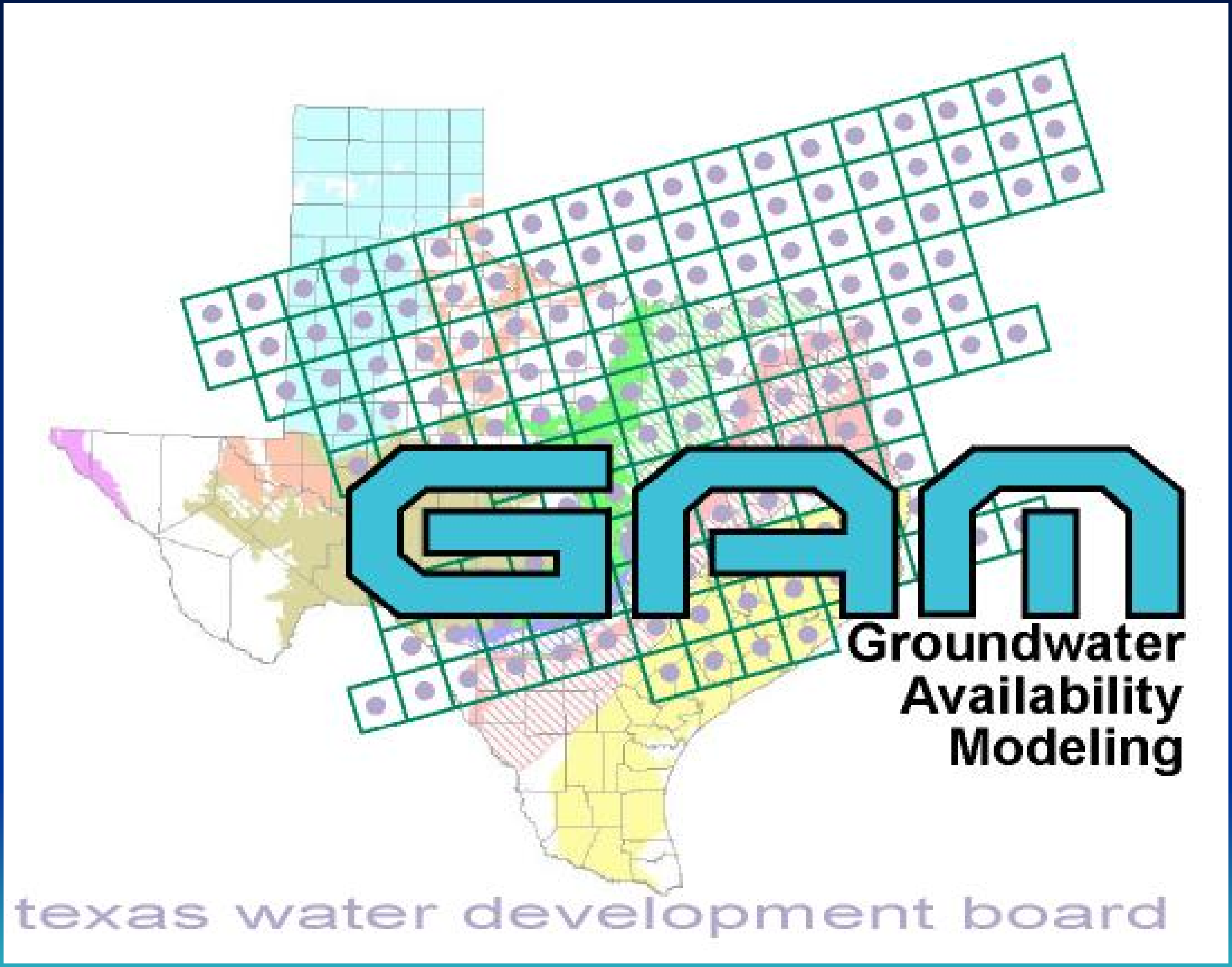
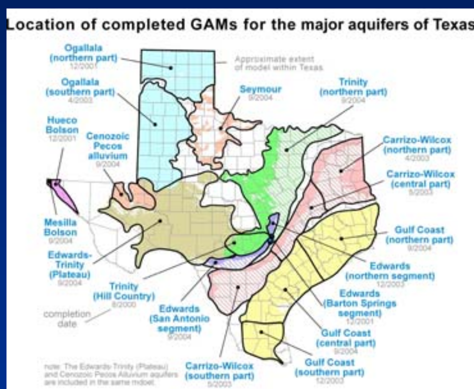
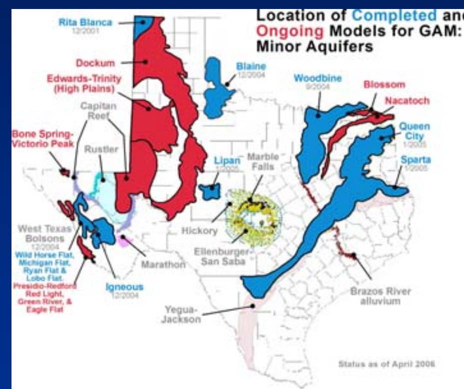
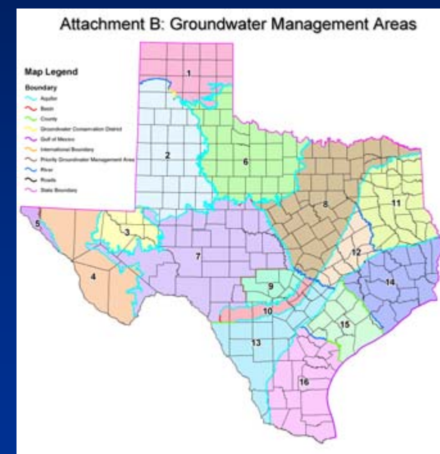
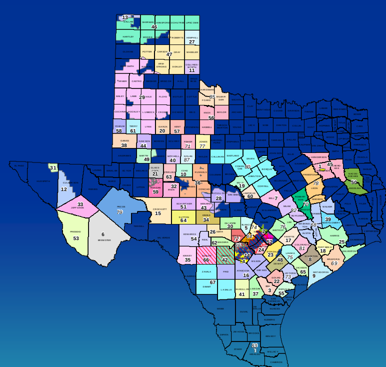

GAM
Groundwater
Availability
Modeling
texas water development board

Groundwater Availability Modeling





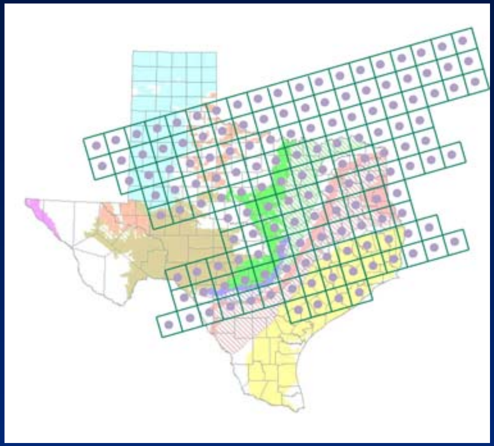




Contract Manager

Ted Angle

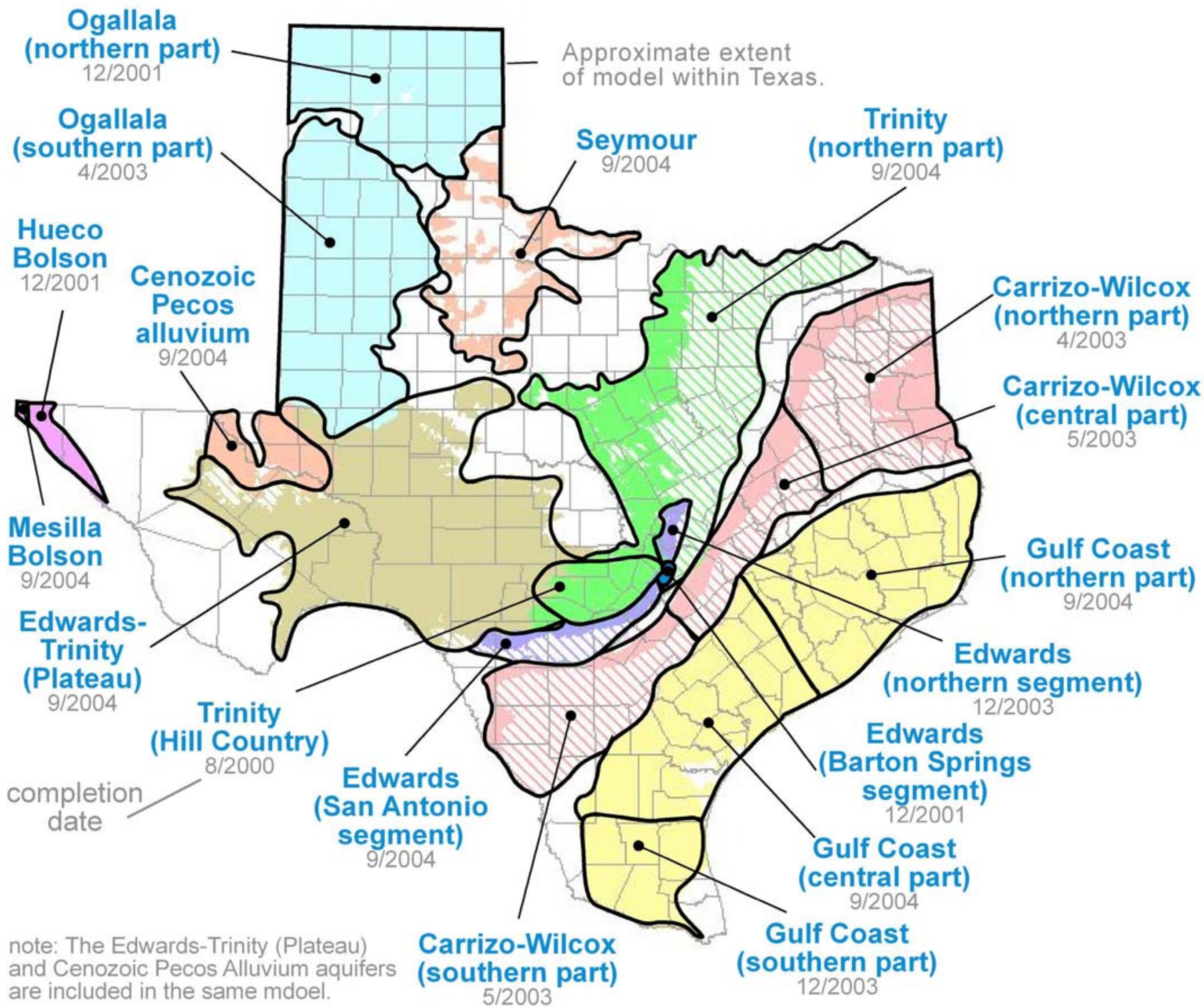
Texas Water Development Board

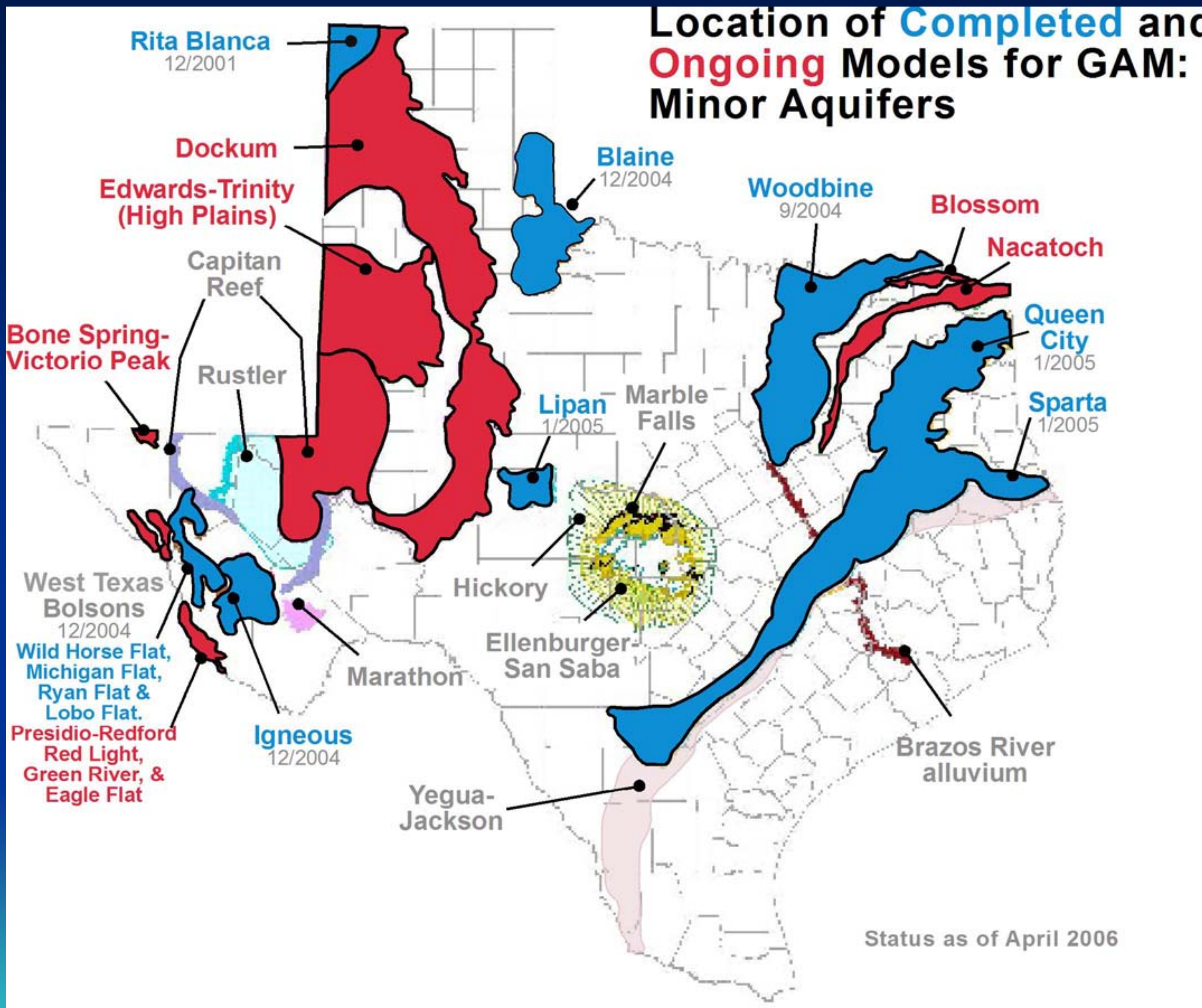


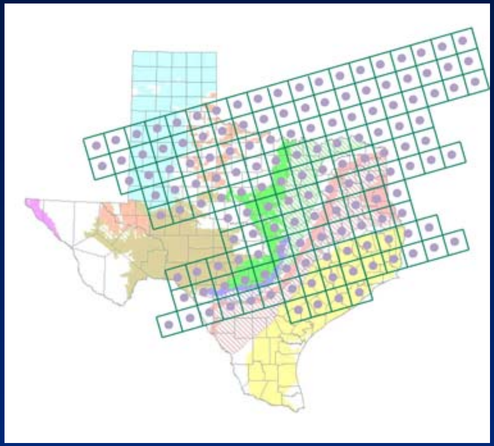
GAM

- 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

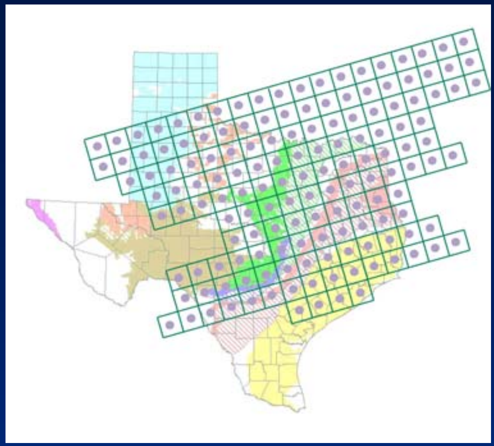



Location of Completed and Ongoing Models for GAM: Minor Aquifers
Rita Blanca
12/2001
Dockum
Edwards-Trinity (High Plains)
Capitan Reef
Bone Spring-Victorio Peak
Rustler
Blaine
12/2004
Woodbine
9/2004
Blossom
Nacatoch
Queen City
1/2005
Sparta
1/2005
Lipan
1/2005
Marble Falls
Hickory
Ellenburger-San Saba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



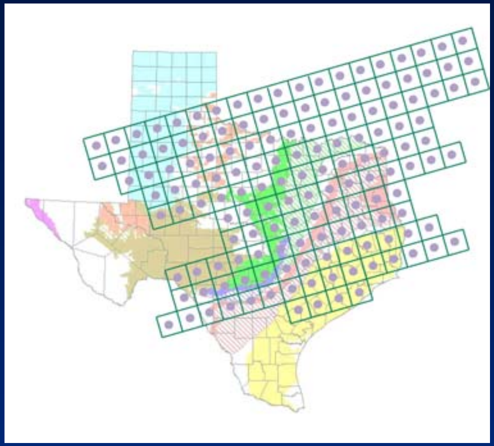
What is groundwater availability or MAG?

- 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.



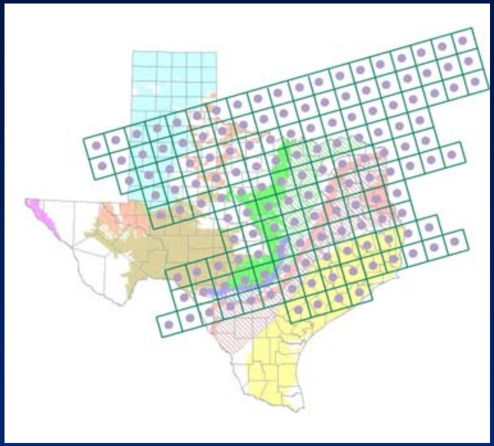
Do we have to use GAM?

- 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



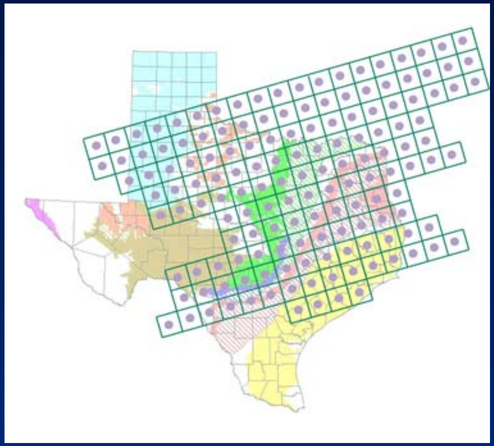
How do we use GAM?

- 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
  - Ted Angle

Comments:

Ted Angle
ted.angle@twdb.state.tx.us
(512) 463-3879
www.twdb.state.tx.us/gam

2nd Stakeholder Advisory Forum for West Texas Bolson GAM

May 29, 2007

LBG-GUYTON ASSOCIATES

in association with

Eddie Collins, Bureau of Economic Geology

Barry Hibbs, California State University, LA

John Shomaker & Associates, Inc.

Daniel B. Stephens & Associates, Inc.

Kevin Urbanczyk, Sul Ross State University

General Location Map

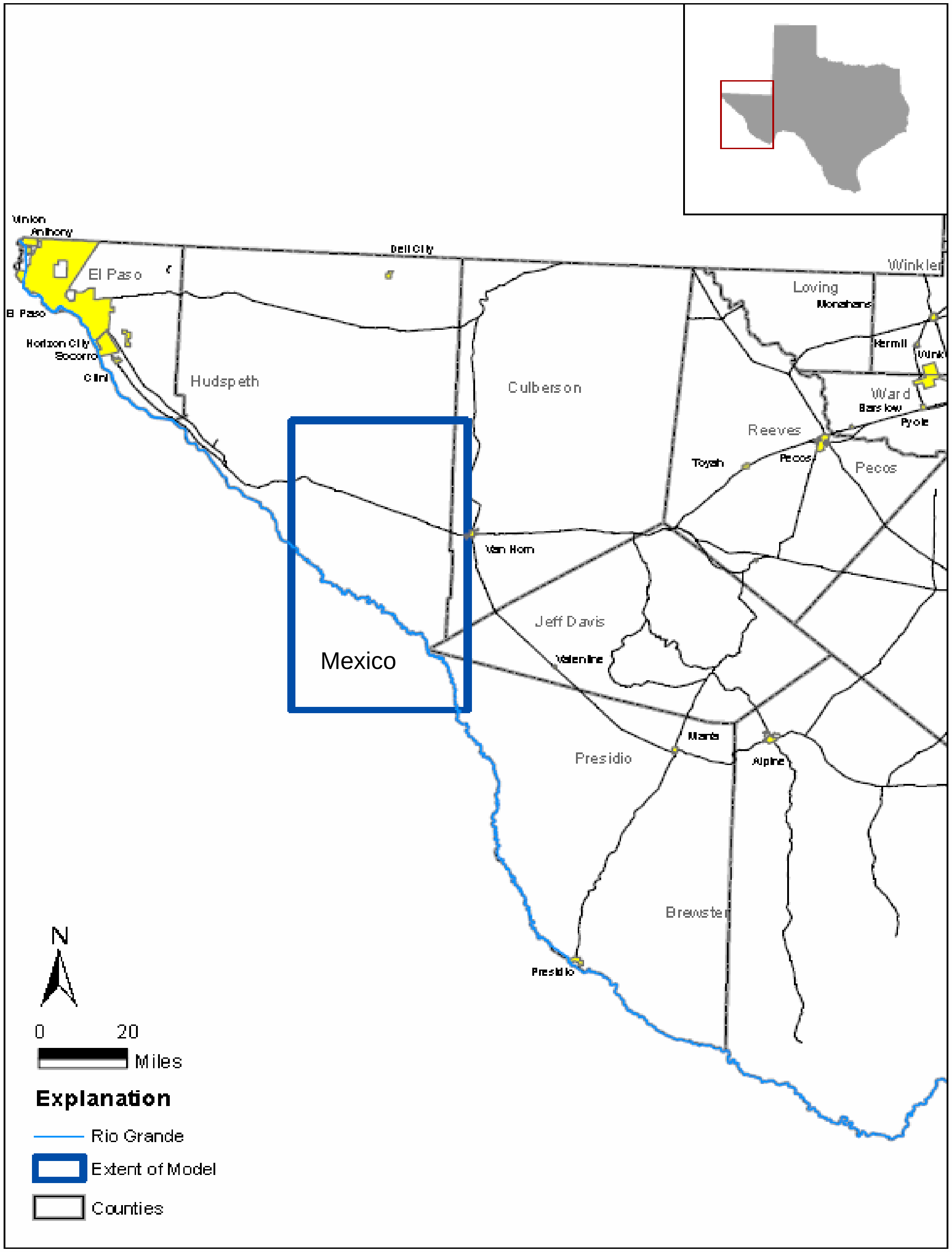


Figure 2.1.1 - Location of the Study Area

Location of the West Texas Bolsons Aquifer

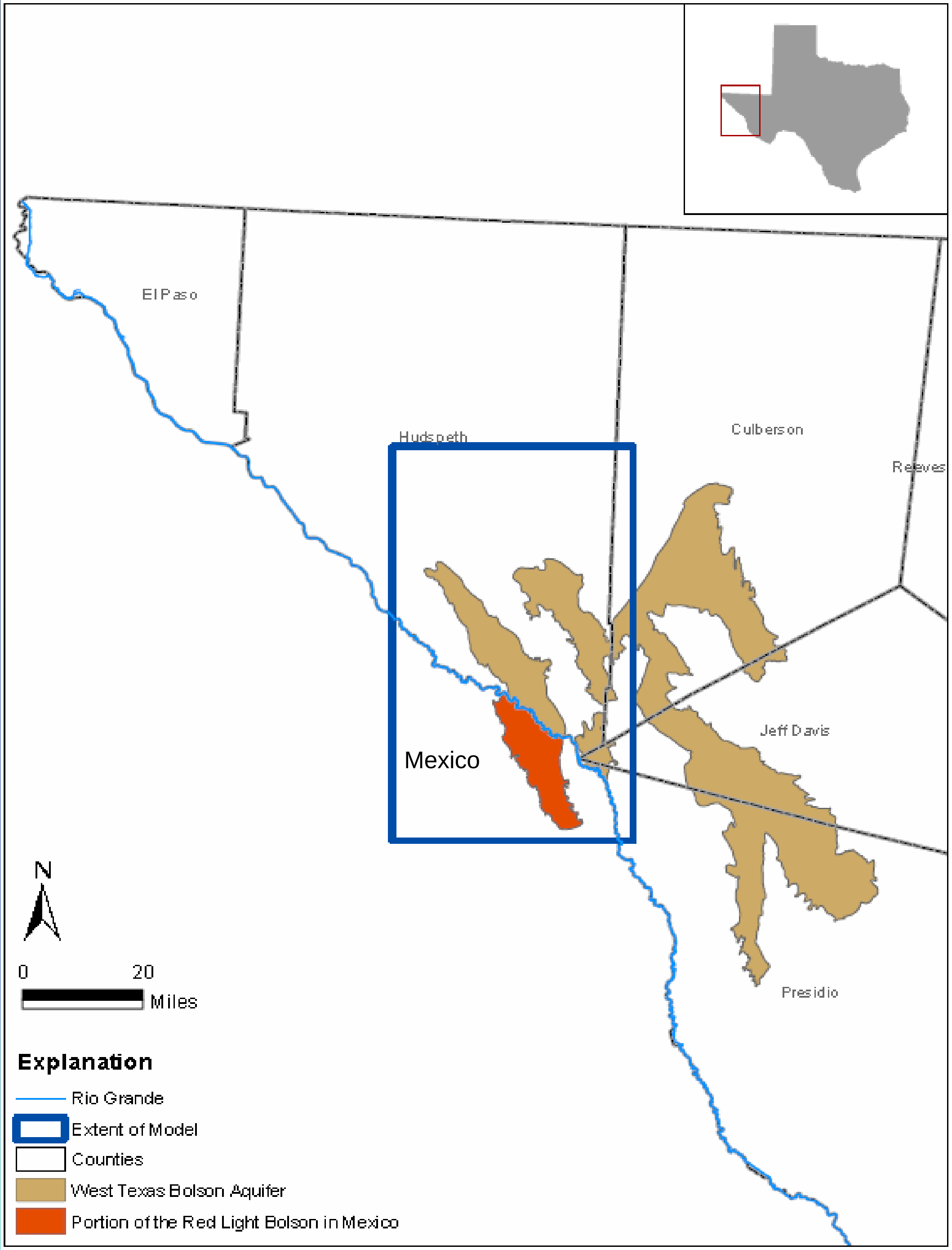


Figure 2.1.2 - Location of the West Texas Bolson Aquifer

Location of the West Texas Bolsons Aquifer

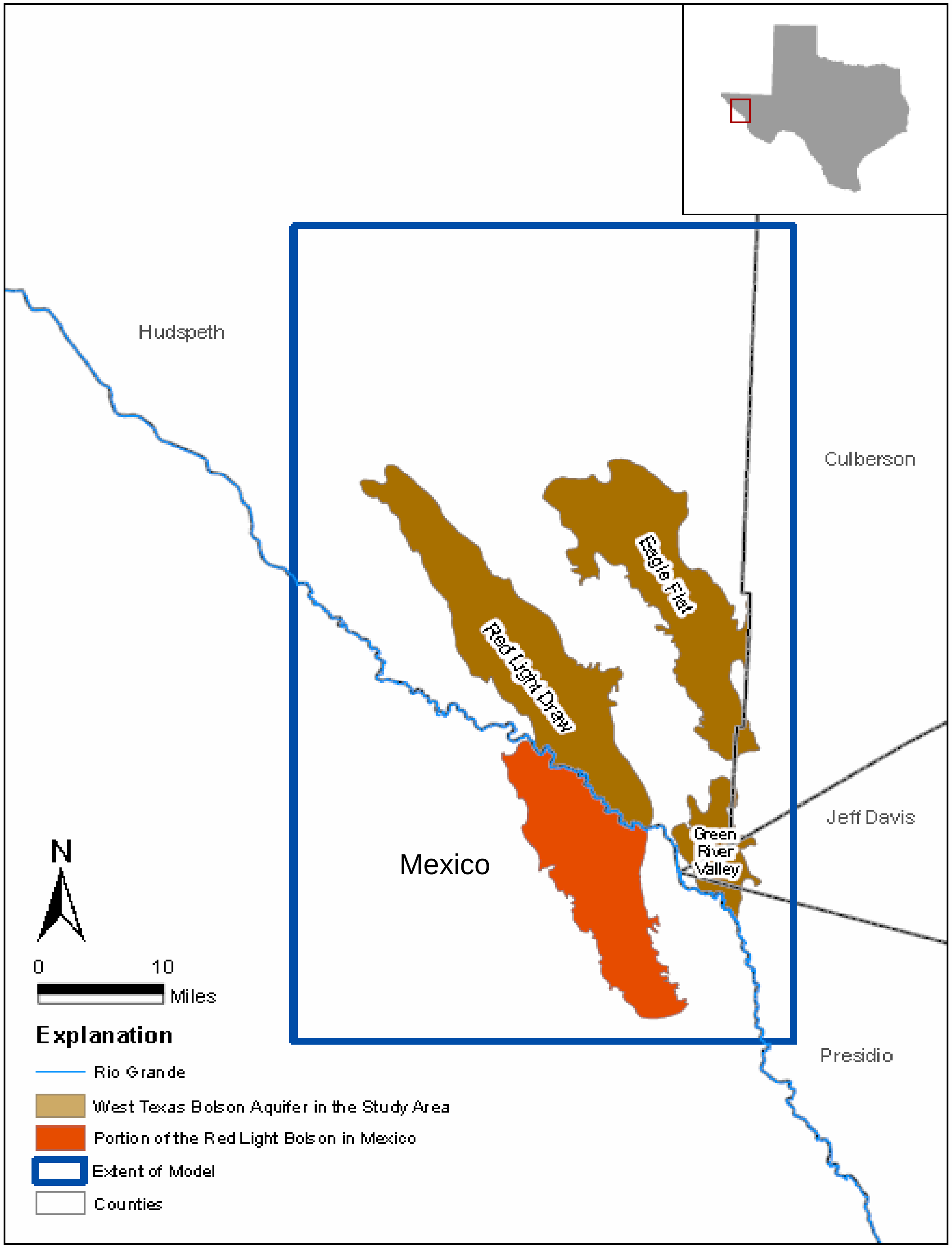


Figure 2.1.3 - Location of the West Texas Bolson Aquifer

Regional Water Planning Groups

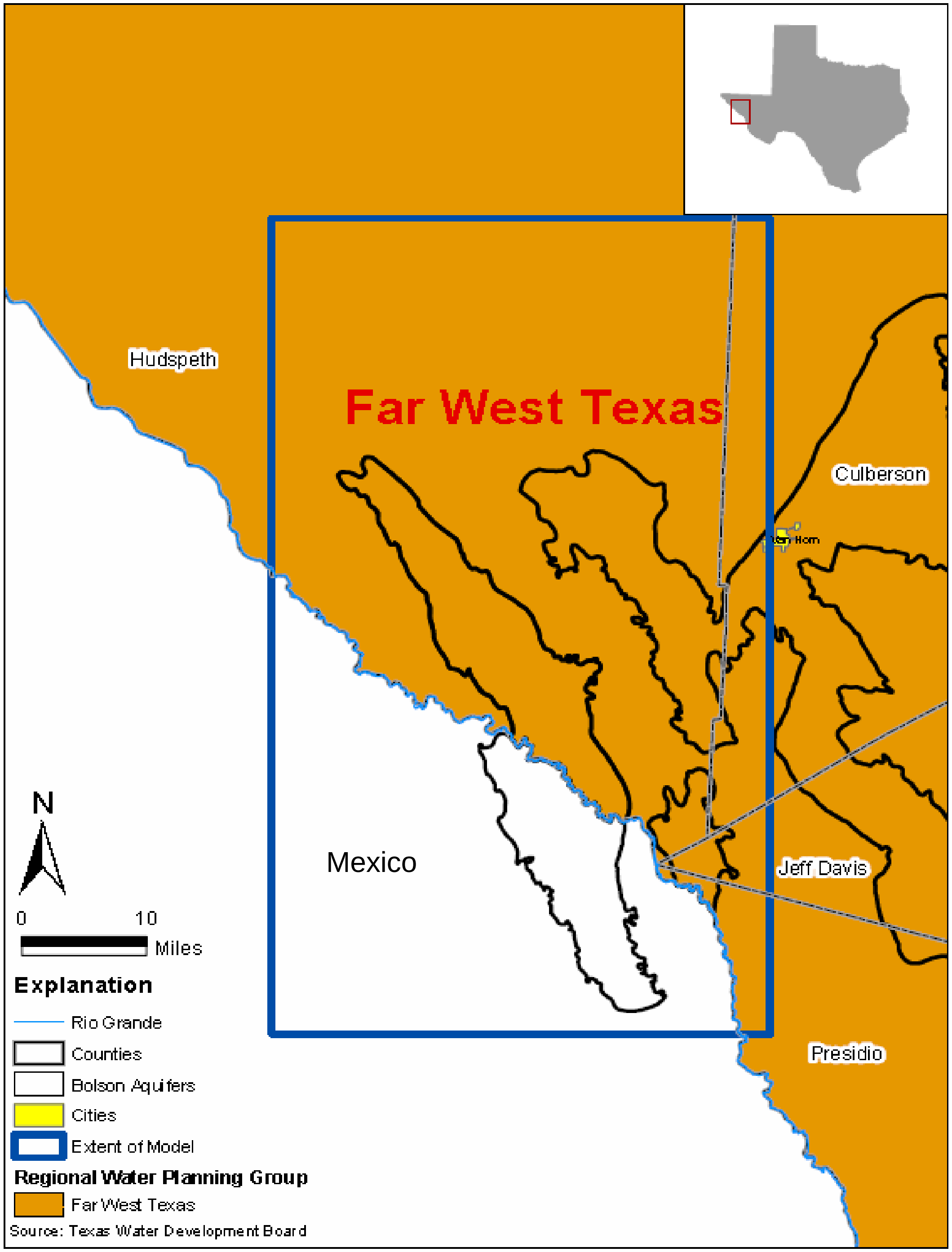


Figure 2.1.4 - Regional Water Planning Groups

Groundwater Conservation Districts

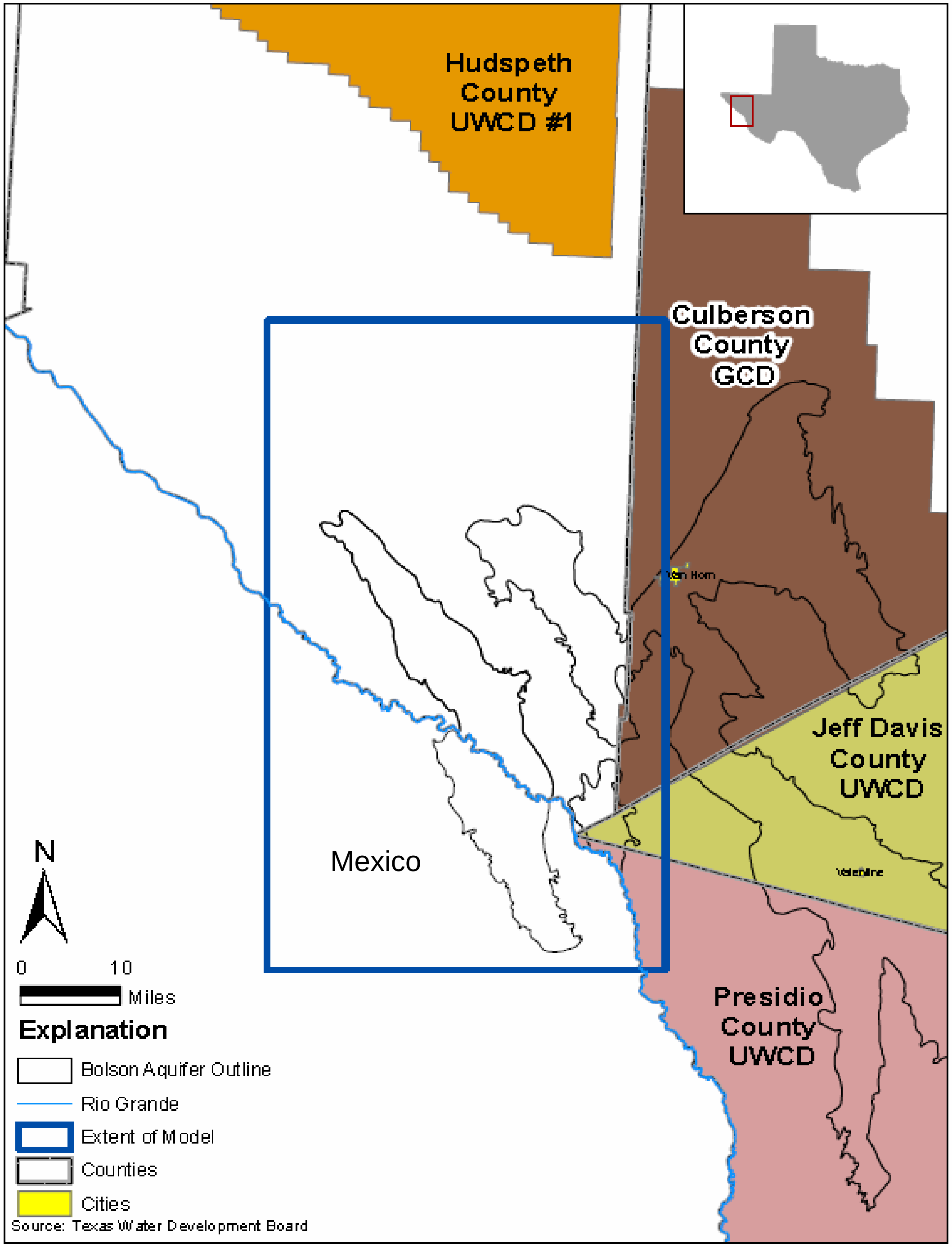


Figure 2.1.5 - Groundwater Conservation Districts

Groundwater Management Areas

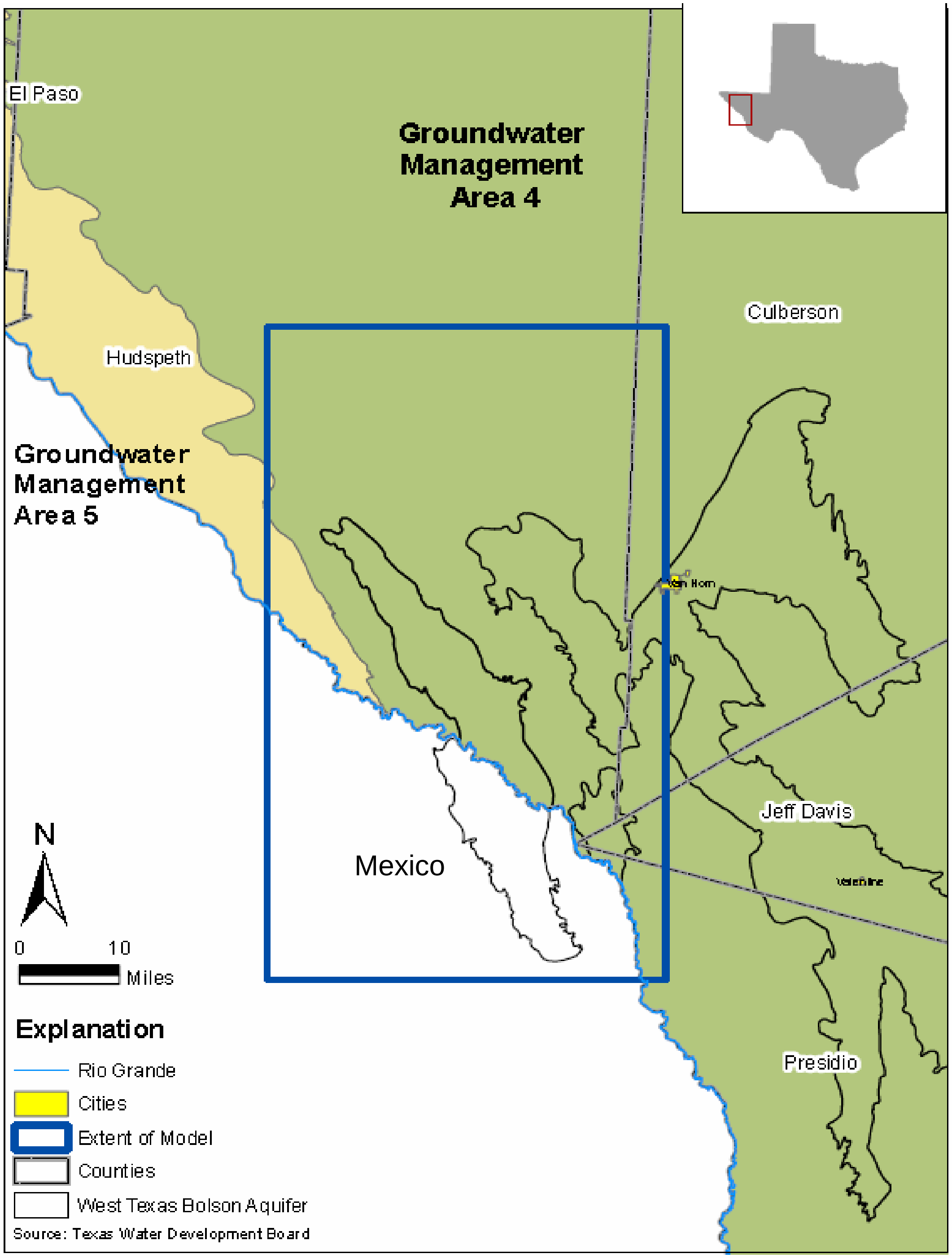


Figure 2.1.6 - Groundwater Management Areas

Topography

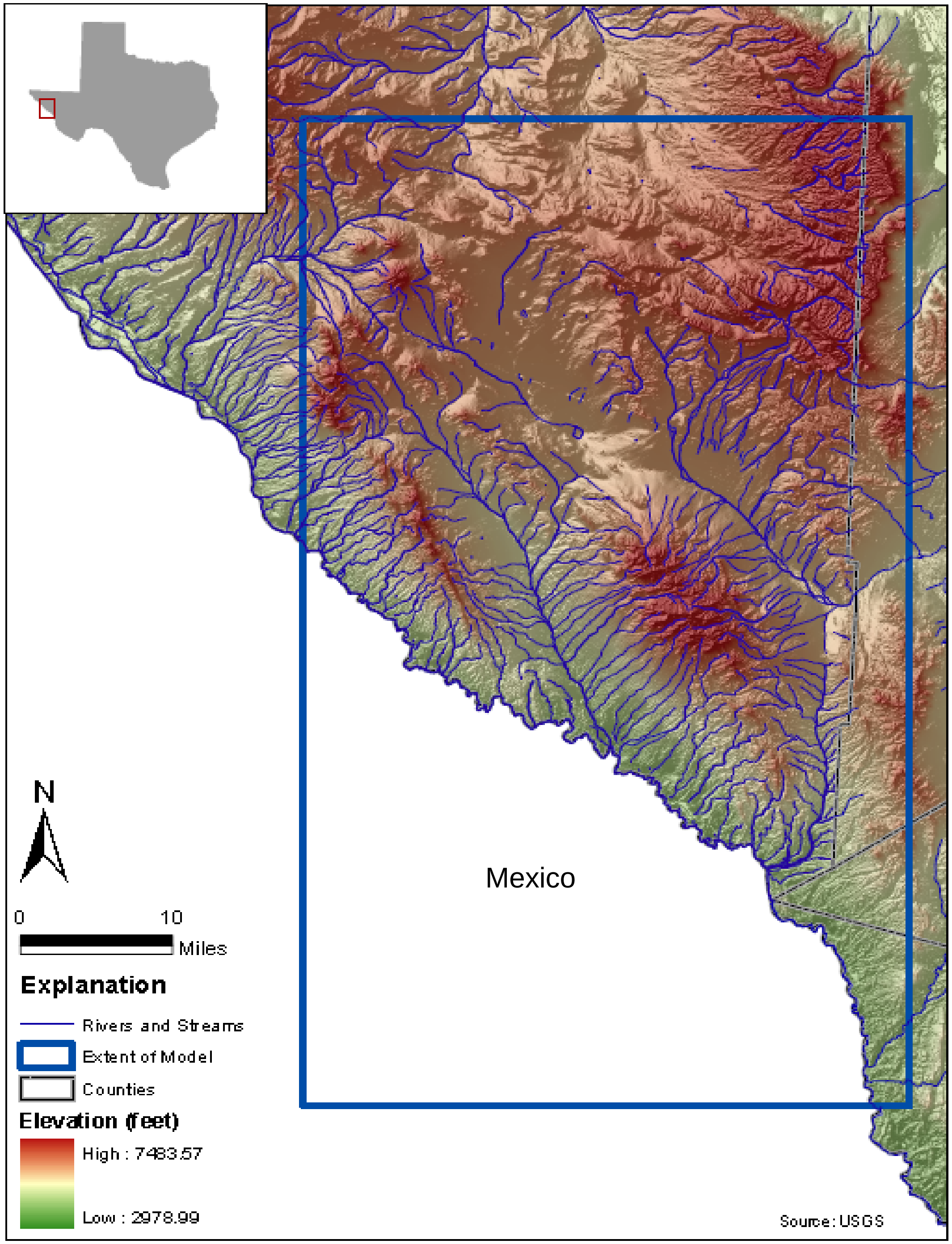


Figure 2.2.2 - Topography

Physiographic Provinces

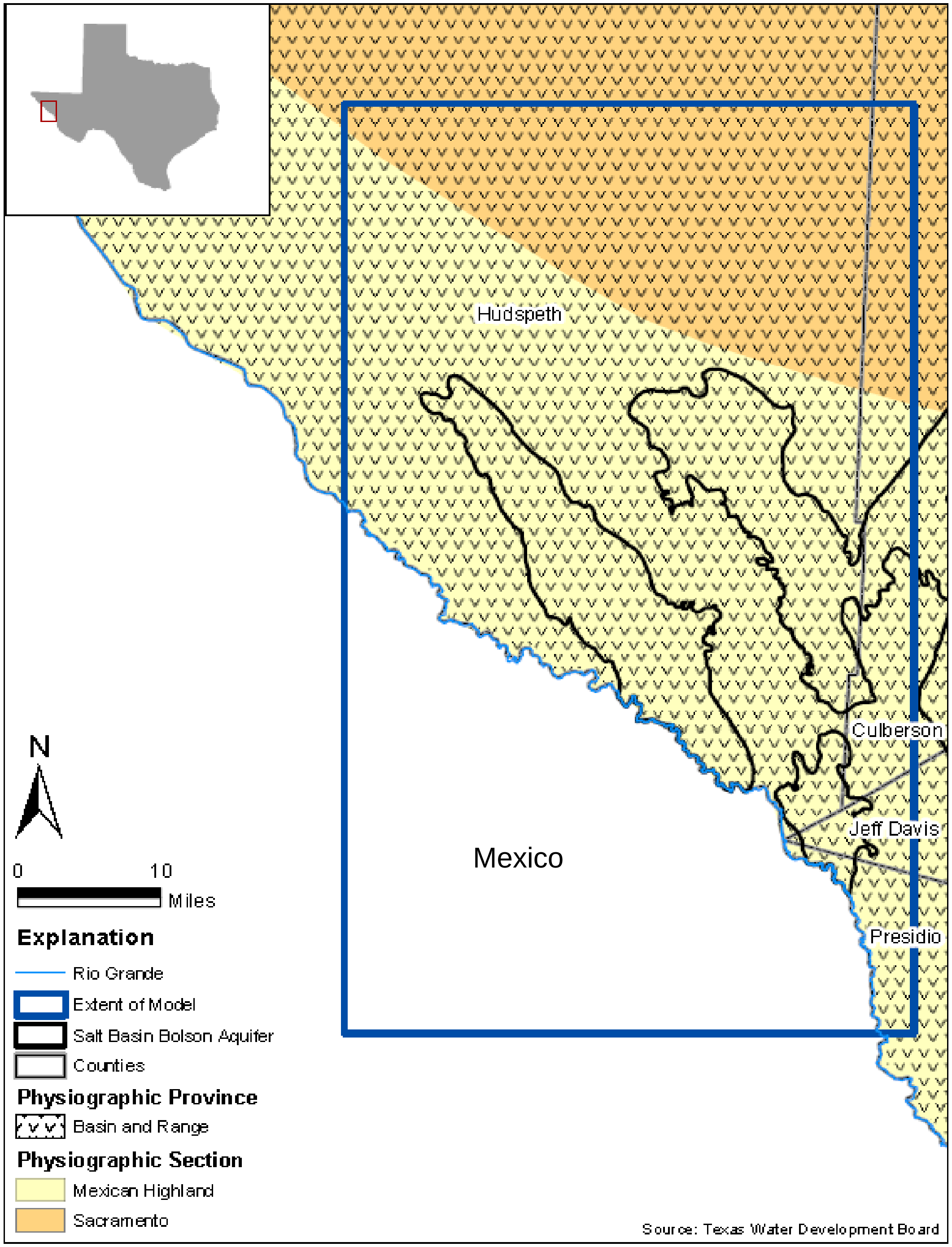


Figure 2.2.1 - Physiographic Provinces and Sections

Land Use Land Cover

(USGS)

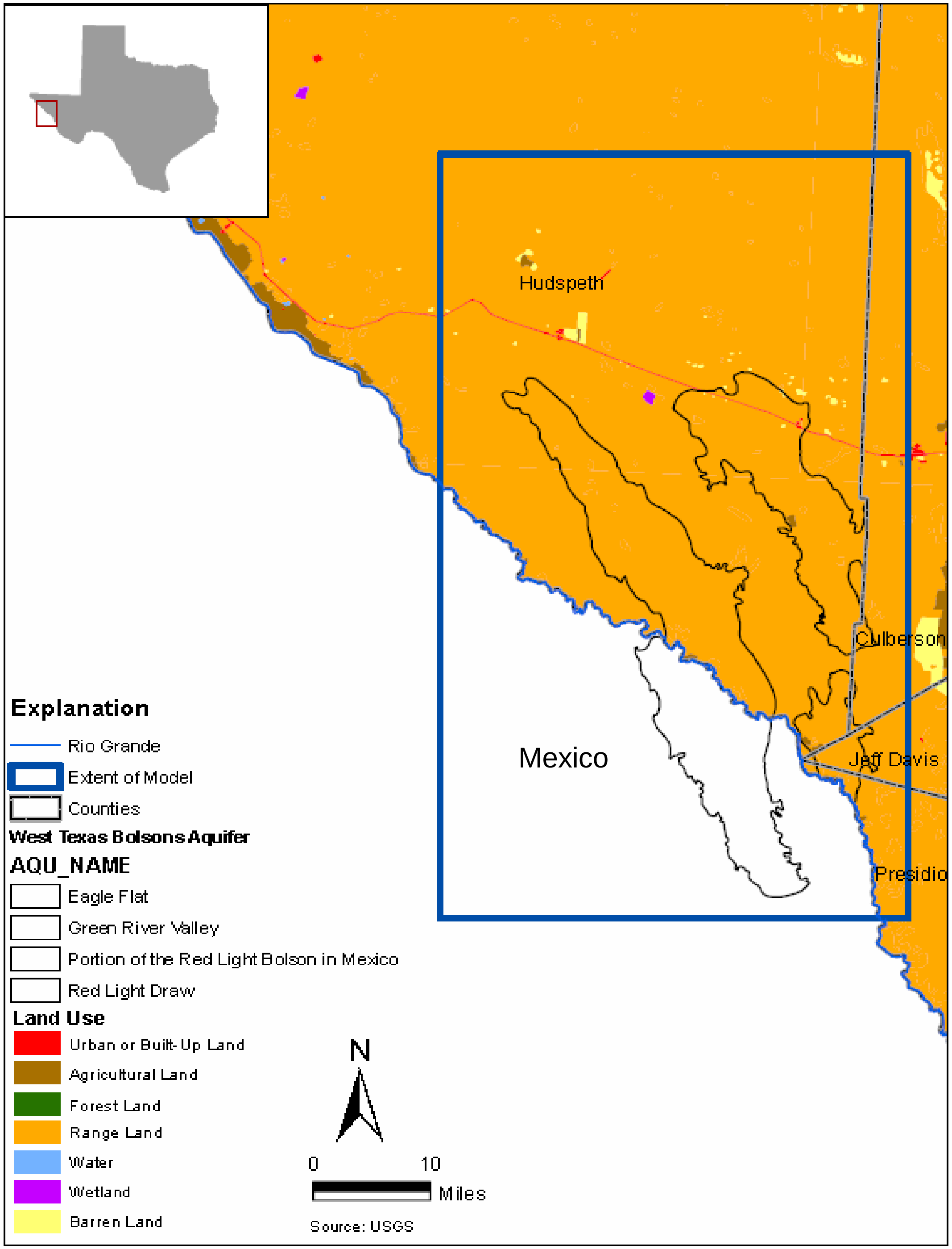


Figure 2.4.2 - Land Use

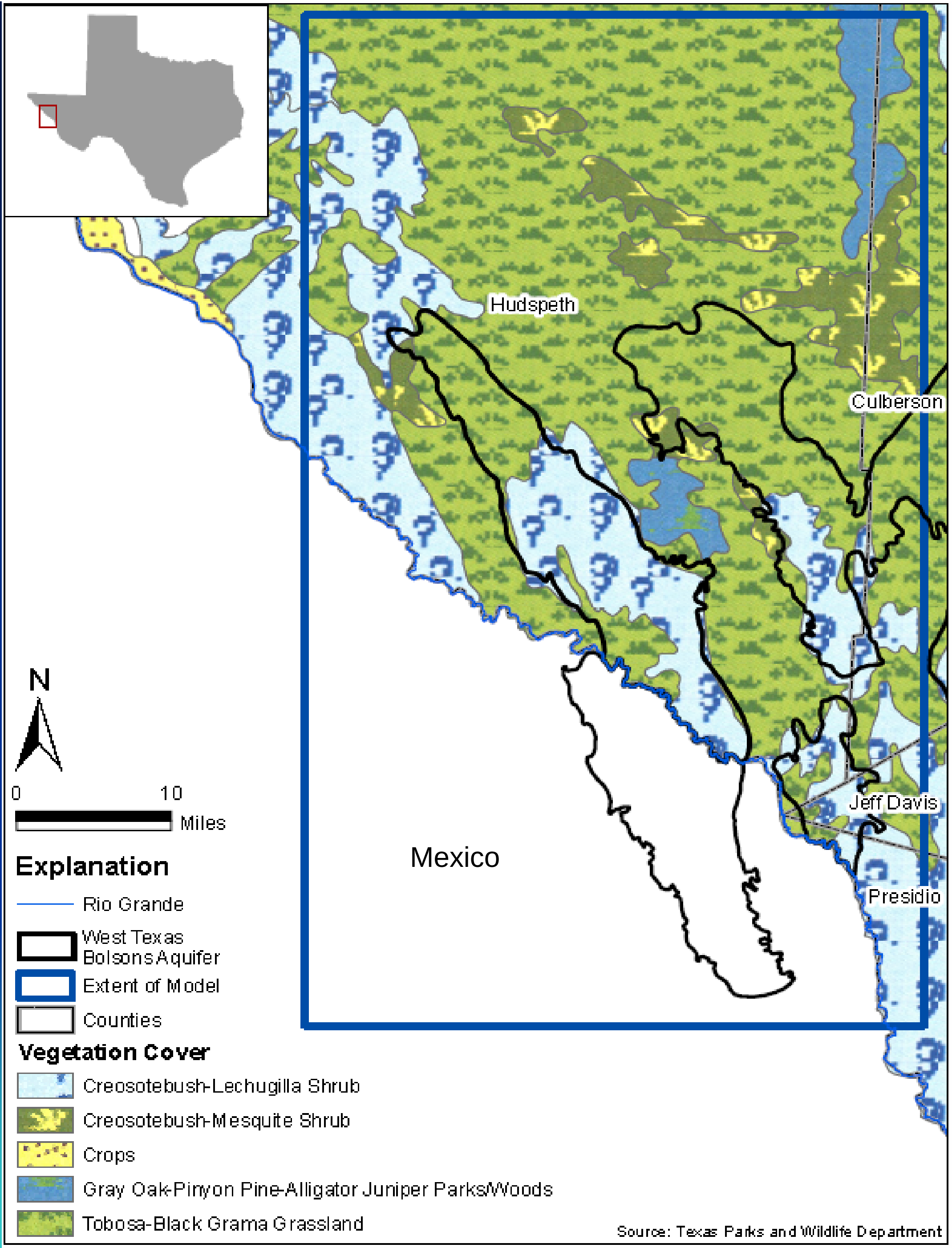


Figure 2.4.1 - Distribution of Vegetation

Vegetation

(Texas Parks & Wildlife)

GAP?

Weather Stations With Historical Precipitation

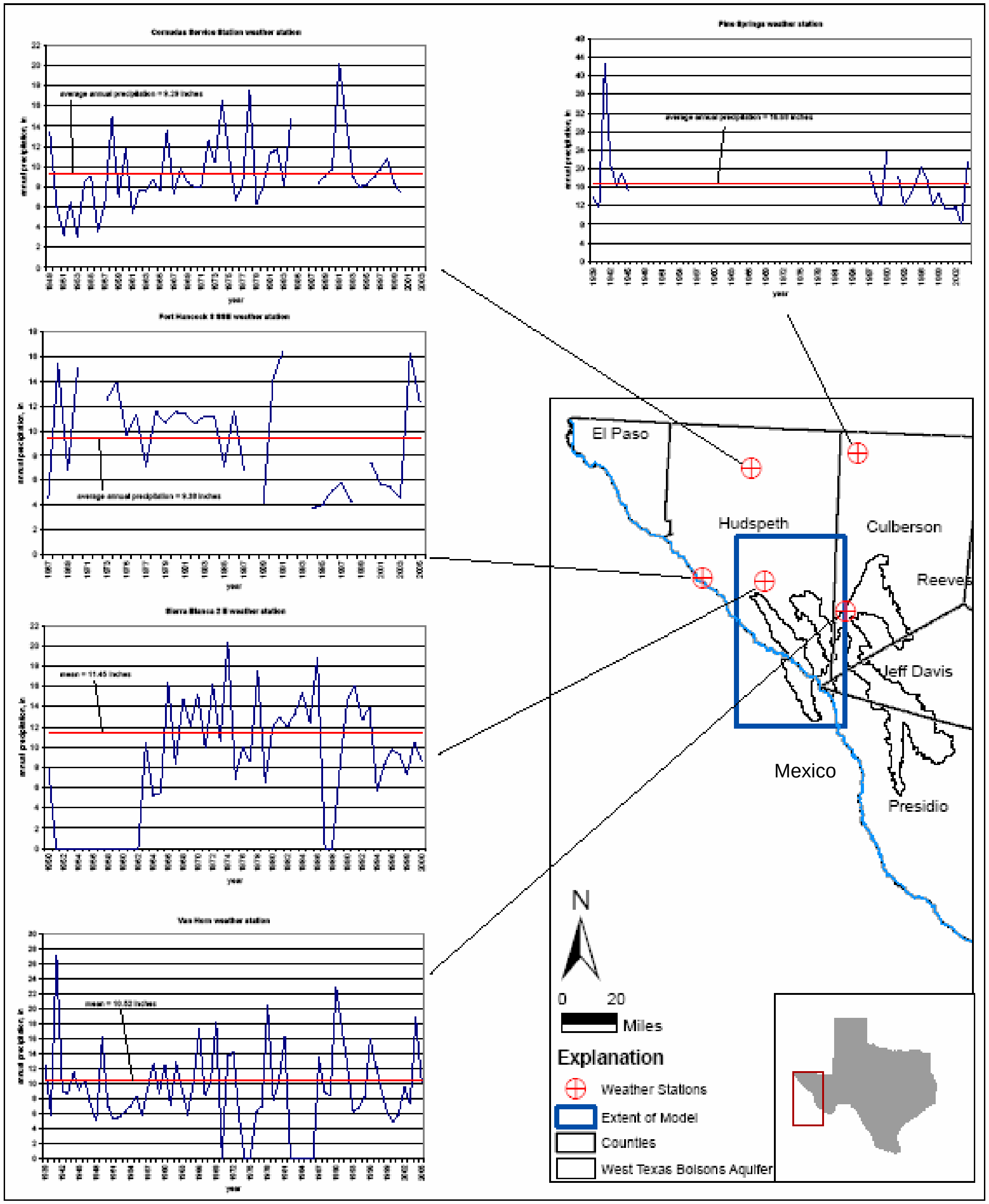


Figure 2.3.3 - Selected Weather Stations with Historic Precipitation Data

Precipitation
(inches/year)

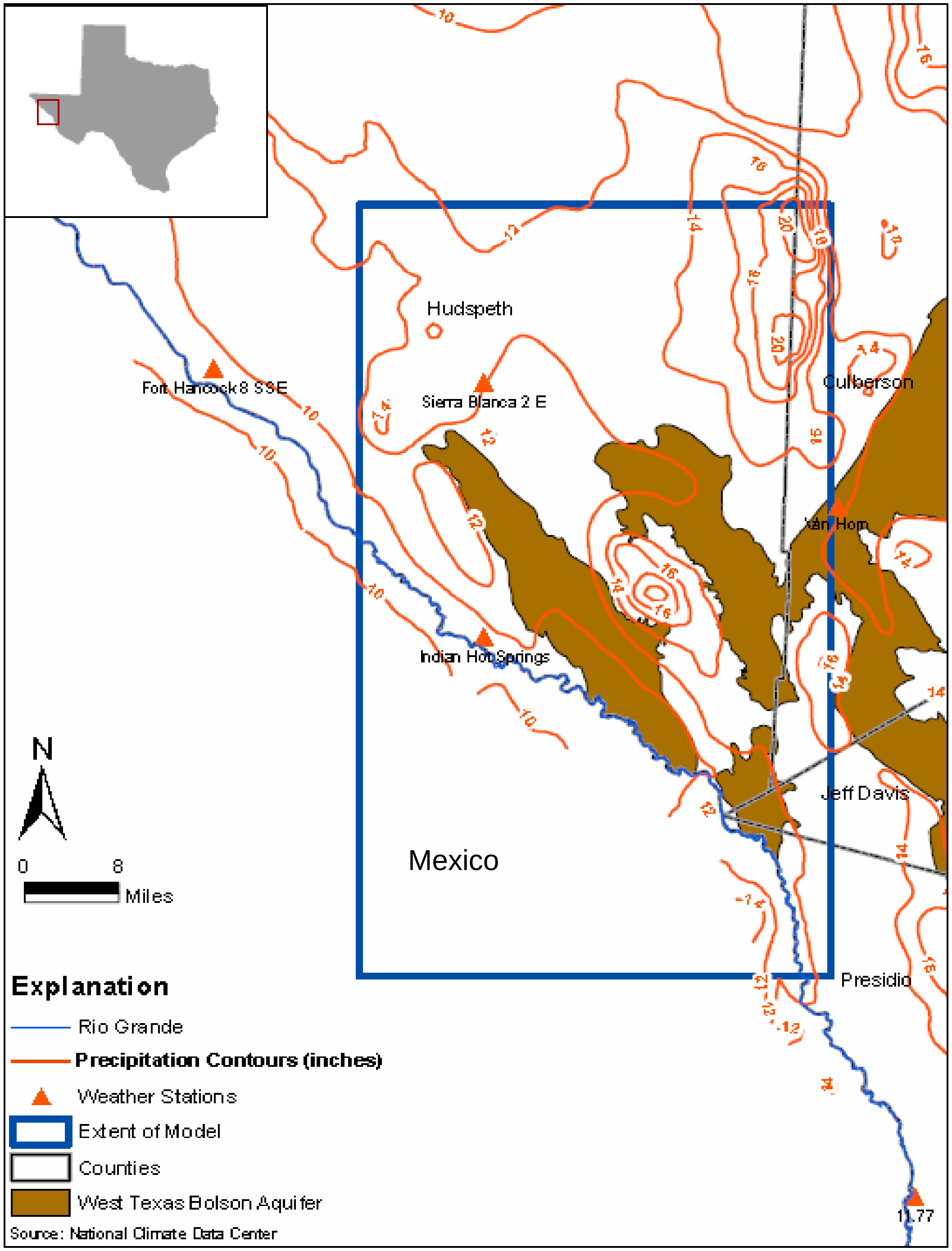


Figure 2.3.1 - Mean Annual Precipitation

Evaporation
(inches/year)

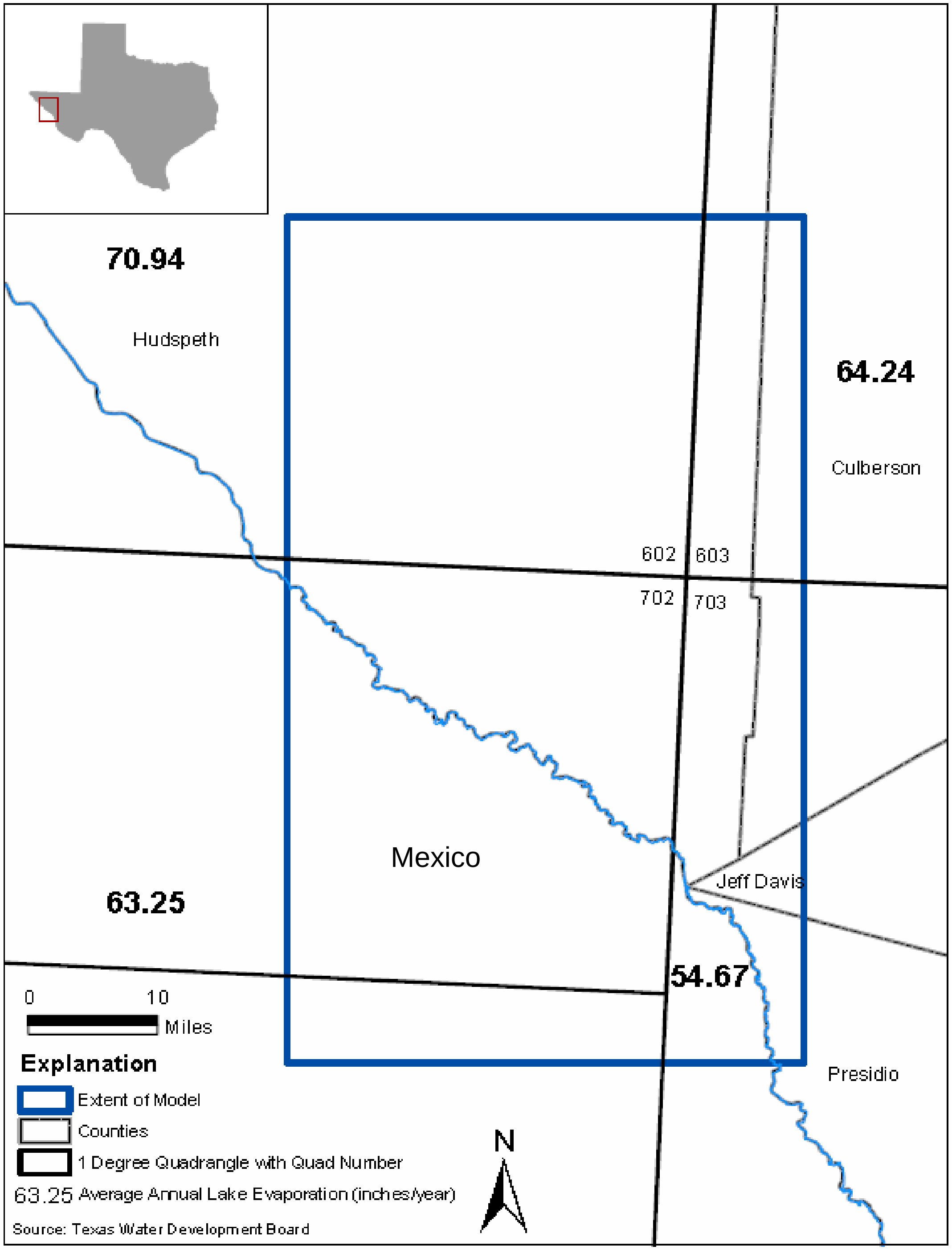
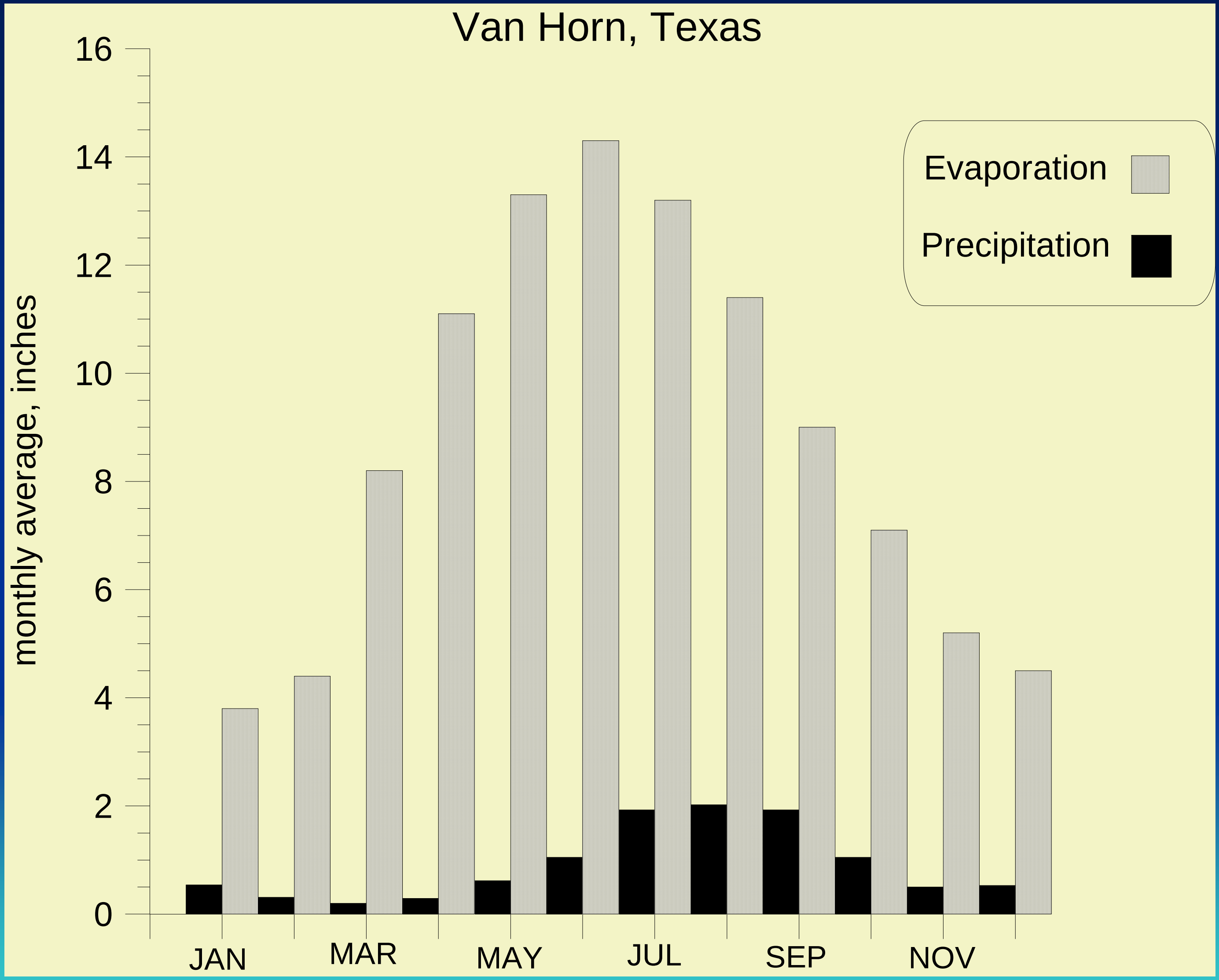


Figure 2.3.2 - Average Annual Lake Evaporation

EVAPORATION EXCEEDS PRECIPITATION INDICATING RECHARGE OCCURS FROM INFILTRATION OF STORM RUNOFF



Geology

Surface Geology

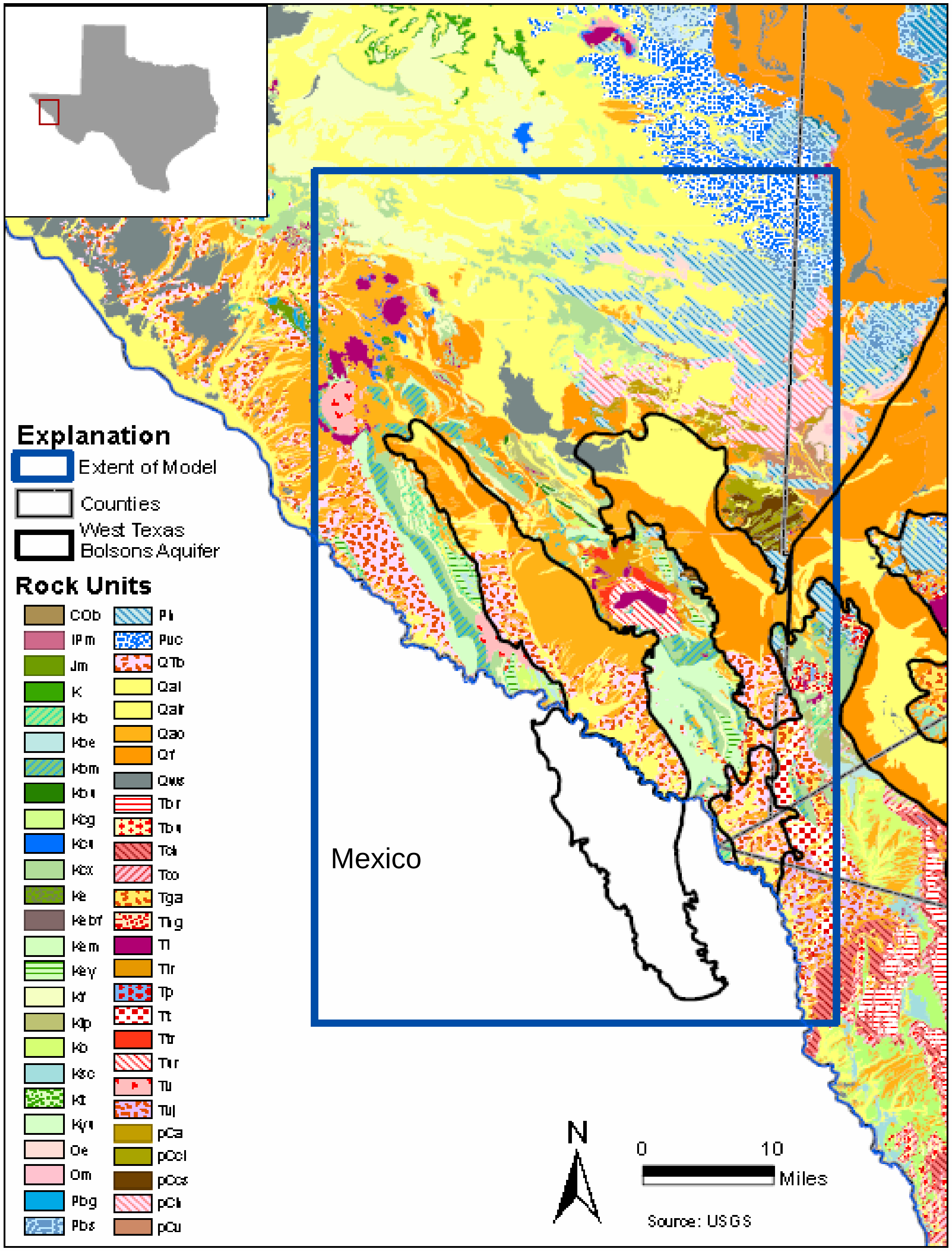


Figure 2.5.1 - Surface Geology

Surface Geology

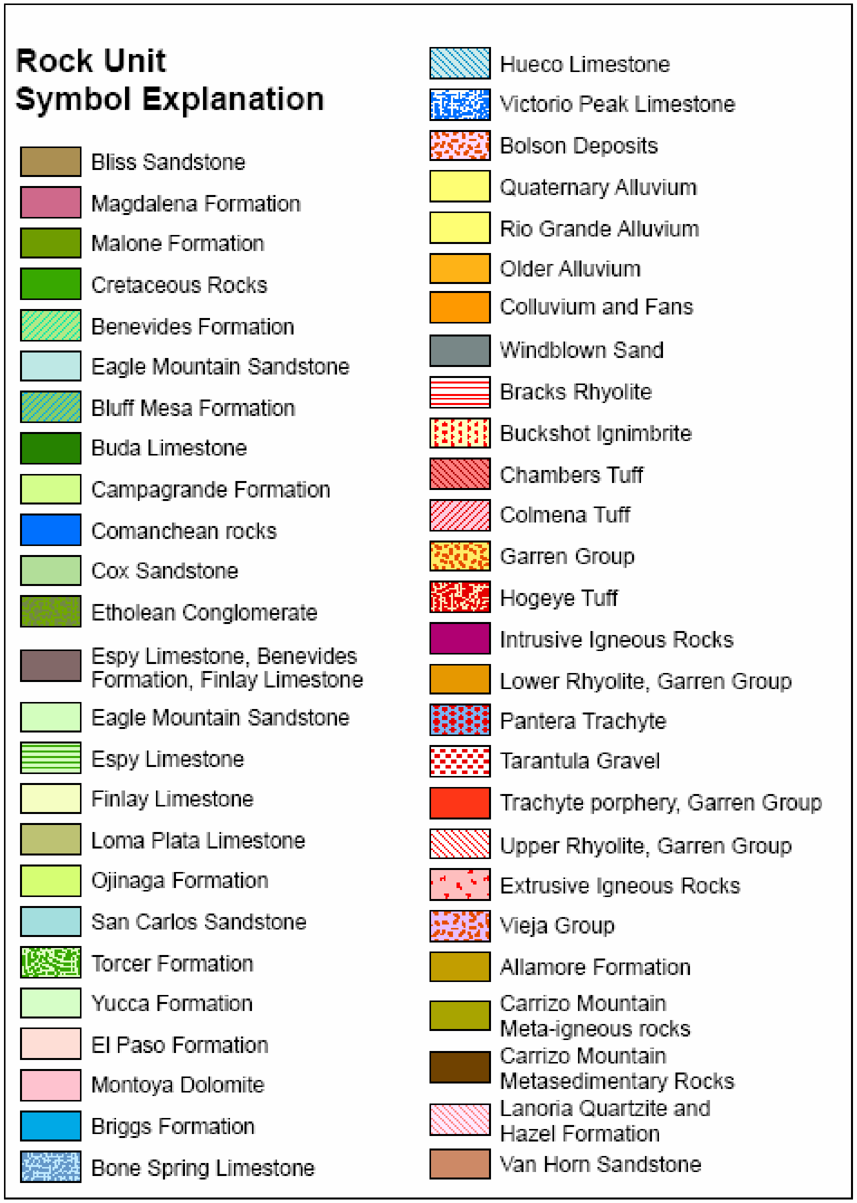


Figure 2.5.1 - Surface Geology Continued

Cross-sections

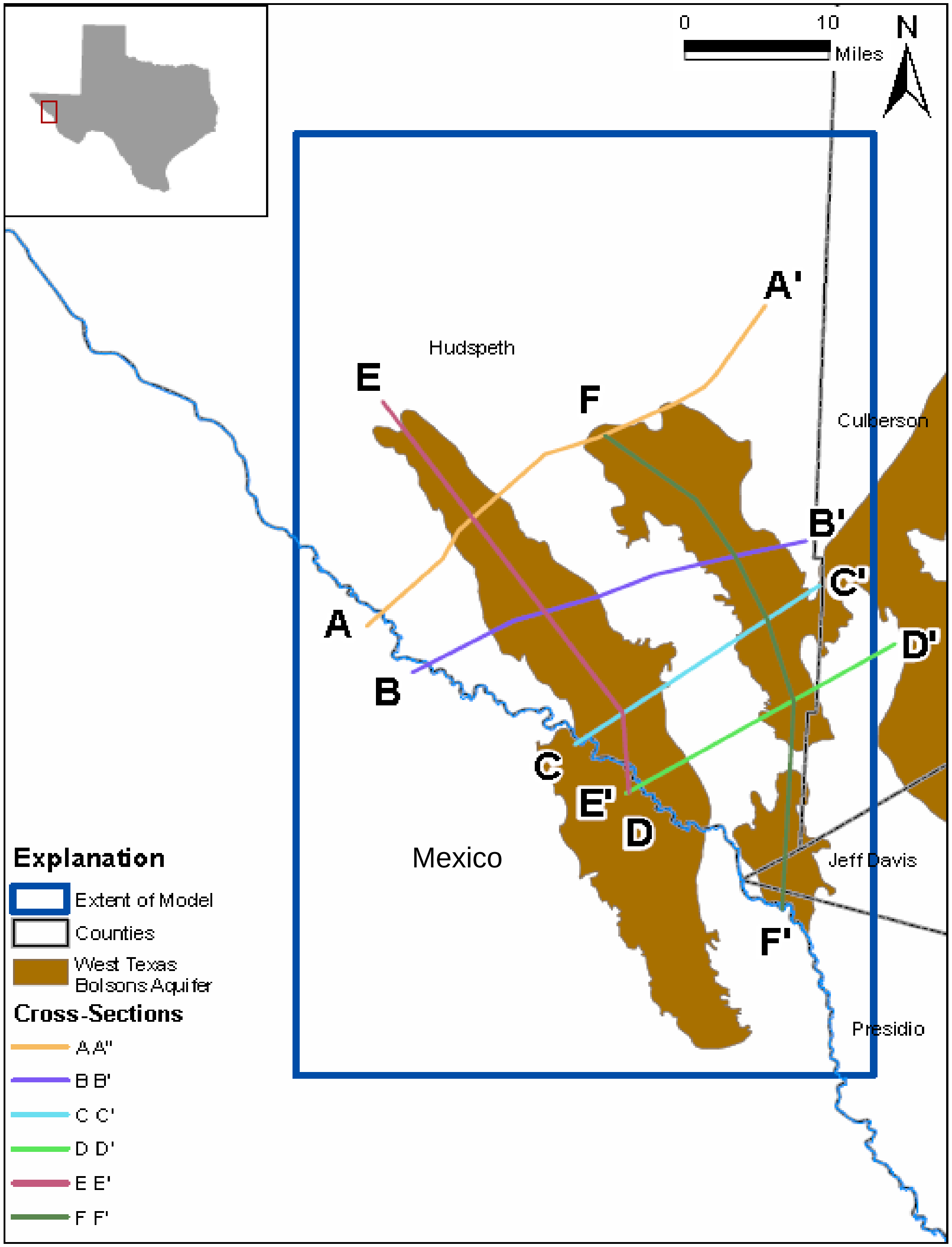
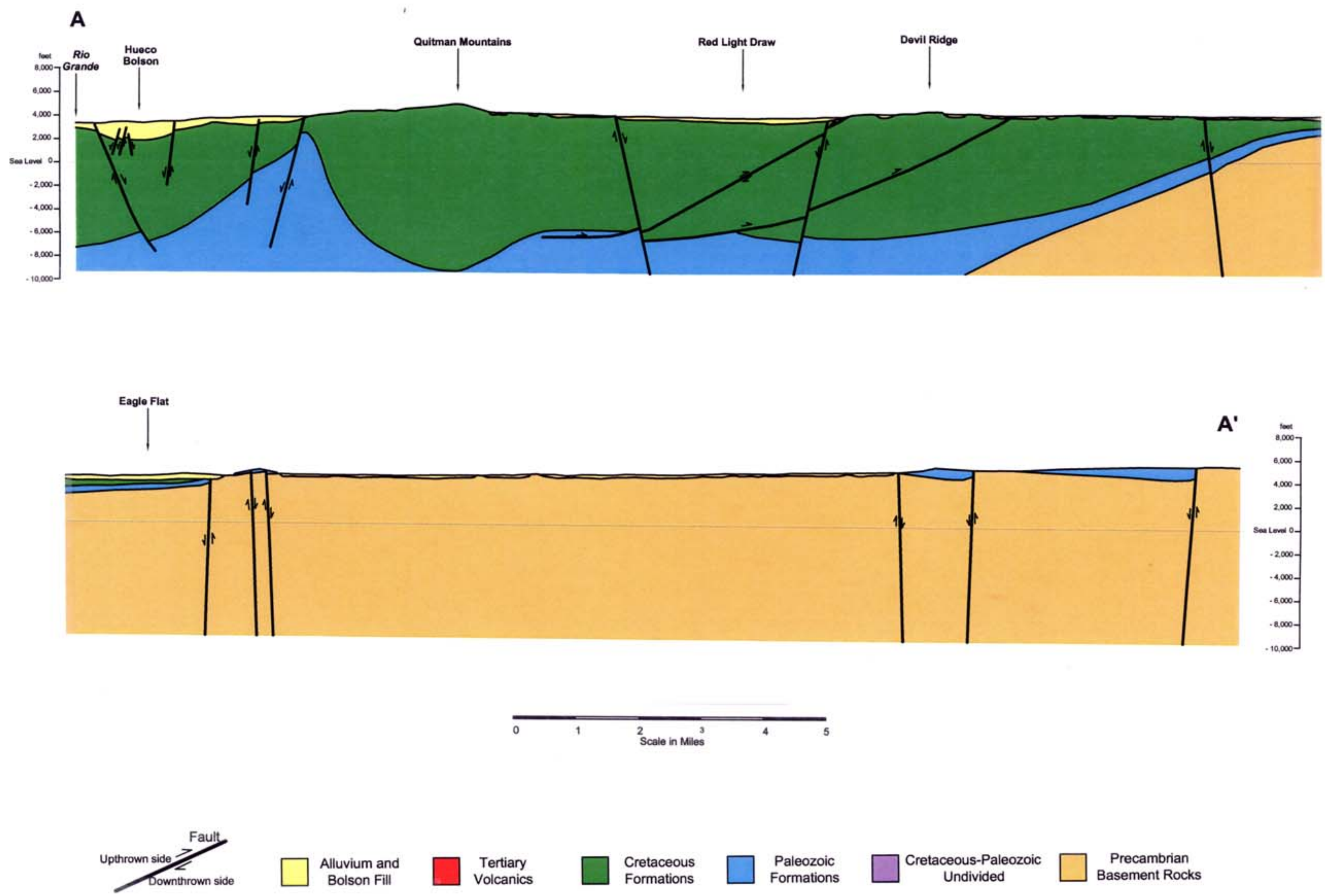


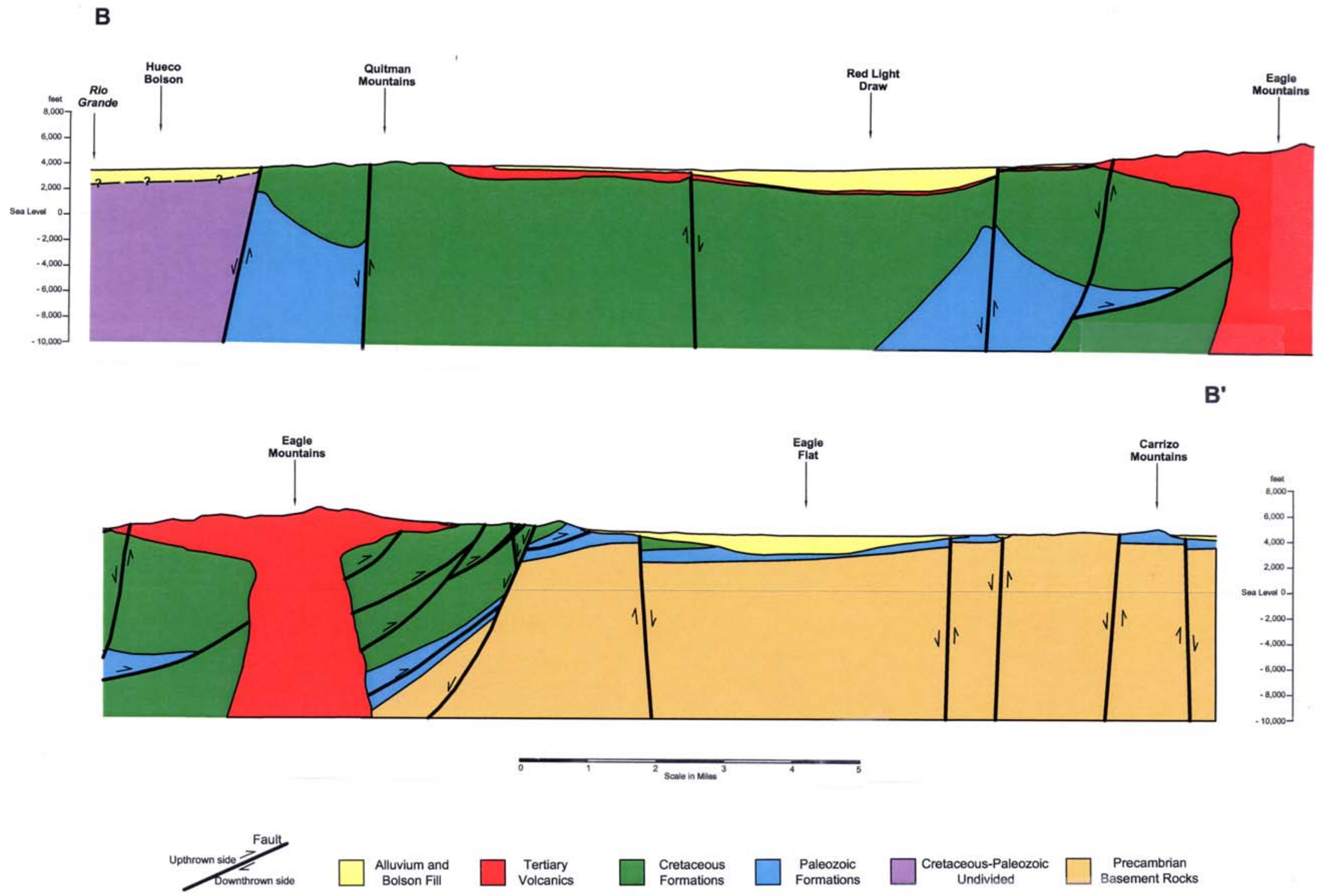
Figure 4.1 - Location of Cross-Sections

A-A'



Interpretations of the area's geologic framework are based largely on previous studies by Underwood (1963), Albritton and Smith (1965), King (1965), Jones and Reasor (1970), Twiss (1979), Gates and others (1980), Dietrich and others (1968), Raney and Collins (1993), and Collins and Raney (1997).

B-B’



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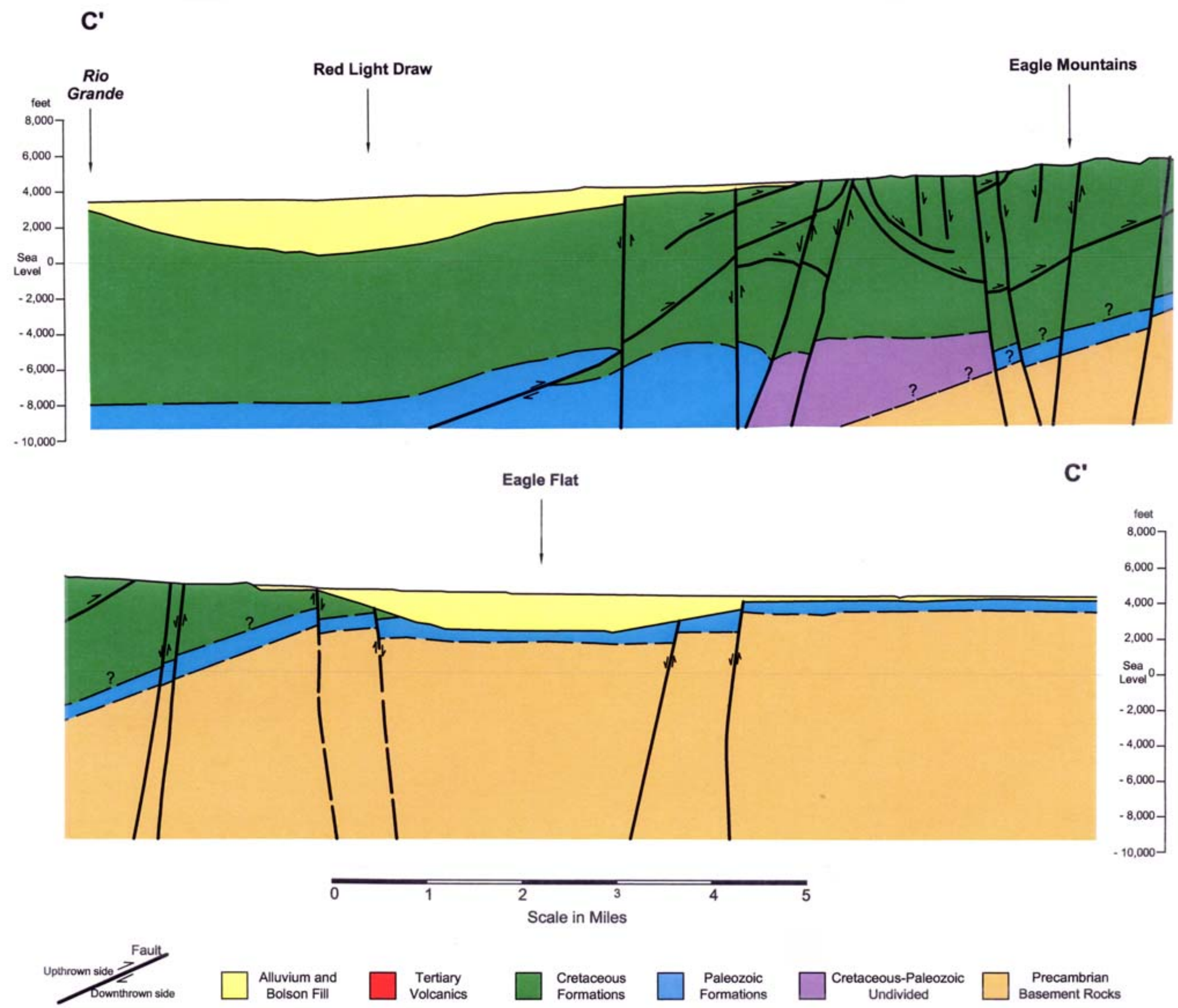
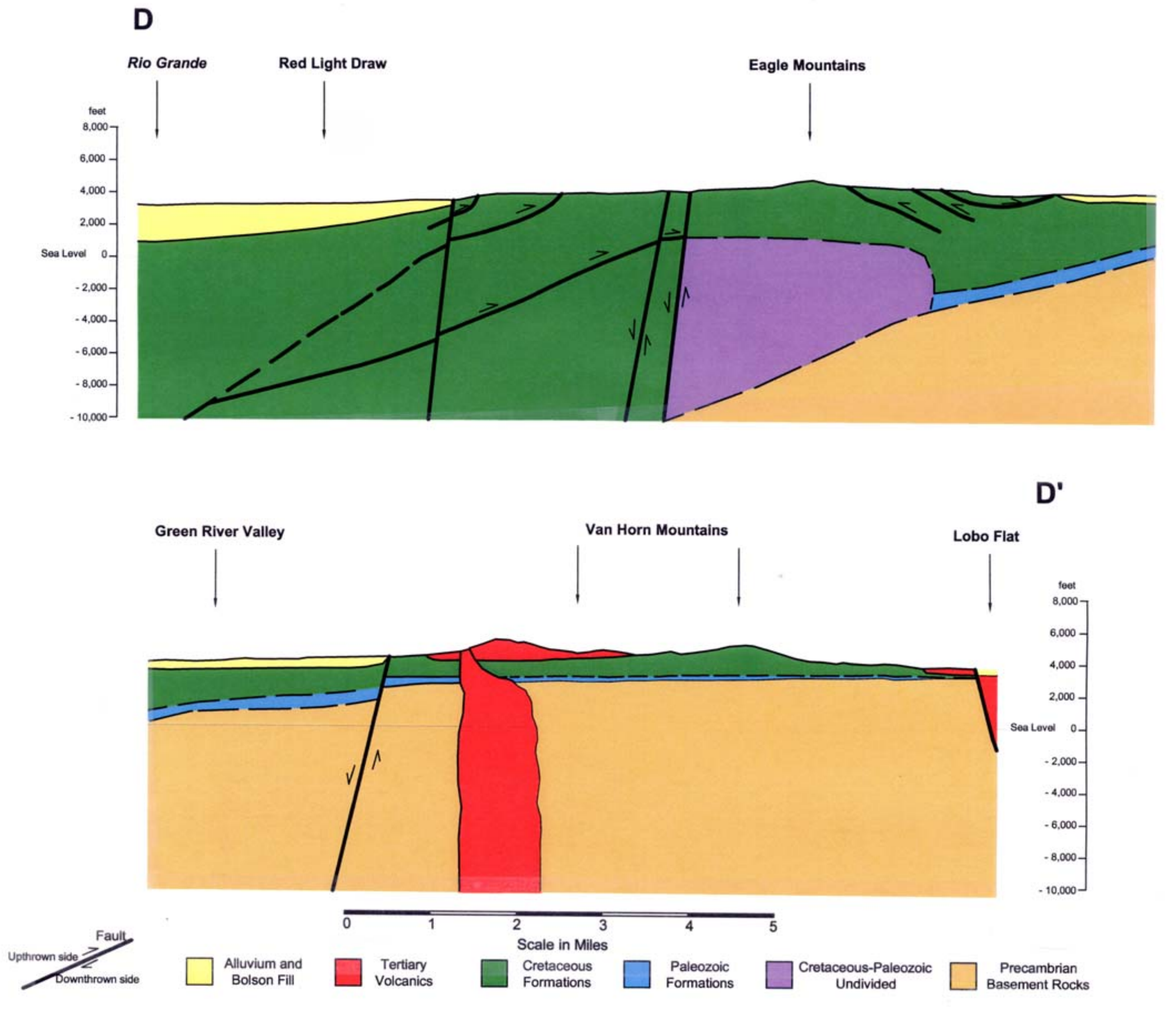
C-C’



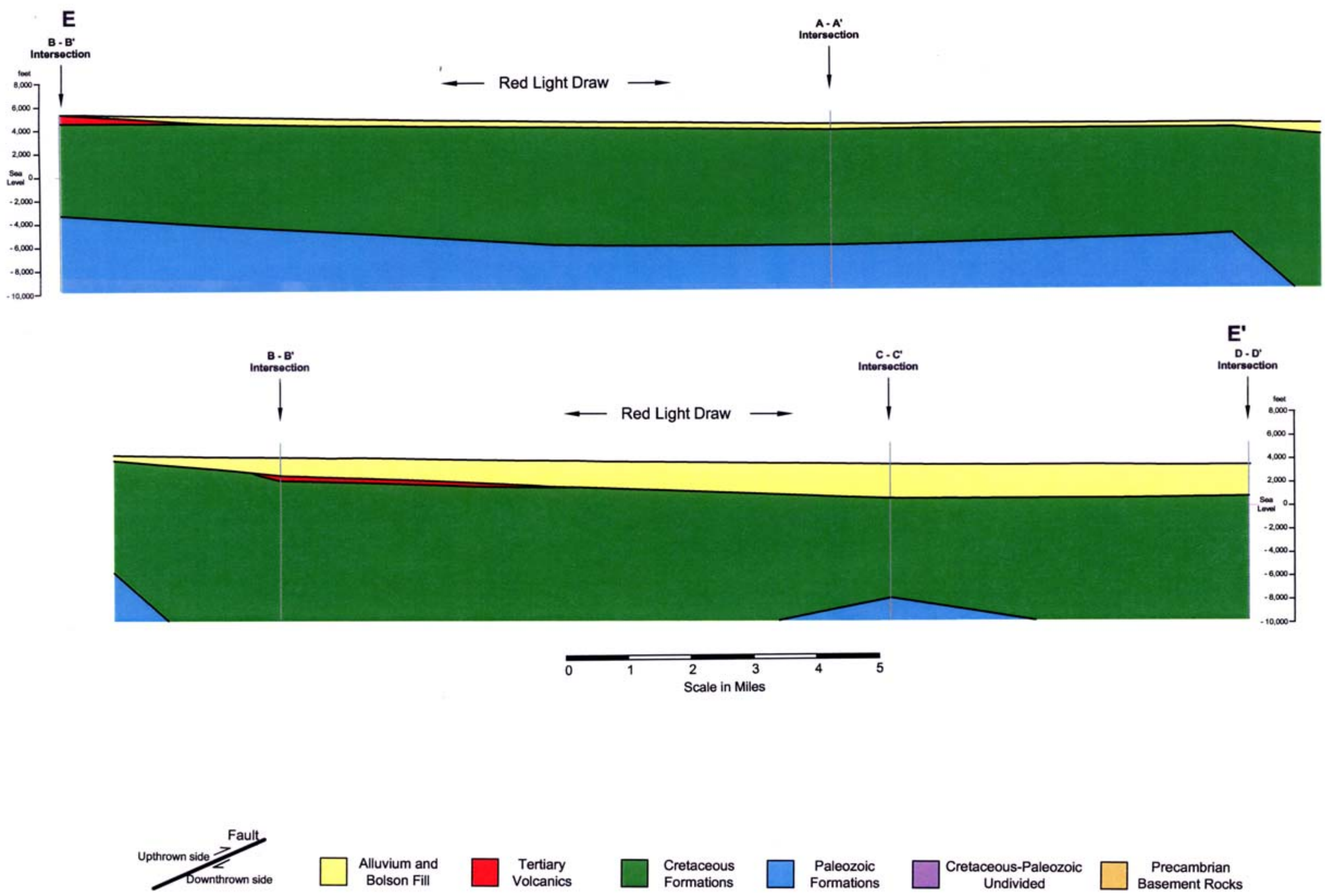
Interpretations of the area's geologic framework are based largely on previous studies by Underwood (1963), Albritton and Smith (1965), King (1965), Jones and Reasor (1970), Twiss (1979), Gates and others (1980), Dietrich and others (1968), Raney and Collins (1993), and Collins and Raney (1997).

D-D’



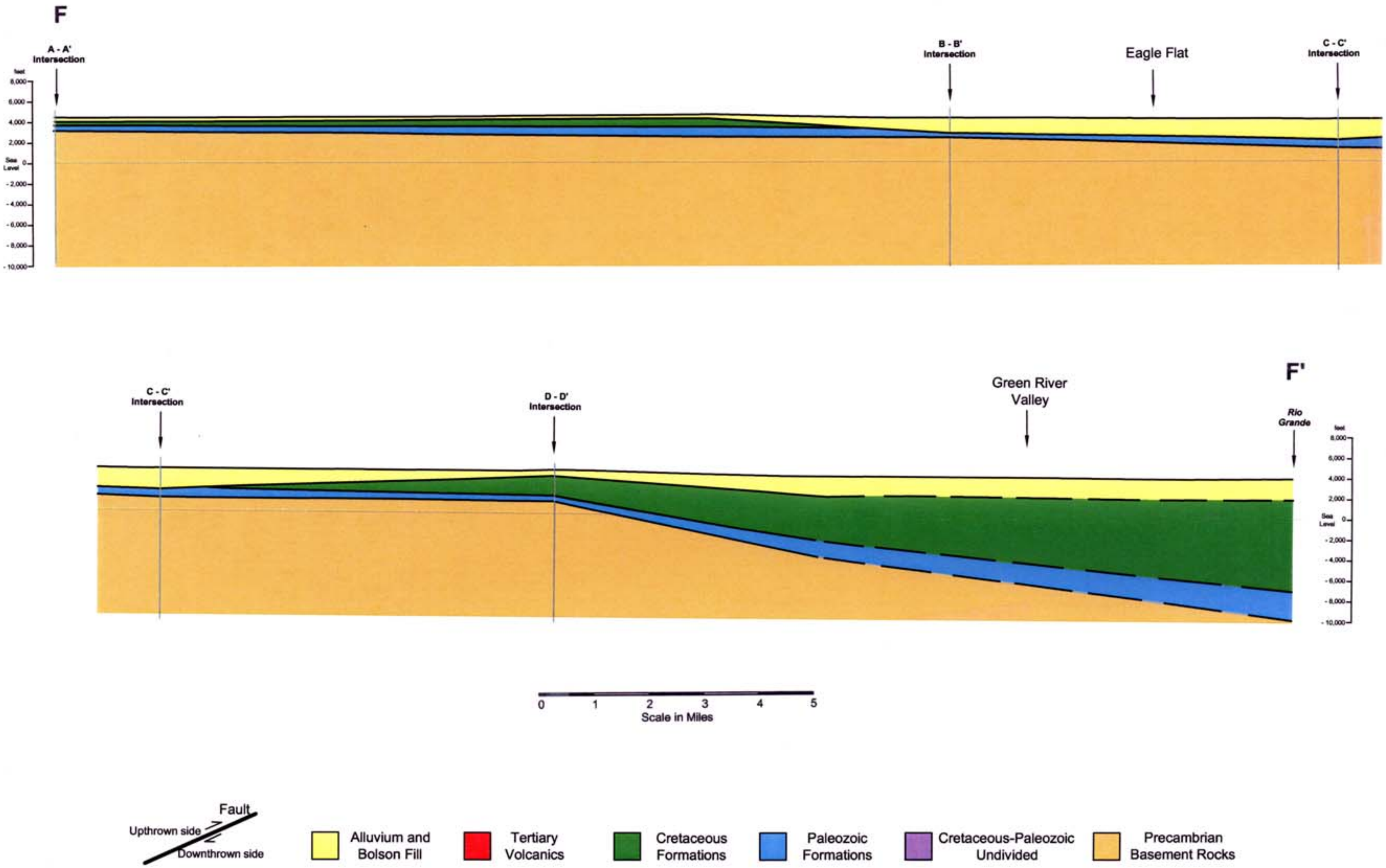
Interpretations of the area's geologic framework are based largely on previous studies by Underwood (1963), Albritton and Smith (1965), King (1965), Jones and Reasor (1970), Twiss (1979), Gates and others (1980), Dietrich and others (1968), Raney and Collins (1993), and Collins and Raney (1997).

E-E'



Adapted from interpretation of the area's geologic framework based largely on previous studies by Underwood (1963), Allbritton and Smith (1965), King (1965), Jones and Reasor (1970), Twiss (1979), Gates and others (1980), Dietrich and others (1968), Raney and Collins (1993) and Collins and Raney (1997).

F-F'



Adapted from interpretation of the area's geologic framework based largely on previous studies by Underwood (1963), Allbritton and Smith (1965), King (1965), Jones and Reasor (1970), Twiss (1979), Gates and others (1980), Dietrich and others (1968), Raney and Collins (1993) and Collins and Raney (1997).

Geologic Faulting

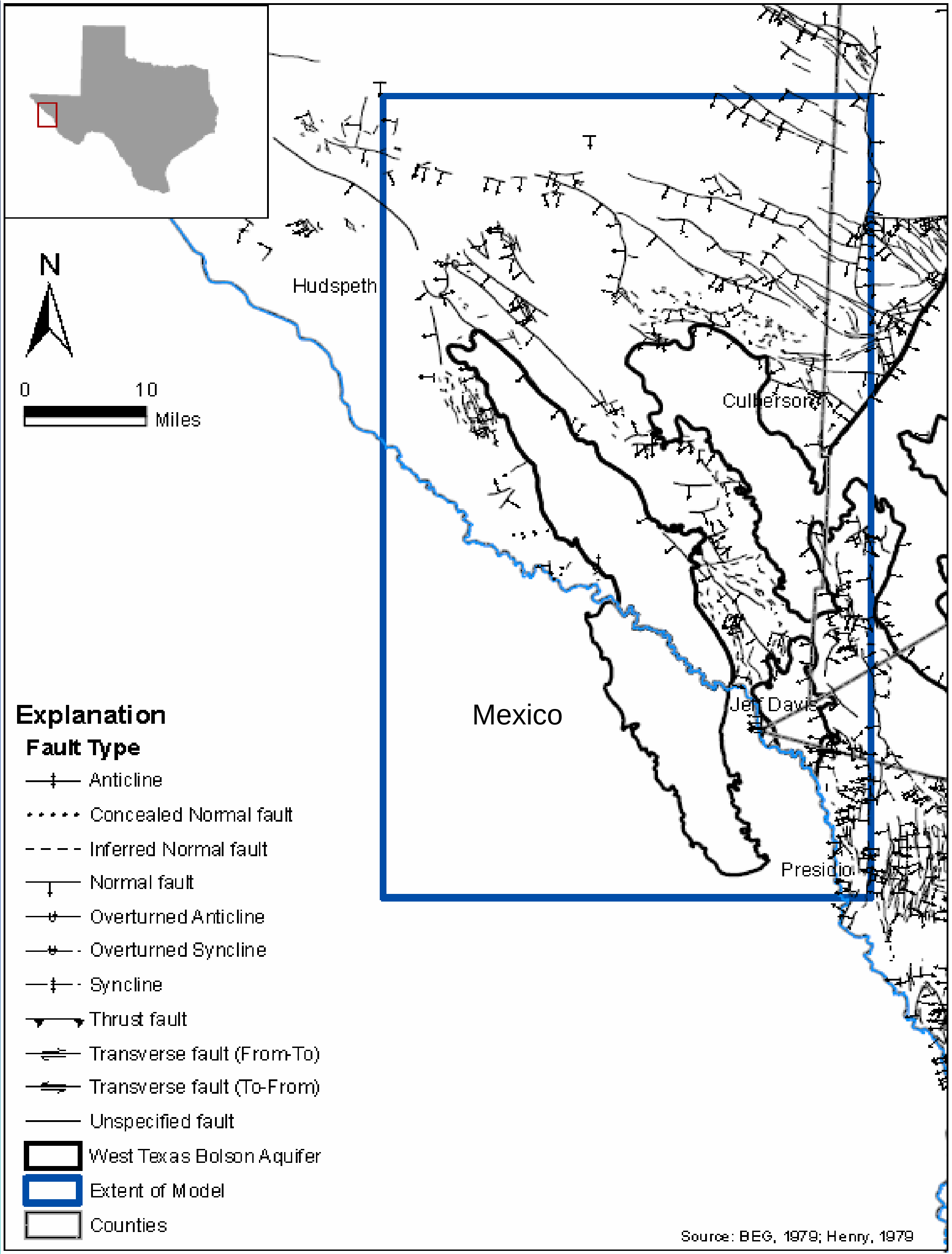
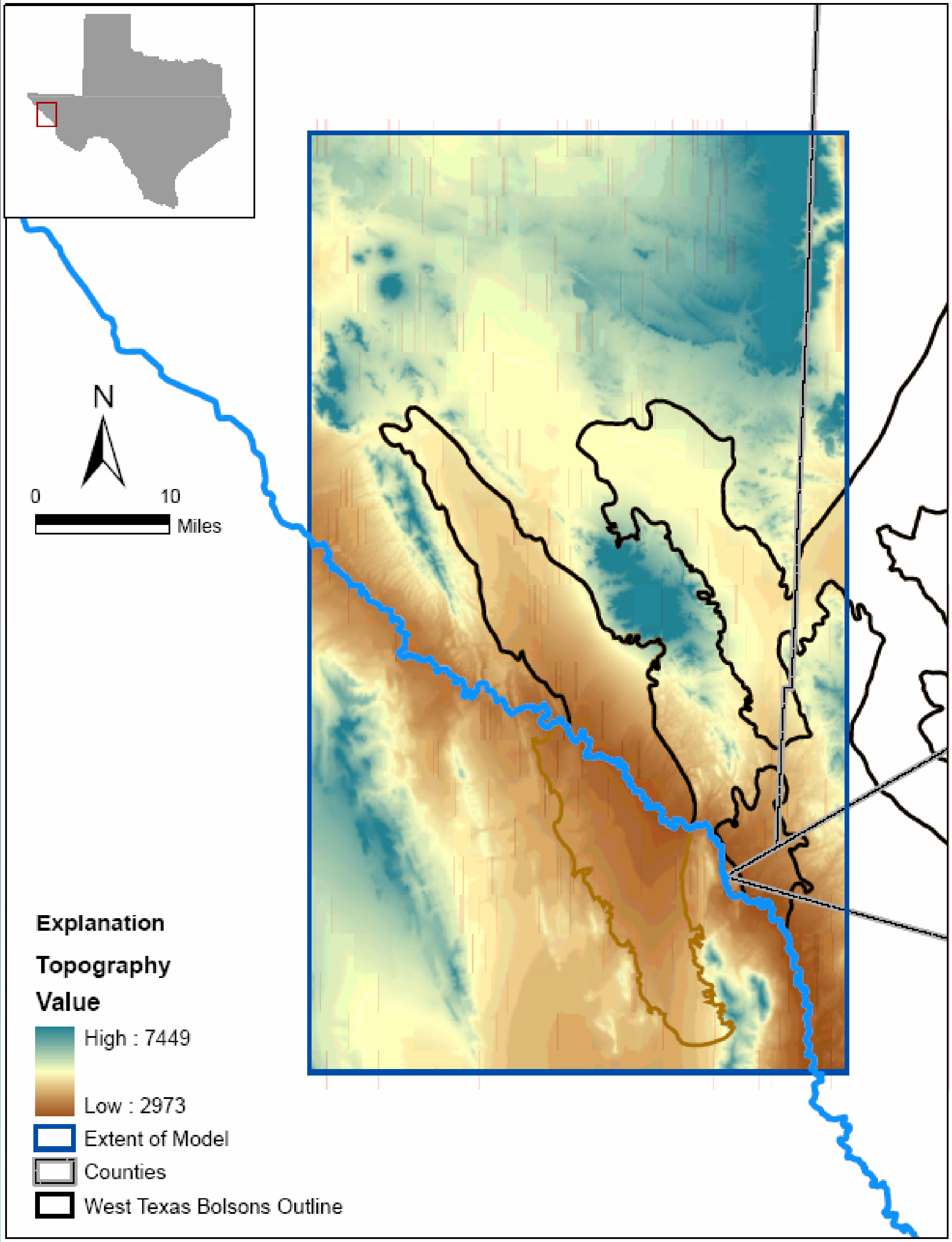


Figure 4.1.3 - Structural Faulting



Topography

- Ground surface is the top of Layer 1 and 2 as appropriate throughout the model area

Elevation of Base of Bolsons

Bottom of Layer 1

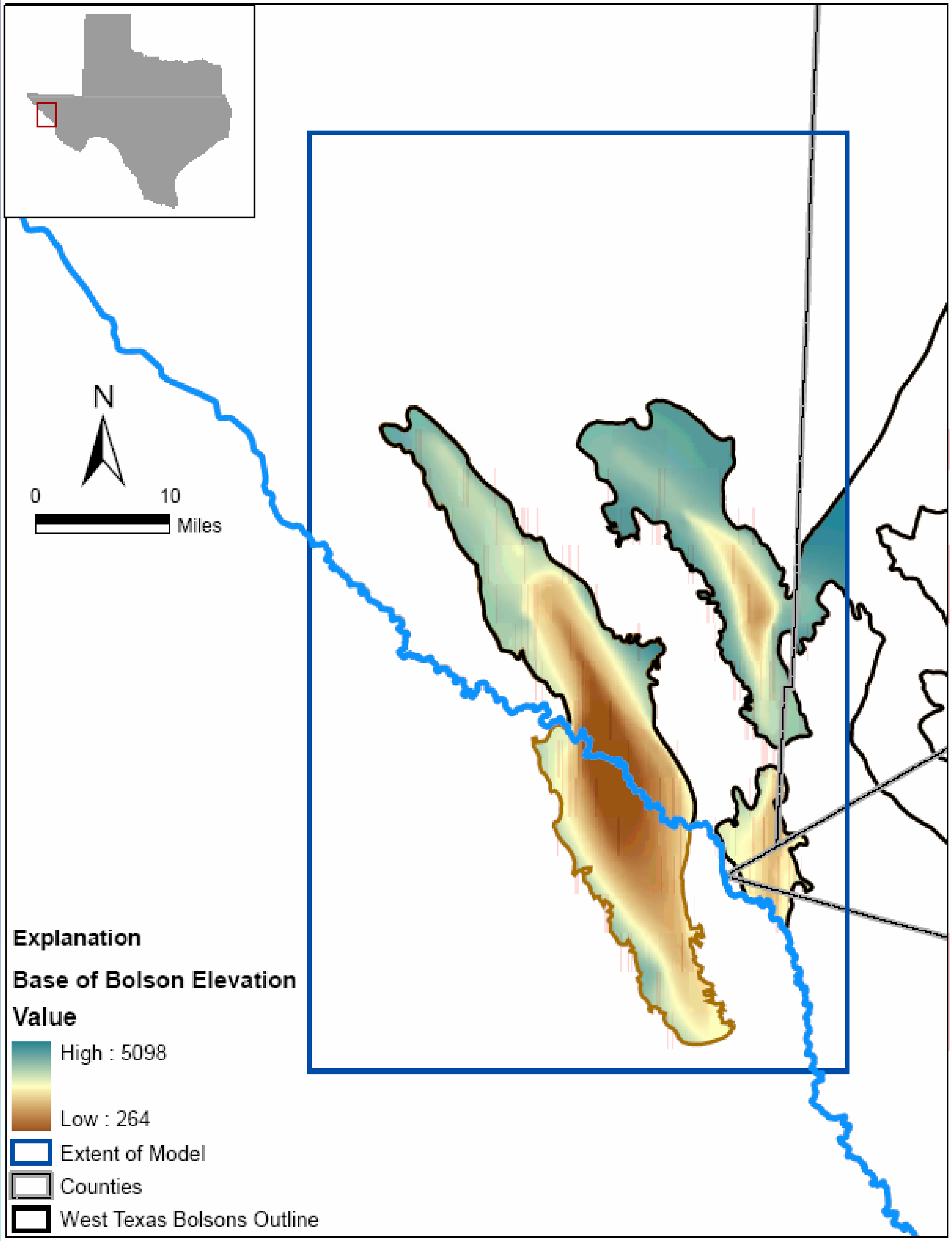


Figure 4._ Elevation of Base of Bolson.

Thickness of Bolsons

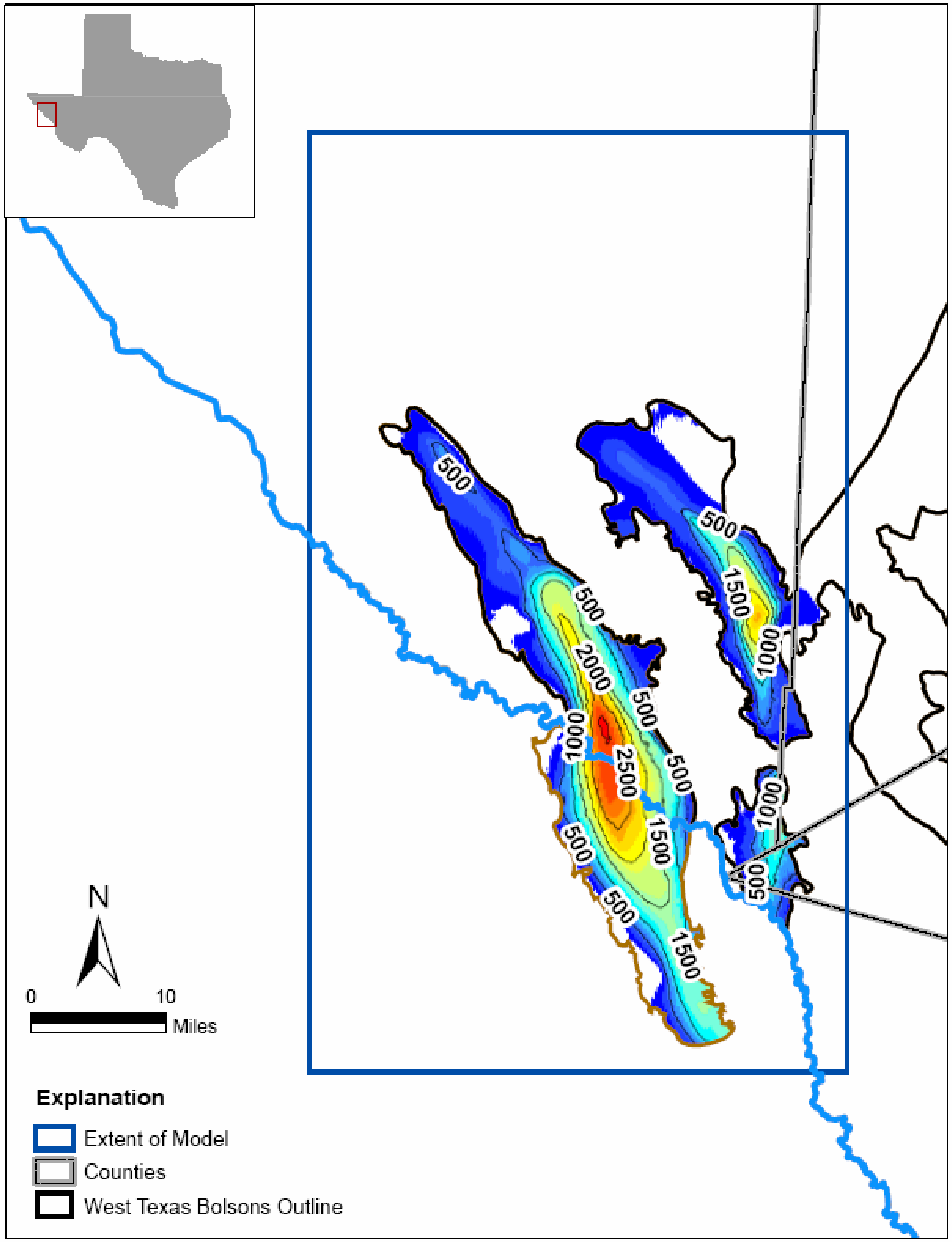
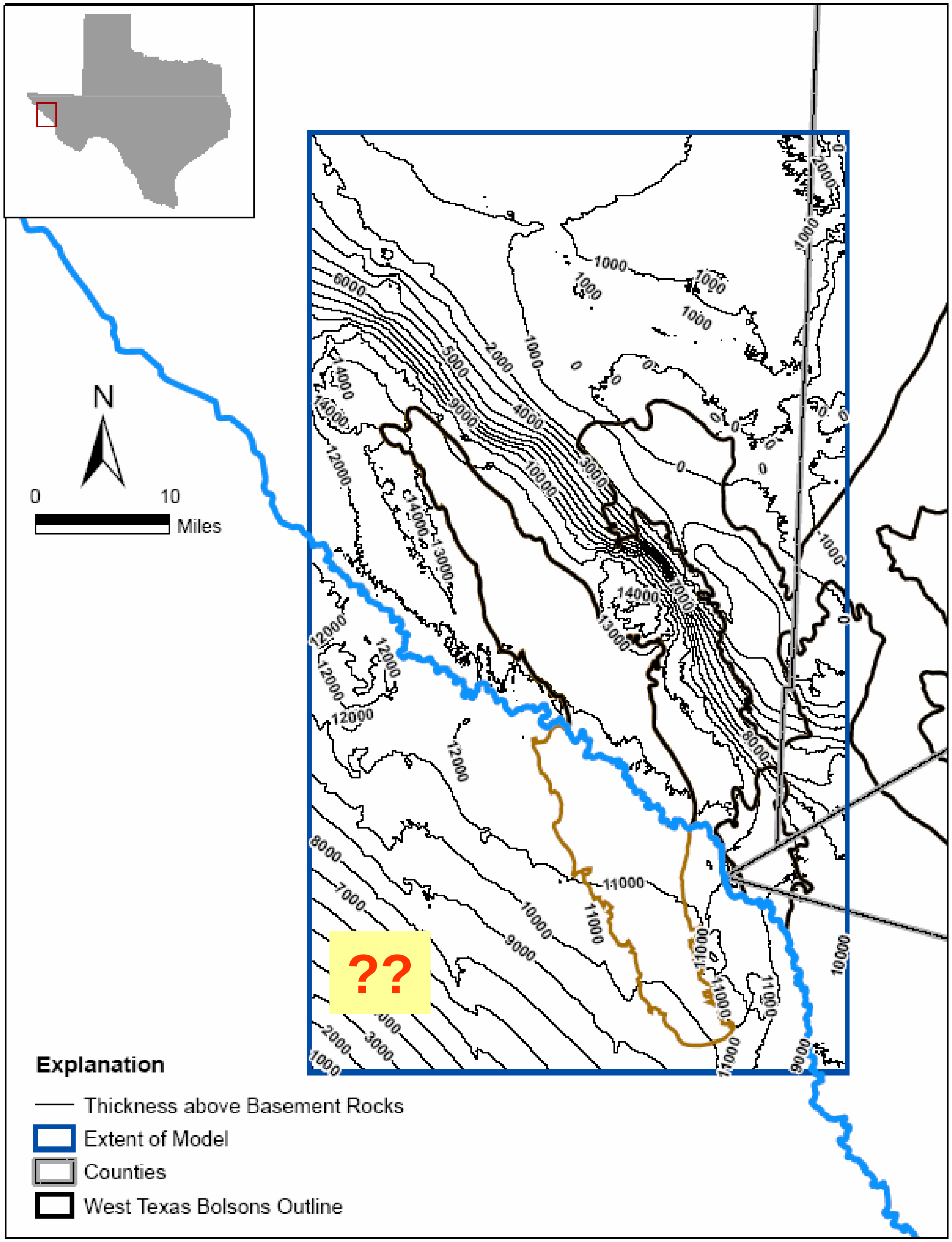


Figure 4._ Thickness of Bolsons.

Thickness of Rocks above Basement



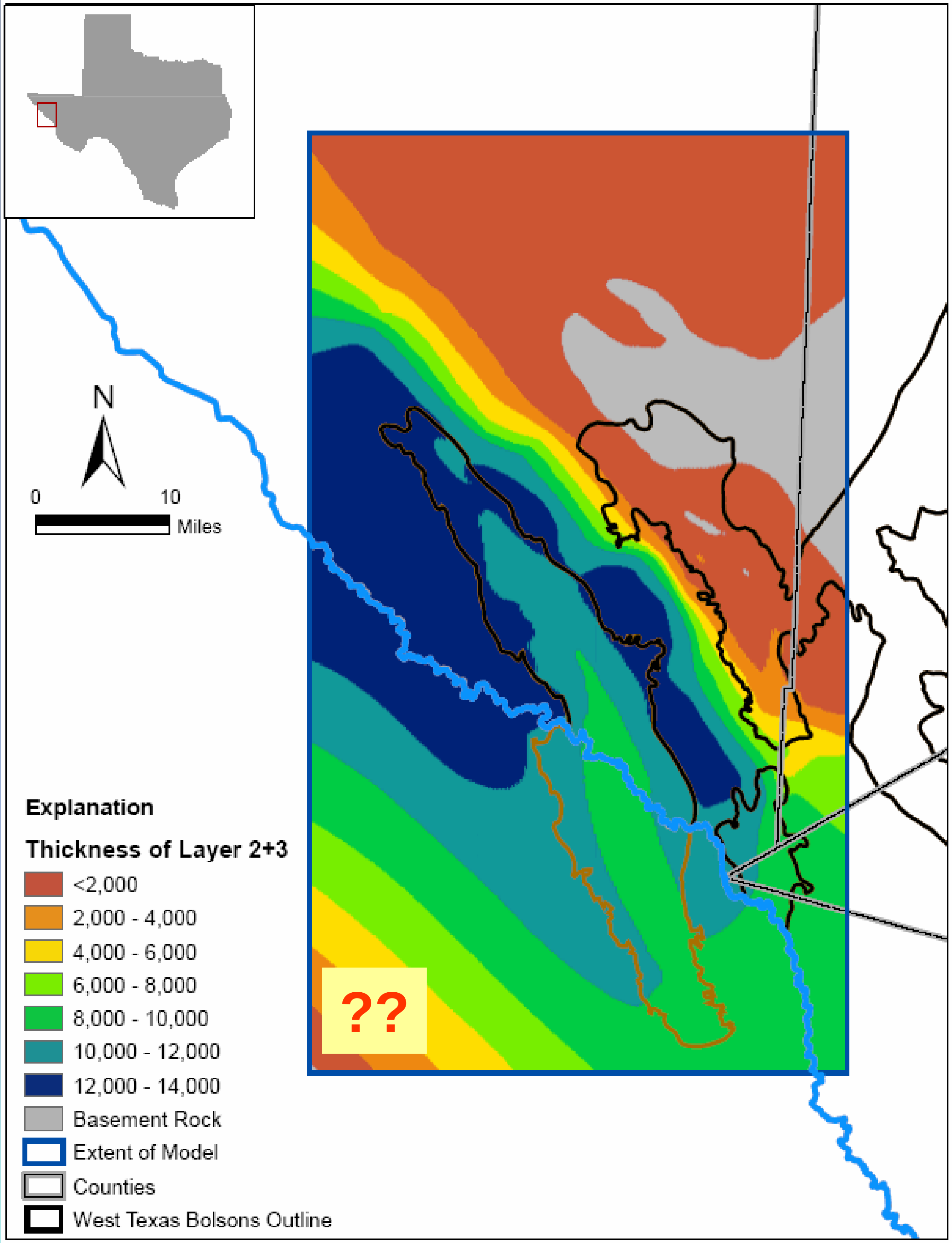


Figure 4._ Thickness of Layers 2 and 3.

Thickness of Layer 2 and 3

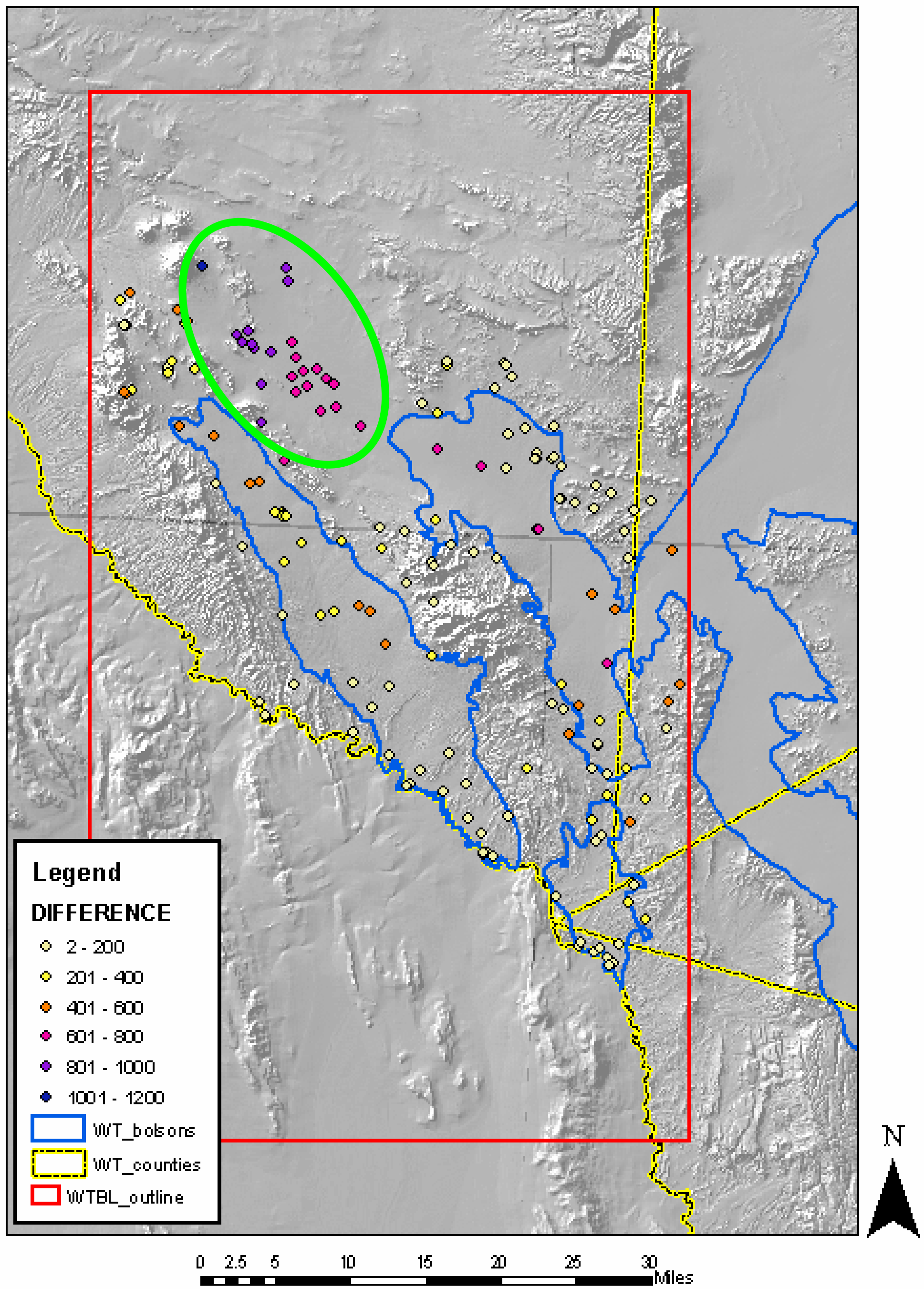
(Cretaceous, Permian, etc.)

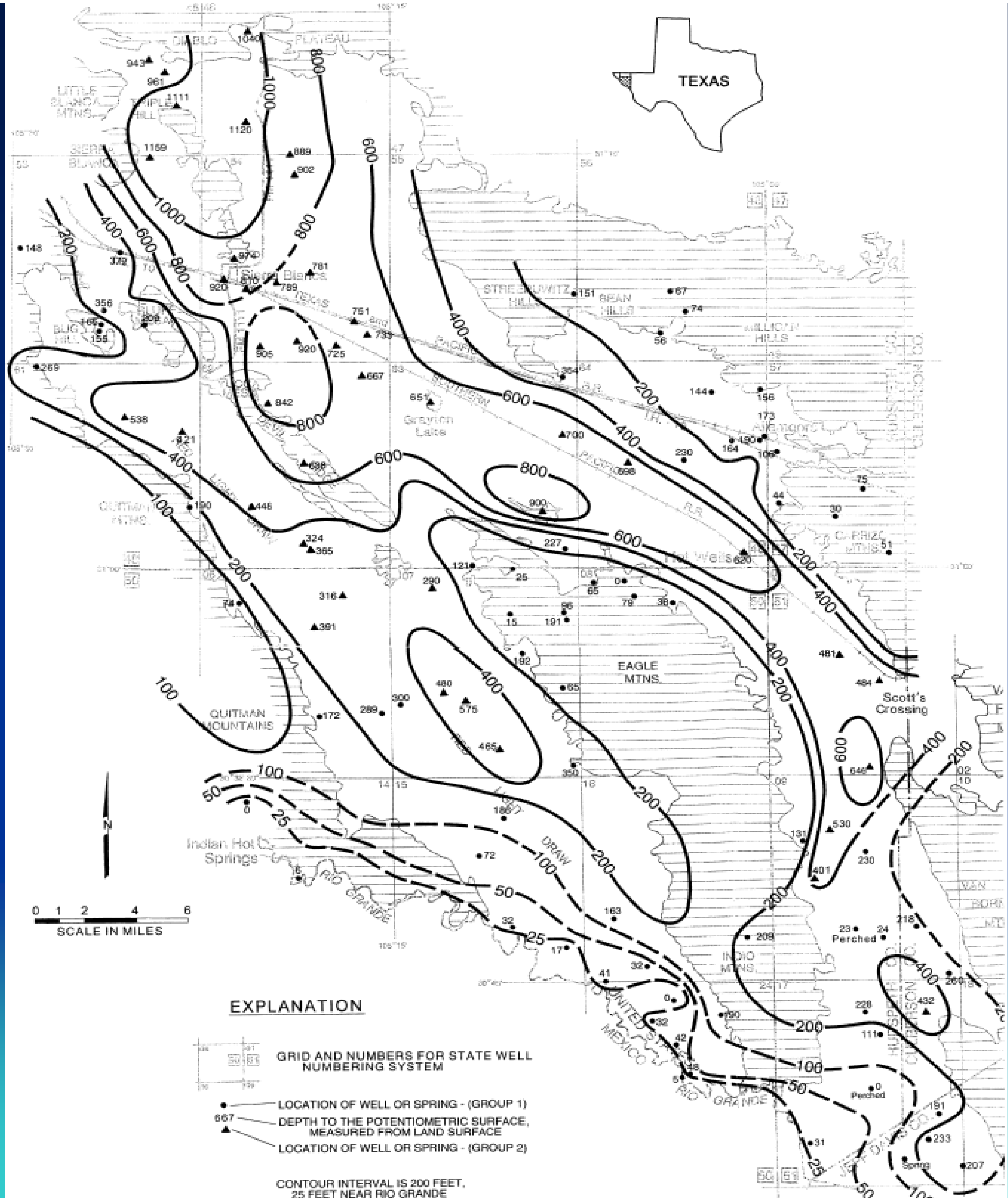
Cretaceous and Permian, etc.

- Layer 2 and 3 Structure
  - Where present, evenly split the total thickness of Cretaceous and Permian, etc. above the basement rock
  - Where not present, assume 1000 feet thickness for basement rock
  - Steady-state calibration will be impacted by deeper rocks, but not 50-year water supply

Water Levels
and
Regional Groundwater Flow

Depth to Water

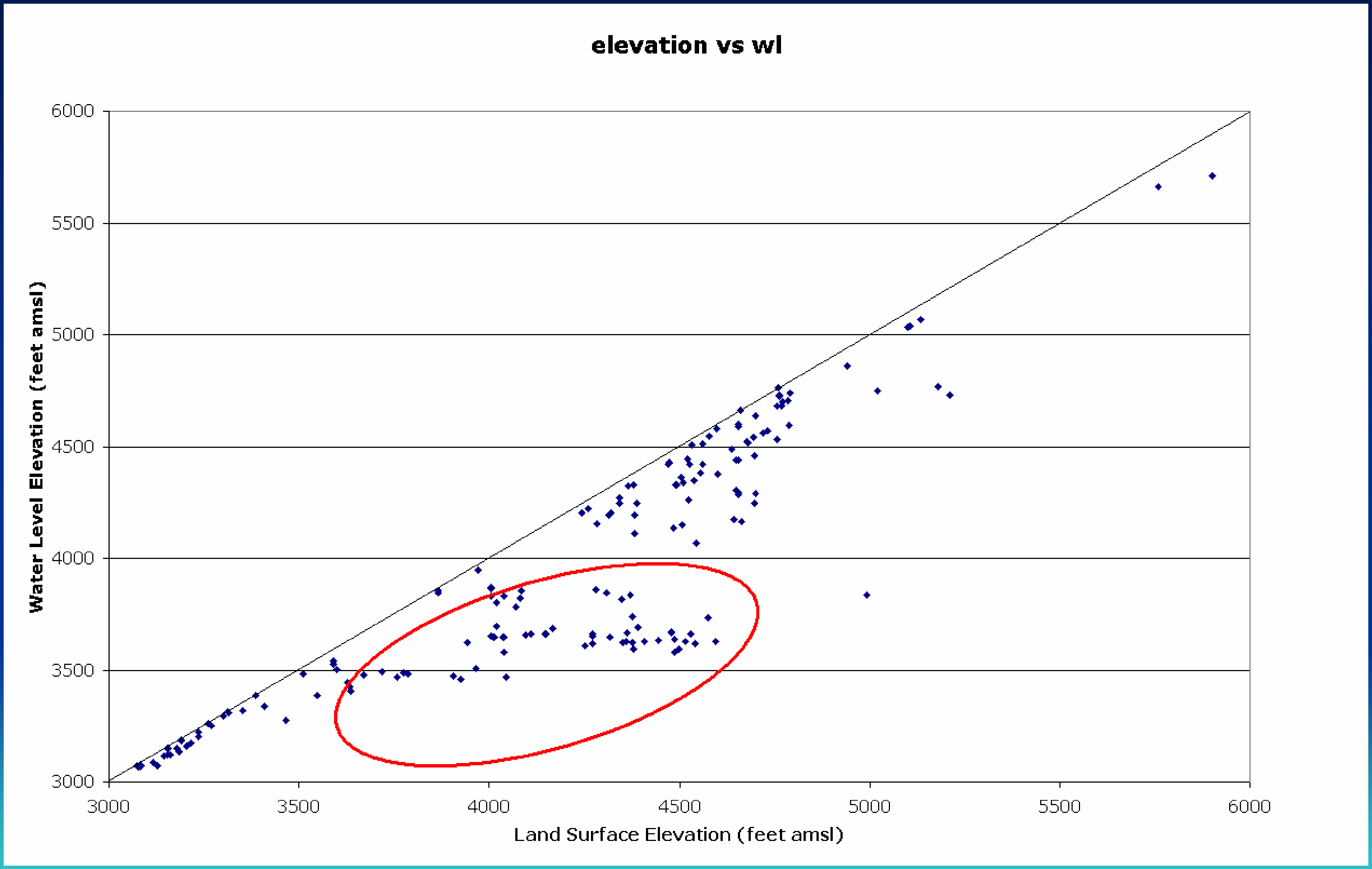




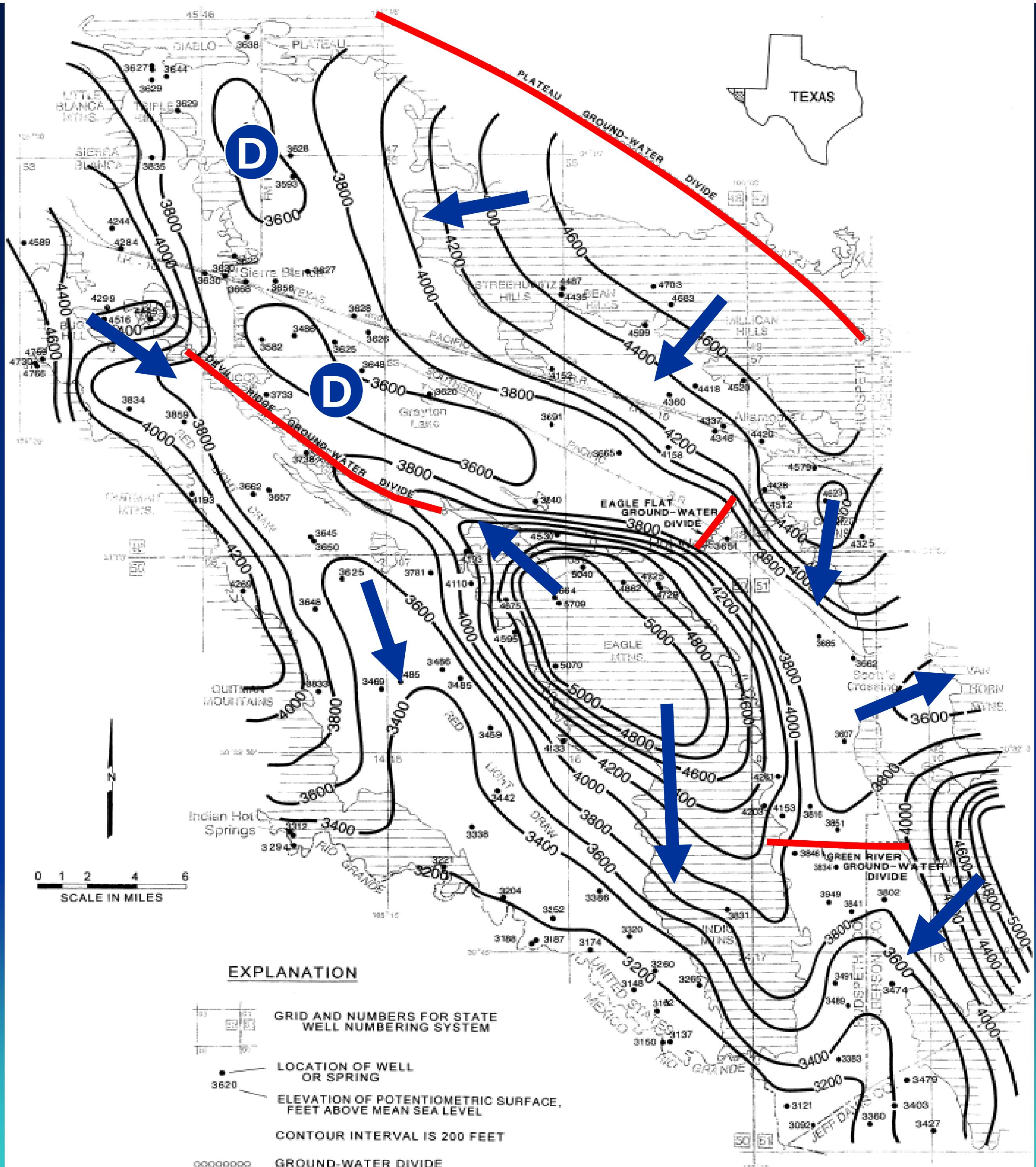
Depth to water

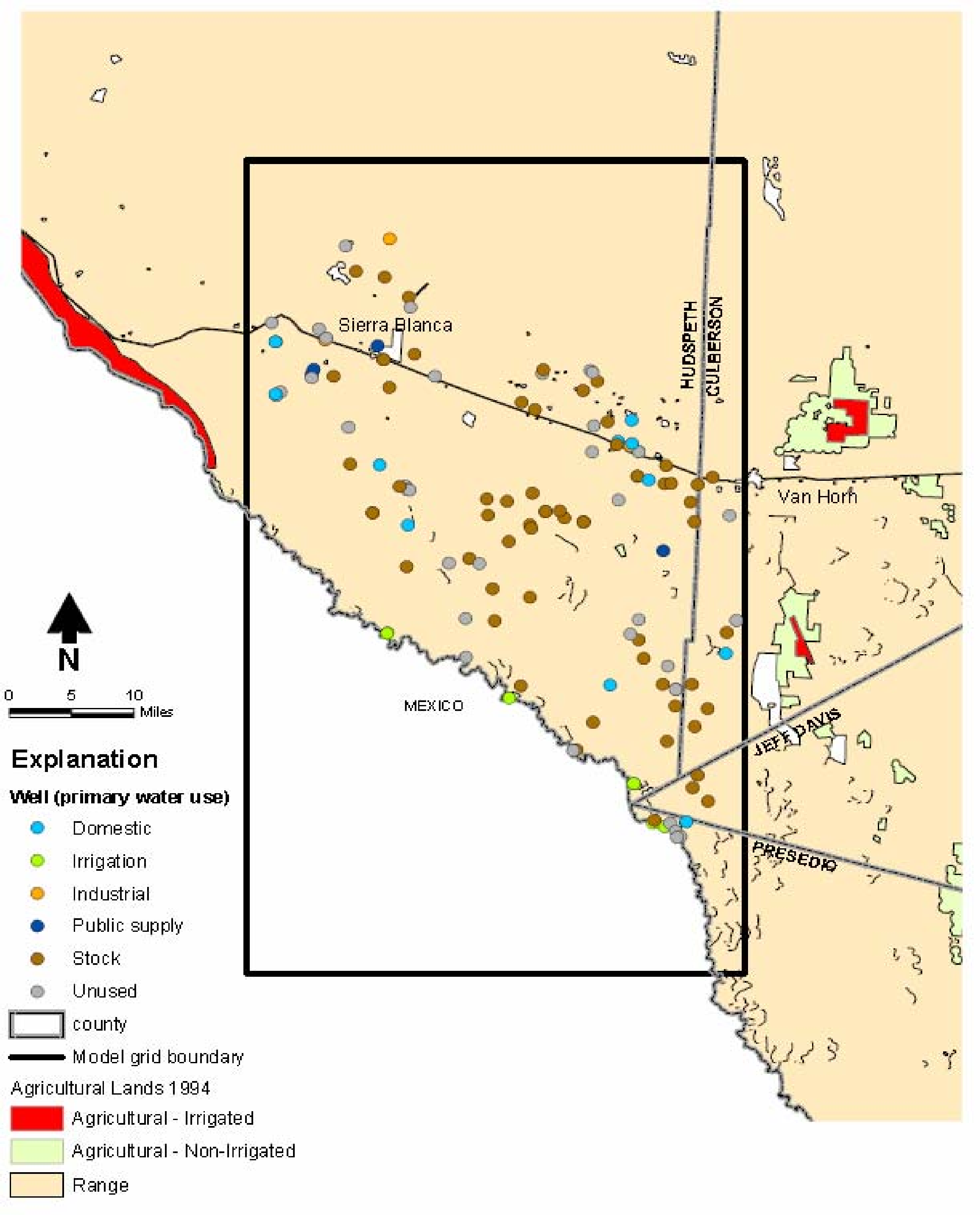
(after Darling, 1997)

Depth to Water



Regional Groundwater Flow Paths

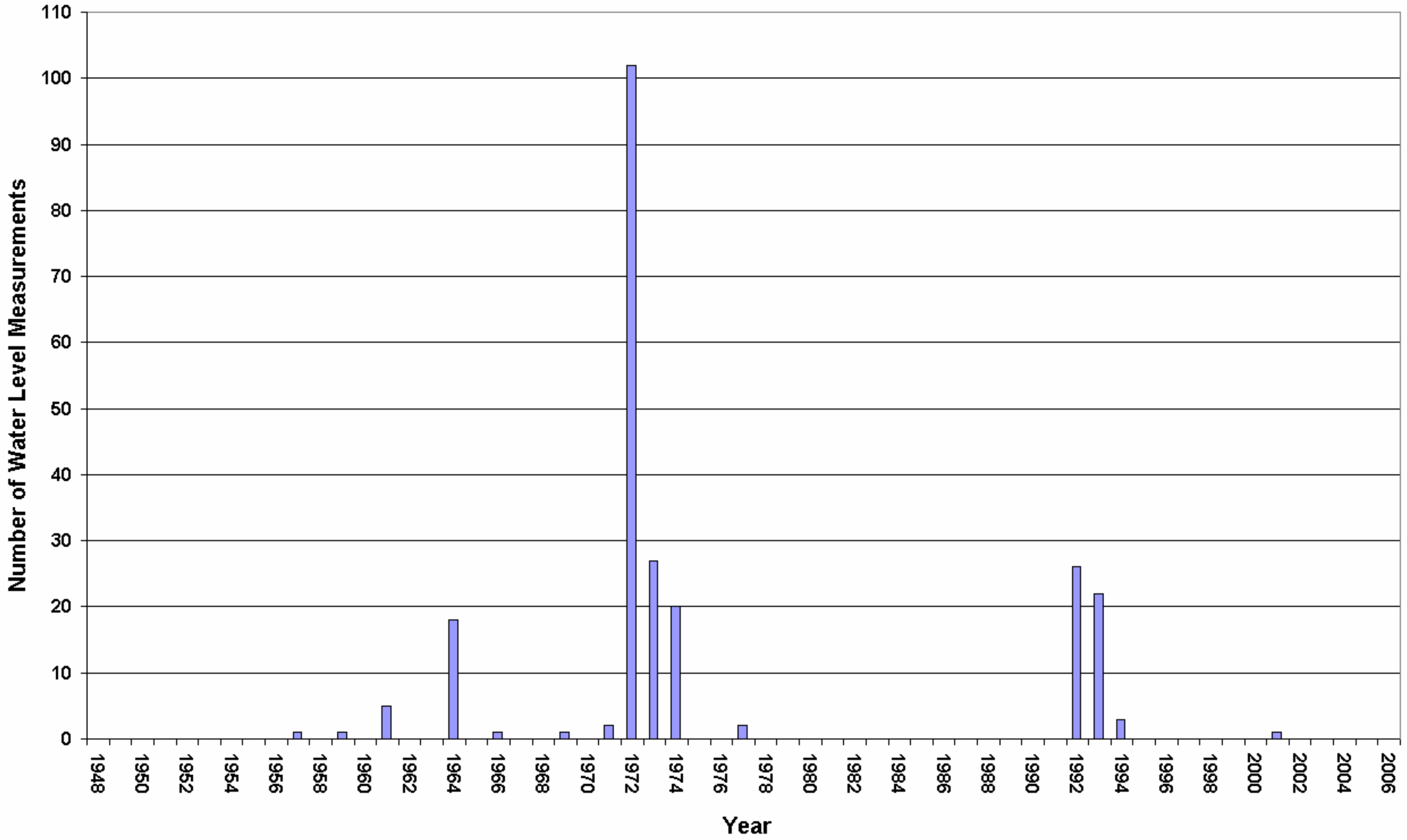




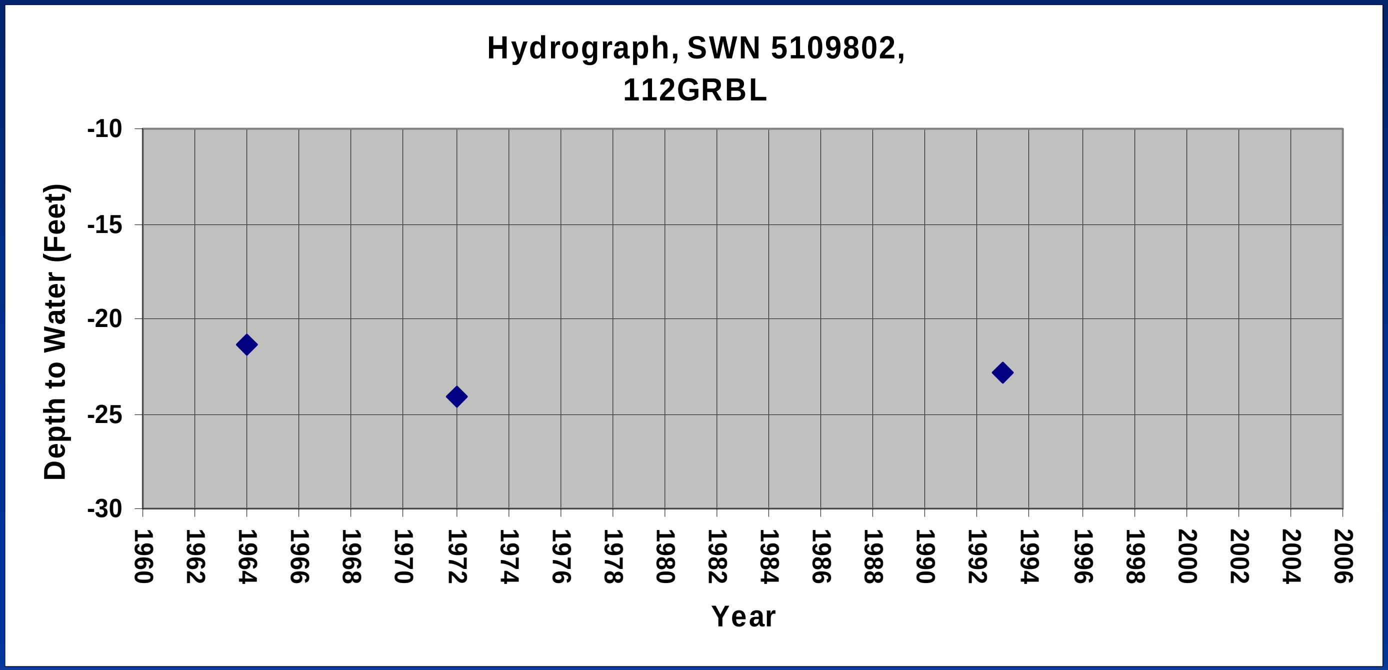
Well Information

- TWDB Record of Wells 184
- TCEQ central records 41

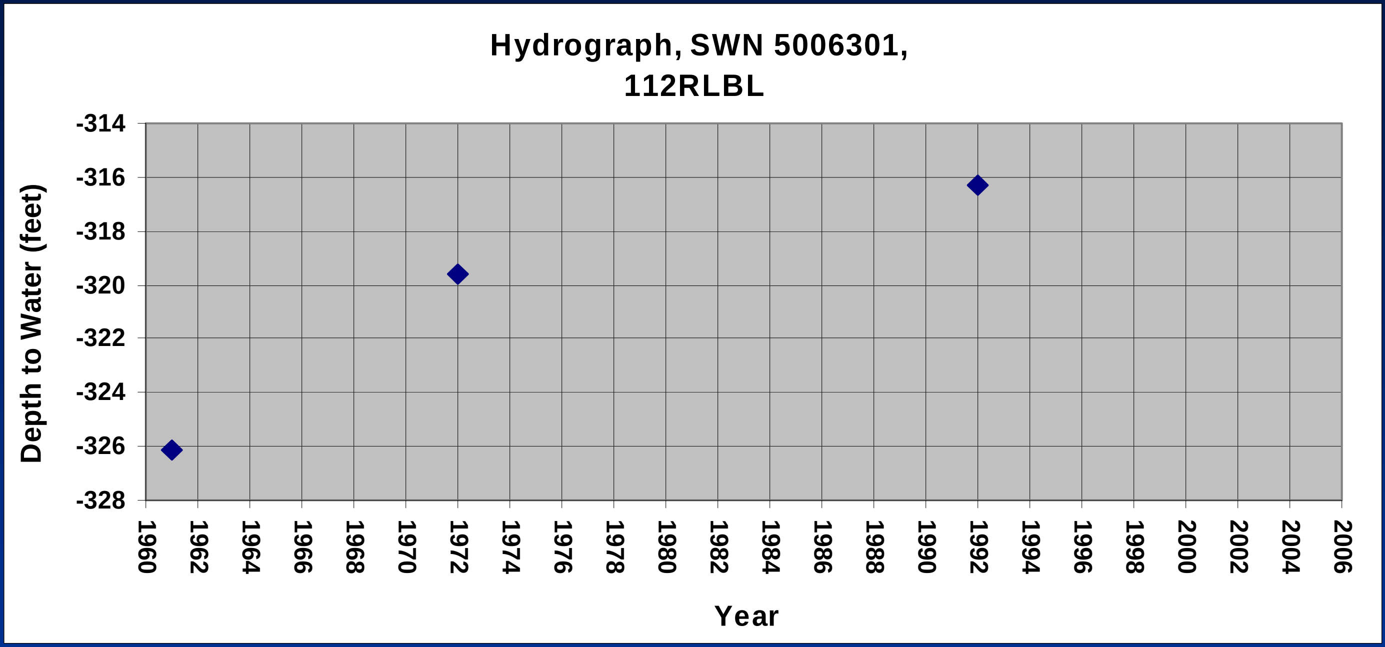
Water Level Data

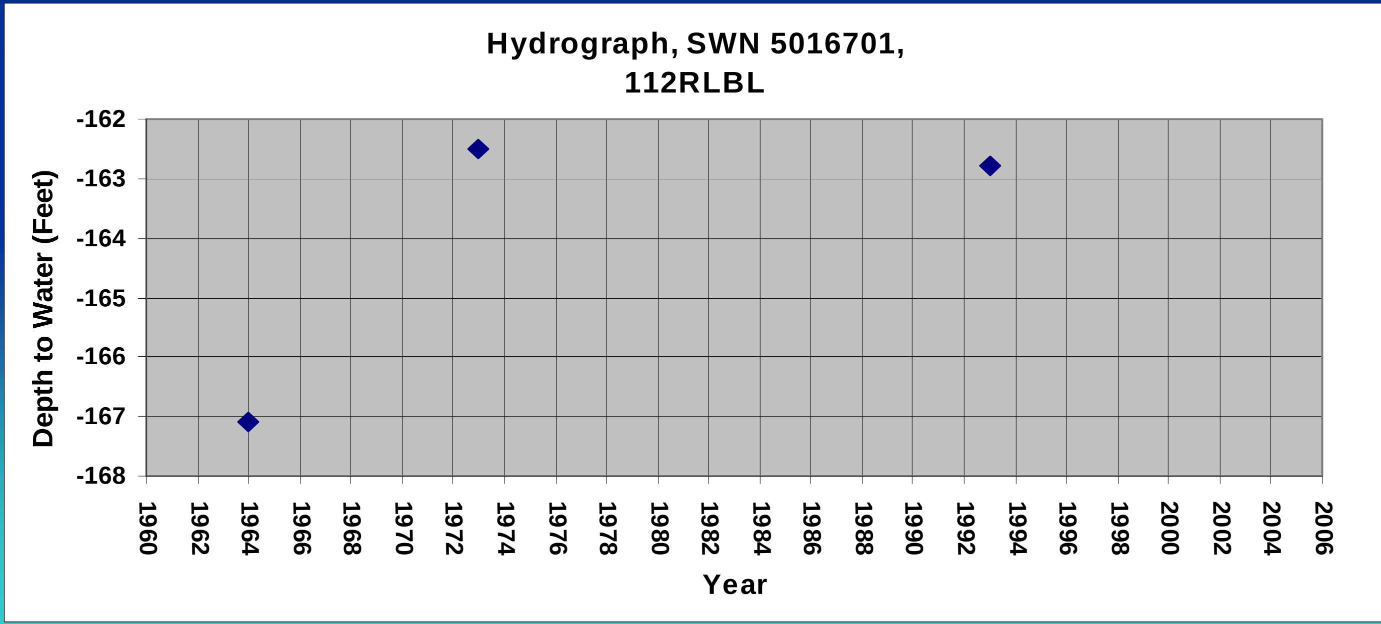


Green River Valley Hydrograph

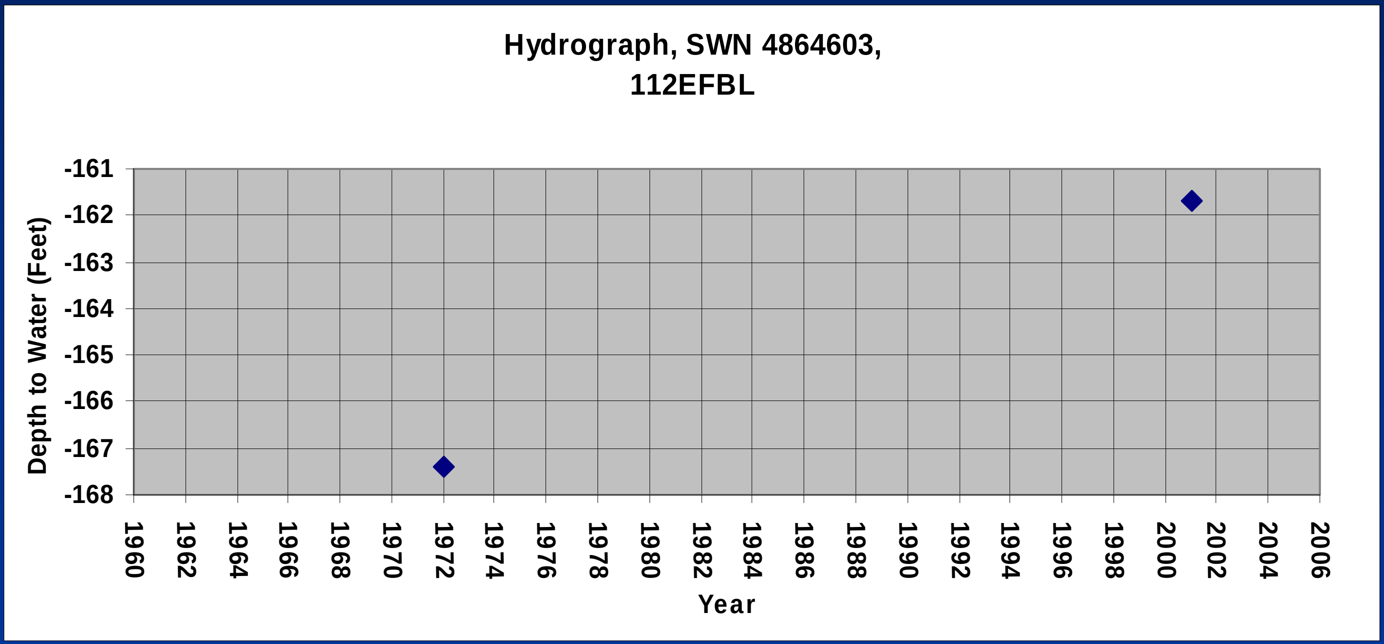


Red Light Draw Hydrographs

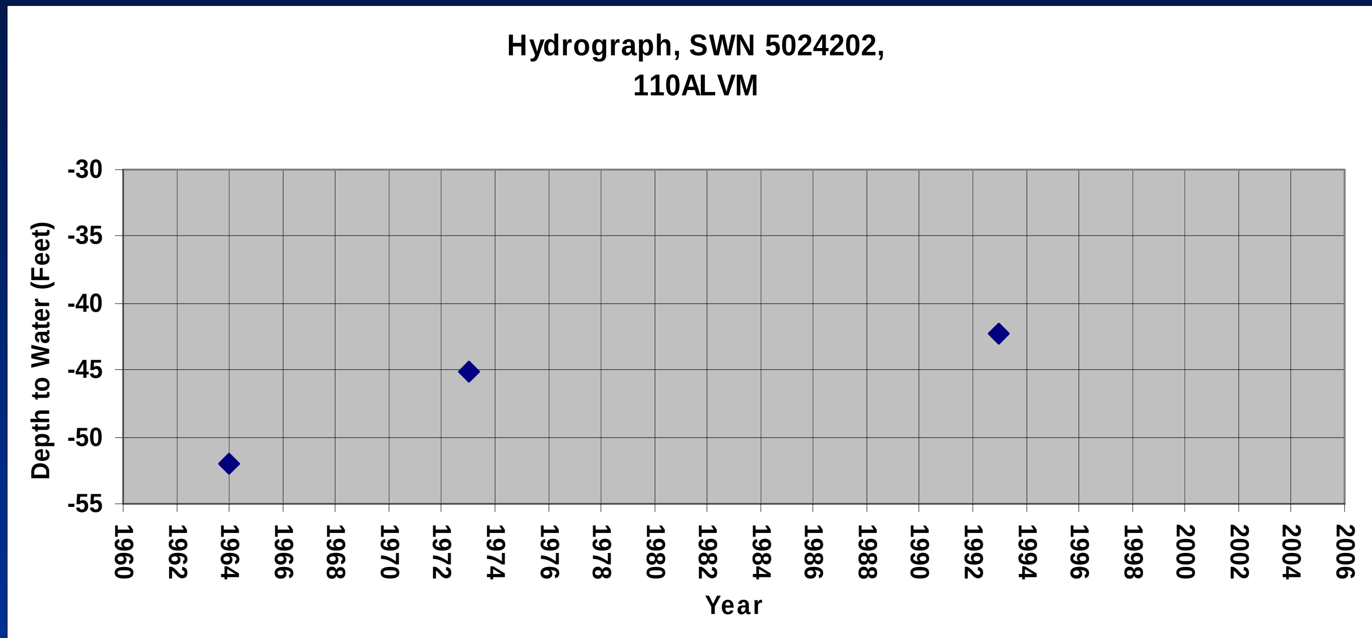


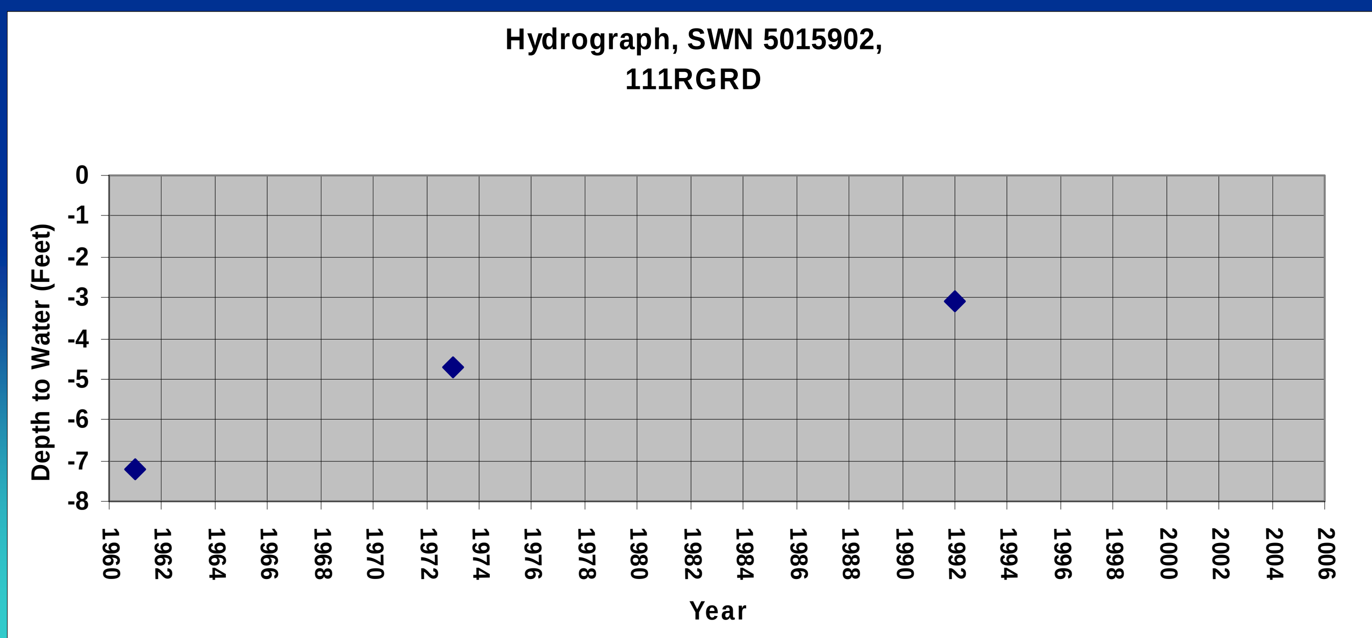


Eagle Flat Hydrograph

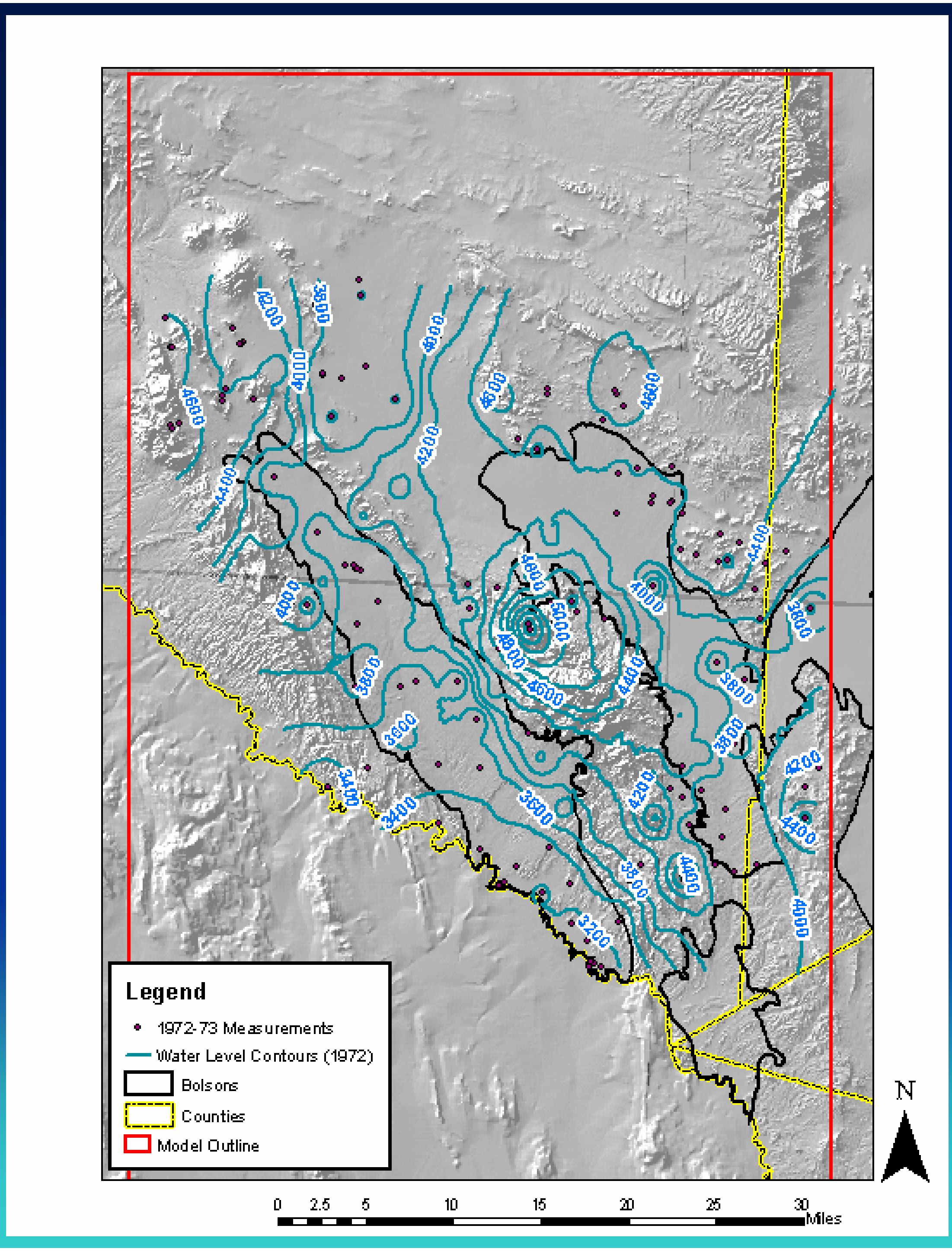


Alluvium Hydrographs

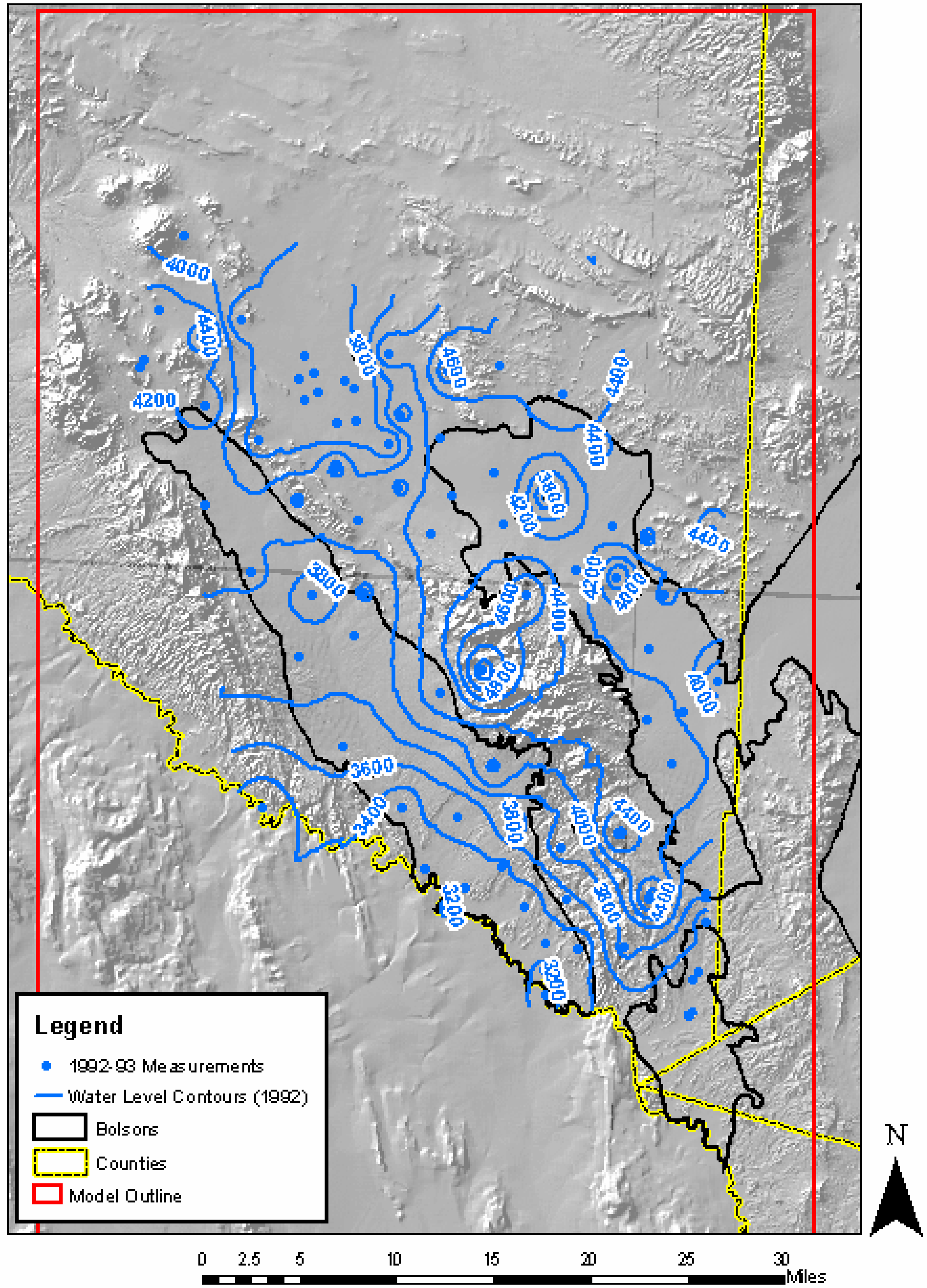




Water Level Contours (1972-73)



Water Level Contours (1992-93)



Data

Precipitation

- Annual
- Daily

Watershed characteristics

- Elevation
- Soil type
- Geology
- Land cover

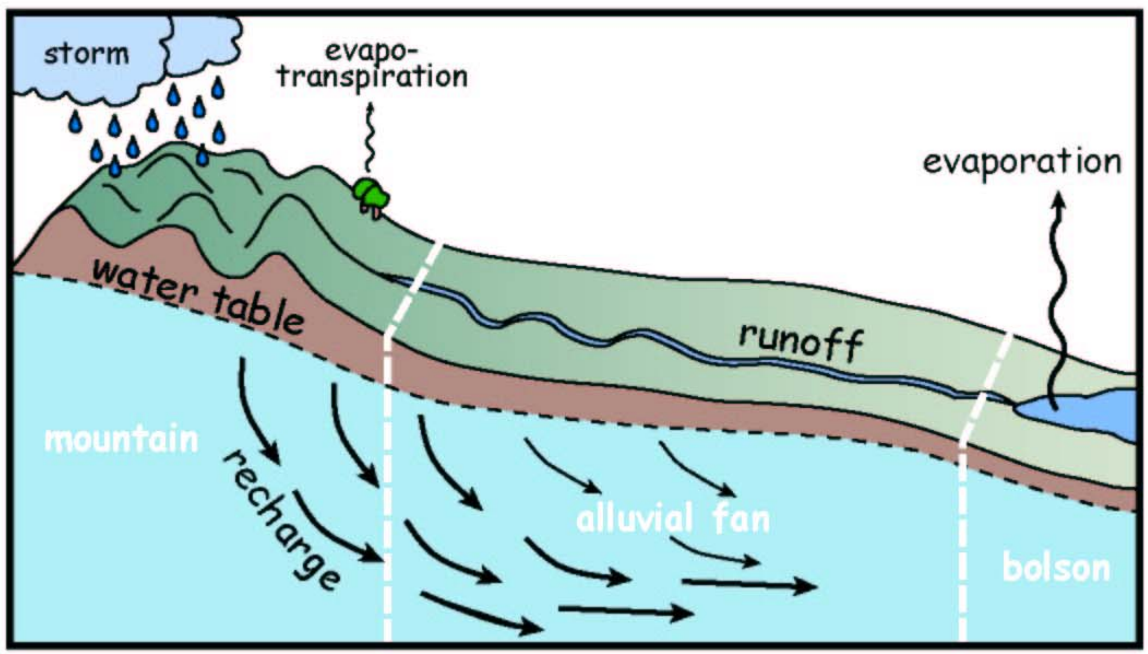
Estimate recharge for each watershed

Total precipitation based on precipitation-elevation relationship

Potential recharge
precipitation
- evapotranspiration

Runoff based on daily precipitation and watershed characteristics

Recharge
potential recharge
- runoff
+ redistributed runoff



RECHARGE METHODS FOR TRANS-PECOS REGION

Method		Reference	
1.	One-Percent Rule	1.	Gates et al. (1978)
2.	Modified Maxey-Eakin	2.	Mayer (1995)
3.	Storm Runoff Infiltration	3.	Finch and Armour (2001)
4.	Runoff Redistribution	4.	Finch and Bennett (2002) Stone et al. (2001) Dunne and Leopold (1978)

RUNOFF RE-DISTRIBUTION METHOD

1. Delineate watershed area and subbasins
2. Determine potential recharge from empirical relationships
3. Calculate runoff for each subbasin
4. Potential recharge - runoff = subbasin recharge
5. Runoff = potential recharge to bolson

Rain Gauges Used for Recharge Analysis

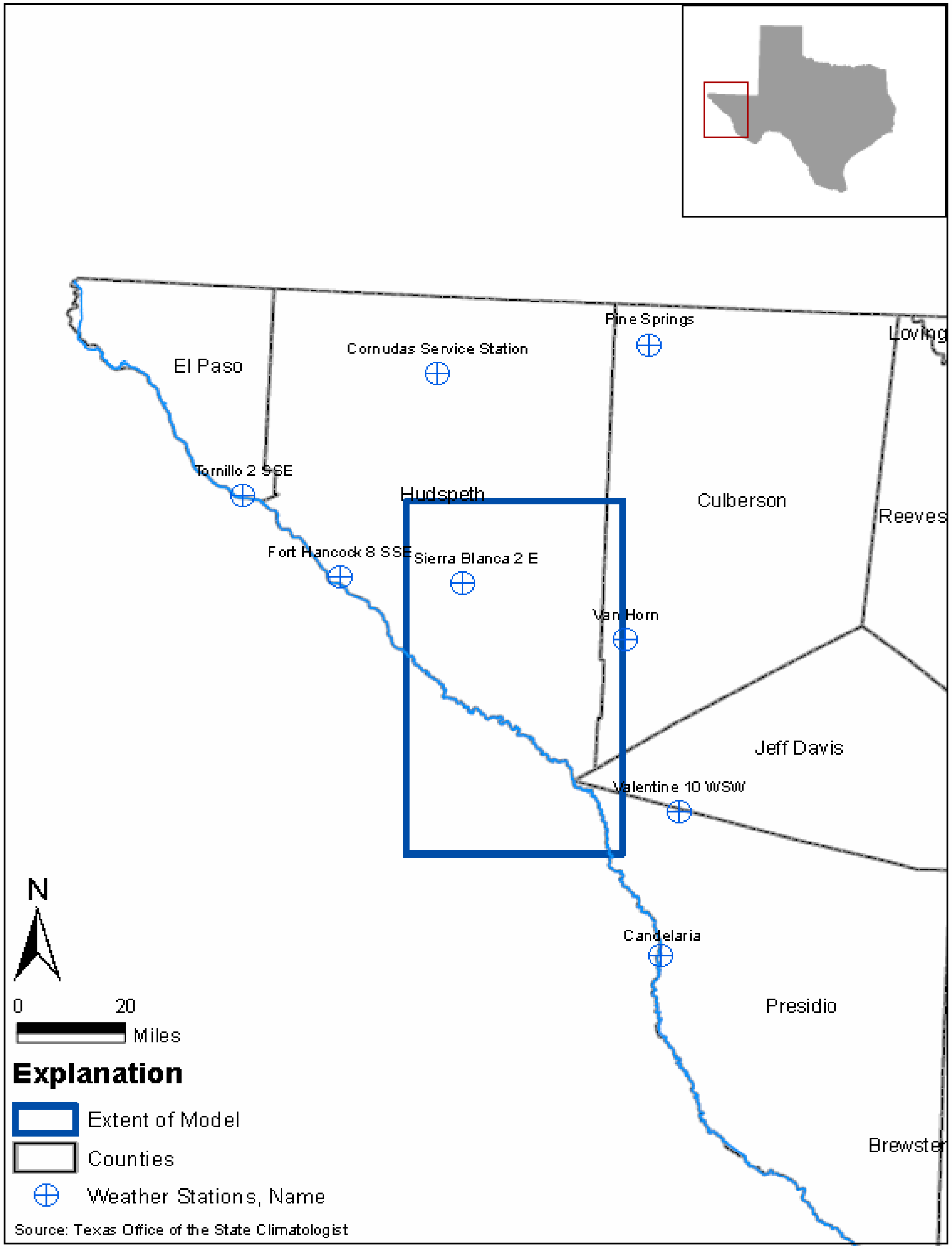
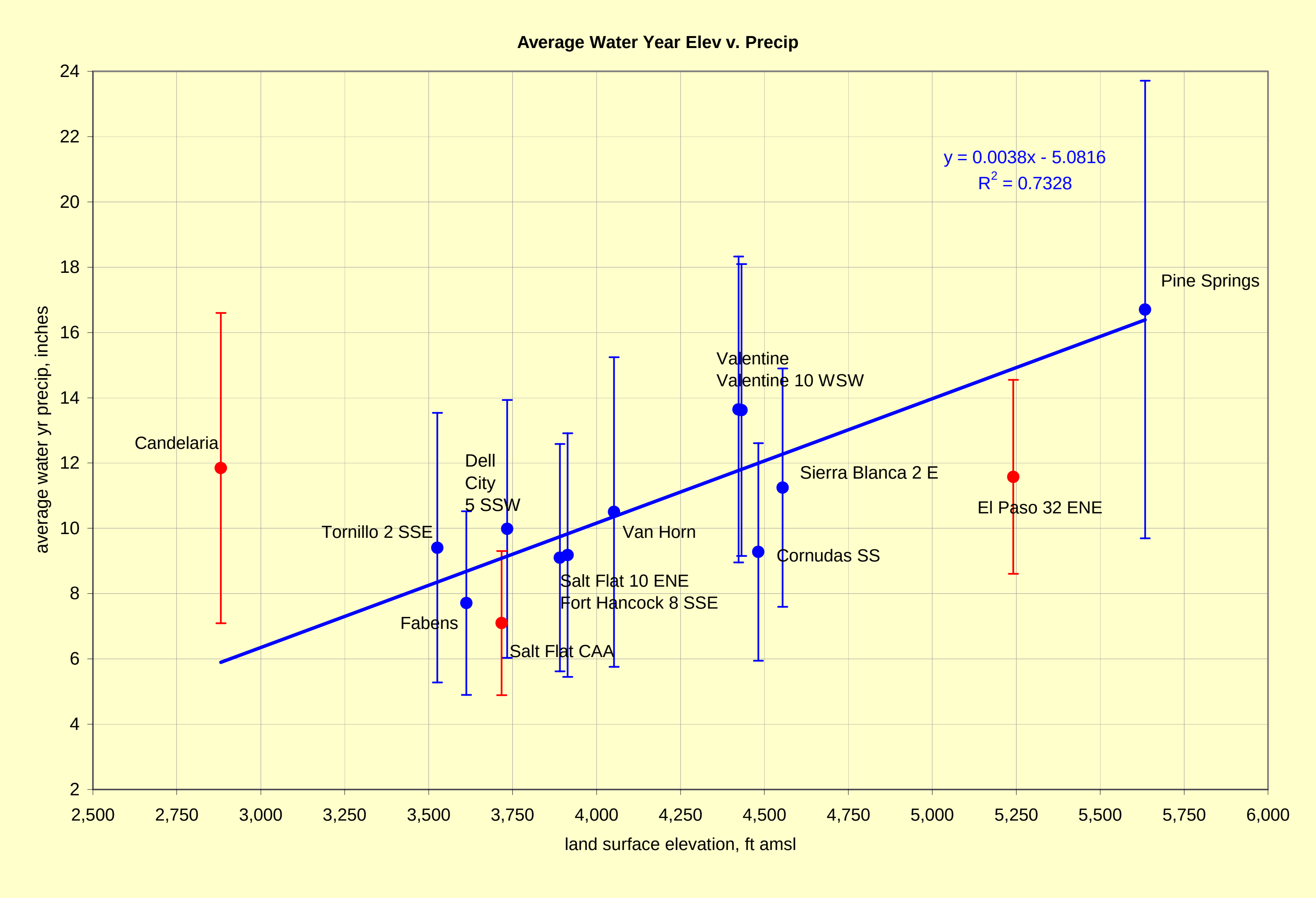
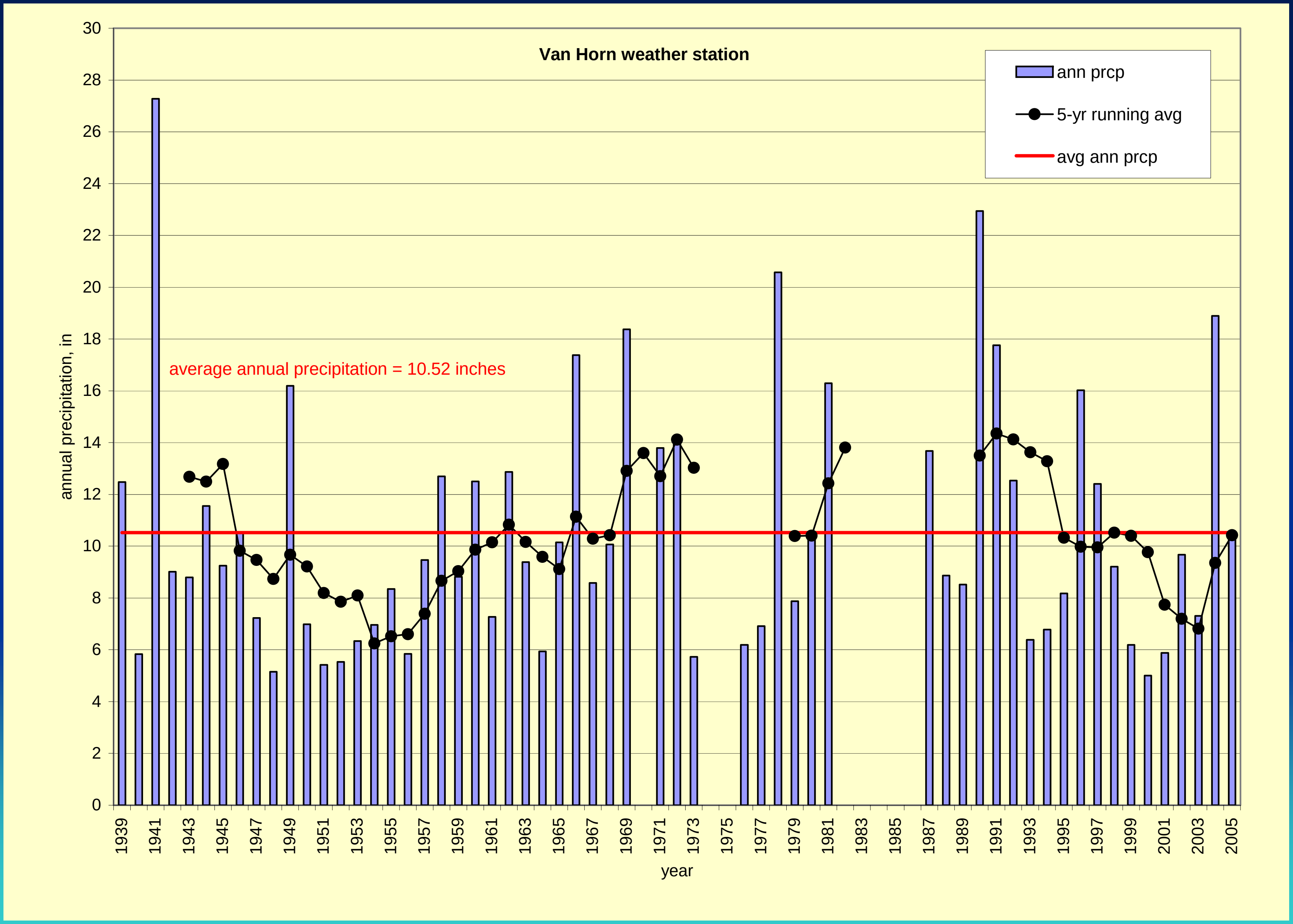


Figure 4.1.13 Location of Rain Gages Used for Recharge Analysis

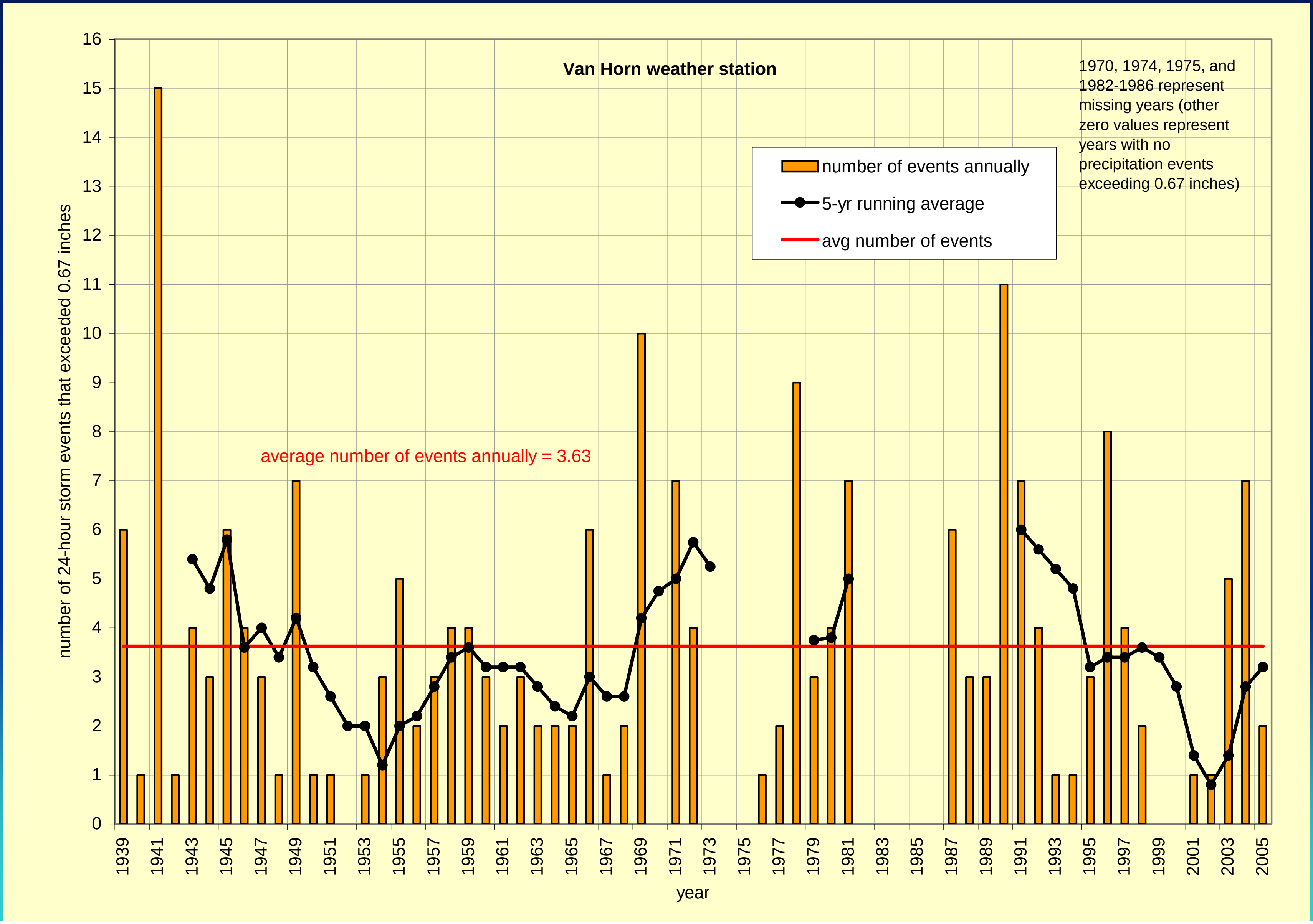
PRECIPITATION VERSUS ELEVATION



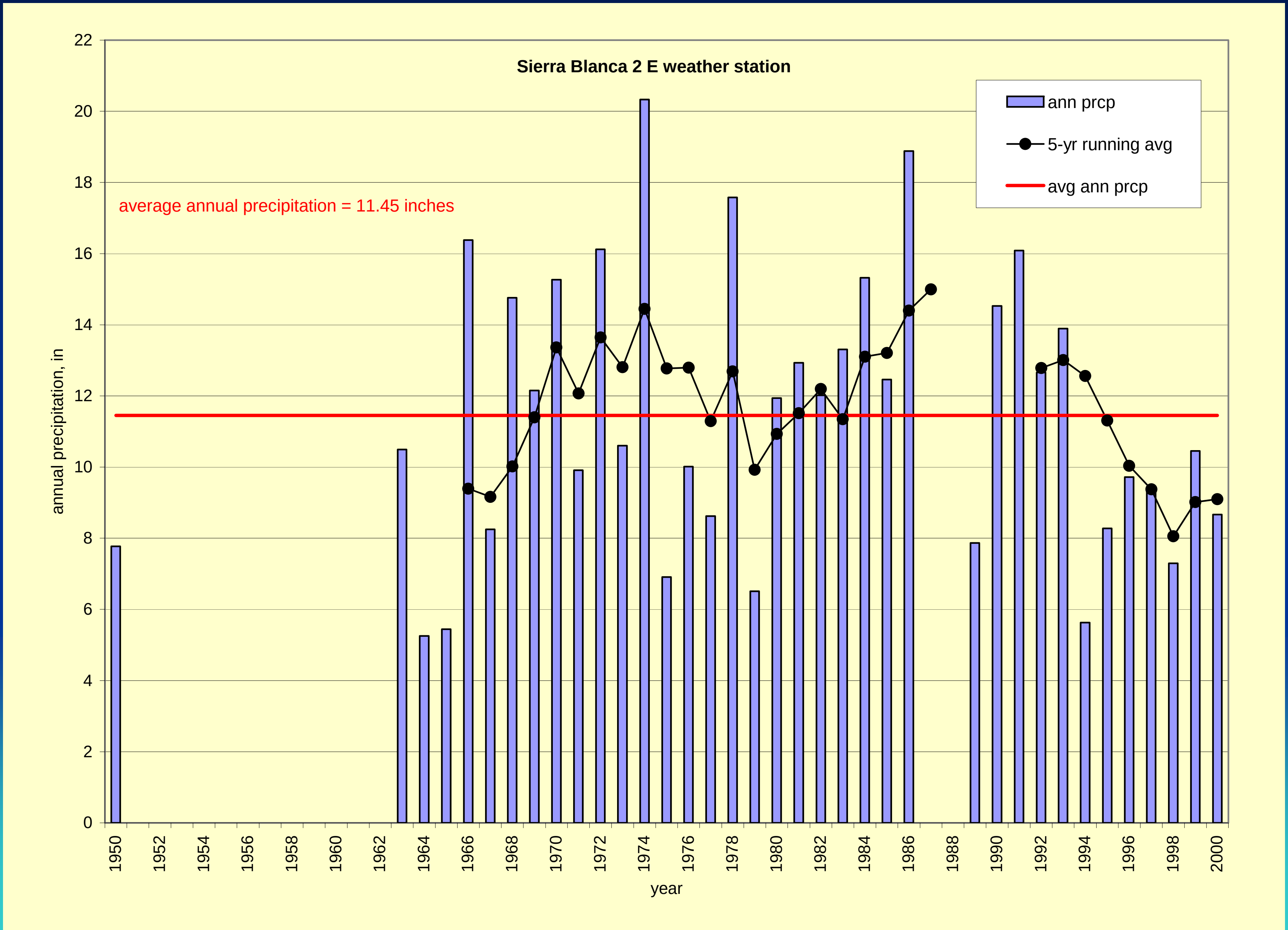
ANNUAL PRECIPITATION FOR PERIOD OF RECORD (1939 – 2005) FOR VAN HORN WEATHER STATION



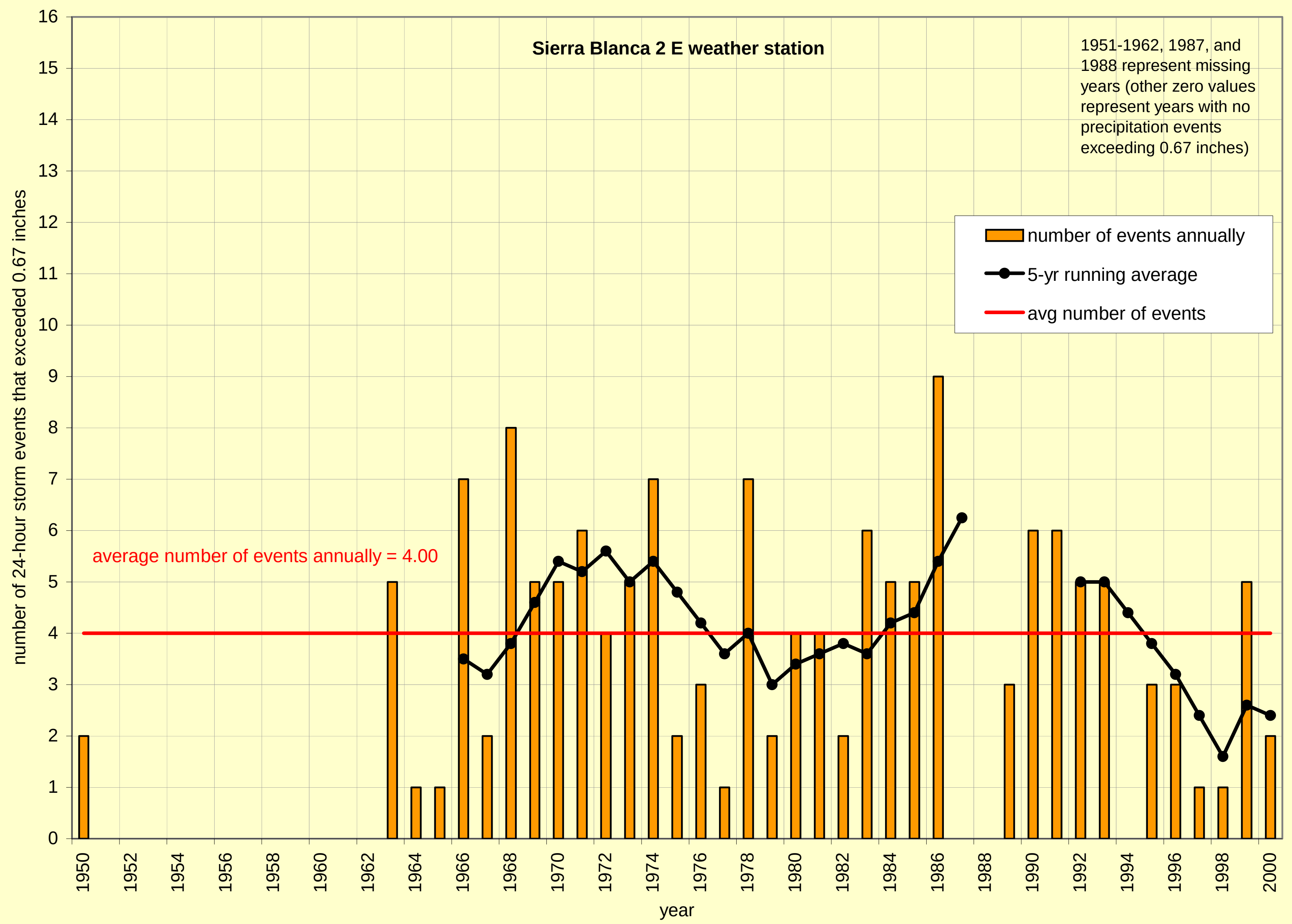
NO. OF POTENTIAL RUNOFF-GENERATING EVENTS AT VAN HORN WEATHER STATION (1939-2005)



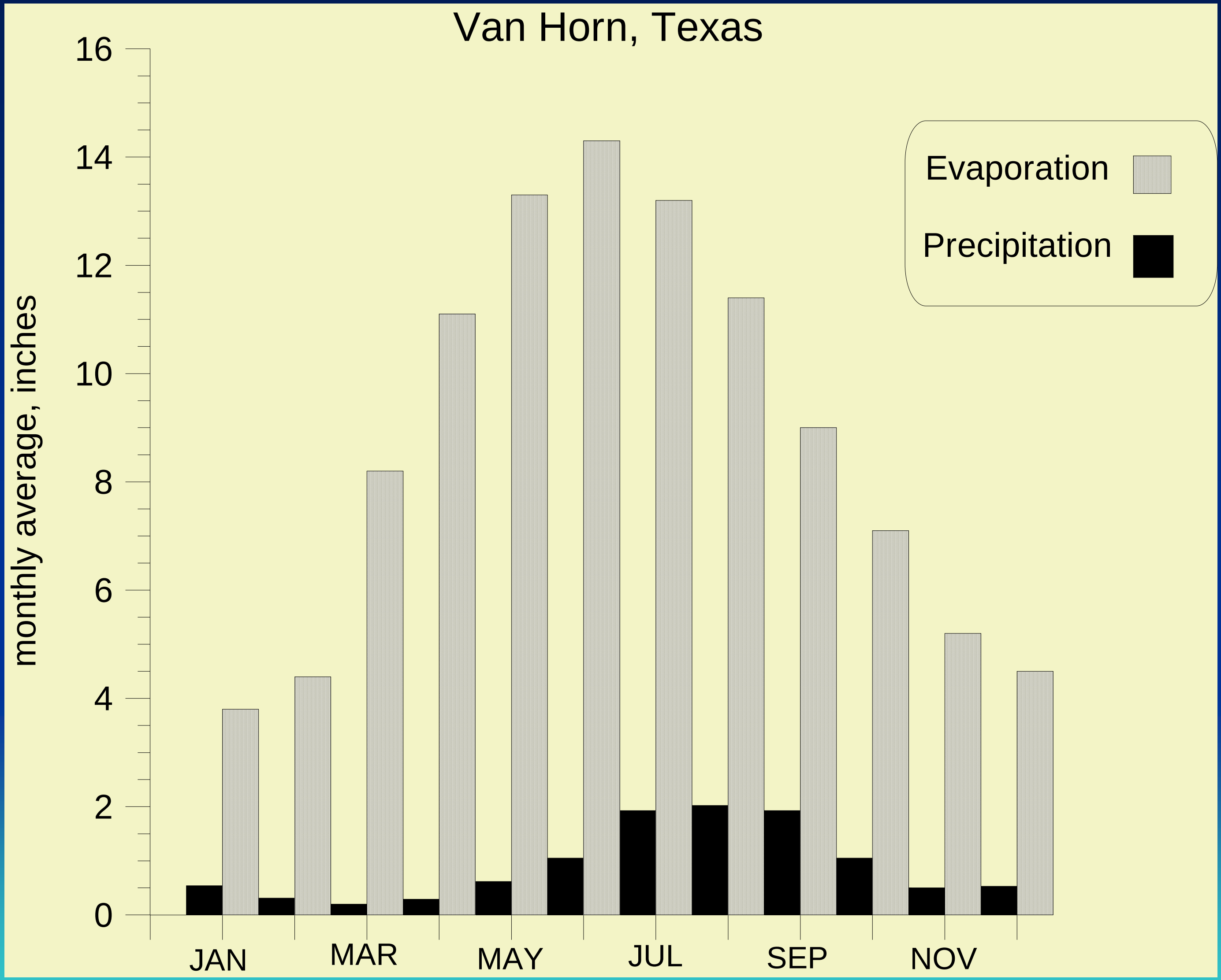
ANNUAL PRECIPITATION FOR PERIOD OF RECORD (1950 – 2000) FOR SIERRA BLANCA 2E WEATHER STATION



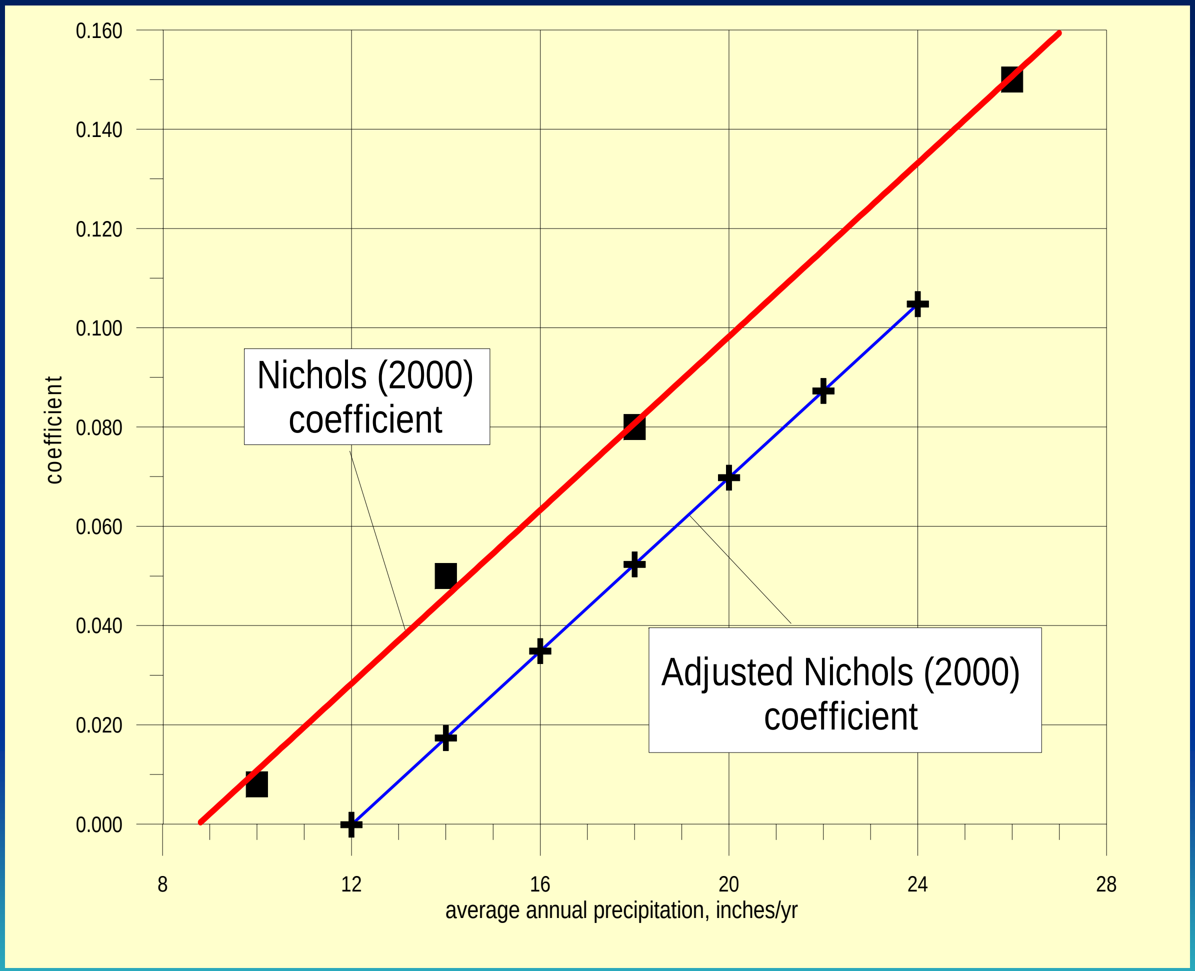
NO. OF POTENTIAL RUNOFF-GENERATING EVENTS AT SIERRA BLANCA 2E WEATHER STATION (1950-2000)



EVAPORATION EXCEEDS PRECIPITATION INDICATING RECHARGE OCCURS FROM INFILTRATION OF STORM RUNOFF



POTENTIAL RECHARGE



- Coefficient based on multiple linear regression model
- Accounts for evapotranspiration

pptn in/yr	potential recharge in/yr
12	0.00
16	0.56
20	1.40

Distribution of Potential Recharge

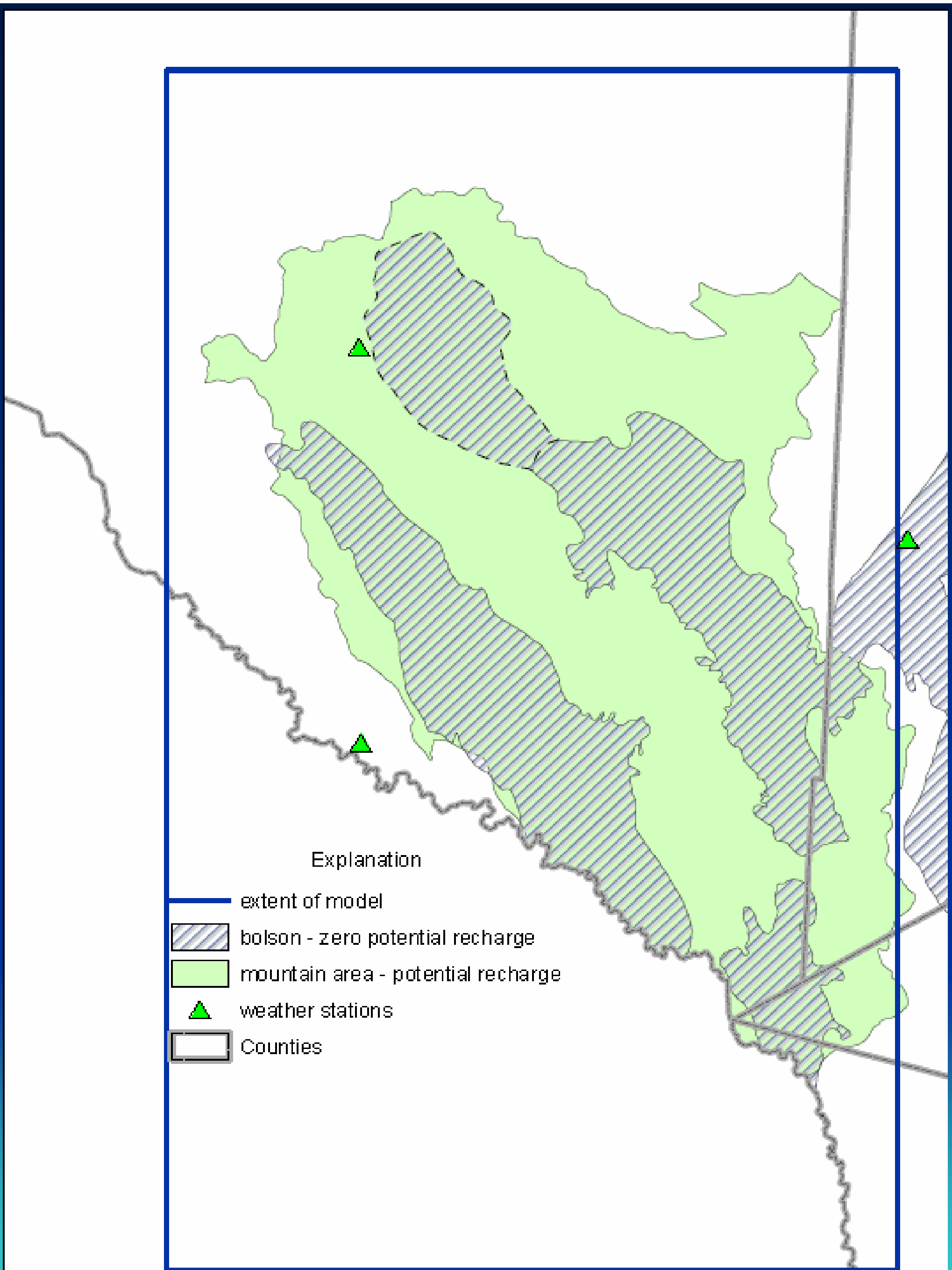


Figure 4.4.2 Distribution of Potential Recharge

Calculation of Runoff

$$Q = \frac{(P-I_a)^2}{(P-I_a)+S}$$

Q = runoff

P = precipitation event

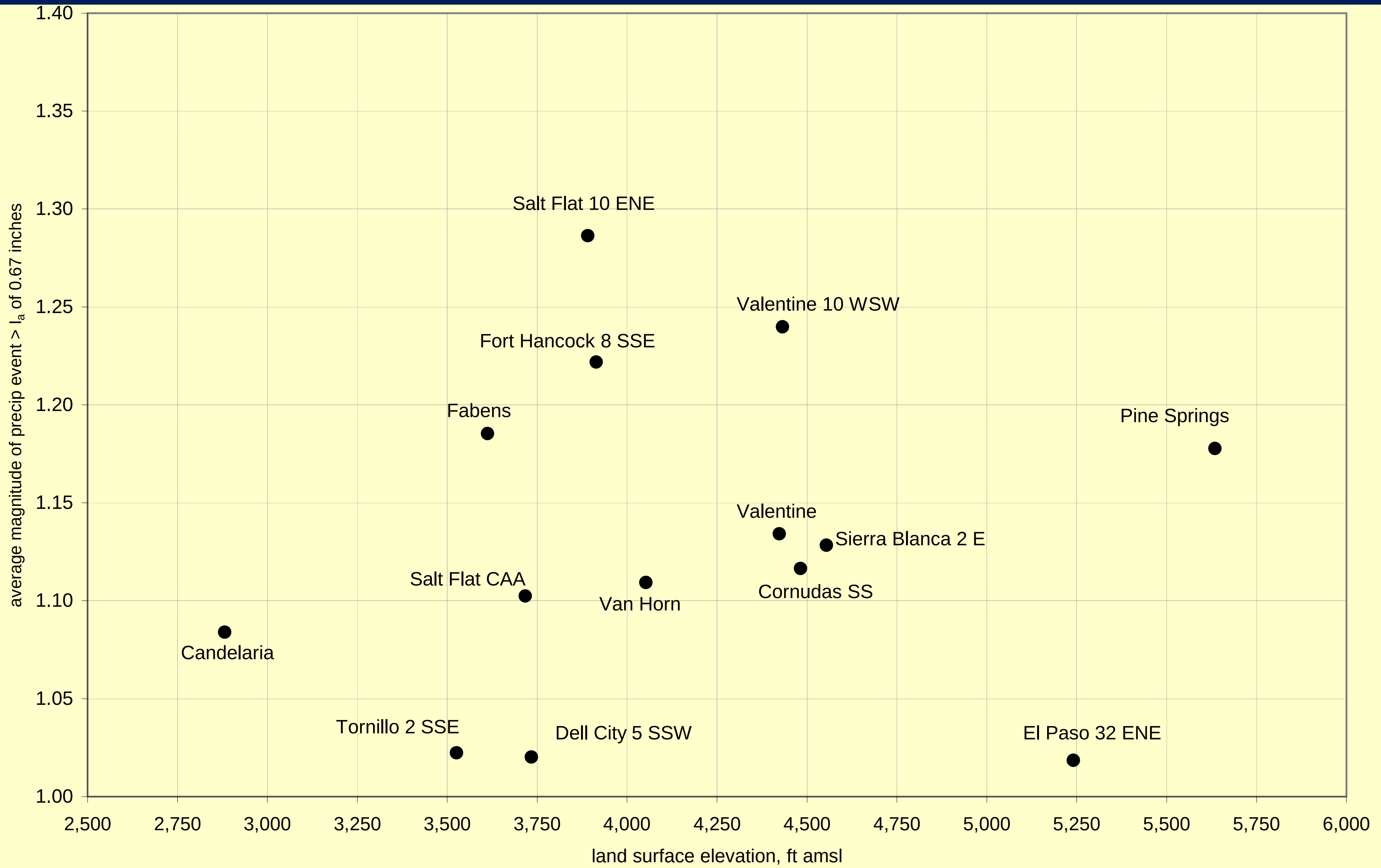
(freq. scaled to elevation)

S = potential max. retention after runoff begins

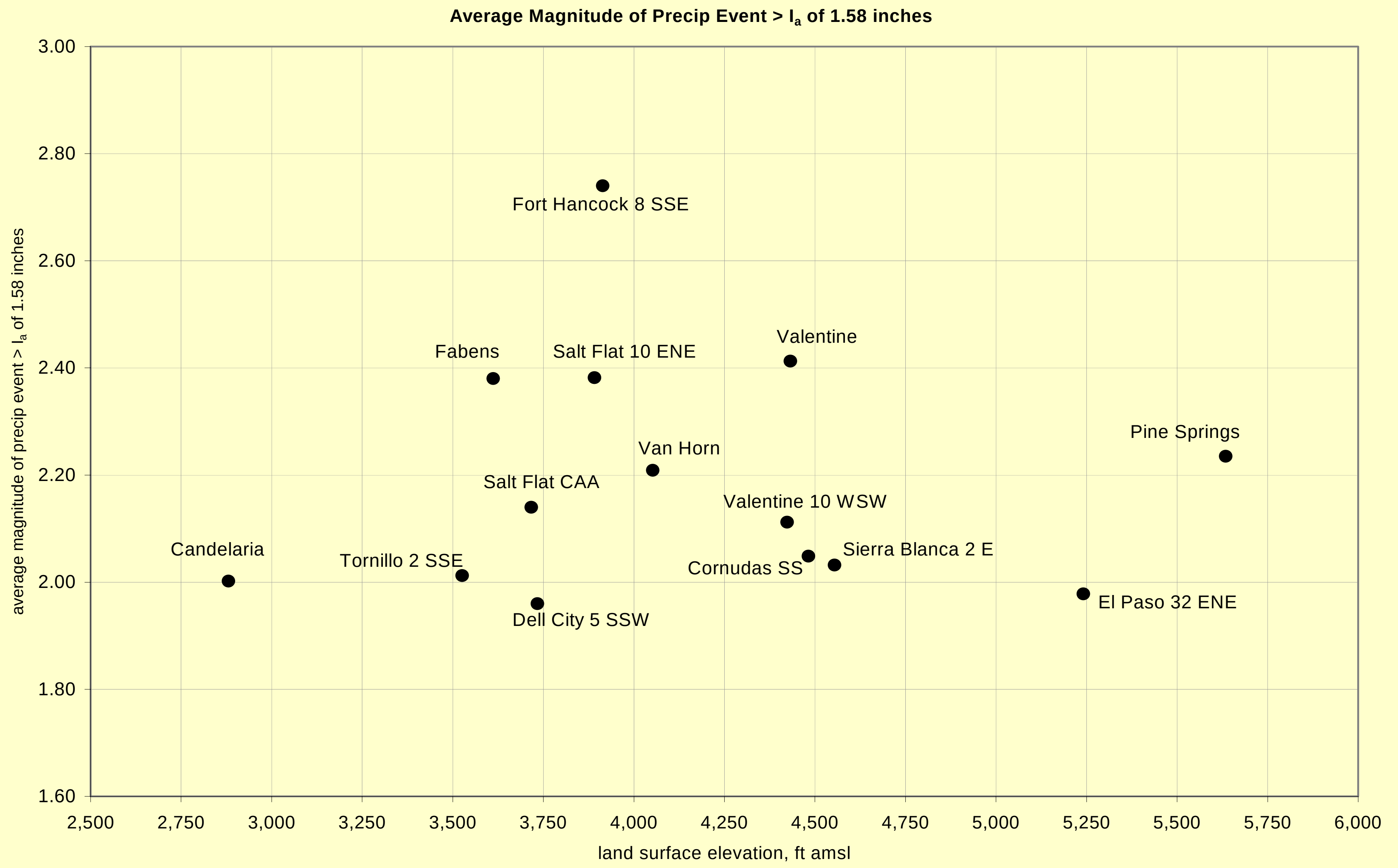
I_a = water retained

- SCS Method
- Based on precipitation events rather than total annual precipitation
- Accounts for vegetation type and density, and hydrologic characteristics of soil or rock

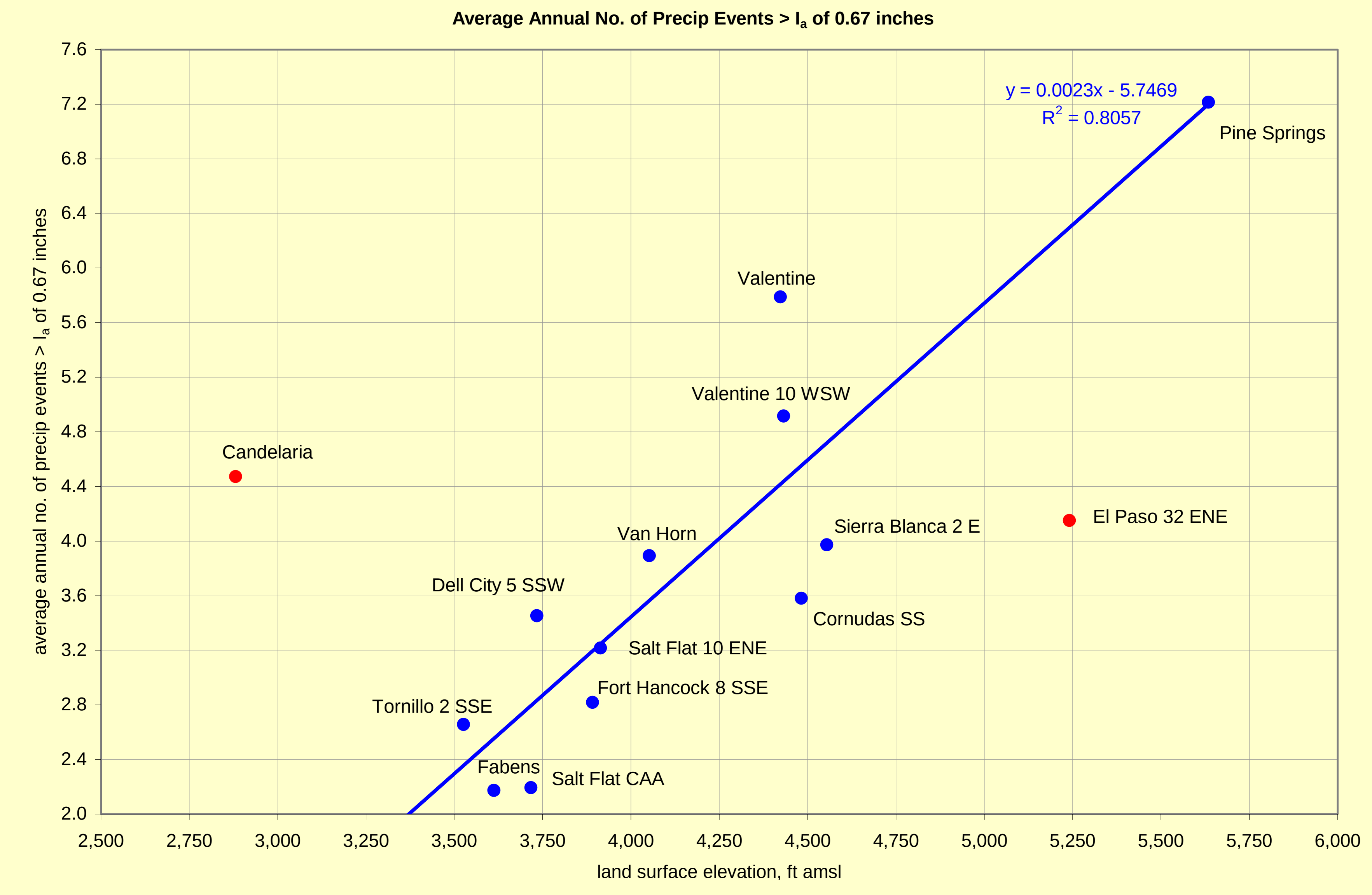
MAGNITUDE OF 24-HR PRECIPITATION EVENTS VERSUS ELEVATION



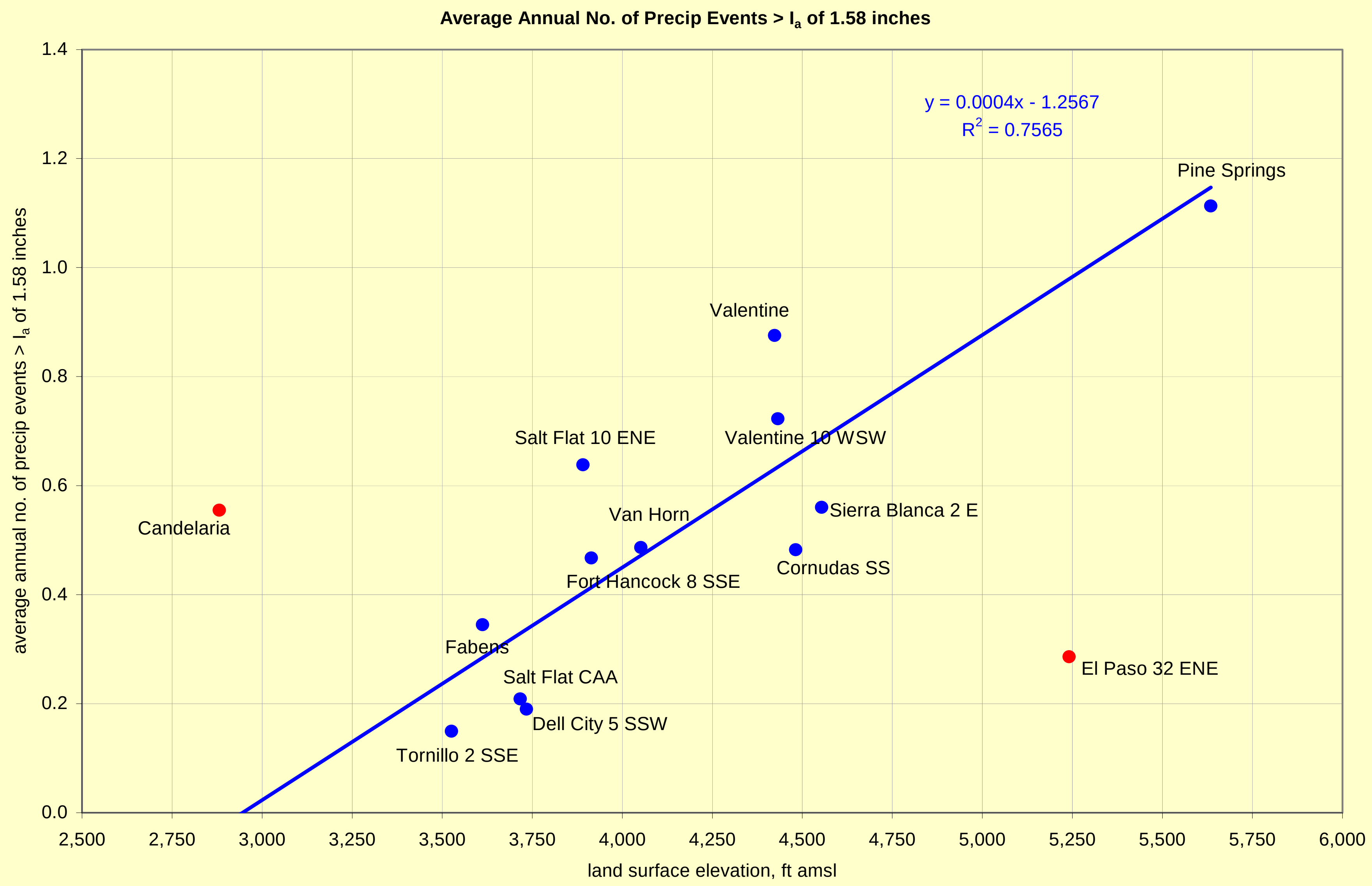
MAGNITUDE OF 24-HR PRECIPITATION EVENTS VERSUS ELEVATION



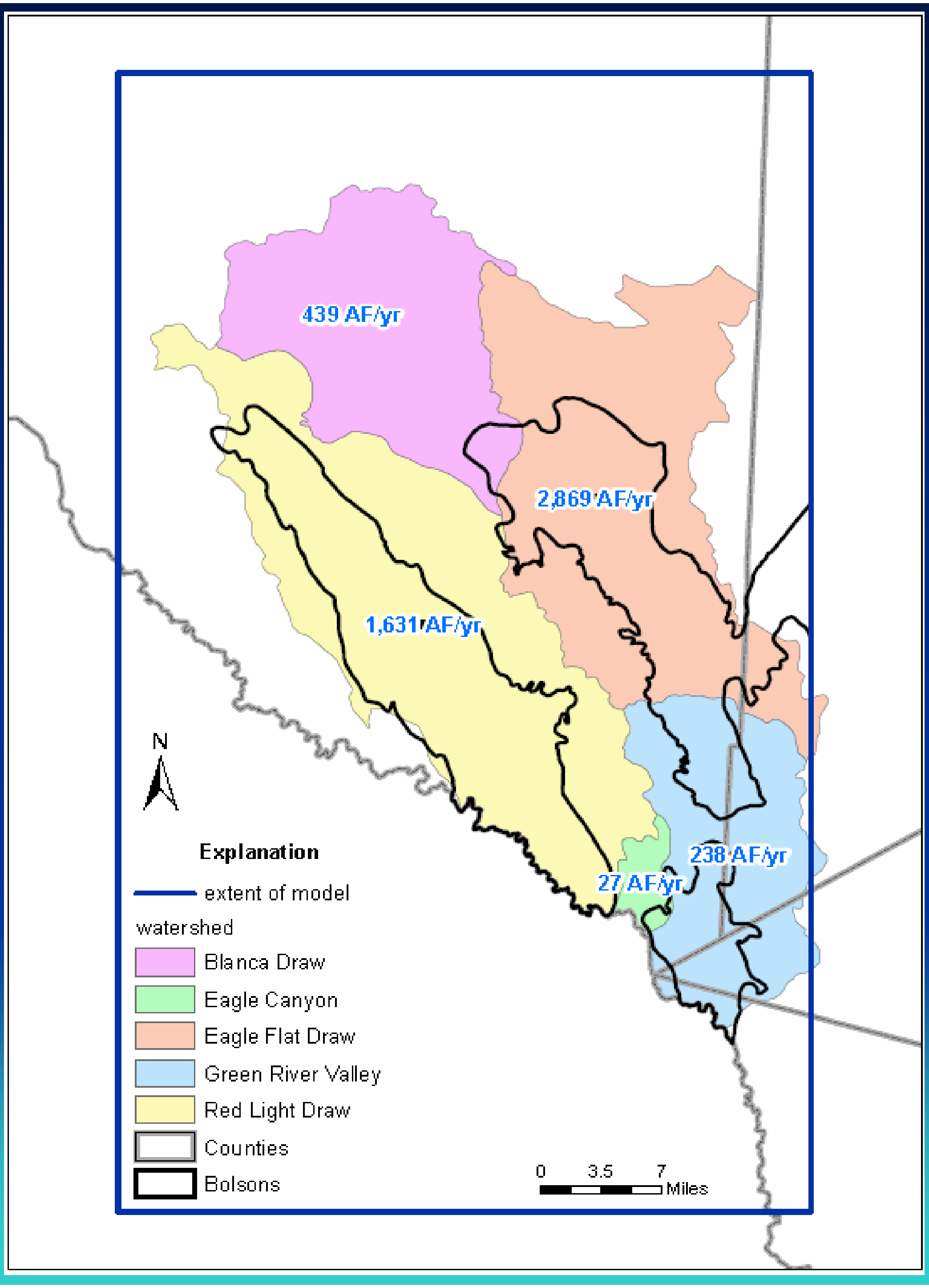
FREQUENCY OF 24-HR PRECIPITATION EVENTS VERSUS ELEVATION



FREQUENCY OF 24-HR PRECIPITATION EVENTS VERSUS ELEVATION



DISTRIBUTION OF RECHARGE



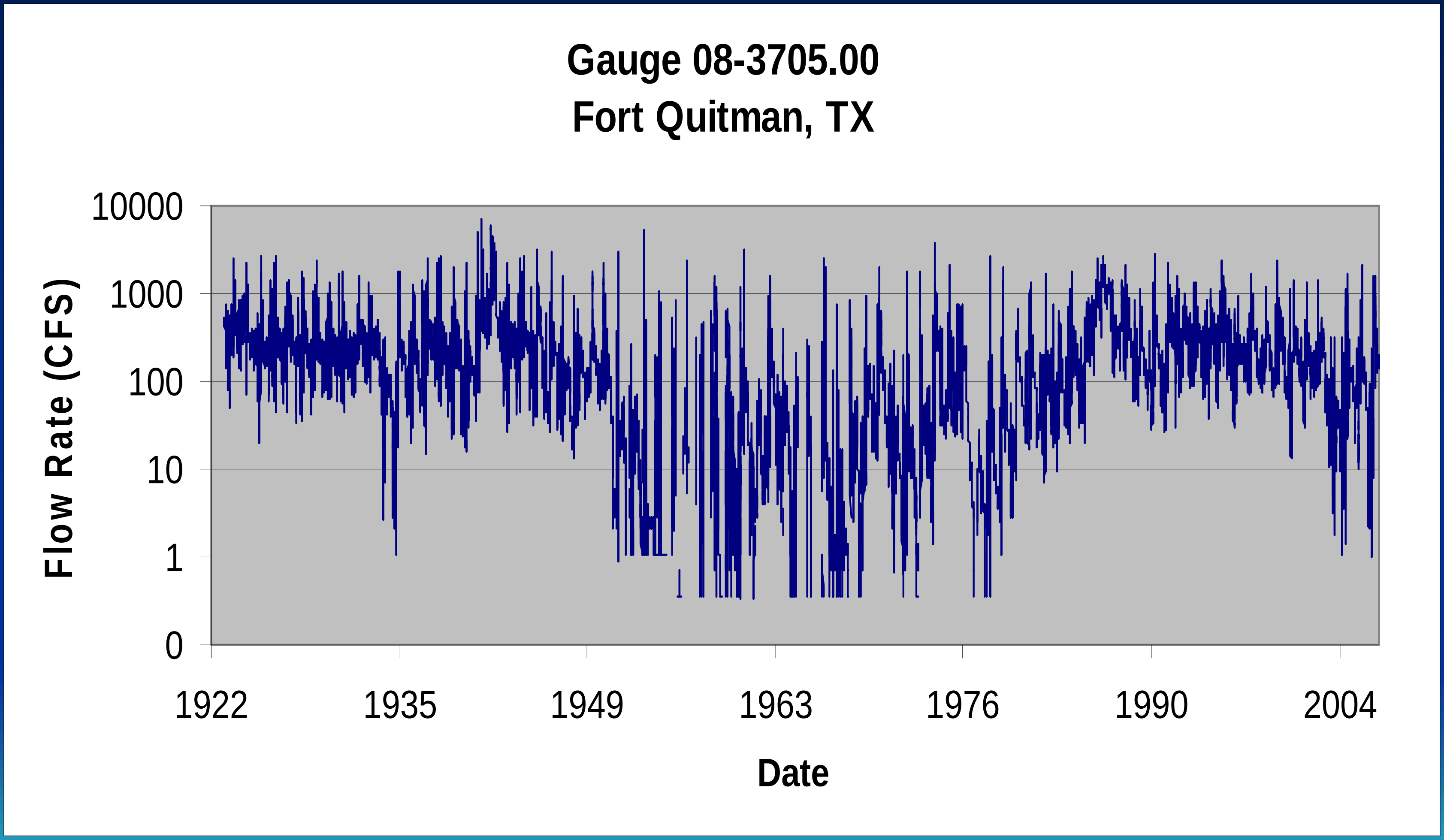
RESULTS OF RECHARGE ANALYSIS USING RUNOFF REDISTRIBUTION METHOD

PARAMETER	UNIT	RED LIGHT DRAW	GREEN RIVER VALLEY	EAGLE FLAT DRAW	BLANCA DRAW	EAGLE CANYON	STUDY AREA
area	acres	227,430	103,210	200,850	131,380	9,530	672,400
total precipitation	ac-ft/yr	203,640	87,780	209,740	125,130	7,070	633,360
estimated areal recharge to mountain block	ac-ft/yr	1,190	80	2,380	130	0	3,780
runoff from mountain block	ac-ft/yr	1,470	560	1,630	1,030	90	4,780
estimated recharge along bolson fringe[a]	ac-ft/yr	441	168	489	309	27	1,434
total estimated recharge to watershed area encompassing bolson	ac-ft/yr	1,631	248	2,869	439	27	5,214
	in/yr	0.09	0.03	0.17	0.04	0.03	0.09
total precipitation that becomes recharge	percent	0.8	0.3	1.4	0.4	0.4	0.8

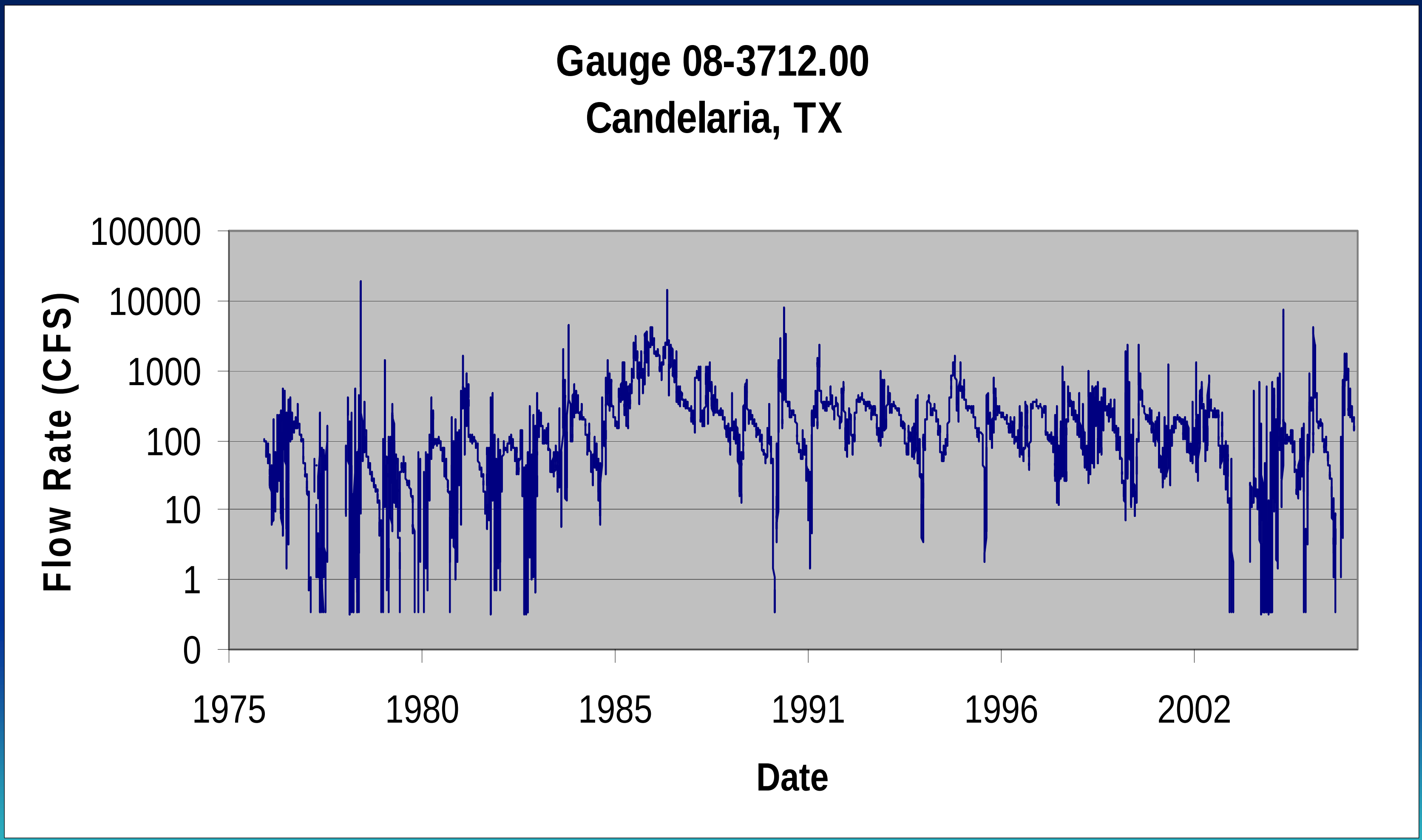
COMPARISON OF RECHARGE METHODS

	Estimated recharge (af/yr)		
method	**Red Light Draw**	**Green River Valley**	**Eagle Flat Draw**
previous work (Table 4.4.1)	280 to 2,000	120 to 1,000	430 to 4,119
Darcy flux check (this study)	915 to 4,576	1,365 to 6,823	53 to 266
modified runoff redistribution (this study)	1,631	248	2,869

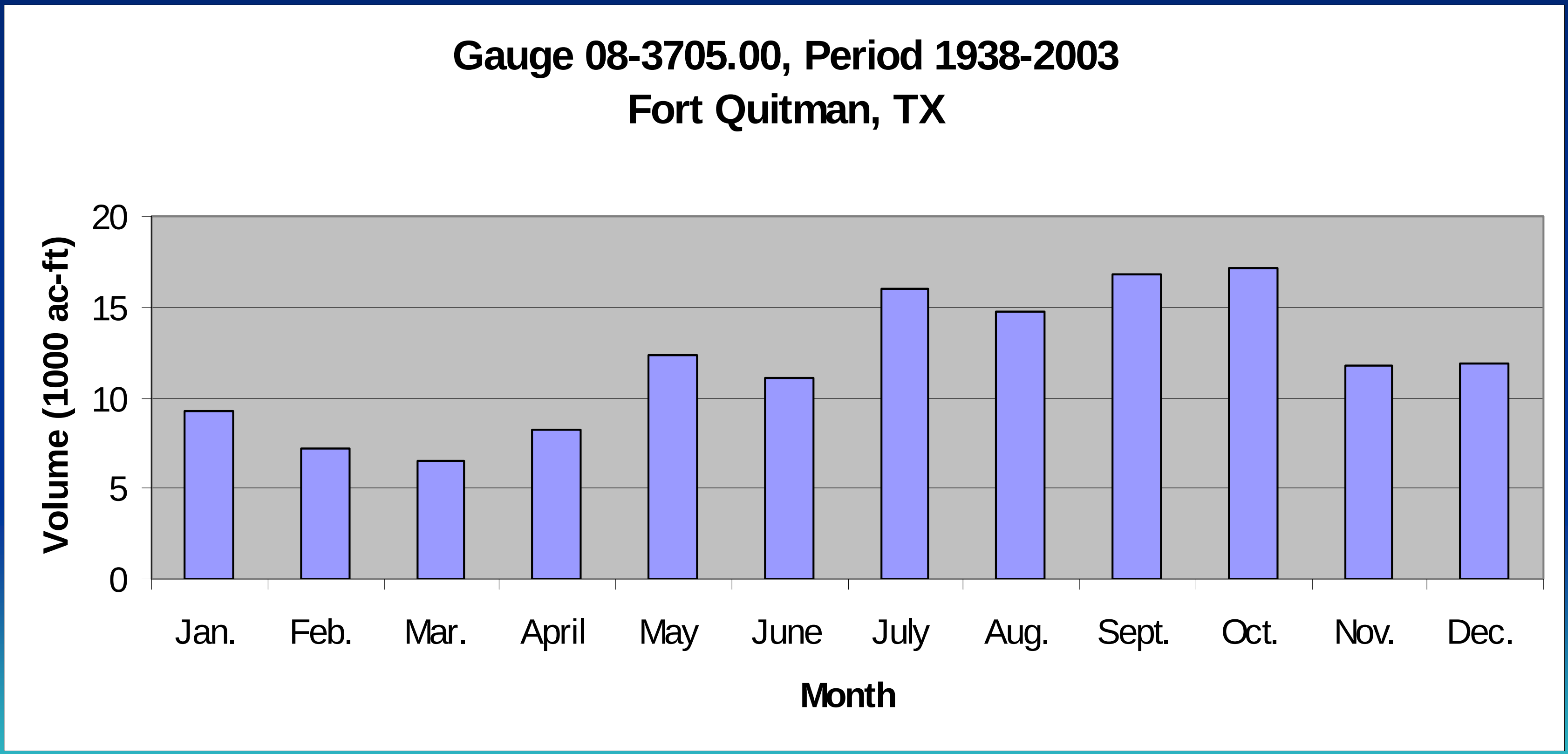
Daily Streamflow Gauging Data



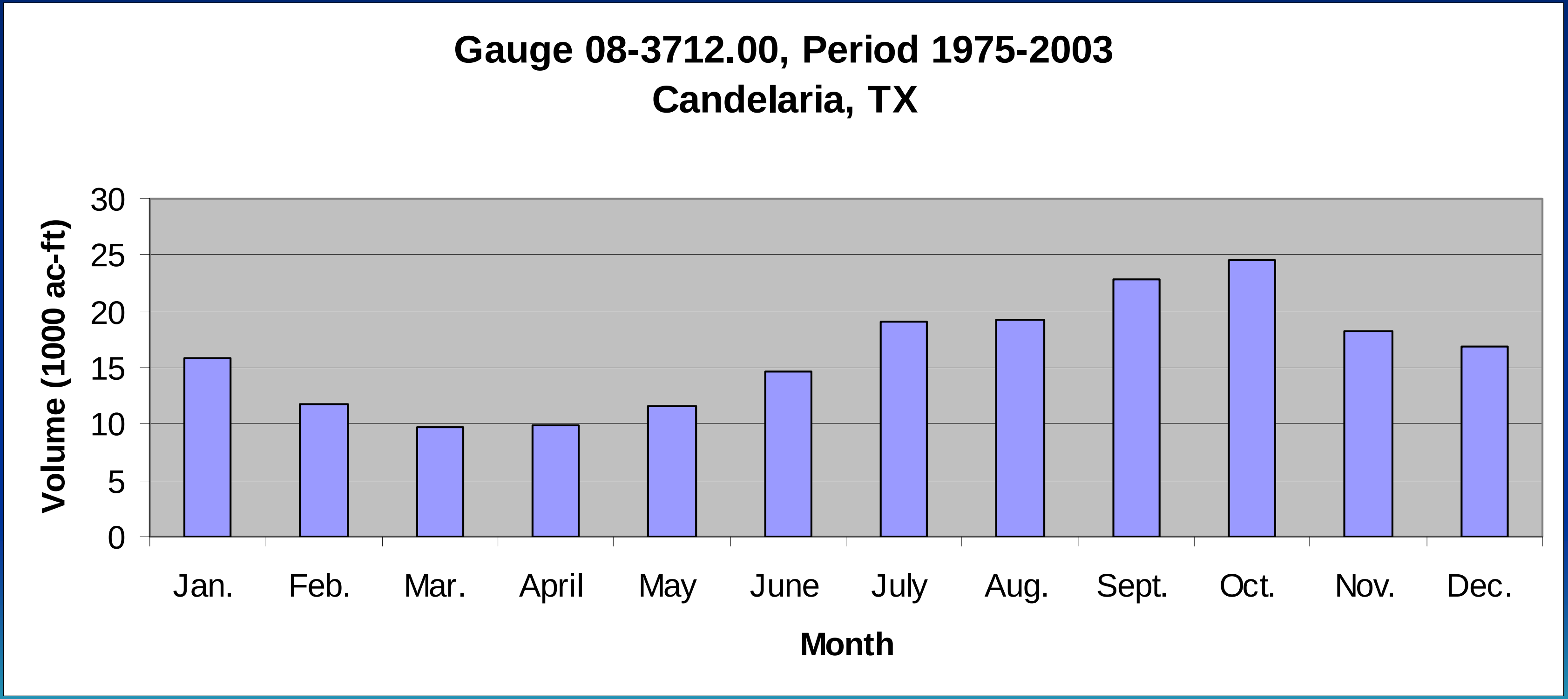
Daily Streamflow Gauging Data



Streamflow Gauging Data
Mean of Monthly



Streamflow Gauging Data
Mean of Monthly



Springs

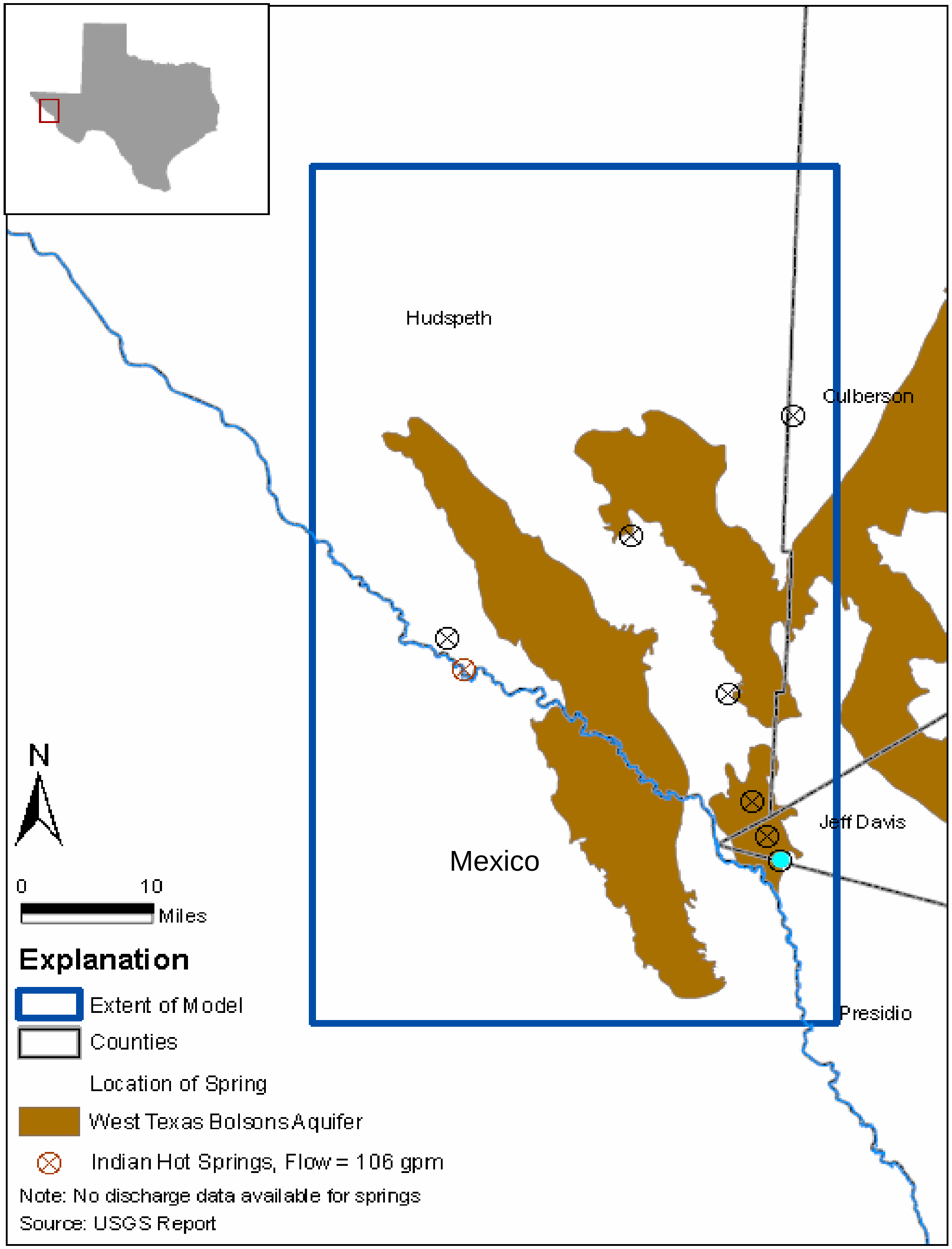


Figure 4.2.4 - Location and Approximate Flow of Springs

Hydraulic Properties

- Bolsons (1)
  - 2 from drillers log (outside model area)
  - 1 pump test from BEG Low-Level studies (Darling)

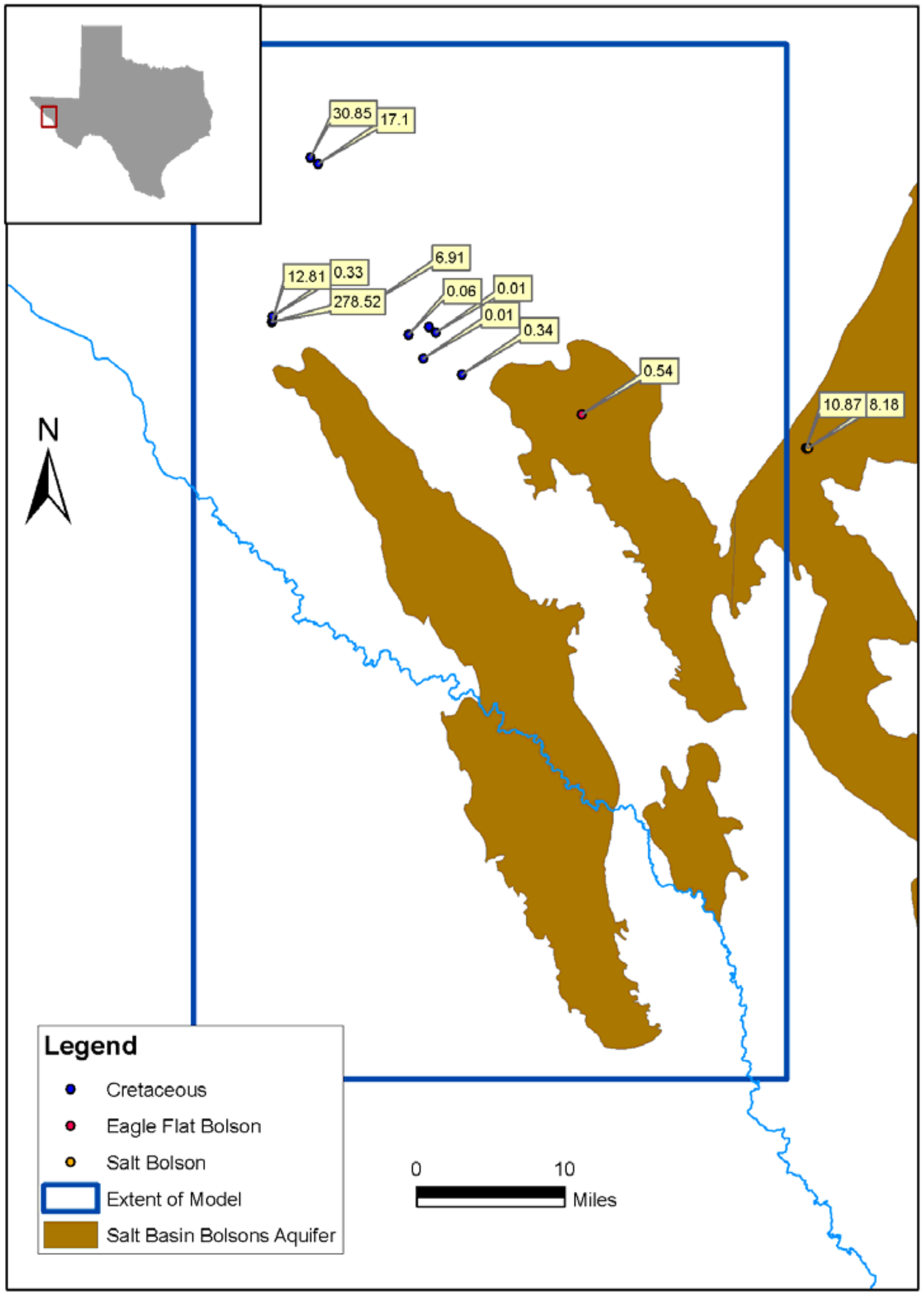
- Cretaceous (11)
  - 6 from drillers log
  - 5 pump tests from BEG Low-Level studies (Darling)

1. Potential pump tests?
2. Potential Region E pump tests?

Hydraulic Properties

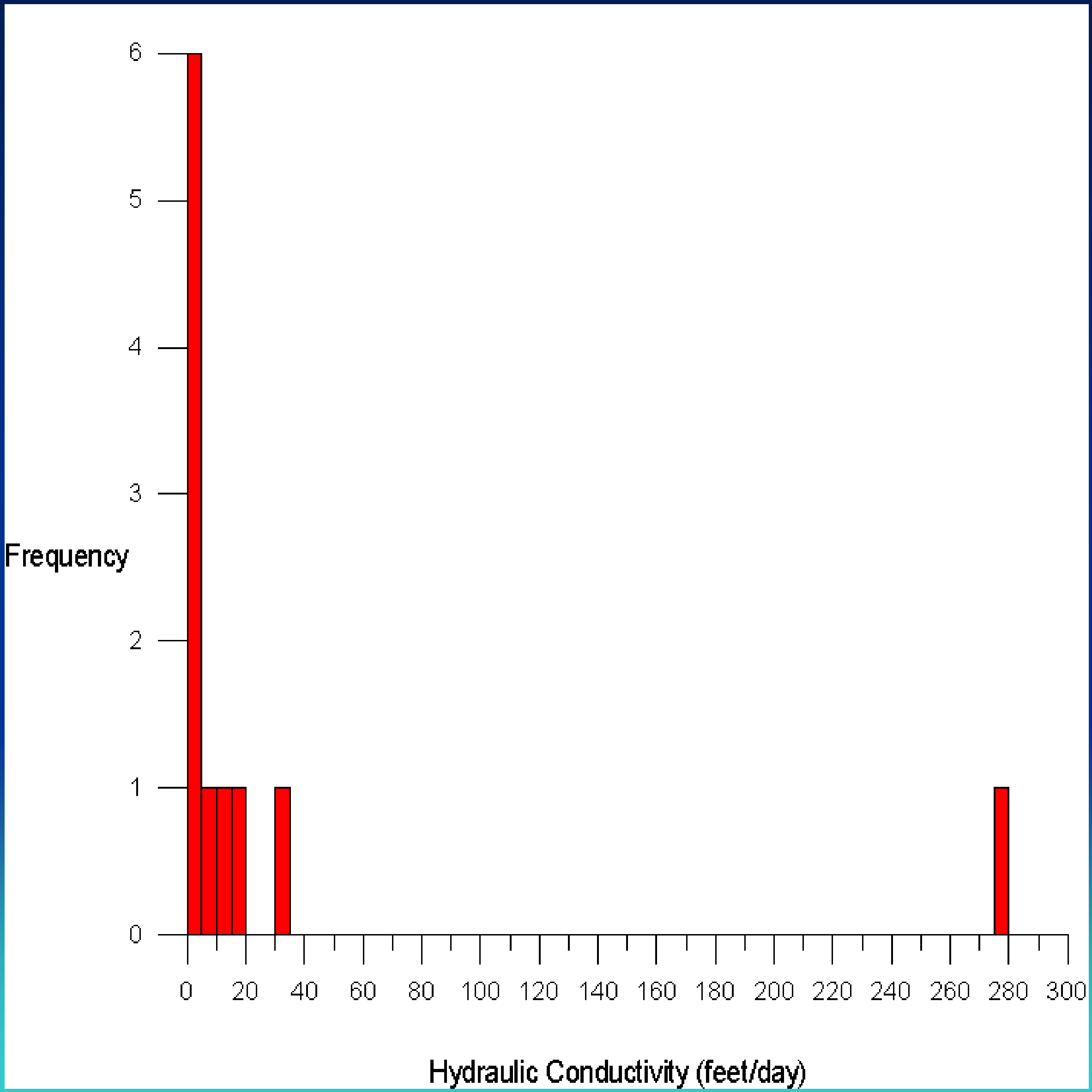
- NO S, Ss, Sy or porosity data
- NO Vertical hydraulic conductivity
- NO Anisotropy

Hydraulic Conductivity Data (feet/day)



Wells with Pumping Tests
With Estimated Hydraulic Conductivities in Feet/day

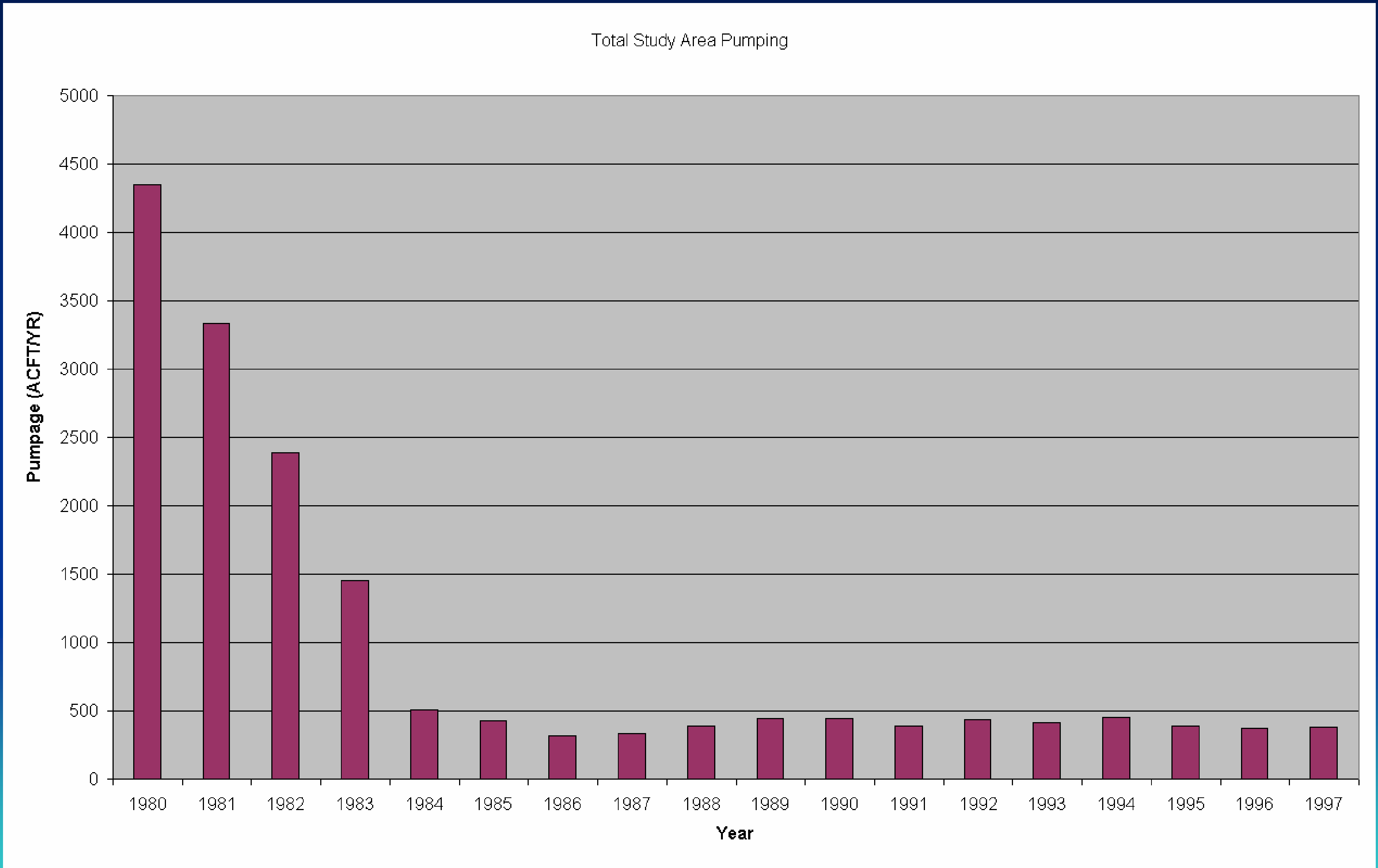
HISTOGRAM OF HYDRAULIC CONDUCTIVITY FOR CRETACEOUS ROCKS



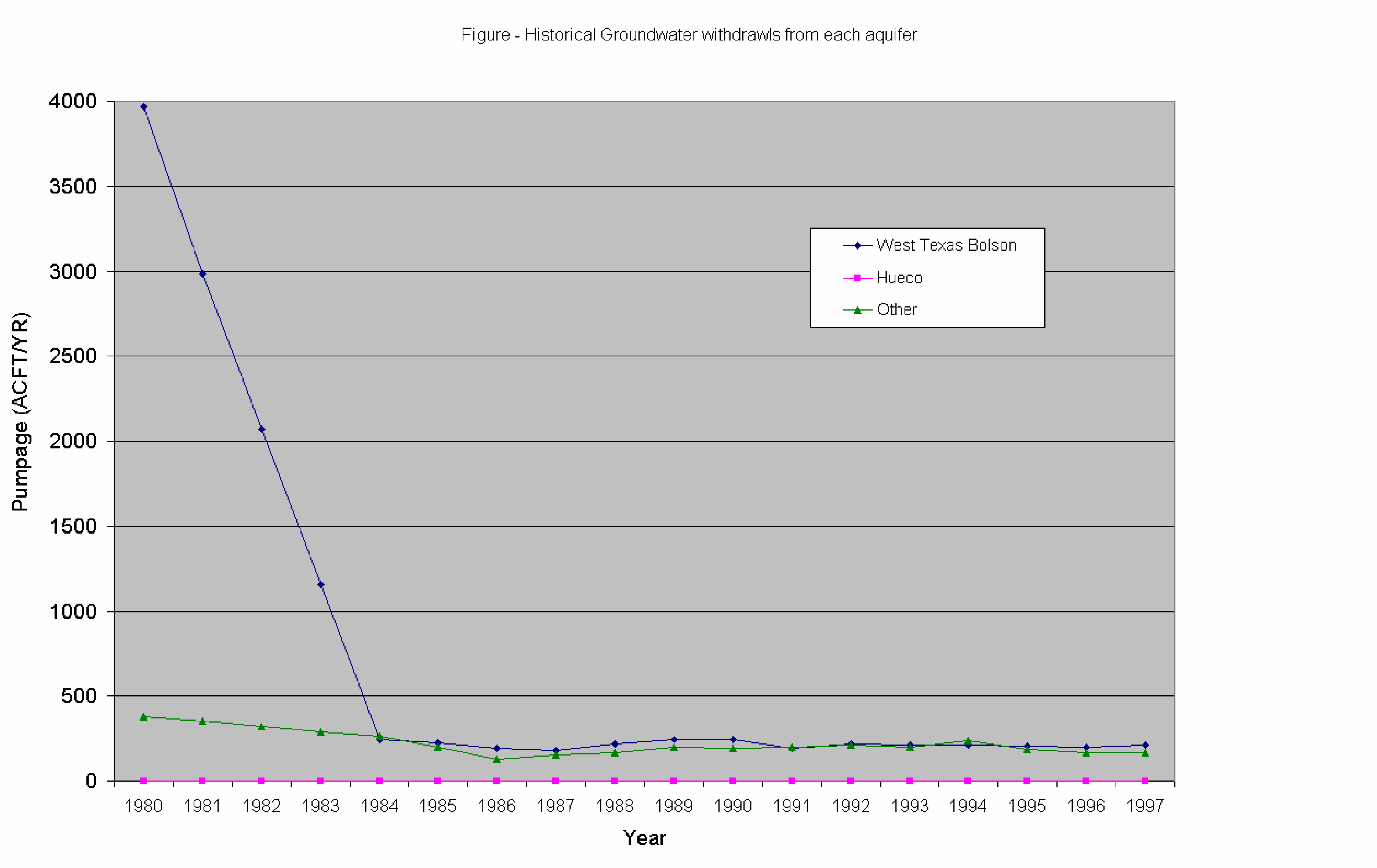
Pumping Data

- TWDB database is primary source of data
- Supplemental data from other source documents
- Pumpamatic

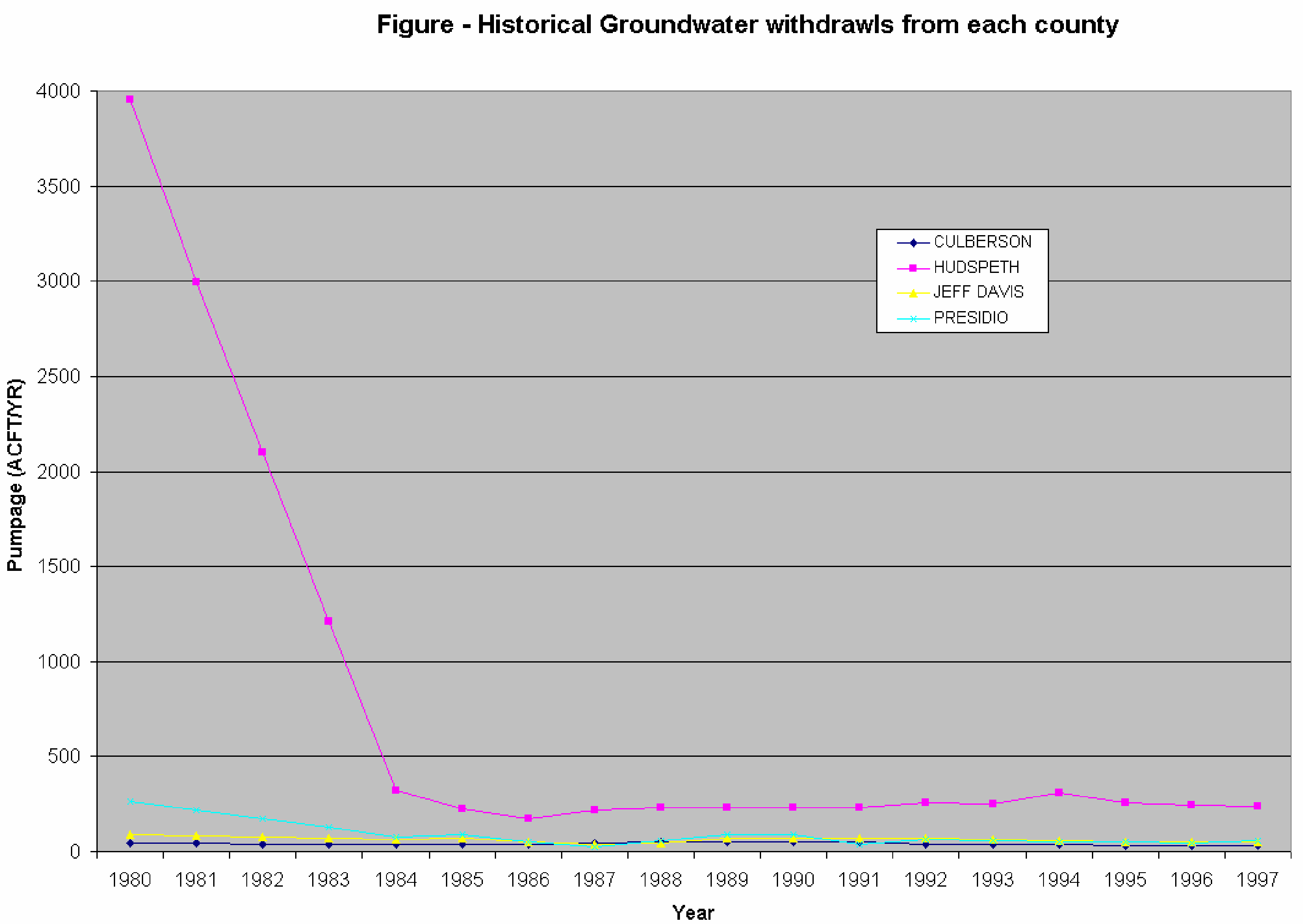
Total Pumping



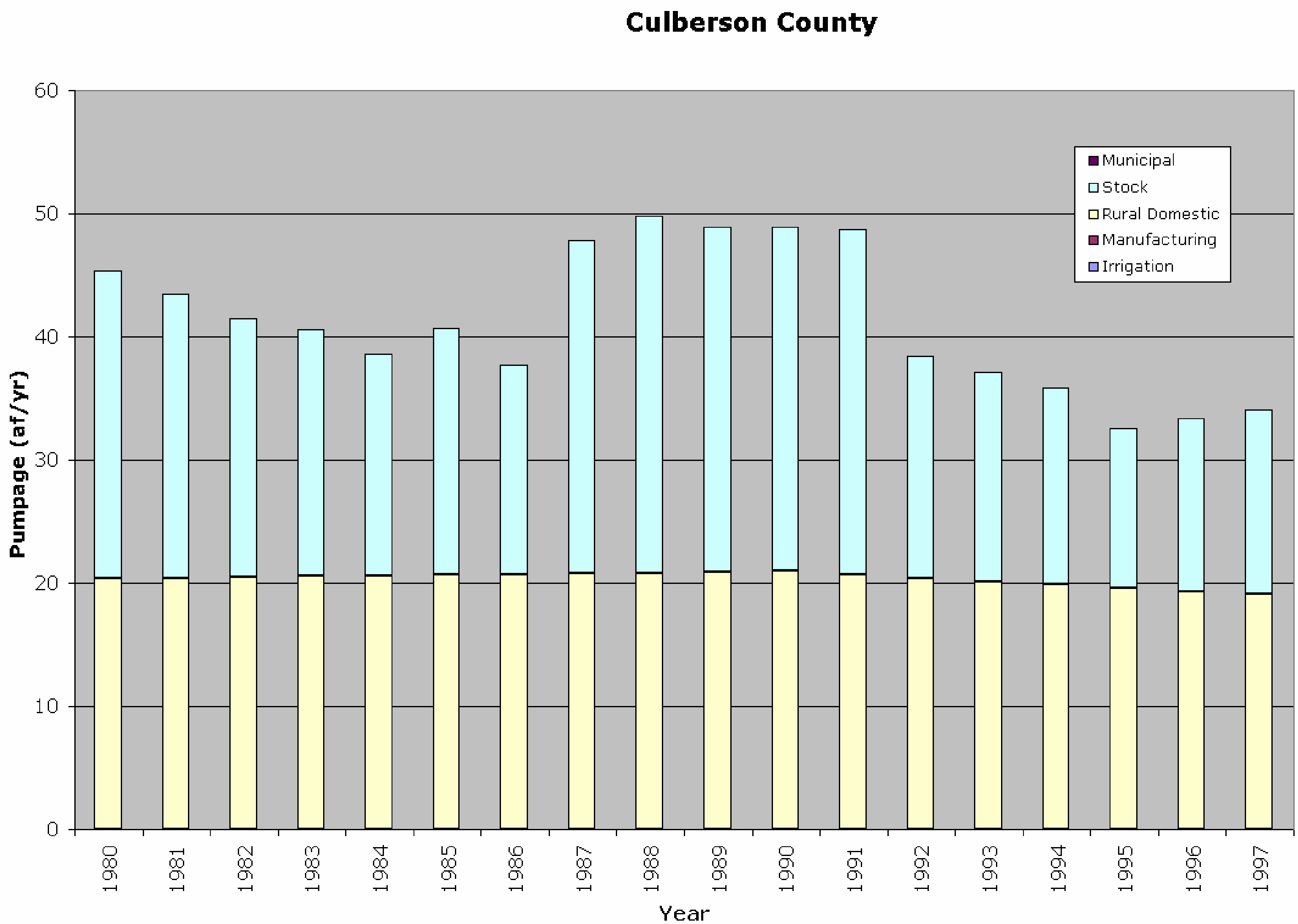
Pumping by Aquifer



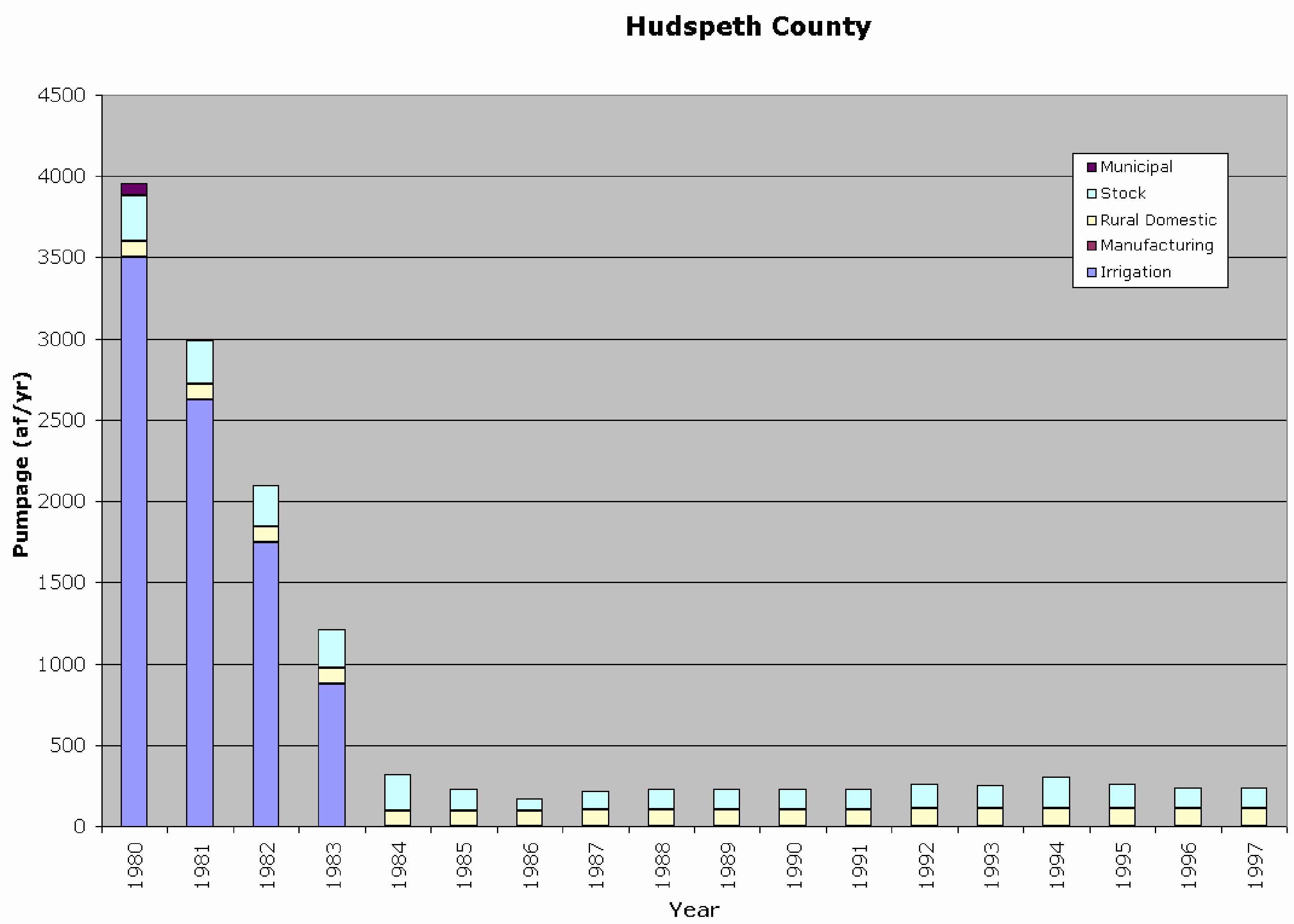
Total Pumping by County



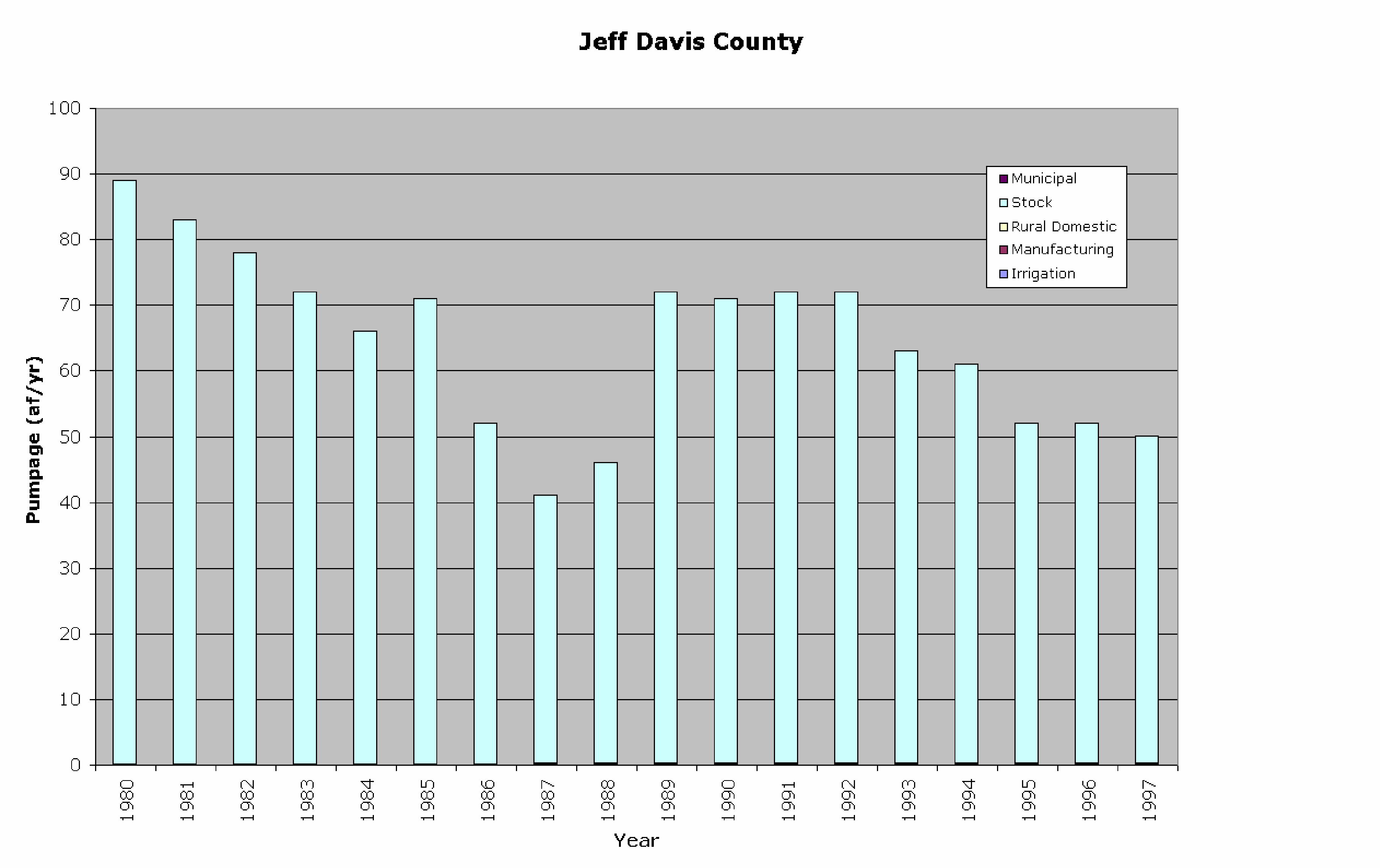
Culberson County



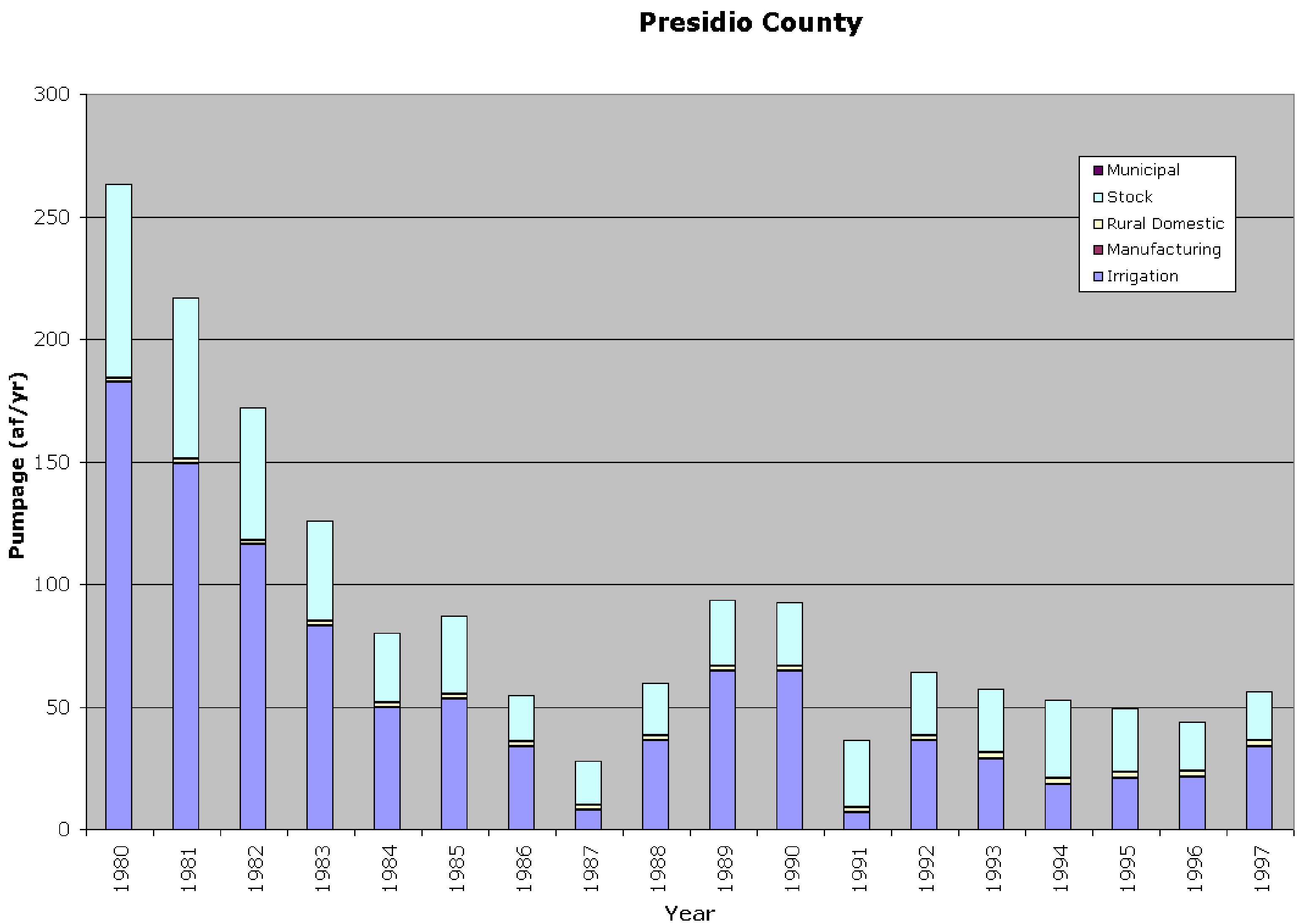
Hudspeth County



Jeff Davis County



Presidio County



Irrigated Agriculture
(1989 and 1994)

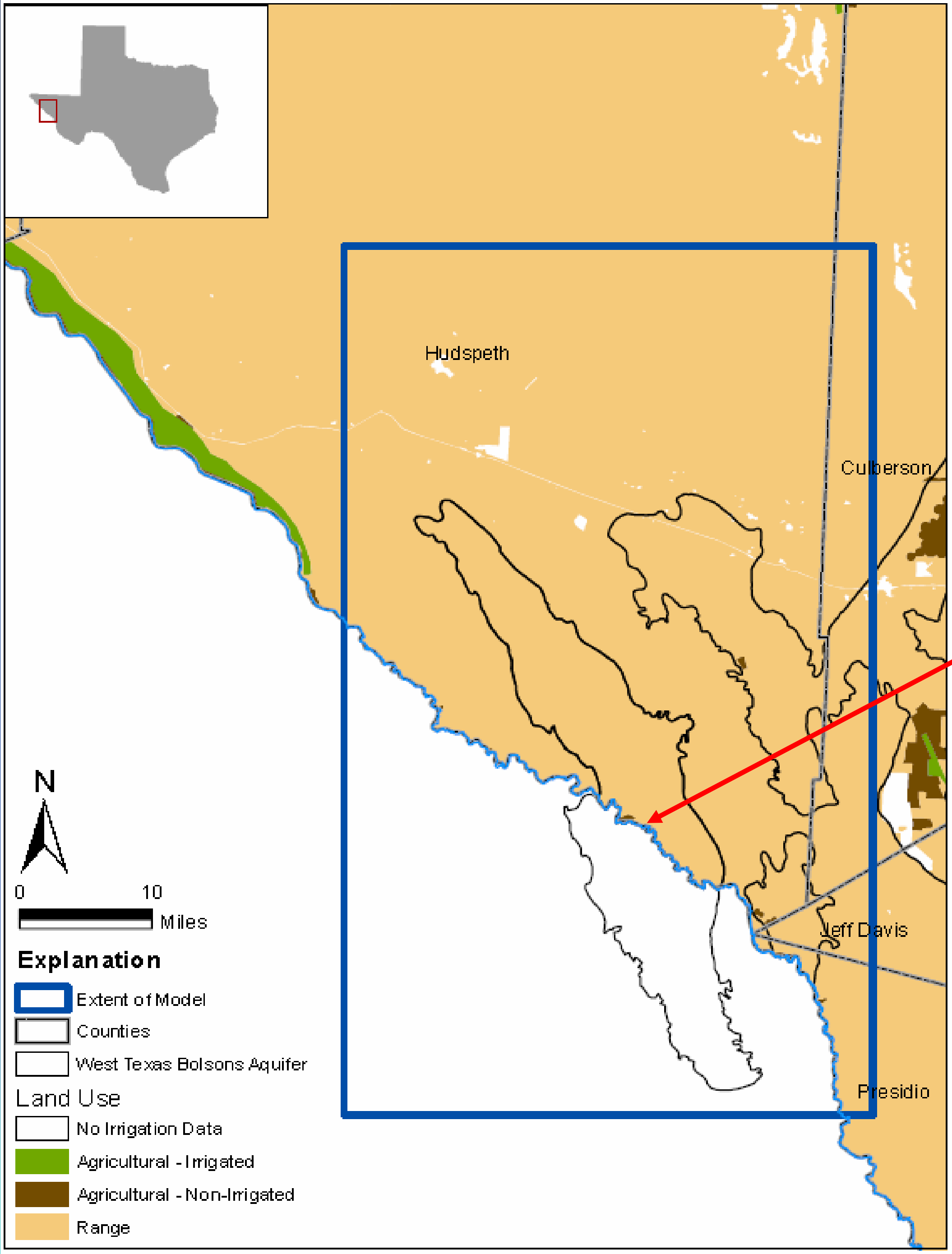


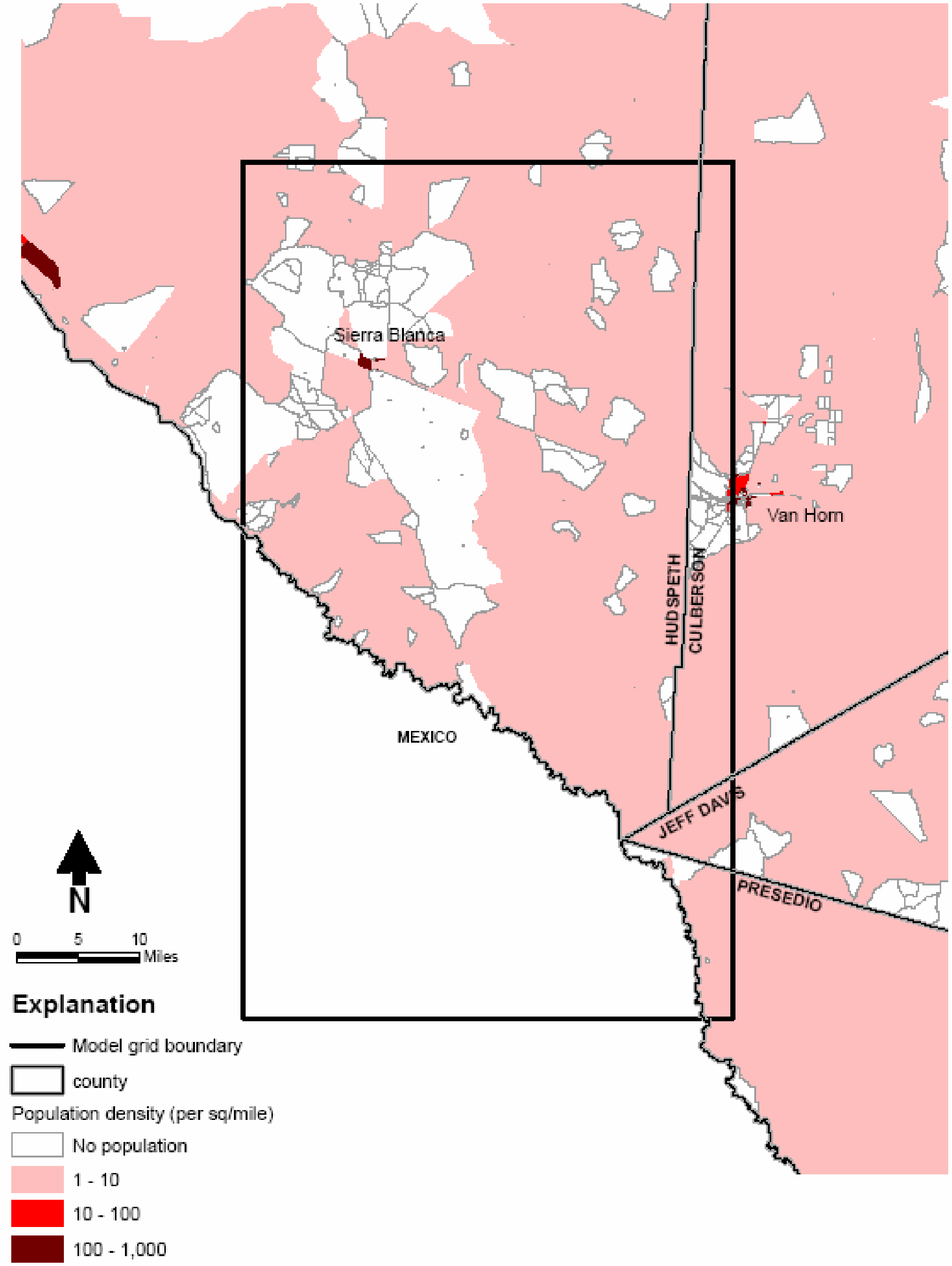
Figure 4.1.18 - Irrigated Land in 1994

Only 3 irrigation wells along river

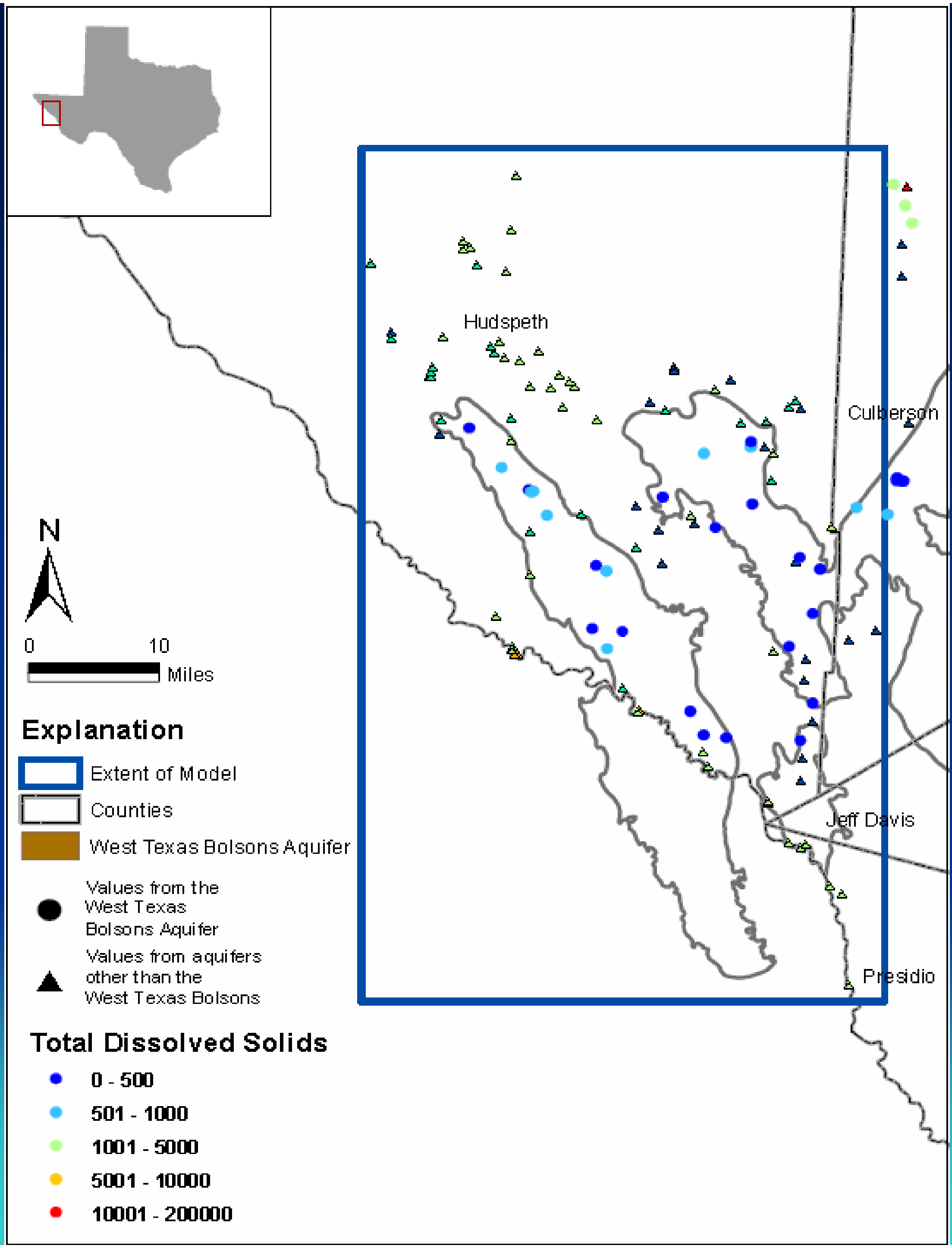
Municipal

- Sierra Blanca
- Pumped wells only in early 1980s
- Will be implemented in model grid cells consistent with well locations

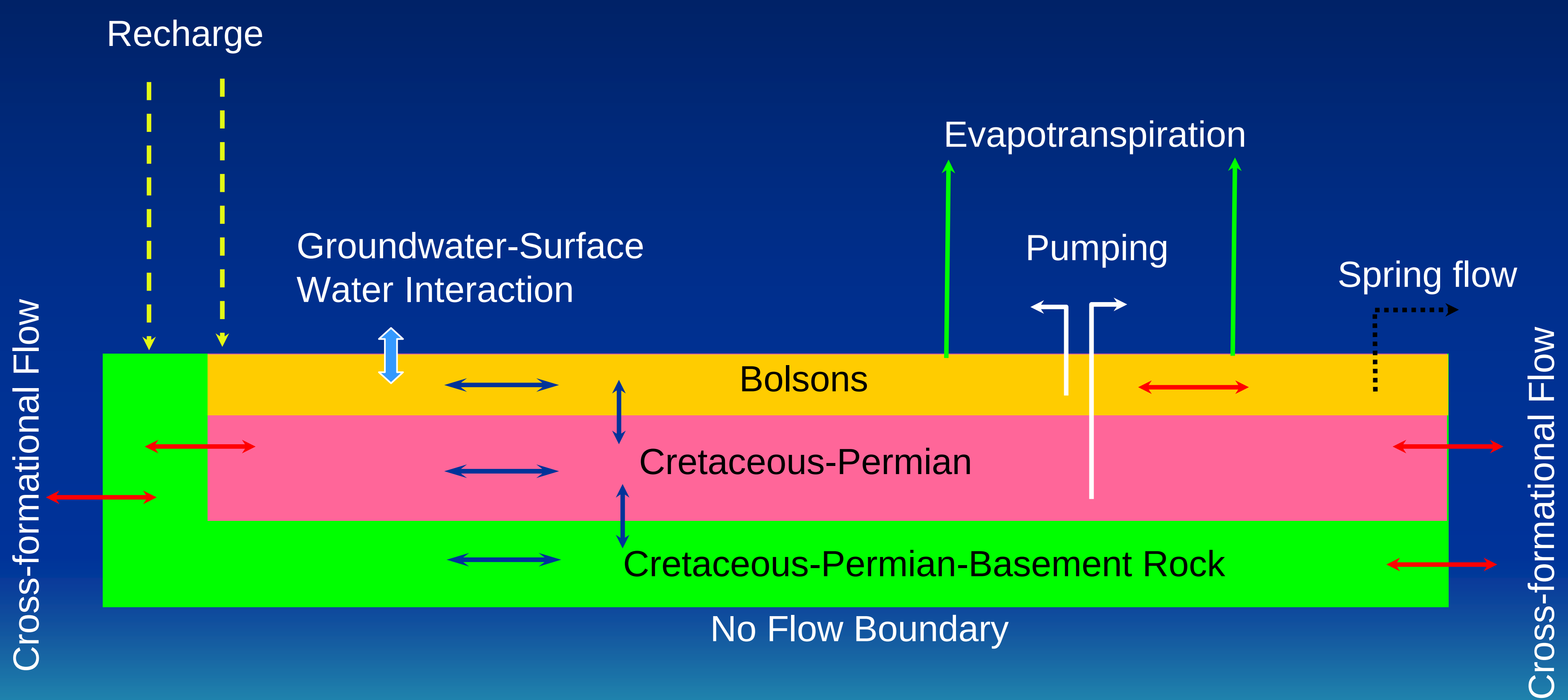
1990 Census Data

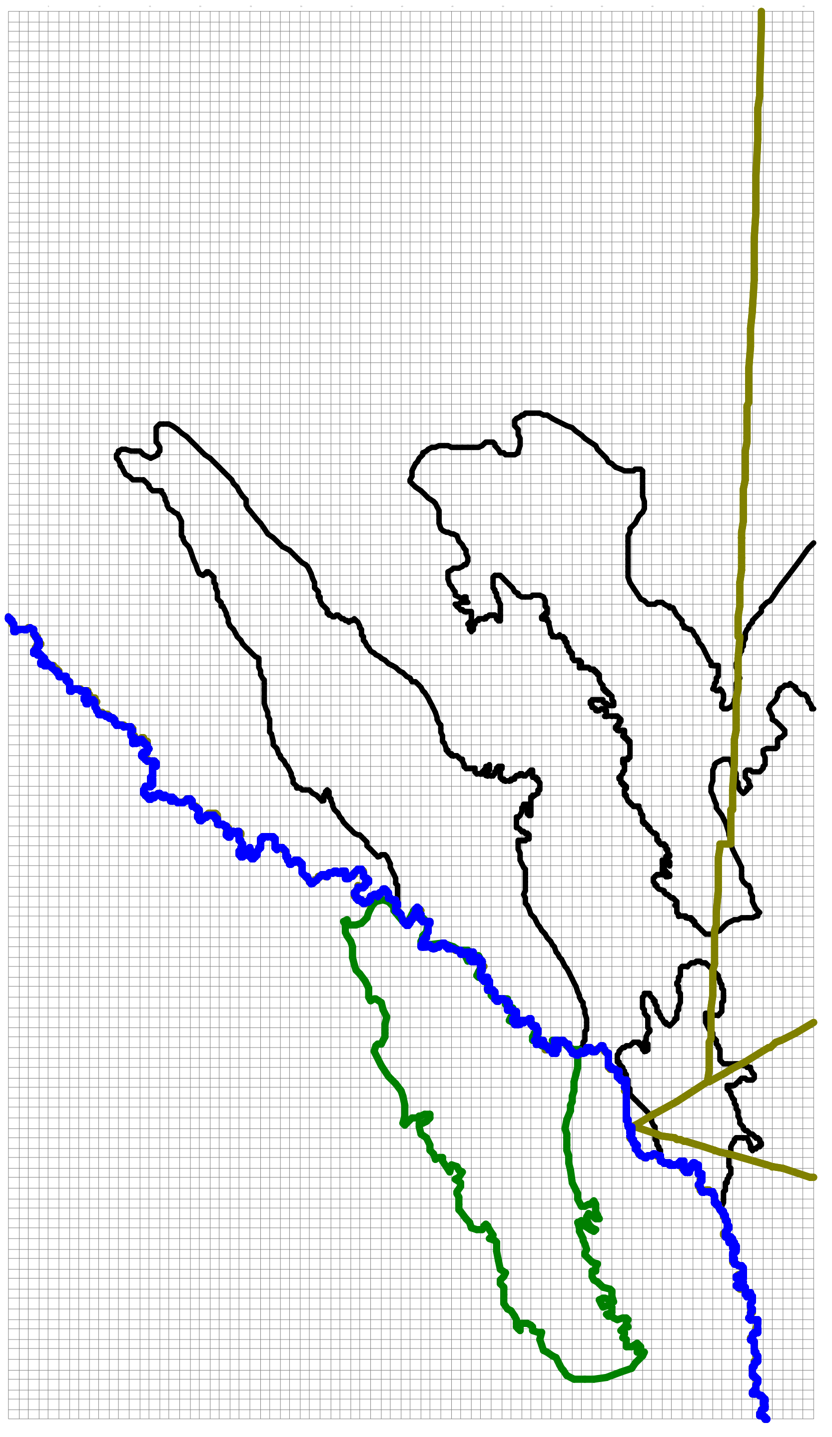


Water Quality



Conceptual Block Diagram

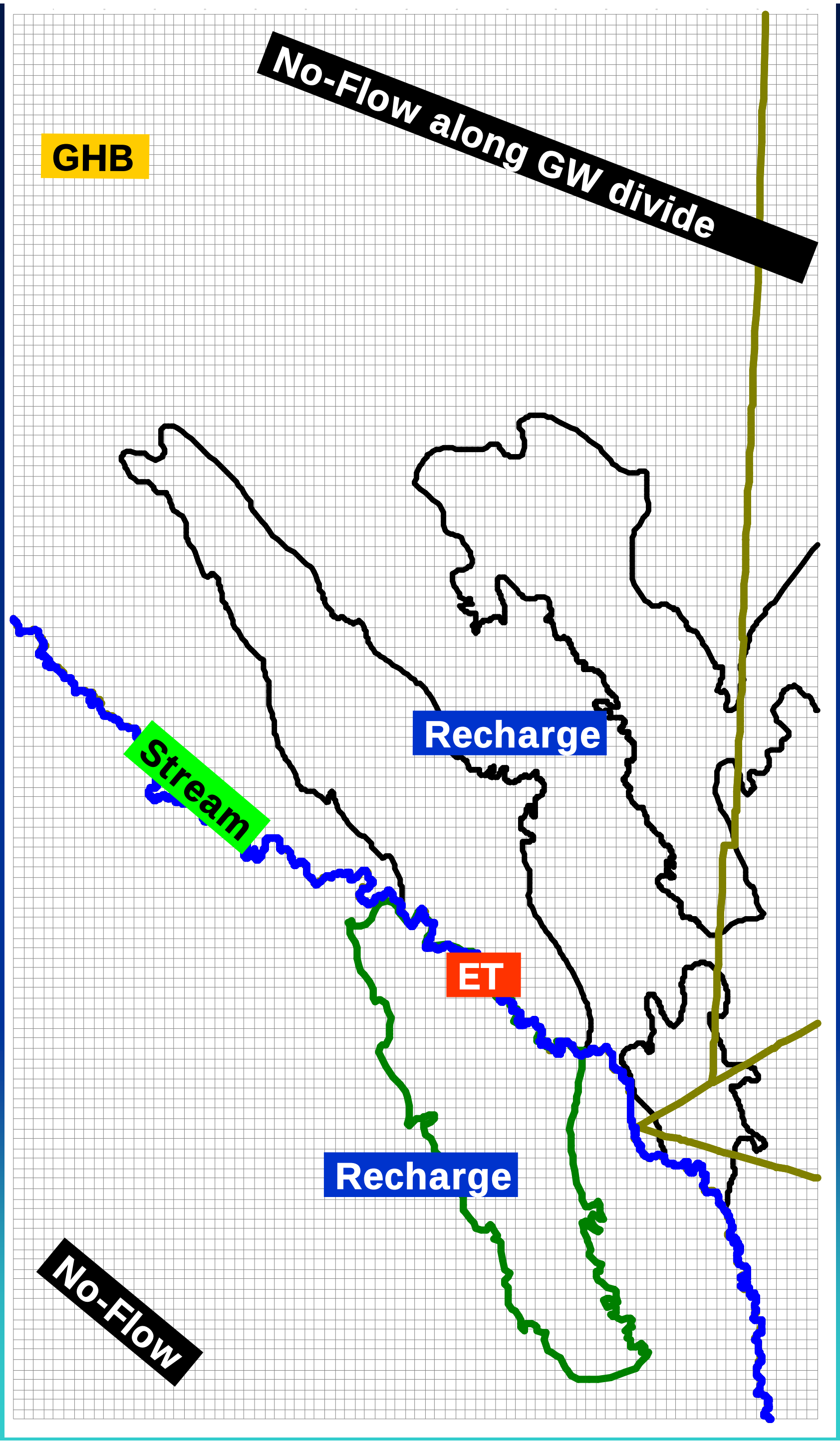




Model Grid
½ - mile

140 x 80 x 3 = 33,600

Layer 1 and 2 Boundary Conditions



Layer 3 Boundary Conditions