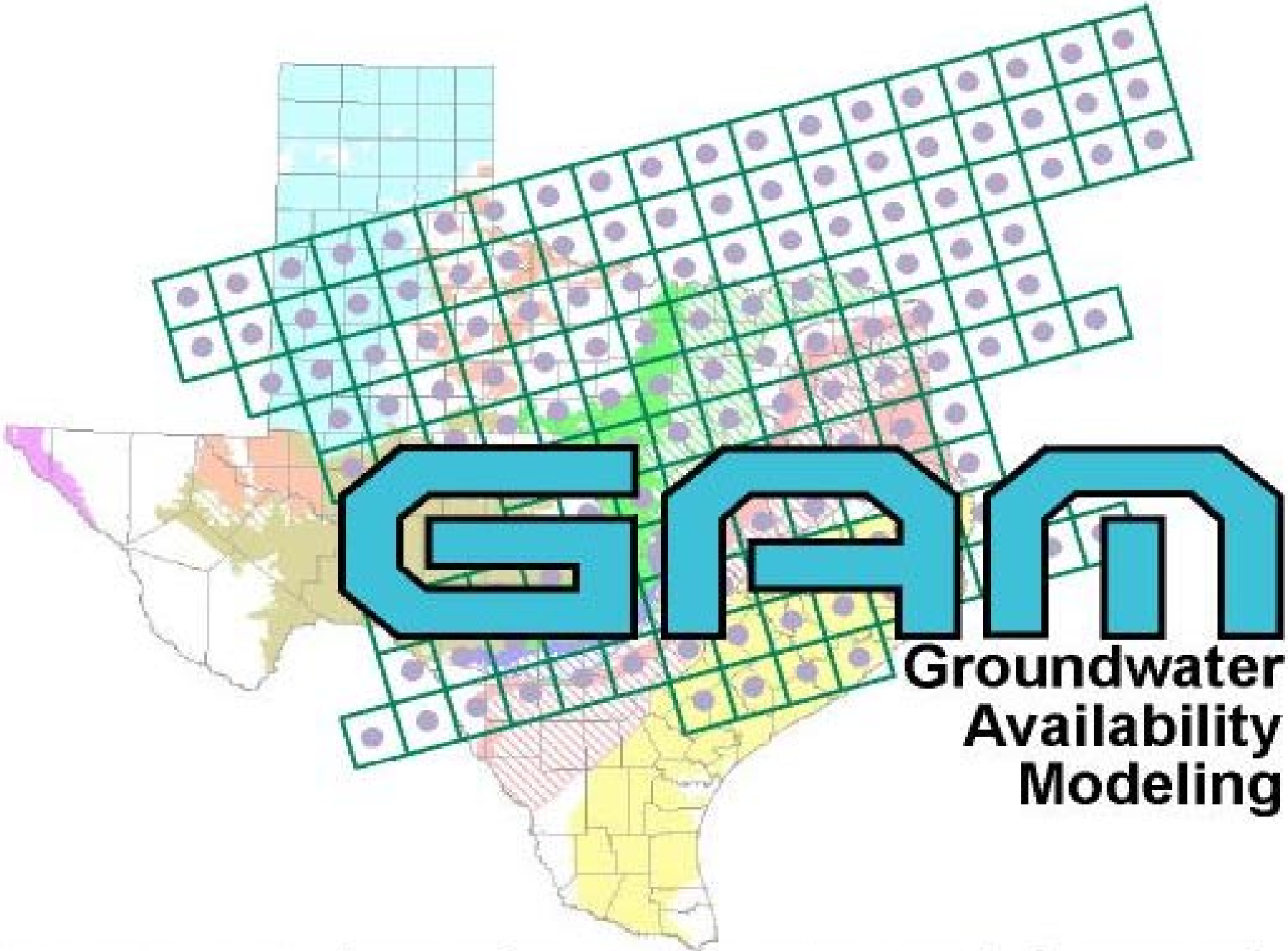
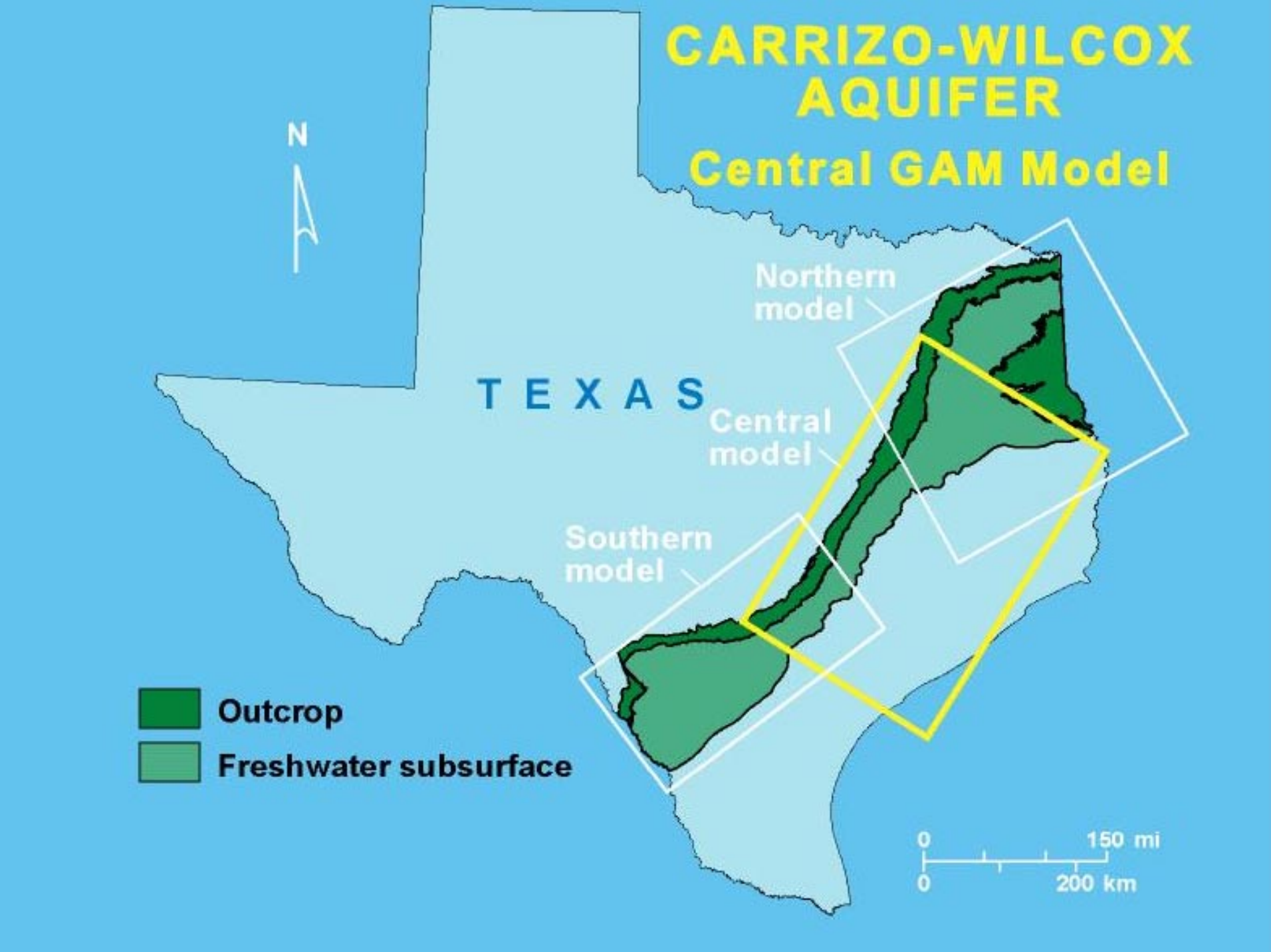

GAM
Groundwater
Availability
Modeling
texas water development board

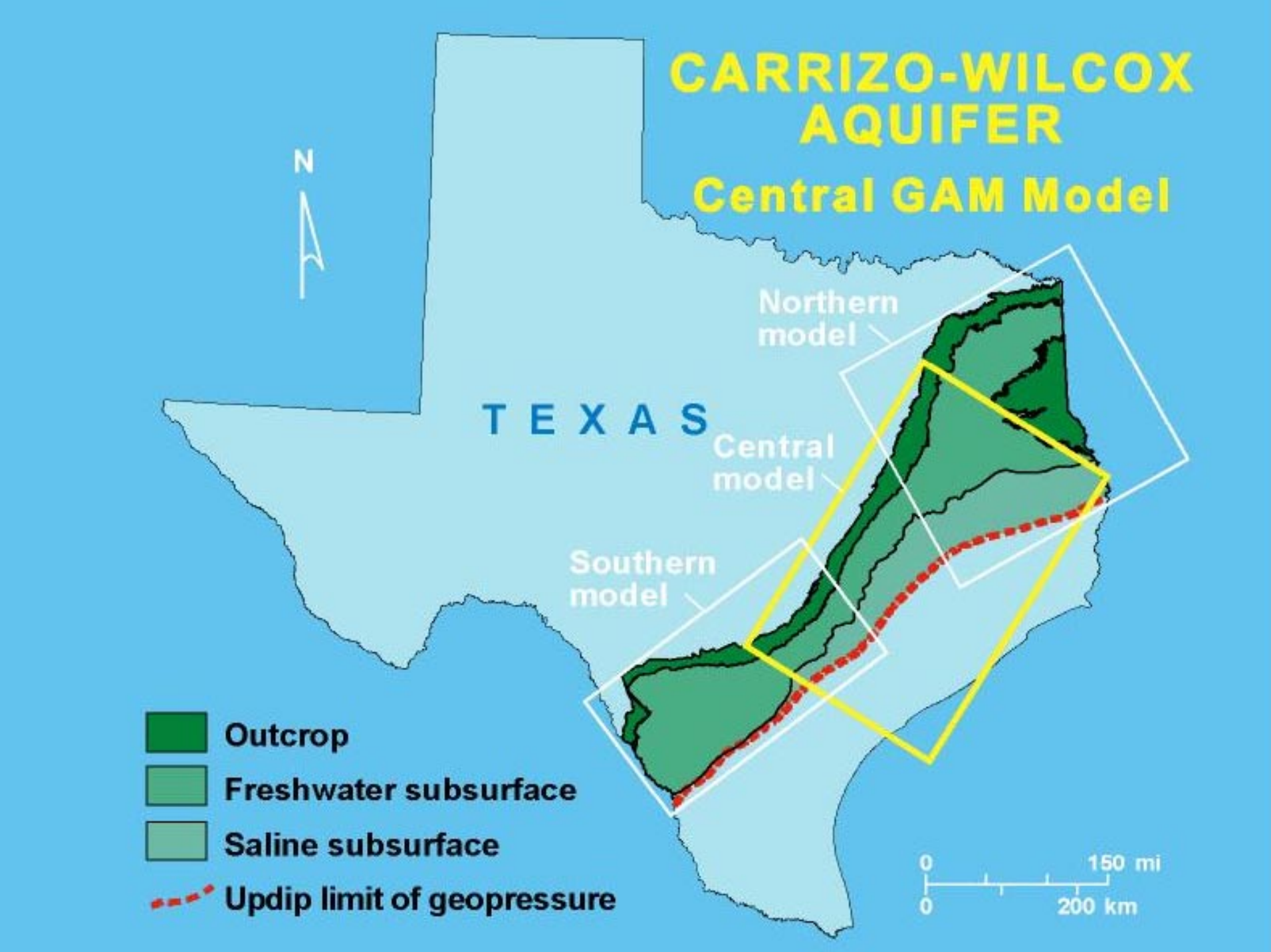

CARRIZO-WILCOX AQUIFER
Central GAM Model
N
TEXAS
Northern model
Central model
Southern model
Outcrop
Freshwater subsurface
0
150 mi
0
200 km

ROLE OF GAM MODEL

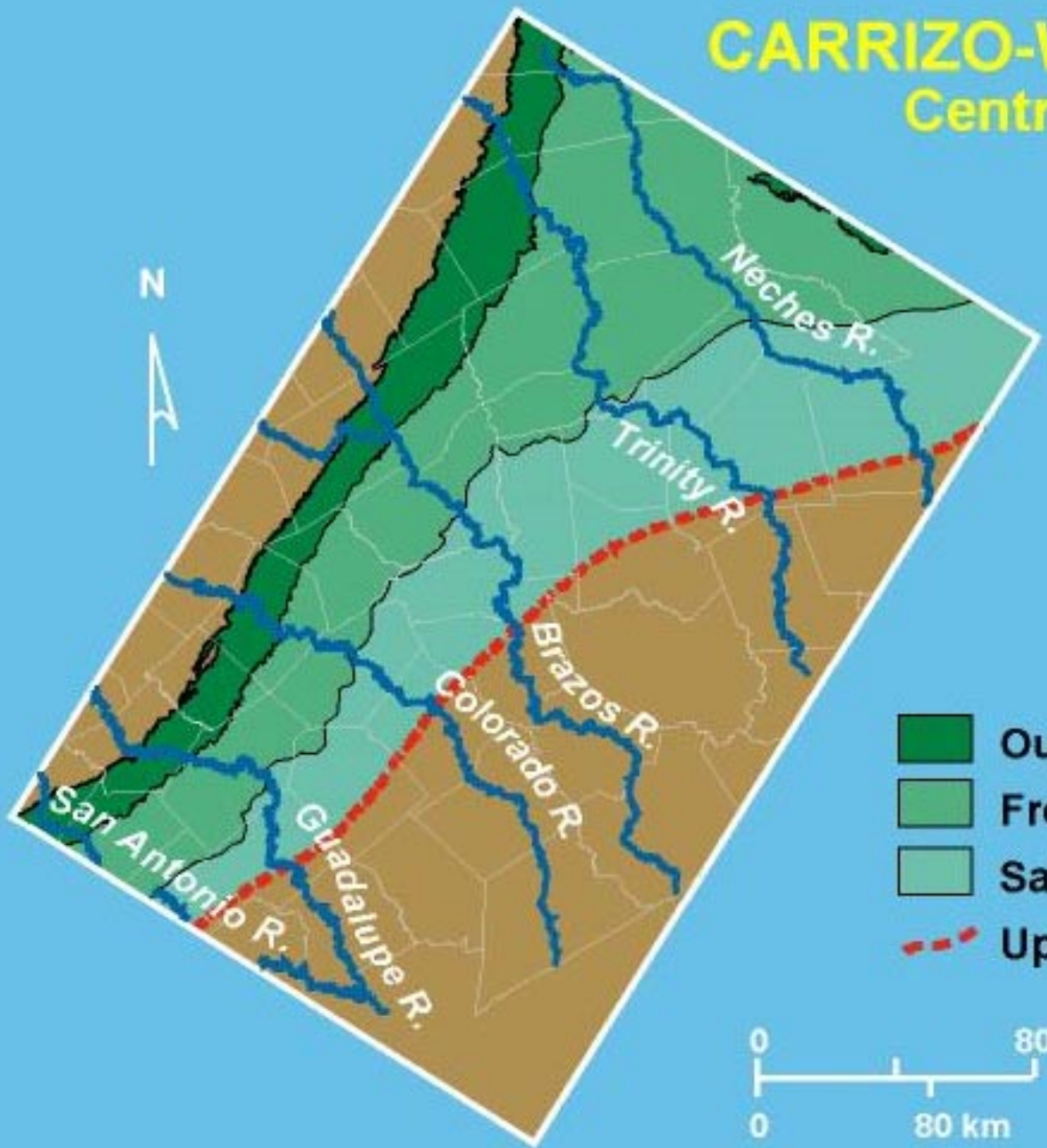
- Goal of GAM project is to develop a realistic and scientifically accurate computer model that represents the aquifer, its water budget, and its groundwater processes such as recharge, discharge, and pumping
- Model will be used by groundwater conservation districts (GWCD), regional water planning groups (RWPG), TWDB, and individuals to evaluate the hydrologic effects of various water use alternatives
- Stakeholder participation is important to ensure the model is accepted as a valid representation of the aquifer
- Once the model is developed, it can be used to assess availability of groundwater

AGENDA
STAKEHOLDER ADVISORY FORUM (SAF) MEETING
July 23, 2001

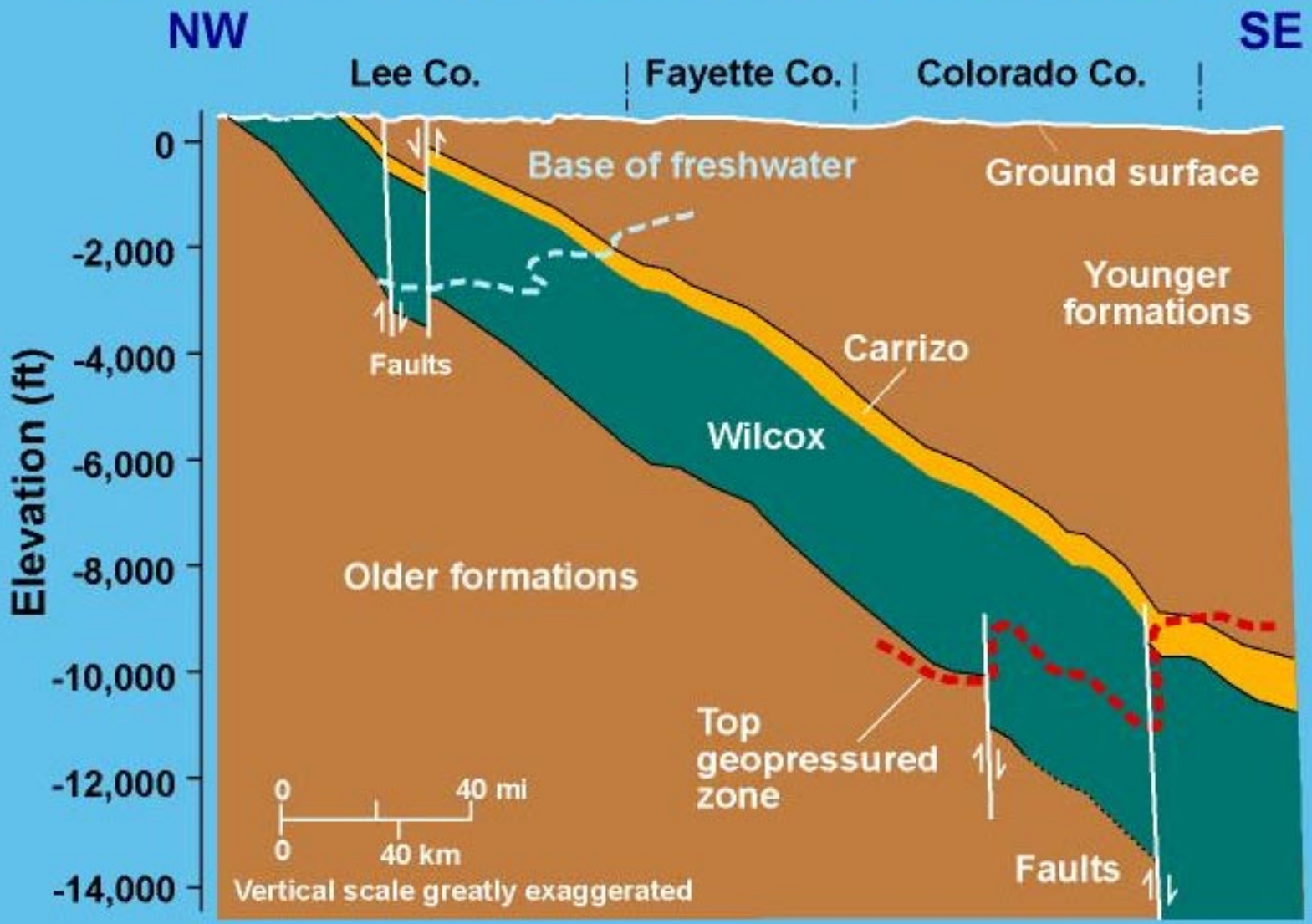
- Review of goals and study area
- Description of the aquifer as a basis for building the computer model (the Conceptual Model)
- Schedule and status of model development


CARRIZO-WILCOX AQUIFER
Central GAM Model
N
TEXAS
Northern model
Central model
Southern model
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure
0
150 mi
0
200 km

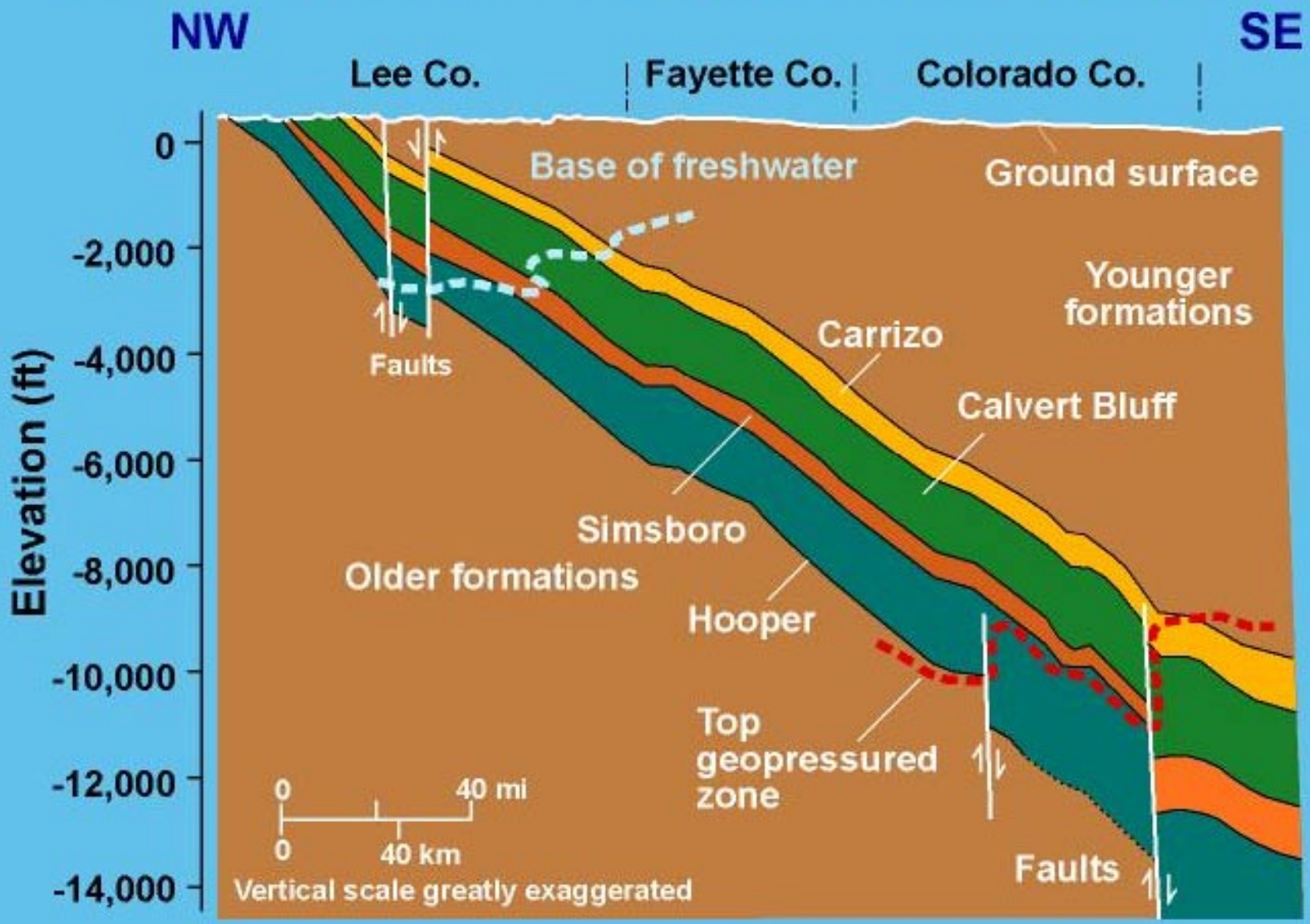
CARRIZO-WILCOX AQUIFER
Central Model Area

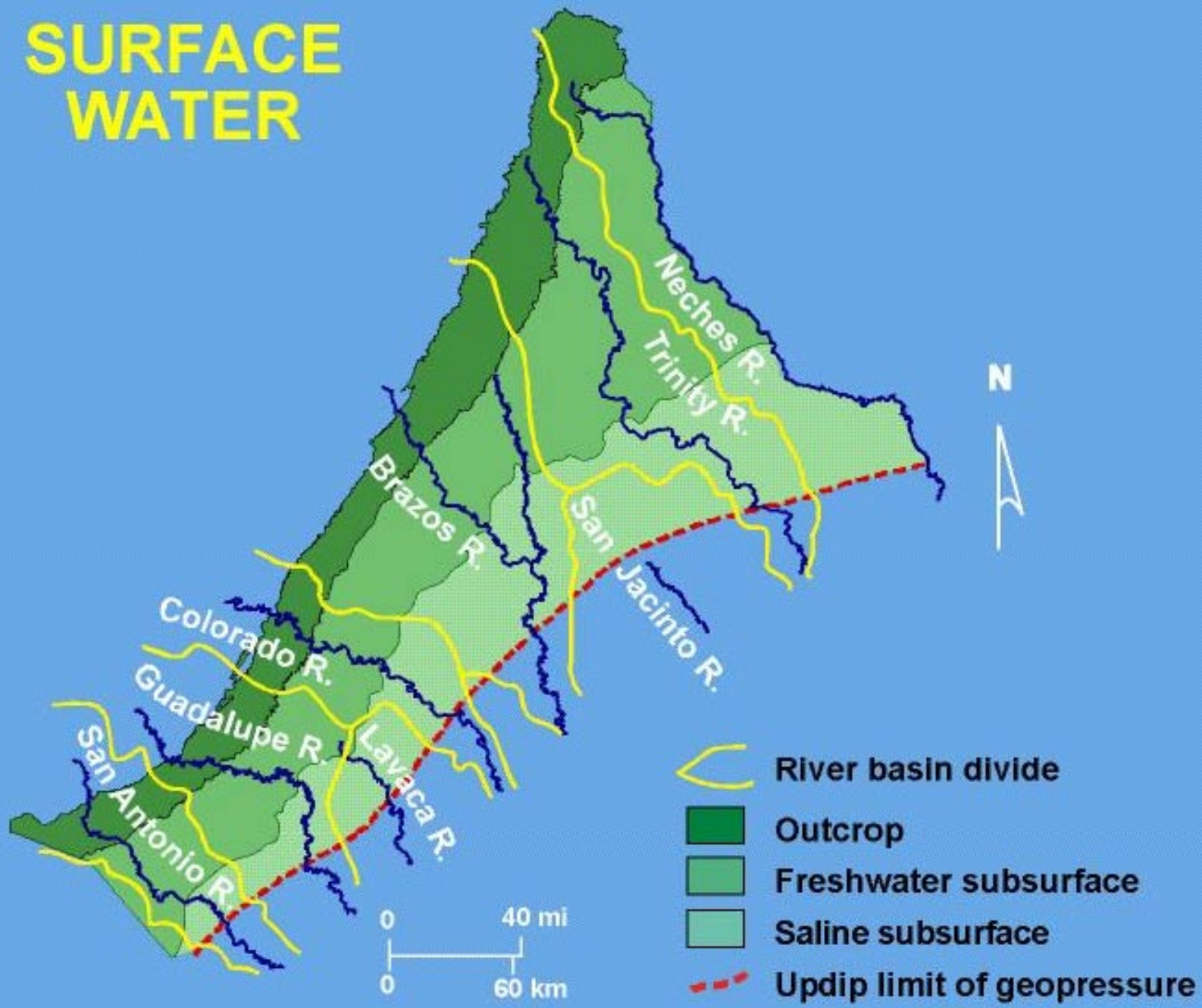


CARRIZO-WILCOX HYDROGEOLOGY

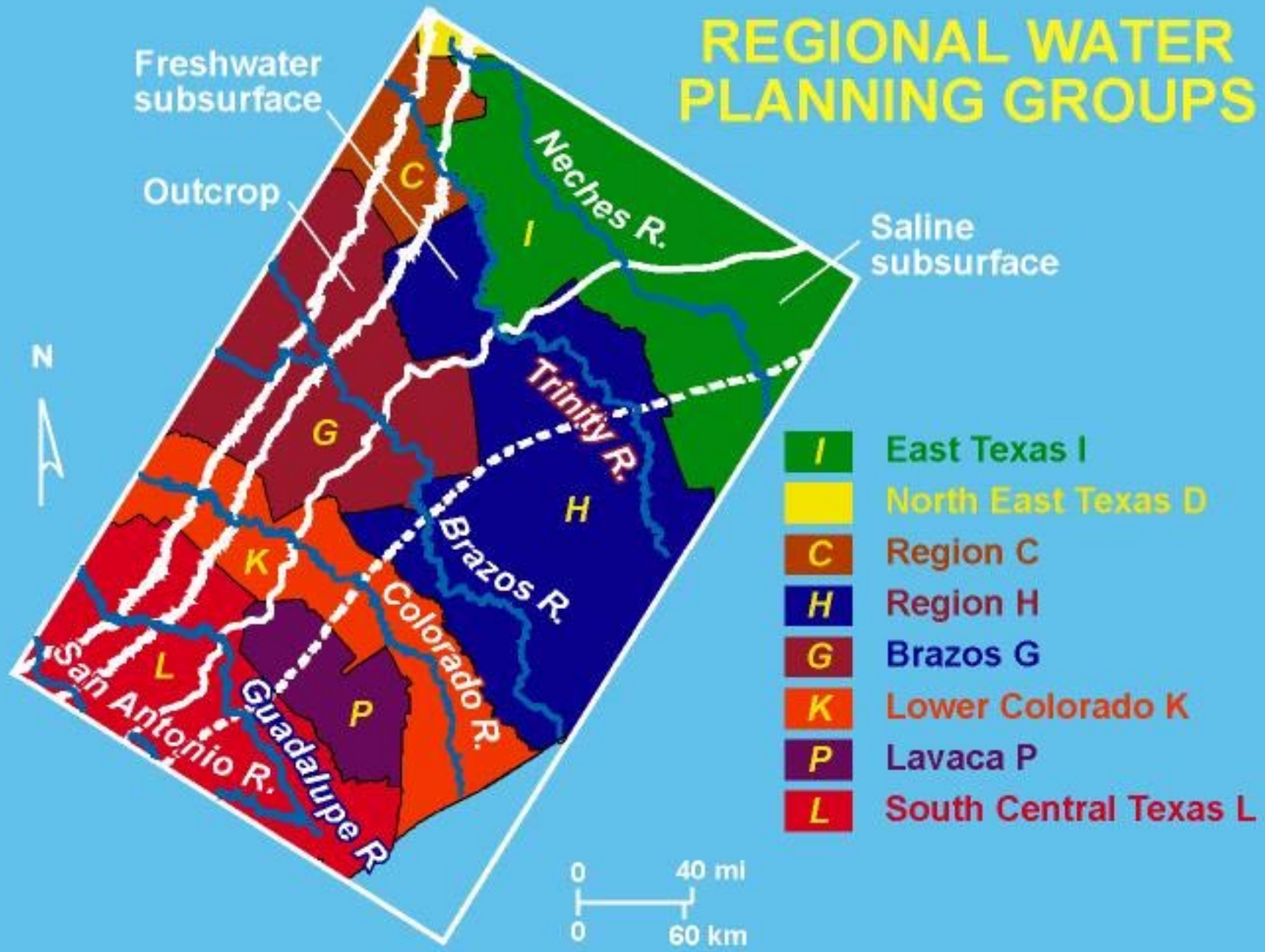


CARRIZO-WILCOX HYDROGEOLOGY




SURFACE WATER
Neches R.
Trinity R.
Brazos R.
San Jacinto R.
Colorado R.
Guadalupe R.
Lavaca R.
San Antonio R.
N
0
40 mi
0
60 km
River basin divide
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure


GROUNDWATER CONSERVATION DISTRICTS
N
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure
0 40 mi
0 60 km
Neches R.
Trinity R.
Brazos R.
Colorado R.
Guadalupe R.
San Antonio R.
1 Anderson County UWCD
2 Brazos Valley GCD
3 Clearwater UWCD
4 Lost Pines GCD
5 Barton Springs/Edwards Aquifer CD
6 Plum Creek CD
7 Edwards Aquifer Authority
8 Guadalupe County GCD
9 Gonzales County CD
10 Evergreen UWCD


REGIONAL WATER PLANNING GROUPS
Freshwater subsurface
Outcrop
Saline subsurface
Neches R.
Trinity R.
Brazos R.
Colorado R.
Guadalupe R.
San Antonio R.
C
I
G
H
K
L
P
N
0
40 mi
0
60 km
I East Texas I
North East Texas D
C Region C
H Region H
G Brazos G
K Lower Colorado K
P Lavaca P
L South Central Texas L

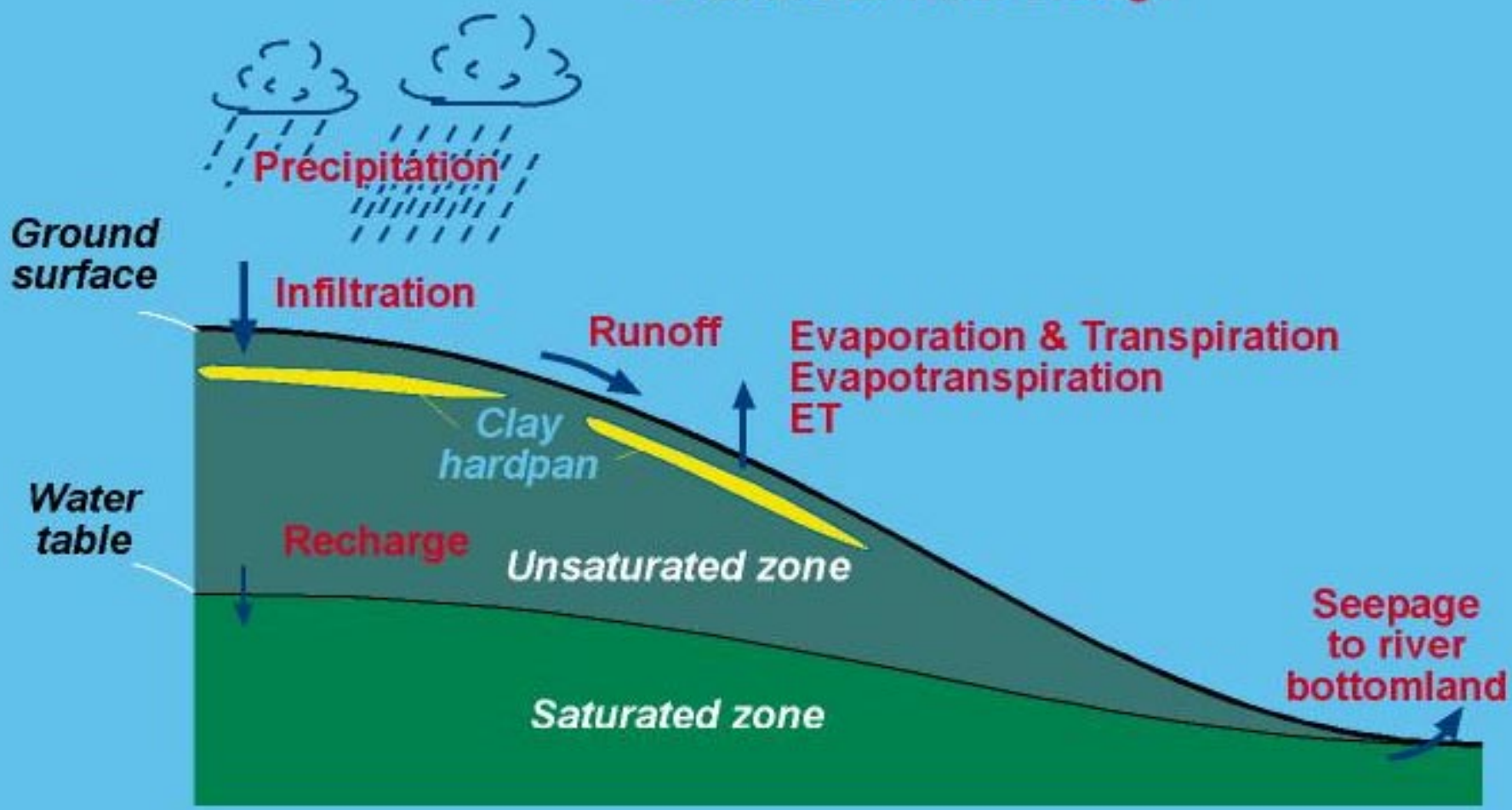
DESCRIPTION OF THE AQUIFER
Conceptual Model

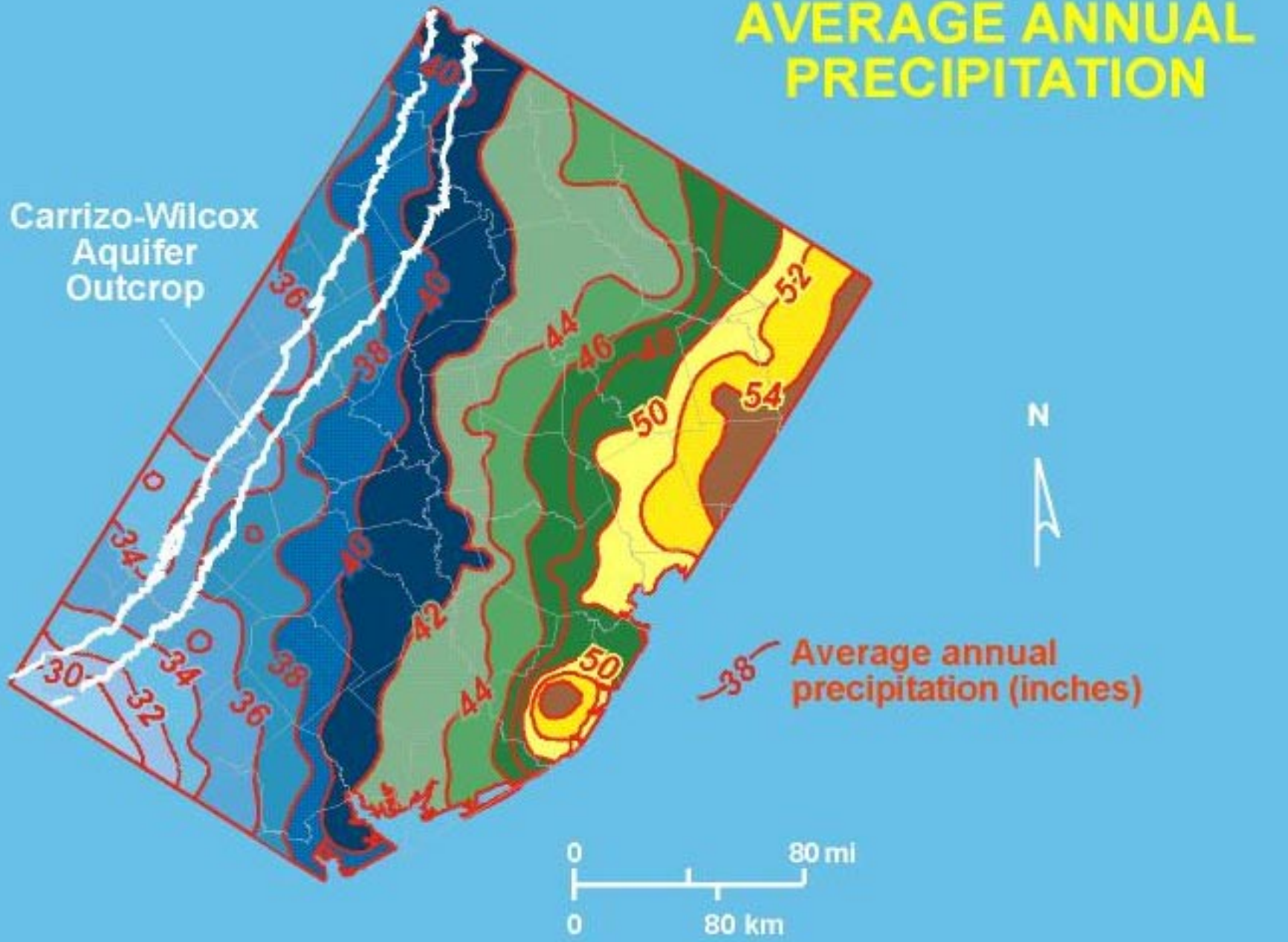
- Recharge
- Discharge
- Surface water and groundwater interaction
- Aquifer geometry
- Boundary conditions
- Aquifer properties
- Water quality

RECHARGE

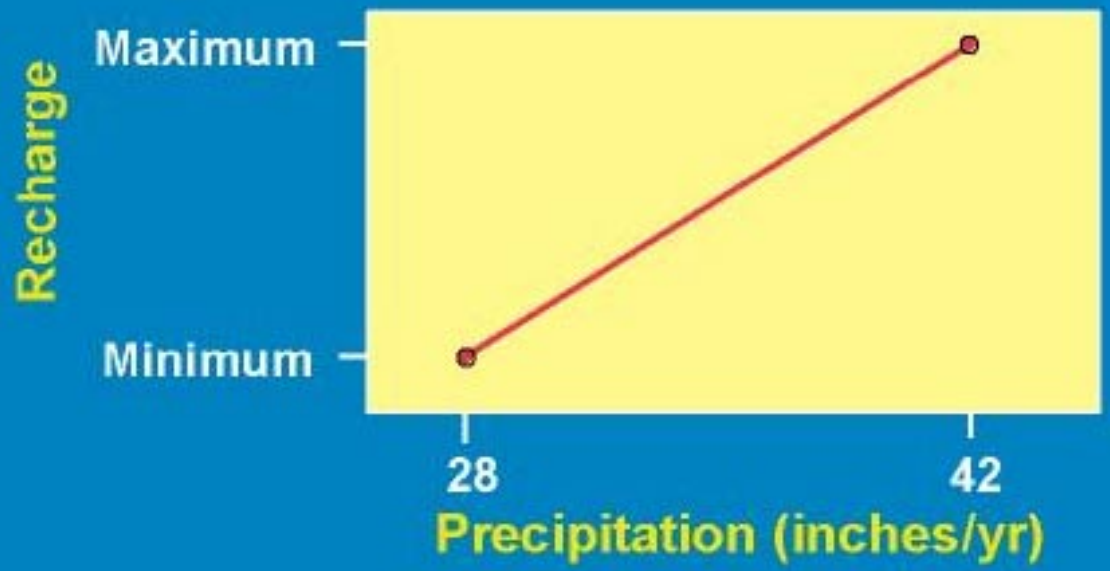
RECHARGE WATER BUDGET

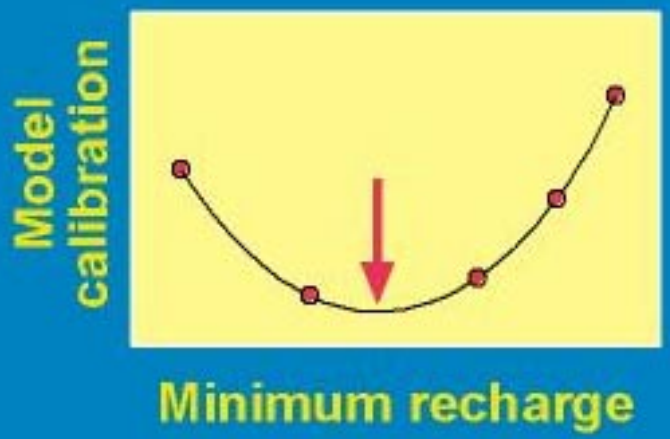
Recharge = Precipitation
- Runoff
- ET
- Gain in Soil-water Storage

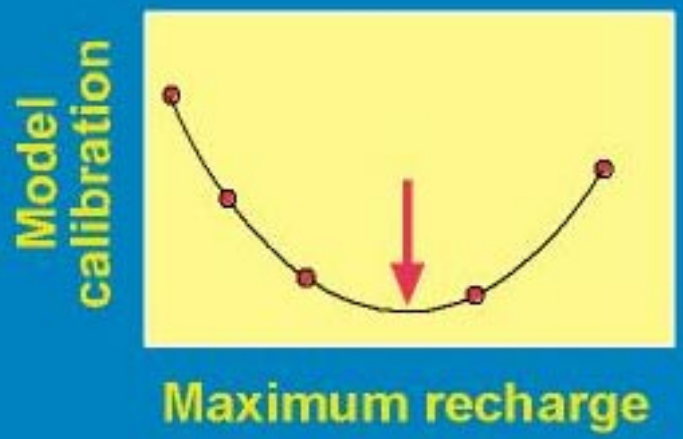



AVERAGE ANNUAL PRECIPITATION
Carrizo-Wilcox Aquifer Outcrop
30
32
34
36
38
40
42
44
46
48
50
52
54
N
38
Average annual precipitation (inches)
0
80 mi
0
80 km

RECHARGE MODELED FROM PRECIPITATION

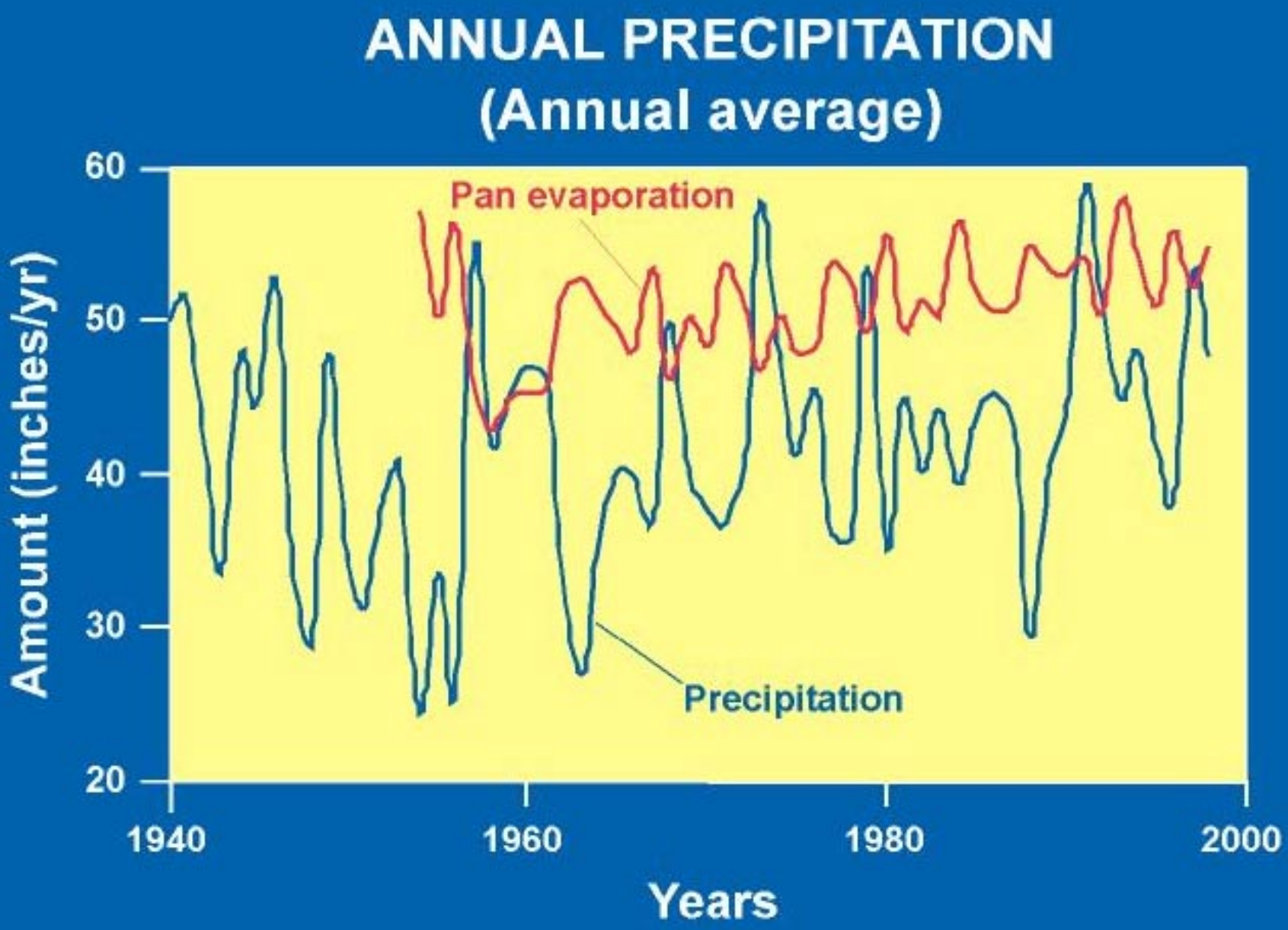


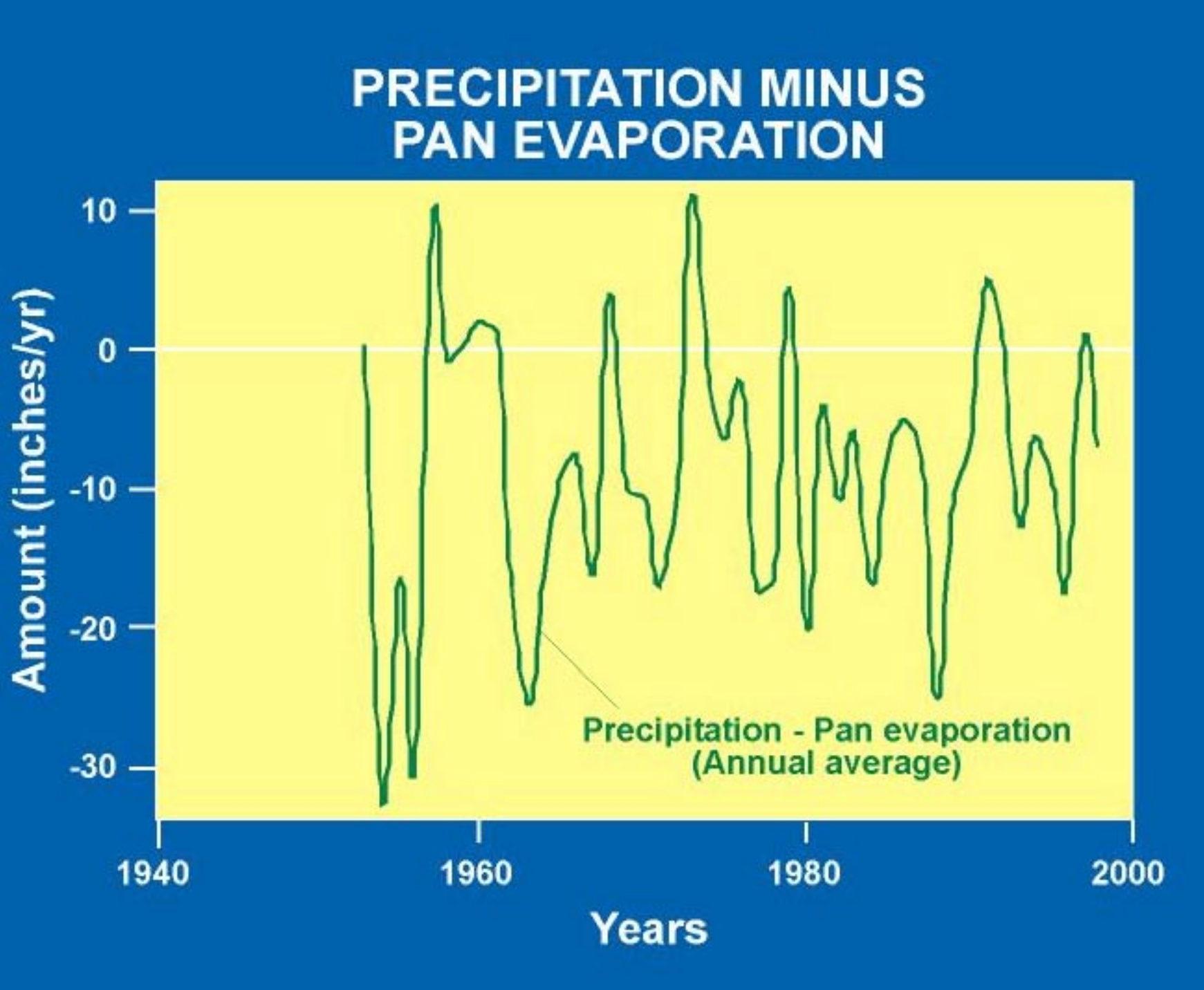


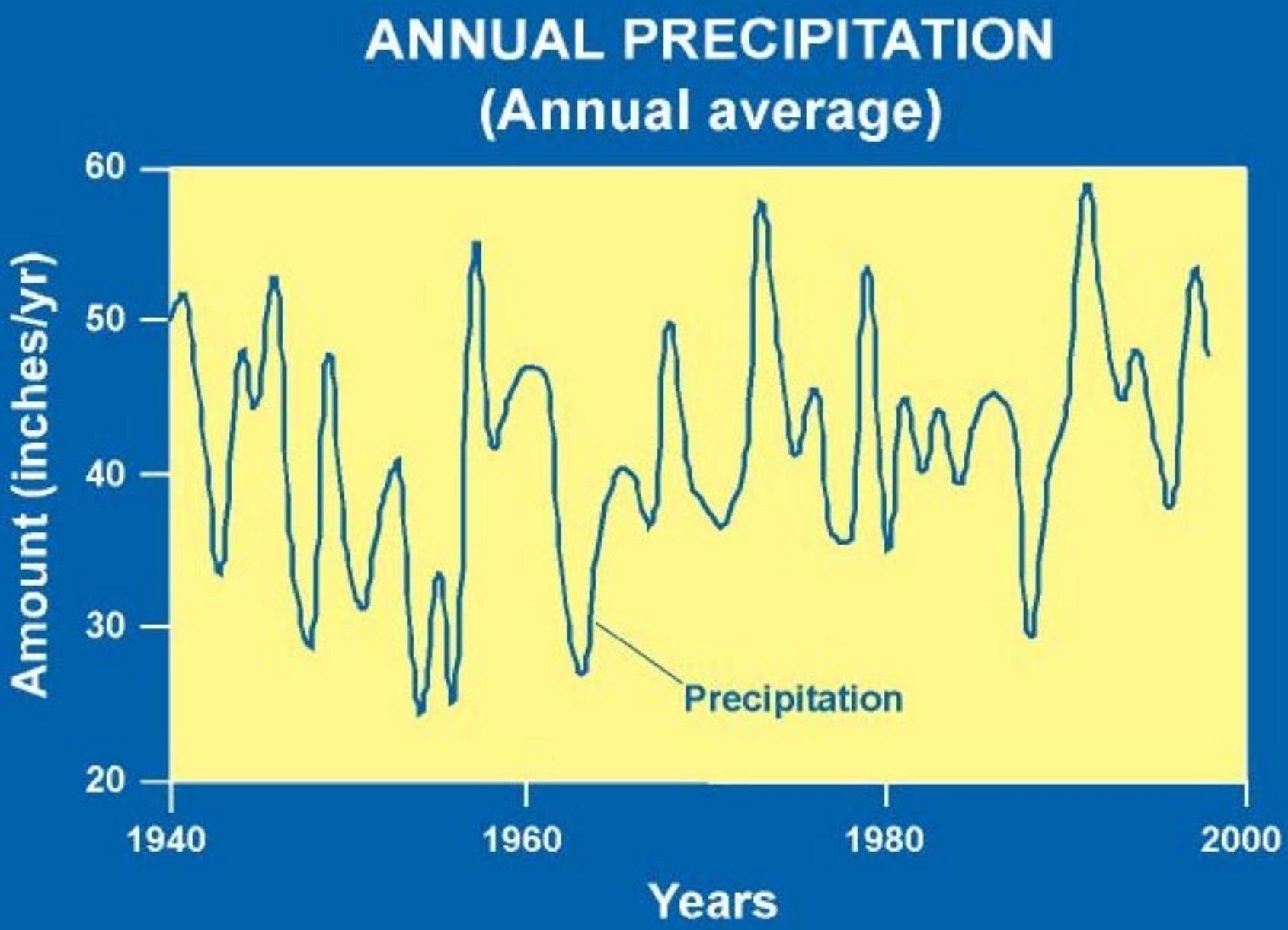


RECHARGE EXPERIMENT

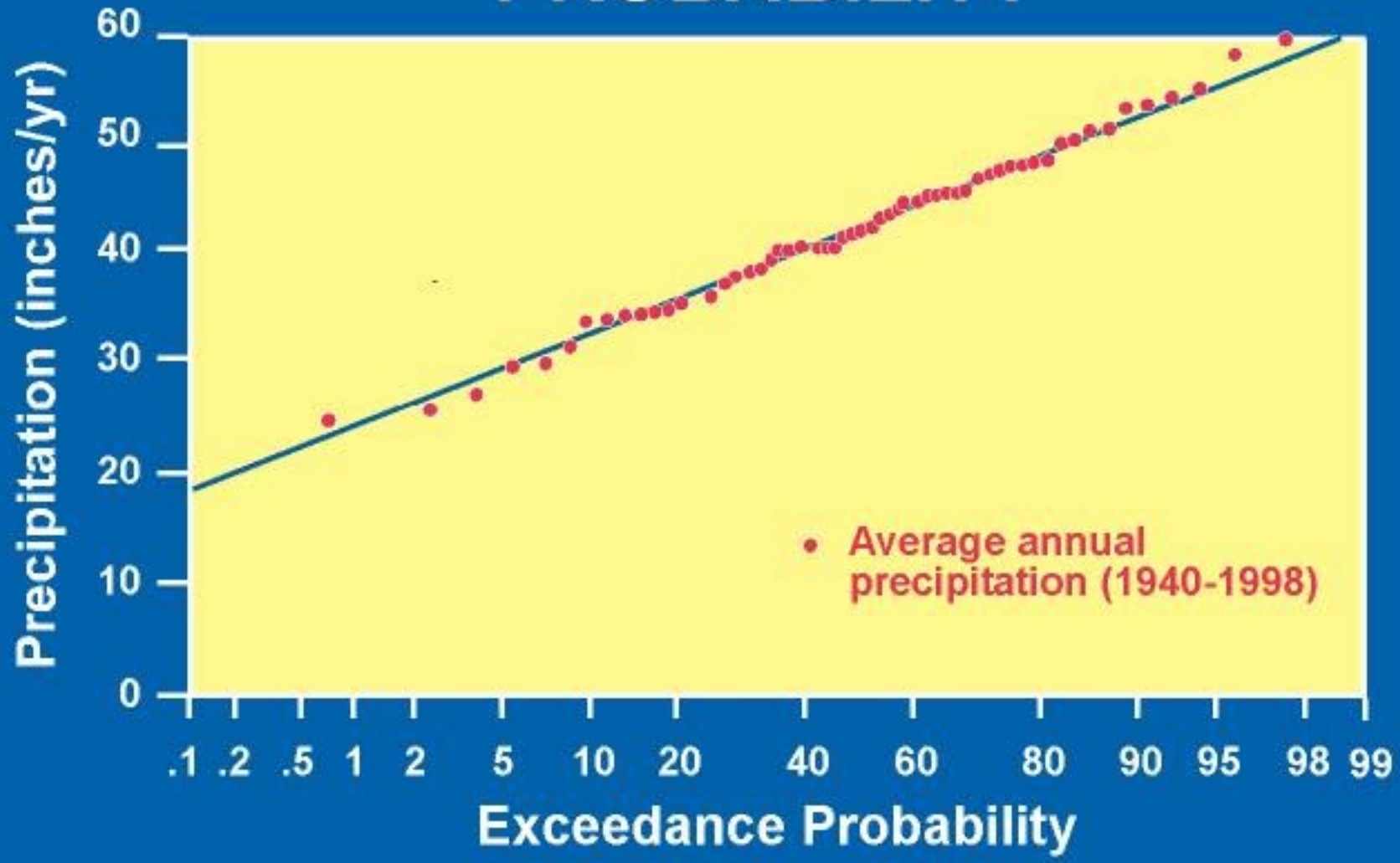
- Difficulty finding appropriate field conditions
  - Depth to water <30 ft
  - Predominantly downward groundwater flow
- Looking for alternative approaches for quantifying recharge in Carrizo-Wilcox using chemical tracers


ANNUAL PRECIPITATION
(Annual average)
Pan evaporation
Precipitation
Amount (inches/yr)
60
50
40
30
20
1940
1960
1980
2000
Years


PRECIPITATION MINUS
PAN EVAPORATION
Amount (inches/yr)
10
0
-10
-20
-30
Precipitation - Pan evaporation
(Annual average)
1940
1960
1980
2000
Years


ANNUAL PRECIPITATION
(Annual average)
Amount (inches/yr)
60
50
40
30
20
Precipitation
1940
1960
1980
2000
Years

ANNUAL PRECIPITATION PROBABILITY



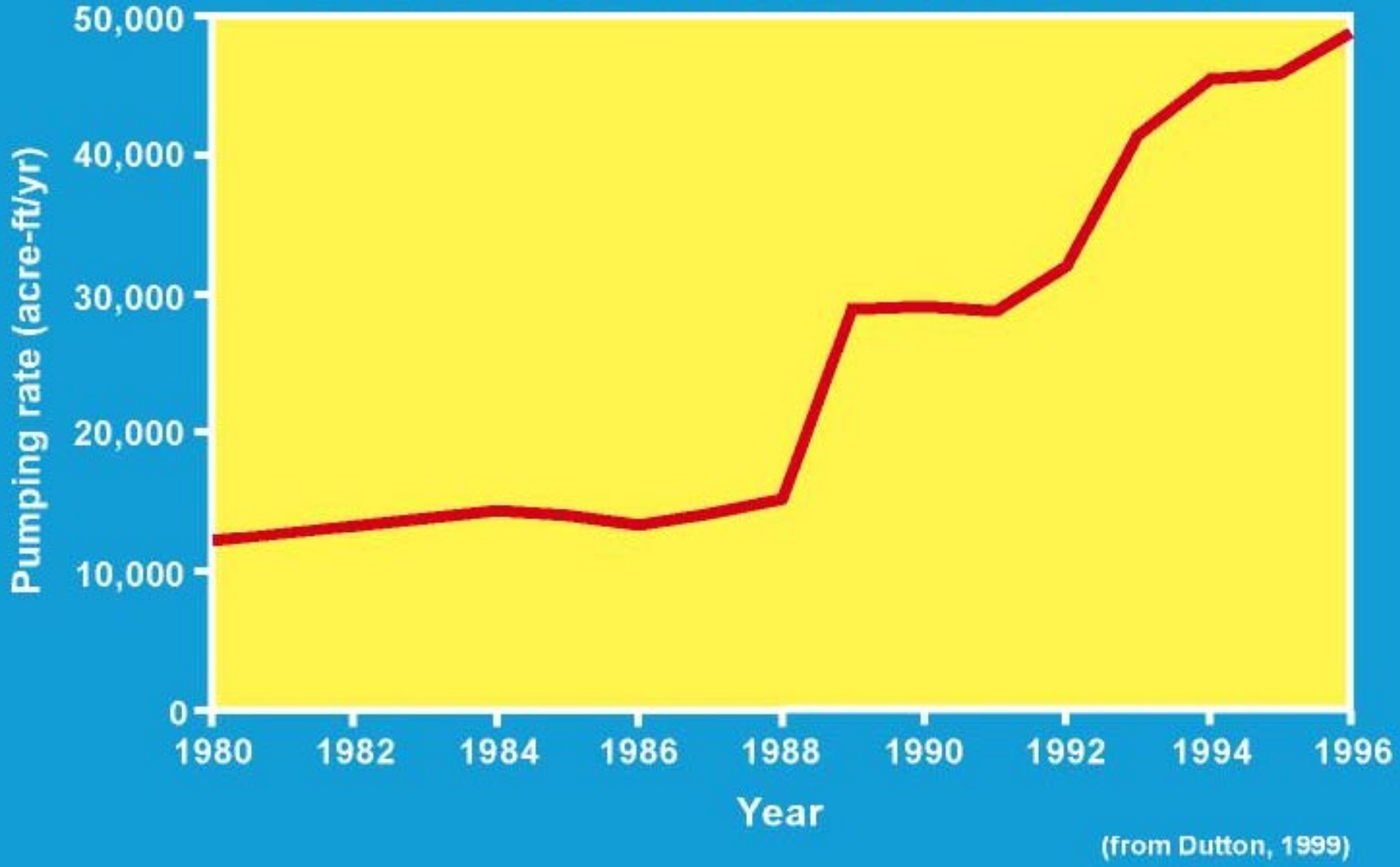
DISCHARGE

DISCHARGE

- Withdrawal by pumping
  - — Municipal
  - — Industrial
  - — Mining
  - — Irrigation
  - — Domestic
  - — Stock
- Exchange of surface water and groundwater
  - — Discharge at springs and seeps along river bottomlands
- Cross-formational flow
- Evapotranspiration

GROUNDWATER WITHDRAWAL FROM CARRIZO-WILCOX AQUIFER

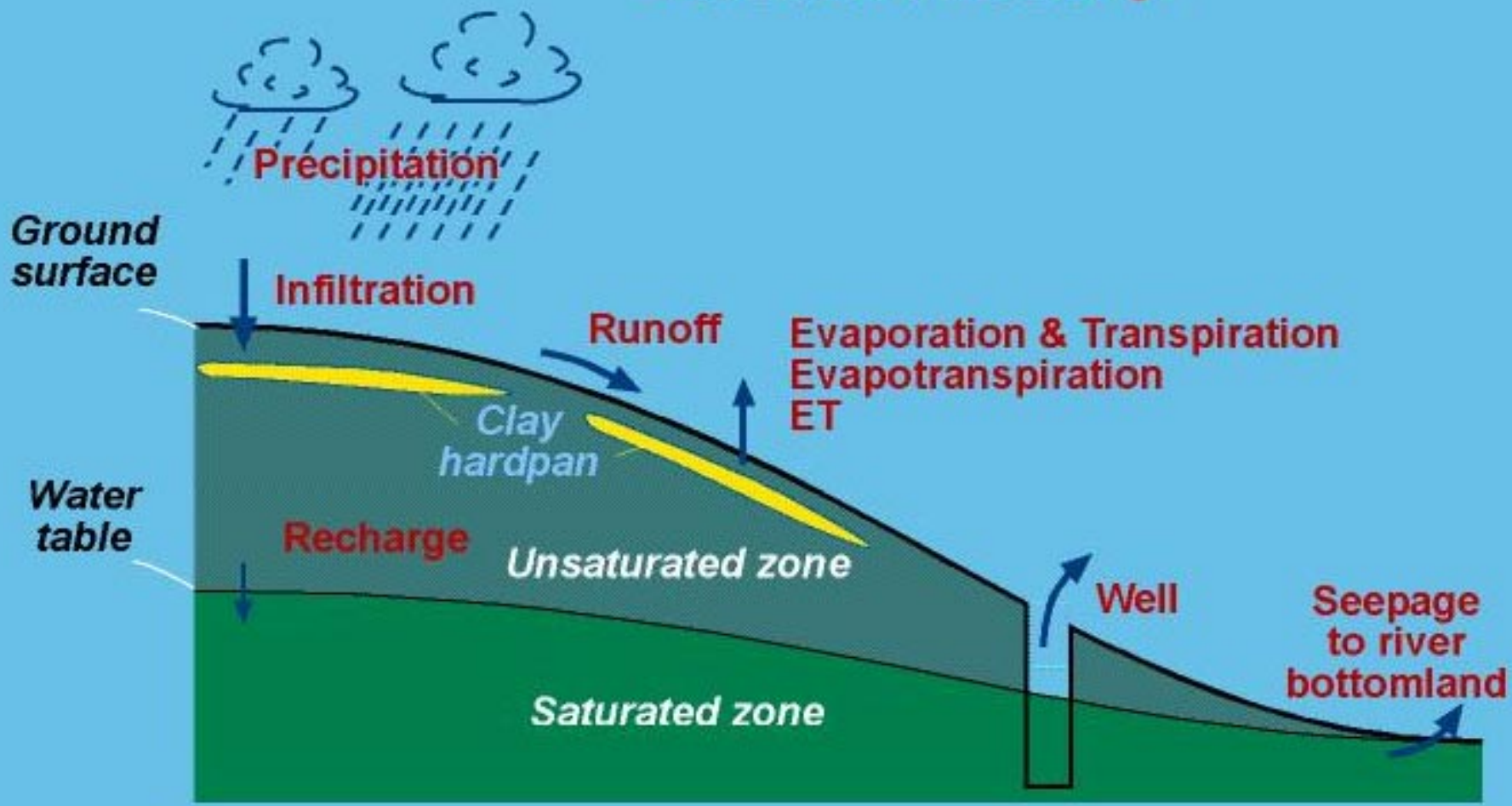
Central Texas Study Area (1980 to 1996)



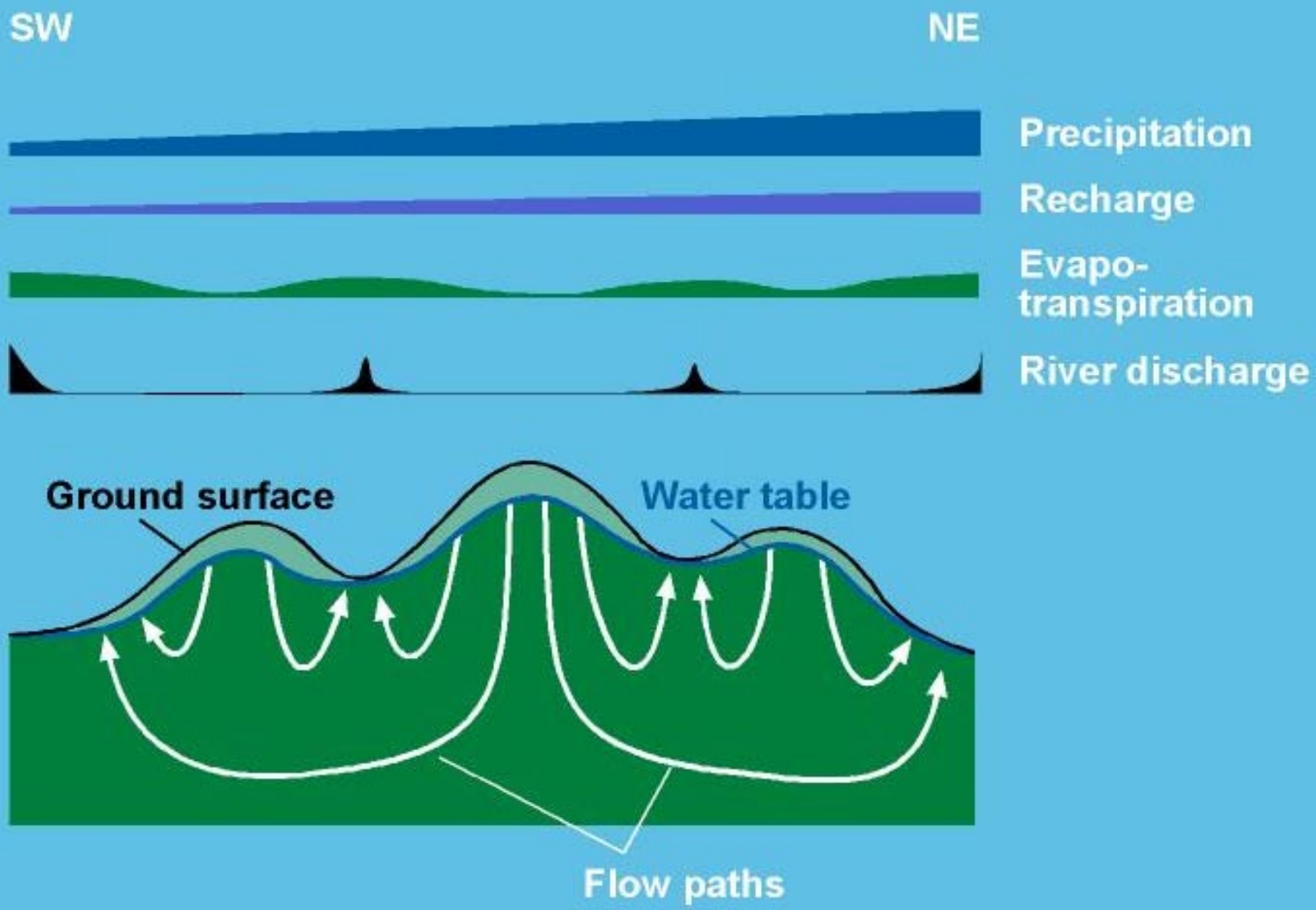
(from Dutton, 1999)

SOURCE OF CAPTURED RECHARGE

Recharge = Precipitation
- Runoff
- ET
- Gain in Soil-water Storage

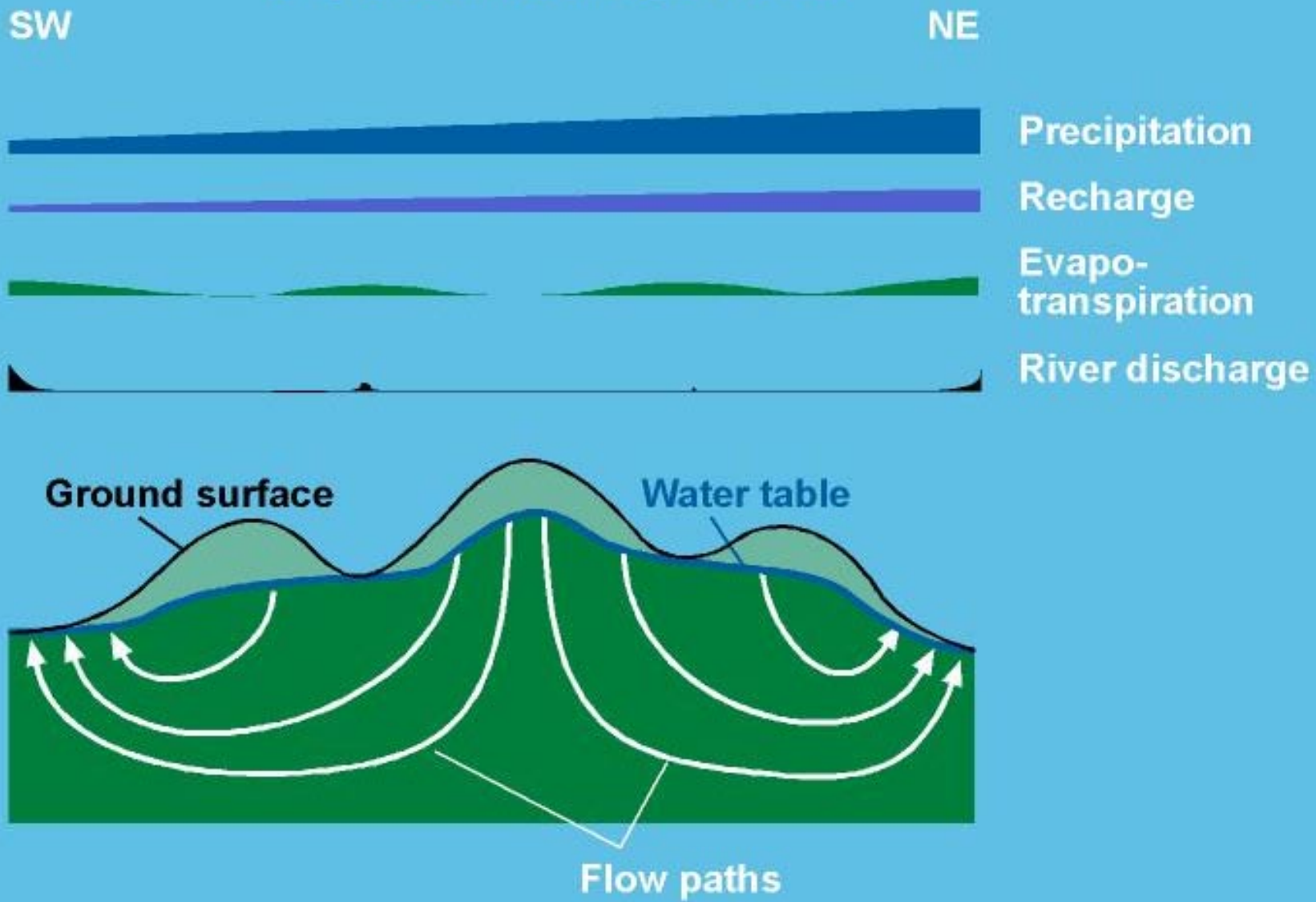


APPROACH FOR MODELING RECHARGE

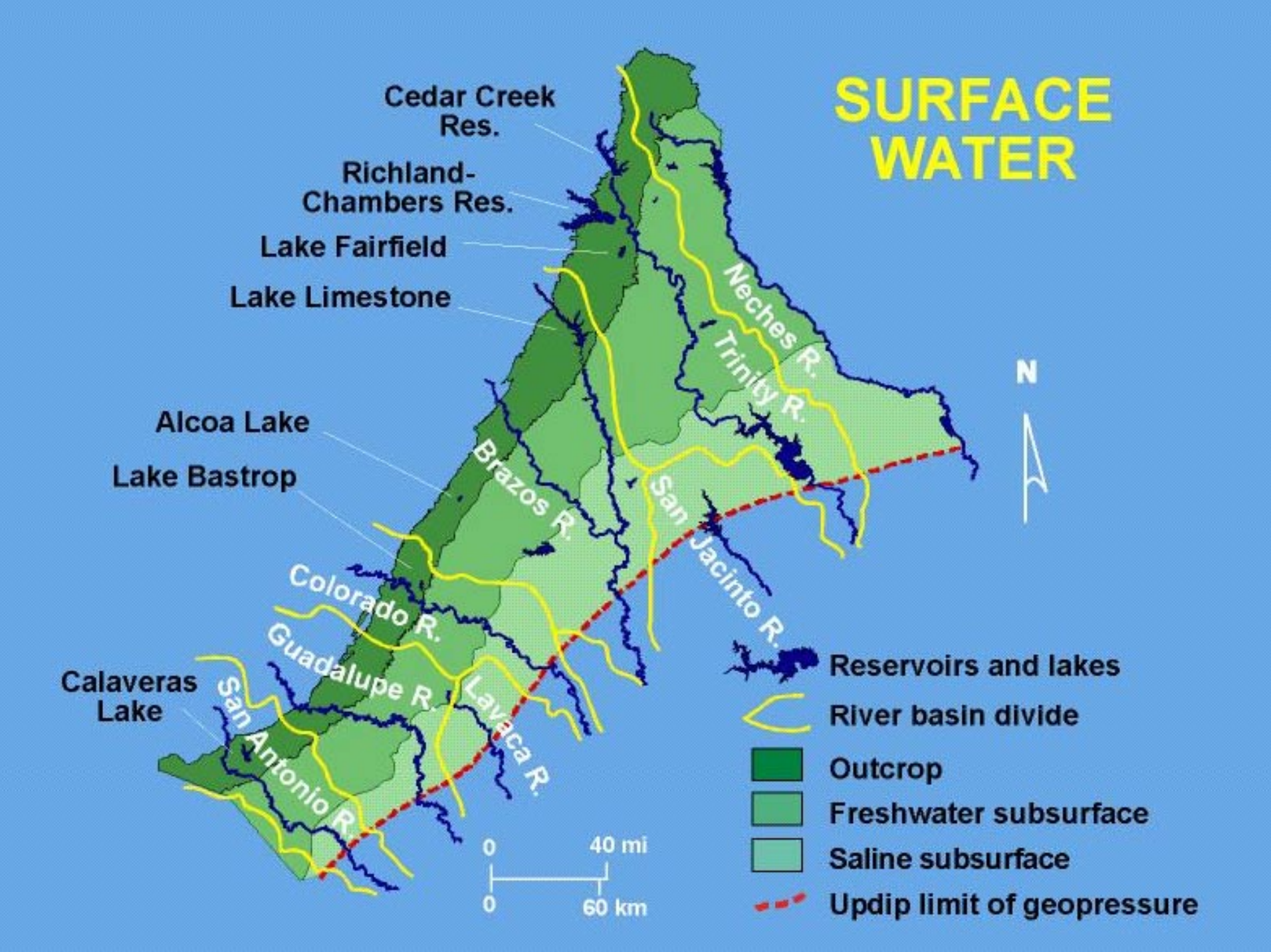


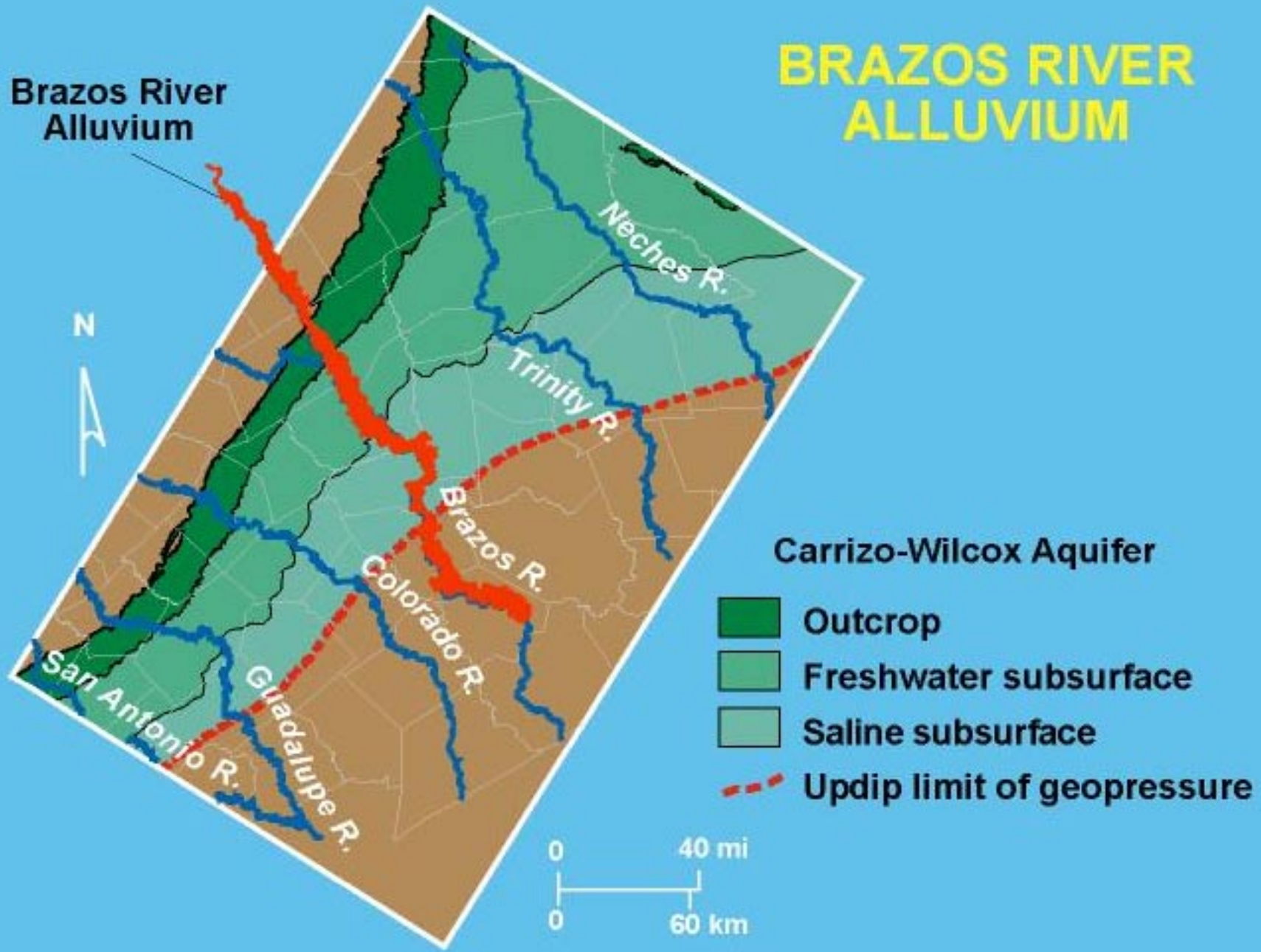
APPROACH FOR MODELING RECHARGE

Captured Recharge Model

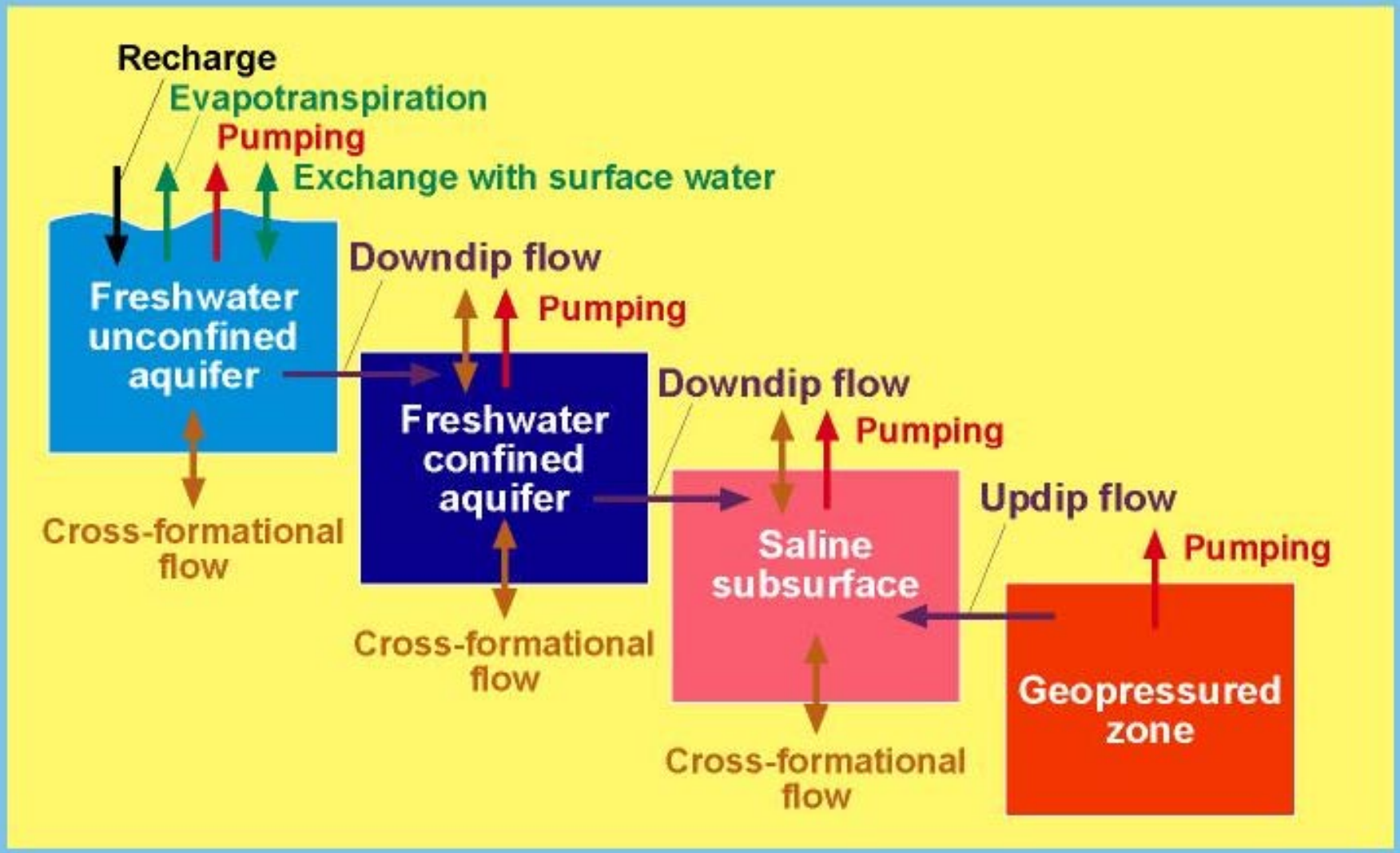


SURFACE WATER AND GROUNDWATER INTERACTION

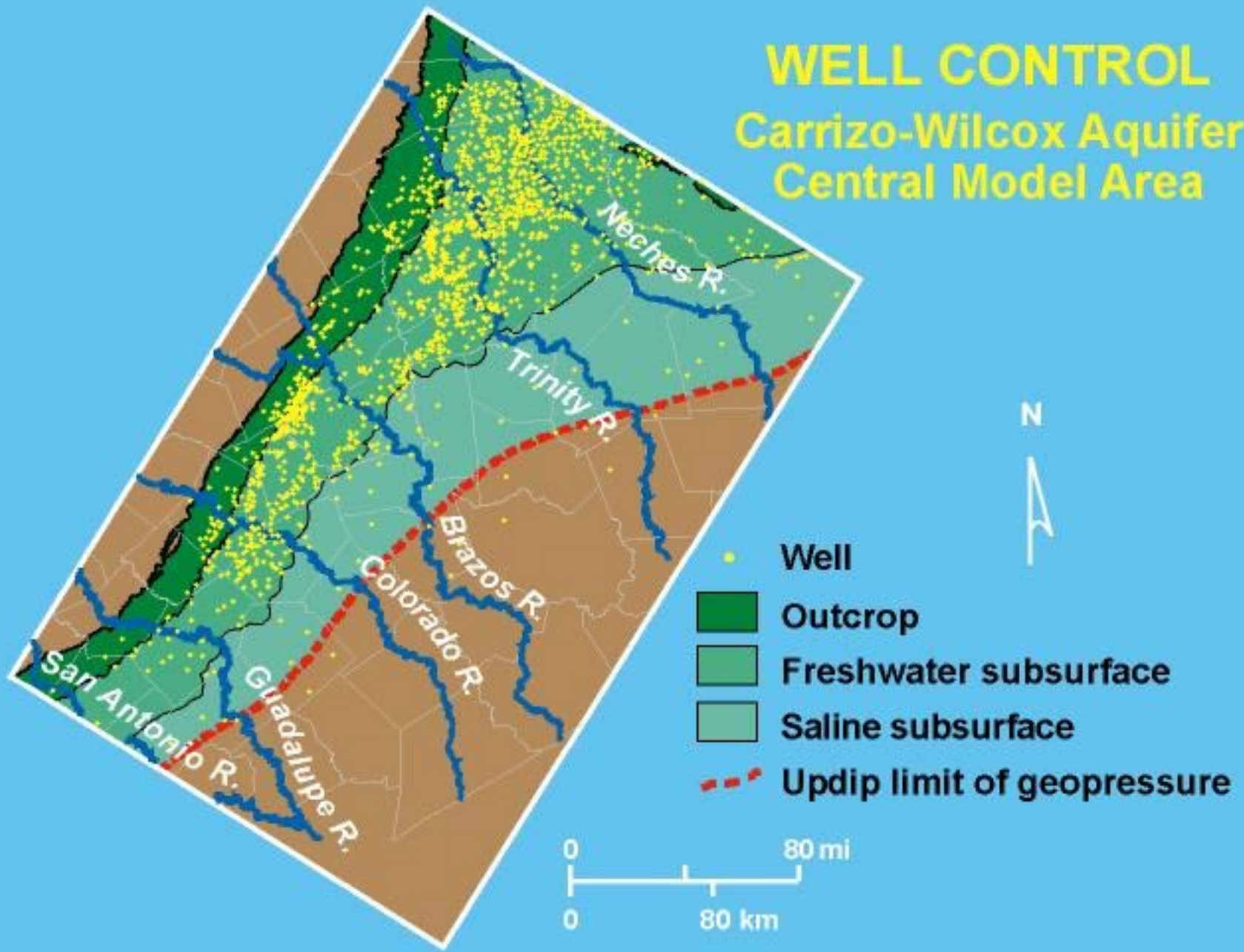

SURFACE WATER
Cedar Creek Res.
Richland-Chambers Res.
Lake Fairfield
Lake Limestone
Alcoa Lake
Lake Bastrop
Calaveras Lake
Neches R.
Trinity R.
Brazos R.
San Jacinto R.
Colorado R.
Guadalupe R.
Lavaca R.
San Antonio R.
N
0
40 mi
0
60 km
Reservoirs and lakes
River basin divide
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure


BRAZOS RIVER ALLUVIUM
Brazos River Alluvium
N
Neches R.
Trinity R.
Brazos R.
Colorado R.
Guadalupe R.
San Antonio R.
Carrizo-Wilcox Aquifer
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure
0
40 mi
0
60 km

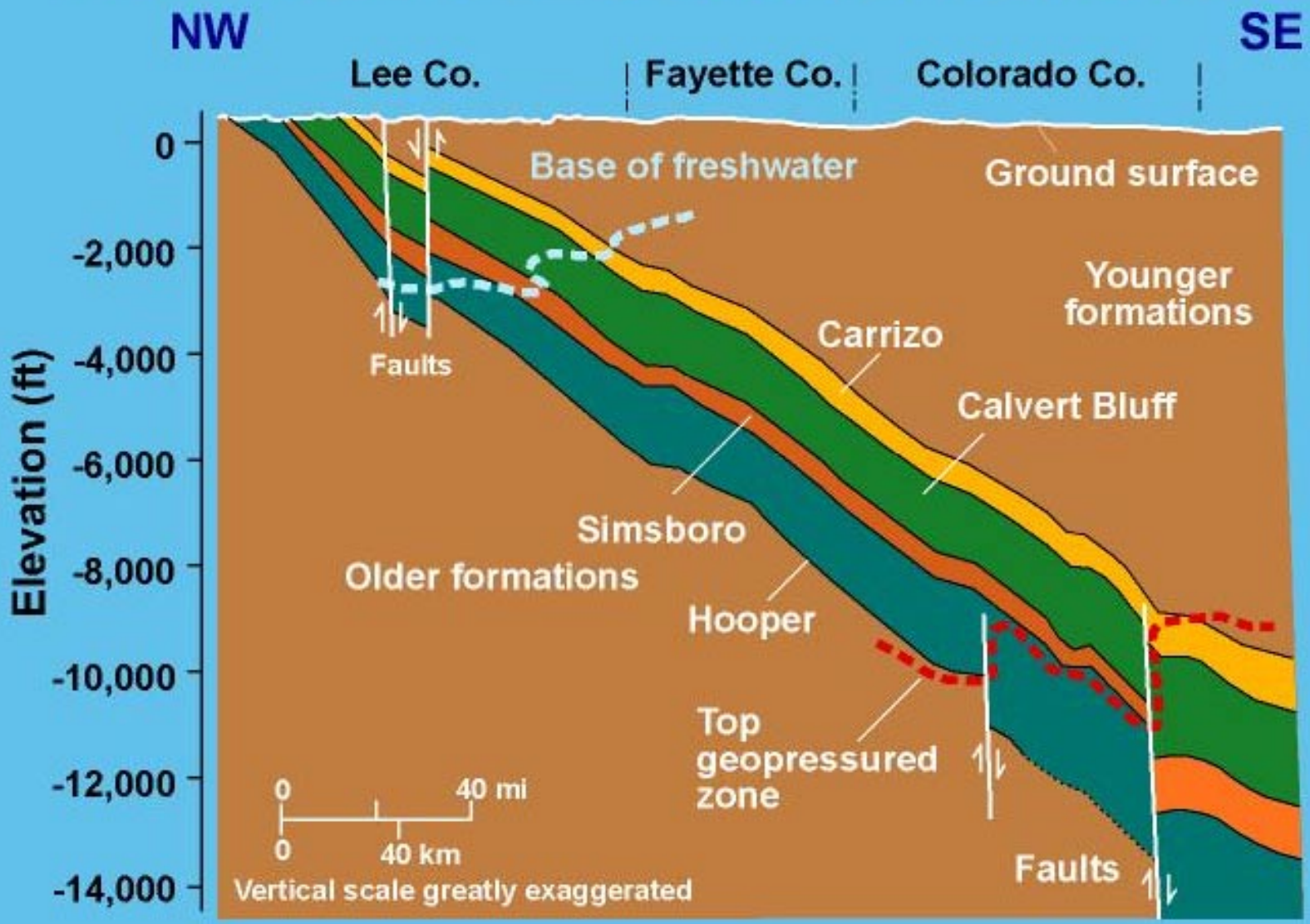
WATER EXCHANGE IN AQUIFER SYSTEM

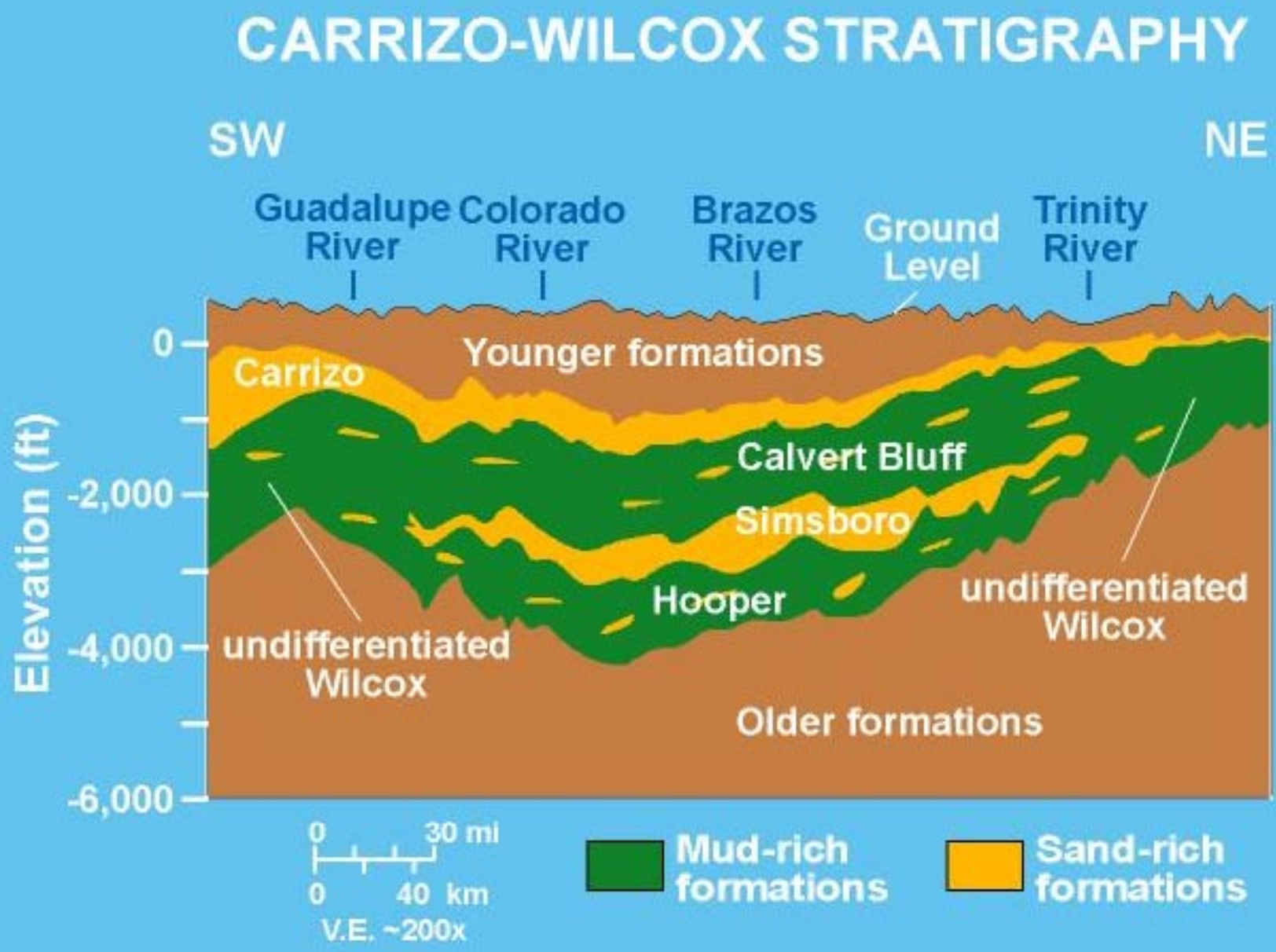


AQUIFER GEOMETRY


WELL CONTROL
Carrizo-Wilcox Aquifer
Central Model Area
Neches R.
Trinity R.
Brazos R.
Colorado R.
Guadalupe R.
San Antonio R.
N
Well
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure
0
80 mi
0
80 km

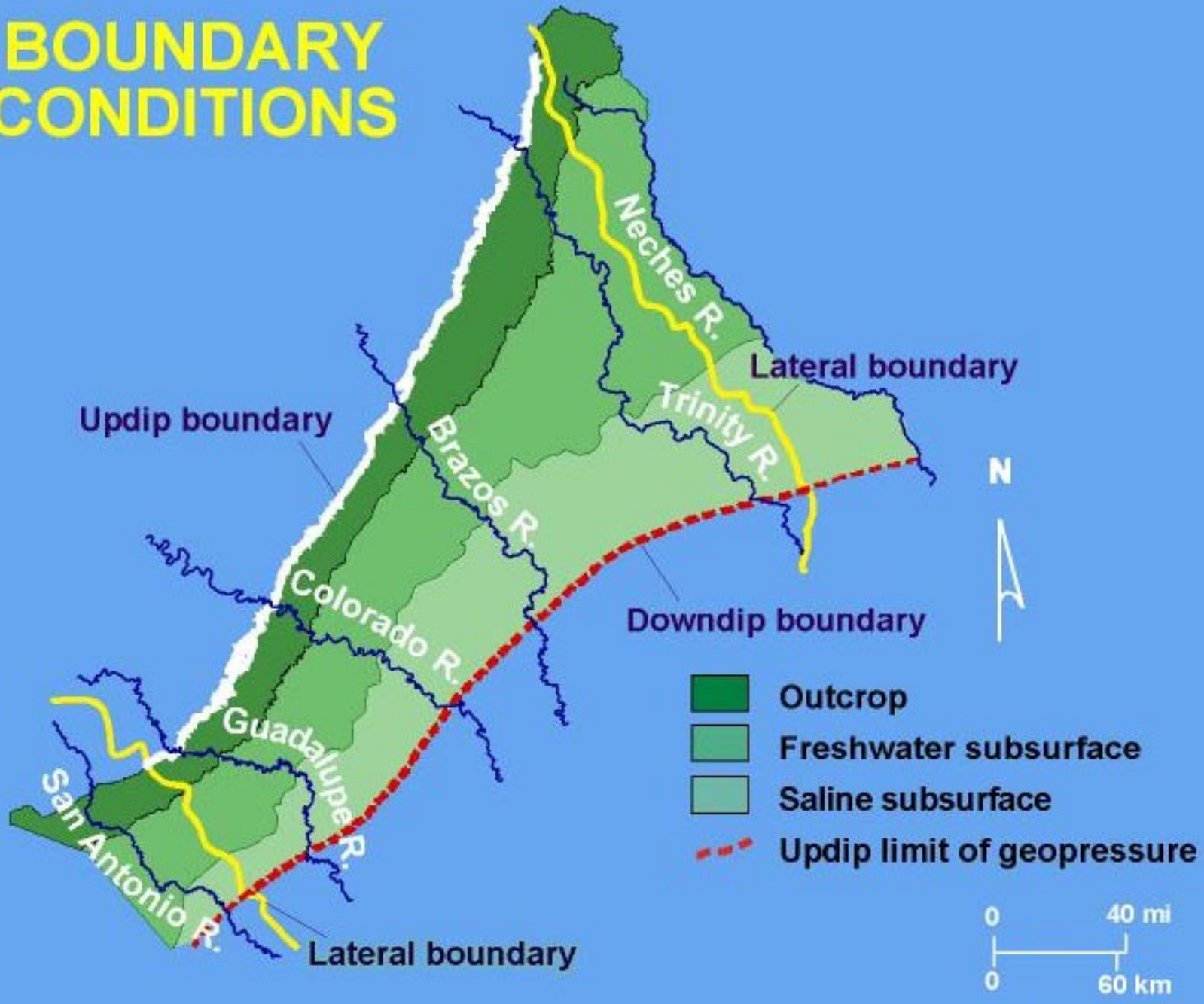
CARRIZO-WILCOX HYDROGEOLOGY



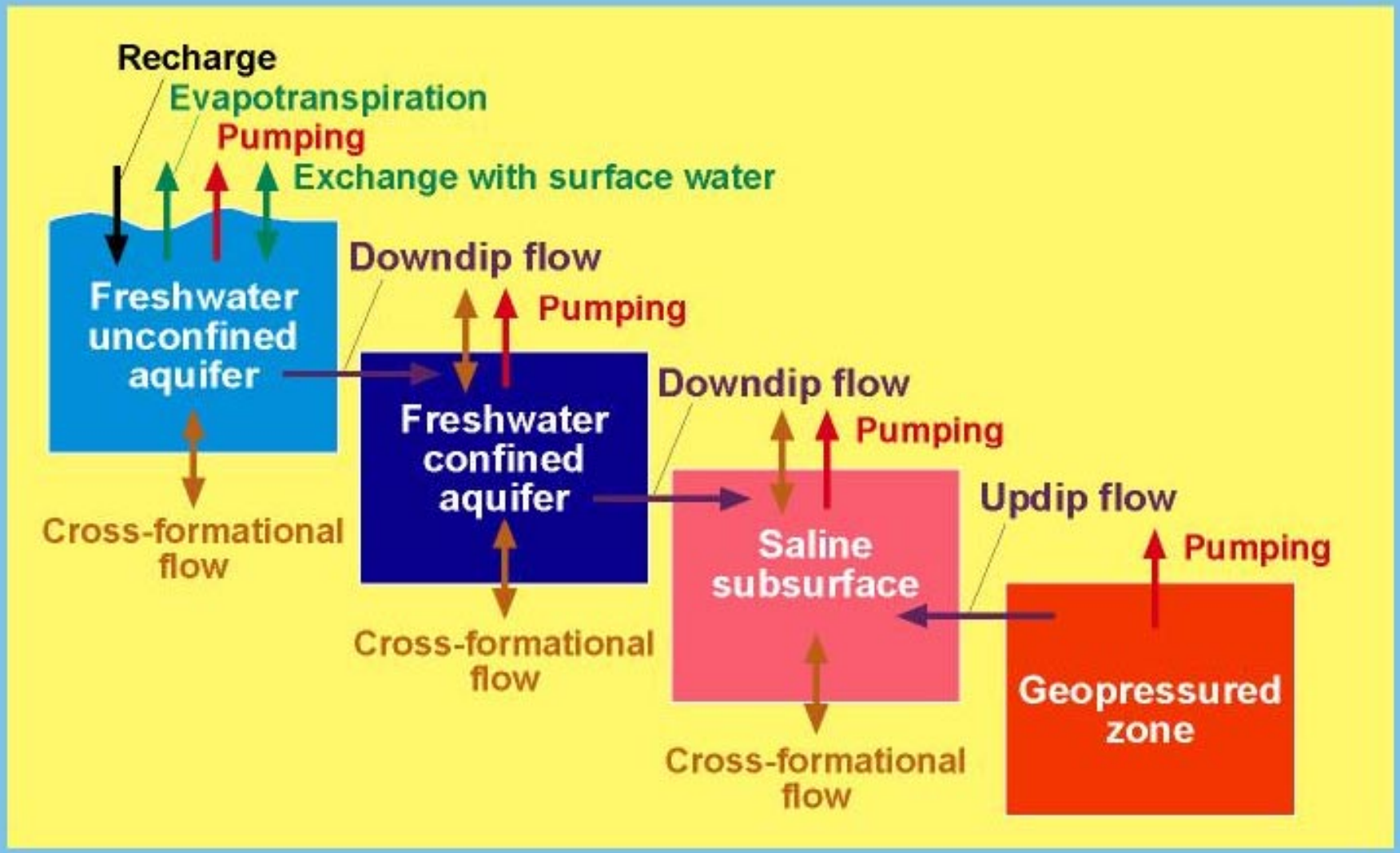

CARRIZO-WILCOX STRATIGRAPHY
SW
NE
Guadalupe River
Colorado River
Brazos River
Ground Level
Trinity River
0
-2,000
-4,000
-6,000
Elevation (ft)
Younger formations
Carrizo
Calvert Bluff
Simsboro
Hooper
undifferentiated Wilcox
undifferentiated Wilcox
Older formations
0
30 mi
0
40 km
V.E. ~200x
Mud-rich formations
Sand-rich formations

BOUNDARY CONDITIONS

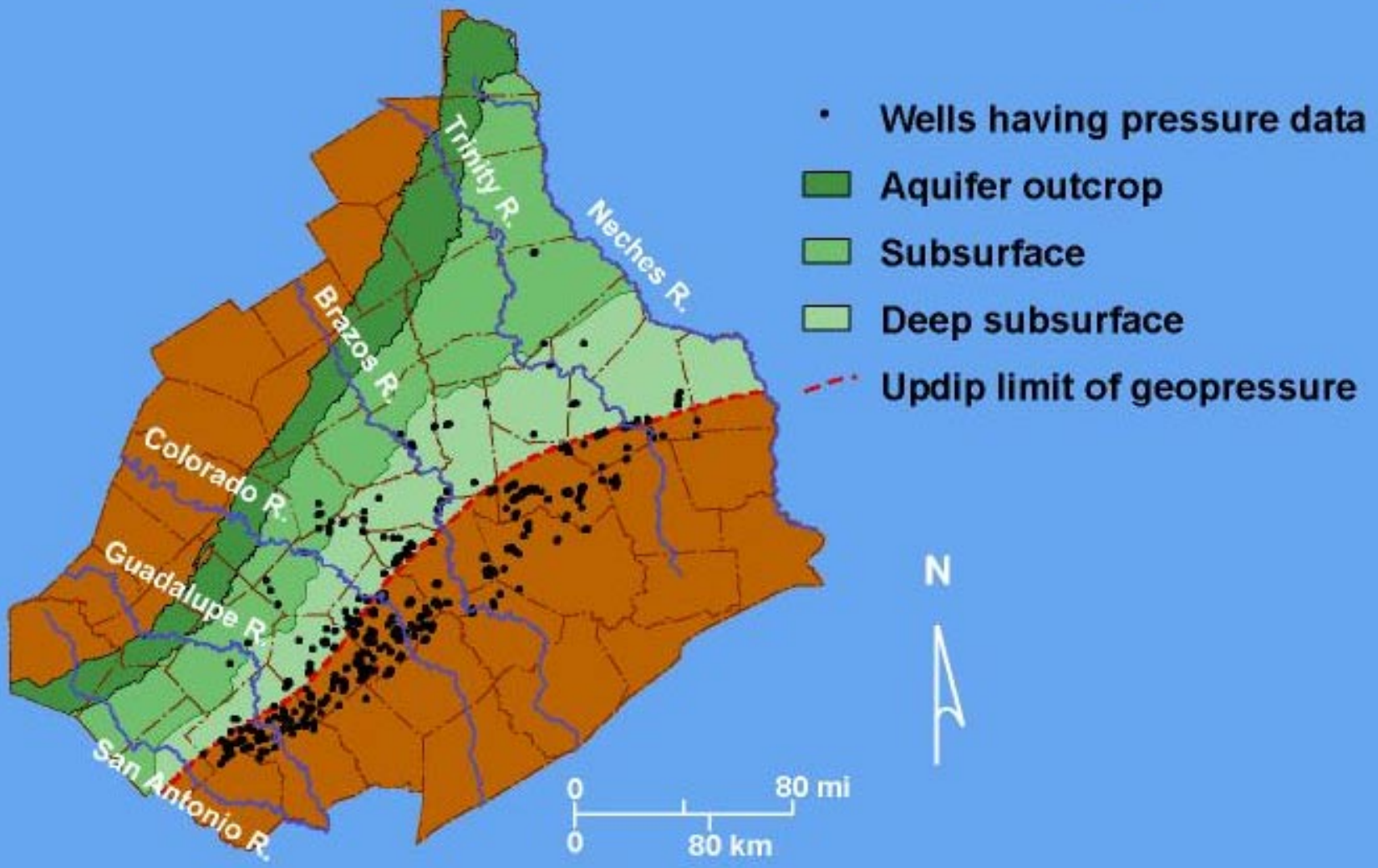
BOUNDARY CONDITIONS



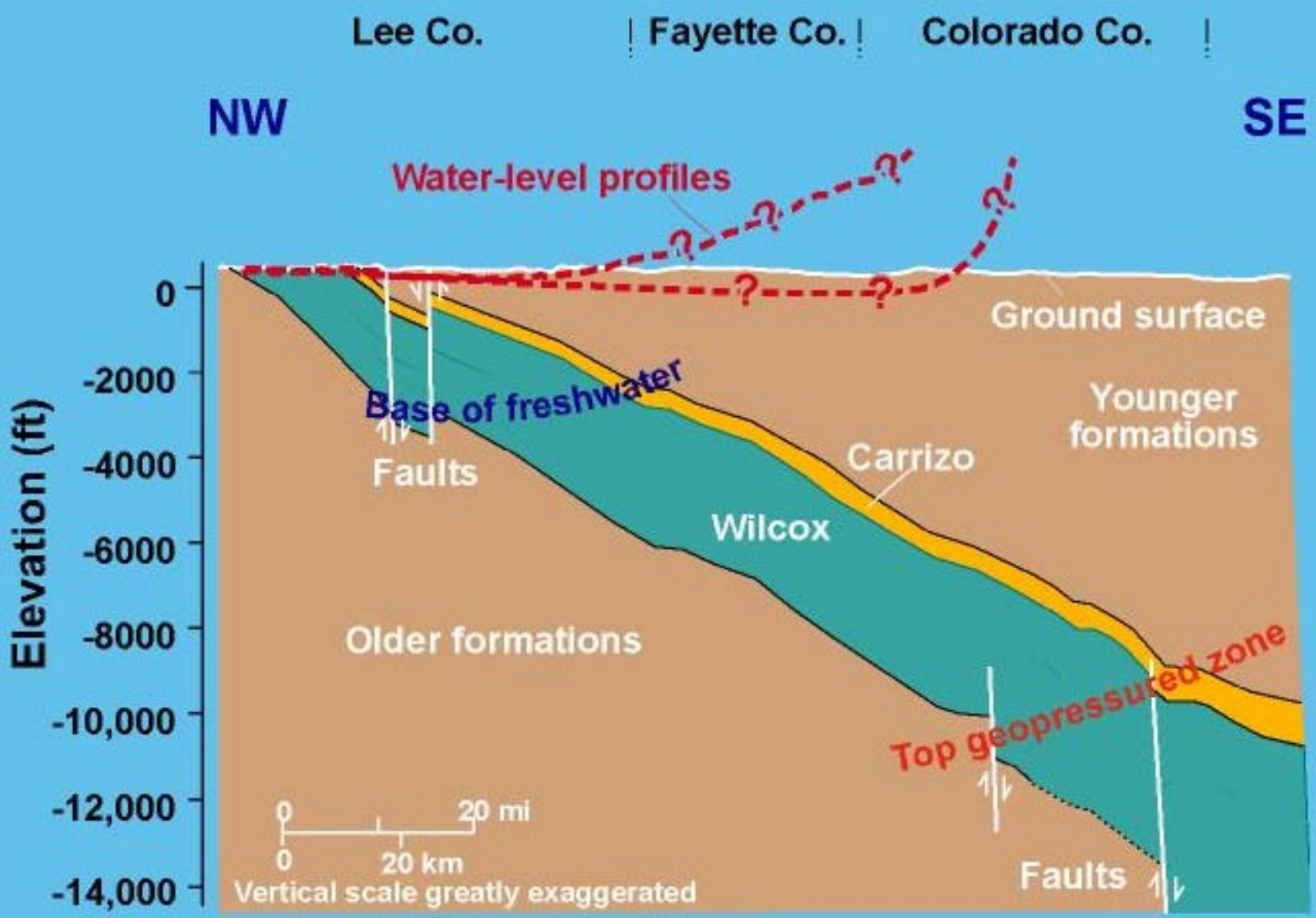
WATER EXCHANGE IN AQUIFER SYSTEM



PRESSURE DATA FROM GAS WELLS
Saline Part of Wilcox Group

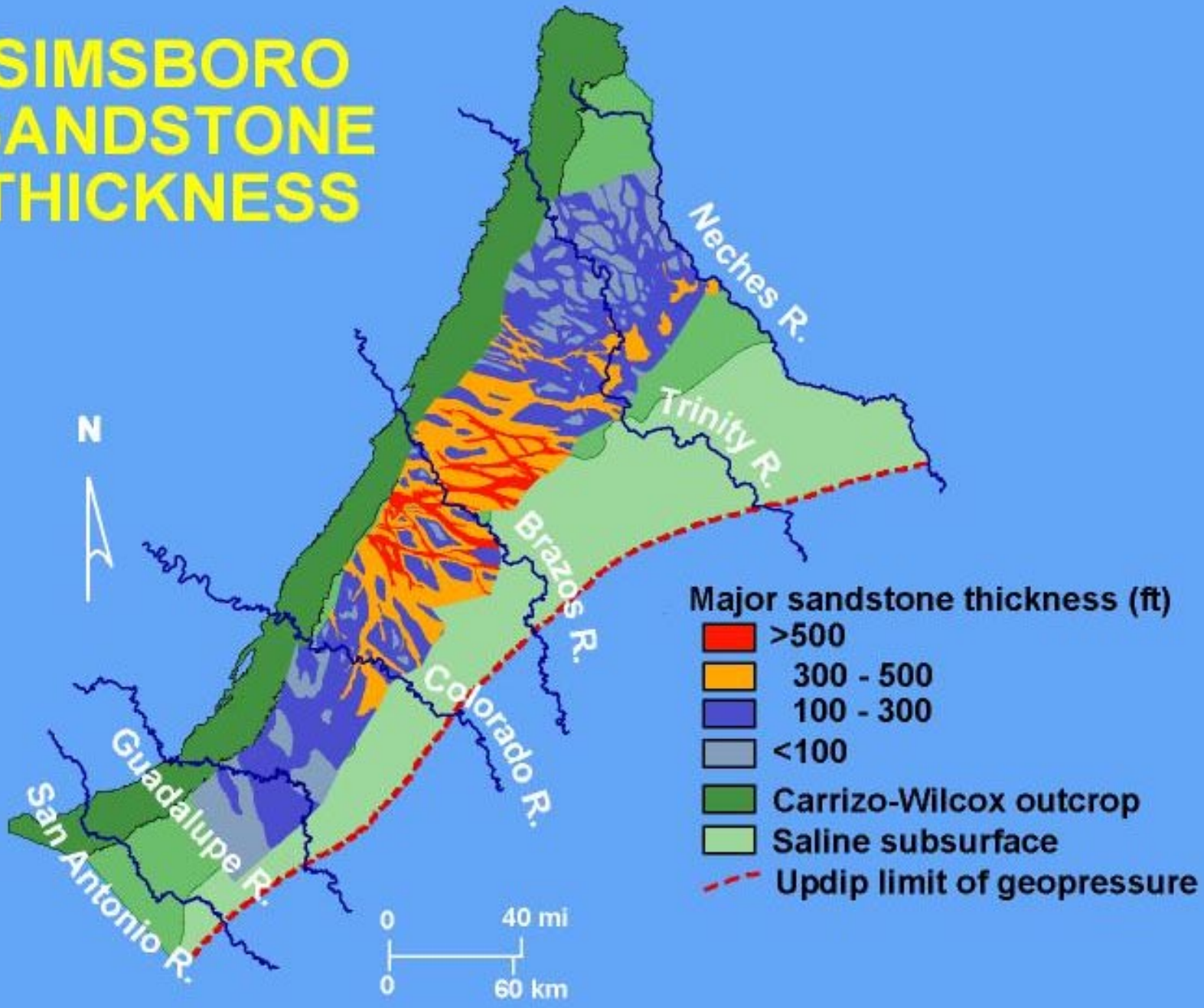


DOWNDIP BOUNDARY CONDITION

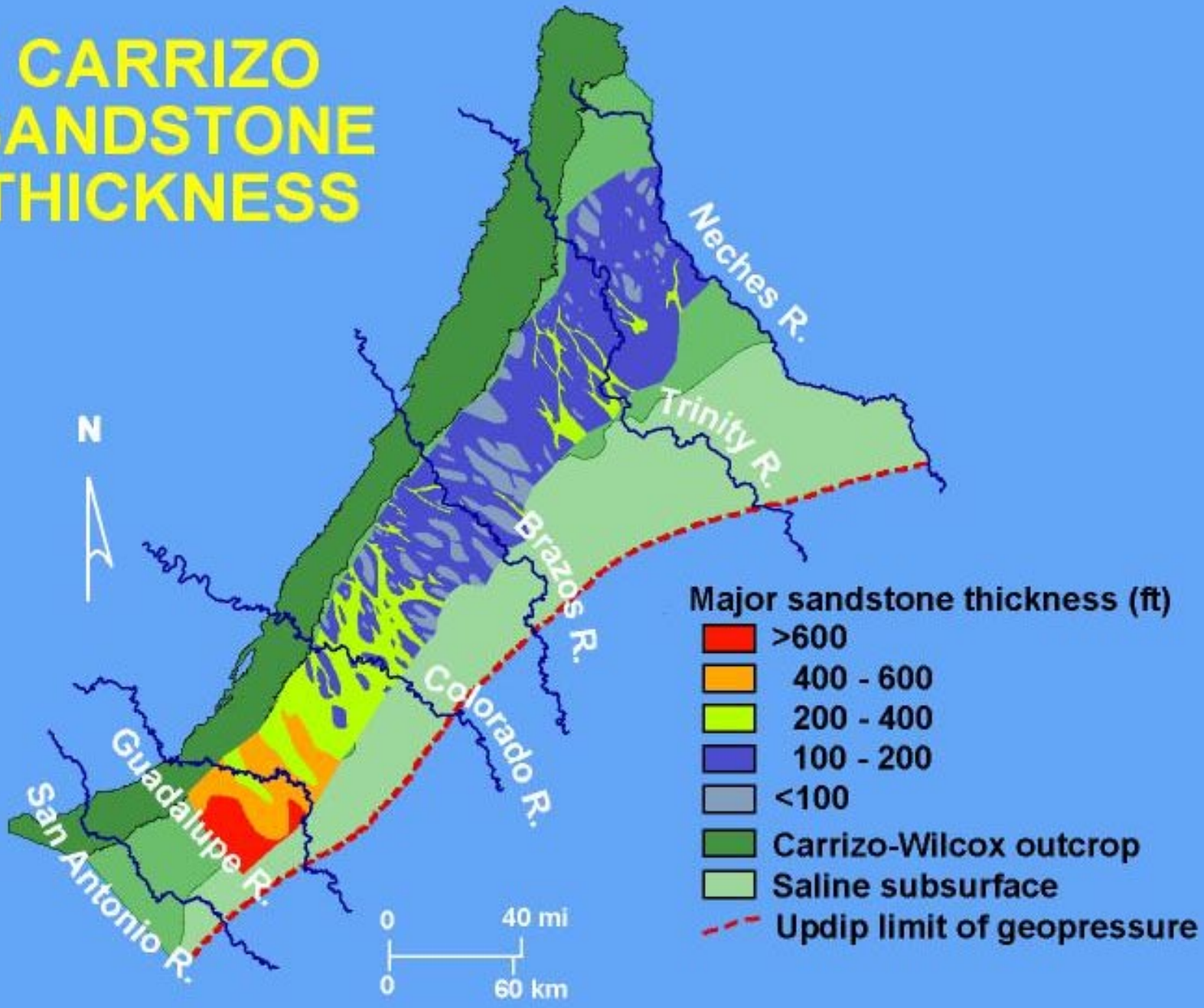


AQUIFER PROPERTIES

SIMSBORO SANDSTONE THICKNESS

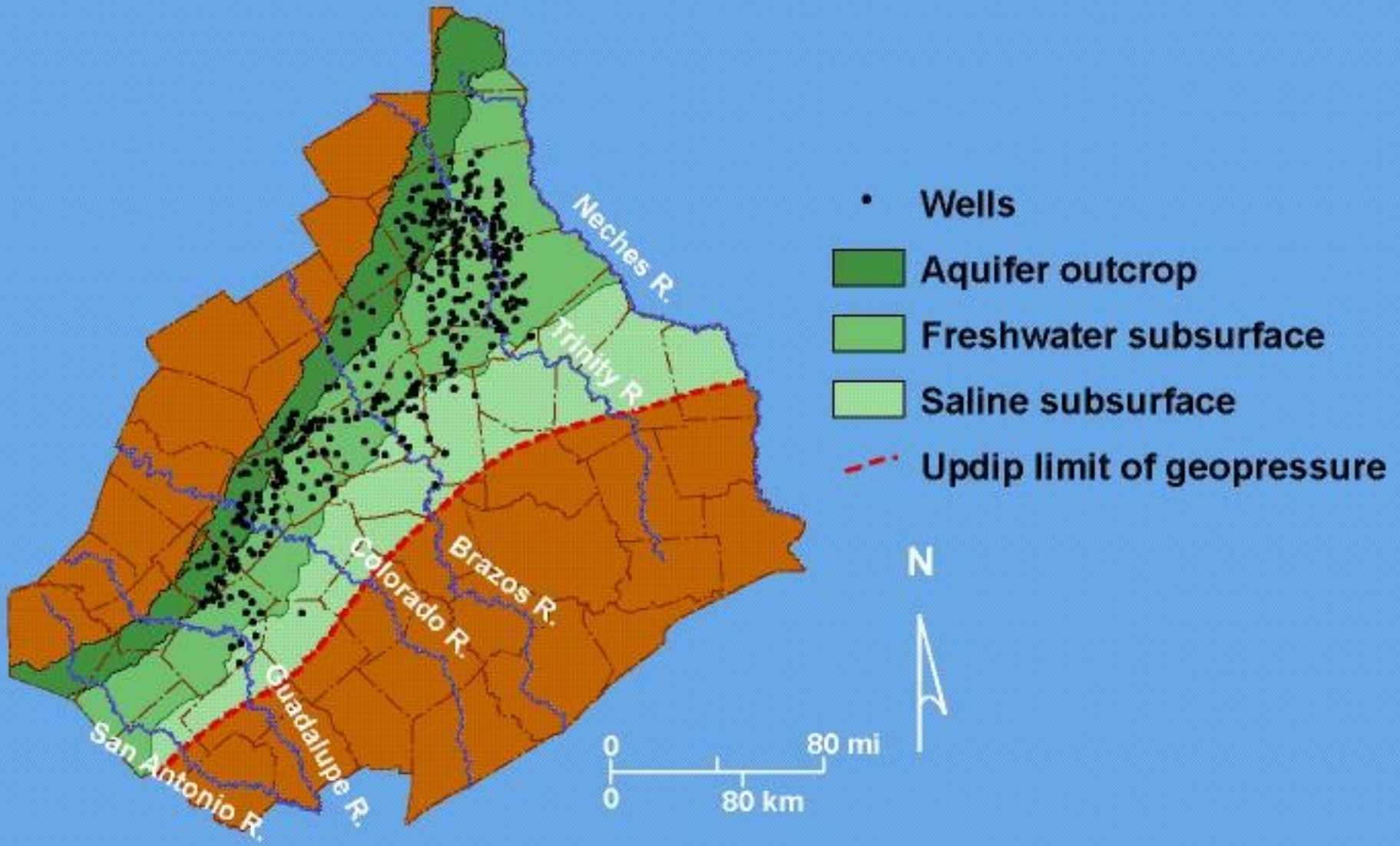


CARRIZO SANDSTONE THICKNESS



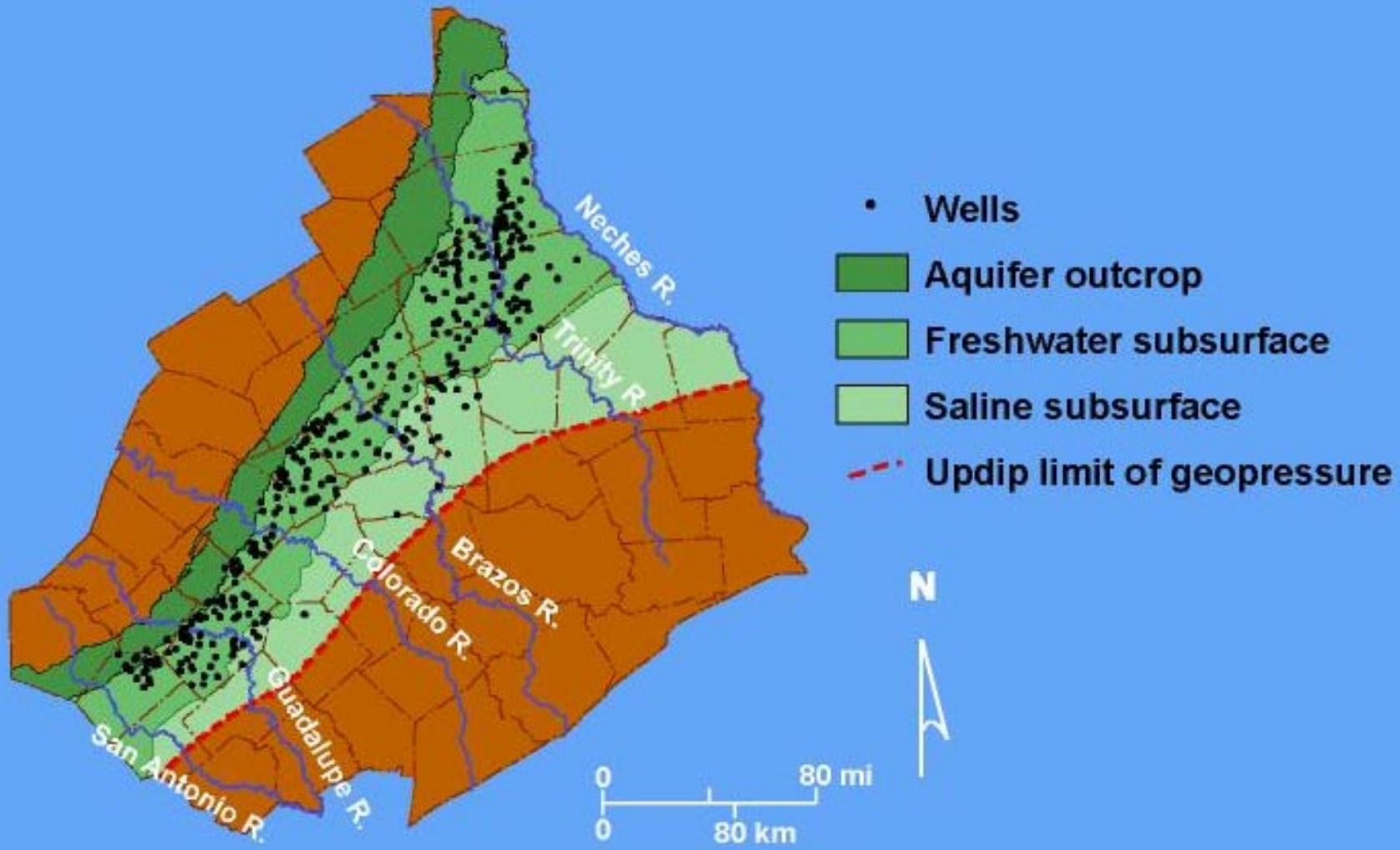
HYDRAULIC CONDUCTIVITY (K) DATA

Simsboro Layer



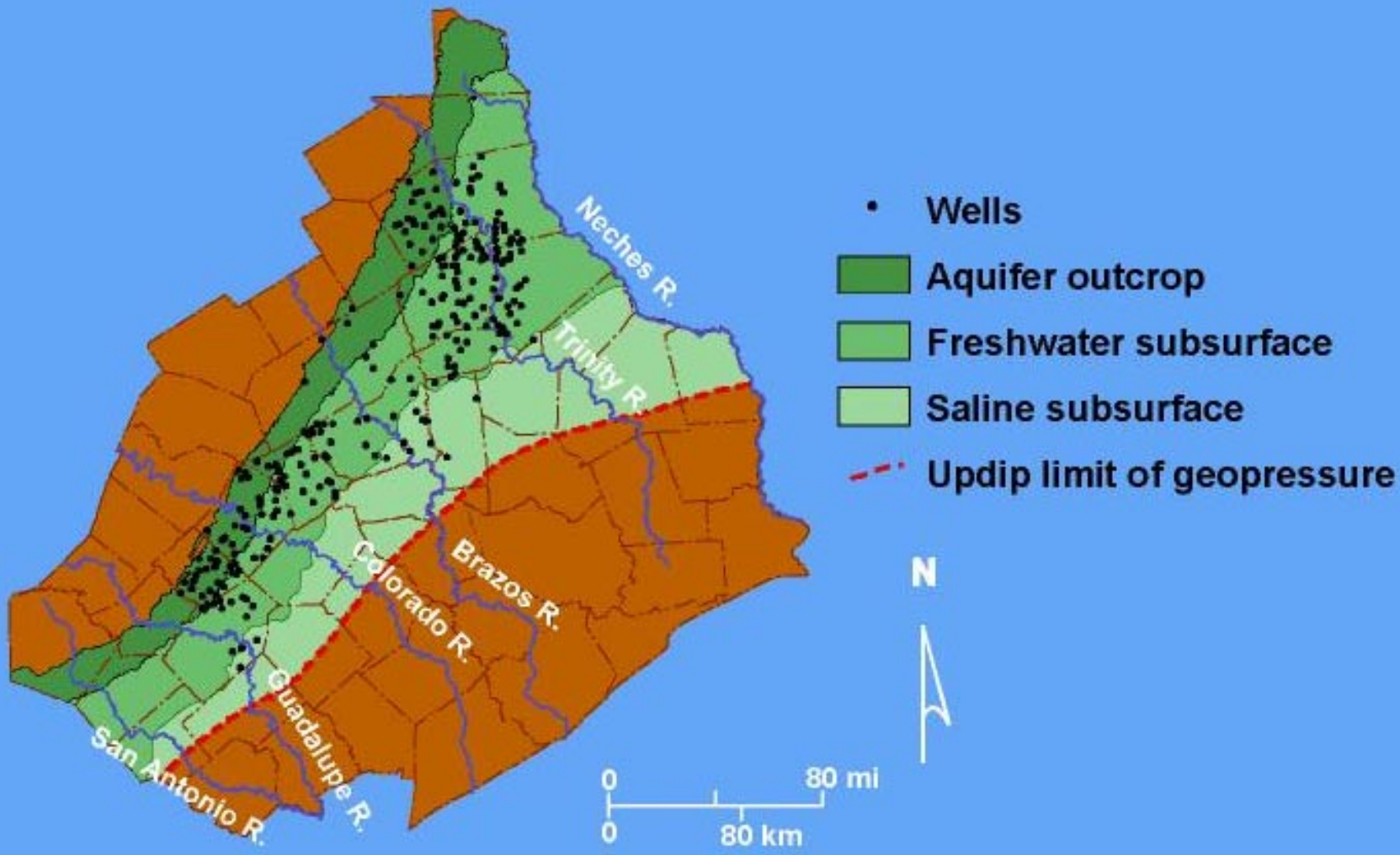
HYDRAULIC CONDUCTIVITY (K) DATA

Carrizo Layer



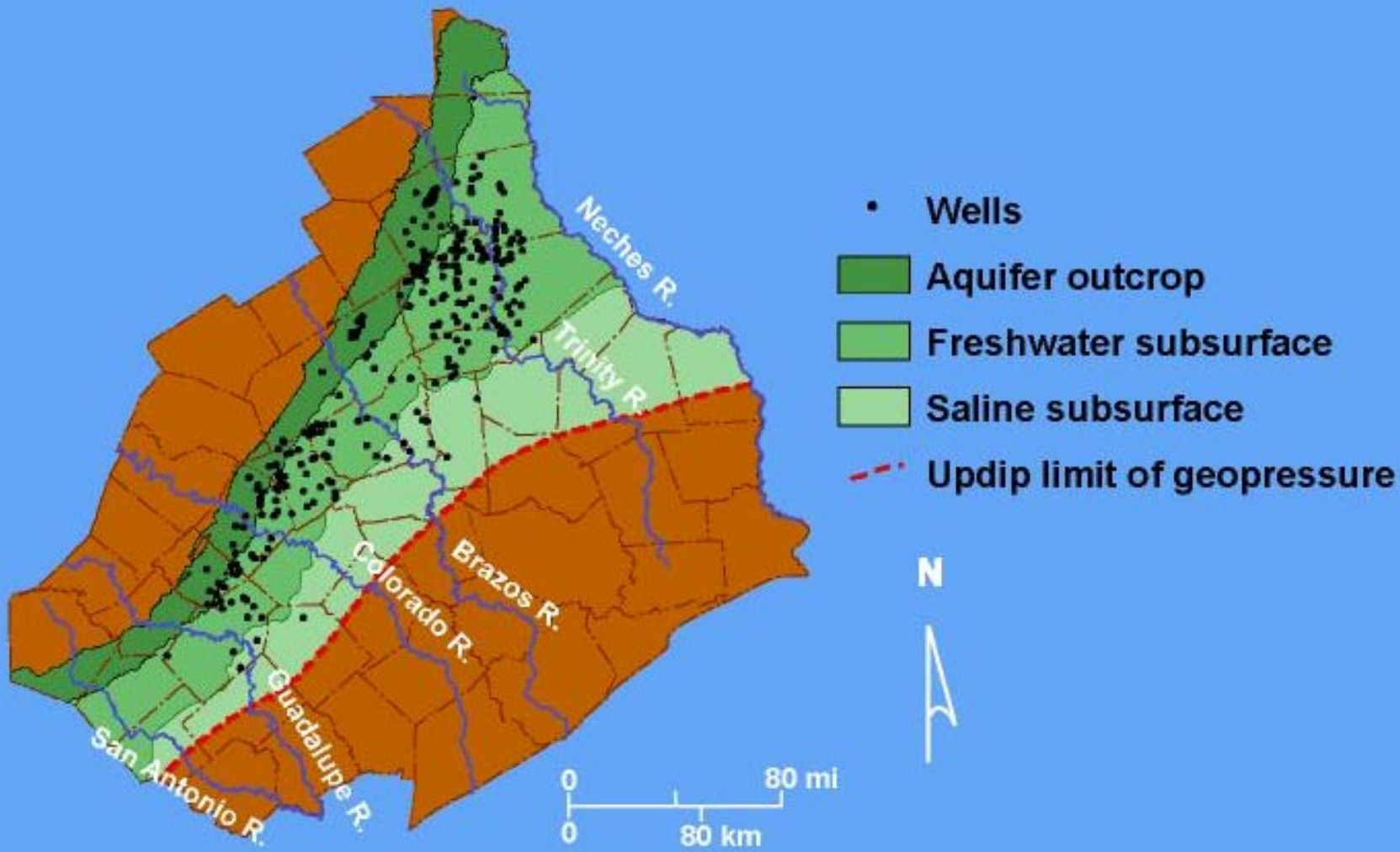
HYDRAULIC CONDUCTIVITY (K) DATA

Hooper Layer



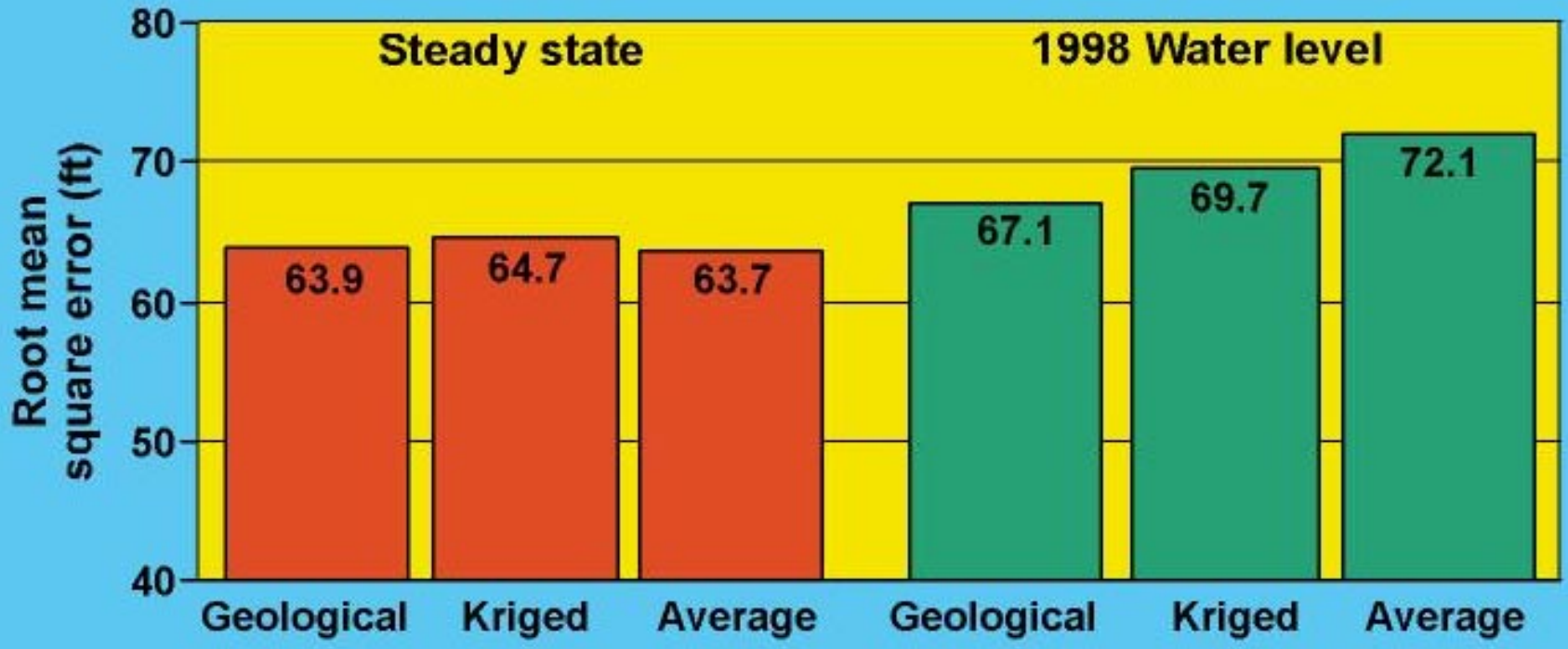
HYDRAULIC CONDUCTIVITY (K) DATA

Calvert Bluff Layer



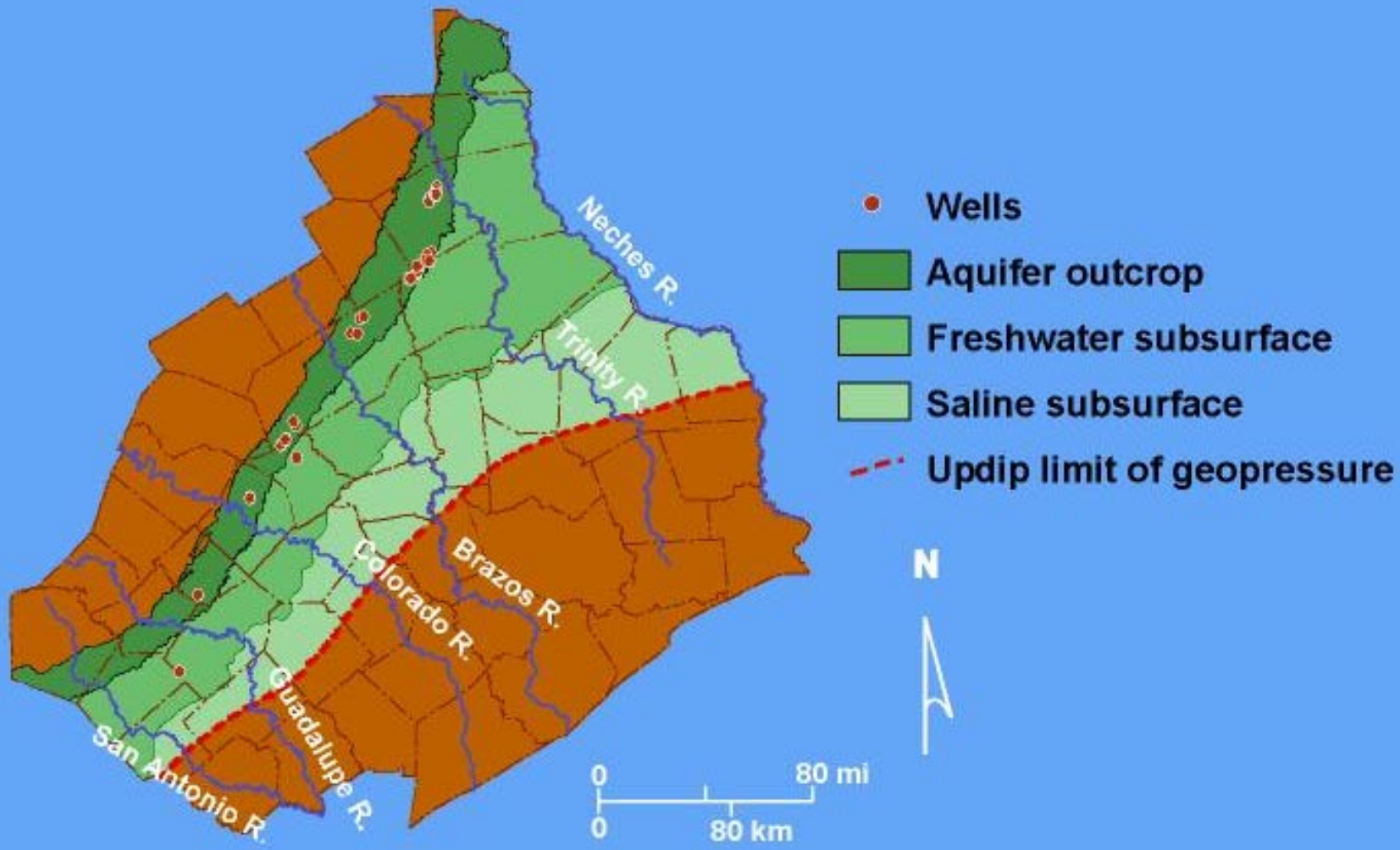
MODEL SENSITIVITY TO HYDRAULIC CONDUCTIVITY

Example from Ogallala Aquifer, Northern Texas Panhandle



STORATIVITY DATA

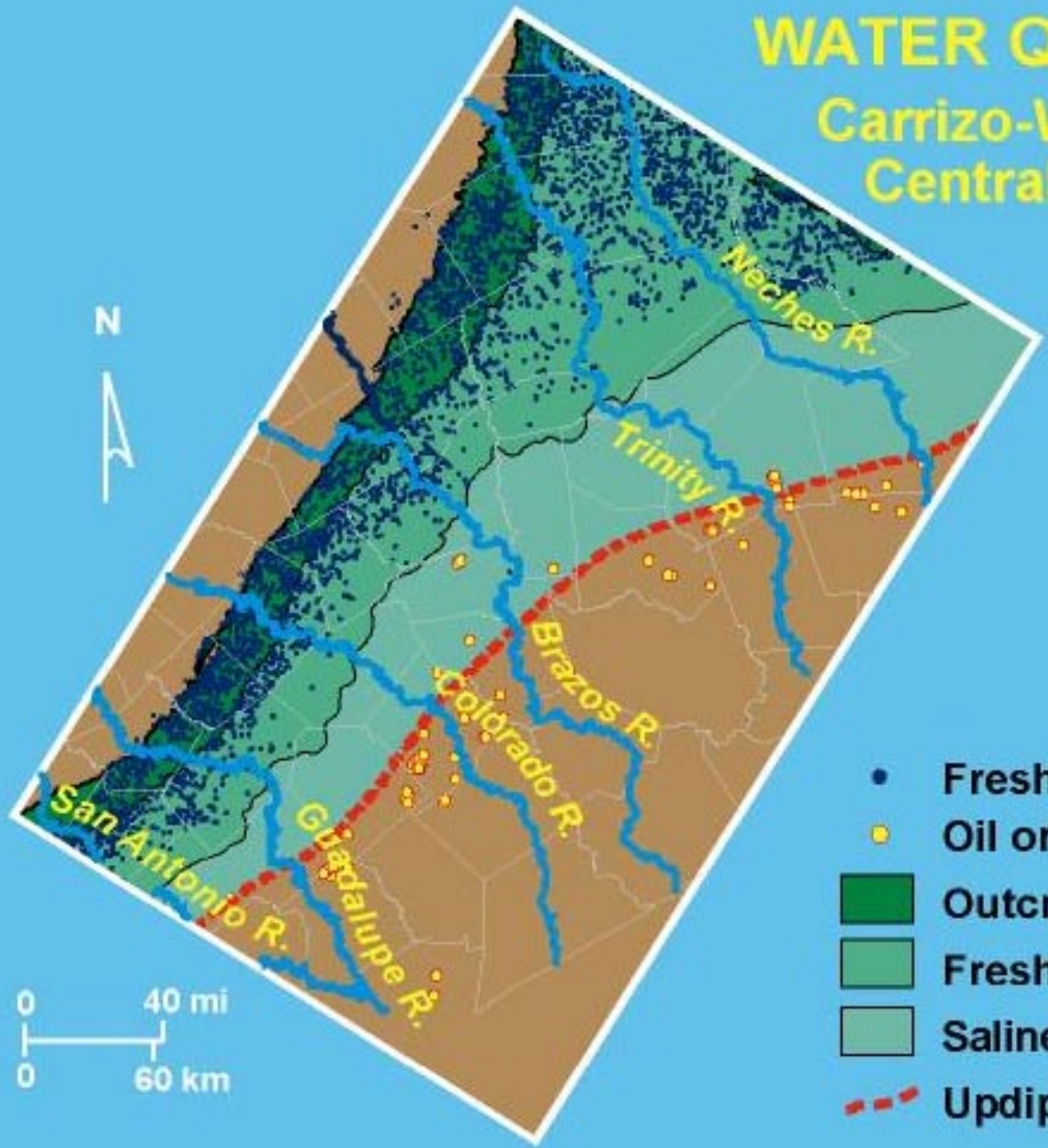
All Layers



WATER QUALITY

WATER QUALITY DATA

Carrizo-Wilcox Aquifer
Central Model Area



- Freshwater Well
- Oil or Gas Well
- Outcrop
- Freshwater subsurface
- Saline subsurface
- Updip limit of geopressure

SCHEDULE AND STATUS OF MODEL CONSTRUCTION

MODFLOW MODEL CONSTRUCTION

- Model grid
- For each layer:
  - Top and bottom of layers
  - Water- level elevations and water-level hydrographs
  - Horizontal hydraulic conductivity
  - Vertical hydraulic conductivity
  - Storativity
  - Pumping rates
  - Effect of fault displacement
- Recharge
- Evapotranspiration
- Streamflow routing information
- Reservoir information
- Downdip boundary condition

PROJECT SCHEDULE

Construct model	Jan 2001	to	July 2001
Conceptual model review				
SAF	July 2001		
TWDB	July 2001		
Steady-state calibration	Aug 2001	to	Oct 2001
Transient calibration & verification	Nov 2001	to	Mar 2002
Predictive simulations	Mar 2002	to	April 2002
Report preparation	May 2002	to	Sept 2002
Draft report due	Sept 2002		
Final report due	Jan 2003		

PROJECT SCHEDULE

Construct model	Jan 2001	to	July 2001
First SAF meeting	April 2001		
Second SAF meeting	July 2001		
Steady-state calibration	Aug 2001	to	Oct 2001
Third SAF meeting	Oct 2001		
Transient calibration & verification	Nov 2001	to	Mar 2002
Fourth SAF meeting	Jan 2002		
Predictive simulations	Mar 2002	to	April 2002
Fifth SAF meeting	April 2002		
Report preparation	May 2002	to	Sept 2002
Sixth SAF meeting	July 2002		
Draft report due	Sept 2002		
Seventh SAF meeting	Oct 2002		
– Comments on draft report			
Final report due	Jan 2003		

Stakeholder Advisory Forum (SAF)
Central Carrizo-Wilcox Aquifer Groundwater Availability Model (GAM)

Forum Meeting No. 2
Monday, July 23, 2001, 1:00 – 4:00 p.m.
College Station Conference Center
College Station, Texas

List of Attendees

Name	Affiliation
Angie Alaniz	Brazos Valley COG
Fred Arce	San Antonio Water System
James Beach	LBG-Guyton Associates
James Bene	R. W. Harden and Associates, Inc
Martina Bluem	LCRA
Russell Bostic	Farmer/ Rancher
John Burke	Aqua Water
Richard L. Burns	Alcoa
Rick Conner	City of Bryan, BVGWCD
Garner Duncan	BVCOG
Zac H. Falkenbury	Grimes County
Larry French	URS Corporation
Michele G. Gangnes	Neighbors for Neighbors
Frank R. Glass	Grimes County
Dr. Tom Gustavson	Bastrop County
Keith Hansberger	Lost Pines Groundwater Conservation District
Bob Harden	R. W. Harden and Associates, Inc
Jobaid Kabir	LCRA
Bob Kier	Lost Pines Groundwater Conservation District
James Kowis	ALCOA
Dr. Robert Mace	Texas Water Development Board
Ann Mesrobian	Lost Pines GCD
Barry Miller	Gonzales Co. UWCD
David Minze	Bluebonnet GWCD
Troy Mode	Milam County
Kevin Morrison	San Antonio Water System
Diane Nolley	Brazos Production Services
Joe Peters	TNRCC
Ernest Rebuck	TWDB
George Rice	NFN
Sheril Smith	Bastrop County Resident – Water Resource Chair Sierra Club
Larry Snook	Grimes County
B.O. Spoonts	Texas Department of Agriculture
Don Strickland	BVCOG
Clifford Whiteley	Milam County

Tom Wilkinson	BVCOG
Eddy Young	Brazos Valley Ground Water Conservation

Questions and Answers
Second Stakeholder Advisory Forum (SAF)
Central Carrizo-Wilcox Aquifer Groundwater Availability Model
Monday, July 23, 2001, at 1:00 p.m.
City of College Station Conference Center
College Station, TX

1. QUESTION: Does presence of clay hardpan affect the amount of recharge?
   ANSWER: Where there is a clay hardpan with a low hydraulic conductivity in the soil profile, it seems likely that infiltrated precipitation will be retained close to ground surface and exposed to evapotranspiration. So less infiltrated water would recharge the aquifer beneath hardpan soils than beneath soils without a hardpan. Recharge will be assigned in the model on the basis of precipitation as well as soil properties, including the presence of hardpan soil horizons. This approach varies recharge rate throughout the model, from cell to cell.

2. QUESTION: How will recharge rates be assigned to the model. Will each county have a specific recharge associated with it, or will it be a range of recharge rates?
   ANSWER: Recharge will be varied from cell to cell on the basis of precipitation and soil properties and calibrated during model development. Recharge on a countywide basis could be summed up from the recharge assigned to each cell in the county.

3. QUESTION: If there are a range of recharge data, will BEG err on the more conservative side of recharge?
   ANSWER: We will use the limited data to constrain recharge rate, but inherent uncertainty means that a range of recharge rates could fit in the model. A range of recharge rates may be described in the final report. As part of a realistic and scientifically accurate computer model, the goal of the GAM models, recharge rate should be based on data and our best estimate of actual rate rather than 'a conservative' estimate. Predictive runs for 2000 to 2050 will include recharge during drought of record low-precipitation years.

4. QUESTION: Can field studies take rejected recharge into account?
   ANSWER: BEG's planned recharge experiment will not take rejected recharge into account. The test is designed to measure actual rate of water reaching or recharging the water table. Rejected recharge has to do with the water budget among the unconfined aquifer, surface water and evapotranspiration in the outcrop, and the confined aquifer.

5. QUESTION: Why was the Bryan/ College Station well field excluded from the 1999 study of the central Carrizo- Wilcox?

ANSWER: The Bryan/ College Station well field was excluded from the 1999 study only due to geographical and time limitations of the 12-week study. The 1999 study was focused on Bastrop, Lee, and Milam Counties. The Bryan/ College Station well field will be included in this study.

6. QUESTION: Would it make a more accurate model to increase the resolution in grid cell size especially in the recharge area?
   ANSWER: Increased resolution or smaller grid-cell size would allow recharge to be varied across smaller unit areas. The limited data on recharge rate, however, probably does not justify a much reduced cell size. A small cell size would give an appearance of more detail, but not necessarily give any more accuracy. The TWDB set up the GAM model contracts specifying 1 square mile grid cells.

7. QUESTION: Does one need to have a specified grid for groundwater flow modeling if varying the grid size does not seem to increase resolution?
   ANSWER: The GAM models are using the computer code MODFLOW, which solves the groundwater flow equation using a grid approach. Previous modeling studies have used a range of grid sizes for the study area (25 square miles–USGS; 4 to 16 square miles–TWDB; 1 square mile–BEG and Region G models). From the TWDB standpoint, there is no point in increasing resolution if data to support higher resolution are not available.

8. QUESTION: Would it be better to increase resolution in those areas where more data are available?
   ANSWER: Because the contract between TWDB and its contractors are tightly written, TWDB is not likely to change the prestated uniform grid size of 1 square mile. This is not to say that in the future resolution would not be increased in a model as more data become available.

9. QUESTION: If no new data is coming in, why should stakeholders and the state invest in this new model of the aquifer?
   ANSWER: This model will have better boundary conditions than previous models, which take into account large amounts of pumping that will be going on. It will also include a more realistic description of how the aquifer might respond to future increased pumping. The model also will use new data that already have been developed but not previously used in a model.

10. QUESTION: How often does TWDB anticipate redoing the model?
    ANSWER: The GAM models might be updated and recalibrated as often as every 5 years if Legislative funding allows.

11. QUESTION: What is the definition of alluvium (pertains to frame no. 30 on Brazos River alluvium in SAF2_CW-c.pdf)?
    ANSWER: Alluvium is a general term for all deposits from modern rivers. In this case, it refers to sand and gravel deposited by the Brazos River as it moved back and forth in its valley during the past several thousands of years. That alluvium now form an aquifer adjacent to the river.

12. QUESTION: Is the Brazos River alluvium the only minor aquifer formed by alluvium in Texas?
    ANSWER: There are other alluvial aquifers in Texas, but the Brazos River alluvial aquifer is designated partly because of the amount of groundwater withdrawal from it. In addition to the Brazos River alluvium, designated a minor aquifer in Texas, we plan to specify alluvium along the Colorado and Trinity rivers in the model.

13. QUESTION: What causes the high pressures in the geopressured zone?
    ANSWER: There are two basic theories that explain the high pressures of the geopressured zone. First, the rate of deposition of sediments in the Gulf of Mexico basin in the past millions of years has been rapid and great thicknesses of sediment have accumulated. The weight of the newer sediment adds pressure to underlying layers. Because of faulting in this area, water often gets trapped and cannot escape to the surface. The pressure on this buried trapped water builds up as the weight of the overlying layers increases. The second theory is that as sediment is buried deeper, the increased pressure and temperature changes clayey minerals, releasing their crystalline bound water. This release of water from clays adds to the water pressure in the sands being trapped by faulted structures.

14. QUESTION: Will BEG take into account increased flow and different directional flow, for example, in Atascosa County water where flows to the southwest, along the boundaries of the model?
    ANSWER: BEG will work with Duke Engineering to account for the transfer of water between the central and south study areas of the Carrizo-Wilcox, and we will take into account flow between the modeled areas.

15. QUESTION: How many wells will you perform water quality analysis on?
    ANSWER: We are not collecting new water-quality data. We have around 670 reported freshwater analyses for wells in the TWDB database, plus about 250 brine analyses from a database of oil and gas wells

16. QUESTION: How old are the data used in water quality analysis?
    ANSWER: There are multiple data entries in the TWDB database for water quality of wells that are repeatedly sampled, especially municipal wells. Some data predate the 1950s.

17. QUESTION: Will this presentation be posted on the web?
    ANSWER: See "SAF2_CW-c.pdf" posted at http://www.twdb.state.tx.us/GAM/czwx_c/czwx_c.htm

18. QUESTION: Will information be posted on the web as BEG develops the model further?
    ANSWER: As the model is developed, there will be many aspects that need to be fine-tuned and reworked. BEG and TWDB do not wish to post model input files, even if only in draft version, that may be revised.

19. QUESTION: Won't showing data help us stakeholders to support the process involved and the results it produces?
    ANSWER: BEG will continue to discuss the data and modeling process during these SAF meetings, including discussion on limitations of data and how they are being interpreted and built into the model.

20. QUESTION: Are there some aspects of the model that can be released before the completed model is finished? Stakeholders are concerned about having to "sign off" in their approval of the model.
    ANSWER: There will be no formal "signing off" of the model by the stakeholders. While TWDB and BEG hope that stakeholders will be satisfied with the accuracy of their presented model, stakeholders do not have to approve of the model in order for it to be made accessible to the public.

21. QUESTION: Recharge seems to be the primary concern of the posted data among the shareholders. Water districts primarily want a good management tool to come out of this modeling process. They want the very best model possible. After recharge, storativity and conductivity numbers are wished to be made public as soon as possible.
    ANSWER: TWDB will post BEG data as soon as possible. As soon as BEG and TWDB agree that the data are accurate, the data will be posted.

22. COMMENT: It would be useful to stakeholders to be able to access the BEG presentation before the next stakeholders meeting.
    ANSWER: BEG will try to post data 5 working days before the next stakeholders meeting.

23. QUESTION: Can BEG and TWDB post steady-state model information as soon as you have it? When would BEG and TWDB be comfortable releasing the steady- state information?
    ANSWER: BEG must meet quality performance targets during the modeling process. Steady state calibration may be revisited after the transient calibration, if the transient calibration target is not met. BEG does not wish to set an deadline for turning over these data and model input files that it proves unable to meet.

24. QUESTION: How will the new GAM models be used in the next round of regional water planning meetings?
    ANSWER: TWDB will use the new GAM model results unless there are better data available.

25. QUESTION: (posed by BEG) What are suggested locations for the next stakeholders meeting in October?
    SUGGESTIONS:Giddings City Hall, Elgin First National Bank, Bastrop Riverside Conference Center, Austin, Blinn College in Bryan, LCRA McKinney Roughs Conference Center