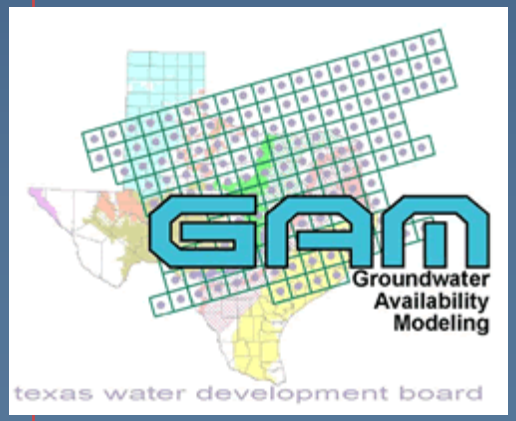
Stakeholder Advisory Forum - 6

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



Northeast Texas Municipal Water District (NETMWD)

Hughes Springs, Texas

August 1st, 2002

INTERA

PARSONS

WATERSTONE
Environmental Hydrology and Engineering, Inc.

Presentation Outline

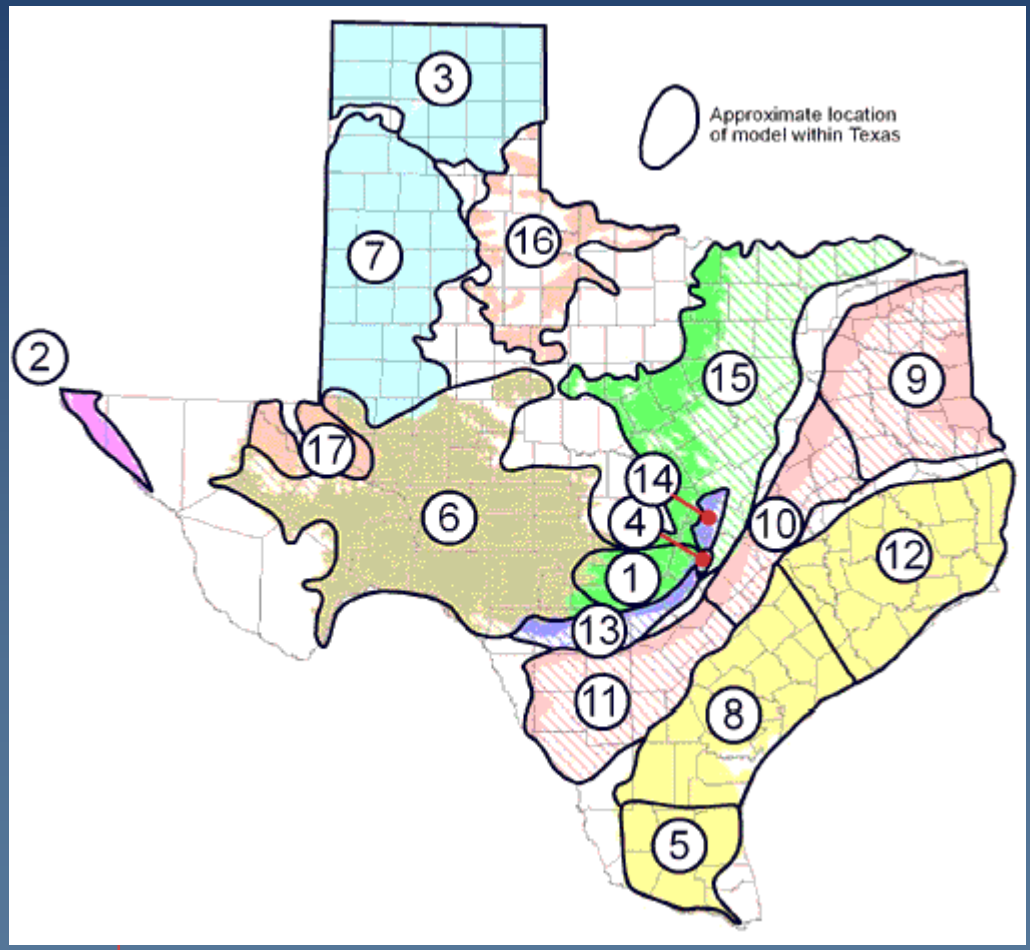
- GAM review
- Model Review and Issues
- Steady-State Model Recap
- Transient Modeling
- Future SAF Meeting

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

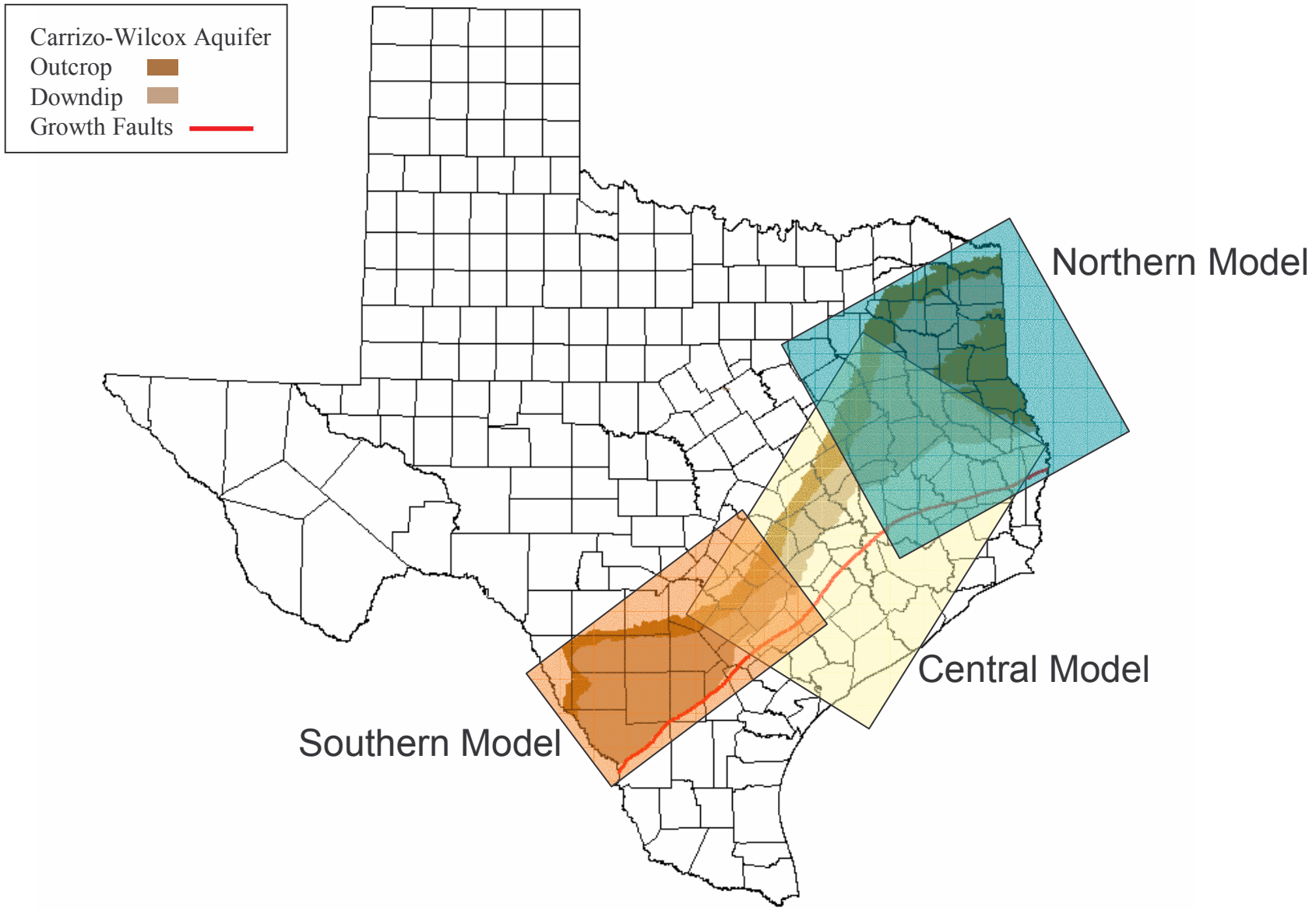
- Ongoing:
  - Carrizo-Wilcox (9-11)
  - Ogallala south (7)
  - Gulf Coast central (8)
  - Gulf Coast north (12)
  - Lower Rio Grande (5)
  - Edwards Trinity (6)
- Completed:
  - Trinity HC (1)
  - Hueco Bolson (2)
  - Ogallala north (3)
  - Edwards - BS (4)



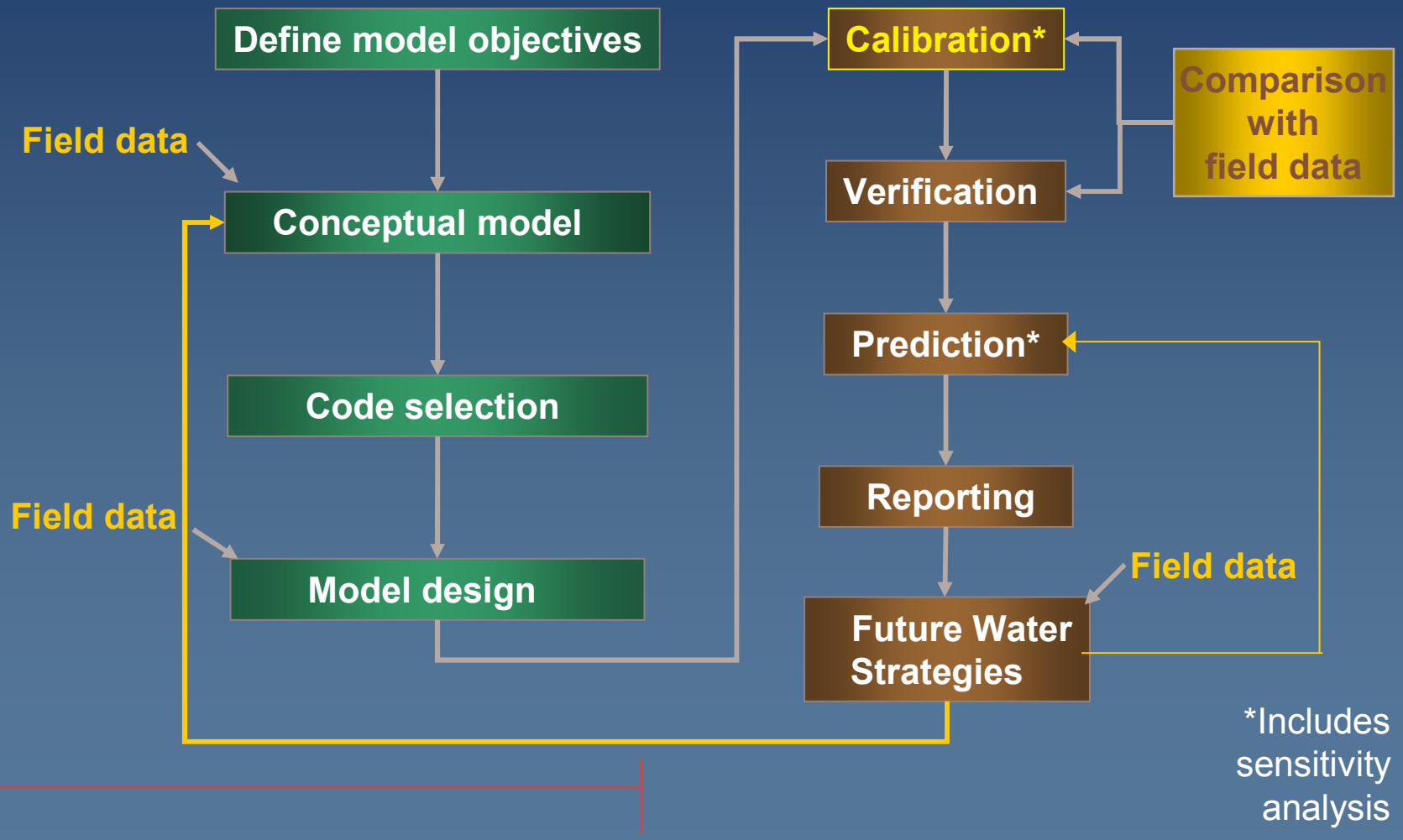
Model Specifications

- Three dimensional (MODFLOW-96)
- Regional scale (100's of mi2)
- Grid spacing of 1 square mile
- Include Groundwater/surface water interaction (Stream routing, Prudic 1988)
- Properly implement recharge
- Stress periods as small as 1 month
- Calibration to within 10% of head drop

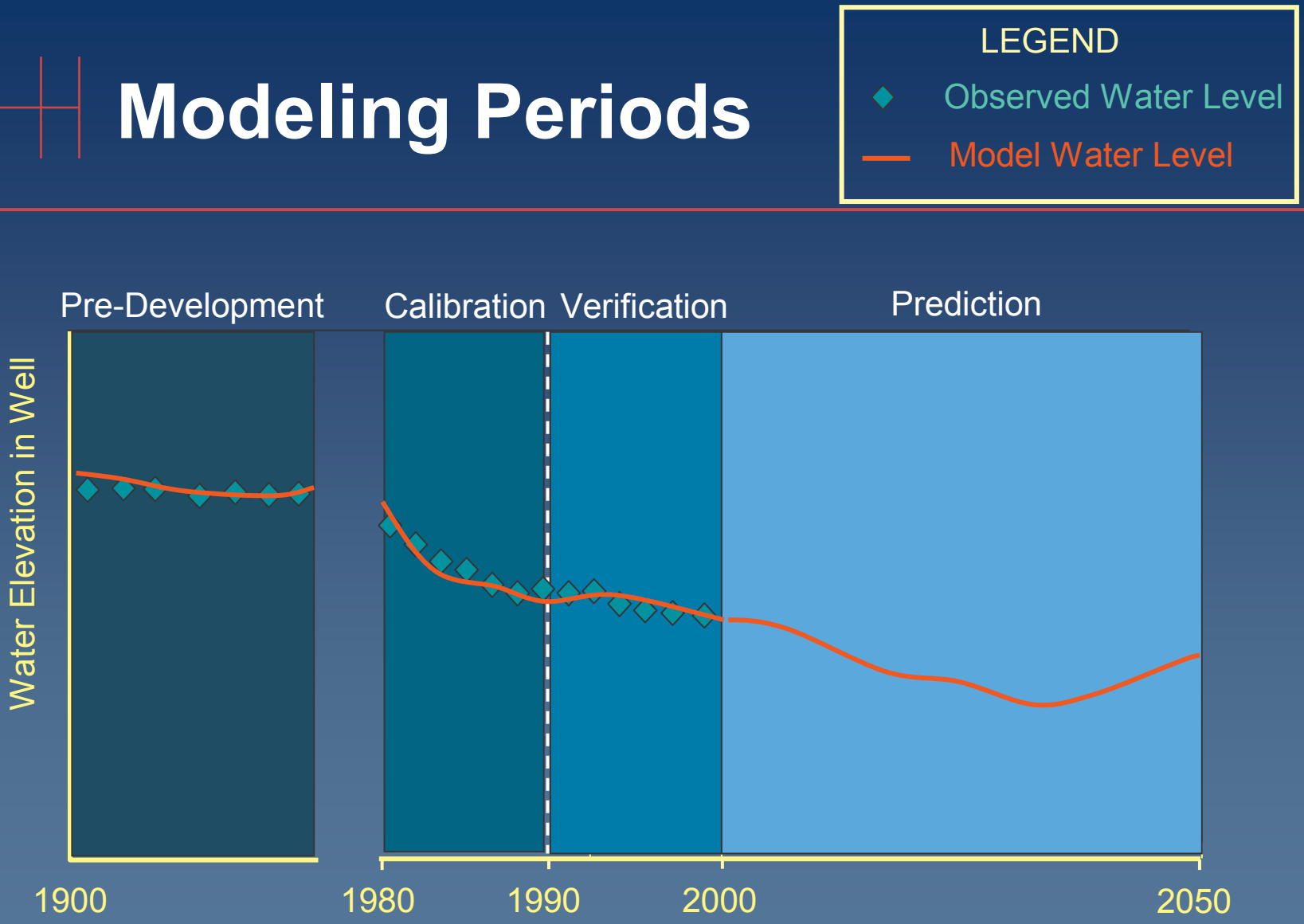
Carrizo-Wilcox GAM Model Domains



Modeling Protocol



Modeling Periods



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- Transient Modeling
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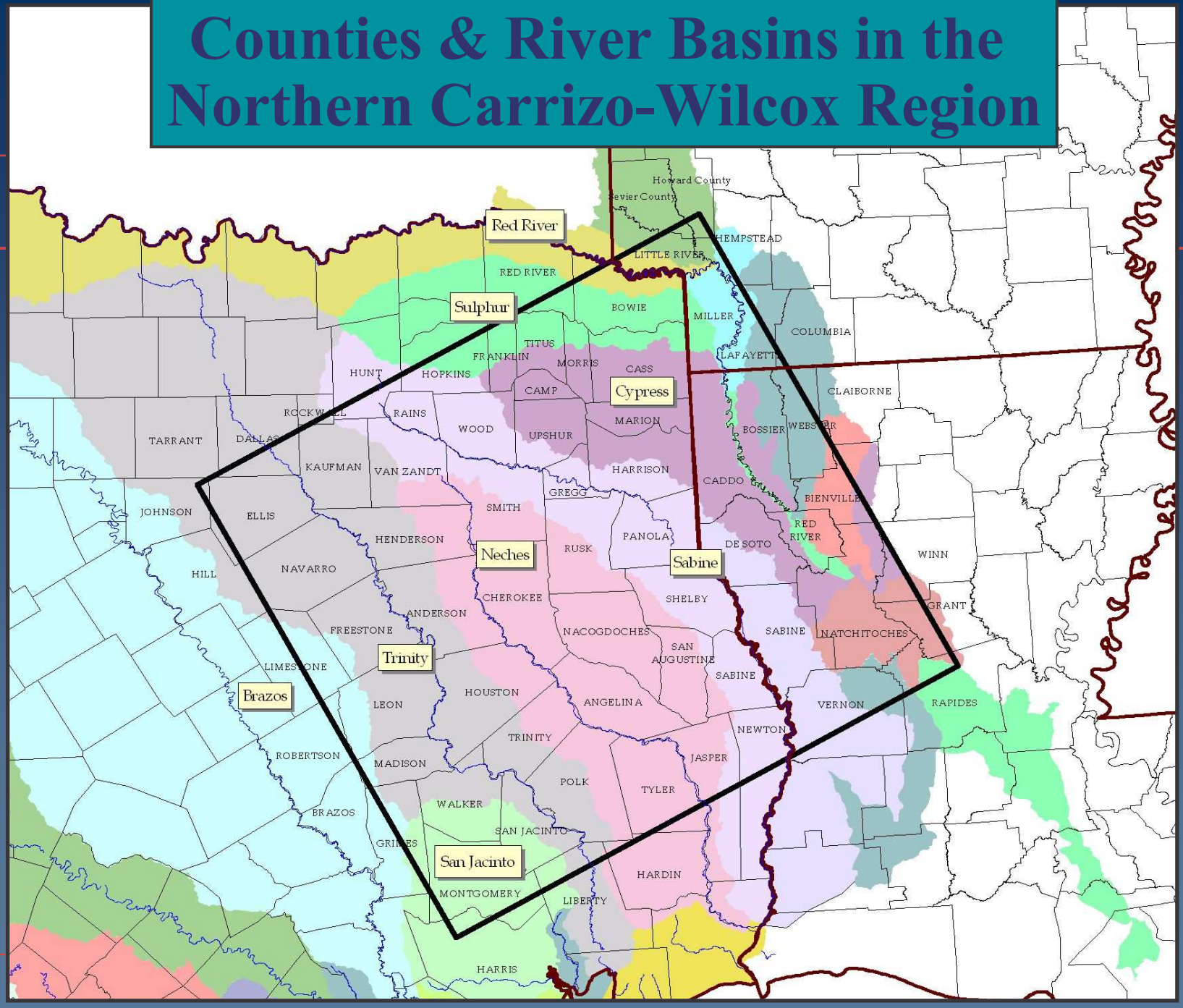
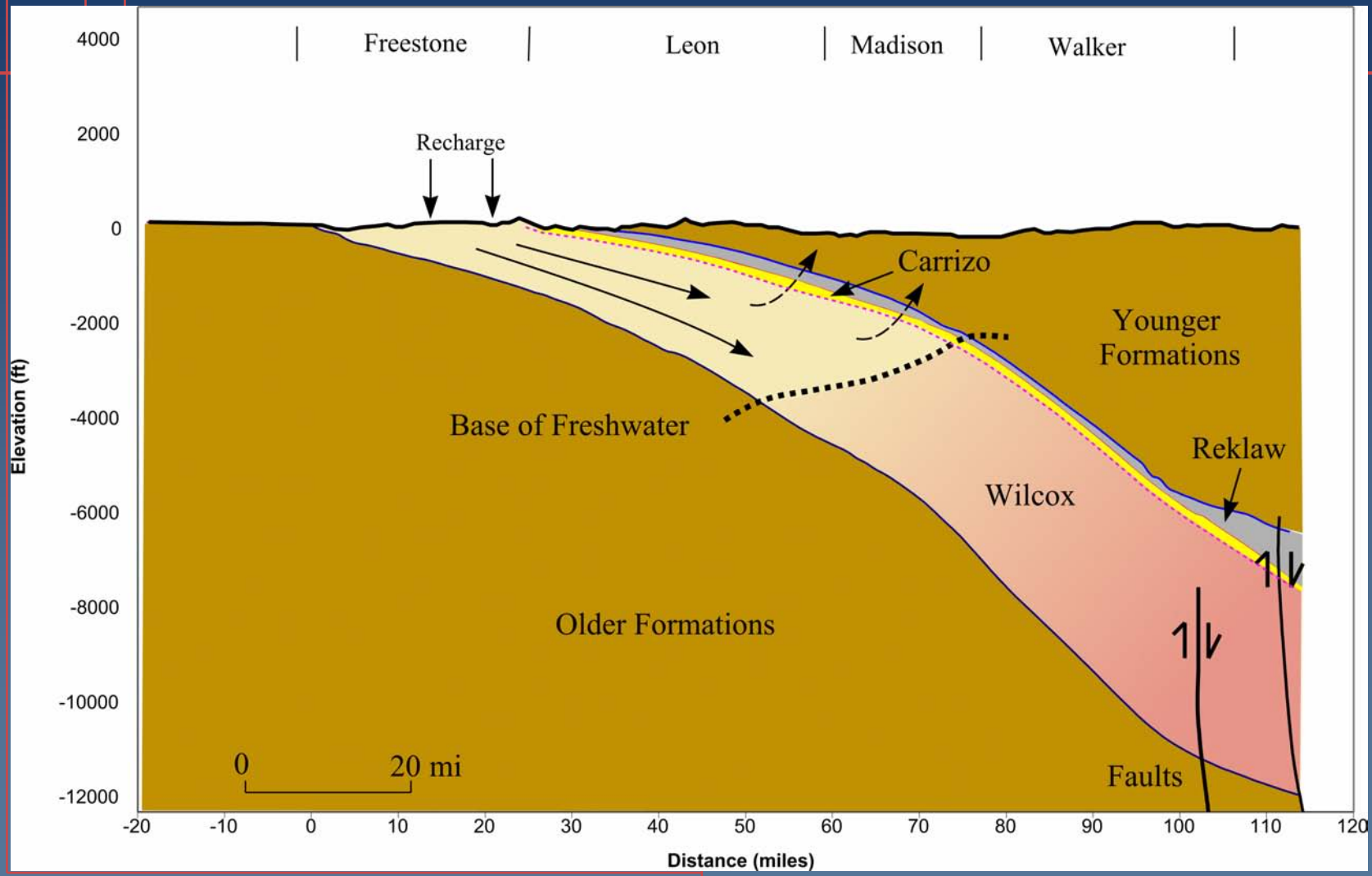
Counties & River Basins in the Northern Carrizo-Wilcox Region

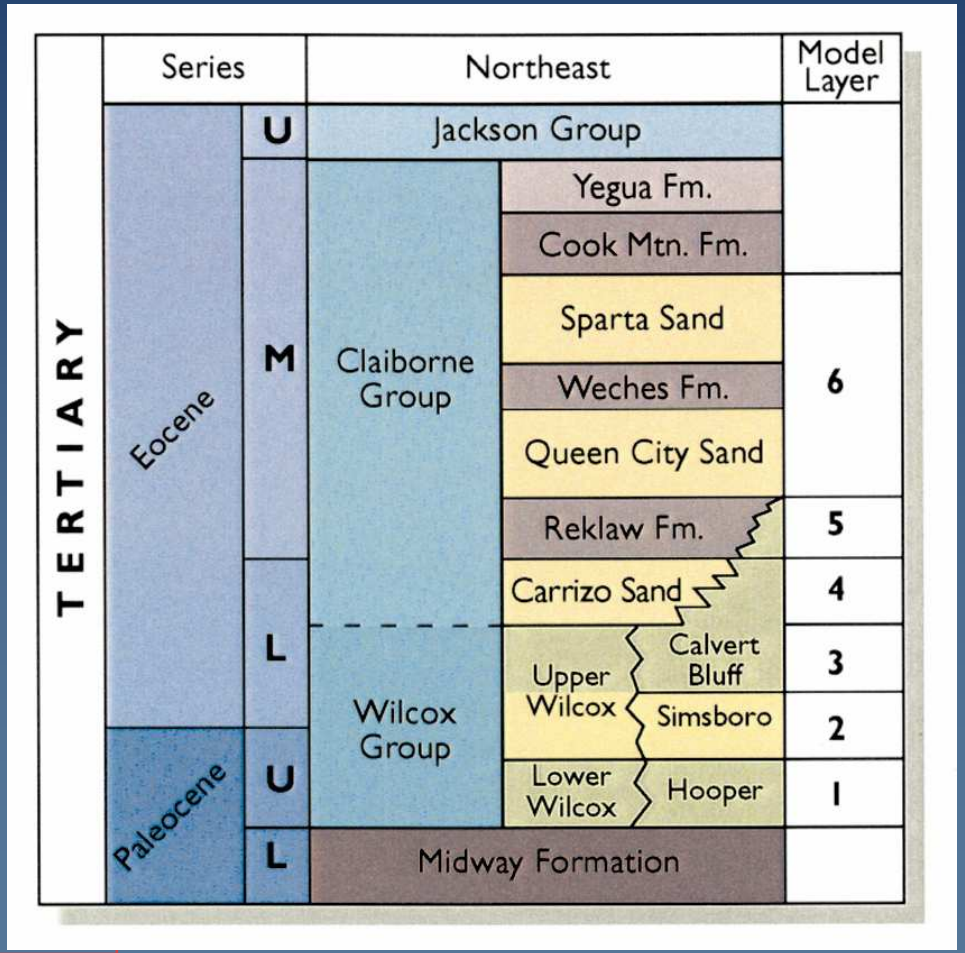


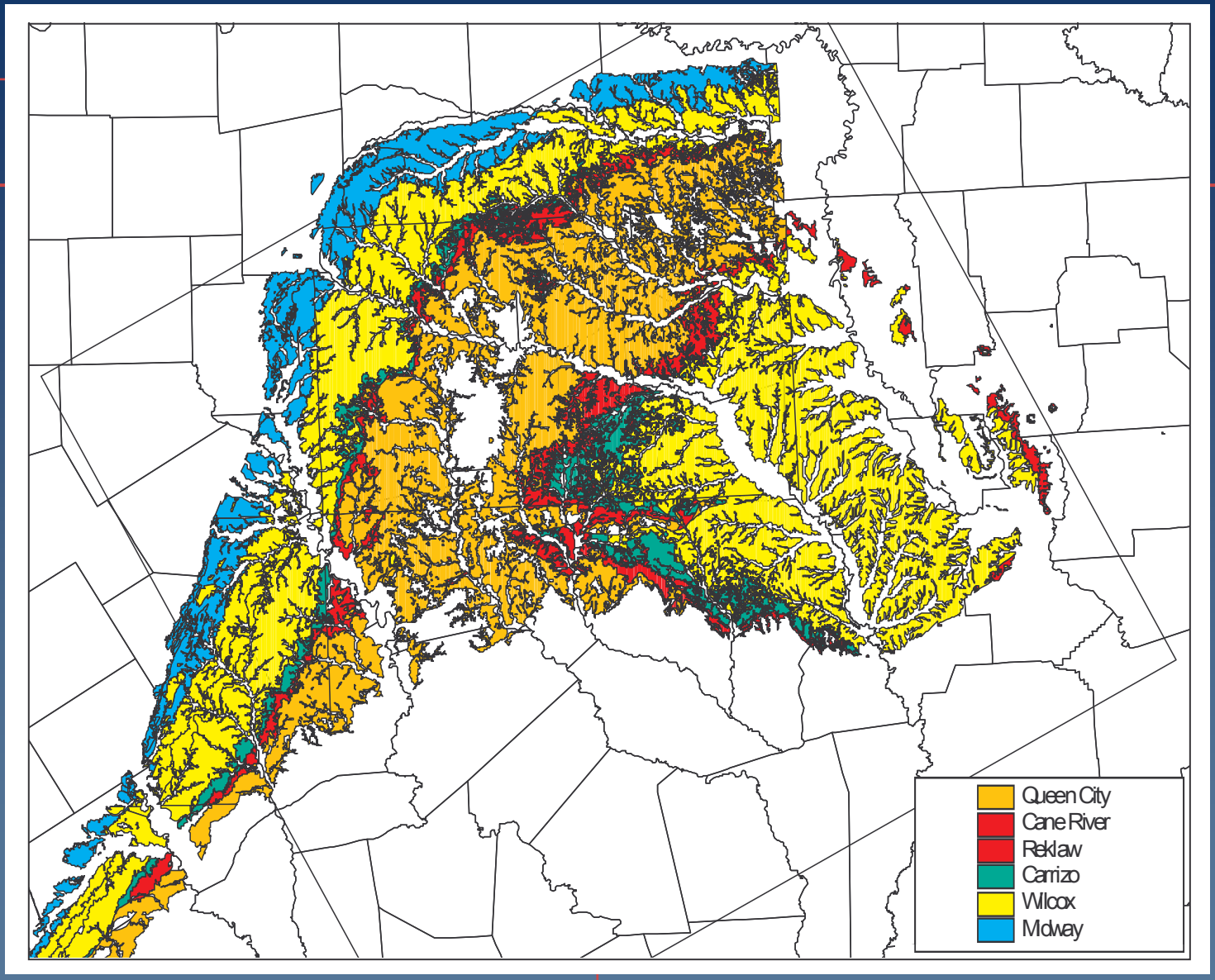
Geologic Framework: X-Section



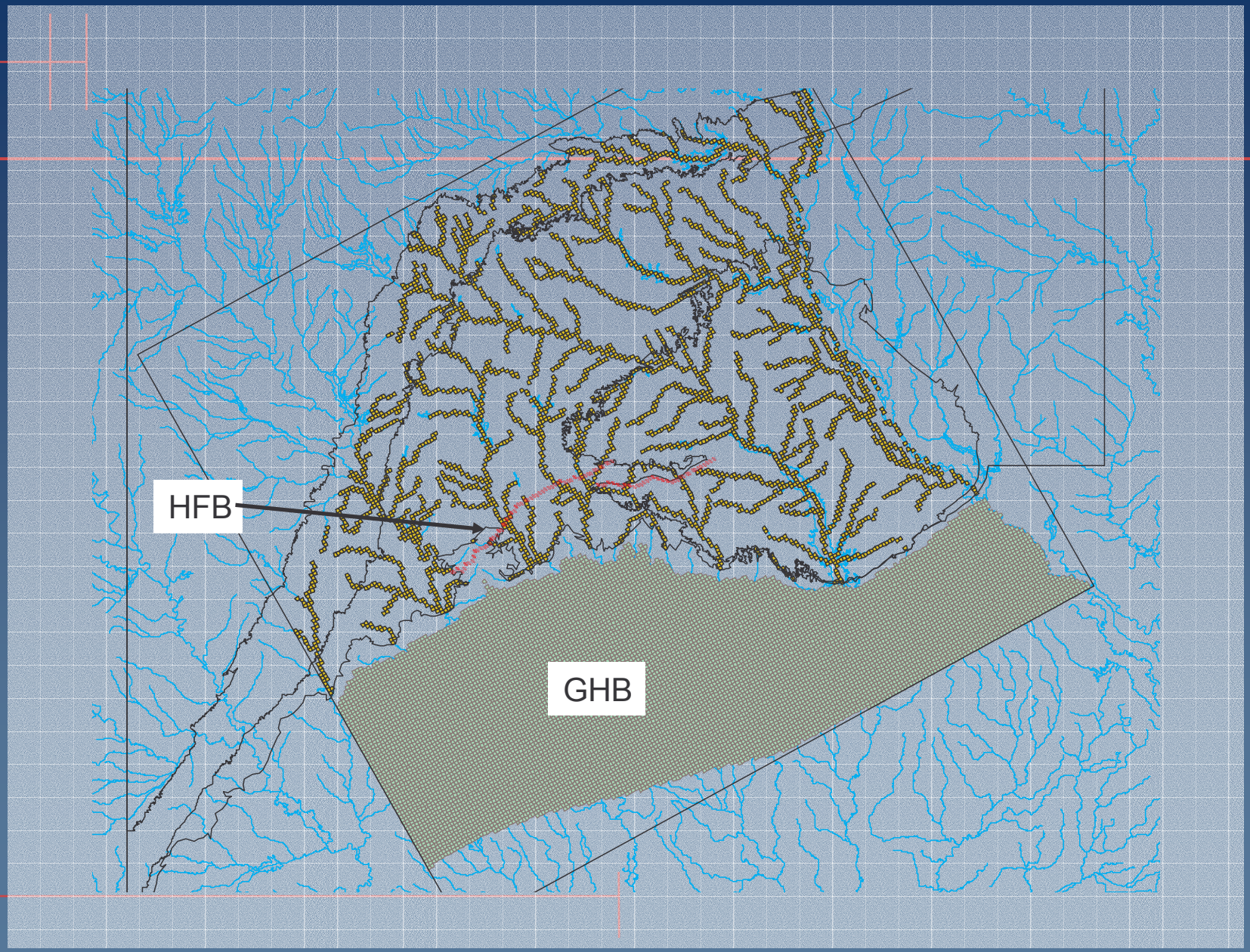
Model Layers

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




Queen City
Cane River
Reklaw
Carrizo
Wilcox
Midway

Model Boundary Conditions



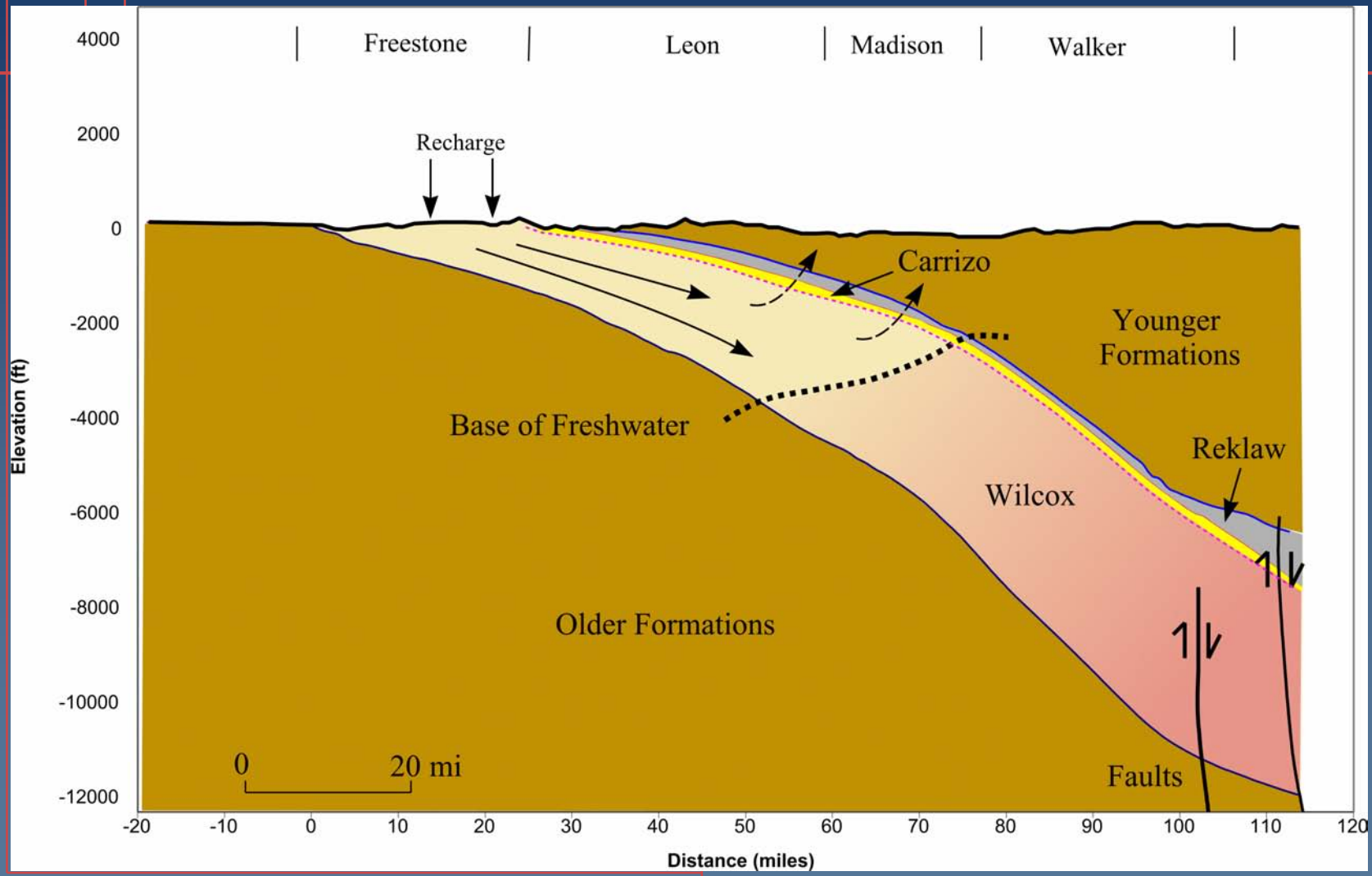
Presentation Outline

- GAM review
- Model Review and Issues
- **Steady-State Model Recap**
- Transient Modeling Results
- Future SAF Meeting

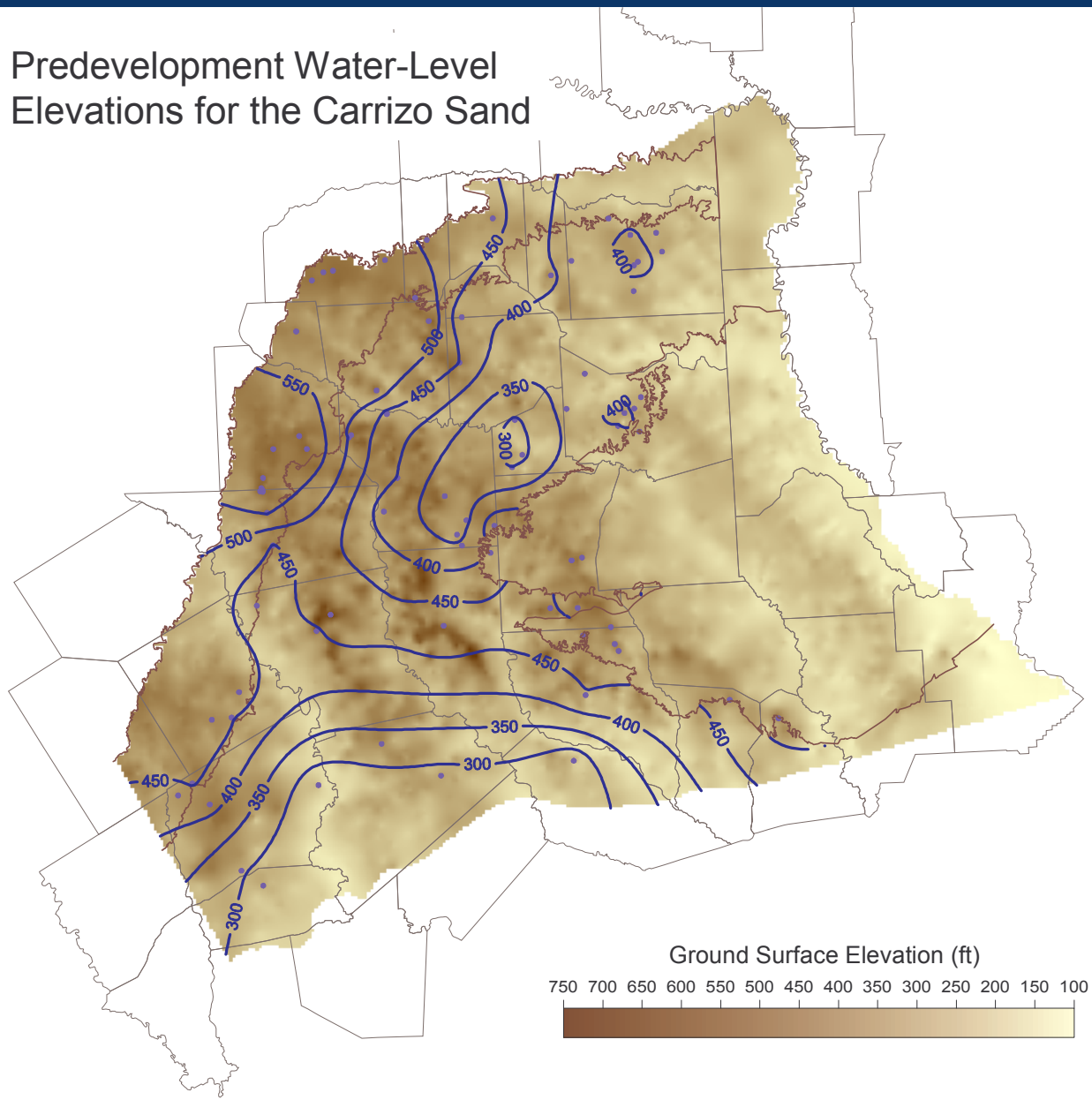
Steady-State Calibration

- Calibration Targets:
  - Pre-development hydraulic heads
- Parameter Variations:
  - Hydraulic conductivity
  - Recharge
- Problem:
  - Potential non-unique solution, i.e., different combination of K and R can produce similar results

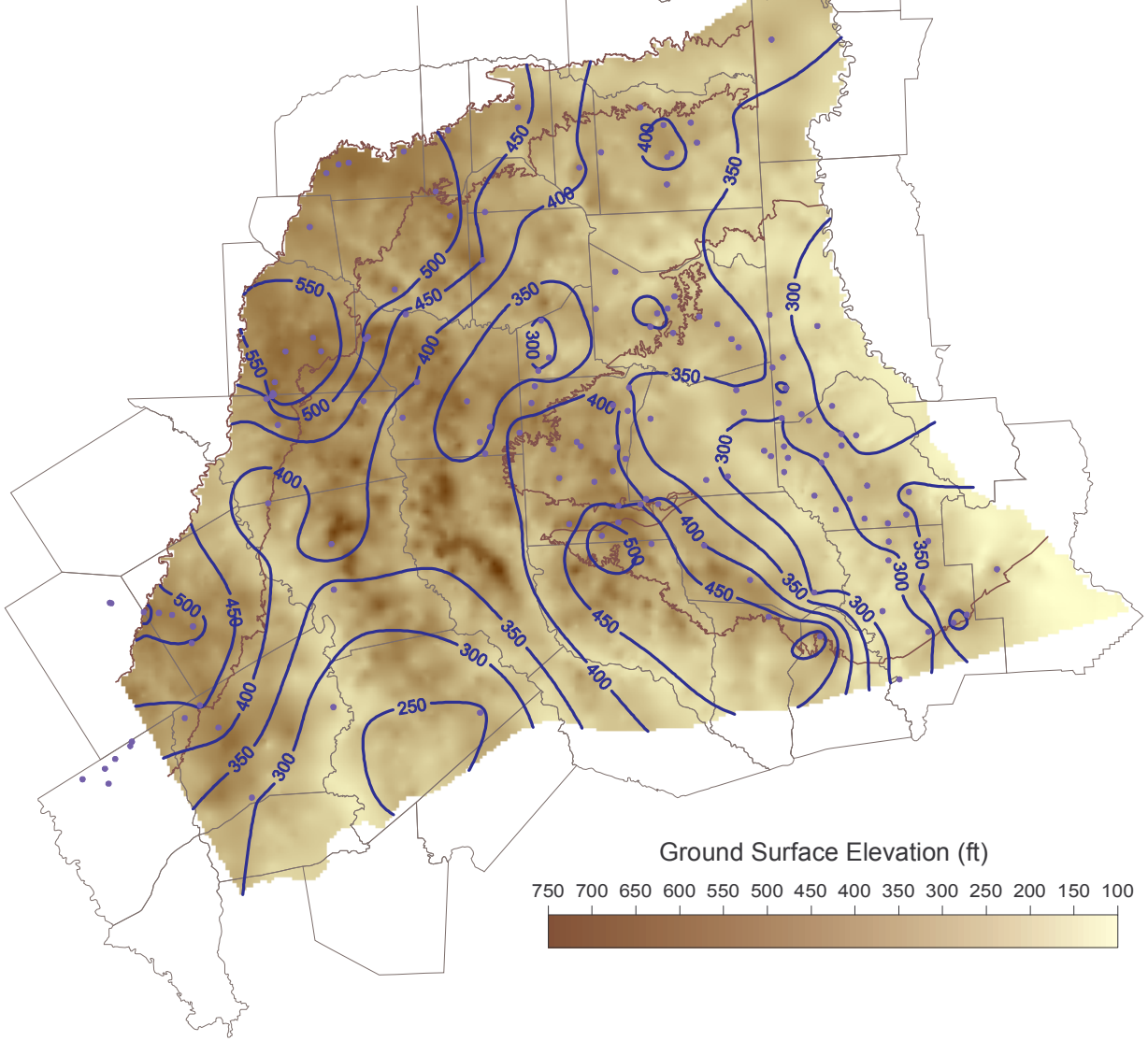
Geologic Framework: X-Section



Predevelopment Water-Level Elevations for the Carrizo Sand



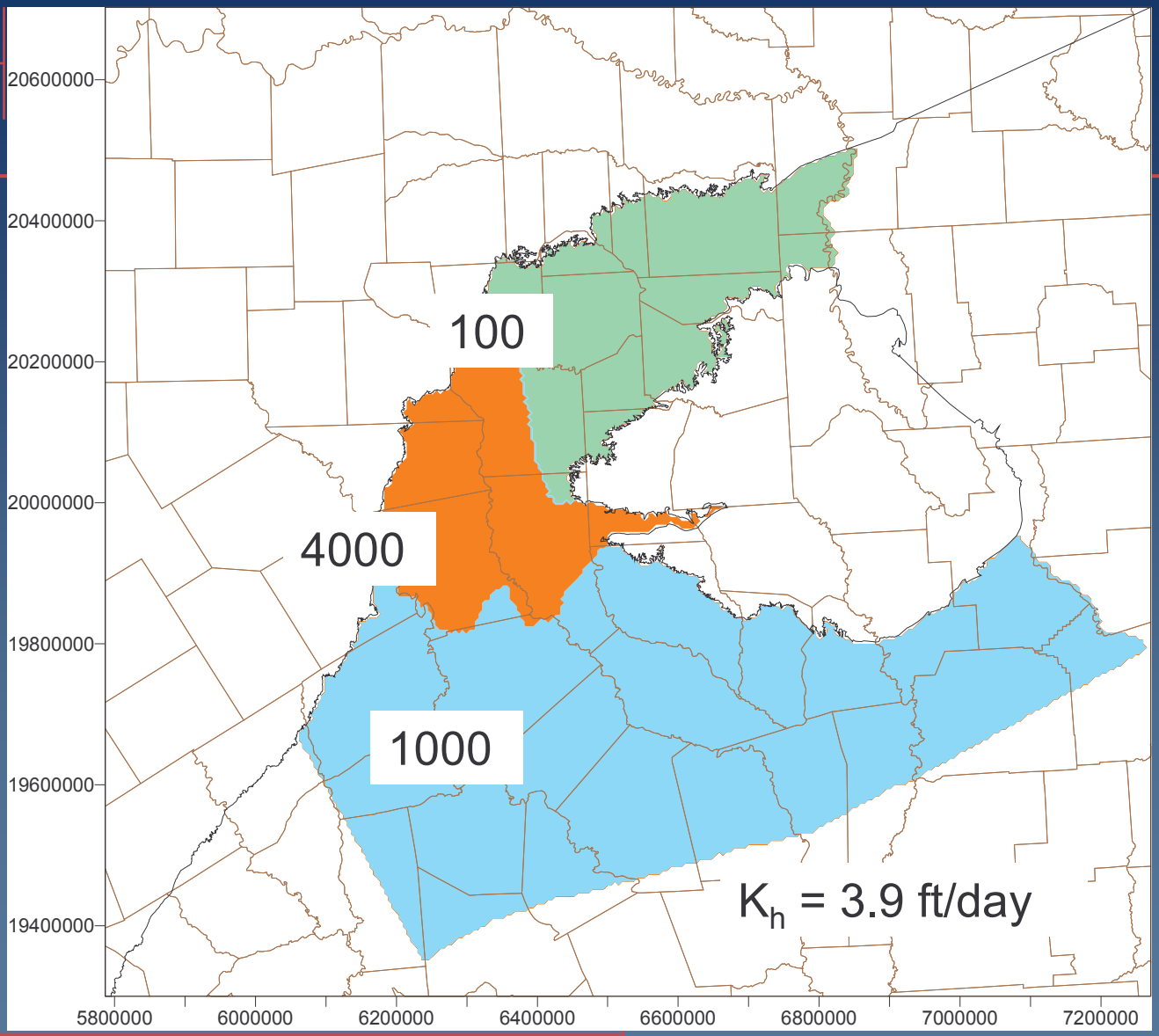
Predevelopment Water-Level Elevations for the Wilcox Group



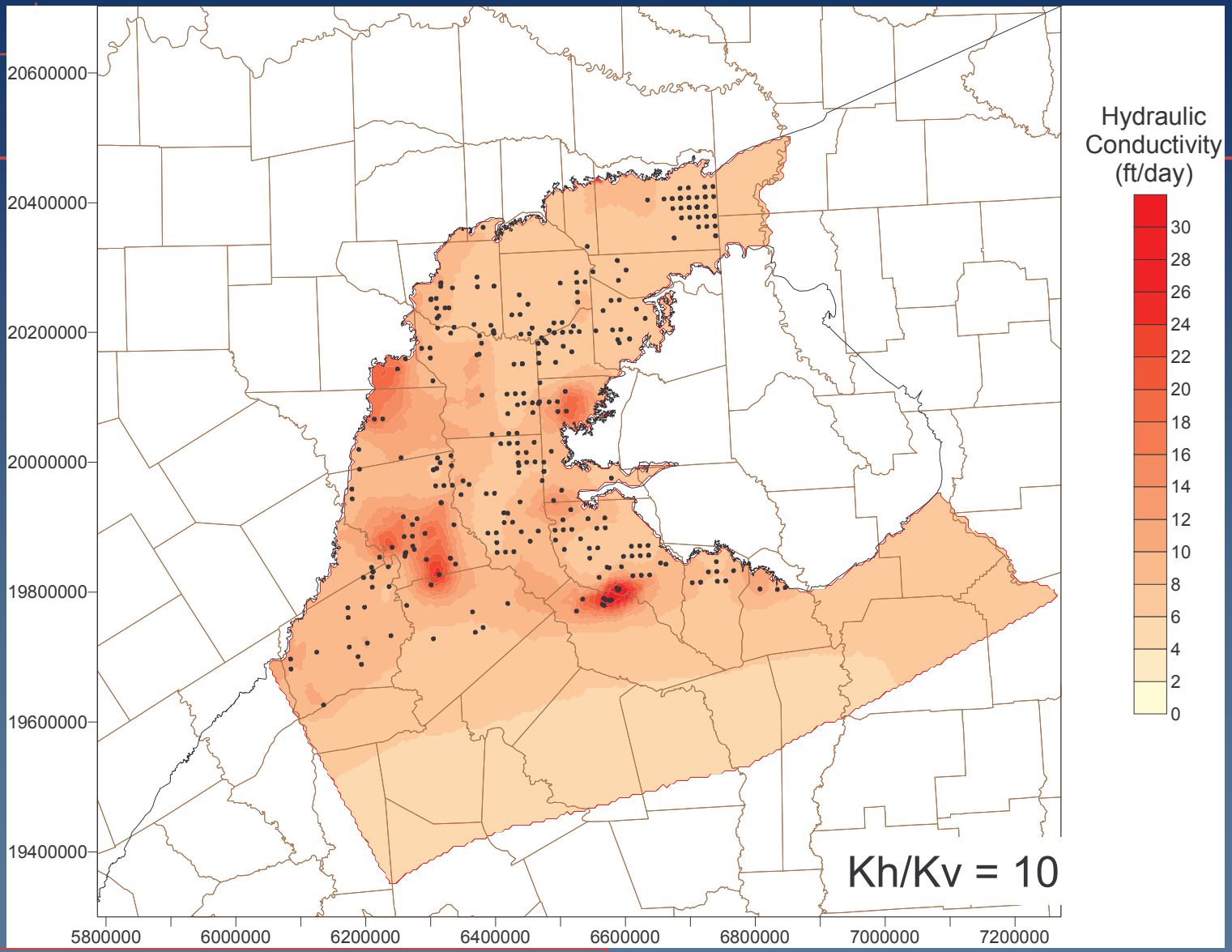
Hydraulic Conductivities

- A good distribution of point measurements are available for the Carrizo-Wilcox (Mace et al, 2000)
- Poor correlation between measured values and estimated sand patterns
- Must scale K_h and K_v to regional grid scale

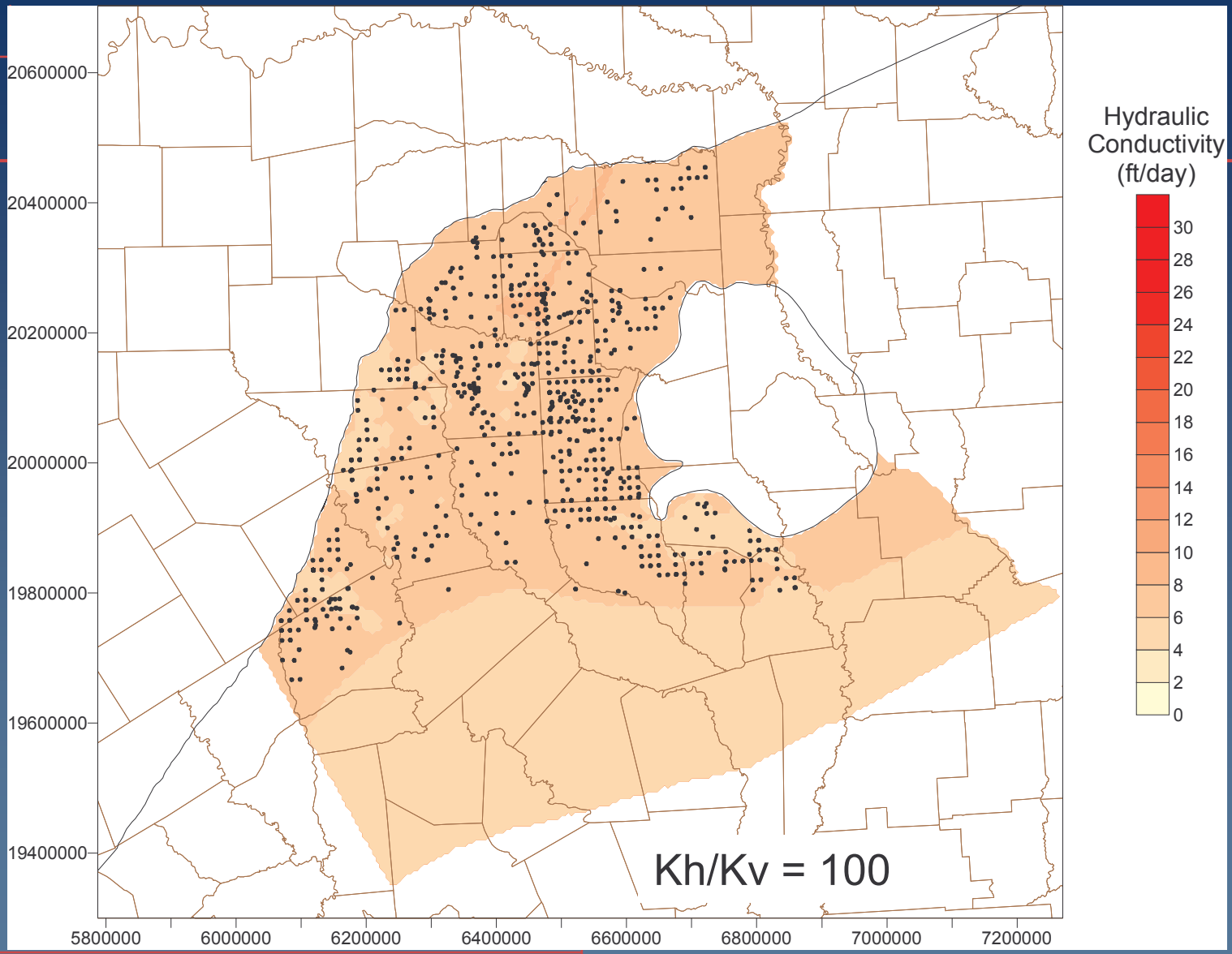
Reklaw K_h/K_v


20600000
20400000
20200000
20000000
19800000
19600000
19400000
5800000
6000000
6200000
6400000
6600000
6800000
7000000
7200000
100
4000
1000
K_h = 3.9 ft/day

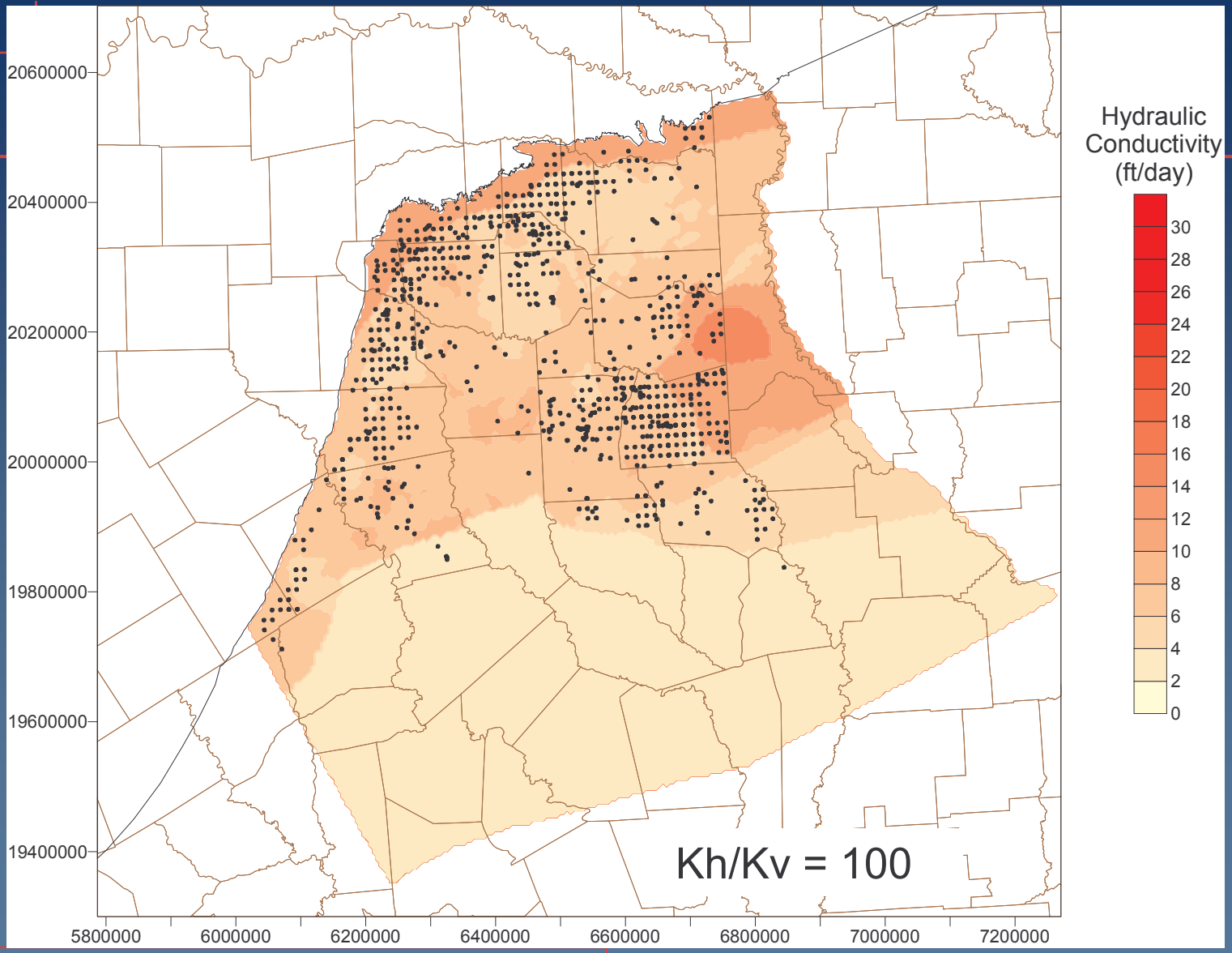
Carrizo Hydraulic Conductivities



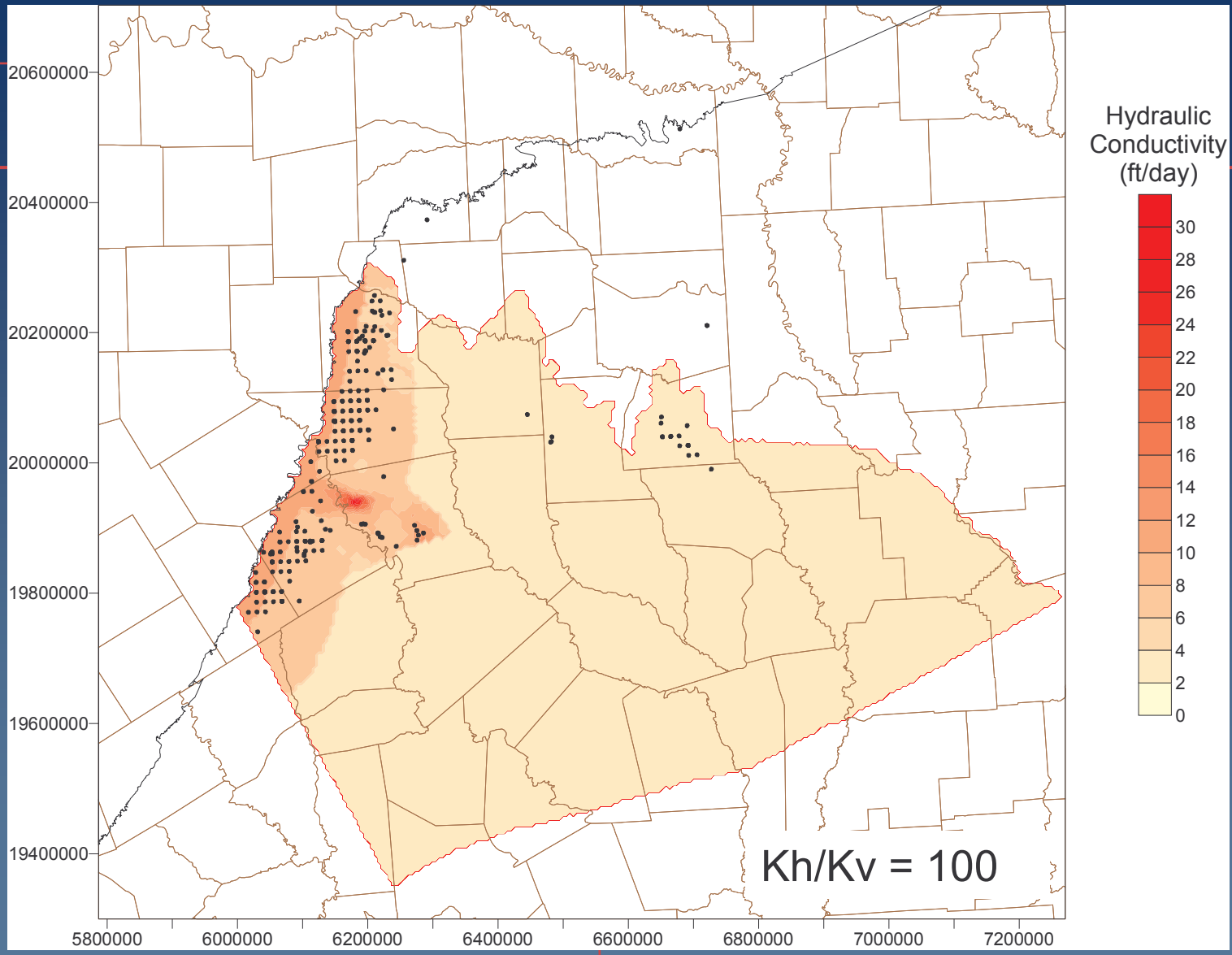
Upper Wilcox Hydraulic Conductivities



Middle Wilcox Hydraulic Conductivities

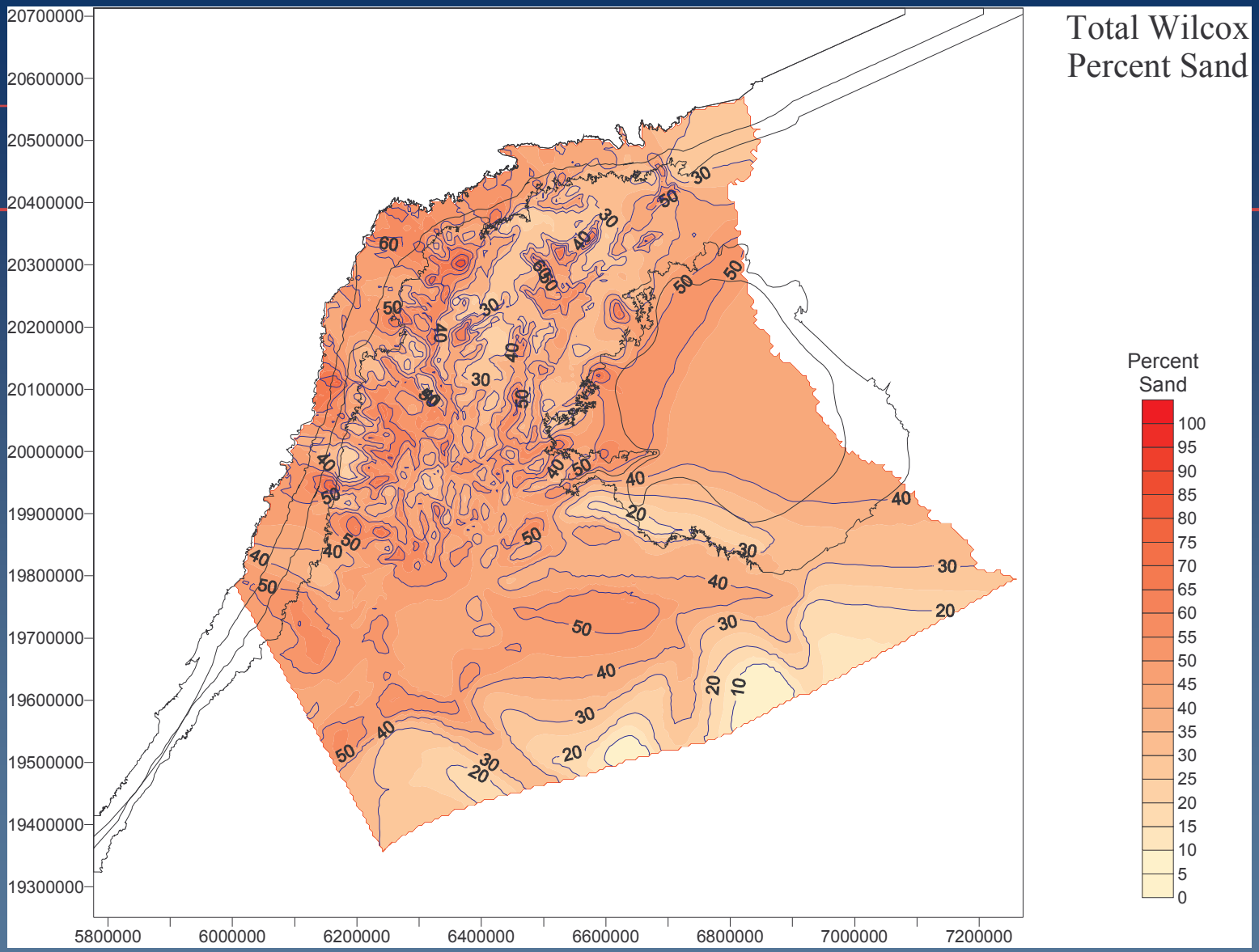


Lower Wilcox Hydraulic Conductivities



Sand Distributions

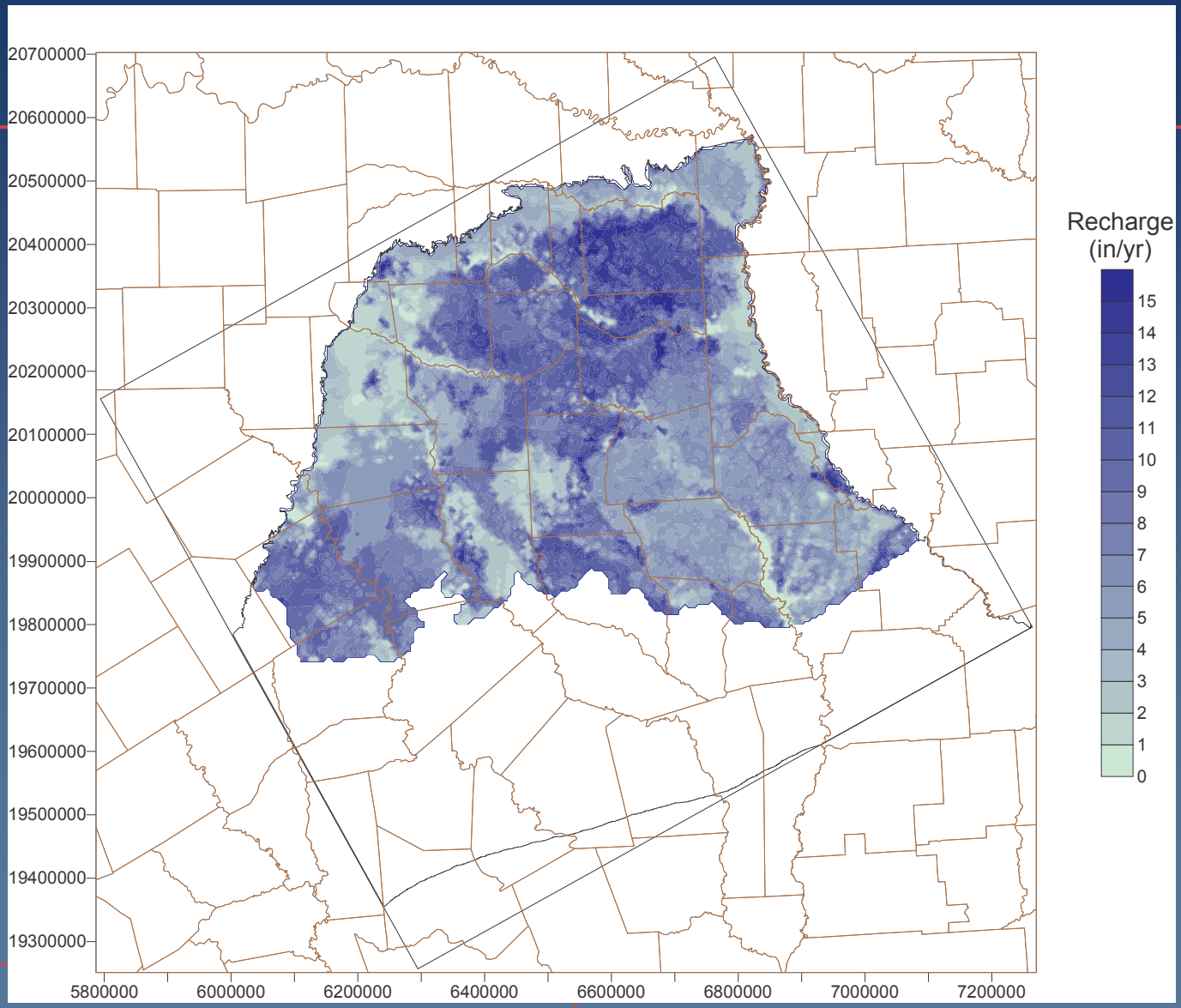
- Wilcox:Used sand thickness maps from Kaiser et. al. (1978) and Fisher and McGowen (1967)
- Split out between Upper, Middle, and Lower Wilcox by percent; 37.5, 37.5, and 25, respectively.
- Carrizo: Assumed to be approximately 100 percent sand.


Total Wilcox
Percent Sand
Percent
Sand
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
20700000
20600000
20500000
20400000
20300000
20200000
20100000
20000000
19900000
19800000
19700000
19600000
19500000
19400000
19300000
5800000
6000000
6200000
6400000
6600000
6800000
7000000
7200000

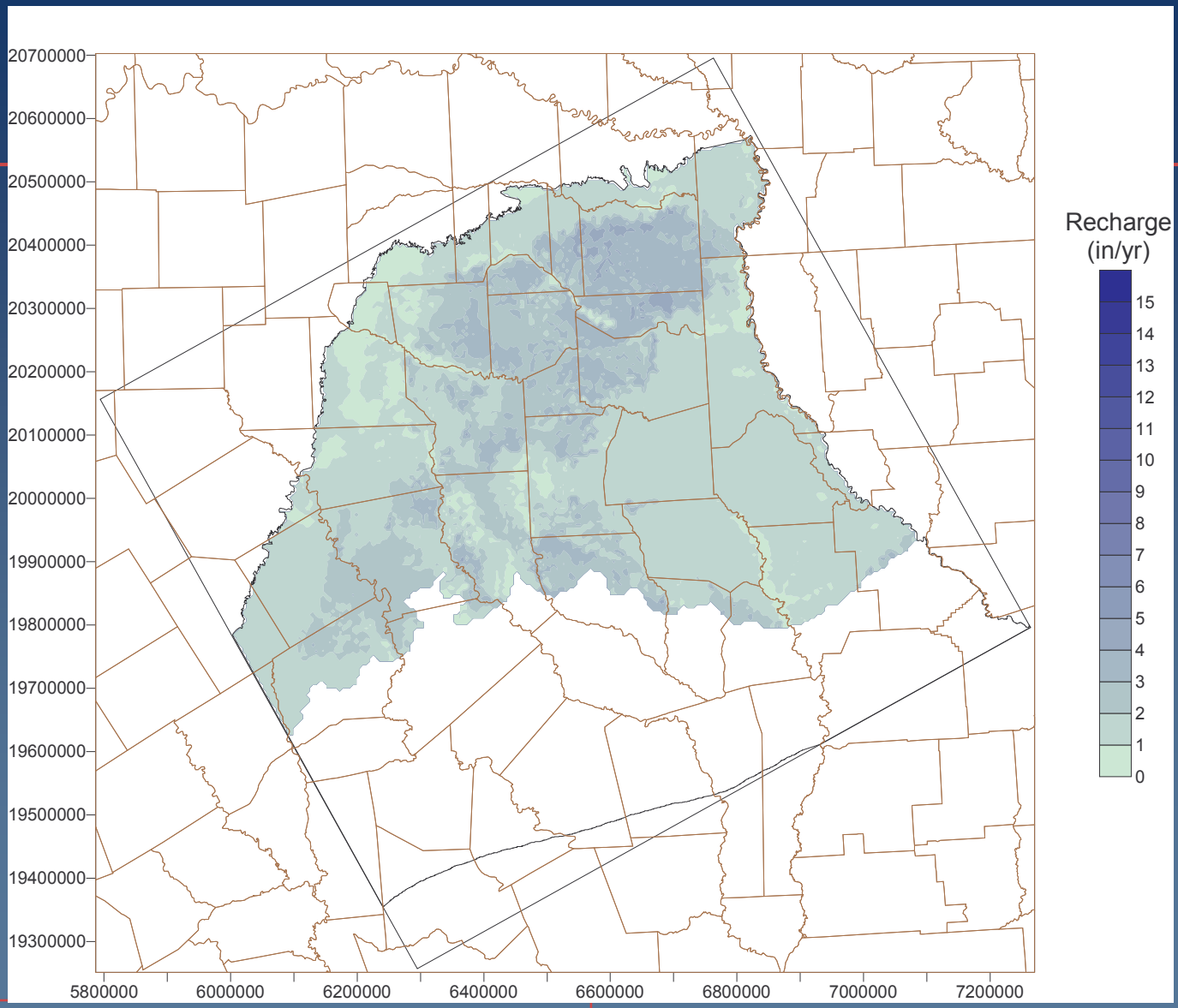
Recharge Estimation: SWAT (Soil and Water Assessment Tool)

- 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
- Steady-State Model: Neglect evapotranspiration

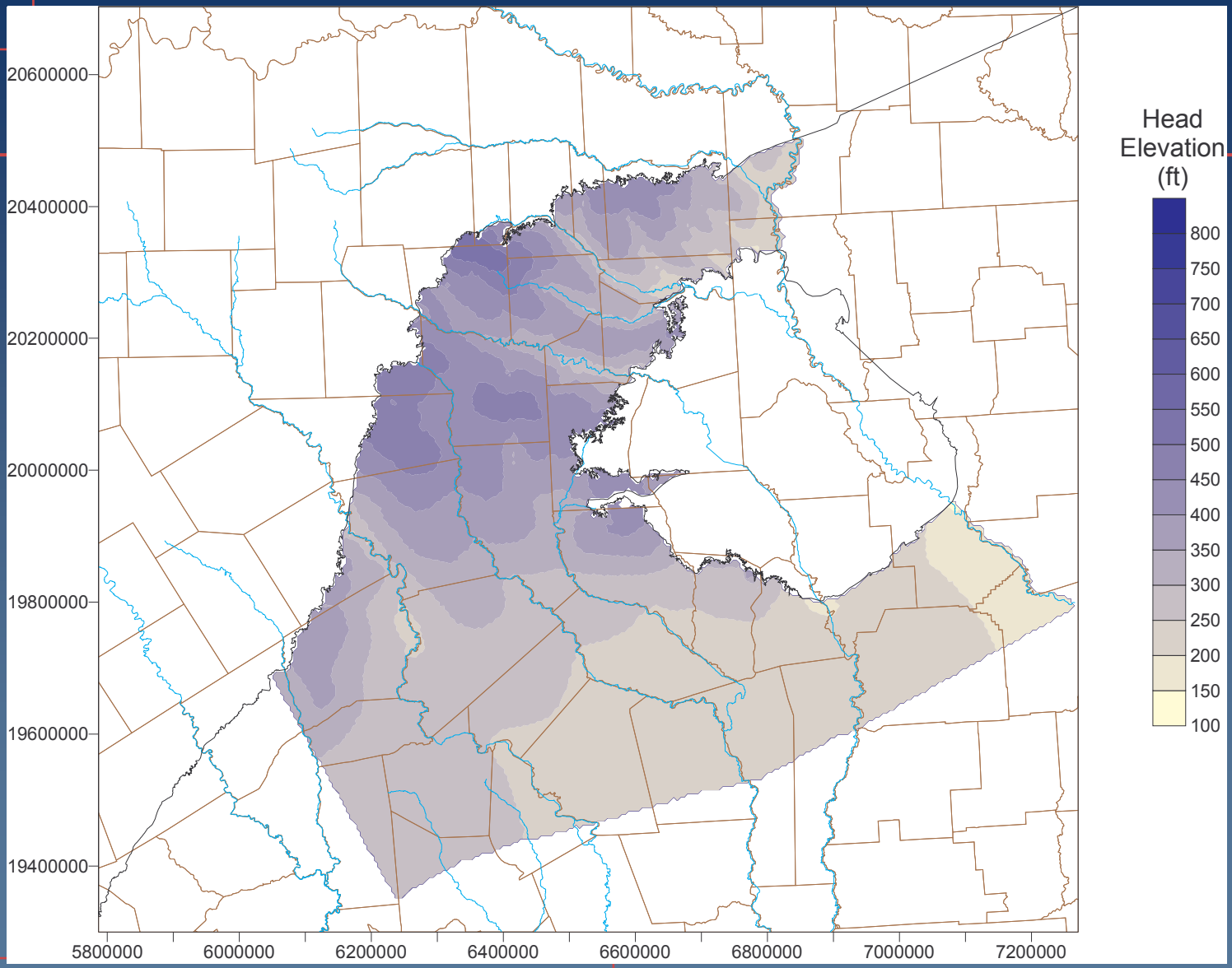
Recharge Estimated by SWAT



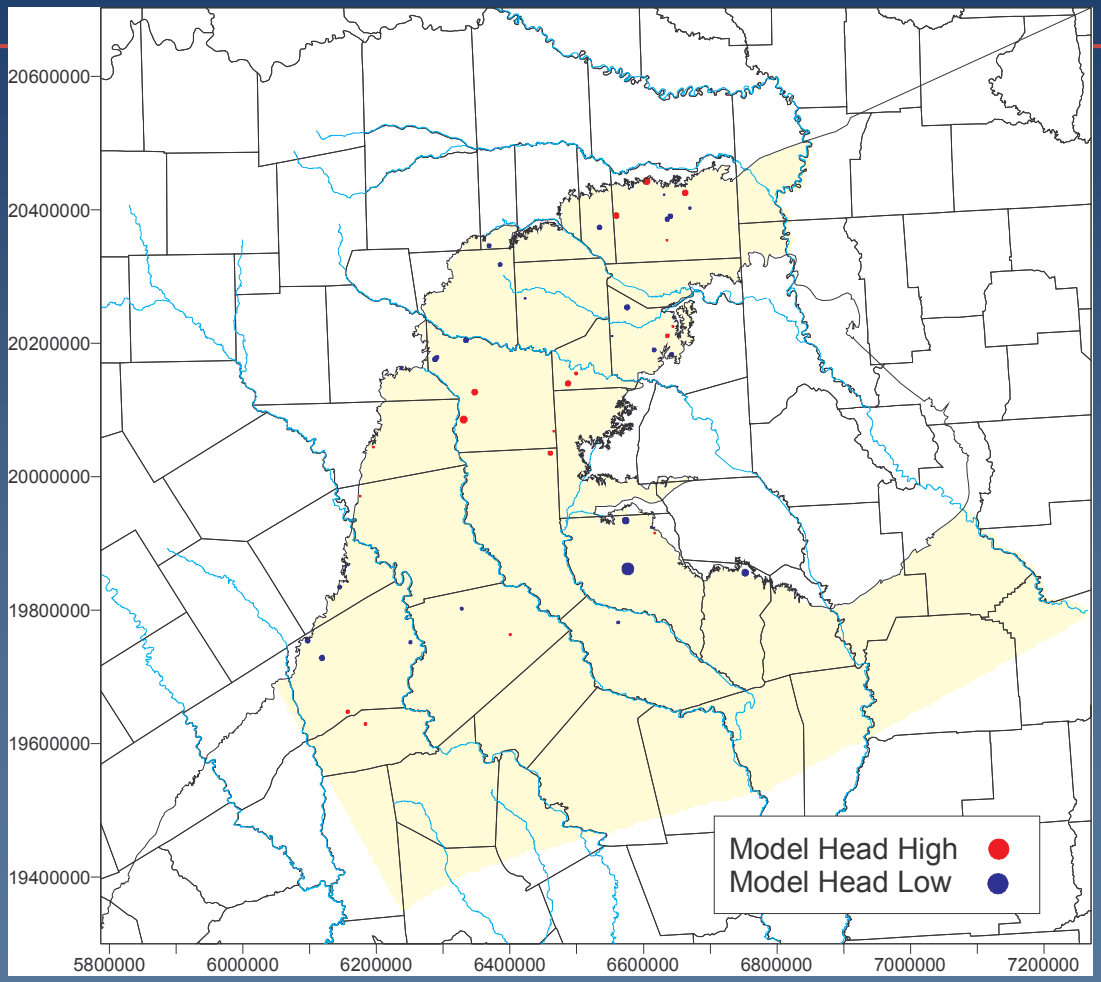
Model Calibrated Recharge



Carrizo Head Elevations

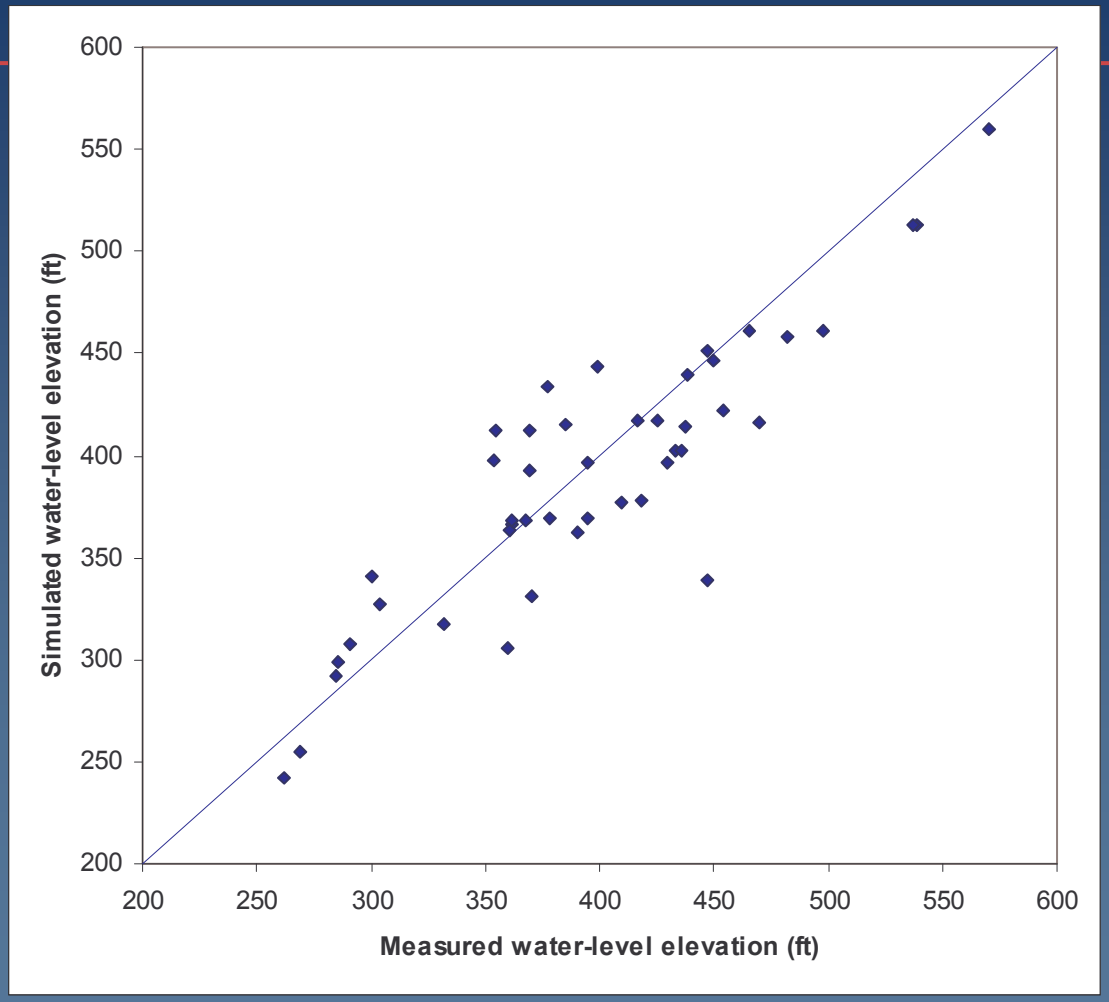


Carrizo Head Targets



Number of Targets	45
Minimum Residual	-57.64
Maximum Residual	108.49
Residual Mea	6.92
Absolute Residual Mean	25.59
RMS	32.93
Observed Head Range	308
RMS/Observed Head Range	0.107

Carrizo Head Targets



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RMS	32.93
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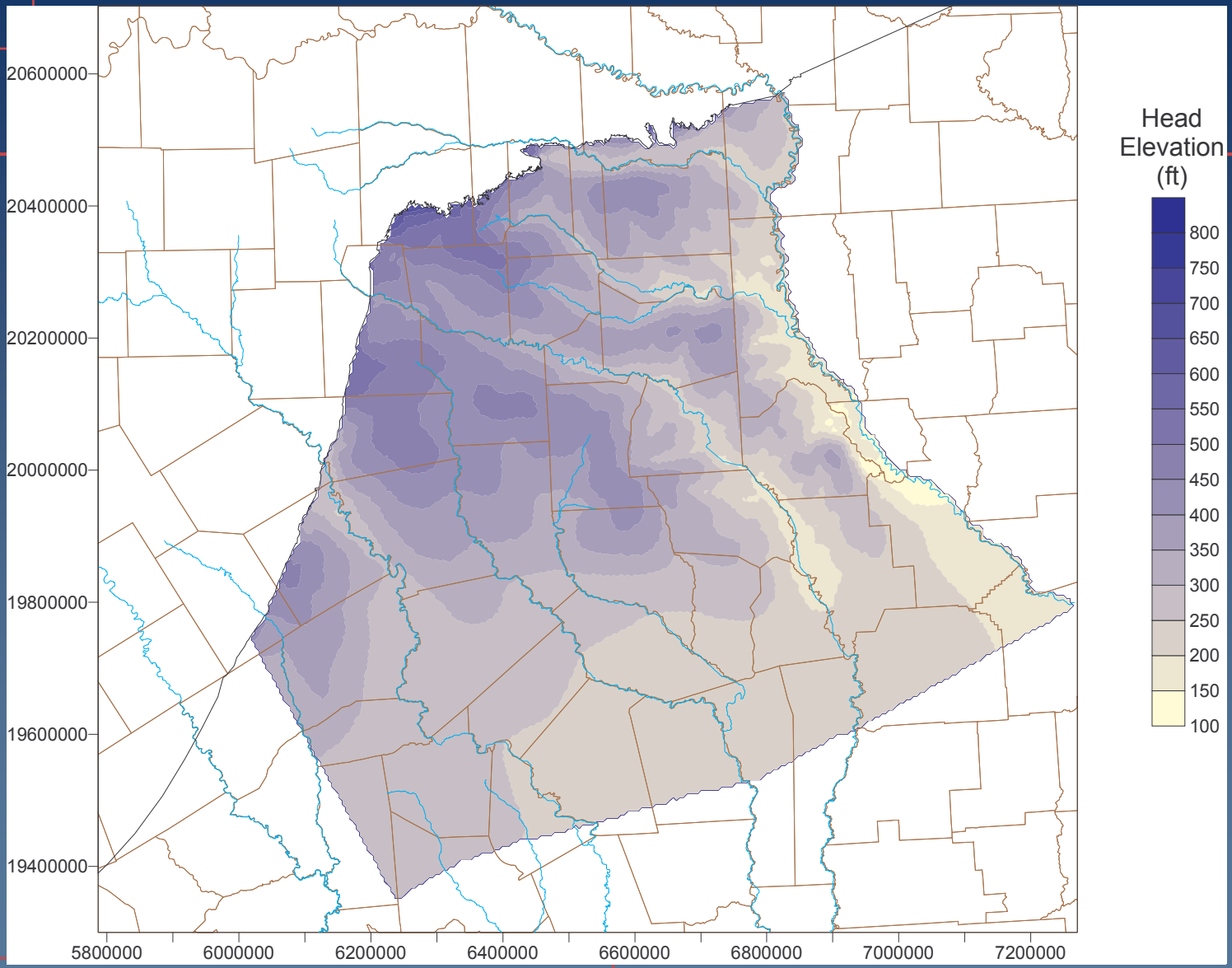
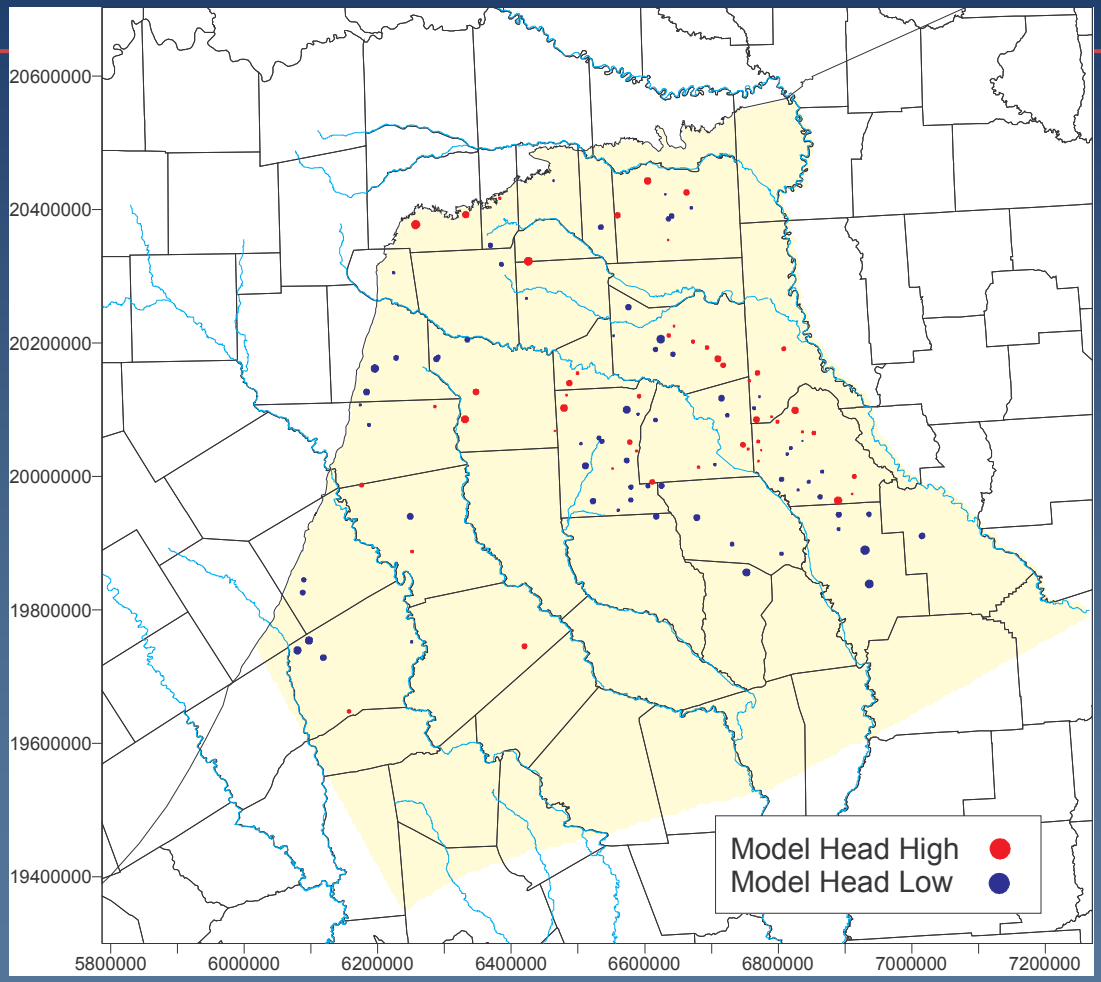
RMS/Observed Head Range	0.107

Middle Wilcox Head Elevations

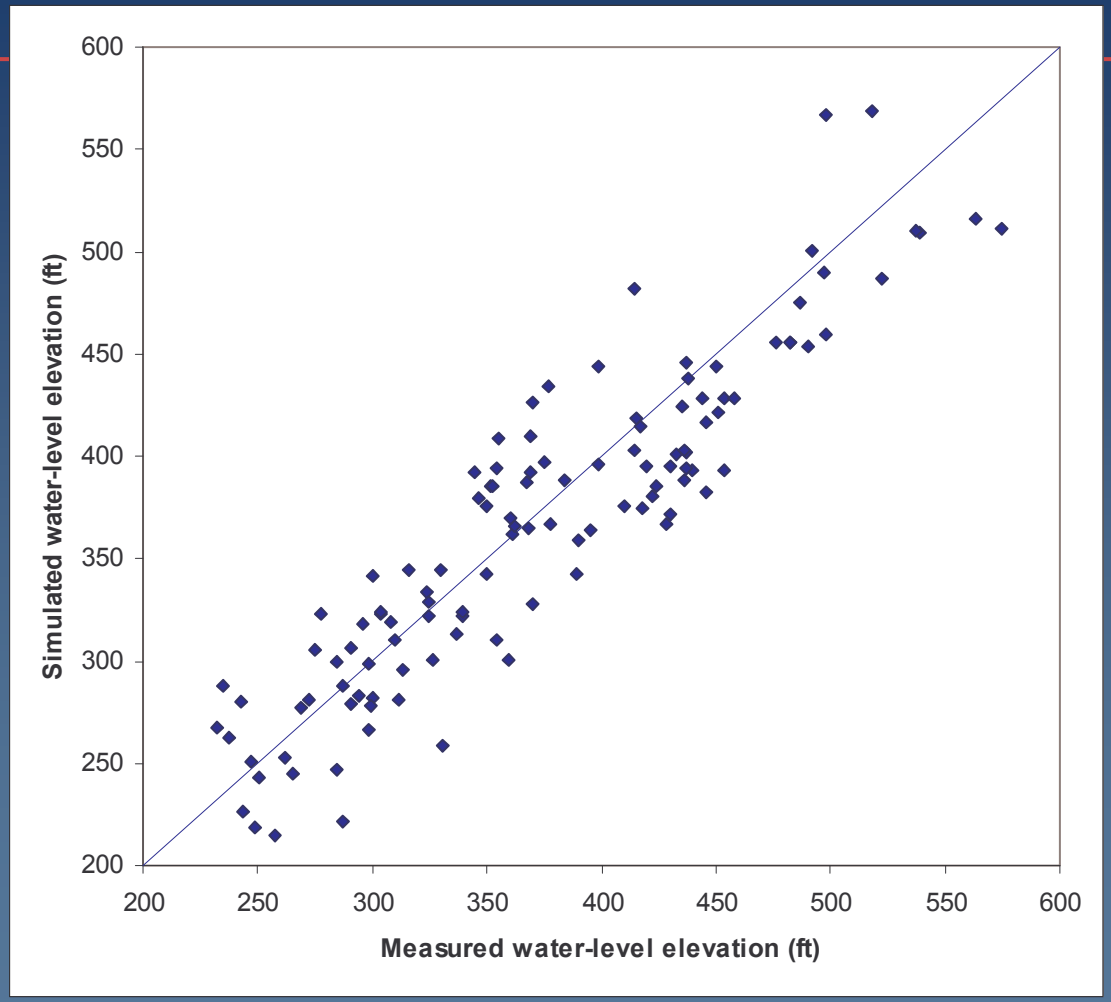


Wilcox Head Targets



Number of Targets	118
Minimum Residual	-68.79
Maximum Residua	71.99
Residual Mean	6.31
Absolute Residual Mean	28.24
RMS	33.70
Observed Head Range	419
RMS/Observed Head Range	0.081

Wilcox Head Targets



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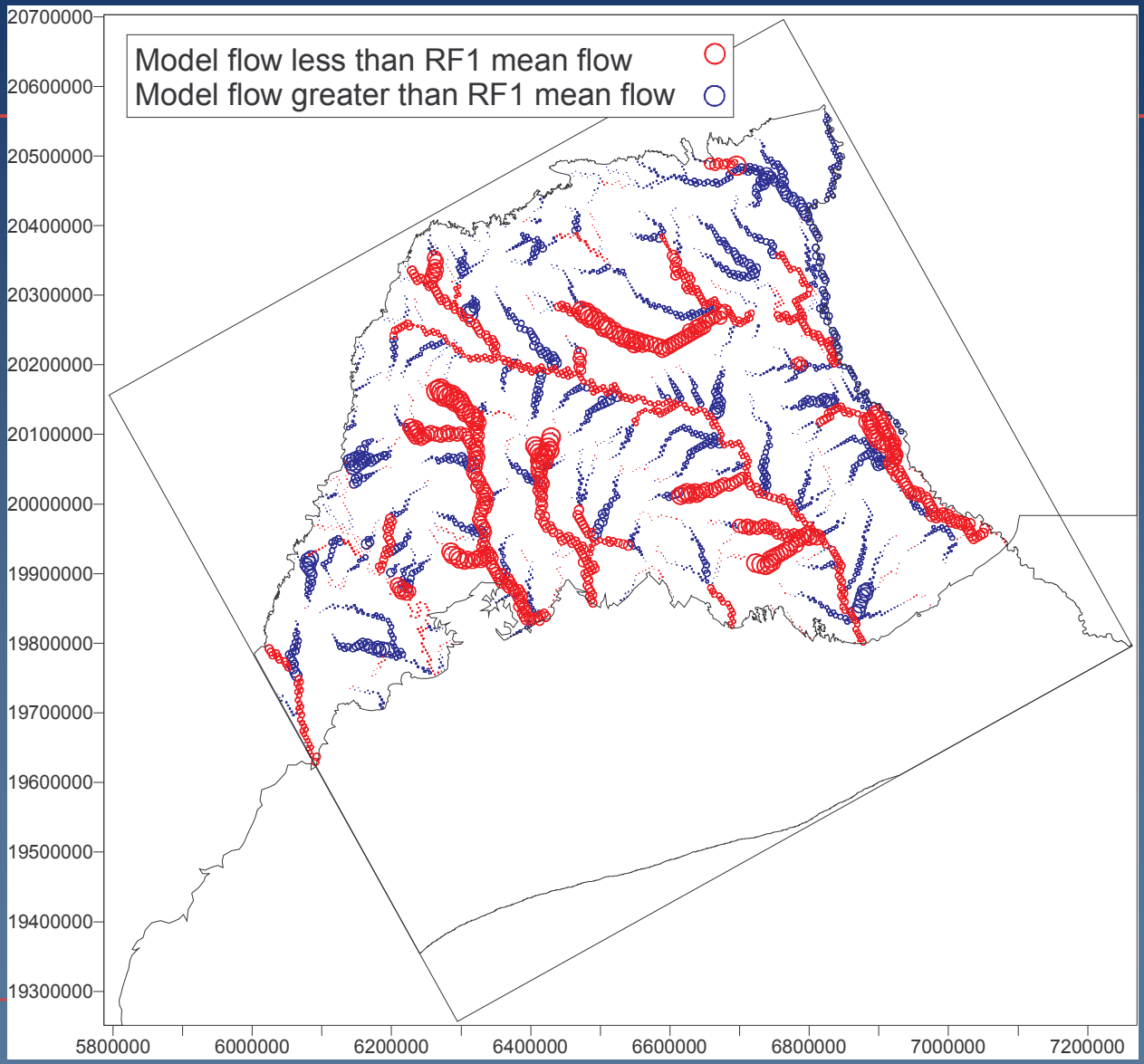
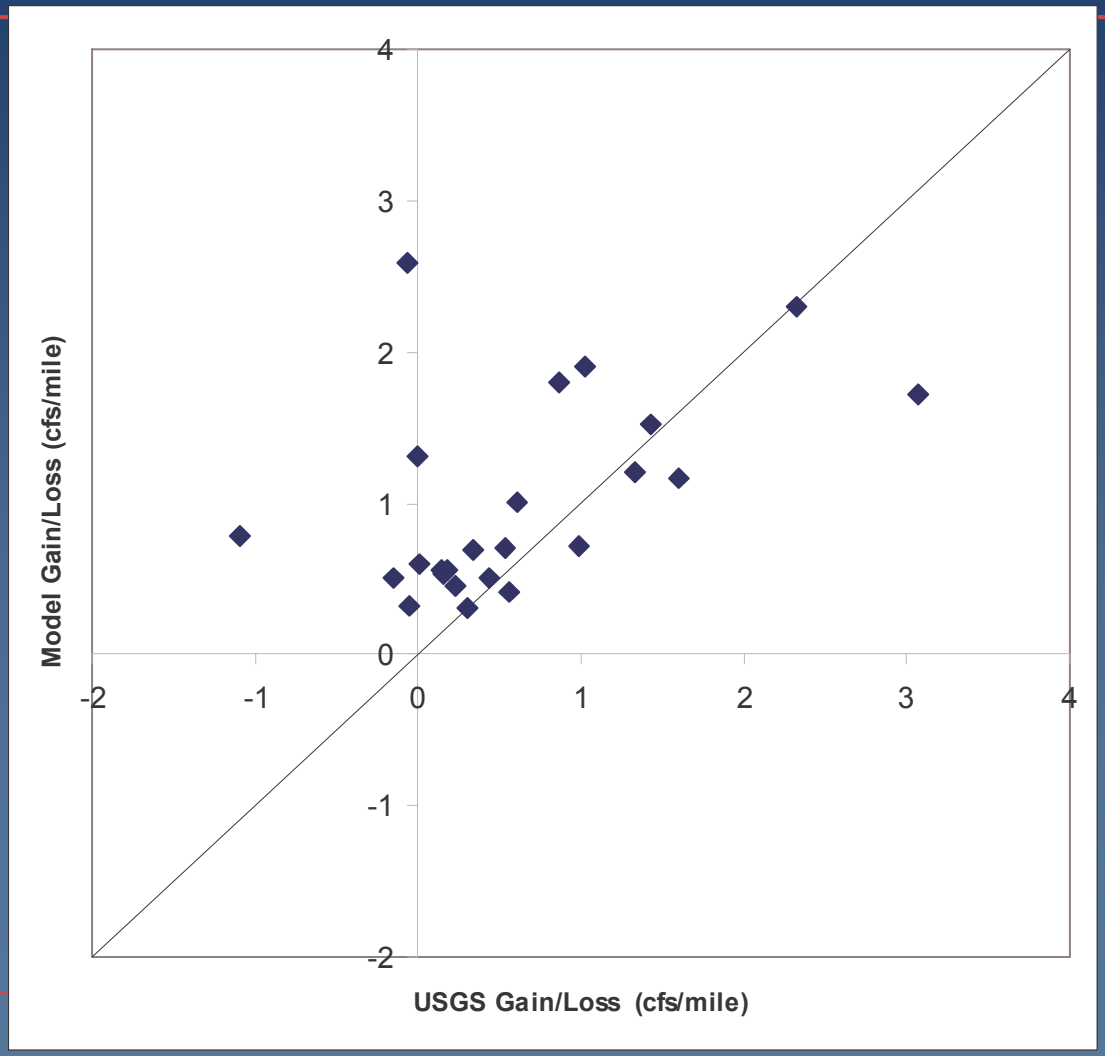
RMS/Observed Head Range	0.081

Comparison of Model Stream Flows to RF1 Mean Flows



Comparison of Model Stream Gain/Loss for the Sabine River to Gain/Loss Values from Slade et al., 2000



USGS	Model
1.33	1.21
1.02	1.90
2.32	2.30
3.06	1.72
-17.78	2.25
1.43	1.52
0.86	1.79
0.61	1.01
0.18	0.56
-0.06	0.32
0.30	0.31
1.60	1.16
-1.10	0.78
57.18	1.90
0.15	0.56
0.16	0.55
0.01	0.60
0.56	0.42
0.34	0.69
0.23	0.45
0.44	0.50
-0.16	0.50
0.99	0.72
0.00	1.31
0.15	0.54
0.53	0.71
-0.07	2.59

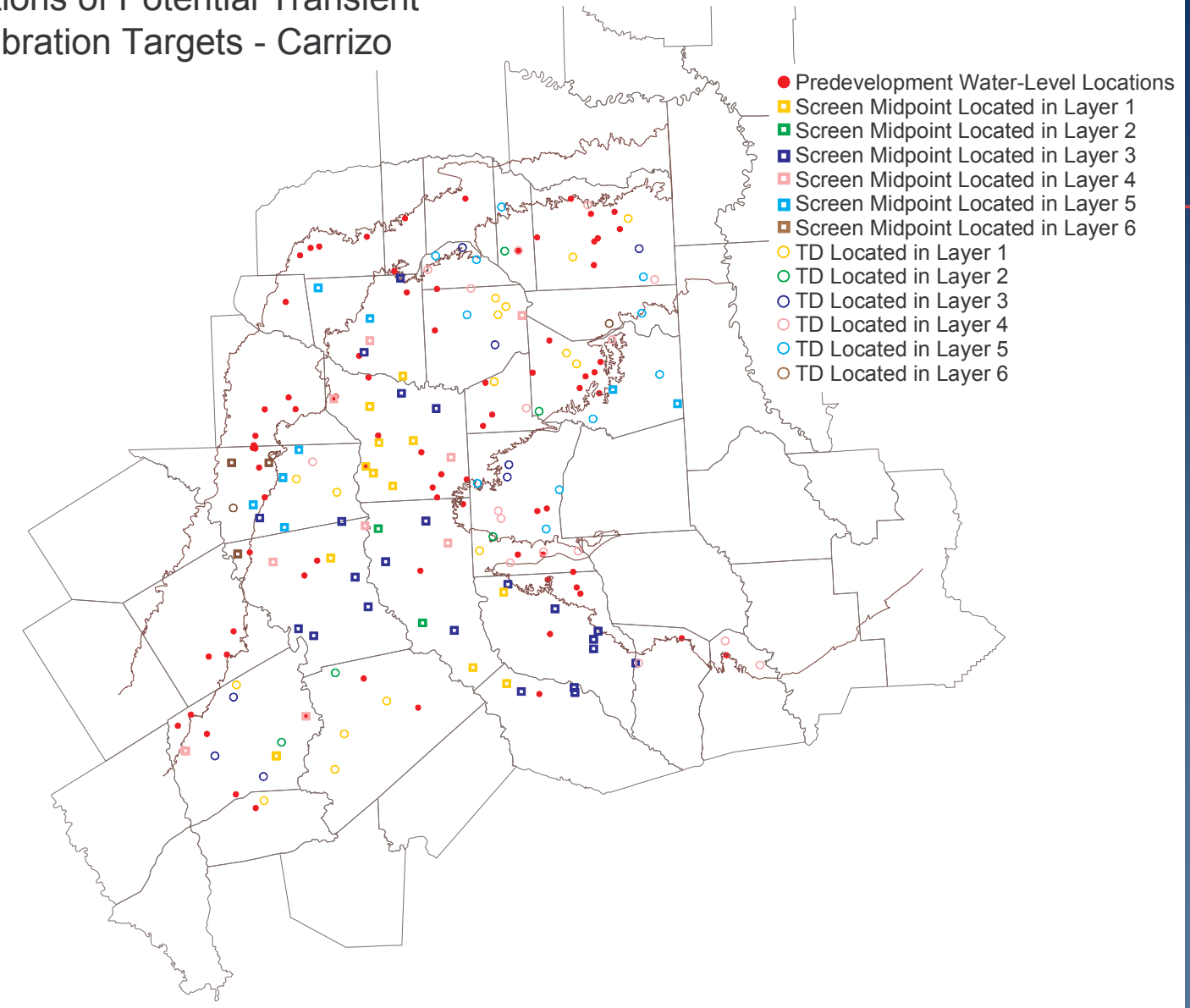
Presentation Outline

- GAM review
- Model Review and Issues
- Steady-State Model Recap
- **Transient Modeling**
- Future SAF Meeting

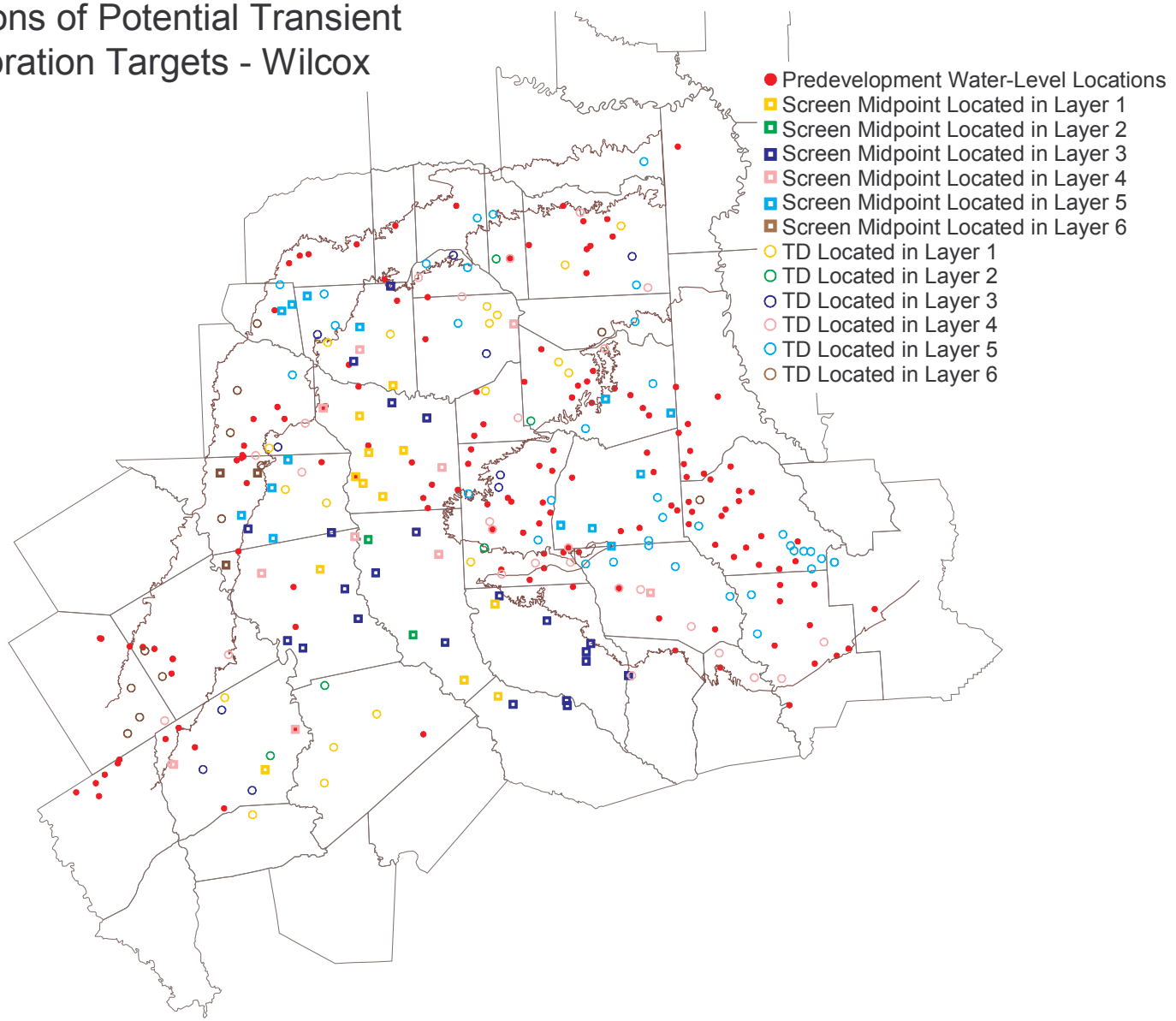
Transient Calibration

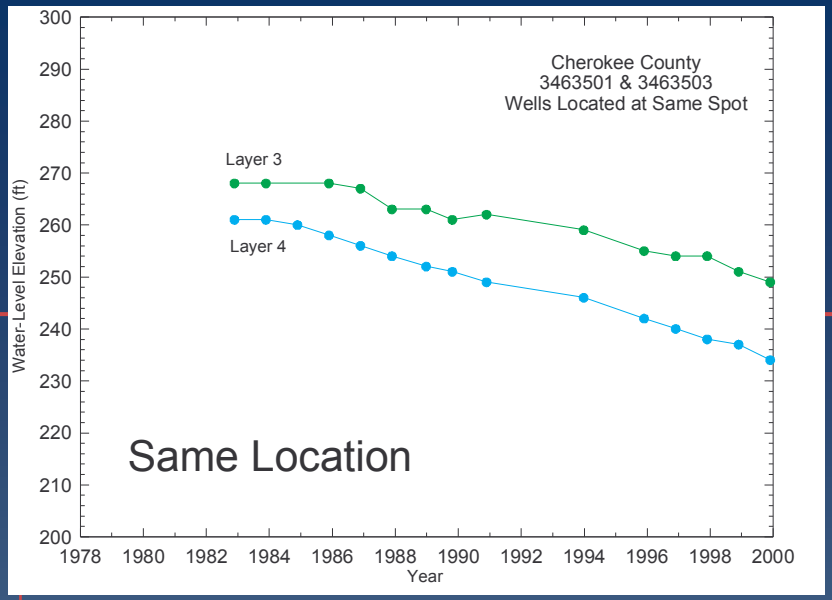
- Calibration Targets:
  - Hydraulic heads between 1980 – 2000
  - Water-levels from wells that are not pumped
- Model Input:
  - Hydraulic conductivity
  - Recharge (seasonal variation)
  - Storativity
  - Pumpage (monthly variation)
  - Stream Flow (surface/groundwater interaction)
- Problem:
  - Better contrained, but more input parameters

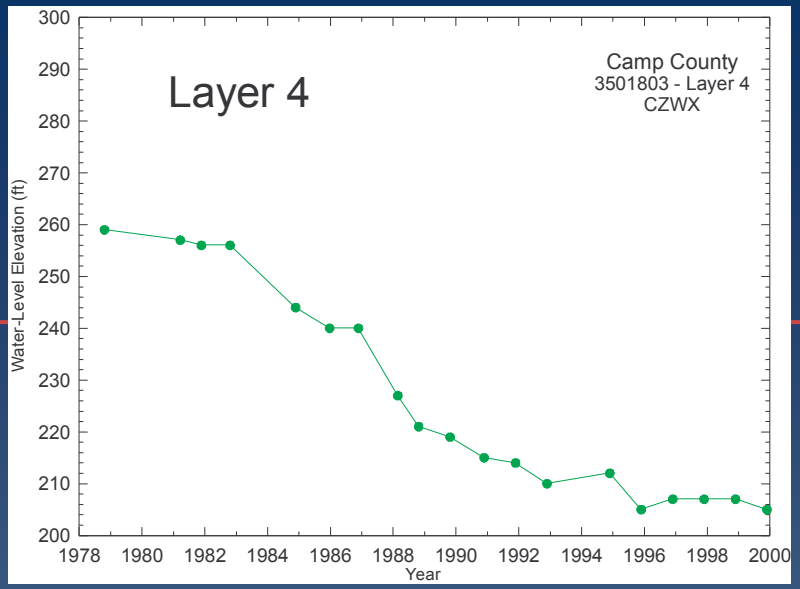
Locations of Potential Transient Calibration Targets - Carrizo

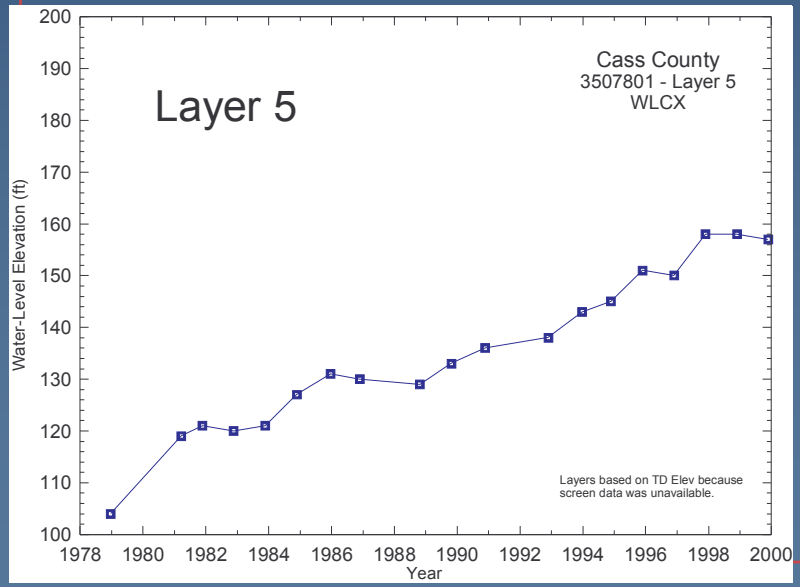


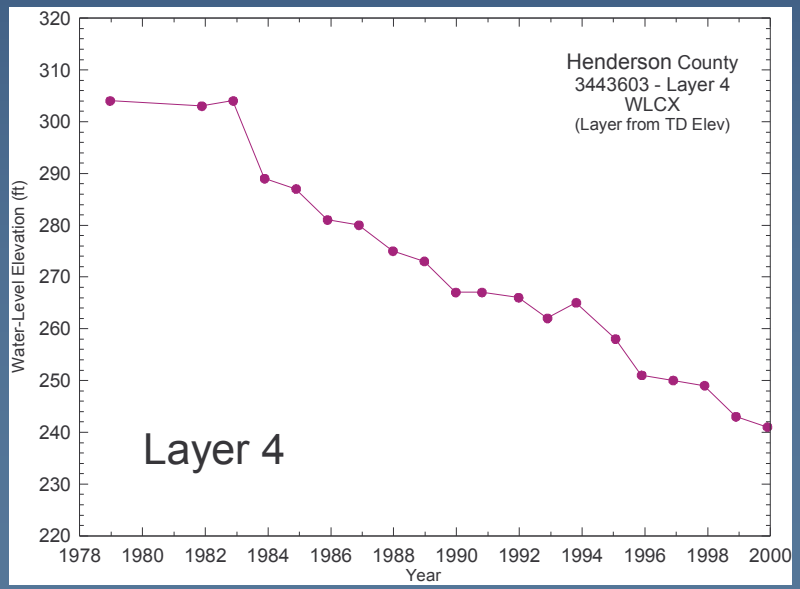
Locations of Potential Transient Calibration Targets - Wilcox



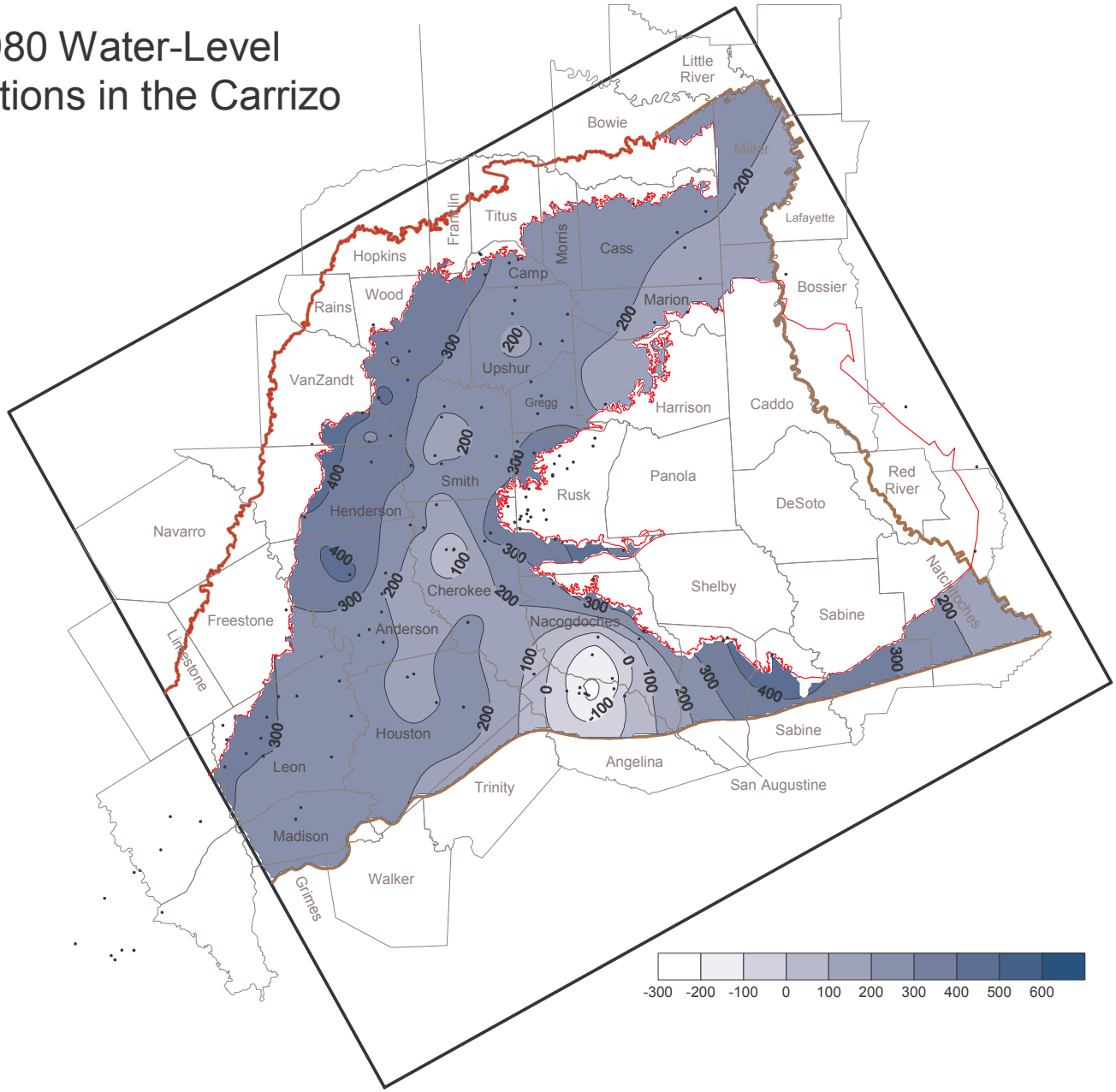

Cherokee County
3463501 & 3463503
Wells Located at Same Spot
Layer 3
Layer 4
Same Location
Water-Level Elevation (ft)
Year


Layer 4
Camp County
3501803 - Layer 4
CZWX
Water-Level Elevation (ft)
Year

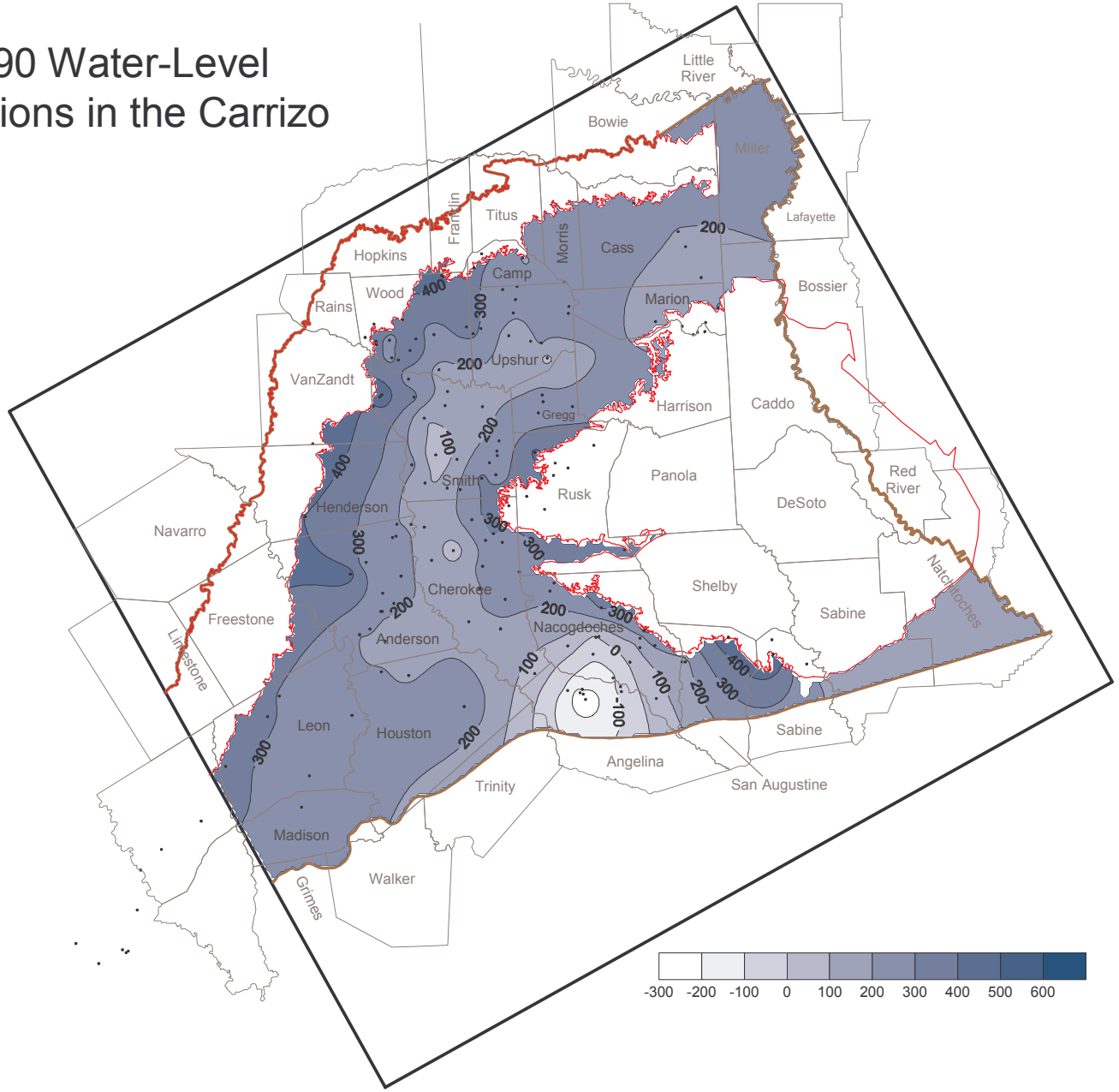

Layer 5
Cass County
3507801 - Layer 5
WLCX
Layers based on TD Elev because screen data was unavailable.
Water-Level Elevation (ft)
Year


Henderson County
3443603 - Layer 4
WLCX
(Layer from TD Elev)
Layer 4
Water-Level Elevation (ft)
Year

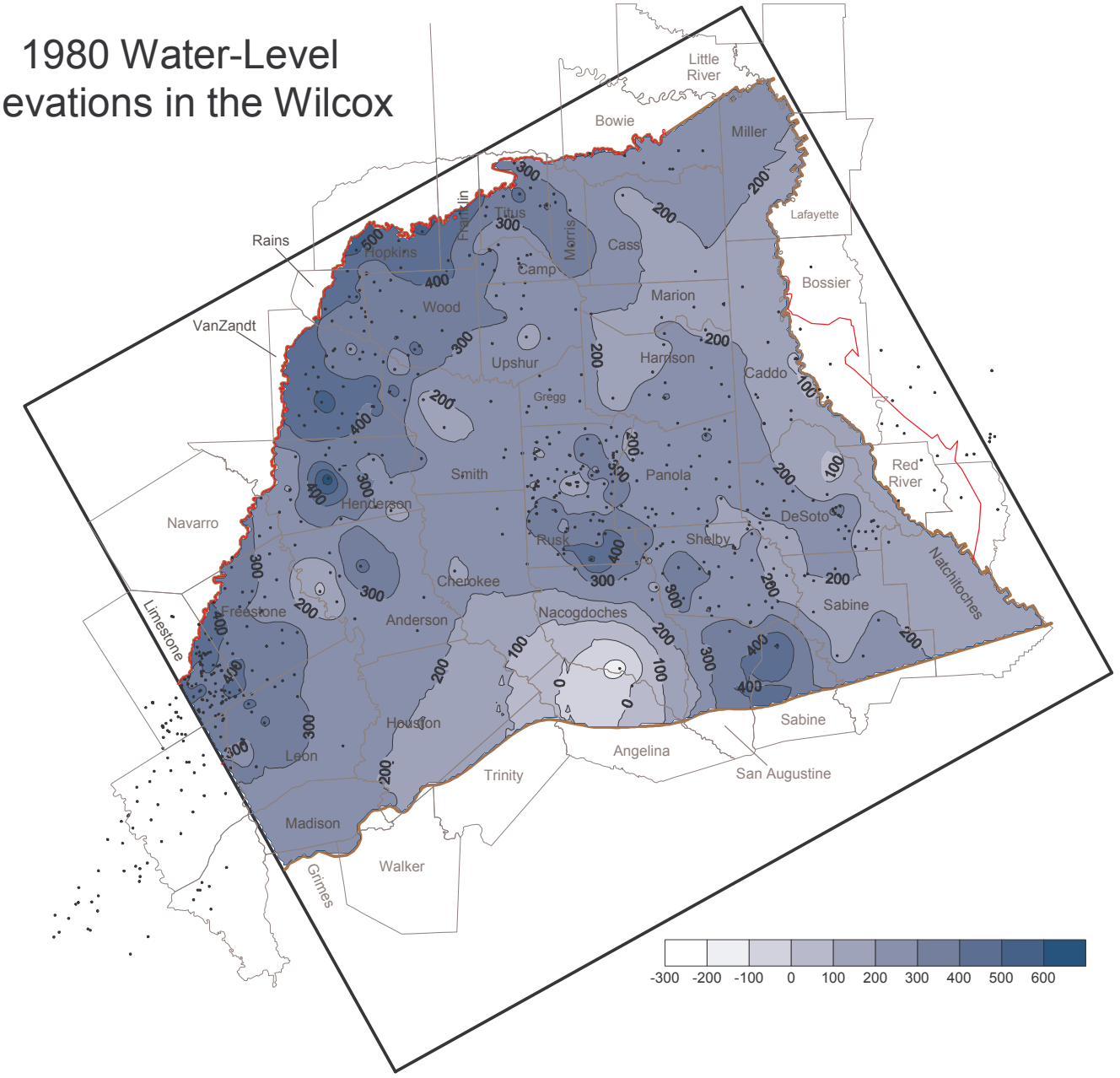
1980 Water-Level Elevations in the Carrizo



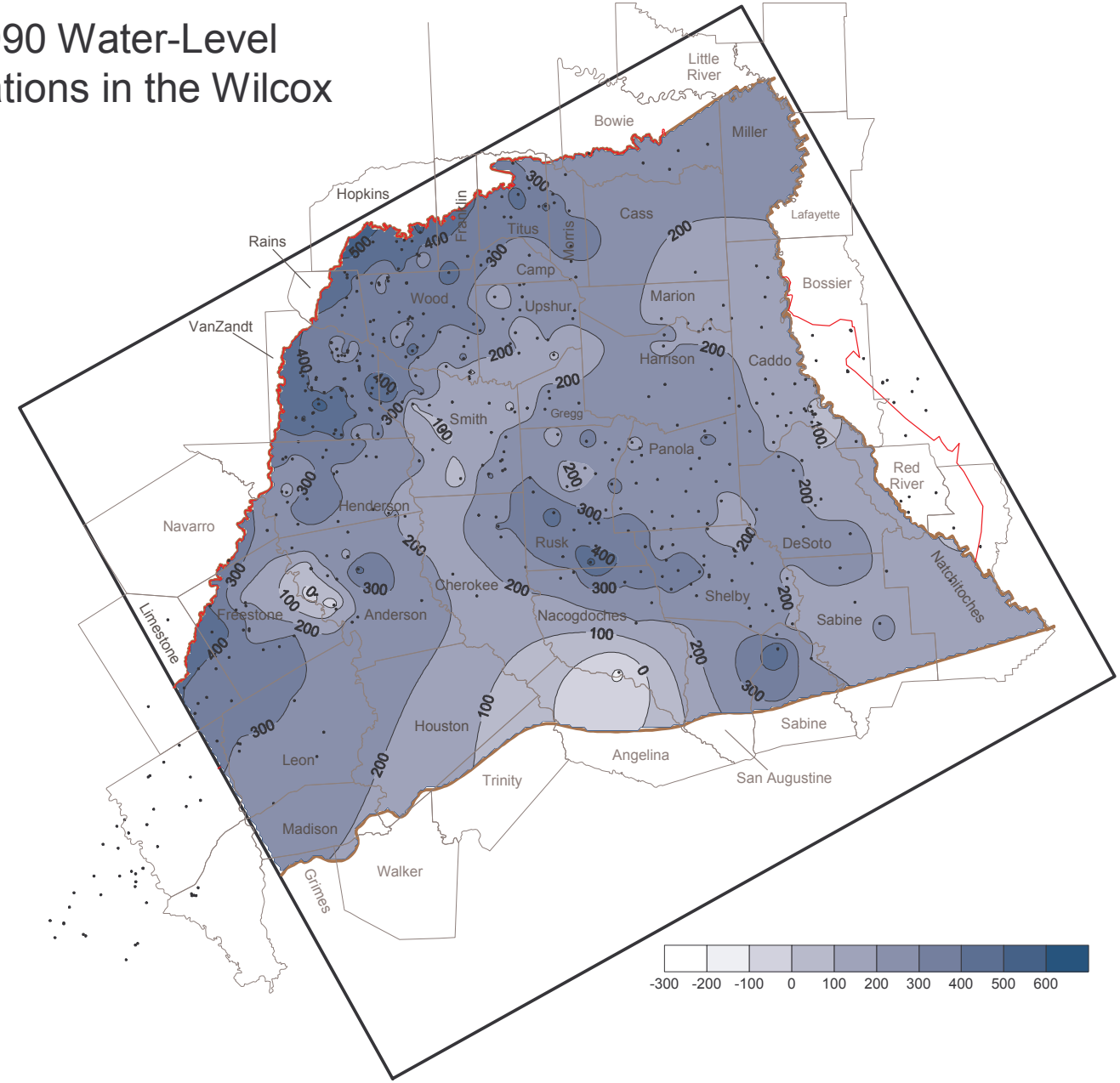
1990 Water-Level Elevations in the Carrizo



1980 Water-Level Elevations in the Wilcox



1990 Water-Level Elevations in the Wilcox



Categories of Groundwater Use

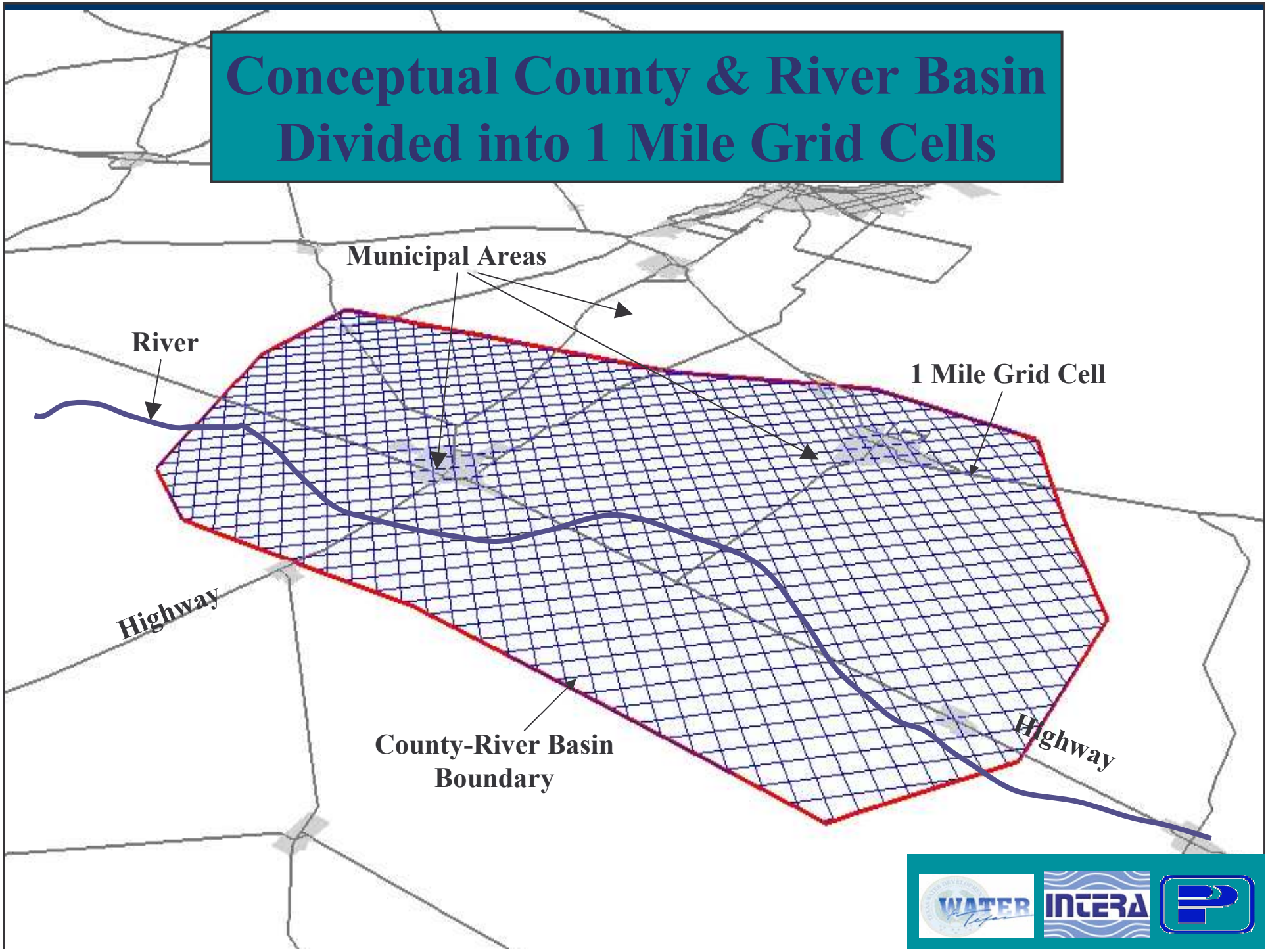
Point Source Data

- Municipal
- Manufacturing
- Power
- Mining

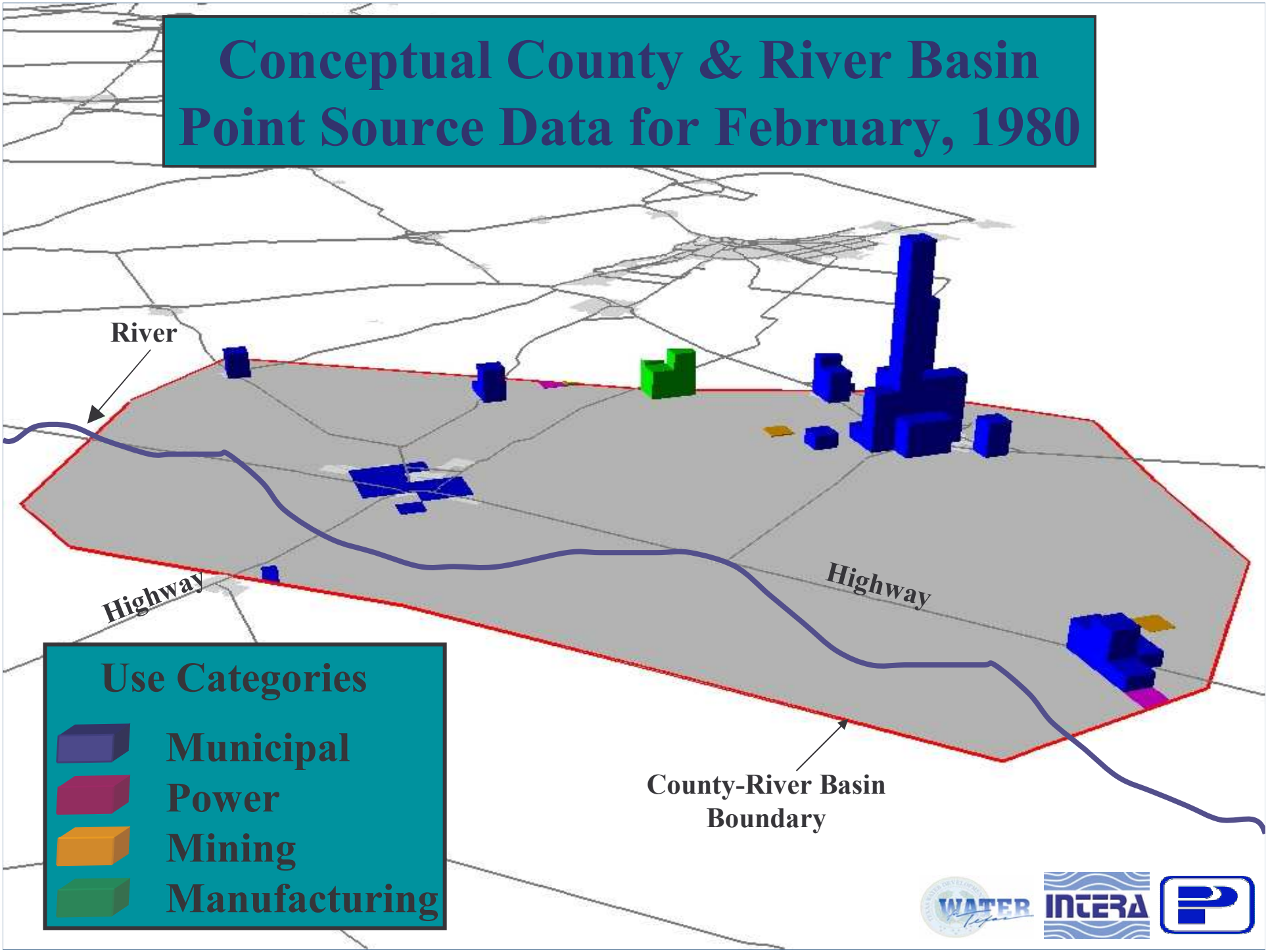
Non-Point Source Data

- 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-Point Source Data

1. Irrigation

- Locate irrigated areas based on land use and land cover records
- Assign monthly pumpage amounts based on rainfall, temperature, and crop demand data
- Well depths assigned from nearby wells in state well database

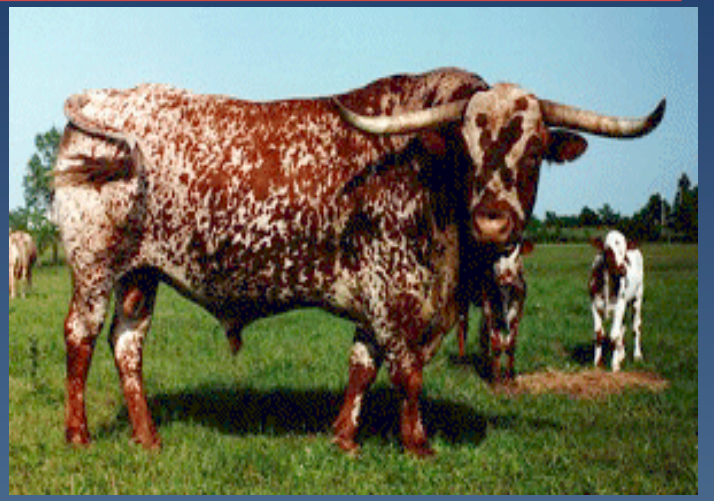
Locate Pumpage Using Non-PointSource Data

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

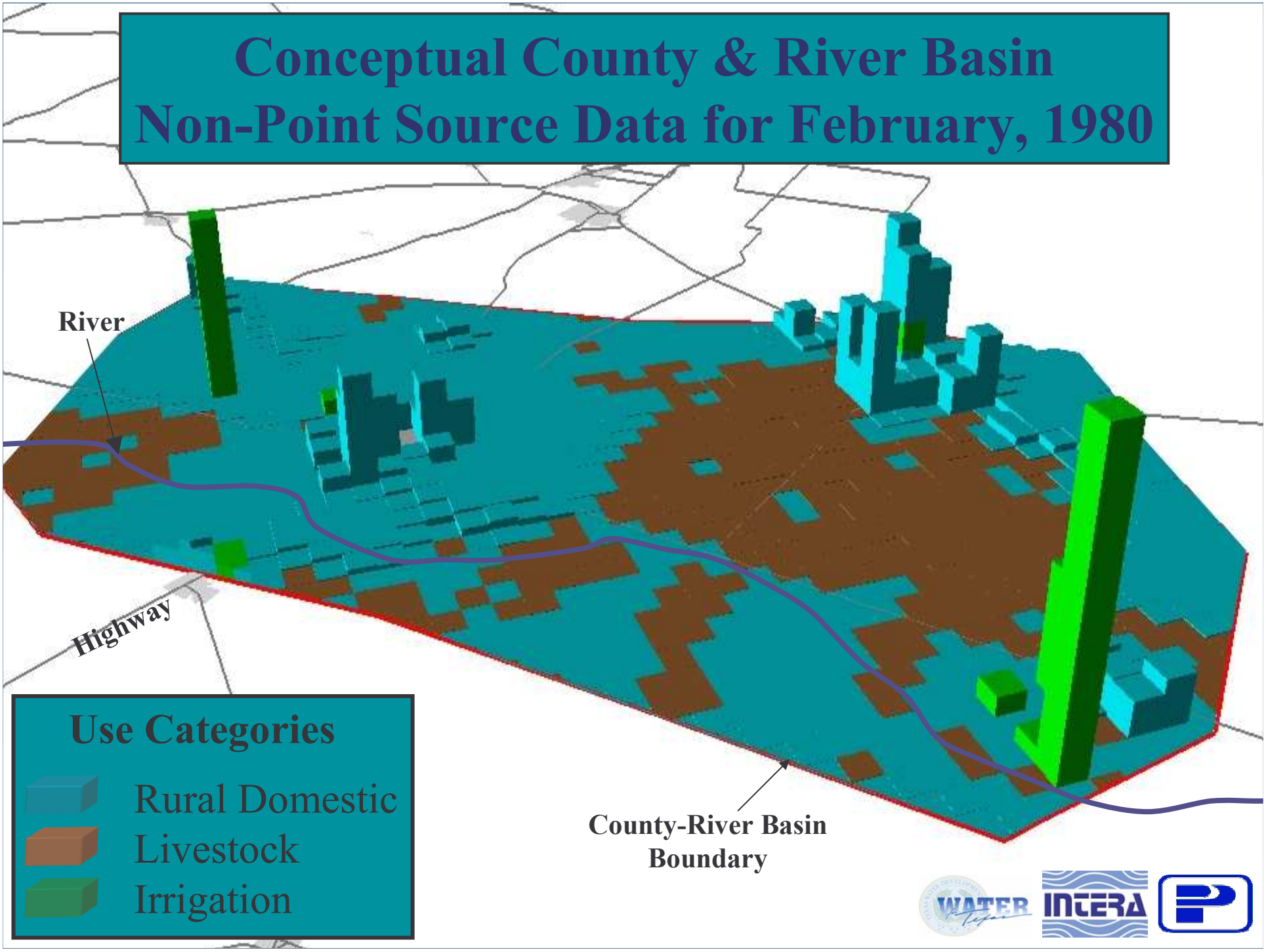
Locate Pumpage Using Non-PointSource Data

3. Livestock Pumpage

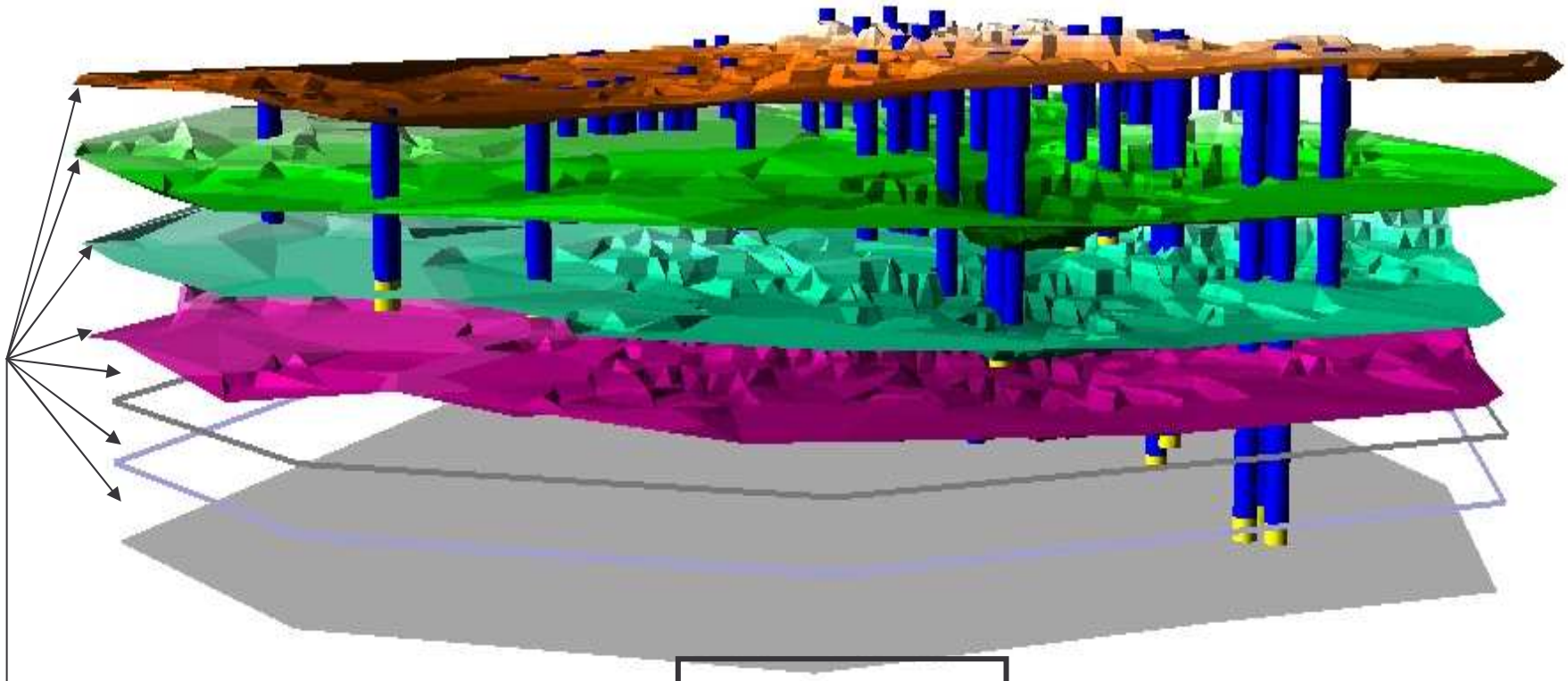


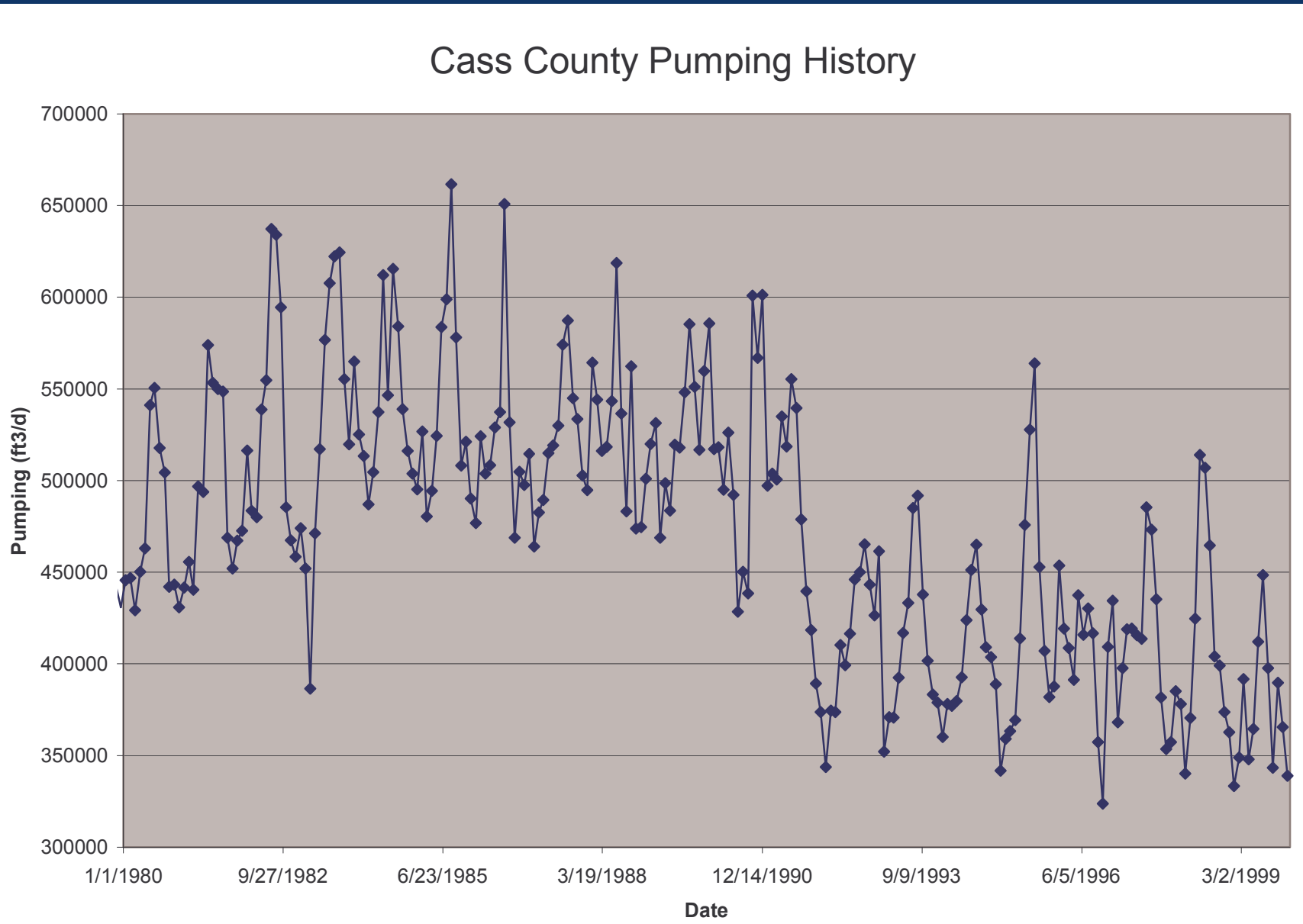
- Locate livestock areas based on land use and land cover records (rangeland and pasture)
- Assign monthly pumpage based on 1/12 of reported annual use
- Well depths assigned to upper-most water bearing unit

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



Conceptual County & River Basin Wells with Various Depths in Multiple Aquifer Layers



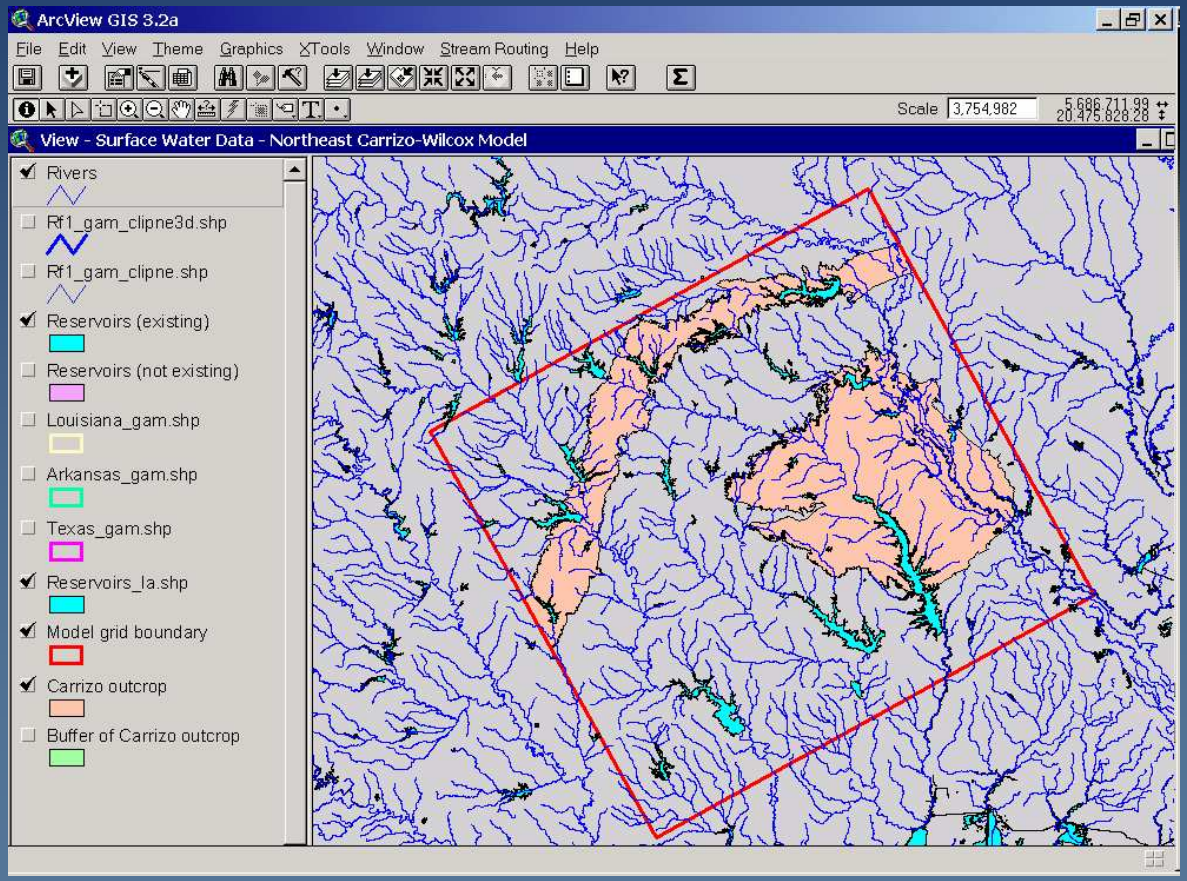

Cass County Pumping History
Pumping (ft3/d)
700000
650000
600000
550000
500000
450000
400000
350000
300000
1/1/1980
9/27/1982
6/23/1985
3/19/1988
12/14/1990
9/9/1993
6/5/1996
3/2/1999
Date

Stream Flow

- Use MODFLOW Stream Routing Package (Prudic, 1988)
- Stream-routing package routes surface water and calculates stream/aquifer interaction (gaining/losing)
- Stream stages are calculated using Manning's equation

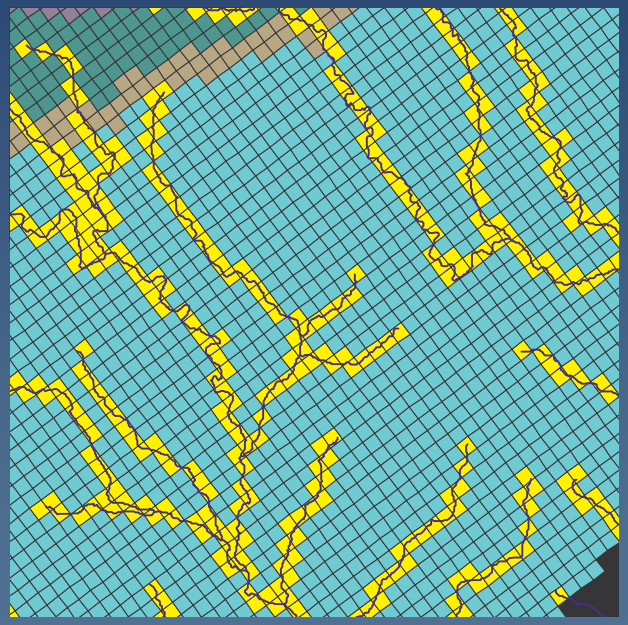
EPA River Reach Data

- EPA river reach data include many attributes needed for the Prudic package: width, depth, stage, roughness, etc.

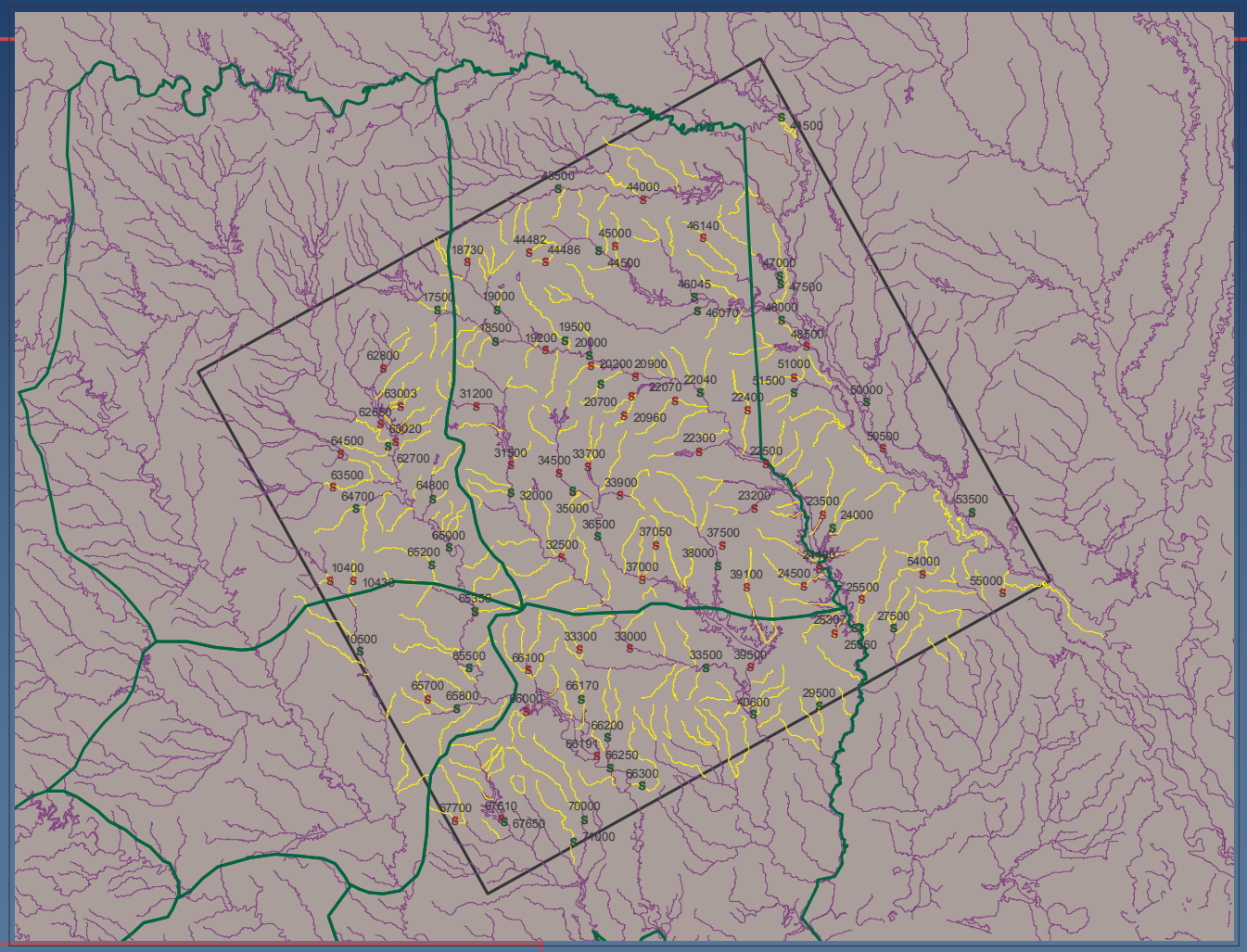


Phased approach to stream routing

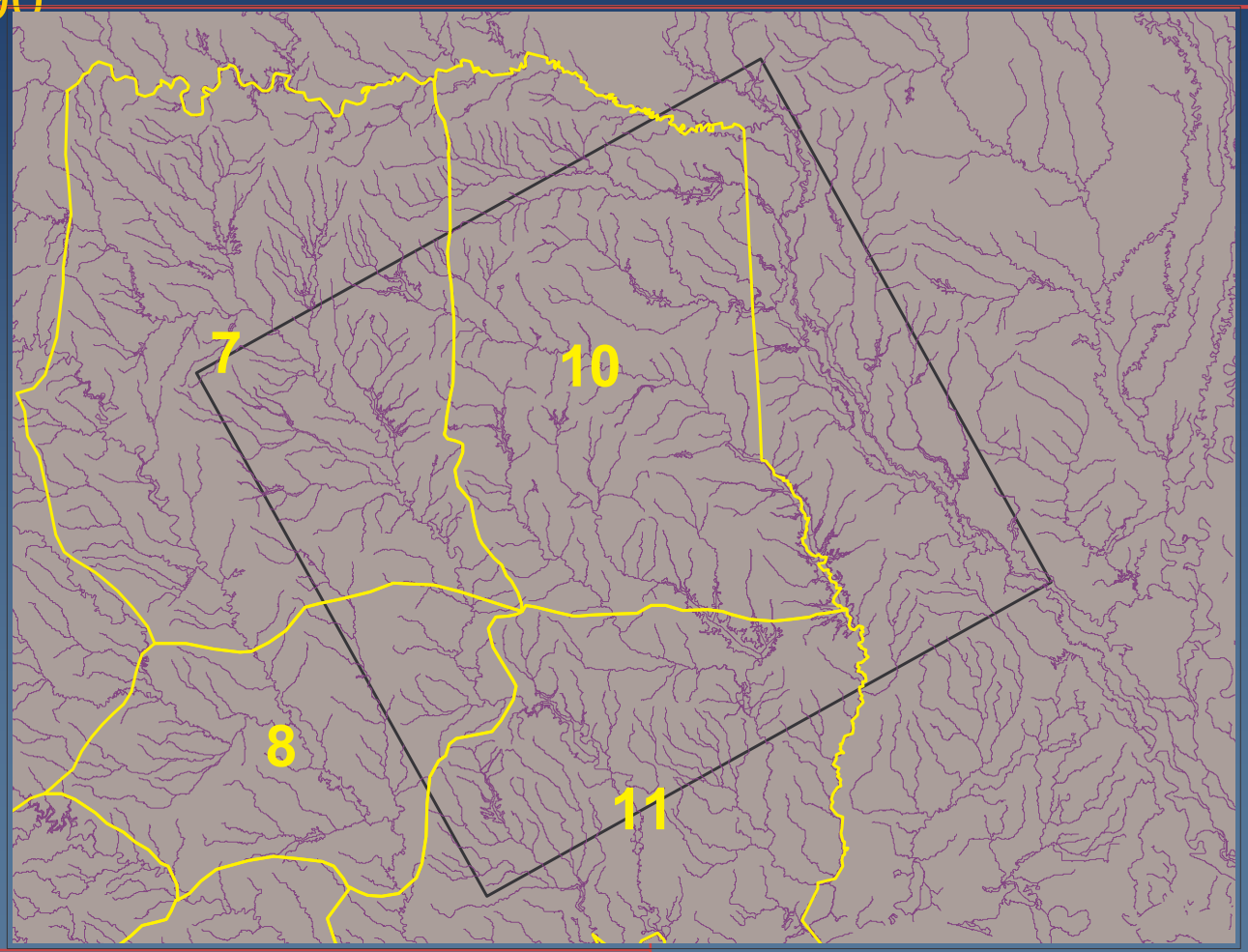
- First, we used average streamflows in the MODFLOW stream-routing package for the steady-state model
  - Average flows from the EPA RF1 data set
- Second, we use transient streamflows to perform the full stream-routing in the transient model
  - Transient streamflow data from USGS stream gages



USGS gages with complete record (1975 – 1998)

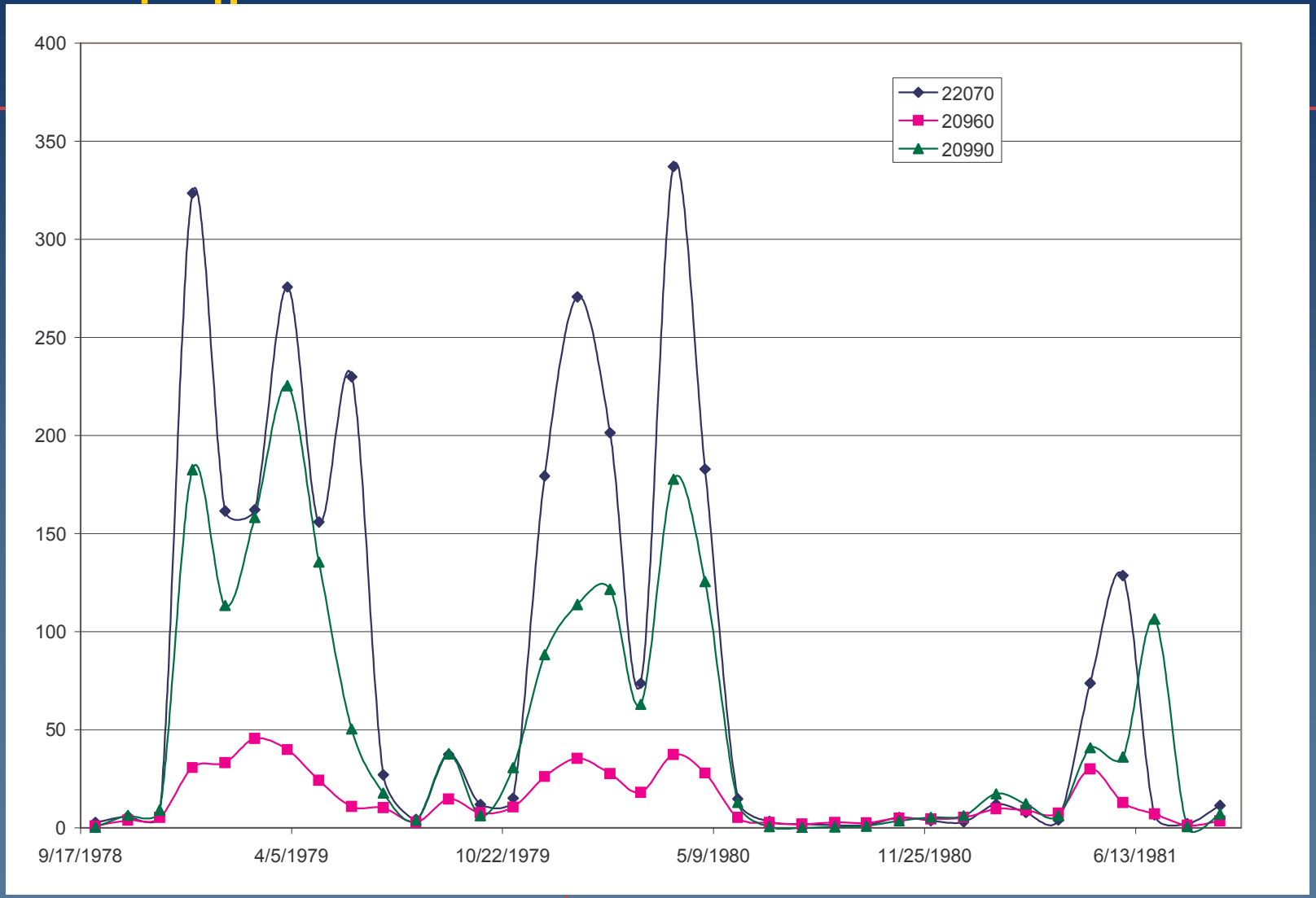


USGS study (Lanning-Rush, 2000): Regional Equations for Estimating Mean Annual and Mean Seasonal Runoff for Natural Basins in Texas, Base Period 1961-90



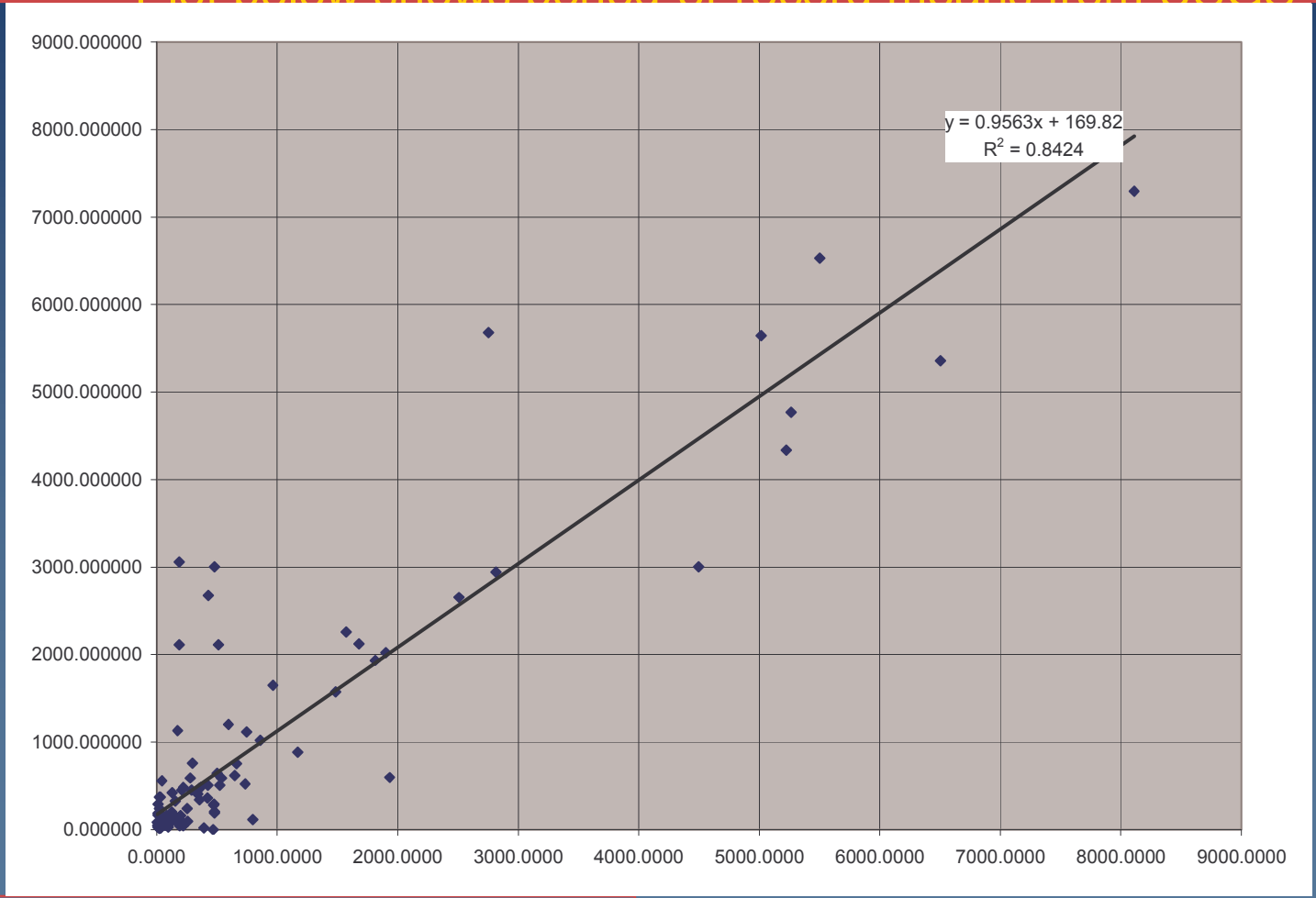
- Response of nearby streams is similar

- Response of nearby streams is

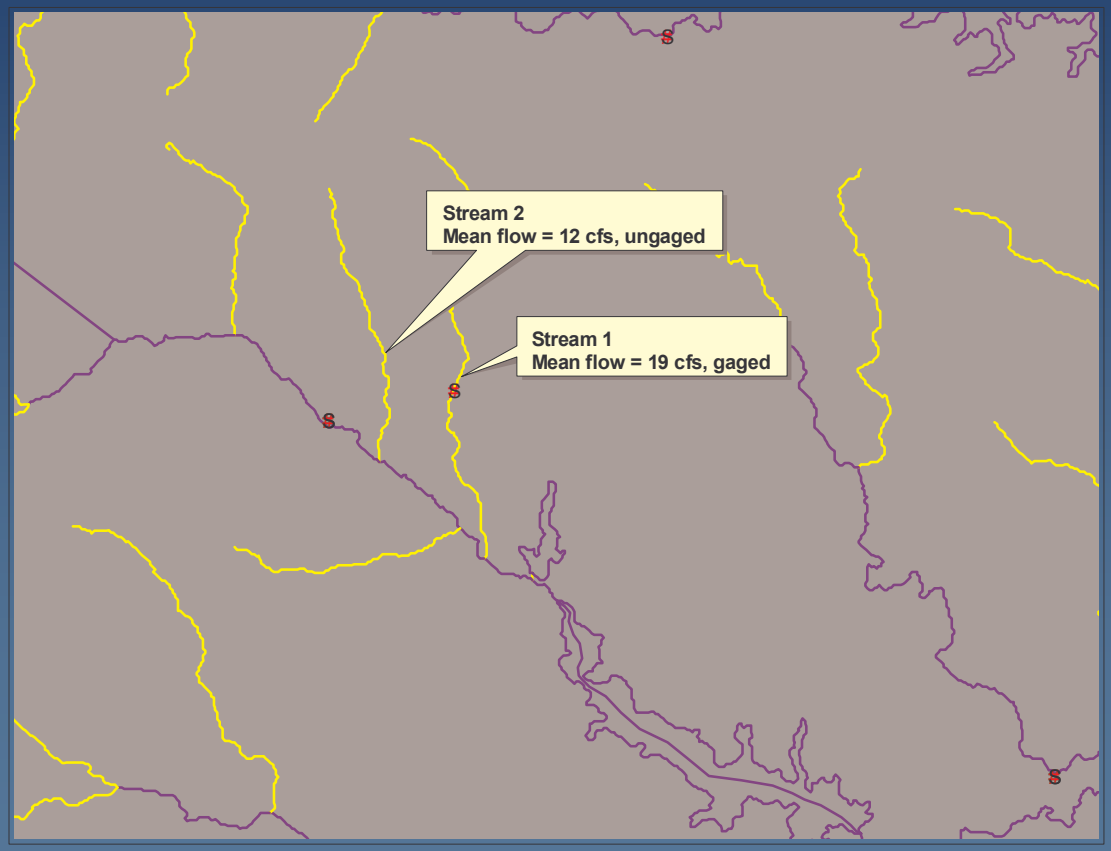


Mean flows were generated from USGS gage data, and a graphical/regression technique

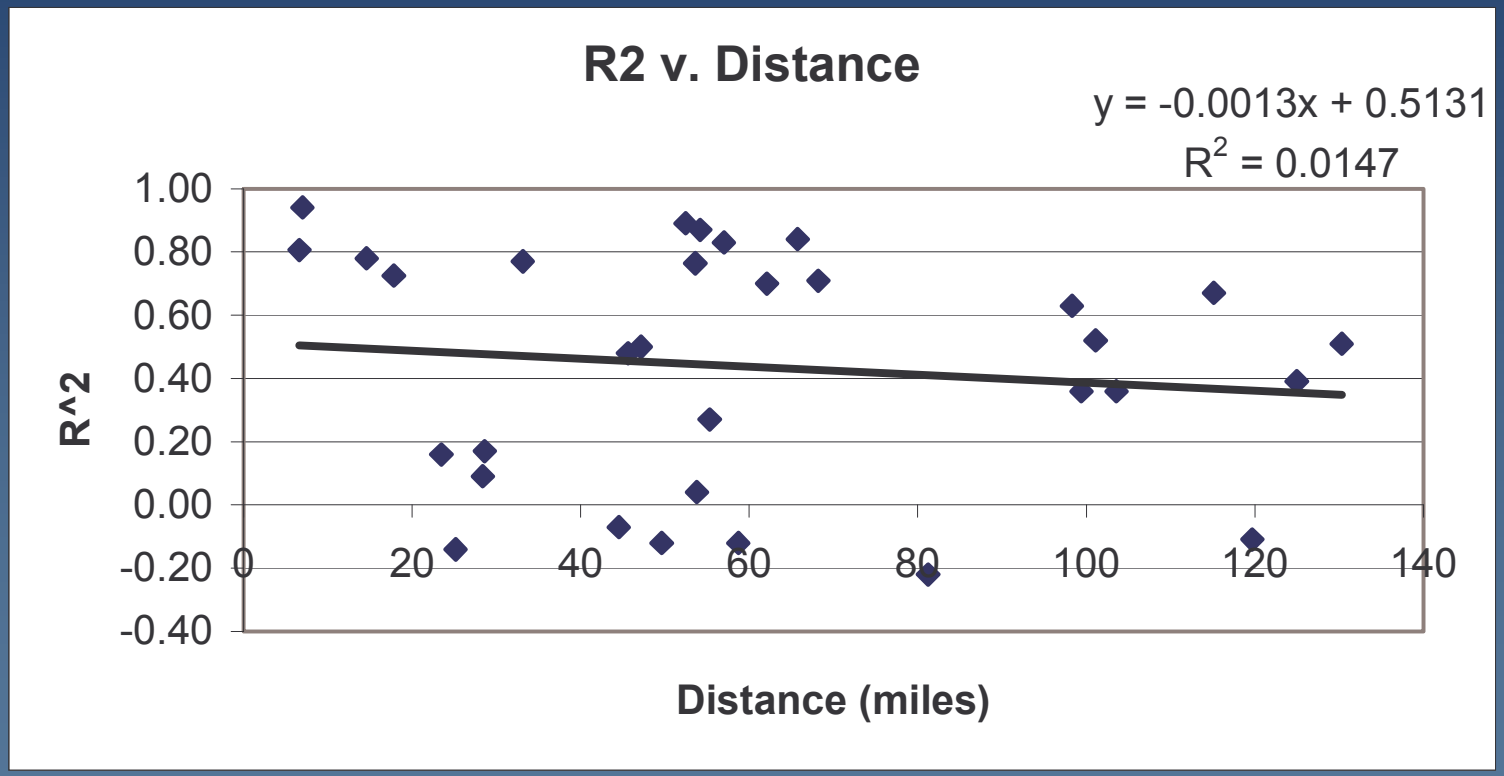
- Plot below shows period-of-record means from USGS



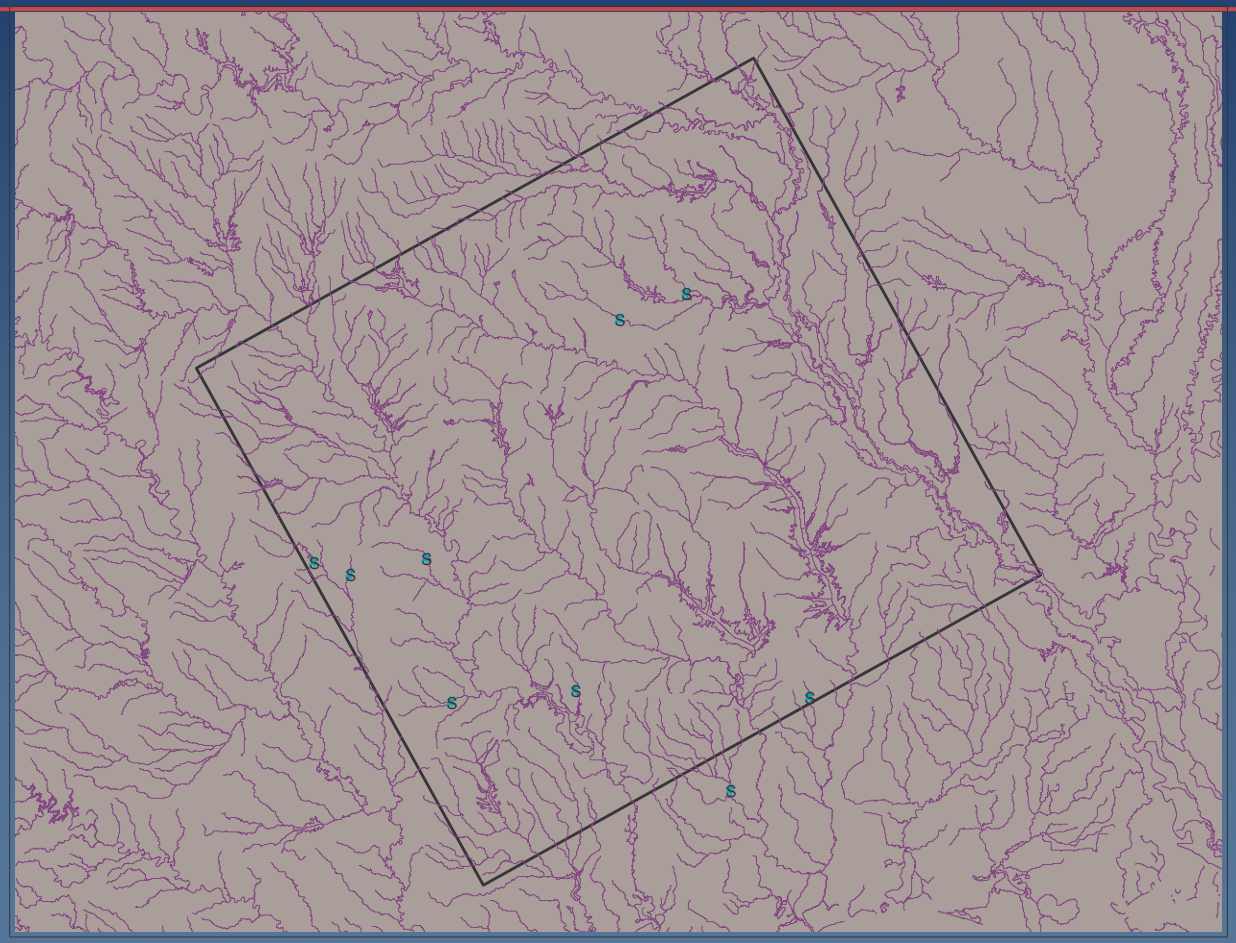
Flow time series of streamflow for ungaged Stream 2 can be approximated using the flow time series from nearby gaged Stream 1



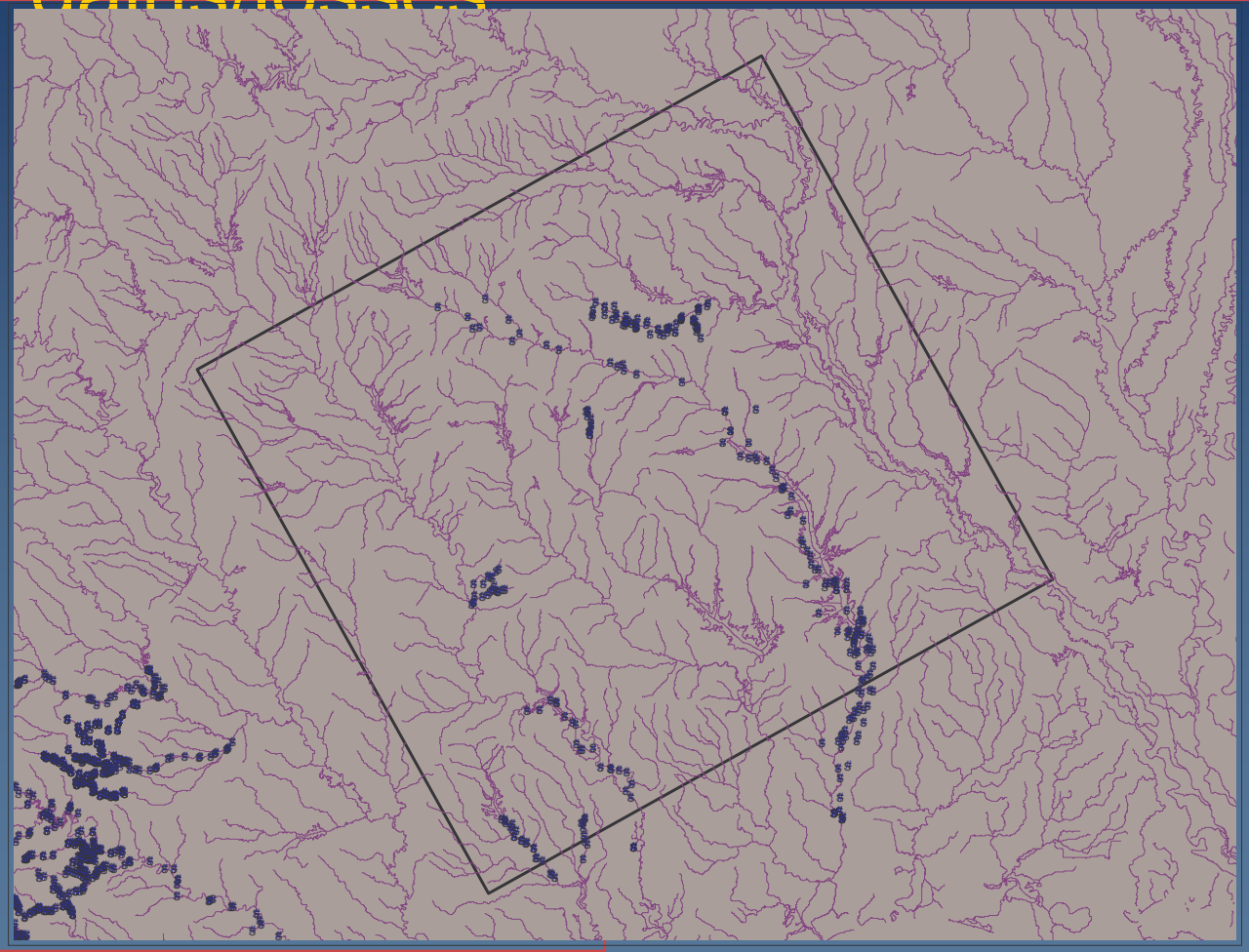
Note: not all correlations between streamflows are good! The R^2 values were calculated by plotting streamflows against each other



HYSEP locations where we have base flows

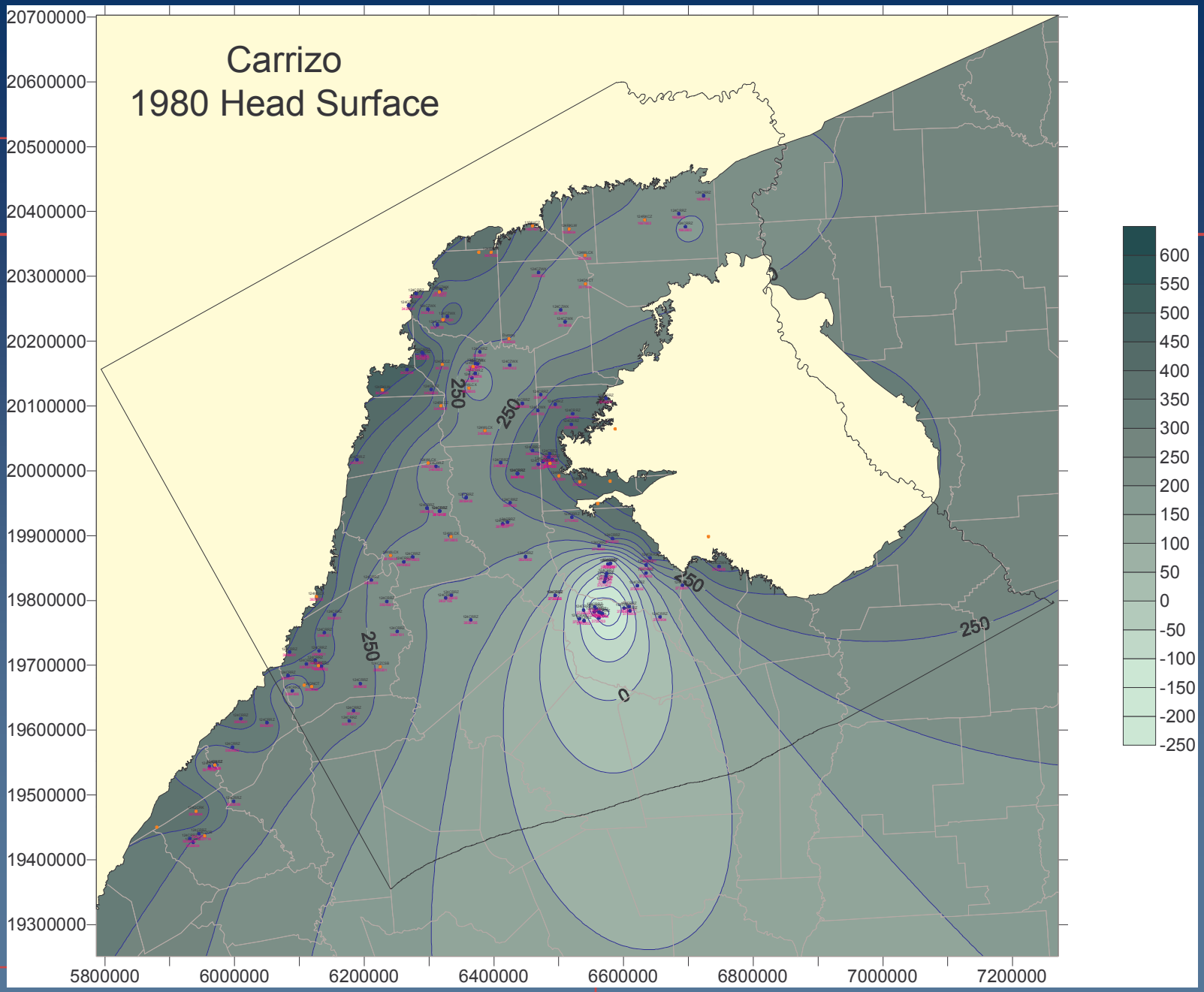


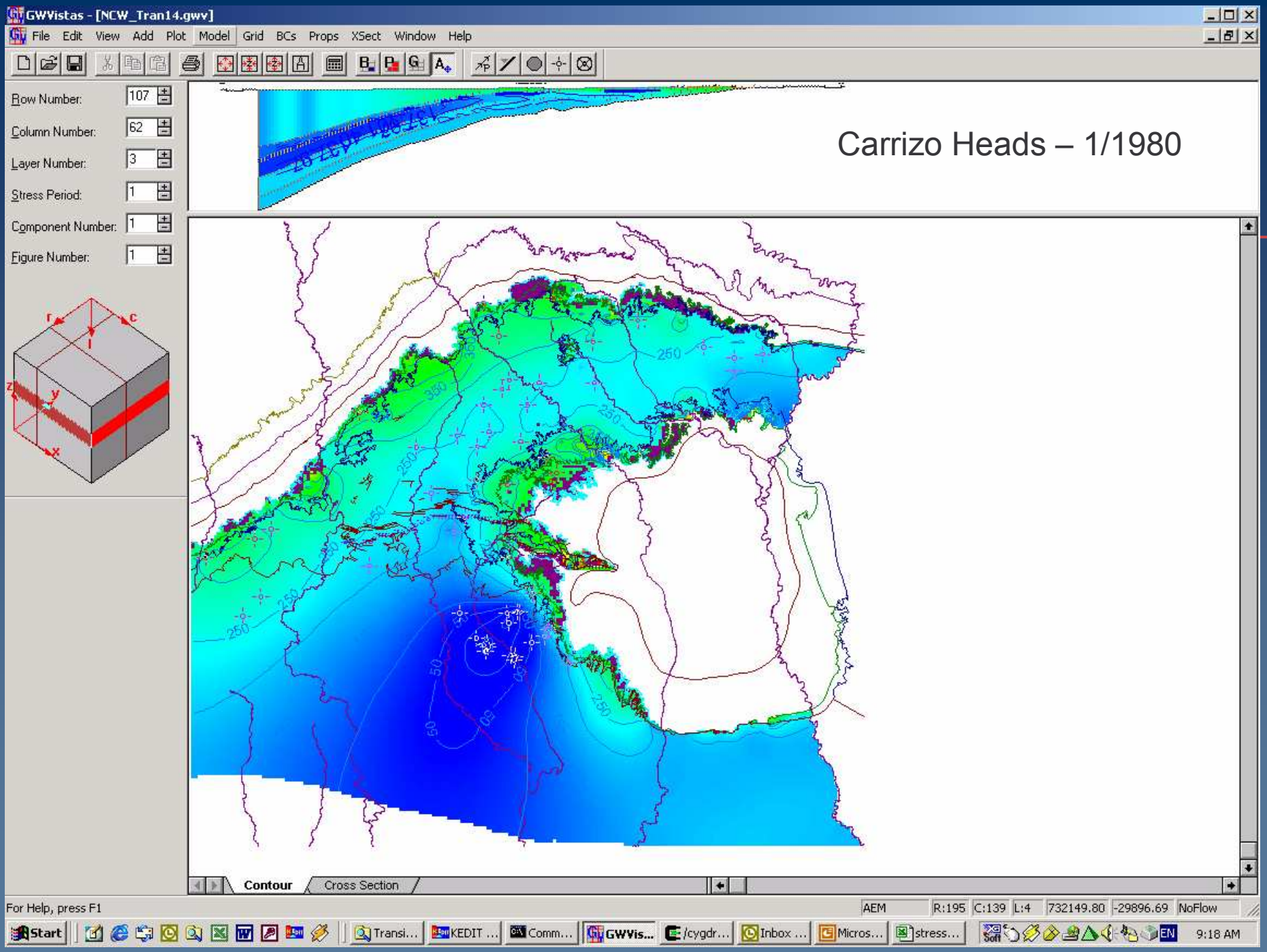
USGS Slade study locations that can be used to calculate baseflow gains/losses

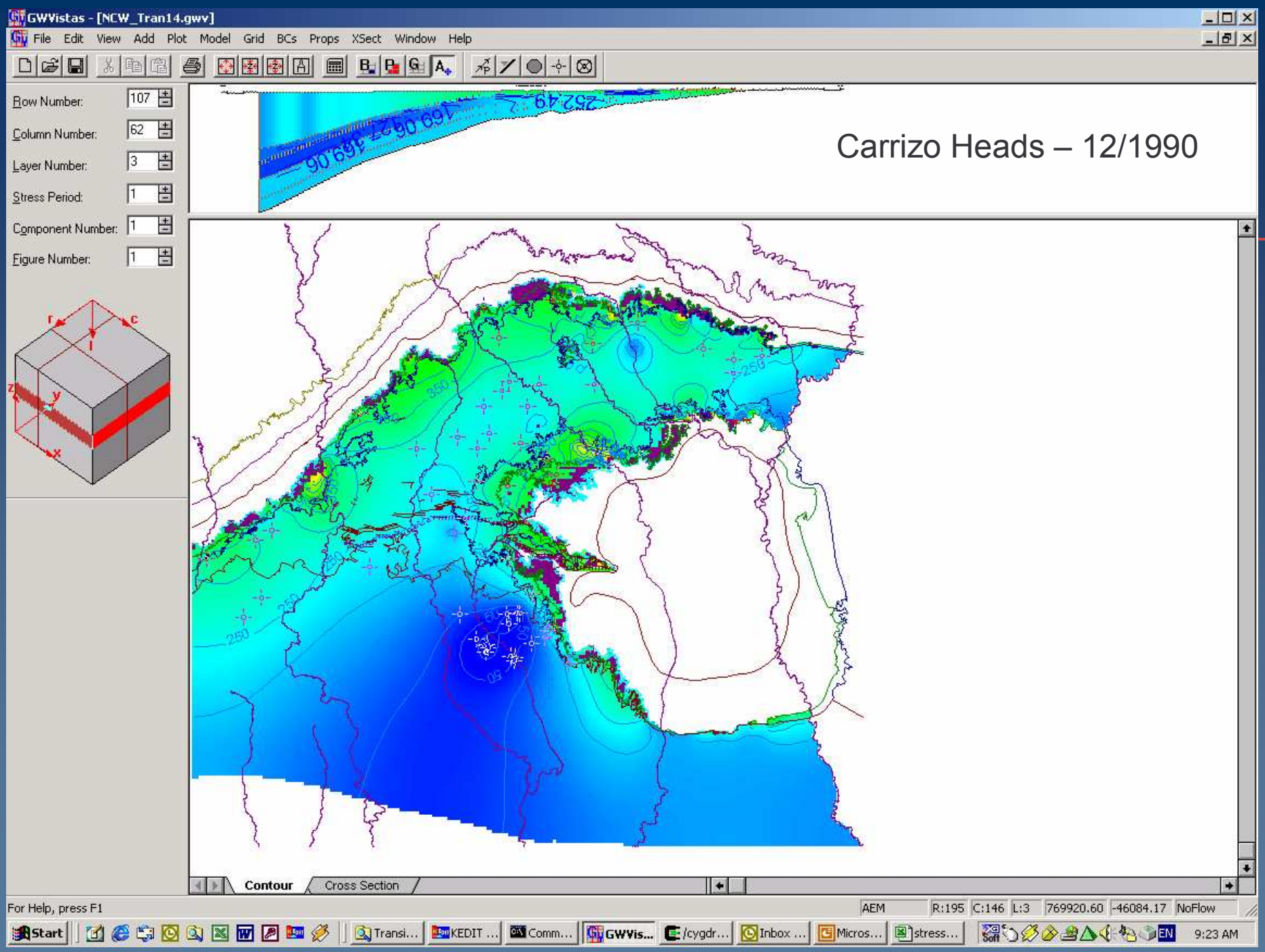


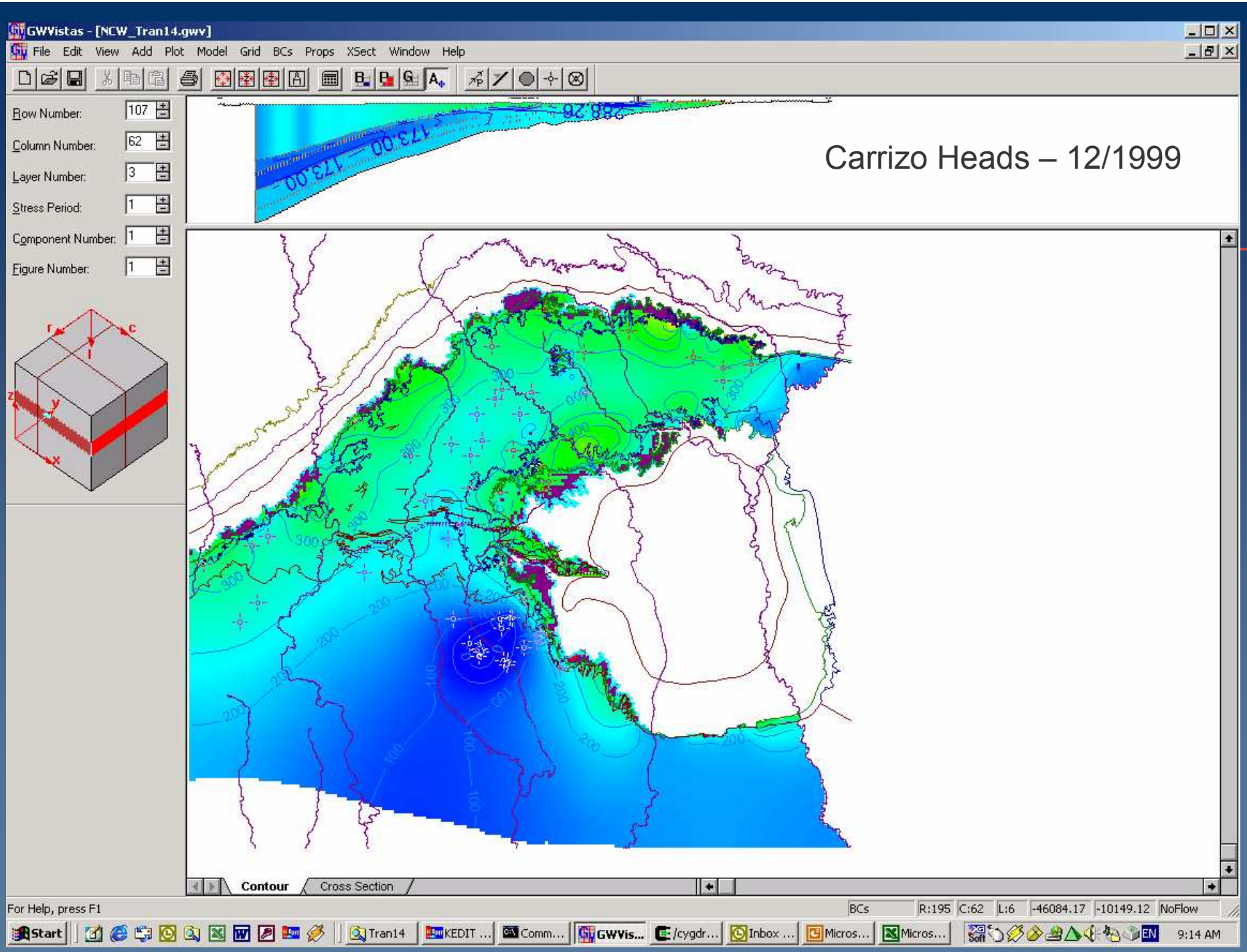
Preliminary Results of Transient Modeling

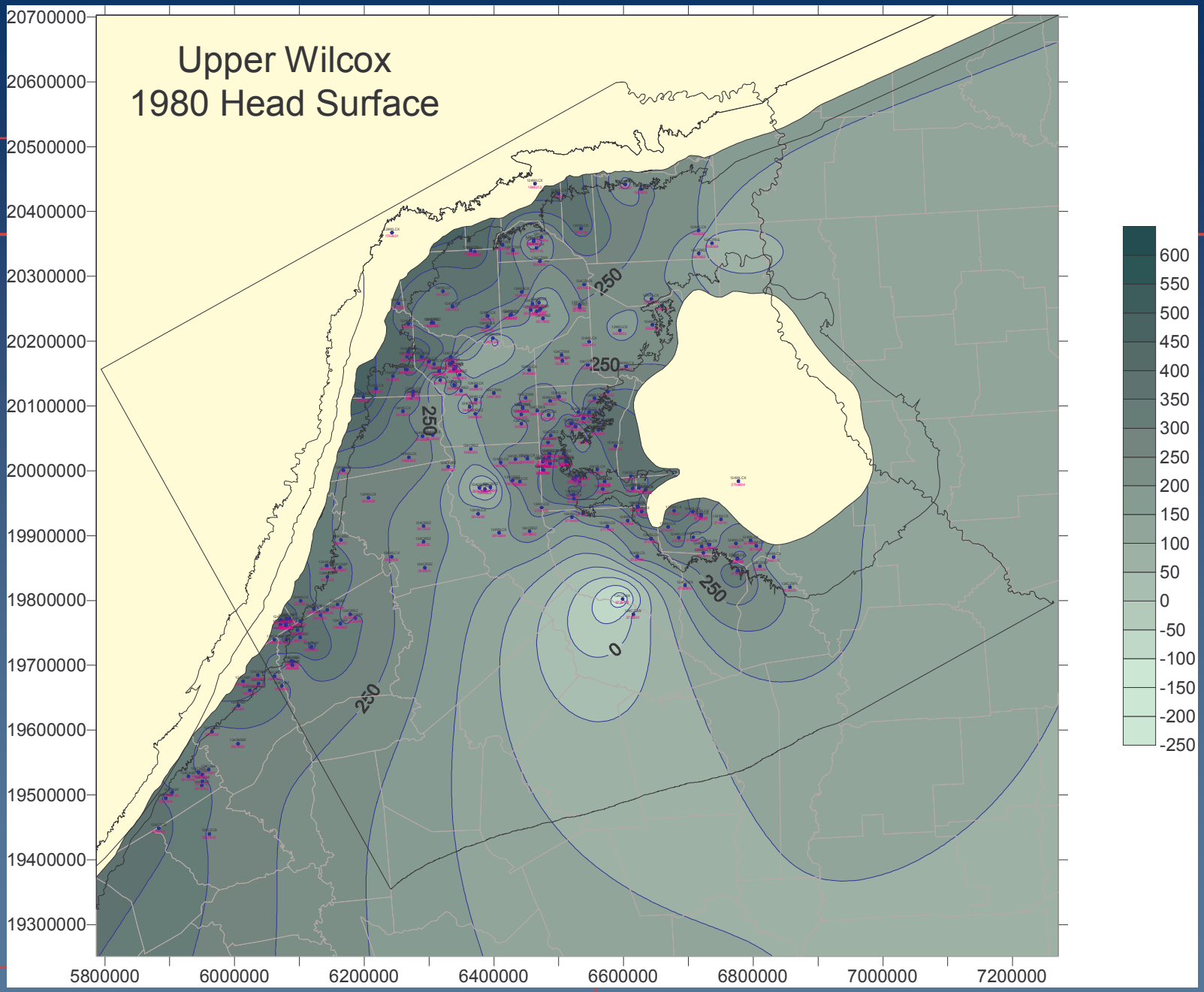
- Transient model calibration (completed)
- Sensitivity Analyses
- Predictive Simulations


Carrizo
1980 Head Surface
20700000
20600000
20500000
20400000
20300000
20200000
20100000
20000000
19900000
19800000
19700000
19600000
19500000
19400000
19300000
5800000
6000000
6200000
6400000
6600000
6800000
7000000
7200000
250
250
250
250
0
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250


GWVistas - [NCW_Tran14.gwv]
File Edit View Add Plot Model Grid BCs Props XSect Window Help
Row Number: 107
Column Number: 62
Layer Number: 3
Stress Period: 1
Component Number: 1
Figure Number: 1
Carrizo Heads – 1/1980
Contour
Cross Section
For Help, press F1
AEM
R:195 C:139 L:4
732149.80
-29896.69
NoFlow
Start
9:18 AM


GWVistas - [NCW_Tran14.gwv]
File Edit View Add Plot Model Grid BCs Props XSect Window Help
Row Number: 107
Column Number: 62
Layer Number: 3
Stress Period: 1
Component Number: 1
Figure Number: 1
Carrizo Heads – 12/1990
Contour
Cross Section
For Help, press F1
AEM
R:195 C:146 L:3
769920.60
-46084.17
NoFlow
Start
9:23 AM


GWVistas - [NCW_Tran14.gwv]
File Edit View Add Plot Model Grid BCs Props XSect Window Help
Row Number: 107
Column Number: 62
Layer Number: 3
Stress Period: 1
Component Number: 1
Figure Number: 1
Carrizo Heads – 12/1999
Contour
Cross Section
For Help, press F1
BCs R:195 C:62 L:6 -46084.17 -10149.12 NoFlow
Start
Tran14
KEDIT ...
Comm...
GWVis...
/cygdr...
Inbox ...
Micros...
Micros...
9:14 AM


Upper Wilcox
1980 Head Surface
20700000
20600000
20500000
20400000
20300000
20200000
20100000
20000000
19900000
19800000
19700000
19600000
19500000
19400000
19300000
5800000
6000000
6200000
6400000
6600000
6800000
7000000
7200000
250
250
250
250
0
600
550
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450
400
350
300
250
200
150
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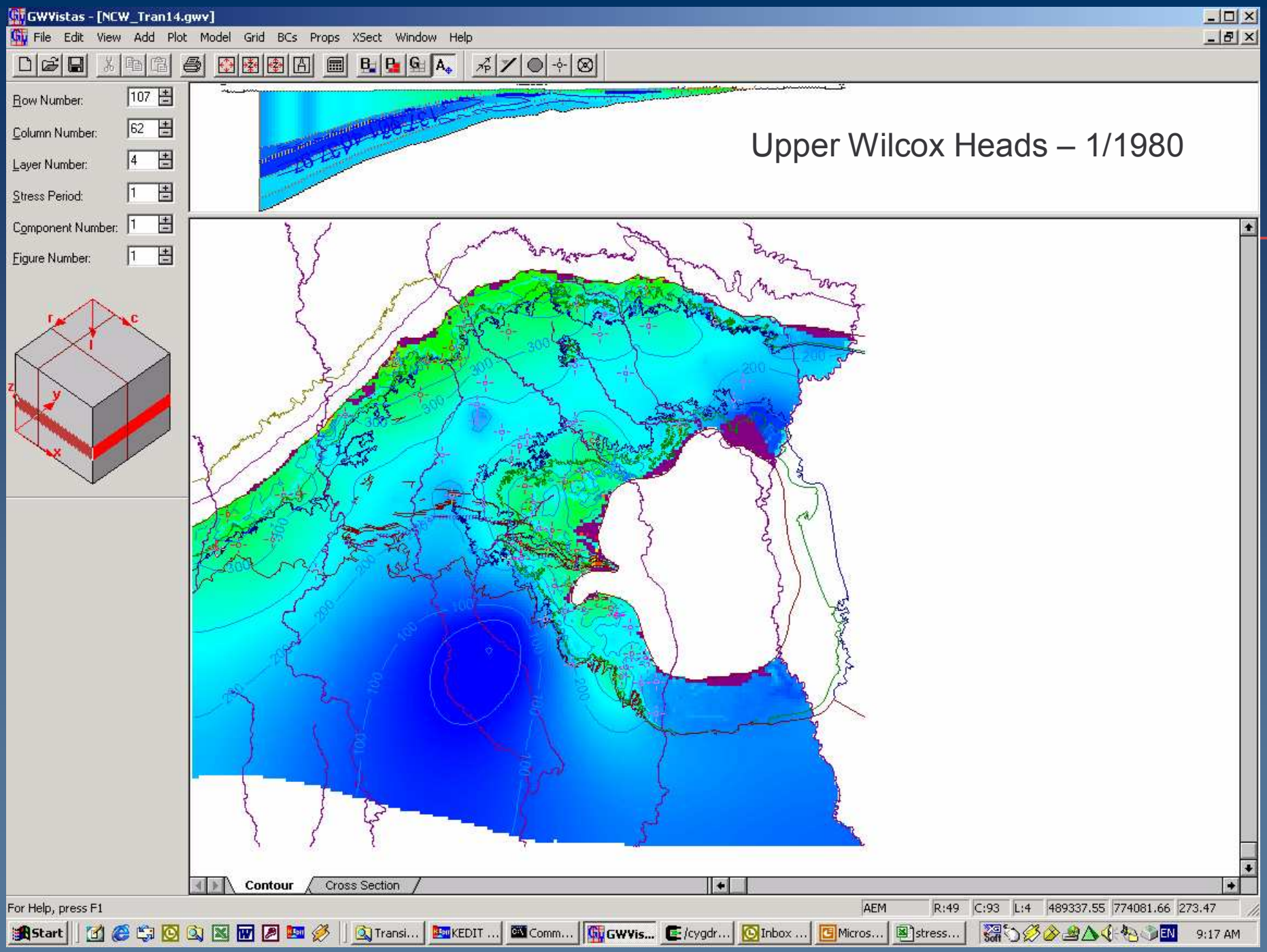
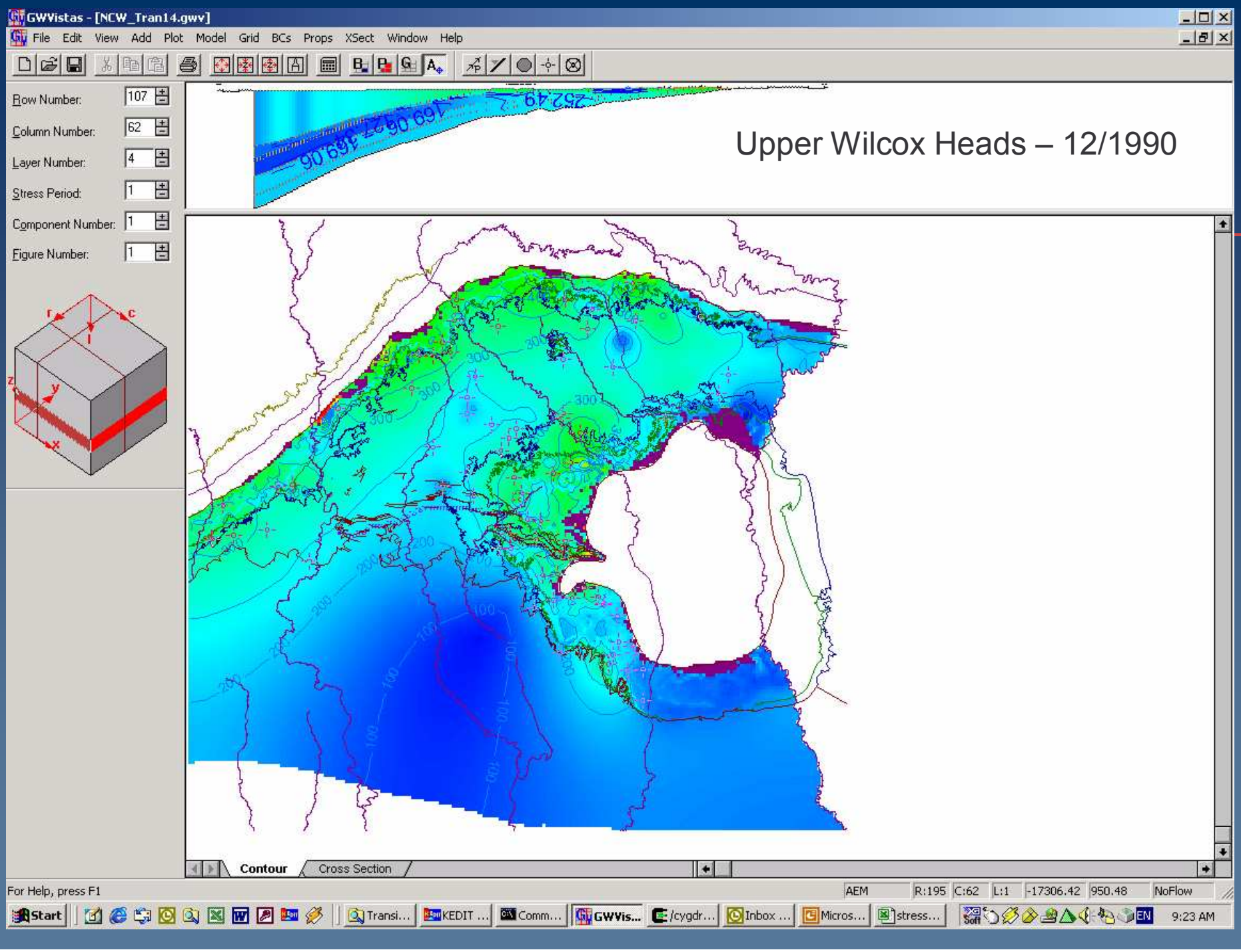
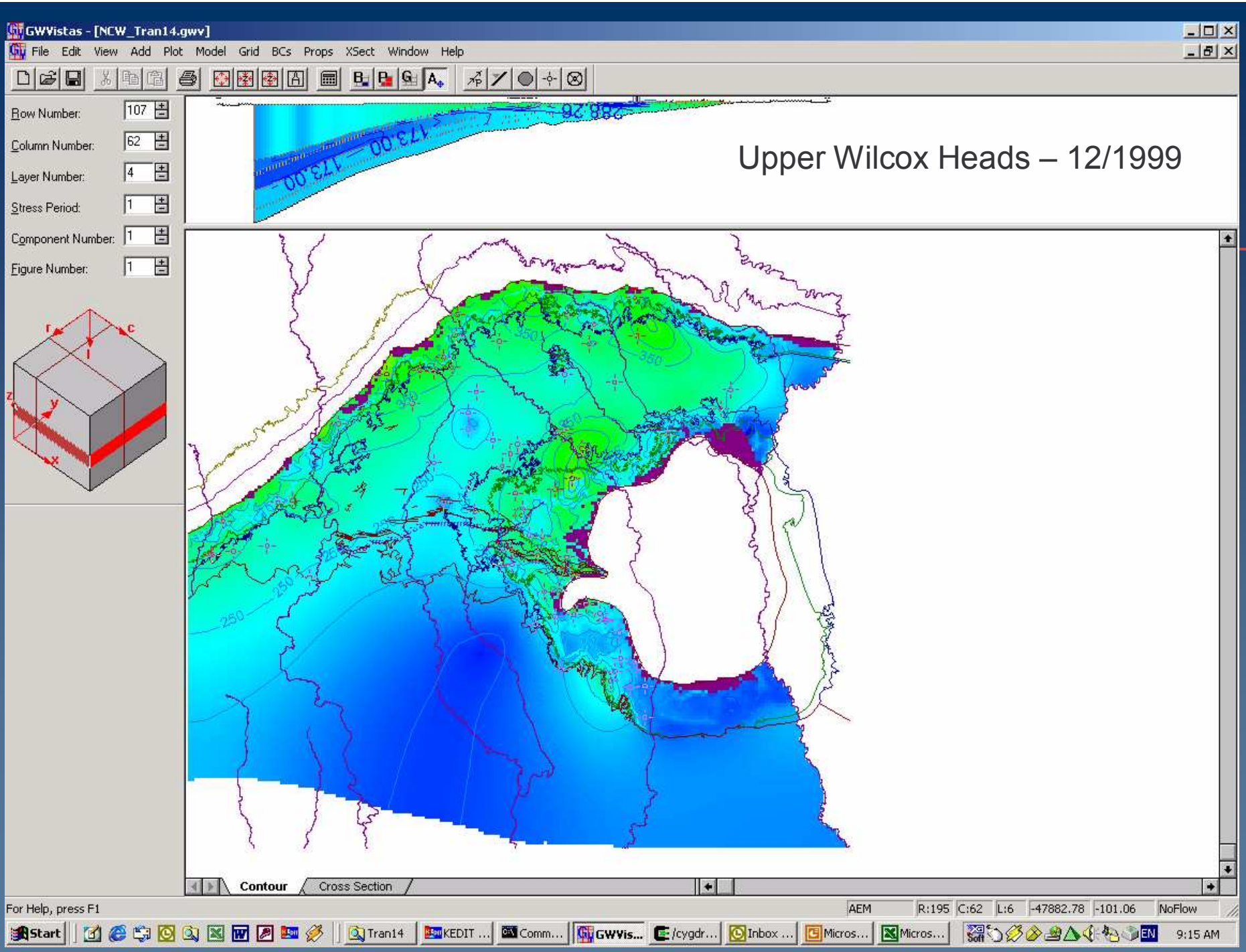
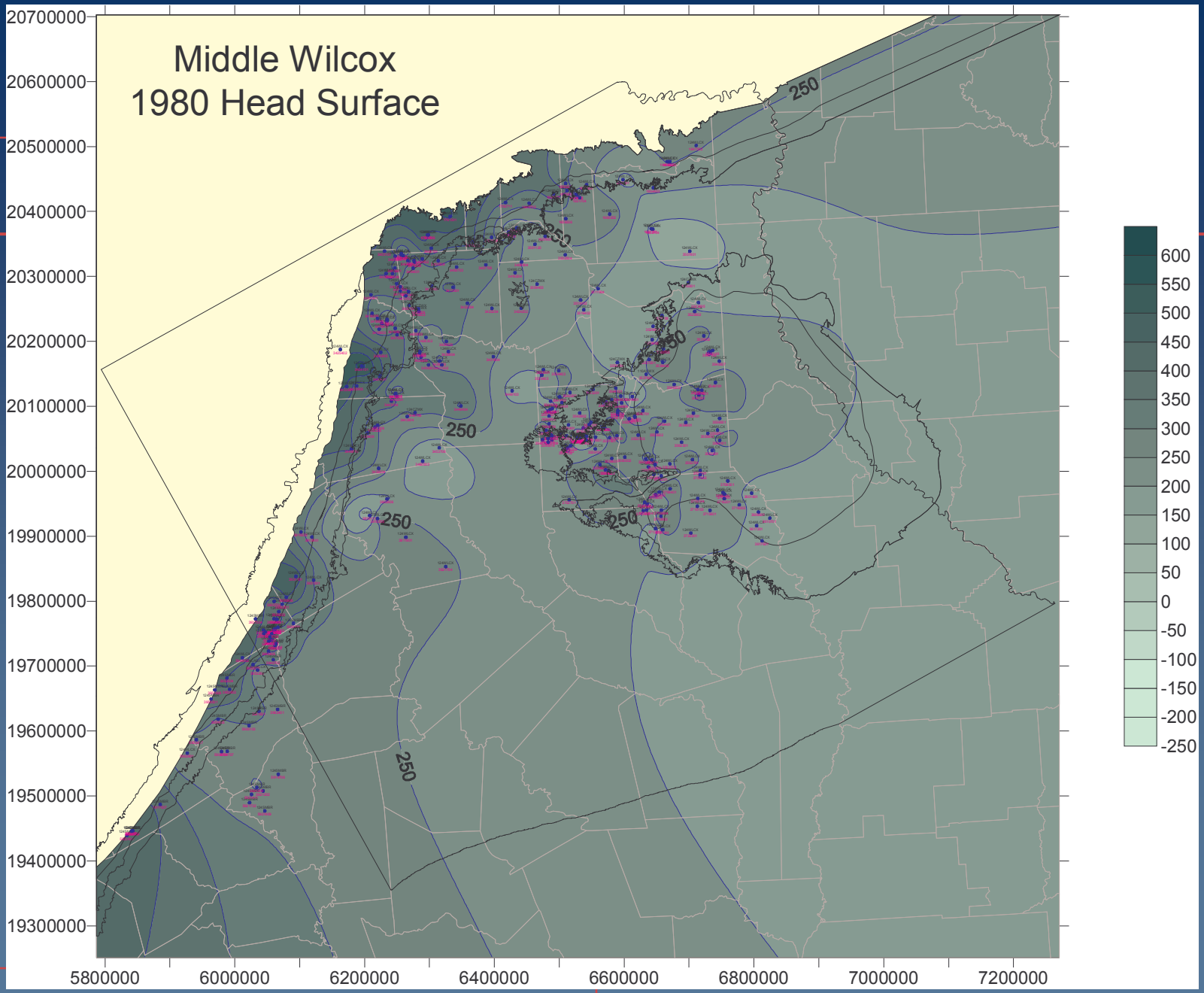
50
0
-50
-100
-150
-200
-250

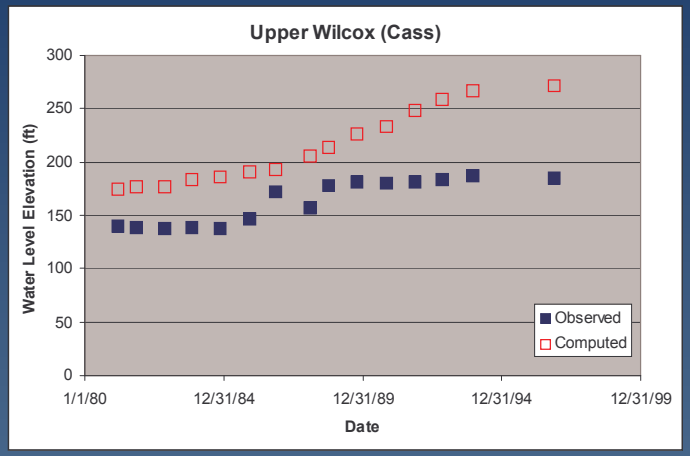

GWVistas - [NCW_Tran14.gwv]
File Edit View Add Plot Model Grid BCs Props XSect Window Help
Row Number: 107
Column Number: 62
Layer Number: 4
Stress Period: 1
Component Number: 1
Figure Number: 1
r
c
l
z
y
x
Upper Wilcox Heads – 1/1980
Contour
Cross Section
For Help, press F1
AEM
R:49
C:93
L:4
489337.55
774081.66
273.47
Start
Transi...
KEDIT ...
Comm...
GWVis...
/cygdr...
Inbox ...
Micros...
stress...
9:17 AM

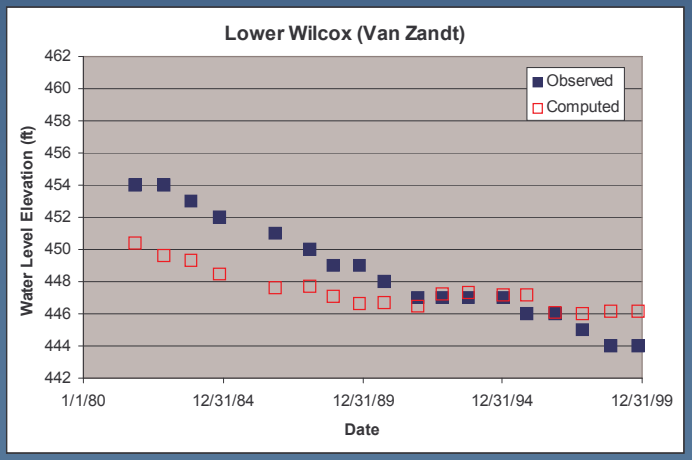

GWVistas - [NCW_Tran14.gwv]
File Edit View Add Plot Model Grid BCs Props XSect Window Help
Row Number: 107
Column Number: 62
Layer Number: 4
Stress Period: 1
Component Number: 1
Figure Number: 1
r
c
l
z
y
x
Upper Wilcox Heads – 12/1990
Contour
Cross Section
For Help, press F1
AEM
R:195
C:62
L:1
-17306.42
950.48
NoFlow
Start
Transi...
KEDIT ...
Comm...
GWVis...
/cygdr...
Inbox ...
Micros...
stress...
9:23 AM

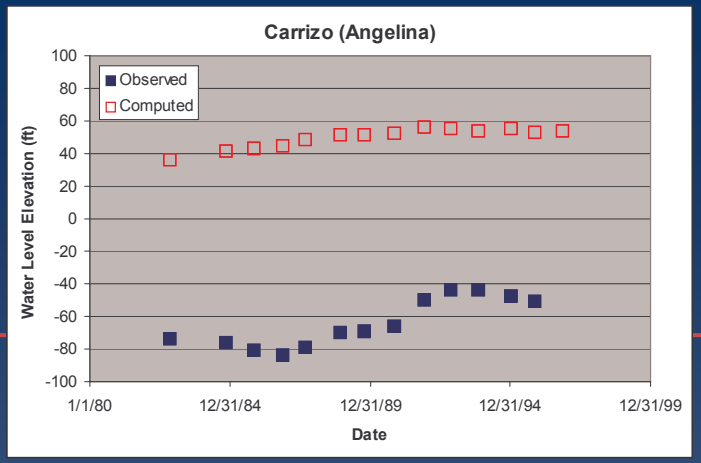

GWVistas - [NCW_Tran14.gwv]
File Edit View Add Plot Model Grid BCs Props XSect Window Help
Row Number: 107
Column Number: 62
Layer Number: 4
Stress Period: 1
Component Number: 1
Figure Number: 1
r
c
l
z
y
x
Upper Wilcox Heads – 12/1999
288.26
173.00
350
300
250
250
Contour
Cross Section
For Help, press F1
AEM
R:195
C:62
L:6
-47882.78
-101.06
NoFlow
Start
Tran14
KEDIT ...
Comm...
GWVis...
/cygdr...
Inbox ...
Micros...
Micros...
9:15 AM

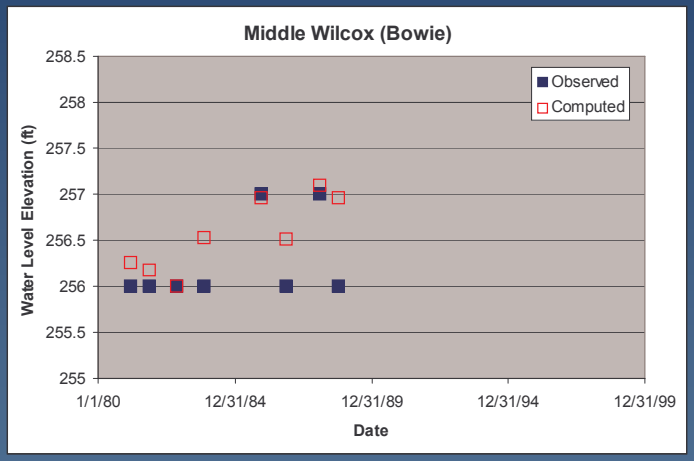

Middle Wilcox
1980 Head Surface
20700000
20600000
20500000
20400000
20300000
20200000
20100000
20000000
19900000
19800000
19700000
19600000
19500000
19400000
19300000
5800000
6000000
6200000
6400000
6600000
6800000
7000000
7200000
250
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250

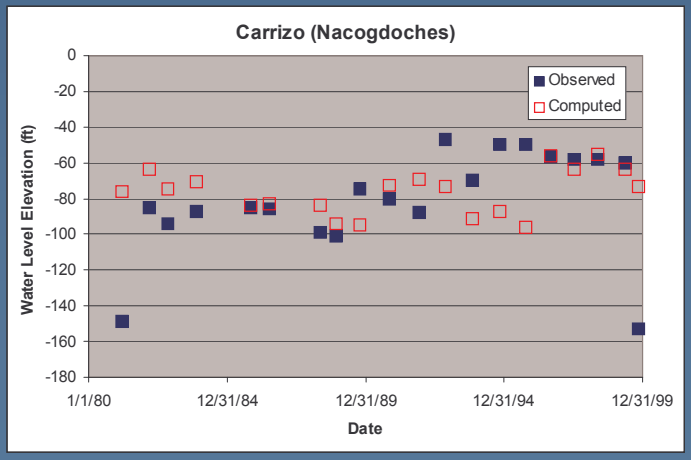
Comparison of Observed to Simulated Water Level Elevations







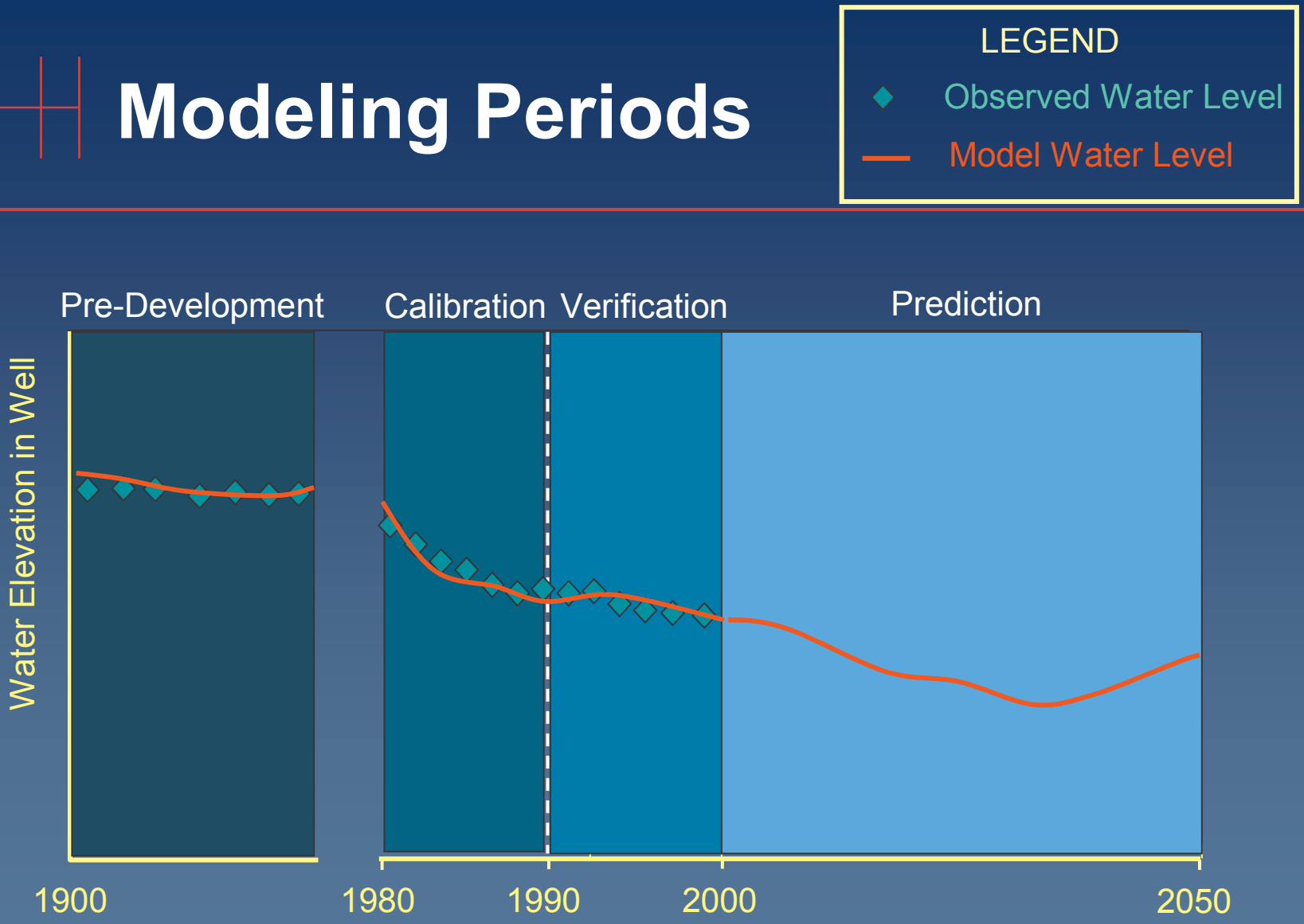




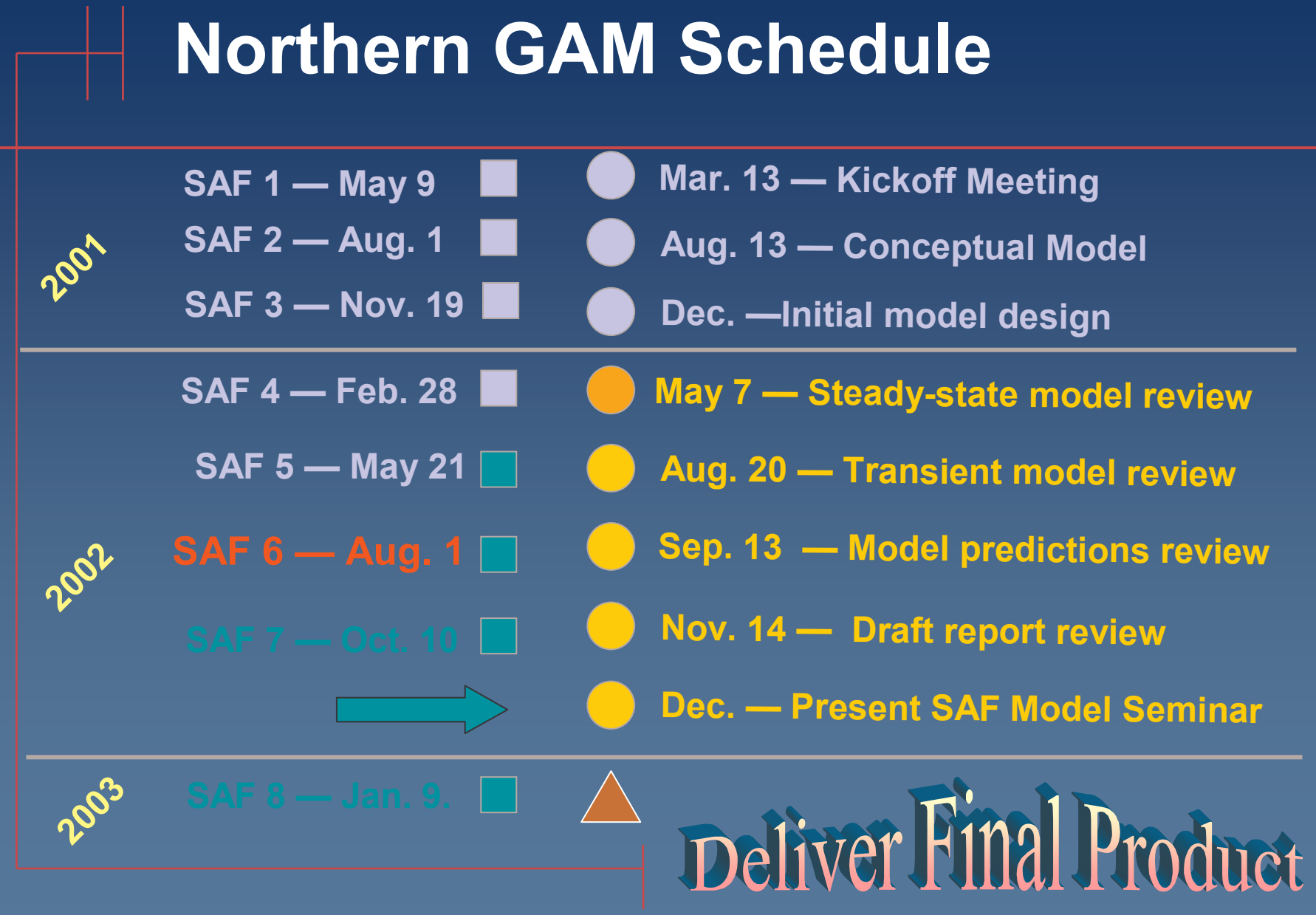
Expected SAF-7 Discussion

- Transient model calibration (completed)
- Sensitivity Analyses
- Predictive Simulations

Modeling Periods



Northern GAM Schedule



SIGN-UP SHEET

Northern Carrizo-Wilcox Aquifer
Groundwater Availability Modeling (GAM)
6th Stakeholder Advisory Forum

August 1, 2002
Hughes Springs, Texas

Name	Affiliation
A.D. Kleinman	SOSONET
Melvin Reynolds	SOSONET
John Wade	Upshur/Gregg SWCD #417
Reeves Hayter	Hayter Engineering
David Smith	City of Nacogdoches
Terry Winn	KSA Engineers
Kelly Mills	TNRCC
Cecil Wallace	
Rainer Senger	Intera, Inc.
Sanjeev Kalaswad	TWDB

List of Stakeholders' Questions and Comments
6th SAF: Northern Carrizo-Wilcox GAM
August 1, 2002
Hughes Springs, Texas

Questions:

1. Q: Why does the water-level curve on the graph ("Modeling Periods" graph) start to rise in the year 2030?
   A: This is only hypothetical; it assumes that some conservation measure would be implemented in the future to reverse the current trend of continued water-level declines.

2. Q: Can the presentation be made available to the public?
   A: Yes the presentation is available from the TWDB web site: http://www.twdb.state.tx.us/Gam/

3. Q: How will the Queen City/Sparta aquifer be tied to the Carrizo-Wilcox aquifer when it is modeled in the next round of GAMs?
   A: The Queen City/Sparta aquifer, to be investigated in the next round of GAMs, will be added to the existing Carrizo-Wilcox GAM models to consider potential interaction with the underlying Carrizo-Wilcox aquifer. In the northern Carrizo-Wilcox GAM, the Queen City Formation is already included.

4. Q: How was geological information for the model obtained?
   A: Geologic information was based mainly on published reports by a variety of investigators. The different layers for the Carrizo-Wilcox aquifer, layer thickness, and sand distributions were presented at the 5th SAF, which can be reviewed on the TWDB web site above.

5. Q: Will the final report contain information on the depths to the various aquifers/layers?
   A: Yes, all the geologic information used in the model will be available in the final report, which will include contour maps of the different layer surfaces.

6. Q: Will water quality information be shown for the different layers, in terms of how much good water is available?
   A: Water quality information will be presented in terms of total dissolved solids and selected other constituents that are of major concern. A preview of these data was presented during the 4th SAF. Again, the presentation of that meeting can be accessed from the TWDB web site. However, the information is probably not detailed enough to identify the water quality at a particular location, because of general lack of vertical resolution in water quality data.

7. Q: Is 15% usable water an accurate value for the Carrizo-Wilcox aquifer?
   A: This is difficult to say; we have a rough estimate of sand percentage, indicating that the Wilcox contains as much as 50% sand; however, this does not mean that all the sand contains usable water.

8. Q: Why are there no pre-development water levels shown for the Carrizo layer in Louisiana?
   A: There were no early water-level data available from Louisiana that was suitable for defining pre-development heads.

9. Q: What is causing the drawdowns in the Nacogdoches area between 1980 and 1990?
   A: The drawdown is caused by significant pumpage, mainly for municipal and industrial usage in this area.

10. Q: What category of pumping is shown in Cass County?
A: The pumpage shown for Cass County includes all the different pumpage categories.

11. Q: Is MODFLOW capable of taking into account the reservoirs in the area?
A: Yes, MODFLOW can take reservoirs into account through its Reservoir Package, which considers the water level and release into the streams.

12. Q: How were you able to distinguish between pumping in the Carrizo and Wilcox aquifers?
A: This is done based on the given well depth, information on well screens, and available aquifer designation, which are compared and checked to the constructed structure maps for the Carrizo and Wilcox layers. For rural domestic wells, where specific information is not available, it was assumed that they pump from the same aquifer unit as nearby wells, where specific information was available.

13. Q: Are there any plans to update the model in the future?
A: Yes, it is anticipated that the model will be updated in the future to incorporate new information that becomes available.

14. Q: Will the GAMs for the three project areas of the Carrizo-Wilcox aquifer have separate reports?
A: Yes, the three GAMs for the Carrizo-Wilcox will be prepared as separate reports, which will be available from the TWDB web site.

15. Q: When and where will the next SAF be?
A: The next SAF meeting for the northern Carrizo-Wilcox will be sometime in early October, following the review meeting with the TWDB. We have not yet decided on a location.

16. Q: Will the influence of reservoirs be included in the final model?
A: Yes, the reservoirs will be incorporated in the final version of the model.

Comments:

1. Stakeholder: The results of the influence of reservoirs on the model would be interesting.
Intera, Inc: This will be studied in the model; in general, they are considered to have only limited impact on the groundwater flow in this model.

2. Stakeholder: The GAM projects are important and would be very useful to many in the area.
Intera, Inc. and TWDB: The GAMs are designed to be readily available to any user, particularly RWPGs and GCDs for future use in assessing groundwater availability in their specific area. For this, a training session for using the GAMs is tentatively scheduled for January 2003.

Action Items:

Two stakeholders requested links to TWDB's GAM site on the WWW. This information was sent to them on 08/06/02.