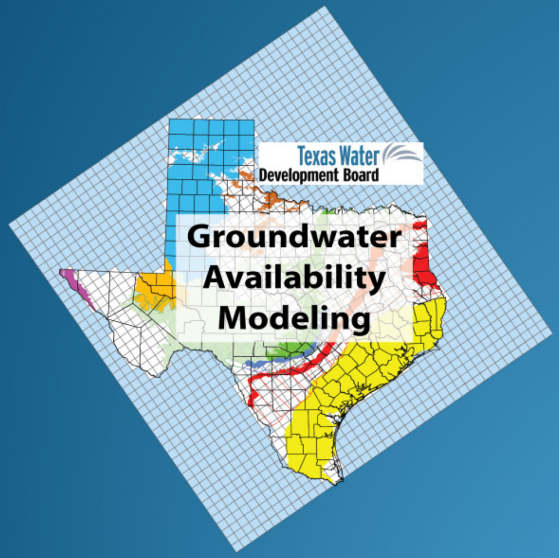
Capitan Reef Complex Aquifer GAM Stakeholder Advisory Forum Number 3



Fort Stockton, Texas

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Texas Water Development Board

Disclaimer

The following presentation is based upon professional research and analysis within the scope of the Texas Water Development Board's statutory responsibilities and priorities but, unless specifically noted, does not necessarily reflect official Board positions or decisions.

Outline

- Introduction
- Overview of Capitan Reef Complex Aquifer
- Groundwater availability model
  - Model files
  - Model calibration
  - Model limitations
  - Future improvements
- Project schedule

INTRODUCTION

Groundwater Availability Modeling Program

- **Aim**: Develop groundwater flow models for the major and minor aquifers of Texas.
- **Purpose**: Tools that can be used to aid in groundwater resources management by stakeholders.
- **Public process**: Stakeholder involvement during model development process.
- **Models**: Freely available, standardized, thoroughly documented. Reports available over the internet.
- **Living tools**: Periodically updated.

How we use Groundwater Models?

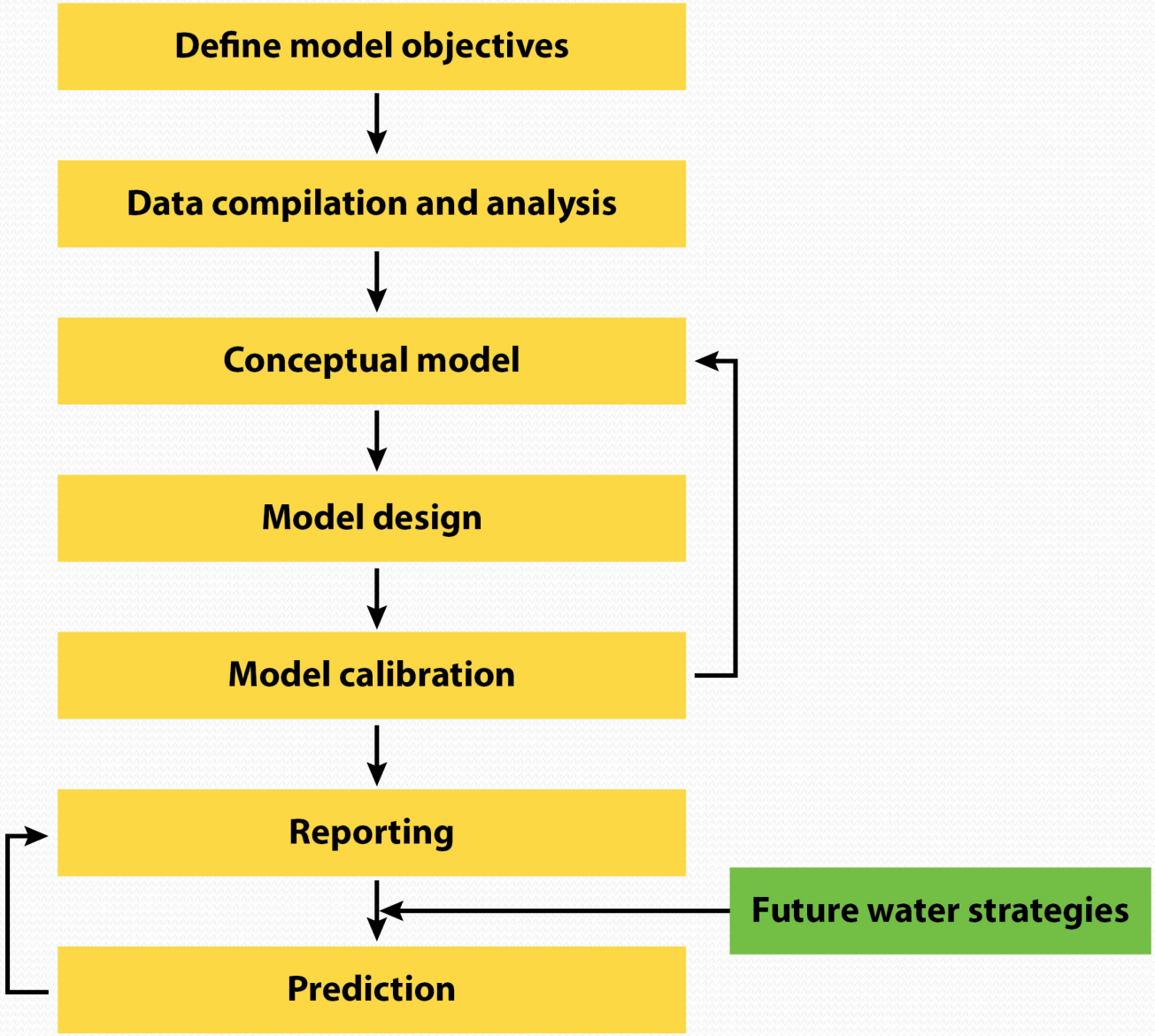
- Provide groundwater conservation districts with water budget data for their management plans.
- Assisting groundwater management areas in determining desired future conditions.
- Calculating Modeled Available Groundwater.
- Calculating Total Estimated Recoverable Storage.

Groundwater Modeling

Definition

- A mathematical device that represents an approximation of an aquifer *(The Compendium of Hydrogeology)*
- Simulation of groundwater flow by means of a governing equation used to represent the physical processes that occur in the aquifer, together with equations that describe heads or flows along the boundaries of the model *(Anderson and Woessner, 2002)*

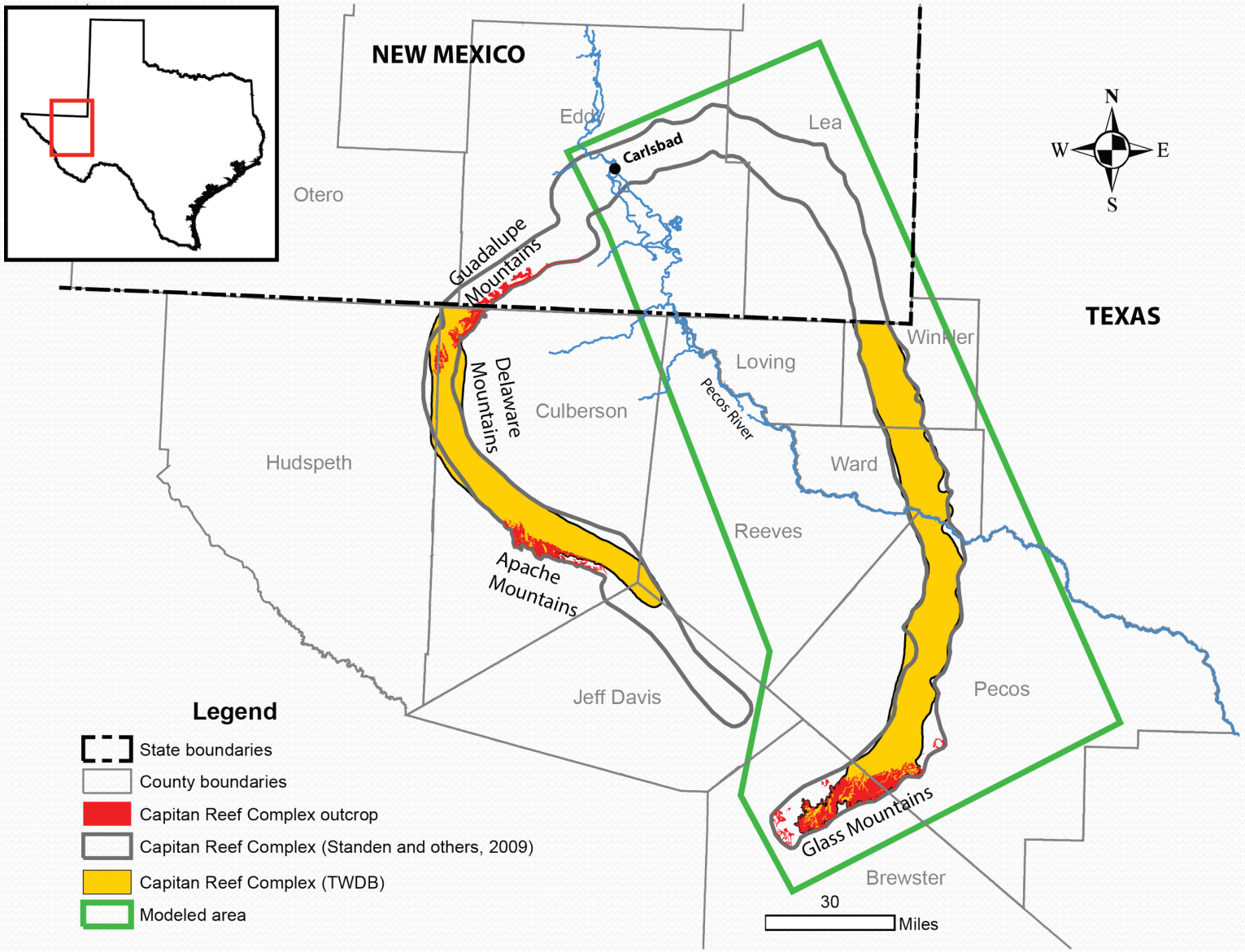
Modeling Process



CAPITAN REEF COMPLEX AQUIFER GROUNDWATER AVAILABILITY MODEL

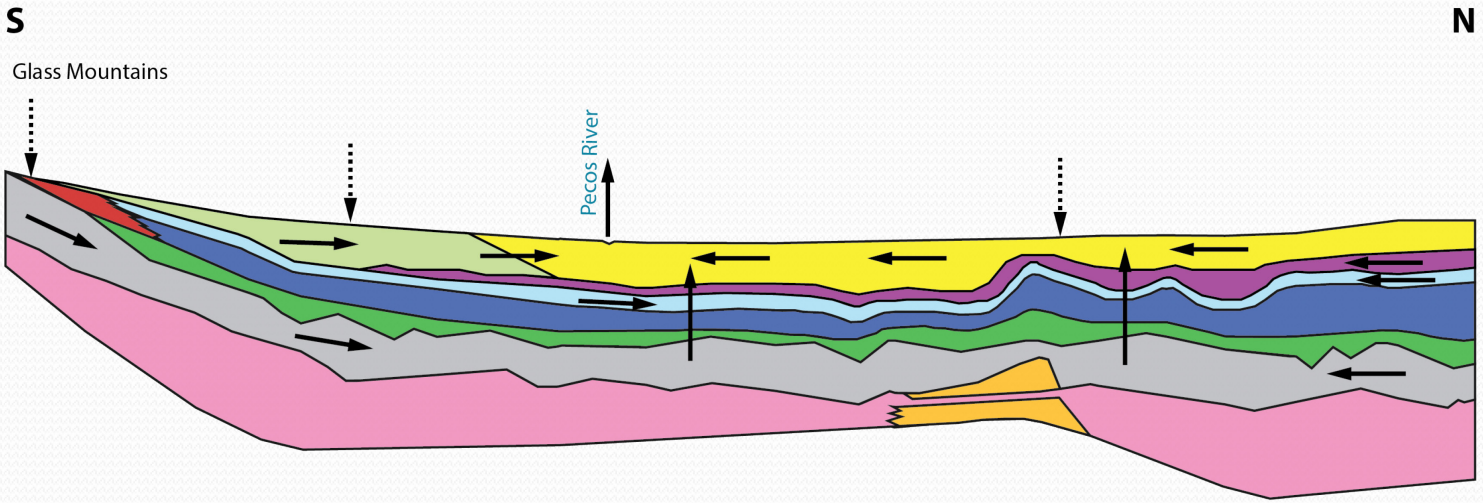
Study Area

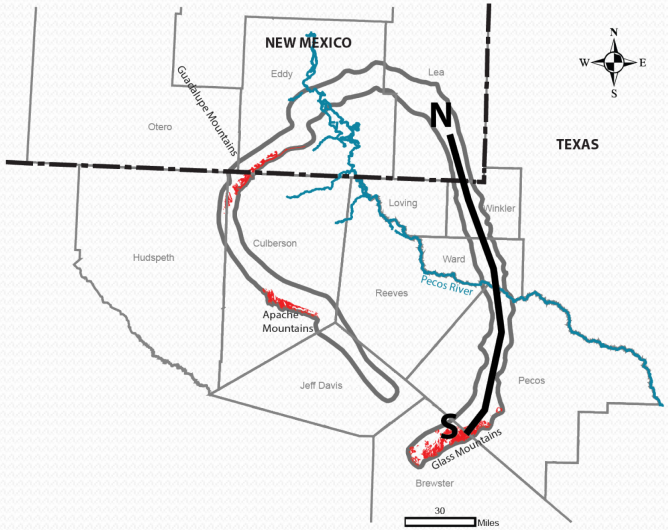
Aquifer Boundaries

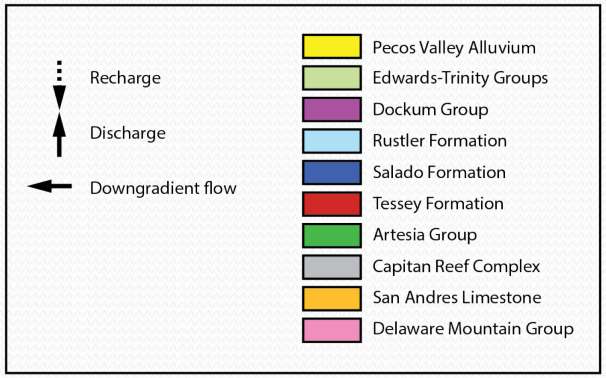


CONCEPTUAL MODEL

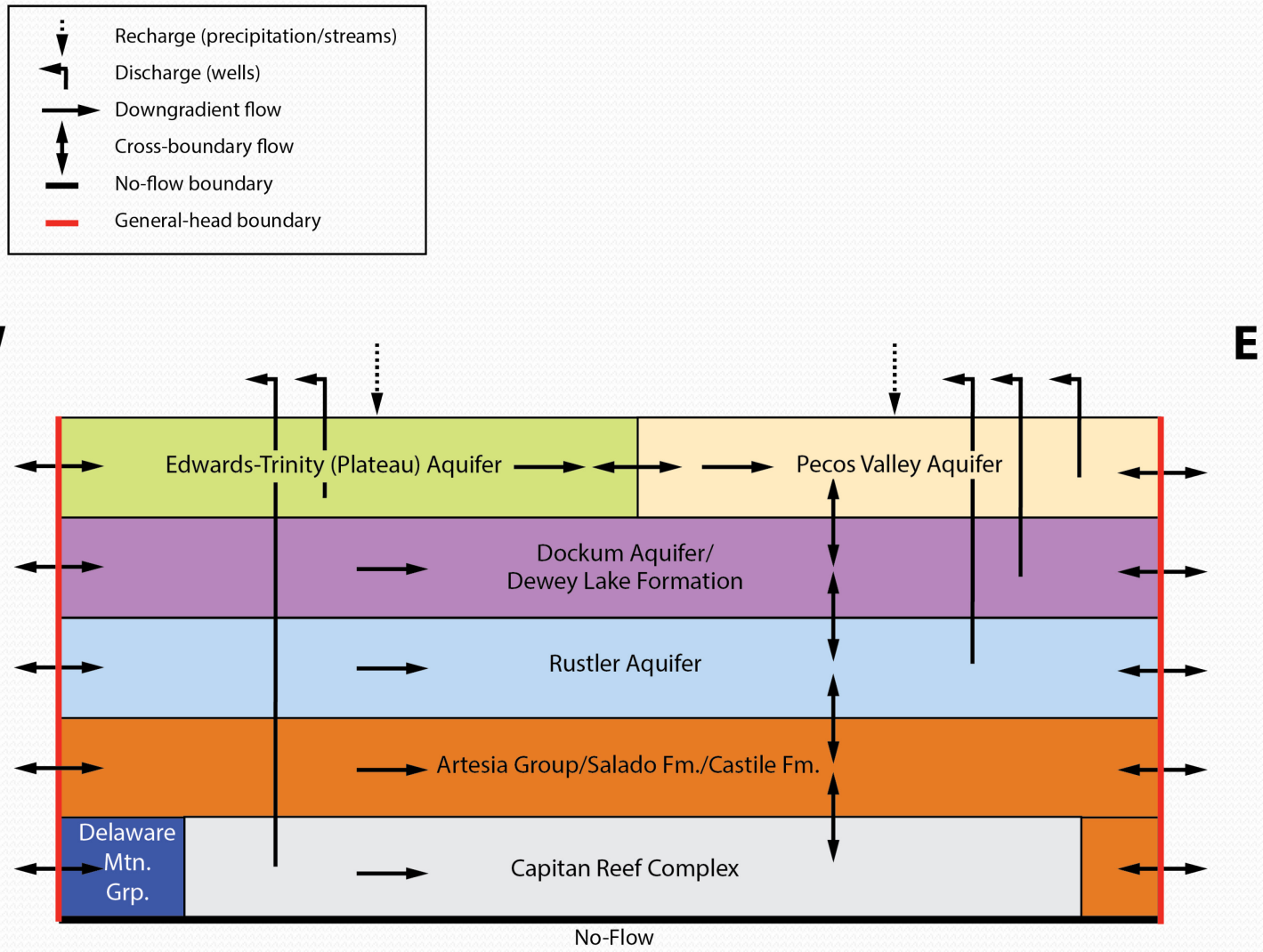
Conceptual Model







Conceptual Model



Conceptual Model

Pecos River: Main discharge zone

Conceptual Model

Glass Mountains: Main recharge zone

MODEL FILES

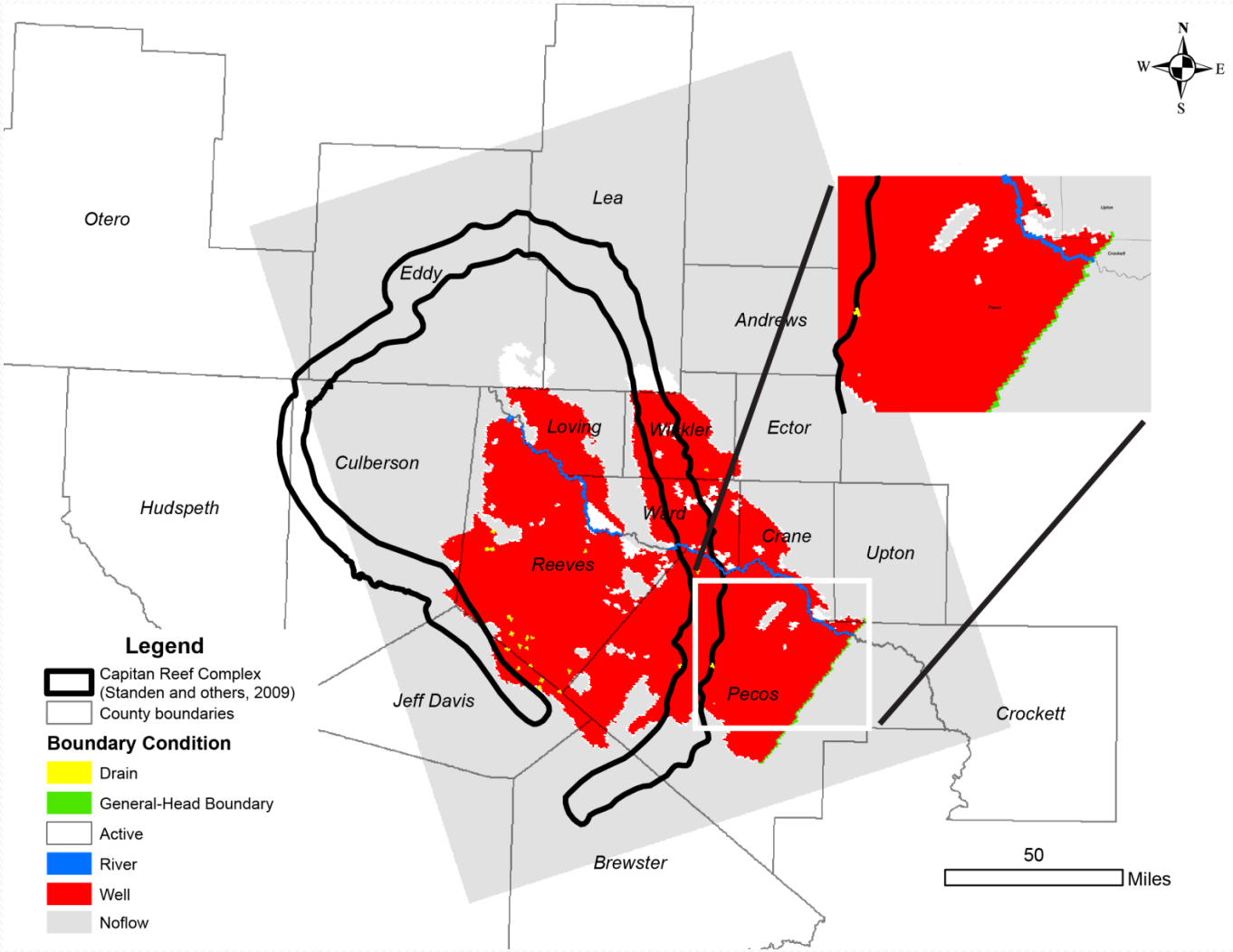
Model Input Packages/Filenames

Packages	Input Files
Basic (BAS6)	Capitan.bas
Discretization (DIS)	Capitan.dis
Layer-Property Flow (LPF)	Capitan.lpf
Well (WEL)	Capitan.wel
Drain (DRN)	Capitan.drn
River (RIV)	Capitan.riv
General-Head Boundary (GHB)	Capitan.ghb
Recharge (RCH)	Capitan.rch
Horizontal Flow Barrier (HFB6)	Capitan.hfb
Evapotranspiration (EVT)	Capitan.evt
Output Control (OC)	Capitan.oc
Preconditioned Conjugate-Gradient Solver (PCG)	Capitan.pcg

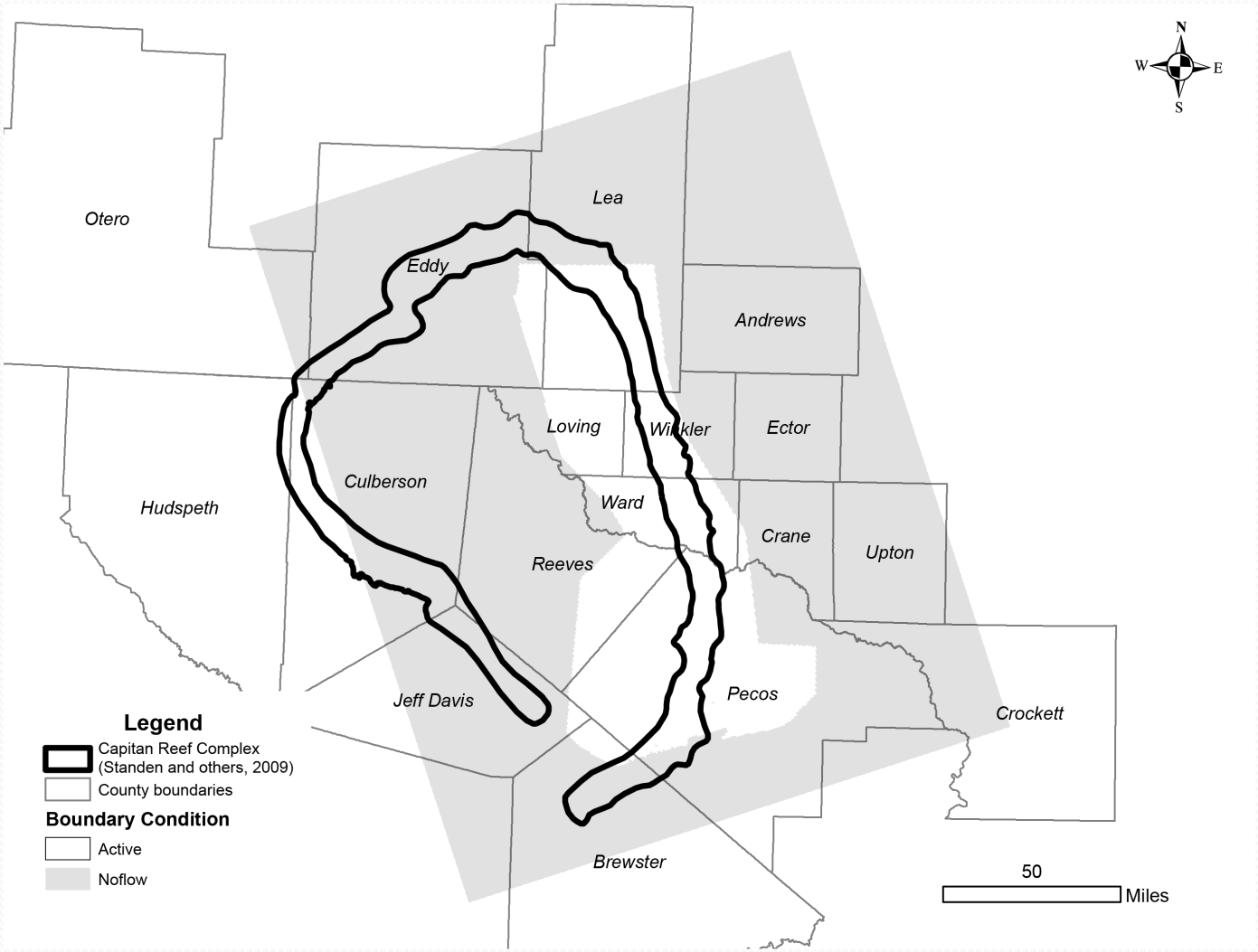
Model Output Filenames

Packages	Output Files
LIST (LST)	Capitan.lst
Cell-by-Cell Budgets (CBB)	Capitan.cbb
Heads (HDS)	Capitan.hds
Drawdown (DDN)	Capitan.ddn

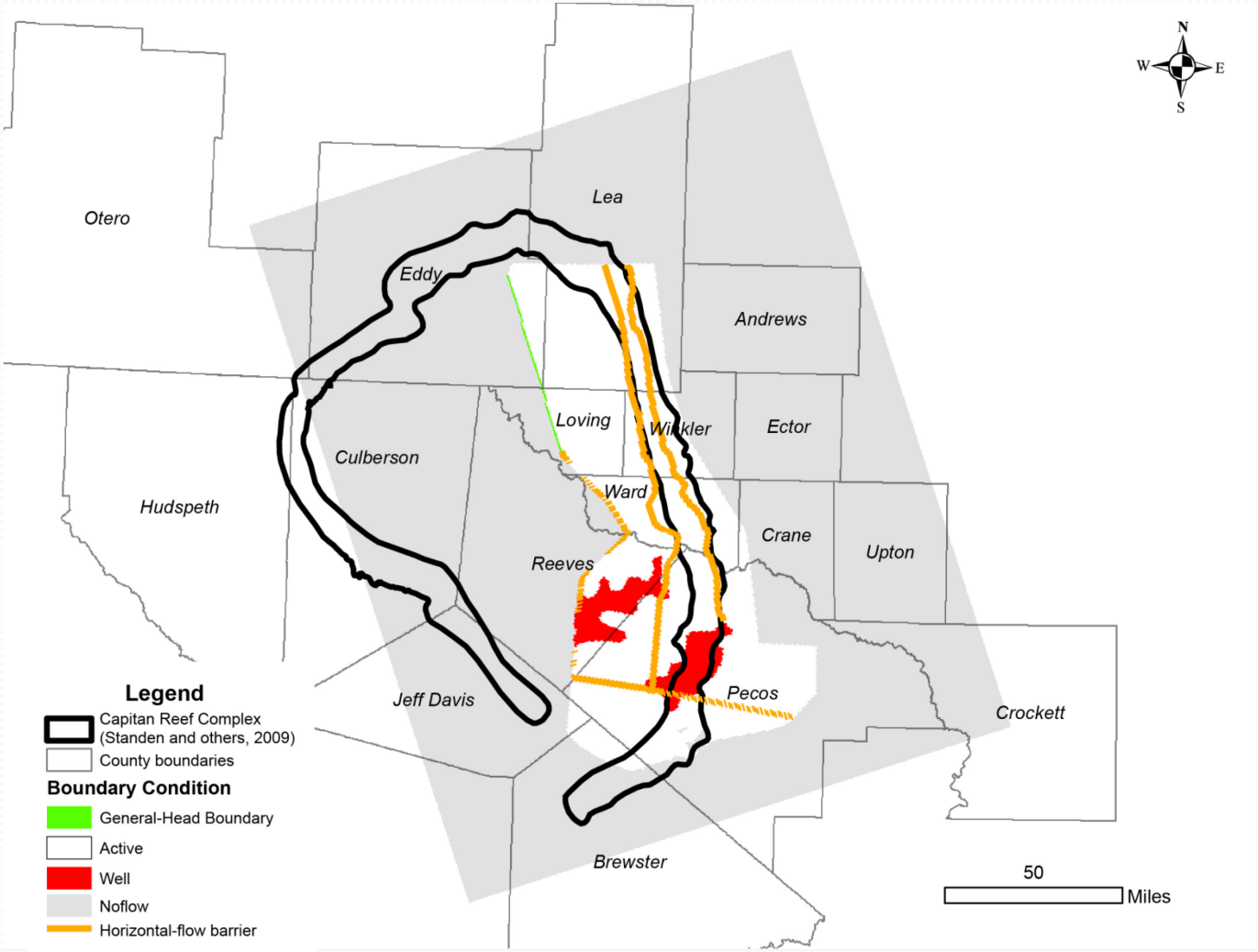
Active Cells/Boundary Conditions: Layer 1



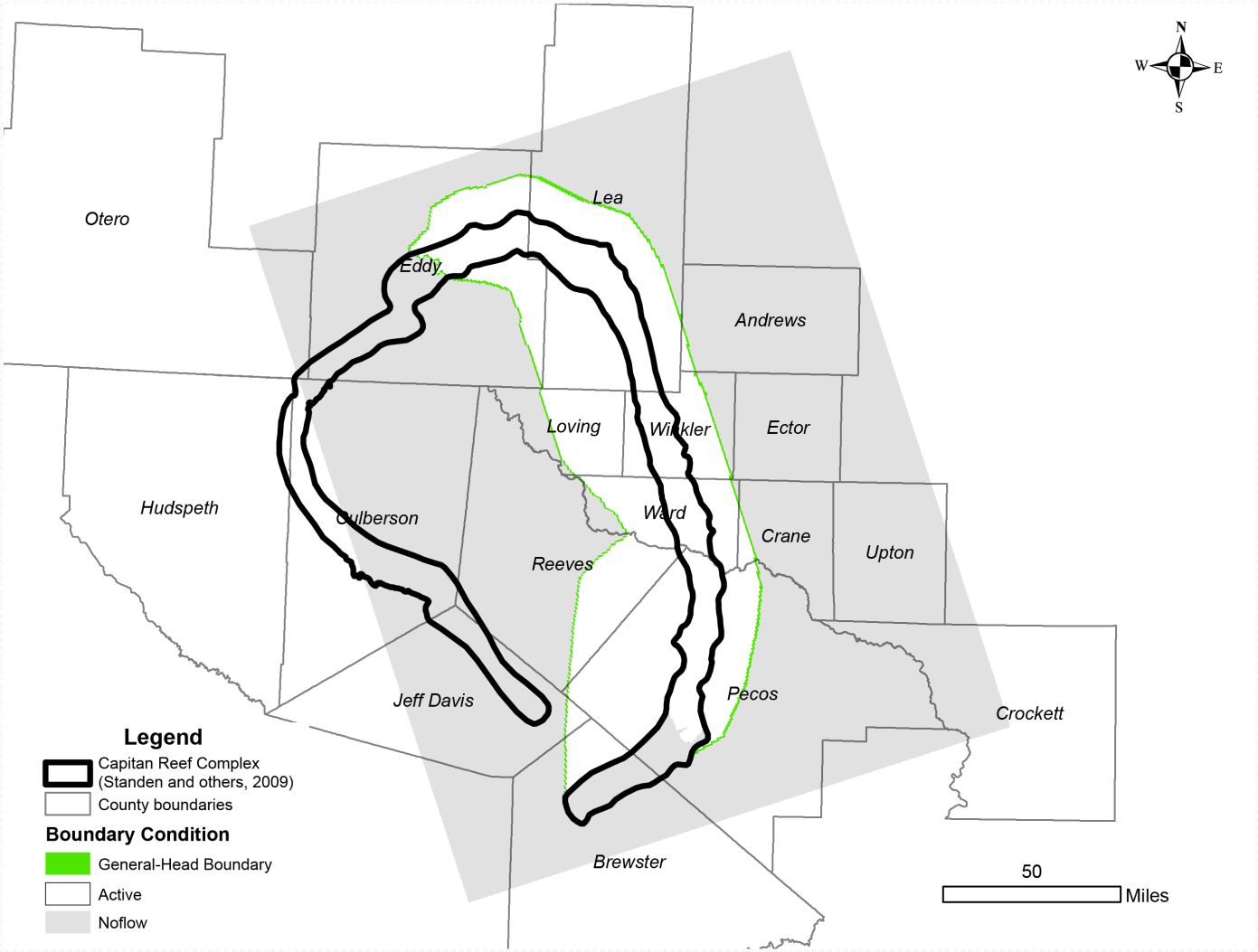
Active Cells/Boundary Conditions: Layer 2



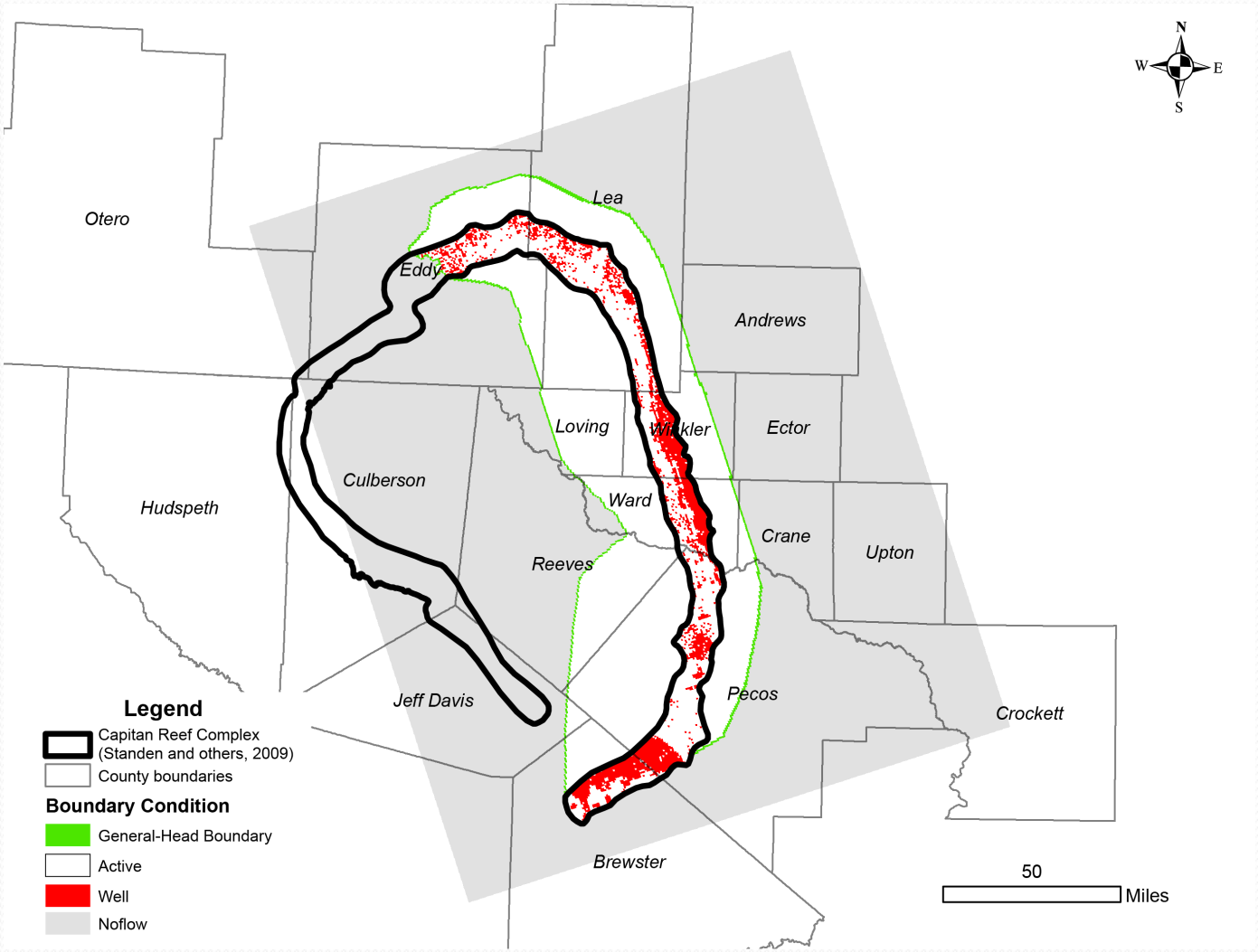
Active Cells/Boundary Conditions: Layer 3



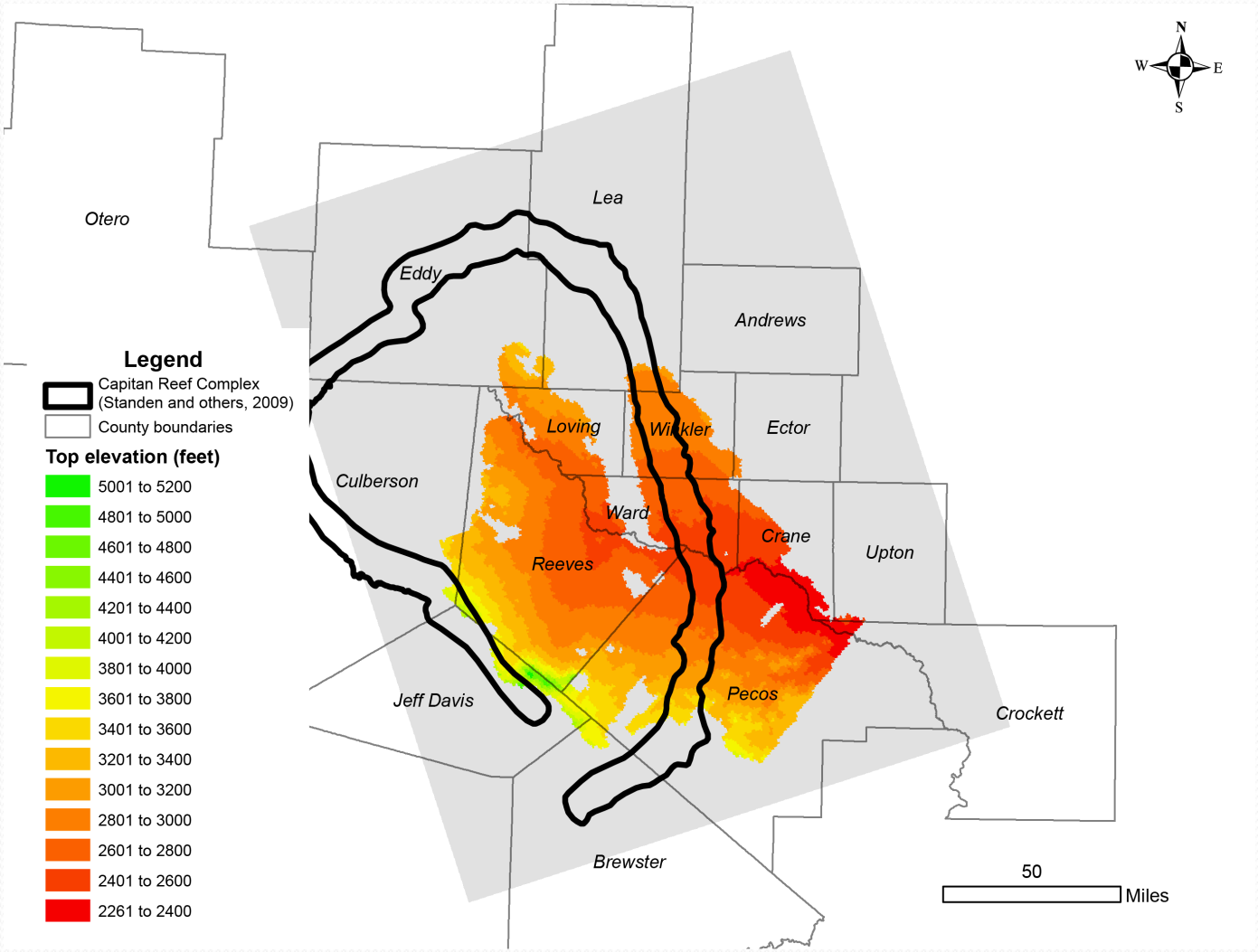
Active Cells/Boundary Conditions: Layer 4



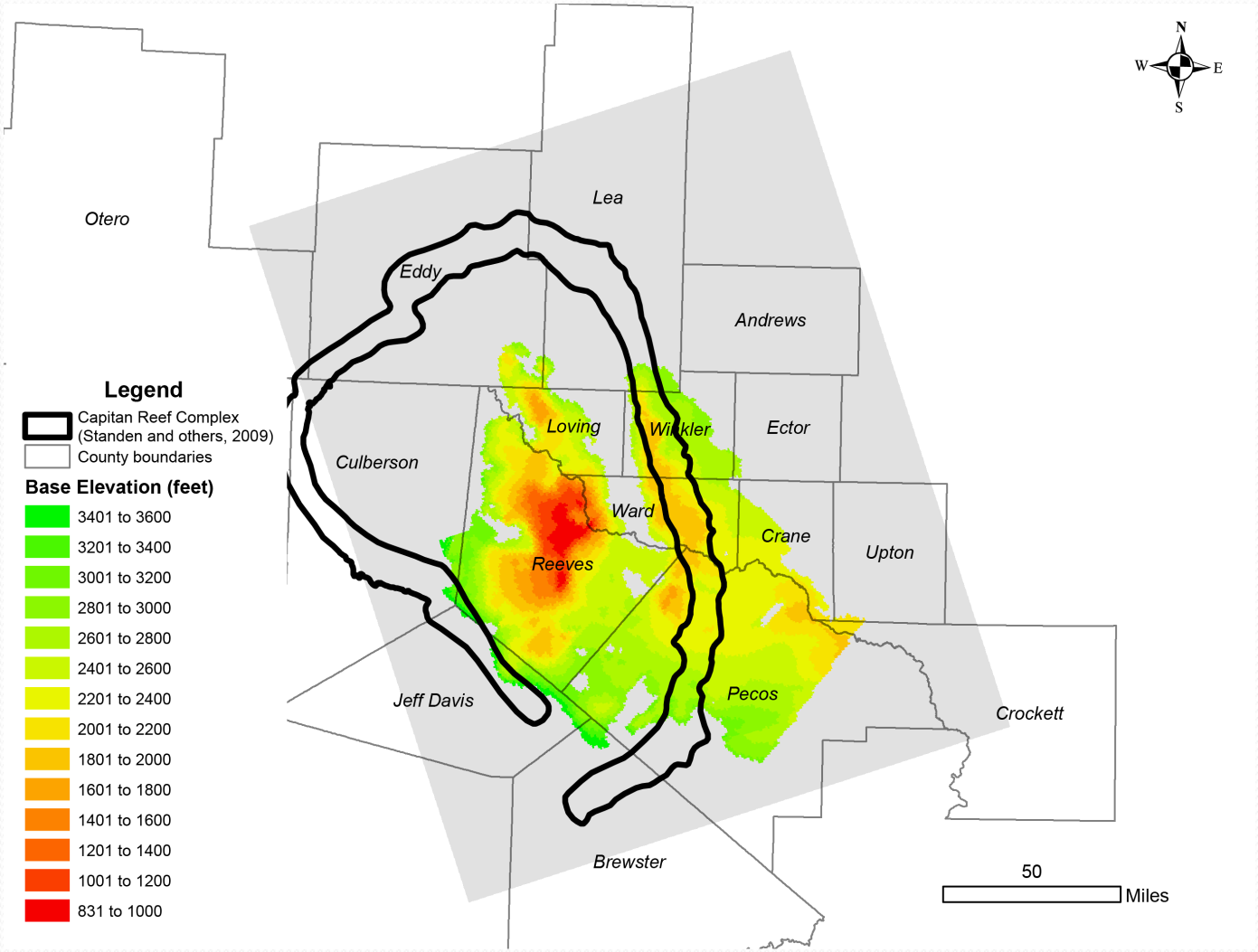
Active Cells/Boundary Conditions: Layer 5



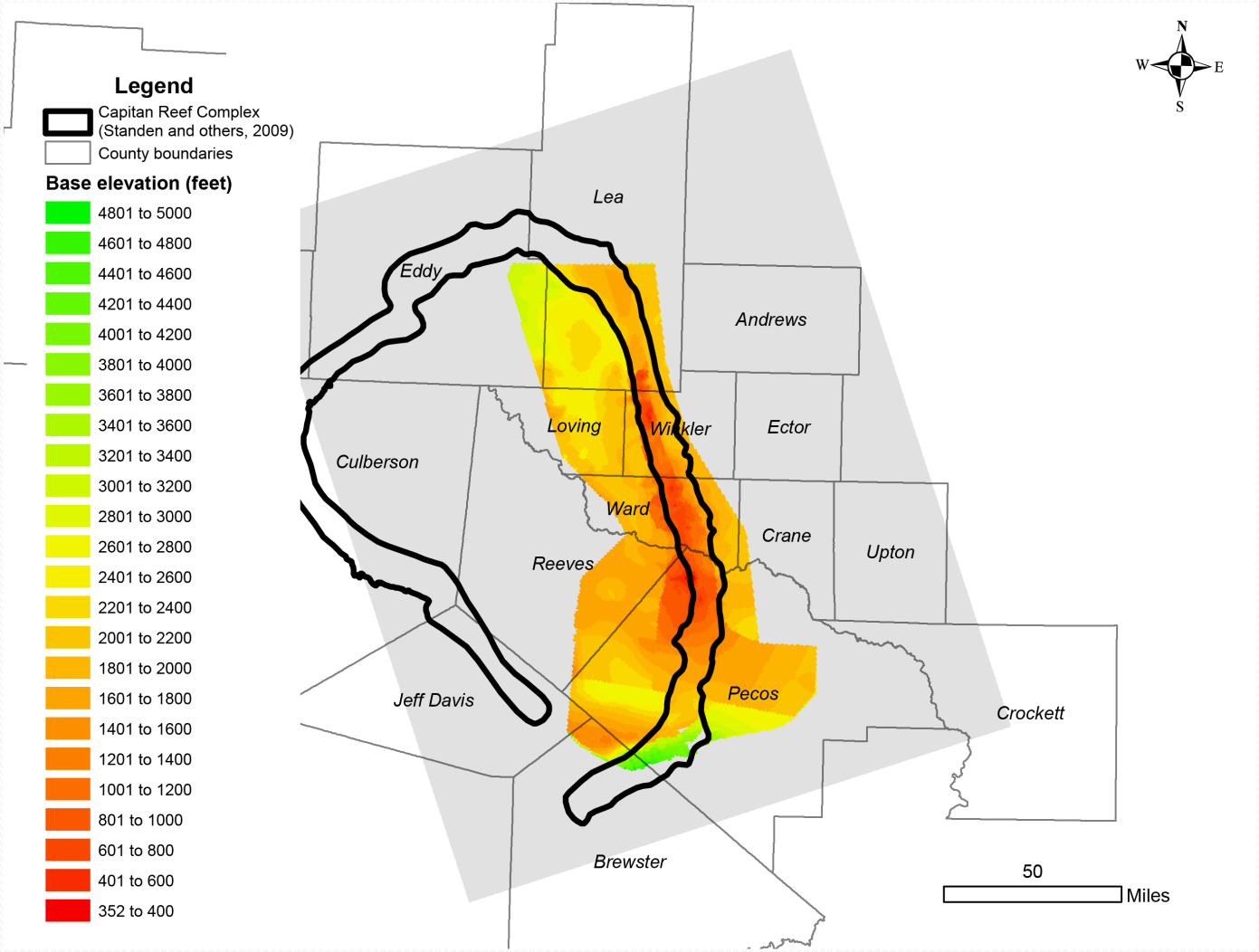
Top Elevations: Layer 1



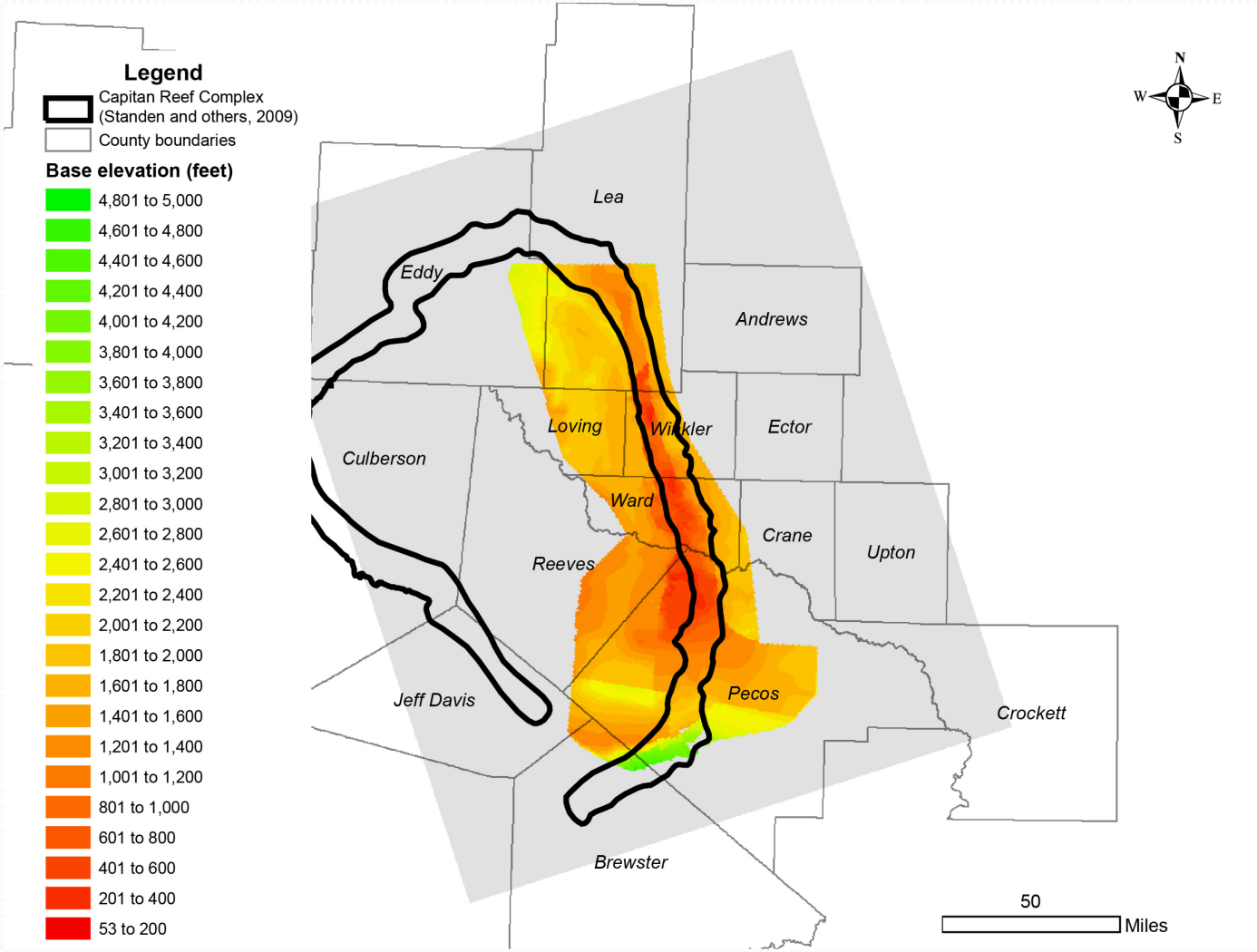
Base Elevations: Layer 1



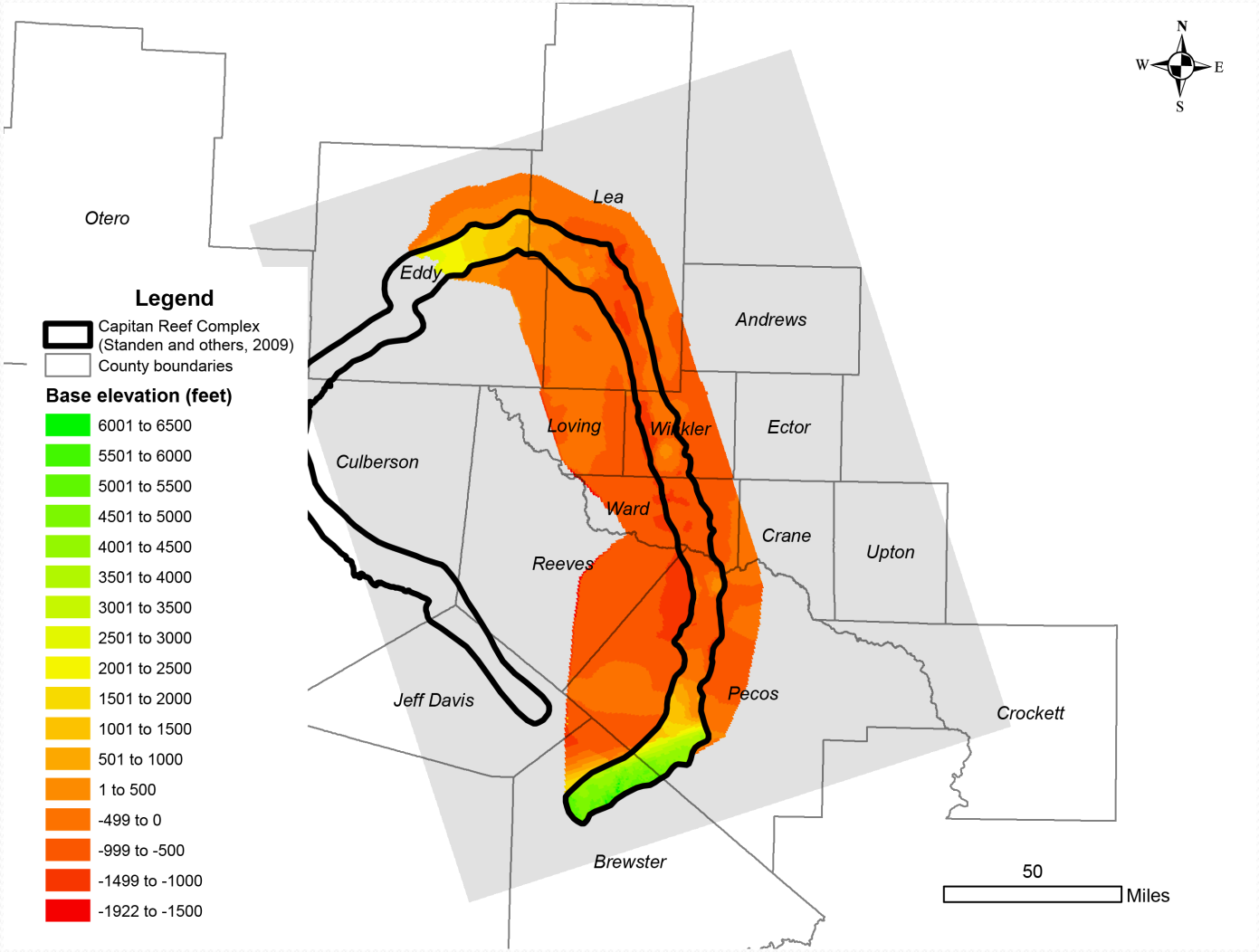
Base Elevations: Layer 2



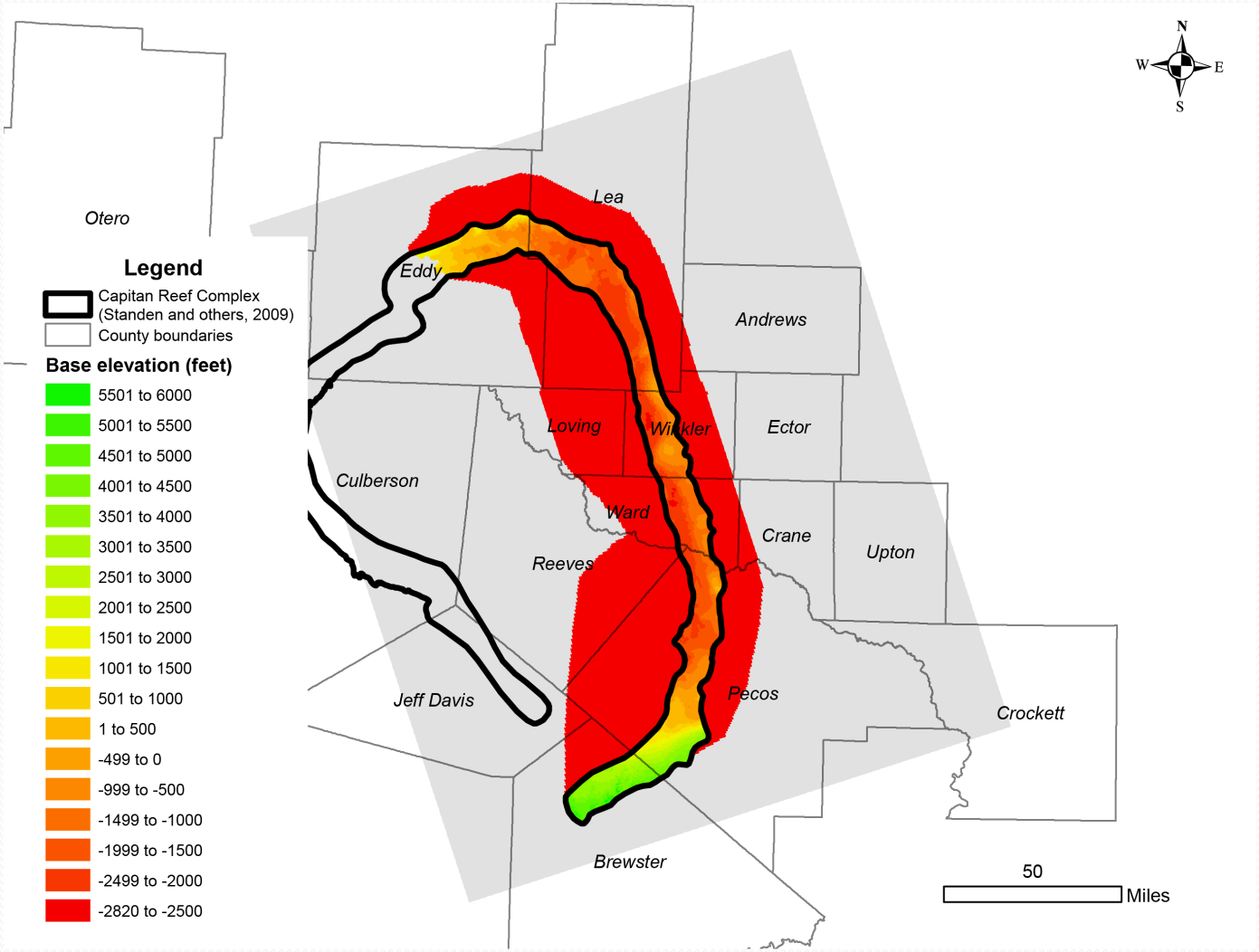
Base Elevations: Layer 3



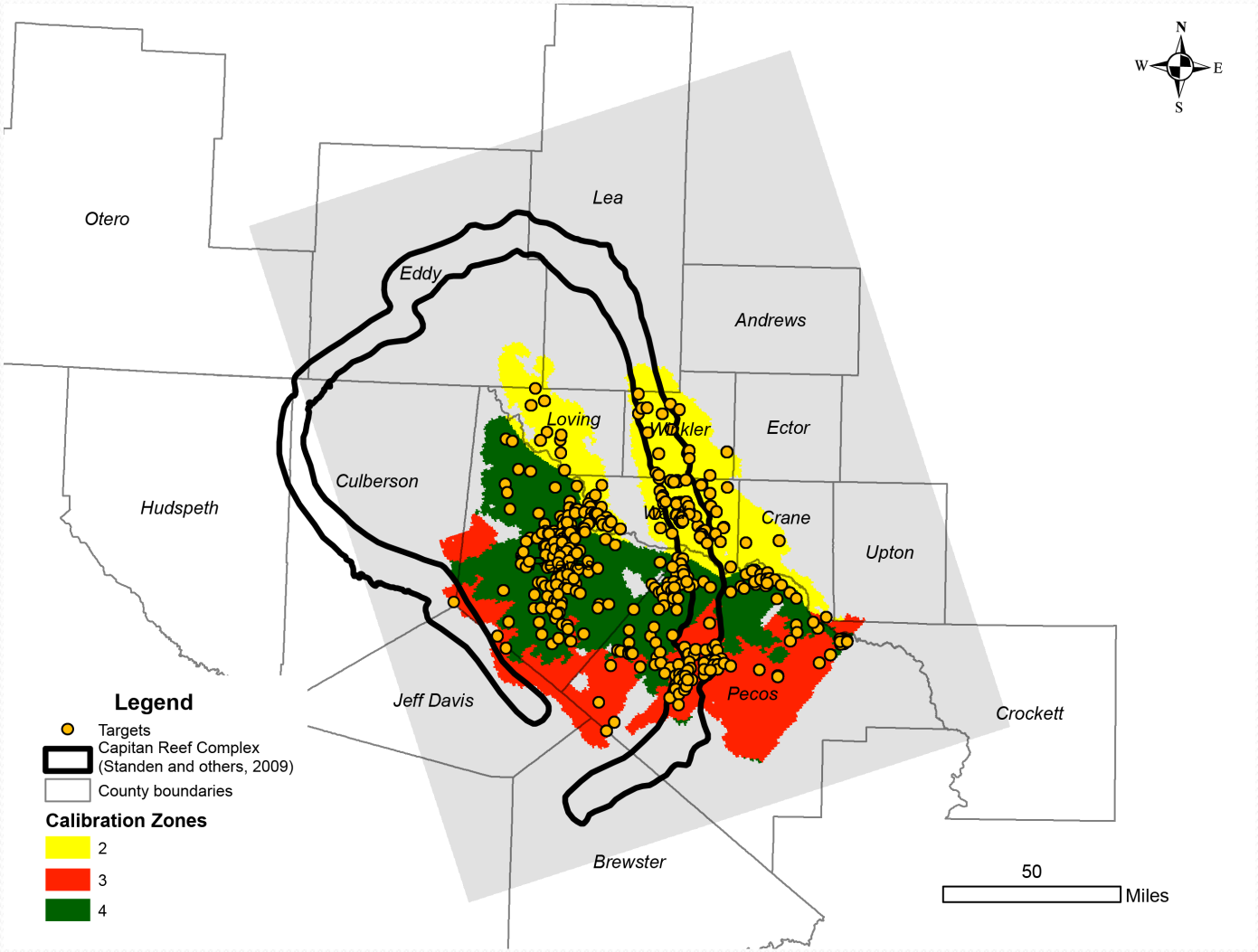
Base Elevations: Layer 4



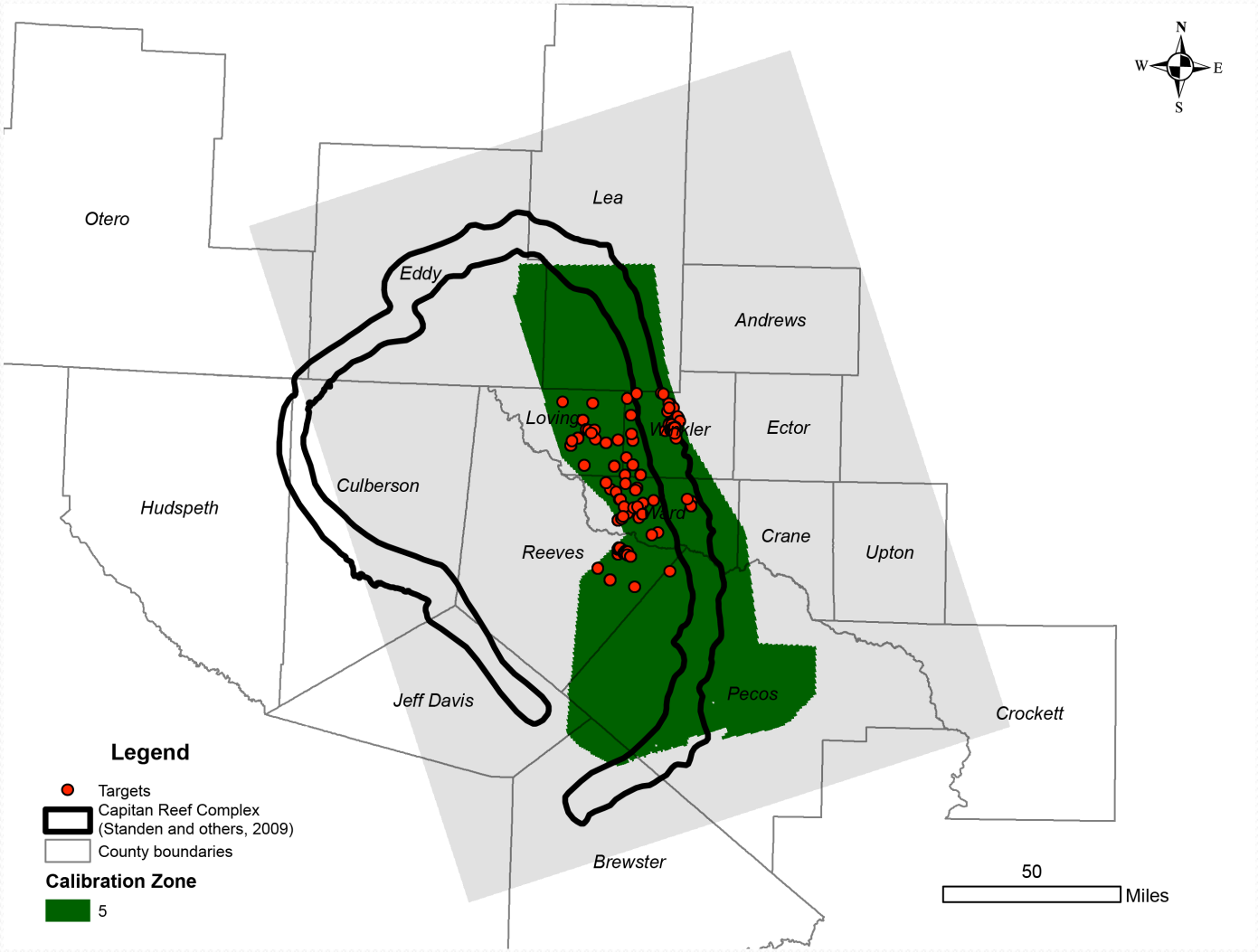
Base Elevations: Layer 5



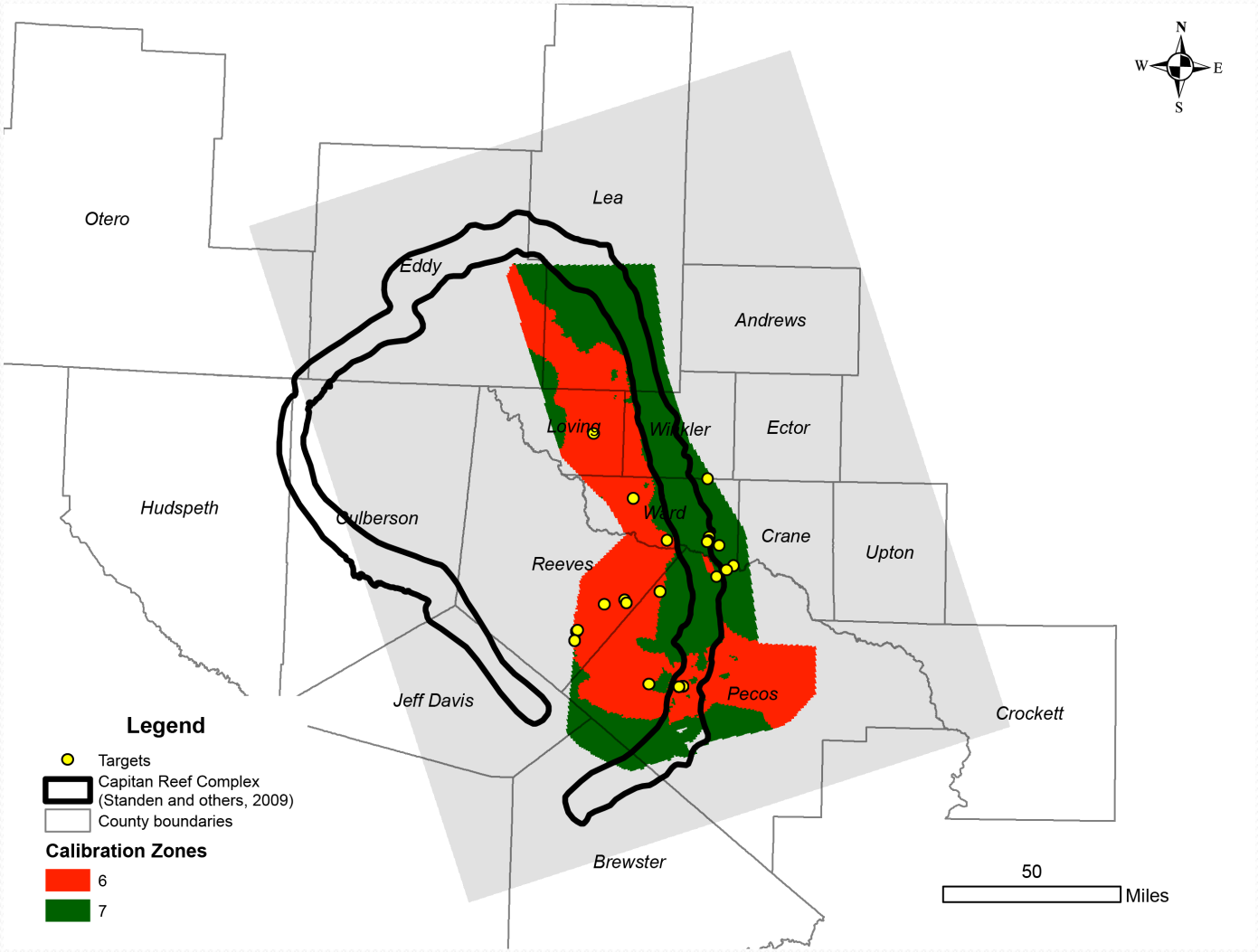
Calibration Zones: Layer 1



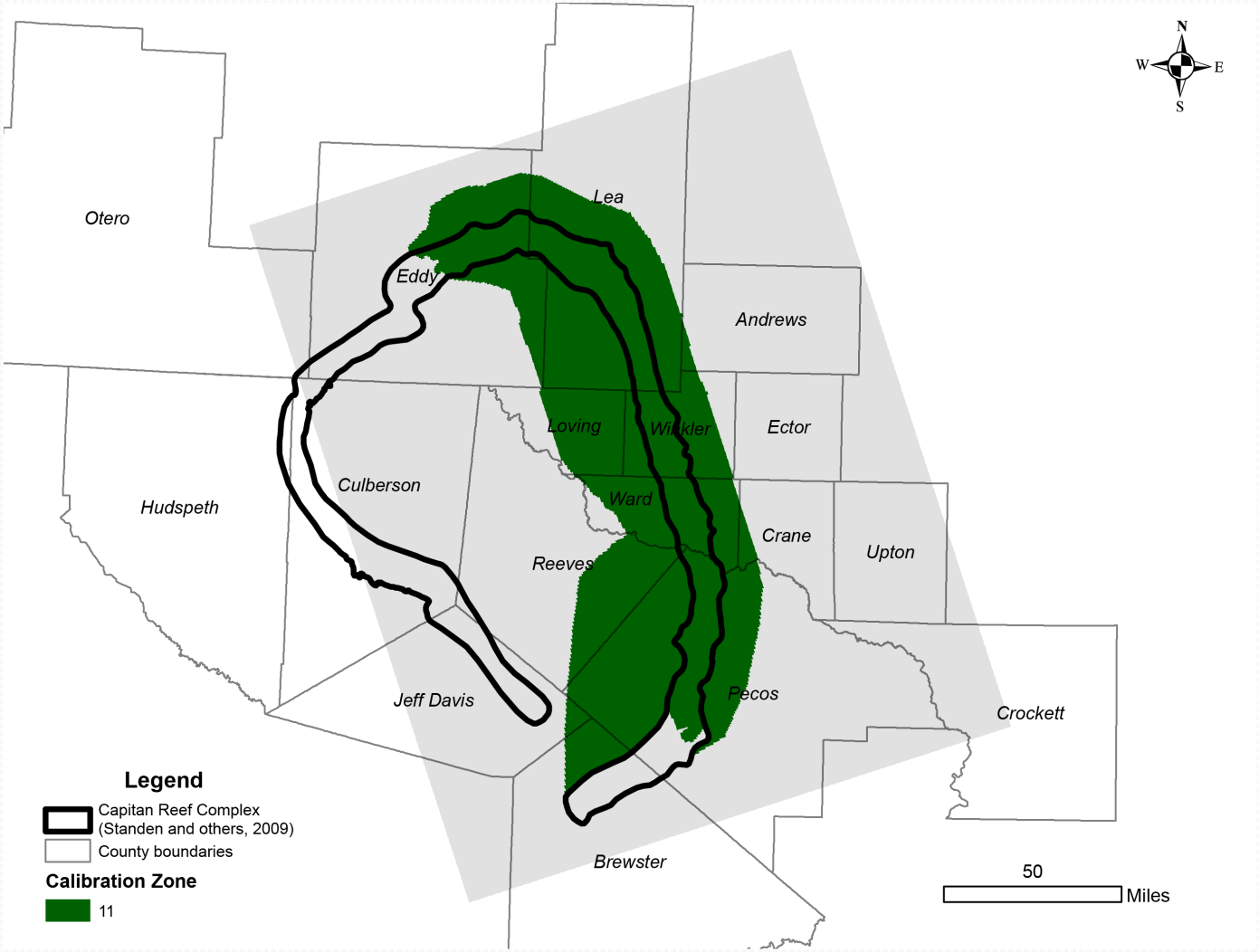
Calibration Zones: Layer 2



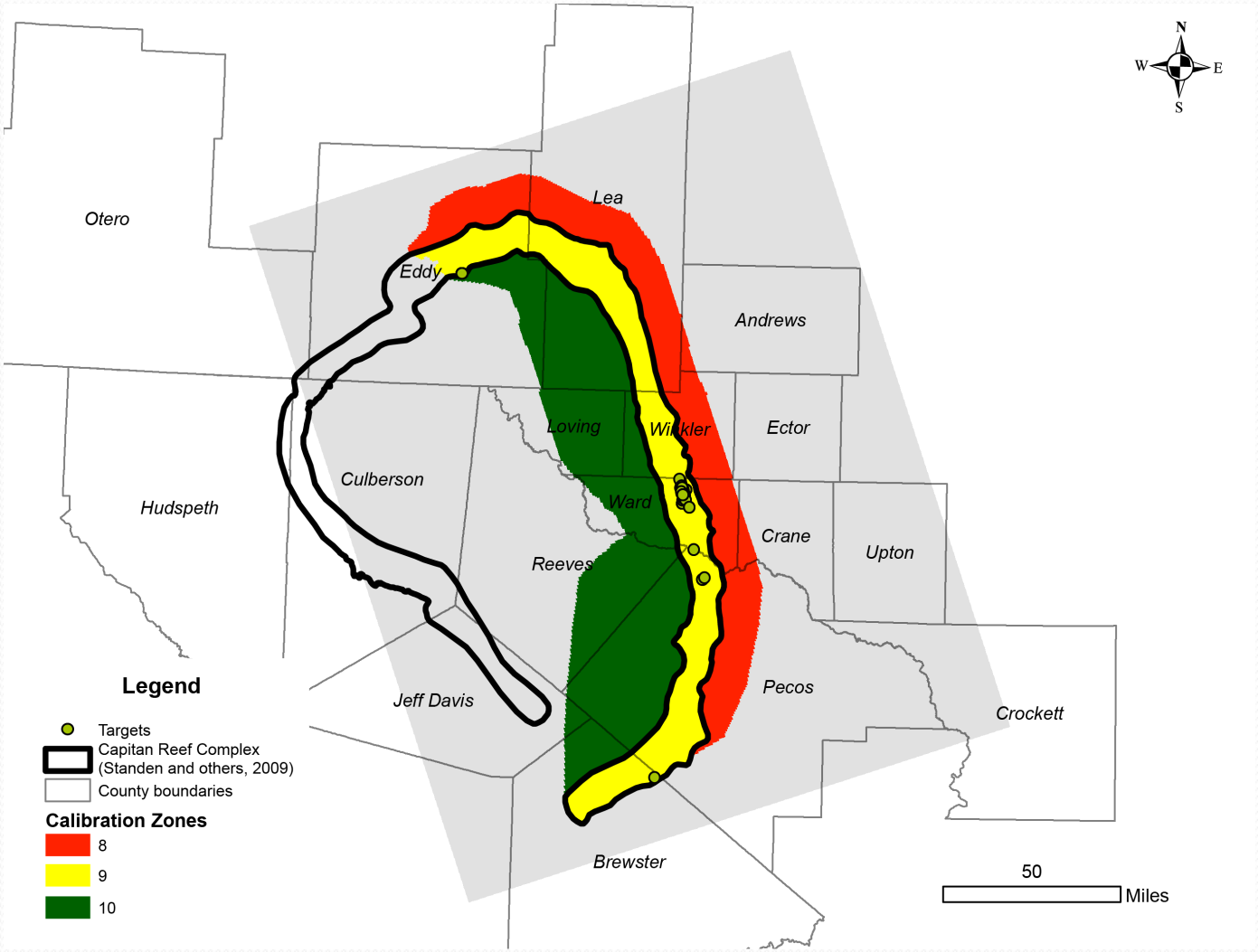
Calibration Zones: Layer 3



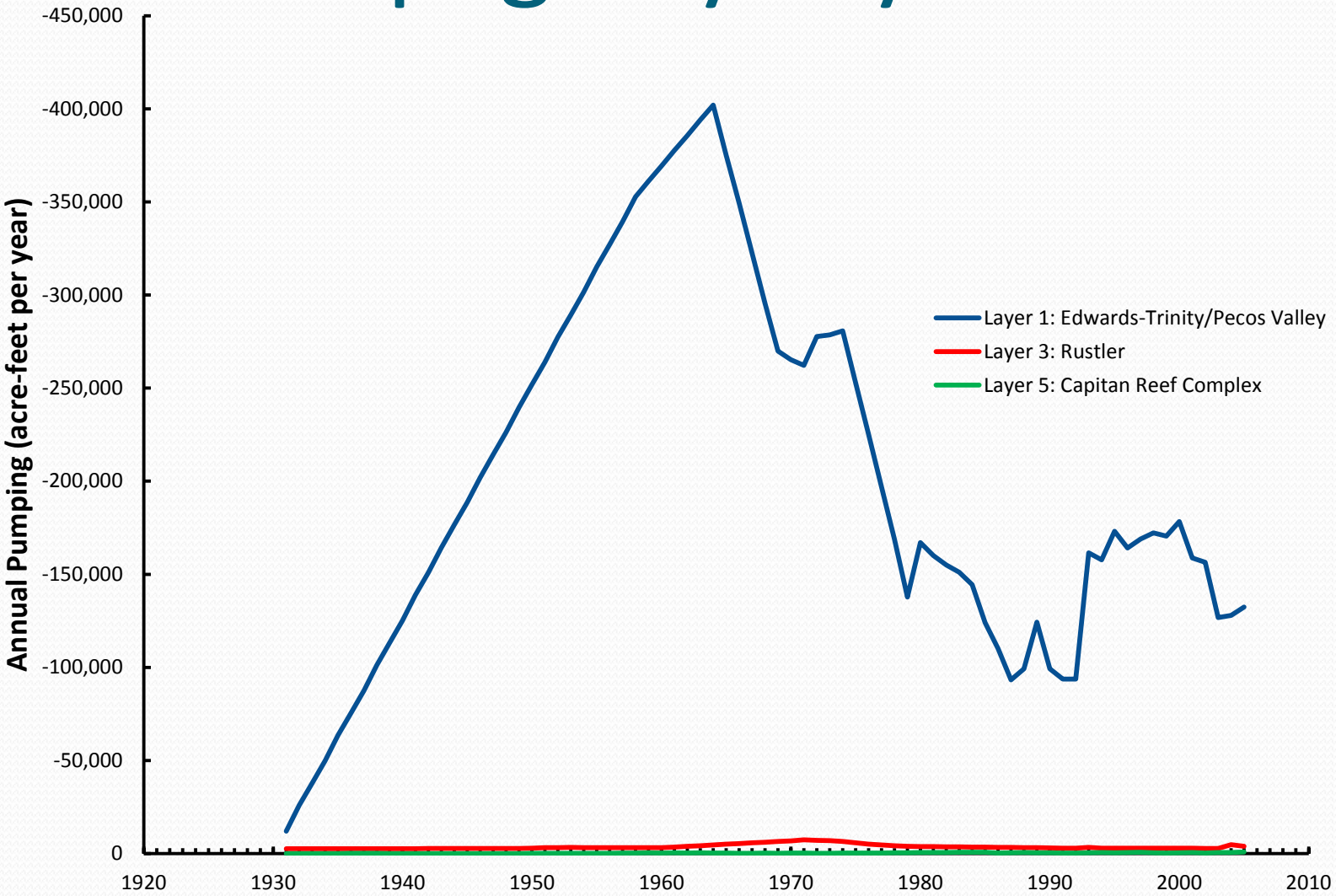
Calibration Zones: Layer 4



Calibration Zones: Layer 5

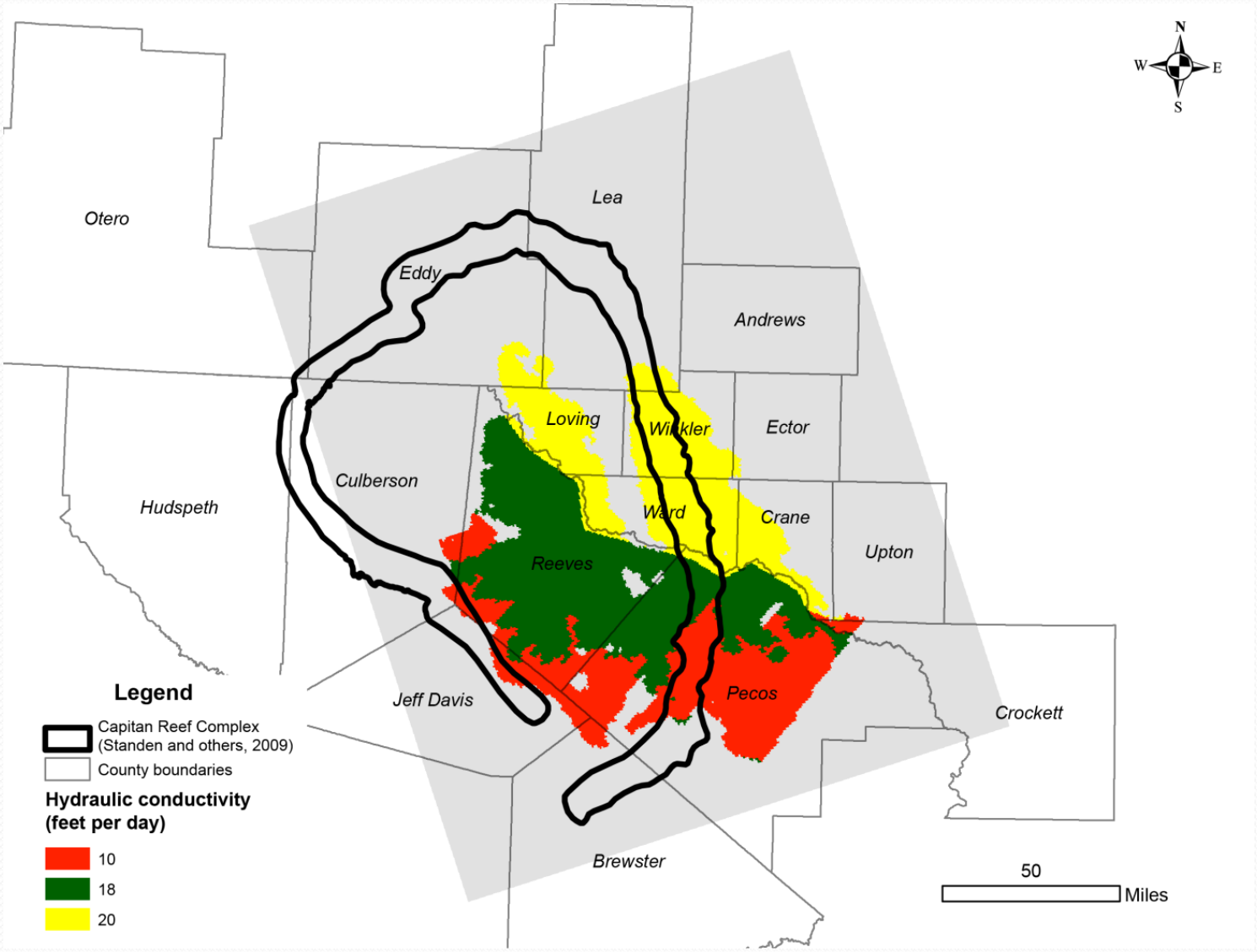


Total Pumpage by Layer

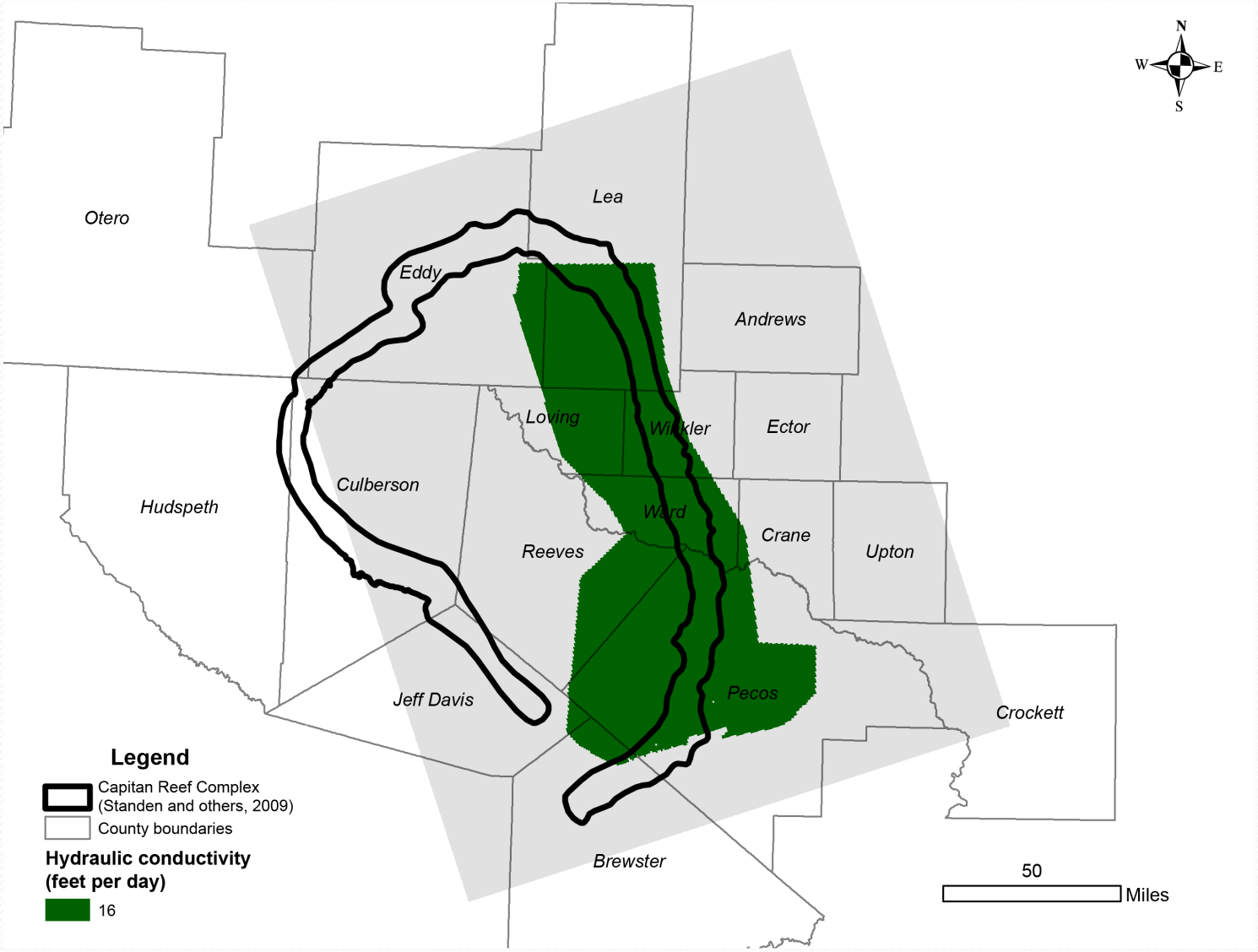


MODEL CALIBRATION

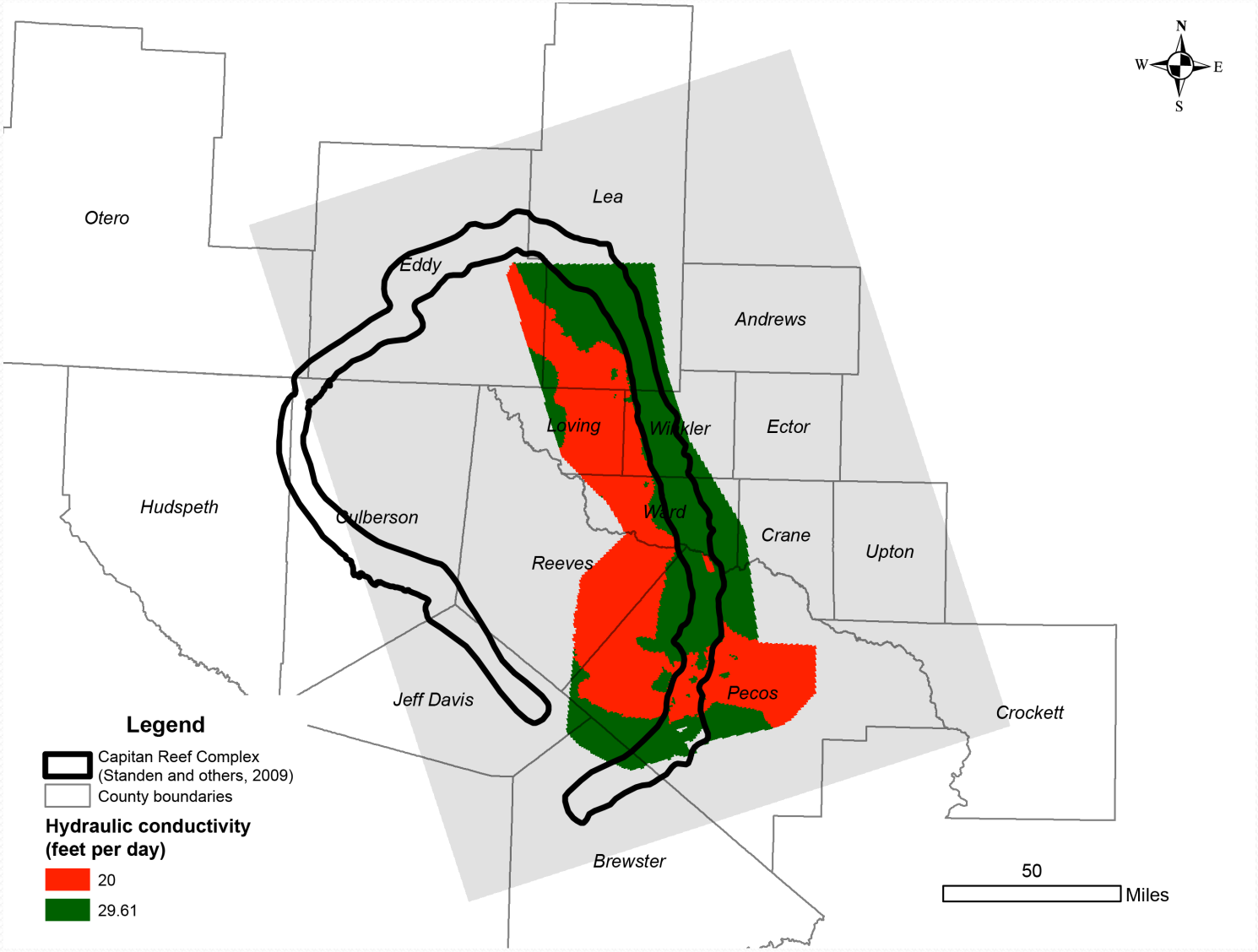
Hydraulic Conductivity: Layer 1



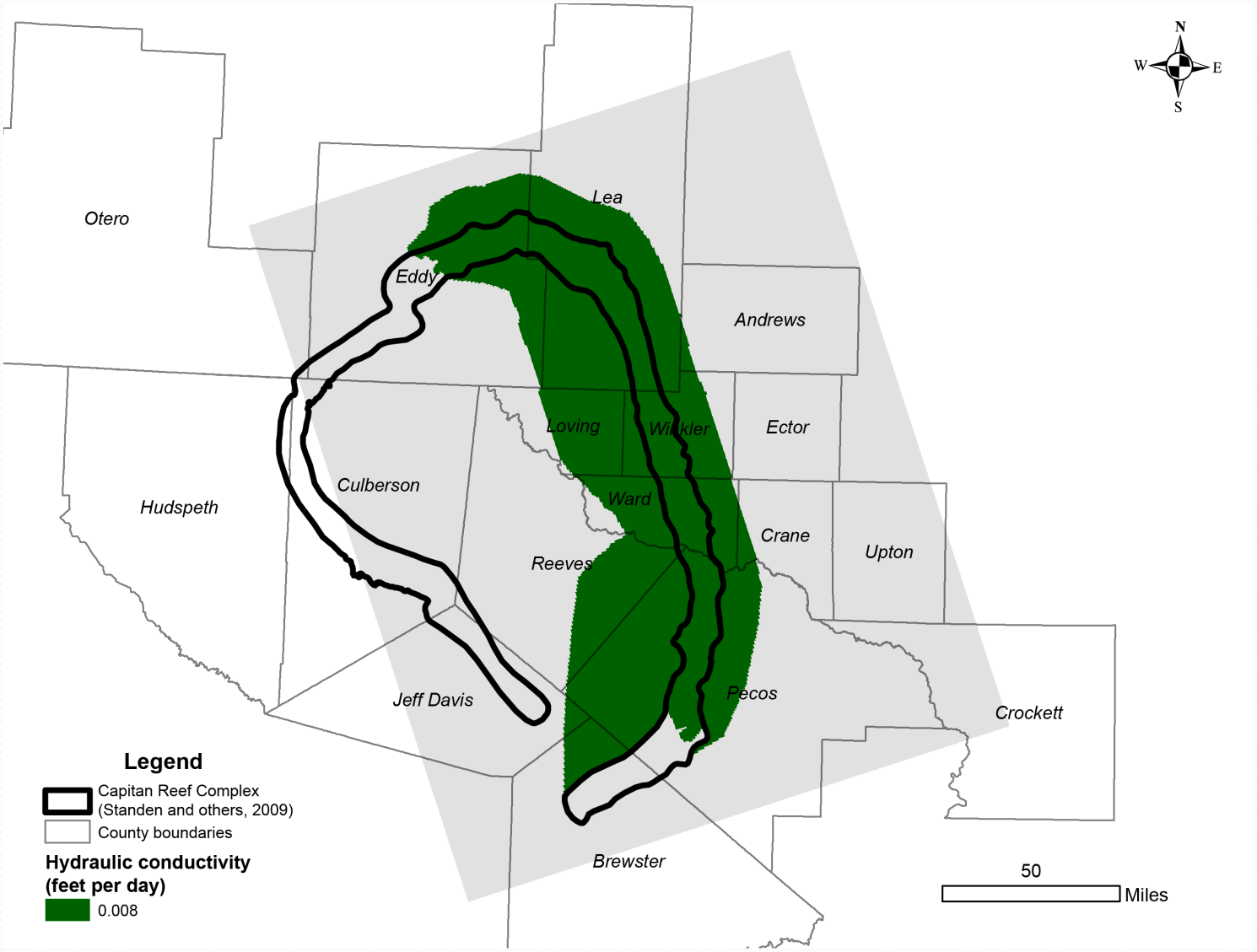
Hydraulic Conductivity: Layer 2



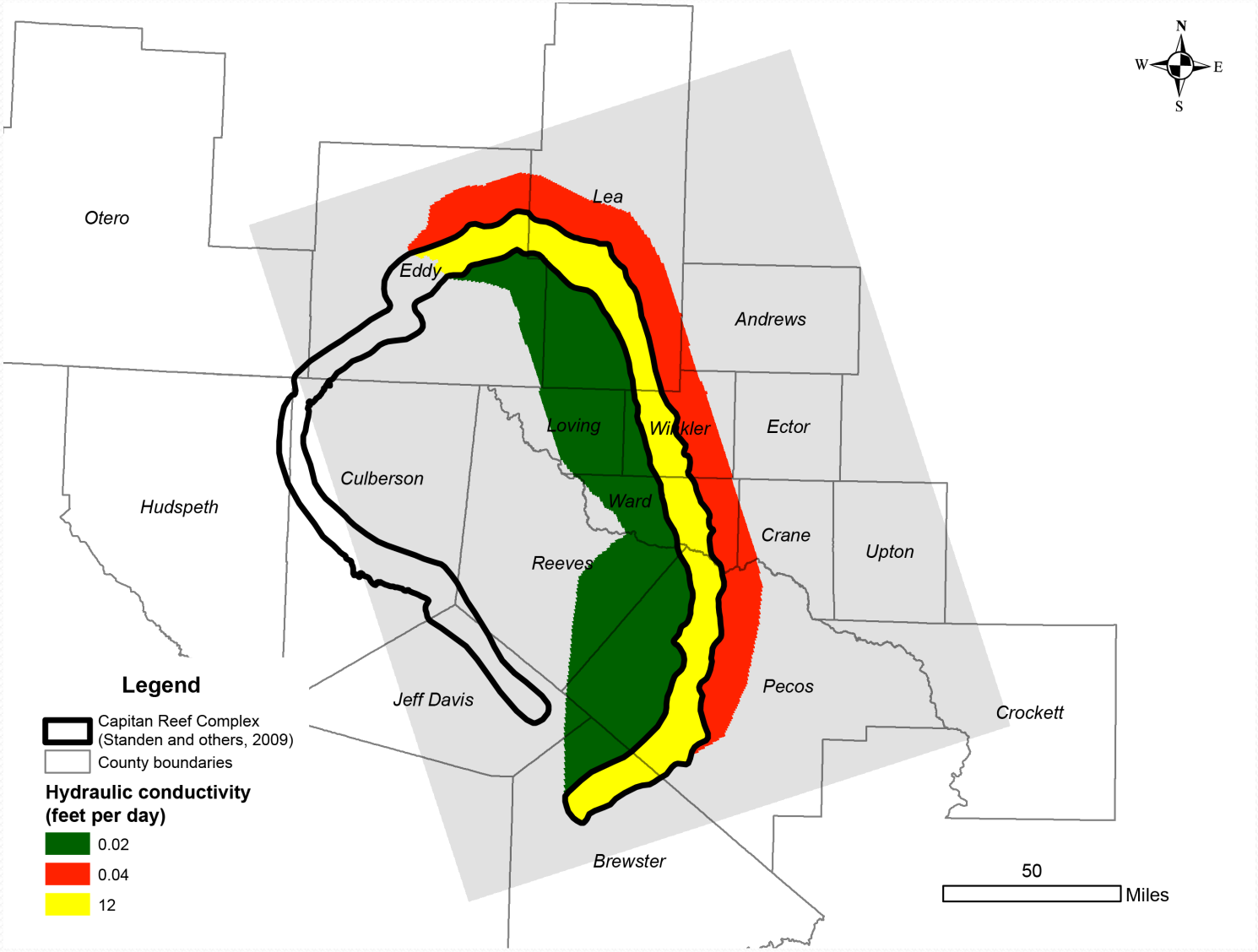
Hydraulic Conductivity: Layer 3



Hydraulic Conductivity: Layer 4



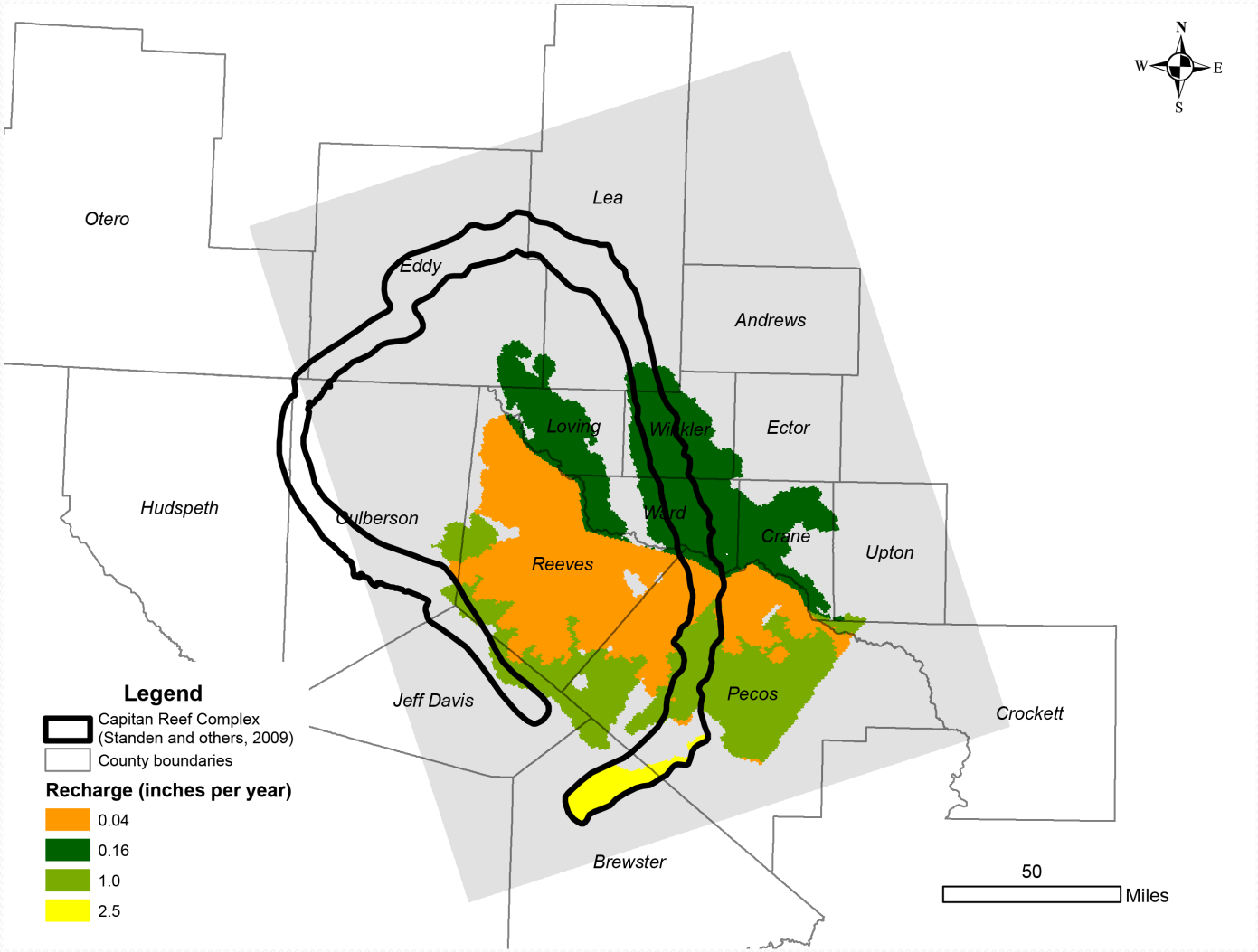
Hydraulic Conductivity: Layer 5



Specific Storage

Zone	Zone Number	Value
Pecos Valley-North	2	2.53×10^{-4}
Edwards-Trinity (Plateau)	3	2.79×10^{-4}
Pecos Valley-South	4	1.66×10^{-4}
Dockum/Dewey Lake	5	1×10^{-6}
Rustler 1	6	1.5×10^{-6}
Rustler 2	7	5.6×10^{-6}
Shelf Deposits	8	1×10^{-6}
Capitan Reef Complex	9	1×10^{-4}
Basin Deposits	10	4.44×10^{-7}
Confining Unit	11	1×10^{-6}

Recharge


N
W
E
S
Otero
Lea
Eddy
Andrews
Loving
Winkler
Ector
Hudspeth
Culberson
Ward
Crane
Upton
Reeves
Pecos
Jeff Davis
Crockett
Brewster
Legend
Capitan Reef Complex (Standen and others, 2009)
County boundaries
Recharge (inches per year)
0.04
0.16
1.0
2.5
50
Miles

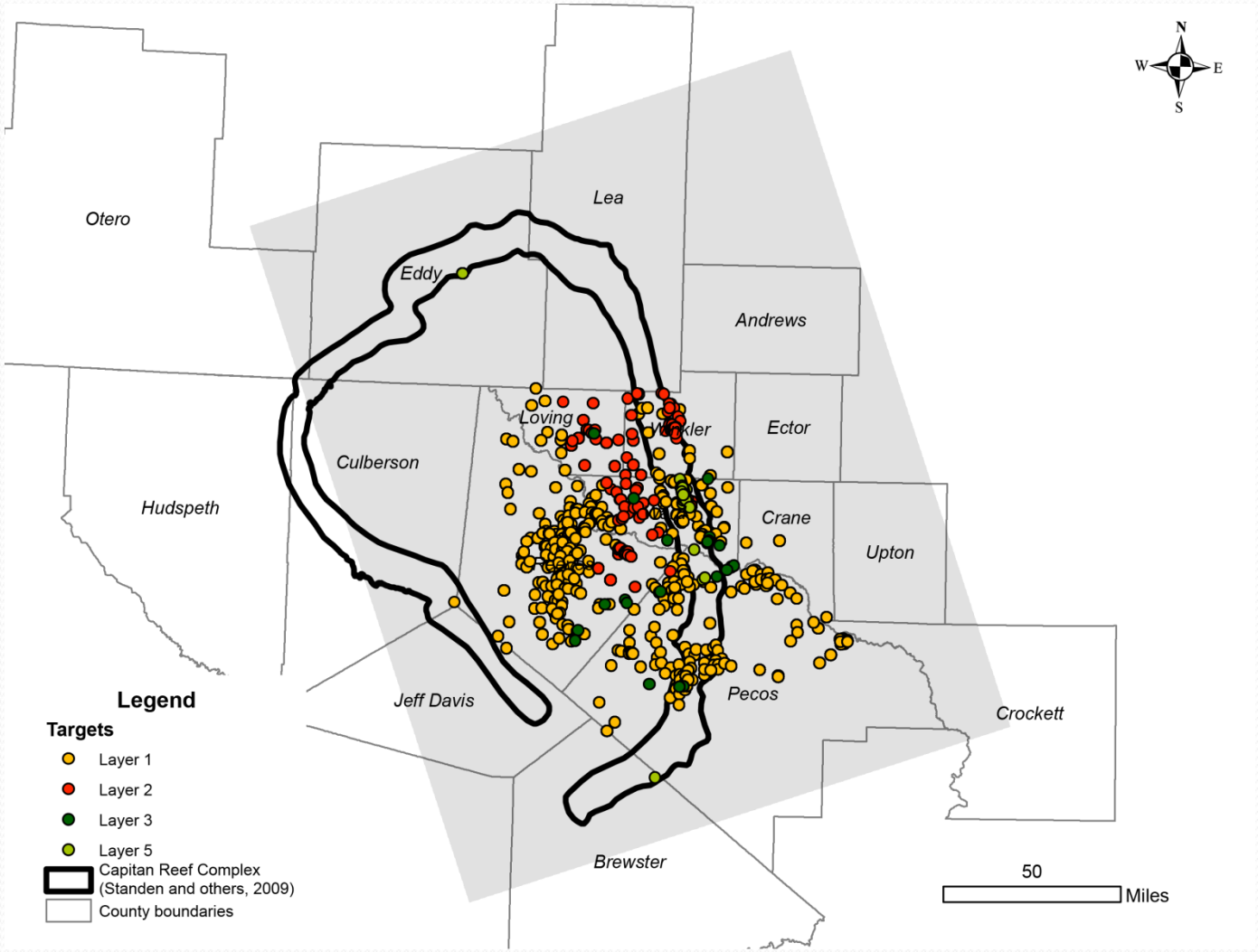
Calibration Statistics: Model-wide

Mean Error (feet)	-59
Mean Absolute Error (feet)	102
Root Mean Square Error (feet)	129
Range (feet)	1,809
Root Mean Square Error/Range (percent)	7

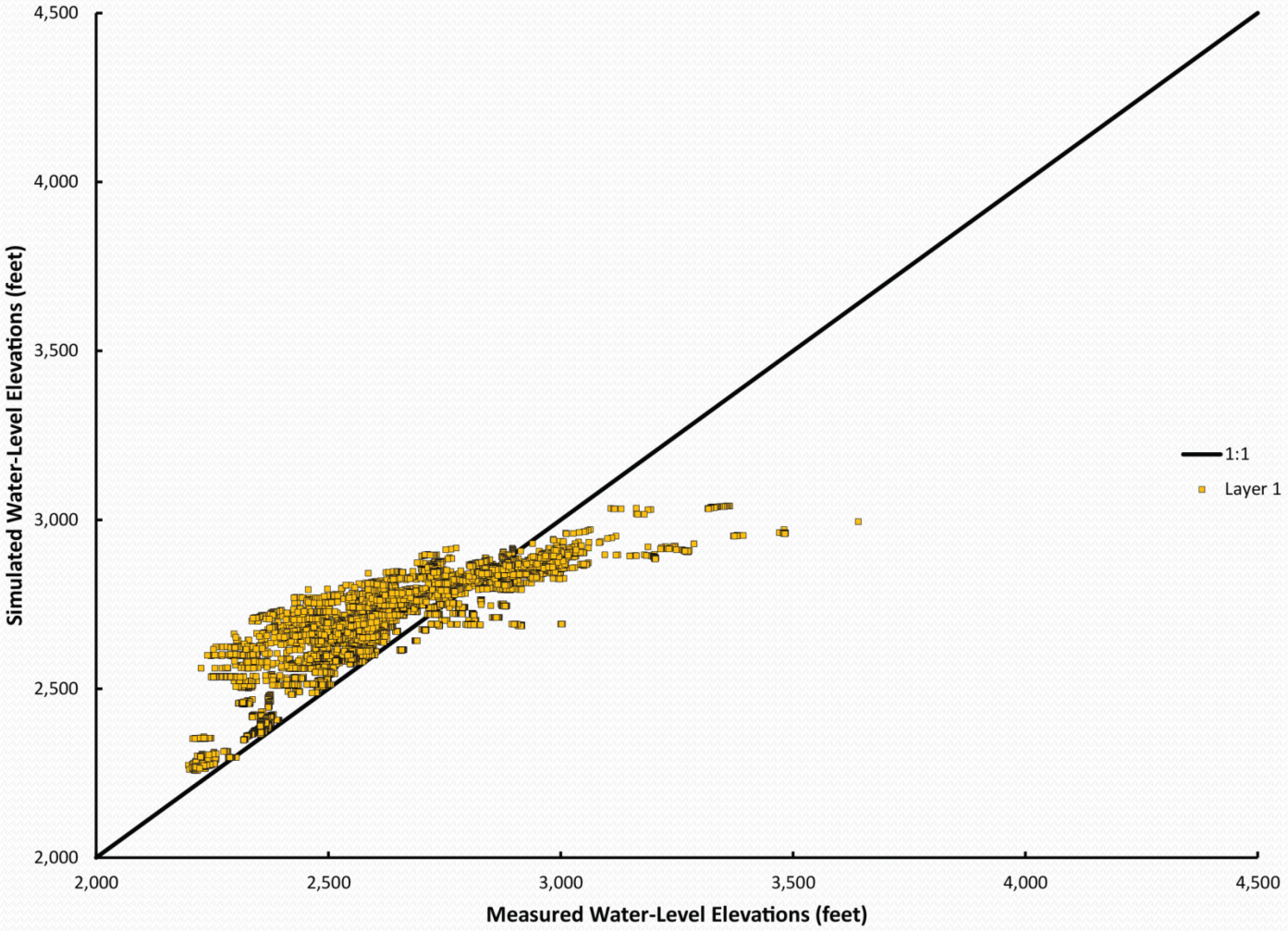
Calibration Statistics: Capitan

Mean Error (feet)	24
Mean Absolute Error (feet)	80
Root Mean Square Error (feet)	104
Range (feet)	1,456
Root Mean Square Error/Range (percent)	7

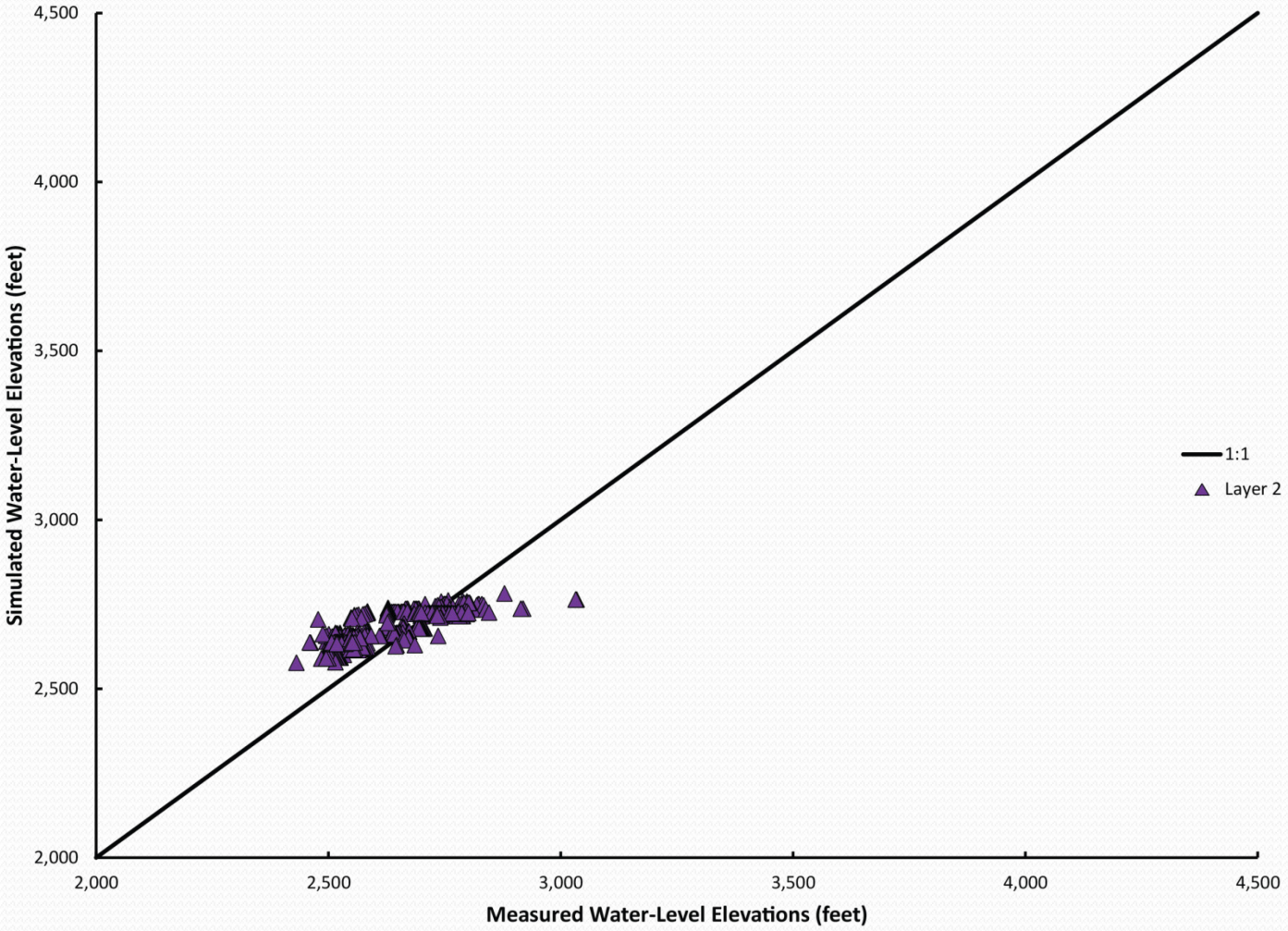
Water-Level Target Locations



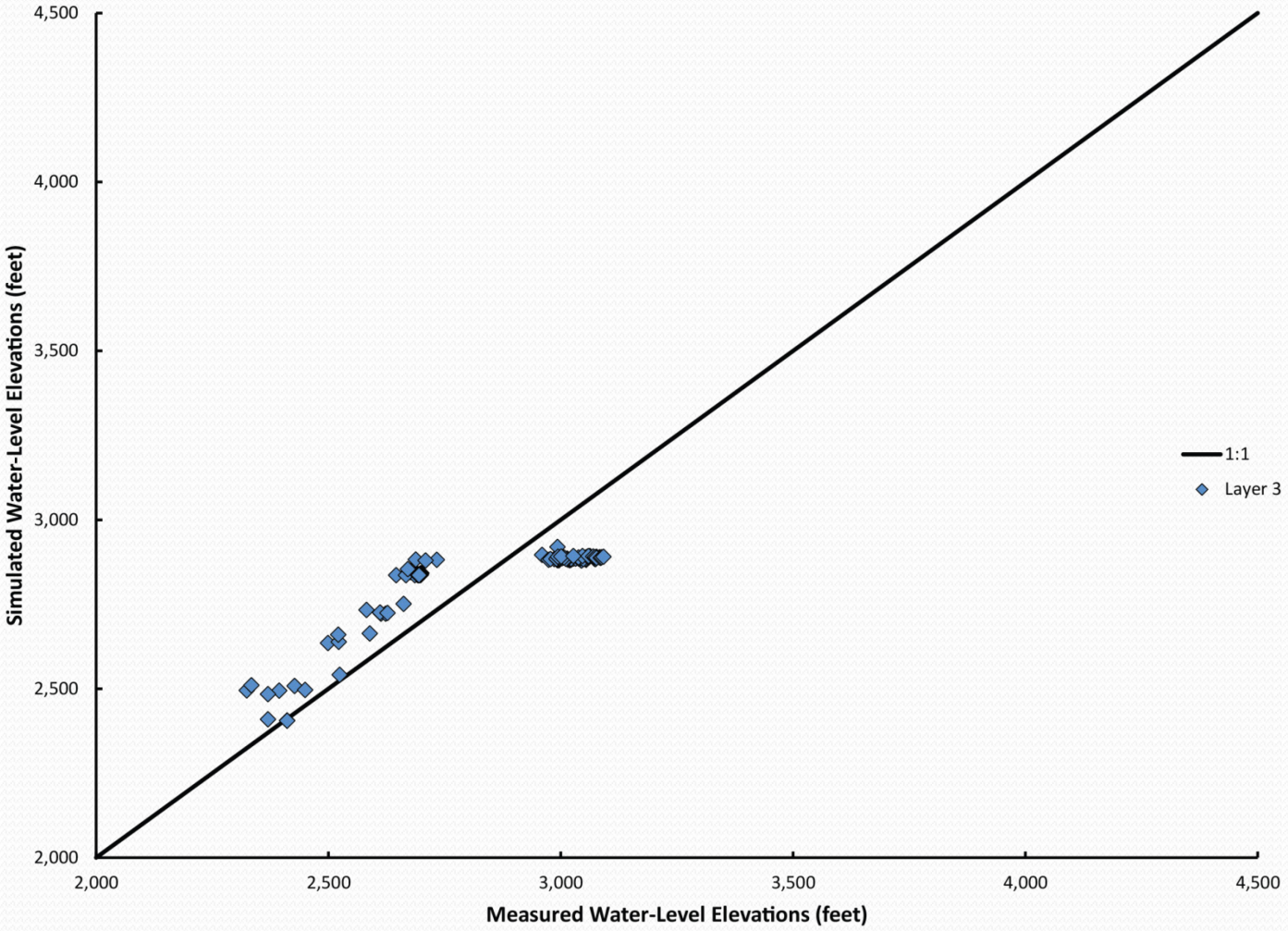
Measure vs. Simulated Water Levels: Layer 1



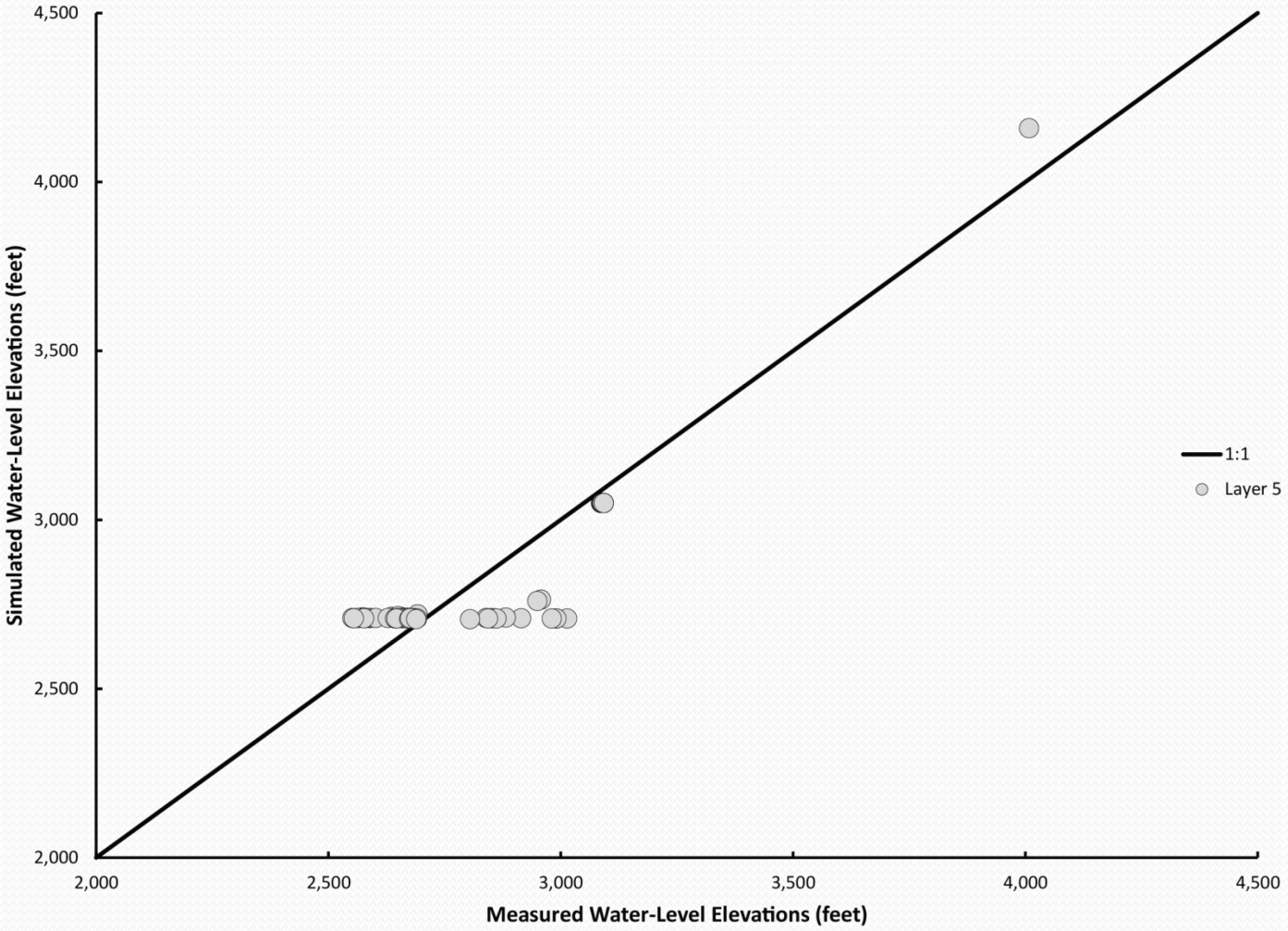
Measure vs. Simulated Water Levels: Layer 2



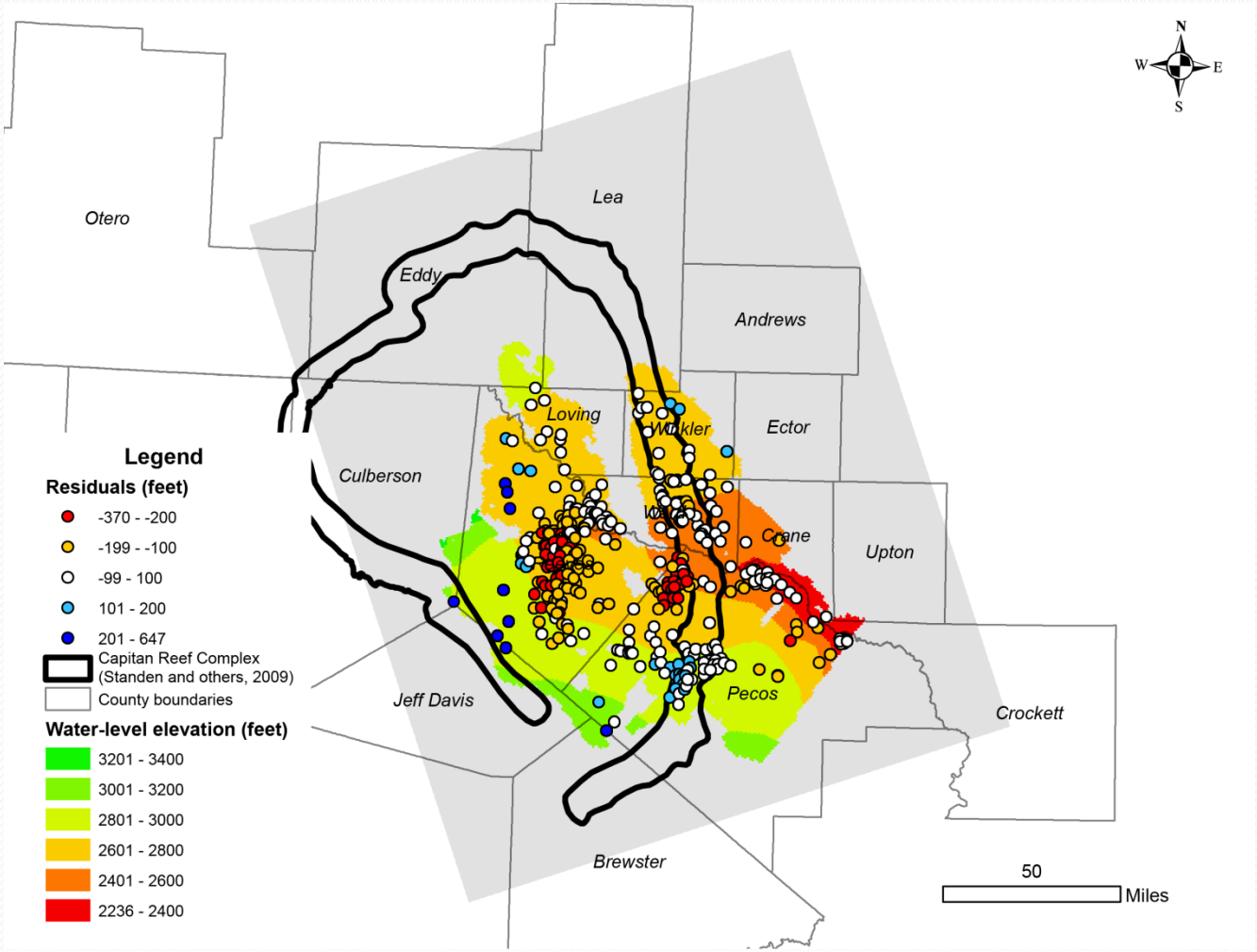
Measure vs. Simulated Water Levels: Layer 3



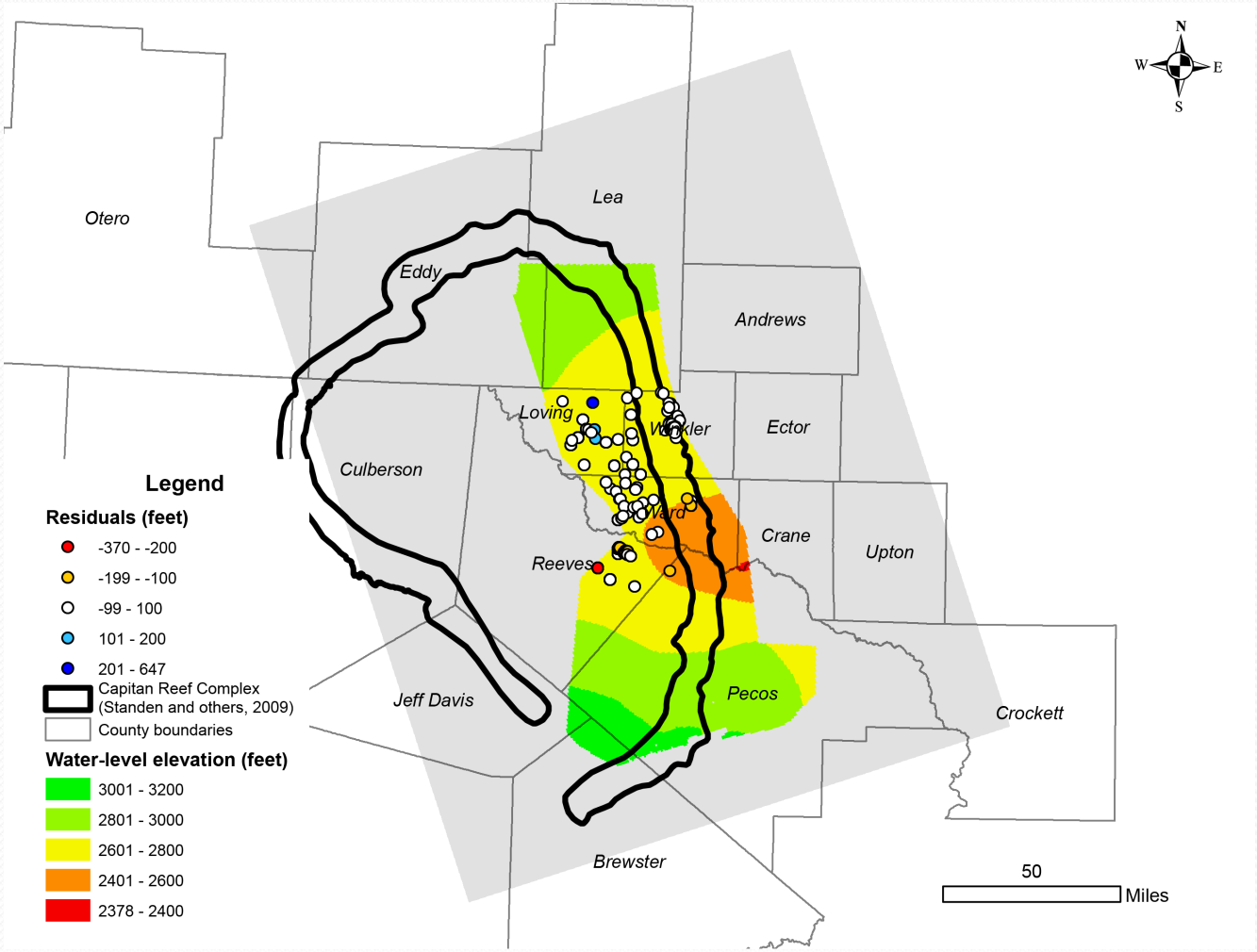
Measure vs. Simulated Water Levels: Layer 5



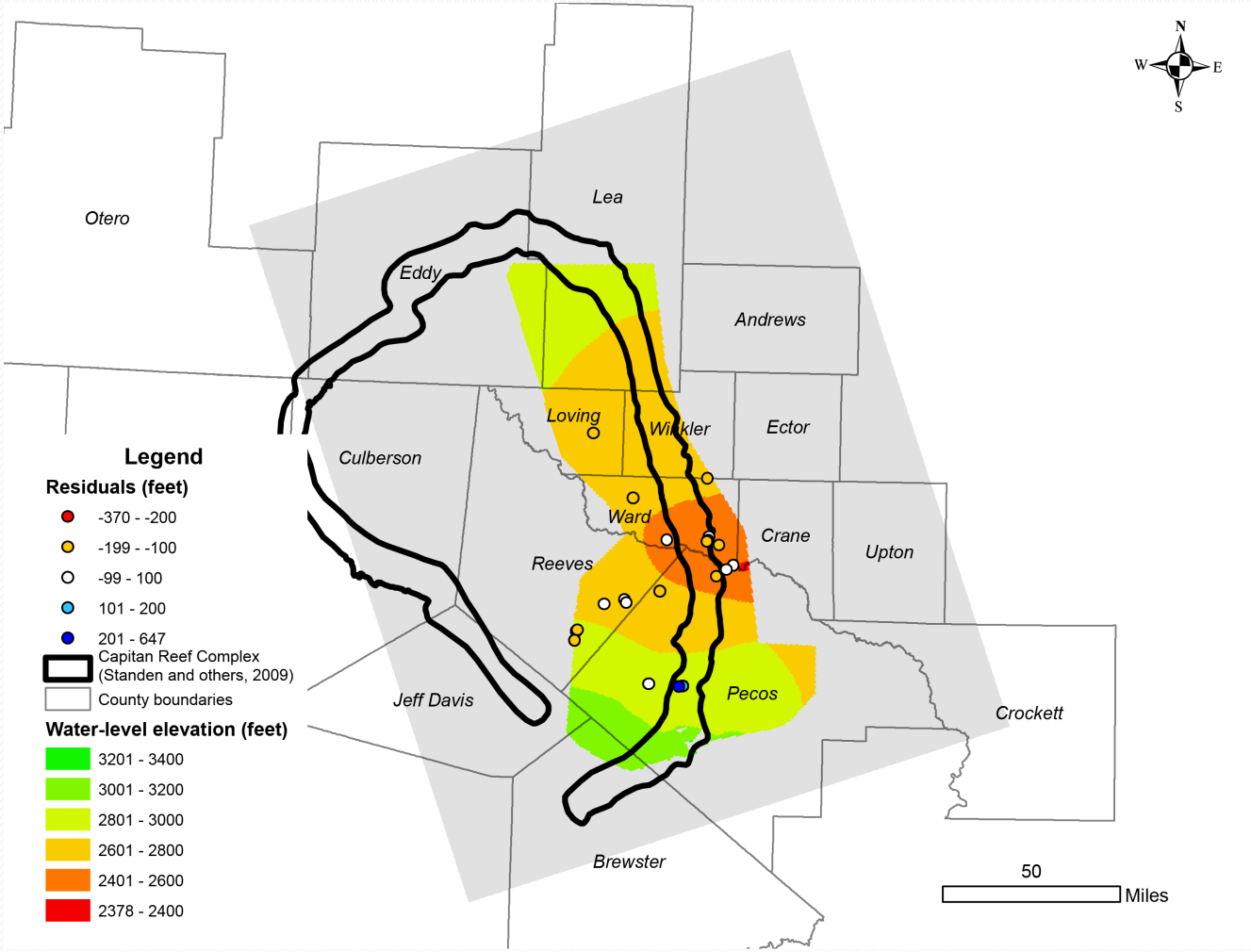
Residuals: Layer 1



Residuals: Layer 2



Residuals: Layer 3



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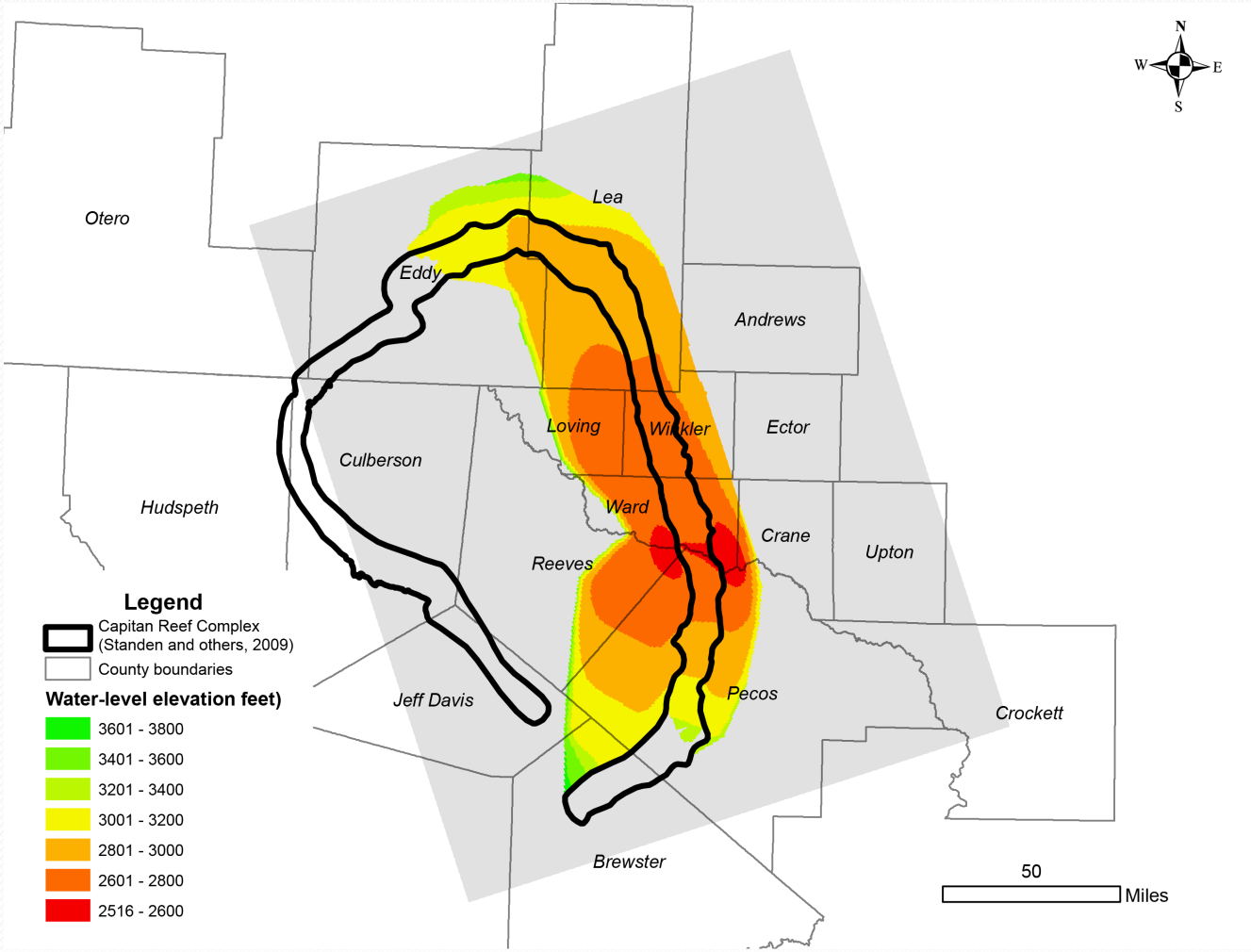
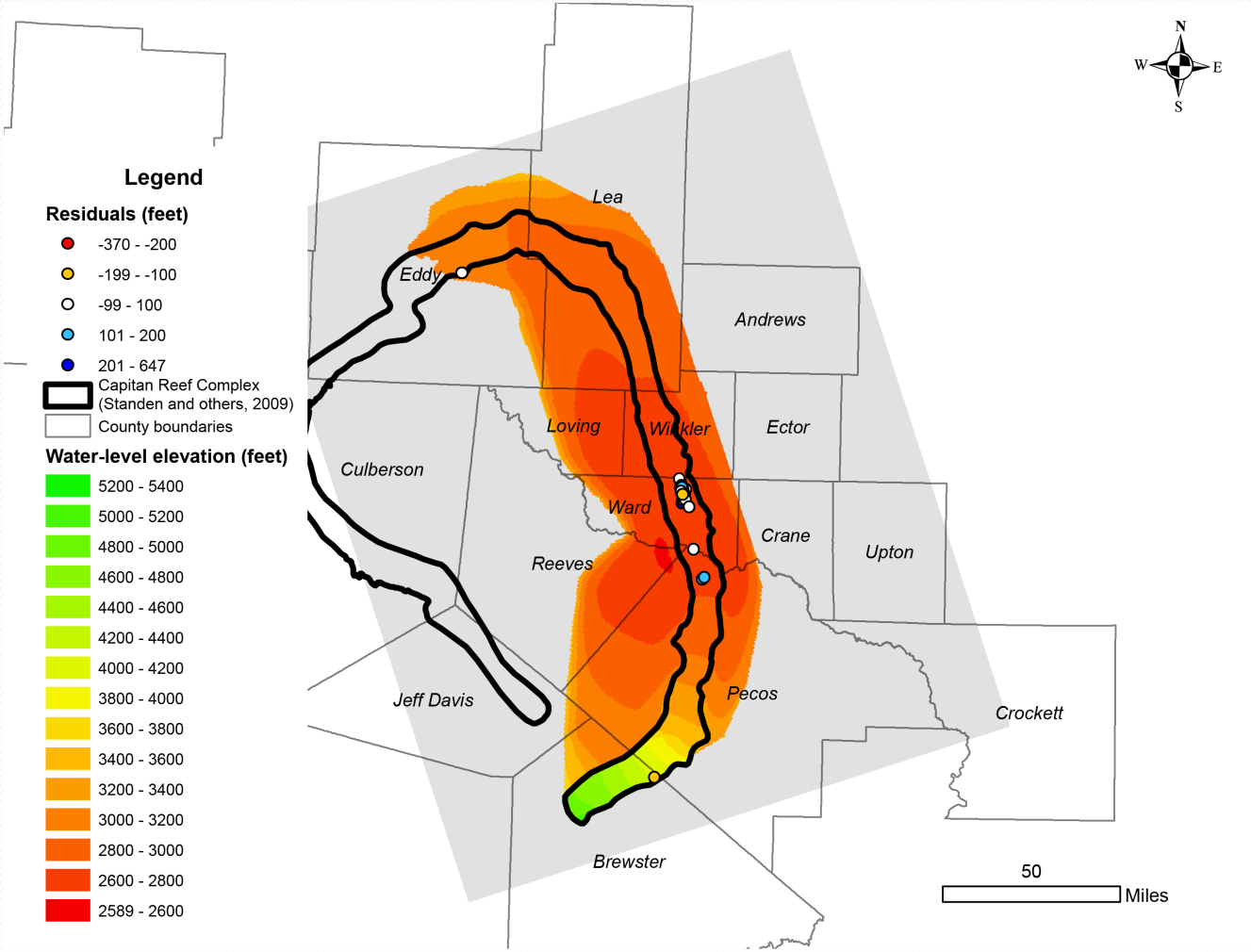
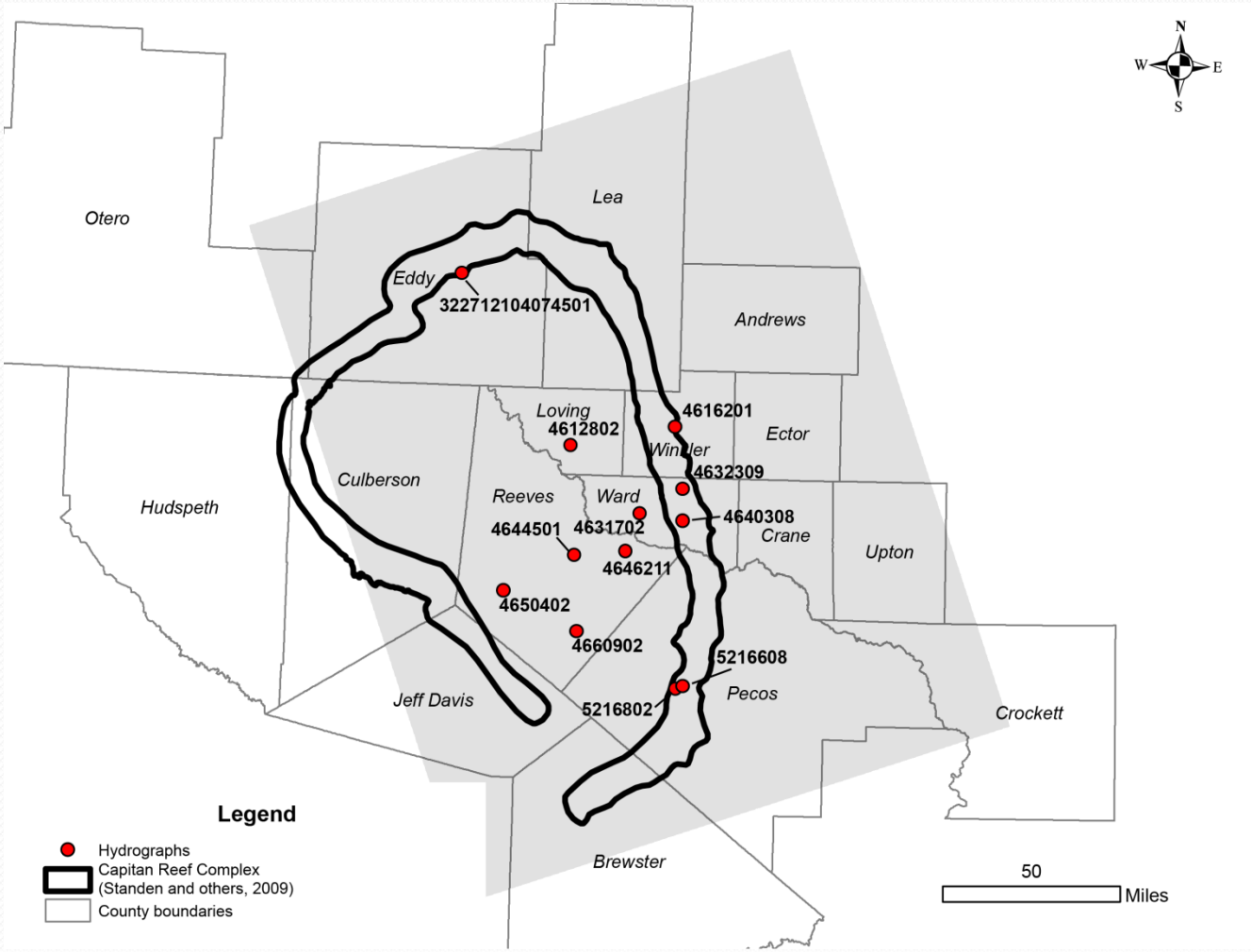


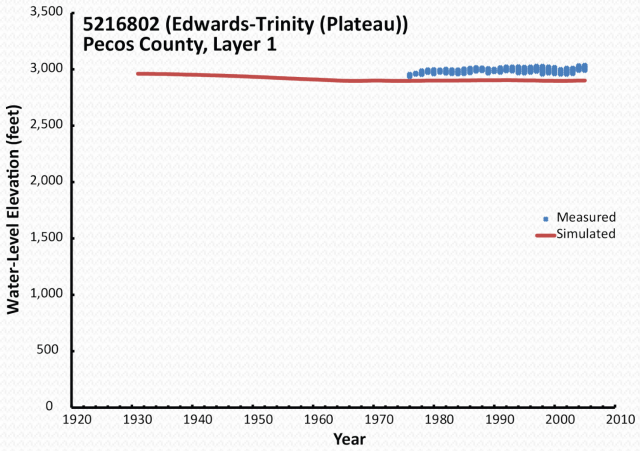
Residuals: Layer 5

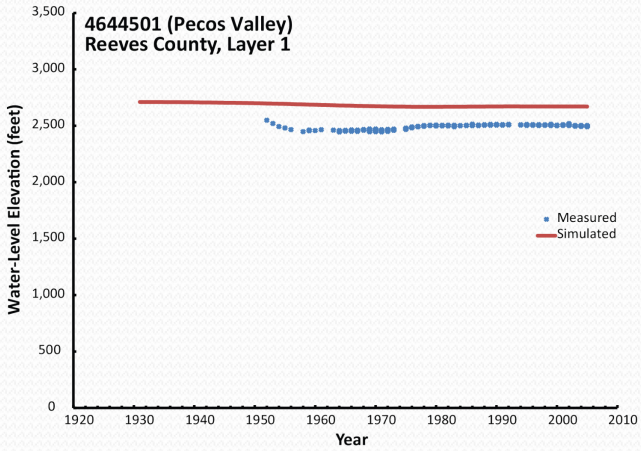


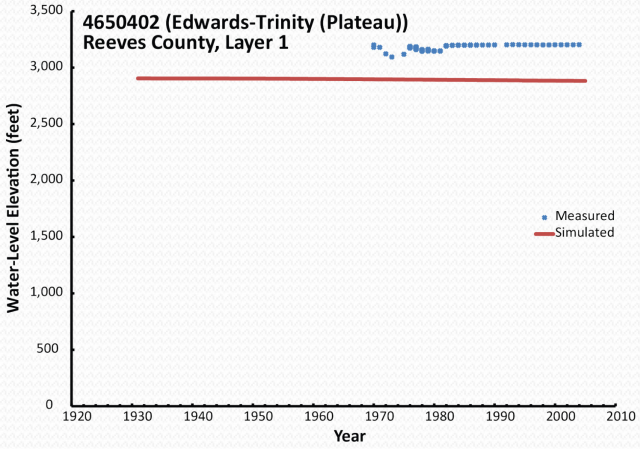
Hydrographs

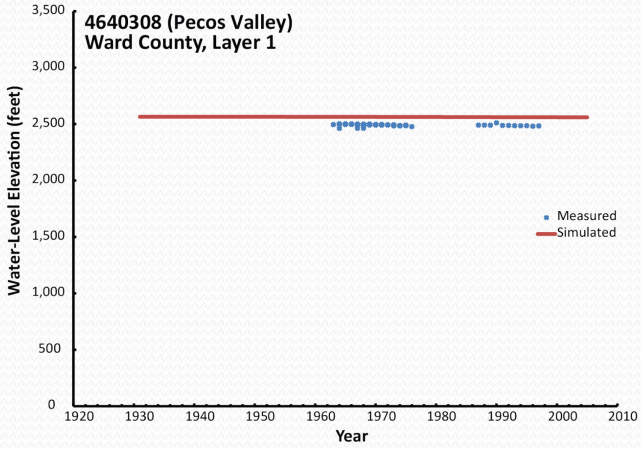


Hydrographs

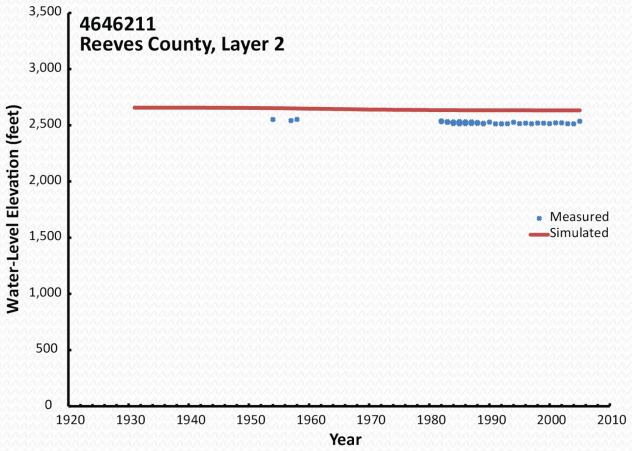


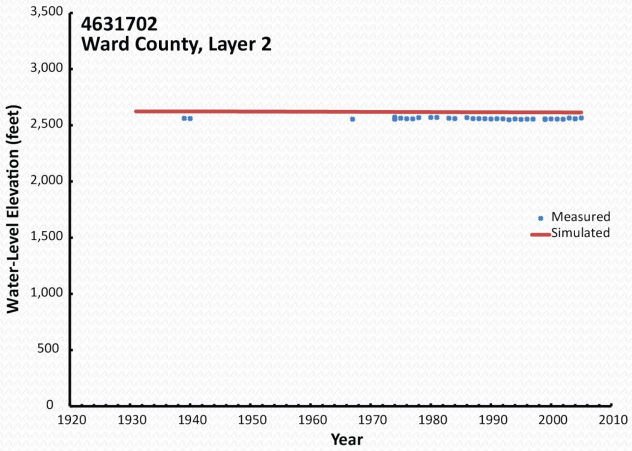


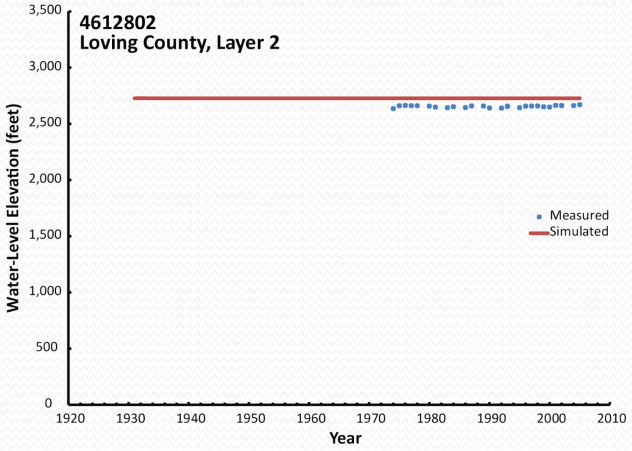


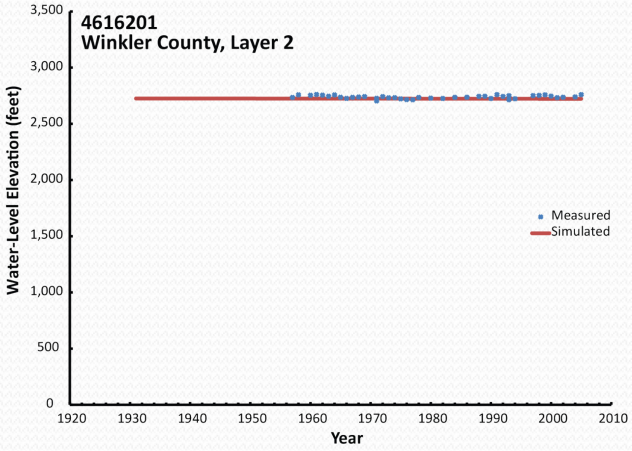


Hydrographs

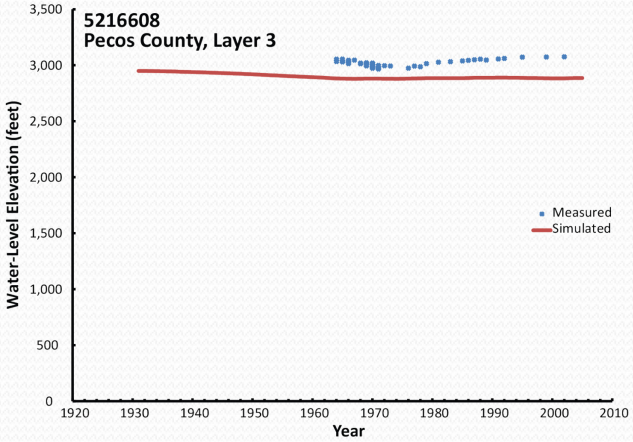


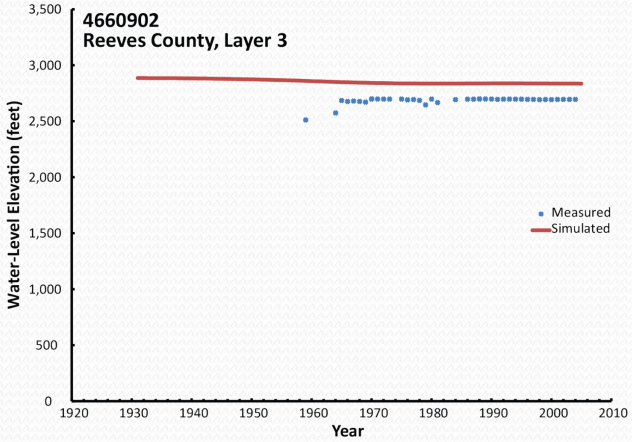


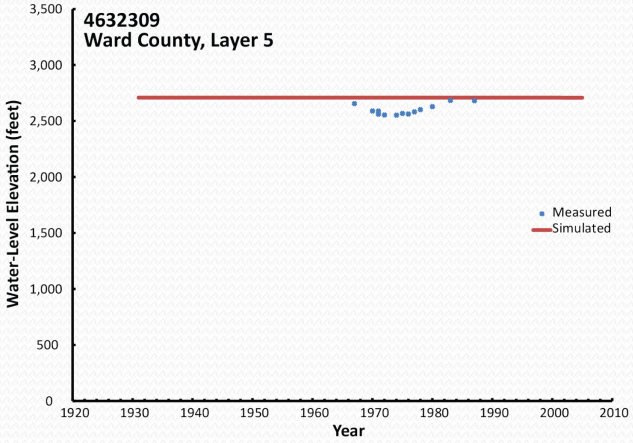


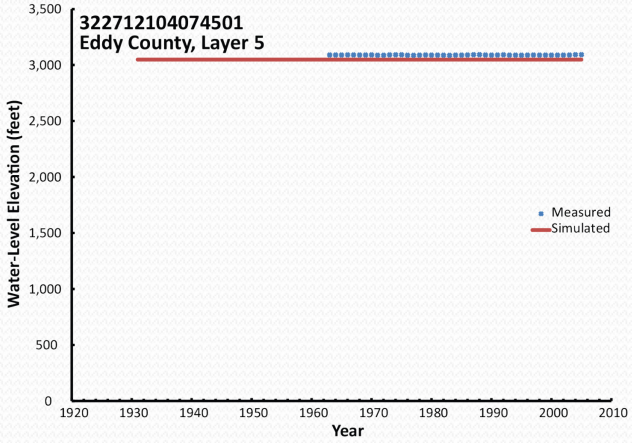


Hydrographs





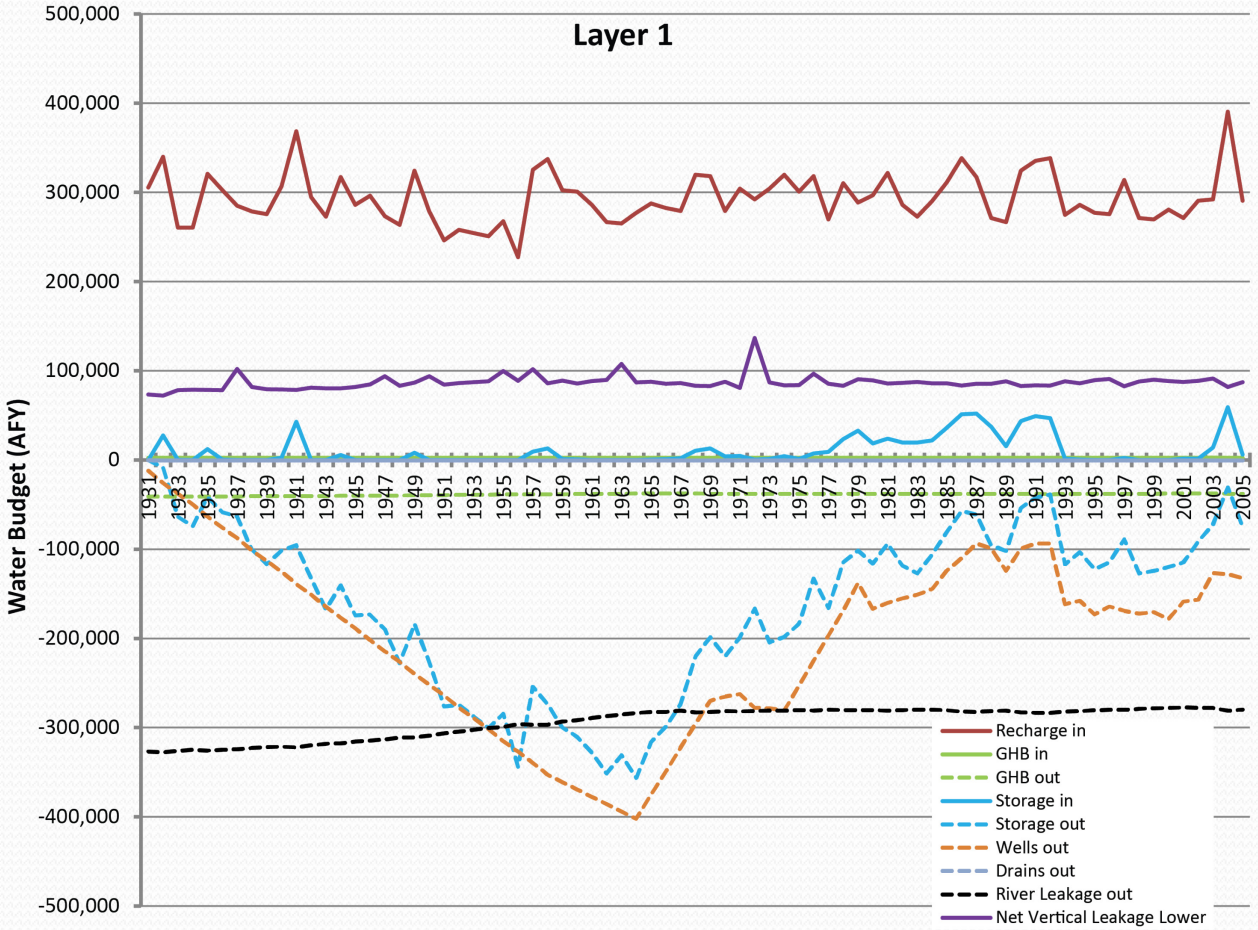




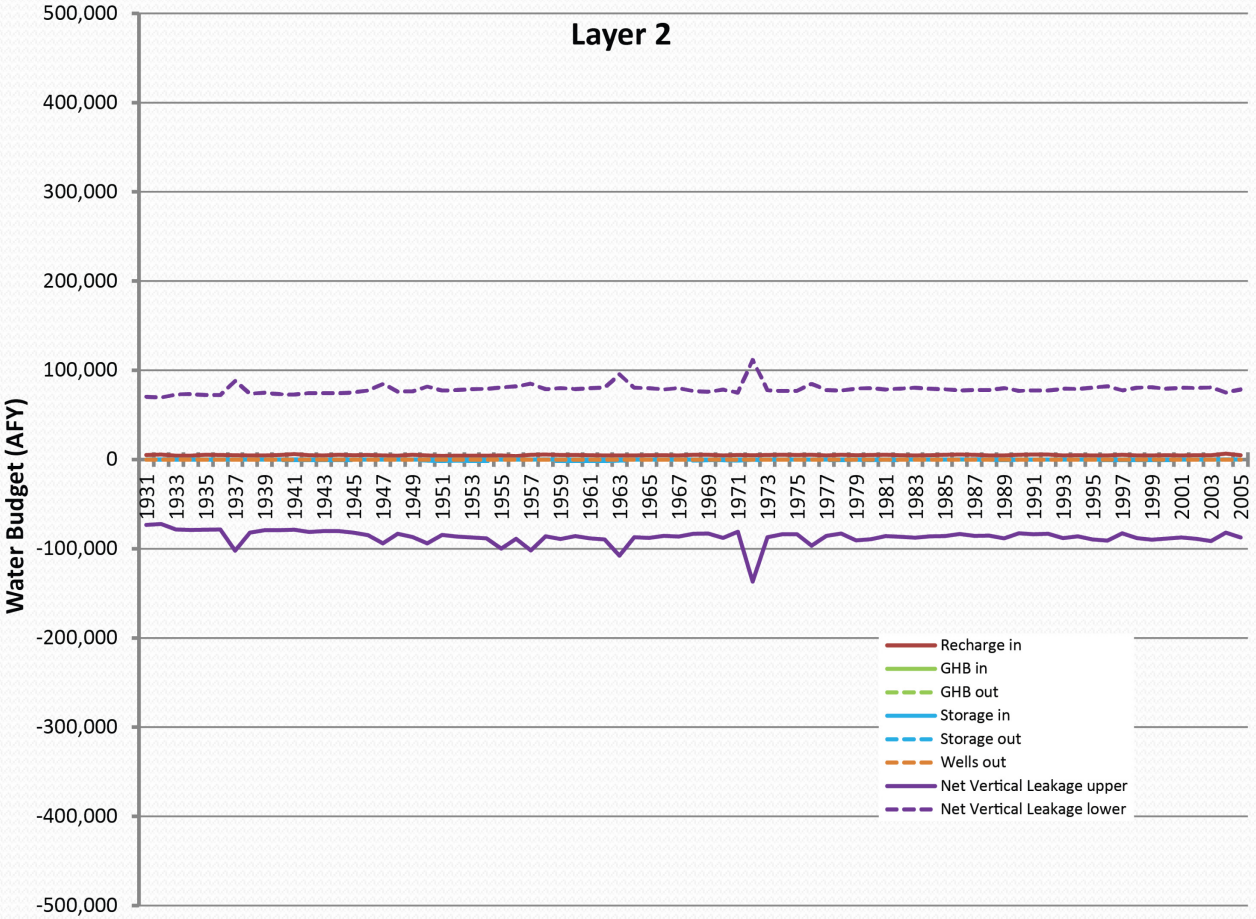
Water Budget: Steady-State

Flux	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Overall
Inflow						
General-Head Boundary	2,555	0	5,110	13,870	24,455	45,990
Lateral Flow	140,890	141,620	102,565	1,095	49,275	435,445
Recharge	305,505	5,110	365	365	36,500	347,845
Vertical Leakage (Lower)	283,970	208,780	70,080	56,940	0	
Vertical Leakage (Upper)	0	210,605	138,335	0	730	
Outflow						
Drains	365	0	0	0	0	365
General-Head Boundary	40,880	0	730	0	4,745	46,355
Lateral Flow	140,525	141,985	103,660	730	49,640	436,540
River Leakage	326,675	0	0	0	0	326,675
Vertical Leakage (Lower)	210,605	138,335	0	730	0	
Vertical Leakage (Upper)	0	283,970	208,780	70,080	56,940	
Wells	12,045	0	2,555	0	0	14,600

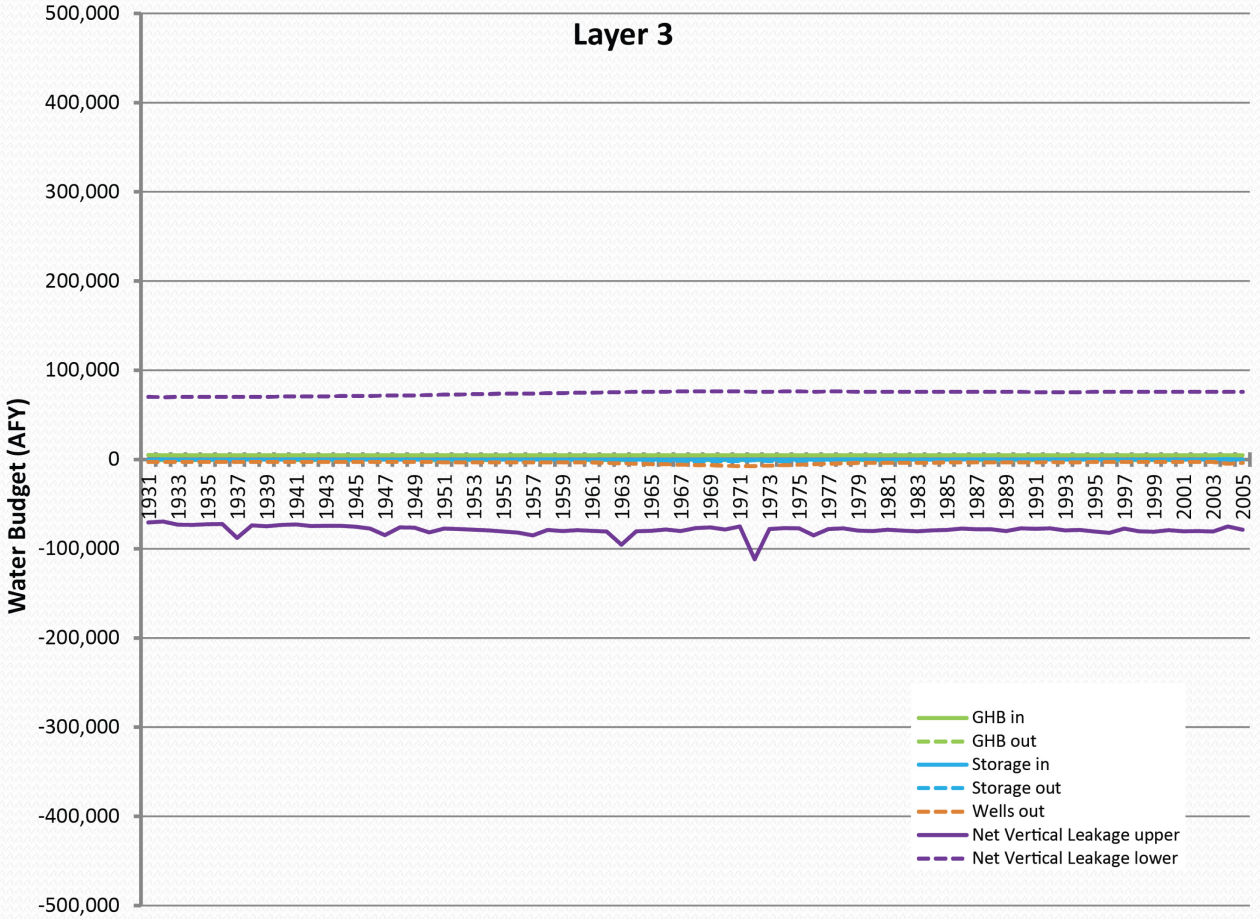
Water Budget: Layer 1



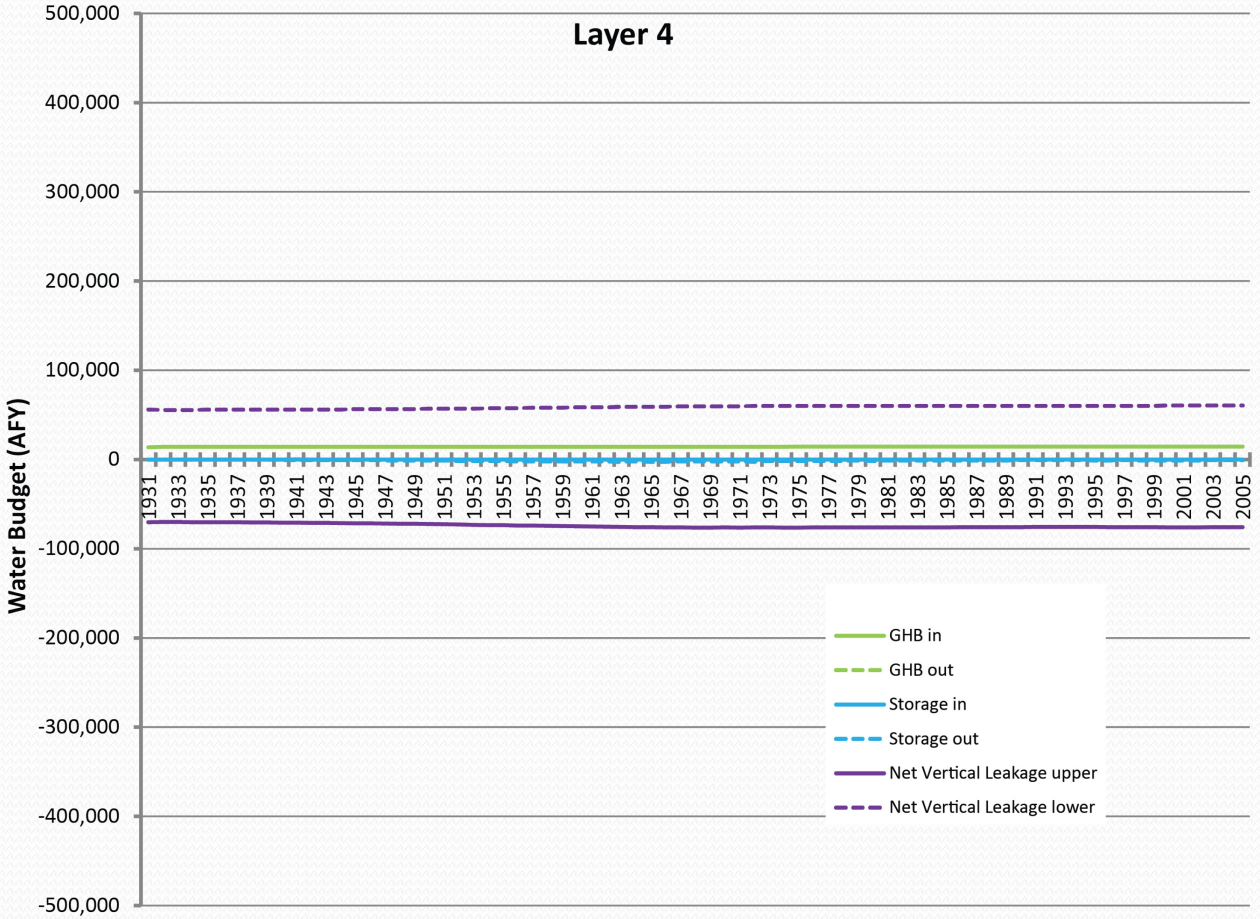
Water Budget: Layer 2



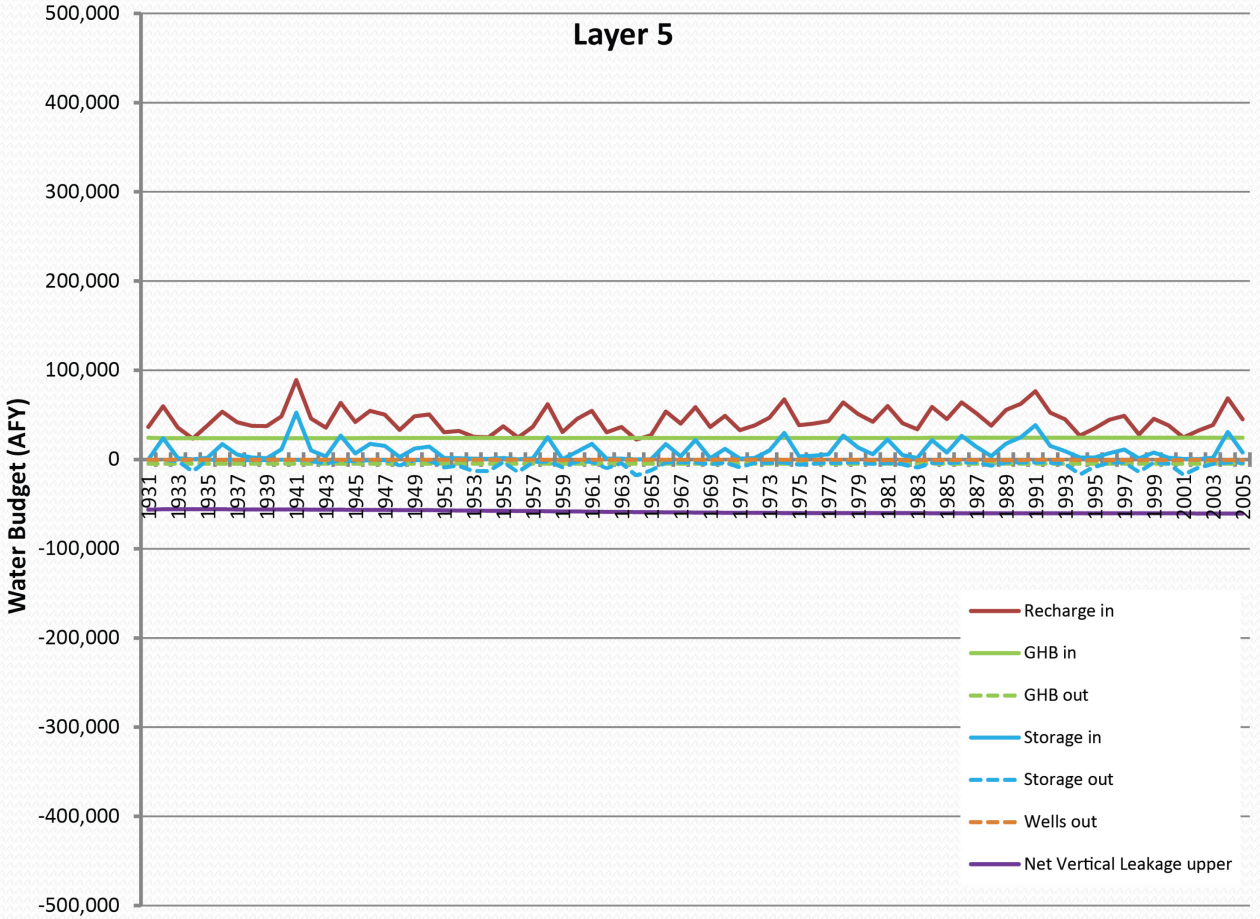
Water Budget: Layer 3



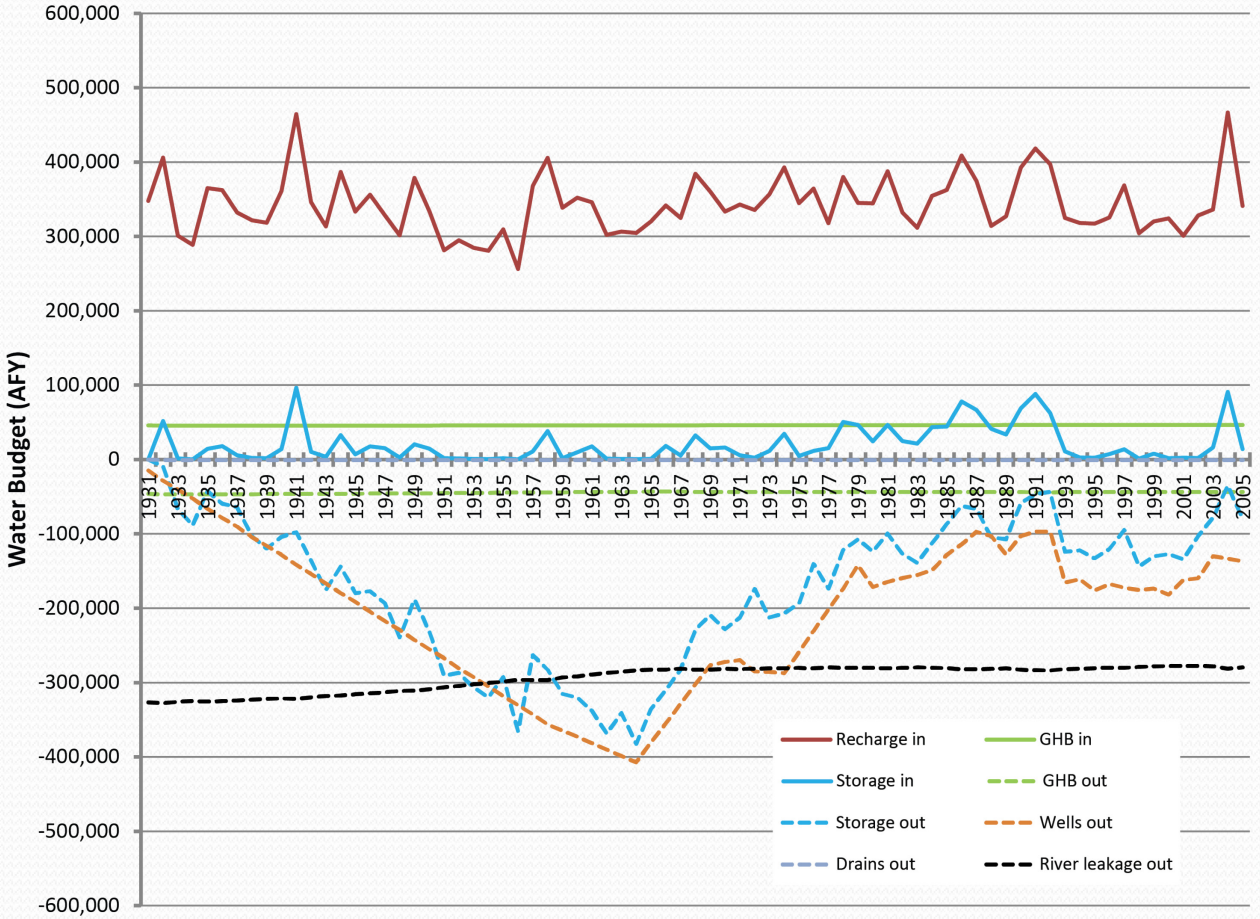
Water Budget: Layer 4



Water Budget: Layer 5

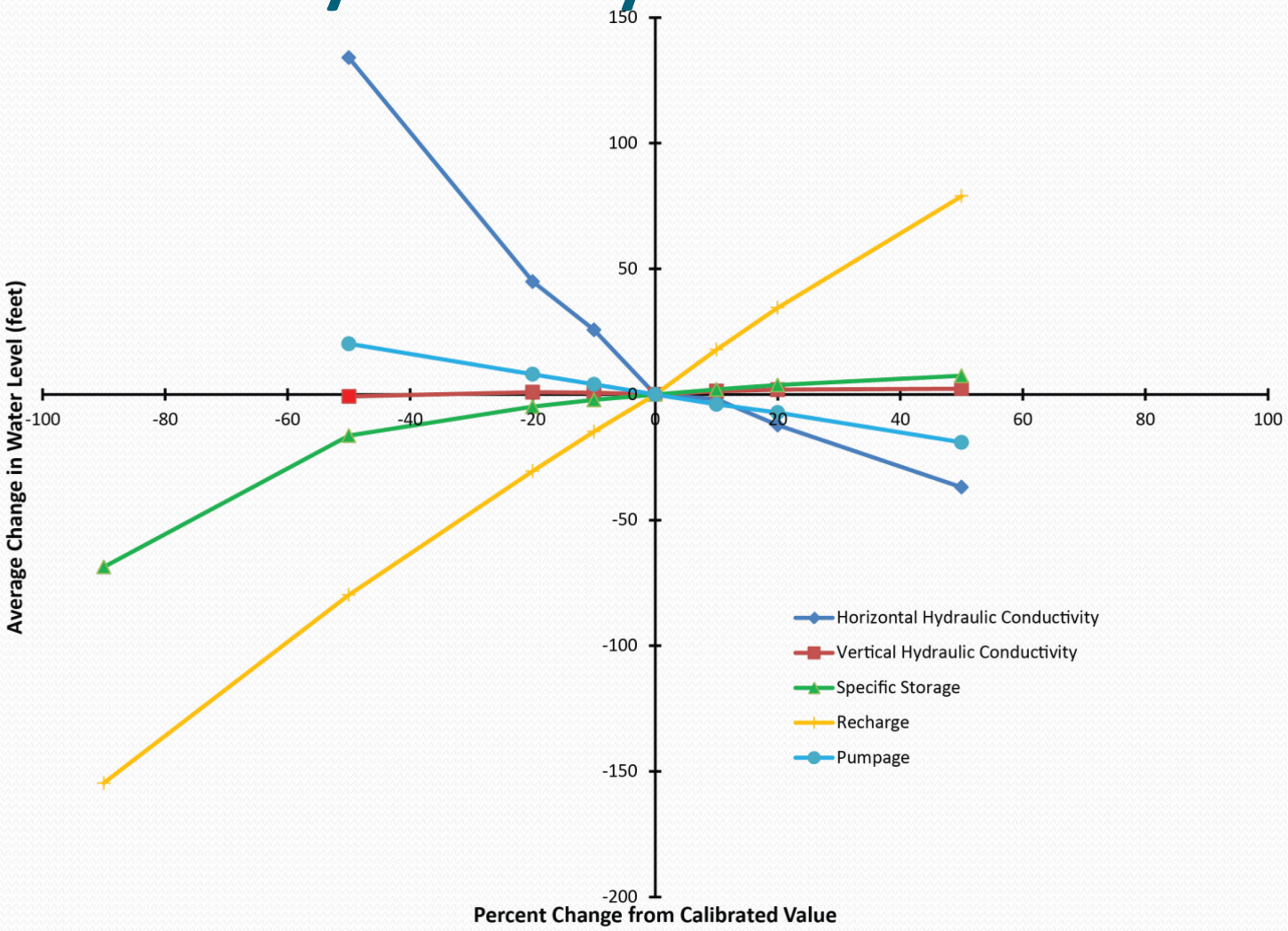


Water Budget: Model



SENSITIVITY ANALYSIS

Sensitivity Analysis



MODEL LIMITATIONS

Model Limitations

- Purpose of model
  - Regional scale
  - Capitan Reef Complex Aquifer in Texas
- Understanding of the aquifer
- Quantity and quality of data
  - Limited target, hydrologic, pumping data
- Assumptions
  - Spatial distribution of hydraulic properties
  - Occurrence of no-flow boundaries
  - Distribution of pumping

SUMMARY AND CONCLUSIONS

Summary and Conclusions

- Groundwater availability model of the eastern arm of the Capitan Reef Complex Aquifer
  - Five layers simulating the Capitan Reef Complex Aquifer and interaction with overlying hydrostratigraphic units
  - Regional scale model
- Capitan Reef Complex Aquifer
  - Recharge in Glass Mountains outcrop
  - Groundwater inflows from surrounding confining units and the western arm of the aquifer
  - Most discharge through upward inter-aquifer flow

Summary and Conclusions

- Calibration statistics
  - Root mean squared error
    - Model: 129 feet
    - Capitan Reef Complex Aquifer: 104 feet
  - Model calibration meet GAM requirements
    - Relative error: 7 percent
    - GAM requirement is relative error less than 10 percent

FUTURE IMPROVEMENTS

Future Improvements

- Continued data collection
- Investigation of groundwater flow in the Glass Mountains
- Possible inclusion of Tessey Limestone
- Spatially variable hydraulic properties
- Combination of upper 3 model layers
- Investigation of the confining units adjacent to the Capitan Reef Complex Aquifer
  - Hydraulic properties
  - Hydrologic interconnectivity

REVISED PROJECT SCHEDULE

Project Tasks and Proposed Schedule

Milestone	Completion Date
Stakeholder Advisory Forum #1	October 2012
Draft Conceptual Model Report	April 2014
Stakeholder Advisory Forum #2	May 2014
Final Conceptual Model Report	June 2014
Model construction & calibration/draft model report	February 2016 (deadline for comments March 29)
Stakeholder Advisory Forum # 3	March 2016
Final Report	August 2016

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Texas Water
Development Board

MEETING MINUTES FOR THE THIRD CAPITAN REEF COMPLEX AQUIFER GROUNDWATER AVAILABILITY MODEL STAKEHOLDER ADVISORY FORUM

March 22, 2016

Pecos County Courthouse, Fort Stockton, Texas Water Development Board

The third Stakeholder Advisory Forum (SAF) for the Capitan Reef Complex Aquifer Groundwater Availability Model (GAM) was held on Tuesday, March 22, 2016 at 11 am at the Pecos County Courthouse located at 103 West Callaghan Street in Fort Stockton. A list of meeting participants is provided at the end of this meeting note.

The purpose of the third SAF was to discuss the draft groundwater availability model for the eastern arm of the Capitan Reef Complex Aquifer. The meeting also provided a forum for discussing the revised project schedule and provided an opportunity for feedback from stakeholders.

SAF Presentation: Ian Jones, Ph.D., P.G., Texas Water Development Board

Dr. Jones made a prepared presentation structured according to the following outline:

1. Overview of Capitan Reef Complex Aquifer
2. The groundwater availability model of the Capitan Reef Complex Aquifer
3. Project schedule

Questions and Answers:

Q: Are you going to be looking at the San Andres as to what communication there is?

A: It was our intent to investigate all of that. I did a quick check of our well database, and I think at the very most there may be five San Andres wells. Problem is, [San Andres] is not an official aquifer. Our emphasis has been on the official aquifers.

Q: This model versus the [Capitan] model that came before: how much new data is in this new one?

A: This is the first Capitan model ever put together. There's a model that includes part of the western arm of the Capitan Reef.

Q: Would you consider looking a fundamental change in the conceptual model, that is, discharge? You have all the discharge going out to the Pecos River, while Bill Hiss in his work from the 1970s said all discharge went out to the shelf margin. I was wondering if this is something you'd consider in the sensitivity analysis

A: Hiss was looking primarily in New Mexico. He did not have much Texas data. I believe there is a possibility of flow into the shelf, but just on the basis of water levels there seems to be convergence on the Pecos River. We have to further investigate what's happening in the shelf area. There may be more flow into the shelf units that this model has indicated.

Q: I could not see in the model files how the pumping is allocated. Did you use the pumping from the Chevron-O'Brian field that's out in Ward County for model calibration?

A: No. I did not have any data for that field. I base a lot of the pumping on the distribution of oil drilling over time.

Q: Do you plan on doing other studies, like isotope interpretation, and look at other reports like that at the Ochoa mine project, or the monitoring well in Fort Stockton where you have on-the-ground data?

A: I've taken the Ochoa into consideration and included it in the conceptual model. I have done some isotope analyses interpretation, and they too are included in the conceptual model.

Q: Do they corroborate the findings of the model quantitatively?

A: Yes.

Q: Have you considered the sensitivity analysis just for the Capitan, since it is the focus?

A: Not at this point. The sensitivity analysis [I've shown] was done model-wide.

Q: For layer 5 you used an uniform, homogenous horizontal hydraulic conductivity of 10, and an anisotropy of 1, right? How does work out for Brewster County – we have complete heterogeneity there.

A: That's why I mentioned the need for investigating more in the Glass Mountains area. Right now, the model is simple, and in the future we'll have to add more complexity.

Q: Can this model be used for groundwater management purposes, DFCs, etc.?

A: In terms of big-picture use, general trends – yes. Does it need improvement? Yes.

Q: If GMA 7, for example, has a DFC of 200 feet of drawdown in the artesian part, and 15 feet of drawdown in the unconfined part, how would you advise them to use the model, given the accuracy of it for GMA7.

A: I'd really prefer not to address this question at this time. Those are very specific numbers.

Q: Did you adjust recharge by elevation?

A: Yes.

Q: Did you have any flux targets, or just water-level targets?
A: Water-level targets.

Q: Did you consider the uncertainty in the water-level measurements?

A: How precise the readings were? No.

Q: Looks like you're under-fitting in a lot of places, and your [water level] clusters are laid over.You're not hitting the highs and the lows.

A: Layers 1, 2, and 3 were not really the focus of the model, because there are other models that do a better job incorporating the data for those aquifers.

Q: You've used a lot of Steve's recharge numbers, and he included the Tessey, Capitan, Gilliam, and even the Word formations in his estimates. Your recharge was about 300 AF more than what Steve had projected. You also exclude the Word, and exclude the Tessey as storage value.

A: I allowed recharge through the Tessey, but did not simulate flow through the Tessey. I made an assumption that the amount of recharge in that area is an overestimate relative to how much water would come from the Tessey into the Capitan.

Q: How about the Word? I don't think that it has 2,200 [AF] coming in. How did you derive 36,500 AF for layer 5?

A: Our areas have different assumptions regarding area over which recharge is taking place.

Q: Do you have any constraints on the flux? On can have very high recharge and very high K, and have the same water level distribution.

A: Yes, but on the other hand, there are certain limits on the recharge, to how much recharge one can put into the model.

MEETING MINUTES FOR THE THIRD CAPITAN REEF COMPLEX AQUIFER GROUNDWATER AVAILABILITY MODEL STAKEHOLDER ADVISORY FORUM

March 22, 2016

Attendance

Name	Affiliation
Ian Jones	Texas Water Development Board
Radu Boghici	Texas Water Development Board
Eddie McCarthy	FSH
Mike Thornhill	TGI
Marty Jones	Sprouse Law
Steve Finch	JSAI
Raymond L. Straub, Jr.	Straub Corporation
Gil Van Deventer	Trident Environmental
Glenn Honaker	Belding Farms
Mike Gershon	Middle Pecos Groundwater Conservation District
Jerry McGuairt	Middle Pecos Groundwater Conservation District
George Vaughn	Sul Ross State University
Kevin Urbanczyk	Sul Ross State University
Shawna Graves	Sul Ross State University
Jeremy White	U.S. Geological Survey
Linzy Foster	U.S. Geological Survey
Sail Reeves	Middle Pecos Groundwater Conservation District
Melissa Mills	Middle Pecos Groundwater Conservation District
Nan Zeman	Reeves County Groundwater Conservation District
Alan R. Zeman	Reeves County Groundwater Conservation District
Bill Stevens	Wind River Associates
Alyson McDonald	Texas A&M AgriLife
Kenneth Heritage	Landowner
Kevin Krueger	Canadian River Municipal Water District
Rick Dudman	JMAC
Jeremy Gonzalez	FS Pioneer
Elise Sibley Chandler	Glass Mountain Ranch
James Perkins	Republic Water Company
Alan Murphy	STW Water Process & Tech.
Terry Whigham	Middle Pecos Groundwater Conservation District
Homer Mills	7V Ranch

Name	Affiliation
Gordon Buescher	Boss Ranch
David Disselhorst	Pecos County Extension Agent
Clayton Moss	Geologist
John Hayes	Geologist
Scott Courtrey	Premier Hydro
Chris Alexander	City of Fort Stockton
Frank Rodriguez	Pecos County
Joe Shuster	Pecos County
Jeff Williams	FSH
Gary Bryant	Fort Stockton
Ernest Woodward	Fort Stockton
Gerald Lyda	La Escalera Ranch
Fred Tyler	La Escalera Ranch
Merrell Daggett	Fort Stockton
M.R. Gonzalez	Fort Stockton
Tommy Ervin	Self
Welden Blackwelder	Middle Pecos Groundwater Conservation District
Paul Weatherby	Middle Pecos Groundwater Conservation District