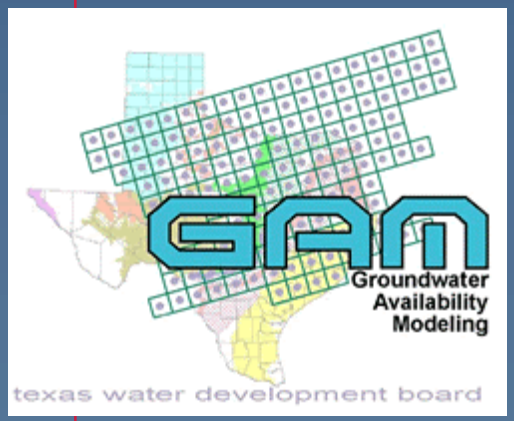
Stakeholder Advisory Forum - 5

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



Guaranty Bank
Community Room

Gonzales, Texas

May 30, 2002

INTERA

PARSONS

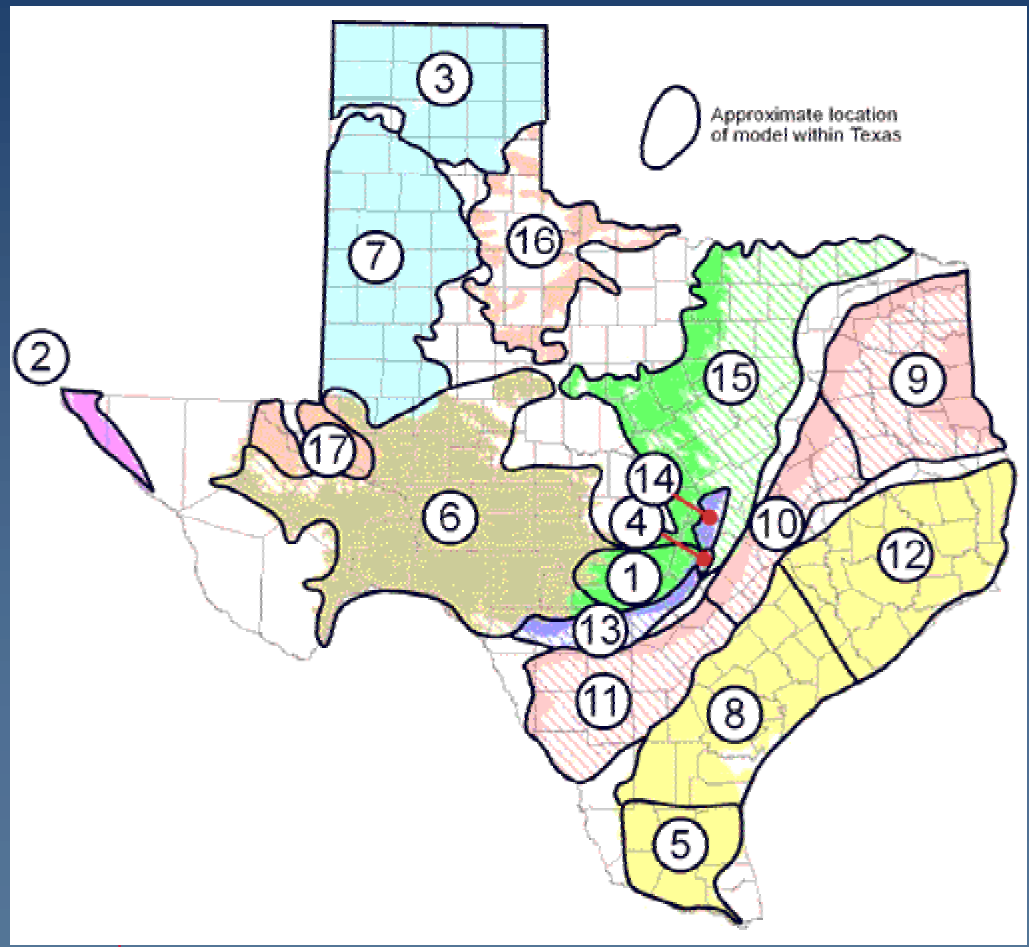
WATERSTONE
Environmental Hydrology and Engineering, Inc.

Presentation Outline

- GAM Program Review
- Conceptual Model Review
- Model Structure/Layers
- Hydraulic Head Review
- Model Boundaries
- Recharge
- Hydraulic Properties
- Steady-State Model Results

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)



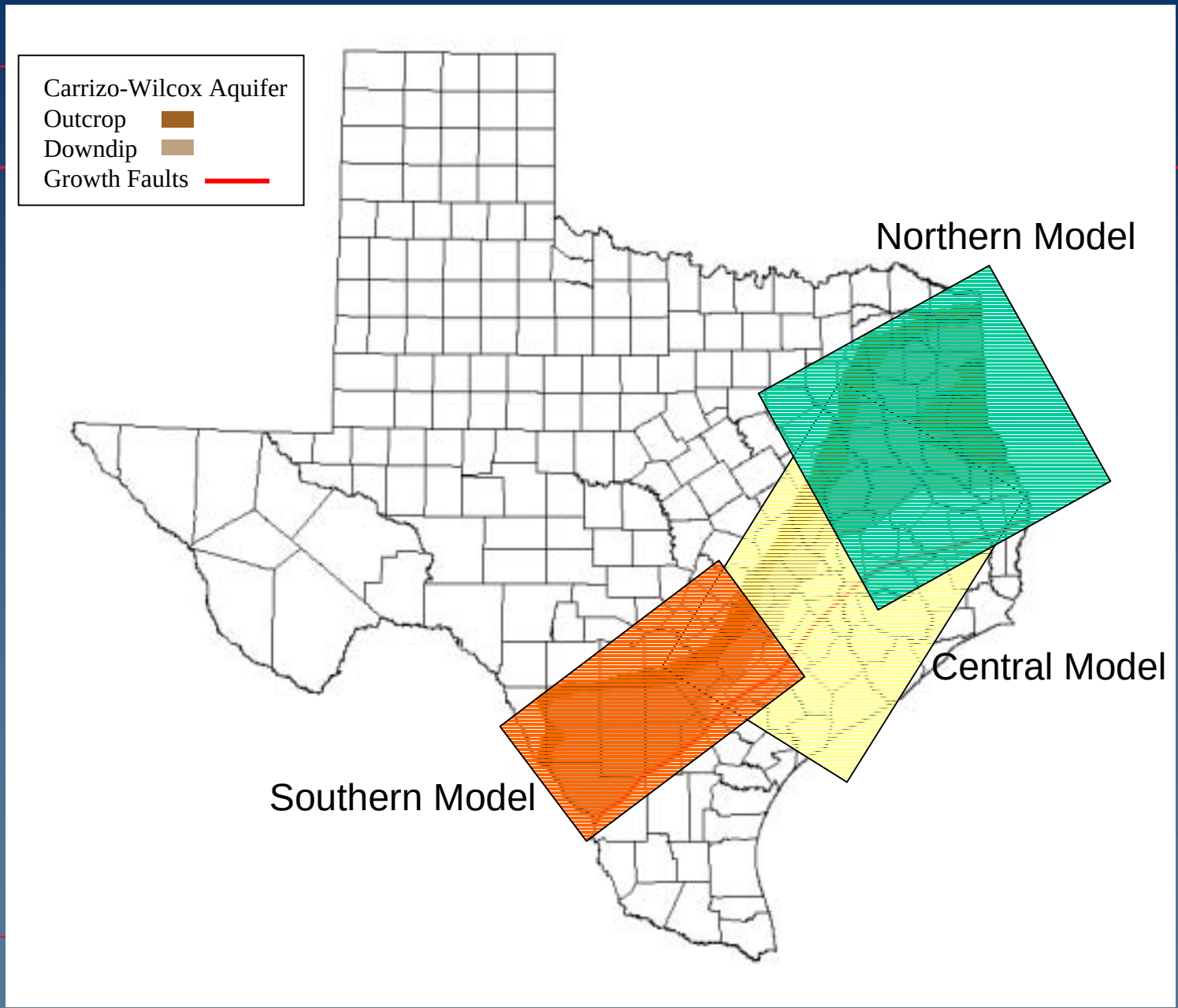
GAM Objectives

- 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

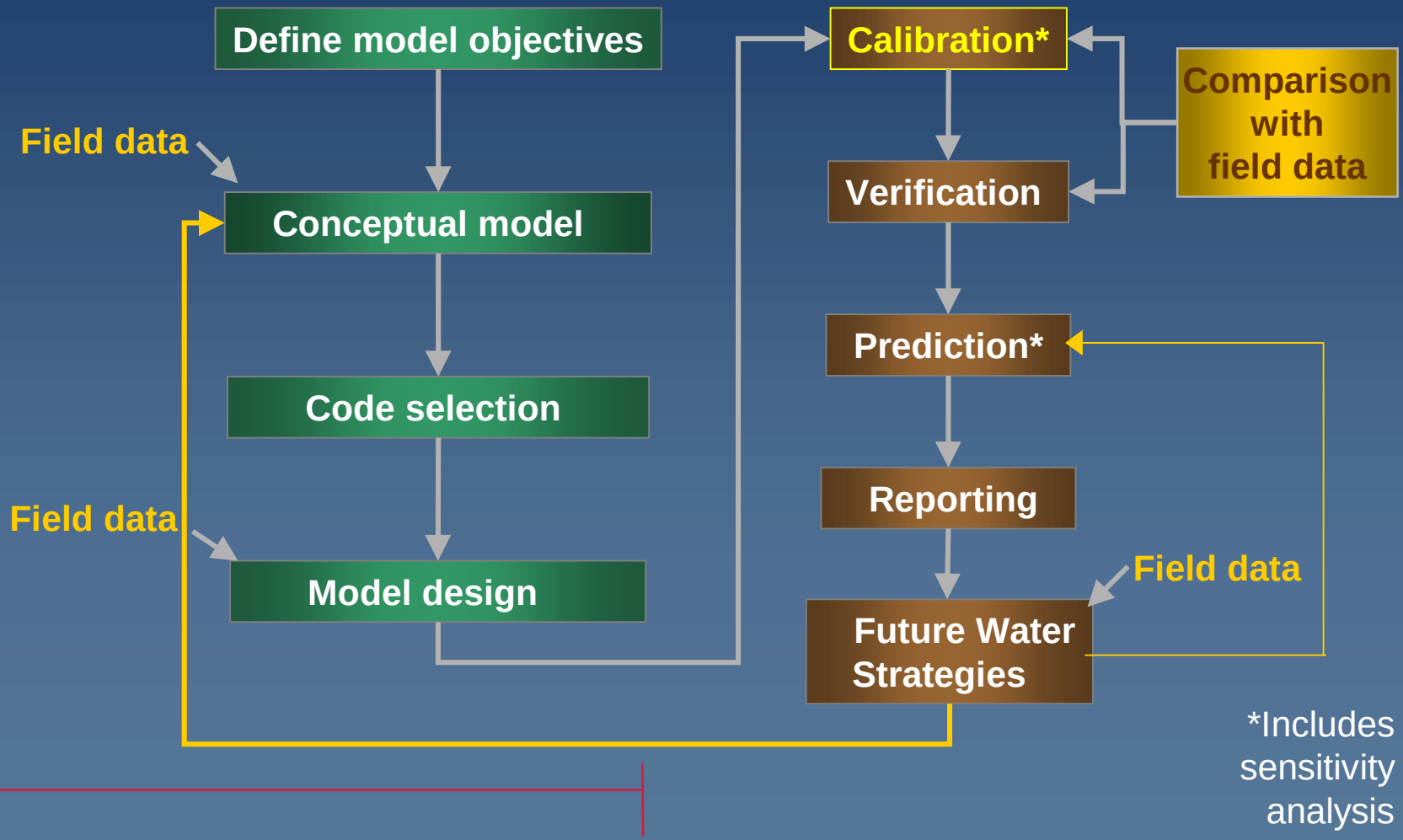
Model Specifications

- 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

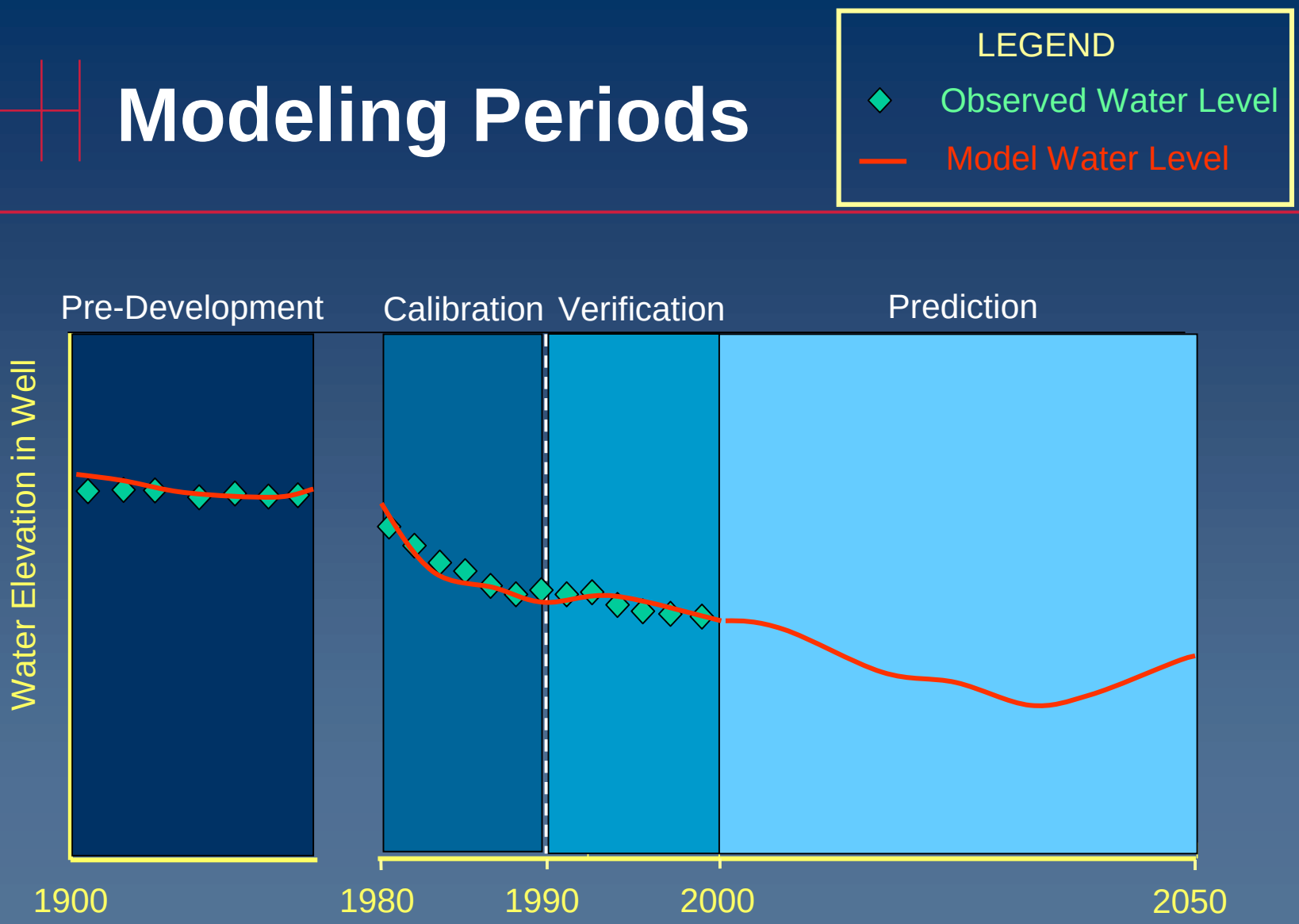
Carrizo-Wilcox GAM Model Domains



Modeling Protocol



Modeling Periods



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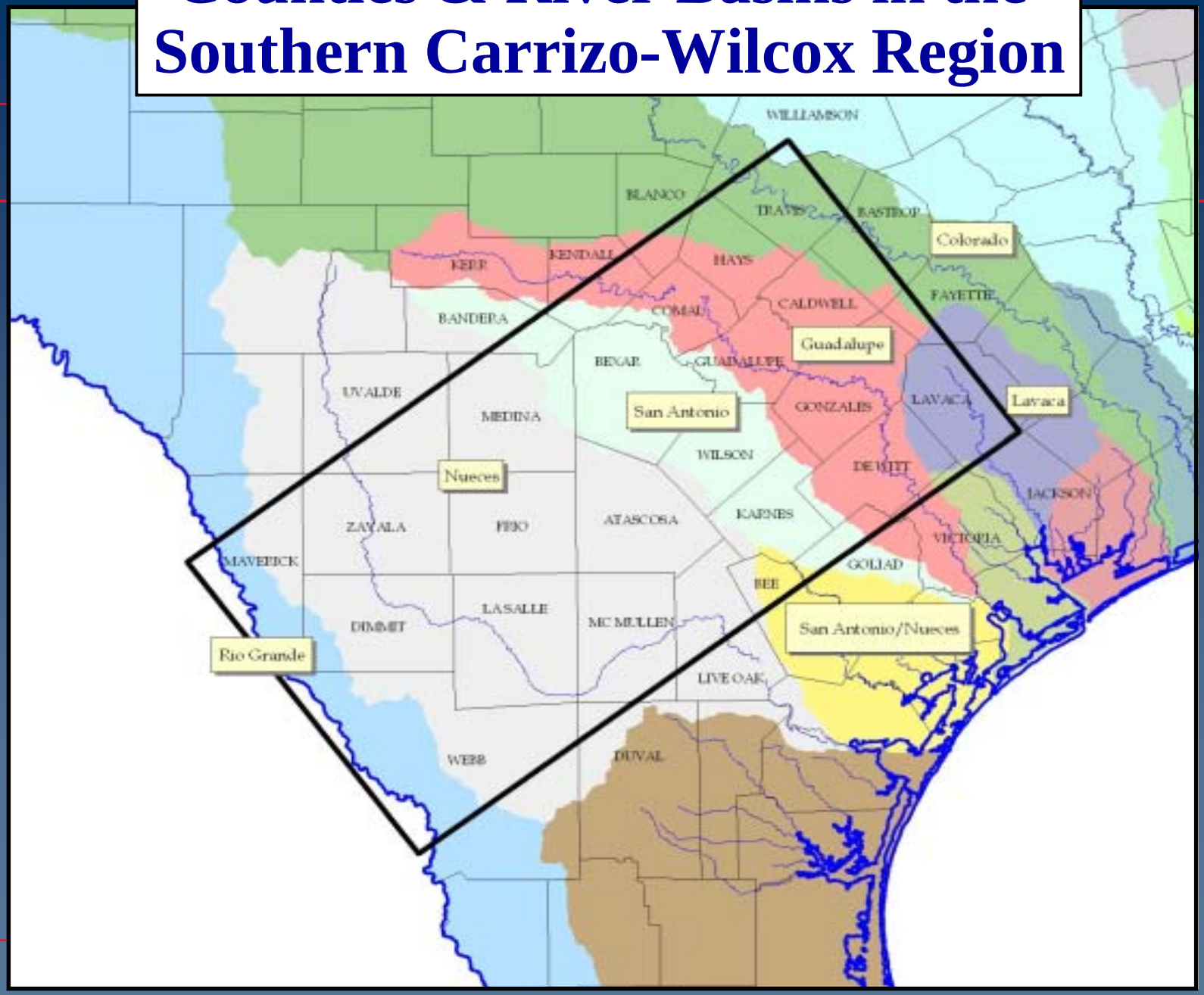
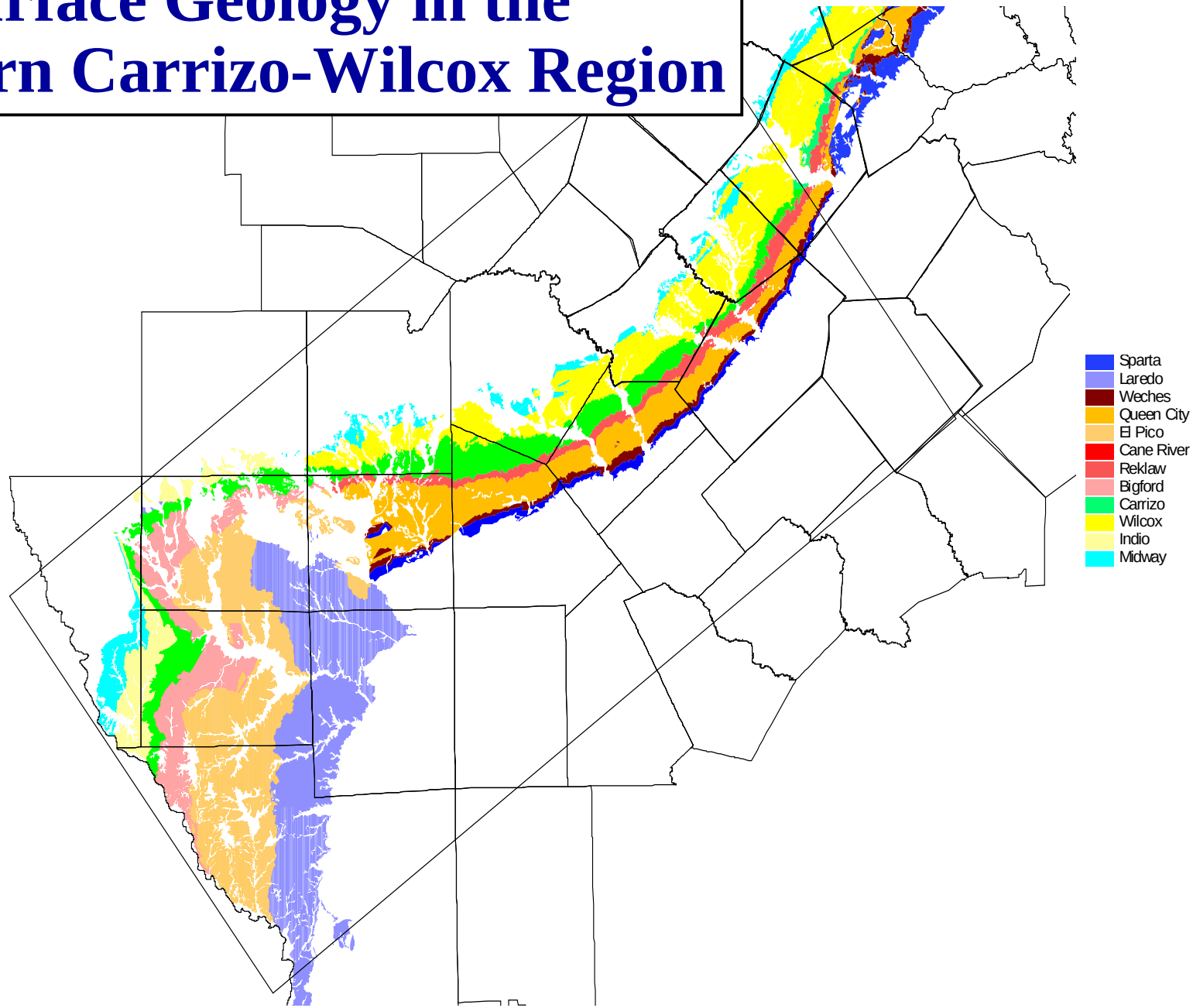
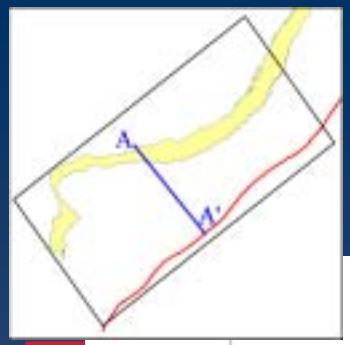
Counties & River Basins in the Southern Carrizo-Wilcox Region

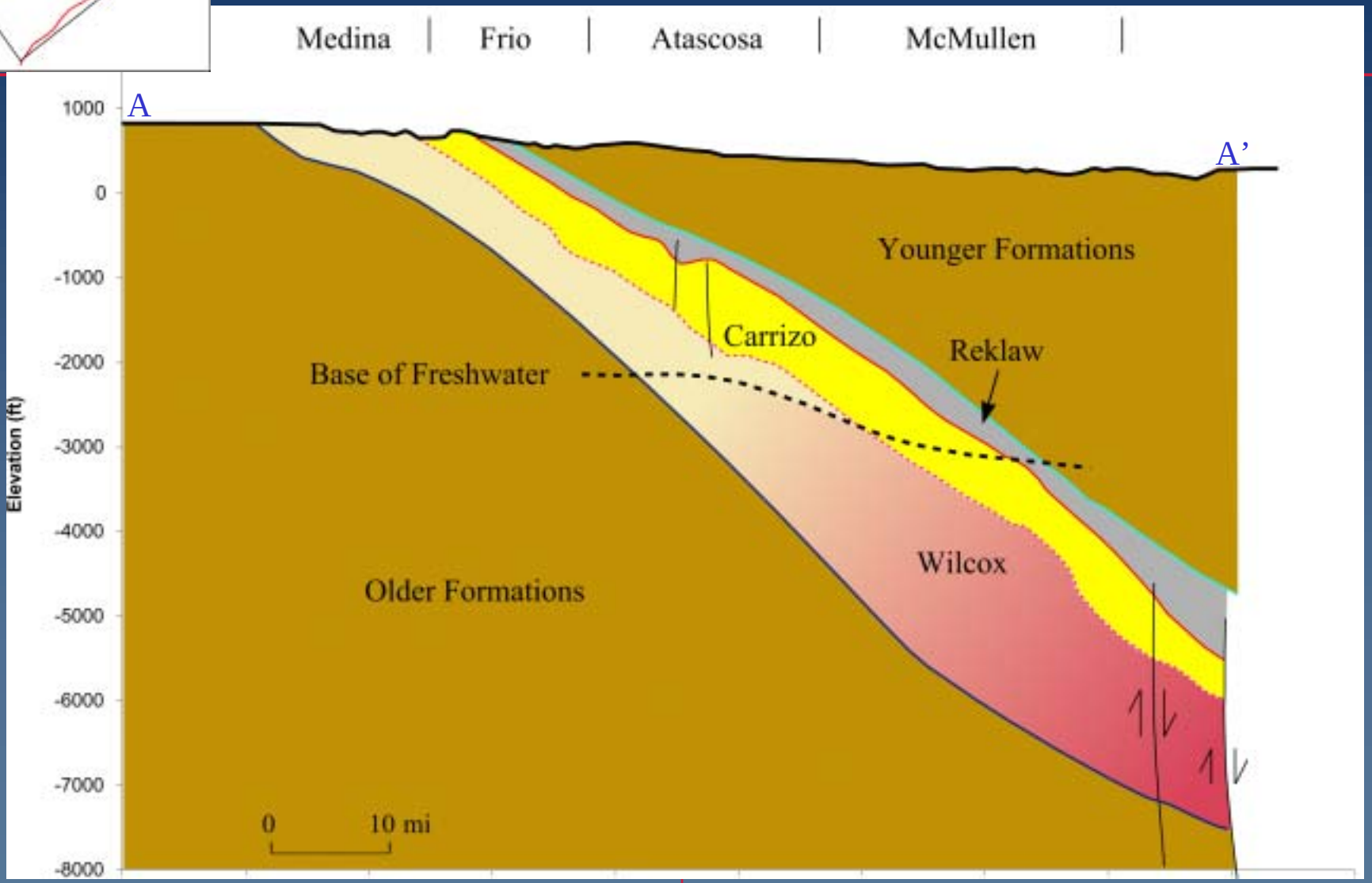


Surface Geology in the Southern Carrizo-Wilcox Region

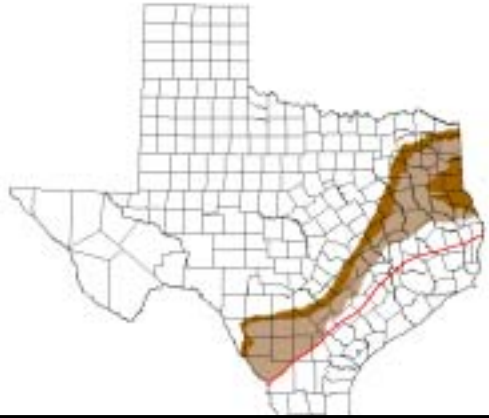


Carrizo-Wilcox Aquifer Down-dip Boundary





Geologic Framework — Stratigraphy



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

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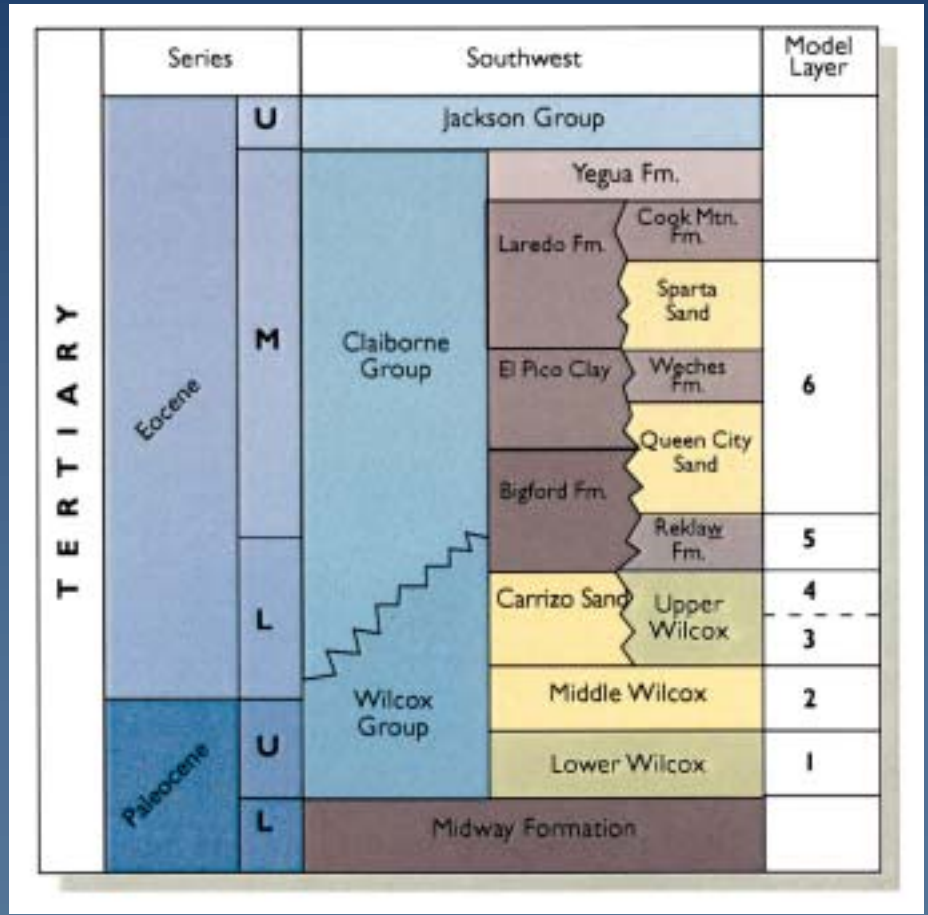
Model Layers

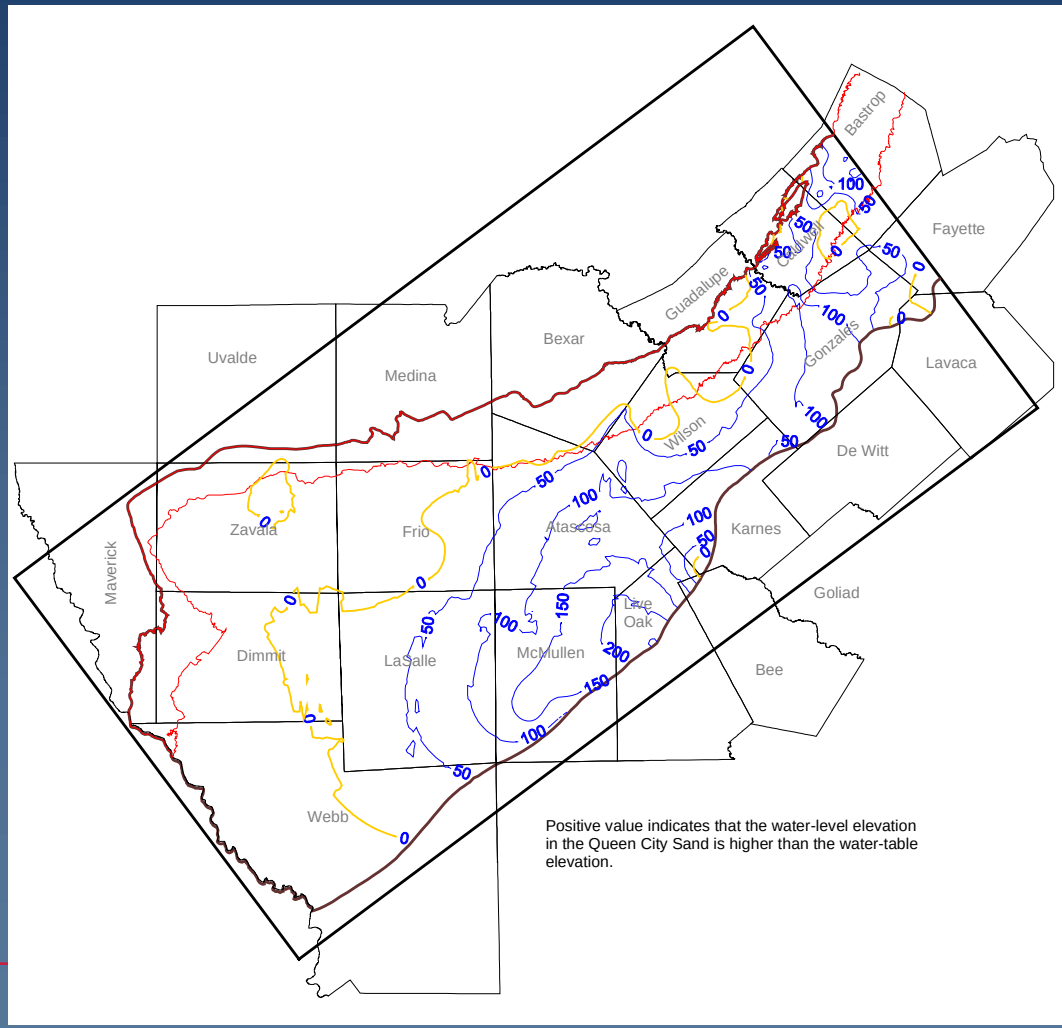
- Total of six layers
  - Carrizo
  - Upper, Middle and Lower Wilcox
  - Reklaw: major confining unit
  - Shallow aquifers above Reklaw
- West of Frio River:
  - Reklaw → Bigford Fm.
  - Queen City/Weches → Bigford/El Pico
  - Sparta → Laredo Fm.



Expert Panel Review

- Initial model structure assumed
  - Queen City head is nearly equivalent to the water table and
  - Queen City/WT head is constant (transient model).
- Requested we check these assumptions
- If they were false, consider making model layer 1 the Queen City with a GHB attached to the water table in the confined portions of the Queen City

Head Difference Between QC and Water Table - Predevelopment



Guevara & Garcia (1972)

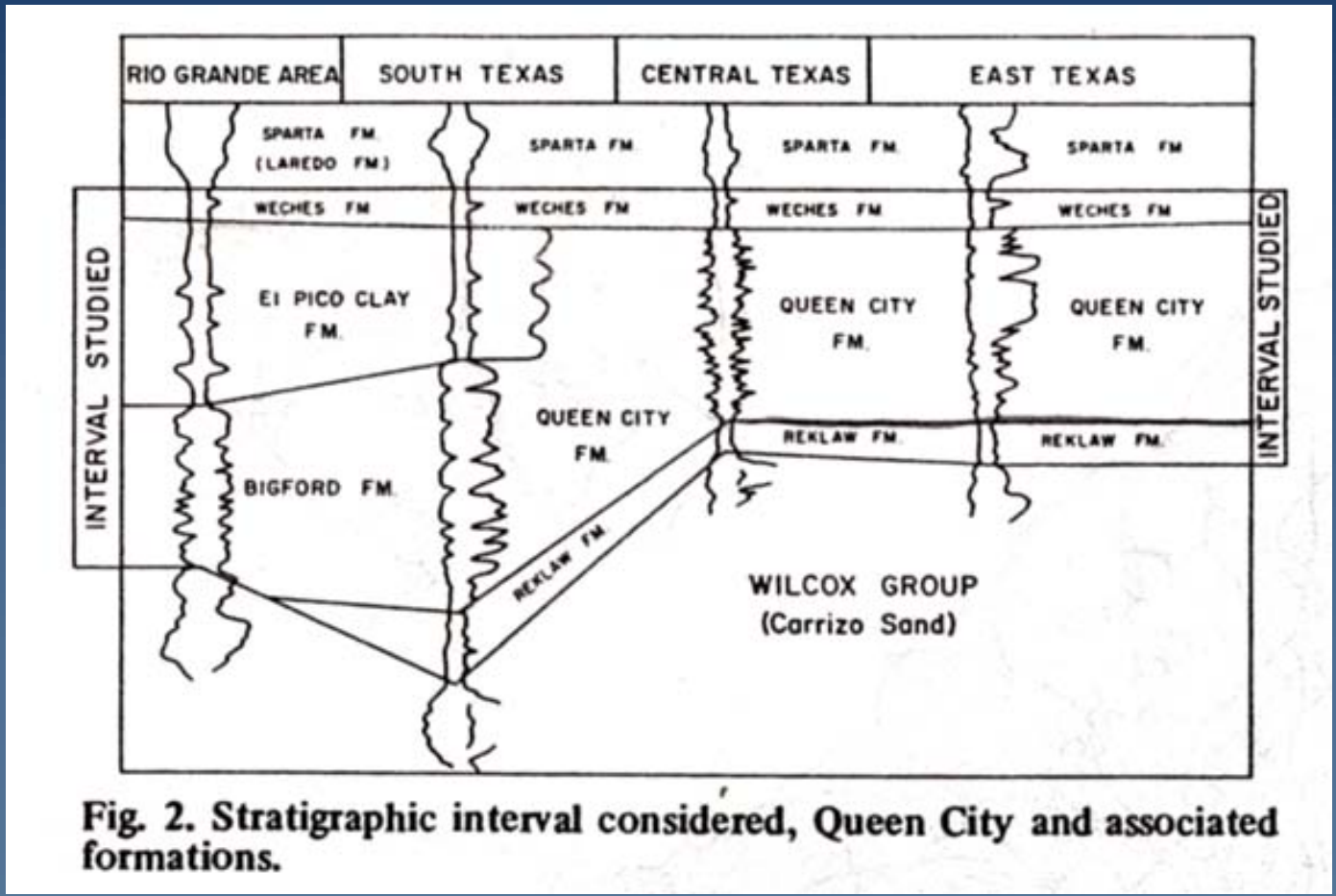


Fig. 2. Stratigraphic interval considered, Queen City and associated formations.

Model Layers – Now and Then

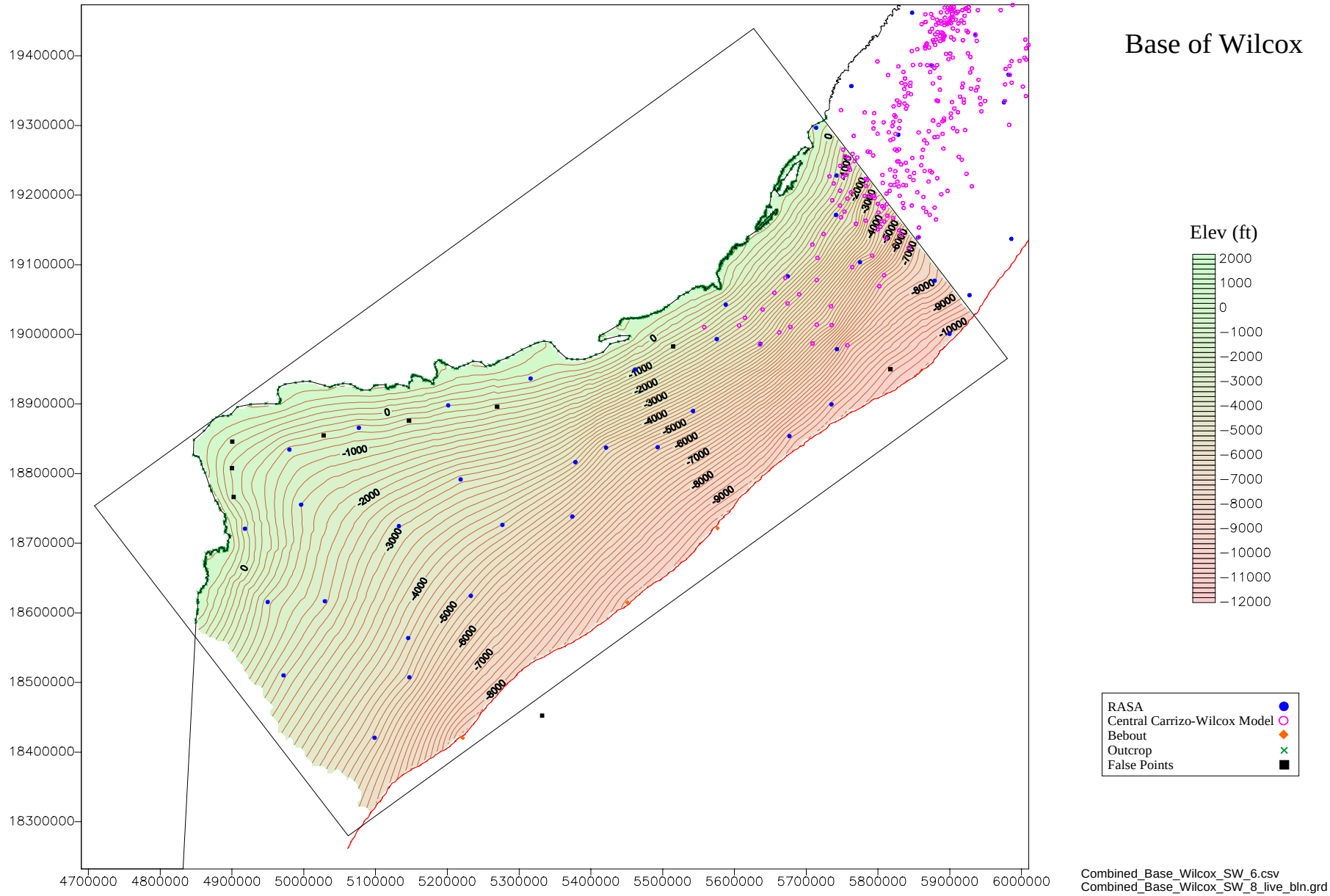
Data Sources

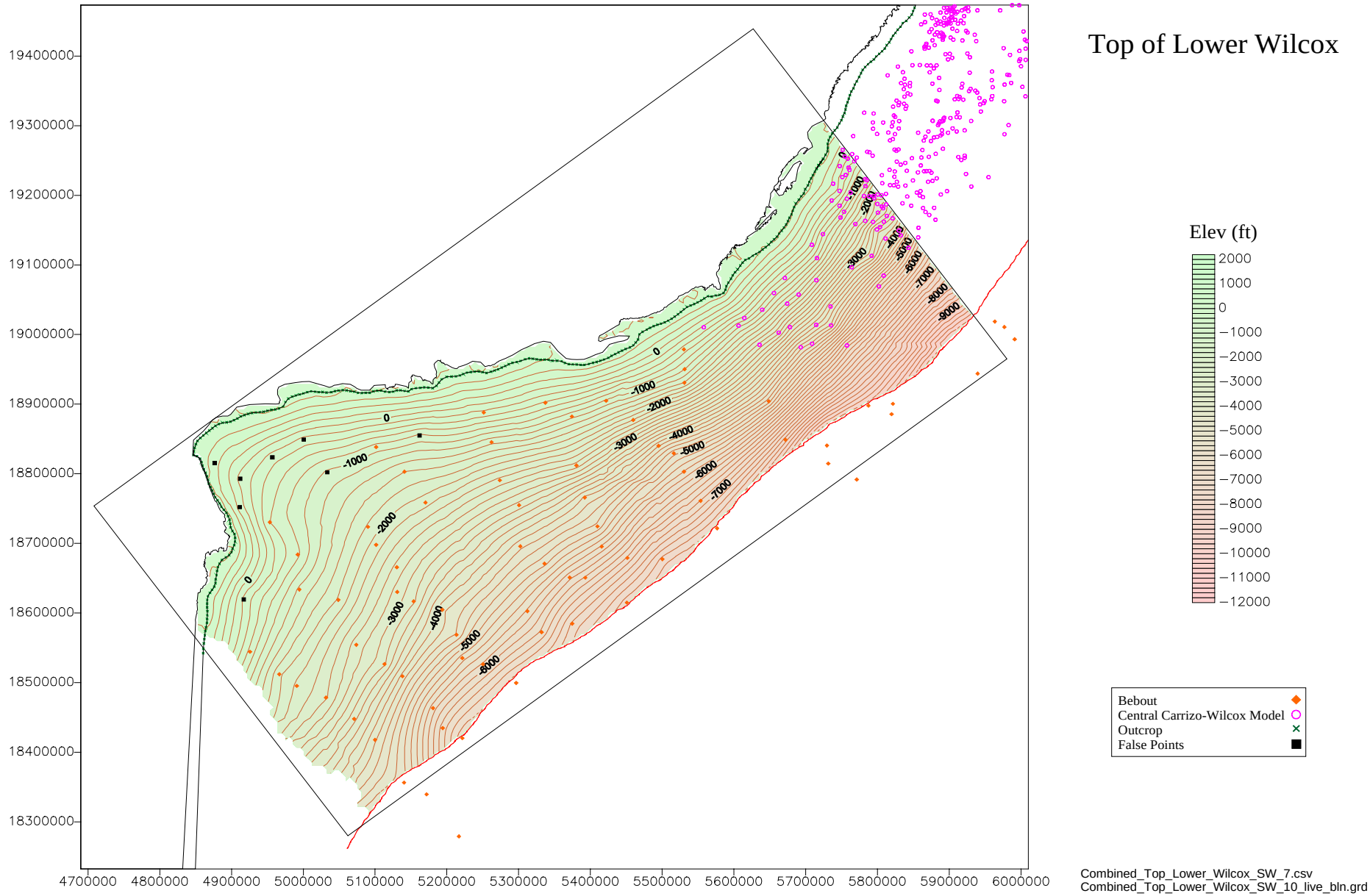
Data Sources for Layer Elevations for the Southern Carrizo-Wilcox Model:

Model Layer Boundary	**HDR (1998)**	**Klemt et al. (1976) (TWDB)**	**Wilson and Hosman (1987) (USGS)**	**TWDB (1972)**	**County Reports for Gonzales & Karnes Counties**	**Hamlin (1988) (BEG)**	**Bebout et al. (1982) (BEG)**	**Central Carrizo-Wilcox GAM Model**	**Surface Elevations (USGS)**
Top of Queen City/El Pico	X								X
Top of Reklaw/Bigford	X		X		X			X	X
Top of Carrizo		X		X				X	X
Top of Wilcox		X						X	X
Top of Middle Wilcox						X	X		X
Top of Lower Wilcox							X	X	X
Base of Wilcox			X				X	X	X

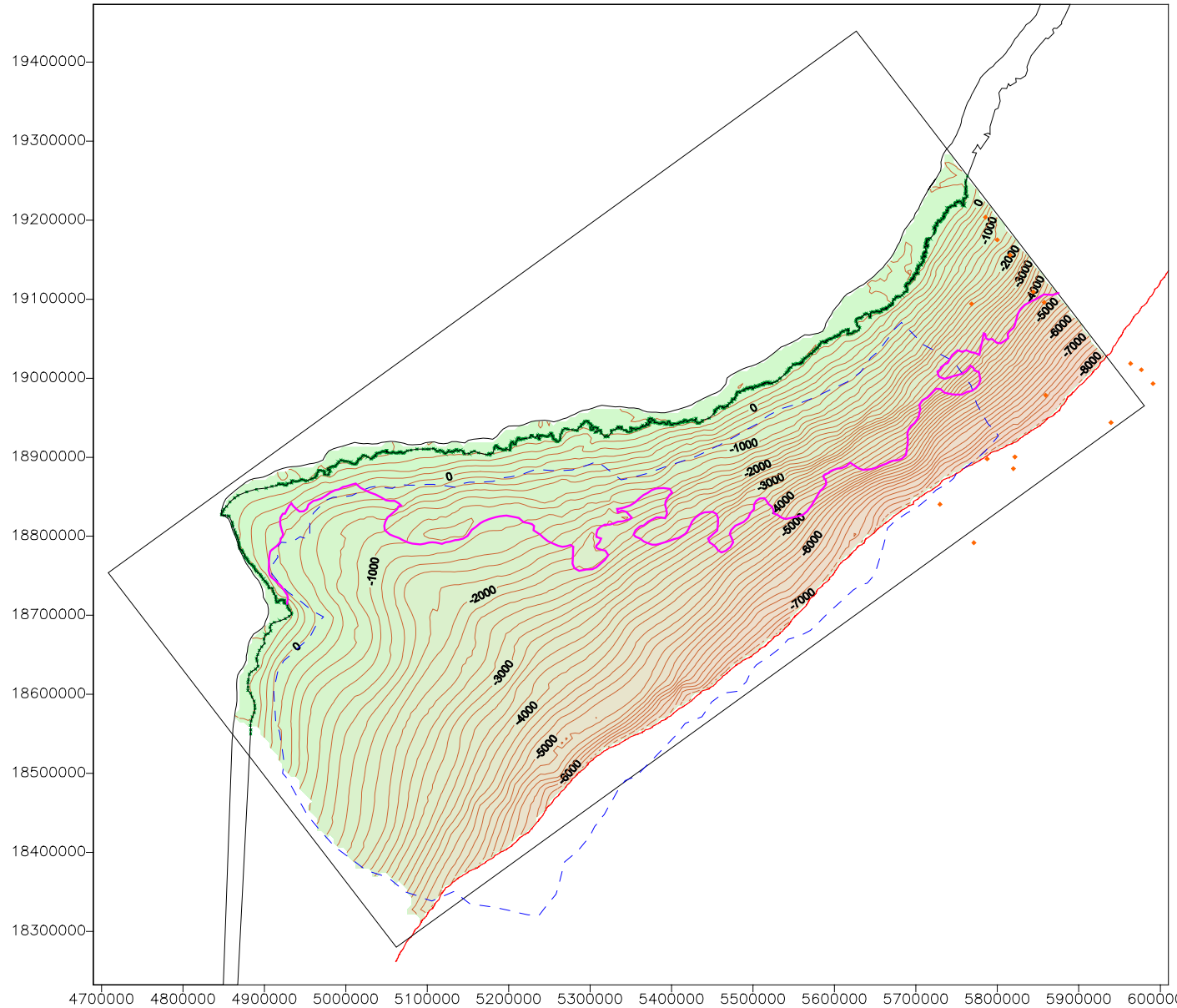
Data Format for the Various Sources:

Data Source	**Report Number**	**Format**
Klemt et al. (1976)	TWDB Report 210	Arc Info files of elevation contours provided by the Austin office of the USGS.
Wilson and Hosman (1987)	USGS Open-File Report 87-677	Printed tables.
TWDB (1972)	TWDB Report 157	Elevation contour map.
Shafer (1965) (Gonzales County)	TWDB Report 4	Geologic sections and a base map.
Anders (1960) (Karnes County)	TBWE Bulletin 6007	Geologic sections and a base map.
Hamlin (1988)	BEG ROI No. 175	Elevation contour map and isopach map.
Bebout et al. (1982)	BEG ROI No. 117	Geologic sections and a base map.
Central Carrizo-Wilcox GAM Model		Text files containing x, y, and elevation.
Surface Elevations		DEM files.

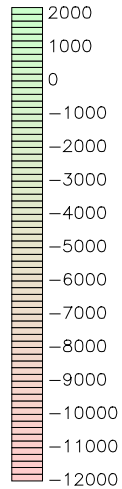

Base of Wilcox
Elev (ft)
2000
1000
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
−8000
−9000
−10000
−11000
−12000
RASA
Central Carrizo-Wilcox Model
Bebout
Outcrop
False Points
19400000
19300000
19200000
19100000
19000000
18900000
18800000
18700000
18600000
18500000
18400000
18300000
4700000
4800000
4900000
5000000
5100000
5200000
5300000
5400000
5500000
5600000
5700000
5800000
5900000
6000000
Combined_Base_Wilcox_SW_6.csv
Combined_Base_Wilcox_SW_8_live_bln.grd


Top of Lower Wilcox
Elev (ft)
2000
1000
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
−8000
−9000
−10000
−11000
−12000
Bebout
Central Carrizo-Wilcox Model
Outcrop
False Points
19400000
19300000
19200000
19100000
19000000
18900000
18800000
18700000
18600000
18500000
18400000
18300000
4700000
4800000
4900000
5000000
5100000
5200000
5300000
5400000
5500000
5600000
5700000
5800000
5900000
6000000
Combined_Top_Lower_Wilcox_SW_7.csv
Combined_Top_Lower_Wilcox_SW_10_live_bln.grd

Top of Middle Wilcox

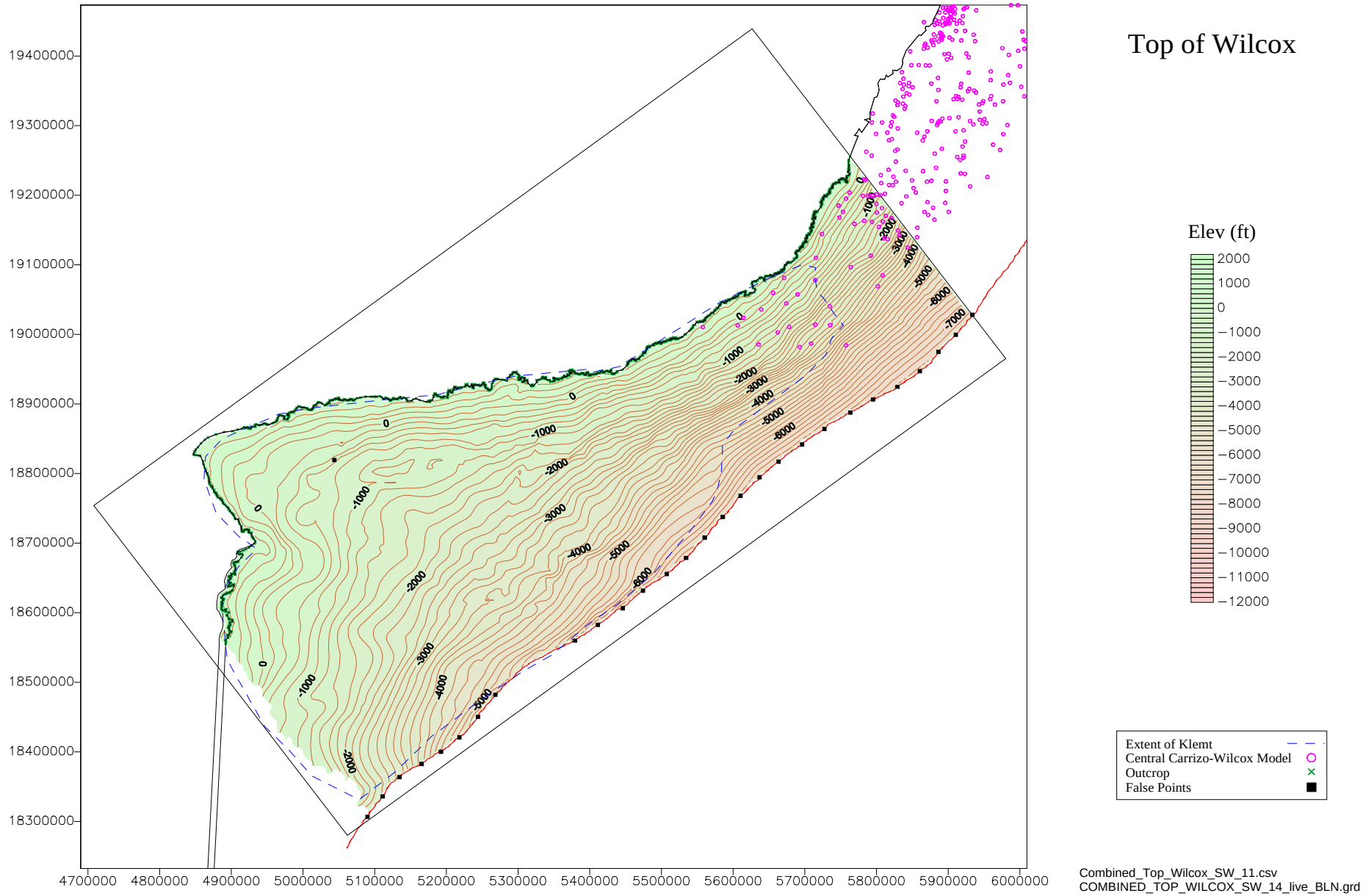


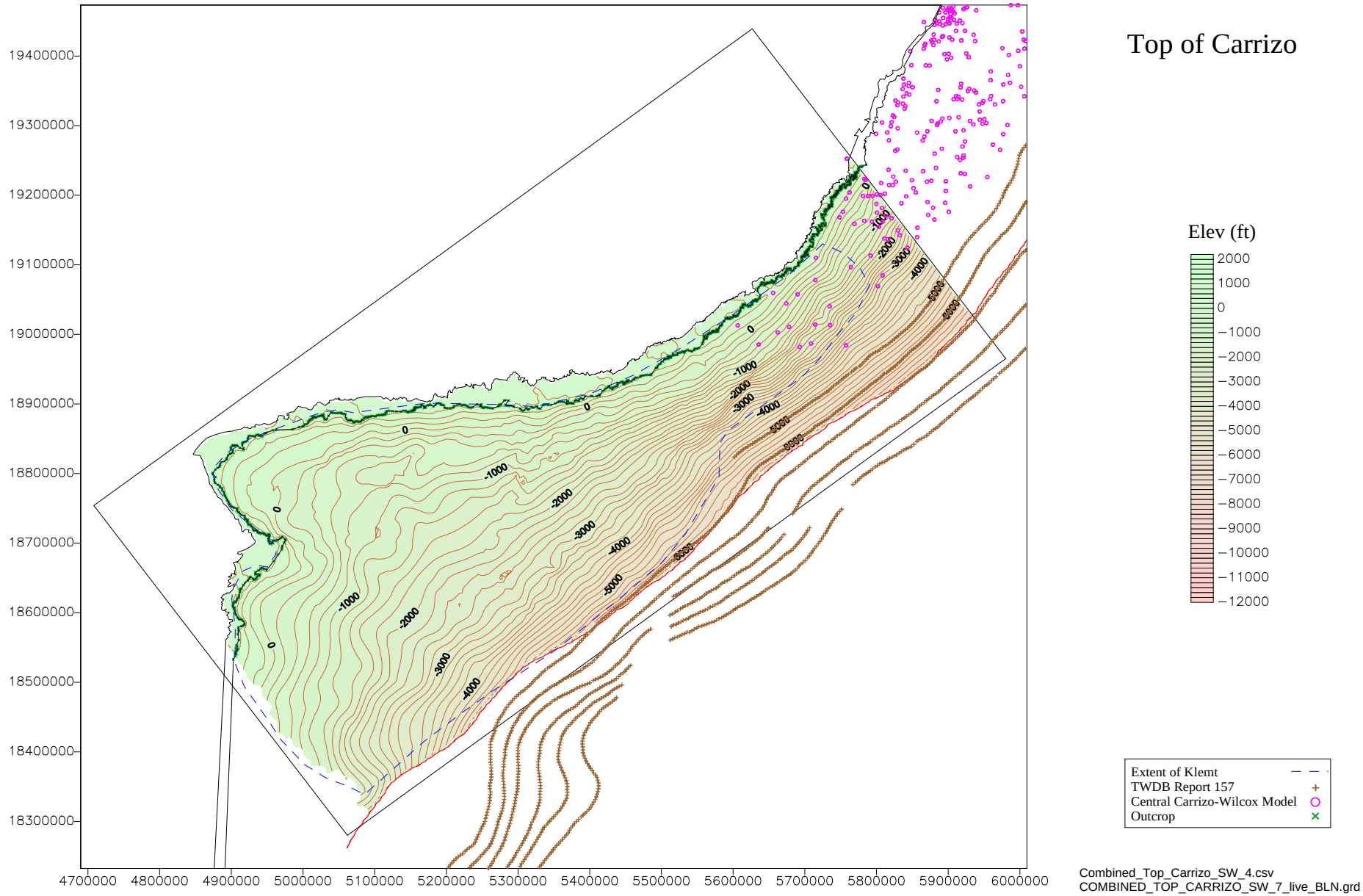
Elev (ft)

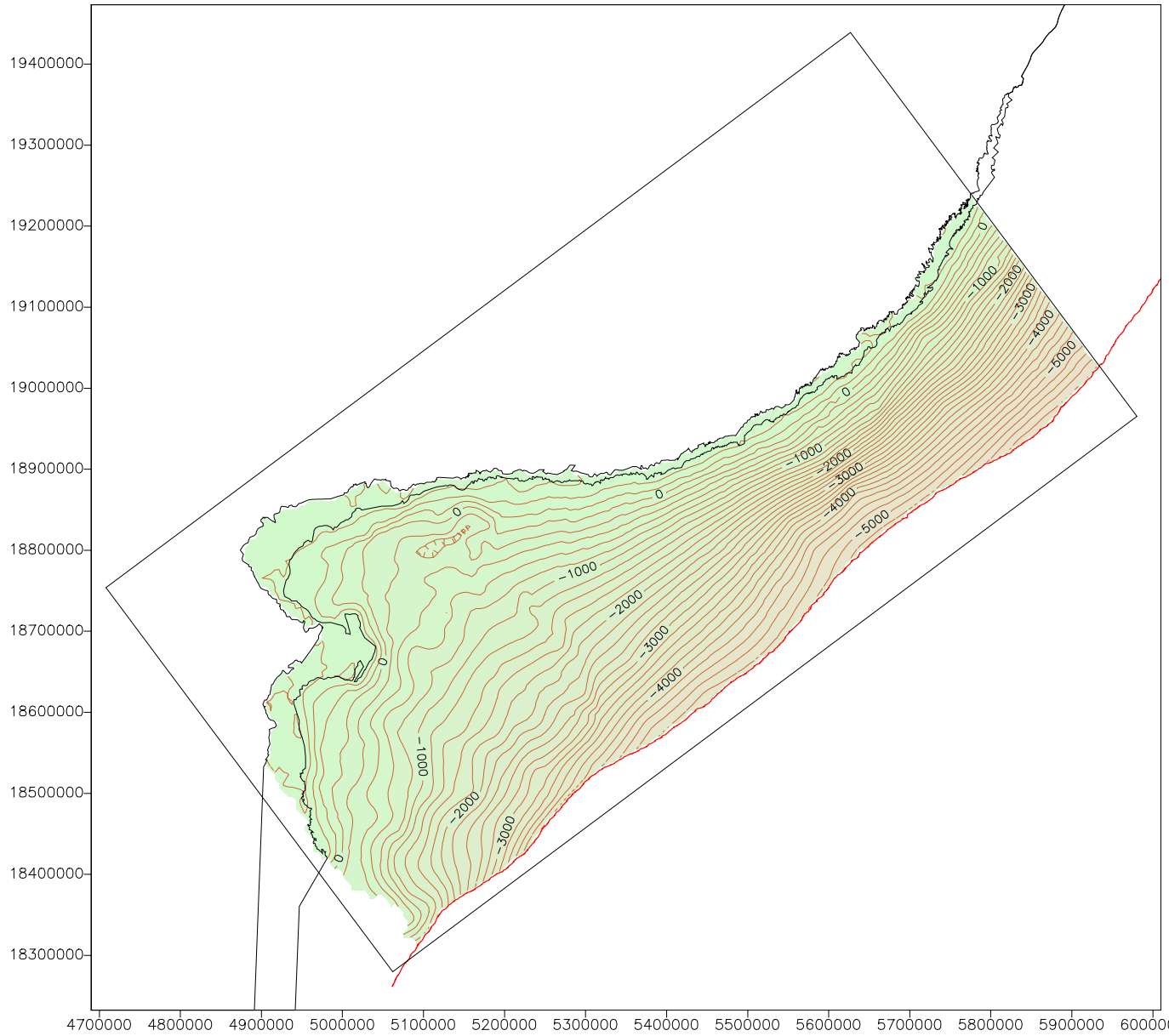


Extent of Hamlin
Bebout
Outcrop
False Points
Updip Extent of the Upper Wilcox

Combined_Top_Middle_Wilcox_SW_4.csv
Combined_Top_Middle_Wilcox_SW_7_live_bln.grd


Top of Wilcox
Elev (ft)
2000
1000
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
−8000
−9000
−10000
−11000
−12000
Extent of Klemt
Central Carrizo-Wilcox Model
Outcrop
False Points
19400000
19300000
19200000
19100000
19000000
18900000
18800000
18700000
18600000
18500000
18400000
18300000
4700000
4800000
4900000
5000000
5100000
5200000
5300000
5400000
5500000
5600000
5700000
5800000
5900000
6000000
Combined_Top_Wilcox_SW_11.csv
COMBINED_TOP_WILCOX_SW_14_live_BLN.grd

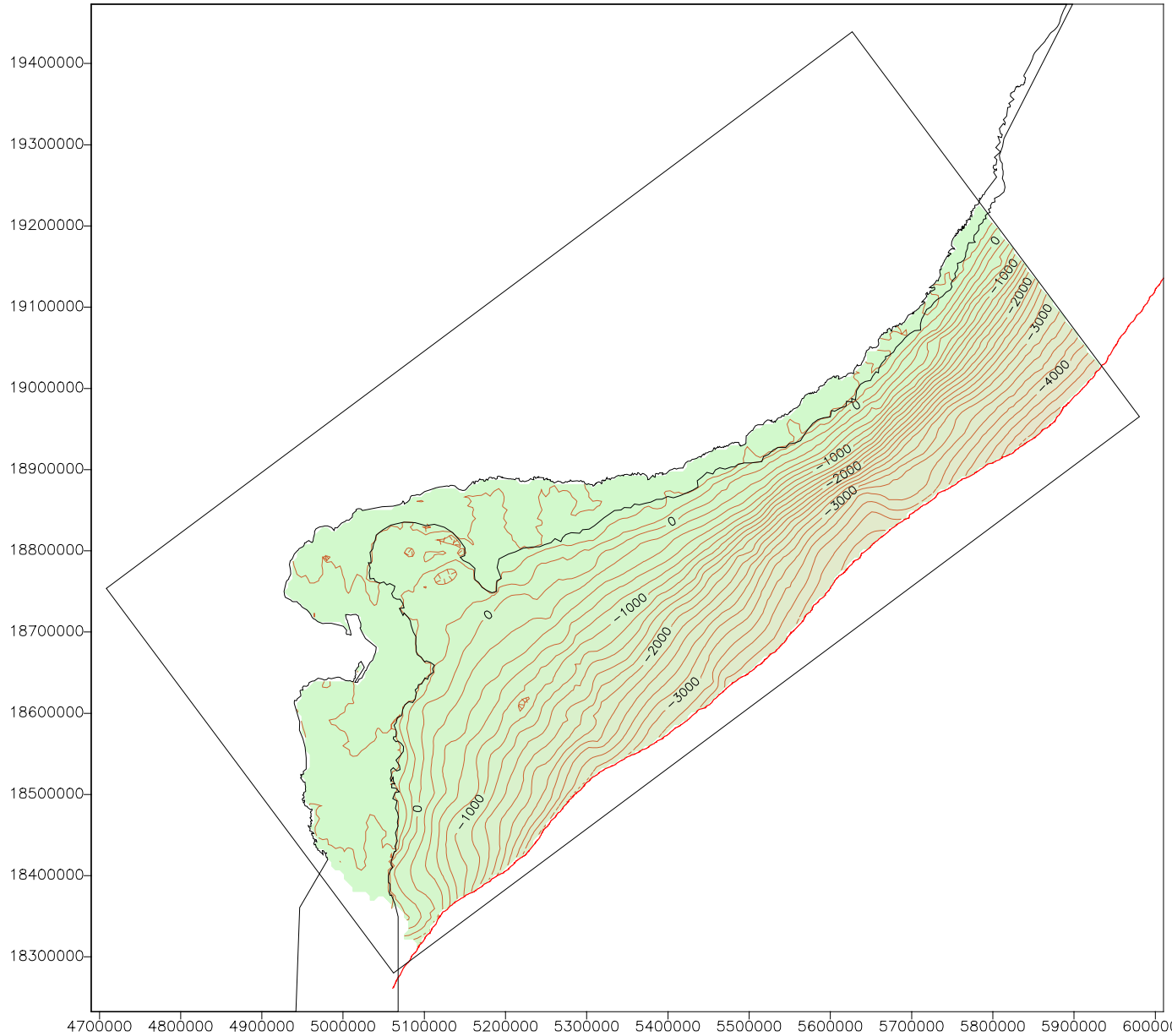

Top of Carrizo
Elev (ft)
2000
1000
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
−8000
−9000
−10000
−11000
−12000
19400000
19300000
19200000
19100000
19000000
18900000
18800000
18700000
18600000
18500000
18400000
18300000
4700000
4800000
4900000
5000000
5100000
5200000
5300000
5400000
5500000
5600000
5700000
5800000
5900000
6000000
Extent of Klemt
TWDB Report 157
Central Carrizo-Wilcox Model
Outcrop
Combined_Top_Carrizo_SW_4.csv
COMBINED_TOP_CARRIZO_SW_7_live_BLN.grd



Top of Reklaw

Elev (ft)

2000
1000
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
−8000
−9000
−10000
−11000
−12000

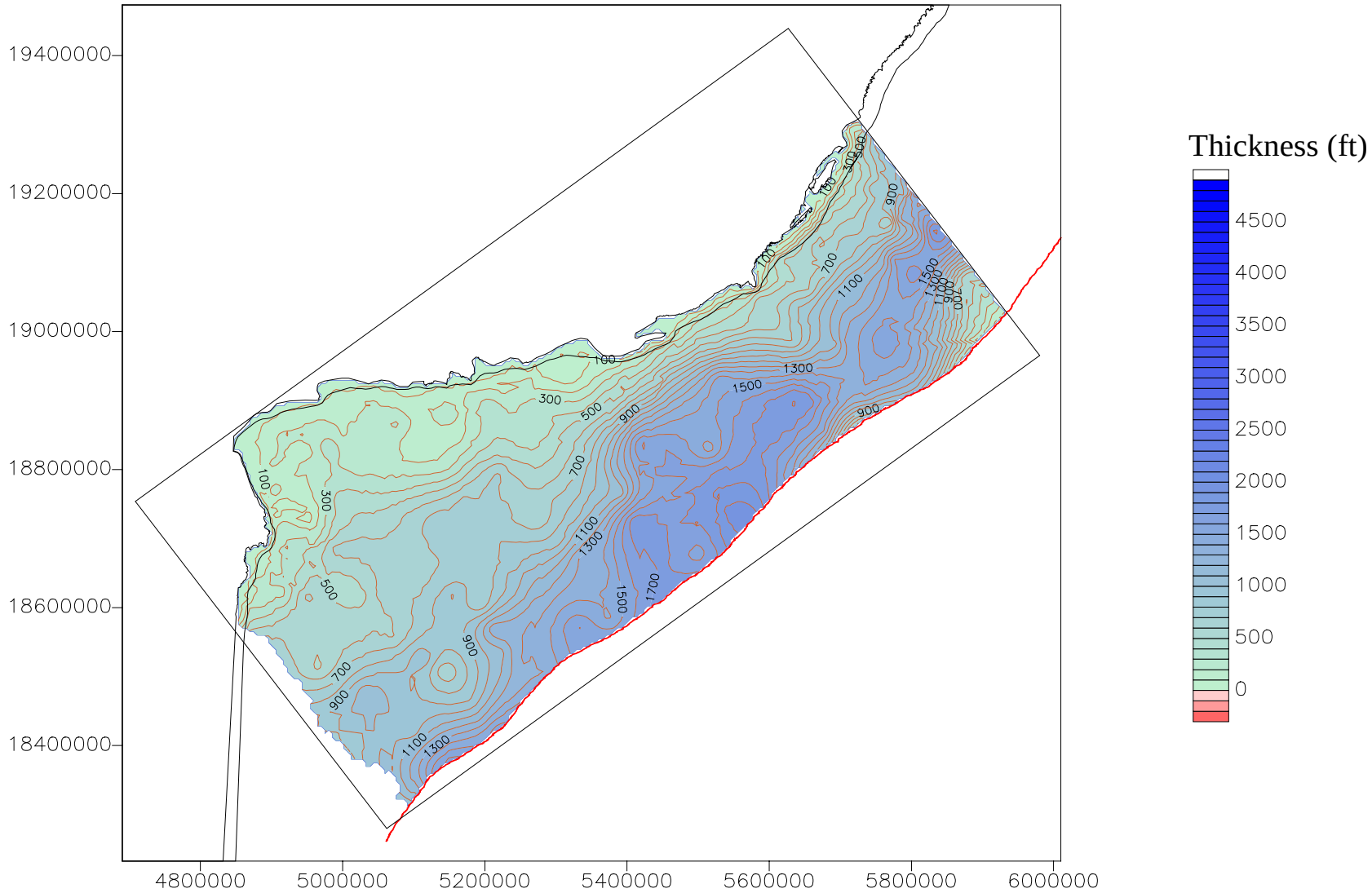


Top of Queen City

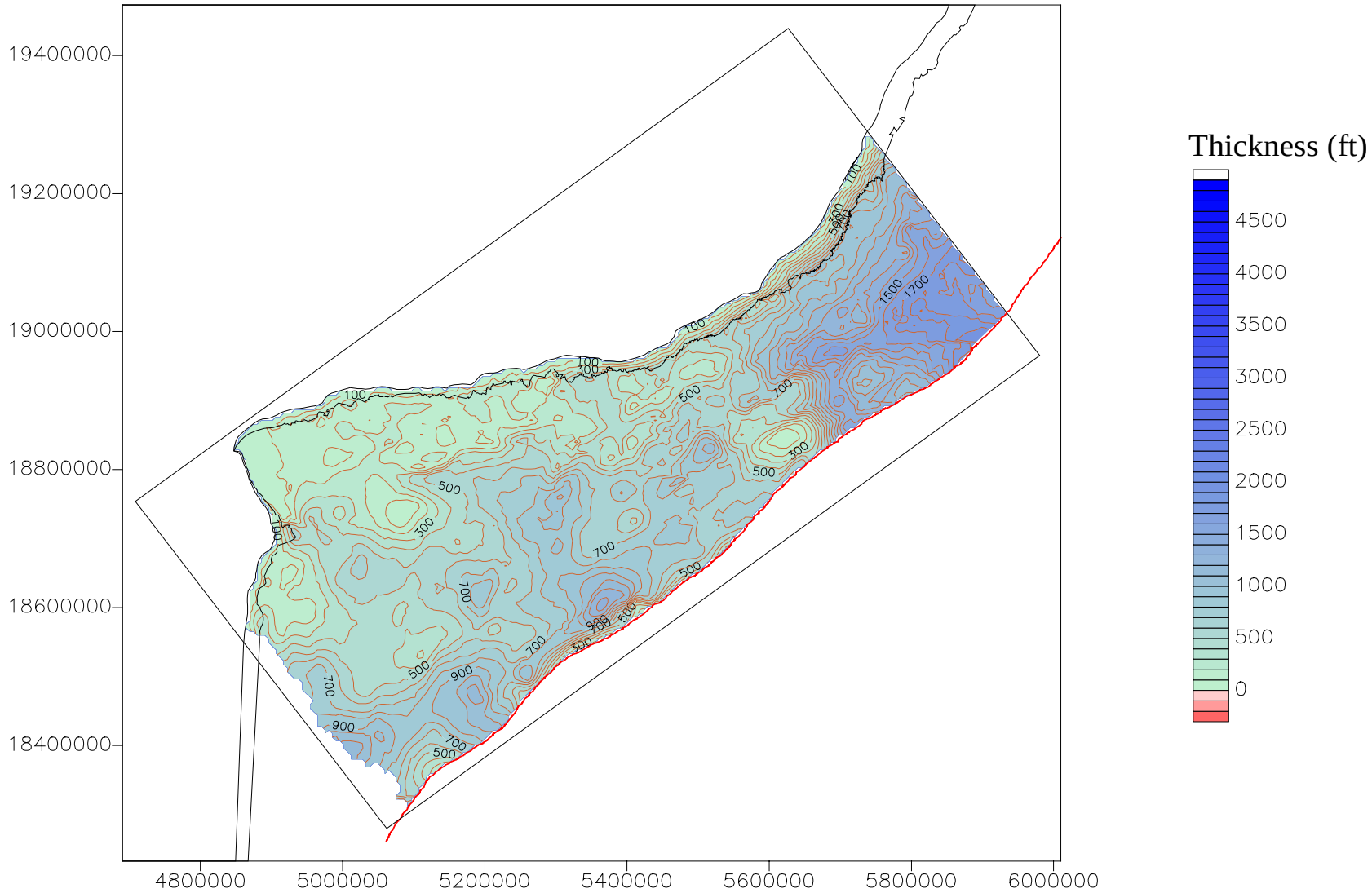
Elev (ft)

1800
1200
600
0
-600
-1200
-1800
-2400
-3000
-3600
-4200
-4800
-5400
-6000
-6600
-7200
-7800
-8400
-9000
-9600
-10200
-10800
-11400
-12000

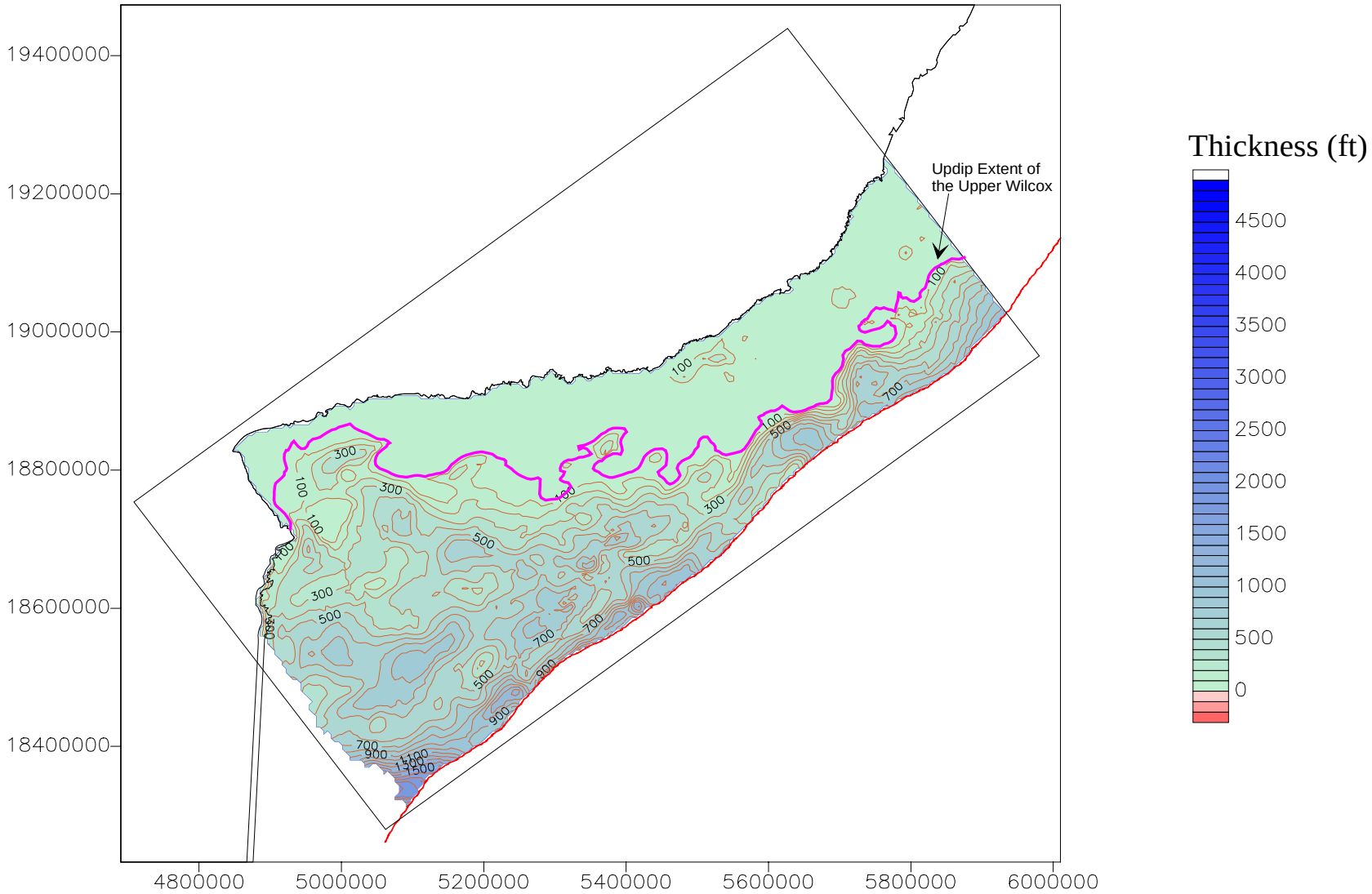
Thickness of Lower Wilcox (TLW10-BW8)



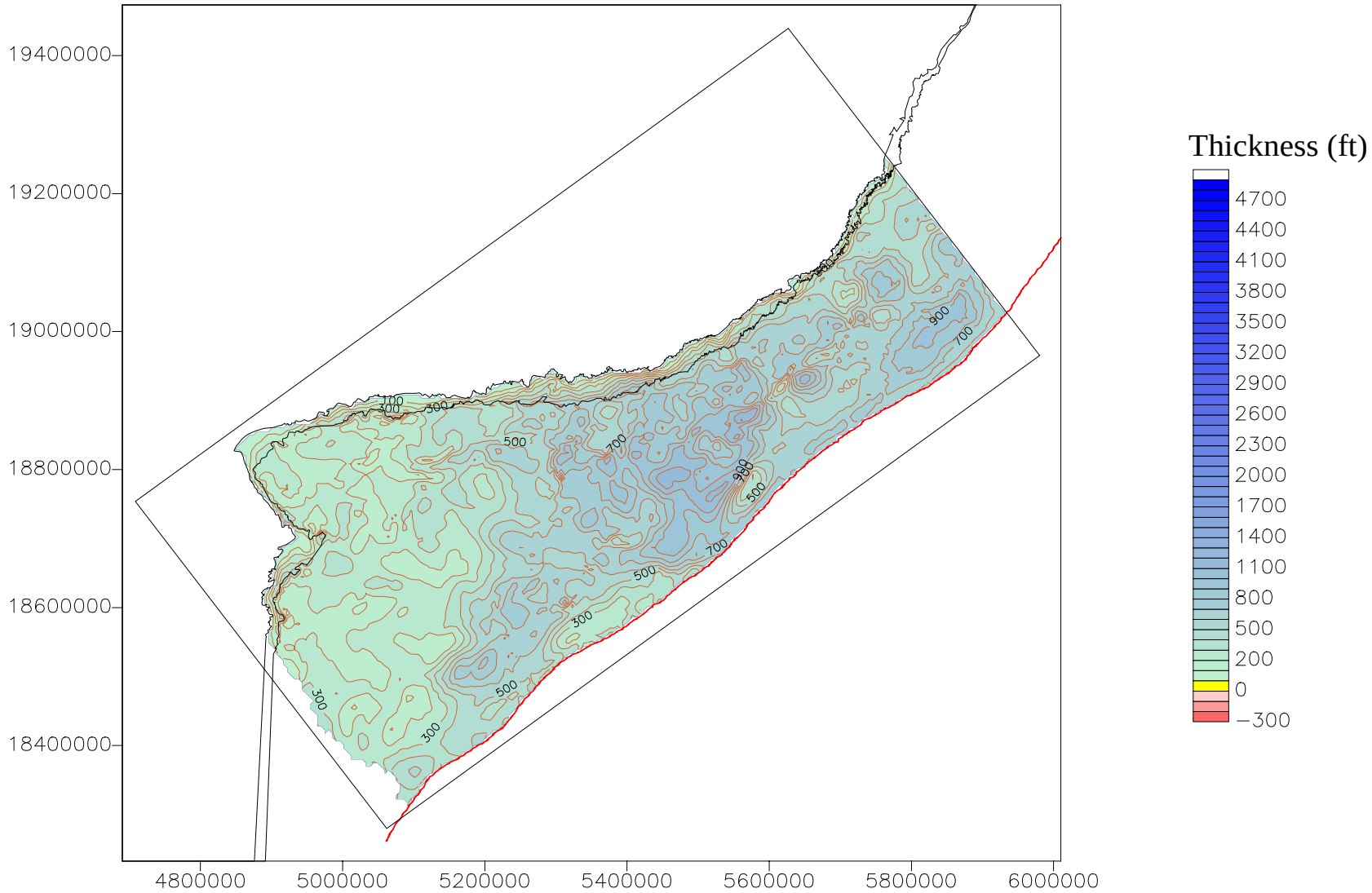
Thickness of Middle Wilcox (TMW7-TLW10)



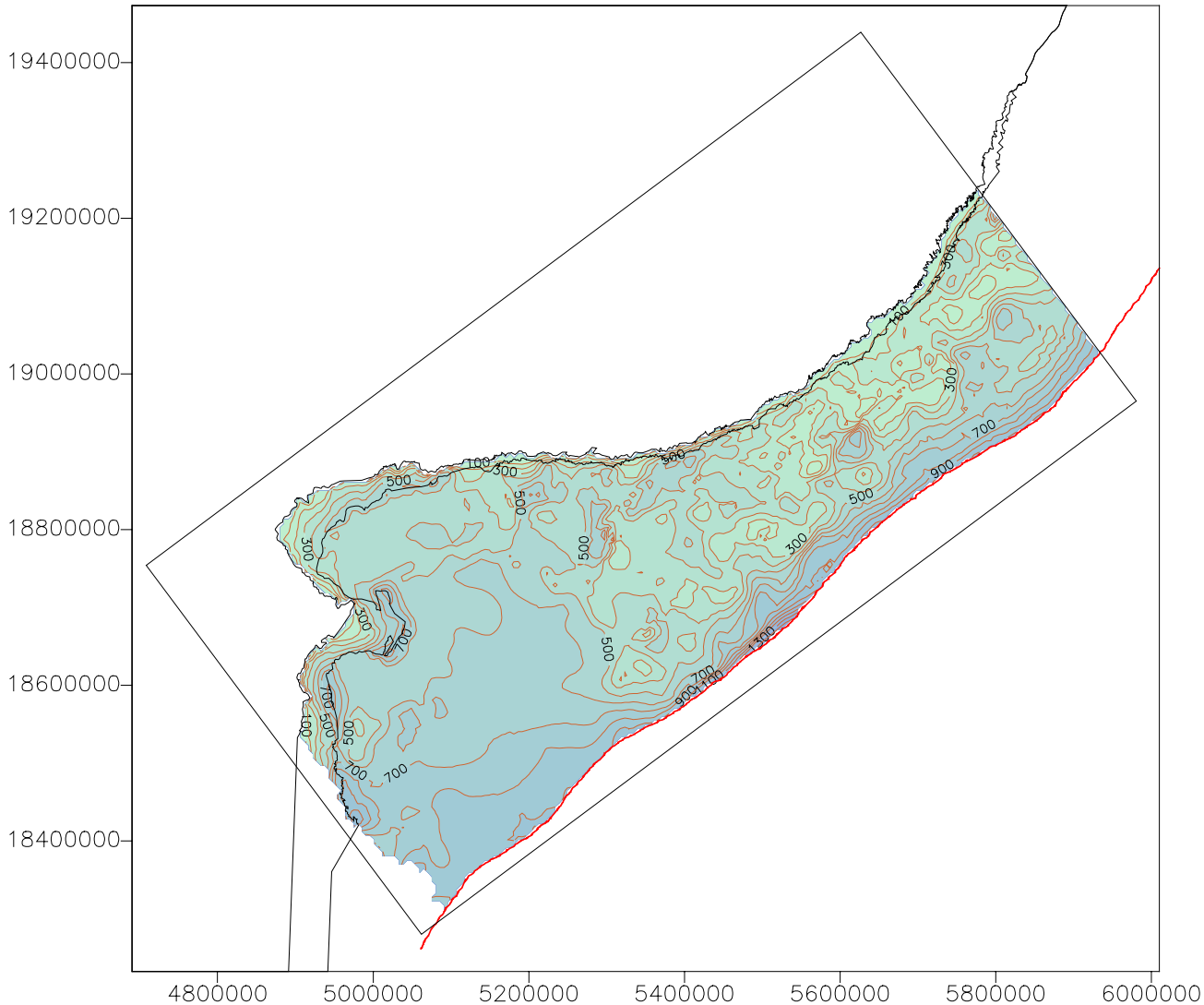
Thickness of Upper Wilcox (TW14-TMW7)



Thickness of Carrizo (TC7-TW14)



Thickness of Reklaw/Bigford (TR16-TC7)

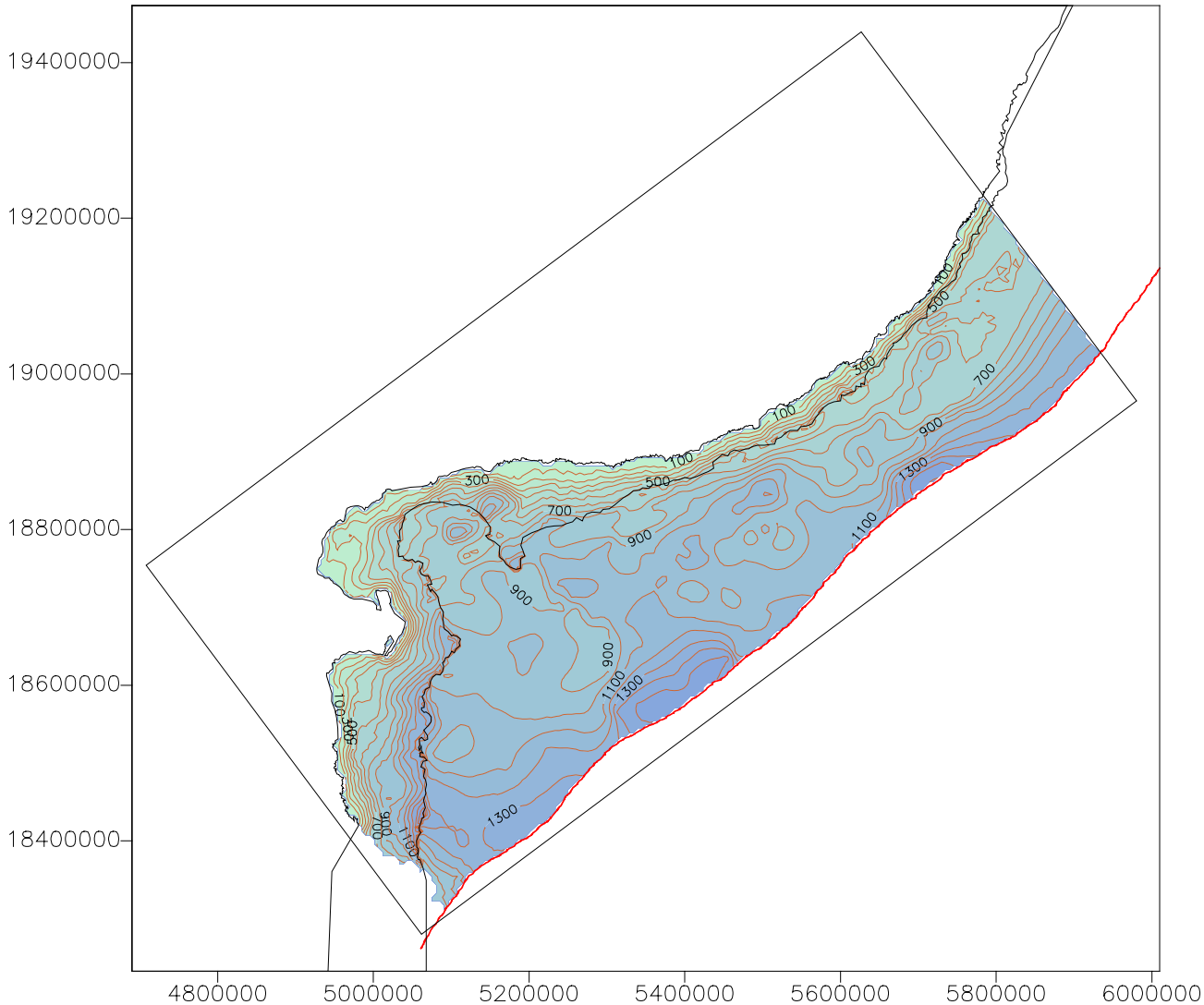


Thickness (ft)

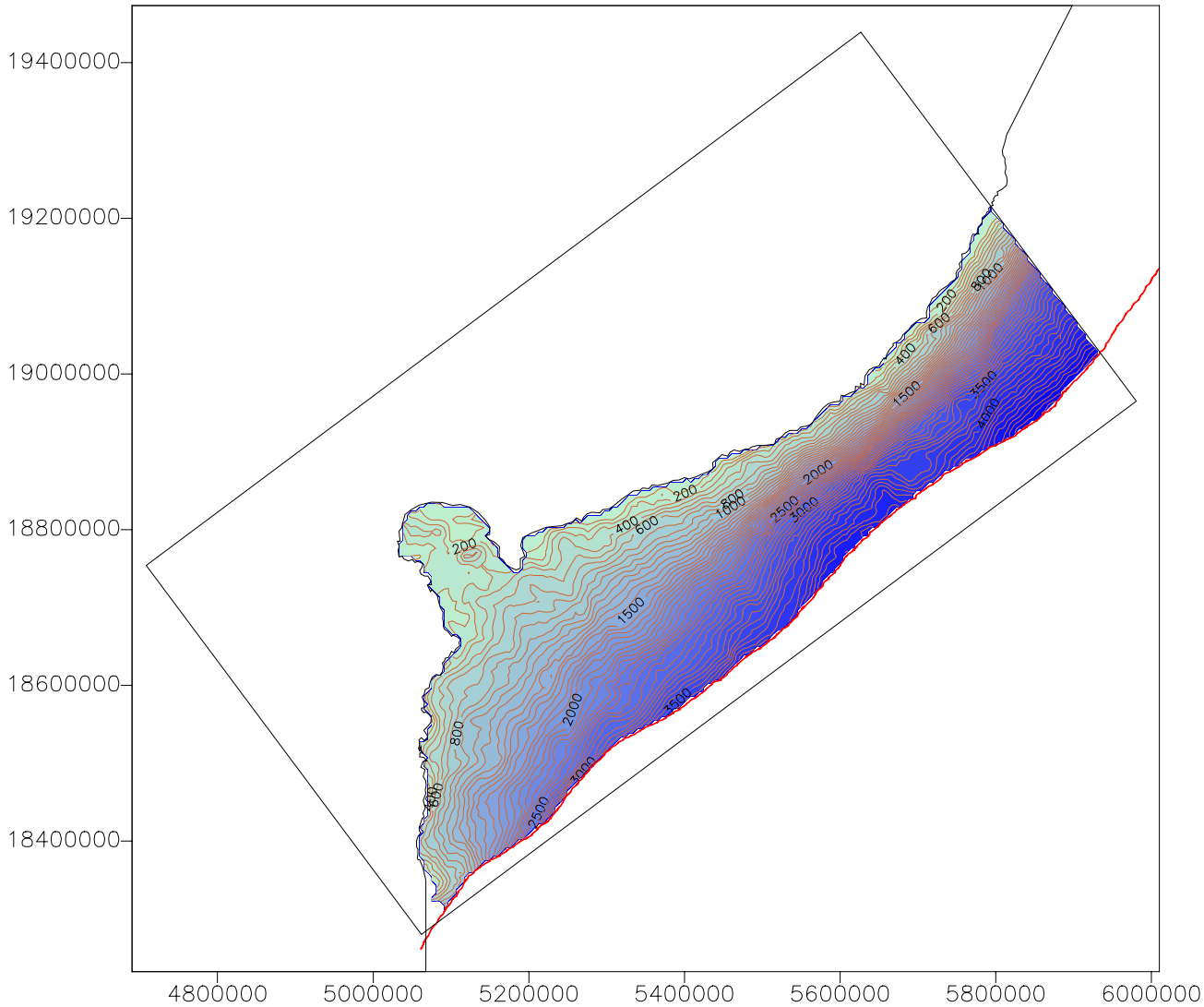
4700
4400
4100
3800
3500
3200
2900
2600
2300
2000
1700
1400
1100
800
500
200
0
−300

Min 20
Max 1493

Thickness of Queen City - El Pico (TQC4-TR16)



Thickness of Younger Sediments (TY3-TQC4)



Thickness (ft)

6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0

Min 20
Max 4960

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- GAM Program Review
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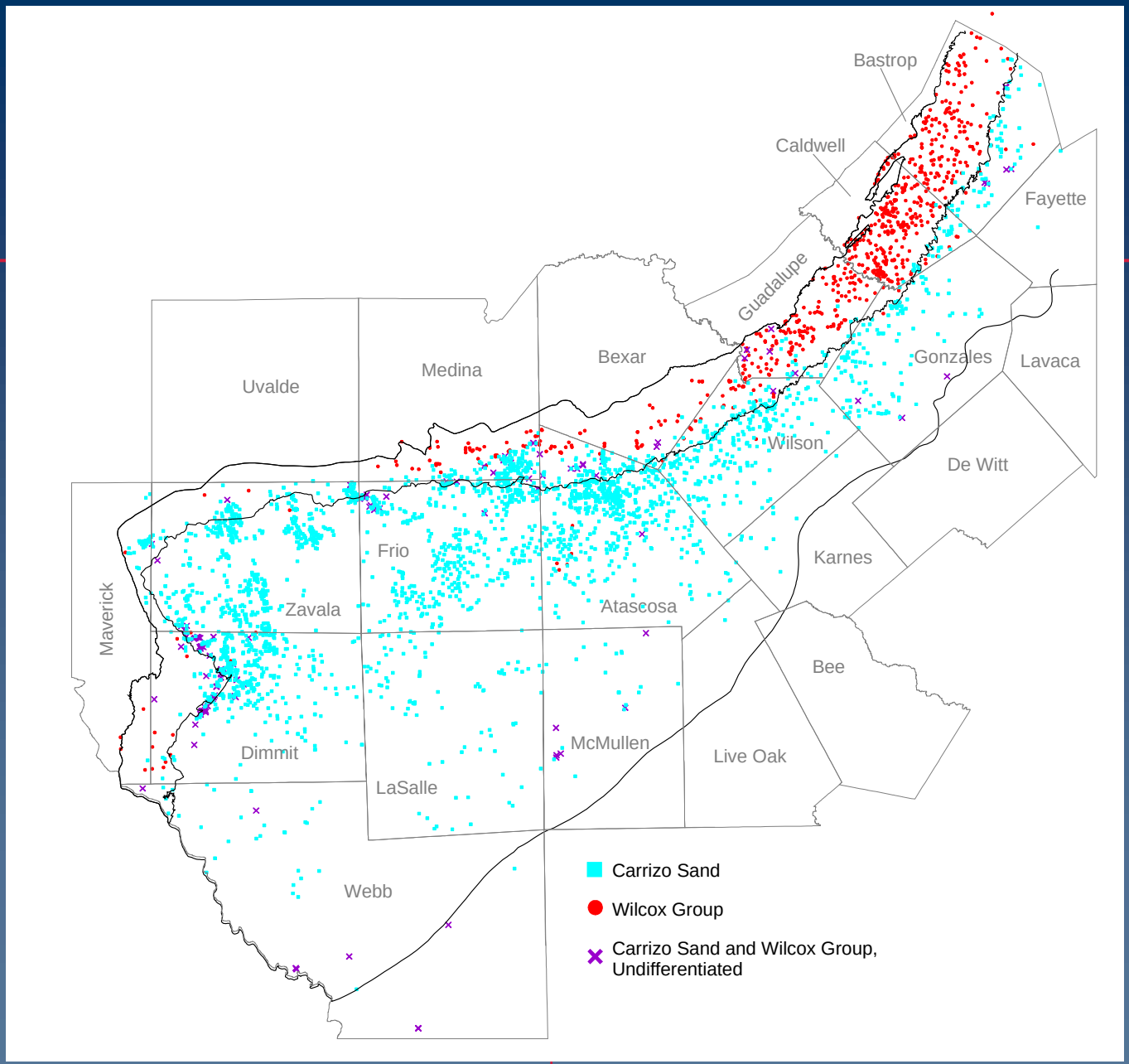
- Recharge
- Hydraulic Properties
- Steady-State Model Results

Predevelopment Heads

- Evaluated water-level data on a county by county basis
- Conducted a literature review on the historical development of the Carrizo and Wilcox in each county

Predevelopment Heads

- Literature Review Indicated:
  - The Carrizo Sand and Wilcox Group are hydraulically connected in and near the outcrop areas and in Caldwell and Bastrop Counties
  - Outside of the areas indicated above, only the Carrizo Sand is an active aquifer
  - In many areas, artesian pressures within the aquifer were originally sufficient to drive water above ground surface


Bastrop
Caldwell
Fayette
Guadalupe
Bexar
Medina
Uvalde
Gonzales
Lavaca
Wilson
De Witt
Karnes
Frio
Zavala
Atascosa
Maverick
Bee
Dimmit
McMullen
Live Oak
LaSalle
Webb
Carrizo Sand
Wilcox Group
Carrizo Sand and Wilcox Group, Undifferentiated

Methodology (continued)

- The history of well development and pumpage was compared to dates of water-level measurements
- Maximum water-level measurements (regardless of time) were compared to maps showing the locations of originally flowing wells and to ground elevation maps

Methodology (continued)

- Actual water-level data were used to generate the predevelopment water-level elevation contours at all locations except
  - Dimmit County
  - northwestern LaSalle County
  - southern Zavala County

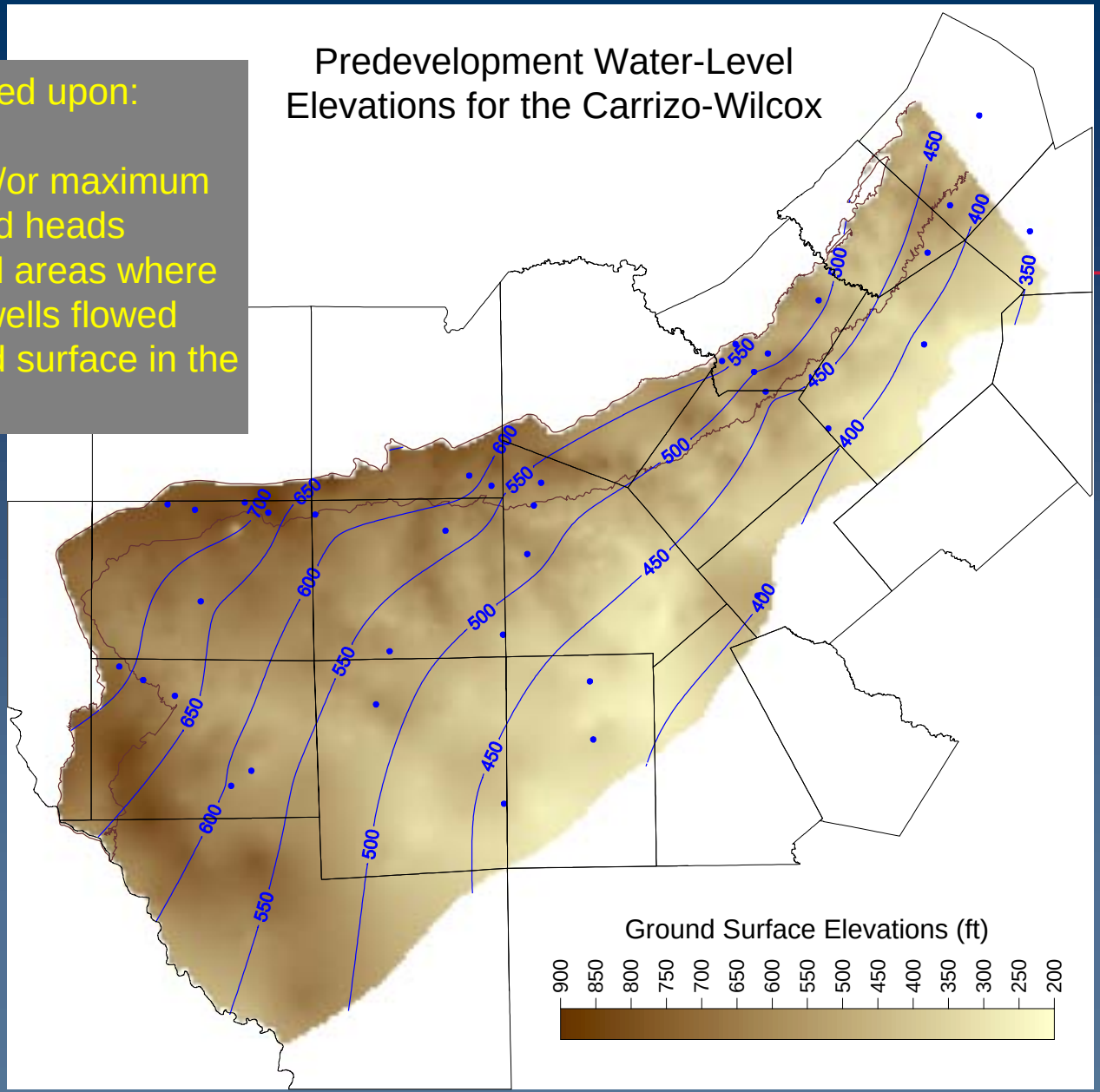
  where all water-level measurements reflected the effects of pumpage

Methodology (continued)

- In the areas with all data affected by pumpage, maximum measured water-level elevations were increased between 75 and 125 ft

Levels based upon:

- First and/or maximum measured heads
- Reported areas where Carrizo wells flowed at ground surface in the past



Methodology (continued)

- A comparison of the predevelopment heads generated for the GAM to those of Ryder (1988) (RASA model) show:
  - The same flow direction
  - GAM heads about 50 feet higher than Ryder heads east of Wilson County and in northern Atascosa and Frio Counties

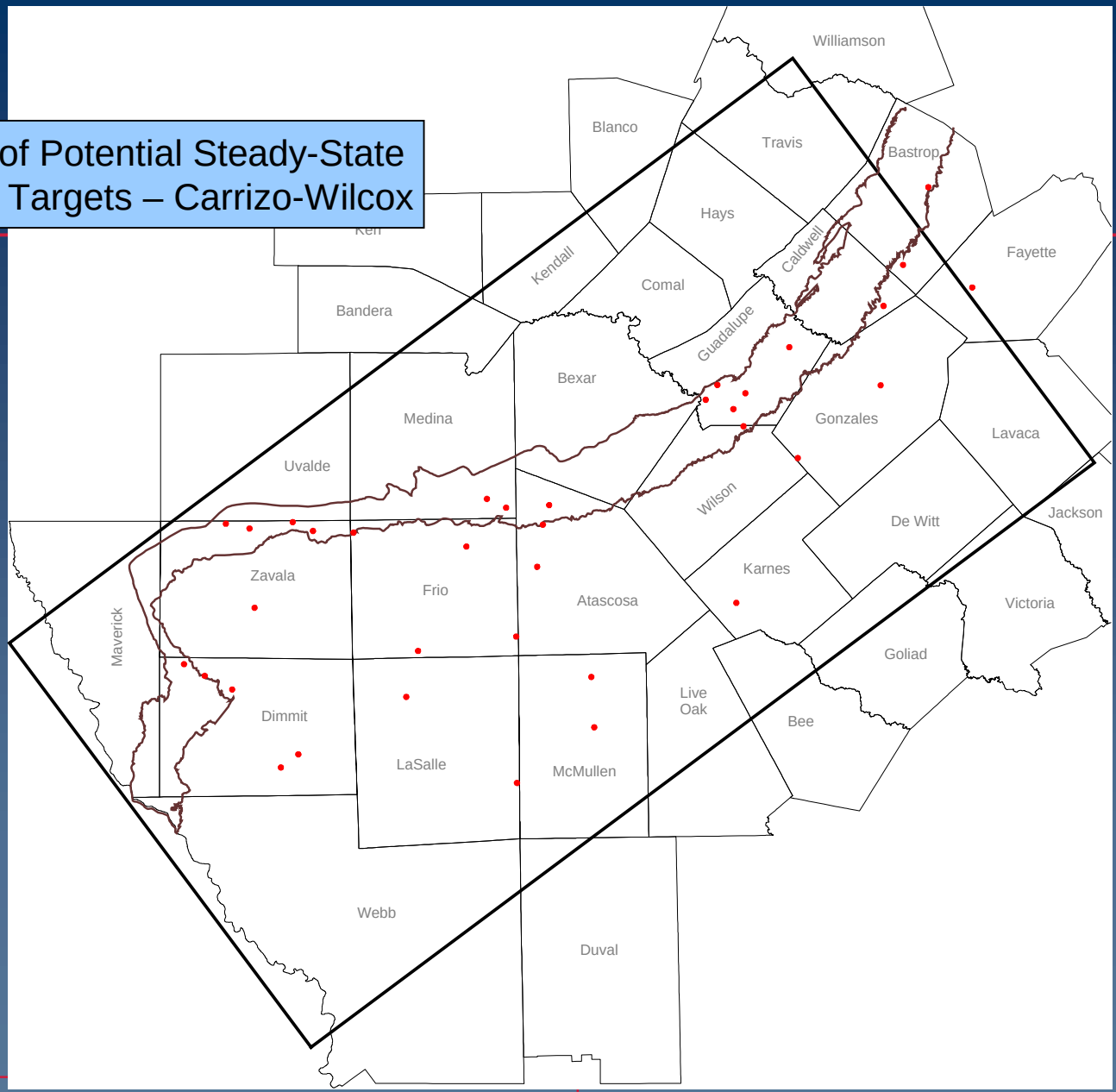
Methodology (continued)

- Comparison (continued)
  - GAM heads about 100 feet higher than Ryder in southern Atascosa and Frio Counties, and in LaSalle, Dimmit, and Zavala Counties
  - Ryder contours are below ground surface in northern LaSalle County, Dimmit County, and southern Zavala County which is inconsistent with historical data

Calibration Targets

- Steady-State Calibration
  - Calibration targets consist of selected predevelopment water-level elevations in both outcrop and the confined portions of the aquifer

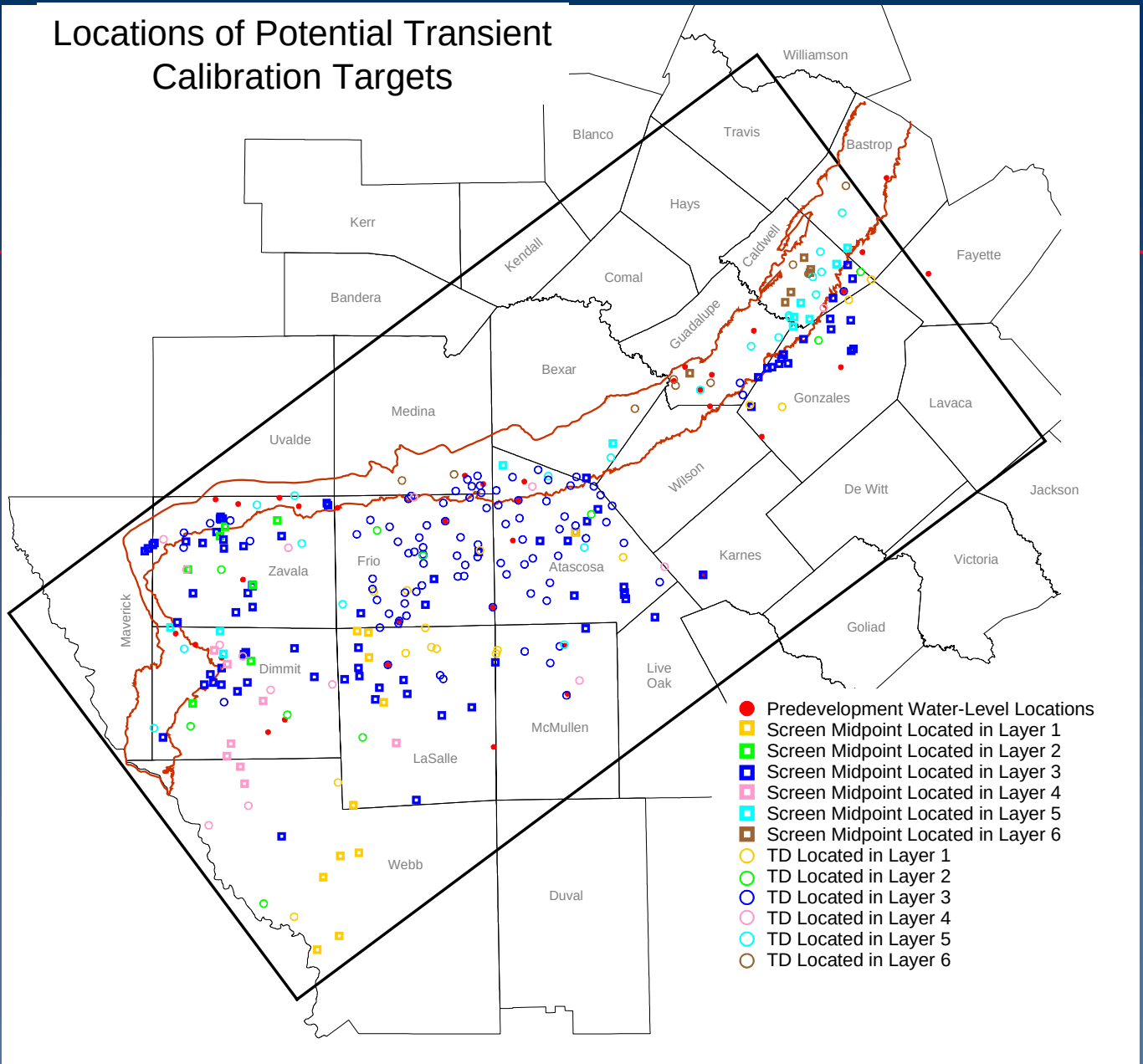
Locations of Potential Steady-State Calibration Targets – Carrizo-Wilcox

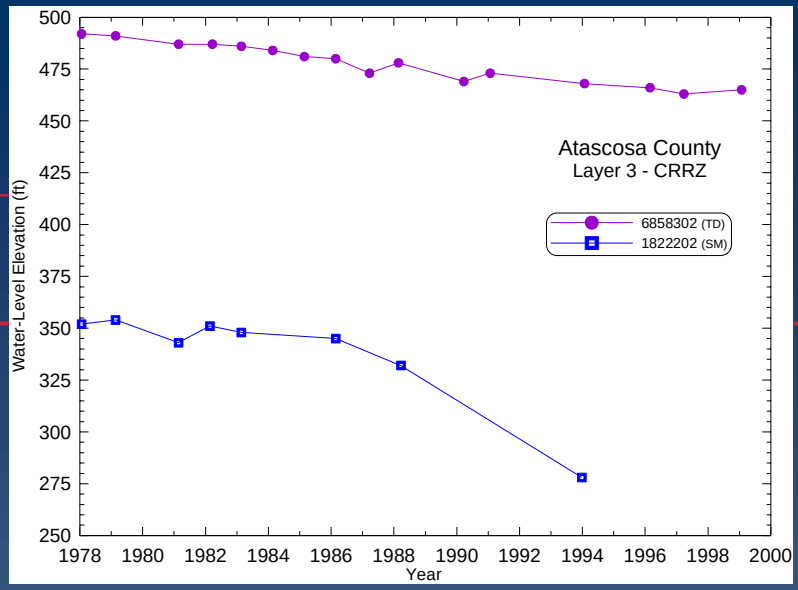


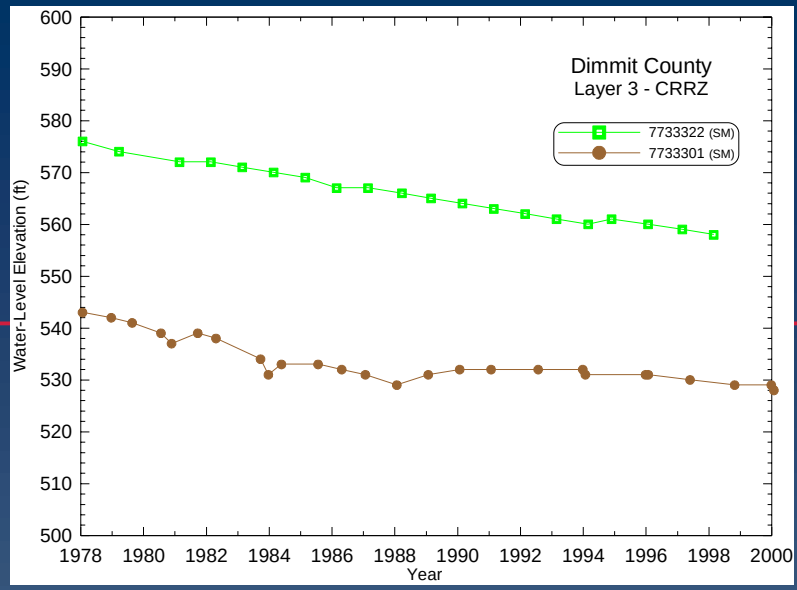
Calibration Targets

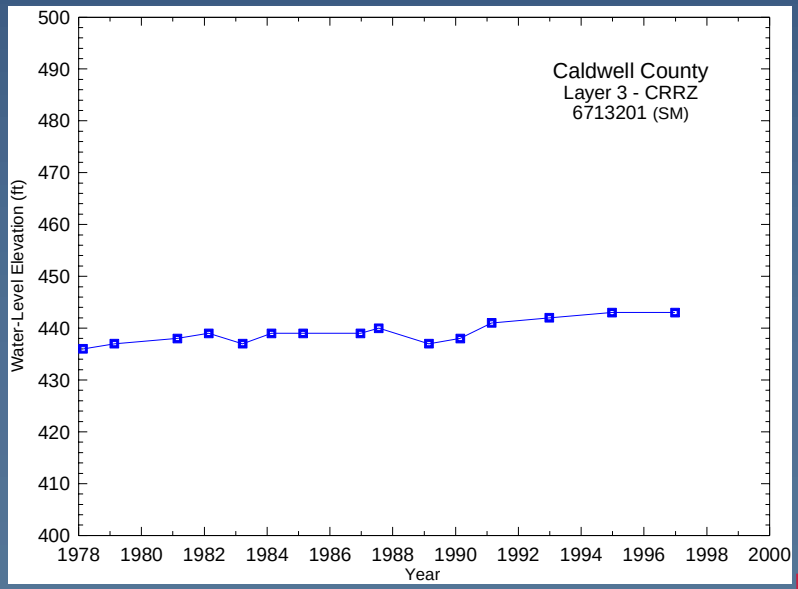
- Transient Calibration
  - Calibration targets will consist of selected hydrographs from various lateral and vertical locations within the model region

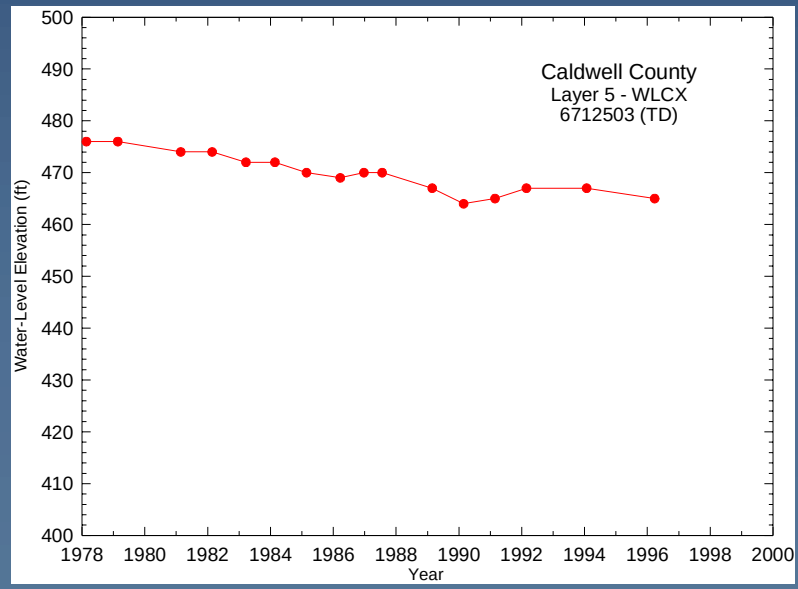
Locations of Potential Transient Calibration Targets



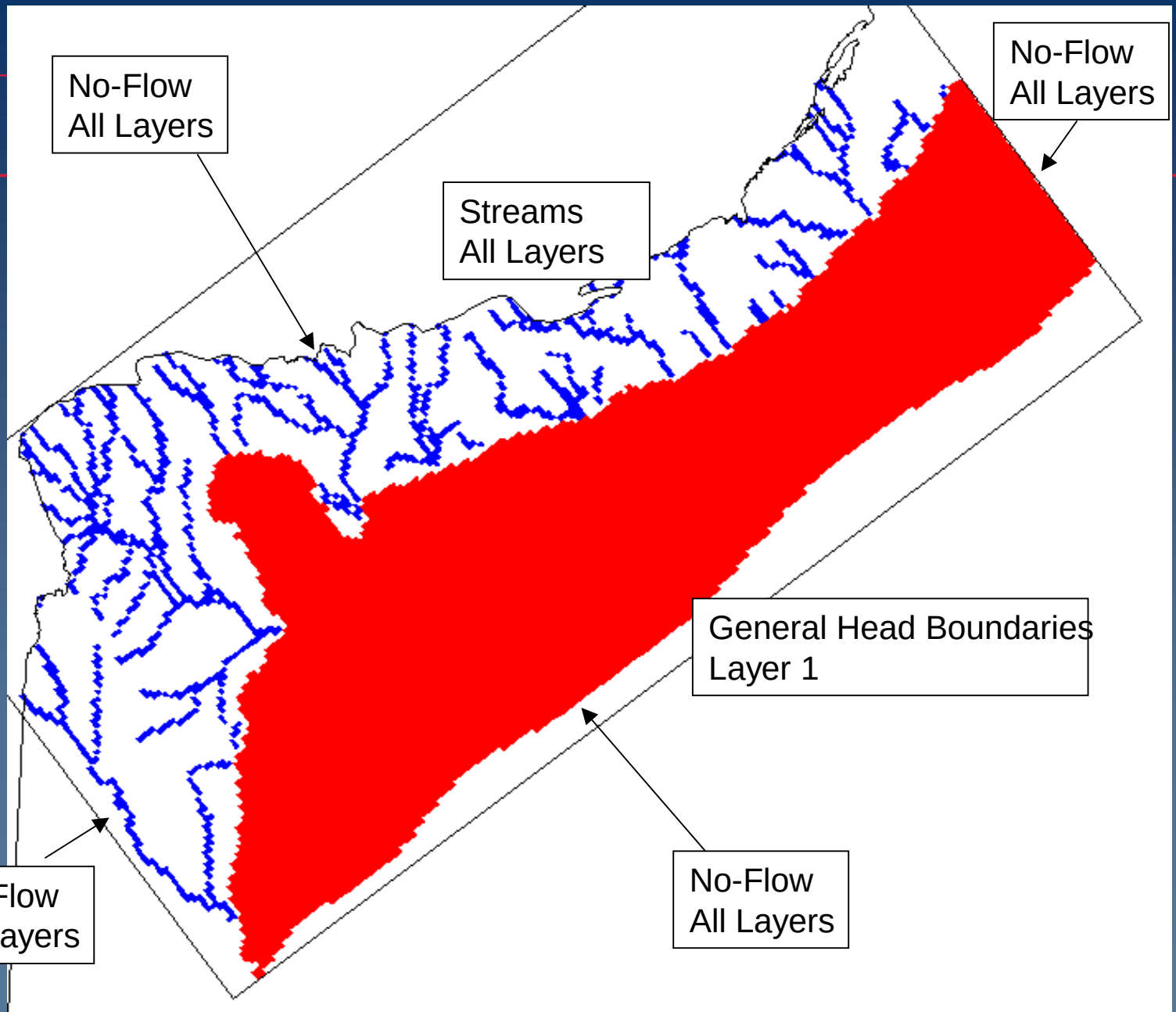

Atascosa County
Layer 3 - CRRZ
6858302 (TD)
1822202 (SM)
Water-Level Elevation (ft)
Year


Dimmit County
Layer 3 - CRRZ
7733322 (SM)
7733301 (SM)
Water-Level Elevation (ft)
Year


Caldwell County
Layer 3 - CRRZ
6713201 (SM)
Water-Level Elevation (ft)
Year


Caldwell County
Layer 5 - WLCX
6712503 (TD)
Water-Level Elevation (ft)
Year

Model Boundaries



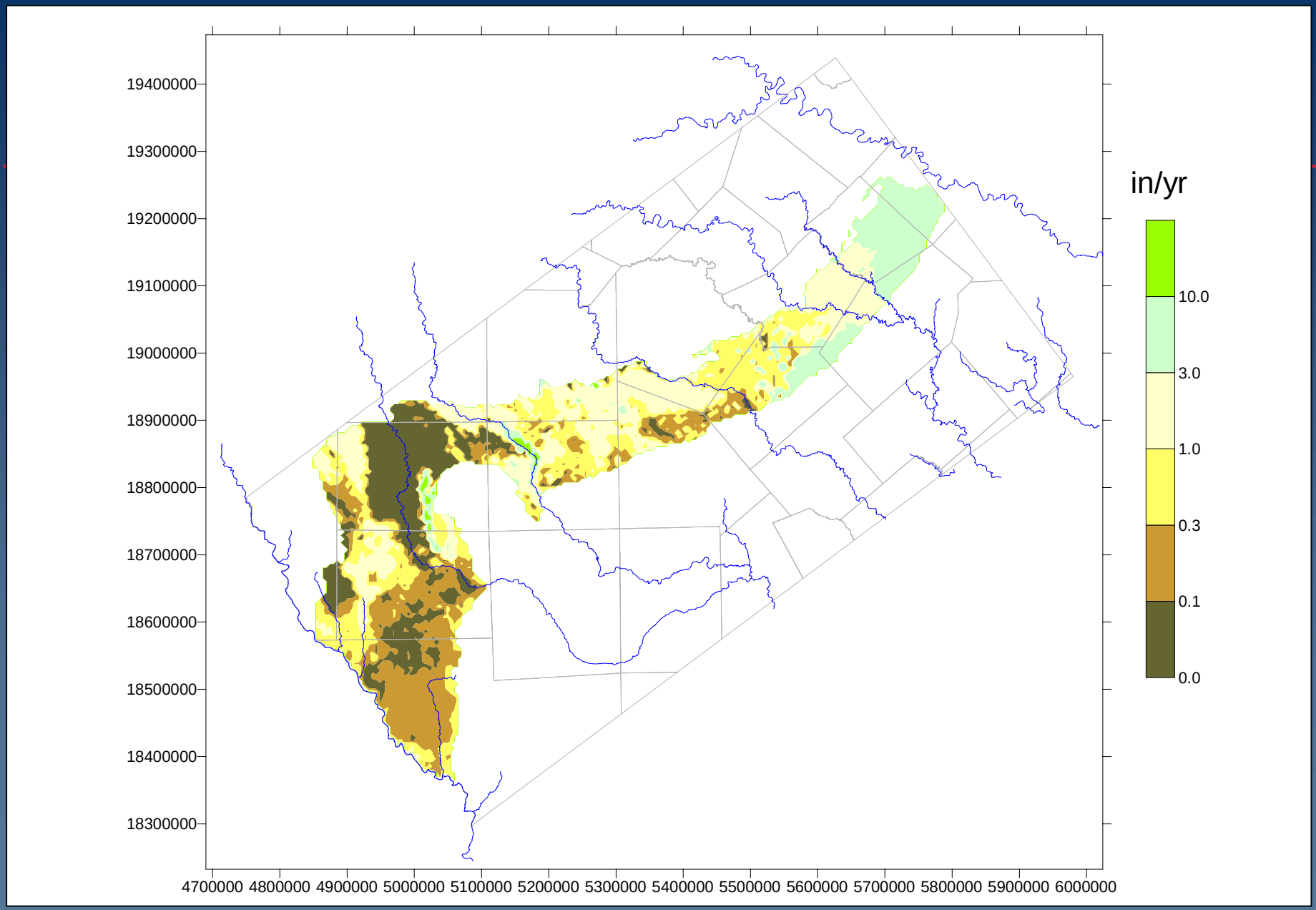
Predevelopment - Modeled Streams

- Initial stream conductance estimated from RF1 reach file parameters
- Variation in modeled conductance primarily due to stream width
- Relative bed conductivity scaled during calibration

Recharge
Soil and Water Assessment Tool

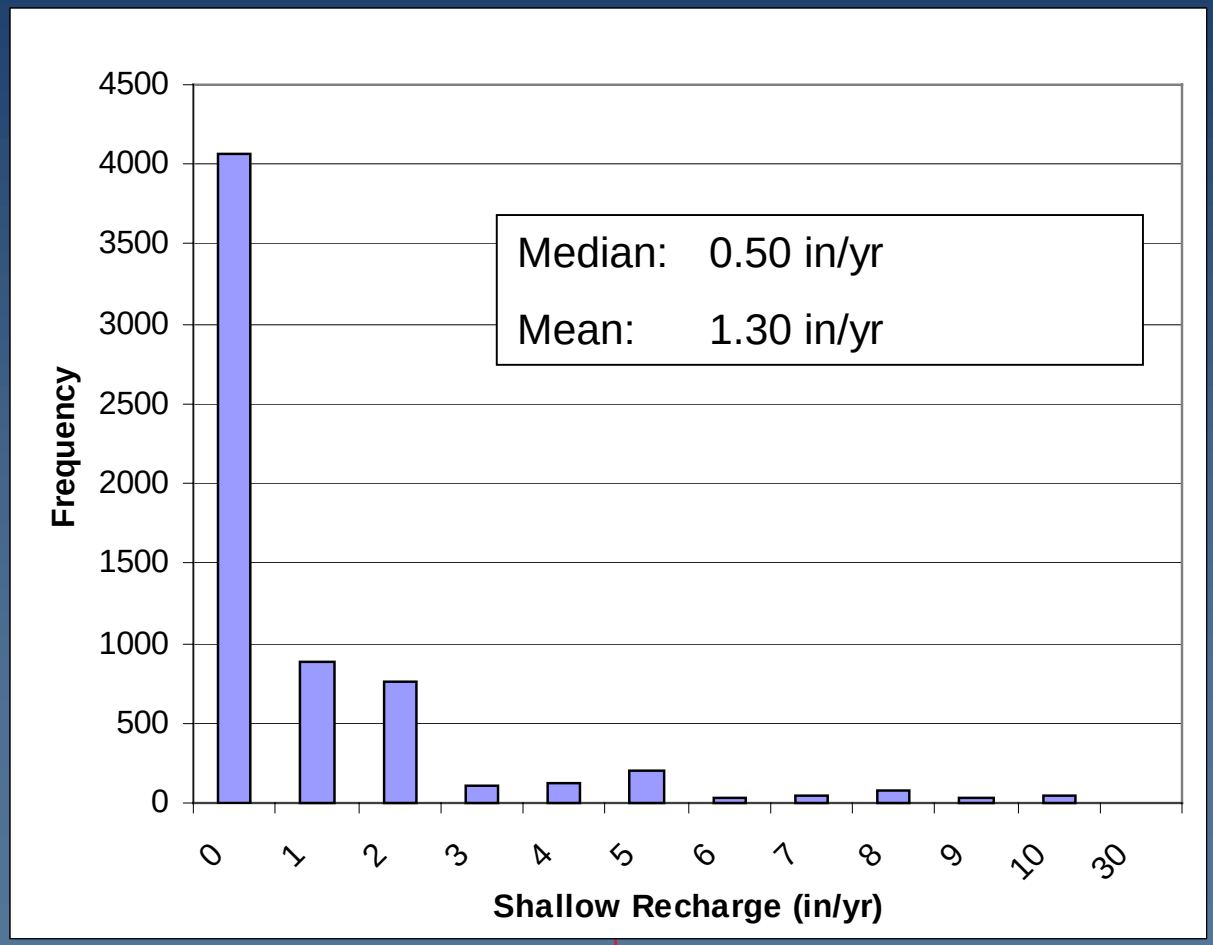
- SWAT (Blacklands Research Center)
- Physically based (primarily) watershed scale model
- Infiltration/runoff based on SCS Curve Number method (daily timestep)
  - Land use
  - Soil type
  - Antecedent soil moisture condition
- Recharge = Infiltration – Evapotranspiration
- Steady-state model: Neglect ET from water table (initially)

Average Recharge 1975-1999



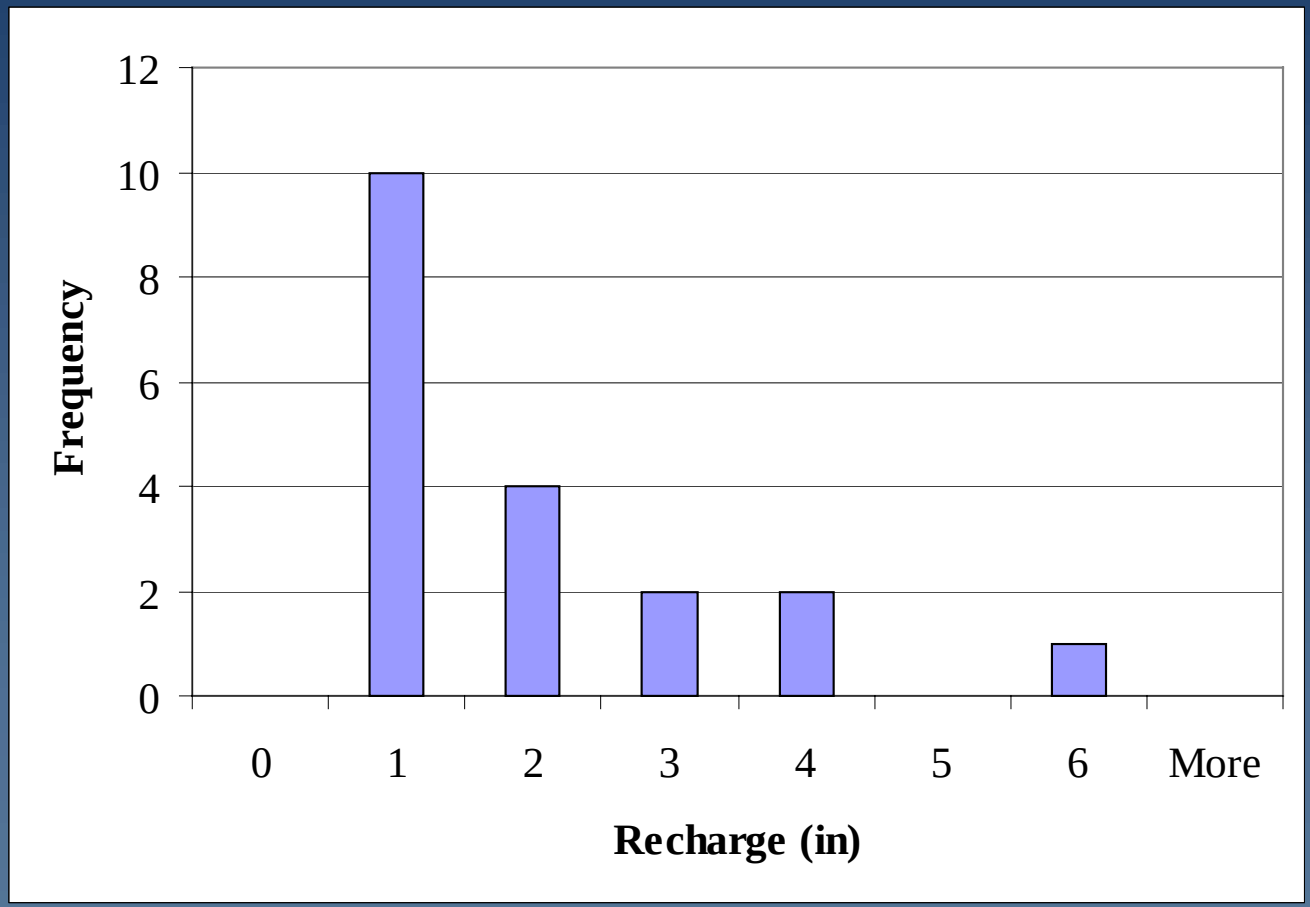
SWAT - Example Results

25-year average annual recharge Southern C-W



Recharge Comparison

Annual recharge from Scanlon (2001)



Presentation Outline

- GAM Program Review
- Conceptual Model Review
- Model Structure/Layers
- Hydraulic Head Review
- Model Boundaries
- Recharge
- Hydraulic Properties
- Steady-State Model Results

Hydraulic Conductivity

- Horizontal hydraulic conductivity point measurements are available (Mace et al, 2000)
- Poor correlation between measured values and estimated sand patterns
- Must scale K_h and K_v to regional grid scale
- Vertical hydraulic conductivity is not measurable at the grid scale.

Effective Horizontal Conductivity

- Estimate block center K through kriging
- Calculate a weighted-arithmetic mean K

$$K_h \text{ effective} = \frac{(\text{net sand})(K_{sand}) + (\text{layer b} - \text{net sand})(K_{other})}{\text{layer b}}$$

K_{sand} = kriged value

$K_{other} = K_{clay} <= K_{other} < K_{sand}$

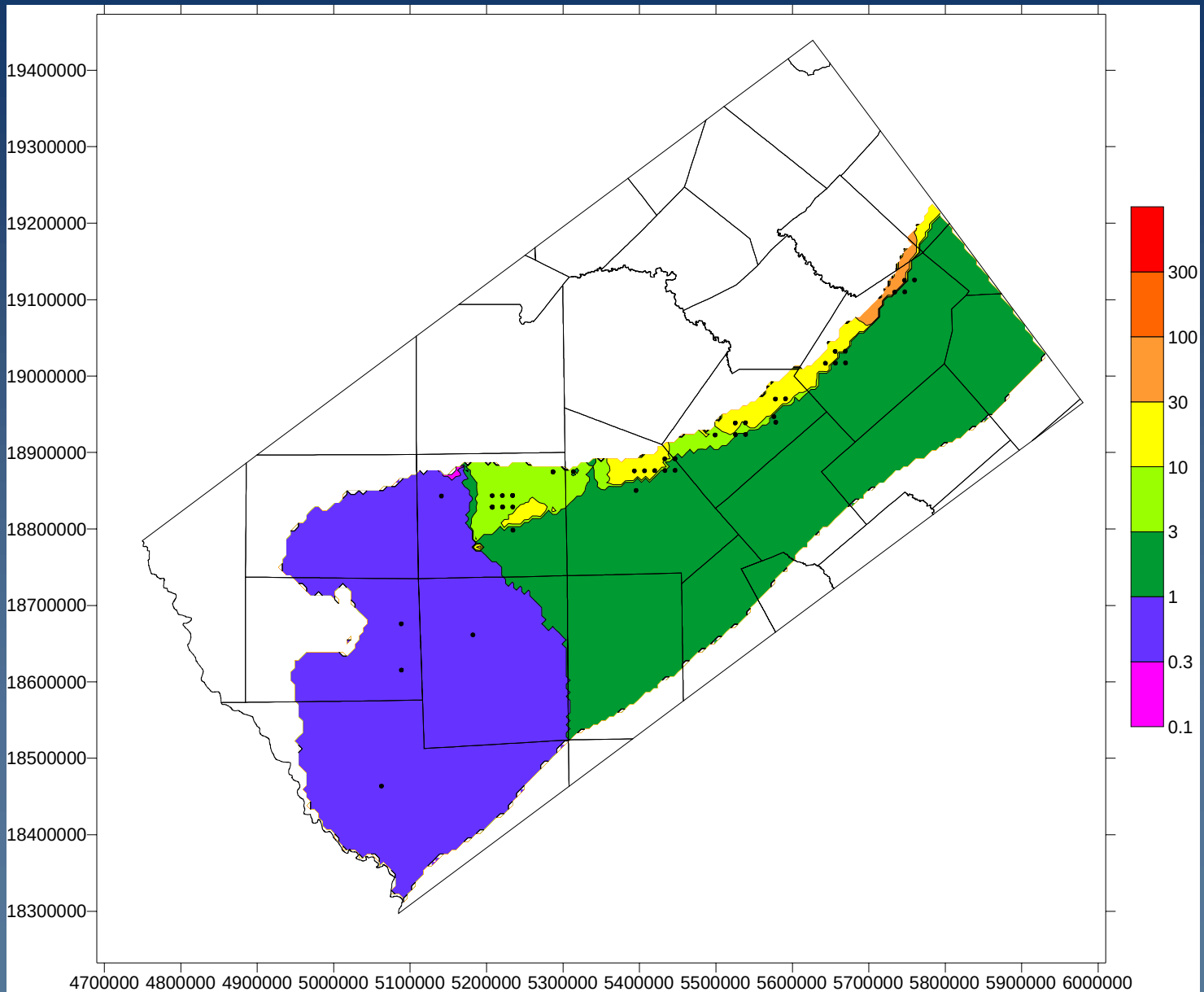
Effective Vertical Conductivity

- No measurements at model scale
- Kh/Kv will be a calibrated parameter based on:
  - P vs D profiles after Fogg (1983)
  - X-formational flow by 10,000 ppm
  - Specification of recharge
  - Depositional environments/sand distributions

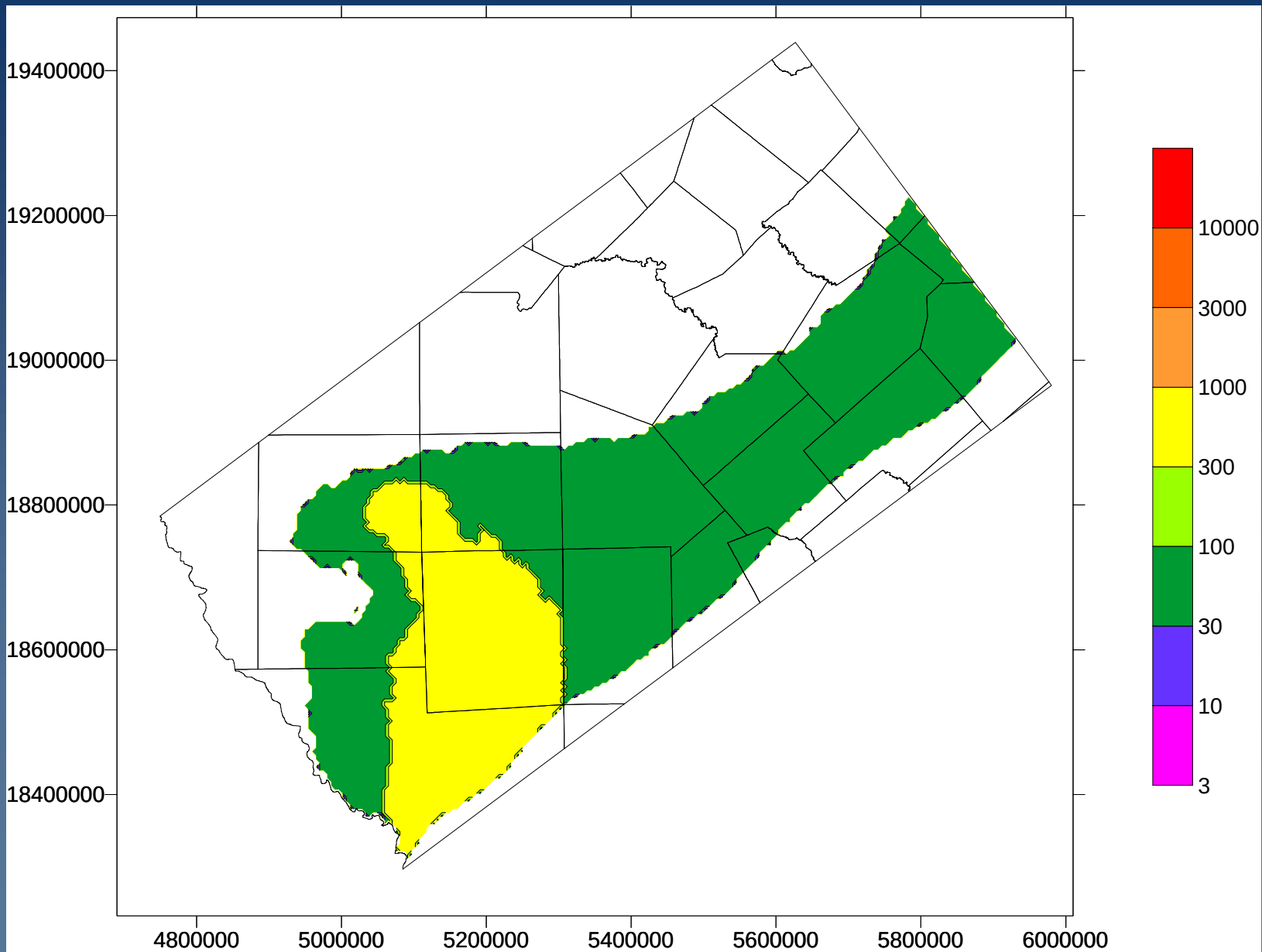
Hydraulic Conductivity Database Review

- Criteria 1- Confine data to model area
- Criteria 2 - Split data by layers
- Criteria 3 - Delete slug & bail tests plus log data estimates
- Criteria 4 - Remove TRRC Data
- Criteria 5 – Remove TNRCC data

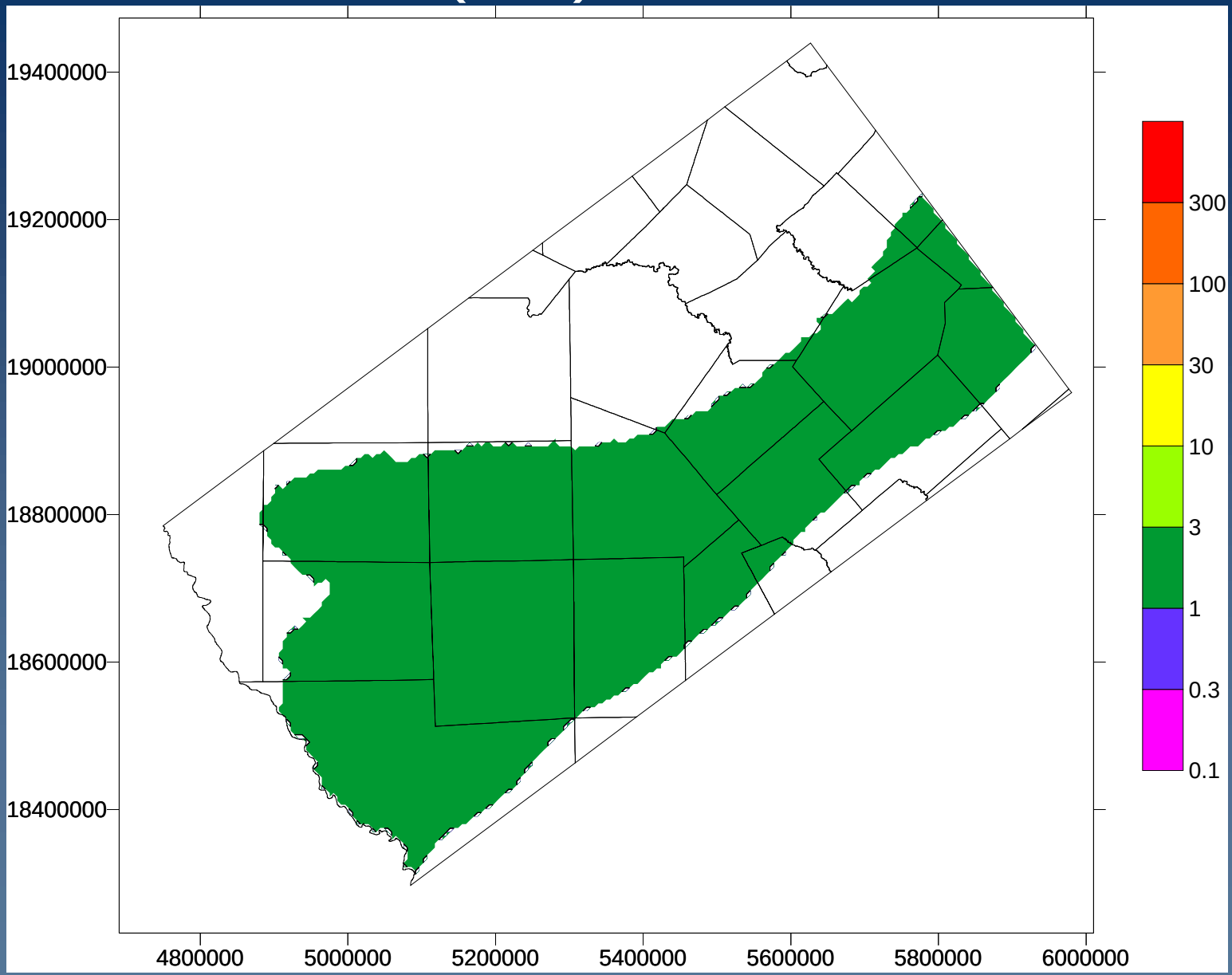
Queen City Kh (ft/d)



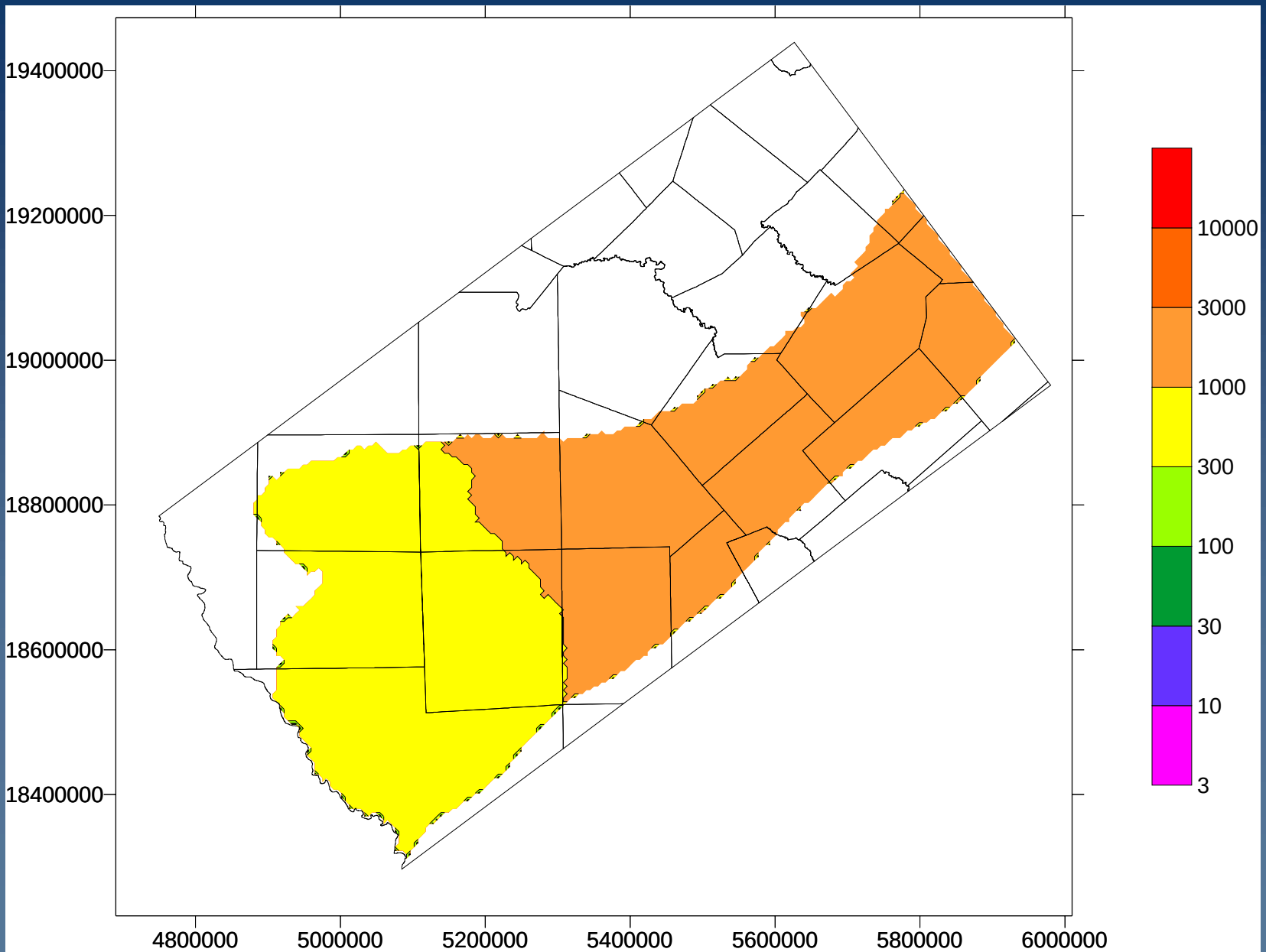
Queen City Kh/Kv Ratio



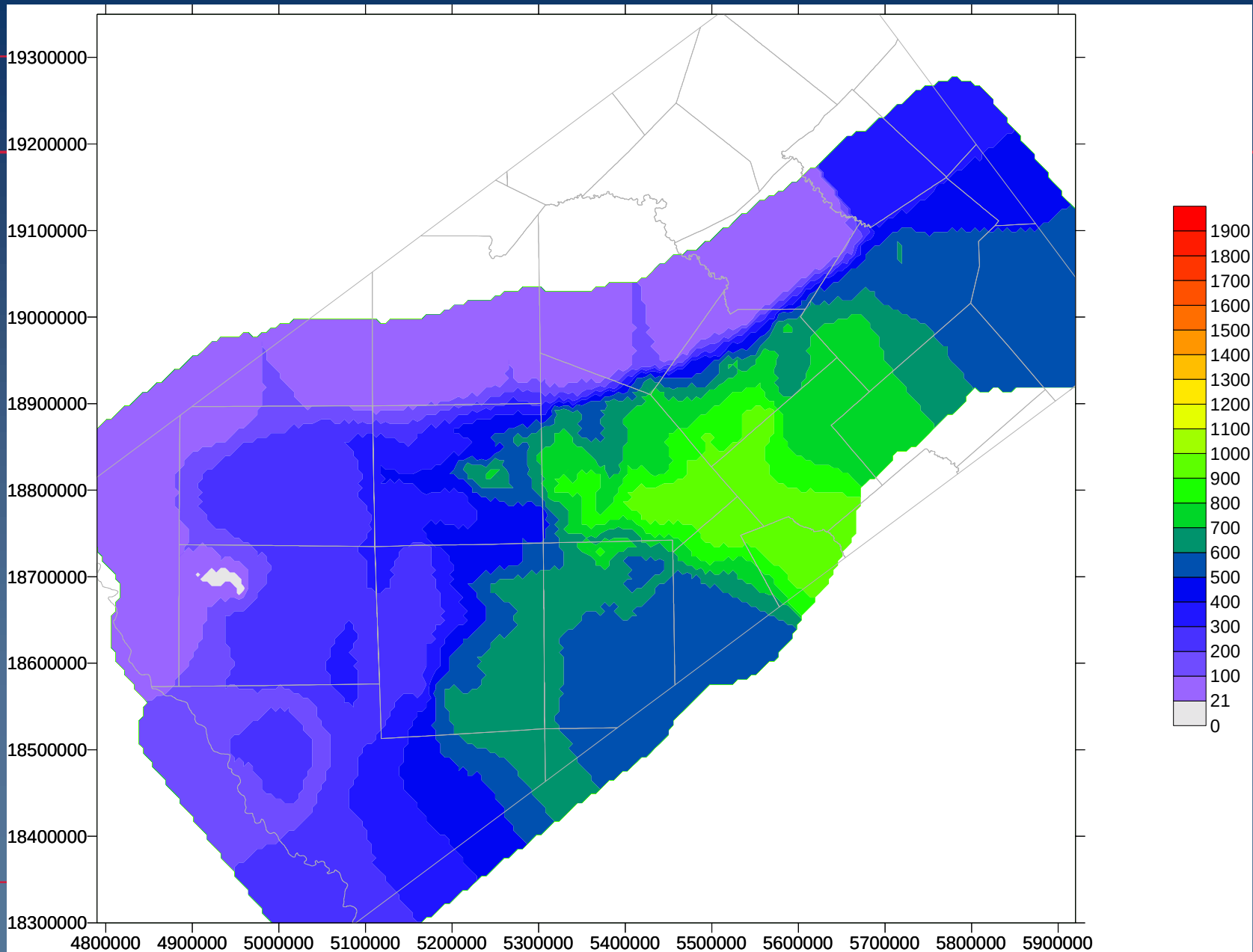
Reklaw Kh (ft/d)



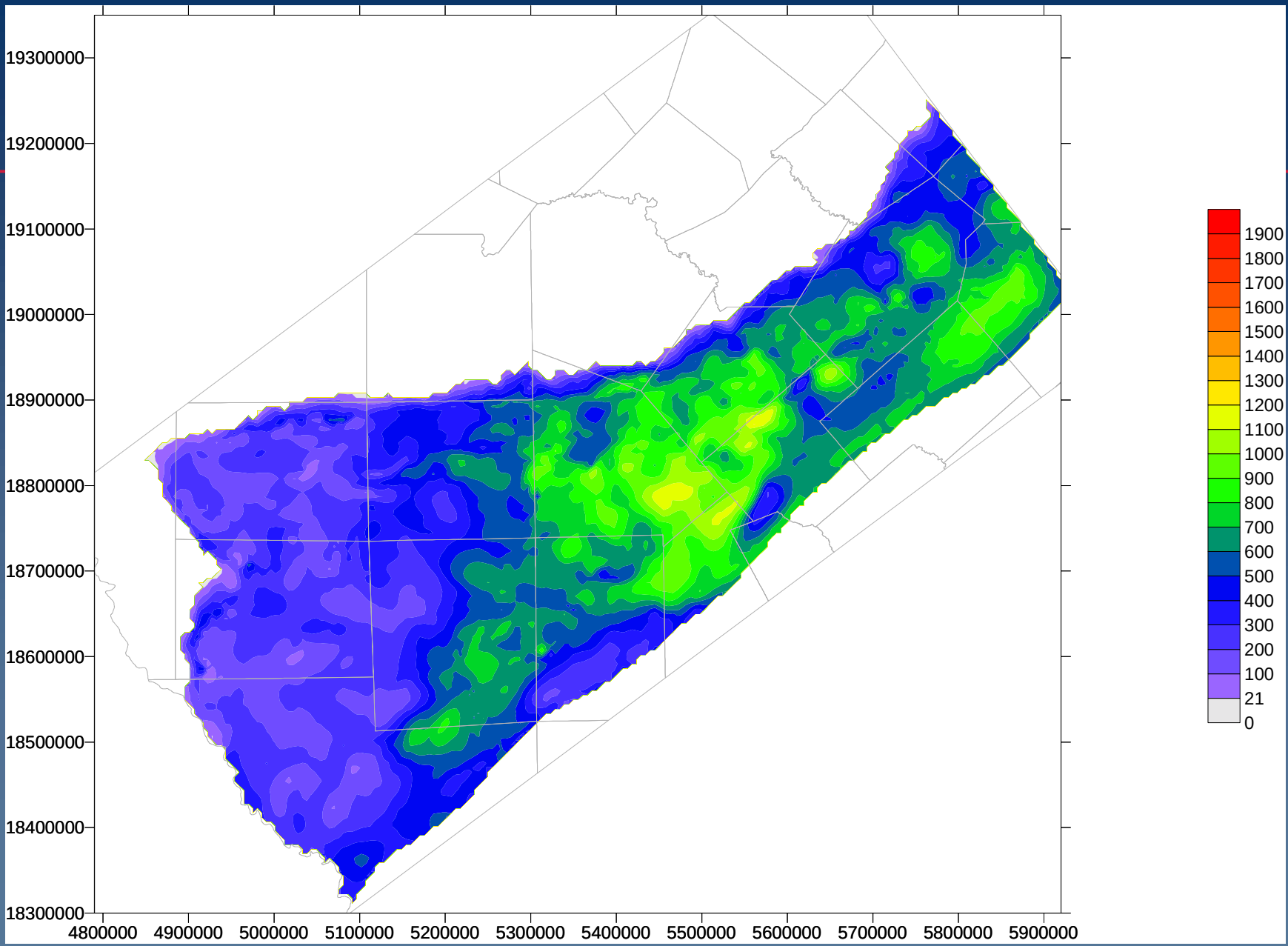
Reklaw Kv/Kh Ratio



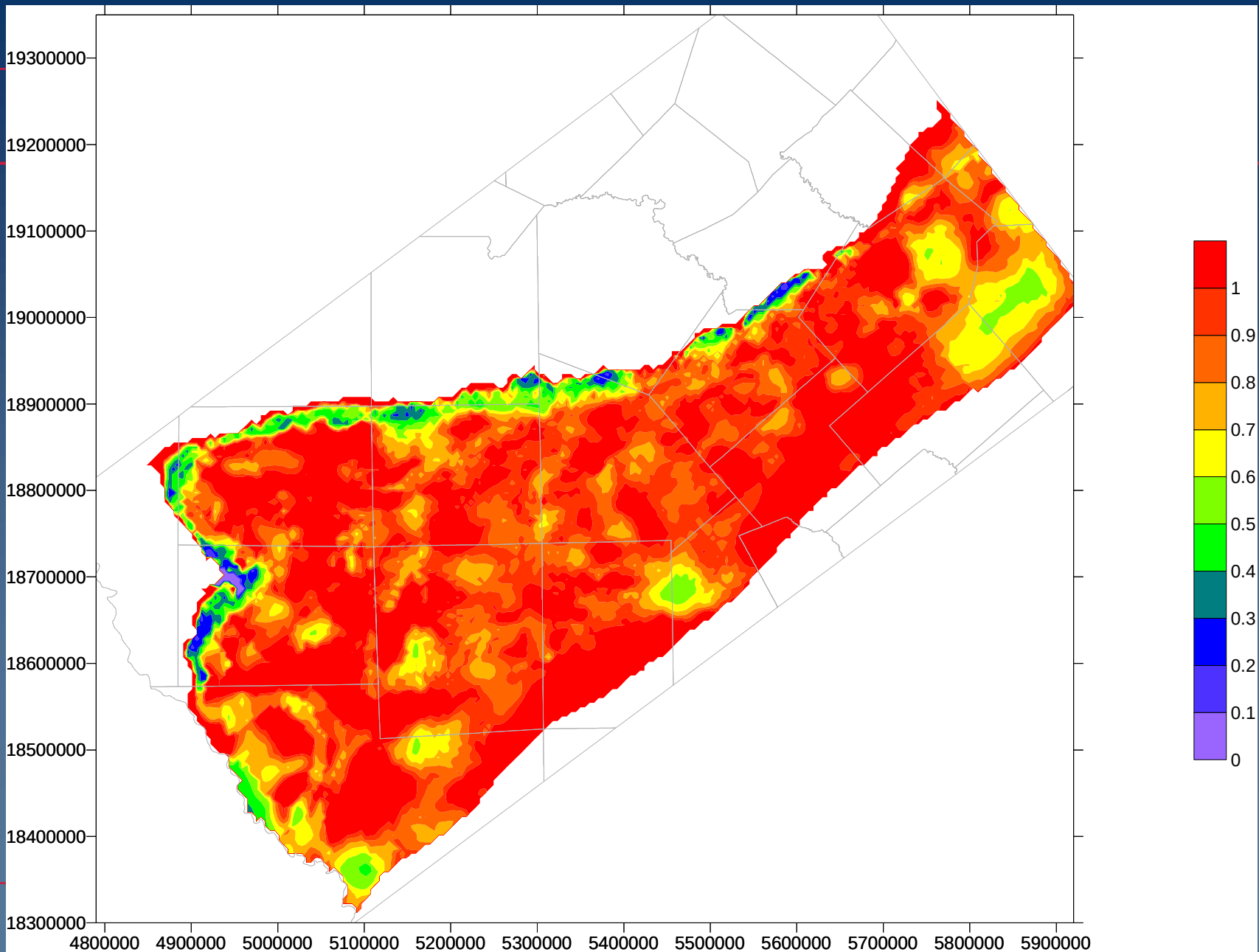
Carrizo Sand Thickness



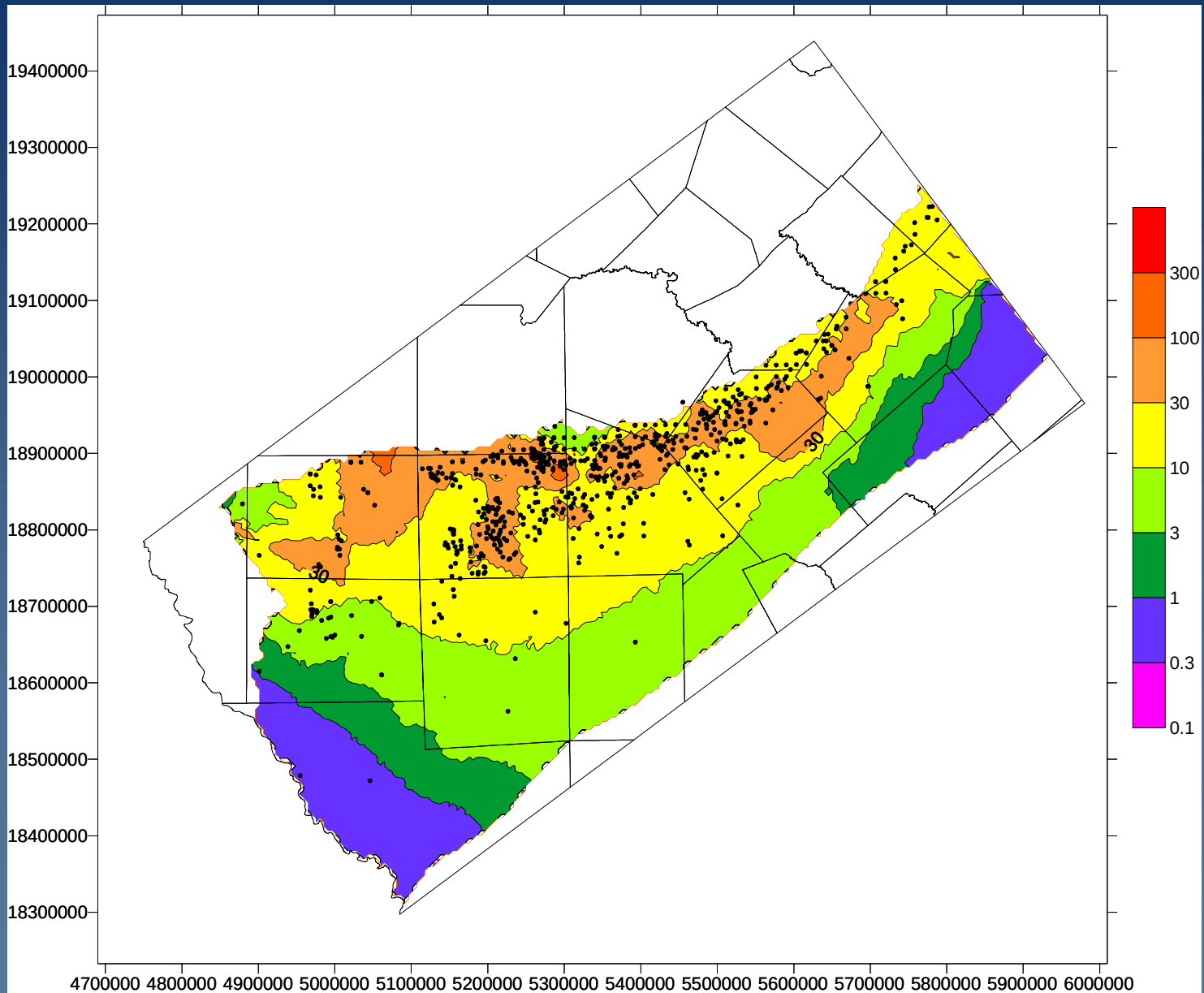
Carrizo Thickness



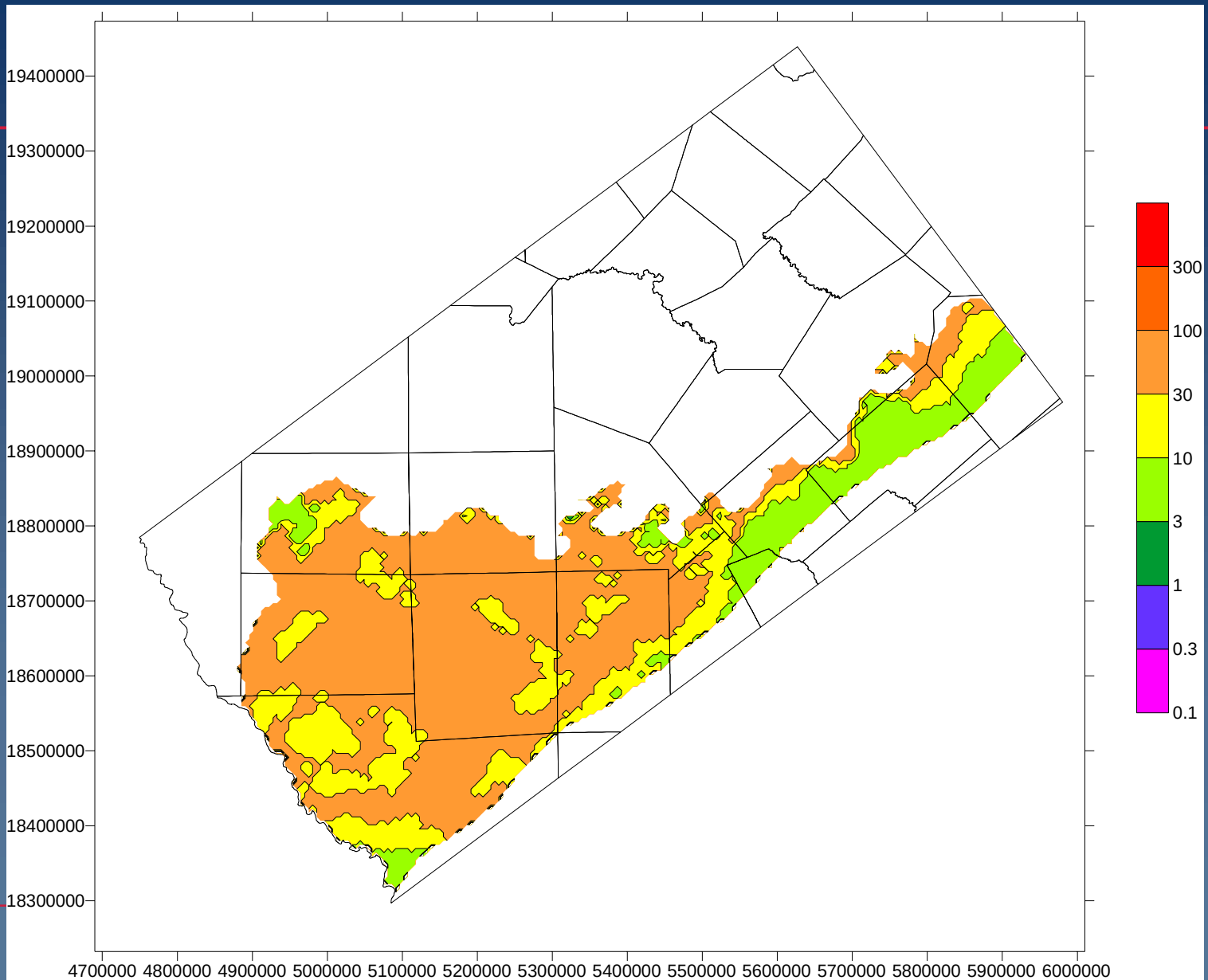
Carrizo Sand Fraction



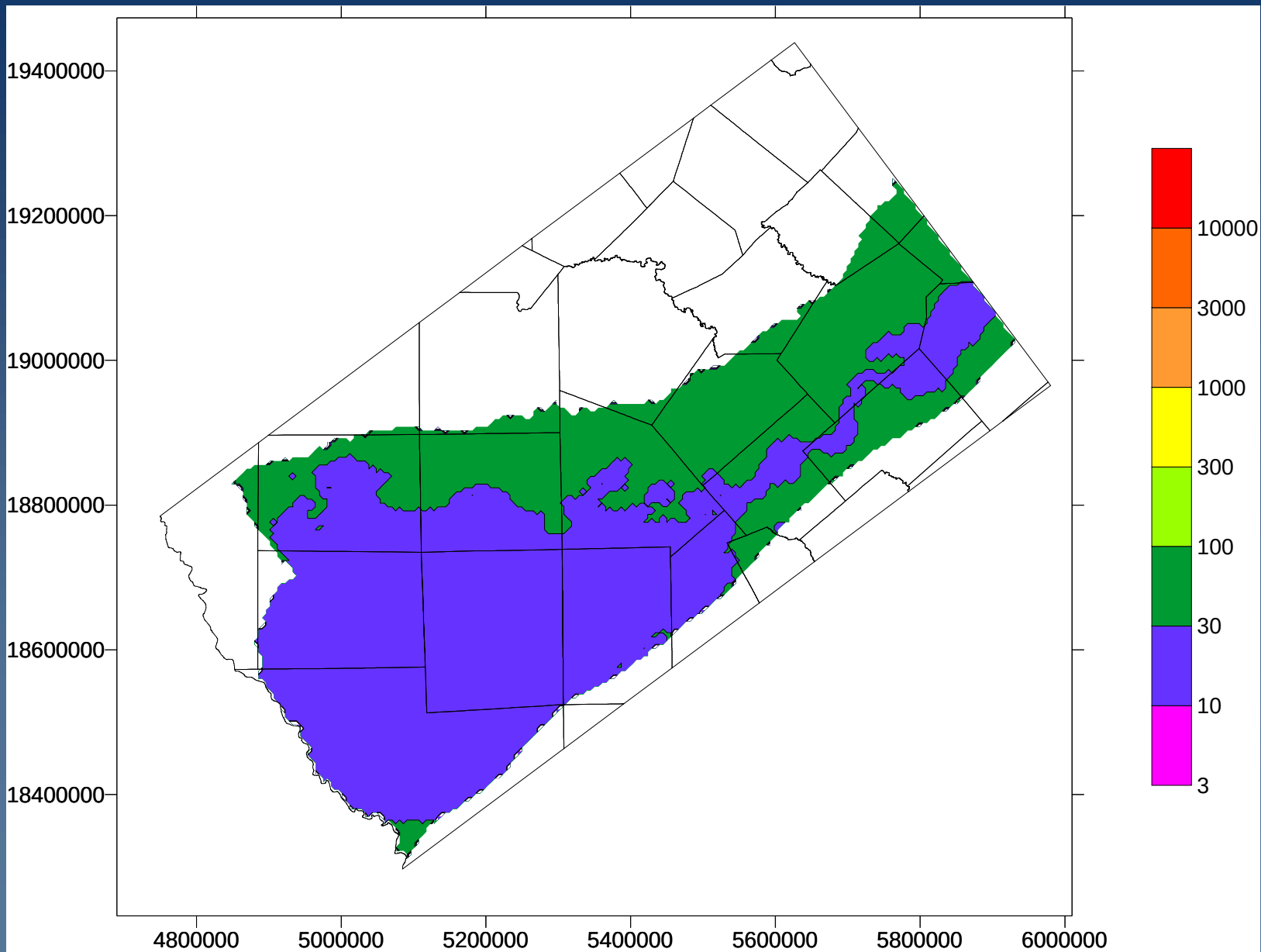
Carrizo Kh (ft/d) (Kh/Kv = 3)



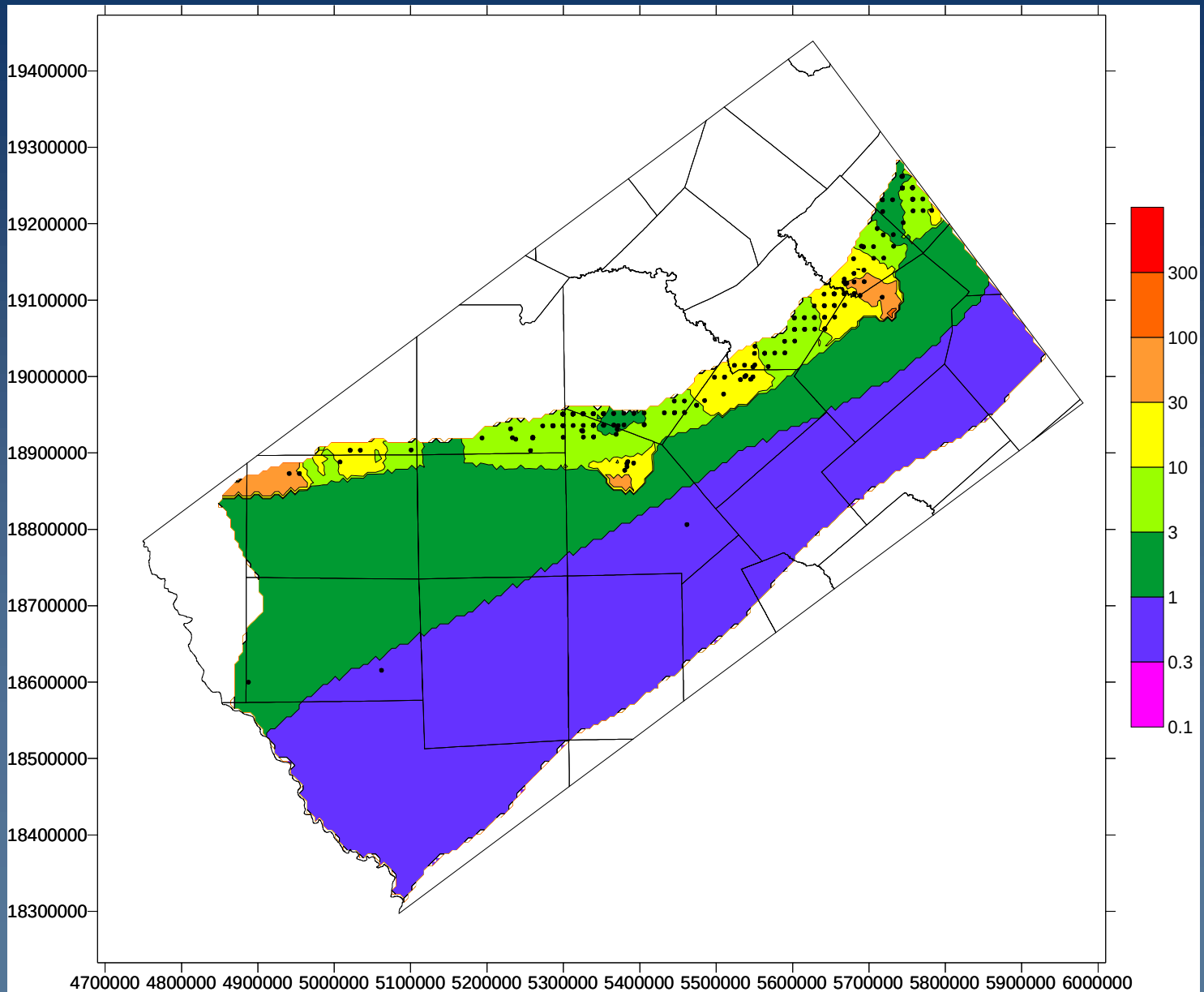
Upper Wilcox Kh (ft/d)



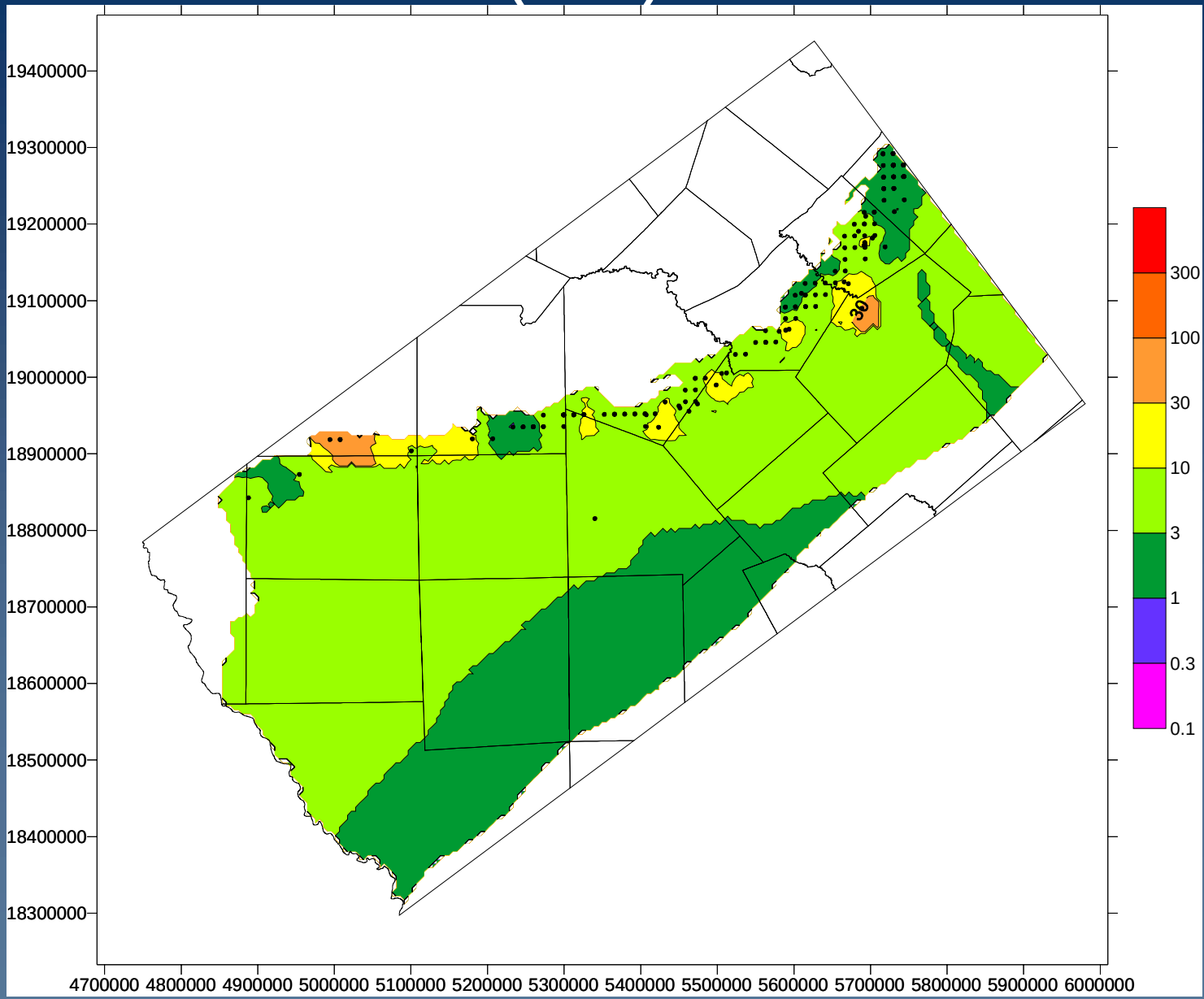
Upper Wilcox Kh/Kv Ratio



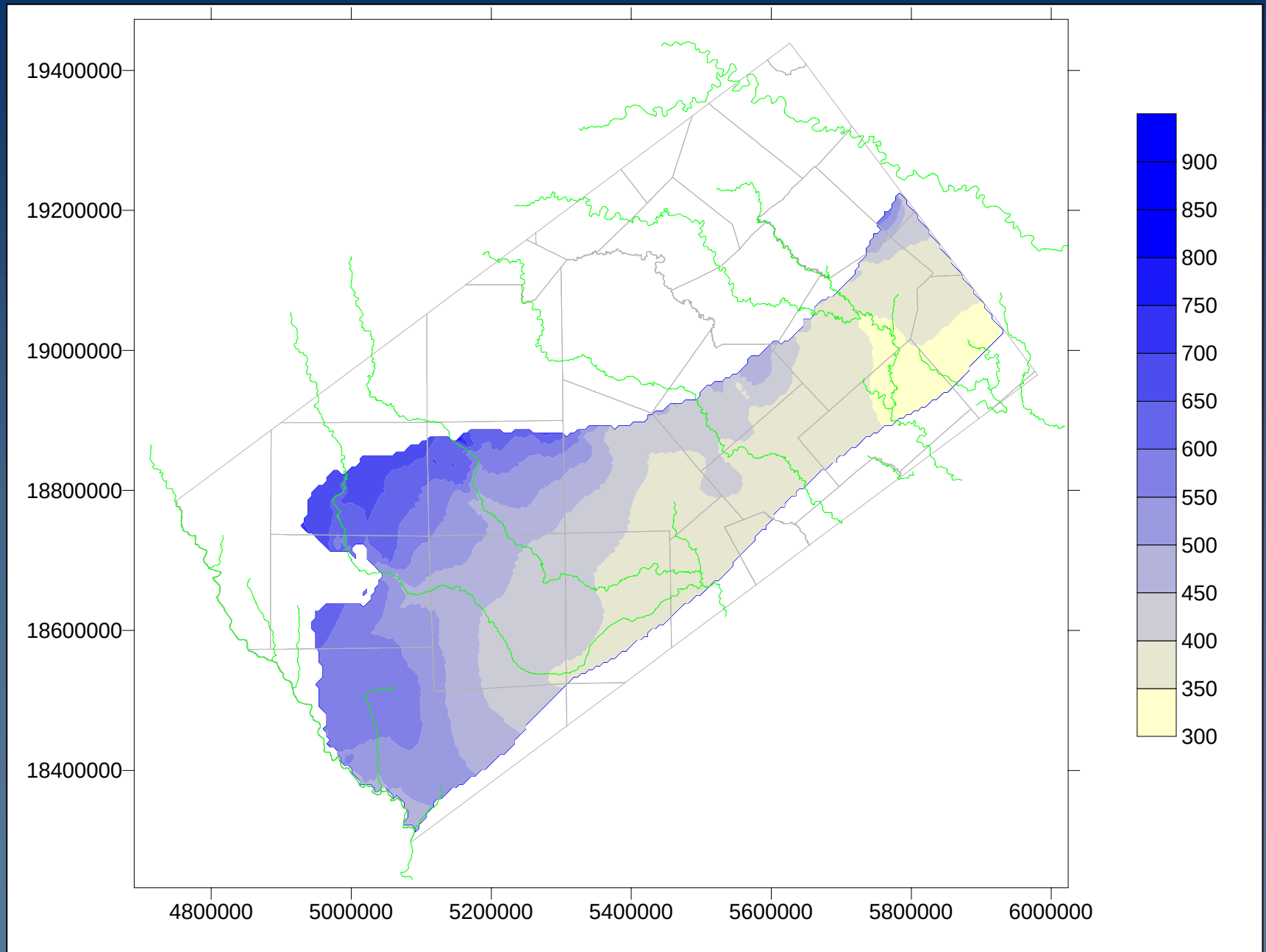
Middle Wilcox Kh (ft/d) Kh/Kv = 30



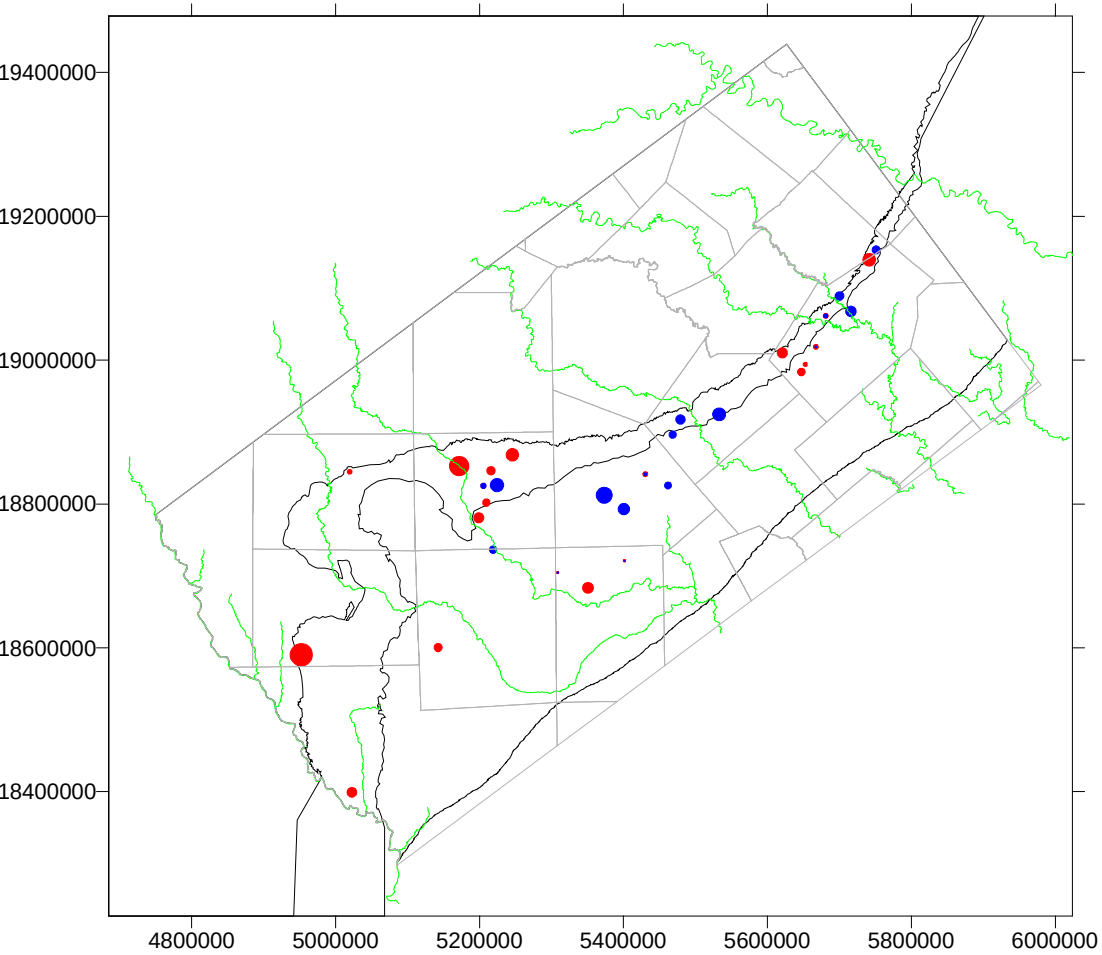
Lower Wilcox Kh (ft/d) Kh/Kv = 30

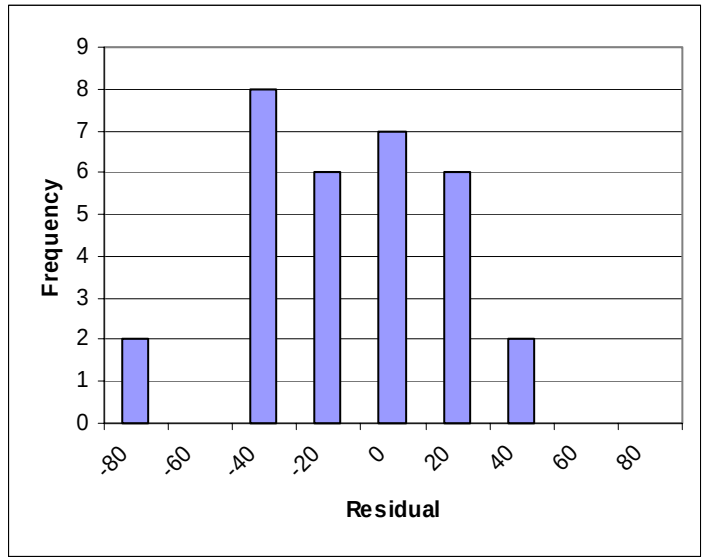


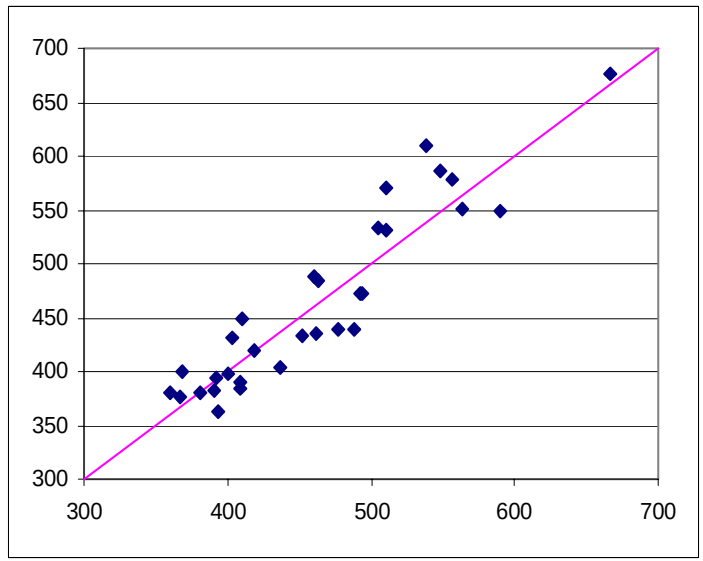
Queen City Head Results



Queen City Residuals

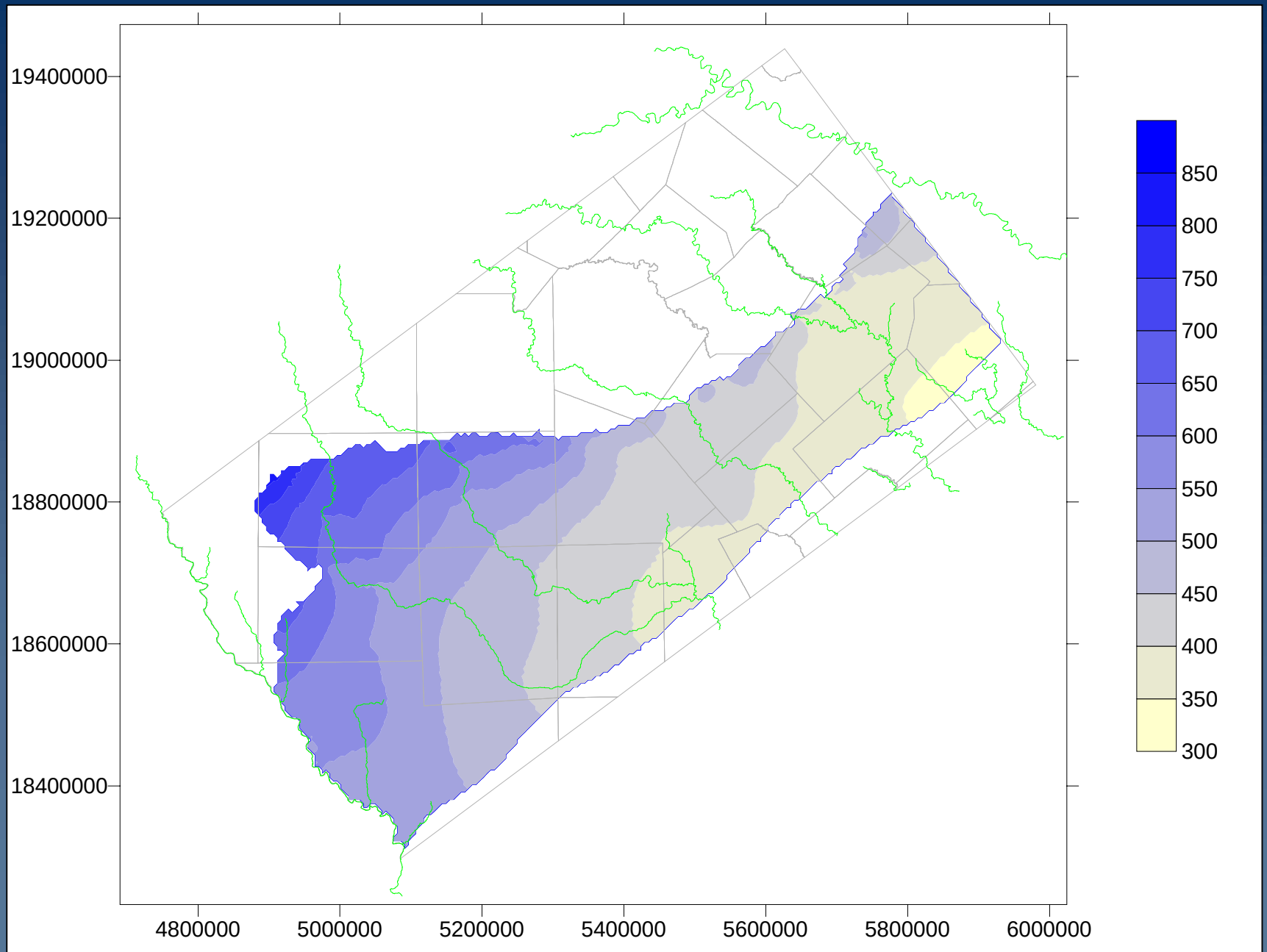




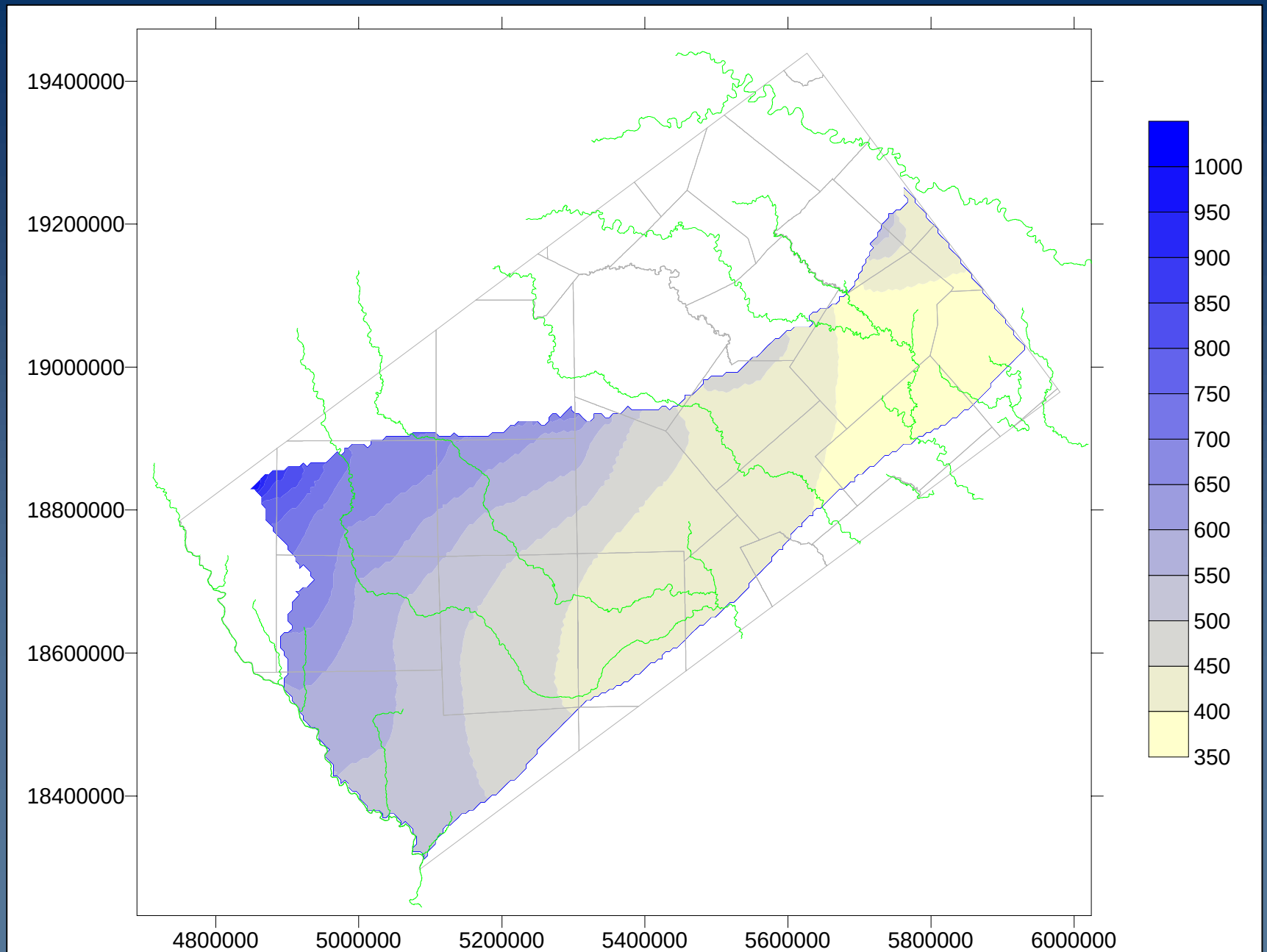


Residual Mean	-2.85
Residual Stdev	29.73
Range in Head	306.60
Stdev/Range	0.097

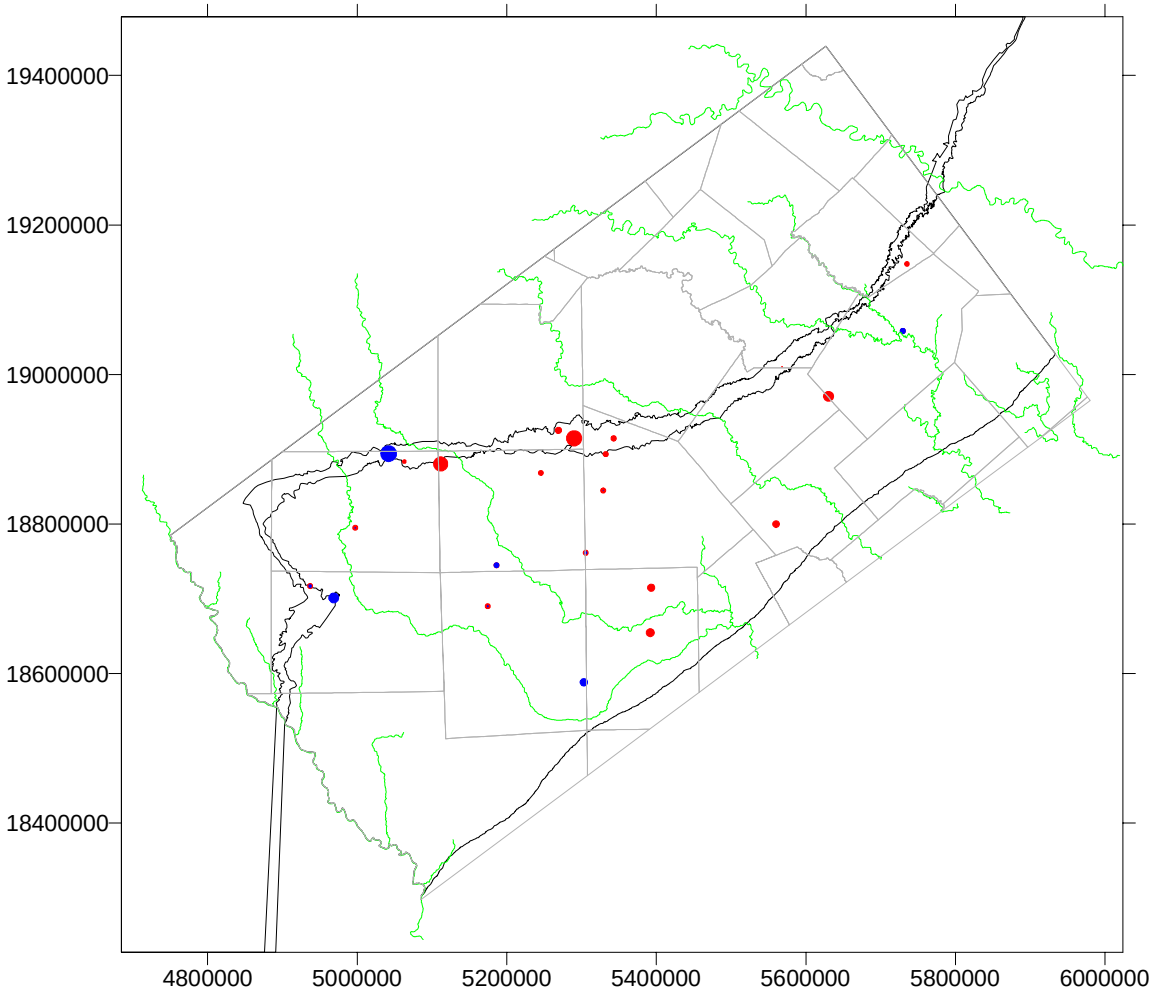
Reklaw Head Results

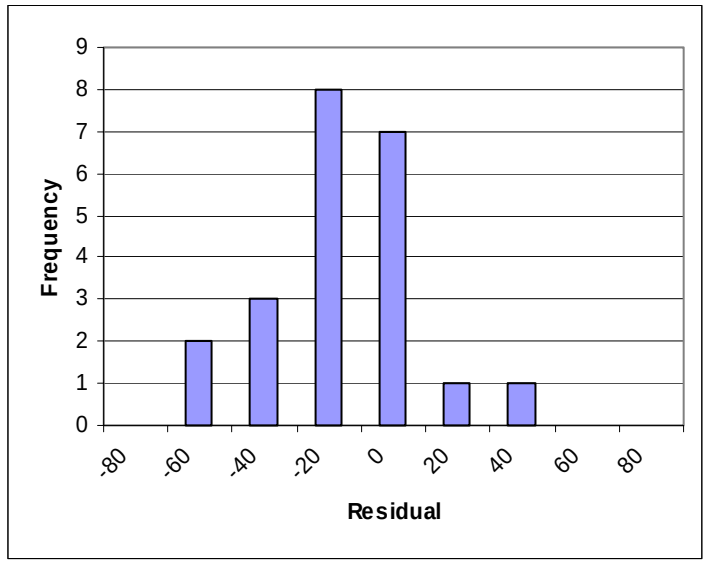


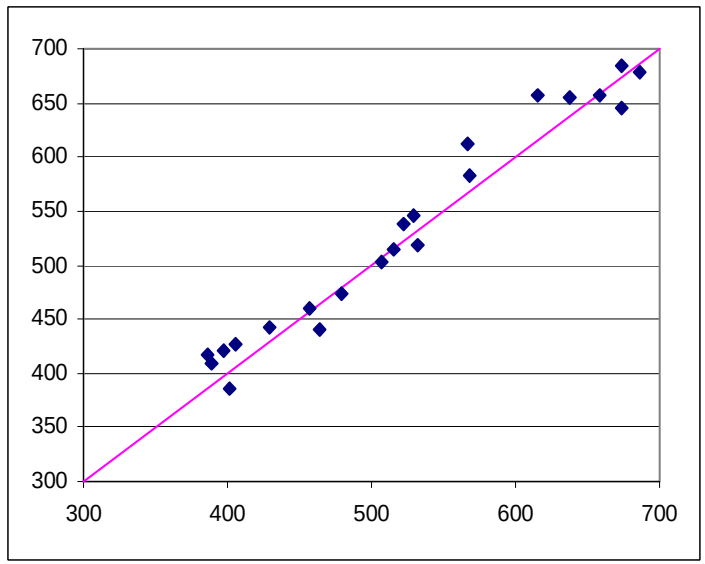
Carrizo Head Results



Carrizo Residuals

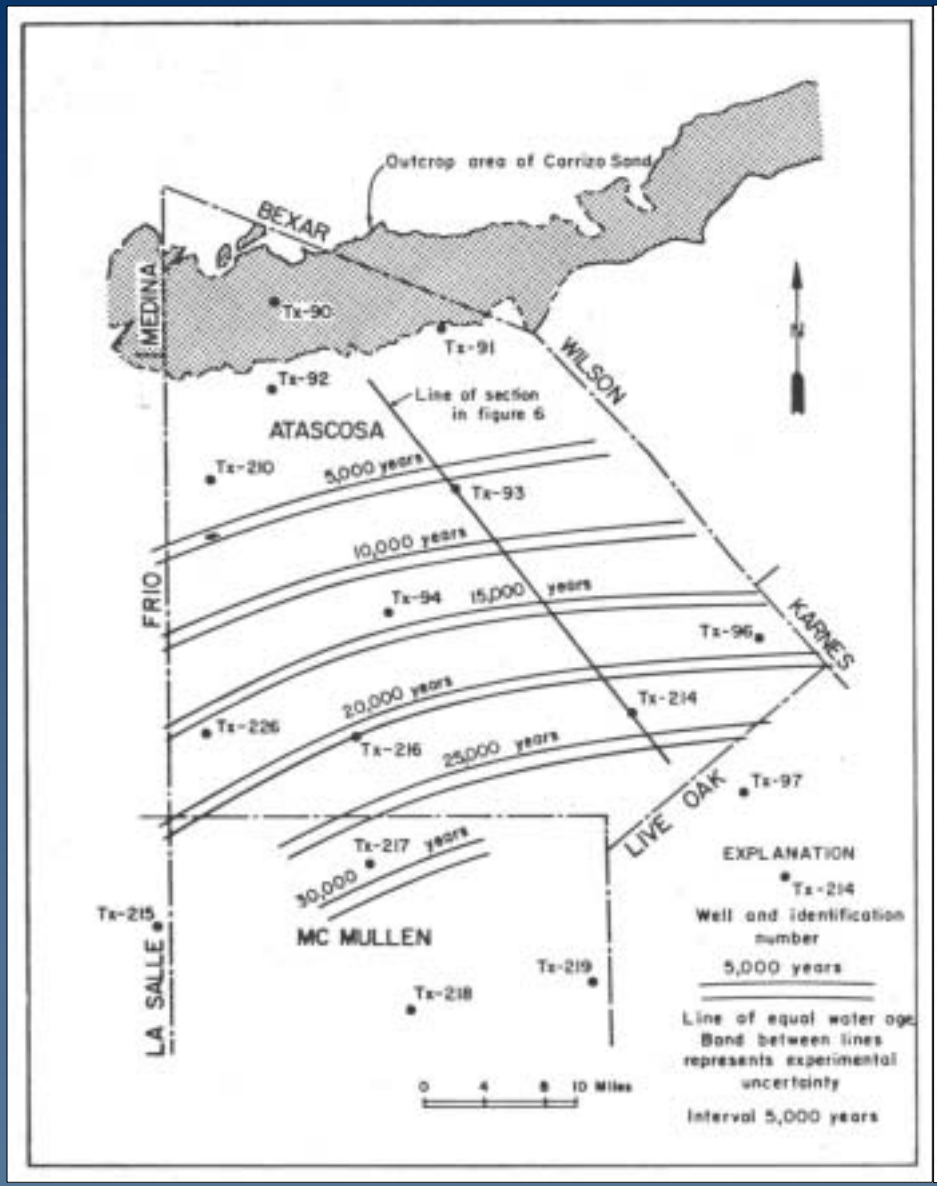


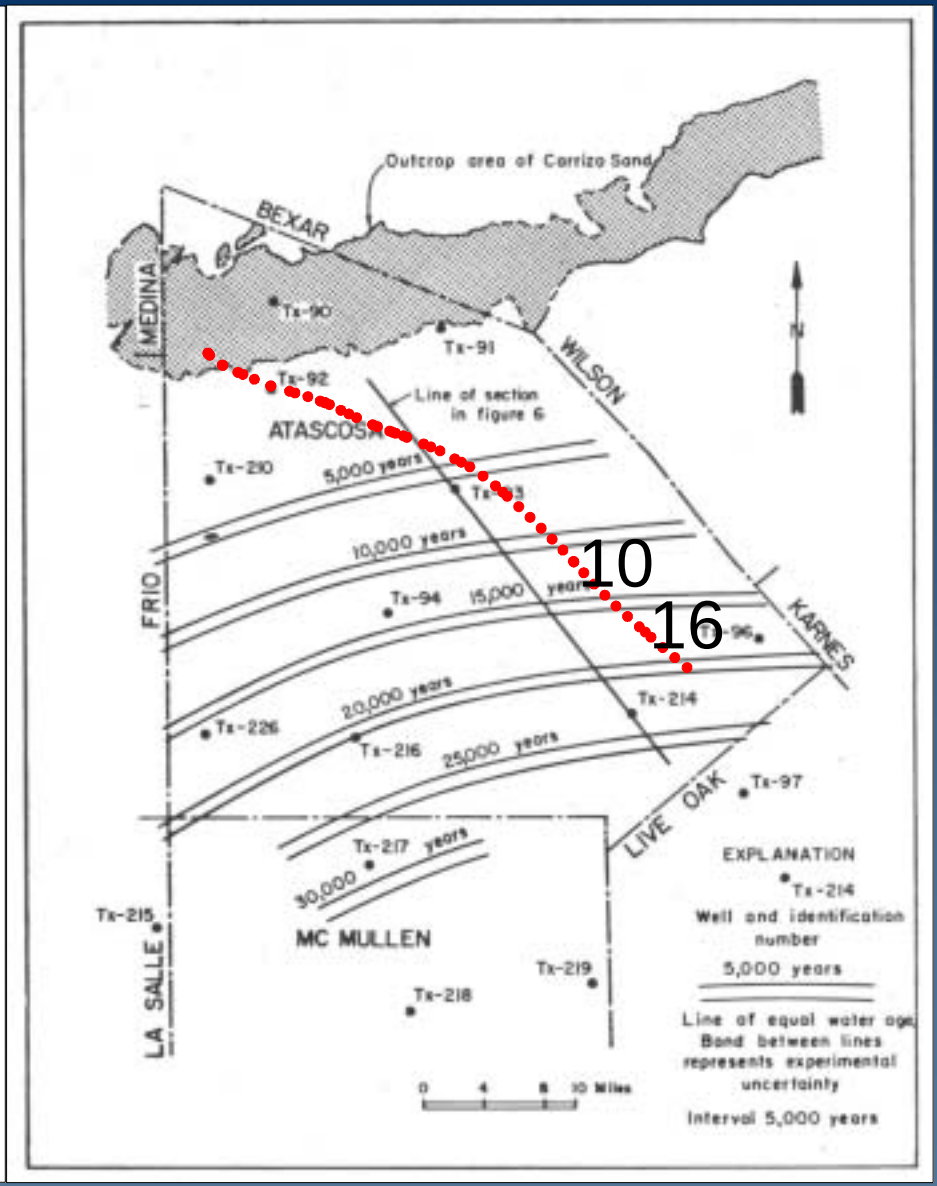




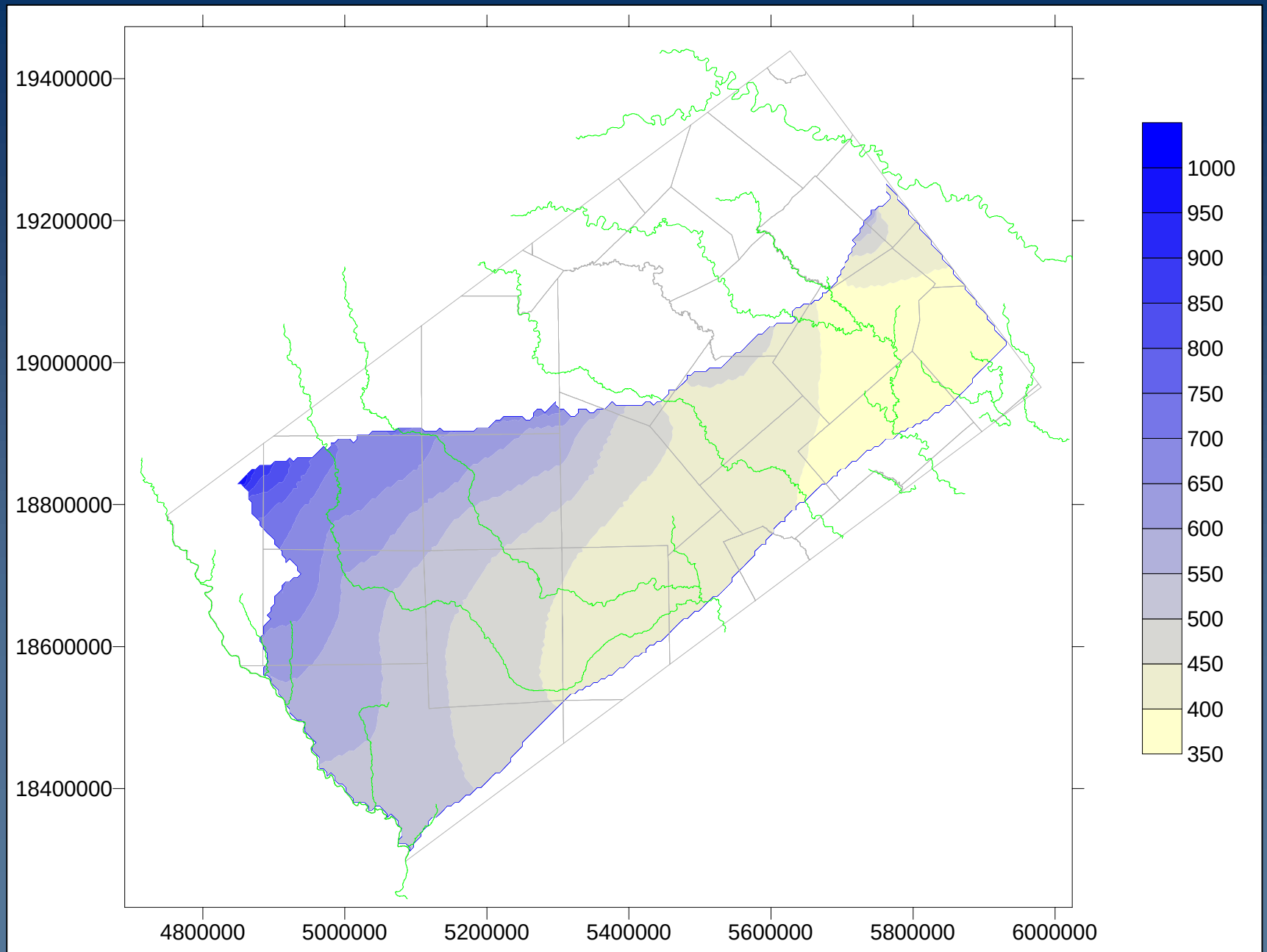
Residual Mean	-5.45
Residual Stdev	21.77
Range in Head	353.40
Stdev/Range	0.062

Carrizo Particle Travel Time

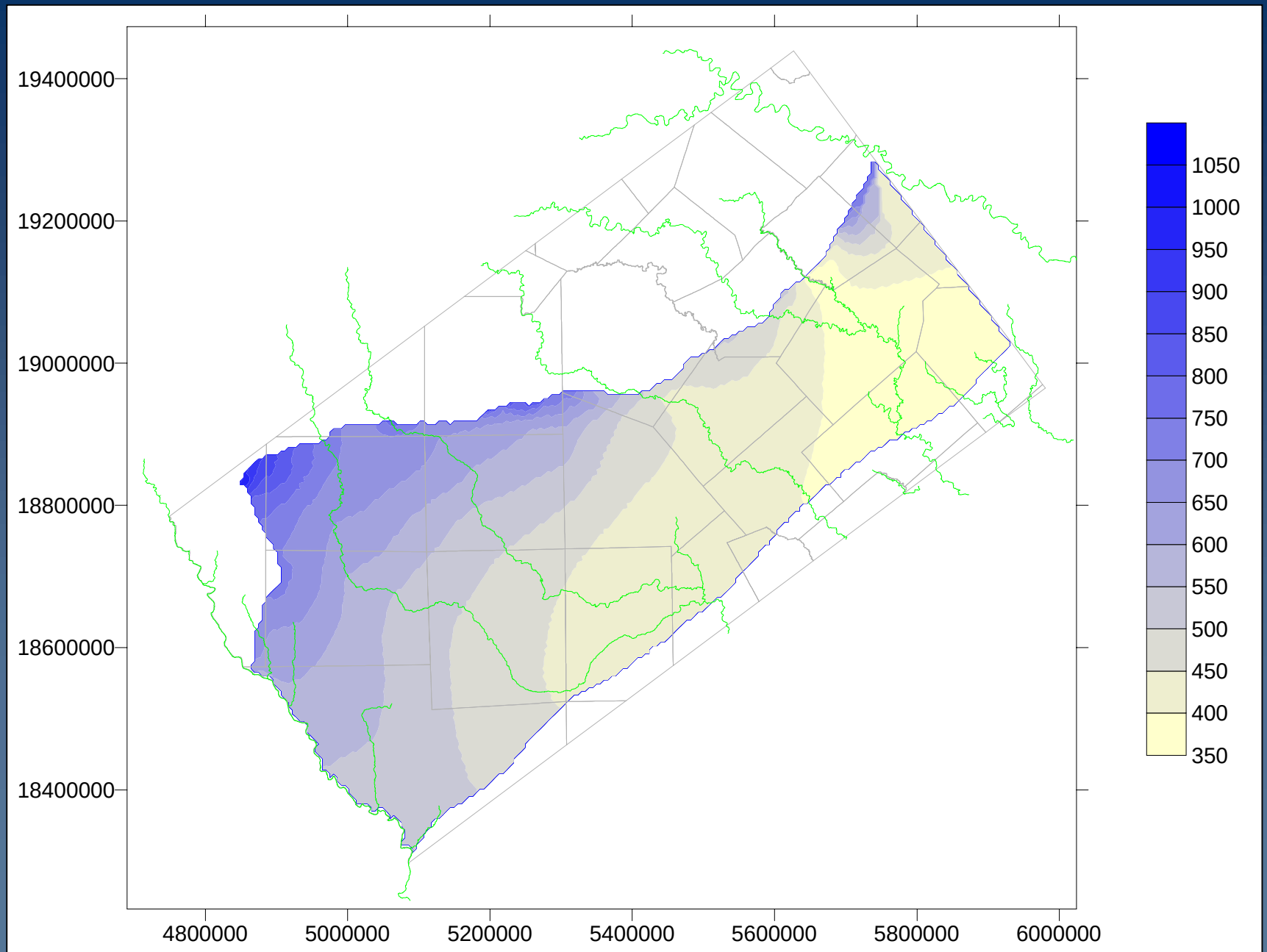




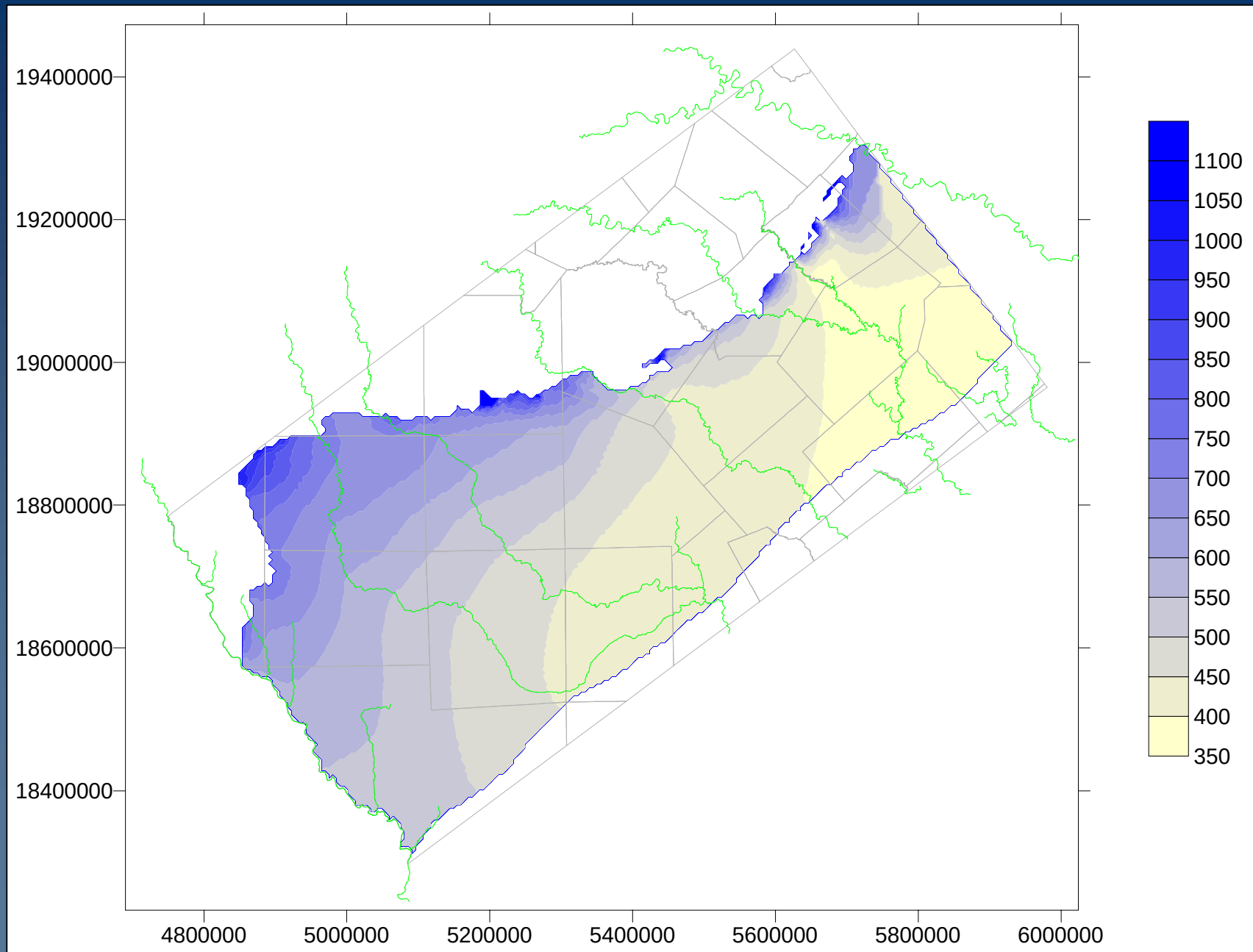
Upper Wilcox Head Results



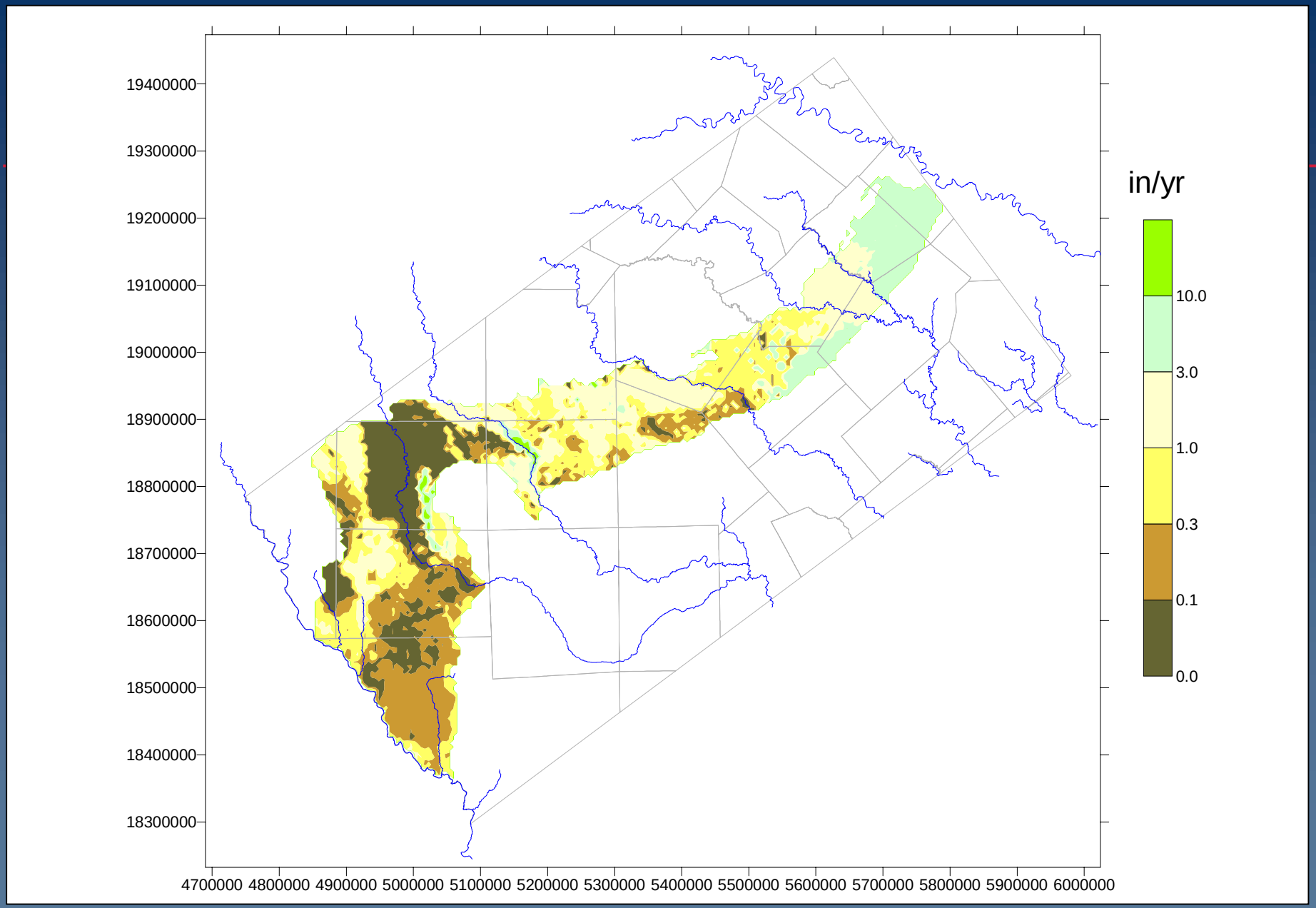
Middle Wilcox Head Results



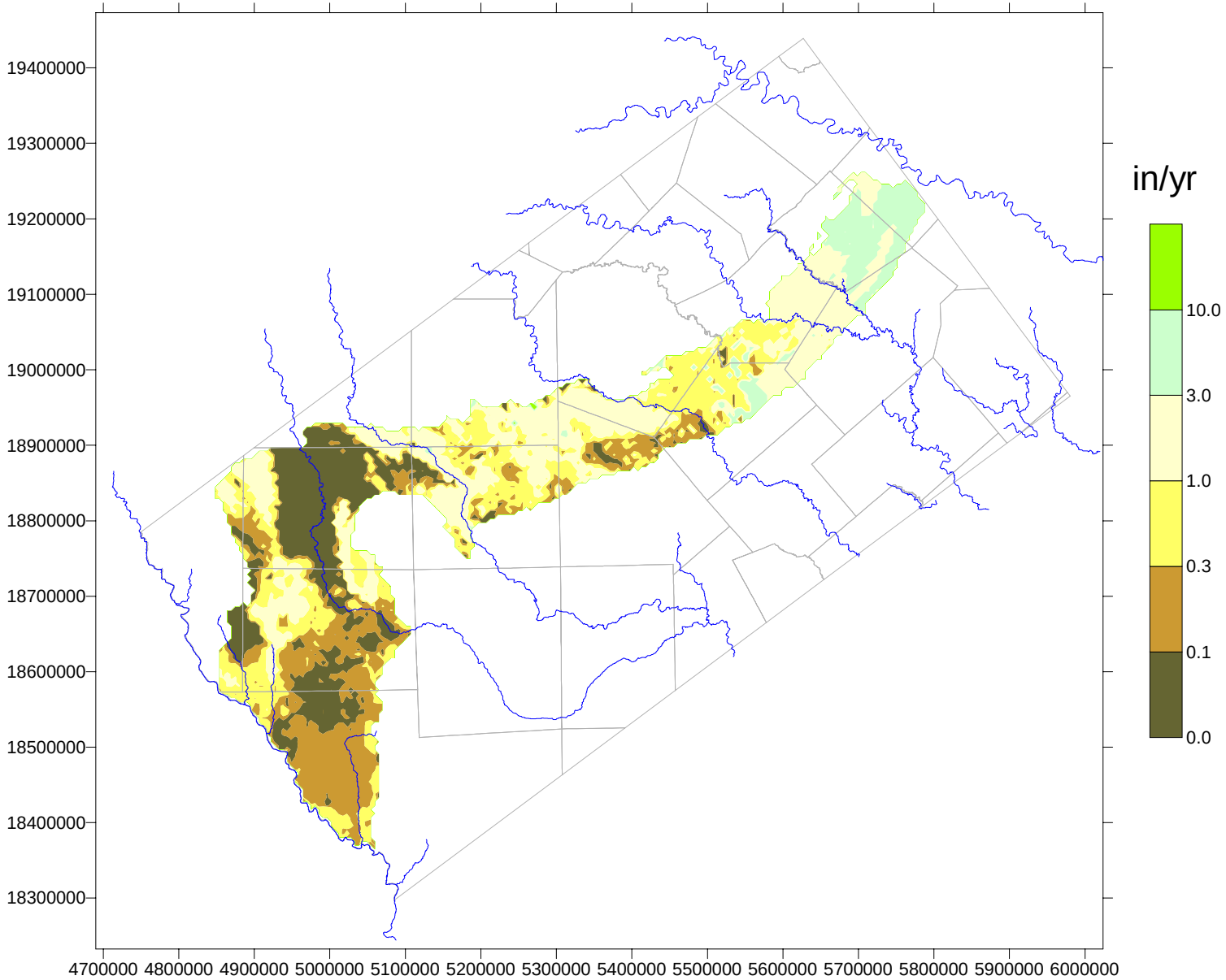
Lower Wilcox Head Results



Average Recharge 1975-1999

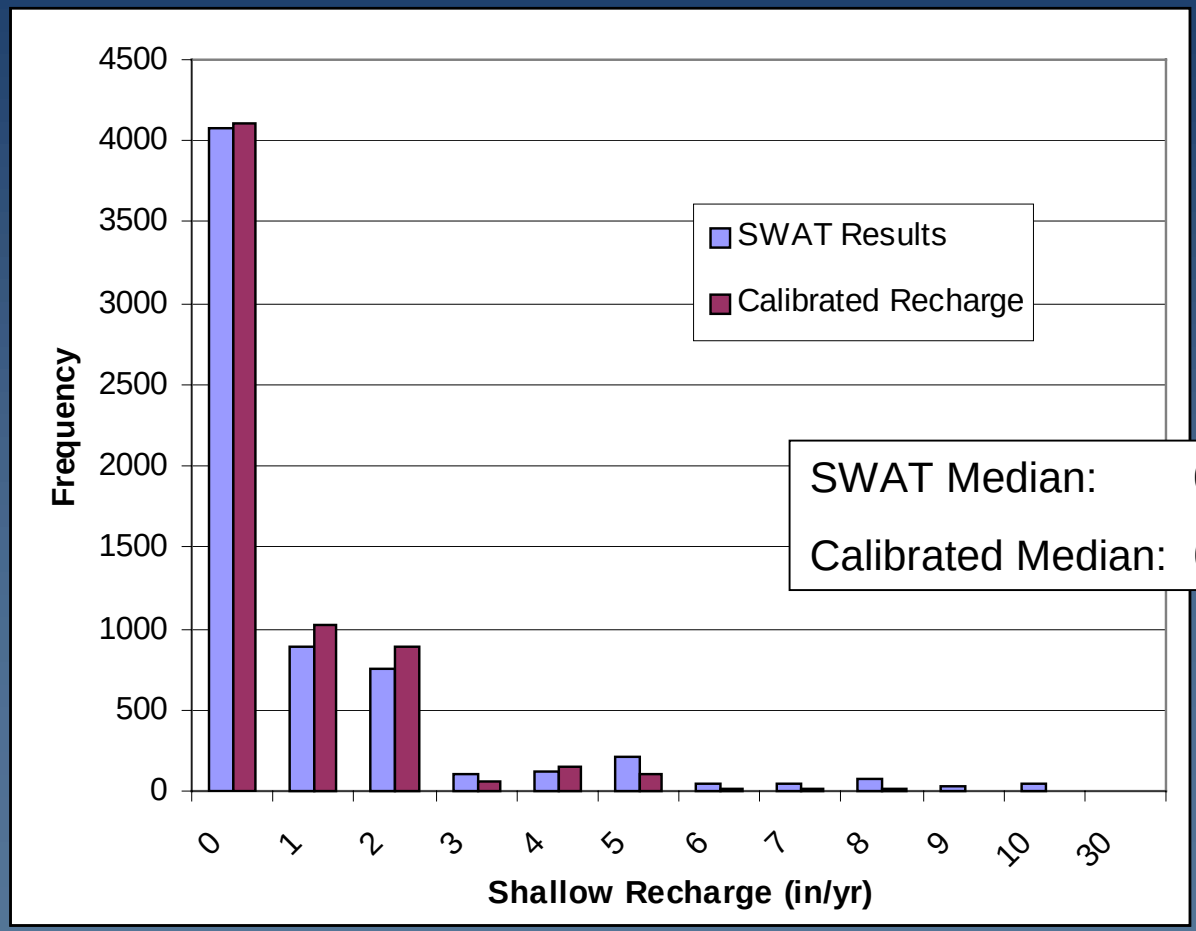


Calibrated Recharge SS Model

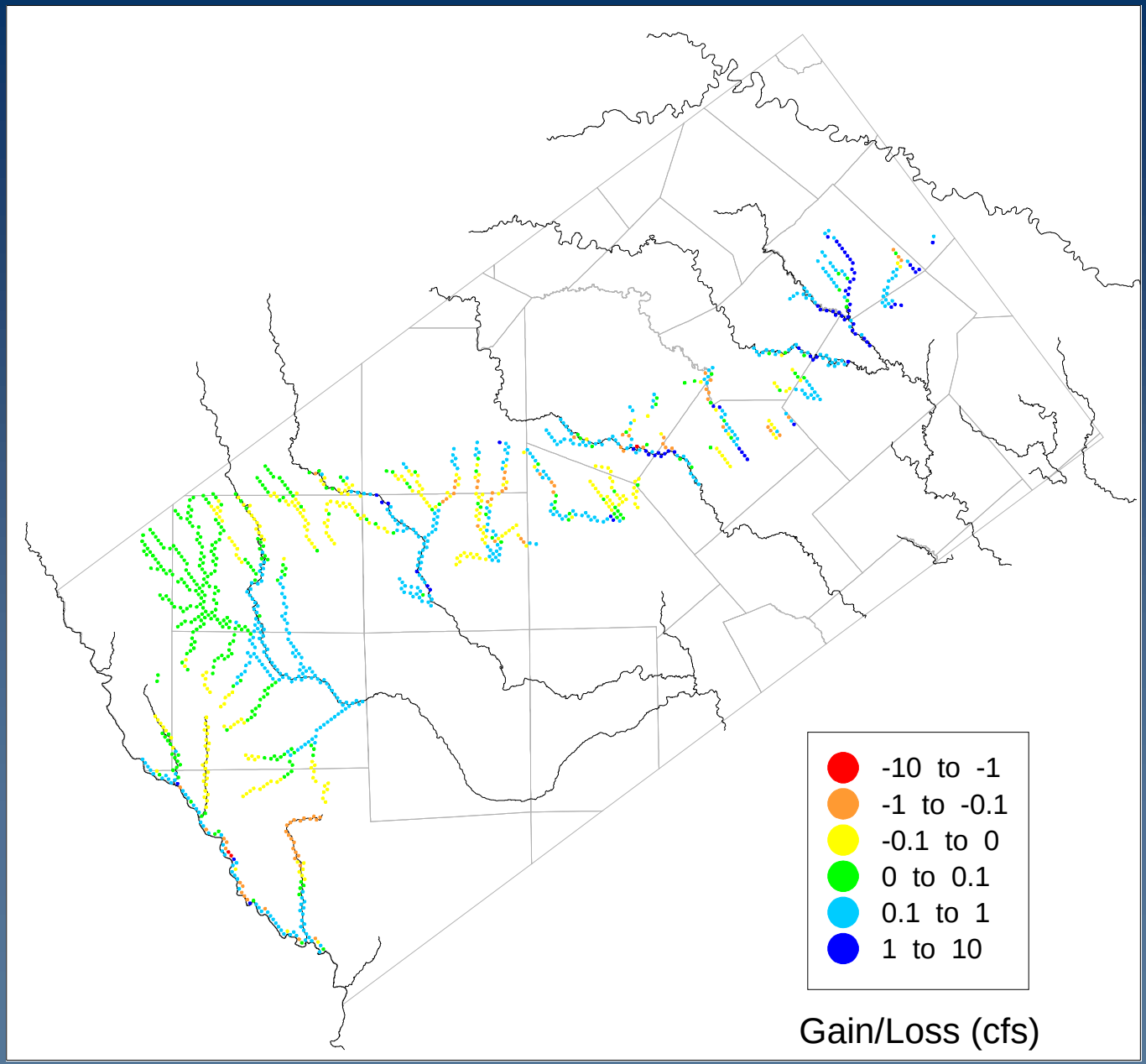


SWAT - Example Results

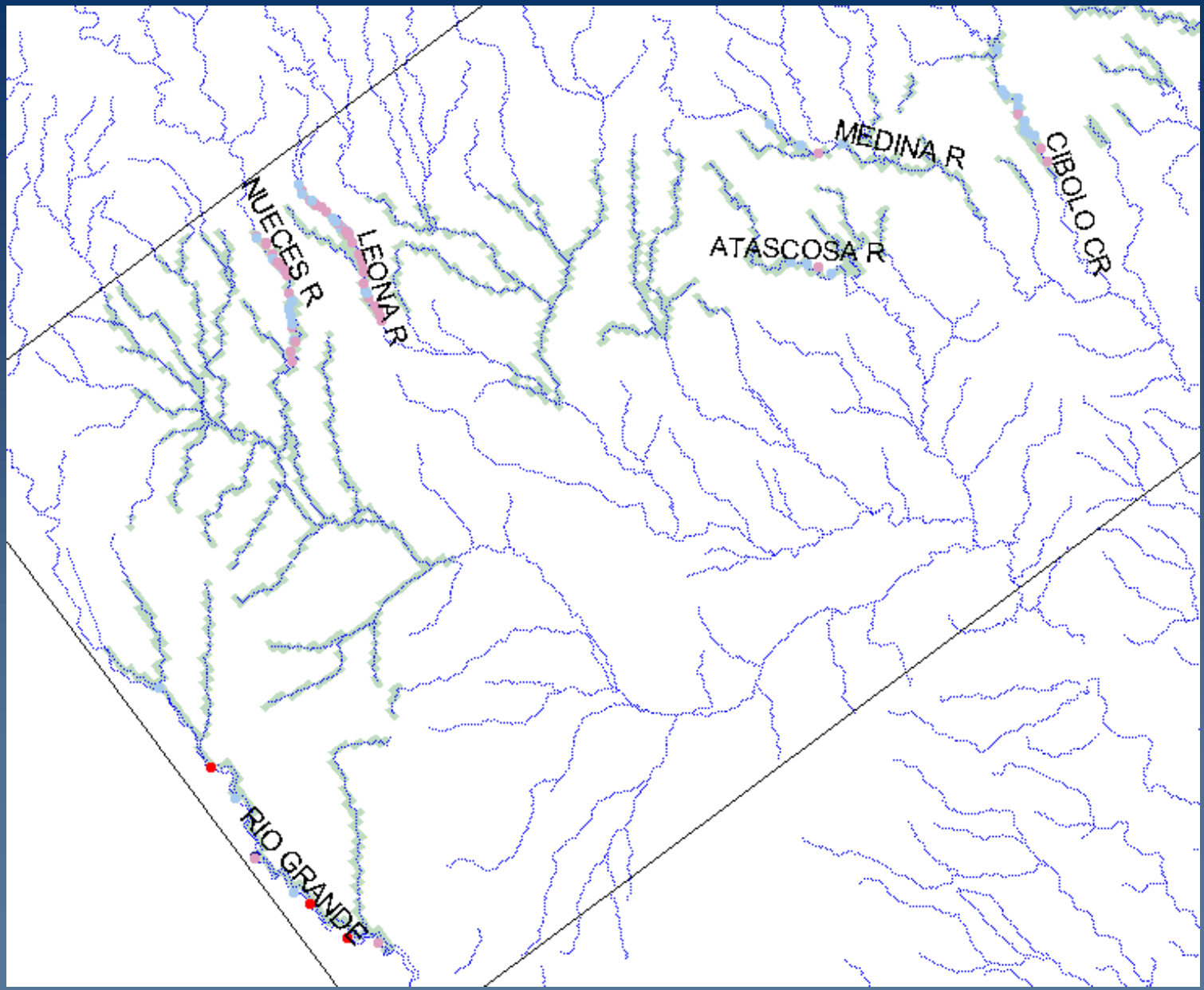
25-year average annual recharge Southern C-W



Gain/Loss Results



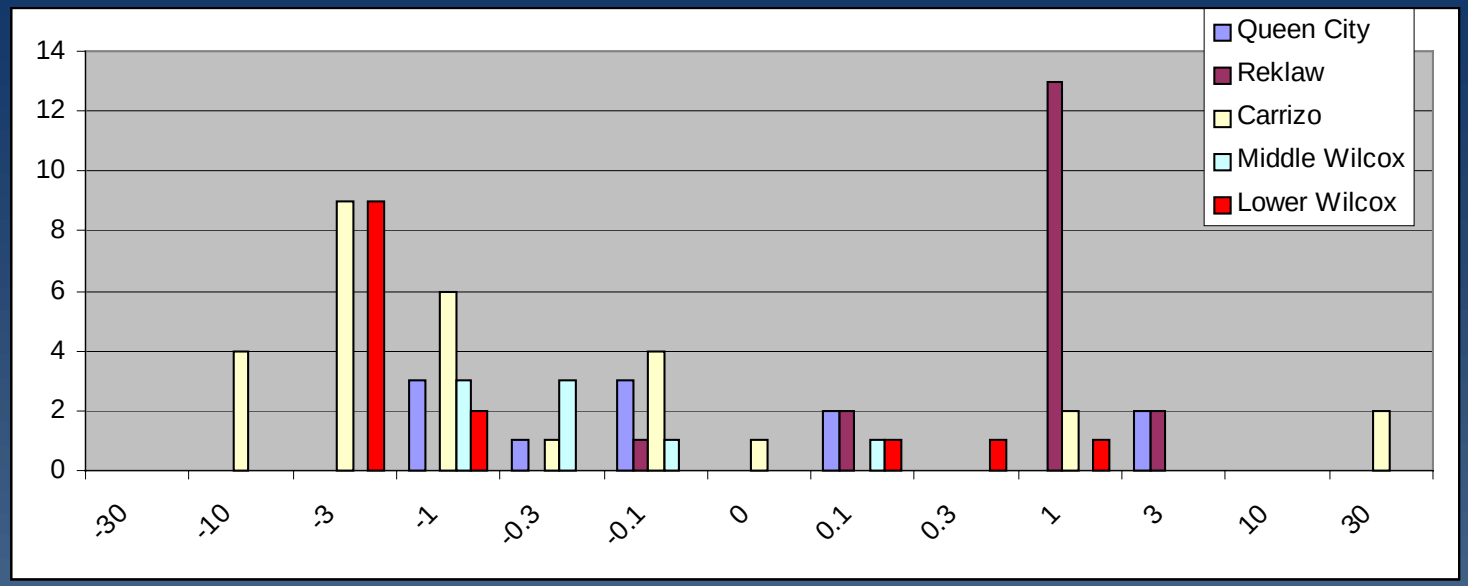
Relevant Gain/Loss Studies



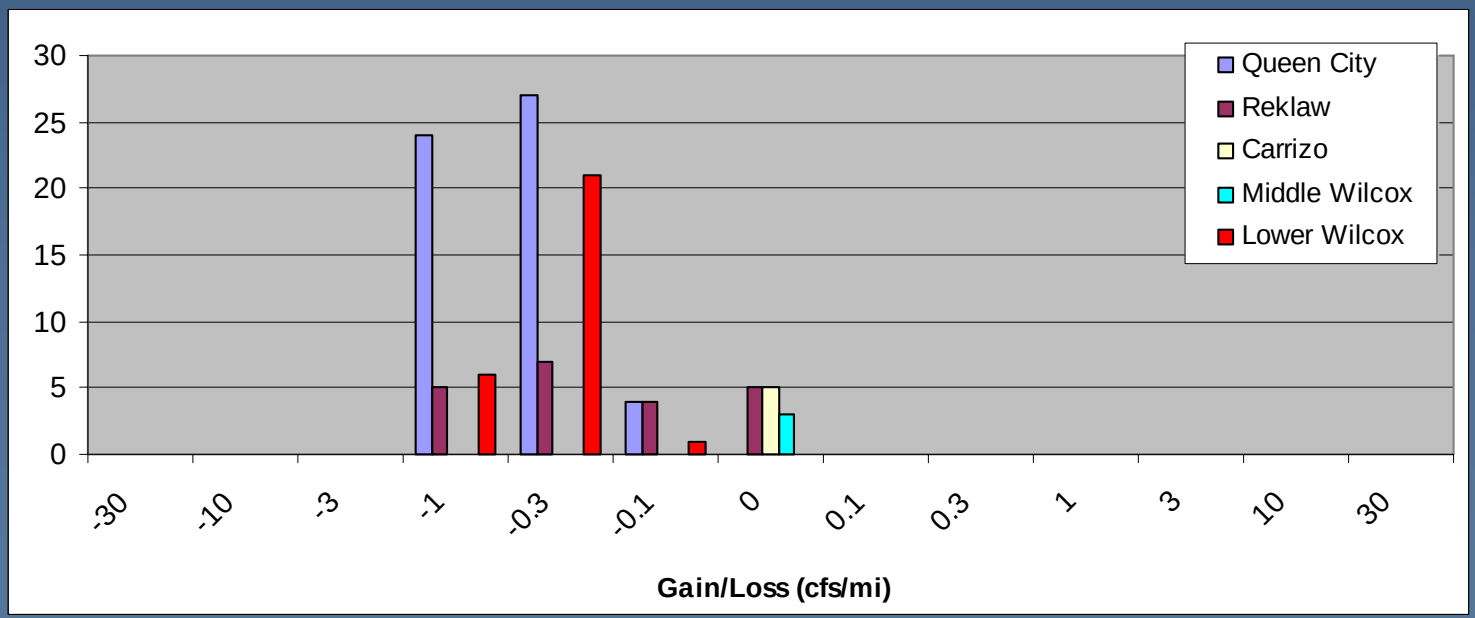
Stream Gain/Loss Results

Nueces River

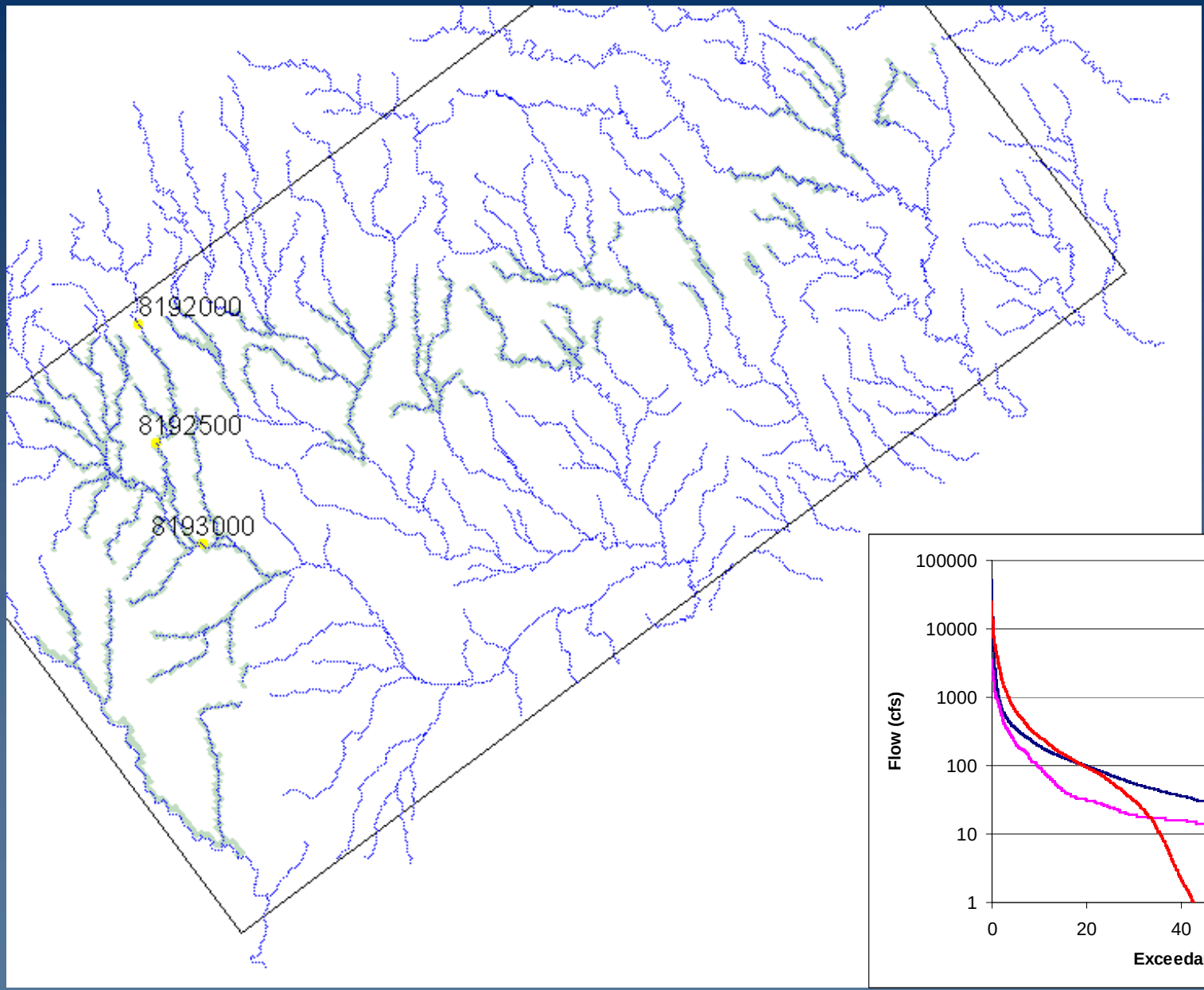
Slade



Model



Streamflow (Nueces)



Model Mass Balance (ft^3/day)

Inflow						
	Recharge	Stream	GHBs	Top	Bottom	Total
Queen City	14,370,000	766,000	1,039,000	0	17,400,000	33,575,000
Reklaw	5,026,000	836,000	0	5,063,000	18,306,000	29,230,000
Carrizo	7,841,000	465,000	0	7,841,000	16,053,000	32,200,000
Upper Wilcox	536,000	5,000	0	10,839,000	9,978,000	21,358,000
Middle Wilcox	9,761,000	513,000	0	5,070,000	9,991,000	25,335,000
Lower Wilcox	7,257,000	105,000	0	6,386,000	0	13,748,000
Model	44,790,000	2,690,000	1,039,000			155,446,000
Outflow						
	Recharge	Stream	GHBs	Top	Bottom	Total
Queen City	0	12,698,000	15,904,000	0	5,063,000	33,665,000
Reklaw	0	4,001,000	0	17,400,000	7,841,000	29,242,000
Carrizo	0	3,097,000	0	18,306,000	10,839,000	32,241,000
Upper Wilcox	0	235,000	0	16,053,000	5,070,000	21,358,000
Middle Wilcox	0	8,980,000	0	9,978,000	6,386,000	25,344,000
Lower Wilcox	0	3,768,000	0	9,991,000	0	13,759,000
Model	0	32,778,000	15,904,000			155,609,000

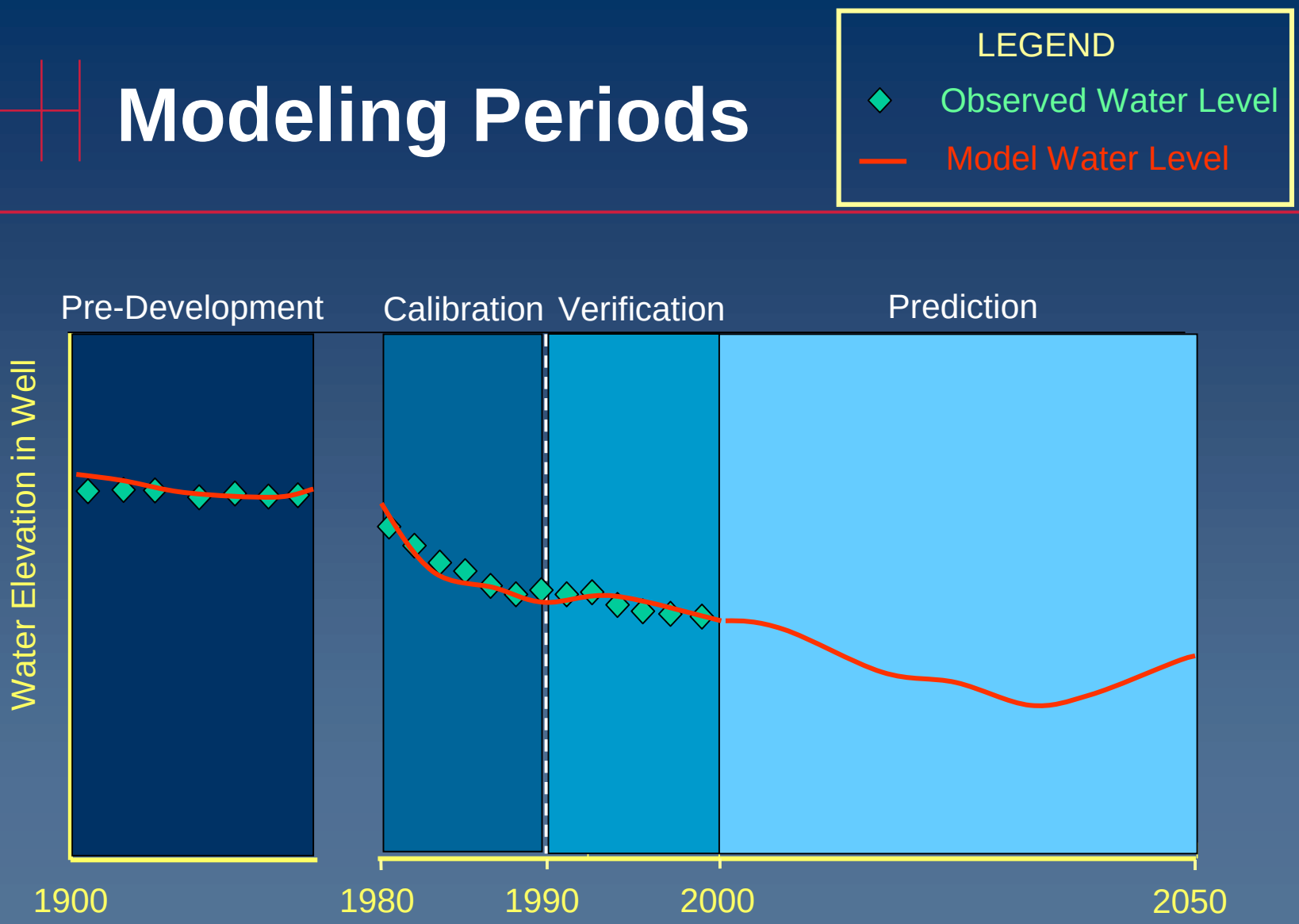
Model Mass Balance (%)

Inflow					
	Recharge	Stream	GHBs	Top	Bottom
Queen City	43	2	3	0	52
Reklaw	15	3	0	17	63
Carrizo	23	1	0	24	50
Upper Wilcox	2	0	0	51	47
Middle Wilcox	29	2	0	20	39
Lower Wilcox	22	1	0	46	0
Model	92	6	2		
Outflow					
	Recharge	Stream	GHBs	Top	Bottom
Queen City	0	38	47	0	15
Reklaw	0	14	0	60	27
Carrizo	0	10	0	57	34
Upper Wilcox	0	1	0	75	24
Middle Wilcox	0	35	0	39	25
Lower Wilcox	0	27	0	73	0
Model	0	67	33		

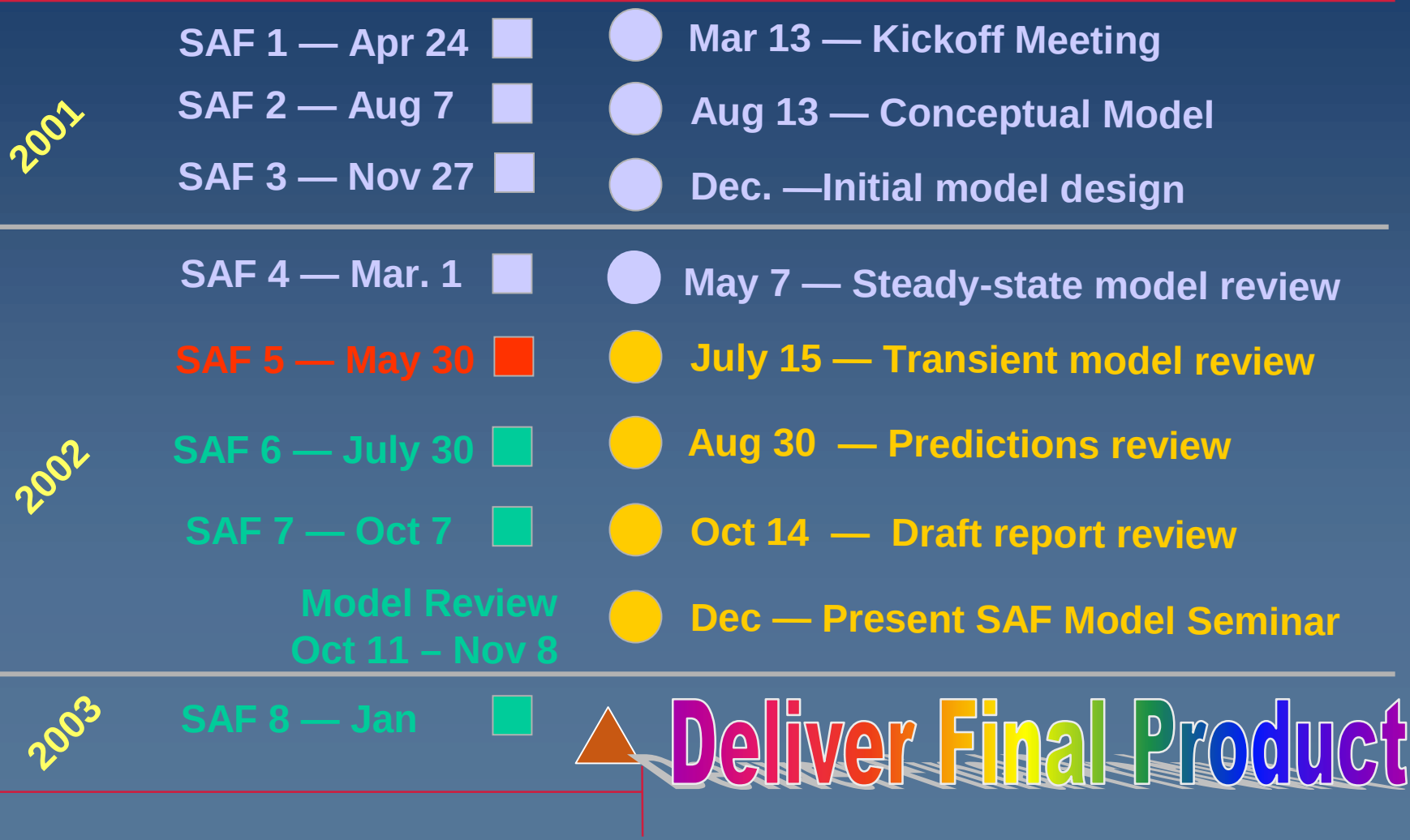
Expected SAF-6 Discussion

- Steady-state model sensitivity analysis
- Transient model parameterization
- Transient model calibration

Modeling Periods



Southern GAM Schedule



Meeting Minutes for the

Fifth Southern Carrizo-Wilcox Groundwater Availability Model (GAM) Stakeholder Advisory Forum (SAF) Meeting

May 30, 2002

Guaranty Bank Community Room

Gonzales, Texas

The fifth Stakeholder Advisory Forum (SAF) Meeting for the Southern Carrizo-Wilcox Groundwater Availability Model (GAM) was held on May 30th from 1:00 until 3:00 PM at the Guaranty Bank Community Room in Gonzales, Texas. Attachment A of these meeting minutes provides a list of all participants who signed up as attending the meeting.

The purpose of the fifth SAF meeting was to present a review of the model design and to present the steady-state (predevelopment) model calibration results. The presentation also reviewed the GAM objectives and expectations as is done in all SAF presentations. The presentation material is available at the TWDB GAM website (www.twdb.state.tx.us/gam).

Meeting Introduction: Ted Angle, TWDB, Barry Miller, GonzalesCounty UWCD

The meeting was initiated by Ted Angle of the Texas Water Development Board (TWDB). Mr. Angle provided a brief overview of upcoming GAMs and a summary of progress on currently active GAMs. Barry Miller welcomed the meeting participants to Gonzales.

SAF Presentation: Van Kelley, INTERA

After the introduction by Mr. Angle, Van Kelley, Project Manager for the INTERA Southern Carrizo-Wilcox Team presented a prepared presentation. The presentation was structured according to the following outline:

1. Review of the GAM Project, Objectives, and Expectations
2. Model Design: Conceptual Model Review
3. Model Design: Model Structure/Layers
4. Model Design: Hydraulic Head Review
5. Model Design: Model Boundaries
6. Model Design: Recharge
7. Model Design: Hydraulic Properties
8. Model Calibration: Steady-State Model Results
9. GAM Schedule: SAF Meetings and Project Milestones

The presentation is available on the GAM website (*www.twdb.state.tx.us/gam)*.

Questions and Answers: Open Forum:

Q. Is the recharge shown for the Carrizo-Wilcox aquifer or for the Carrizo only?

A. Recharge was calculated for all outcrop areas, including the Wilcox, Carrizo, Reklaw, Bigford, Queen City, and El Pico formations.

Q. What is the recharge in the vicinity of Gonzales?

A. Recharge calculated near Gonzales ranges from about one to three inches. Barry Miller noted that this range agrees with recharge estimates used by GCUWCD (10% of precipitation).

Q. Is the SAF presentation available on the internet?

A. The SAF 5 presentation is posted at the GAM website (*www.twdb.state.tx.us/gam)*.

Q. Are there hydrographs available for other counties than those shown in the presentation?

A. Hydrographs have been plotted for most of the counties in the model area for use in the transient calibration.

Q. What does the steady-state model indicate about cross-formational flow in the vicinity of the Guadalupe River?

A. Generally, flow under pre-development conditions is upward near the Guadalupe River.

Q. Is leakage along the annulus of wells causing calibration problems?

A. This is not a problem for the pre-development steady-state model, but may be an issue during transient calibration.

Q. Is the scheduled January 2003 completion date "set in stone?"

A. The date for final GAM reports is a hard deadline.

Q. What will be the source of pumping volumes for the predictive simulations?

A. Pumping estimates from the current regional water plans will be used for the predictive simulations for inclusion in the final GAM report. Once the model is finished and made available to stakeholders, new pumping estimates can be incorporated.

Q. Can the model be used for evaluating ASR?

A. Yes.

Q. Can the model be used to determine sustainable pumping?

A. Yes.

Q. Region L adopted sustainability as a goal. Can the model be used to determine sustainable pumping levels?

A. Yes.

Q. What is the source of the recharge values? The water plan for Wilson County shows about twice as much recharge as pumpage, but water levels are still declining.

A. Recharge estimates for the model were developed using the Soil and Water Assessment Tool (SWAT), a physically based watershed scale model.

ATTACHMENT A: SIGN-UP SHEET

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