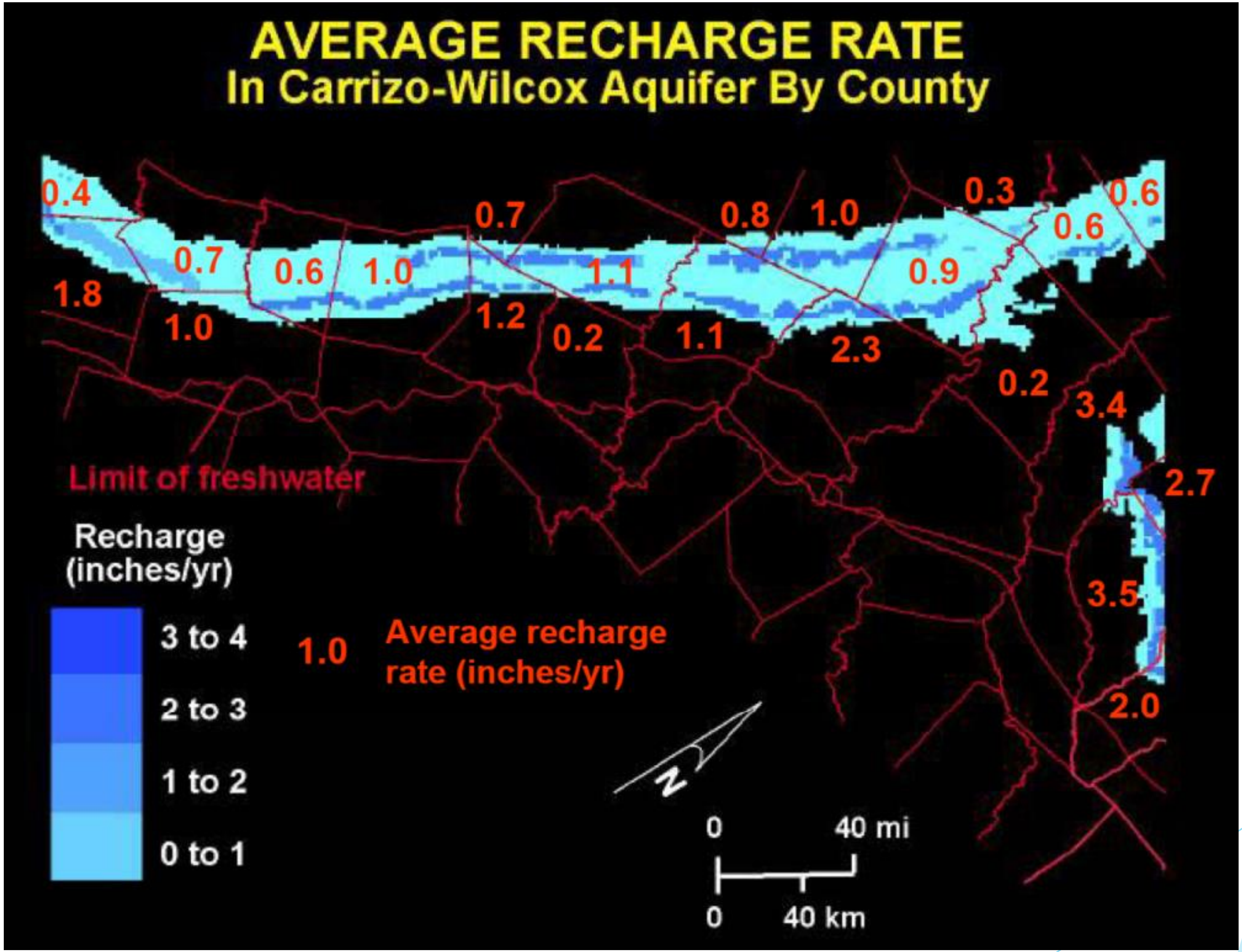
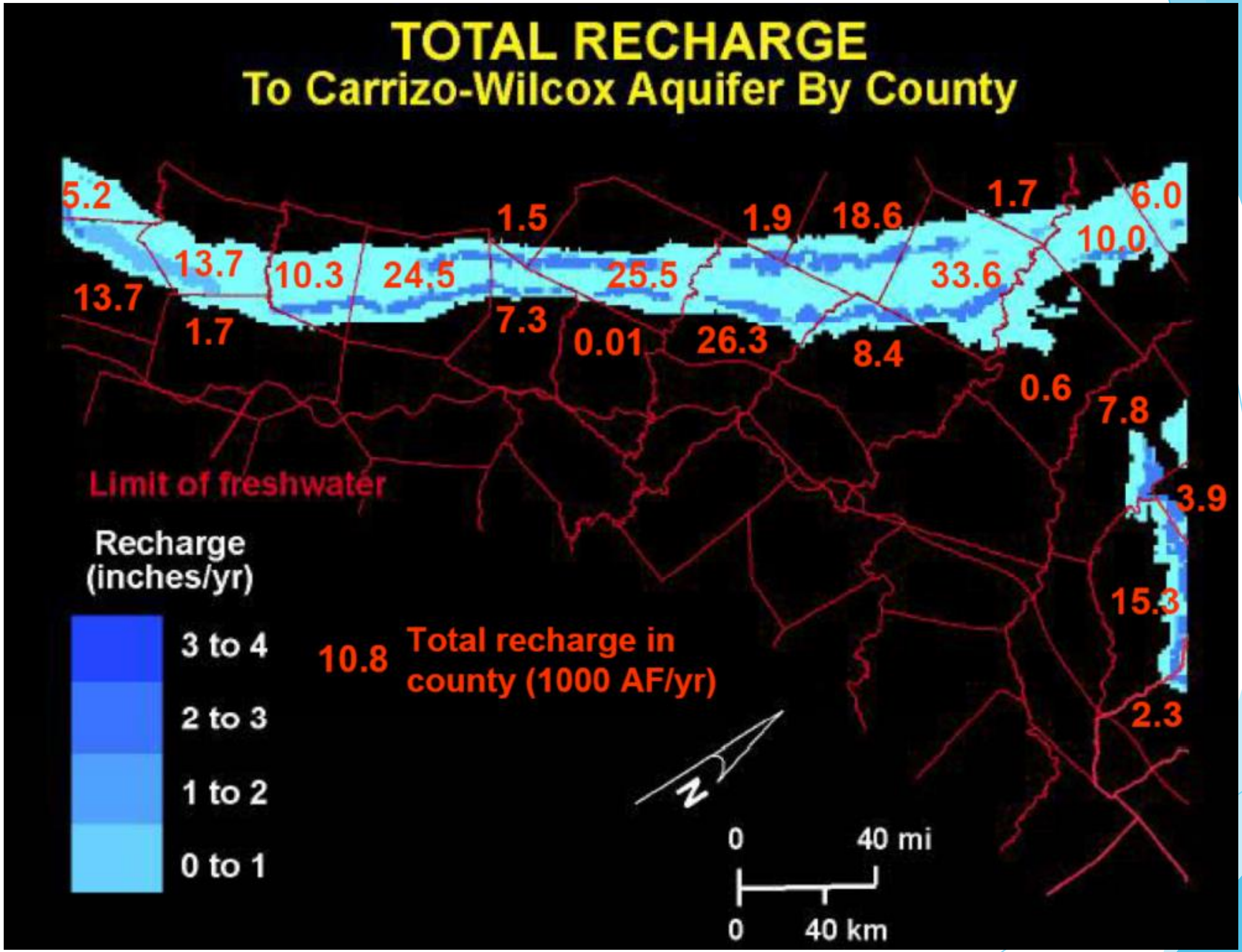
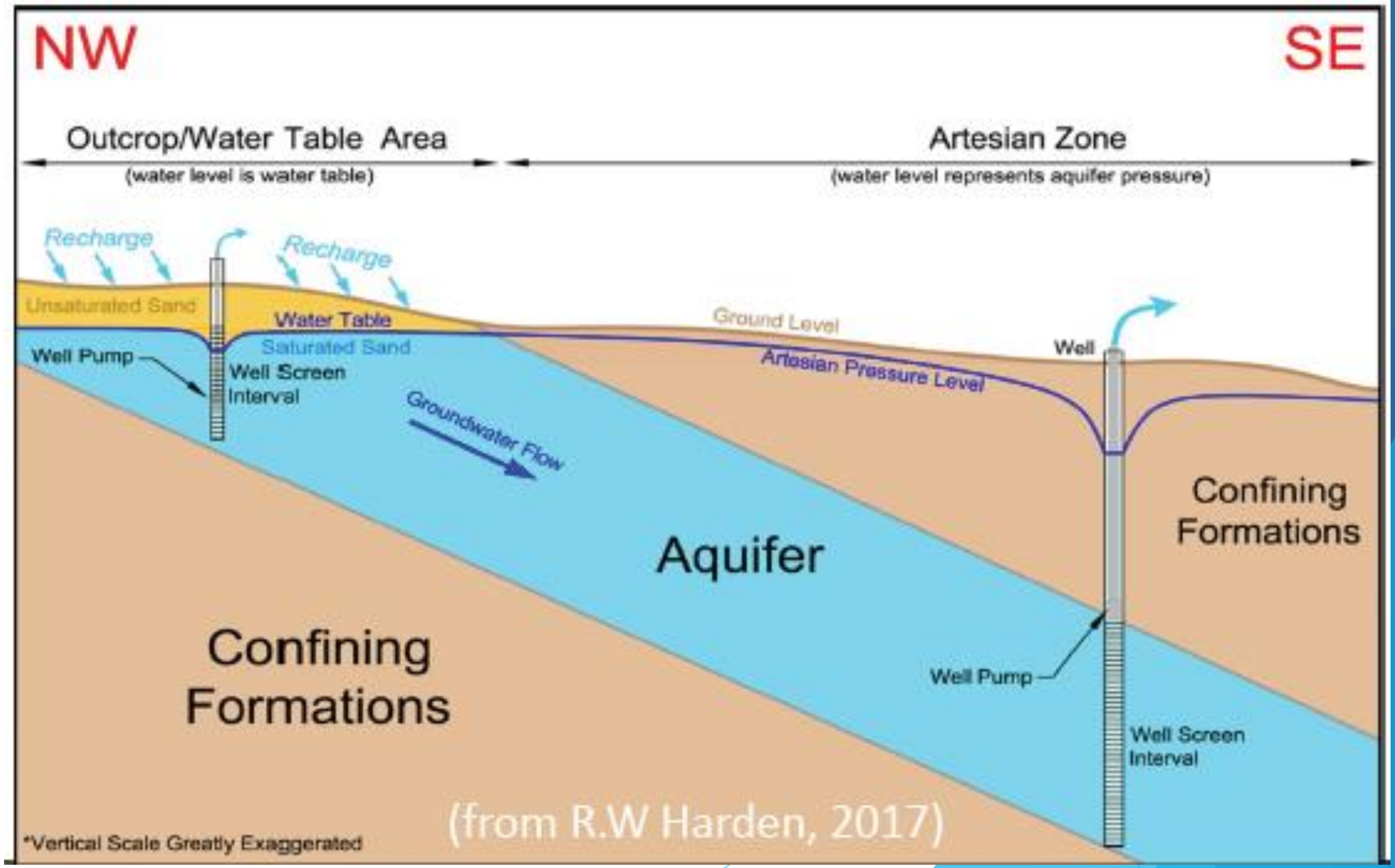



AVERAGE RECHARGE RATE
In Carrizo-Wilcox Aquifer By County
0.4
0.7
0.8
1.0
0.3
0.6
0.6
0.7
0.6
1.0
1.1
0.9
1.8
1.0
1.2
0.2
1.1
2.3
0.2
3.4
2.7
3.5
2.0
Limit of freshwater
Recharge (inches/yr)
3 to 4
2 to 3
1 to 2
0 to 1
1.0
Average recharge rate (inches/yr)
N
0 40 mi
0 40 km

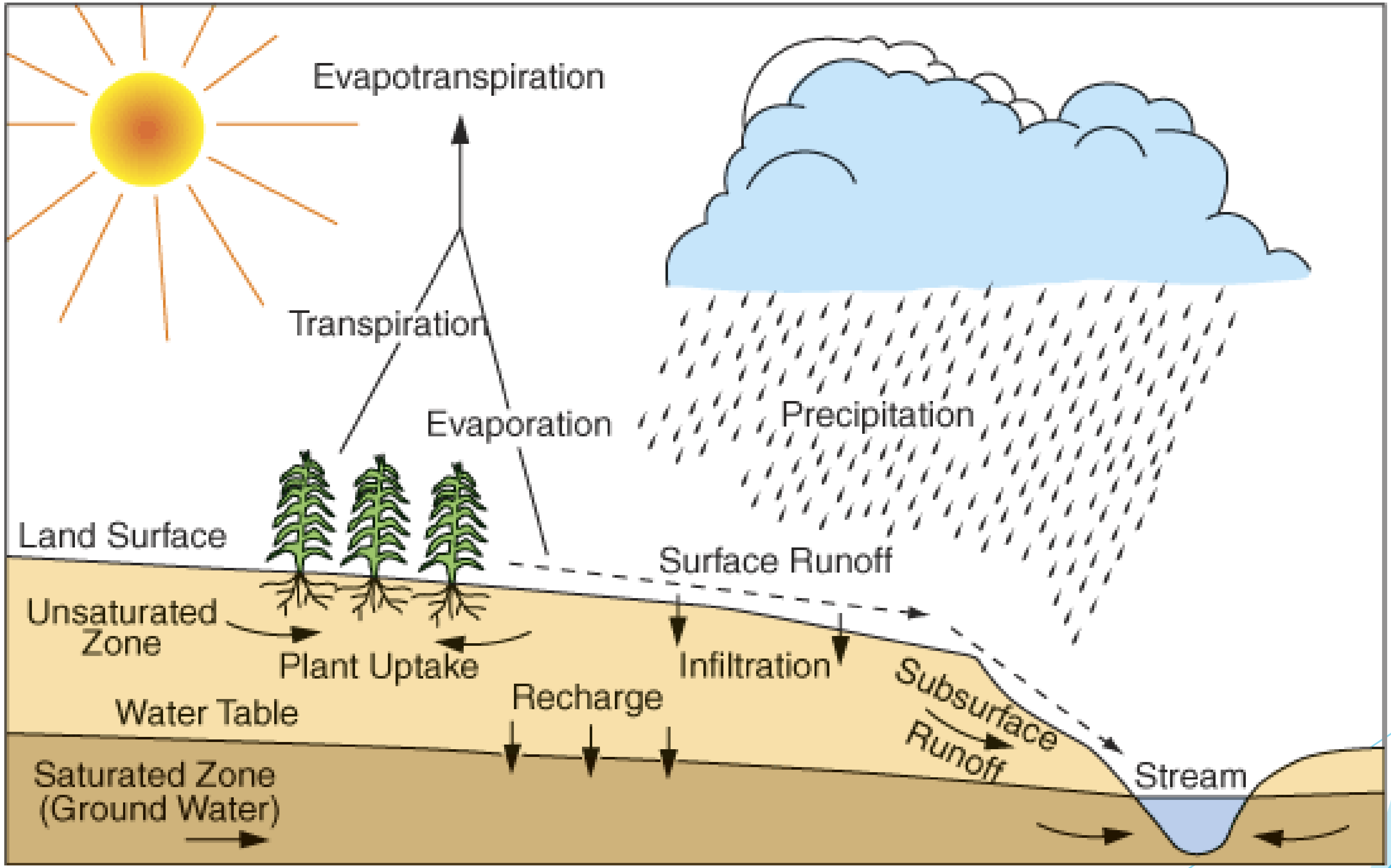

TOTAL RECHARGE
To Carrizo-Wilcox Aquifer By County
5.2
13.7
13.7
1.7
10.3
24.5
1.5
7.3
0.01
25.5
26.3
1.9
18.6
8.4
33.6
1.7
6.0
10.0
0.6
7.8
3.9
15.3
2.3
Limit of freshwater
Recharge
(inches/yr)
3 to 4
2 to 3
1 to 2
0 to 1
10.8
Total recharge in
county (1000 AF/yr)
N
0
40 mi
0
40 km

Current Drawdown Theory

- Outcrop/Shallow Groundwater Zone is resistant to drawdown
- Drawdown spreads far in confined zone
- Current recharge estimate for Carrizo-Wilcox:
  - 1.1 inches
  - 25,500 ac-ft per year
- Then pumping 75,000 ac-ft a year should lower unconfined wells by 2 inches a year



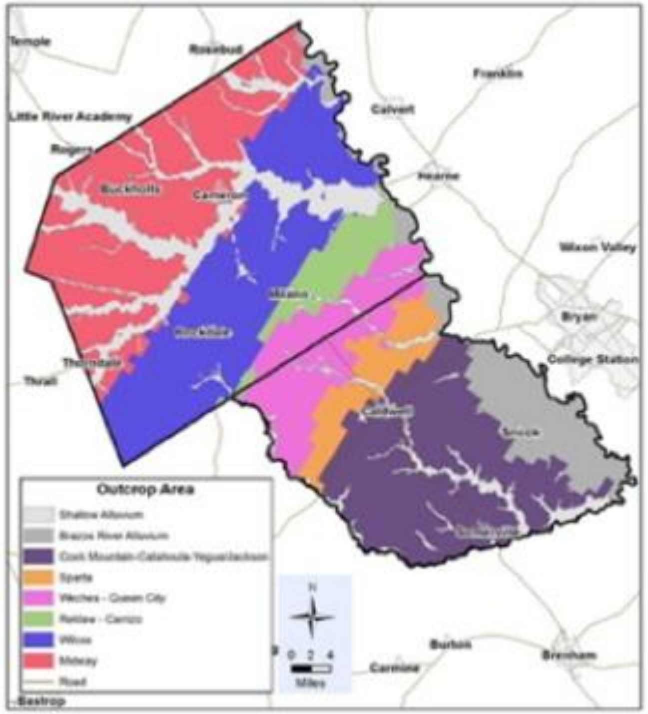
Factors Affecting Recharge



Groundwater Regulation

- Texas - Rule of Capture: All the water you pump from wells on your land belongs to you, without limit!
- Groundwater Conservation Districts
  - Must be approved by voters in the counties they manage
  - Funded by taxes or (almost always) by fees
  - Regulatory authority to manage pumping
  - Must manage production to meet, but not exceed "Defined Future Conditions"
- Defined Future Conditions (DFCs)
  - Set of goals for the Aquifer (level of drawdown, storage level, subsidence, …) for 50 years in the future.
  - State computes a Managed Available Groundwater (MAG) limit – how much can be pumped every year to meet the District's DFC.

Post Oak Savannah Groundwater Conservation District



- Milam and Burleson counties, Created in 2002
- Most DFCs are drawdown based.
- Sets different goals for shallow and deep wells
- Growing monitoring network
- MAG of about 50,000 acre-feet for Carrizo-Wilcox
- 2 acre-feet / acre permitting rate, about 1,000,000 acres over aquifer
  - 2.5% of land is enough to pump entire MAG
- Carrizo-Wilcox is fairly full in the District at this time
- Vista Ridge Project will start pumping 50,000 acre-feet of water per year in 2020.
- Management rules are complex and subject to several interpretations
  - Vista Ridge publicly states that they can’t be restricted.
- Other large projects are under consideration

Modeled Drawdown from Vista Ridge

The Vista Ridge pumping would:

- Reduce hydraulic heads in the Hooper, Simsboro, Calvert Bluff, Carrizo, and Queen City aquifers
- Where these aquifers are confined, the reduced heads would cause water levels in wells to decline
- Where these aquifers are unconfined (recharge areas), the reduced heads would cause dewatering of portions of the aquifers
- Results in the LPGCD and POSGCD exceeding their adopted Simsboro Aquifer DFCs by 2060
- Reduce groundwater discharge to the Colorado and Brazos rivers, thereby reducing the amount of water flowing in these streams

Figure 2
GAM Predictino of Drawdowns in the Simsboro Aquifer Due to Vista Ridge Pumping, 2060
Line of equal drawdown in Simsboro Aquifer, feet of drawdown in 2060

From George Rice
September 22, 2015

Post Oak Savannah GCD
Aquifer Conservancy Program

- 5, 10 or 20 year binding contract:
  - No non-exempt wells
  - Cannot sell or lease water rights
  - Pays landowners $5, $7 or $8 per acre (estimates)
  - Land must be over the Carrizo-Wilcox Aquifers and in Milam or Burleson County and water rights must be retained
- District pays for the plan out of increased permit fees
- Conservation land does not in any way impact the amount of water that will be pumped from the Carrizo-Wilcox Aquifers, nor does it conserve the water under the land

Milam County Groundwater: Lots of Unknowns

- Will recharge increase with increased pumping?
- How long will it take for drawdown to dewater shallow wells?
  - 10 years? 300 years?
- How quickly will shallow wells recover if pumping is reduced?
  - 10 years? 300 years?
- If additional large projects are started will the GCD be able to manage drawdown?
- In the future will new sources of affordable water be available?
  - Desalination?