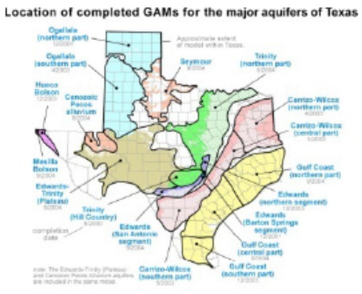
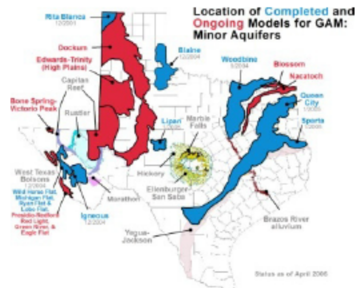
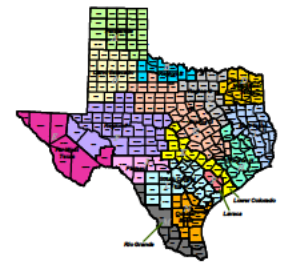
Groundwater Availability Modeling







Cindy Ridgeway

Contract Manager

Rustler Aquifer Groundwater Availability Model (GAM)

Texas Water Development Board

GAM Program

- **Purpose:** to develop groundwater flow models to help GCDs, RWPGs, and others with managing their groundwater resources
- **Public process**: encouraged and continue to encourage stakeholder participation in model development and model improvements
- **Freely available**: standardized, thoroughly documented, with reports available over the internet
- **Living tools**: periodically updated

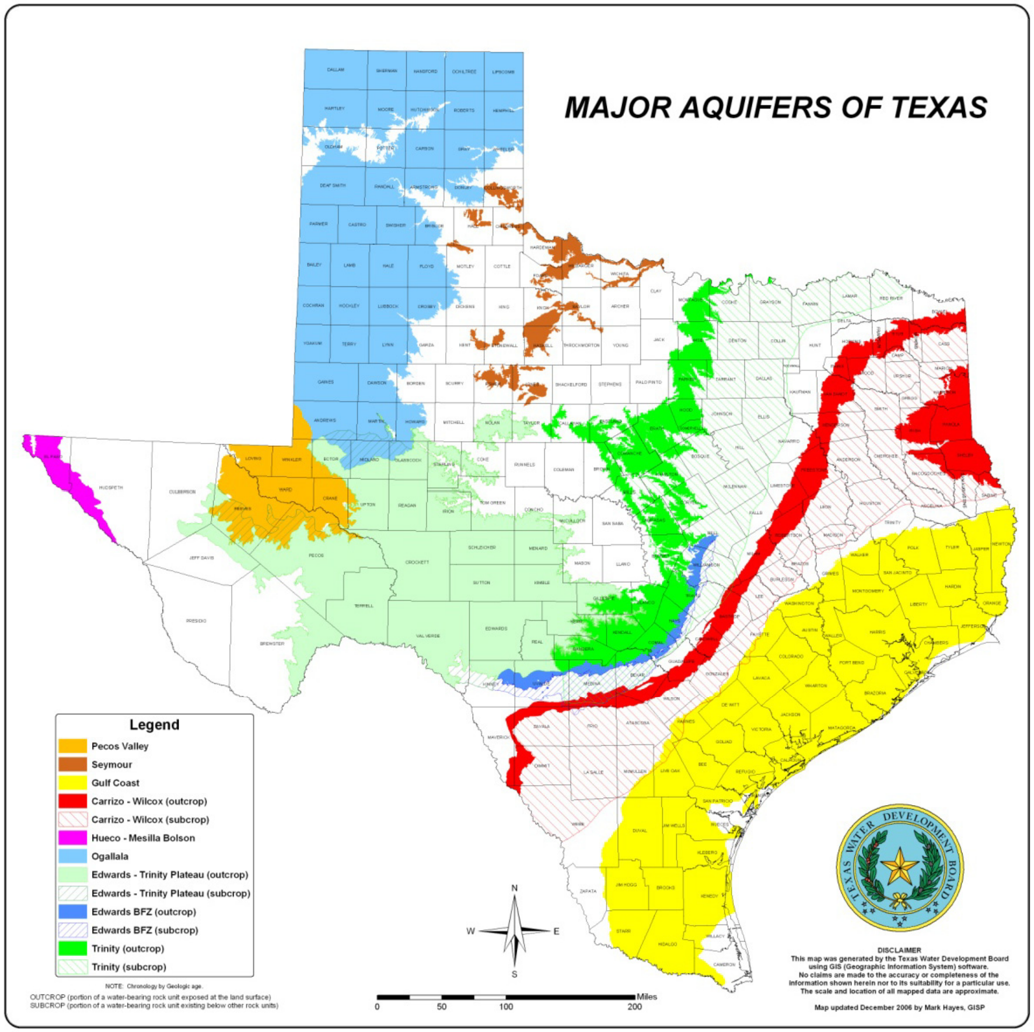
What is Groundwater Availability?

Science + Policy = Groundwater Availability

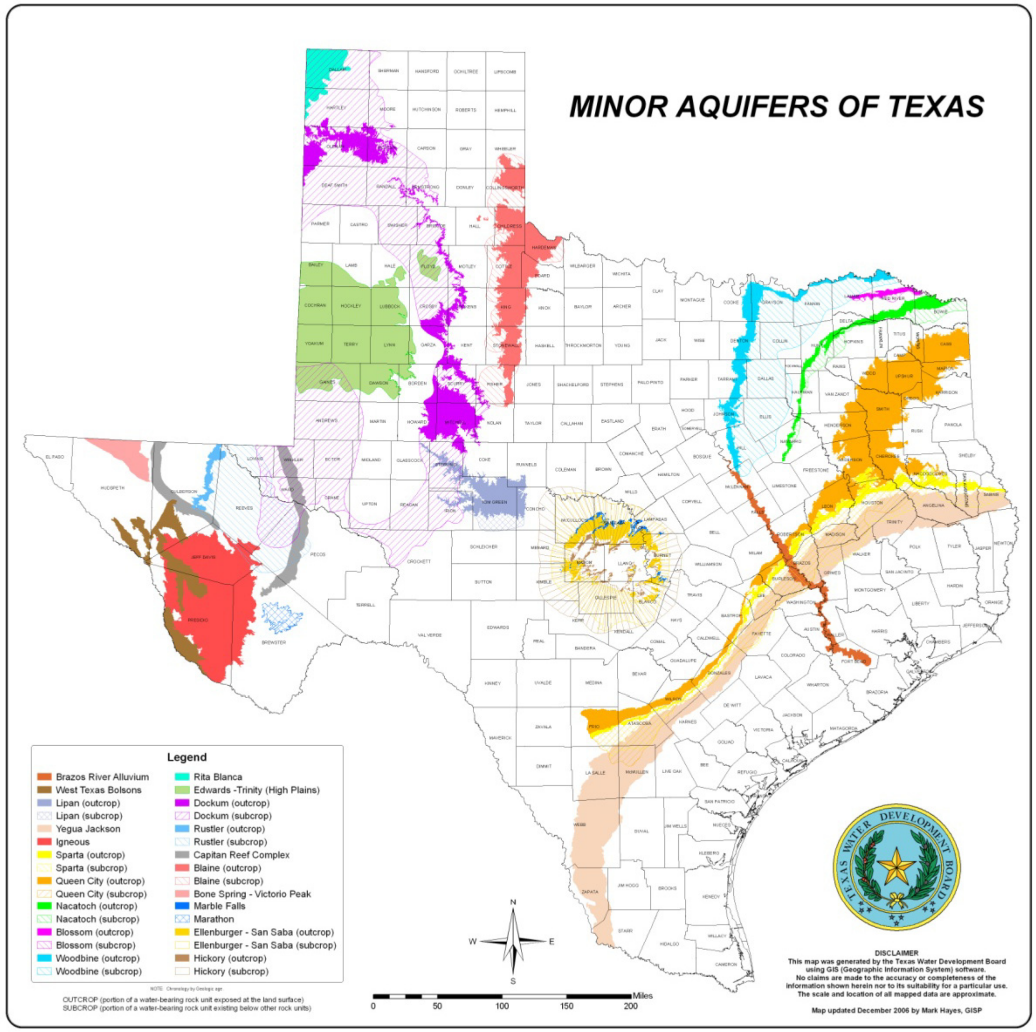
GAM or other tool + Desired Future Conditions = Modeled Available Groundwater

Goal: informed decision-making

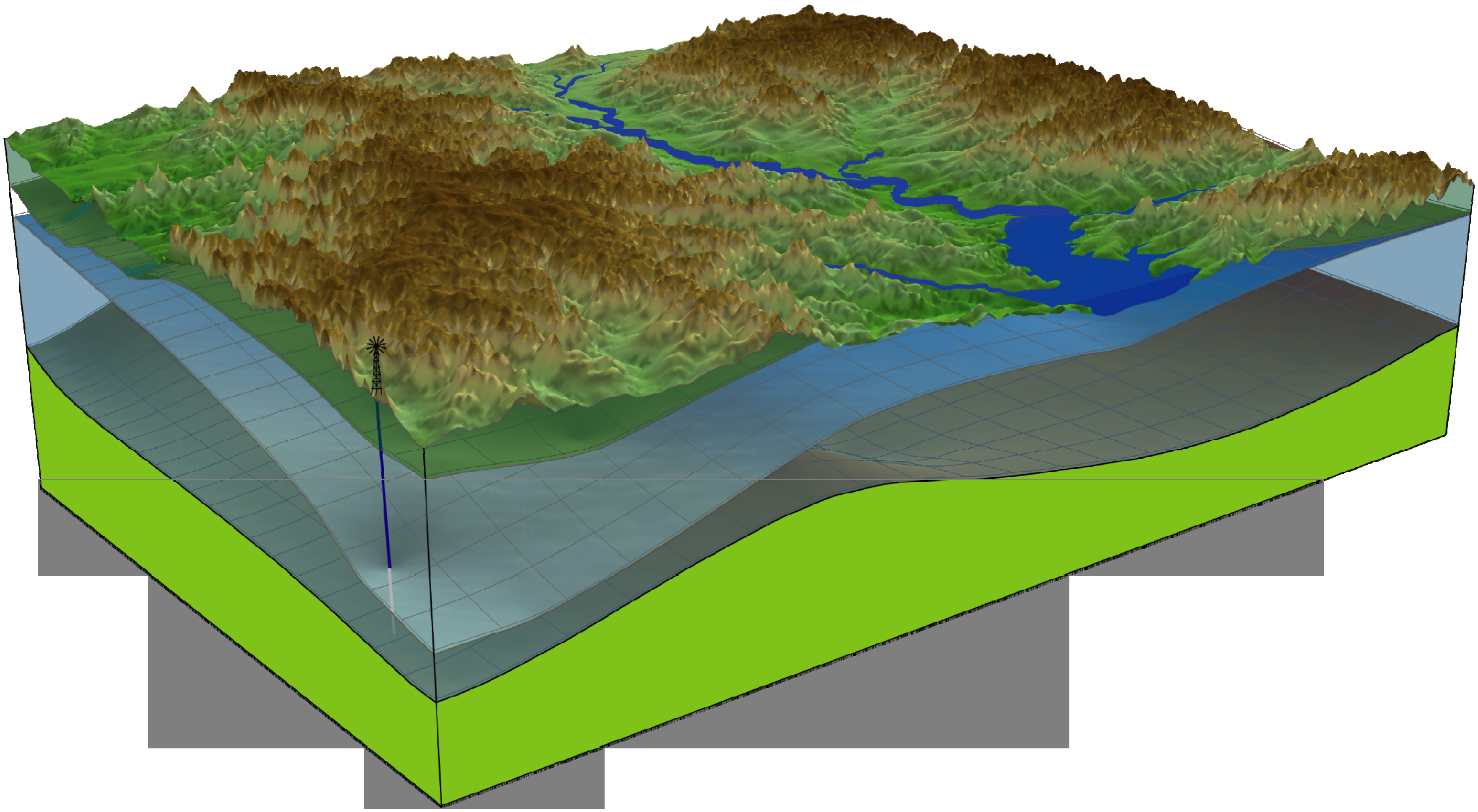
Major Aquifers



Minor Aquifers



Groundwater Model



How we use Groundwater Models

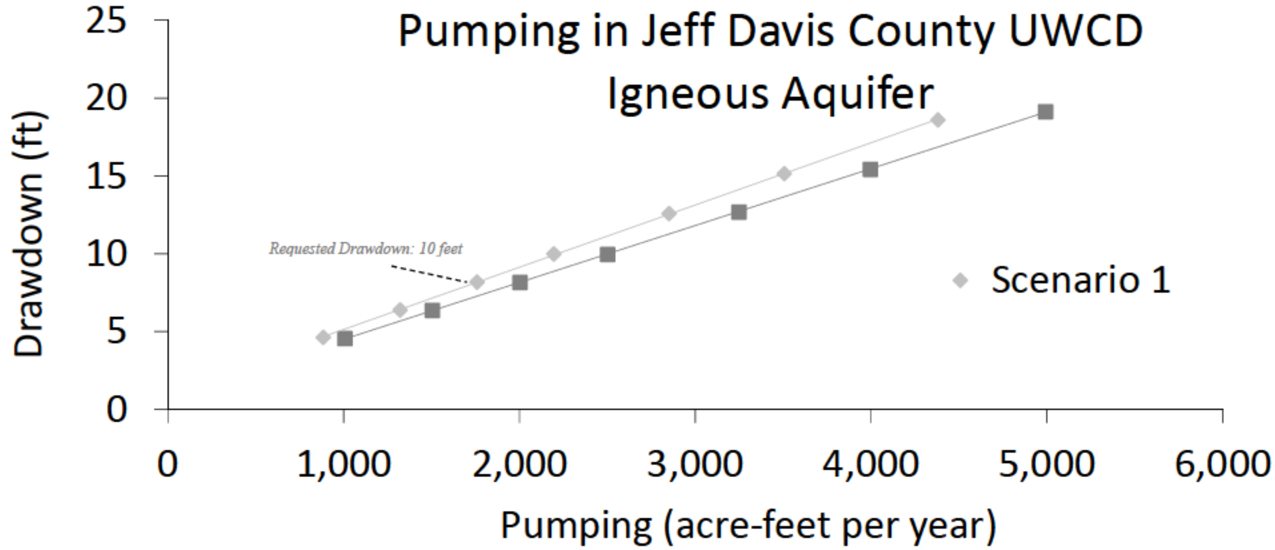
- Inform groundwater districts about historical conditions in the aquifer

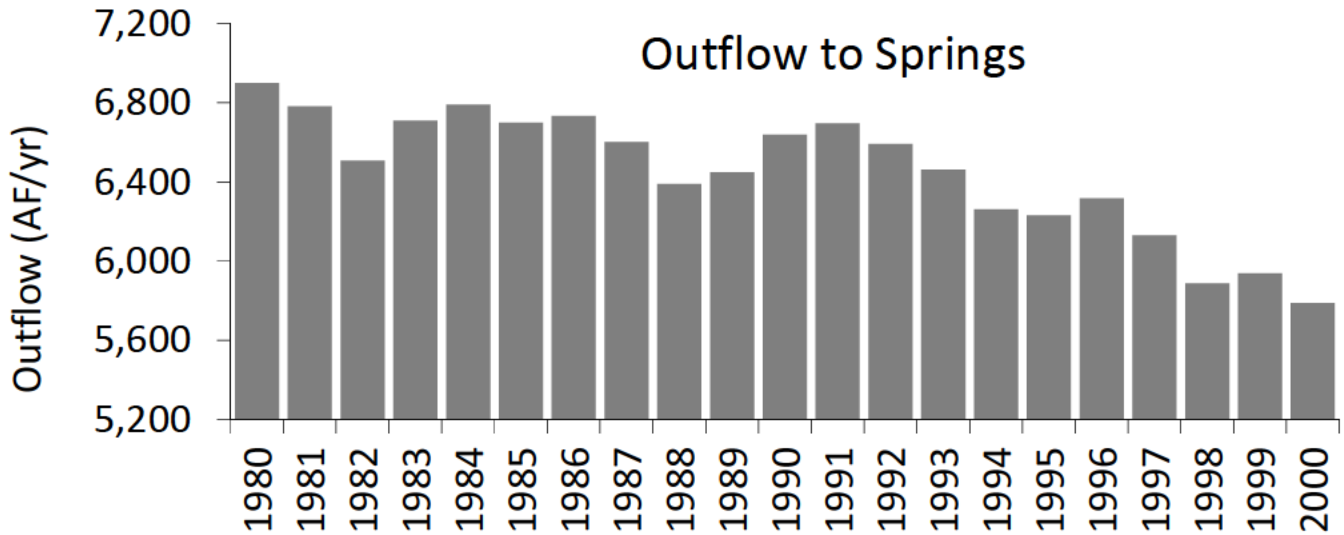
Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Edwards-Trinity (Plateau) Aquifer	140,509
	Pecos Valley Aquifer	14,115
	Dockum Aquifer	0
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Edwards-Trinity (Plateau) Aquifer	31,222
	Pecos Valley Aquifer	9,804
	Dockum Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	32,993
	Pecos Valley Aquifer	3,441
	Dockum Aquifer	554

How you use Groundwater Models

- Determine desired future conditions (DFCs)

DFC: Desired, quantified condition of groundwater resources (such as water levels, water quality, spring flows, or volumes) for a specified aquifer within a management area at a specified time or times in the future.

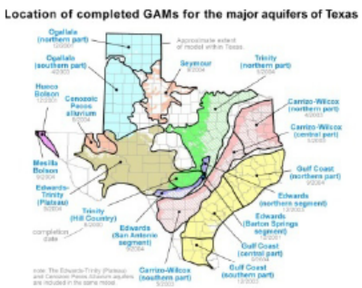


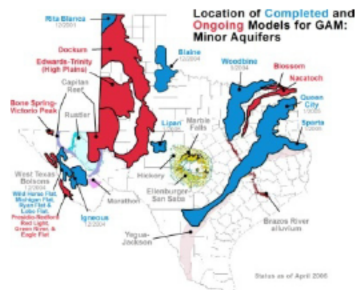


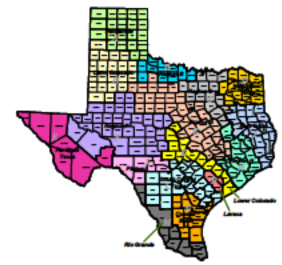
Stakeholder Advisory Forums

- Keep updated about progress of the model development
- Understand how the groundwater model can, should, and should not be used
- Provide input and data to assist with model development

Contact Information





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http://www.twdb.texas.gov/groundwater/

http://www.twdb.texas.gov/groundwater/models/gam/rslr/rslr.asp

Stakeholder Advisory Forum 3
Groundwater Availability Model for the Rustler Aquifer

July 6, 2012

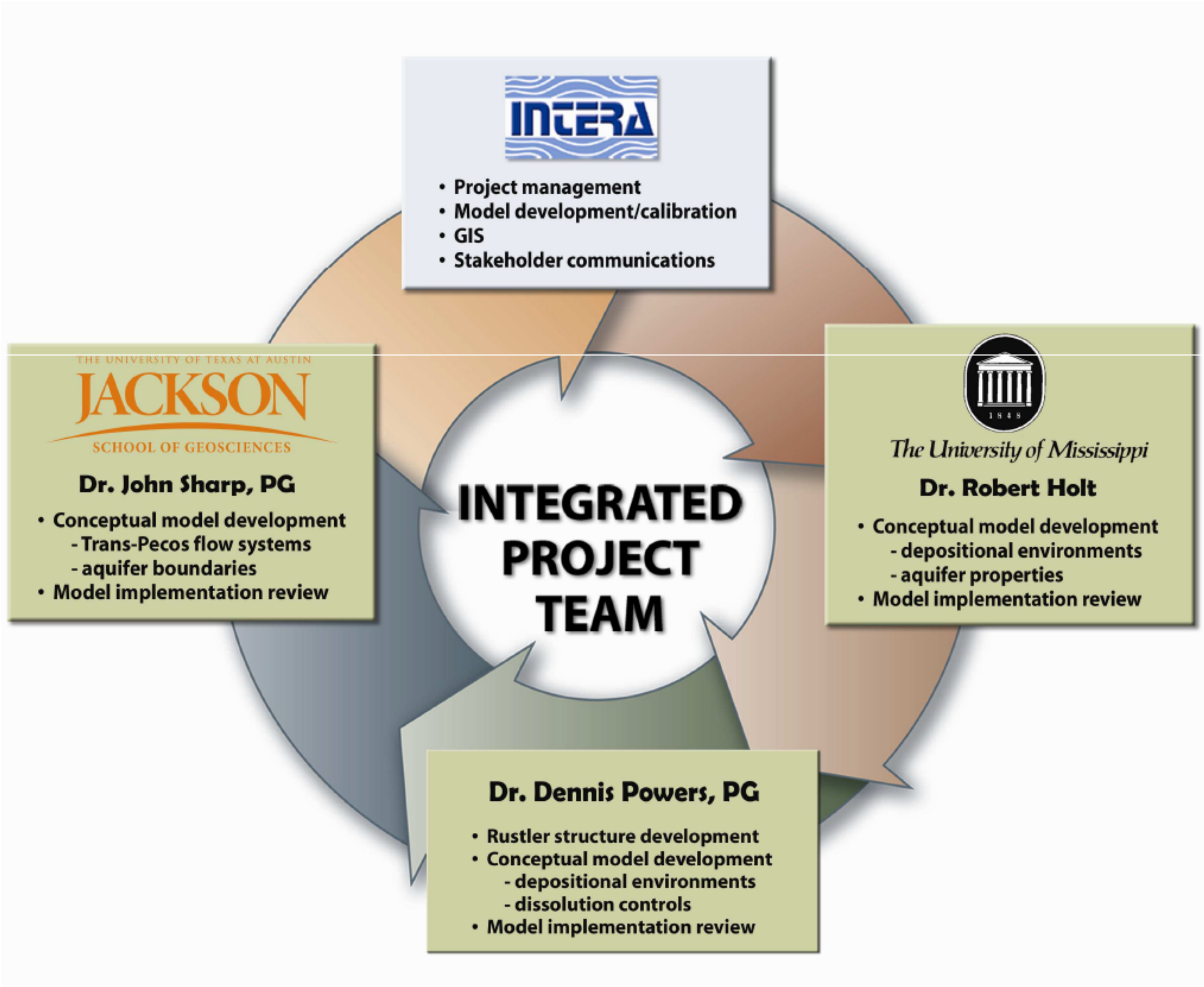
John Ewing, P.E.
Van Kelley, P.G.

Dr. Dennis Powers, P.G.
Dr. Jack Sharp, P.G.
Dr. Bob Holt

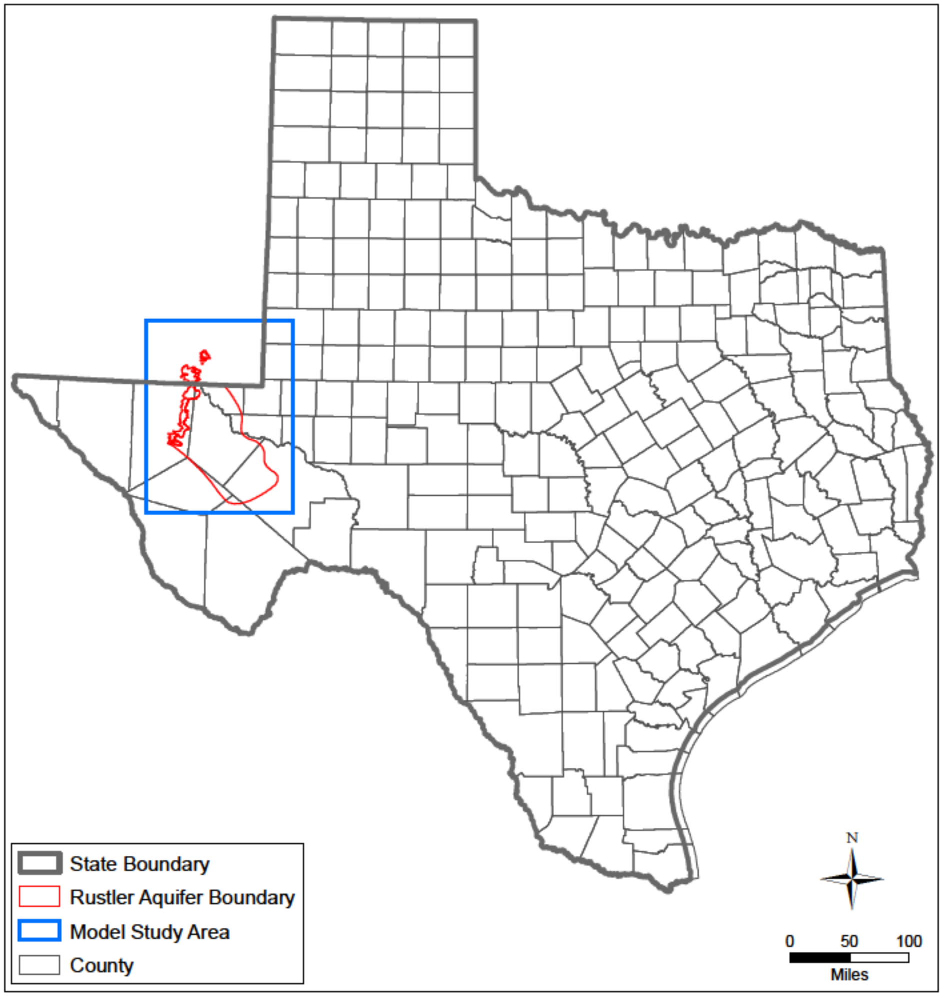
Outline

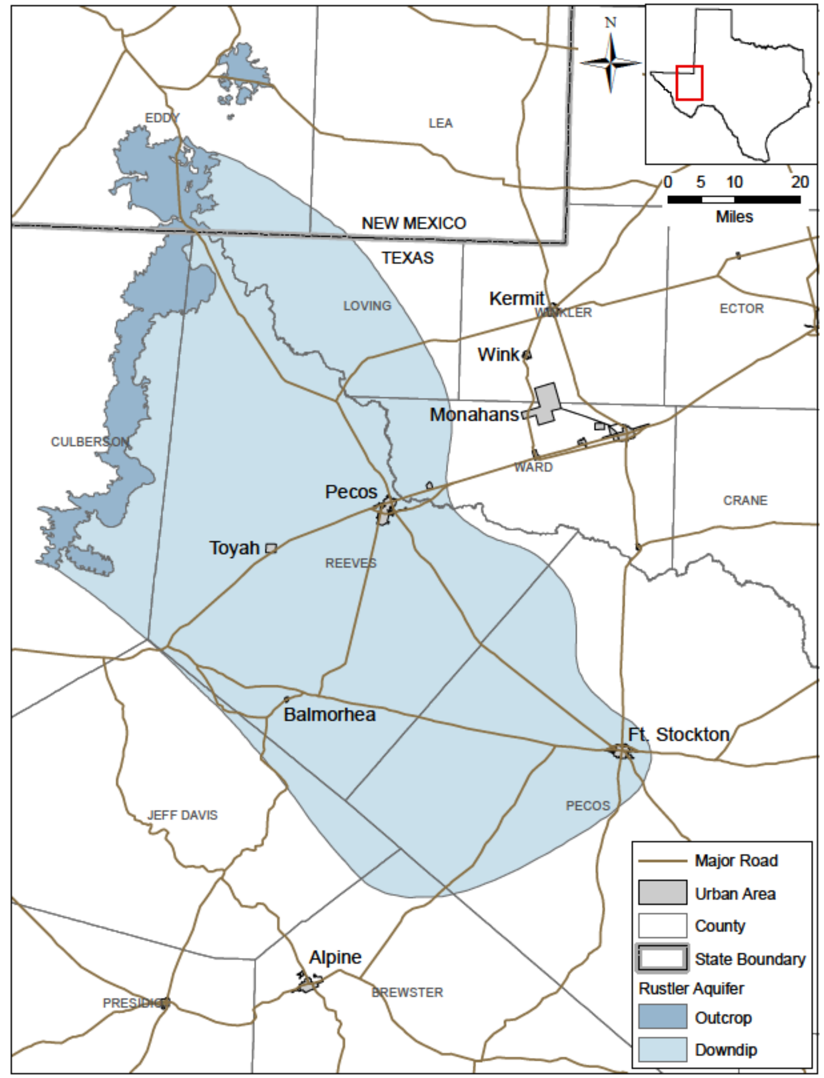
- Review of Study Area
- Review of Rustler Aquifer Conceptual Model for Groundwater Flow
- Rustler Aquifer GAM Implementation
- Rustler Aquifer GAM Calibration
- Recommendations and Limitations of Study

Project Team and Responsibilities



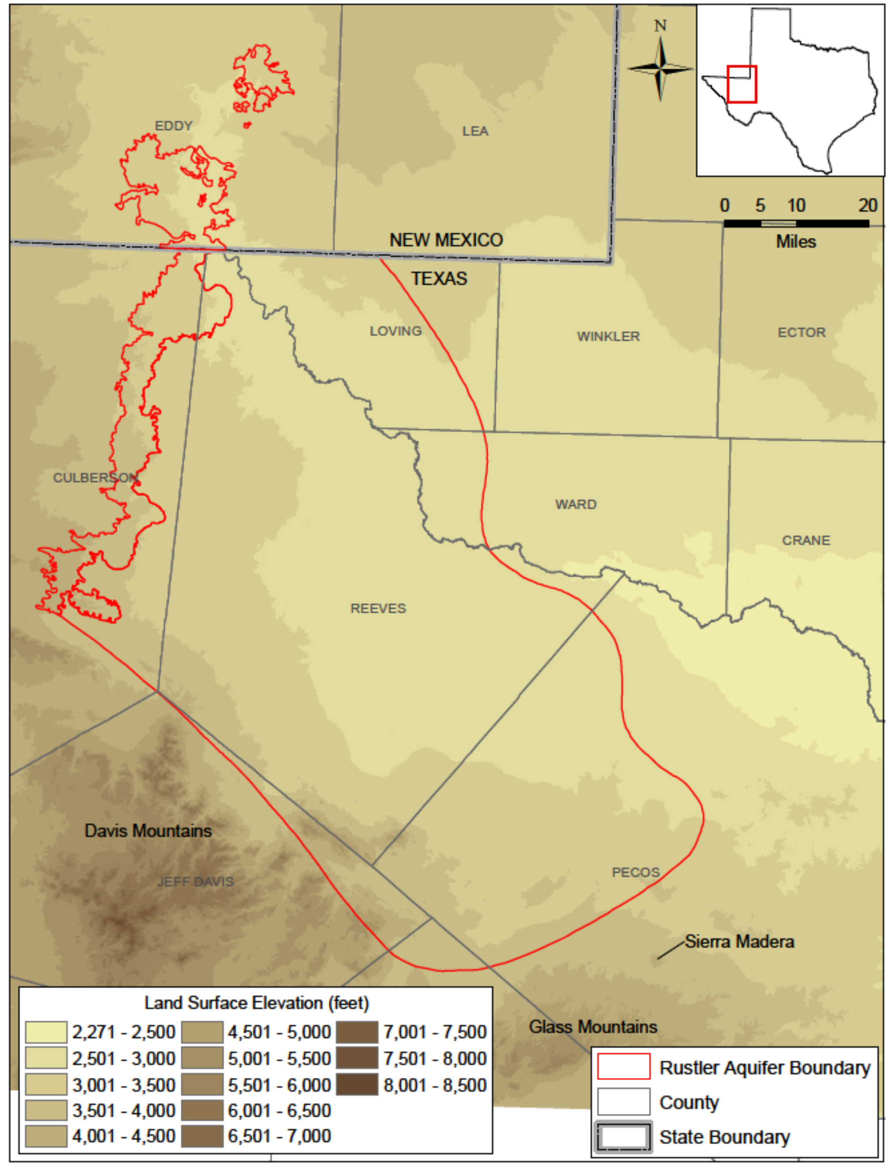
Aquifer Study Area





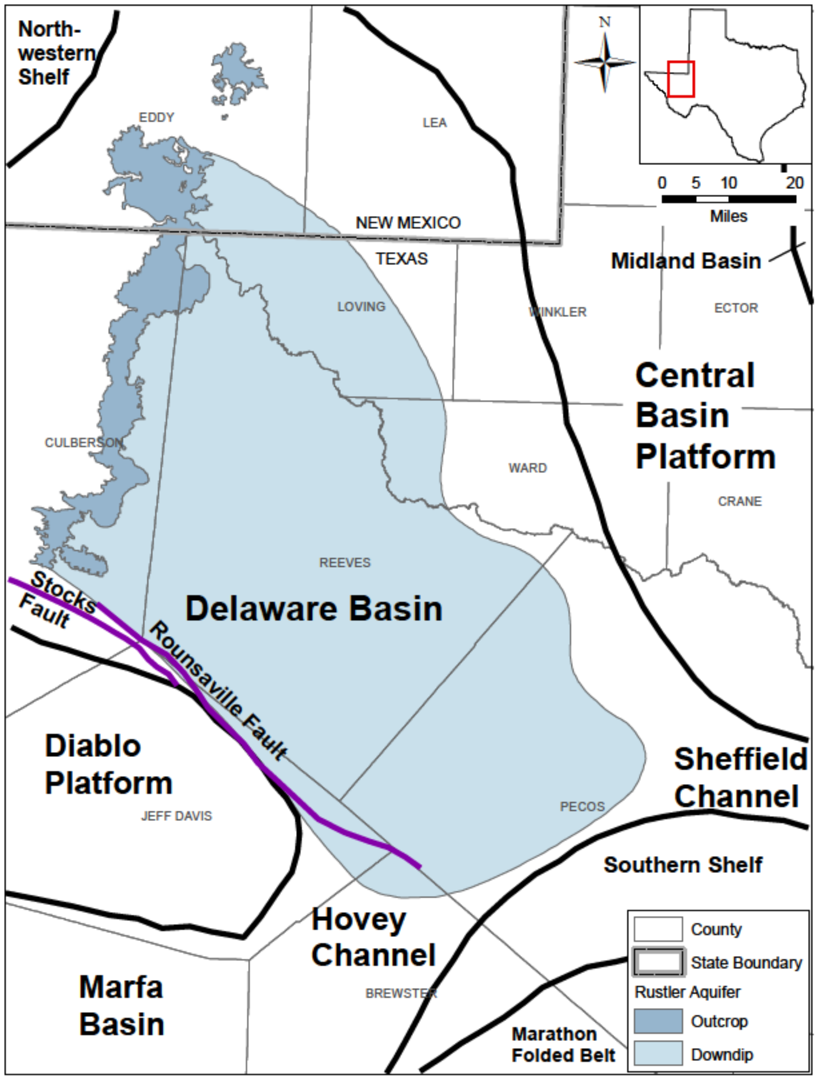
INTERA

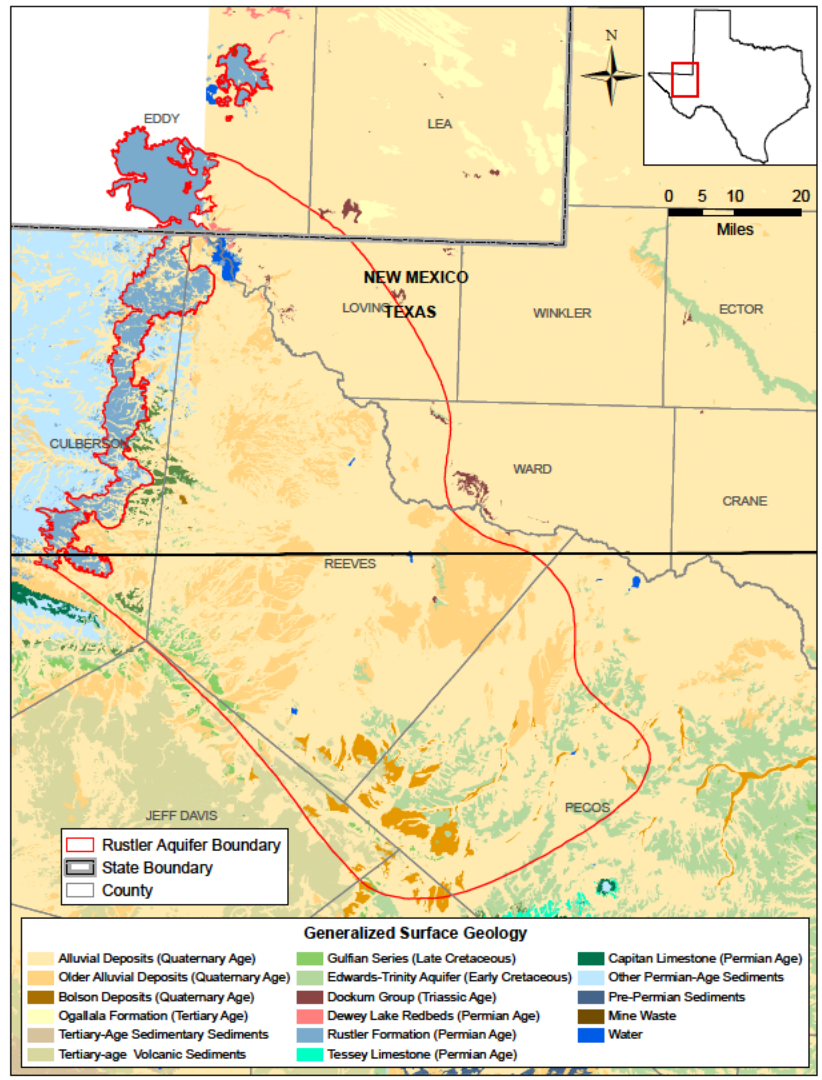
Topography



INTERA

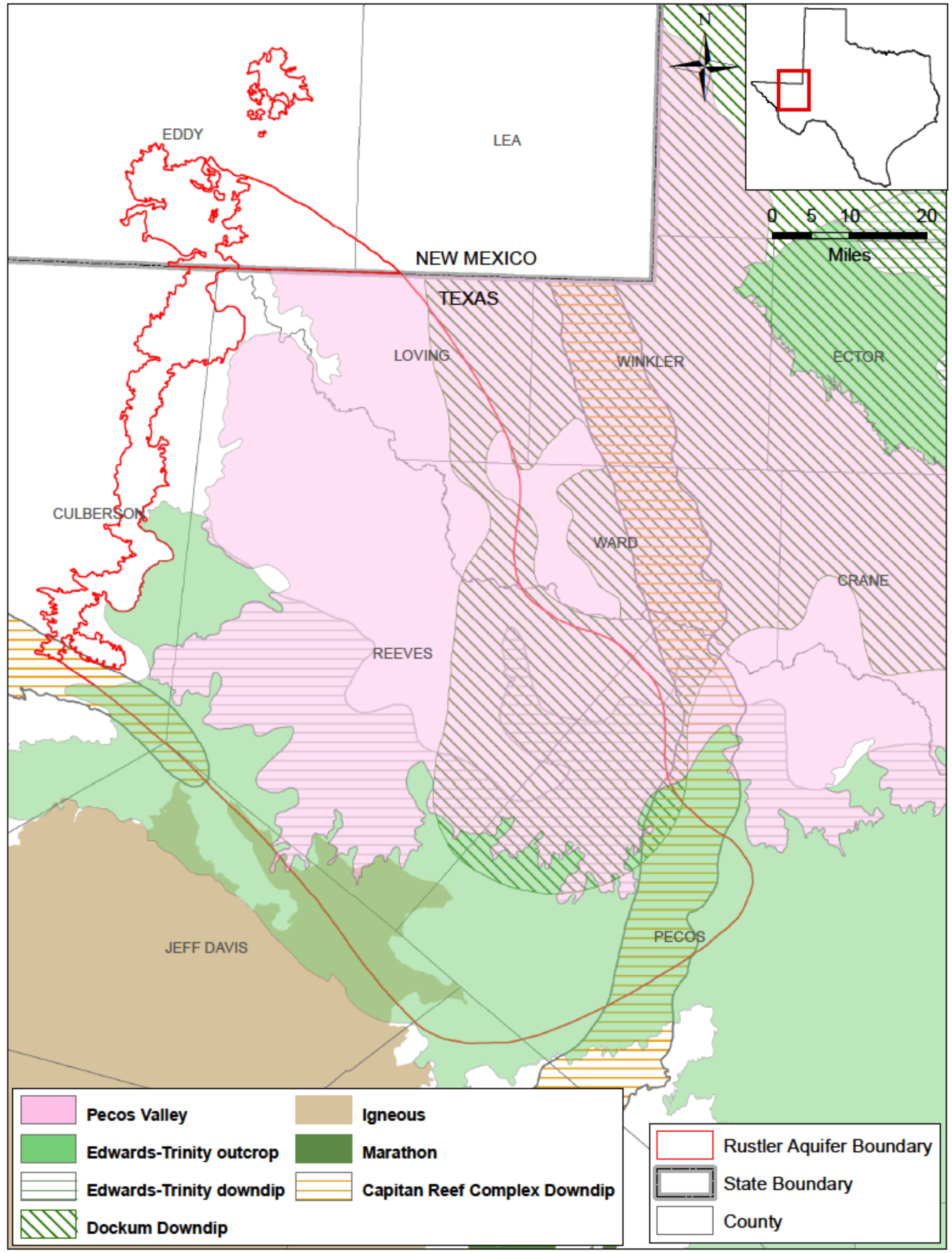
Structure Features/Surface Geology





Other Aquifers in the Study Area

- Major
  - Pecos Valley
  - Edwards-Trinity Plateau
- Minor
  - Dockum
  - Capitan
  - Igneous
  - Marathon

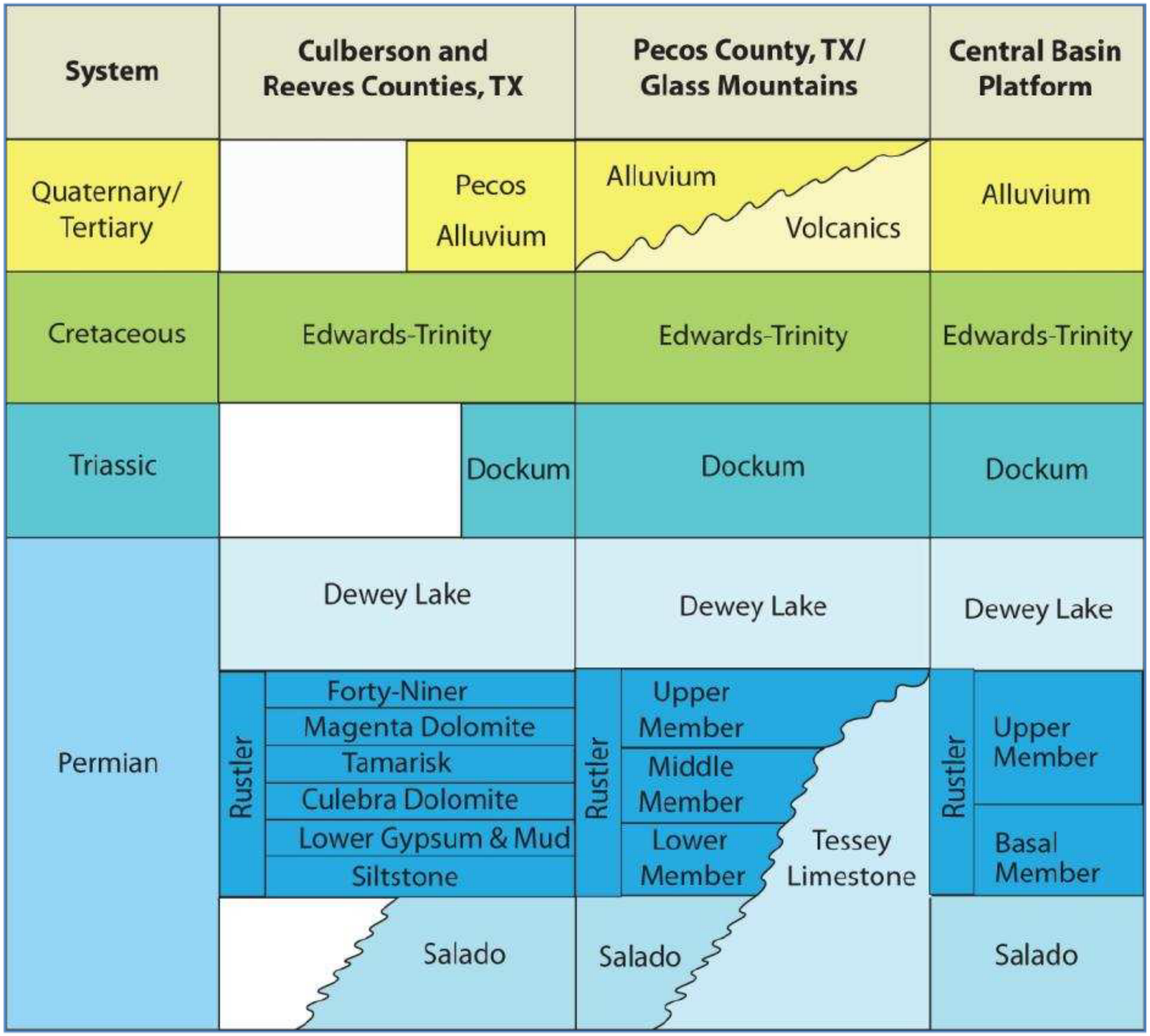


INTERA

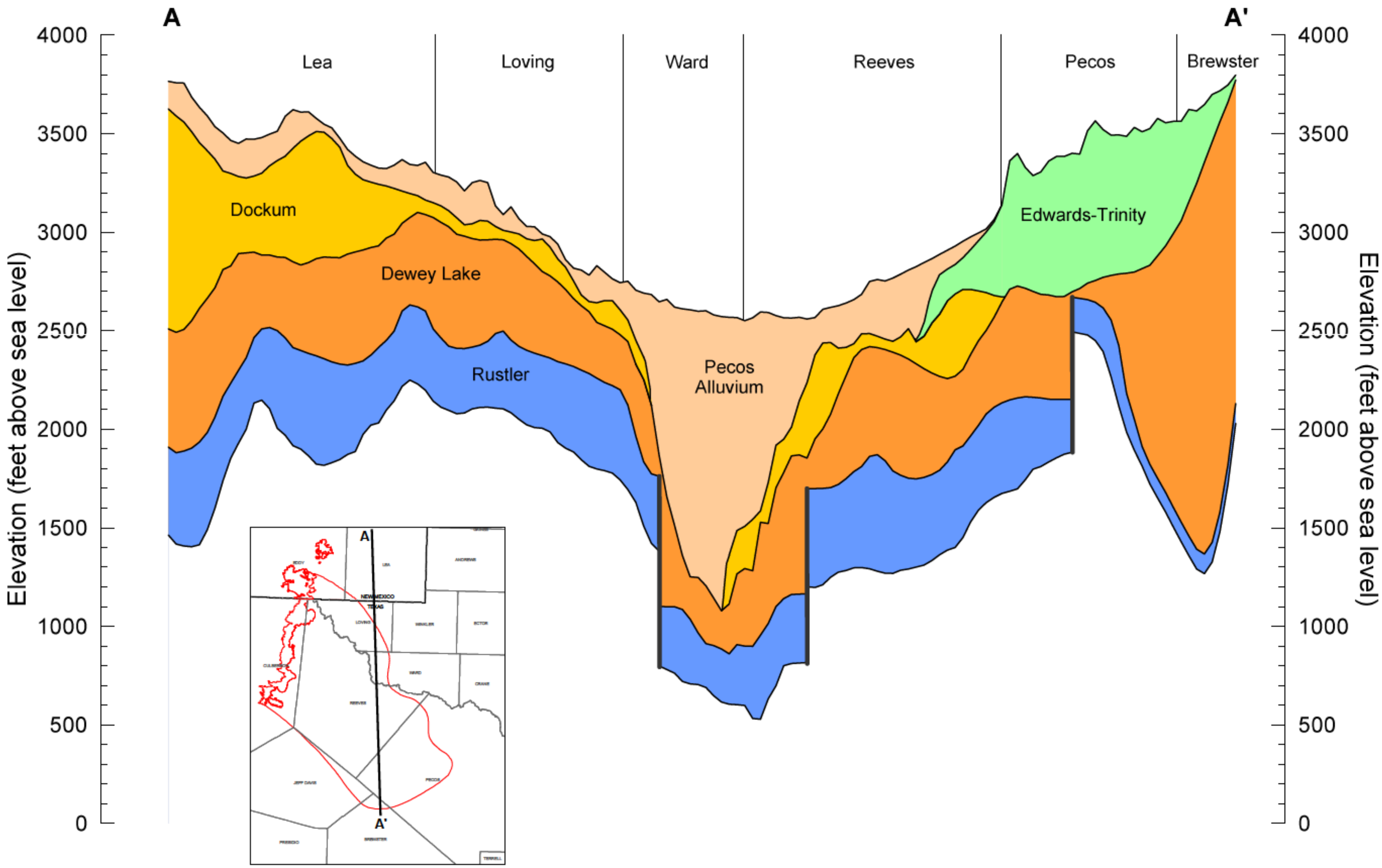
Review of the

CONCEPTUAL MODEL FOR GROUNDWATER FLOW

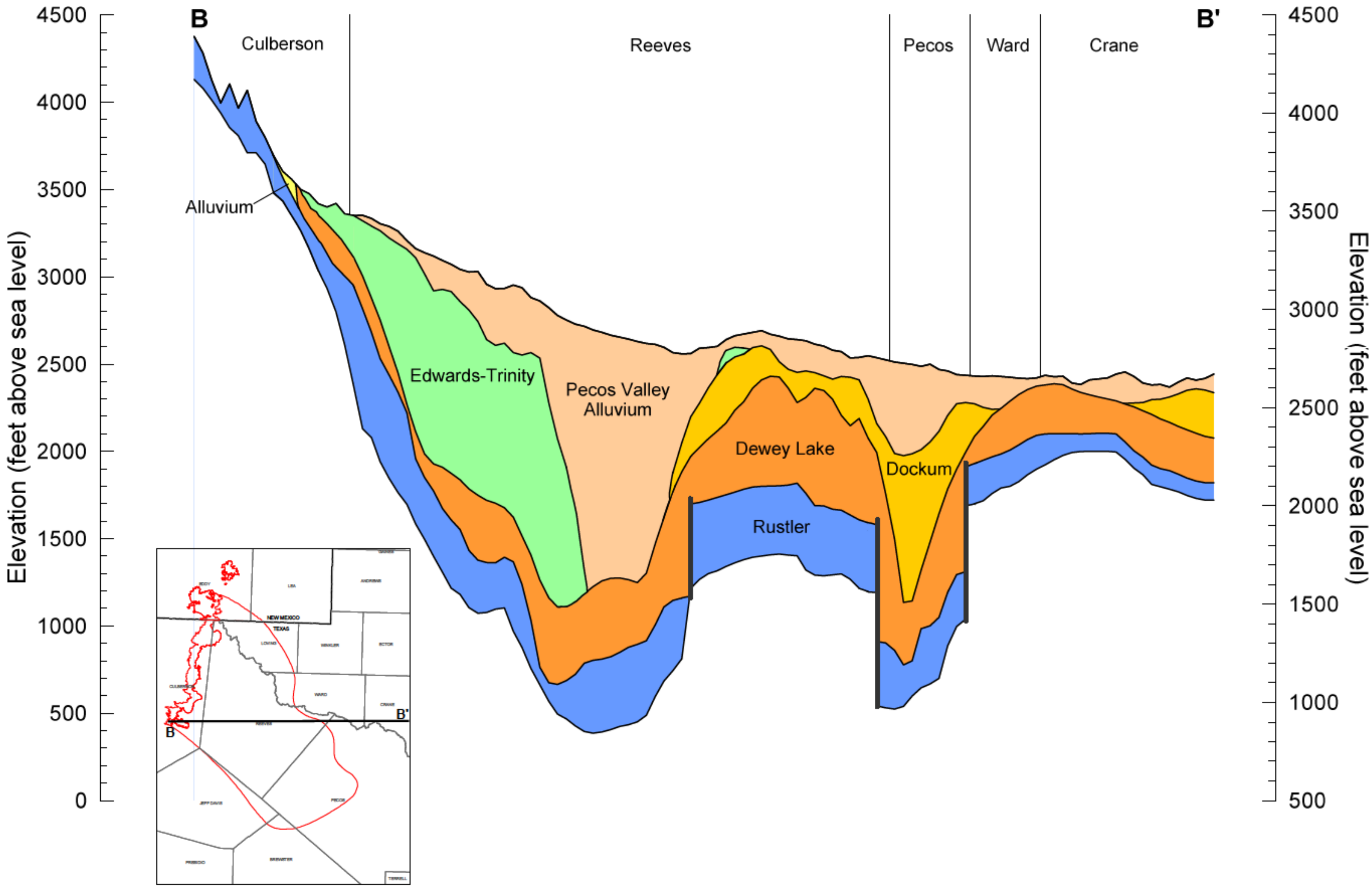
General Regional Stratigraphy



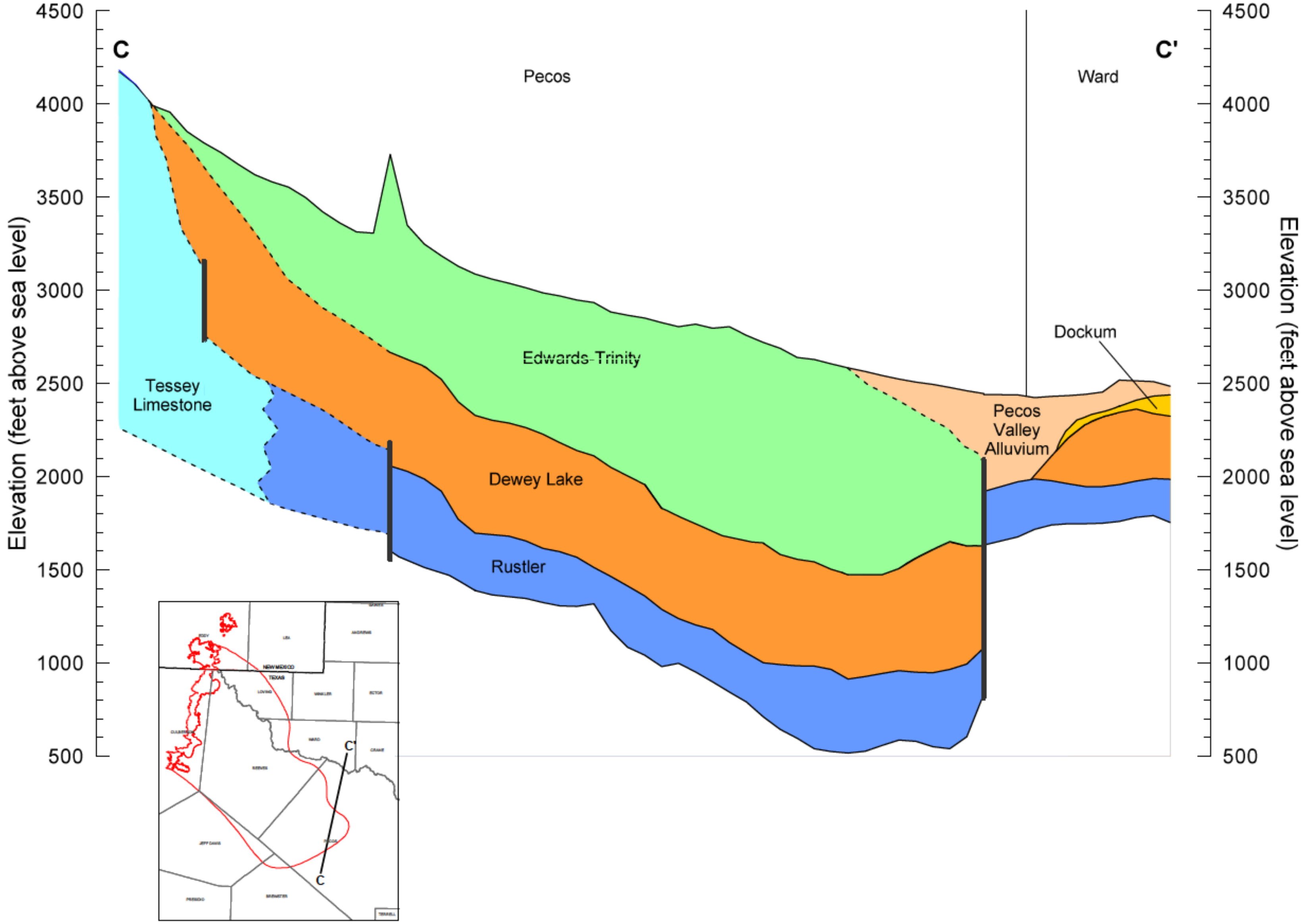
North-South Cross-Section



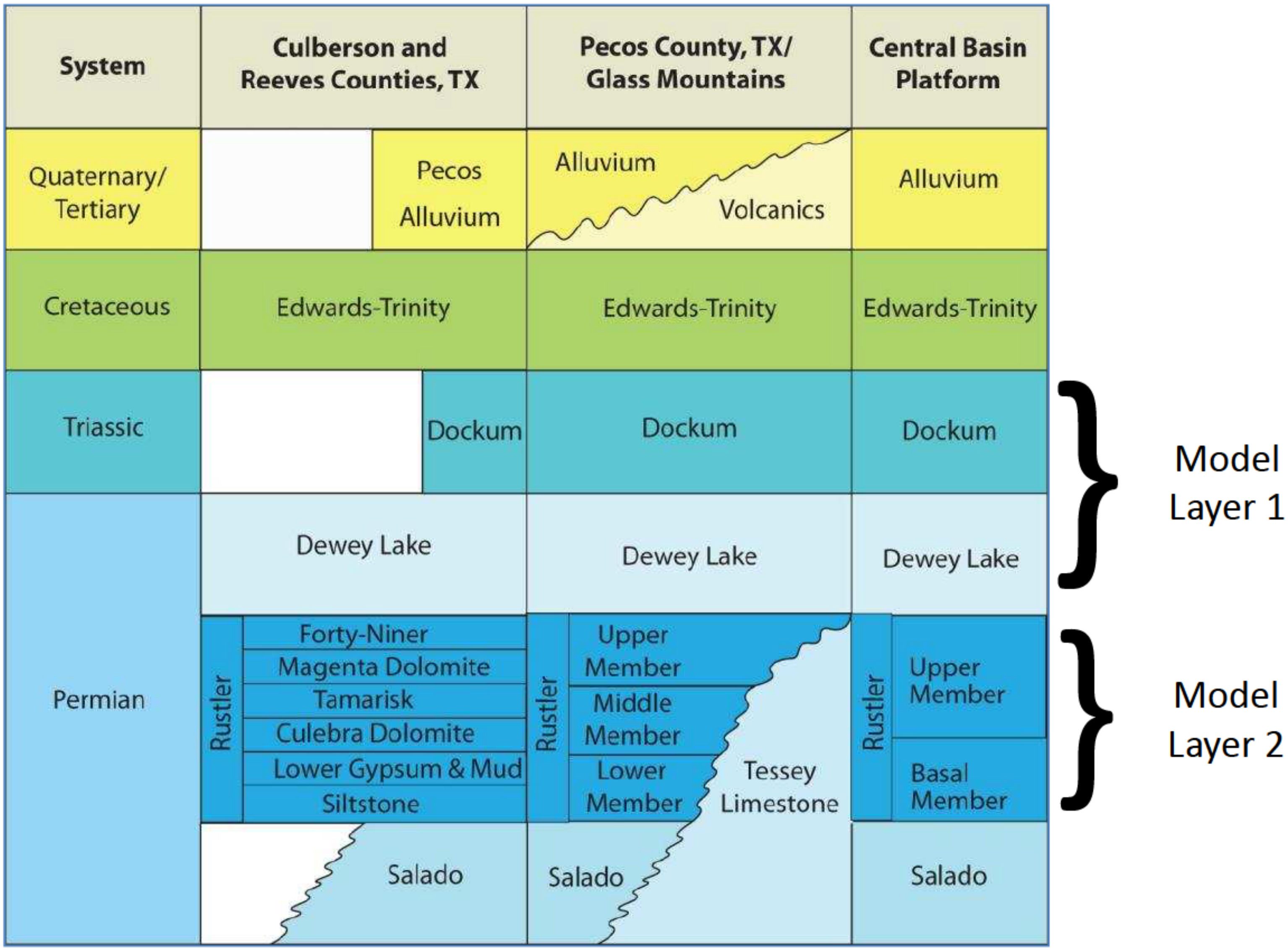
East-West Cross-Section



Southwest-Northeast Cross-Section



General Regional Stratigraphy

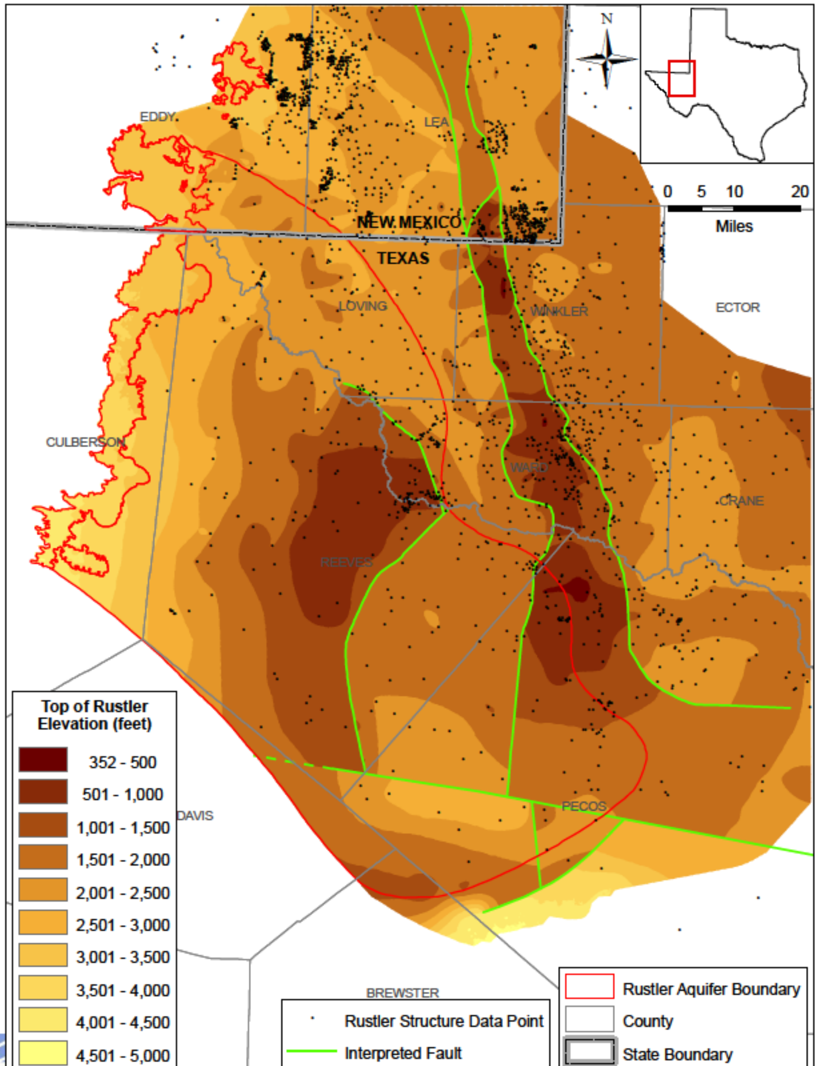


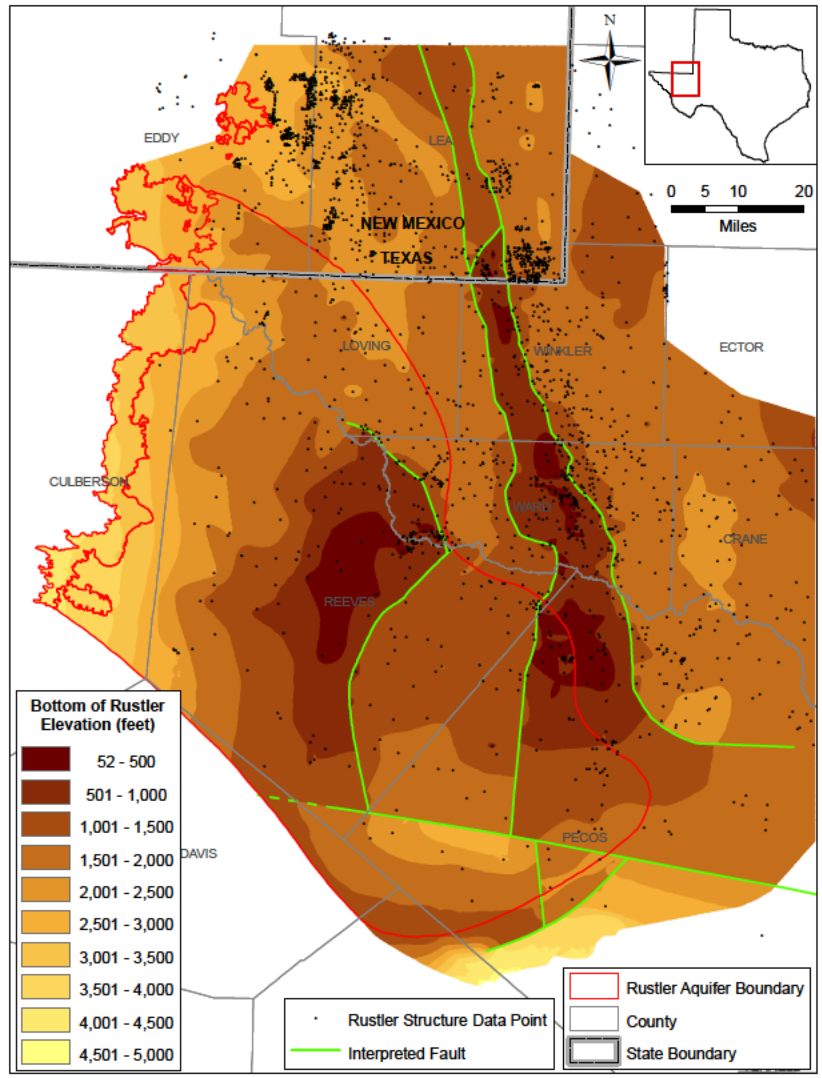
Rustler Structure Source Data

- Hiss (1976)
- 2,305 electric logs interpreted by Powers in this study
- 1,953 electric logs interpreted by BRACs (Myers)
  - Younger interval contacts from BRACs
  - Known collisions with current GAMs
- Hand contoured surfaces that were later digitized

INTERA

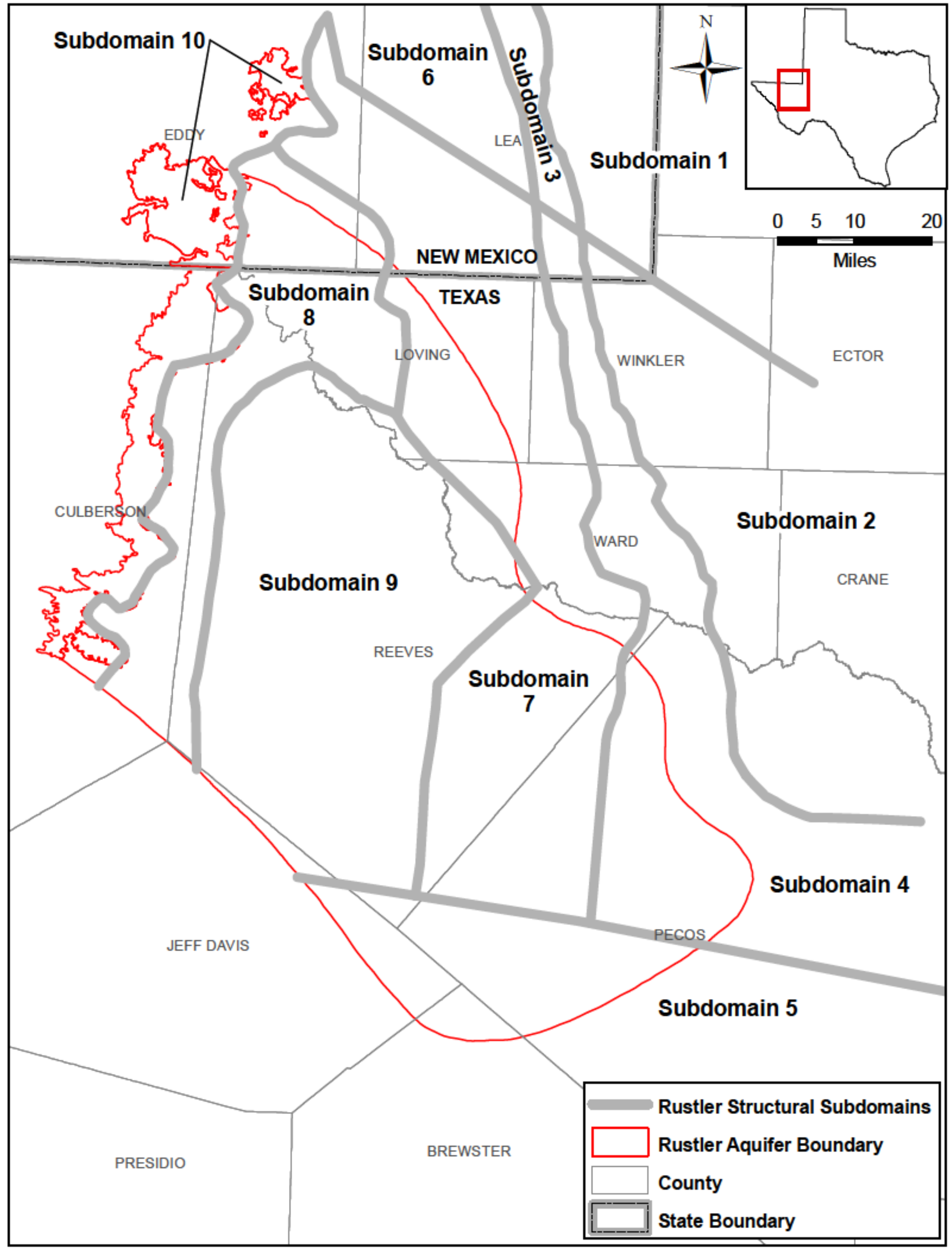
Rustler Top & Bottom Elevations





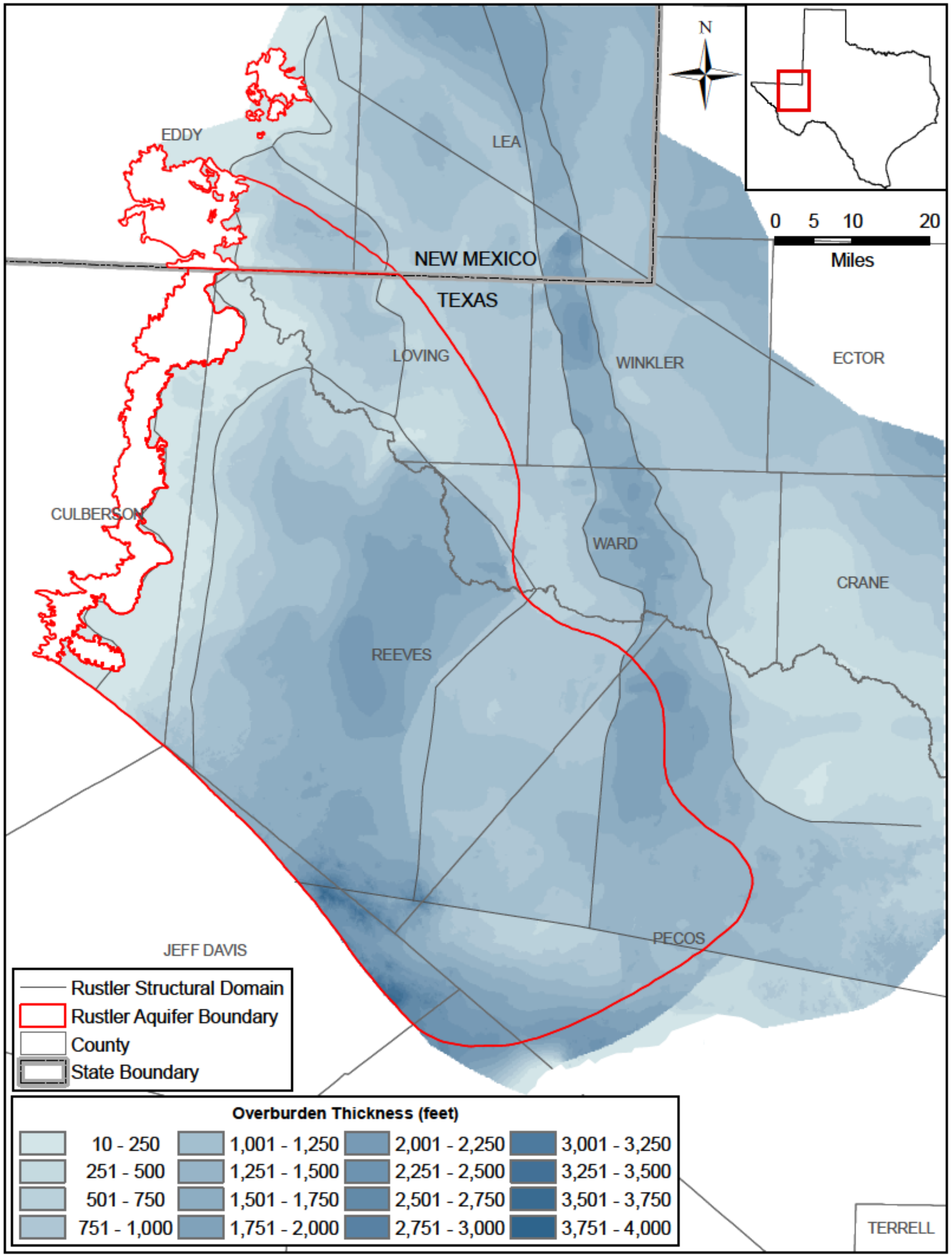
Structural Domains

- Zones defined as being structurally similar based upon
  - Outcrop/subcrop
  - Depth of burial
  - Aquifer stratigraphy/ mineralogy
  - Salado dissolution



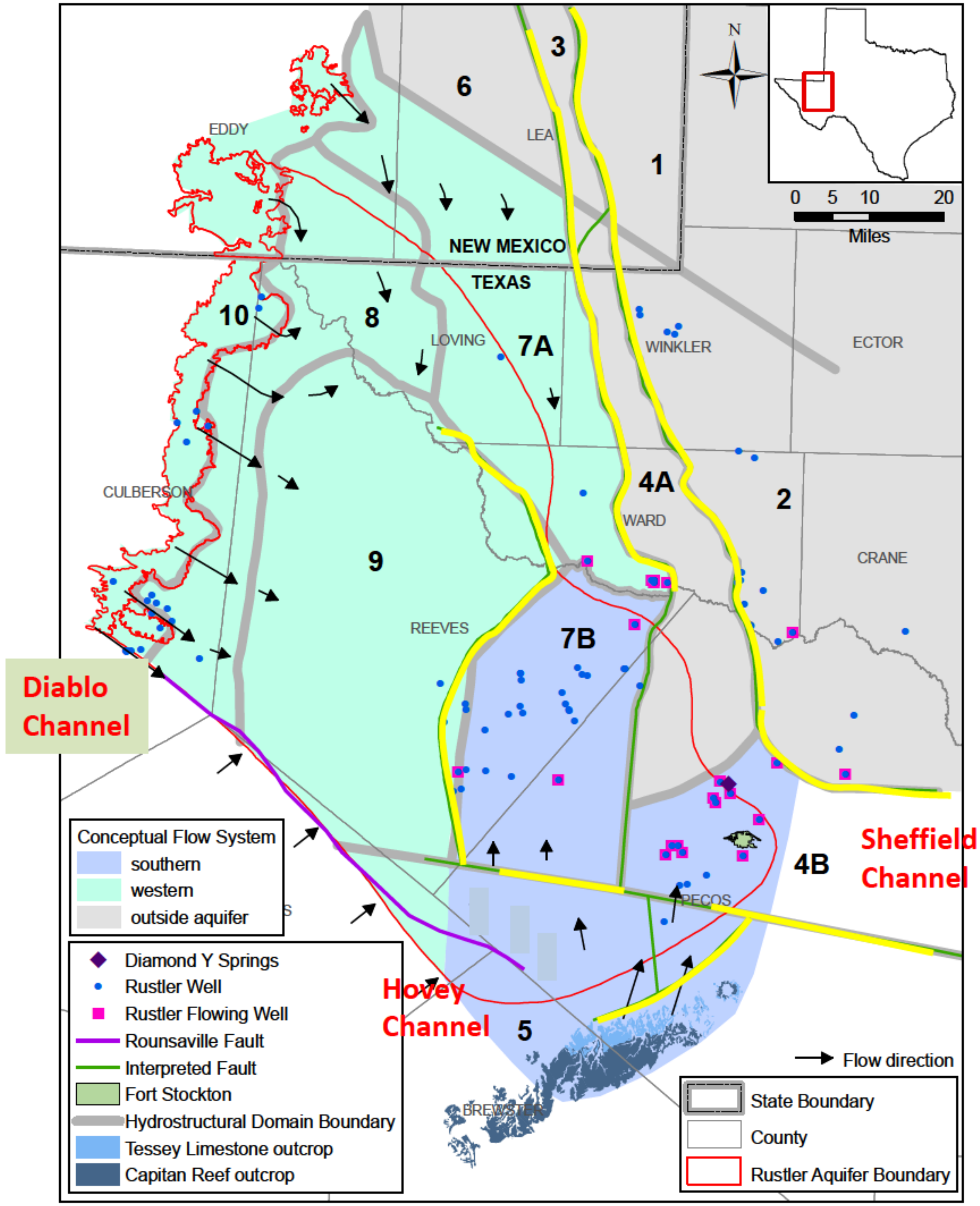
Depth of Burial – Top Rustler

Ranges from zero to approximately 4,000 feet



Conceptual Flow Systems

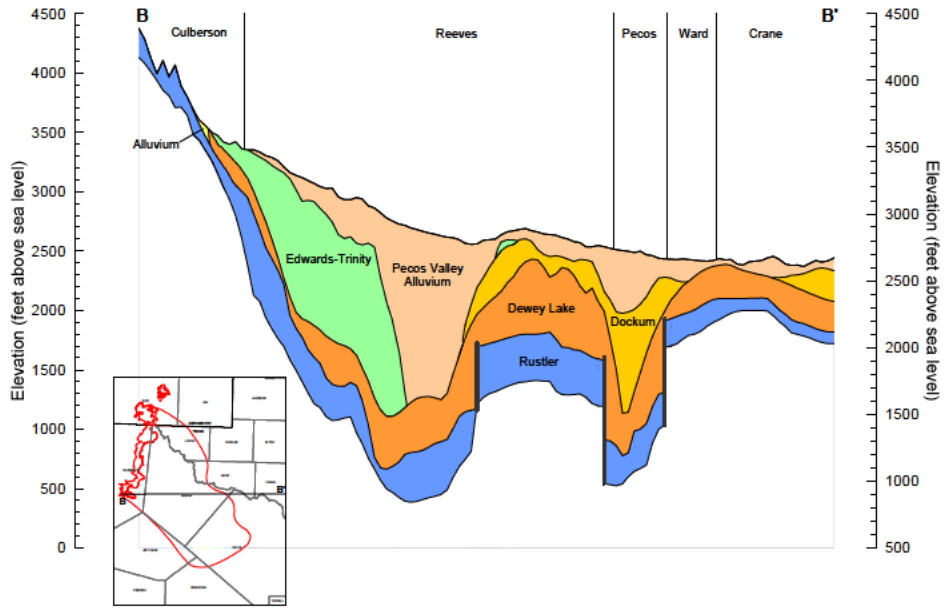
- Surficial recharge
  - Culberson Co.
  - Glass Mountains
- Boundary flows
- Discharge
  - Springs
  - Cross-formational
  - ET
- Structural controls on groundwater flow are significant

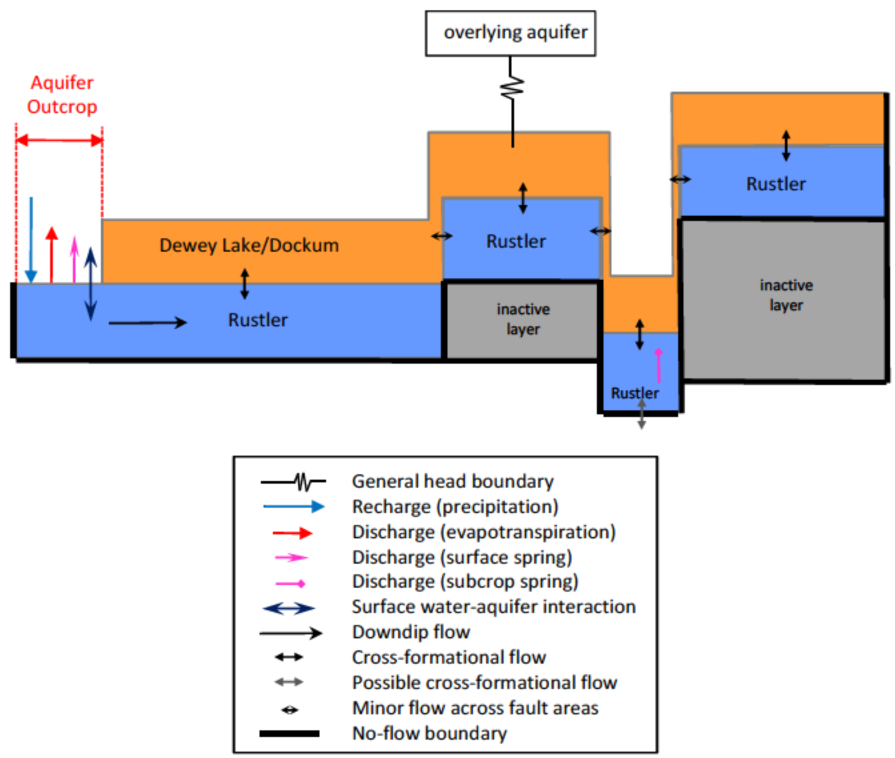


INTERA

Conceptual Flow Cross-Section

- Model Implementation
  - Two model layers
  - Faults - hydraulic flow barrier package
  - General head boundary above Dockum/Dewey Lake
  - No flow at the Rustler/Salado contact
    - *Belding/Coyanosa ??*

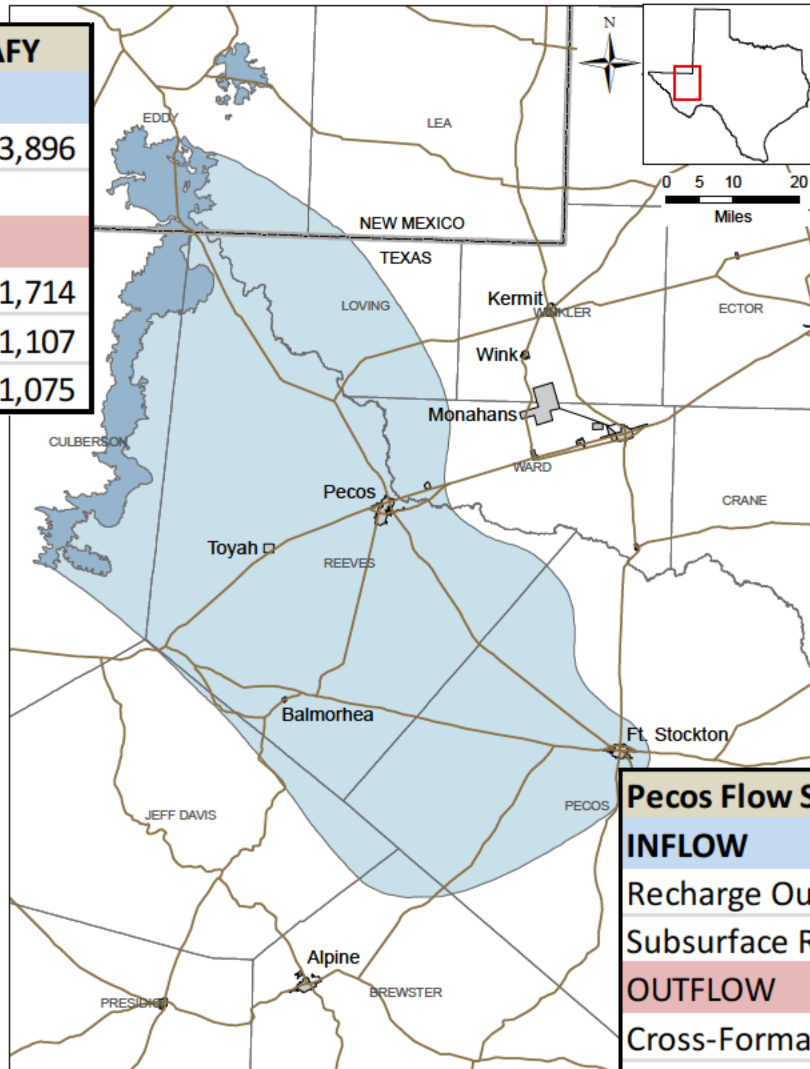




INTERA

Conceptual Flow Balance

Western Flow System	AFY
INFLOW	
Recharge Outcrop	3,896
Subsurface Recharge	
OUTFLOW	
Cross-Formational	1,714
Stream Gain Outcrop	1,107
Springs Outcrop	1,075



Pecos Flow System	AFY
INFLOW	
Recharge Outcrop	2,600
Subsurface Recharge	1,000
OUTFLOW	
Cross-Formational	2,551
Subcrop Springs	1,049

Review of

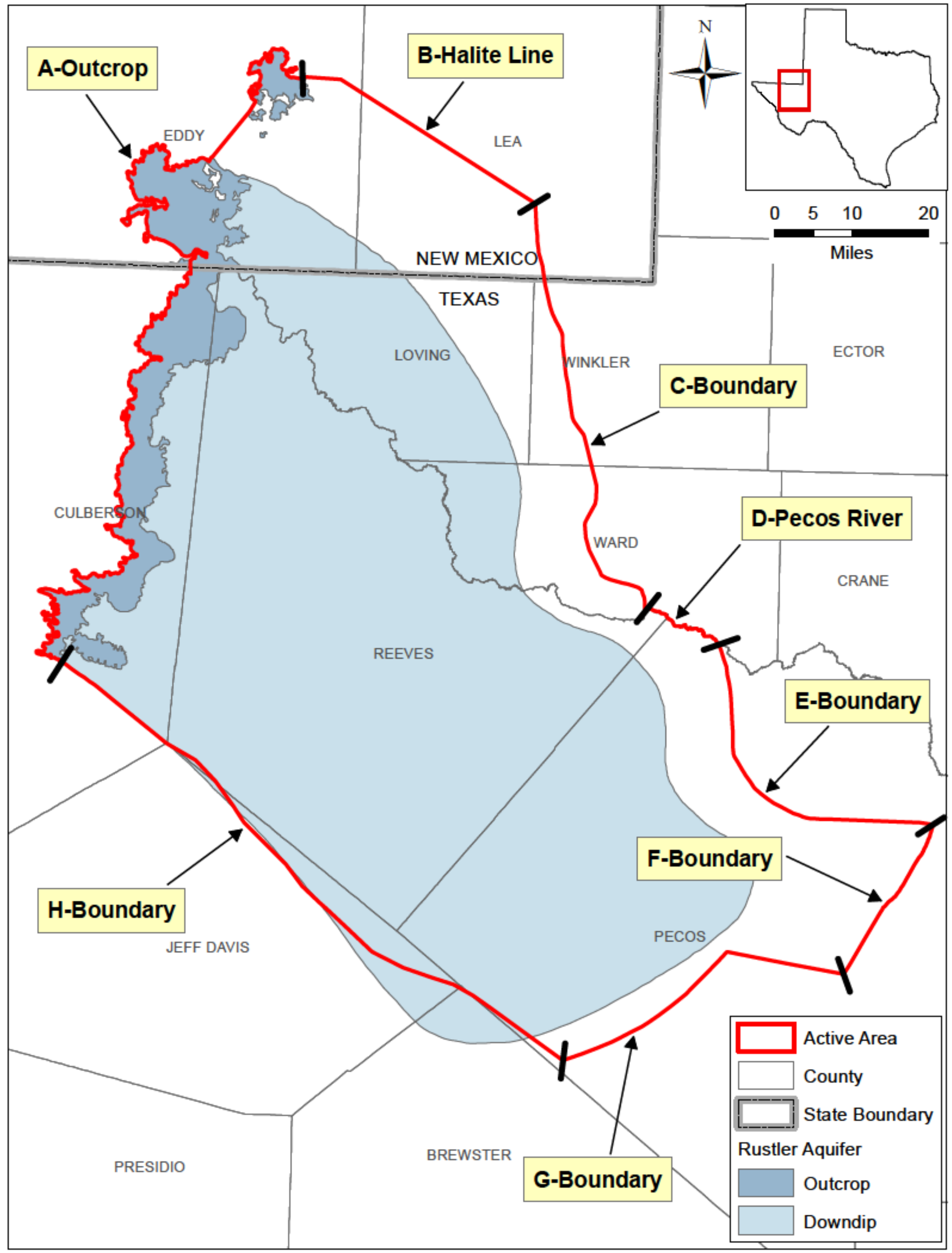
MODEL IMPLEMENTATION

GAM Software and Grid

- MODFLOW-NWT (Niswonger and others, 2011)
- Groundwater Vistas for Windows Version 6.0
- Regular grid ¼ mile by ¼ mile
  - 466 columns by 526 rows
  - Active models cells = 226,240

Active Model Domain and Boundaries

A – Outcrop – No Flow
B - No- Flow (halite line)
C, E – No-flow (fault)
D – No-flow
F – Distance Boundary
G, H – Specified Flow



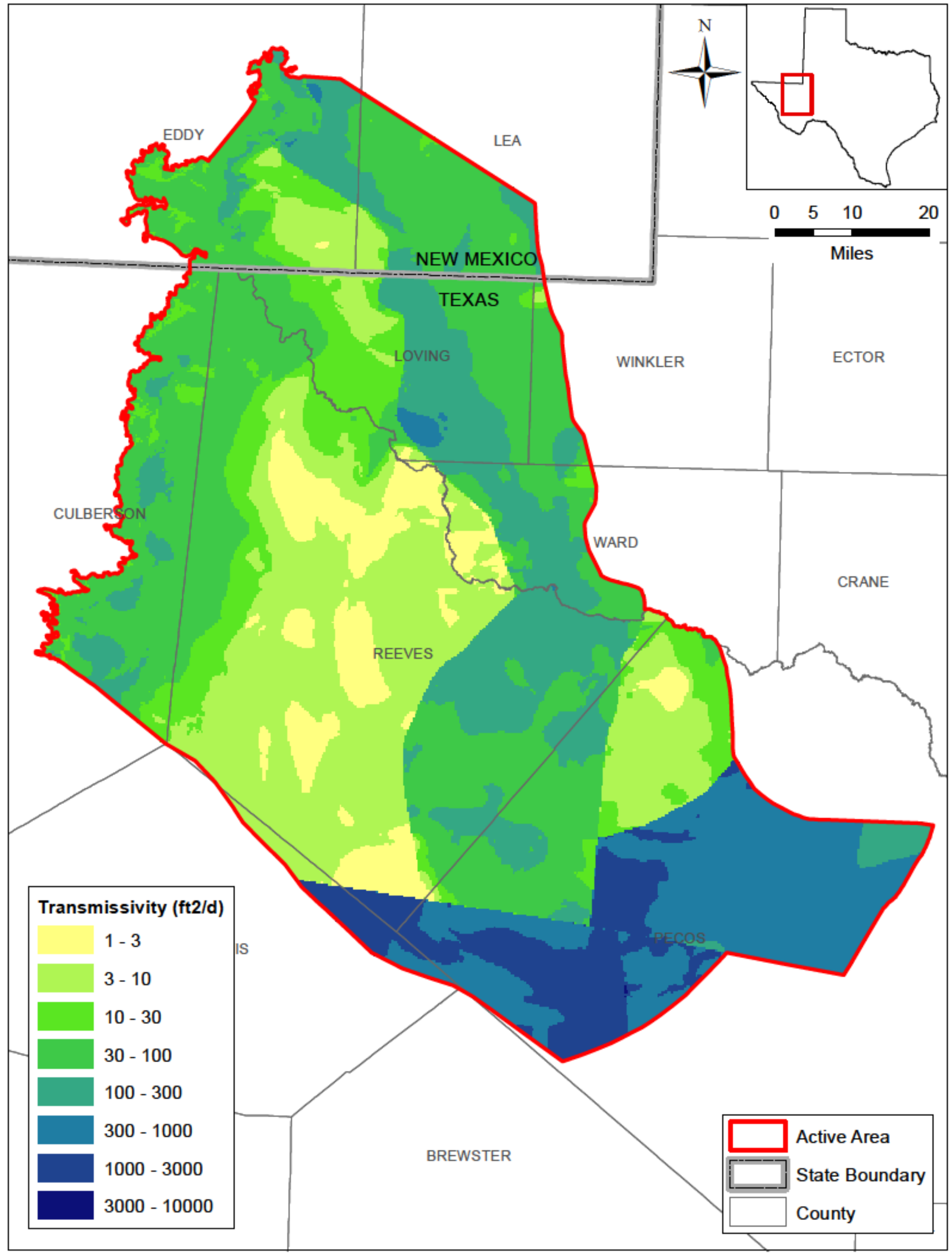
INTERA

Hydraulic Conductivity and Storage

- Kh based upon measurements of transmissivity, aquifer character and depth
- Kv was initially set based upon anisotropy = 1,000 – later calibrated by zone as needed
- Storage:
  - Unconfined - 0.15
  - Confined Specific Storage 1 x 10^{-6} 1/ft

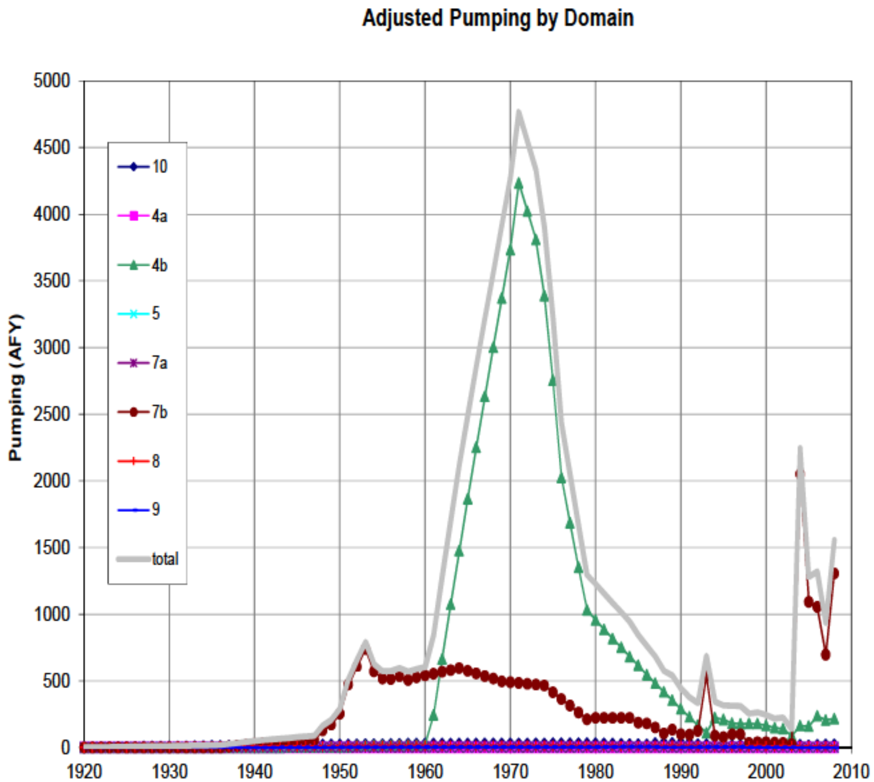
Subdomain	Upper Salado Dissolution	Presence of Rustler Halite	Thickness of Overburden	Observed Transmissivity Range (ft2/day)	Comments
1	None	Yes	Applicable	Non reported	Very tight and outside active model domain
2	Rare	Unknown	Applicable	2,941 to 7,952	Some productivity in Ward County, acidized?
3	Yes	Likely	Applicable	Non reported	Very tight and outside active model domain
4a	Yes	None	Applicable	Non reported	Very deep, thick Dewey Lake, likely isolated
4b	Yes	None	Applicable	139,906	Very productive area, flowing wells and springs from Rustler
5	Not Applicable	Not Applicable	Applicable	Non reported	Tessy outcrop, Kartsic limestone
6	None	Yes	Applicable	0.04 to 1.9	Very tight and outside active model domain
7a	None	None	Applicable	4.4 to 1,474	May have to impose a decreasing trend west to east and to south
7b	Likely	None	Applicable	Non reported	Higher transmissivity due to increase dolomite and basal sand
8	Yes	None	Applicable	Non Reported	Thin to absent Dewey Lake
9	Yes	None	Applicable	Non reported	Western edge has Upper Salado dissolution - other unknown
10	Yes	None	Not Applicable	Non reported	Rustler outcrop - Karst features in places

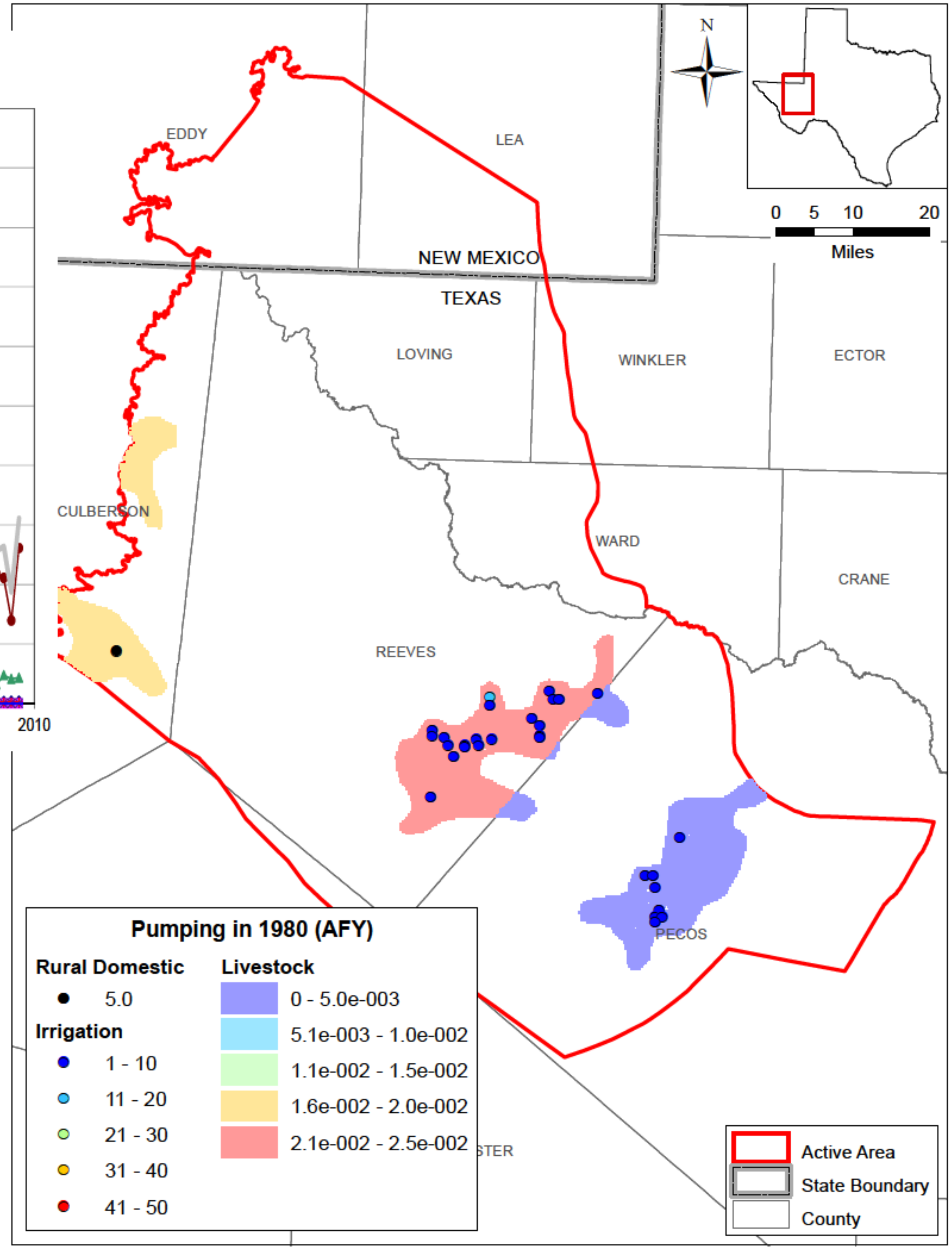
Rustler Horizontal Transmissivity (ft2/day)



Recharge

- Outcrop
  - One percent of precipitation (0.146 in/year)
  - Adjusted as a function of topography
  - Maximum rate = 0.3 in/year
- Glass Mountains
  - Initial inflow = 1,800 AFY (approx 7% of precipitation)
- Davis Mountains underflow
  - Calibrated





Pumping:

Adjusted during transient calibration to:

- fit Belding hydrographs
- fit vertical gradients in zone 7B

INTERA

Review of

MODEL CALIBRATION

Calibration

- Steady-State Calibration
  - Poorly constrained but assumed to be prior to 1919
- Transient Calibration
  - 1919 through 2008
- Targets
  - Conceptual flow balance
  - Heads
  - Stream and Spring flows

Cross-formational Flow is unknown as a calibration constraint but is very important

INTERA

Calibrated Properties Summary

Parameter	Units	Layer	Minimum	Maximum	Median	Arithmetic Mean	Geometric Mean
Horizontal Hydraulic Conductivity	feet/day	1	uniform 0.1[a] or 10[b]				
		2	0.01	5.0	0.201	0.813	0.156
Vertical Hydraulic Conductivity	feet/day	1	uniform 0.0001[a] or 0.01[b]				
		2	1.2×10^{-7}	0.0705	0.00015	0.000866	0.000128
Storativity	--	1	0.0001	0.00254	0.000523	0.00052	0.00043
		2	0.0001	0.00979	0.000375	0.00109	0.000541
Specific Yield	--	1	not applicable				
		2	uniform 0.15				

[a] Dewey Lake and Dockum formations present

[b] Layer 1 in the absence of Dewey Lake and Dockum formations

Steady State Calibration

Table 8.2.1 Calibration statistics for the steady-state model.

Aquifer	Number	ME (feet)	MAE (feet)	RMS (feet)	Range (feet)	Adjusted MAE
Rustler	47	43.6	55.1	74.6	1,711	0.032

ME = mean error MAE = mean absolute error RMS = root mean square

Table 8.2.2 Water budget for the steady-state model (all rates reported in acre-feet per year).

Layer	Cross-Formational Flow	Recharge	Lateral Flow	Springs	ET	GHBs	Streams
1	4,697	0	0	0	0	-4,697	0
2	-4,697	3,896	3,237	-1,176	-1,008	0	-256
Sum	0	3,896	3,237	-1,176	-1,008	-4,697	-256

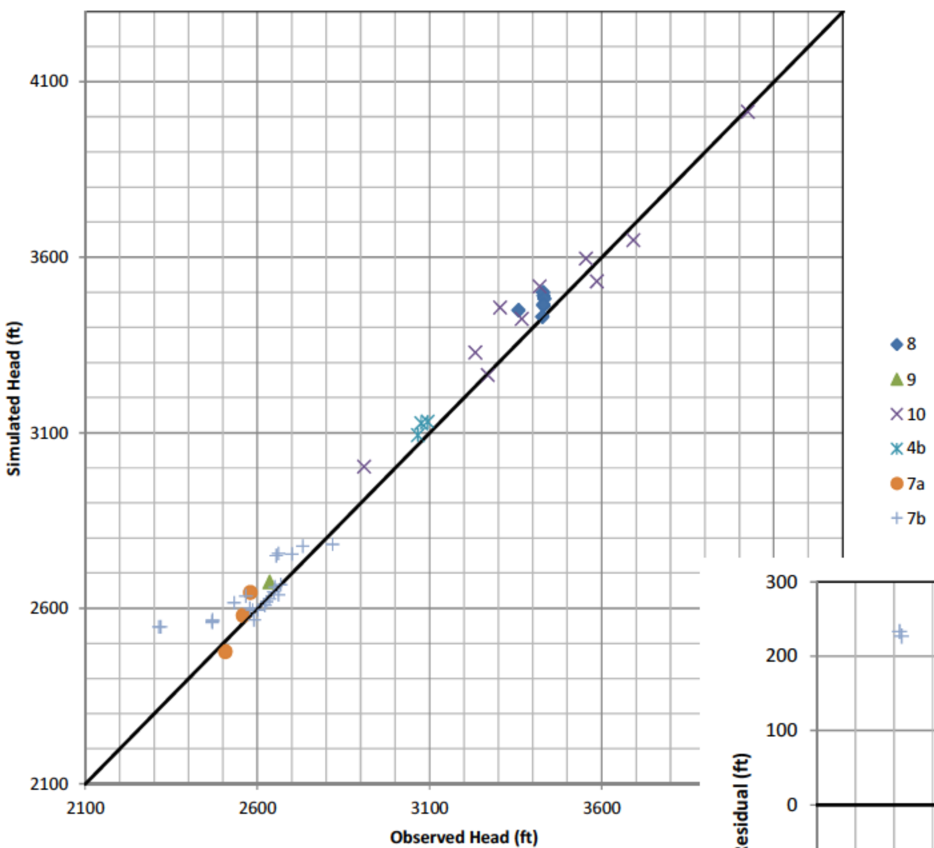
GHBs = general-head boundaries ET = evapotranspiration

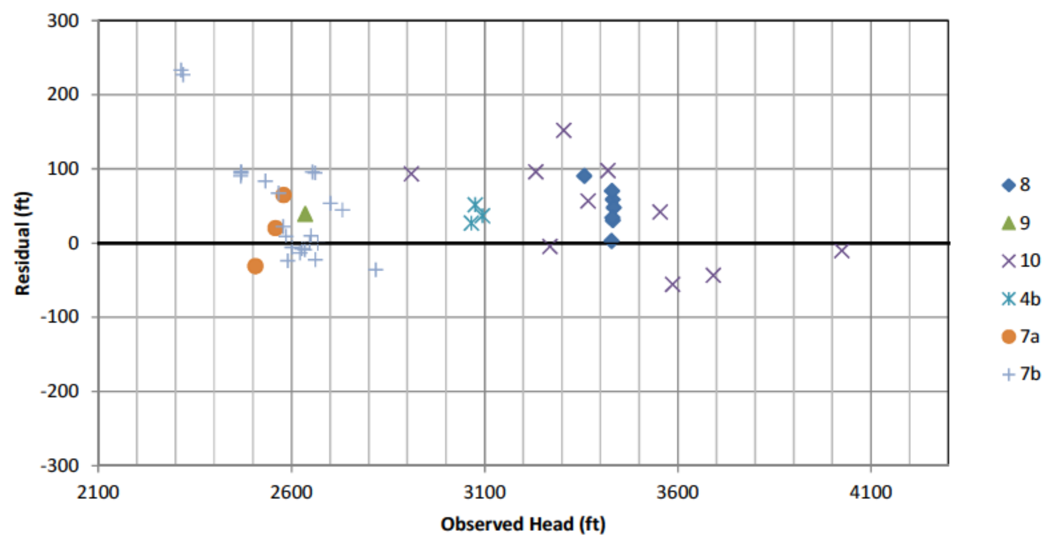
Table 8.2.3 Water budget for the steady-state model with values expressed as a percentage of total inflow.

Layer	Cross-Formational Flow	Recharge	Lateral Flow	Springs	ET	GHBs	Streams
1	66%	0%	0%	0%	0%	-66%	0%
2	-66%	55%	45%	-16%	-14%	0%	-4%
Sum	0%	55%	45%	-16%	-14%	-66%	-4%

GHBs = general-head boundaries ET = evapotranspiration

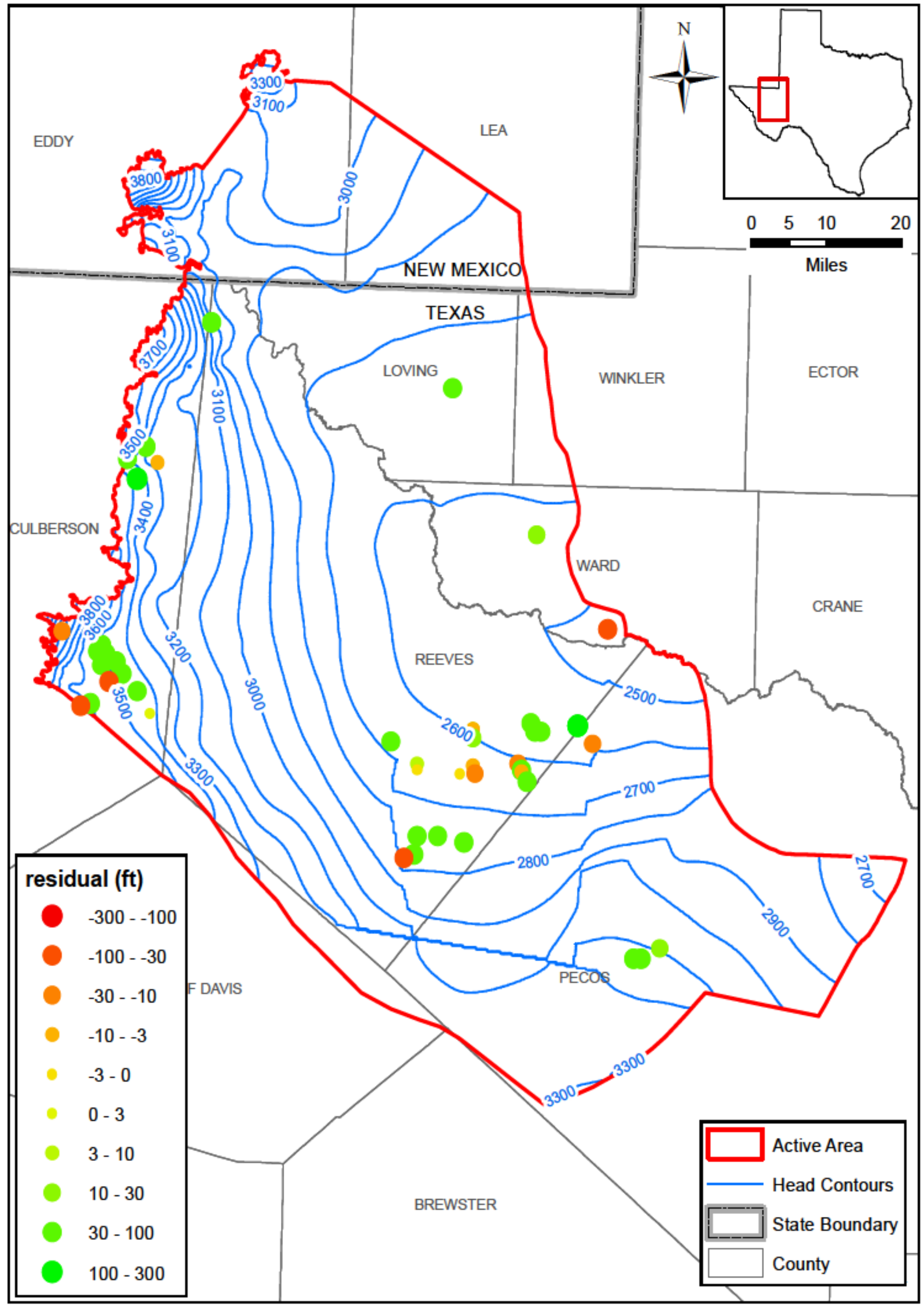
Steady-State Calibration



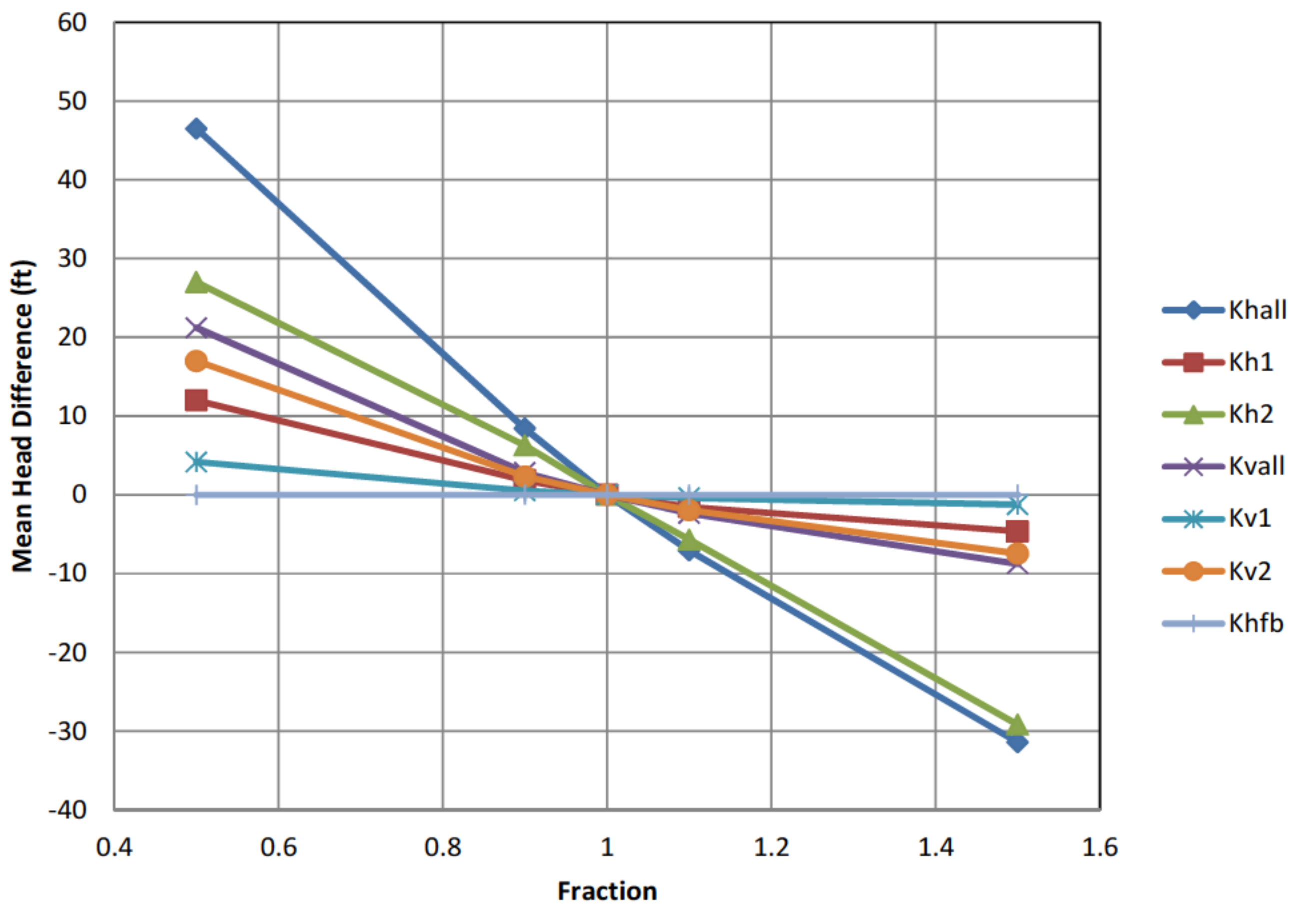


Steady-State Heads and Residuals

- 30% low, 70% high
- Diamond Y
  - Observed = 1,049 AFY
  - Simulated = 981 AFY
- Flowing Wells in 4b
  - 7 of 8 flowing in PreD

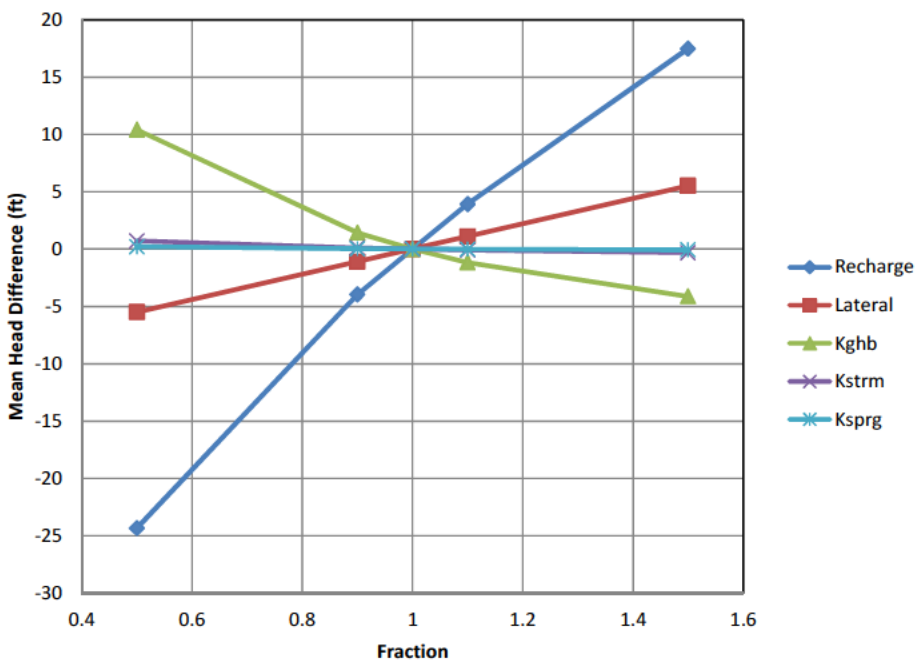


Steady-State Sensitivity



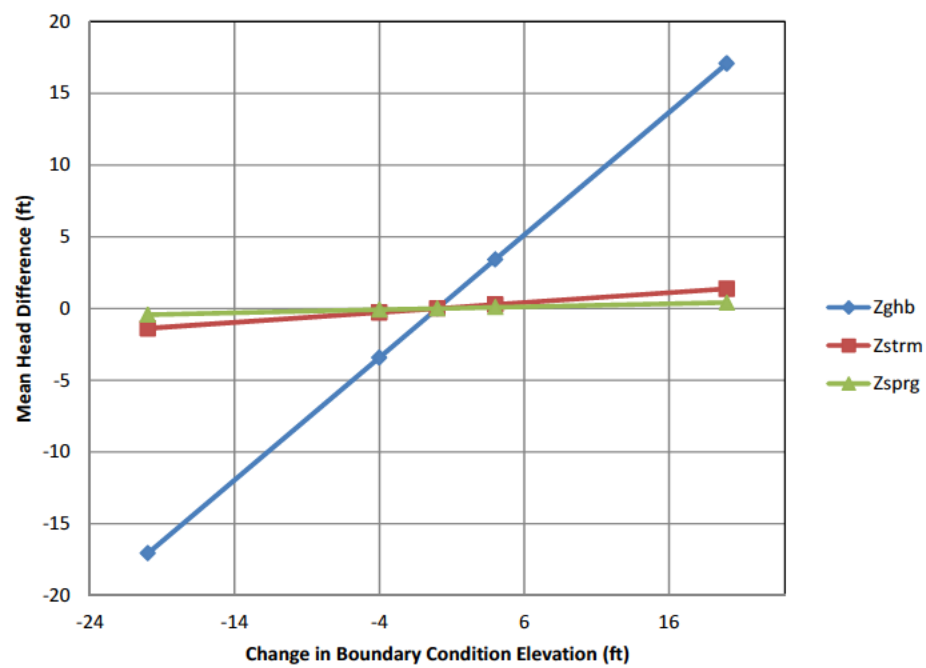
Head sensitivity to changes in hydraulic conductivity

Steady-State Sensitivity



Head sensitivity to changes in boundary Condition flows and conductance

Head sensitivity to changes in boundary Condition elevations

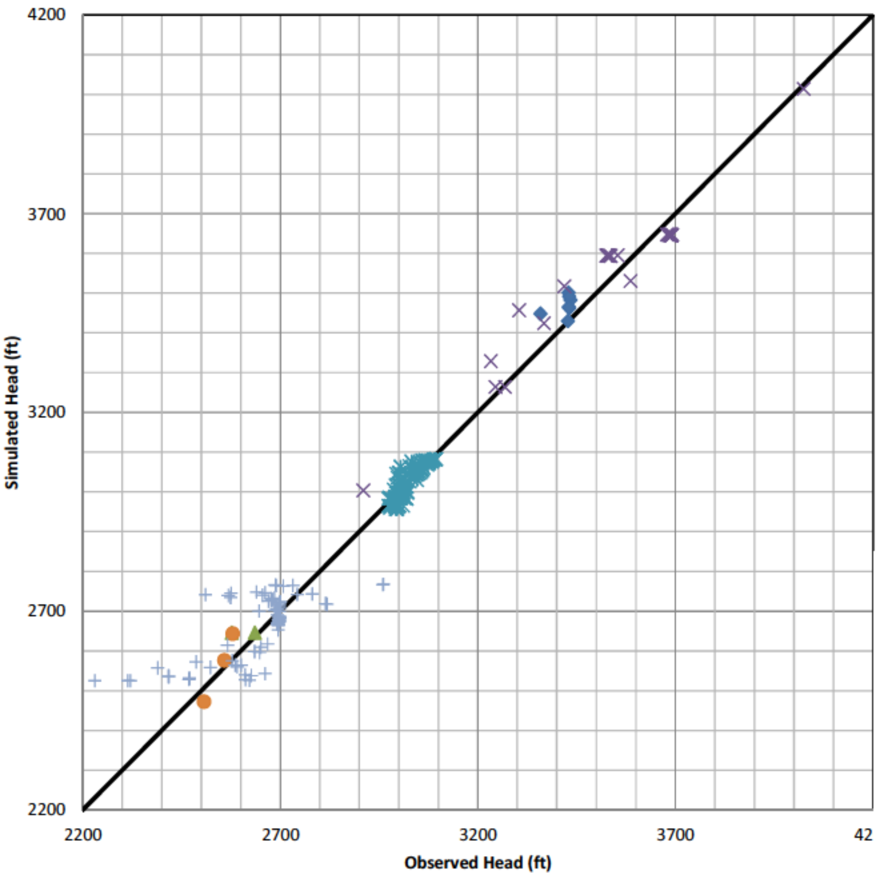


INTERA

Transient Calibration

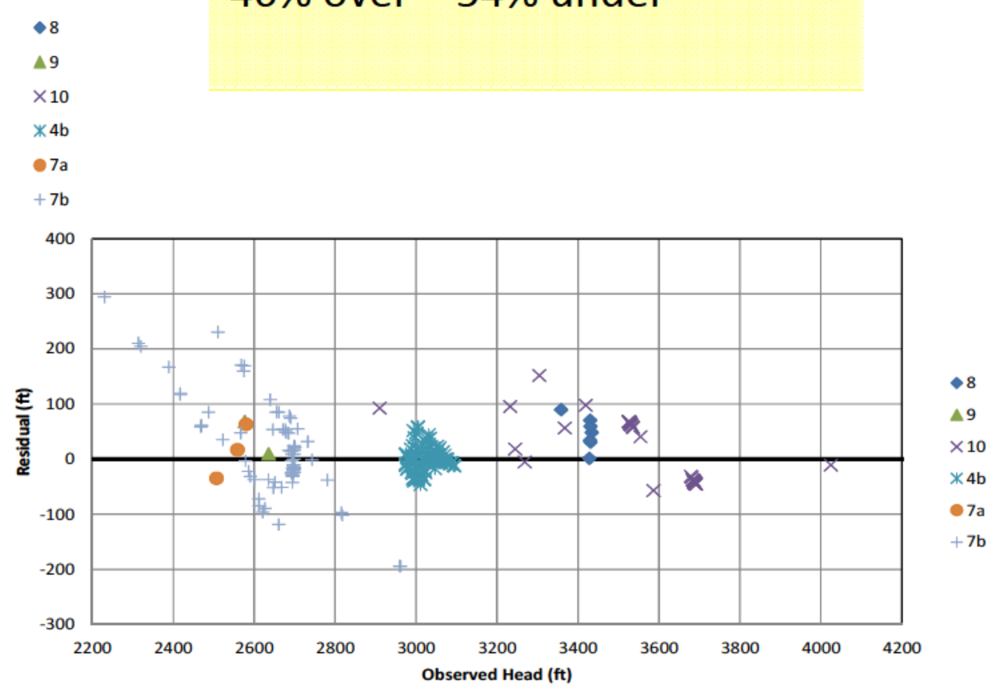
Layer	Number of Targets	ME (feet)	MAE (feet)	RMS (feet)	Range (feet)	Adjusted MAE
Rustler	231	10.0	40.2	59.9	1794	0.022

ME = mean error MAE = mean absolute error RMS = root mean square

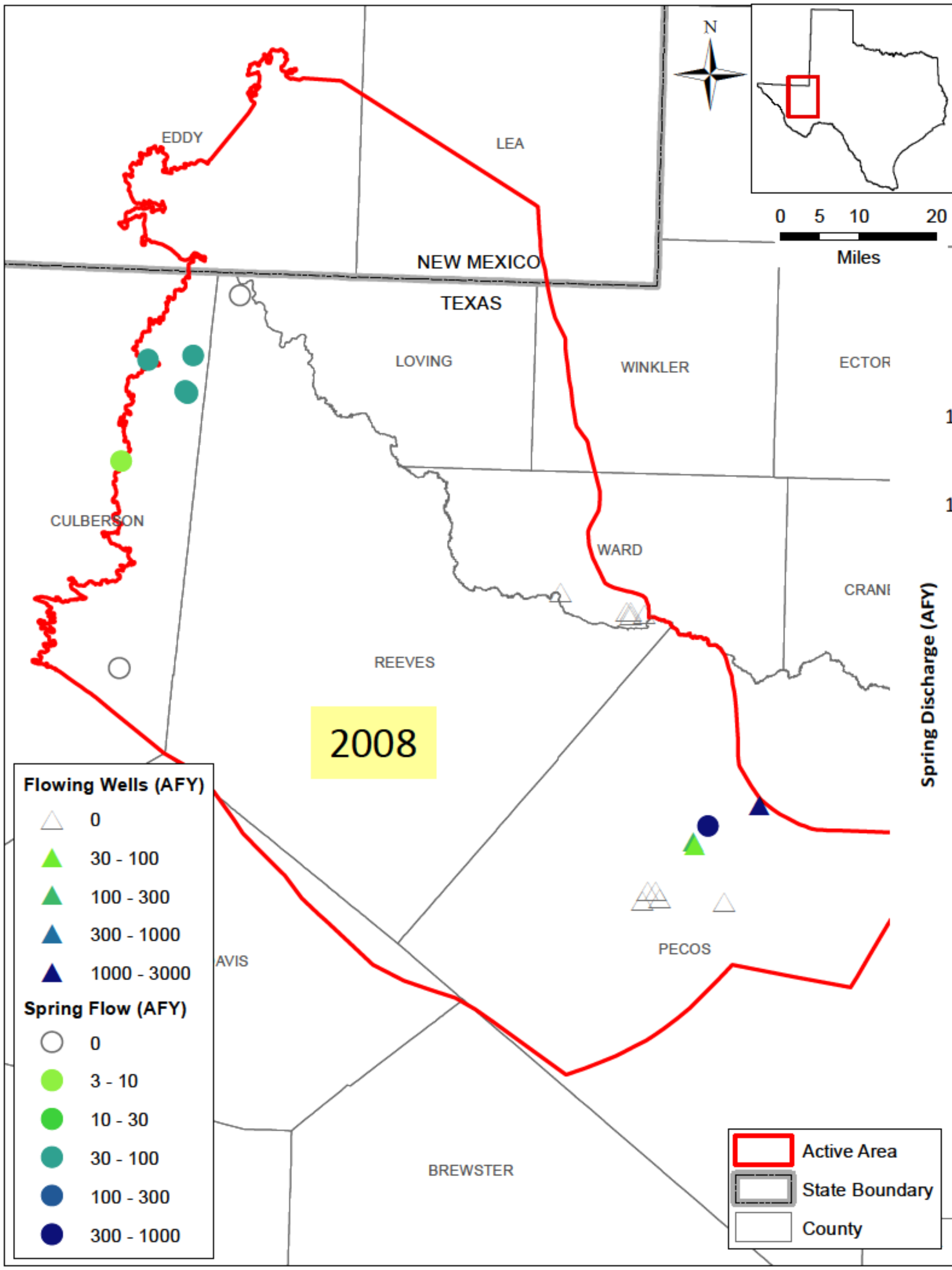


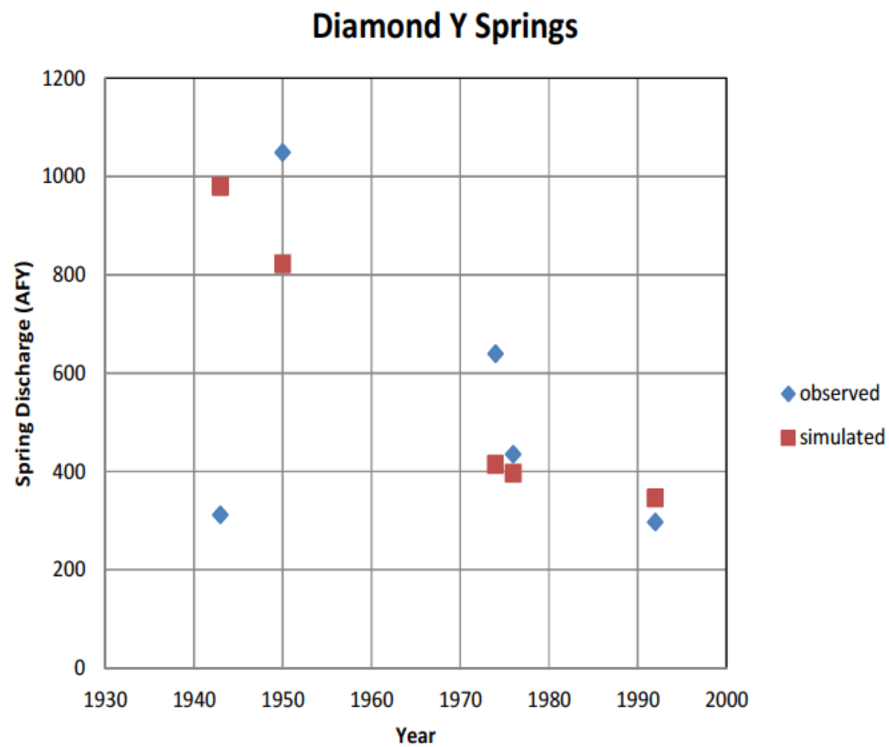
1918 -2008
231 head targets – 50 locations

46% over – 54% under

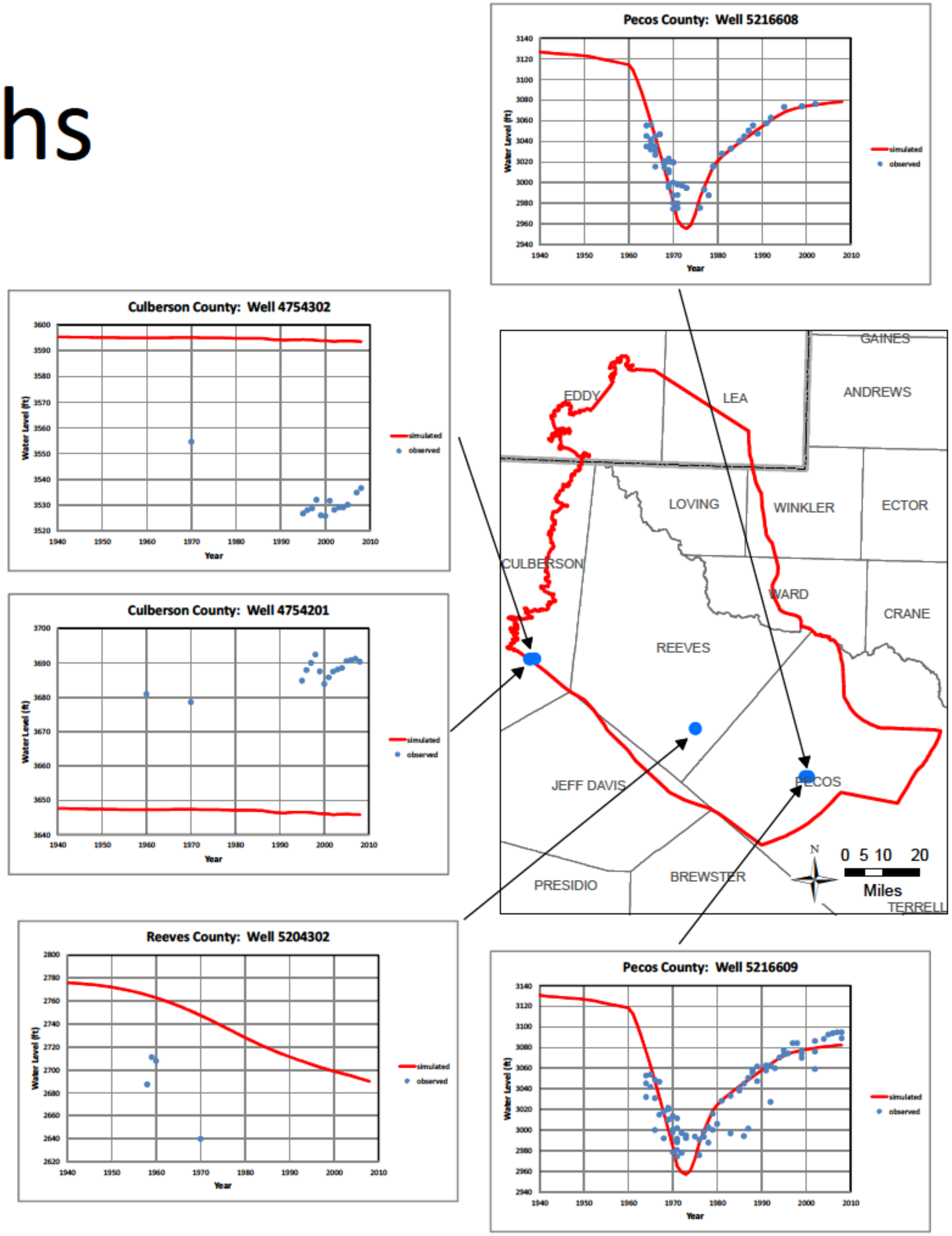


Flow Targets

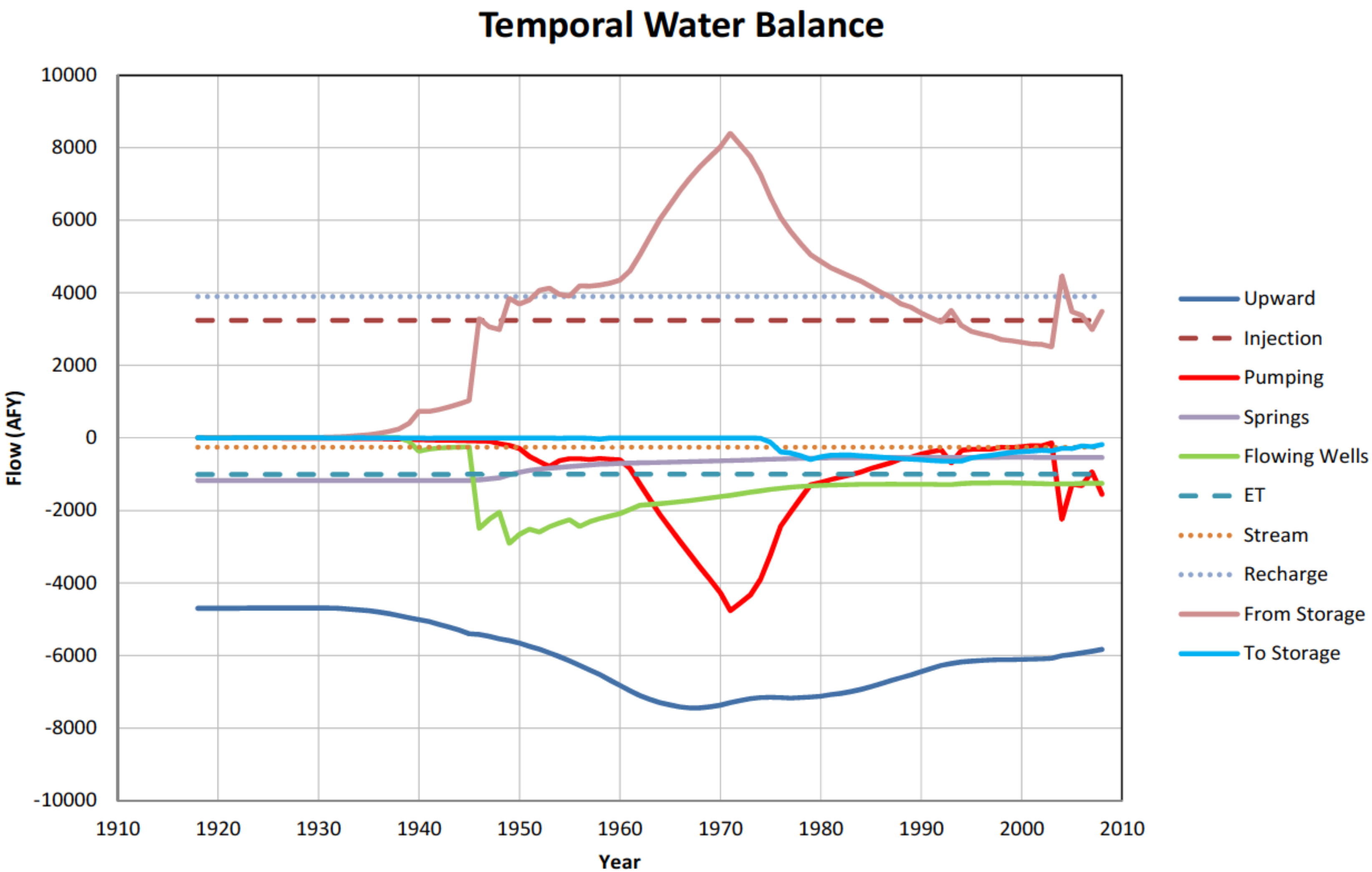




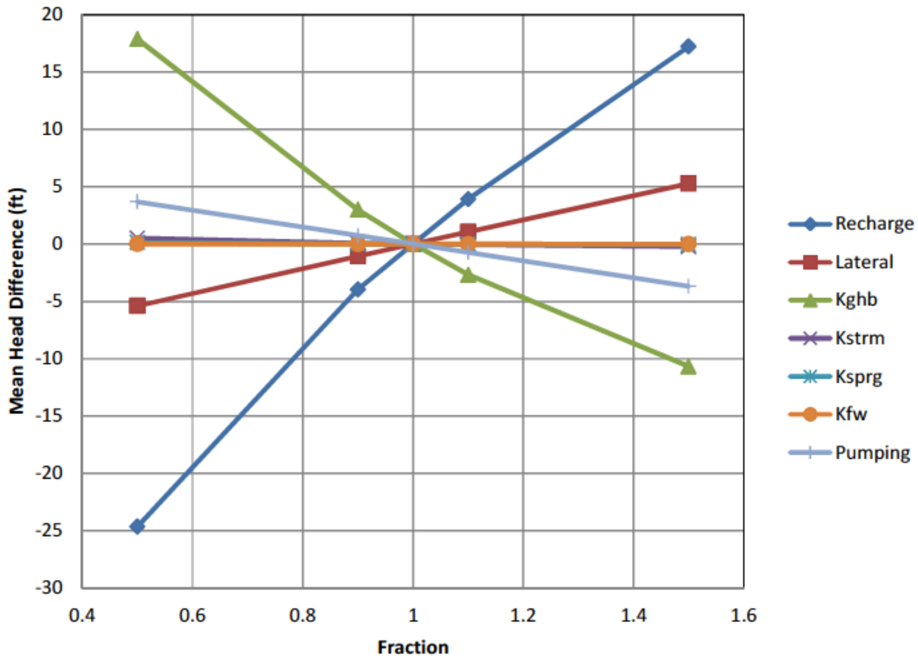
Hydrographs



Transient Flow Summary (AFY)

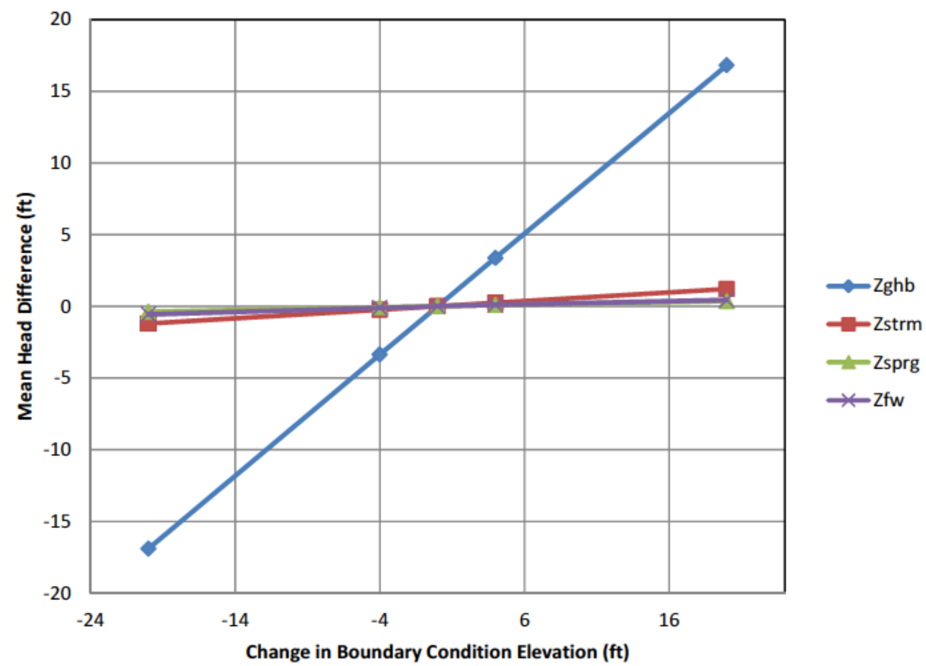


Transient Sensitivity



Head sensitivity to changes in boundary Condition flows and conductance

Head sensitivity to changes in boundary Condition elevations



Review of

SUMMARY OF RECOMMENDATIONS AND LIMITATIONS

Model Limitations – Supporting Data

- Limited Hydraulic head targets both spatially and temporally,
- Recharge/Discharge flow balance and magnitude of cross-formational flow
- Limited Frequency of water-level measurements to describe seasonal trends in the aquifer,
- Limited Water-level measurements within the underlying Capitan Reef Complex Aquifer,
- High variability of the stream gain/loss estimates,
- Limited hydraulic property data over the active portion of the Rustler Aquifer,
- Limited data quantifying cross-formational flow between the underlying/overlying aquifers and the Rustler Aquifer,
- Limitations to data defining pumping from the Rustler Aquifer,
- Many wells are dual-completions into the Rustler and other aquifers limiting the utility of associated water-level measurements as calibration targets, and
- Uncertain structural data over many areas of the active model area under the Rustler Aquifer.

INTERA

Important Assumptions

- Use of General Head Boundaries to represent the younger units above the Dockum/Dewey Lake
- No flow lower model boundary

Key Improvements

- Include all aquifers – Capitan through to surface – in one GAM
  – This may better constrain cross-formational flows
- Expand the model into areas not currently defined by the TWDB as the Rustler Aquifer
  – Oil and gas activity
  – Brackish resources

Schedule

- **Study Completion – August 31, 2012**

INTERA

Questions - Comments

Meeting minutes for the third Rustler Aquifer groundwater availability model (GAM) stakeholder advisory forum (SAF) meeting

July 6, 2012

Pecos County Courthouse, Ft. Stockton, Texas

The third Stakeholder Advisory Forum (SAF) meeting for the Rustler Groundwater Availability Model (GAM) was held on Friday, July 6, 2012 at 1:00 PM at the Pecos County Courthouse located at 103 West Callaghan in Ft Stockton, 79735. A list of meeting participants is provided at the end of these meeting notes.

The primary purpose of the third SAF meeting was to review the model developed for the Rustler Aquifer and to solicit any comments from stakeholders regarding the model. The draft Model Report will be posted on the TWDB website until July 31, 2012 for public comment. Comments should be submitted to Van Kelley at vkelley@intera.com or Cindy Ridgeway at cindy.ridgeway@twdb.texas.gov before close of business on July 31, 2012.

SAF Presentation:

Cindy Ridgeway, manager of the Groundwater Availability Modeling Section at the Texas Water Development Board, opened the meeting and gave a brief introduction to the GAM program, how models are developed, and how they are used. Then Van Kelley of INTERA, Inc. (the contractor developing the model) gave a presentation on:

- Review of the Study Area;
- Review of the Rustler Aquifer Conceptual Model for Groundwater Flow;
- Rustler Aquifer GAM Implementation;
- Rustler Aquifer GAM Calibration;
- Conclusions, Recommendations and Limitations of the Study.

The presentation has been submitted to the TWDB and is available at the following website:
http://www.twdb.texas.gov/groundwater/models/gam/rslr/rslr.asp

Questions and Answers:

Discussions during the presentation included:

Question: Example of a water budget provided in the presentation represents which county?
Answer: The conceptual flow balance presented is for the Rustler aquifer as a whole. In the slide the flow balance was divided between the two primary recharge regions, the western Culberson County – Toyah Basin System and the southwestern Pecos-Glass Mountains System which includes underflow from Jeff Davis County and potentially the Diablo Channel.

Question: Does New Mexico have same modeling program?
Answer: No, they have developed some models. More information is available online at http://www.ose.state.nm.us/.

Question: Does INTERA have a copy of the Hiss 1976 map cited in the source data slide?
ANS: Can be provided upon request.

Question: Was seismic data used for development of the [framework]?
Answer: No, the INTERA team and TWDB Innovative Water Technologies staff worked with geophysical logs to collaboratively define the top of the Rustler. In addition INTERA used the Hiss 1976 map The United States Geological Survey may have some data for shallower units.

Question: Please clarify Rustler Aquifer and the Pecos River flow system around Ft Stockton.
Answer: The predevelopment system is conceptualized with inflow originating in the Glass Mountains and entering the Rustler through the Tessey Limestone [Rustler equivalent] and discharge to Diamond Y and/or maybe upward flow to Pecos River. It is also possible that there is subsurface inflow from the Rounsaville Fault System and areas to the northwest.

Question: Is TWDB planning on expanding the footprint of the Rustler Aquifer [to include brackish water]?
Answer: Not at this time. The current footprint includes water with total dissolved solids up to 5,000 parts per million. The TWDB is considering including an exceptional item to our 2014-2015 budget for possibly modeling the brackish groundwater in Texas (http://www.twdb.texas.gov/board/2012/06/Finance/Fin02.pdf).

Question: Please clarify how heads were estimated for units above the Rustler.
Answer: Used TWDB two-layer model and adjusted in places as appropriate and needed based upon observed heads at selected long-term hydrographs.

Question: Please clarify ET [evapotranspiration] in the model.
Answer: Restricted to outcrop and riparian areas. Values used are very low and appear constant [in water budget] since they represent annual conditions.

Question: How do we get copies of the model and files?
Answer: The files are available upon request for draft review and also at the end of the project. More information is provided:
http://www.twdb.texas.gov/groundwater/models/gam/rslr/rslr.asp or
http://www.twdb.texas.gov/groundwater/aquifer/minors/rustler.asp

Rustler Aquifer GAM Stakeholder Advisory Forum 3
July 6, 2012

Attendance

Name	Affiliation
Van Kelley	INTERA
Cindy Ridgeway	TWDB
Darrell Peckham	Water Quest.
Jeff Williams	Williams Ranch
Gary Bryant	Texas AgriLife
Alyson McDonald	Texas AgriLife
Paul Weatherby	Middle Pecos GCD
Harvey Gray	Middle Pecos GCD
Rudy Garcia	Presidio County GCD
Jennifer Samp	KOSA CBS 7