Groundwater Availability Modeling (GAM) for the Lipan Aquifer

LBG-Guyton Associates

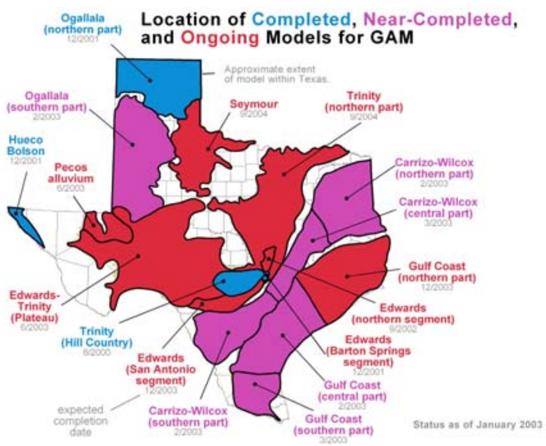
Presented to

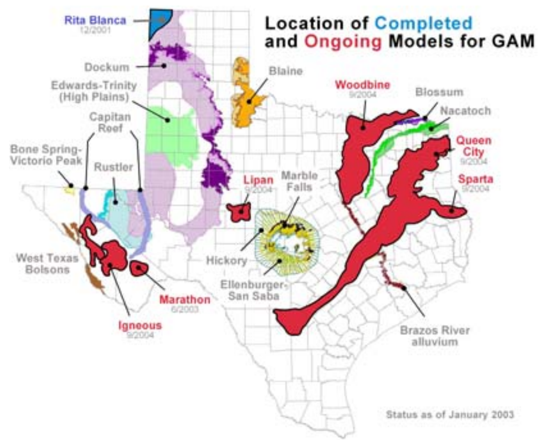
Stakeholder Advisory Forum

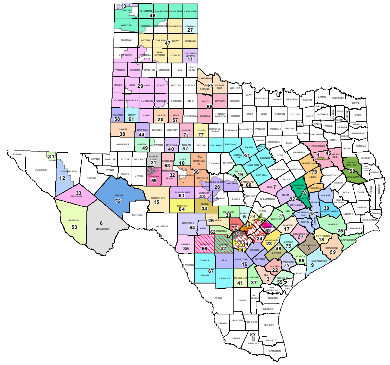
San Angelo, Texas

March 31, 2004

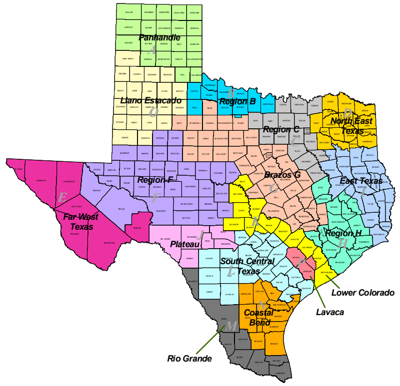
Groundwater Availability Modeling



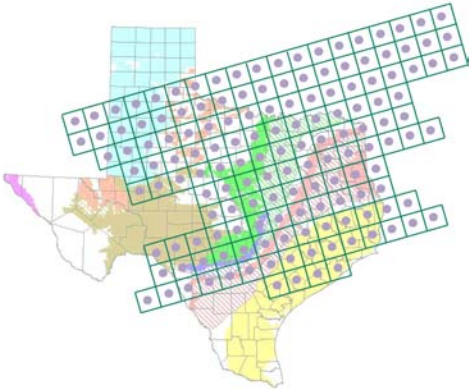




Contract Manager



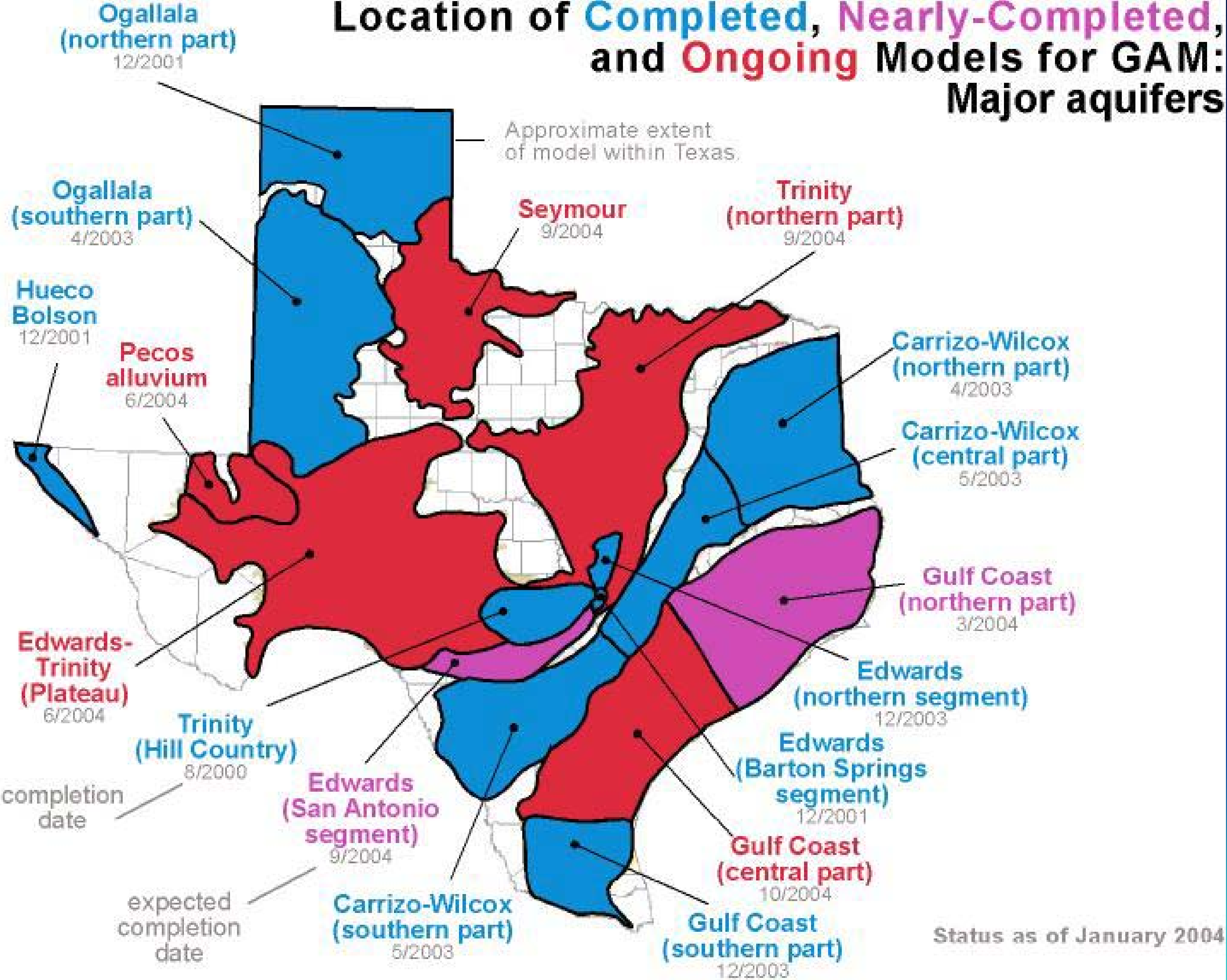
- Texas Water Development Board



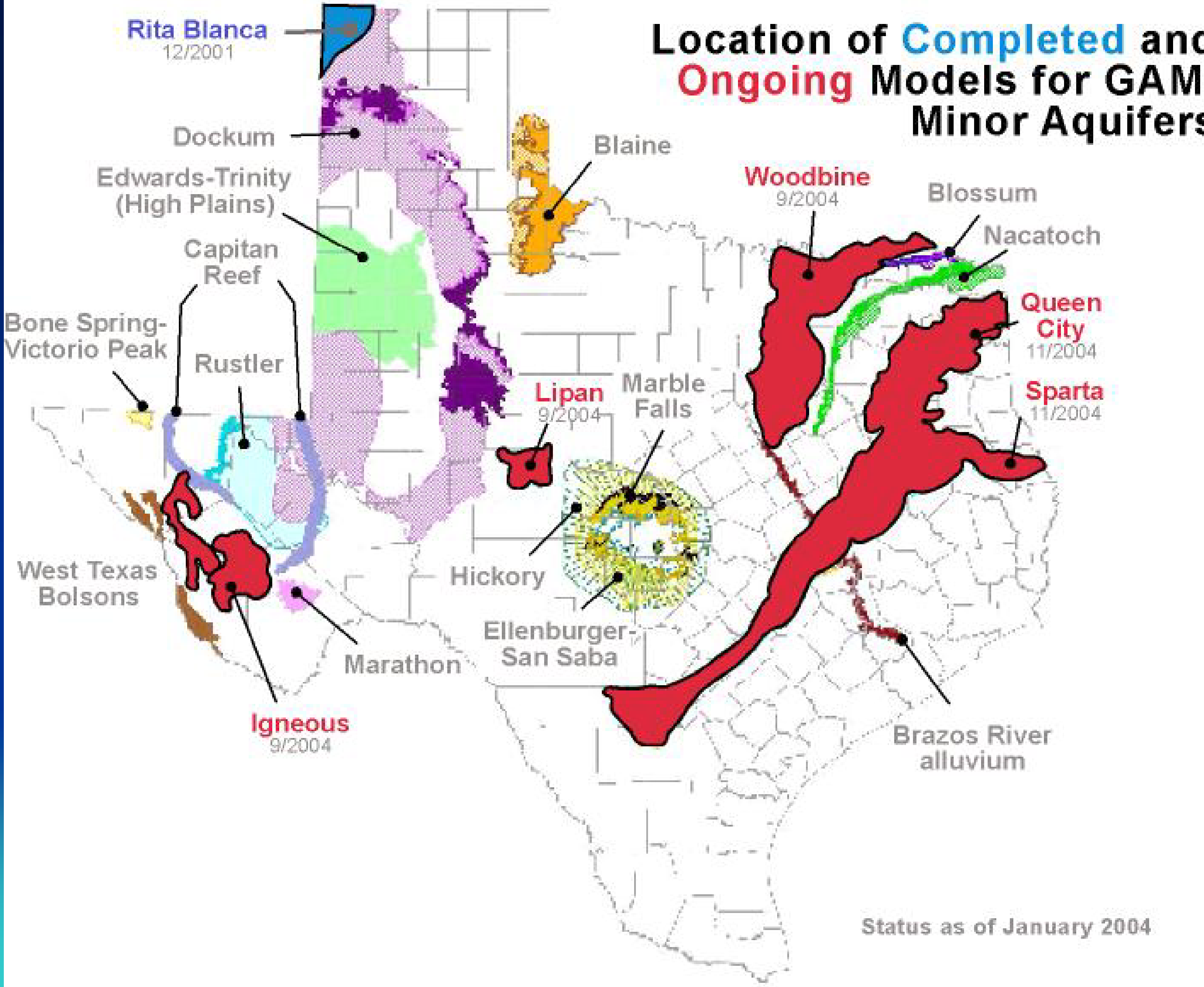
GAM

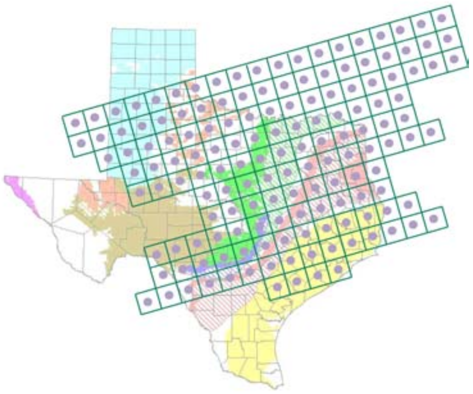
- Purpose: to develop the best possible groundwater availability model with the available time and money.
- Public process: you get to see how the model is put together.
- Freely available: standardized, thoroughly documented, and available over the internet.
- Living tools: periodically updated.

Location of Completed, Nearly-Completed, and Ongoing Models for GAM: Major aquifers



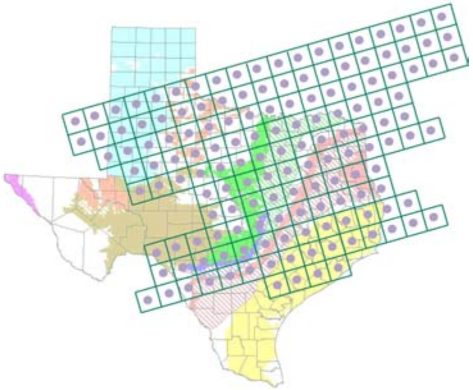
Location of Completed and Ongoing Models for GAM: Minor Aquifers





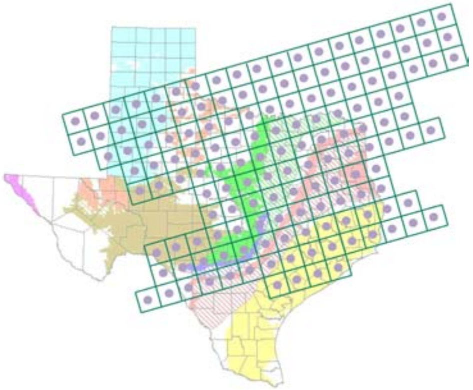
What is groundwater availability?

- …the amount of groundwater available for use.
- The State does not decide how much groundwater is available for use: GCDs and RWPGs decide
- A GAM is a <u>tool</u> that can be used to assess groundwater availability once GCDs and RWPGs decide how to define groundwater availability.



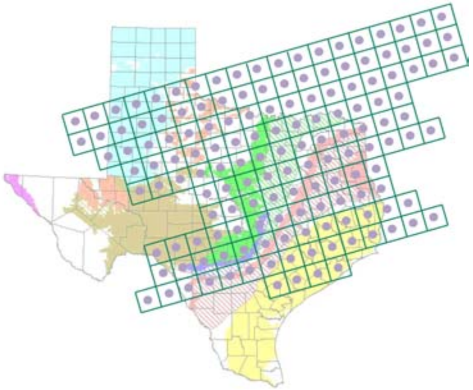
Do we have to use GAM?

- Water Code & TWDB rules require that GCDs use GAM information. Other information can be used in conjunction with GAM information.
- TWDB rules require that RWPGs use GAM information unless there is better site specific information available



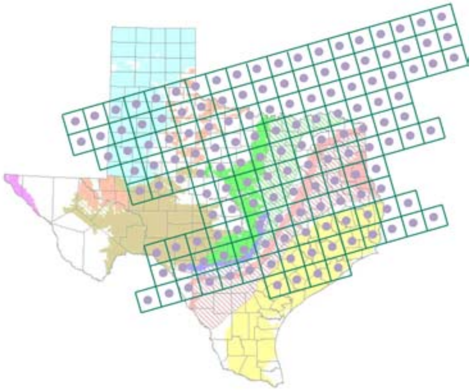
How do we use GAM?

- The model itself
  - predict water levels and flows in response to pumping and drought
  - effects of well fields
- Data in the model
  - water in storage
  - recharge estimates
  - hydraulic properties
- GCDs and RWPGs can request runs



Living tools

- GCDs, RWPGs, TWDB, and others collect new information on aquifer
- This information can enhance the current GAMs
- TWDB plans to update GAMs every five years with new info
- Please share information and ideas with TWDB on aquifers and GAMs



Participating in the GAM process

- SAF meetings
  - hear about progress on the model
  - comment on model assumptions
  - offer information (timing is important!)
- Report review
  - Deadline for comments on the IBGAM is **April 9, 2004**. The final draft report is posted on TWDB website
- Contact TWDB
  - Robert Mace
  - Richard Smith

Comments:

Richard Smith

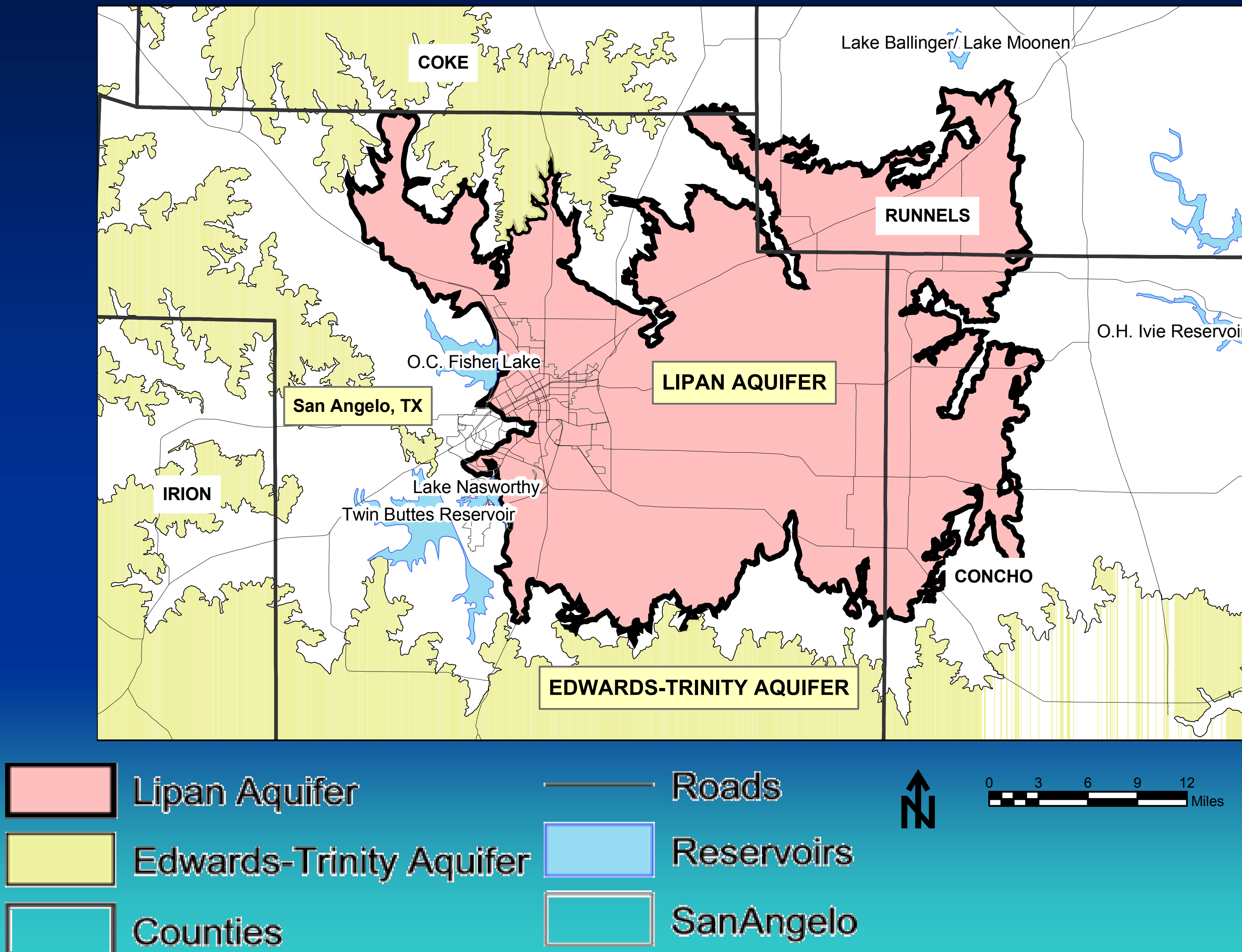
richard.smith@twdb.state.tx.us

(512)936-0877

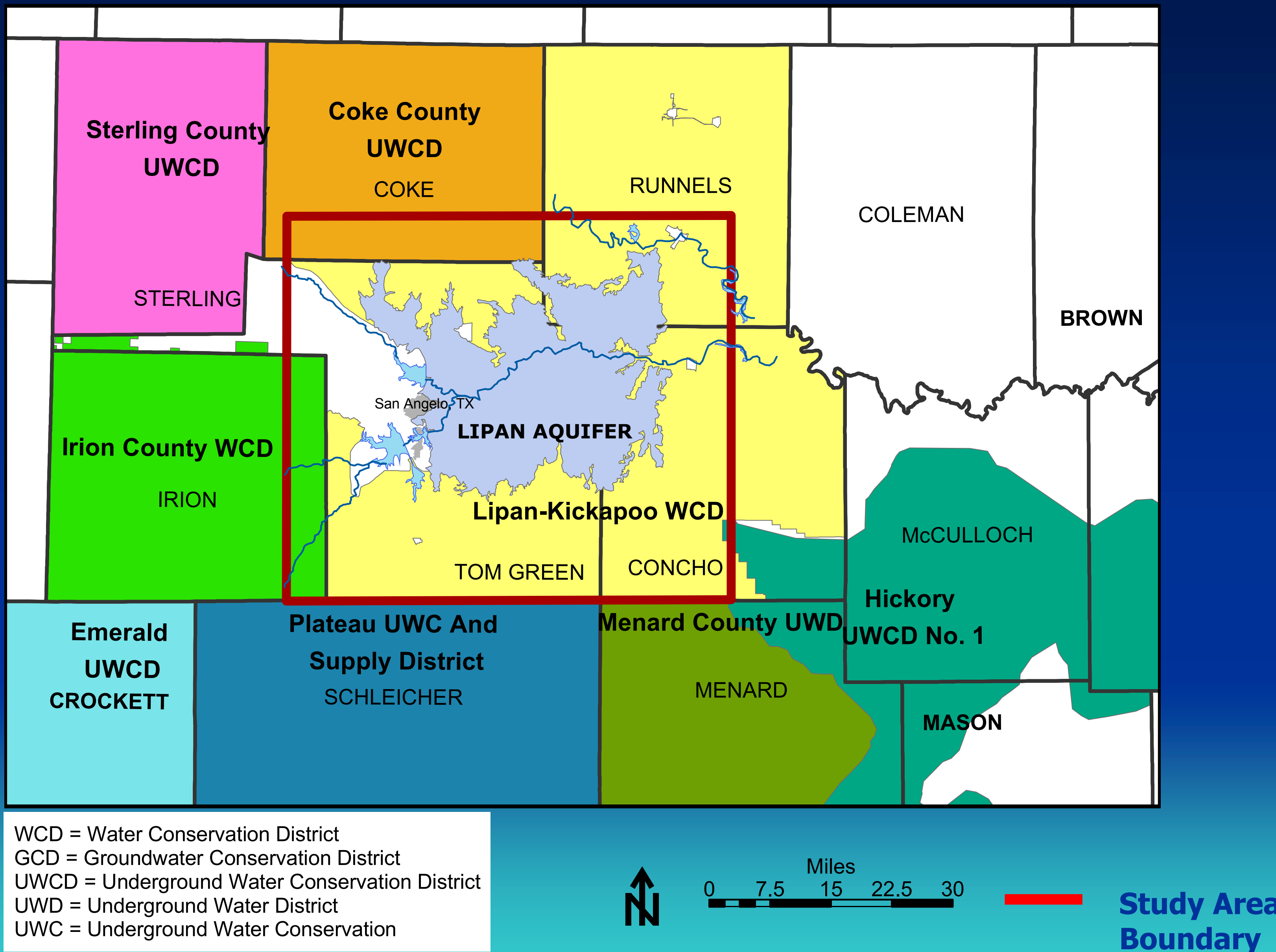
www.twdb.state.tx.us/gam

Review of Conceptual Model

TWDB Aquifers

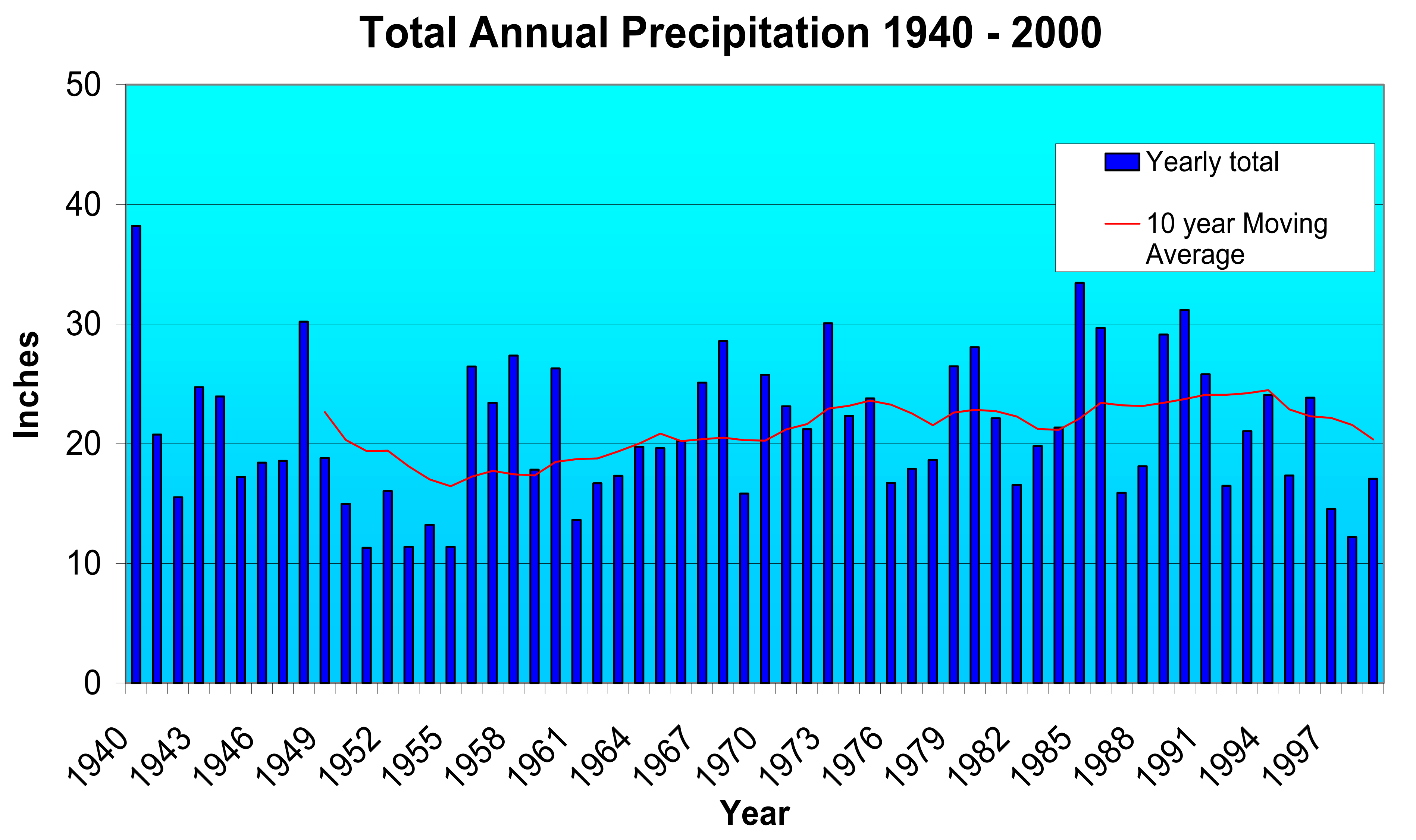


Groundwater Conservation Districts

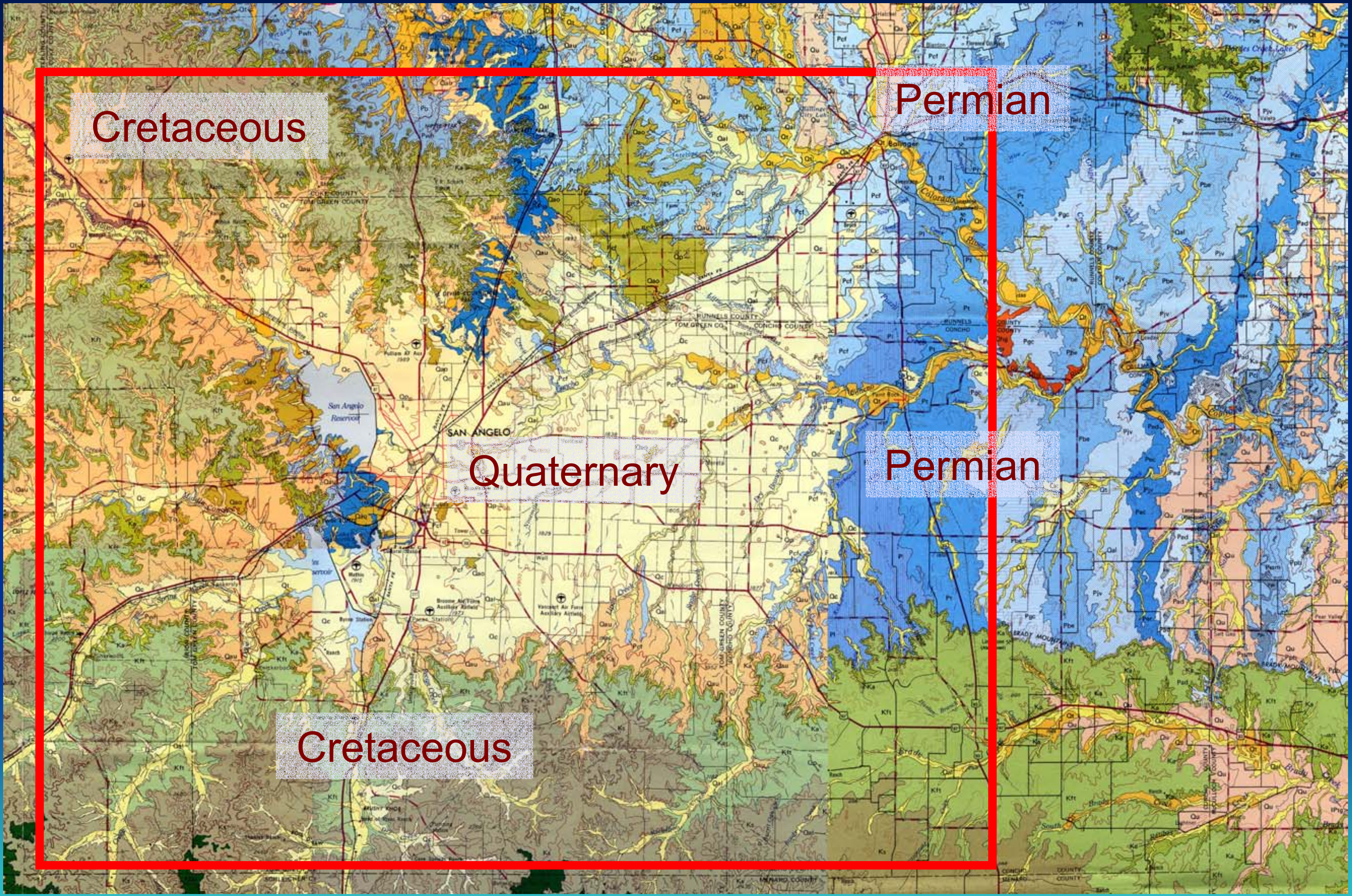


WCD = Water Conservation District
GCD = Groundwater Conservation District
UWCD = Underground Water Conservation District
UWD = Underground Water District
UWC = Underground Water Conservation

Annual Precipitation
(TWDB Quad 607)

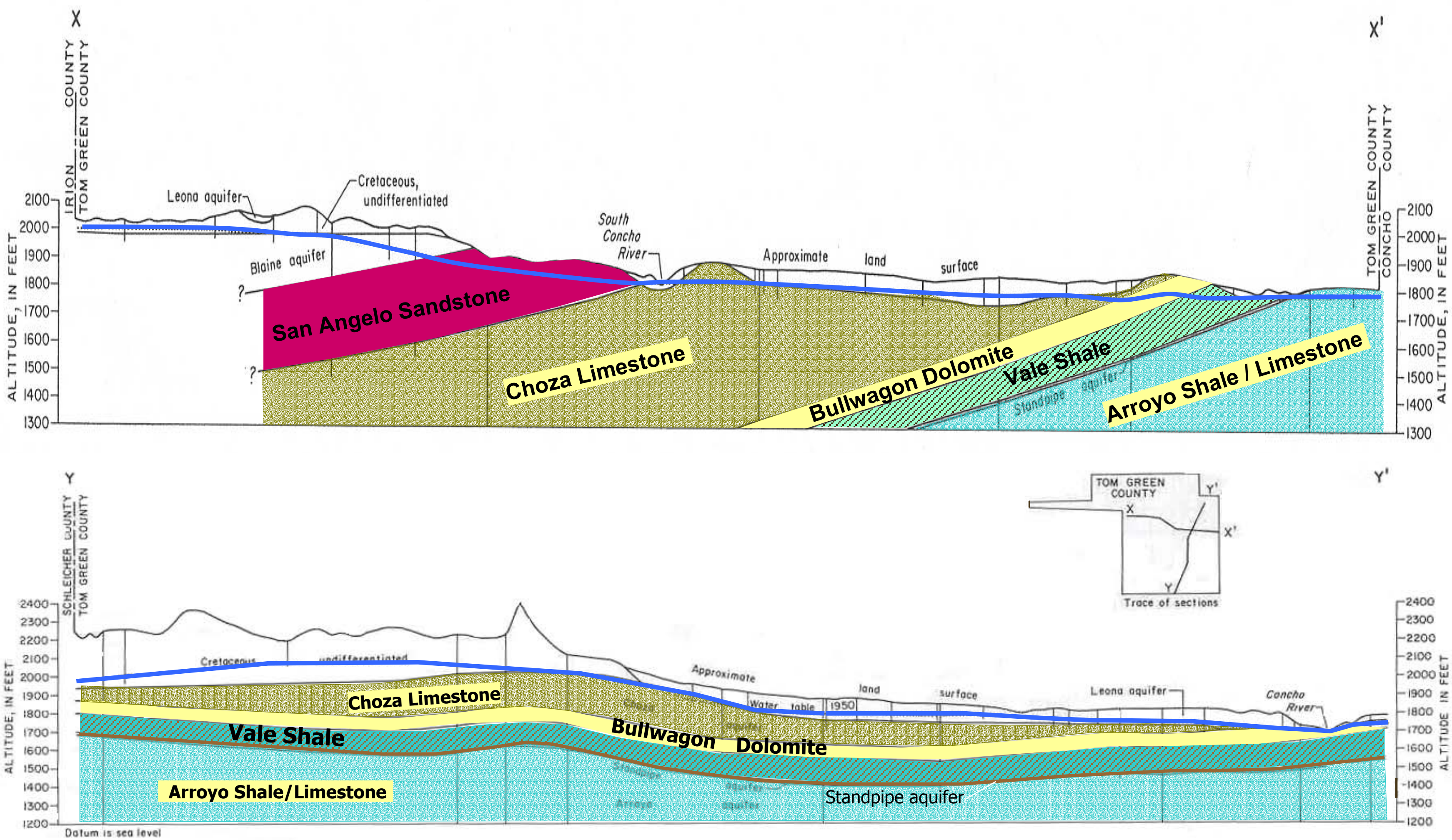


Surface Geology

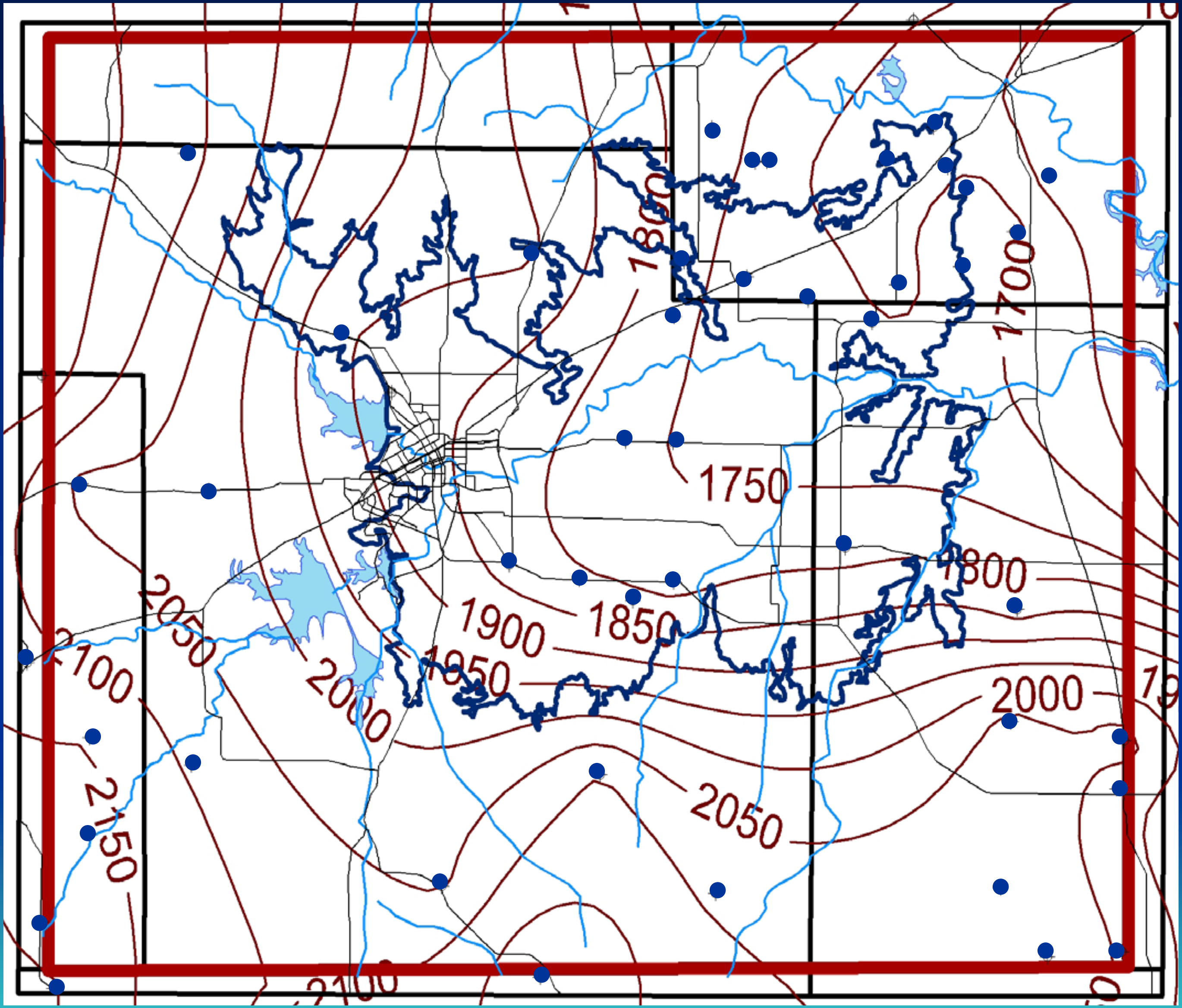


Model boundary

Geologic Cross-Sections (after Lee, 1986)

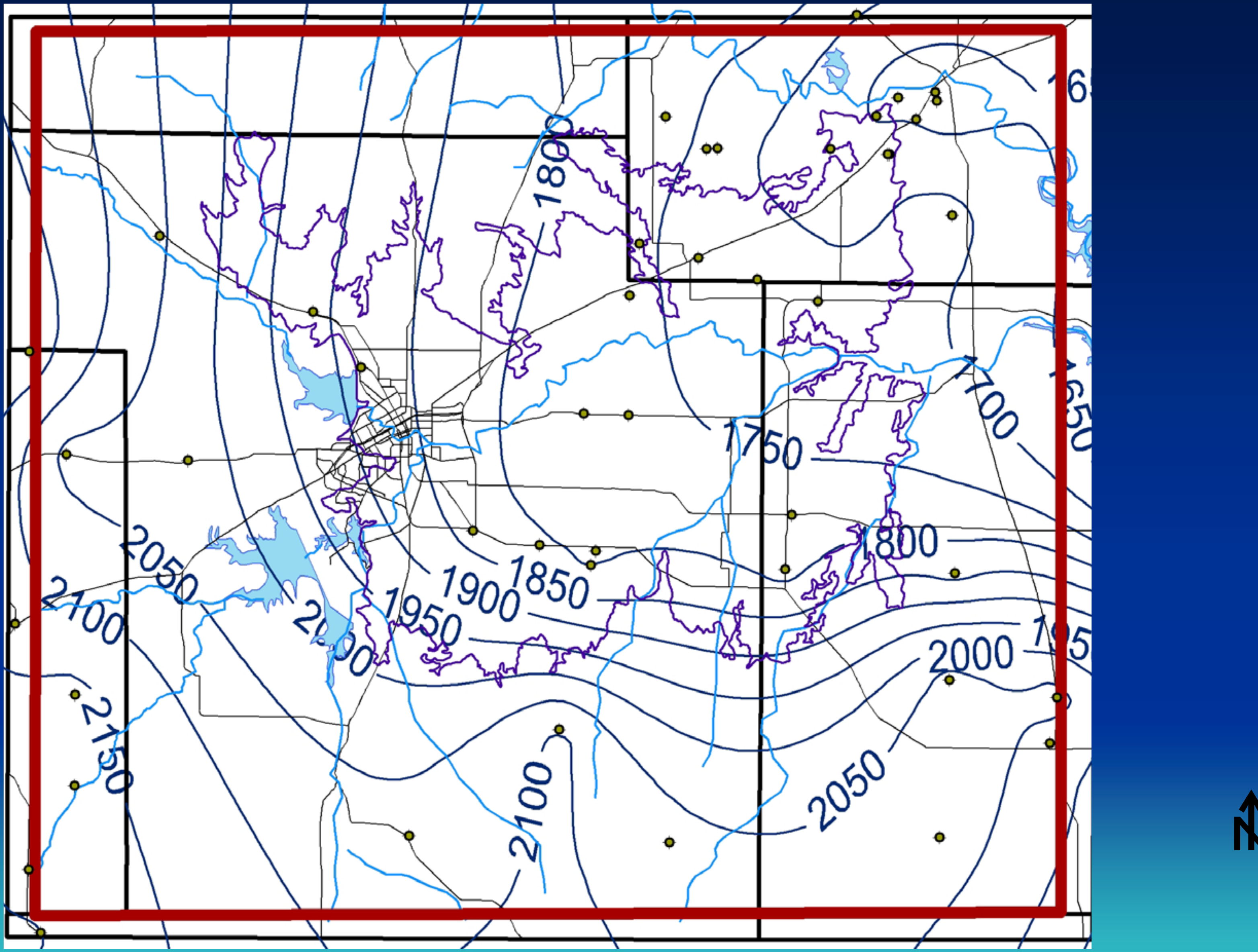


Water Levels - 1981



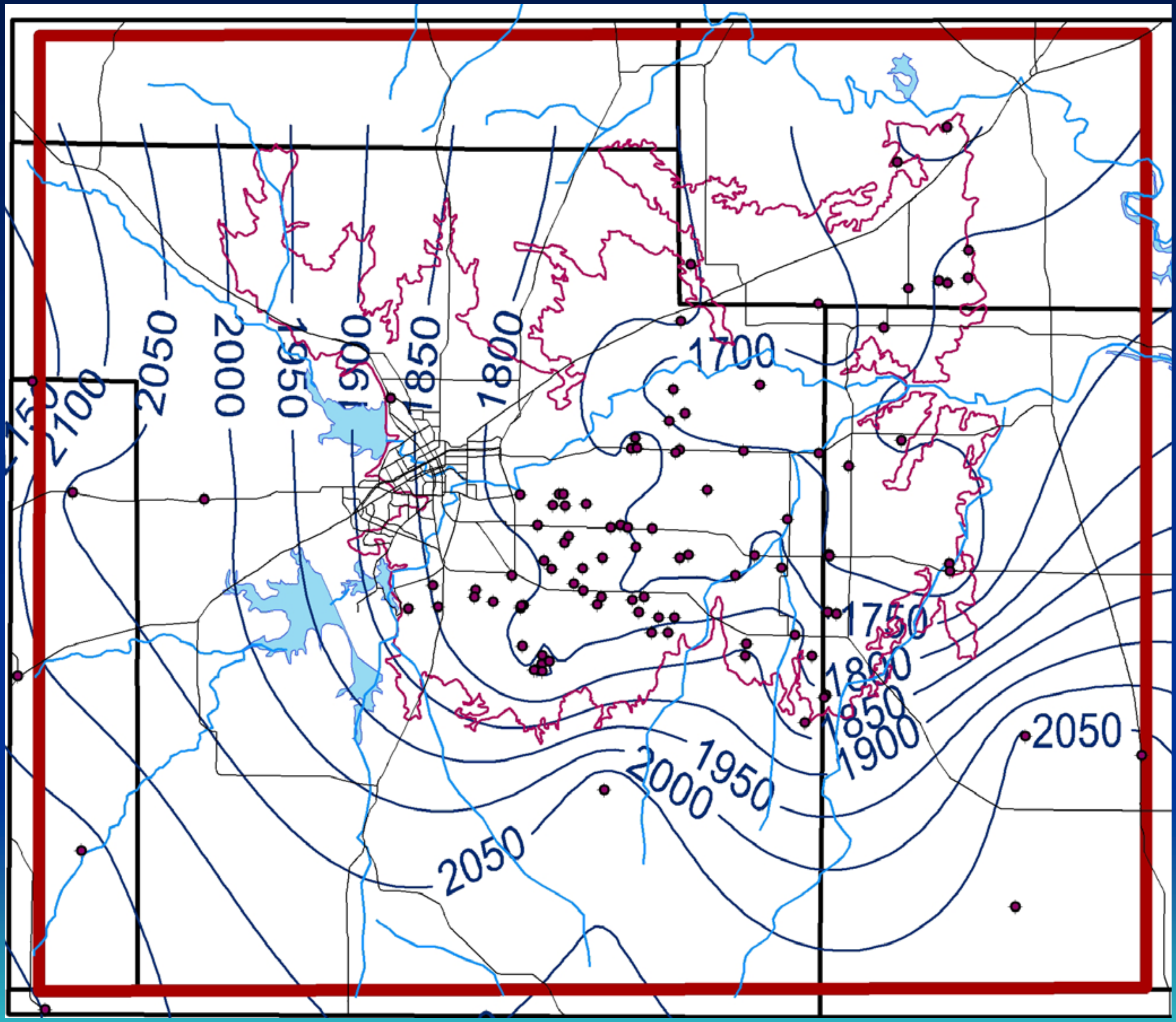
Study Area Boundary

Water Levels - 1990



Study Area Boundary

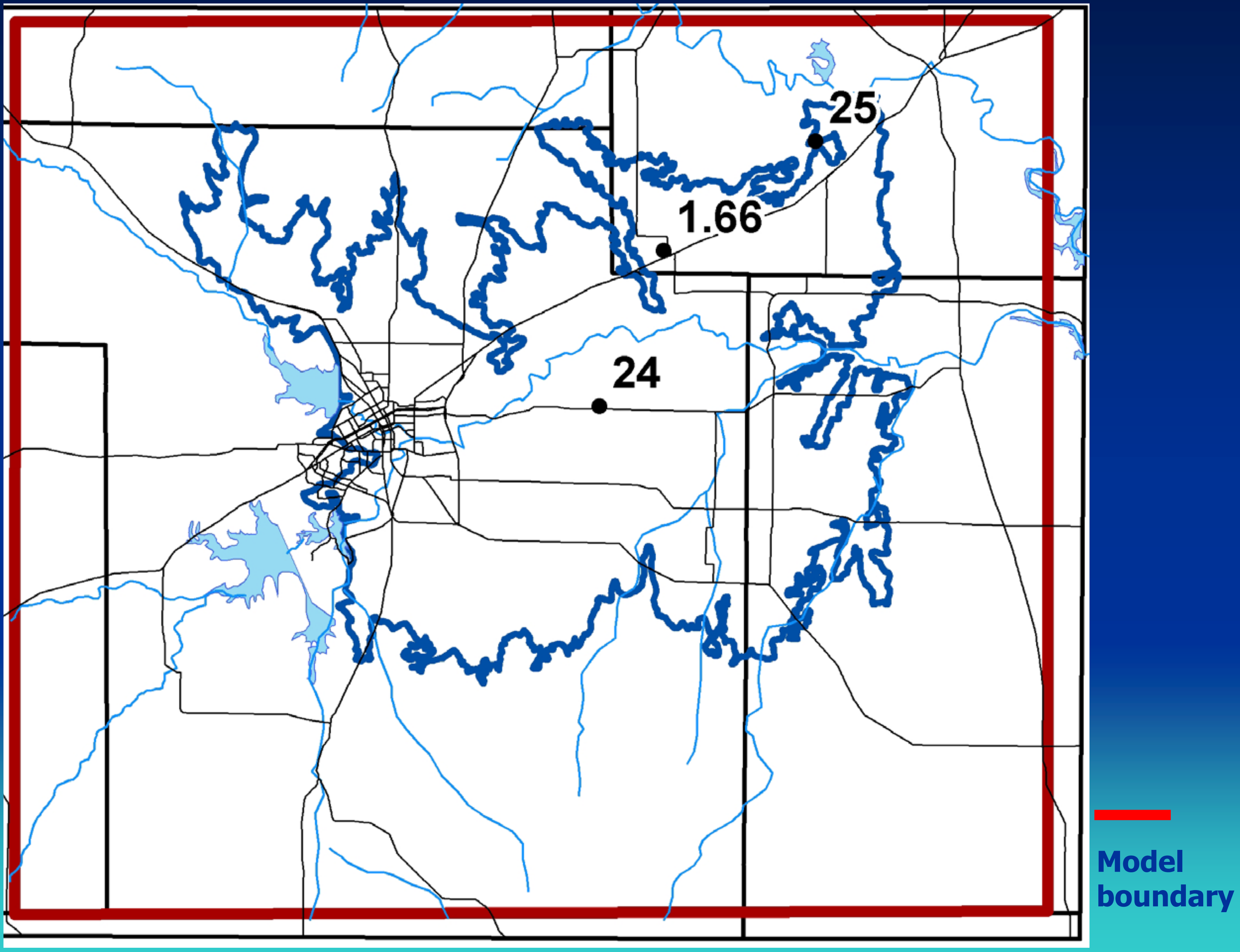
Water Levels - 2000



Added LKWCD Data to TWDB Data

Study Area Boundary

Specific-Capacity Data in TWDB Database



Estimating Specific-Capacity and Transmissivity using Production Capacity

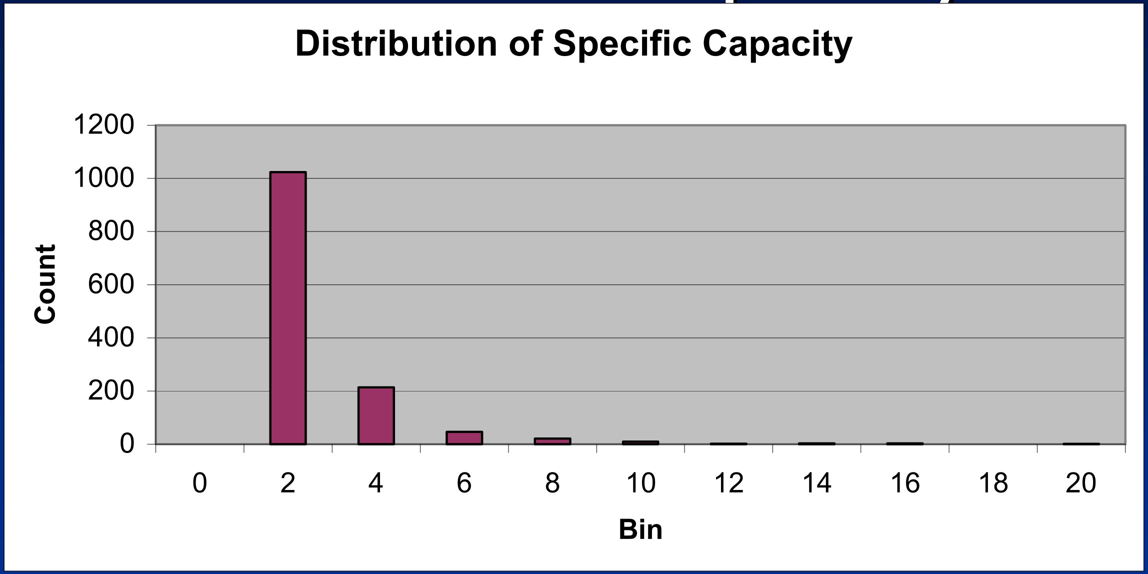
Specific-Capacity from Production Capacity

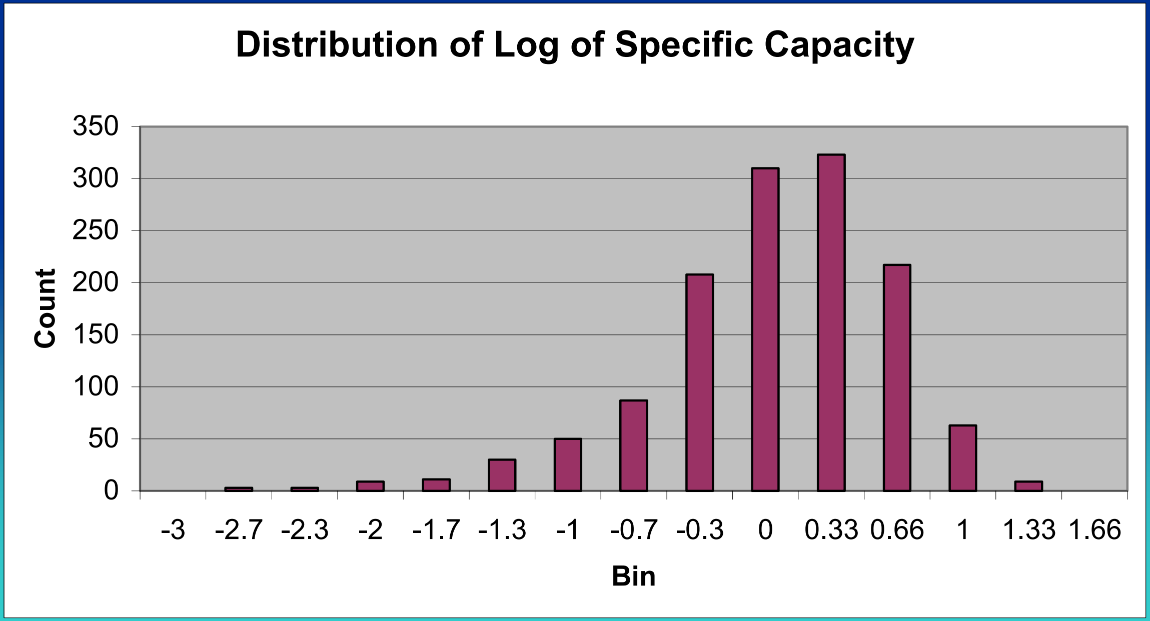
- Use Production Capacity (Q) and Saturated thickness in Well (b)
- Assume Specific-Capacity (Sc) = Q/b
- Assume Q is in gallons per minute
- Sc is in Gallons per minute per foot

Transmissivity from Specific-Capacity

- Used "Estimating Transmissivity Using Specific-Capacity Data" (Mace, 2000) Appendix A
- Assumptions: 10 minute Pumping time, 8" Well Diameter, Storativity (S) of 0.0001
- Estimated Transmissivity Values range from 0.3 to 4000 ft^2/day

Estimated Specific-Capacity Based on Production Capacity





Groundwater Pumping

- TWDB specified 7 categories of Pumping
- Irrigation, rural domestic, and Livestock pumping were distributed based on land use land cover and irrigated farmland information
- City municipal, mining, manufacturing, and power are all assigned as point stresses.
- Of these 7 categories, all but power were included in the Lipan GAM.

Assigning Irrigation Distribution for 1990 – 2000

- Use the 1994 Irrigation polygon GIS coverage.
- Overlaid this with the outline of the areas of observed higher production capacity.
- Intersect these two coverages with the model grid.
- Determine which model cells are in the higher production areas.
- In a spreadsheet, distribute the irrigation pumping by assigning cells in the higher production areas more pumping than cells in the low areas.
- Make sure the total irrigation pumping is consistent with TWDB reported value.

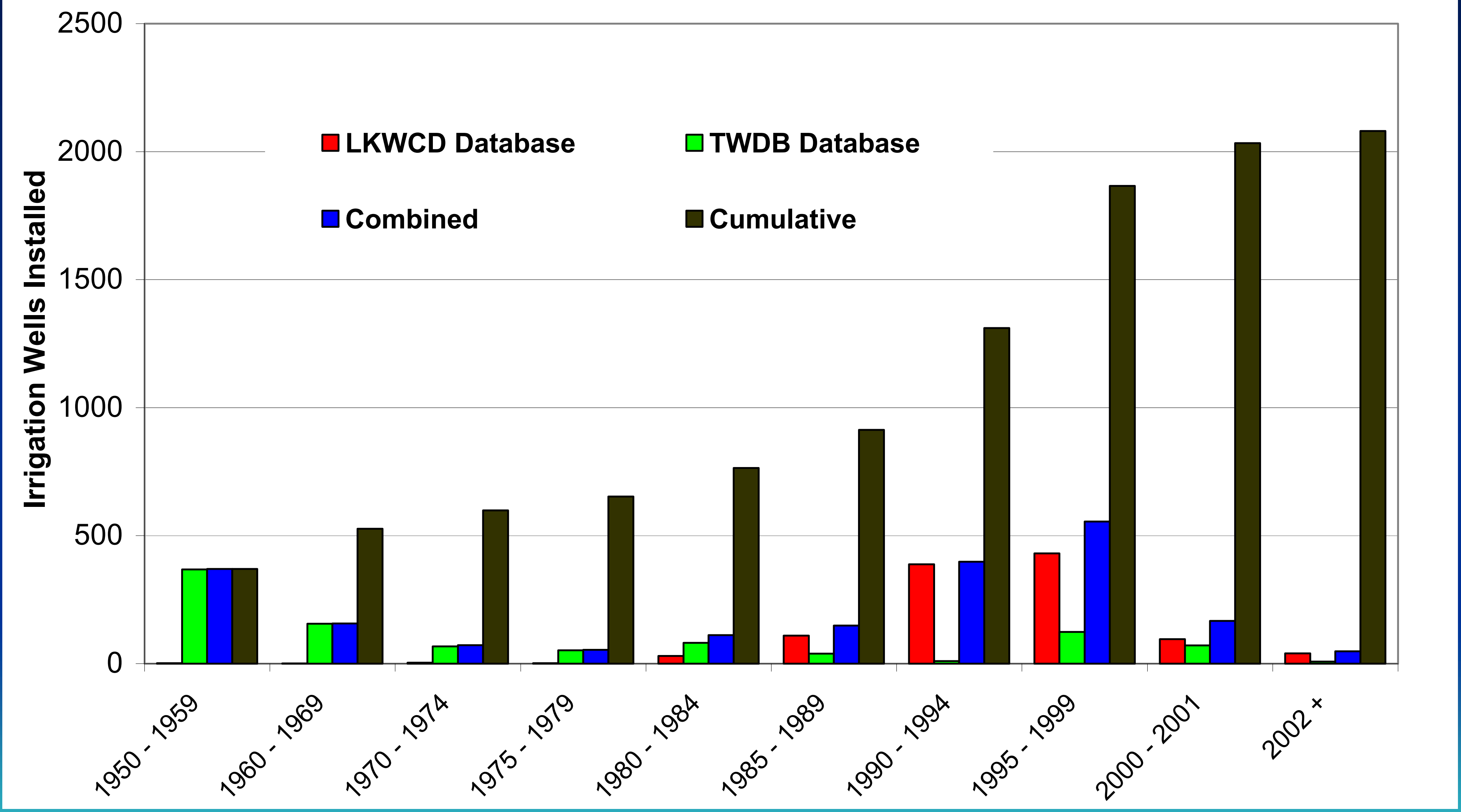
Assigning Rural Domestic Pumping

- Based on Census data.
- Used 1990 Census for the Transient Calibration period and 2000 Census for the Verification Period.
- Census give us Population Density = people/sq. mi.
- TWDB gives us estimated total rural domestic pumping per county per year.
- Remove all areas corresponding to metropolitan areas (> 500 people).
- Determine “pumping per person” for each county.
- Distribute this on the model grid using GIS tools to intersect the model grid with the Census data.

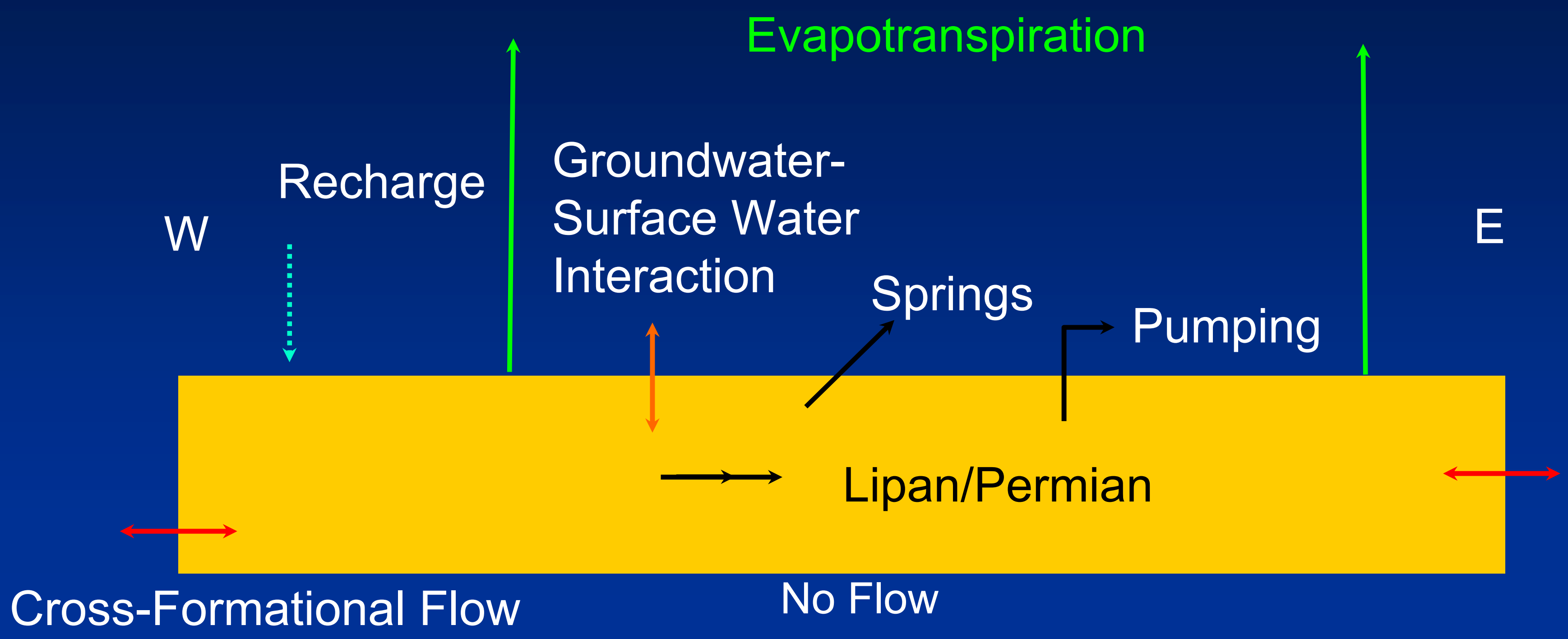
Other Pumping

- Assign livestock pumping similar to rural domestic pumping using Land Use / Land Cover data to delineate potential livestock areas.
- City municipal, a point source, corresponds to Goodfellow Air Force Base
- Manufacturing is also a point source coverage and is located at two manufacturing locations identified by TWDB.
- Mining, Manufacturing, City Municipal and Livestock pumping account for 0.03% to 0.7% of the total pumping

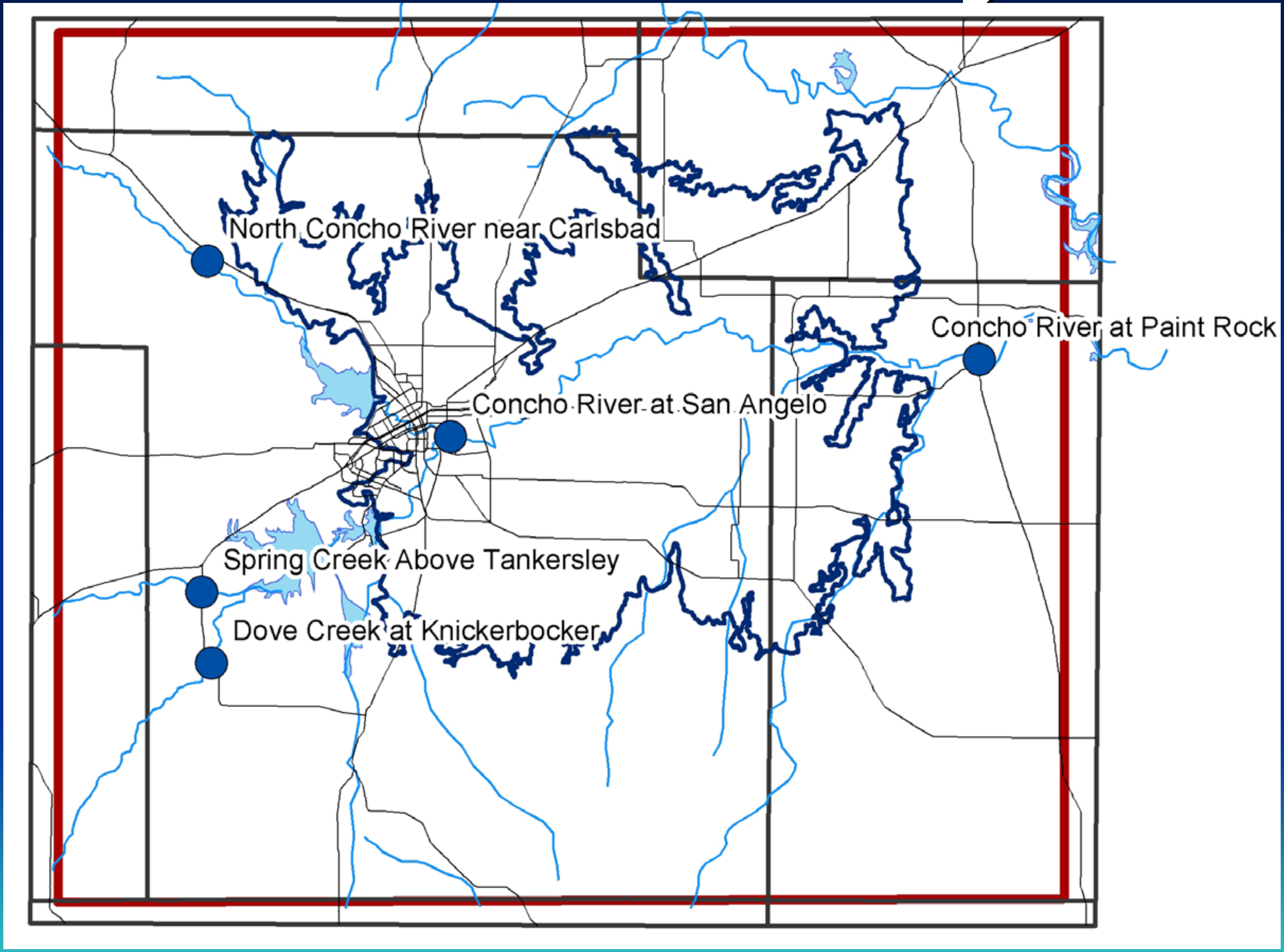
Irrigation Wells Installed Since 1950



Numerical Model Block Diagram

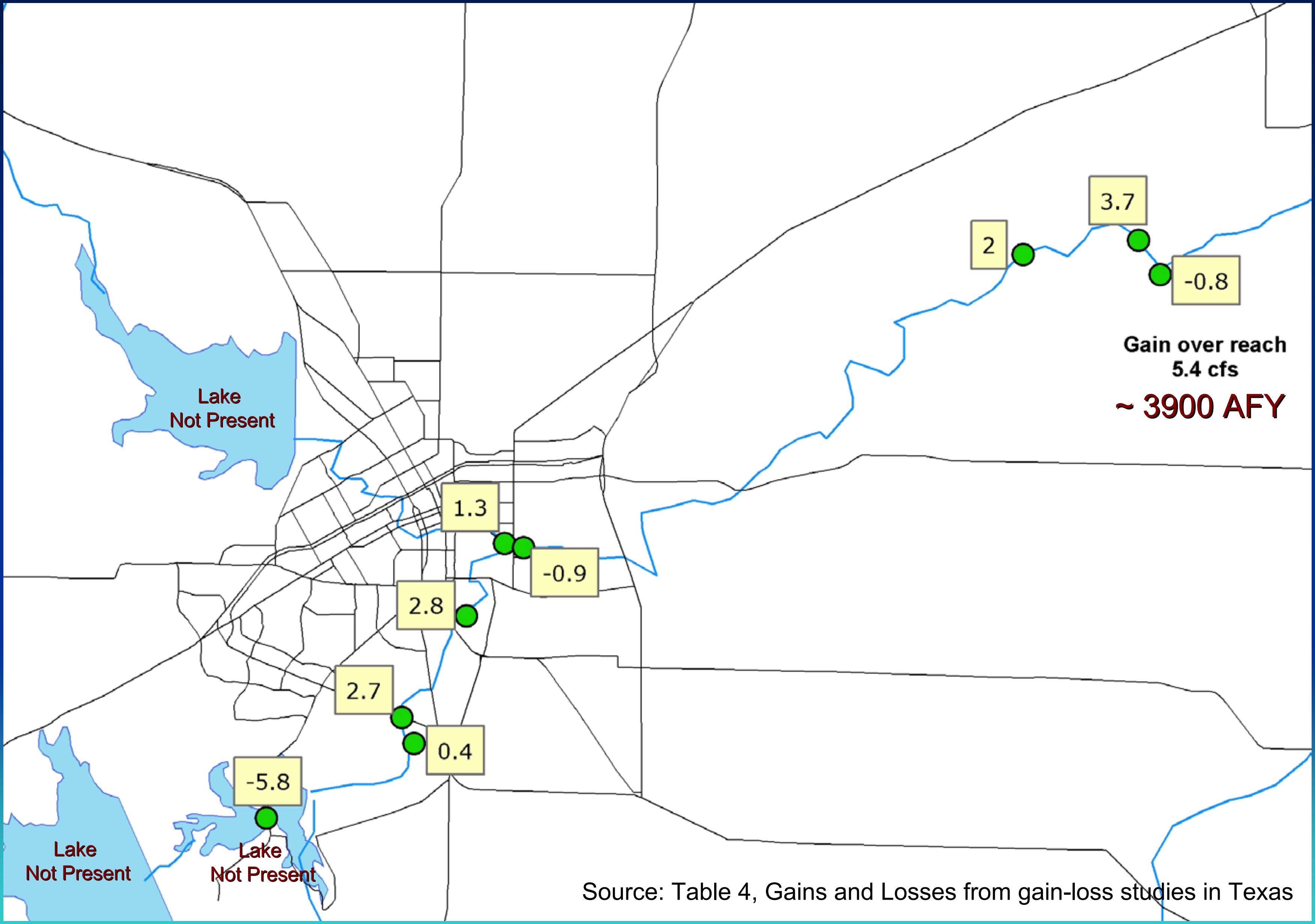


USGS Stream Gages



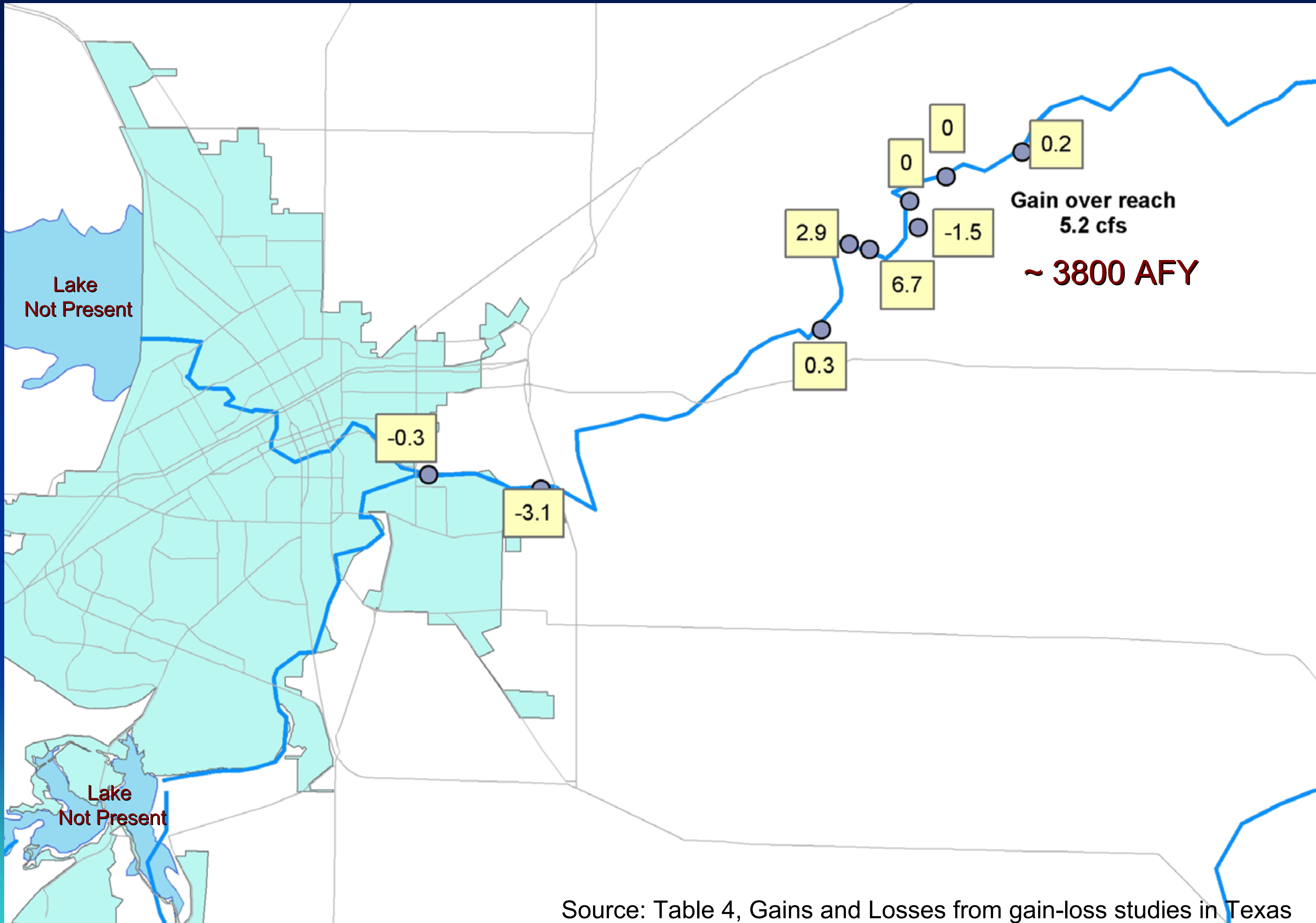
Concho River at Paint Rock (Nov 13, 2003)

USGS Gain-Loss Study 1918

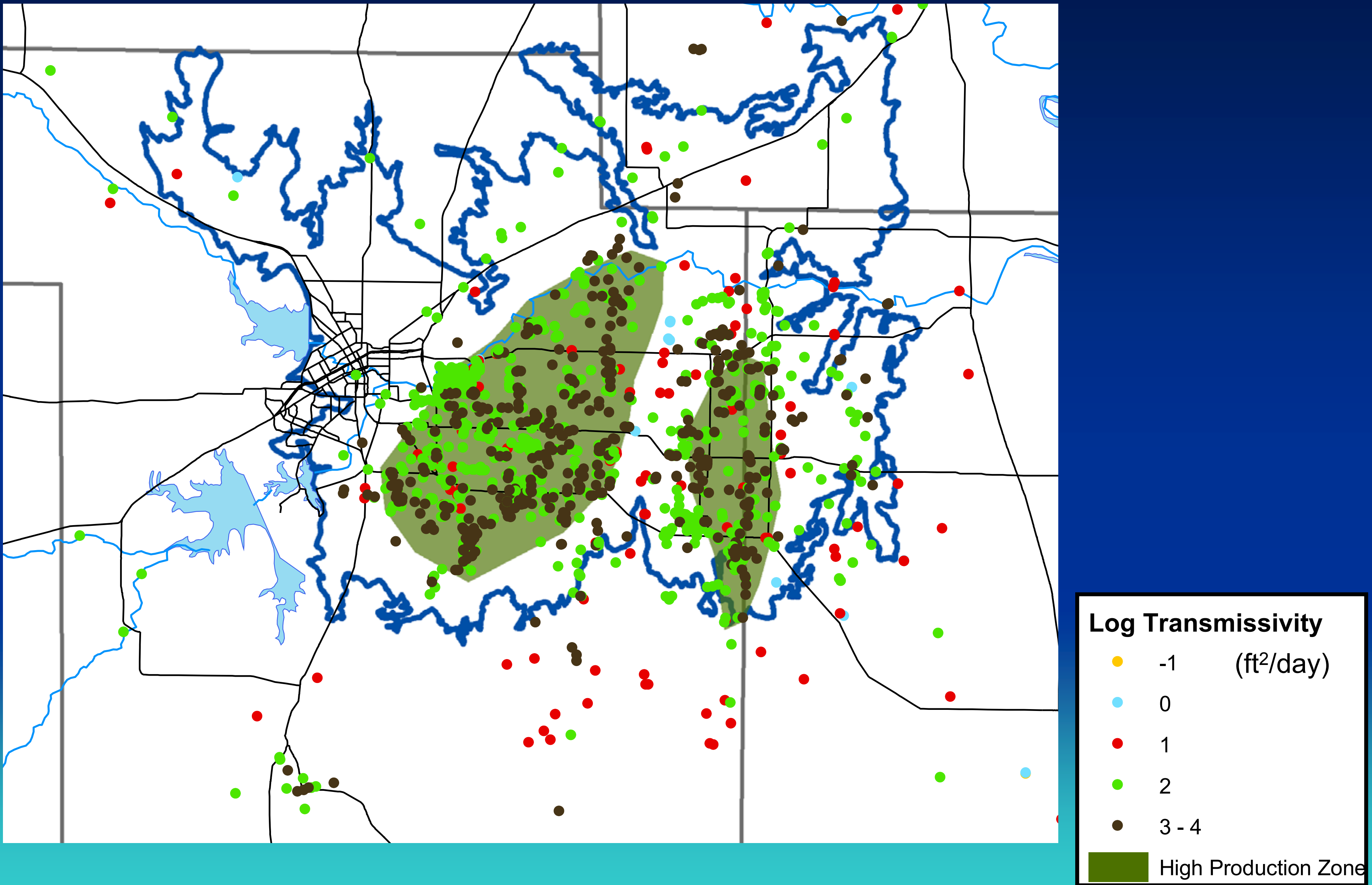


Source: Table 4, Gains and Losses from gain-loss studies in Texas

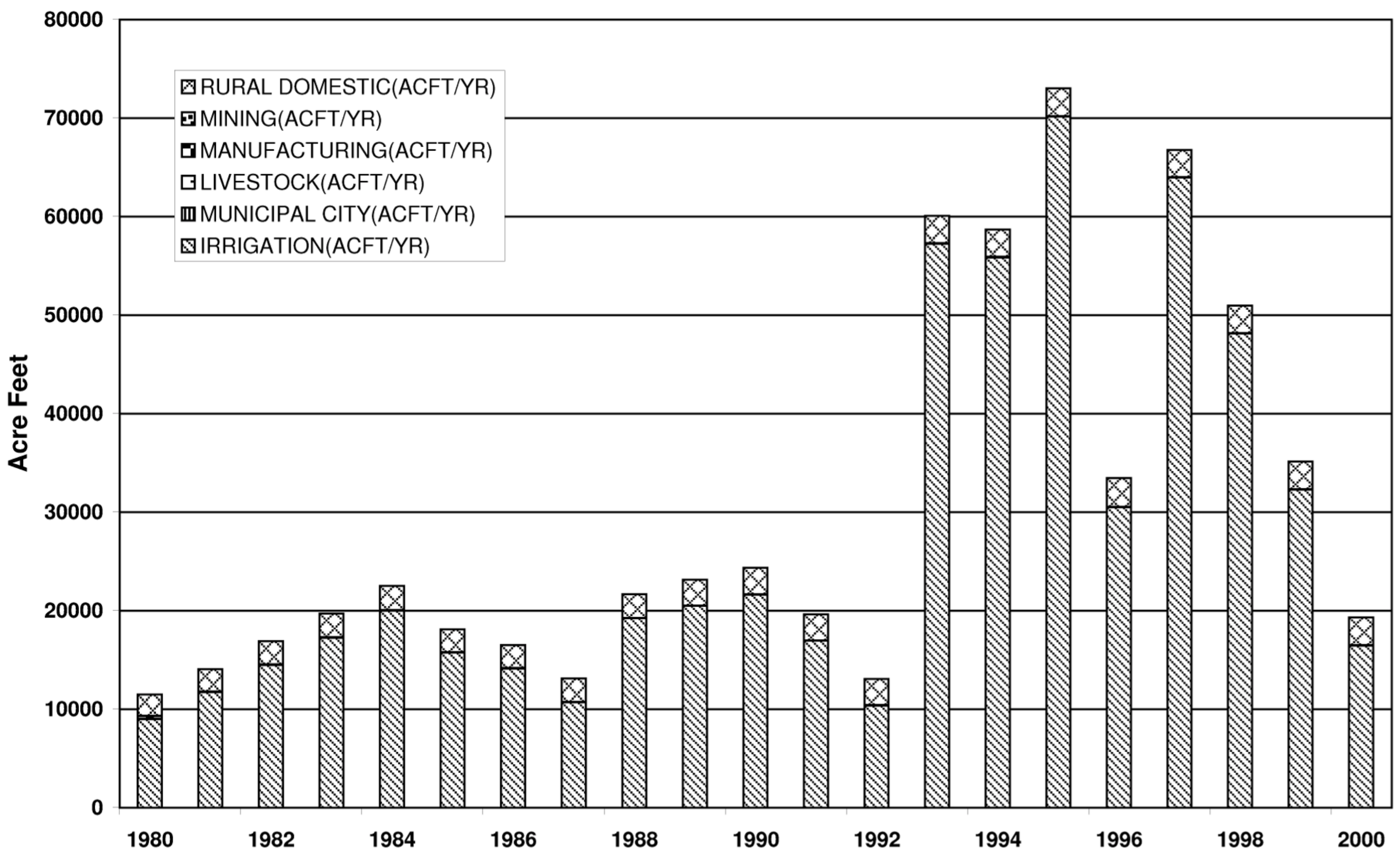
USGS Gain-Loss Study 1925



Estimated Transmissivity
(based on production data)

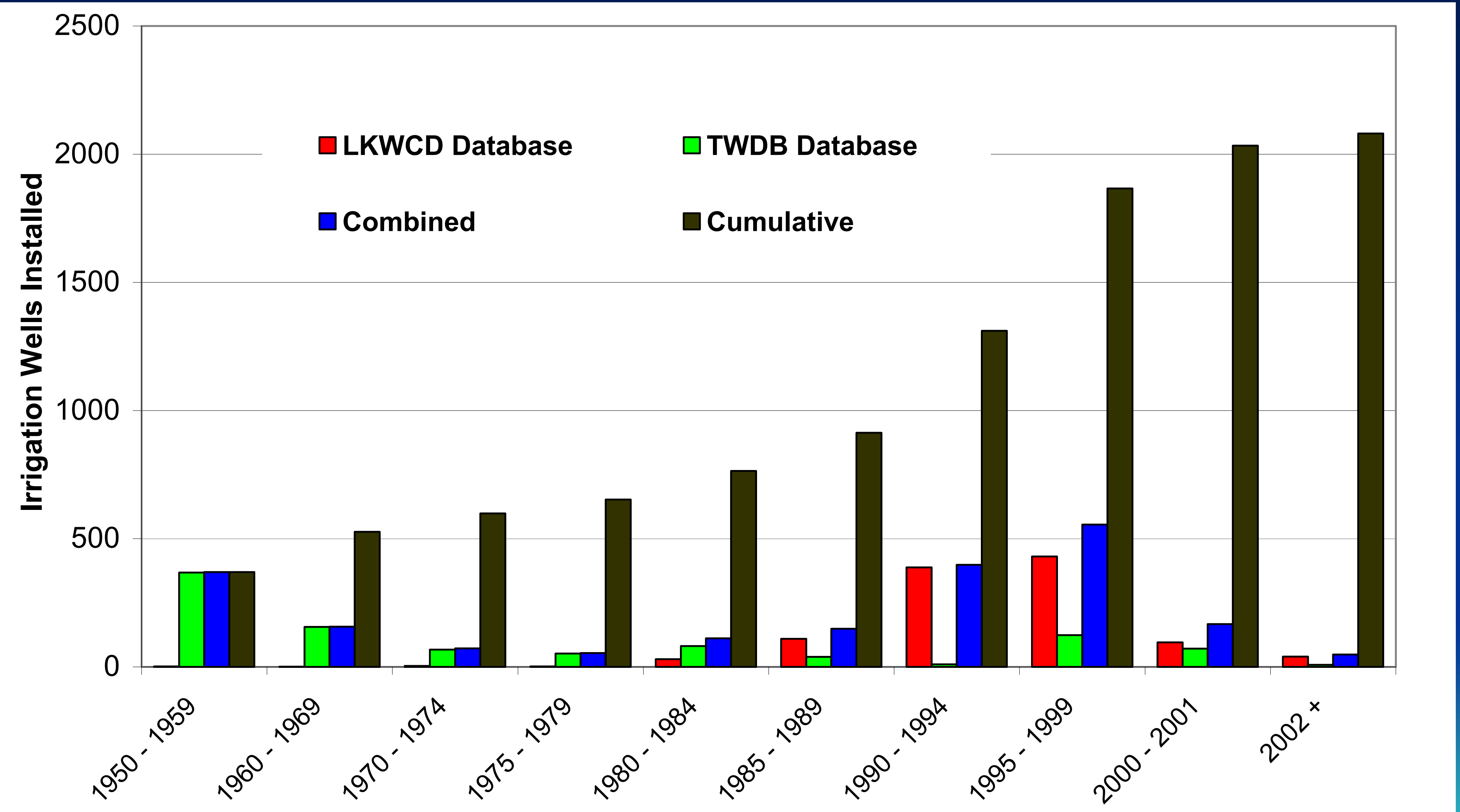


Pumping

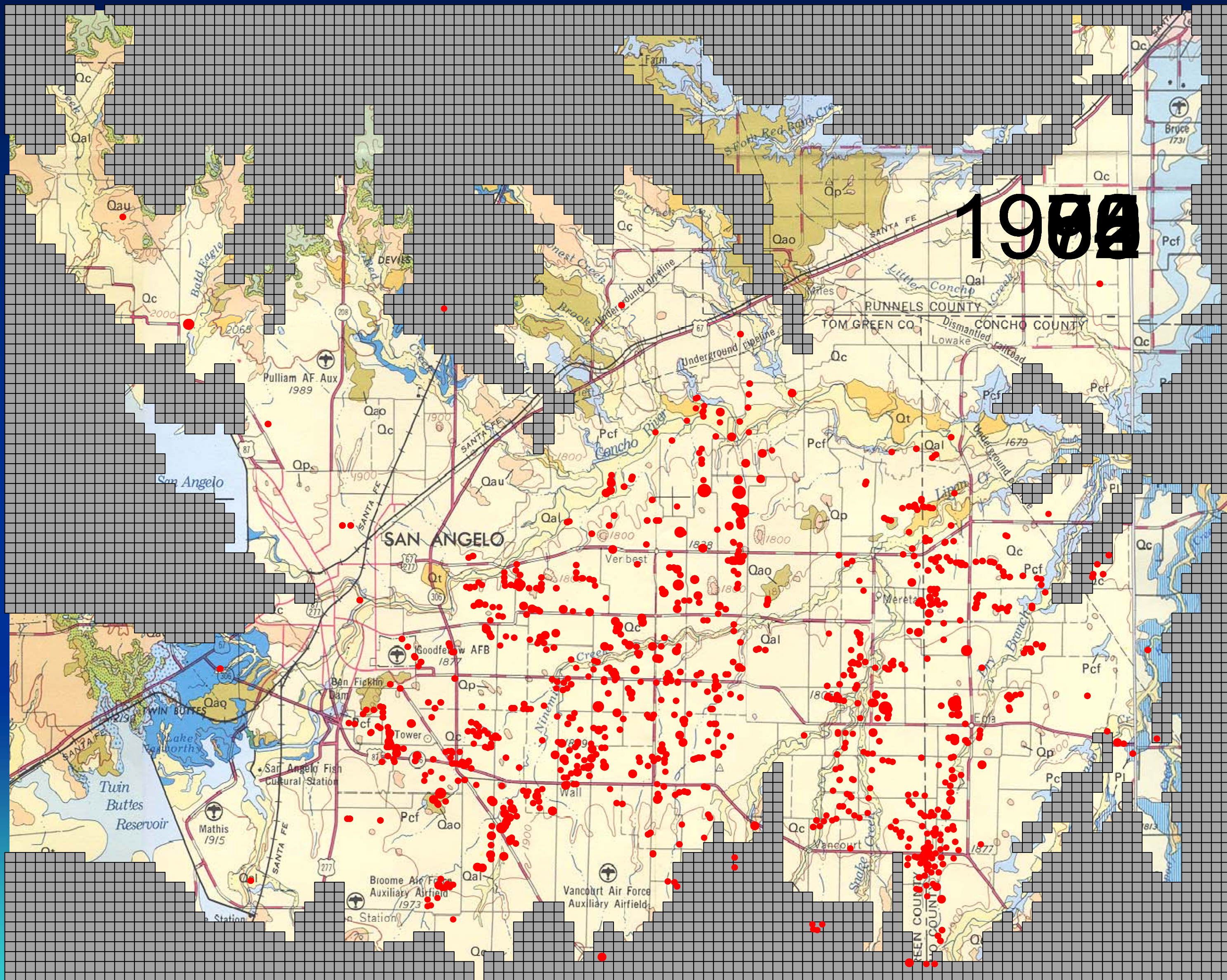


Acre Feet
80000
70000
60000
50000
40000
30000
20000
10000
0
RURAL DOMESTIC(ACFT/YR)
MINING(ACFT/YR)
MANUFACTURING(ACFT/YR)
LIVESTOCK(ACFT/YR)
MUNICIPAL CITY(ACFT/YR)
IRRIGATION(ACFT/YR)
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000

Irrigation Wells in Lipan Flats



Irrigation Well Distribution



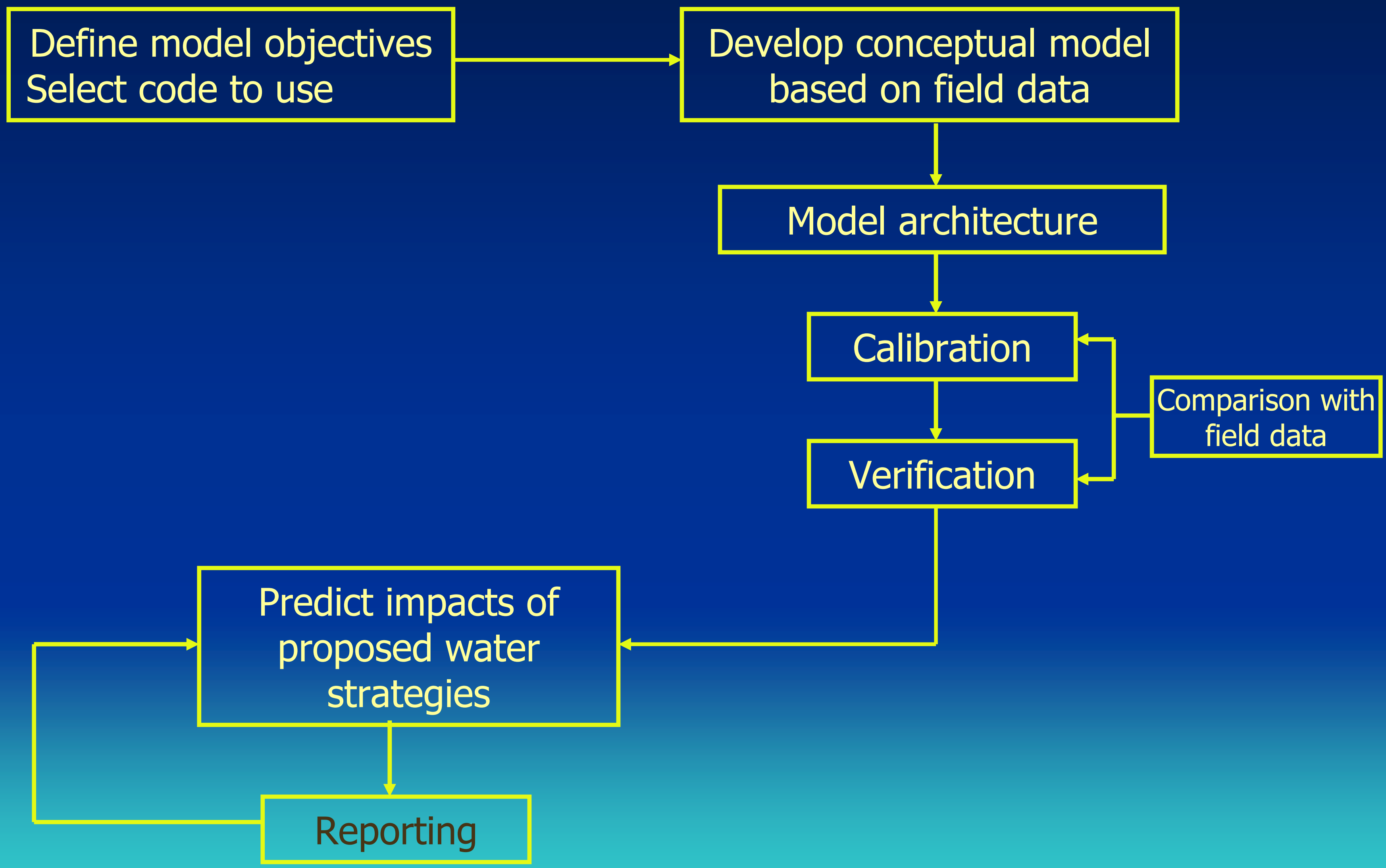
Data from Lipan-Kickapoo Water Conservation District

Model Architecture

Model Specifications

- Three dimensional (MODFLOW-96)
- Regional scale
- Includes ground/surface water interaction
- Grid spacing = ½-mile
- Calibration to within 10% of head drop

GAM Modeling Protocol



Boundary Conditions and Properties

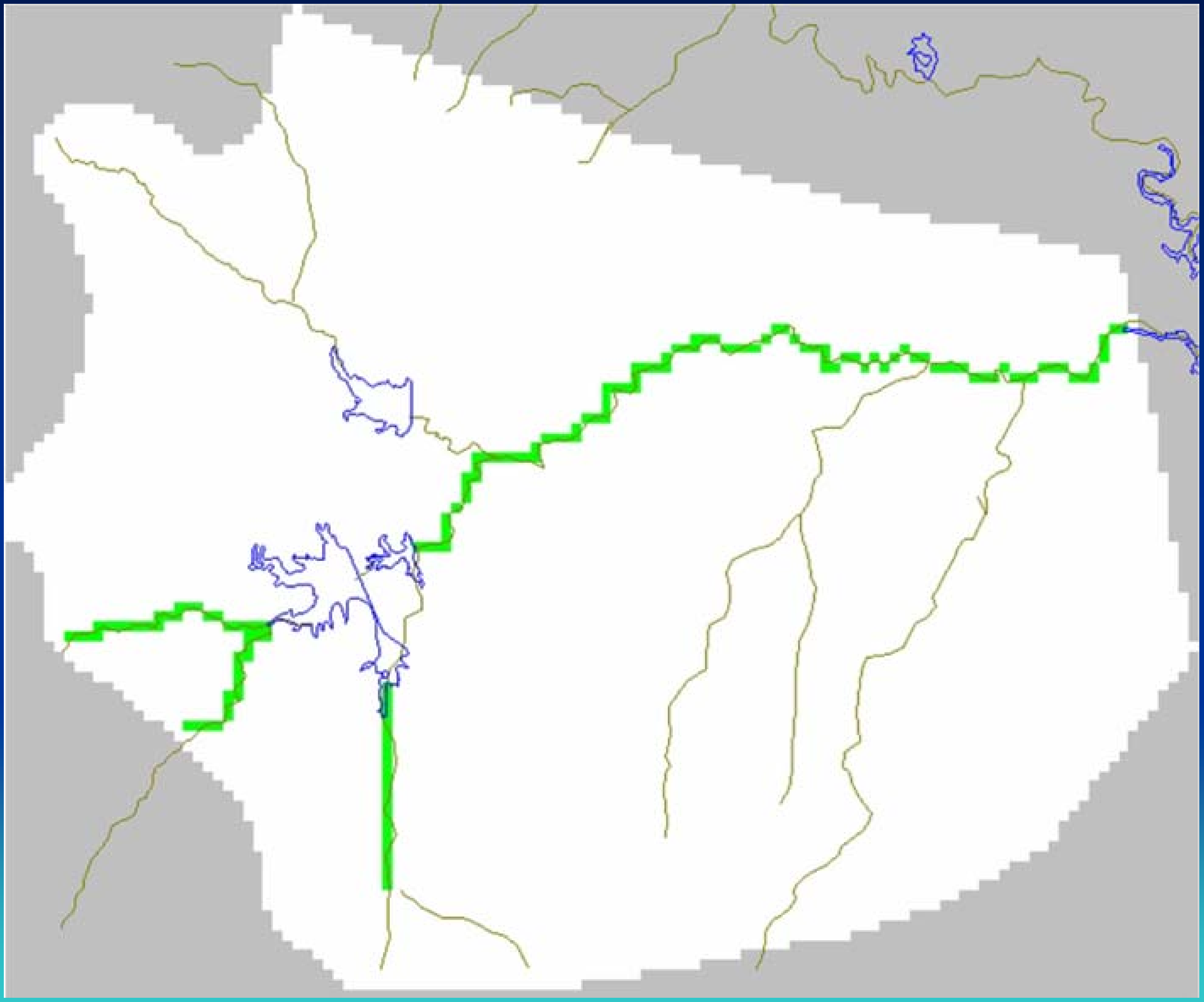
Boundary Conditions

1. Wells
2. Streams
3. Lakes
4. General Head Boundaries
5. Drains

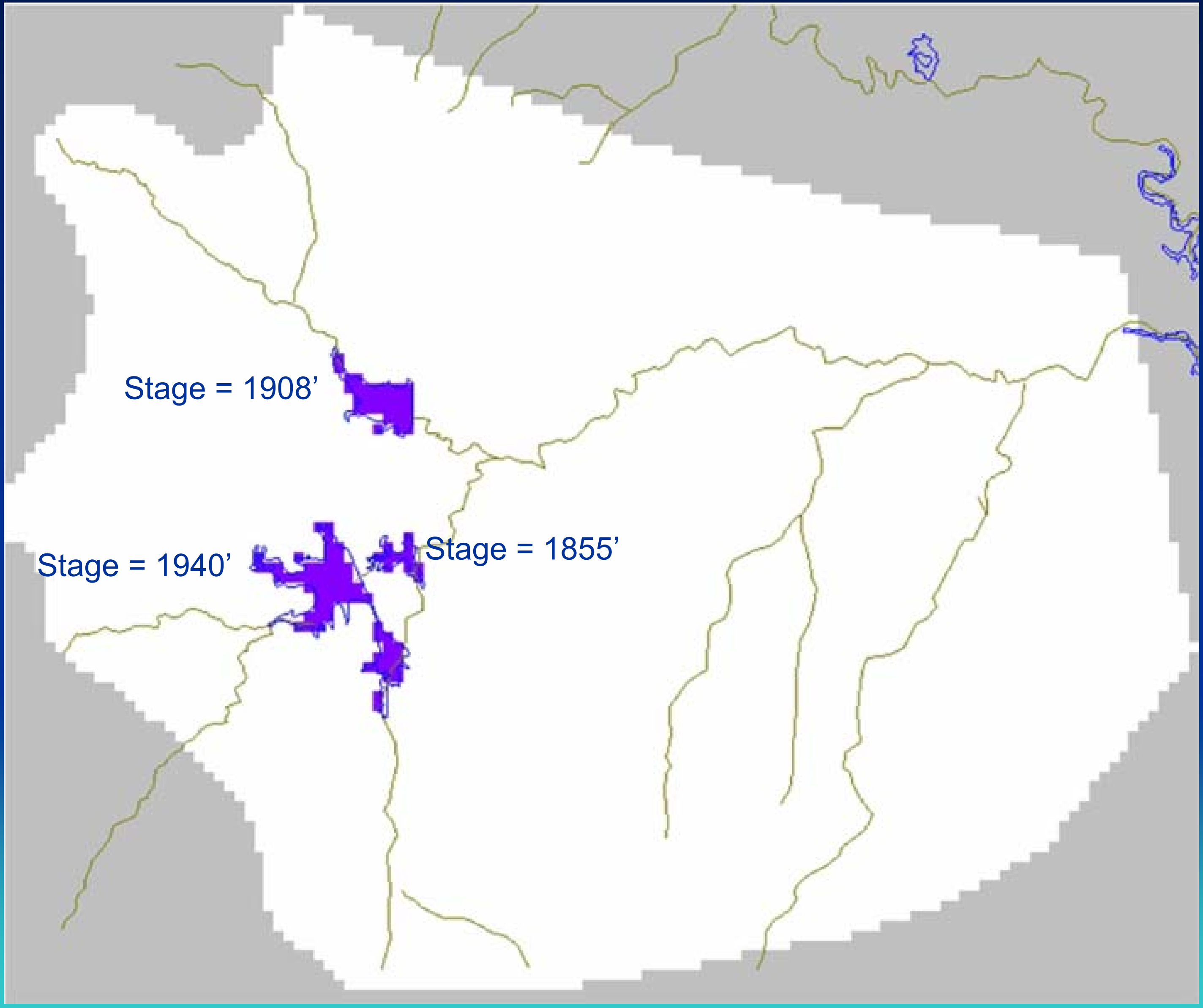
Parameters

1. Hydraulic Conductivity
2. Specific Yield
3. Recharge
4. Evapotranspiration

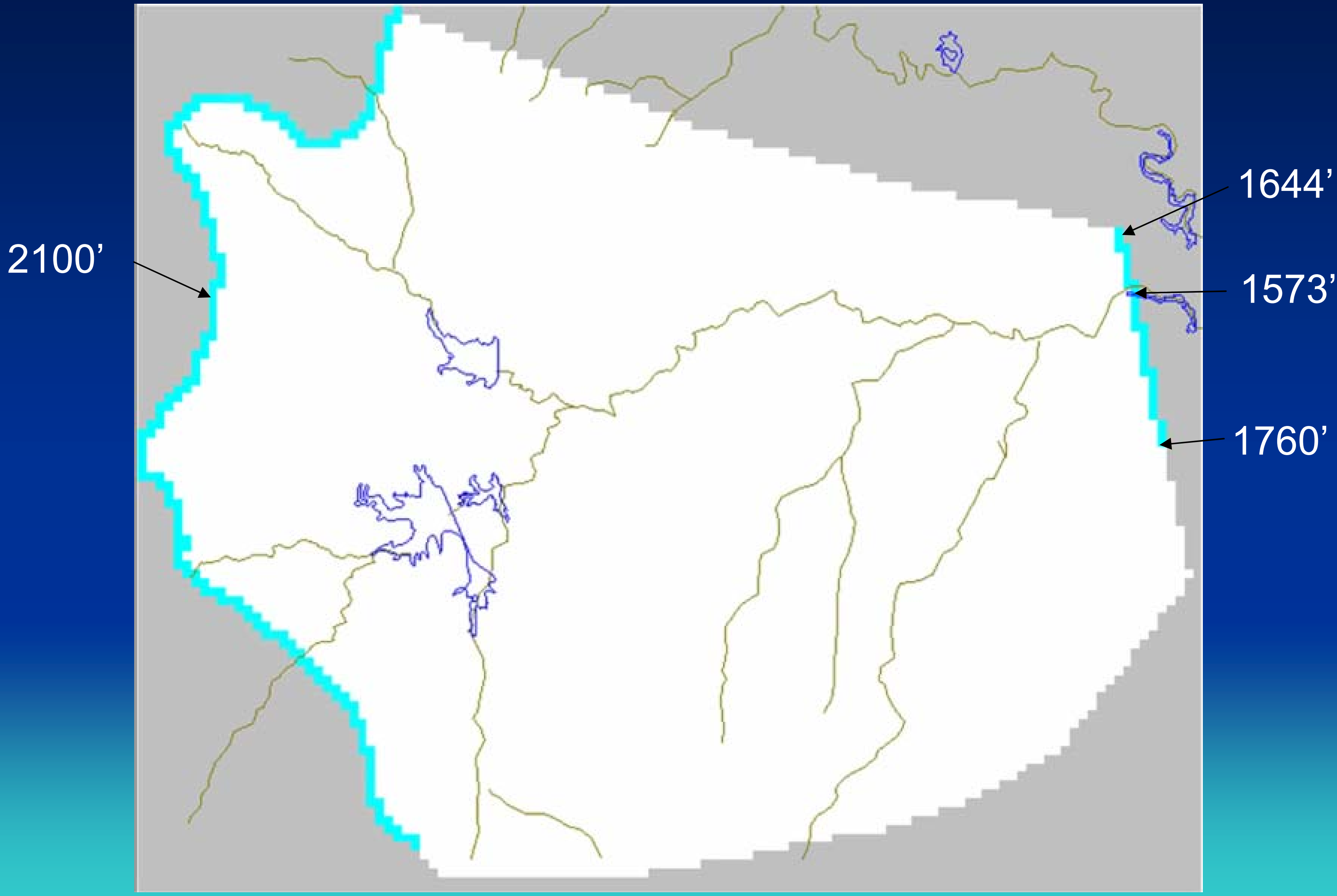
Streams



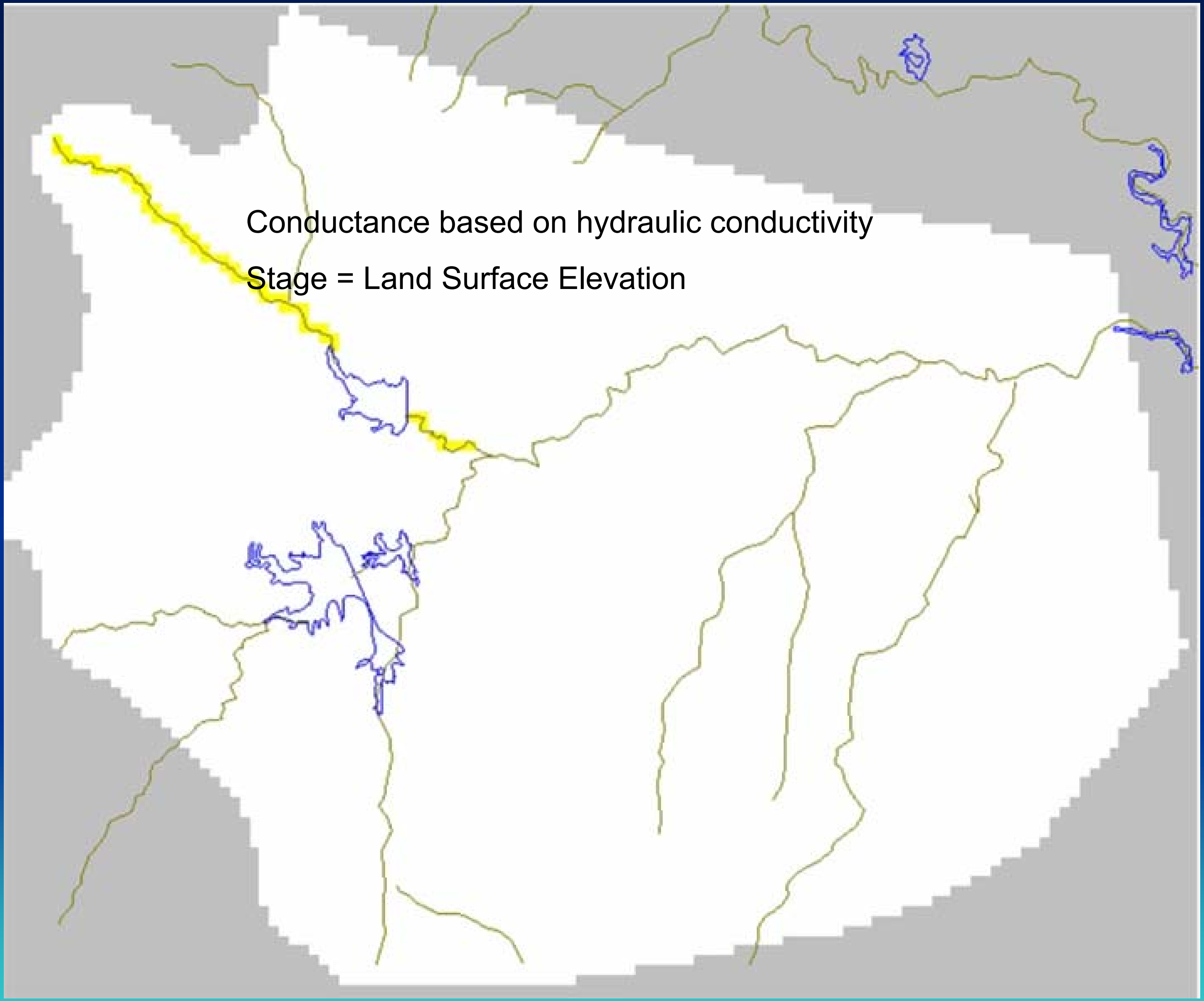
Lakes



General Head Boundaries

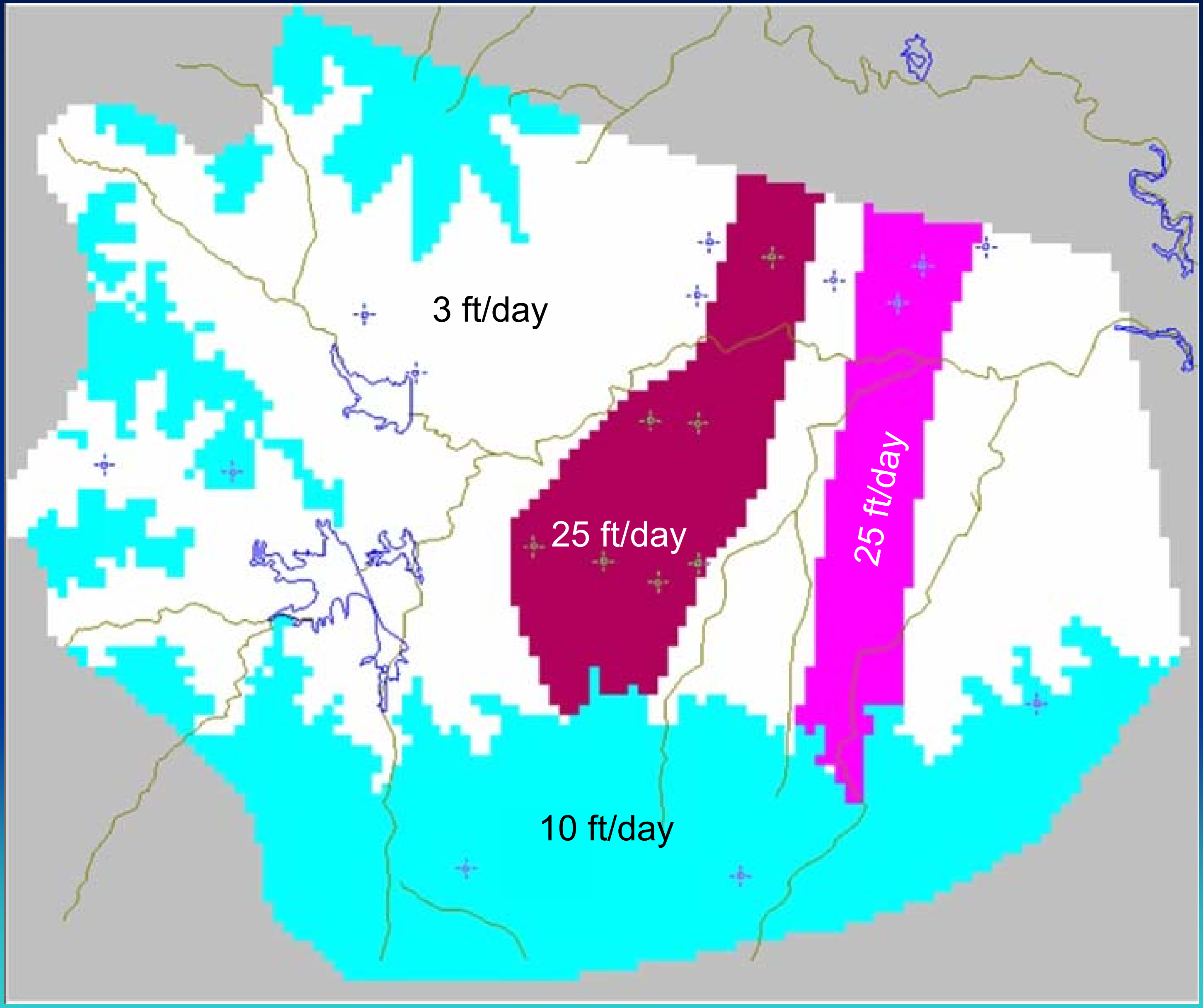


Drains

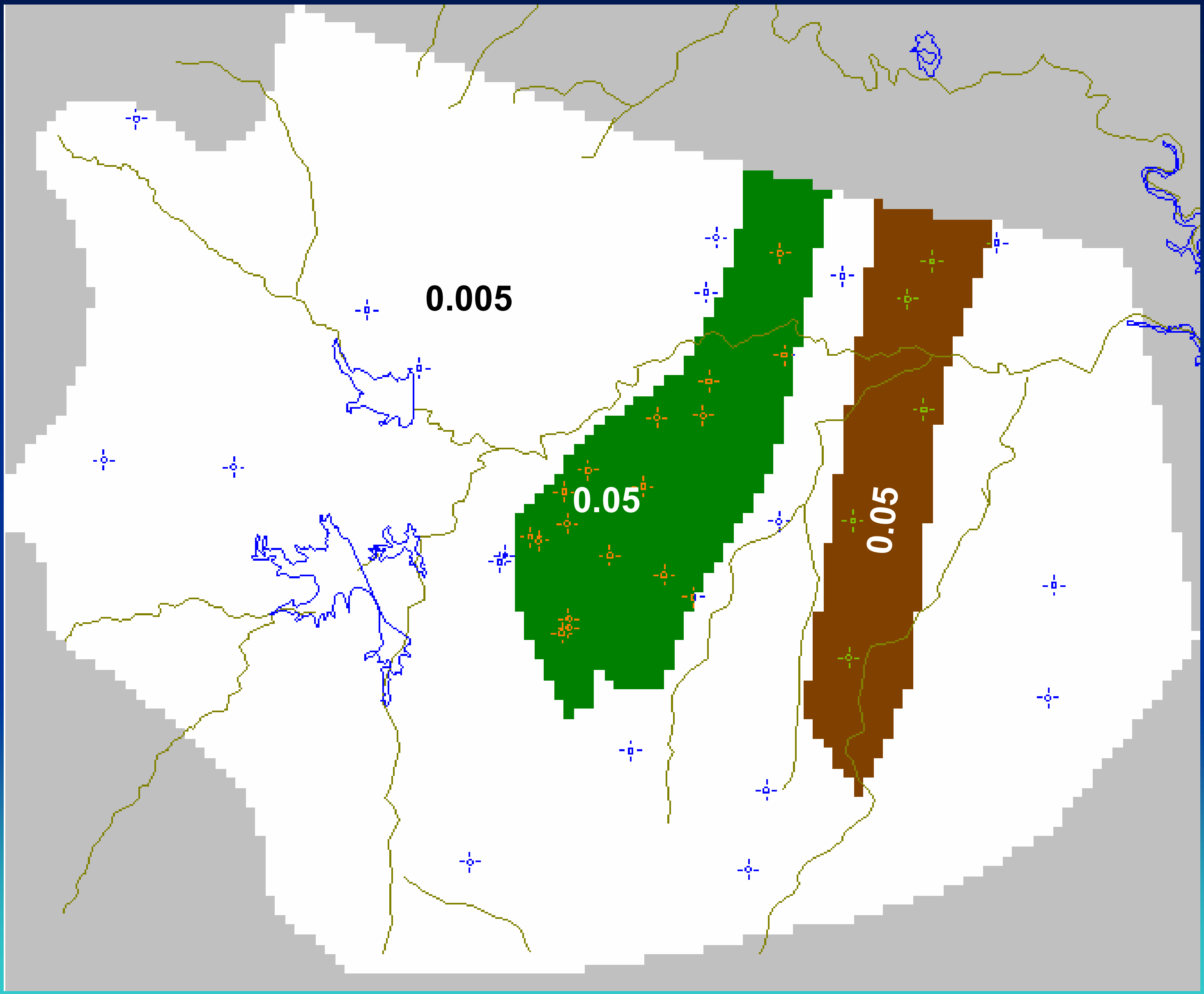


Conductance based on hydraulic conductivity
Stage = Land Surface Elevation

Hydraulic Conductivity



Specific Yield

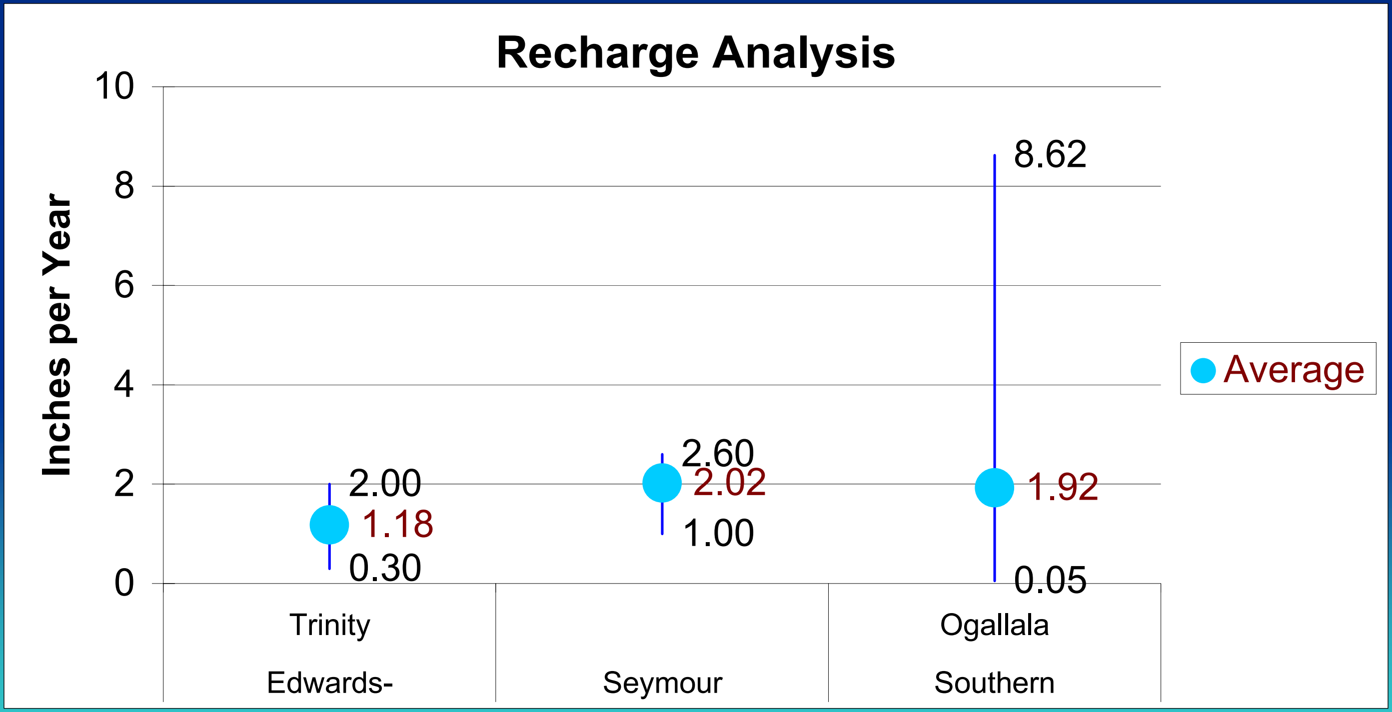


Sources of Recharge

- Precipitation
- Irrigation Return Flow
- Stream and River Leakage
- Lake and Pond Leakage
- Injection Wells

Nearby Recharge Estimates

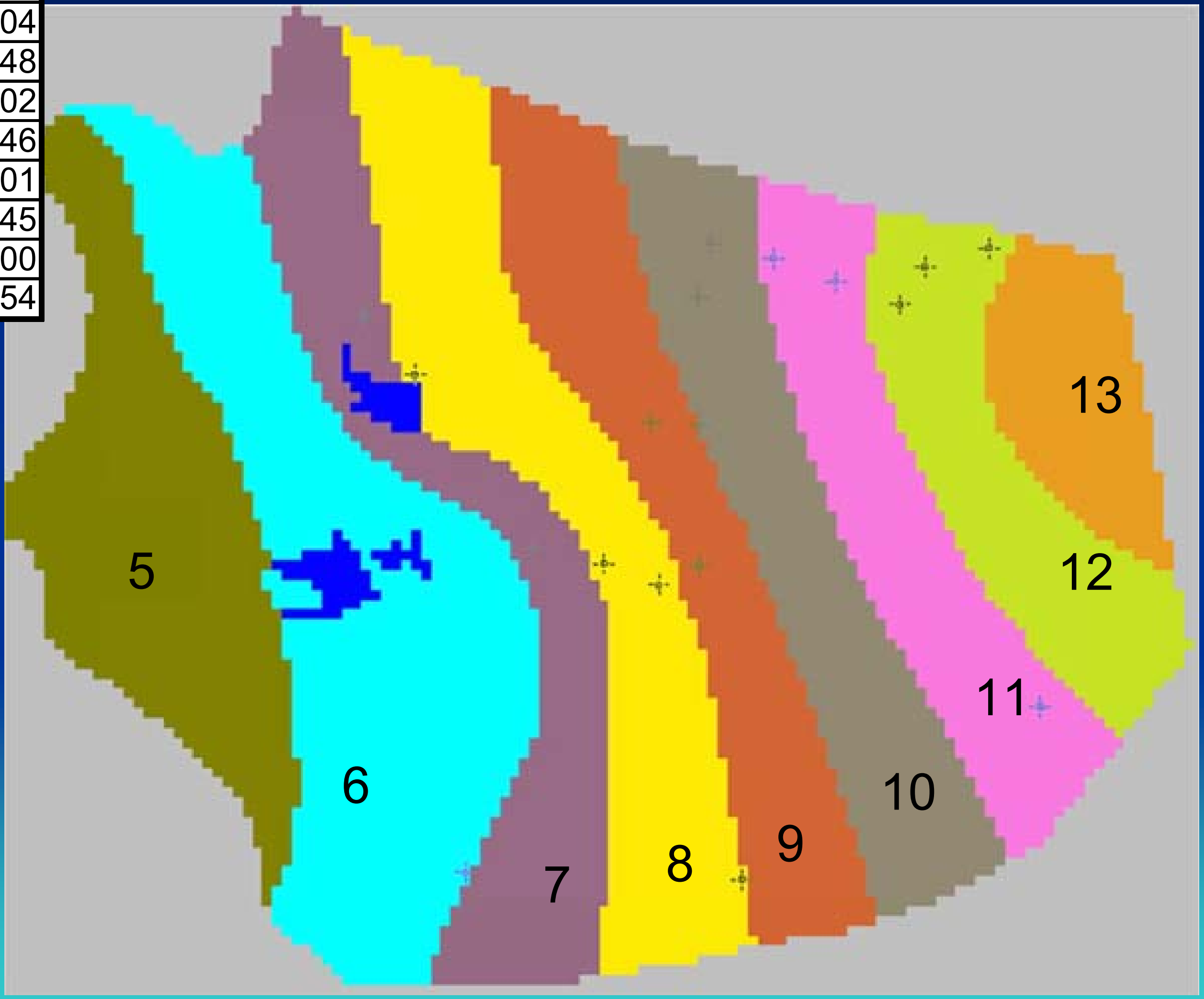
	Aquifer		
Recharge Rate (in/yr)	Edwards-Trinity	Seymour	Southern Ogallala
Min	0.30	1.00	0.05
Max	2.00	2.60	8.62
Average	1.18	2.02	1.92
Count	4	5	17



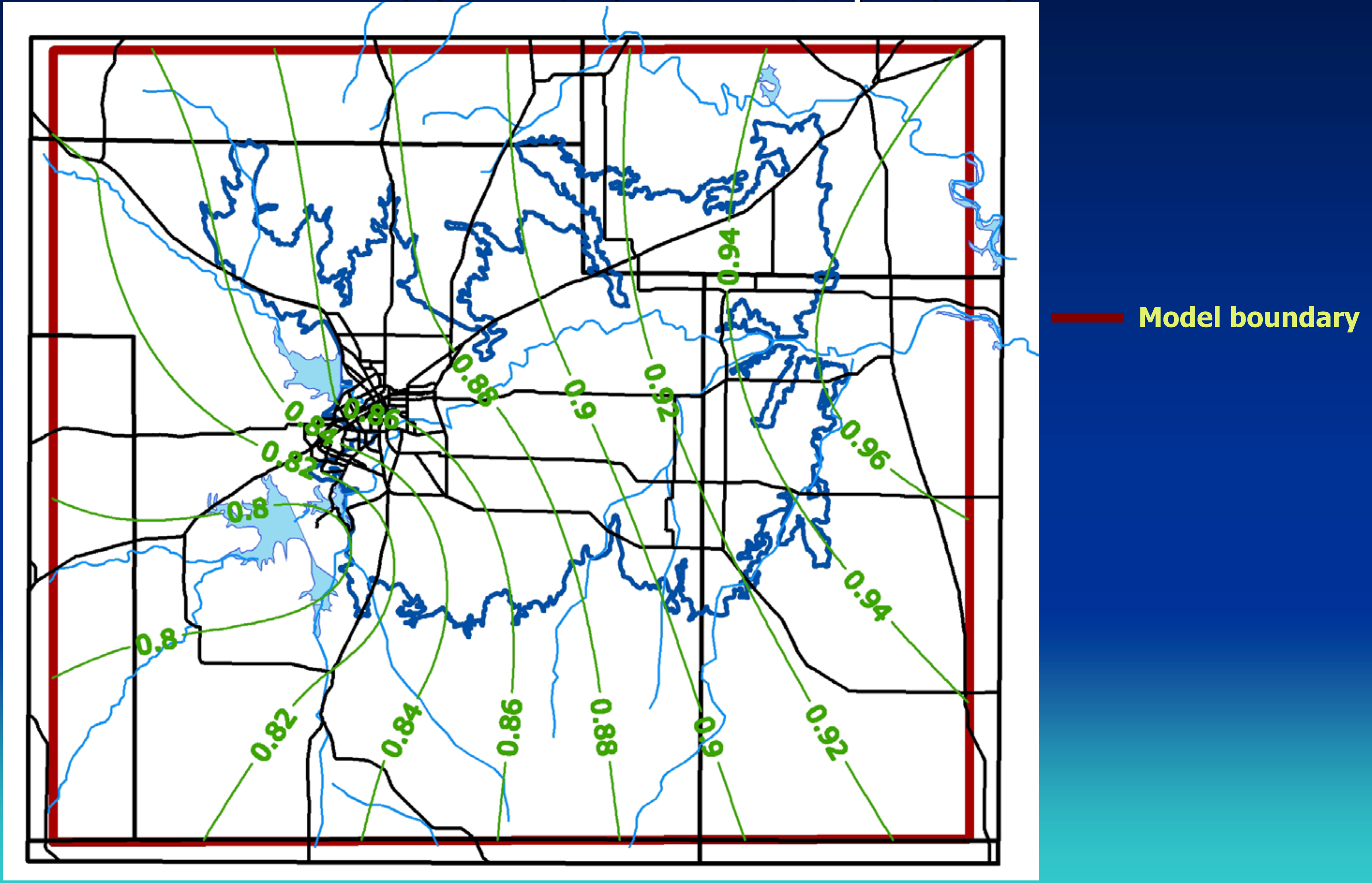
Recharge

Zone	Recharge in/yr	Rainfall in/yr
5	0.41	20.49
6	0.42	21.04
7	0.43	21.48
8	0.44	22.02
9	0.45	22.46
10	0.46	23.01
11	0.47	23.45
12	0.48	24.00
13	0.49	24.54

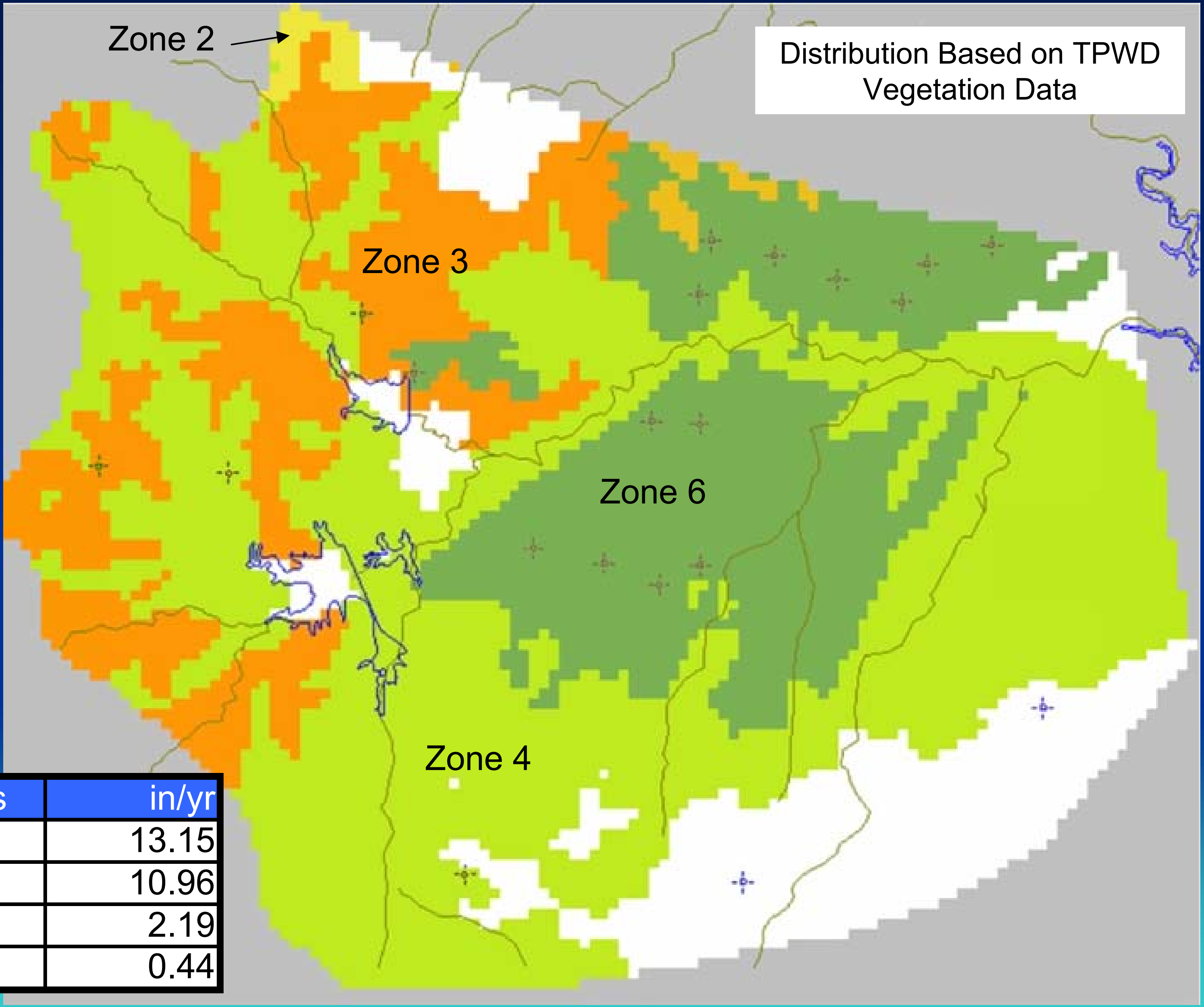
Recharge = 2% of Rainfall



Initial Estimate of Recharge as 4% of Mean Annual Historic Precipitation

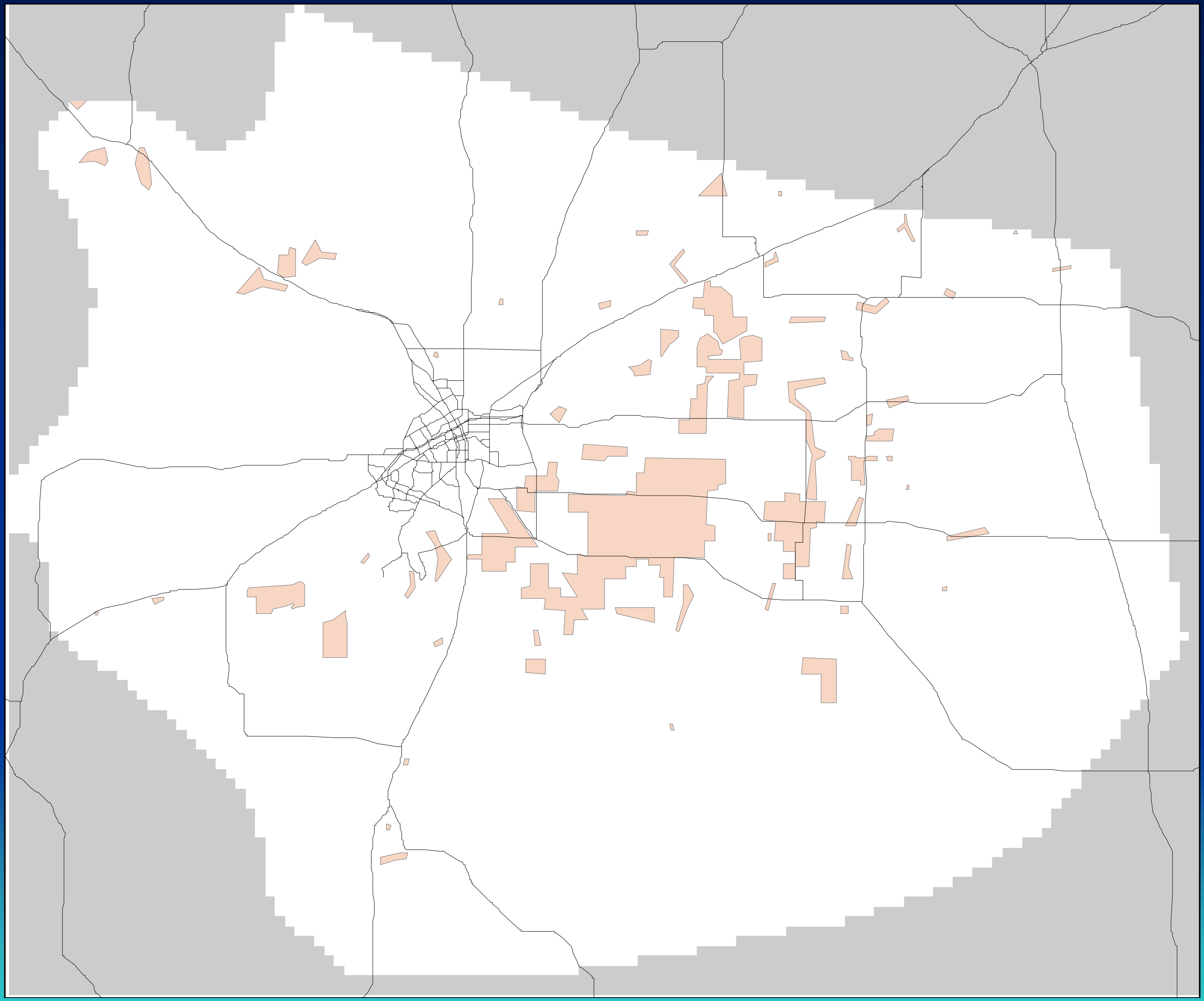


Evapotranspiration

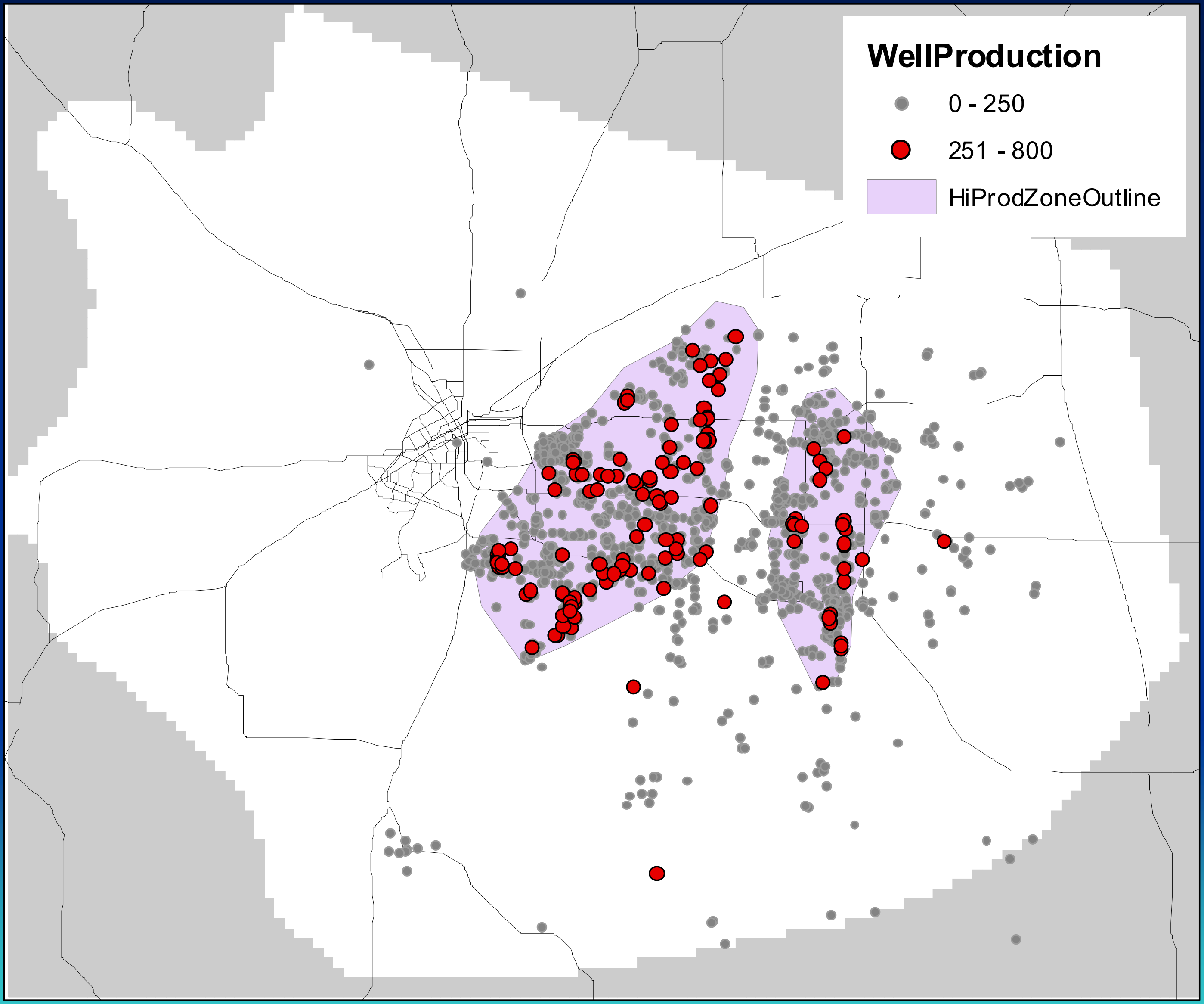


Zones	in/yr
2	13.15
3	10.96
4	2.19
6	0.44

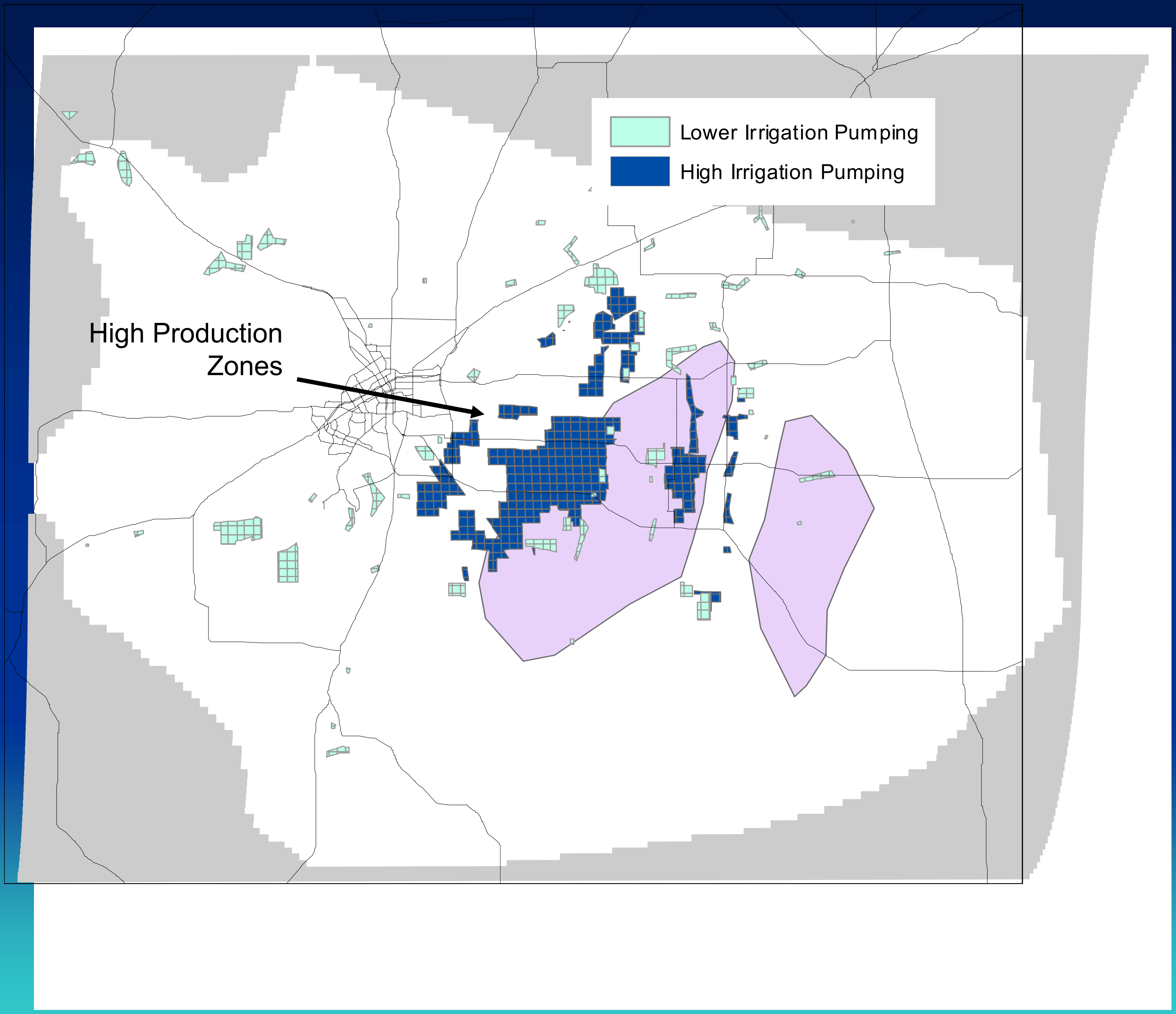
1994 Groundwater and Mixed Irrigated Lands



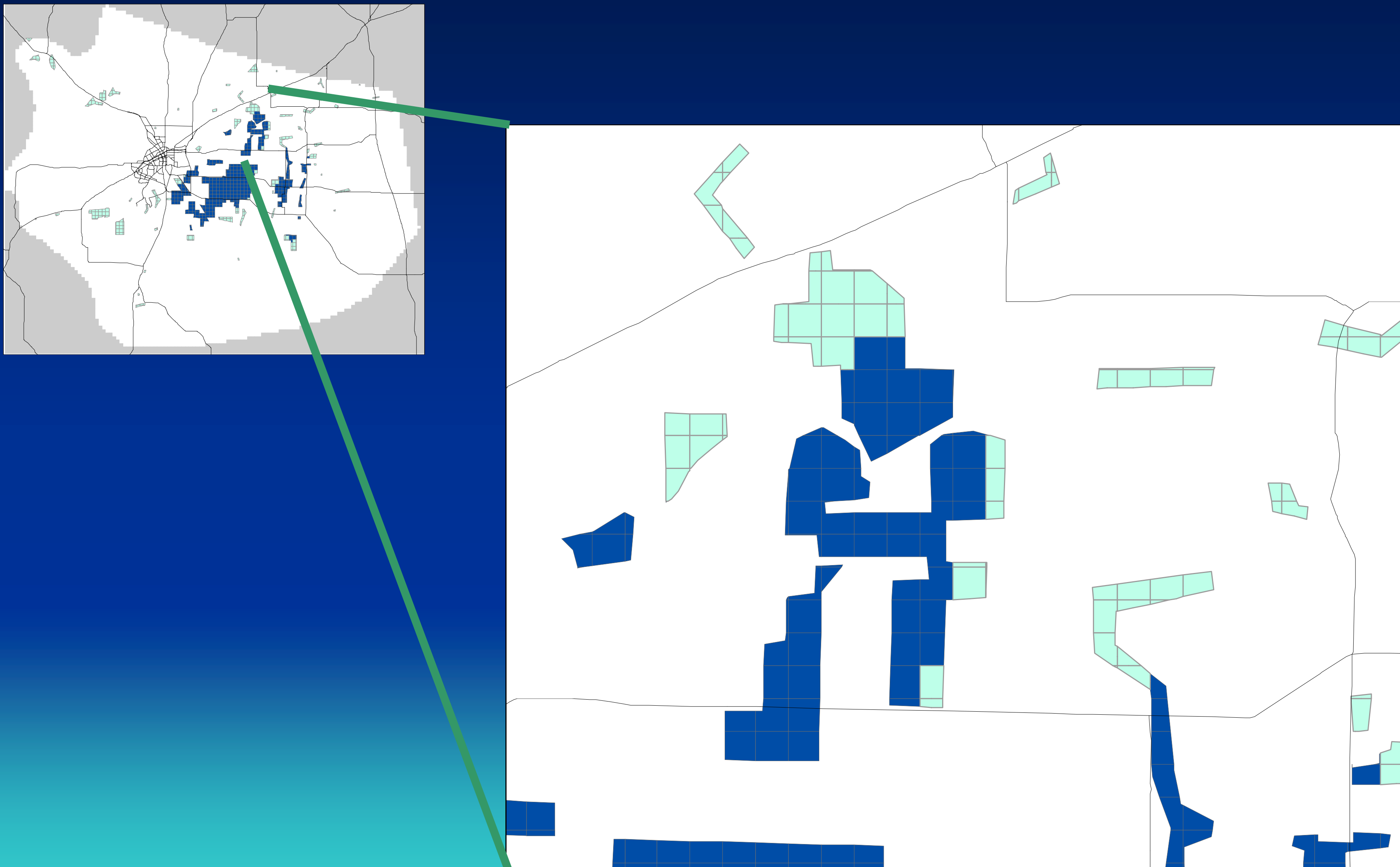
Higher Production Capacity Zones



Irrigation Pumping Distribution

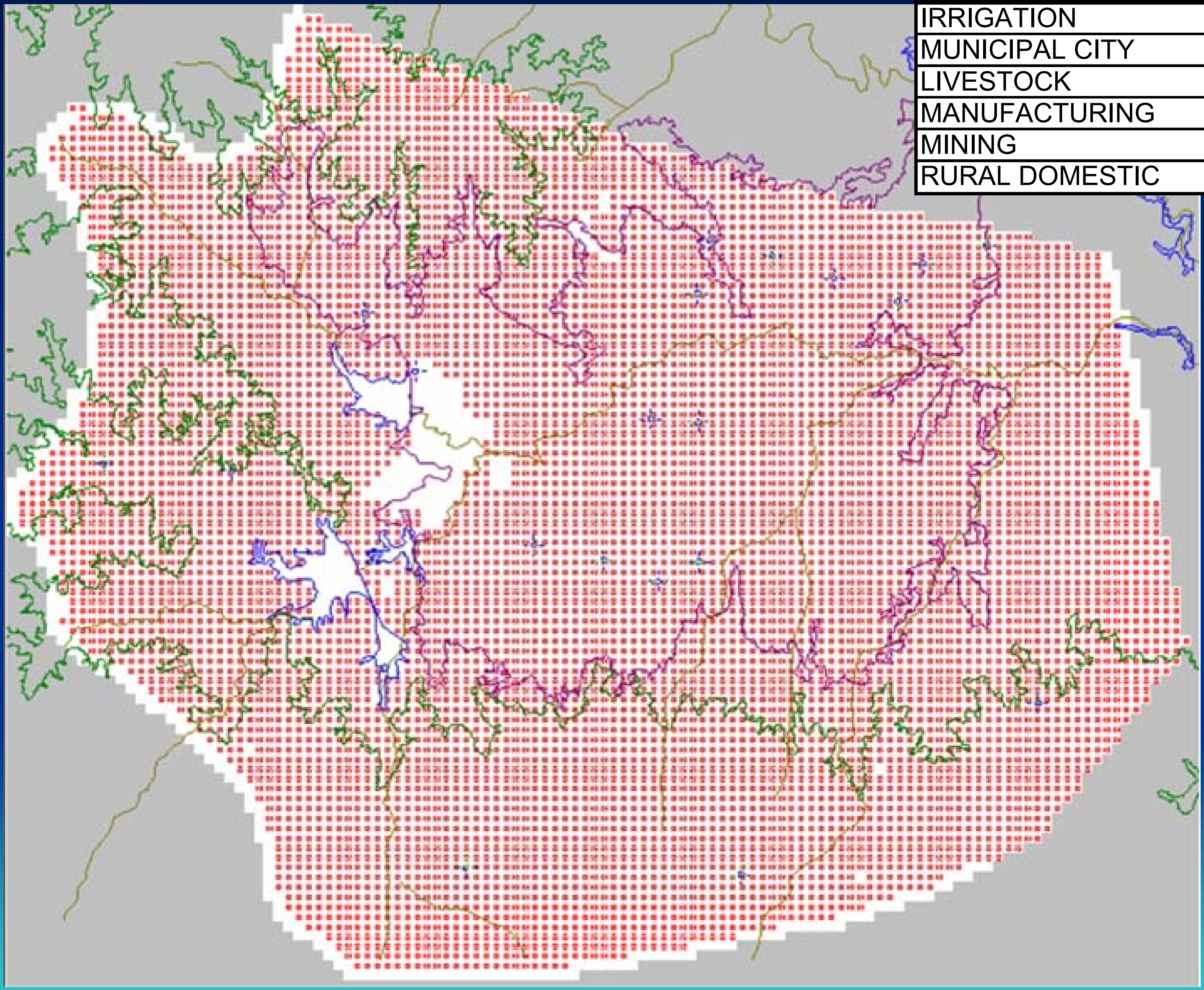


Close-up of Irrigation Distribution



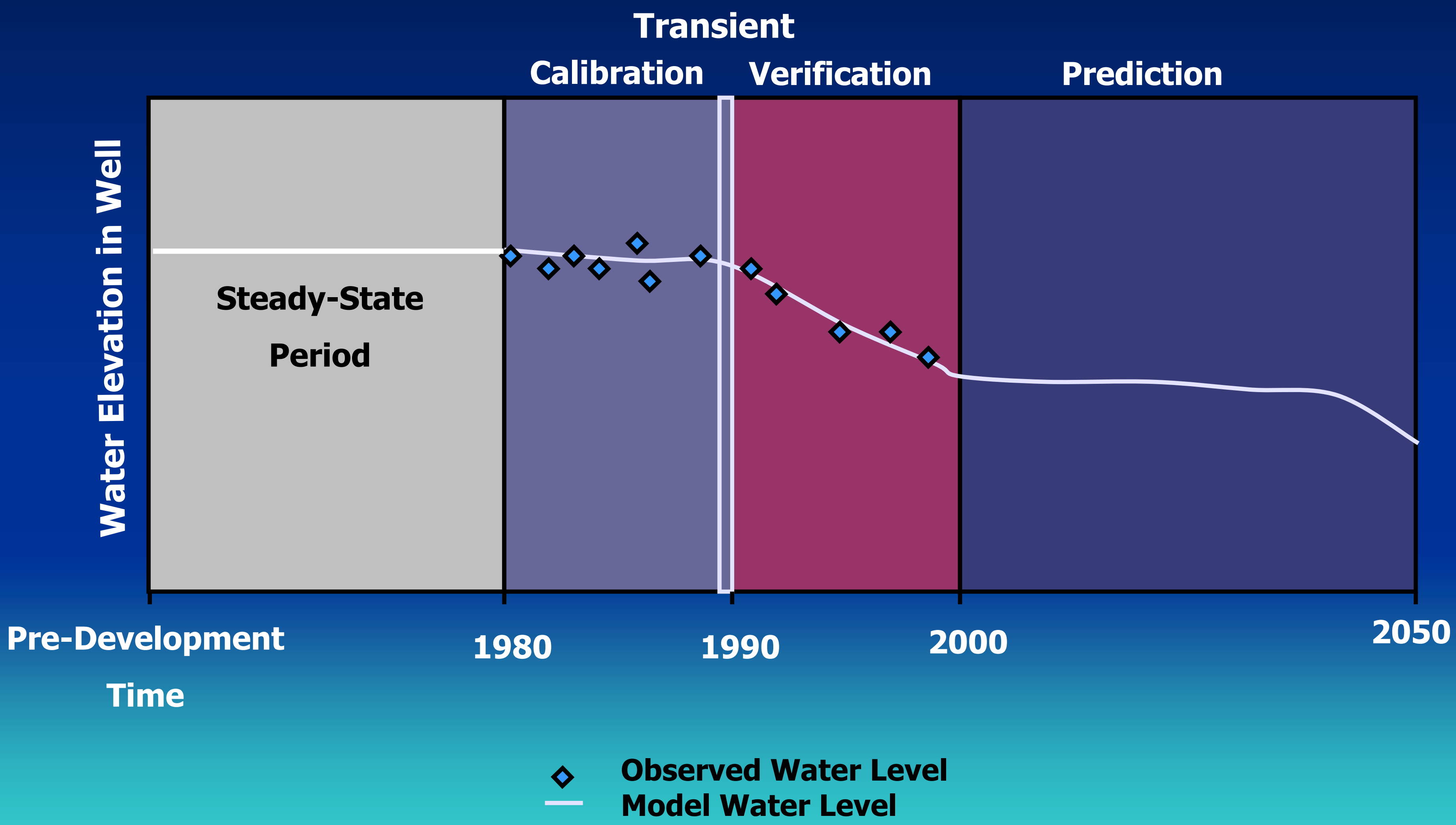
1980 Wells

Type	Acre-Feet/yr
IRRIGATION	8990.00
MUNICIPAL CITY	0.12
LIVESTOCK	27.00
MANUFACTURING	44.73
MINING	0.007
RURAL DOMESTIC	1364.36



Model Calibration Results

Lipan GAM Modeling Periods

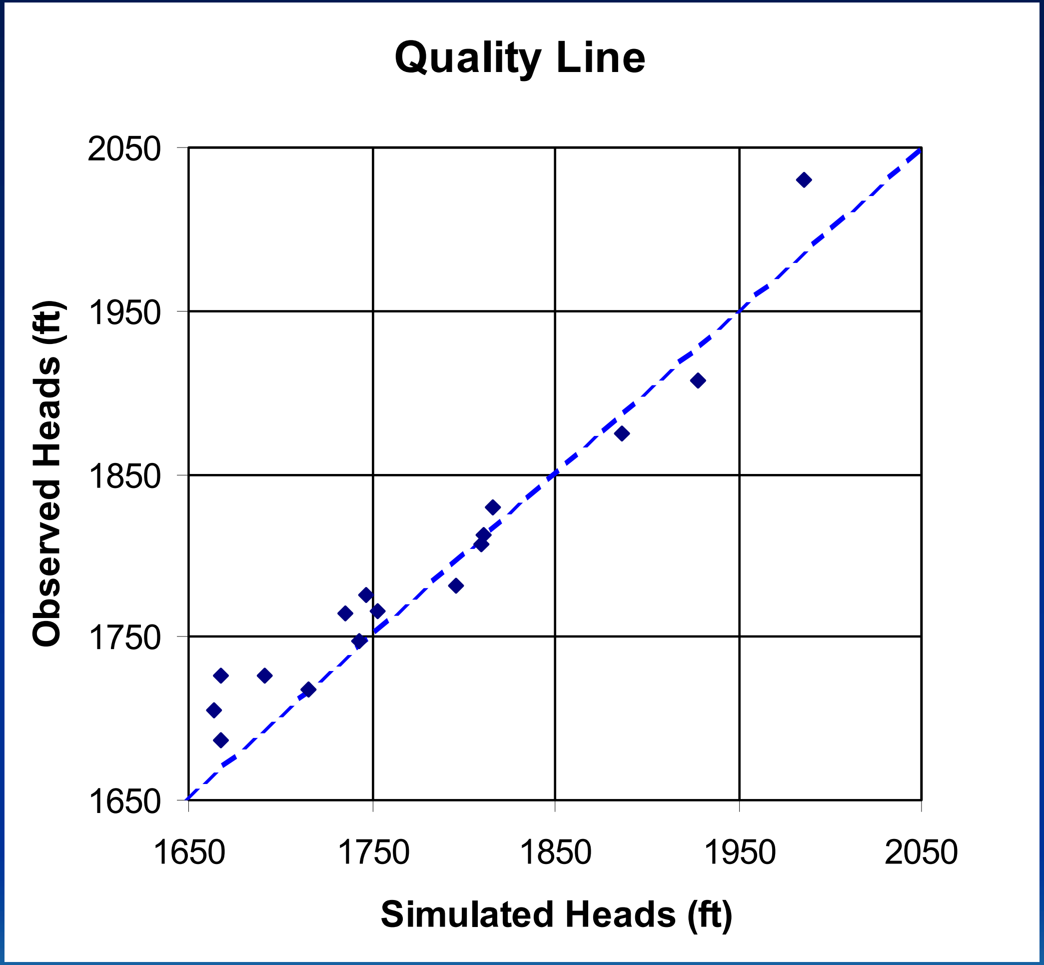


Simulation Time Frame

- Modeled 1980 as Steady-State
- Incorporated 1980 Pumping Stresses
- Transient Calibration 1980 – 1990
- Transient Verification 1990 – 2000
- Predictive Simulations 2000 - 2050

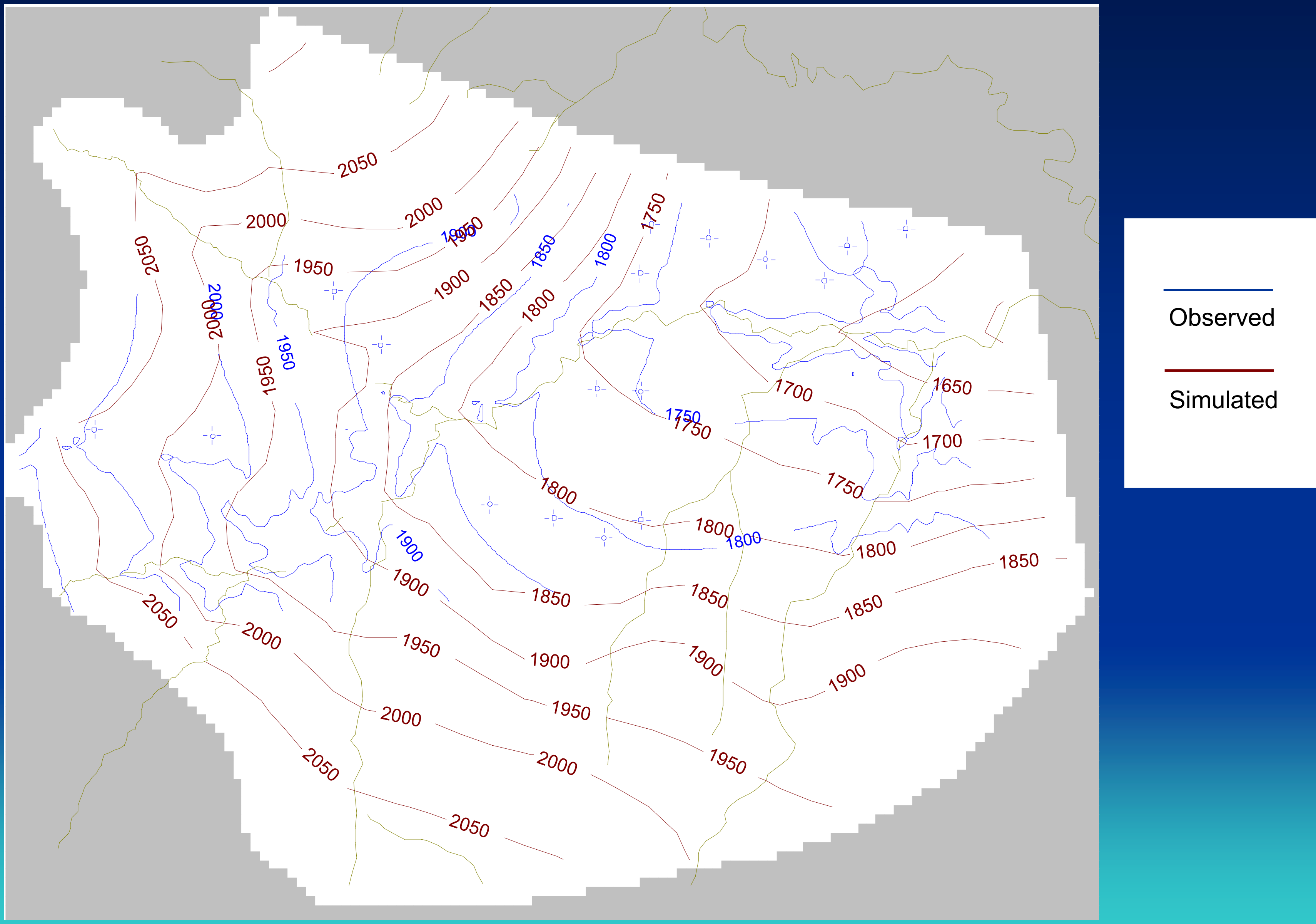
Time Frame	Stress Periods	Years
Steady-State	1	< 20,000
Transient	20	20
Predictive	50	50

Analysis of Steady-State Calibration

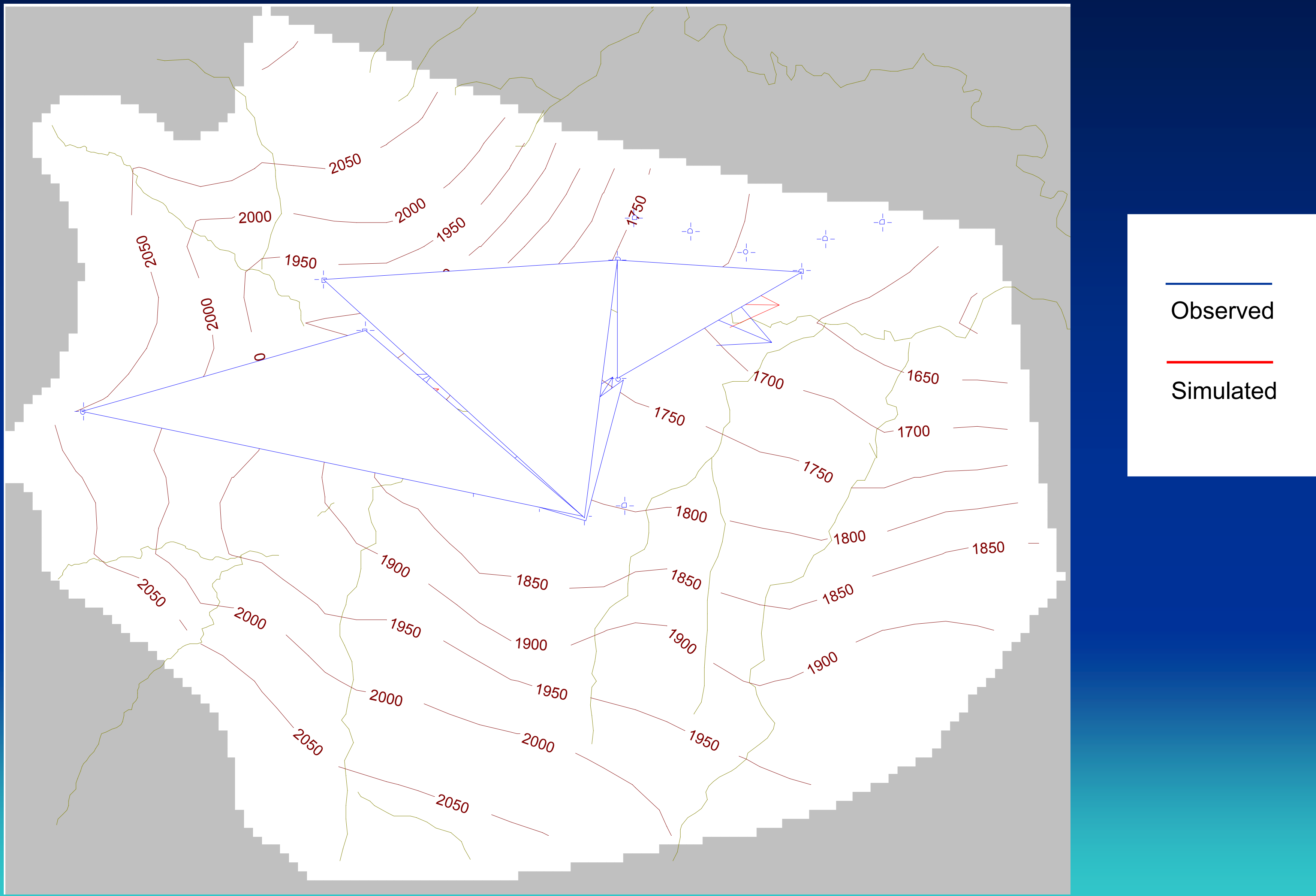


Mean Residual	12.80 ft
Mean Absolute Error	21.17 ft
RMS Error	26.33 ft
Range	343.03 ft
RMSE /Range	7.68 %

Simulated Water Levels



Gradients


2050
2000
1950
1750
1700
1650
1800
1850
1900
Observed
Simulated

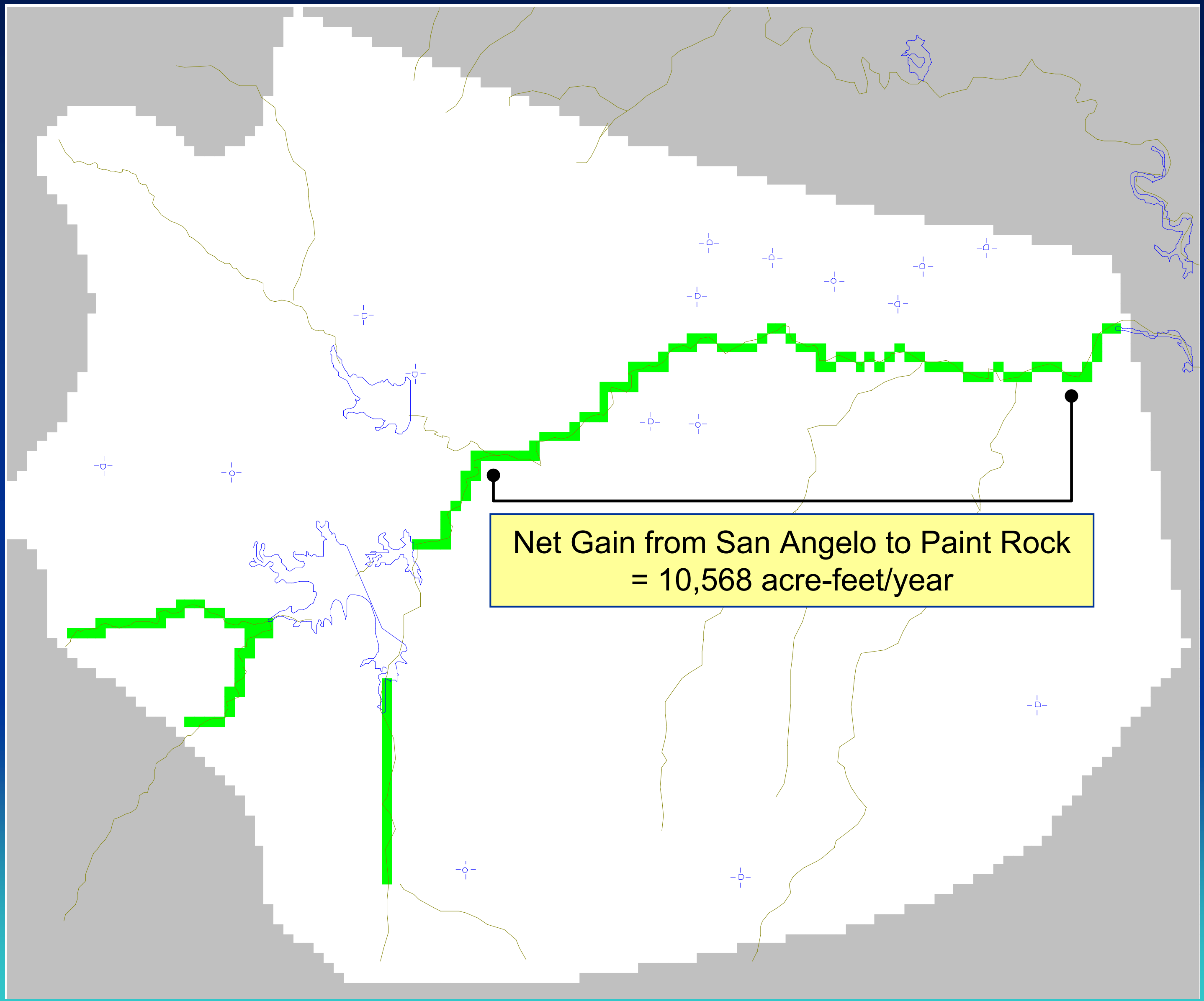
Concho River Low Flow Analysis 1979 - 1981

Average Minimum Flows 1979 - 1981		
Gage Location		
San Angelo	8.19	cfs
Paint Rock	25.00	cfs
Gain (+) / Loss (-)	16.81	cfs
Ft3/day	1,452,035.08	
Acre-ft/Year	12,175.29	

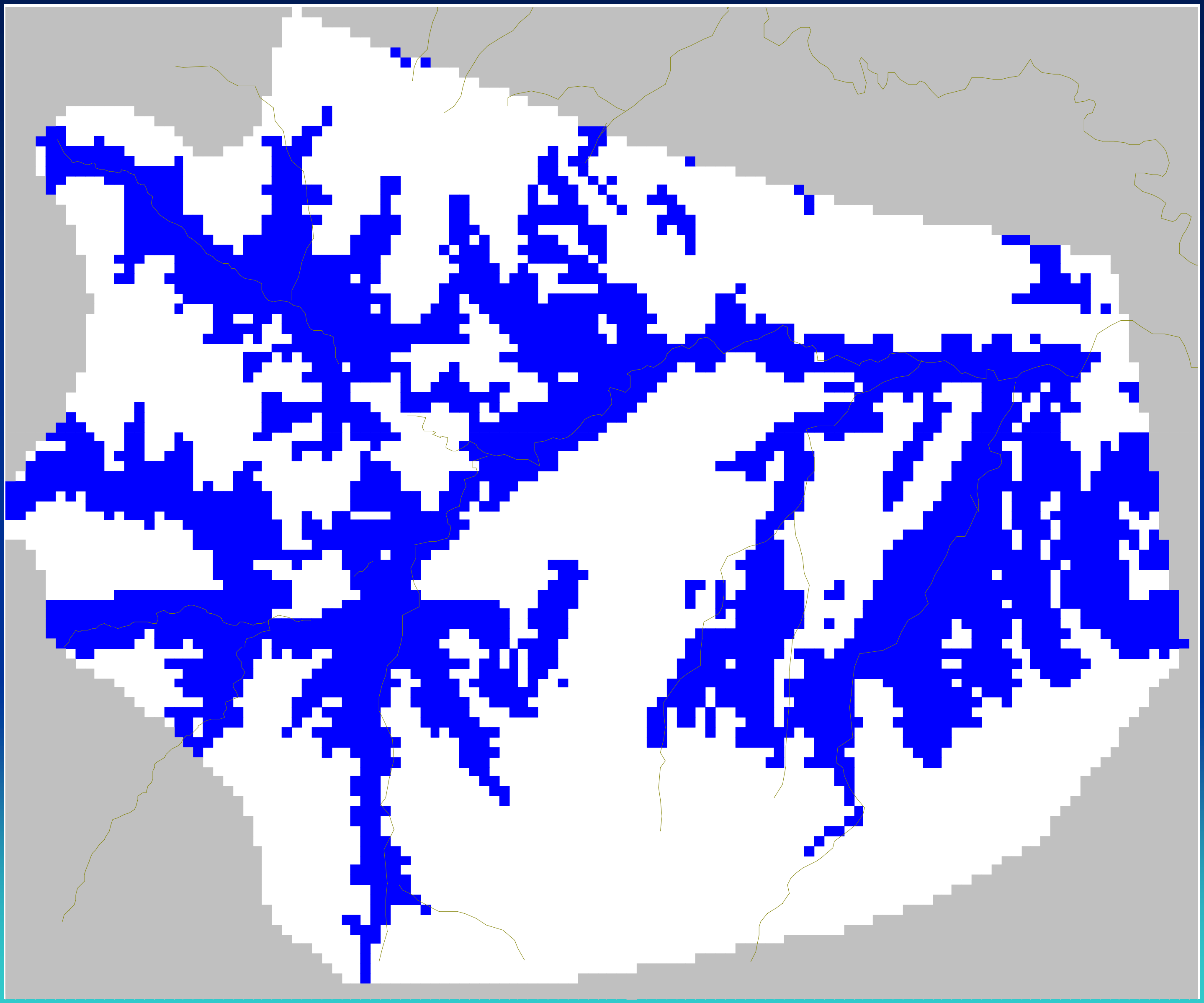
Stream Flow Responses

- For different Calibration simulations, river gains from San Angelo to Paint Rock varied from 1,000 acre-feet per year to over 15,000 acre-feet per year.
- Amount of gain or loss in the river is sensitive to ET Depth, ET Rate and Recharge.

Simulated Concho River Gain

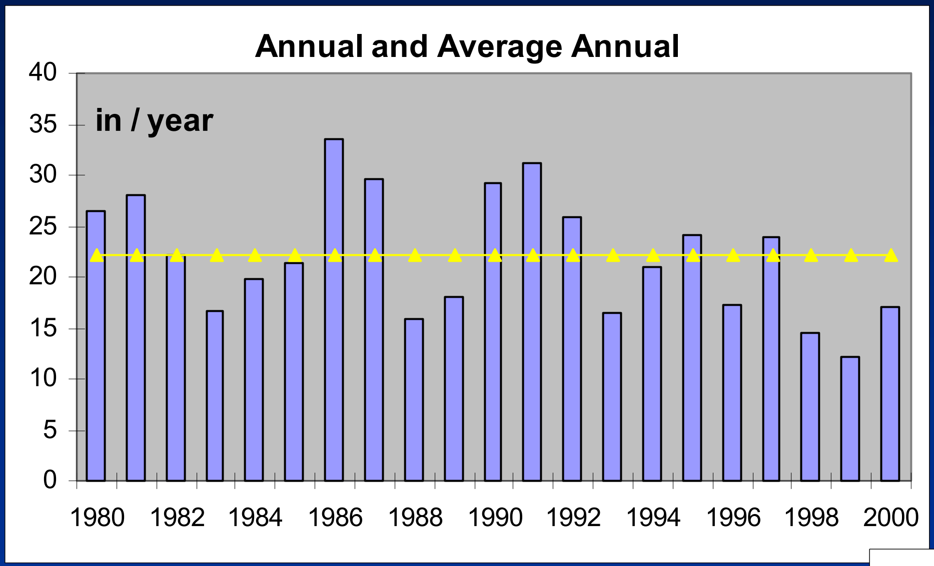


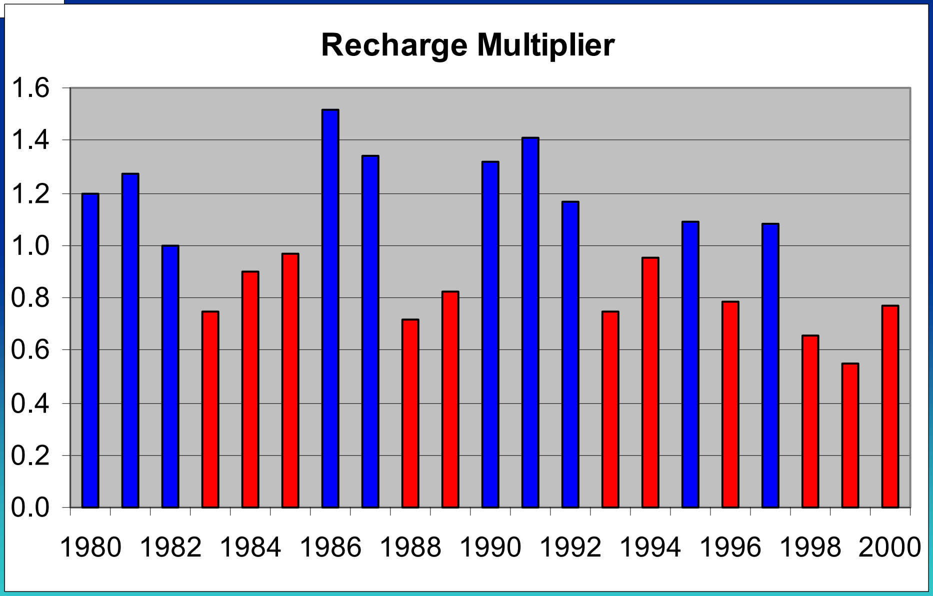
Area of Active ET Steady-State Model



Transient Calibration and Verification

Transient Recharge 1980 - 2000

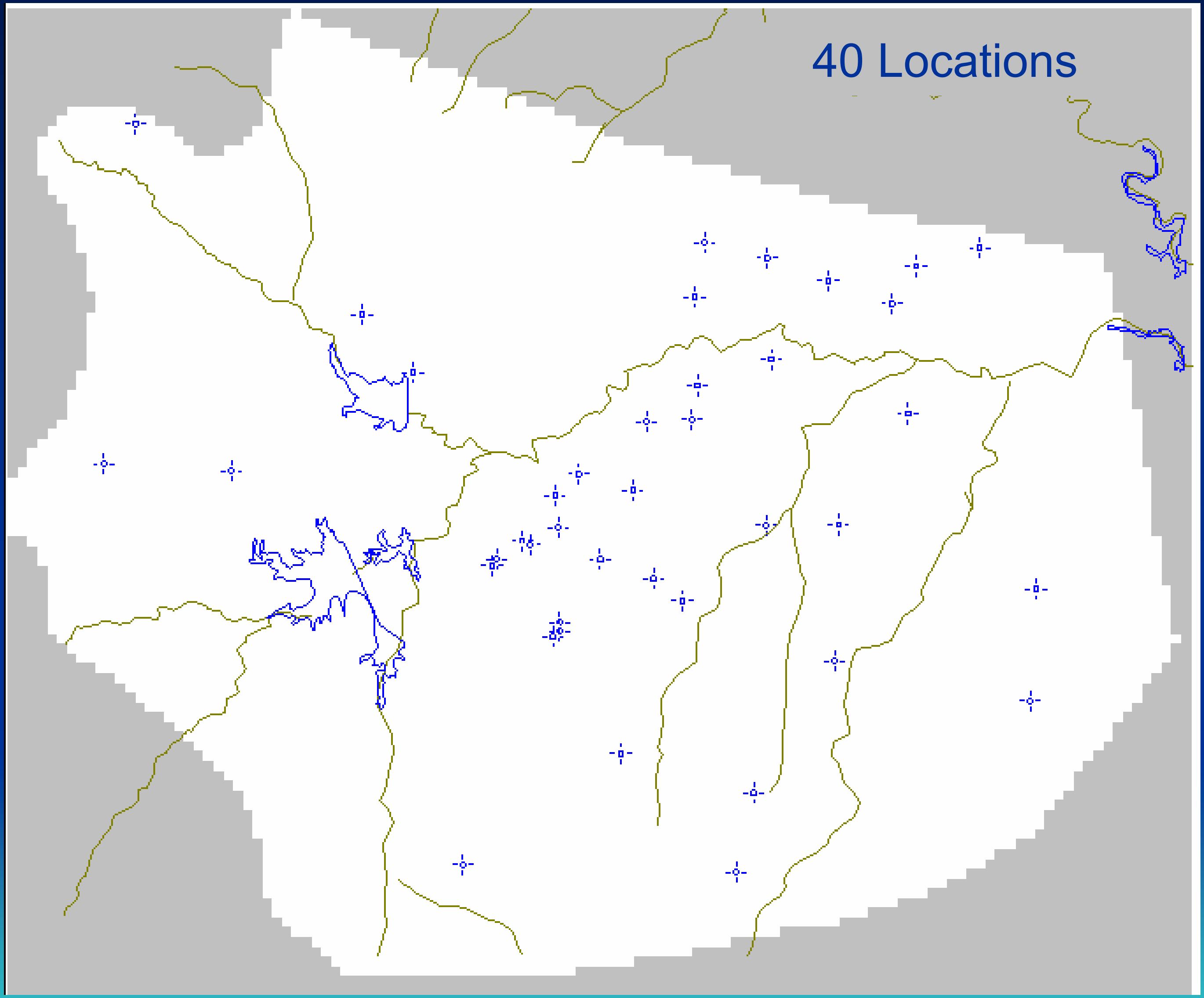




Increased Recharge

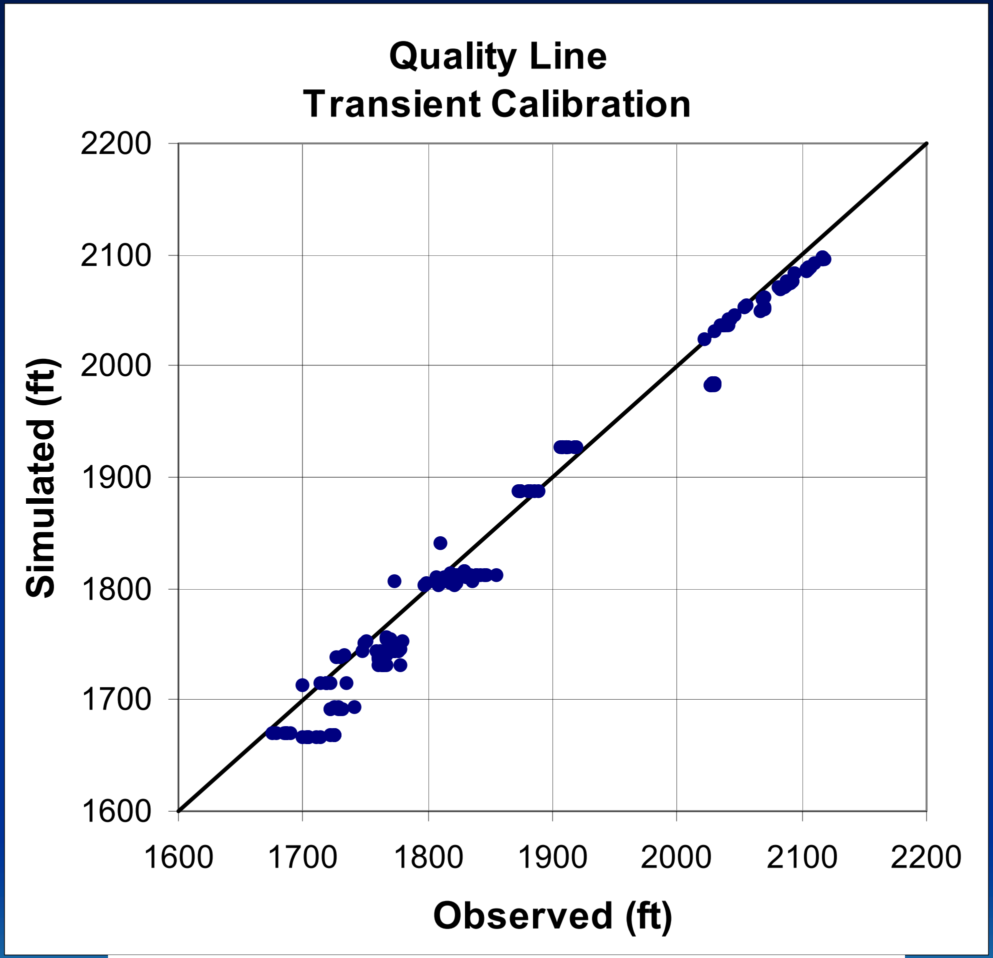
Decreased Recharge

Wells used in Calibration and Verification



Analysis of Transient Calibration

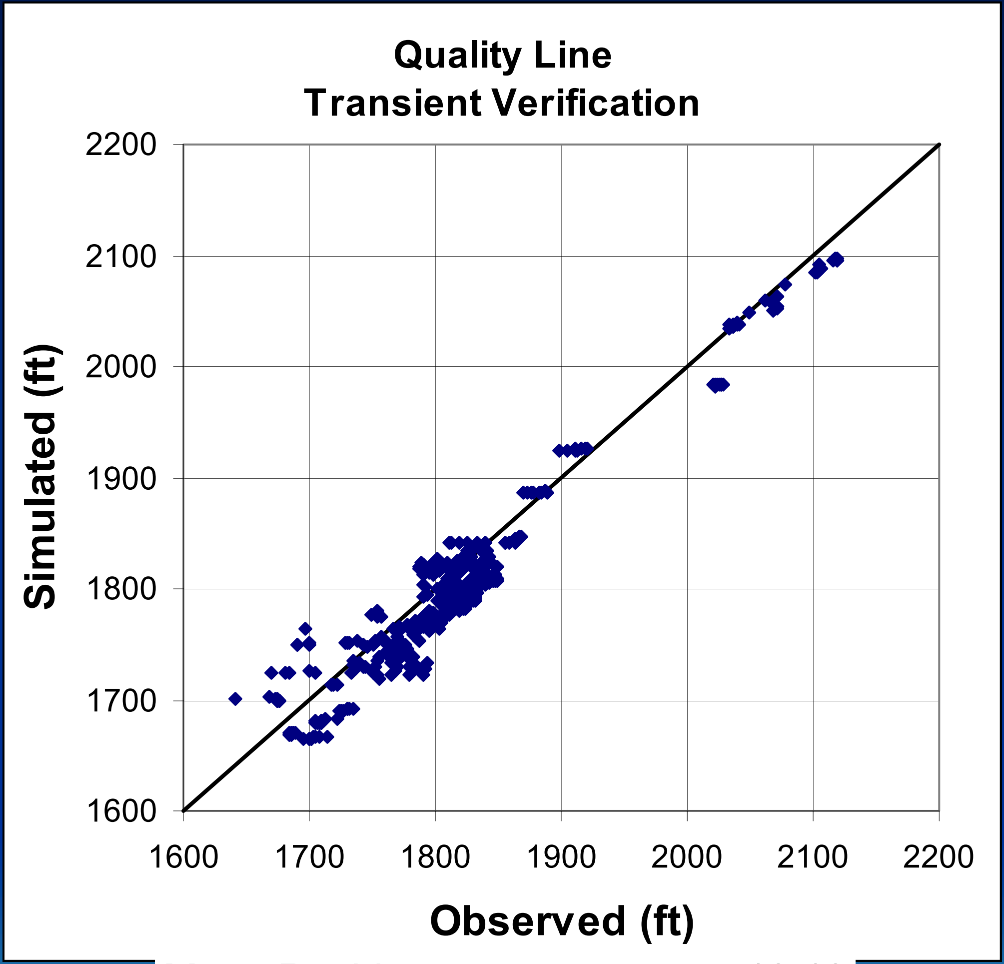
174 Data Points



Mean Residual	16.24
Mean Absolute Error	20.06
RMS Error	24.75
Range	442.39
Percent RMSE / Range	5.60

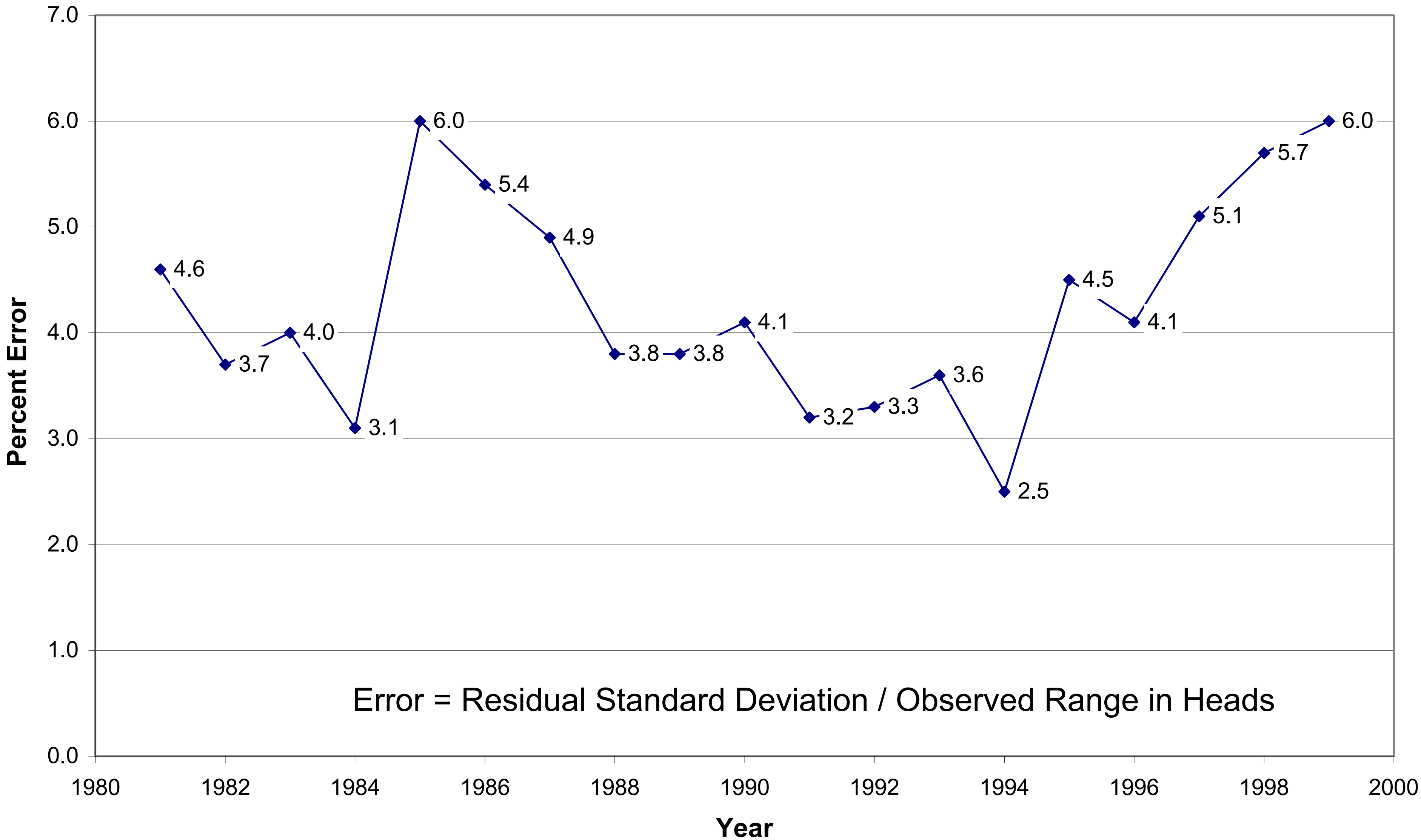
Analysis of Transient Verification

576 Data Points

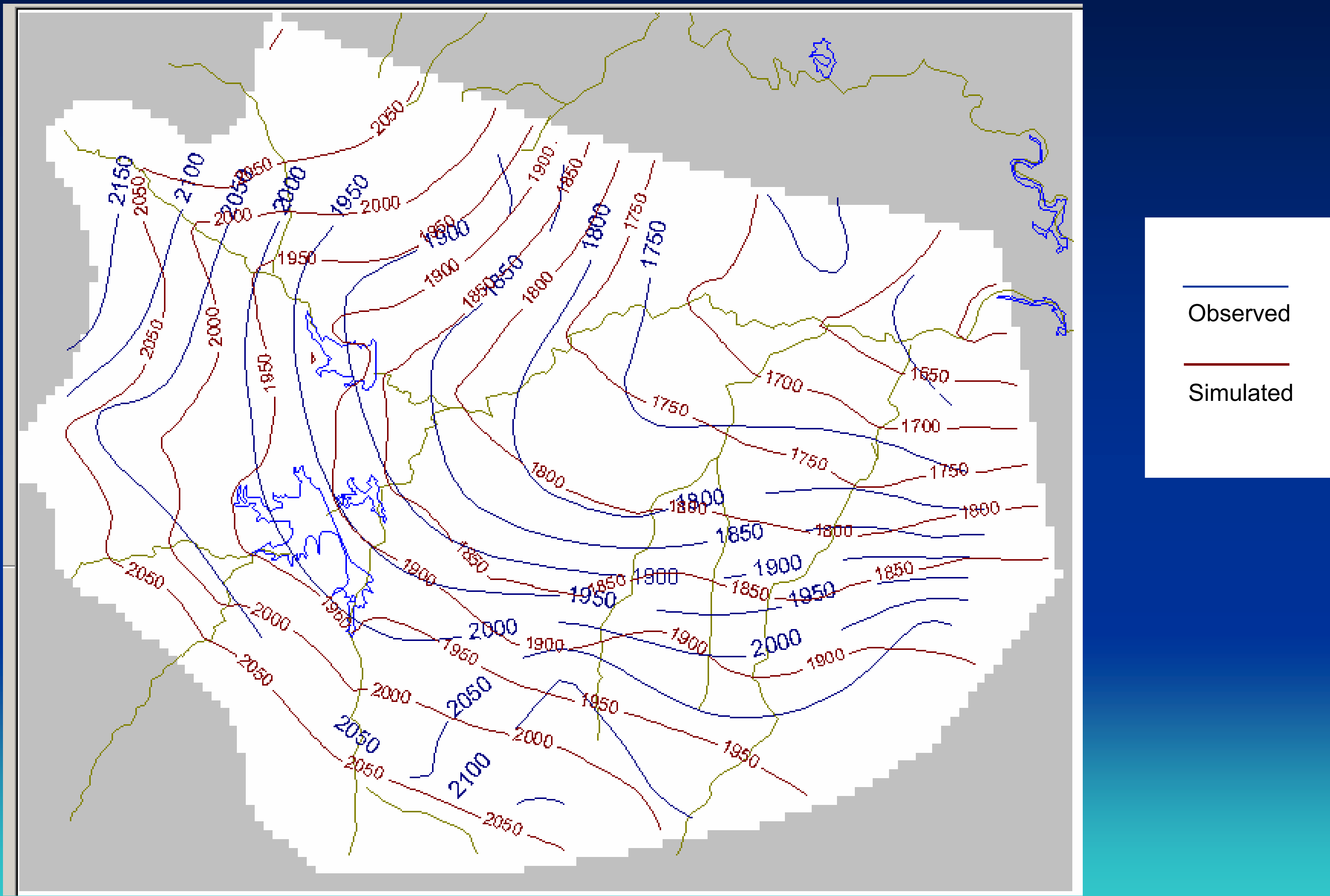


Mean Residual	18.18
Mean Absolute Error	24.45
RMS Error	27.36
Range	478.01
Percent RMSE / Range	5.72

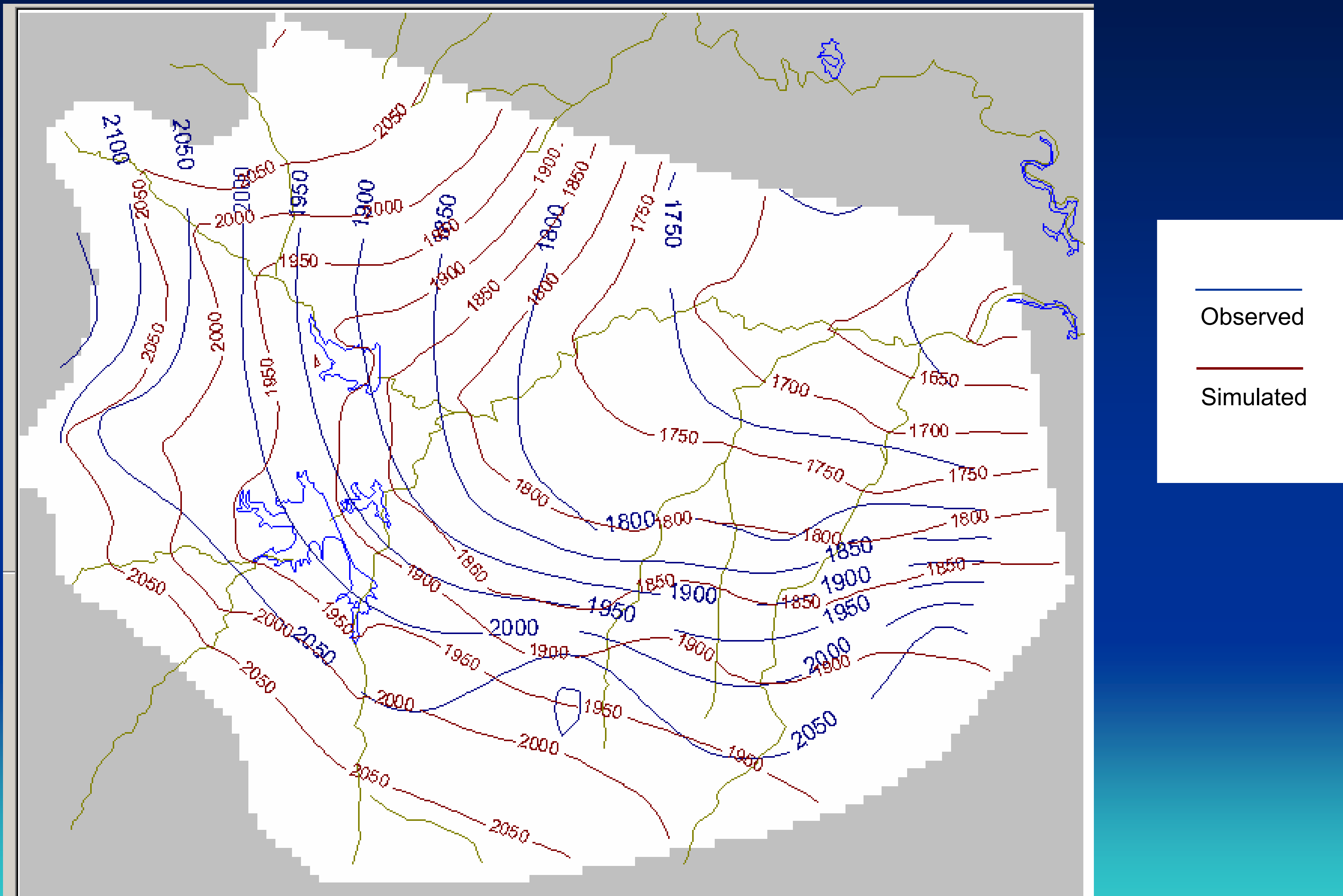
Error during Calibration and Verification



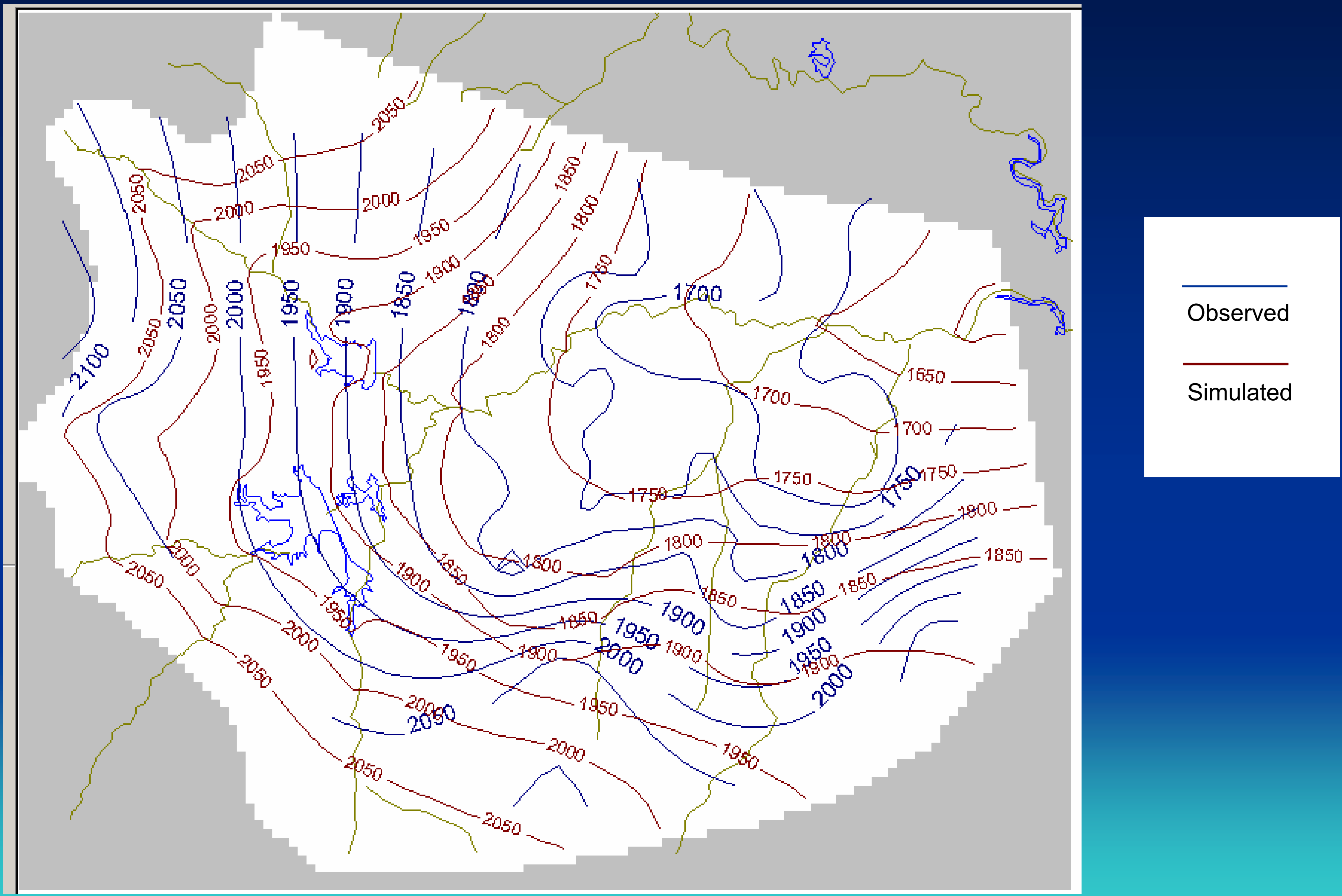
Simulated Water Levels 1981



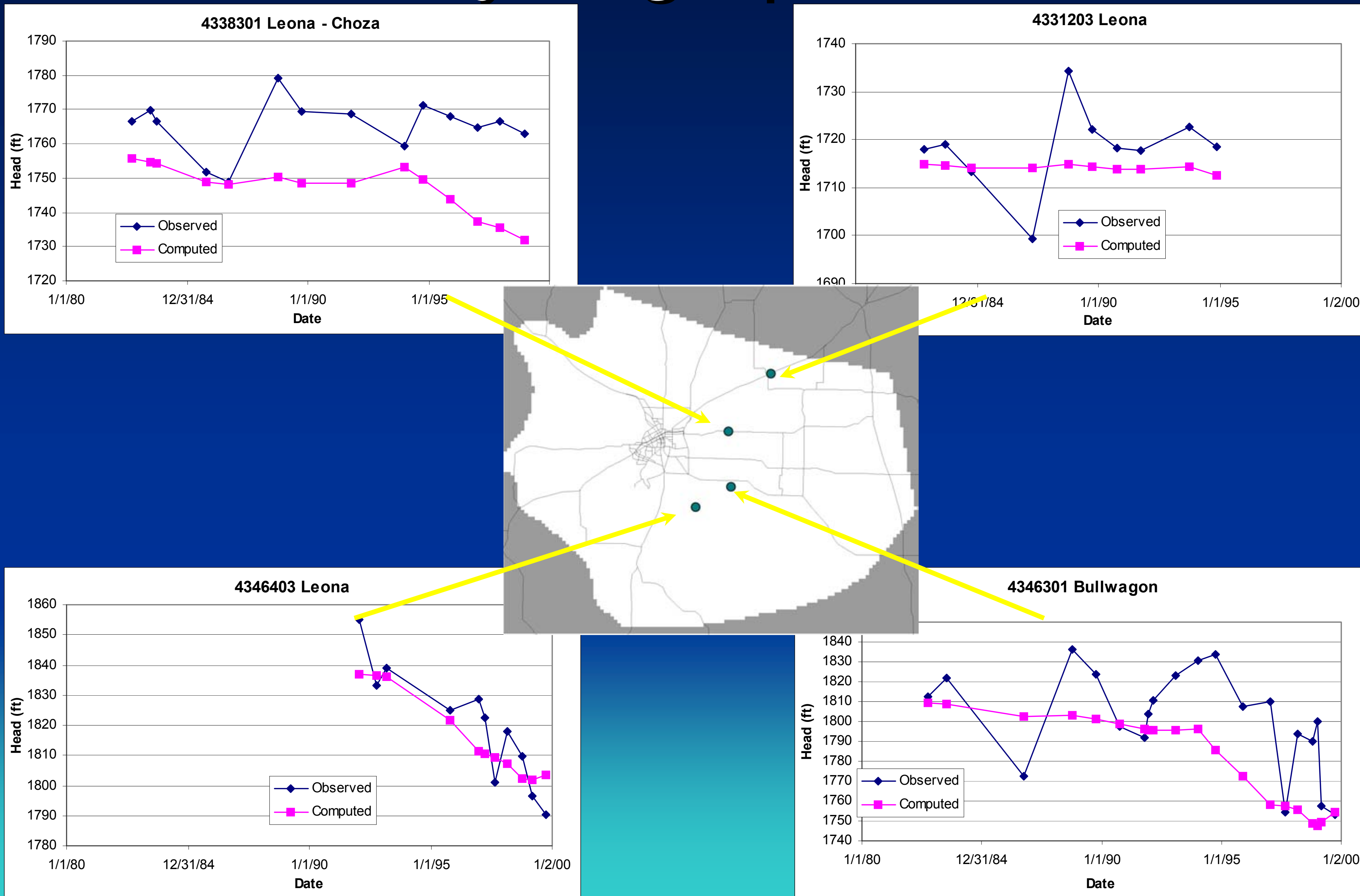
Simulated Water Levels 1990



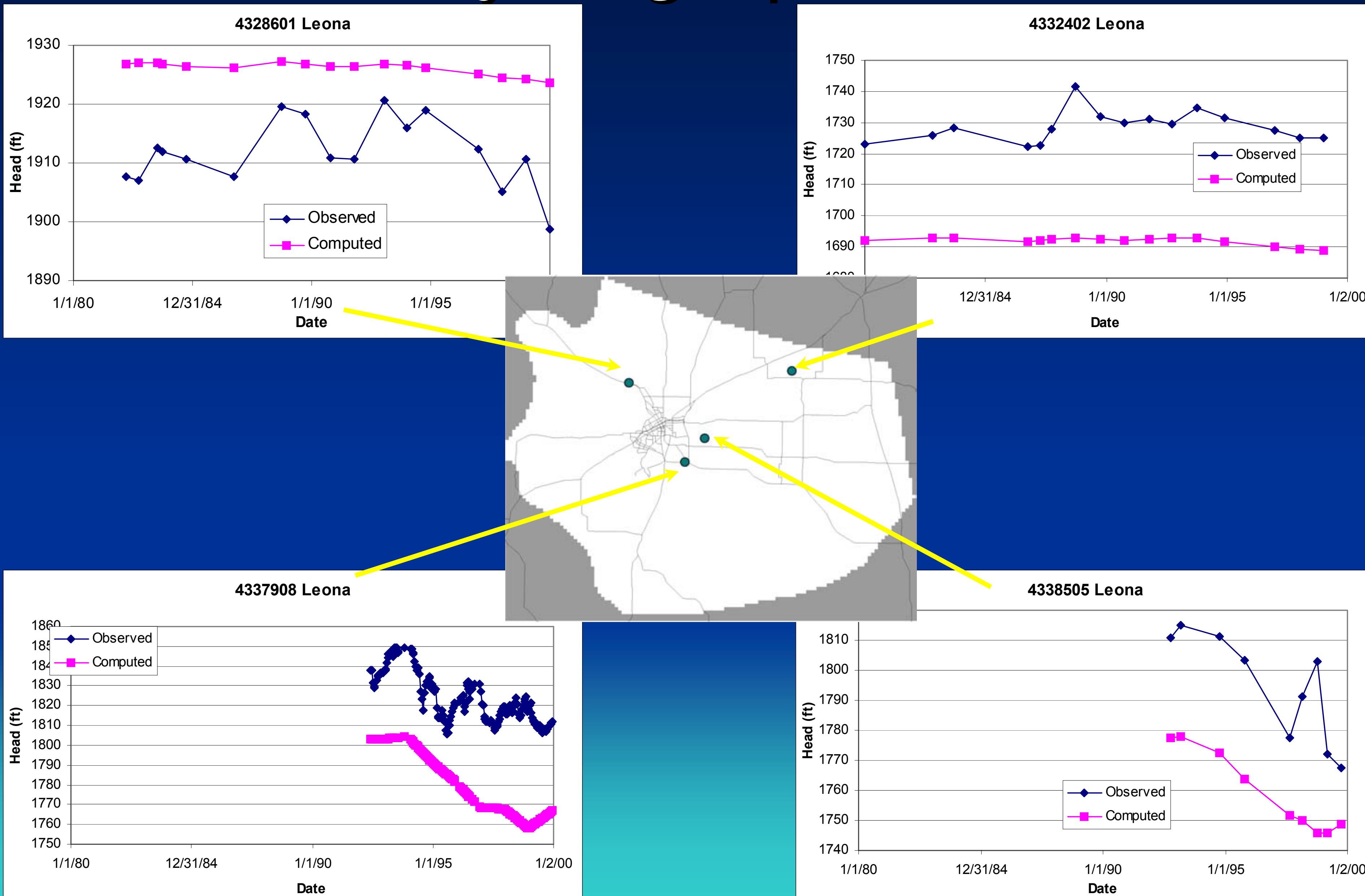
Simulated Water Levels 2000



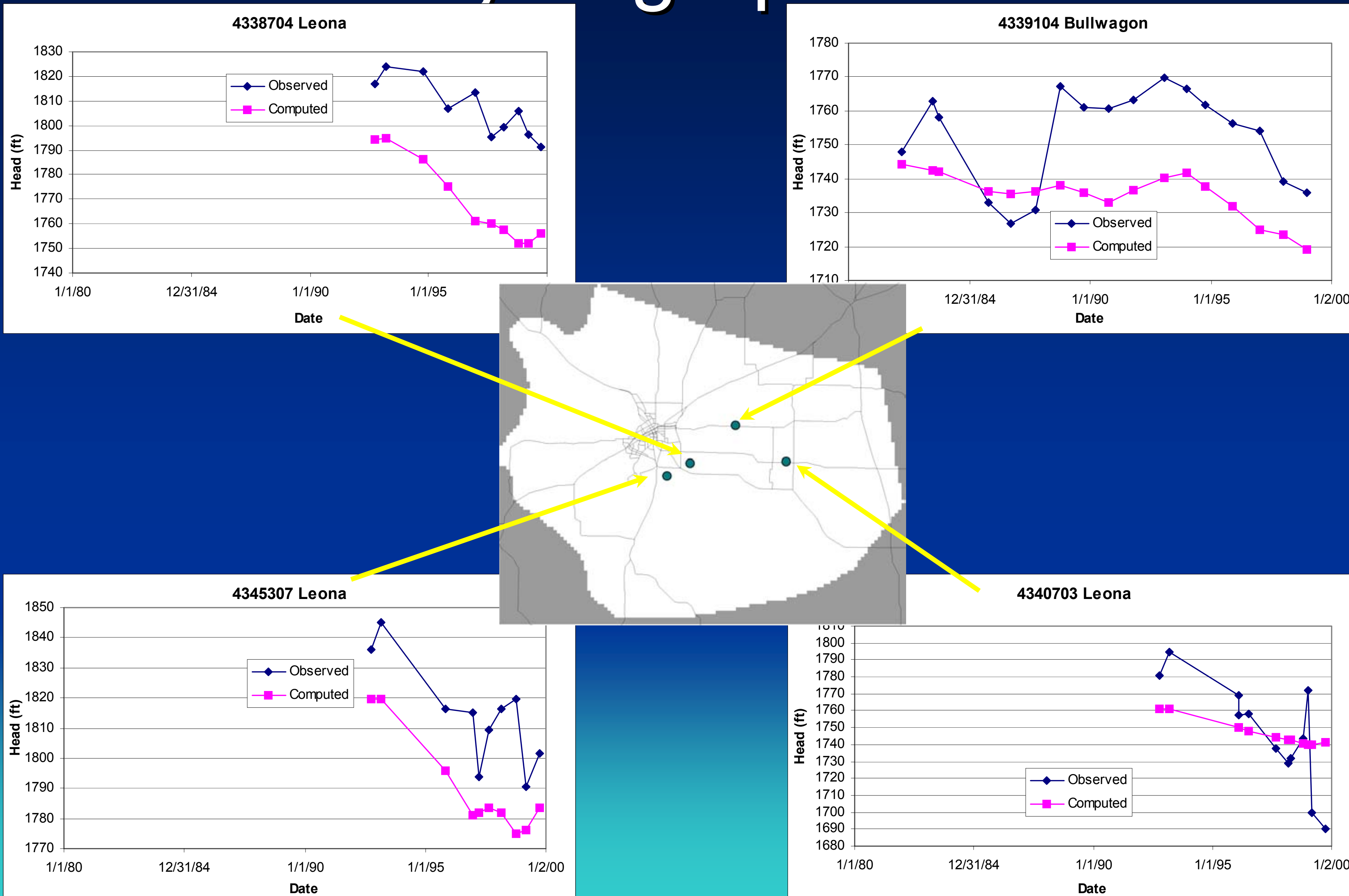
Hydrographs 1



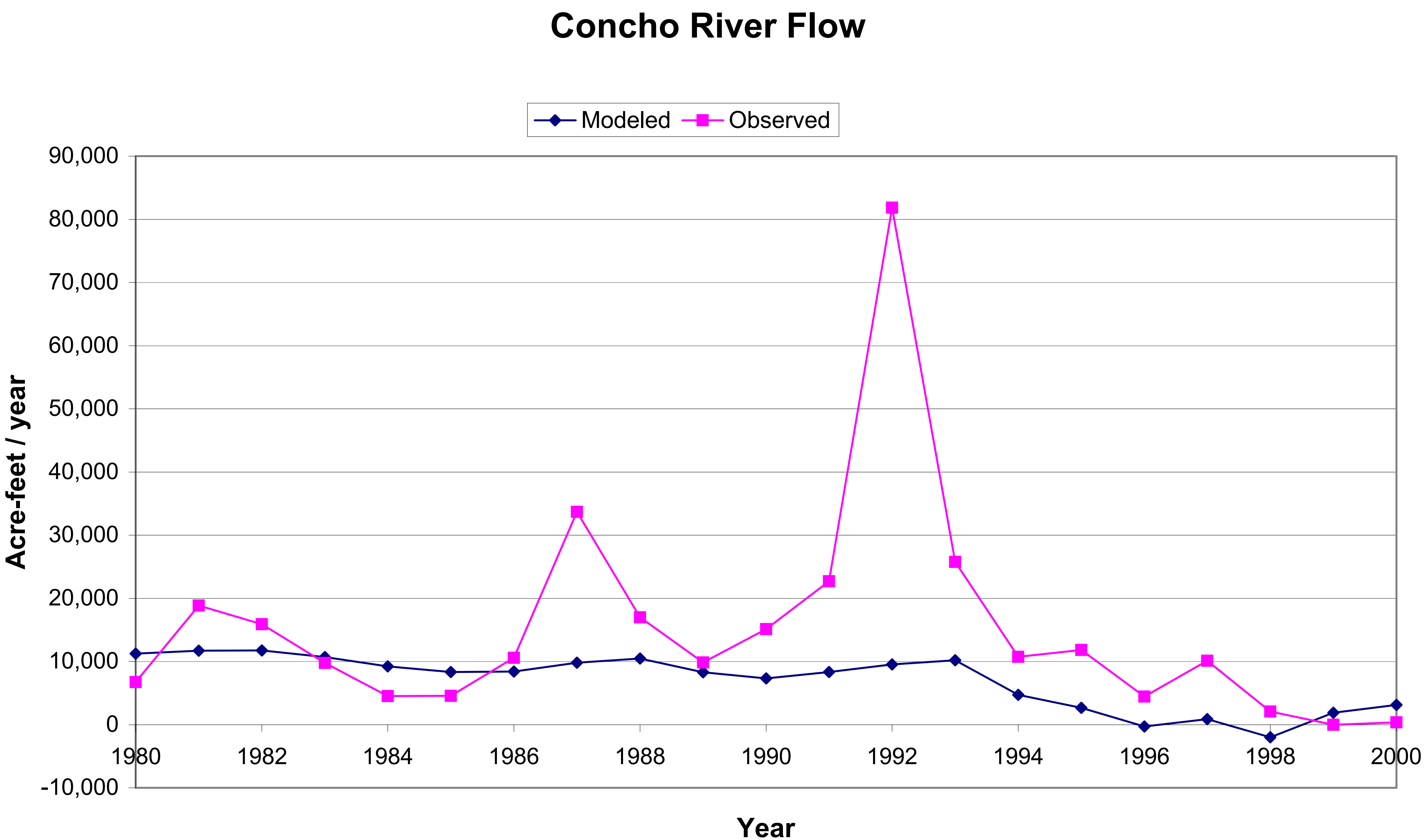
Hydrographs 2



Hydrographs 3

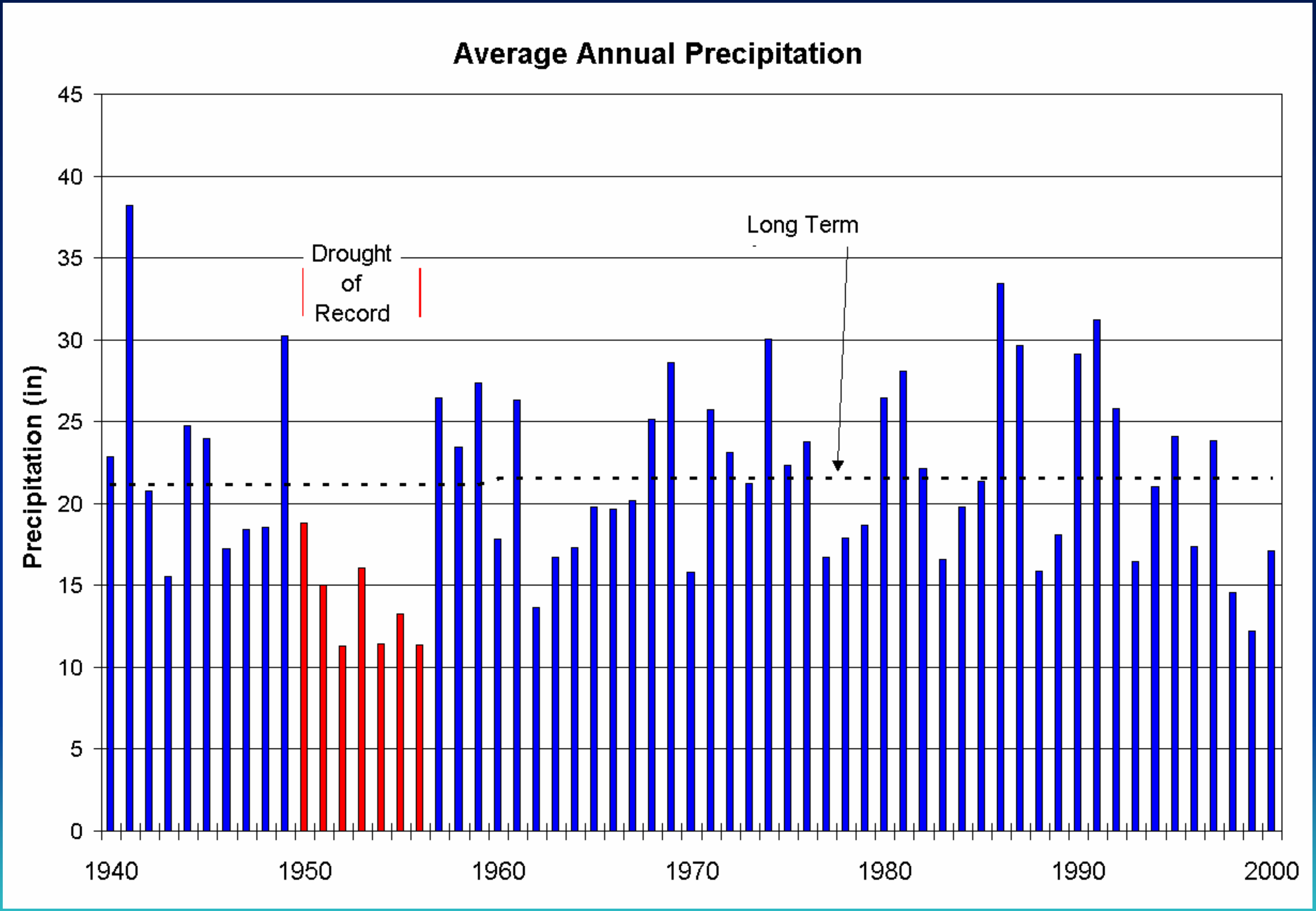


Concho River Flow Analysis 1980 - 2000



Predictive Simulations

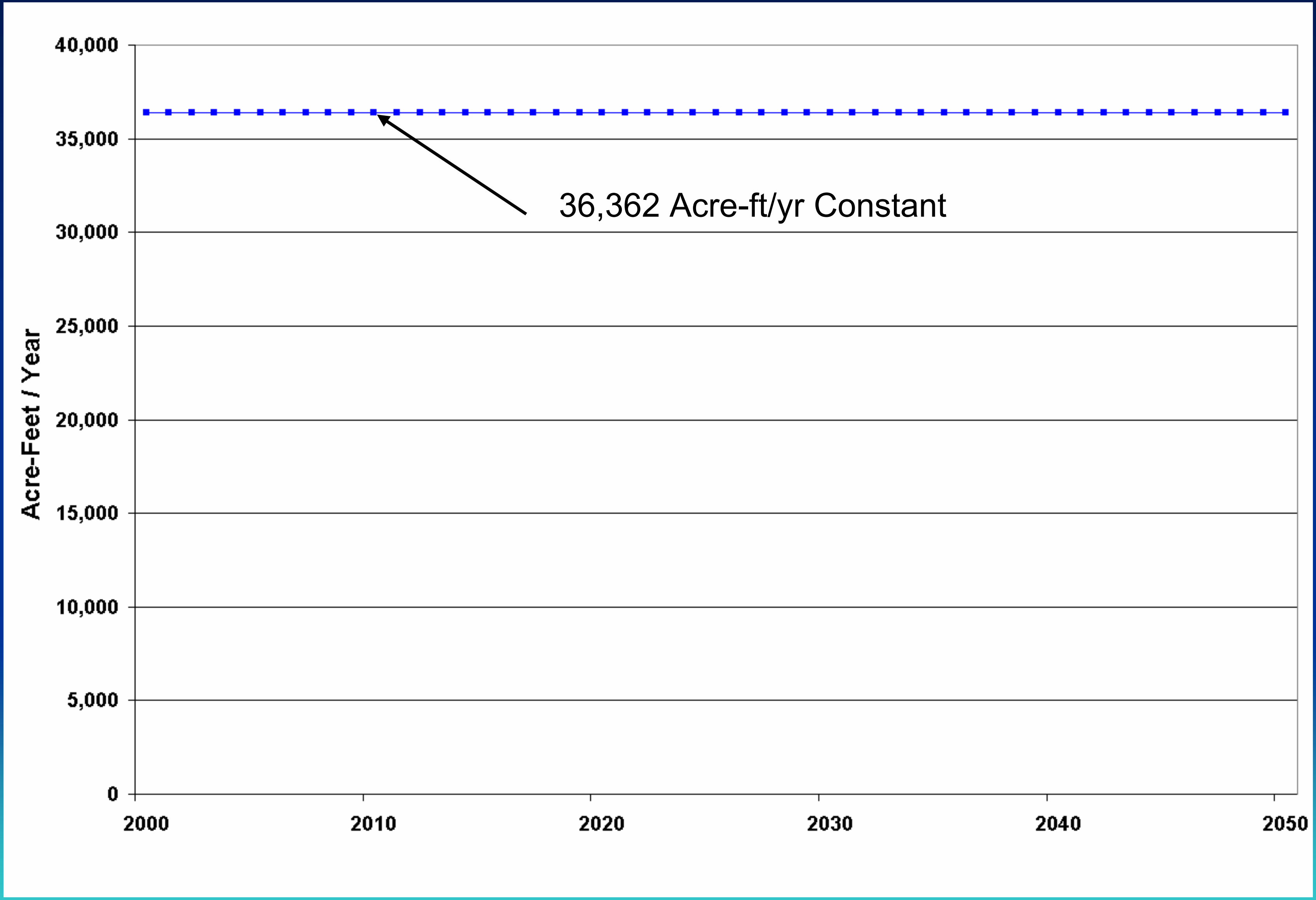
Drought of Record



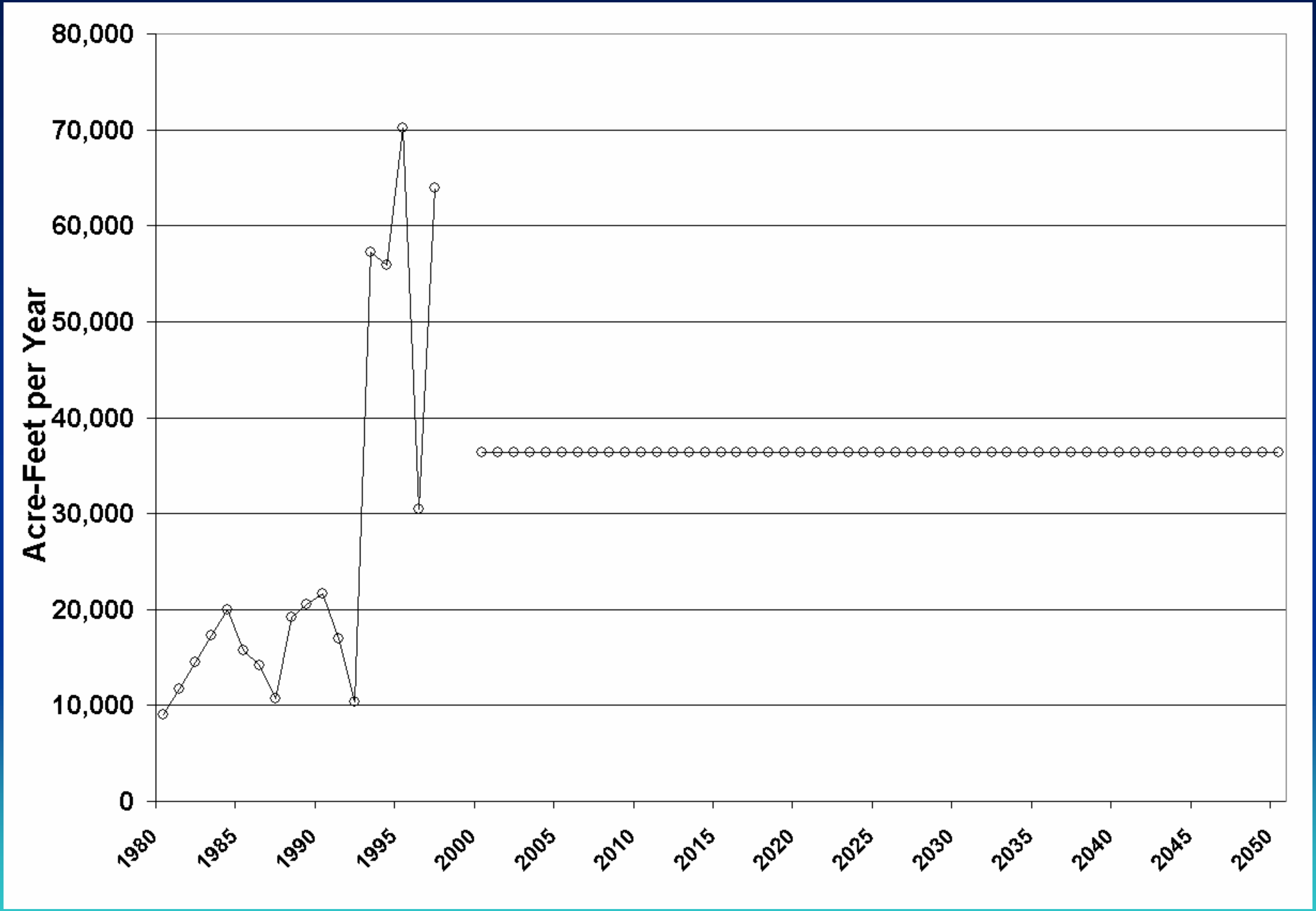
Recharge from Drought of Record

- Drought of Record from 1950 – 1956
- Precipitation in these 7 years was 65% of Normal
- Assigned Recharge for these 7 Years by Reducing Recharge in Each Zone by the Percentage of the Average Recharge in the Model Area

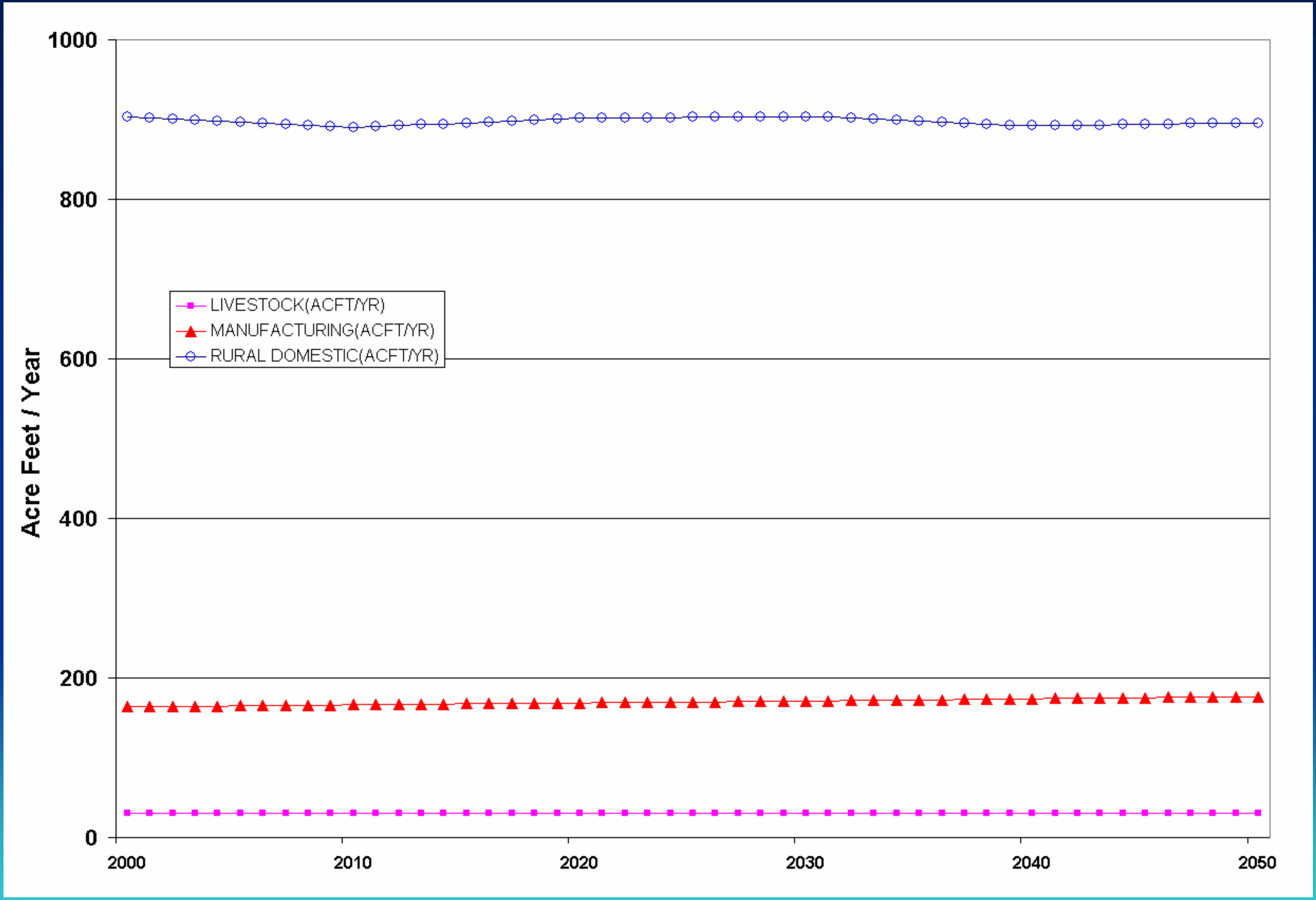
Predictive Irrigation Pumping 2000 - 2050



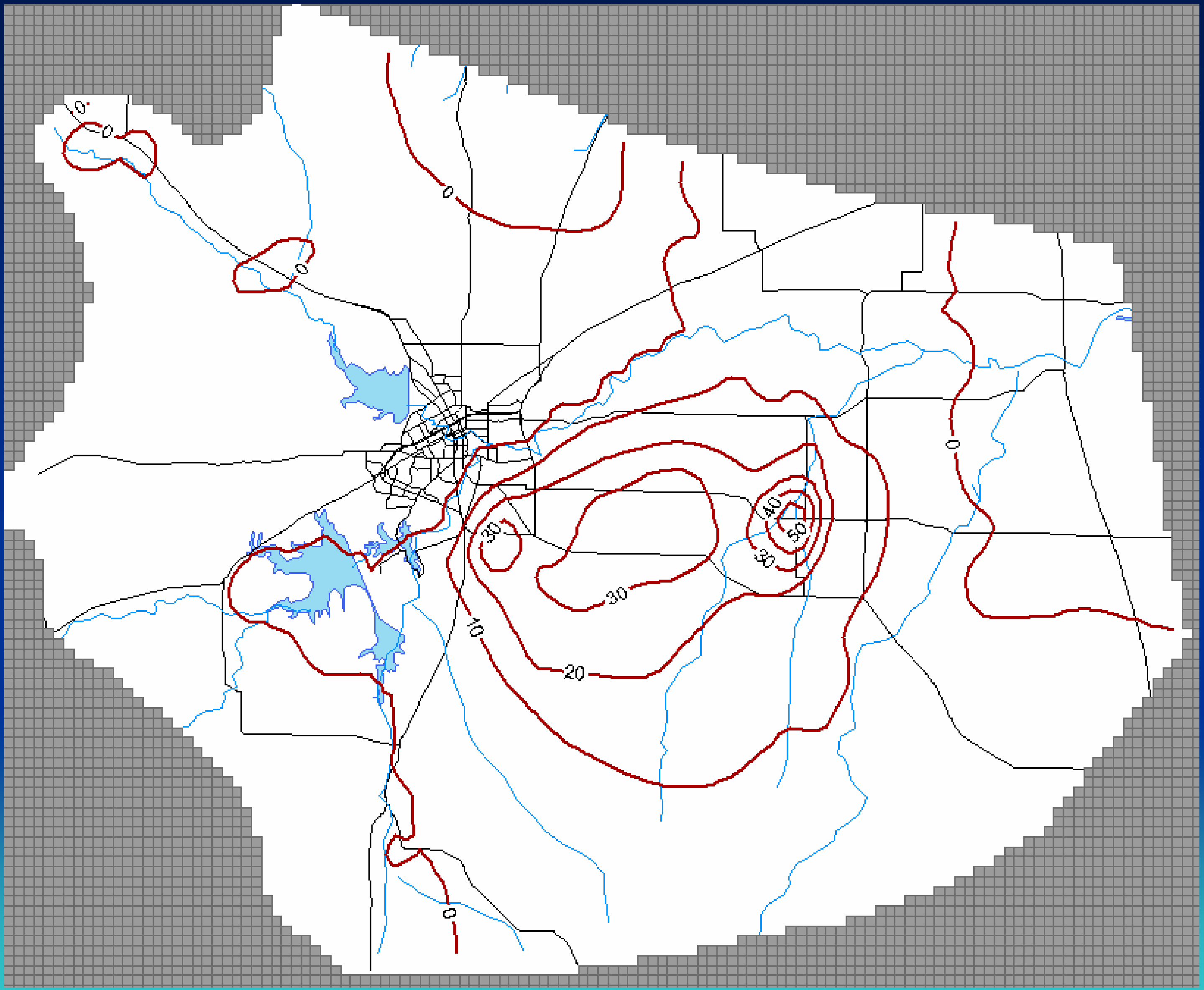
Historical and Predictive Irrigation Pumping



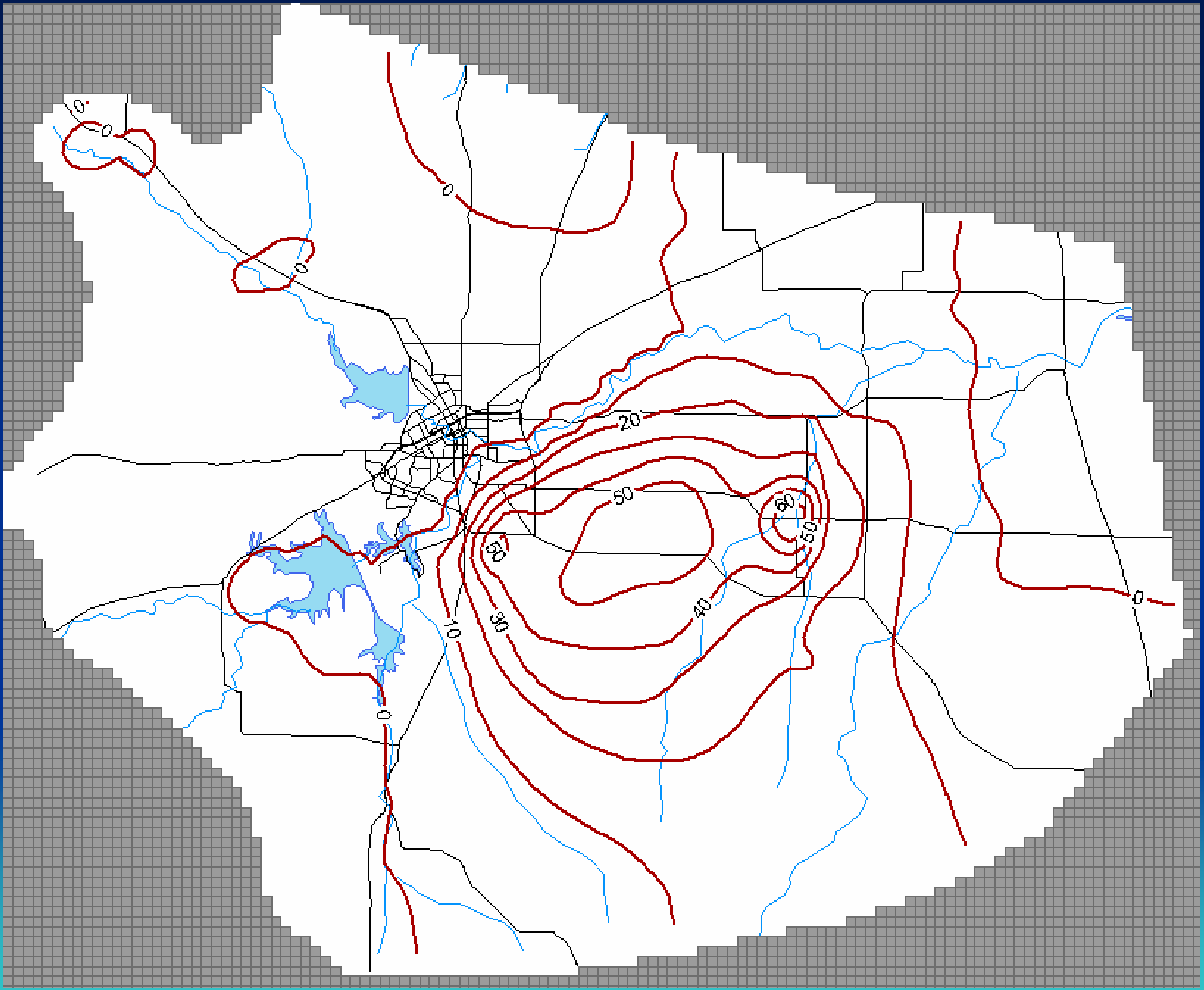
Other Predictive Pumping



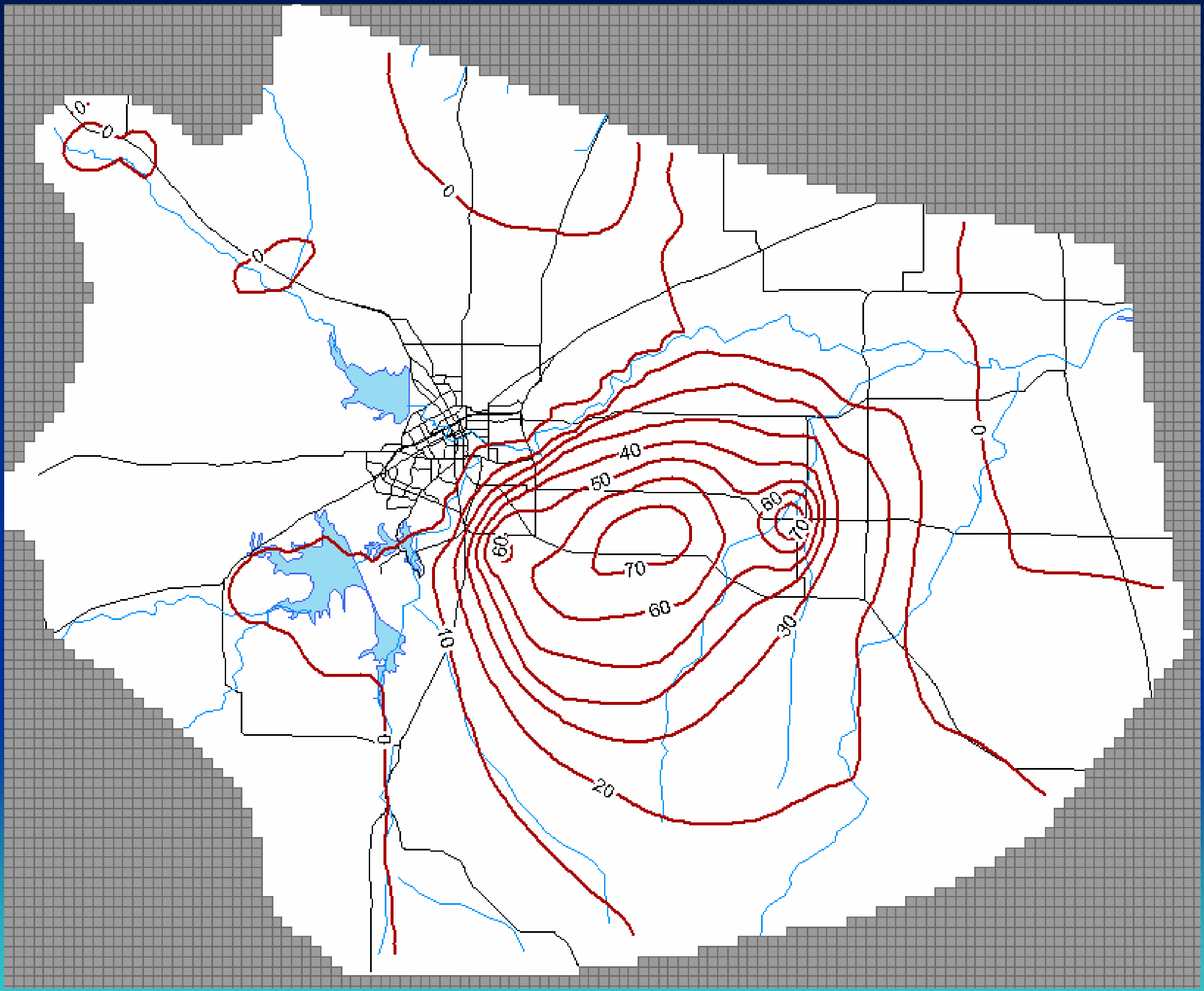
Drawdown at 2010 – Average Recharge



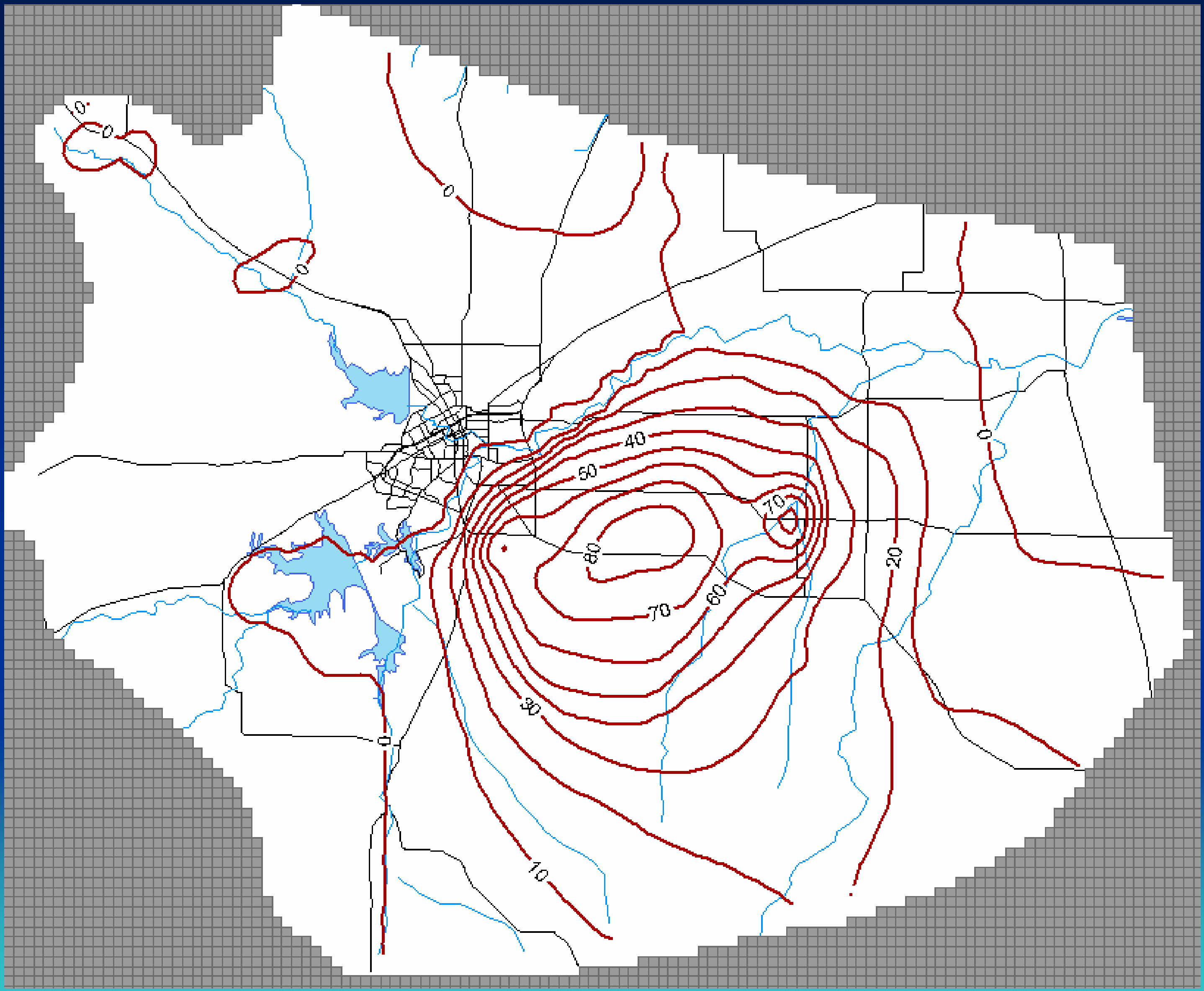
Drawdown at 2020 – Average Recharge



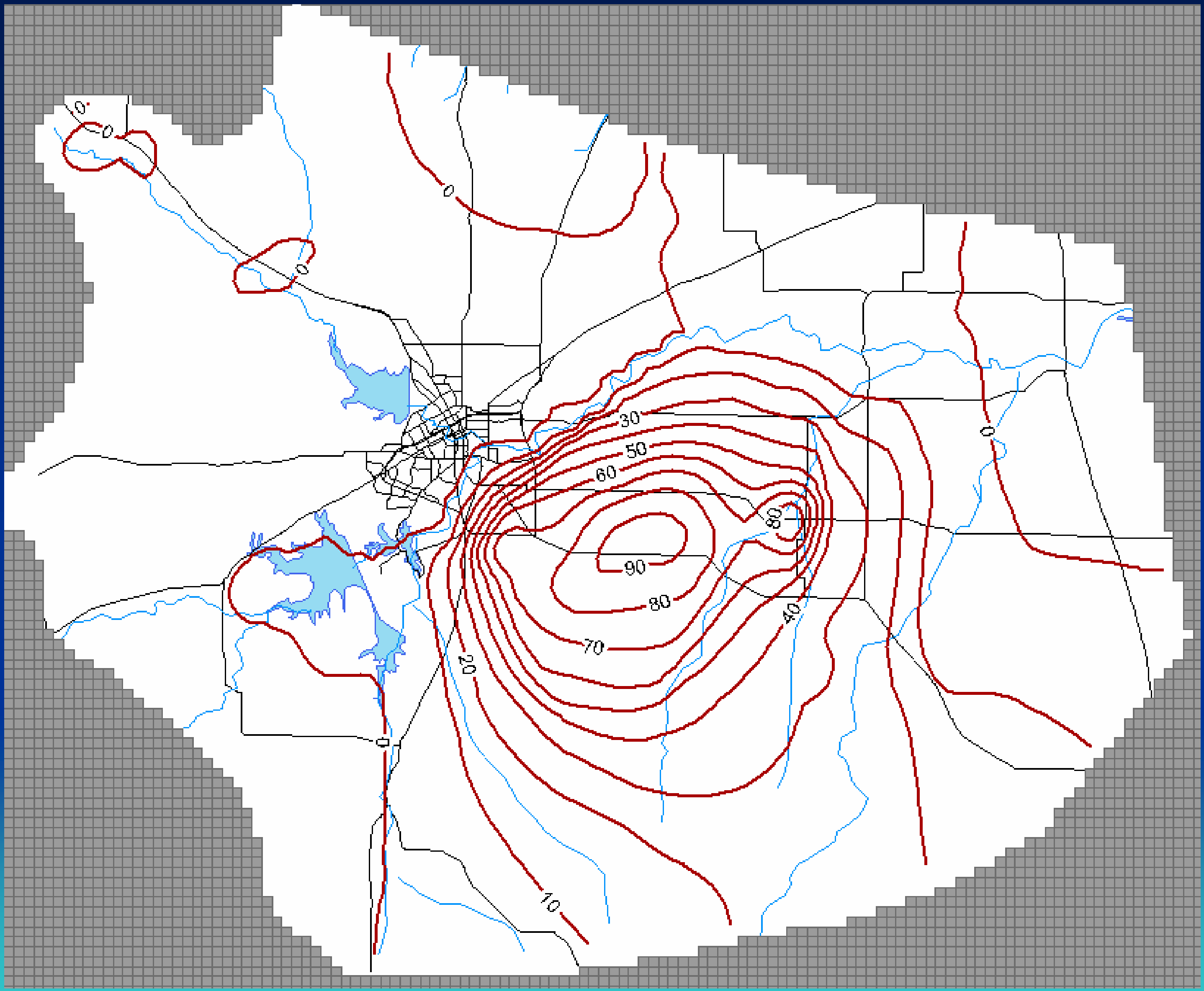
Drawdown at 2030 – Average Recharge



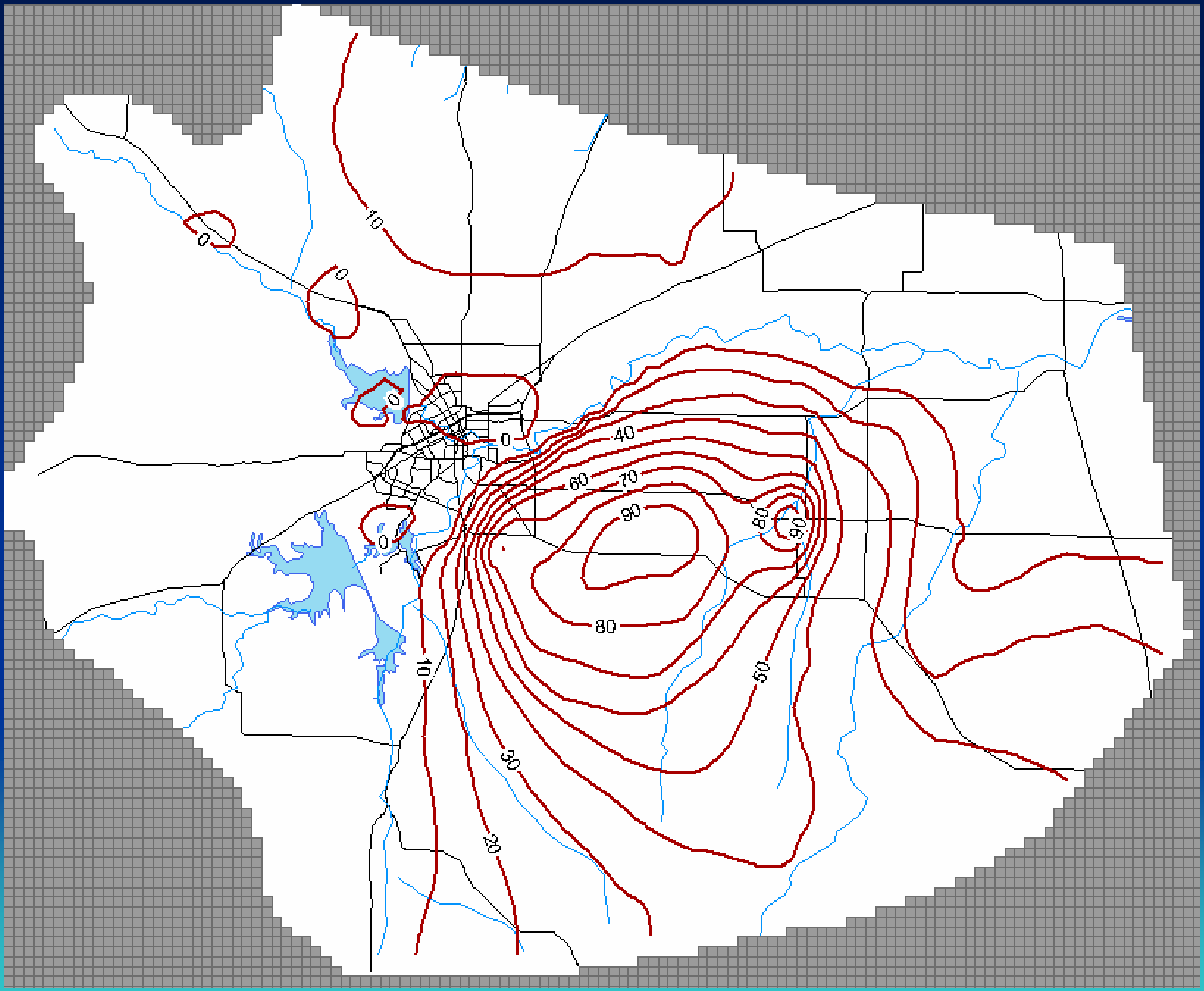
Drawdown at 2040 – Average Recharge



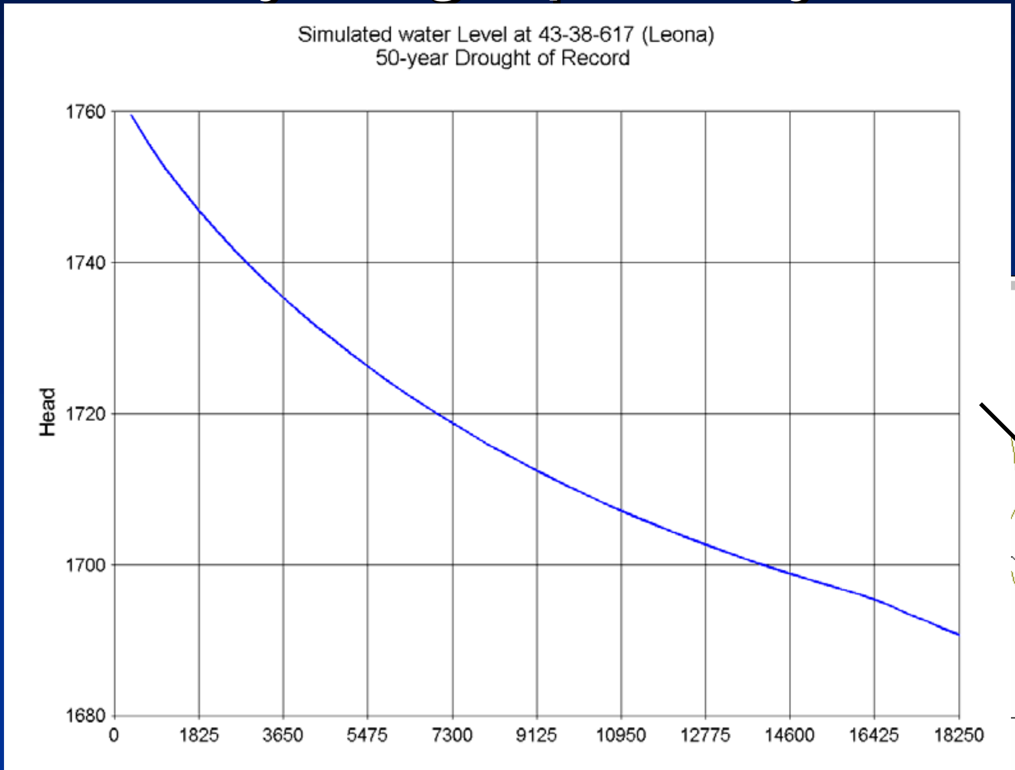
Drawdown at 2050 – Average Recharge

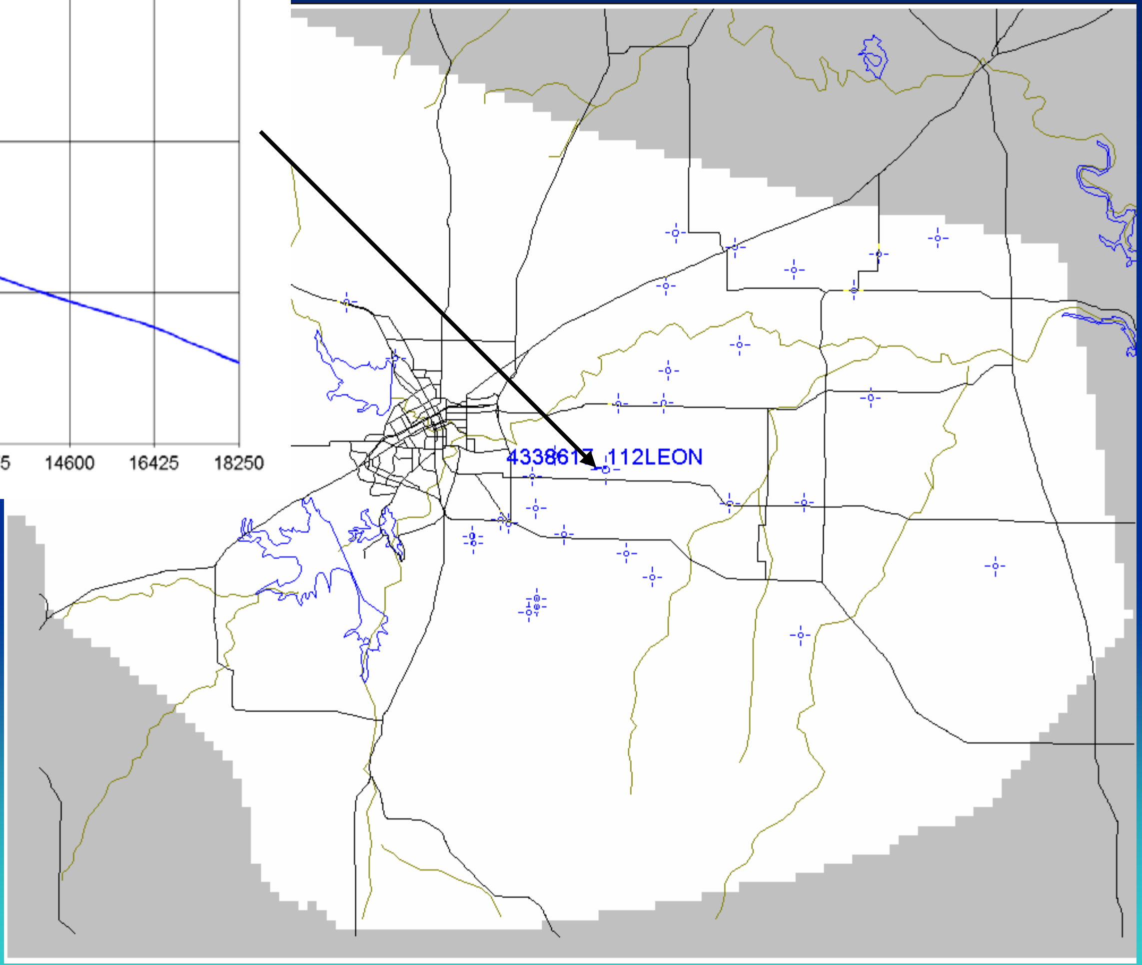


Drawdown at 2050 – Drought of Record Last 7 Years

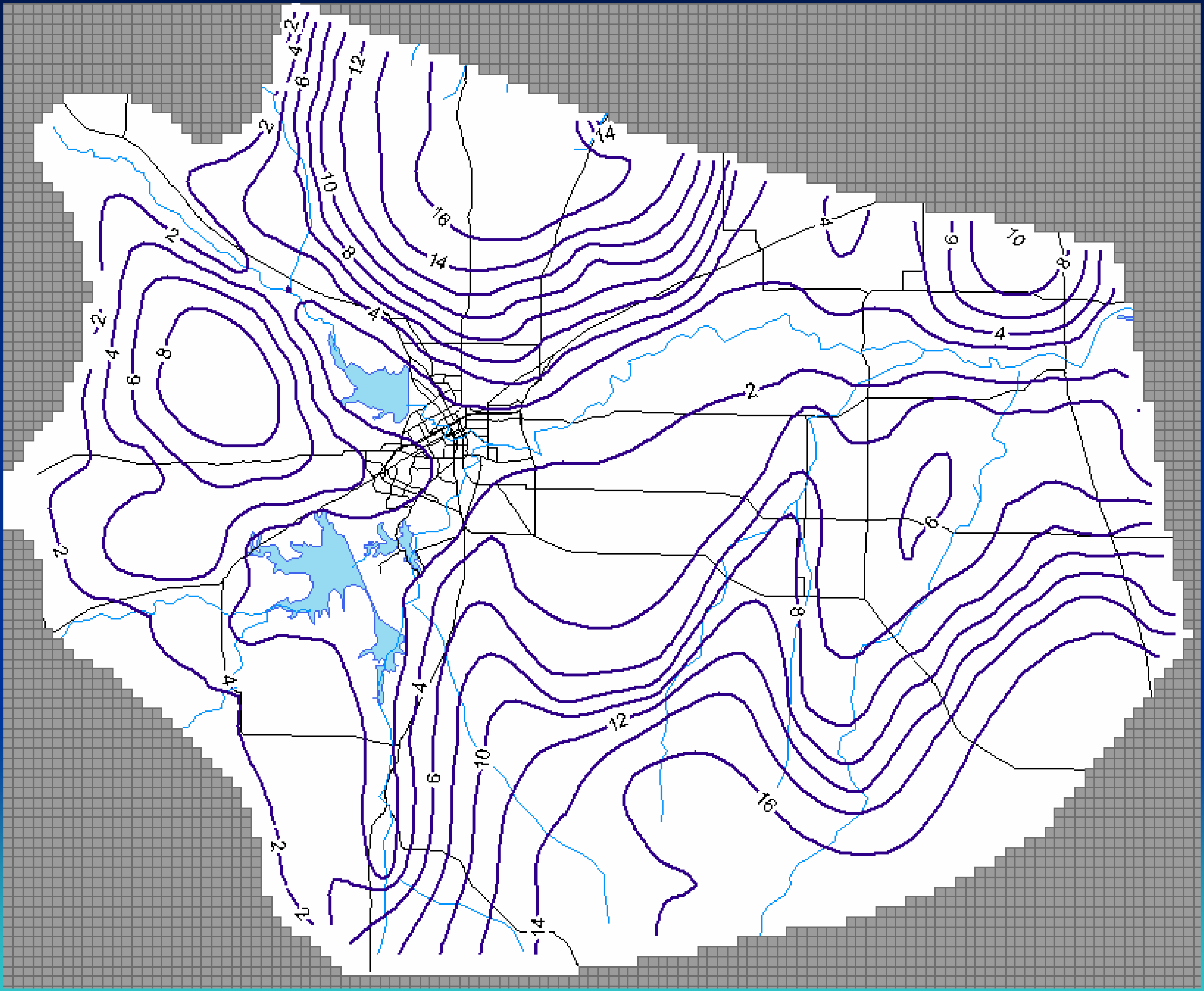


Hydrograph 50-year Drought of Record

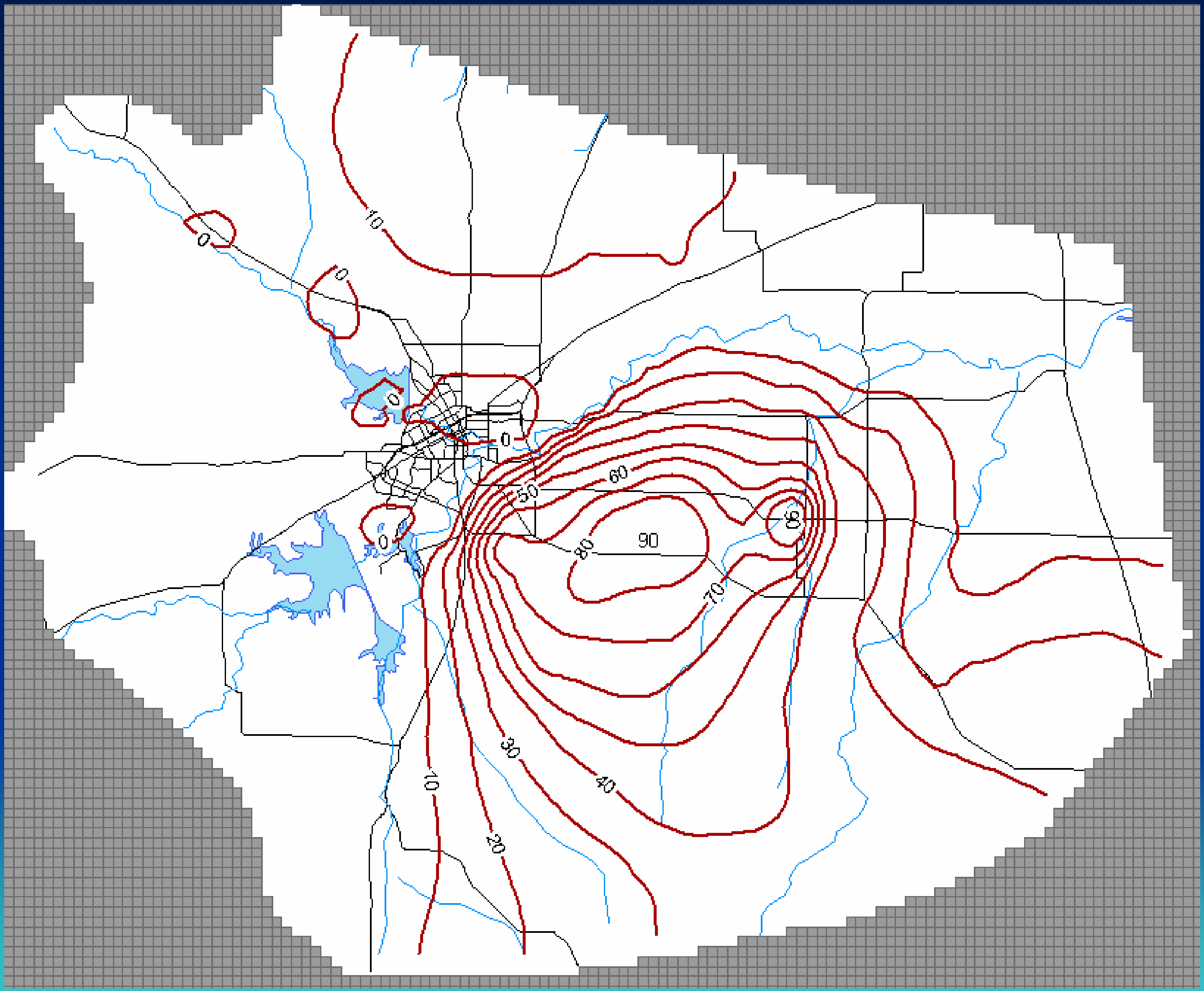




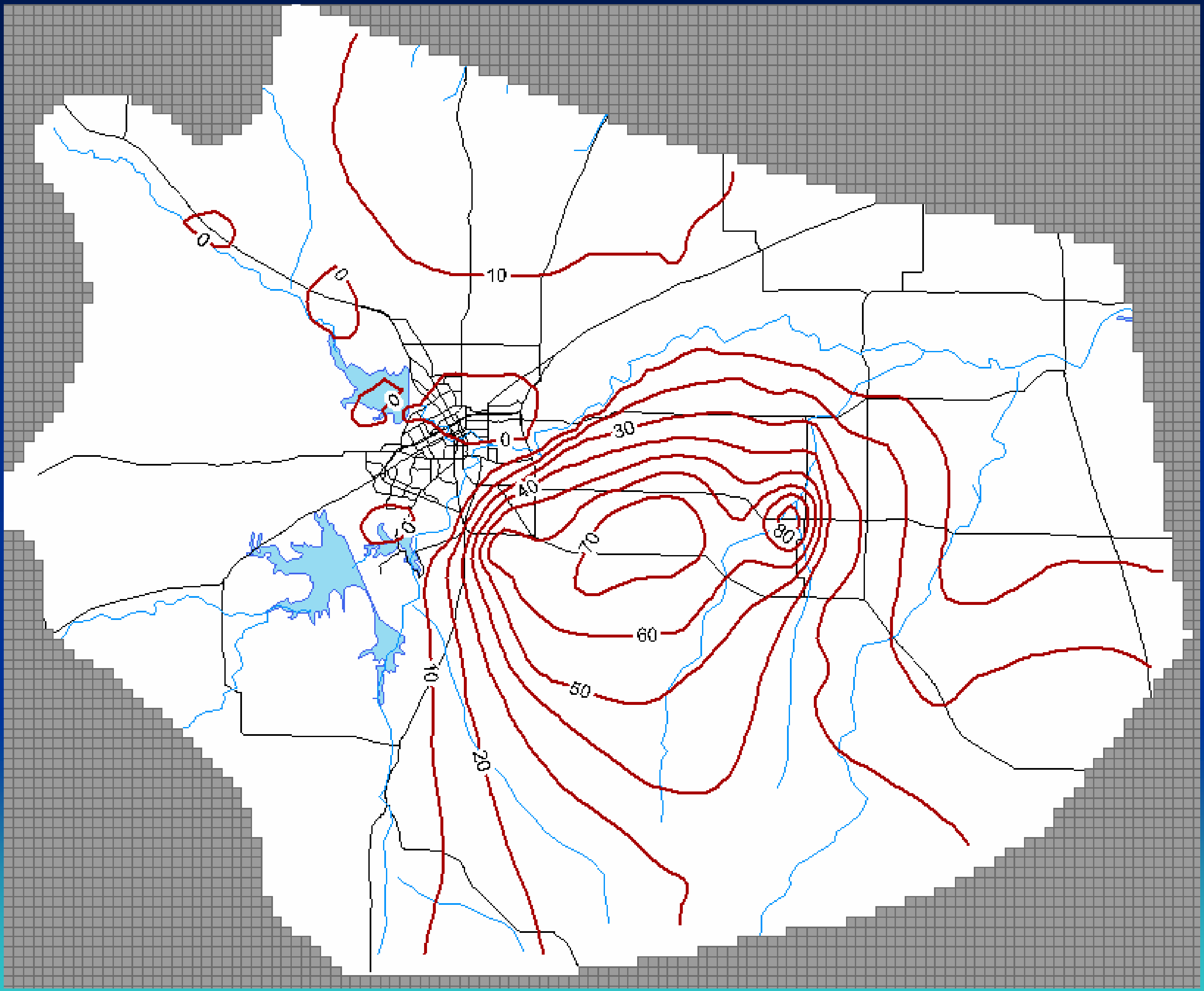
Difference Between Average Recharge and Drought of Record Recharge - 2050



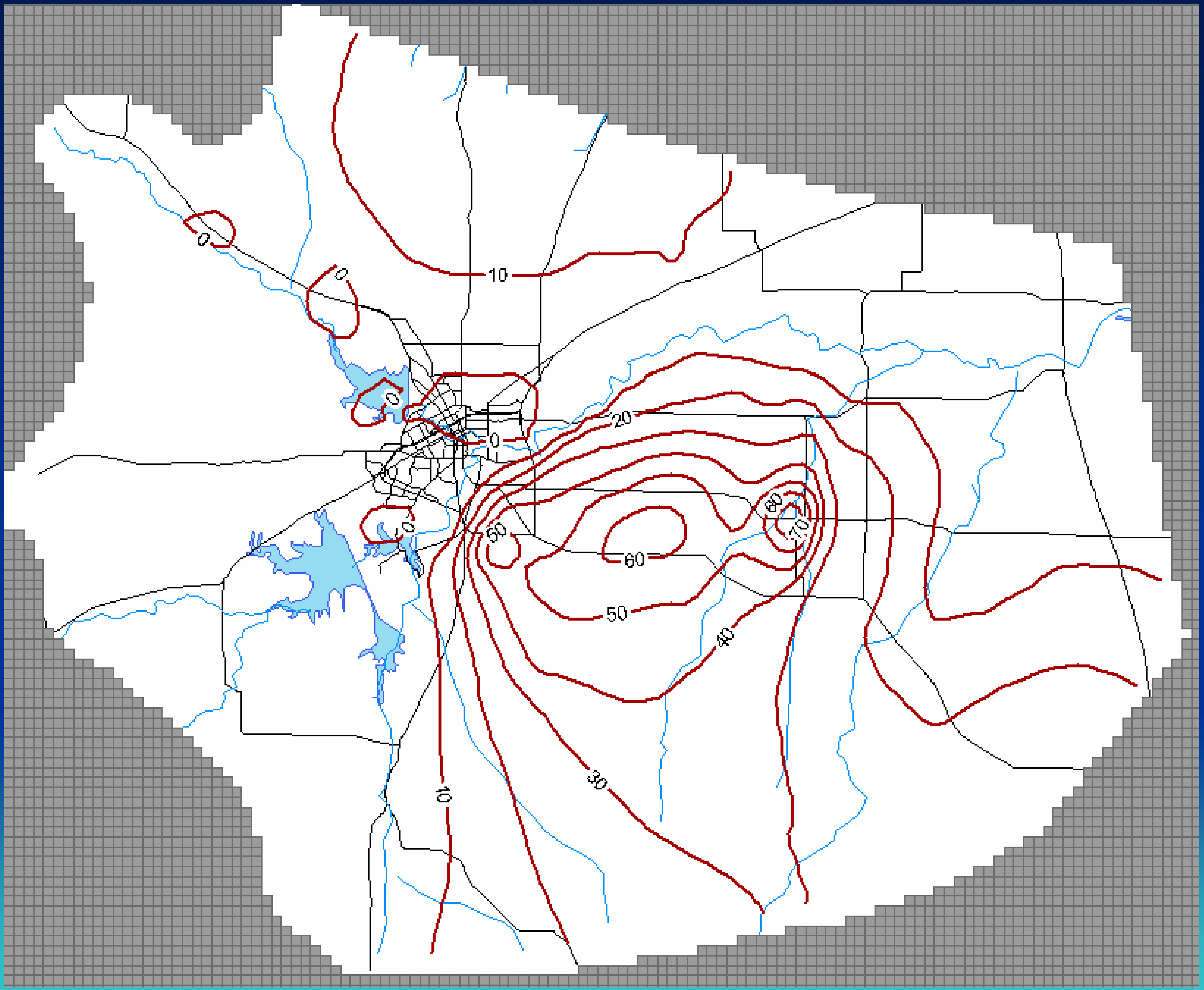
Drawdown at 2040 – Drought of Record Last 7 Years



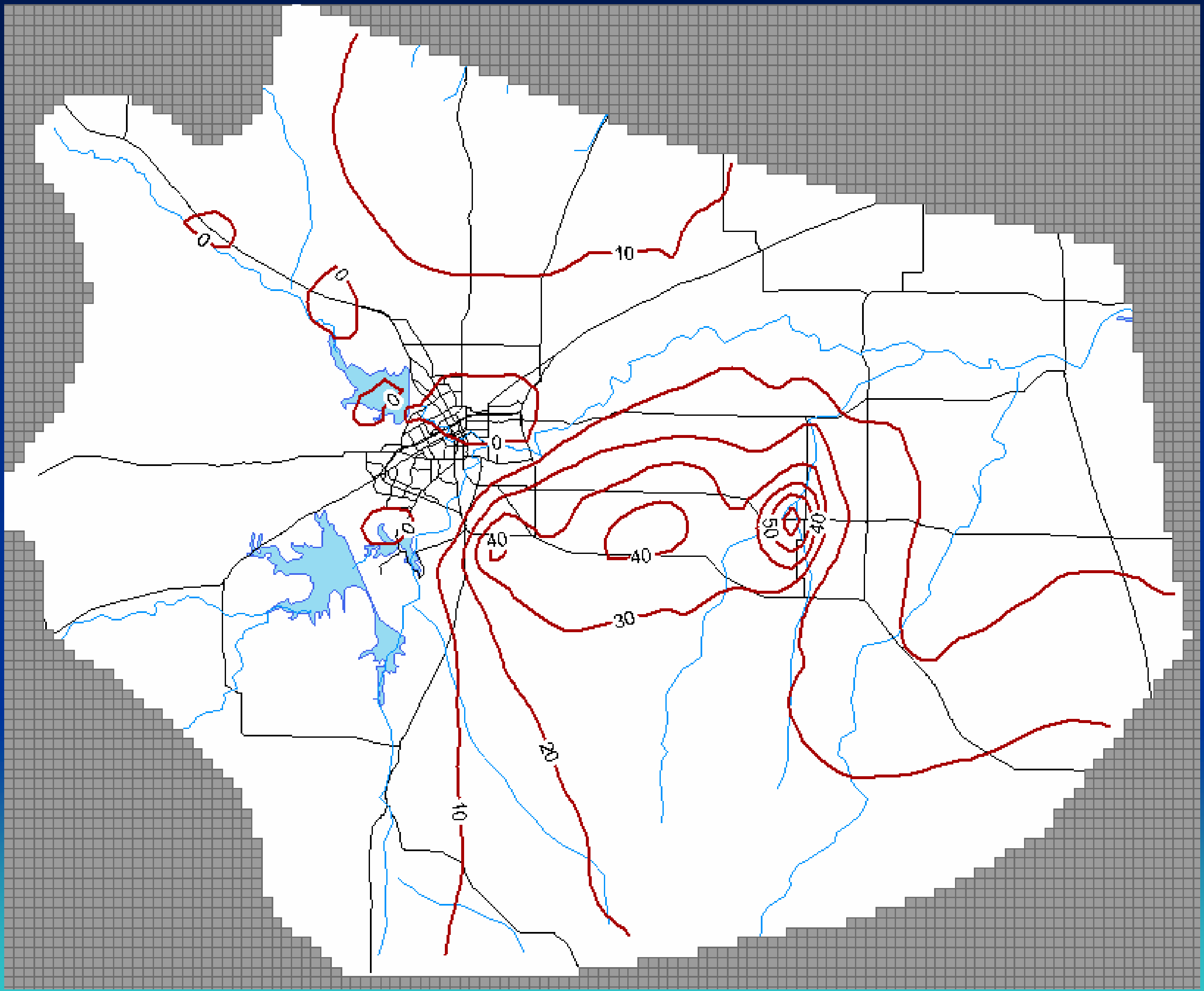
Drawdown at 2030 – Drought of Record Last 7 Years

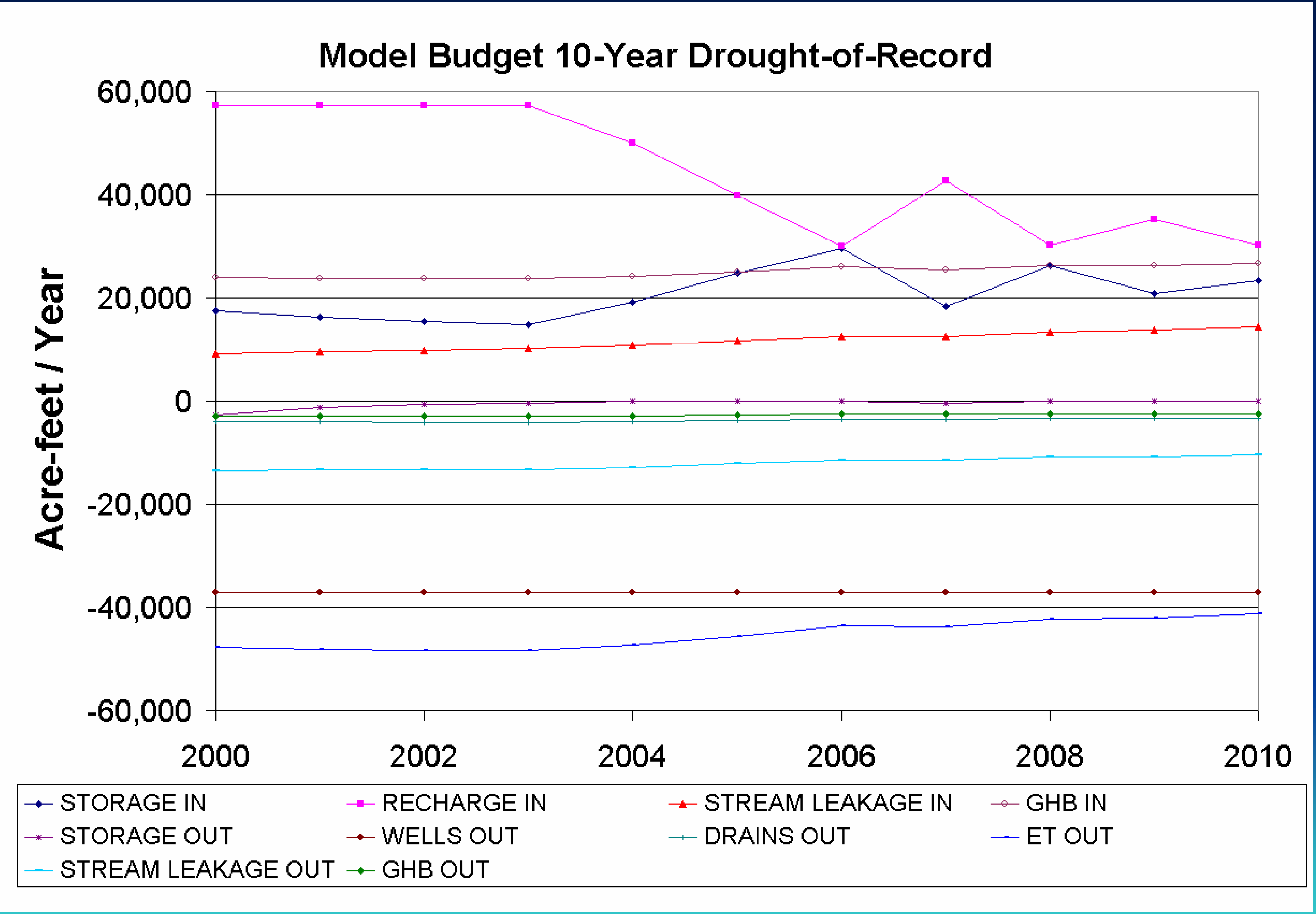


Drawdown at 2020 – Drought of Record Last 7 Years

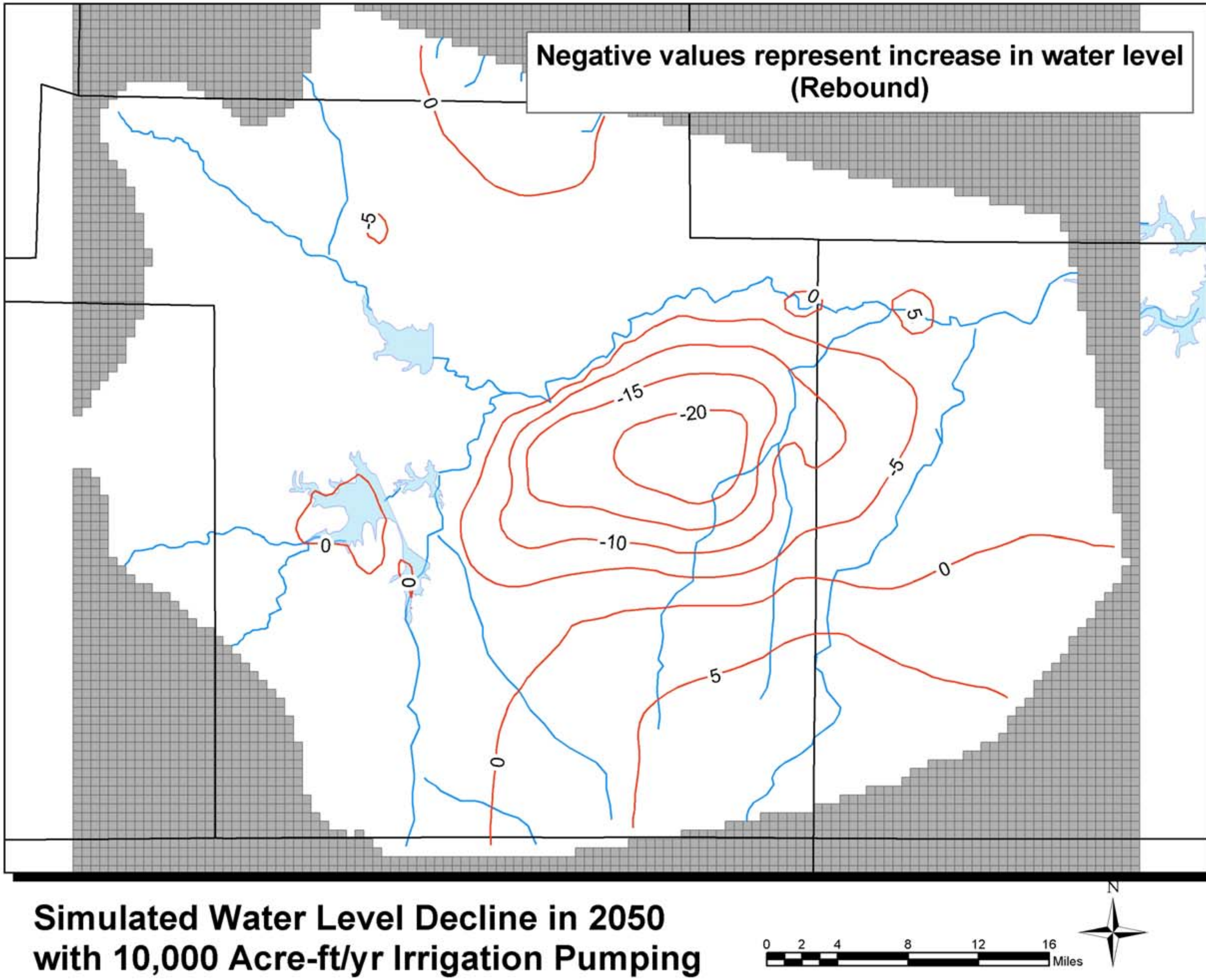


Drawdown at 2010 – Drought of Record Last 7 Years

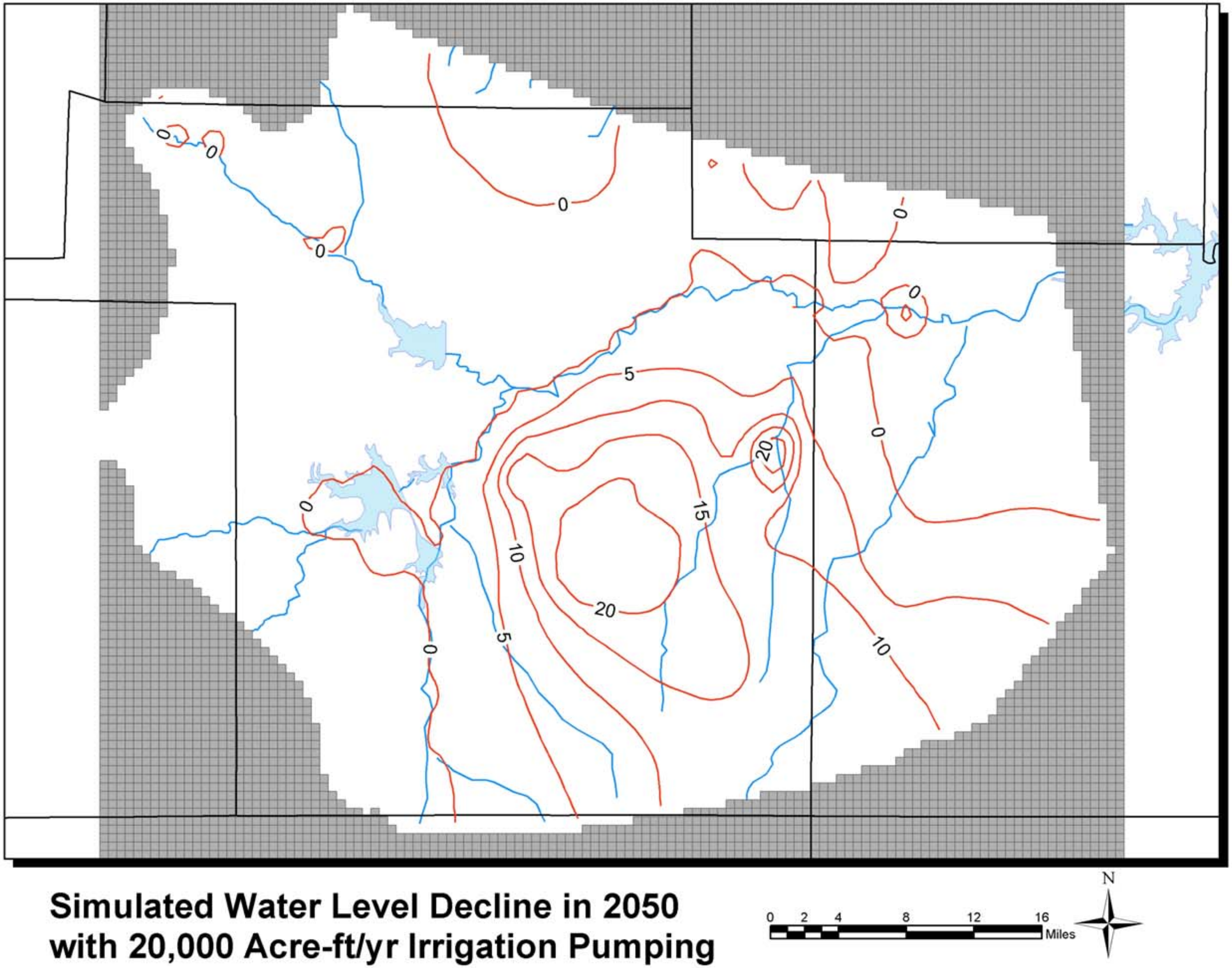




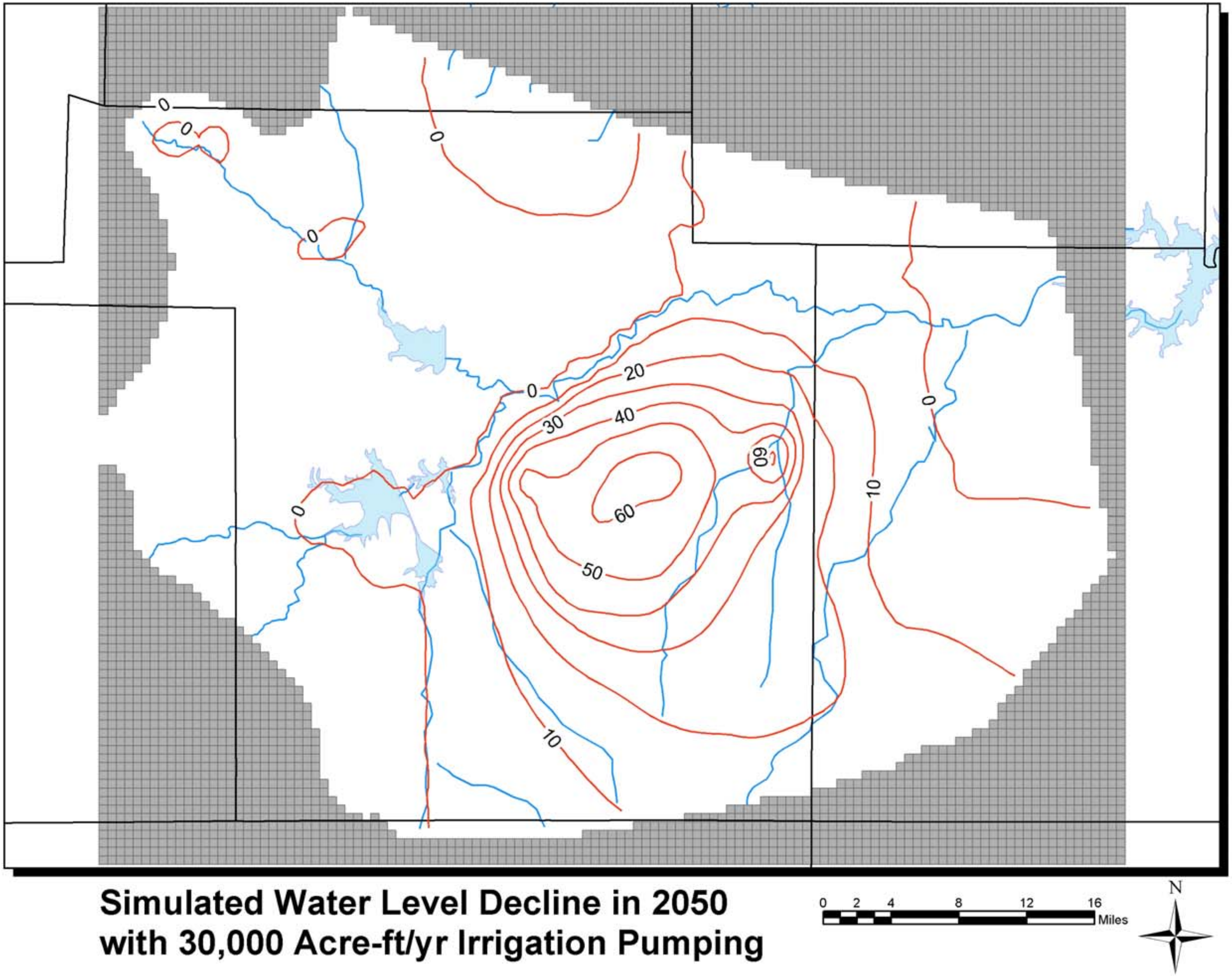
Model Budget 10-Year Drought-of-Record
Acre-feet / Year
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
2000
2002
2004
2006
2008
2010
STORAGE IN
RECHARGE IN
STREAM LEAKAGE IN
GHB IN
STORAGE OUT
WELLS OUT
DRAINS OUT
ET OUT
STREAM LEAKAGE OUT
GHB OUT



Simulated Water Level Decline in 2050 with 10,000 Acre-ft/yr Irrigation Pumping

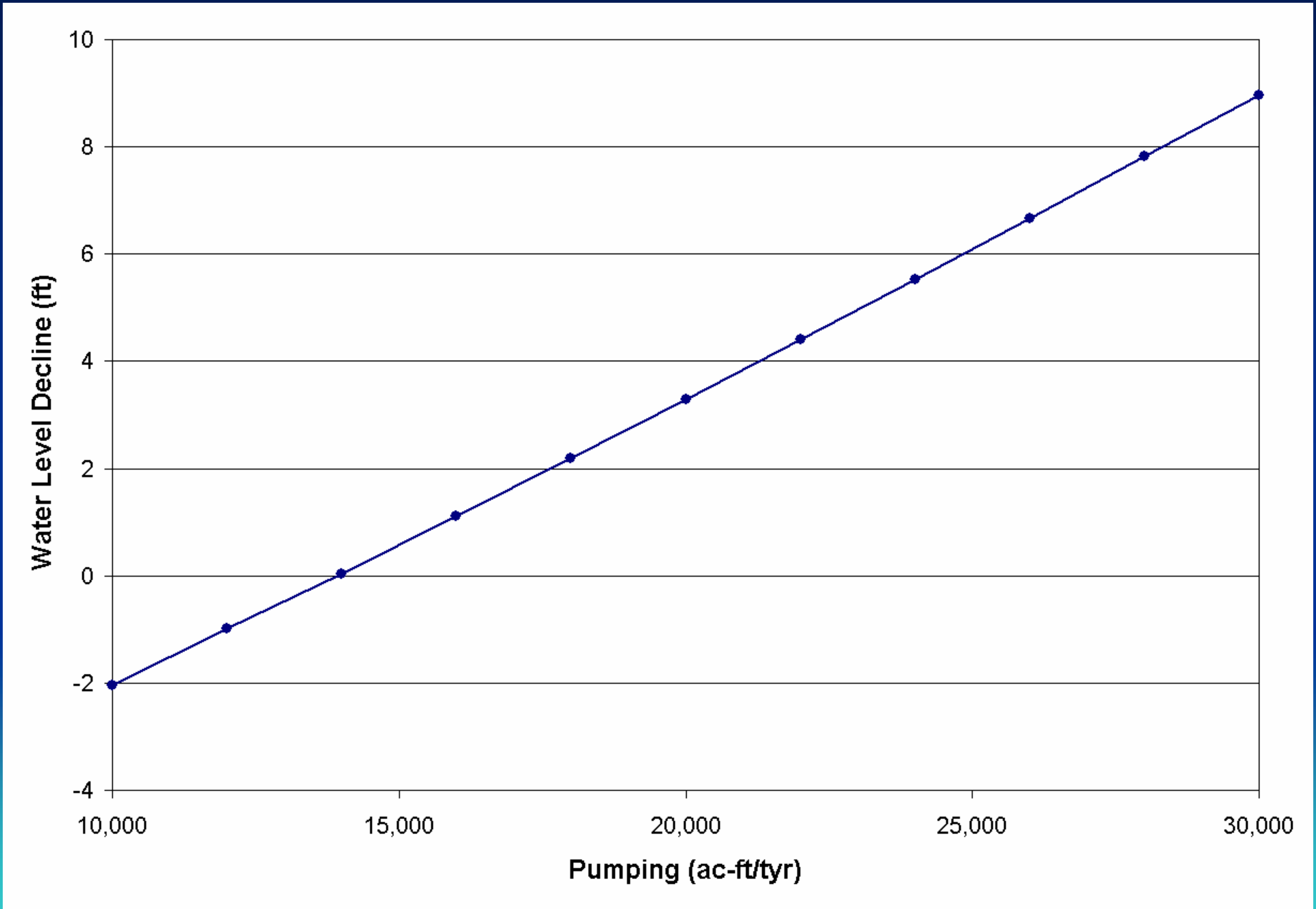


Simulated Water Level Decline in 2050 with 20,000 Acre-ft/yr Irrigation Pumping



Simulated Water Level Decline in 2050 with 30,000 Acre-ft/yr Irrigation Pumping

Pumping Sensitivity



Model Limitations

- Supporting Data
  - hydrogeology, hydraulic properties, fractures, heterogeneity
  - Accuracy of pumping data
- Limiting Assumptions
  - Continuous porous media model
  - “Lumped-layer” conceptualization
- Limits of Applicability
  - Only a tool
  - Use only for generalized regional modeling

Conclusions

- Model meets GAM calibration/verification requirements
- Model is a good tool for RWP efforts
- Good tool to assess regional drawdown from proposed pumping and changes in recharge
- Not a good tool for detailed evaluations


Thanks!
Any Questions ?

5th Stakeholder Advisory Forum
March 31st, 2004
Lipan GAM
List of Attendees

Name	Affiliation
James Beach	LBG-Guyton Associates
Richard Smith	TWDB
Chico Denis	Lipan -Kickapoo WCD
Bill Lange	Lange Drilling Company
Virgil Polecek	Sutton Co. UWD
Winton Milliff	Coke Co. UWCD
Gregory Phinney	Farmer/Rancher
John Book	
Michael Hoclsek	
Nolan Nichues	Farmer
Leon Bradey	
Allan Lange	Lipan -Kickapoo WCD
Cindy Cawley	Plateau/Sutton
Ed Trotter	
Allen Gully	Farmer
Will Wilde	City of San Angelo
Don Davis	Lipan -Kickapoo WCD
Gene Davis	Rancher

Lipan Aquifer Groundwater Availability Model (GAM)
5th Stakeholder Advisory Forum (SAF) Meeting
March 31, 2004
San Angelo, Texas

Meeting Summary

The fifth Stakeholder Advisory Forum (SAF) meeting for the Lipan Aquifer Groundwater Availability Model (GAM) was held on March 31st from 7:00 to 8:30 PM at the Texas A&M Research Center in San Angelo, Texas. TWDB project manager Richard Smith gave an introduction to the GAM program and introduced LBG-Guyton Associates.

James Beach of LBG-Guyton made a presentation to an audience consisting of about 15 attendees. The presentation, along with a list of participants who signed up at the meeting, is available at the TWDB GAM website (www.twdb.state.tx.us/gam). The presentation was structured to review key components of the conceptual model, MODFLOW model calibration, and predictive results.

The questions and answers from the SAF are presented below.

Questions and Answers

Q: *Why does the model simulate flow with one layer when we know that there are unique zones in the limestone that are usually one to two feet thick that produce most of the water in the wells?*

A: MODFLOW uses a continuous porous media conceptualization to simulate groundwater flow. This basically means that the aquifer material in each model layer is the same throughout the thickness of that model layer. To appropriately implement a model with many layers, we would need to know where each of the high permeability zones is located in each well, as well as how contiguous that zone is in the surrounding area. That level of information does not exist; therefore the aquifer has been conceptualized to contain one layer and that layer is assumed to represent the overall transmissivity of the aquifer. The transmissivity value in each model grid block represents the overall "productivity" of the aquifer in that area. This conceptualization is consistent with the overall GAM model objectives and the level of data that is available at this time. This approach has been used successfully to simulate overall ground-water availability in aquifers that have similar vertical variation in hydraulic properties.

Q: *The results indicate that water levels could decrease another 90 feet by 2050. If that happened, some of the wells in that area would be dry, but your model doesn't indicate that, why?*

A: This is partly due to the conceptual model, which was discussed in the previous question. The model is designed to represent typical conditions in the aquifer, but doesn't simulate well hydraulics in individual wells. Although some wells would be dry under those conditions, the model layer representing the "average" aquifer dimensions is deeper than most of those wells. Because the model assumes that the wells are completed all the way to the base of the aquifer, they would not be dry under those conditions.