Groundwater Availability Modeling (GAM) for the Northern Carrizo-Wilcox Aquifer

A Presentation to:

Stakeholder Advisory Forum
Holly Lake Ranch
Hawkins, Wood County
August 1st, 2001

Duke Engineering & Services
A Duke Energy Company

Outline

- Review of GAM Project, Objectives, and Expectations
- Description of the Conceptual Model for the Northern Carrizo-Wilcox Aquifer
- GAM Schedule - SAF Meetings & Project Milestones

Northern Carrizo-Wilcox Aquifer GAM Team

- Duke Engineering & Services
  - Project Lead, Stakeholder Comm., Reporting
  - Model Development
- Parsons Engineering Science
  - GIS, Demand and Pumping
  - Water quality
- Waterstone
  - Modeling support
- Senior Technical Experts
  - Dr. Graham Fogg (UC—Davis)
  - Dr. Steven Gorelick (Stanford)

GAM Objectives

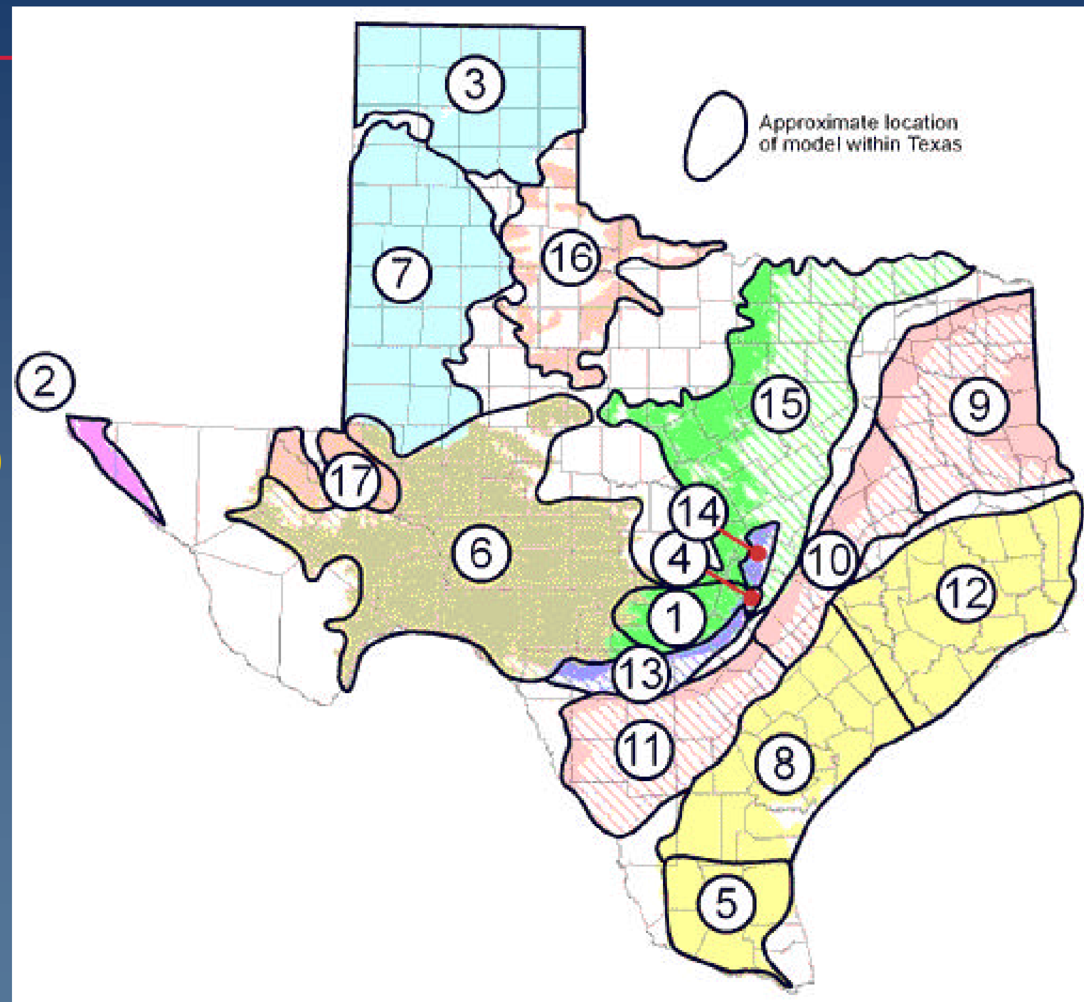
- GAM is a tool that will be used to provide reliable and timely information on GW availability to ensure adequate supplies or recognize inadequate supplies through 2050
- Develop realistic & scientifically accurate GW flow models representing the physical characteristics of the aquifer and incorporating the relevant processes

GAM Expectations

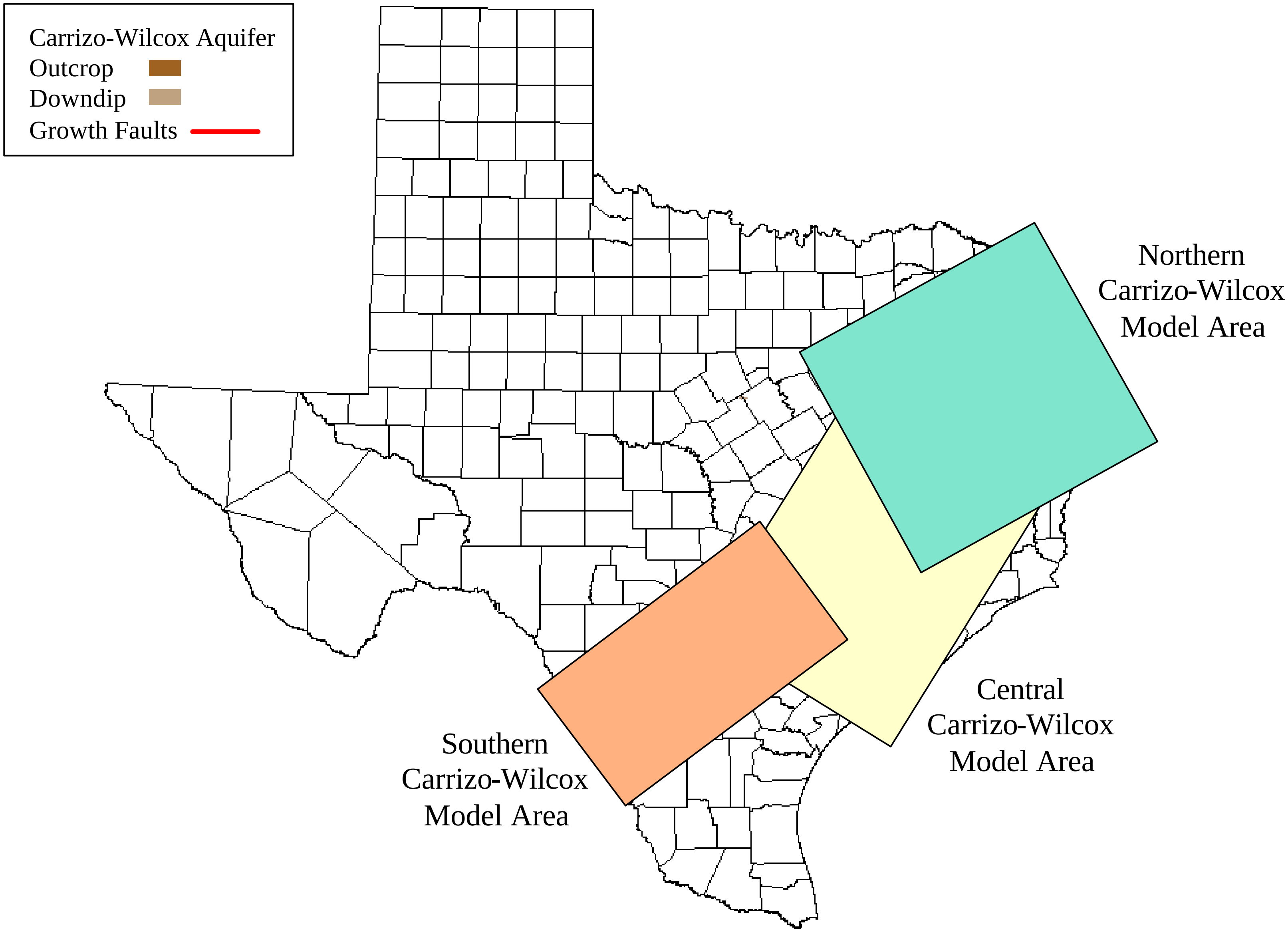
- Result in standardized, thoroughly documented, and publicly available numerical GW models and data
- Include stakeholder input to ensure the models include relevant data and address relevant issues, so they can be used as a water management tool for RWPGs or GWCDs

GAM Models

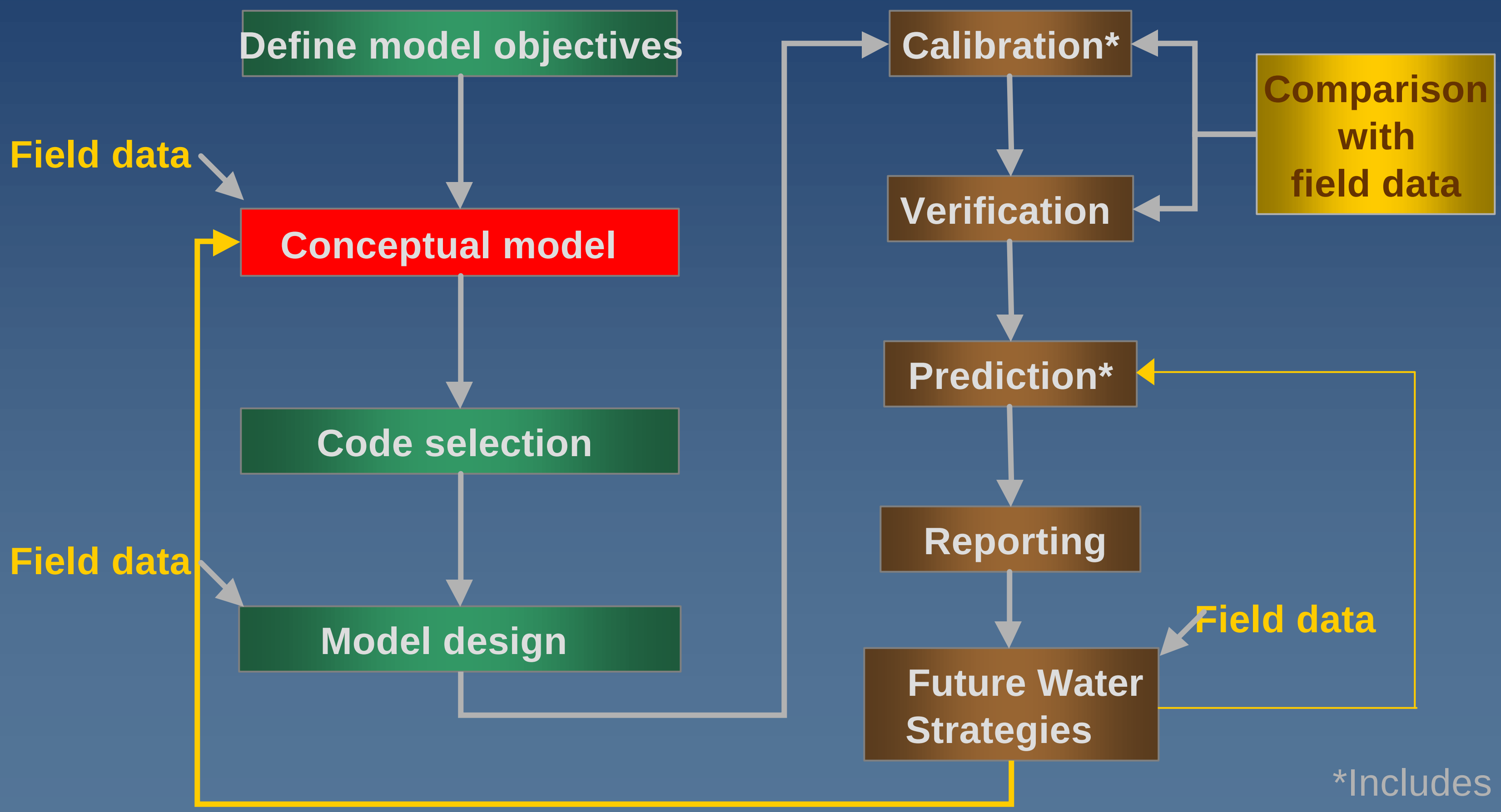
- Ongoing:
  - Carrizo-Wilcox (9-11)
  - Ogallala south (7)
  - Gulf Coast central (8)
  - Gulf Coast north (12)
  - Lower Rio Grande (5)
  - Edwards Trinity (6)
- Completed:
  - Trinity HC (1)
  - Hueco Bolson (2)
  - Ogallala north (3)
  - Edwards - BS (4)



Carrizo-Wilcox GAM Model Domains



Modeling Protocol

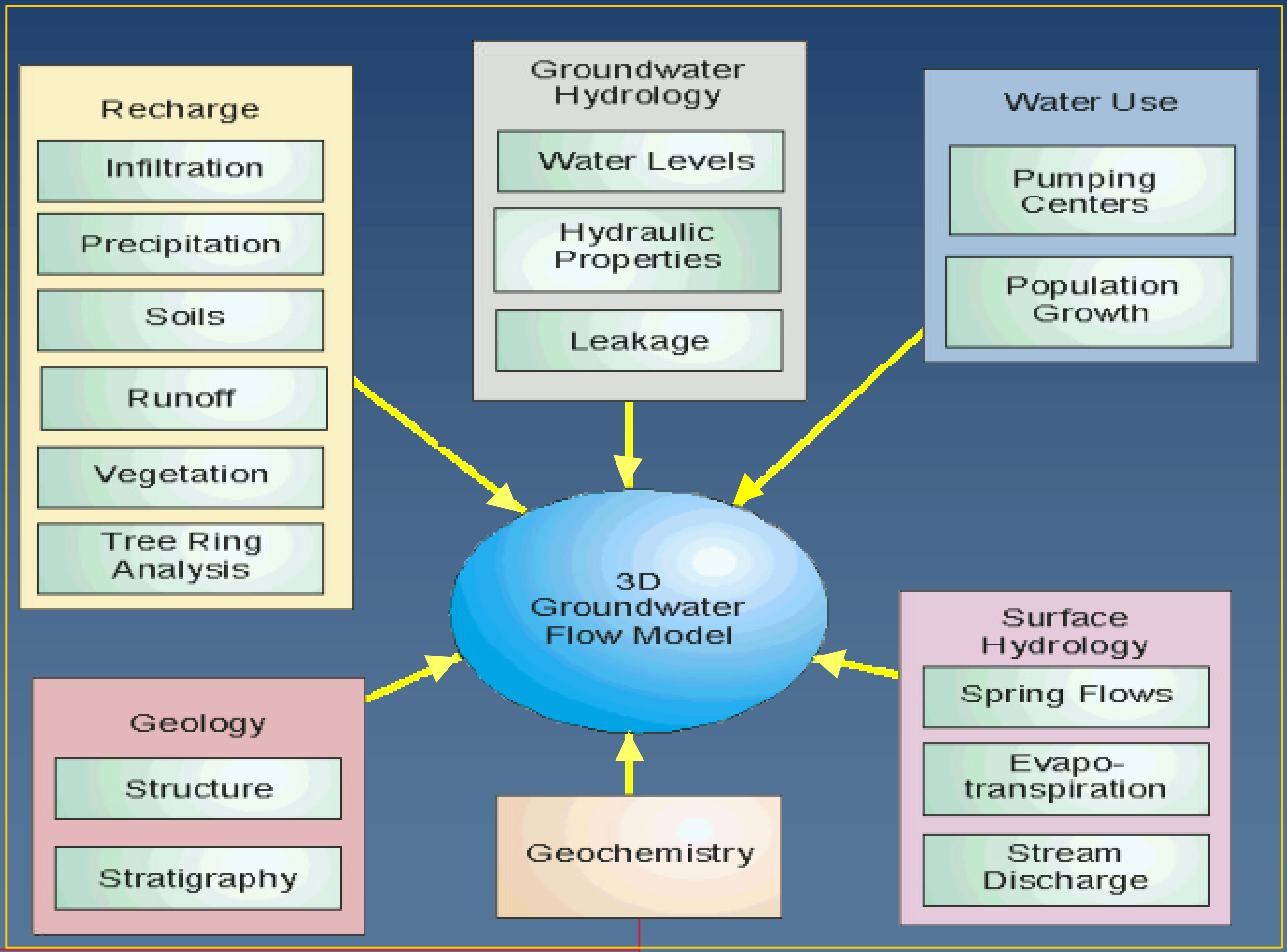


*Includes sensitivity analysis

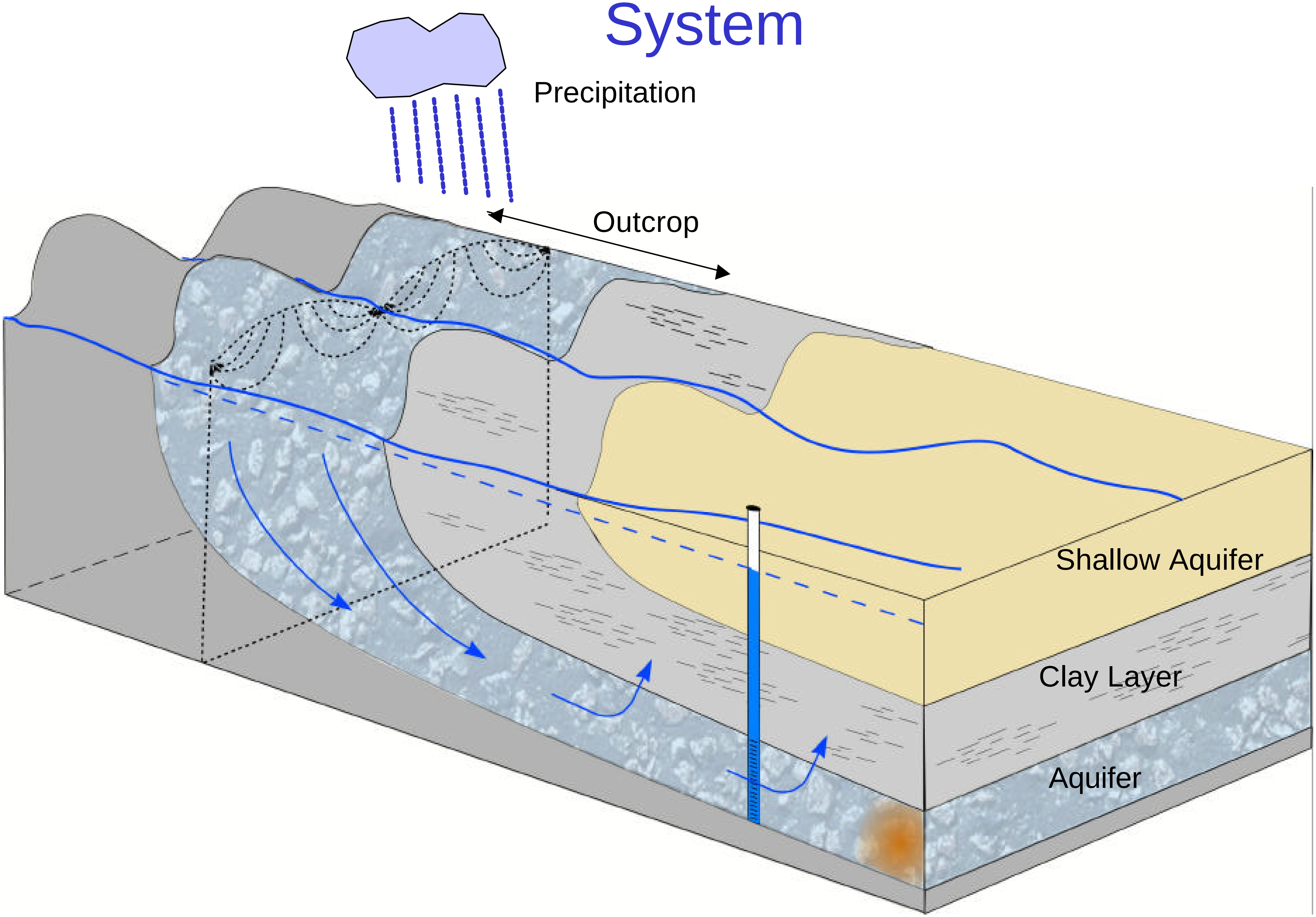
Conceptual Model Description

- Major components of flow in the aquifer
- Aquifer Geometry
  - Hydrostratigraphy
  - Geology, Structure, and Boundaries
- Aquifer Properties
- Physiography and Climate
- Recharge/Discharge
- Surface/groundwater interaction
- Water levels and regional groundwater flow

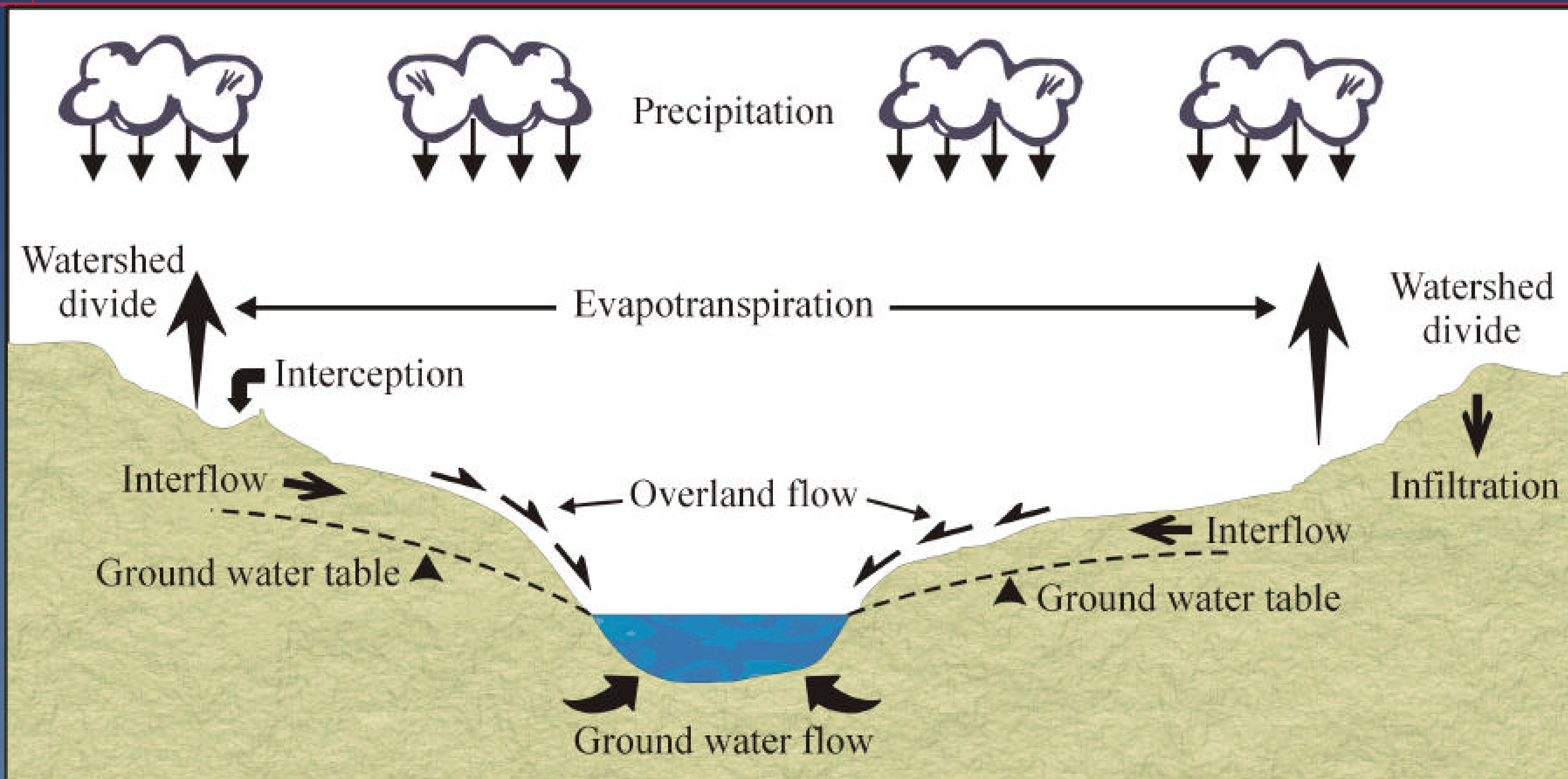
Groundwater Model Input



Schematic Aquifer System



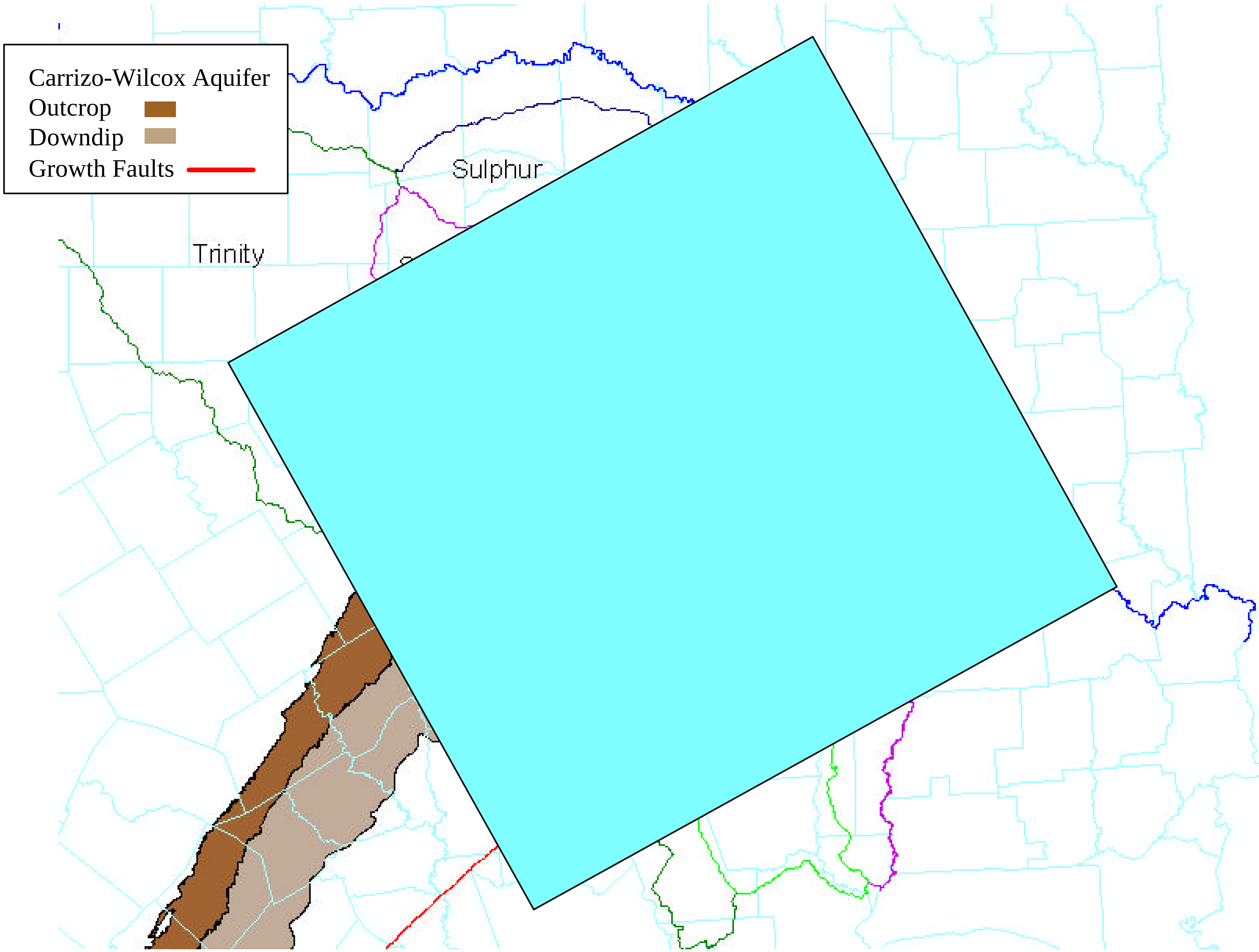
Shallow Aquifer Flow System



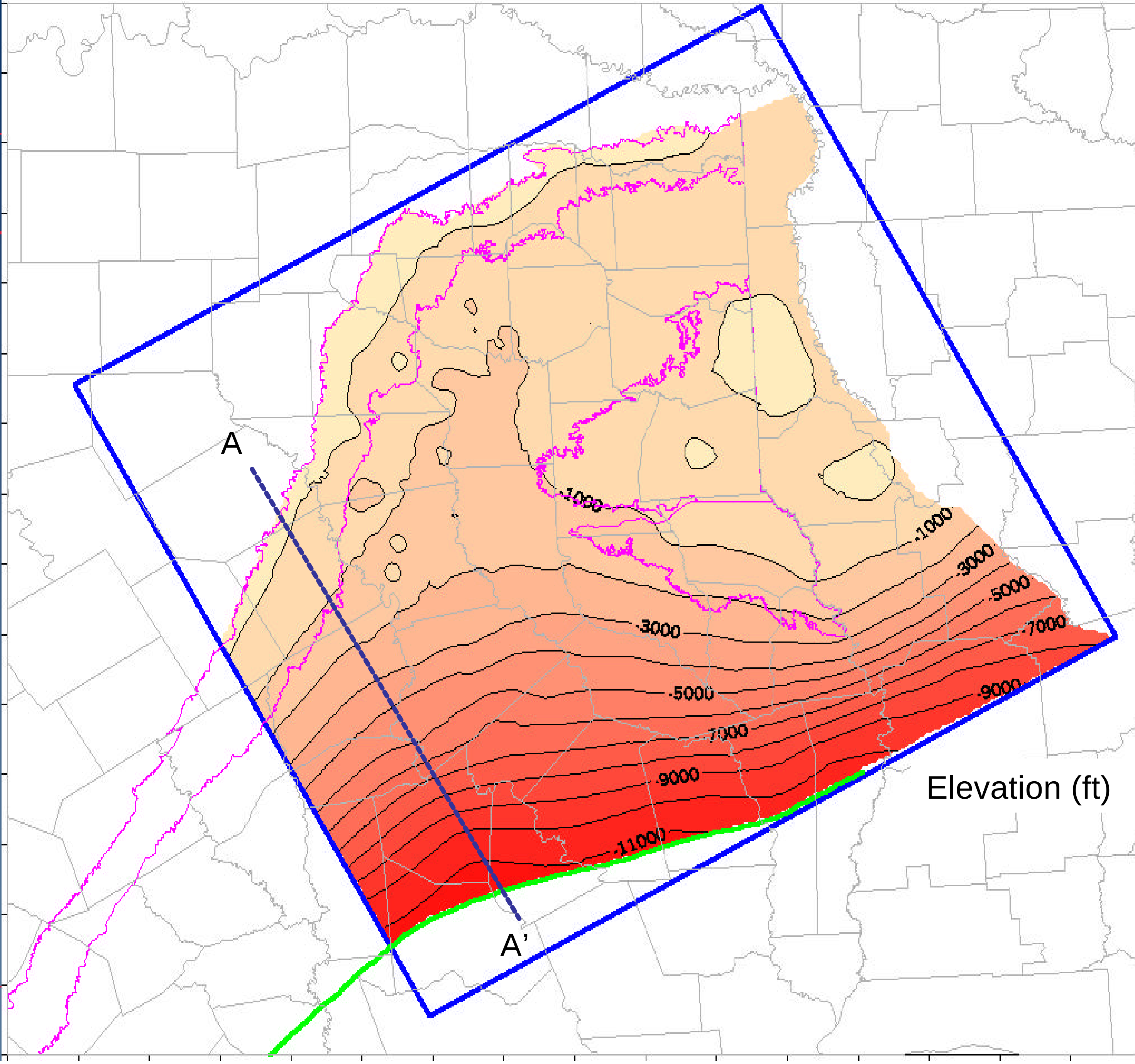
Aquifer Geometry

- Geology and Structure
- Hydrostratigraphy
- Boundaries

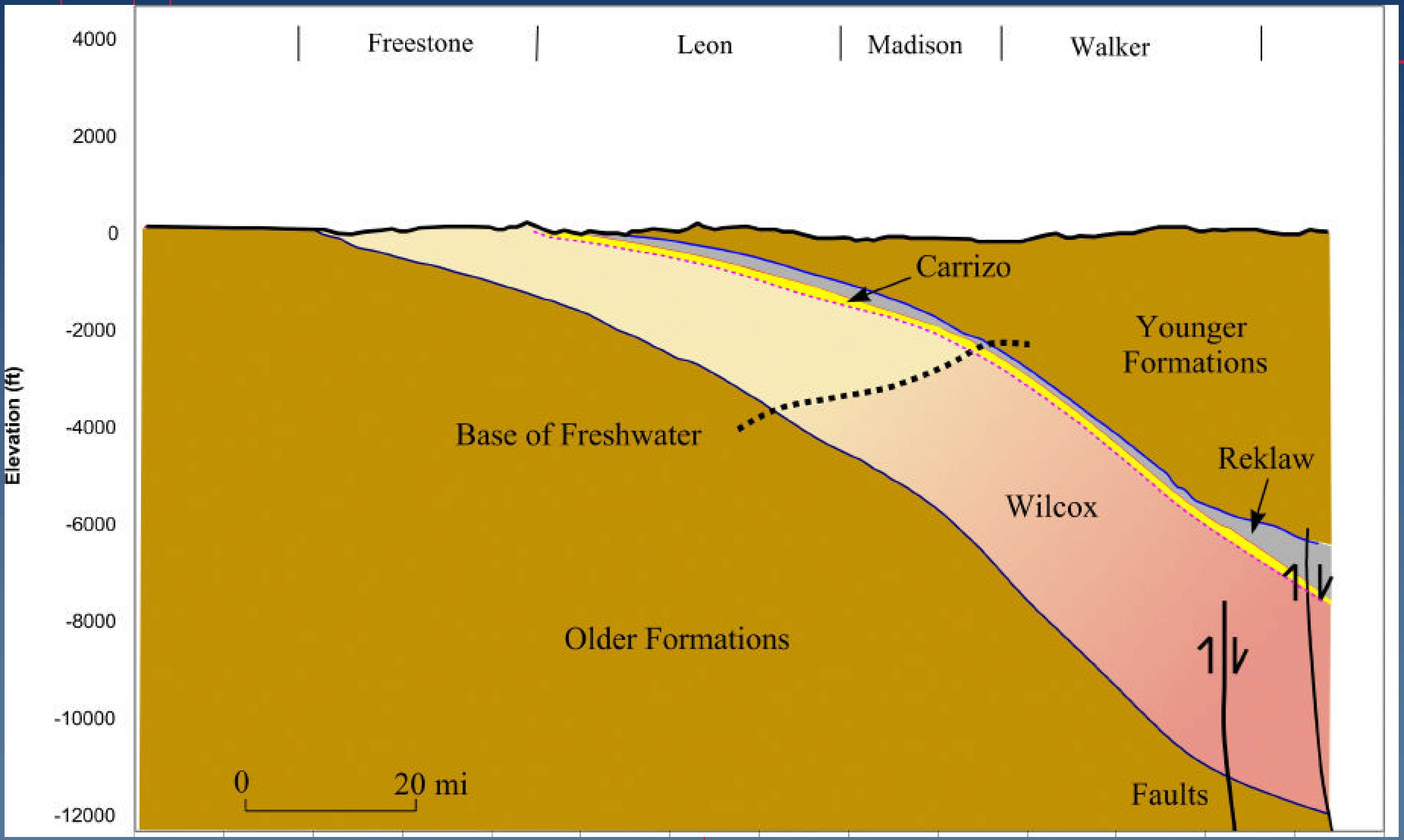
Northeast Carrizo-Wilcox GAM Model Domain



Base of Wilcox

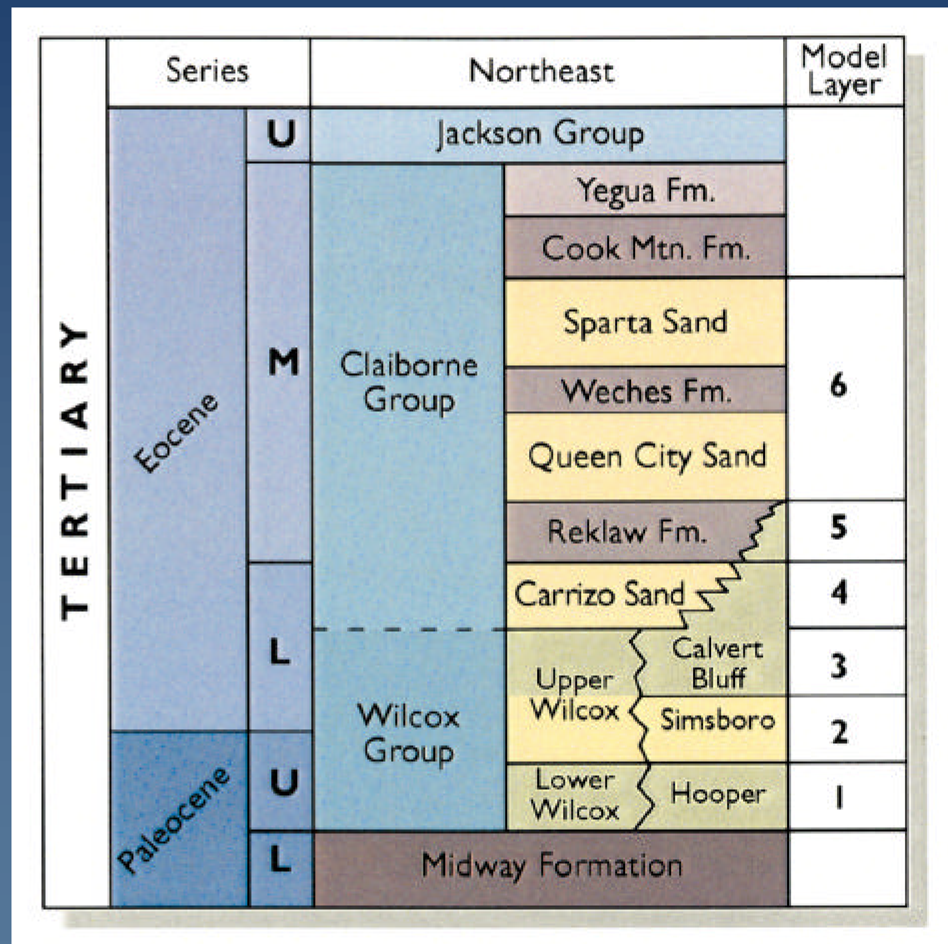


Carrizo-Wilcox Aquifer



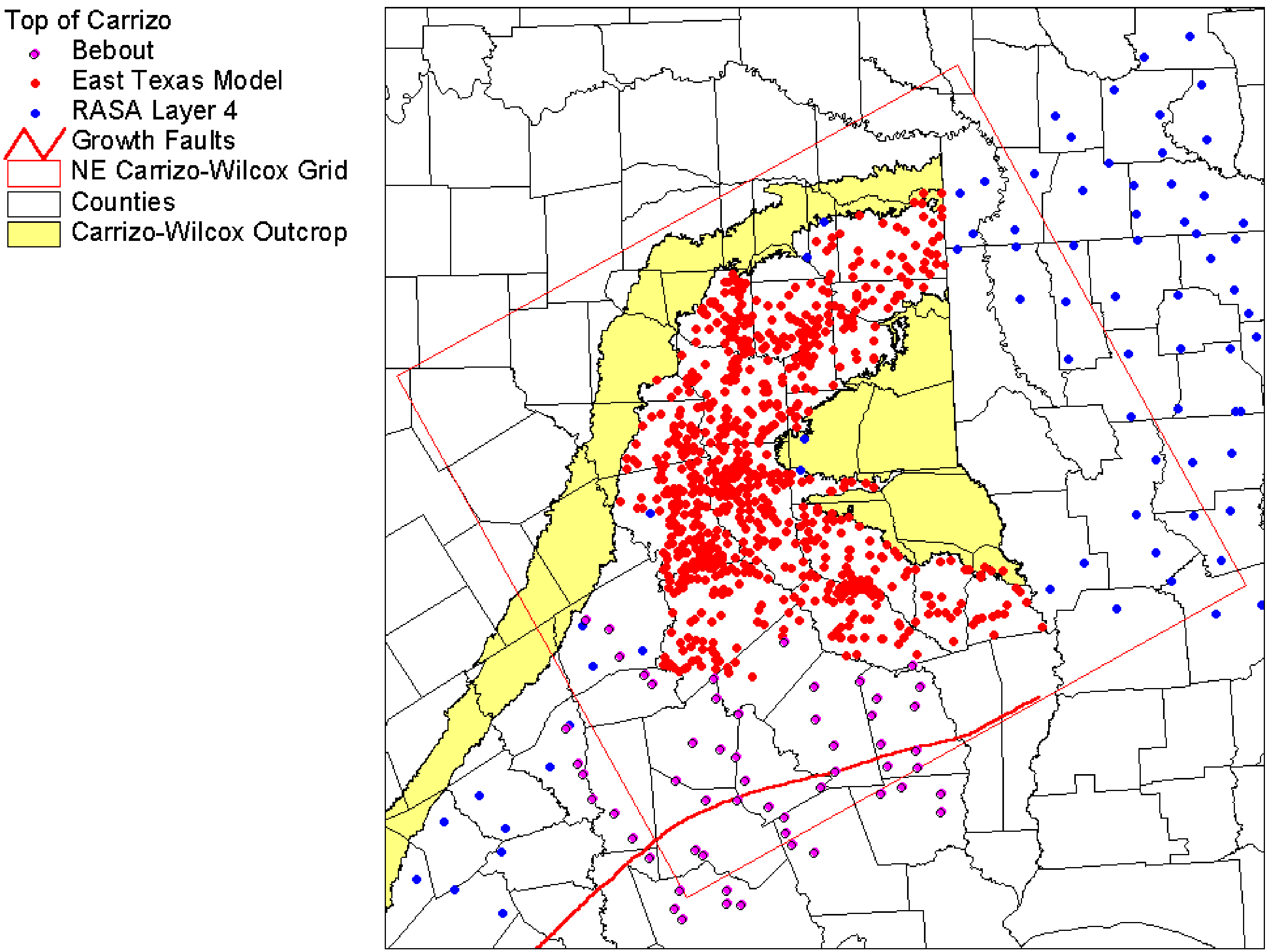
Model Layers

- Total of six layers
  - Lower Wilcox (Hooper)
  - Middle Wilcox (Simsboro)
  - Upper Wilcox (Calvert Bluff)
  - Carrizo Sand
  - Reklaw Fm
  - Shallow aquifers
    - (QC, W, S)



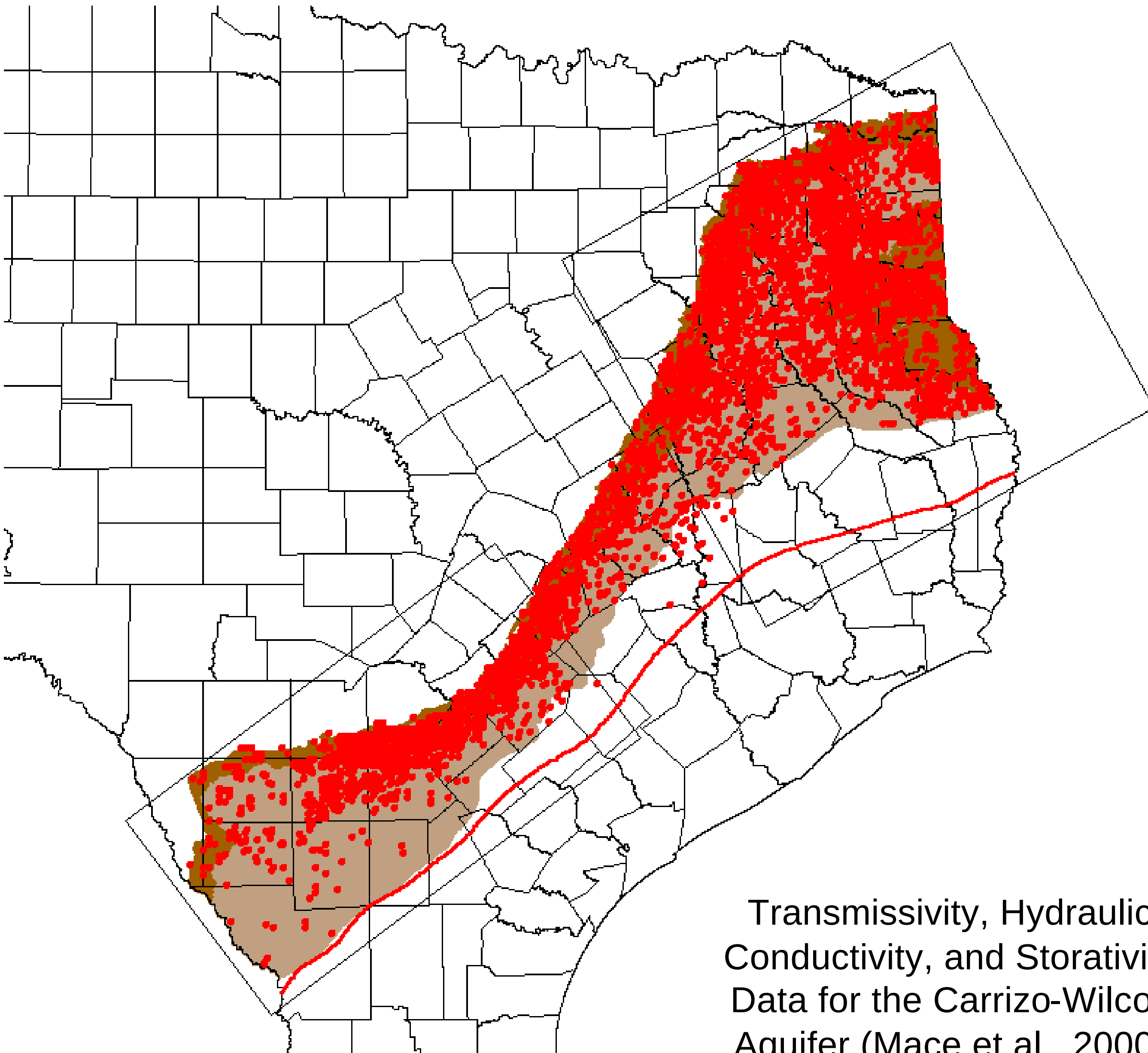
Stratigraphic Data Sources

- TWDB East Texas Model
  - Wilcox, Carrizo, Reklaw, Queen City, Weches, Sparta
- USGS RASA (Texas - LA - MS)
  - Lower Claiborne-Upper Wilcox (NE: Carrizo)
  - Middle Wilcox (TX: entire Wilcox)
- Kaiser (1990) (Sabine Uplift)
  - 2 layers for Wilcox
- Bebout et al. (1982) (Texas)
  - 3 layers for Wilcox


Top of Carrizo
Bebout
East Texas Model
RASA Layer 4
Growth Faults
NE Carrizo-Wilcox Grid
Counties
Carrizo-Wilcox Outcrop

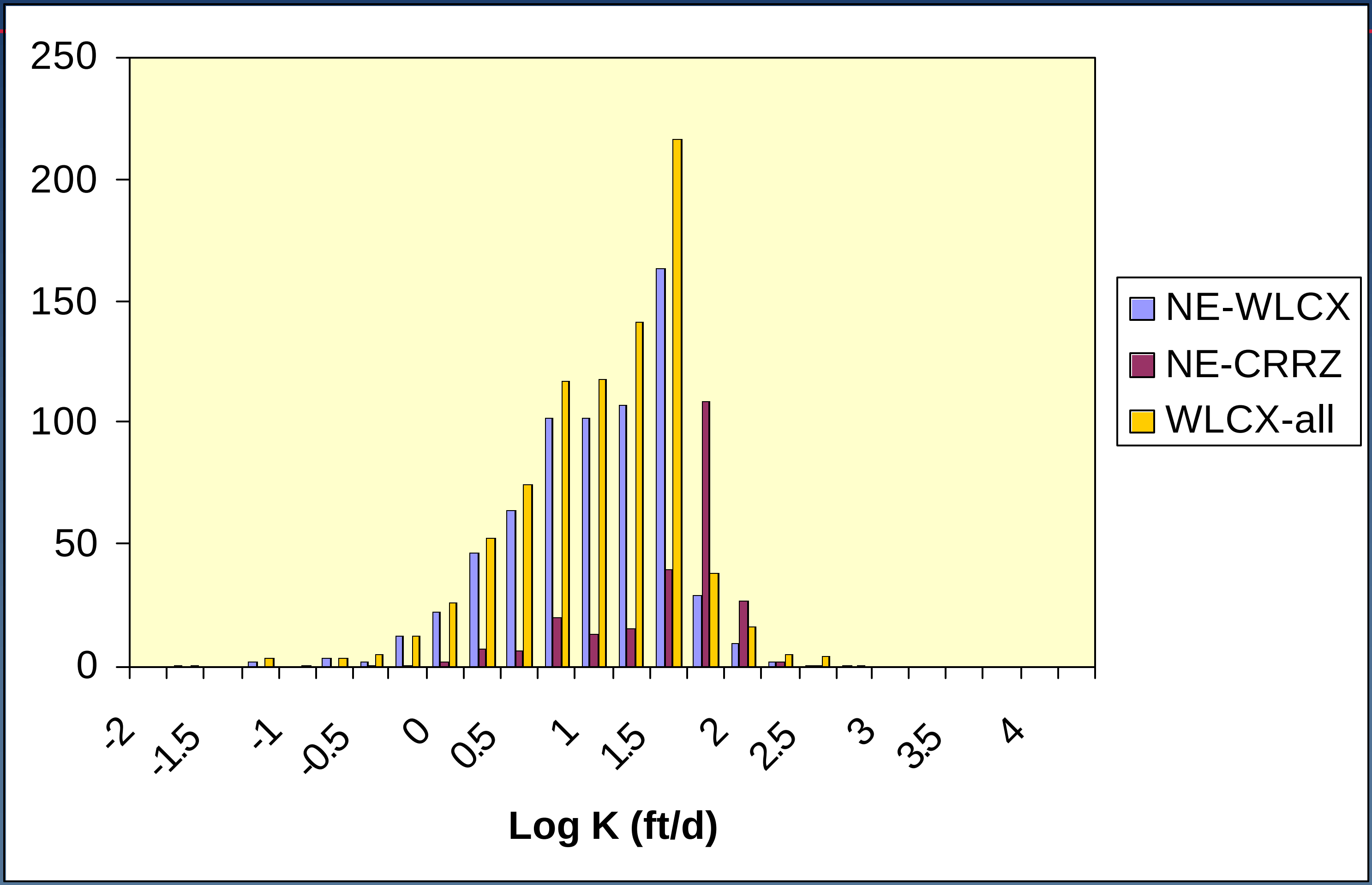
Aquifer Properties

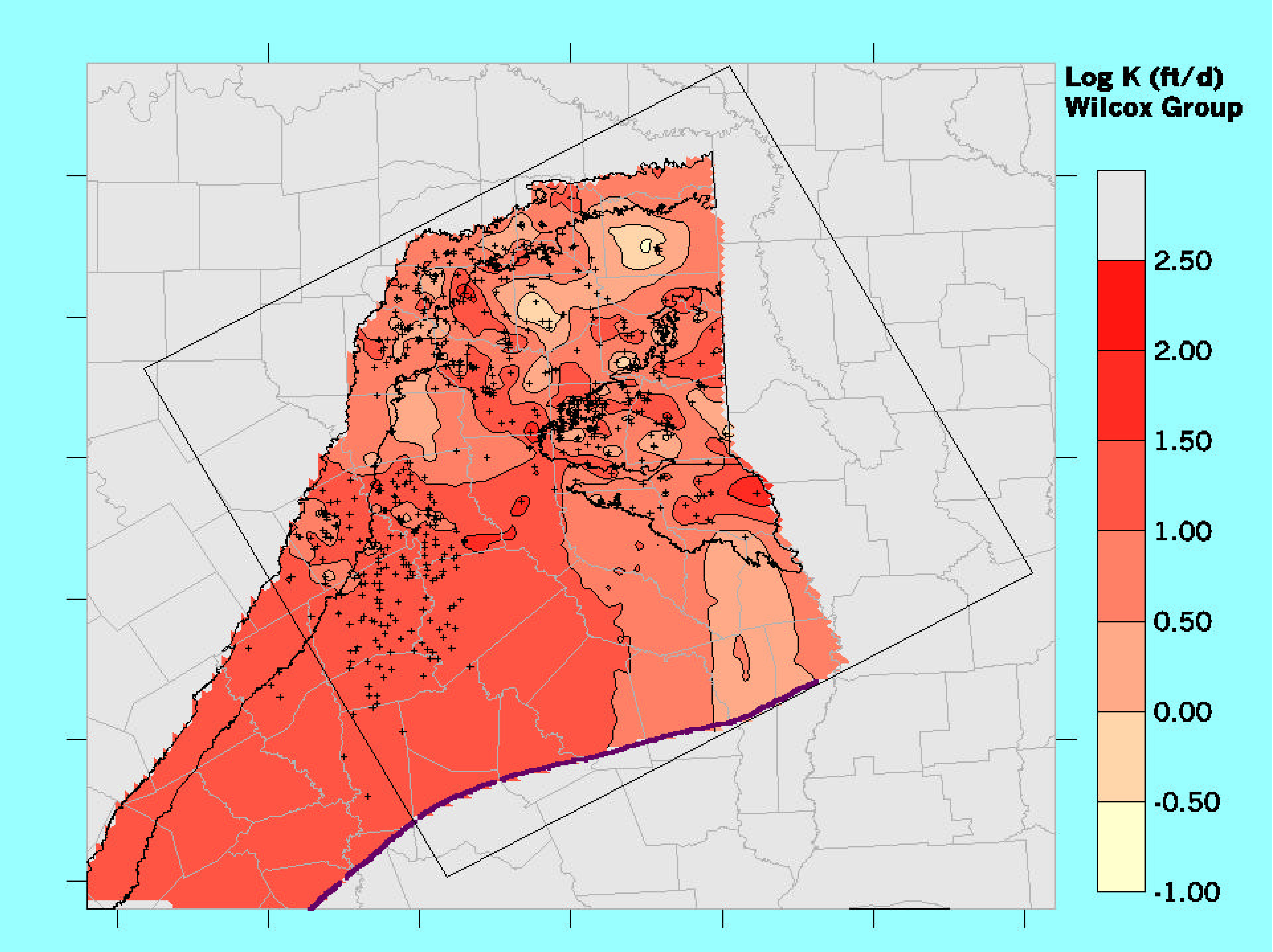
- Hydraulic Conductivity
  - horizontal
  - vertical
- Storativity
  - unconfined (specific yield)
  - confined

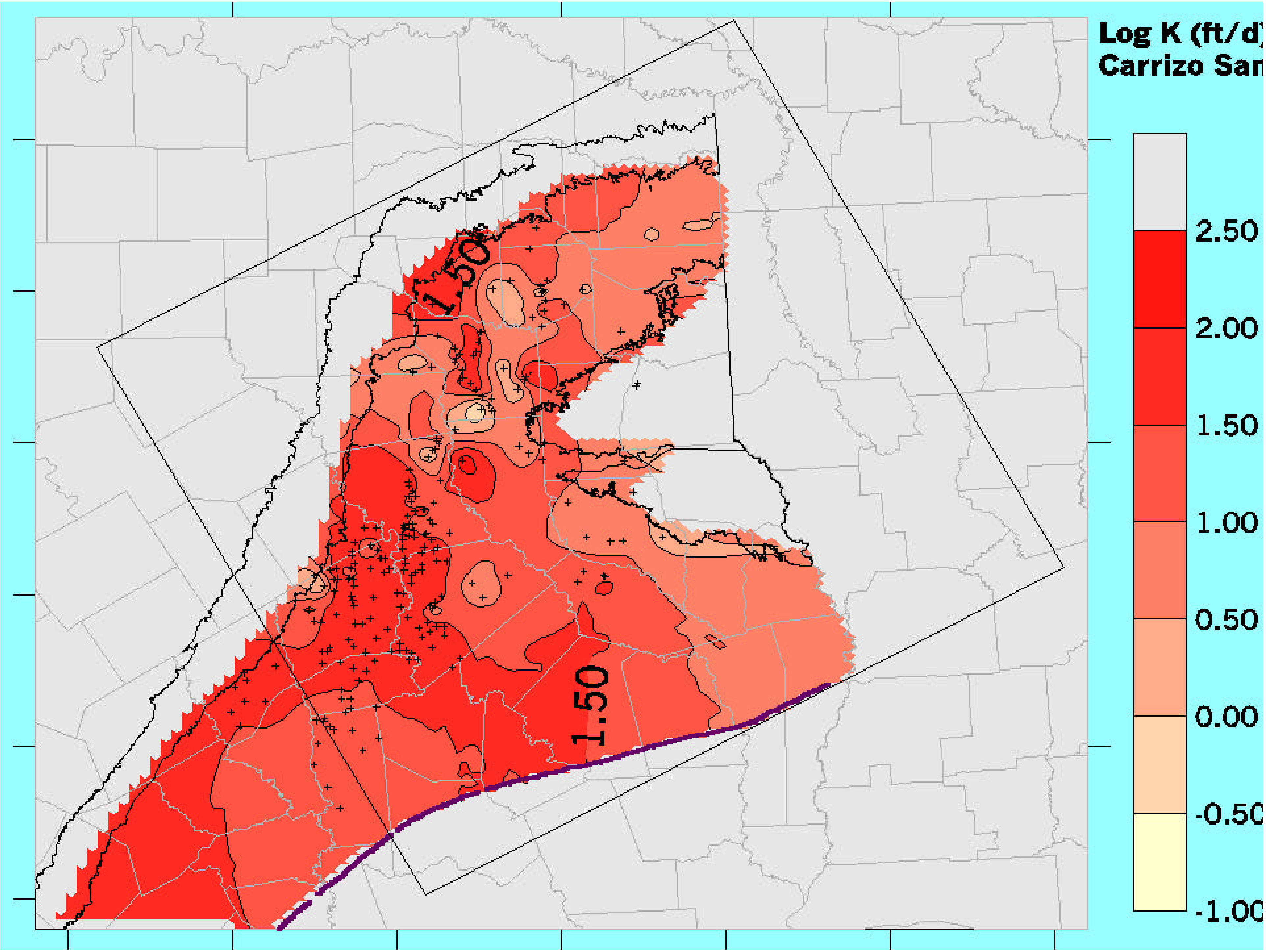


Transmissivity, Hydraulic Conductivity, and Storativity Data for the Carrizo-Wilcox Aquifer (Mace et al., 2000)

Hydraulic Conductivity Data

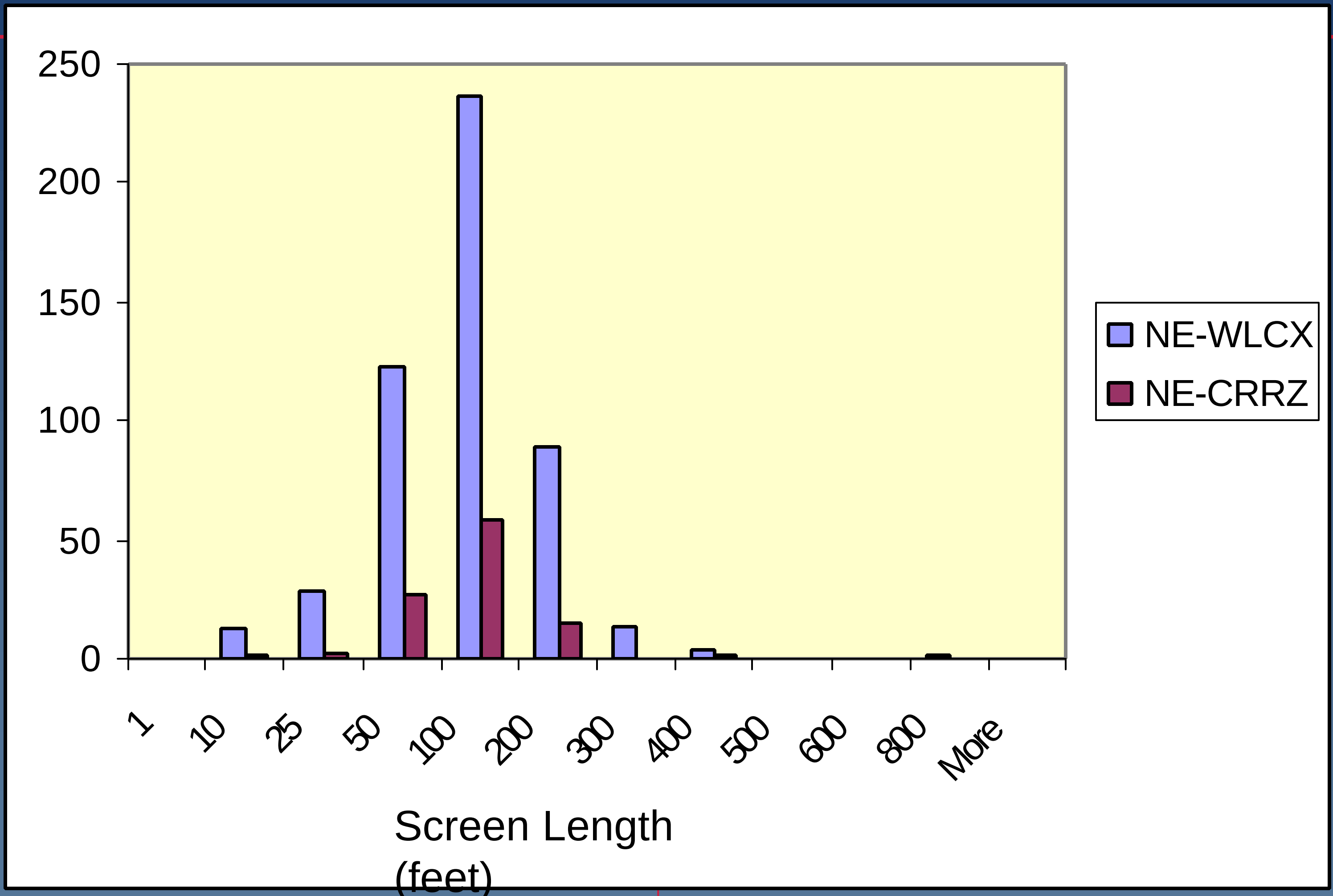



Log K (ft/d)
Wilcox Group
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00



Log K (ft/d)
Carrizo San
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
1.50
1.50

Well Screen Length (feet)



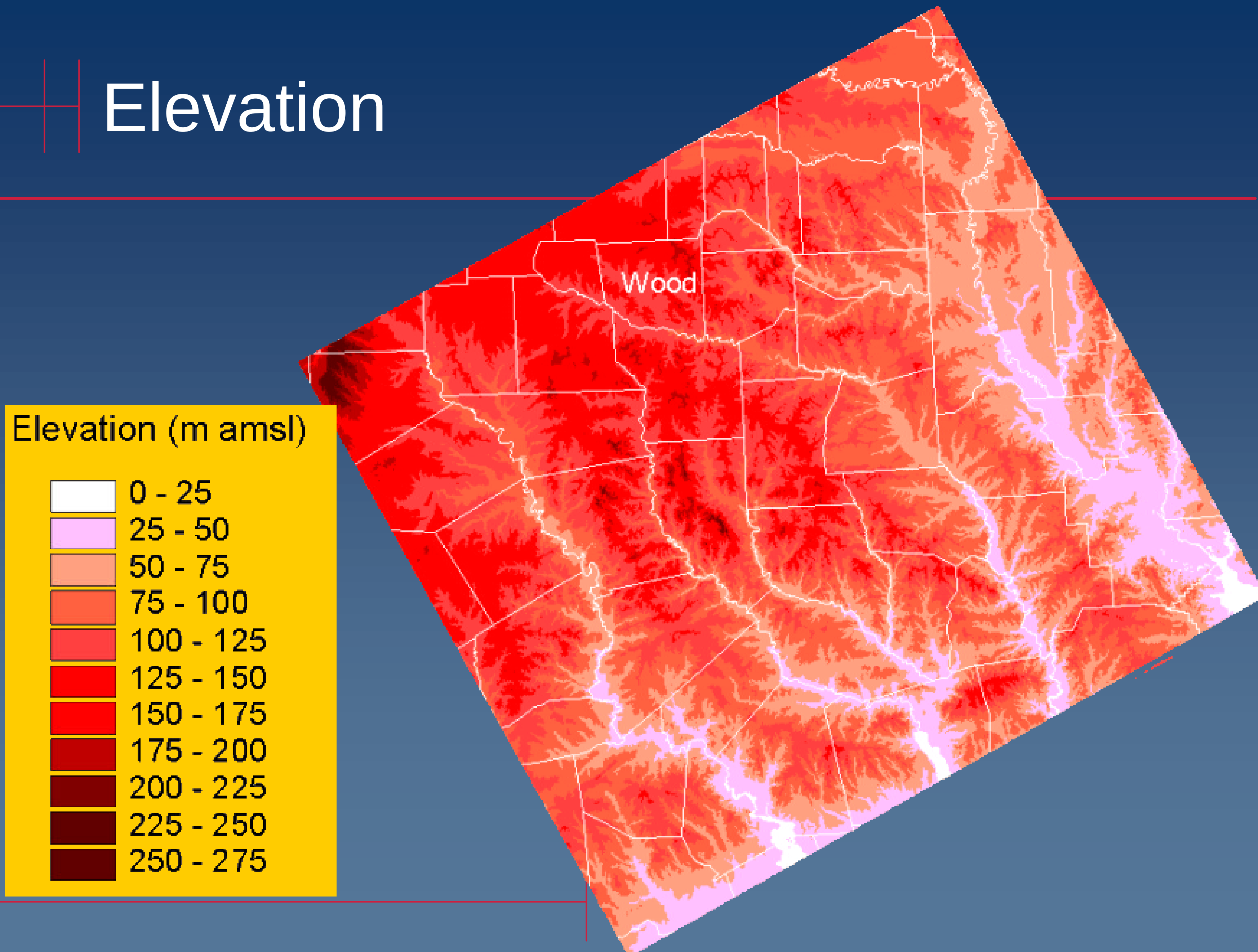
Sources for Sand Distribution

– NE Model:
  - sand distributions for upper and lower Wilcox from Kaiser (1990)
  - extend into the deeper section using Bebout(1982)

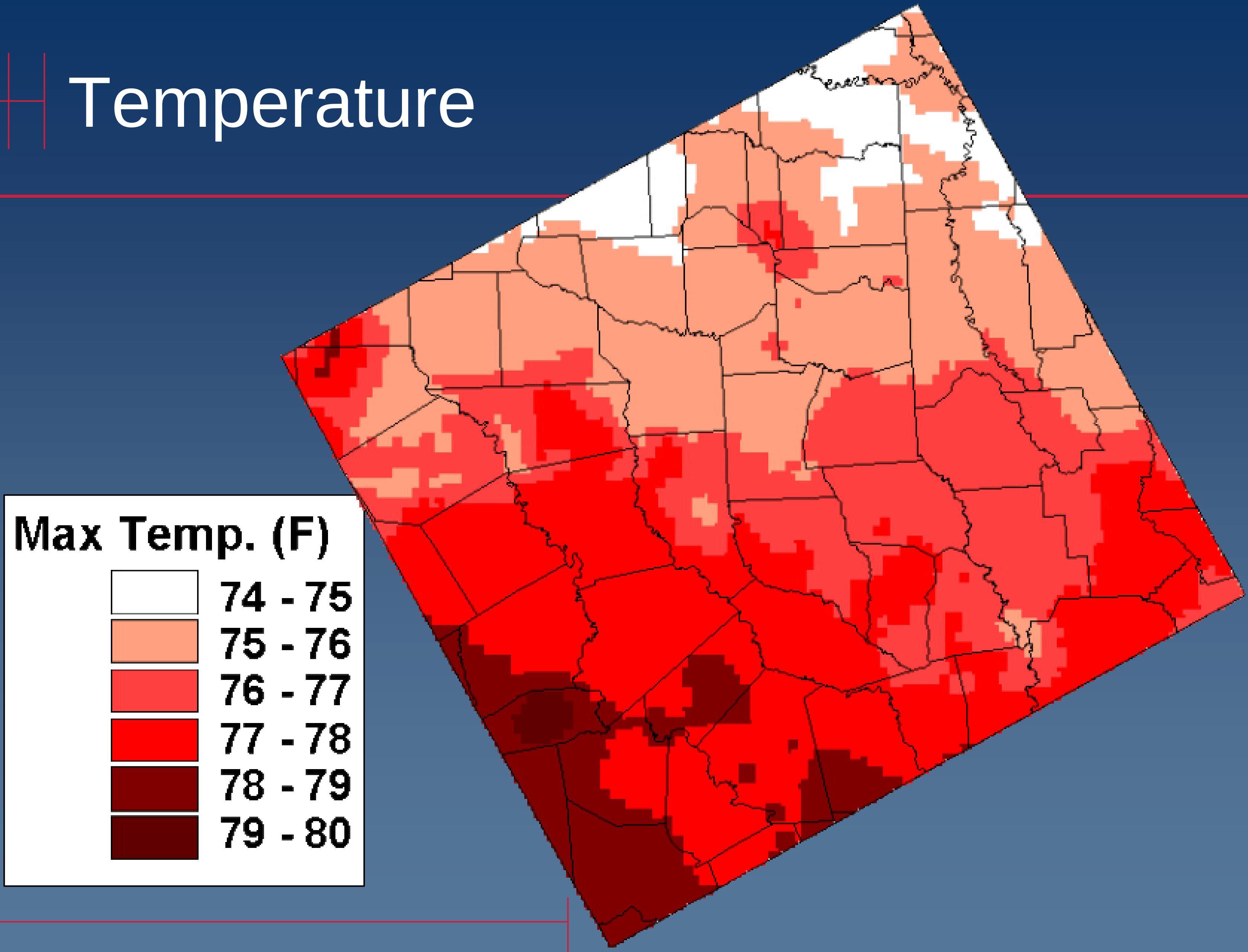
Physiography and Climate

- Landsurface Elevation
- Temperature
- Precipitation

Elevation


Elevation (m amsl)
0 - 25
25 - 50
50 - 75
75 - 100
100 - 125
125 - 150
150 - 175
175 - 200
200 - 225
225 - 250
250 - 275
Wood

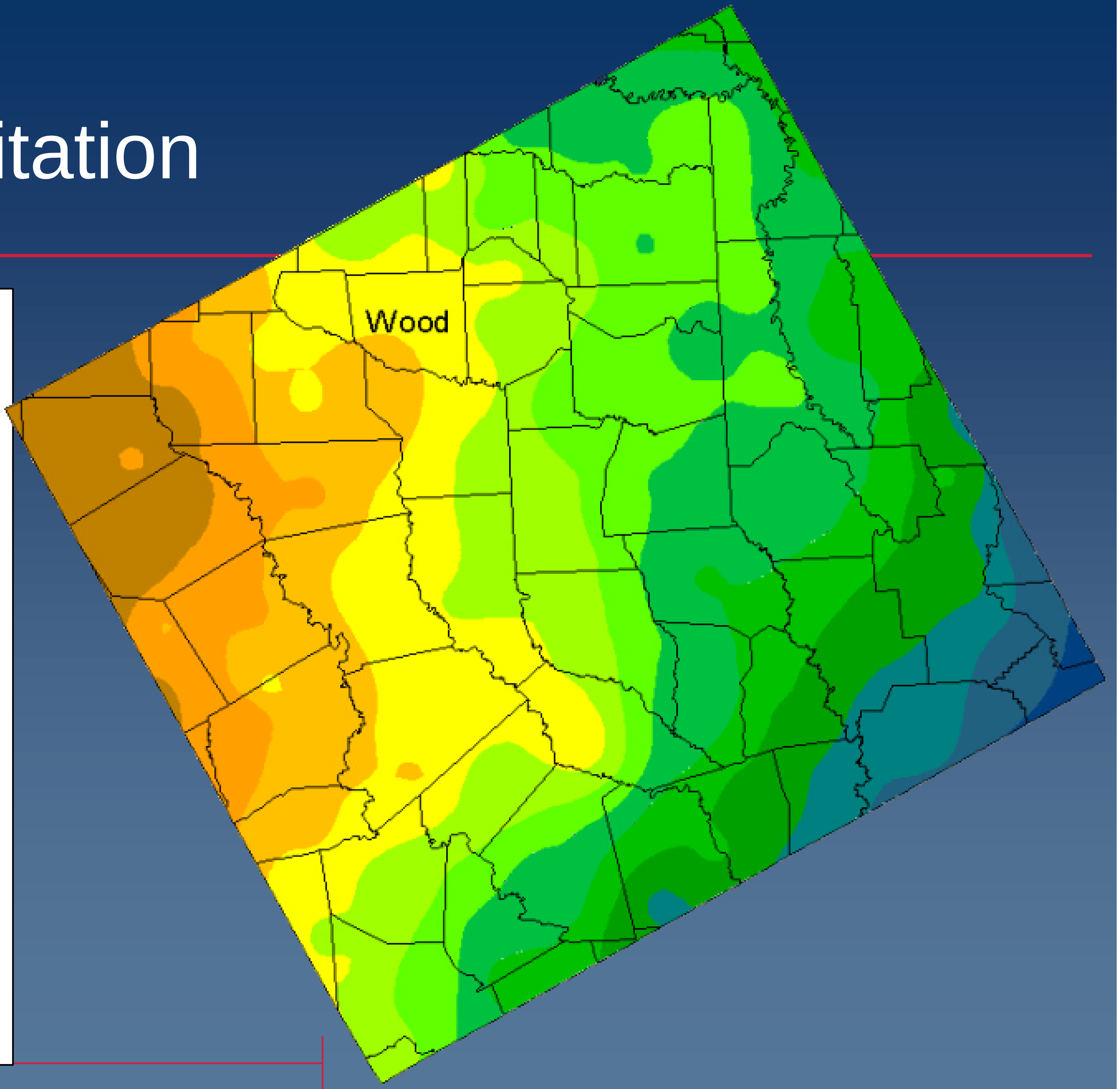
Temperature



Precipitation

Average Annual Precipitation (in)

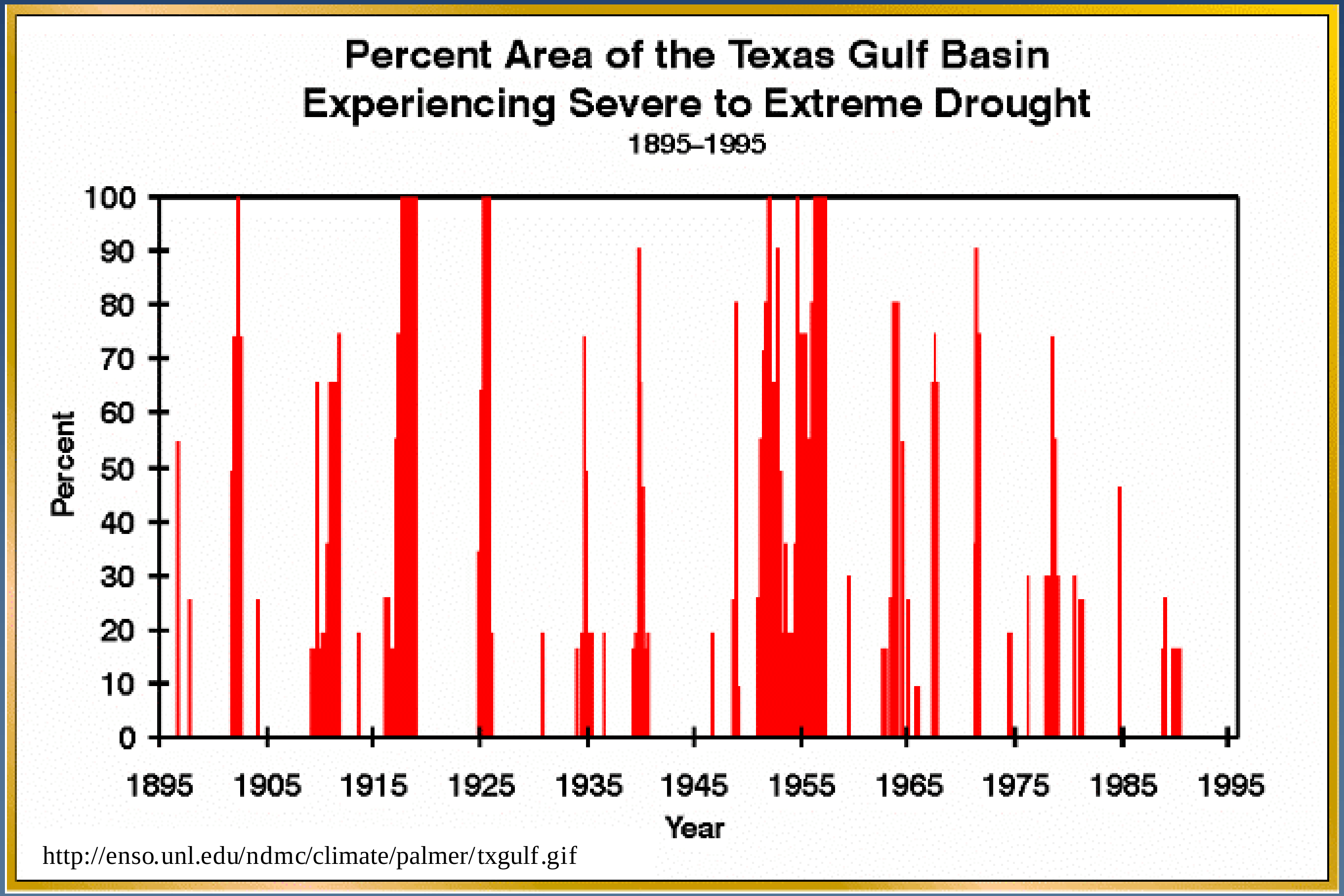
- 35 - 37
- 37 - 39
- 39 - 41
- 41 - 43
- 43 - 45
- 45 - 47
- 47 - 49
- 49 - 51
- 51 - 53
- 53 - 55
- 55 - 57
- 57 - 59



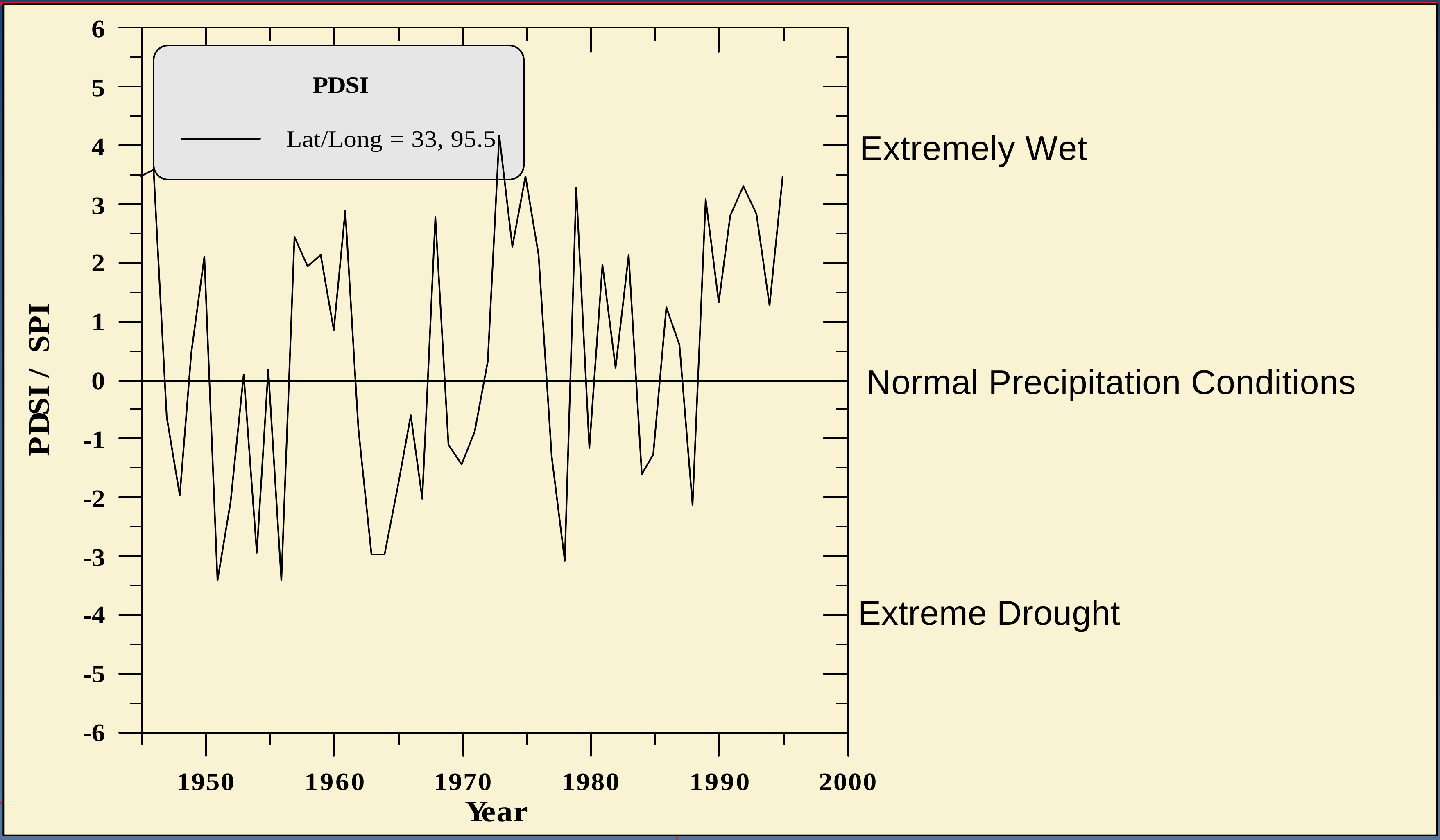
Climate Characterization

- GAM requires definition of one period representing the drought of record (DOR) for our model area.
- Future model simulations (years 2000-2050) will incorporate climatic conditions equivalent to the DOR
- We are currently reviewing precipitation, streamflow, and agricultural drought indices to define DOR

Drought, a Historical Perspective



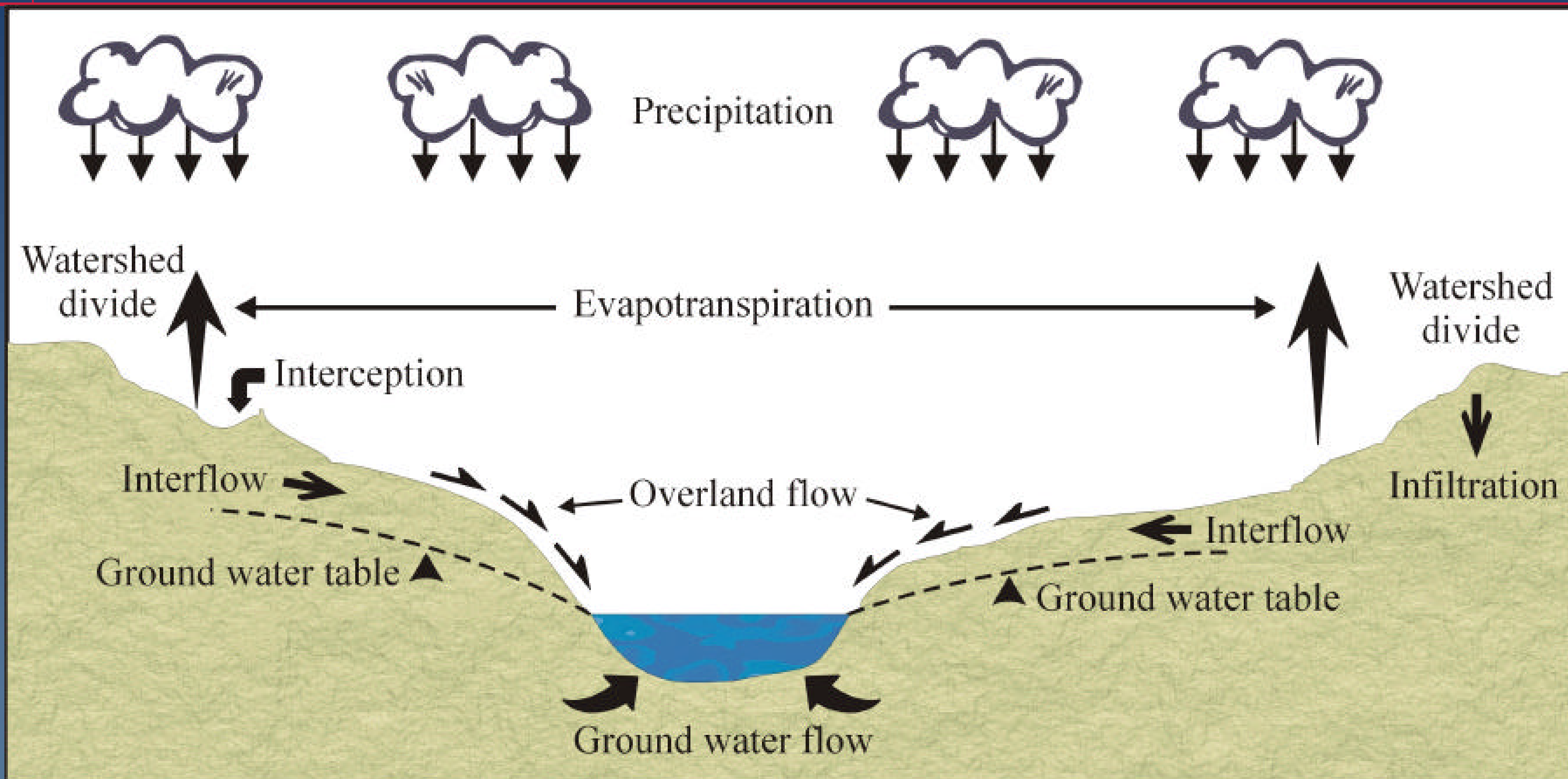
Palmer Drought Severity Index (PDSI)



Recharge/Discharge

- Approach
- Limitations
- Model Calibration

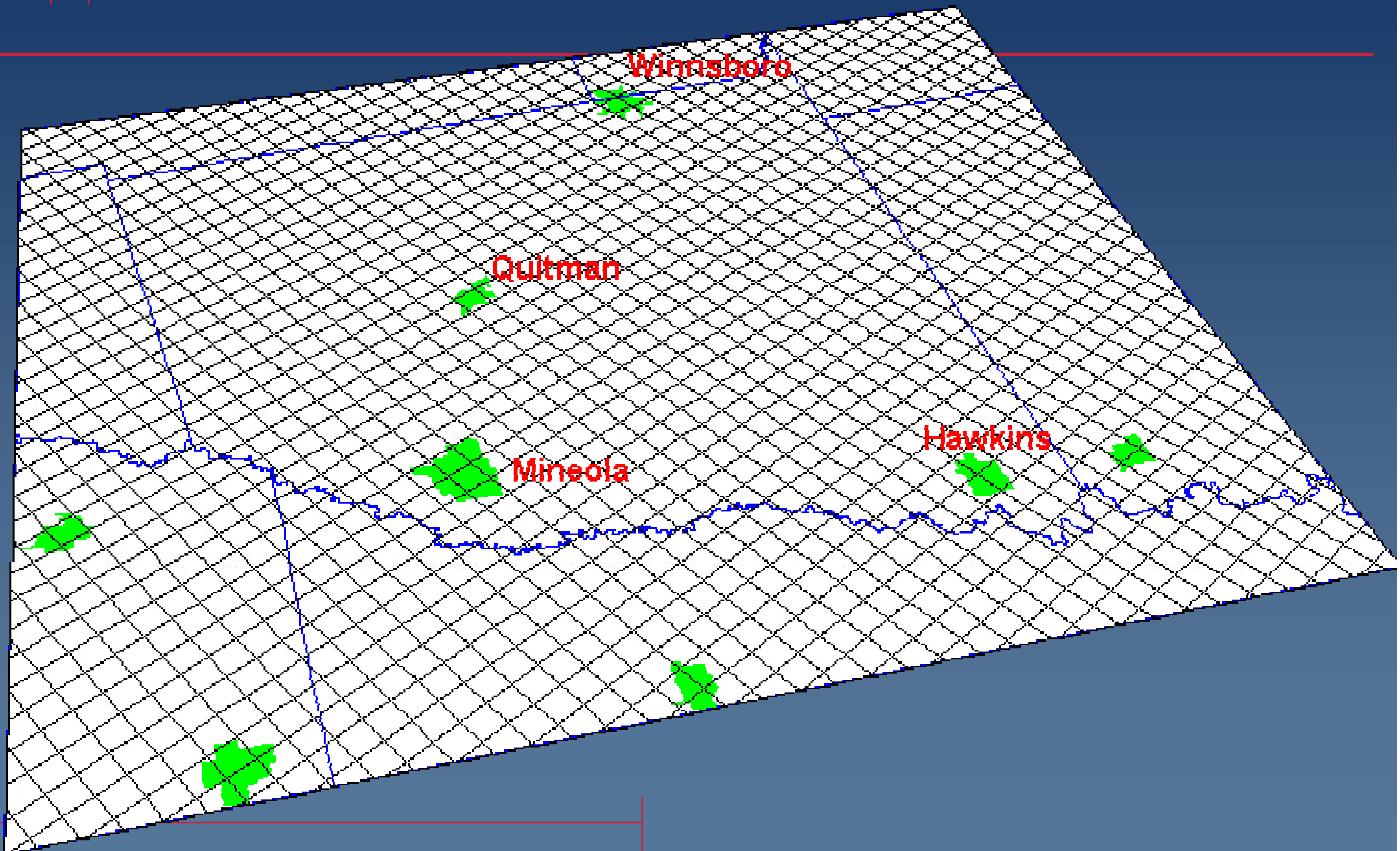
Hydrologic Cycle and Recharge



Recharge - Approach

- Recharge is a complex function of precipitation, evapotranspiration, and runoff and varies with location and time
- Develop an overlay technique capable of integrating spatial heterogeneity to determine recharge:
  - transiently (monthly analysis)
  - a per grid cell basis

Model Grid Scale

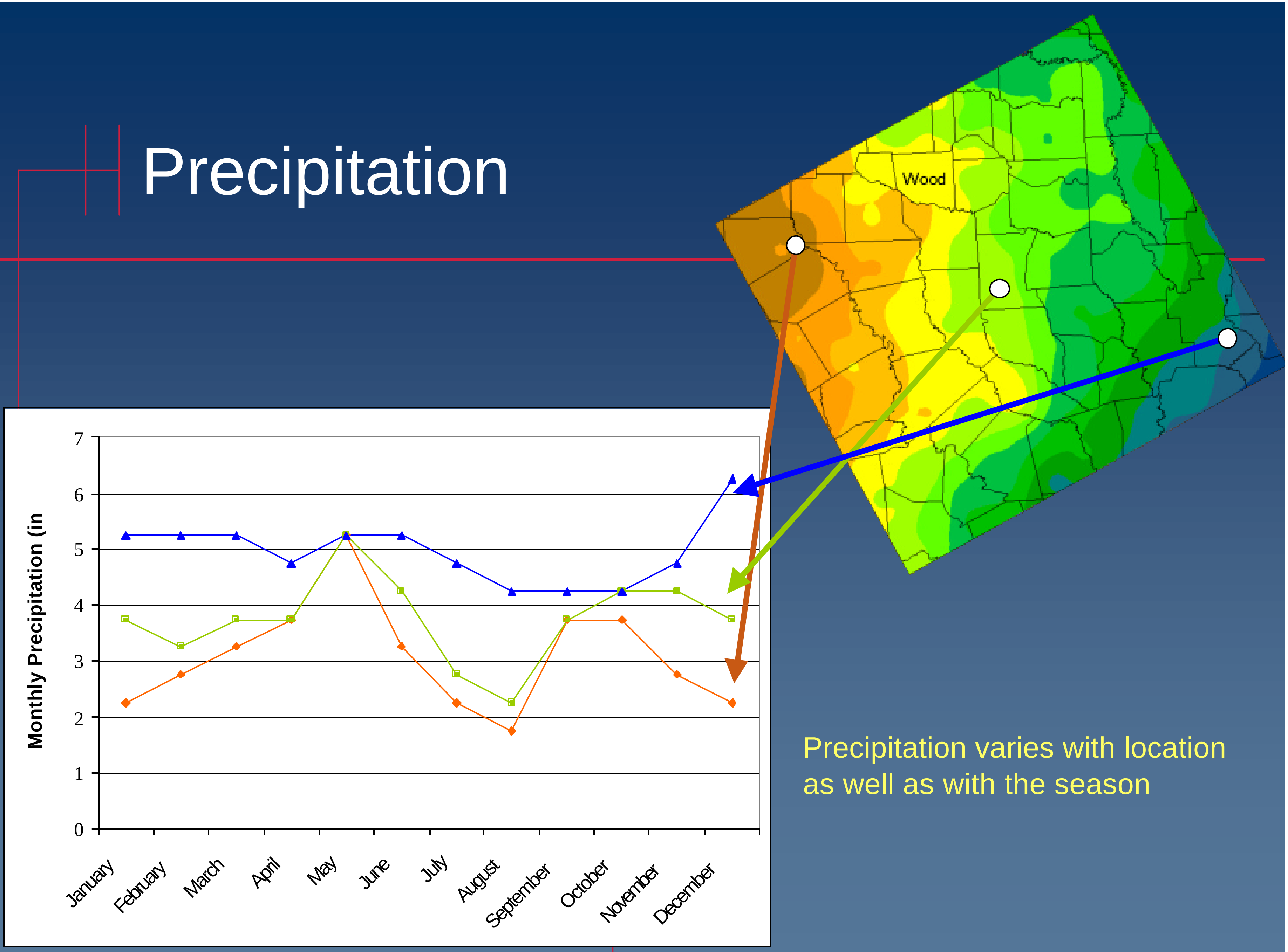


Recharge - Approach

- On a grid cell basis estimate:
  - precipitation and irrigation
  - runoff
  - Evapotranspiration

- Infiltration = Precipitation - Runoff
- Recharge = Infiltration - ET

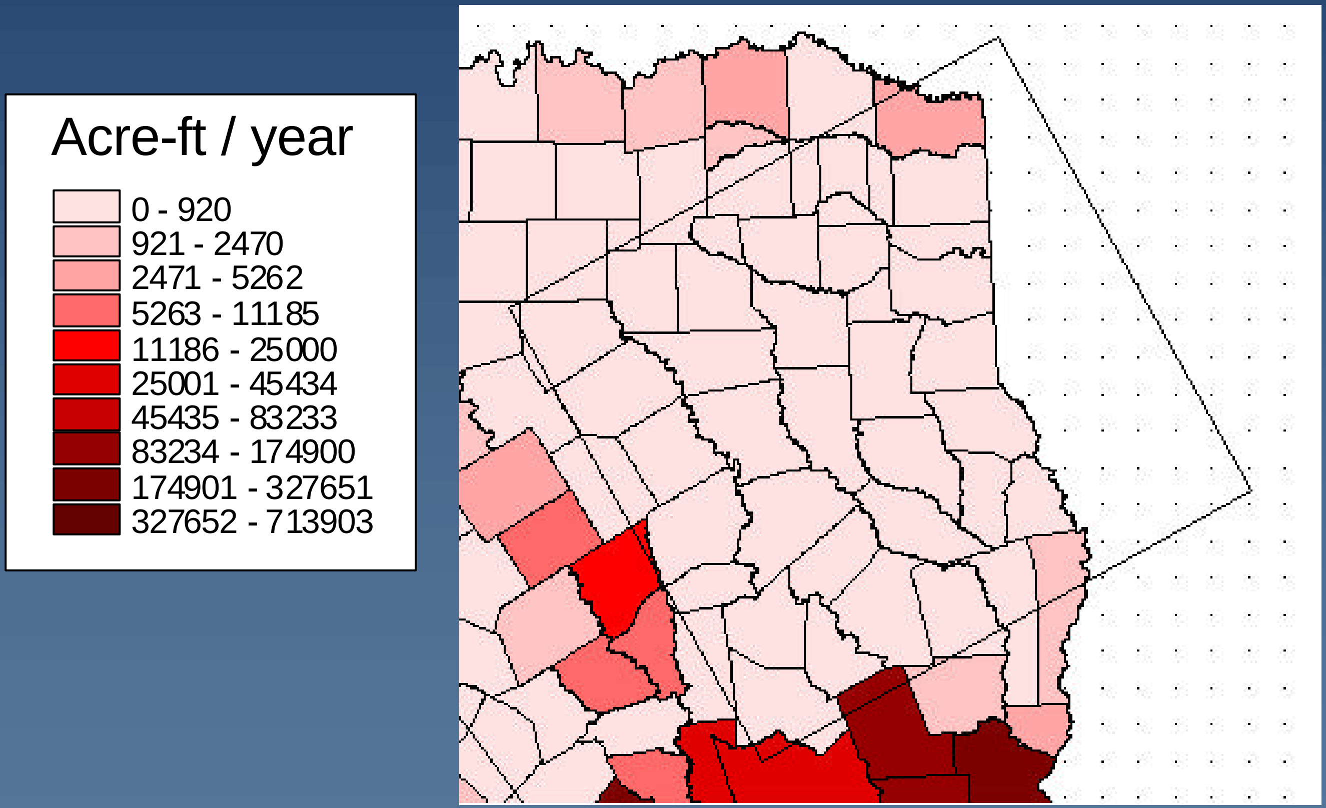
Precipitation



Precipitation varies with location as well as with the season

Recharge - Irrigation

- Irrigation not significant in Northeast



Recharge - Evapotranspiration

- Reference ET (E_{rc}) from pan measurements

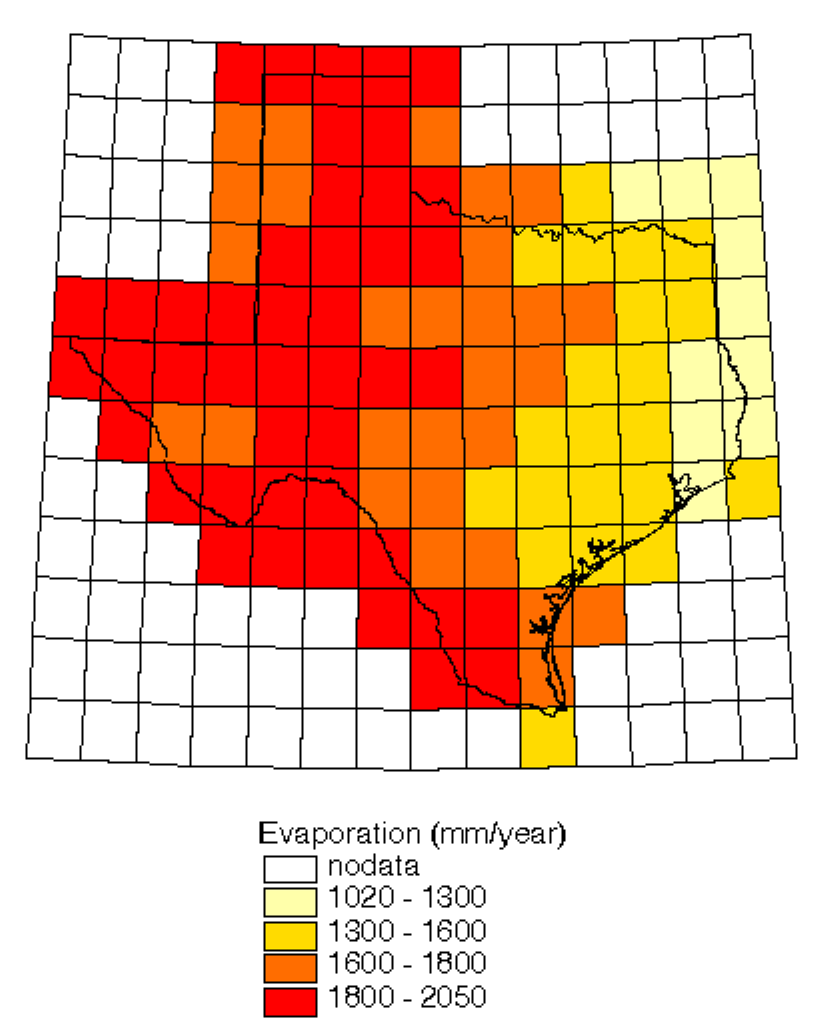
$$E_{rc} = k_{pan} E_{pan}$$

- Actual ET (E) determined by:

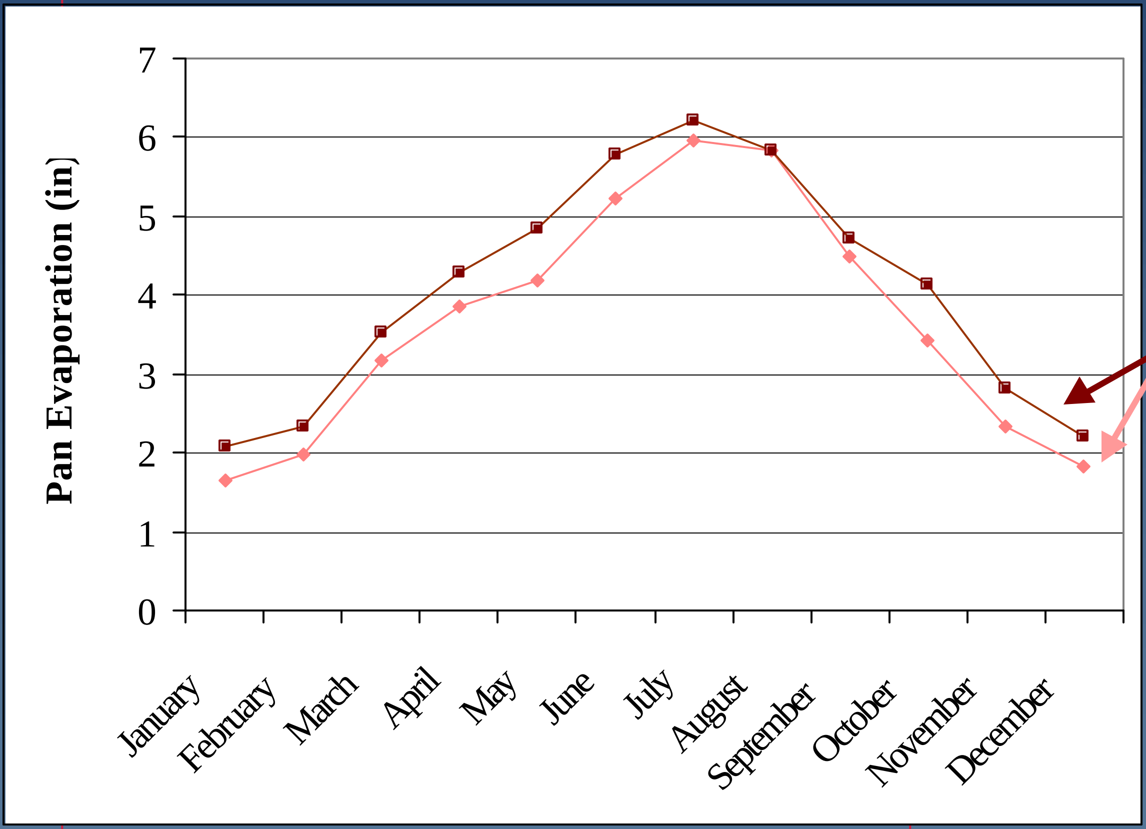
$$E = K_s K_{co} E_{rc}$$

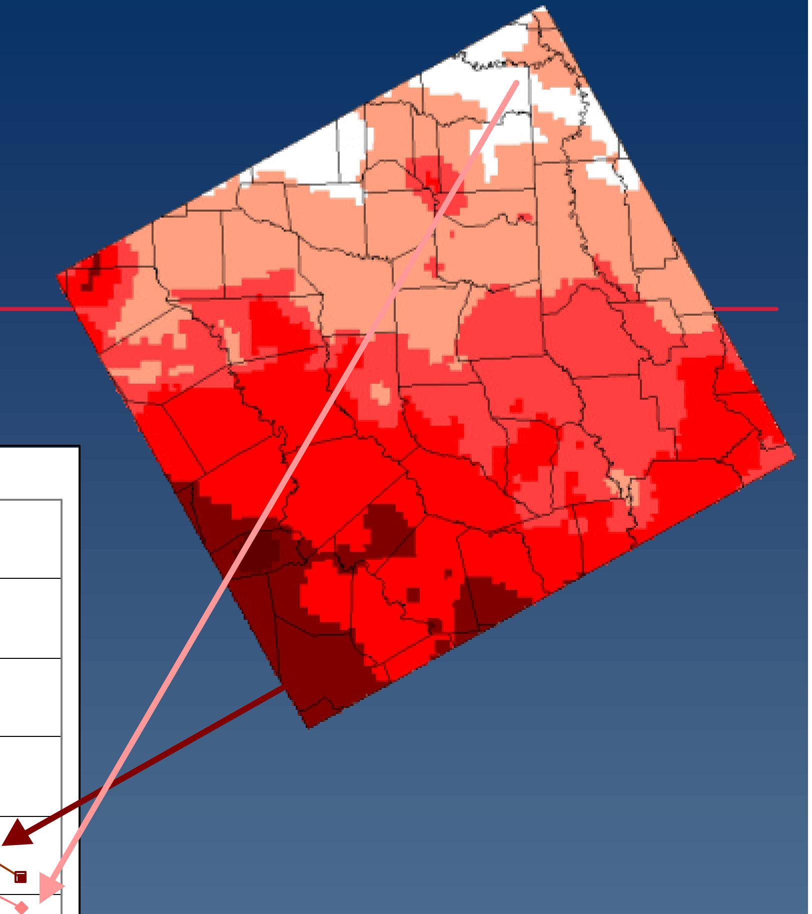
  - K_s is soil moisture
  - K_{co} is the crop coefficient, function of season and vegetation type

- Varies with location and time

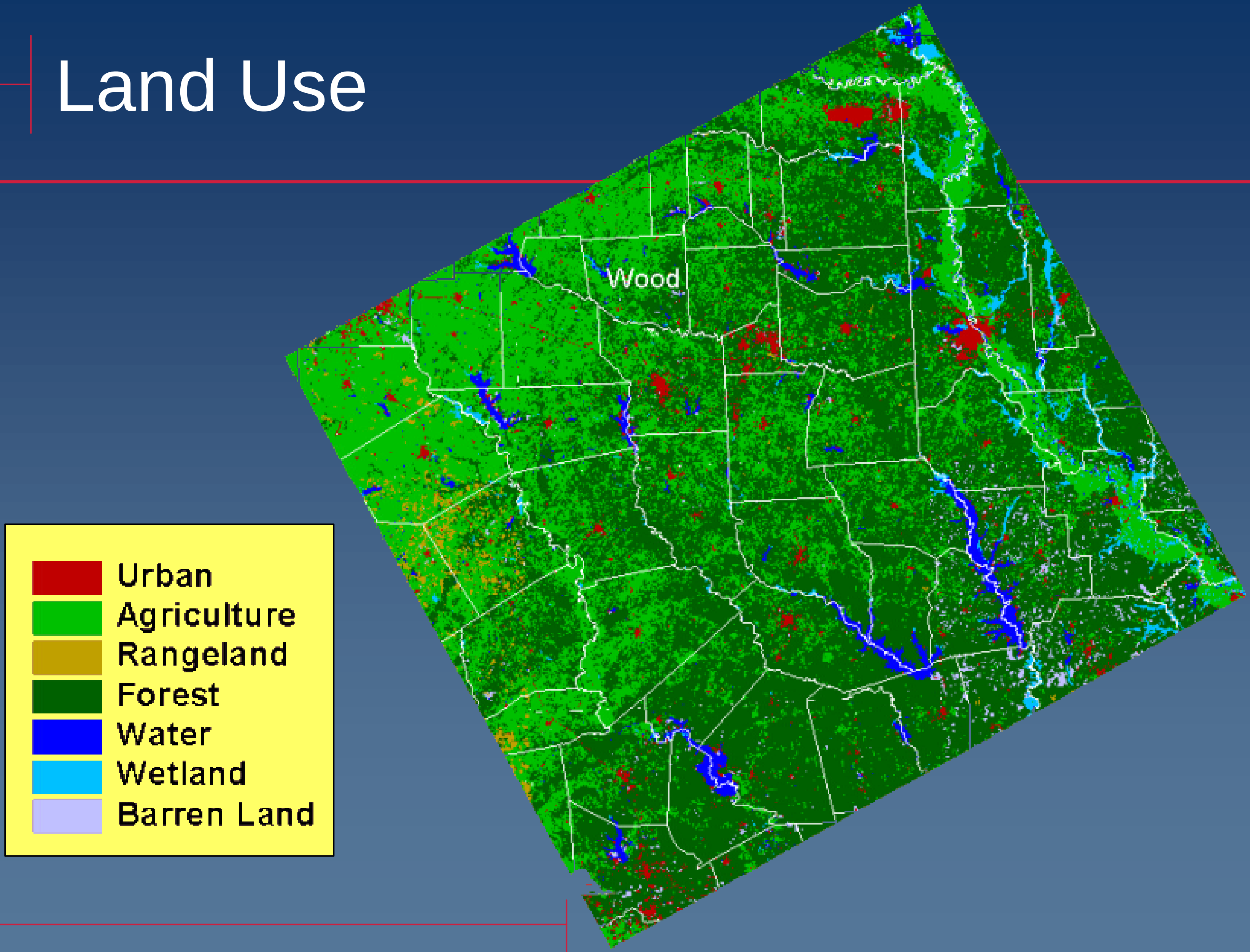


Pan Evaporation





Land Use


Wood
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren Land

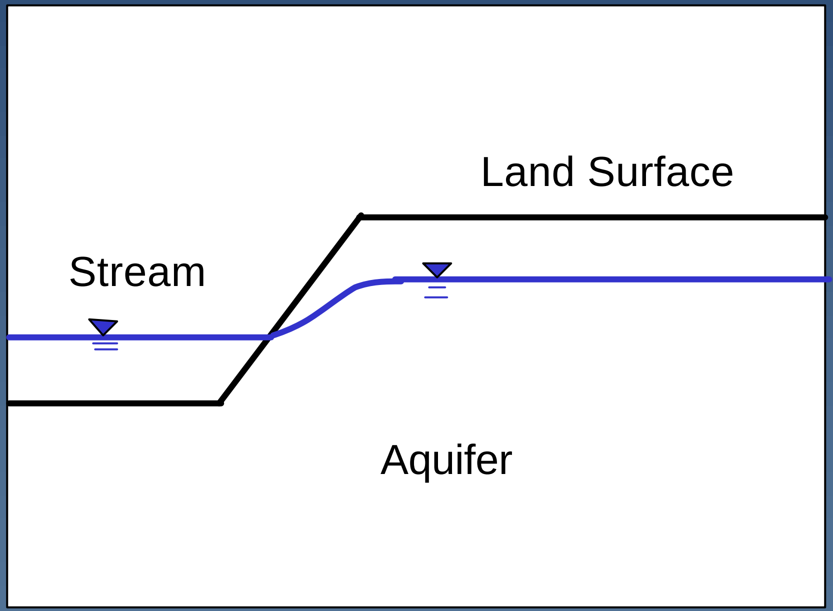
Recharge - Validation Approach

- Compare model recharge estimates to:
  - Past modeling studies
  - Survey data compiled by Scanlon
  - Baseflow studies (USGS)
- Compare runoff estimates to streamflow data
- Water table fluctuation methods
  - Calibrate to a few select hydrographs in the unconfined portion of the aquifer which show significant fluctuation with climate
- LANDSAT 7 SEBAL estimates of actual ET

Discharge to Surface Water

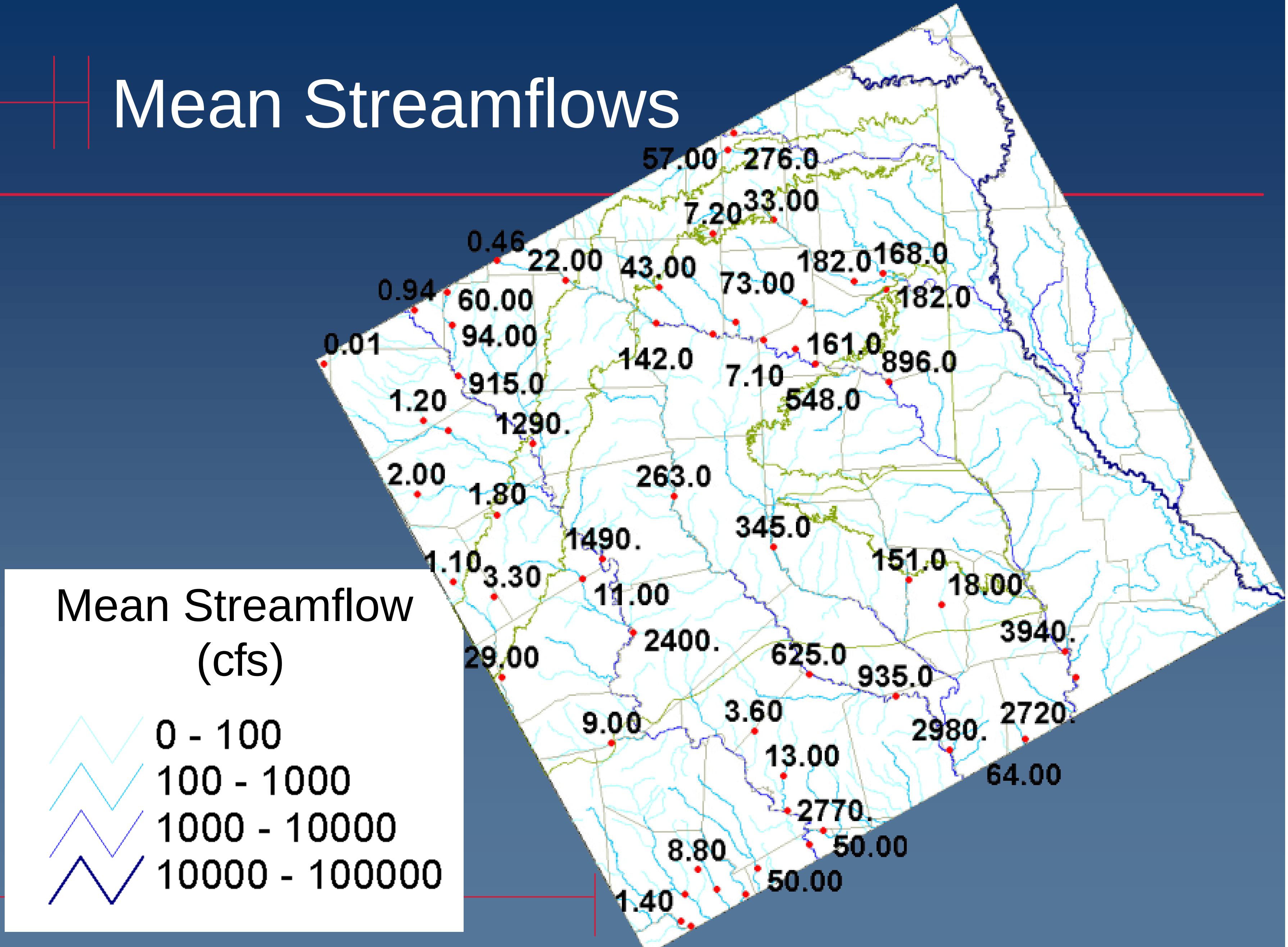
- Surface water/ Groundwater interaction is an important process to the Northern Carrizo/Wilcox Aquifer
- Streams in the model area are historically gaining (receive groundwater flow)
- Reservoirs are an important part of the surface water system
- Springs are prevalent and an important cultural resource

Aquifer Stream Interaction



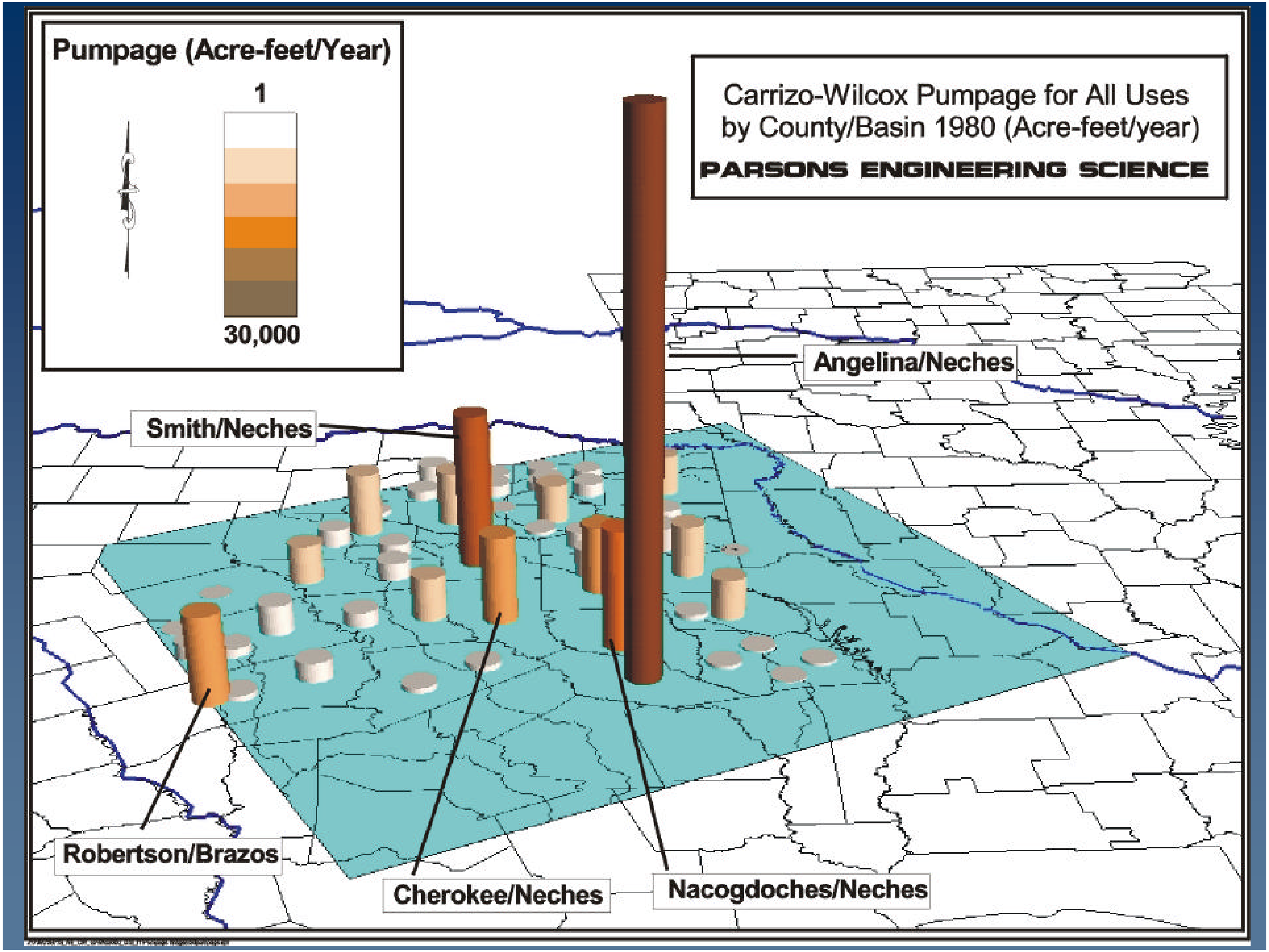
- Gaining Stream
- Flow originates from:
  - Surface Runoff
  - Groundwater (baseflow)

Mean Streamflows



Discharge from Pumping

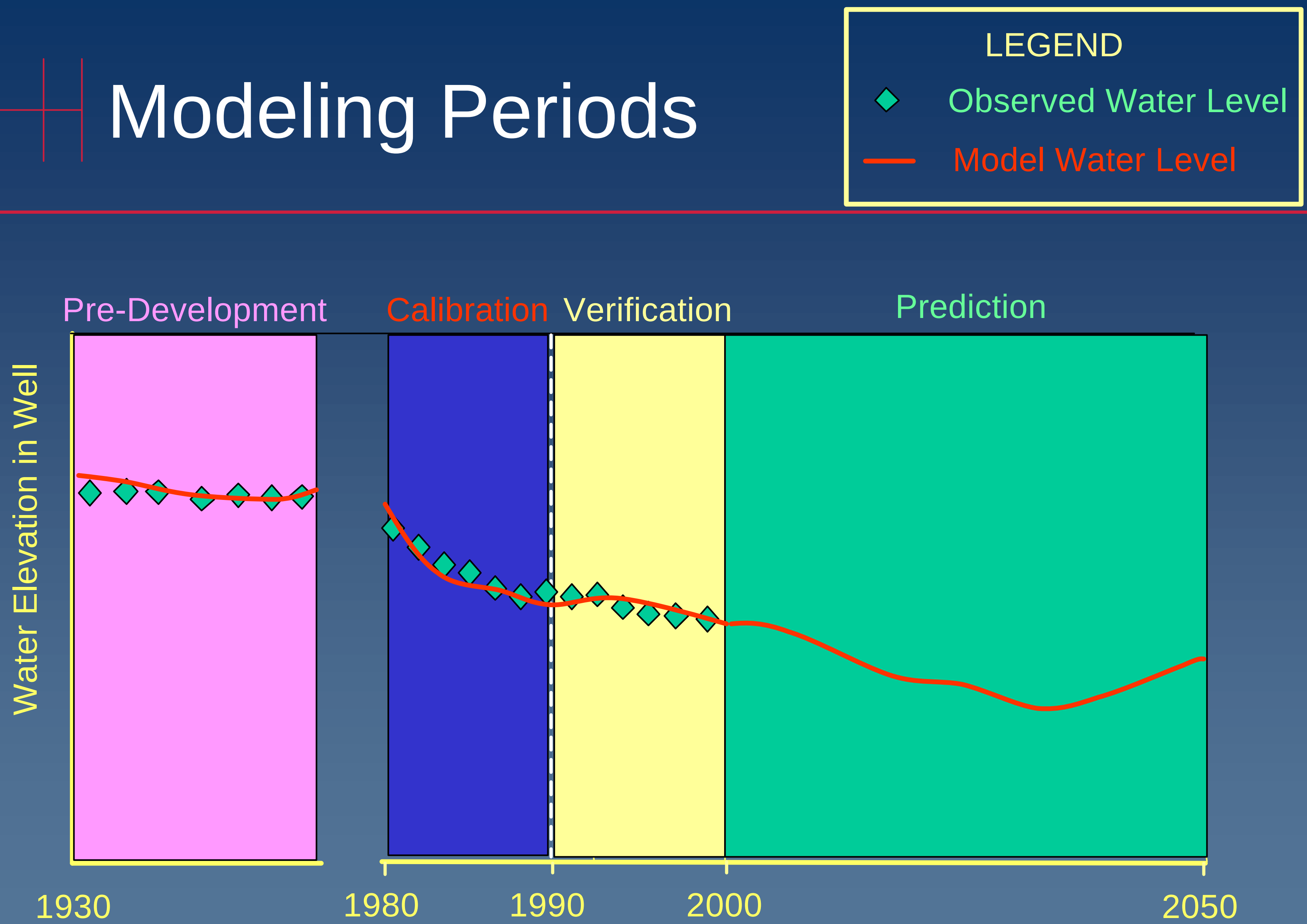
- Pumping is distributed to the 1 mile square model grid based upon:
  - Specific Wells
    - Power
    - Mining
    - Manufacturing
    - Municipal
  - Land Use/ Population Density
    - Rural/Domestic
    - Livestock
    - Irrigation


Pumpage (Acre-feet/Year)
1
30,000
Carrizo-Wilcox Pumpage for All Uses
by County/Basin 1980 (Acre-feet/year)
PARSONS ENGINEERING SCIENCE
Angelina/Neches
Smith/Neches
Robertson/Brazos
Cherokee/Neches
Nacogdoches/Neches

Water Levels and Regional GW Flow

- Objectives
  - Develop potentiometric maps:
    - Predevelopment water levels for model initial.
    - 1990 water levels for model calibration
    - 2000 water levels for model verification
  - Select hydrographs for calibration
  - Assess transient water level changes for use as boundary conditions
  - Evaluate cross-formational flow

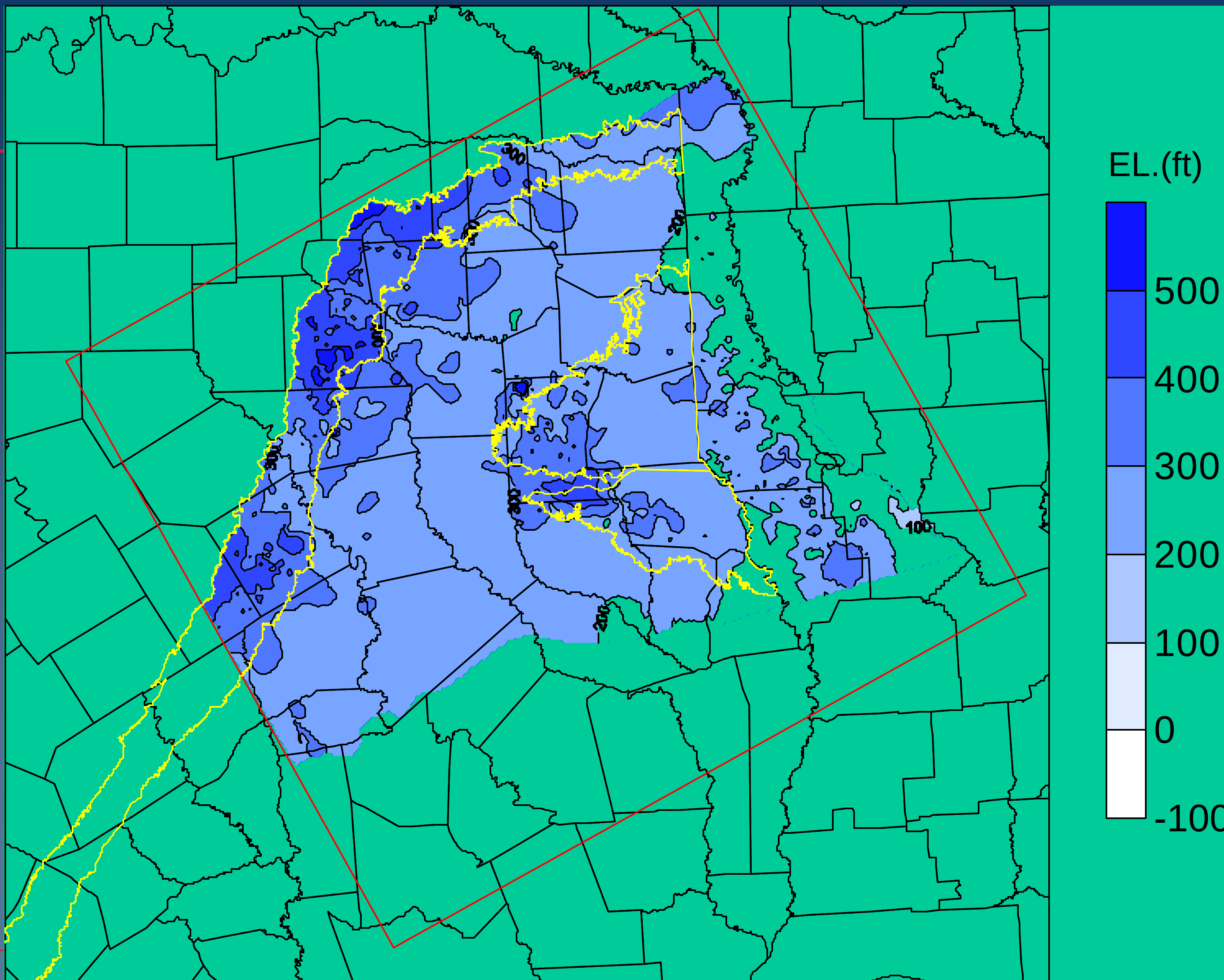
Modeling Periods



Approach for Predevelopment WL Contours

- Selected maximum value measured in each well regardless of measurement date
  - 1829 wells in Texas
  - 1536 wells in Louisiana
  - 20 well in Arkansas
- Removed all water-level elevations <200 ft in Texas because they reflected pumping
  - 1676 wells left in Texas (removed 153 measurements)
- Total number measurements used was 3232

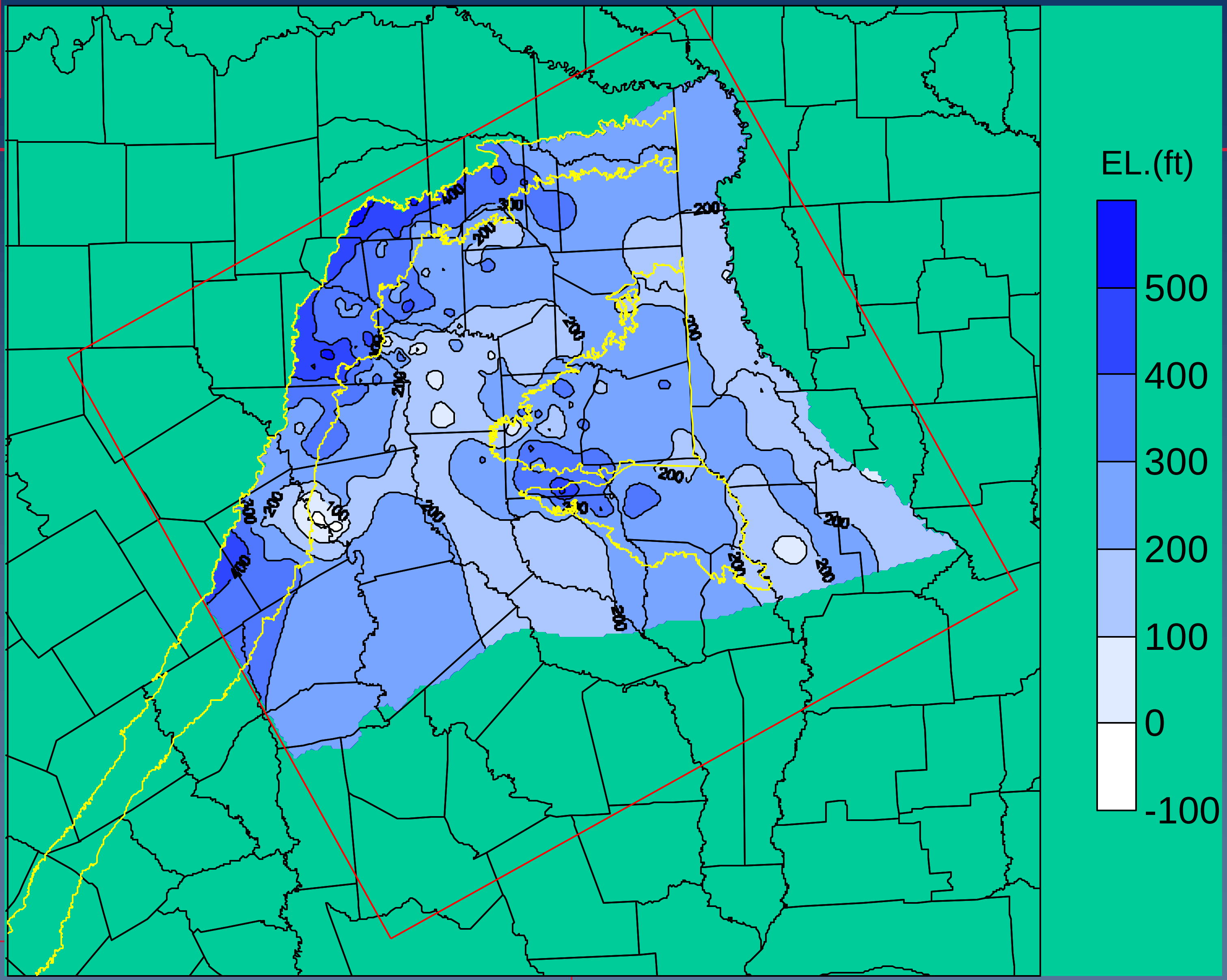
Wilcox Group - Predevelopment Water Levels



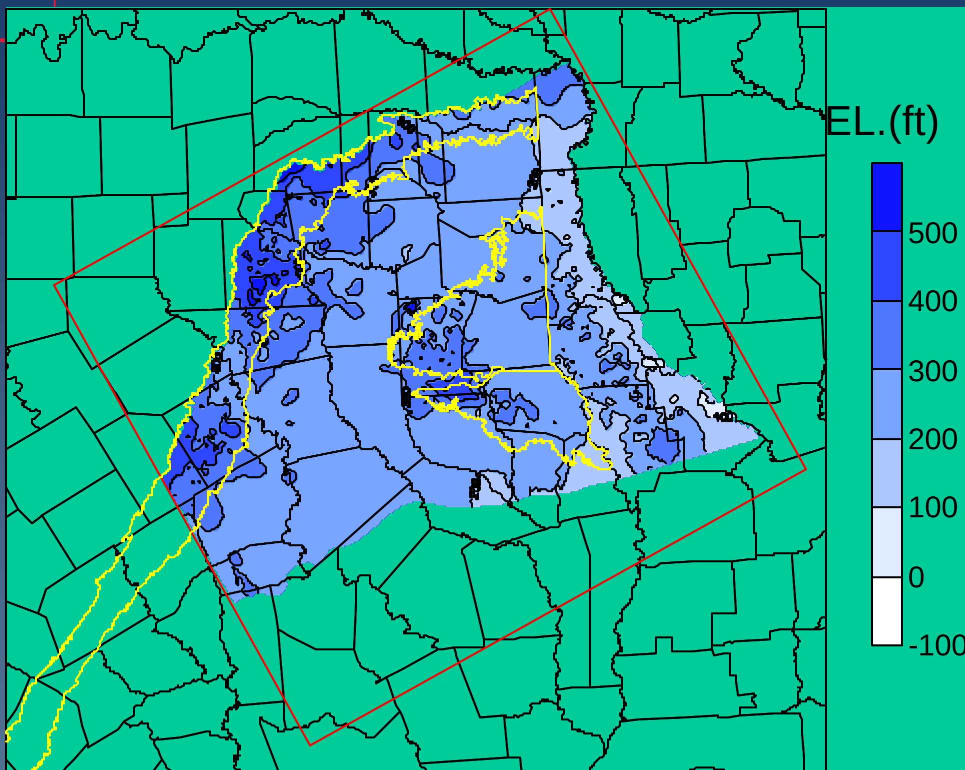
Approach for 1990 WL Contours

- Calculated average water-level elevation for the years 1988 through 1992
  - 397 wells in Texas
  - 116 wells in Louisiana
  - 0 well in Arkansas
- Did not make any adjustments to the data
- Total number measurements used was 513

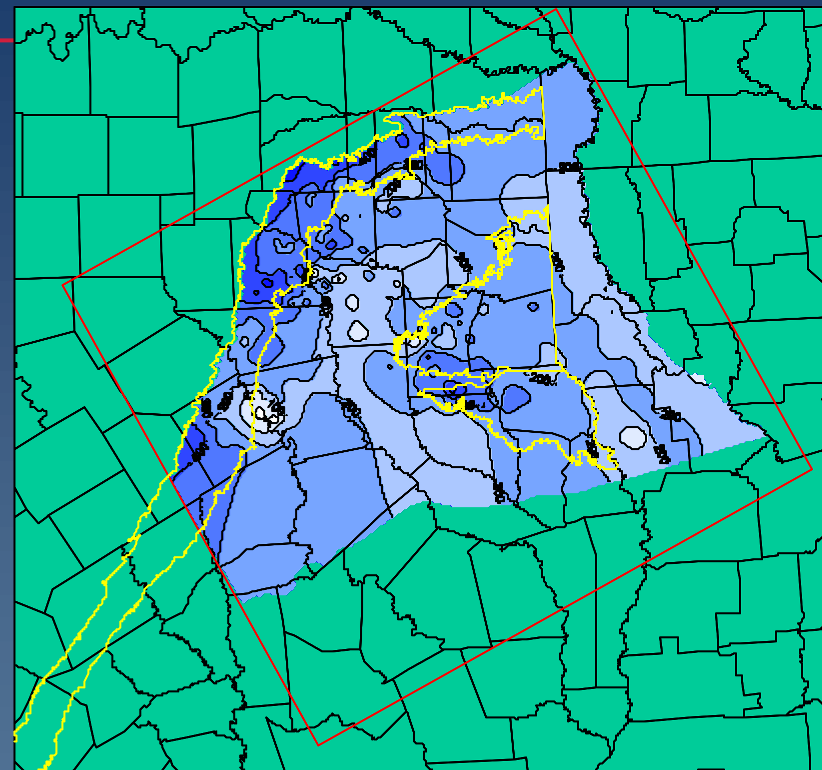
Wilcox Group - 1990 Water Level Elevations



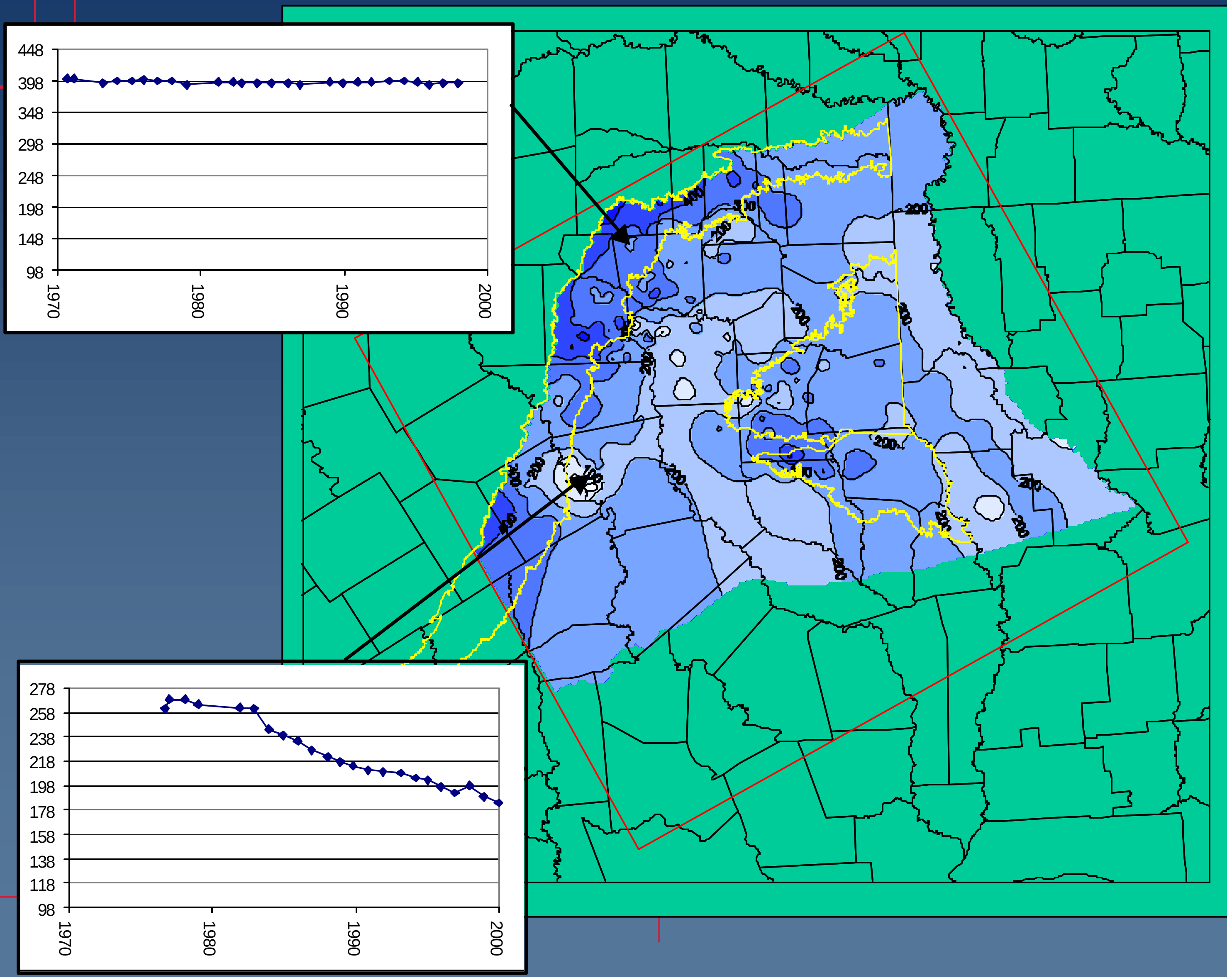
Predevelopment



1990

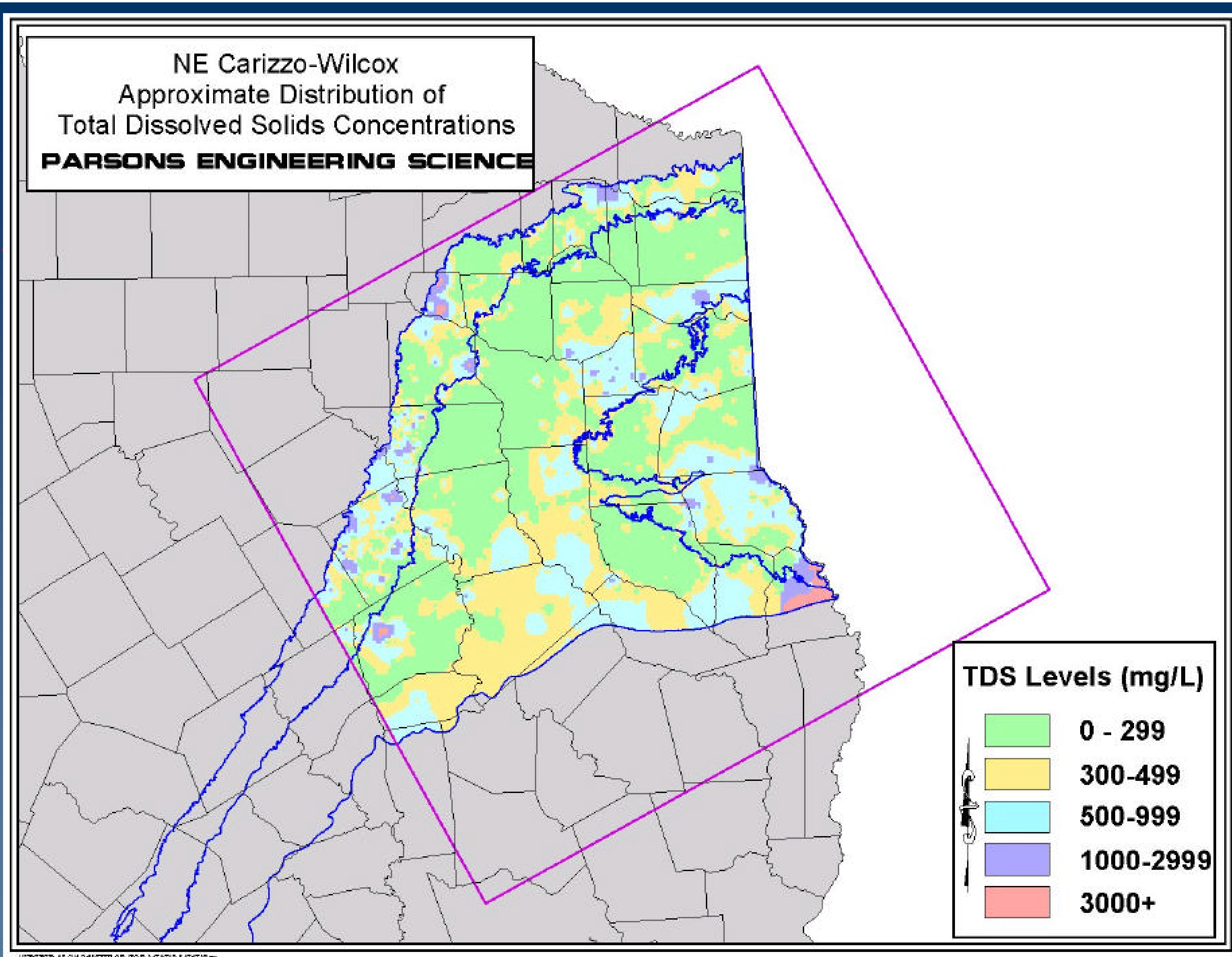


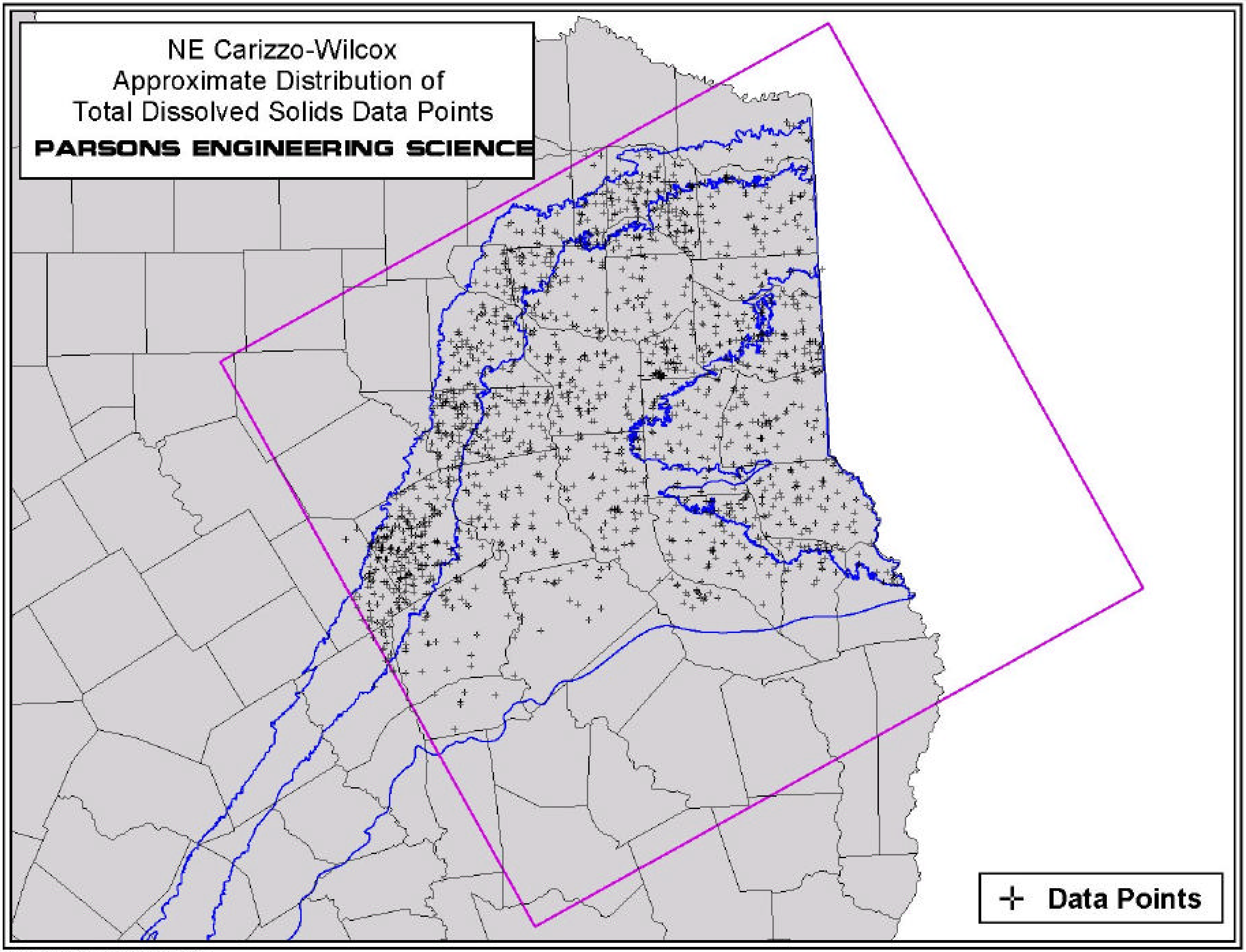
Sample Hydrographs for Calibration



Water Quality

- The GAM model does not explicitly account for groundwater quality differences through concentration or density
- As part of the GAM effort, we are developing water quality distributions for TDS and another constituent of interest to stakeholders……feedback


NE Carizzo-Wilcox
Approximate Distribution of
Total Dissolved Solids Concentrations
PARSONS ENGINEERING SCIENCE
TDS Levels (mg/L)
0 - 299
300-499
500-999
1000-2999
3000+


NE Carizzo-Wilcox
Approximate Distribution of
Total Dissolved Solids Data Points
PARSONS ENGINEERING SCIENCE
Data Points

Northern GAM Schedule

2001	SAF 1 — May 9	
	SAF 2 — Aug 1	Aug 14 — Conceptual Model
	SAF 3 — Nov	Oct. —Initial model design
		Dec. —Calibrate steady-state model
2002	SAF 4 — Jan.	Mar. —Calibrate transient model
	SAF 5 — Apr.	Jun. —Complete model predictions
	SAF 6 — July	Sept. —Prepare draft report
	SAF 7 — Sept.	Dec. —Present SAF Model Seminar
2003	SAF 8 — Jan.	Deliver Final Product

List of Attendees from
Second Stakeholder Advisory Forum
Northern Carrizo-Wilcox GAM
held
August 1, 2001
Holly Lake Ranch, Wood County, Hawkins

Name	**Affiliations**
Russ Bruner	HLR Resident
K. Darkany	Cypress Springs WSC
Frances Delk	Jones WSC
Reeves Hayter	Hayter Engineering
Sally Houk	SOSONET
Sanjeev Kalaswad	TWDB
Maryann Kennhner	SOSONET
A.D. Kleinman	SOSONET
Kelly Mills	TNRCC – Austin
Mary Morrow	Holly Lake Ranch Resort
John Pickens	Duke Engineering & Services project team
Arnold Pierce	Schaumburg & Polk, Inc.
Louis Pyle	SOSONET
Melvin Reynolds	Upshur/Gregg SWCD # 417
Linda Rutherford	SOSONET
Walt Sears	Northeast Texas MWD
Rainer Senger	Duke Engineering & Services
B.O. Spoonts	Texas Dept. of Agriculture
Burgess Stengl	Schaumburg & Polk
Charles Still	Upshur Co. Judge
John Wade	Upshur/Gregg SWCD # 417
Cecil Wallace	Holly Lake Ranch Resort
Terry Winn	Glenwood WSC

Questions & Responses from
Second Stakeholder Advisory Forum
Northern Carrizo-Wilcox GAM
held
August 1, 2001
Holly Lake Ranch, Wood County, Hawkins

Introduction

The second Stakeholder Advisory Forum (SAF) for the Northern Carrizo-Wilcox Groundwater Availability Model (GAM) was held on August 1st at Holly Lake Ranch, near Hawkins. The presentation included a review of the GAM Project Team and GAM Objectives and Expectations, and presentation of the Conceptual Model of Groundwater Flow in the Northern Carrizo-Wilcox Aquifer. The presentation material is posted at the TWDB GAM website at:
http://www.twdb.state.tx.us/gam/czwx_n/SAF2_CW-n.PDF

Meeting Questions & Responses: (not necessarily listed in the order in which they were asked or discussed)

1. Are the dots, shown on the borehole location map, all wells?

Response: The dots show the locations of boreholes that have logs available for interpreting the geology. Wells were constructed at some, but not all, of these locations.

2. How does the water in a stream enter the aquifer?

Response: If the hydraulic head or piezometric level below a stream is lower than the water level in a stream, then it is called a losing stream and water will flow from the stream down into the aquifer.

3. Are the hydraulic conductivities (K) an average for the total thickness of the aquifer?

Response: The hydraulic conductivities are typically determined based on the screen length in a well. Typical screen lengths are 100 to 200 feet. Tests are biased to the more permeable intervals of the aquifer because these are the intervals that are targeted for water supply.

4. Have major recharge areas in the model area been mapped/delineated?

Response: Greater recharge is expected in the outcrop areas that have higher hydraulic conductivities, higher elevations, and higher relative amounts of precipitation. The areal and temporal variation of recharge used to calibrate the model will be included in the model documentation.

5. What temporal data is available for streamflow?

Response: The streamflow data shown in the presentation are mean flows for the history of the gage and stream flow measurements performed by USGS personnel (R. Slade).

Also, streamflow data for selected river basins in Texas is available on a daily basis for the past 18 months on the USGS website at: http://tx.water.usgs.gov/nwisbin/current/?group=basin&type=unit

6. Why does Angelina County withdraw so much groundwater?

Response: A large percentage of water pumped is for industrial use in Angelina County.

7. Is the water-level elevation a depth to water?

Response: The water-level elevation is calculated as the elevation of the top of the well minus the depth to water measured from the top of the well. Flow directions in the aquifer can be determined based on differences in water-level elevation in different wells.

8. What was the time period of the hydrographs?

Response: The time period was from 1970 to 2000.

9. In what part of Wood County is the well located for the presented hydrograph?

Response: It is taken from a well in the northwestern corner of Wood County

10. What is the depth below ground surface for the Wilcox?

Response: The Wilcox outcrops at ground surface at its updip limit in the north or northwest. Downdip, it varies from about 500 feet depth to more than 10,000 feet depth below ground surface along the southern model boundary.

11. Will the baseline data be available on the TWDB website? When the model is complete, will the information be available on a 1-mile square basis?

Response: Yes, the model and all supporting data will be posted on the TWDB website at the conclusion of the project. We will interpolate between actual data points to develop data input on 1-mile square basis. Data may be averaged over the 1-mile area and also vertically over the model layer thickness. This is a model limitation on representativeness of the model to actual conditions.

12. Is the TDS data biased to wells that are producing and have good quality water?

Response: Yes, this is likely true. Water quality may be checked before a well is completed. If quality were poor, the well would not be completed or not completed at that depth. If a well is not completed, there may not be a report submitted and recorded in State records. TDS concentration may vary with depth at a particular location.

13. Would it be possible to differentiate in the model between producing and nonproducing zones?

Response: The model is limited to the layers that are defined to represent the geology or hydrostratigraphy (i.e., shallow aquifers, Reklaw, Carrizo, Upper Wilcox, Middle Wilcox, and Lower Wilcox). The model will not be able to model vertical intervals smaller than these model layers. We may plot TDS along several cross sections to address the question of variation of water quality at various producing depths.