Groundwater 101: How Aquifers Work

Serving the citizens of Milam and Burleson Counties

Michael Redman, AGM,
POSGCD

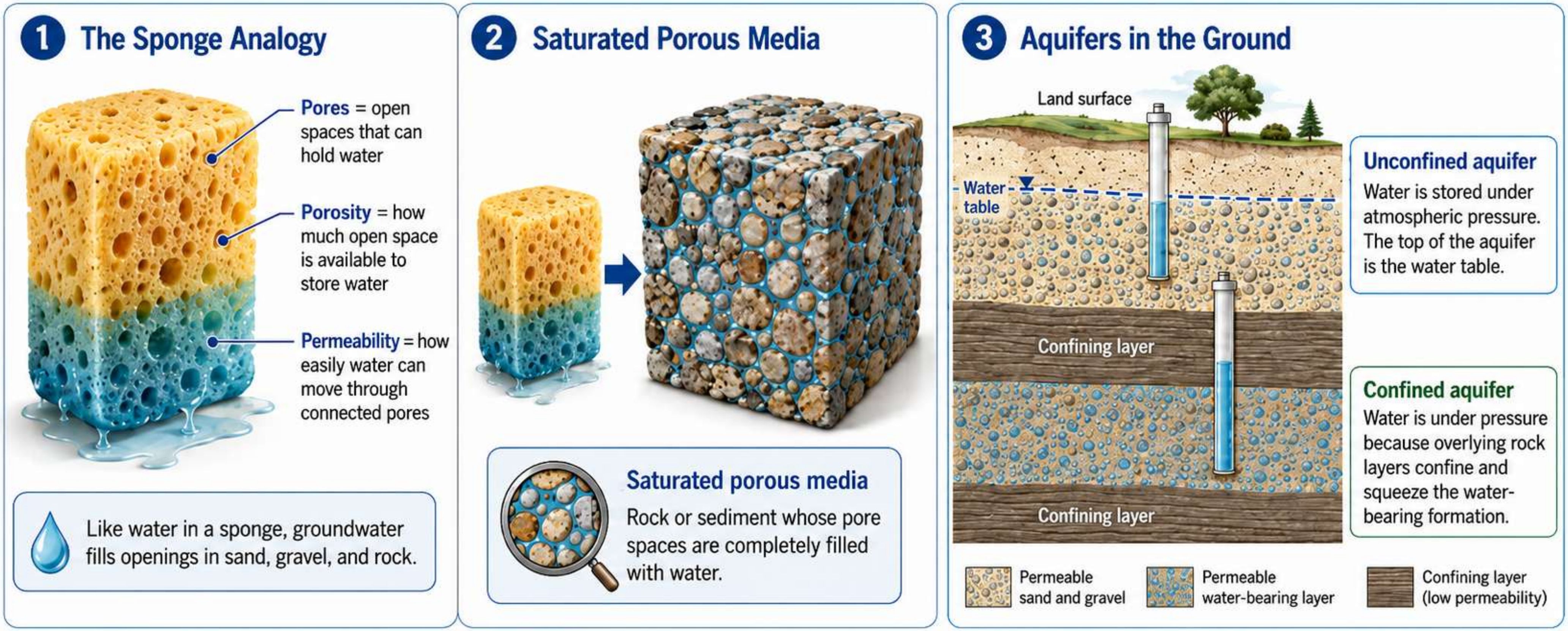
Nick Lamkey, PG,
INTERA

12th Annual Groundwater Summit

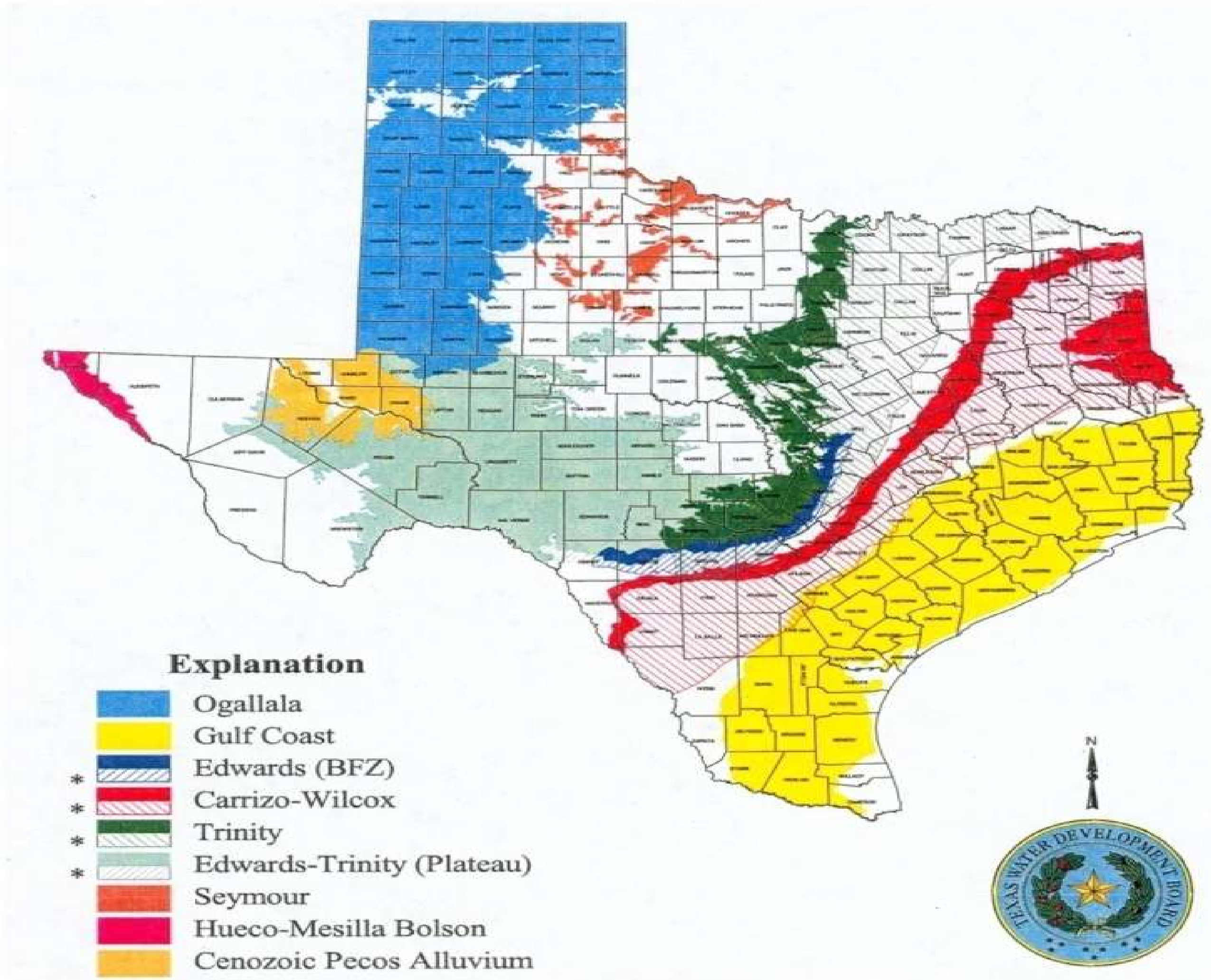
What is an aquifer?

- An underground layer of rock or sediment that stores and transmits groundwater.
- Made up of materials like sand, gravel, or fractured rock that have spaces or pores for water to fill.
- Acts as a natural reservoir, allowing groundwater to be extracted through wells for use.

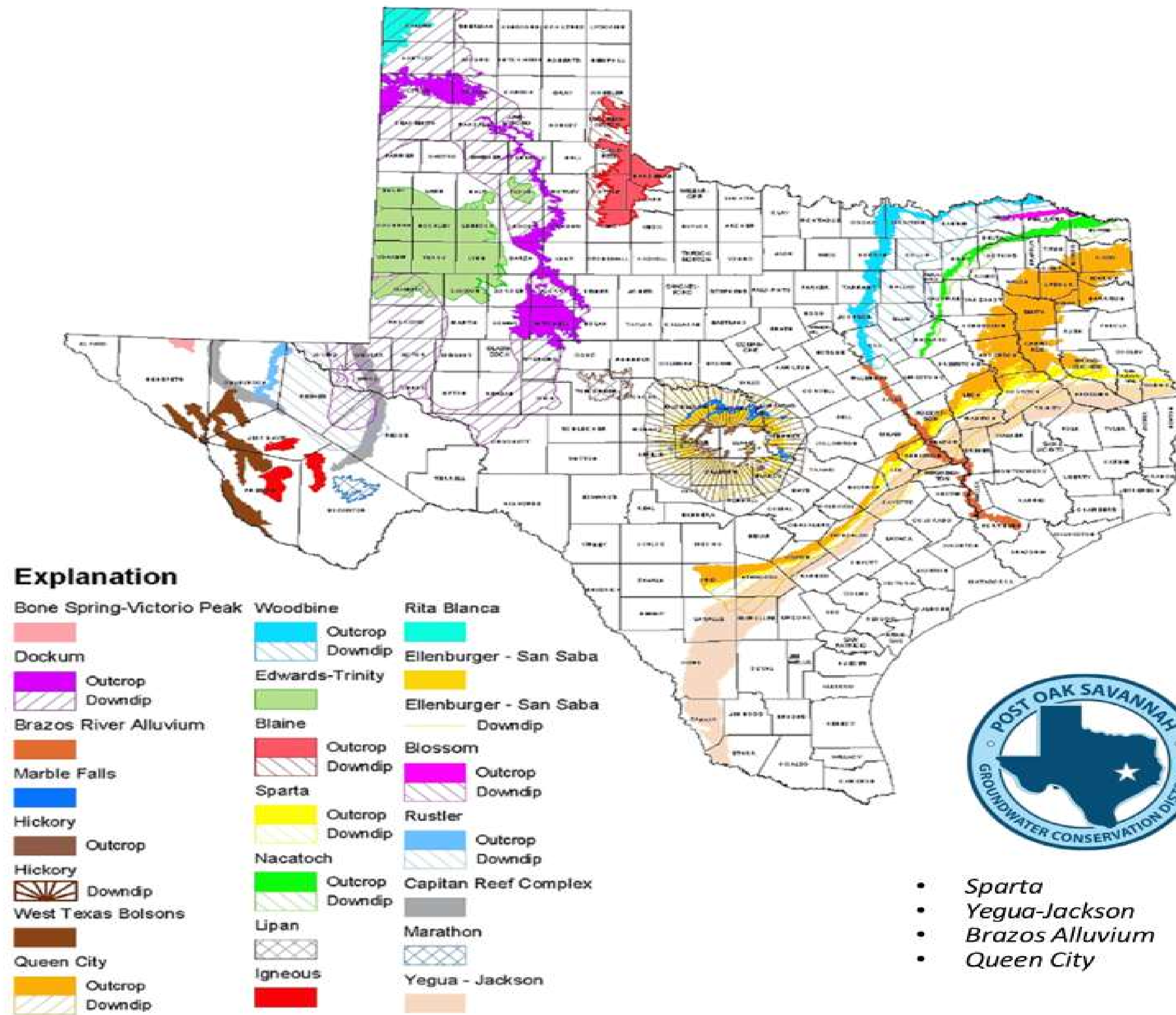
How do they work?



Major Aquifers of Texas



Minor Aquifers of Texas



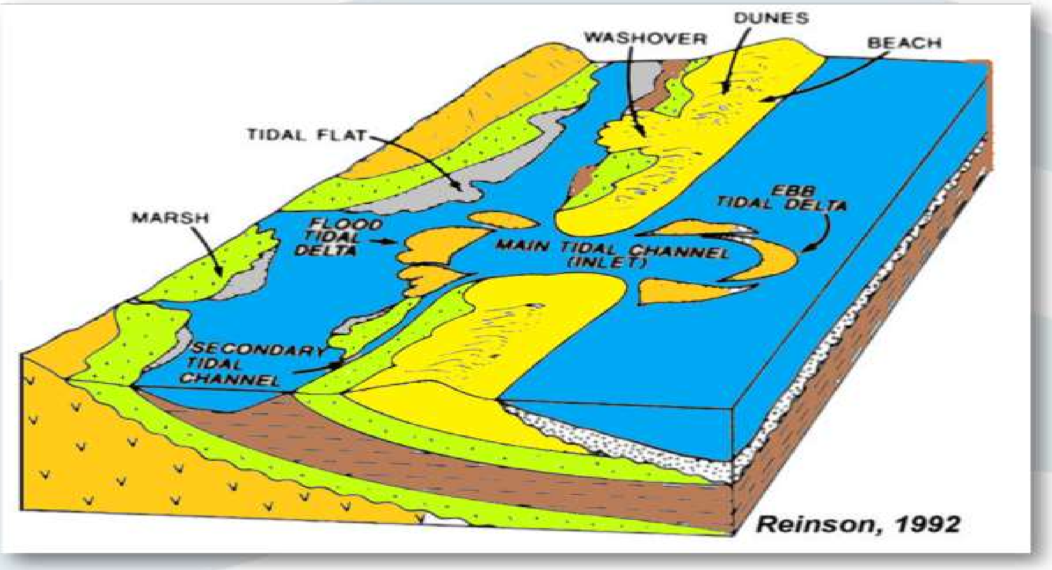
POST OAK SAVANNAH GROUNDWATER CONSERVATION DISTRICT

- *Sparta*
- *Yegua-Jackson*
- *Brazos Alluvium*
- *Queen City*

Carrizo-Wilcox Aquifer System

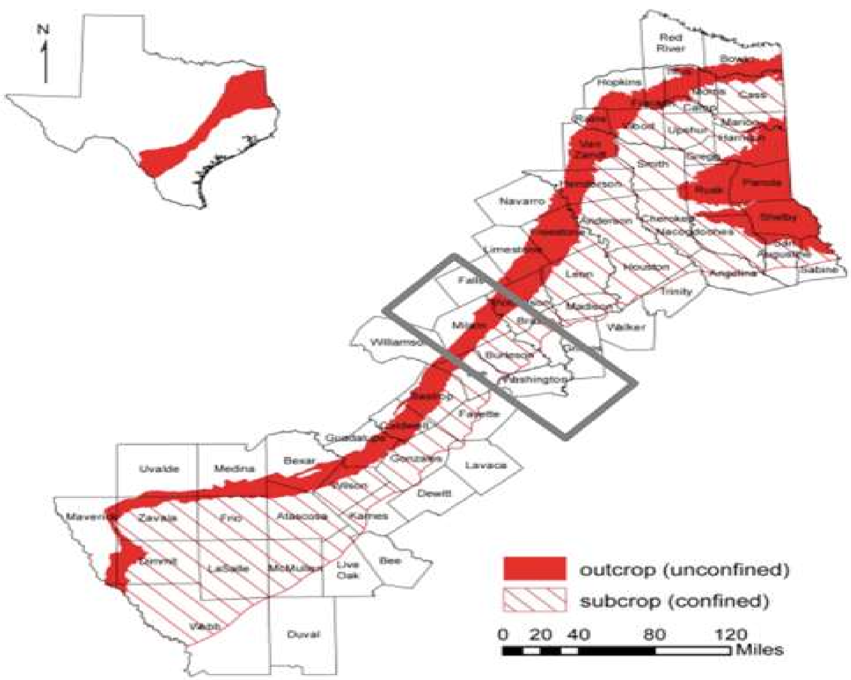
Depositional Environments

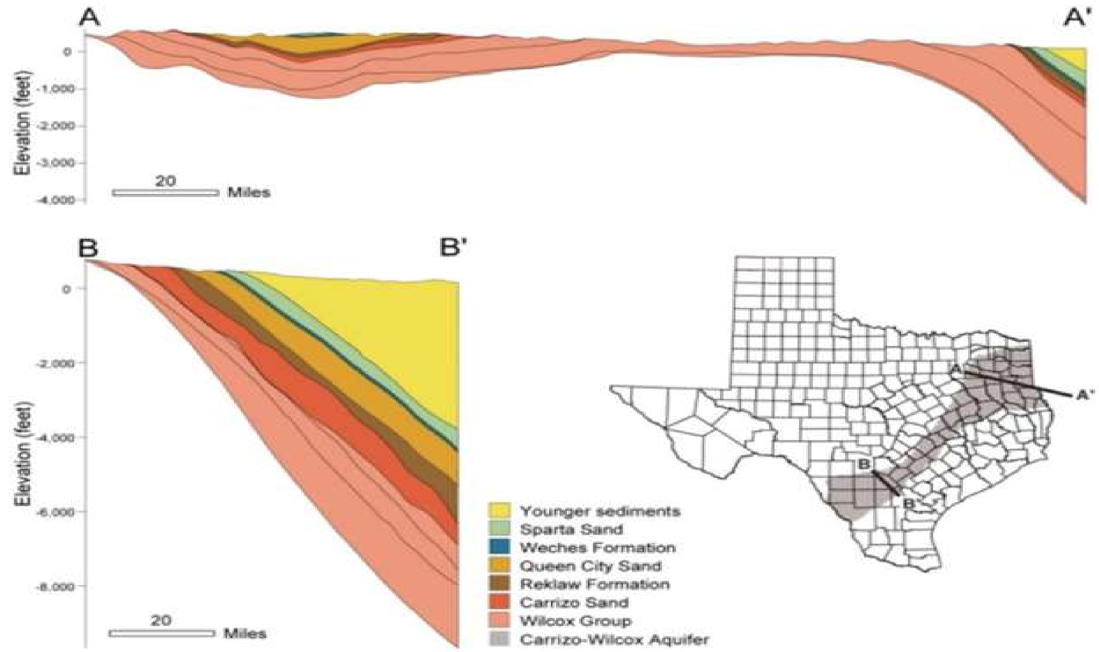
- Carrizo-Wilcox is stack of Paleocene-Eocene coastal-plain sediments deposited along the ancestral Gulf Coast
- Aquifer is mostly sand that is interbedded with gravel, silt, clay and lignite
- Depositional Environments
  - Moderate to high energy braided streams and rivers
  - Coastal Barrier, lagoonal, and estuarine settings
  - Clay, silt and lignite – rich floodplain /coastal-plain deposits
- Non-uniform heterogeneous aquifer system where best water-producing zones are controlled by where thick, laterally continuous sand bodies were deposited



INTERA

Regional Setting





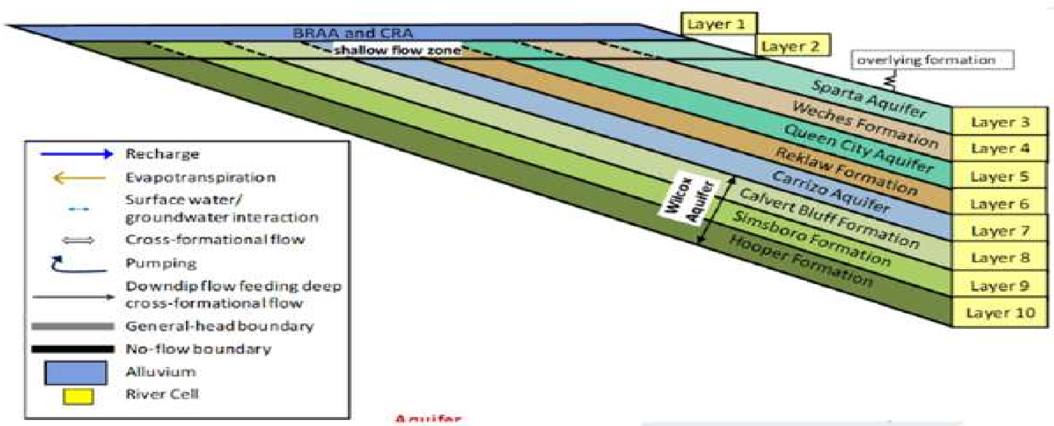
Hydrostratigraphy

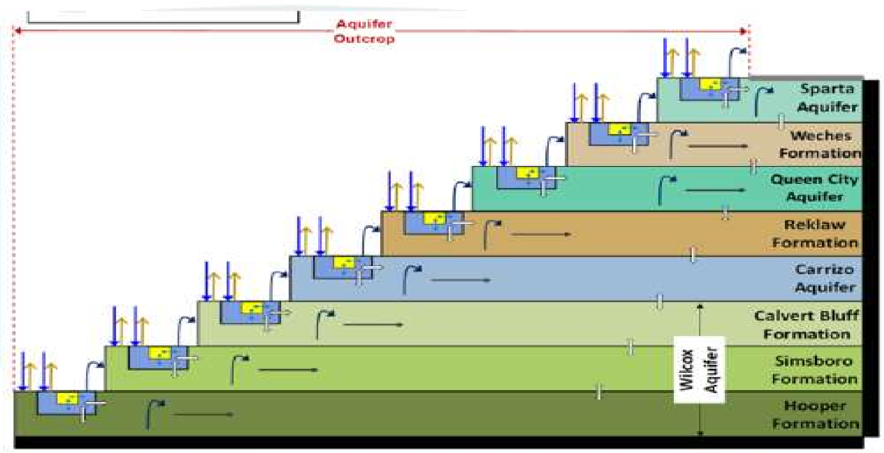
In Central Texas the Carrizo and Simsboro are the primary water-bearing units

Calvert Bluff and Hooper are mixed and can act as leaky aquitards

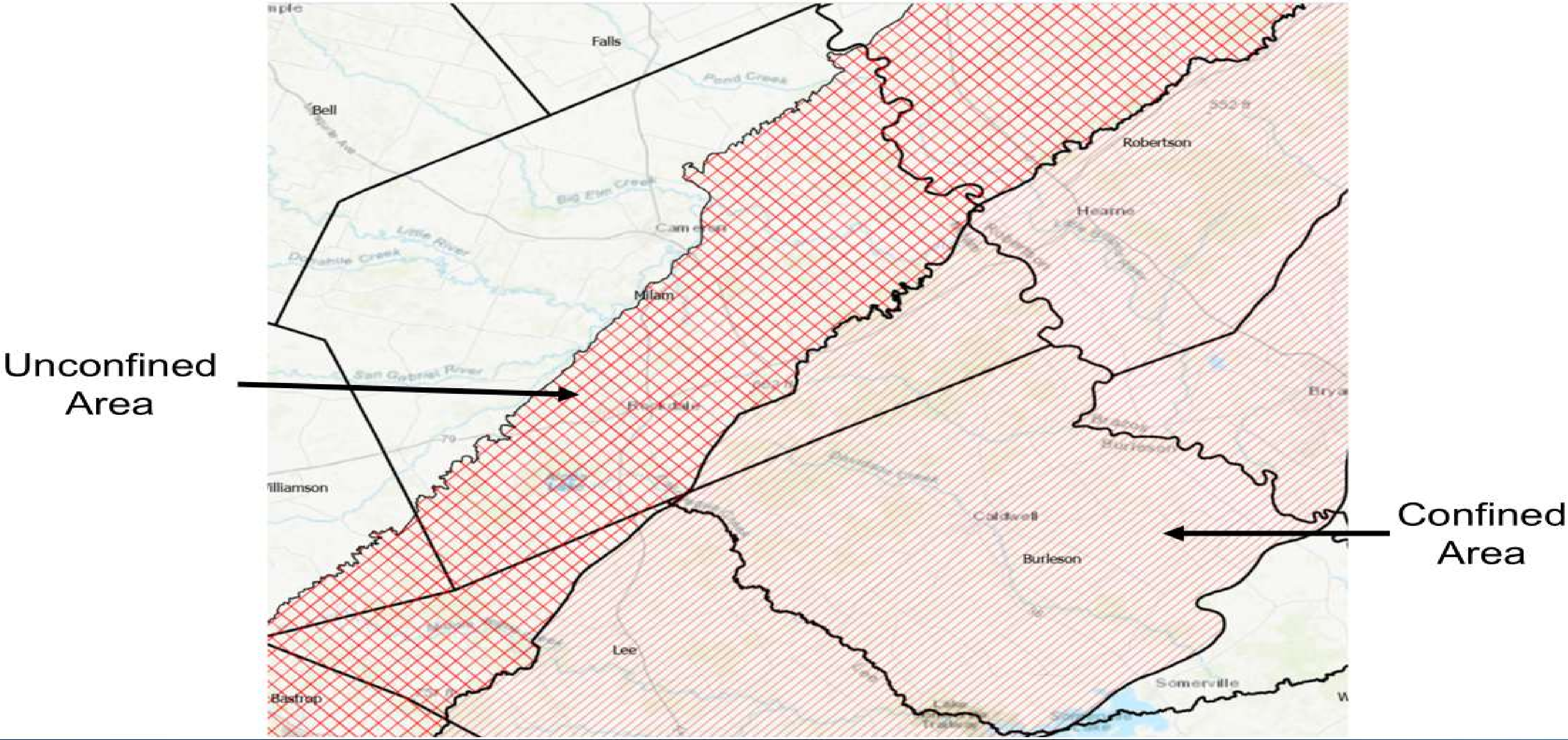
Series			South Texas		Central Texas		Sabine uplift	
Tertiary	Eocene	U	Jackson Group		Jackson Group		Jackson Group	
		M	Claiborne Group	Yegua Fm.	Claiborne Group	Yegua Fm.	Claiborne Group	Yegua Fm.
				Cook Mountain Fm.		Cook Mountain Fm.		Cook Mountain Fm.
				Sparta Sand		Sparta Sand		Sparta Sand
				Weches Fm.		Weches Fm.		Weches Fm.
				Queen City sand		Queen City sand		Queen City sand
				Reklaw Fm.		Reklaw Fm.		Reklaw Fm.
		L	Wilcox Group	Carrizo sand / Upper Wilcox	Wilcox Group	Carrizo sand	Wilcox Group	Carrizo sand
						Calvert Bluff Fm.		Upper Wilcox
				Middle Wilcox		Simsboro Fm.		Middle Wilcox
	Paleocene	U		Lower Wilcox		Hooper Fm.		Lower Wilcox
		L	Midway Formation		Midway Formation		Midway Formation	

Figure 6-2. **Stratigraphy and hydrogeology in the Carrizo-Wilcox Aquifer (modified from Mace and others, 2000). *(Fm = Formation; U = Upper; M = Middle; L = Lower)***



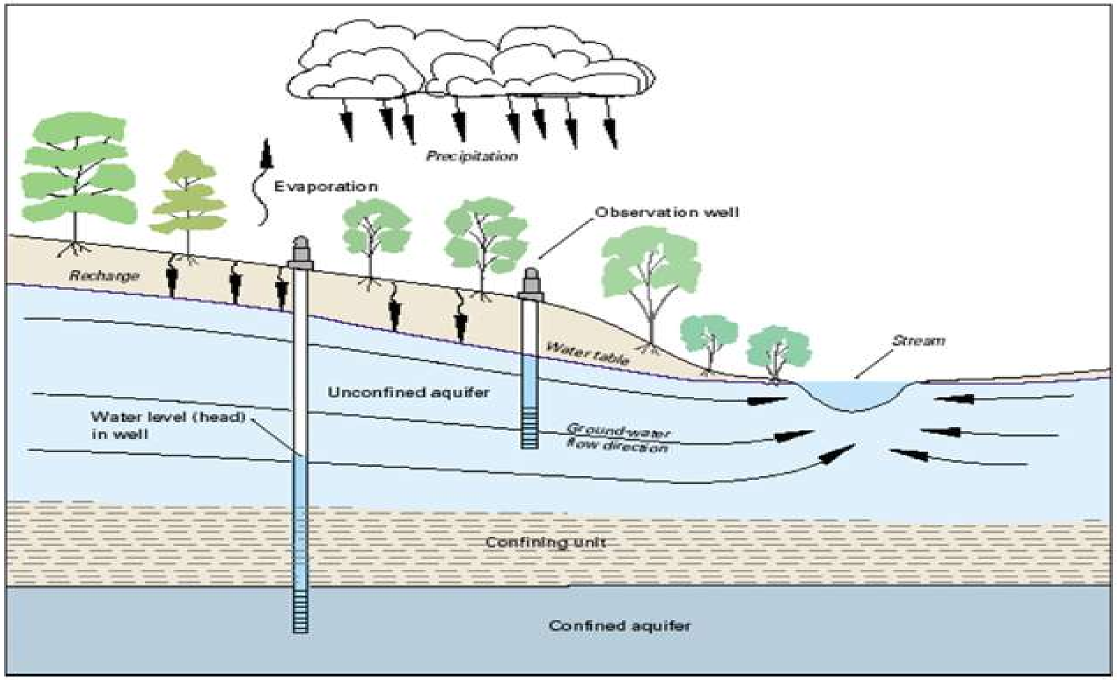


INTERA



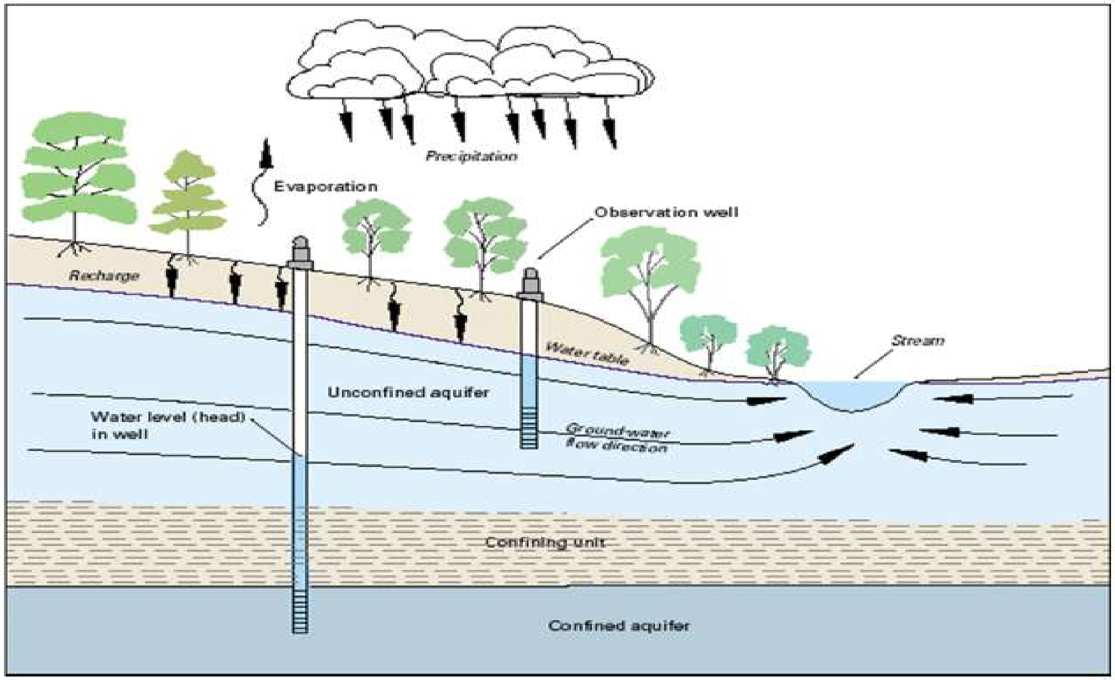
Outcrop and Subsurface Extent of Carrizo-Wilcox Aquifer

- Where the water level in a well occurs below the top of an aquifer, typically at aquifer outcrops
- Recharges directly from surface water
- A decline in a well's water level represents a reduction in the aquifer thickness because water is removed from the pore spaces between sands and clay.



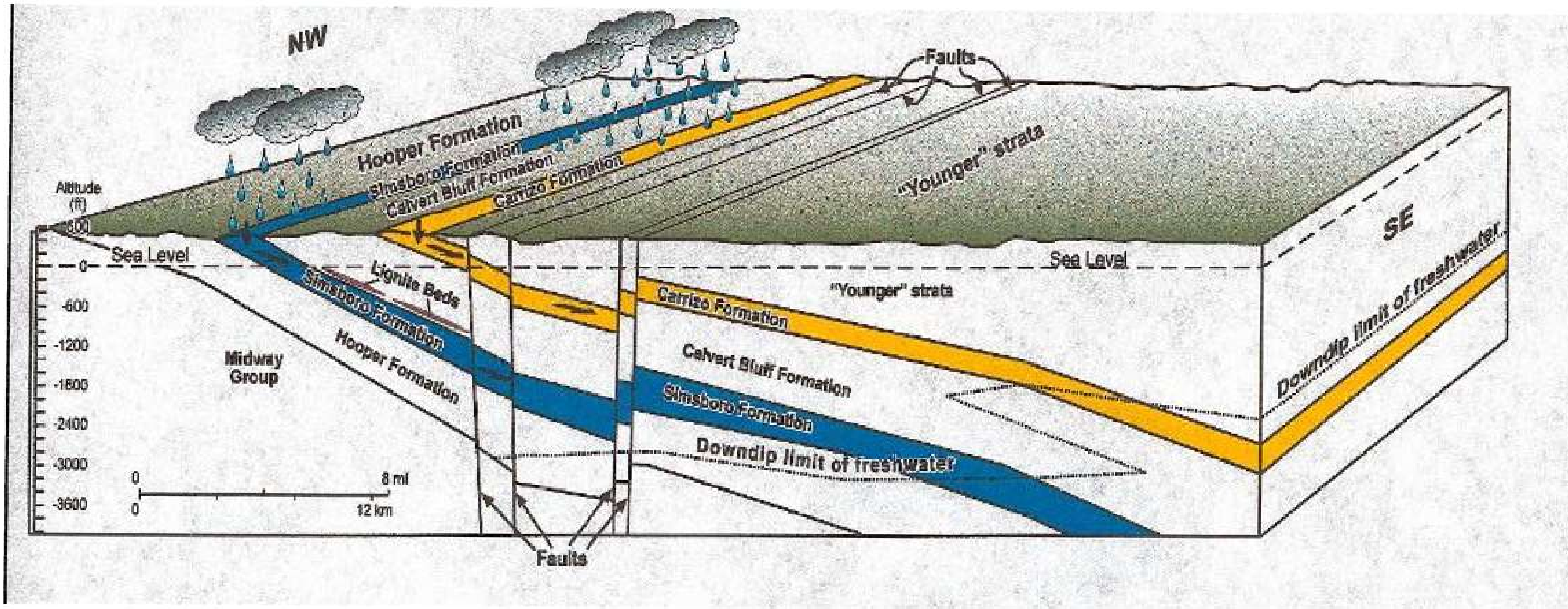
Unconfined

- Lies beneath a layer of impermeable rock or clay.
- Water is under pressure due to the overlying impermeable layer.
- Can produce water that rises above the aquifer level due to pressure.
- A decline in a water well represents a change in hydraulic pressure of the groundwater in a saturated aquifer.

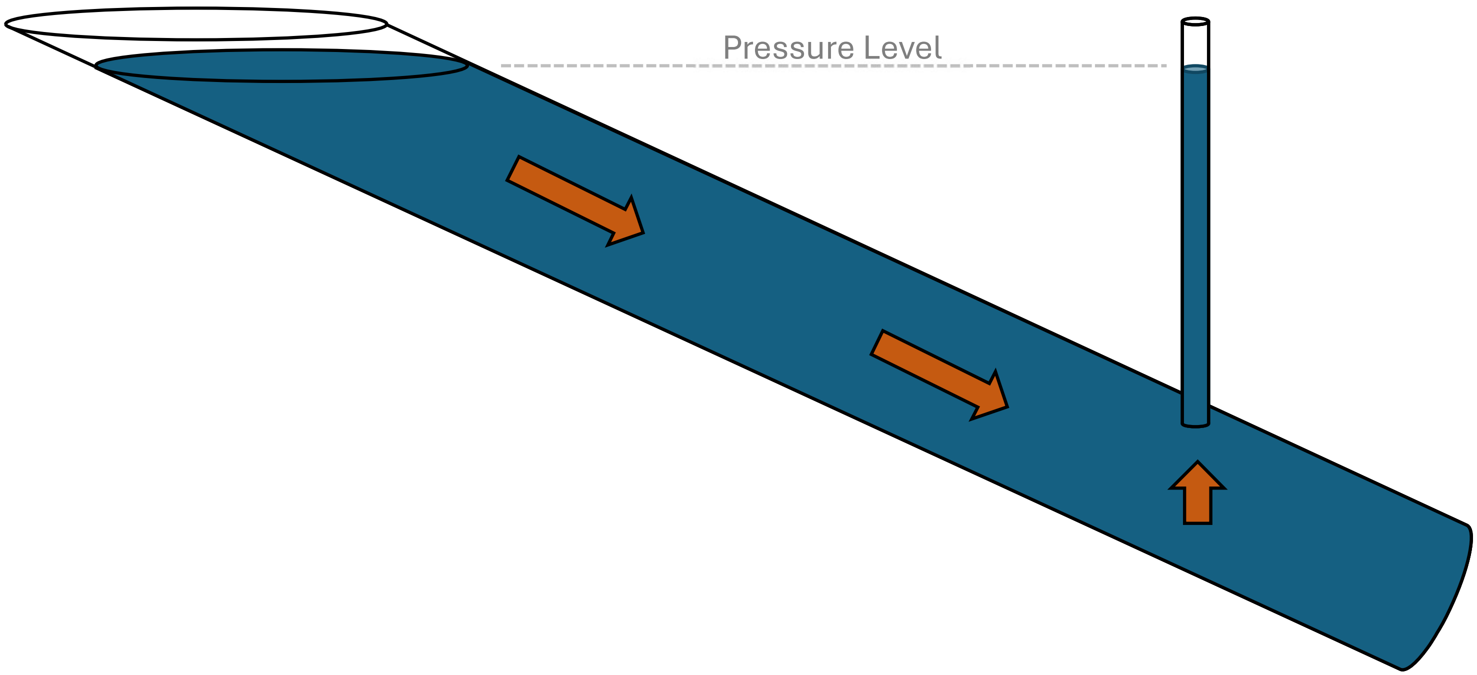


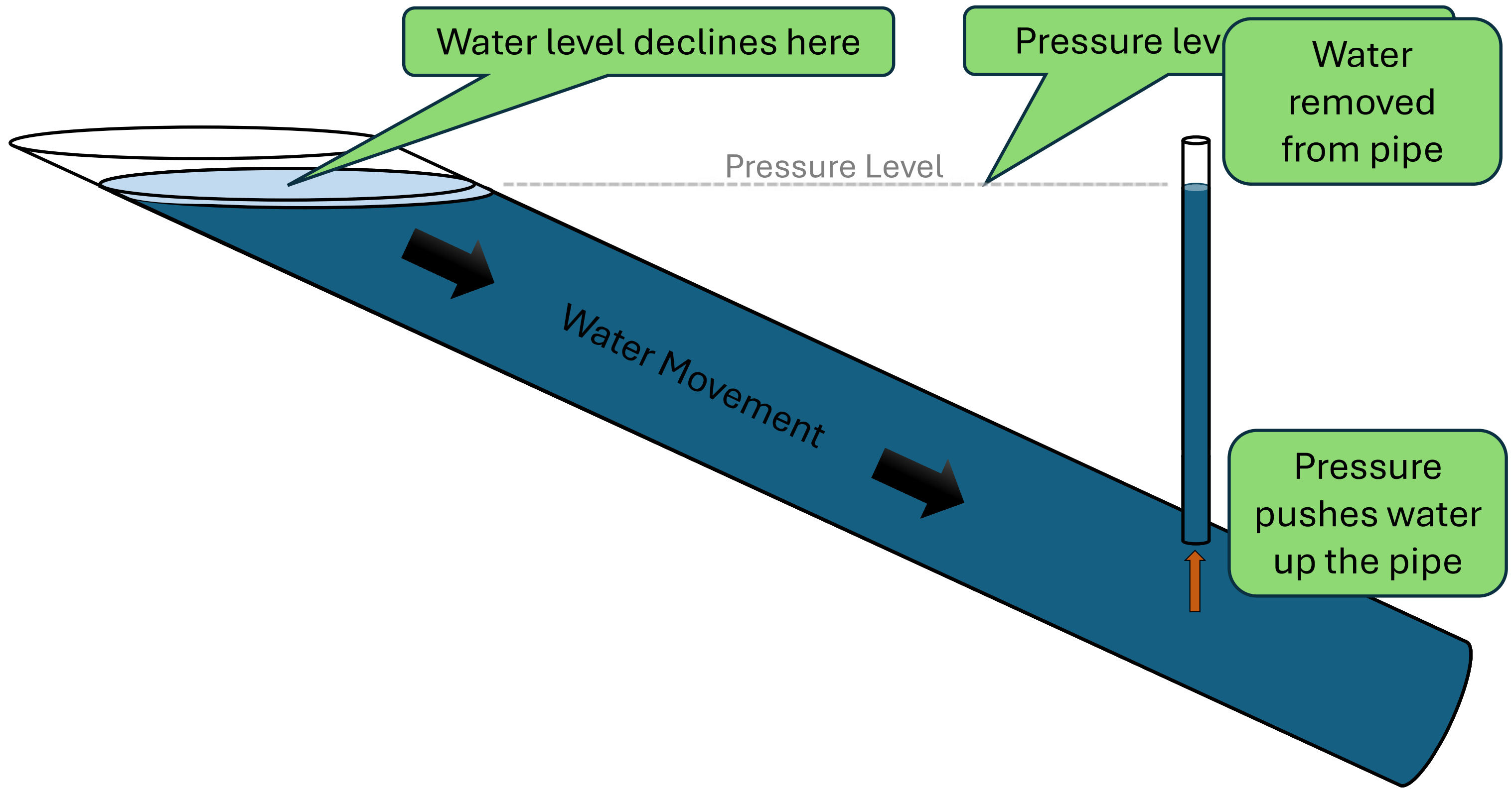
Confined

Geologic Cross Section Carrizo-Wilcox Aquifer Fault Zones

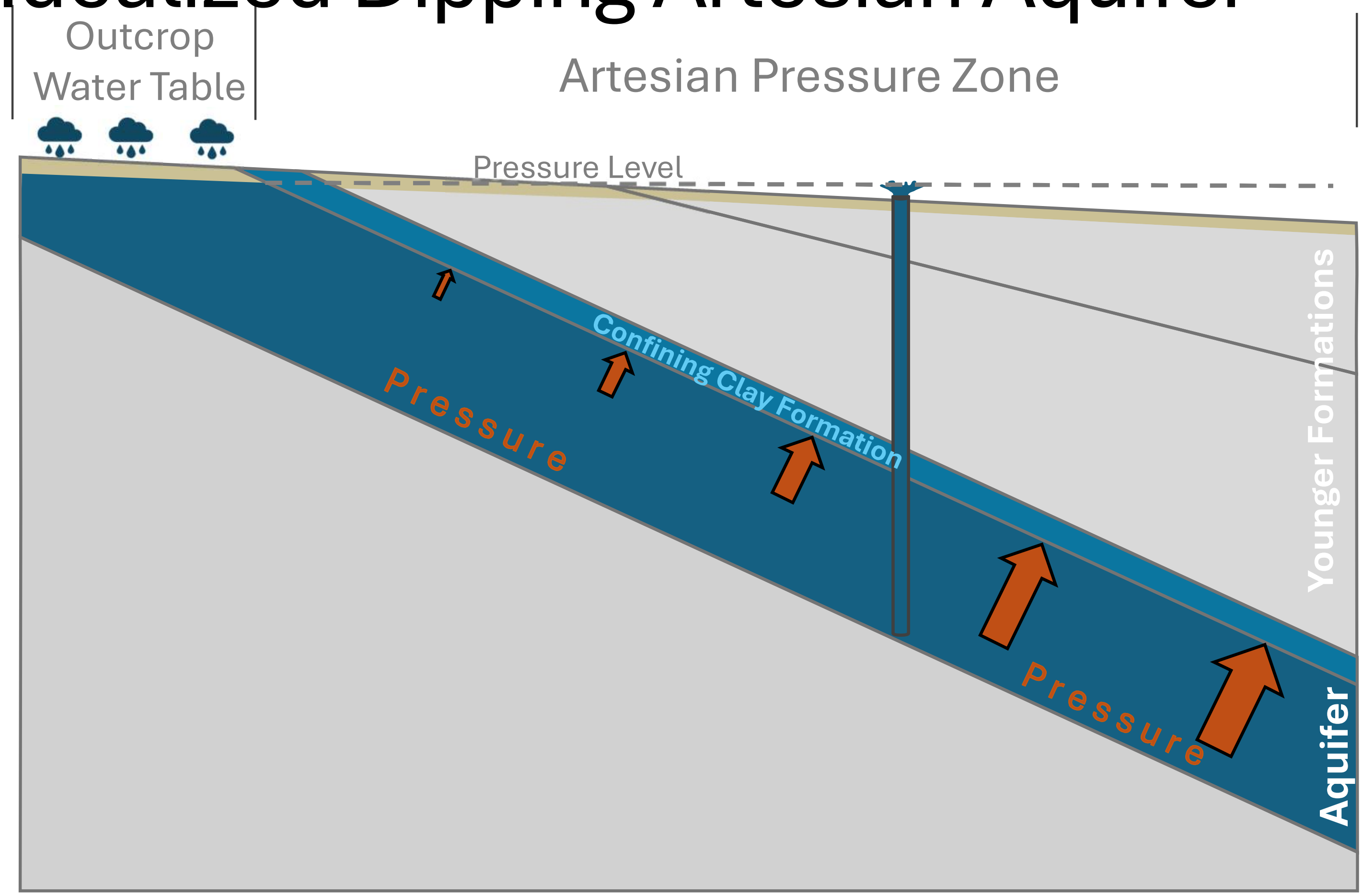


Pressure Example

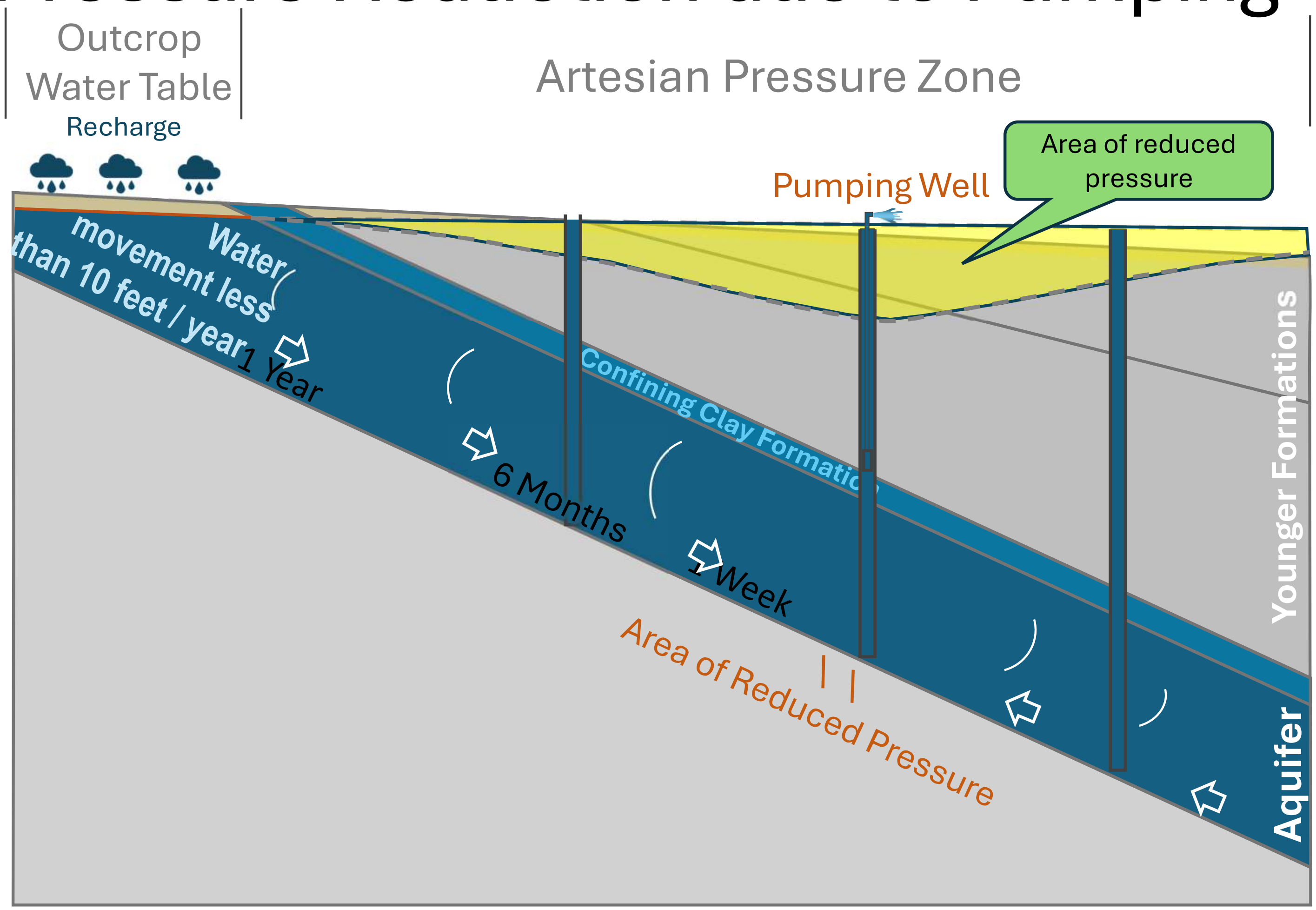



Water level declines here
Pressure lev
Water removed from pipe
Pressure Level
Water Movement
Pressure pushes water up the pipe

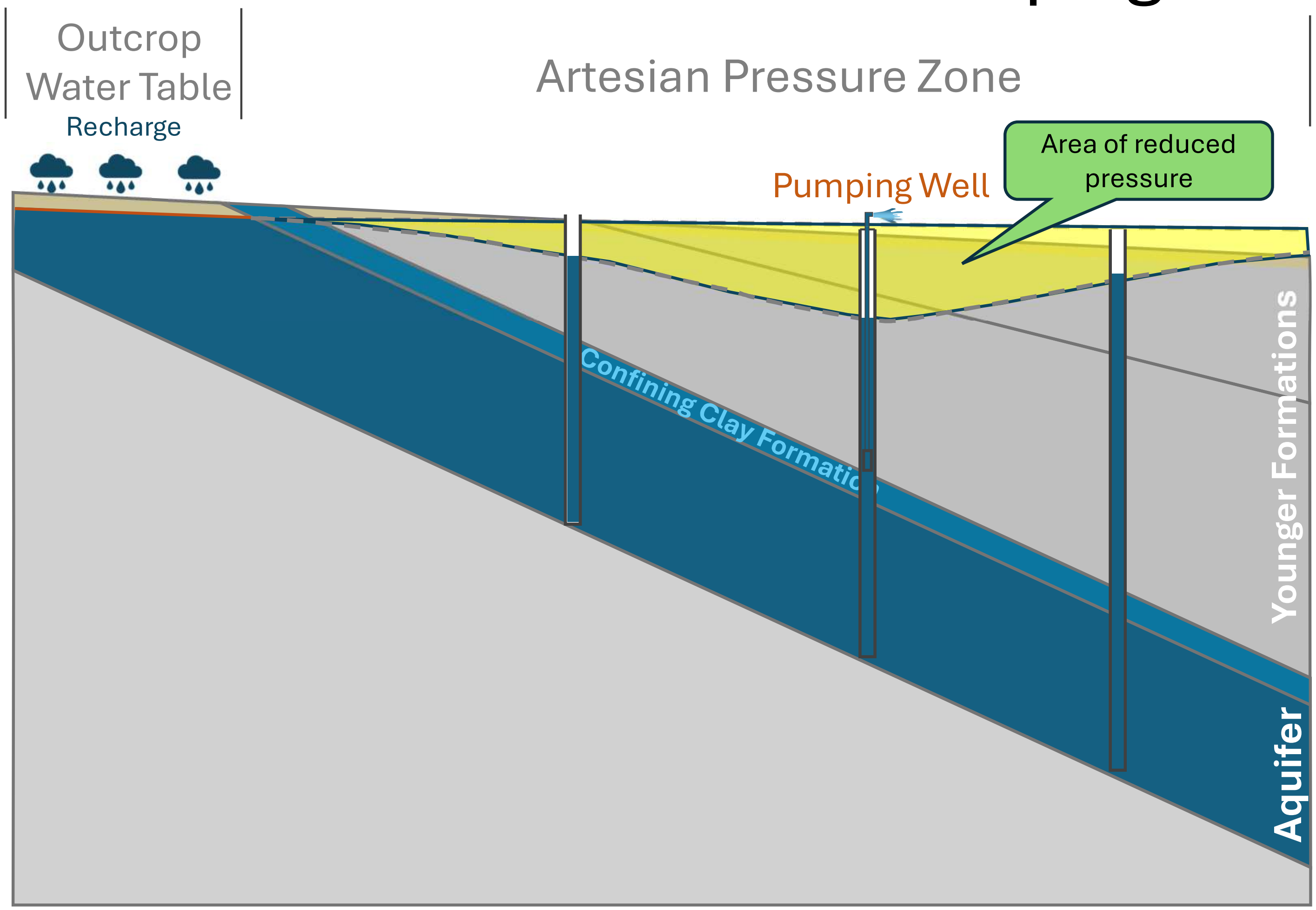
Idealized Dipping Artesian Aquifer



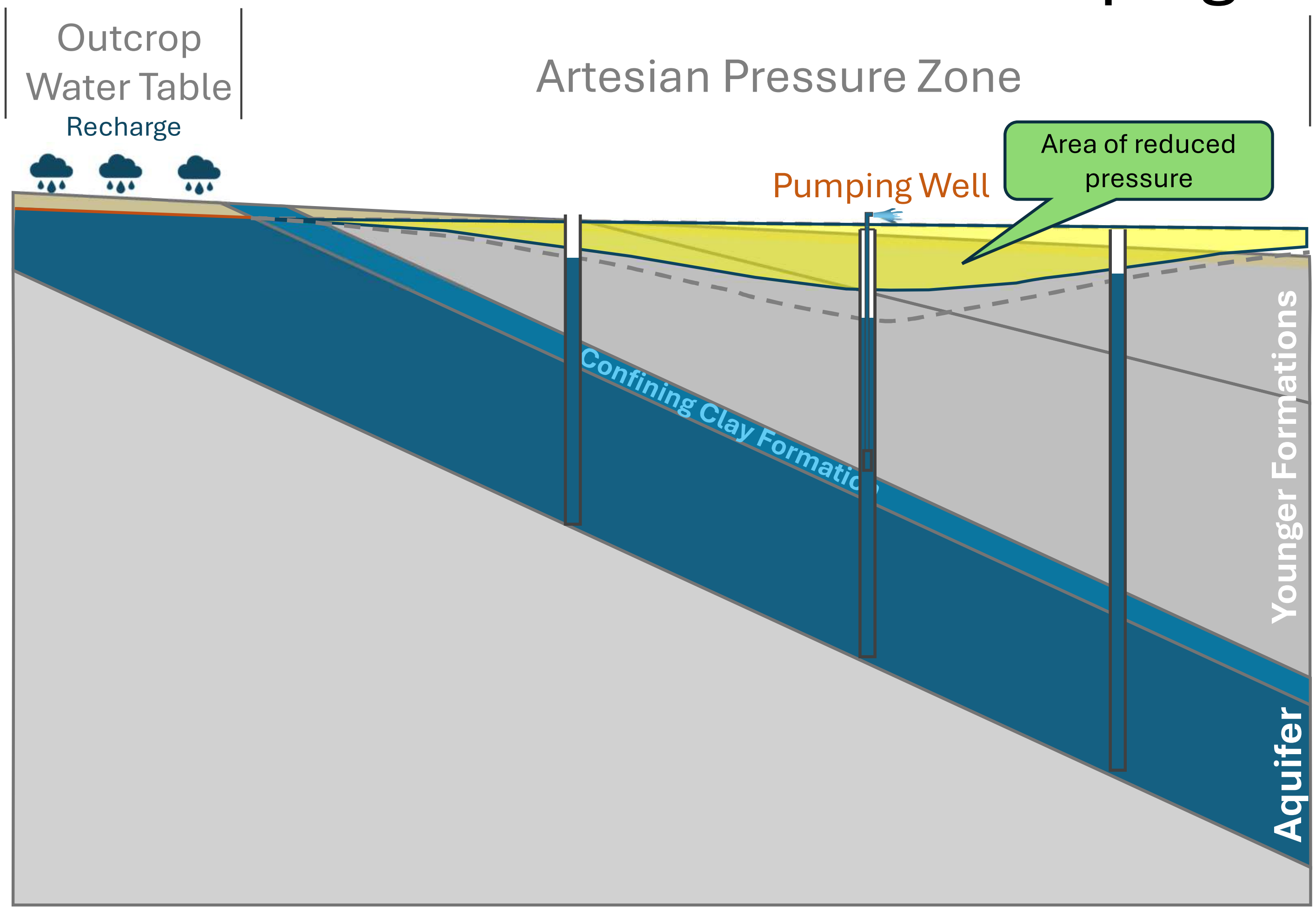
Pressure Reduction due to Pumping



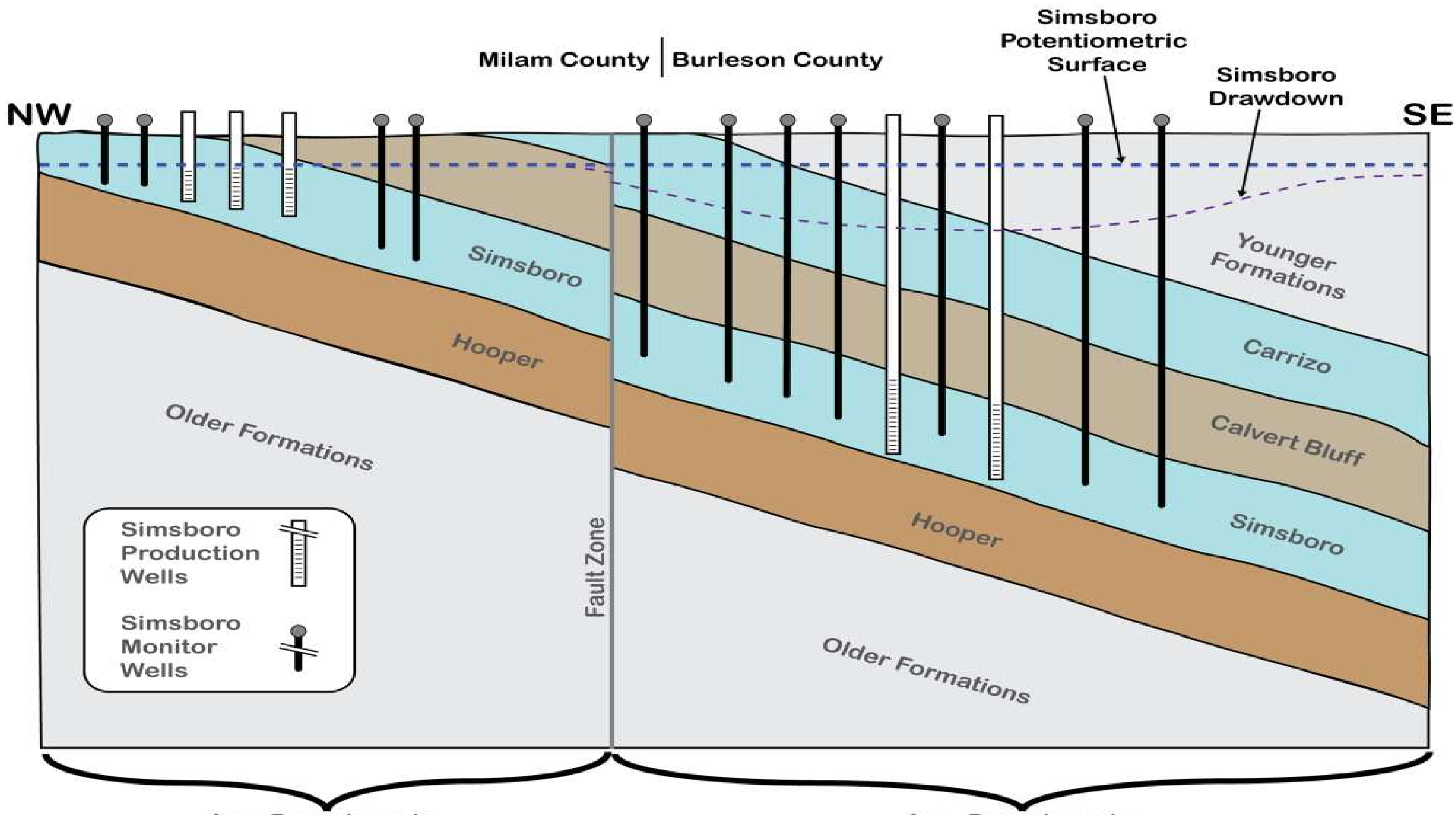
Pressure Reduction due to Pumping



Pressure Rise with Decrease in Pumping



Schematic Cross Section
Simsboro Drawdown



Avg. Drawdown in
Shallow Simsboro Wells
is 15' x 326 sq. miles

Avg. Drawdown in
Deep Simsboro Wells
is 400' x 809 sq. miles

Hydraulic Properties

Hydraulic Conductivity

Measure of how easily a porous material allows water to flow through its pore spaces and fractures – material property

Transmissivity

Represents an aquifers overall capacity to transmit water

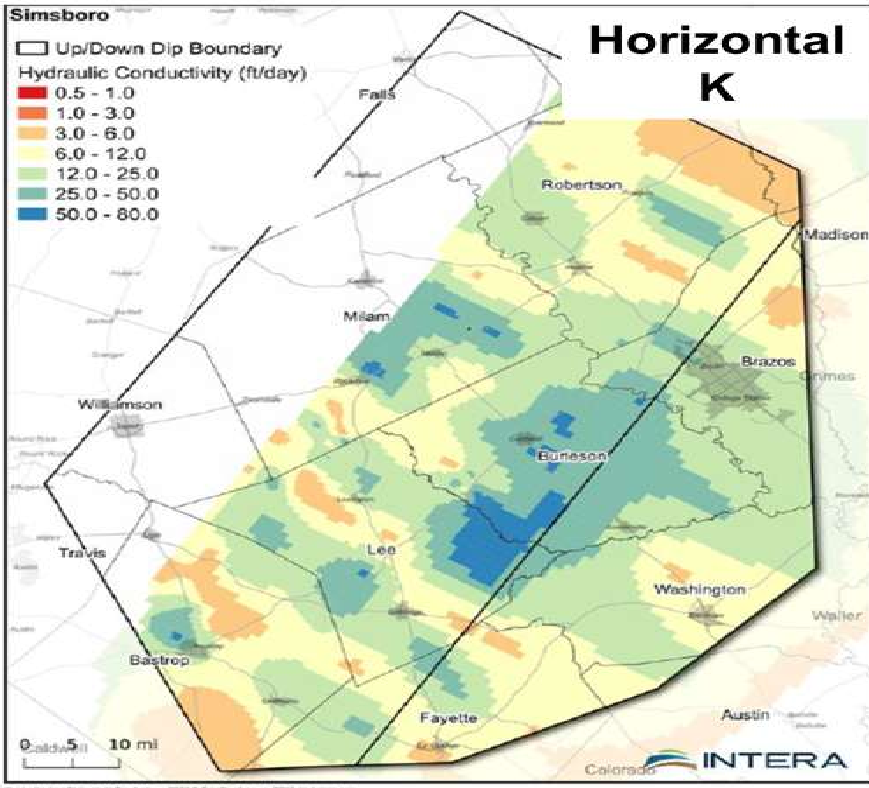
Specific Storage

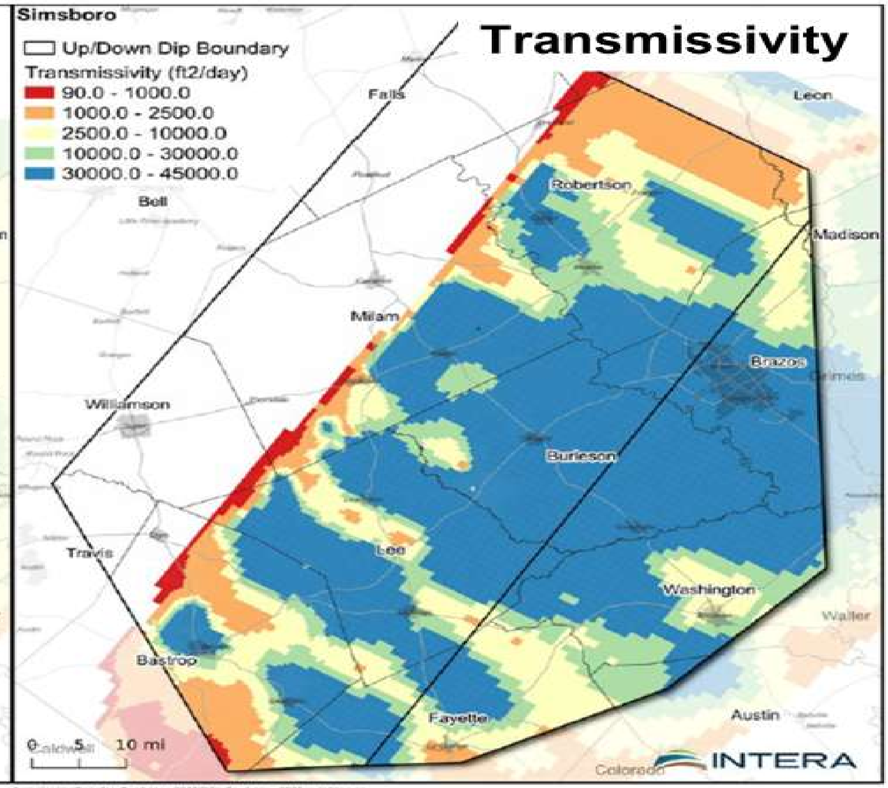
Water released per unit volume of aquifer per foot of pressure drop (decline in head)

Aquifer	Region in AOI	Hydraulic Conductivity (ft/day)		Transmissivity (ft^2/day)	Specific Storage (1/ft)
		Horizontal	Vertical		
Carrizo	Up Dip	8	1.3E-02	2,218	1.1E-06
	Down Dip	6	2.6E-03	2,454	3E-07
Calvert Bluff	Up Dip	2	7.2E-04	1,391	3.3E-67
	Down Dip	1	4.3E-05	1,320	3.1E-07
Simsboro	Up Dip	16	1.0E-02	7,651	4.9E-07
	Down Dip	16	7.9E-04	10,206	1.9E-07
Hooper	Up Dip	1	9.1E-04	740	1.6E-06
	Down Dip	1	1.2E-04	747	3.2E-07
Outcrop	n/a	22	1.1E-02	2,531	3E-05

INTERA

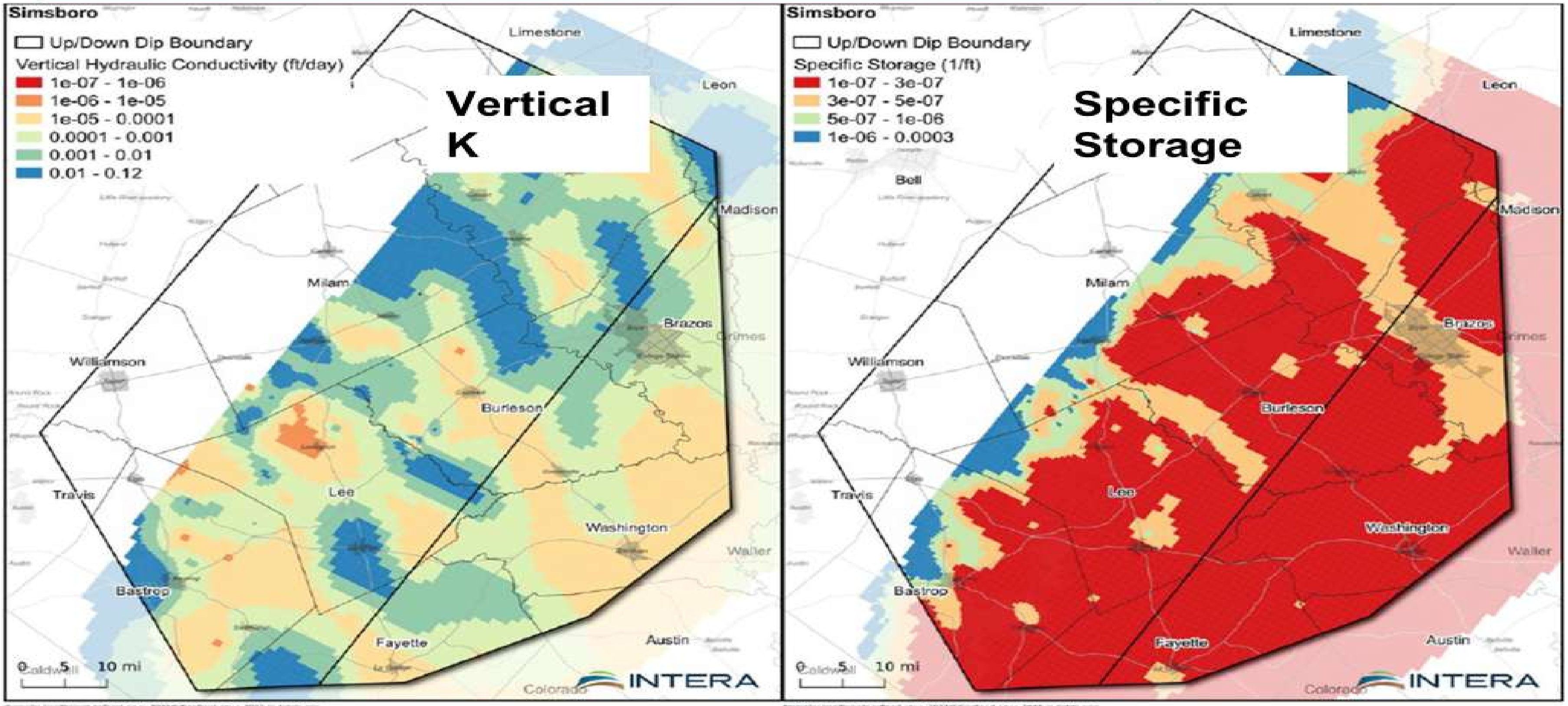
Spatial Distribution of Hydraulic Properties





INTERA

Spatial Distribution of Hydraulic Properties

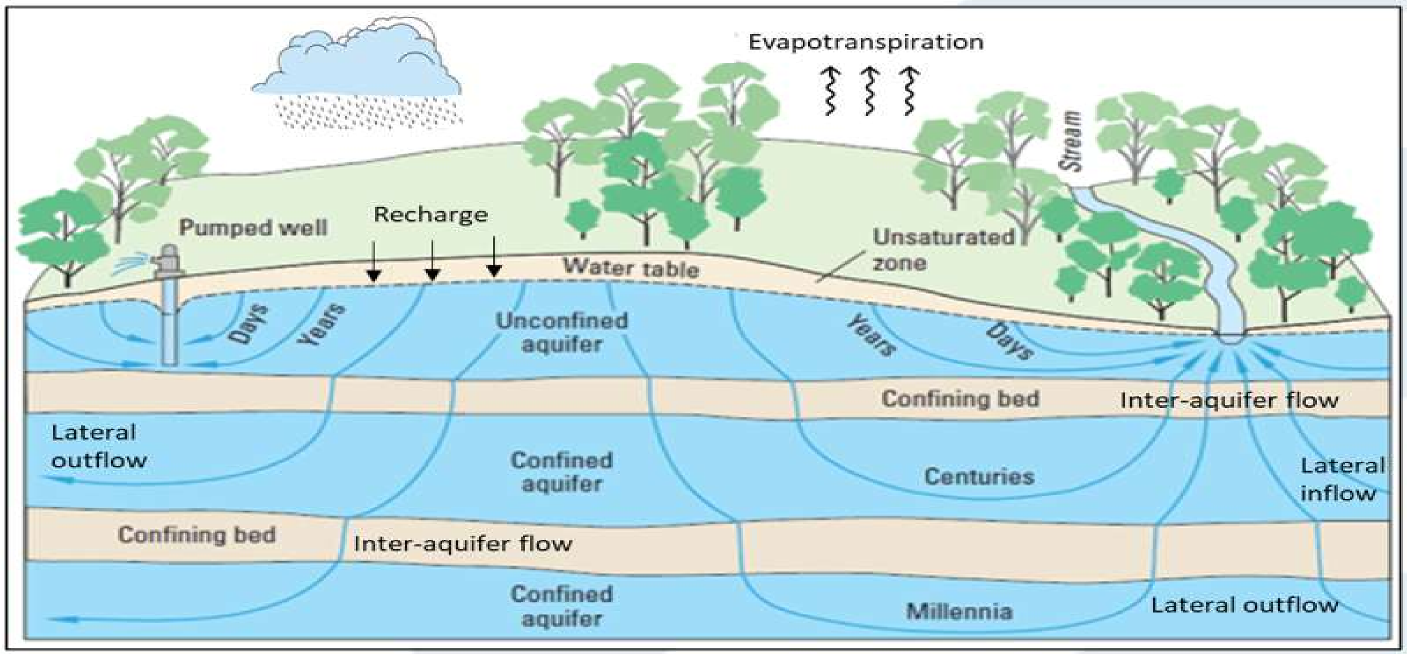


INTERA

Recharge

Recharge occurs primarily in the outcrop

Downdip or confined regions of the aquifer can receive recharge through streams



Recharge

Table 11-2. Recharge rates by zones based on chloride mass balance analysis of groundwater chloride concentrations.

Region	Zone	Number of wells	Outcrop area (mi^2)	Precipitation (in/yr)	Cl_P (mg/L)	Cl_{GW} (mg/L)	Recharge (in/yr)	Recharge (af/yr)	Recharge (in/yr)	Recharge (af/yr)
South	1	124	1,223	24.4	0.82	49	0.4 (2)	26,500	0.9 (3)	131,000
	2	73	648	30.9	1.18	37	1.0 (3)	34,300		
	3	48	944	36.1	1.14	30	1.4 (4)	69,800		
Central	4	95	812	36.3	0.98	29	1.2 (3)	52,800	1.8 (5)	241,000
	5	165	1,657	40.5	0.78	15	2.1 (5)	188,000		
North	6	124	936	42.8	0.68	7.9	3.7 (9)	183,000	3.6 (7)	1,160,000
	7	83	789	45.4	0.62	11	2.5 (6)	107,000		
	8	58	906	49.6	0.60	9.0	3.3 (7)	158,000		
	9	358	3,332	51.3	0.70	9.0	4.0 (8)	711,000		

Note: Zones and well locations are shown in Figure 11-4. Precipitation represents 1971–2000 mean (SCAS, 2004). Precipitation chloride concentrations were multiplied by two to account for dry fallout. Groundwater chloride concentration represents the 25th percentile of zone well population. Values in parentheses represent percentages of annual precipitation. Recharge values in (af/yr) units calculated by multiplying recharge by outcrop area. Mean area-weighted recharge rates are provided for groups of zones that approximately correspond to the modeled zones.

Cl_P = chloride concentration in precipitation; Cl_{GW} = chloride concentration in groundwater; mi^2 = square miles; af/yr = acre-feet per year; in/yr = inches per year; mg/L = milligrams per year

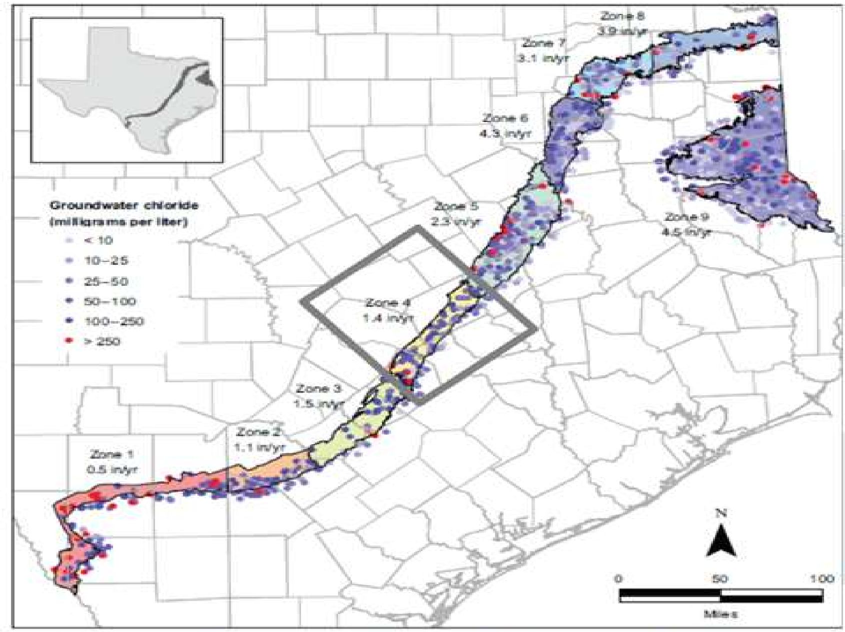


Figure 11-4. Groundwater chloride concentrations and chloride mass balance recharge rates for nine zones in the Carrizo-Wilcox outcrop area. Points represent groundwater wells located inside and within 5 miles downdip of the outcrop area. Chloride mass balance recharge rates are based on 25th percentile chloride concentrations for wells in each zone.

in/yr – inches per year

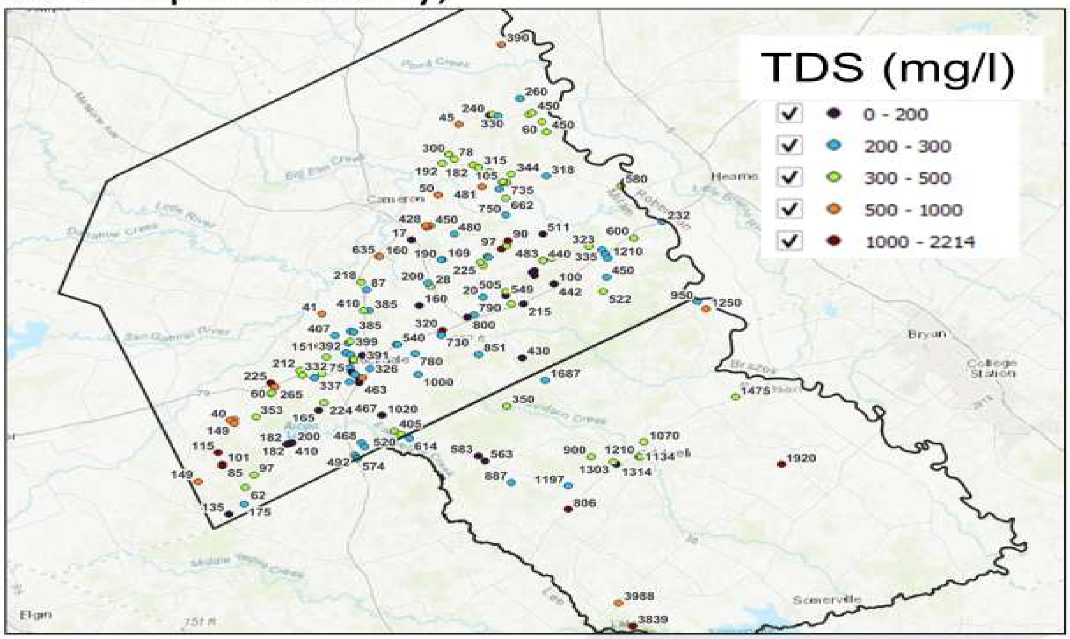
Chloride Mass balance methods serve as proxy for the fraction of total precipitation that successfully bypasses the ET system to become recharge

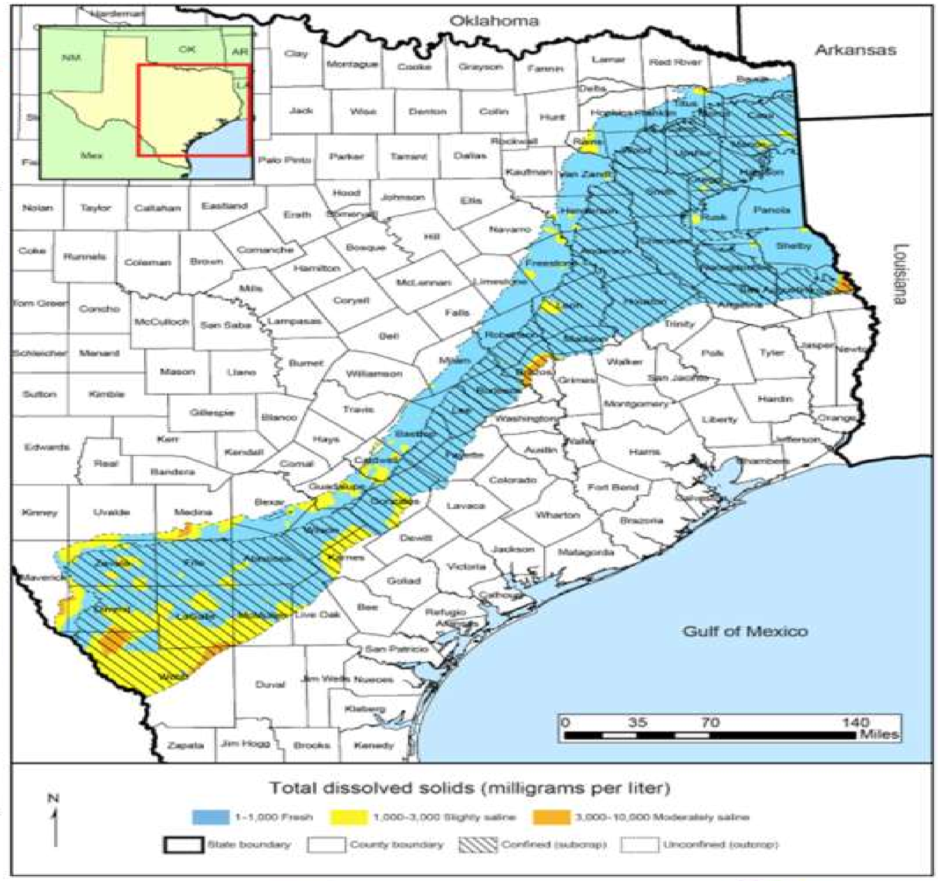
Hutchison, W. R., Davidson, S. C., Brown, B. J., & Mace, R. E. (Eds.). (2009). Aquifers of the Upper Coastal Plains of Texas (Report 374). Texas Water Development Board.

INTERA

Water Quality

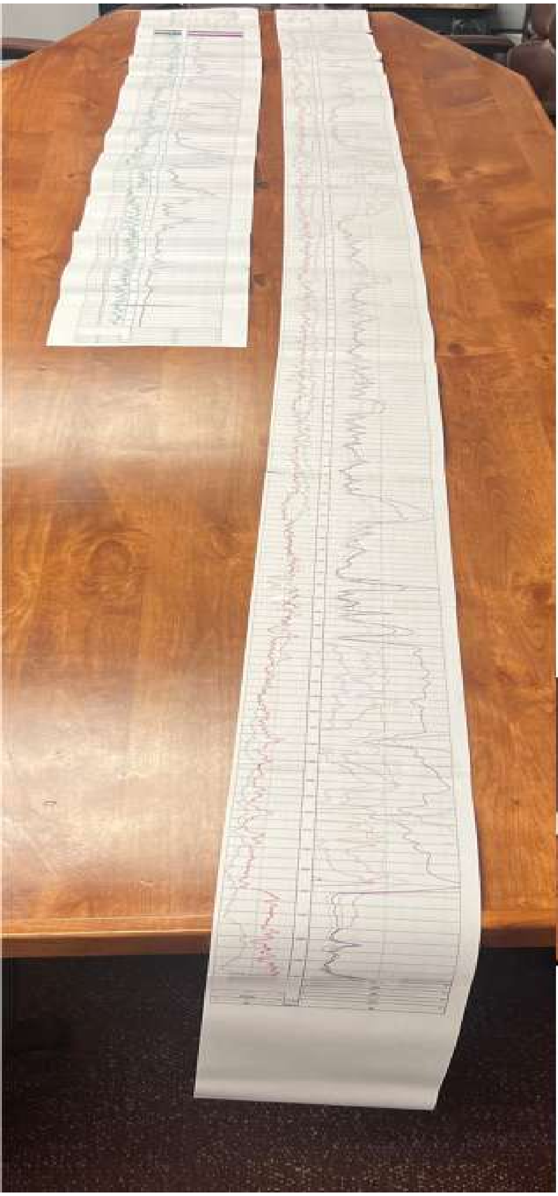
Generally fresh but brackish zones occur downdip and locally,





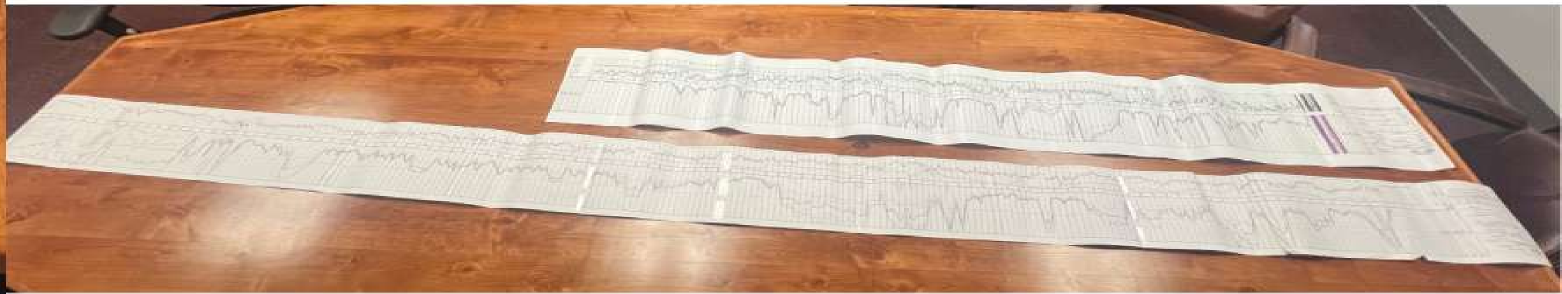
Numbers show well depth
Colors show TDS

INTERA



Geophysical Logs

- Shows Top and Bottom of Aquifers at certain depths
- Shows how productive a zone can be or how non-productive zones can be
- Can distinguish between sand layers and clay layers

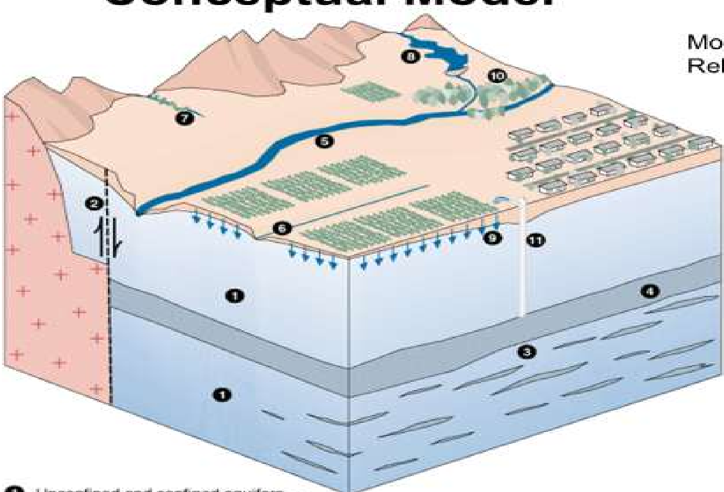


Short Log is in Outcrop
Long Log is downdip

Description of a Groundwater Model

- Take all known hydrogeological information about a site (conceptual model) and input it into a computer program that solves equations that calculate water levels and water flow (numerical model) = **Groundwater Model**
- Enable you to forecast water levels and flows in a particular area and/or test various scenarios to understand how the system will respond to a particular stress like drought or more pumping

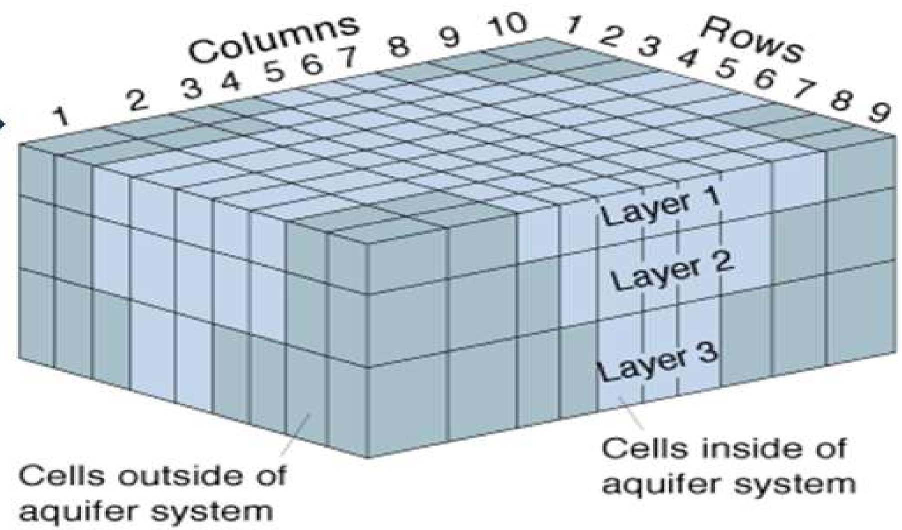
Conceptual Model



1 Unconfined and confined aquifers — Ground-water flow and storage changes
2 Faults and other barriers — Resistance to horizontal ground-water flow
3 Fine-grained confining units and interbeds
4 Confining units — Ground-water flow and storage changes
5 Rivers — Exchange of water with aquifers
6 Drains and springs — Discharge of water from aquifers
7 Ephemeral streams — Exchange of water with aquifers
8 Reservoirs — Exchange of water with aquifers
9 Recharge from precipitation and irrigation
10 Evapotranspiration
11 Wells — Withdrawal or recharge at specified rates

Numerical Model

Modified from Leake, S.A., 1997, Modeling Ground-Water Flow with MODFLOW and Related Programs, U.S. Geological Survey Fact Sheet 121-97.



Questions?

Michael Redman, AGM, POSGCD
mredman@posgcd.org

Nick Lamkey, PG, Intera
nlamkey@intera.com