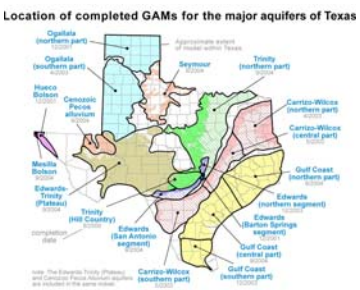
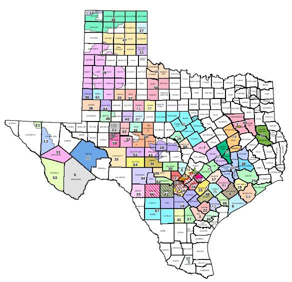
GAM

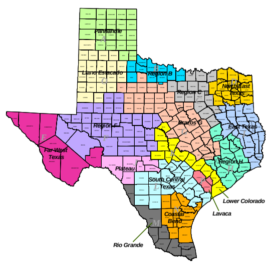
Groundwater Availability Modeling

texas water development board

Groundwater Availability Modeling





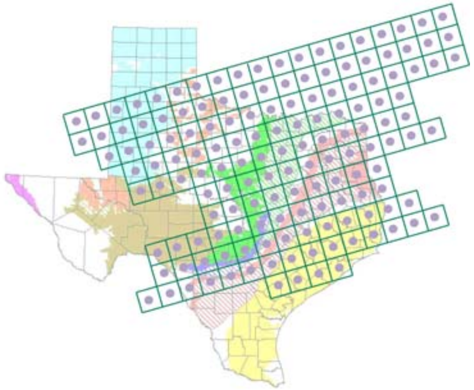


Cindy Ridgeway

Contract Manager

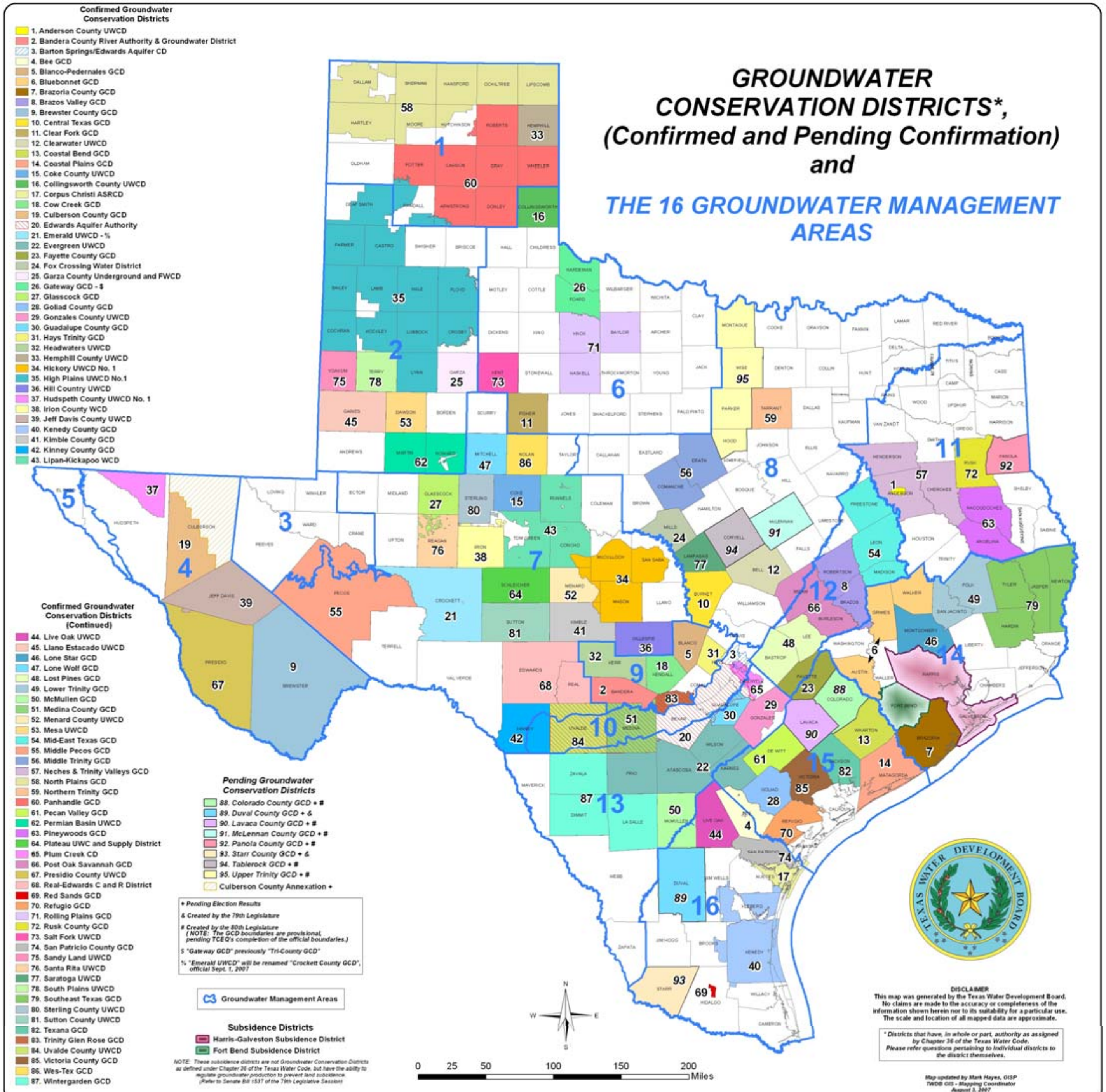
Yegua-Jackson Aquifer "GAM"

Texas Water Development Board



what is the gam program?

- Purpose: to develop tools that can be used to help Groundwater Conservation Districts, Regional Water Planning Groups, and others understand and manage their groundwater resources.
- Public process: you get to see how the model is put together.
- Freely available: models are standardized, thoroughly documented. Reports available over the internet.
- Living tools: periodically updated.

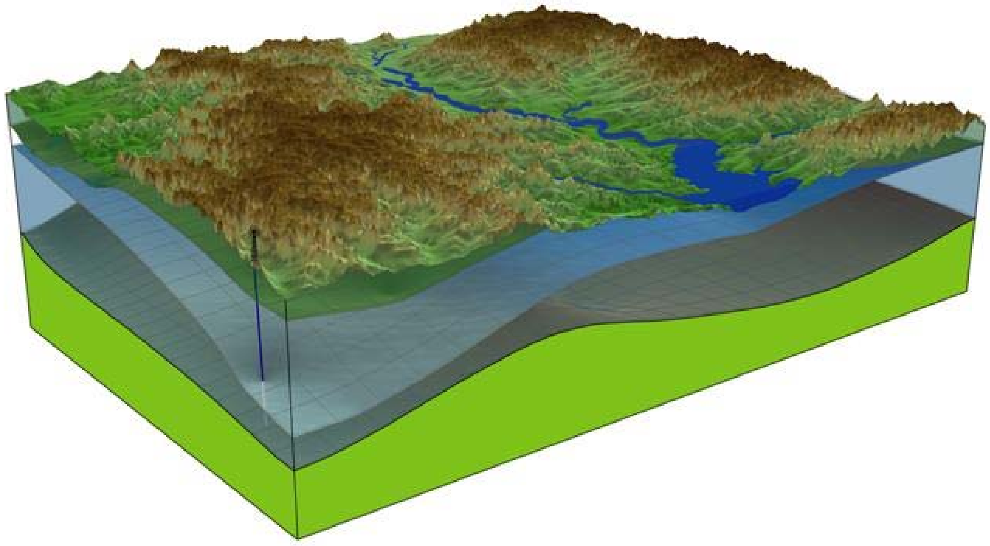

GROUNDWATER CONSERVATION DISTRICTS*, (Confirmed and Pending Confirmation) and
THE 16 GROUNDWATER MANAGEMENT AREAS
Confirmed Groundwater Conservation Districts
1. Anderson County UWCD
2. Bandera County River Authority & Groundwater District
3. Barton Springs/Edwards Aquifer CD
4. Bee GCD
5. Blanco-Pedernales GCD
6. Bluebonnet GCD
7. Brazoria County GCD
8. Brazos Valley GCD
9. Brewster County GCD
10. Central Texas GCD
11. Clear Fork GCD
12. Clearwater UWCD
13. Coastal Bend GCD
14. Coastal Plains GCD
15. Coke County UWCD
16. Collingsworth County UWCD
17. Corpus Christi ASRCD
18. Cow Creek GCD
19. Culberson County GCD
20. Edwards Aquifer Authority
21. Emerald UWCD - %
22. Evergreen UWCD
23. Fayette County GCD
24. Fox Crossing Water District
25. Garza County Underground and FWCD
26. Gateway GCD - $
27. Glasscock GCD
28. Goliad County GCD
29. Gonzales County UWCD
30. Guadalupe County GCD
31. Hays Trinity GCD
32. Headwaters UWCD
33. Hemphill County UWCD
34. Hickory UWCD No. 1
35. High Plains UWCD No.1
36. Hill Country UWCD
37. Hudspeth County UWCD No. 1
38. Irion County WCD
39. Jeff Davis County UWCD
40. Kenedy County GCD
41. Kimble County GCD
42. Kinney County GCD
43. Lipan-Kickapoo WCD
Confirmed Groundwater Conservation Districts (Continued)
44. Live Oak UWCD
45. Llano Estacado UWCD
46. Lone Star GCD
47. Lone Wolf GCD
48. Lost Pines GCD
49. Lower Trinity GCD
50. McMullen GCD
51. Medina County GCD
52. Menard County UWCD
53. Mesa UWCD
54. Mid-East Texas GCD
55. Middle Pecos GCD
56. Middle Trinity GCD
57. Neches & Trinity Valleys GCD
58. North Plains GCD
59. Northern Trinity GCD
60. Panhandle GCD
61. Pecan Valley GCD
62. Permian Basin UWCD
63. Pineywoods GCD
64. Plateau UWC and Supply District
65. Plum Creek CD
66. Post Oak Savannah GCD
67. Presidio County UWCD
68. Real-Edwards C and R District
69. Red Sands GCD
70. Refugio GCD
71. Rolling Plains GCD
72. Rusk County GCD
73. Salt Fork UWCD
74. San Patricio County GCD
75. Sandy Land UWCD
76. Santa Rita UWCD
77. Saratoga UWCD
78. South Plains UWCD
79. Southeast Texas GCD
80. Sterling County UWCD
81. Sutton County UWCD
82. Texana GCD
83. Trinity Glen Rose GCD
84. Uvalde County UWCD
85. Victoria County GCD
86. Wes-Tex GCD
87. Wintergarden GCD
Pending Groundwater Conservation Districts
88. Colorado County GCD + #
89. Duval County GCD + &
90. Lavaca County GCD + #
91. McLennan County GCD + #
92. Panola County GCD + #
93. Starr County GCD + &
94. Tablerock GCD + #
95. Upper Trinity GCD + #
Culberson County Annexation +
+ Pending Election Results
& Created by the 79th Legislature
# Created by the 80th Legislature
(NOTE: The GCD boundaries are provisional, pending TCEQ's completion of the official boundaries.)
$ "Gateway GCD" previously "Tri-County GCD"
% "Emerald UWCD" will be renamed "Crockett County GCD", official Sept. 1, 2007
Groundwater Management Areas
Subsidence Districts
Harris-Galveston Subsidence District
Fort Bend Subsidence District
NOTE: These subsidence districts are not Groundwater Conservation Districts as defined under Chapter 36 of the Texas Water Code, but have the ability to regulate groundwater production to prevent land subsidence. (Refer to Senate Bill 1537 of the 79th Legislative Session)
0 25 50 100 150 200 Miles
N W E S
TEXAS WATER DEVELOPMENT BOARD
DISCLAIMER
This map was generated by the Texas Water Development Board. No claims are made to the accuracy or completeness of the information shown herein nor to its suitability for a particular use. The scale and location of all mapped data are approximate.
* Districts that have, in whole or part, authority as assigned by Chapter 36 of the Texas Water Code. Please refer questions pertaining to individual districts to the district themselves.
Map updated by Mark Hayes, GISP
TWDB GIS - Mapping Coordinator
August 3, 2007

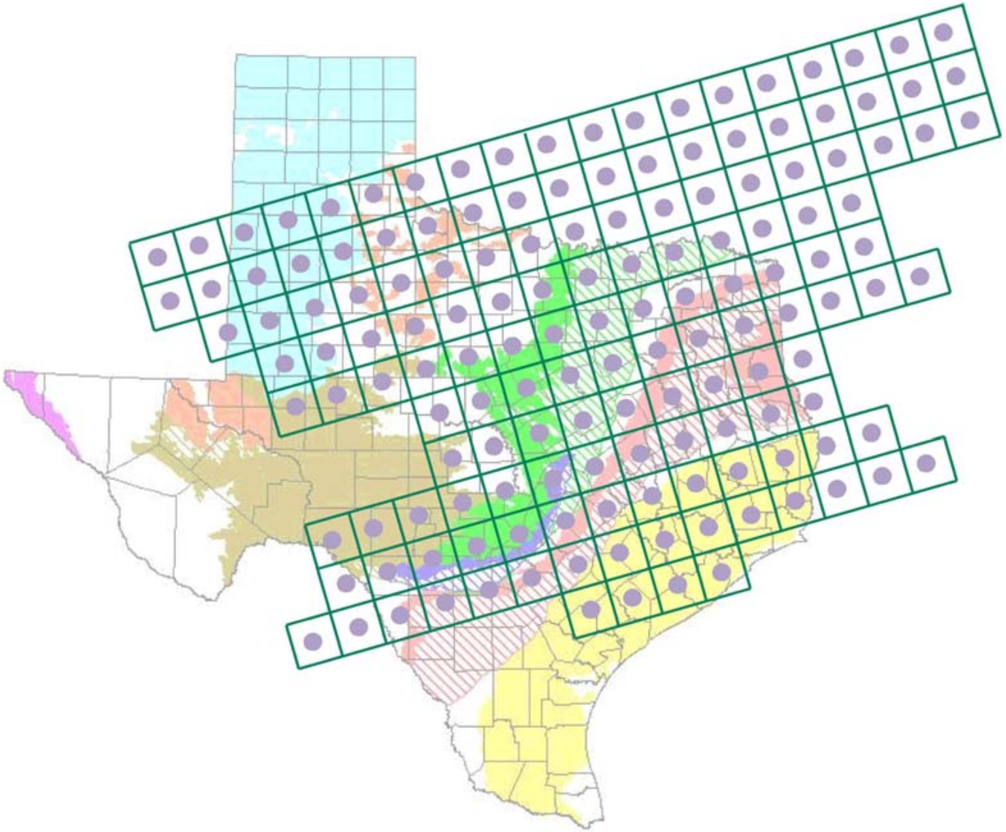
what is a groundwater model?

- mod•el (mod′l), *n*. 10. a simplified representation of a system or phenomenon….. Webster's Dictionary
- "A model is any device that represents an approximation of a field situation" Anderson and Woessner (1992)
- "a representation of reality that attempts to explain some aspect of it and is always less complex than the system it represents" Domenico (1972)
- "representation of reality" = numerical representation of a groundwater flow system
- <u>simplified</u> numerical representation of a <u>complex</u> groundwater flow system

process to develop a model

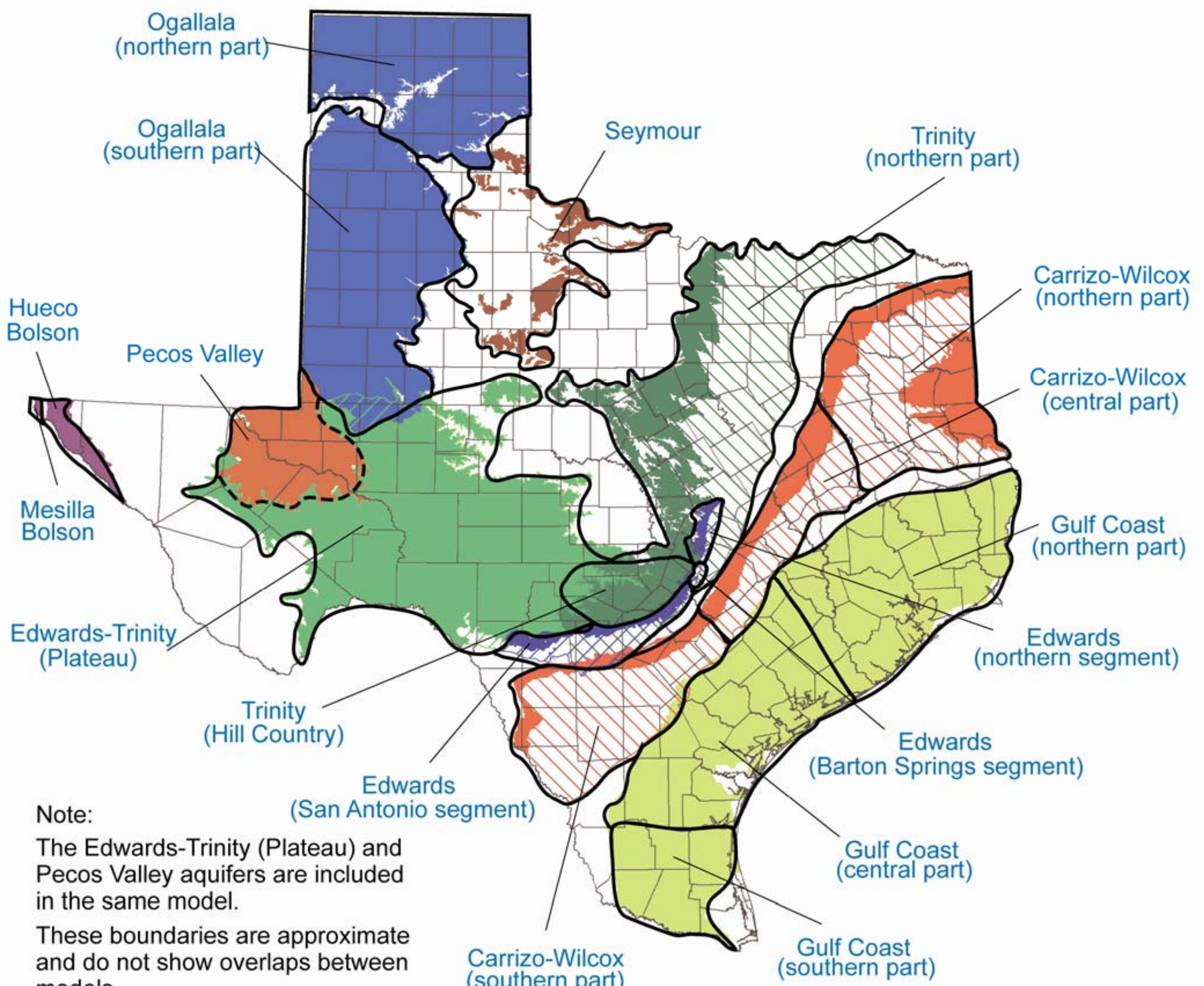
- Gather data
- Create conceptual model
- Develop model
- Calibrate to measured data
- Make predictions
- Bonus: develop graphics to help understand resource





what is the status of the models?

17 models completed for the major aquifers

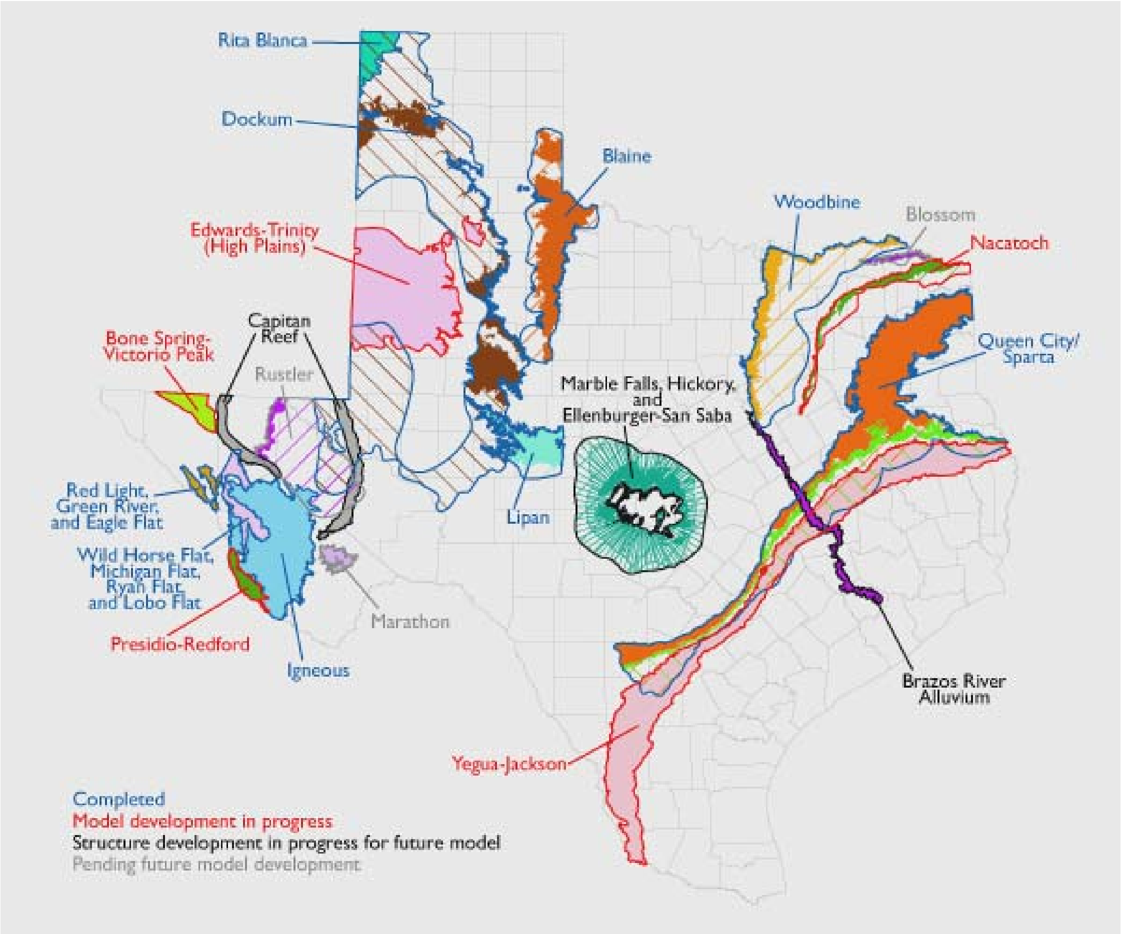


Note:

The Edwards-Trinity (Plateau) and Pecos Valley aquifers are included in the same model.

These boundaries are approximate and do not show overlaps between models.

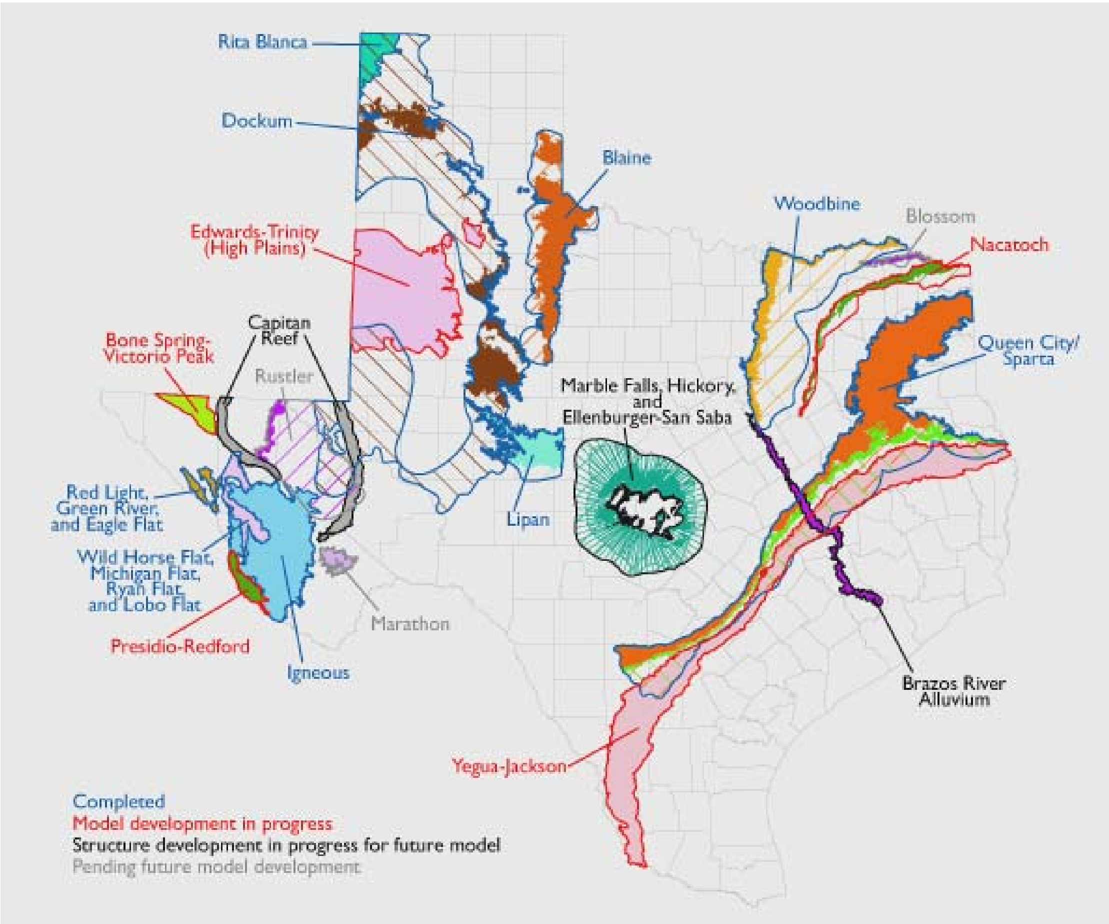
models completed for the minor aquifers



1. Rita Blanca
2. Blaine
3. Woodbine
4. Nacatoch*
5. Queen City
6. Sparta
7. Lipan
8. Igneous
9. Parts of West Texas Bolsons
10. Dockum
11. Edwards-Trinity (High Plains)*

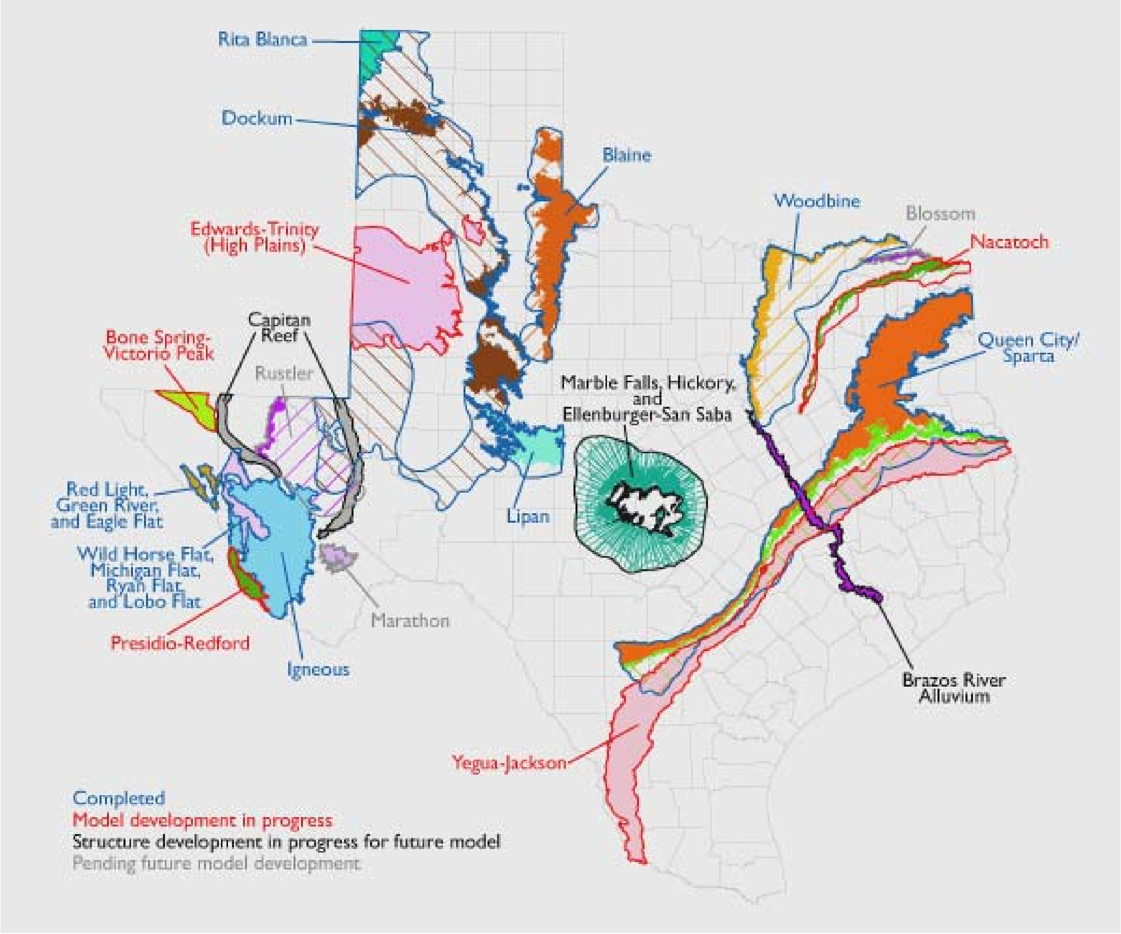
*Under going final review

models under development for the minor aquifers

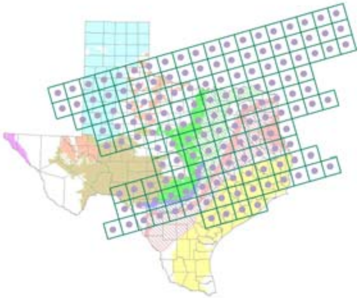


1. Yegua-Jackson
2. Presidio portion of West Texas Bolsons
3. Independent model of Bone Spring-Victorio Peak

models to be completed for the minor aquifers

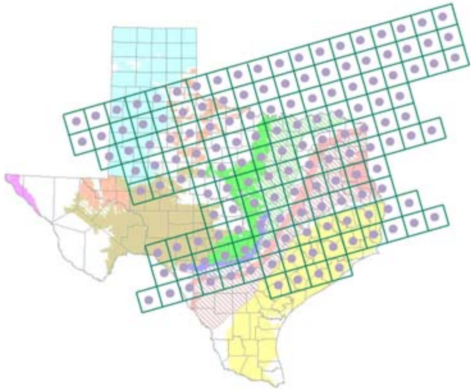


1. Brazos River Alluvium
2. Llano Uplift—Marble Falls, Ellenburger-San Saba, & Hickory
3. Capitan Reef Complex
4. Blossom
5. Marathon
6. Rustler (next to be modeled)



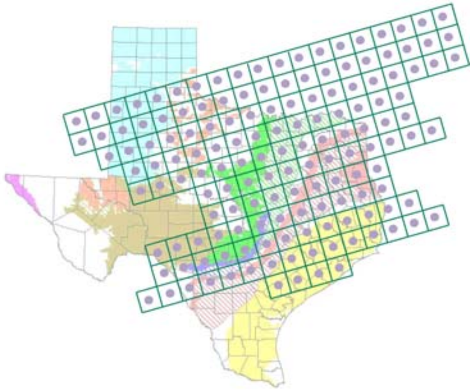
how do we use GAM?

- 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
- Groundwater Management Areas, Groundwater Conservation Districts and Regional WaterPlanning Groups can request runs



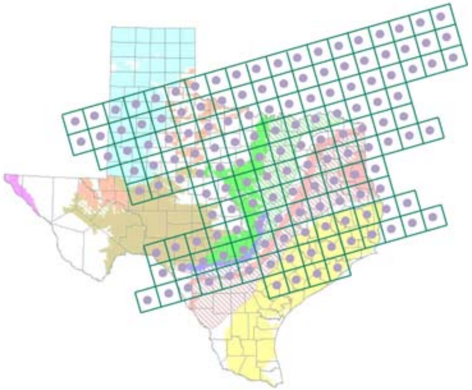
do we have to use GAM?

- Water Code & Texas Water Development Board rules require that Groundwater Conservation Districts use GAM information, if available, for their management plans.
- TWDB rules require that Regional Water Planning Groups use managed available groundwater estimates, if developed in time for the planning cycle



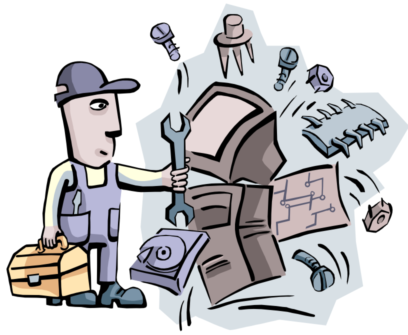
what is groundwater availability or a MAG?

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



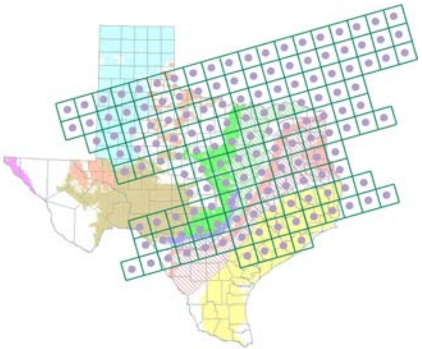
GAM are living tools…

- Groundwater Conservation Districts, Regional Water Planning Groups, Texas Water Development Board, and others collect new information on aquifer.
- Texas Water Development Board plans to update GAMs every five years with new information.
- Please share information and ideas with TWDB on aquifers and GAMs.



GAM are living tools...

- Working on refining structure and researching recharge for Gulf Coast Aquifer from Brazos River to Rio Grande
- Working on localized model of the Seymour Aquifer
- Updating the Edwards-Trinity (Plateau) and Pecos Valley aquifers model
- Almost done working on updating the Hill Country portion of the Trinity Aquifer model
- Completed various updates to Ogallala Aquifer models, Carrizo-Wilcox Aquifer models, and southern Gulf Coast Aquifer model



participating in the GAM process

- Stakeholder Advisory Forums (SAF)
  - hear about progress on the model
  - comment on model assumptions
  - offer information (timing is important!)
  - http://www.twdb.state.tx.us/gam/GamSH.asp
- Report review
  - Conceptual model http://www.twdb.state.tx.us/gam/ygjk/ygjk.htm
  - at end of project
- Contact Texas Water Development Board
  - contract manager

comments:

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cindy.ridgeway@twdb.state.tx.us
(512)936-2386

Texas Water Development Board
1700 North Congress Avenue
P.O. Box 13231
Austin, Texas 78711-3231

Web information:
www.twdb.state.tx.us/gam

Groundwater Availability Model for the Yegua-Jackson Aquifer

Stakeholder Advisory Forum #2
San Antonio, TX

April 10, 2009

Cindy Ridgeway

Van Kelley and Neil Deeds

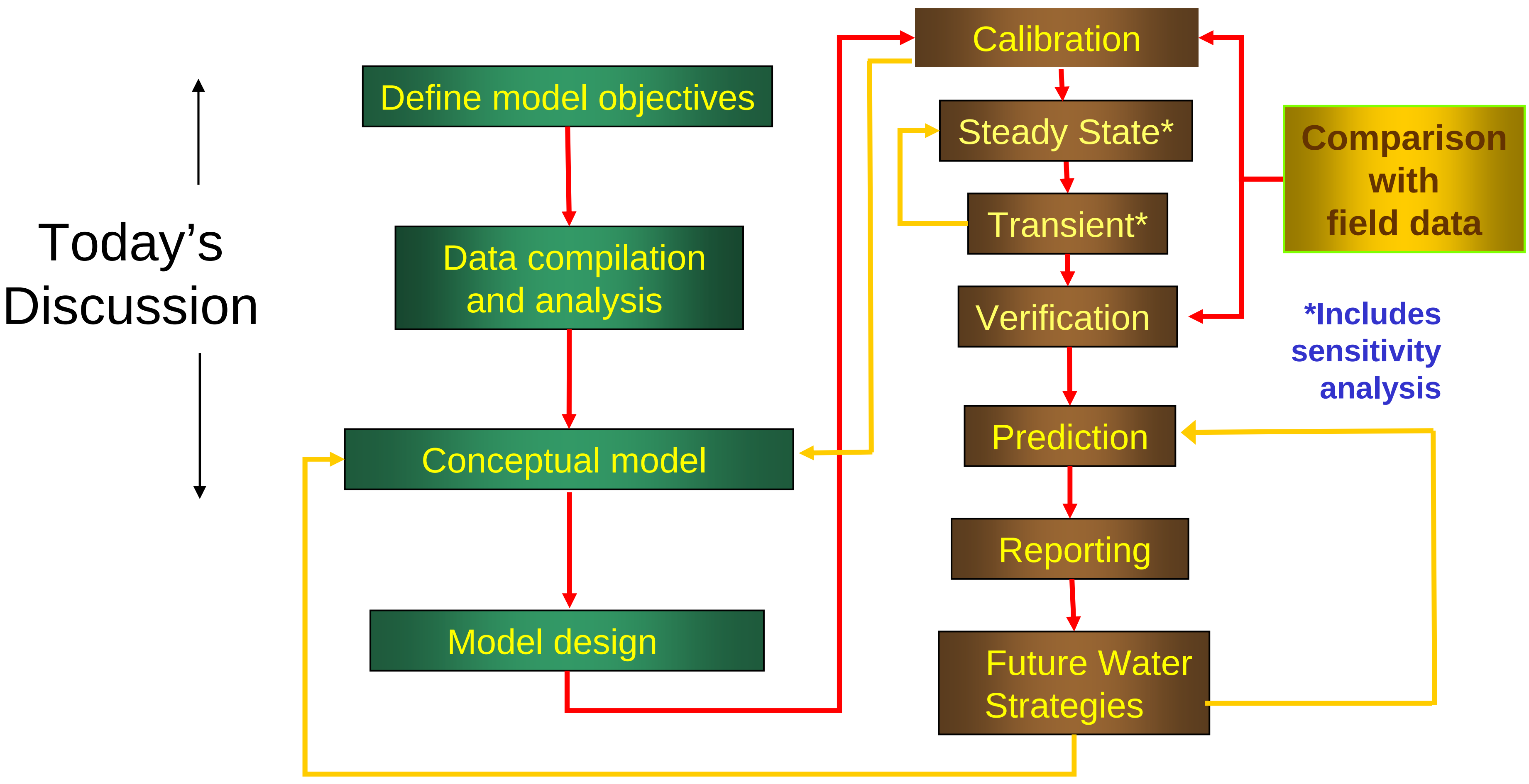
Outline of Presentation

- Yegua-Jackson GAM Team
- What is a Conceptual Model?
- Structure
- Water Levels and Groundwater Flow
- Hydraulic Properties
- Surface Water
- Recharge and Natural Discharge
- Pumping
- Groundwater Quality
- Summary of Conceptual Model
- Review of Project Milestones and Schedule

Yegua-Jackson GAM Team

- INTERA
  - Project management
  - SAF meetings
  - Heads and calibration targets
  - Recharge implementation
  - Surface water / groundwater interaction
  - Pumping data and implementation
  - Water quality
  - Model construction/calibration/SA
  - Project reporting/deliverables
- Baer Engineering **(Paul Knox)**
  - Geology/structure
- URS **(Steve Young)**
  - Aquifer Properties
- Graham Fogg
  - Senior Technical Review

Modeling Protocol

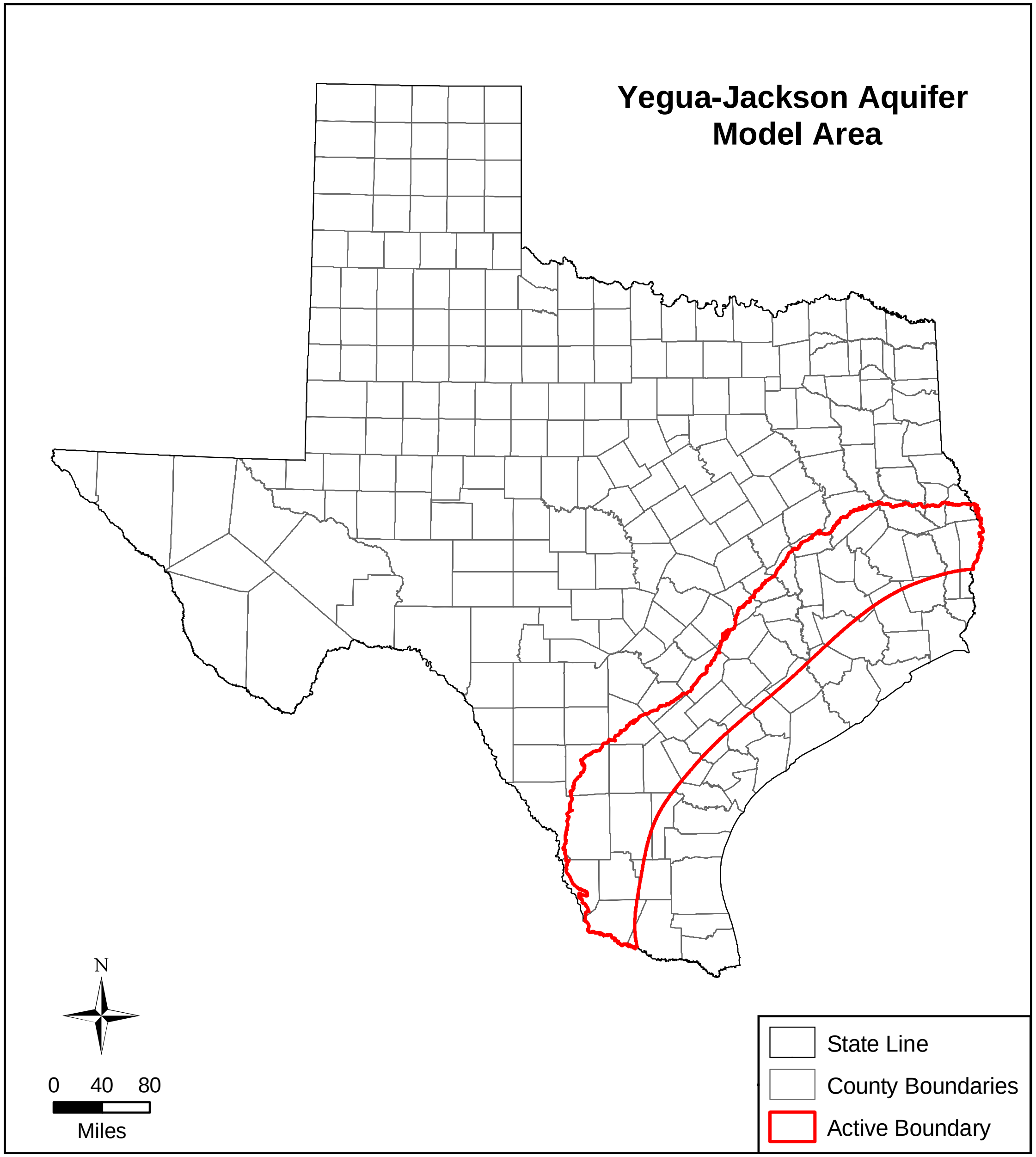


Conceptual Model

- Identify relevant processes and physical elements controlling flow in the aquifer:
  - Geologic Framework
  - Hydrologic Framework
  - Hydraulic Properties
  - Heads, Sources & Sinks (Water Budget)
- Determine Data Deficiencies
- The conceptual model dictates how you translate the “real world” to a mathematical model

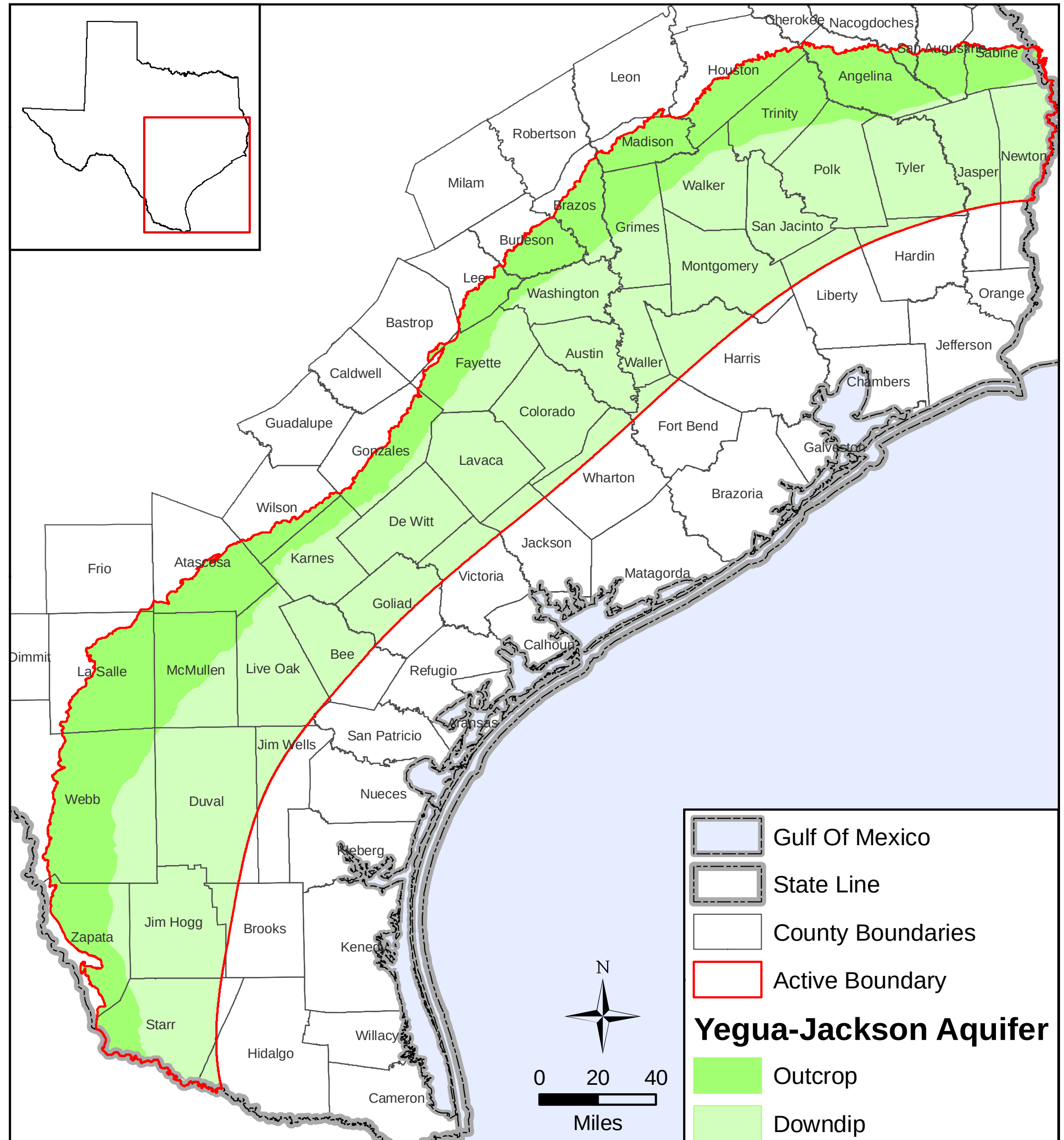
Study Background

Yegua-Jackson Study Area



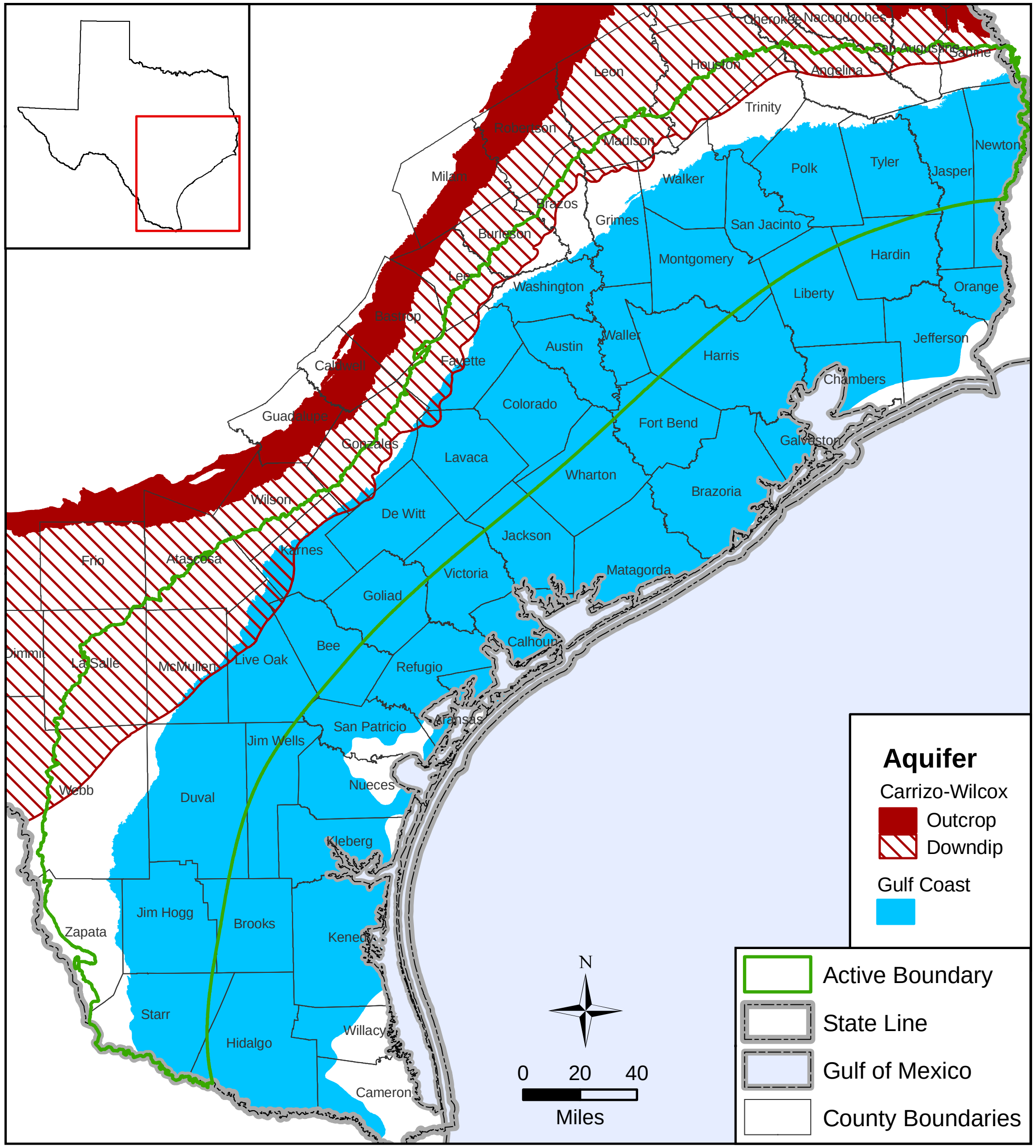
Active Model Boundary for the Yegua-Jackson Aquifer GAM

- **Y-J Aquifer is considered a minor aquifer in Texas as of the 2002 State Water Plan**
- **Exists primarily in the outcrop and near-outcrop regions of the Yegua Formation and Jackson Group**



Source: Online: Texas Water Development Board, March 2007

Major Aquifers in the Study Area



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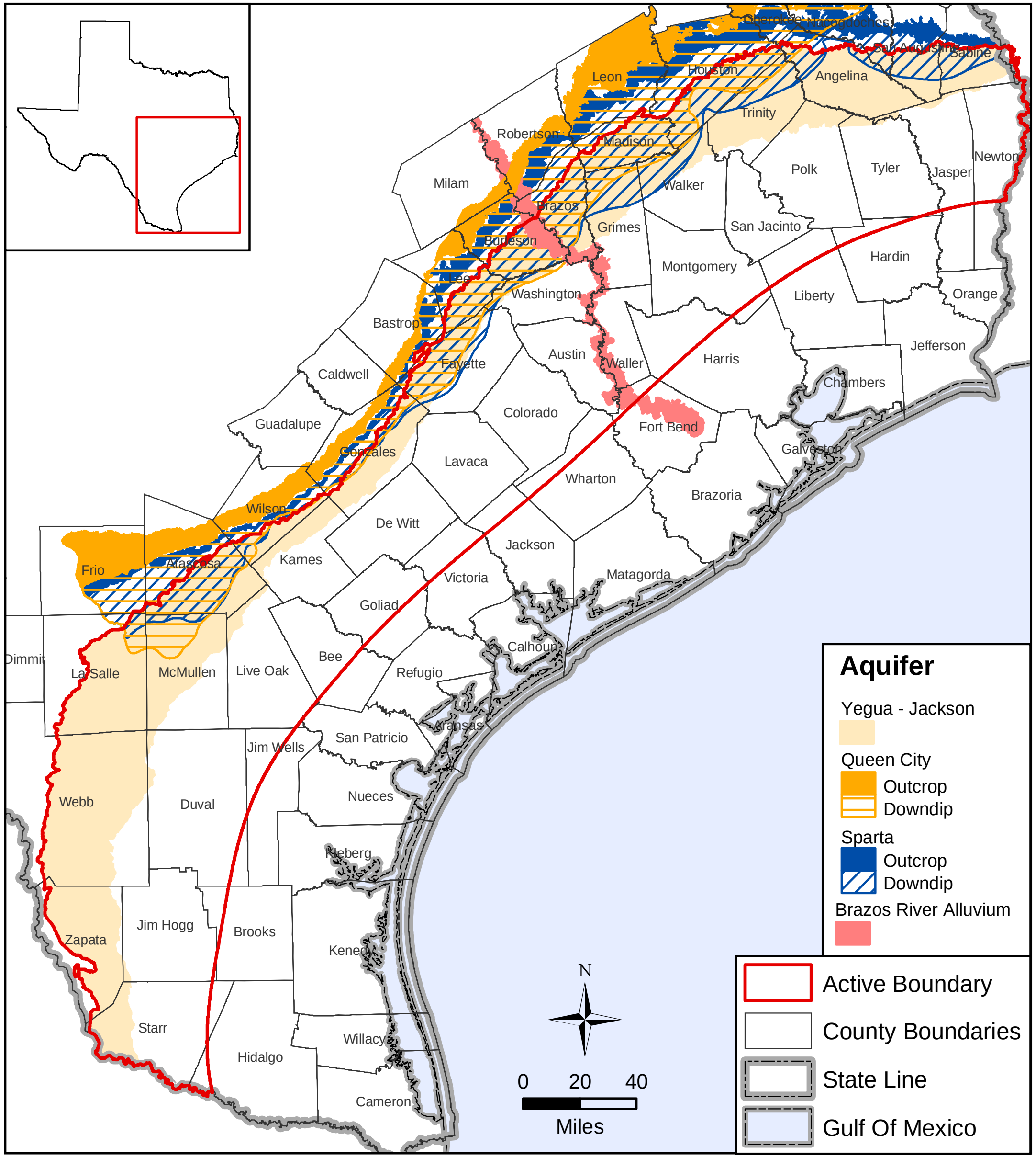
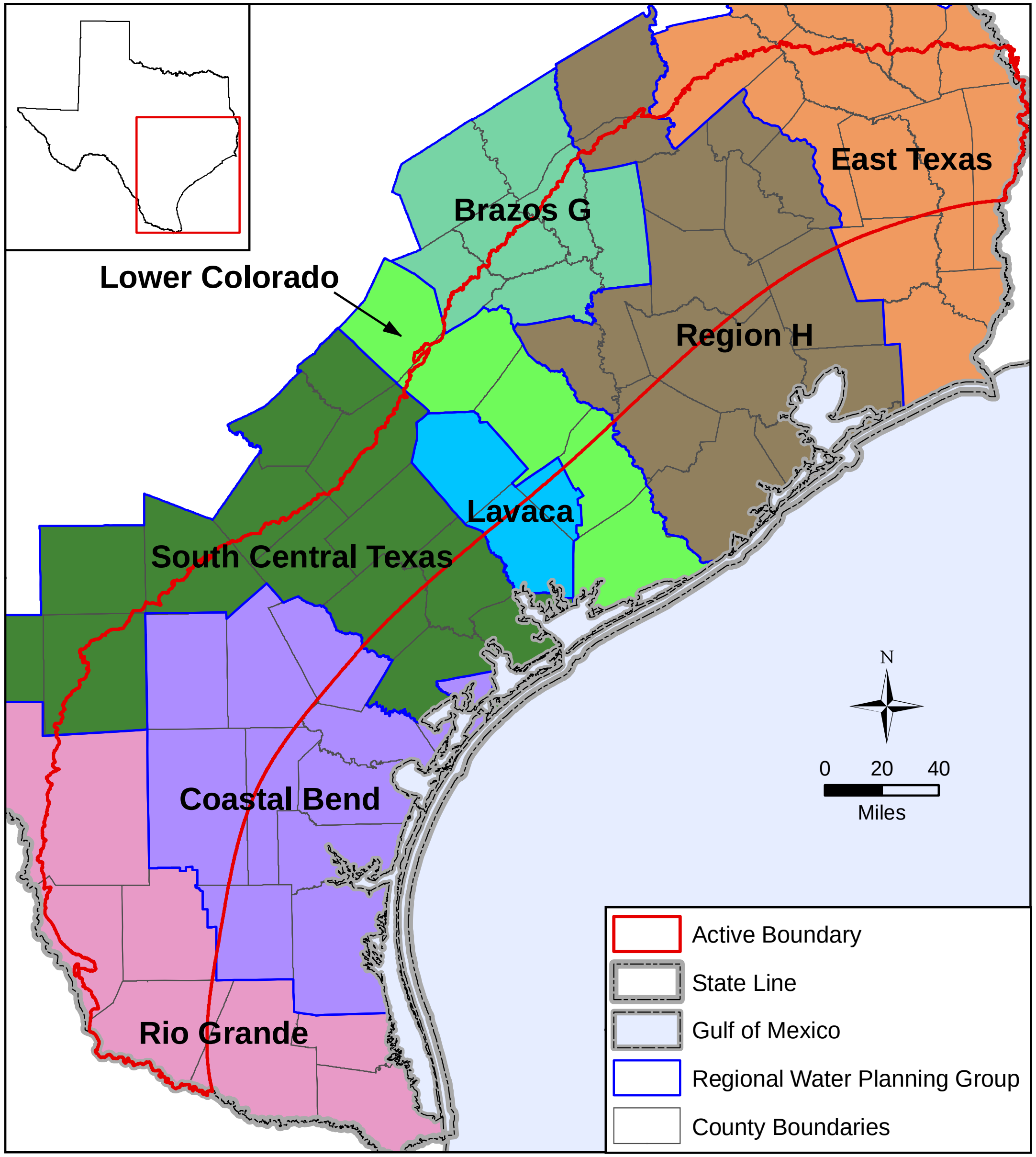
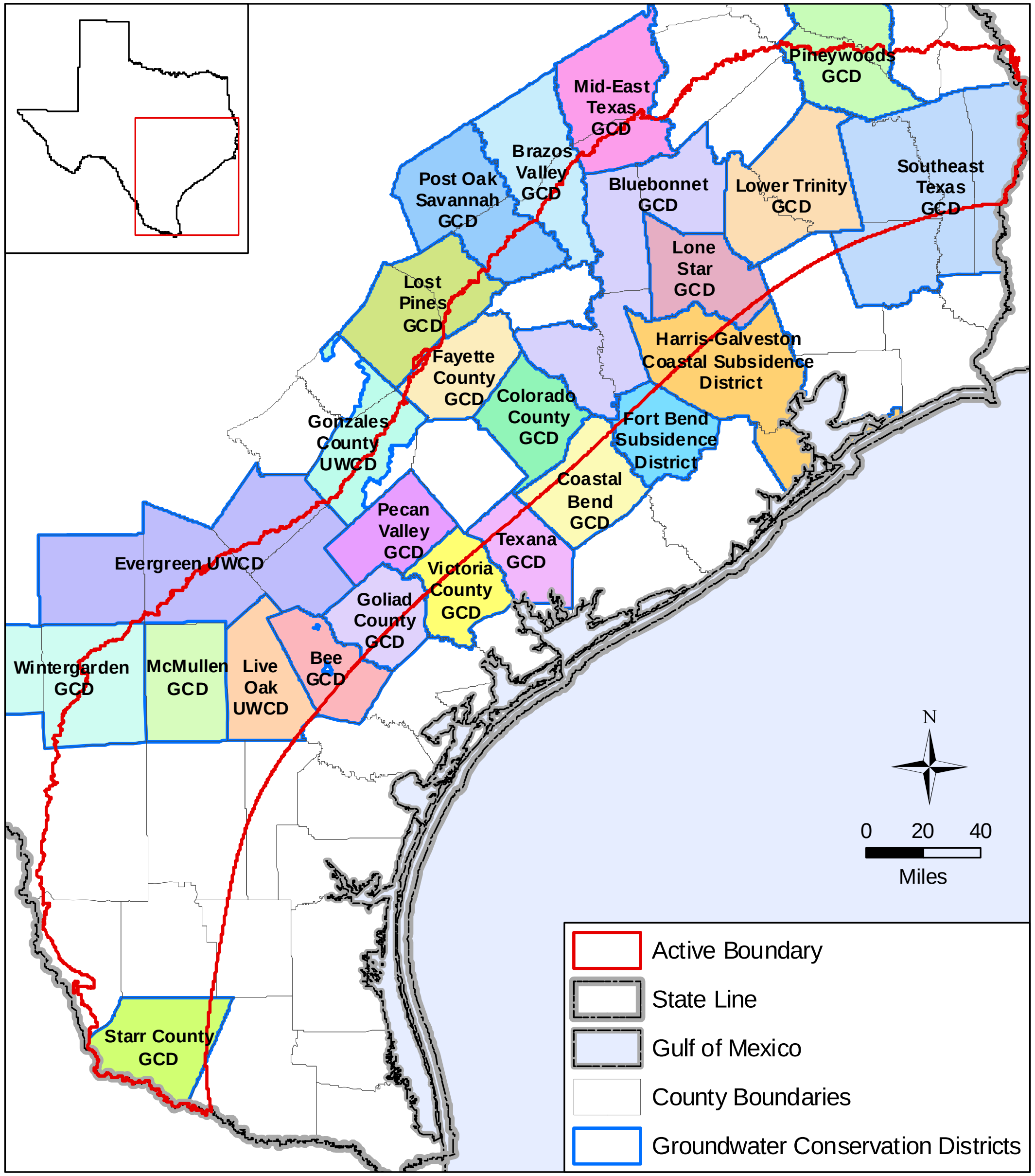
Minor Aquifers in the Study Area



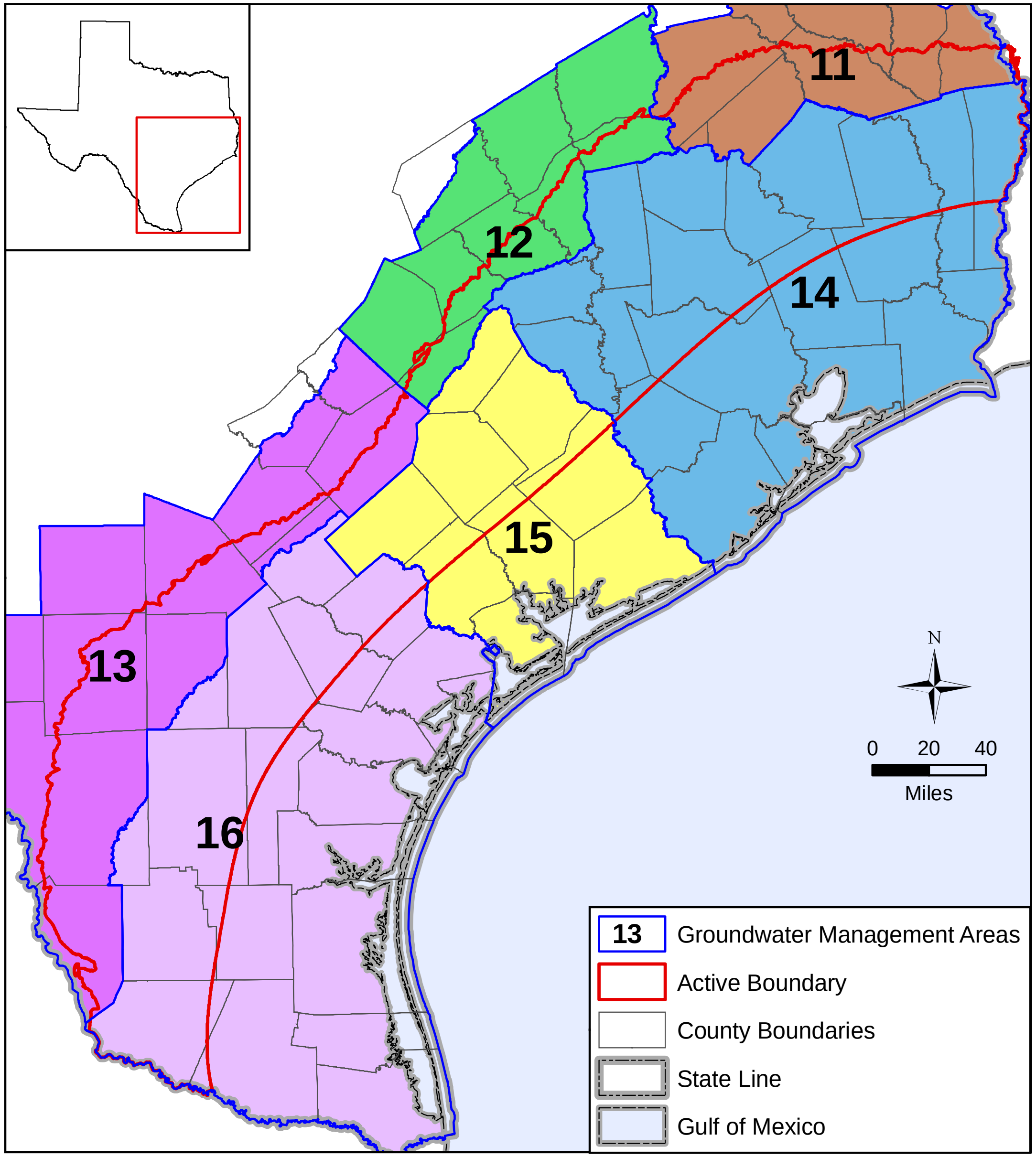
Regional Water Planning Groups



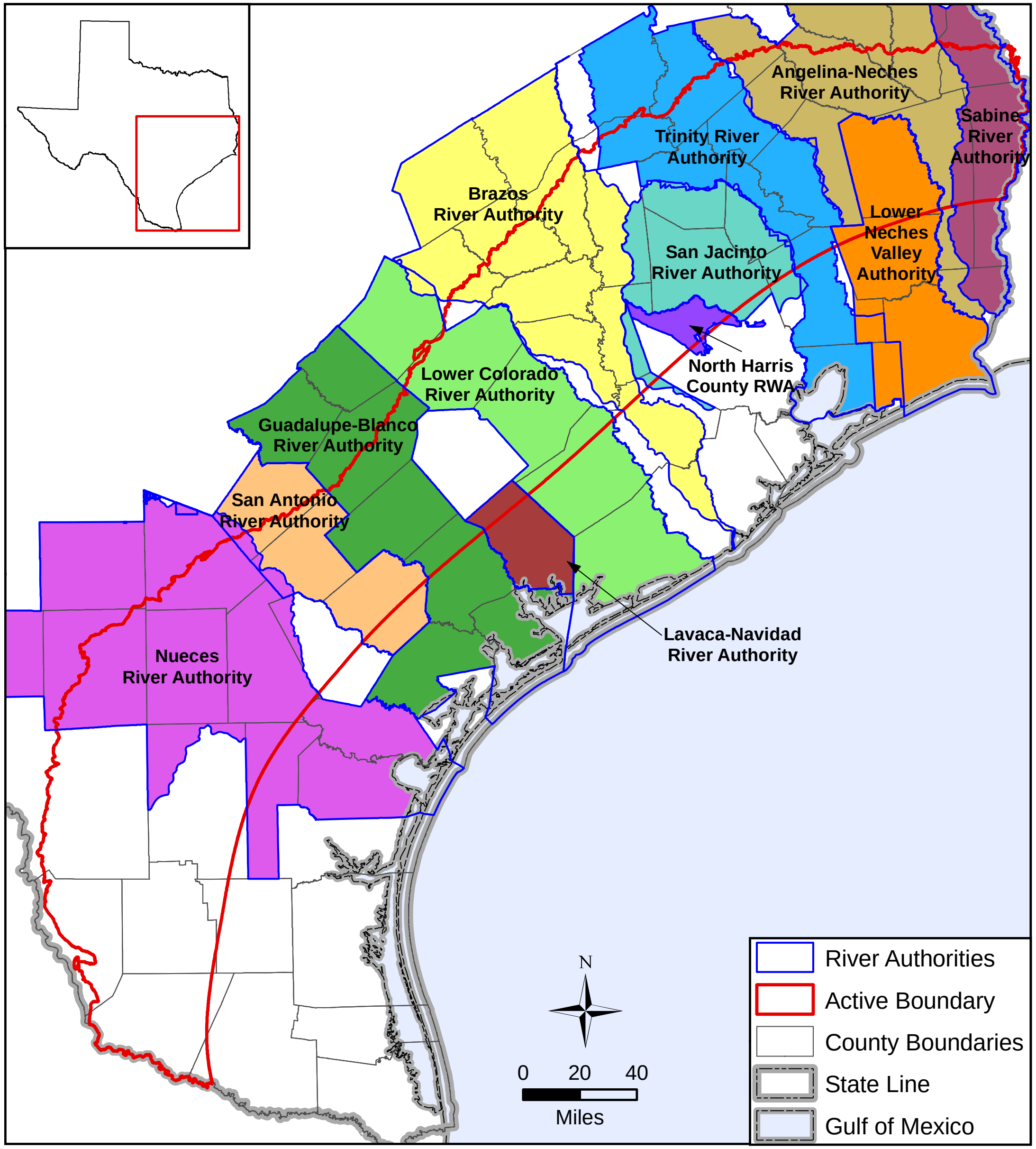
Groundwater Conservation Districts



Groundwater Management Areas

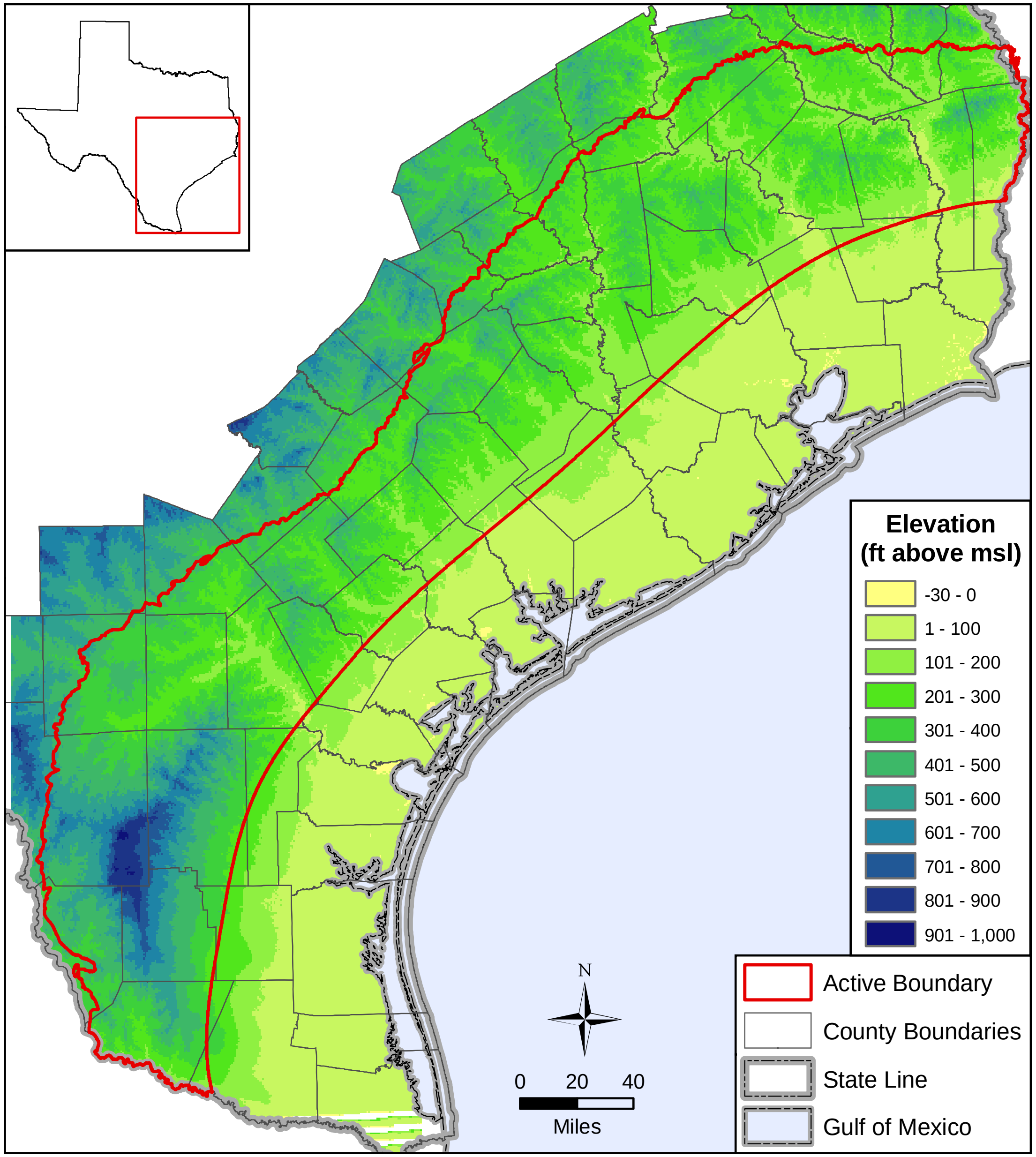


River Authorities



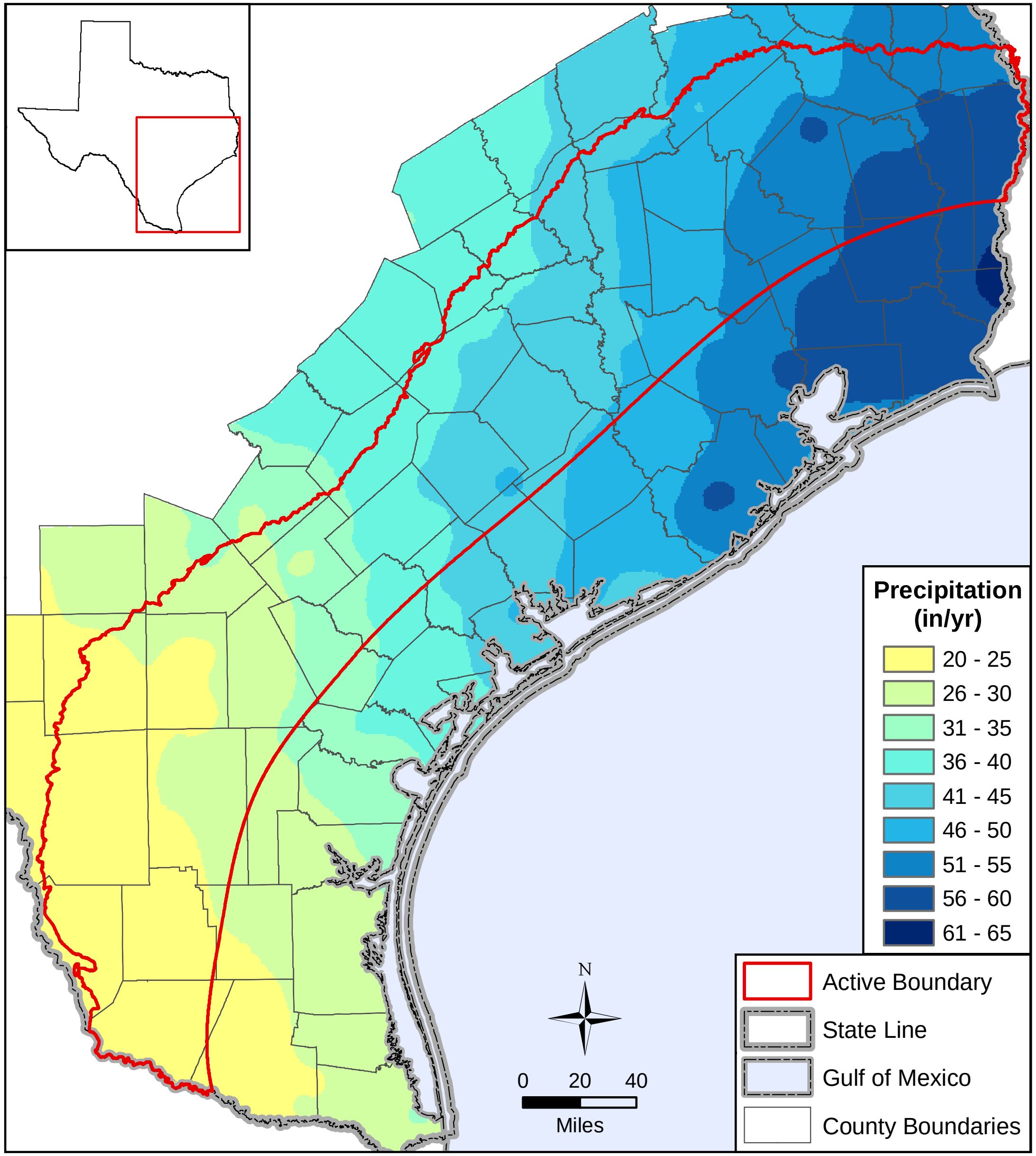
Primary River Basins

Topography

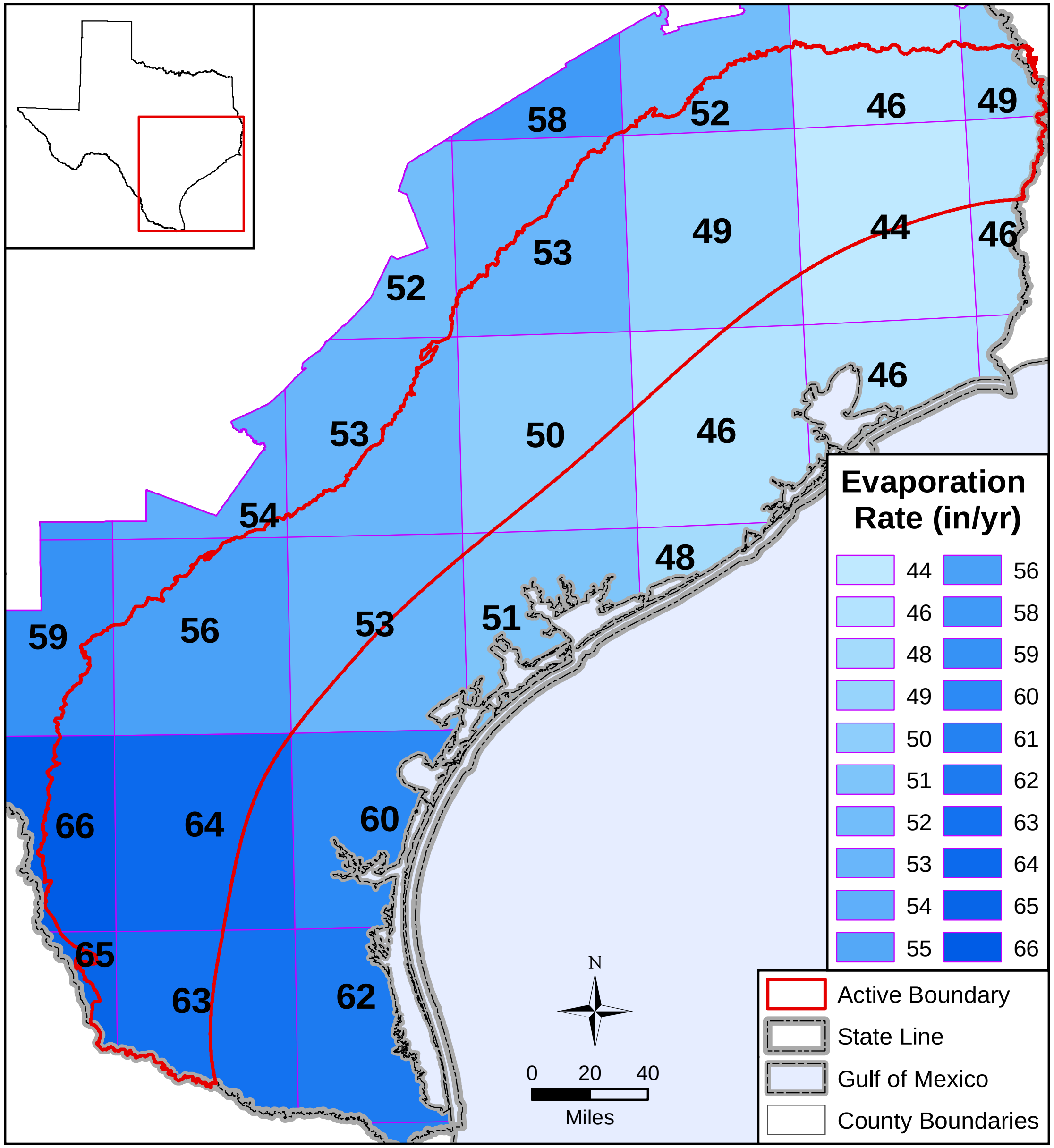


Elevation
(ft above msl)
-30 - 0
1 - 100
101 - 200
201 - 300
301 - 400
401 - 500
501 - 600
601 - 700
701 - 800
801 - 900
901 - 1,000
Active Boundary
County Boundaries
State Line
Gulf of Mexico
N
0
20
40
Miles

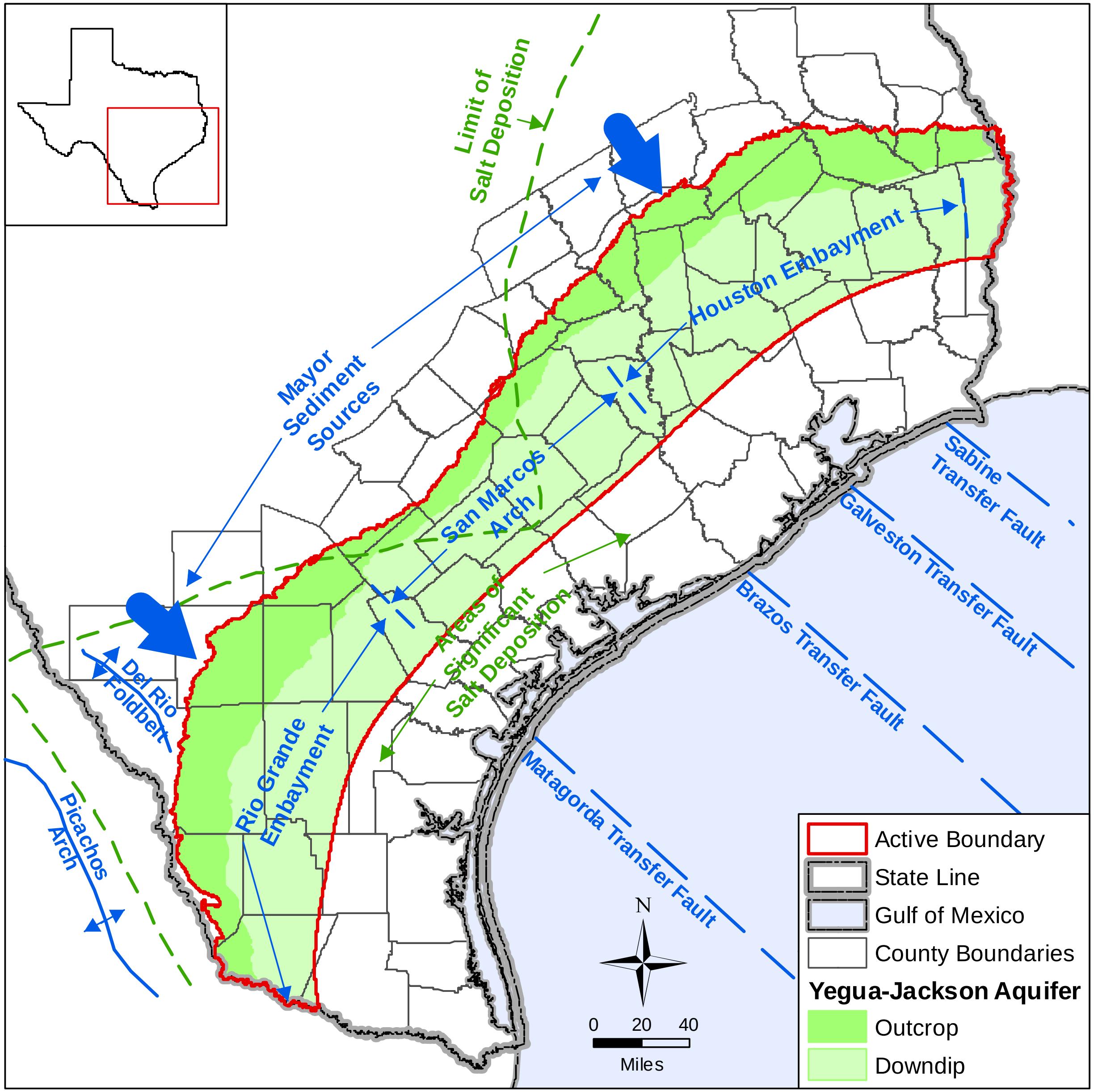
Average Annual Precipitation



Average Annual Lake Evaporation



Major Structural Features



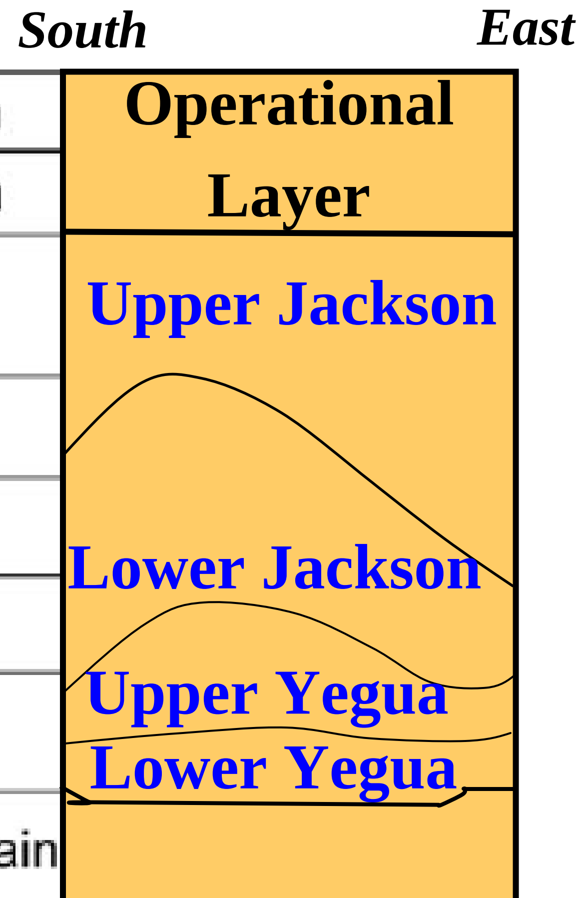
Generalized Stratigraphic Section

Series			Group	Formation
Tertiary	Oligocene			Catahoula
	Eocene-Oligocine		Jackson	Whitsett
	Eocene	Upper		Manning
				Wellborn
				Caddell
		Middle	Upper Claiborne	Yegua
				Cook Mountain

After Preston, 2007

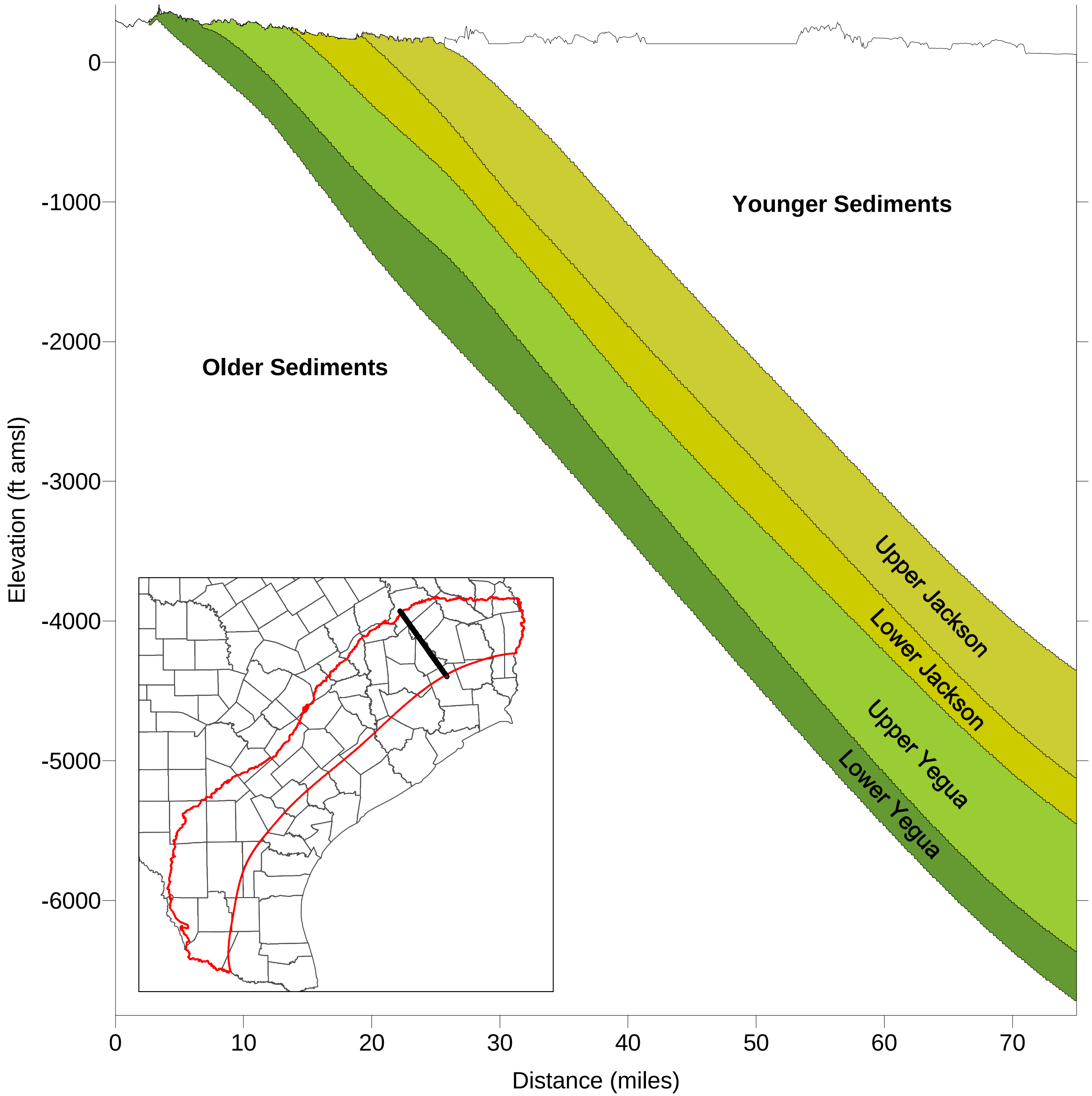
Yegua-Jackson Aquifer Subdivision

Series			Group	Formation
Tertiary	Oligocene			Catahoula
	Eocene-Oligocene		Jackson	Whitsett
	Eocene	Upper		Manning
				Wellborn
				Caddell
		Middle	Upper Claiborne	Yegua
				Cook Mountain

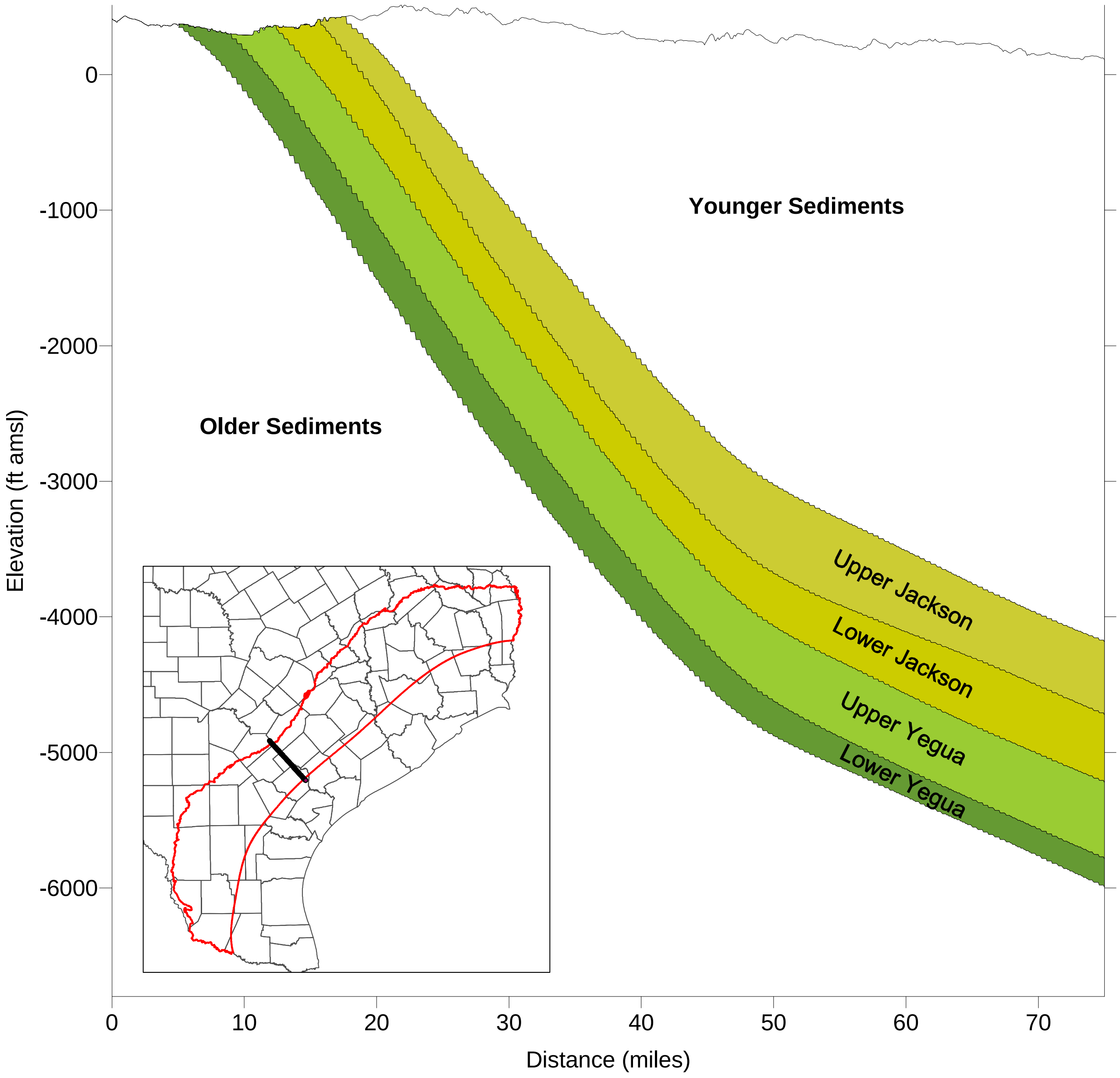


Knox et al.,2007

Structural Cross-section in Houston Embayment



Structural Cross-section over the San Marcos Arch

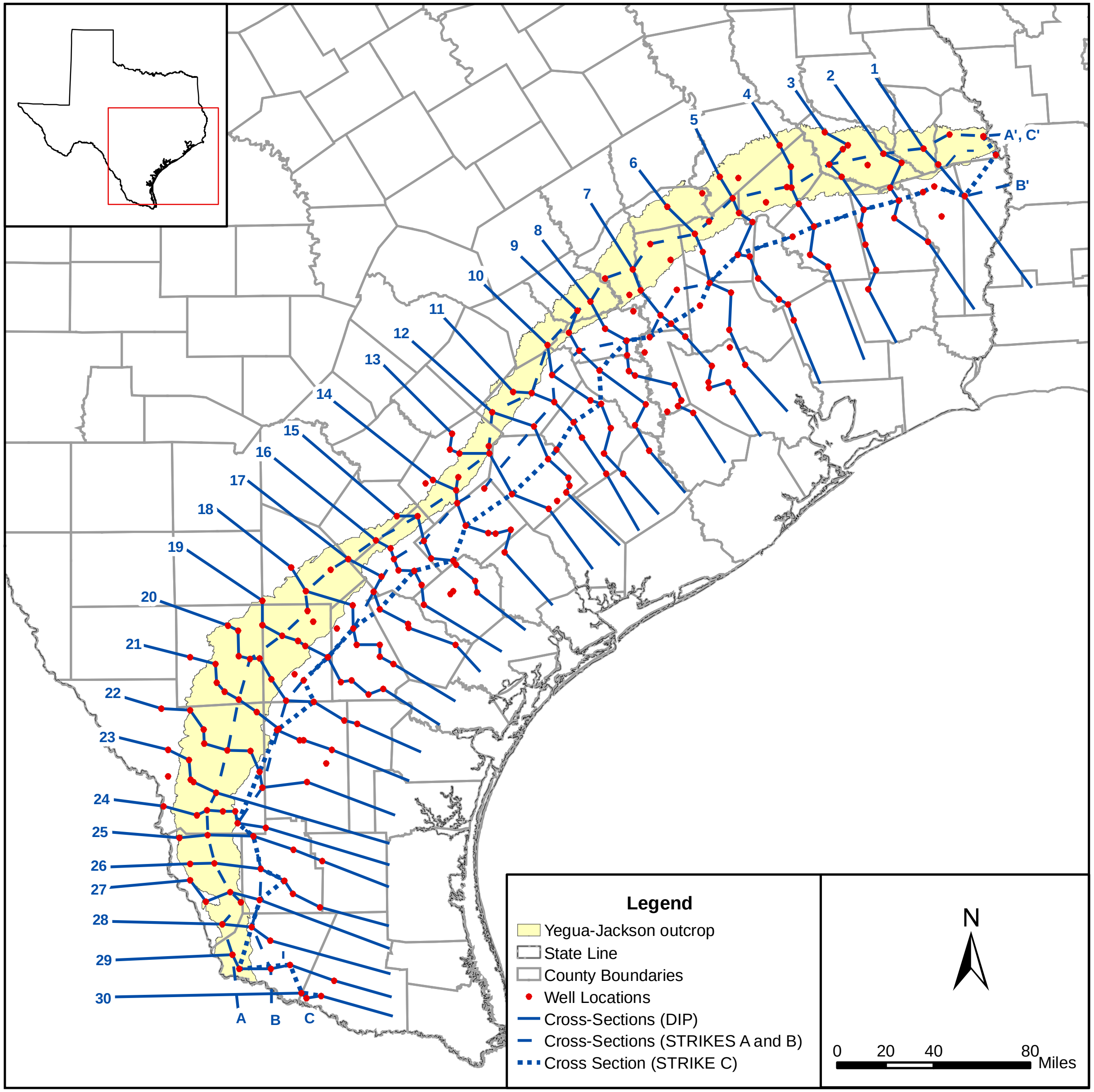


Structure

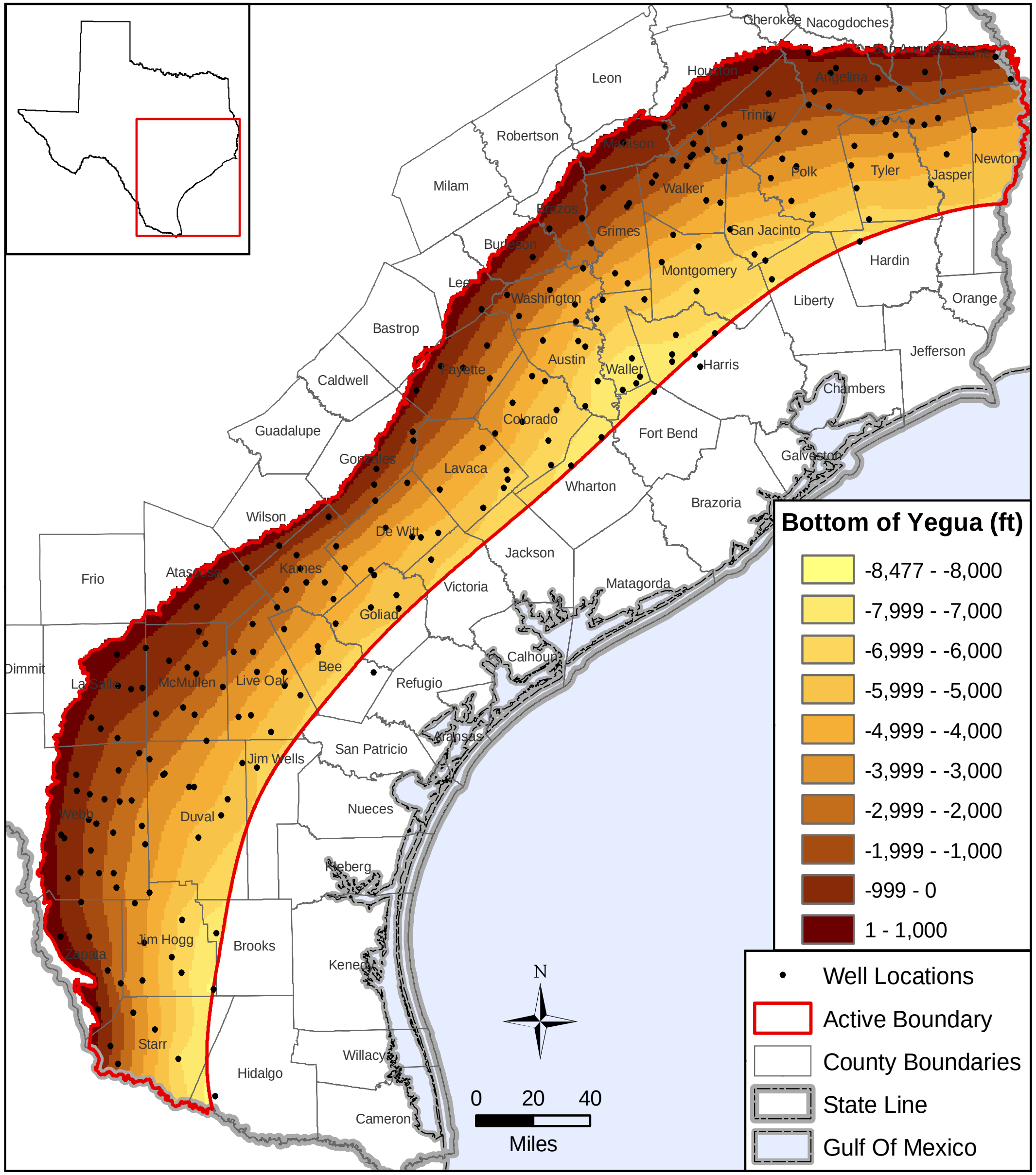
Yegua-Jackson Structure Study - 2007

- **Structure completed for the TWDB by INTERA and Baer Engineering in 2007**
- **Divided into four units based upon a sequence stratigraphy approach**
  - Upper Jackson
  - Lower Jackson
  - Upper Yegua
  - Lower Yegua
- **Also mapped**
  - Net sand
  - Depositional Environments
  - Faults

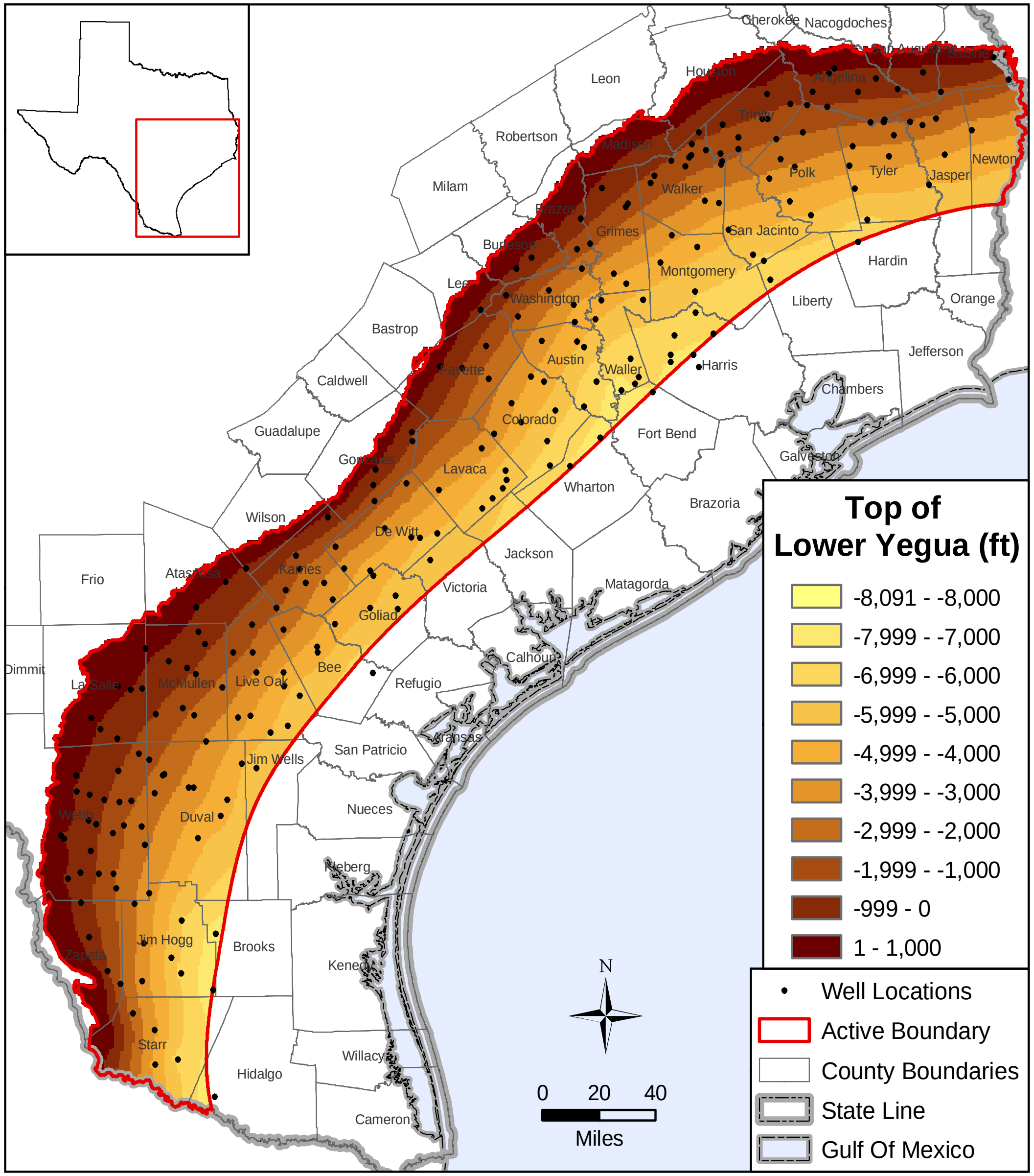
Stratigraphic Correlation Basemap with Cross-section Lines



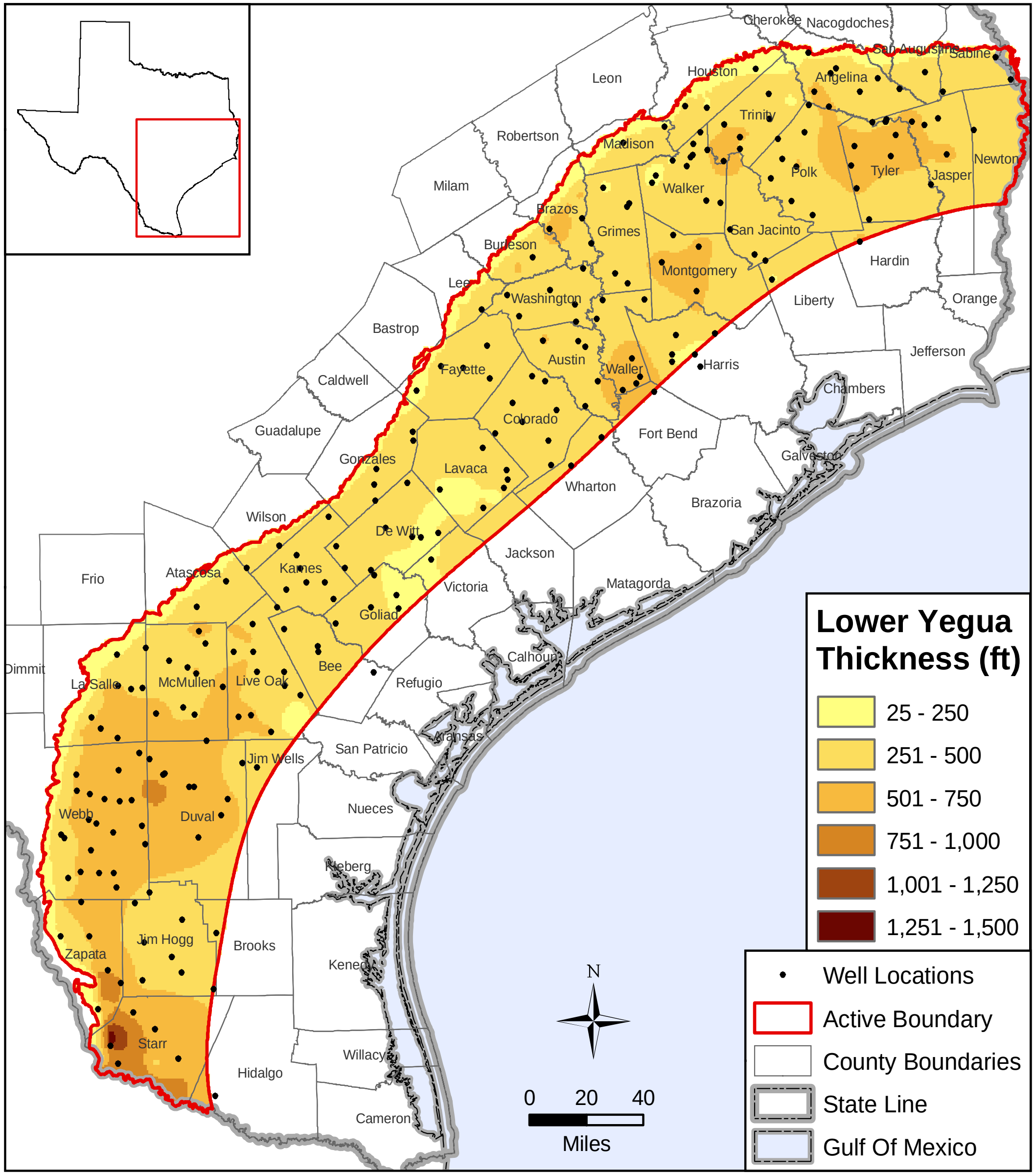
Base of Yegua-Jackson Aquifer



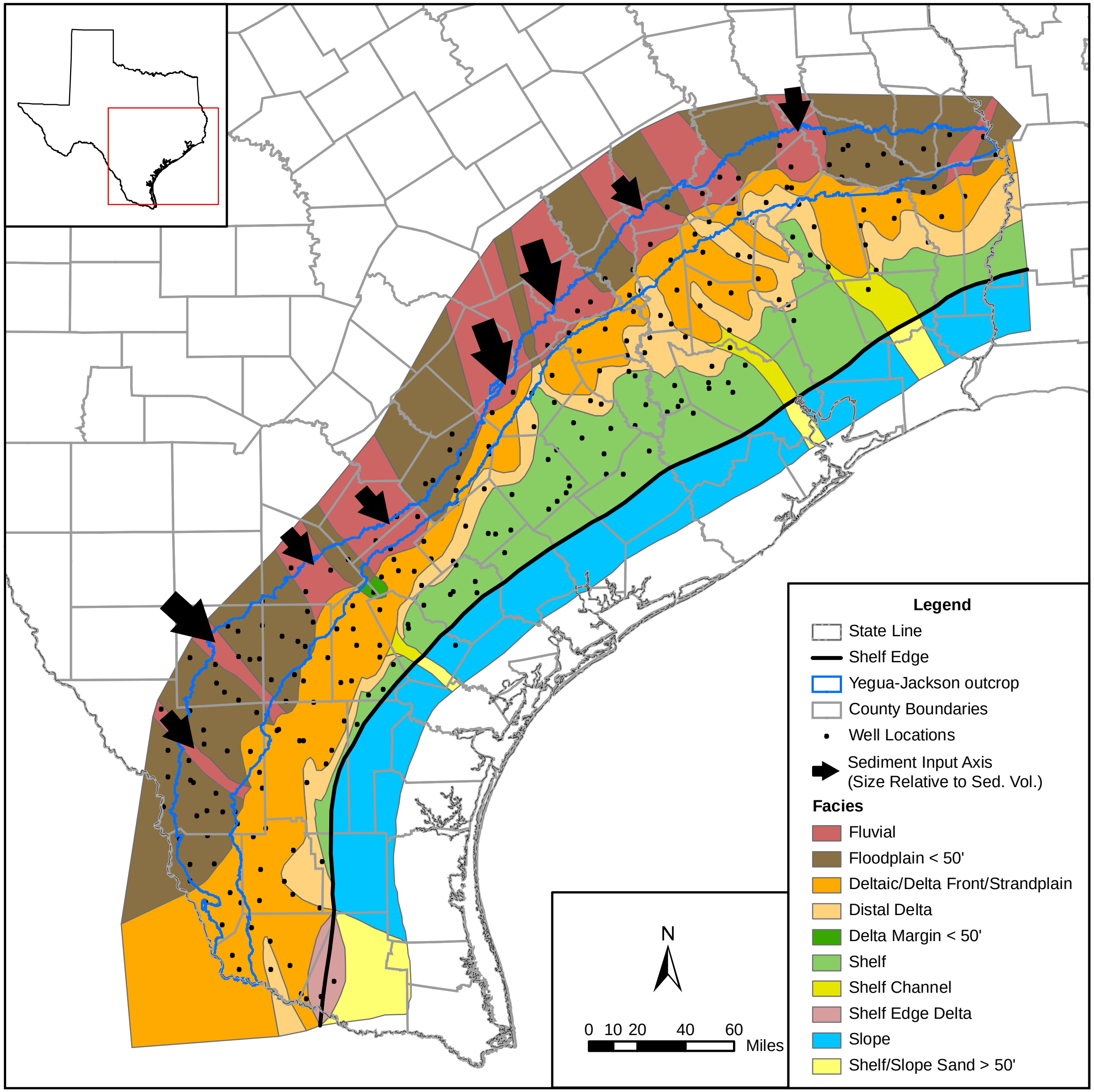
Top of Lower Yegua Unit



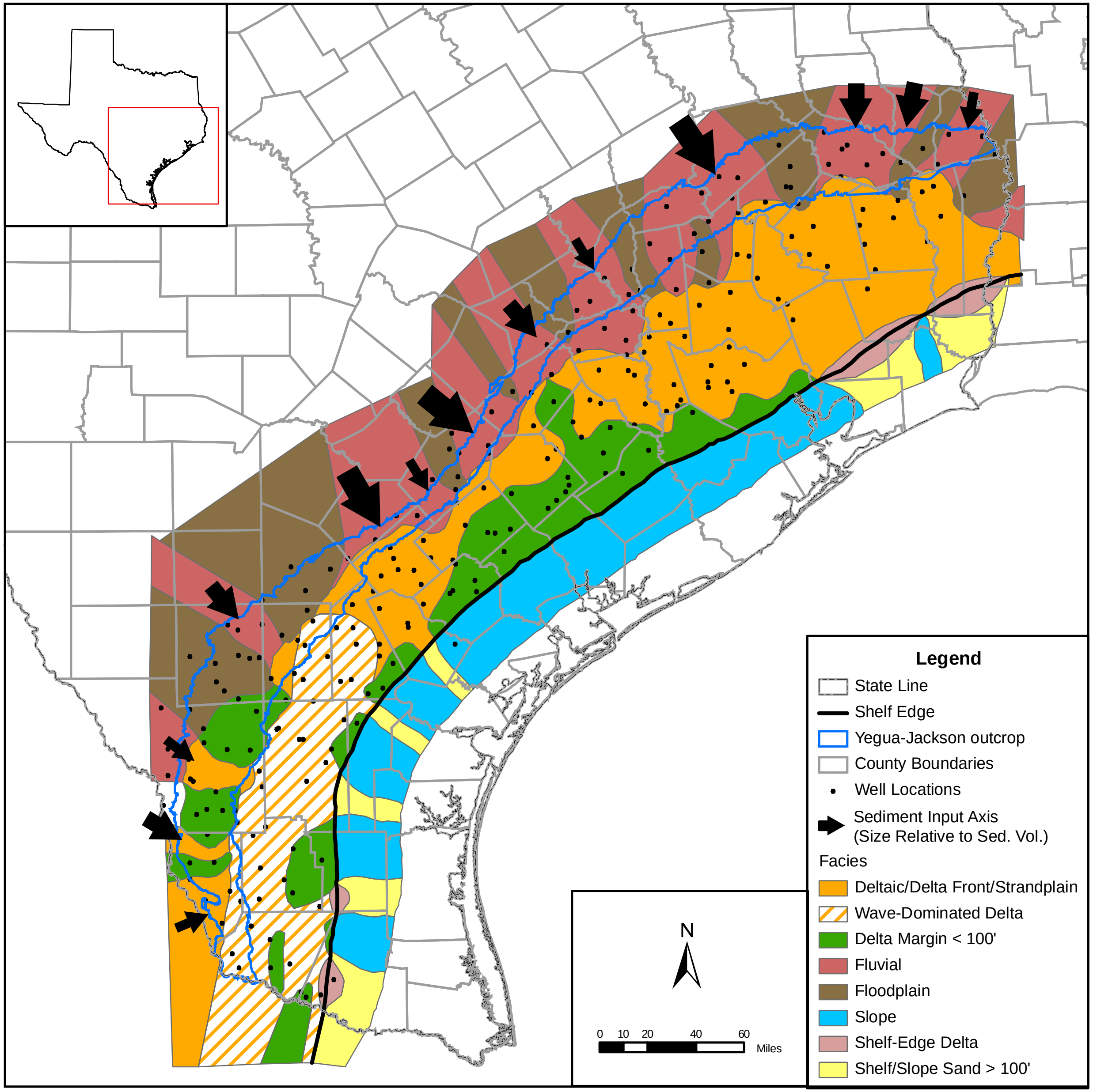
Thickness of Lower Yegua Unit



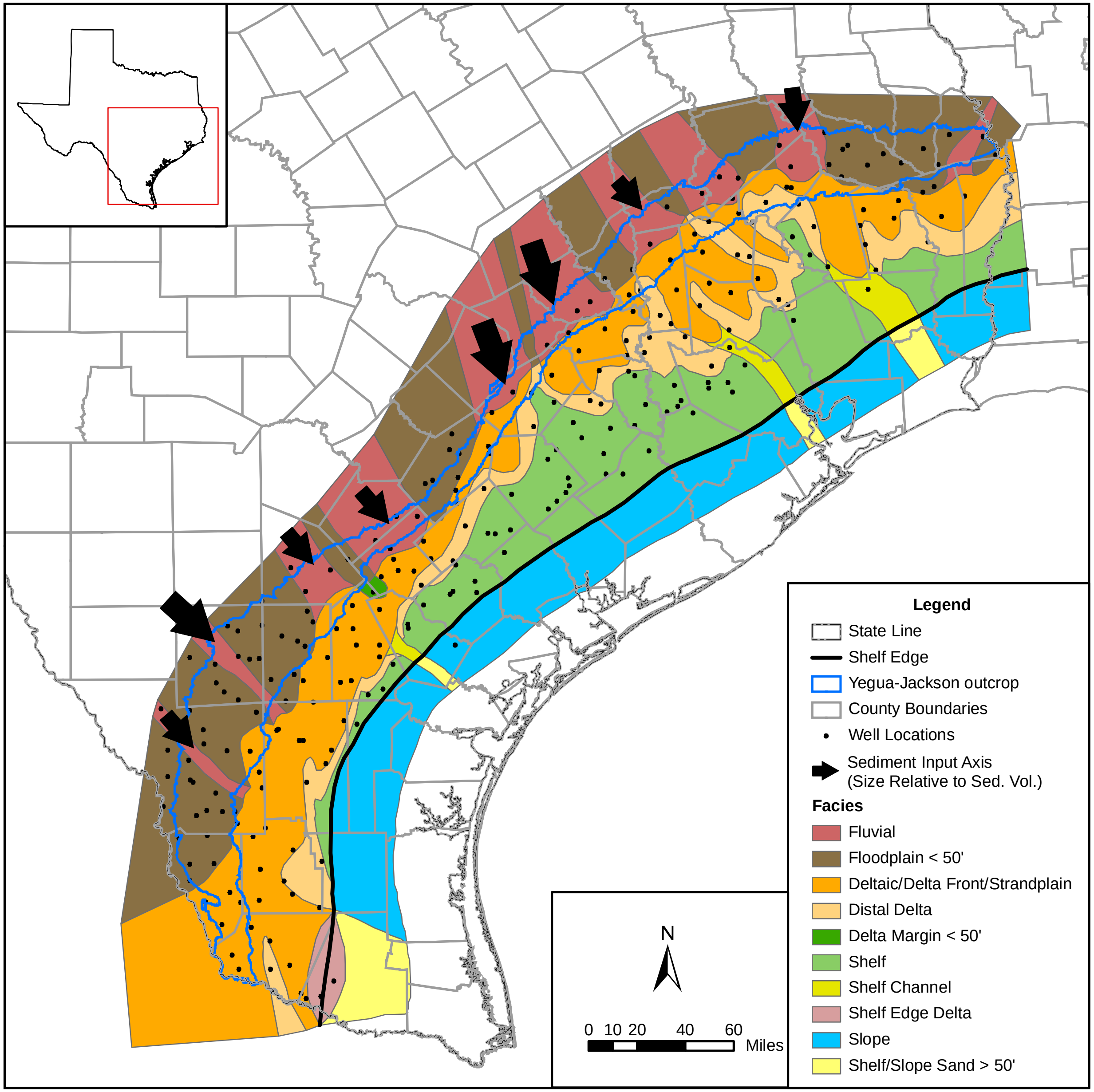
Lower Yegua Depositional Facies Map



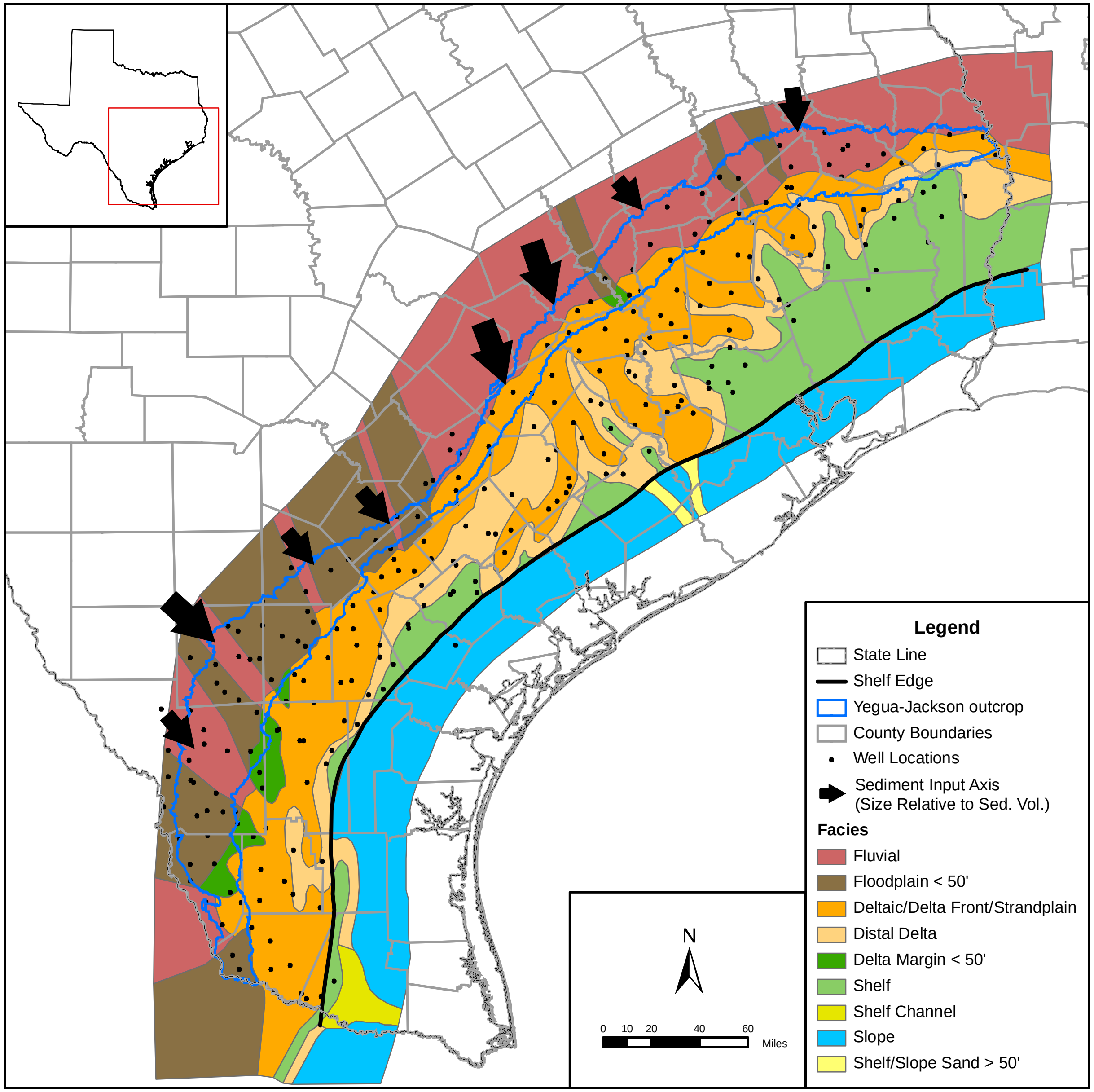
Upper Yegua depostional facies map



Lower Jackson depositional facies map



Upper Jackson depositional facies map

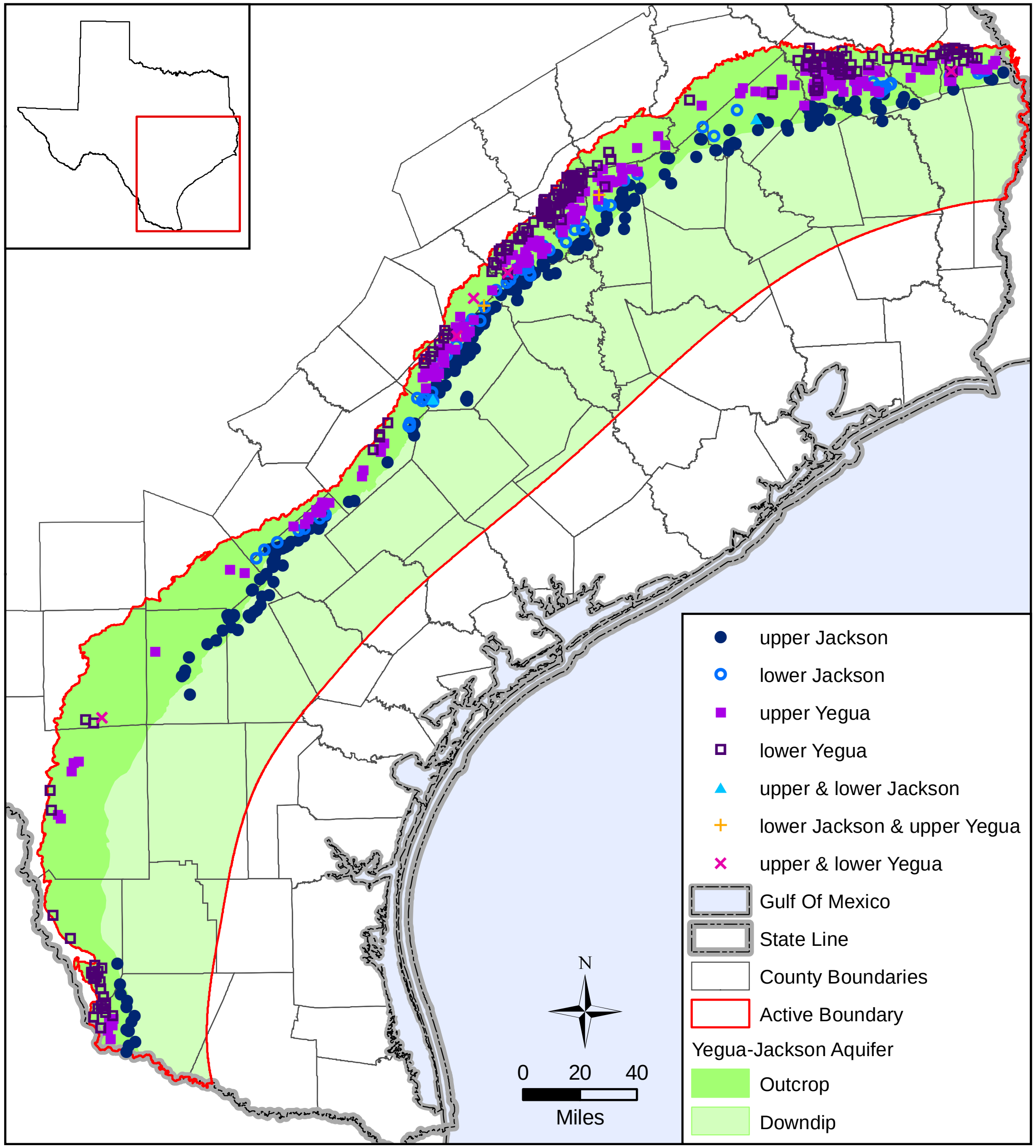


Water Levels

Water Levels

- **Data Sources**
  - TWDB well database
  - USGS Groundwater for the Nation
- **Objectives**
  - Regional groundwater flow
  - Estimate steady-state conditions in the aquifer
  - Estimate conditions in the aquifer at the beginning, middle, and end of the transient model calibration (i.e.,1980, 1990, and 1997)
  - Evaluate transient water-level conditions
  - Evaluate cross-formational flow
- **Evaluated individually for the four aquifer layers**
  - Compared completion interval or total depth to structural top and bottom of aquifer layers
  - Used only data for which a layer could be determined

Locations with Water-Level Data



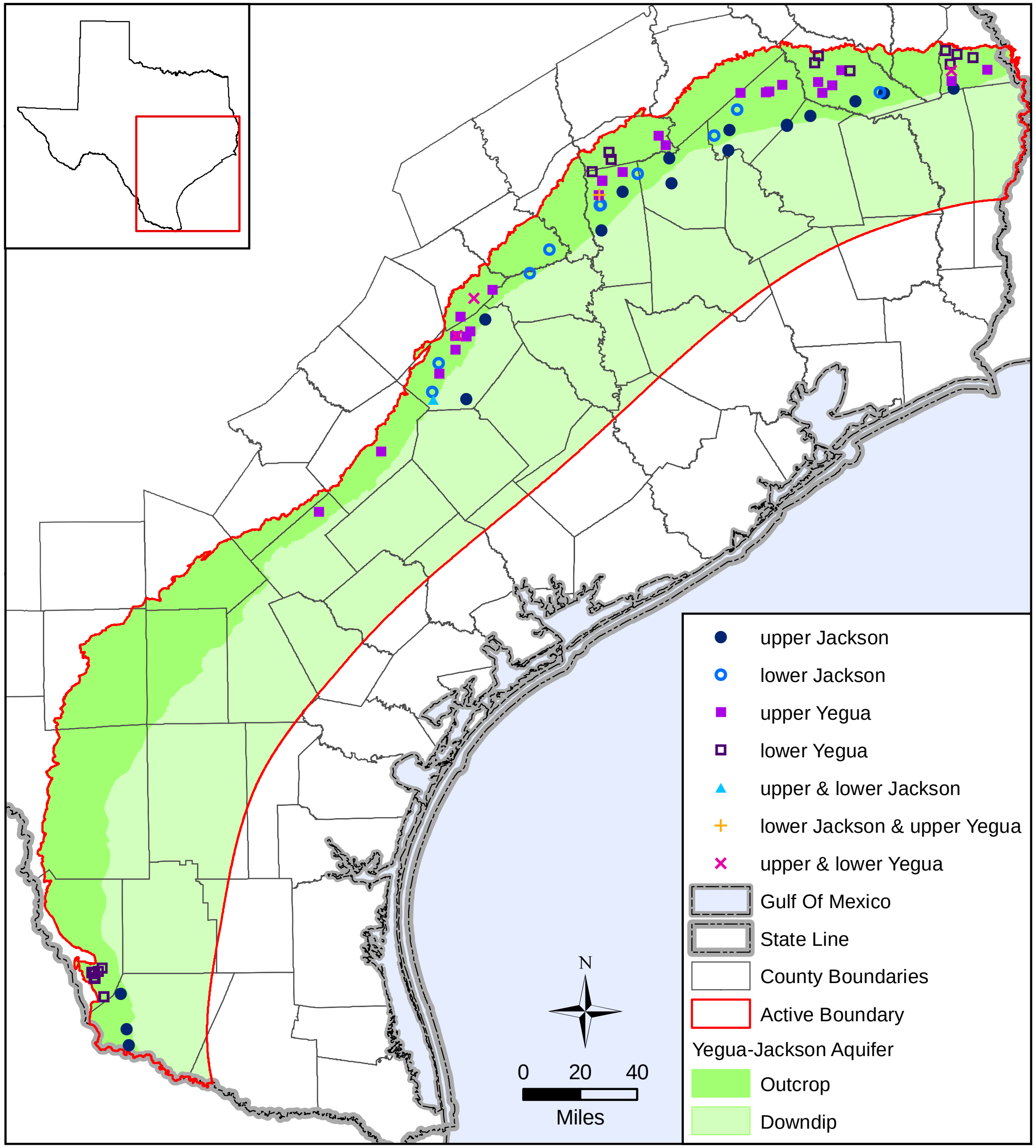
Regional Groundwater Flow

- **Outcrop areas**
  - Influenced by topography
  - Flow is from topographic highs along drainage divides to topographic lows in creeks and rivers
- **Confined portion**
  - Flows horizontally along the dip of the aquifer
  - Flows vertically across formations
  - Dip of the land and the aquifer is towards the Gulf of Mexico

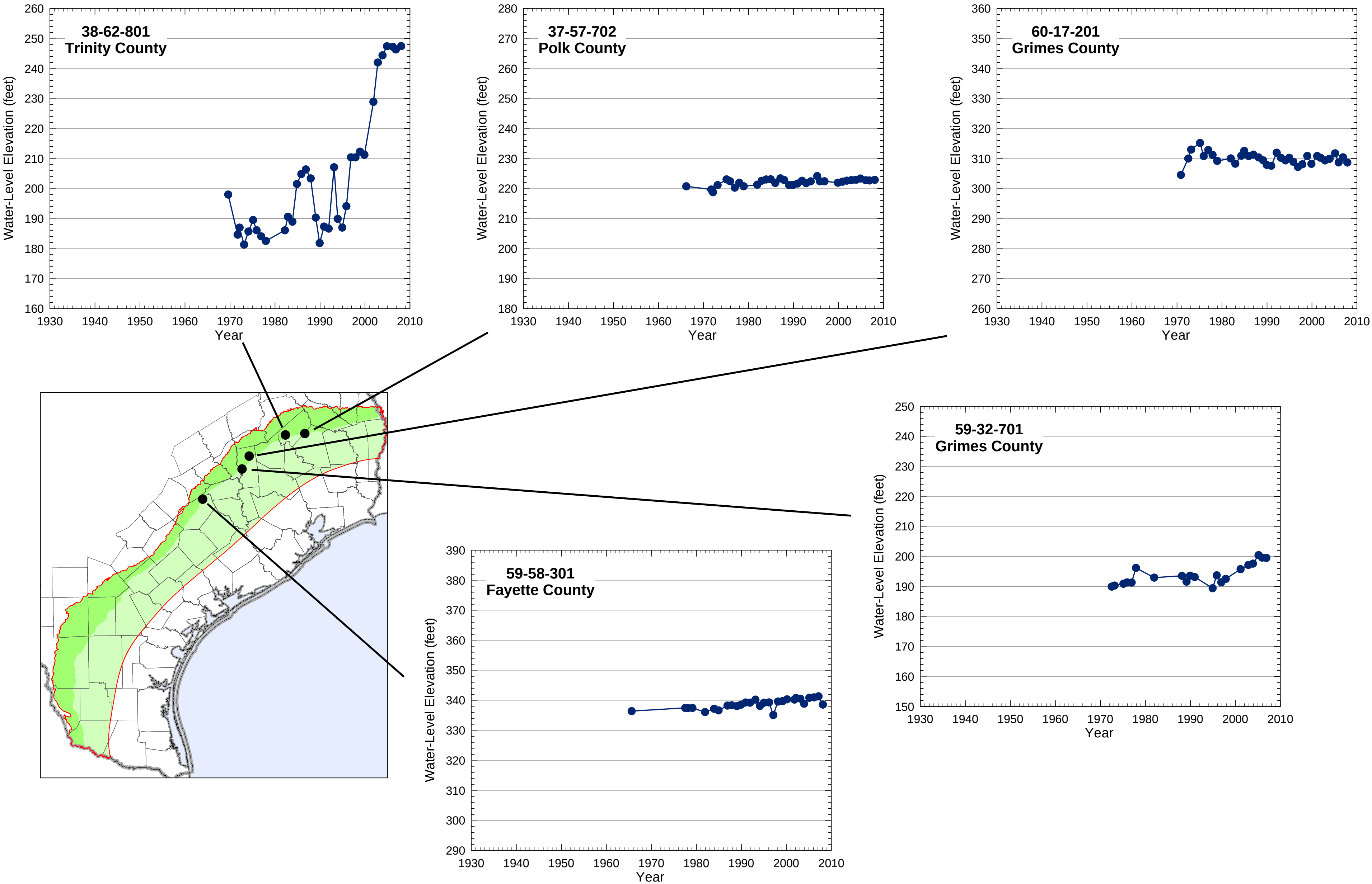
Steady-State Water Levels

- **Some pumping for rural domestic, livestock and municipal purposes as early as 1900**
  - Relatively small and likely did not result in significant drawdown
- **Water-level data prior to 1950 was assumed to be representative of steady-state conditions**
- **Data insufficient to contour**
  - Relationship between ground surface and water levels explored
  - Steady-state surface produced from this relationship
  - In the end, the **calibrated** model will provide the best estimate of steady-state heads

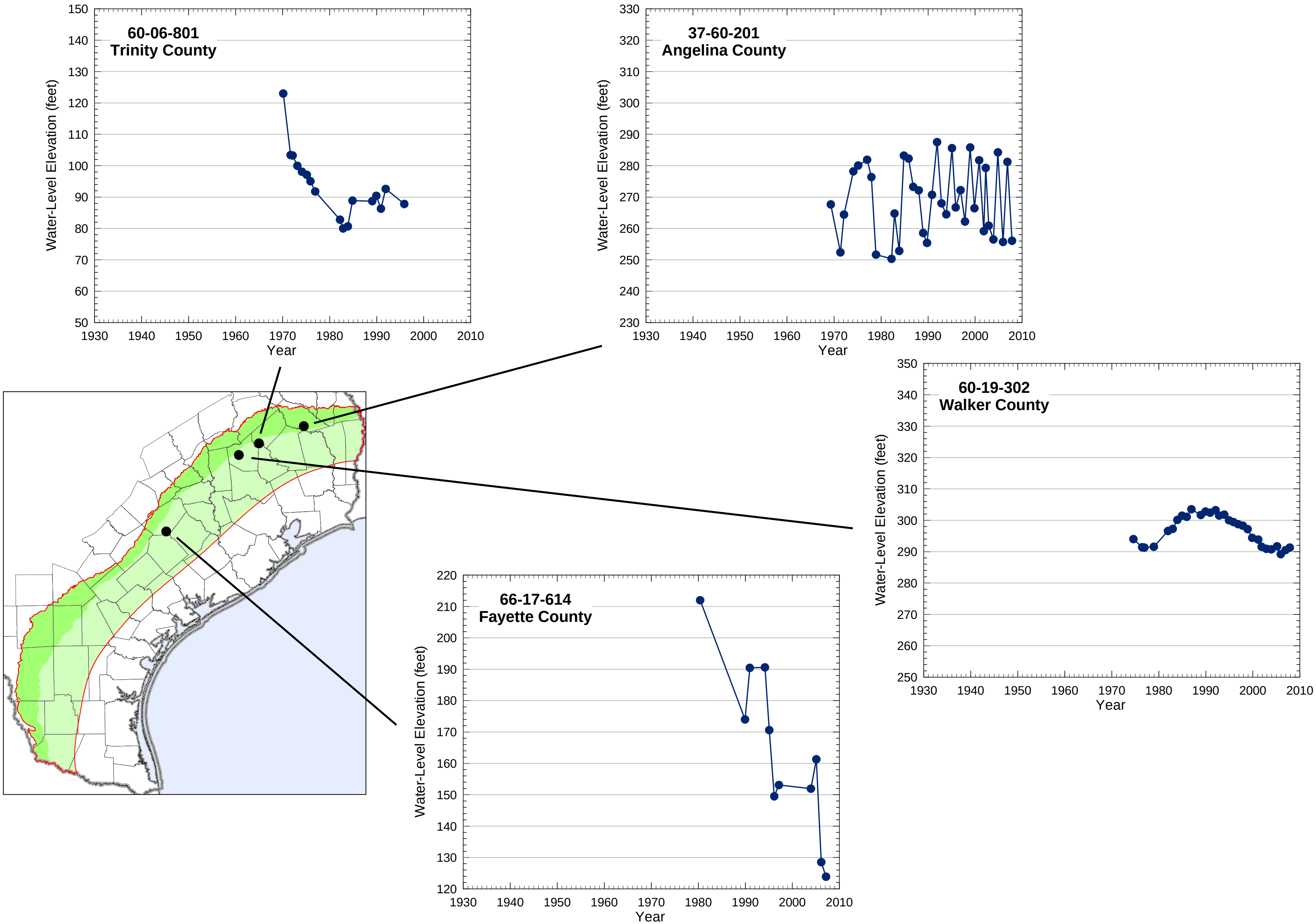
Transient Water-Level Data - Locations



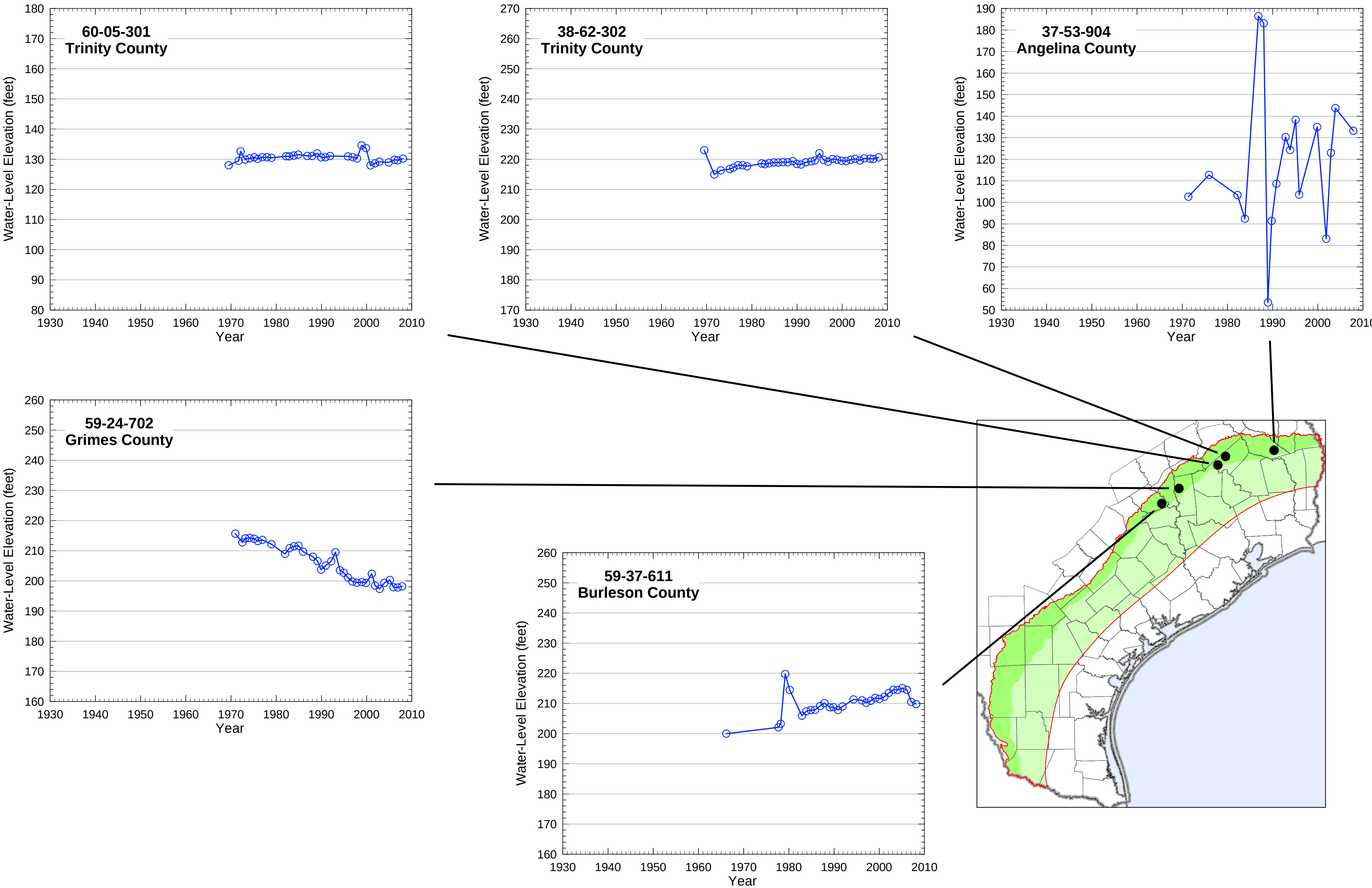
Transient Water Levels – Upper Jackson Unit



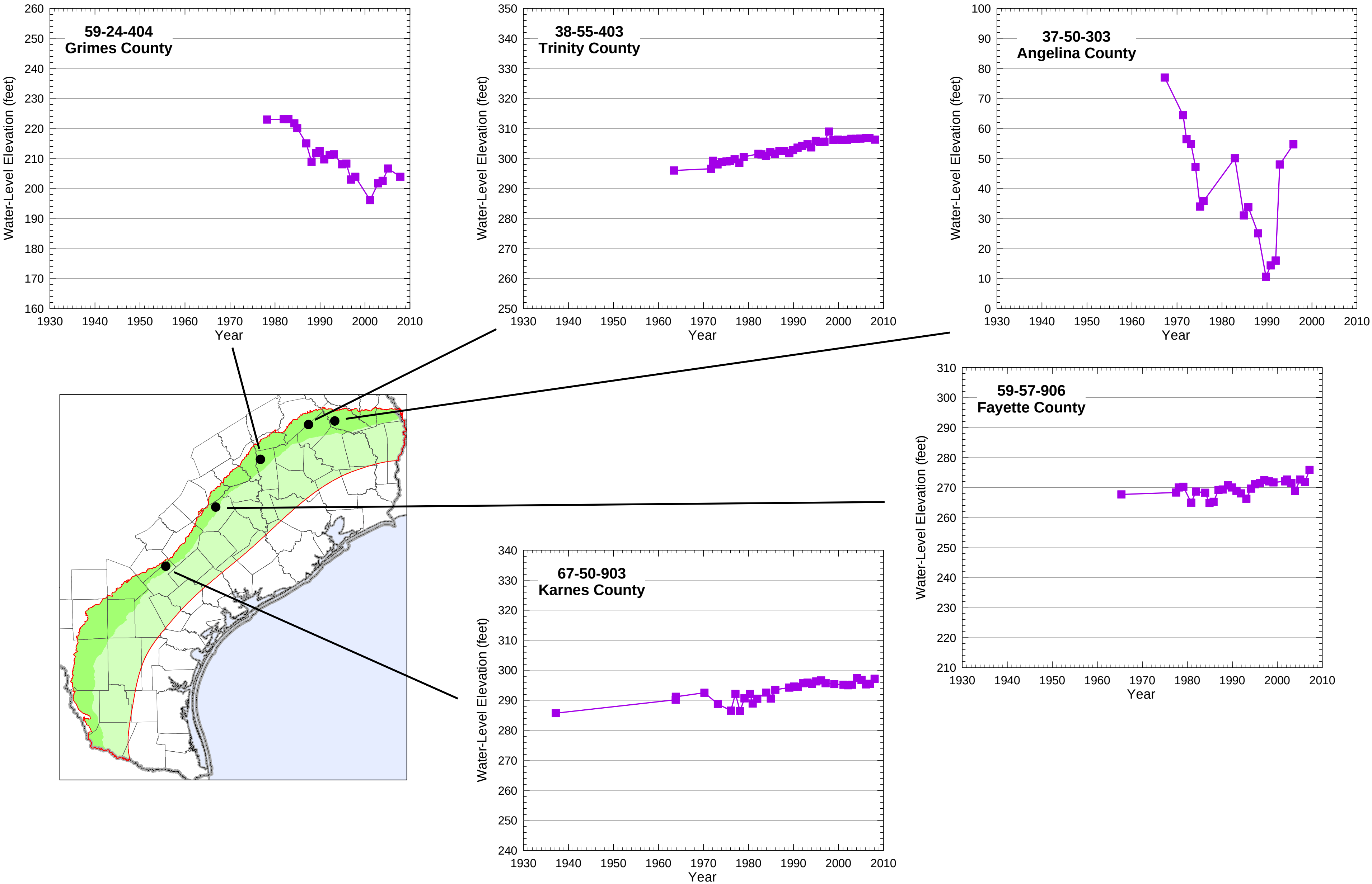
Transient Water Levels – Upper Jackson Unit (cont'd)



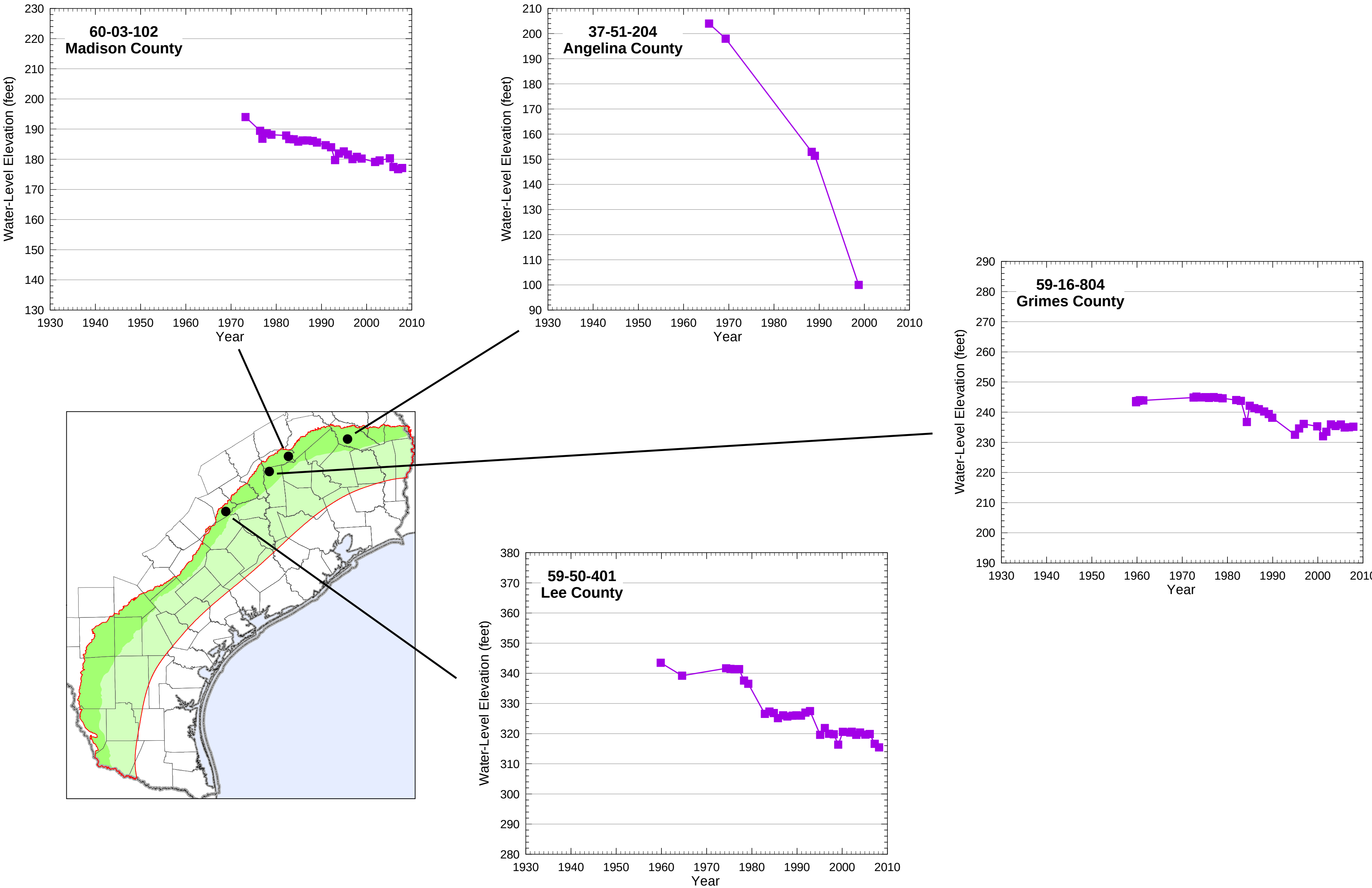
Transient Water Levels – Lower Jackson Unit



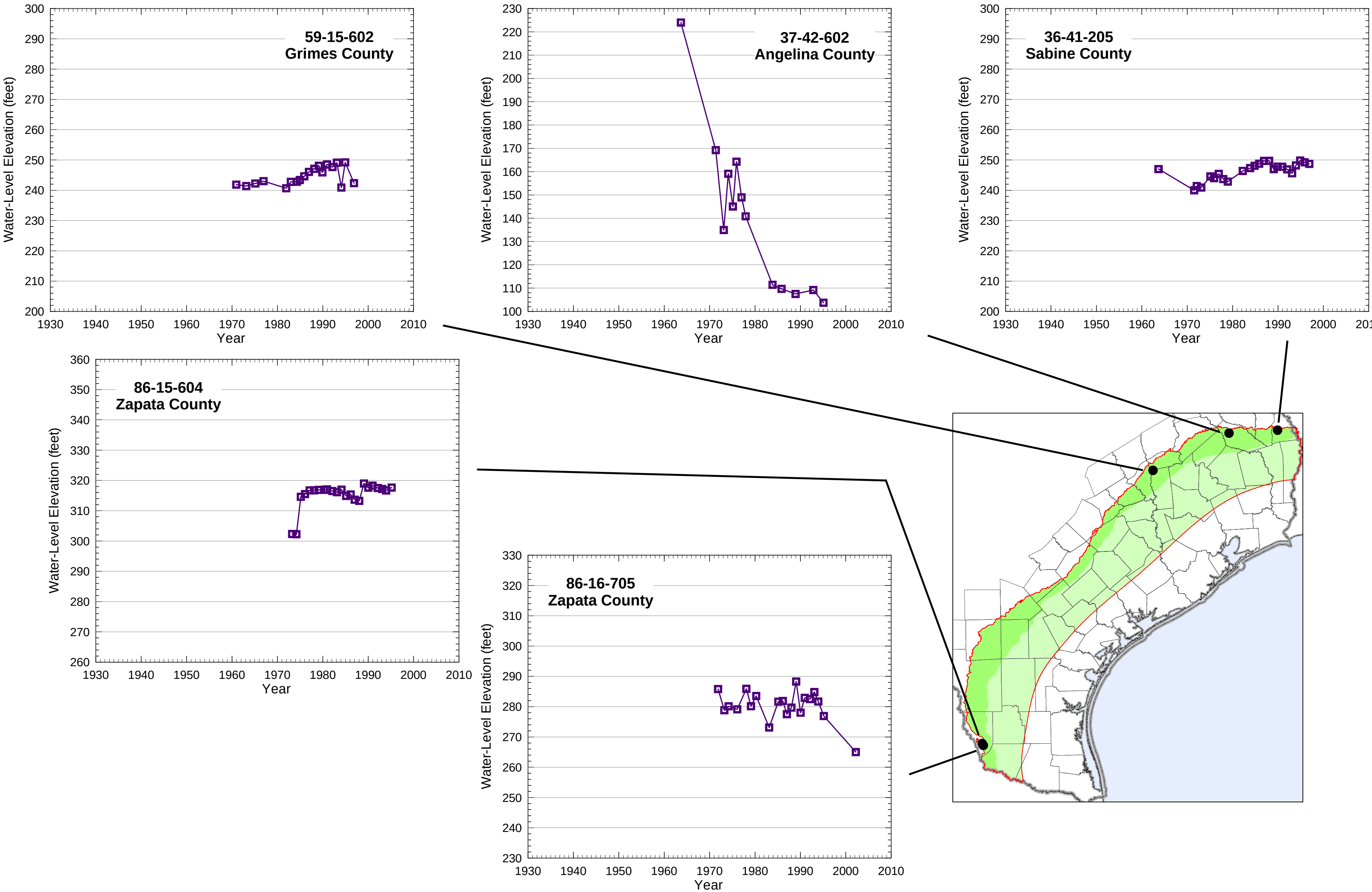
Transient Water Levels – Upper Yegua Unit



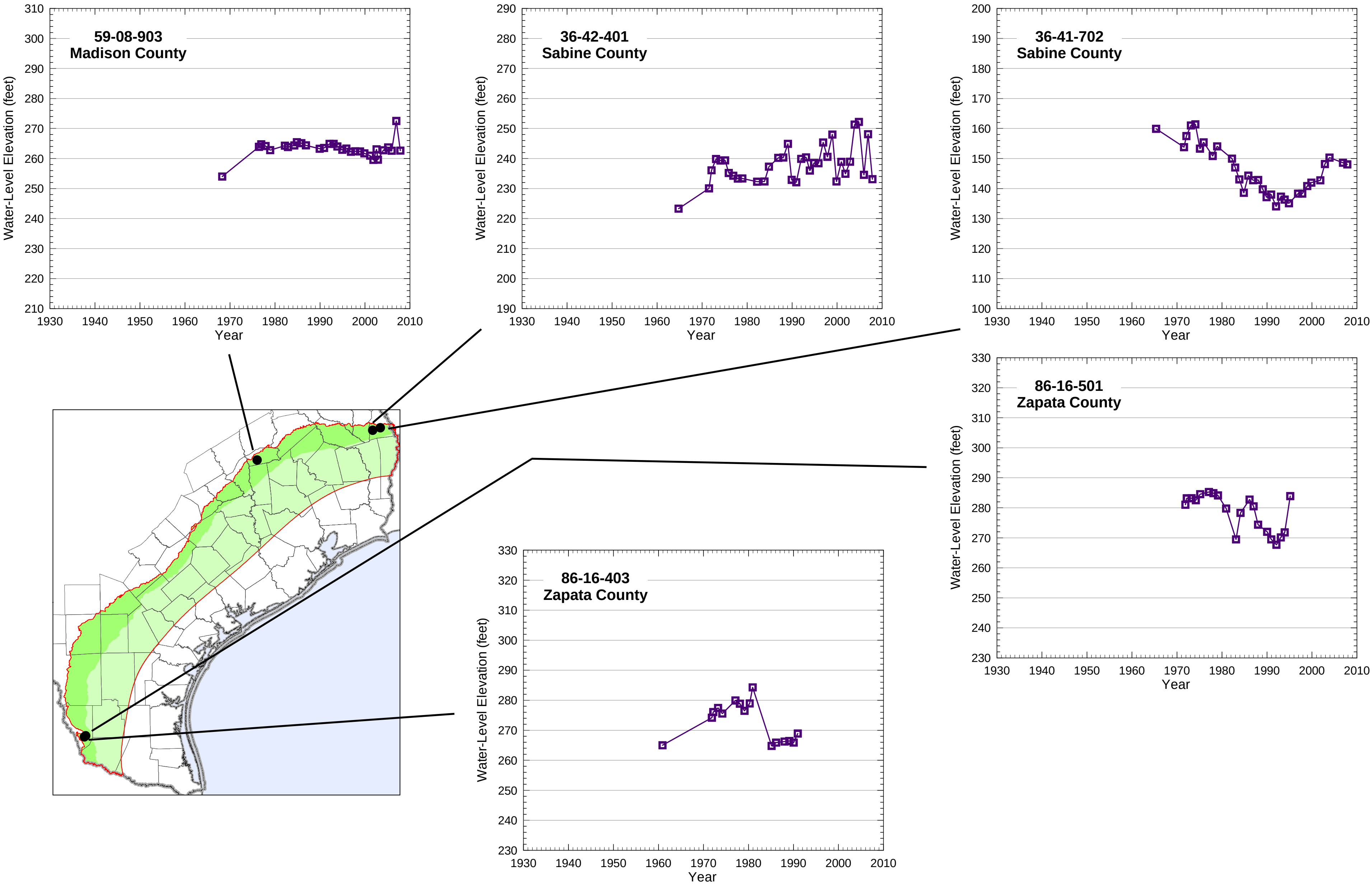
Transient Water Levels – Upper Yegua Unit (cont'd)



Transient Water Levels – Lower Yegua Unit



Transient Water Levels – Lower Yegua Unit (cont'd)



Hydraulic Properties

Information Sources for Estimating Hydraulic Properties

- **Lithologic data available from Knox (2007) study of the Yegua-Jackson structure**
- **Aquifer descriptions from USGS and TWDB reports**
- **No data available from Myers (1969)**
- **Pumping Test Results available from Texas Commission on Environmental Quality**
- **Hydraulic Properties available in the Oil & Gas Literature**

Results from TCEQ Public Water Supply Pumping Tests

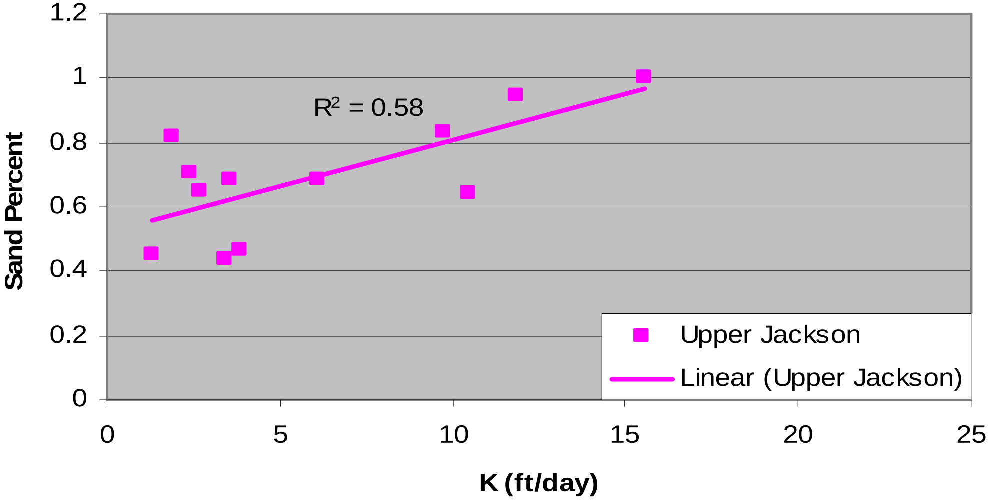
- **75 Pumping Tests were Identify within Yegua-Jackson footprint**
- **Screening Process Eliminate about 50% of wells**
  - Well screen information missing or questionable
  - Well screen interval above the aquifer
  - Drawdown data could not be analyzed using Cooper-Jacob straight-line analysis method
- **41 of the Pumping Tests were Accepted**
  - Constant pumping rate for several hours
  - Lithological information available from driller logs
  - Cooper Jacob fit R^2 greater than 0.80

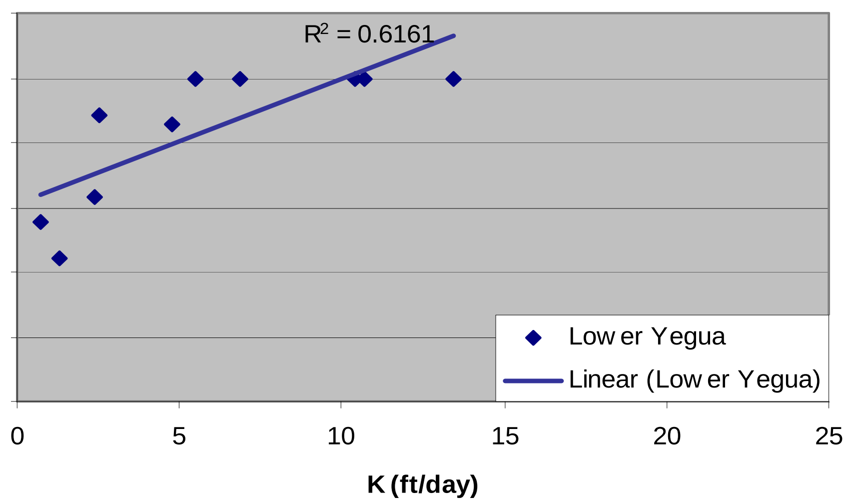
Summary of Pumping Test Results

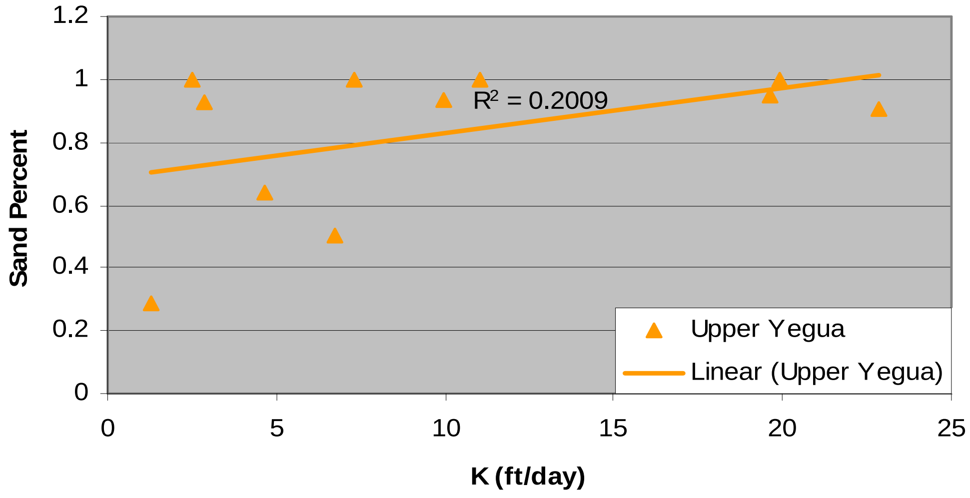
Geologic Unit	Number of Tests	Average Depth of Test	Hydraulic Conductivity (ft/day)				
			Arithmetic Mean	Geometric Mean	Standard Deviation	Minimum Value	Maximum Value
Upper Jackson	14	539	6.6	5.0	5.0	1.3	15.6
Lower Jackson	1	605	12	12	NA	12	12
Upper Yegua	11	408	9.9	7.0	5.0	1.3	22.8
Lower Yegua	11	610	5.8	4.2	7.6	0.8	13.4

Note: At least 60% of well screen required to intersect the geologic unit

Relationship Between Conductivity and Sand Percent



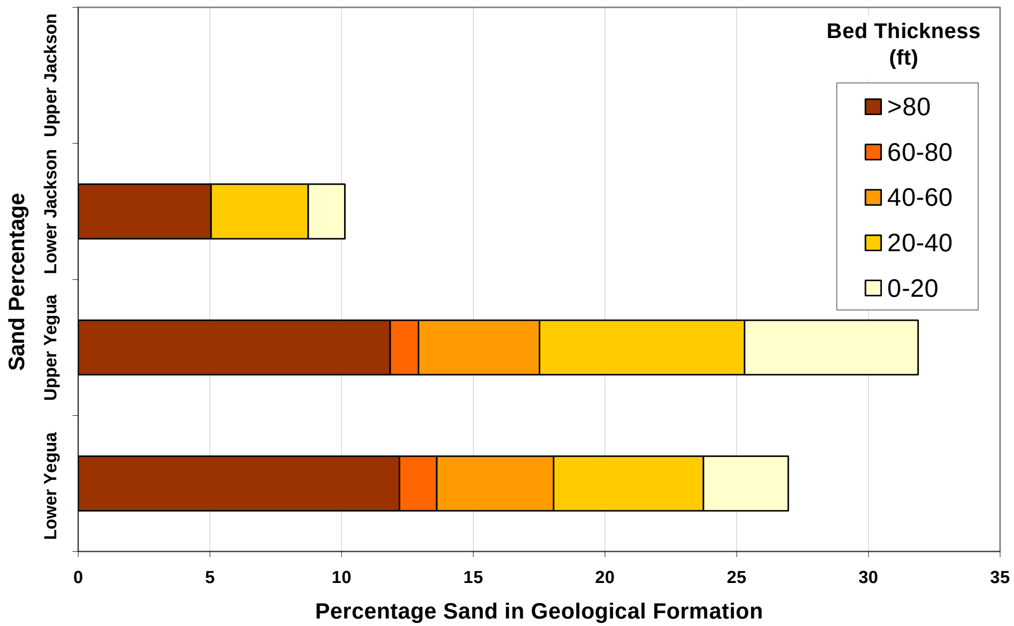


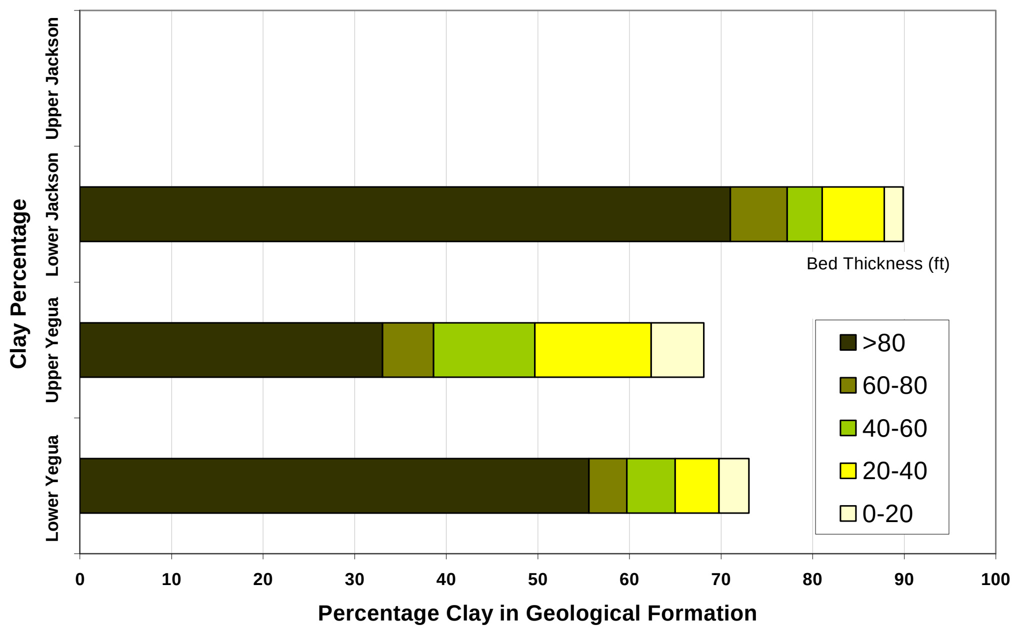


Approach for Generating Hydraulic Properties

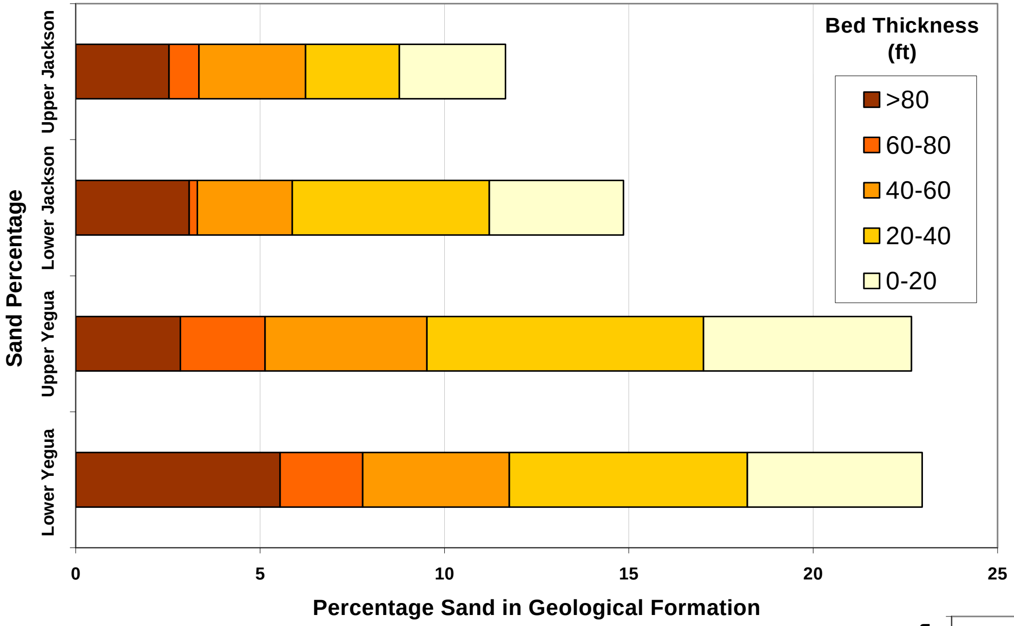
- **Highlights from Pumping Tests Analysis**
  - Hydraulic conductivity values (2 to 20 ft/day) form TCEQ information consistent with limited values from other reports
  - Most information in up-dip regions, limited data from down-dip regions
- **Approach for Populating Hydraulic Conductivity Field**
  - Use guidelines and relationships between geologic properties and hydraulic properties extracted from field data and other studies
  - Use depositional facies and lithology from Knox and others (2007)
  - Consider relationships developed by oil & gas geoscientists from Yegua-Jackson and Gulf Coast deposits
  - Consider relationships developed from TWDB GAM studies

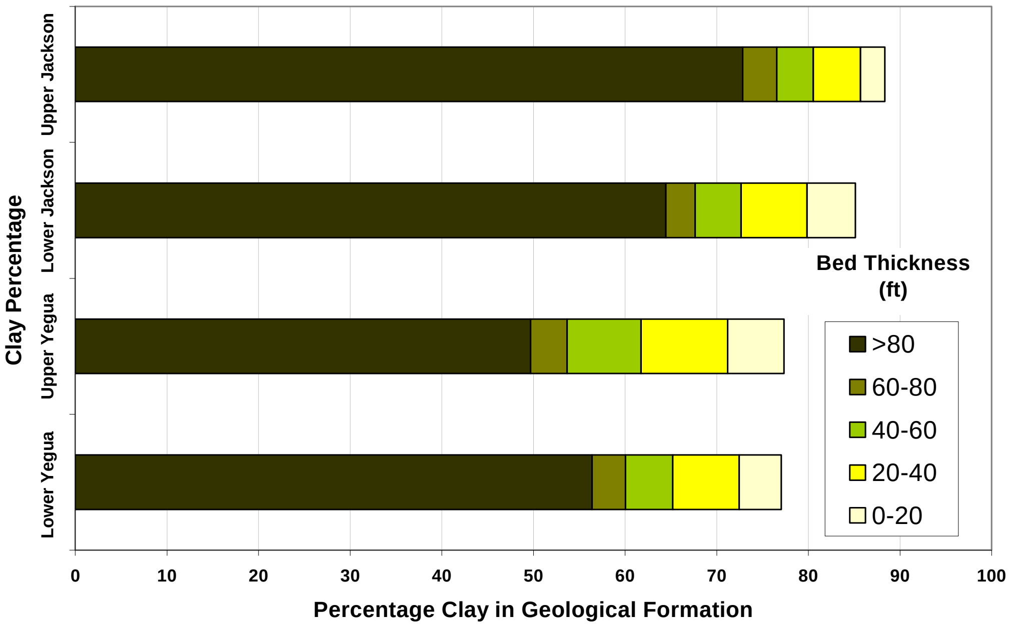
Bed Thickness and Sand Percentage – Fluvial Facies





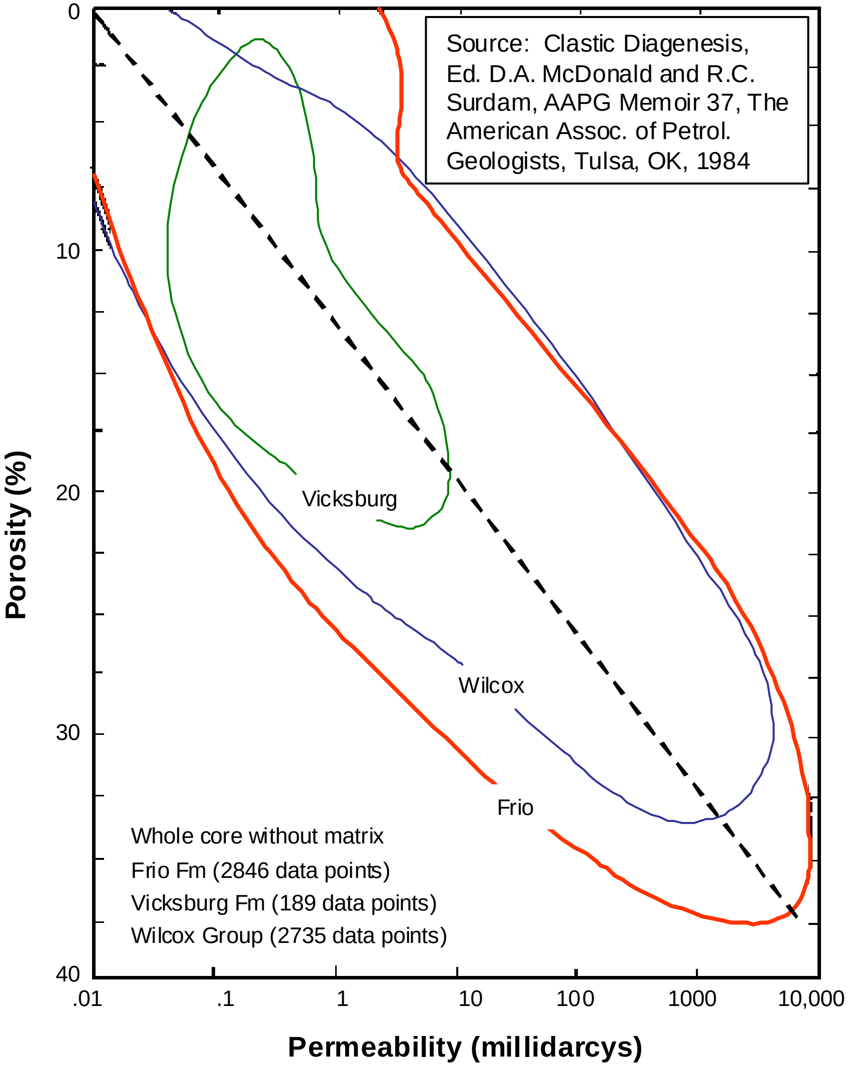
Bed Thickness and Sand Percentage – Deltaic Facies





Porosity and Permeability Data from Oil and Gas Studies

Geological Formations		Porosity Loss per 1000 ft of depth of burial
Miocene		1.34
Frio	Areas 1-6	1.28
	Areas 1-3	1.48
	Areas 4-6	2.05
Vicksburg		1.32
Jackson/Yegua		2.28
Queen City		1.86
Wilcox		1.51

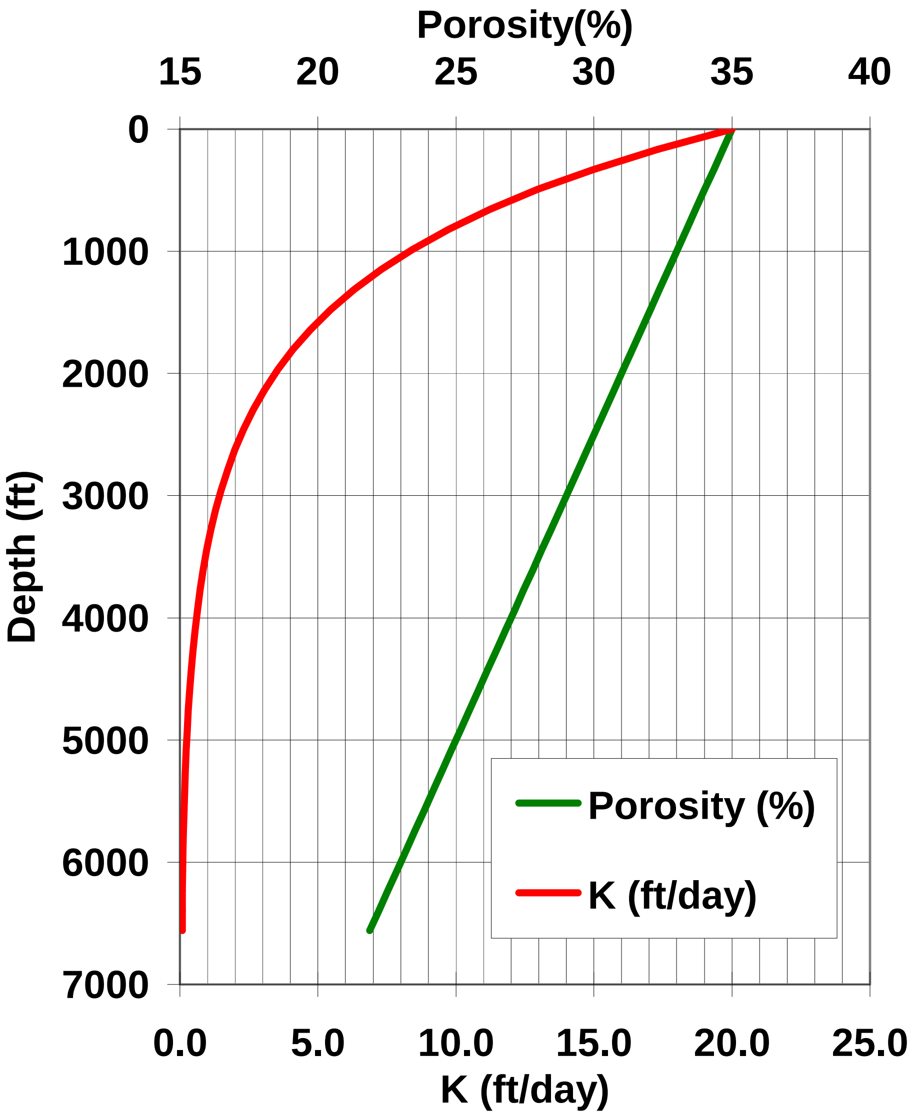


Conceptual Framework for Hydraulic Properties

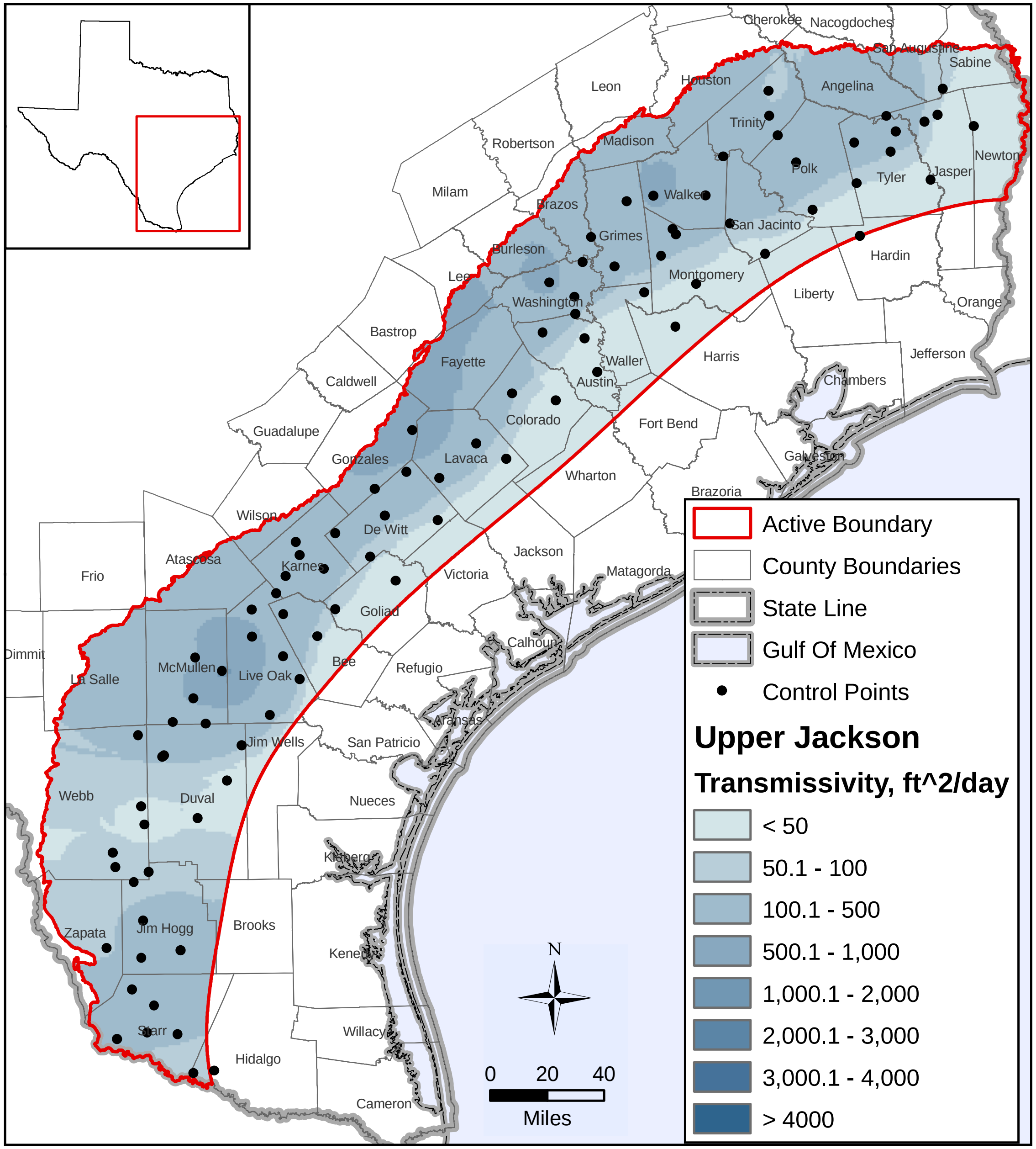
- **Transmissivity can be estimated by multiplying the total amount of sand in a geological unit by the average hydraulic conductivity of the sand in the unit**
- **Within a geologic unit, the hydraulic conductivity among different sand bodies will vary and one of the factors that affects this variation is the depositional facies of the sand**
- **Hydraulic conductivity decreases as a function of depth**

Initial Assumptions Regarding Hydraulic Conductivity Field

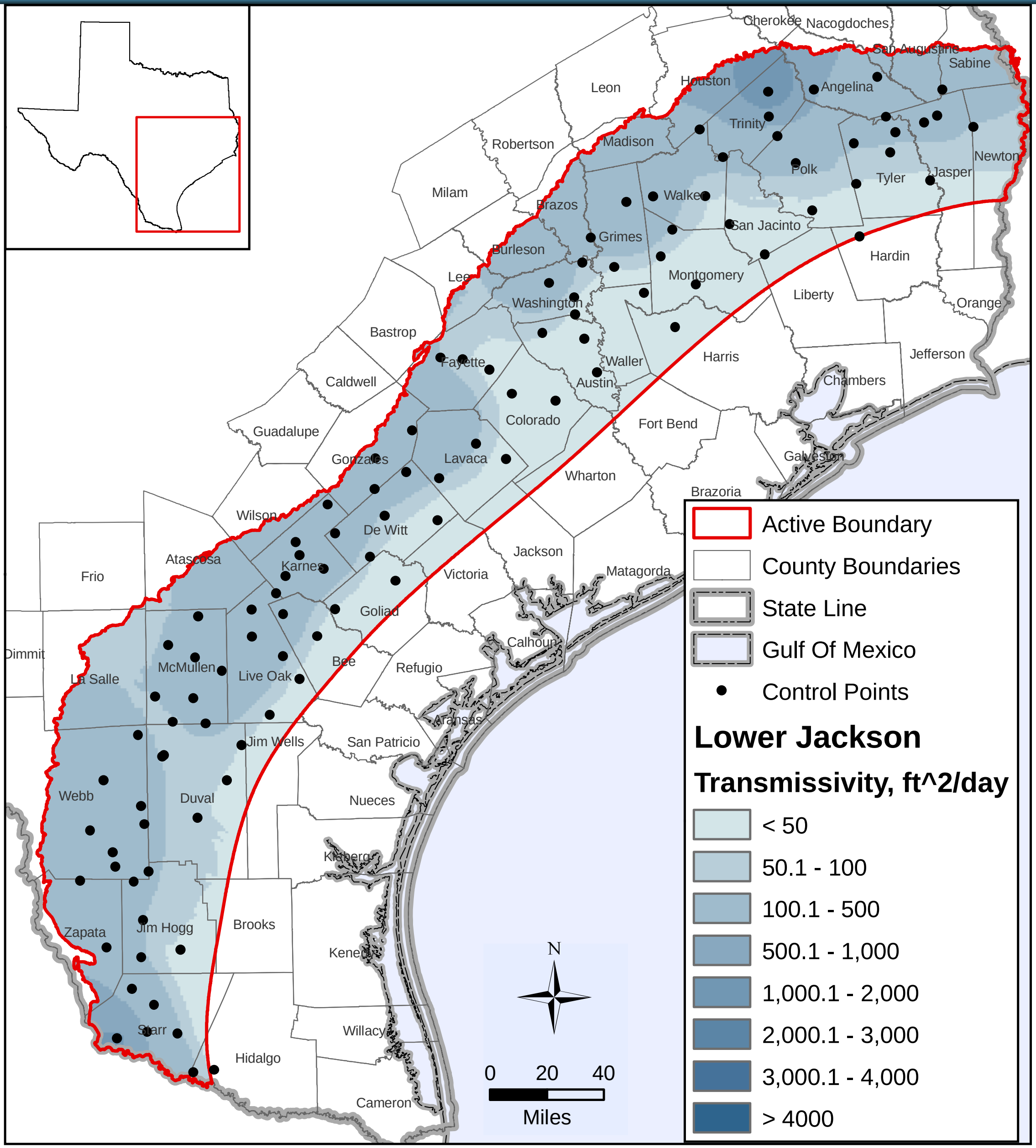
Geology Unit	Major Facies Groupings	Hydraulic Conductivity (ft/day)	
		Sand	Clay
Upper Jackson	Fluvial	15	0.01 * K sand
	Delta	8	0.01 * K sand
	Shelf	5	0.01 * K sand
Lower Jackson	Fluvial	15	0.01 * K sand
	Delta	8	0.01 * K sand
	Shelf	5	0.01 * K sand
Upper Yegua	Fluvial	20	0.01 * K sand
	Delta	15	0.01 * K sand
	Shelf	5	0.01 * K sand
Lower Yegua	Fluvial	20	0.01 * K sand
	Delta	15	0.01 * K sand
	Shelf	5	0.01 * K sand



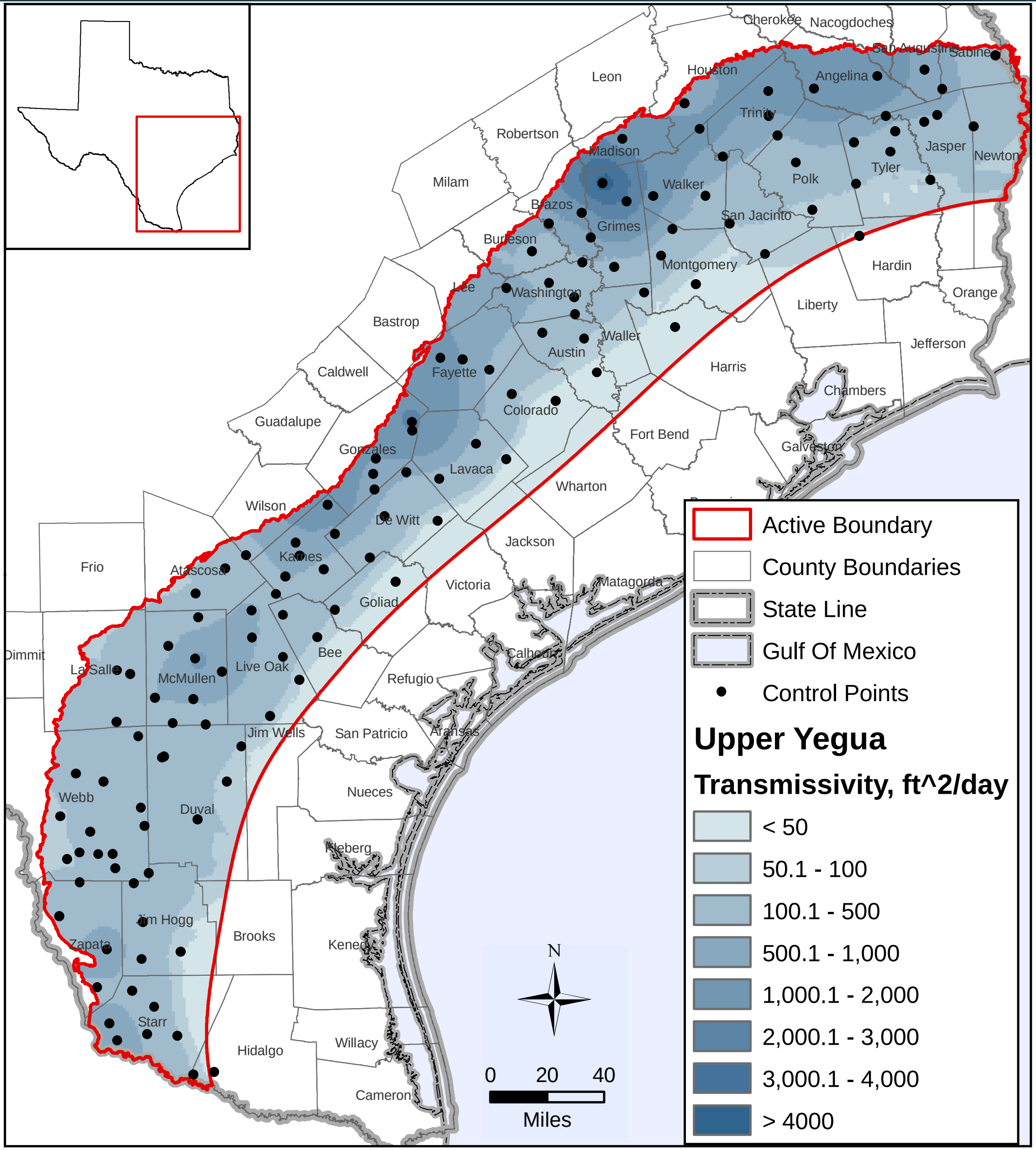
Estimated Transmissivity – Upper Jackson



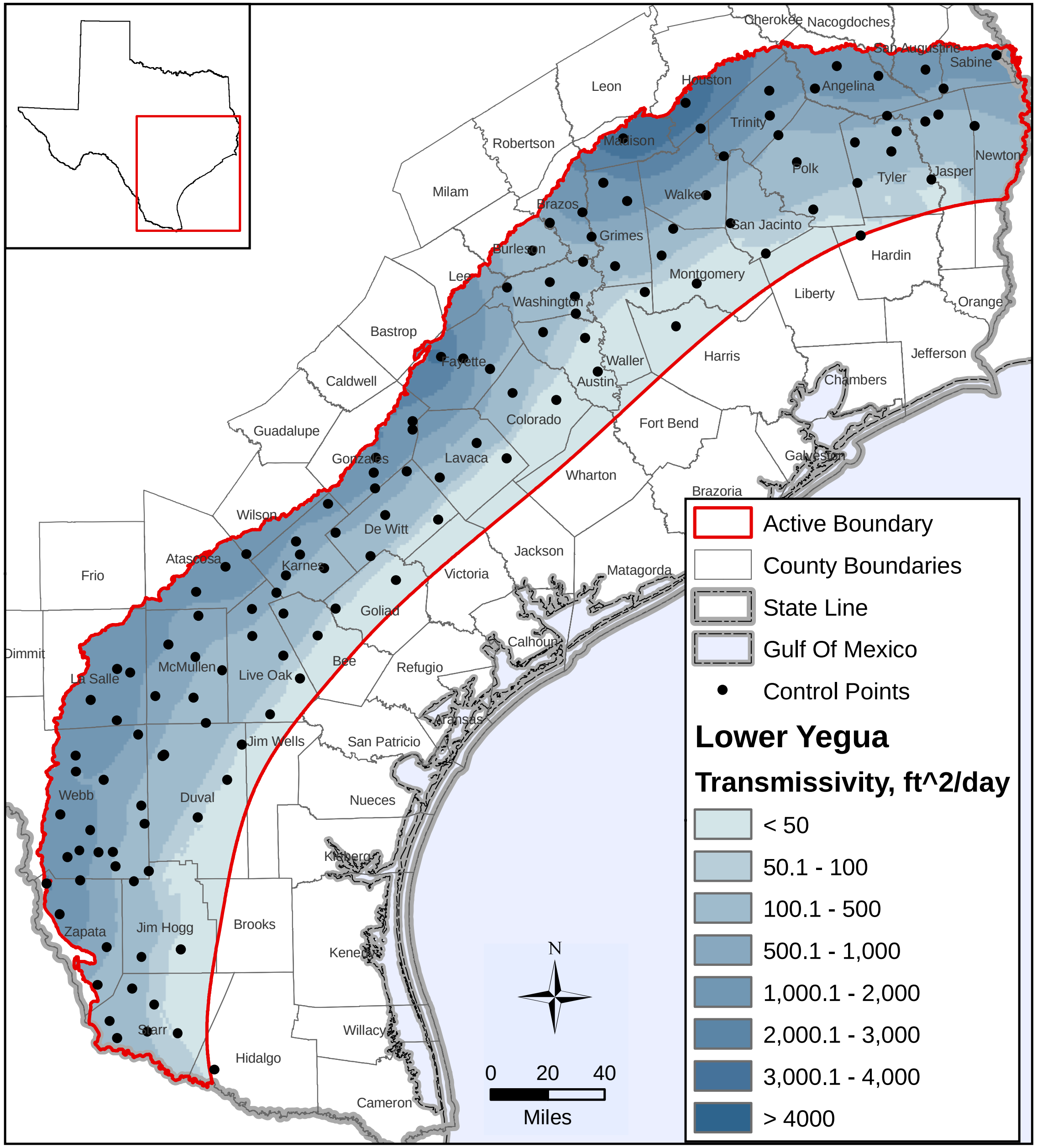
Estimated Transmissivity – Lower Jackson



Estimated Transmissivity – Upper Yegua



Estimated Transmissivity – Lower Yegua



Vertical Conductivity

- **Weighted harmonic mean**

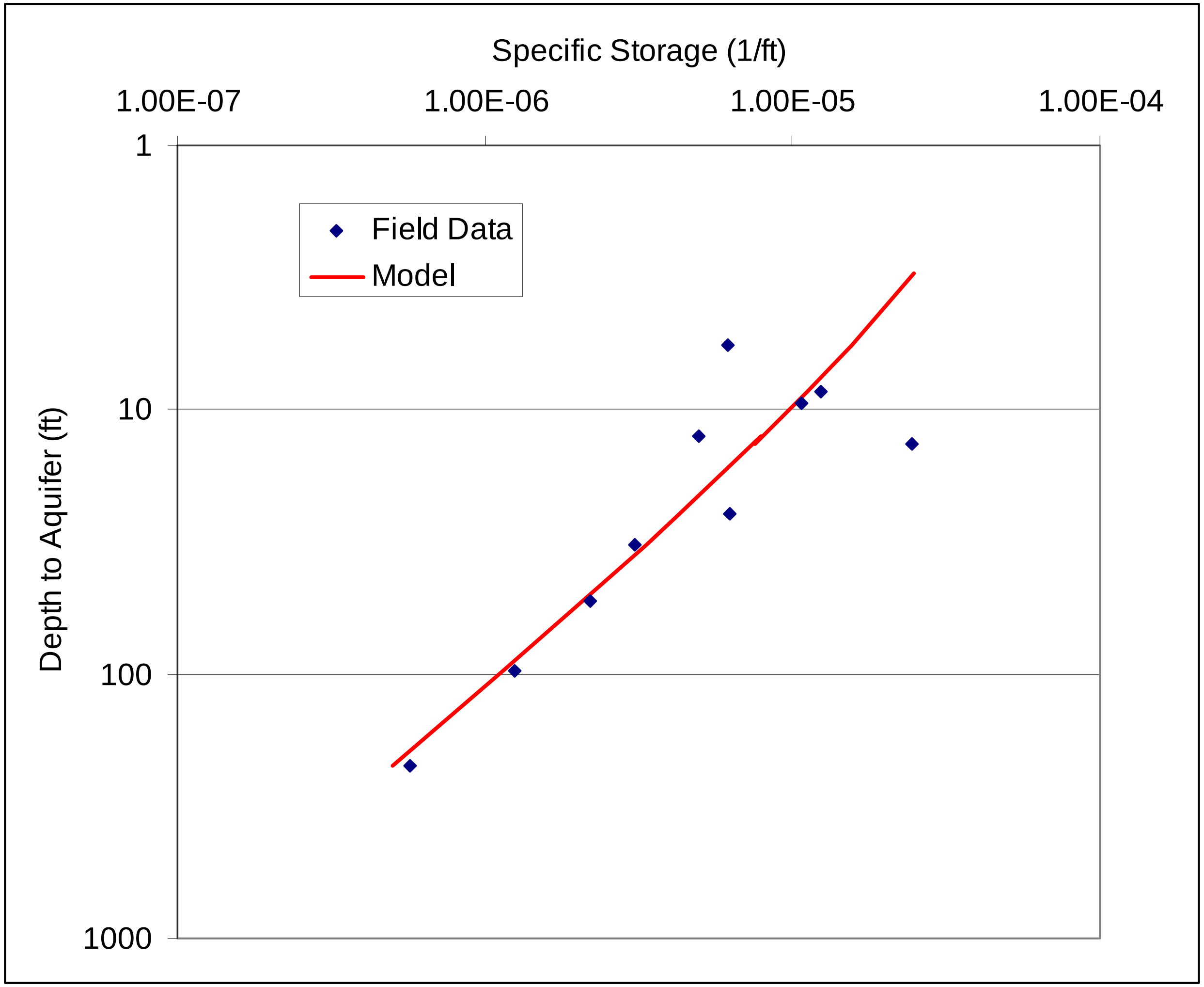
$$Kv = B/[(bs/Kvs) + (bc/Kvc)]$$

Kv = effective vertical hydraulic conductivity of deposit
Kvs = vertical hydraulic conductivity of sand
bs = total layer thickness of sand deposits
Kvc = horizontal hydraulic conductivity of clay
bc = total layer thickness of clay deposits
B = total aquifer thickness

- **Initial values of 0.0003 ft/day for all clay deposits and 0.02 ft/day for all sand deposits, after Young and others (2008)**

Storage

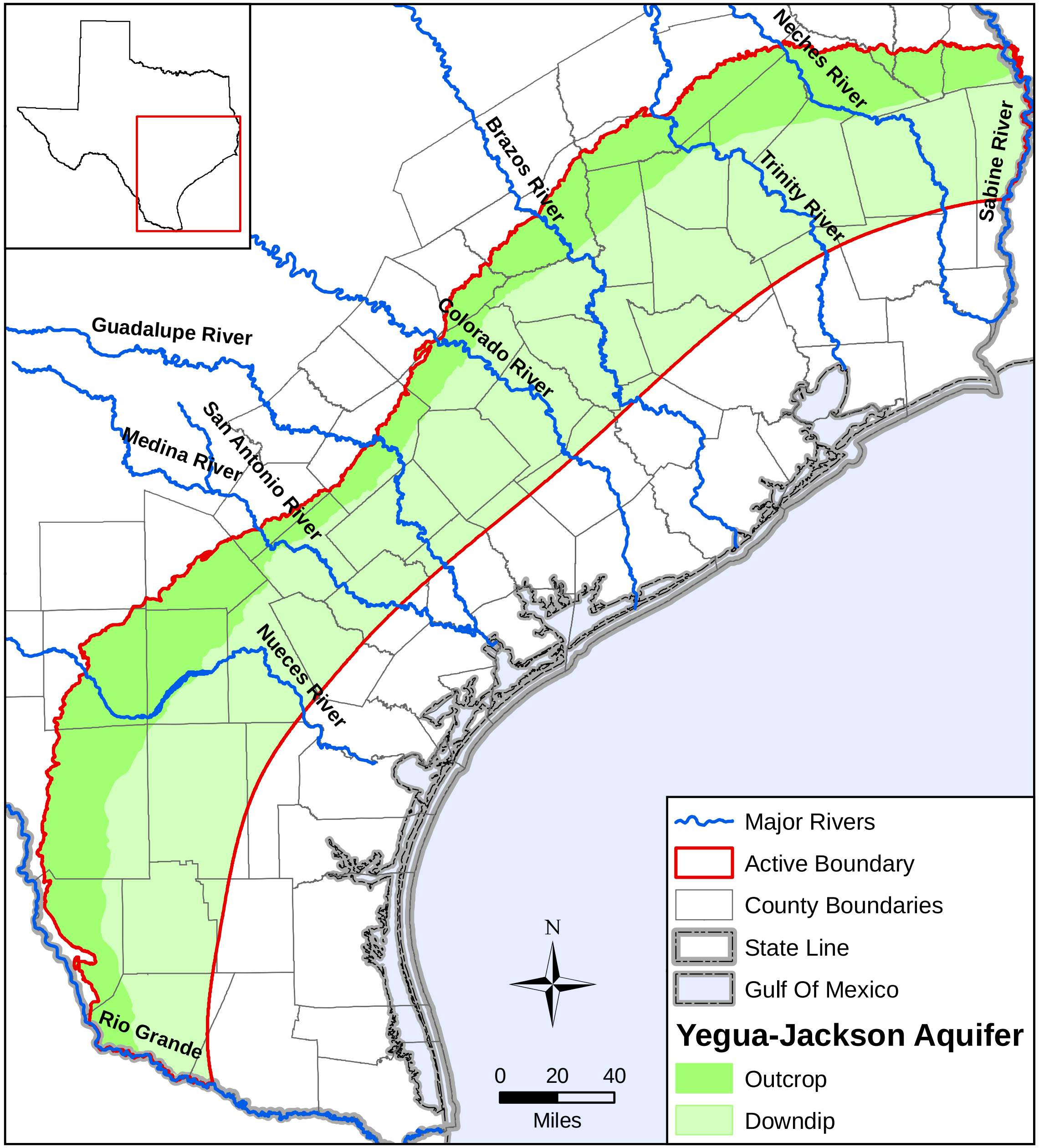
Shestakov (2002)



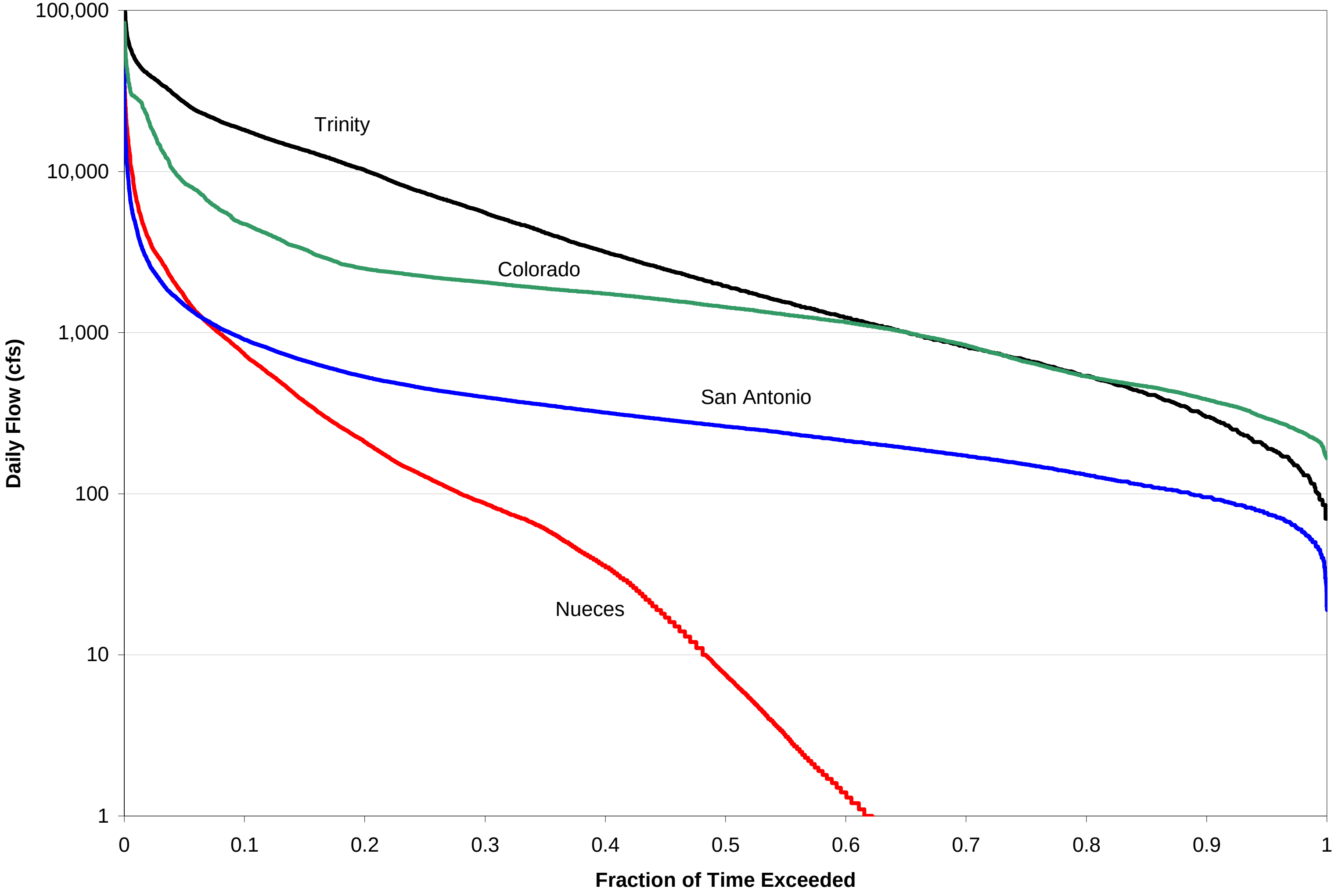
Ss = A / [D + z0]   A and z0 are parameters, and D is depth.

Surface Water

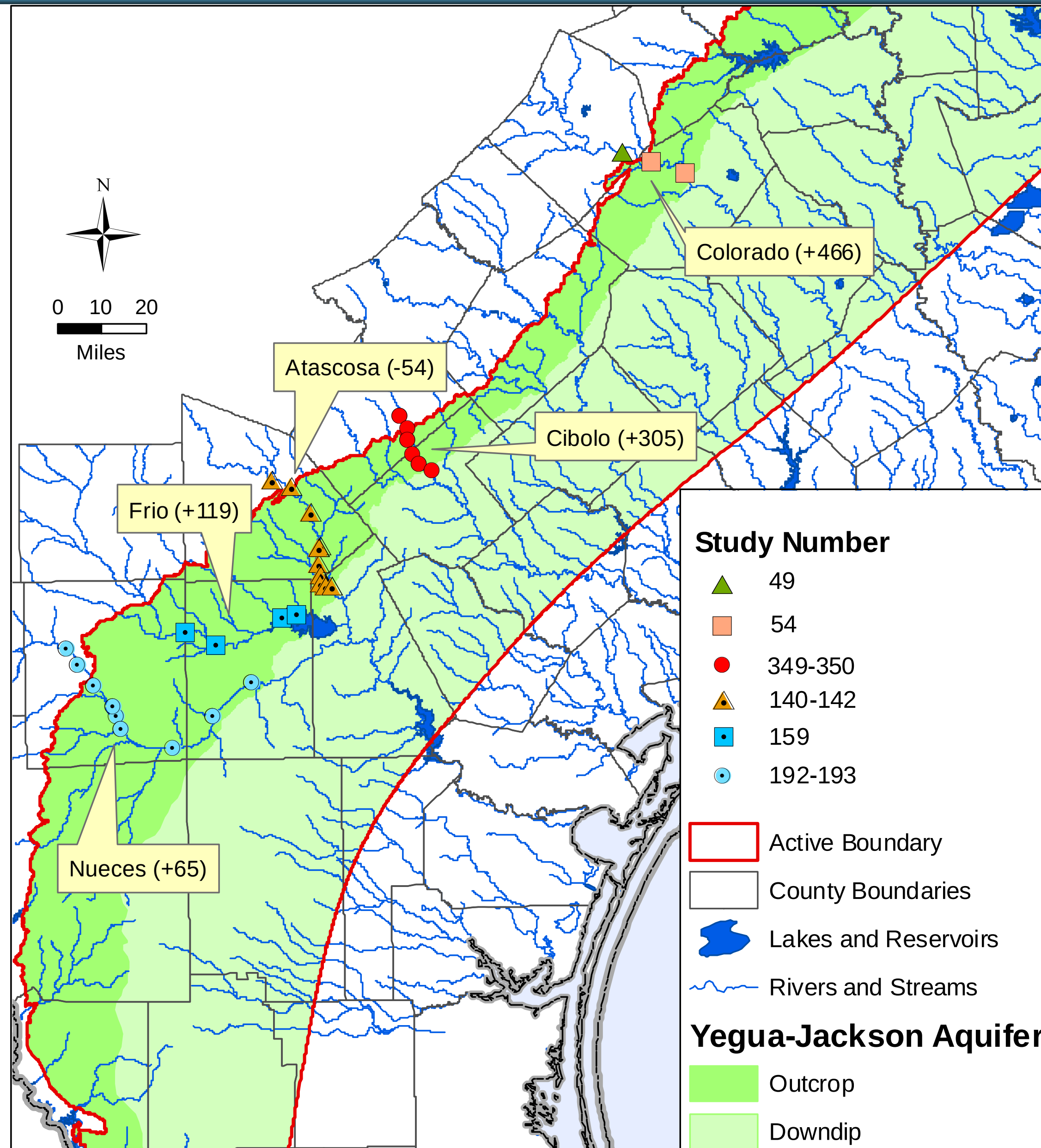
Major Rivers



Flow Exceedance Curves



Slade (2002) Gain-Loss Studies



Other Gain-Loss Studies

- **San Antonio River: +724 afy/mi**
- **Cibolo Creek:**

  0 afy/mi
- **Colorado River:**

  -22 cfs

  represents the only estimated loss for the study

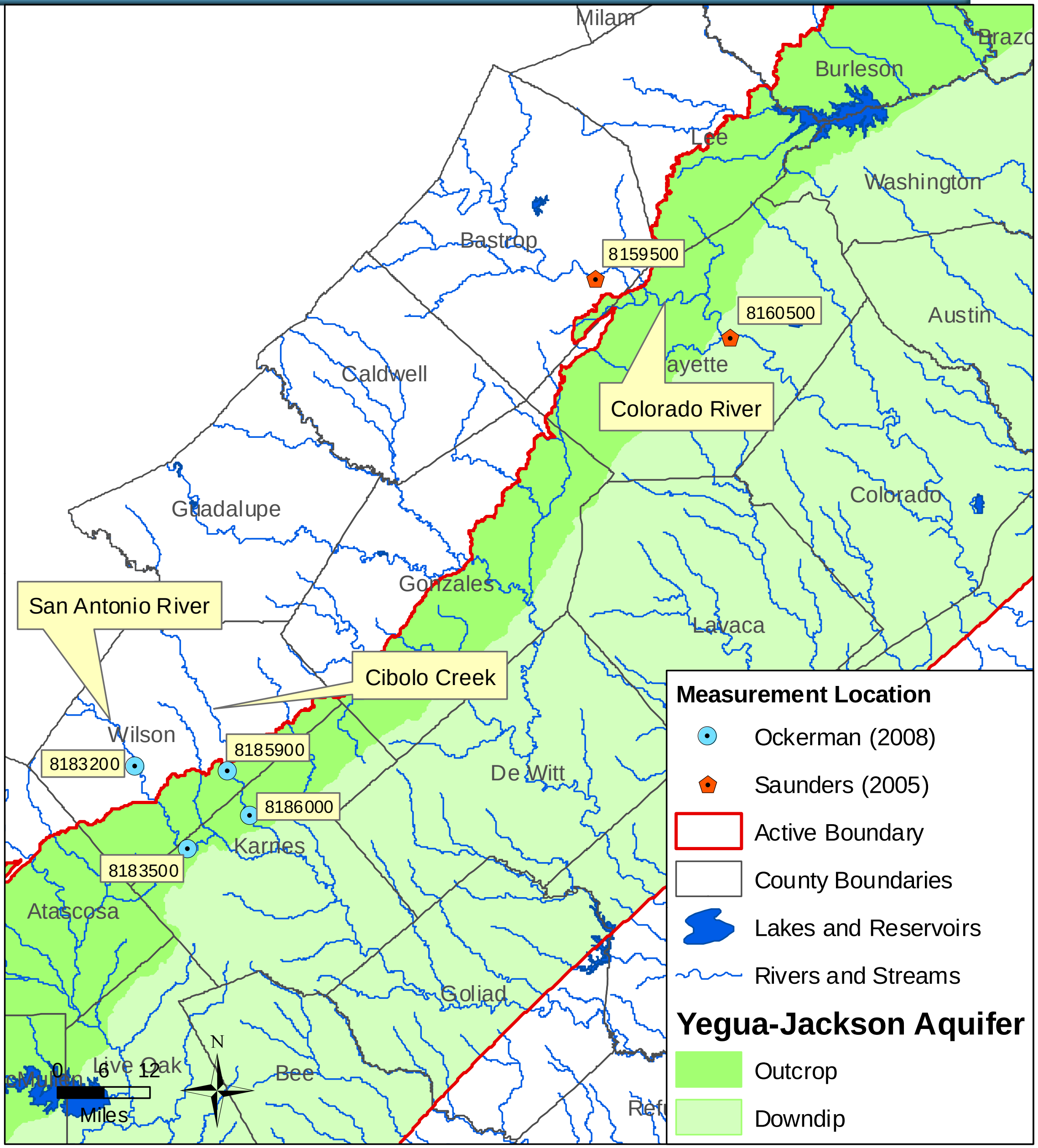
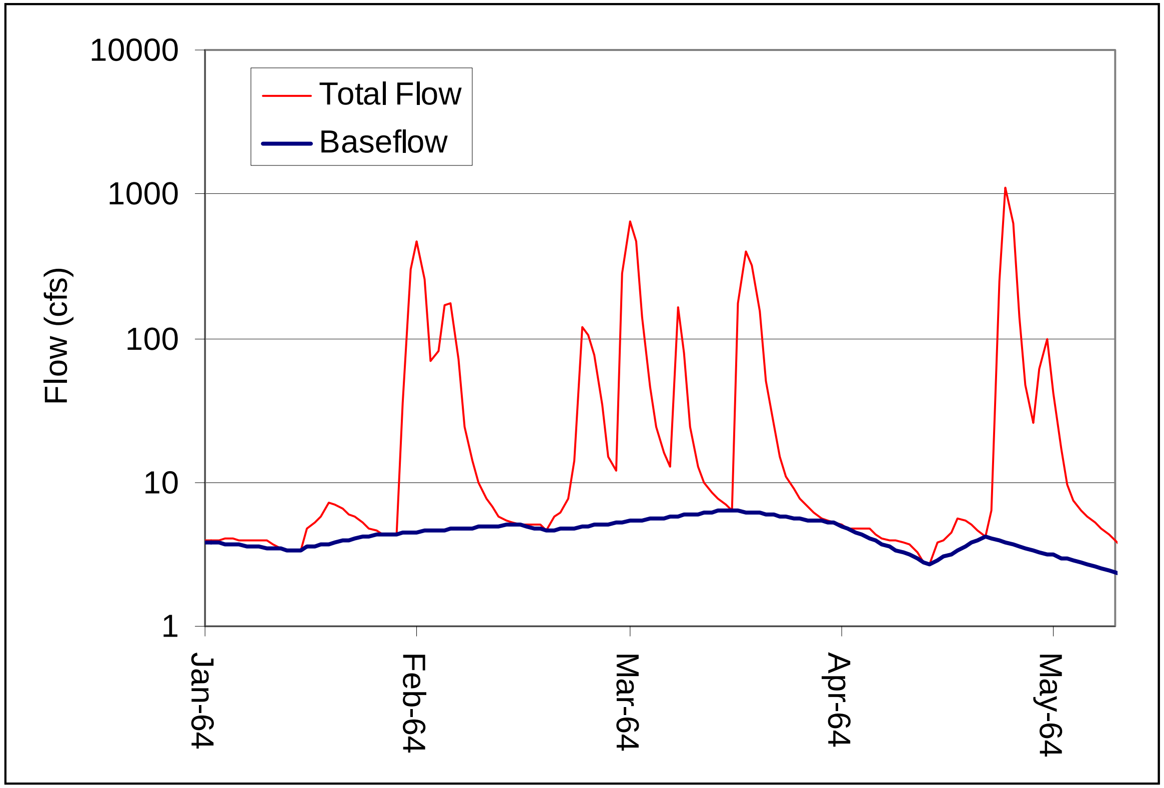
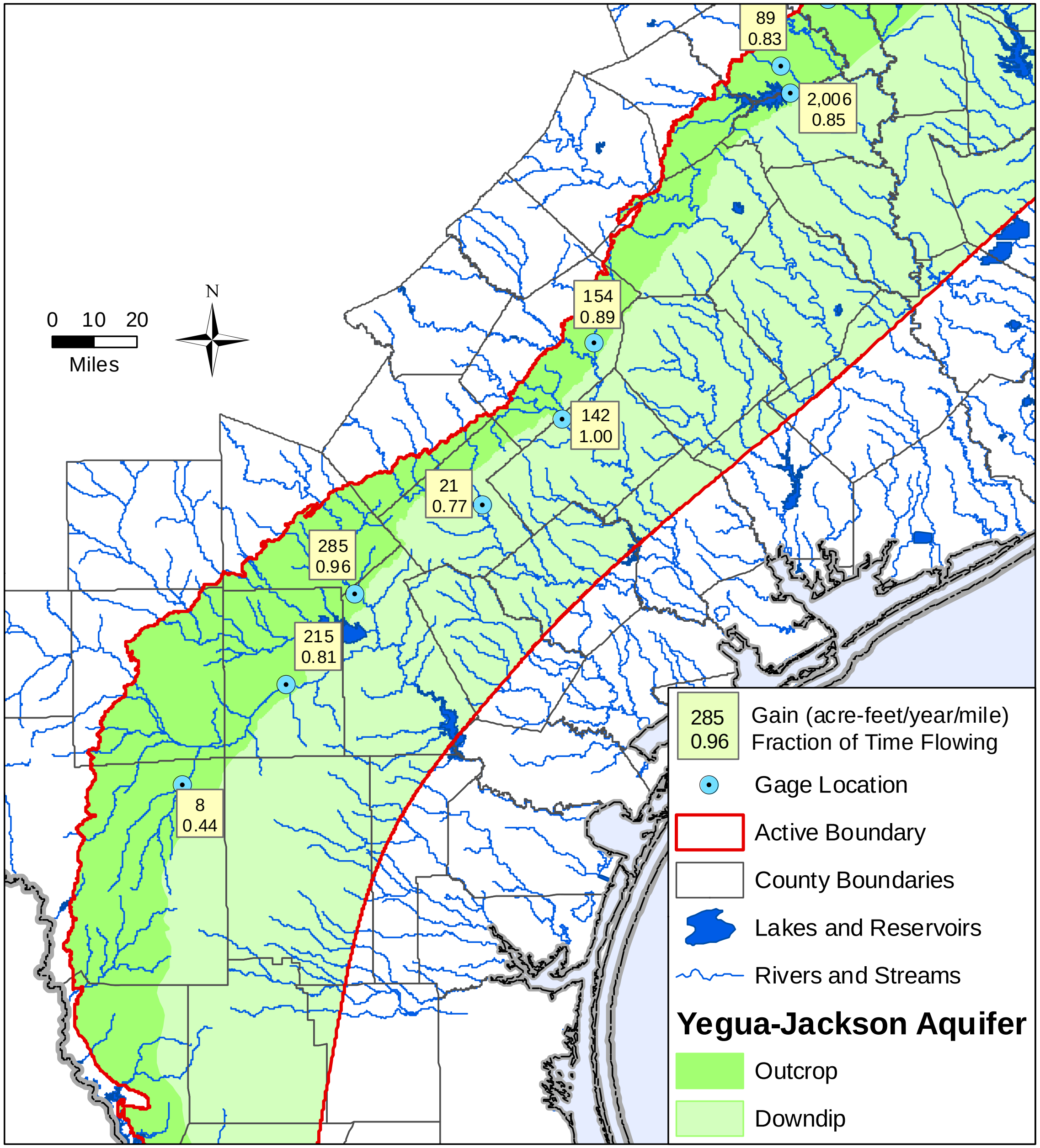


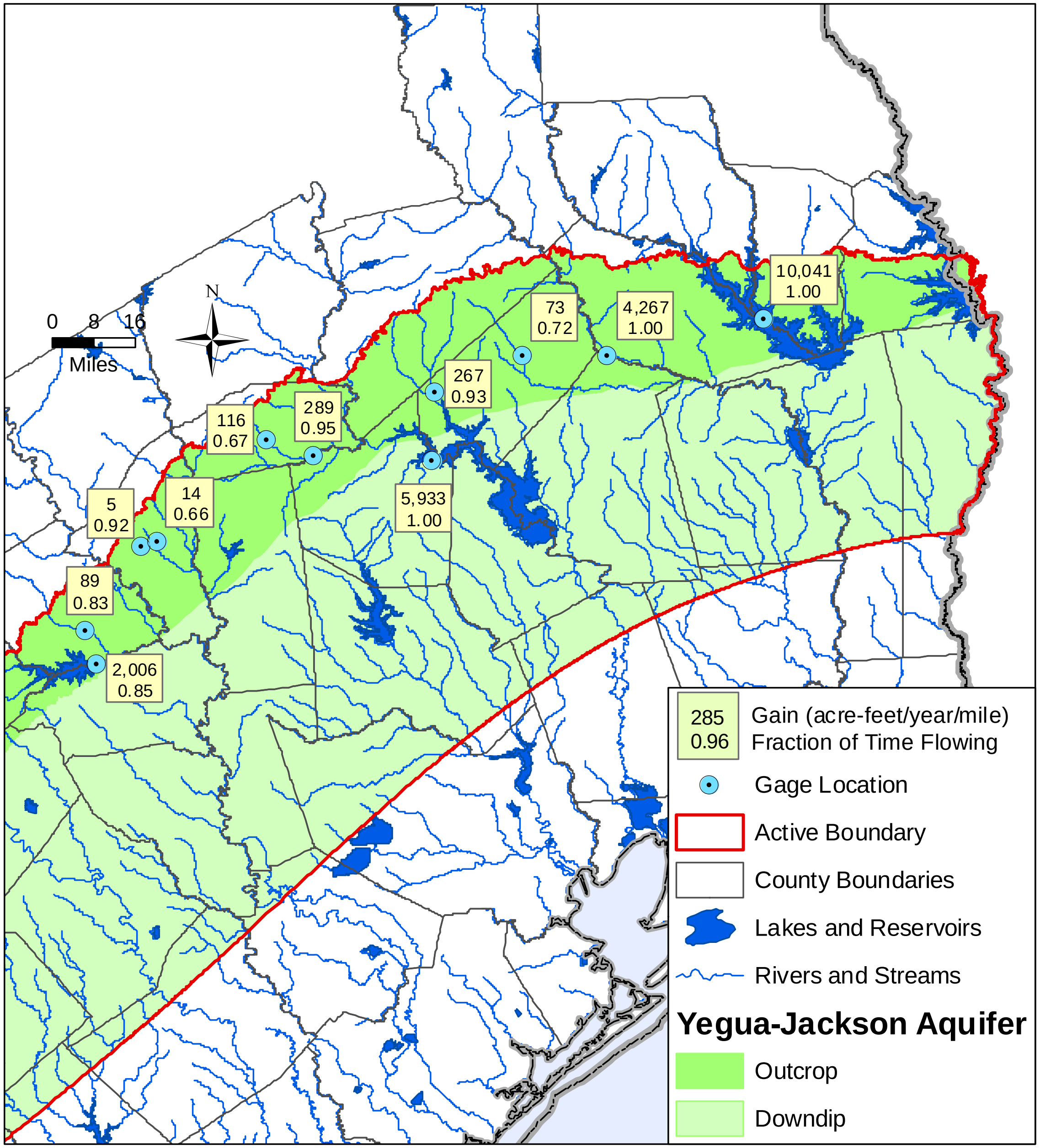
Illustration of Hydrograph Separation



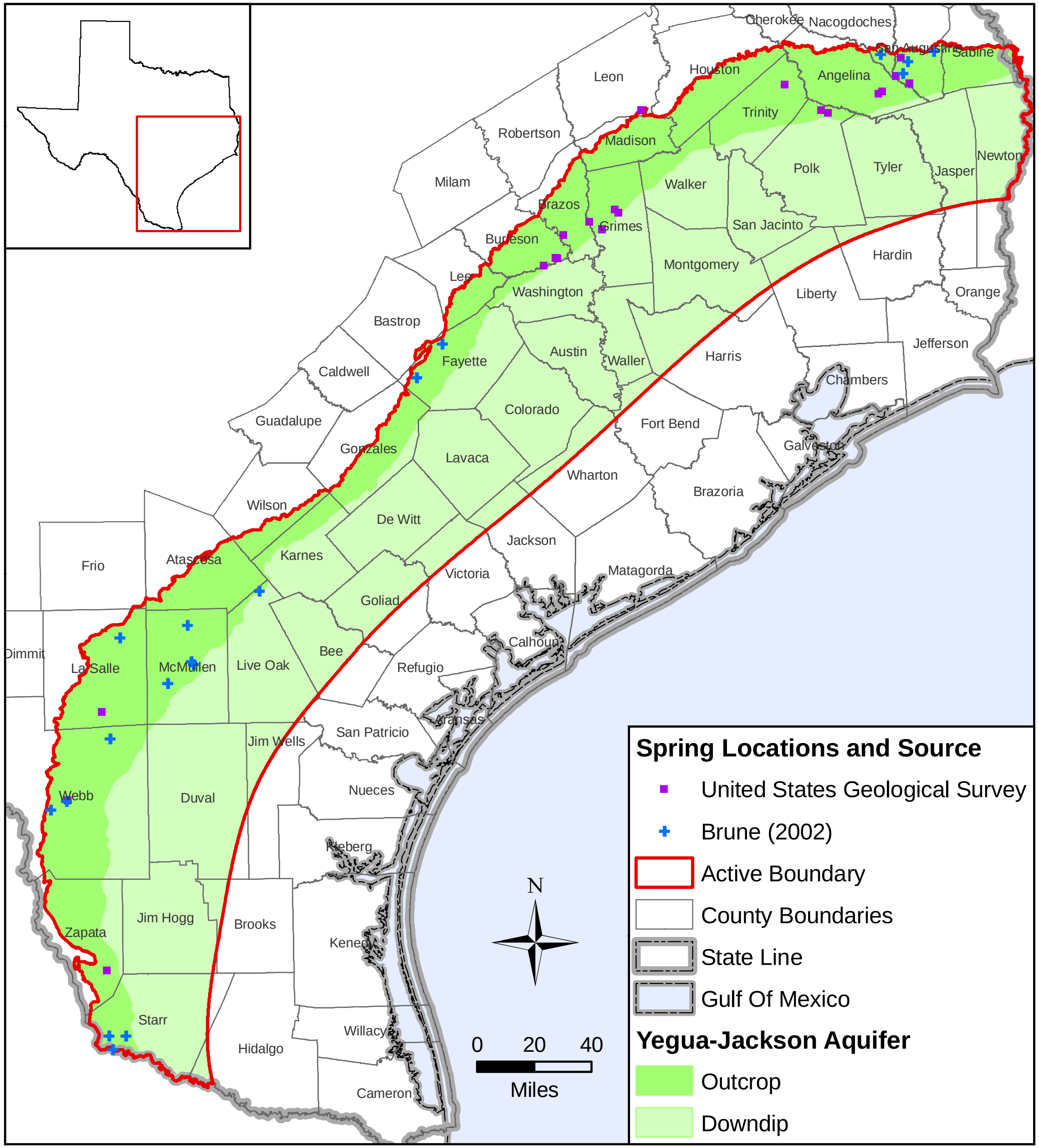
Hydrograph Separation Results



Hydrograph Separation Results

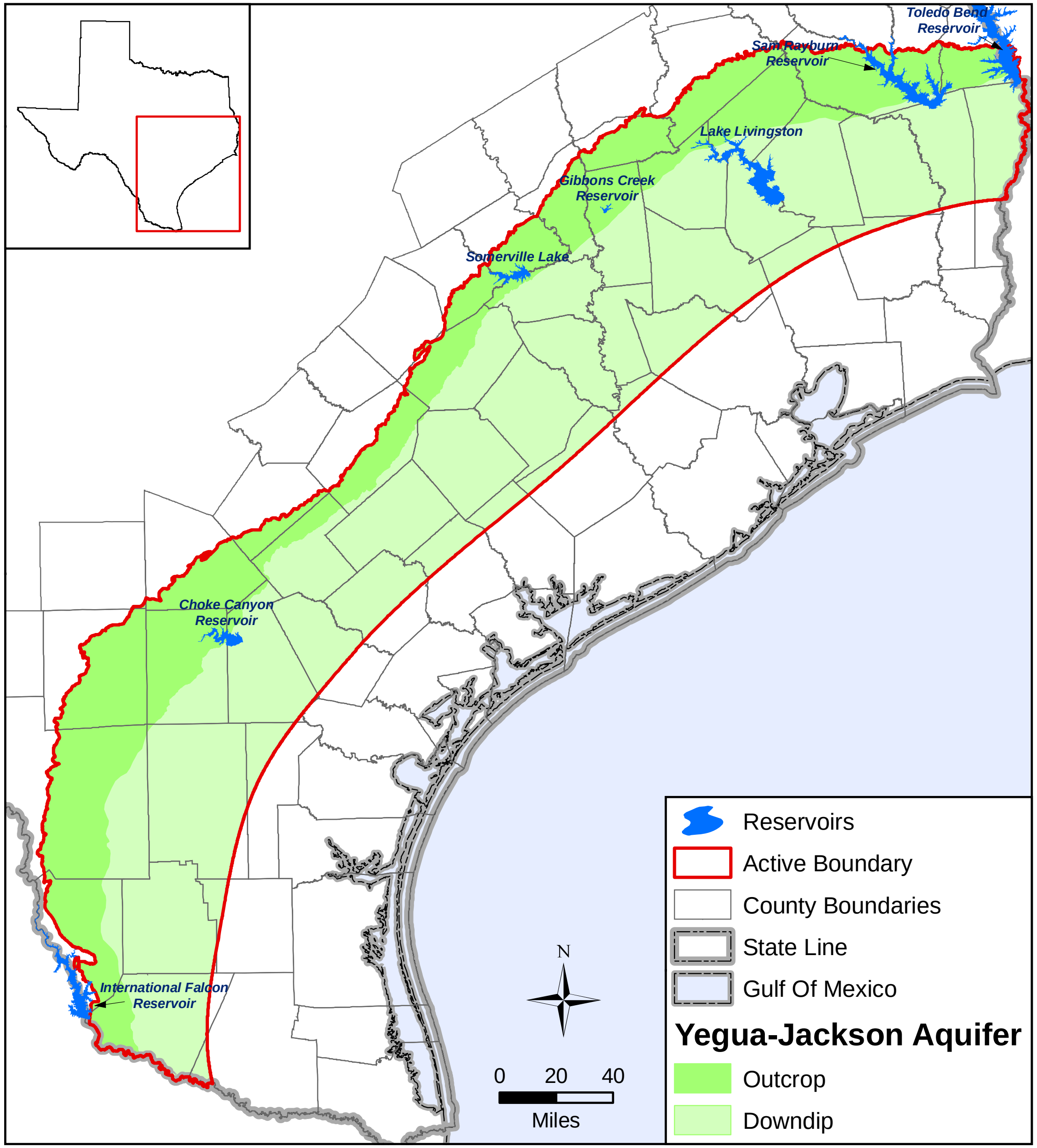


Springs



Cherokee
Nacogdoches
San Augustine
Sabine
Leon
Houston
Angelina
Trinity
Robertson
Madison
Polk
Tyler
Jasper
Newton
Milam
Walker
Brazos
Grimes
San Jacinto
Burleson
Montgomery
Hardin
Lee
Washington
Liberty
Orange
Bastrop
Austin
Waller
Harris
Jefferson
Fayette
Caldwell
Chambers
Colorado
Guadalupe
Fort Bend
Gonzales
Galveston
Lavaca
Wharton
Brazoria
Wilson
De Witt
Jackson
Frio
Atascosa
Karnes
Victoria
Matagorda
Goliad
Calhoun
Dimmit
Bee
La Salle
McMullen
Live Oak
Refugio
Aransas
San Patricio
Jim Wells
Webb
Duval
Nueces
Kleberg
Jim Hogg
Brooks
Kenedy
Zapata
Starr
Willacy
Hidalgo
Cameron
N
0 20 40
Miles
Spring Locations and Source
United States Geological Survey
Brune (2002)
Active Boundary
County Boundaries
State Line
Gulf Of Mexico
Yegua-Jackson Aquifer
Outcrop
Downdip

Reservoirs

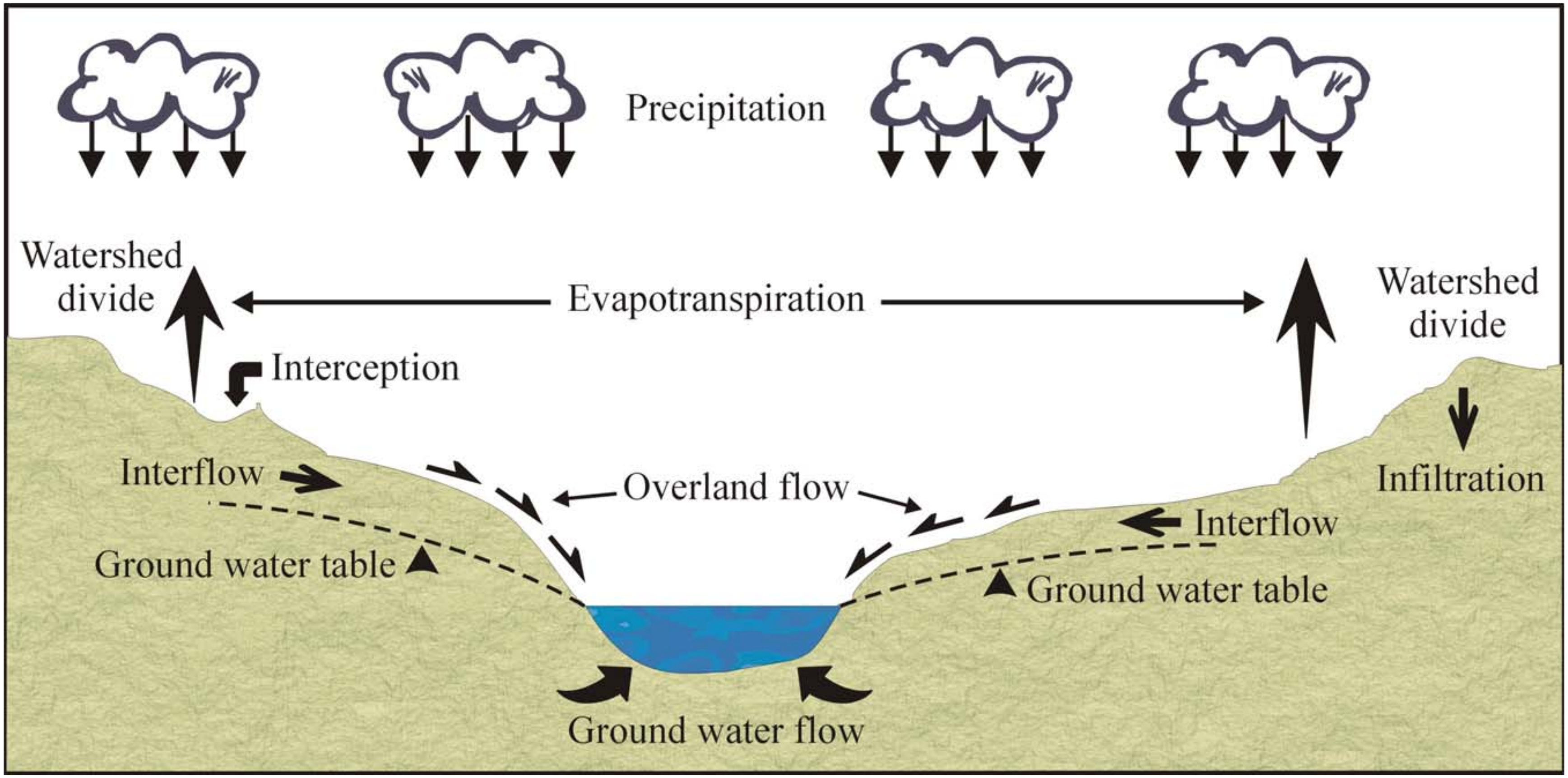


Toledo Bend Reservoir
Sam Rayburn Reservoir
Lake Livingston
Gibbons Creek Reservoir
Somerville Lake
Choke Canyon Reservoir
International Falcon Reservoir
N
0 20 40
Miles
Reservoirs
Active Boundary
County Boundaries
State Line
Gulf Of Mexico
Yegua-Jackson Aquifer
Outcrop
Downdip

Recharge and Natural Discharge

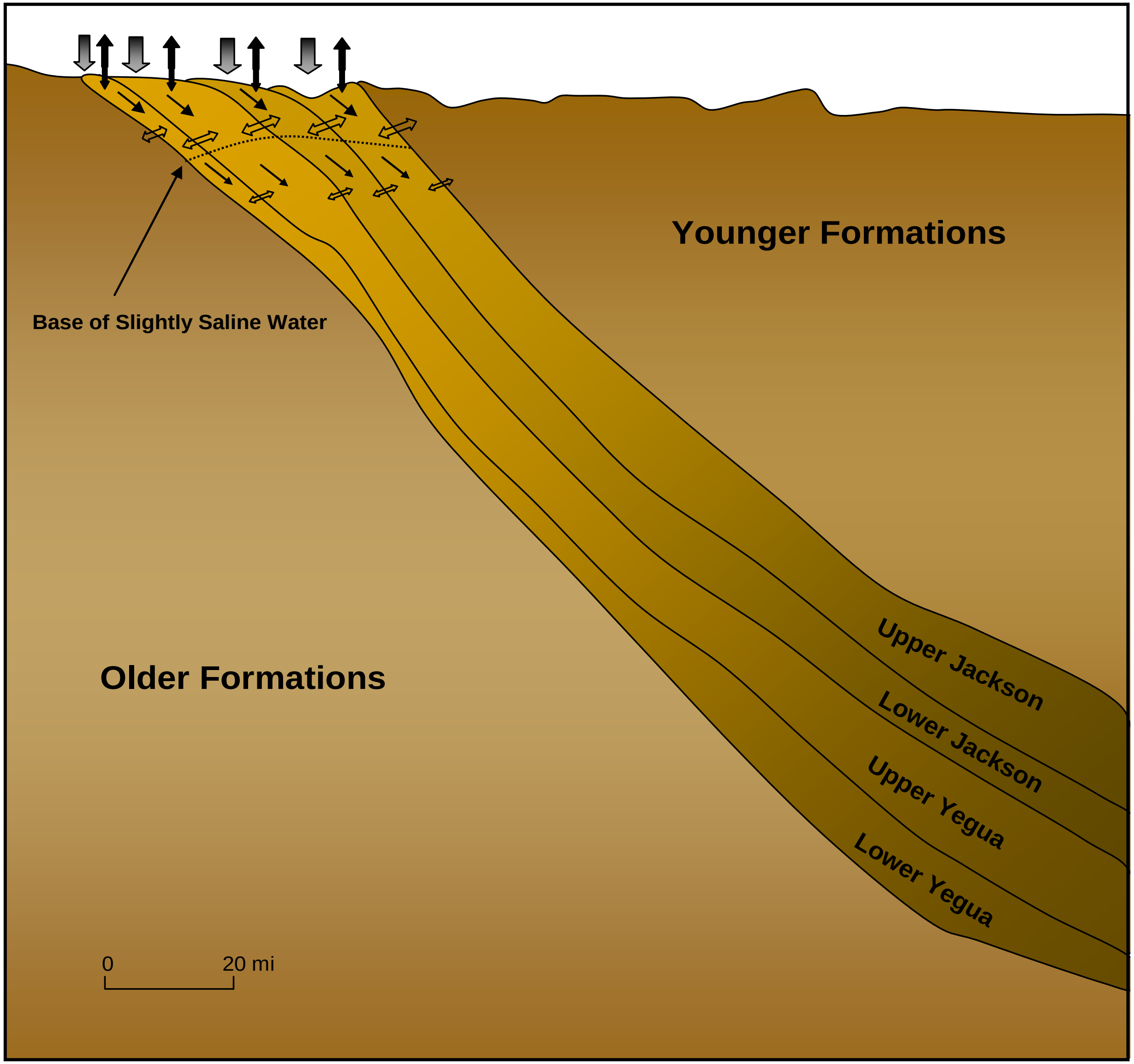
Recharge

Conceptualization of Shallow Recharge and Discharge



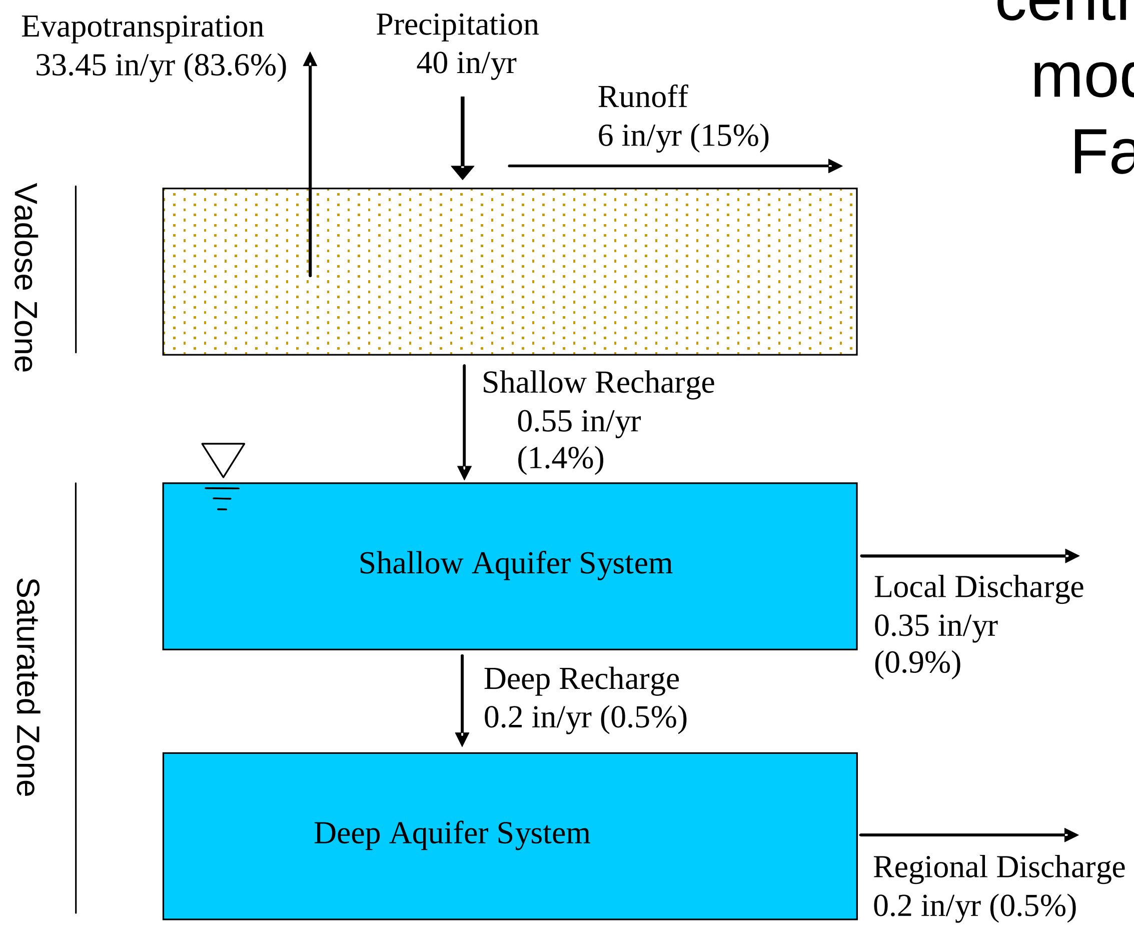
Recharge

Conceptualization of Deep Recharge and Discharge



Recharge: A Conceptual Water Balance

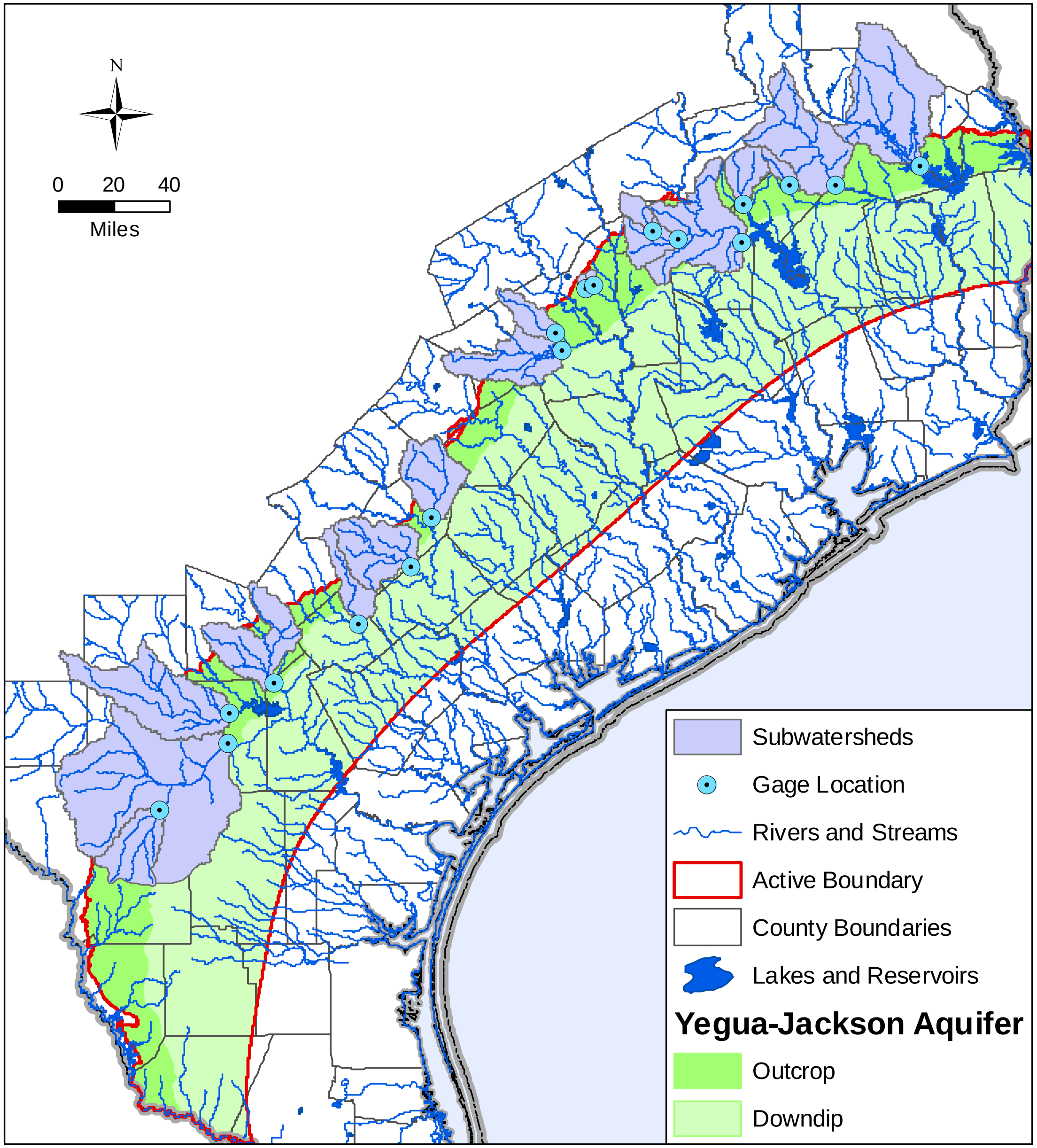
Approximate values for central portion of the model region, e.g. Fayette County



Relating Recharge and Discharge

- Components of shallow recharge can be determined by estimating discharge components
- Baseflow is assumed to be a major component of shallow discharge
- Discharge through groundwater evapotranspiration is assumed to be less than that of baseflow
- Shallow recharge estimated through baseflow should be considered a minimum value, due to the unknown impact of groundwater evapotranspiration

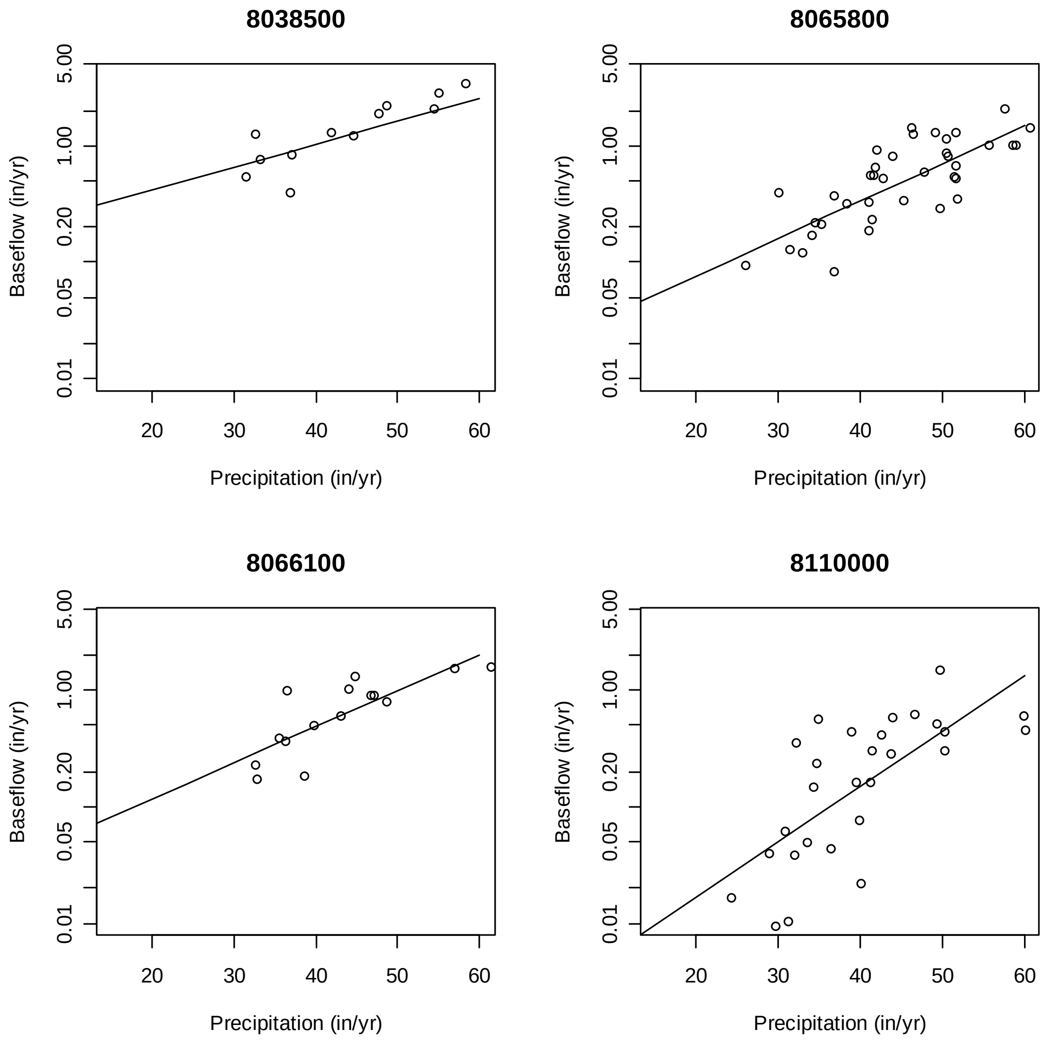
Catchment Areas for Gages where Hydrograph Separation was Performed



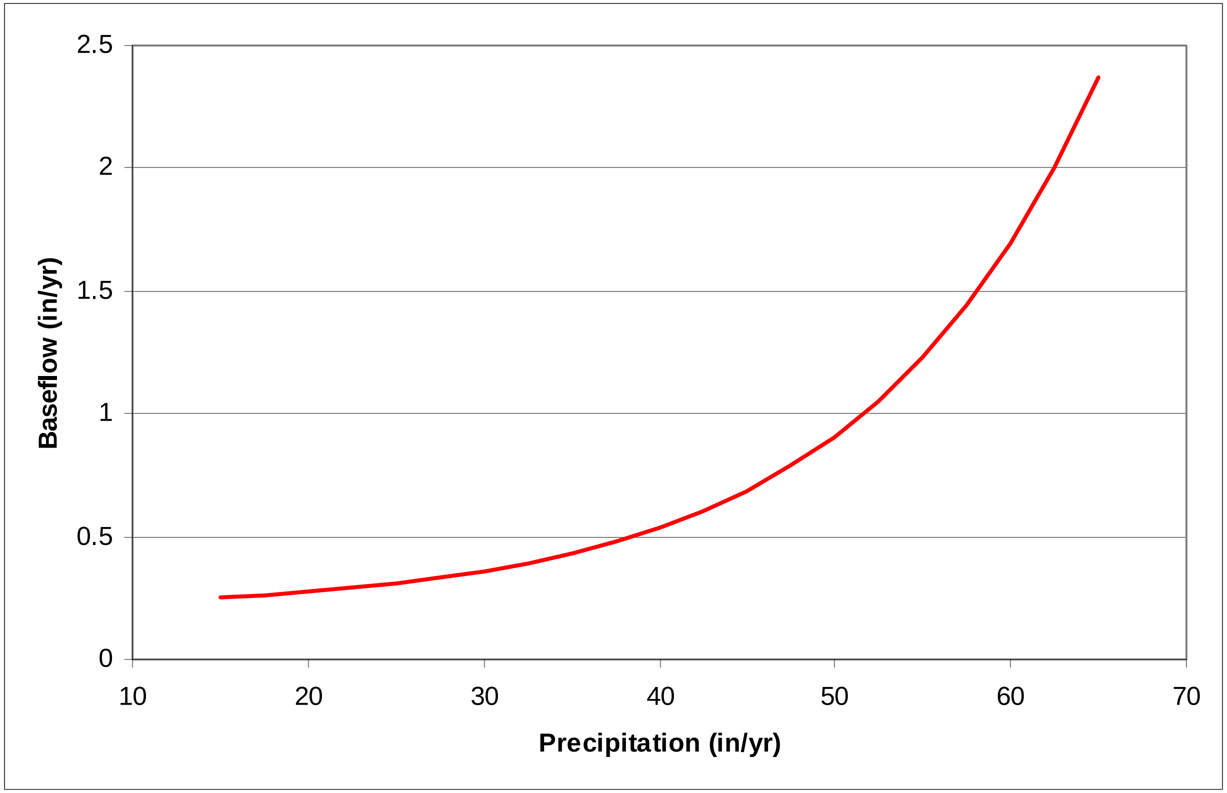
Relationship between Precipitation and Baseflow

- **Hypothesize that some long-term average relationship exists between precipitation and baseflow**
- **Take annual average precipitation over a given catchment area and regress versus annual basflow, with a time lag of several months**
- **Use general relationship to distribute recharge with precipitation**
- **Irrigation return flow is considered to have a minimal impact on recharge for the Yegua-Jackson**
  - Only small amounts of irrigation pumping
  - Surface water use for irrigation (primarily Rio Grande) mostly outside the outcrop areas in Starr and Webb counties

Relationship between annual recharge and annual precipitation



Recharge

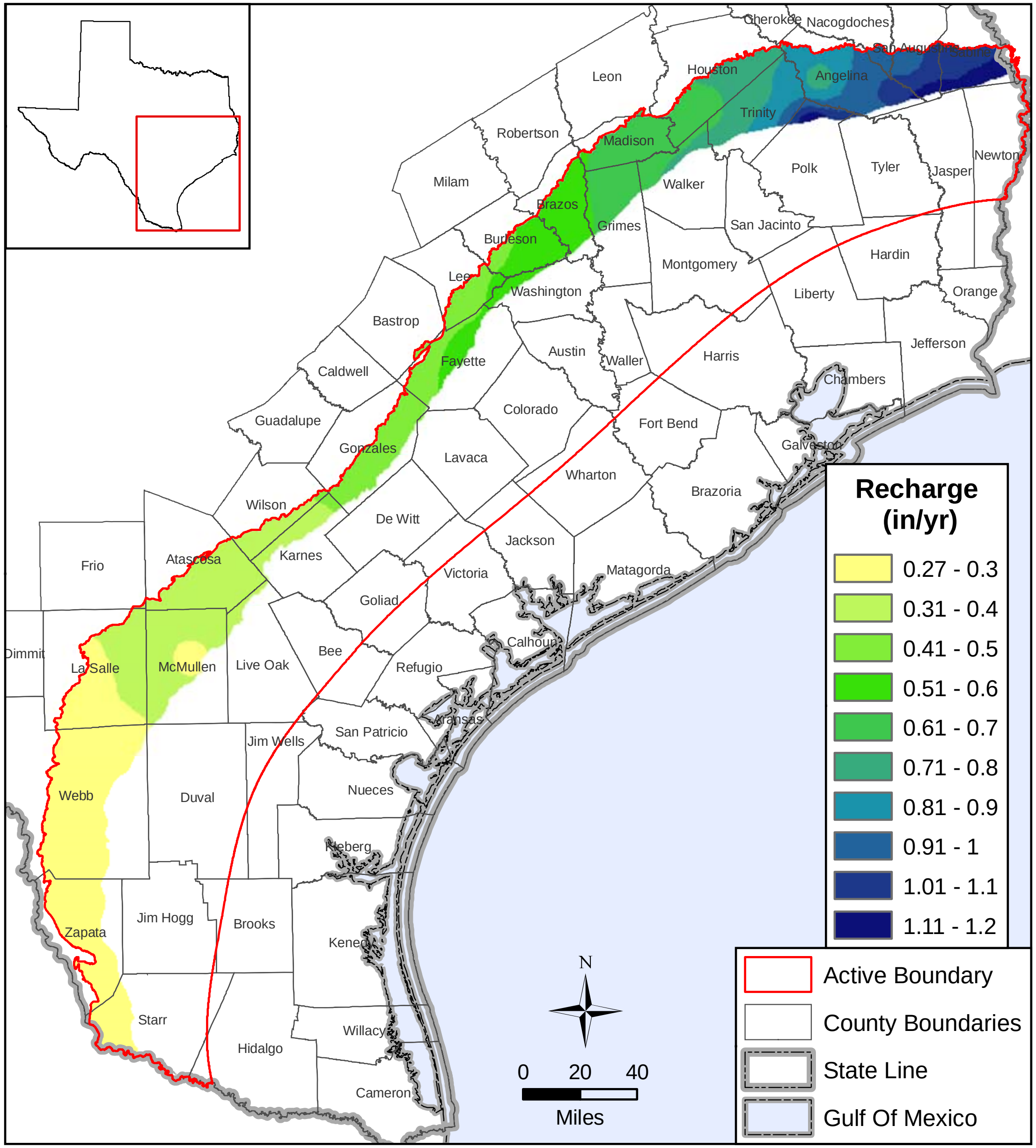


Recharge = 10^(0.032*precipitation-1.78)+(deep recharge)

Deep recharge estimate of 0.2 in/yr deep recharge from report for Grimes County

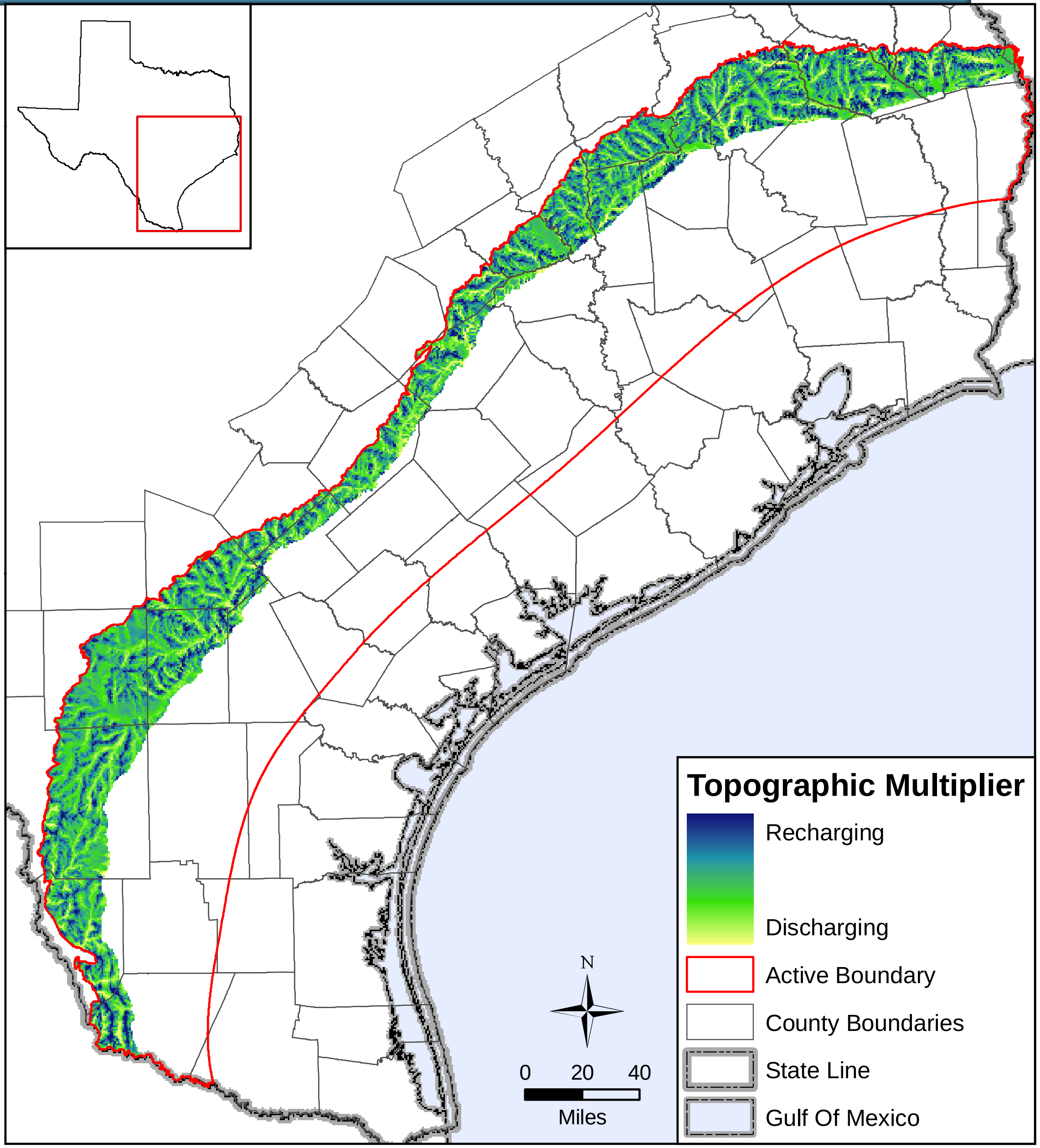
Estimate of Average Recharge

- **Estimates may be high in southwestern portion of the region (few constraints available)**
- **Slade (2002) studies show some gaining streams in the southwestern area which is at odds with conventional wisdom**



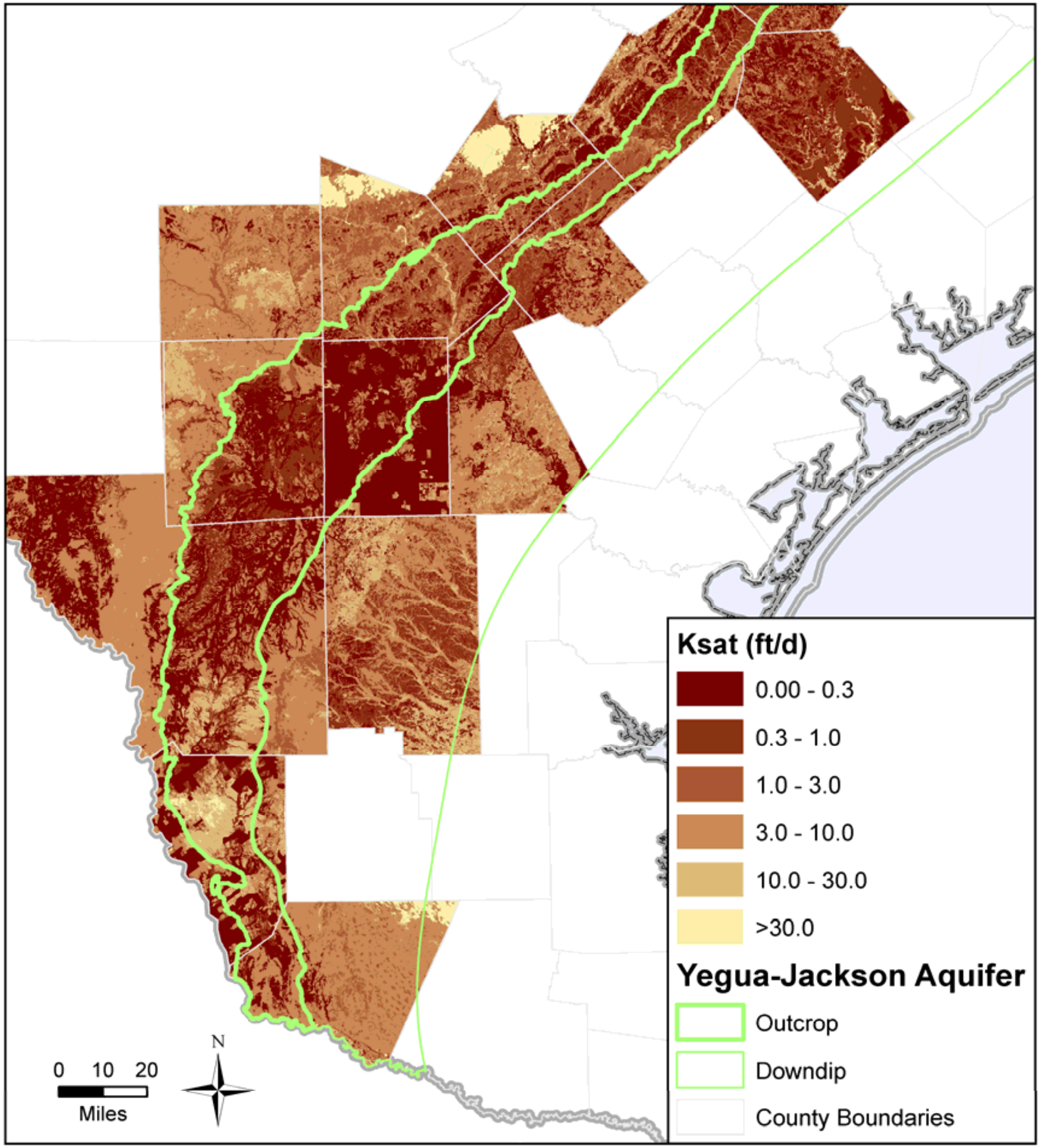
Variation of Recharge with Topography

- **Recharge highest in upland areas and lowest in lowland areas**
- **This approach improves model calibration in the outcrop**

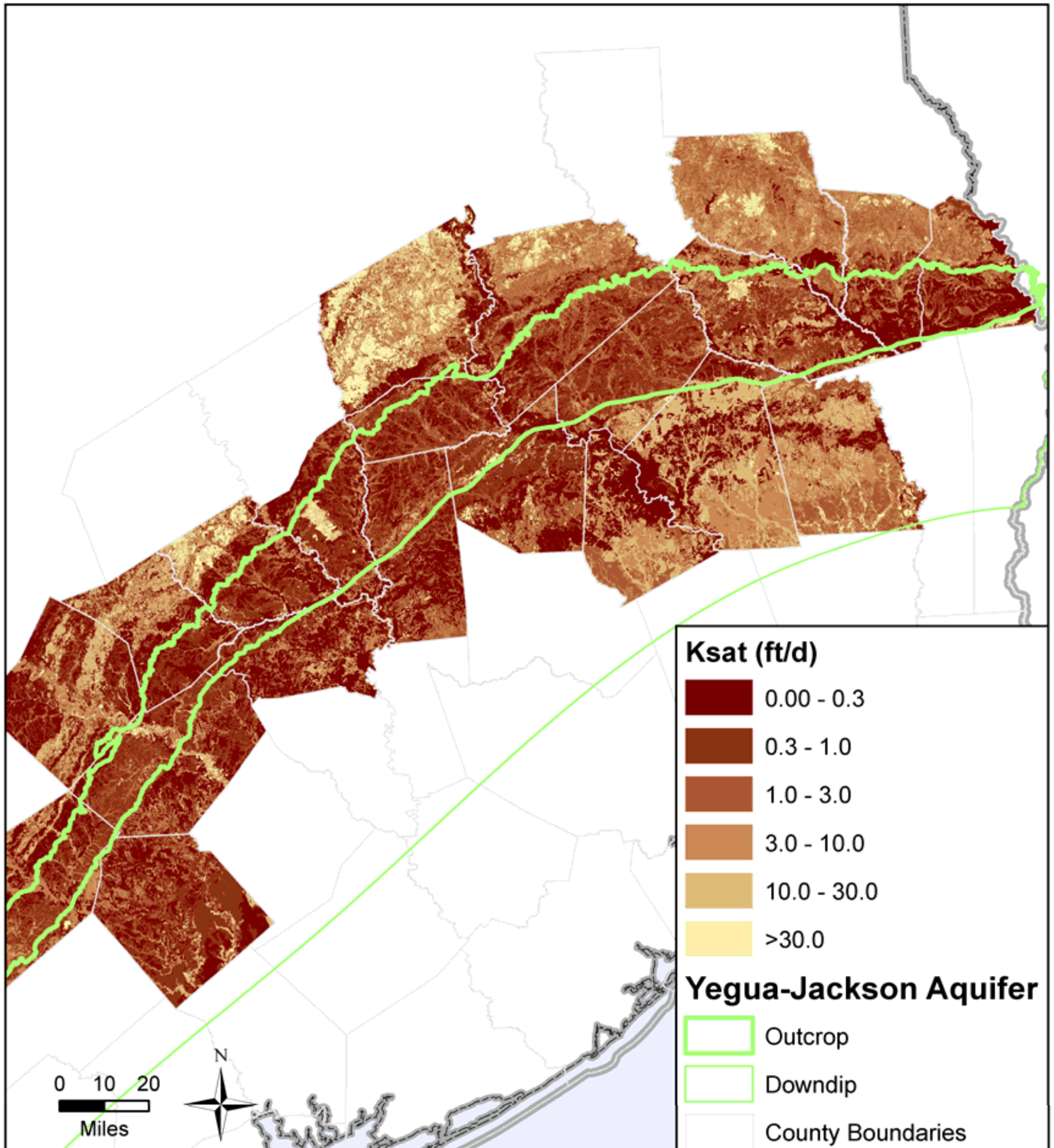


Vertical soil conductivity estimated from SSURGO

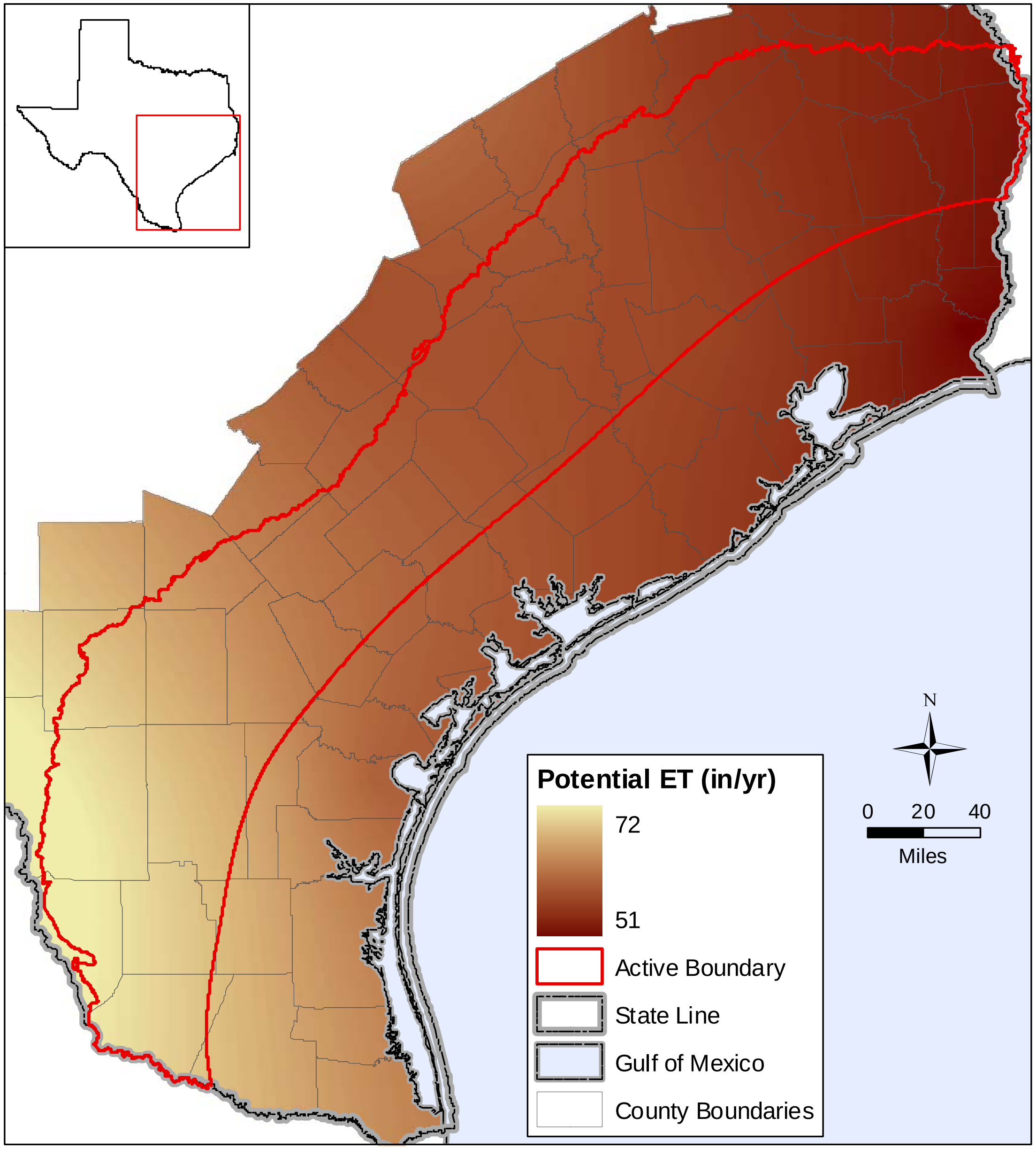
- **SSURGO soil horizons harmonically averaged**
- **Weighted geometric average taken for each spatial unit, based on existing percentage**



Vertical soil conductivity estimated from SSURGO

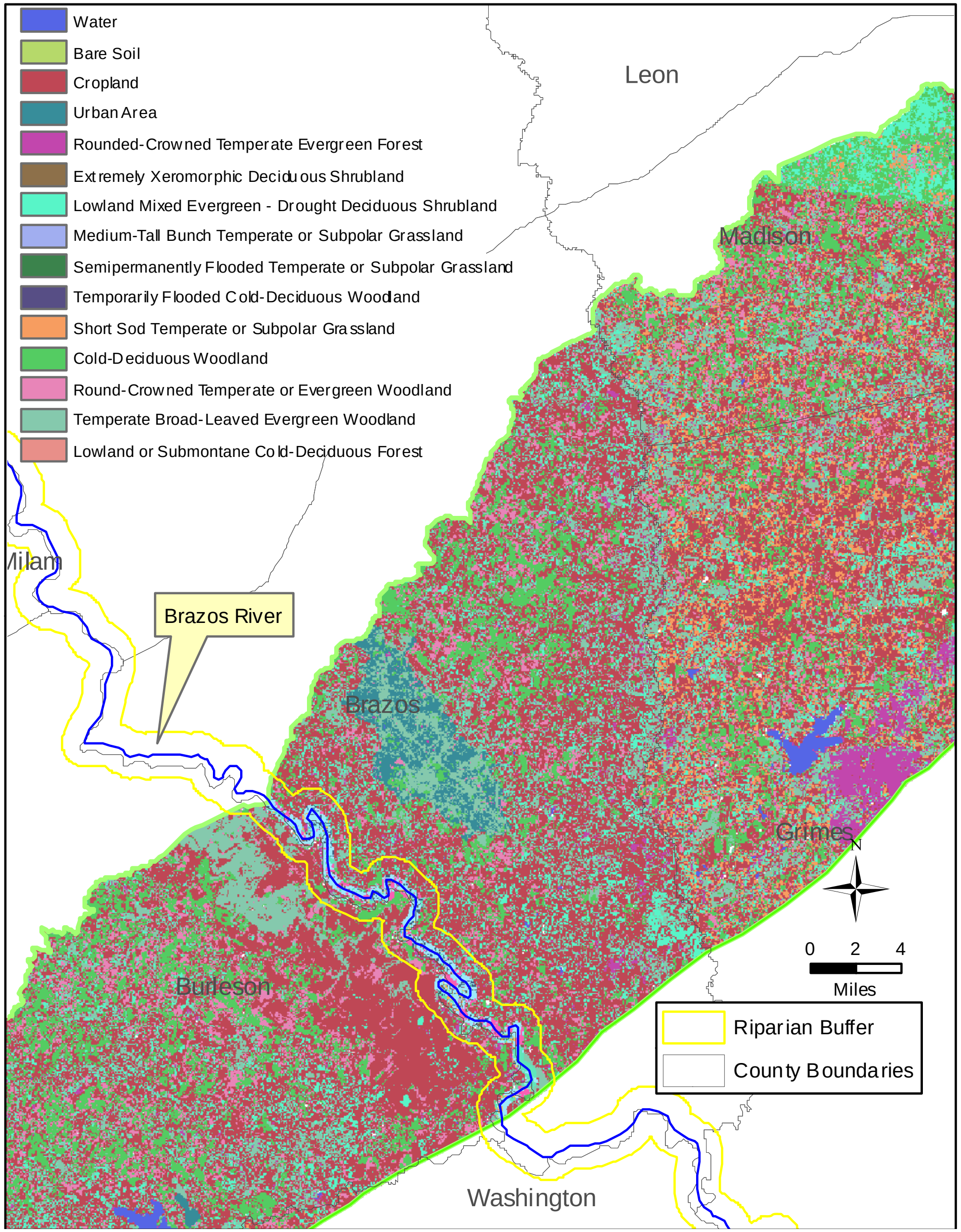


Potential Evapotranspiration (ET)



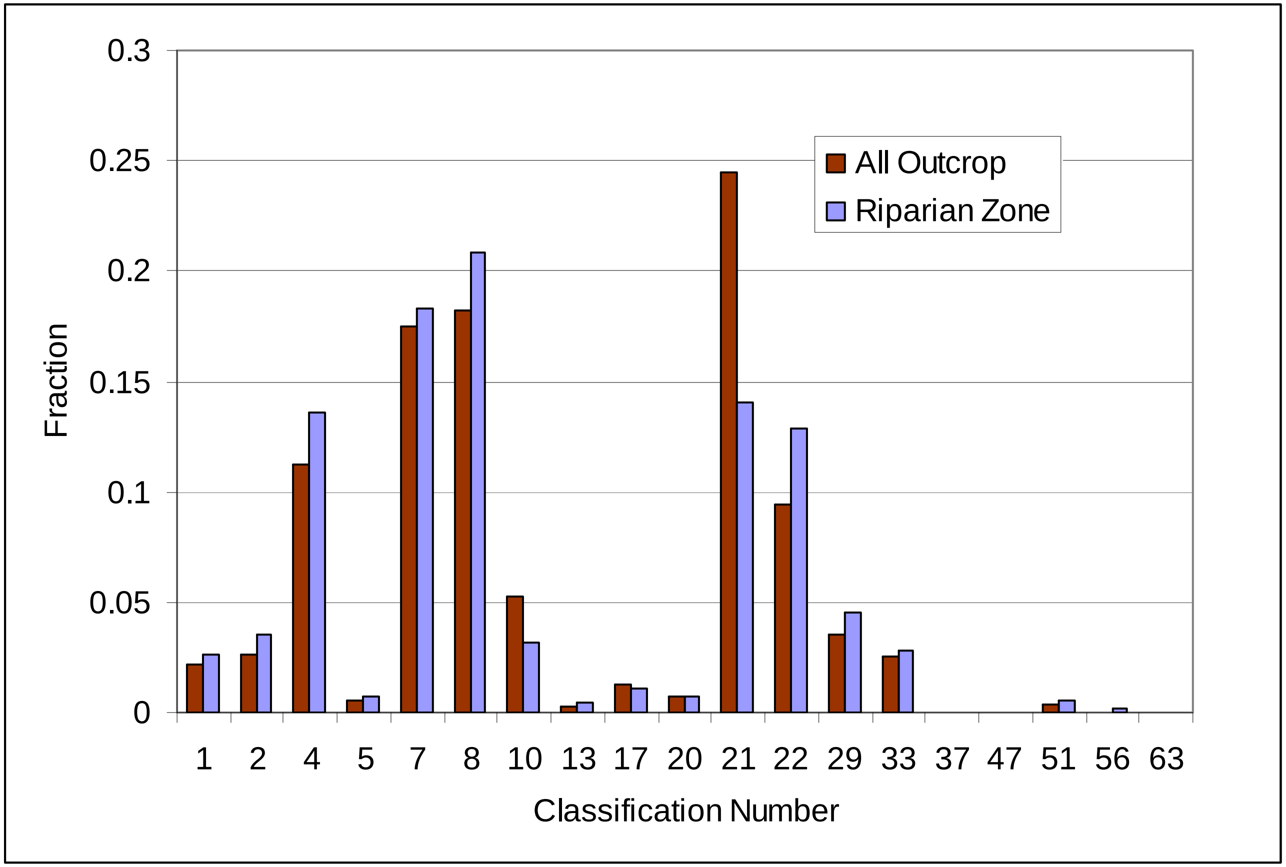
ET: GAP Vegetation Classification

- **TX-GAP program provides relatively detailed estimates of vegetation types**
- **Vegetation types compared between riparian buffer areas and overall outcrop area**



ET: GAP Vegetation Classification

Little difference evident between riparian and overall outcrop regions



ET: Estimating Vegetation Coefficients and Rooting Depths

$$ETVmax = PET * Kc$$

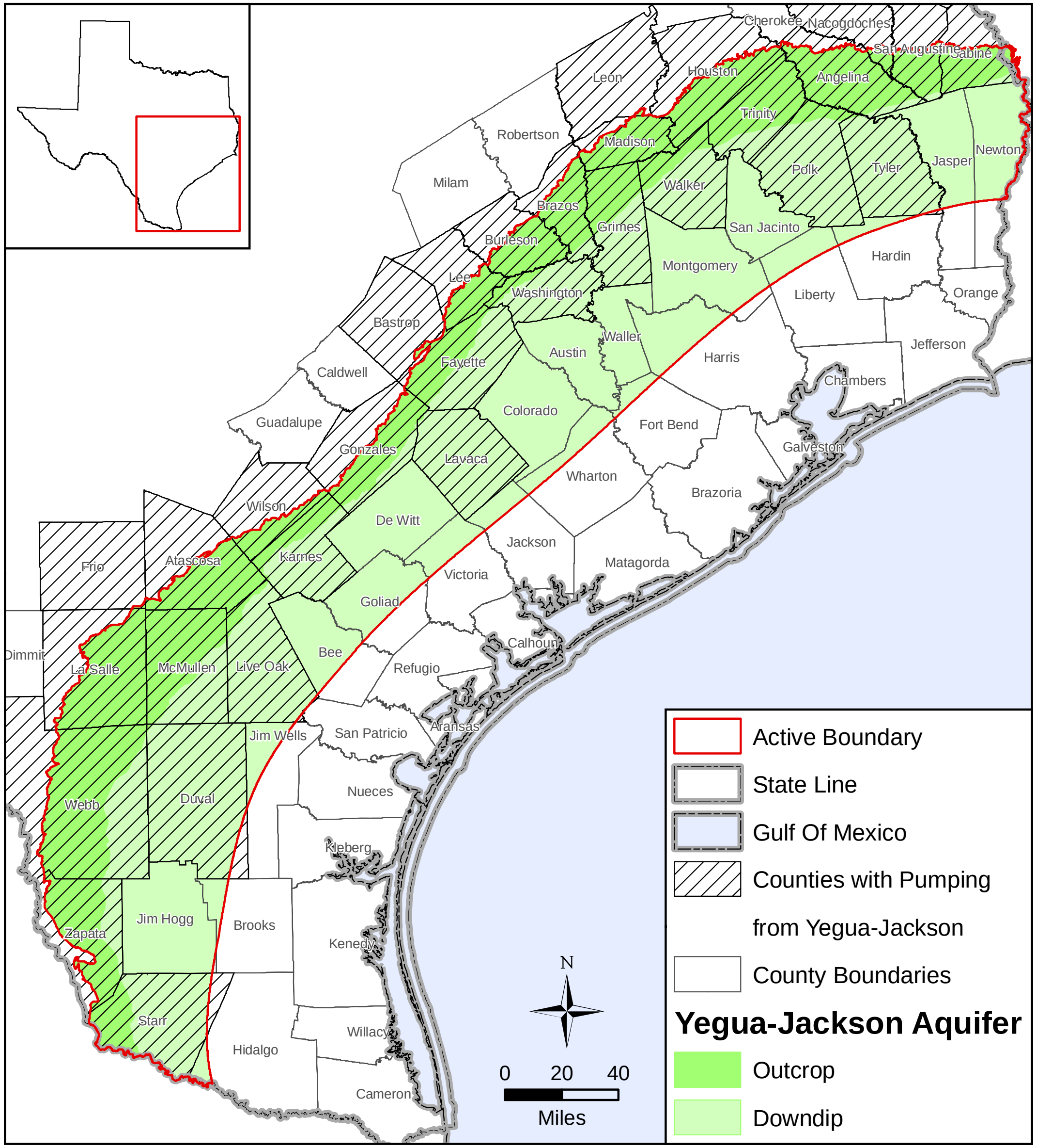
Vegetation Type	**Kc**	**Rooting Depth (ft)**
Mesquite	0.54	6 to 50
Grassland	0.70	2.
Pine	0.53	7.
Post Oak	0.5*	5.*
Cropland	0.6*	1.

Discharge through Pumping

Pumping

- **Pumping discharge estimates developed for both the calibration period (1980-1997) and the period before calibration (1900 – 1980).**
- **Assume that significant pumping from Yegua-Jackson comes only from outcrop portions**
  - Further down-dip, water quality is poor, and the more productive Gulf Coast Aquifer system is typically used
  - Only counties with some part of Yegua-Jackson outcrop were selected
- **Calibration period has annual pumping for each county and each category**
  - Categories are : municipal, manufacturing, mining, agriculture, livestock, and rural-domestic
- **Pre-Calibration period has decadal pumping for each county and each category**

Counties with Pumping from Yegua-Jackson



Calibration Period (1980 – 1997) Pumping

- **Estimates of groundwater pumping throughout Texas for the transient calibration period (1980 – 1997) are provided in the TWDB pumping geodatabase (pumpamatic).**
- **Pumpamatic has pumping estimates for municipal, manufacturing, power generation, mining, livestock, and irrigation.**
- **Rural-Domestic pumping was estimated from county-specific rural population (obtained from TWDB census blocks shape file) and per-capita annual GW usage factors provided in the TWDB geodatabase.**

Calibration Period (1980 – 1997) Pumping

- **Pumpamatic does not explicitly identify Yegua-Jackson as a GW source in the pumpamatic (lumped as "Other Aquifer")**
- **Proportion of 'Other Aquifer' pumping for Yegua-Jackson was decided on a county-by-county basis**
- **County reports were used to come up with a list of all minor aquifers that could potentially be part of the 'other aquifer' category.**
  - For counties where such reports were unavailable, information from neighboring counties and spatial coverages of water-bearing outcropping formations were used

Pre-1980 Pumping

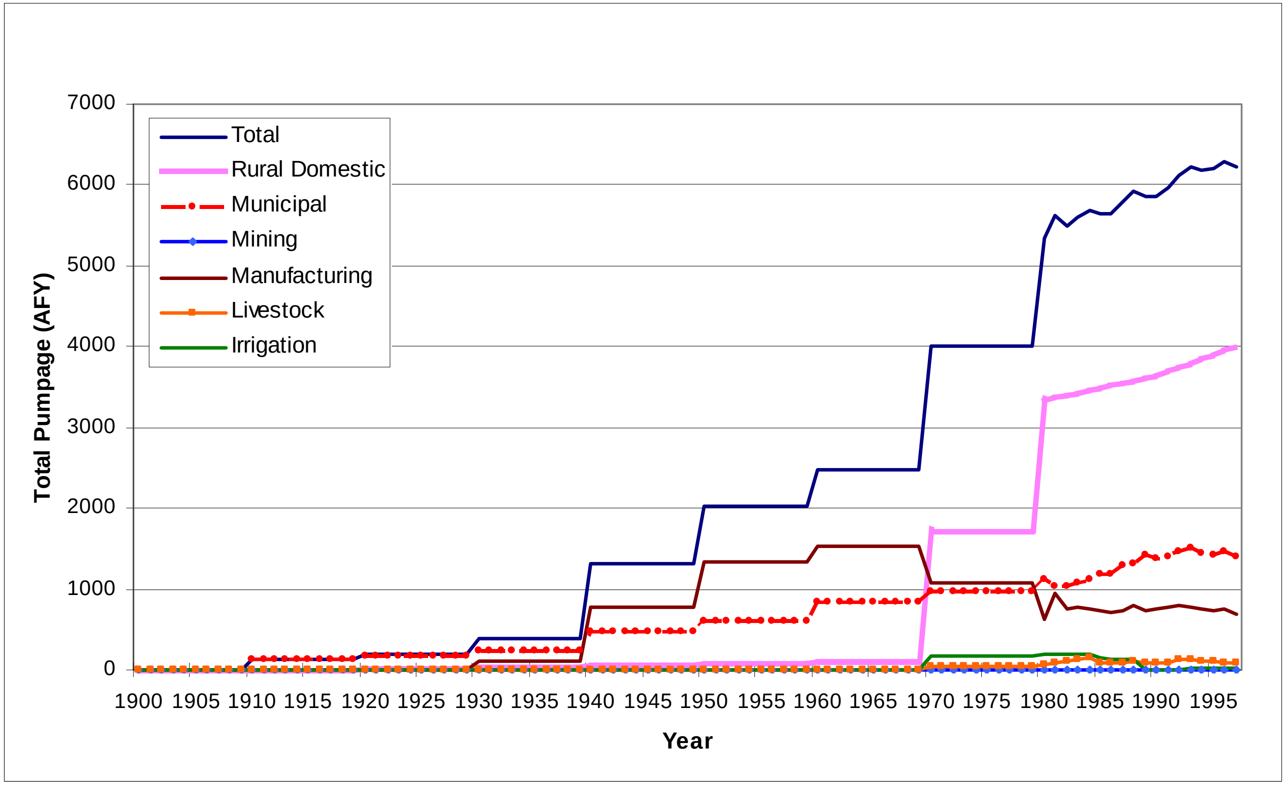
- **Rough estimated of pumping history were generated using a combination of sources to account for groundwater withdrawals before 1980**
  - TWDB wells database
  - Published County reports
  - 1981 TWDB Inventory of Irrigation in Texas
- **Due to the poor temporal resolution of available information, average pumping was estimated over 10 year periods**
- **The TWDB wells database was primarily used to identify the earliest period for pumping from Yegua-Jackson Aquifer**
  - In most cases rural-domestic pumping was reported as far back as the 1900s

Pumping Results - Discussion

- Period between 1900 and 1980 has a step-like pumping curve, due to the decadal estimates
- Rural domestic and livestock are the largest pumping types in most cases
- Irrigation is typically not a significant pumping category
- All pre-1980 pumping ‘ramp up’ to calibration period estimates since the 1980 – 1989 decadal average is used in the interpolation of intermediate decades
- Some representative pumping results are shown in following slides

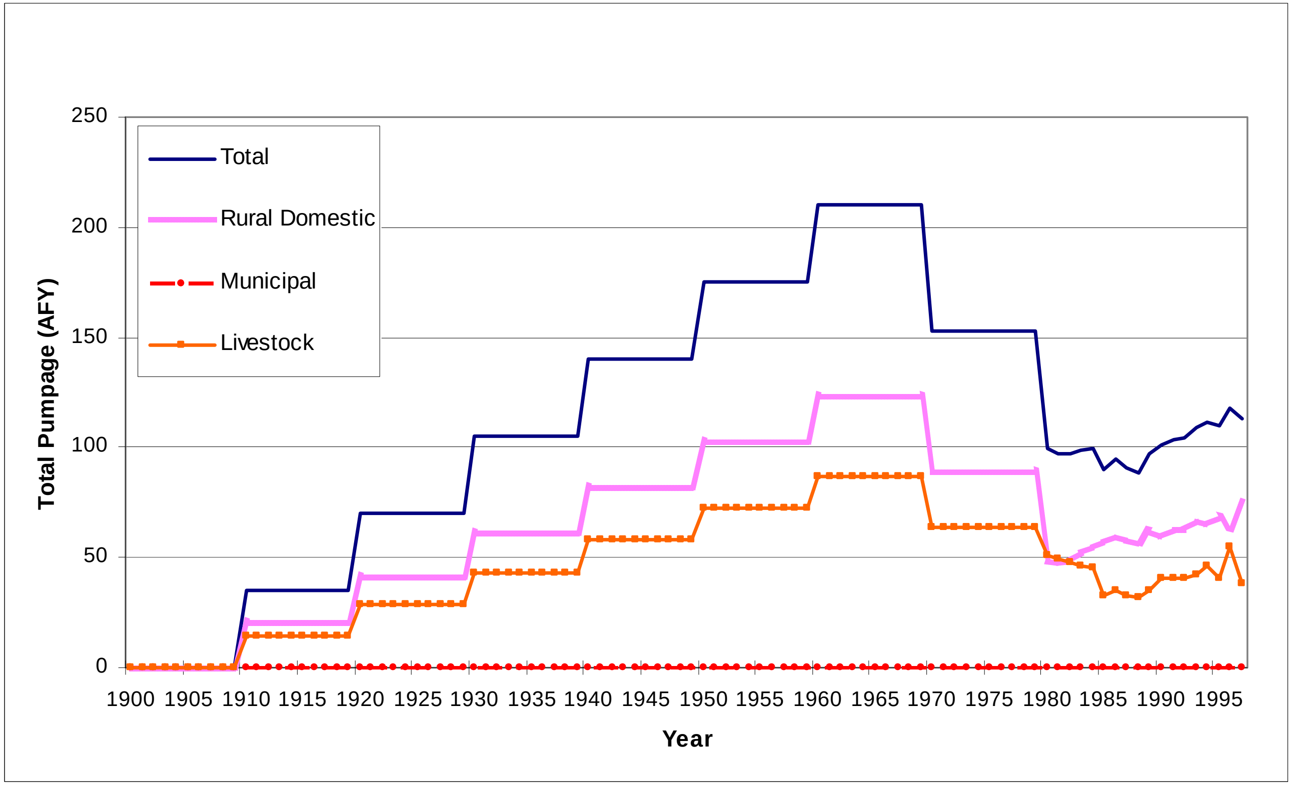
Representative Pumping Results

- **Pumping estimates for Angelina county**
  - Has the highest total pumping from Yegua-Jackson
  - Rural domestic pumping is the most significant category post 1980
  - Municipal and manufacturing are significant pre 1980
  - Steady increasing trend in pre-1980 estimates



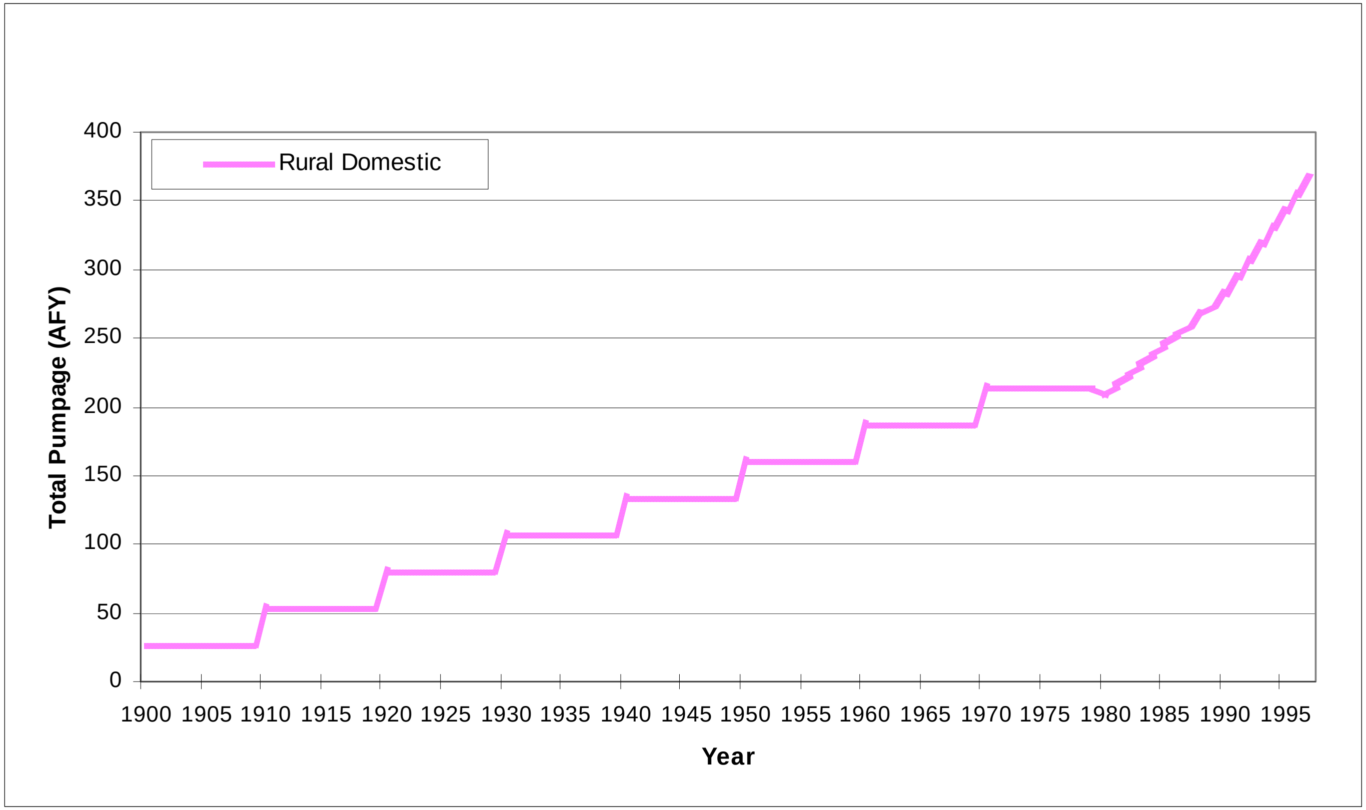
Representative Pumping Results

- **Pumping estimates for Nacogdoches county**
  - Rural-domestic and municipal are the two major pumping categories
  - Pre-1980 pumping peaks in the 1960s



Representative Pumping Results

- **Pumping estimates for Wilson county**
  - Like many other counties, rural-domestic is the only significant pumping category



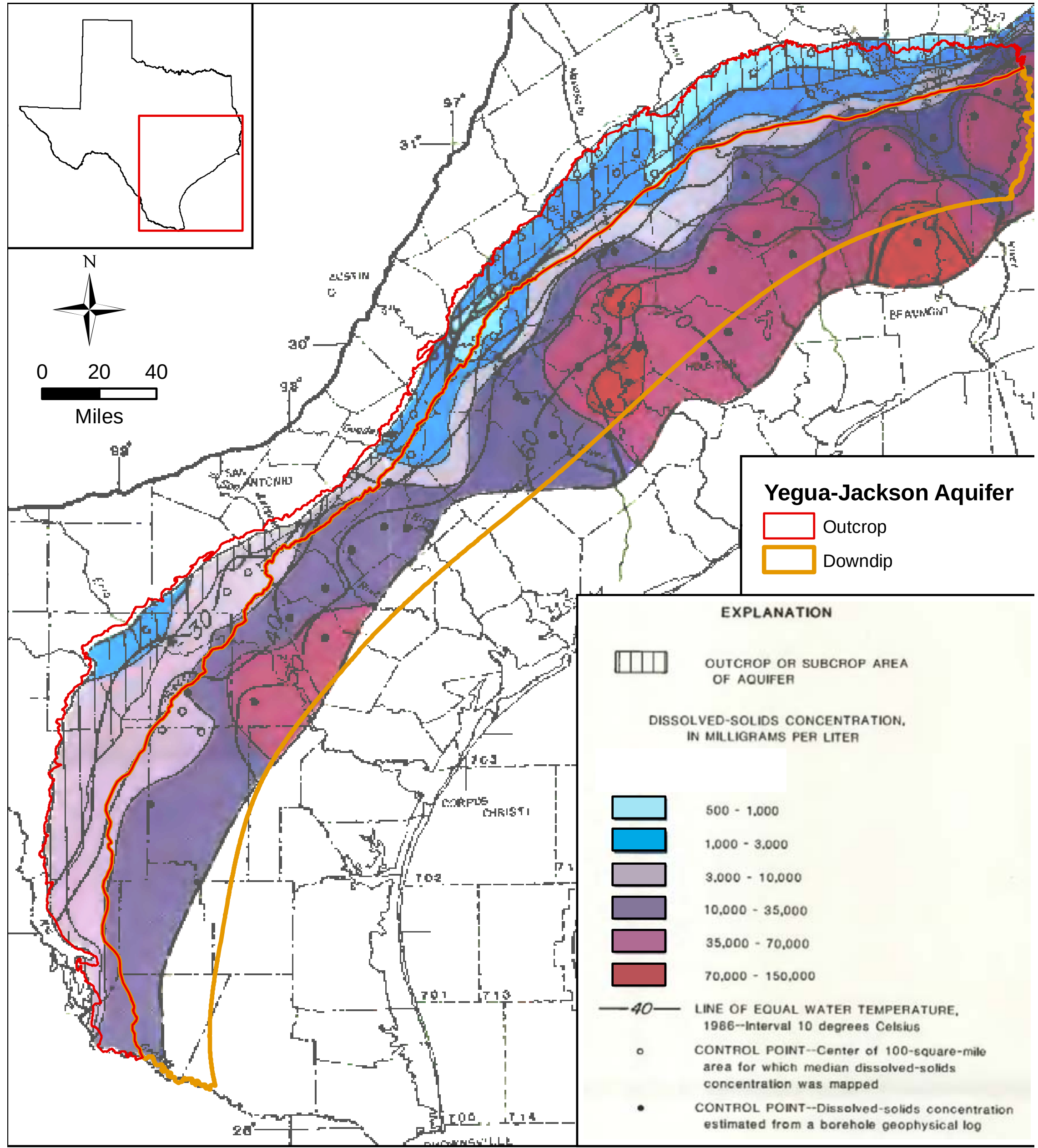
Water Quality

Water Quality

- **Water quality can vary dramatically over short distances in the Yegua-Jackson Aquifer**
- **Water quality is generally poor a short distance downdip of the outcrop**
- **Based on measurements in the TWDB groundwater database, common constituents exceed MCLs a for a signficant percentage of measurements in many wells**

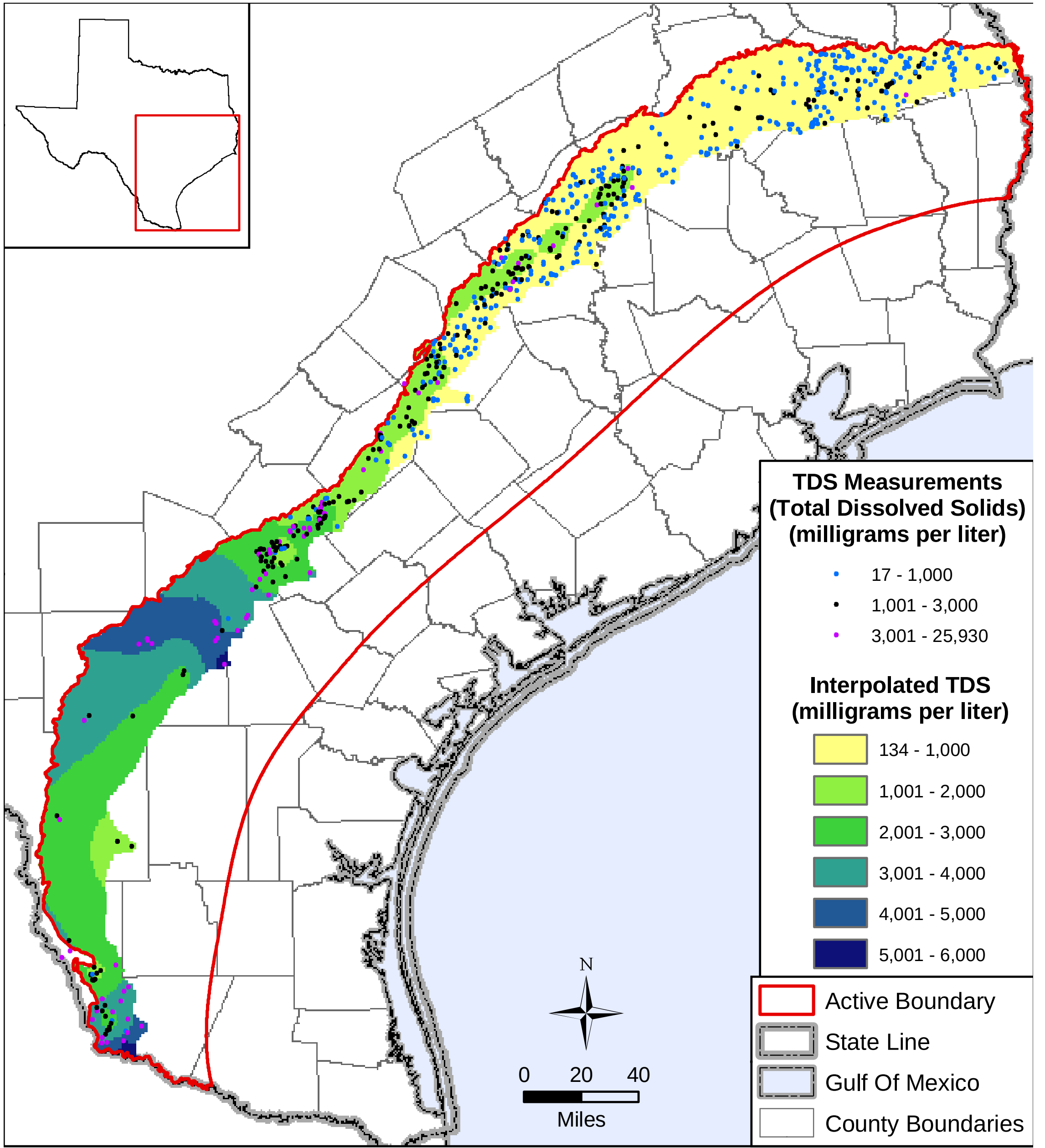
Water Quality: TDS

- **Total dissolved solids estimate modified from Pettijohn and others (1988)**
- **TDS generally increases from northeast to southwest**



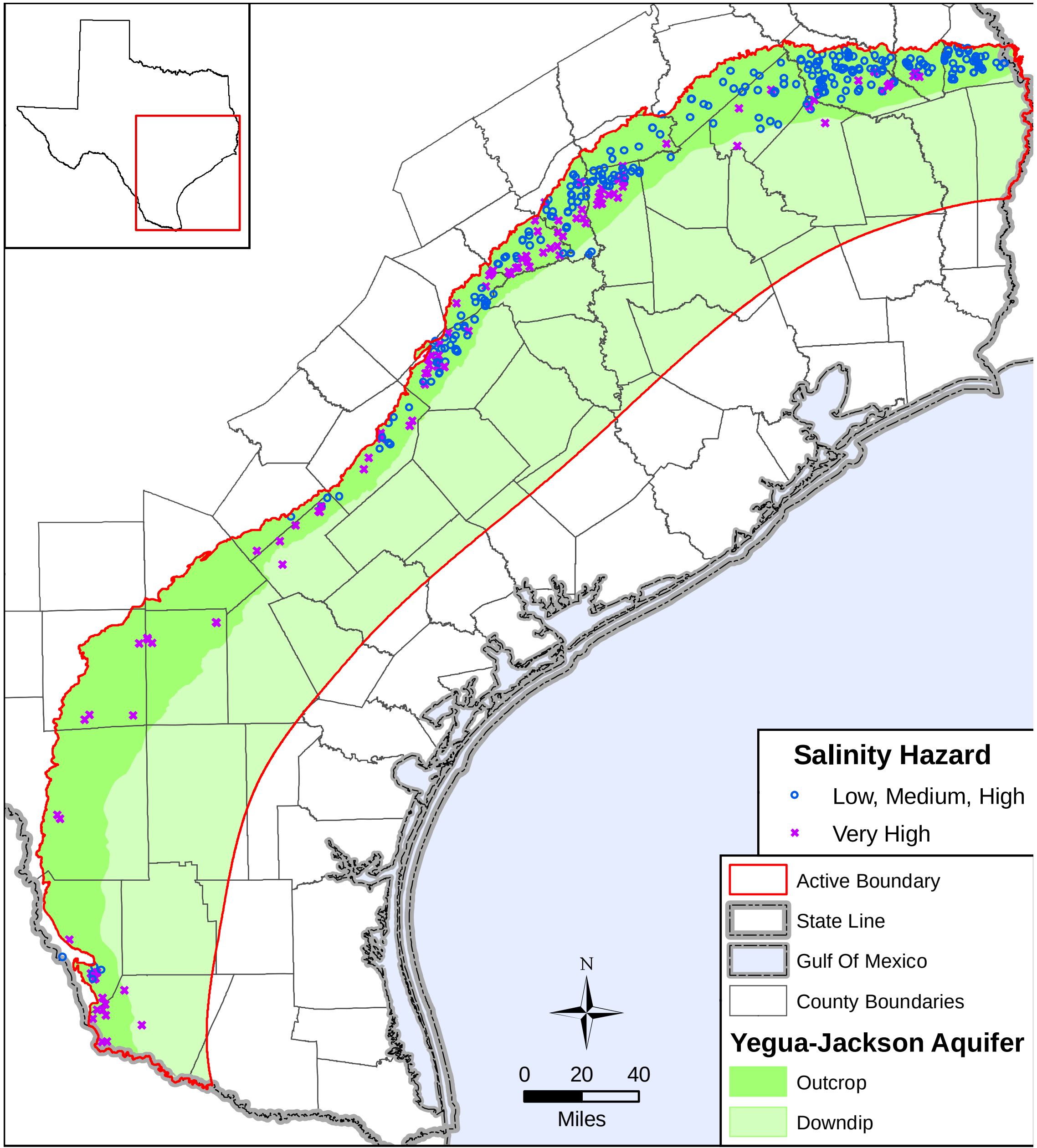
Water Quality: TDS

- **Total dissolved solids estimated from TWDB groundwater database values**
- **Most recent values used for a given well**
- **TDS generally increases from northeast to southwest**
- **Long term trends not assessed due to lack of multiple temporally spaced measurements**



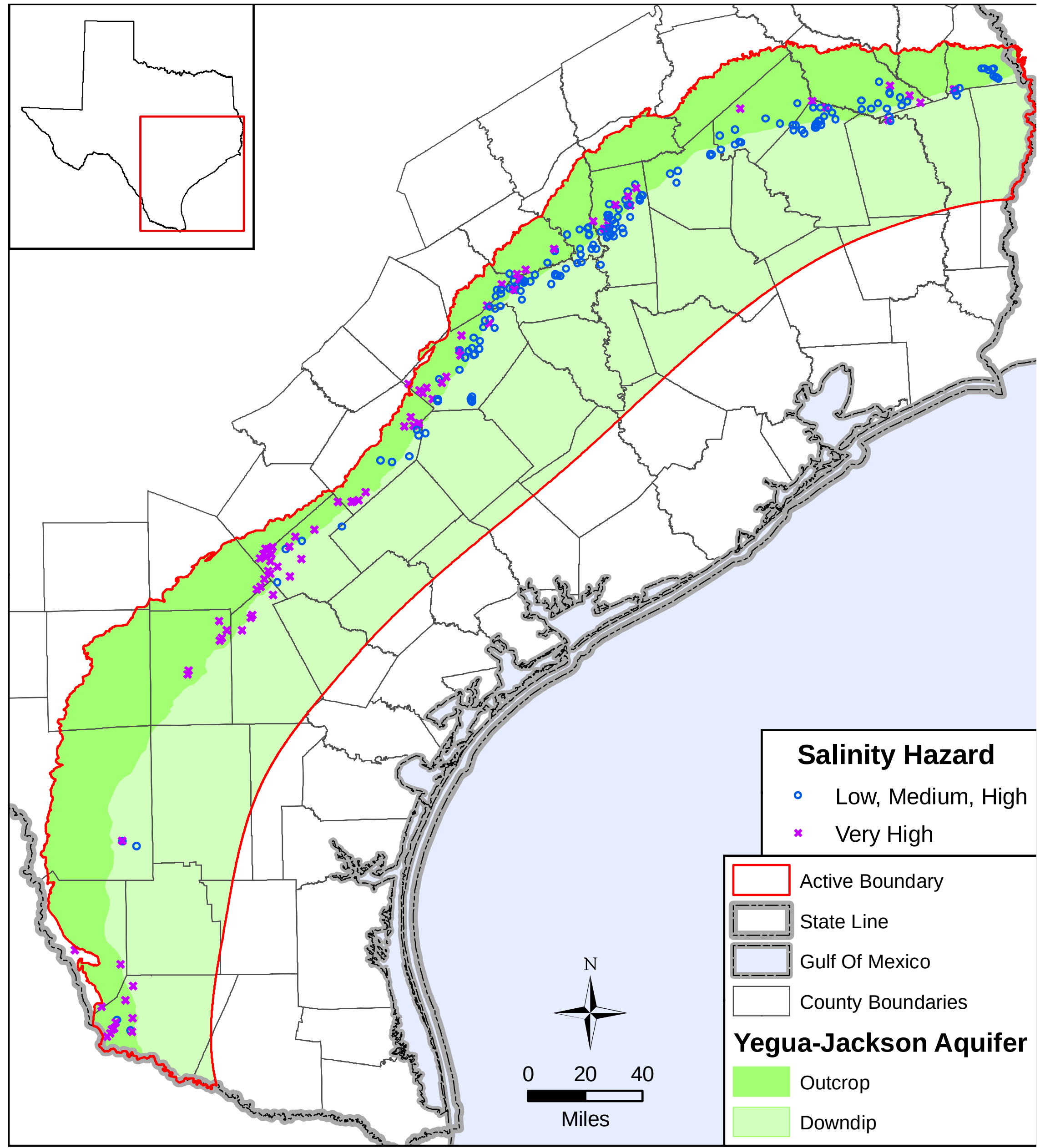
Water Quality: Yegua Salinity Hazard

- **Salinity Hazard is one indicator of irrigation water quality**
- **For the Yegua Formation, 81 percent of measurements exhibit a high salinity hazard, and 28 percent of the wells have exhibited a very high salinity hazard.**



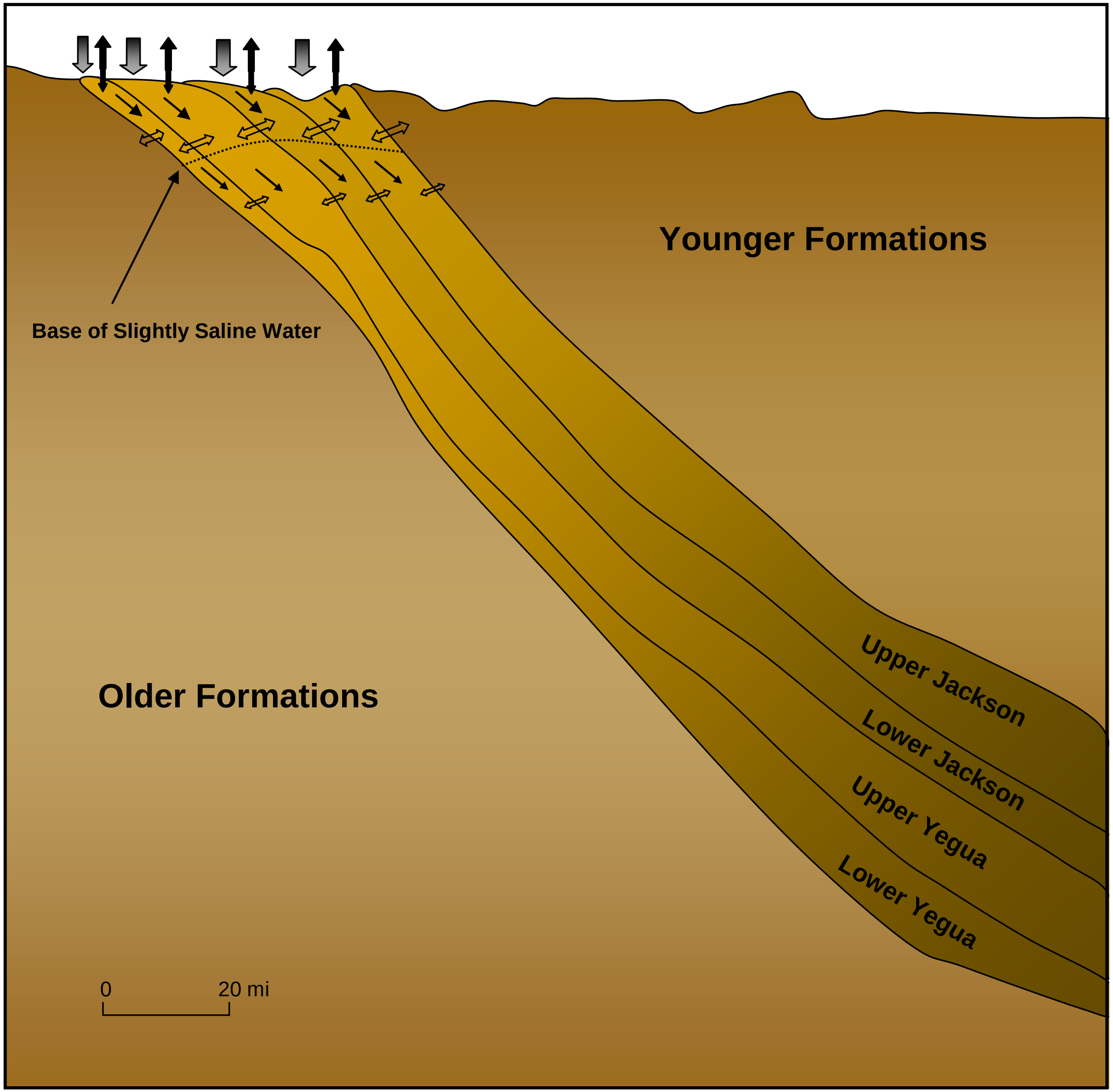
Water Quality: Jackson Salinity Hazard

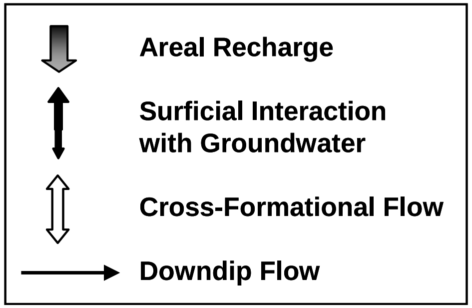
- **Salinity Hazard is one indicator of irrigation water quality**
- **For the Jackson Group, 77 percent of the wells exhibit a high salinity hazard, and 34 percent of the wells exhibit a very high salinity hazard.**



Summary of the Conceptual Model

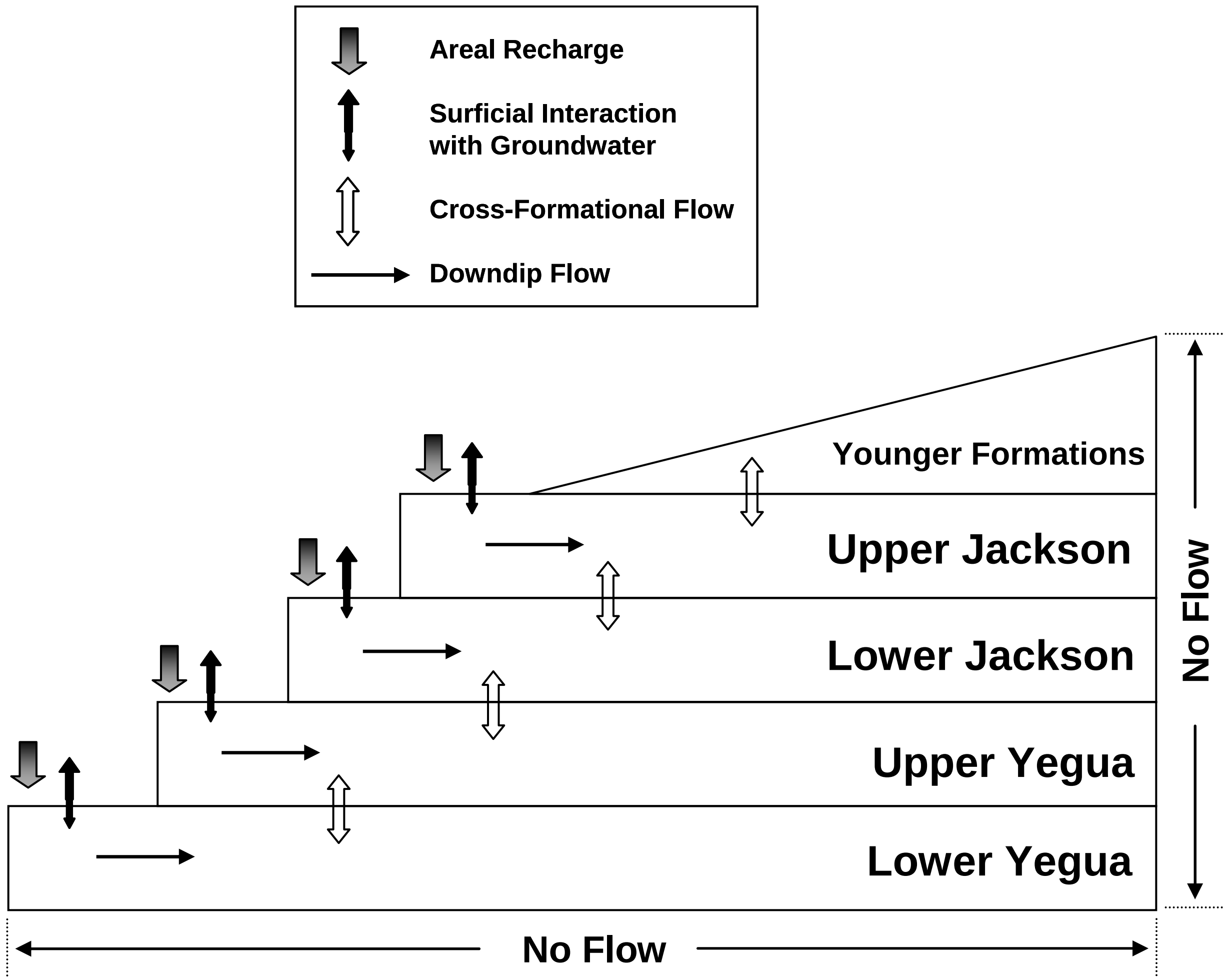
Conceptual Model (Predevelopment)





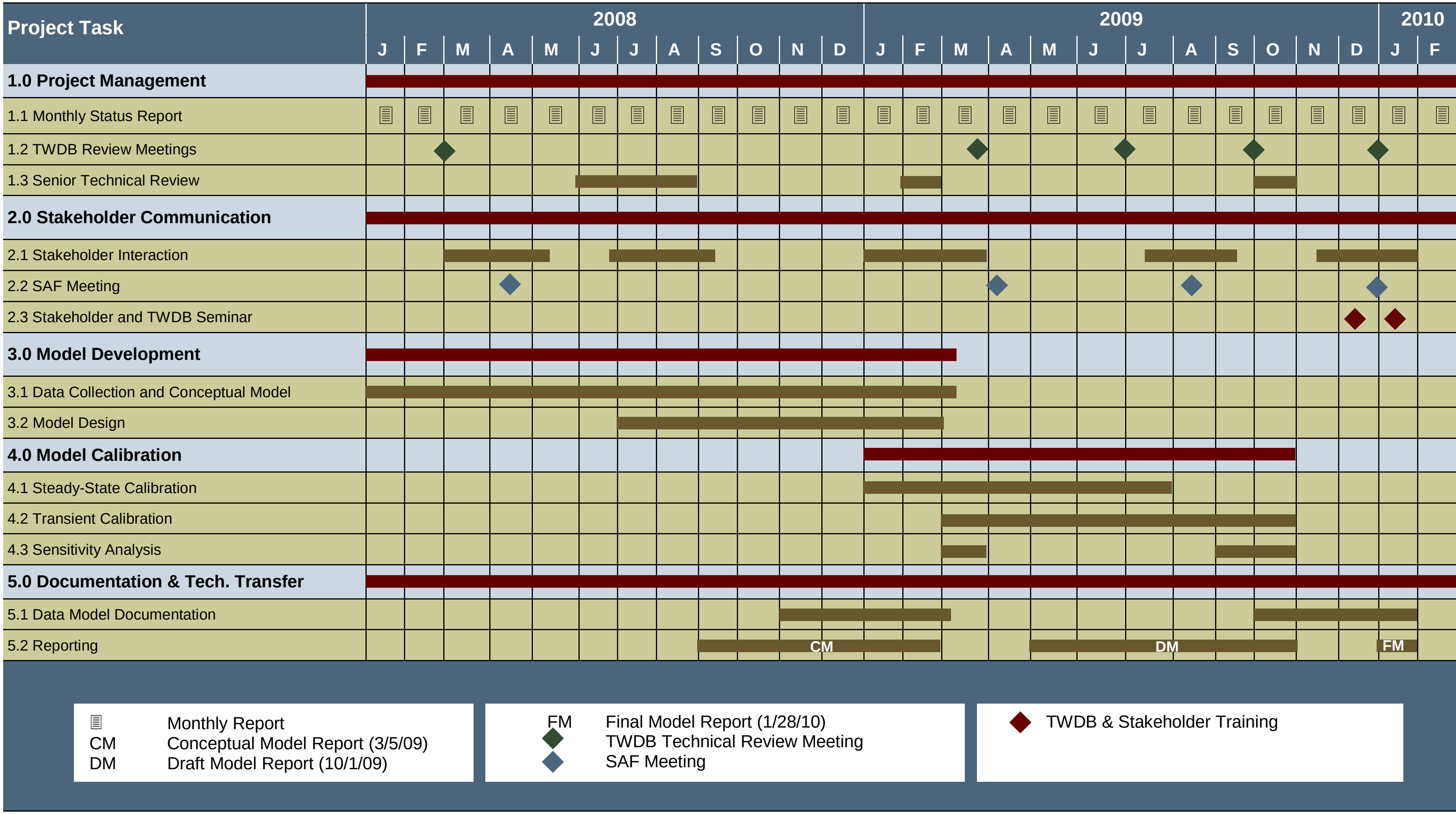
- Water input through areal recharge and losing streams or other surface water bodies
- Water output through shallow discharge and cross-formational flow
- Downdip flow decreases quickly with depth
- A minimal amount of cross-formational flow occurs between the Lower Yegua and the older formations, but we will approximate with a no-flow boundary

Conceptual Model Block Diagram



- No flow boundaries downdip and at the base of the Yegua
- After development, pumping would be included as a discharge component

Schedule


Project Task
2008
2009
2010
J F M A M J J A S O N D J F M A M J J A S O N D J F
1.0 Project Management
1.1 Monthly Status Report
1.2 TWDB Review Meetings
1.3 Senior Technical Review
2.0 Stakeholder Communication
2.1 Stakeholder Interaction
2.2 SAF Meeting
2.3 Stakeholder and TWDB Seminar
3.0 Model Development
3.1 Data Collection and Conceptual Model
3.2 Model Design
4.0 Model Calibration
4.1 Steady-State Calibration
4.2 Transient Calibration
4.3 Sensitivity Analysis
5.0 Documentation & Tech. Transfer
5.1 Data Model Documentation
5.2 Reporting
CM
DM
FM
Monthly Report
CM Conceptual Model Report (3/5/09)
DM Draft Model Report (10/1/09)
FM Final Model Report (1/28/10)
TWDB Technical Review Meeting
SAF Meeting
TWDB & Stakeholder Training

Thank You

Questions

Meeting Minutes for the Second Yegua-Jackson Groundwater Availability Model (GAM) Stakeholder Advisory Forum (SAF) Meeting

April 10, 2009

San Antonio River Authority Board Room
100 E. Guenther Street
San Antonio, Texas

The second Stakeholder Advisory Forum (SAF) Meeting for the Yegua-Jackson Groundwater Availability Model (GAM) was held on Friday, April 10th, 2009 at 1:30 PM at the San Antonio River Authority Board Room, 100 E. Guenther Street in San Antonio. A list of meeting participants is provided at the end of these meeting notes.

The primary purpose of the first SAF meeting was to provide an introduction to the Yegua-Jackson GAM Team and their proposed approach to developing the model and to solicit input from stakeholders including any available data that could be made public. The meeting also provided a forum for discussing the project schedule and provided an opportunity for feedback from stakeholders.

Meeting Introduction: Cindy Ridgeway, TWDB

The meeting was initiated by Ms. Cindy Ridgeway of the Texas Water Development Board (TWDB). She gave a brief introduction to the GAM Program and discussed how GAMs are used in Texas water resources planning. She then discussed GAMs and how they relate to Managed Available Groundwater as well as the importance of the stakeholder process.

SAF Presentation: Neil Deeds and Van Kelley, INTERA Inc

Neil Deeds and Van Kelley (INTERA) presented a prepared presentation structured according to the following outline:

1. Yegua-Jackson GAM Team
2. What is a Conceptual Model?
3. Structure
4. Water Levels and Groundwater Flow
5. Hydraulic Properties
6. Surface Water
7. Recharge and Natural Discharge
8. Pumping
9. Groundwater Quality
10. Summary of Conceptual Model
11. Review of Project Milestones and Schedule

The presentation is available on the GAM website:

(http://www.twdb.state.tx.us/gam/ygjk/ygjk.htm)

Questions and Answers: Cindy Ridgeway (TWDB) Presentation:

Q Does the Queen City and Sparta Aquifer extend west past the Frio River? In the official TWDB outline, the aquifer appears to end at the Frio.

A: *The analogous sediments extend past the Frio River, but the TWDB delineation terminates due to the water quality degradation. The Queen City and Sparta GAM does model the sediments west of the Frio River.*

Questions and Answers: Van Kelley and Neil Deeds (INTERA) Presentation:

Q: In the Yegua-Jackson Aquifer does the water turn saline in the downdip portion?

A: *Yes, the water quality degrades quickly in the Yegua-Jackson moving downdip from the outcrop. Most of the fresh to slightly-saline water is in the actual outcrop or in the near downdip (10s of miles) regions of the aquifer.*

Q: Will the formation be more or less productive downdip?

A: *Although we do not have well tests to prove it, our working conceptualization is that the formation will be less productive downdip. The hydraulic properties section of the conceptual model report details why this is likely the case.*

Q: Is the Catahoula Formation part of the Gulf Coast Aquifer?

A: *The Catahoula is considered part of the Gulf Coast Aquifer in the outcrop portion, but the water quality degrades significantly moving downdip.*

Q: Is this the first time that the chronostratigraphic approach was used for delineating the aquifer structure in a Texas GAM?

A: *This is the first time for a GAM. However, the same approach is being used to delineate the structure of the Gulf Coast aquifer for the entire state, to support the update of the Gulf Coast GAMs. Also, this approach was used to develop the Gulf Coast Aquifer model for the LCRA-SAWS water project.*

Q: In reference to the structure map, are the wells that serve as control points predominantly oil wells?

A: *Yes. Because there is so little fresh water in the downdip portion of the aquifer, logs from water wells were not available as a source. Conversely, the oil well logs often did not extend into the shallower portions, making data selection a challenge at times.*

Q: In reference to the water level hydrographs, who monitors the water levels in the wells? How are these wells identified for a particular aquifer?

A: *Water level measurements are either made by TWDB staff, USGS staff, or other local entities such as GCDs. The TWDB has a comprehensive database of water level information that is available on their website. Information about very early water levels can sometimes be found in county reports.*

The aquifer structure was used in association with information about screen depths to locate wells in particular units.

Q: In reference to the hydrograph separation results, why does the San Antonio River show flow only 77% of the time?

A: *The gage on which the hydrograph separation was performed was not on the main channel of the San Antonio, but rather on a feeder creek. One of the difficulties with hydrograph separation is that the gage must be for a mostly uncontrolled catchment, a condition that is rare for the main river channels.*

Yegua-Jackson Aquifer GAM Stakeholder Advisory Forum 2
April 10, 2009

Attendance

Name	Affiliation
Dub Smothers	Concerned Citizen
Rudy R. Farias	SARA
Melissa Bryant	SARA
Steve Raabe	SARA
Landon Yosko	SARA
Van Kelley	INTERA
Neil Deeds	INTERA
Cindy Ridgeway	TWDB