

Mapping Brackish Groundwater in Aquifers of the Upper Coastal Plains, Central Texas

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Summary Slide

- Introduction to TWDB and BRACS
- Study area overview
- Methods
- Mapping results
- Future improvements and conclusions

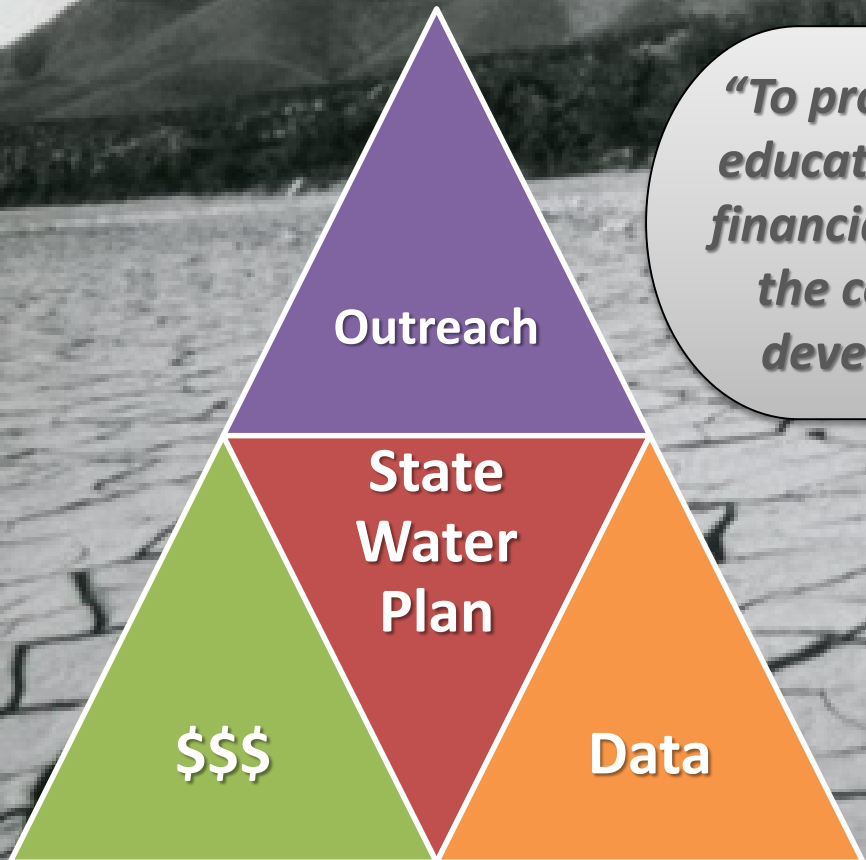
Texas Water Development Board
Report 3xx

**Brackish Groundwater in Aquifers of the
Upper Coastal Plains, Central Texas**

by
John E. Meyer, P.G.
Andrea D. Croskrey, P.G.
Alysa K. Suydam, GIT
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Month 2020

Texas Water Development Board



“To provide leadership, information, education, and support for planning, financial assistance, and outreach for the conservation and responsible development of water for Texas”

HOW WE PLAN



WHY WE PLAN



Projected **73%** population increase over the next **50 years**



Water demand is projected to **increase 17%**



Texas' existing water supplies are expected to **decline 11%**

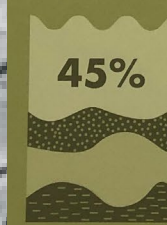
8.9 million acre-feet



The potential total water shortage in a drought of record is **8.9 million acre-feet** in 2070

SOURCES OF NEW WATER in 2070

The 2017 State Water Plan recommends 5,500 water management strategies



Surface Water



Conservation and drought management



Reuse



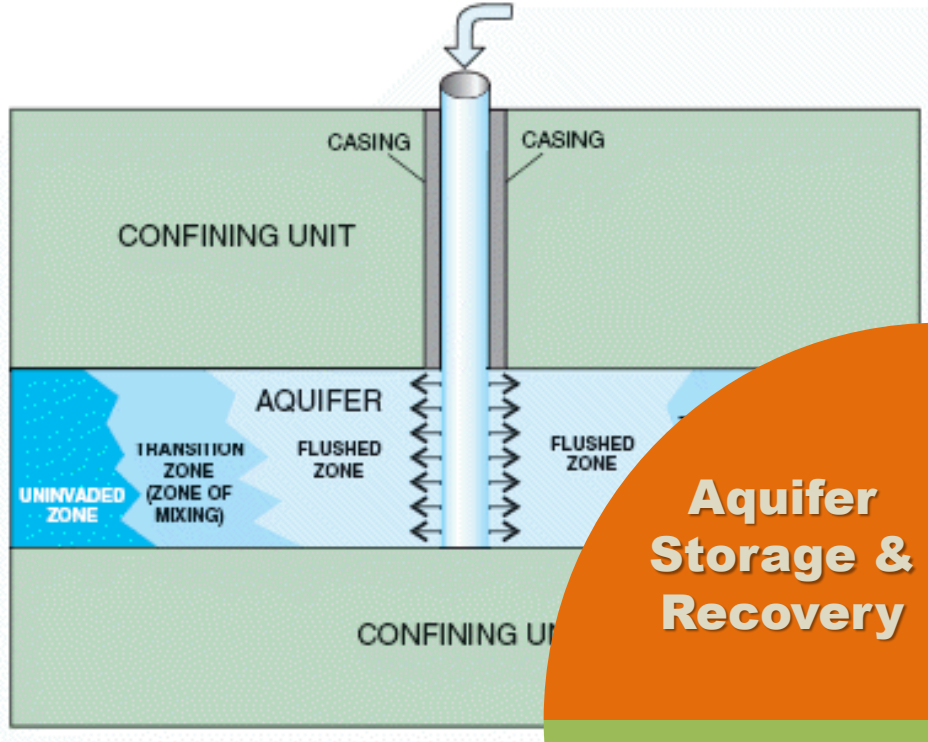
Groundwater



Seawater

If implemented, these strategies would provide 8.5 million acre-feet per year in additional water supplies by 2070

Innovative Water Technologies

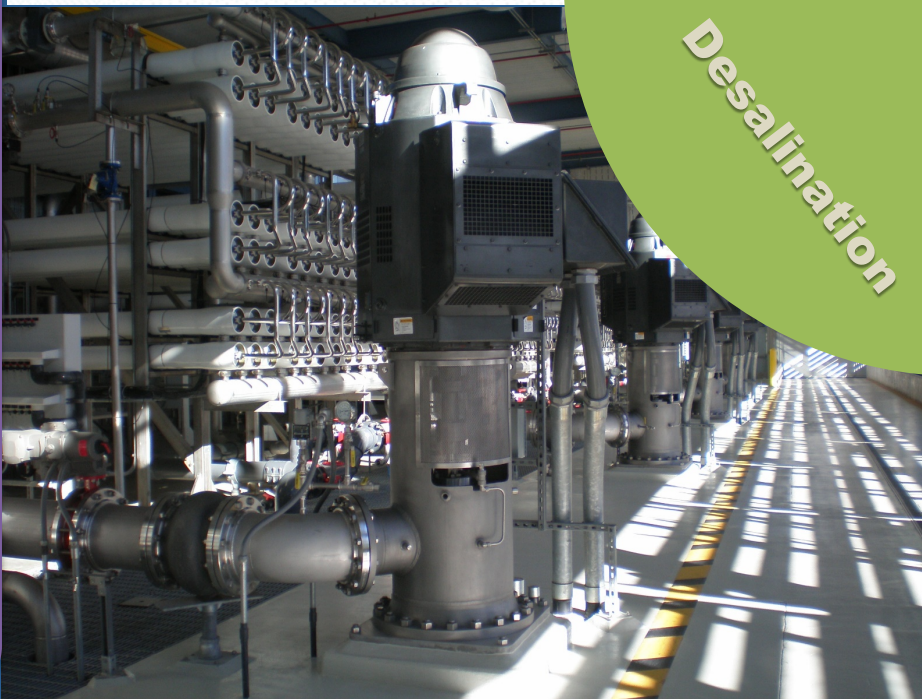


**Aquifer
Storage &
Recovery**

**Water
Reuse**

Desalination

**Brackish
Groundwater**



“Our mission is to educate the water community on the use of nontraditional water supplies.”

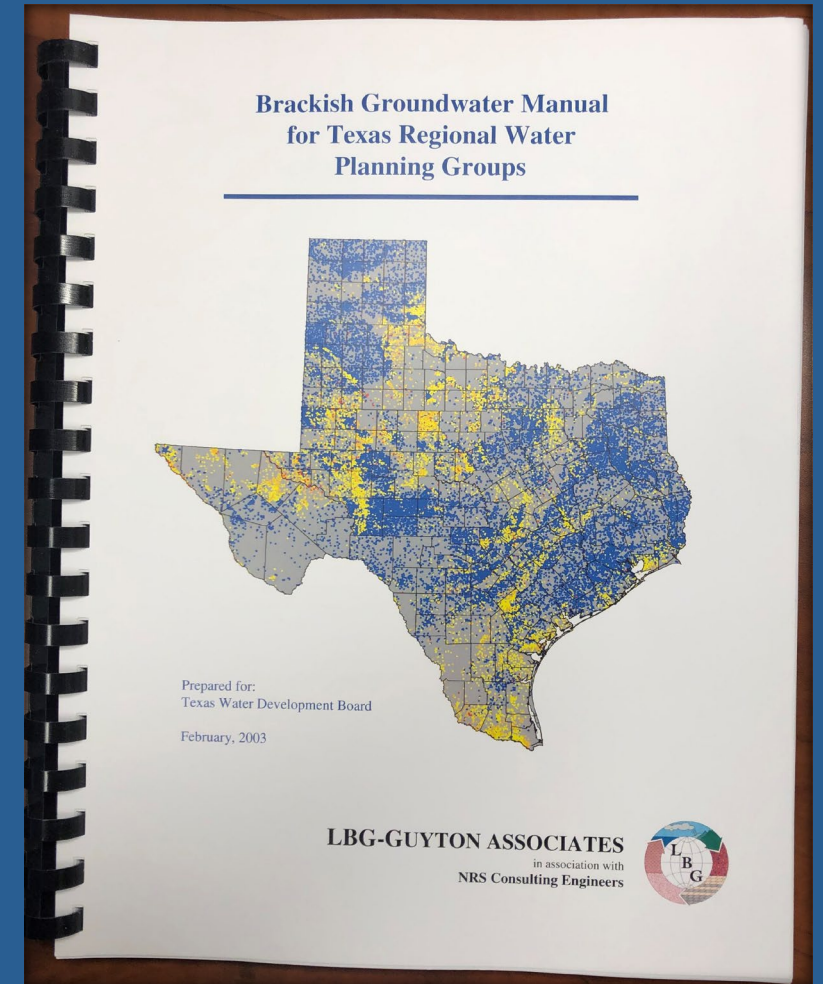


Brackish Resources Aquifer Characterization System (BRACS)

Map brackish groundwater!

1. Stratigraphy
2. Lithology
3. Water Quality
4. Volumes

<http://www.twdb.texas.gov/innovativewater/bracs/studies.asp>



What is brackish groundwater?

"saltier than fresh water, less salty than seawater"
or
1,000-10,000 mg/L Total Dissolved Solids

BRACKISH

PWS →

BUQ →

USDW →

Groundwater Salinity Classification	Salinity Zone Code	Total Dissolved Solids (milligrams per liter)
Fresh	FR	0 to 1,000
Slightly Saline	SS	1,000 to 3,000
Moderately Saline	MS	3,000 to 10,000
Very Saline	VS	10,000 to 35,000
Brine	BR	Greater than 35,000

Most Texas Major/Minor Aquifer Mapped Limit

← Seawater

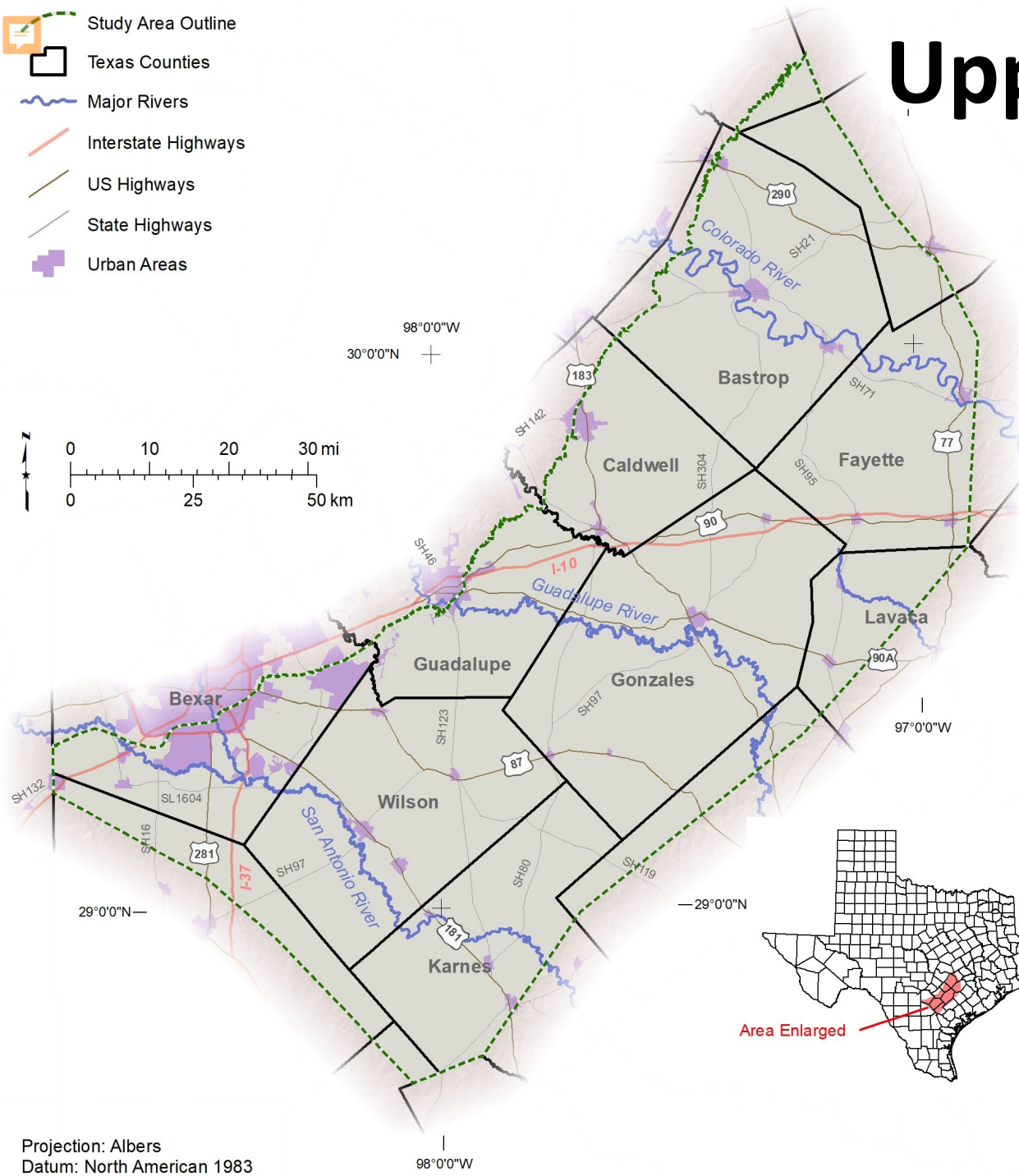
PWS: Public Water System threshold for fresh water, TX Commission on Environmental Quality

BUQ: Base Useable Quality water, TX Railroad Commission

USDW: Underground Source Drinking Water, US Environmental Protection Agency ⁶

modified from Winslow and Kister (1956) USGS WSP 1365

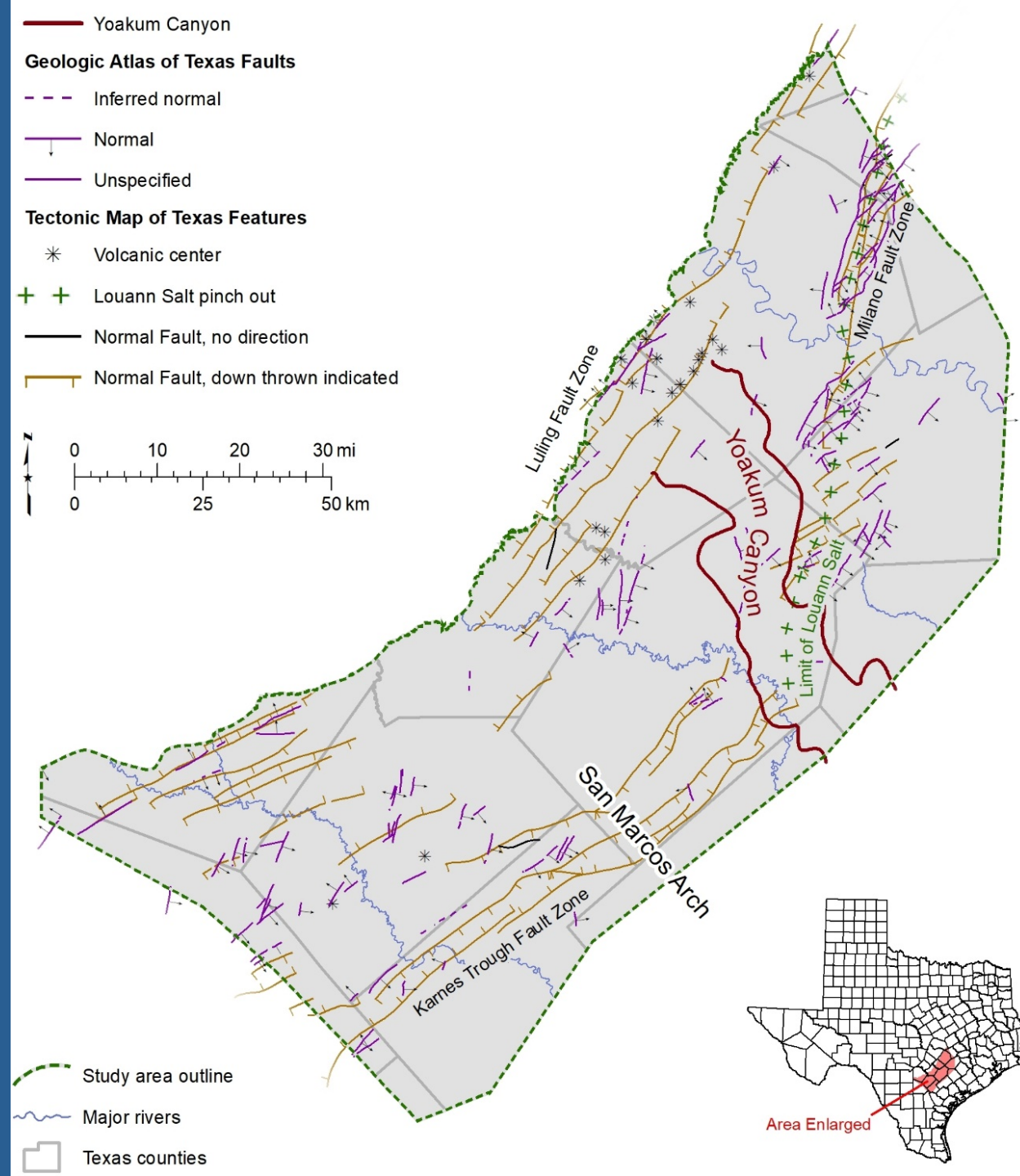
Upper Coastal Plains – Central Study Overview



- Parts of 14 counties in central Texas
- 8 Eocene stratigraphic units mapped
 - (Yegua, Cook Mountain, Sparta, Weches, Queen City, Reklaw, Carrizo, Wilcox)
- 5 aquifers
 - (Yegua, Sparta, Queen City, Carrizo, Wilcox)

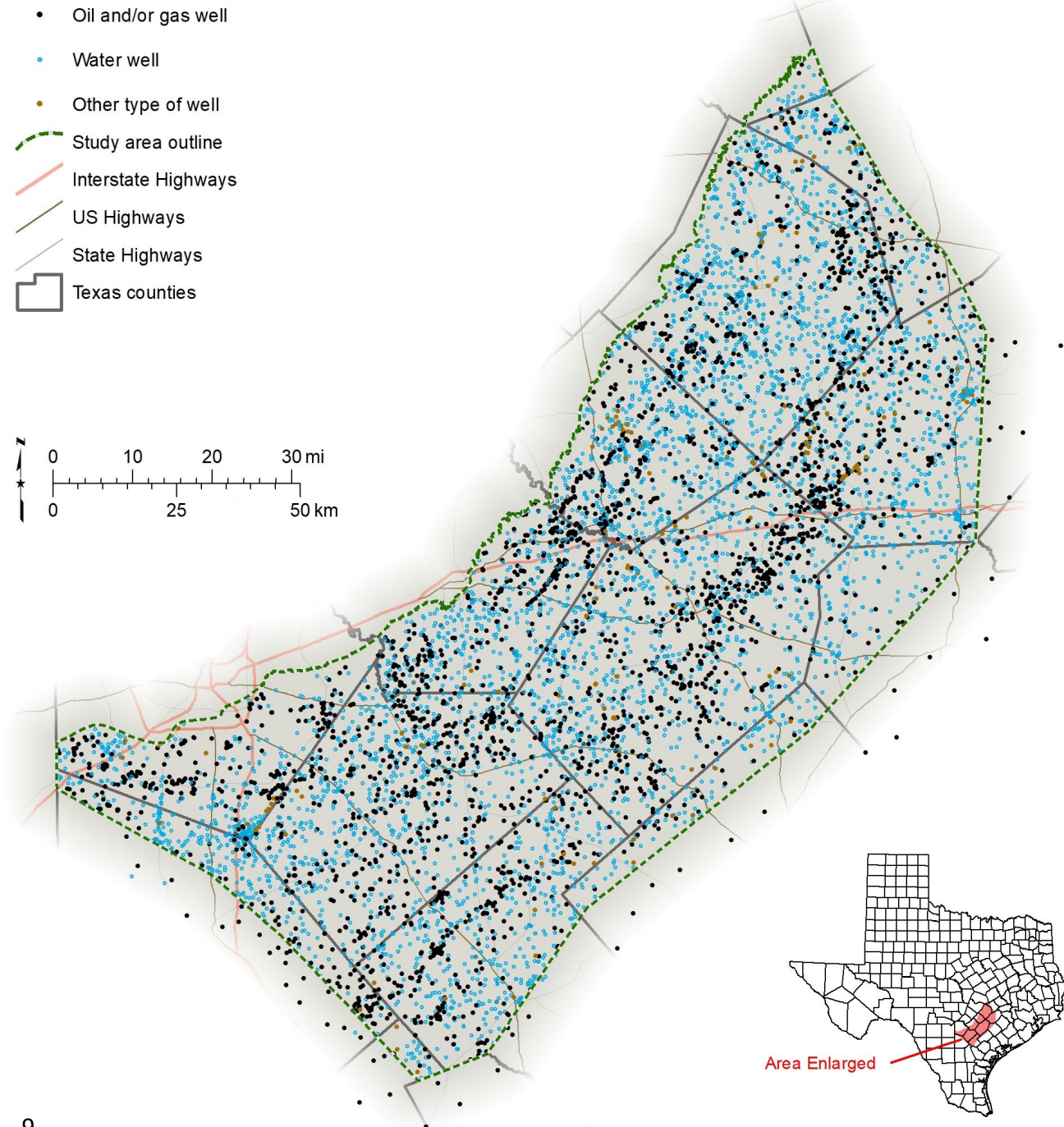
Regional Geologic Structures

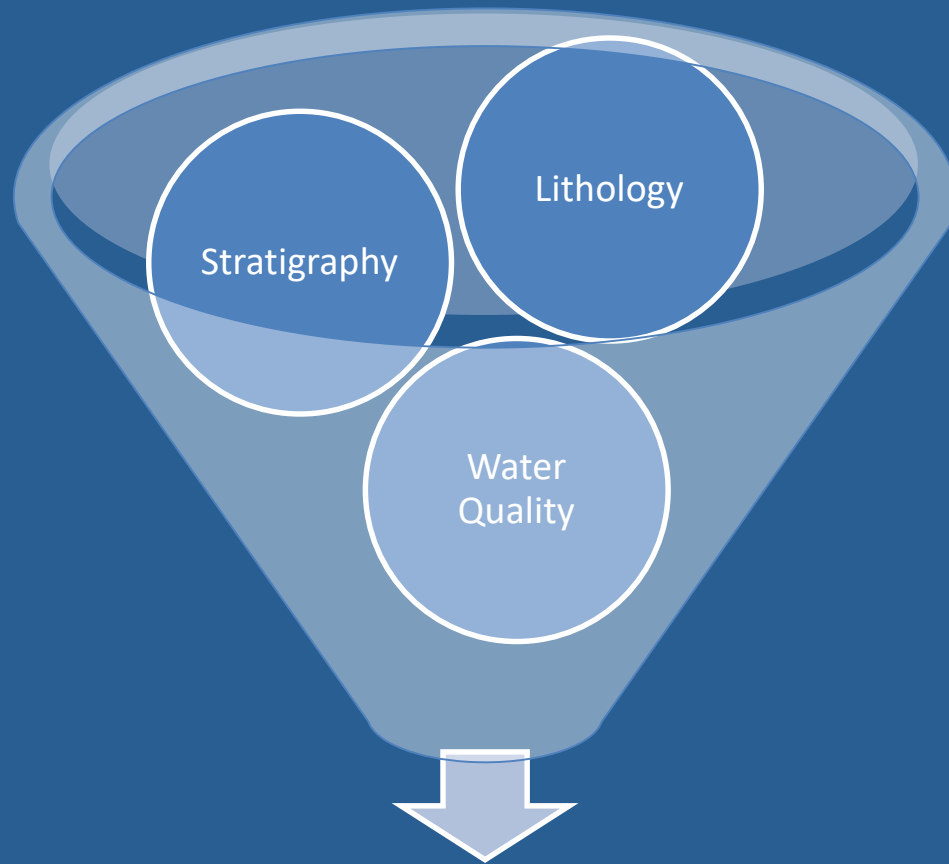
- Yoakum Canyon, based on our mapping and Dingus and Galloway (1990).
- Faults, digital Geologic Atlas of Texas (TWDB, 2007)
- More faults, volcanic centers, and Louann Salt pinch out, Tectonic Map of Texas (Breton, 2013; Ewing, 1991).



Study well control

- 8,130 wells total
 - 4,978 water wells
 - 2,941 oil and gas wells
 - 211 “other” wells

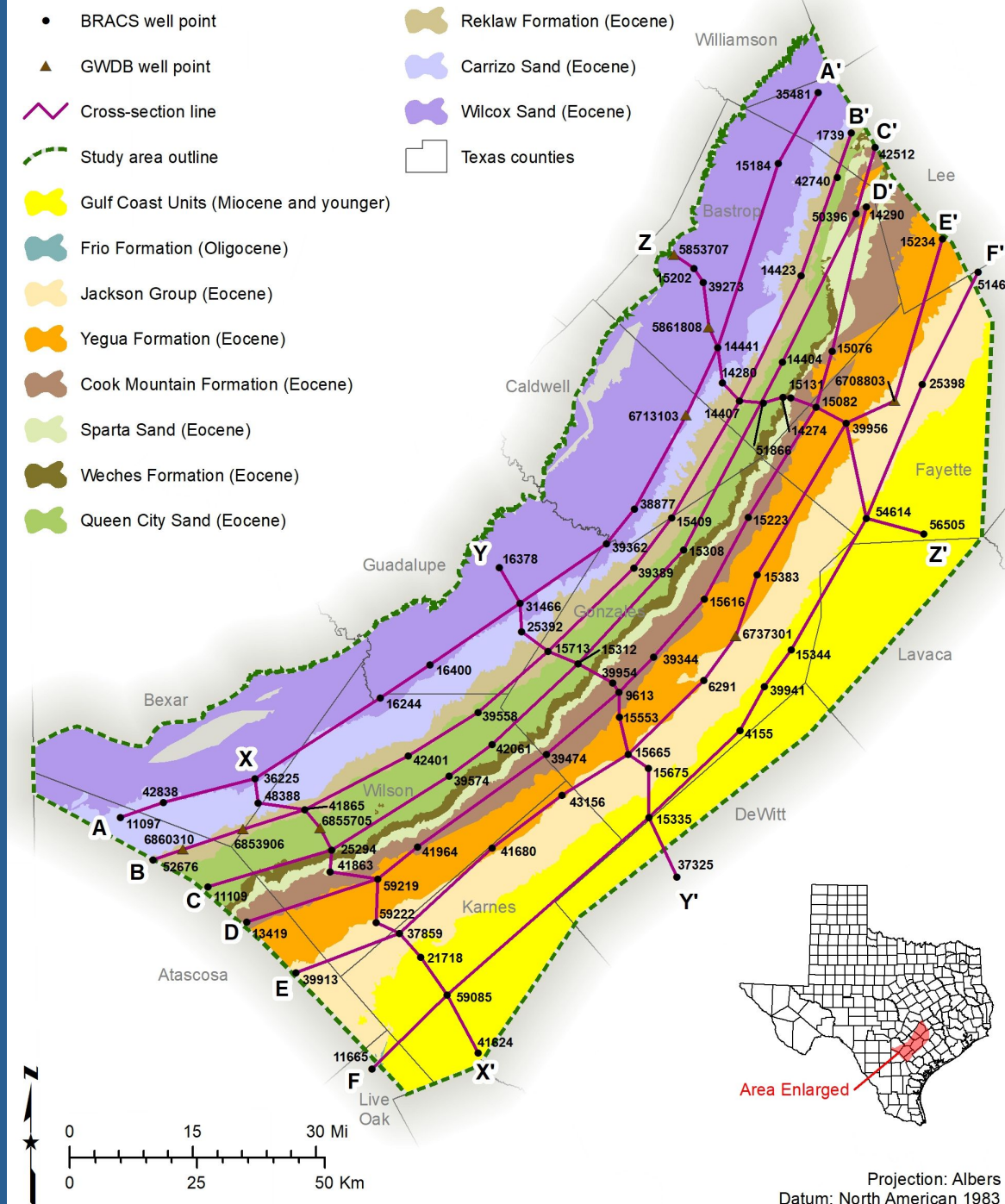




**Volume and Quality of
Brackish Groundwater**

$$\begin{aligned} &\text{Area (Extent)} \\ &\quad \times \\ &\text{Saturated Thickness (Net Sand)} \\ &\quad \times \\ &\text{Porosity (Specific Yield)} \\ &\quad = \\ &\text{Volume (acre-feet)} \end{aligned}$$

Epoch	Group	Formation	USGS nomenclature	Texas Hydrogeologic unit	
Eocene	Jackson	Caddell	Vicksburg-Jackson confining unit	Yegua-Jackson Aquifer	
		Moody's Branch			
	Claiborne	Yegua	Upper Claiborne Aquifer	Confining unit	
		Cook Mountain	Middle Claiborne Confining unit		
		Hiatus	Middle Claiborne Aquifer	Sparta Aquifer	
		Sparta		Confining unit	
		Weches	Queen City Aquifer	Confining unit	
		Hiatus			
		Queen City	Lower Claiborne confining unit	Confining unit	
		Reklaw			
		Wilcox	Hiatus	Lower Claiborne – upper Wilcox Aquifer	Carrizo-Wilcox Aquifer
			Carrizo		
	Hiatus		Middle Wilcox Aquifer	Confining unit	
	Sabinetown				
Rockdale	Middle Wilcox Aquifer		Confining unit		
Seguin					
Paleocene	Midway	Wills Point	Midway confining unit	Confining unit	



Stratigraphic column showing relationship between the epochs, formations, and hydrogeologic units. The United States Geological Survey (USGS) nomenclature is based on Ryder (1996). Texas hydrogeologic units are based on TWDB (2007a) and George and others (2011). This table does not reflect the entire Jackson or Midway group stratigraphy. This table is not scaled vertically in uniform units of time.

Stratigraphy

- Studied cross-sections
- Picks from geophysical well logs
- Stored in BRACS Database (MS Access)
- Interpolated to surfaces in ArcGIS

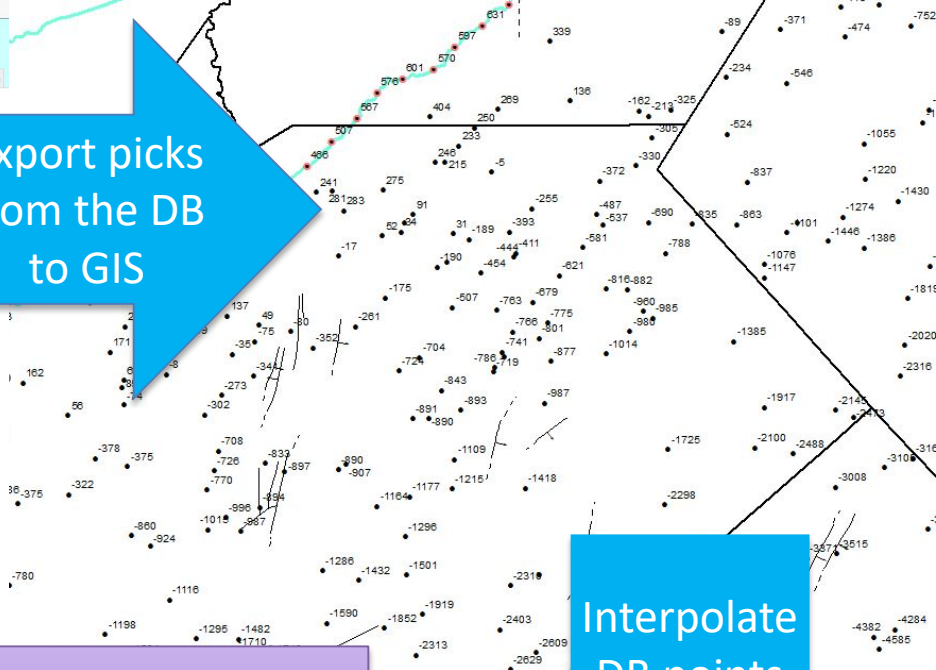
TWDB WSC IWT BRACS Geophysical Log Search Task

BRACS Well ID: 42051

Location and Well IDs | Lithology and Stratigraphy | Digital Well Logs | TDS Analysis using Geophysical Well Logs | Aquifer Test Information | Water Quality | Static Water Level | Well Construction

Lithologic Description					Stratigraphic Description				
Record Number	Geologic Pick	Top Depth Bottom Depth Thickness	Lithologic Description	Source of Data Initials Last Change	Record Number	Geologic Pick	Top Depth Bottom Depth Thickness	Stratigraphic Description	Source of Data Initials Last Change
6	Lithologic	0	No Record		1	Stratigraphic	0	Queen City Formation	Geophysical Well Log
		70	No Record				160		
		70	GEOPHYSICAL WELL LOG				160		12/19/2012
7	Lithologic	70	Sand		2	Stratigraphic	160	Reklaw Formation	Geophysical Well Log
		90	Sand				270		8/24/2015
		20	GEOPHYSICAL WELL LOG				110		8/24/2015
8	Lithologic	90	Clay		3	Stratigraphic	270	Carizzo Formation	Geophysical Well Log
		125	Clay				992		8/24/2015
		35	GEOPHYSICAL WELL LOG				722		8/24/2015
9	Lithologic	125	Clay		4	Stratigraphic	992	Wilcox Group	Geophysical Well Log
		130	Clay				2040		2/16/2015
		5	GEOPHYSICAL WELL LOG				1048		2/16/2015
10	Lithologic	130	Sand		5	Stratigraphic	2040	Midway Group	Geophysical Well Log
		145	Sand						2/16/2015
		15	GEOPHYSICAL WELL LOG						2/16/2015
11	Lithologic	145	Clay with Sand						
		150	Clay with Sand						
		5	GEOPHYSICAL WELL LOG						

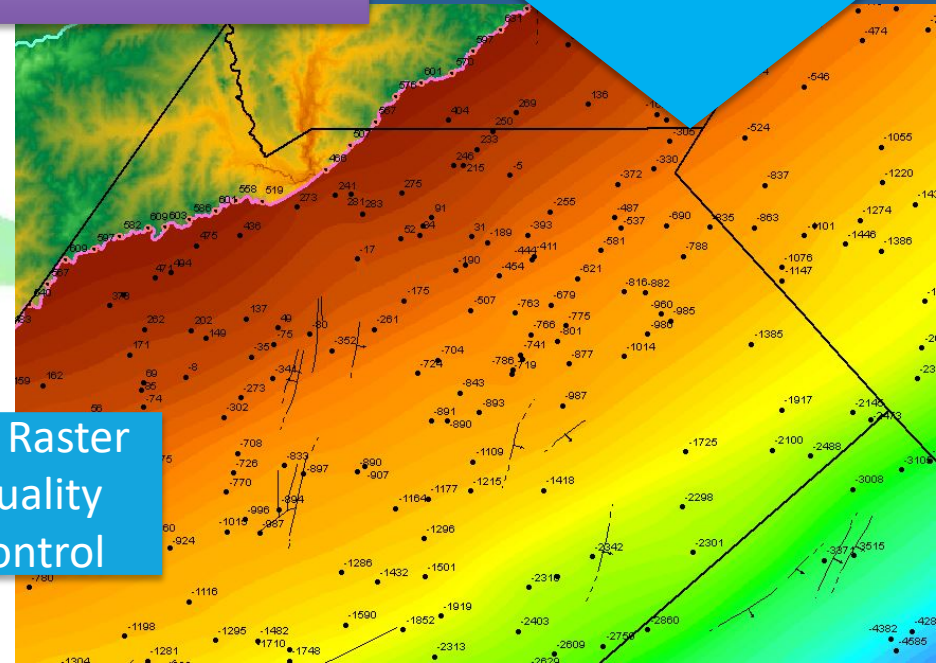
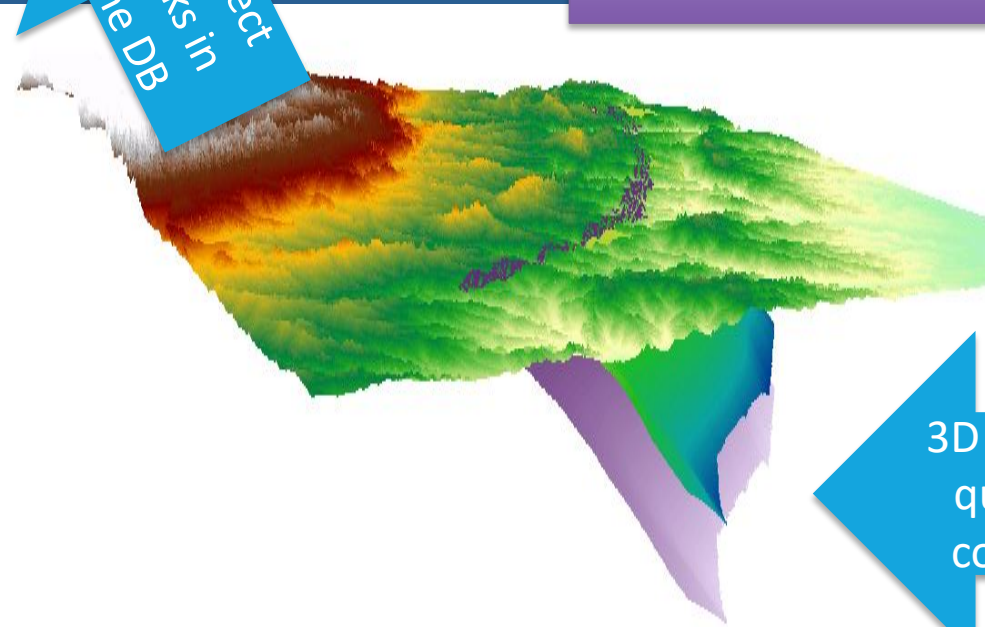
Export picks from the DB to GIS



Interpolate DB points to rasters

BRACS Study Iterative Workflow

Correct picks in the DB



3D Raster quality control

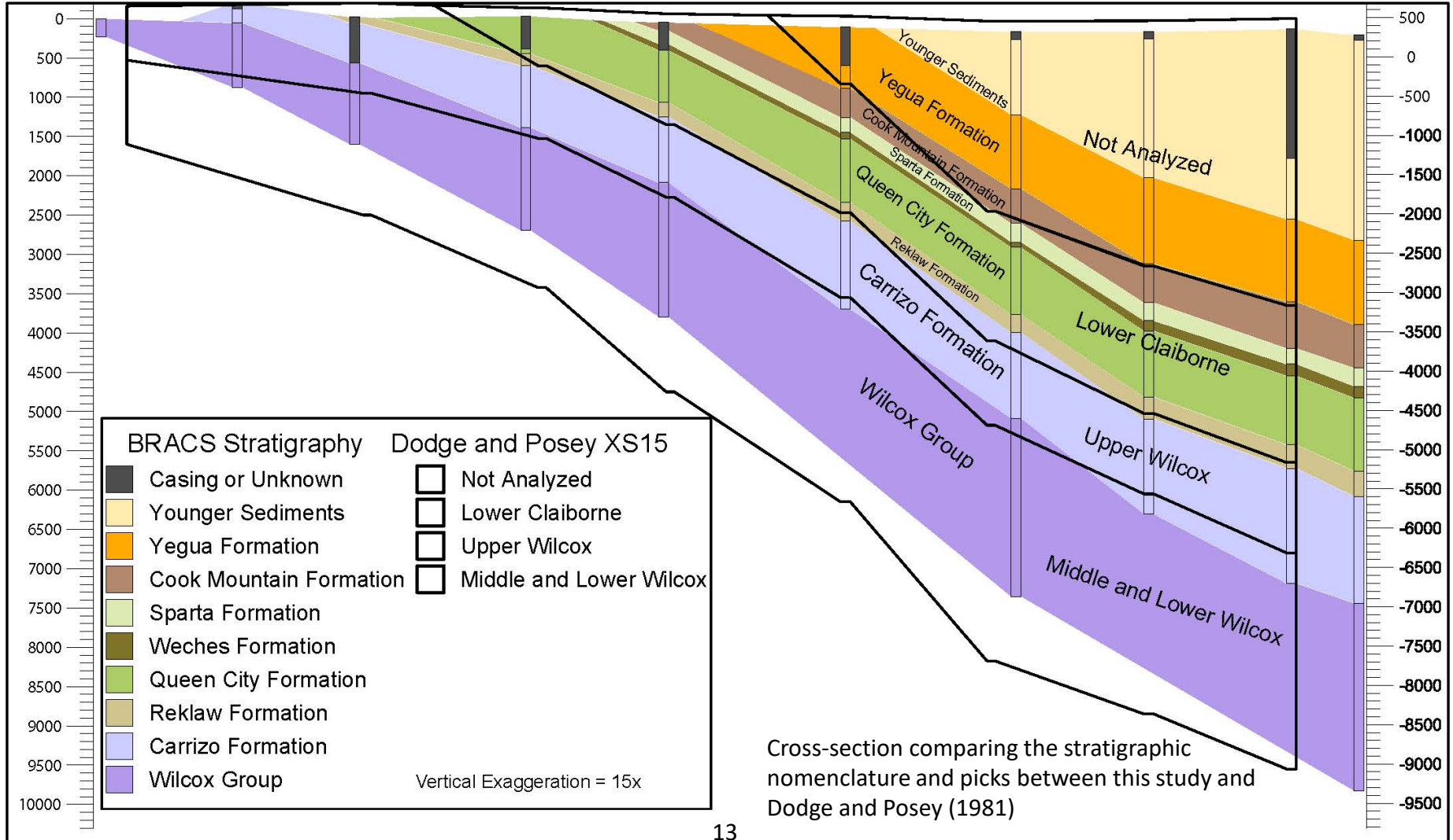
XS2
NW

XS2'
SE

Wilson County

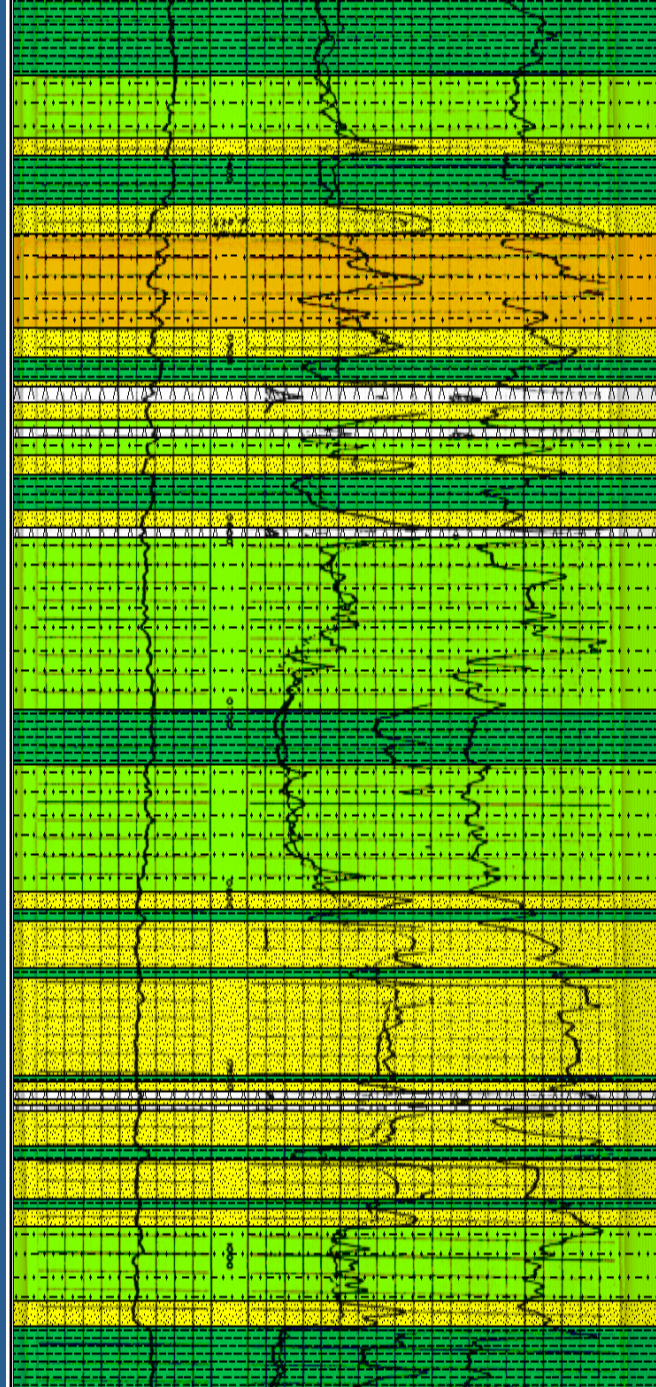
Karnes County

BRACS ID: 41936 15-1 41938 20942 42042 15-3 20951 15-4 4726 15-5 41603 15-6 4311 15-7 9621 15-8 21720



Net Sands

- Only done on aquifers
- Lithology interpreted from geophysical well logs and from driller's reports from the TDLR and GWDB
- Categorized as sand, sand with clay, clay with sand, or clay
- Data distribution varied by source
- Interpolated to surfaces in ArcGIS



BRACS Well ID 14385

Lithology: DESCRIPTION & COLOR OF FORMATION MATERIAL

Top (ft.)	Bottom (ft.)	Description
0	4	BROWN CLAY
4	9	RED CLAY
9	46	WHITE-YELLOW CLAY/IRON ROCK
46	60	SANDY GRAY SHALE/IRON ROCK
60	95	BLACK-GRAY SAND/IRON ROCK
95	170	SWAMPY GREEN-GRAY SHALE
170	198	SANDY BROWN SHALE/SAND
198	230	GRAY SHALE/SMALL ROCKS/LIGNITE
230	267	SANDY GRAY SHALE/LIGNITE/SAND
267	304	FINE TO MEDIUM GRAY SAND/ROCKS
304	358	CRUMBLY GRAY-BROWN SHALE
358	370	ROCKY/CRUMBLY GRAY-BROWN SHALE
370	371	ROCK

Simplified Lithology

Clay (0%)

Sandy clay (35%)

Sand (100%)

Clay (0%)

Sandy clay (35%)

Clay (0%)

Sand (100%)

Shale (0%)

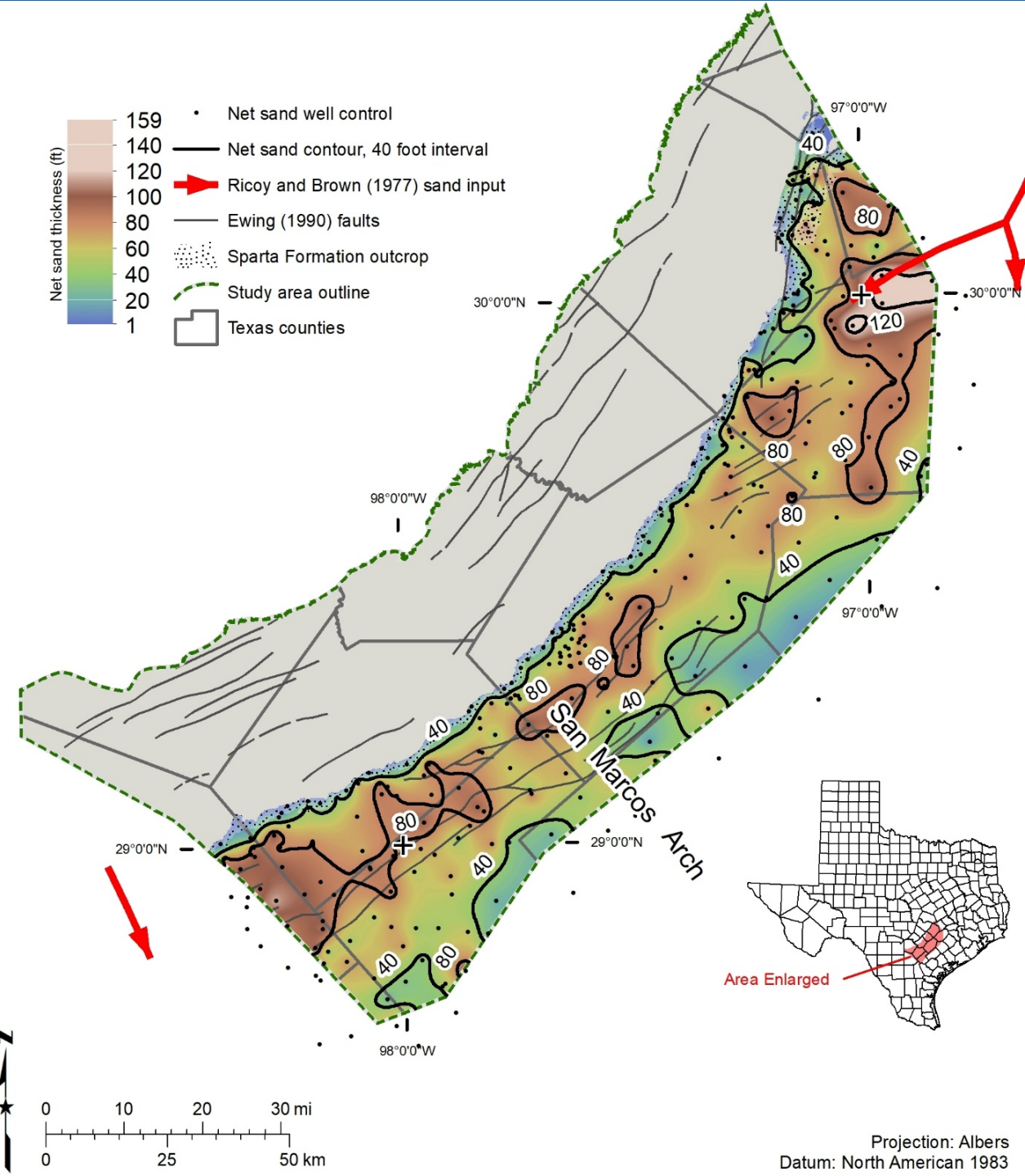
Unknown (0%)

BRACS Well ID 14271

<https://www2.twdb.texas.gov/apps/waterdatainteractive/GetReports.aspx?Num=42017&Type=SDR-Well>

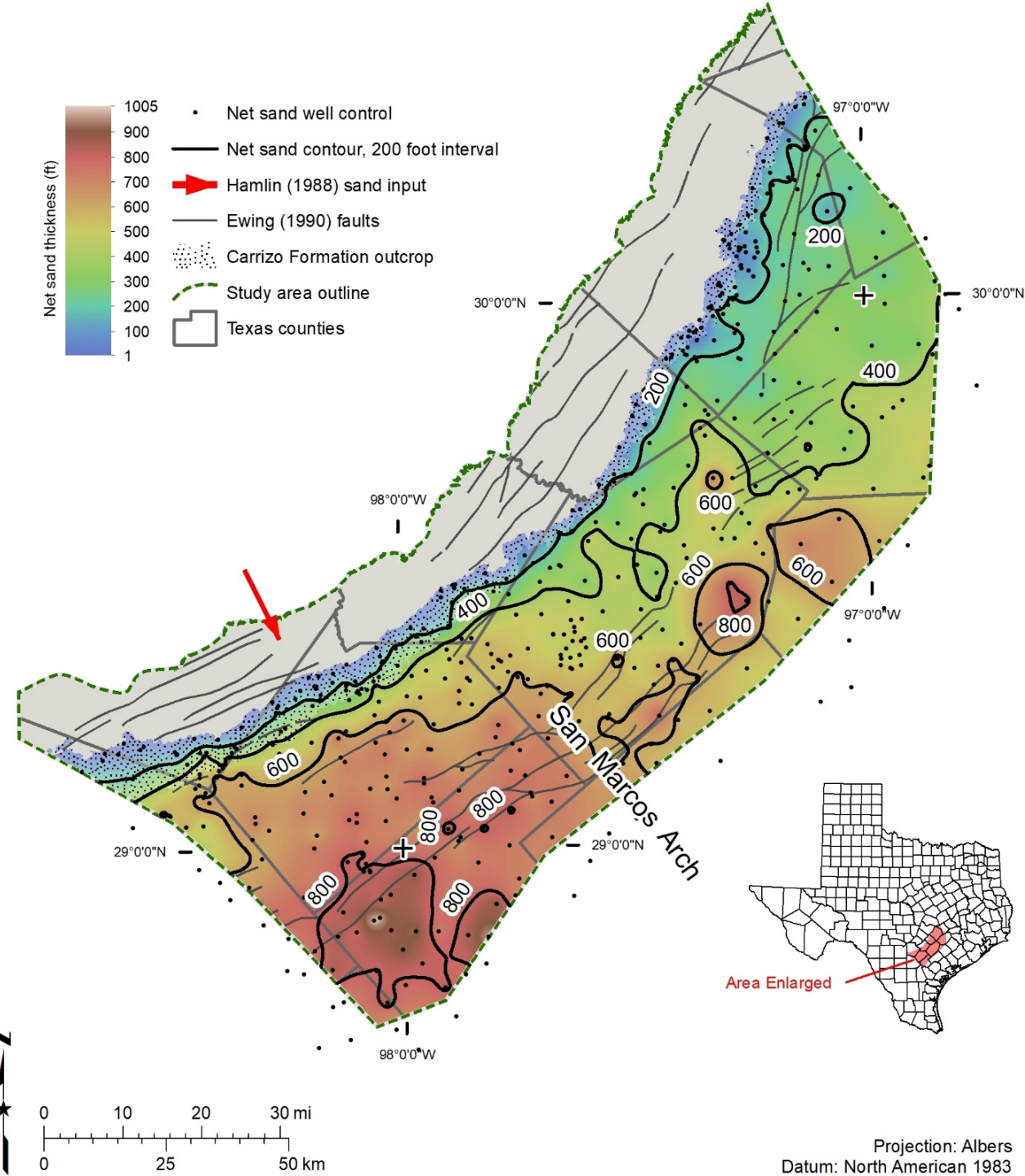
Sparta Aquifer Net Sands

- 0 to >140 feet
- 335 wells
 - Well types
 - 155 water wells
 - 175 oil and gas
 - 5 “other” wells
 - Data Sources
 - 197 geophysical logs interpreted
 - 138 drillers’ descriptions simplified
- Sand inputs outside the study area



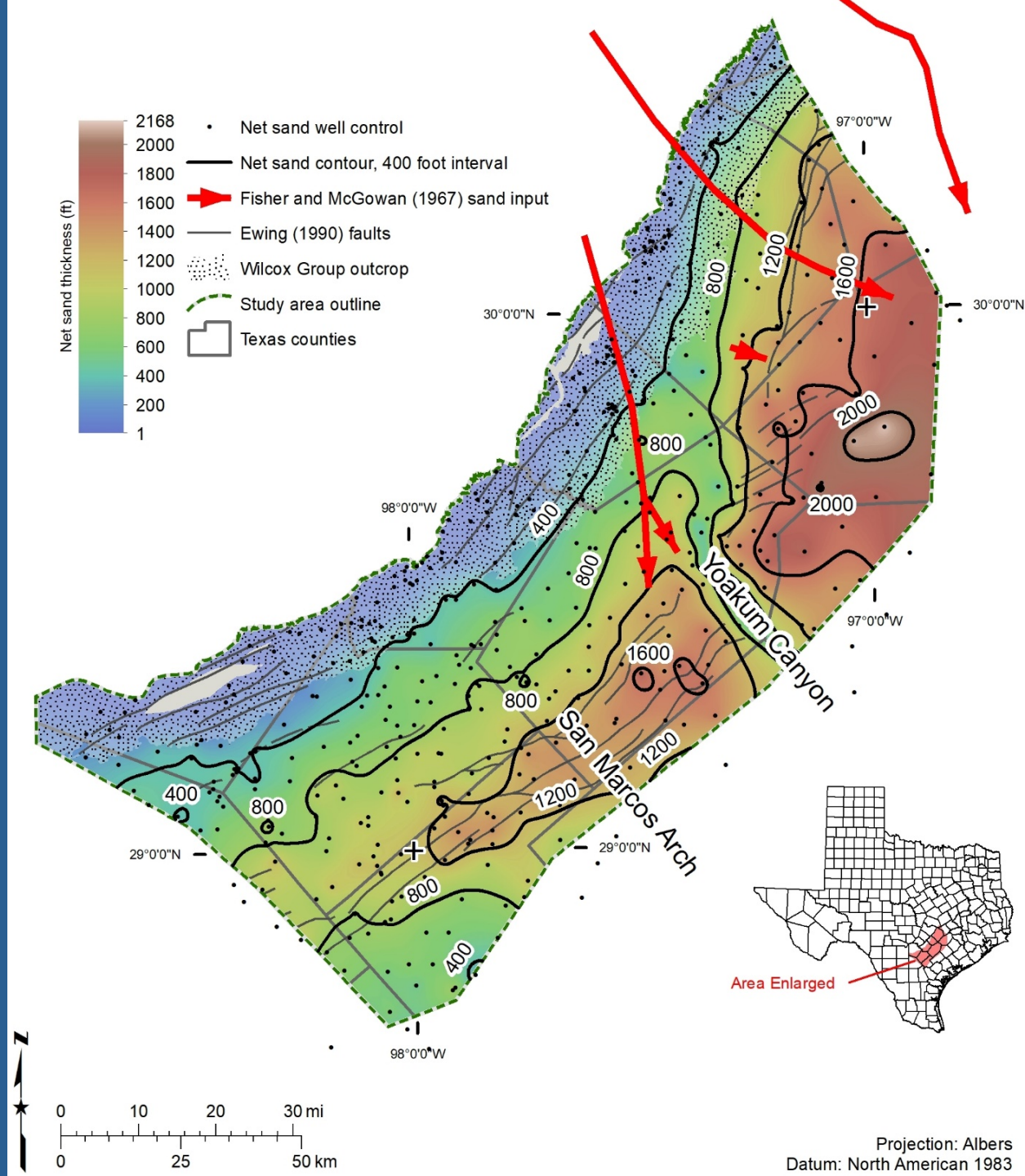
Carrizo Aquifer Net Sands

- 0 to >1,000 feet
- 526 wells
 - Well types
 - 202 water wells
 - 302 oil and gas
 - 22 “other” wells
 - Data Sources
 - 327 geophysical logs interpreted
 - 199 drillers’ descriptions simplified
- Sand input south of San Marcos Arch
- Yoakum Canyon thickening?



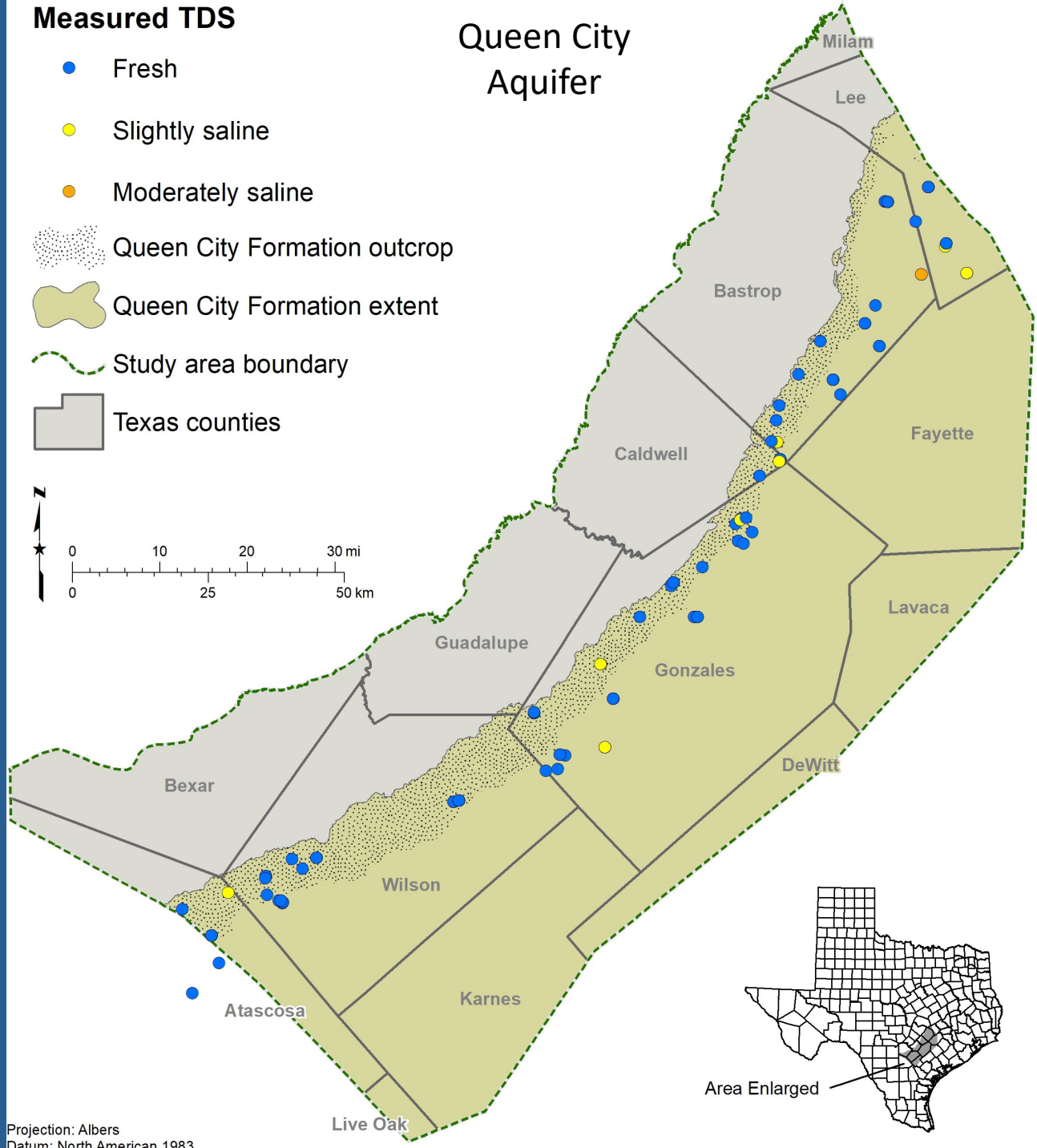
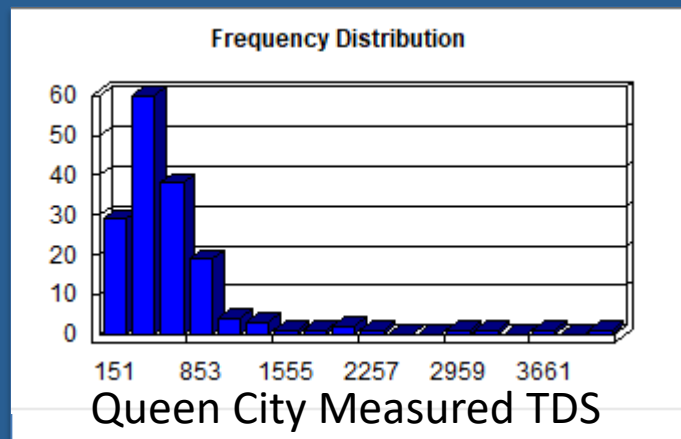
Wilcox Aquifer Net Sands

- 0 to >2,000 feet
- 499 wells
 - Well Types
 - 136 water wells
 - 356 oil and gas
 - 7 “other” wells
 - Data source
 - 366 geophysical logs interpreted
 - 133 drillers’ descriptions simplified
- Sand input north of San Marcos Arch
- Bifurcated by Yoakum Canyon



Water Quality, measured

- Groundwater Database
- Water Data Interactive Viewer
- <https://www2.twdb.texas.gov/apps/waterdatainteractive/groundwaterdataviewer>
- Data distribution biased by where wells were drilled
- Aquifer determination



Water Quality, calculated (TDS_{calc})

- 911 oil & gas wells with 5,139 TDS_{calc} values
- The R_{wa} Minimum Method (Resistivity Water Apparent) is based on the relationship between water salinity and resistivity.
- A simplified version of Archie's equation (1942) assumes 100% water saturation and Winsauer factor = 1 :

$$R_w = R_o \cdot \phi^m$$

where:

- R_o = resistivity of the formation (units: ohm-meter)
- R_w = resistivity of water (units: ohm-meter)
- ϕ = porosity (units: percent)
- m = cementation exponent (units: dimensionless)

- **Resistivity → specific conductance → total dissolved solids**
- Presentation with all the math and parameters:

http://www.twdb.texas.gov/innovativewater/bracs/doc/PowerPoints/4-1_Croskrey_Utilizing_Resistivity_Logs_QC_Fm_TDS_20190325.pdf

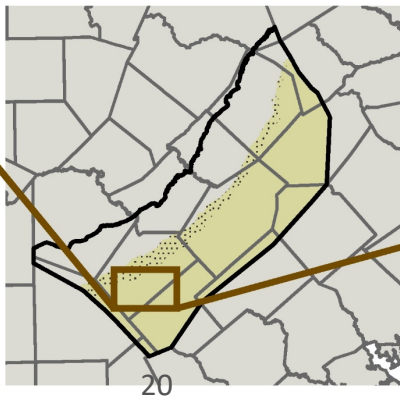
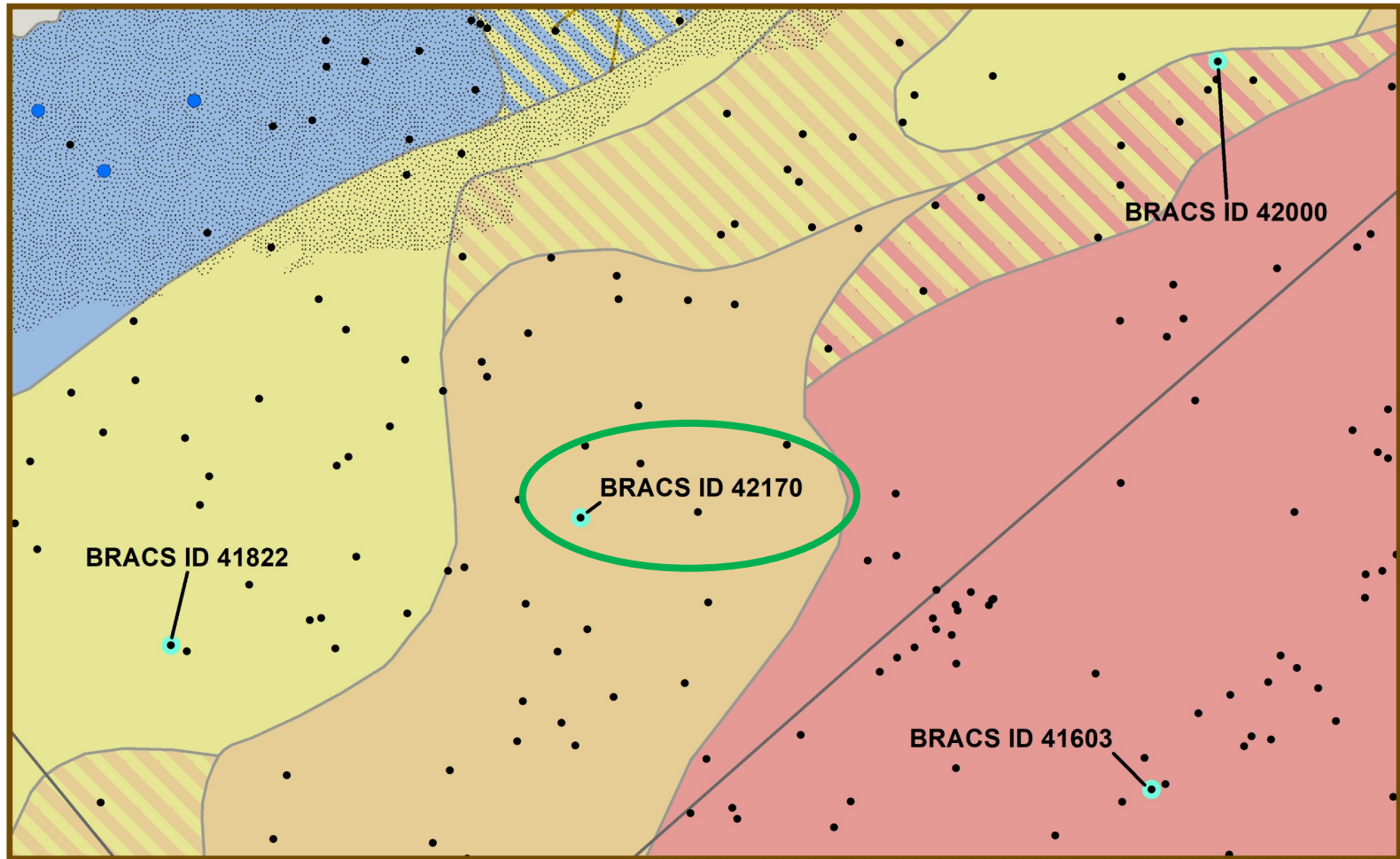


Measured TDS

- Fresh
- Slightly saline
- Moderately saline

Salinity zone

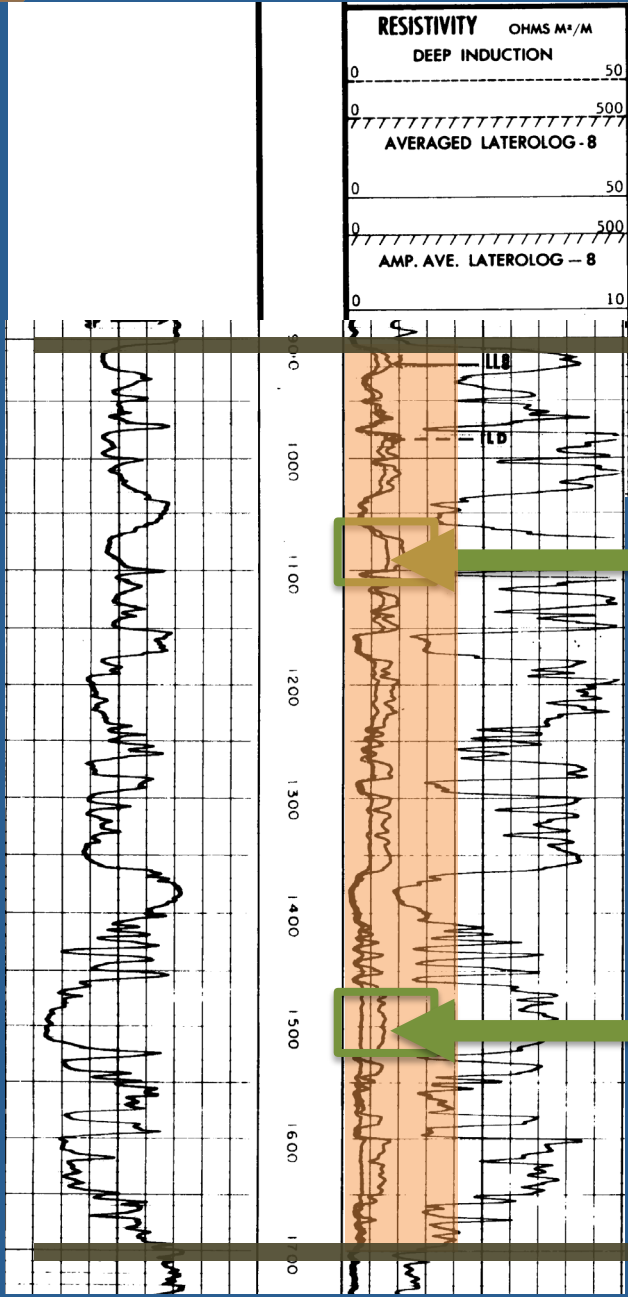
- Fresh
- Fresh and slightly saline mixed zone
- Slightly saline
- Slightly saline and moderately saline mixed zone
- Slightly saline, moderately saline, and very saline mixed zone
- Moderately saline
- Very saline
- Well used in the study with a geophysical well log
- Queen City Formation outcrop
- Queen City Formation extent
- Texas counties



Projection: Albers
Datum: North American 1983



Moderately saline well 42170



Top of the Queen City Formation at 903 feet below Kelly Bushing

8,889 mg/L

Bottom of the Queen City Formation at 1,702 feet below Kelly Bushing

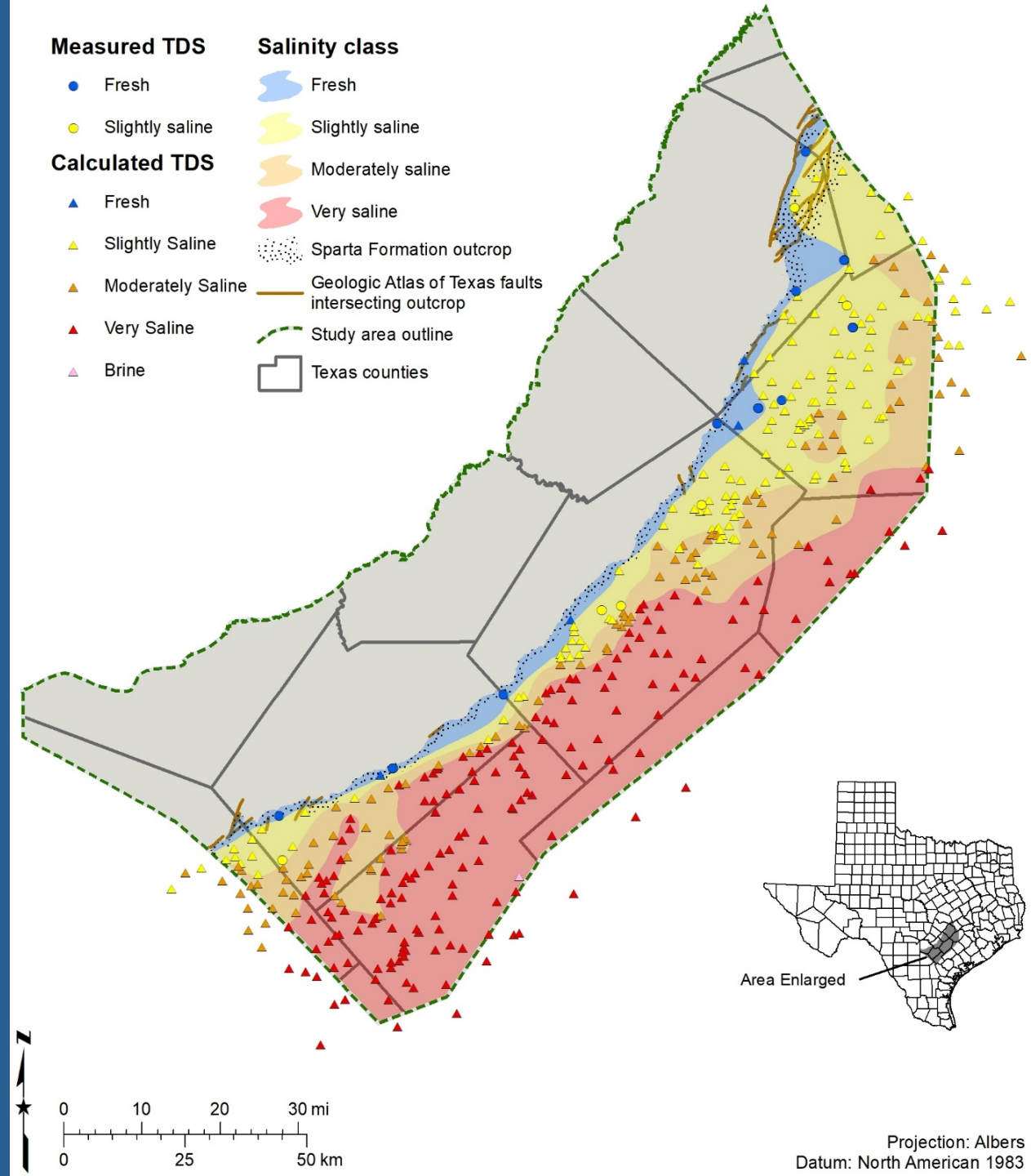
Value	Parameter	Units
7903	Depth total (bottom of borehole), Dt	Feet below Kelly Bushing
1090	Depth formation, Df	Feet below Kelly Bushing
69	Temperature surface, Ts	Degrees Fahrenheit
201	Temperature bottom hole, Tbh	Degrees Fahrenheit
7.5	Deep resistivity, Ro	Ohm-meter
0.39	Porosity, ϕ	Percent
0.56	ct conversion factor, ct	Dimensionless
1.75	Cementation exponent, m	Dimensionless
1	Water quality correction factor, R_{wCRw}	Dimensionless

$$TDS = ct * \frac{10,000}{\frac{\phi^m * Ro}{R_{wCRw}} * \frac{(Tbh - Ts * Df + Ts) + 6.77}{77 + 6.77}}$$

$$= 3,478 \text{ mg/L}$$

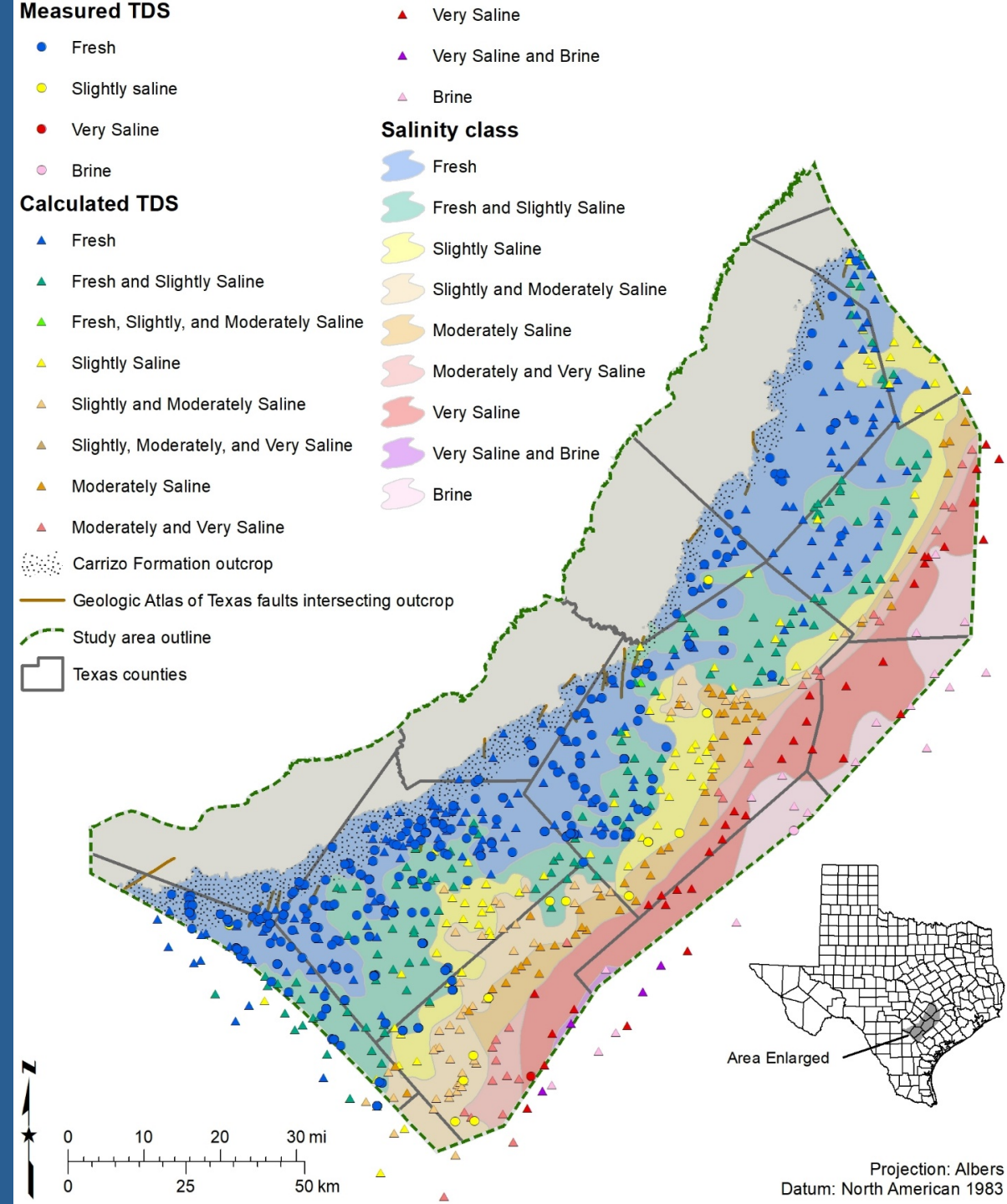
Sparta Aquifer Salinity Classes

- water quality samples
 - 31 wells:
 - 21 fresh,
 - 9 slightly saline, and
 - 1 moderately saline
- Estimated salinity geophysical well logs
 - 427 wells with 427 calculations
 - 427 wells with 427 salinity class intervals:
 - 4 fresh,
 - 136 slightly saline,
 - 112 moderately saline,
 - 174 very saline, and
 - 1 brine



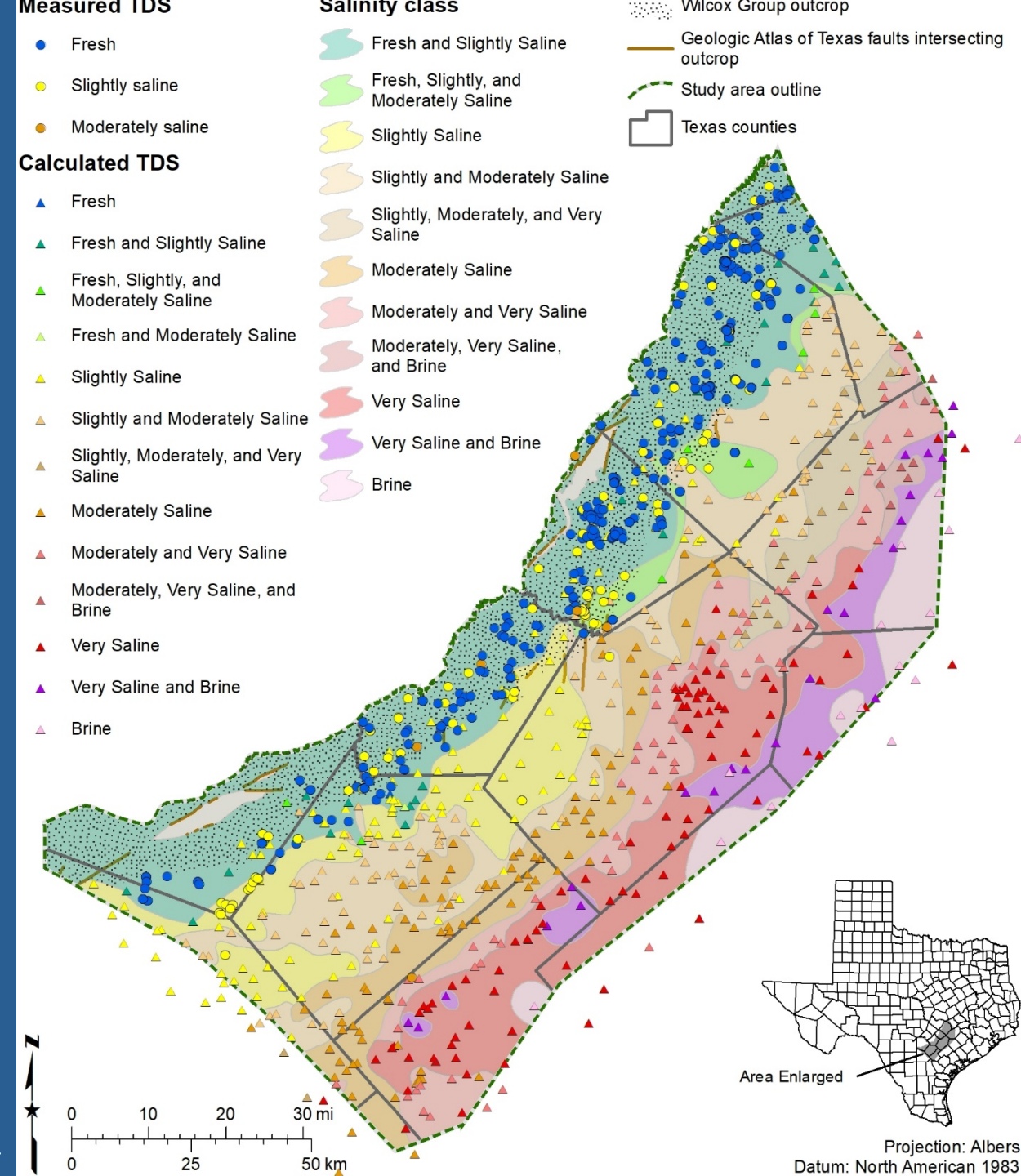
Carrizo Aquifer Salinity Classes

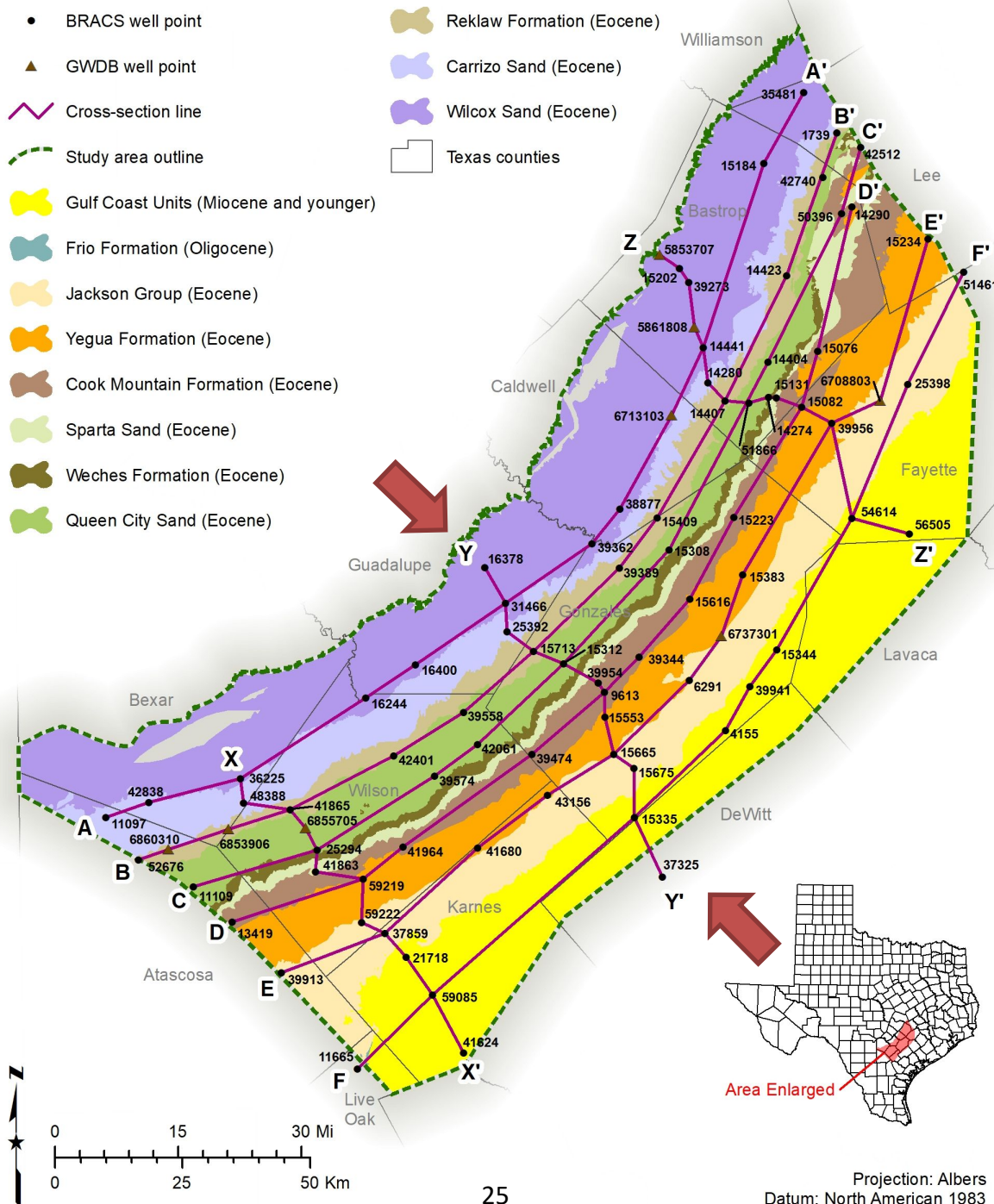
- Water quality samples
 - 250 wells:
 - 229 fresh,
 - 16 slightly saline,
 - 1 very saline,
 - and 1 brine
- Estimated salinity geophysical well logs
 - 590 wells with 1,283 calculations
 - 587 wells with 870 salinity class intervals:
 - 306 fresh,
 - 297 slightly saline,
 - 170 moderately saline,
 - 72 very saline, and
 - 25 brine



Wilcox Aquifer Salinity Classes

- Water quality samples
 - 384 wells:
 - 286 fresh,
 - 92 slightly saline, and
 - 6 moderately saline
- Estimated salinity geophysical well logs
 - 618 wells with 1,867 calculations
 - 612 wells with 952 salinity class intervals:
 - 36 fresh,
 - 302 slightly saline,
 - 345 moderately saline,
 - 222 very saline, and
 - 47 brine





Volumes

Aquifer	Pure brackish (1,000-10,000 mg/L TDS)	Total groundwater
Yegua	42	78
Sparta	6	11
Queen City	20	52
Carrizo	57	204
Wilcox	112	321

- Units are millions of acre-feet
- In-place water, all this water is NOT recoverable
- Brackish groundwater volume doesn't include areas where brackish groundwater is mixed or stacked with fresh, very saline, or brine groundwater

Future improvements

TDS calculations

1. Acquire higher salinity water quality samples to support calibrating log analysis
2. Evaluate correction factors for mixed ion groundwater
3. Determine cementation factors
4. Evaluate the effect and presence of grain-coating (pore-filling) clay, and
5. Develop techniques for carbonate rocks

Brackish Groundwater Research

1. Productivity
2. Impact of development
3. Sustainability
4. Site specific drilling and monitoring will be required

Study conclusions

- Resistivity logs can be used to estimate water quality
- Quality of the calculations depends on:
 - Correlations, parameters, water quality type, complete log headers
- 4 of the 5 aquifers have mixed/stacked water quality regions
- All 5 aquifers in the study area have millions of acre-feet of brackish groundwater
- Provides regional understanding of sand and salinity distribution

QUESTIONS?

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Innovative Water Technologies

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<http://www.twdb.texas.gov/innovativewater/index.asp>

2017 Water Plan:

<http://www.twdb.texas.gov/waterplanning/swp/2017/index.asp>