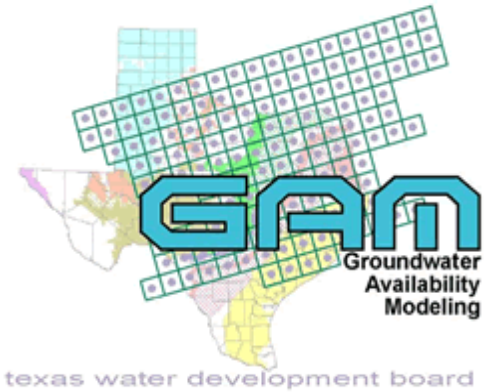
Stakeholder Advisory Forum - 7

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



City of Nacogdoches, Parks and Recreation Center

Nacogdoches, Texas

October 29th, 2002

INTERA

PARSONS

WATERSTONE
Environmental Hydrology and Engineering, Inc.

Presentation Outline

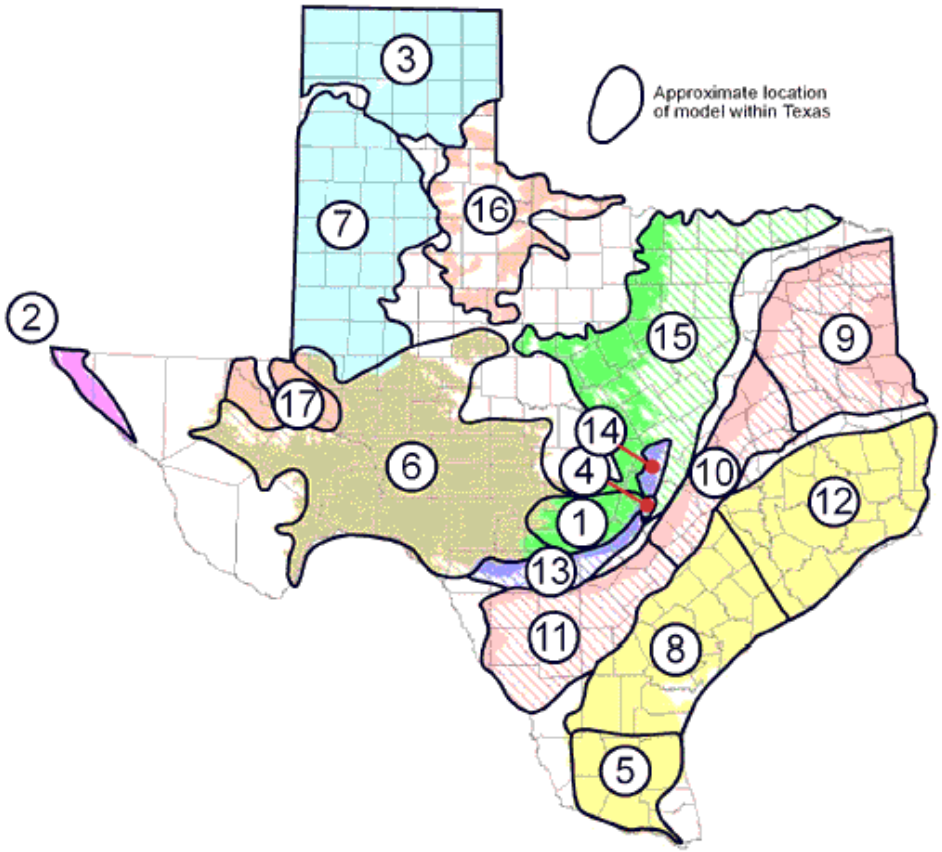
- GAM Review
- Model Review and Issues
- Transient Modeling
- Predictive Modeling
- Conclusions/Issues
- GAM Schedule

GAM Objectives

- Develop realistic and scientifically accurate GW flow models representing the physical characteristics of the aquifer and incorporating the relevant processes
- The models are designed as tools to help GWCD, RWPGs, and individuals assess groundwater availability
- Stakeholder participation is important to ensure that the model is accepted as a valid model of the aquifer

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)



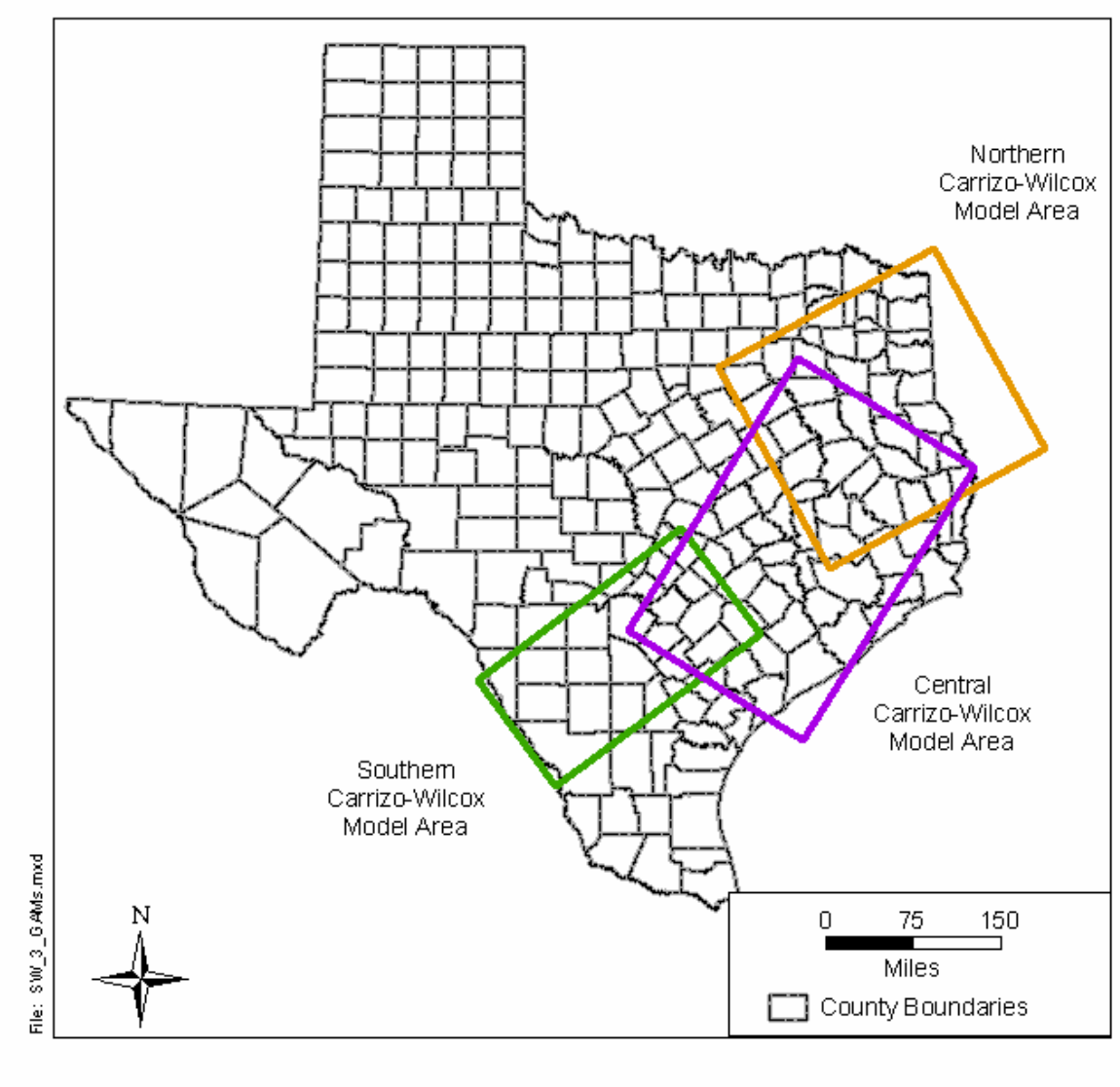
Model Specifications

- Three dimensional (MODFLOW-96)
- Regional scale (100's of mi2)
- Grid spacing of 1 square mile
- Include Groundwater/surface water interaction (Stream routing)
- Properly implement recharge
- Stress periods as small as 1 month
- Calibration within 10% of head drop

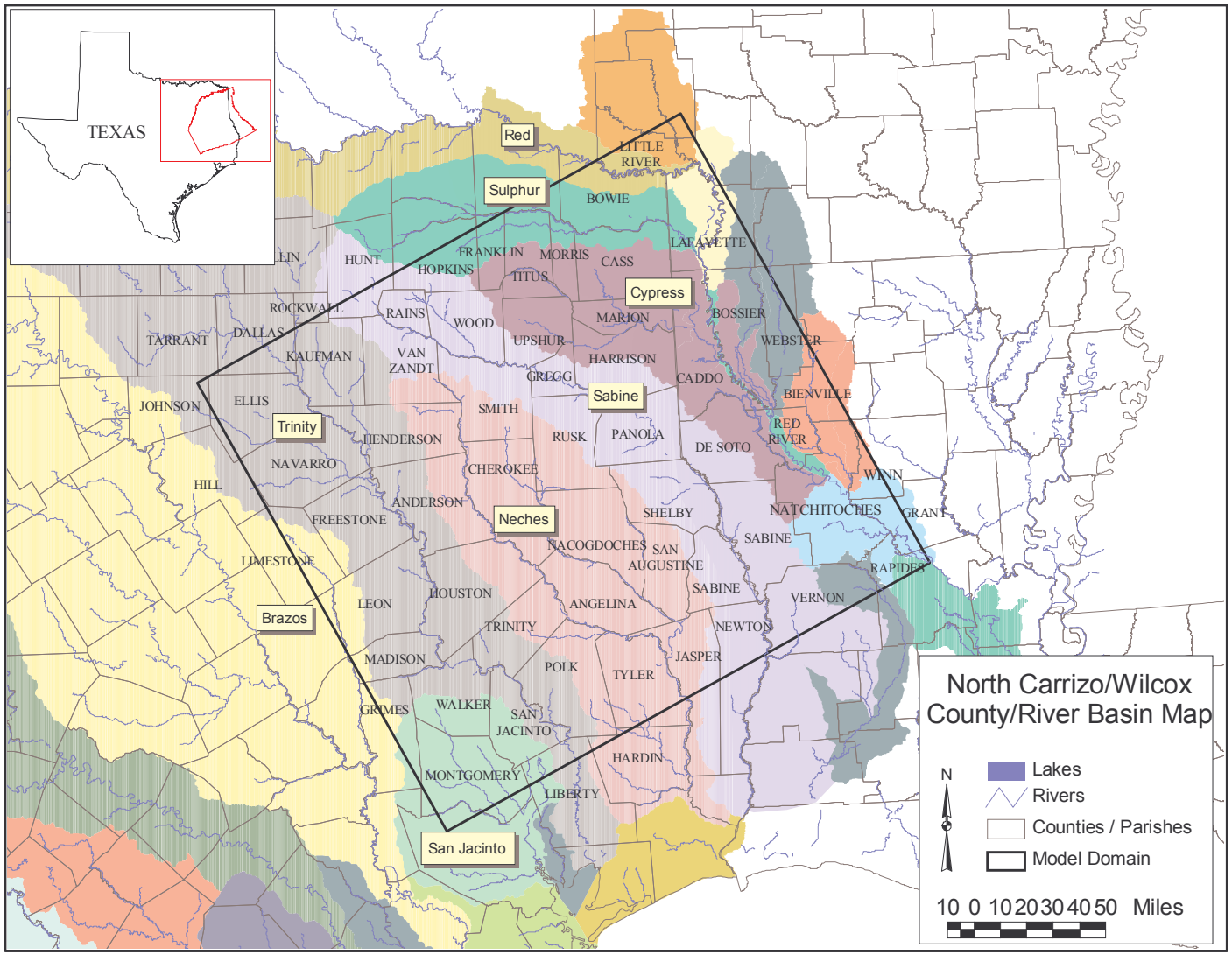
Presentation Outline

- GAM Review
- Model Review
- Transient Modeling
- Predictive Modeling
- Model Limitations
- GAM Schedule

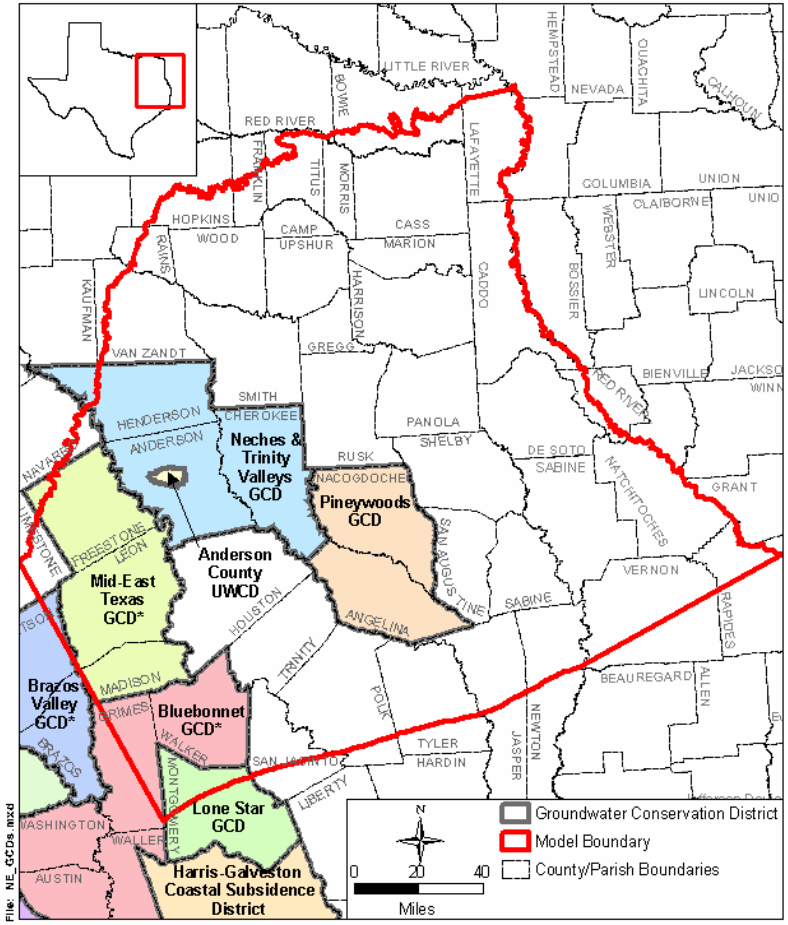
Carrizo-Wilcox GAMs



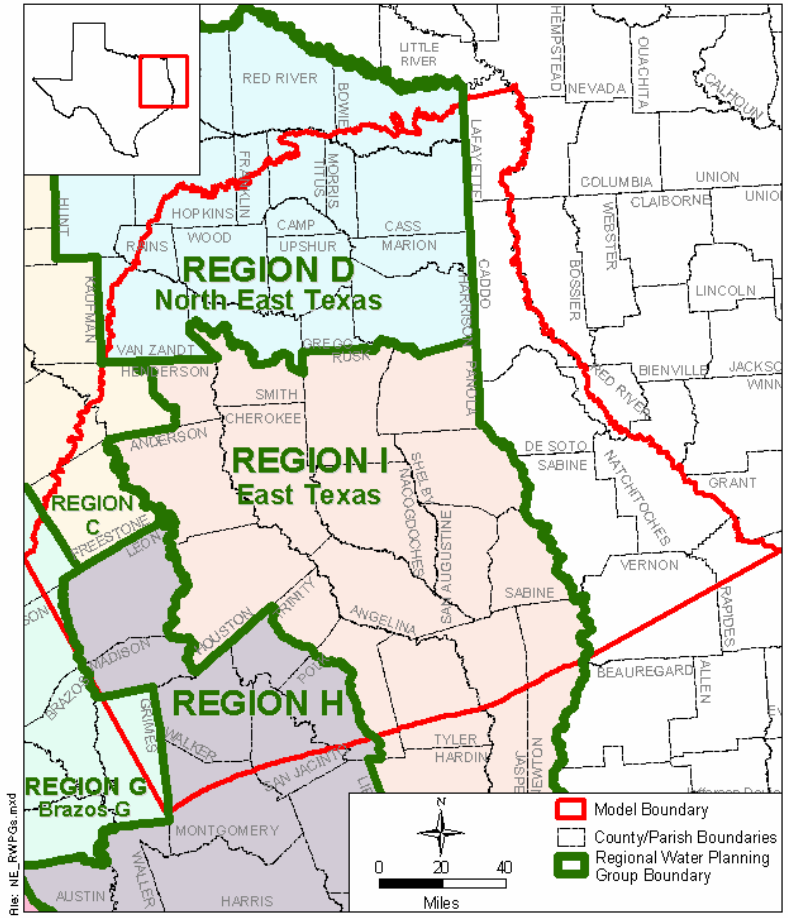
Northern Carrizo-Wilcox GAM



GWCDs & RWPGs

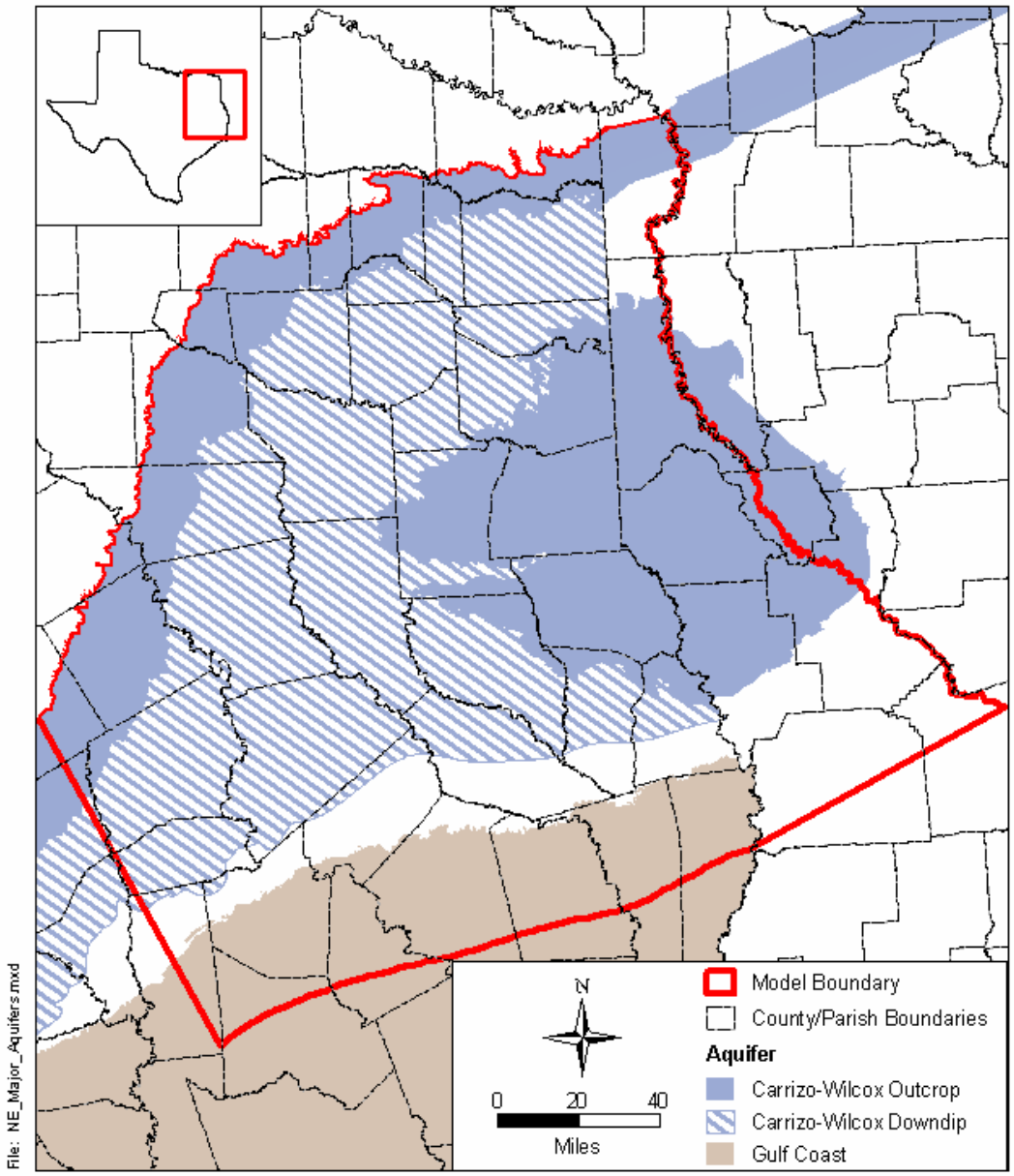


*=Pending Confirmation
UWCD=Underground Water Conservation District
GCD=Groundwater Conservation District
Source: Online: Texas Water Development Board, August 2002



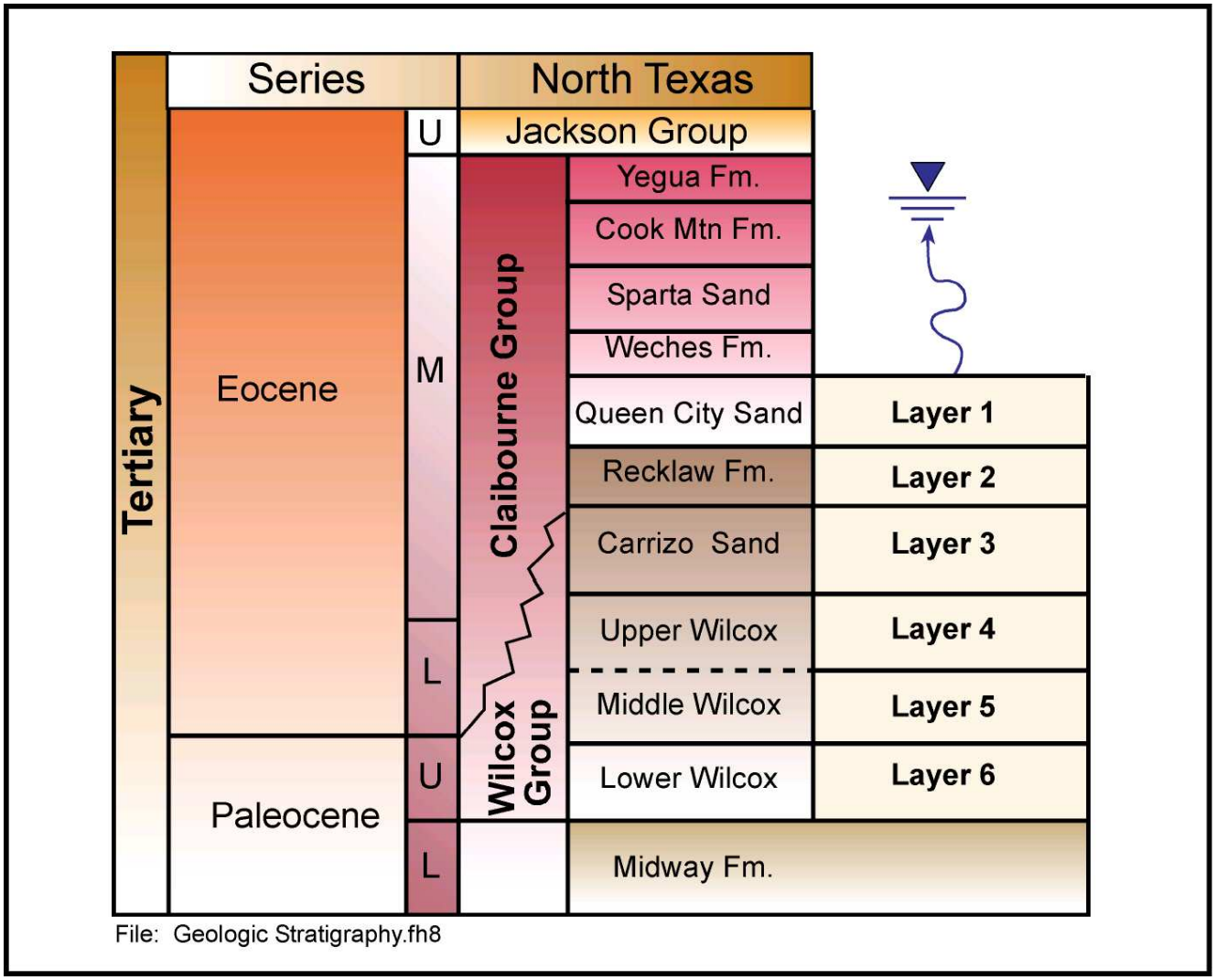
Source: Online: Texas Water Development Board, September 2002

Outcrop of major Aquifers

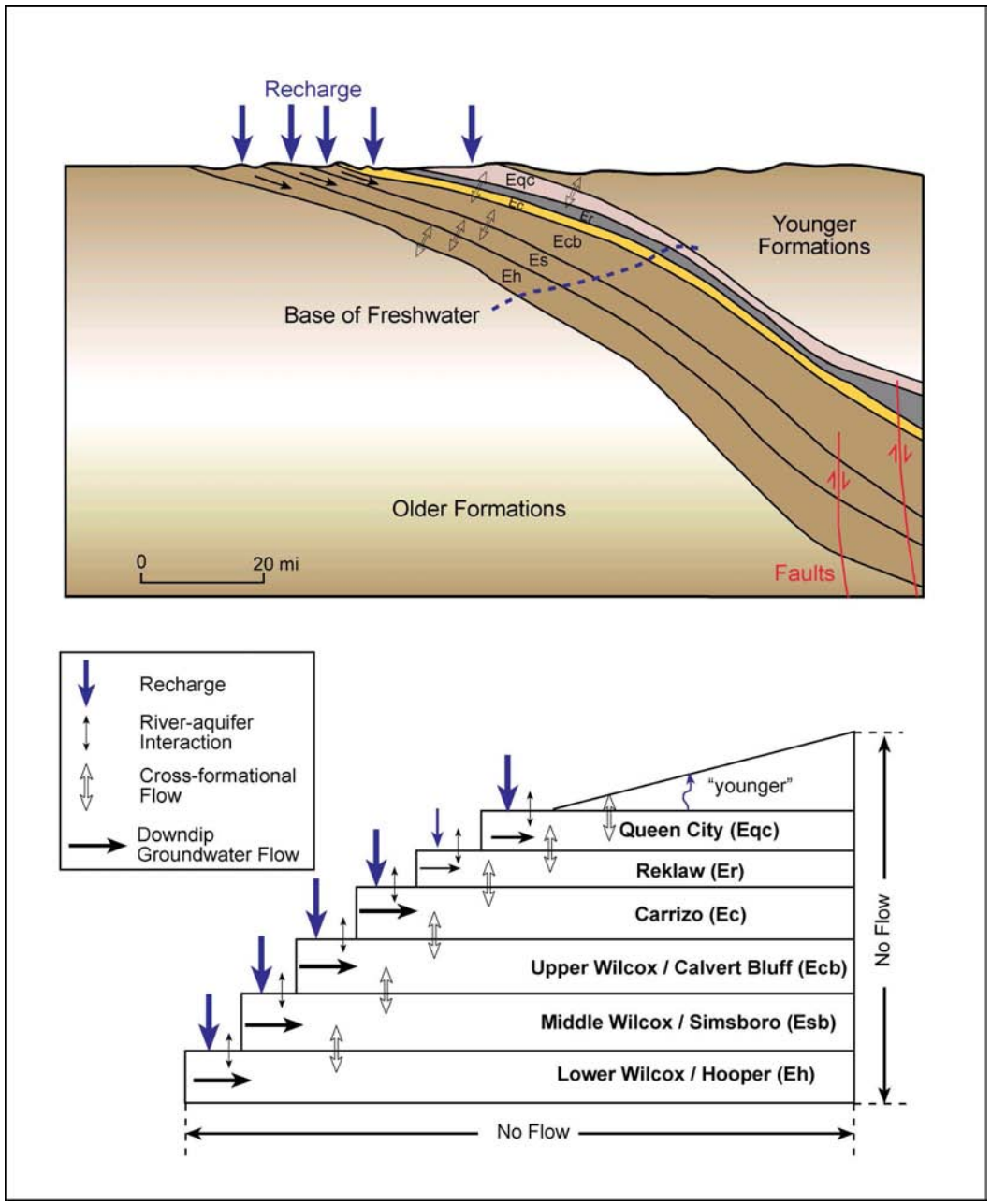


Source: Online: Texas Water Development Board, September 2002, Bureau of Economic Geology

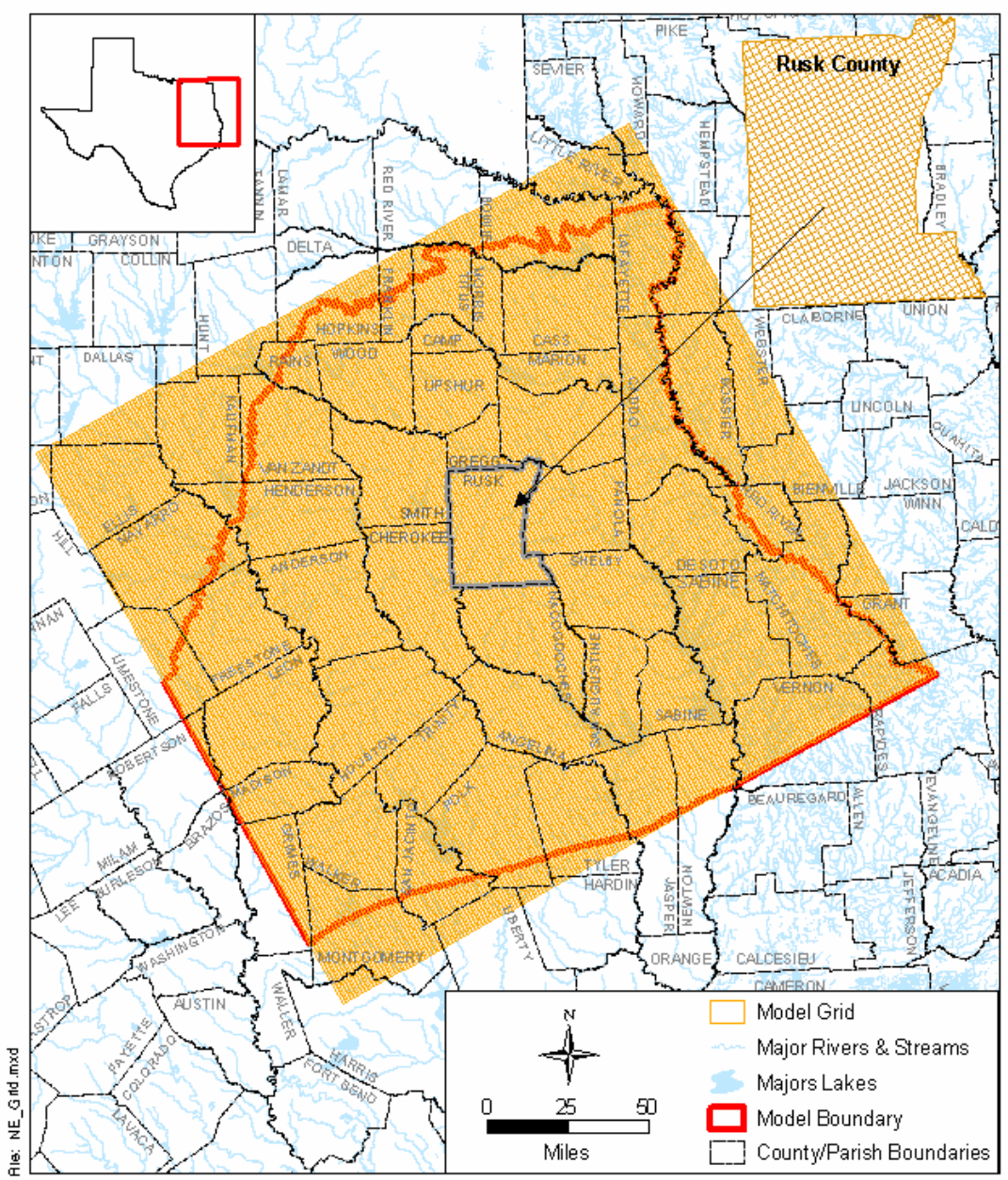
Hydrostratigraphy and Model Layers



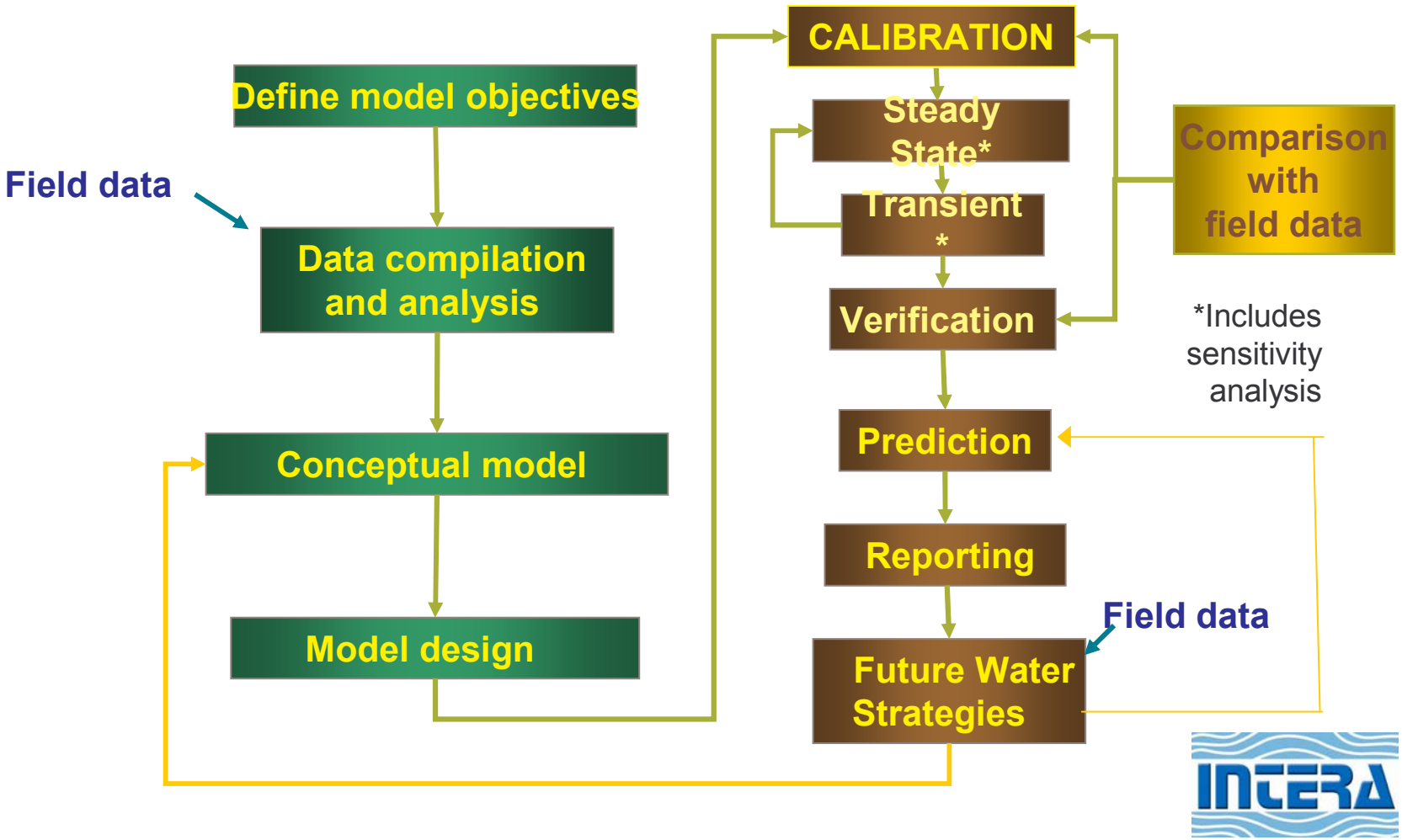
Conceptual GW Flow Model



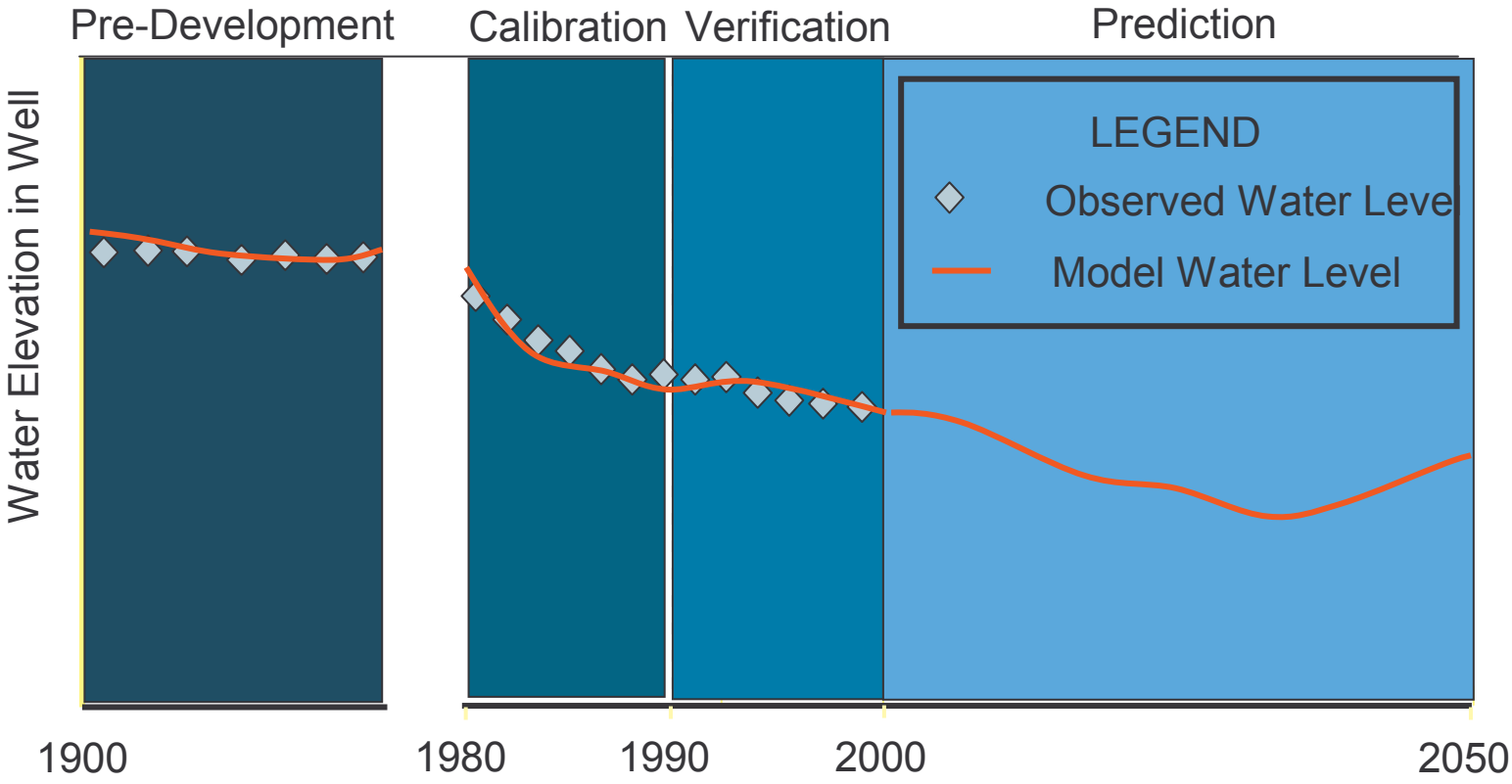
Model Grid


Rusk County
PIKE
SEVIER
HOWARD
LITTLE RIVER
HEMPSTEAD
BRADLEY
LAMAR
RED RIVER
DELTA
GRAYSON
COLLIN
HUNT
DALLAS
HOPKINS
FRANKLIN
TITUS
WOOD
CAMP
CASS
MARION
UPSHUR
MORRIS
CHEROKEE
ANDERSON
HENDERSON
VAN ZANDT
SMITH
GREGG
RUSK
PANOLA
SHELBY
NACOGDOCHES
SABINE
AUGUSTINE
JASPER
NEWTON
ORANGE
TYLER
HARDIN
JEFFERSON
CHAMBERS
LIBERTY
MONTGOMERY
WALLER
HARRIS
FORT BEND
AUSTIN
WASHINGTON
BRAZOS
ROBERTSON
LIMESTONE
FALLS
LEON
FREESTONE
NAVARRO
ELLIS
HILL
CLAIBORNE
UNION
WEBSTER
BOSSIER
UNCOLN
JACKSON
WINN
DESOTO
GRANT
VERNON
BEAUREGARD
ACADIA
CALCASIEU
CAMERON
N
0
25
50
Miles
Model Grid
Major Rivers & Streams
Majors Lakes
Model Boundary
County/Parish Boundaries
File: NE_Grid.mxd

Modeling Protocol



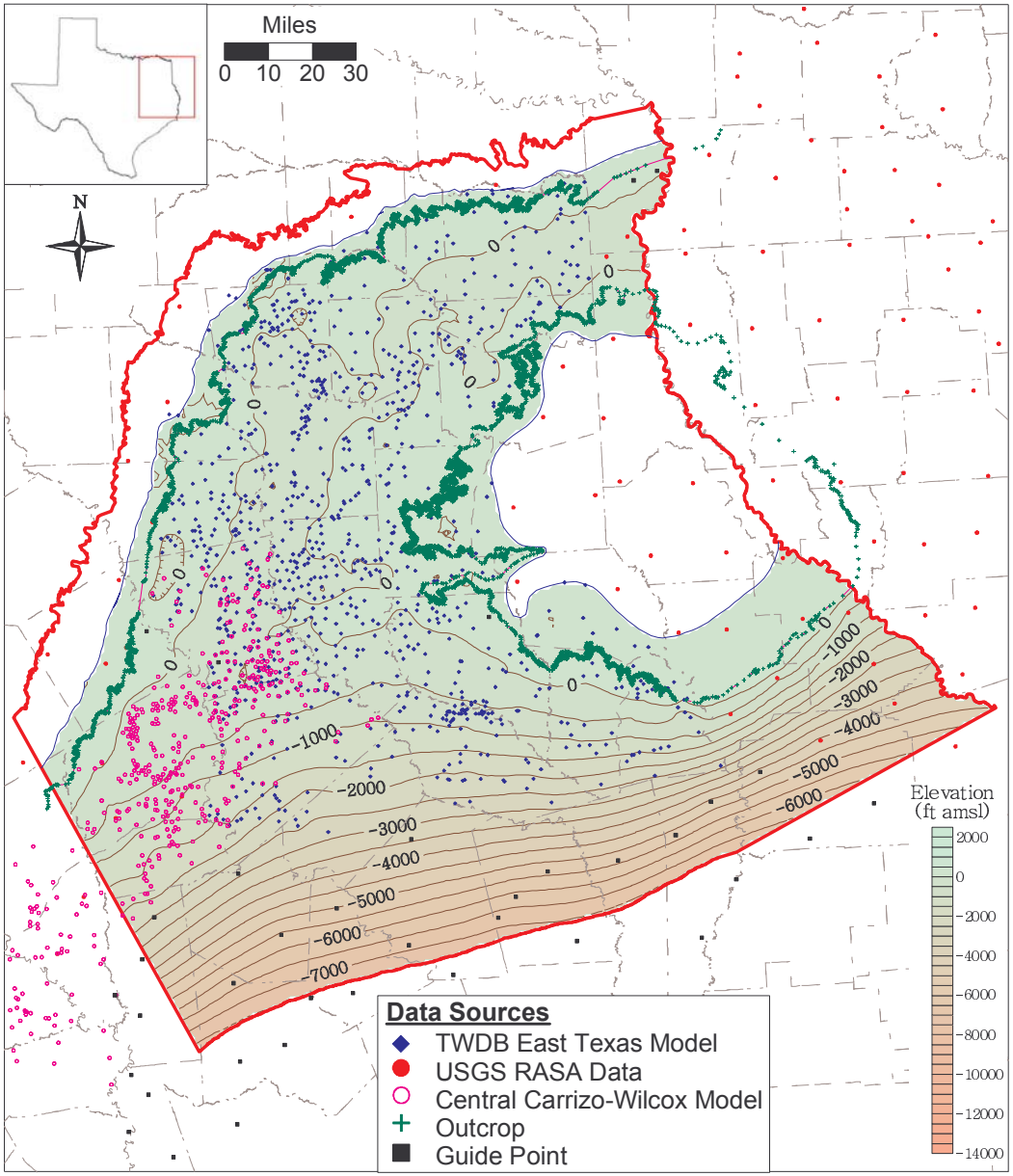
Modeling Periods



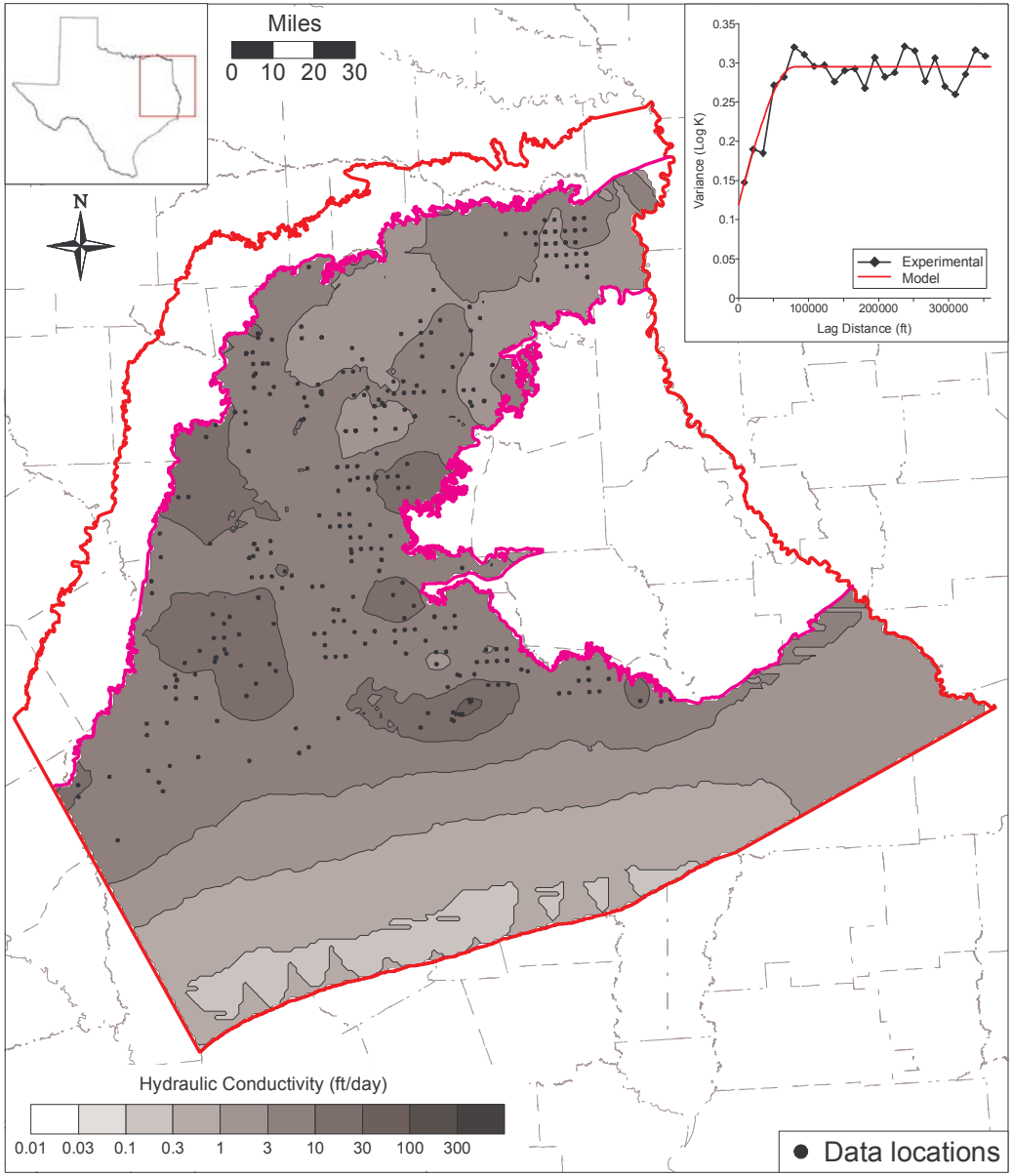
Model Input

- Hydrostratigraphic Surfaces for each Layer
- Hydraulic Properties:
  - Sand Thickness
  - Hydraulic Conductivity
  - Storativity (transient)
- Recharge
- Stream Flow
- Pumpage (transient)
- Reservoir Stages

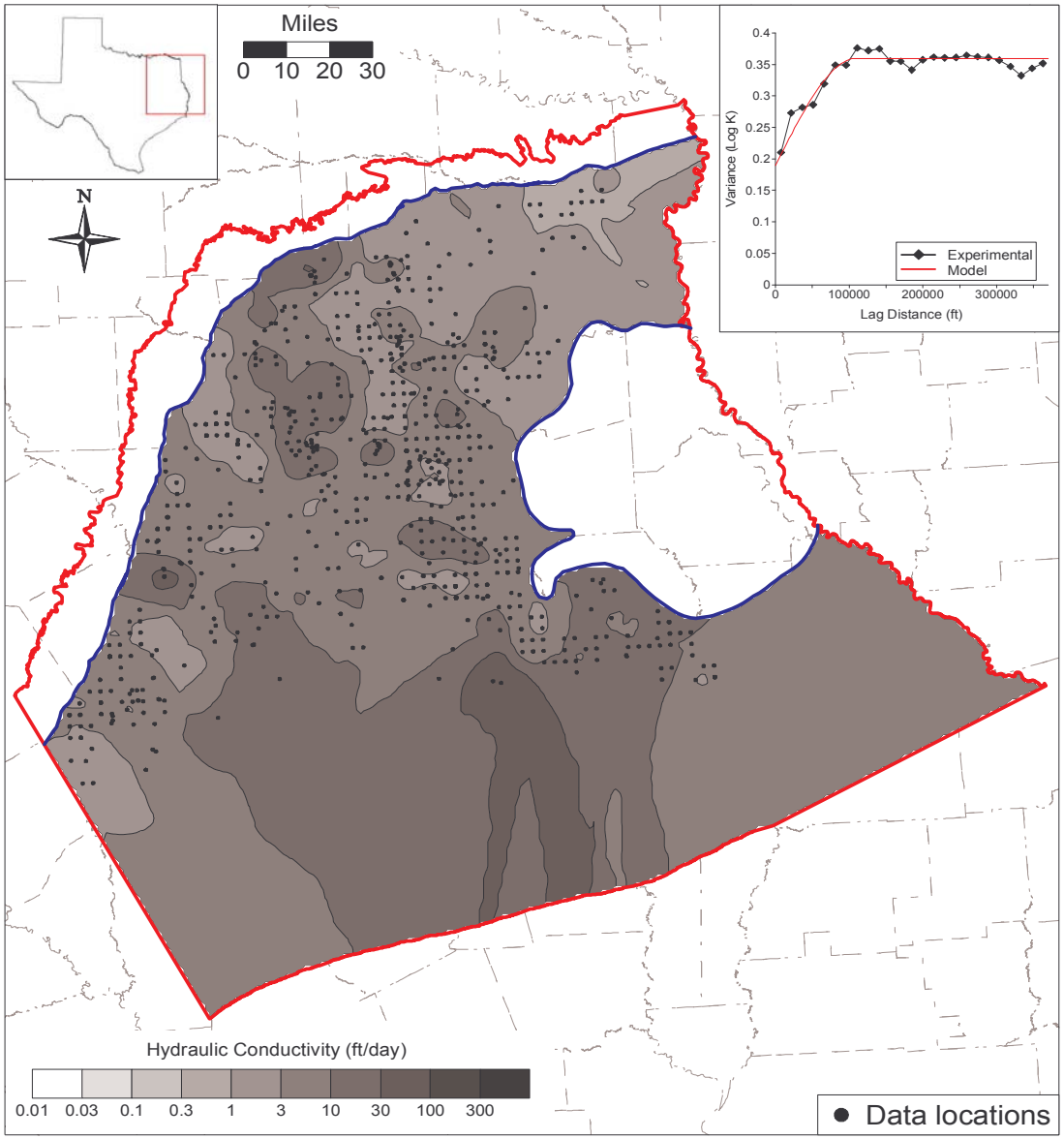
Structure Top of Wilcox



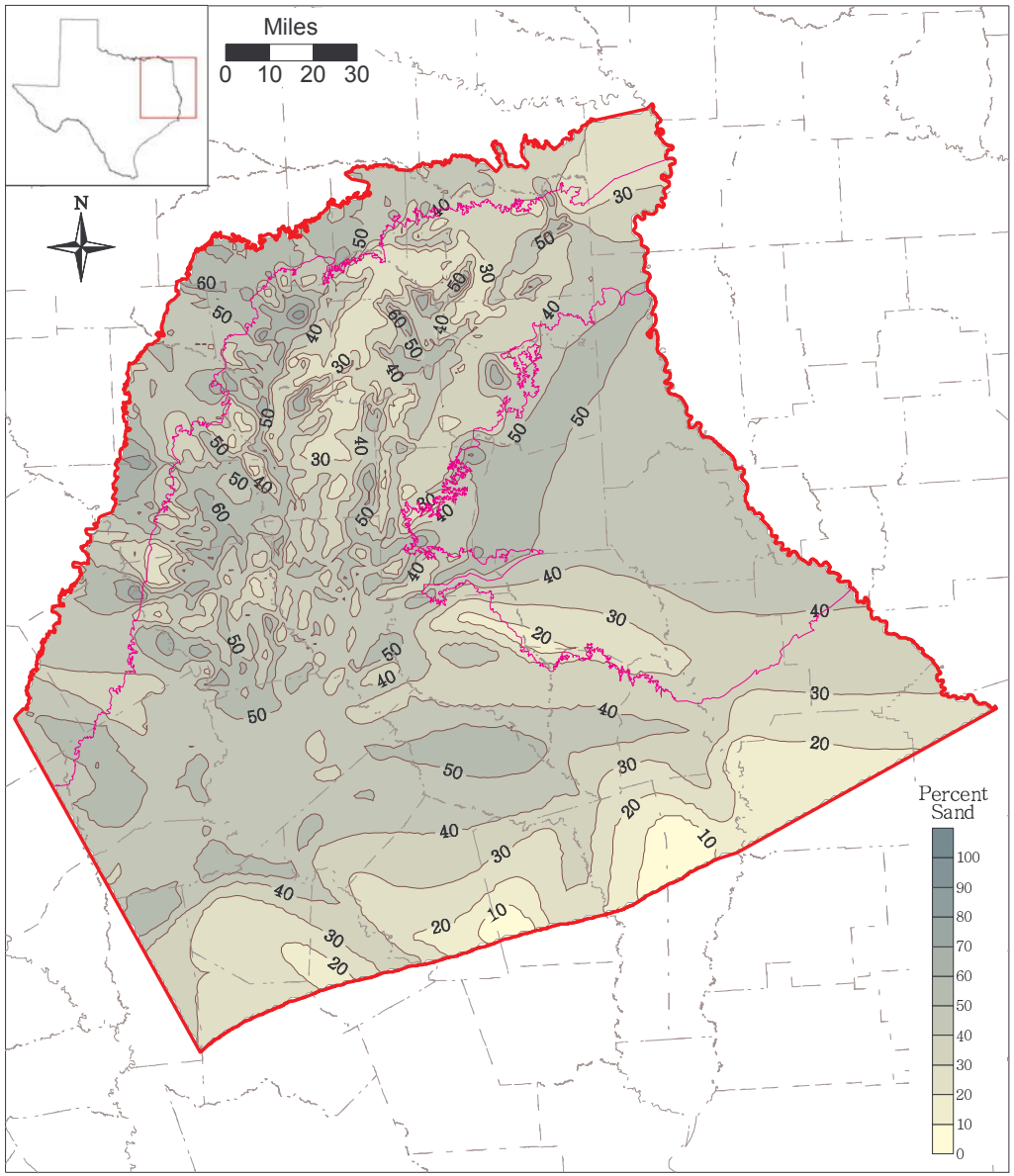
Carrizo: Hydraulic Conductivity



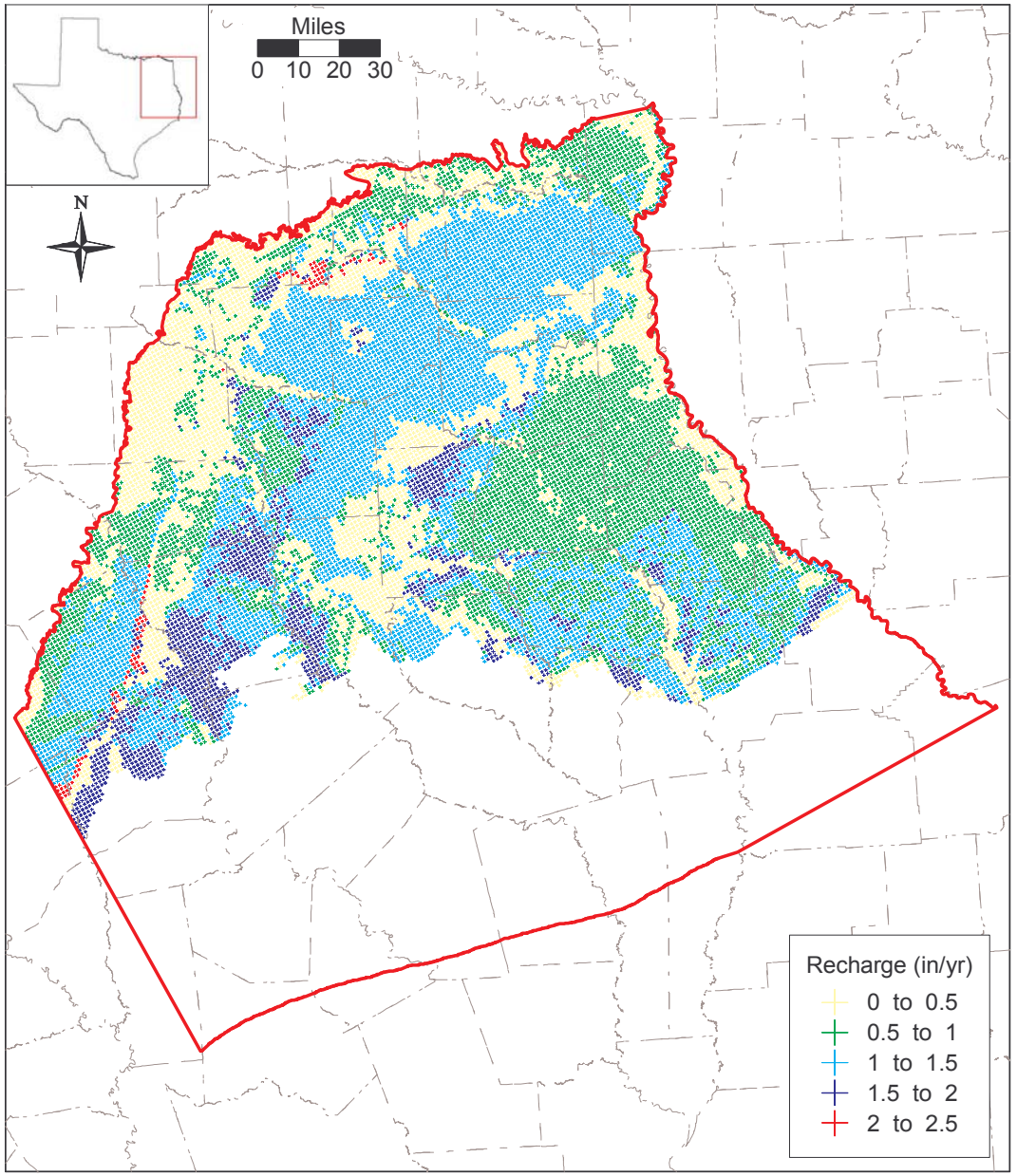
Upper Wilcox Hydraulic Conductivity



Sand Percent Wilcox



SWAT Recharge Distribution, calibrated for steady-state conditions



Recharge Estimation: SWAT (Soil and Water Assessment Tool)

- SWAT developed by Blacklands Research Center
- Physically based (primarily) watershed scale model
- Infiltration/runoff based on SCS Curve Number method (daily timestep)
  - Land use
  - Soil type
  - Antecedent soil condition
- Recharge = Infiltration – Evapotranspiration

Categories of Groundwater Use

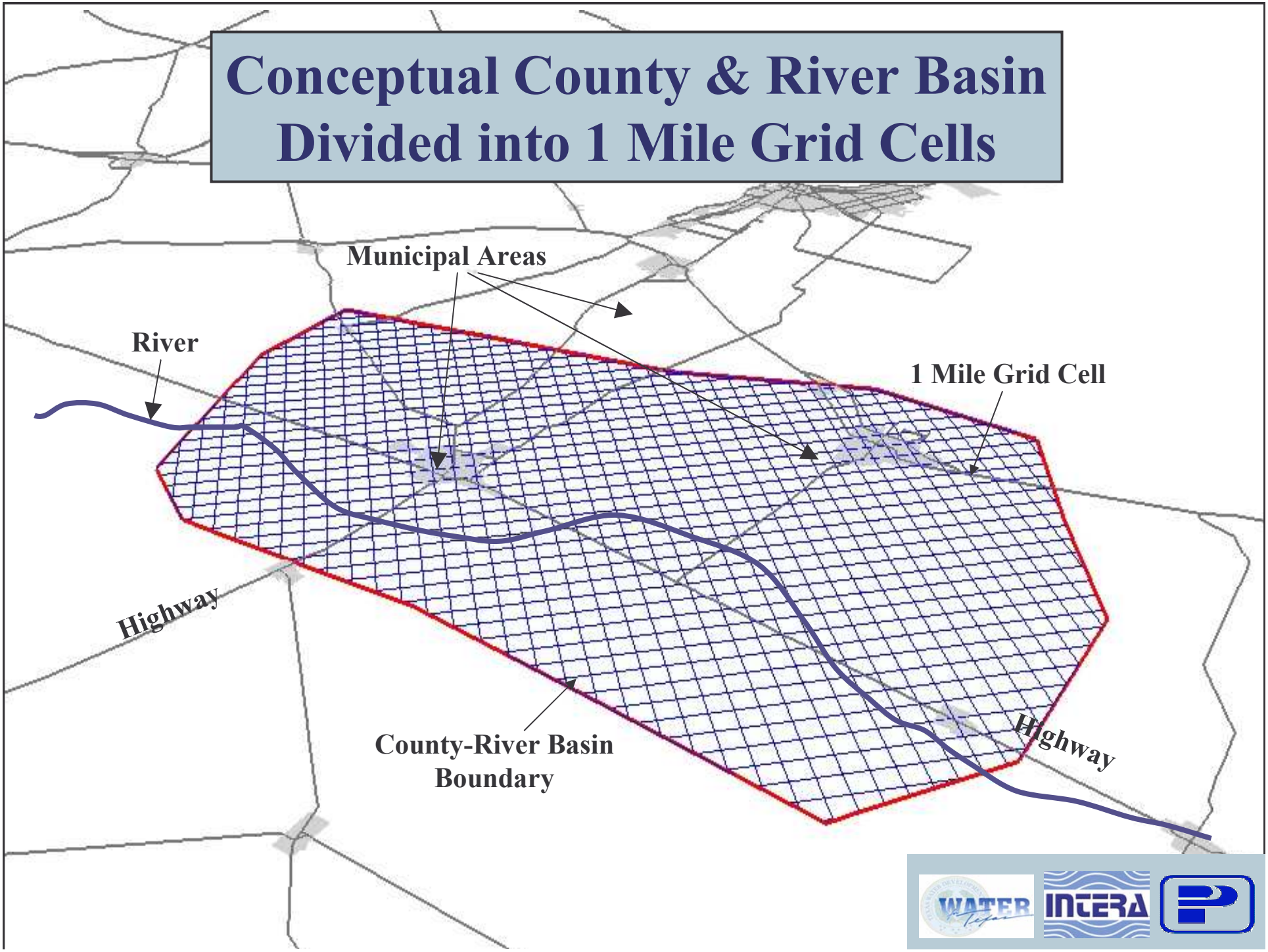
Point Source Data

Municipal
Manufacturing
Power
Mining

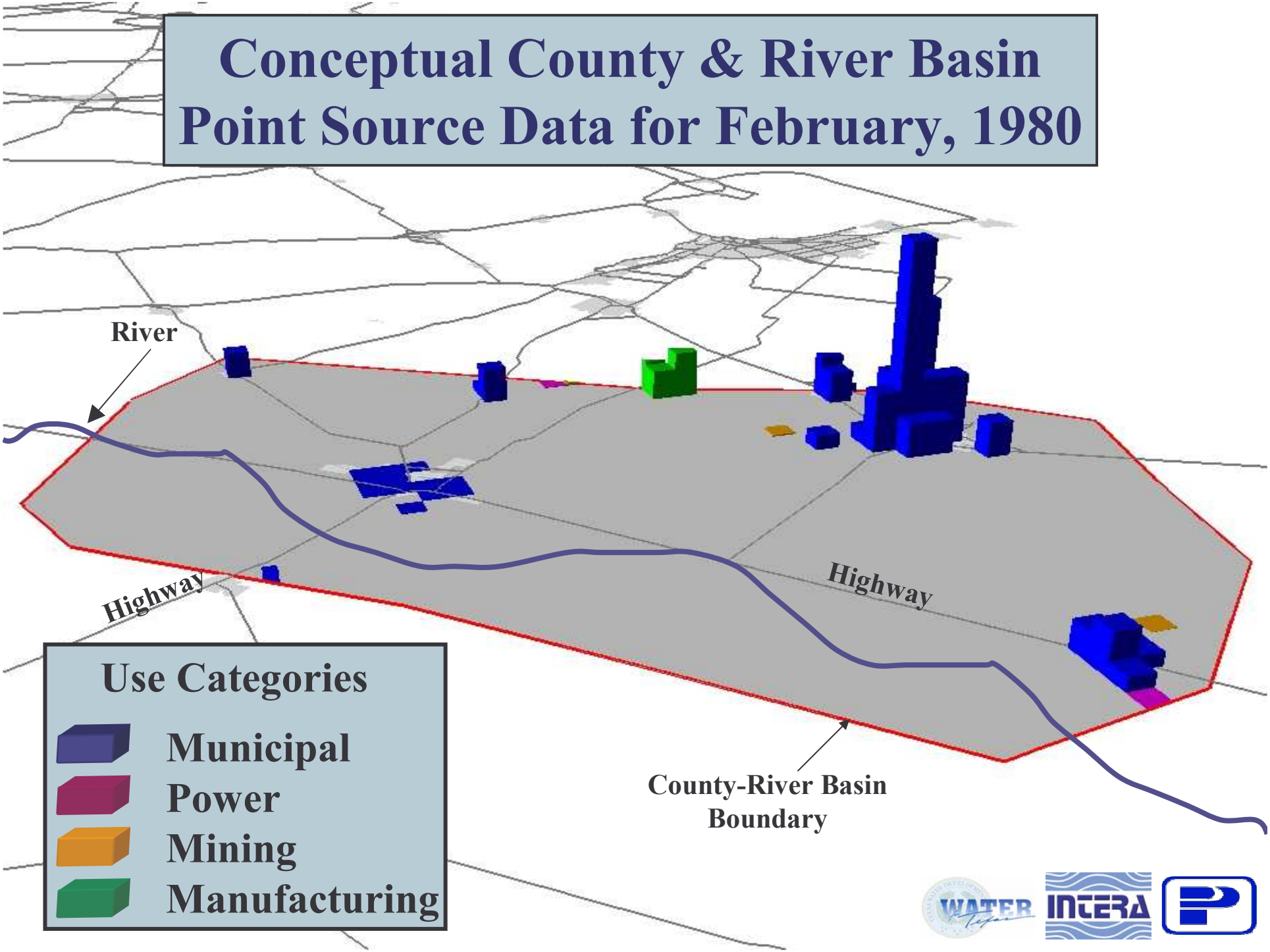
Non-Point Source Data

- **Irrigation**
- **Livestock**
- **Rural Domestic**

Conceptual County & River Basin Divided into 1 Mile Grid Cells



Conceptual County & River Basin Point Source Data for February, 1980



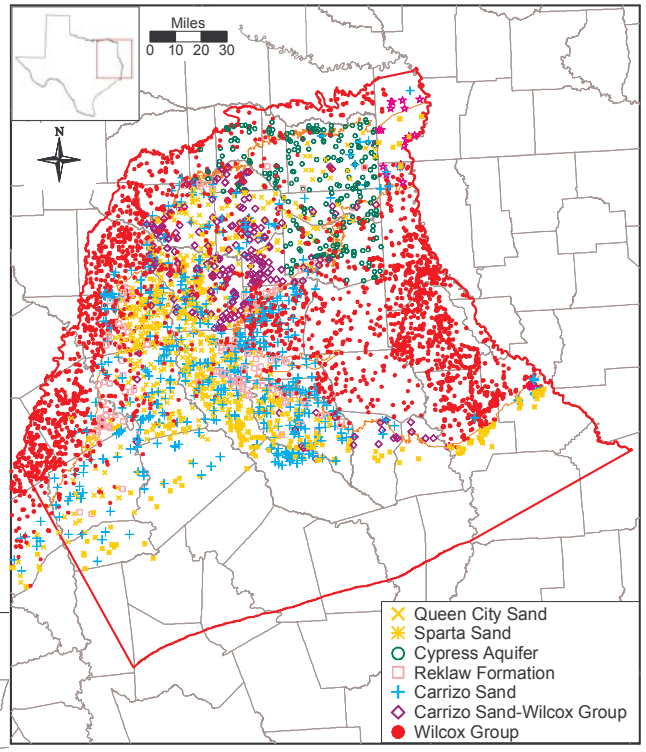
Locate Pumpage Using Non-PointSource Data

2. Rural Domestic Pumpage

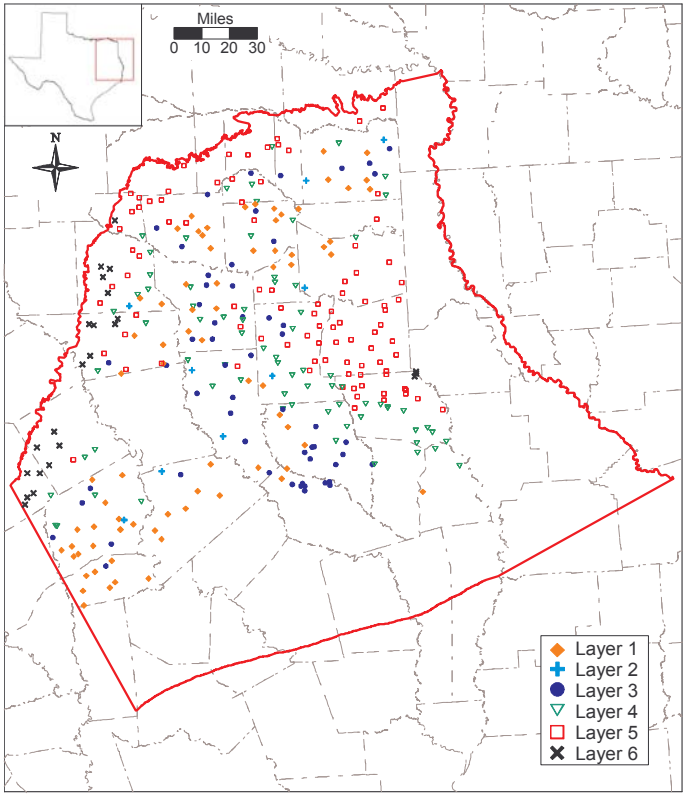
- Distribute pumpage data based on population density, excluding municipalities with a Public Water Supply
- Distribute annual pumpage into monthly increments in proportion to nearby larger municipalities
- Well depths assigned from nearby wells in TWDB well database

Water-Level Data

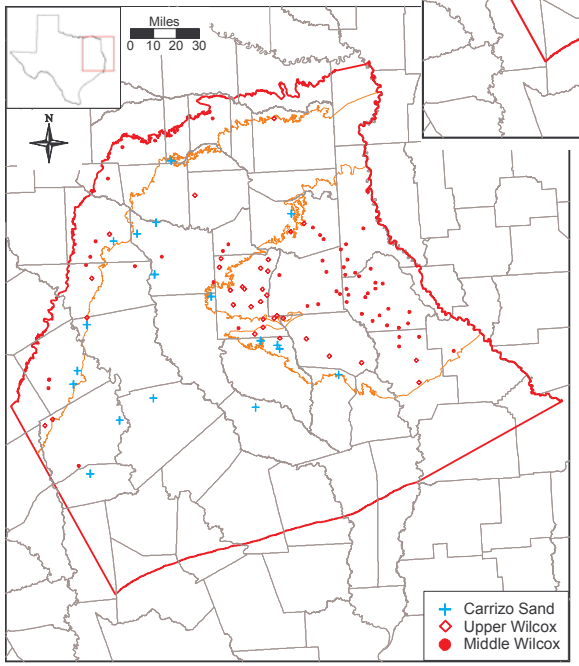
All data



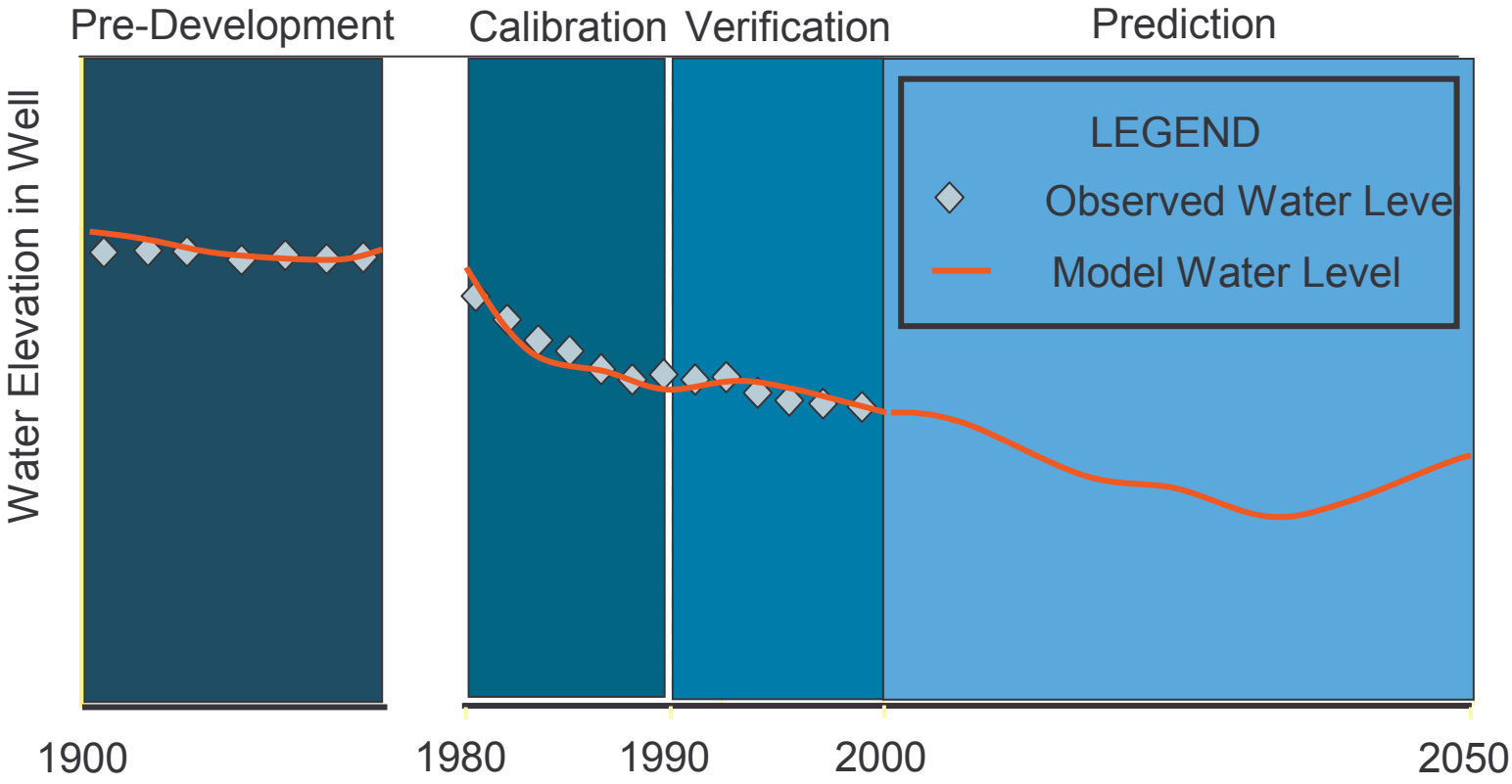
Transient Calibration



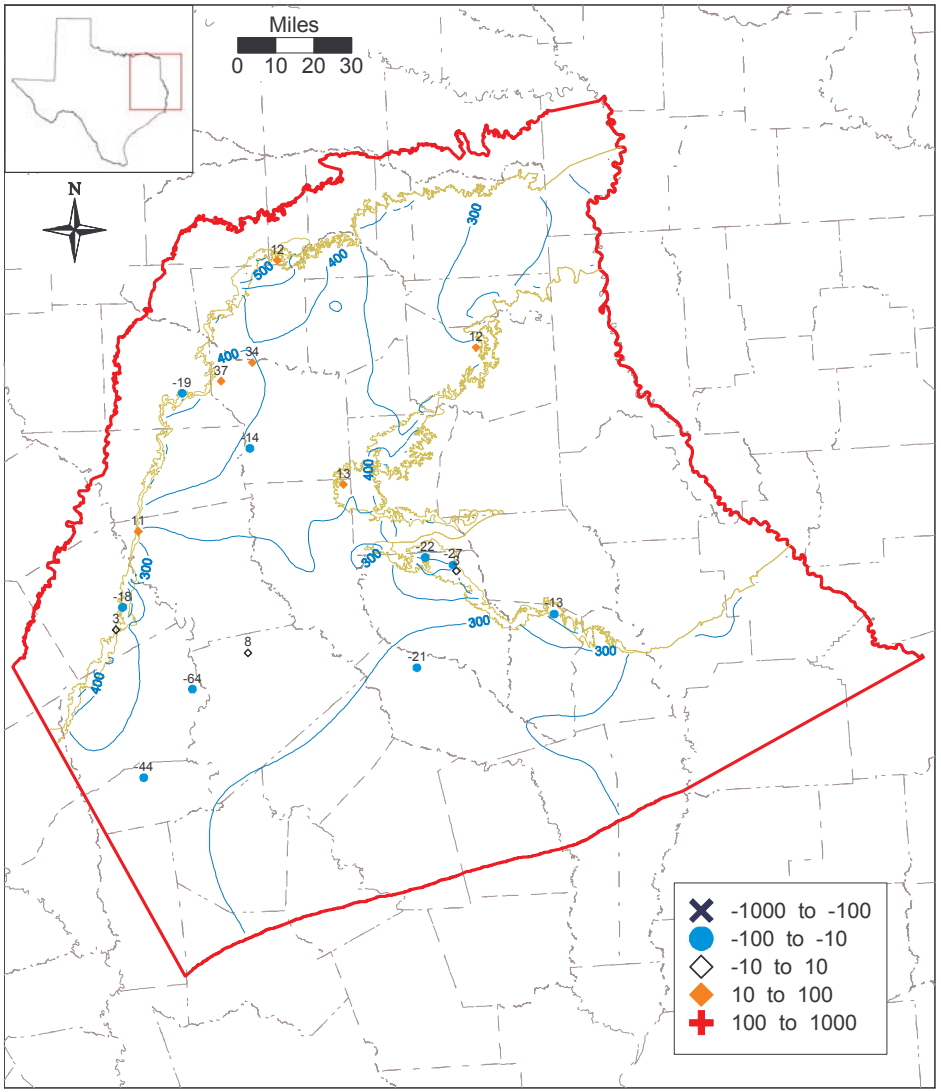
Pre-Development

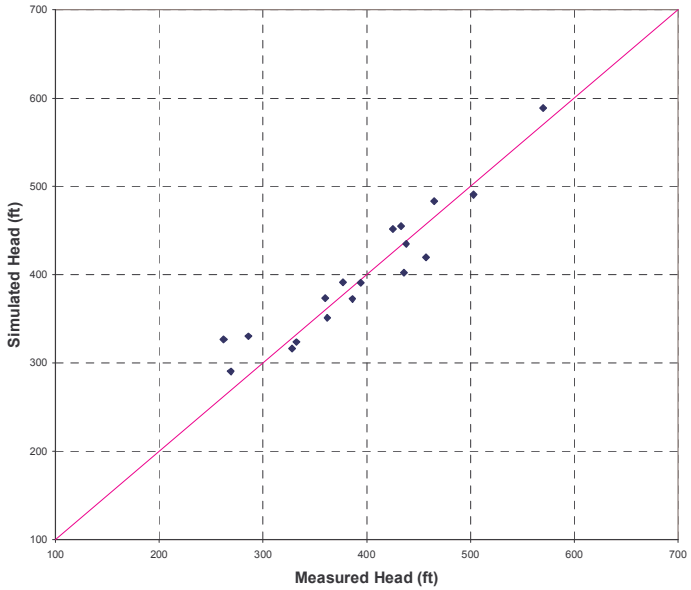


Modeling Periods



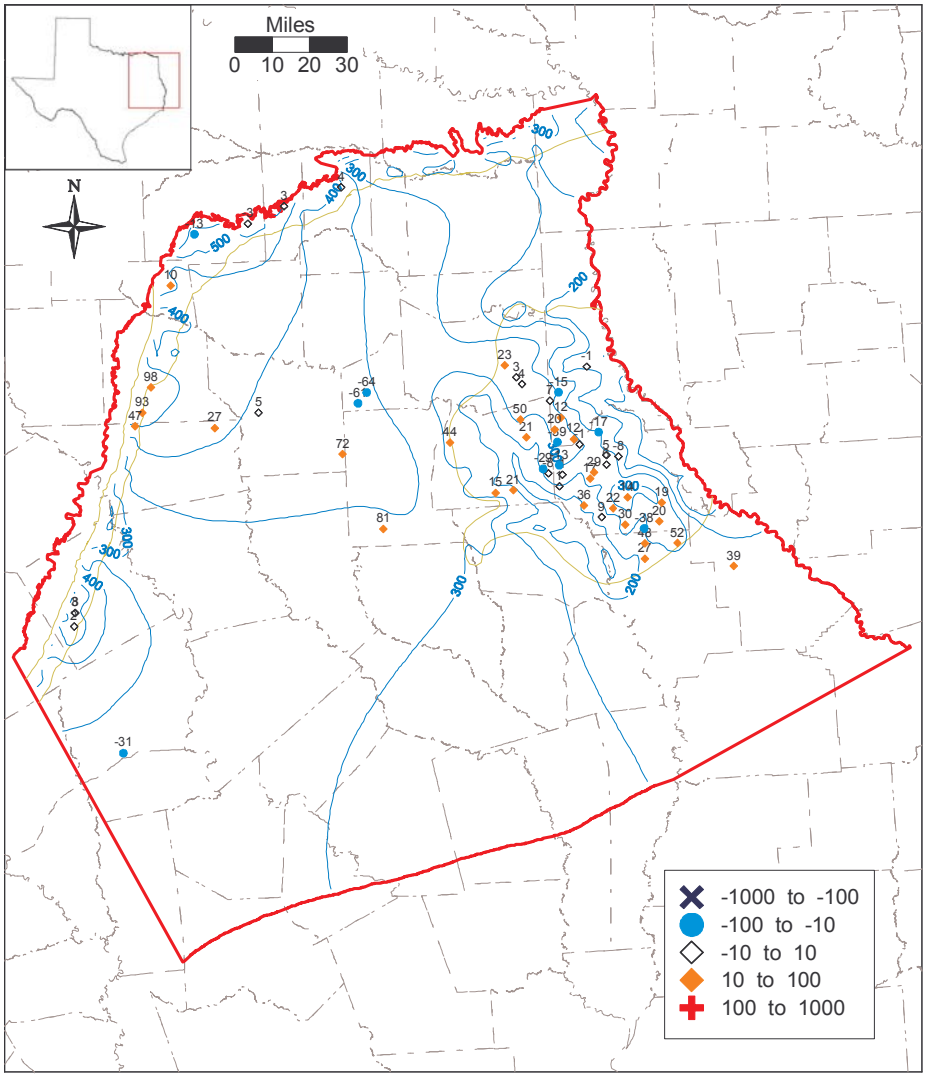
Pre-development Calibration: Carrizo

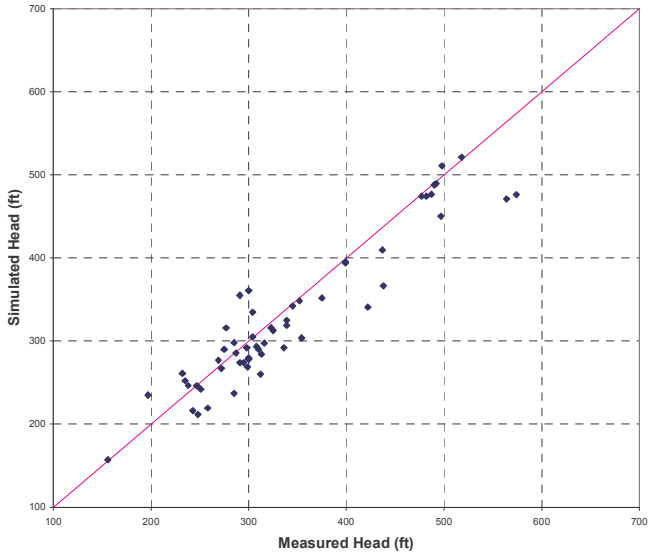




Layer	Total RMS (ft)	Range (ft)	Adj. RMS
Layer 1	45.8	366	0.13
Layer 3	25.9	308	0.08
Layer 4	38.5	257	0.15
Layer 5	33.9	418	0.08

Pre-development Calibration: Middle Wilcox





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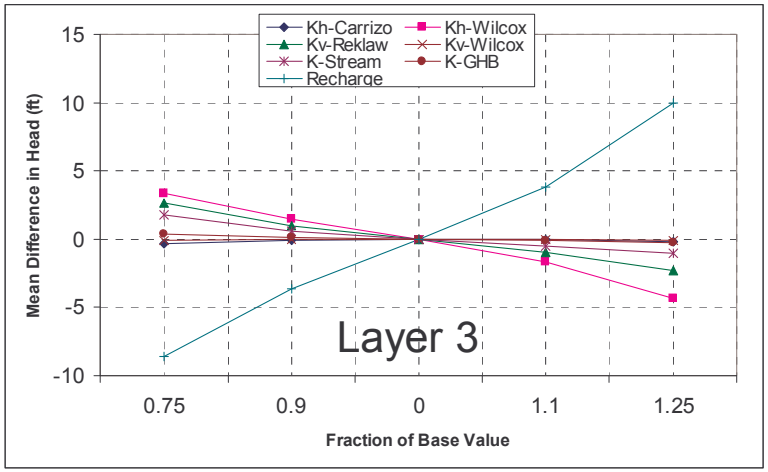
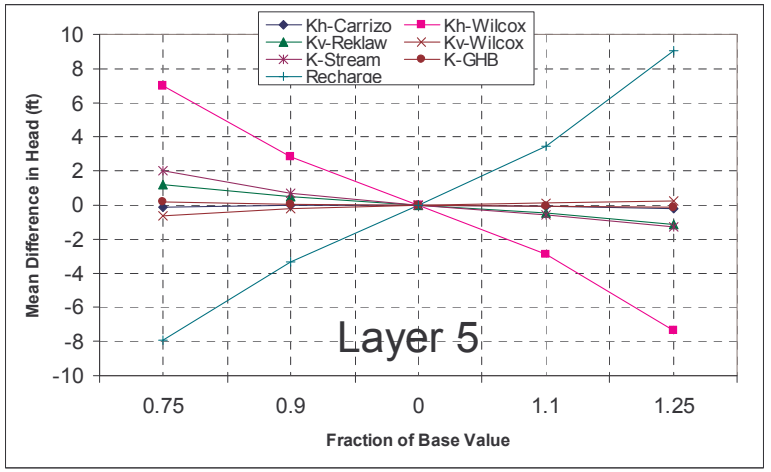
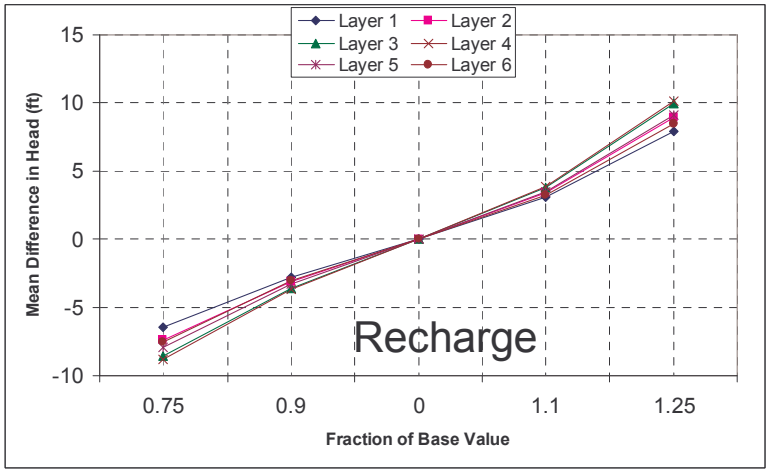
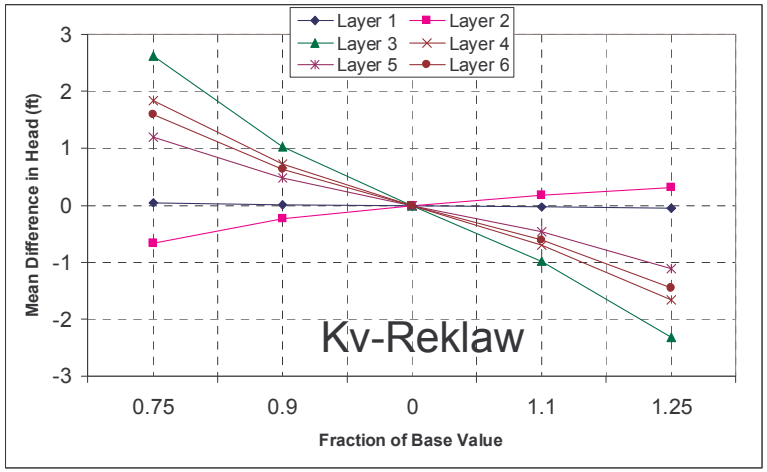
Steady-State Sensitivity Analysis



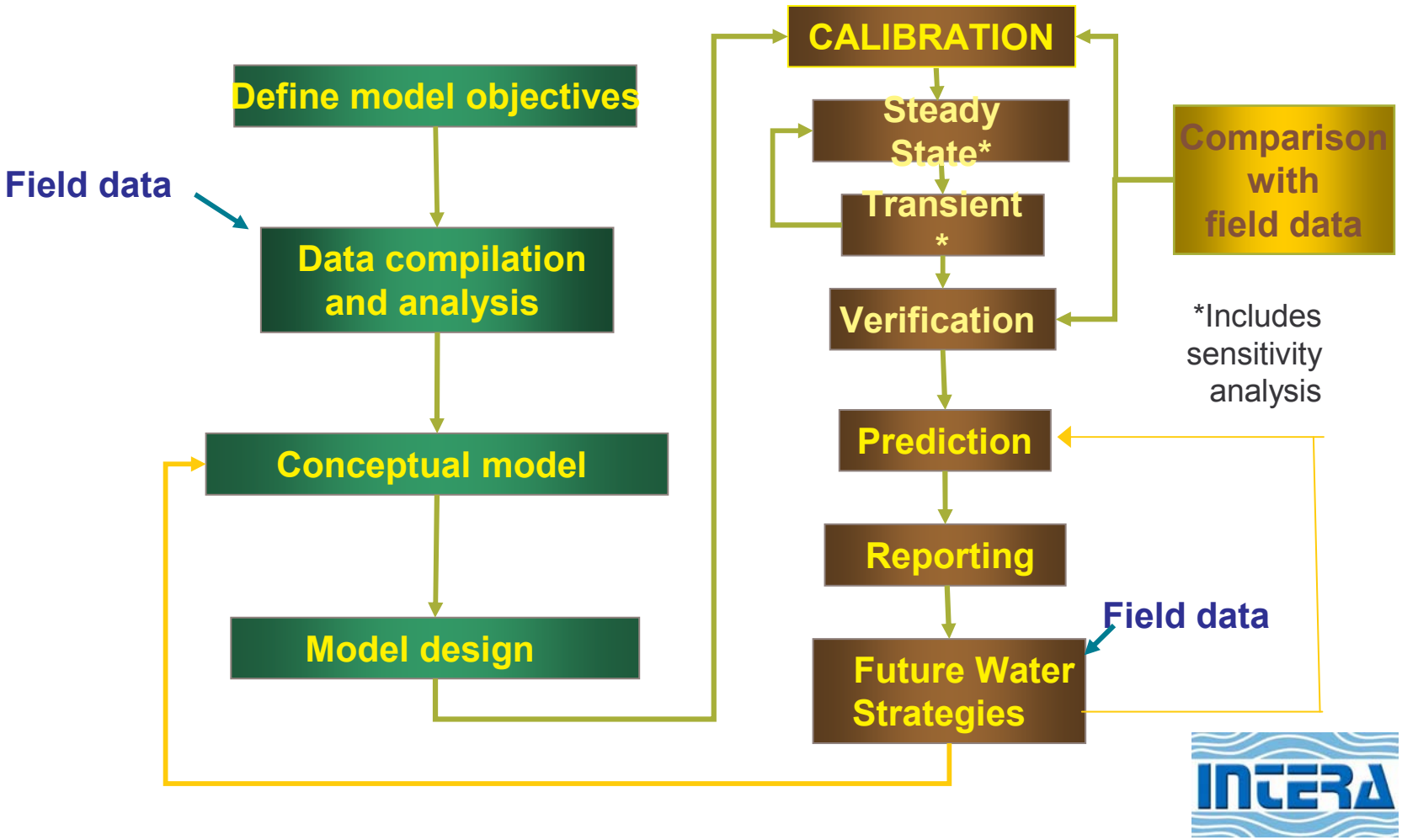




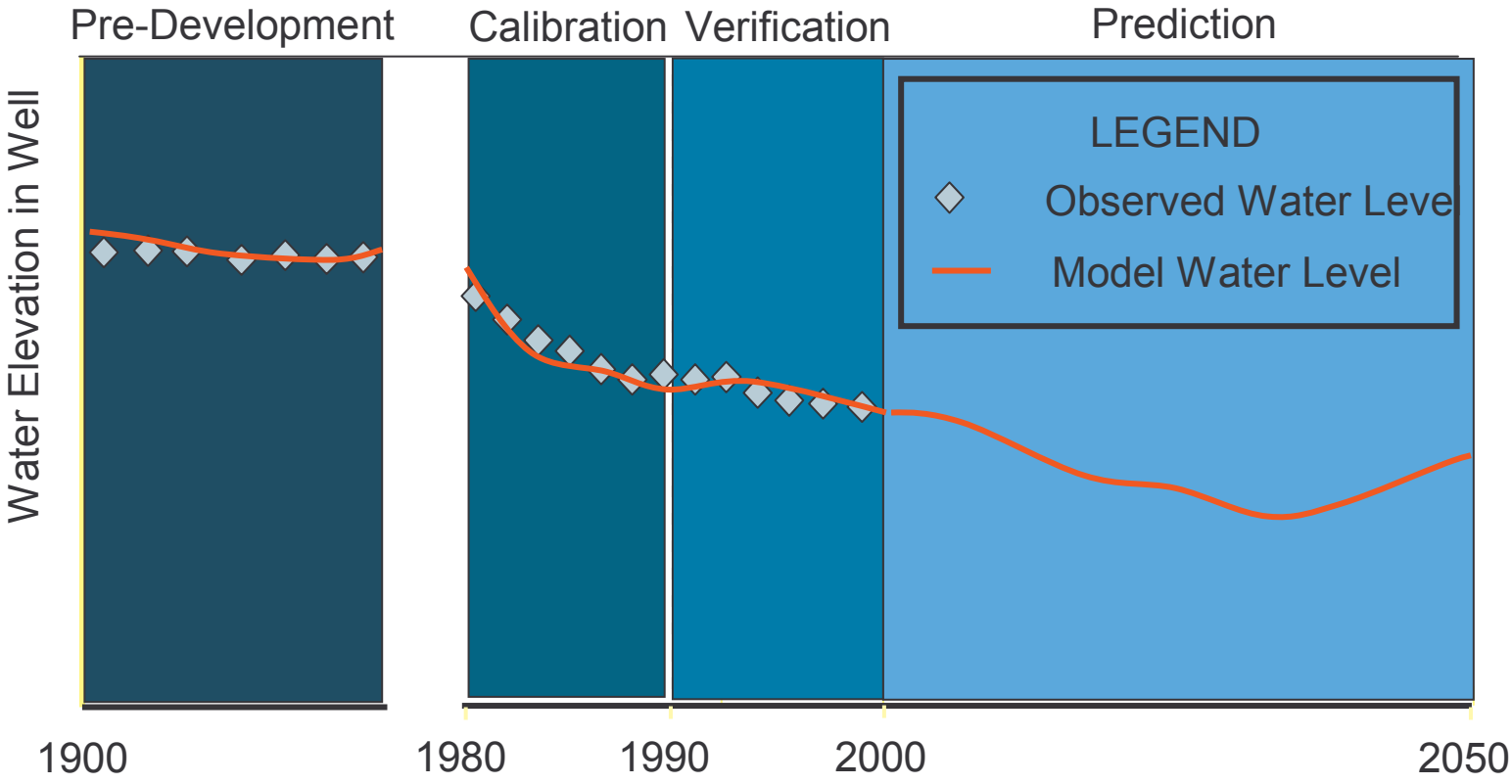


$$MD = \frac{1}{n}\sum_{i=1}^{n}\left(h_{sens,i} - h_{cal,i}\right)$$

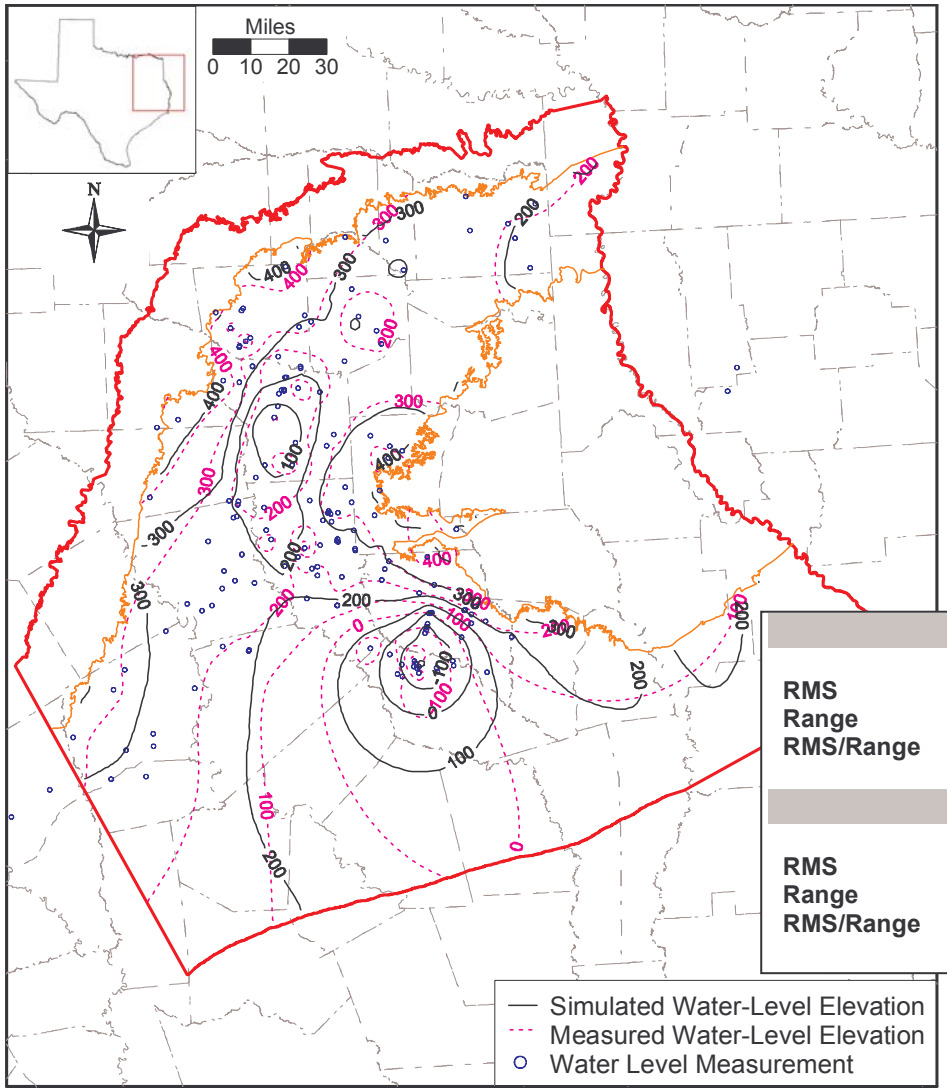
Modeling Protocol

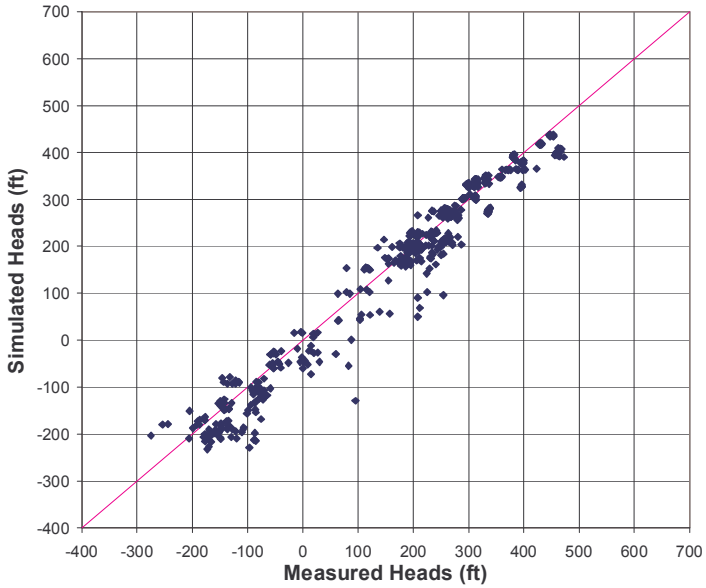


Modeling Periods



Transient Calibration: Carrizo

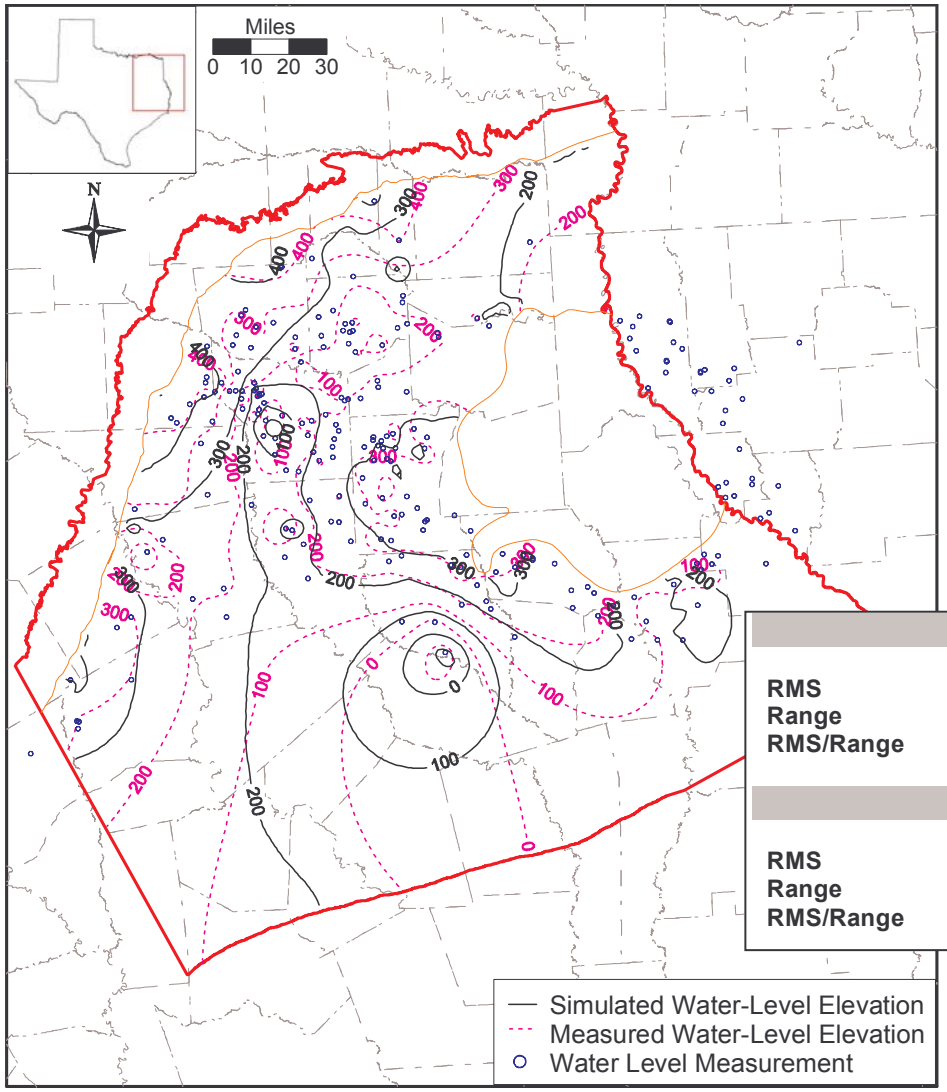


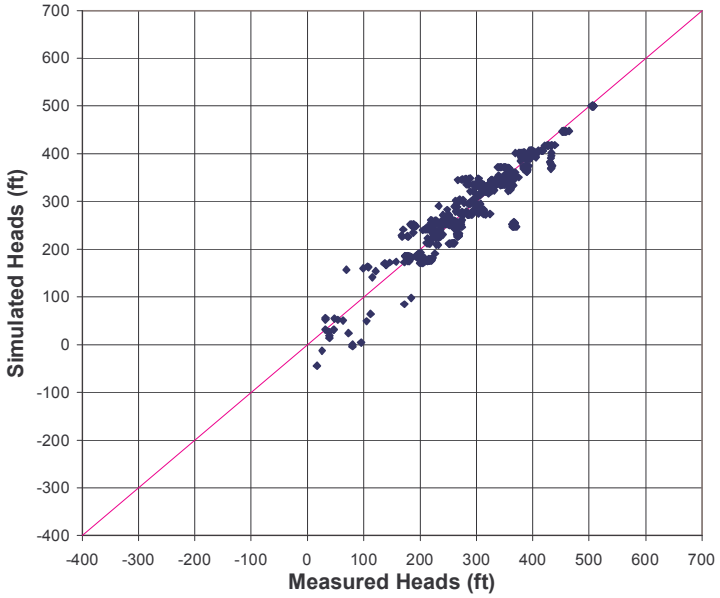


Calibration period (1980-1989)	Layer 1	Layer 3	Layer 4	Layer 5	Layer 6
RMS	40.87	35.14	26.57	31.74	24.70
Range	433	743	491	523	310
RMS/Range	0.094	0.047	0.054	0.061	0.080

Verification period (1990-1999)	Layer 1	Layer 3	Layer 4	Layer 5	Layer 6
RMS	41.08	42.10	34.37	38.44	31.01
Range	459	821	660	523	300
RMS/Range	0.090	0.051	0.052	0.073	0.103

Transient Calibration: Upper Wilcox





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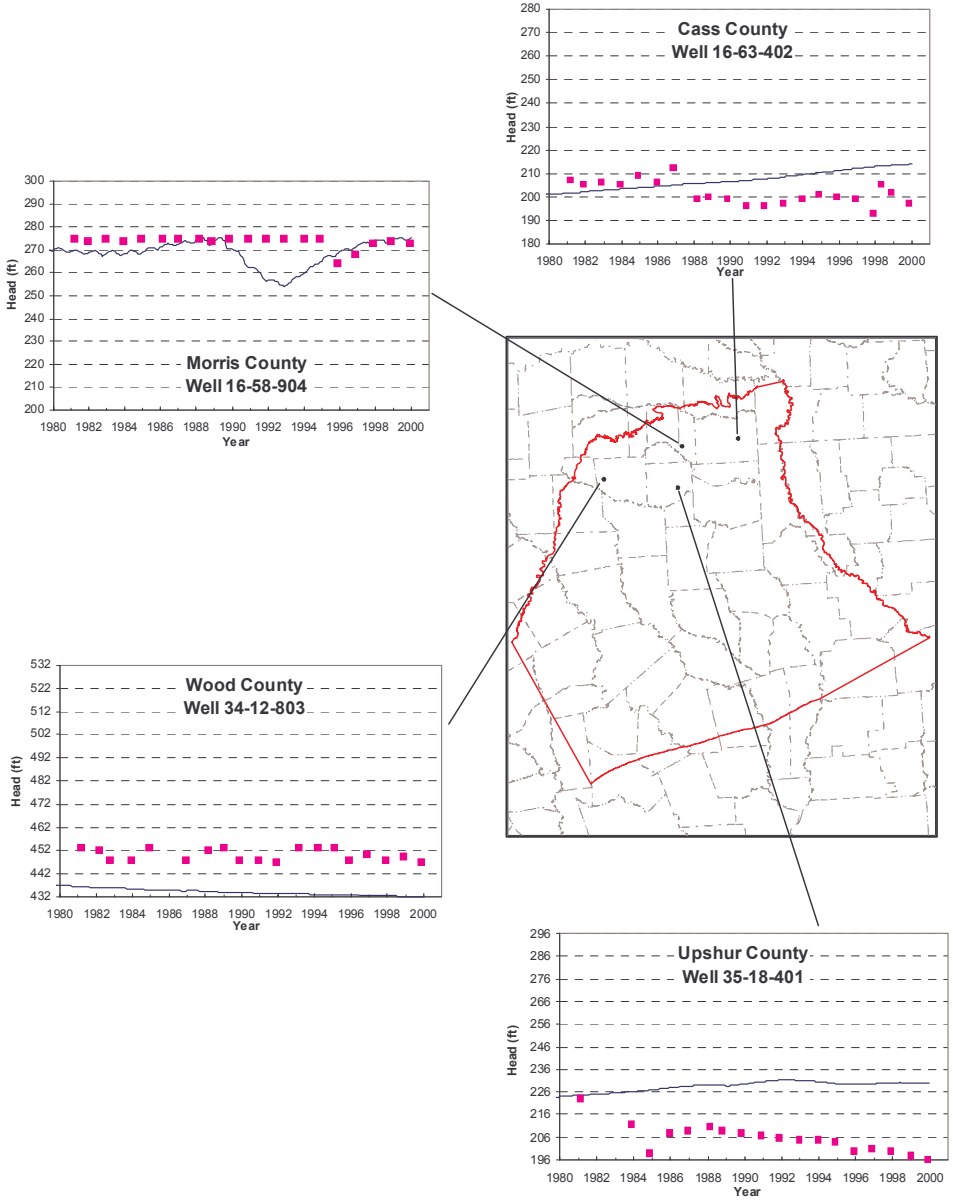
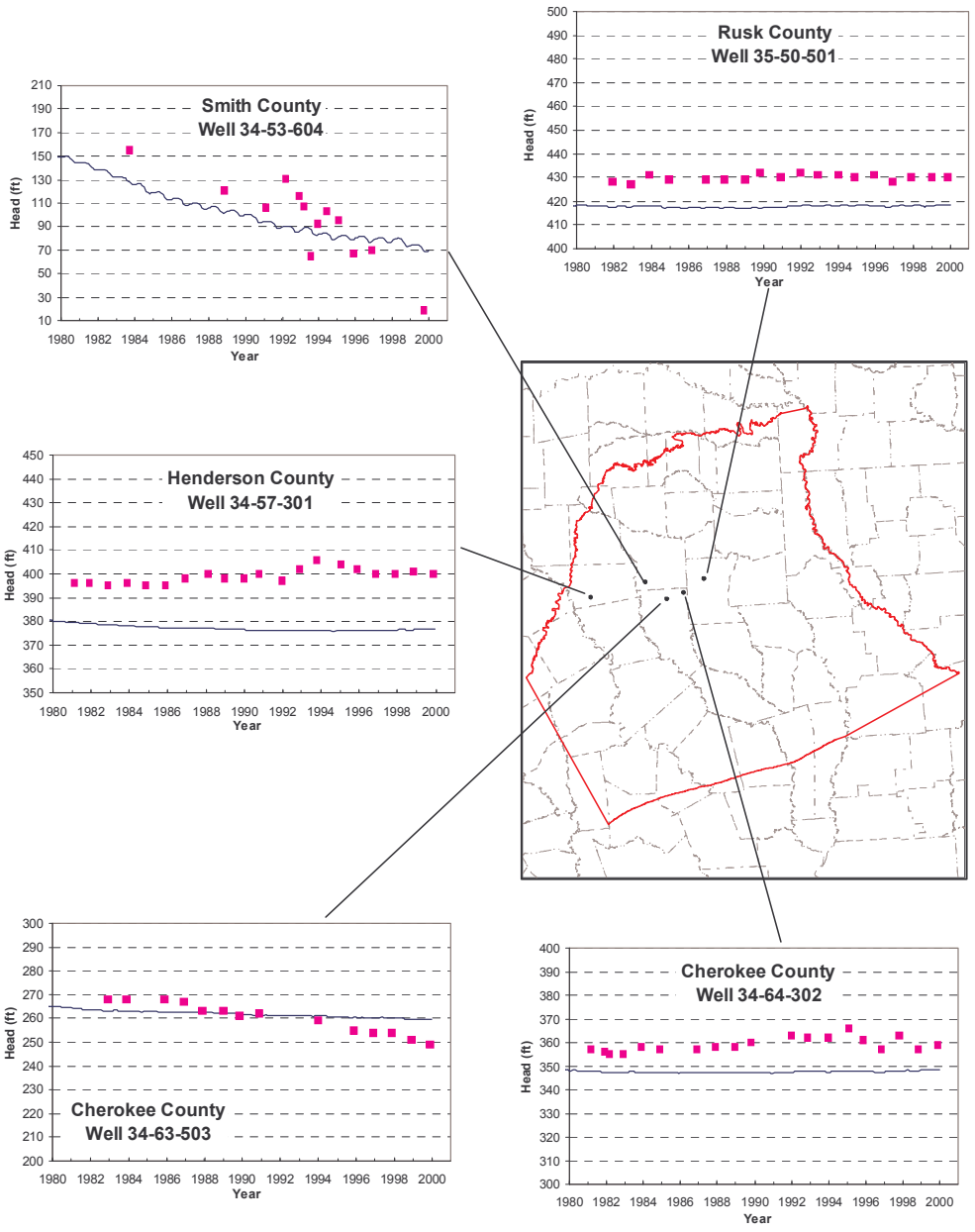
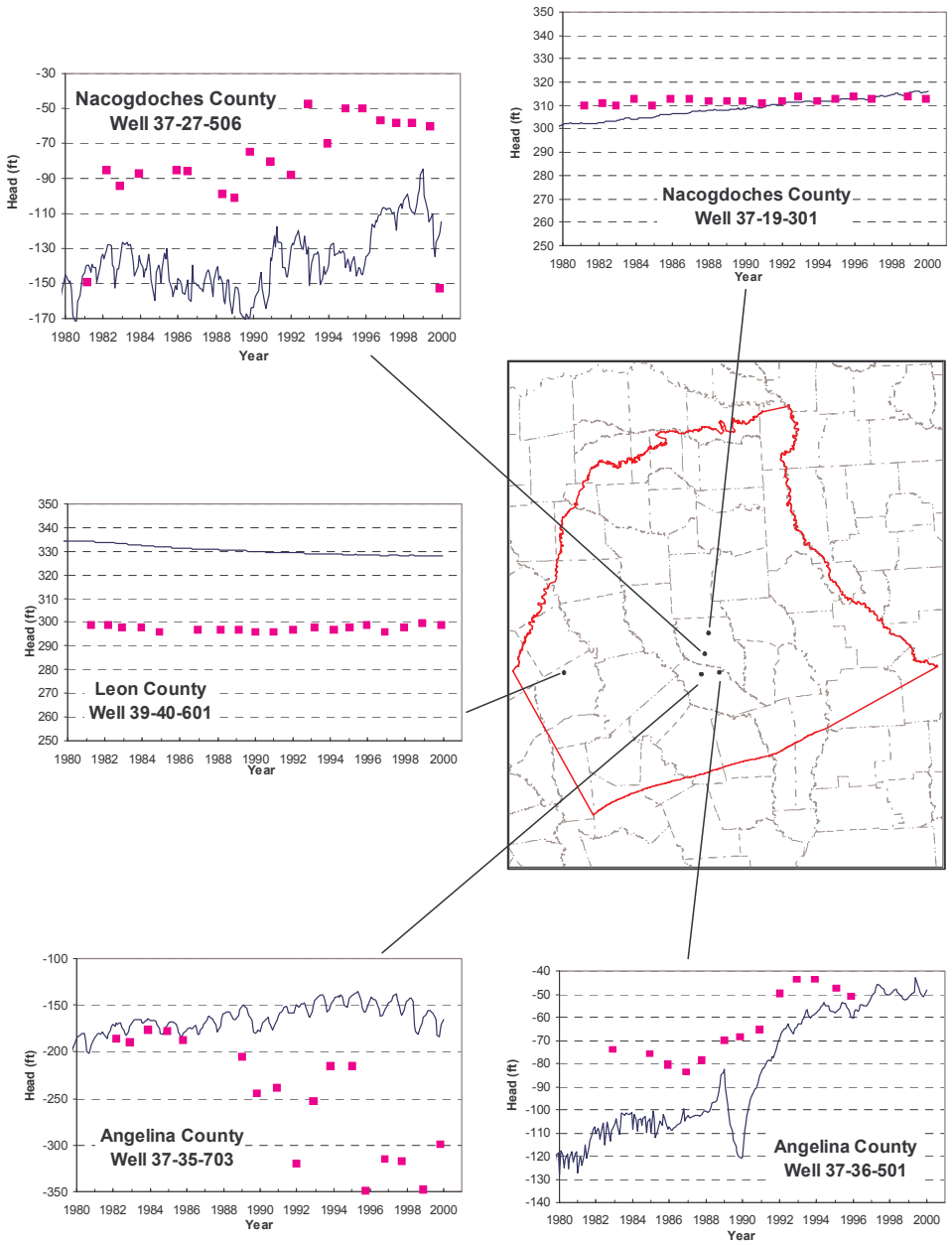
Hydrographs: Carrizo



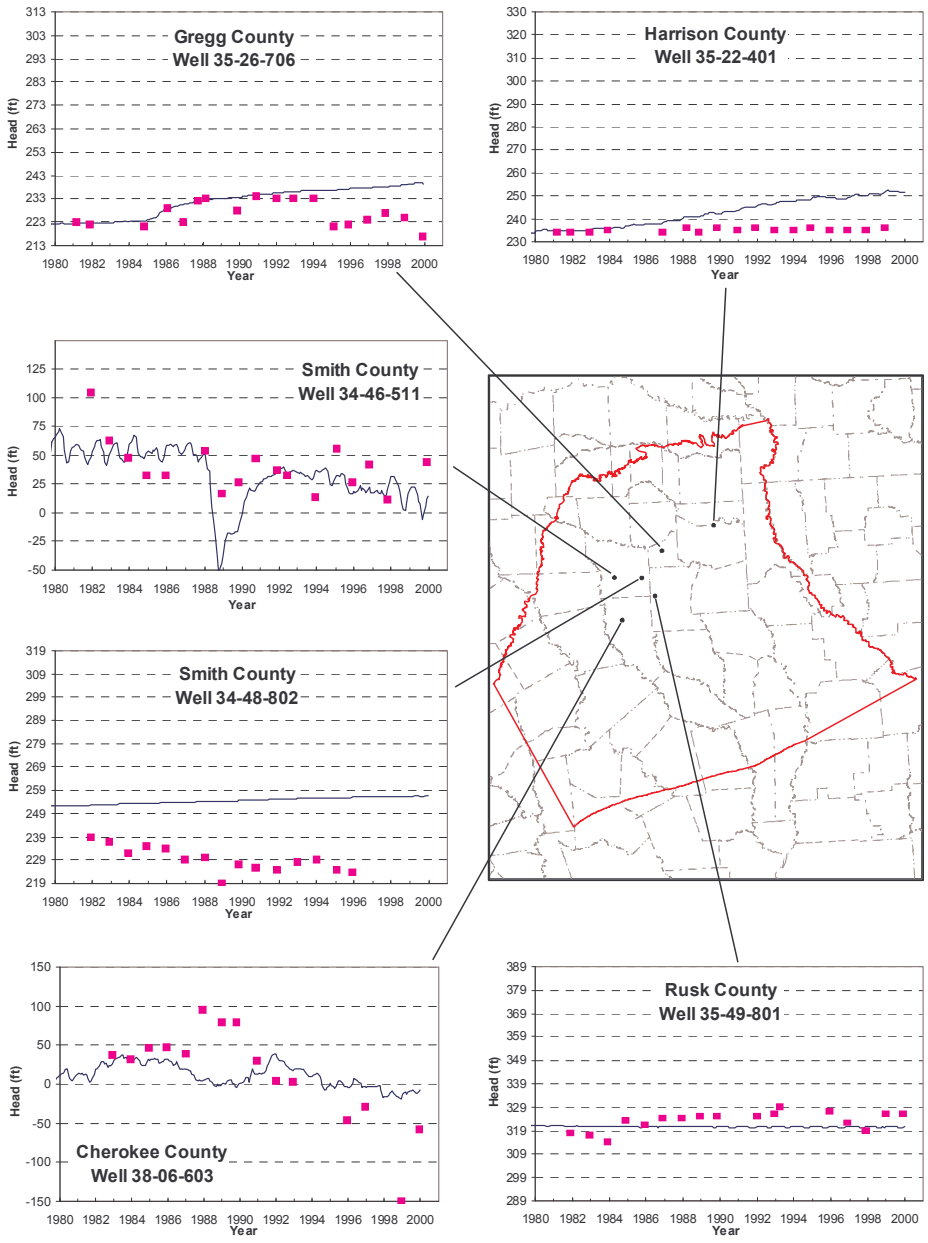
Hydrographs: Carrizo



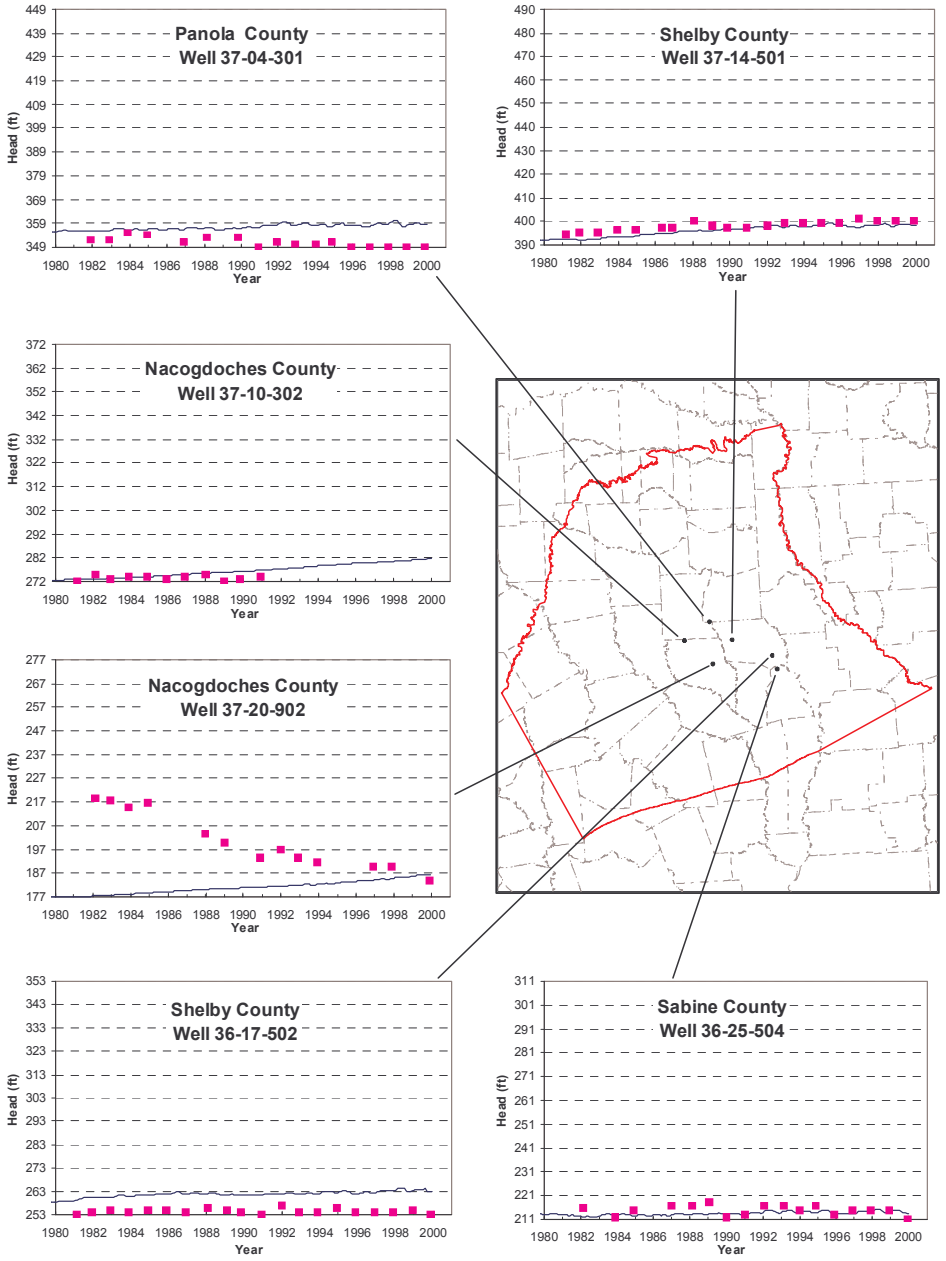
Hydrographs Carrizo



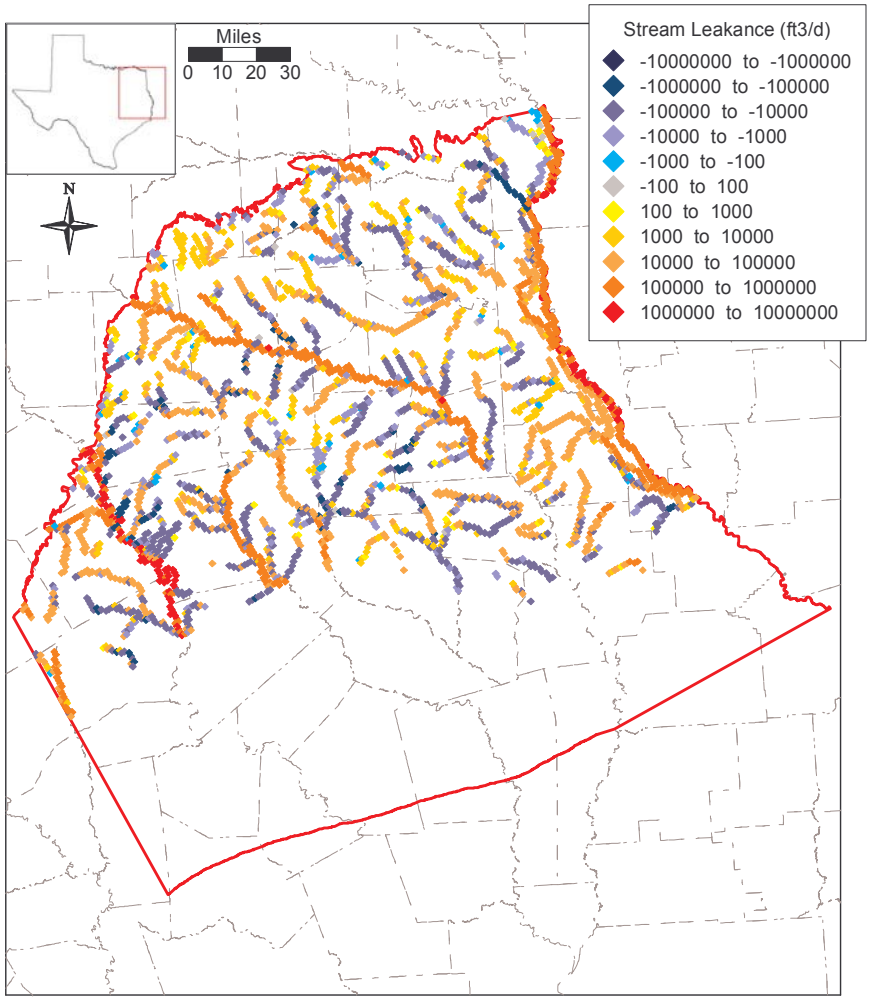
Hydrographs: Upper Wilcox



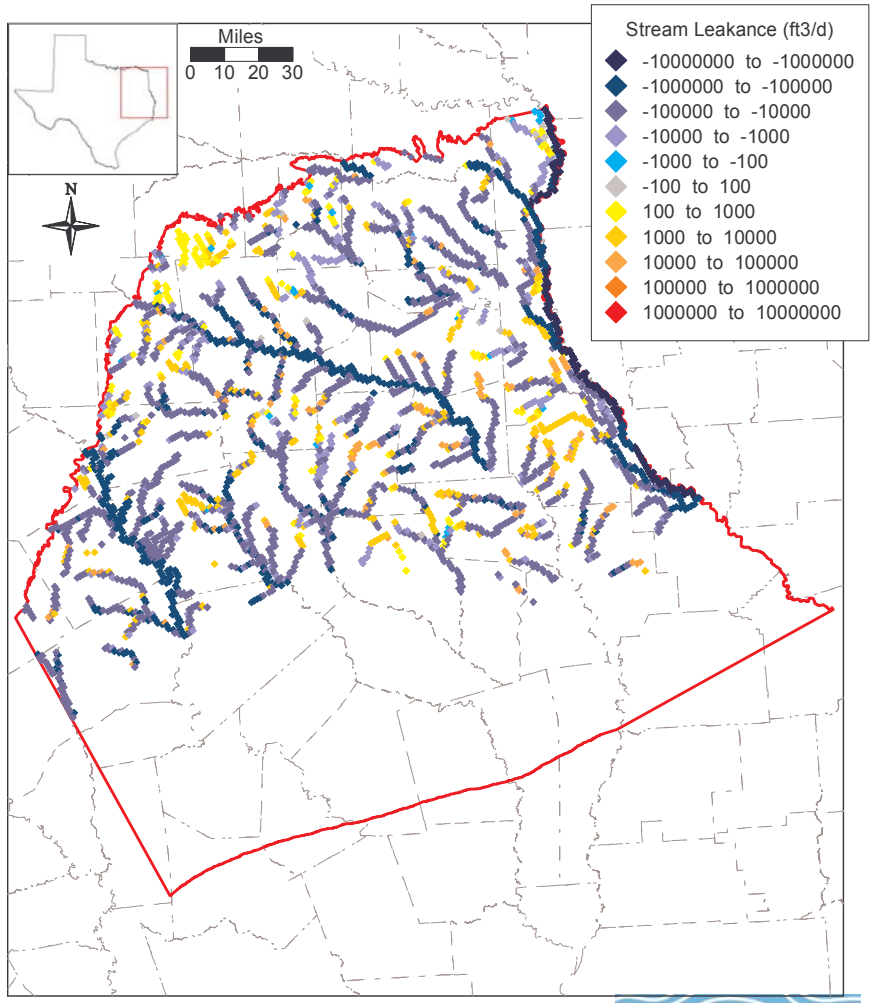
Hydrographs: Upper Wilcox



Transient Calibration: Simulated Stream Flow

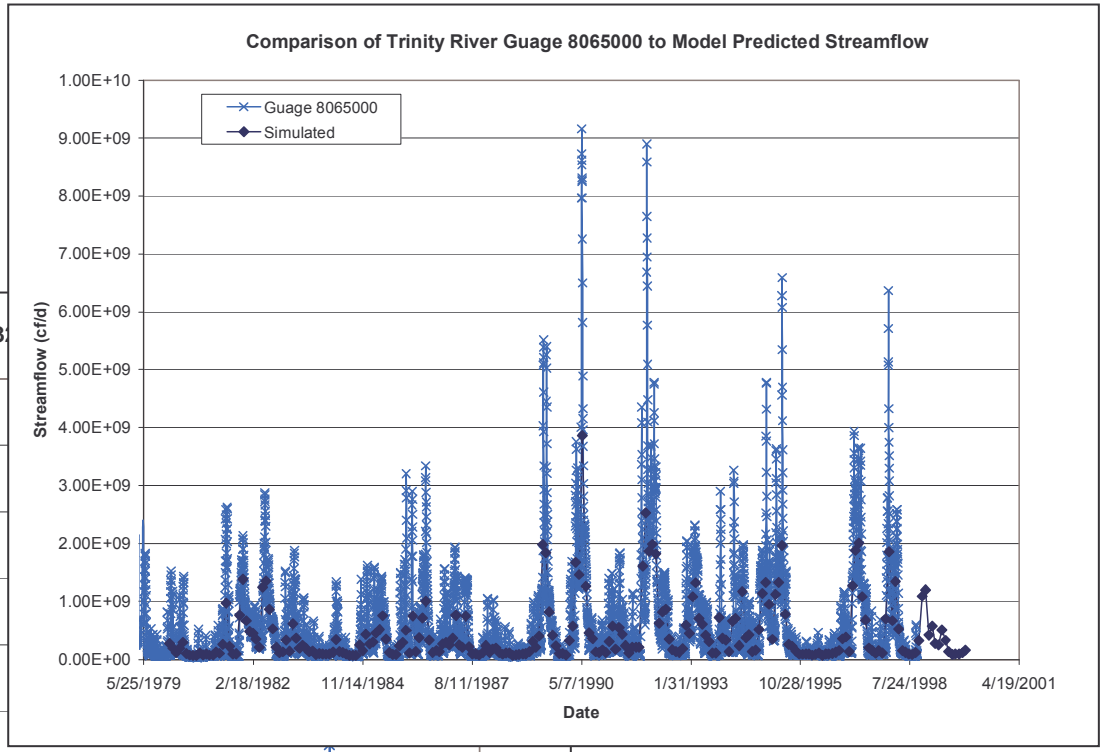


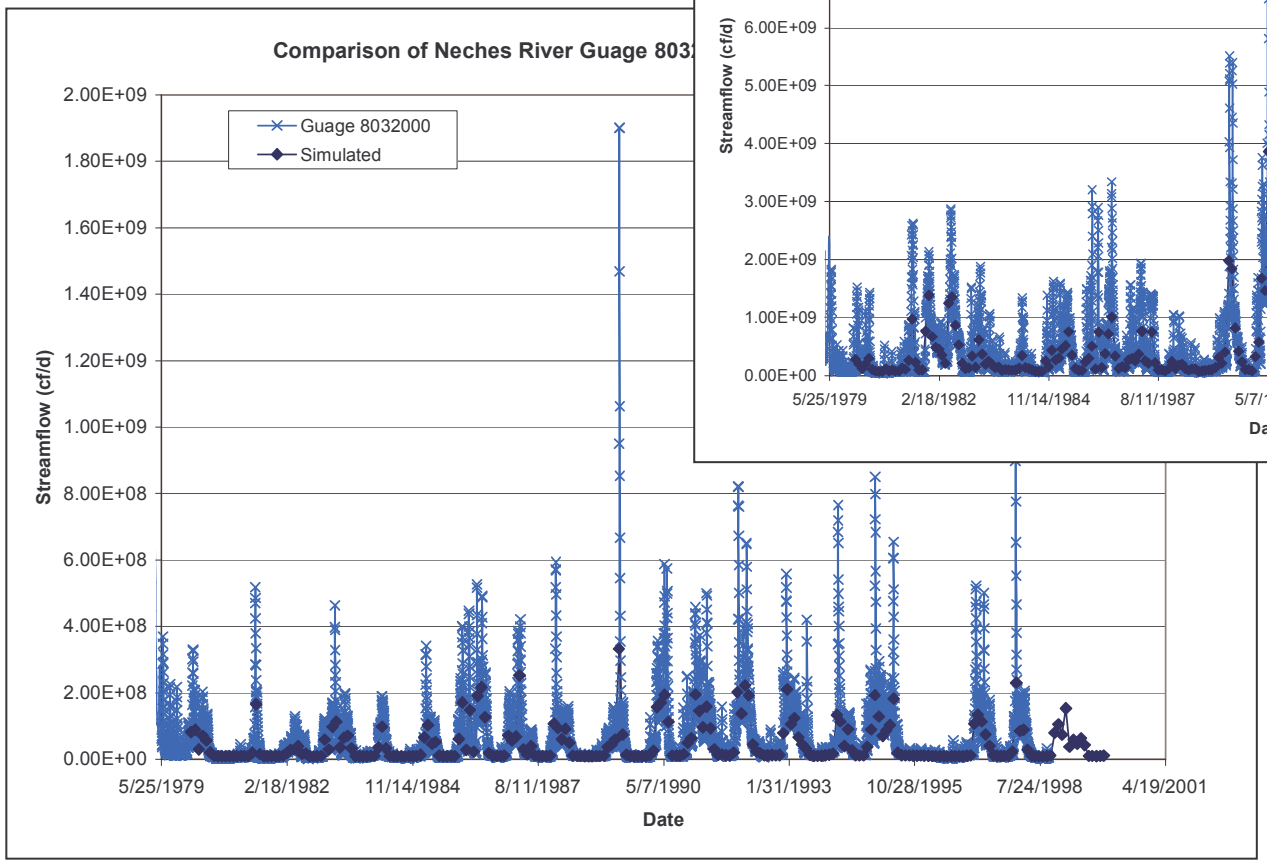
May 1989



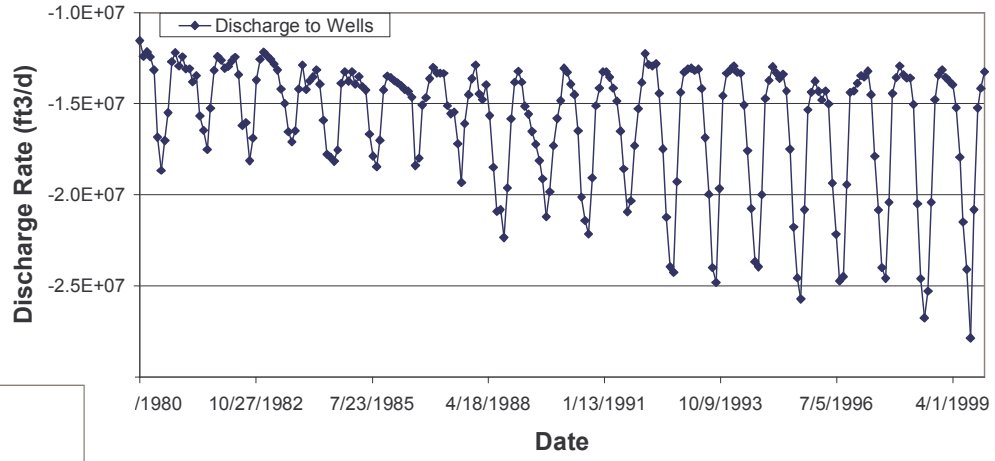
November 1989

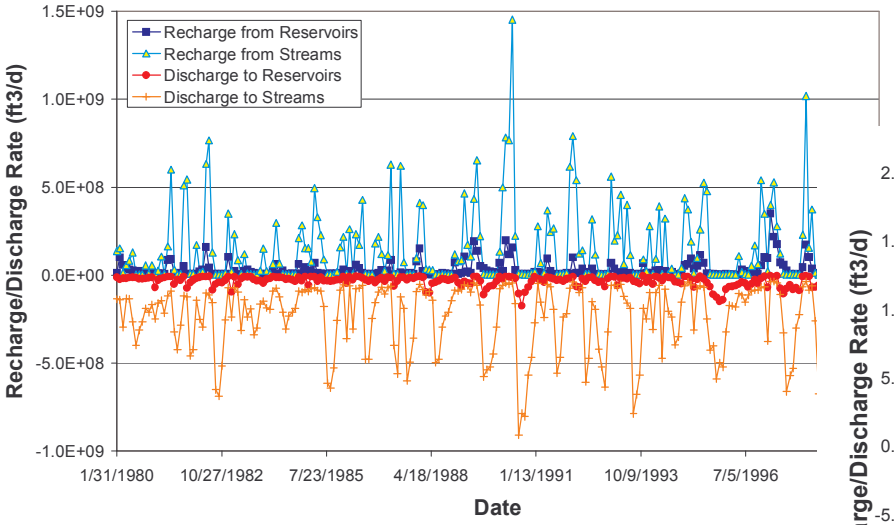
Stream Gage Comparison

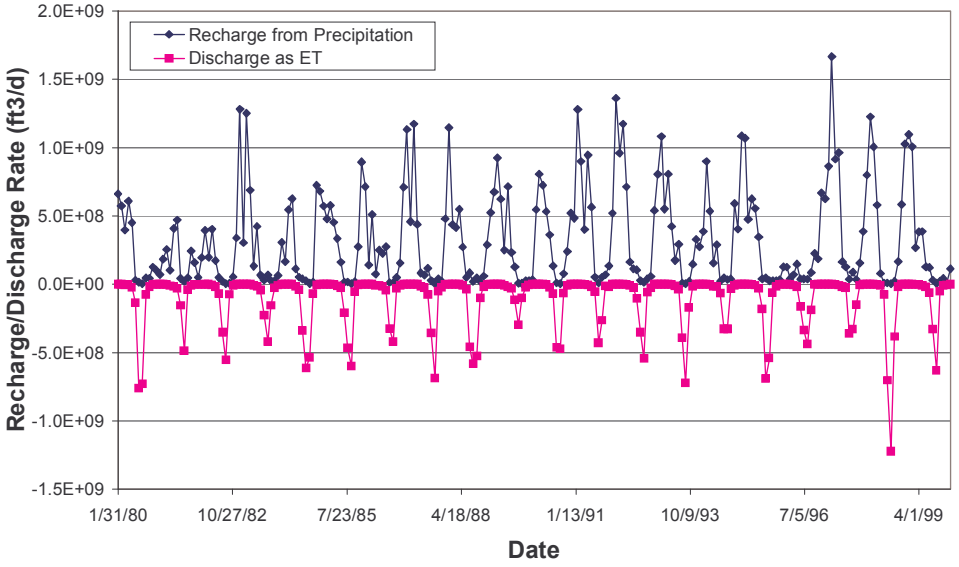




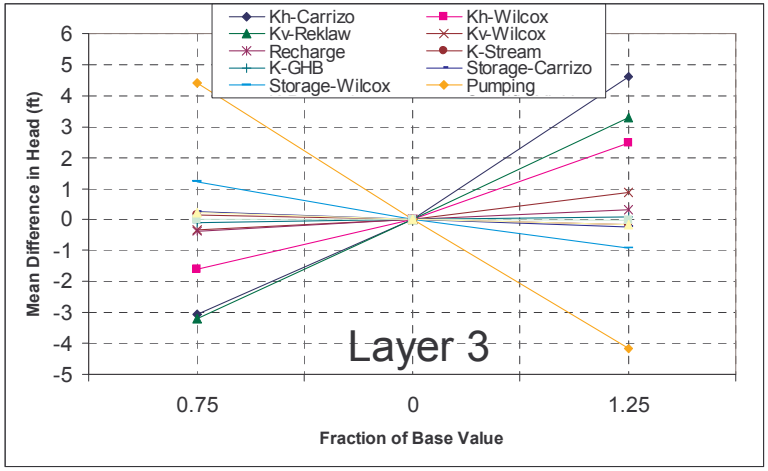
Recharge/ Discharge

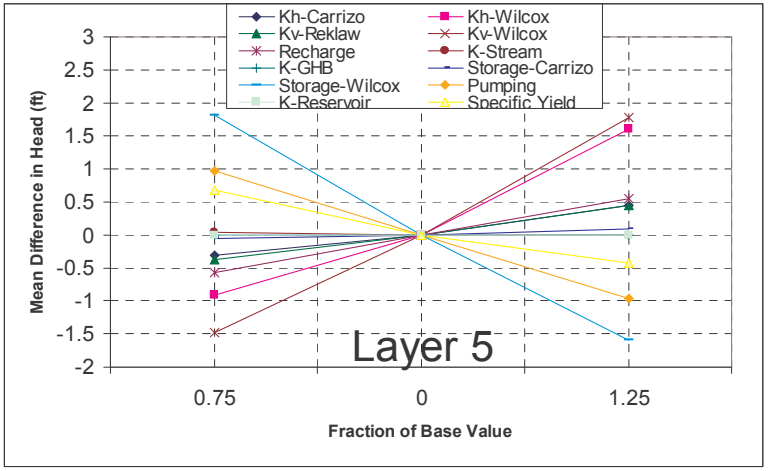


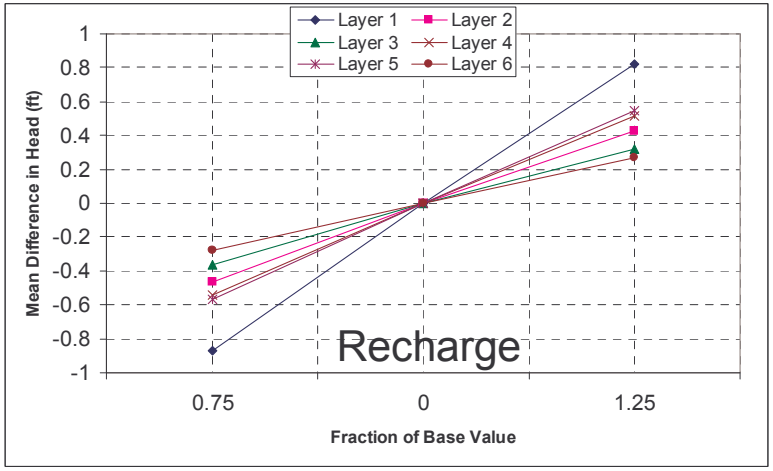


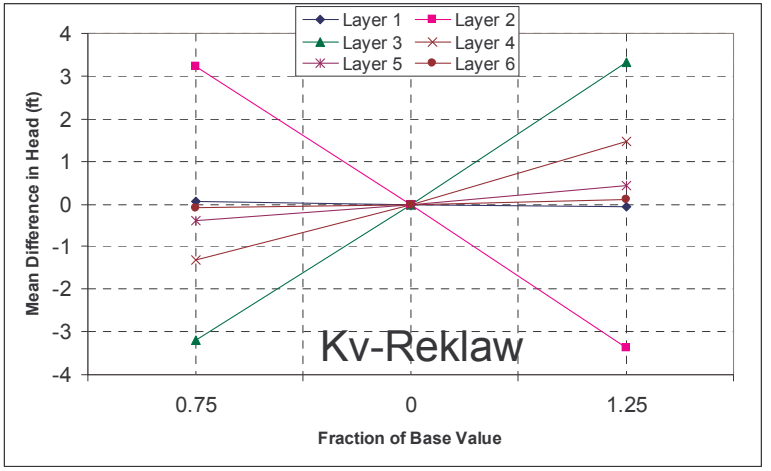


Transient Sensitivity Analysis









$$MD = \frac{1}{n}\sum_{i=1}^{n}\left(h_{sens,i} - h_{cal,i}\right)$$

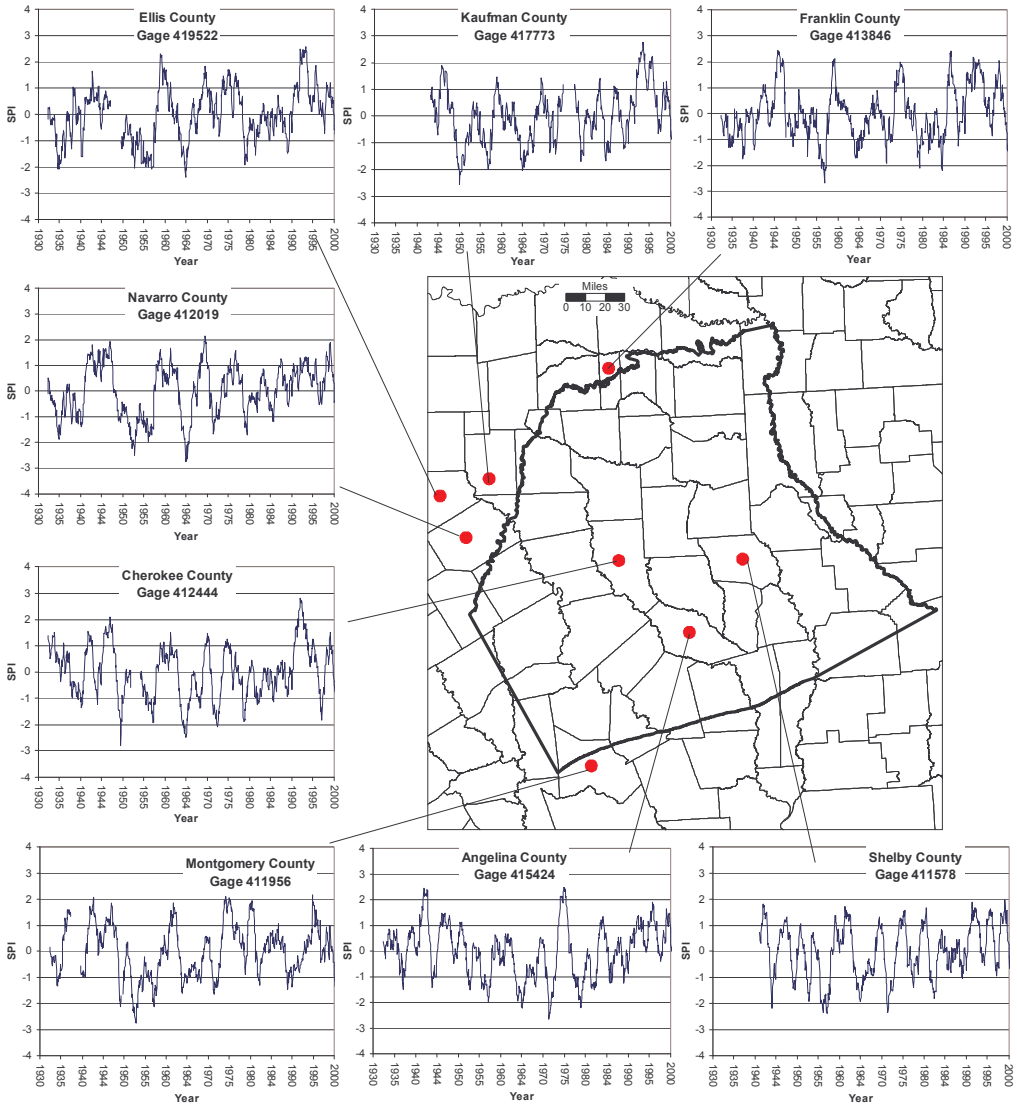
Model Calibration

- Average pre-development recharge is lower than from transient calibration
  - R(steady-state) = 0.93 inches/yr
  - R(transient) = 2.6 inches/yr
  - Difference may represent “rejected recharge”, though result may be affected by steady-state model limitations, which restricted ET to be less than R.
- Transient calibration required:
  - Reduced K_v(Reklaw), particularly in the Smith Co. area
  - Increased K_v(Reklaw) in Nacogdoches Co.
  - Reduced K_h(Carrizo, Upper Wilcox) in central area (Smith Co.)
  - Assume significant portion of pumpage, allocated to Queen City, is from Carrizo-Wilcox

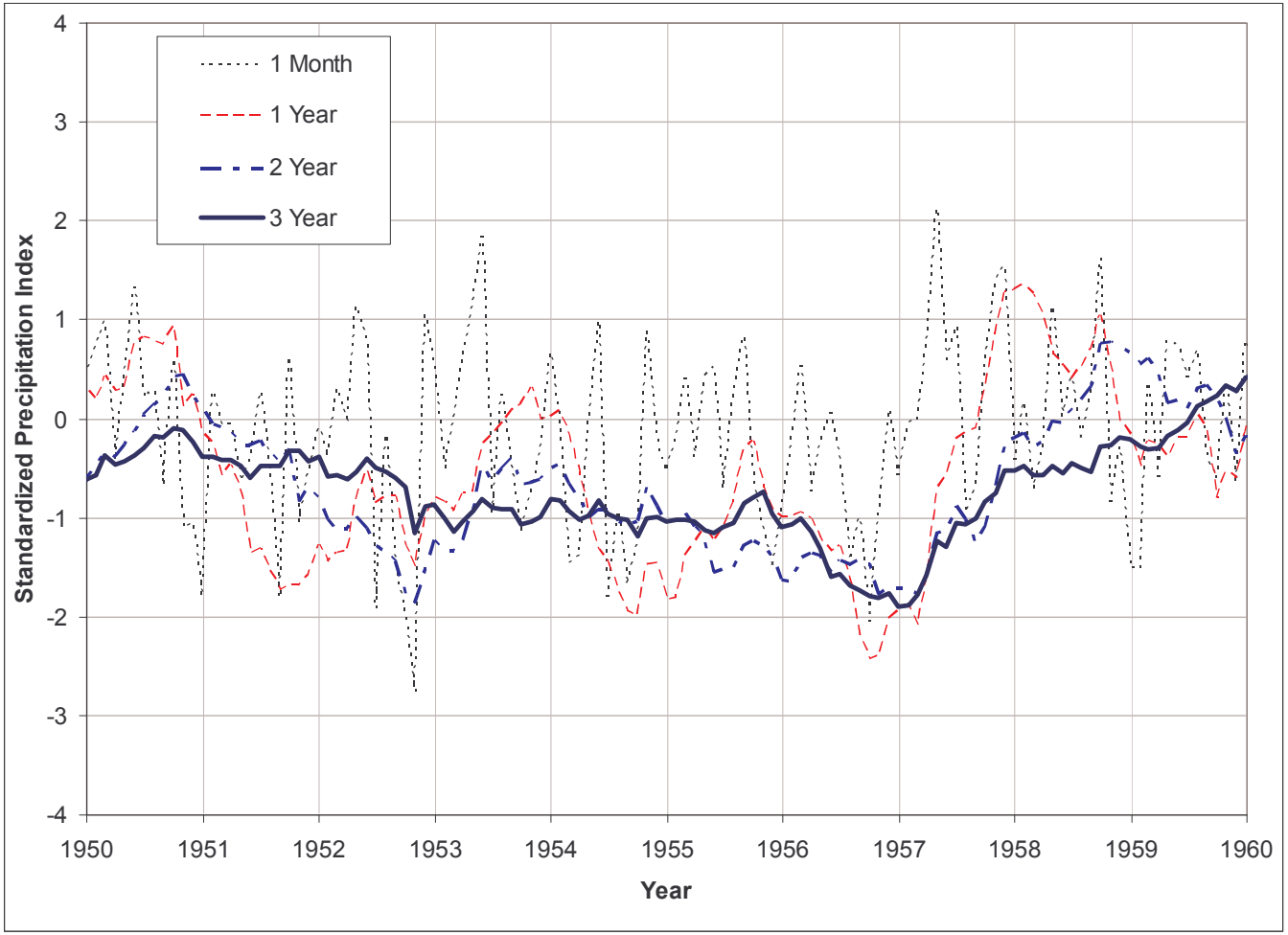
Predictive Simulation (2000-2050)

- Predictive Pumpage based on RWPs
- Six Model Scenarios:
  - Average Recharge Conditions through 2050
  - Average Recharge Conditions ending with the drought of record (DOR) in 2010
  - Average Recharge Conditions ending with the drought of record (DOR) in 2020.
  - Average Recharge Conditions ending with the drought of record (DOR) in 2030.
  - Average Recharge Conditions ending with the drought of record (DOR) in 2040.
  - Average Recharge Conditions ending with the drought of record (DOR) in 2050.

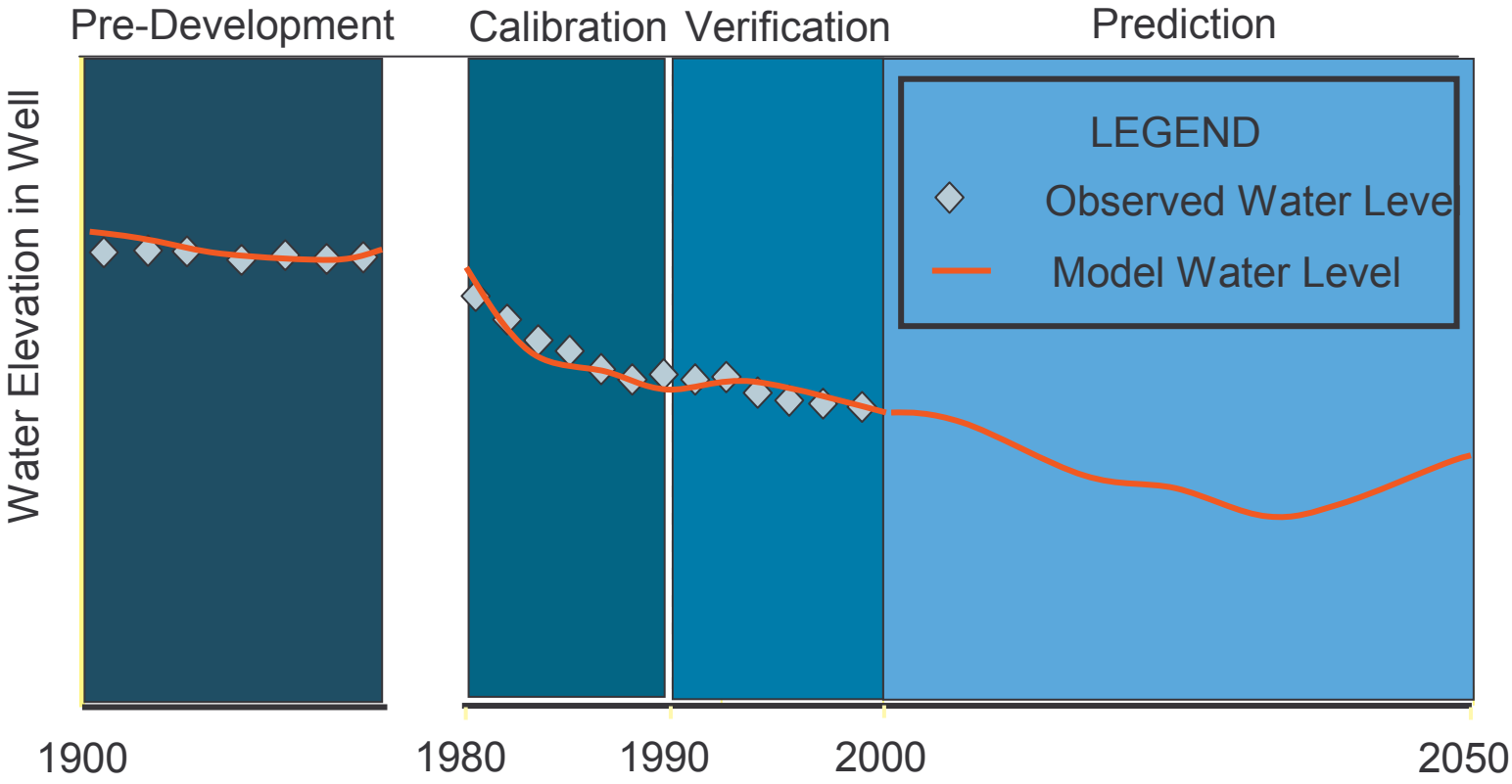
Drought of Record (DOR)



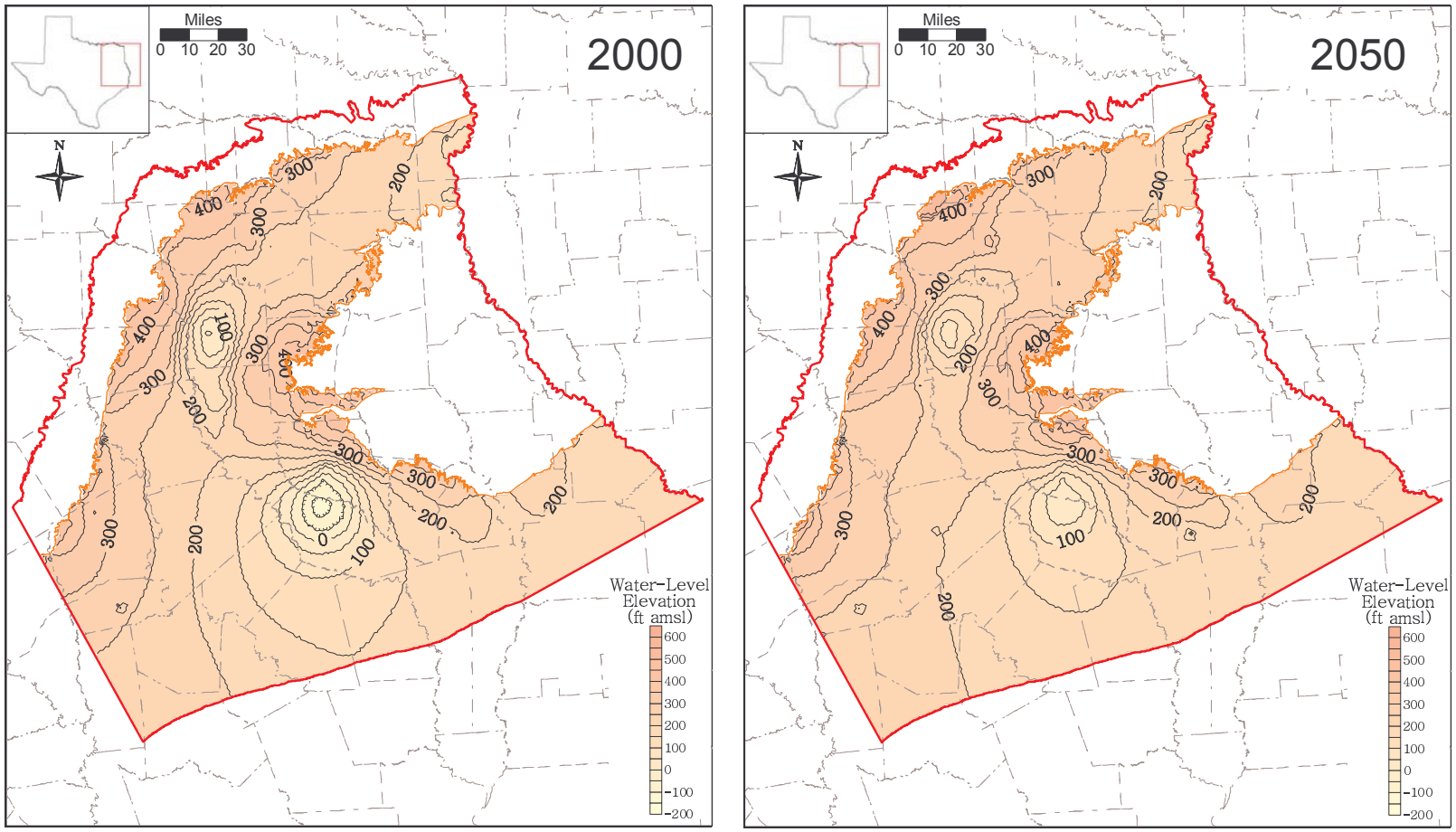
DOR Definition



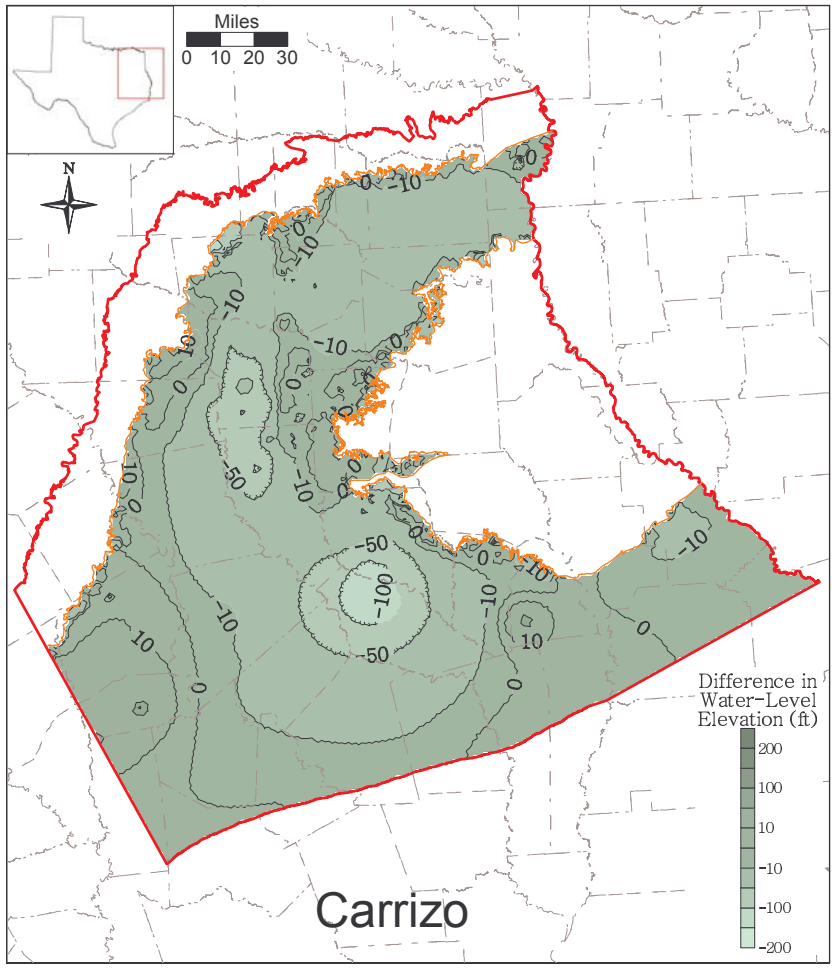
Modeling Periods

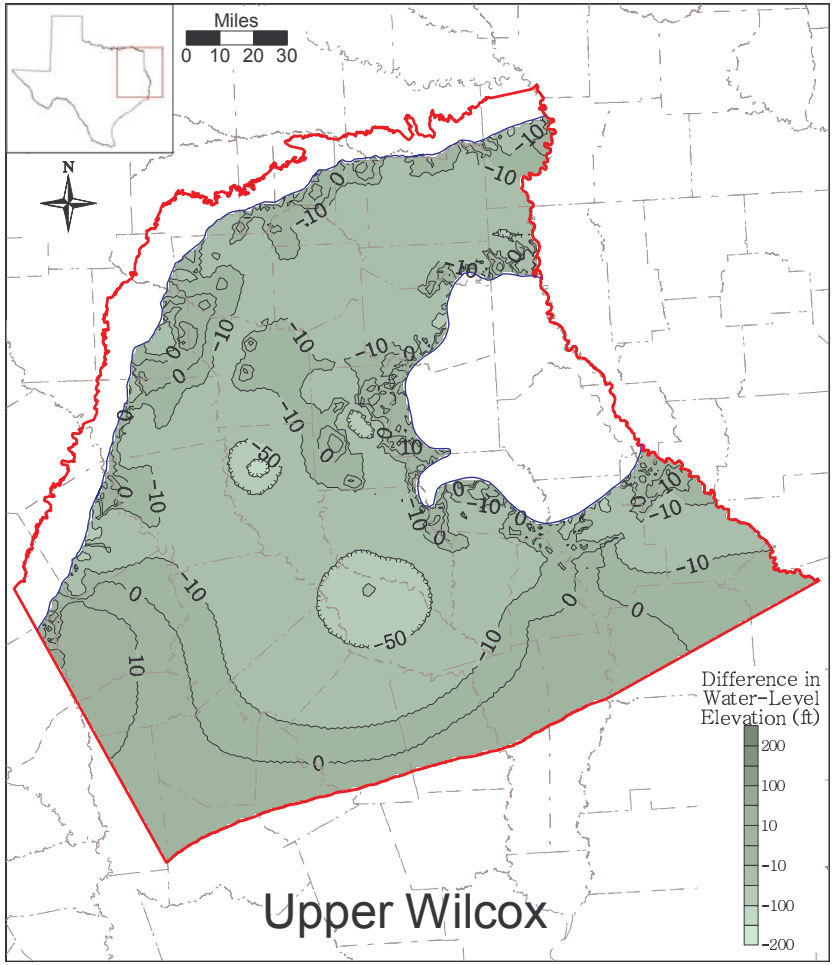


Prediction 2050 (no DOR): Carrizo

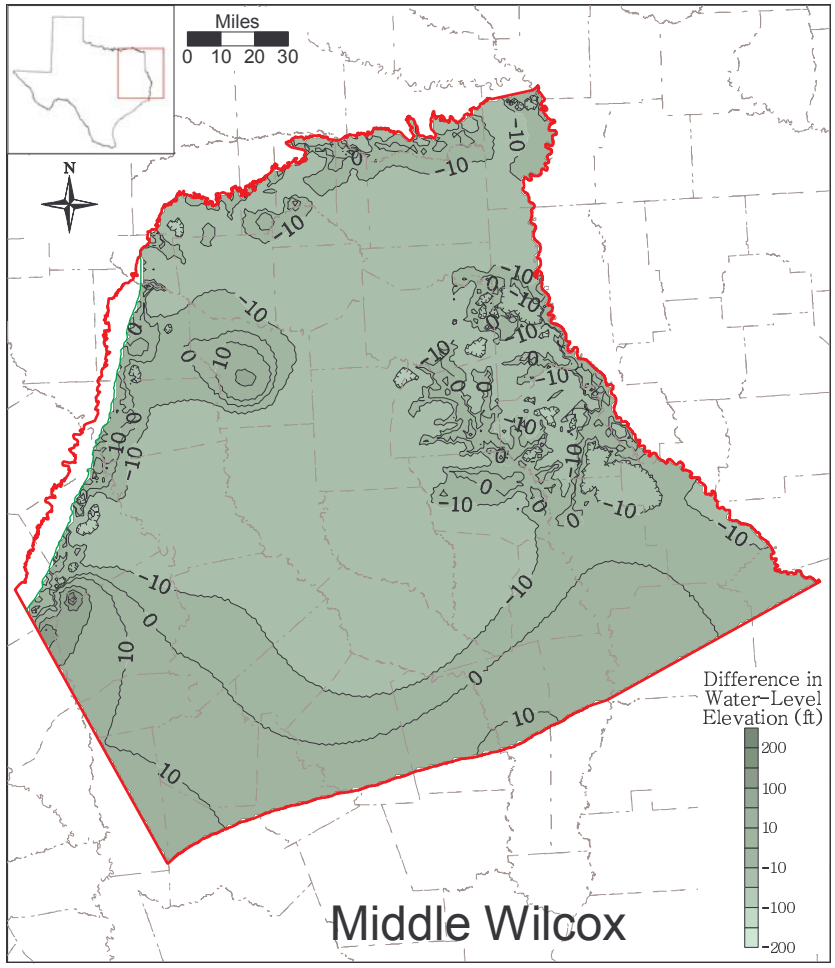


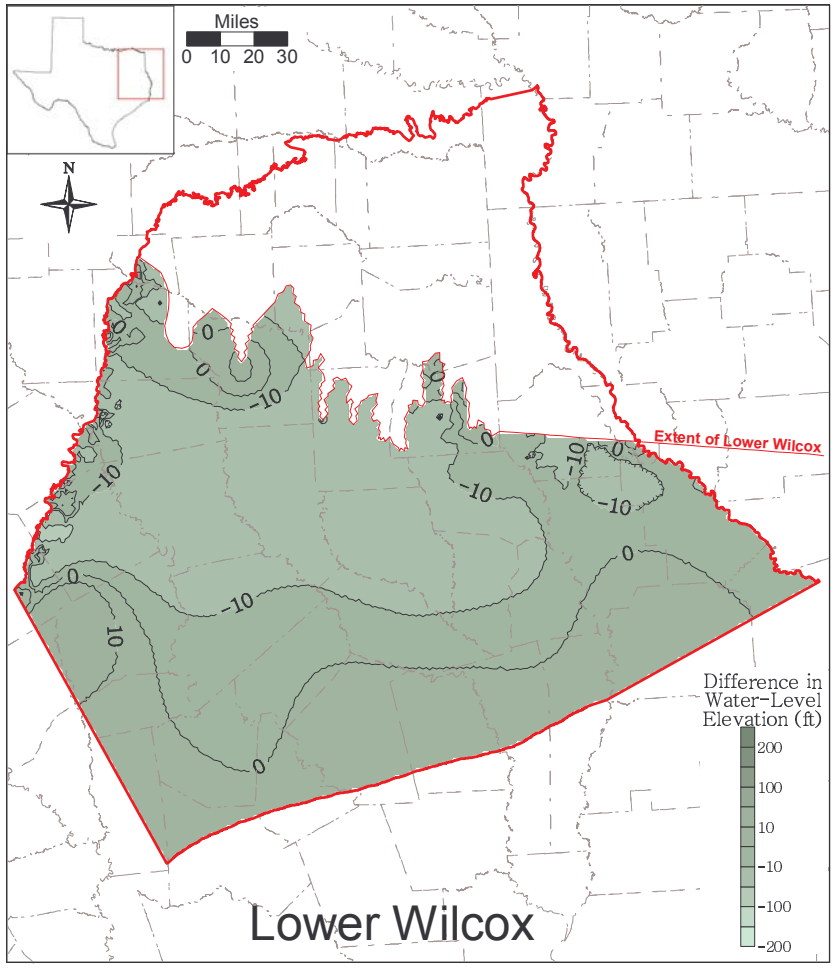
Head Difference: 2000 - 2050



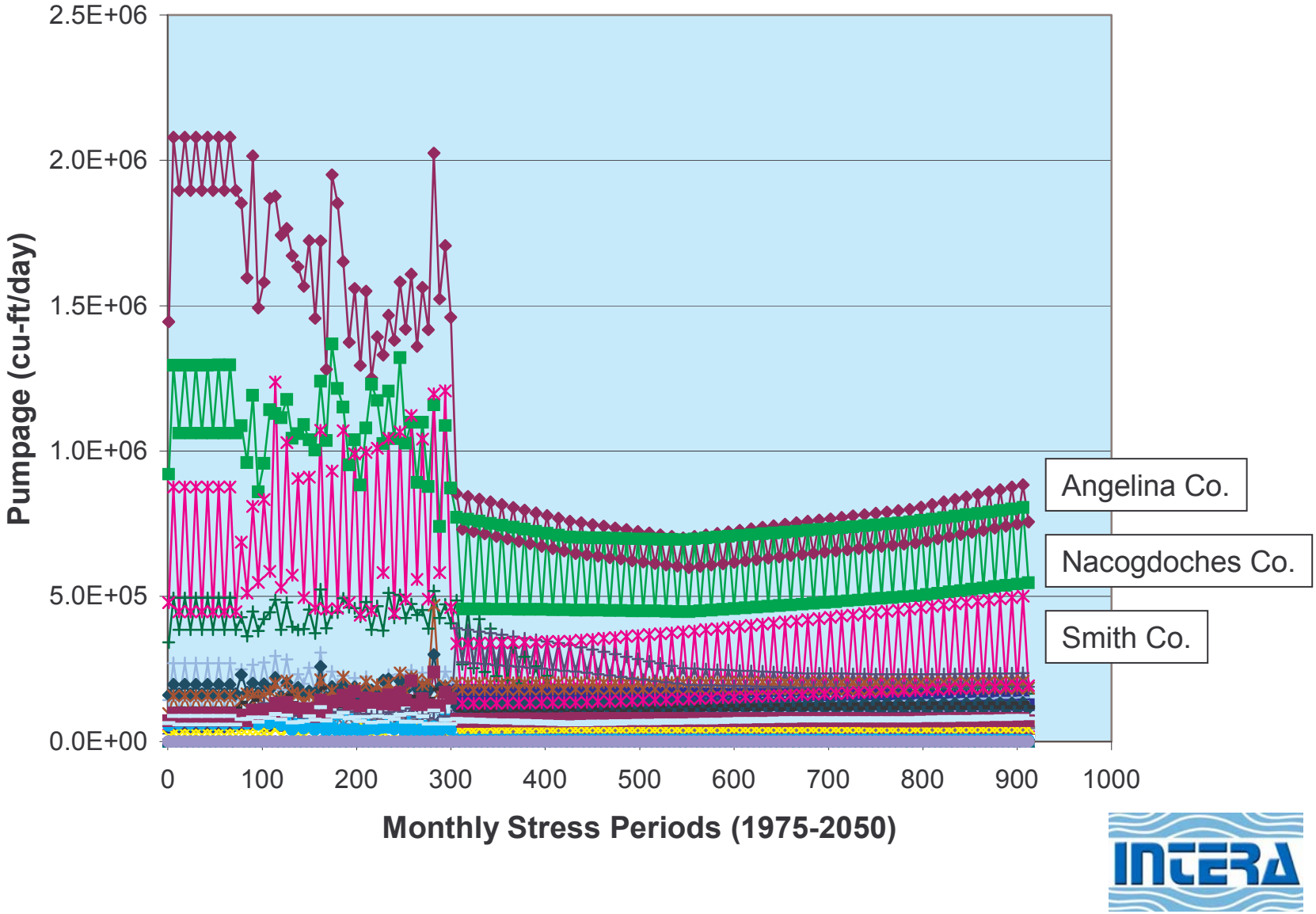


Head Difference: 2000 - 2050

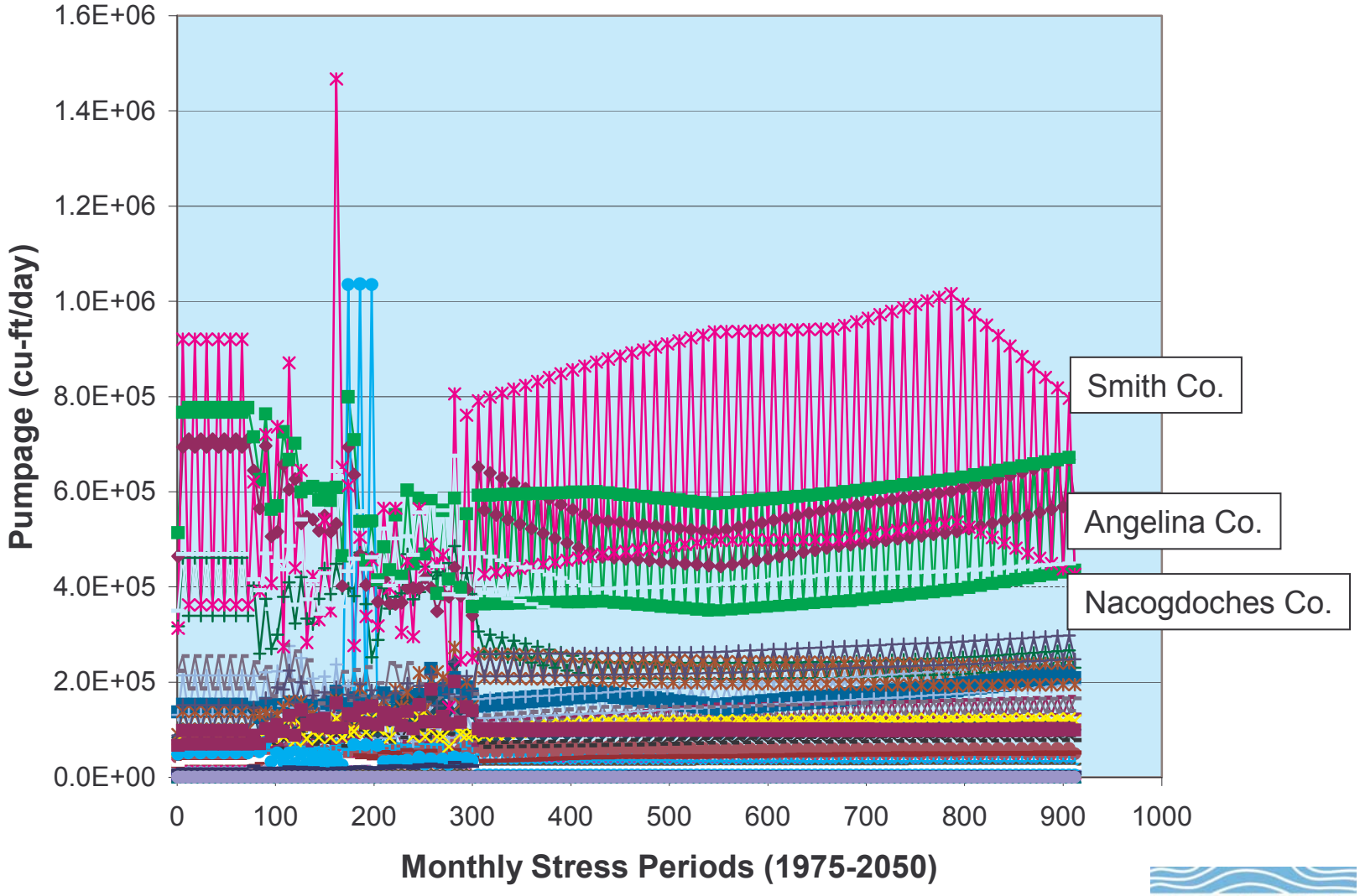




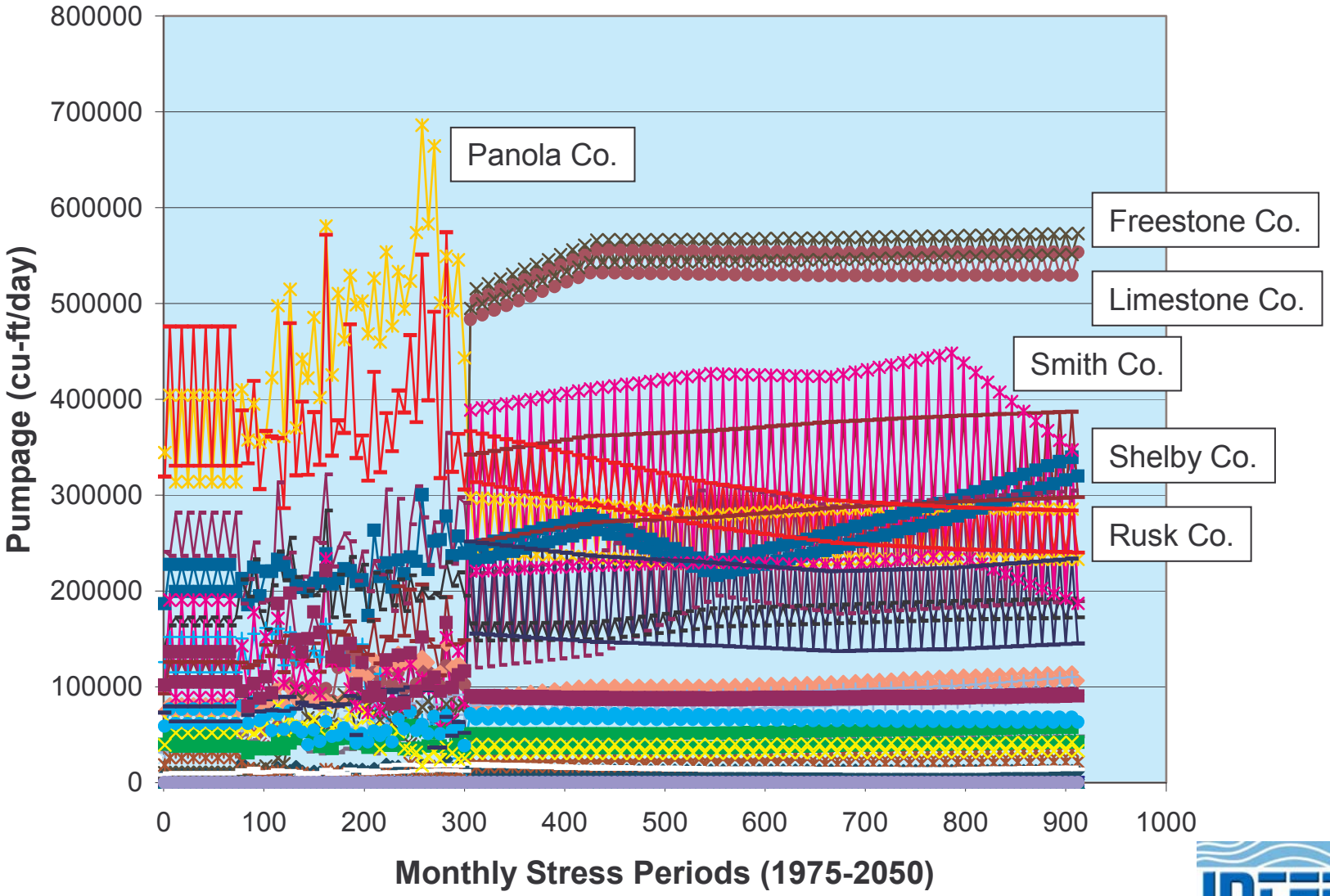
Pumpage in Layer 3



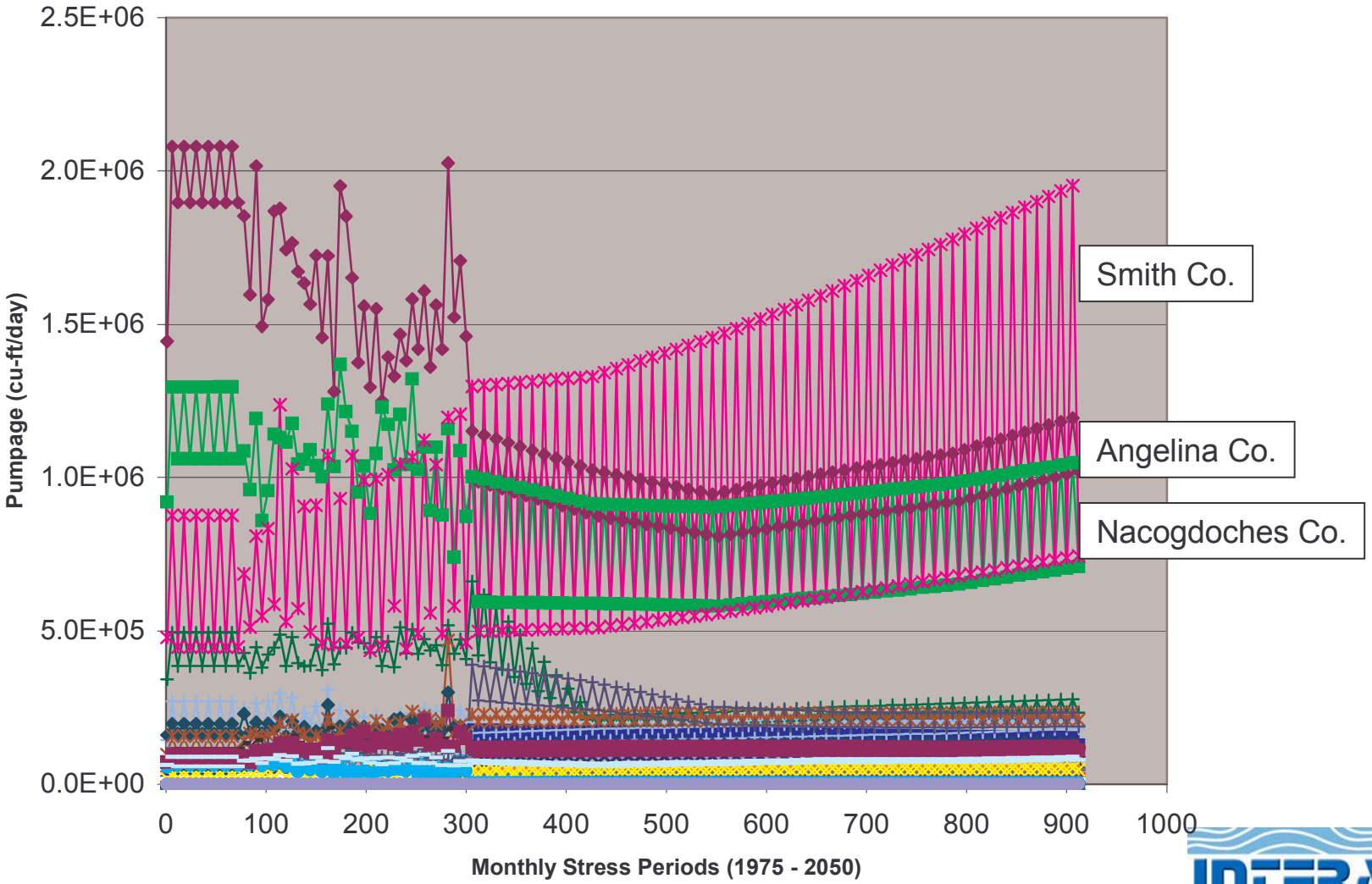
Pumpage in Layer 4 (Upper Wilcox)



Pumpage in Layer 5

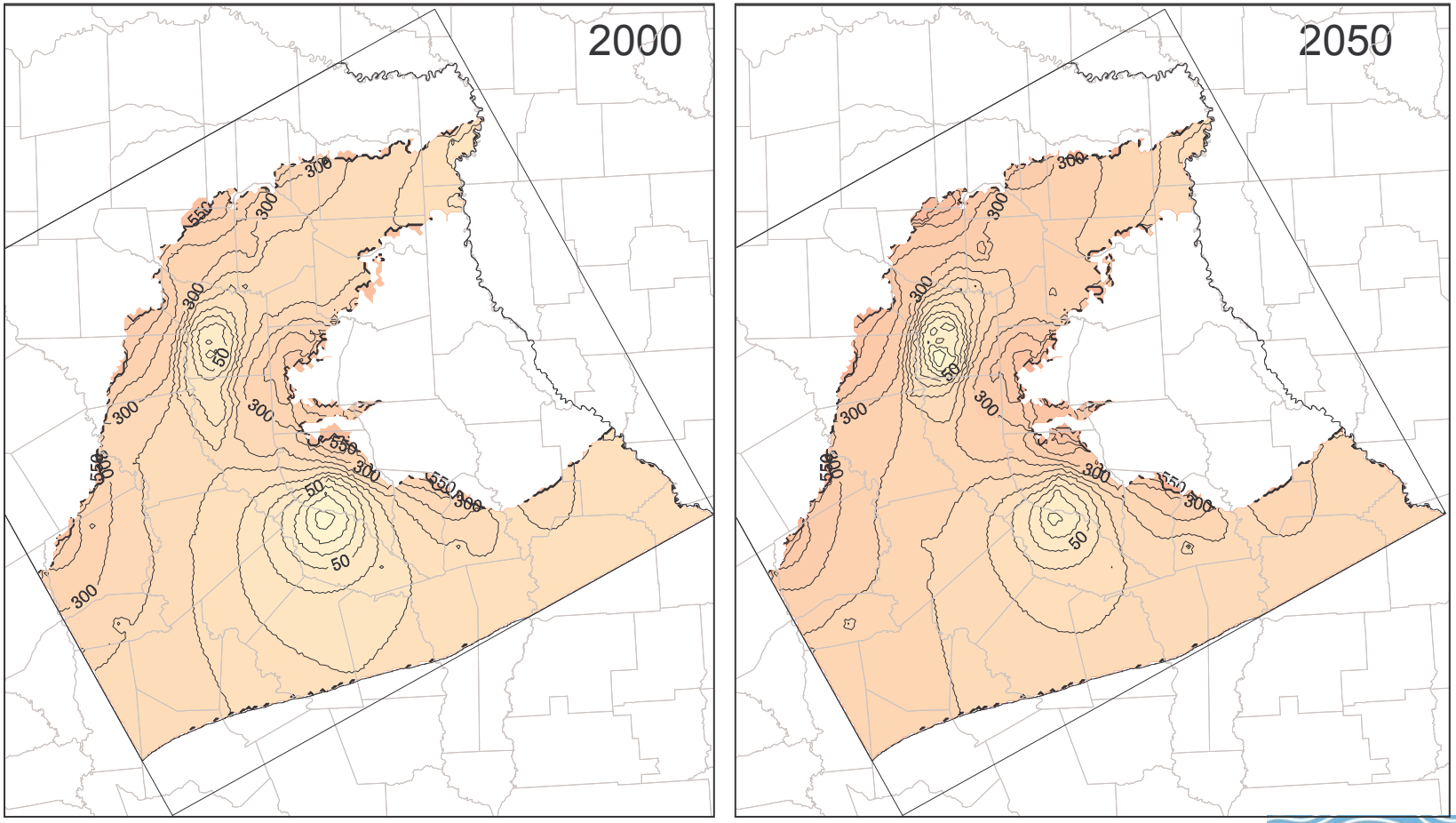


Pumpage in Layer 3 (adjusted)



Prediction 2050 (no DOR): Carrizo

(w/ adjusted pumpage)



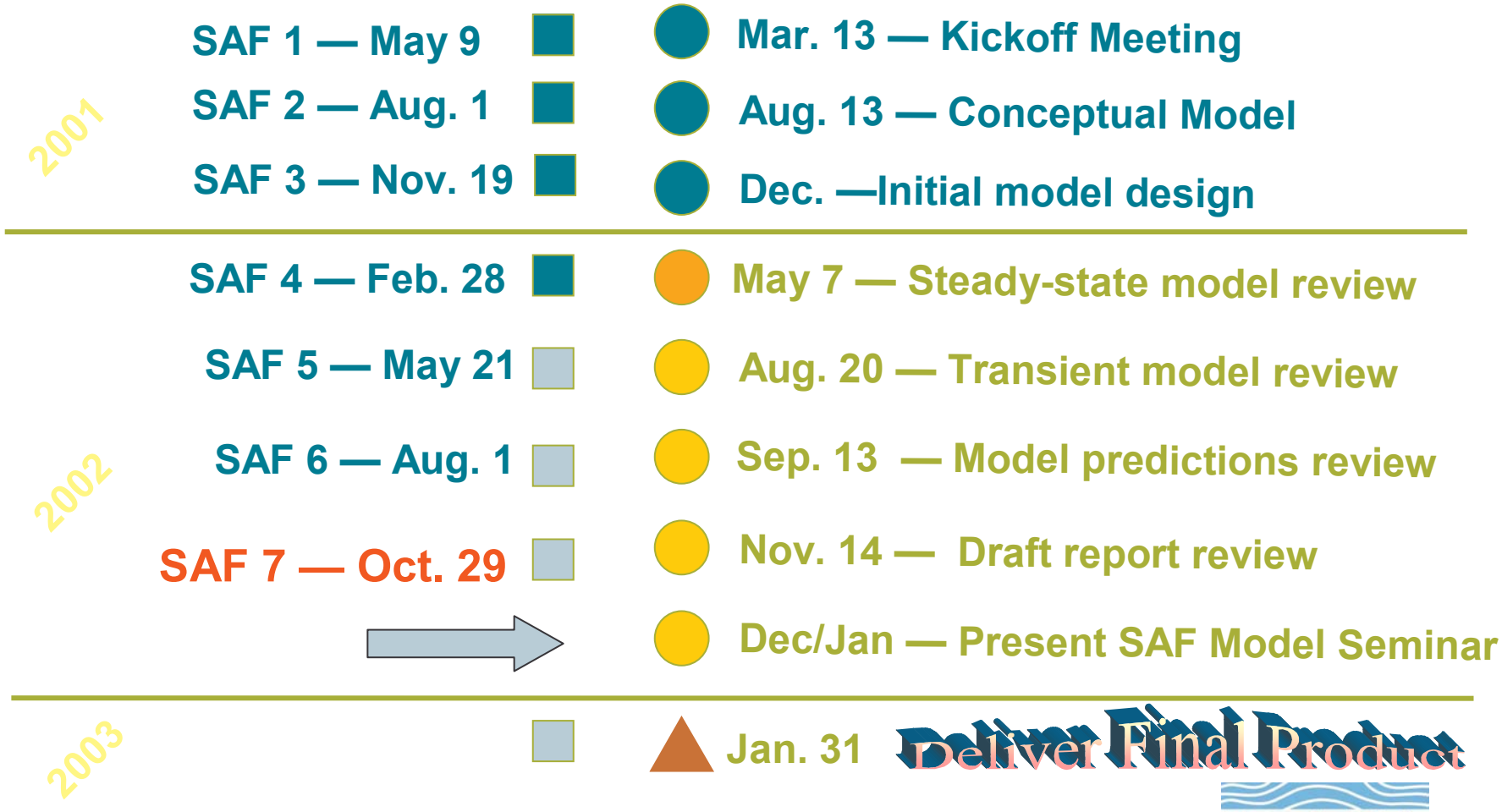
Conclusions

- **GAM for northern Carrizo-Wilcox Aquifer:**
  - **Incorporated all relevant features, data on aquifer properties, recharge estimates, and pumpage**
  - **Calibrated to pre-development conditions, transient, and verification period**
  - **Required some adjustment of properties during transient calibration.**

Conclusions (cont.)

- **Predictive Simulations based on Pumpage from RWPs:**
  - **No noticeable effect of DOR, since DOR only reflects recharge but not potential increase in pumpage**
  - **Significant rebound in Nacogdoches, Angelina Counties**
  - **Potential inconsistency in pumpage allocation for different layers between historical and projected pumpage**

Northern GAM Schedule



Northern Carrizo-Wilcox Aquifer
Groundwater Availability Modeling (GAM)
7th Stakeholder Advisory Forum
October 29th, 2002
Nacogdoches, Texas

Name	Affiliation
Sanjeev Kalaswad	TWDB
Buzz Patrick	Temple Inland Forest Products Corporation
David Smith	City of Nacogdoches
Jim Armstrong	Lake Country GCD
Gerry Meek	Lake Country GCD
A.D. Kleinman	Lake Country GCD
David Alford	Piney Woods GCD
Kevin Grant	City of Nacogdoches
Henry L. Simon	City of Nacogdoches
Brad Randall	City of Nacogdoches
J. Leon Young	SFASU, ET RWPG Region I

List of Questions
SAF No. 7
City of Nacogdoches Recreation Center
Nacogdoches, Texas
October 29, 2002

Questions:

1. Are you still predicting conservation to start at around 2030 (modeling periods graph)?
   A: The modeling periods graph is a schematic representation of potential water-level trends in the future and is not based on real data.

2. Is the figure (modeling periods) based on actual data or is a schematic representation?
   A: The modeling periods graph is a schematic representation and is not based on actual data.

3. Is the figure (modeling periods) strictly for the Carrizo-Wilcox GAM?
   A: The modeling periods figure is general and not specific to the Carrizo-Wilcox

4. Why is there a difference in simulated and measured heads in the hydrograph for Wood County?
   A: The simulated water levels agree with the measured trend but are offset by as much as 20 ft, which is likely due to topographic variability within the 1-by 1-mile grid block represented in the model.

5. Where are the major areas of recharge in the model area?
   A: The major areas of recharge for the Carrizo-Wilcox aquifer are along the western outcrop area and in the Sabine Uplift area. In areas of significant drawdown in the Carrizo-Wilcox aquifer, vertical leakage from the shallow Queen City aquifer can contribute significant amounts of water to the underlying Carrizo-Wilcox aquifer.

6. Why are there no stream flow points in the southern part of the study area?
   A: The southern part of the study area represents the area where the Queen City Formation dips beneath younger formations, which is represented in the model by general head boundary conditions. This boundary condition accounts for vertical flow between the Queen City aquifer and the shallow water table in the younger formations, but does not specifically track stream flow in this part of the model.

7. Can water availability conditions/water levels be predicted with the model for each decade?
   A: Yes, the model calculated water levels monthly throughout the 50-year period and water-level distributions for each decade were presented in the draft report which is posted on the TWDB's web site: http://www.twdb.state.tx.us/Gam/czwx_n/czwx_n.htm.

8. Can problem areas in Texas be predicted over the long-term with this model? Would you know what these problems might be?
A: Yes, the GAM model can identify areas where water levels decline significantly due to projected excess pumpage or potential drought conditions during certain future time periods. The problems would consist of water-levels that may fall below the depth of the pumping wells. The model could not show potential problems associated with deteriorating water quality.

9. Are the closed lines shown on the water-level map, cones of depression?
A: The closed contour lines represent a cone of depression due to significant pumpage.

10. Do actual water-level measurements have an effect on the model?
A: Actual water-level measurements are used to calibrate the model; the goodness of fit based on the comparison between simulated and measured hydraulic heads indicate how well the model represents the hydraulic behavior of the aquifer. The better the model reproduces the measured water-level data, the better is the confidence for the model to predict water levels in the future

11. Is not the projected reduction in groundwater usage (in Wood County?) due to conversion to surface water?
There is a distinct drop in overall annual pumpage between 1999 (based on historical data) and 2000 (based on predicted pumpage from the RWPGs) for Wood County. Between 2000 and 2050, predictive pumpage data indicates a gradual increase. The sudden change in pumpage suggests that there is a problem in pumpage allocation between the historical pumpage data set and the predictive pumpage data set and does not represent conversion to surface water. This discrepancy between historical and predicitive pumpage data sets needs to be examined in more detail.

12. Is recharge applied uniformly over the entire model area rather than just over the outcrops?
A: Recharge is applied to the entire surface of the model area, except for the southern part, which is represented by a general head boundary condition. This boundary condition effectively calculated recharge or discharge at the surface based on difference in water levels between the shallow water table and calculated water levels in the underlying layers. In the northern area, the applied recharge varies spatially and seasonally, which is based on information on precipitation, temperature, and soil conditions throughout the year.

13. Is the sensitivity analysis being pushed the wrong way?
A: No, it is based on individual simulations whereby a specific parameter is increased or decreased by a certain fraction of the initial value. However, this initial value is associated with some uncertainty and may be biased toward the low or high side.

14. If population increases in a county (Wood County), will not groundwater pumping also increase?
A: Yes, predictive pumpage estimates are based on projected population increases and pumpage typically increases with increasing population, unless the increased demand is covered by additional surface water.

15. Do you expect advance conservation to be a major player in the area in the future?
A: Probably to a limited extend, because there are a large number of surface reservoirs, which are being tapped for additional water demands.

Comments:

1. STAKEHOLDER: There appears to be a discrepancy between the historical groundwater usage numbers and those projected by the RWPGs for the predictive groundwater usage.

   INTERA: We will be examining these in more detail.

2. STAKEHOLDER: The GAM is an important tool for integrating the relevant hydrogeologic data as well as pumpage data, and will be very useful to groundwater conservation districts in the area to assess groundwater availability for the next fifty years.

   INTERA AND TWDB: The model can be used to update new information and to assess potential water management strategies that were not included in the current RWPGs or that are being planned in the future.