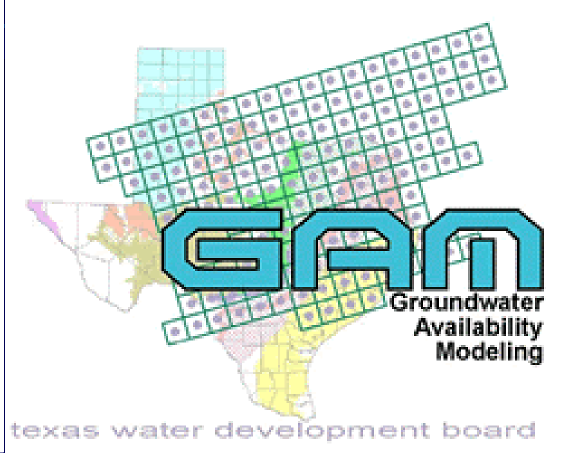
Northern Trinity / Woodbine Groundwater Availability Model

Stakeholder Advisory Forum (SAF)

February 25, 2004

R. W. Harden & Associates, Inc.
Hydrologists – Geologists - Engineers



Meeting Outline

- GAM program overview
- Overview of groundwater flow modeling
- Northern Trinity/Woodbine model design
- Results of precalibration simulations (1880 – 1980)
- Results of calibration/verification simulations (1980 – 2000)
- Results of predictive simulations (2000-2050)
- Groundwater supply issues for the Northern Trinity-Woodbine
- Model expectations and schedule
- Questions and answers

Goals of the GAM Program

- Include substantial stakeholder input
- Provide reliable groundwater supply information
- Predict groundwater conditions over a 50-year planning period
- Produce publicly available groundwater models and supporting data

GAM Project Team

- R.W. Harden & Associates, Inc.
  - Project lead, geology, hydrology, modeling, and reporting
- LBG-Guyton Associates
  - Aquifer characteristics and water levels
- HDR, Inc.
  - Groundwater – surface water interaction
- Freese & Nichols, Inc.
  - Climatic data and stakeholder/RWPG interfacing

Project Team – (continued)

- United States Geological Survey
  - Aquifer data and modeling expertise
- Dr. Joe Yelderman, Jr.
  - Conceptualization of aquifer
- TWDB Staff
  - Technical oversight and assistance
- Stakeholders
  - Real world experience and Project needs/interests

Why is a Model Needed?

- Numerical model allows for more complex analysis than is possible with analytical methods
- Can be used to assess and interpret certain types of groundwater availability issues and/or concepts
- Allows for comparative analysis and testing and understanding of ‘what-if’ scenarios
- Capable of performing predictive analysis

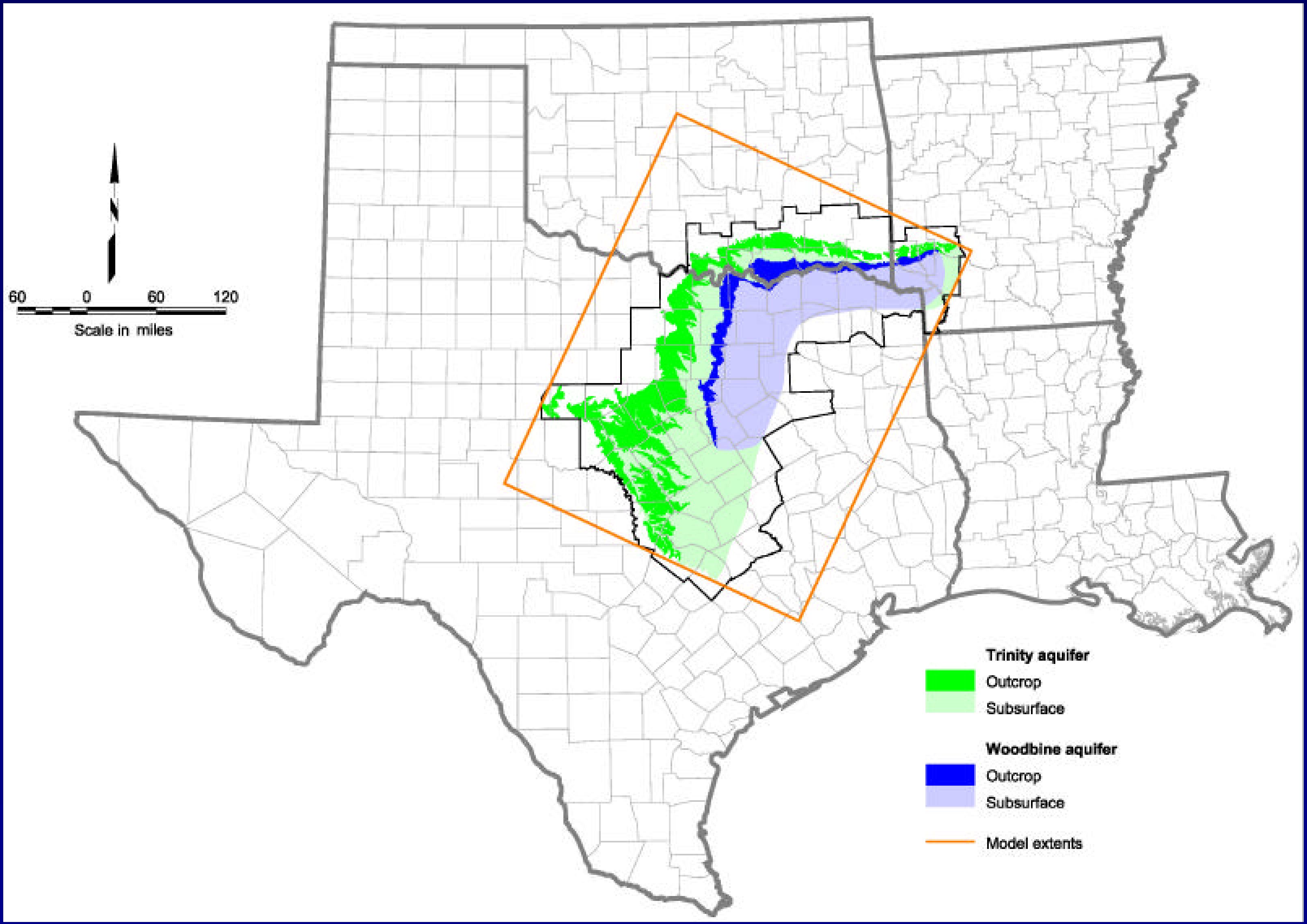
Stakeholder Advisory Forum

- Stakeholder participation is important
- SAF Meetings
  - Held about once every four months
- Contact with Project Team encouraged
- SAF presentation materials and GAM information to be posted on TWDB website: http://www.twdb.state.tx.us/gam/trnt_n/trnt_n.htm

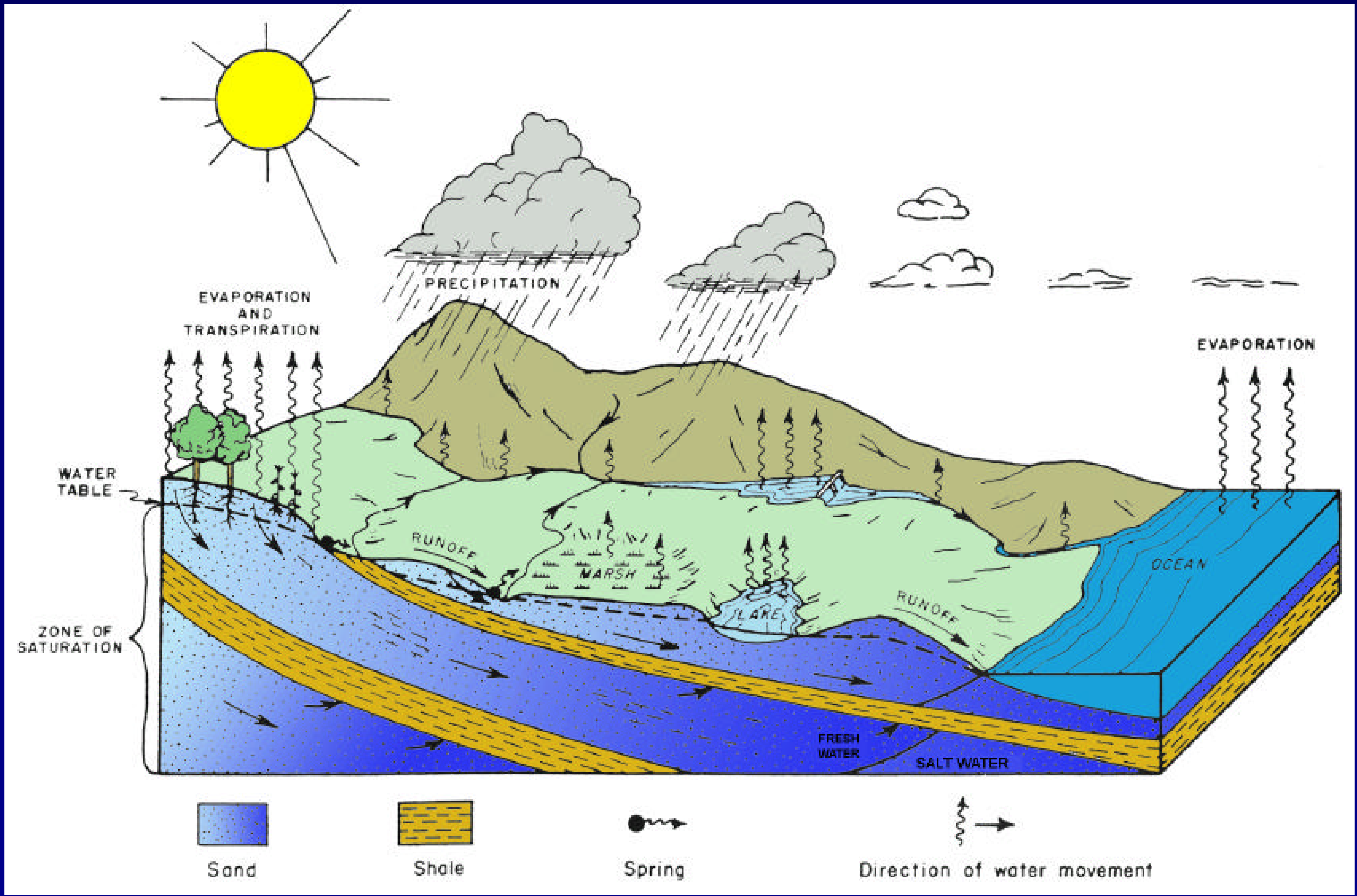
Project Work Steps

- Aquifer characterization
  - Data components of hydrologic cycle (Done)
  - Aquifer stratigraphy (Done)
  - Hydraulic characteristics (Done)
  - Water levels (Done)
  - Historical pumpage (Done)
- Computer model
  - Design and initial assignments (Done)
  - Predevelopment simulations (Done)
  - Calibration, verification and prediction (Current work)
- Final Report and data presentation (Current work)

Study Area


60 0 60 120
Scale in miles
Trinity aquifer
Outcrop
Subsurface
Woodbine aquifer
Outcrop
Subsurface
Model extents

Hydrologic Cycle



Geology / Hydrostratigraphy

<table>
<tr><th>System</th><th>Series</th><th>Groups</th><th colspan="5">Formation</th><th colspan="2">Approximate Maximum Thickness</th><th>Model Layers</th></tr>
<tr><th colspan="3"></th><th colspan="2">North</th><th colspan="3">South</th><th>North</th><th>South</th><th></th></tr>
<tr><td>Tertiary</td><td colspan="9">Undifferentiated</td><td></td></tr>
<tr><td rowspan="19">Cretaceous</td><td rowspan="5">Gulfian</td><td>Navarro</td><td colspan="2" rowspan="5">Undifferentiated</td><td colspan="3" rowspan="5">Undifferentiated</td><td>800</td><td>550</td><td rowspan="4">GHB</td></tr>
<tr><td>Taylor</td><td>1500</td><td>1,100</td></tr>
<tr><td>Austin</td><td>700</td><td>600</td></tr>
<tr><td>Eagle Ford</td><td>650</td><td>300</td></tr>
<tr><td>Woodbine</td><td>700</td><td>200</td><td>1</td></tr>
<tr><td rowspan="14">Comachian</td><td rowspan="4">Washita</td><td colspan="2">Grayson Marl</td><td colspan="3">Buda, Del Rio</td><td rowspan="4">1,000</td><td>150</td><td rowspan="7">2</td></tr>
<tr><td colspan="2">Mainstreet, Pawpaw, Weno, Denton</td><td colspan="3" rowspan="2">Georgetown</td><td rowspan="2">150</td></tr>
<tr><td colspan="2">Fort Worth, Duck Creek</td></tr>
<tr><td colspan="2">Kiamichi</td><td colspan="3">Kiamichi</td><td>50</td></tr>
<tr><td rowspan="3">Fredricksburg</td><td colspan="2" rowspan="2">Goodland</td><td colspan="3">Edwards</td><td rowspan="3">250</td><td>175</td></tr>
<tr><td colspan="3">Comanche Peak</td><td>150</td></tr>
<tr><td colspan="2">Walnut Clay</td><td colspan="3">Walnut Clay</td><td>200</td></tr>
<tr><td rowspan="7">Trinity</td><td rowspan="7">Antlers</td><td>Paluxy</td><td colspan="3">Paluxy</td><td>400</td><td>200</td><td>3</td></tr>
<tr><td>Glen Rose</td><td colspan="3">Glen Rose</td><td>1,500</td><td>1,500</td><td>4</td></tr>
<tr><td rowspan="5">Twin Mountains</td><td rowspan="5">Travis Peak</td><td>Hensell</td><td>Hensell</td><td rowspan="5">1,000</td><td rowspan="5">1,800</td><td>5</td></tr>
<tr><td rowspan="3">Pearsall</td><td>Cow Creek</td><td rowspan="3">6</td></tr>
<tr><td>Hammett</td></tr>
<tr><td>Sligo</td></tr>
<tr><td>Hosston</td><td>Hosston</td><td>7</td></tr>
<tr><td>Paleozoic</td><td colspan="9">Undifferentiated</td><td></td></tr>
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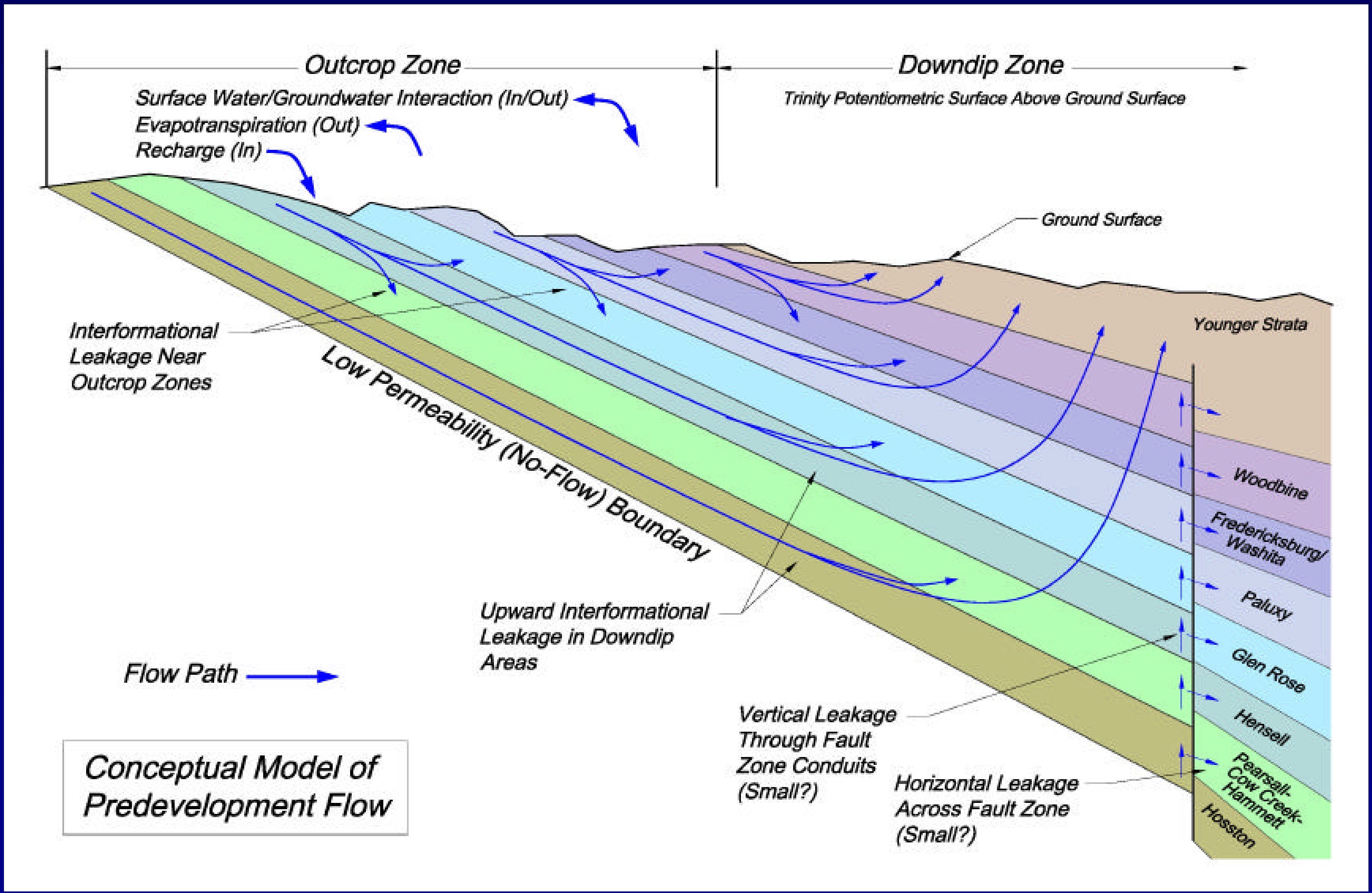
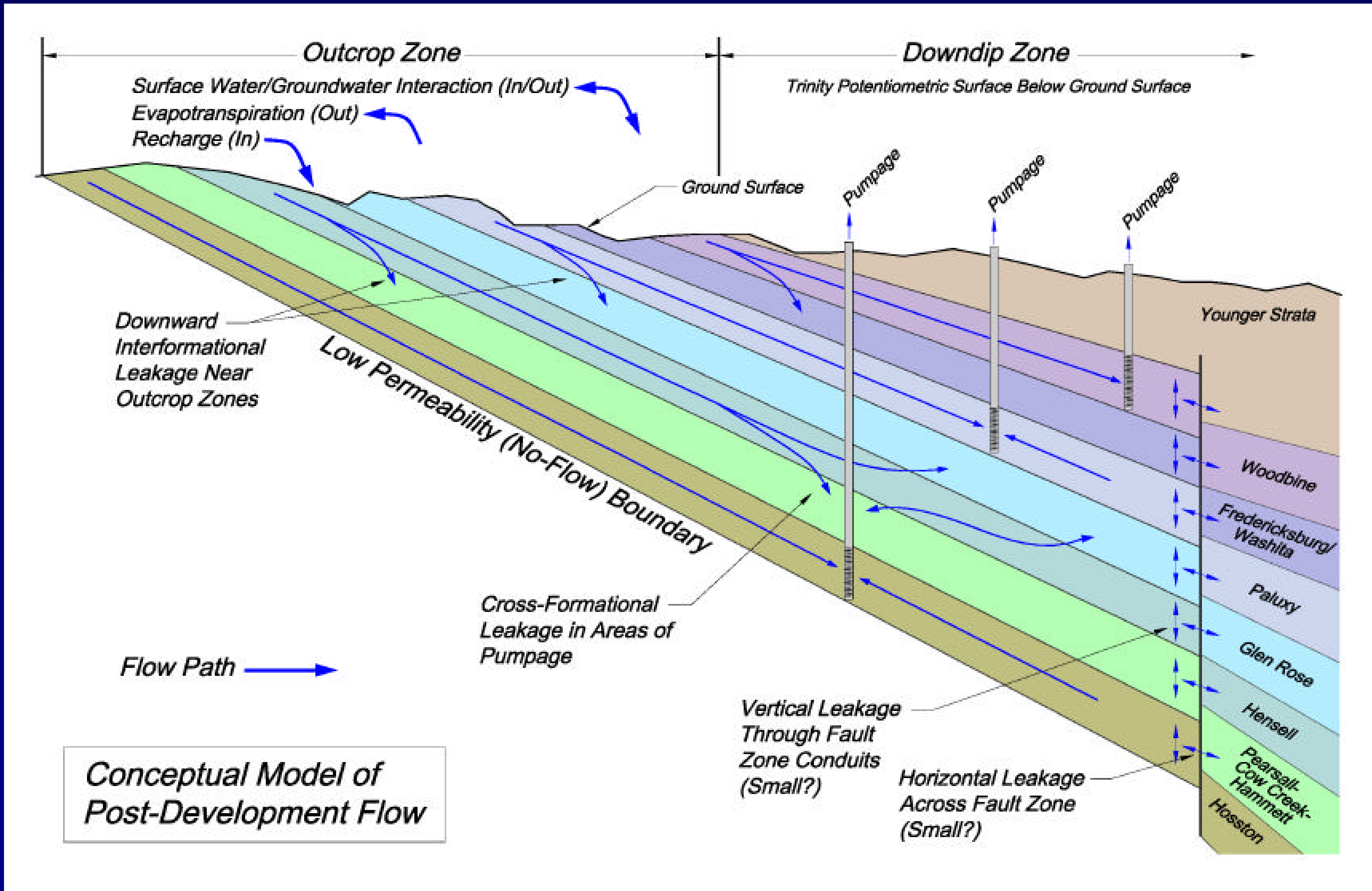
Conceptual Flow - Predevelopment



Conceptual Flow – Post-Development



Model Construction

- Structure defined from geophysical logs and National Elevation Dataset (NED)
- Outcrop areas digitized from Bureau of Economic Geology (BEG) Geologic Atlas of Texas maps
- Hydraulic parameters collated from pump test analysis, net sand thickness, and estimated values
- Upper (General Head) boundaries applied to simulate vertical flow flow though the wedge of sediments overlying the confined portion of the Woodbine

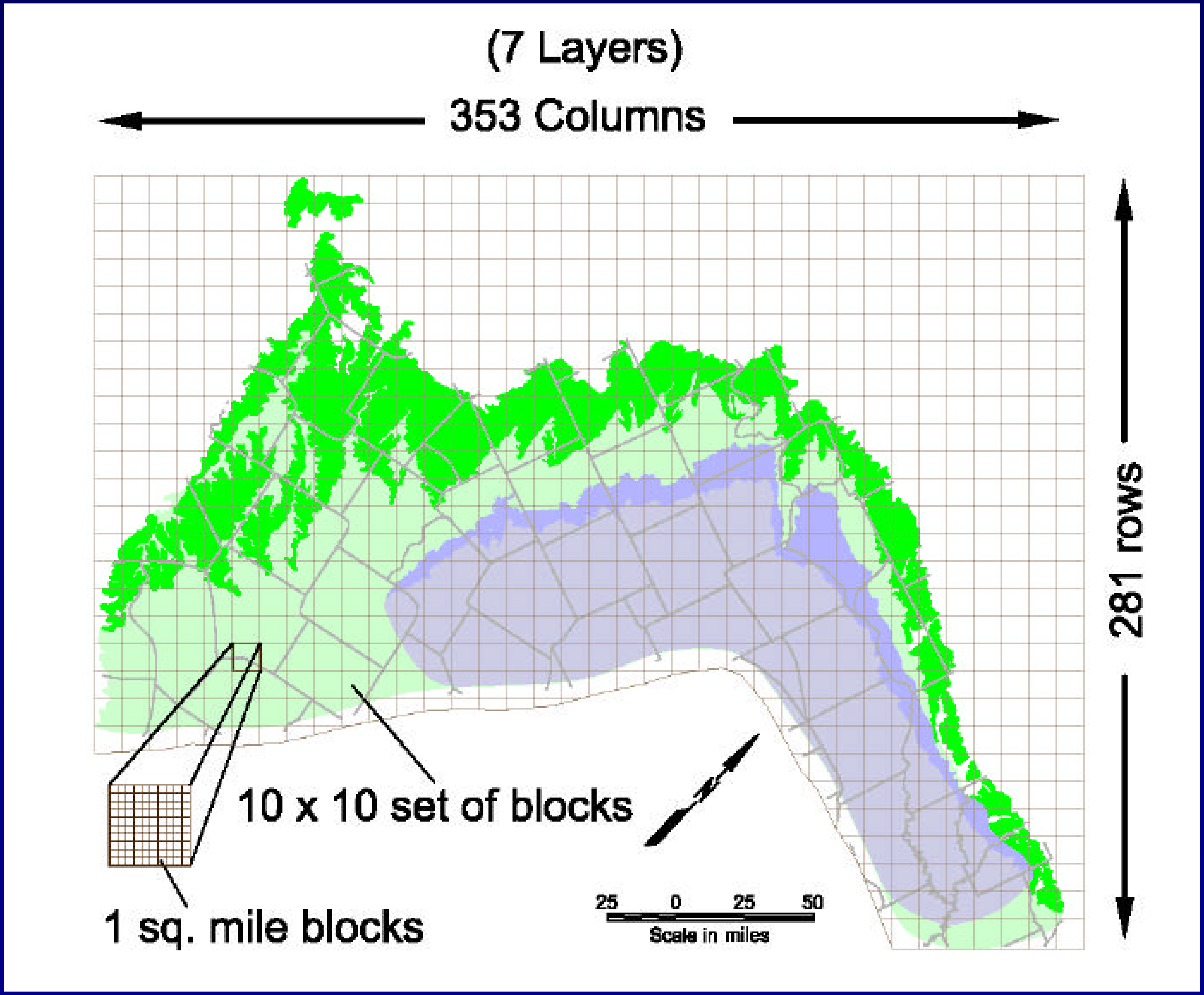
Model Construction Cont.

- Stream package employed to simulate surface/groundwater interaction between hydrologic units and major rivers and streams
- Recharge and evapotranspiration were distributed throughout outcrop zones
- Fault locations digitized from BEG Geologic Atlas and Tectonic Map sheets
- Downdip boundary set at the Luling-Mexia-Talco Fault Zone

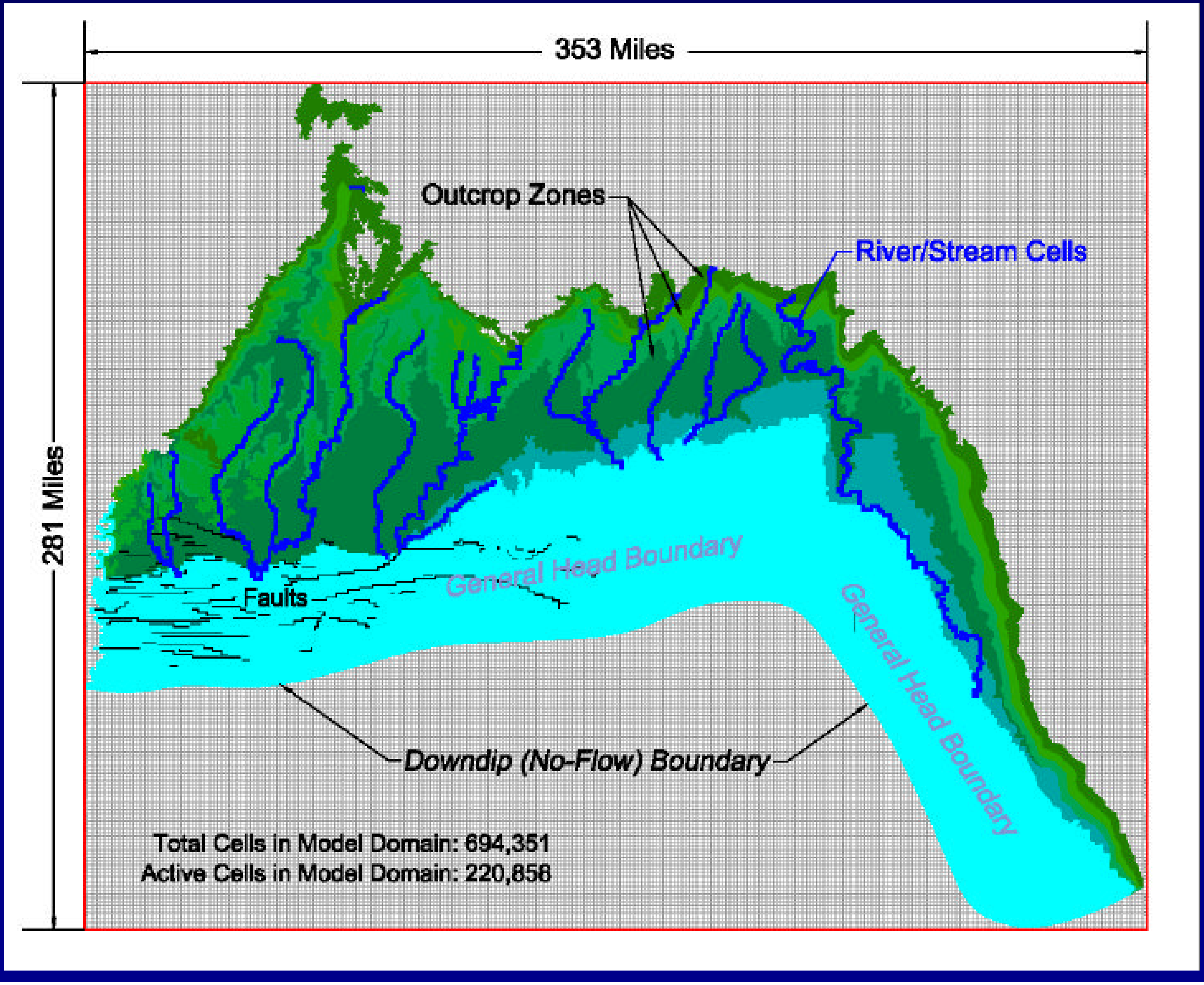
Hydraulic Properties

- Data collected from numerous sources published during the last century
- Much of this data was compiled by R. Mace in 1994
- Raw pump test data was used where available and extrapolated to other areas using net sand thickness maps generated during the conceptual model phase

Model Diagram



Model Boundaries



Precalibration Simulations
1880-1980

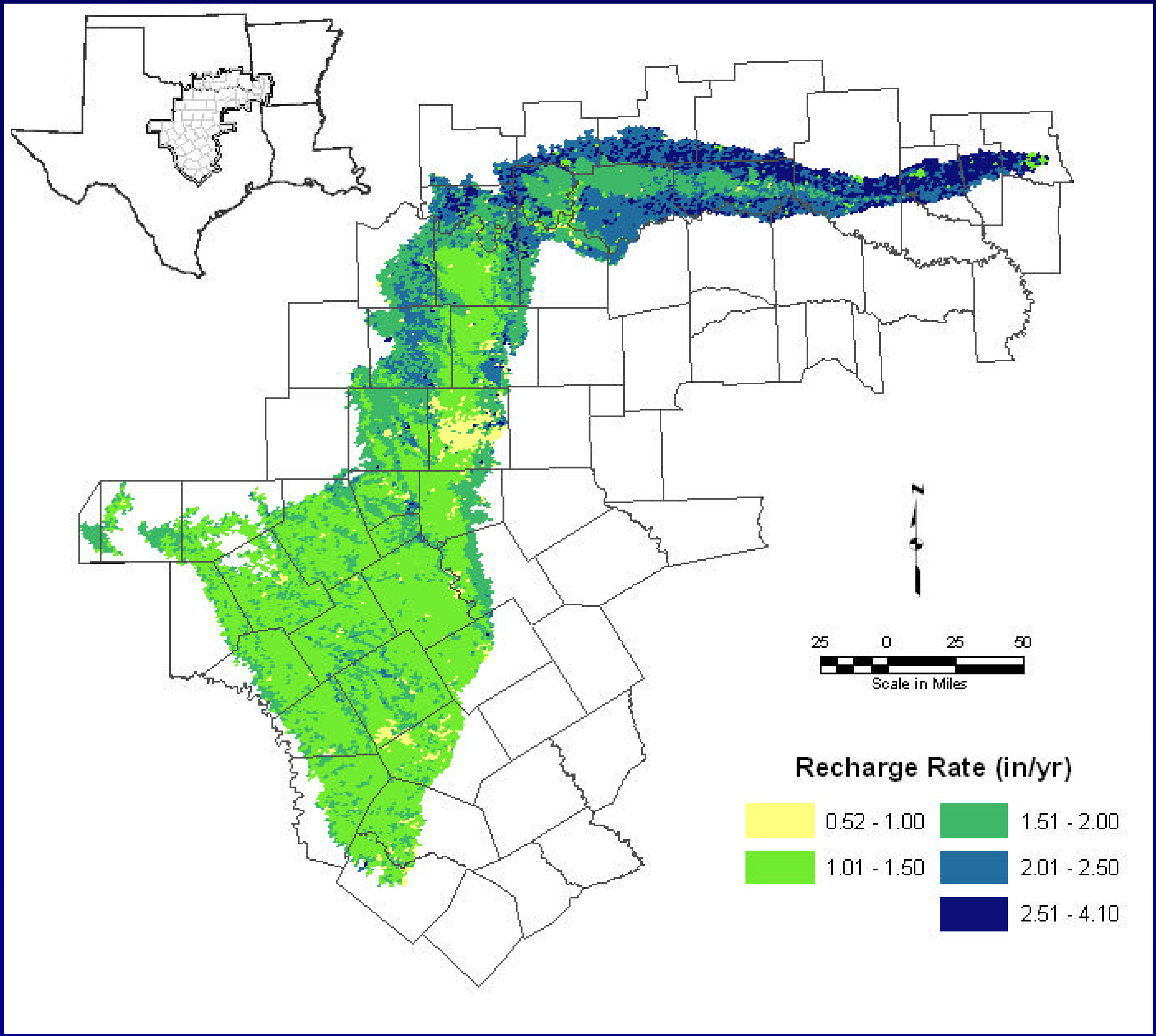
Pre-Calibration/Verification Model Development Strategy

- Develop steady-state model
- Create a simplified pumpage data set through reverse extrapolation of 1980 pumpage
- Apply the extrapolated pumpage and run model through a 100-year simulation period (1880 to 1980)
- Compare results to measured 1980 water levels

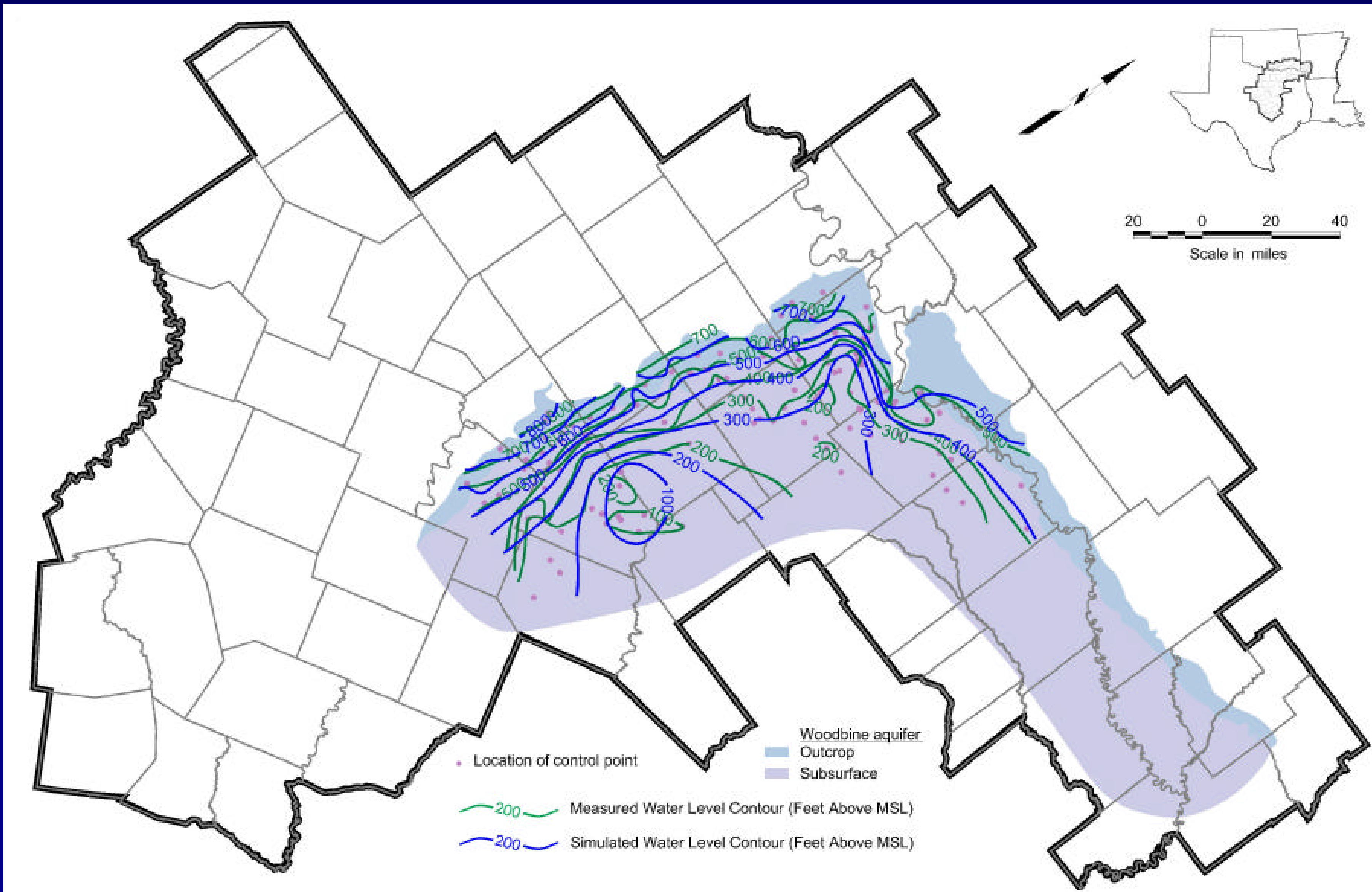
Predevelopment Solution Cont.

- Advantages to transitional model:
  - Insures the smoothest possible transition between steady-state and calibration/verification models
  - Develop an understanding of what drives the aquifer system and what doesn't
  - Define model problem areas while utilizing simplified (static) input parameters
  - Develop rejected/captured recharge function and stabilize water levels in outcrop

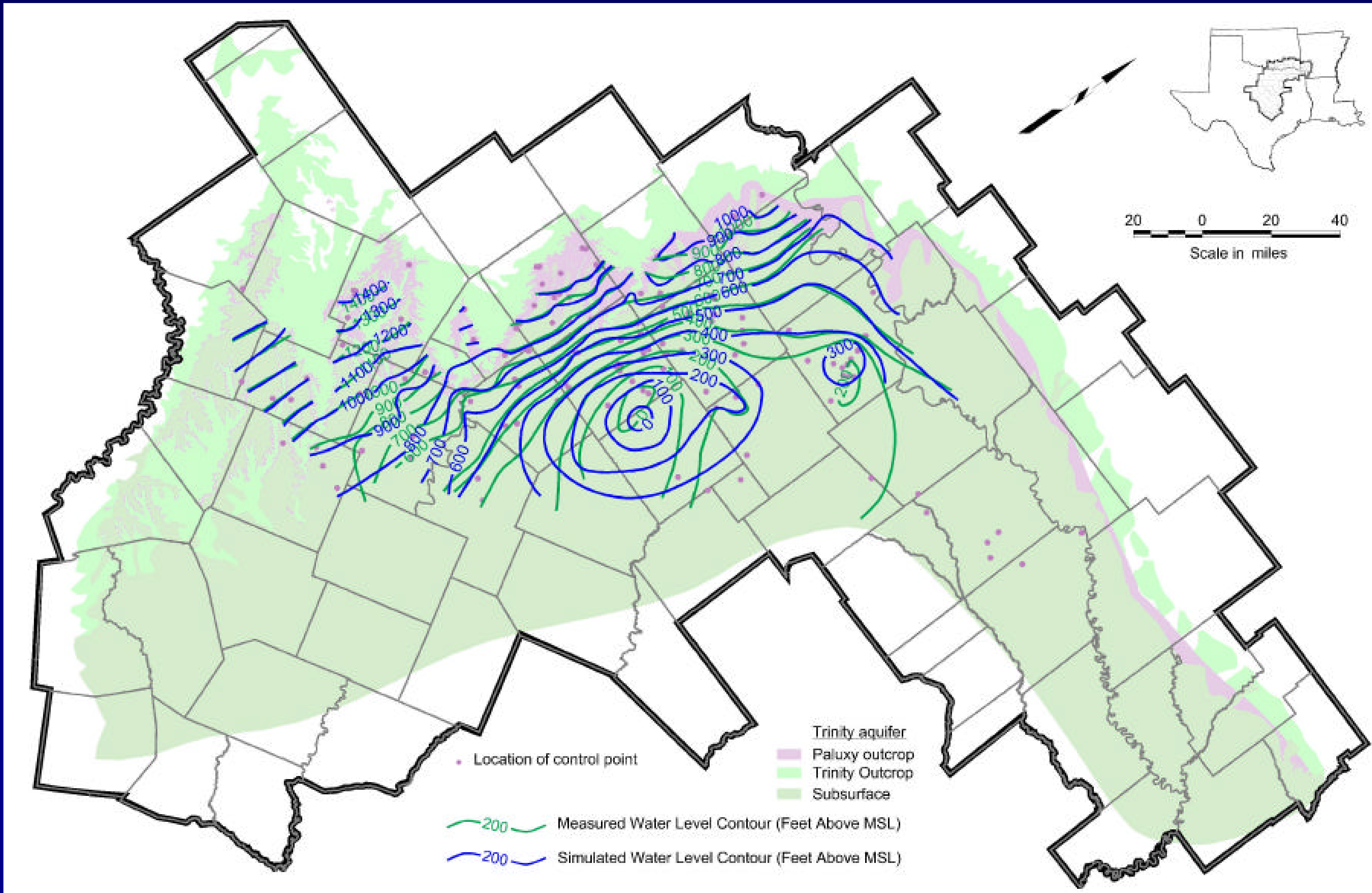
Average Recharge Rate



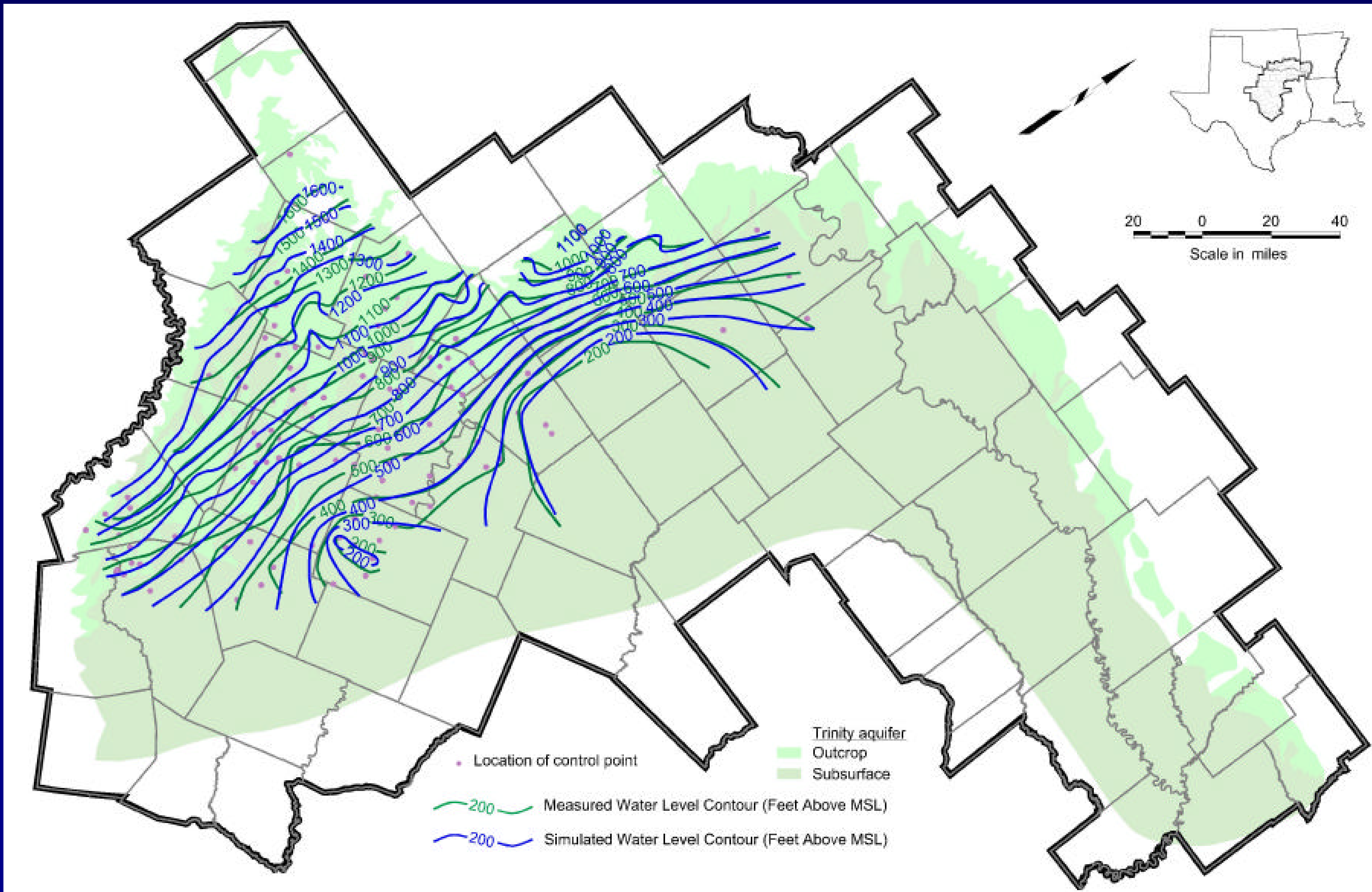
Woodbine Water Level - 1980



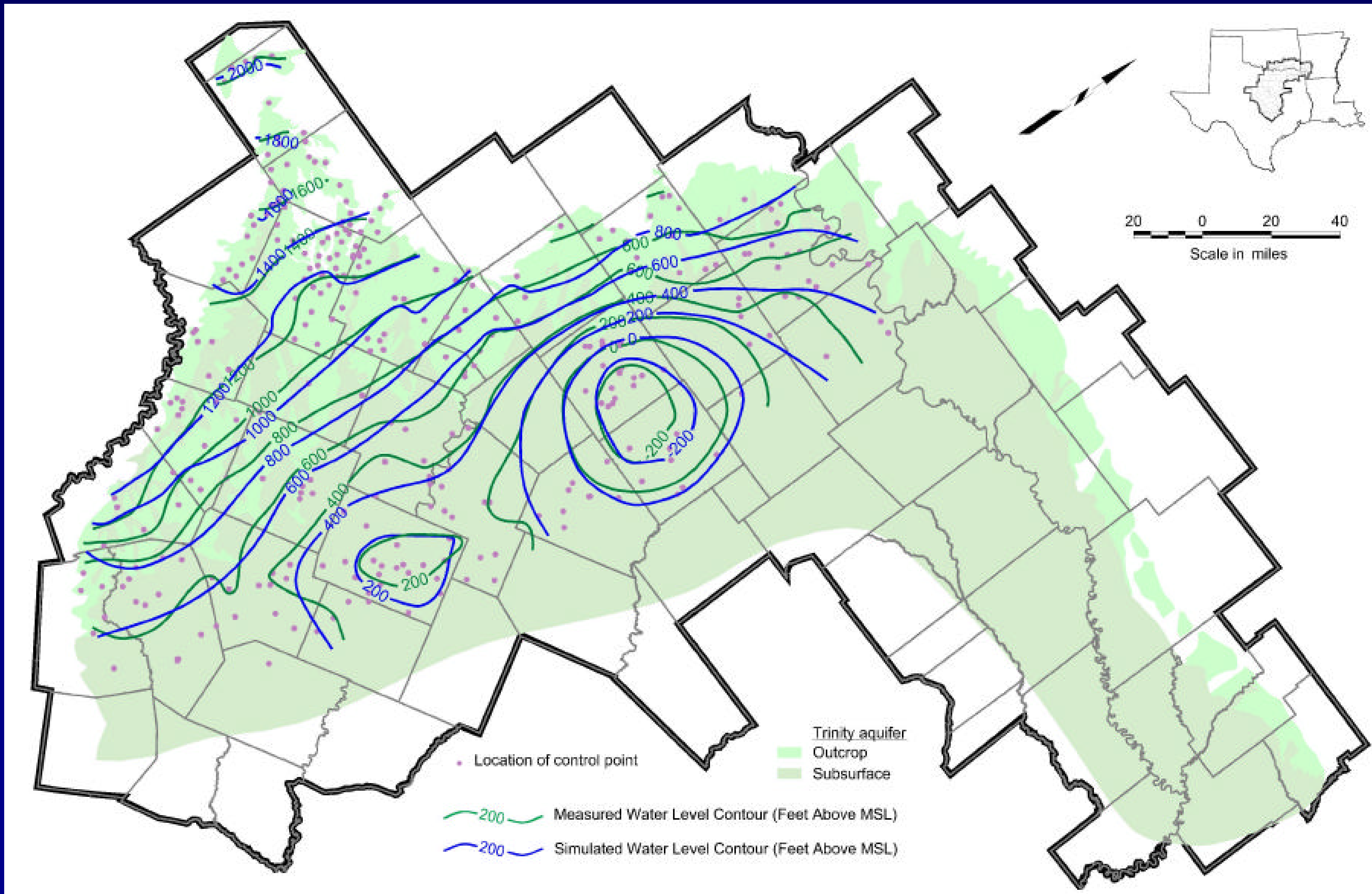
Paluxy Water Level – 1980



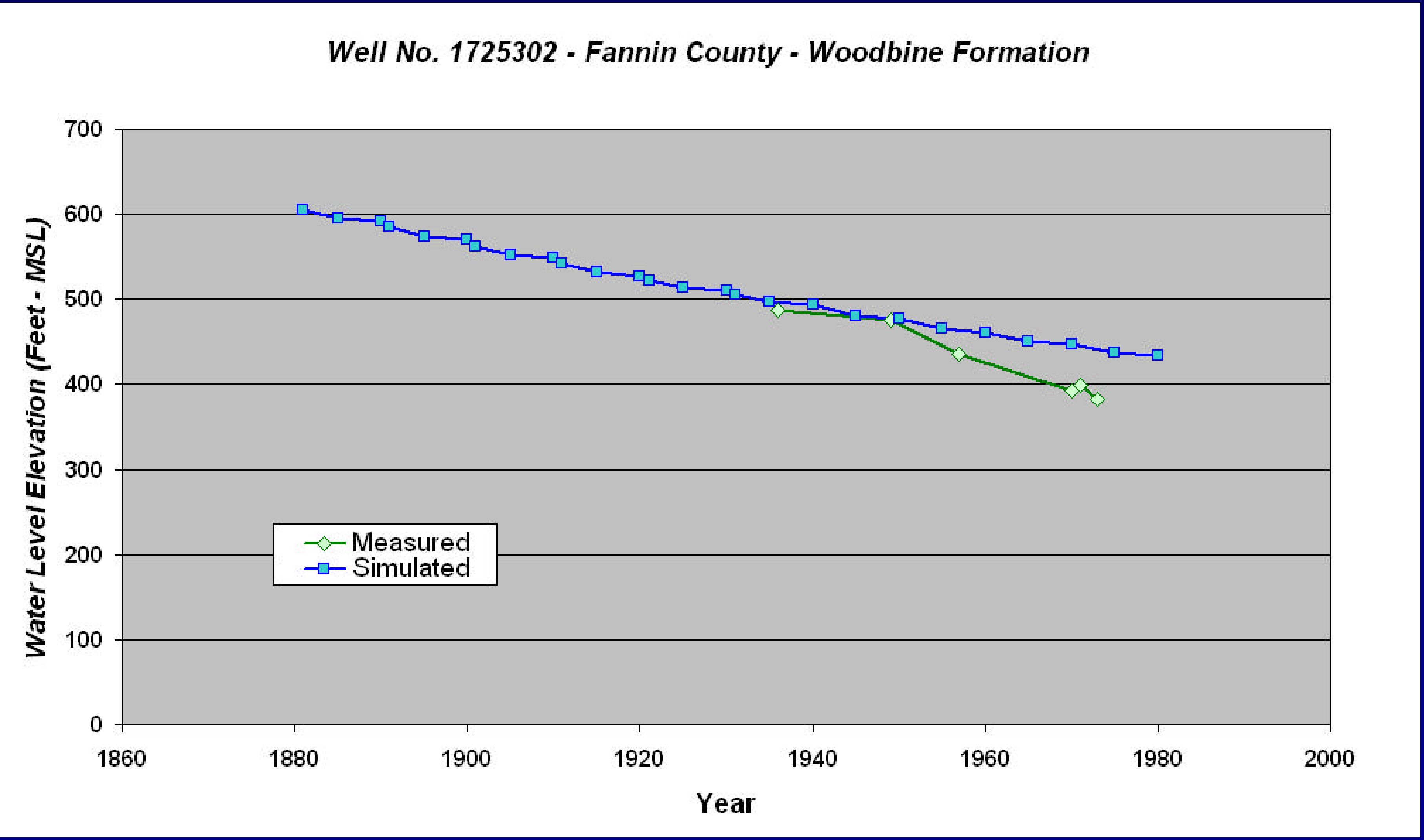
Hensell Water Level - 1980



Hosston Water Level – 1980



Simulated vs. Measured Water Levels



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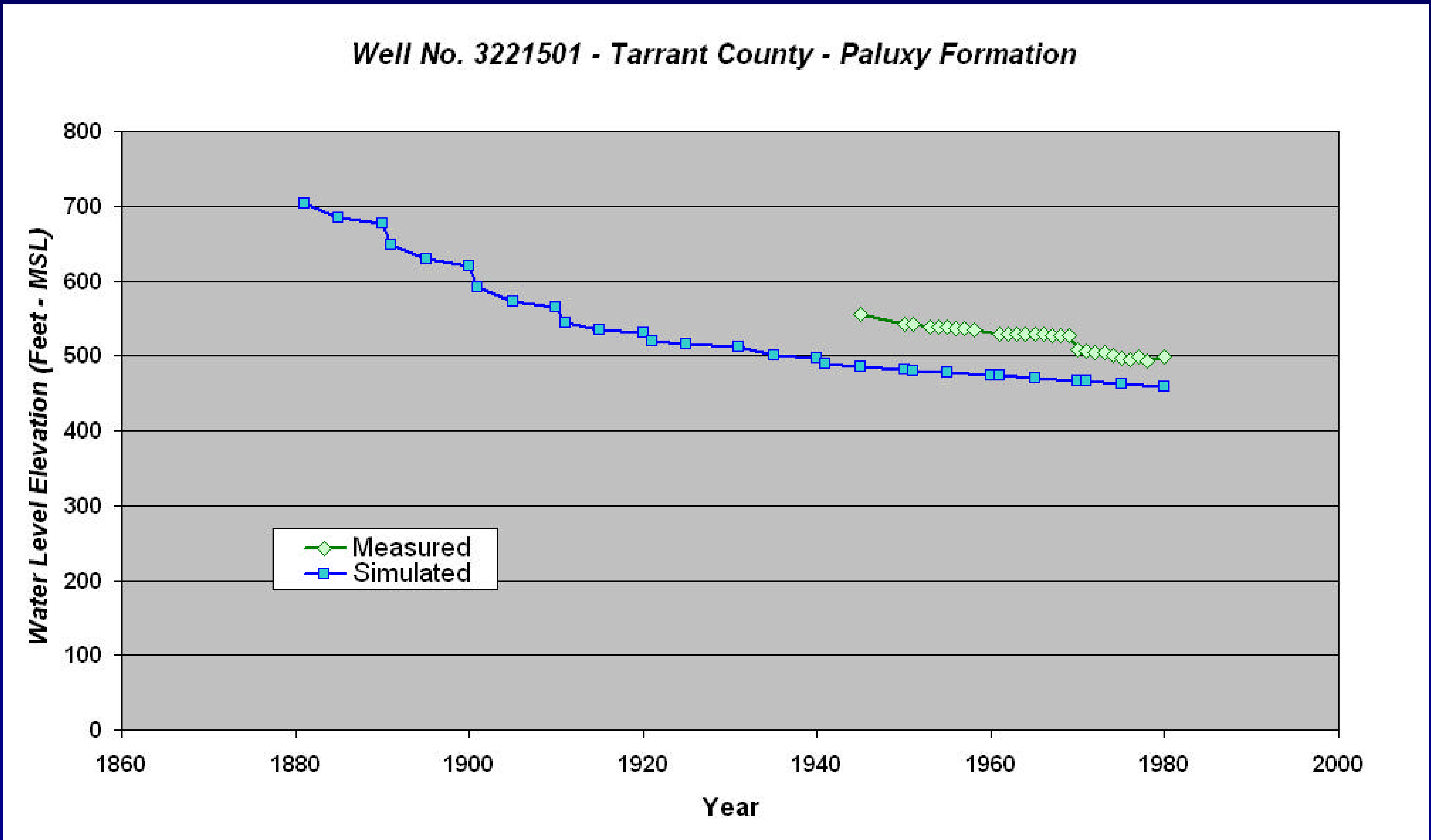
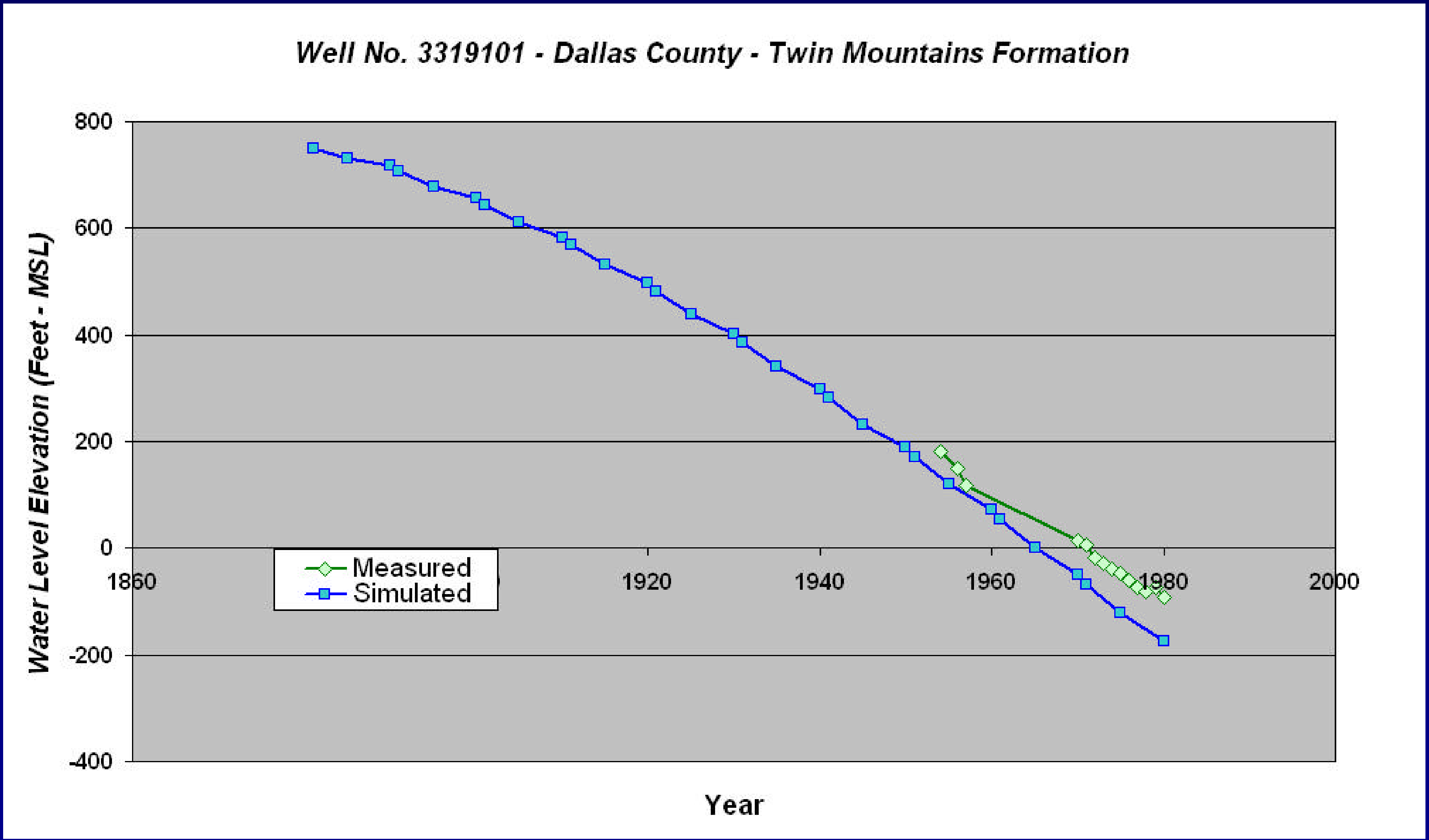
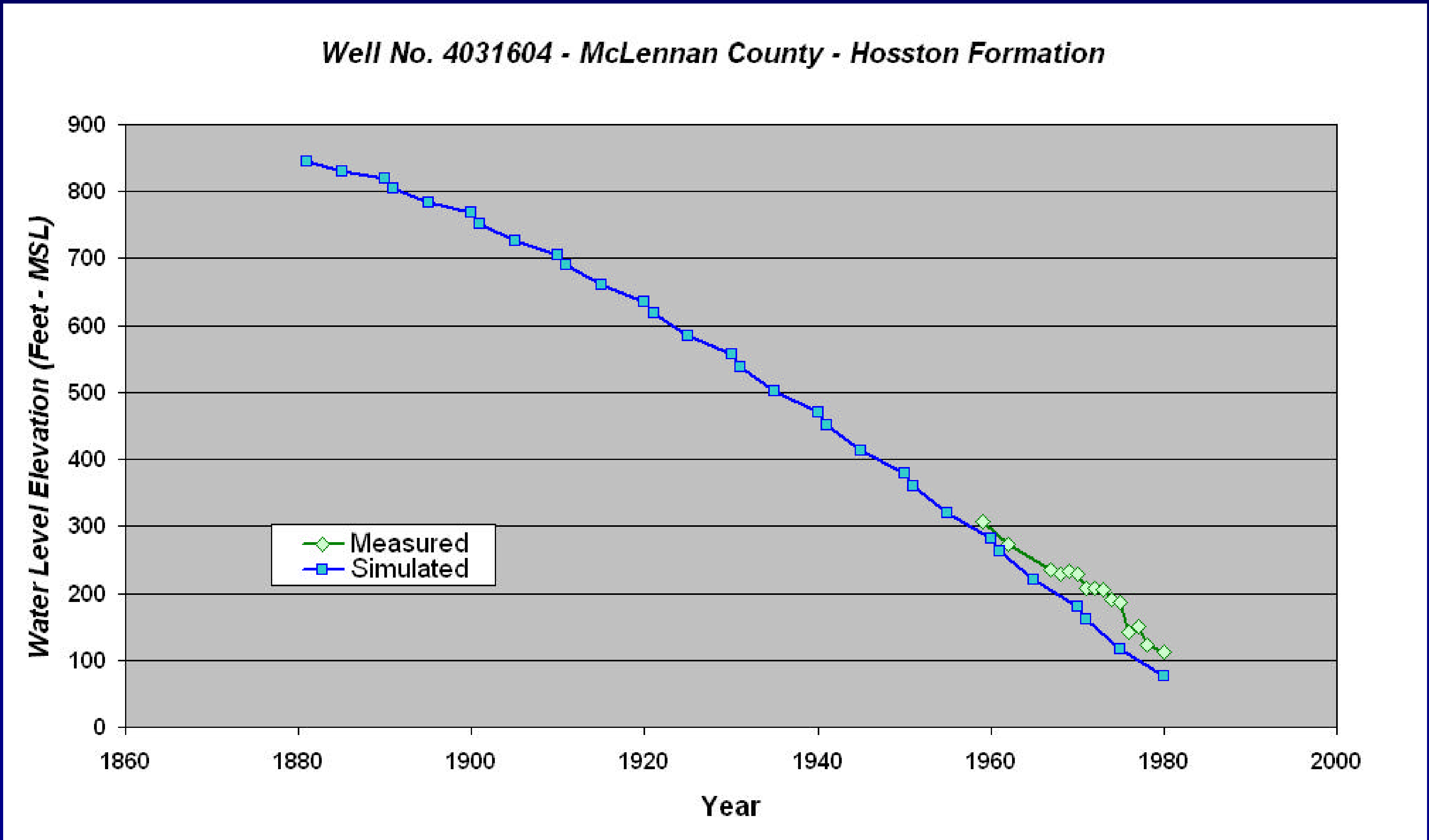


Simulated vs. Measured Water Levels

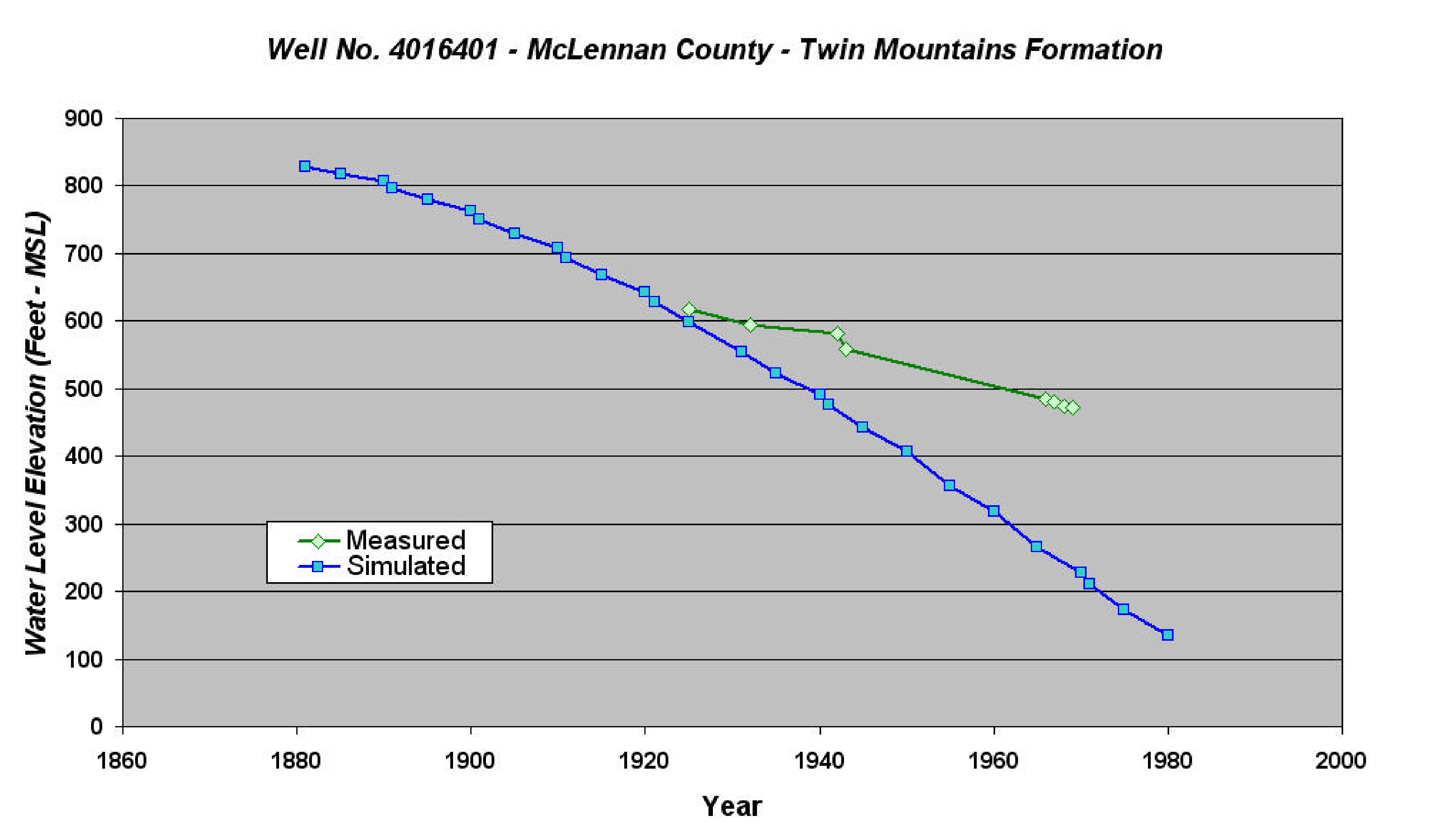


Simulated vs. Measured Water Levels

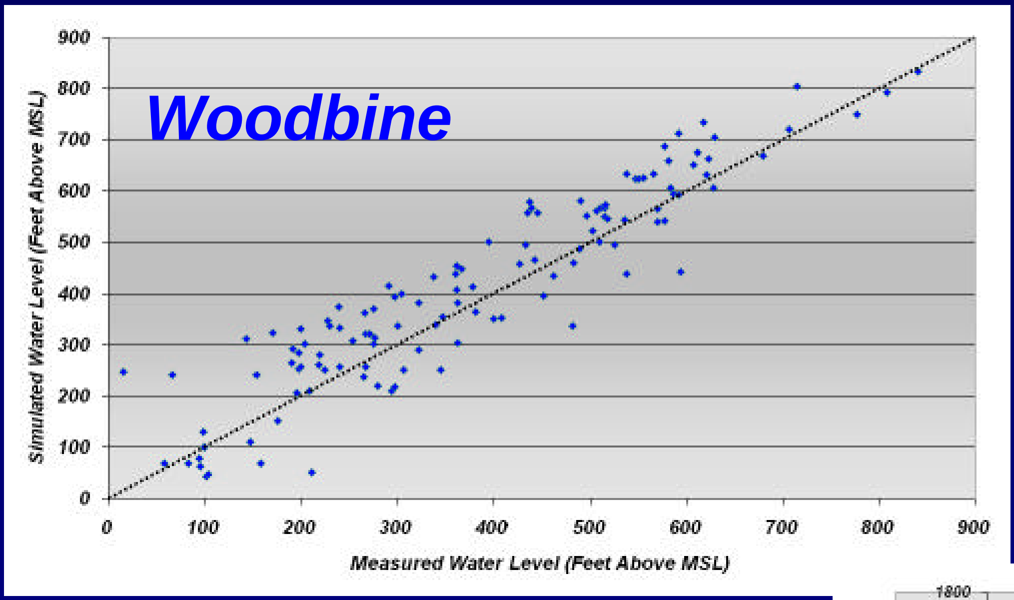


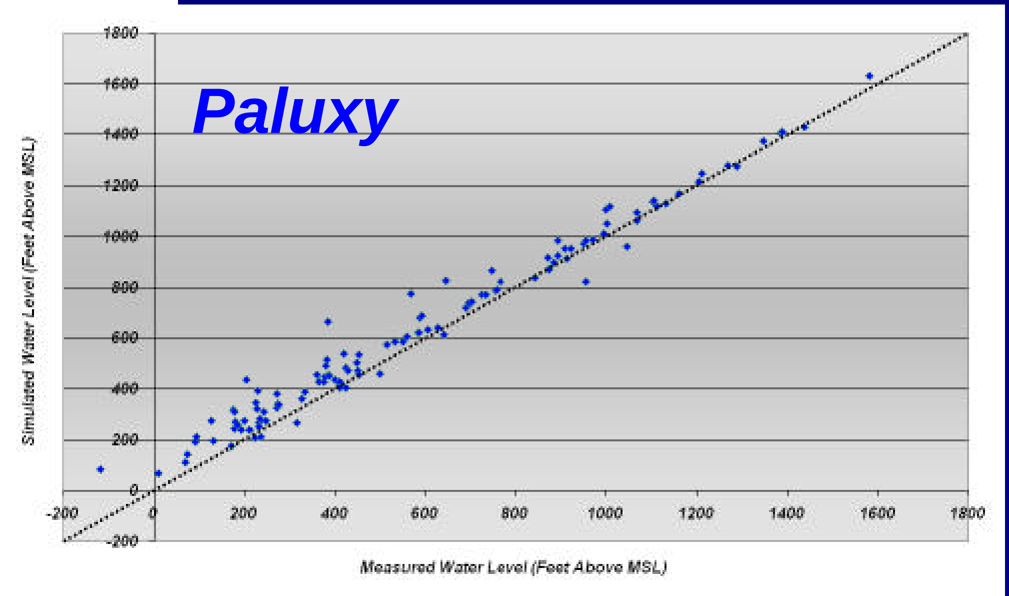
Simulated vs. Measured Water Levels

(Preliminary)

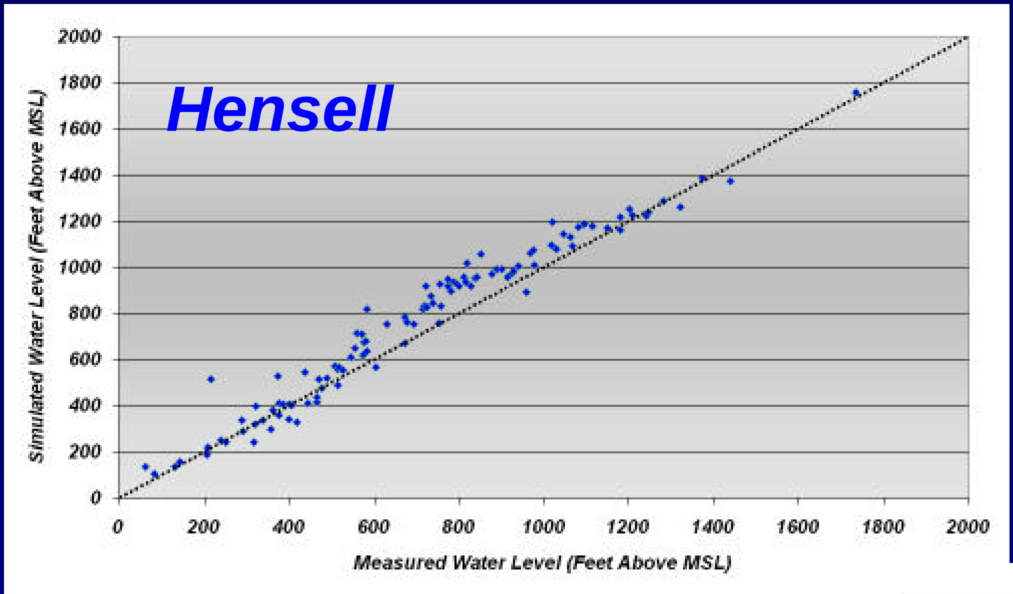


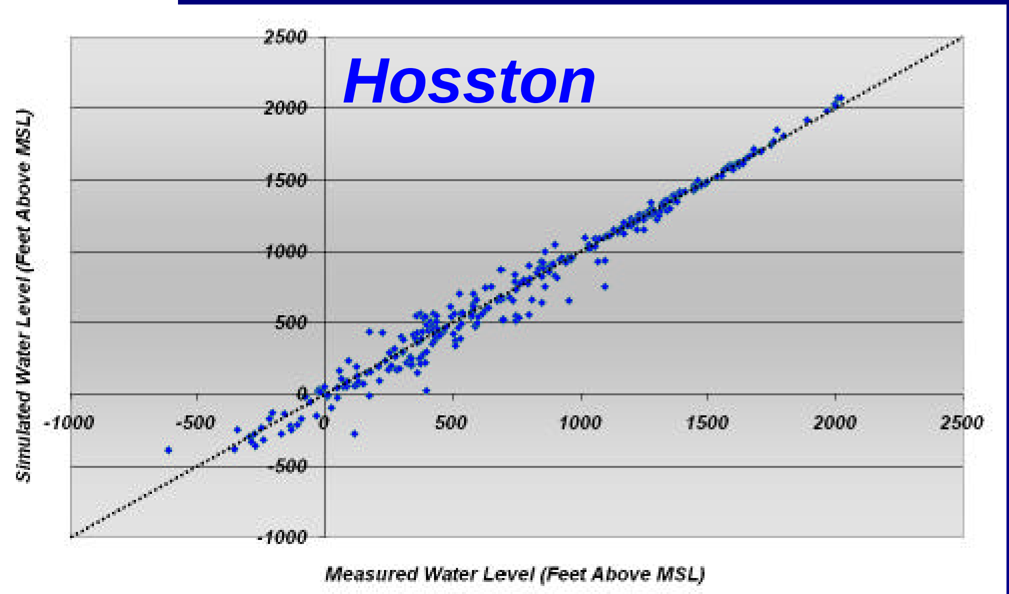
Sim vs. Measured Water Levels - 1980





Sim vs. Measured Water Levels - 1980





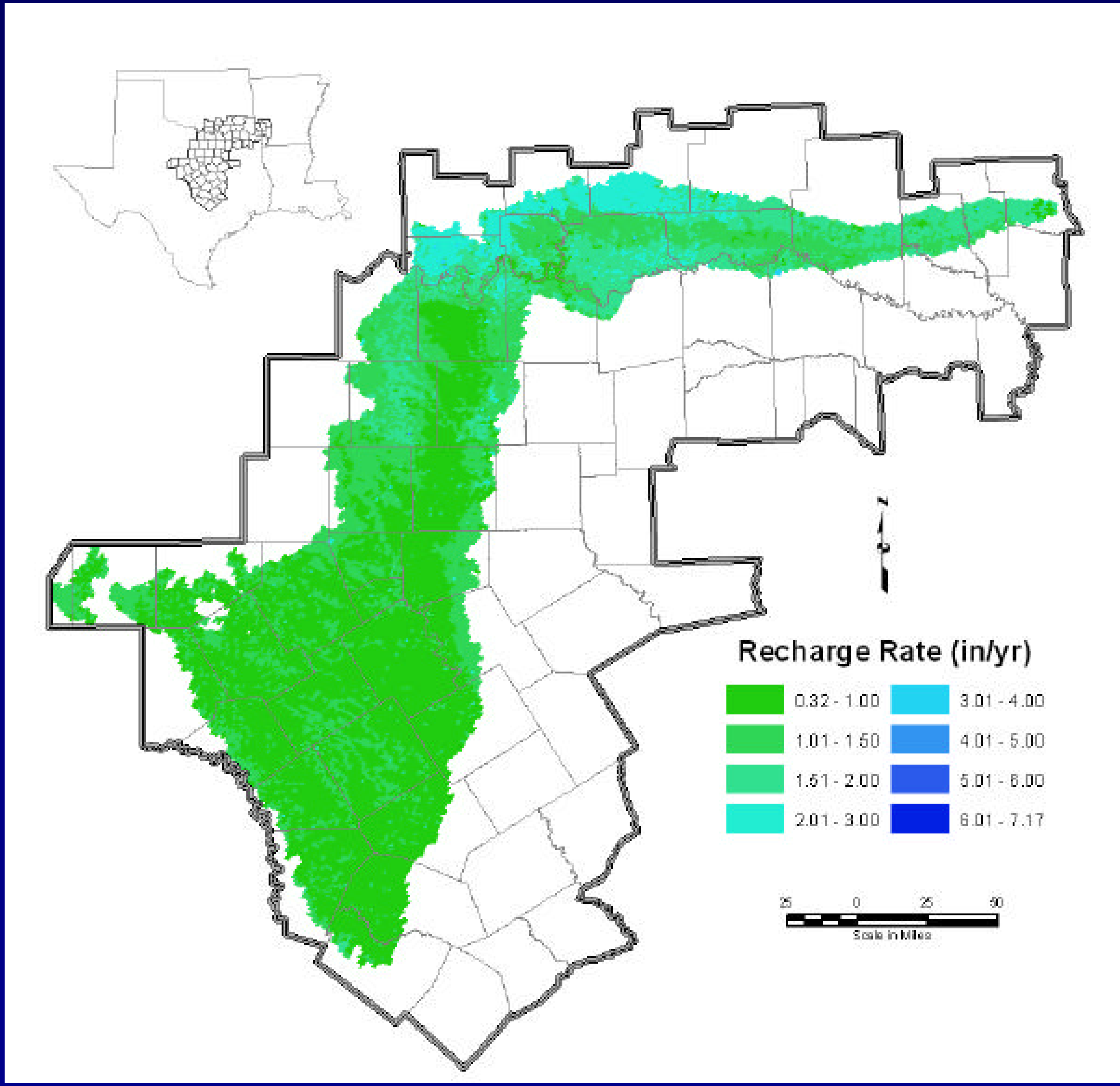
Model Calibration Results - 1980

Aquifer	Mean Residual (ft)	Mean ABS Residual (ft)	RMS Residual (ft)	Total Measured Head Drop (ft)	RMS Percent of Measured Drop
Woodbine	17.7	58.4	73.3	824	8.9%
Paluxy	0.0	48.8	66.3	1,699	3.9%
Hensell	8.4	40.3	57.8	1,672	3.5%
Hosston	-14.6	58.7	85.5	2,639	3.2%

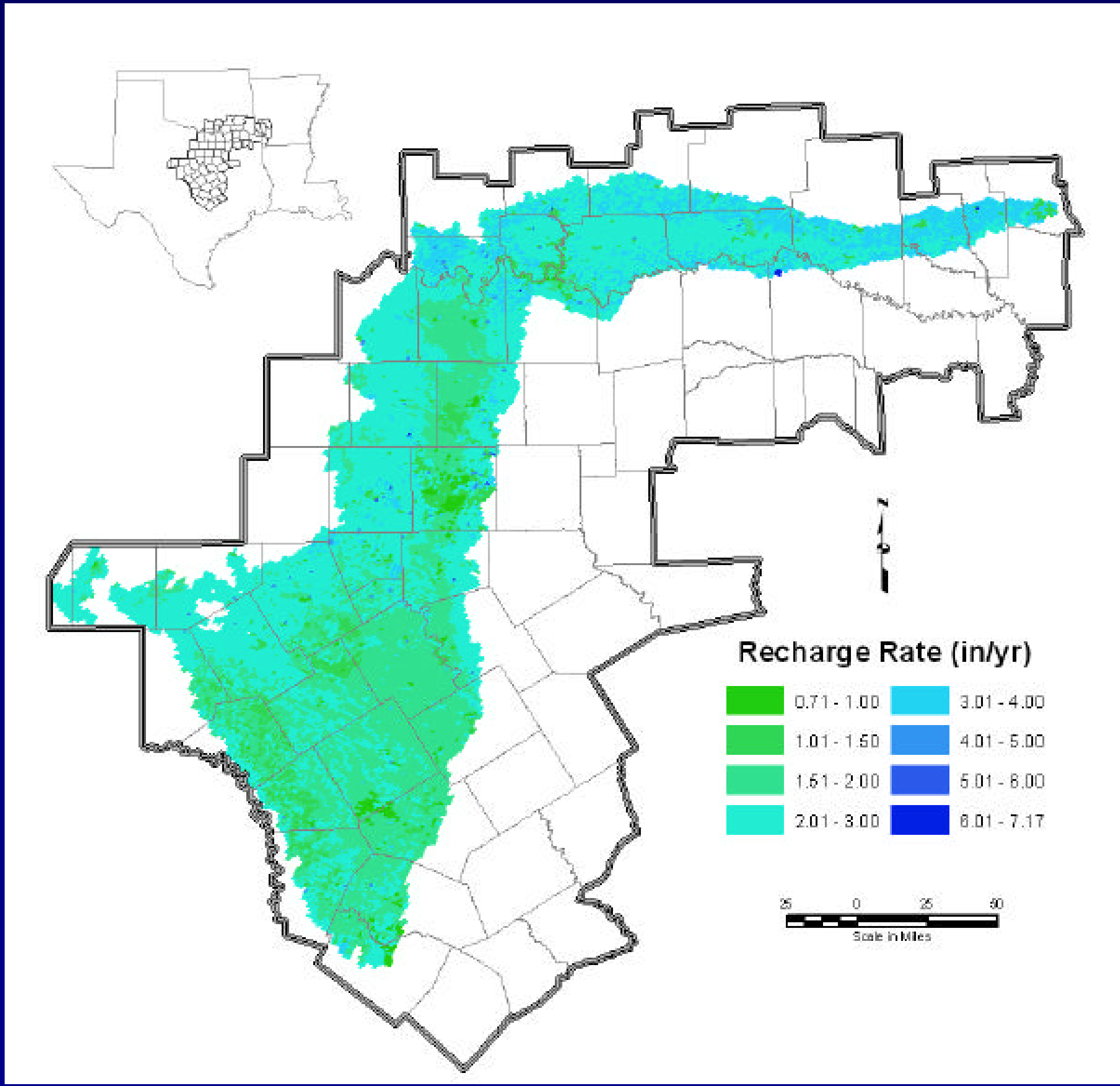
** Total simulated inflow minus outflow is less than 0.01 percent*

Calibration / Verification Results 1980-1990 / 1990-2000

Minimum Recharge Rate (1999)



Maximum Recharge Rate (1992)

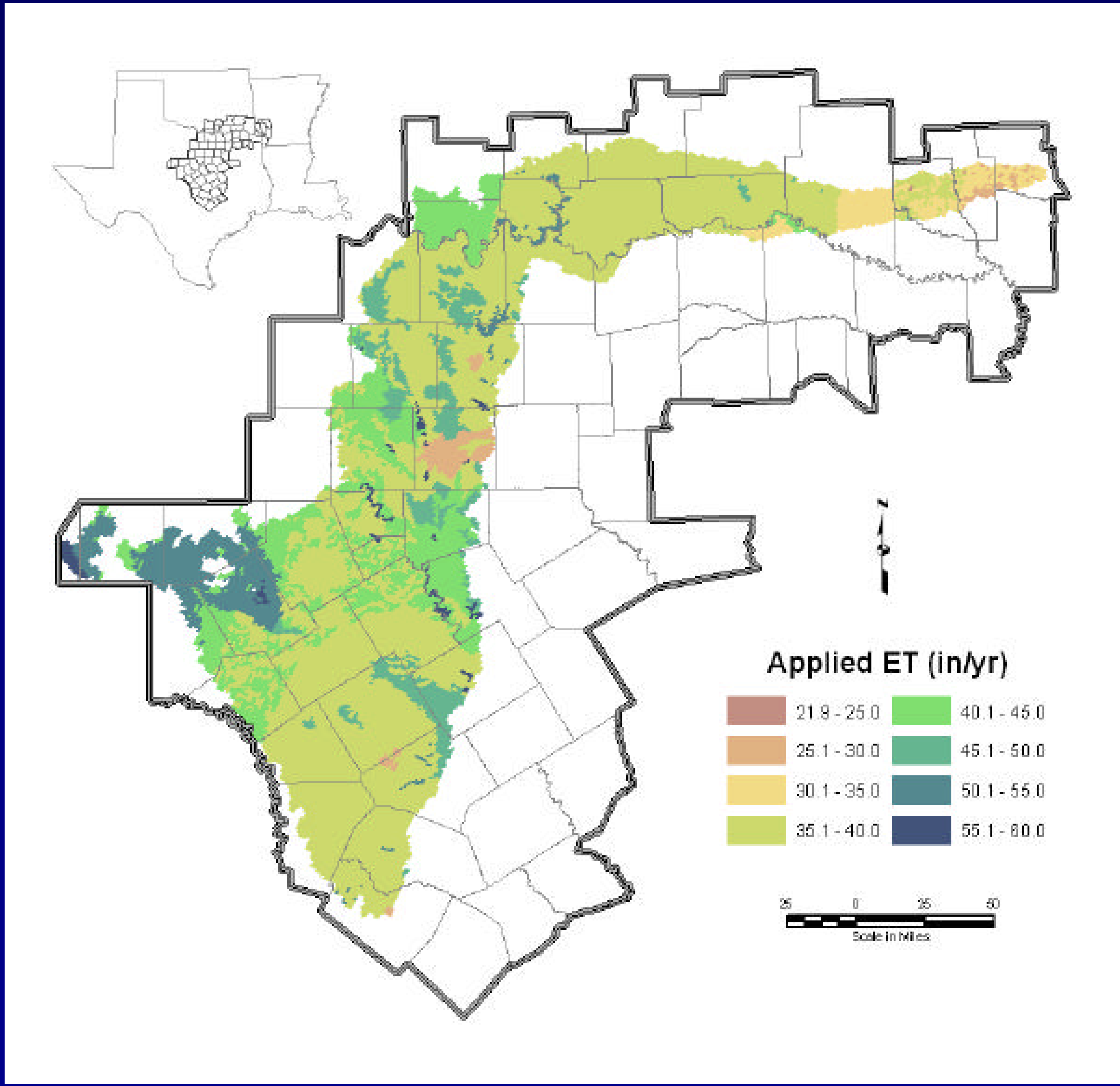


Evapotranspiration Package

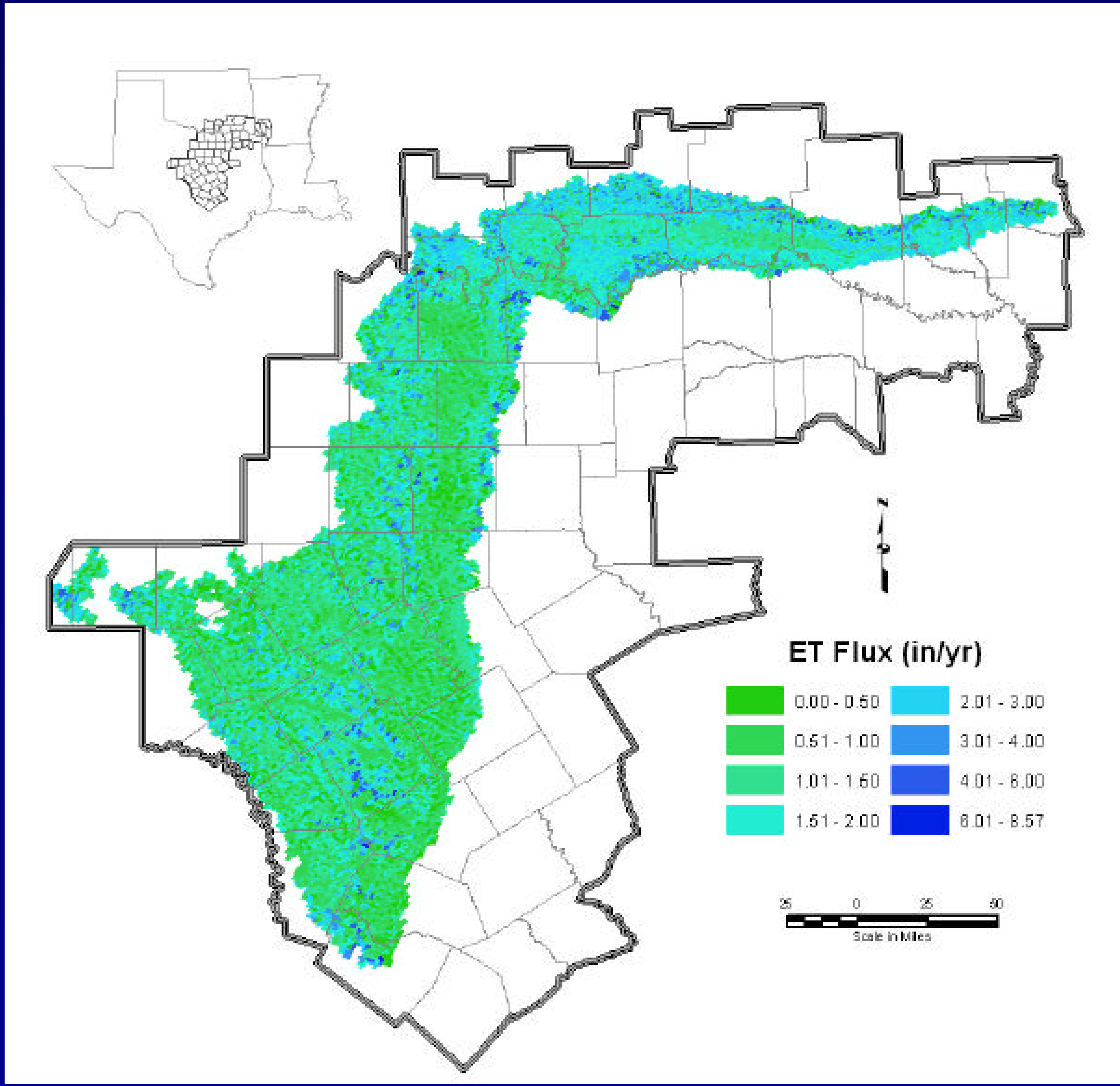
In This Model, MODFLOW ET Package Simulates:

- Evaporation
- Transpiration
- Springs
- Seeps
- Streamflow not specifically modeled

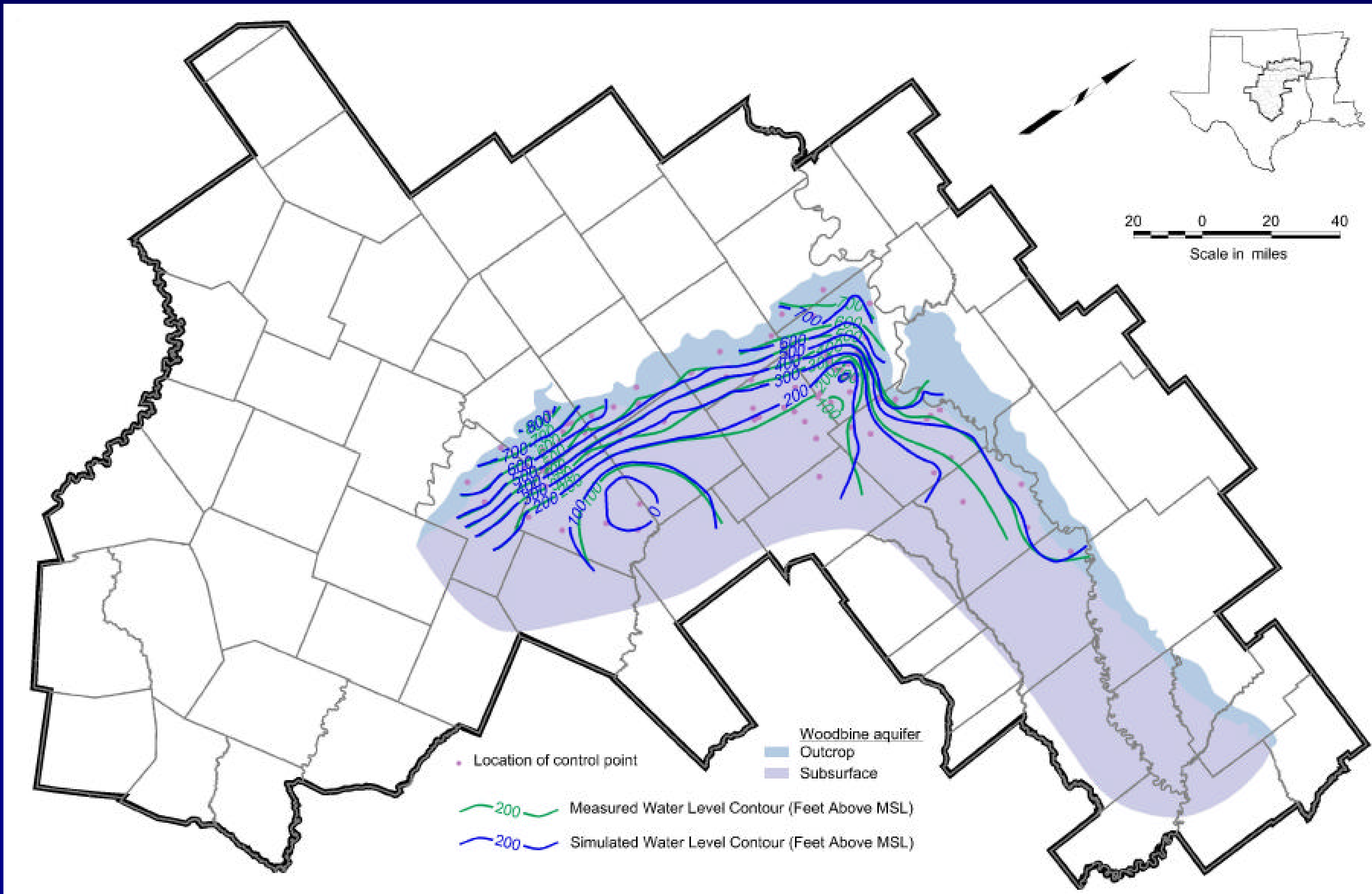
Maximum ET Rate Distribution



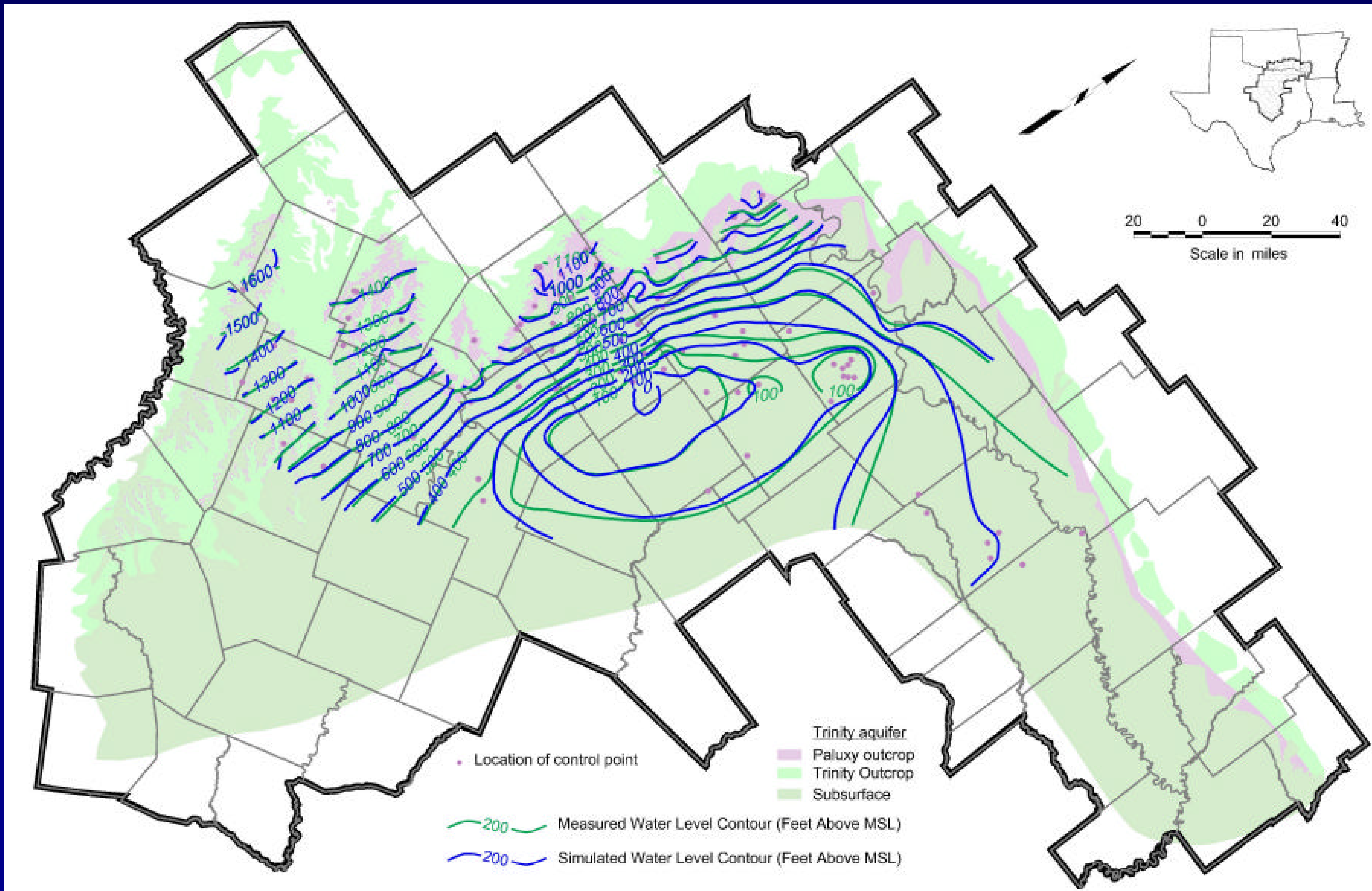
Model ET Flux (2000)



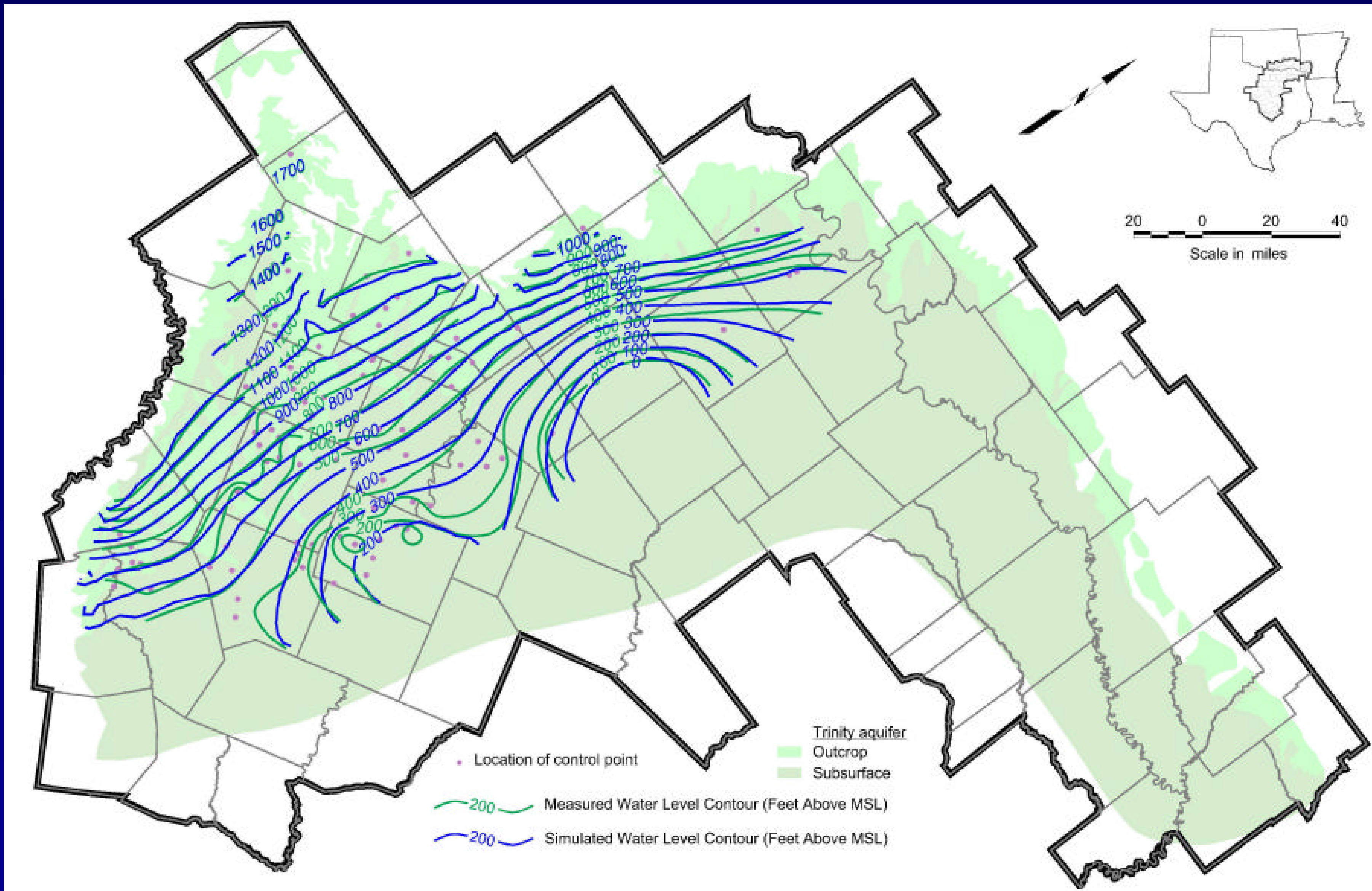
Woodbine Water Level – 1990



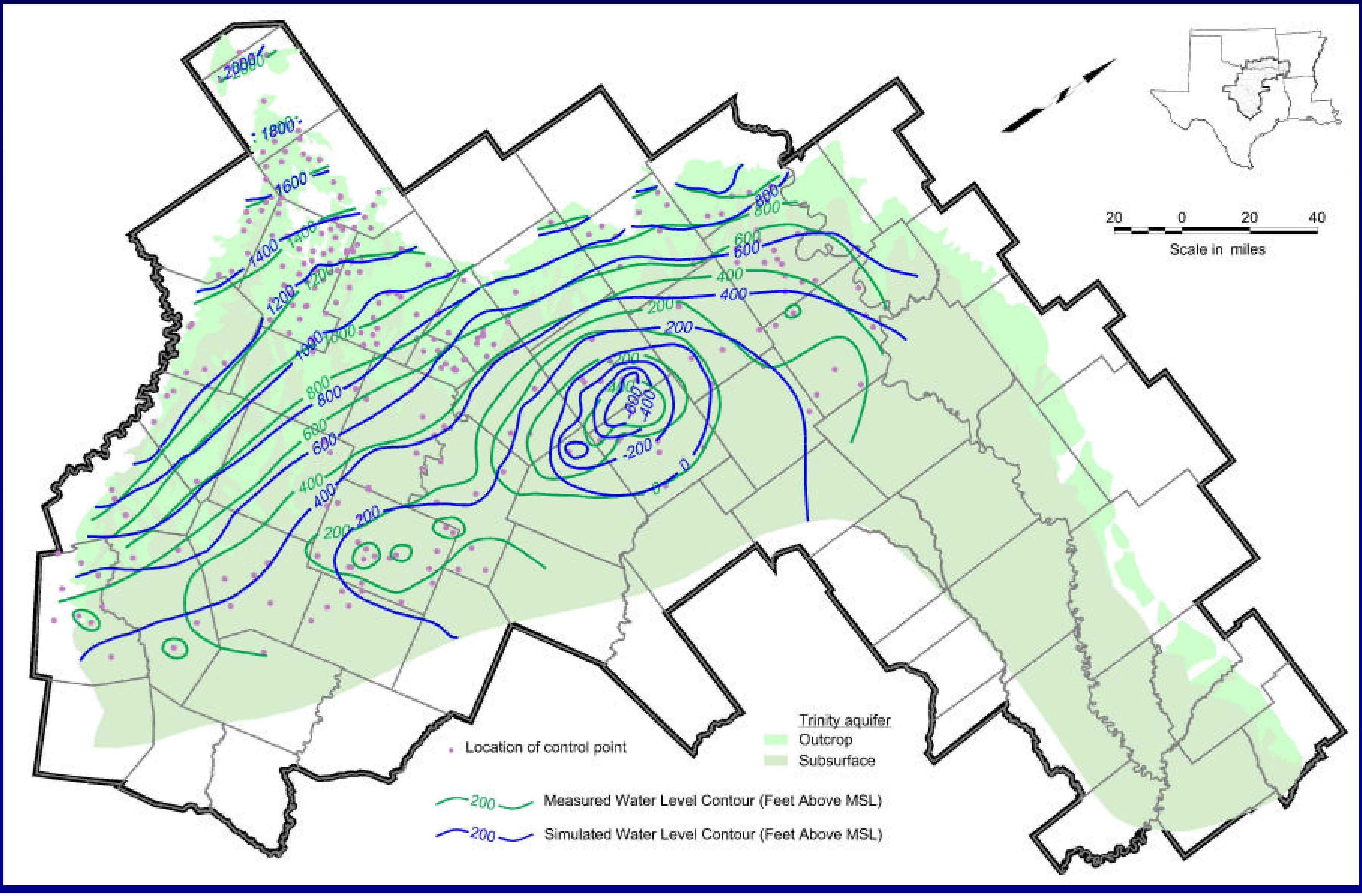
Paluxy Water Level – 1990



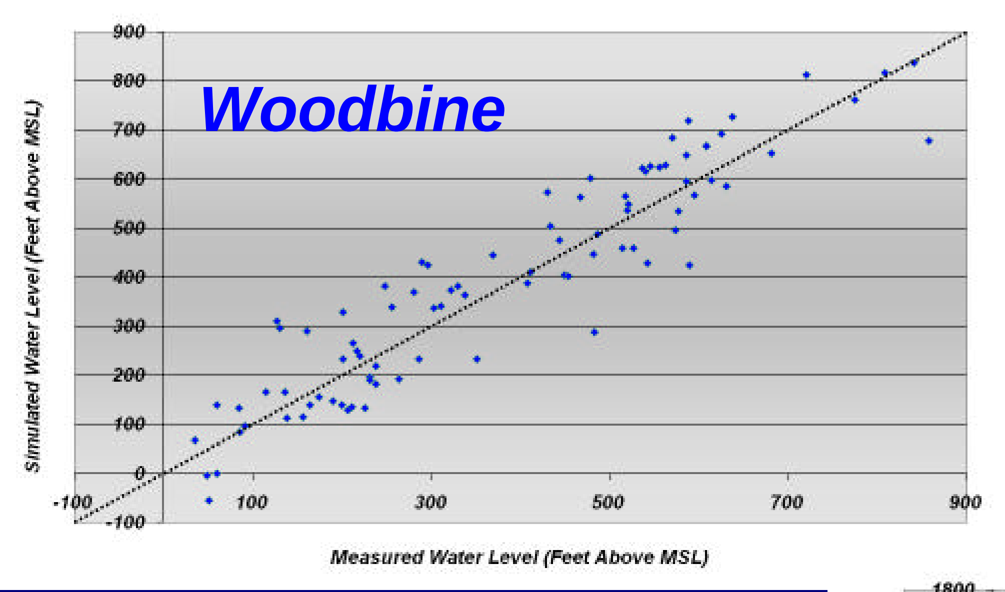
Hensell Water Level – 1990

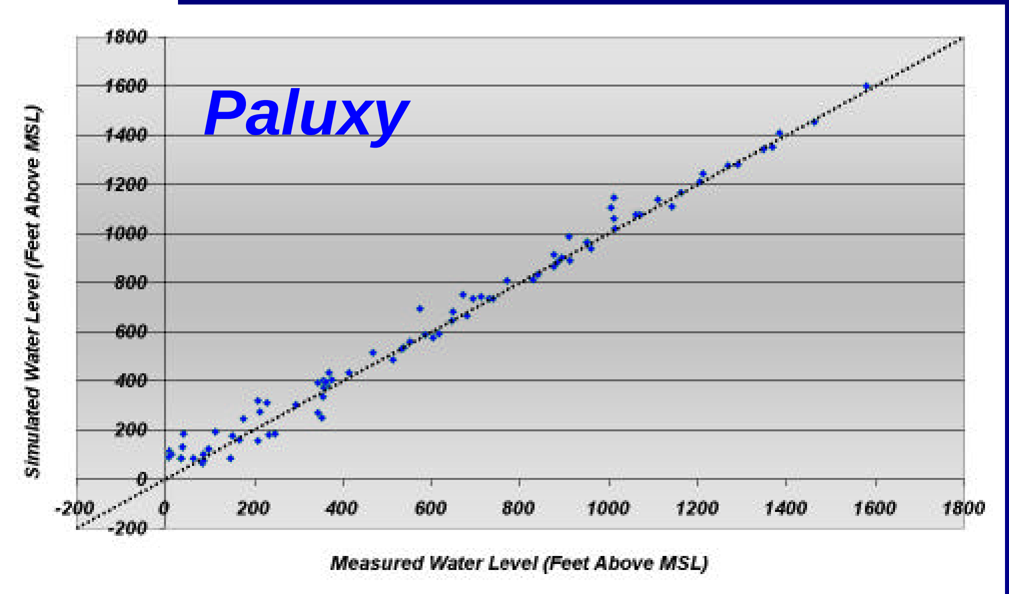


Hosston Water Level – 1990



Sim vs. Measured Water Levels - 1990





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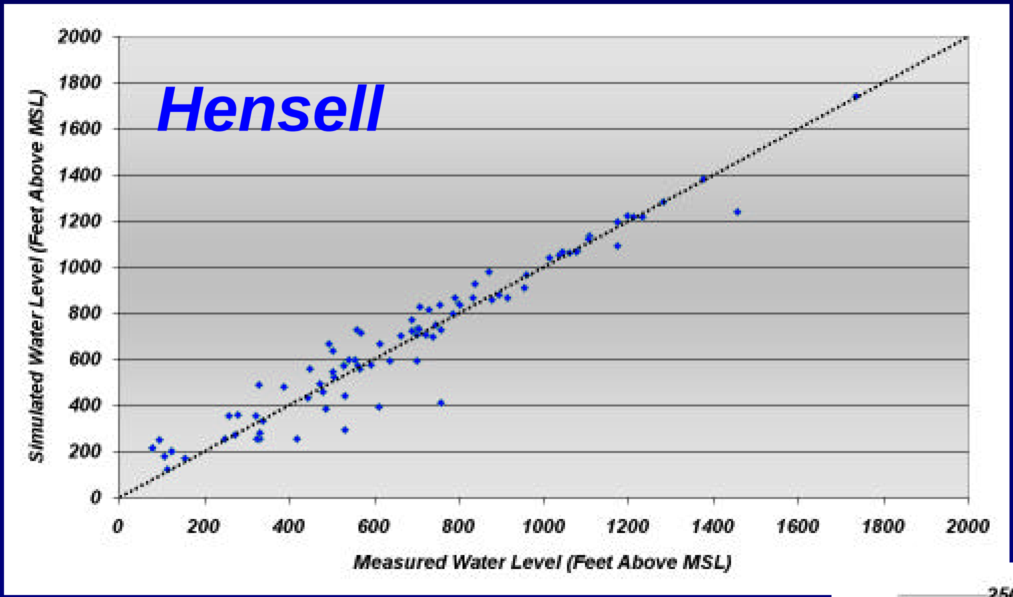
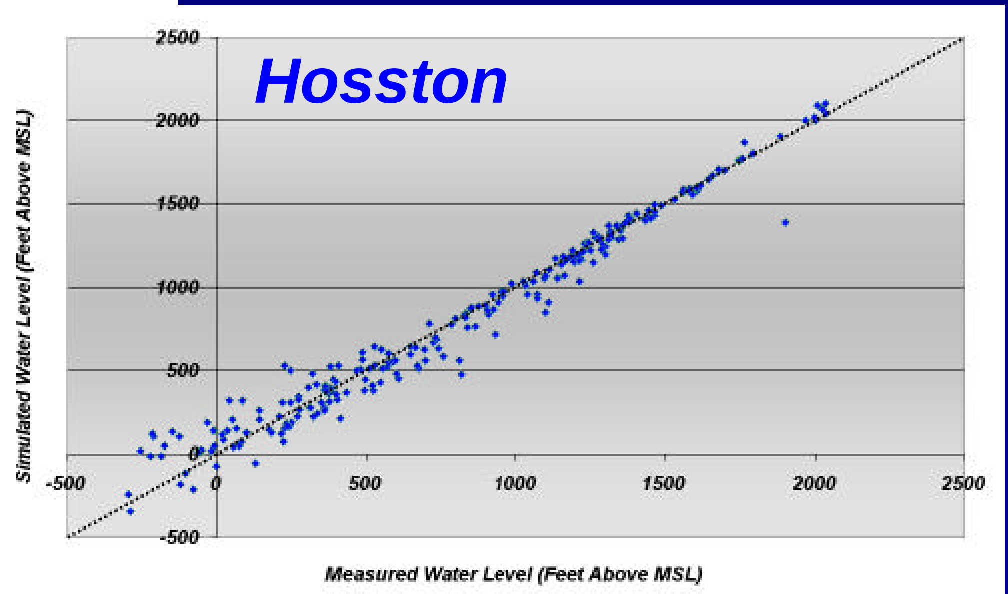


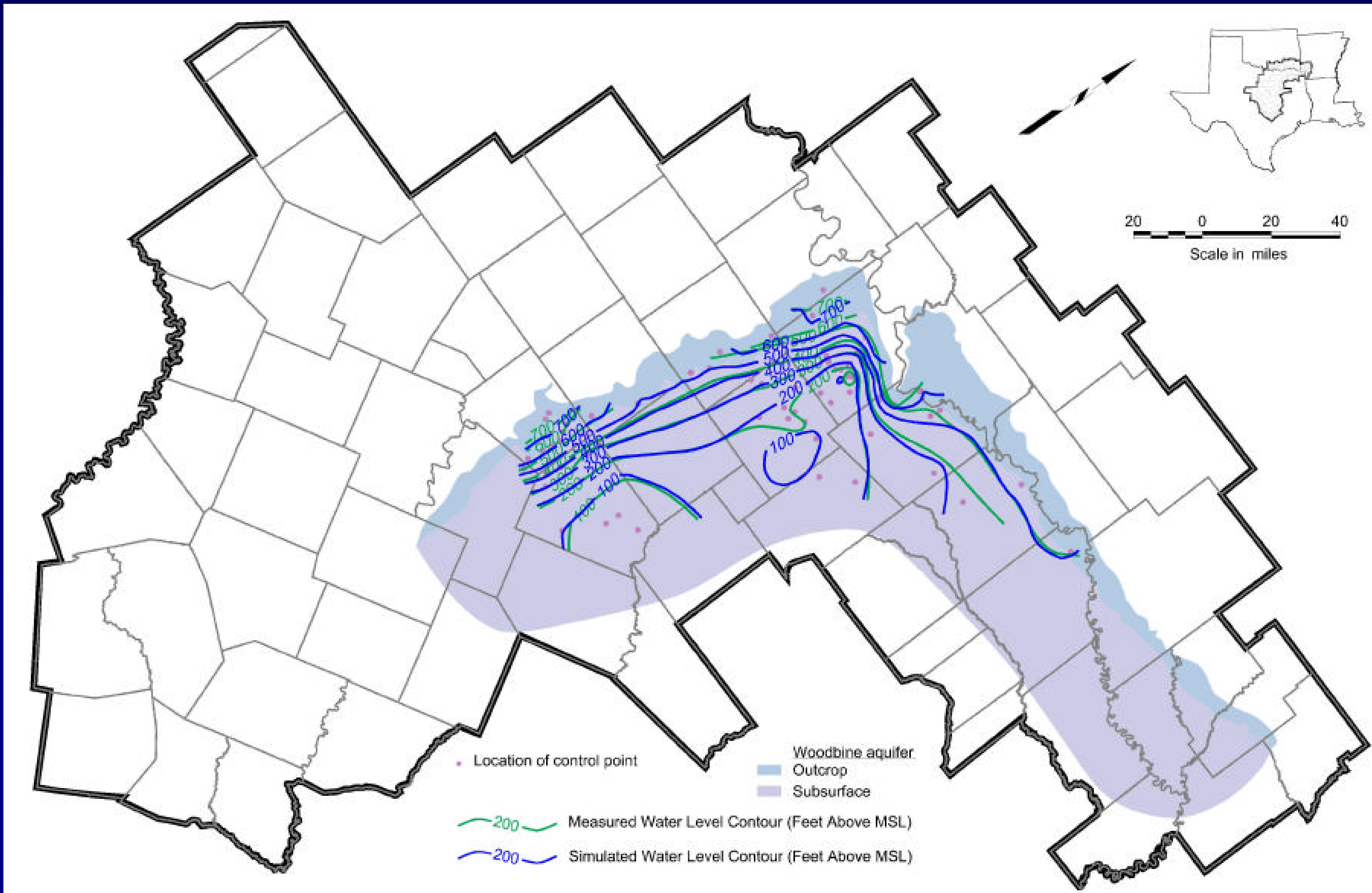


Model Calibration Results - 1990

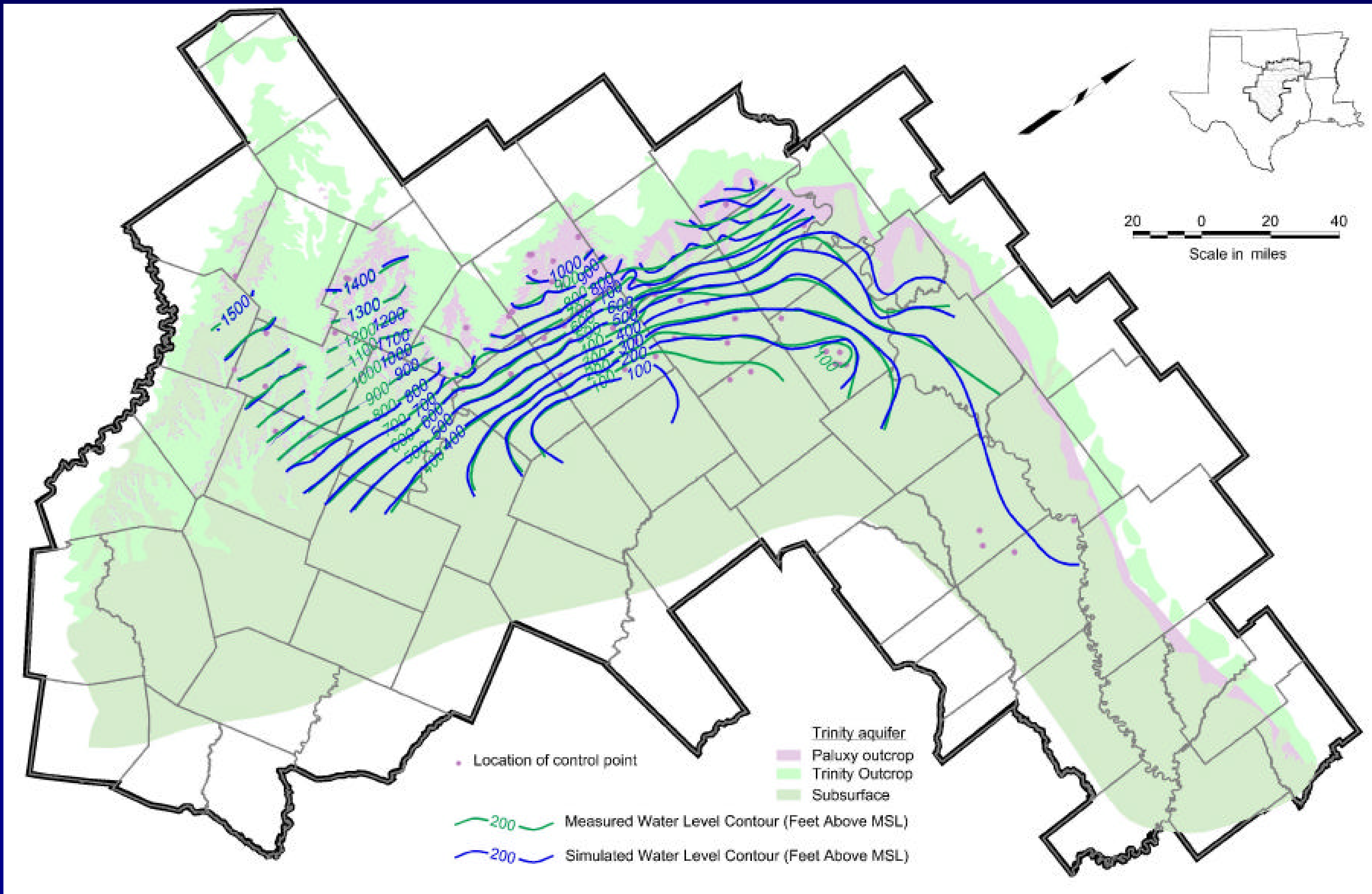
Aquifer	Mean Residual (ft)	Mean ABS Residual (ft)	RMS Residual (ft)	Total Measured Head Drop (ft)	RMS Percent of Measured Drop
Woodbine	13.3	65.0	79.3	822	9.7%
Paluxy	20.9	37.5	50.7	1,572	3.2%
Hensell	18.6	67.0	99.5	1,755	5.7%
Hosston	-7.6	70.0	107.0	2,385	4.5%

** Total simulated inflow minus outflow is less than 0.01 percent*

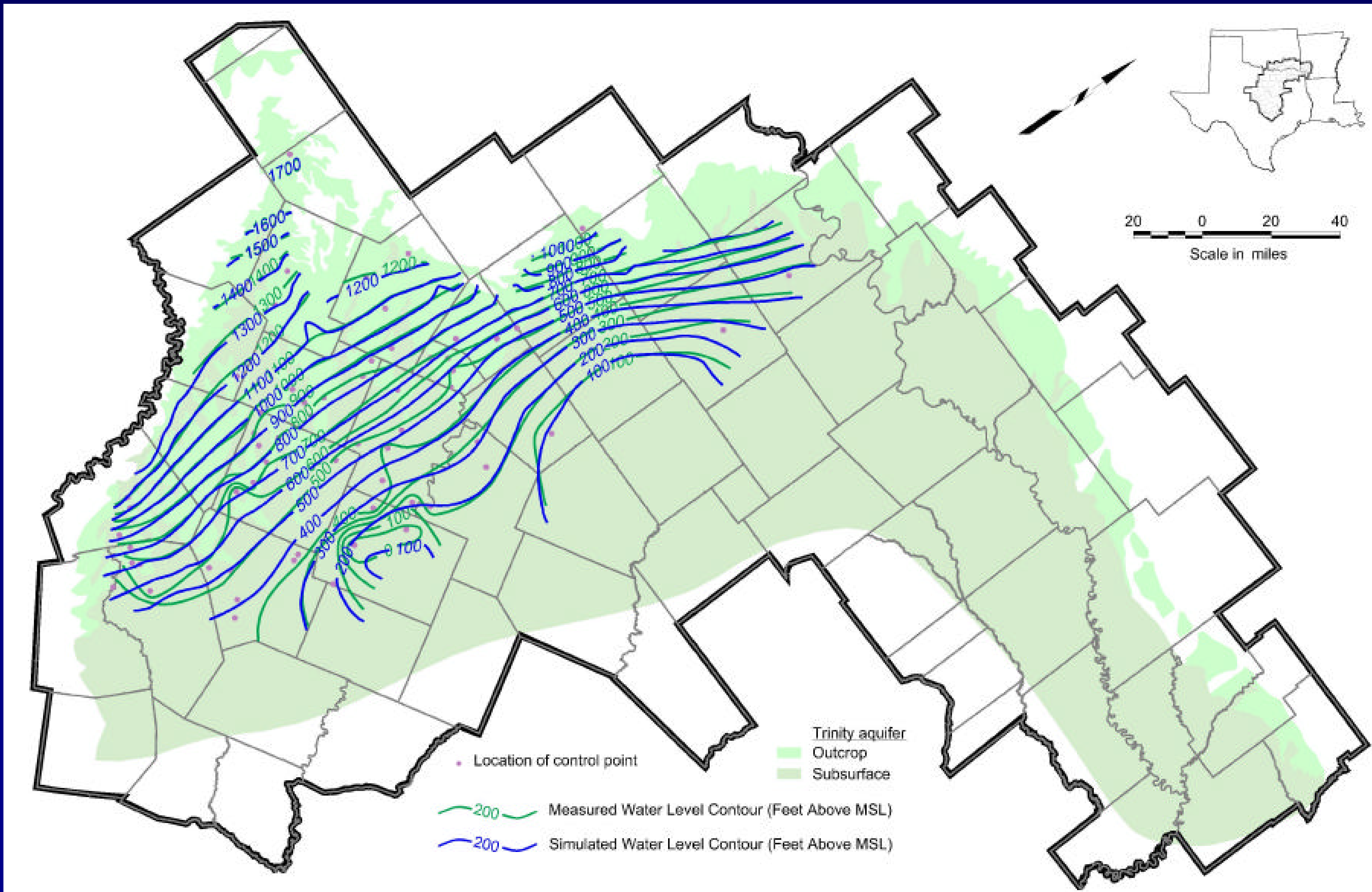
Woodbine Water Level – 2000



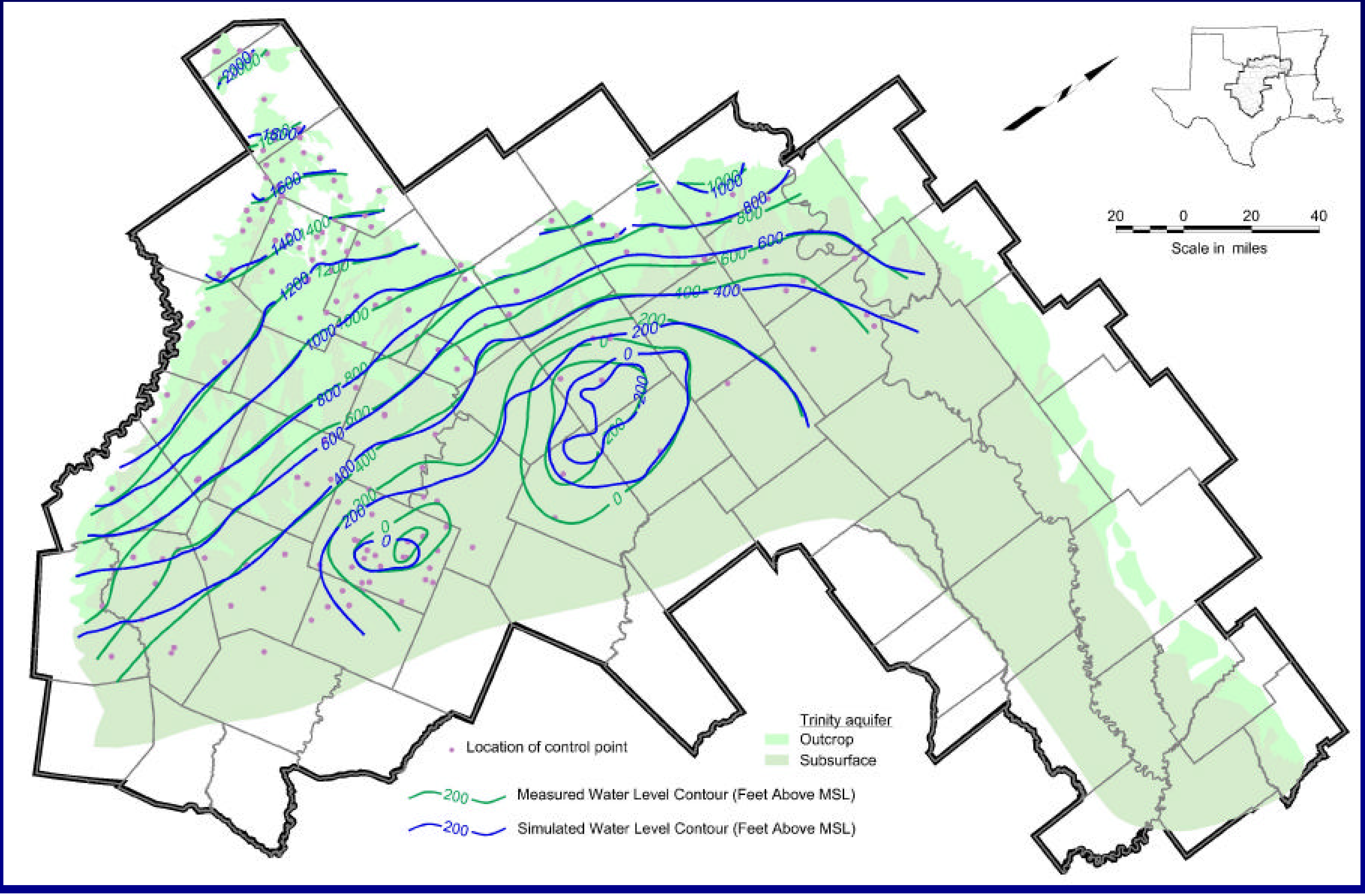
Paluxy Water Level – 2000



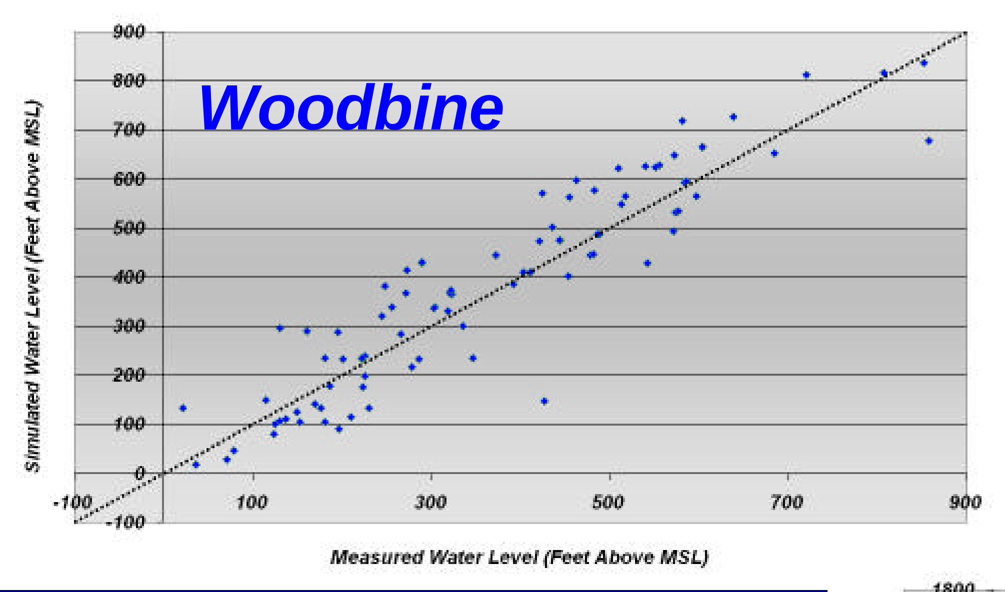
Hensell Water Level – 2000

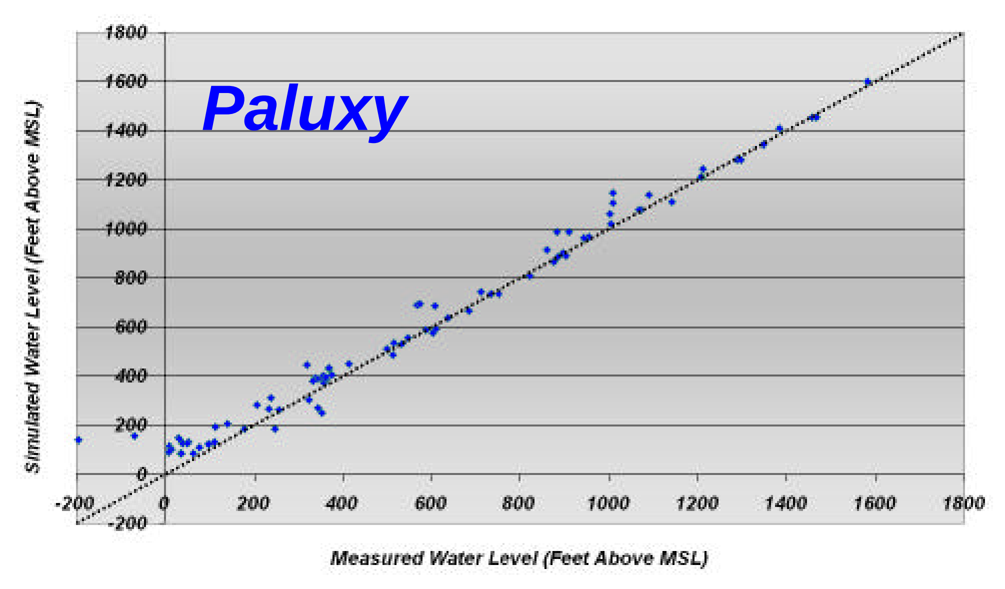


Hosston Water Level – 2000

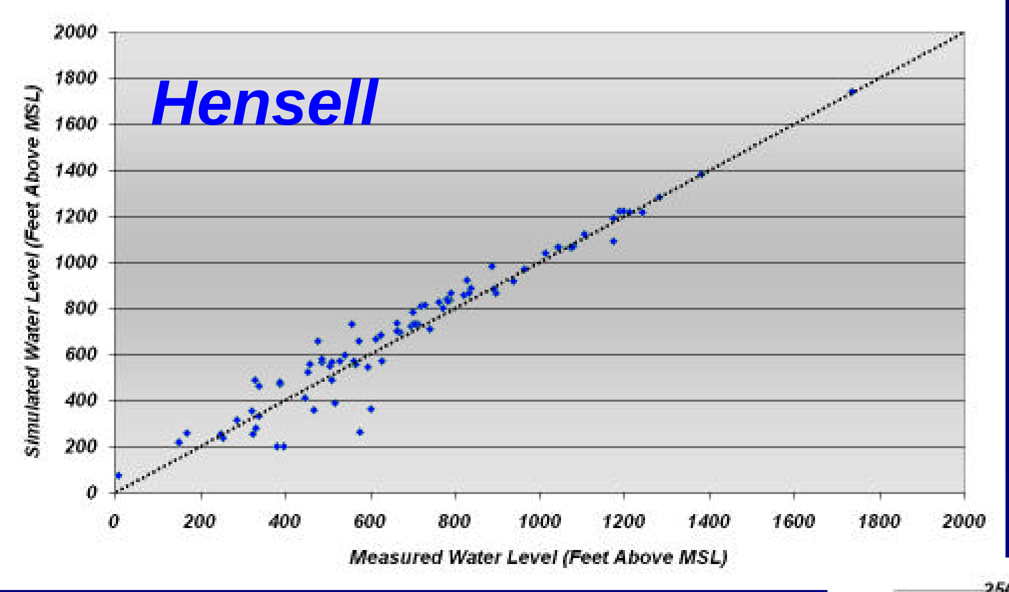


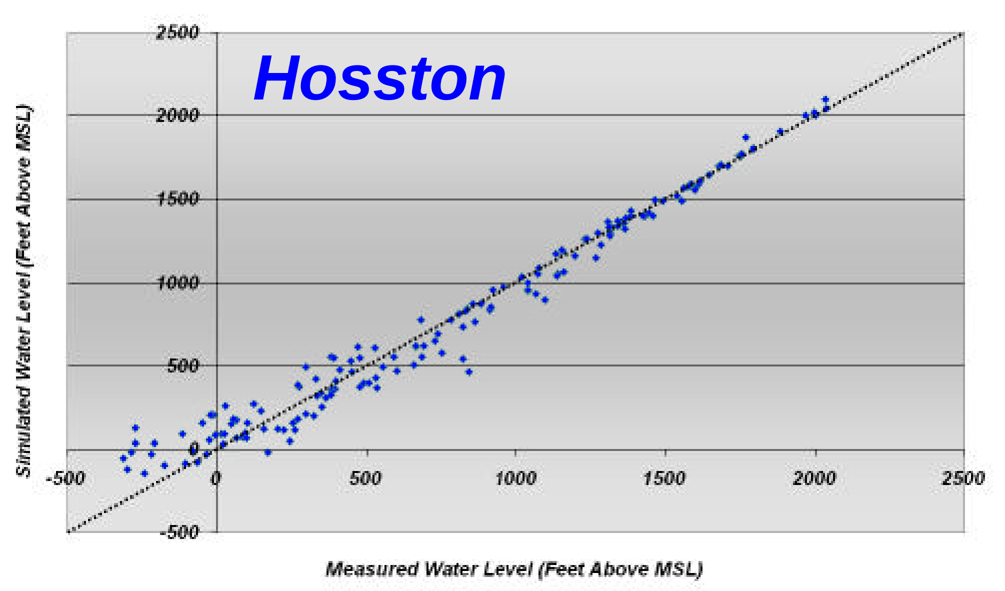
Sim vs. Measured Water Levels - 2000





Sim vs. Measured Water Levels - 2000



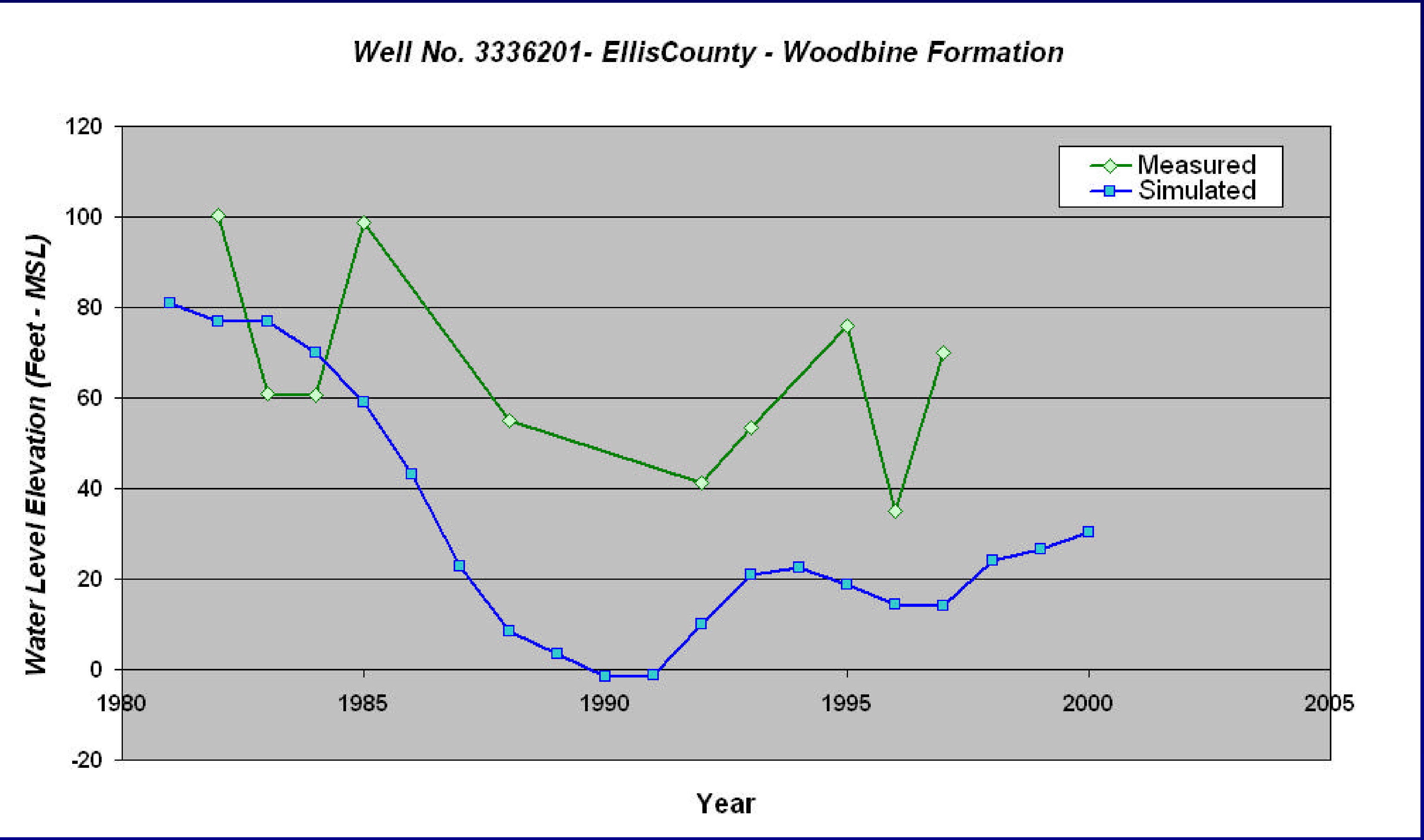


Model Calibration Results - 2000

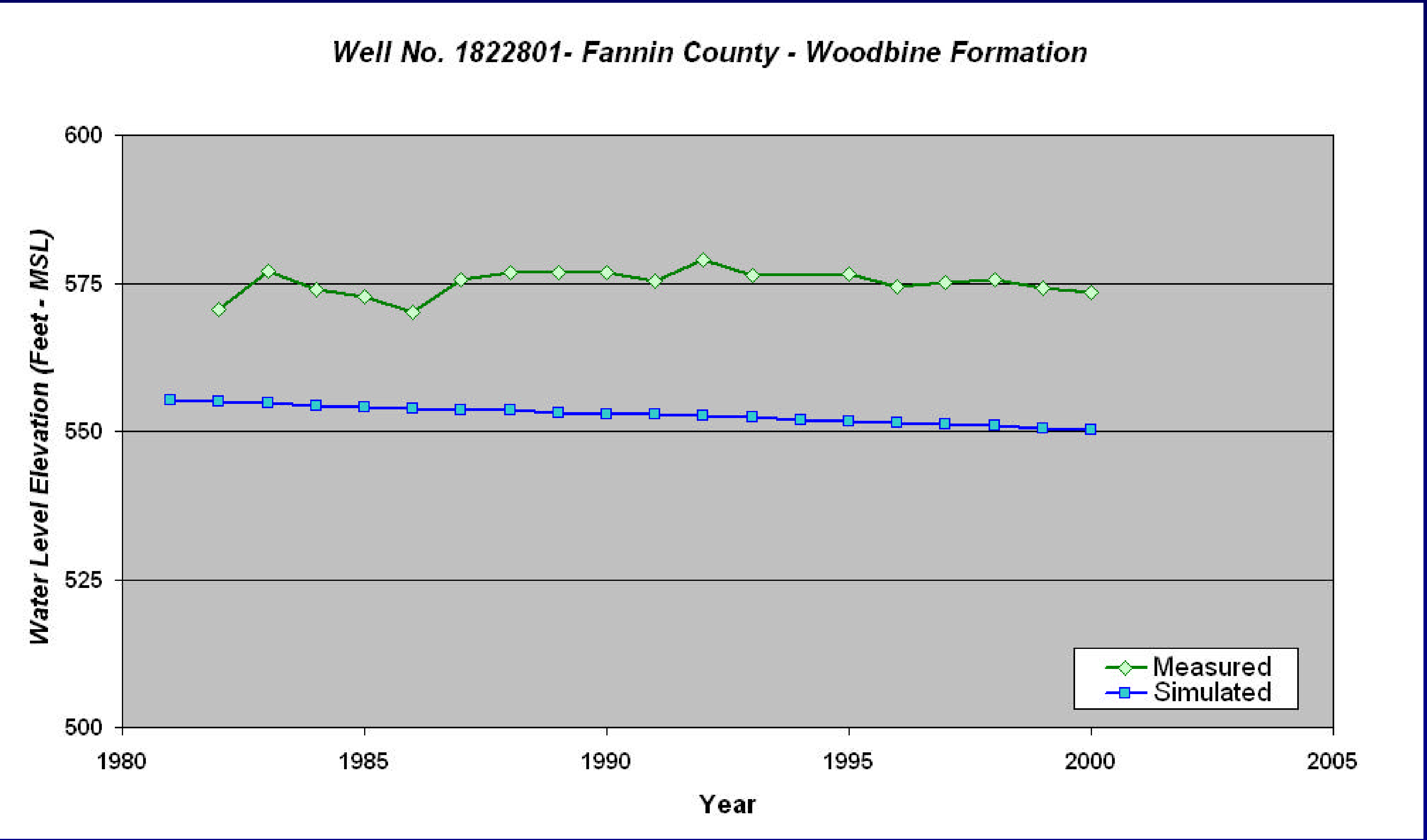
Aquifer	Mean Residual (ft)	Mean ABS Residual (ft)	RMS Residual (ft)	Total Measured Head Drop (ft)	RMS Percent of Measured Drop
Woodbine	16.8	62.9	79.8	836	9.5%
Paluxy	36.8	48.6	70.7	1,778	4.0%
Hensell	26.8	65.9	96.0	1,783	5.4%
Hosston	4.1	74.9	107.1	2,353	4.5%

** Total simulated inflow minus outflow is less than 0.01 percent*

Simulated vs. Measured Water Levels



Simulated vs. Measured Water Levels



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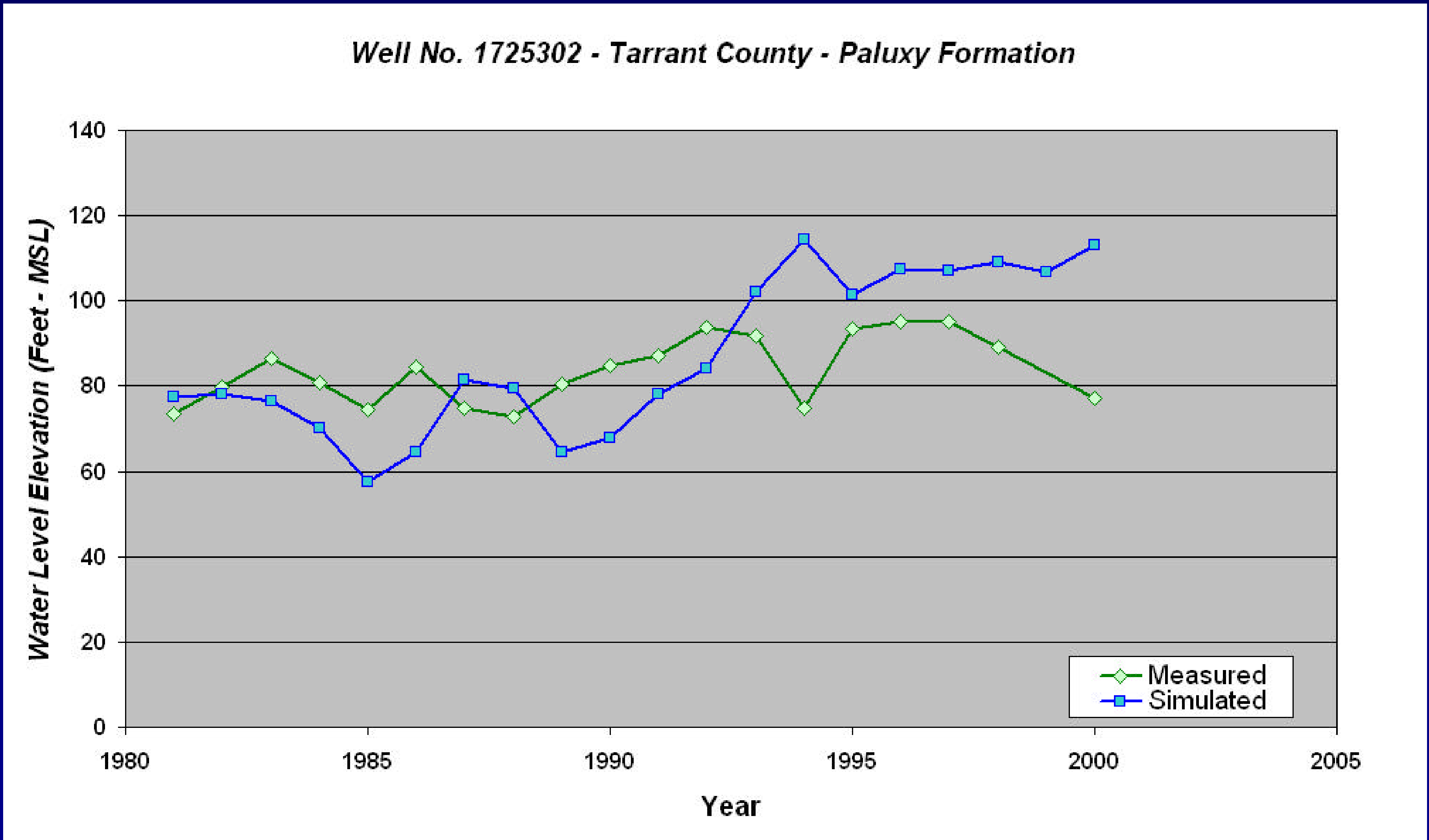

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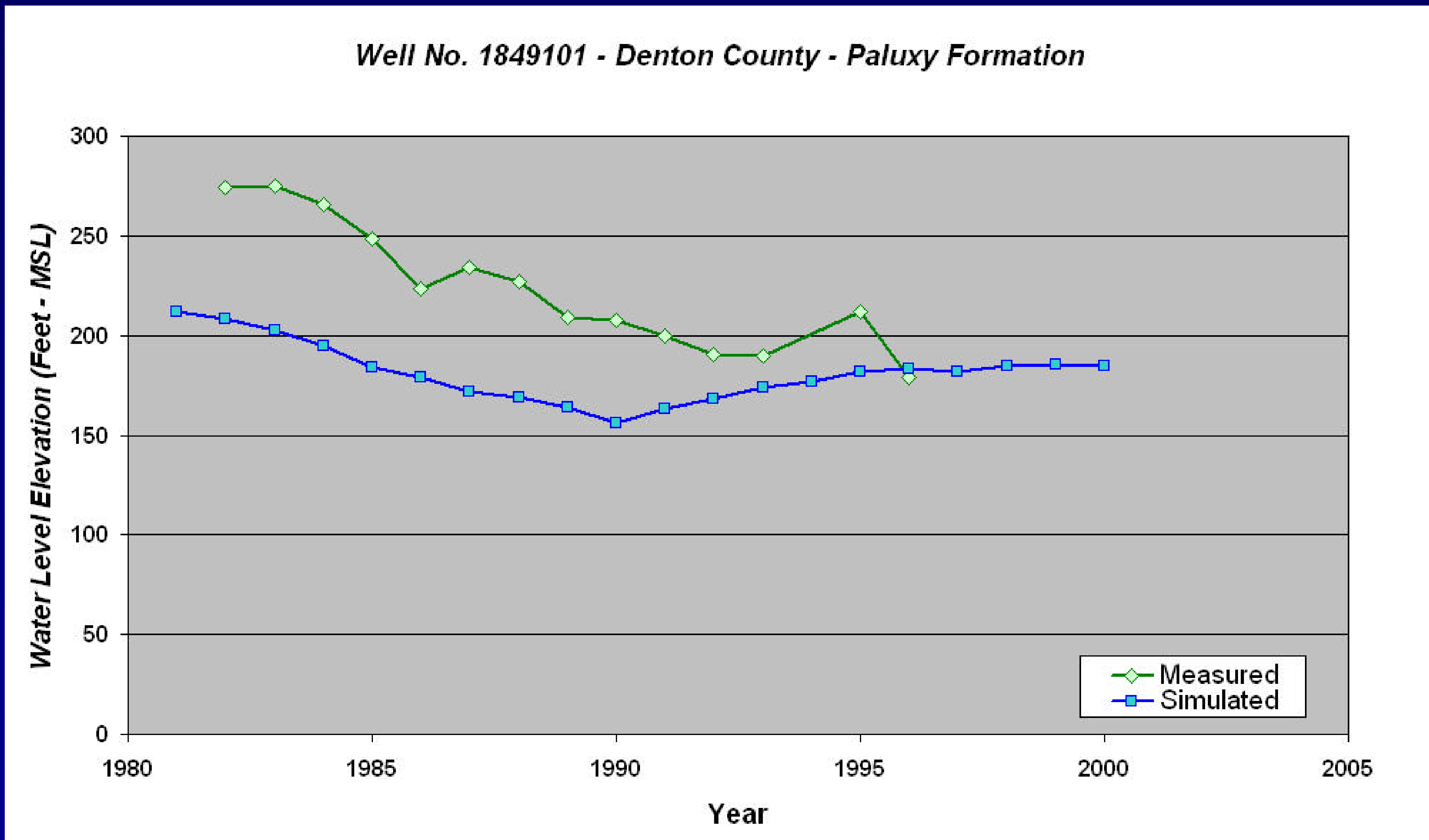

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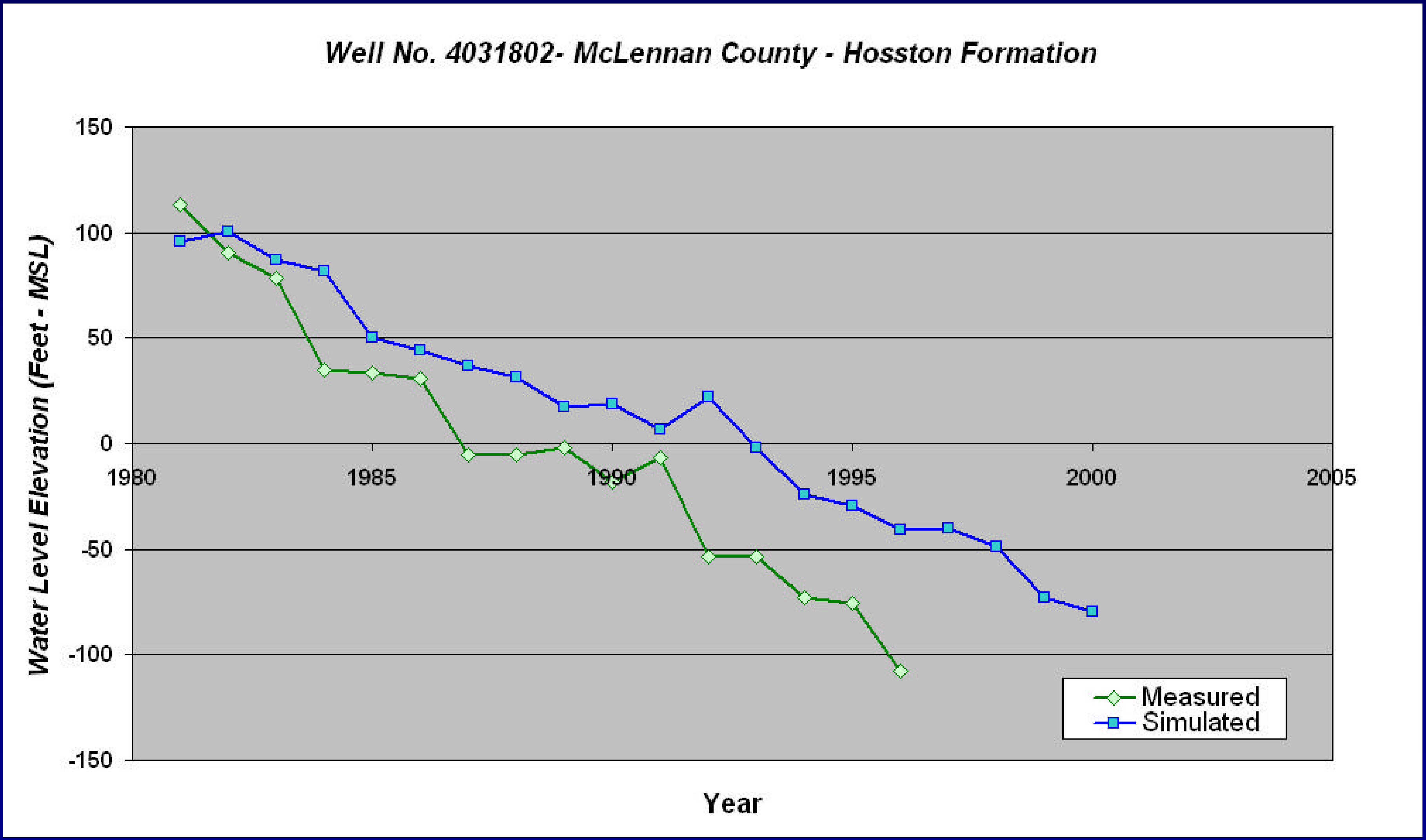
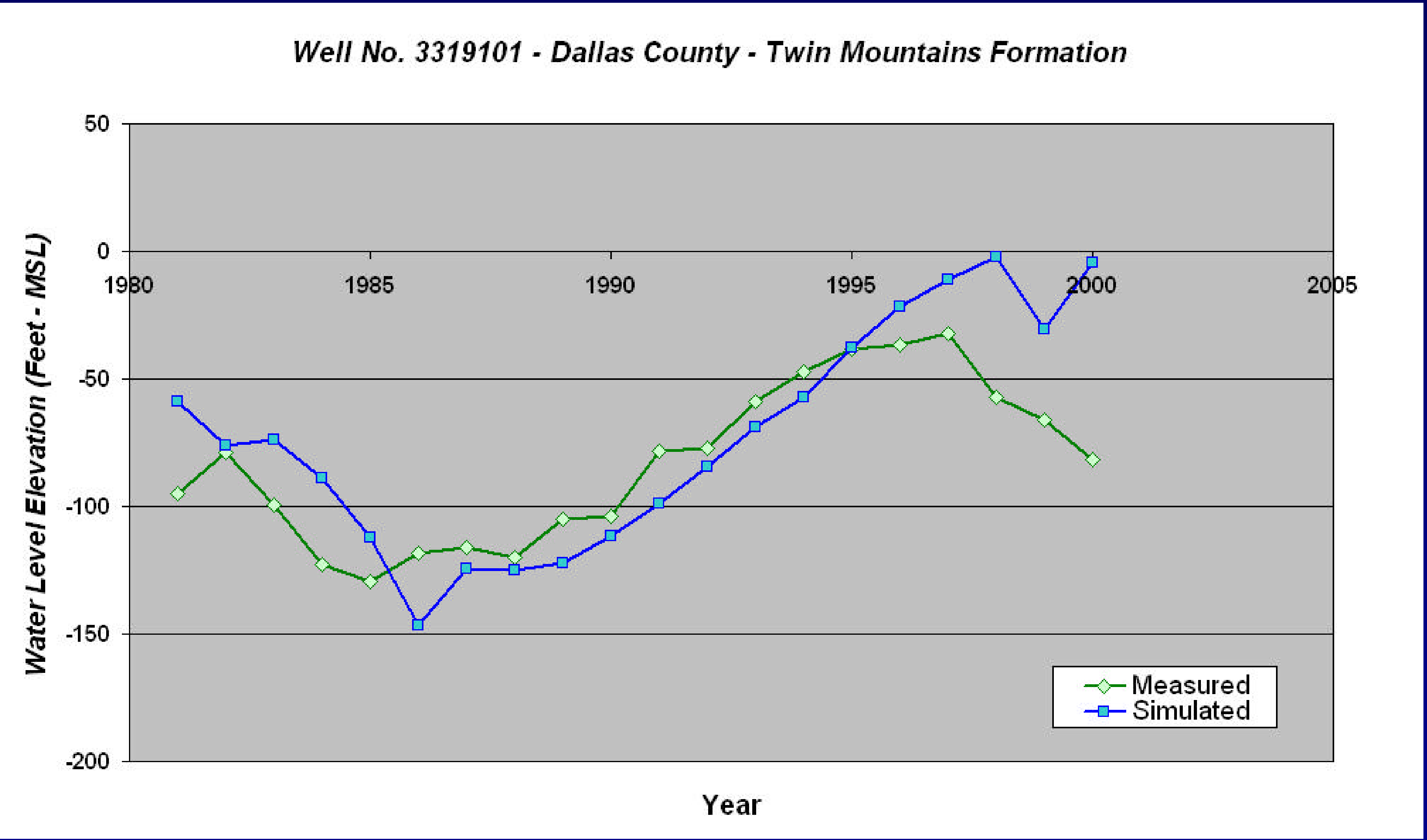
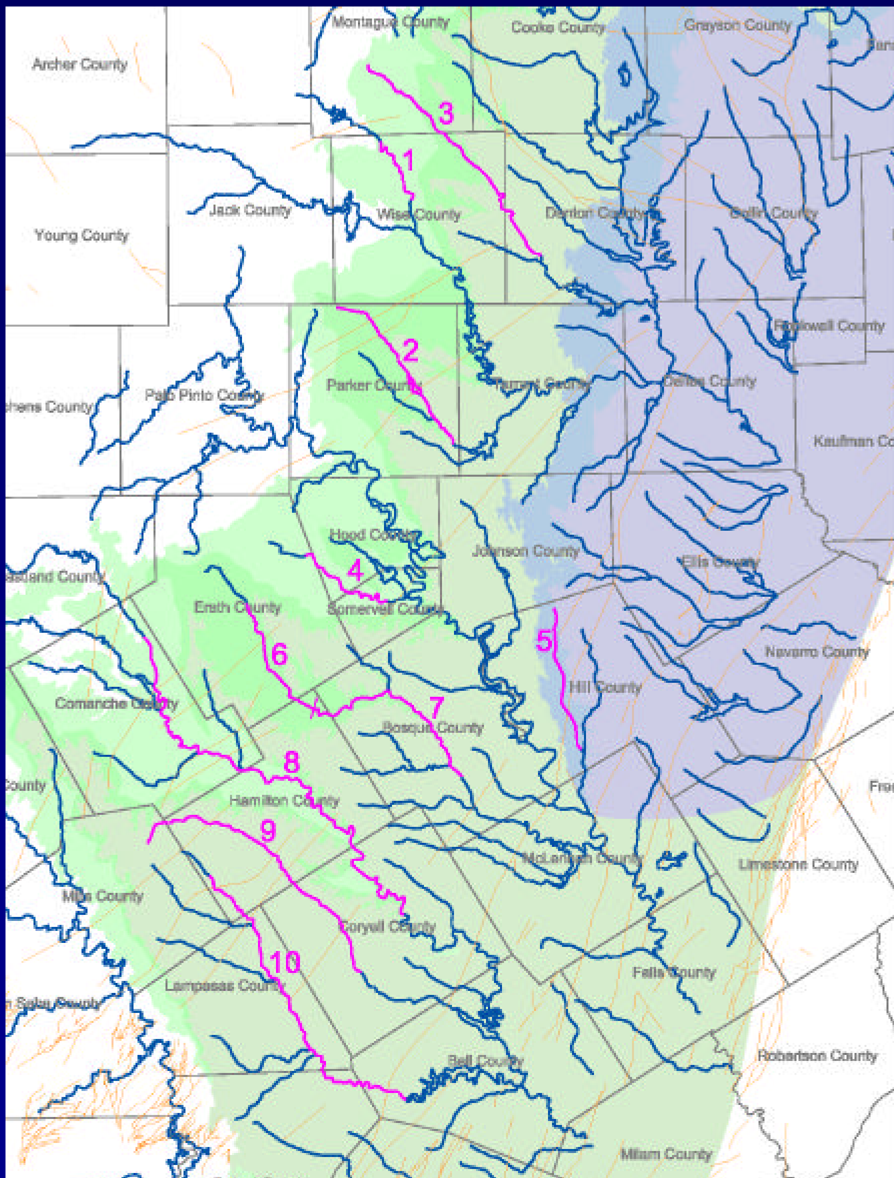


Simulated vs. Measured Water Levels

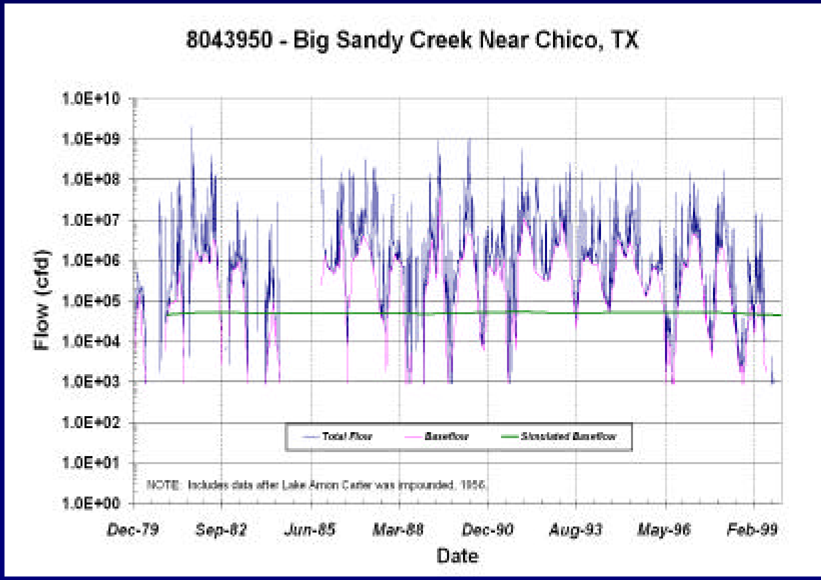


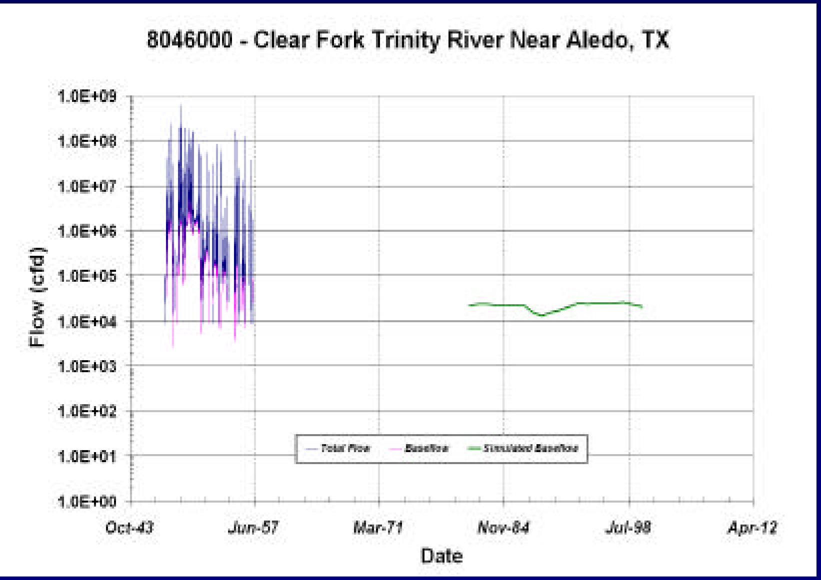
Streamflow Calibration Segments

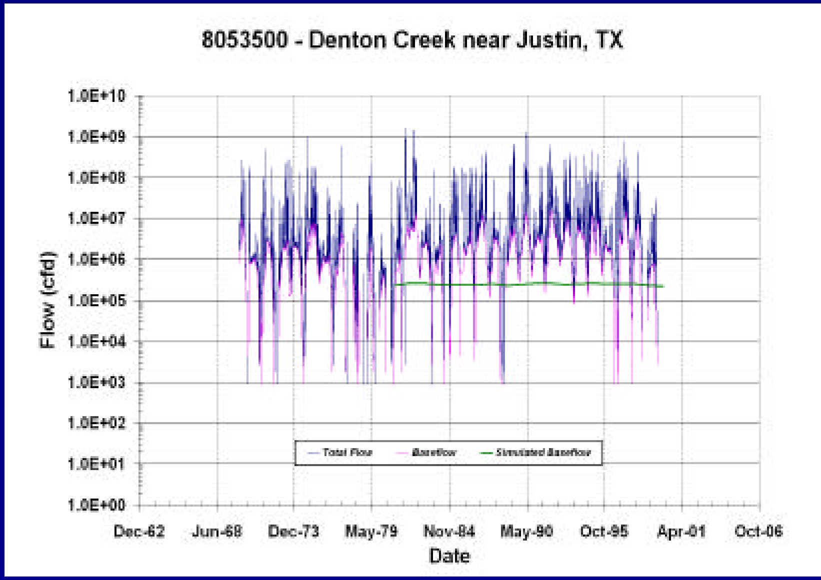


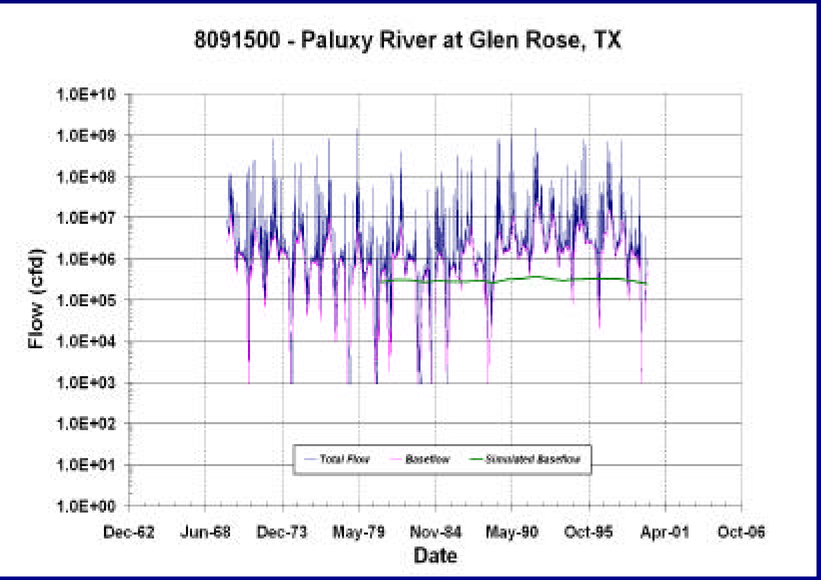
	Segment Description	*Median Flow (Ft^3/Day)*
1	BIG SANDY CREEK	149,472
2	TRINITY RIVER	80,352
3	DENTON CREEK	441,504
4	PALUXY RIVER	812,160
5	AQUILLA CREEK	108,000
6	NORTH BOSQUE RIVER	248,832
7	NORTH BOSQUE RIVER	907,200
8	LEON RIVER	492,480
9	COWHOUSE CREEK	210,816
10	LAMPASAS RIVER	2,160,000

Stream Hydrographs

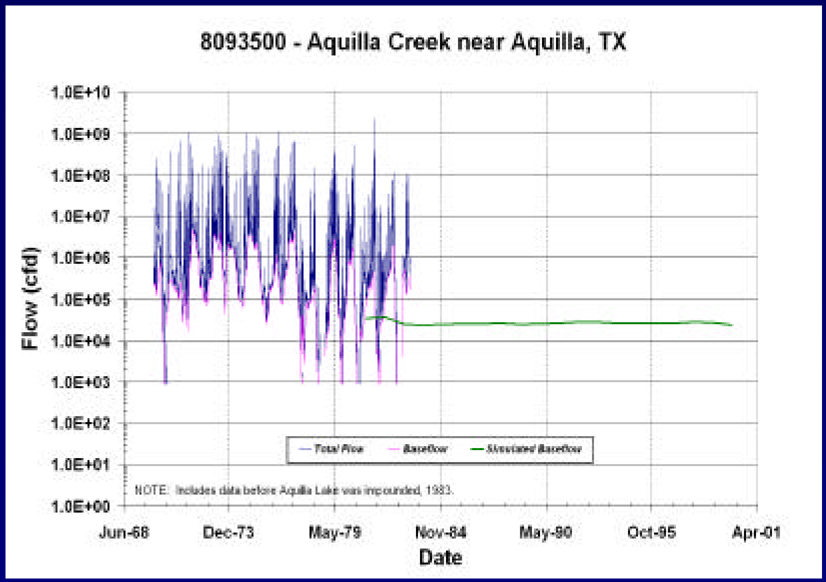


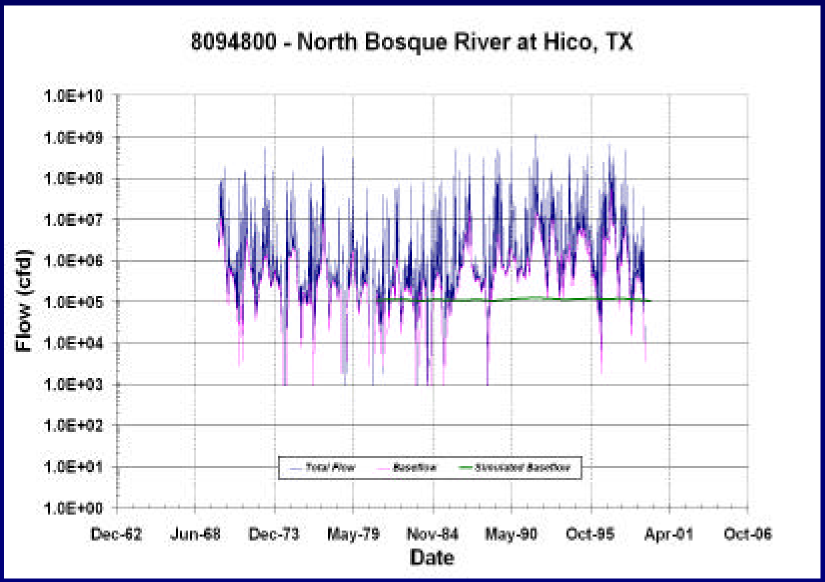


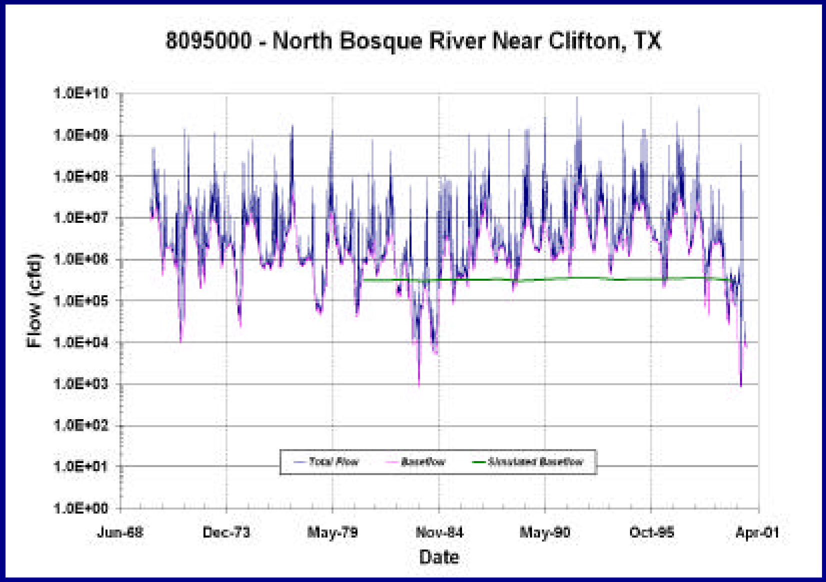


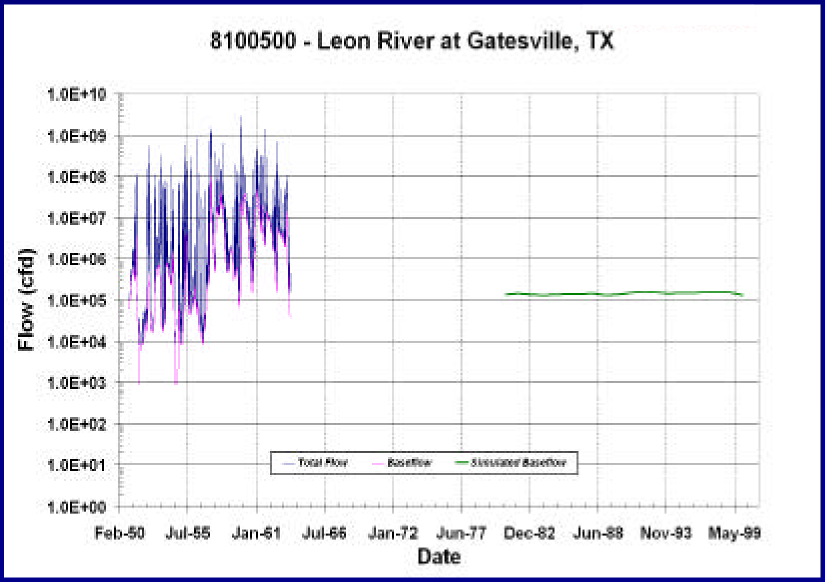


Stream Hydrographs Cont.

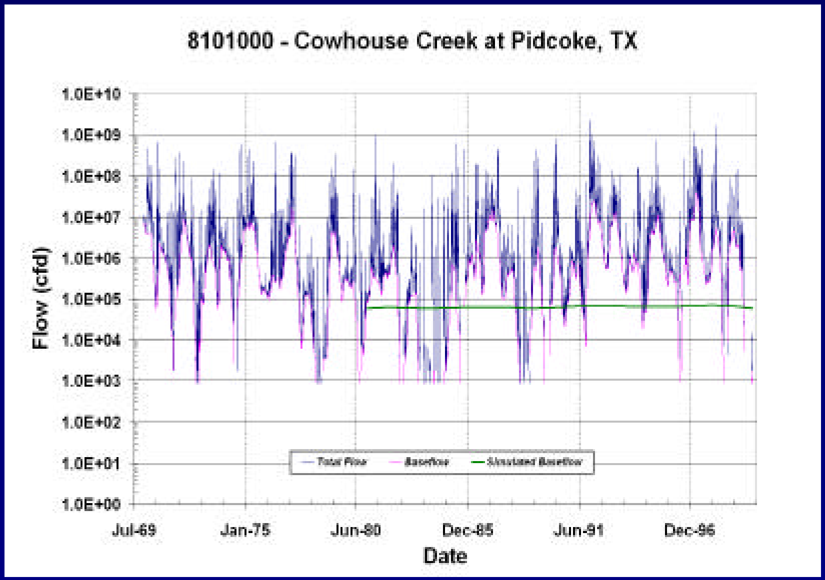


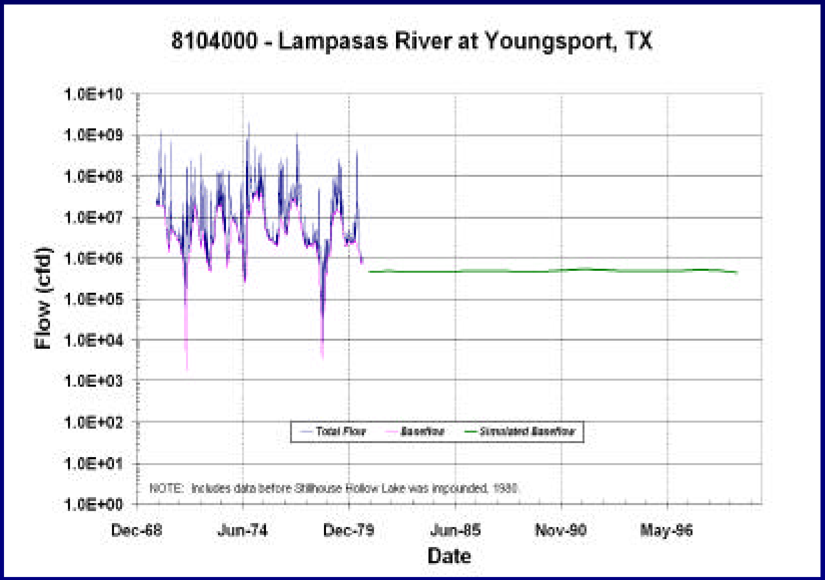




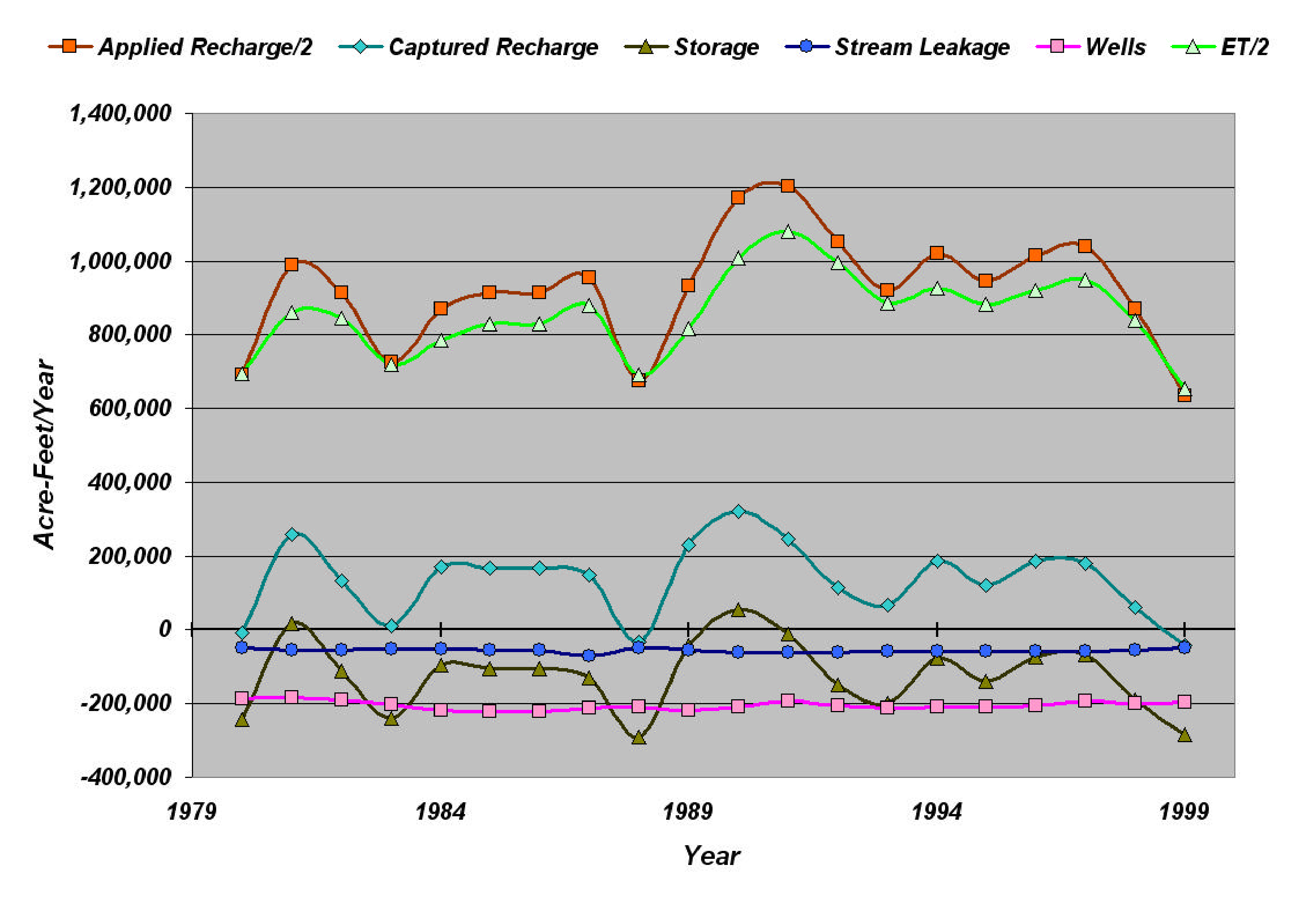


Stream Hydrographs Cont.

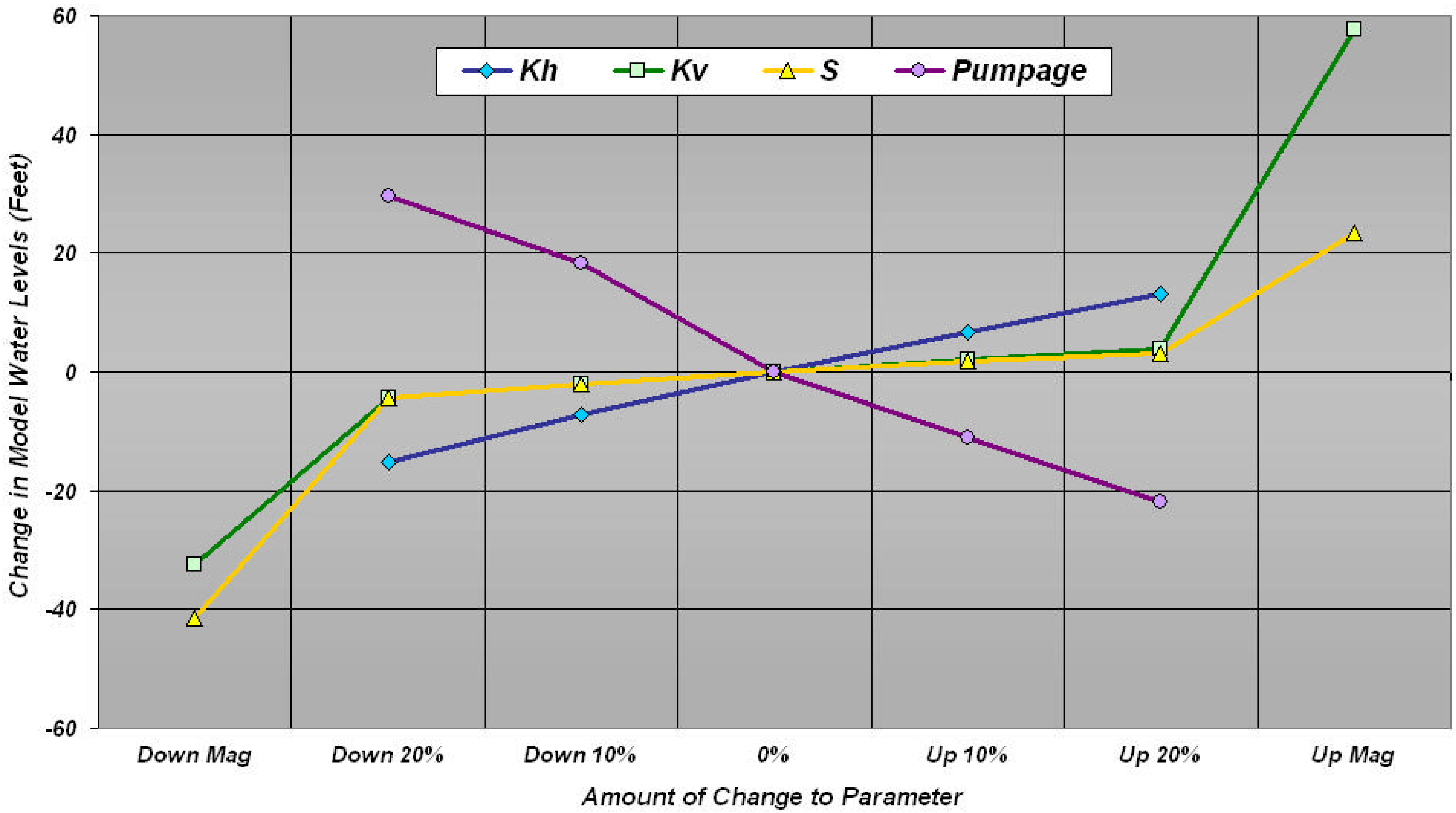




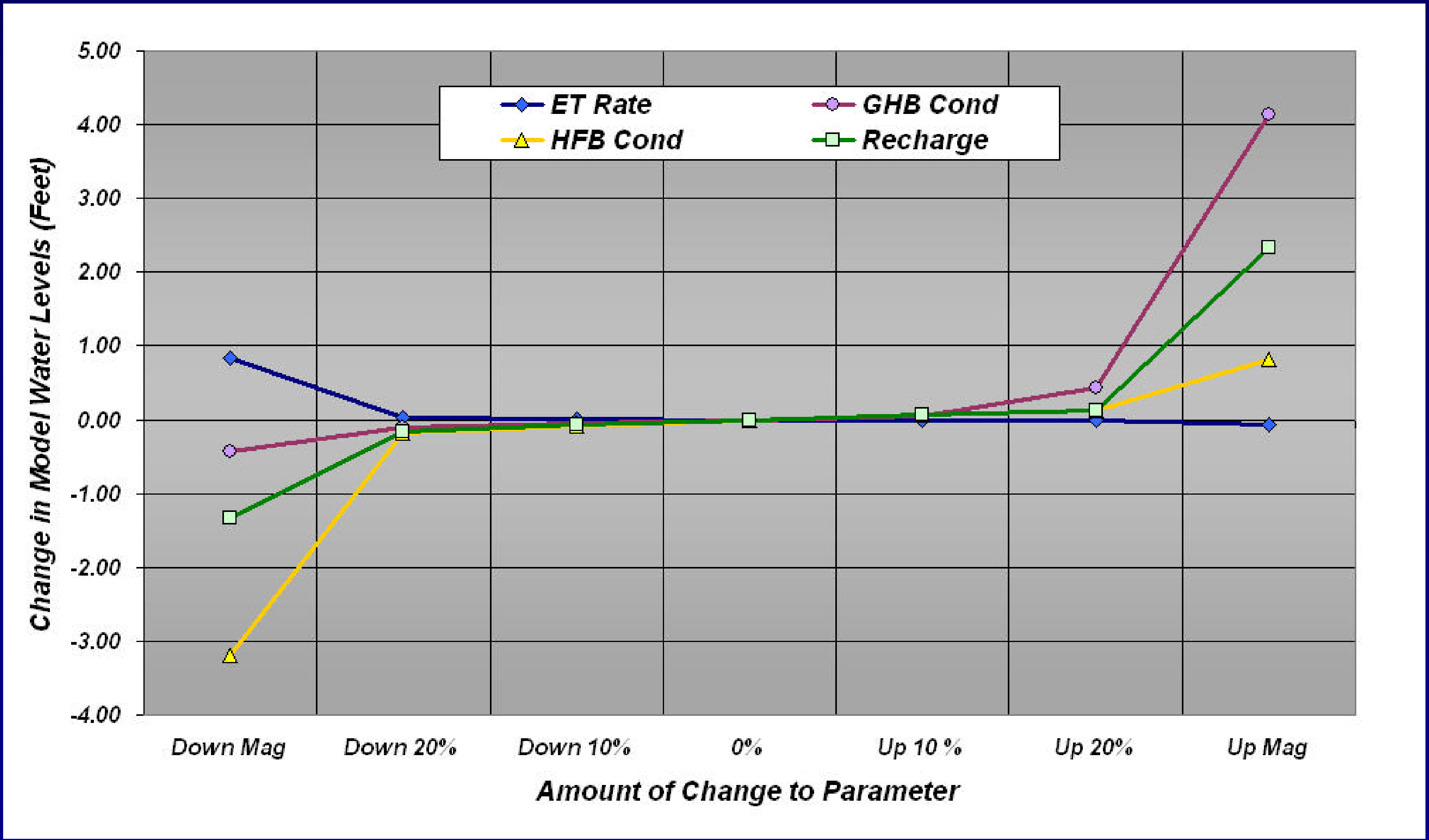
Model Water Budget (1980 – 1999)



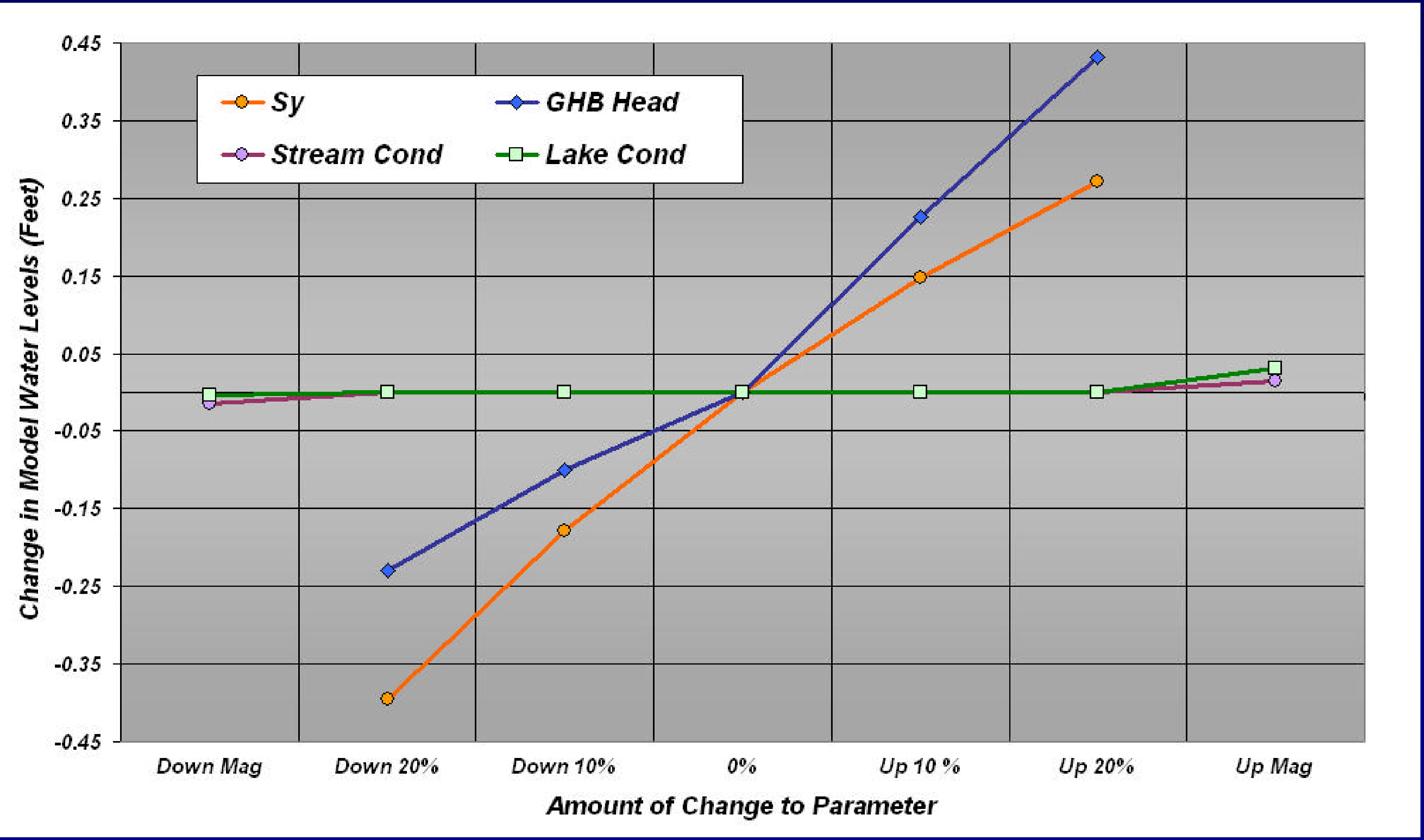
Model Sensitivity



Model Sensitivity Cont.



Model Sensitivity Cont.

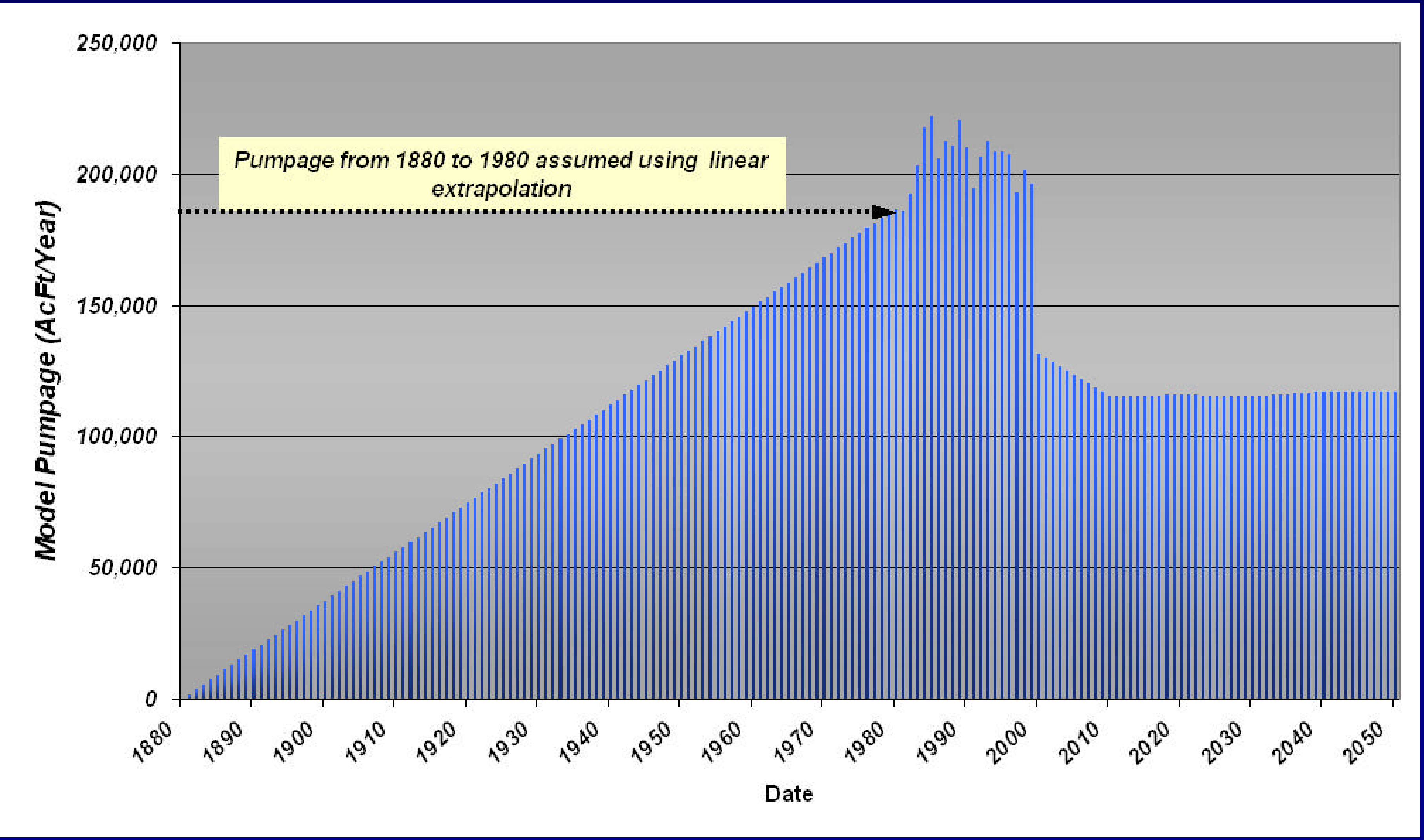


Predictive Simulations 2000 - 2050

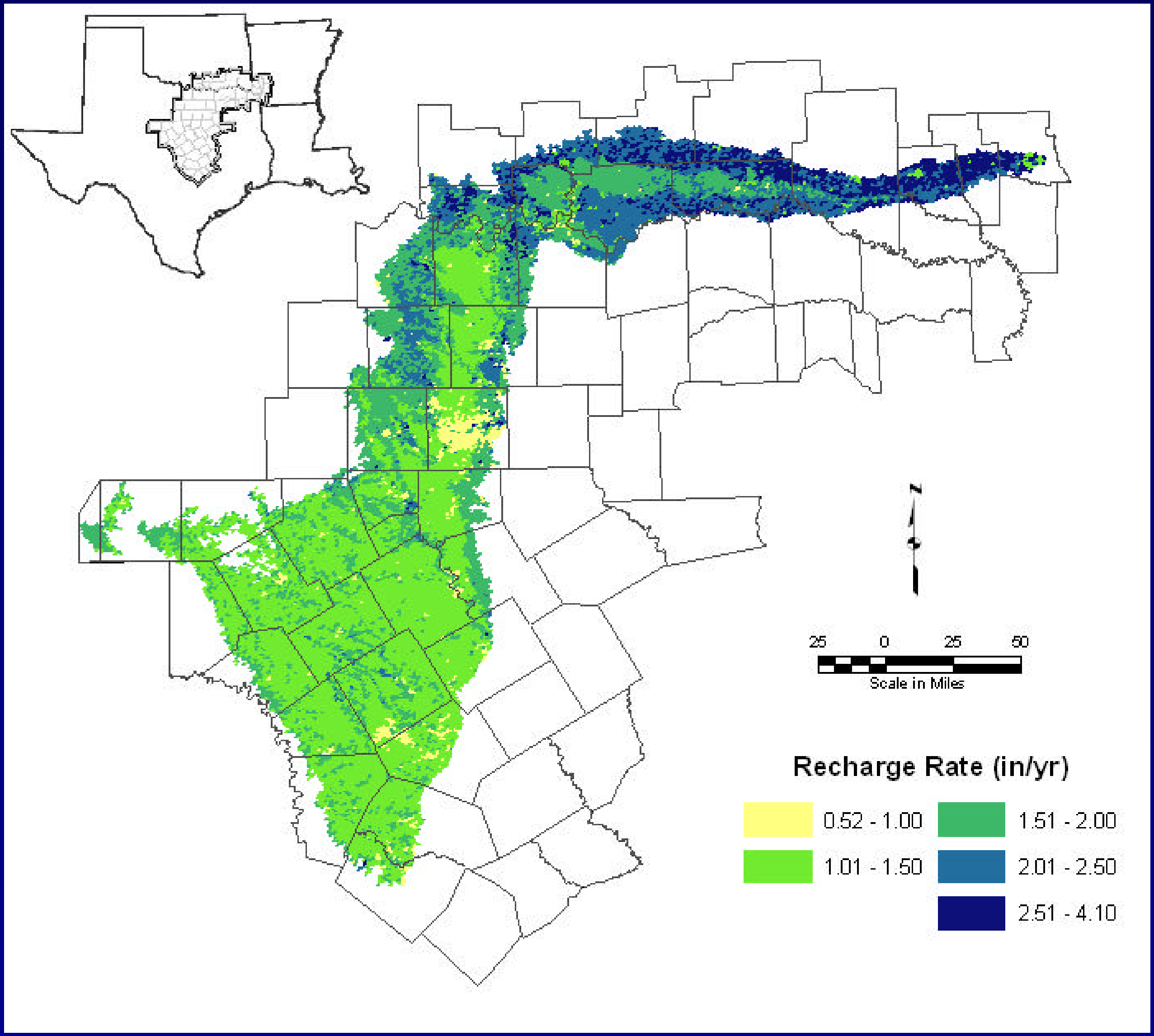
Predictive Simulations

- Pumpage from Regional Water Planning Groups
- Two different recharge assumptions
  - Average recharge
  - Each decade ending in drought of record recharge

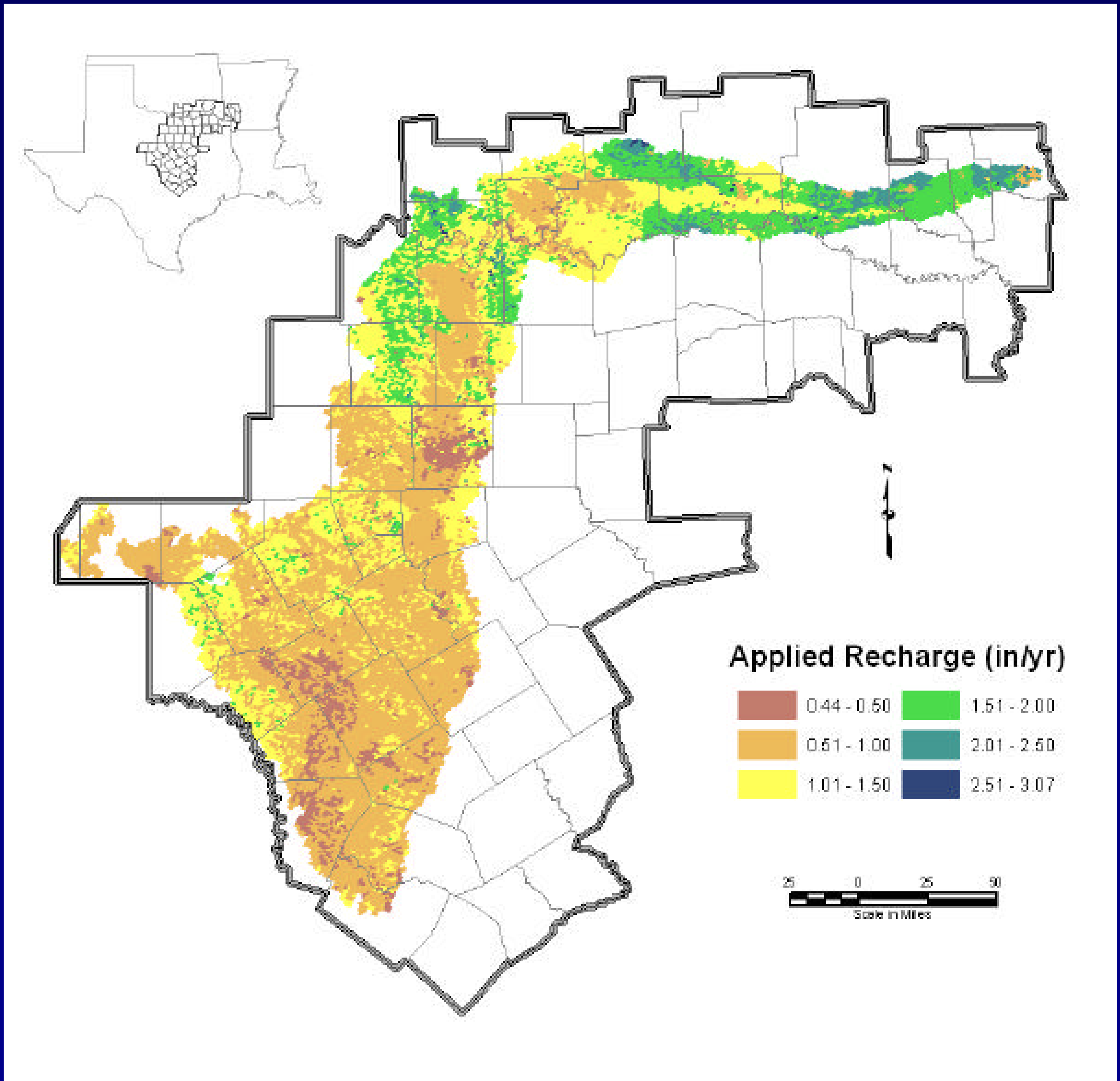
Total Model Pumpage



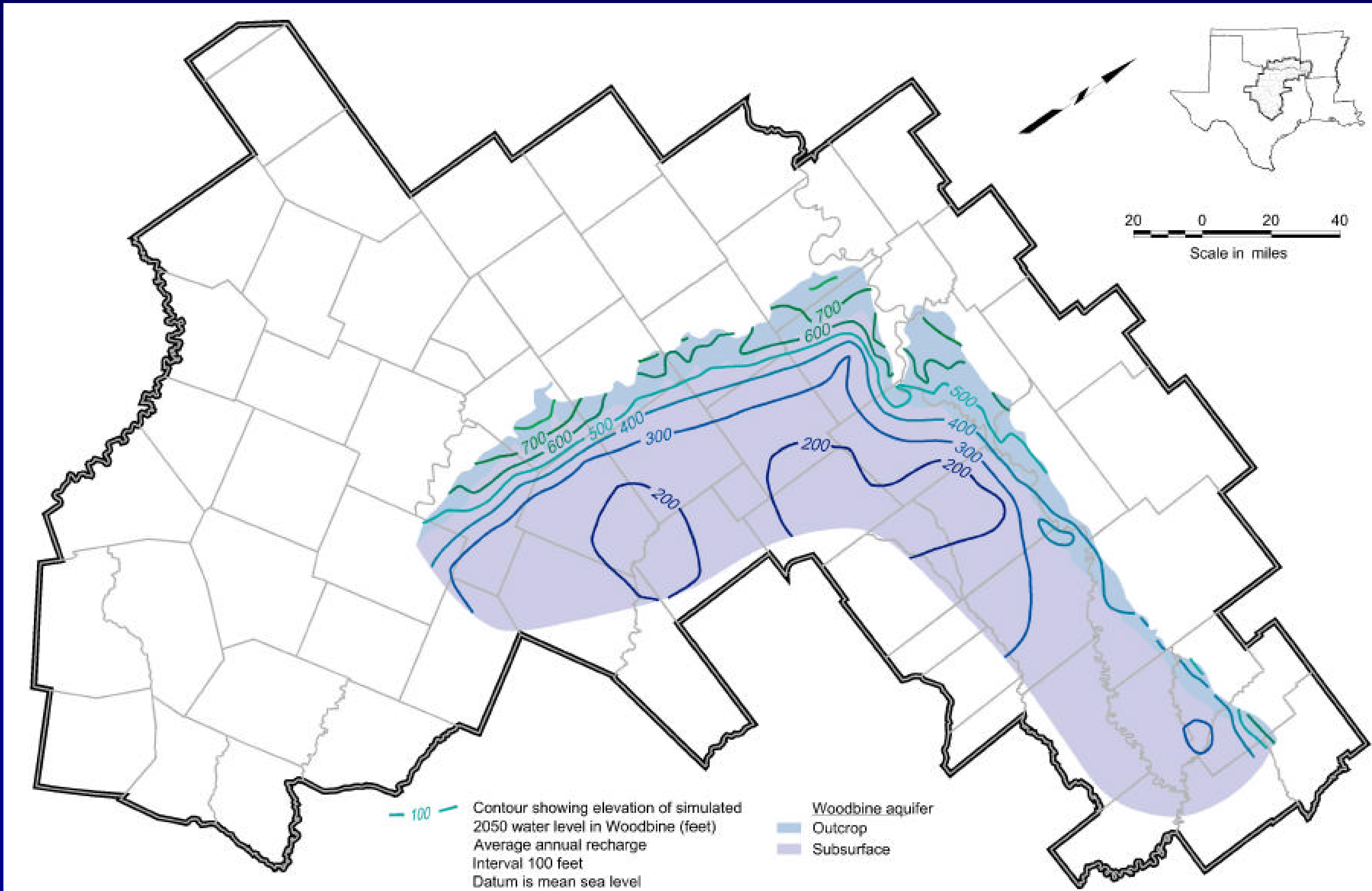
Average Recharge Rate



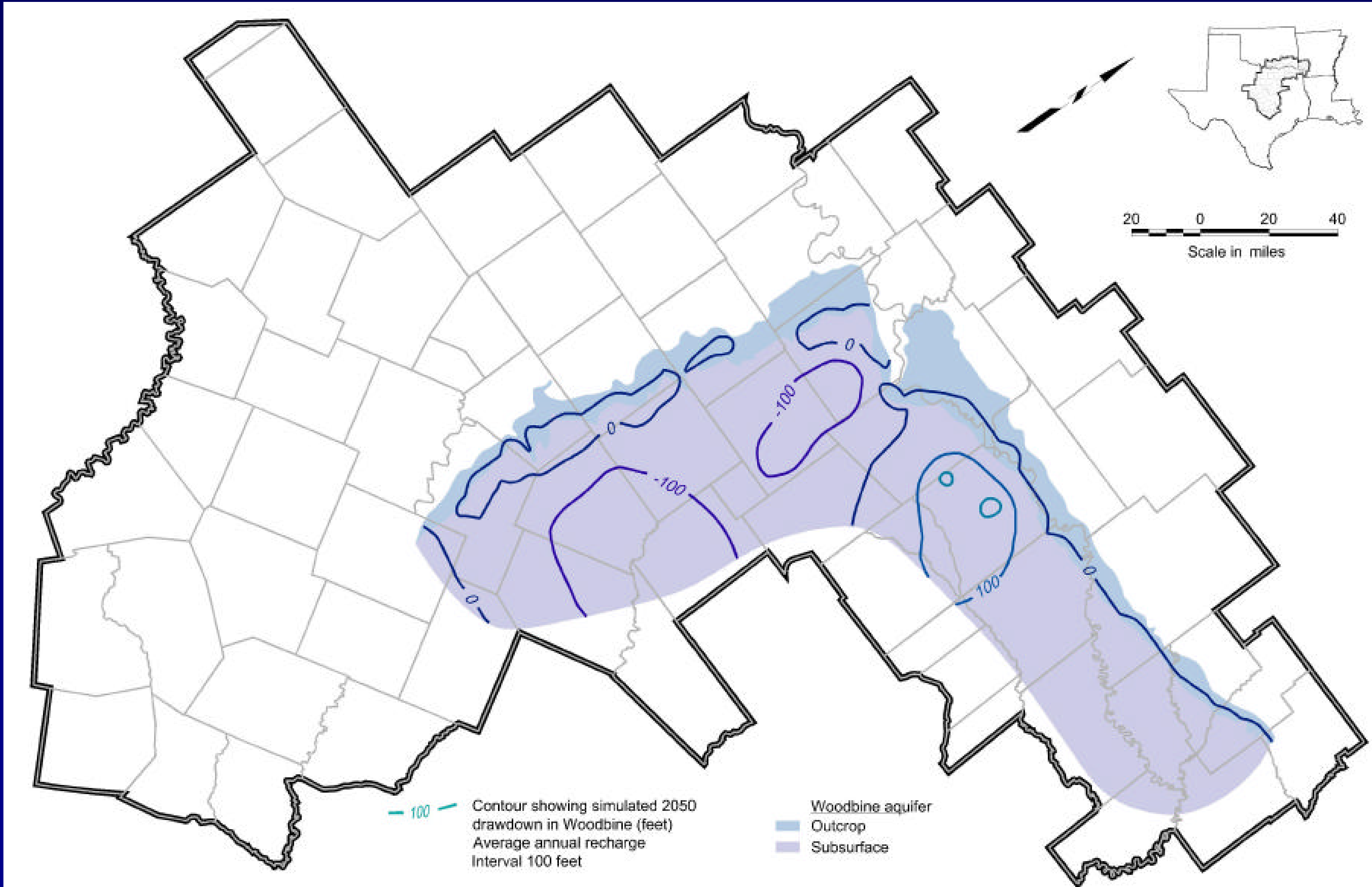
Drought of Record Recharge



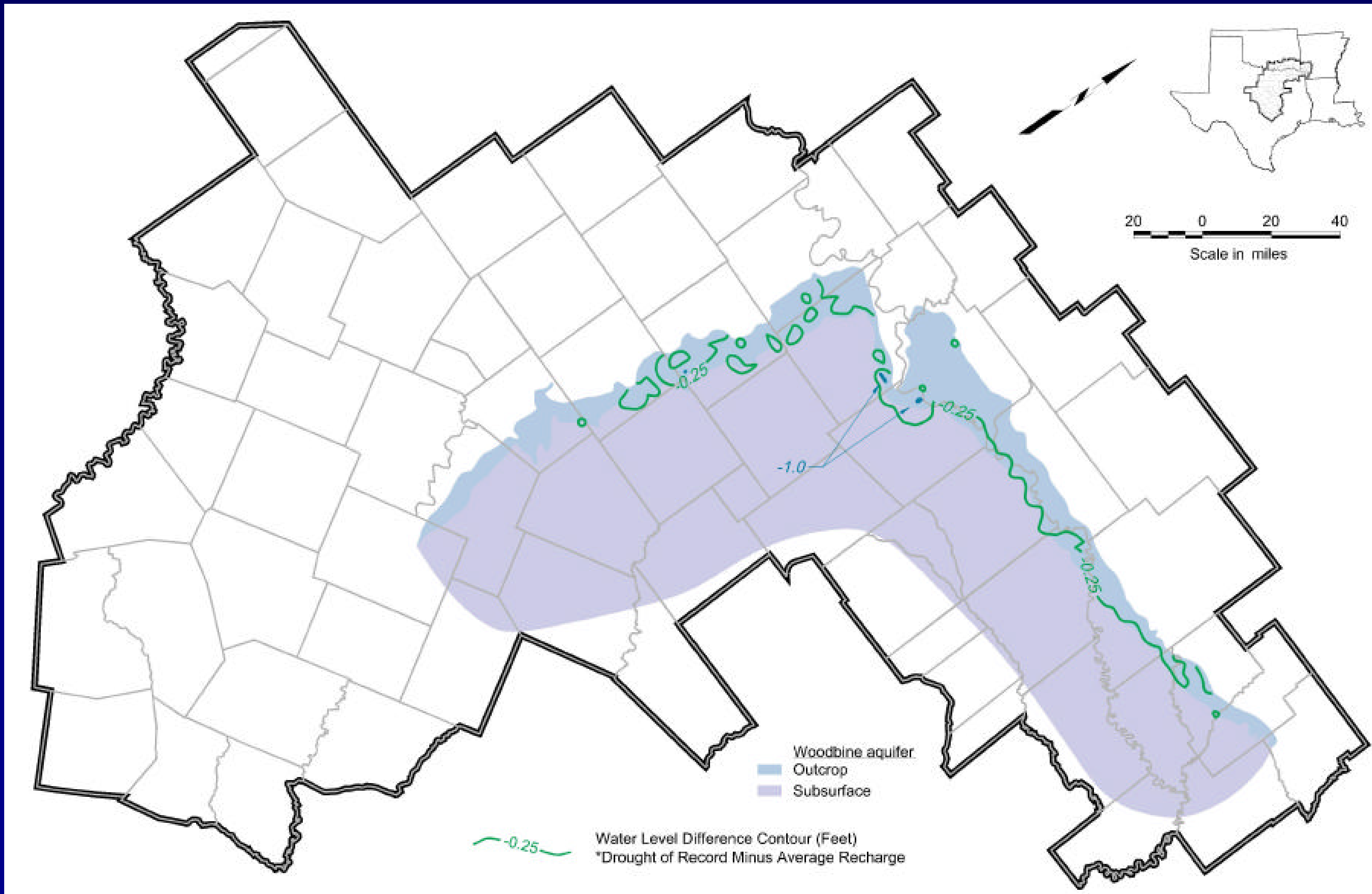
WL Woodbine – Avg. Recharge - 2050



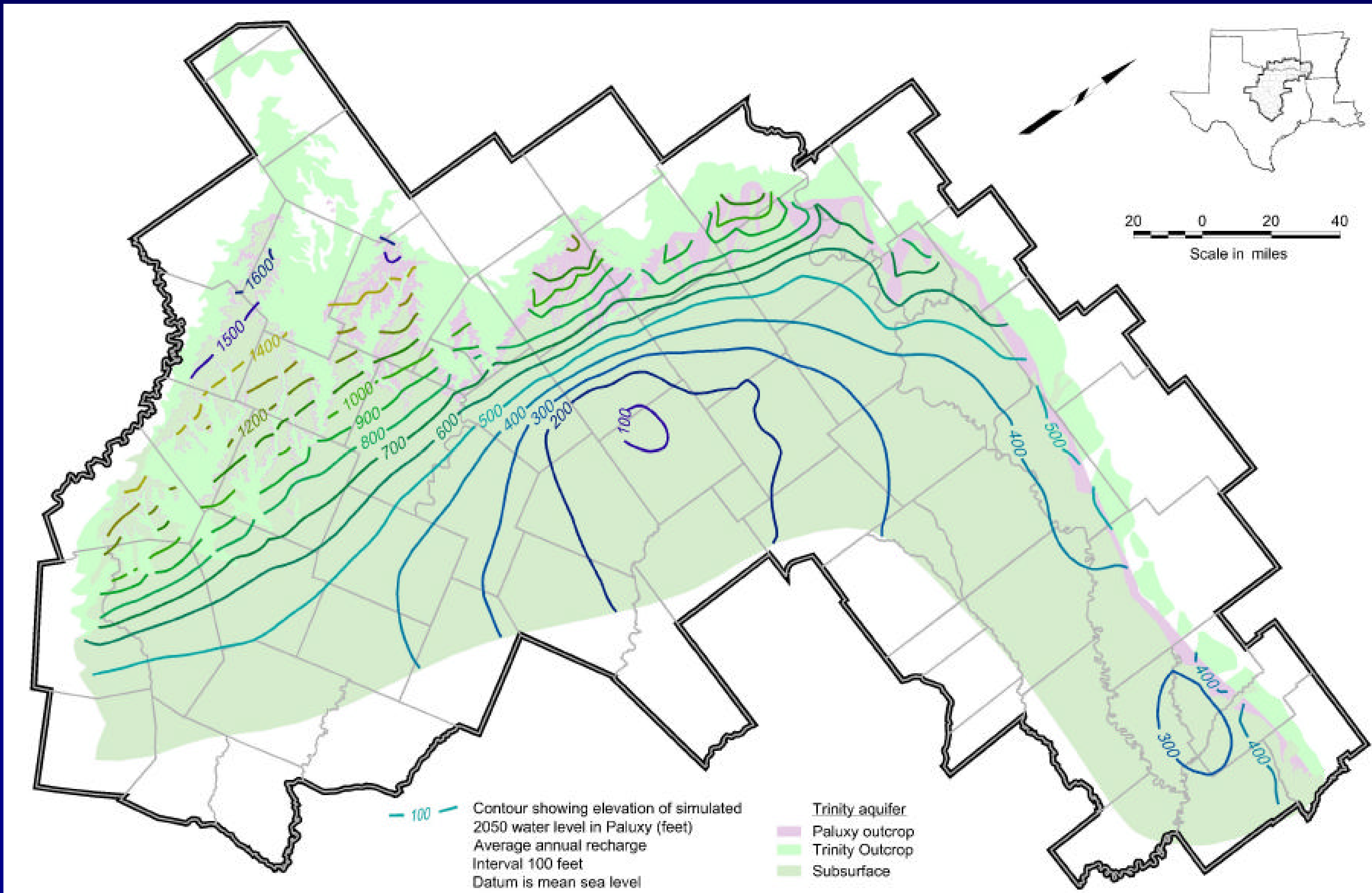
DD Woodbine – Avg. Recharge – 2050



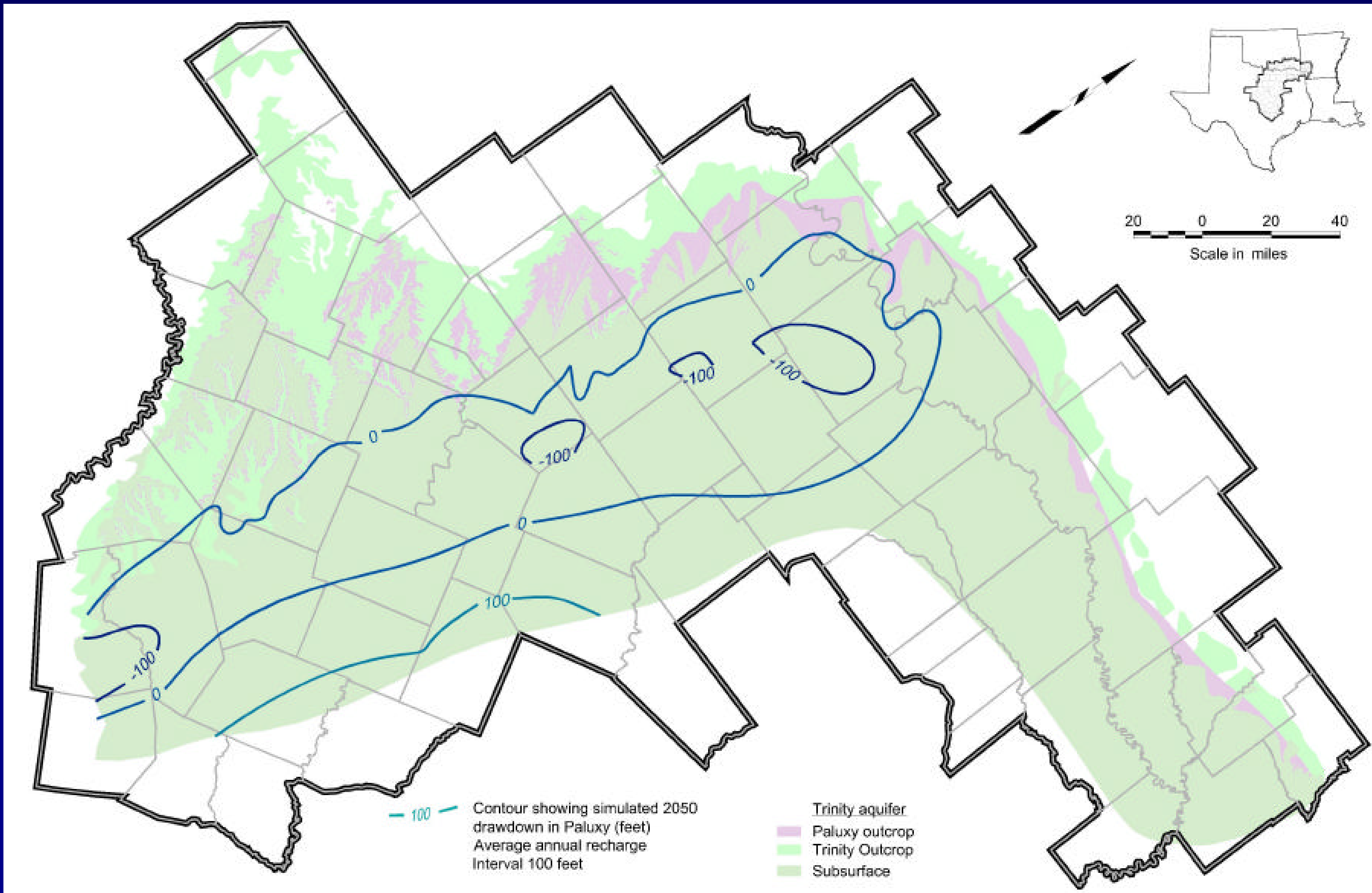
Woodbine – WL Difference – 2050 (Drought of Record vs. Avg. Recharge)



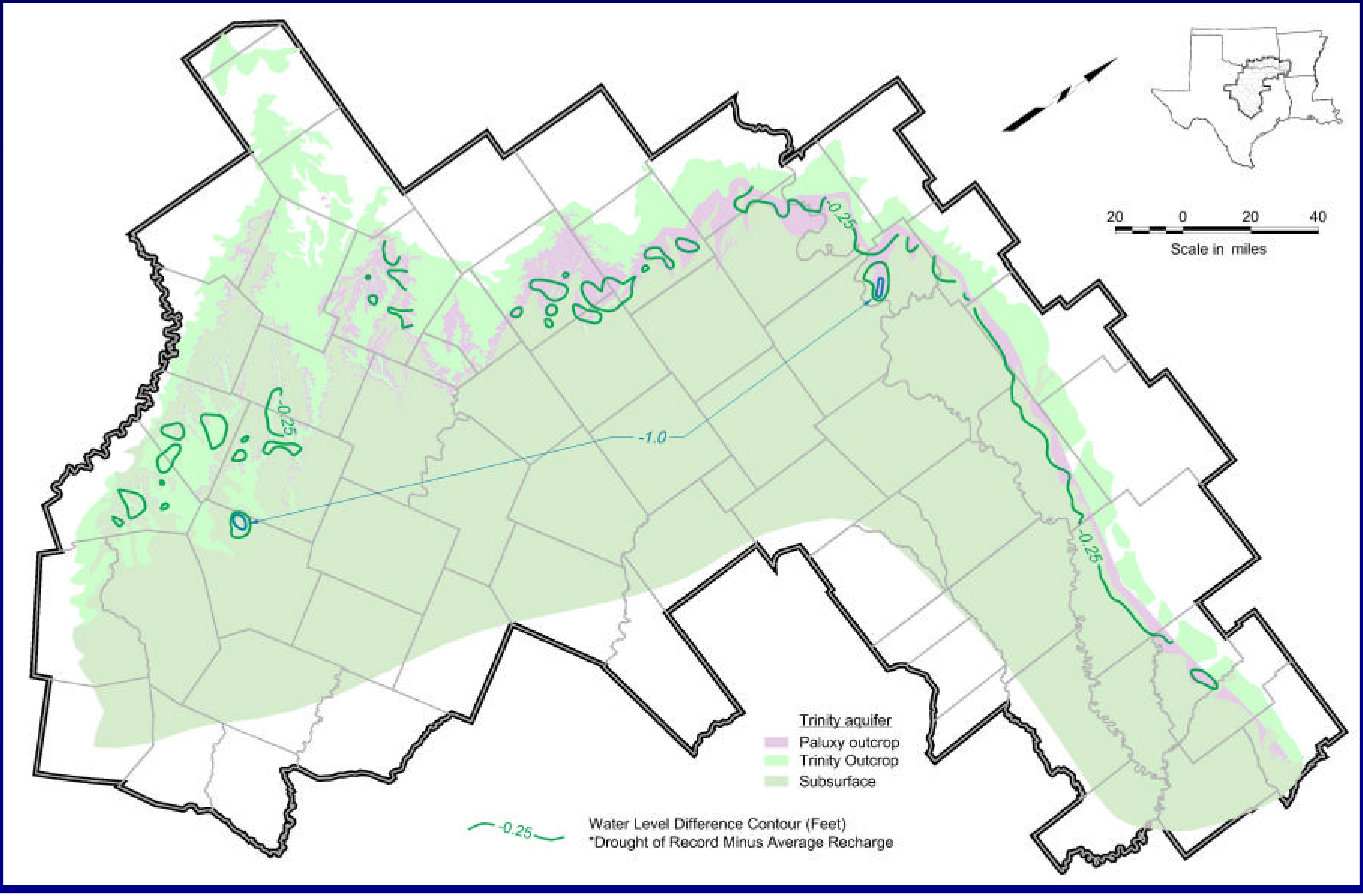
WL Paluxy – Avg. Recharge – 2050



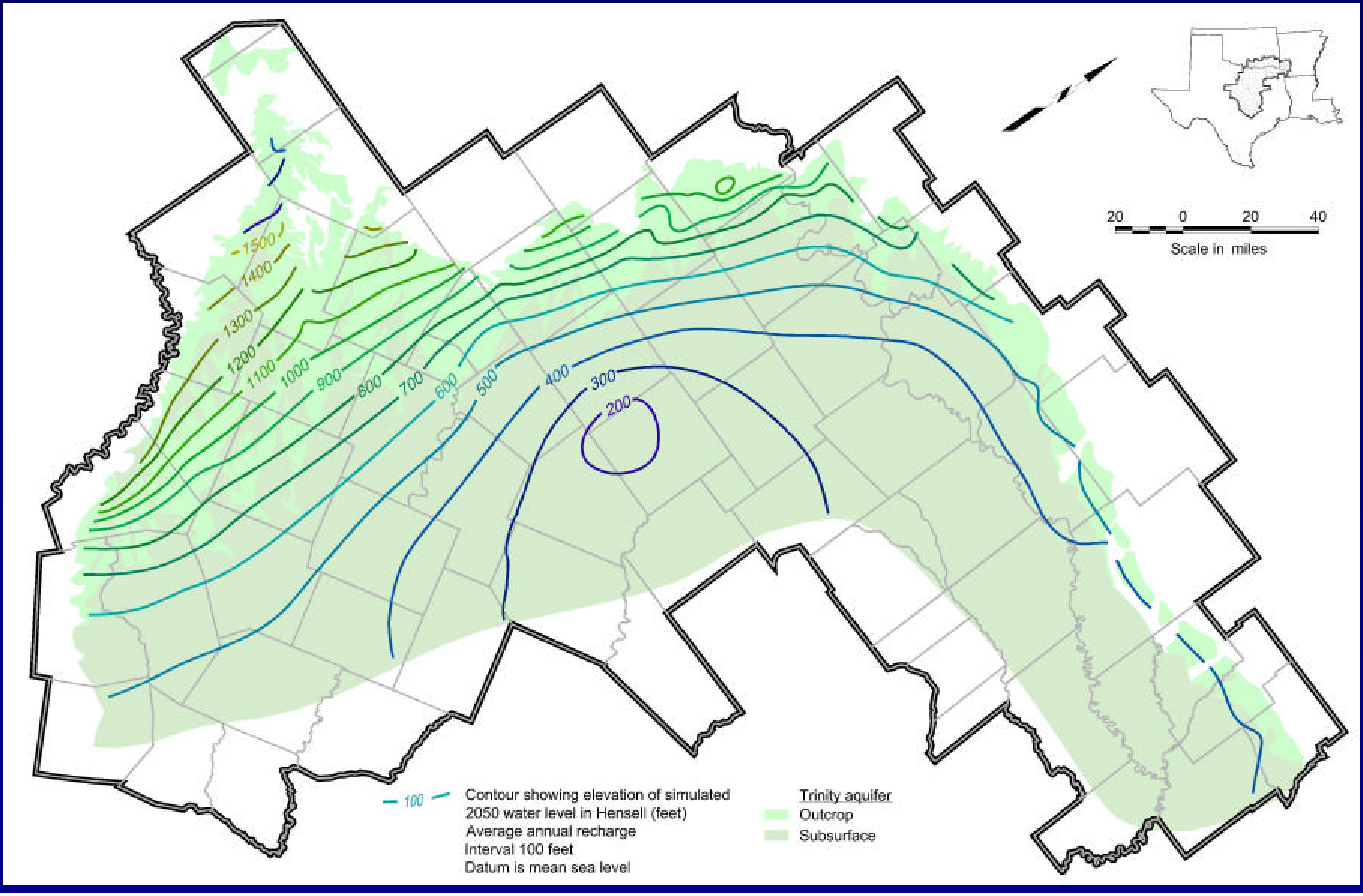
DD Paluxy – Avg. Recharge – 2050



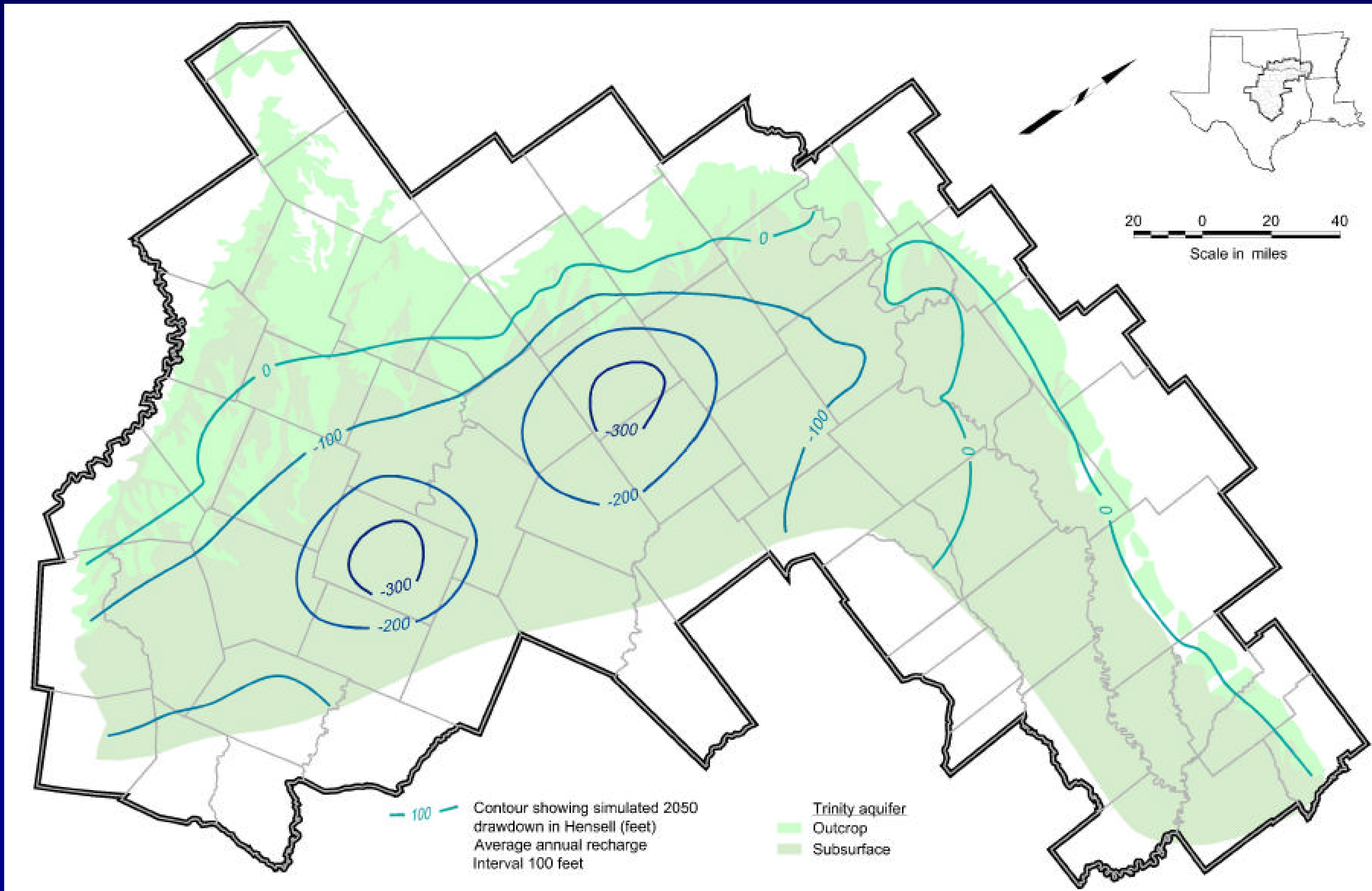
Paluxy – WL Difference – 2050 (Drought of Record vs. Avg. Recharge)



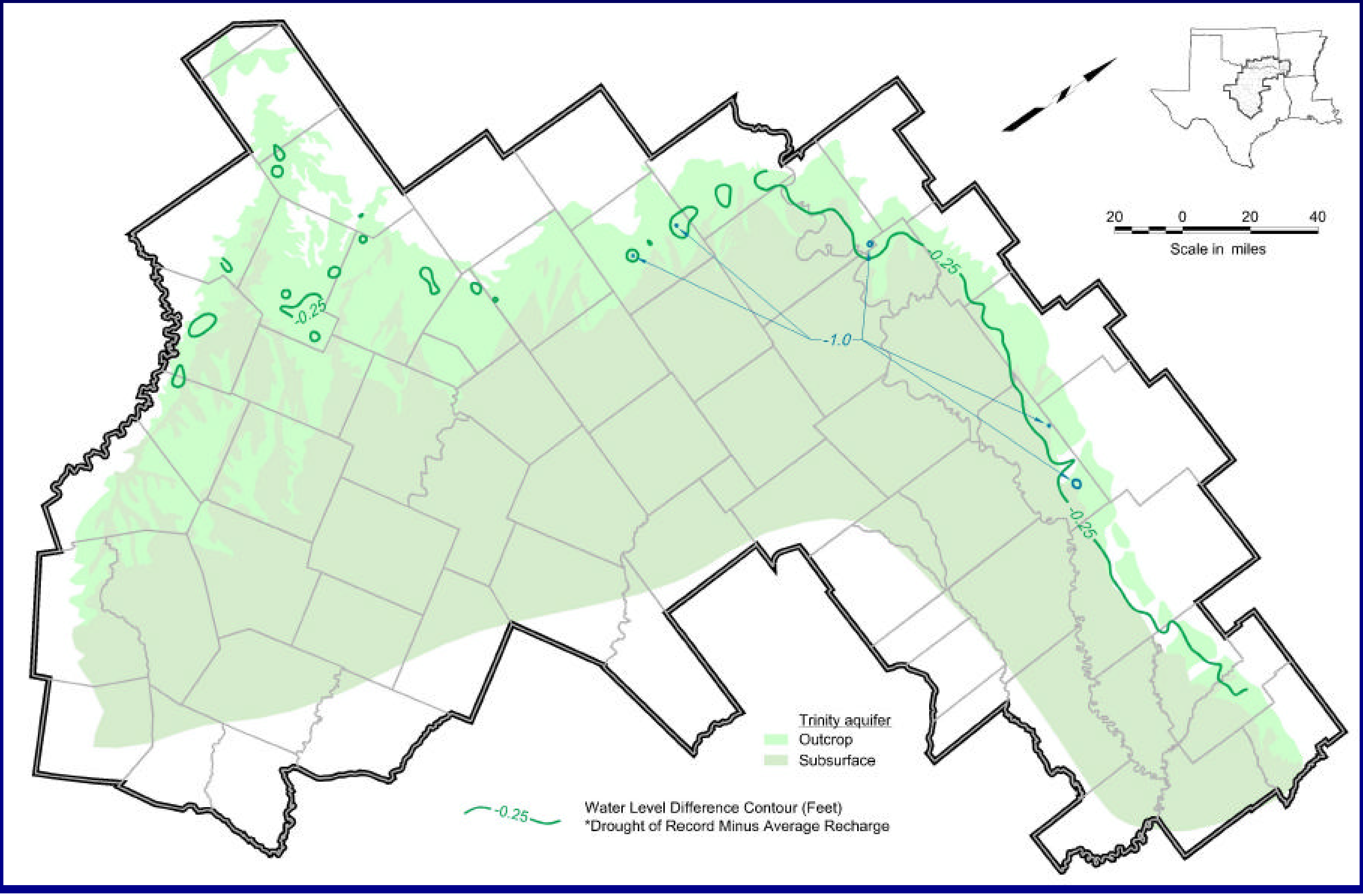
WL Hensell – Avg. Recharge – 2050



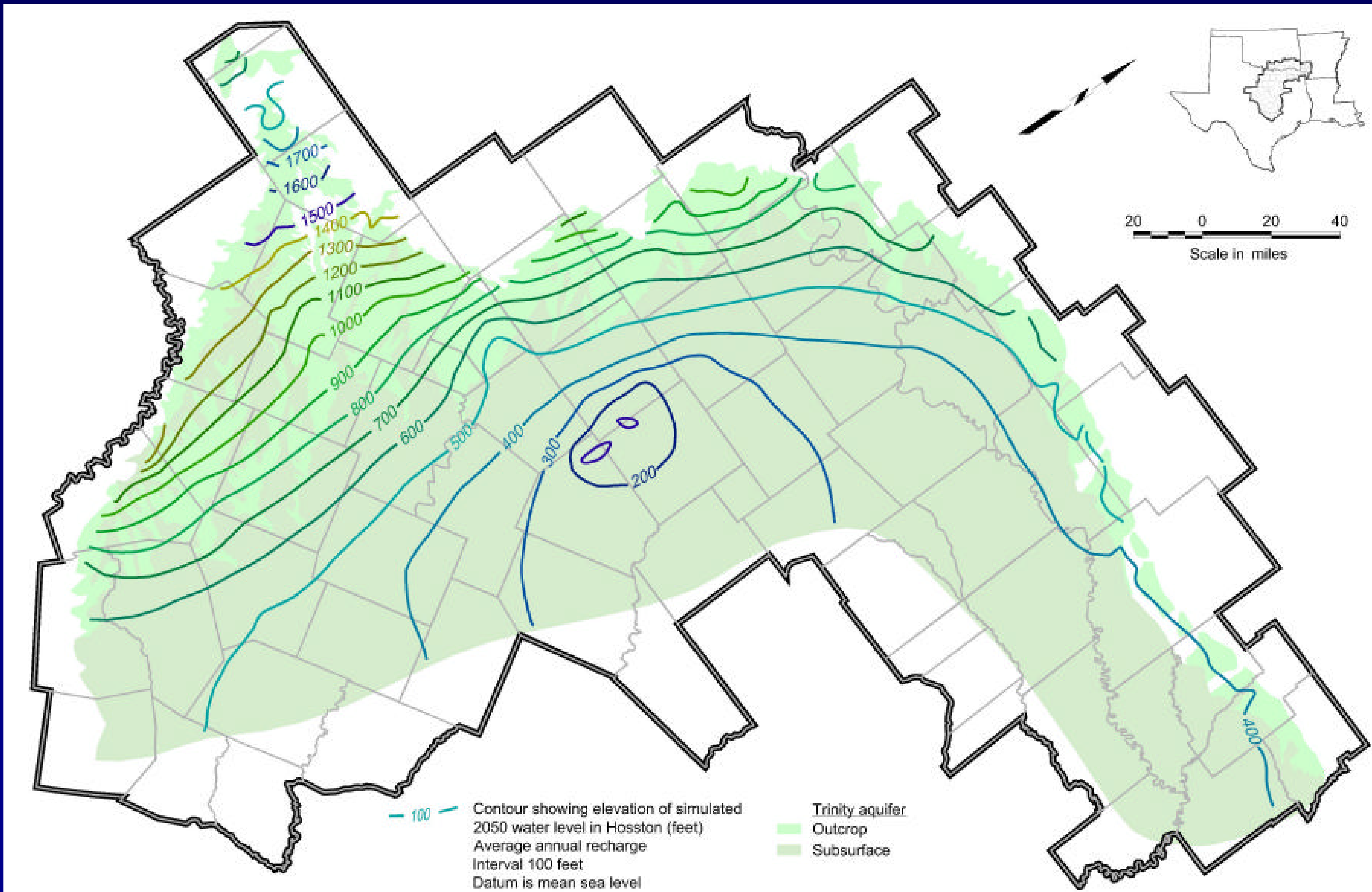
DD Hensell – Avg. Recharge – 2050



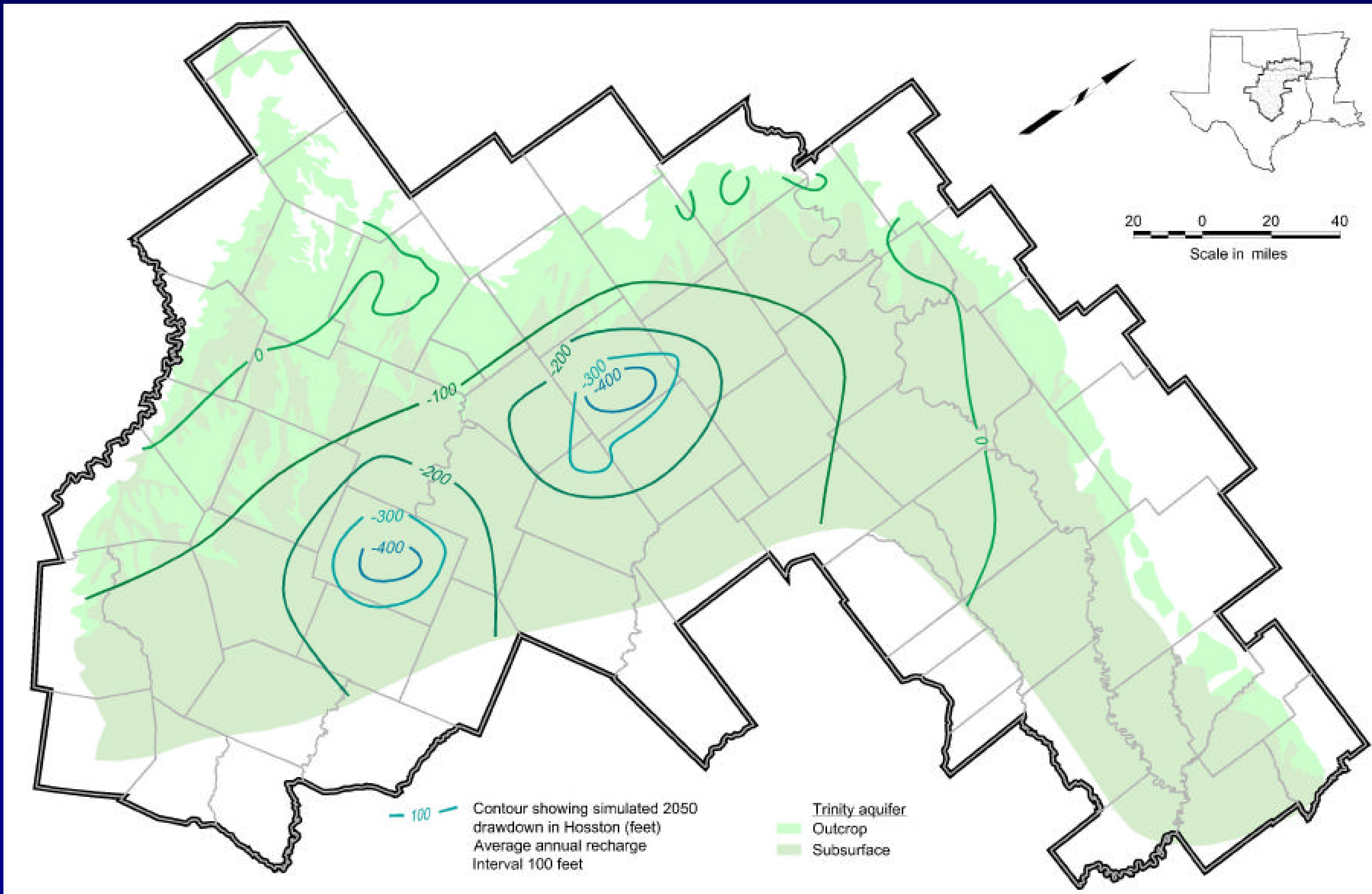
Hensell – WL Difference – 2050 (Drought of Record vs. Avg. Recharge)



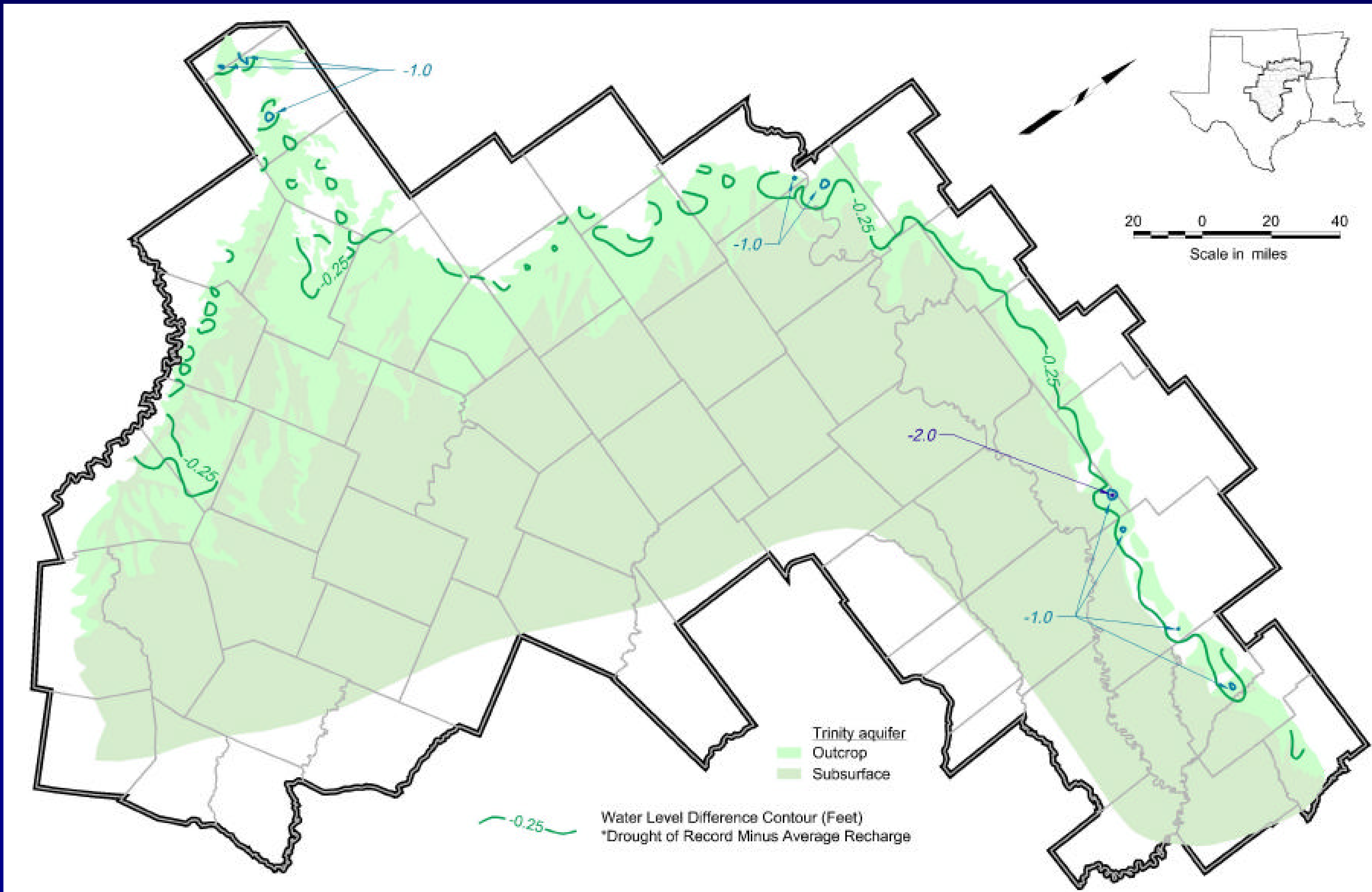
WL Hosston – Avg. Recharge – 2050



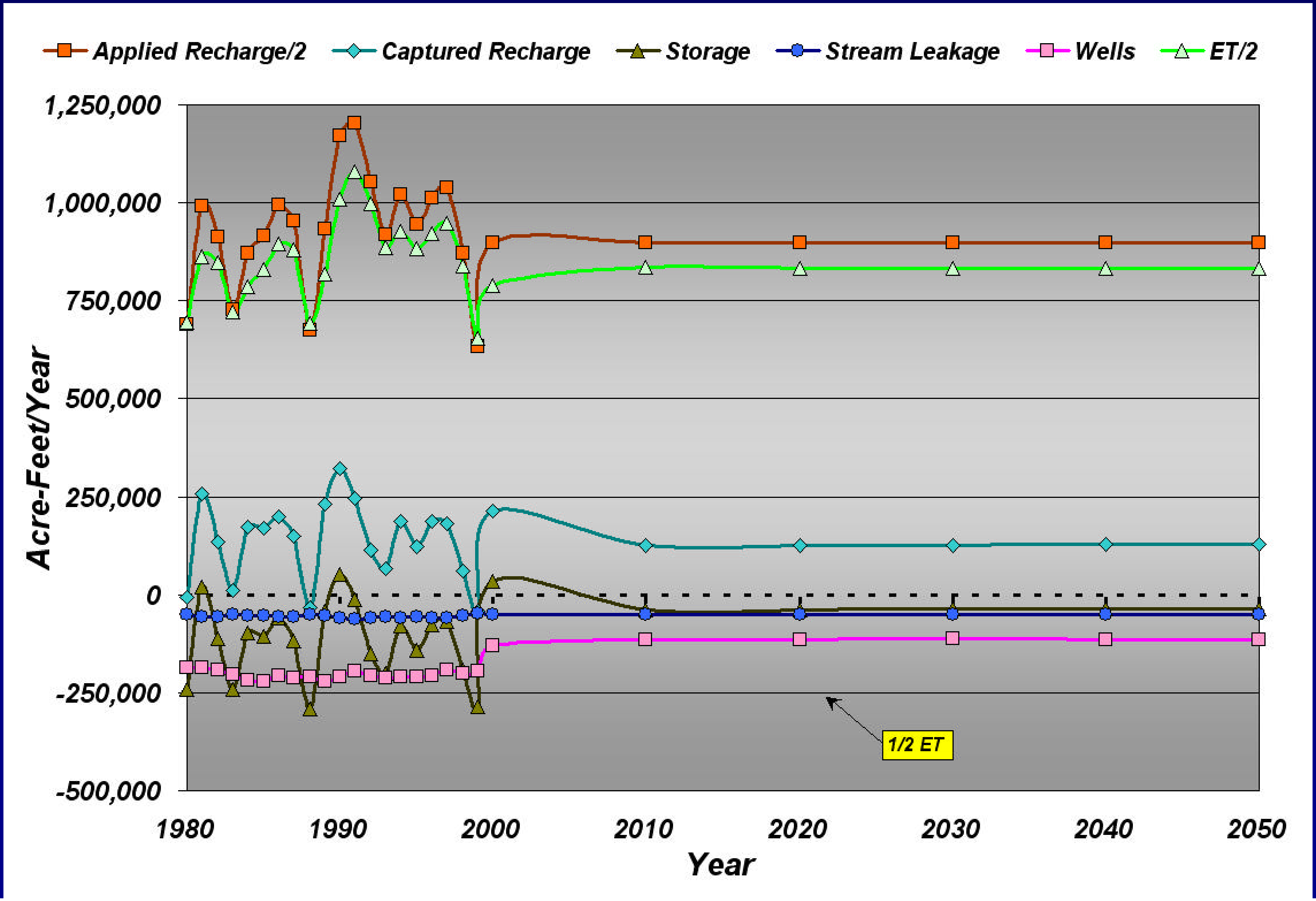
DD Hosston – Avg. Recharge – 2050



Hosston – WL Difference – 2050 (Drought of Record vs. Avg. Recharge)

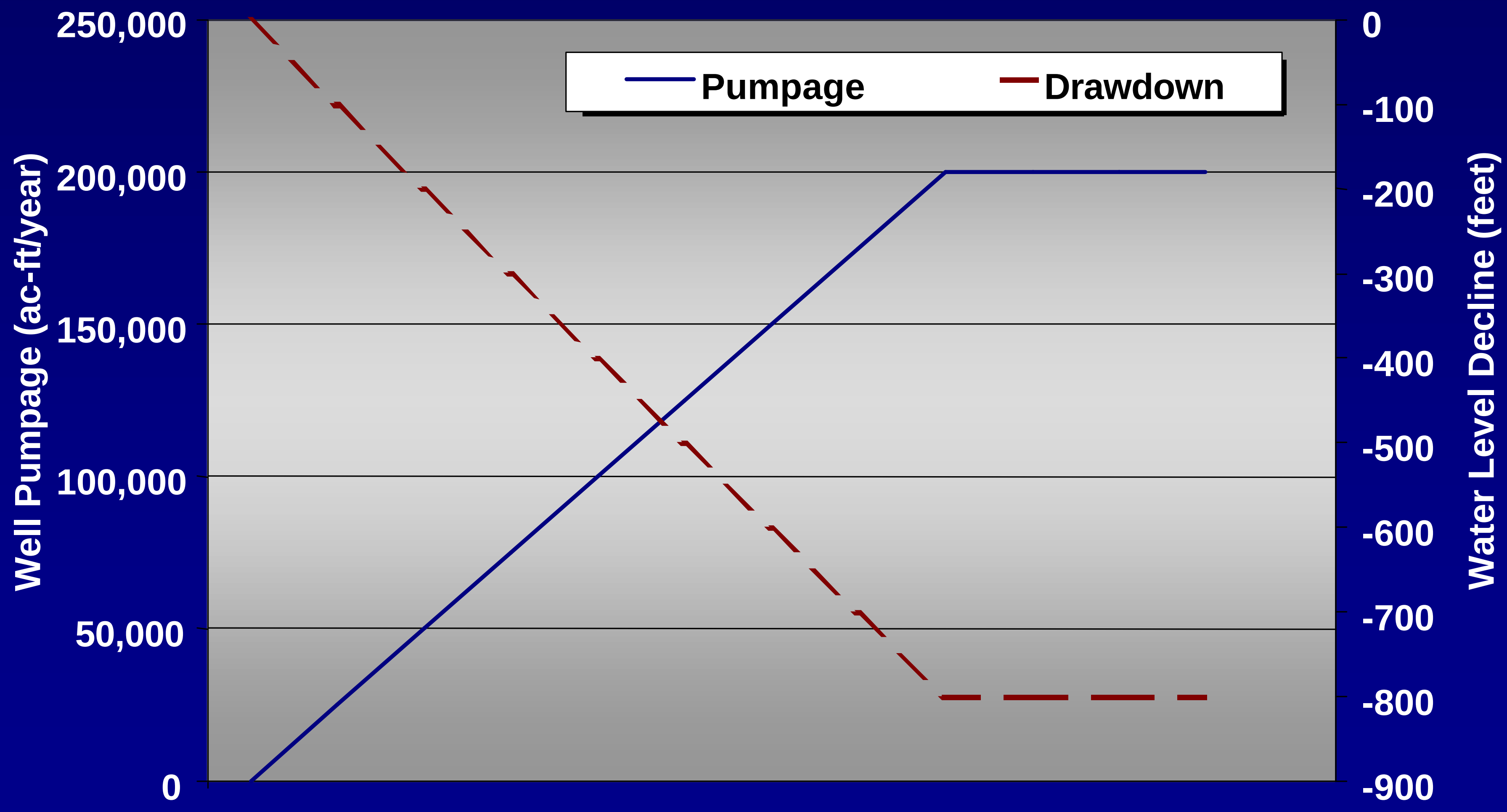


Water Budget (1980 – 2050)

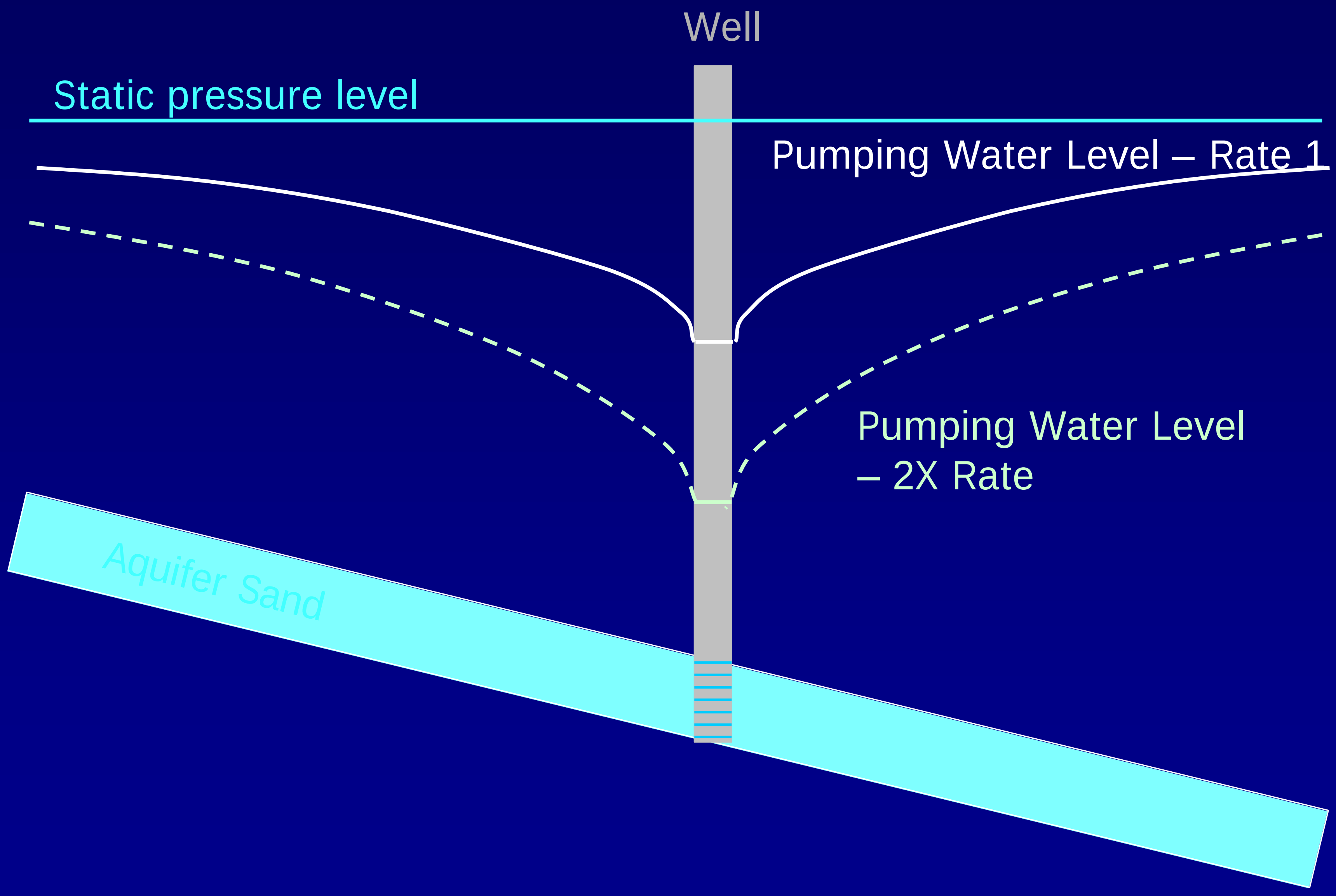


Water Levels vs. Pumpage Rate

- Artesian drawdown directly proportional to pumpage rate



Well Pumping Characteristics



Supply Issues for Aquifer

- Distinguish between:
  - Annual average pumping rate
    - Controls long-term water level trend of aquifer
  - Peak pumping rate
    - Typically summer use
    - Higher rate than annual average use

Project Schedule Milestones

- Project Initiation - January 2003
- Draft Conceptual Model Complete – August 2003
- Model Development Begins – Sept. 2003
- Study Completion Date – March 2004
- Final Report - August 2004

Northern Trinity / Woodbine Groundwater Availability Model

SAF Open Discussion / Questions

Stakeholder Advisory Forum Meeting
Northern Trinity-Woodbine Aquifer GAM
25-Feb-04

Name	Representing
Bob Harden	R.W. Harden & Associates, Inc.
Ron Sellman	City of Gainsville
Jerry Chapman	Greater Texans Utility Authority
George Shannon	TRWD
Ali Chowdhury	T.W.D.B.
Leon Byrd	TCEQ
Alfredo Rodriquez	Brazos River Authority
Victor Ratliff	Texoma Area
Ron Haynes	City of Hurst
Kraig Kahler	City of Weatherford
Dr. Paul Phillips	City of Weatherford
Denis Qualls	City of Dallas
David Gattis	City of Sherman
Natalie Houston	USGS
Abiy Berehe	TCEQ
David Wachal	City of Denton
Stephanie Griffin	Freese & Nichols, Inc.
David O'Rourke	HDR, Inc. `

Summary of Questions/Answers
SAF No. 4
Quoin Offices
Dallas, Texas
February 25th, 2004

1. Q: Can you use groundwater/surface water supplies in a way to meet peak demands?
A: Typically, it is cost effective to use groundwater supplies to meet peak demands. However, with a low transmissivity aquifer such as these, it requires a higher level of engineering and pumping lift cost to achieve this in heavier use areas.

2. Q: Where do you send comments?
A: Send comments to Ali Chowdury at the Texas Water Development Board.

3. Q: What happens if the projected decrease in use in the RWPG projected demands does not occur?
A: Most likely the model would indicate water levels would remain near current conditions.

4. Q: Could such a model run be done in this study? Would a letter from water user groups requesting this help?
A: This is beyond the GAM program scope of work, but provided time and budget allows this it could be readily done.

5: Q: Can we expect future decrease in pumpage followed by regulation?
A: Currently, that is dependent upon local implementation of a groundwater district. Overall, the Trinity has historically been a self-regulating aquifer because of higher pumping lifts and relatively low volumes of production.

6: Q: How much pumpage can cells handle over time? What if you increase pumpage say 5 times?
A: We would have to make this analysis to answer this question definitively, but generally speaking it would require many, many more wells to accomplish this. The greatest cones of depression are in areas of high use.

7: Q: How has the aquifer responded to distance from outcrop?
A: From a regional standpoint, the artesian pressure declines in the aquifer are not draining the outcrop quickly.

8: Q: Under strong drawdown, does that impact quality?
A: That has not been studied but could be added to the model. Generally speaking, historical drawdown has not caused large regional quality changes. Locally, well bore issues can cause inner-well leakage and create water quality changes in small local areas of the aquifer. But these are typically very small areas.

9: Q: What does mean seal level mean?
A: The distance above or below the Gulf of Mexico. Water level elevations are driven by use and/or topography.

10:Q: How slowly does water move through the Trinity?
A: Velocities of groundwater are on the order of 10 feet a year or a few tens of feet per year. Very near pumping wells movement rates can be higher. Same for the Woodbine.

11:Q: Does water quality decrease downdip?
A: Yes – the water becomes more mineralized.