Quality Scientific Analysis for the Long Term

Hydrogeology and Simulation of Ground-Water Flow and Land-Surface Subsidence in the Chicot, Evangeline, and Jasper Aquifers, Houston Area, Texas

Mark C. Kasmarek & Eric W. Strom

In Cooperation with: Texas Water Development Board, Harris-Galveston Coastal Subsidence District, San Jacinto River Authority, and the City of Houston

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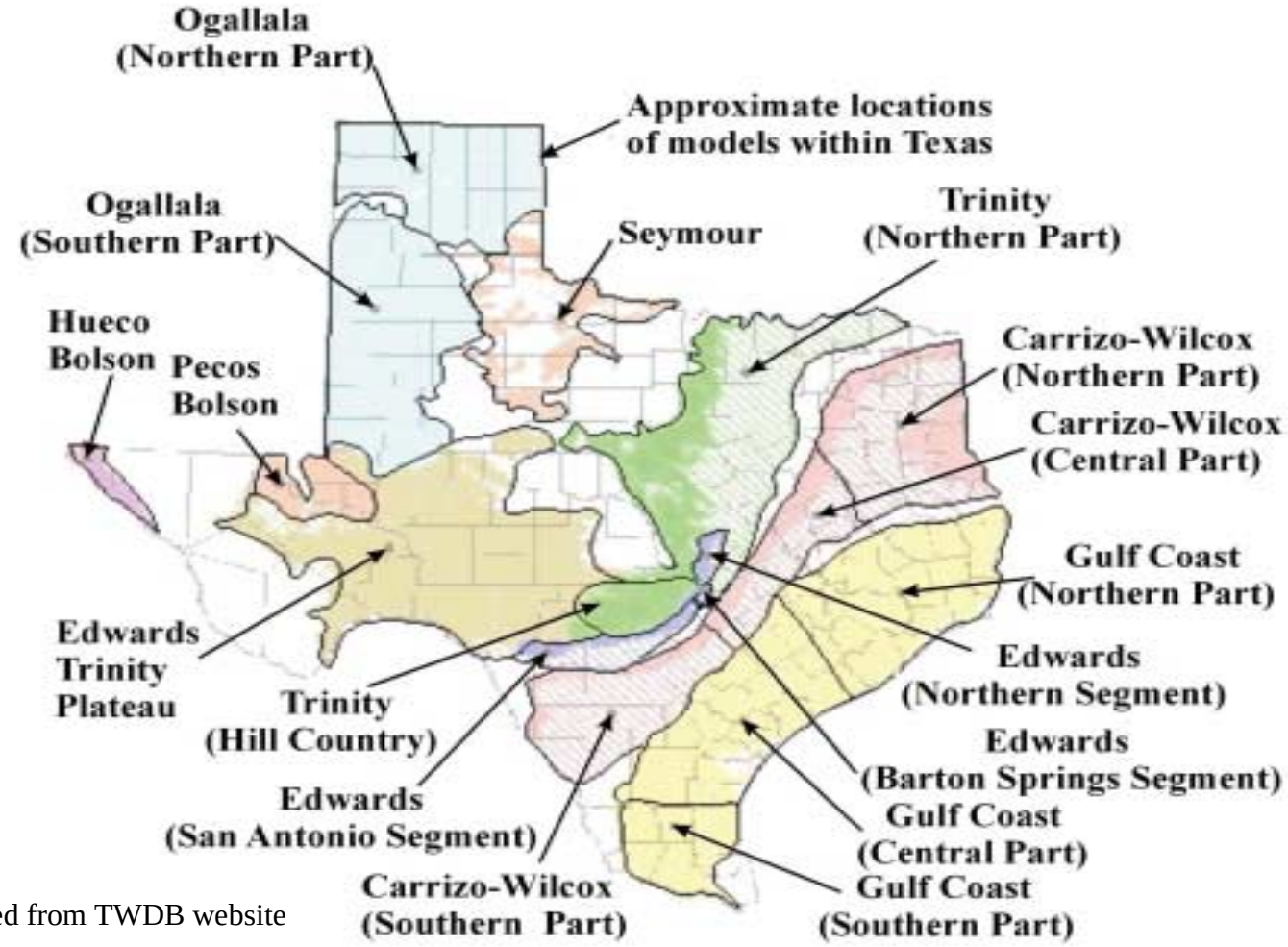
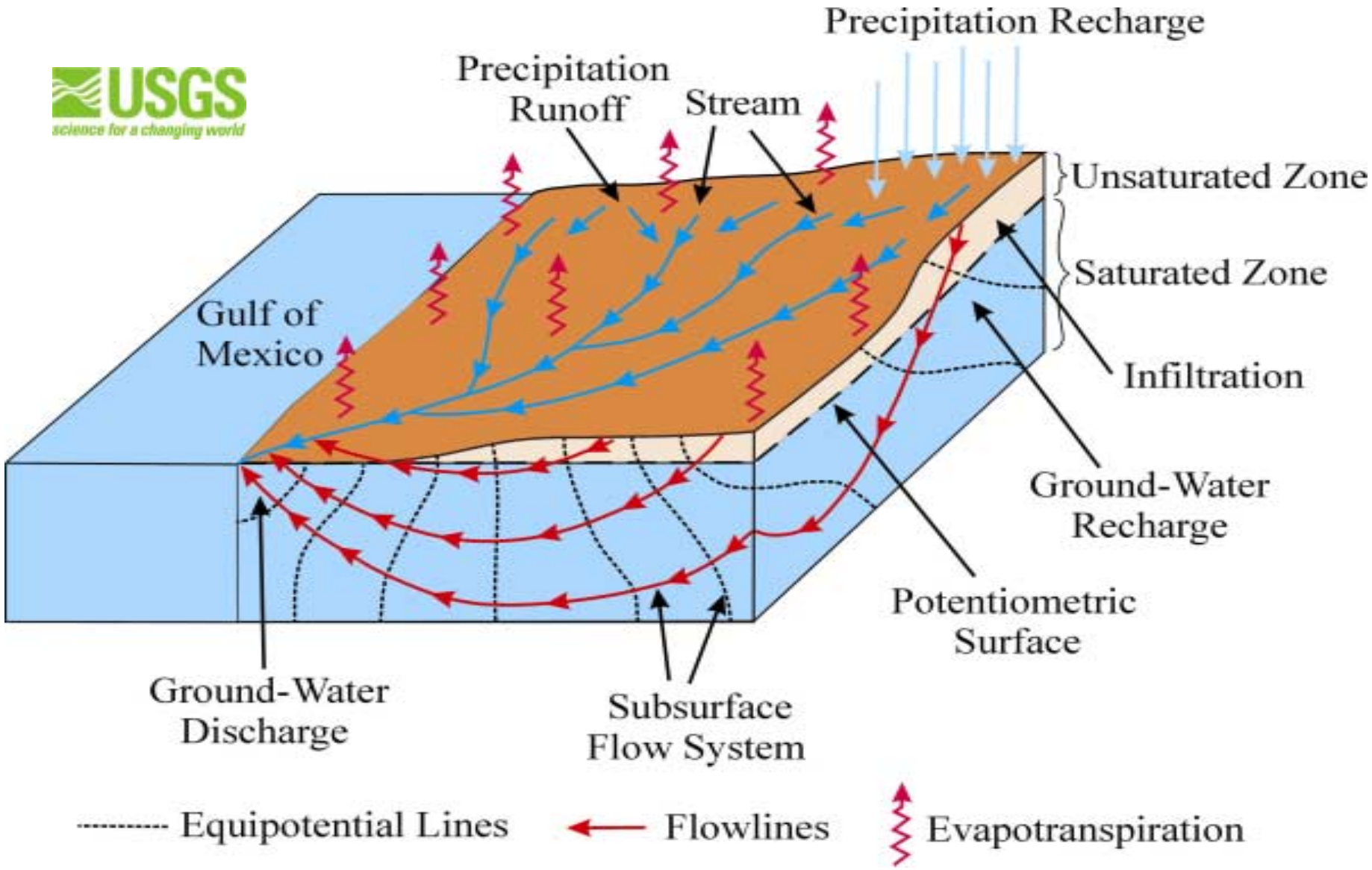
TWDB Ground-Water Availability Models in Texas

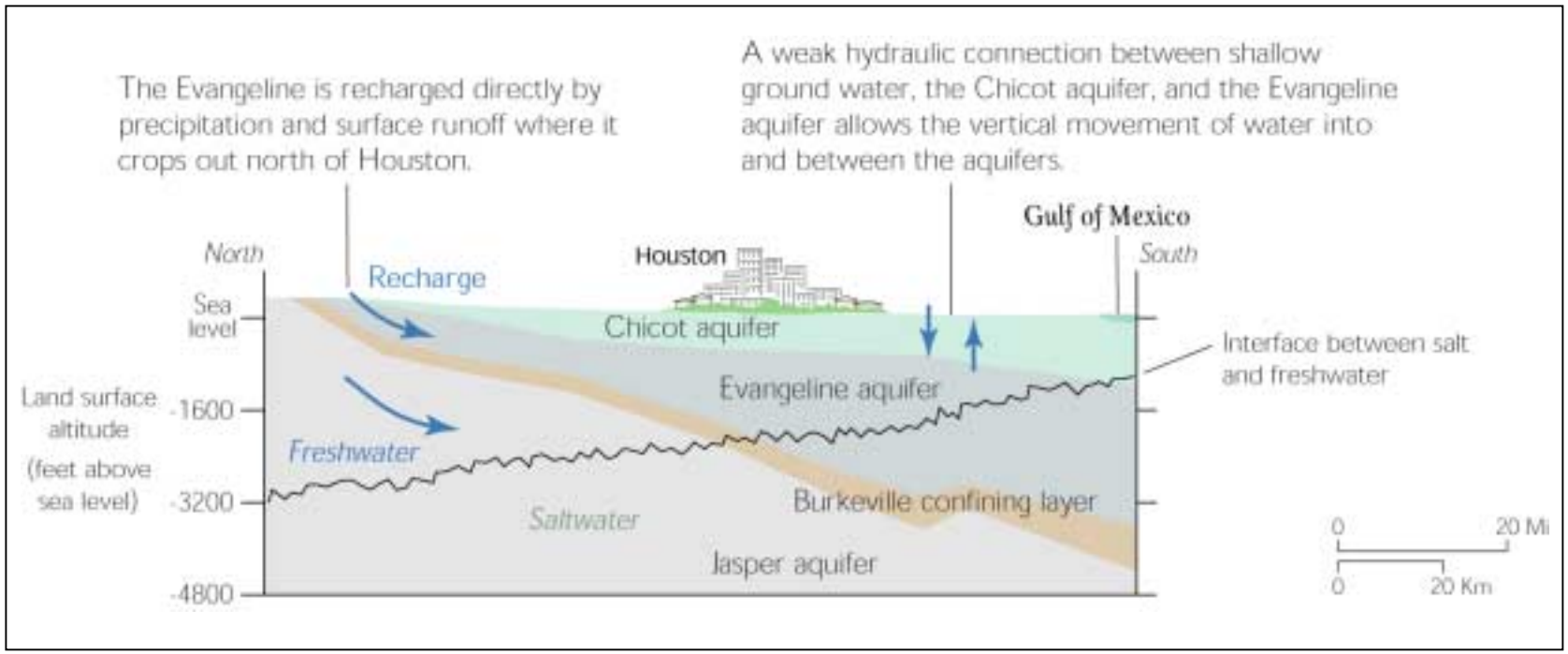


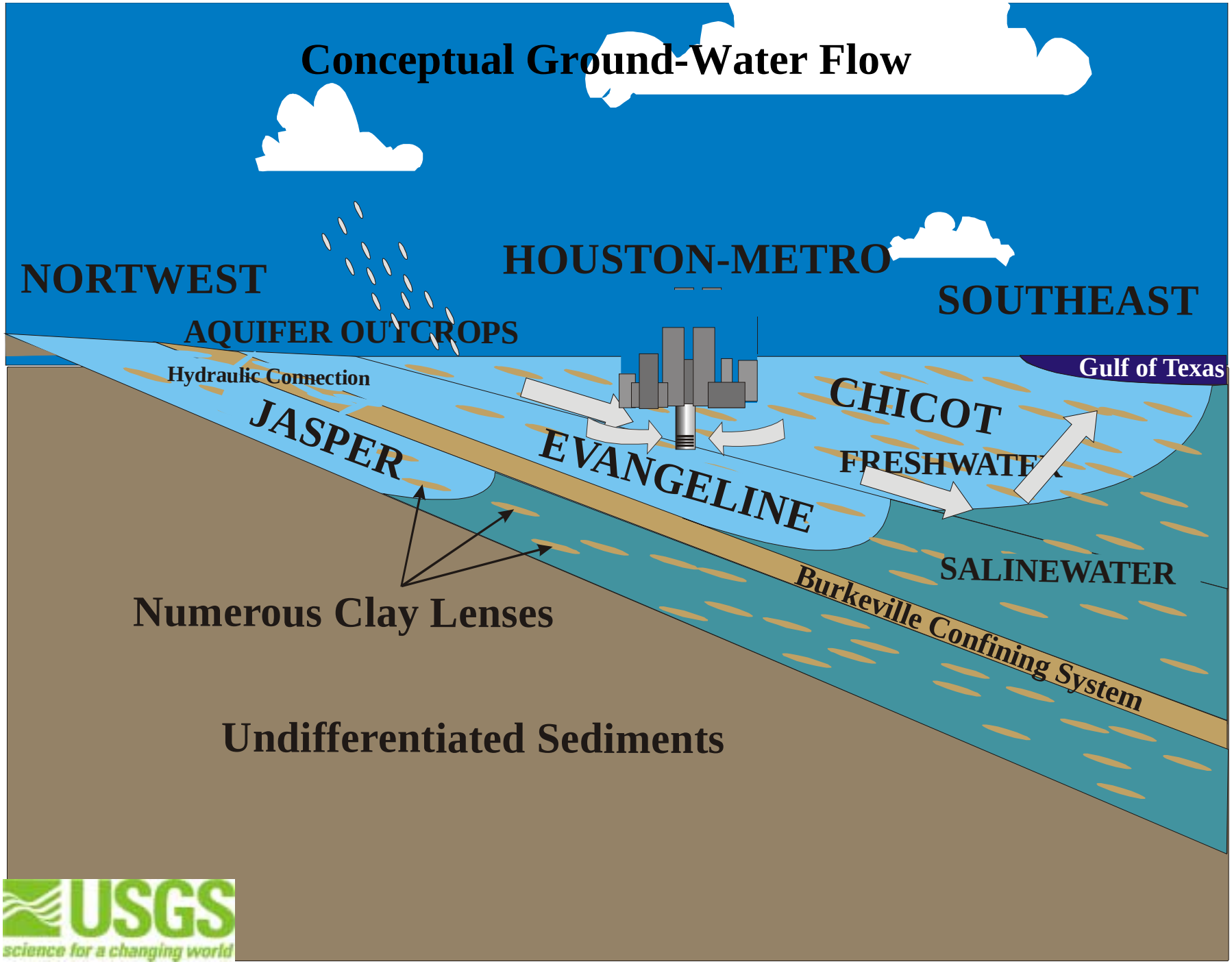
Modified from TWDB website

Conceptual Chicot Aquifer Flow System



Conceptual Ground-Water Flow




Conceptual Ground-Water Flow
NORTWEST
HOUSTON-METRO
SOUTHEAST
AQUIFER OUTCROPS
Hydraulic Connection
Gulf of Texas
JASPER
EVANGELINE
CHICOT
FRESHWATER
SALINEWATER
Burkeville Confining System
Numerous Clay Lenses
Undifferentiated Sediments
USGS
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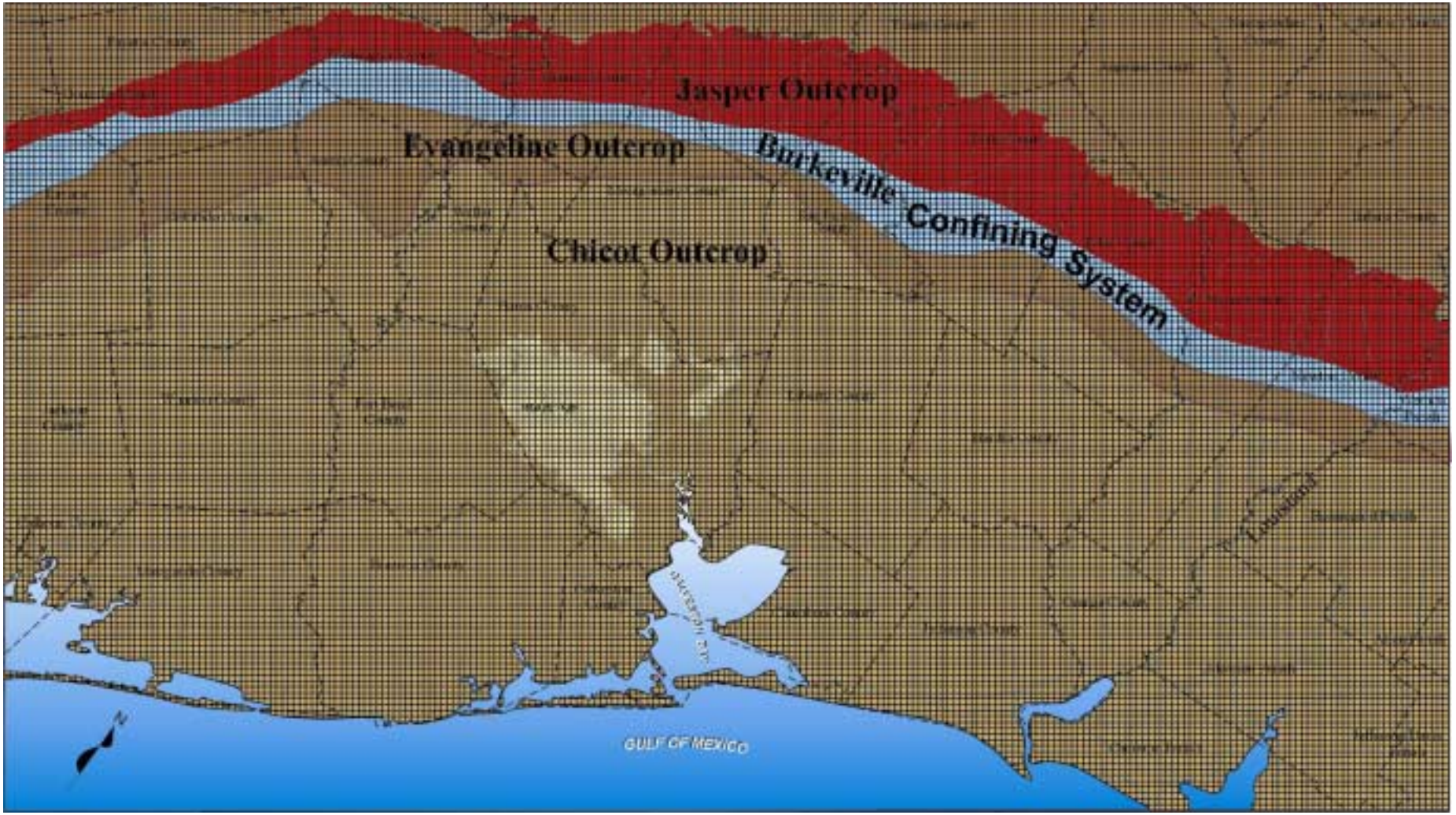
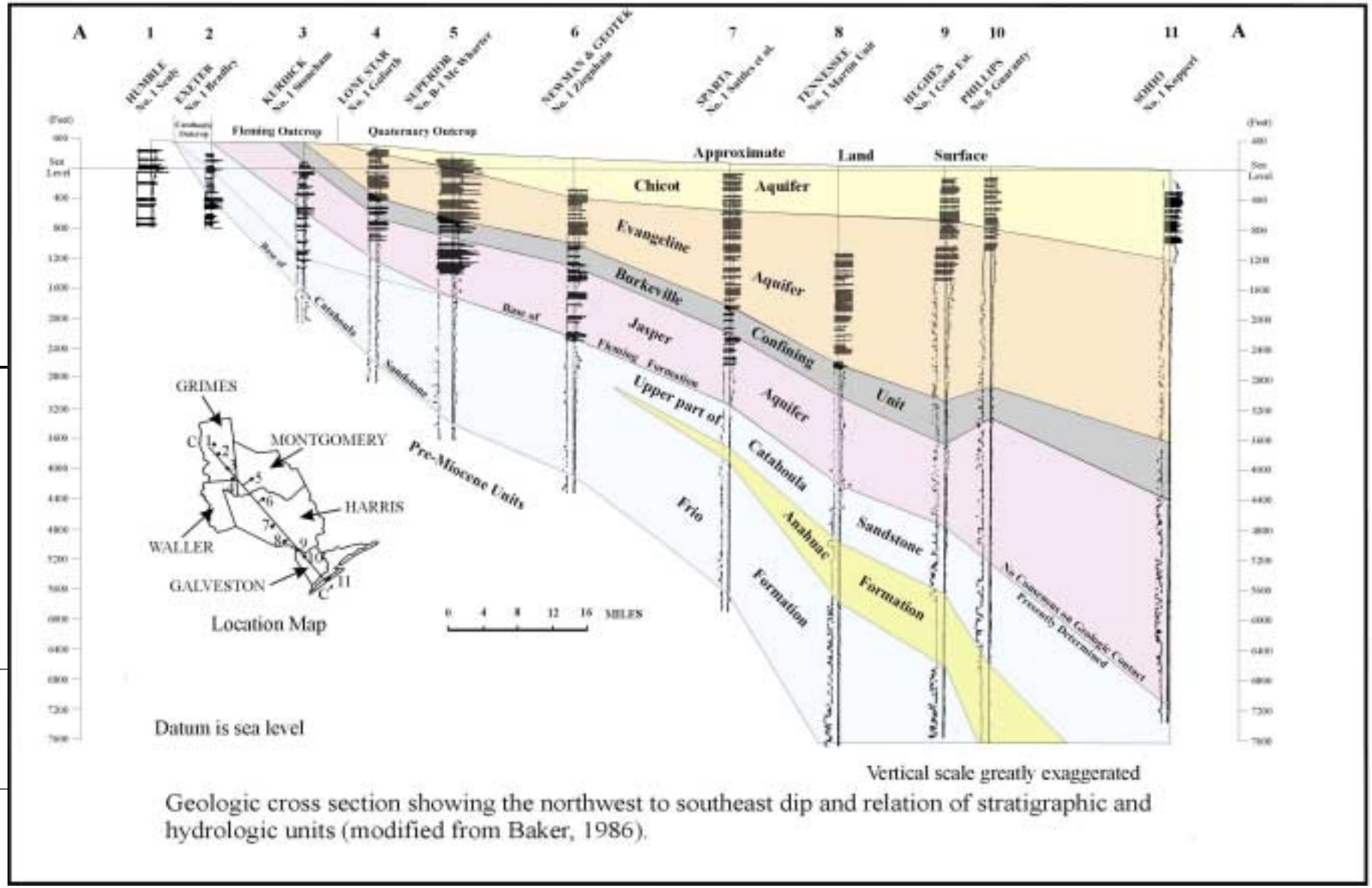
Upper Gulf Coast GAM Aquifer Outcrops

Upper Gulf Coast GAM Grid

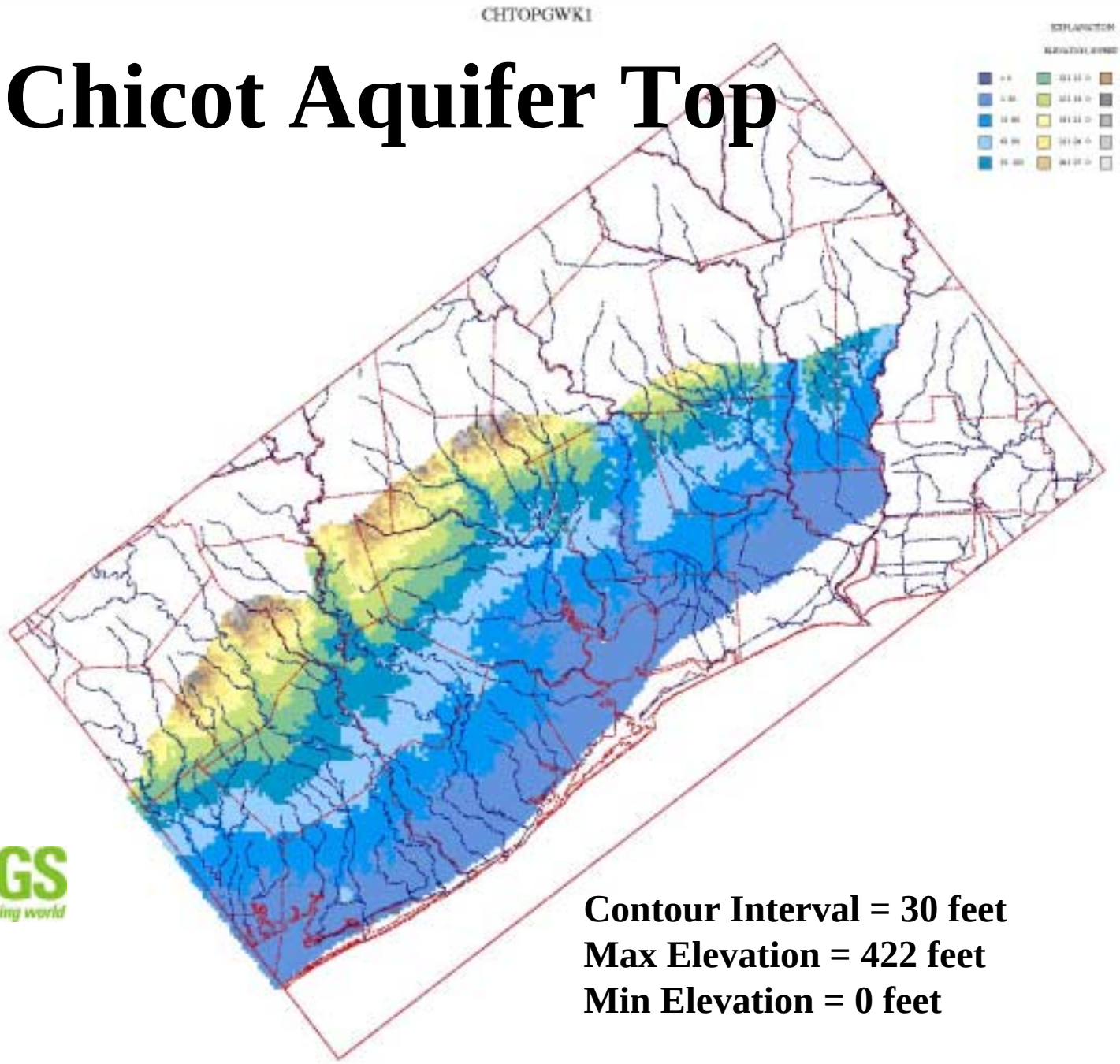


Stratigraphic and Hydrologic Sections



Geologic cross section showing the northwest to southeast dip and relation of stratigraphic and hydrologic units (modified from Baker, 1986).

GAM Chicot Aquifer Top



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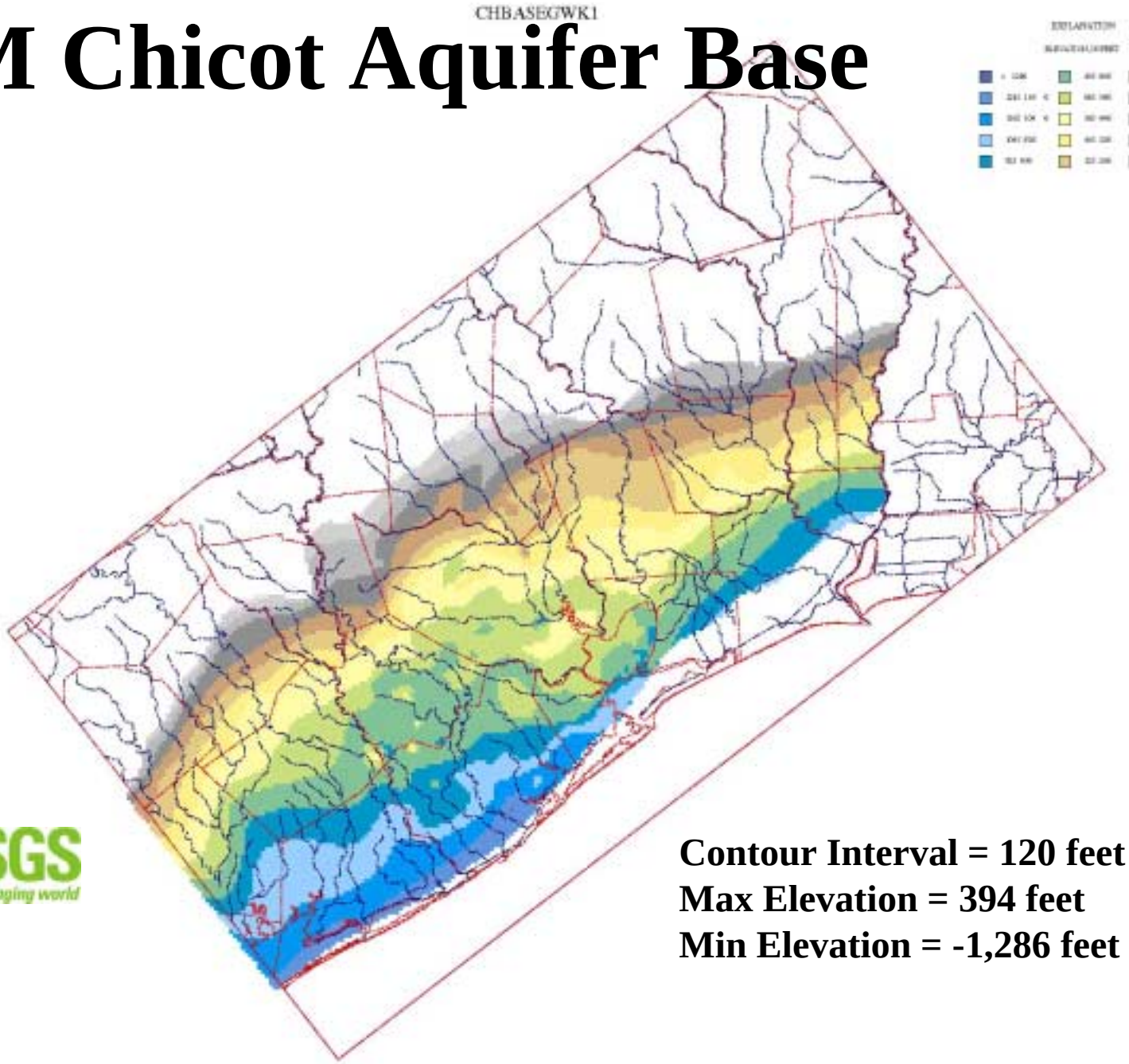
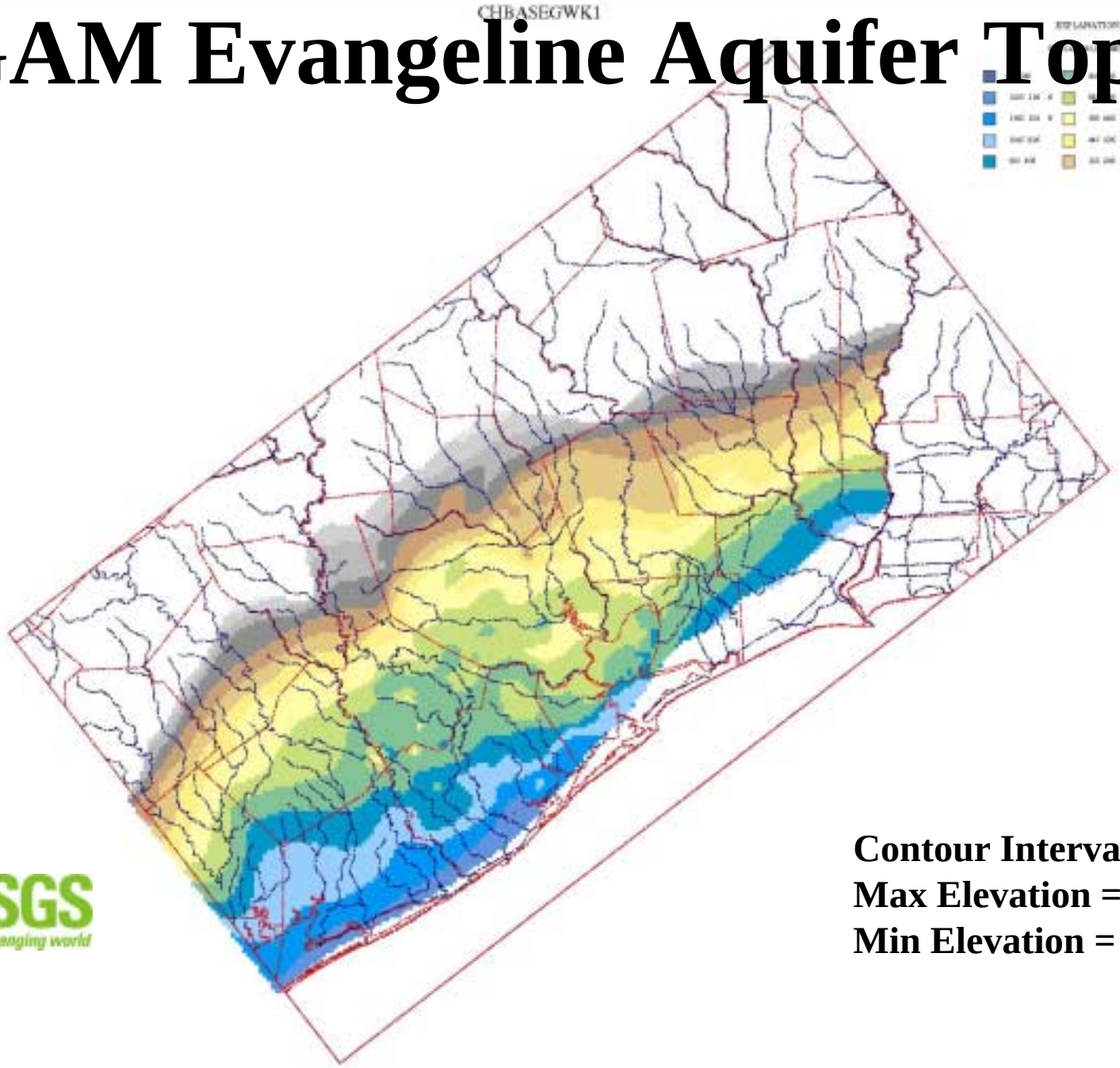
Contour Interval = 30 feet
Max Elevation = 422 feet
Min Elevation = 0 feet

AM Chicot Aquifer Base



Contour Interval = 120 feet
Max Elevation = 394 feet
Min Elevation = -1,286 feet

GAM Evangeline Aquifer Top



Contour Interval = 120 feet
Max Elevation = 394 feet
Min Elevation = -1,286

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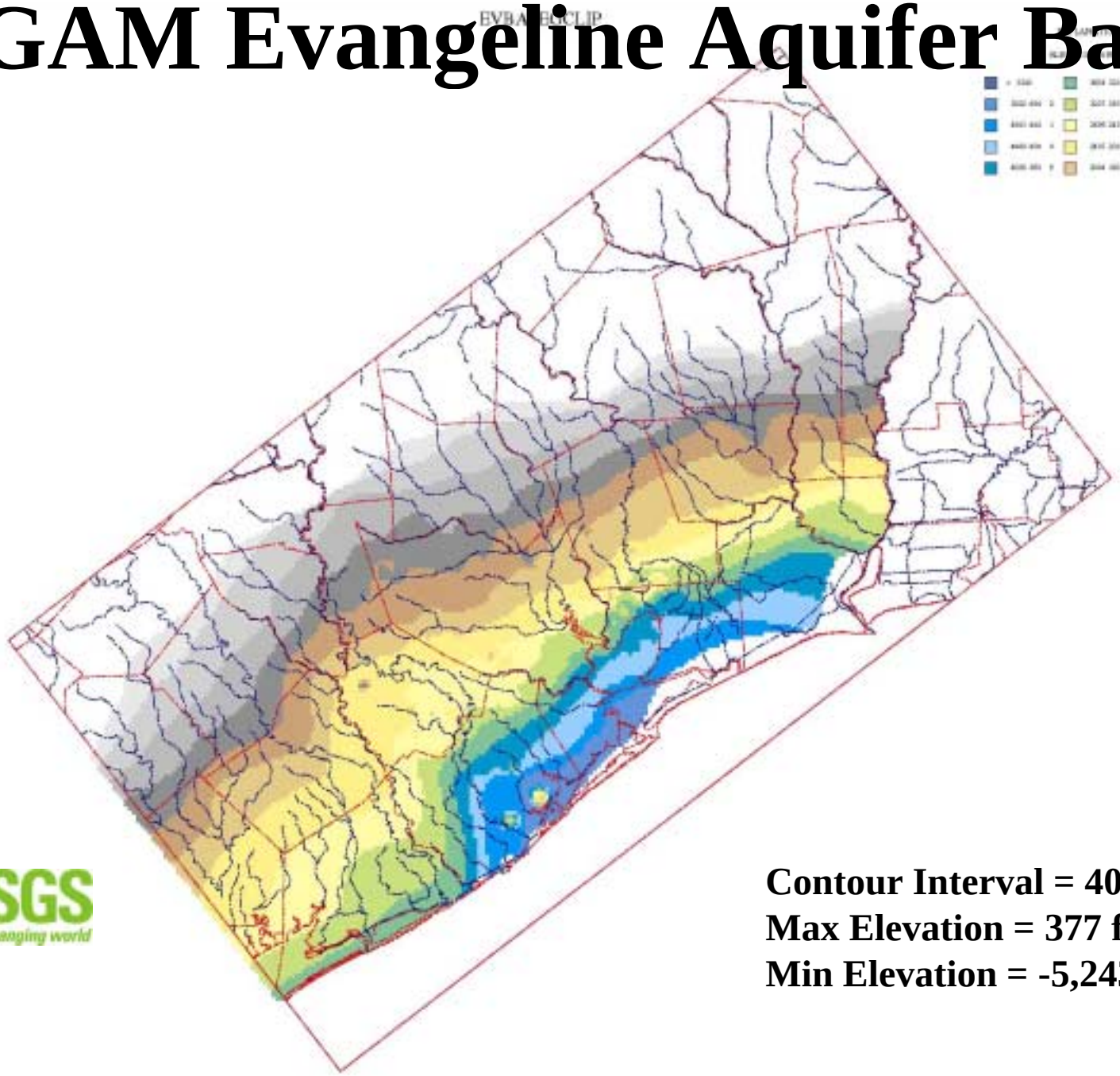
GAM Evangeline Aquifer Base



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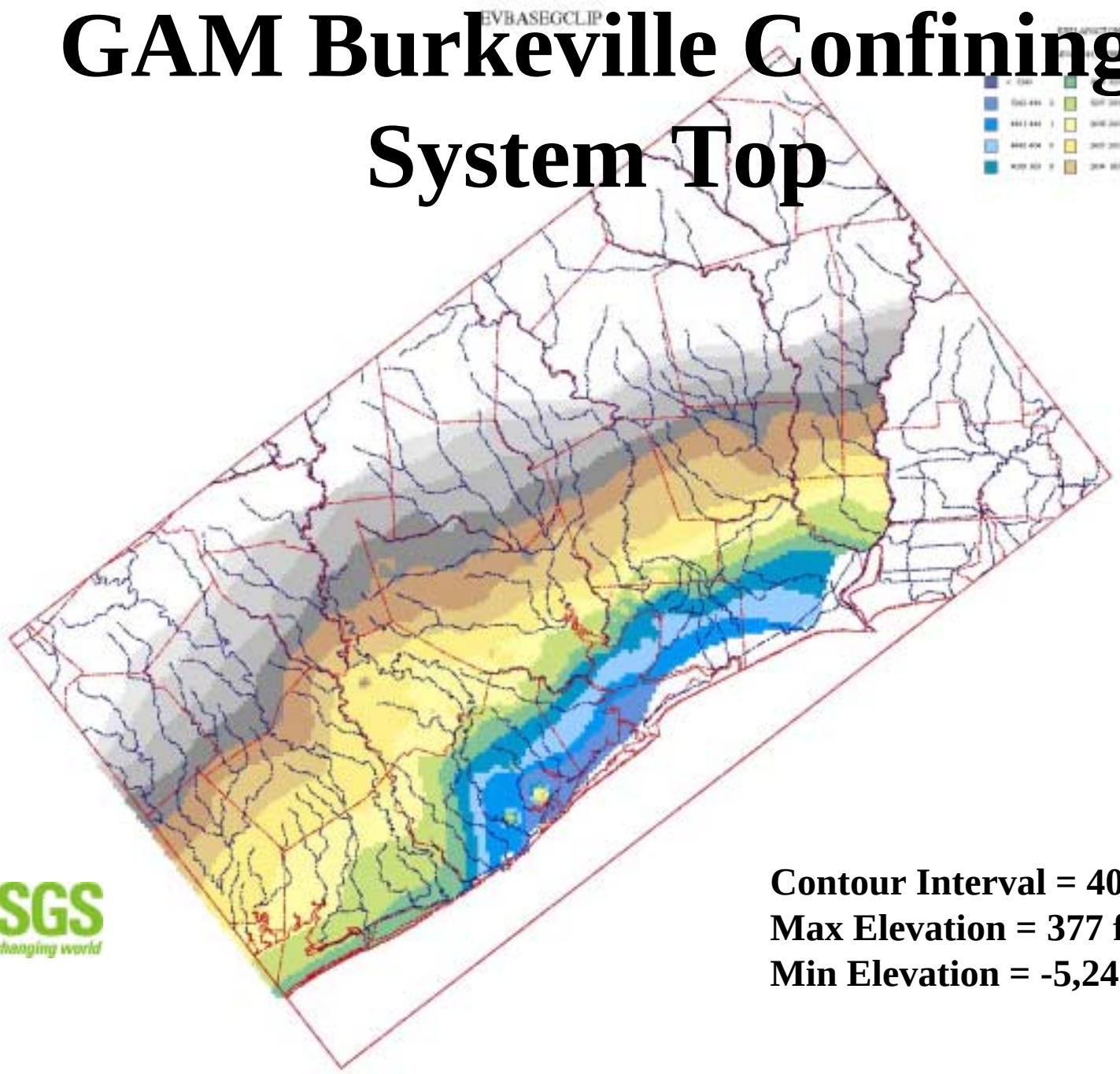
Contour Interval = 401 feet
Max Elevation = 377 feet
Min Elevation = -5,243 feet

GAM Burkeville Confining System Top



USGS
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Contour Interval = 401 feet
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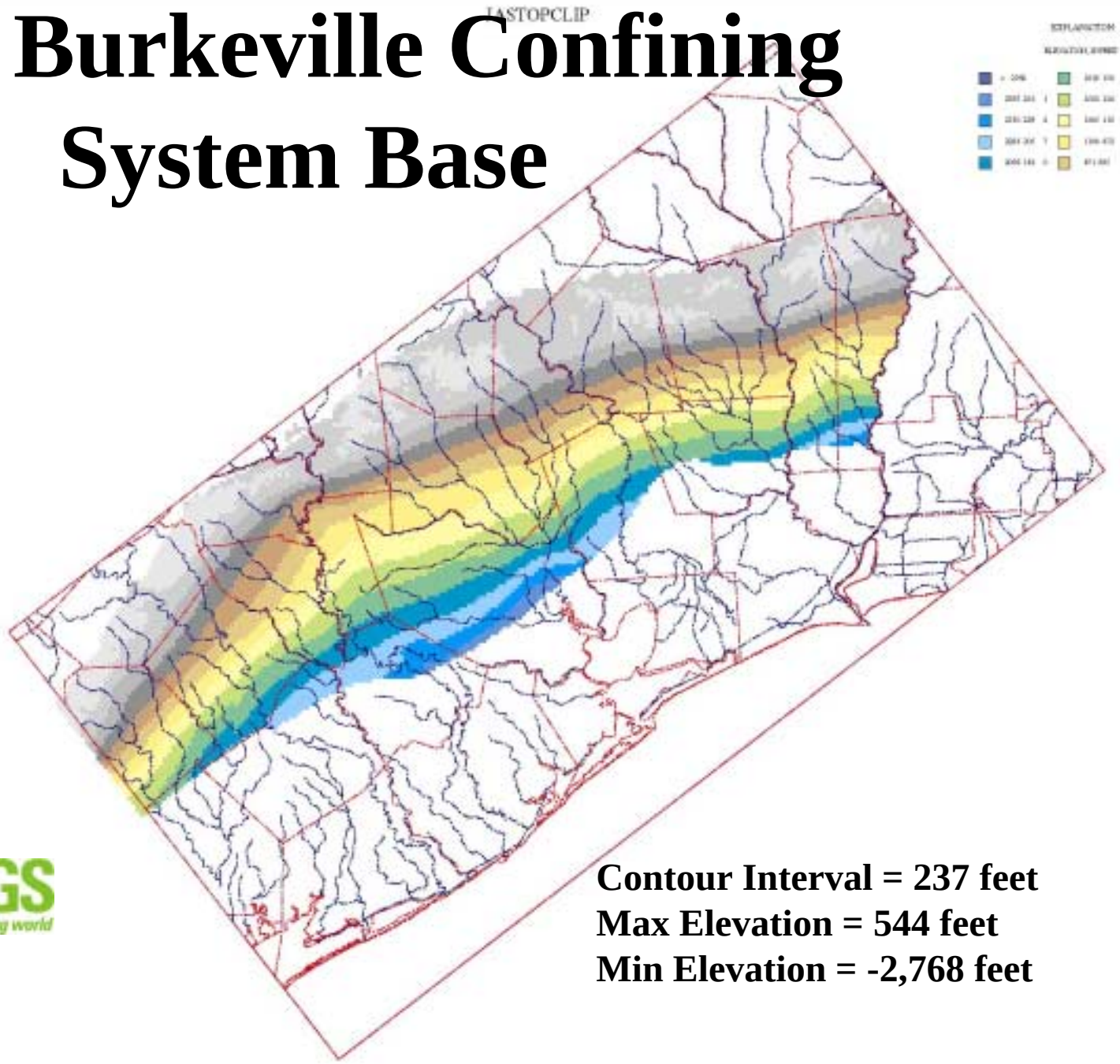
GAM Burkeville Confining System Base



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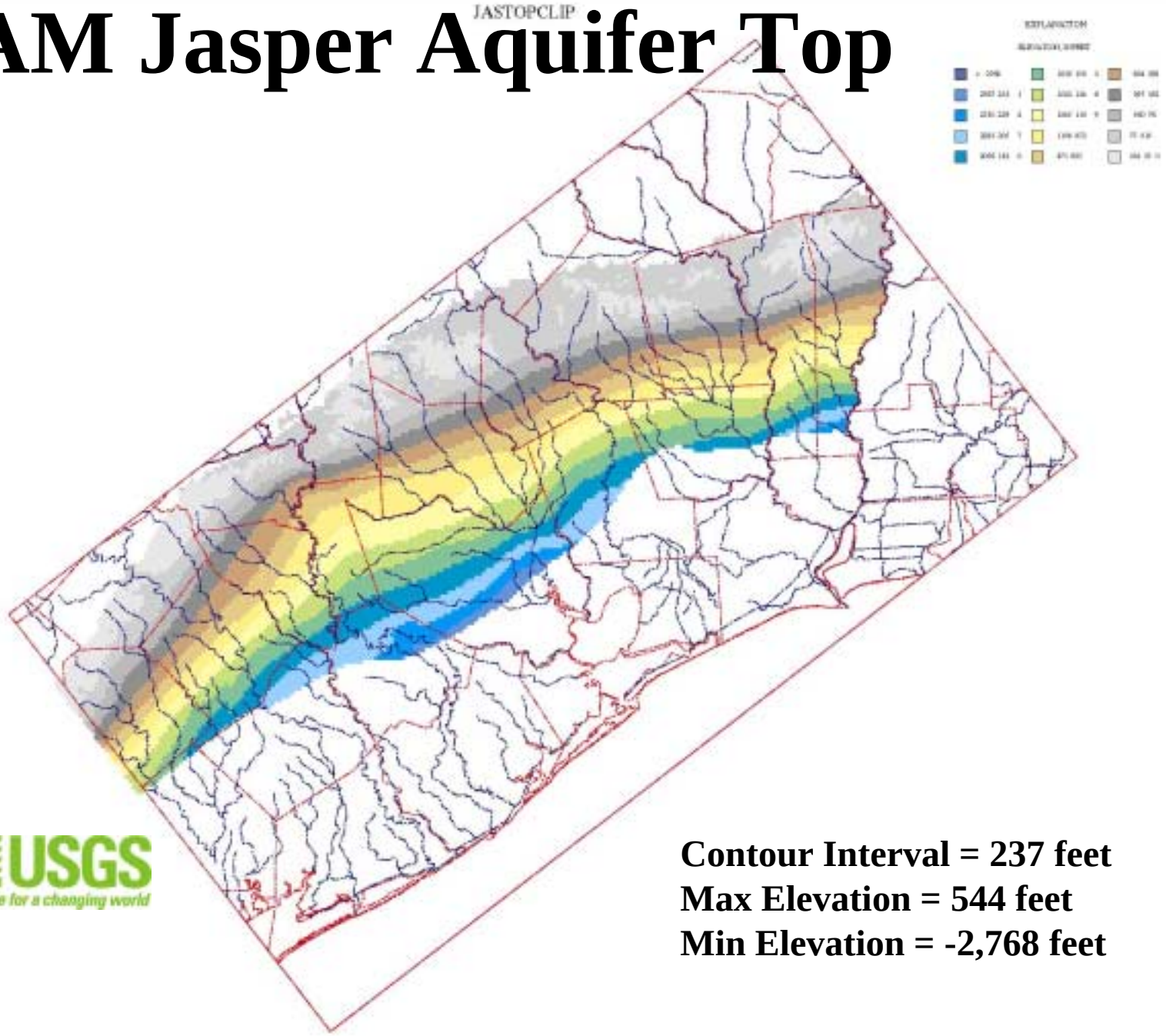
Contour Interval = 237 feet
Max Elevation = 544 feet
Min Elevation = -2,768 feet

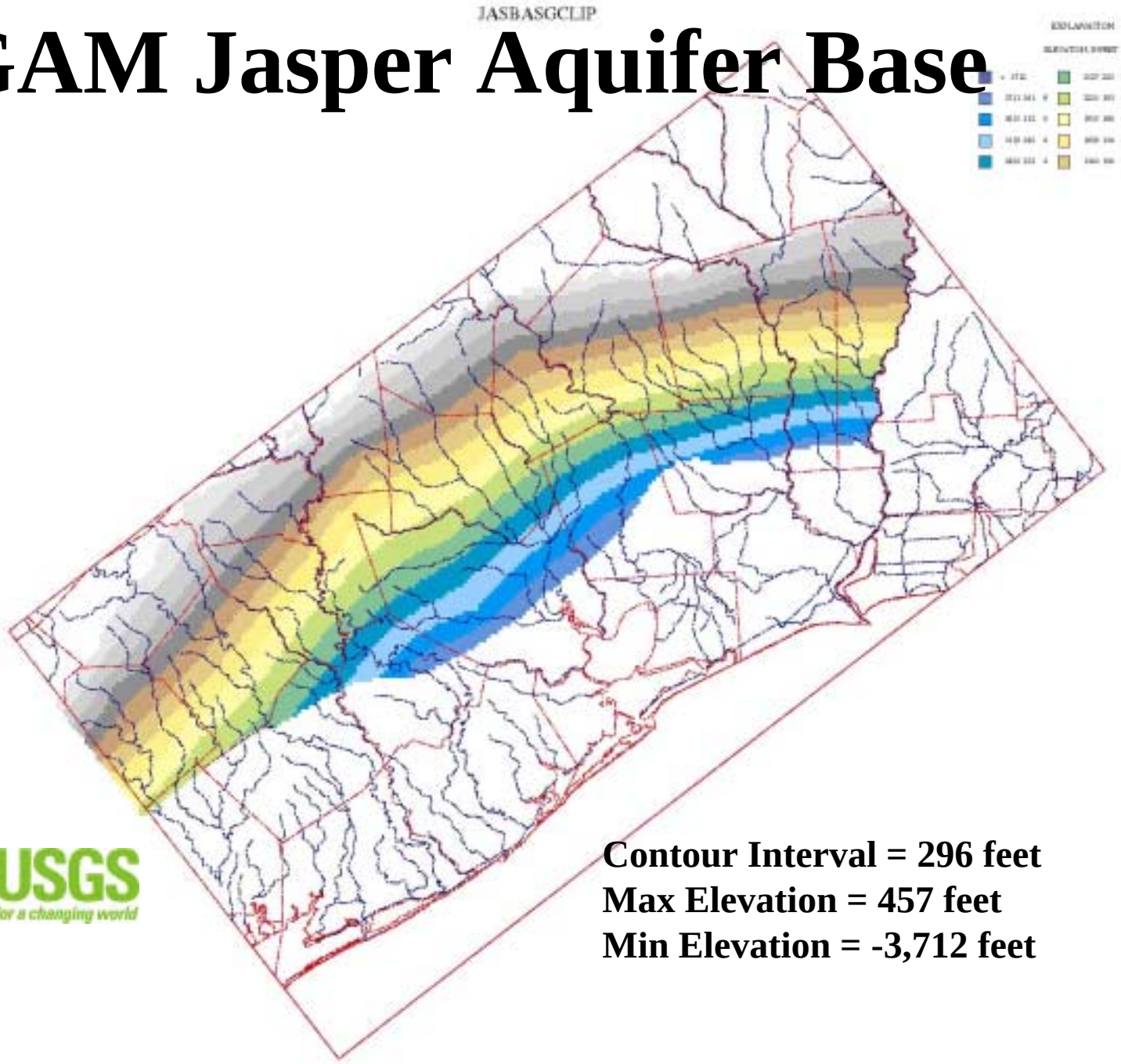
GAM Jasper Aquifer Top



USGS
science for a changing world

Contour Interval = 237 feet
Max Elevation = 544 feet
Min Elevation = -2,768 feet

GAM Jasper Aquifer Base



USGS
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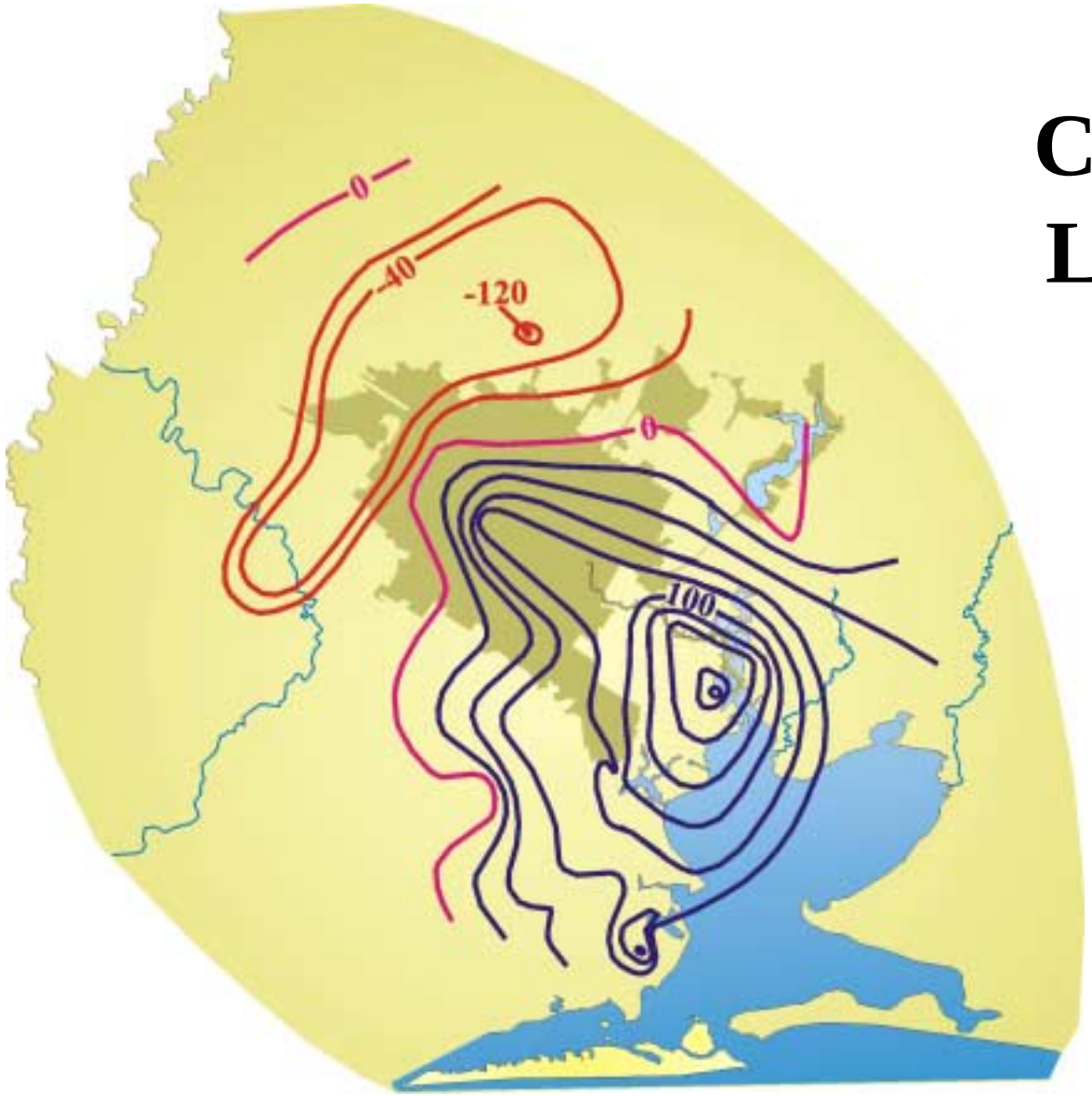
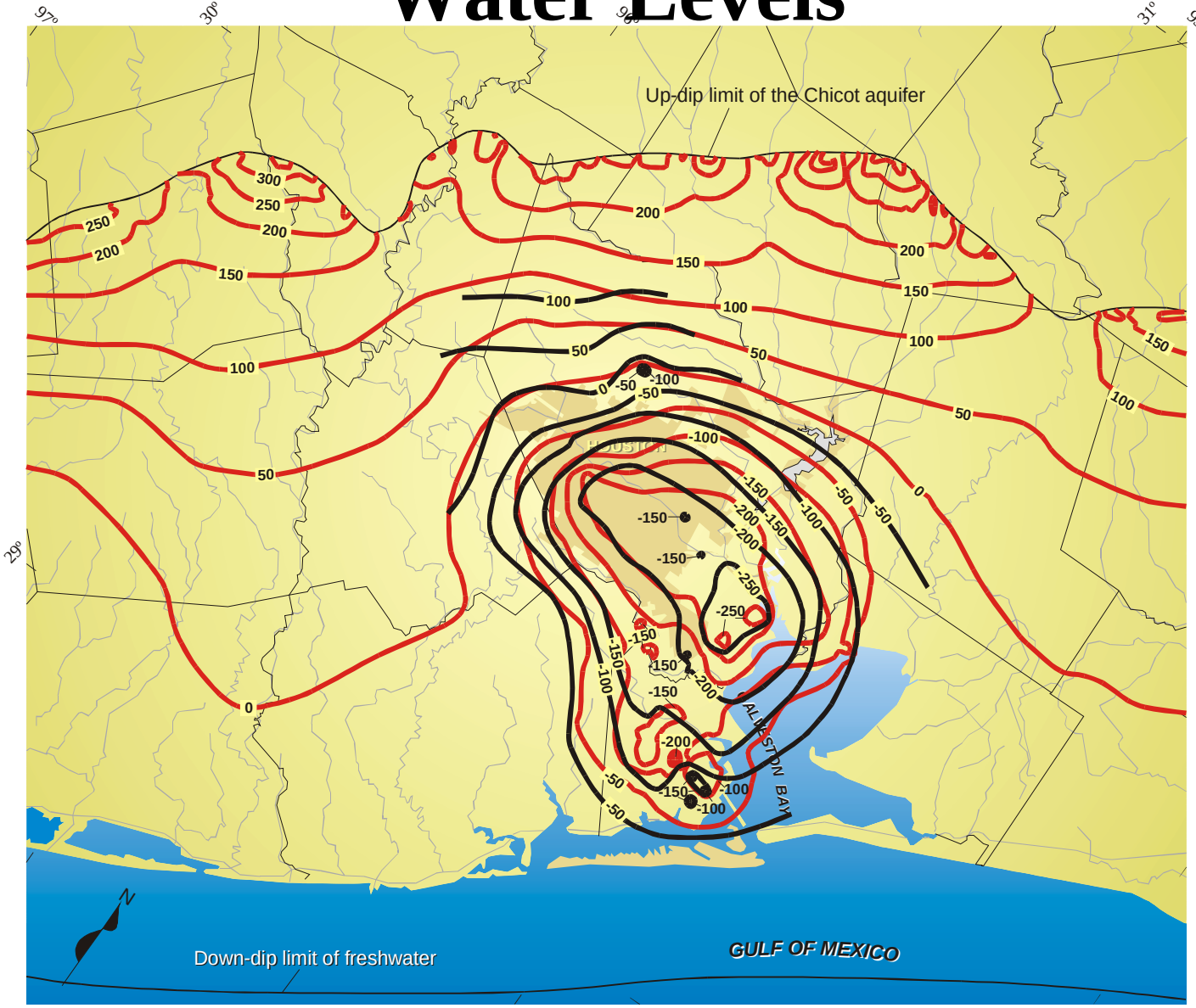
Contour Interval = 296 feet
Max Elevation = 457 feet
Min Elevation = -3,712 feet



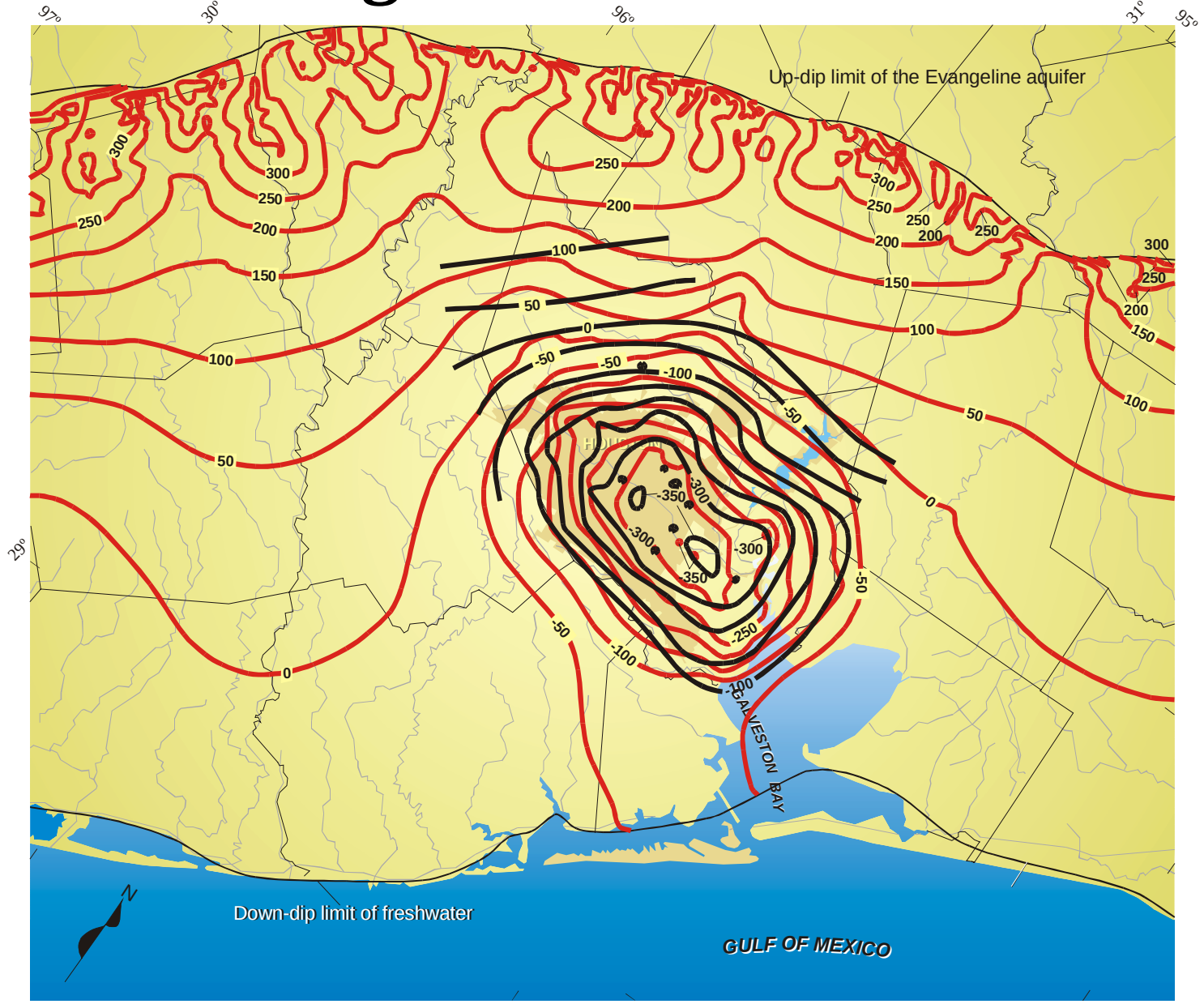
Chicot Water-Level Change Map

1977-1999

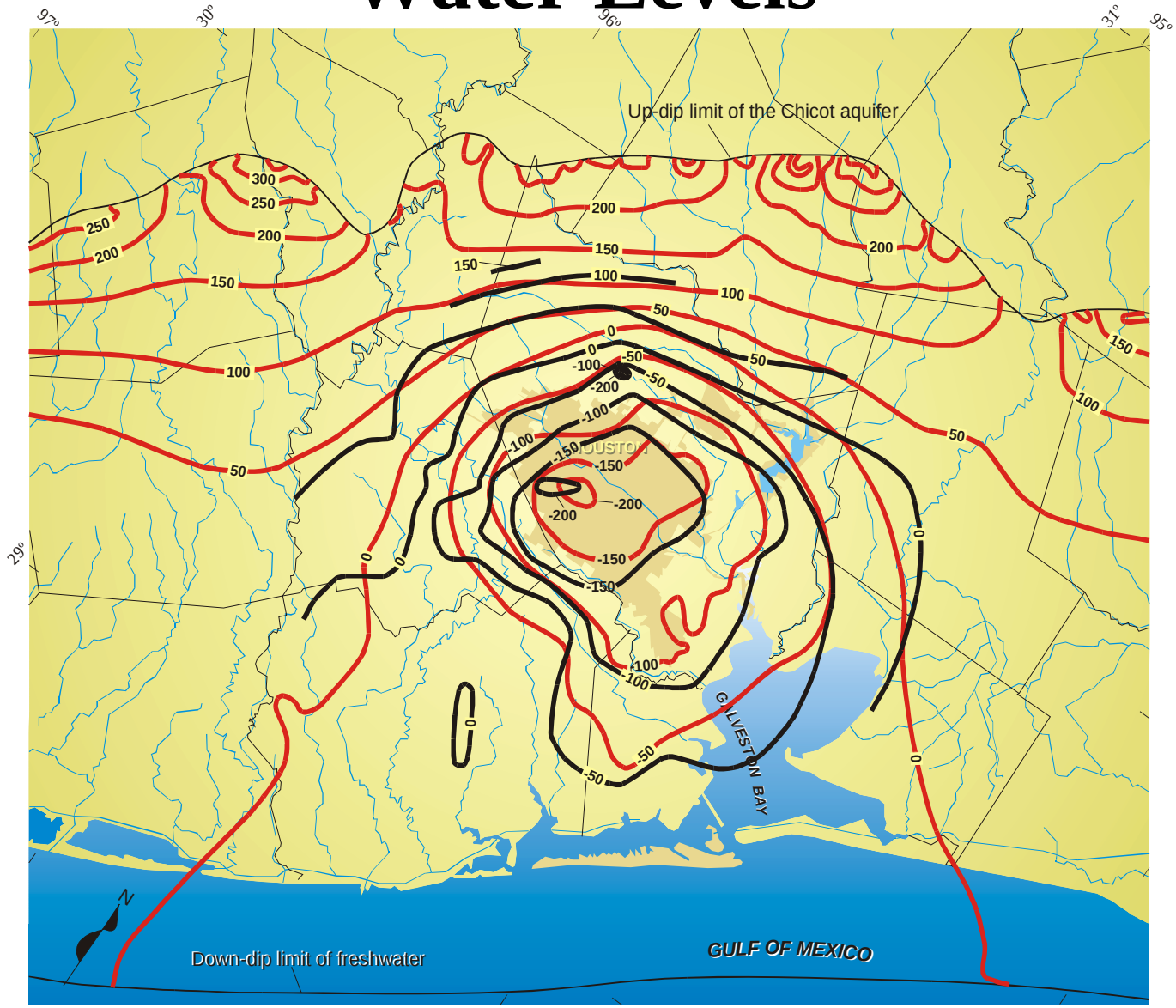
1977 Measured and Simulated Chicot Water Levels



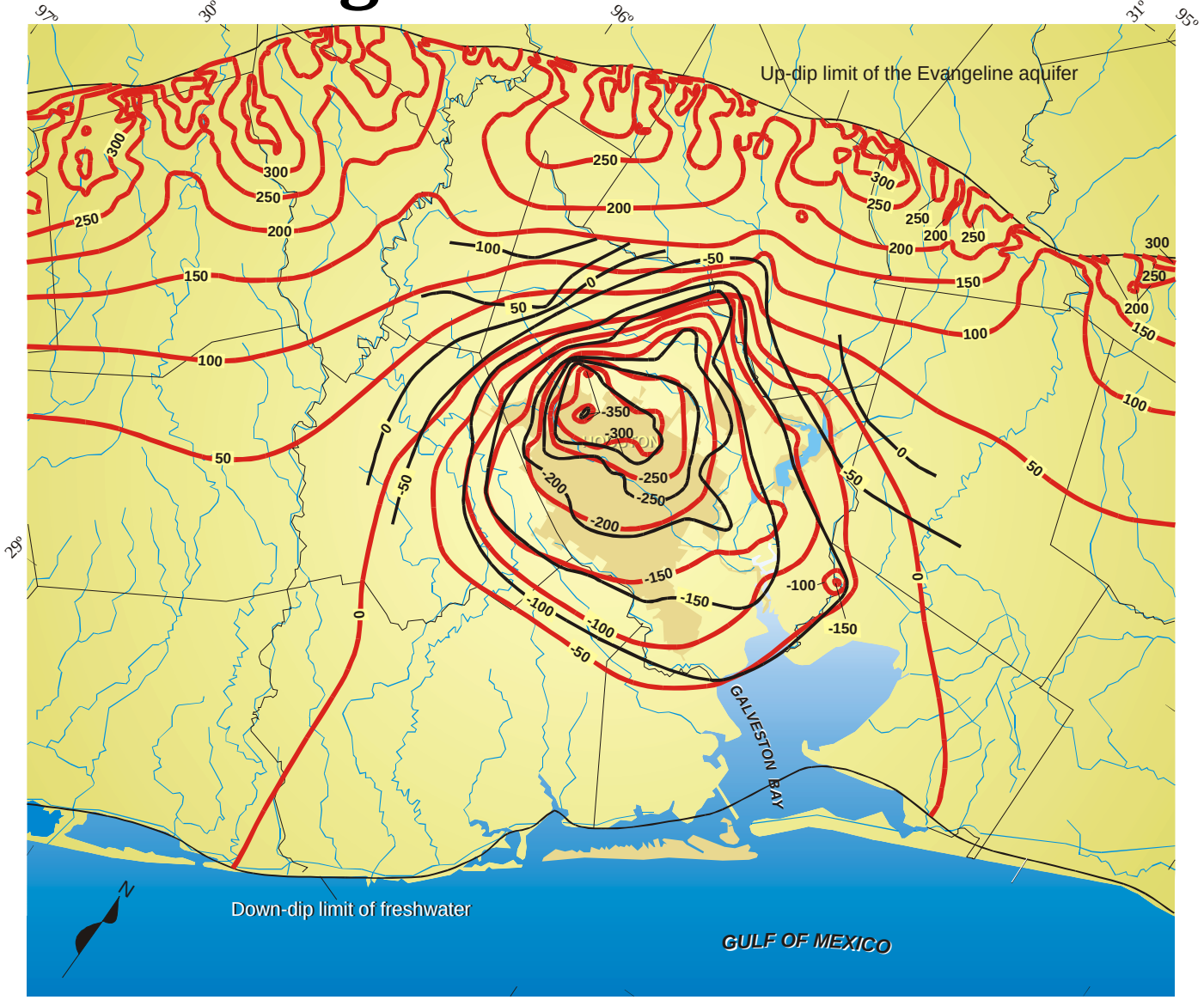
1977 Measured and Simulated Evangeline Water Levels



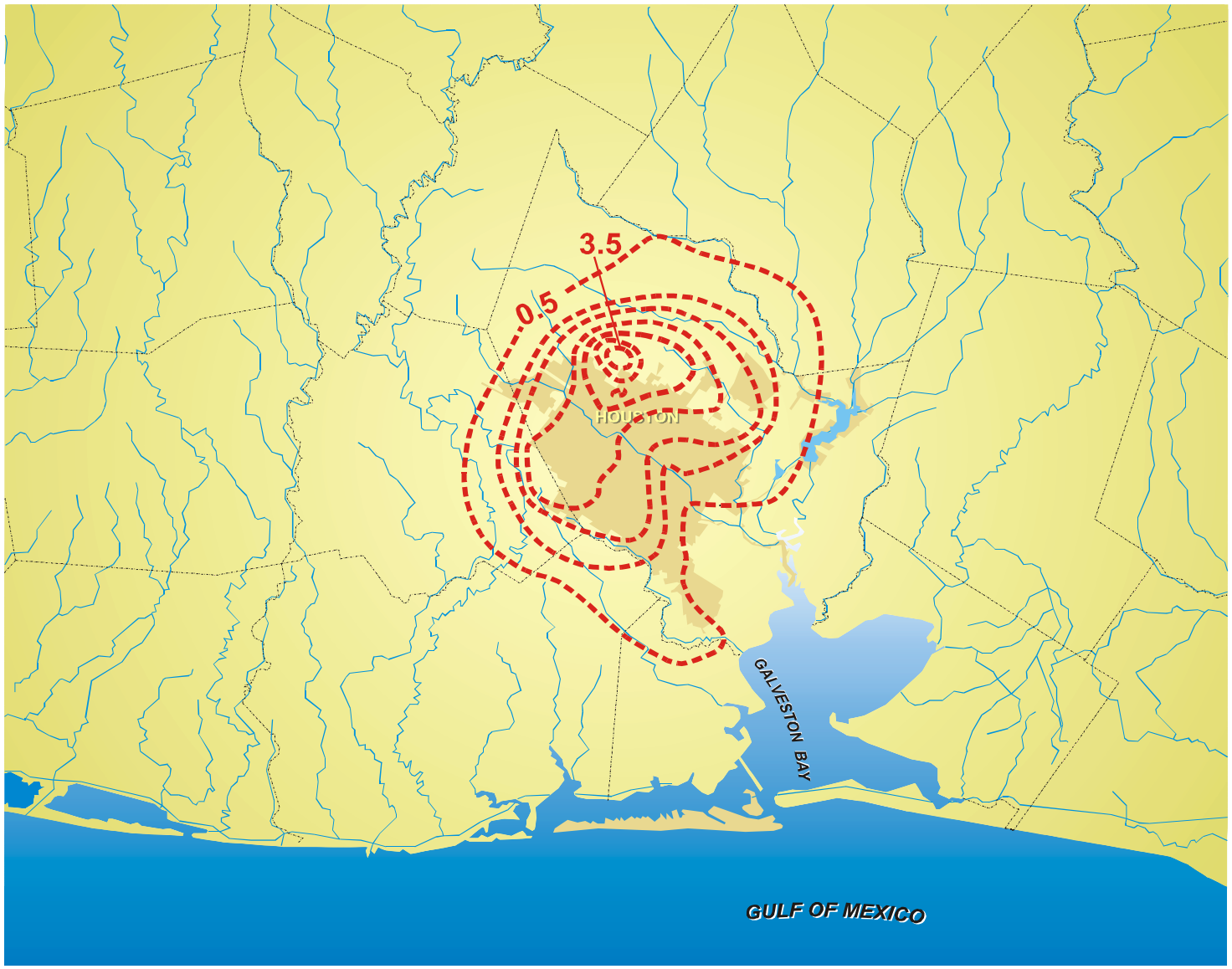
1996 Measured and Simulated Chicot Water Levels



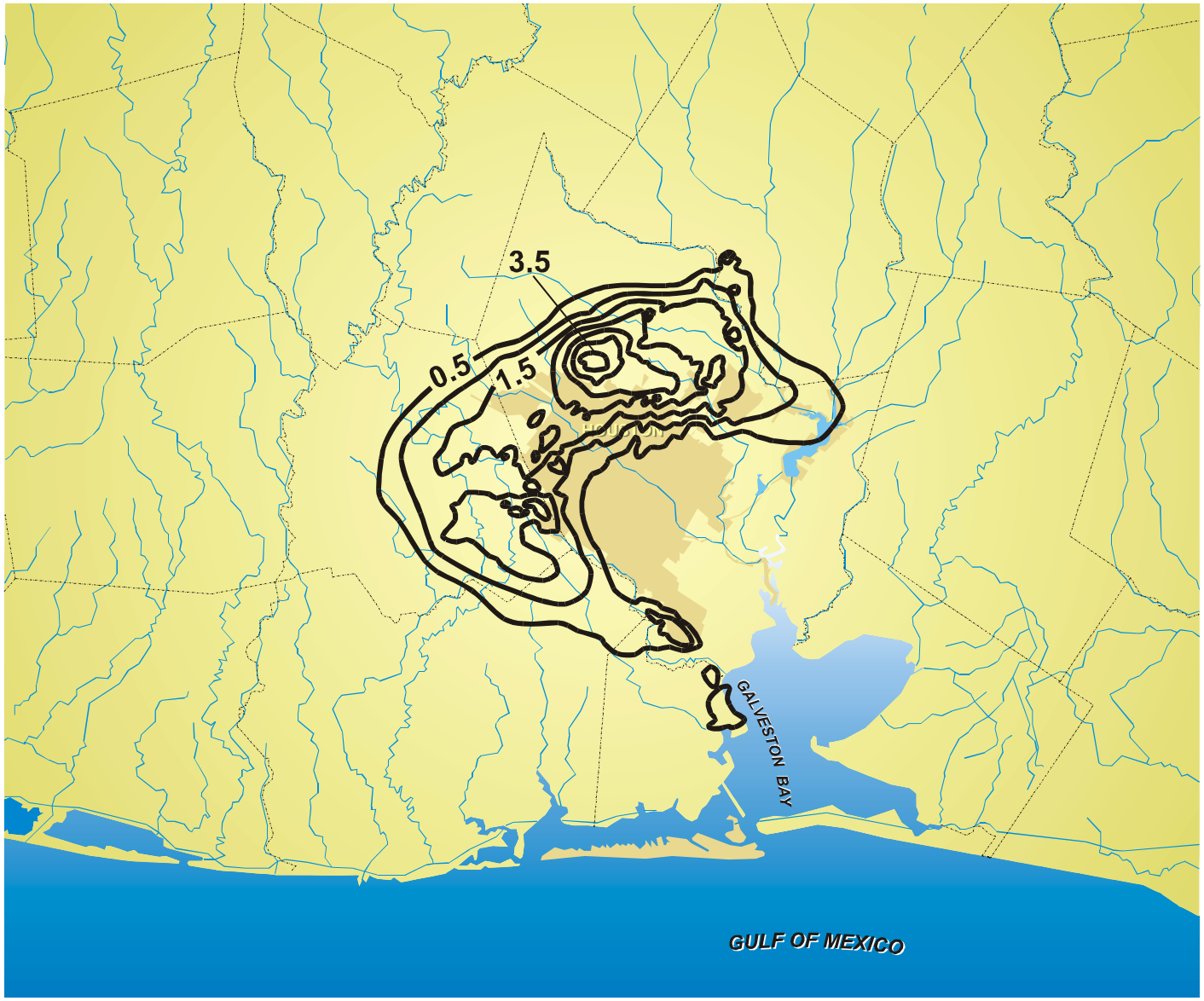
1996 Measured and Simulated Evangeline Water Levels



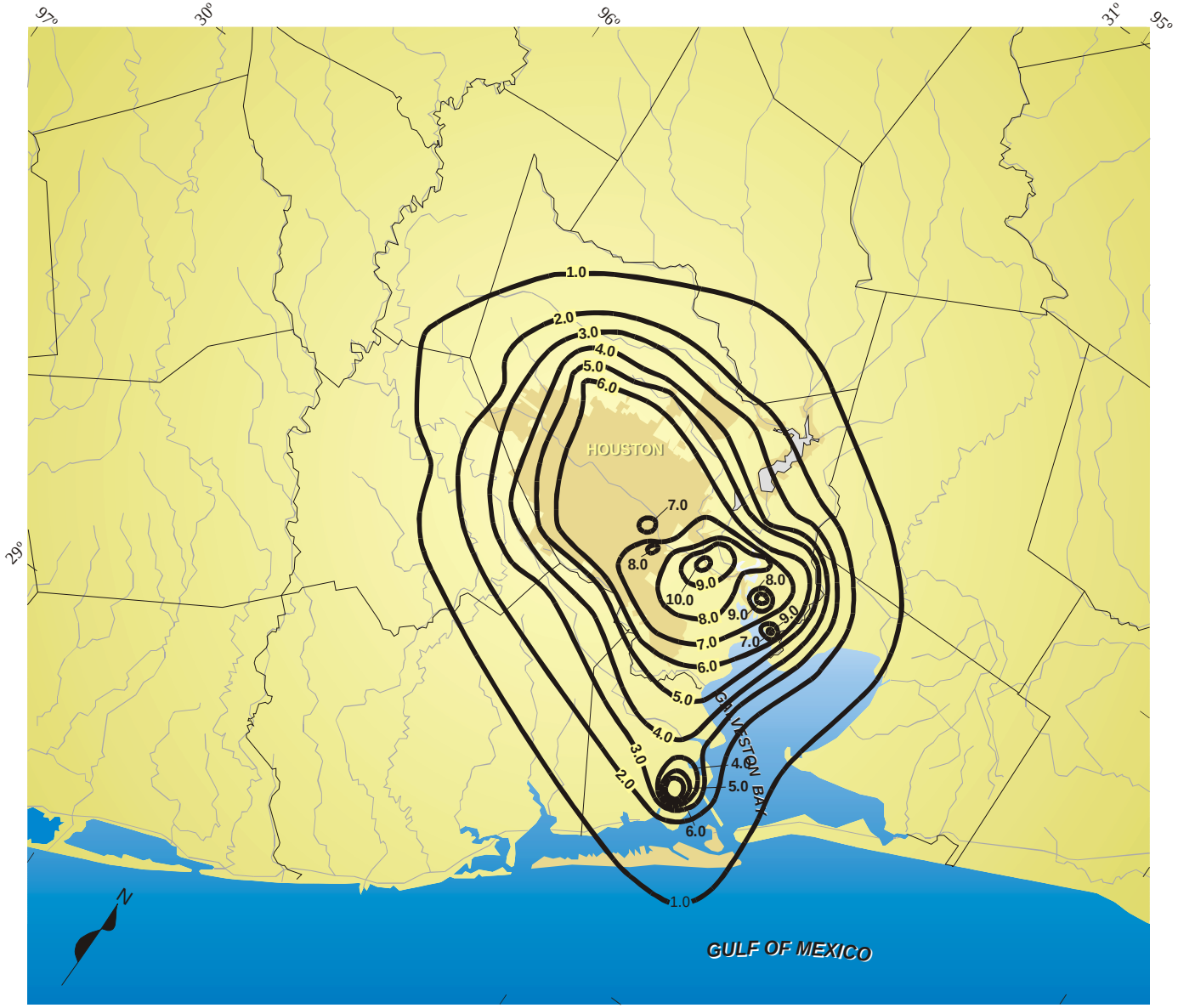
1978-1995 Measured Land-Surface Subsidence



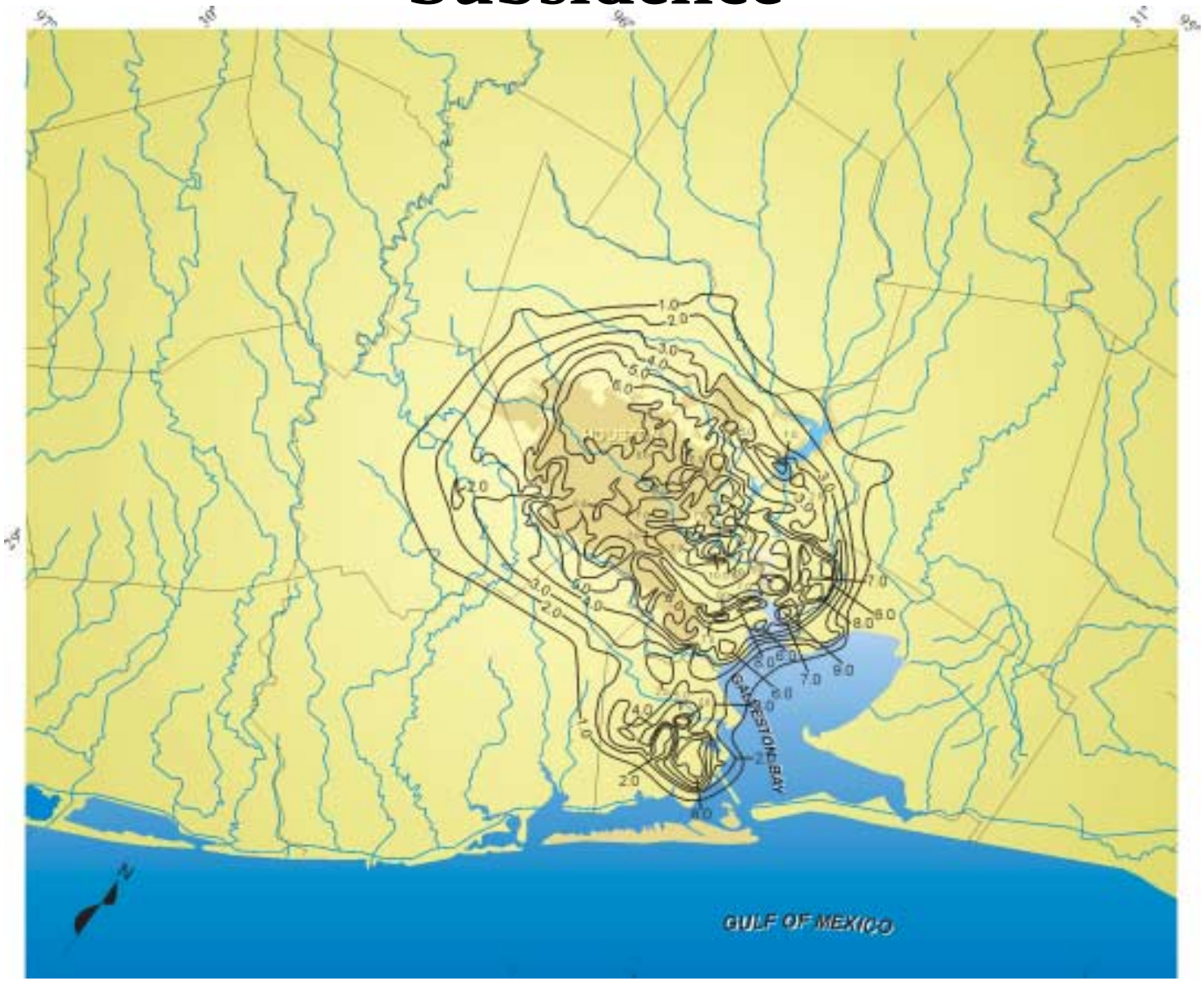
1978-1995 Simulated Land-Surface Subsidence



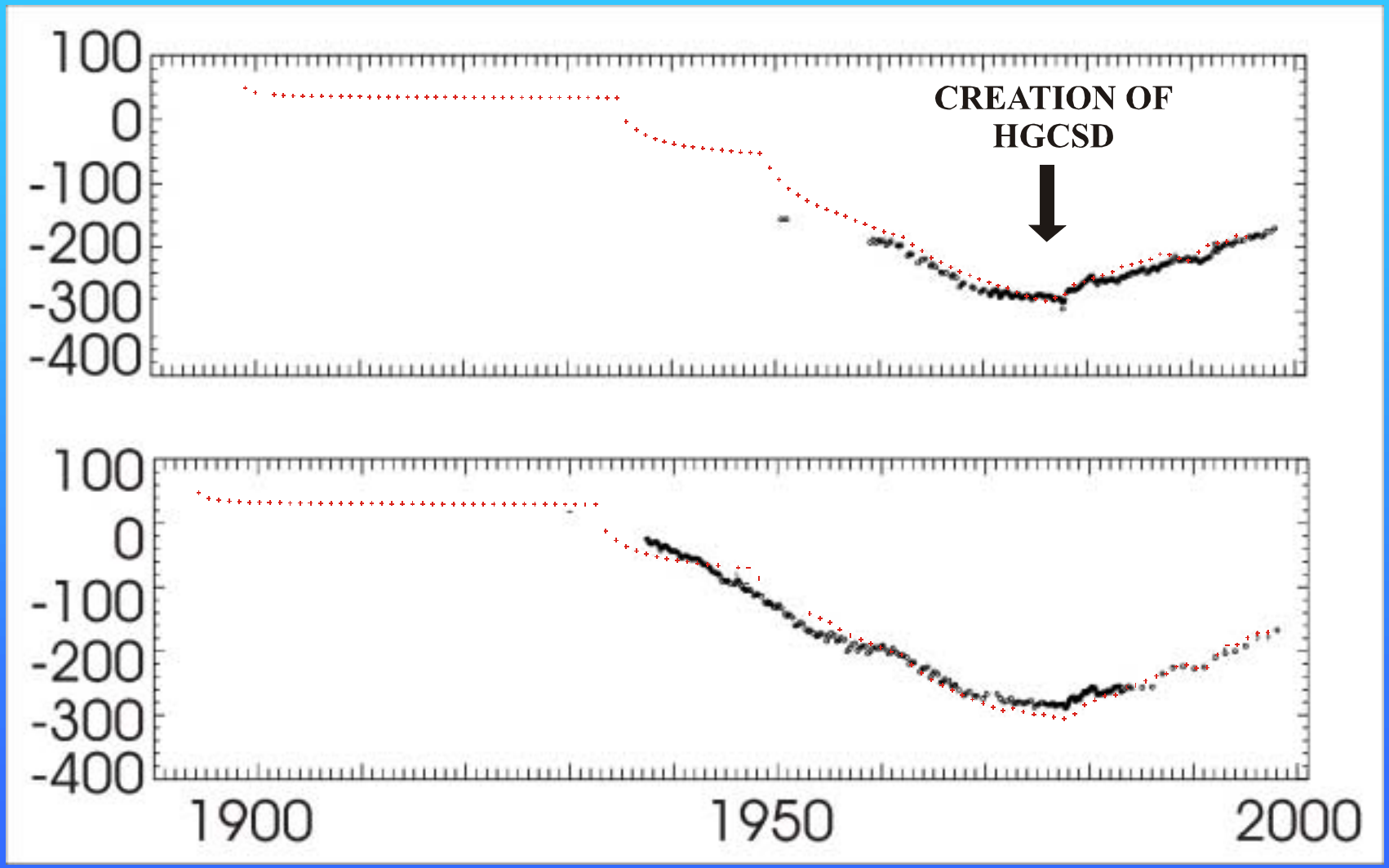
1906-1995 Measured Land-Surface Subsidence



1891-1995 Simulated Land-Surface Subsidence



Long-Term Water-Level Trends



Hydrographs from Wells Screened in the Evangeline Aquifer Used for Model Calibration

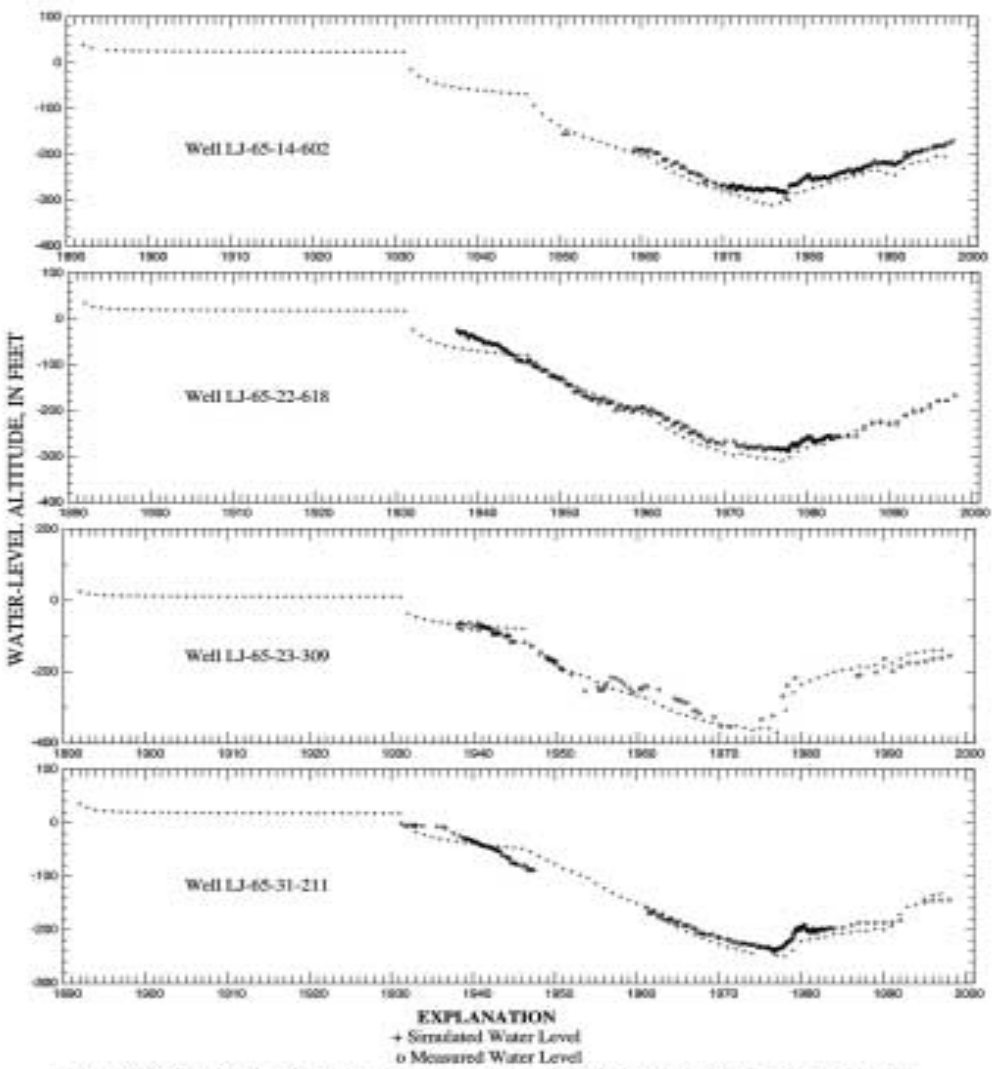


Figure 23. Simulated and measured water levels in selected observation wells screened in the Evangeline aquifer in Harris County.

Hydrographs from Wells Screened in the Chicot and Jasper Aquifer

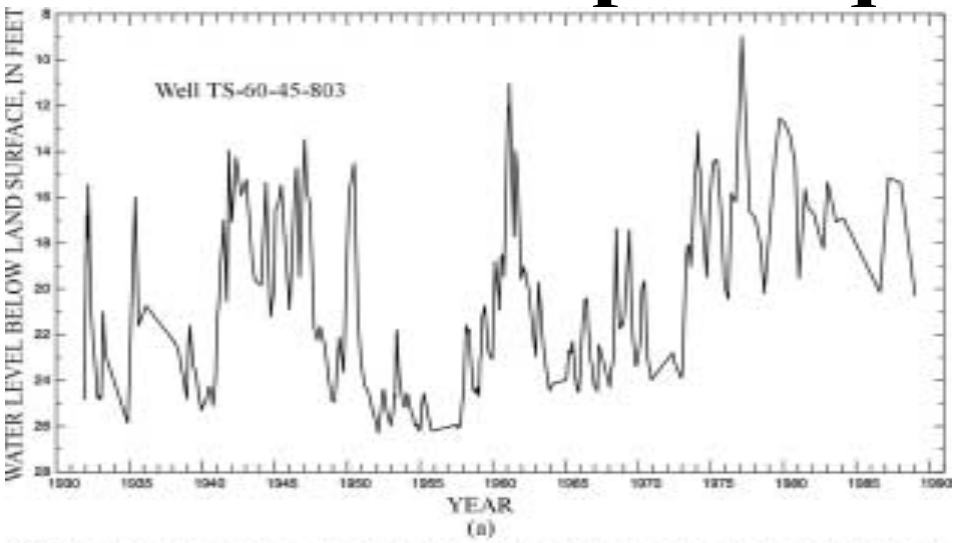


Figure 13. Hydrographs of wells screened in the outcrops of the Chicot aquifer (a) and Jasper aquifer (b) in Montgomery County.

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Pre-Development Water-Budget-Flow Rates

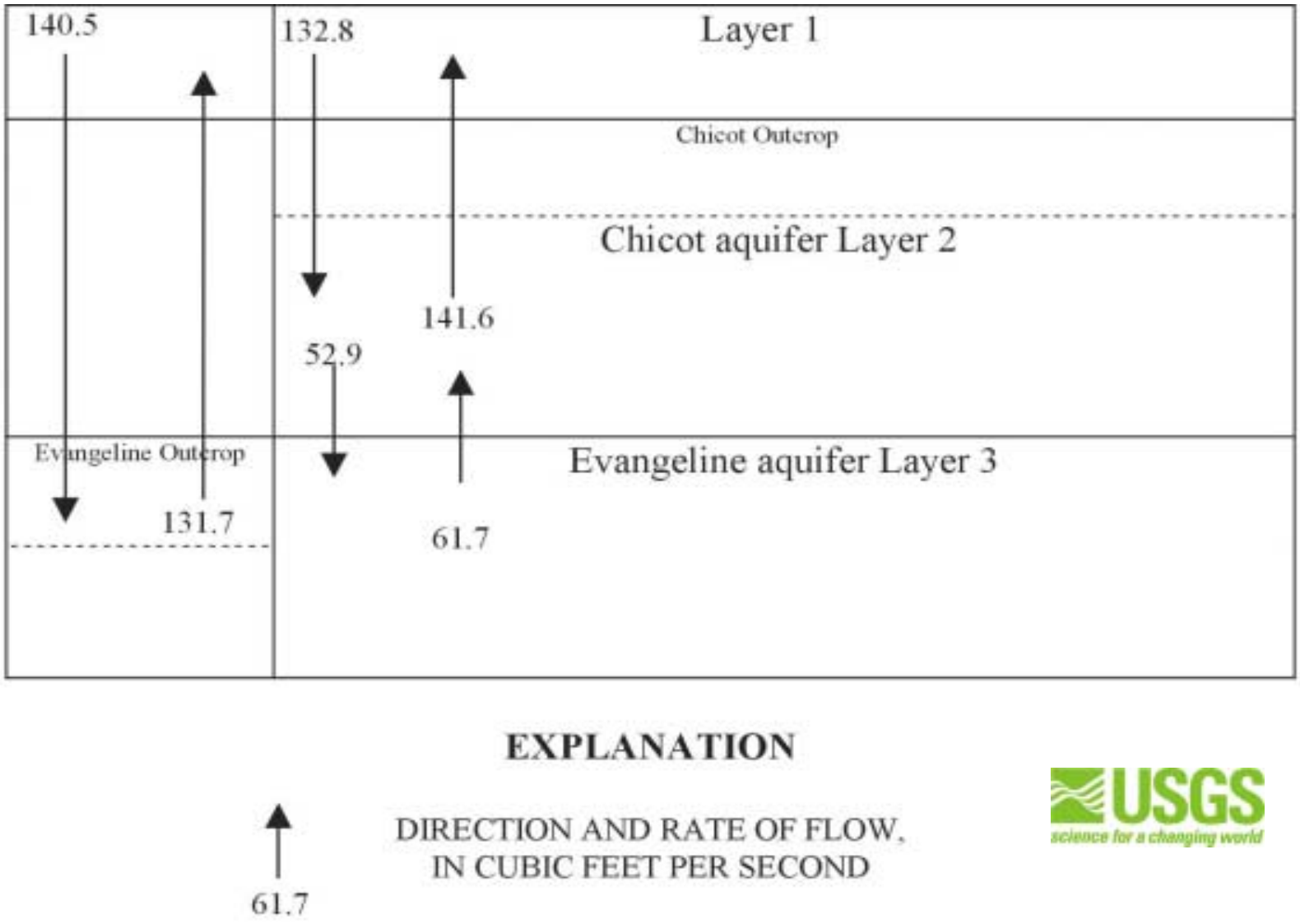


Figure 32. Simulated pre-development water-budget-flow rates for layers 1, 2, and 3.

1996 Water-Budget-Flow Rates

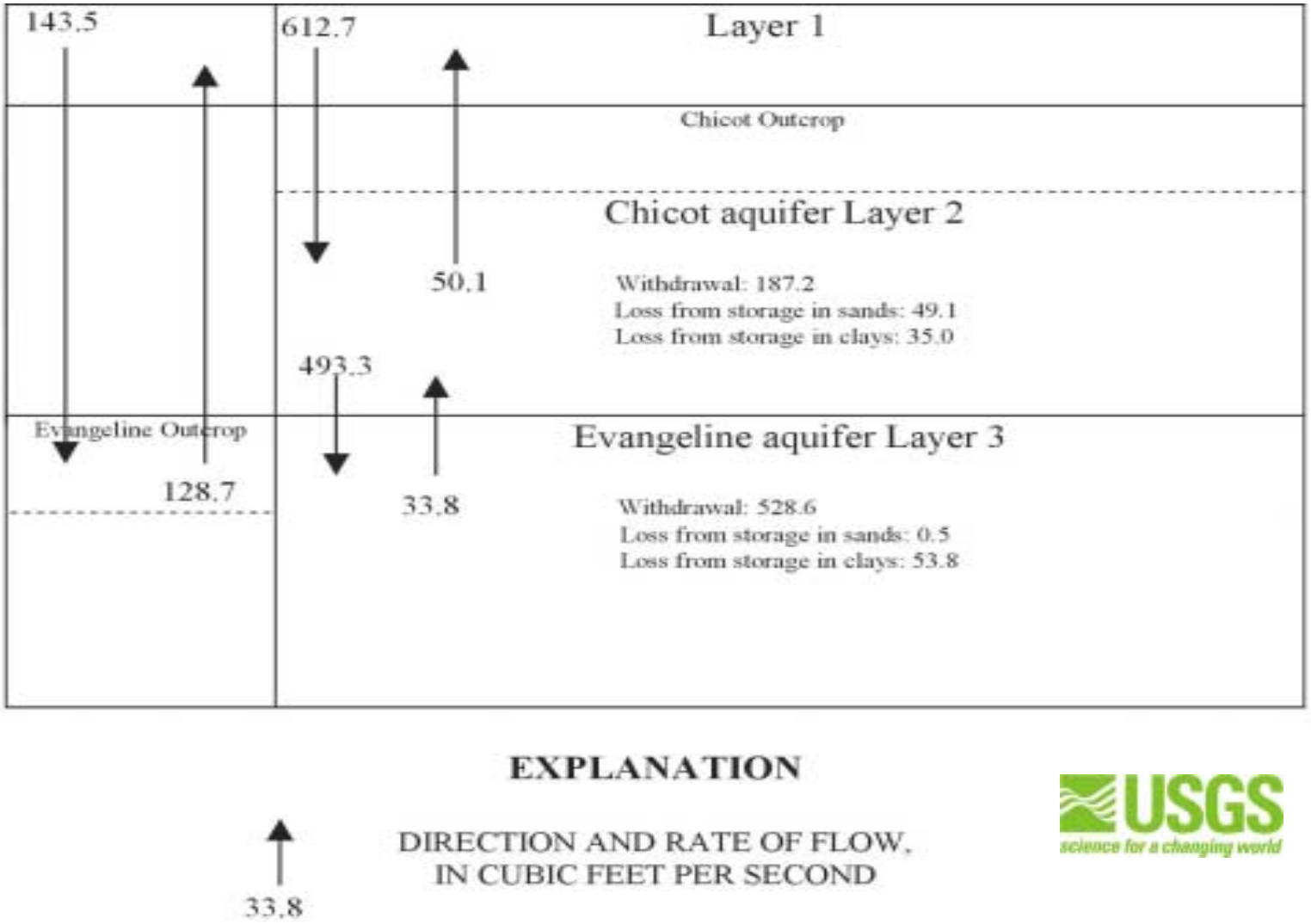


Figure 29. Simulated 1996 water-budget-flow rates for layers 1, 2, and 3.

Model Sensitivity to Changes in Aquifer Parameters

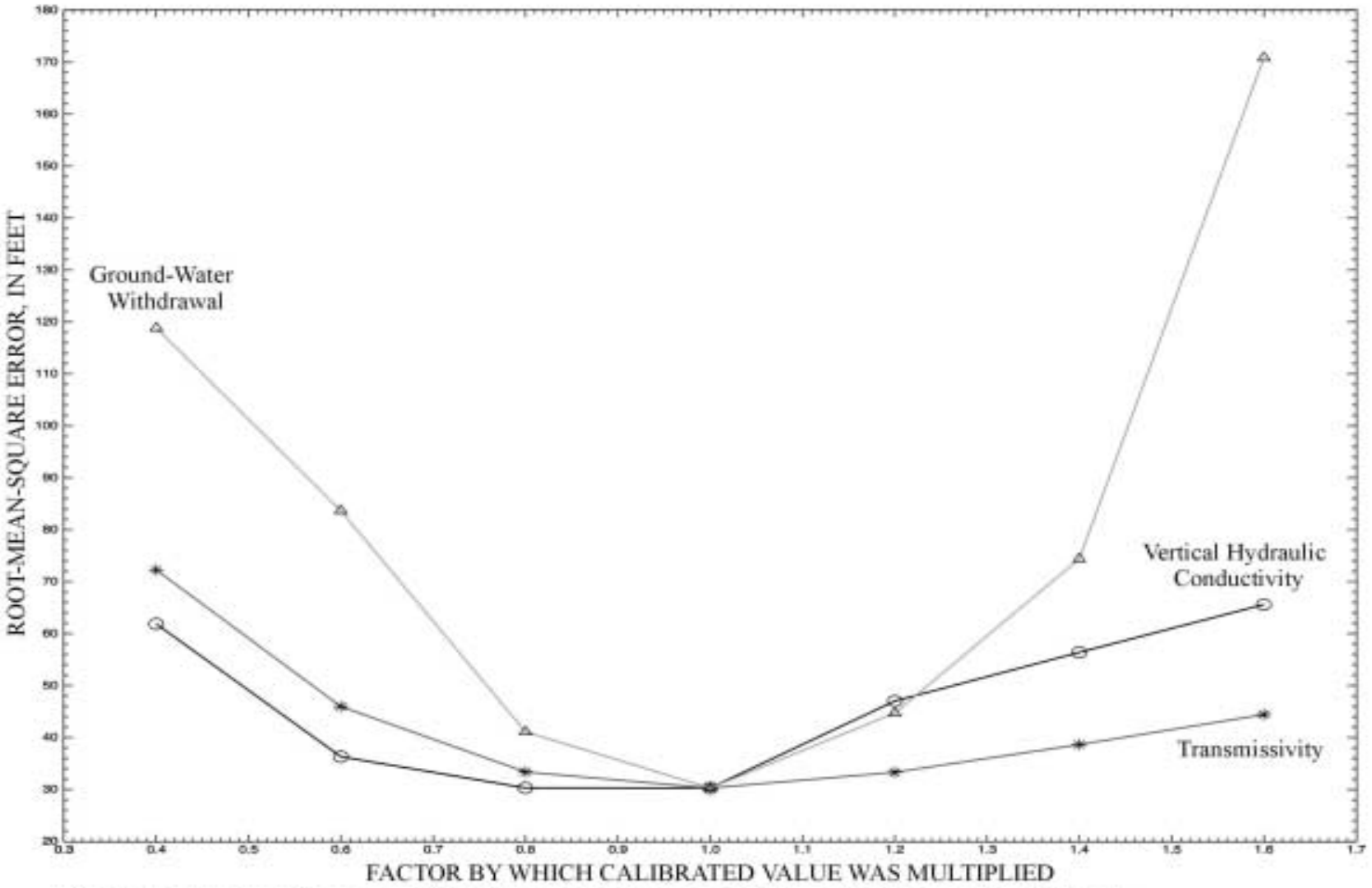


Figure 41. Sensitivity of the model of the Chicot and Evangeline aquifers to changes in aquifer parameters.

Model Sensitivity to Changes in Clay and Sand Storage Parameters

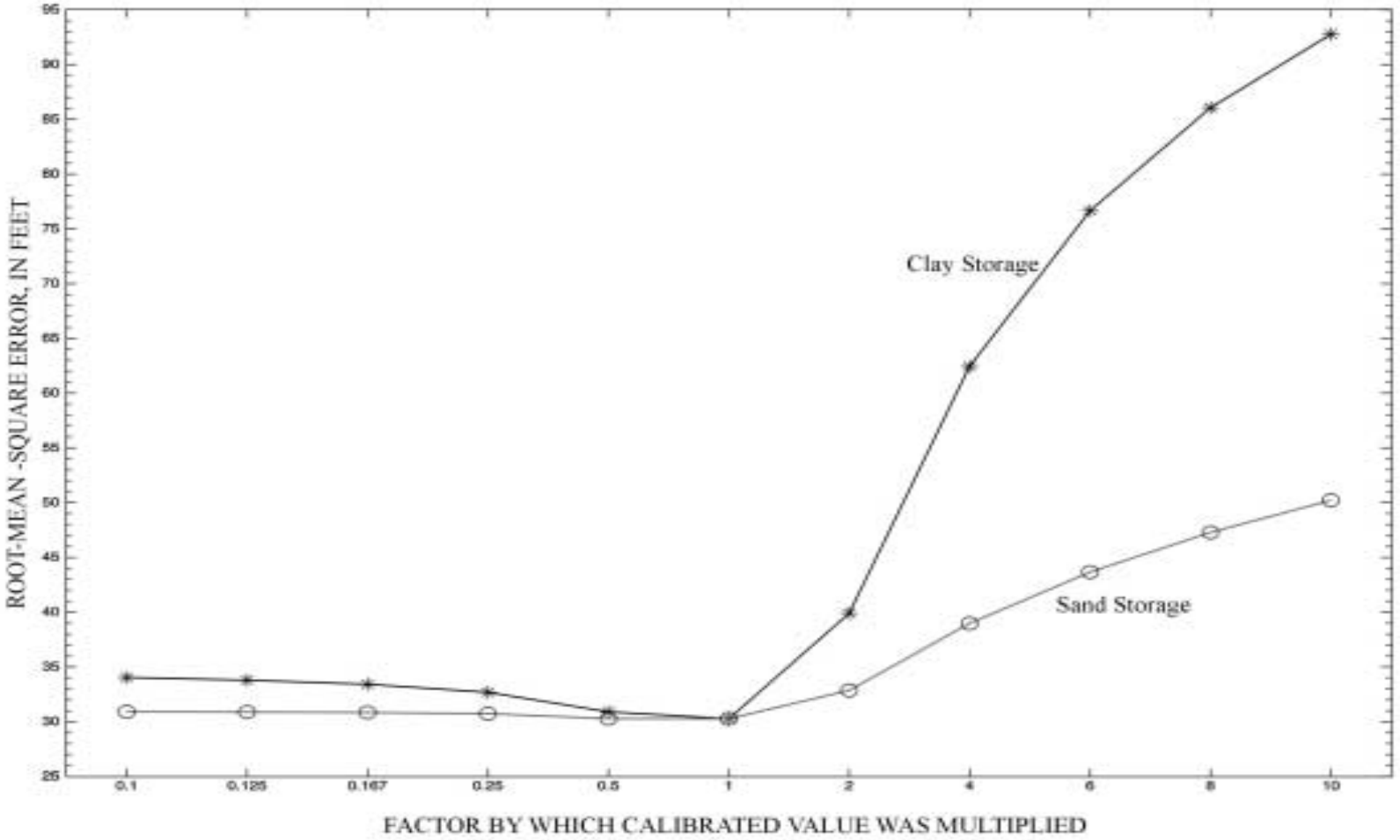


Figure 42. Sensitivity of the model of the Chicot and Evangeline aquifers to changes in clay and sand storage parameters.

Extensometer Sites in Harris and Galveston Counties

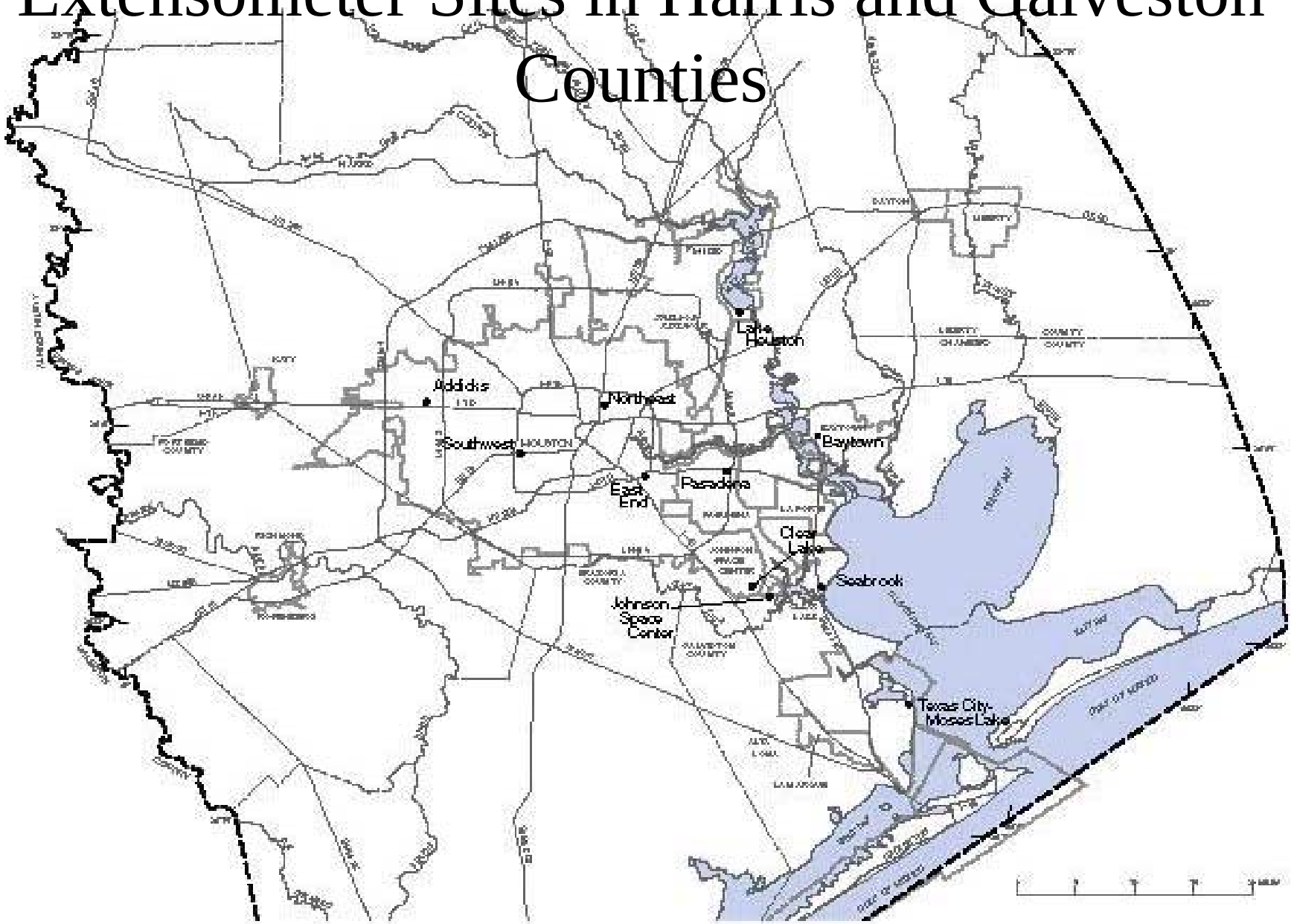


Figure 7. Map showing location of extensometer sites, Houston-Galveston Region, Texas.

Exhibit 19

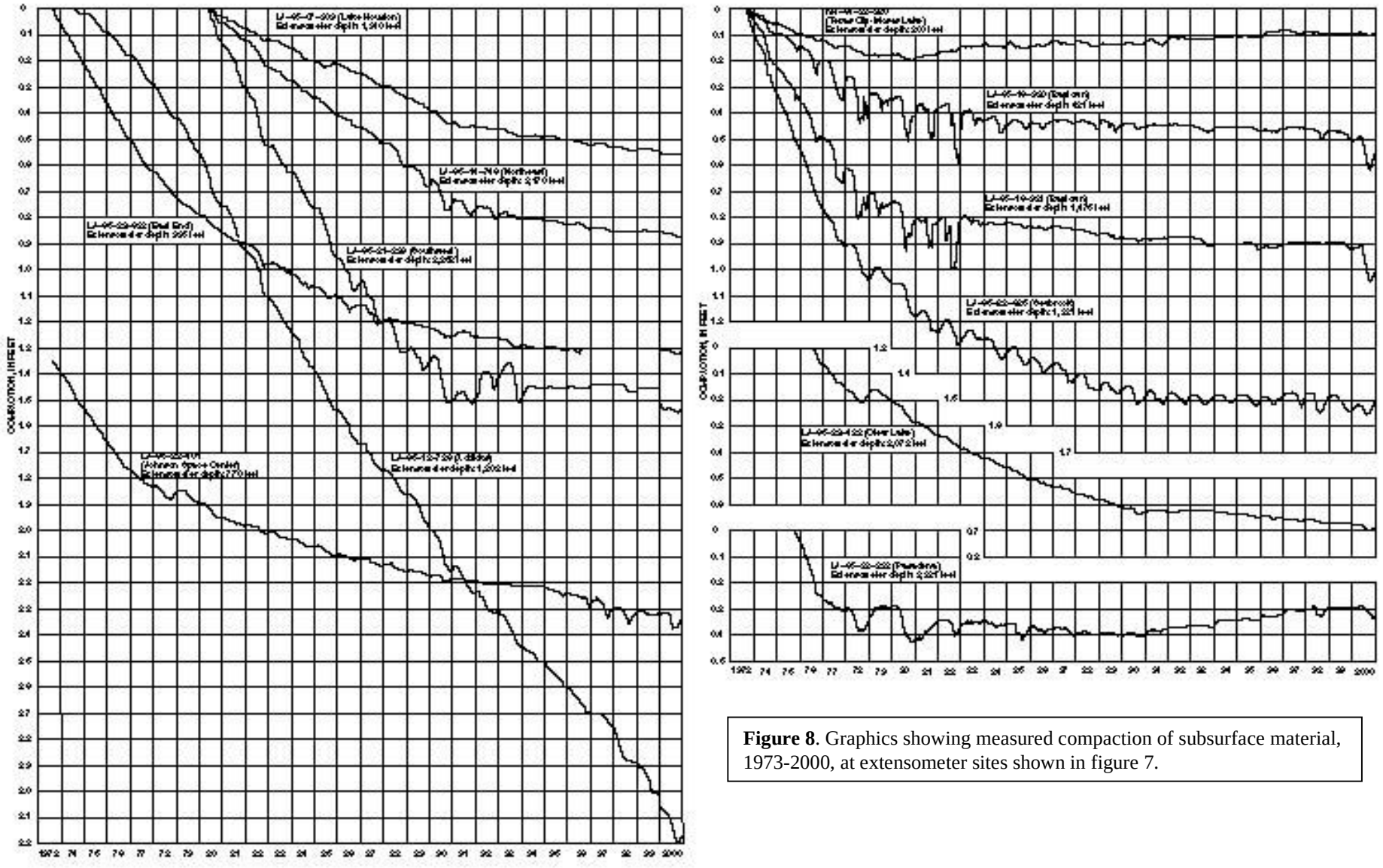
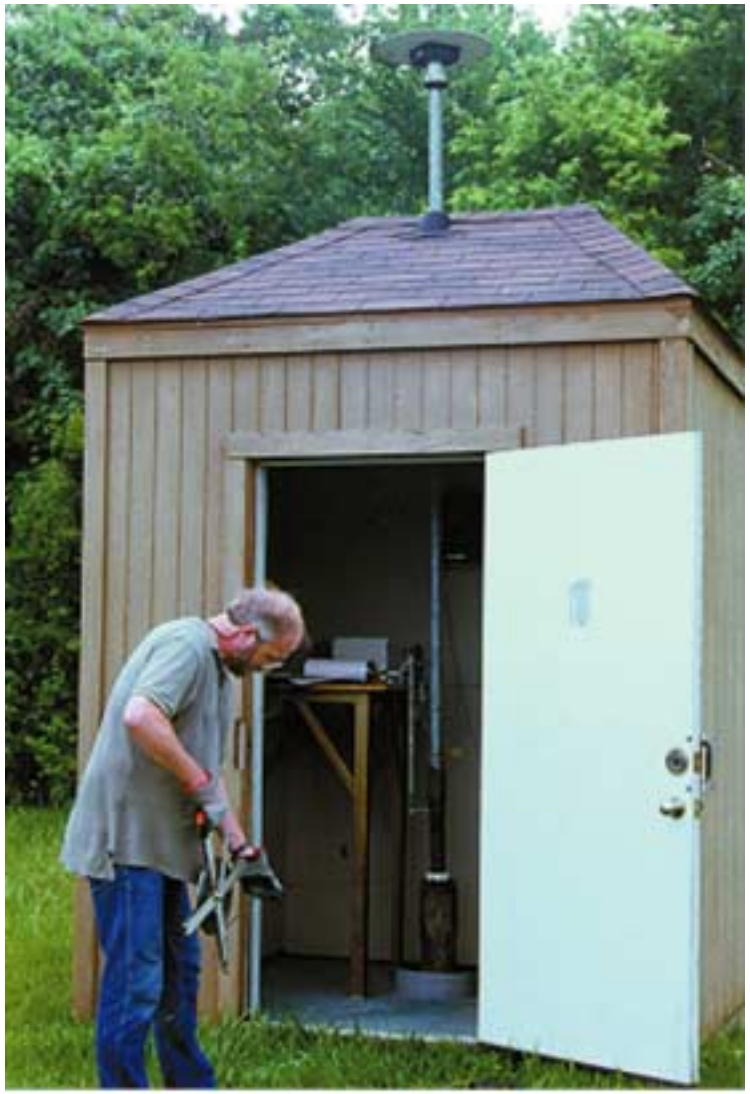
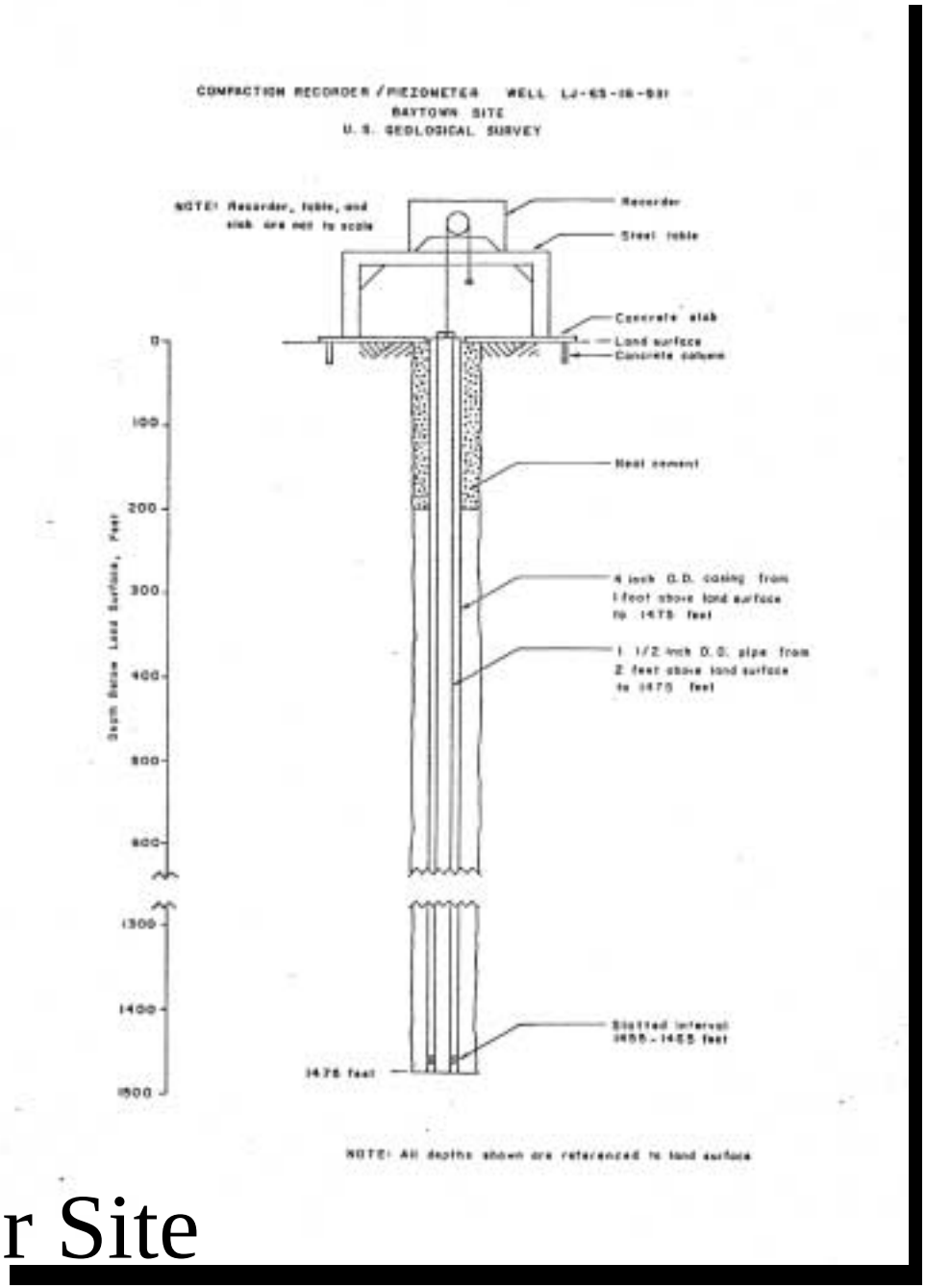


Figure 8. Graphics showing measured compaction of subsurface material, 1973-2000, at extensometer sites shown in figure 7.

2000 Line Graph Data from Extensometer Sites

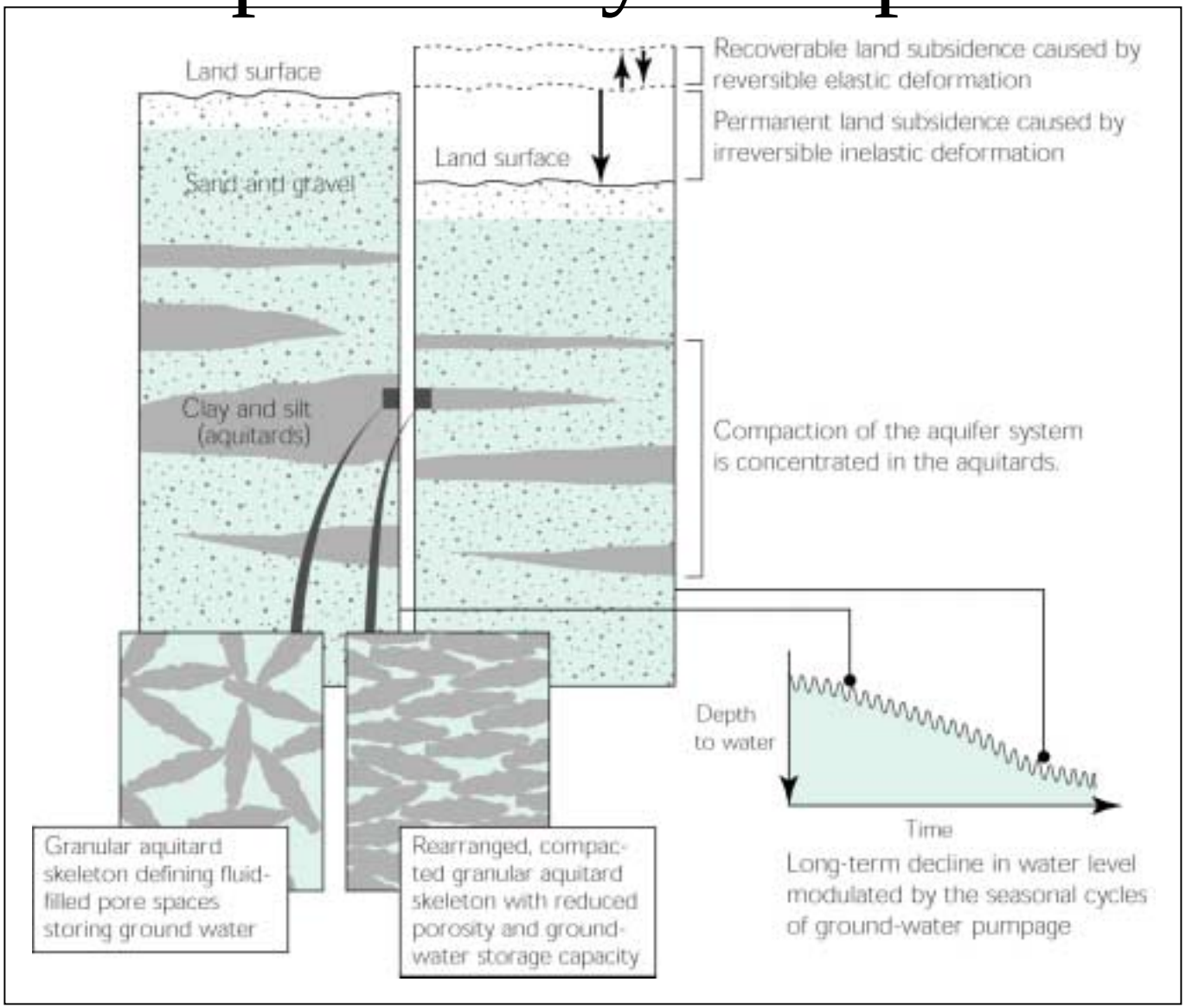
Exhibit 20





Typical Extensometer Site

Conceptual Clay Compaction



2001 Water-Level Altitude in the Chicot Aquifer

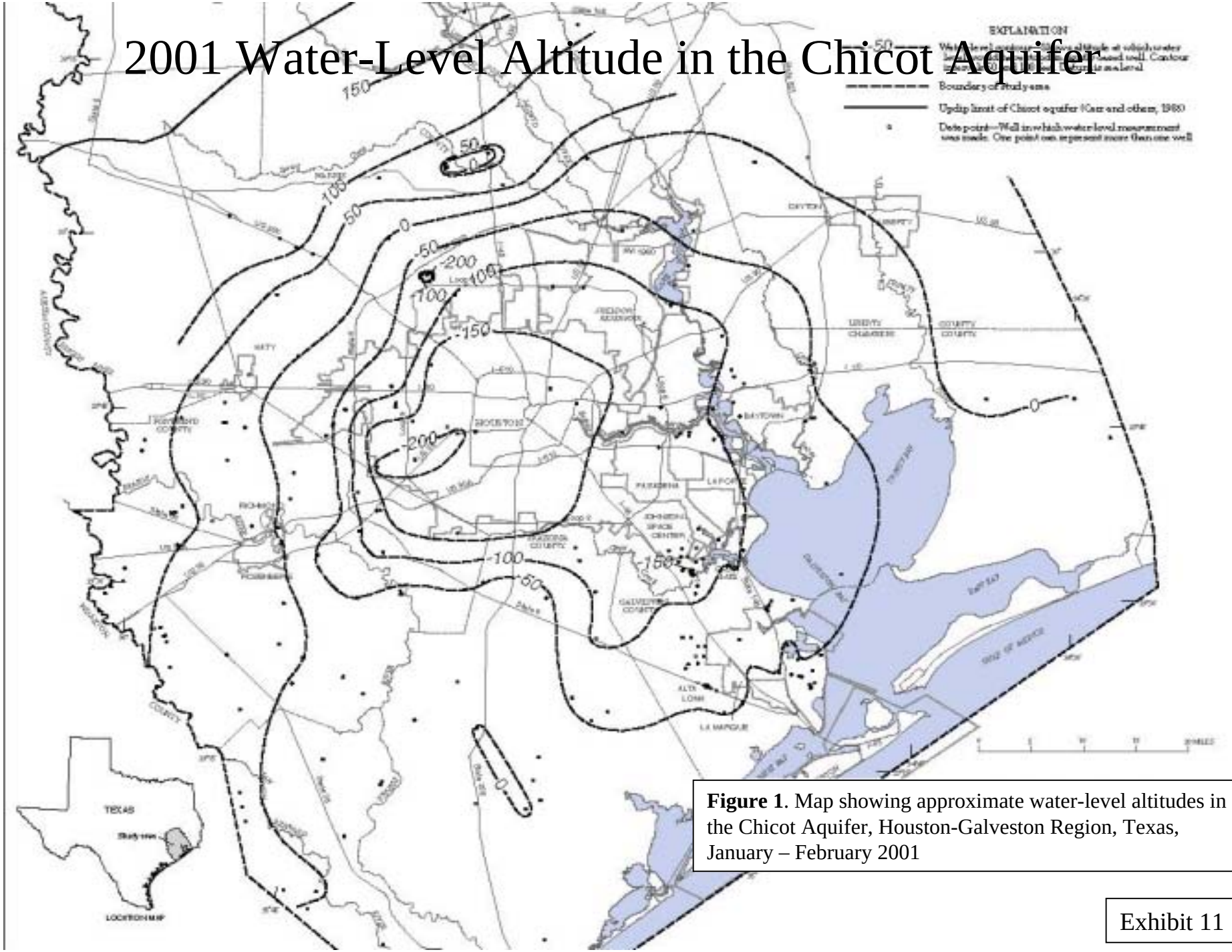


Figure 1. Map showing approximate water-level altitudes in the Chicot Aquifer, Houston-Galveston Region, Texas, January – February 2001

Exhibit 11

1977-2001Water-Level Change Map in the Chicot Aquifer

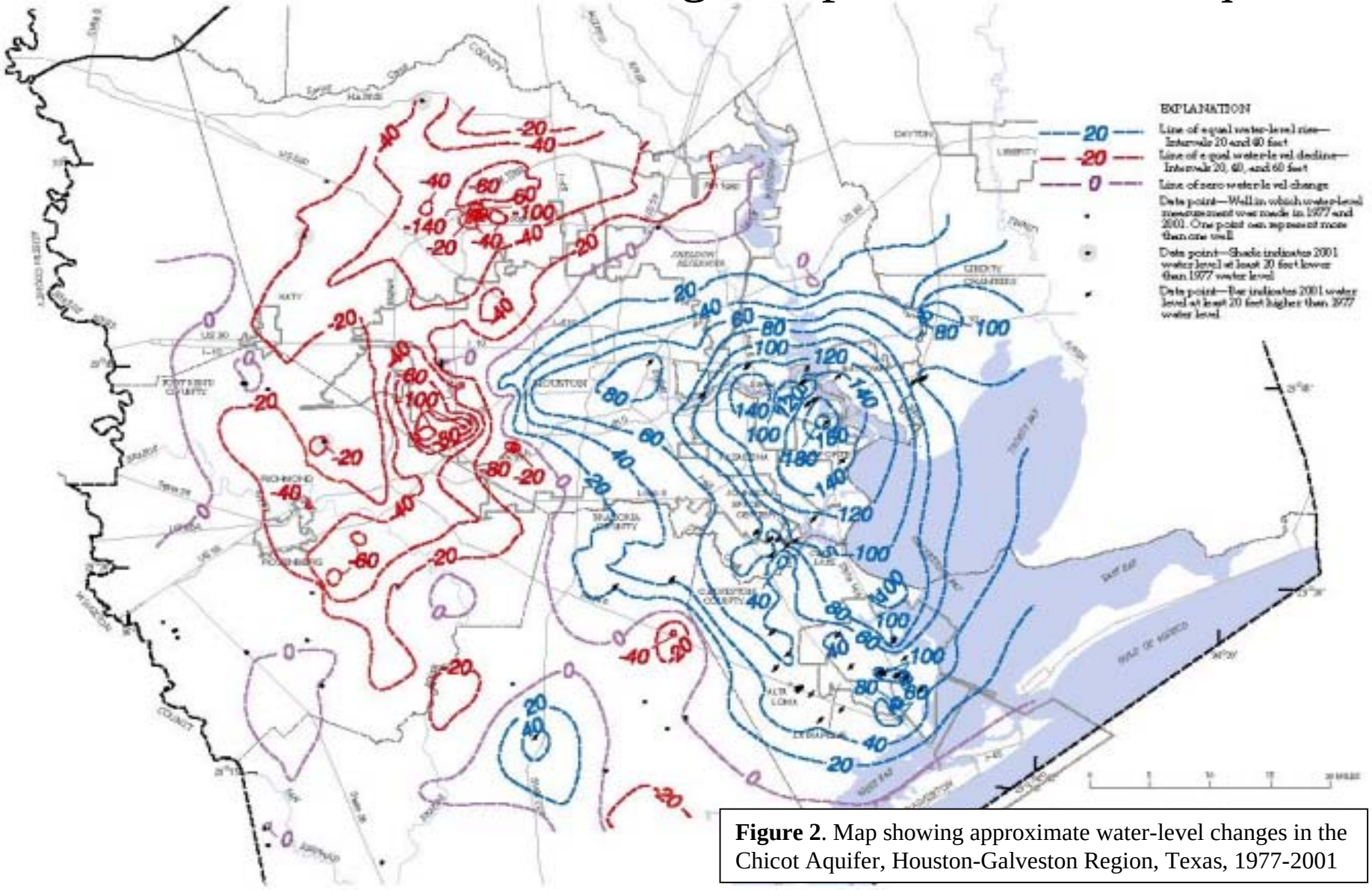


Figure 2. Map showing approximate water-level changes in the Chicot Aquifer, Houston-Galveston Region, Texas, 1977-2001

Exhibit 12

Zero Water-Level Changes in the Chicot Aquifer

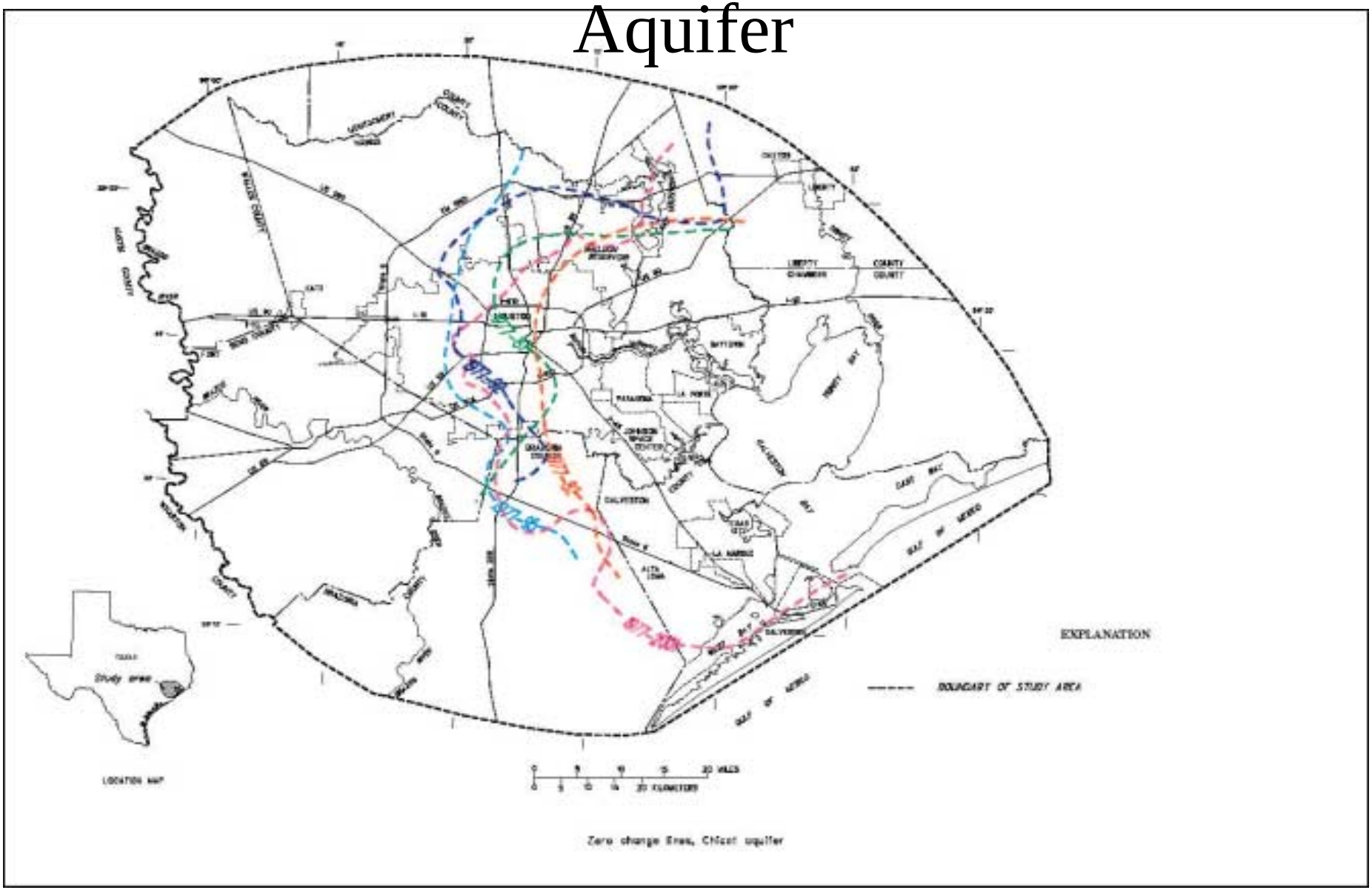


Exhibit 14

2001 Water-Level Altitude in the Evangeline Aquifer

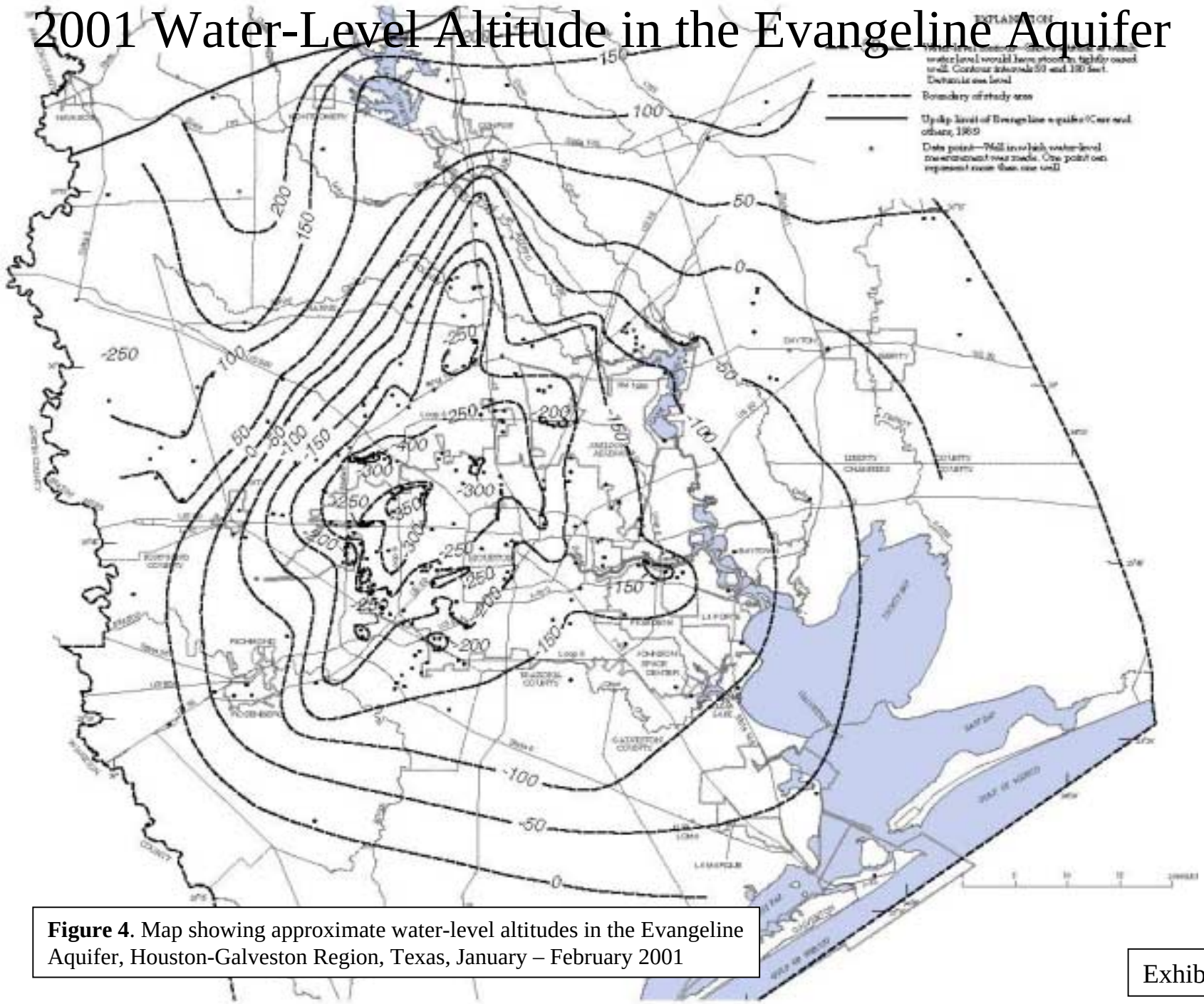


Figure 4. Map showing approximate water-level altitudes in the Evangeline Aquifer, Houston-Galveston Region, Texas, January – February 2001

Exhibit 15

1977-2001 Water-Level Change Map in the Evangeline Aquifer

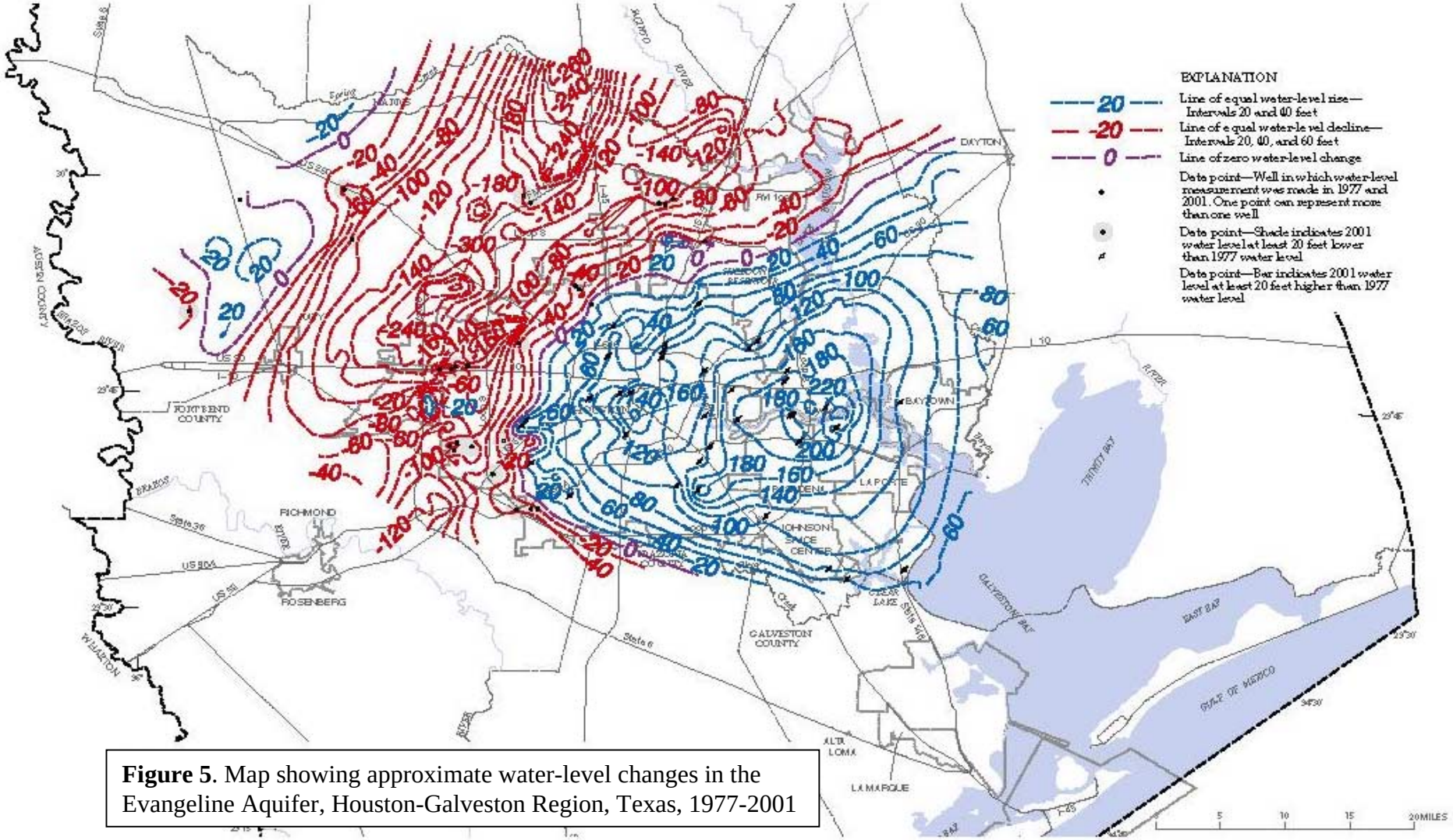


Figure 5. Map showing approximate water-level changes in the Evangeline Aquifer, Houston-Galveston Region, Texas, 1977-2001

Exhibit 16

Zero Water-Level Changes in the Evangeline Aquifer

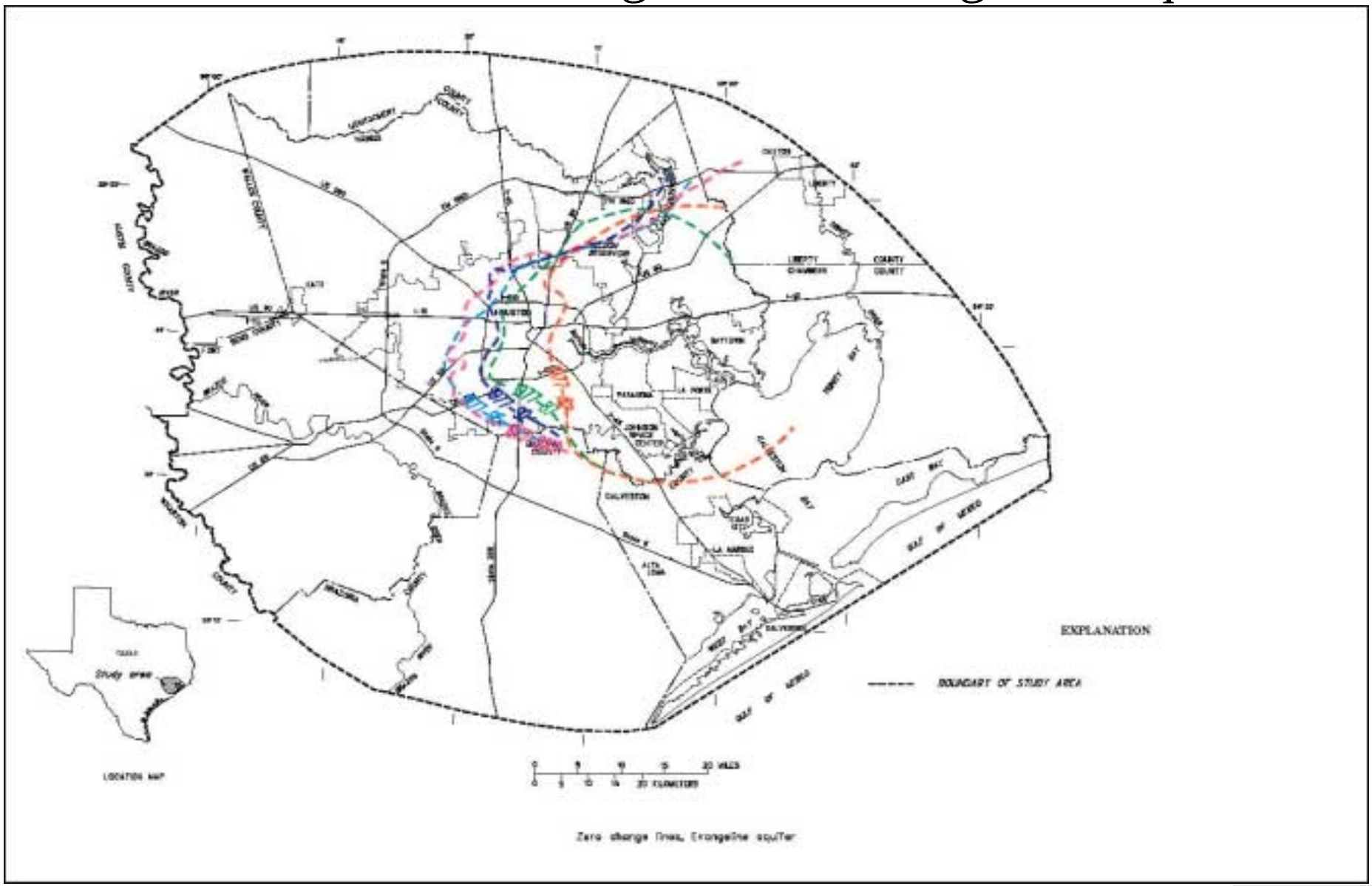


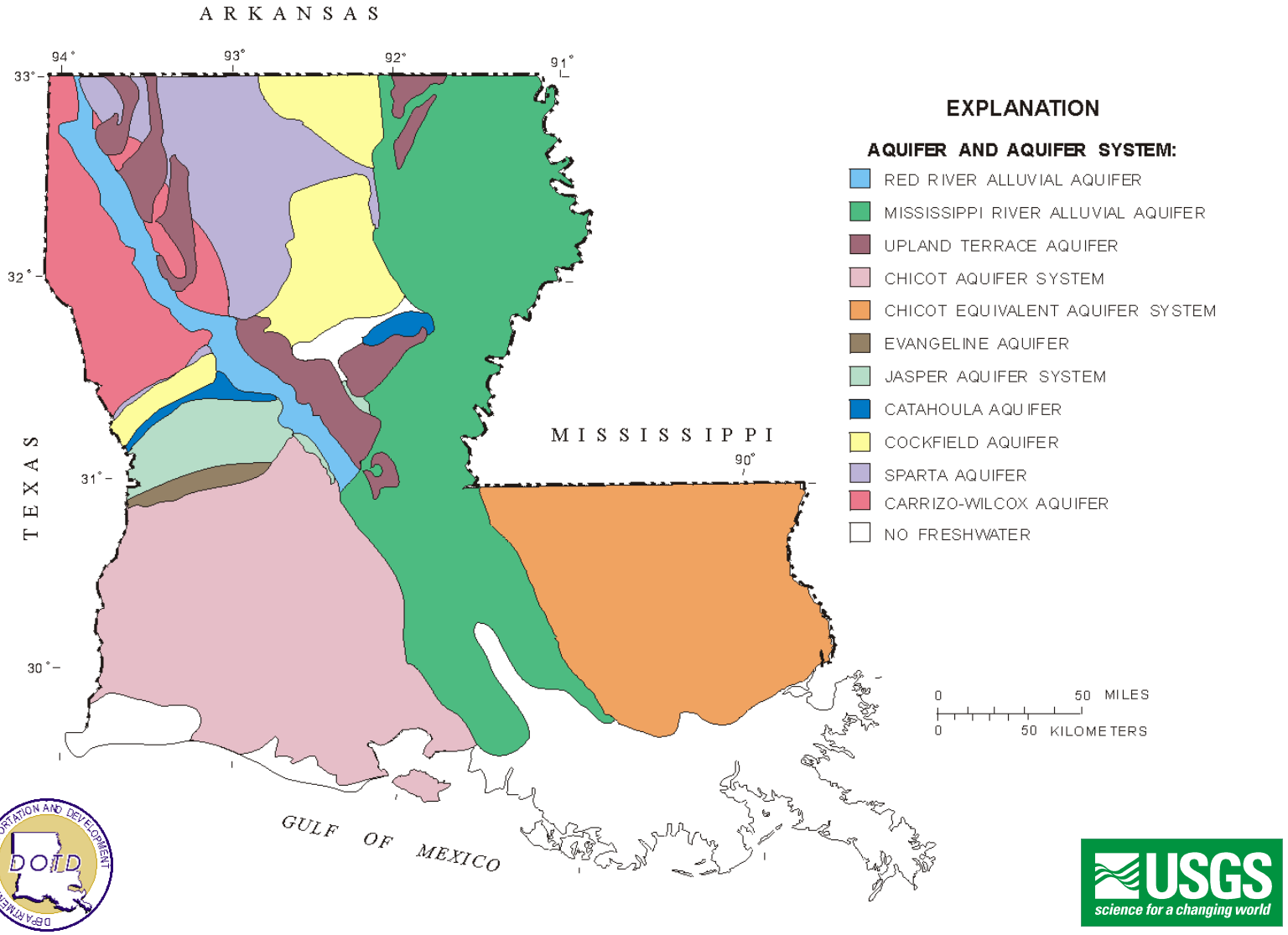
Exhibit 18

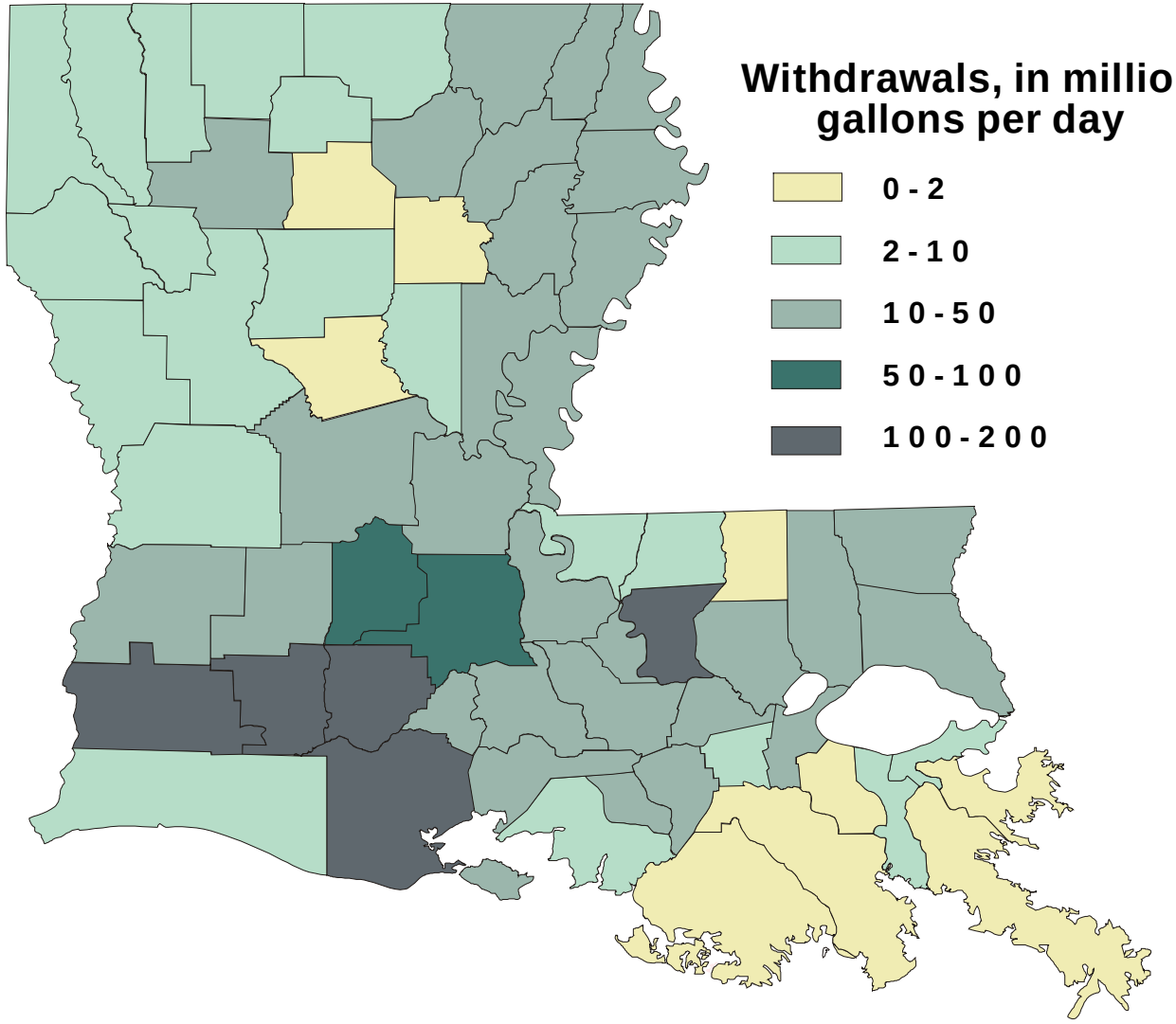
THE CHICOT AQUIFER SYSTEM OF SOUTHWESTERN LOUISIANA

prepared by the

U.S. Geological Survey

Surface extent of Louisiana's aquifers and aquifer systems





GROUND-WATER WITHDRAWALS IN LOUISIANA BY PARISH, 2000

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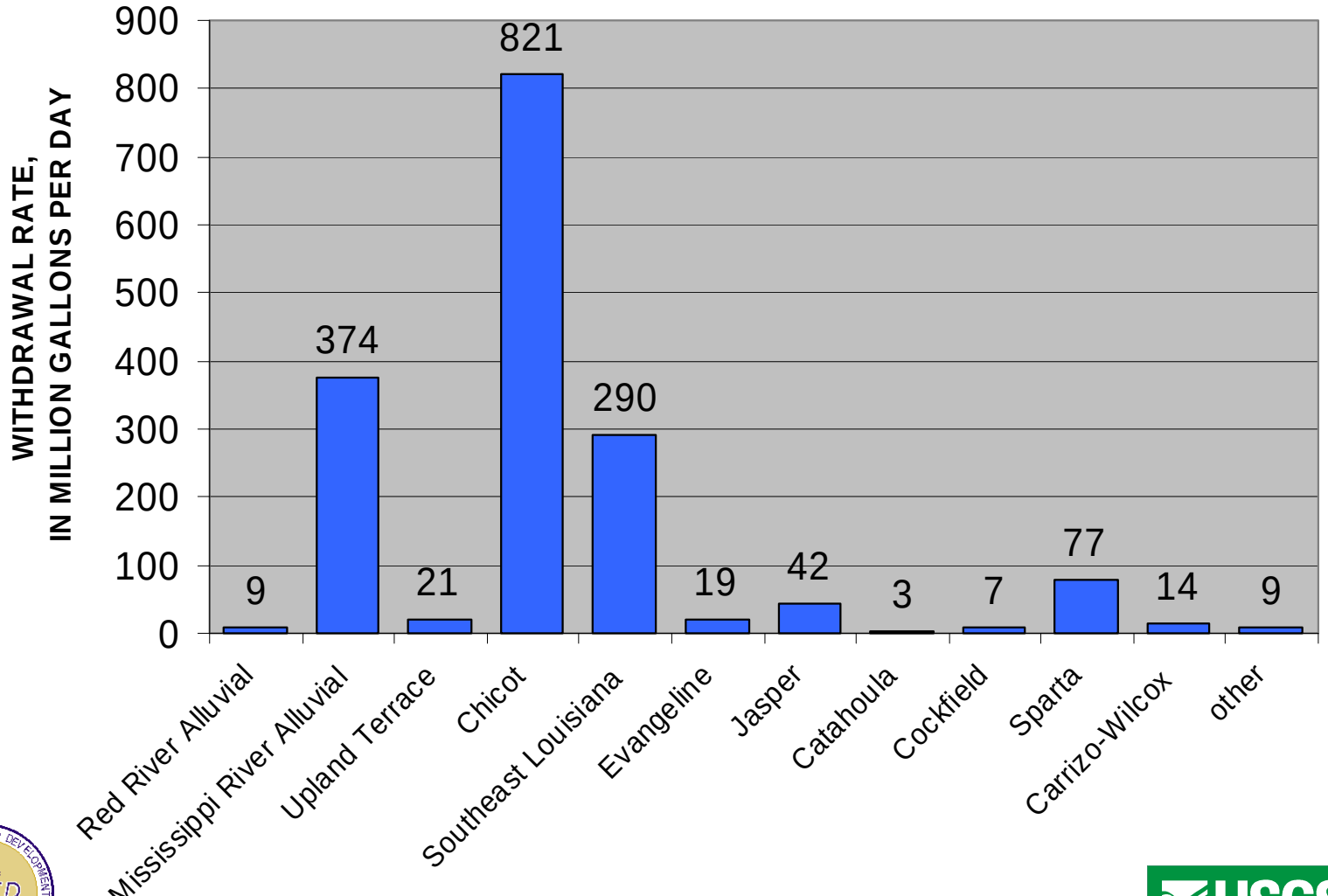
PUMPAGE BY MAJOR AQUIFER OR AQUIFER SYSTEM, 2000



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PROBLEMS/CONCERNS

- Ground-water withdrawals are lowering water levels in some areas of the Chicot aquifer systems.
- In certain areas, these withdrawals are creating conditions favorable for saltwater encroachment.

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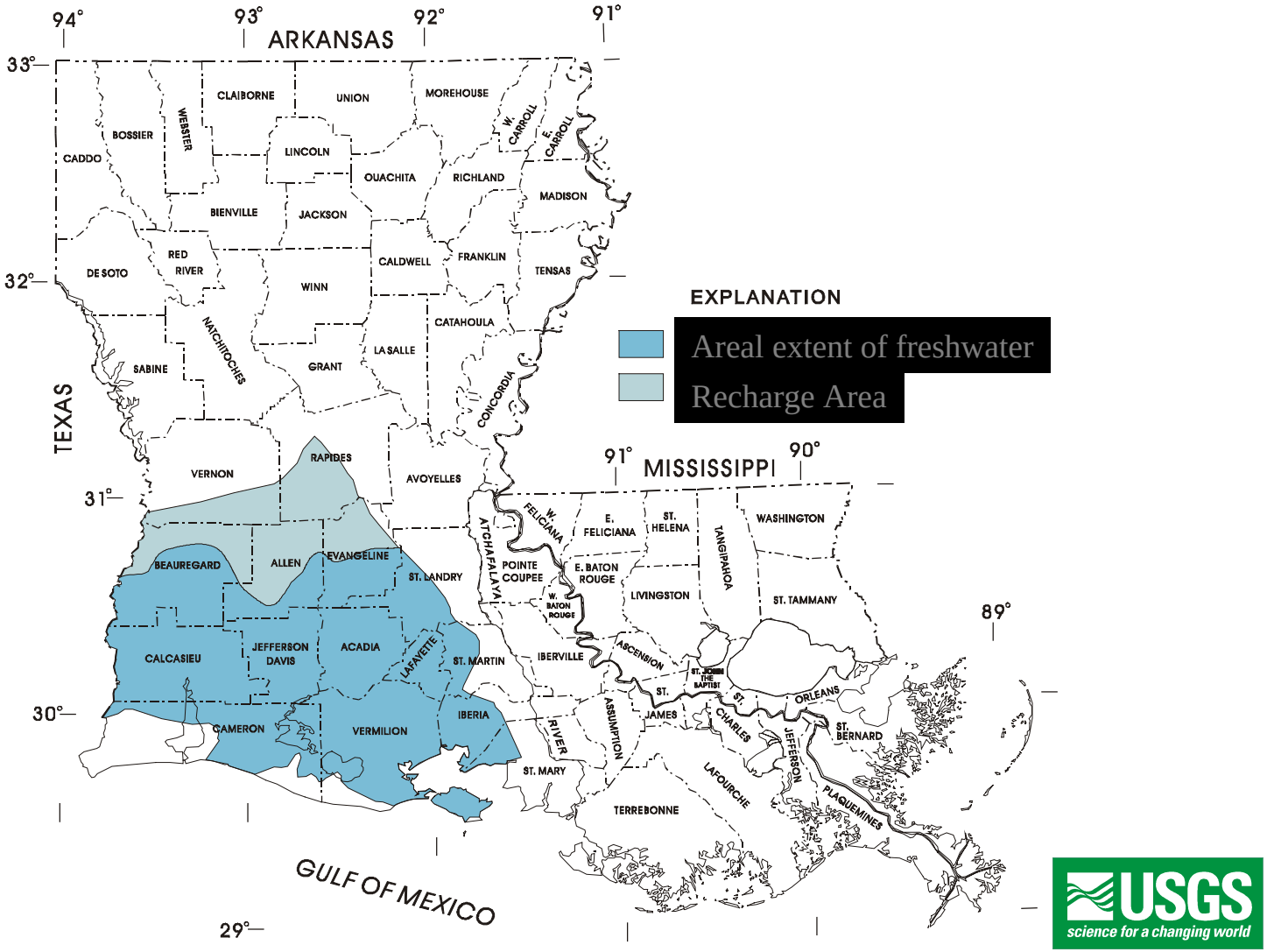
Chicot aquifer system



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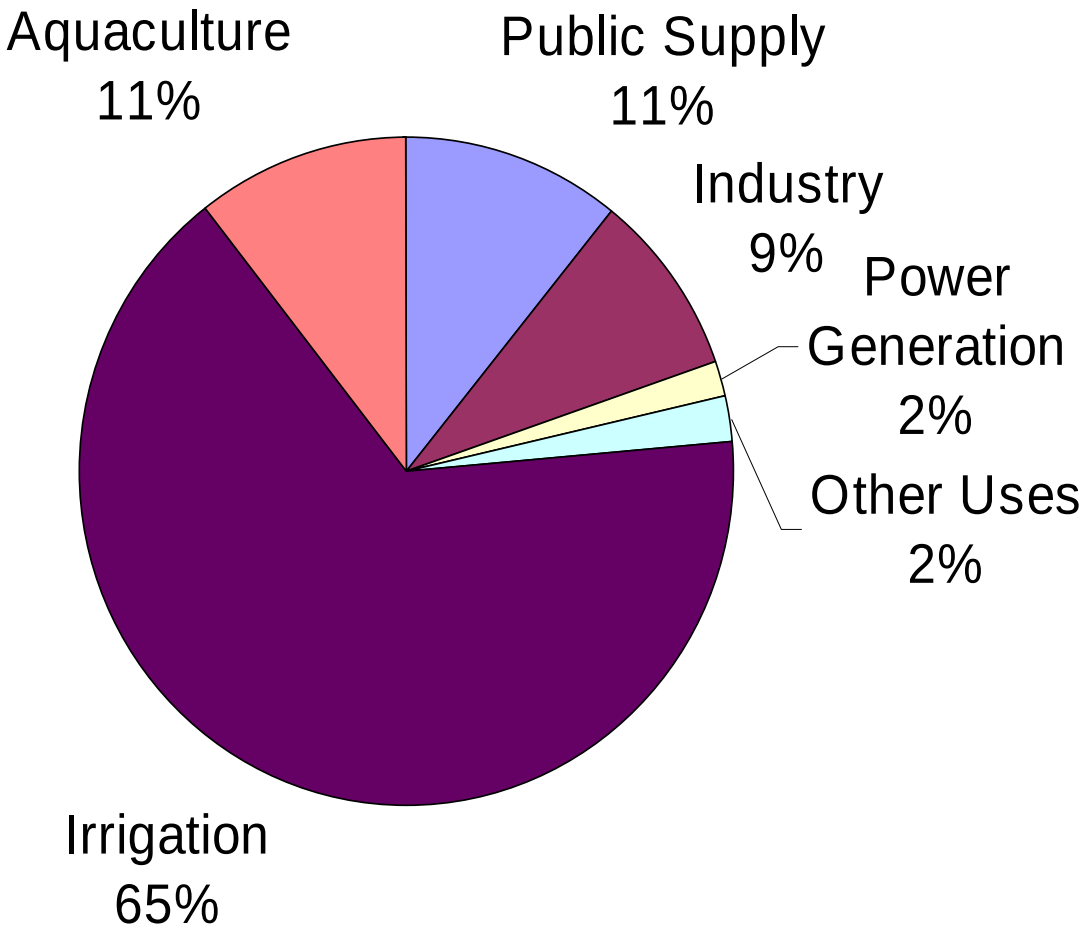
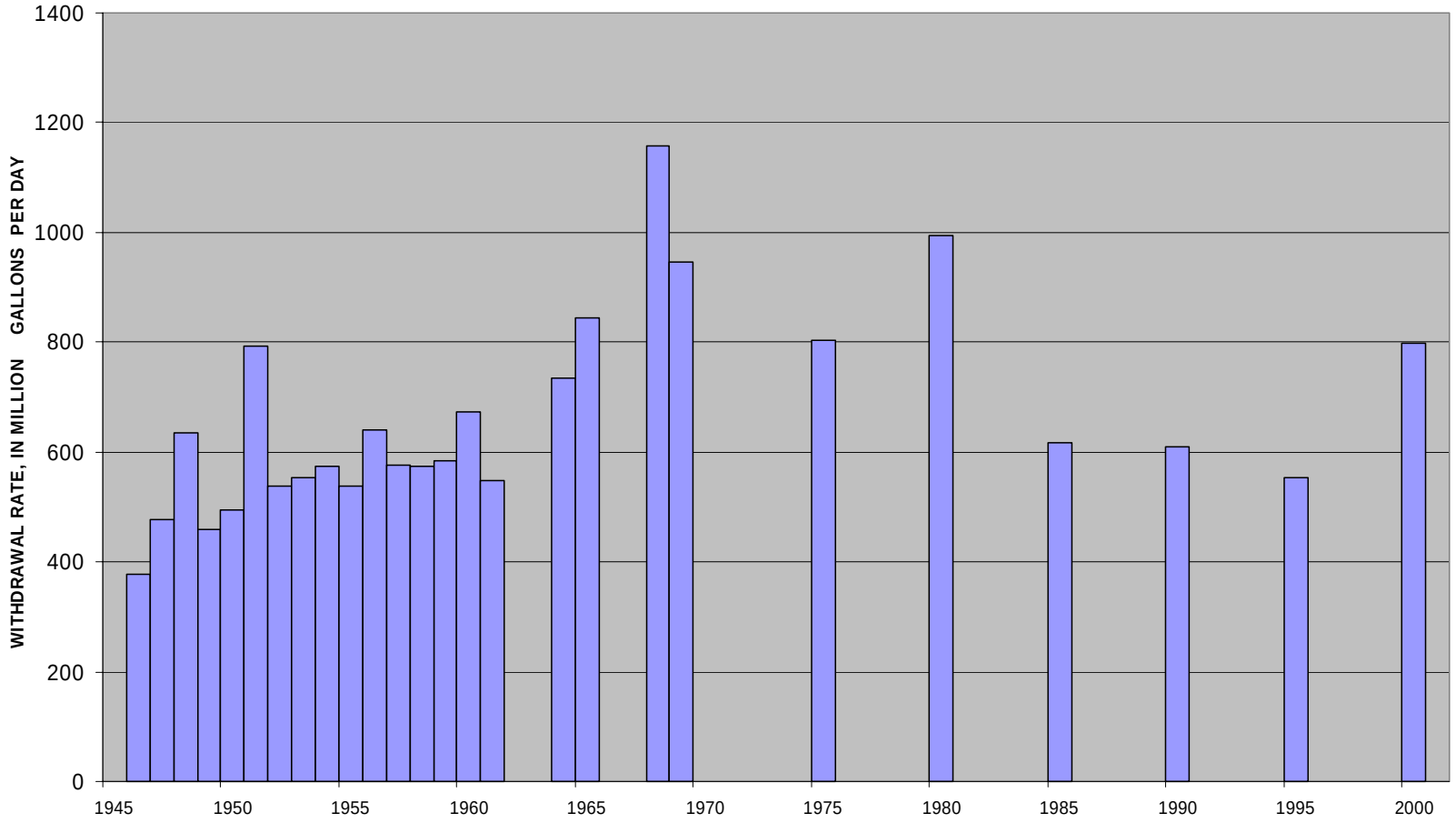


WITHDRAWALS FROM THE CHICOT AQUIFER SYSTEM, 2000

WITHDRAWALS FROM THE CHICOT AQUIFER SYSTEM, 1946-2000



DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
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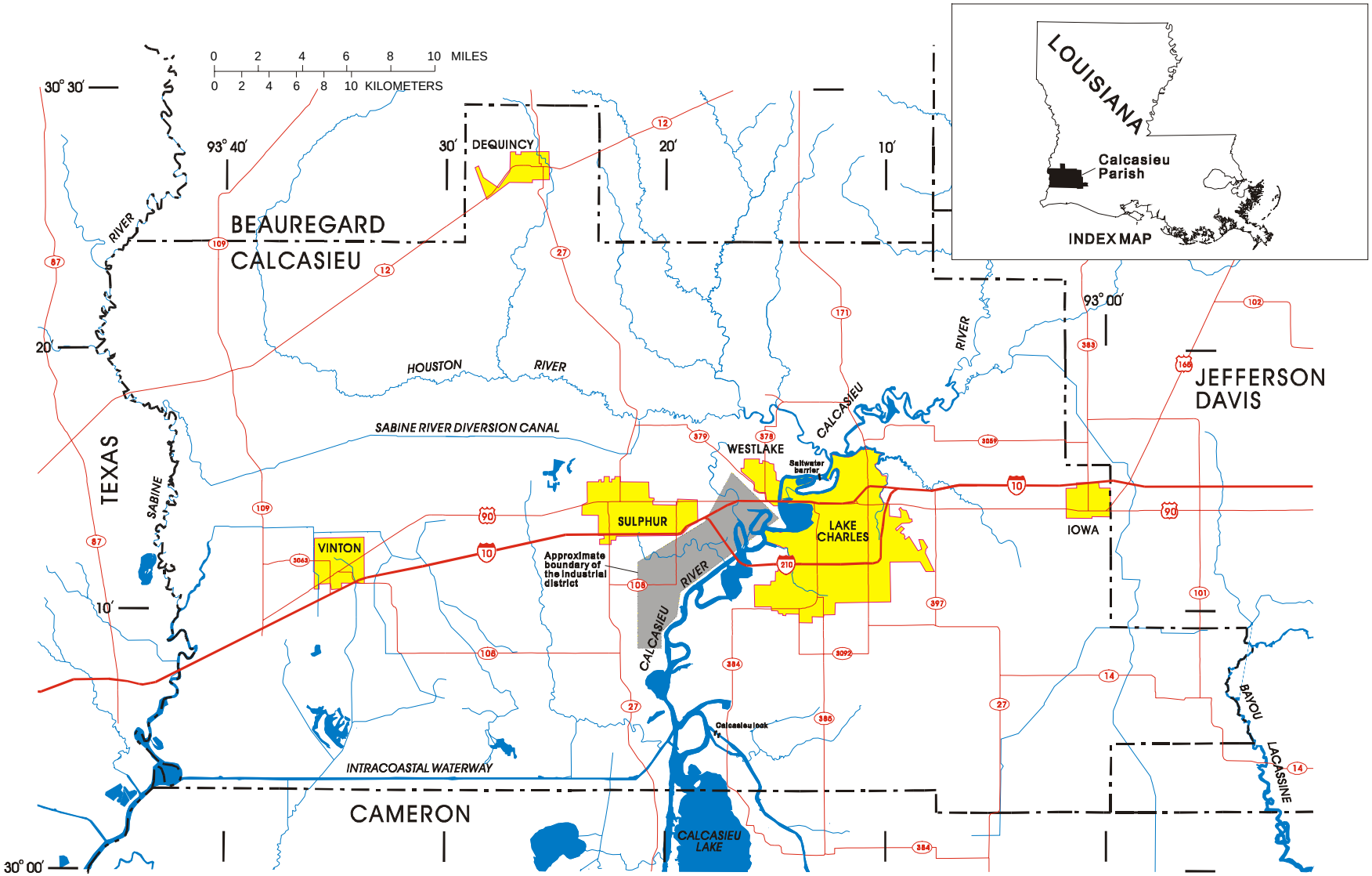
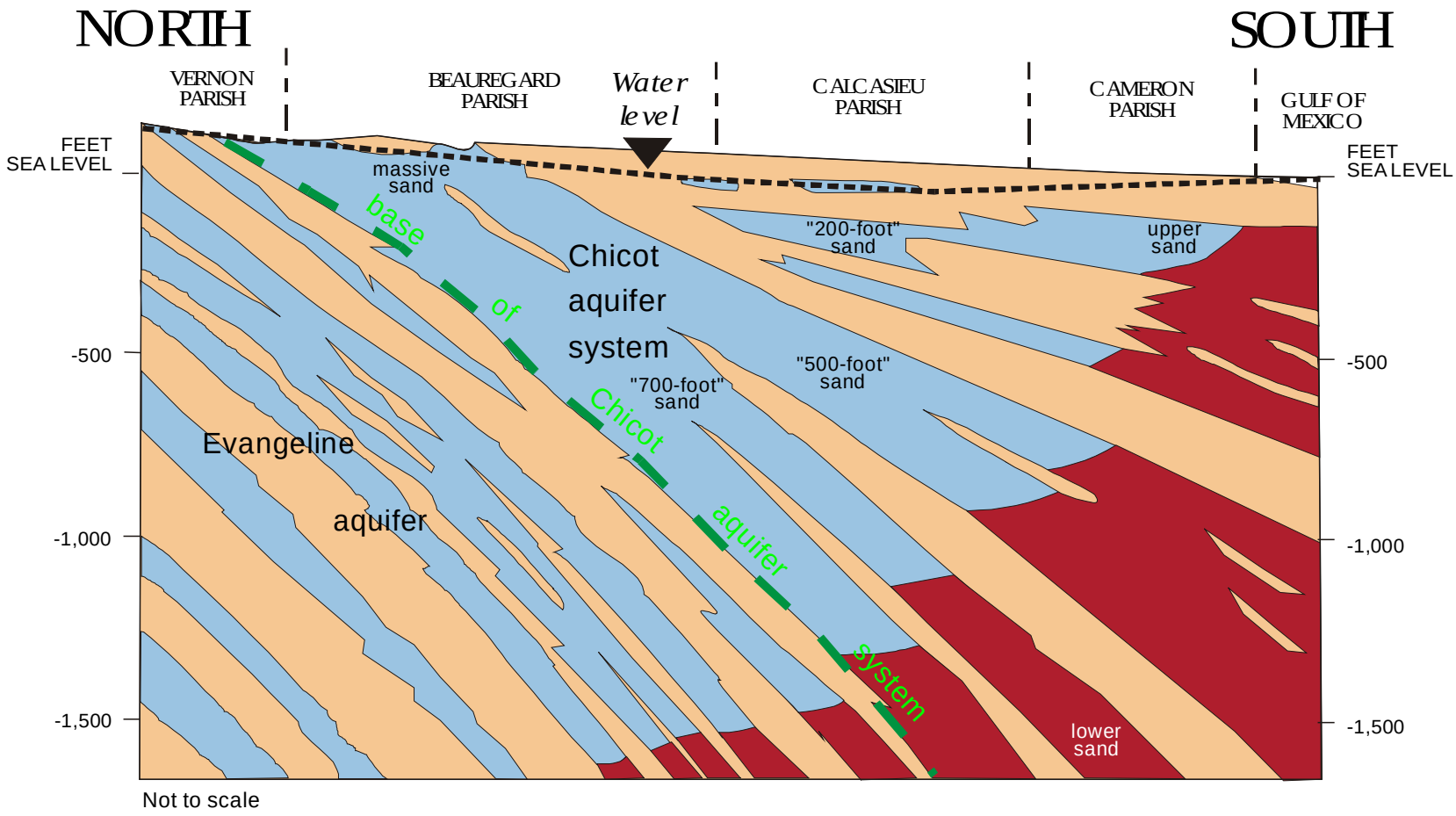
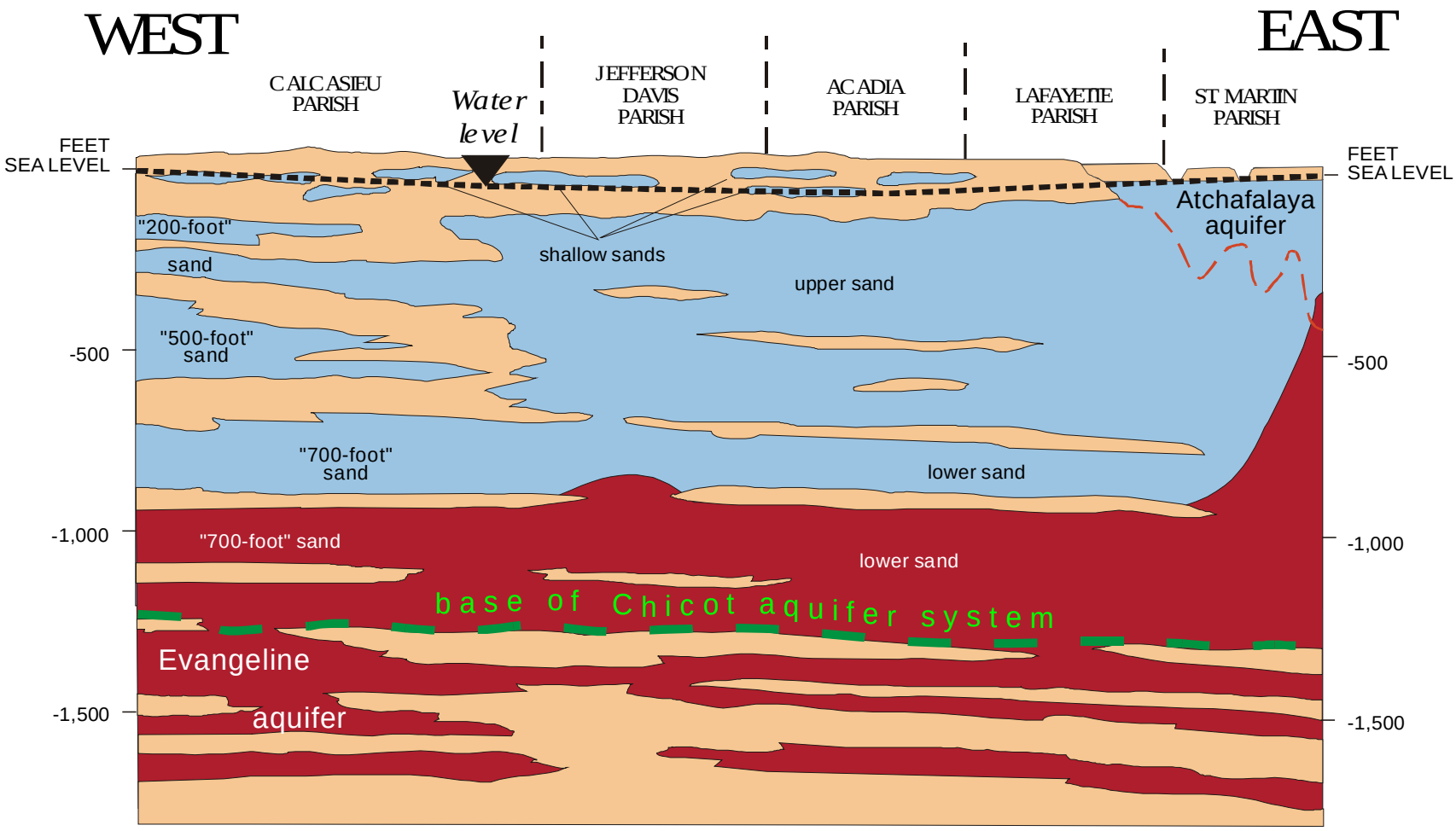

0 2 4 6 8 10 MILES
0 2 4 6 8 10 KILOMETERS
LOUISIANA
Calcasieu Parish
INDEX MAP
30° 30′
93° 40′
30′
20′
10′
93° 00′
DEQUINCY
BEAUREGARD
CALCASIEU
JEFFERSON DAVIS
TEXAS
HOUSTON RIVER
SABINE RIVER DIVERSION CANAL
SABINE RIVER
CALCASIEU RIVER
WESTLAKE
Saltwater barrier
SULPHUR
LAKE CHARLES
IOWA
VINTON
Approximate boundary of the industrial district
Calcasieu lock
INTRACOASTAL WATERWAY
CAMERON
CALCASIEU LAKE
BAYOU LACASSINE
30° 00′

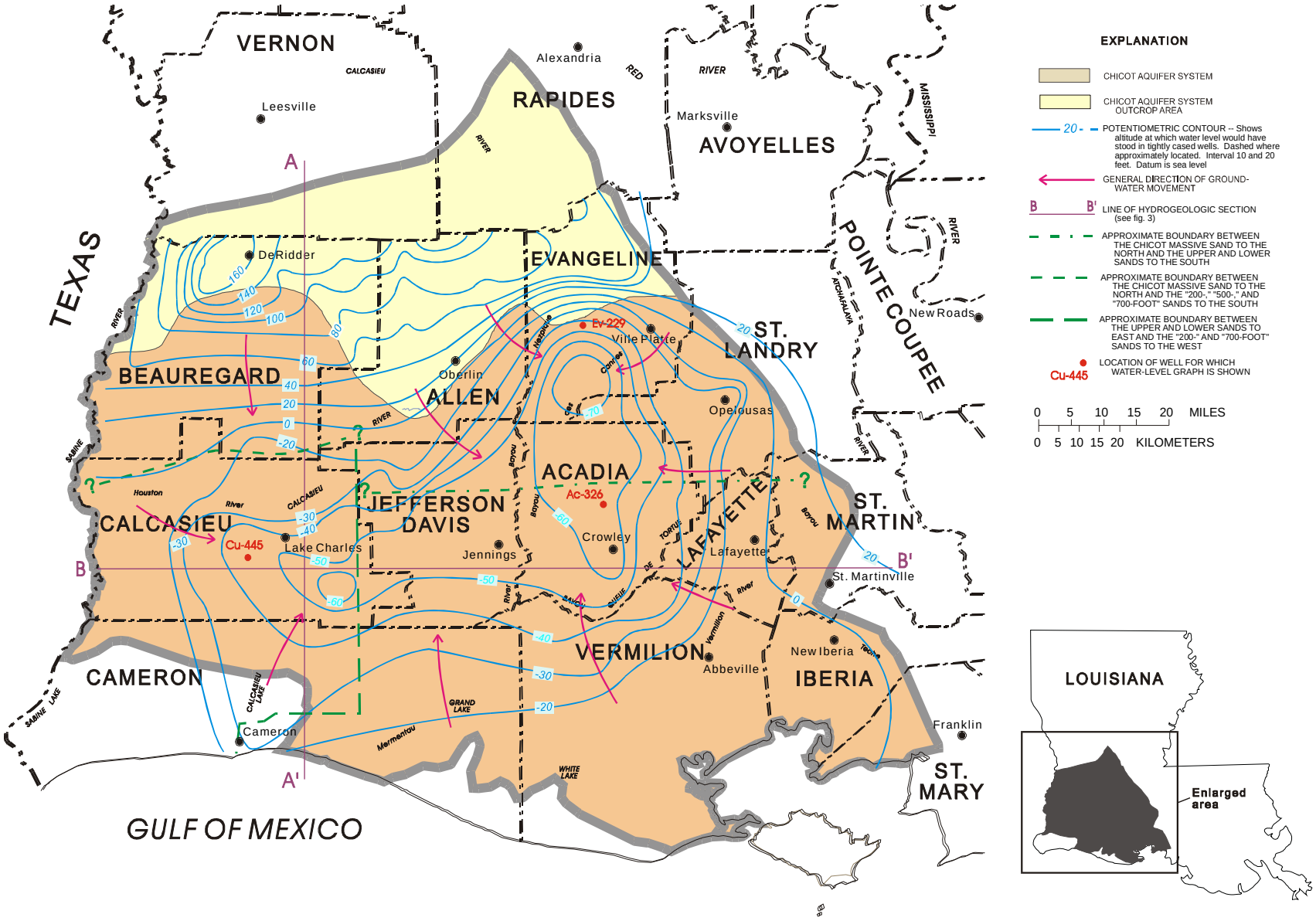


USGS science for a changing world



Not to scale
Trace of sections shown on figure 1

USGS science for a changing world



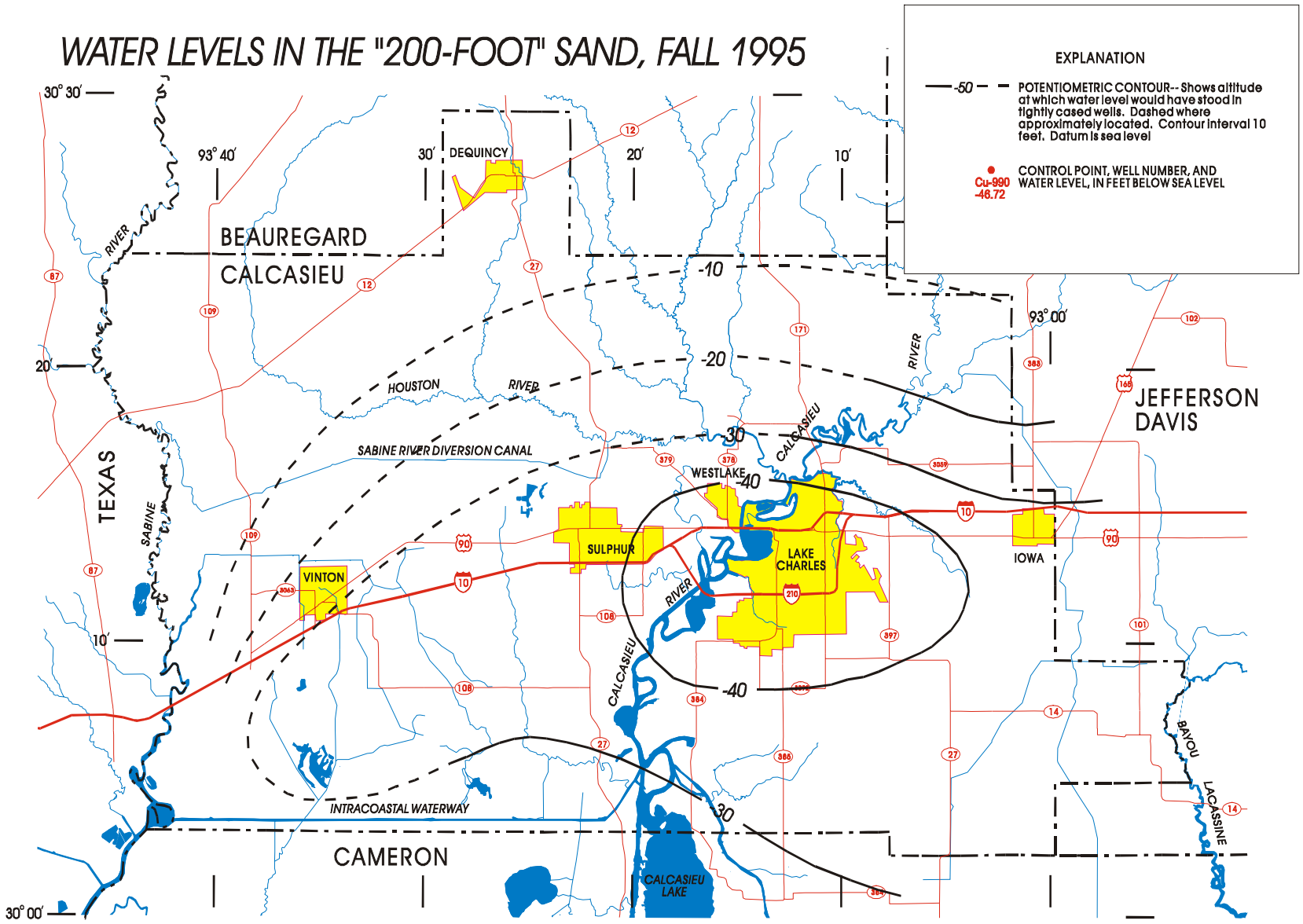
EXPLANATION

- CHICOT AQUIFER SYSTEM
- CHICOT AQUIFER SYSTEM OUTCROP AREA
- 20 — POTENTIOMETRIC CONTOUR -- Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Interval 10 and 20 feet. Datum is sea level
- GENERAL DIRECTION OF GROUND-WATER MOVEMENT
- B B' LINE OF HYDROGEOLOGIC SECTION (see fig. 3)
- APPROXIMATE BOUNDARY BETWEEN THE CHICOT MASSIVE SAND TO THE NORTH AND THE UPPER AND LOWER SANDS TO THE SOUTH
- APPROXIMATE BOUNDARY BETWEEN THE CHICOT MASSIVE SAND TO THE NORTH AND THE "200-," "500-," AND "700-FOOT" SANDS TO THE SOUTH
- APPROXIMATE BOUNDARY BETWEEN THE UPPER AND LOWER SANDS TO EAST AND THE "200-" AND "700-FOOT" SANDS TO THE WEST
- Cu-445 LOCATION OF WELL FOR WHICH WATER-LEVEL GRAPH IS SHOWN

0 5 10 15 20 MILES

0 5 10 15 20 KILOMETERS

WATER LEVELS IN THE "200-FOOT" SAND, FALL 1995



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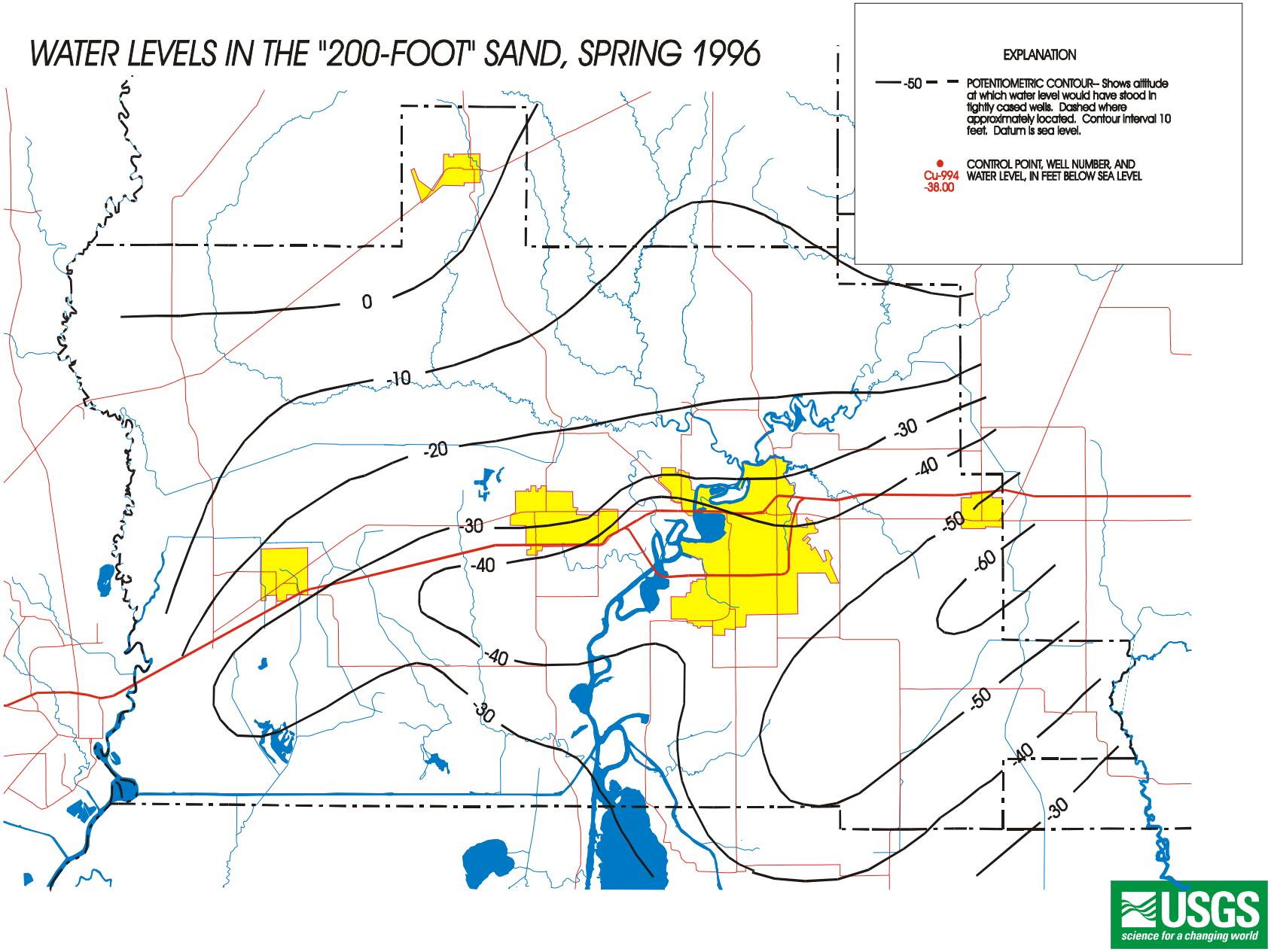
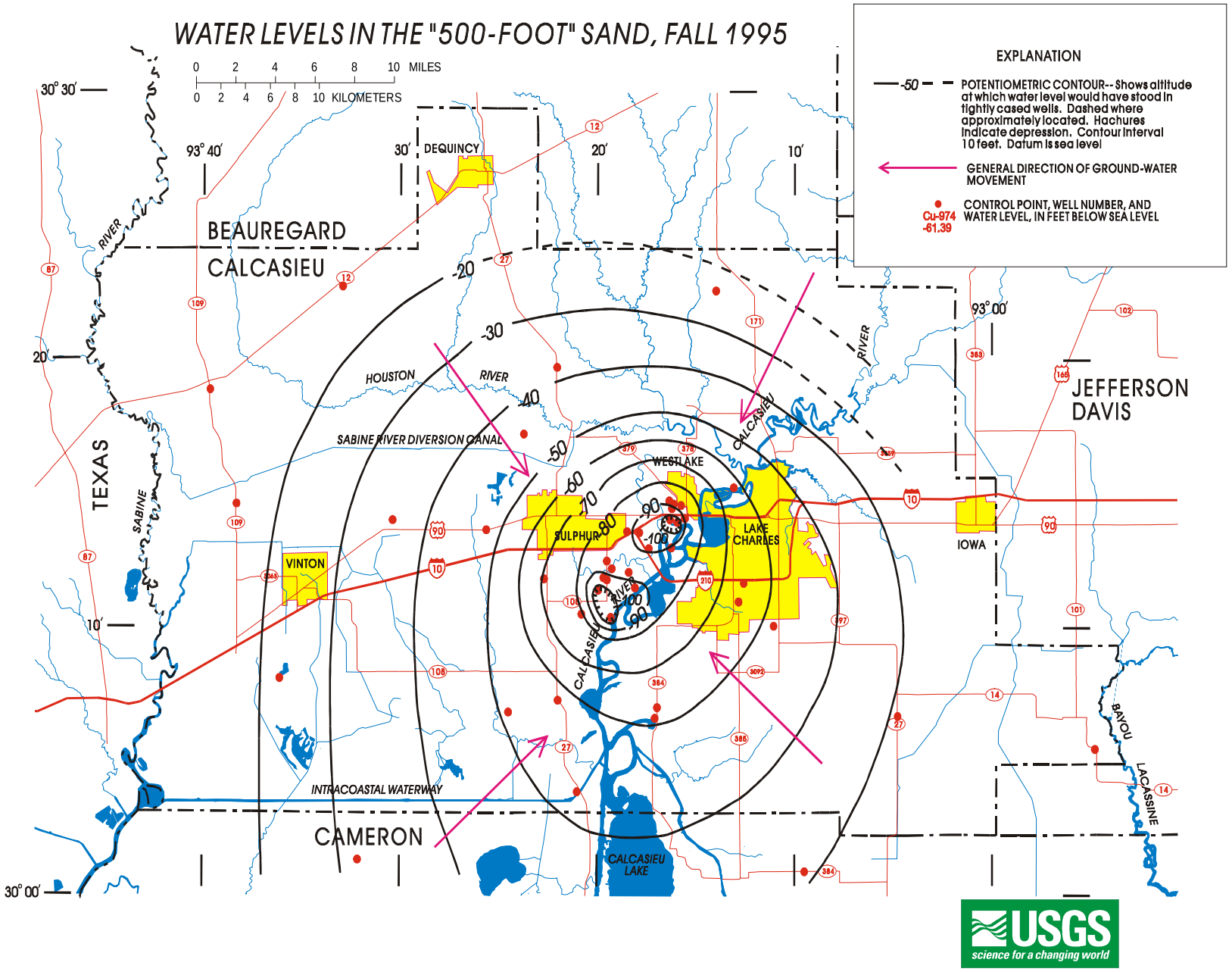
WATER LEVELS IN THE "200-FOOT" SAND, SPRING 1996




WATER LEVELS IN THE "500-FOOT" SAND, FALL 1995
0 2 4 6 8 10 MILES
0 2 4 6 8 10 KILOMETERS
EXPLANATION
-50 POTENTIOMETRIC CONTOUR-- Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Hachures indicate depression. Contour interval 10 feet. Datum is sea level
GENERAL DIRECTION OF GROUND-WATER MOVEMENT
Cu-974 -61.39 CONTROL POINT, WELL NUMBER, AND WATER LEVEL, IN FEET BELOW SEA LEVEL
30° 30′
93° 40′
30′
20′
10′
93° 00′
30° 00′
DEQUINCY
BEAUREGARD
CALCASIEU
CAMERON
JEFFERSON DAVIS
TEXAS
IOWA
VINTON
SULPHUR
WESTLAKE
LAKE CHARLES
CALCASIEU LAKE
HOUSTON RIVER
SABINE RIVER
CALCASIEU RIVER
BAYOU LACASSINE
SABINE RIVER DIVERSION CANAL
INTRACOASTAL WATERWAY
-20
-30
-40
-50
-60
-70
-80
-90
-100
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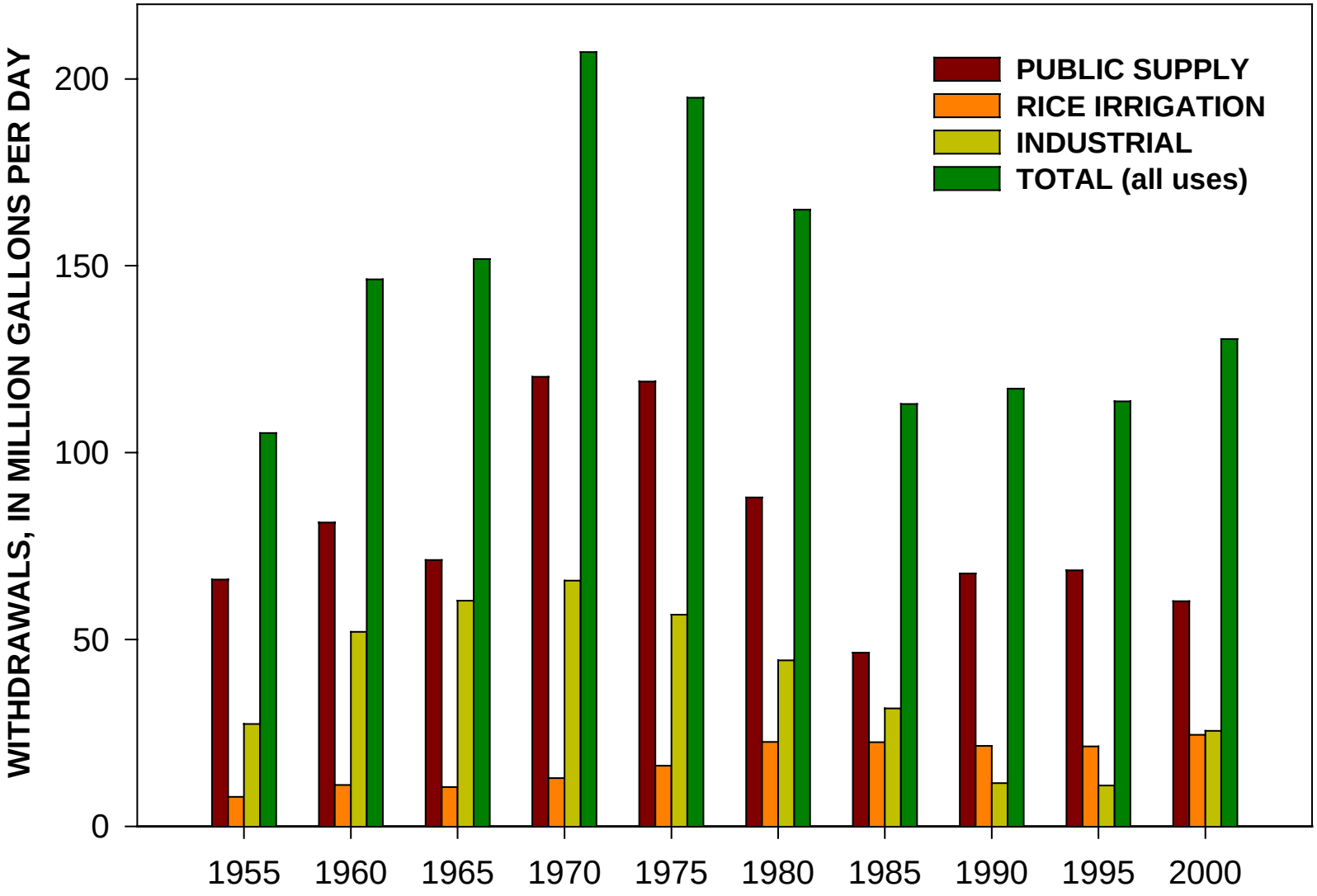
GROUND-WATER WITHDRAWALS IN CALCASIEU PARISH, 1955-2000



Upper Gulf Coast GAM Aquifer Outcrops

Attendance list at the 3rd Stakeholder Advisory Forum for the northern Gulf Coast aquifer Groundwater Availability Model, November 15, 2001

Names	**Affliation**
Ali Chowdhury	Texas Water Development Board
David W. Minze	Bluebonnet GWCD
Eric Strom	US Geological Survey
Ernest Roebuck	Texas Water Development Board
Haskell L. Simon	Region K -Regional Water Planning Group
Ian Jones	Texas Water Development Board
Jim Adams	SJRA
Joe Broadus	US Geological Survey
John Nelson	LBG-Guyton Associates
Mark C. Kasmarek	US Geological Survey
Robert K. Gabrysch	Consultant Hydrogeologist
Ron Neighbors	Harris-Galveston Coastal Subsidence District
Steve Musick	Texas Natural Resources Conservation Commission
Tom Michel	Harris-Galveston Coastal Subsidence District

Discussion at the 3rd Stakeholder Advisory Forum for the northern Gulf Coast aquifer Groundwater Availability Model; November 15, 2001

Question: What are the model boundaries?

Response: The northern model boundary is the updip limit of the Jasper Aquifer outcrop, the eastern boundary is the Sabine River, the southern boundary is the Gulf of Mexico, and the western boundary is the surface water divide of the Lavaca-Navidad River basins.

Question: You suggest that most of the water down-dip in the Jasper aquifer is brackish/saline but in Matagorda County we produce fresh water from the Jasper aquifer – is there an inconsistency?

Response: In the outcrop areas, the waters in the Jasper aquifer are fresh but as they move down-dip, they become more saline particularly near the coastline.

Question: Is there a vertical connection between the Burkeville and the Jasper aquifers?

Response: Yes, in some of the northern updip areas of the Burkeville Confining System, the Burkeville sediments contain greater percentages of sand that allows the sediments to be more transmissive than the down-dip Burkeville sediments that have a large percentage of clay. When groundwater is withdrawn from wells in the updip outcrop areas of the Evangeline aquifer, water can potentially flow from the Jasper aquifer upwards through the transmissive areas of the Burkeville Confining System and into the Evangeline aquifer.

Question: Is there no recharge from the rainfall into the Chicot aquifer near the coastline?

Response: Most recharge into the Chicot aquifer enters through the updip outcrop areas. Using Tritium isotope age dating of the ground water in the Chicot and Evangeline aquifers, it has been determined that the age groundwater is increasingly older the further downdip the water is sampled. The time that it would take for a drop of precipitation to enter the aquifer system at the coast would be determined by the thickness of the clay beds as the water moved vertically down through the sediments. Additionally, the presence of the Beaumont Clay also impedes vertical flow rates. Groundwater travel time in the outcrop areas on the other hand is relatively fast (50 ft/yr.).

Question: Can we use the model to determine spacing of wells or interference between wells due to pumping?

Response: This is a regional groundwater flow model. On a county basis, the model should yield groundwater availability values, but may not provide answers to address local issues unless the model is reconstructed with a finer mesh and populated with additional data. This regional model can be split up into small ones to address local concerns.

Question: What is the use of the model if we as a groundwater district cannot use it?

Response: The model should provide answers to regional groundwater issues. Countywide groundwater availability values can also obtained using this model.

Comments: A stakeholder indicated that the first model developed by the USGS is an analog model. With time, successive models are attempting to better simulate the groundwater flow conditions. Using better hydrogeologic data, each successive model increases our understanding of the hydraulic and stratigraphic complexities of the Gulf Coast Aquifer System. The Chicot and Evangeline model that was created with a cooperative agreement with the City of Houston and the USGS is at present being finalized and prepared for publication. Using MODFLOW with the Interbed Storage Package, transient model calibration determined that considerable amounts of water are released from the numerous clay interbeds as these interbeds are depressurized and subsequently compact. Models improve over time with addition of new hydrogeologic data and increased understanding of the aquifer system. The previous and current models are the first models to use subsidence interactively during transient model calibration.

Question: At this stage of model calibration and creation, do we need to meet each quarter when not much new information is presented? It would make more sense if we have these quarterly meetings when some results are available in mid - 2002.

Response: We will look into this. If the contract allows, we will allow the next meeting to be held in 6 months.

Question: As a follow-up of a question from the previous SAF meeting concerning the validity of the Sabine River being the eastern model boundary due to the impact of ground-water withdrawal in the Lake Charles geographic area.

Response: We have consulted with the Louisiana USGS Office on this matter. Ongoing cooperative agreements in western Louisiana and eastern Texas have produced water-level data from wells and subsequent interpretive Open File Reports showing recently created water level altitude maps for adjacent areas east and west of the Sabine River. These data show conclusively that the Sabine River is an appropriate eastern model boundary.