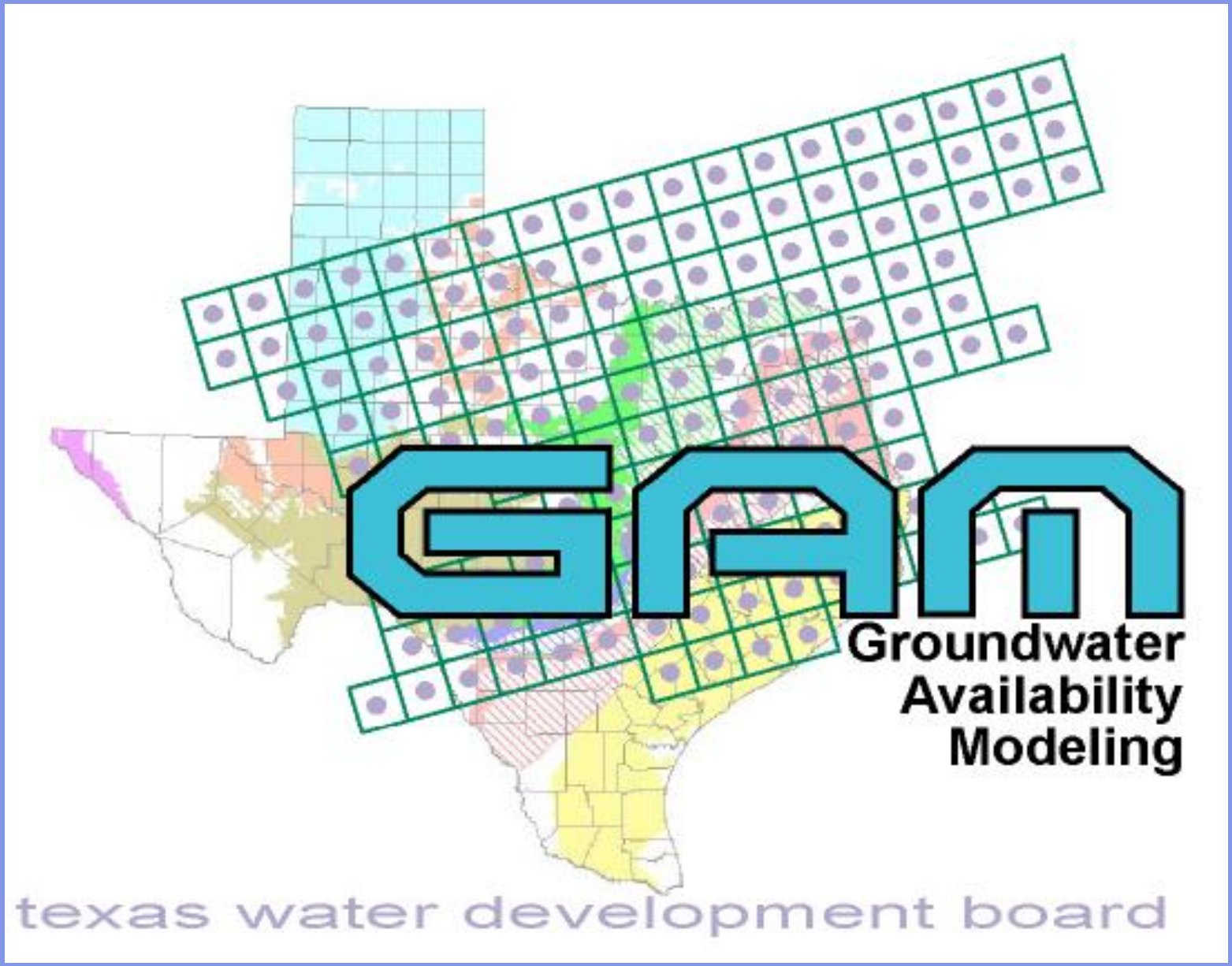
Groundwater Availability Model (GAM) for the Nacatoch Aquifer

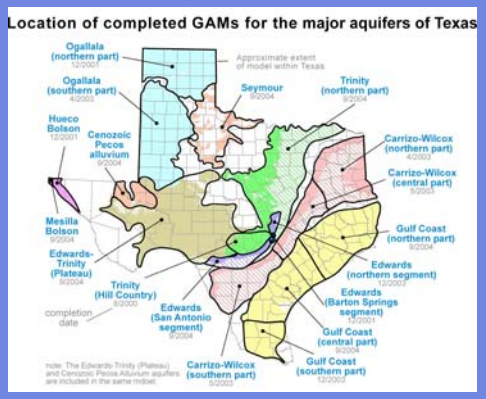
Online presentation of

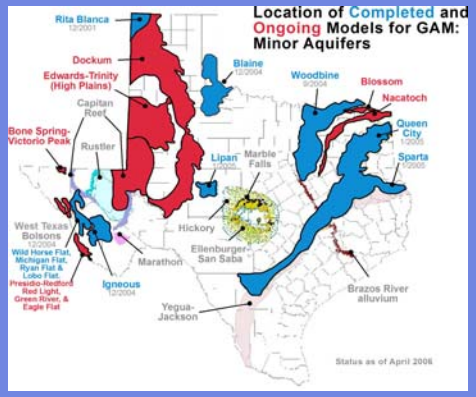
2nd Stakeholder Advisory Forum

June 2007

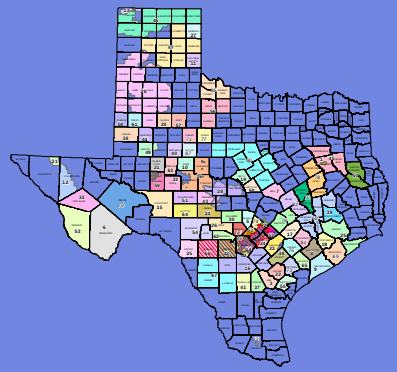

GAM
Groundwater
Availability
Modeling
texas water development board

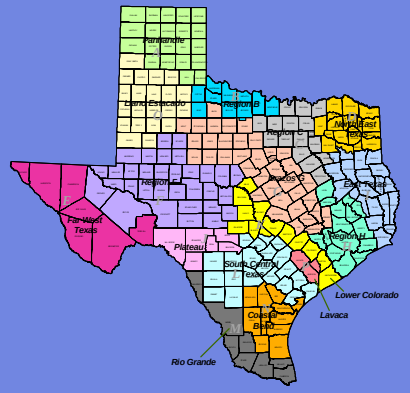
Groundwater Availability Modeling



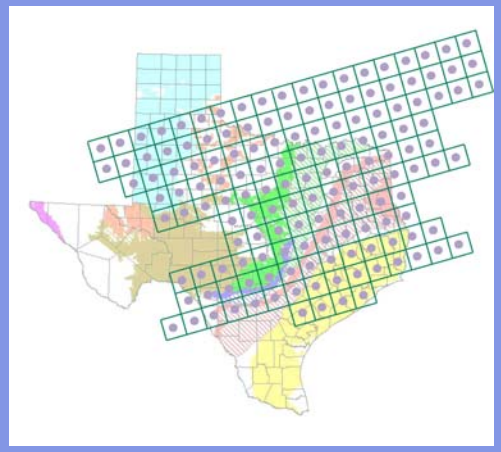


Contract Manager
Andrew Donnelly





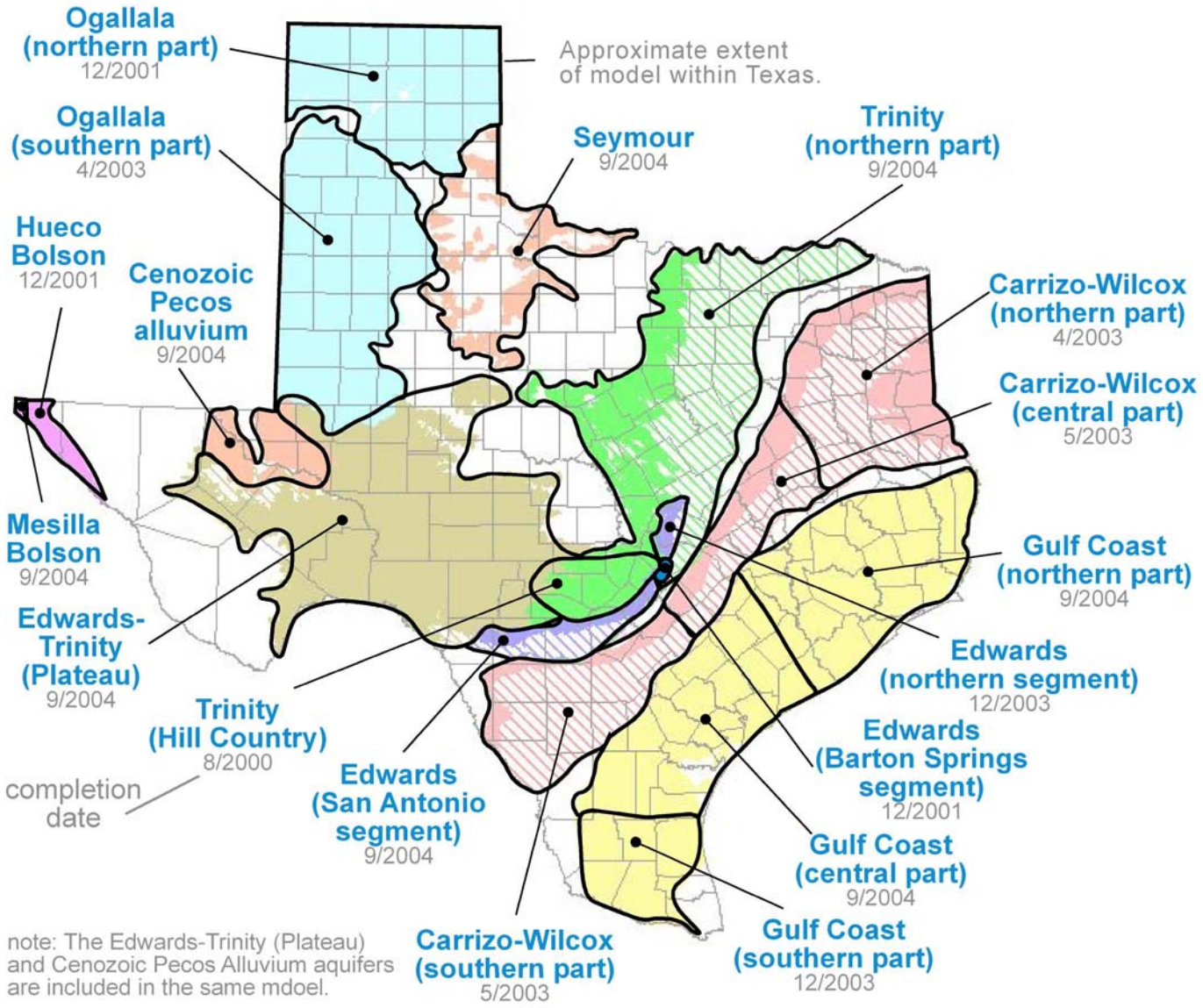
Texas Water Development Board

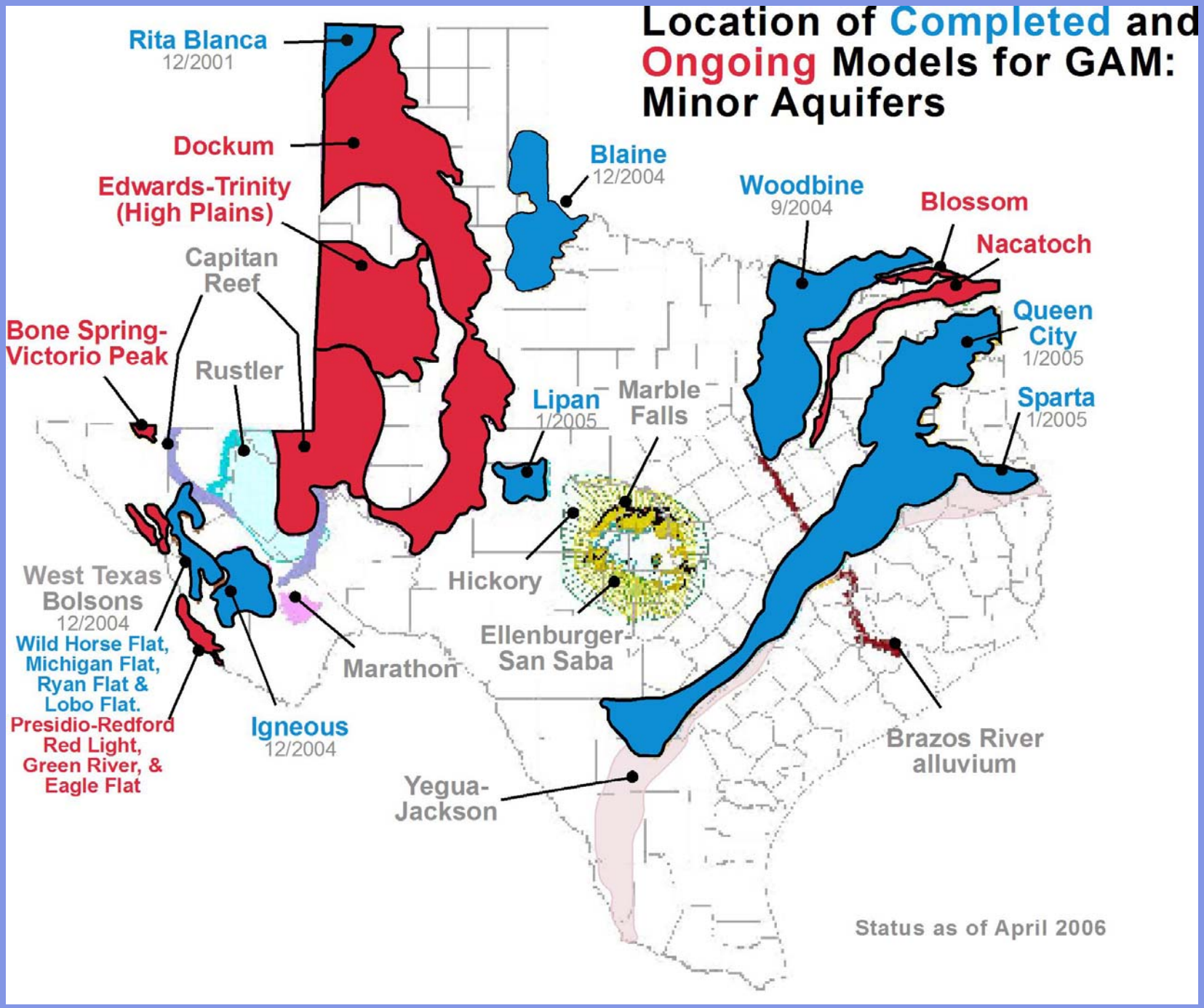


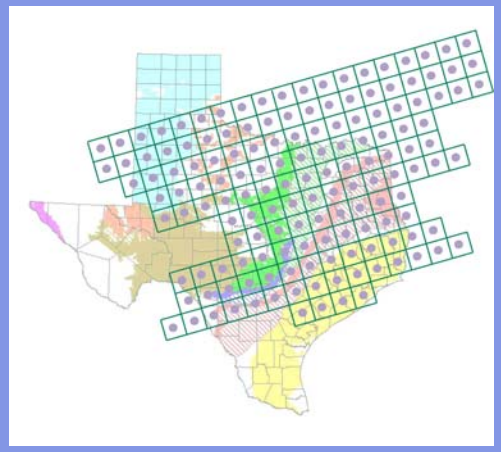
GAM

- Purpose: to develop tools that can be used to help GCDs, RWPGs, and others assess groundwater availability.
- 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 GAMs for the major aquifers of Texas



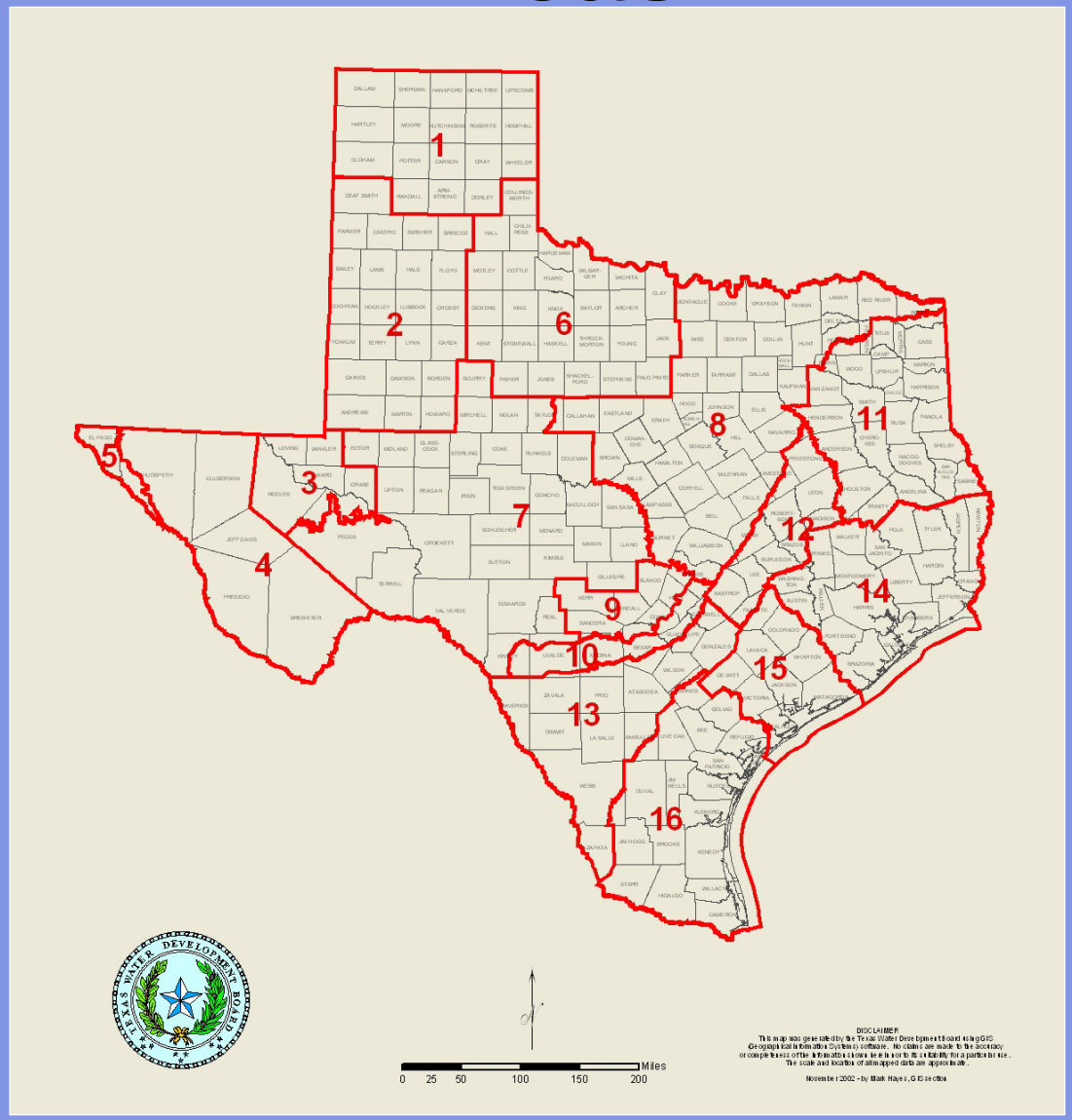

Location of Completed and Ongoing Models for GAM: Minor Aquifers
Rita Blanca
12/2001
Dockum
Edwards-Trinity (High Plains)
Capitan Reef
Bone Spring-Victorio Peak
Rustler
Blaine
12/2004
Woodbine
9/2004
Blossom
Nacatoch
Queen City
1/2005
Sparta
1/2005
Lipan
1/2005
Marble Falls
Hickory
Ellenburger-San Saba
West Texas Bolsons
12/2004
Wild Horse Flat, Michigan Flat, Ryan Flat & Lobo Flat.
Presidio-Redford
Red Light, Green River, & Eagle Flat
Marathon
Igneous
12/2004
Yegua-Jackson
Brazos River alluvium
Status as of April 2006

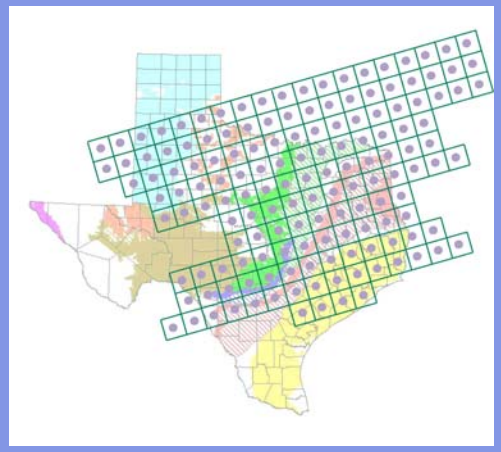


What is groundwater availability or MAG?

- Managed available groundwater (MAG)…the amount of groundwater available for use.
- The State does not directly decide how much groundwater is available for use: GCDs will through GMA process
- A GAM is a tool that can be used to assess groundwater availability once GCDs and GMAs decide on the desired future condition of the aquifer.

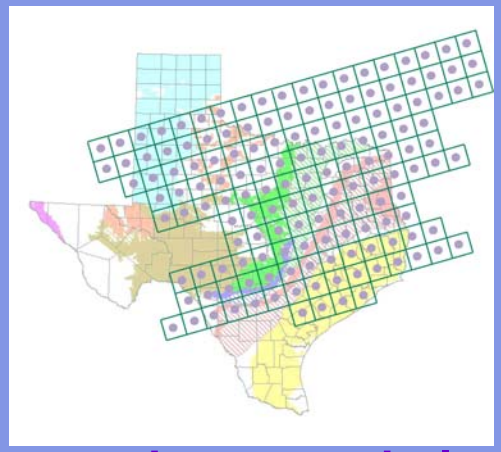
Groundwater Management Areas





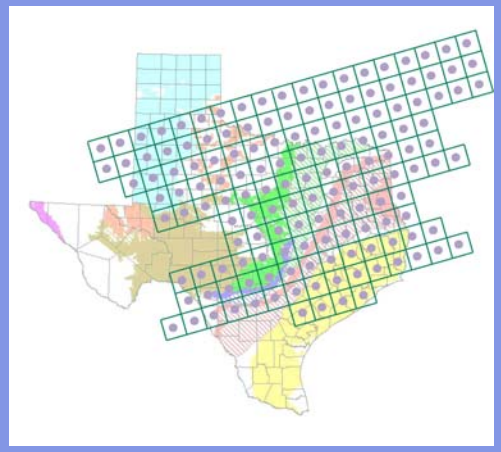
Do we have to use GAM?

- Water Code & TWDB rules require that GCDs use GAM information, if available, for their management plans.
- TWDB rules require that RWPGs use managed available groundwater estimates, if developed in time for the planning cycle



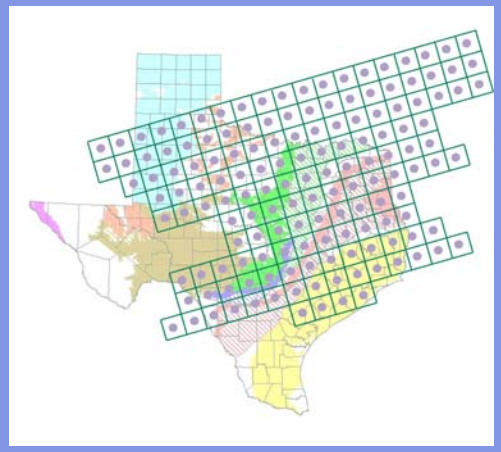
How do we use GAM?

- The model
  - 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 information.
- 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
  - at end of project
- Contact TWDB
  - contract manager

Comments:

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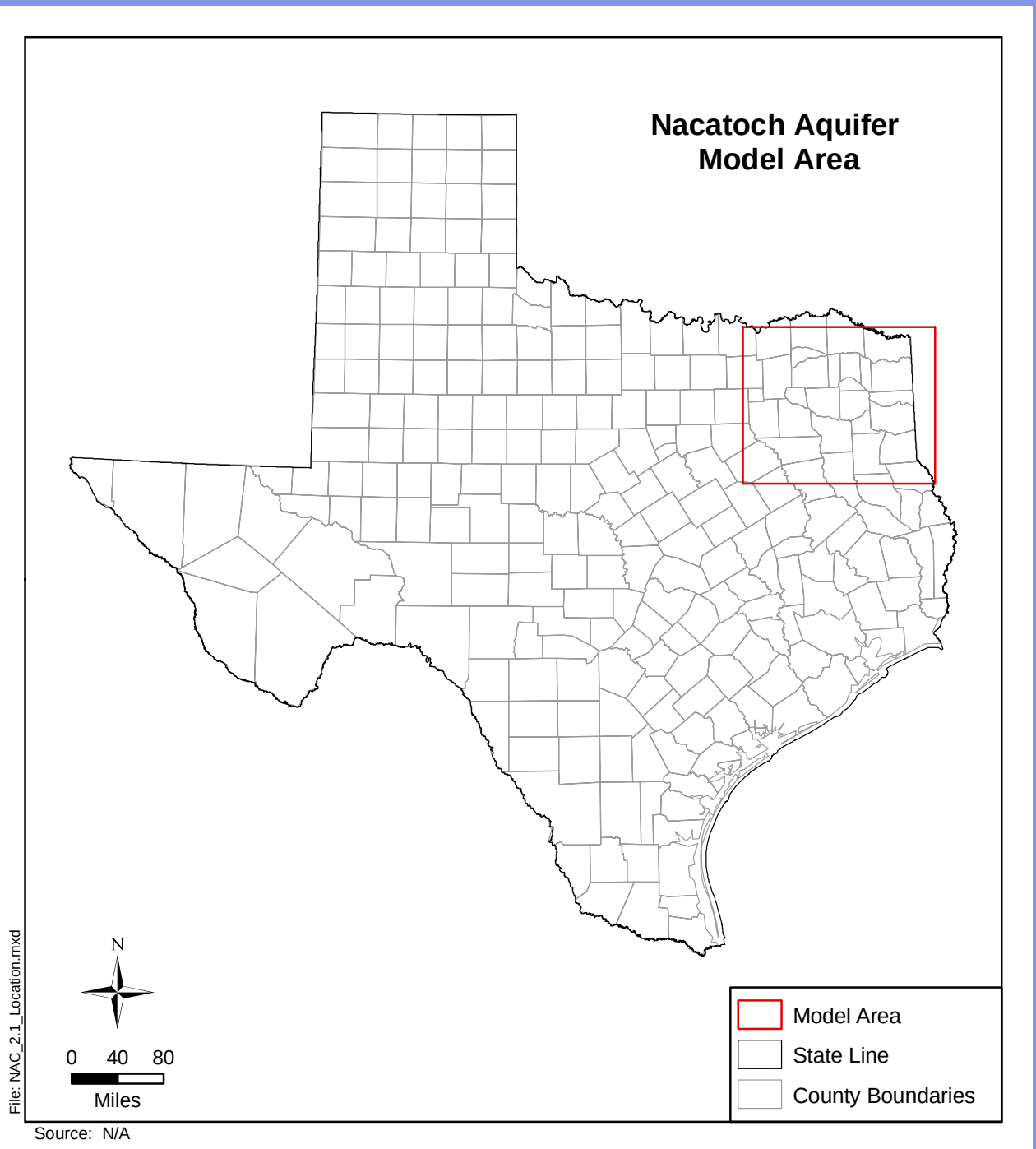
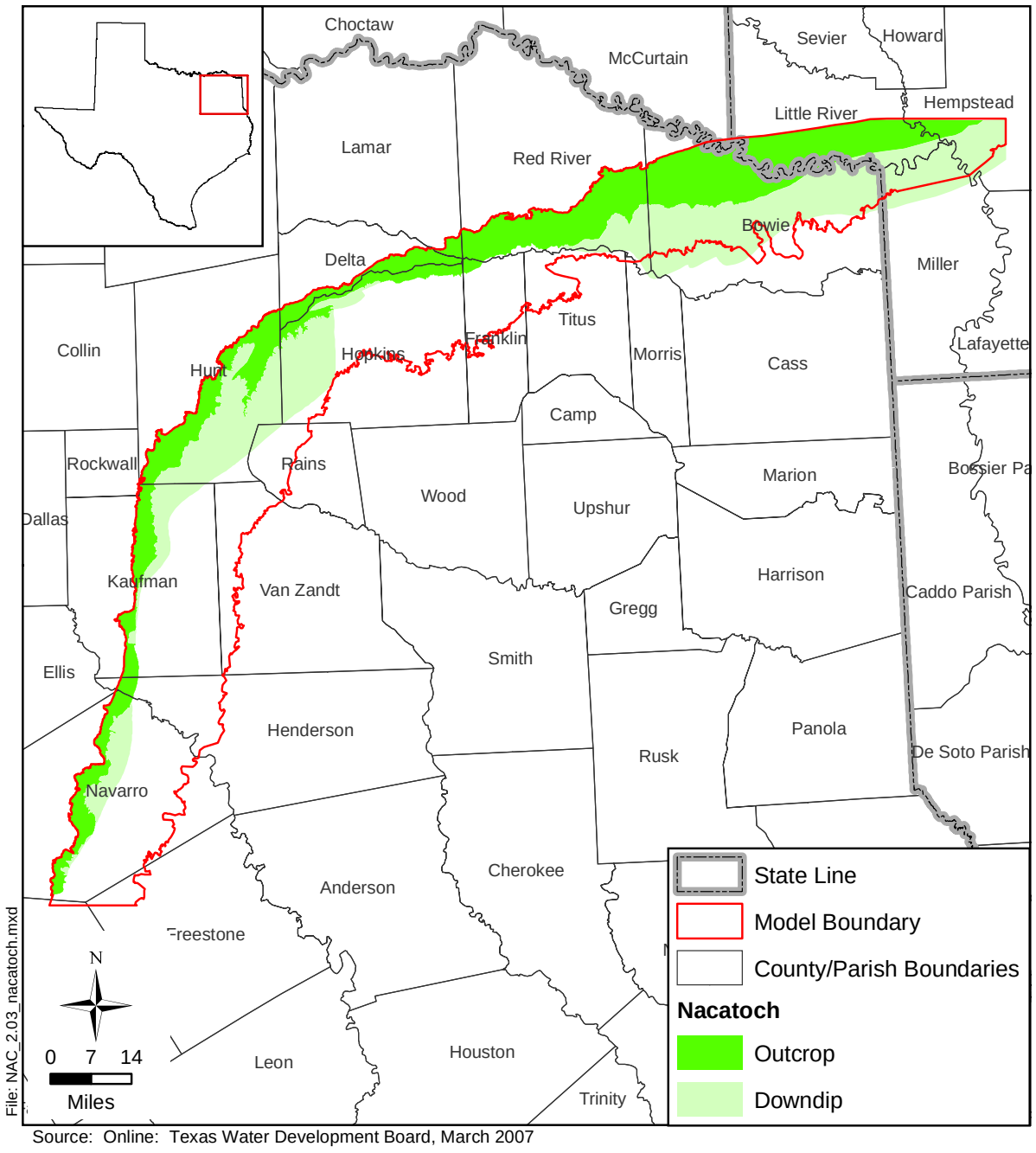
Andy.Donnelly@twdb.state.tx.us
(512) 463-3132
www.twdb.state.tx.us/gam

General Info

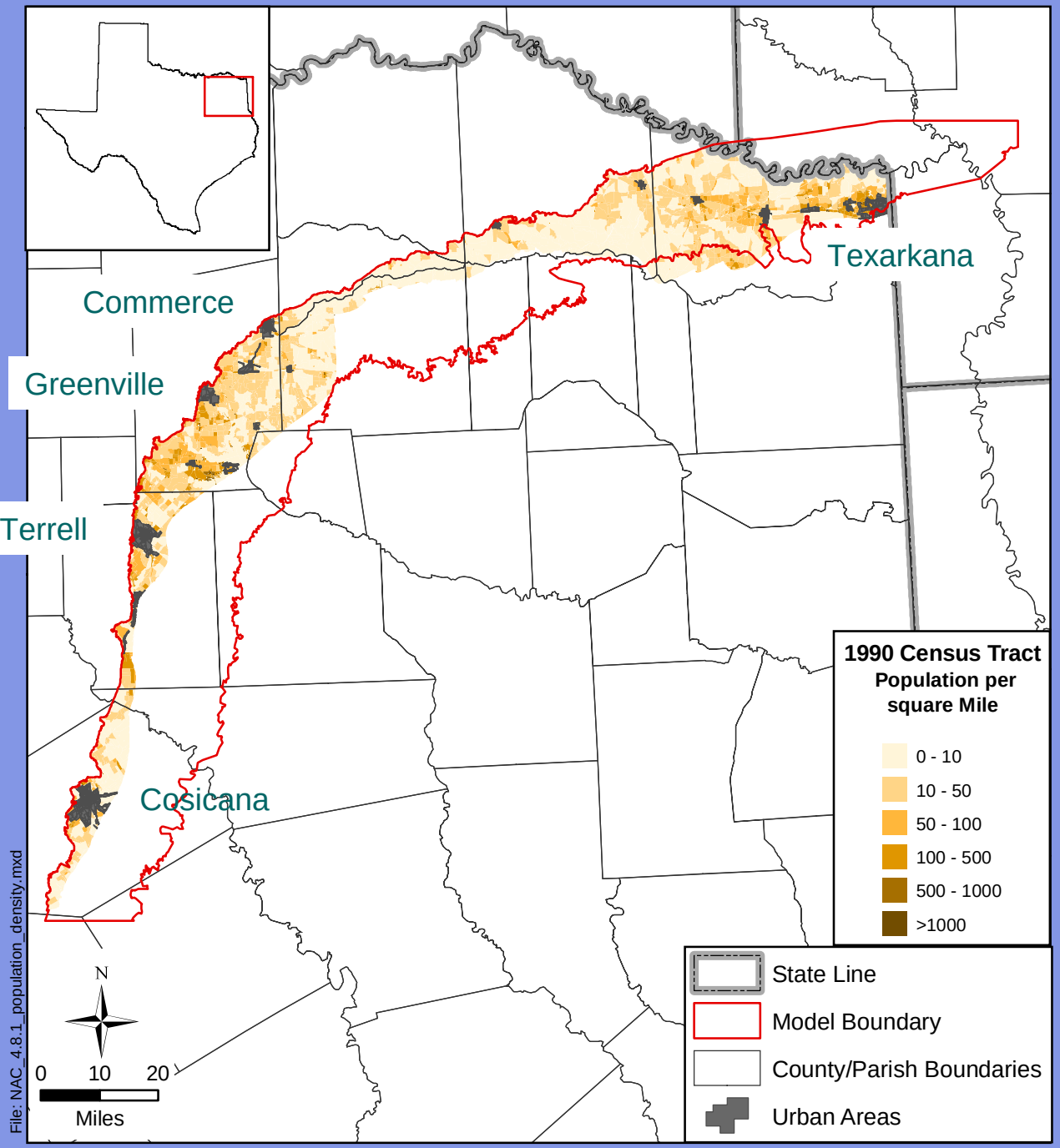
General Location Map



Location of the Nacatoch Aquifer

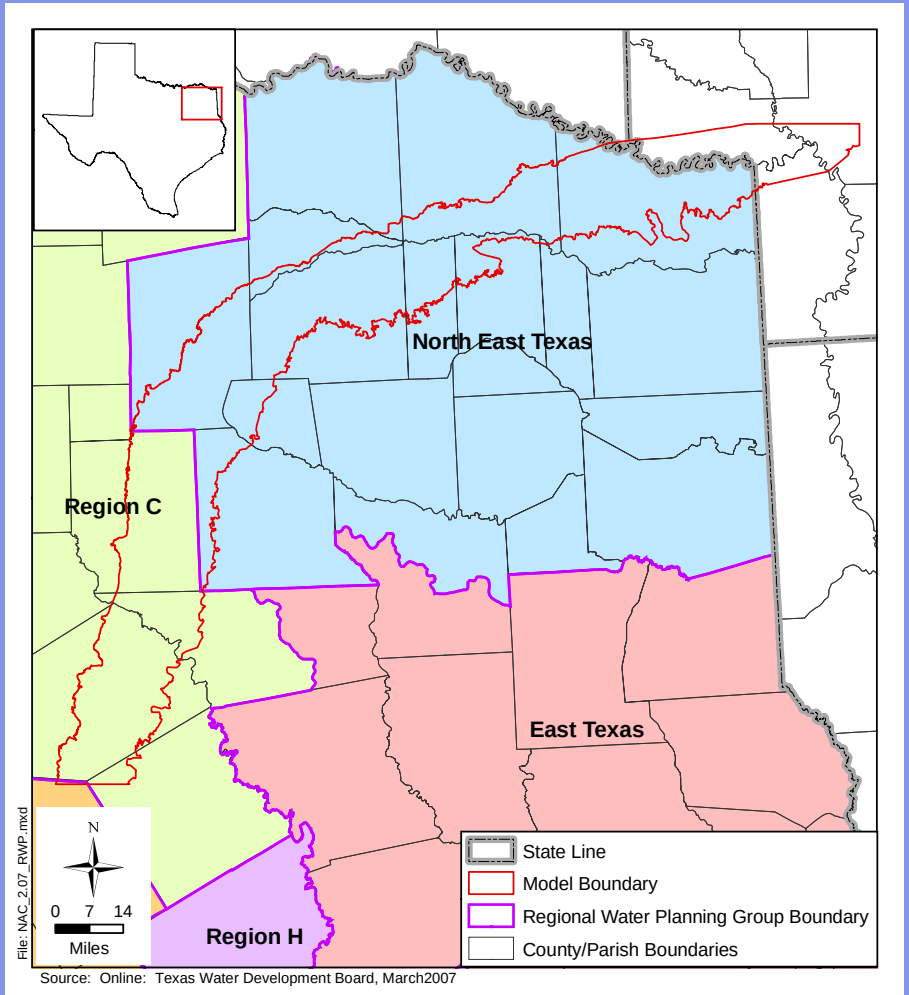


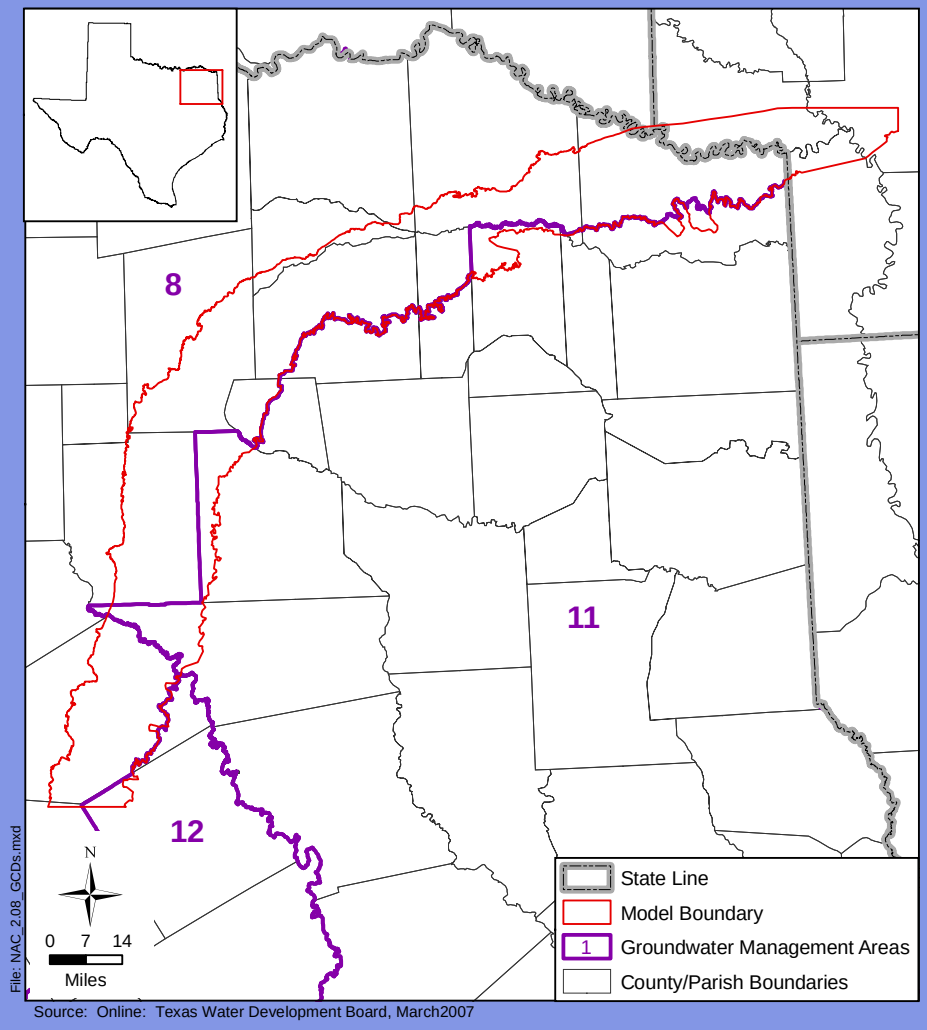
Source: Online: Texas Water Development Board, March 2007



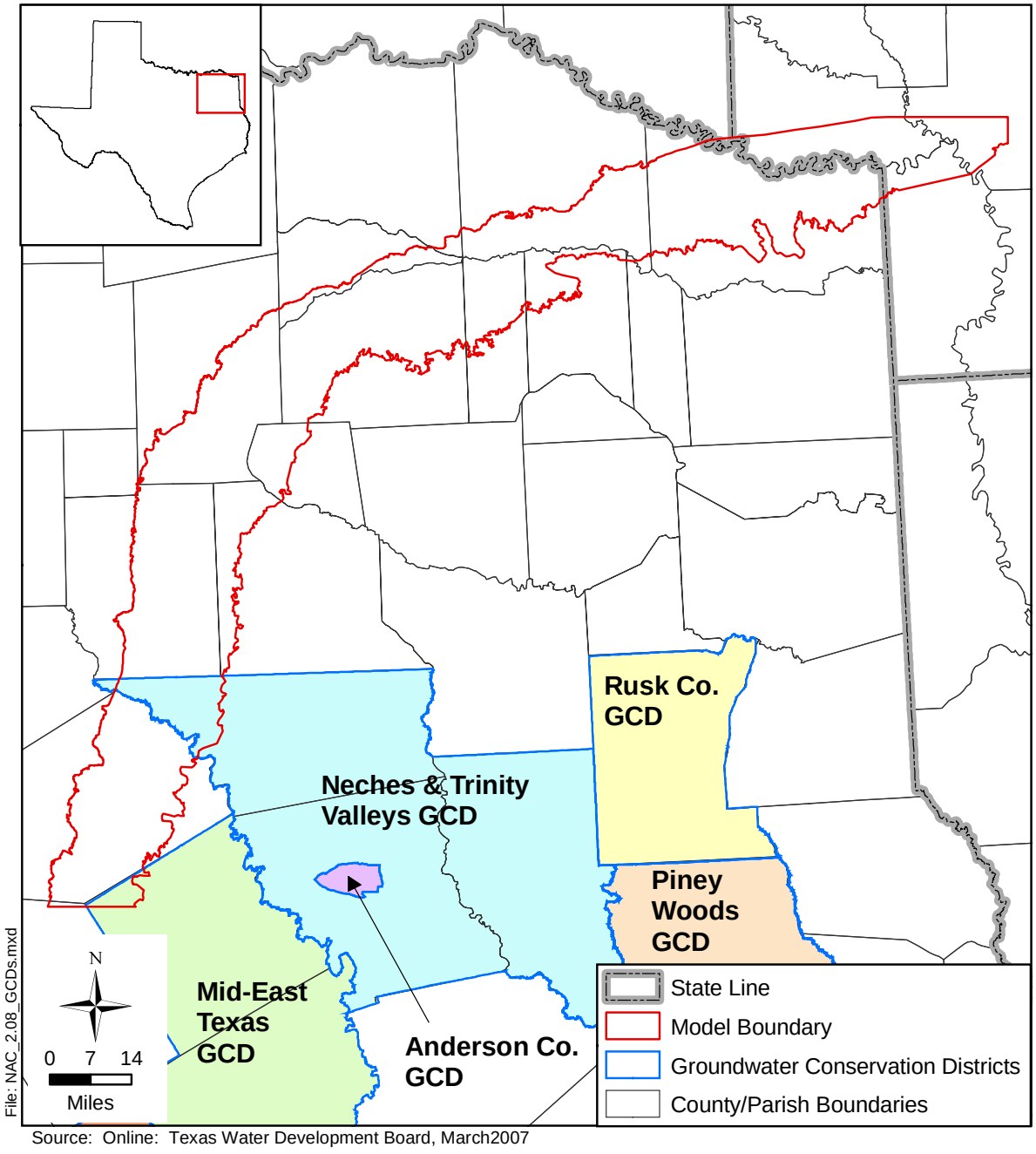
1990 Census Data and Major Cities

Regional Water Planning Groups & Groundwater Management Areas

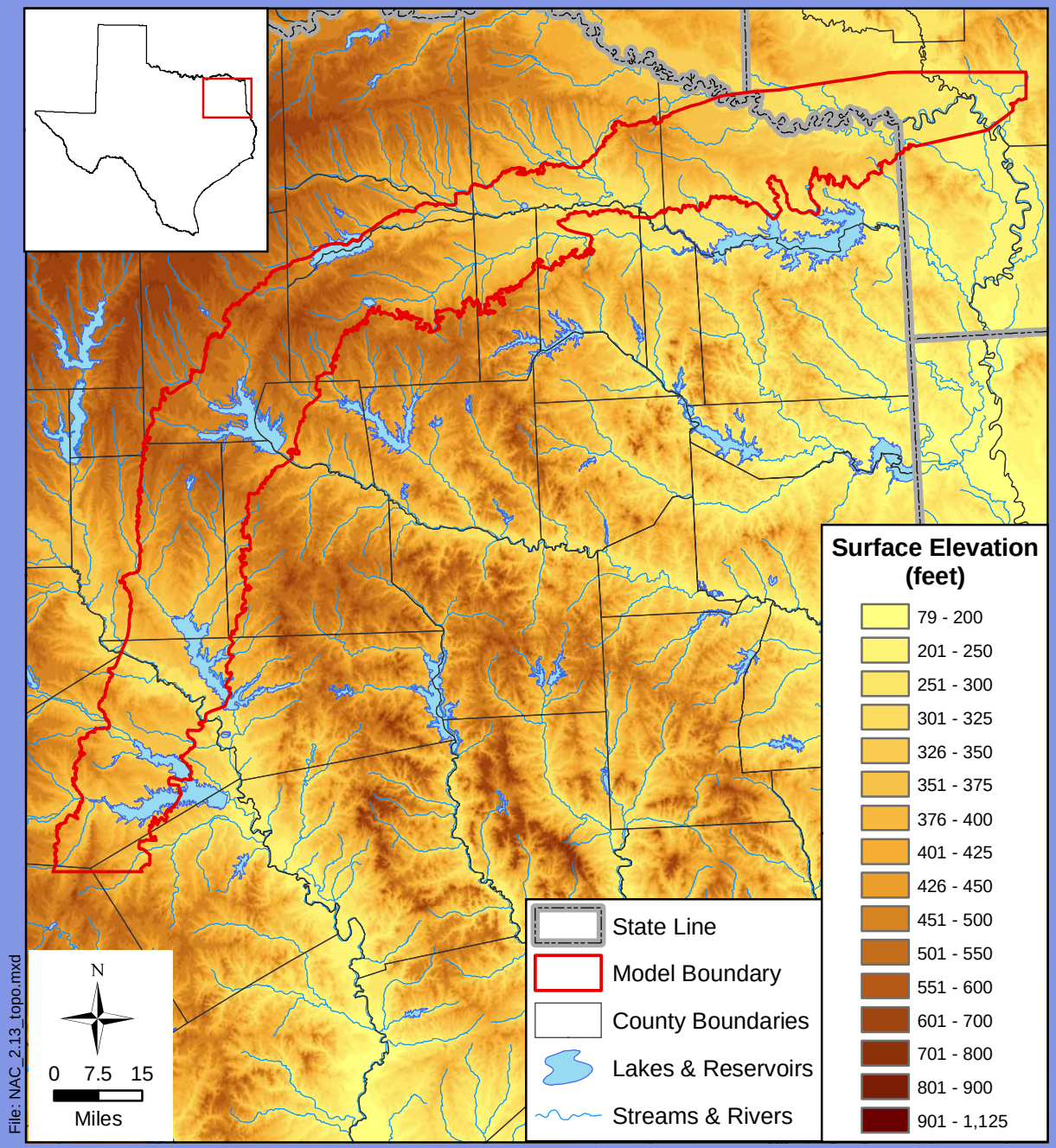




Groundwater Conservation Districts

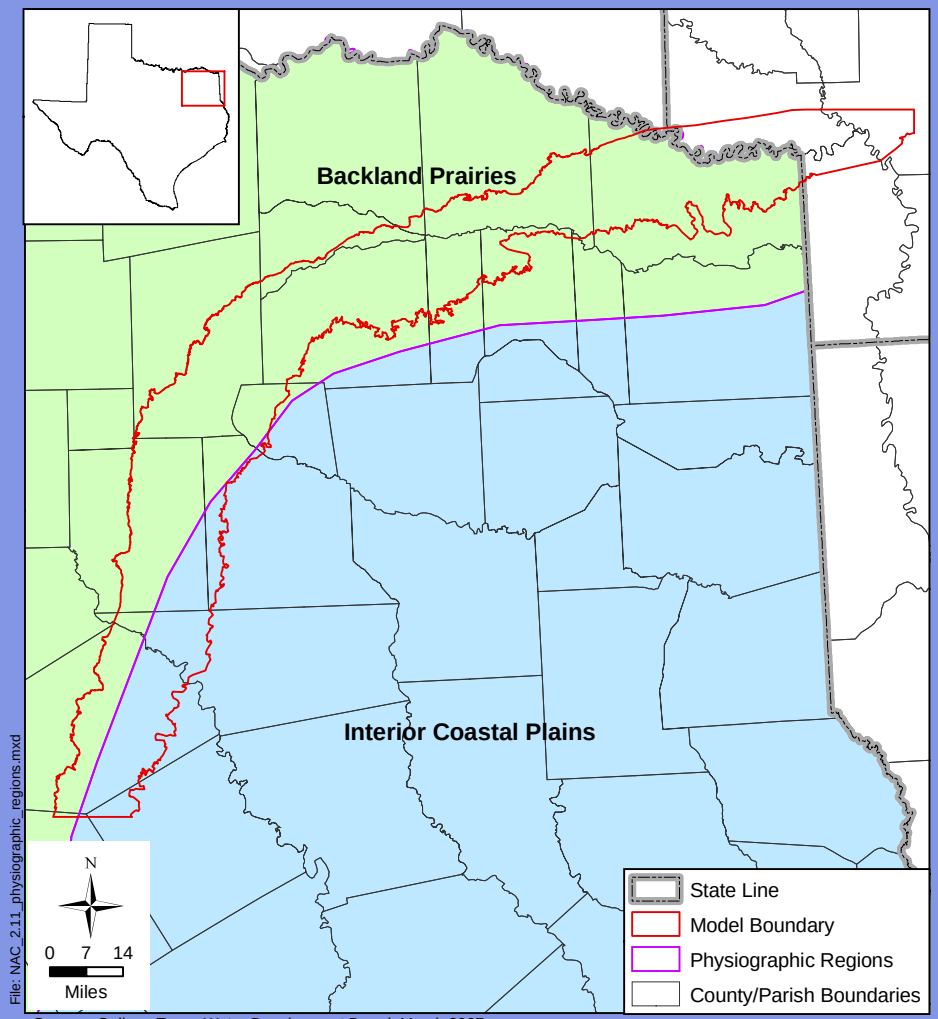


Topography

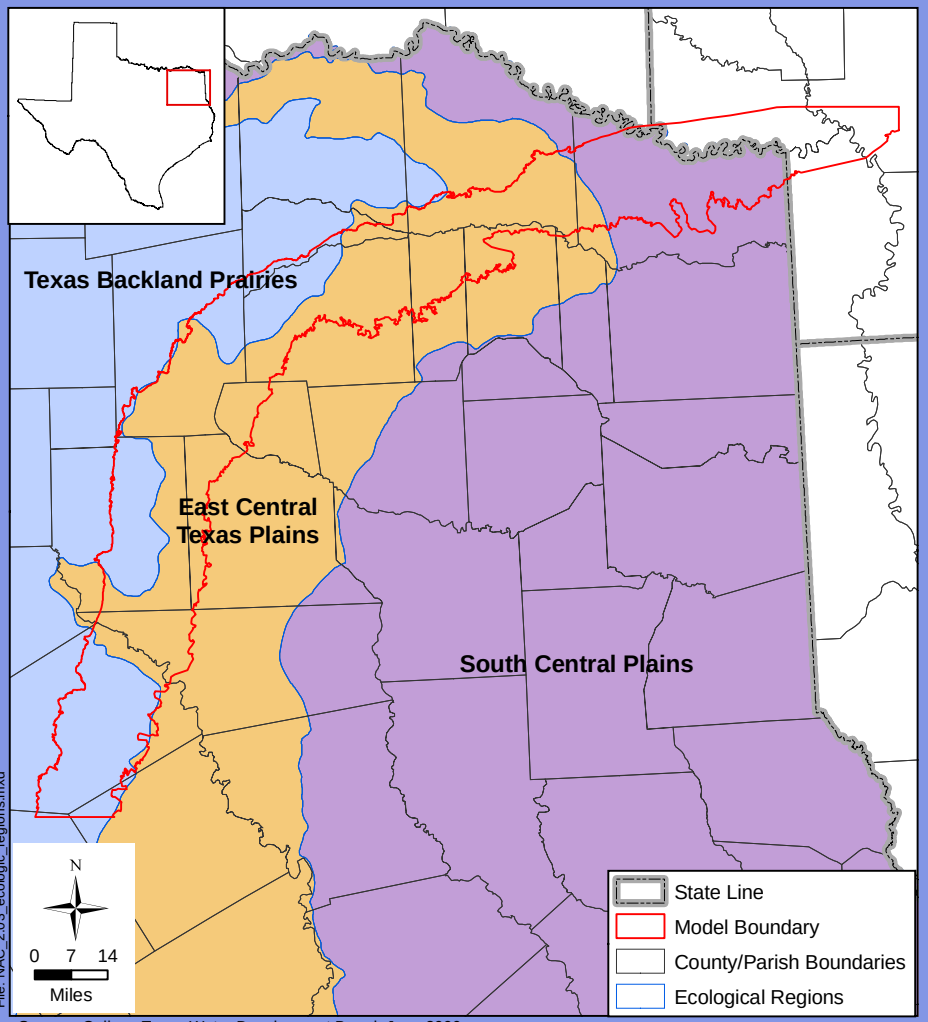


Source: Online: Texas Water Development Board; USGS seamless 1" NED, March 2007

Physiographic Provinces & Ecological Regions

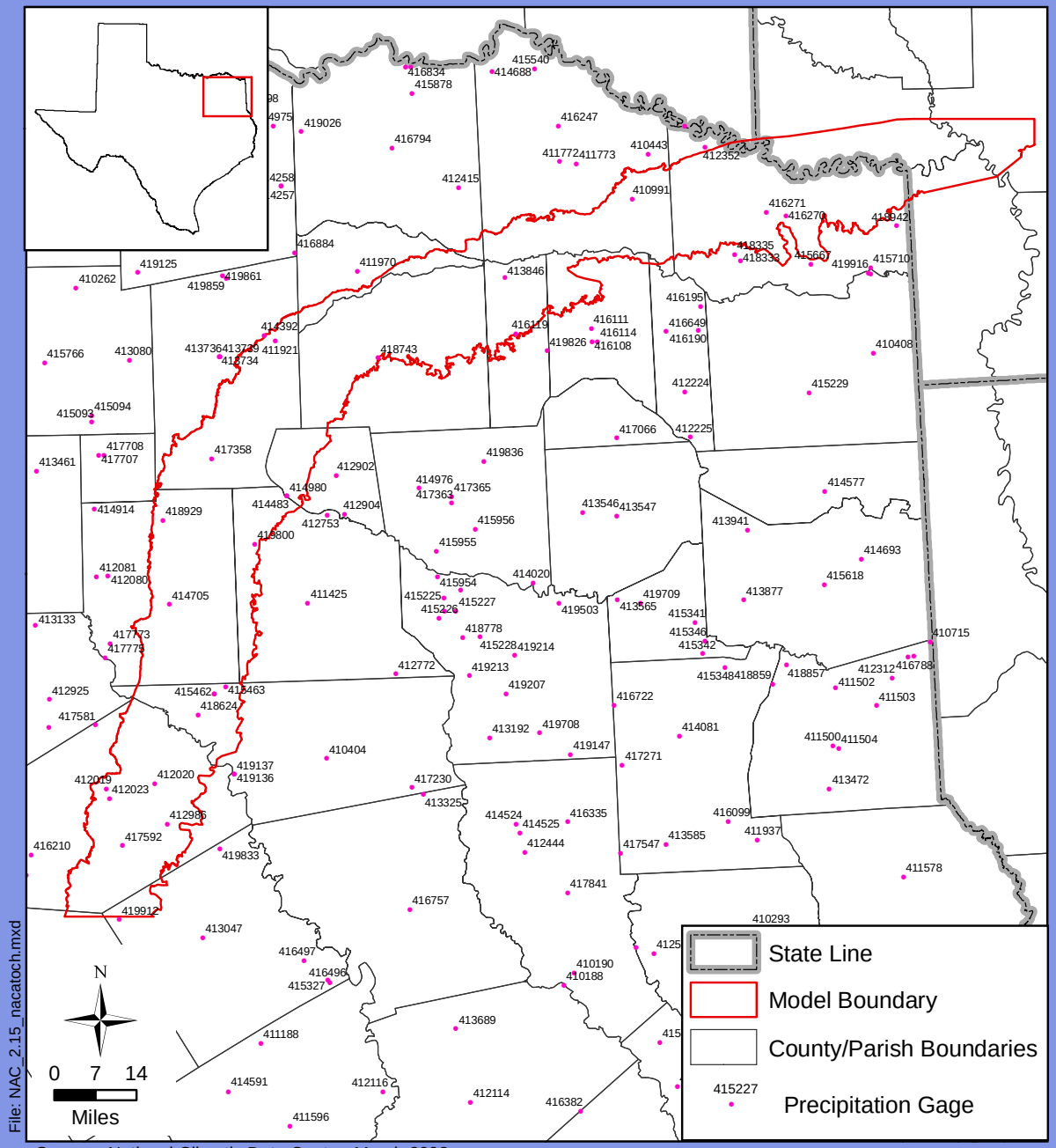


Source: Online: Texas Water Development Board, March 2007



Source: Online: Texas Water Development Board, June 2006

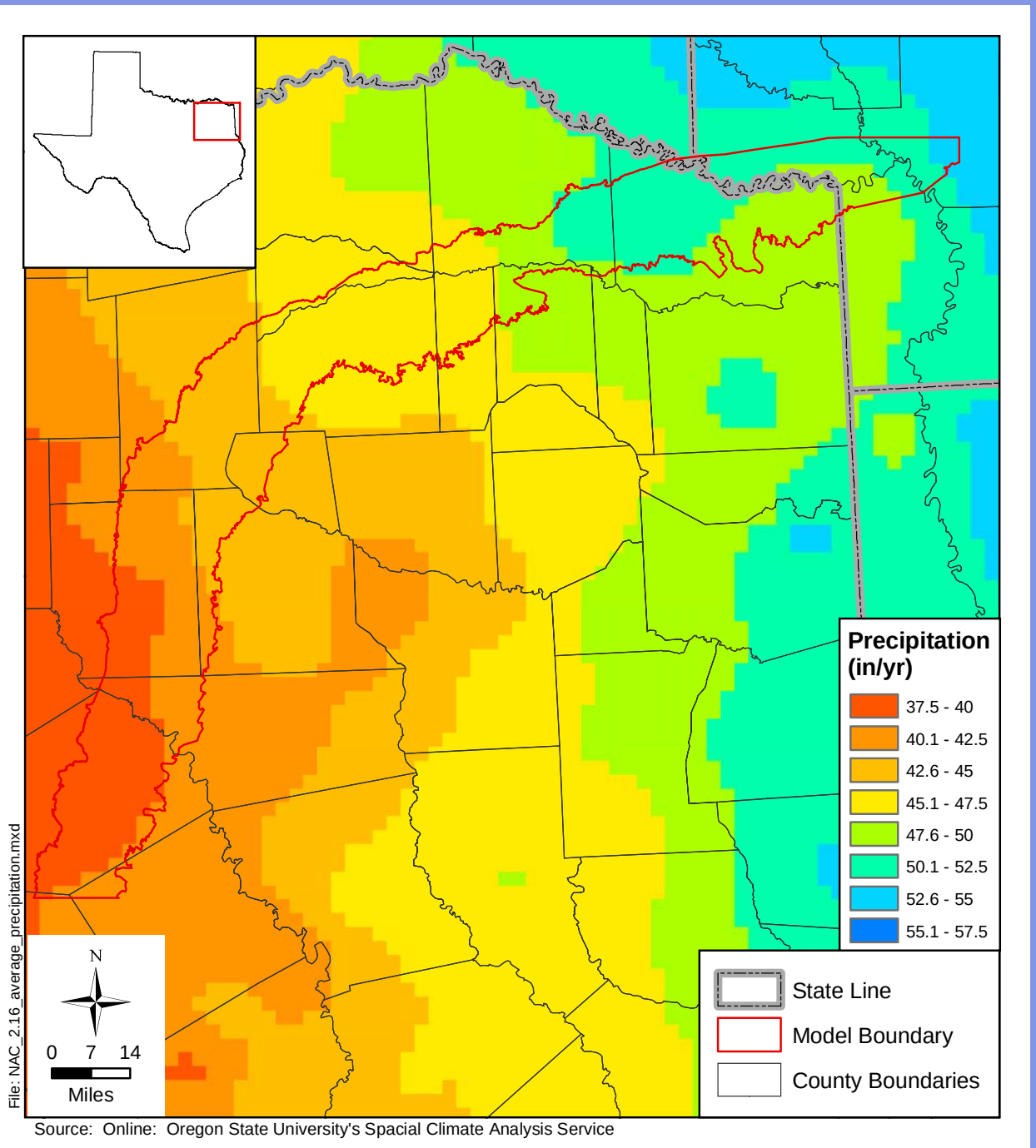
Weather Stations With Historical Precipitation Data



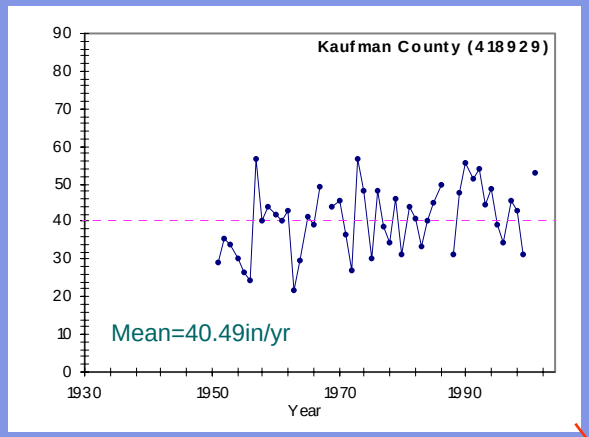
Source: National Climatic Data Center, March 2003

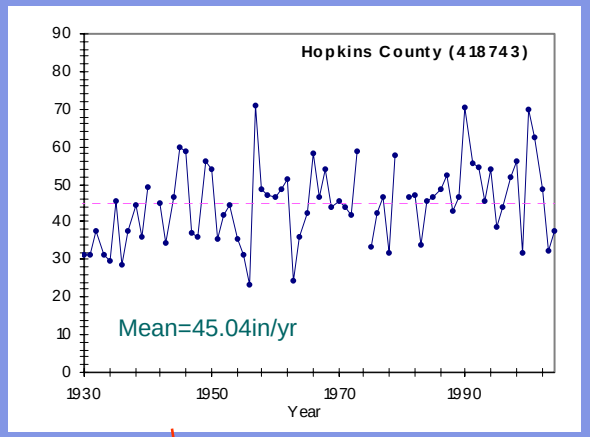
Precipitation

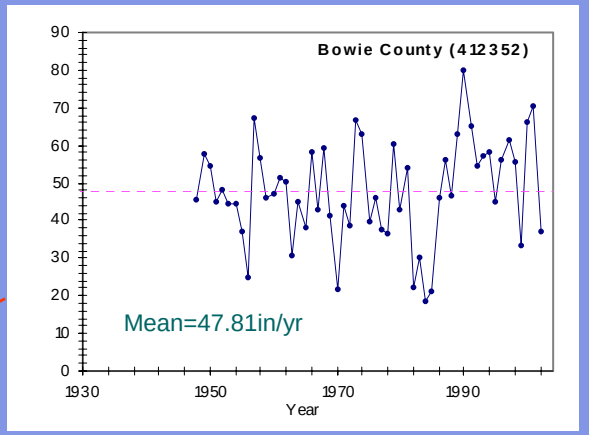
(inches/year)

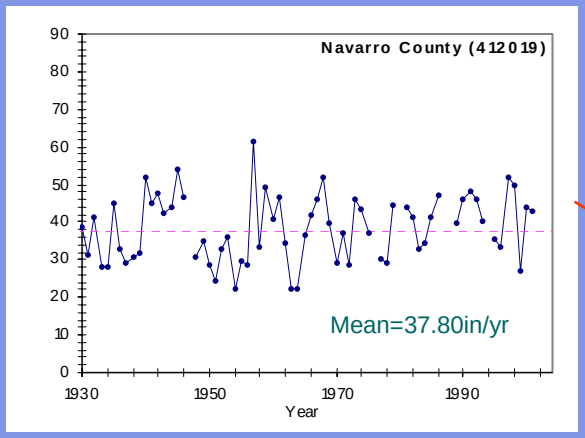


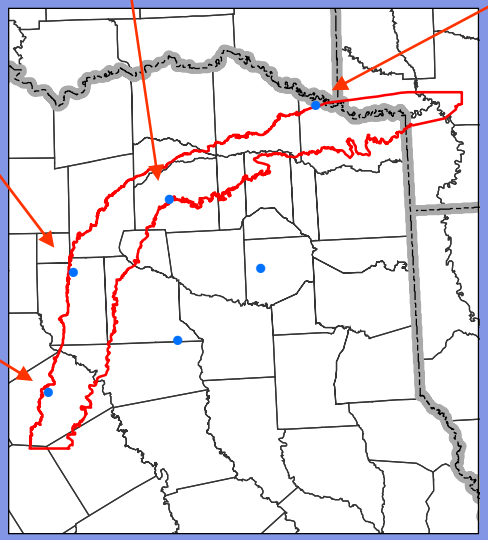
Precipitation Time Series





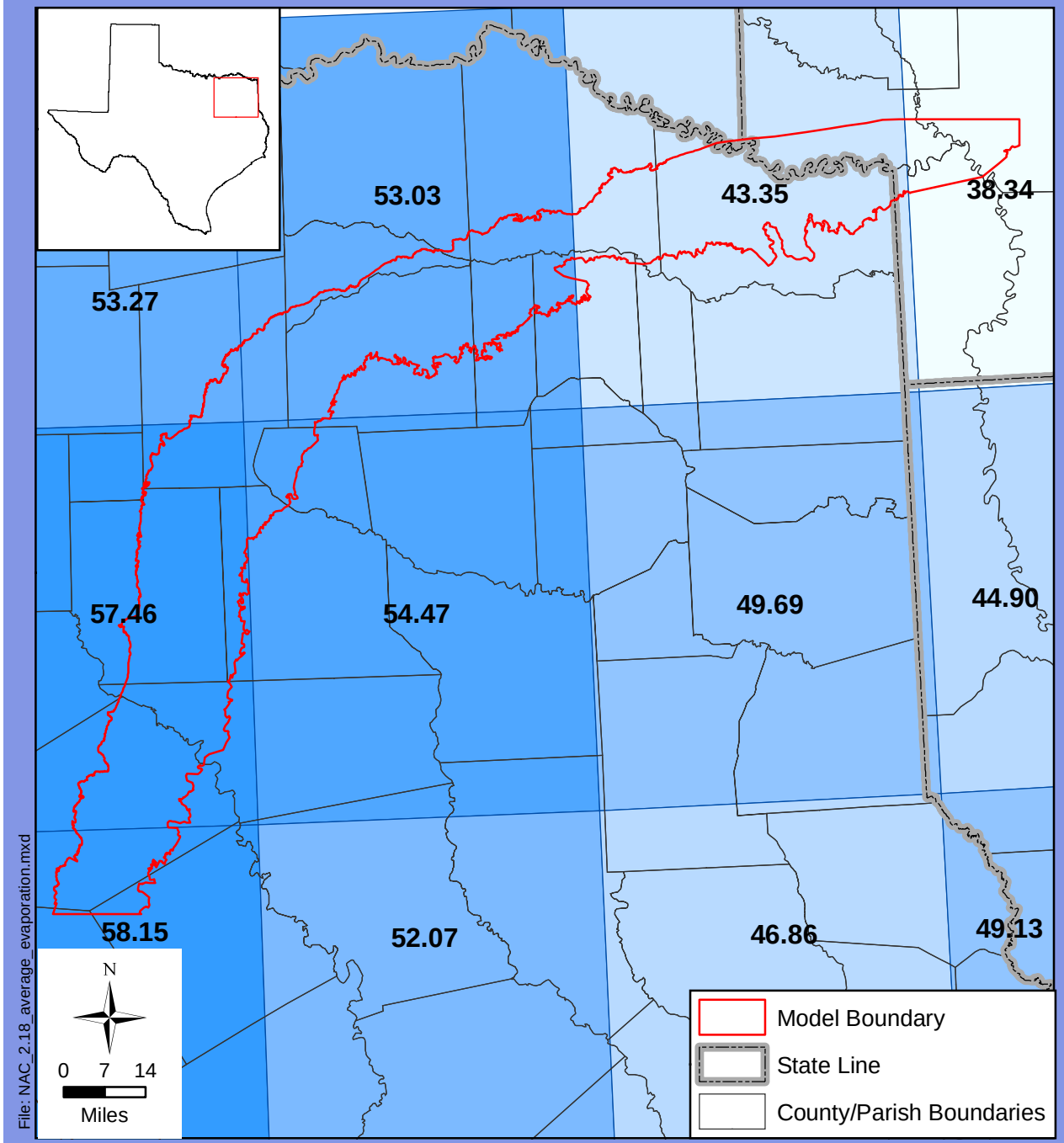






DOR – June 1954 through March 1957

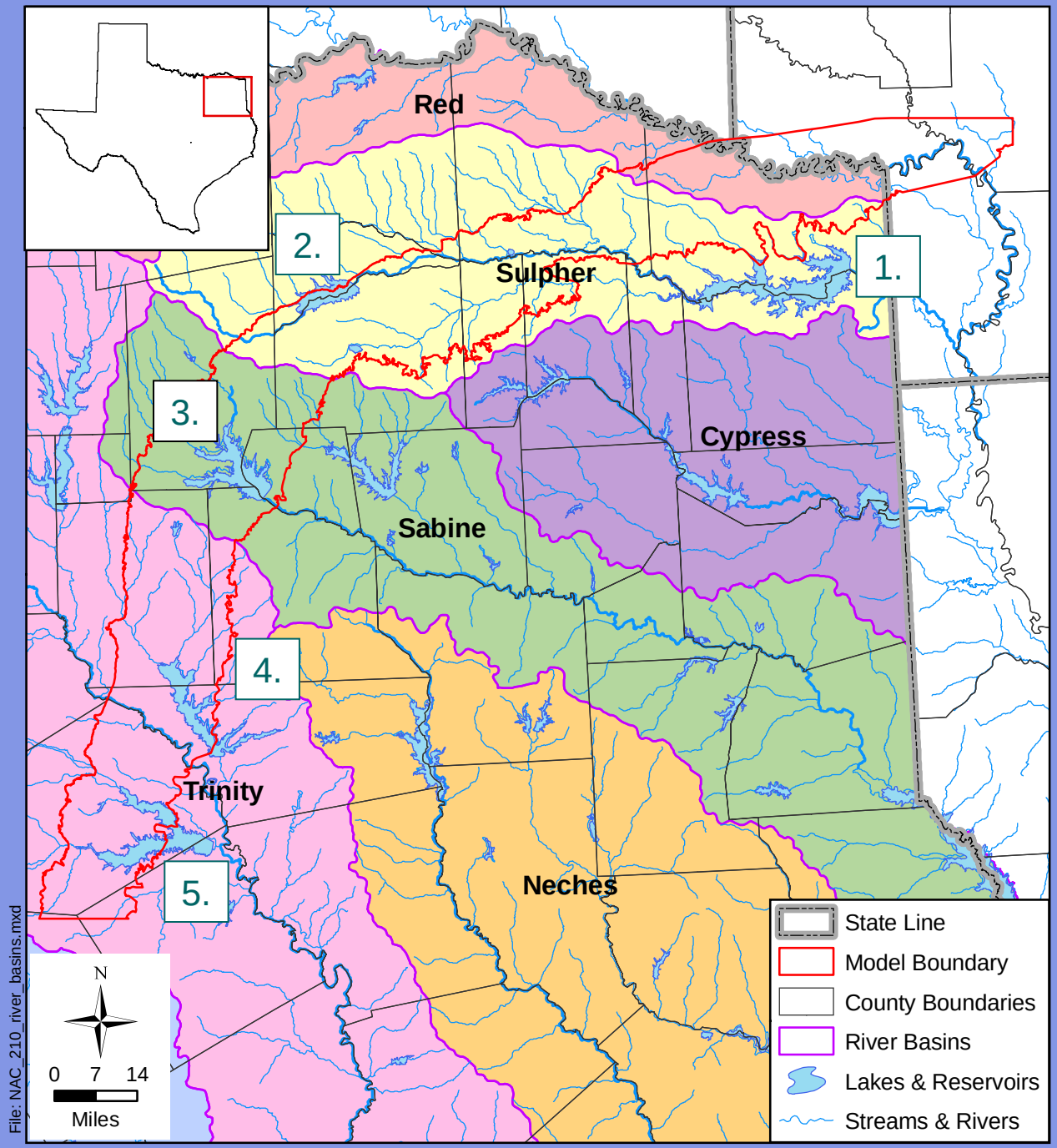
Pan Evaporation (inches/year)



File: NAC_2.18_average_evaporation.mxd

Source: Online: Texas Water Development Board, March 2007

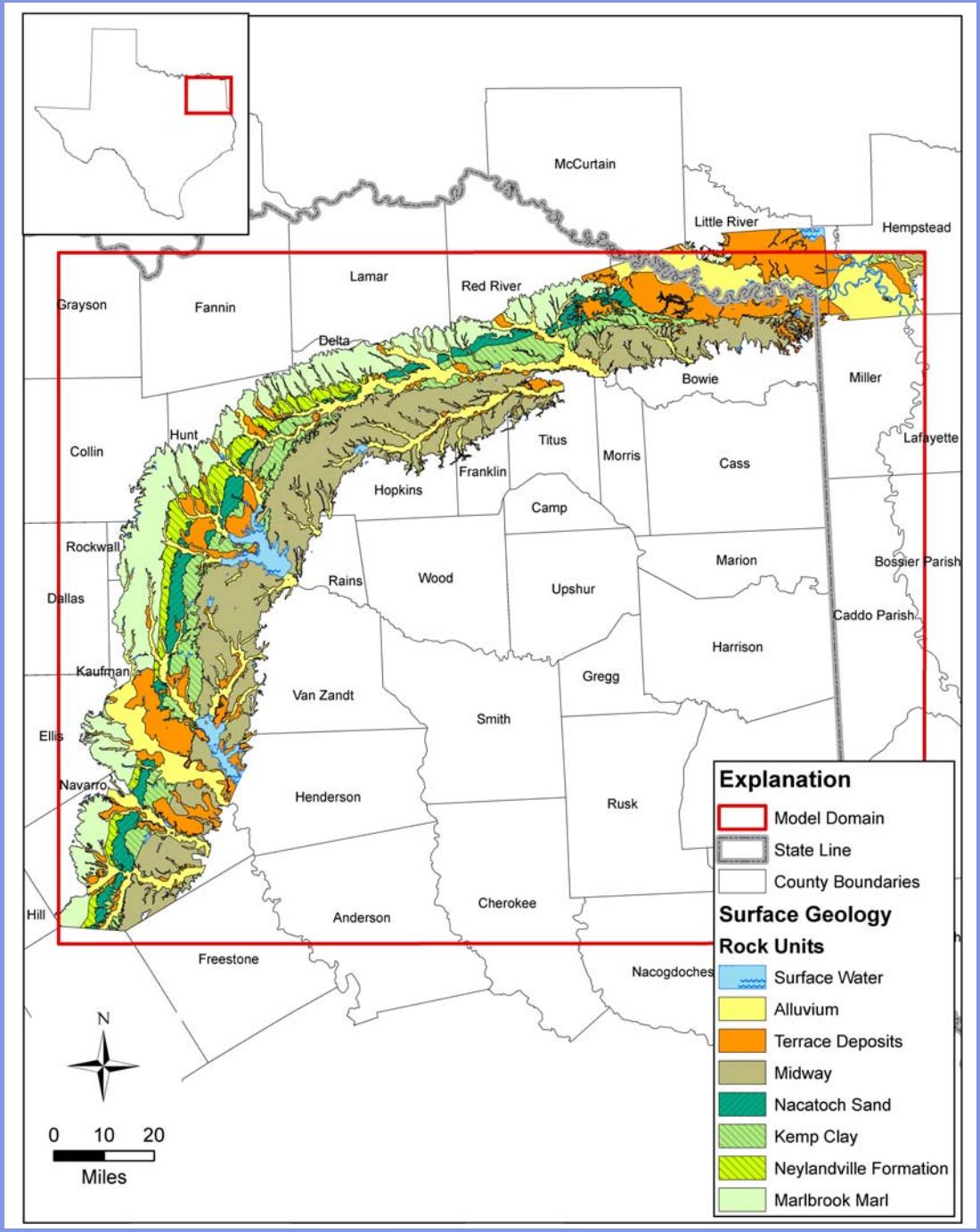
Major River Basins



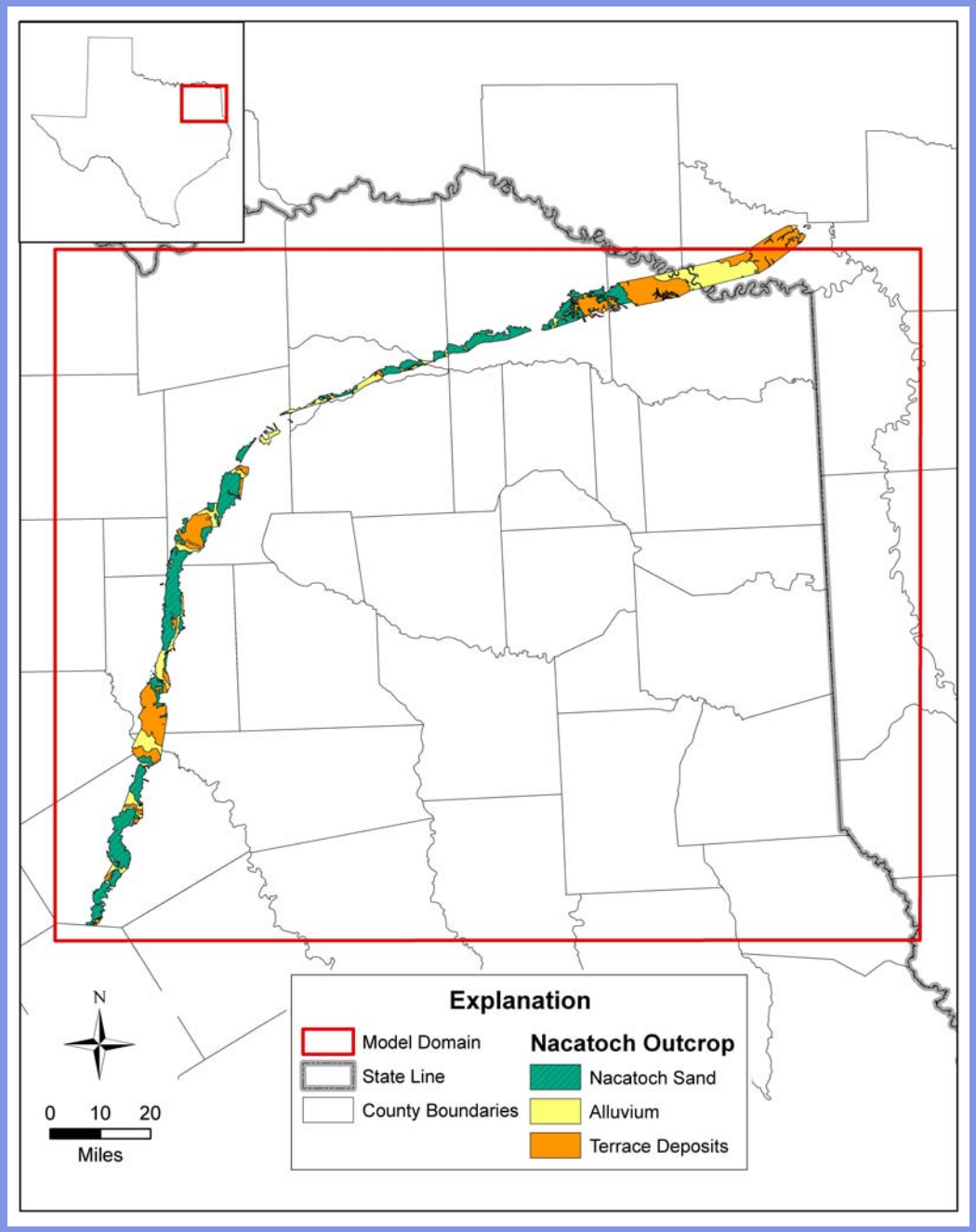
1. Wright Patman
2. Cooper Lake
3. Lake Tawakoni
4. Cedar Creek Res.
5. Richland-Chambers Res.

Source: Online: Texas Water Development Board, March2007

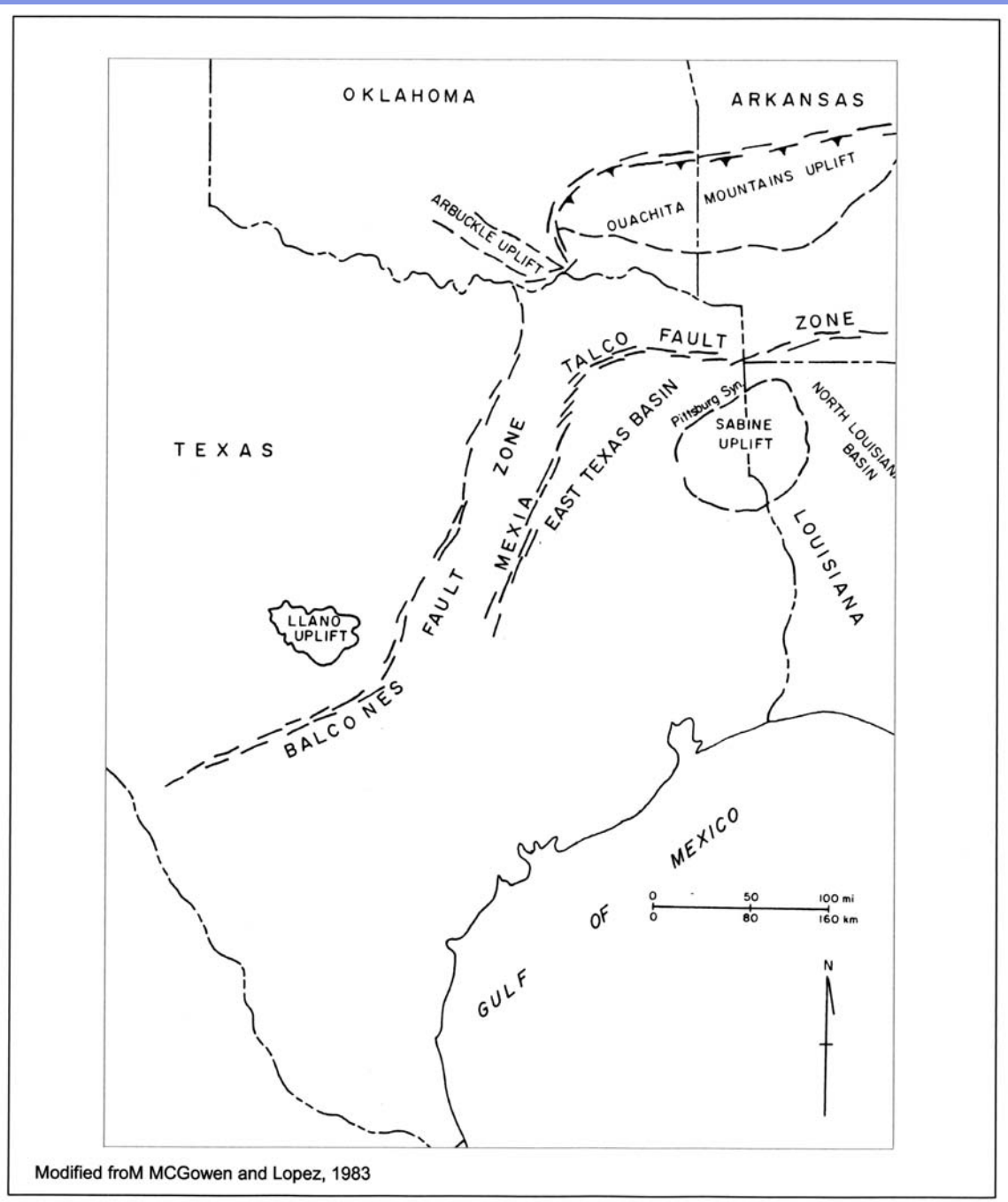
Surface Geology



Nacatoch Outcrop

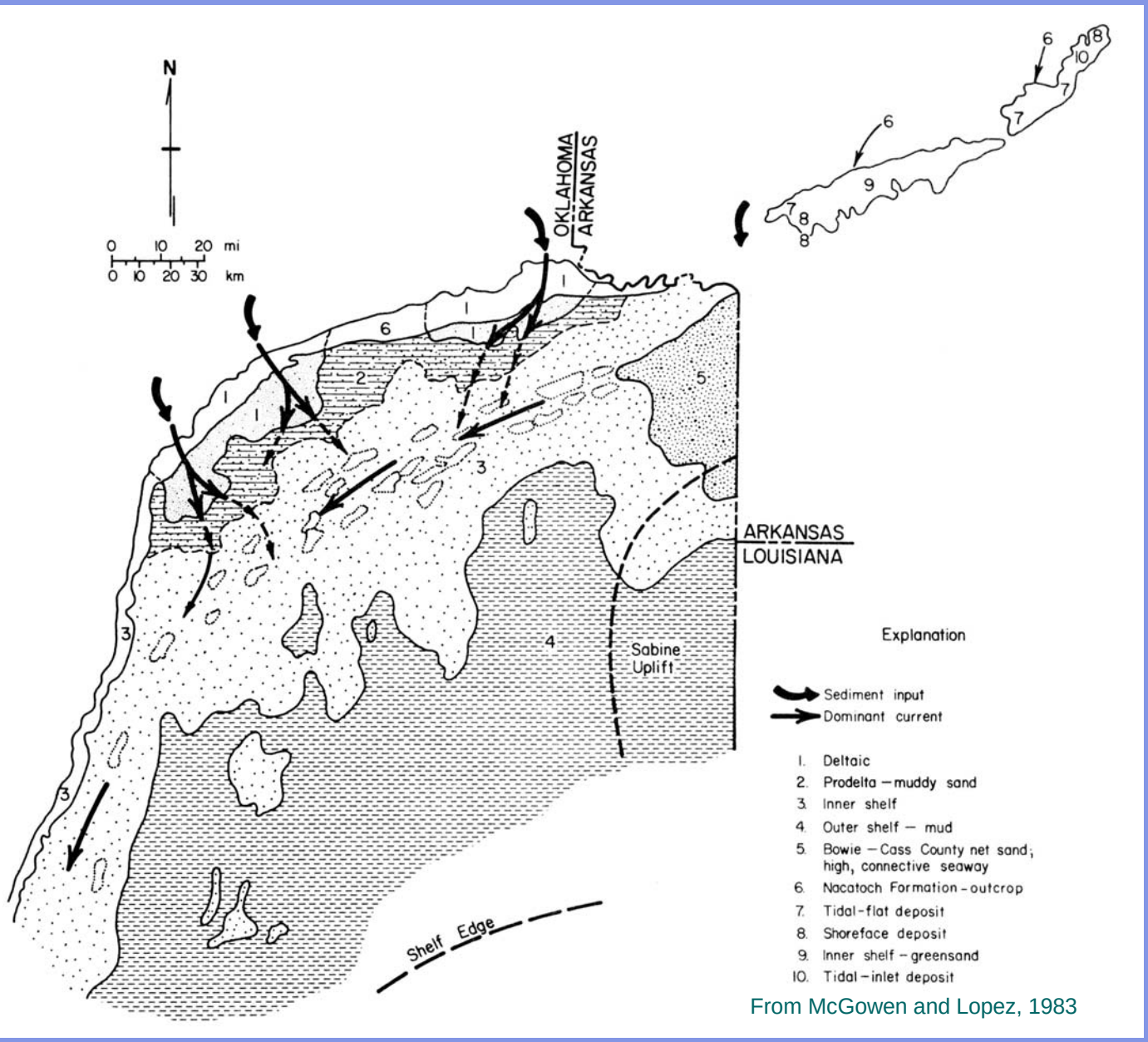


Major Tectonic and Structural Features



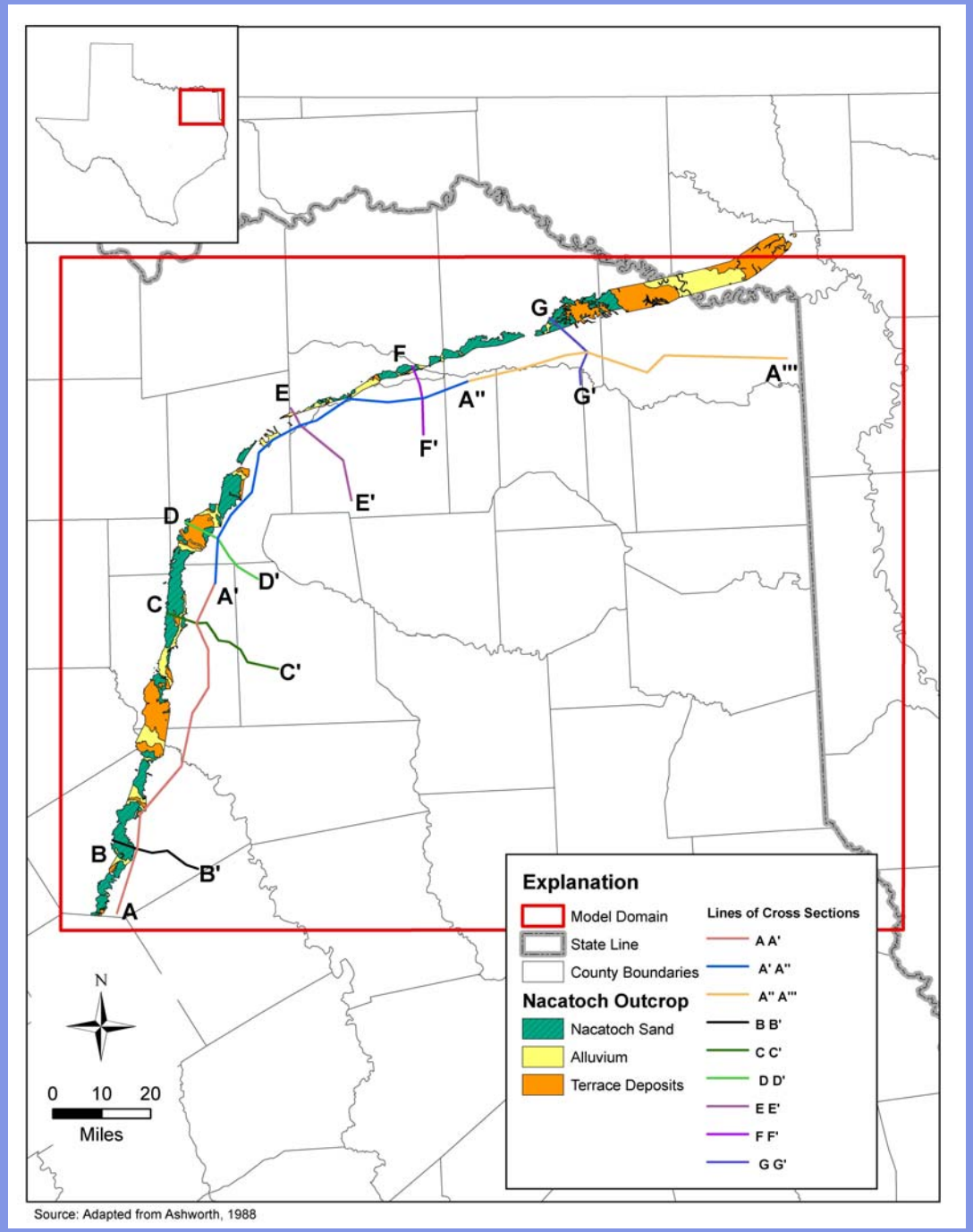
Modified froM MCGowen and Lopez, 1983

Facies Distribution Nacatoch Formation

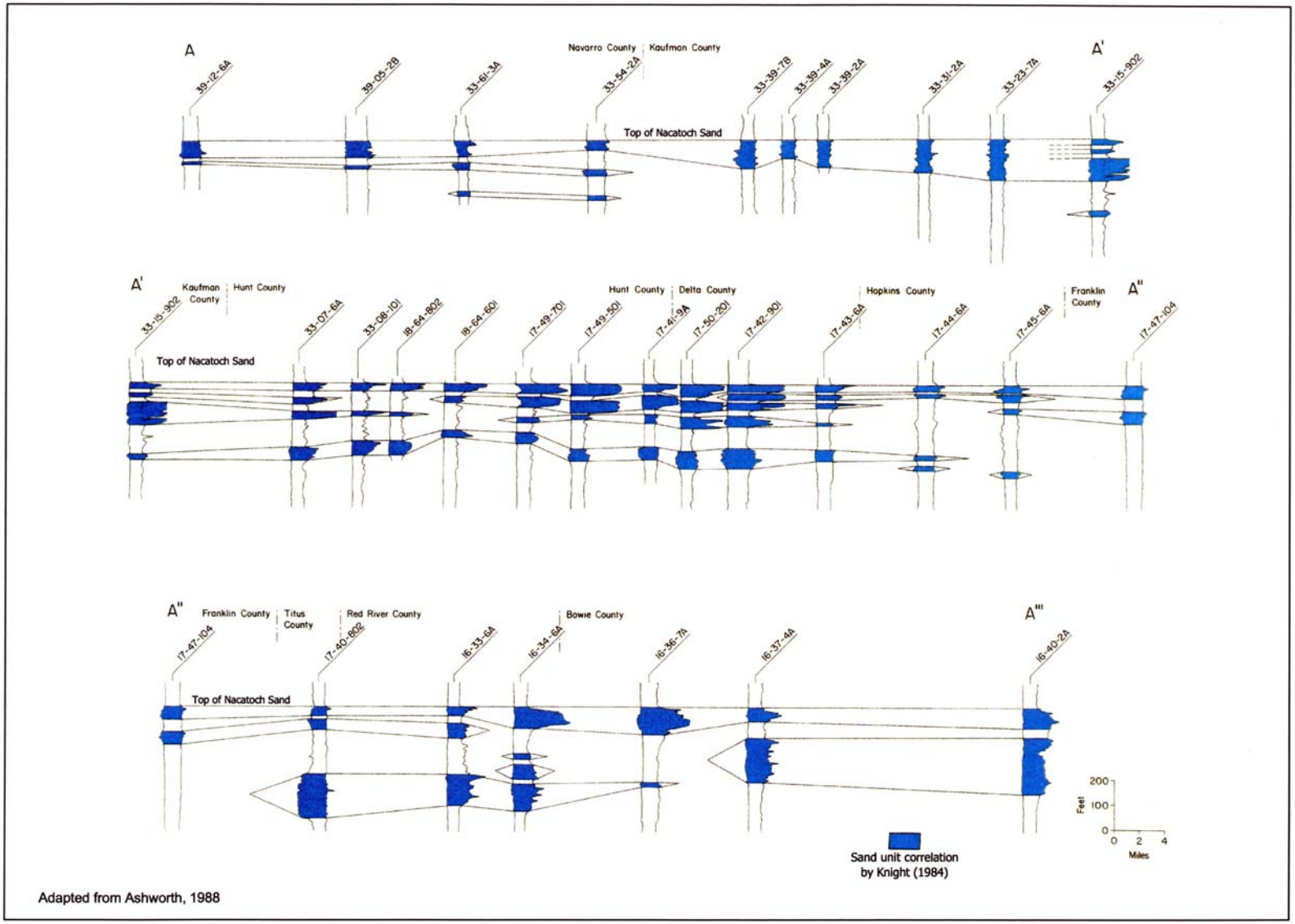


From McGowen and Lopez, 1983

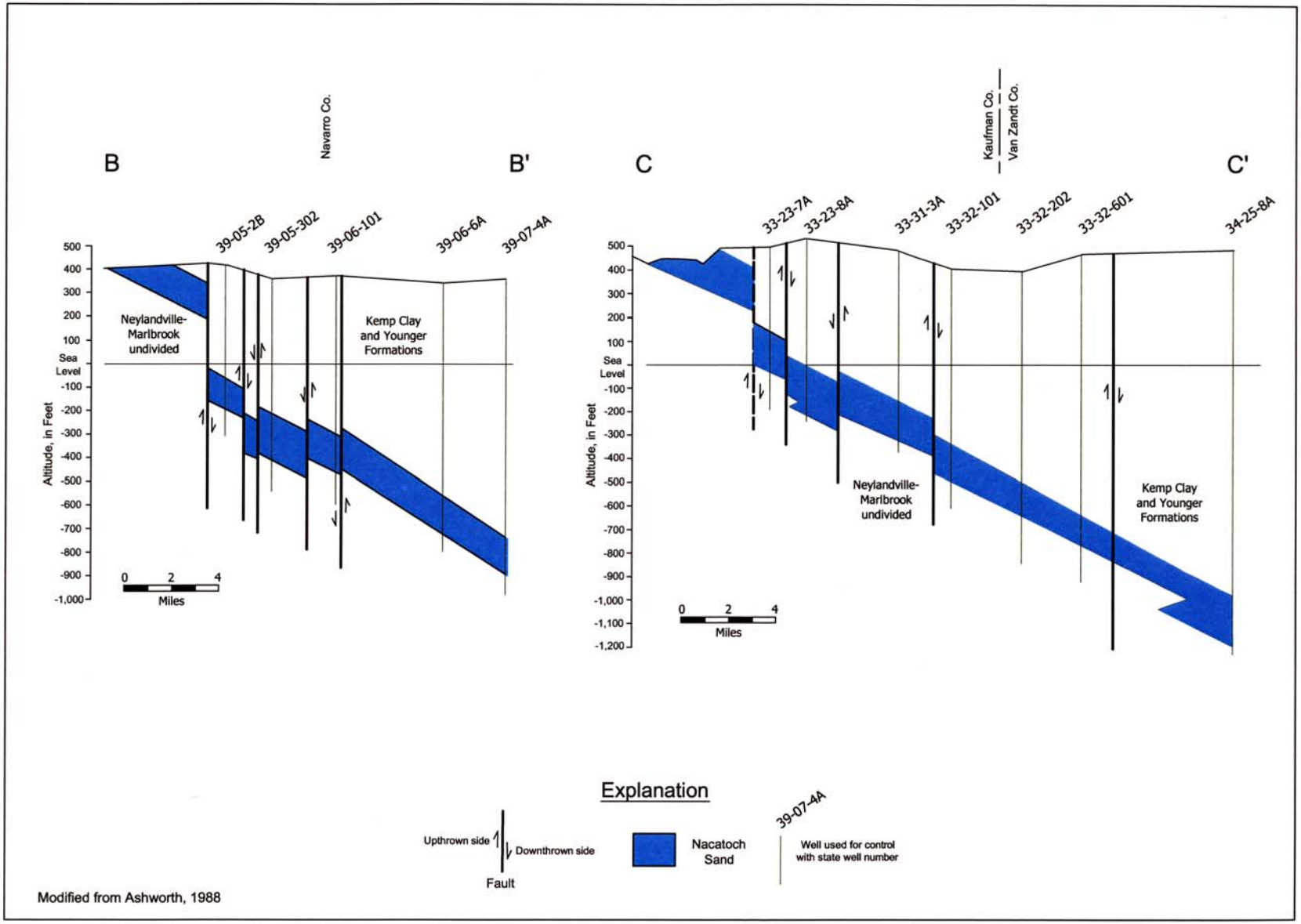
Cross Sections



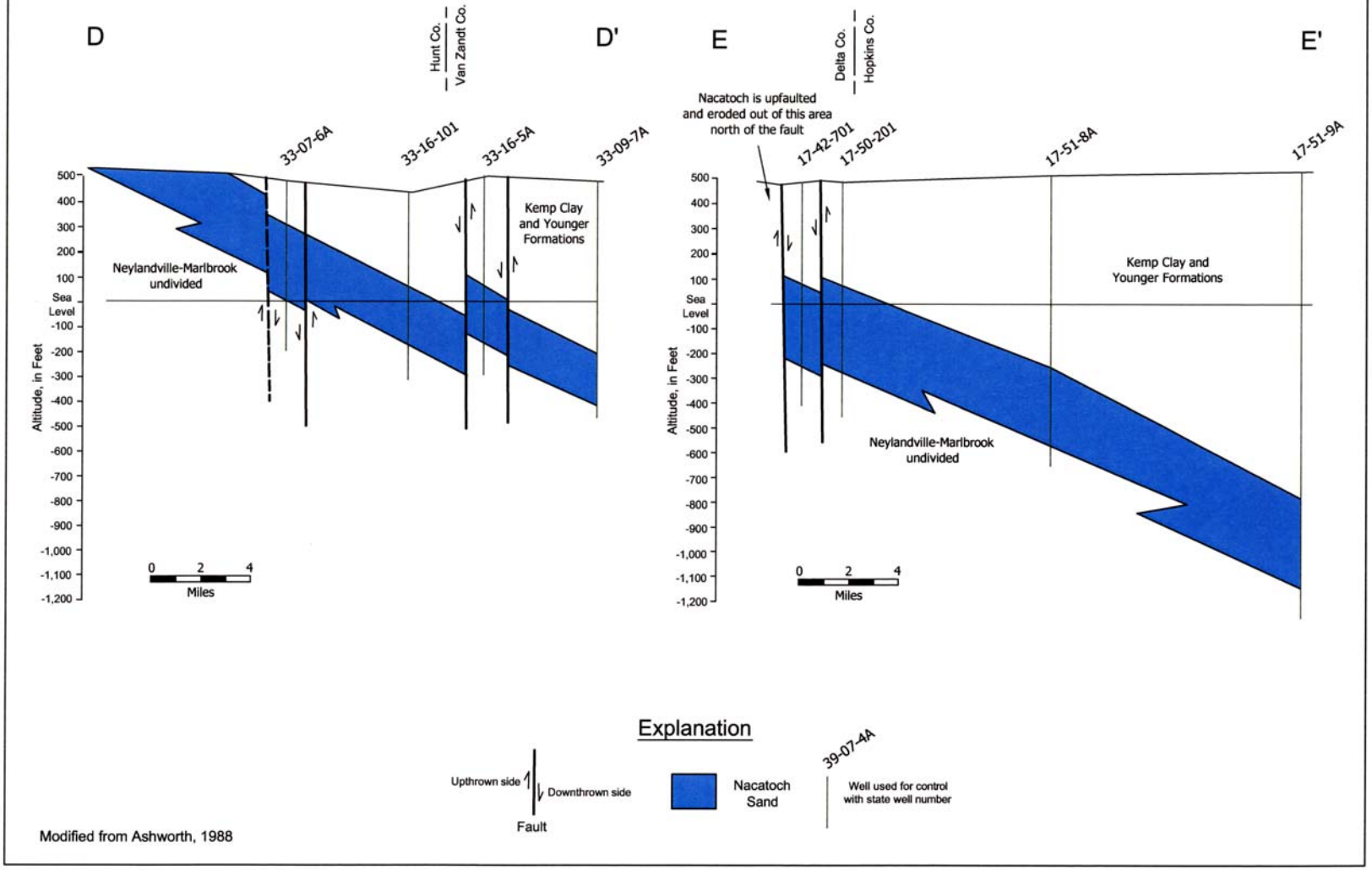
A-A', A'-A'' and A''-A'''


A
Navarro County
Kaufman County
A'
39-12-6A
39-05-2B
33-61-3A
33-54-2A
33-39-7B
33-39-4A
33-39-2A
33-31-2A
33-23-7A
33-15-902
Top of Nacatoch Sand
A'
Kaufman County
Hunt County
Hunt County
Delta County
Hopkins County
Franklin County
A"
33-15-902
33-07-6A
33-08-101
I8-64-802
I8-64-601
I7-49-701
I7-49-501
I7-41-9A
I7-50-201
I7-42-901
I7-43-6A
I7-44-6A
I7-45-6A
I7-47-104
Top of Nacatoch Sand
A"
Franklin County
Titus County
Red River County
Bowie County
A'''
I7-47-104
I7-40-802
I6-33-6A
I6-34-6A
I6-36-7A
I6-37-4A
I6-40-2A
Top of Nacatoch Sand
200
100
0
Feet
0
2
4
Miles
Sand unit correlation by Knight (1984)
Adapted from Ashworth, 1988

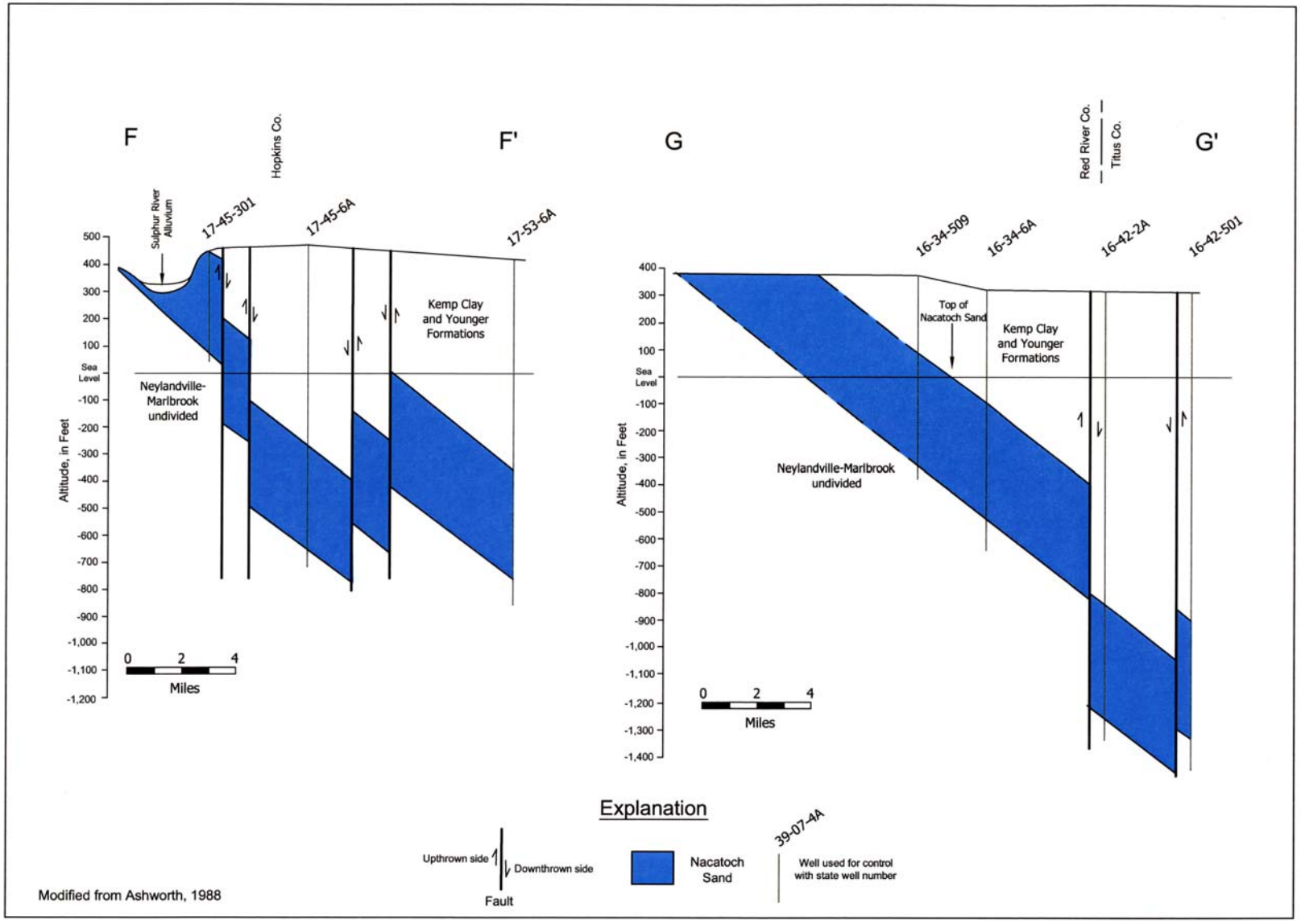
B-B’ and C-C’


B
B'
Navarro Co.
39-05-2B
39-05-302
39-06-101
39-06-6A
39-07-4A
Neylandville-
Marlbrook
undivided
Kemp Clay
and Younger
Formations
Sea
Level
Altitude, in Feet
500
400
300
200
100
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1,000
0
2
4
Miles
C
C'
Kaufman Co.
Van Zandt Co.
33-23-7A
33-23-8A
33-31-3A
33-32-101
33-32-202
33-32-601
34-25-8A
-1,100
-1,200
Explanation
Upthrown side
Downthrown side
Fault
Nacatoch
Sand
Well used for control
with state well number
Modified from Ashworth, 1988

D-D’ and E-E’

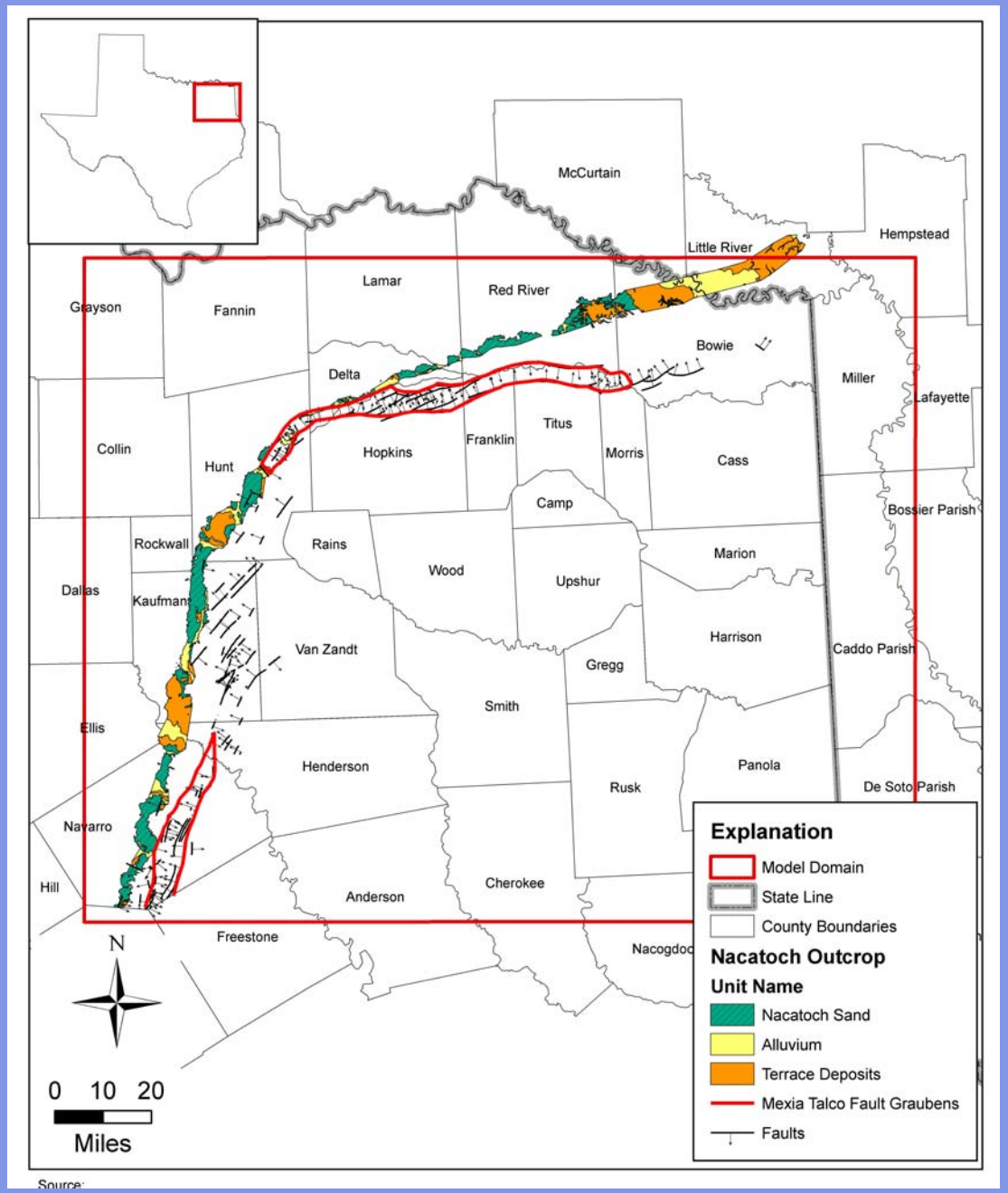

D
D'
Hunt Co.
Van Zandt Co.
33-07-6A
33-16-101
33-16-5A
33-09-7A
Kemp Clay and Younger Formations
Neylandville-Marlbrook undivided
Sea Level
Altitude, in Feet
500
400
300
200
100
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1,000
-1,100
-1,200
0 2 4
Miles
E
E'
Delta Co.
Hopkins Co.
Nacatoch is upfaulted and eroded out of this area north of the fault
17-42-701
17-50-201
17-51-8A
17-51-9A
Kemp Clay and Younger Formations
Neylandville-Marlbrook undivided
Explanation
Upthrown side
Downthrown side
Fault
Nacatoch Sand
39-07-4A
Well used for control with state well number
Modified from Ashworth, 1988

F-F’ and G-G’

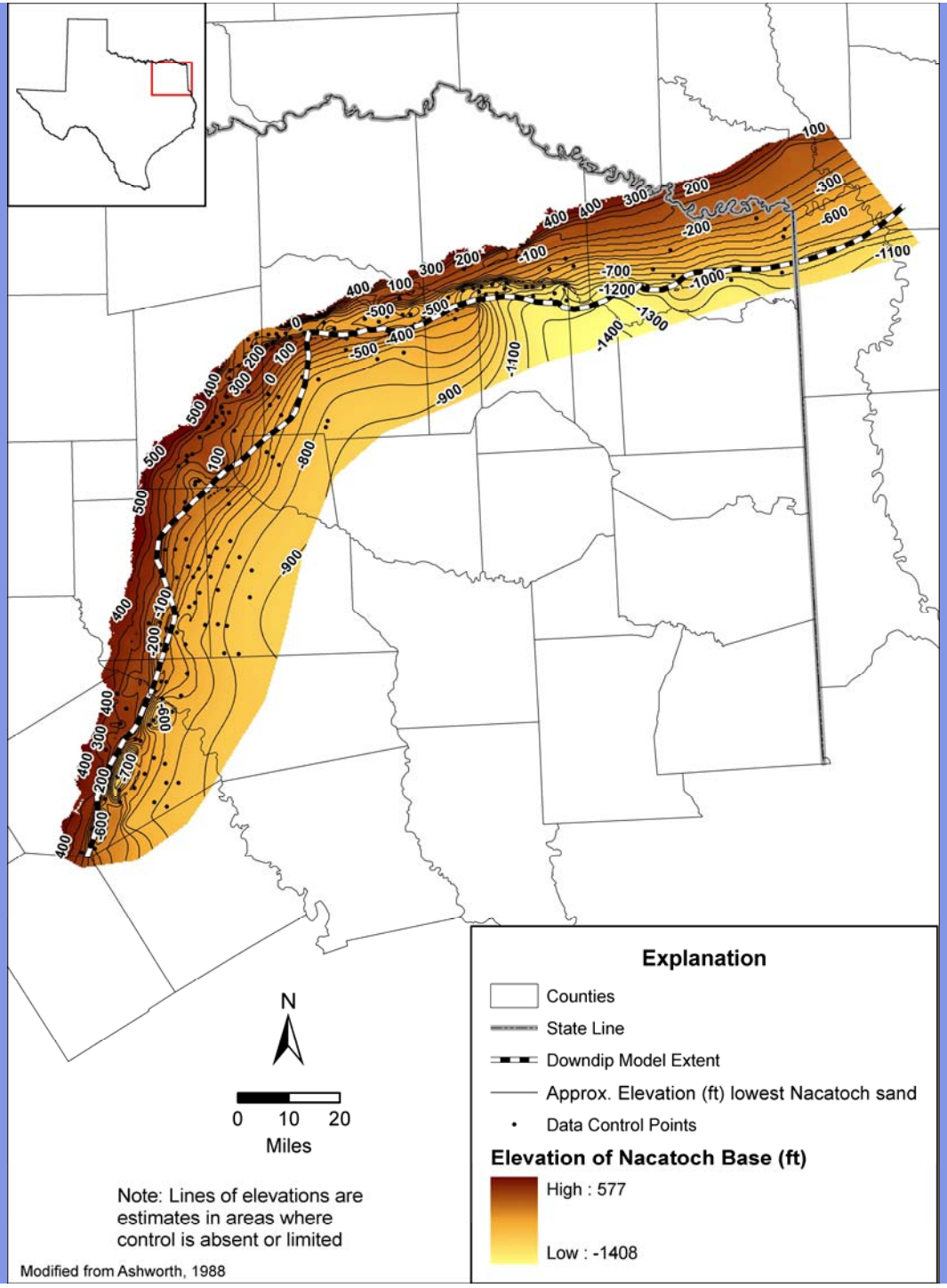

F
F'
Hopkins Co.
Sulphur River Alluvium
17-45-301
17-45-6A
17-53-6A
Kemp Clay and Younger Formations
Neylandville-Marlbrook undivided
Sea Level
Altitude, in Feet
0 2 4
Miles
G
G'
Red River Co.
Titus Co.
16-34-509
16-34-6A
16-42-2A
16-42-501
Top of Nacatoch Sand
Kemp Clay and Younger Formations
Neylandville-Marlbrook undivided
Sea Level
Altitude, in Feet
0 2 4
Miles
Explanation
Upthrown side
Downthrown side
Fault
Nacatoch Sand
39-07-4A
Well used for control with state well number
Modified from Ashworth, 1988

Geologic Faulting

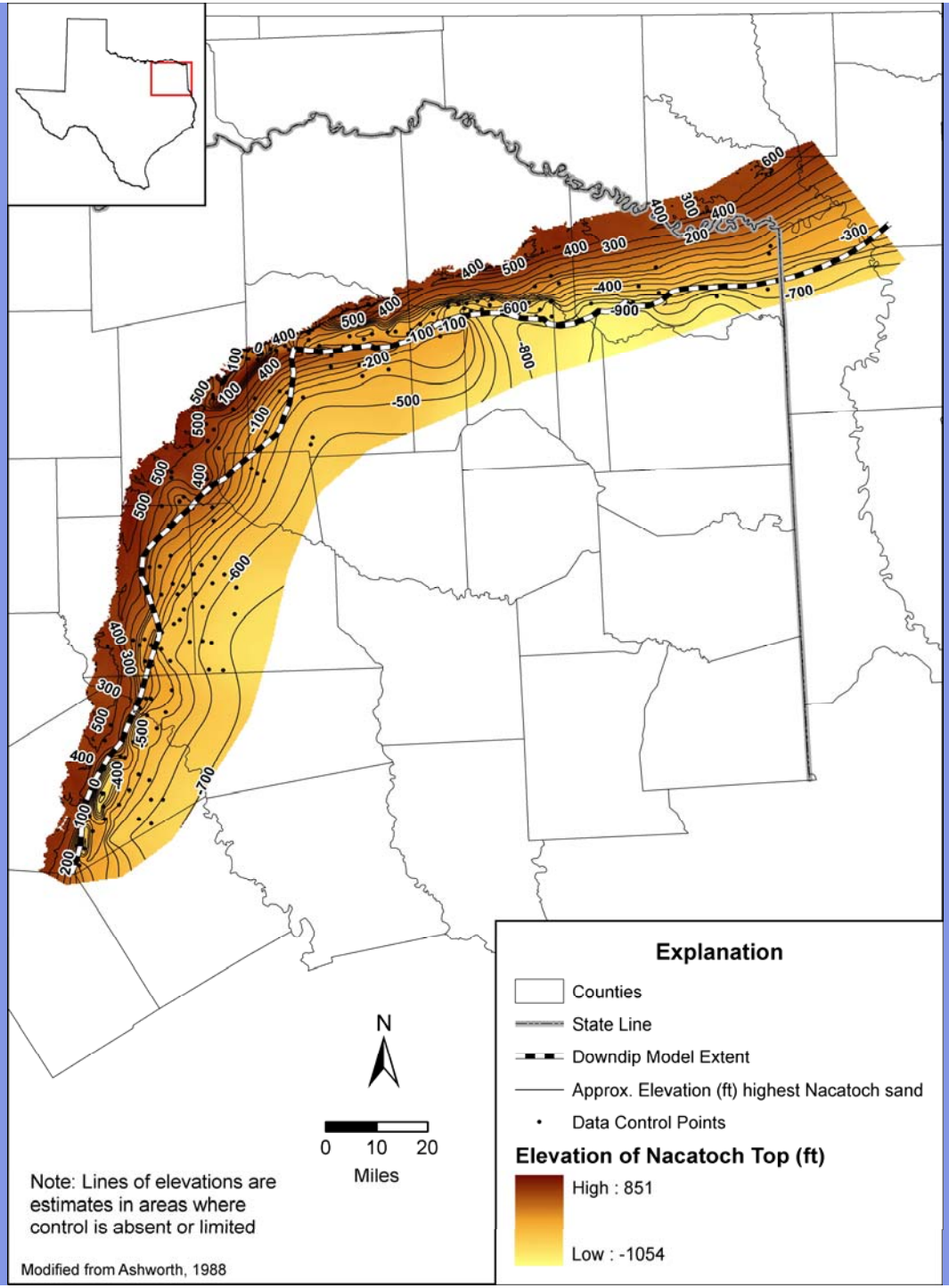
Mexia-Talco Fault Graubens



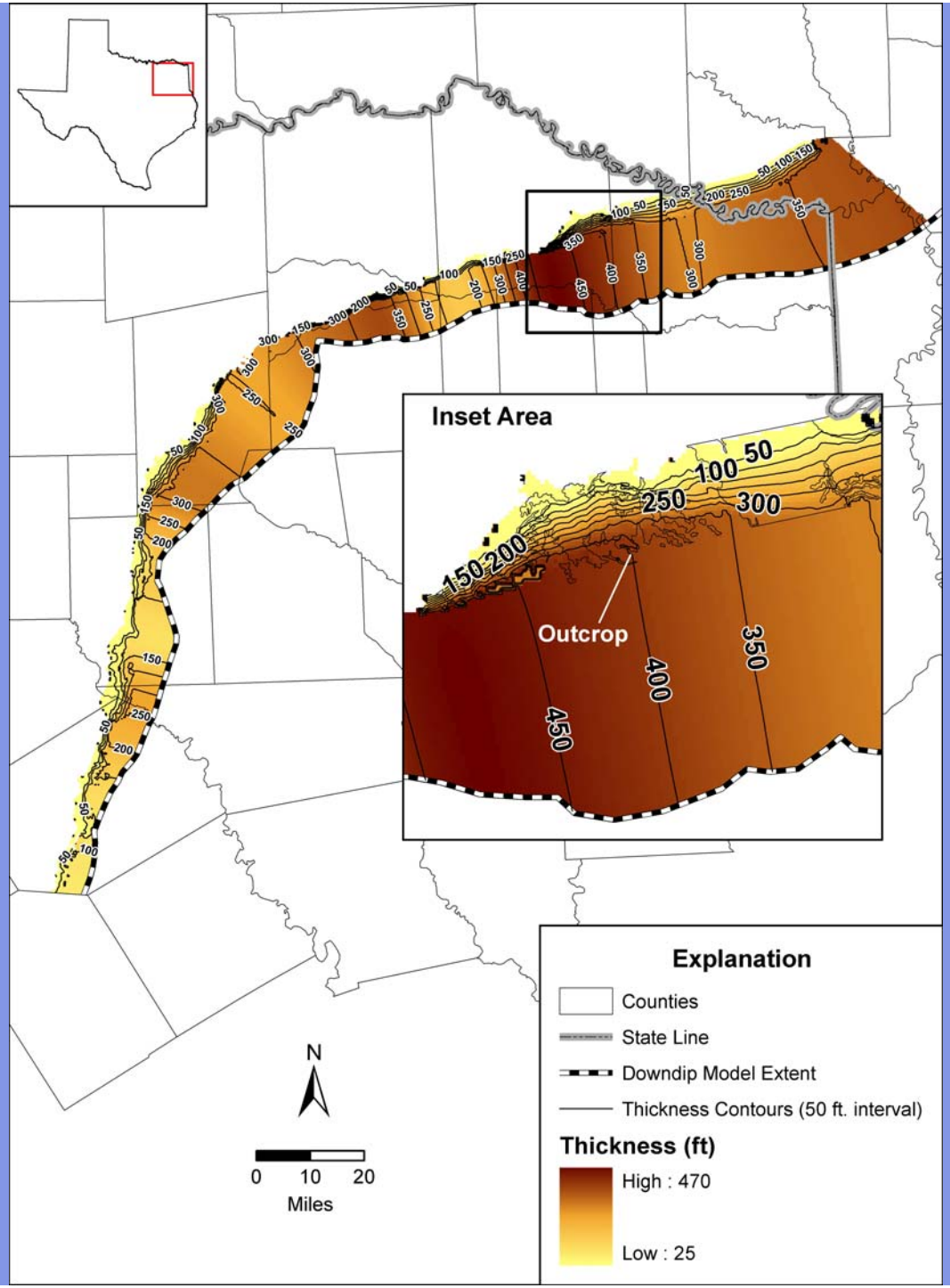
Elevation of Base of Nacatoch

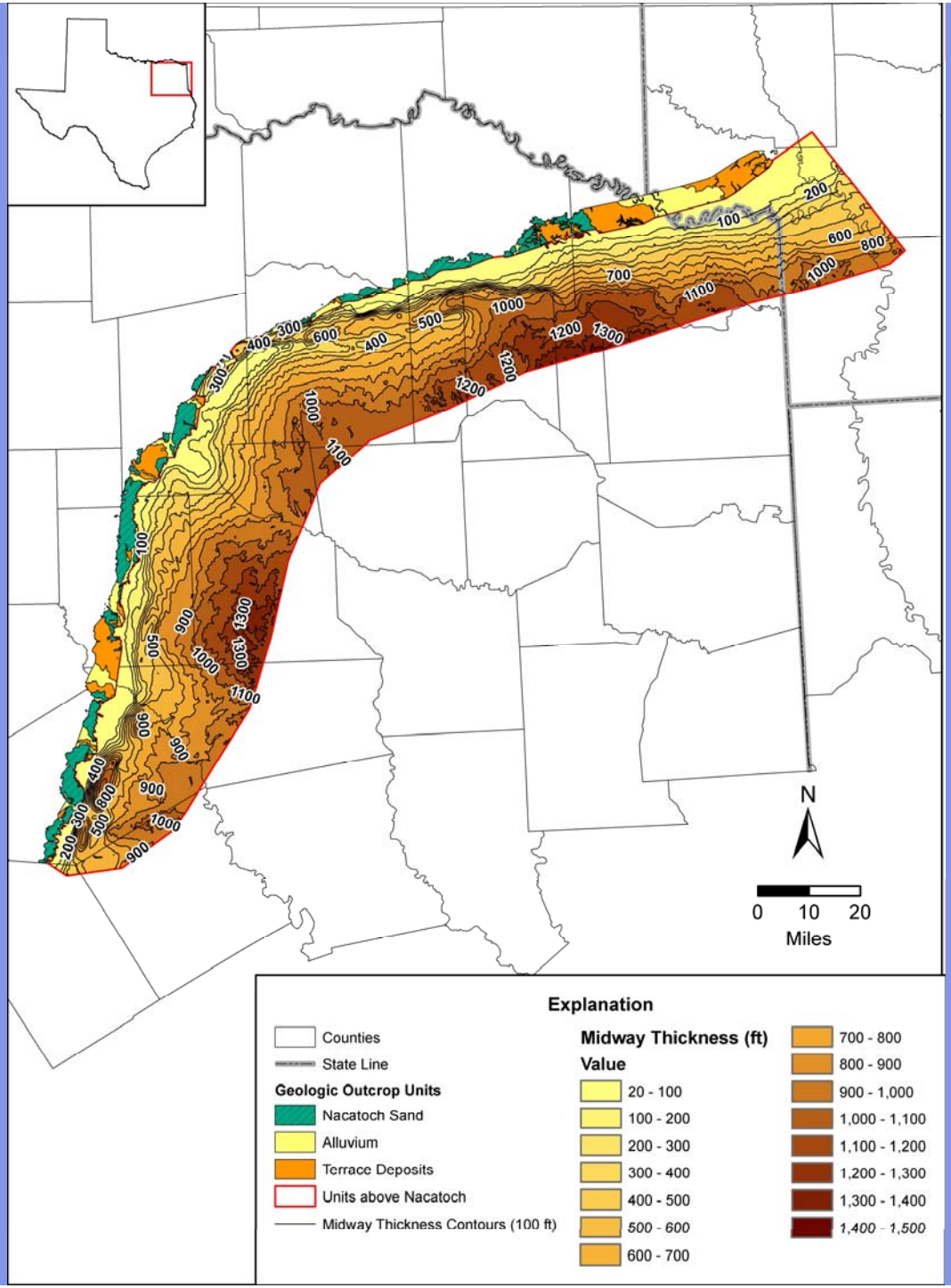


Elevation of the Top of Nacatoch



Thickness of Nacatoch



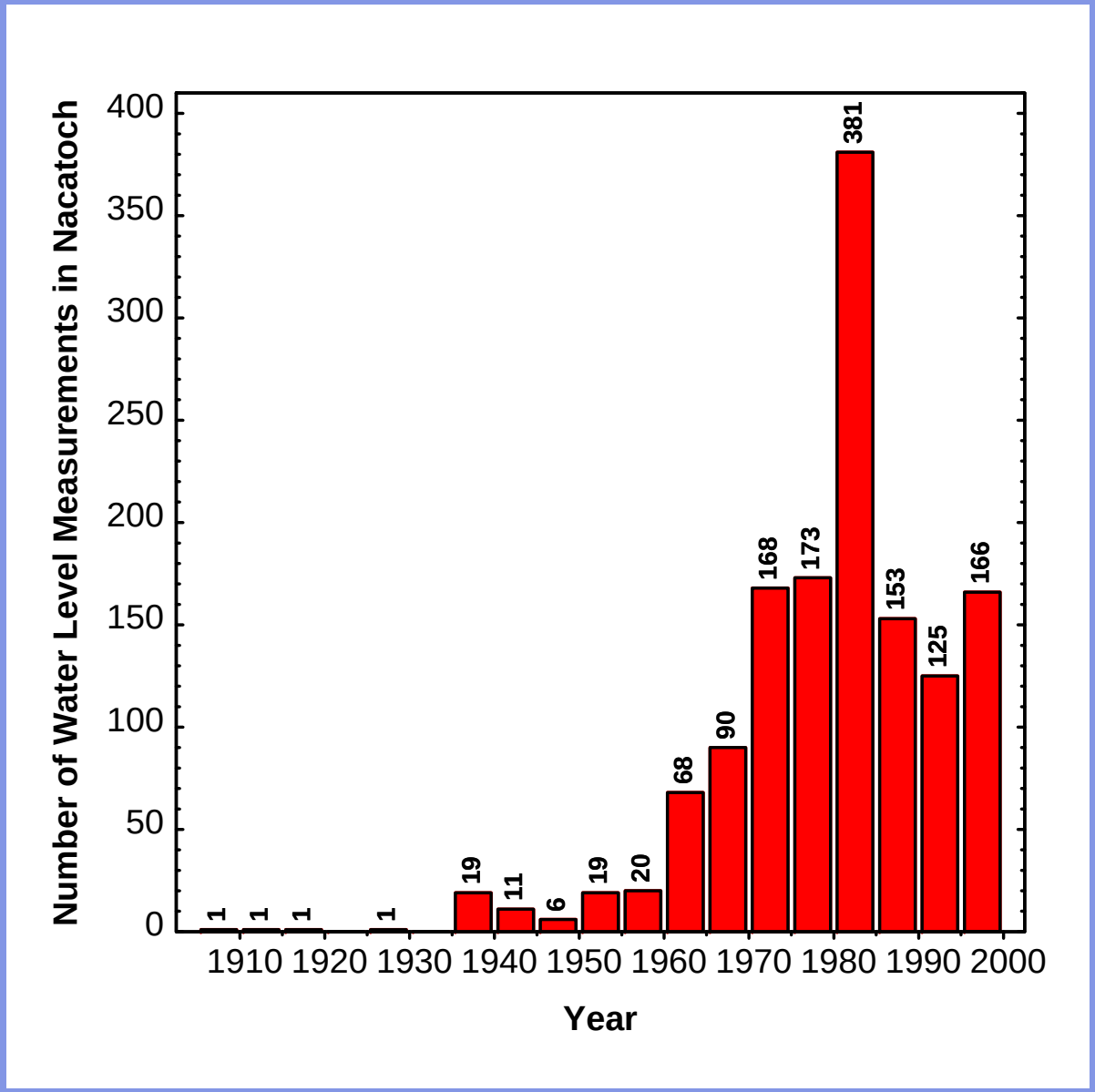


Thickness of Overlying Midway Formation

Head Analysis

- Collected and organized head database for Texas and Arkansas
  - TWDB database and county reports
  - USGS reports
  - Ashworth 1988 (Table 5)
- Developed and analyzed control for Predevelopment, 1980, 1990, 1997 head surfaces
- Developed a regression for head in unconfined section (outcrop) to guide surface development
- Selected wells with adequate time series to be calibration hydrographs

Nacatoch Head Observations

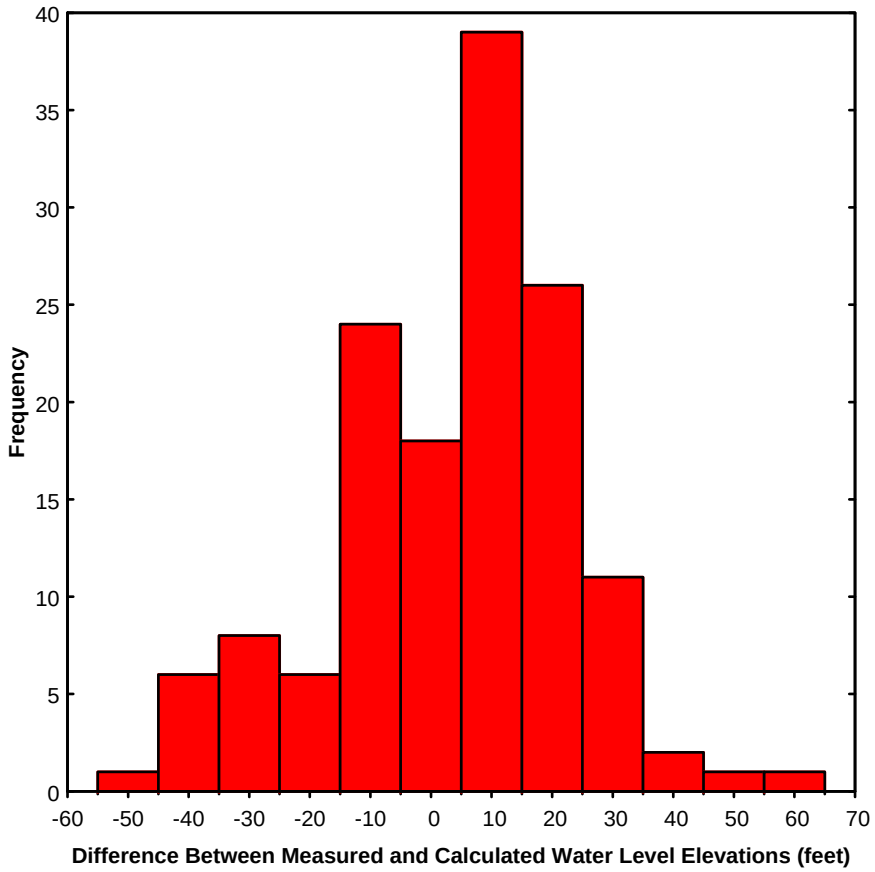


Predevelopment Head Surface Approach

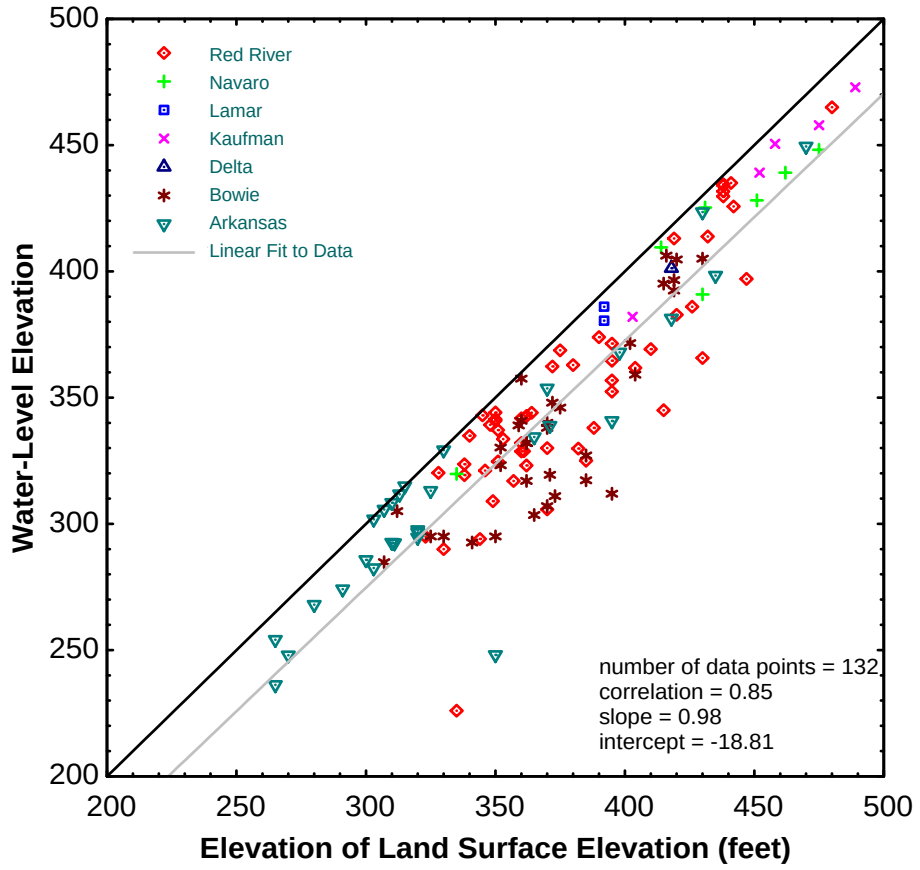
- Used a combination of maximum, earliest measured, and hydrograph extrapolated heads to develop adequate control
- Developed a regression between ground surface elevation and head in outcrop areas
  - Best regression eliminated Hunt and Hopkins Co. wells
- Then contour and iteratively
  - ID inconsistent wells
  - Consider transient head trends
  - Choose predevelopment targets

Head-Land Surface Regression

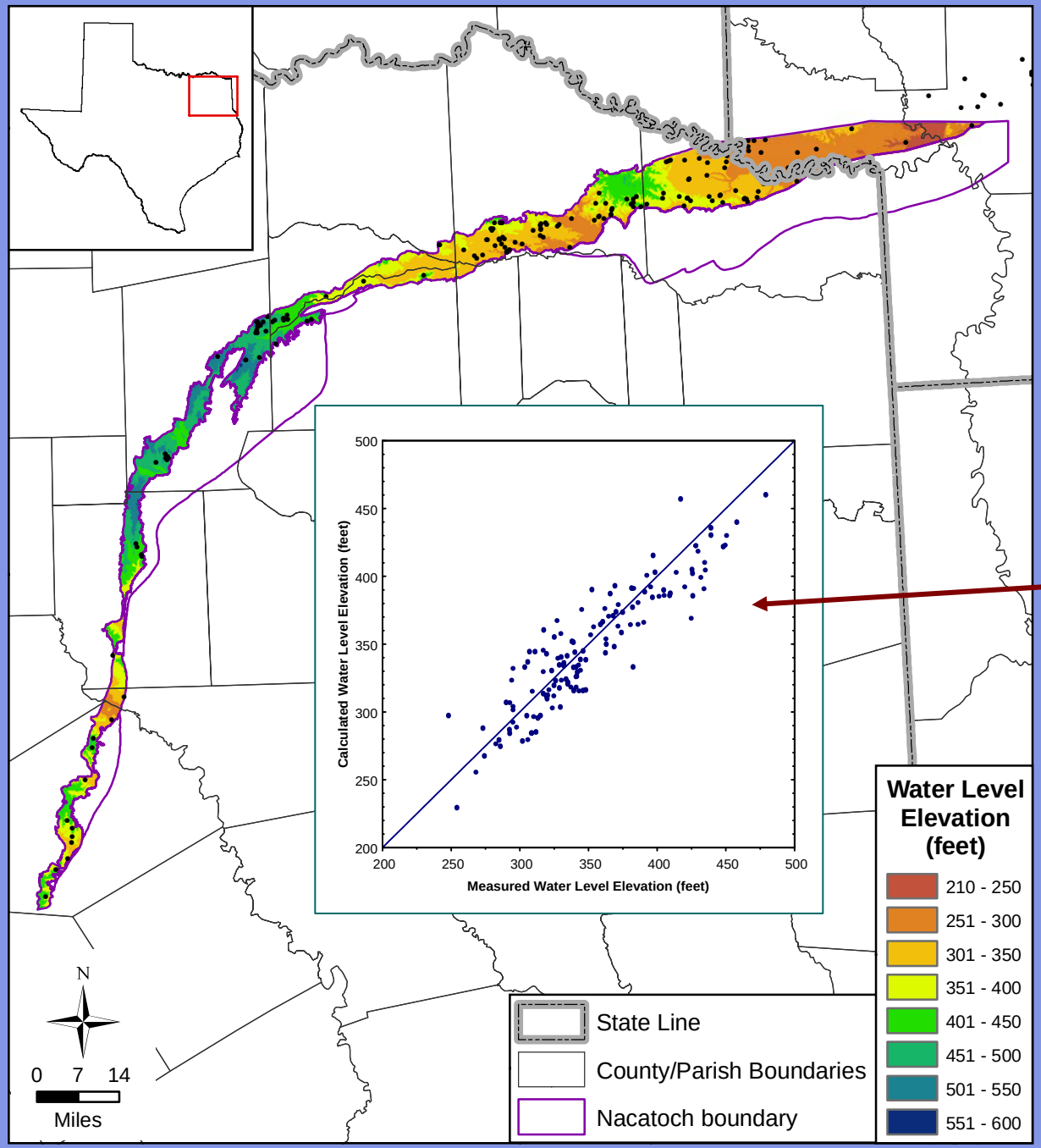
Residuals



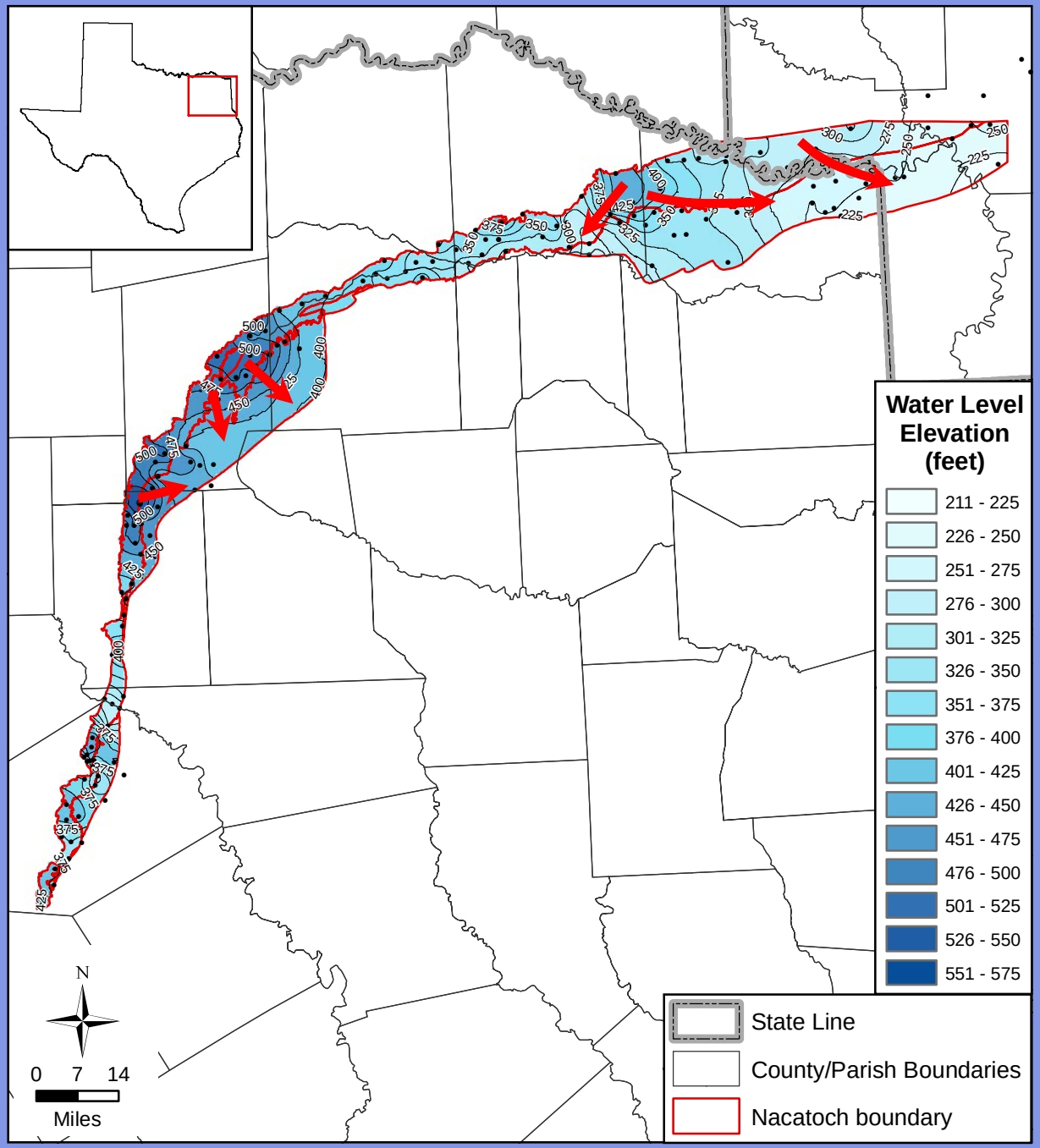
Regression



Regression Surface



Comparison of calculated Water level elevation and Ground surface

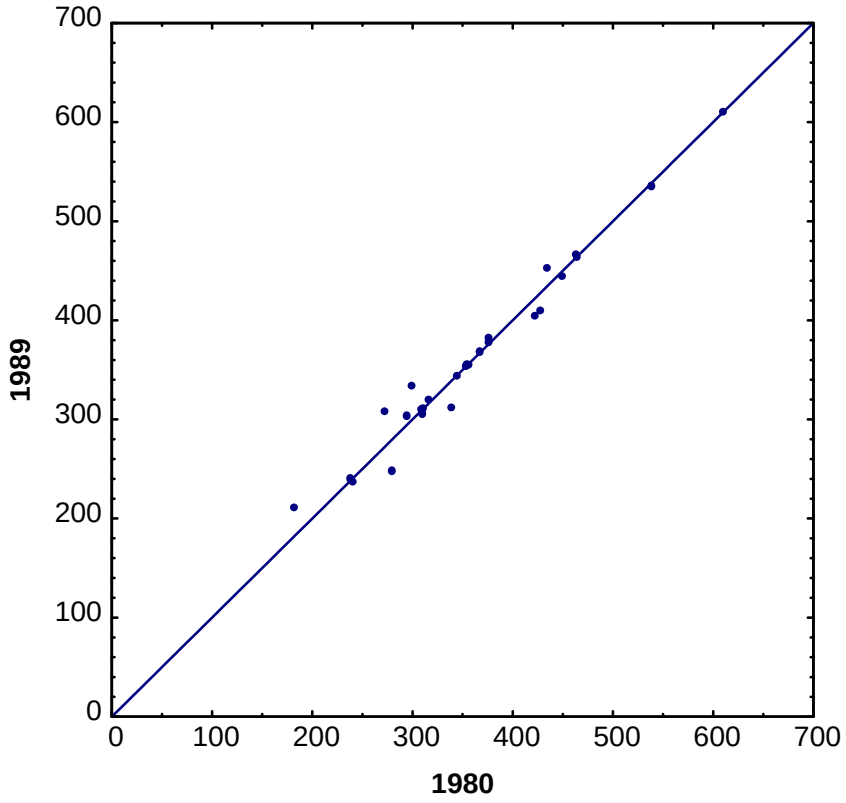


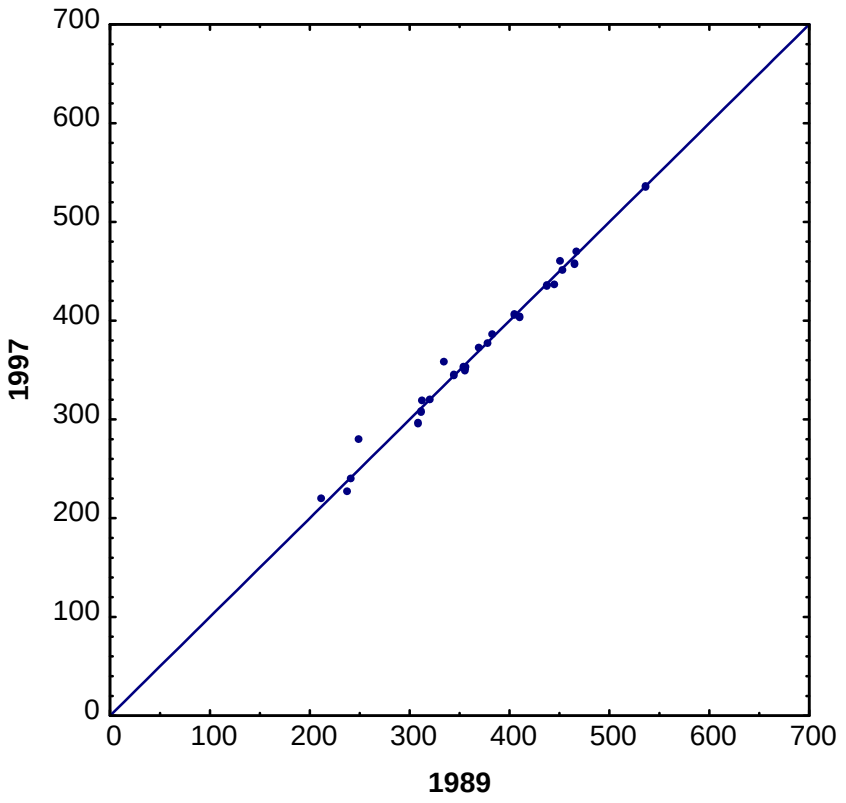
Pre-development Head Surface and Flow Direction

Transient Head Surfaces

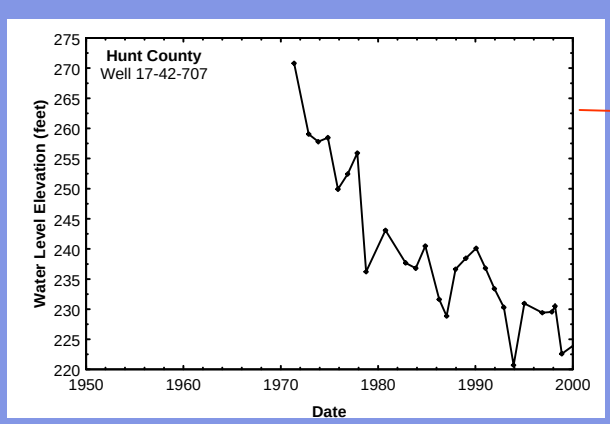
- To have adequate coverage, we used multi-year window around the year of interest (1980, 1990, 1997)
  - Used Ashworth 1988 as a guide on 1980 surface (reported 1982 surface)
- Significant head change has not been observed except in isolated regions
  - Especially since 1980
- We used the regression for guidance in outcrop areas where minimal drawdown was expected

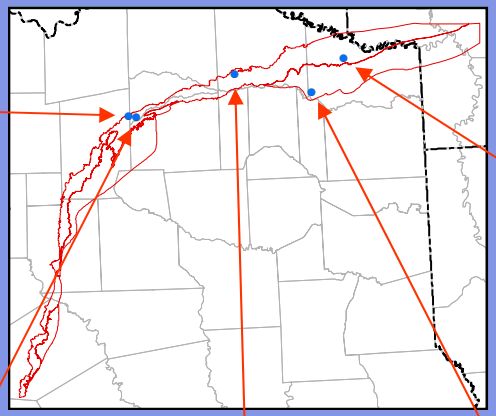
Transient Target Change 1980-1997

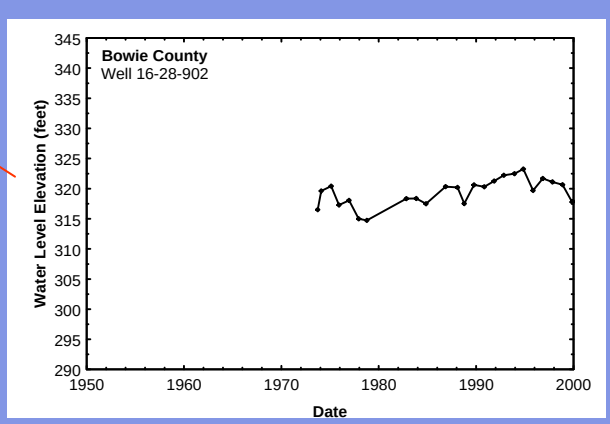


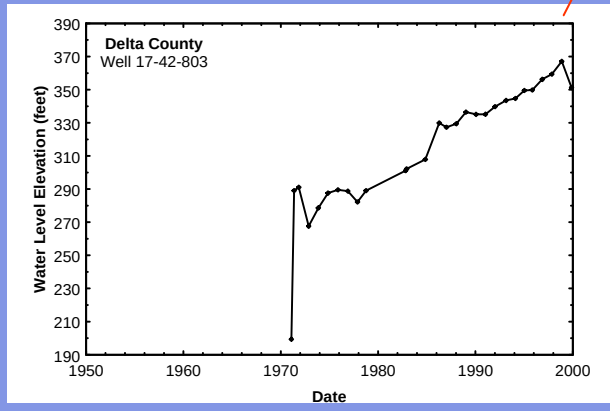


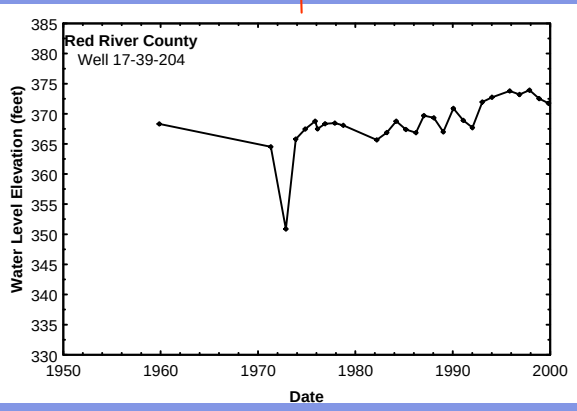
Hydrographs

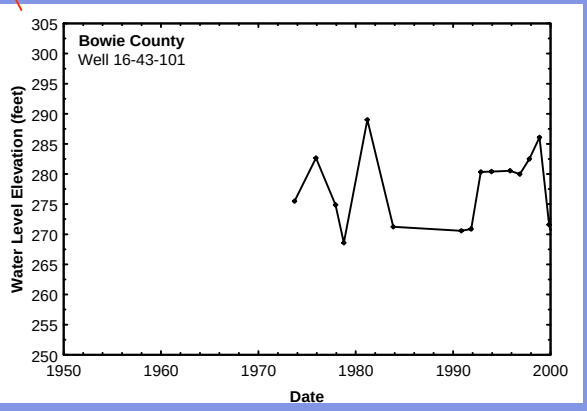




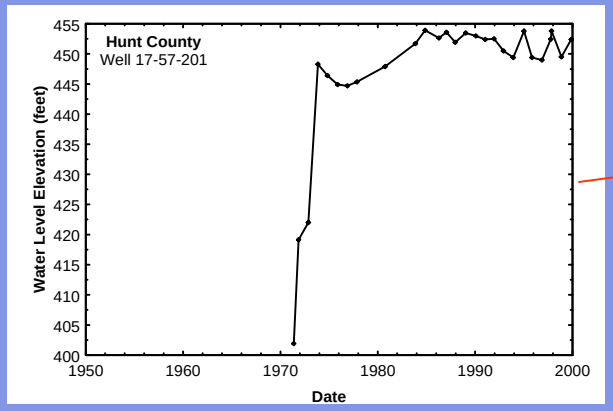


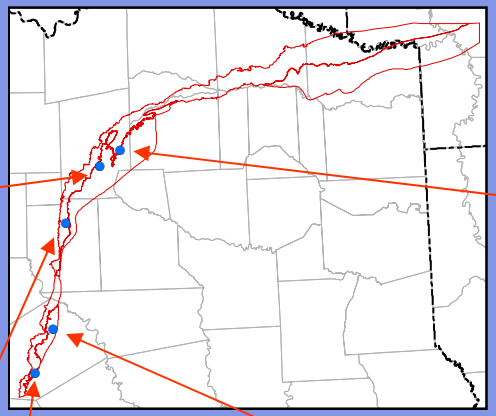


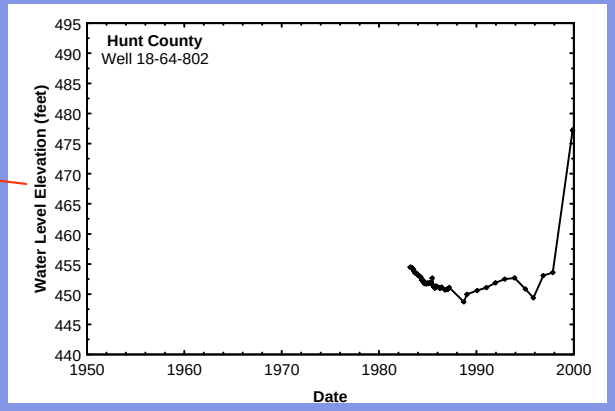


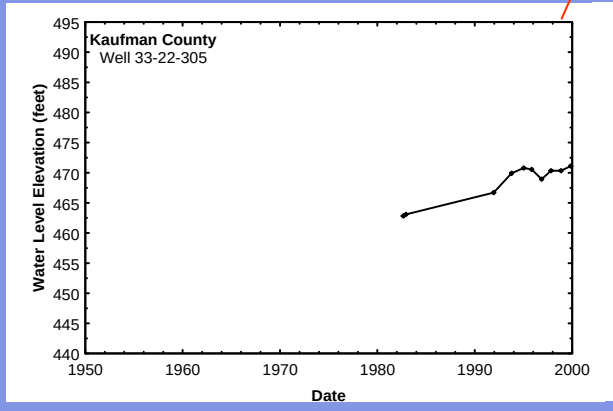


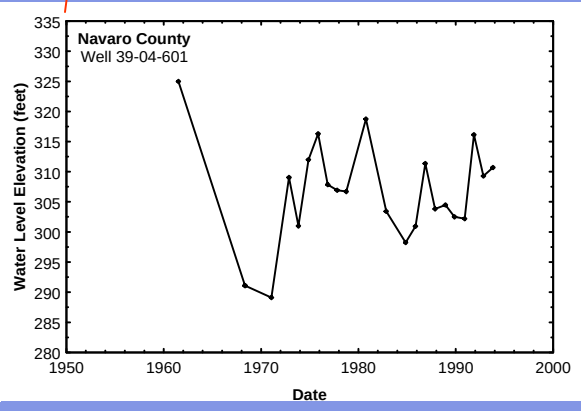
Hydrographs

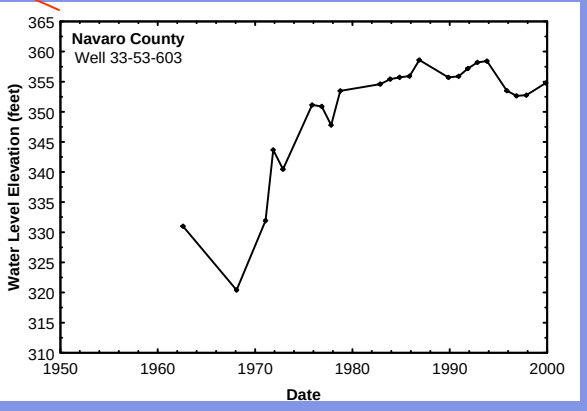




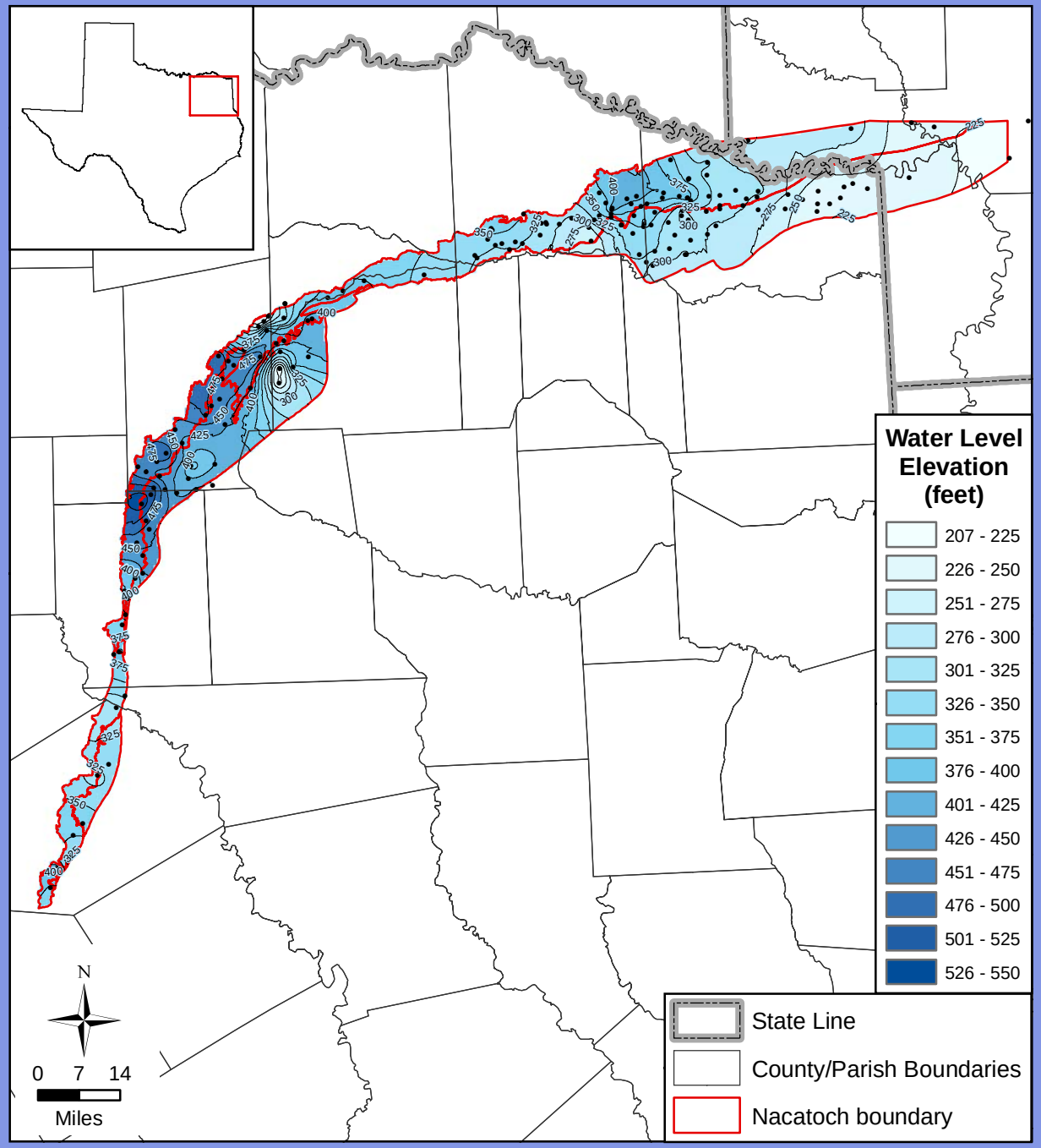




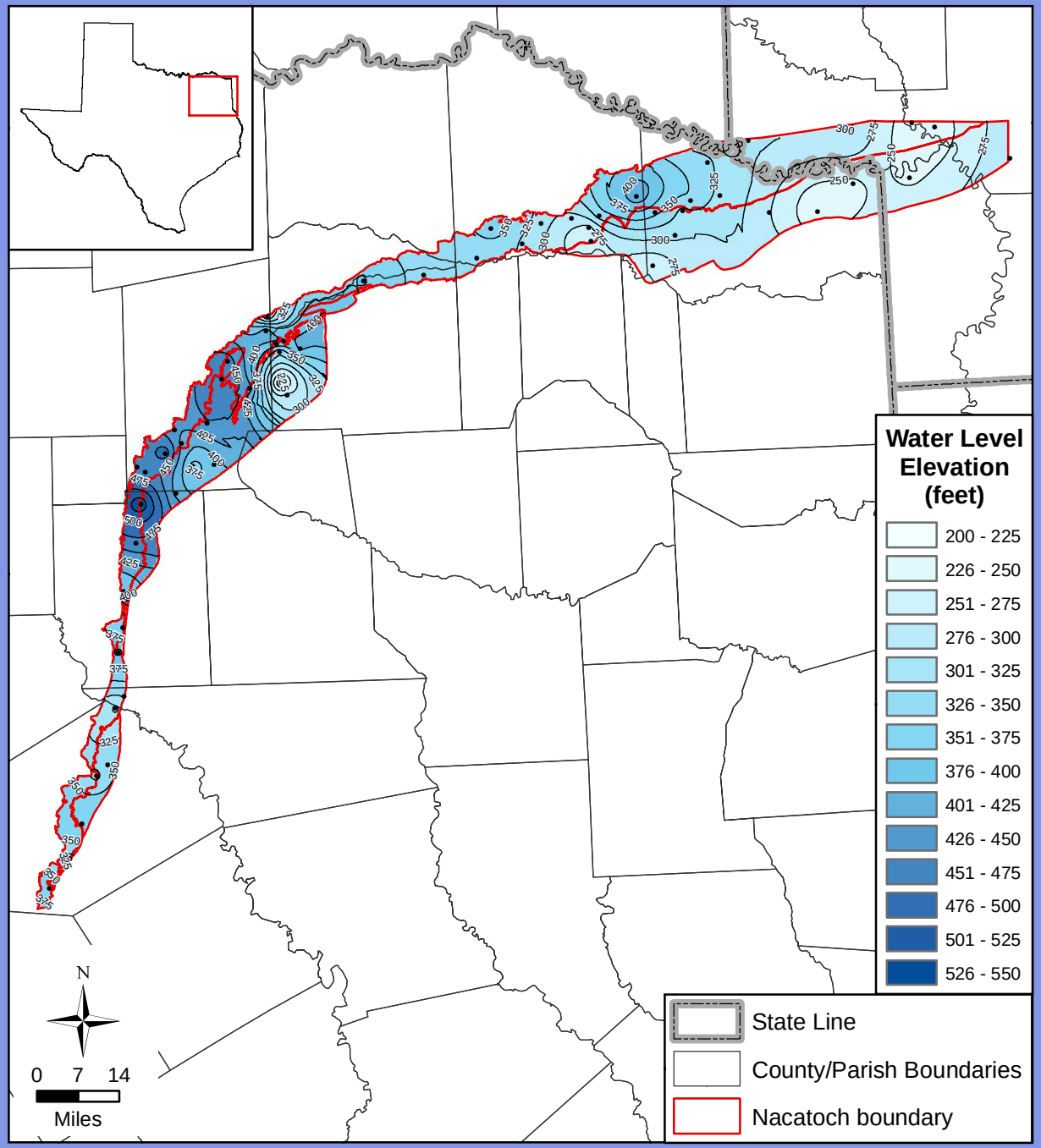




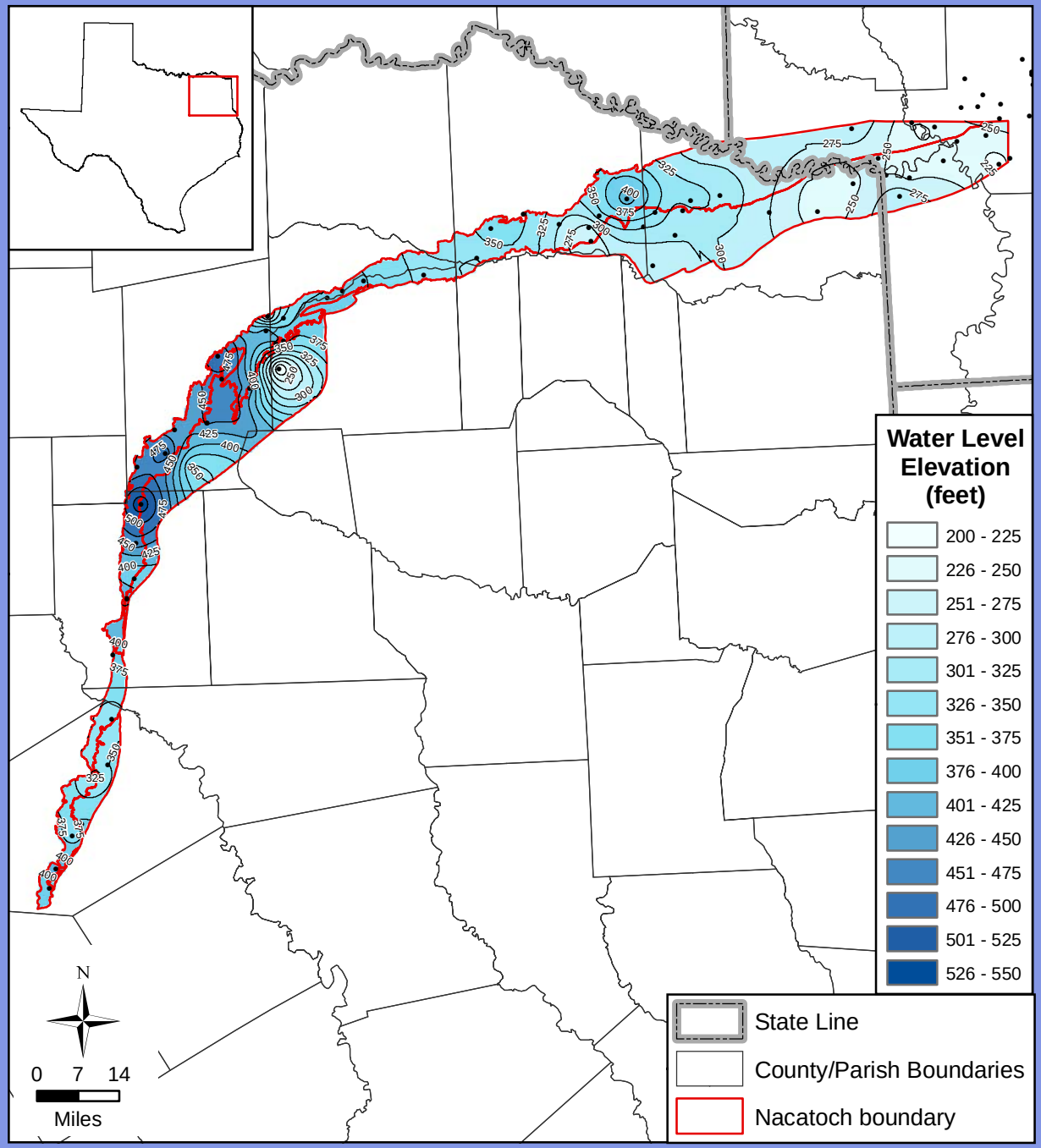
1980 Head Surface
(1978-1982)



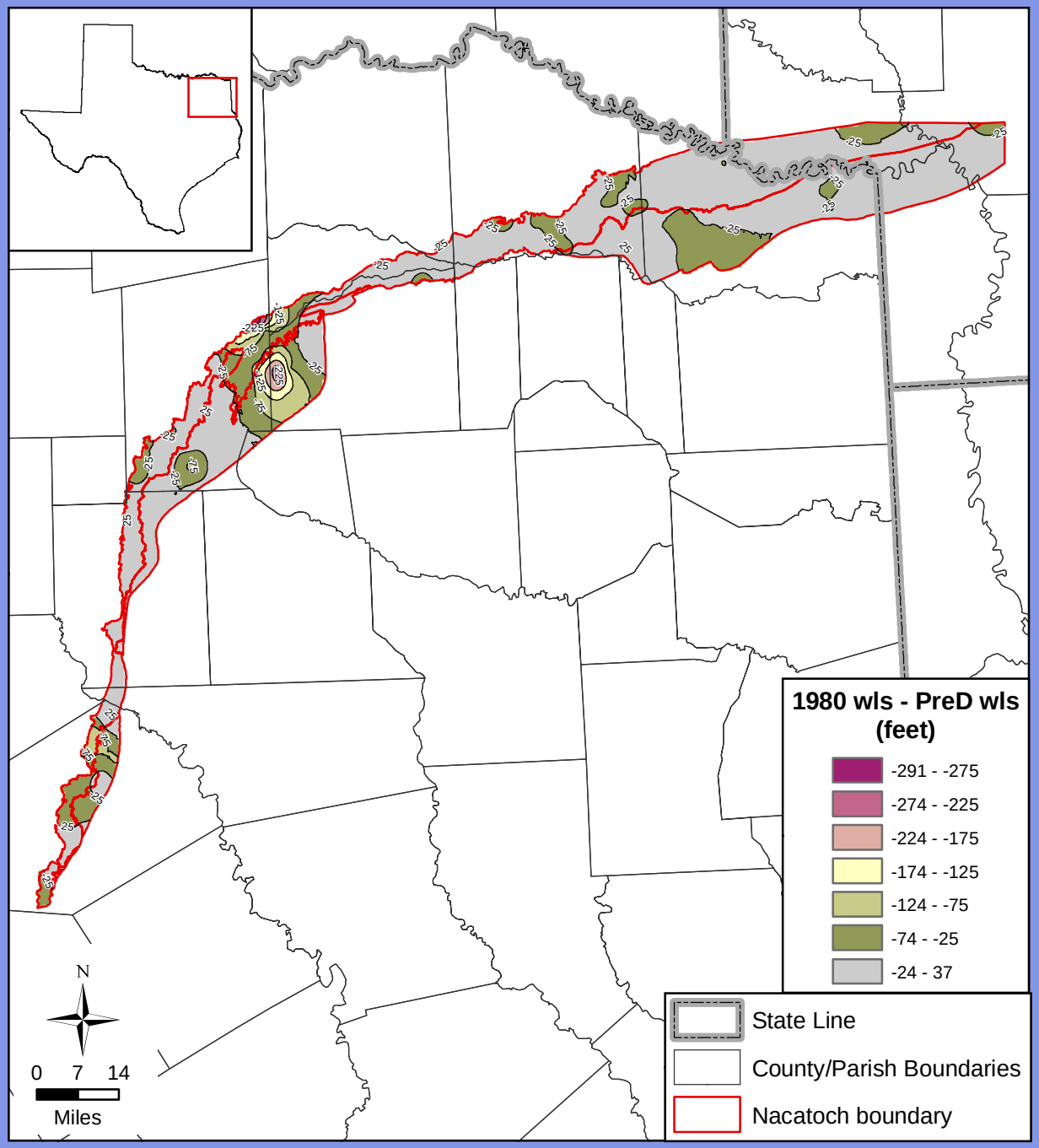
1989 Head Surface
(1988-1991)



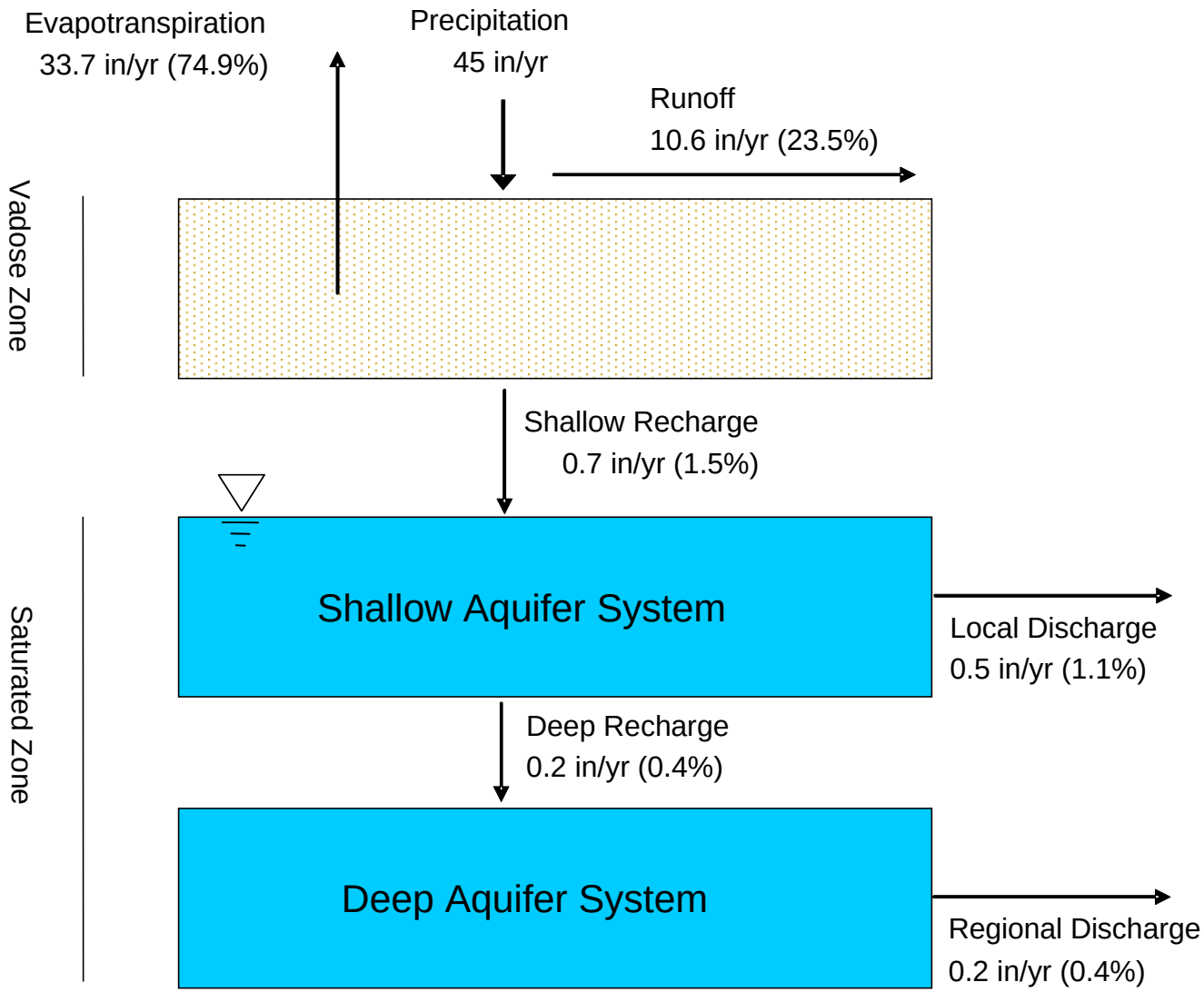
1997 Head Surface (1996-1999)



Drawdown 1980-PreD



Conceptual Water Balance



Deep Recharge

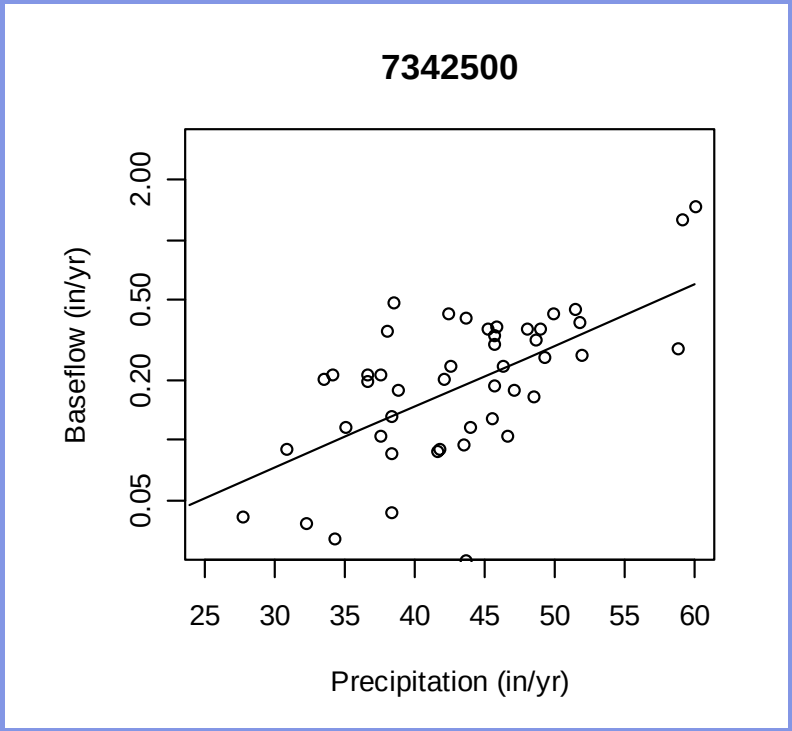
- Muller and Price (1979) estimated 1,500 AFY
- Ashworth (1988) estimated 3,000 AFY based on Darcy's law
- 3,000 AFY equates to approximately 0.5% of precipitation, or 0.2 in/yr recharge

Shallow Recharge

- Performed baseflow separation for several gages in the region
- Area weighted baseflow discharge is approximately 0.5 in/yr in the area
- This would be considered a lower bound for shallow recharge, since we have not accounted for groundwater ET

Variation with Precipitation

- Compared annual baseflow response (log transformed) with annual precipitation in the gage catchment area
- Performed linear regressions including a time lag from zero to ten months



Gage	Lag (months)	Intercept	Slope	R^2
7342465	1	-1.86	0.027	0.45
7342470	2	-1.27	0.016	0.62
7342500	3	-2.06	0.031	0.42
7343200	2	-1.86	0.033	0.60
8017300	3	-1.73	0.013	0.04
8062900	6	-3.74	0.076	0.80
8063500	4	-2.24	0.042	0.39
8064500	5	-2.43	0.053	0.41

Variation with Precipitation

- Derived single equation from series of regression results using the following constraints
  - Should contain coefficients that are bounded by the regression coefficients
  - Should produce average recharge (0.7 in/yr) given average precipitation (45 in/yr)

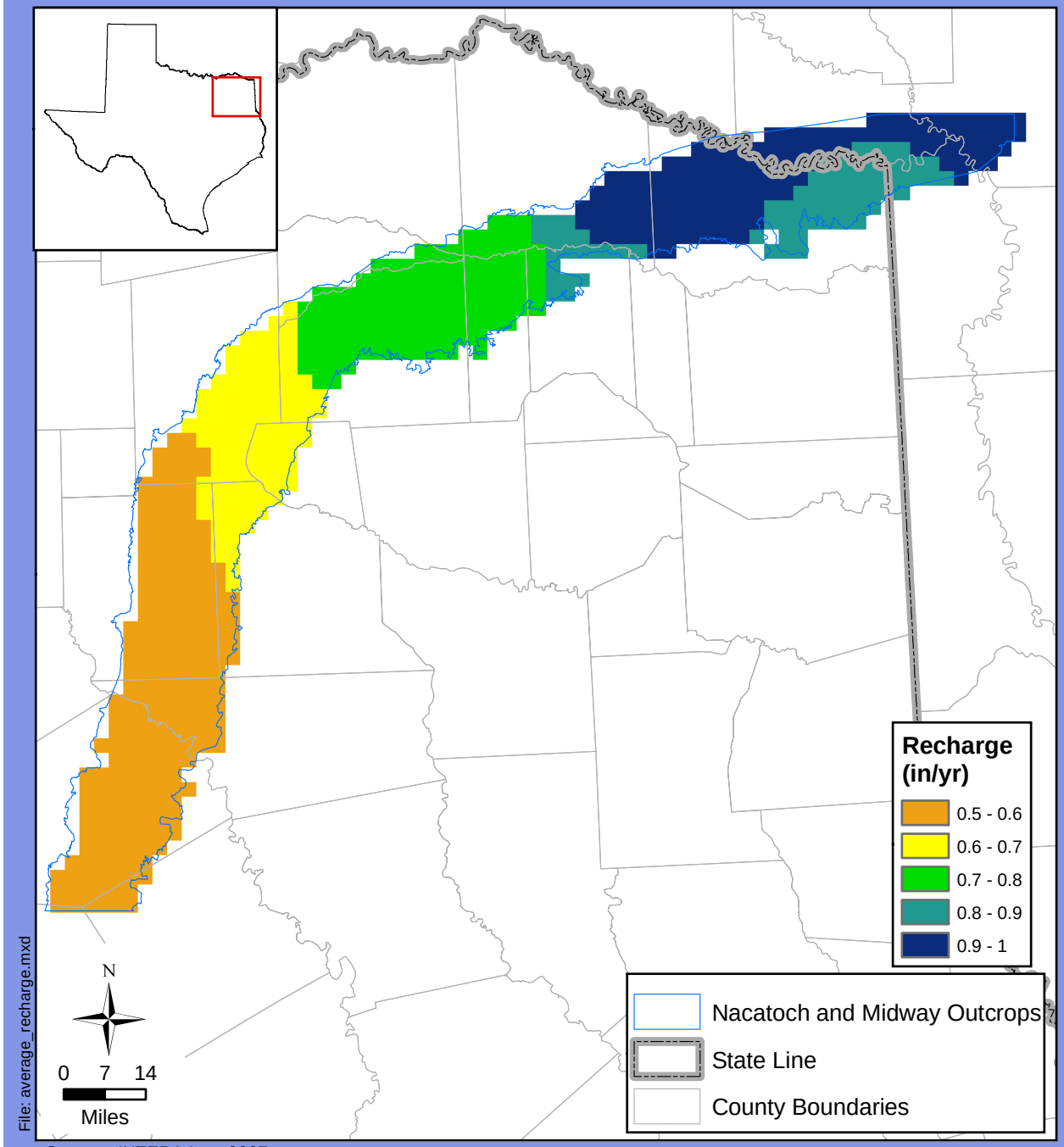
$$\text{Recharge} = 10^{(0.033 \cdot \text{precipitation} - 1.8)} + 0.2$$

Slope

Intercept

Deep

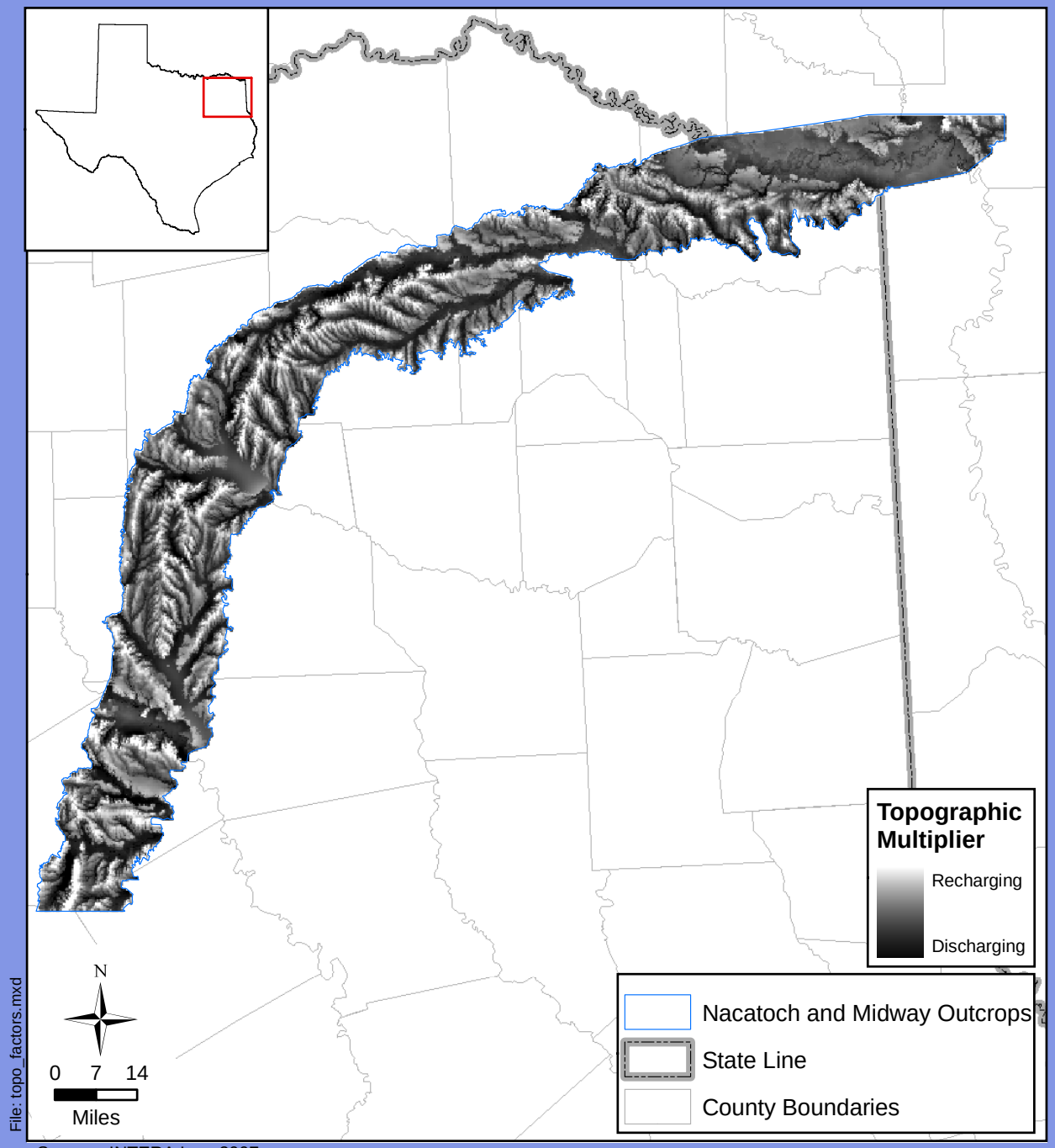
Distribution of Recharge



Source: INTERA Inc., 2007

- Based on along-term average precipitation and derived equation

Influence of Topography



Source: INTERA Inc., 2007

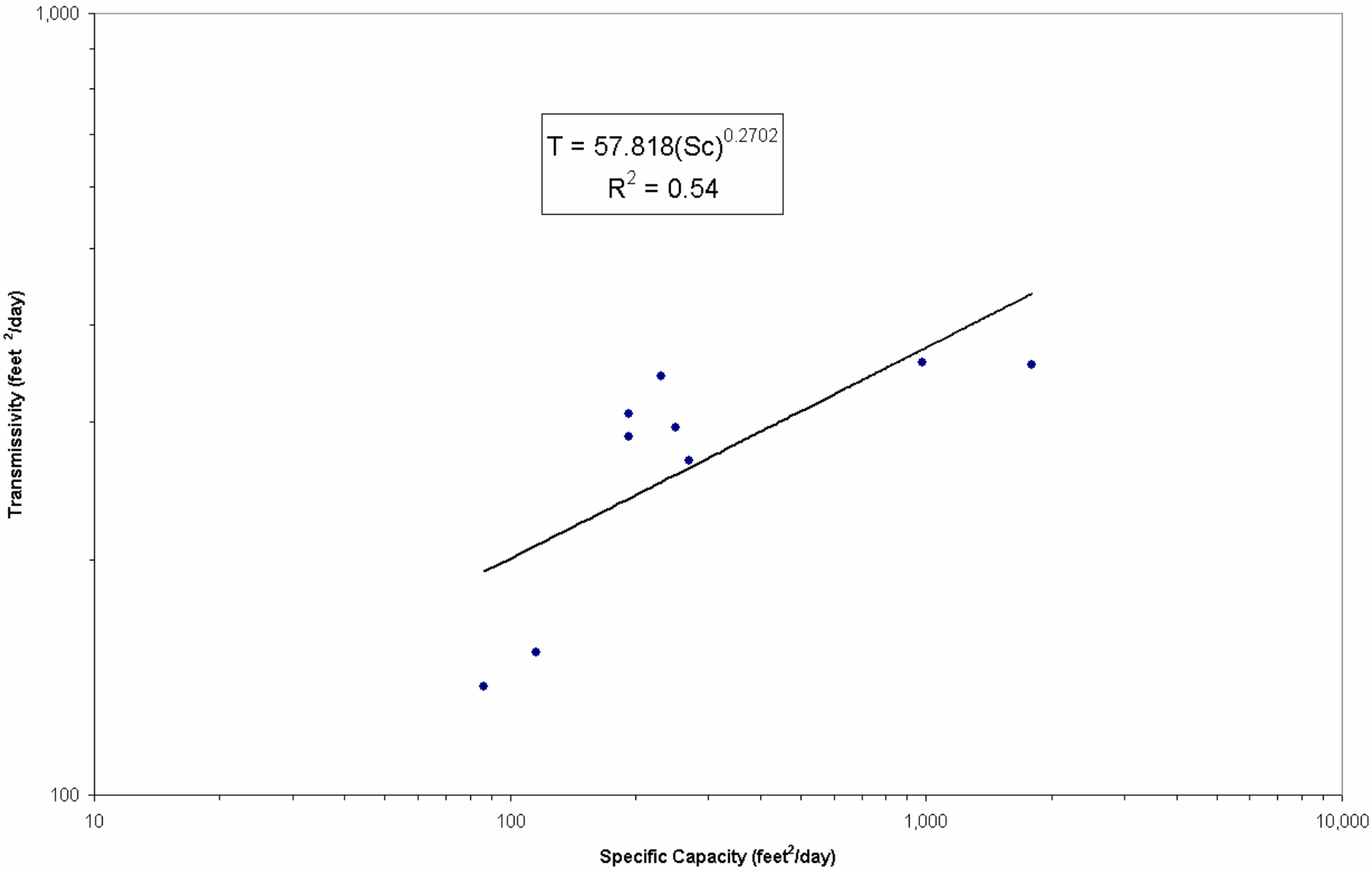
- More recharge in uplands, less in lowlands
- The magnitude of the effect will be calibrated

Hydraulic properties

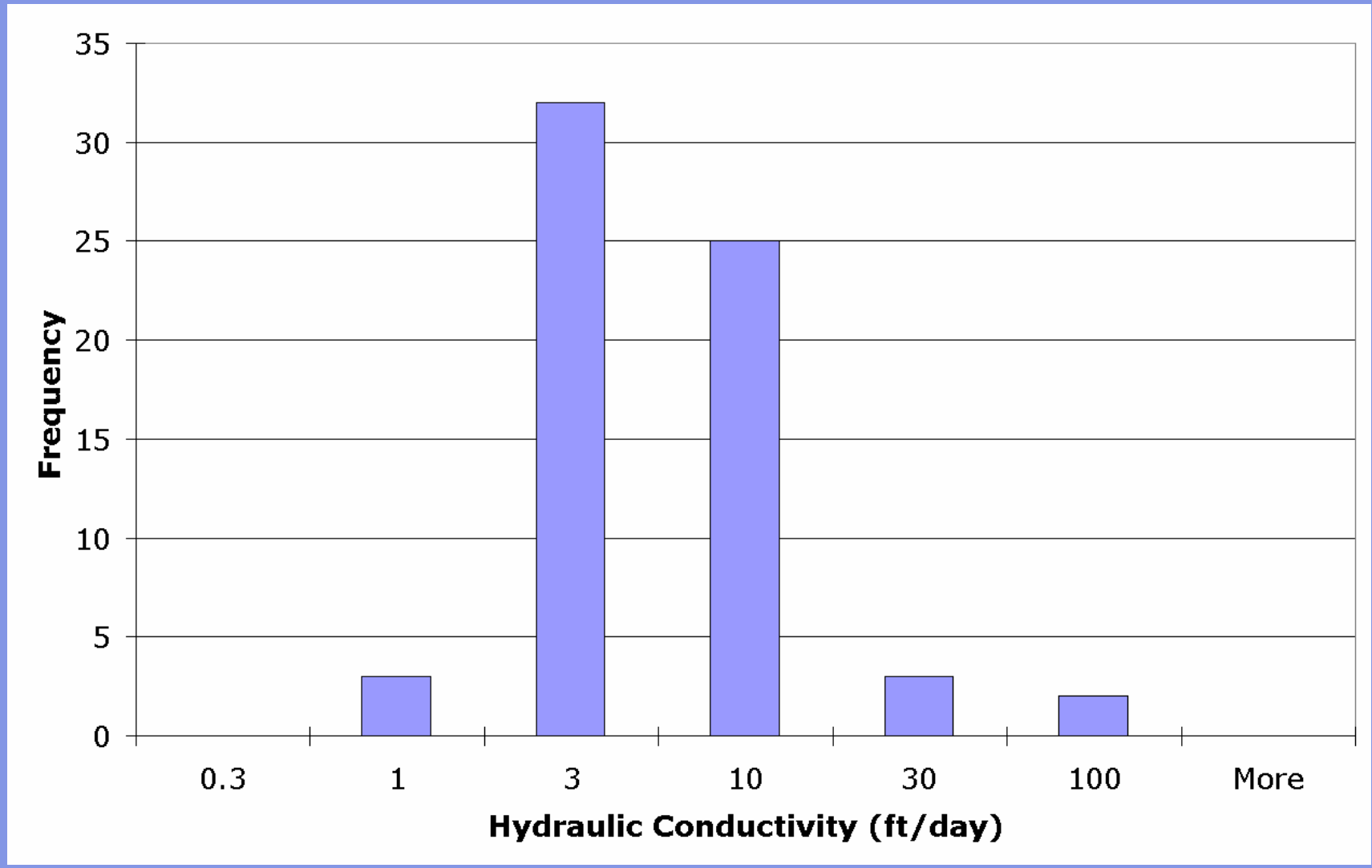
- 9 wells with Sc and T
- 56 other wells with Sc

- 0 wells with storage properties

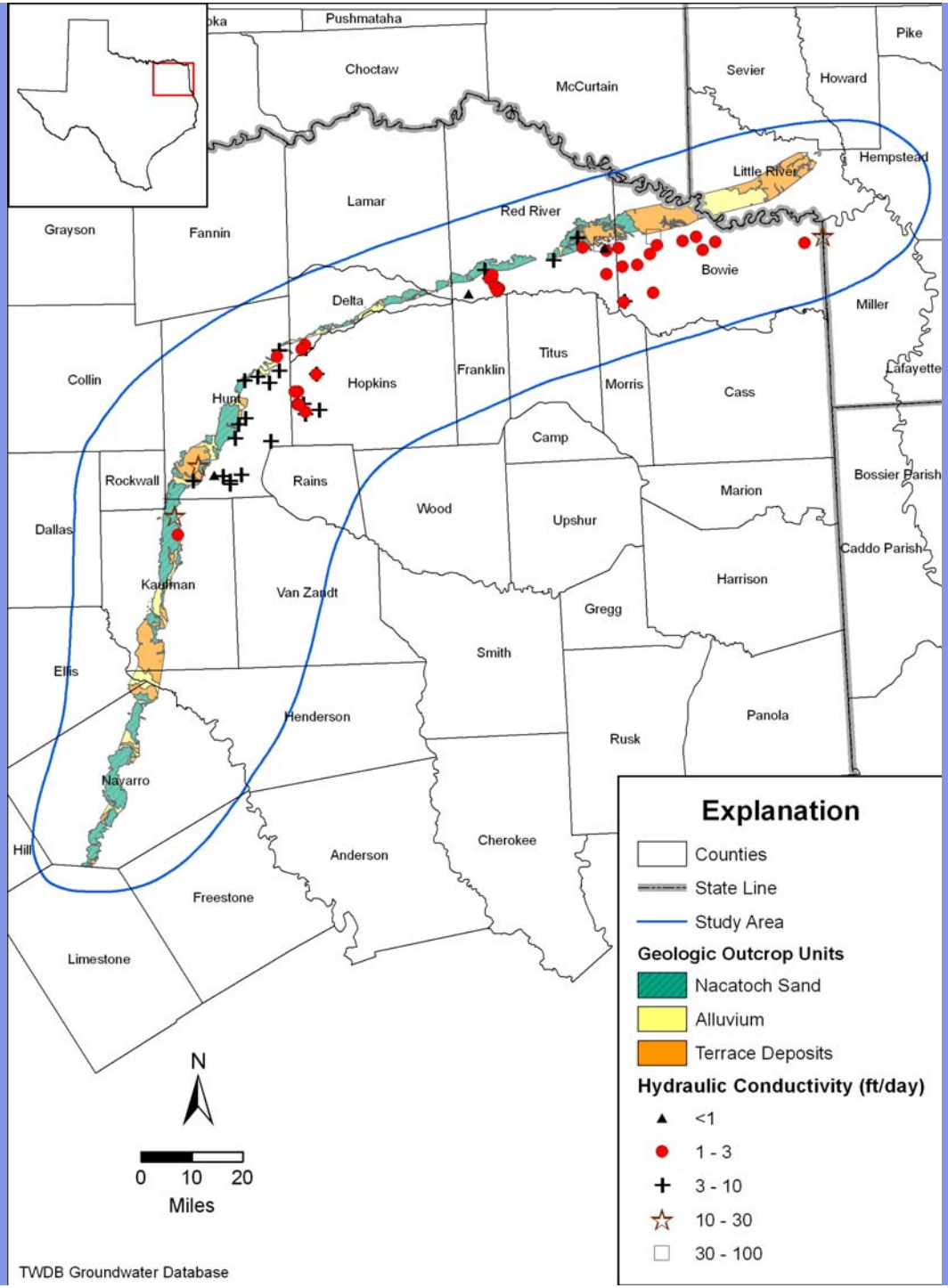
Hydraulic Properties



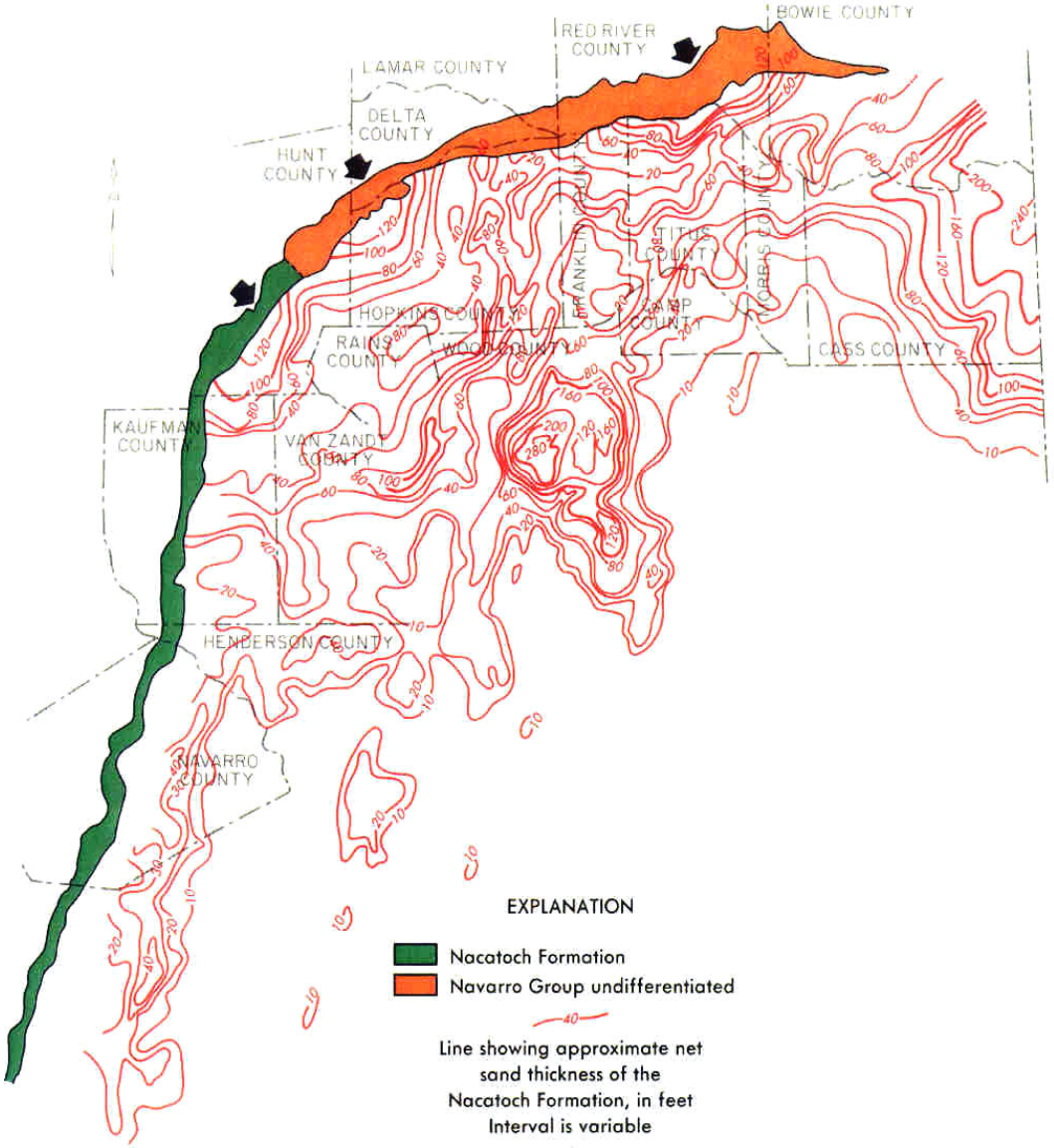
Hydraulic Conductivity



Hydraulic Conductivity Data (feet/day)



Net Sand Thickness



(from Ashworth, (1988) as modified from McGowen and Lopez (1984)

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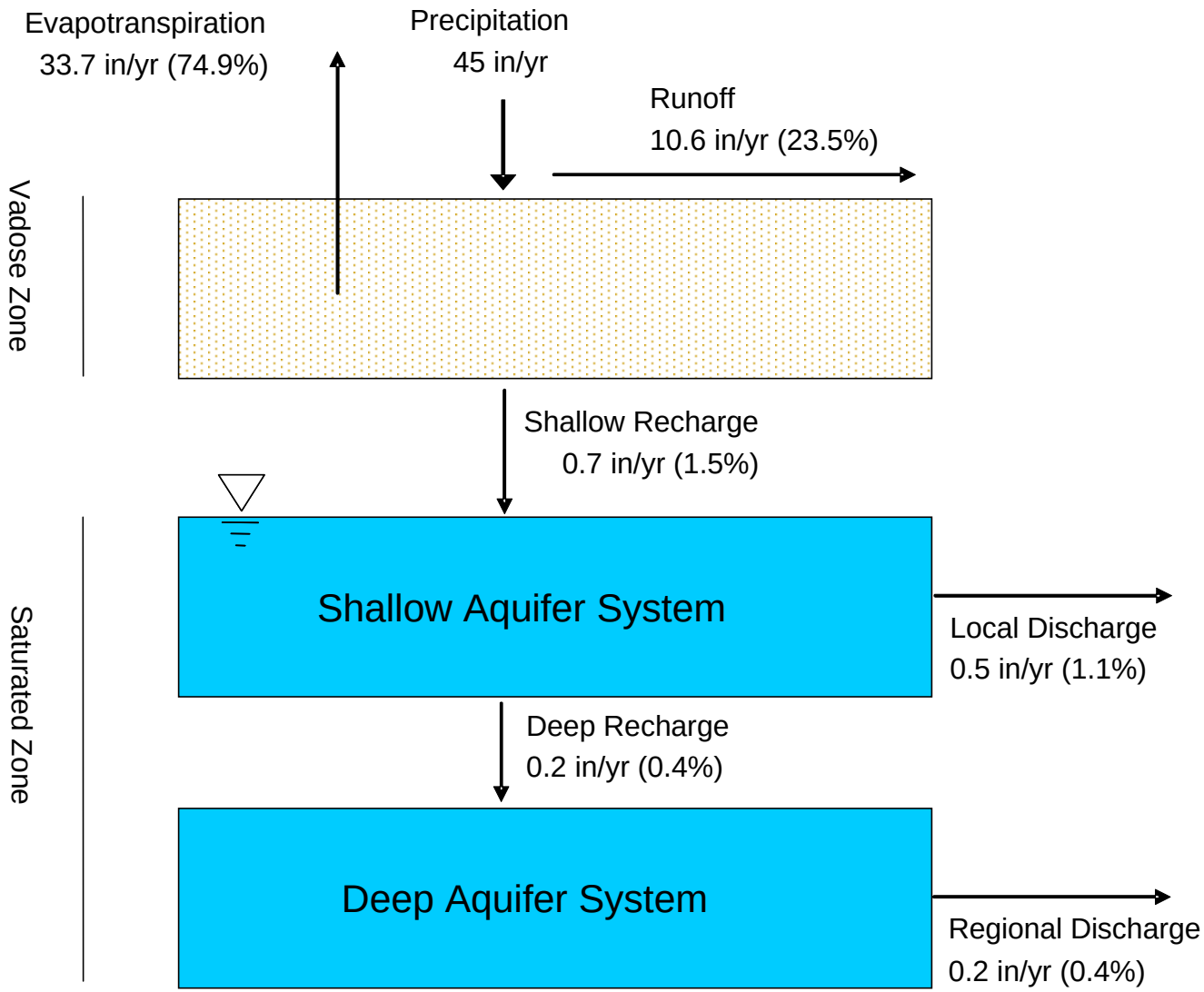

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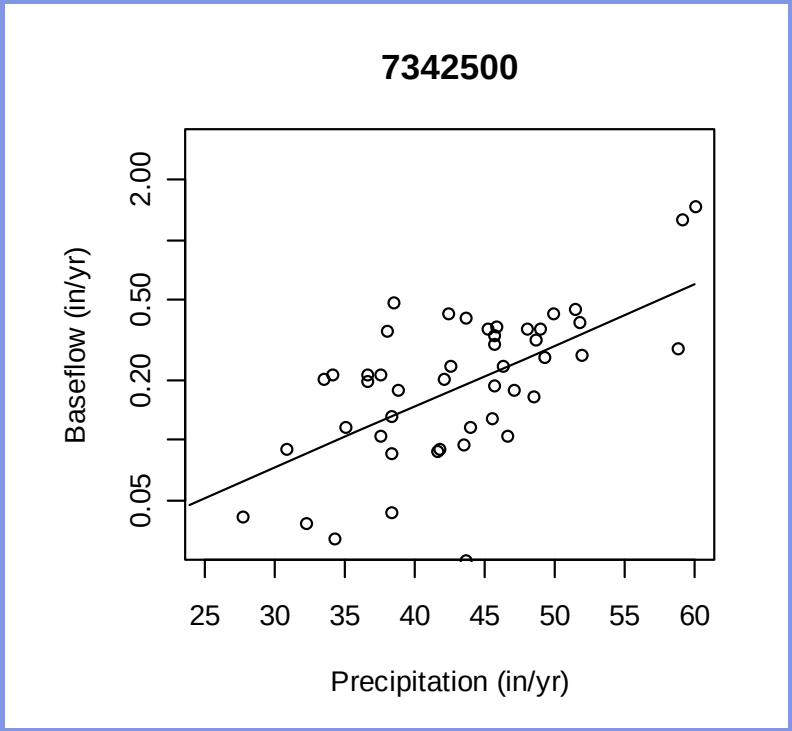

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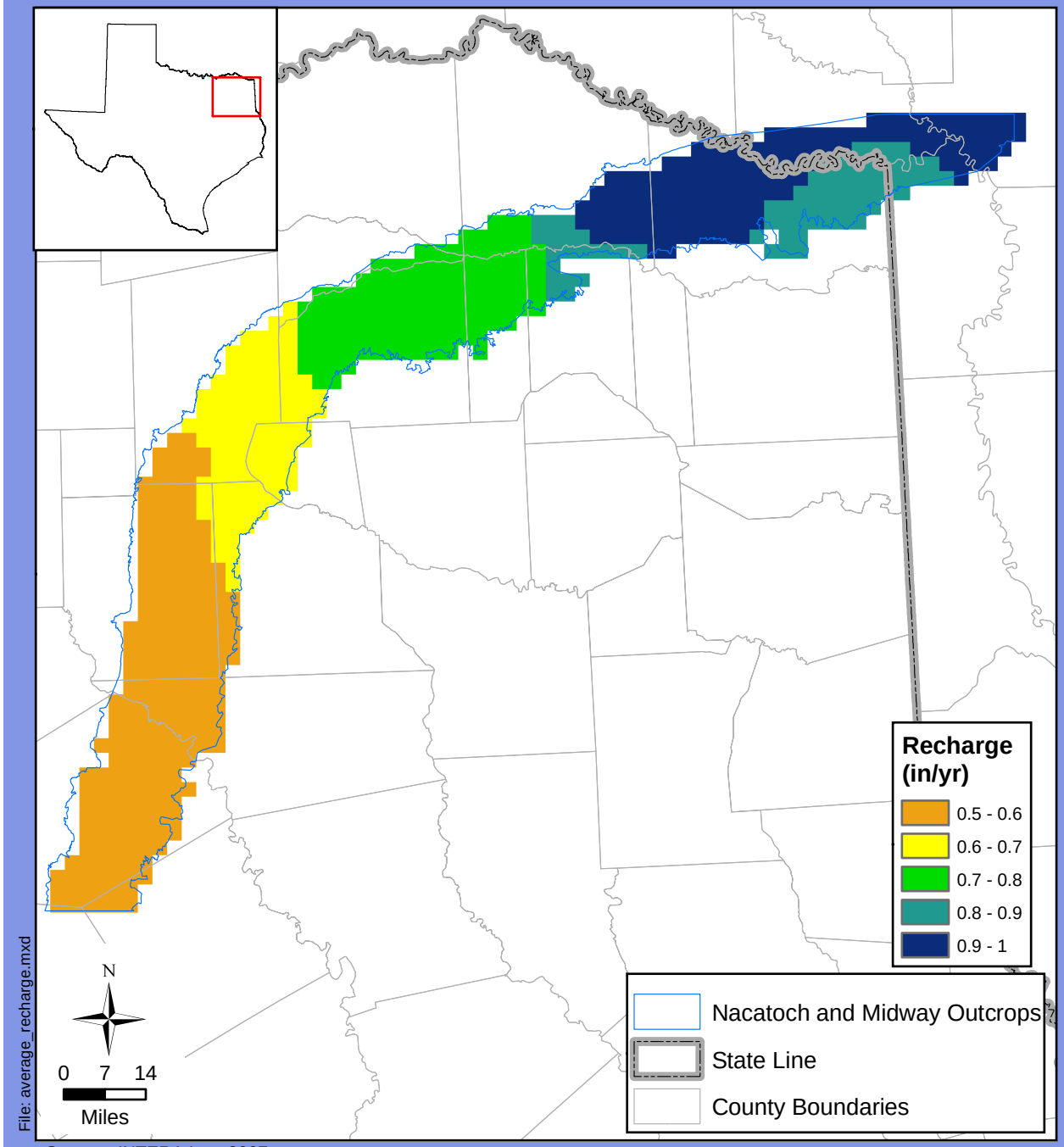

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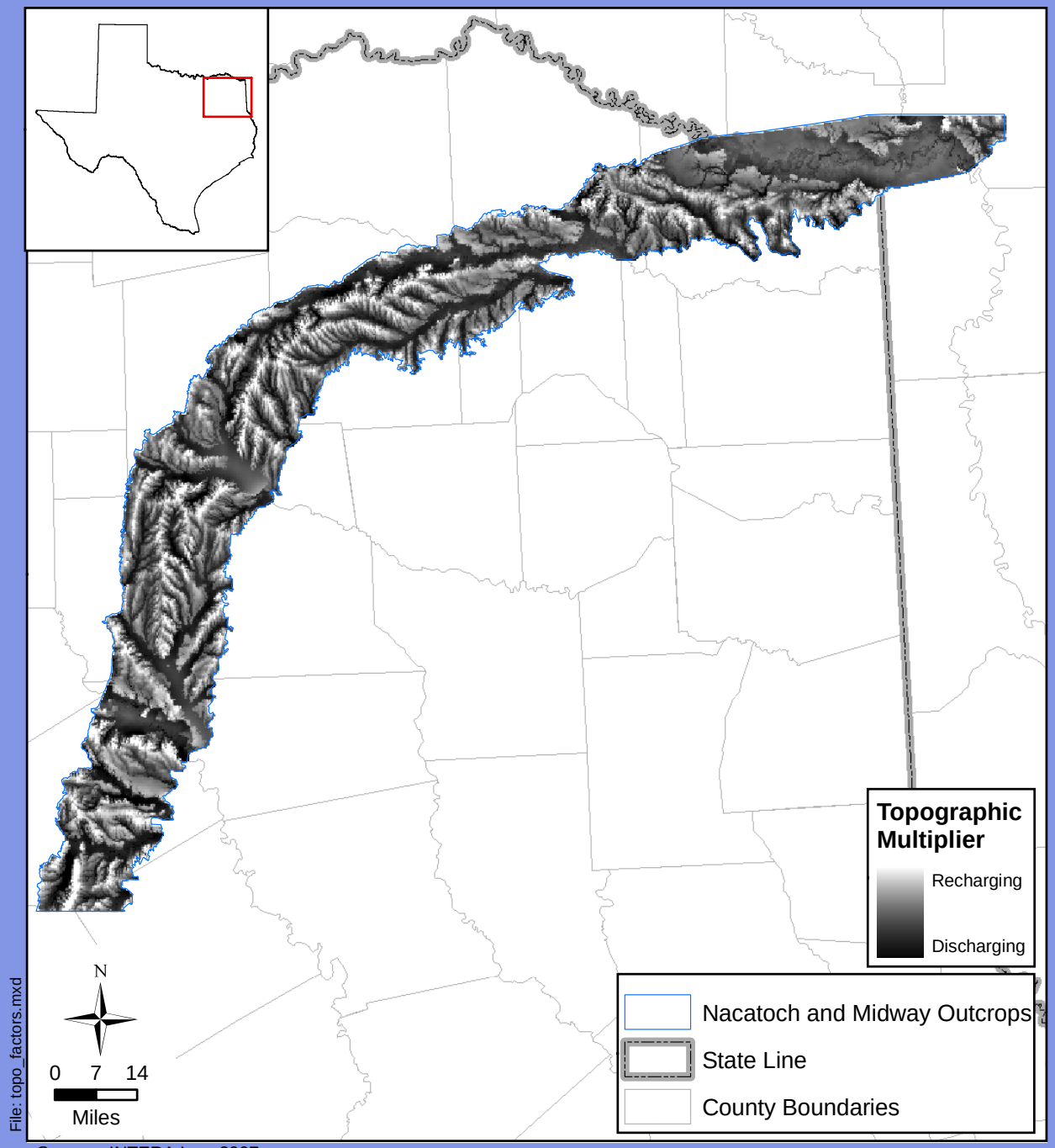

Source: INTERA Inc., 2007

- More recharge in uplands, less in lowlands
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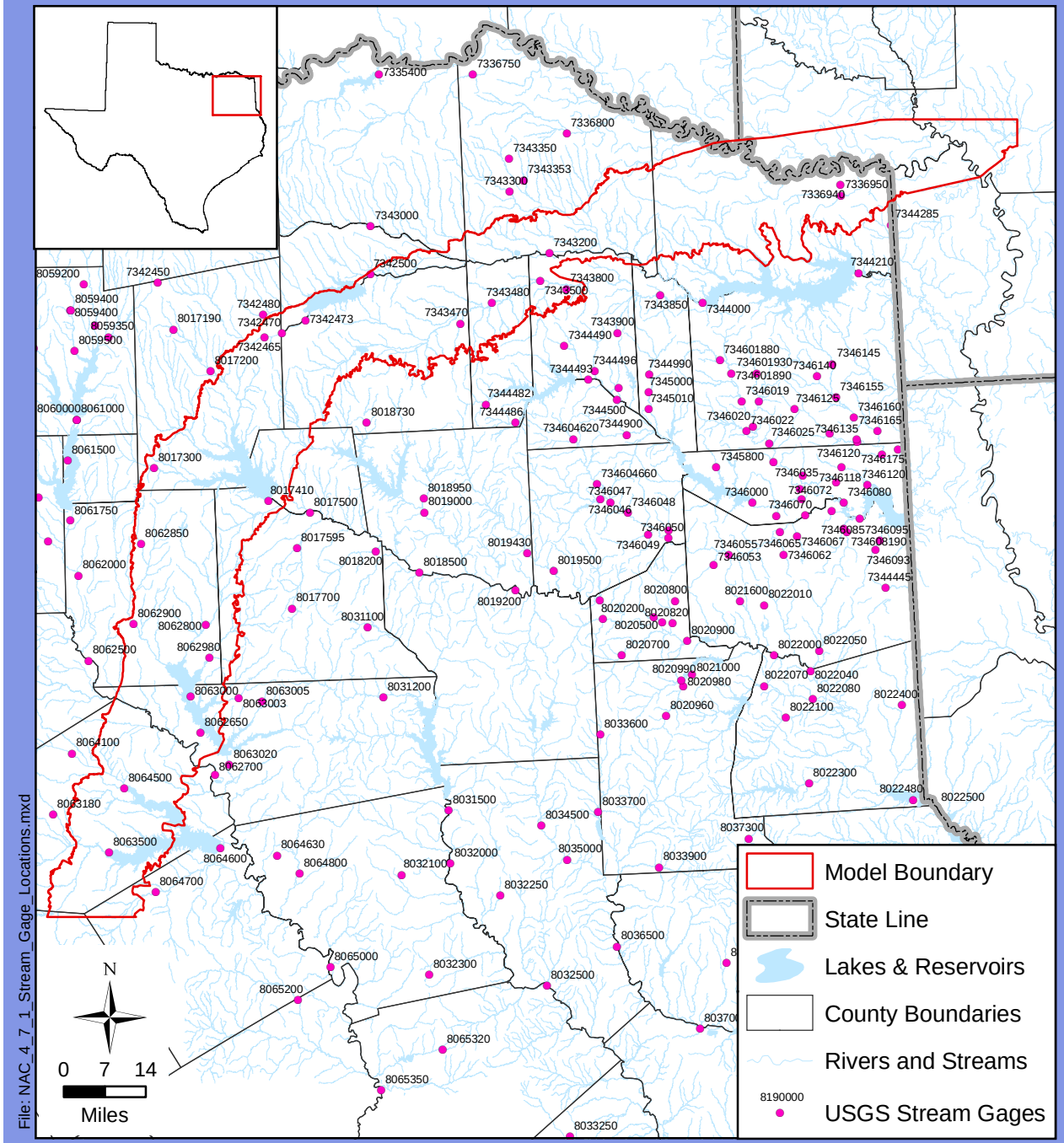
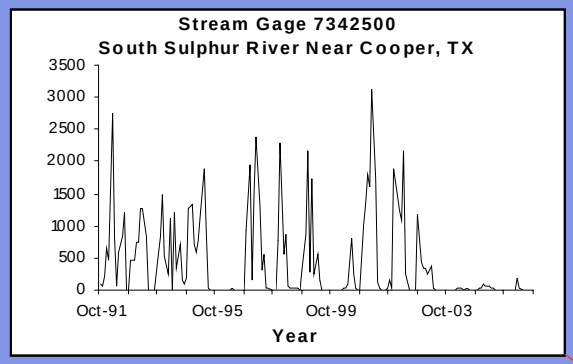
Discharge Processes

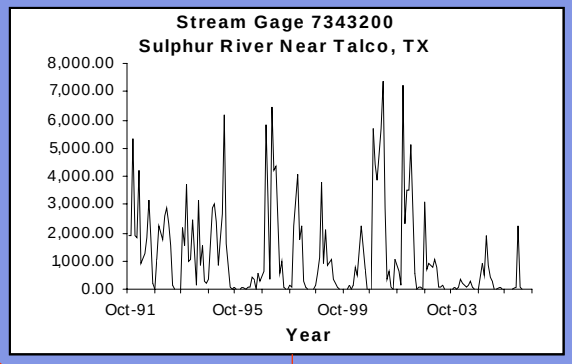
- Natural aquifer discharge
  - Baseflow
  - Groundwater Evapotranspiration
  - Springs
- Pumping

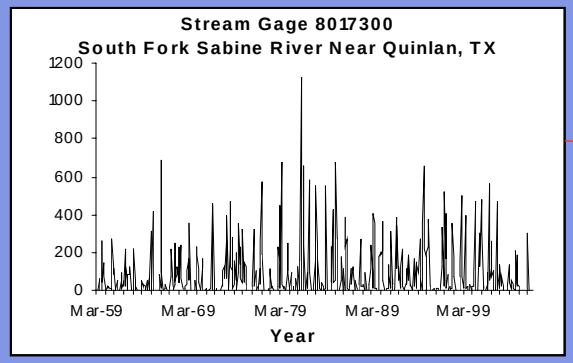
Stream Gage Coverage

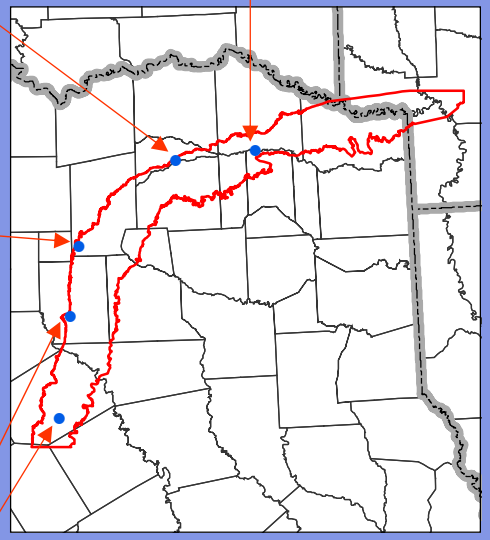


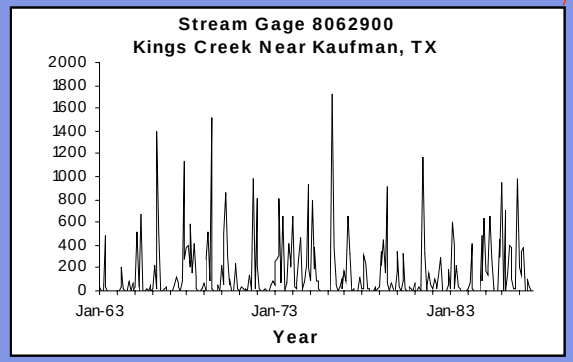
Daily Stream Flow Gauging Data

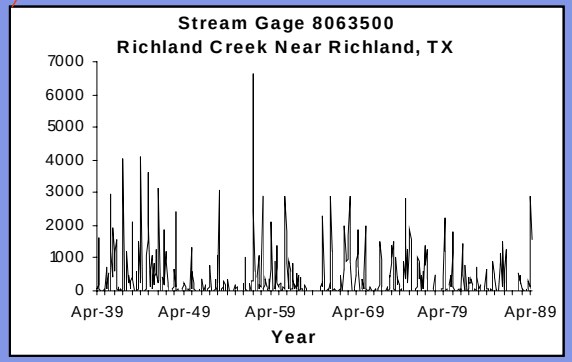






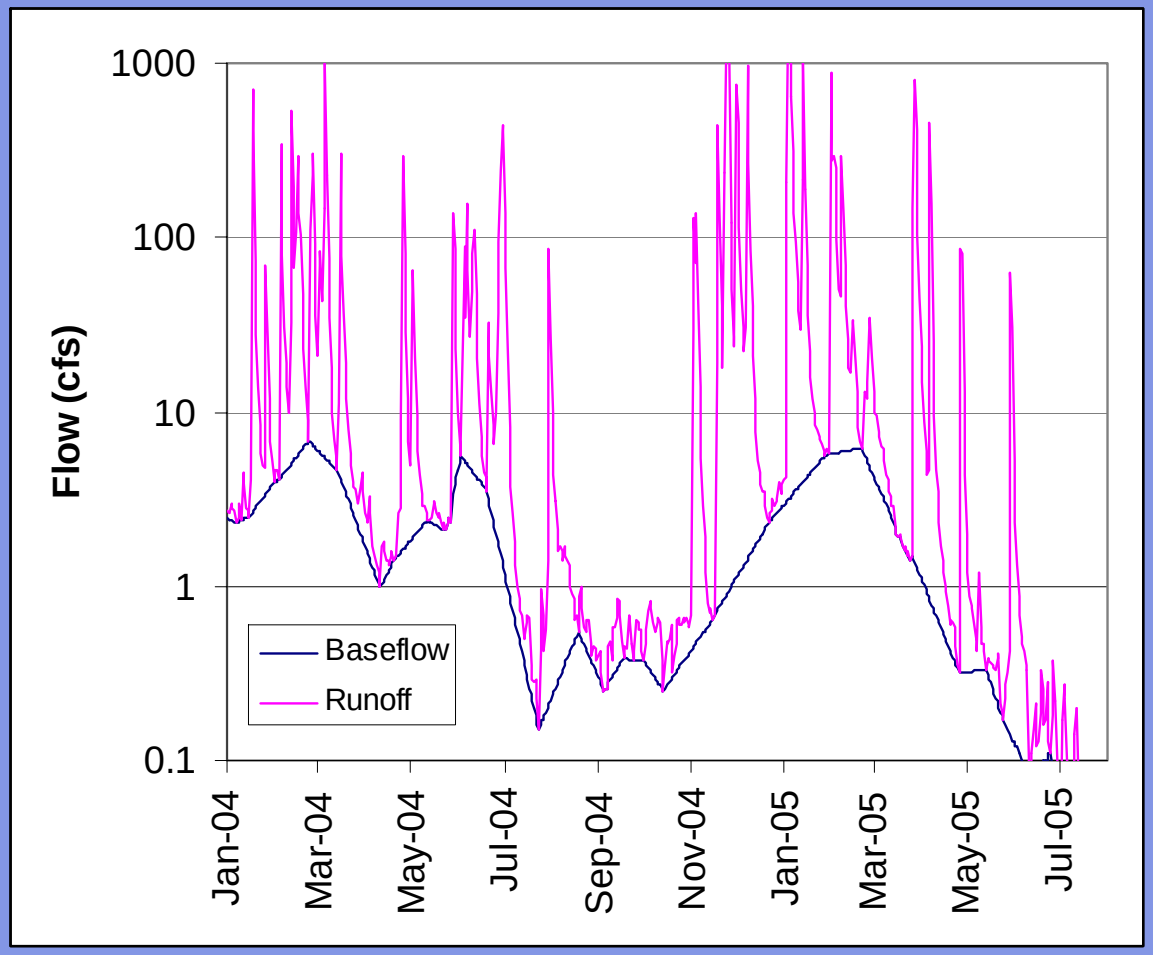






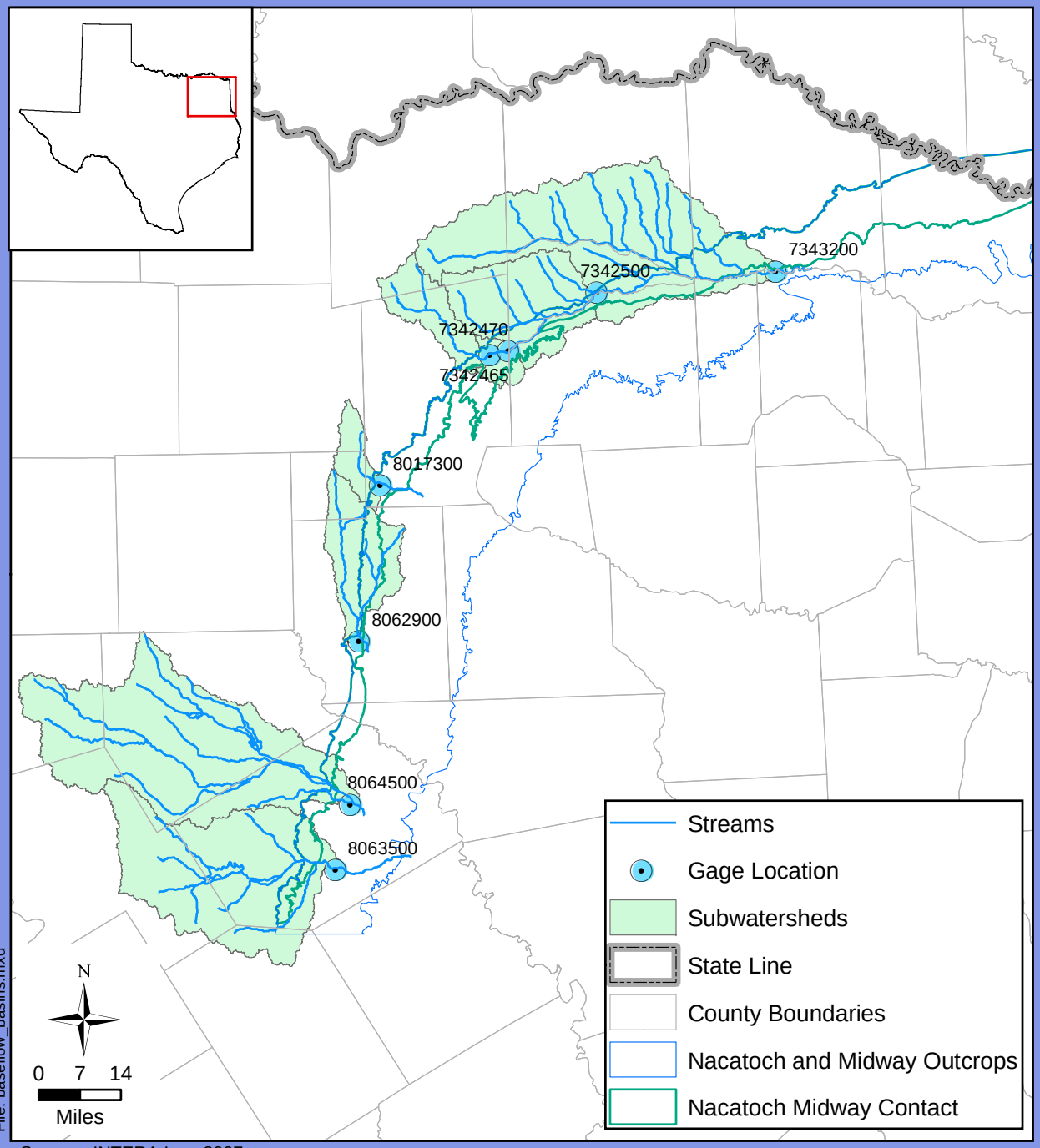
Baseflow

- No low-flow studies available in the area



Performed hydrograph separation analyses using the BFI code to estimate baseflow

Baseflow



Source: INTERA Inc., 2007

Gages and catchment areas for hydrograph separation analysis

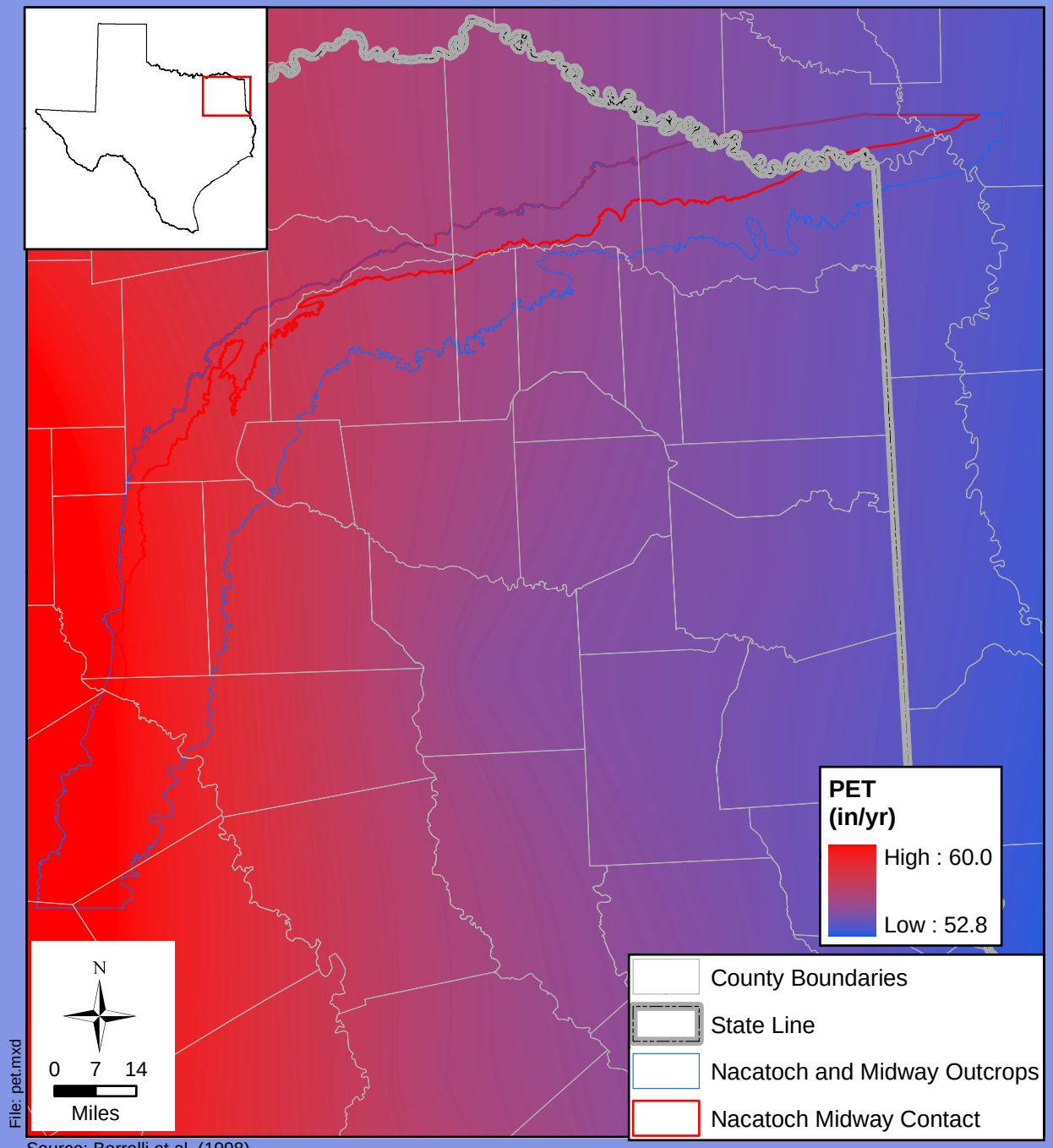
Baseflow

- Hydrograph separation results
- Area-weighted average of 0.5 in/yr

Gage	Station Name	Unregulated Years	Drainage Area (mi^2)	Baseflow (in/yr)	Runoff (in/yr)
7342465	S Sulphur Rv at Commerce, TX	1992-Present	150	0.28	13.7
7342470	S Sulphur Rv nr Commerce, TX	1980-1991	189	0.27	11.1
7342500	S Sulphur Rv nr Cooper, TX	1943-1992	527	0.29	10.6
7343200	Sulphur Rv nr Talco, TX	1957-1992	1405	0.58	12.8
8017300	S Fk Sabine Rv nr Quinlan, TX	1960-Present	78.7	0.18	17.1
8062900	Kings Ck nr Kaufman, TX	1964-1972	233	0.24	8.6
8063500	Richland Ck nr Richland, TX	1940-1963	734	0.45	8.1
8064500	Chambers Ck nr Corsicana, TX	1940-1961	963	0.69	6.4

Groundwater ET

- No measurements available in the area
- Objectives
  - Estimate potential ET
  - Estimate vegetation coefficients
  - Estimate rooting depths

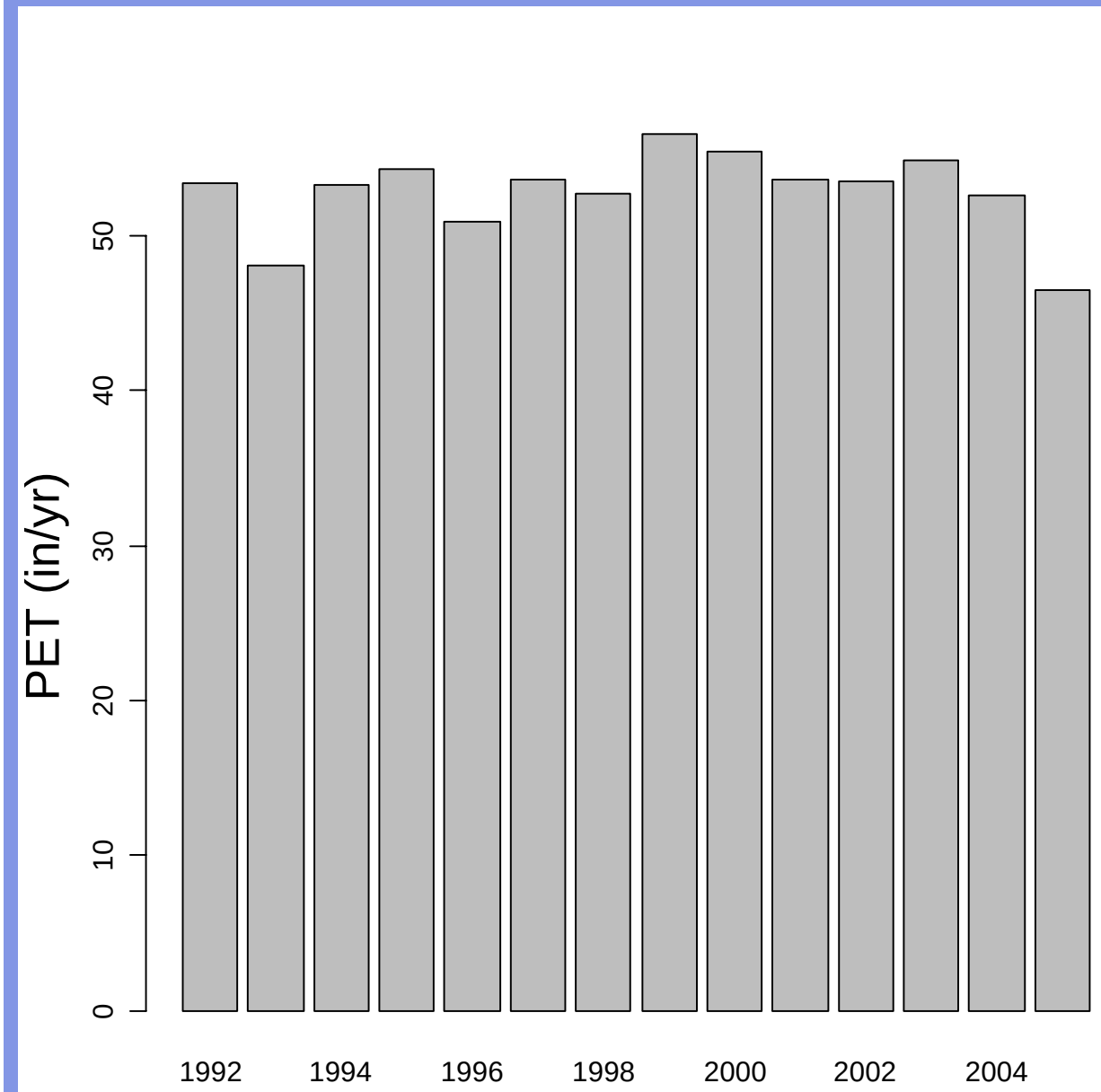


Source: Borrelli et al. (1998)

PET

(long term average)

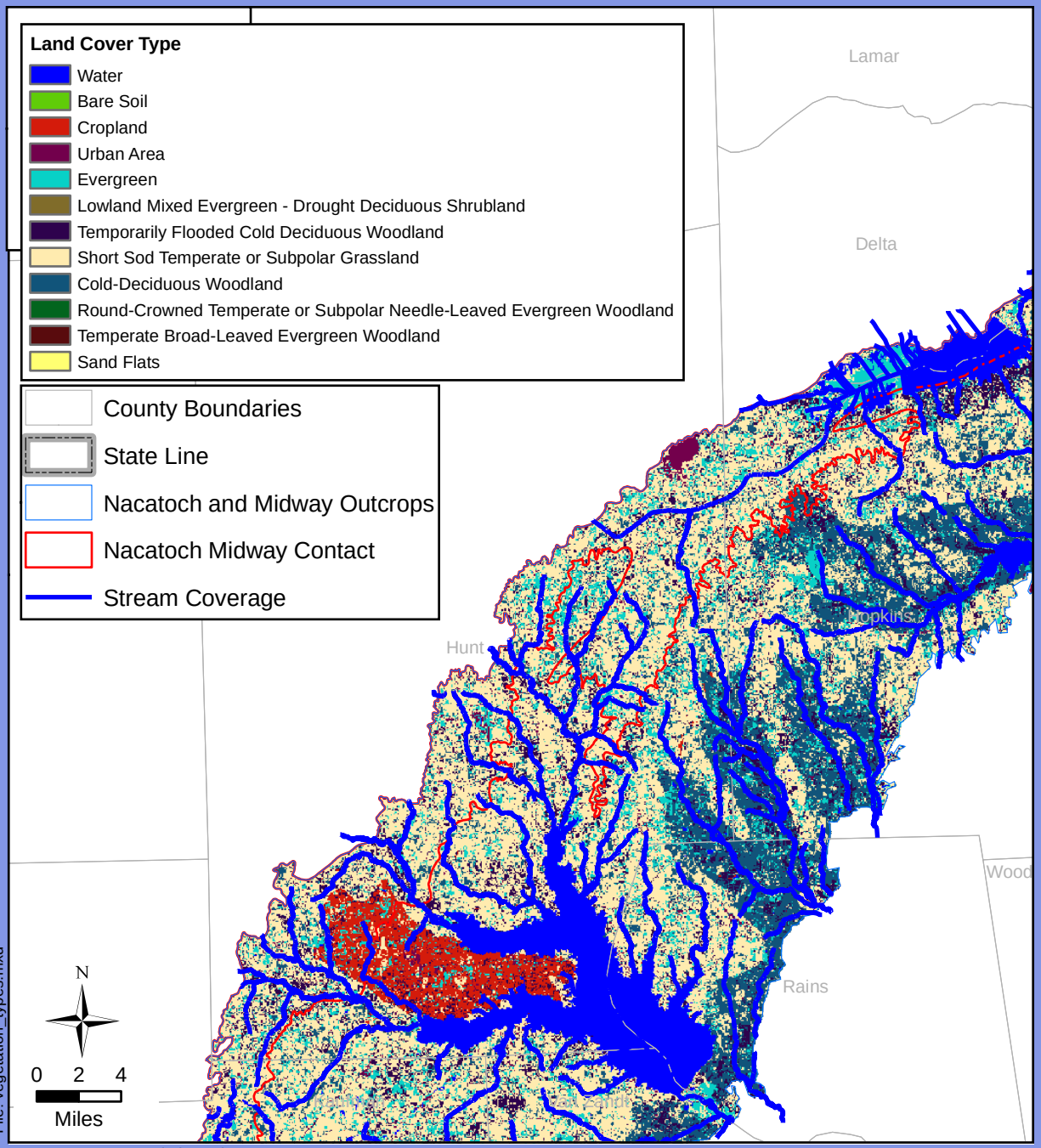
- More correctly called reference ET, and based on the Penmann-Monteith equation
- Does not vary significantly across the model area



PET

(temporal variation)

- Based on the Hargreaves method, uses Tmin and Tmax
- Again, not much annual variation in ET

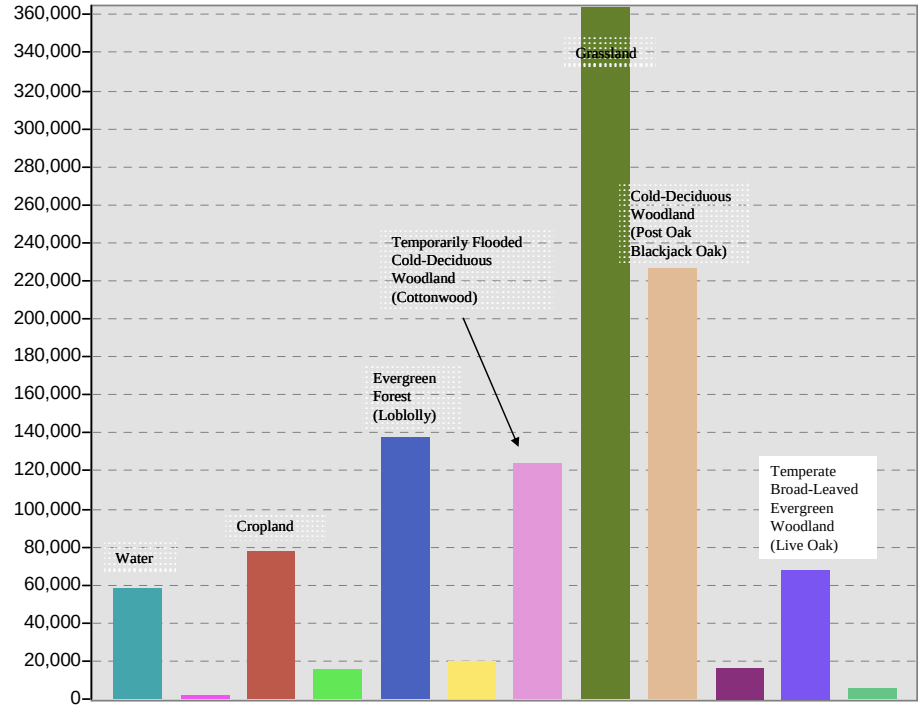


Source: Carter et al. (2003)

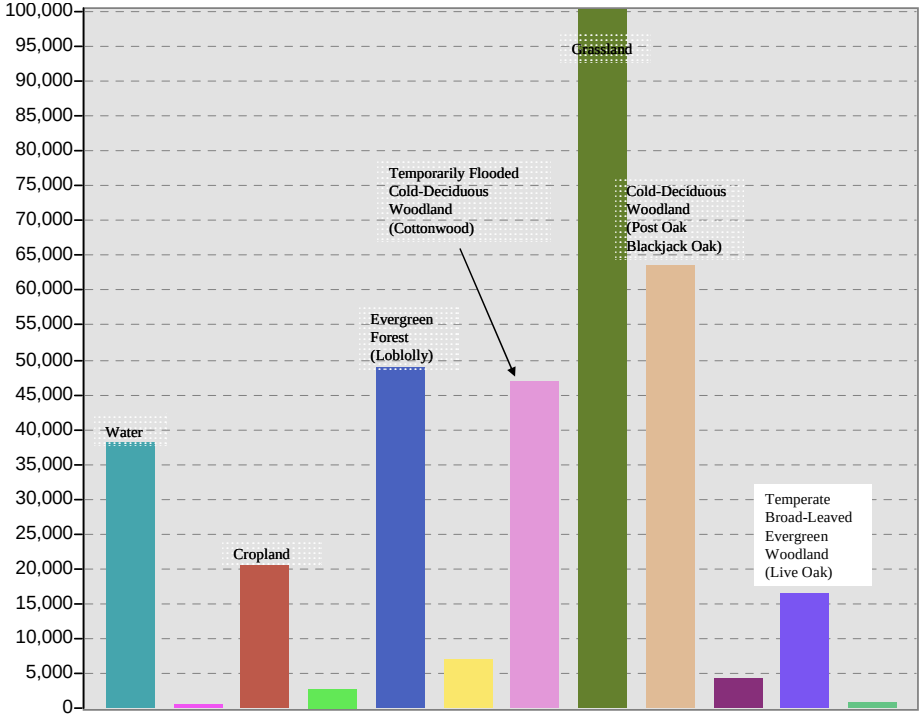
Vegetation Coverage

- Based on Texas GAP analysis program
- Resolution of approximately 300 ft
- Does not show significant vegetation change in riparian areas

Vegetation Coverage



Entire Outcrop



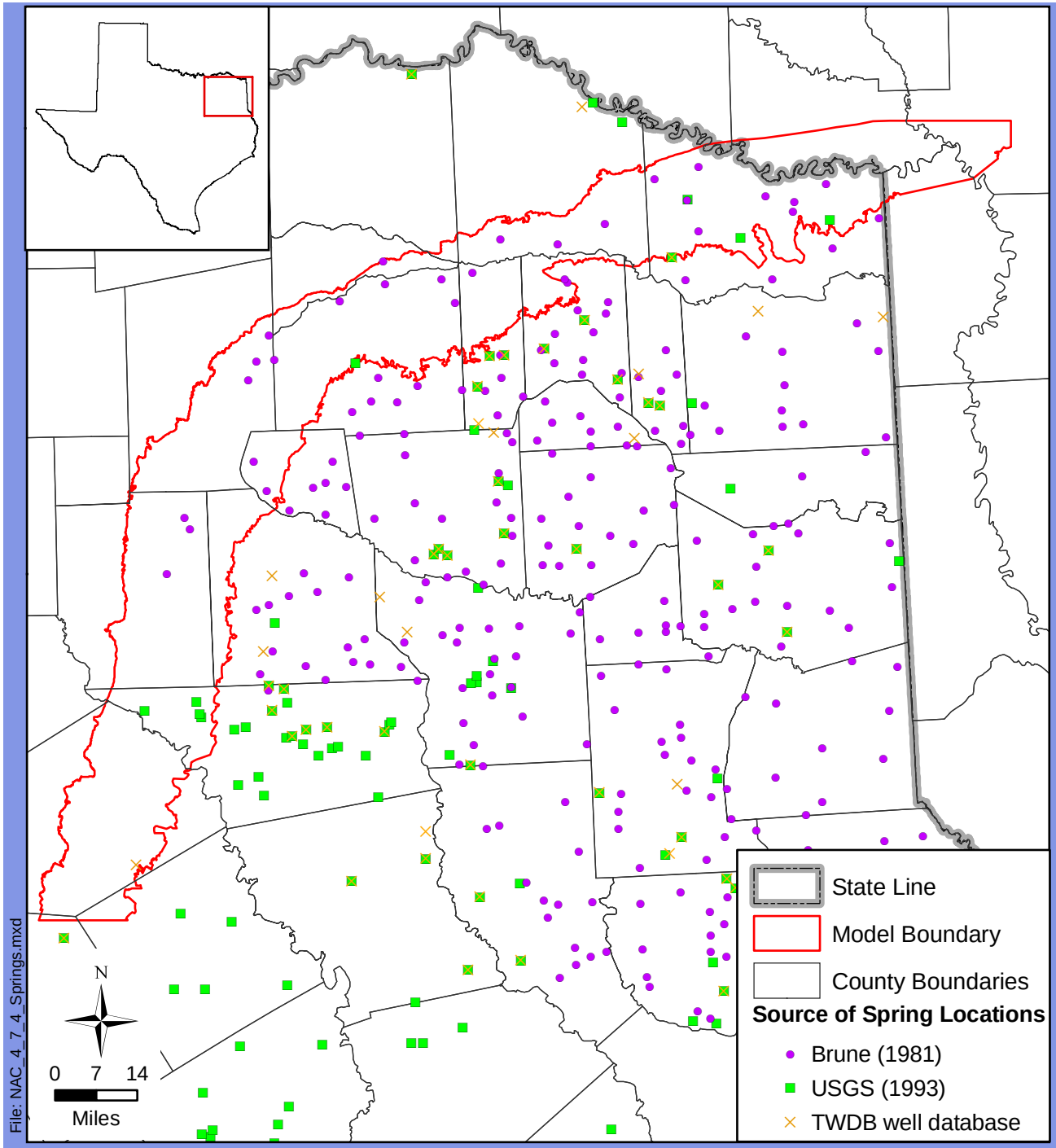
Near Streams

Frequency similar between overall outcrop and riparian areas

Vegetation Coefficients and Rooting Depths

- Based on Scanlon (2005)

Vegetation Type	Kc	Rooting Depth (ft)
Cottonwood	0.37	10.
Grassland	0.70	2.
Pine	0.53	7.
Live Oak	0.5*	5.*
Post Oak	0.5*	5.*
Cropland	0.6*	1.



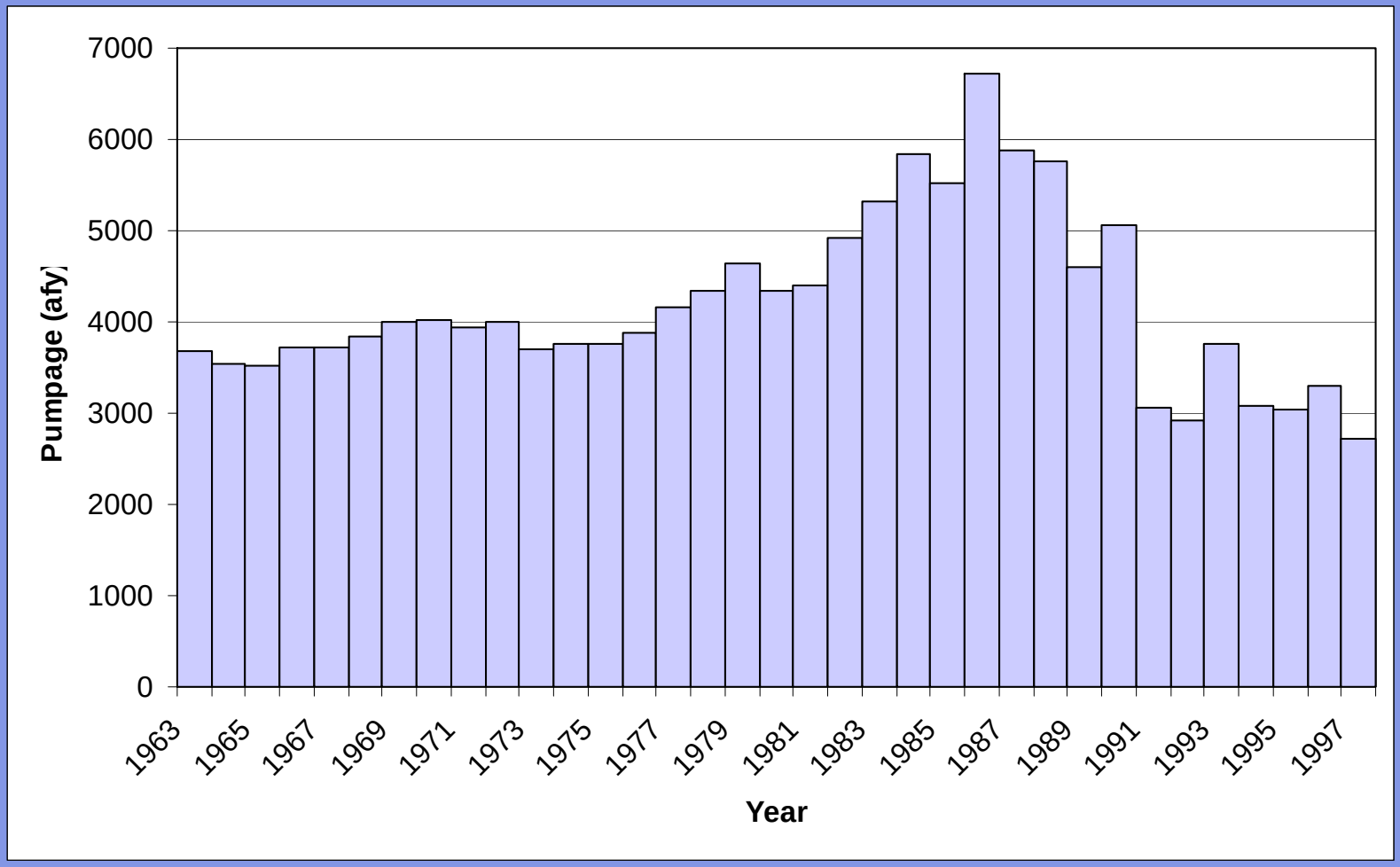
Springs

- A few springs (about 35) documented in the outcrop region
- No time series data available
- Many springs are ephemeral
- Ashworth (1988) notes that springflow has declined in areas of significant drawdown

Pumping Data

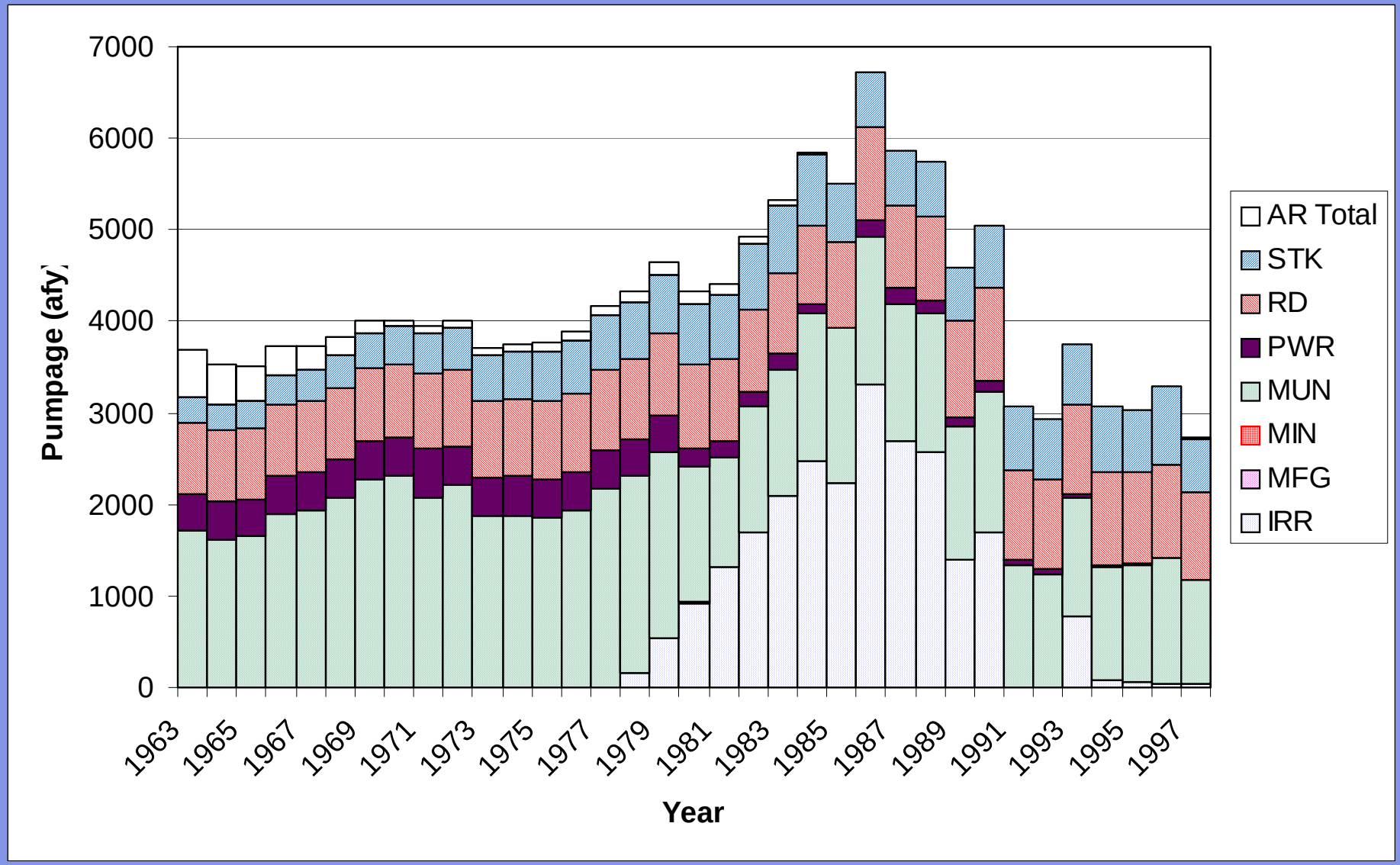
- GAM Calibration Period (1980-1997)
  - TWDB master pumping tables in the pumpage geodatabase
- Historical Period (1963-1980)
  - Ashworth (1988)
  - County Reports and River Basin Reports
- Arkansas (1965-2000)
  - USGS(2004);five year estimates

Total Pumping for Nacatoch 1963-1997



Includes Arkansas counties

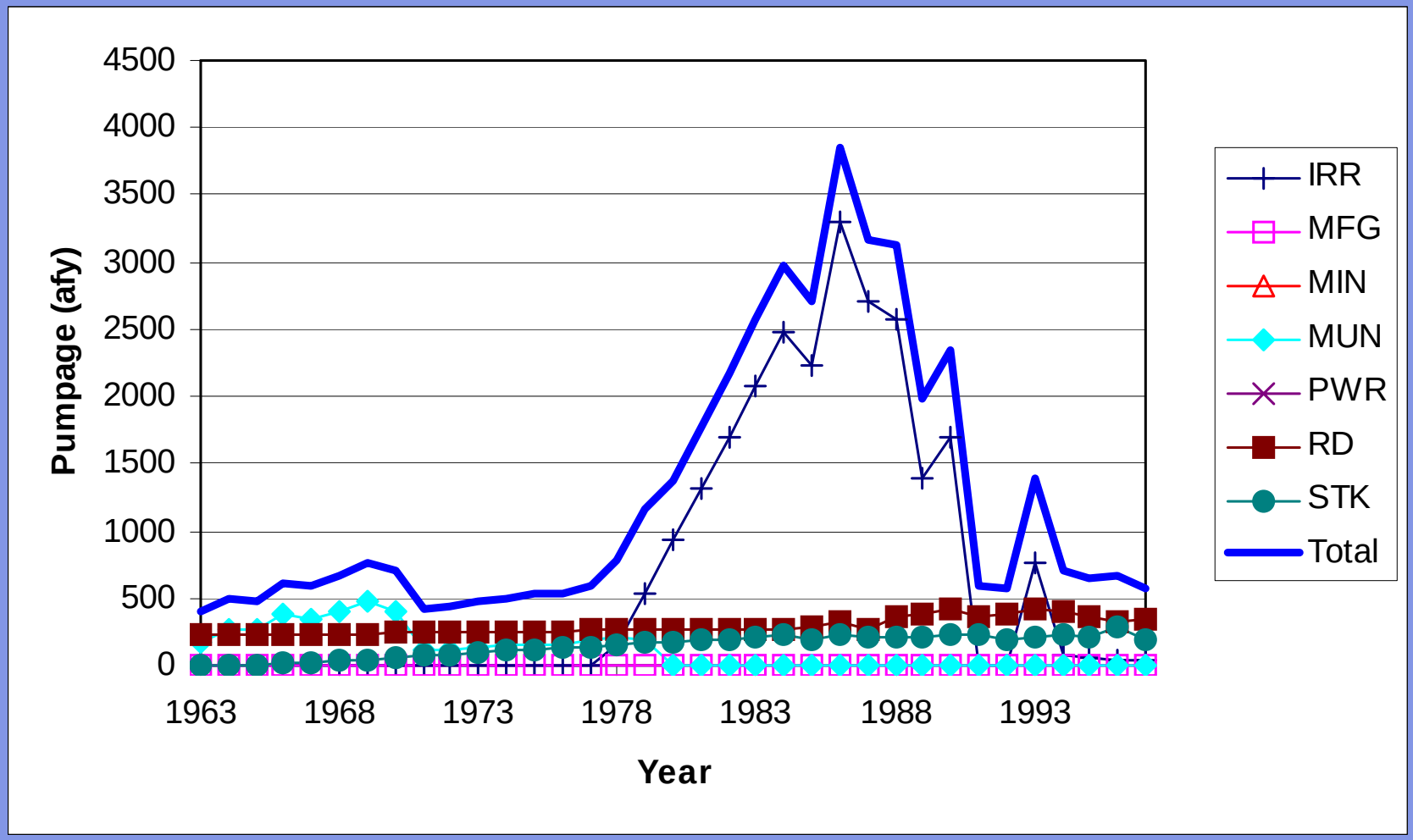
Pumping by Category



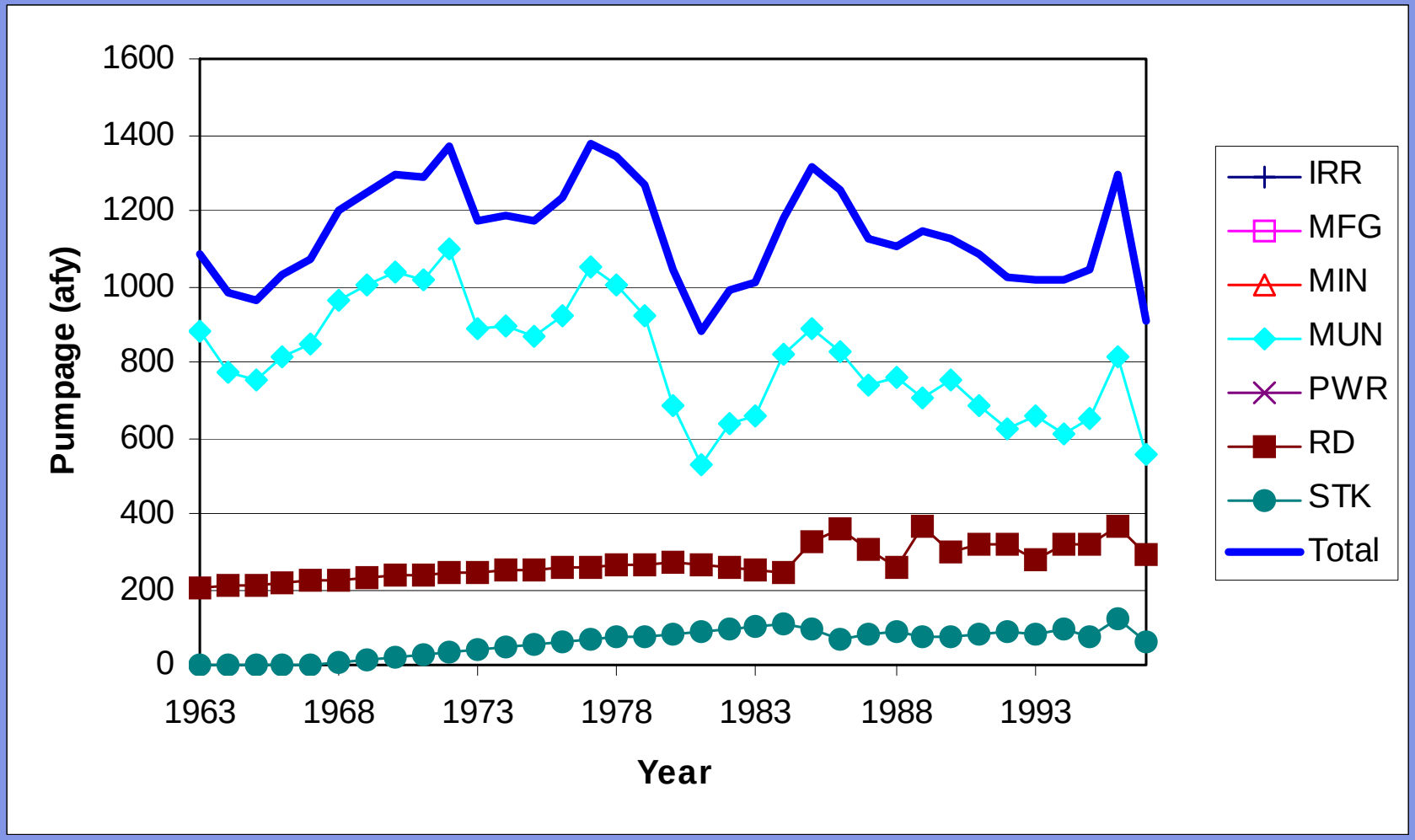
Total Pumping by County (AFY)

Year	1963	1965	1970	1975	1980	1985	1990	1995	1997
Texas Counties									
Bowie	396	483	708	530	1,372	2,709	2,353	643	581
Delta	466	406	563	490	480	497	540	273	268
Franklin	1	1	1	1	1	1	1	1	1
Henderson	5	5	6	8	9	11	13	15	14
Hopkins	189	243	308	360	367	260	303	411	361
Hunt	1,086	963	1,296	1,172	1,041	1,317	1,125	1,045	909
Kaufman	77	77	78	80	82	61	66	75	59
Lamar	-	-	-	-	2	2	1	1	1
Navarro	25	24	28	29	15	15	15	14	11
Rains	3	3	3	4	4	2	4	5	5
Red River	922	924	954	996	750	556	632	549	507
Titus	-	-	-	-	68	80	-	-	1
Texas Total	**3,170**	**3,131**	**3,945**	**3,670**	**4,192**	**5,511**	**5,054**	**3,031**	**2,716**
Arkansas Counties									
Little River	300	224	34	45	69	-	-	-	-
Miller	211	160	34	45	69	-	-	-	13
Arkansas Total	**511**	**384**	**67**	**90**	**139**	**-**	**-**	**-**	**13**
Texas and Arkansas Total	**3,681**	**3,516**	**4,013**	**3,759**	**4,331**	**5,511**	**5,054**	**3,031**	**2,730**

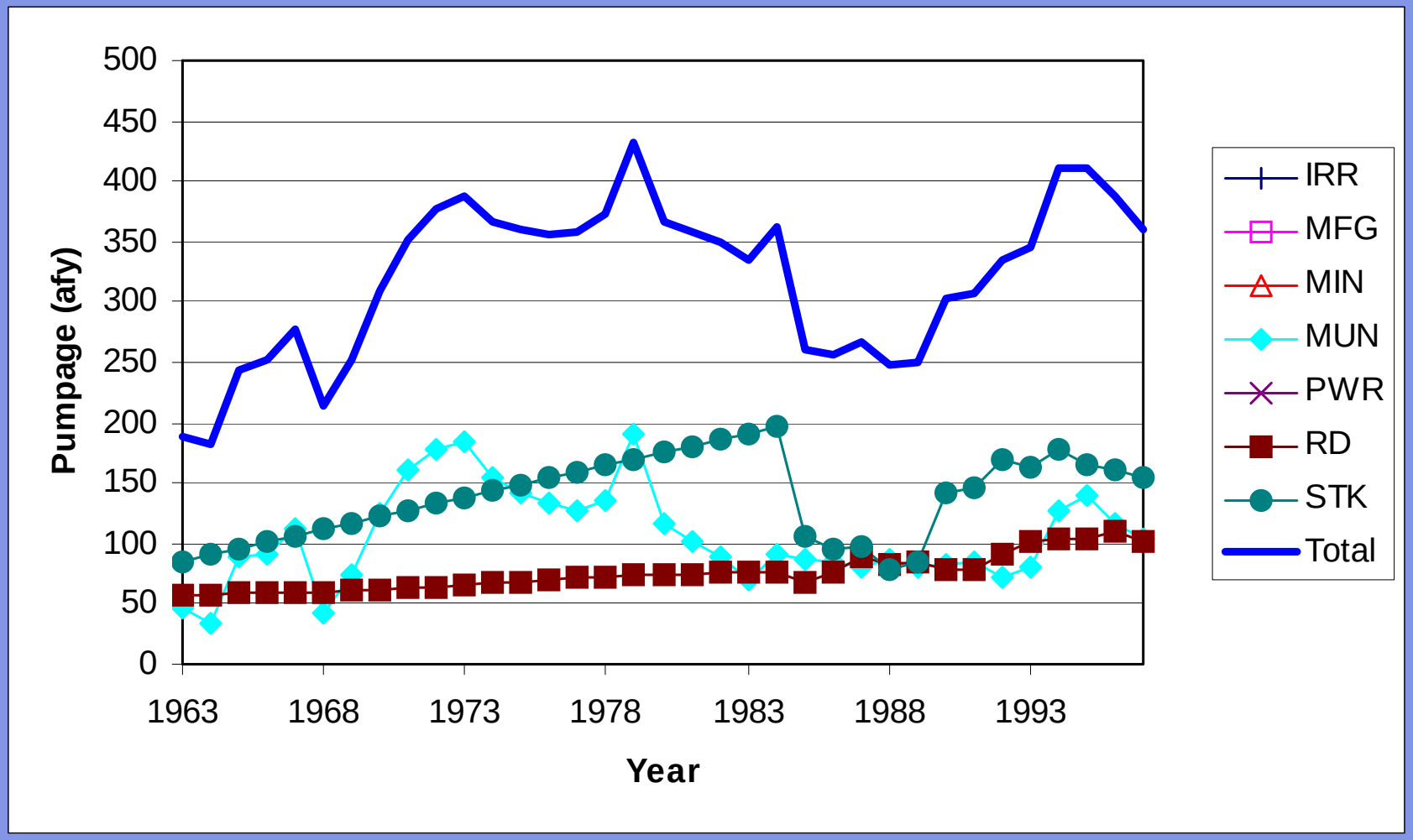
Bowie County



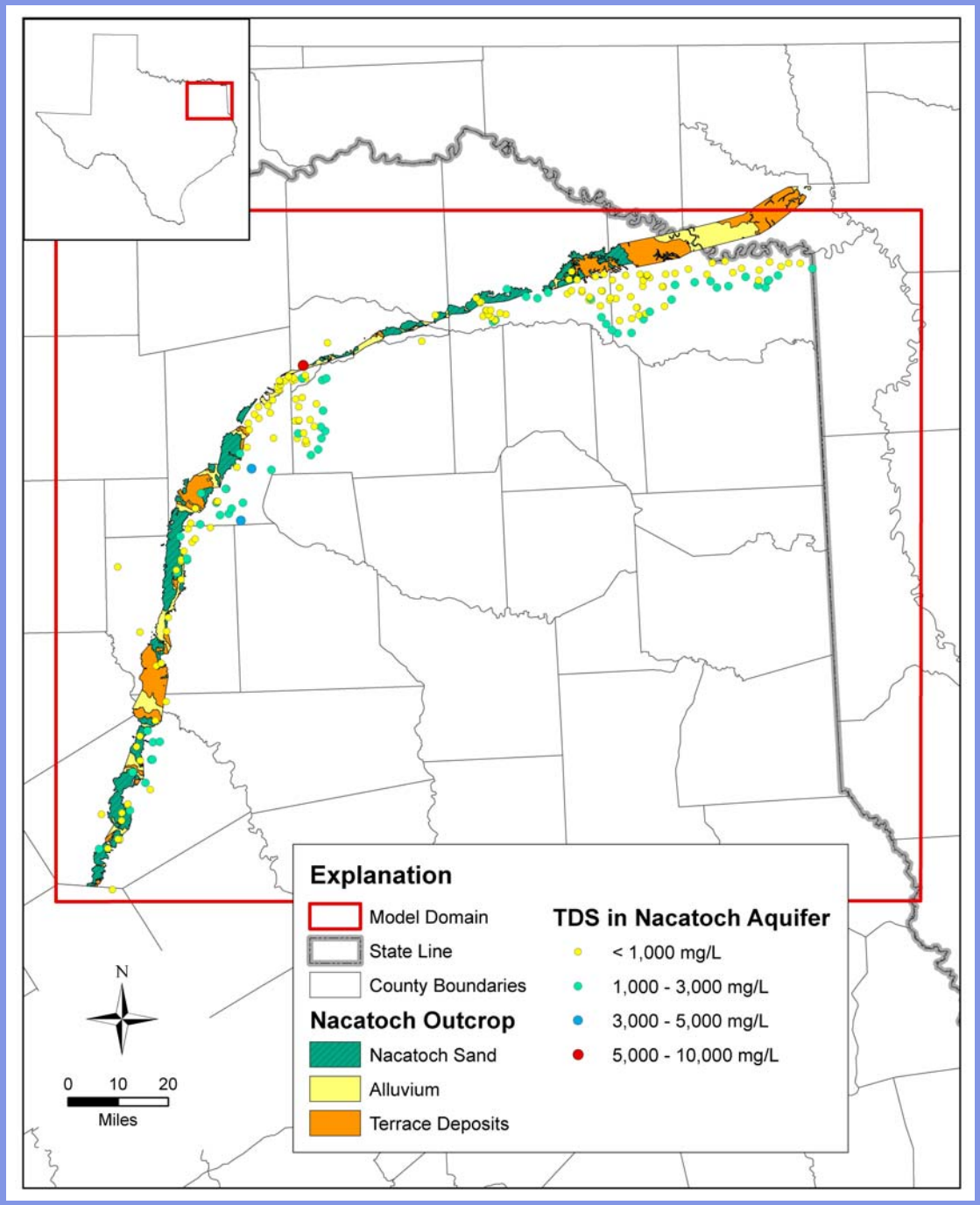
Hunt County


1600
1400
1200
1000
800
600
400
200
0
Pumpage (afy)
1963
1968
1973
1978
1983
1988
1993
Year
IRR
MFG
MIN
MUN
PWR
RD
STK
Total

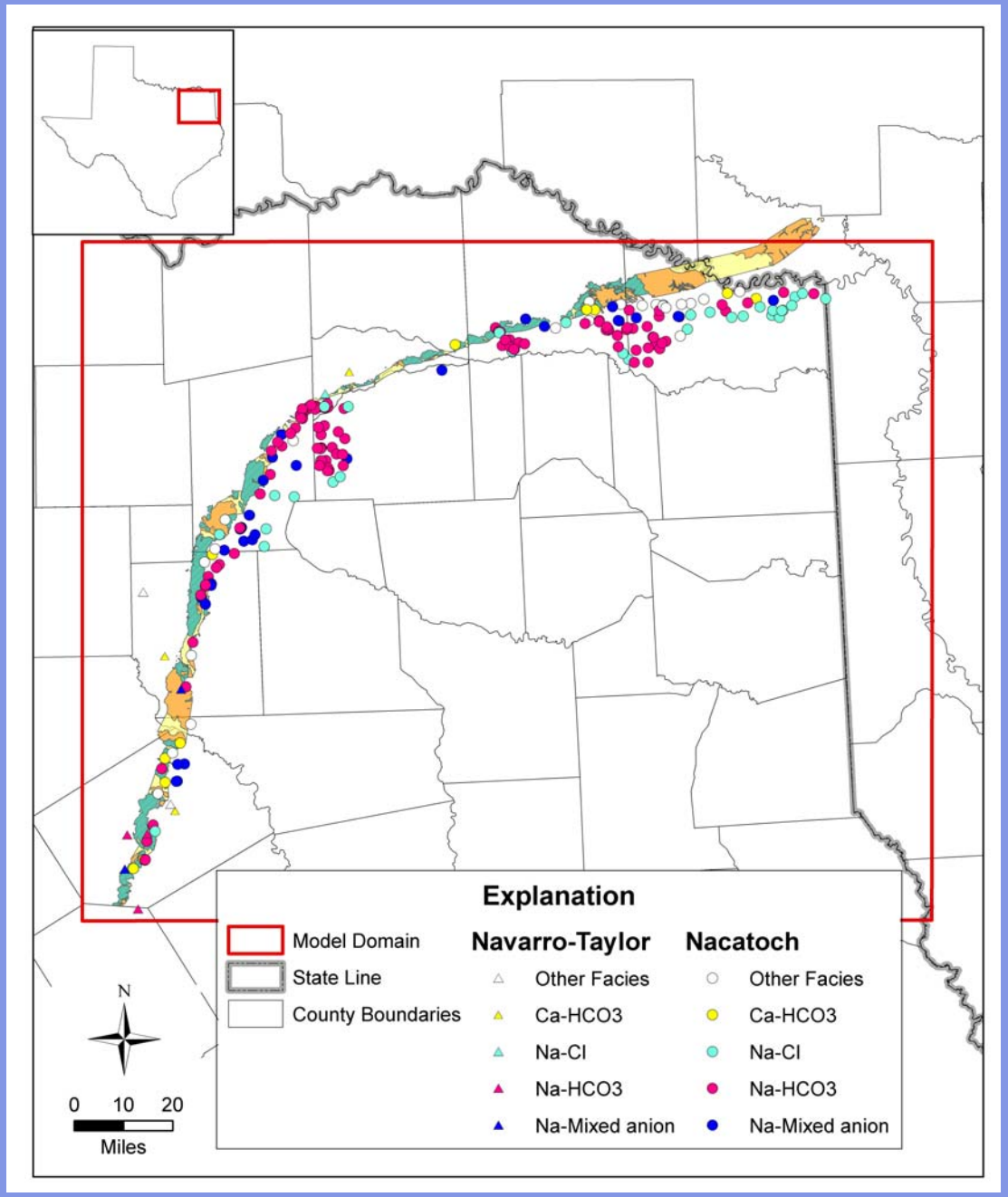
Hopkins County

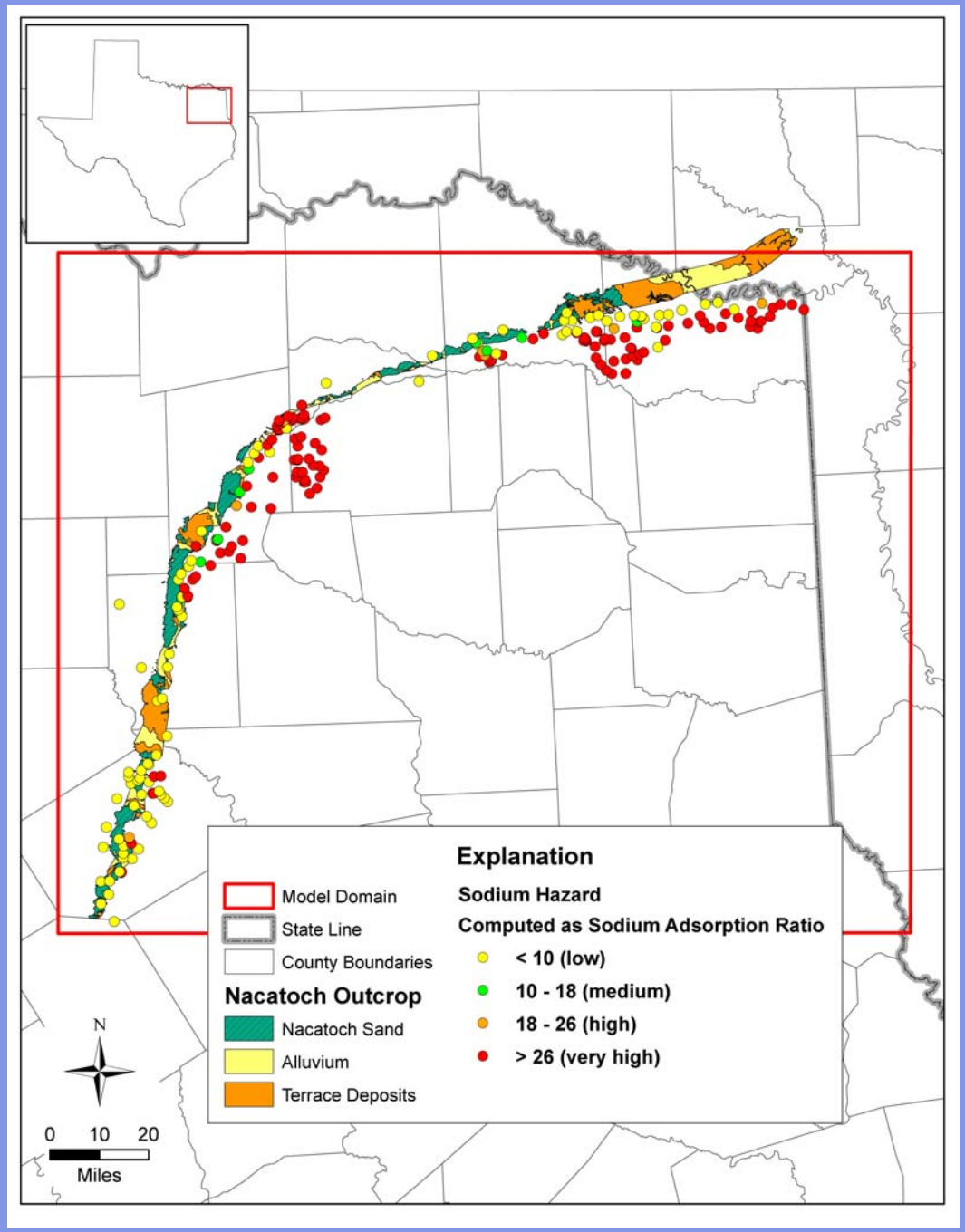


TDS in the Nacatoch Aquifer



Hydrochemical Facies





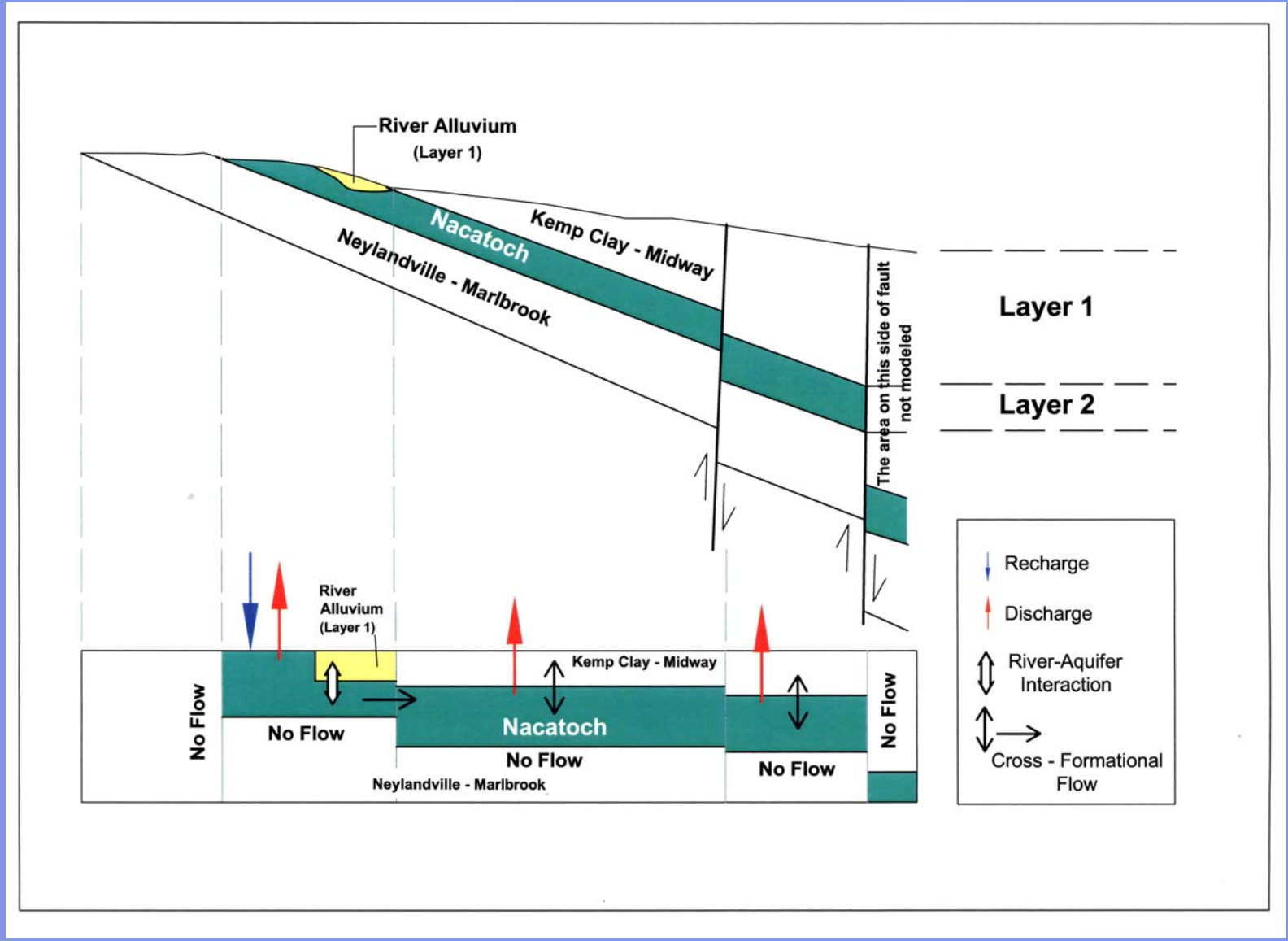
Sodium Hazard in the Nacatoch Aquifer

(Sodium Adsorption Ratio)

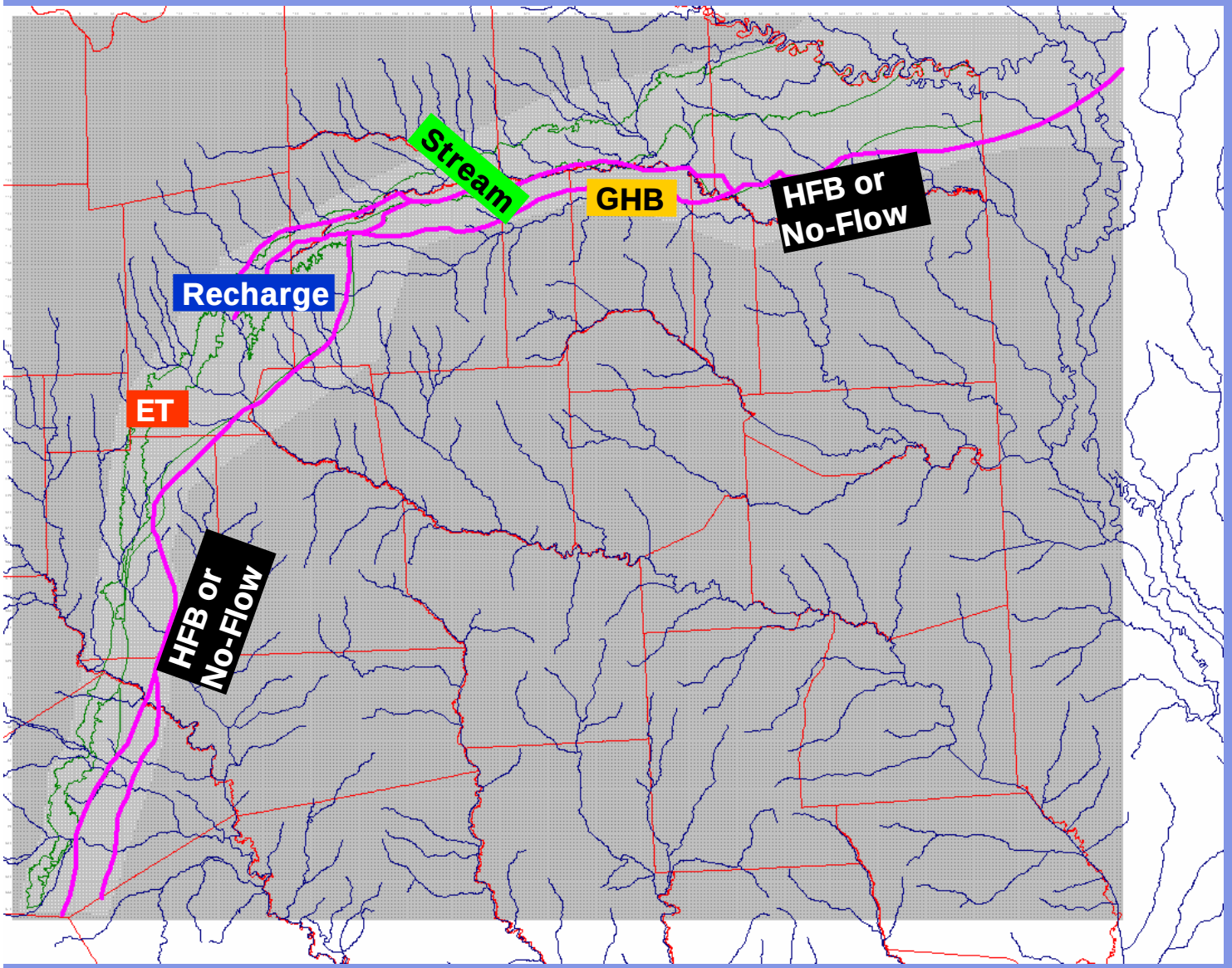
Tabulated Water Quality of Nacatoch Aquifer

Constituent	Type of Standard*	Screening Level	Units	Number of Results	Number of Results Exceeding Screening Level	Percent of Results Exceeding Screening Level	Result < Reporting Limit > MCL
Fluoride	Primary MCL[1]	4	mg/L	200	11	6%	0
Nitrate	Primary MCL[1]	10	mg/L as N	207	14	7%	0
pH	Secondary MCL[1] (lower bound)	7		211	10	5%	0
Chloride	Secondary MCL[1]	300	mg/L	215	50	23%	0
Fluoride	Secondary MCL[1]	2	mg/L	200	39	20%	0
Sulfate	Secondary MCL[1]	300	mg/L	215	20	9%	0
TDS	Secondary MCL[1]	1000	mg/L	208	62	30%	0
SAR	Irrig. Sodium Hazard - Medium[2]	10		209	150	72%	0
SAR	Irrig. Sodium Hazard - High[2]	18		209	140	67%	0
SAR	Irrig. Sodium Hazard - Very High[2]	26		209	131	63%	0
Specific Conductance	Irrig. Salinity Hazard - High[2]	750	µmhos/cm	203	175	86%	0
Specific Conductance	Irrig. Salinity Hazard - Very High[2]	2250	µmhos/cm	203	39	19%	0
Chloride	Irrig. Hazard[3]	1000	mg/L	215	4	2%	0
1. 30 TAC Chapter 290 Subchapter F							
2. United States Salinity Laboratory (1954)							
3. Tanji (1990)							

Layer Model Schematic



Model Grid
¼ - mile



540 rows
670 cols
2 layers
~130,000 active