House Bill 30 Stakeholder Meeting

September 9, 2016
Austin, Texas

The following presentation is based upon professional research and analysis within the scope of the Texas Water Development Board’s statutory responsibilities and priorities but, unless specifically noted, does not necessarily reflect official Board positions or decisions.

Agenda

• Introduction	Robert Mace, TWDB
• H.B. 30 objectives	John Meyer, TWDB
• Carrizo-Wilcox Aquifer	John Meyer
• Gulf Coast Aquifer	Steve Young, INTERA
• Blaine Aquifer	Vince Clause, ARS
• Rustler Aquifer	Van Kelley, INTERA
• Next steps	John Meyer
• Public comments	Robert Mace
• Closing remarks	Robert Mace

House Bill 30, 84th Texas Legislature

- Map brackish groundwater production zones and estimate 30- and 50-year production without causing significant impact to water quality or water quantity in freshwater aquifers
- Make recommendations for reasonable monitoring
- Work with groundwater conservation districts and stakeholders

H.B. 30 Brackish Groundwater Production Zone Criteria

Must have brackish water	In areas of the state with moderate to high availability and productivity
Must have hydrogeologic barriers	Sufficient to prevent significant impacts to fresh water availability or quality
Cannot be within these boundaries	Edwards Aquifer within the Edwards Aquifer Authority and the Barton Springs-Edwards Aquifer Conservation District, Harris-Galveston Subsidence District, and the Fort Bend Subsidence District
Cannot be already in use	Brackish water already serving as a significant source of water supply for municipal, domestic, or agricultural
Cannot be used for wastewater injection	Permitted under Title 2 of Texas Water Code, Chapter 27

H.B. 30 Study Completion Timeline

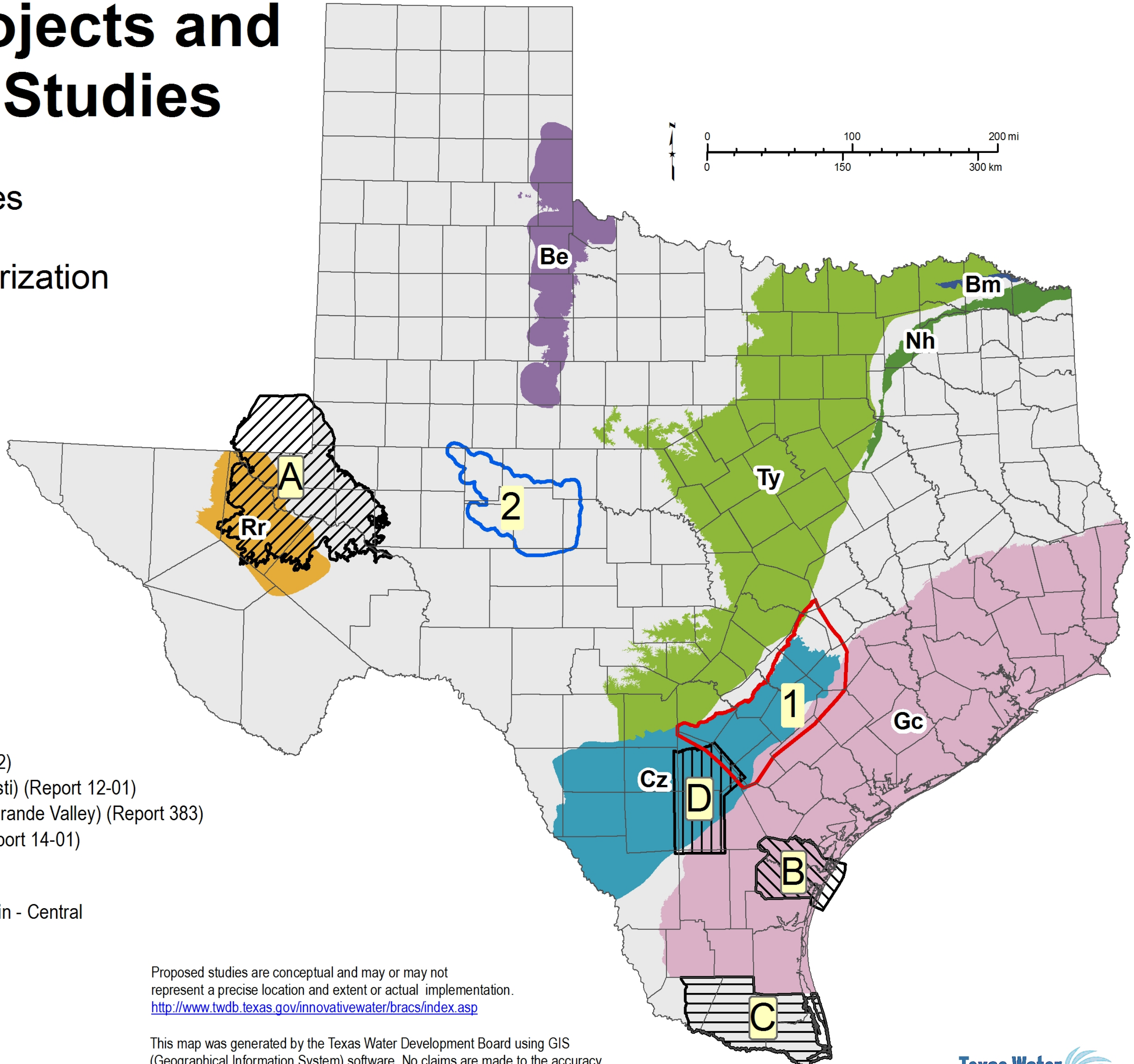
- Four aquifer projects that must be completed by December 1, 2016:
  - the Carrizo-Wilcox Aquifer located between the Colorado River and the Rio Grande,
  - the Gulf Coast Aquifer and sediments bordering that aquifer,
  - the Blaine Aquifer, and
  - the Rustler Aquifer.

- Include status report in every biennial desalination report, next report due December 1, 2016

- Map remaining aquifers in the state by December 1, 2022

H.B. 30 Projects and BRACS Studies

Brackish
Resources
Aquifer
Characterization
System



House Bill 30 Projects

2016 Aquifers

- Be. Blaine
- Cz. Carrizo
- Gc. Gulf Coast
- Rr. Rustler

2017 Aquifers

- Bm. Blossom
- Nh. Nacatoch
- Ty. Trinity

Completed Studies

- A. Pecos Valley Aquifer (Report 382)
- B. Gulf Coast Aquifer (Corpus Christi) (Report 12-01)
- C. Gulf Coast Aquifer (Lower Rio Grande Valley) (Report 383)
- D. Queen City-Sparta aquifers (Report 14-01)

Other Studies

- 1. Aquifers of the upper coastal plain - Central
- 2. Lipan Aquifer

Proposed studies are conceptual and may or may not represent a precise location and extent or actual implementation.
http://www.twdb.texas.gov/innovativewater/bracs/index.asp

Texas Water Development Board 8/23/2016

Lots of stuff on the website!

www.twdb.texas.gov/innovativewater/bracs/HB30.asp

- Projects map
- Enrolled version of H.B. 30
- Request for Qualifications
- Board authorizations and approvals
- Video of the October 26, 2015, stakeholder meeting
- Stakeholder comments
- Meeting announcements
- Stakeholder meeting presentations
- Stakeholder meeting questions and answers
- Study reports

Carrizo-Wilcox Aquifer Study

- Contractor: The University of Texas at Austin
  Bureau of Economic Geology
- 4 Potential Production Areas (PPA) evaluated.
  PPA 1, 2, and 3 in lower Wilcox
  PPA 4 in Carrizo – upper Wilcox
- Two well fields per PPA (updip and downdip)
- Simulated pumping 5,000, 15,000, and 30,000 acre-feet per year
- Two groundwater models per well field

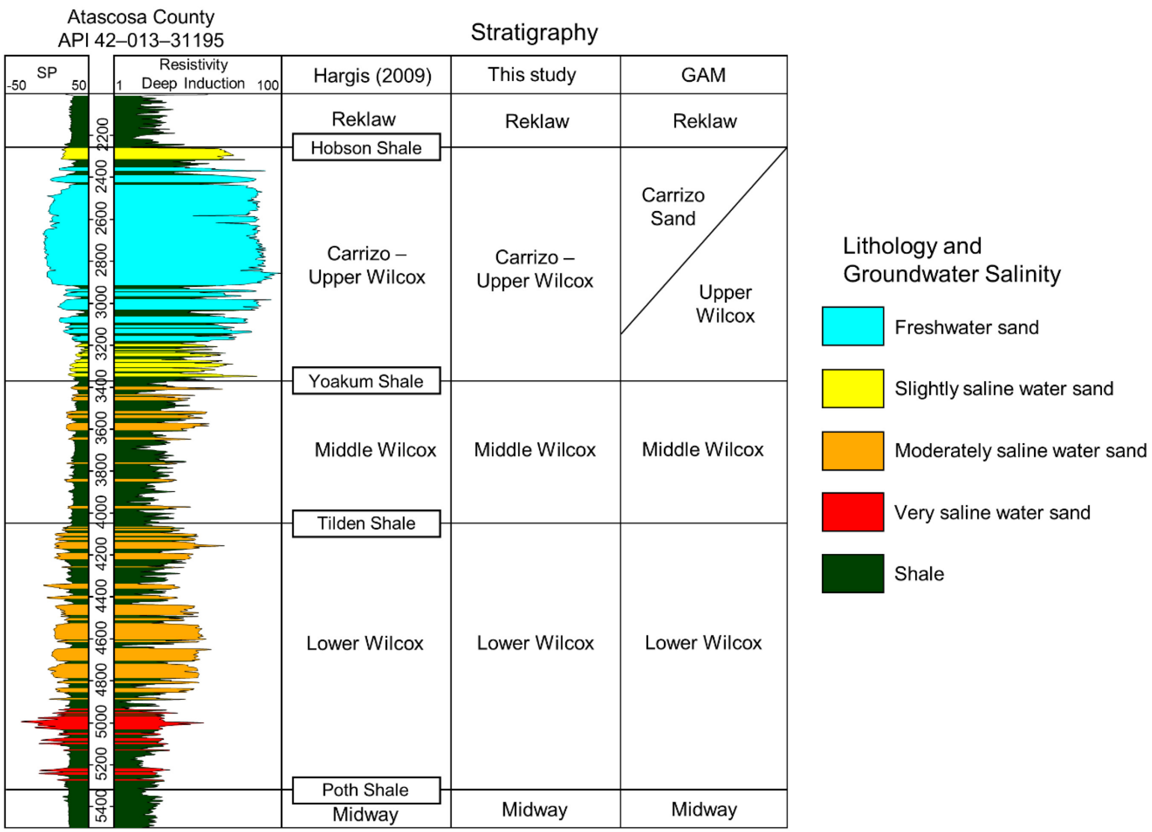
Two groundwater models used to simulate drawdown.

Aquifer properties assigned from:

1) Southern Queen City Sparta (QcSp) Groundwater Availability Model (GAM)

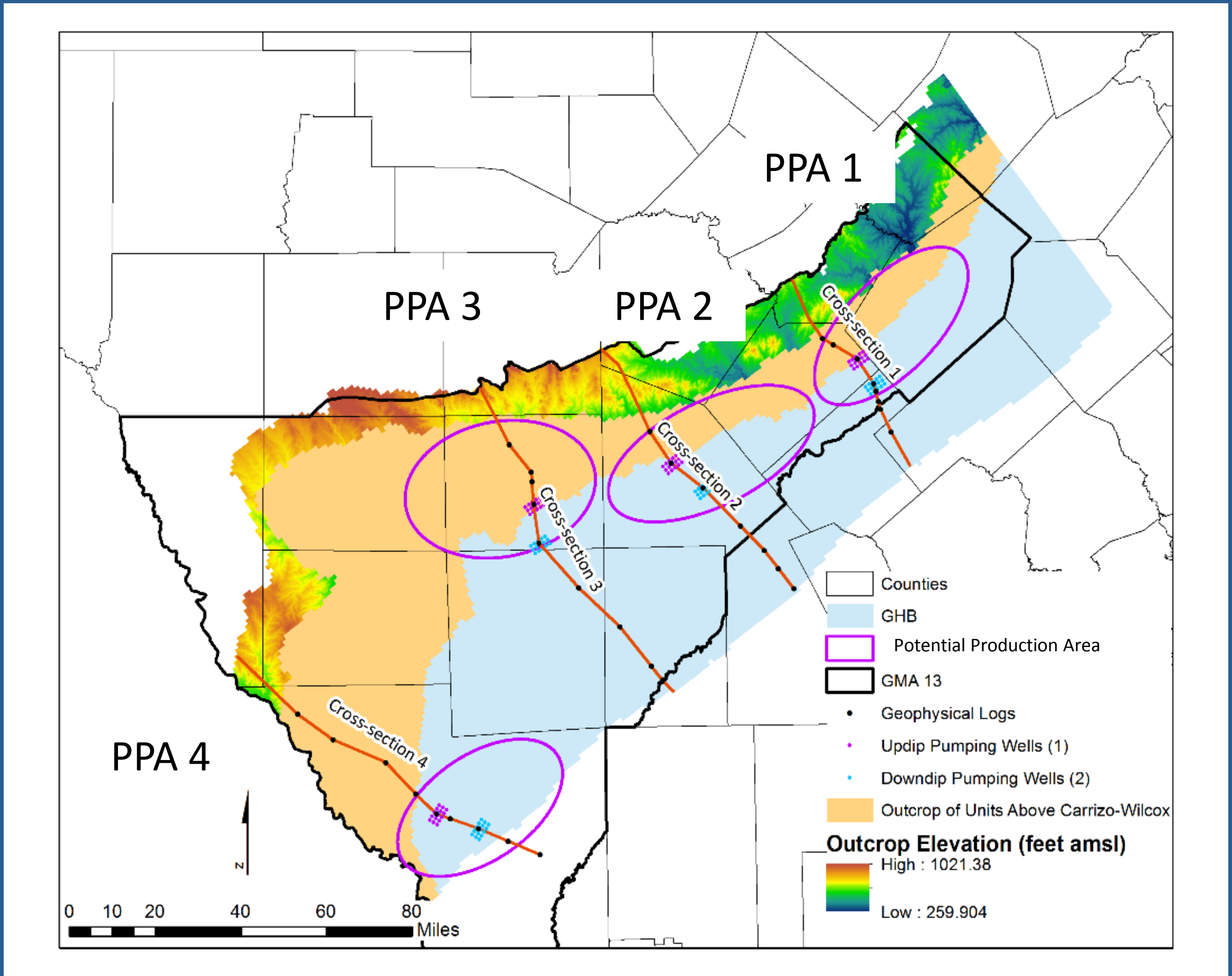
2) Carrizo-Wilcox geohydrostratigraphic model for Carrizo - Wilcox model layers and the QcSp GAM for Queen City and Sparta model layers

Carrizo – Wilcox Stratigraphy and Groundwater Salinity



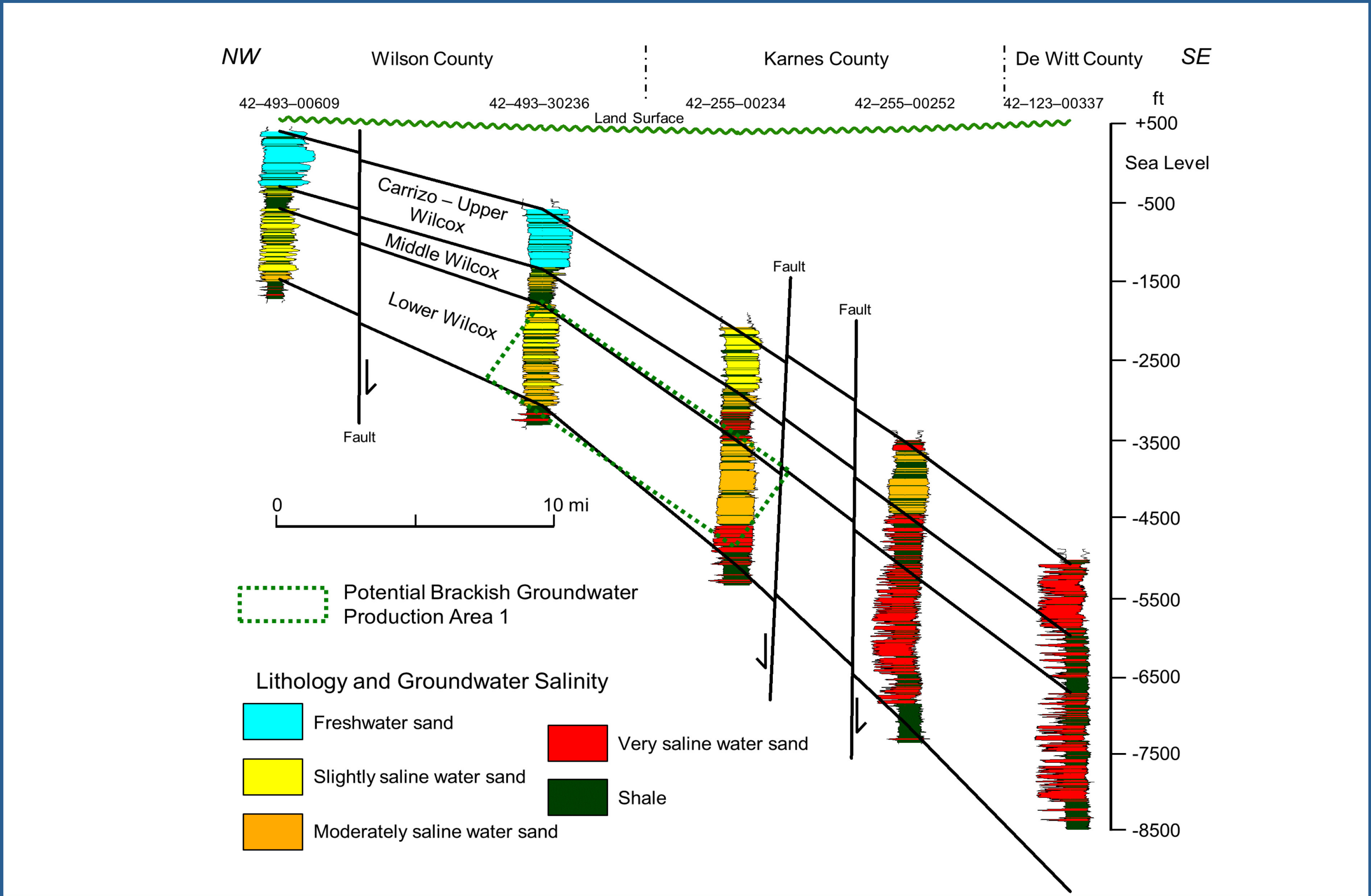
Hamlin and others, 2016

Potential Production Areas (PPA) and wellfield locations



Hamlin and others, 2016

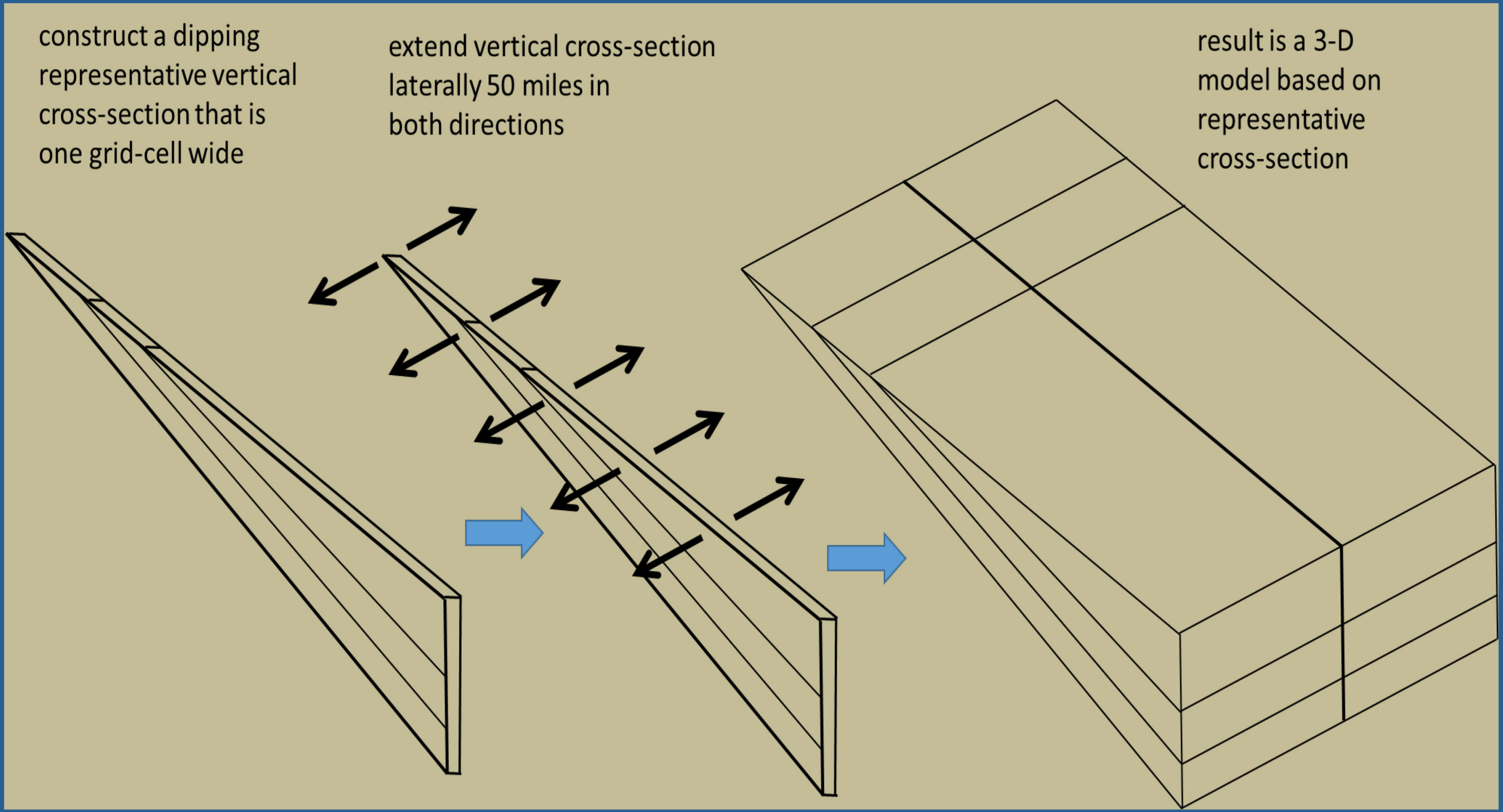
PPA 1 location in the Lower Wilcox.



Hamlin and others, 2016

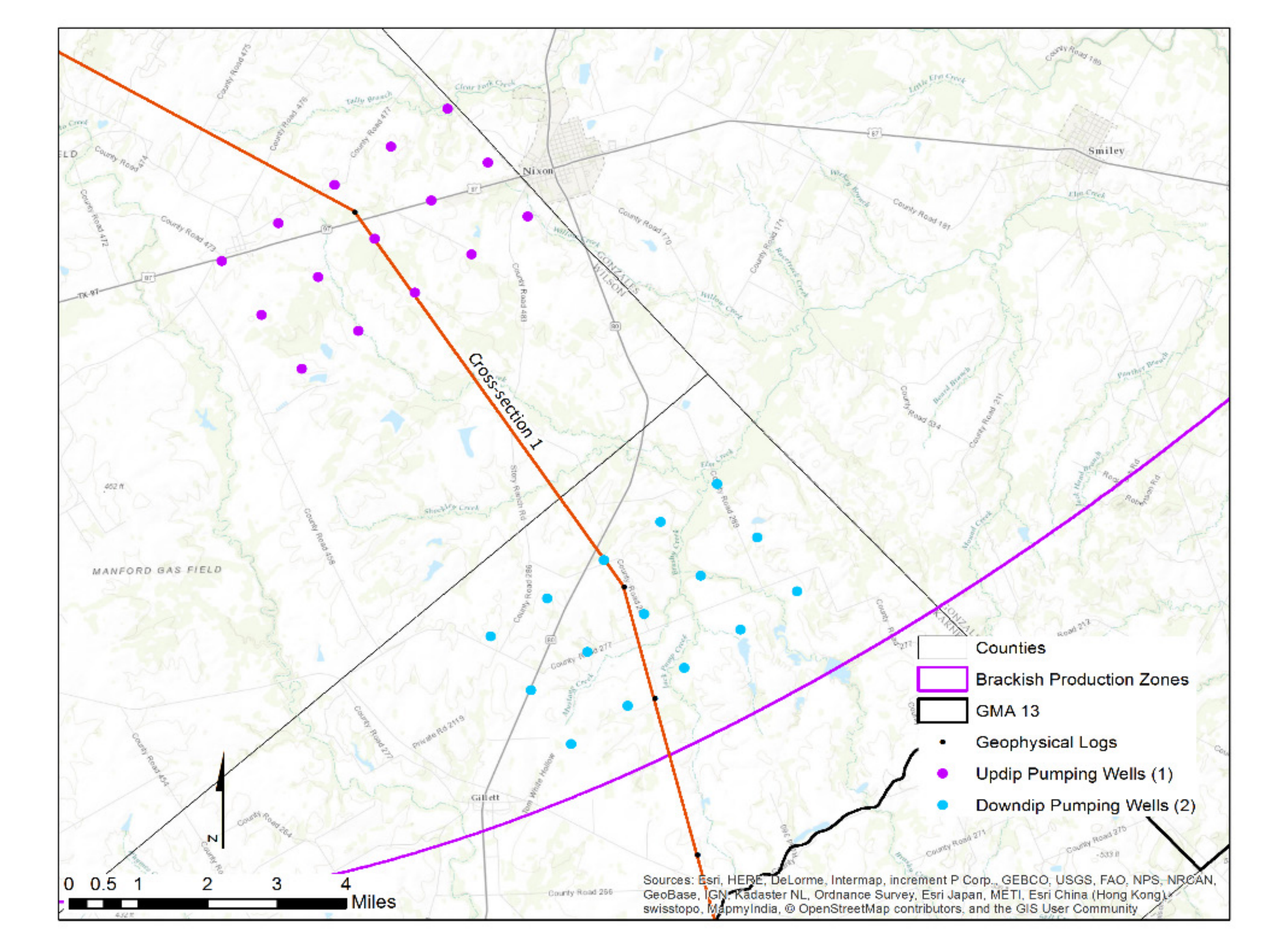
Cross-Section 1 (B)

Lateral outward replication of a vertical cross-section to construct a three-dimensional model that covers a distance of 50 miles on either side of the cross-section



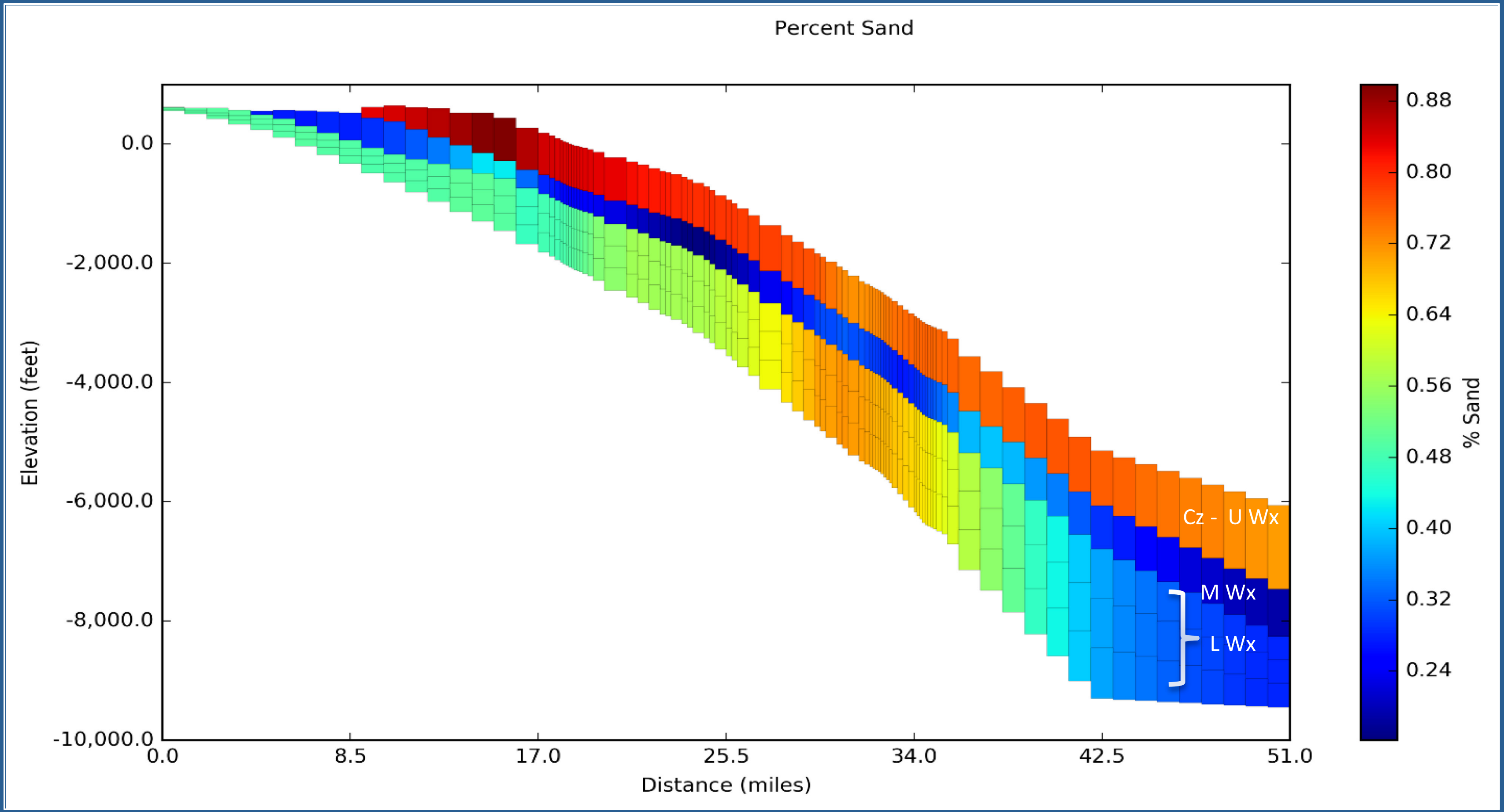
Hamlin and others, 2016

PPA 1. Location of two pumping wellfields and well locations used to model the 30,000 acre-feet per year drawdown



Hamlin and others, 2016

PPA 1. Sand fraction model layers: Carrizo – Upper Wilcox, Middle Wilcox, and Lower Wilcox



Hamlin and others, 2016

PPA 1 Wellfield 2.

Lower Wilcox is pumped.

Simulated drawdown (in feet) at monitoring locations (distance from outcrop) after pumping for 30 years and 50 years.

Wellfield 32 miles from outcrop.

Groundwater model used GAM-based hydraulic properties for the Carrizo-Wilcox Aquifer.

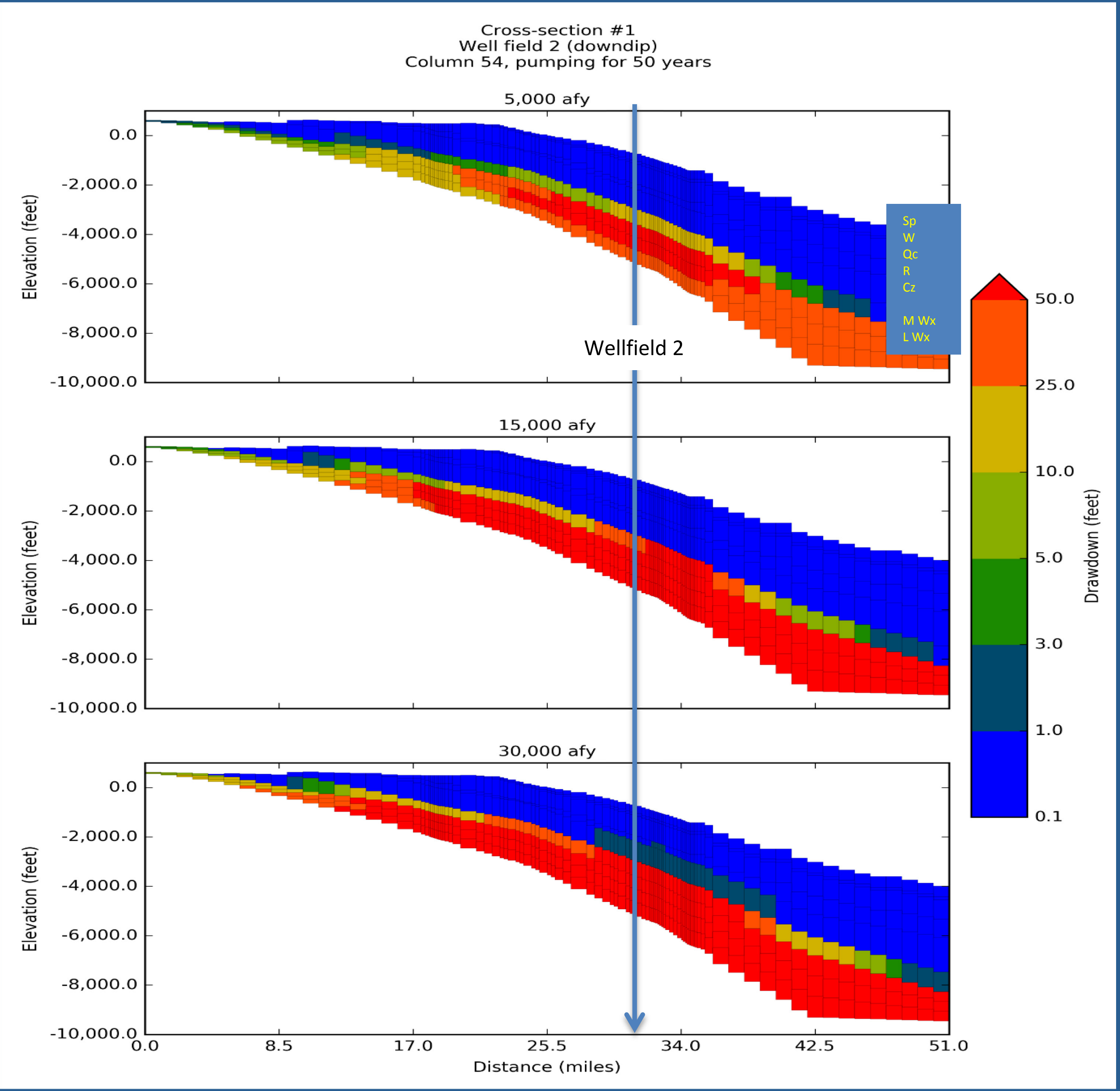
Hamlin and others, 2016

Monitoring Location (miles)	Pumping Rate (AFY)	Carrizo	Middle Wilcox	Lower Wilcox		
		Layer 5	Layer 6	Layer 7	Layer 8	Layer 9
30 Years						
2.5	5,000	Not Present	Not Present	0.59	1.1	1.2
	15,000	Not Present	Not Present	2.83	3.15	3.24
	30,000	Not Present	Not Present	5.63	6.27	6.45
5.5	5,000	Not Present	0.04	0.91	2.69	3.90
	15,000	Not Present	0.13	3.51	5.27	7.04
	30,000	Not Present	0.26	6.98	10.48	14.01
10.5	5,000	0.00	0.29	2.31	5.01	6.69
	15,000	0.01	0.87	7.33	12.54	16.52
	30,000	0.02	1.72	14.55	24.95	32.90
15.5	5,000	0.06	1.28	9.98	9.90	9.85
	15,000	0.18	3.82	29.29	27.49	26.69
	30,000	0.36	7.59	58.05	54.63	53.11
30.5	5,000	0.10	9.64	91.26	139.05	37.49
	15,000	0.29	29.02	269.15	420.99	111.09
	30,000	0.57	57.06	509.04	738.96	218.96
50 Years						
2.5	5,000	Not Present	Not Present	1.23	2.3	2.2
	15,000	Not Present	Not Present	4.95	5.40	5.51
	30,000	Not Present	Not Present	9.87	10.75	10.98
5.5	5,000	Not Present	0.11	1.62	4.28	5.88
	15,000	Not Present	0.36	5.81	8.11	10.43
	30,000	Not Present	0.73	11.58	16.17	20.79
10.5	5,000	0.01	0.53	3.58	7.23	9.45
	15,000	0.02	1.60	11.08	17.44	22.66
	30,000	0.05	3.18	22.05	34.73	45.16
15.5	5,000	0.12	2.19	13.88	13.27	13.35
	15,000	0.35	6.50	40.30	36.02	35.35
	30,000	0.70	12.93	80.04	71.66	70.43
30.5	5,000	0.18	13.32	100.26	147.72	45.21
	15,000	0.52	39.95	295.56	446.38	133.45
	30,000	1.05	78.89	561.82	789.71	263.67

PPA 1 Wellfield 2.

Simulated drawdown at 50 years after pumping at 5,000 AFY, 15,000 AFY, and 30,000 AFY.

Groundwater model used GAM-based hydraulic properties for the Carrizo-Wilcox Aquifer.

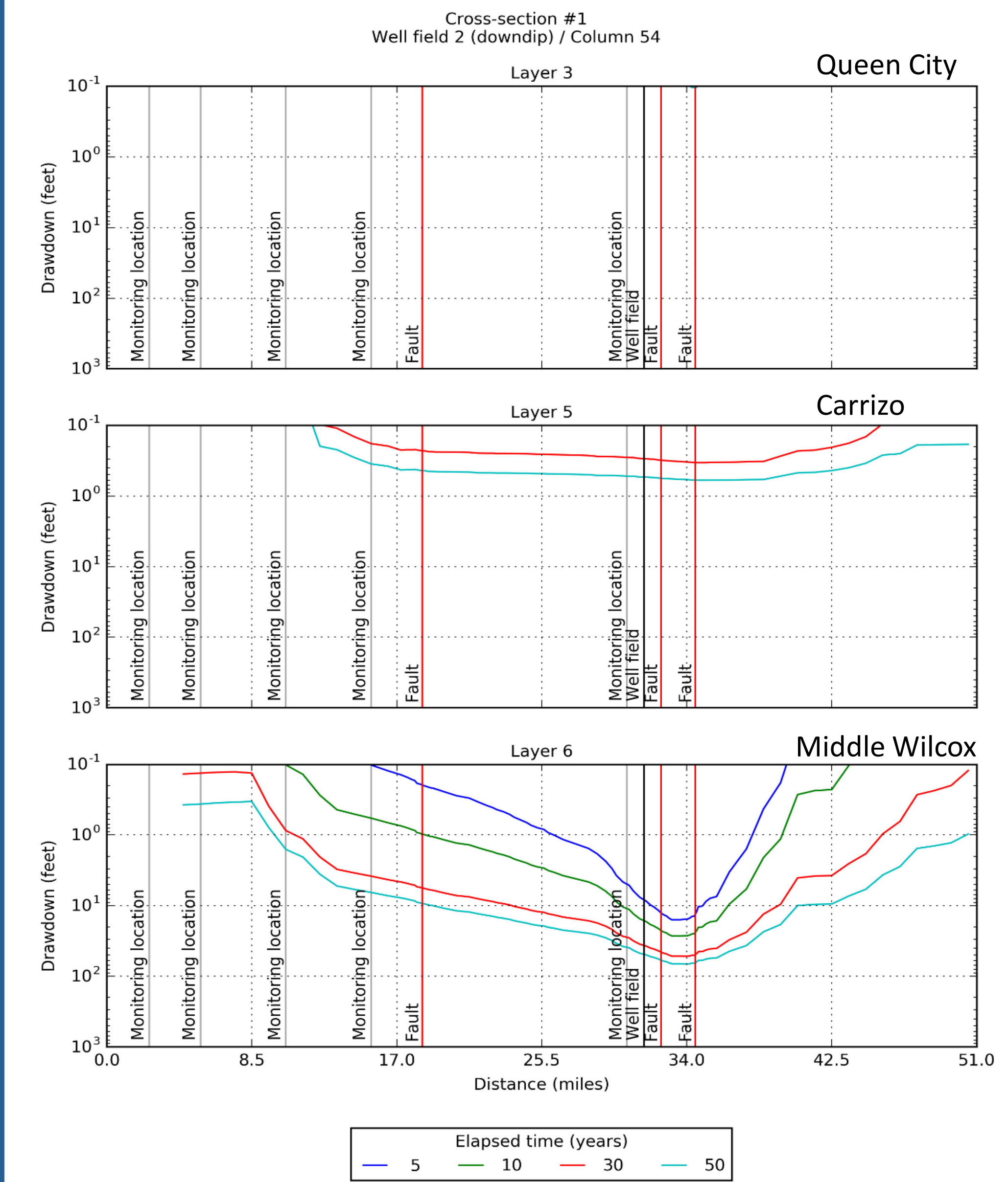


Hamlin and others, 2016

PPA 1 Wellfield 2.

Simulated drawdown at 5, 10, 30, and 50 years after pumping at 15,000 AFY.

Groundwater model used GAM-based hydraulic properties for the Carrizo-Wilcox Aquifer.

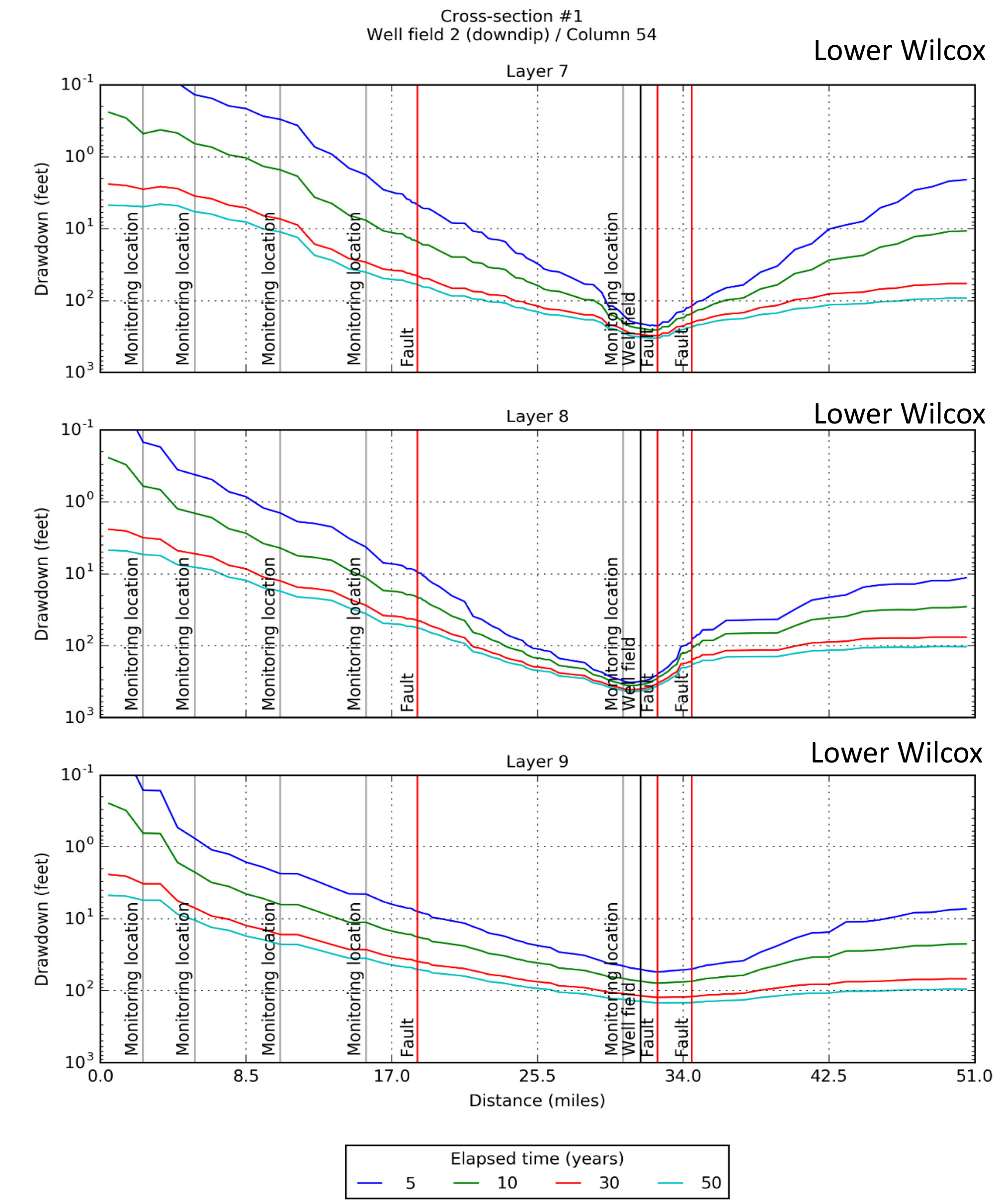


Hamlin and others, 2016

PPA 1 Wellfield 2.

Simulated drawdown at 50 years after pumping the up dip at 5,000 AFY, 15,000 AFY, and 30,000 AFY.

Groundwater model used GAM-based hydraulic properties for the Carrizo-Wilcox Aquifer.



Hamlin and others, 2016

Groundwater Volume (based on Queen City – Sparta Groundwater Availability Model Layers)

Aquifer Unit	Total Volume (Millions of Acre-feet)					Total Volume in Sand (Millions of Acre-feet)				
	Fresh	Slightly saline	Moderately saline	Very saline	Total	Fresh	Slightly saline	Moderately saline	Very saline	Total
Use of Specific Yield in Calculating the Groundwater Volume in an Unconfined Aquifer										
Carrizo	340.6	107.1	43.6	11.6	503	228.1	61.9	23.7	6.7	320.3
Upper Wilcox	69.9	120.3	128	34	352.2	27.4	45	45	10.9	128.3
Middle Wilcox	37	70.3	147.9	224.5	479.7	11.7	24.9	44.8	50.2	131.7
Lower Wilcox	16.4	77.4	144.7	471.3	709.9	3.2	30.1	57.9	108.2	199.4
Total	464	375.1	464.2	741.5	2044.9	270.4	162	171.4	176	779.7
Use of Porosity in Calculating the Groundwater Volume in an Unconfined Aquifer										
Carrizo	736.3	209.7	83.6	22	1051.6	493	120.9	45.1	12.6	671.6
Upper Wilcox	150.5	234.6	239	59.7	683.8	58.5	87.1	83	18.8	247.5
Middle Wilcox	126.5	222.2	421.4	581.2	1351.3	39.4	78.4	129.7	132.6	380.1
Lower Wilcox	58	239.2	413.3	1124	1834.5	11.2	91	162.4	274.6	539.2
Total	1071.3	905.8	1157.2	1786.9	4921.2	602.2	377.4	420.1	438.6	1838.3

Hamlin and others, 2016

Study of Brackish Aquifers in Texas –

PROJECT NO. 1 - GULF COAST AQUIFER

STAKEHOLDER MEETING #3

September 9, 2016

Austin, Texas

Presented by:

Steven Young, Ph.D, P.E., P.G.

INTERA

GEOSCIENCE & ENGINEERING SOLUTIONS

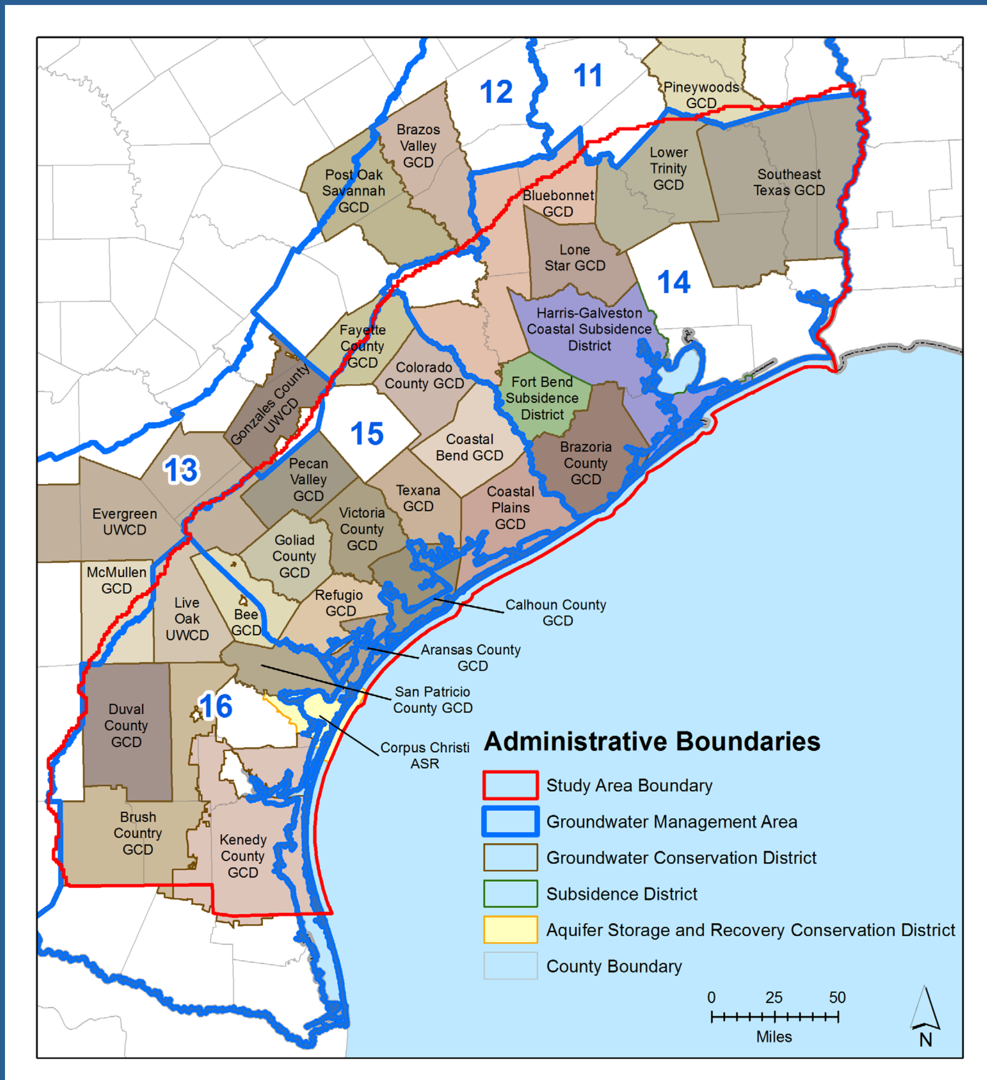
under contract to:

Texas Water Development Board

Outline

- Study Area
- Salinity Zones
- Potential Brackish Productions Areas
- Pumping Scenarios
- Case Examples

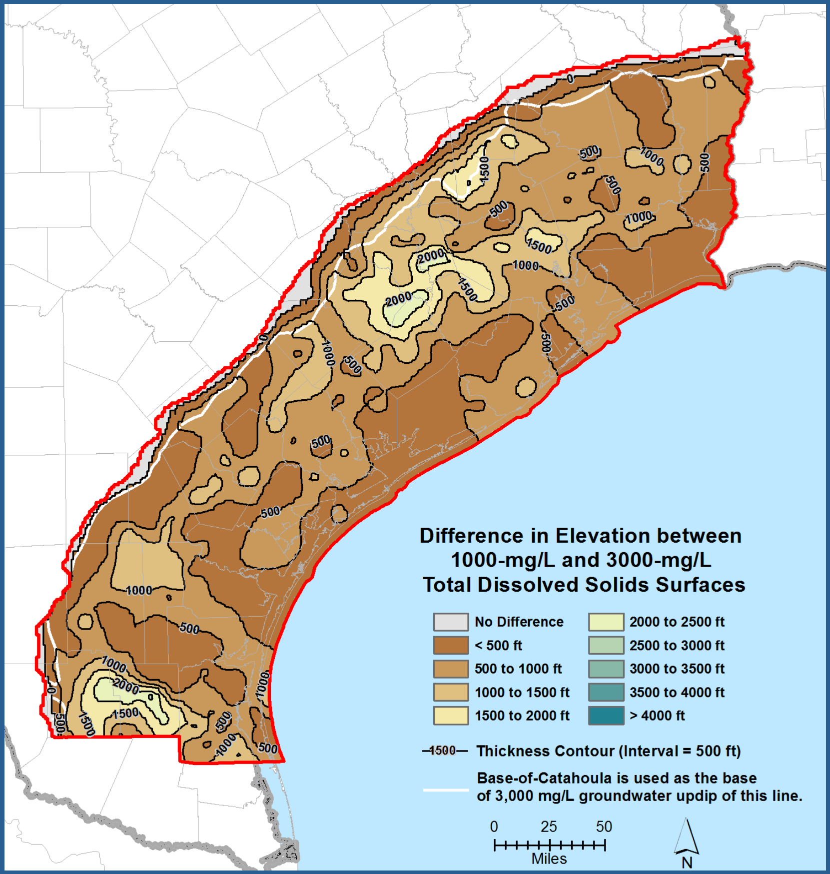
Study Area and Geological Units



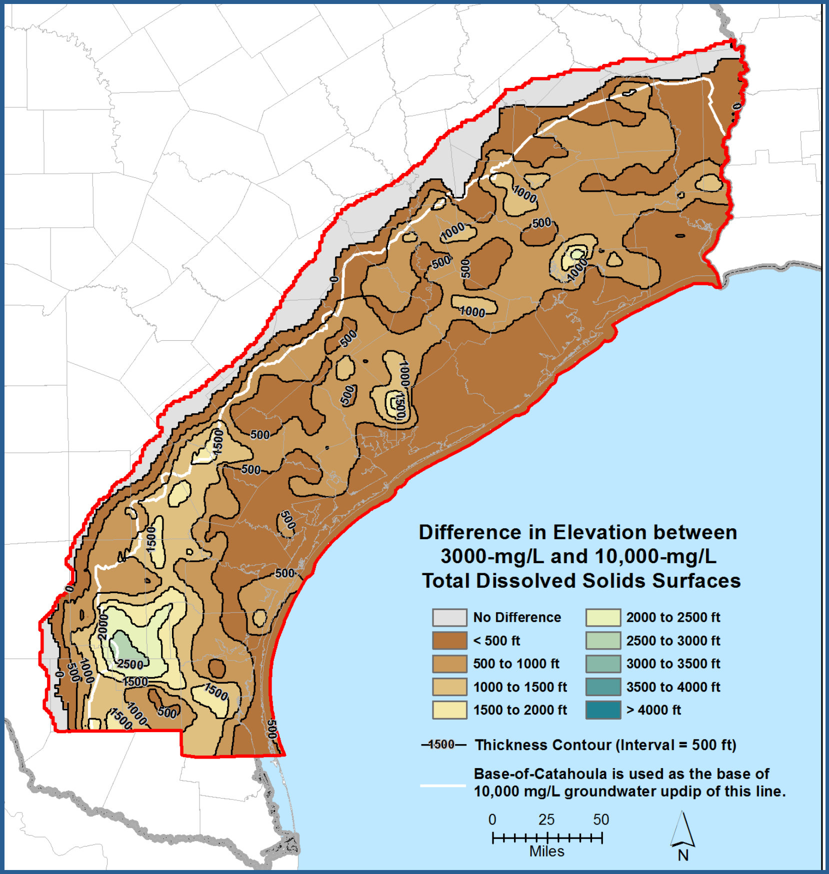
Est. Age (M.Y)	Geologic Unit	Hydrogeologic Unit
0.7	Beaumont	CHICOT AQUIFER
1.6	Lissie	
3.8	Willis	
11.2	Upper Goliad	EVANGELINE AQUIFER
14.5	Lower Goliad	
17.8	Upper Lagarto	
	Middle Lagarto	BURKEVILLE
	Lower Lagarto	JASPER AQUIFER
24.2	Oakville	
32	Frio	CATAHOULA
34	Vicksburg	

Thickness (feet) of Salinity Zones

Slightly Saline
(Total Dissolved Solids Concentrations:
1,000 -3,000 mg/L)



Moderately Saline
(Total Dissolved Solids Concentrations:
3,000 -10,000 mg/L)



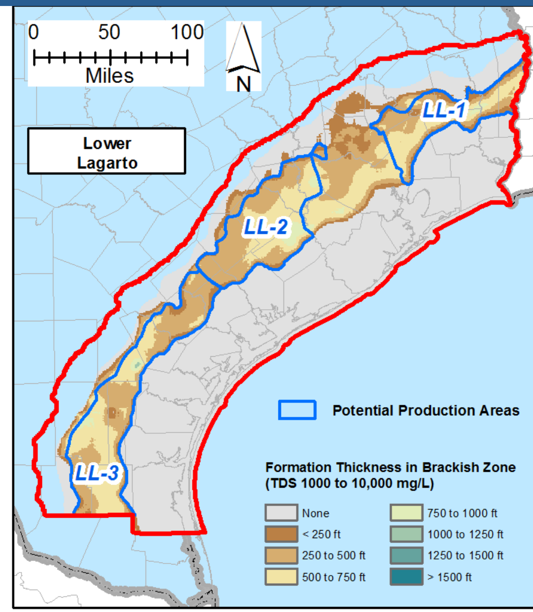
Potential Brackish Production Areas 1, 2, and 3

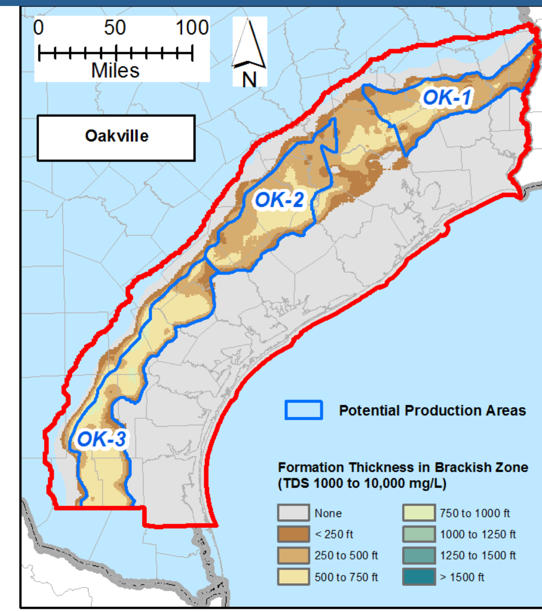
Each Production Area

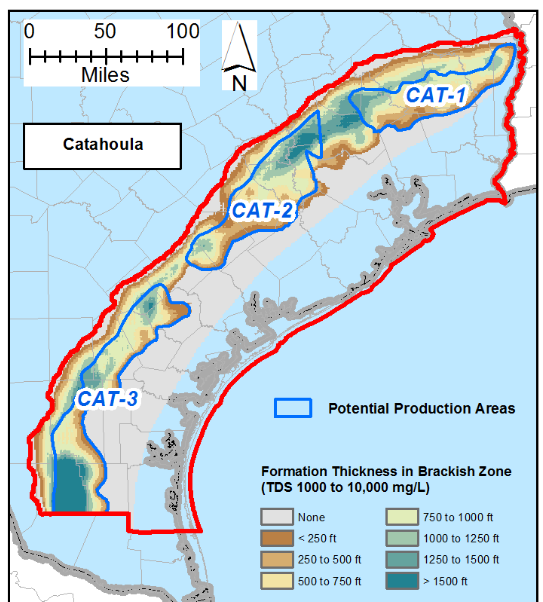
- Includes Portions of Lower Lagarto, Oakville, and Catahoula
- Includes Portions of Slightly Saline and Moderately Saline Groundwater
- Areal extend for each PPA is different for each geologic unit
- Areal extend is adjusted to account for locations of existing wells
- Regional trends in sands thickness and transmissivity is a consideration

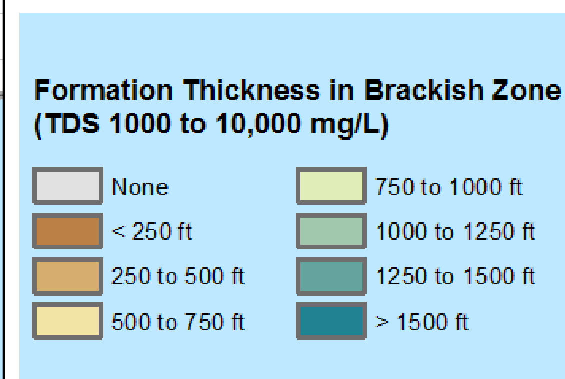
No Production Areas

- Harris-Galveston Subsidence District
- Fort Bend Subsidence District



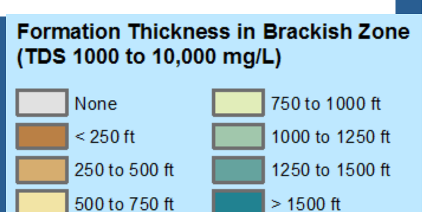


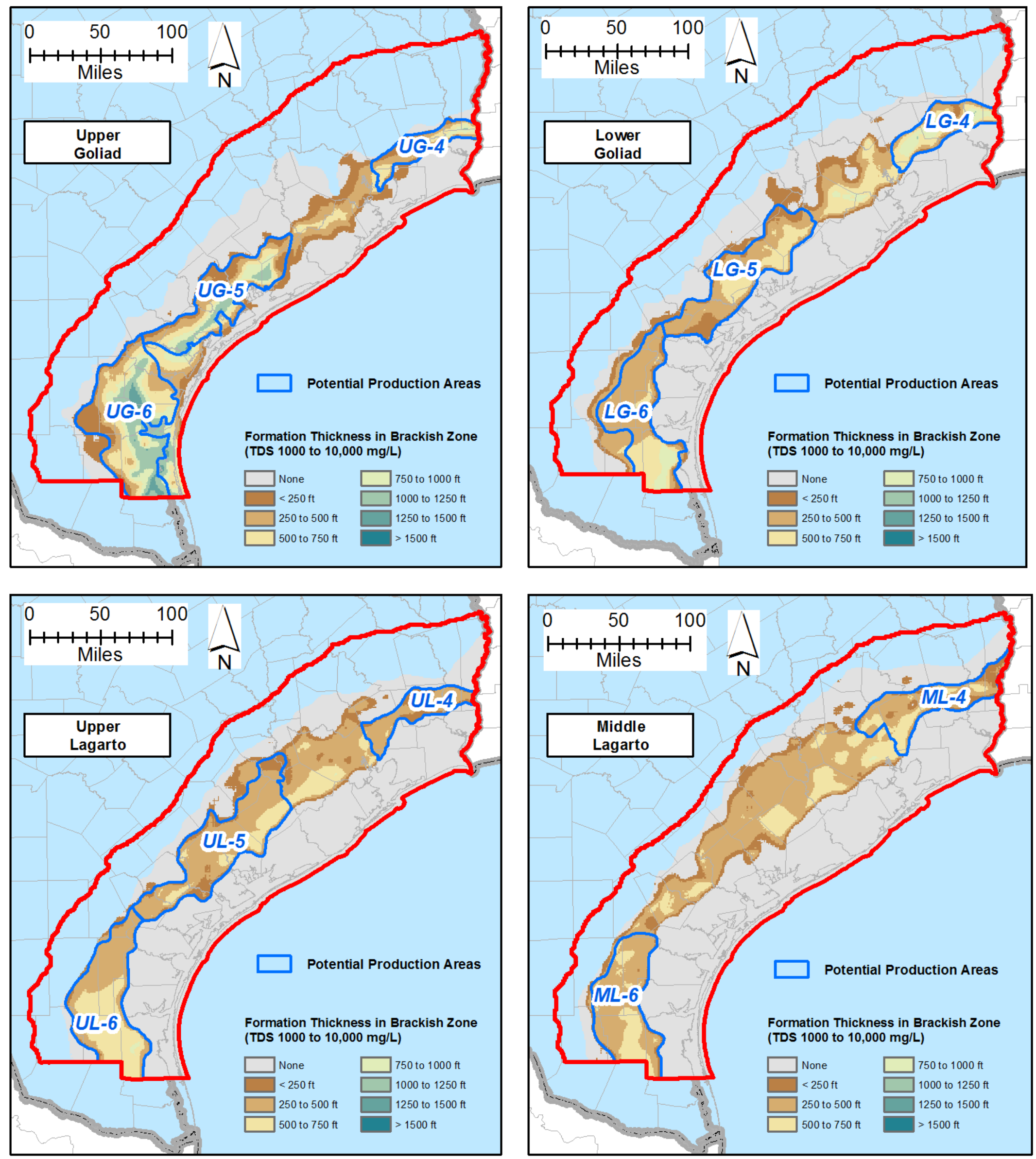




Potential Brackish Production Areas 4, 5, and 6

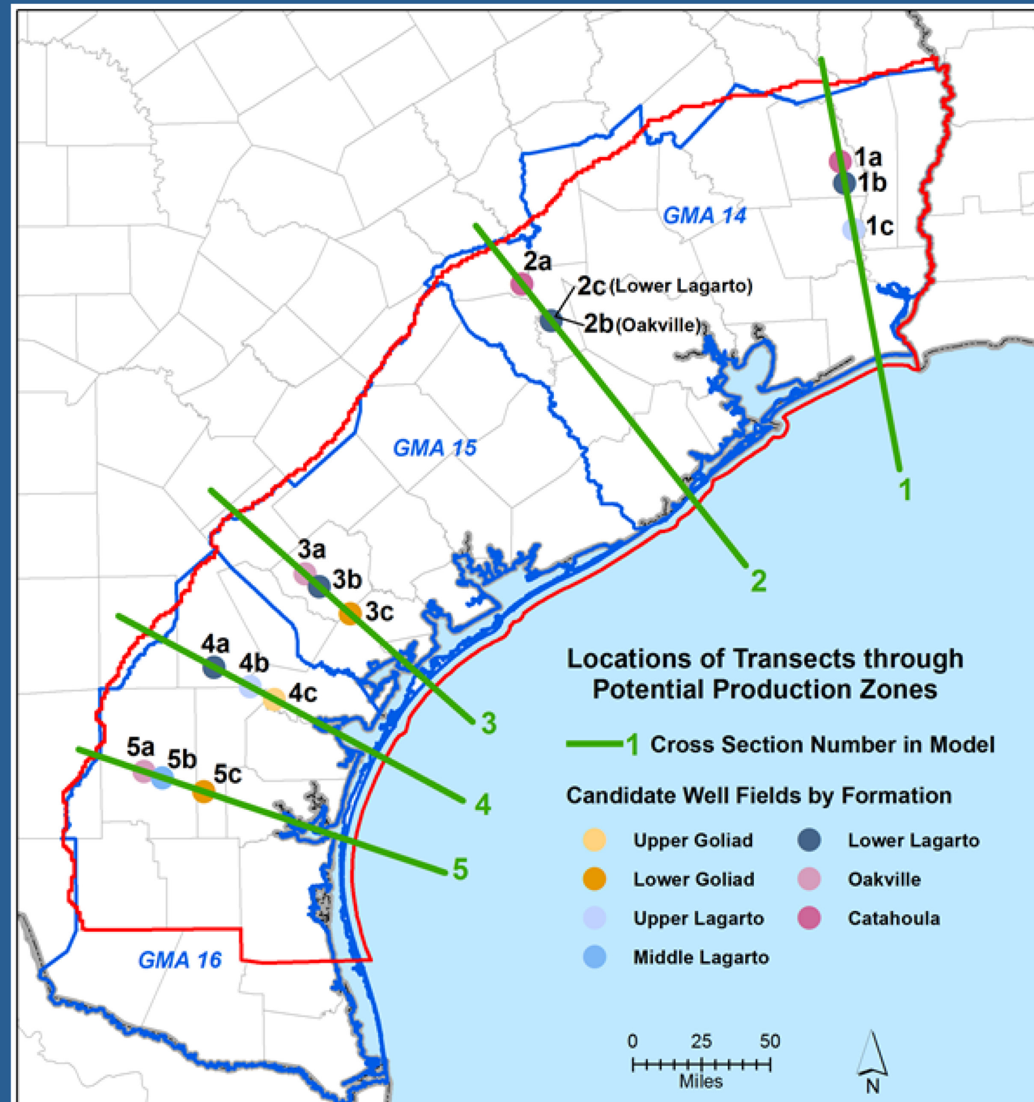
- **Each Production Area**
  - Includes Portions bottom third of Upper Goliad, Lower Goliad, Upper Lagarto, and sometimes the Middle Lagarto
  - Includes Portions of Slightly Saline and Moderately Saline Groundwater
  - Areal extend for each PPA is different for each geologic unit
  - Areal extent is adjusted to account for locations of existing wells
- **No Production Areas**
  - Harris-Galveston Subsidence District
  - Fort Bend Subsidence District





Well Field Locations

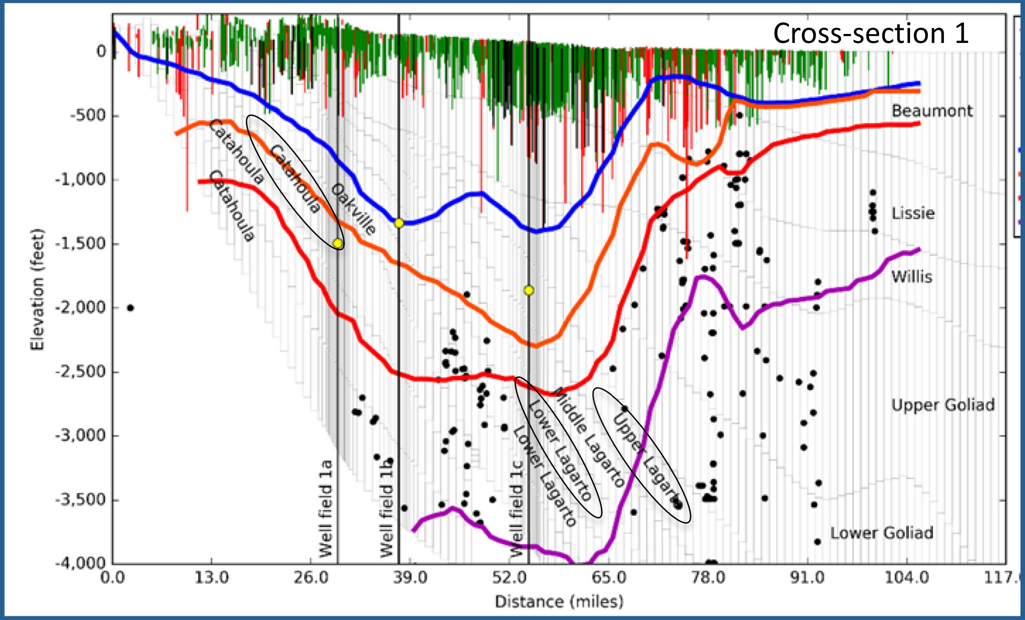
- 15 Well Fields Spread Across Six Potential Brackish Production Areas
- Each well field pumped for 50 years at 3,000 AFY, 10,000 AFY, and 20,000 AFY
- Report provides plots and tables of drawdown at 30 and 50 years
- No pumping except from wells associated with the one single well field

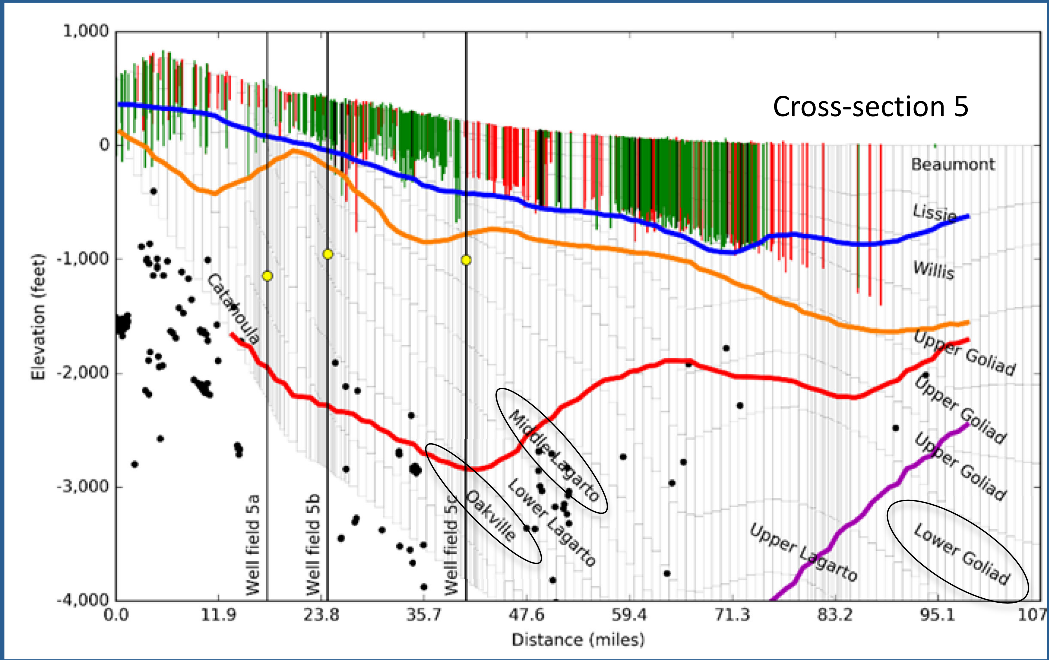


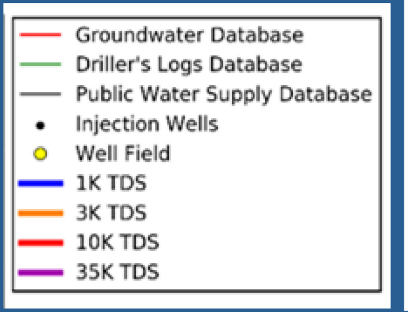
Geological stratum containing water with TDS less than 1,000 mg/l (freshwater) is excluded

Three-dimensional Groundwater Models

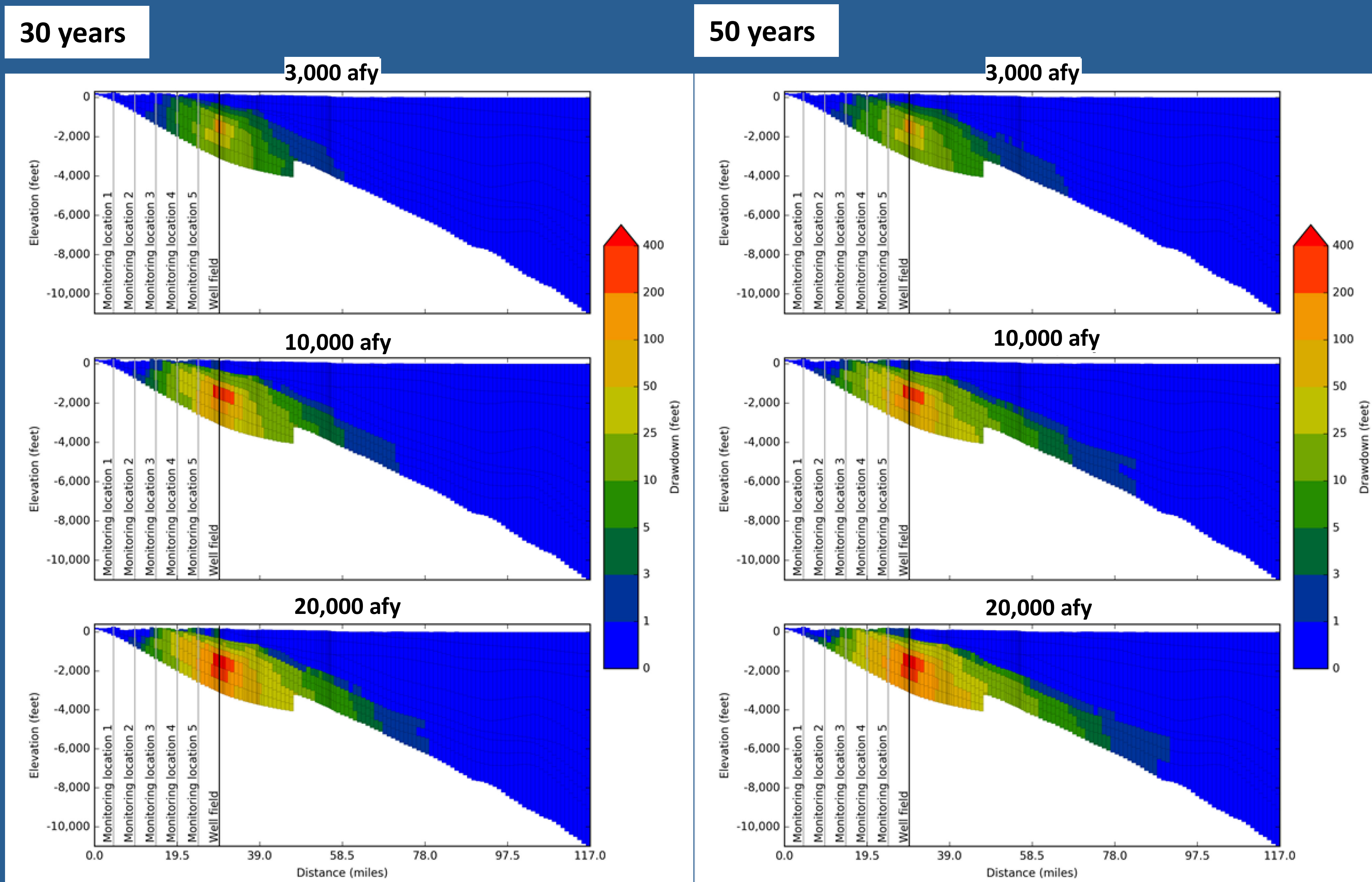
- Three-dimensional model constructed for each cross-section
- Aquifer properties based on:
  - Properties in Groundwater Availability Models
  - Sand Fraction
  - Depth (temperature & porosity)







Well Field 1c Located along Cross-section 1 in Production Area 1 and Pumping the Upper Catahoula

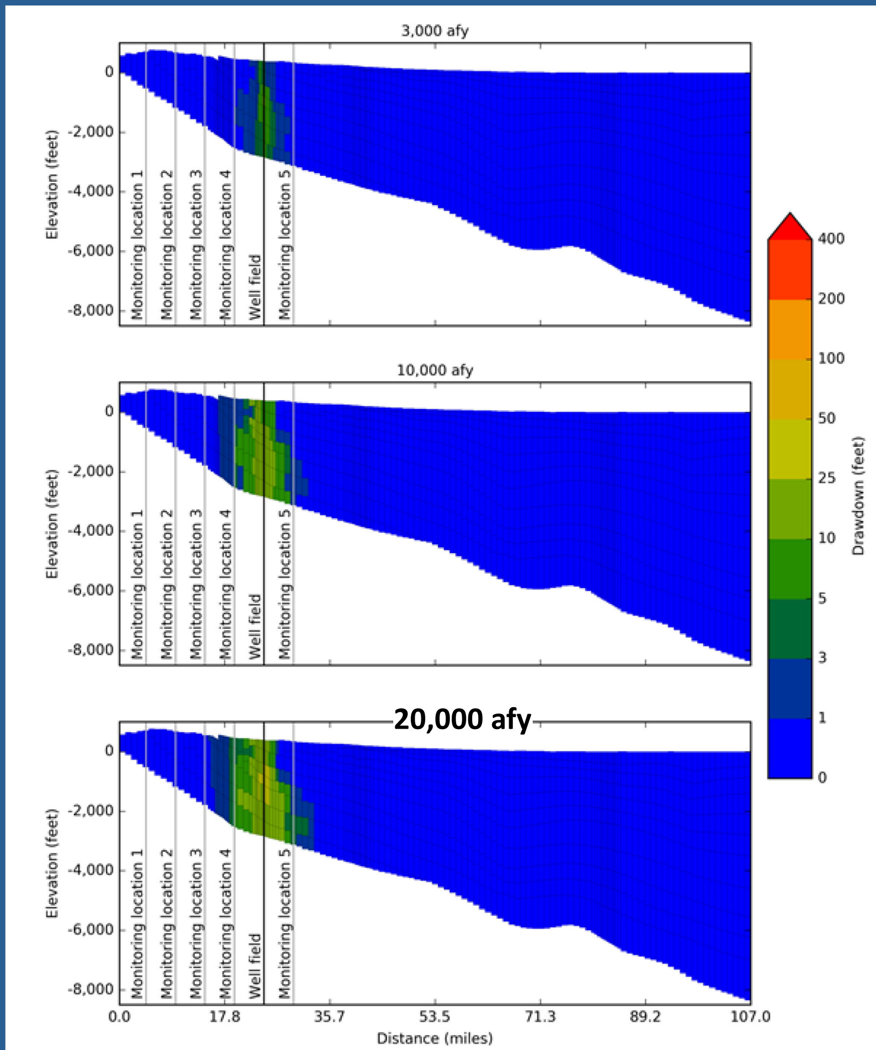


Well Field 1c Located along Cross-section 1 in Production Area 1 and Pumping the Upper Catahoula for 30 Years

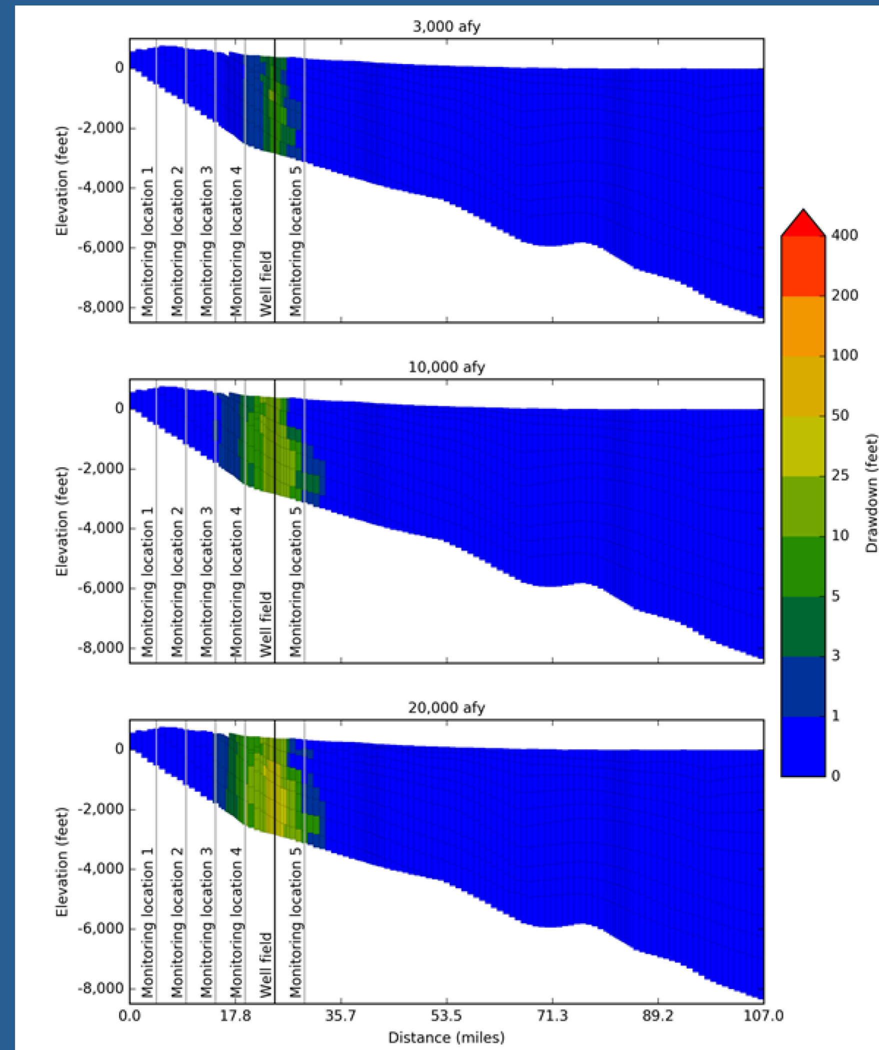
		Beaumont	Lissie	Willis	Upper Goliad	Lower Goliad	Upper Lagarto	Middle Lagarto	Lower Lagarto	Lower Lagarto	Oakville	Catahoula		
		Model Layer												
Location (miles)	Pumping Rate (AFY)	1	2	3	4	5	6	7	8	9	10	11	12	13
		30 Years												
5	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
10	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.3
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	1.2
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	2.3
15	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	2.1	1.3
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.5	7.5	4.5
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	3.8	15.2	8.6
20	3,000	0.2	<0.1	0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	1.8	4.2	5.7	3.6
	10,000	0.6	<0.1	0.6	0.6	<0.1	<0.1	<0.1	<0.1	<0.1	6.0	15.0	19.9	12.6
	20,000	1.2	<0.1	1.2	1.2	<0.1	<0.1	<0.1	<0.1	<0.1	12.4	34.6	39.7	23.9
25	3,000	0.3	<0.1	0.3	0.3	<0.1	<0.1	<0.1	2.2	3.6	9.3	9.3	17.0	14.5
	10,000	1.0	<0.1	1.0	1.0	<0.1	<0.1	<0.1	7.1	11.9	31.4	34.1	60.6	50.1
	20,000	1.9	<0.1	1.9	1.9	<0.1	<0.1	<0.1	13.5	22.6	60.0	78.1	114.5	93.7
30	3,000	0.3	<0.1	0.3	0.3	<0.1	<0.1	2.8	3.7	6.5	28.0	208.5	39.7	21.6
	10,000	1.0	<0.1	1.0	1.0	<0.1	<0.1	9.2	12.1	21.0	85.4	369.7	131.5	73.5
	20,000	2.0	<0.1	2.0	2.0	<0.1	<0.1	17.3	22.8	39.0	147.8	533.8	231.7	137.1
38	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	2.4	3.9	4.9	6.4	8.8	10.9	10.6
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	8.0	13.0	16.4	21.8	30.6	37.6	36.3
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	15.4	25.2	31.9	42.6	60.1	73.3	70.1

Well Field 5b Located along Cross-section 5 in Production Area 6 and Pumping the Middle Lagarto

30 years



50 years



Well Field 5b Located along Cross-section 5 in Production Area 6 and Pumping the Middle Lagarto for 30 years

Location (miles)	Pumping Rate (AFY)	Beaumont	Lissie	Willis	Upper Goliad	Upper Goliad	Upper Goliad	Lower Goliad	Upper Lagarto	Middle Lagarto	Lower Lagarto	Oakville	Catahoula
		Model Layer											
		1	2	3	4	5	6	7	8	9	10	11	12
		30 Years											
5	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
10	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
15	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1	0.1
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	0.3	0.4	0.4
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	0.6	0.7	0.7
18	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.3	0.3	0.3	0.3
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.2	<0.1	1.2	1.2	1.2	1.1
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	2.1	<0.1	2.2	2.1	2.1	2.1
20	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	<0.1	0.6	0.6	0.8	0.7
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	2.4	<0.1	2.4	2.6	3.5	2.9
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	4.2	<0.1	4.3	4.6	5.9	5.1
25	3,000	<0.1	<0.1	<0.1	<0.1	<0.1	3.1	3.1	7.0	7.9	5.9	5.6	5.2
	10,000	<0.1	<0.1	<0.1	<0.1	<0.1	8.1	7.9	16.6	17.9	16.5	15.9	15.2
	20,000	<0.1	<0.1	<0.1	<0.1	<0.1	12.2	11.8	23.5	25.2	24.1	23.6	22.9
30	3,000	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.0	0.1	0.2	0.3	0.6	0.6
	10,000	<0.1	<0.1	<0.1	<0.1	0.2	0.3	0.1	0.2	0.7	1.1	2.4	1.9
	20,000	<0.1	<0.1	<0.1	<0.1	0.3	0.4	0.1	0.4	1.2	1.9	4.1	4.1

HB 30 Stakeholder Meeting on Potential Brackish Groundwater Production Areas

Blaine Aquifer System

Stephen F. Austin Building, Room 170

Austin, Texas

September 9, 2016

DBS&A
Daniel B. Stephens & Associates, Inc.

JOHN SHOMAKER & ASSOCIATES, INC.
WATER-RESOURCE AND ENVIRONMENTAL CONSULTANTS

Allan R. Standen LLC
Groundwater & Natural Resource Consulting

Michelle A. Sutherland, LLC.

Project Area

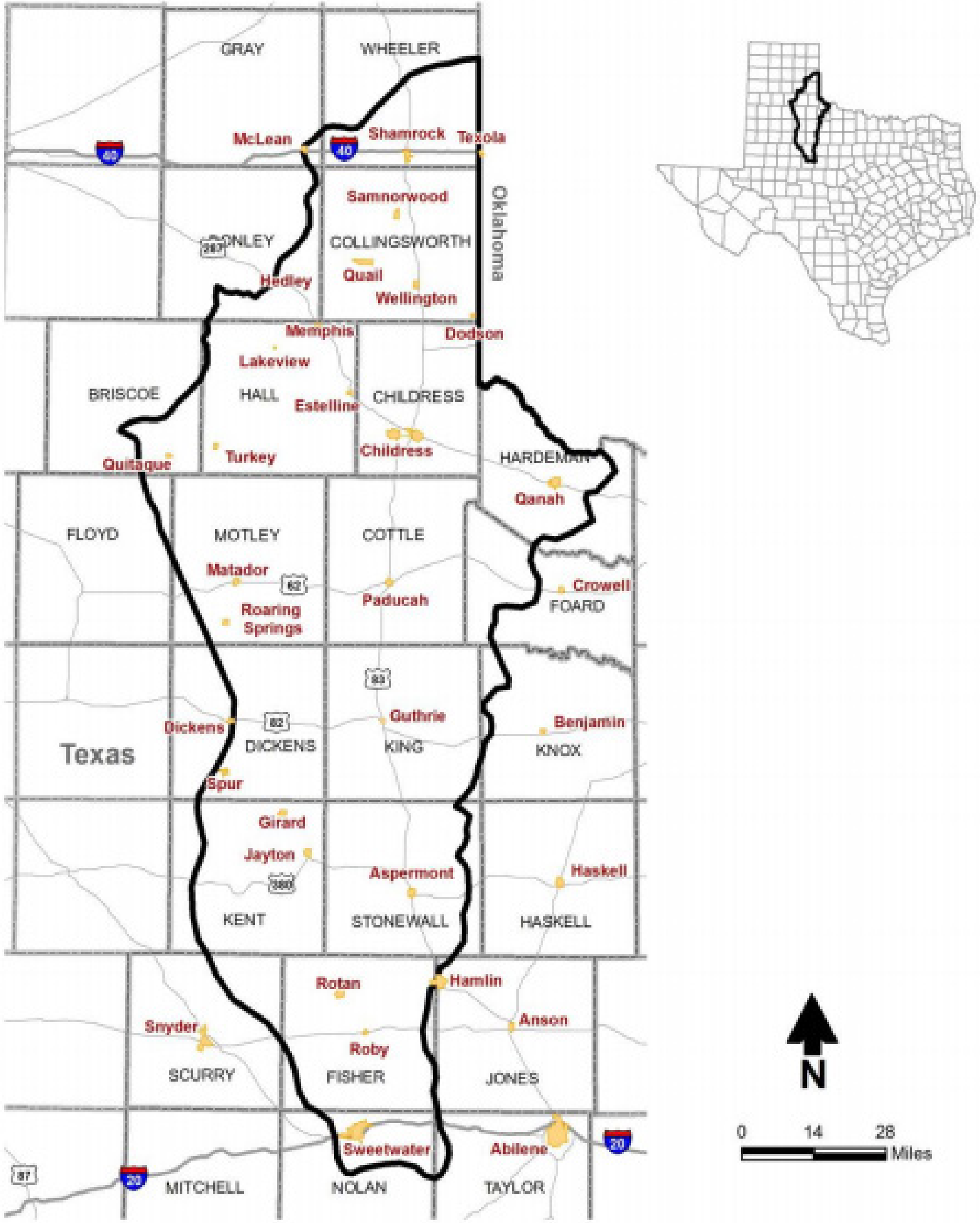


Figure 2-1. Study area.

Surface Geology and Structure

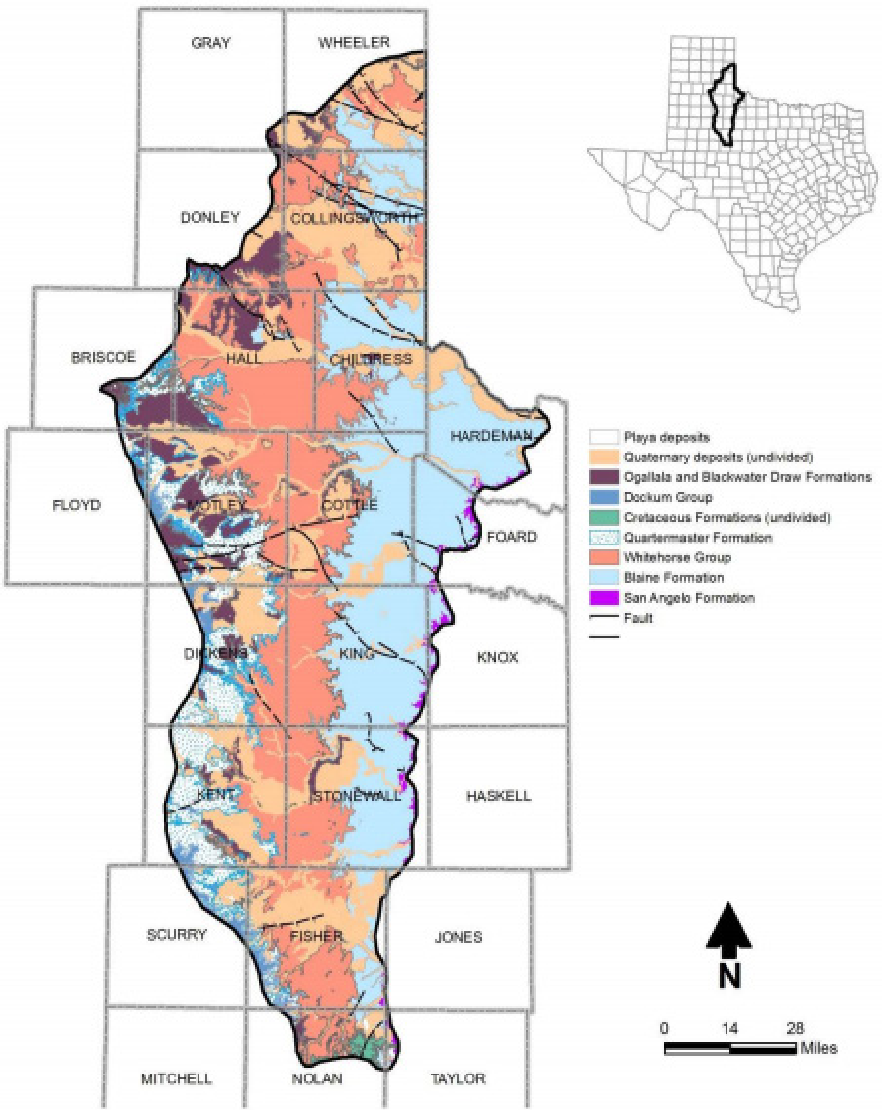
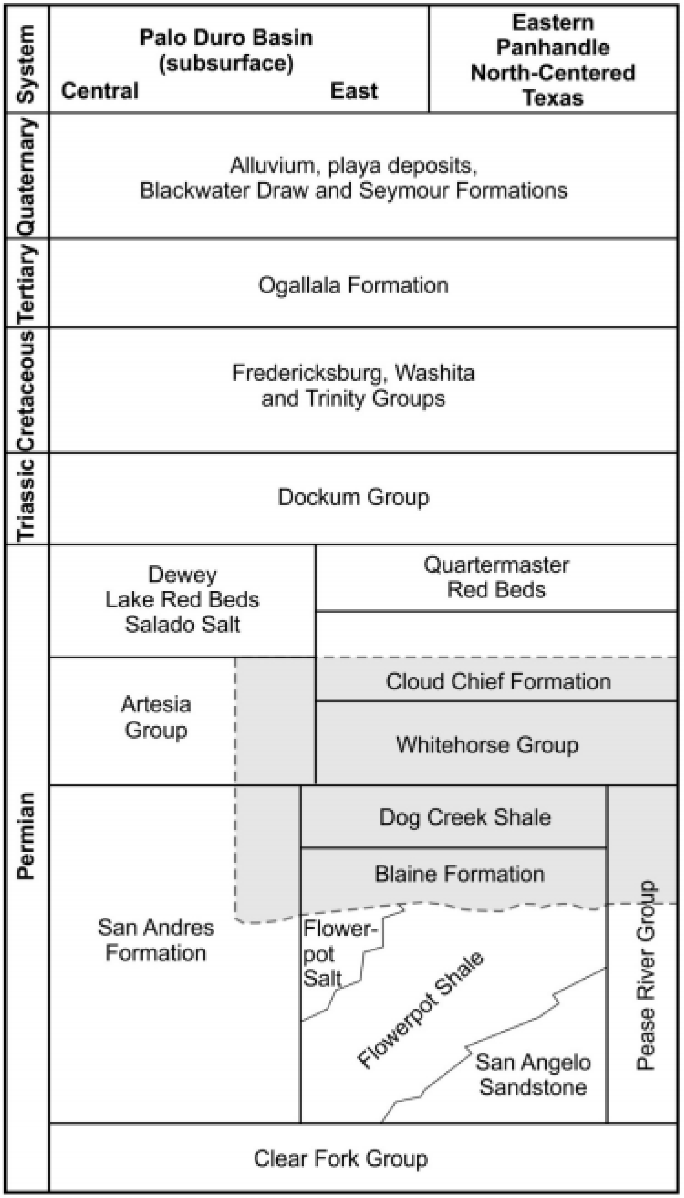


Figure 5-2. Study area surface geology from Geologic Atlas of Texas (Barnes, 1974, Amarillo, Plainview, Lubbock, Big Spring, Wichita Falls-Lawton and Abilene sheets) and structure from Ewing (1991).

Stratigraphy of Project Area



Source: Modified from Johnson,1978; Presley, 1981; and Barnes, 1974

Blaine Aquifer system

Figure 5-3. Generalized stratigraphic chart for the Blaine Aquifer system and adjacent geologic units.

West to East hydrogeological cross section through Kent and Stonewall Counties, Texas

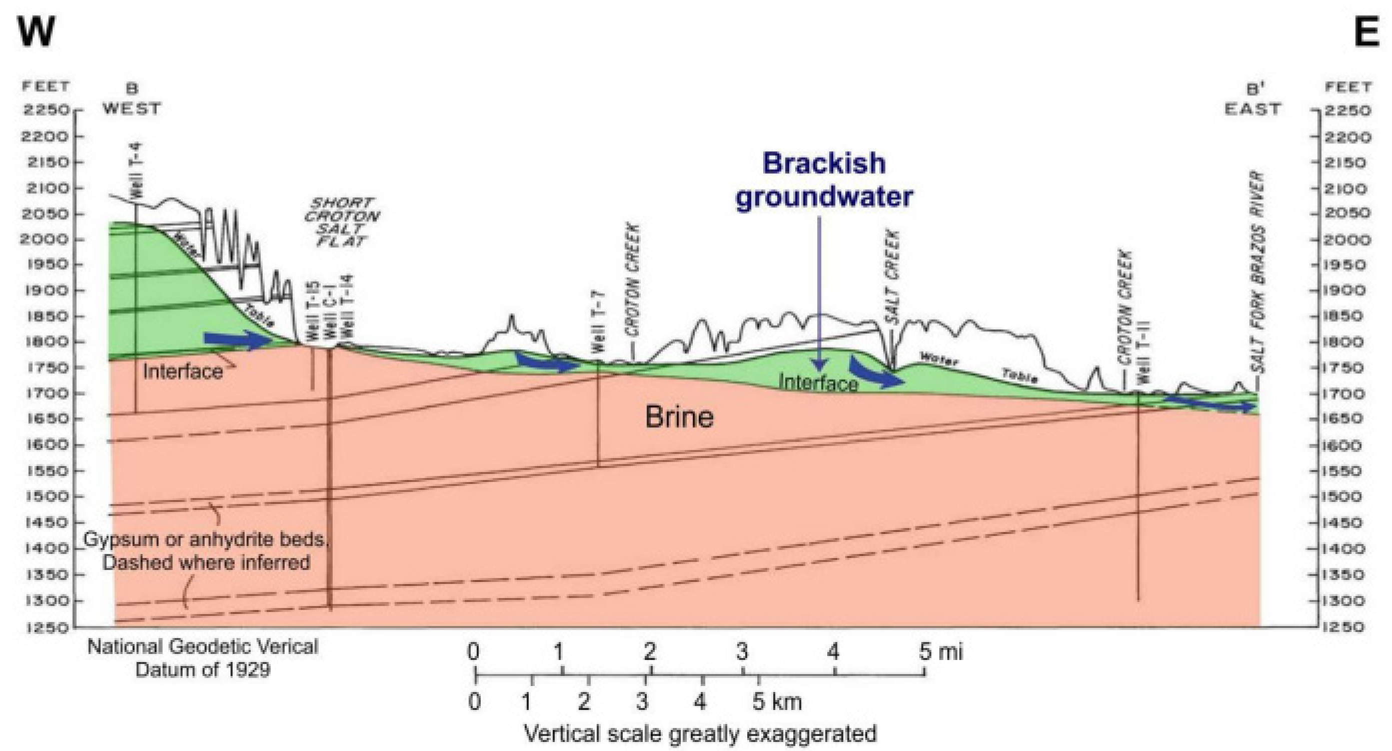
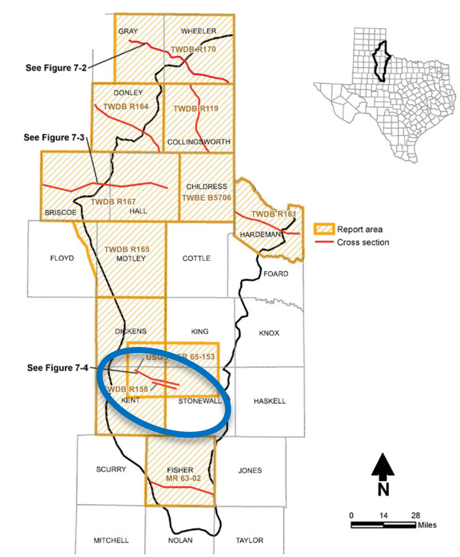


Figure 7-4. Hydrogeologic cross section through Kent and Stonewall Counties from Stevens and Hardt (1965). Features in blue were added to illustrate the conceptual model of gorundwater flow.



Brine Interface

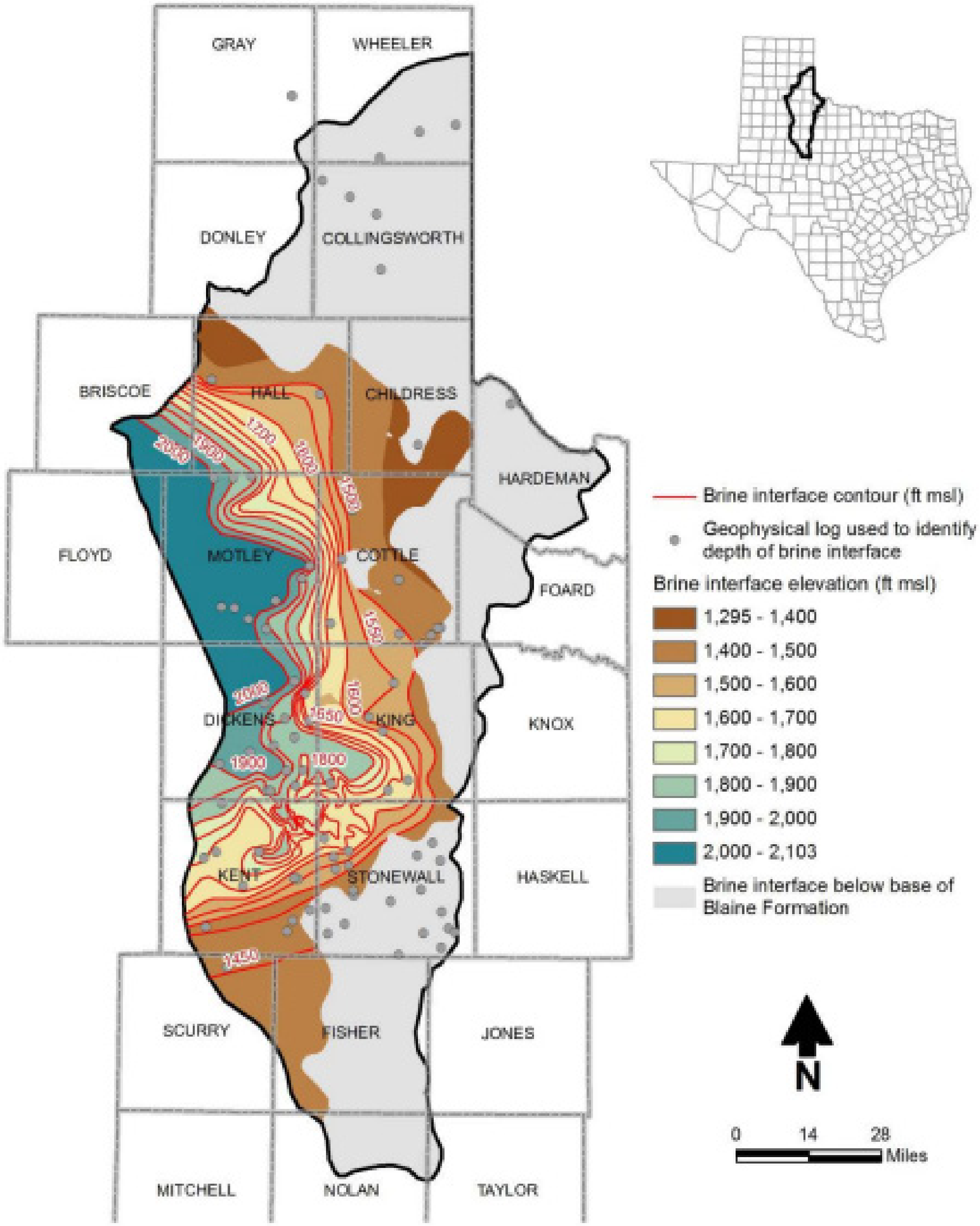


Figure 13-2. Estimated elevation of brine interface where it occurs above the base of the Blaine Formation.

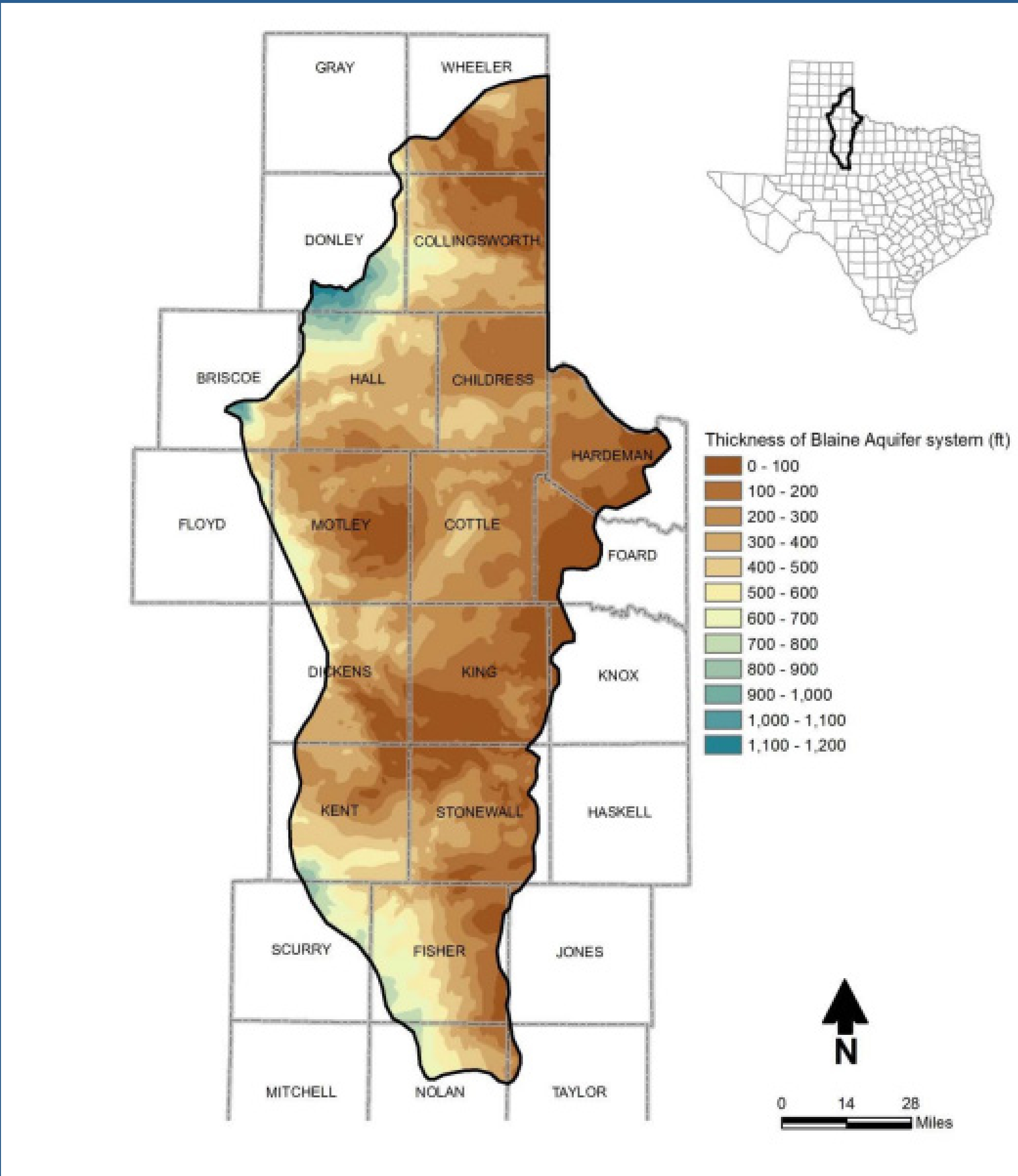


Figure 12-1. Blaine Aquifer system thickness.

Aquifer Thickness

- Bottom of aquifer defined by Flowerpot Shale along eastern margin and in the north
- Bottom of aquifer defined by brine interface in south
- Total thickness of fresh to moderately saline groundwater 0 to ~ 500 feet

Groundwater Volume by Salinity Classification and County (acre-feet)

County	Groundwater volume (acre-feet)			
	Total	Salinity zone (TDS in mg/L)		
		0 – 1,000	1,000 – 10,000	> 10,000
Briscoe	543,568	191,797	351,771	0
Childress	1,192,323	0	1,192,160	163
Collingsworth	1,638,837	451,430	1,187,407	0
Cottle	1,440,603	0	1,440,603	0
Dickens	1,148,223	91,990	1,056,233	0
Donley	1,150,444	64,154	1,086,290	0
Fisher	2,072,861	24,613	2,048,248	0
Floyd	164,953	109,225	55,728	0
Foard	102,753	0	102,753	0
Gray	59,932	0	59,932	0
Hall	2,470,582	14,466	2,456,116	0
Hardeman	462,638	0	462,638	0
Jones	5,240	0	5,240	0
Kent	1,695,978	0	1,695,978	0
King	782,008	0	776,730	5,278
Knox	2,937	0	2,937	0
Motley	1,535,980	99,984	1,420,204	15,793
Nolan	618,964	0	618,964	0
Scurry	588,604	308	588,296	0
Stonewall	1,009,163	0	860,829	148,334
Taylor	27,435	0	27,435	0
Wheeler	564,616	164,860	399,756	0

TDS = Total dissolved solids
mg/L = Milligrams per liter

Table 12-2. Groundwater volume by salinity classification and county

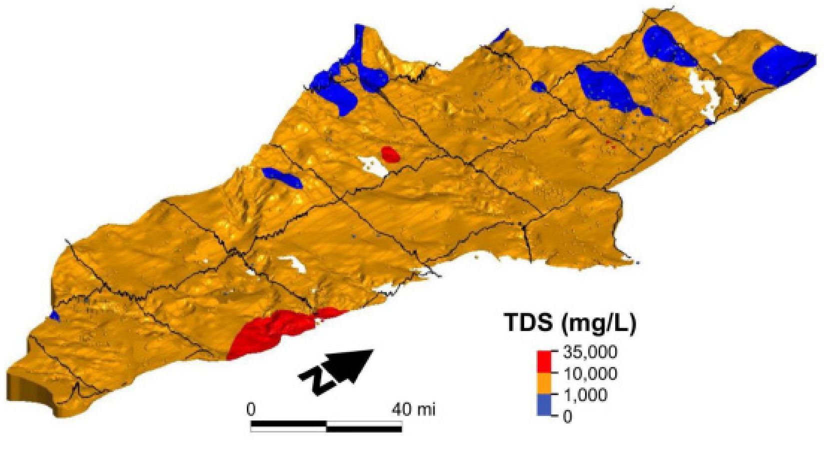
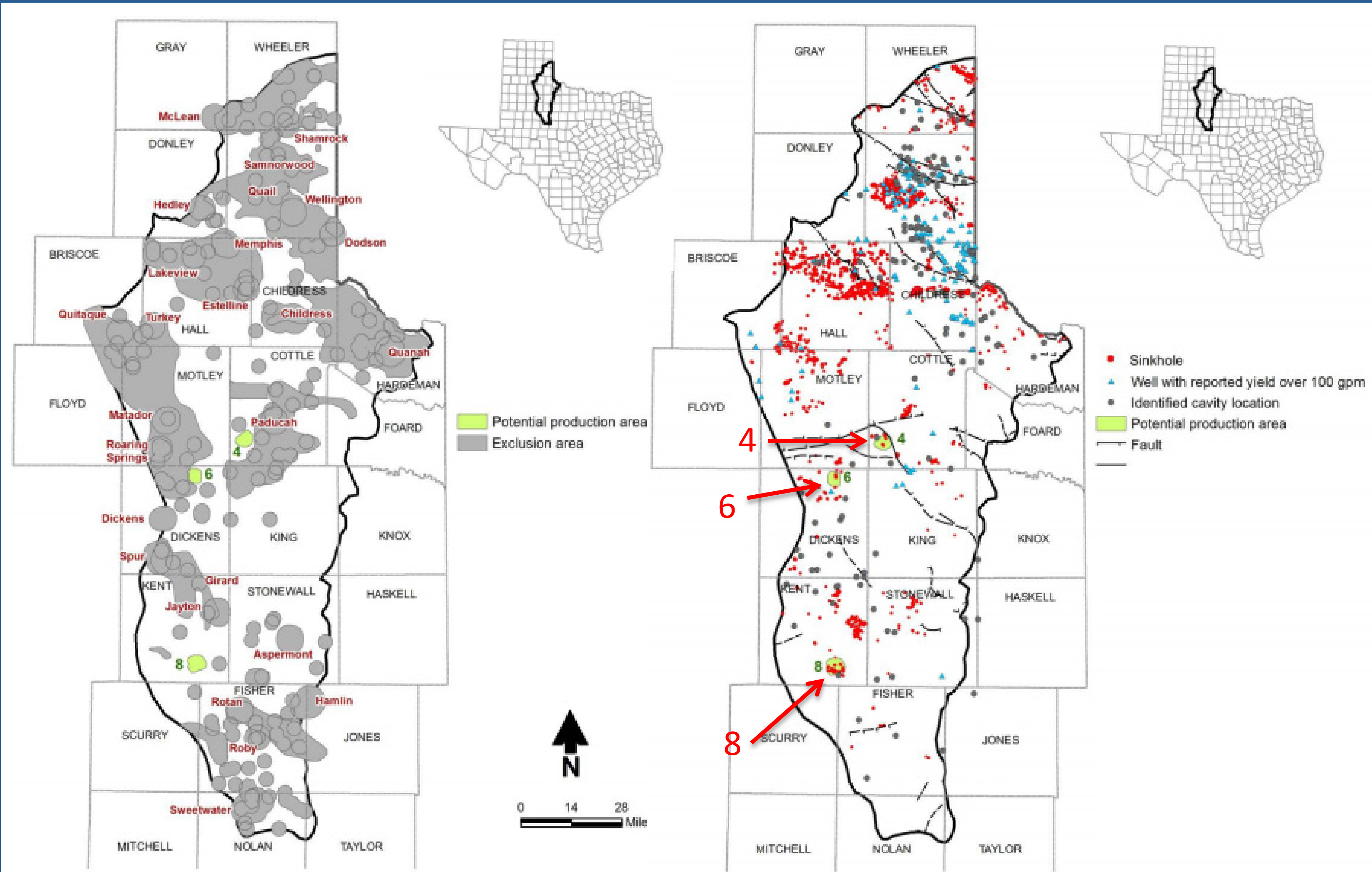


Figure 12-2. Blaine Aquifer system salinity zones illustrated on a three-dimensional visualization of the water table at 50x vertical exaggeration.

Potential Production Areas and Exclusions



Predictive Drawdown Computations

- Conducted using the Theis (1935) equation

$$s = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-u}\,du}{u}$$

where s = drawdown in water level
Q = pumping rate of the well
T = aquifer transmissivity
u = $\frac{r^2 S}{4Tt}$
r = distance from the pumping well to a given point
S = aquifer storage coefficient
t = time since pumping began

Equation 1 is generally written in the form of the well function, W(u), as follows:

$$s = \frac{Q}{4\pi T} W(u)$$

Numerical Modeling Assumptions and Pumping Parameters

- Theis (1935), Assumptions
  - Homogeneous and isotropic hydraulic conductivity
  - Uniform thickness
  - Production wells penetrate full thickness
- Model Inputs
  - Well field - 9 wells, ¾ Mi. spacing
  - 1,000 to 3,000 ac-ft/yr
  - 30 and 50 year scenarios
  - Hydraulic conductivity 40 ft/d
  - 70 % of aquifer thickness
  - 0.01 Storage coefficient

Entity Name	Population	Intake Total (ac-ft/yr)
Anson	2,341	461
Aspermont	885	134
Childress	6,105	1,378
Crowell	895	232
Hamlin	2,037	372
Haskell	3,297	471
Jayton	521	99
Matador	544	120
Mclean	792	186
Memphis	2,235	341
Paducah	1,137	231
Quanah	2,501	335
Roby	631	130
Rotan	1,480	235
Shamrock	2,041	914
Snyder	11,711	2,235
Spur	1,229	209
Sweetwater	10,722	2,253
Wellington	2,090	481

Sources: TWDB web site, accessed on August 26, 2016

ac-ft/yr = acre-feet per year

Table 14-2. Municipal water demand within and near the study area from 2014 water use surveys.

PPA 4 Numerical Modeling (30-yr)

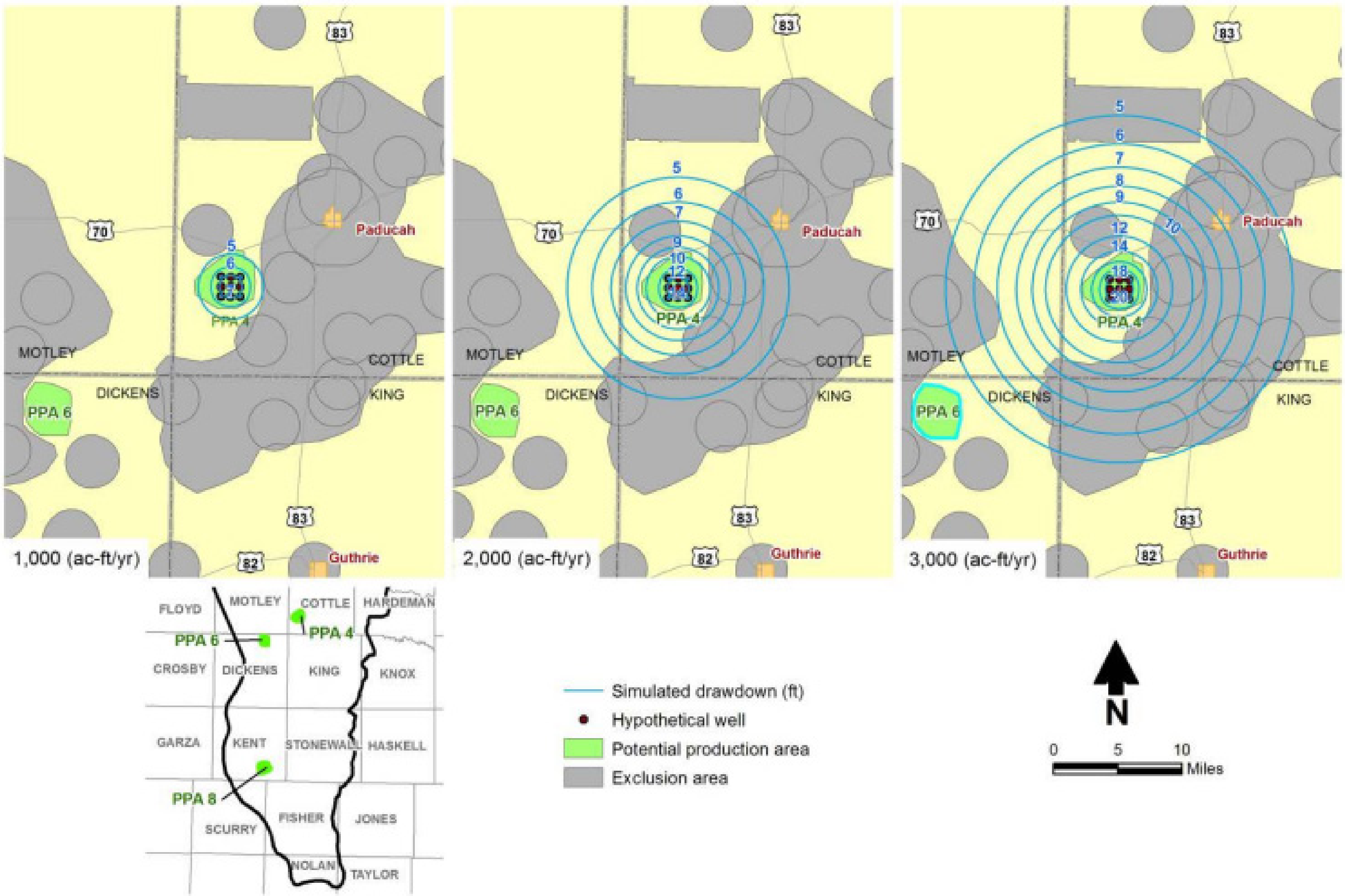


Figure 14-6a. Potential production area 4 simulated 30-year drawdown.

PPA 4 Numerical Modeling (50-yr)

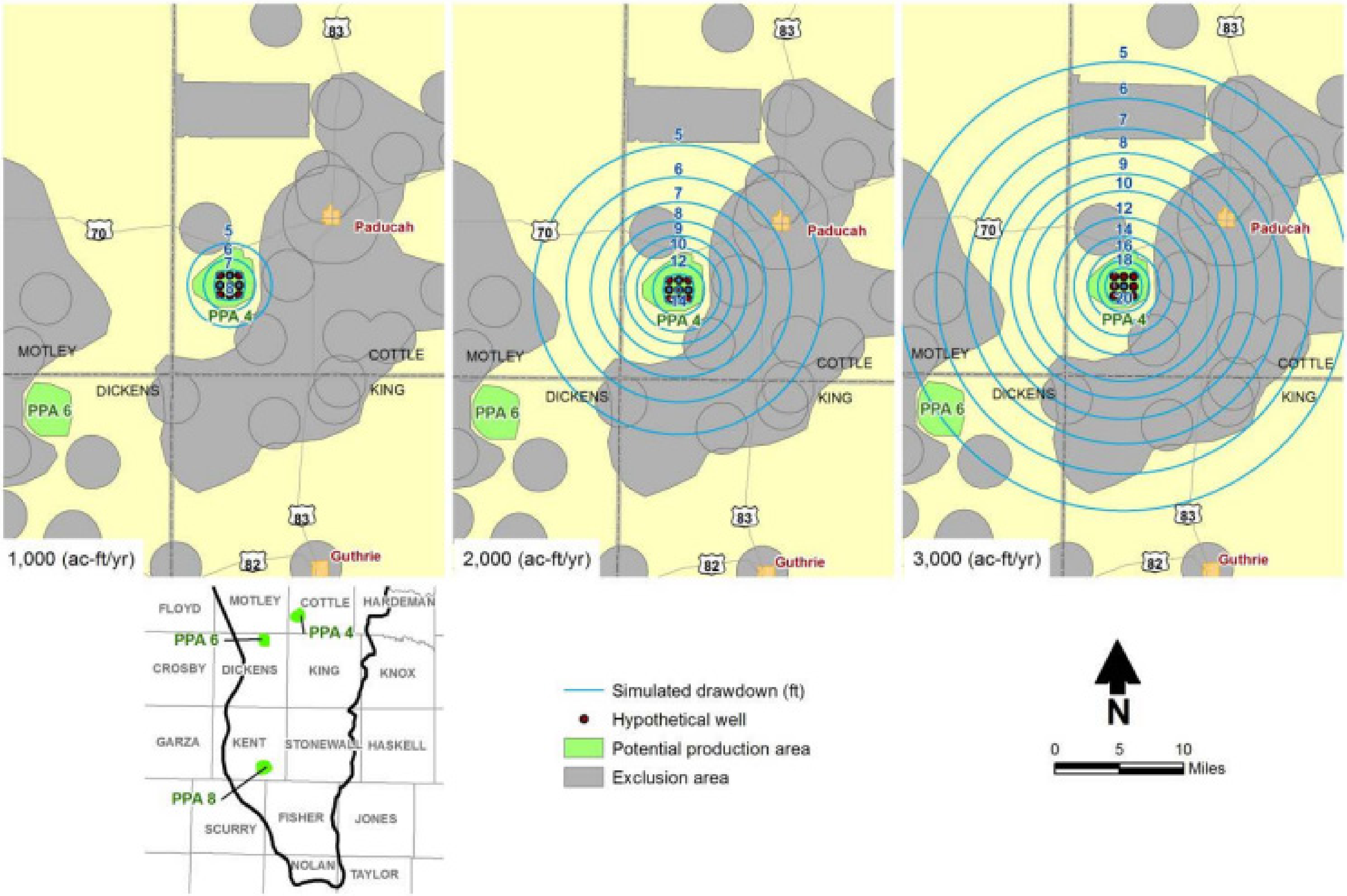


Figure 14-6b. Potential production area 4 simulated 50-year drawdown.

PPA 6 Numerical Modeling (30-yr)

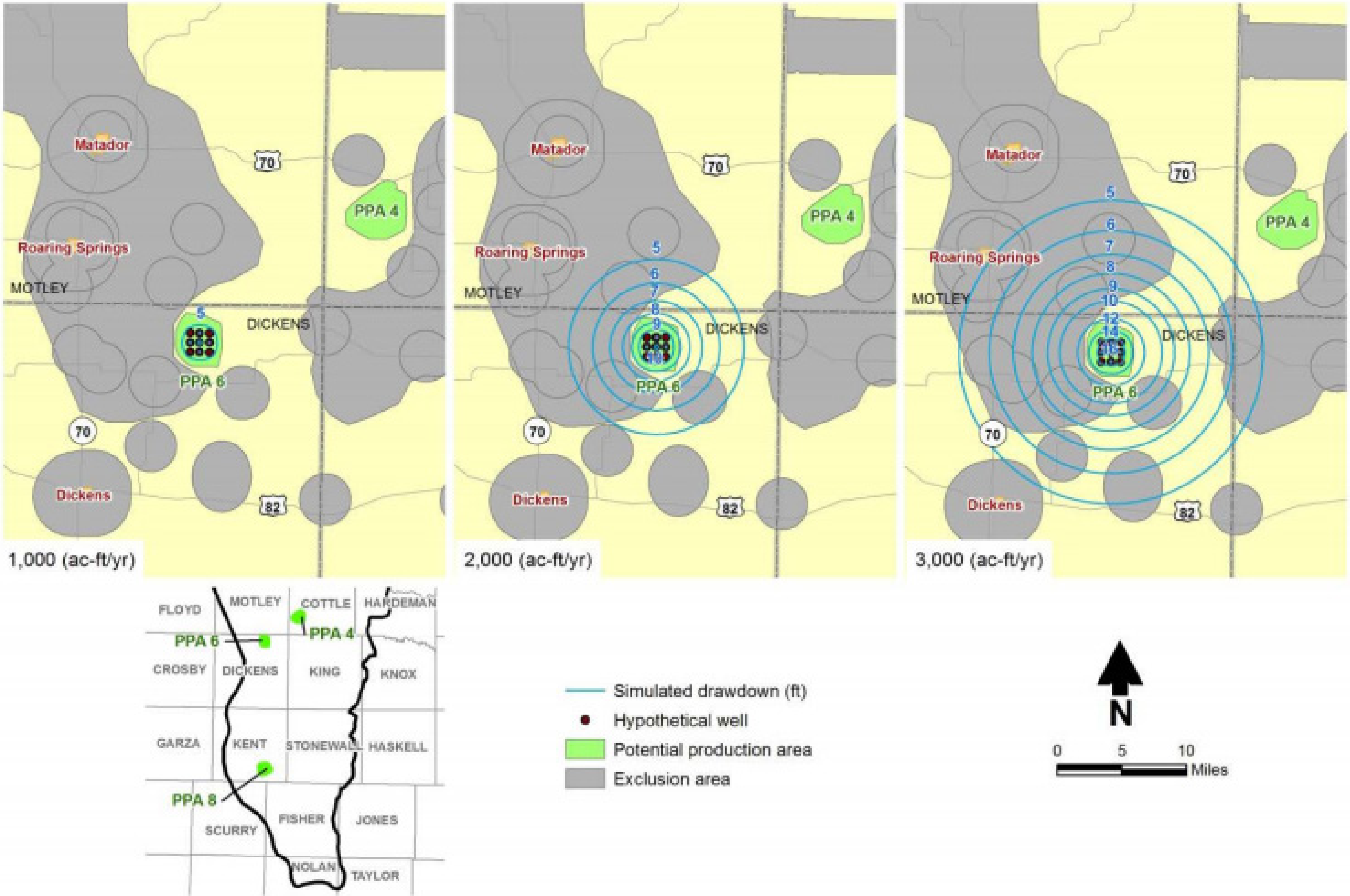


Figure 14-7a. Potential production area 6 simulated 30-year drawdown.

PPA 6 Numerical Modeling (50-yr)

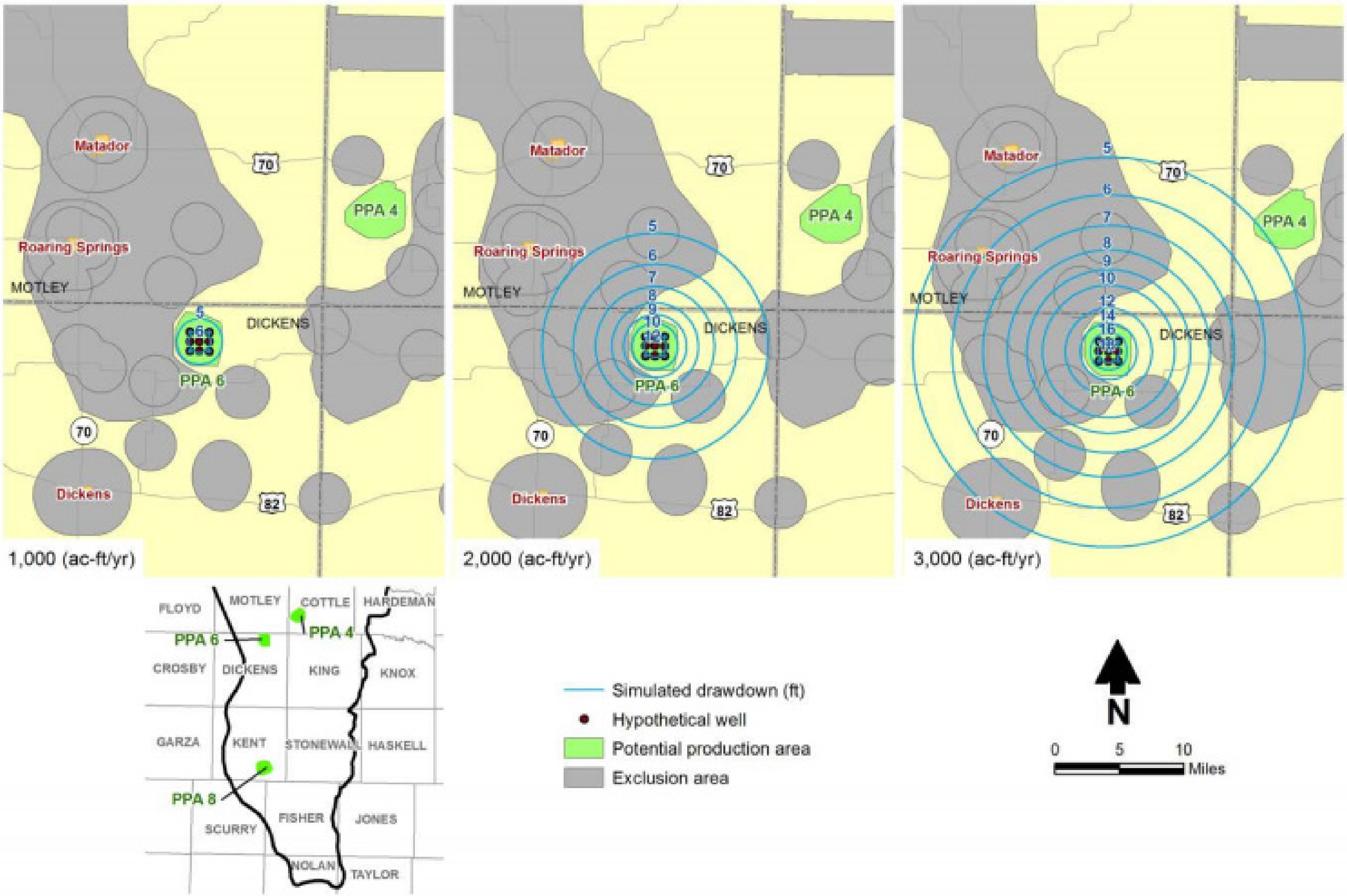


Figure 14-7b. Potential production area 6 simulated 50-year drawdown.

PPA 8 Numerical Modeling (30-yr)

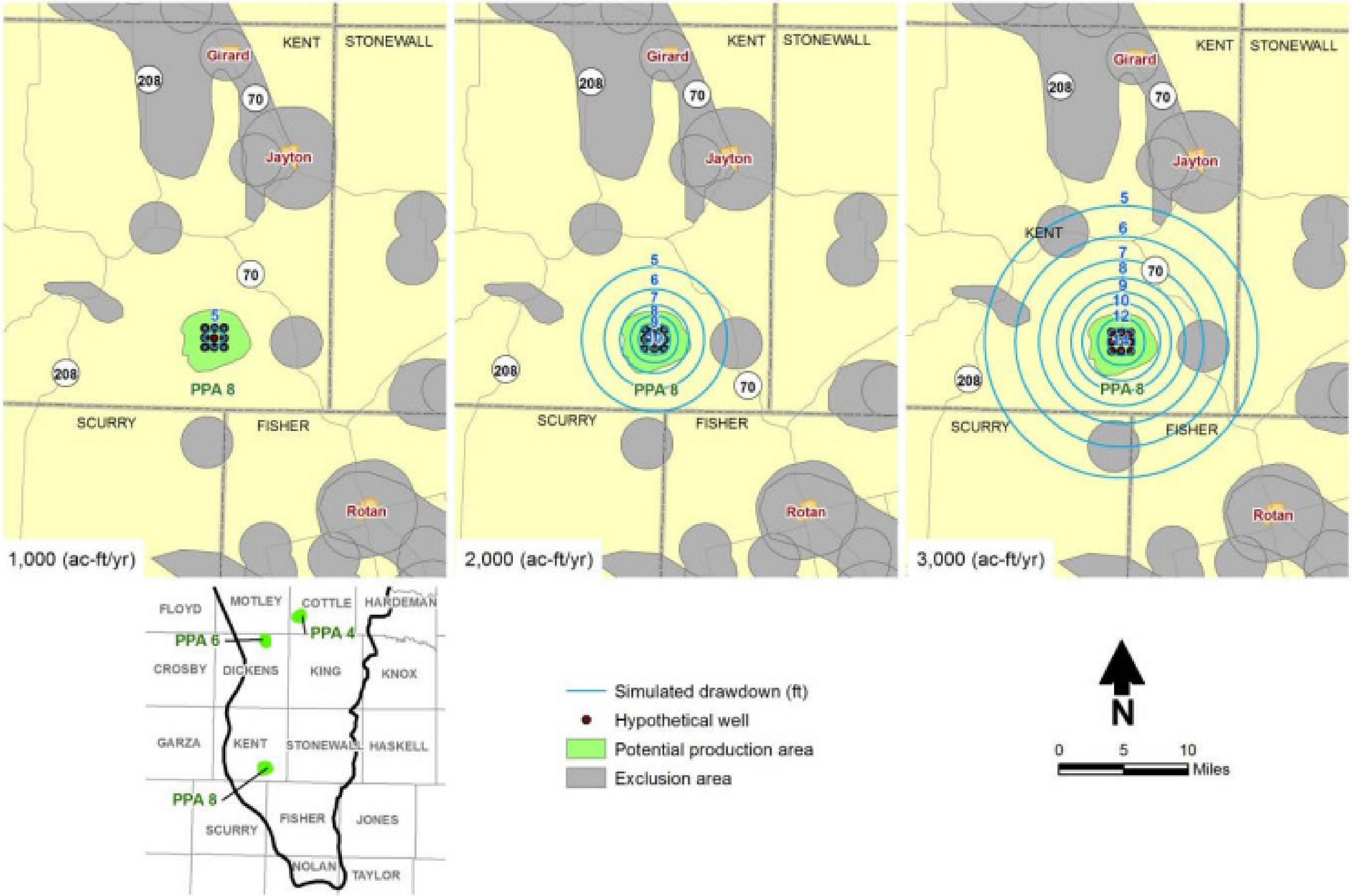


Figure 14-8a. Potential production area 8 simulated 30-year drawdown.

PPA 8 Numerical Modeling (50-yr)

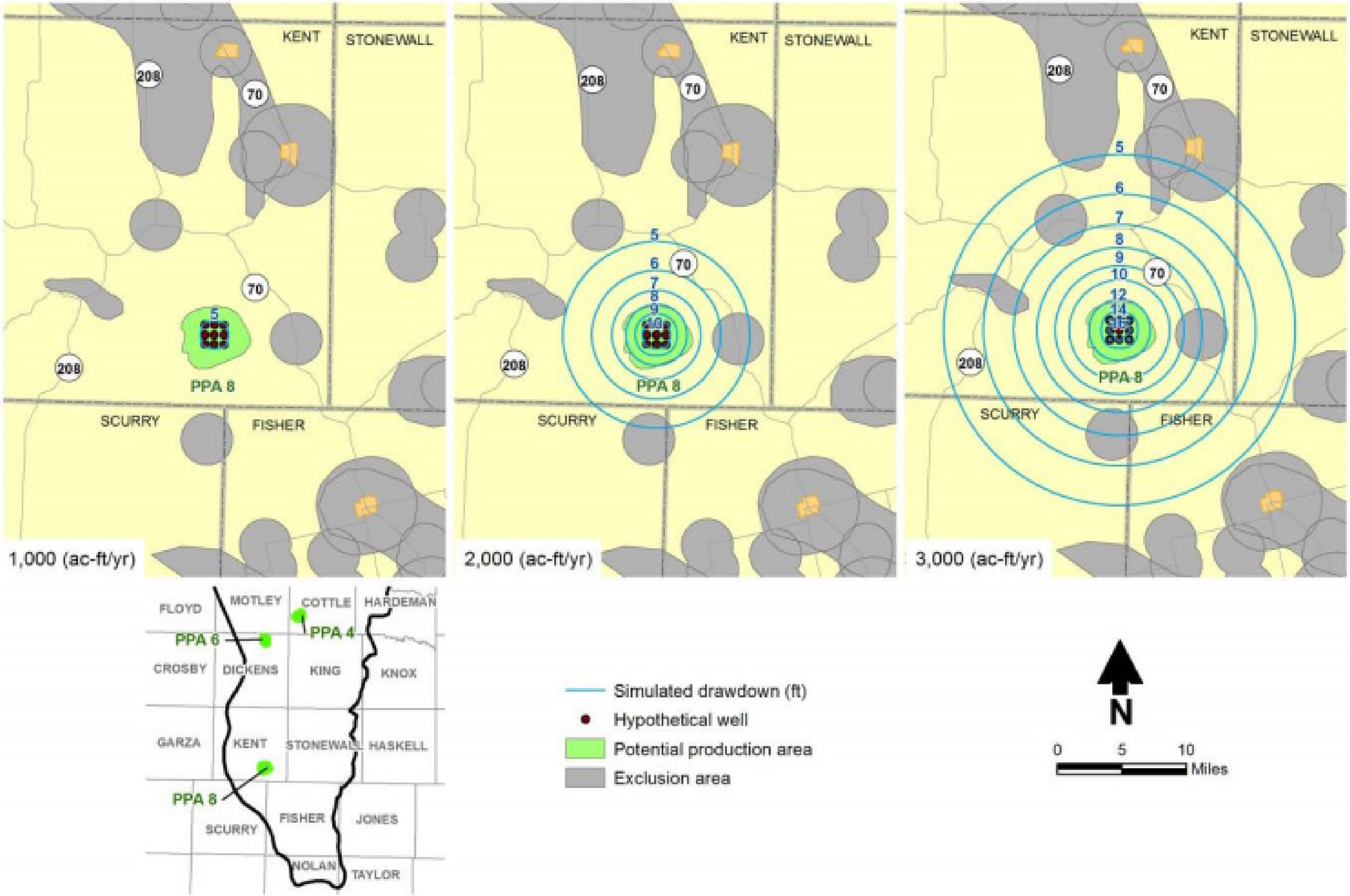


Figure 14-8b. Potential production area 8 simulated 50-year drawdown.

Conclusions Regarding PPAs

- Each PPA appears capable of sustaining the maximum assumed pumping amount of 3,000 ac-ft/yr for both the 30- and 50-year periods.
- Site-specific studies would need to be conducted prior to utilization of any PPA

Identification of Potential Brackish Groundwater Production Areas – RUSTLER AQUIFER

STAKEHOLDER ADVISORY MEETING

Presented by:

INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS

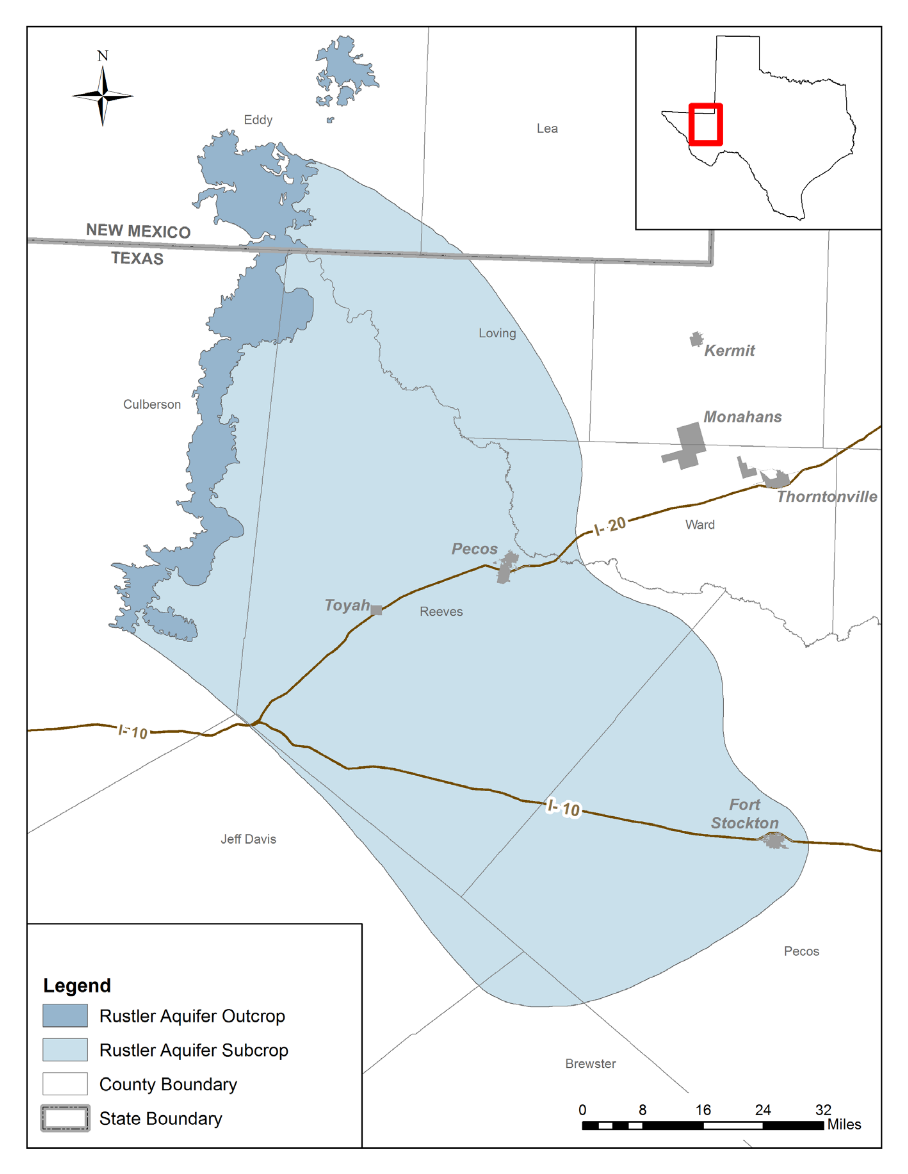
Under Contract to:

Texas Water Development Board

Austin

September 9, 2016

Study Area Location Map

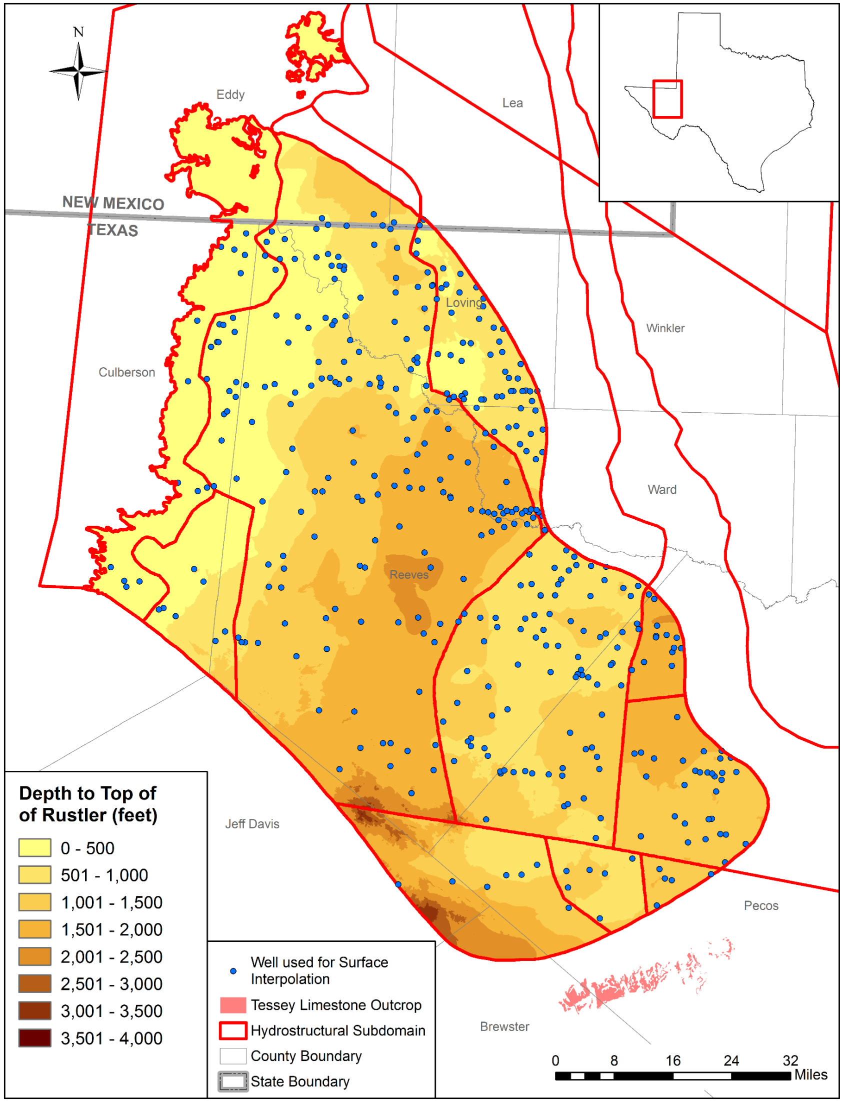


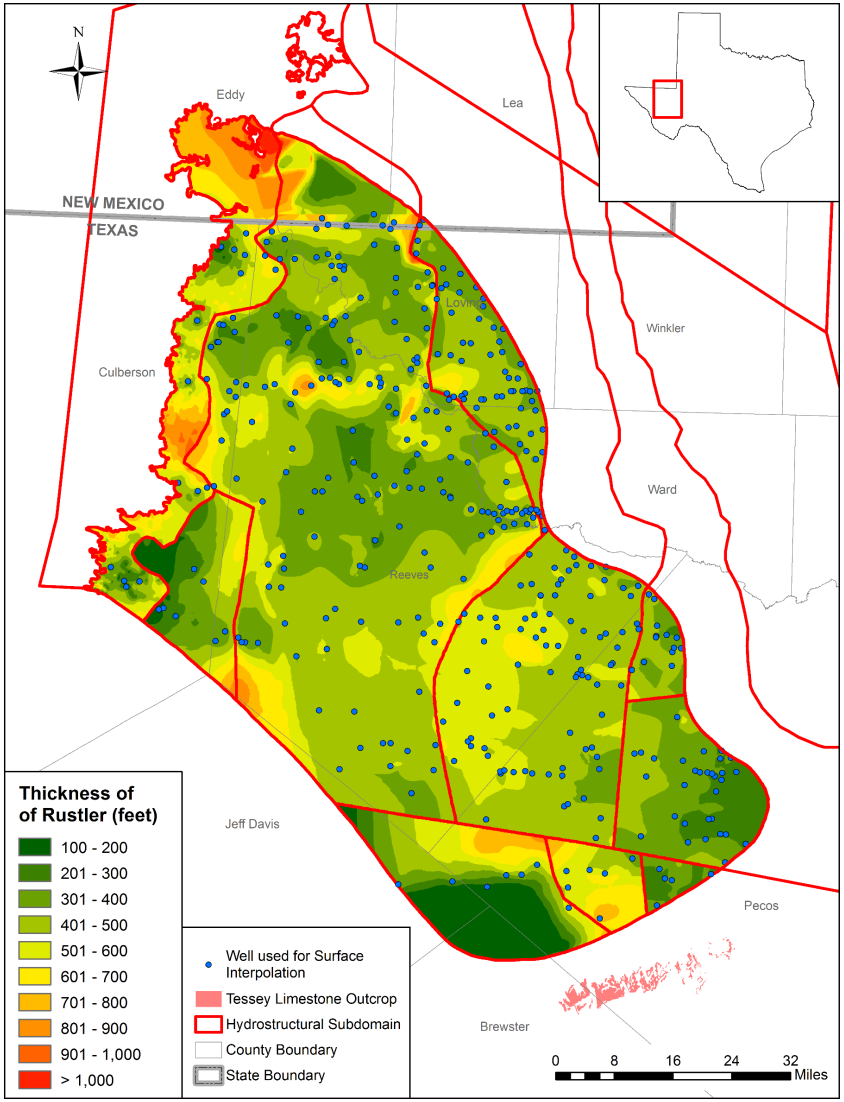
- Project area is based on the extent of the Rustler Aquifer as defined by the Texas Water Development Board (George and others, 2011)
  - Outcrop in the updip portion
  - Large offsetting fault in SW
  - TX/NM border to the north
  - An approximate 5,000 mg/L TDS cutoff

General Project Tasks and Timeline

- Defined structure, stratigraphy, lithology and apparent porosity of the Rustler Formation using geophysical logs
- Used existing, and developed new, techniques in well log analysis to estimate water quality from resistivity logs to supplement the sampled water quality data
- Mapped salinity classes for the Rustler Aquifer based on Winslow and Kister (1956)
- Delineated Potential Production Areas (PPAs)
  - **June 17th Stakeholder Meeting in Fort Stockton**
- Calculated groundwater volumes by salinity class (Winslow and Kister,1956) for the Rustler Aquifer
- Modeled pumping from the Potential Production Areas using the Rustler Aquifer Groundwater Availability Model to evaluate impacts of pumping under various production scenarios
  - **Final Report and supporting data delivered to the TWDB on August 31st**

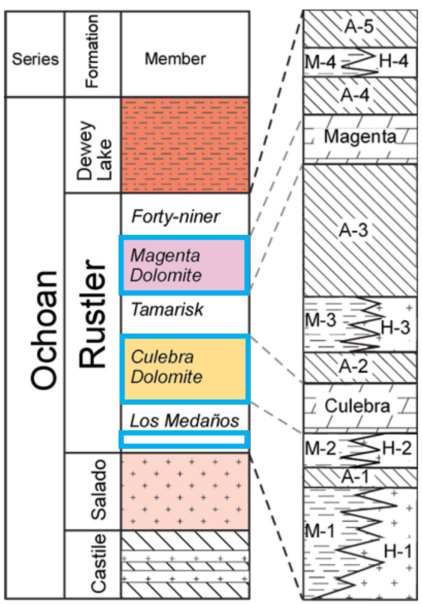
Geology of the Rustler Aquifer

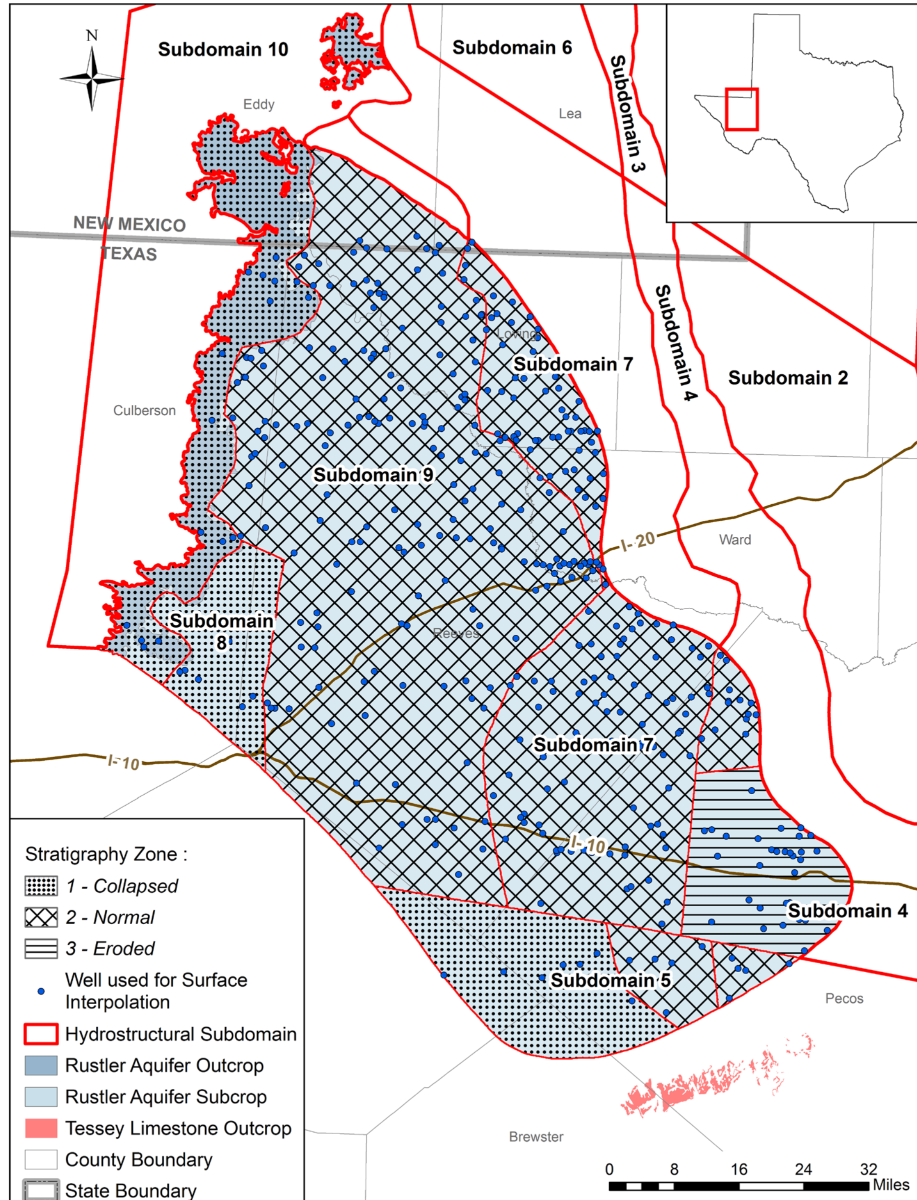




Geology of the Rustler Aquifer

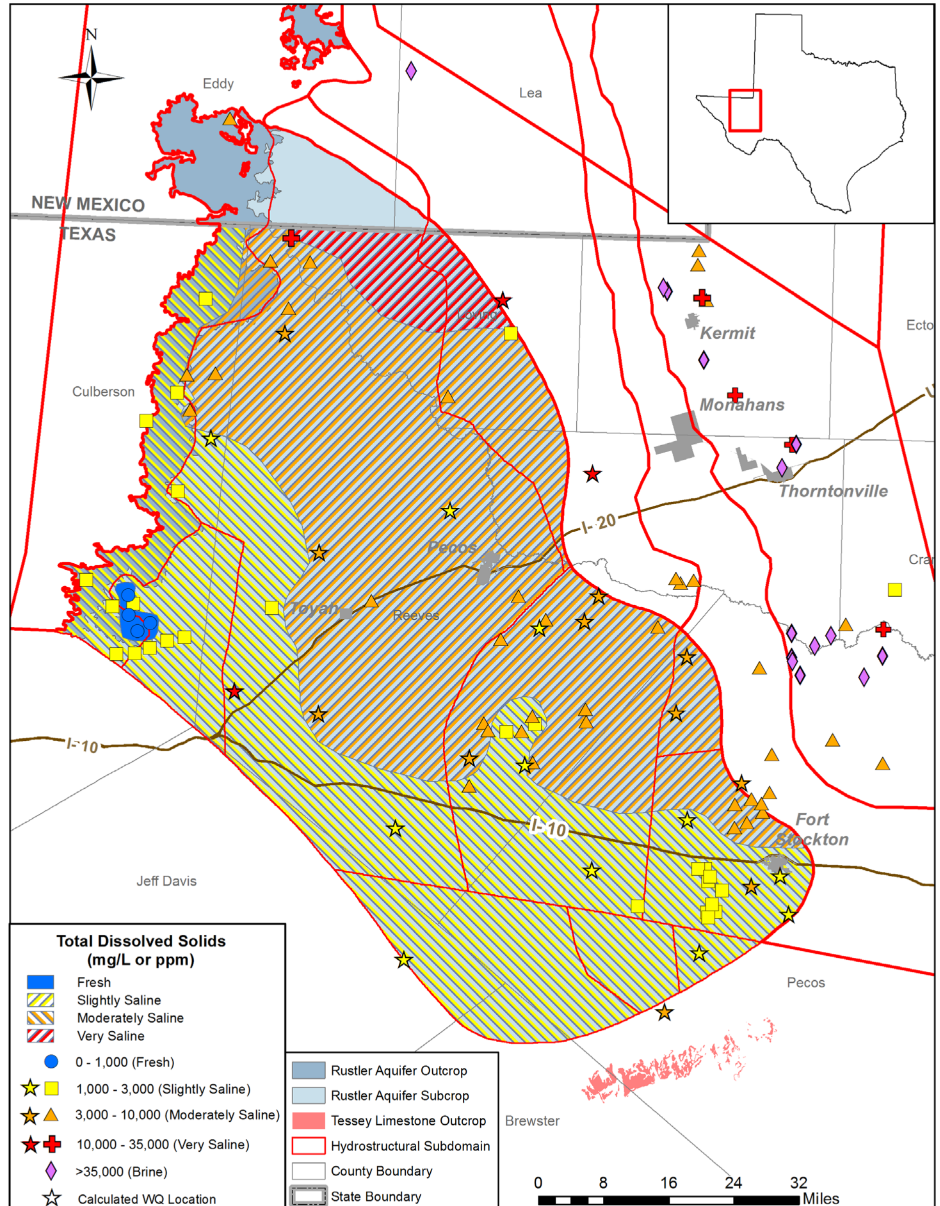
- Rustler stratigraphy distributed according to primary lithologic makeup
  1. Collapse
  2. Full section of member units
  3. Missing A5 through Magenta





Water Quality of the Rustler Aquifer

- Distribution of water quality within the Rustler Aquifer determined by:
  - Evaluation of sampled total dissolved solids measurements from TWDB GWD
  - Calculated total dissolved solids values for individual member units using a combination of resistivity and porosity logs
  - Hand drawn contours based on data distribution

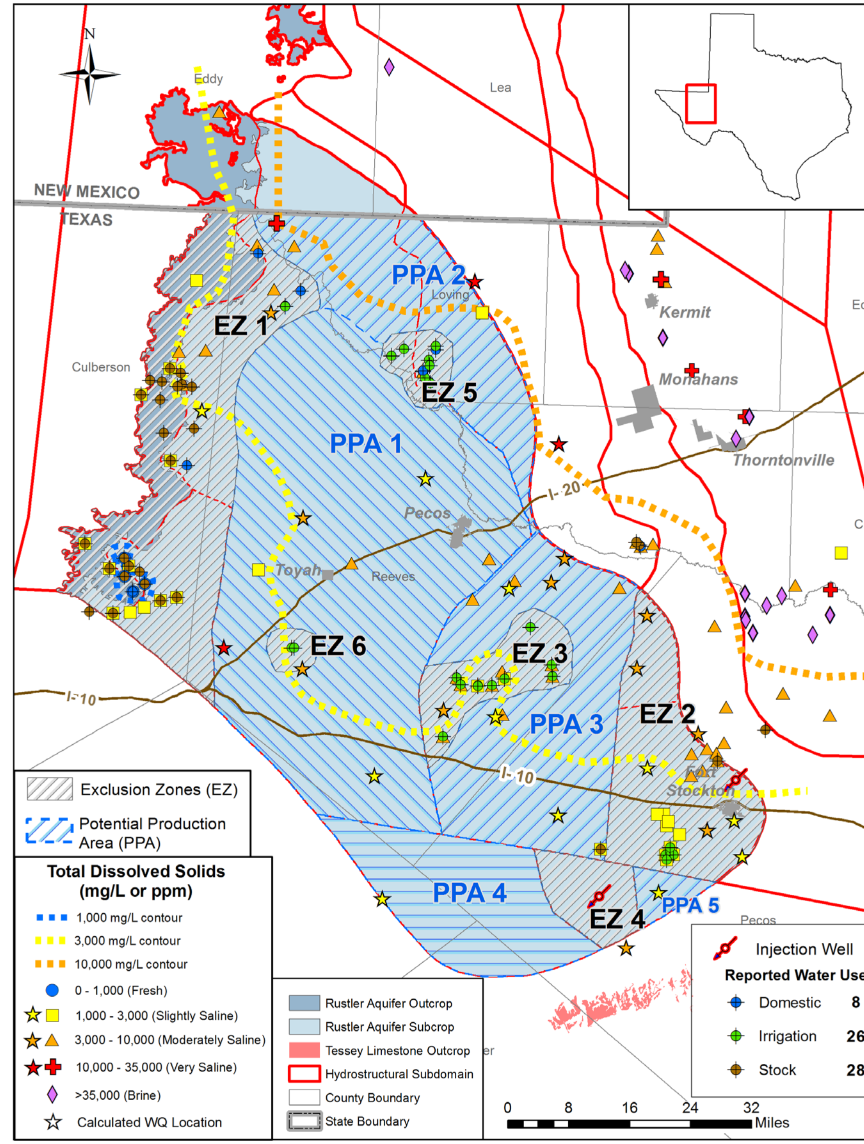


Groundwater Volume by Salinity Class

Aquifer Unit	Total Volume (Acre-feet)				
	Fresh	Slightly saline	Moderately saline	Very saline	Total
Collapse	88,000	5,531,000	213,000	0	5,832,000
Magenta	0	410,000	835,000	82,000	1,327,000
Culebra	0	2,387,000	3,493,000	140,000	6,019,000
Los Medaños	0	1,844,000	3,365,000	151,000	5,361,000
Rustler Aquifer	88,000	10,172,000	7,905,000	373,000	18,538,000

Delineation of Potential Production Areas

Potential Production Area Number	Hydrogeologic Barriers
1	Structural and hydraulic distance boundaries
	Dewey Lake Formation above and Salado Formation below
2	Structural and hydraulic distance boundaries
	Dewey Lake Formation above and Salado Formation below
3	Structural and hydraulic distance boundaries
	Dewey Lake Formation above and Salado Formation below
4	Structural boundaries
	Dewey Lake Formation above and Salado Formation below
5	Structural boundaries
	Dewey Lake above and Salado below



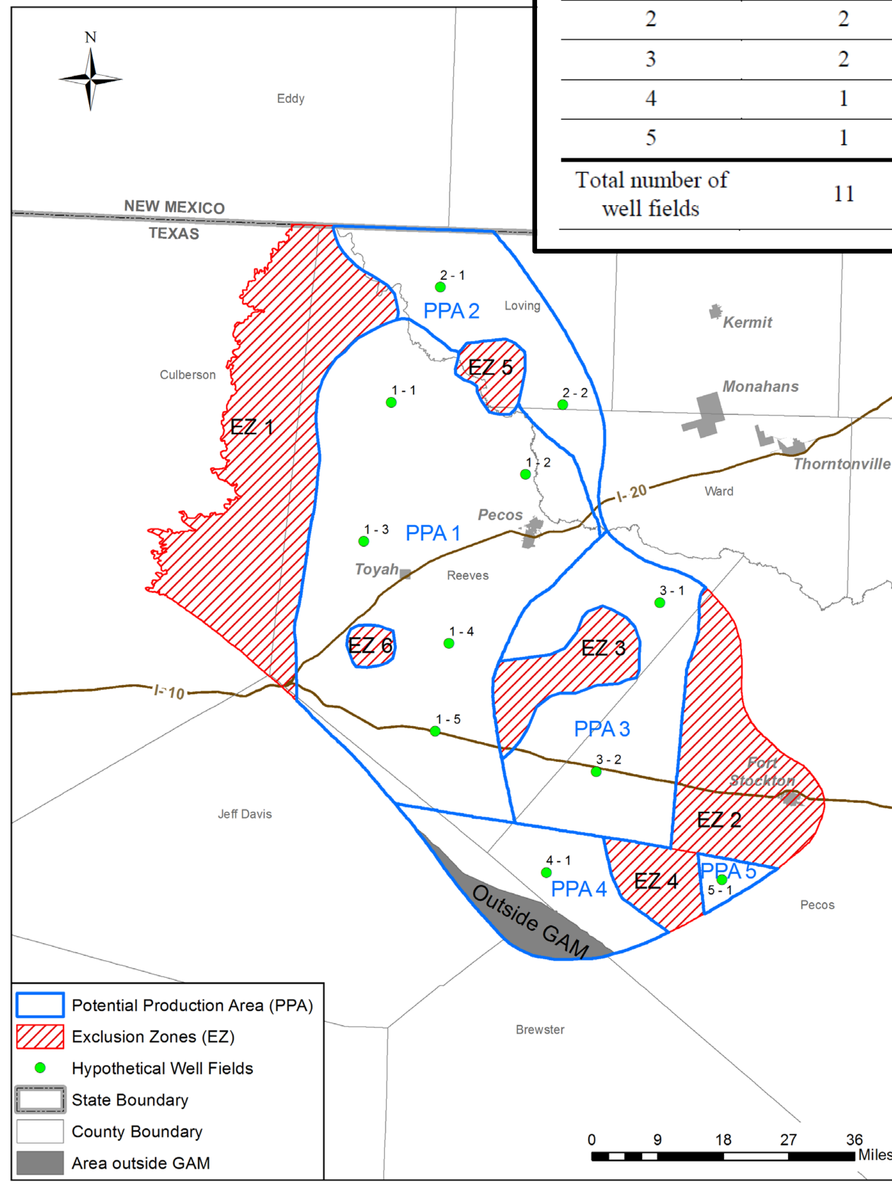
Modeling Approach

Major Feature of the Modeling Approach	Rationale for the Modeling Approach
Modeling Tool	Because of the extreme structural features and the lack of identifiable boundaries, we chose to not use analytical methods but rather use the Rustler Groundwater Availability Model.
Assume Wells Are Fully Completed in the Rustler Aquifer	Most wells in the Rustler Aquifer are completed across the entire formation, which effectively mixes pumped water and water quality from the three potential transmissive units.
Well Field Design and Approach to Production Rates Analyzed	We have assumed that each well field is composed of nine wells in a linear array approximately 1,250 feet apart. Production rates were constrained by drawdown (50 percent of available drawdown)
Location of Well Fields	At least one well field in each potential production area and not having a well field density below one per 400 square miles.
Metric Used for Impacts is Relative Change in Head from Baseline	For all simulations but the base case, results are reported as relative drawdown, not absolute head. This technique allows us to use the Groundwater Availability Model as a superposition model.
Sensitivity Analysis	Because of the uncertainties associated with defining the aquifer properties based on limited field data, a sensitivity analysis was performed. Each sensitivity model simulation involved adjusting one hydraulic property of the Rustler Aquifer at a time.

Modeling of Impacts

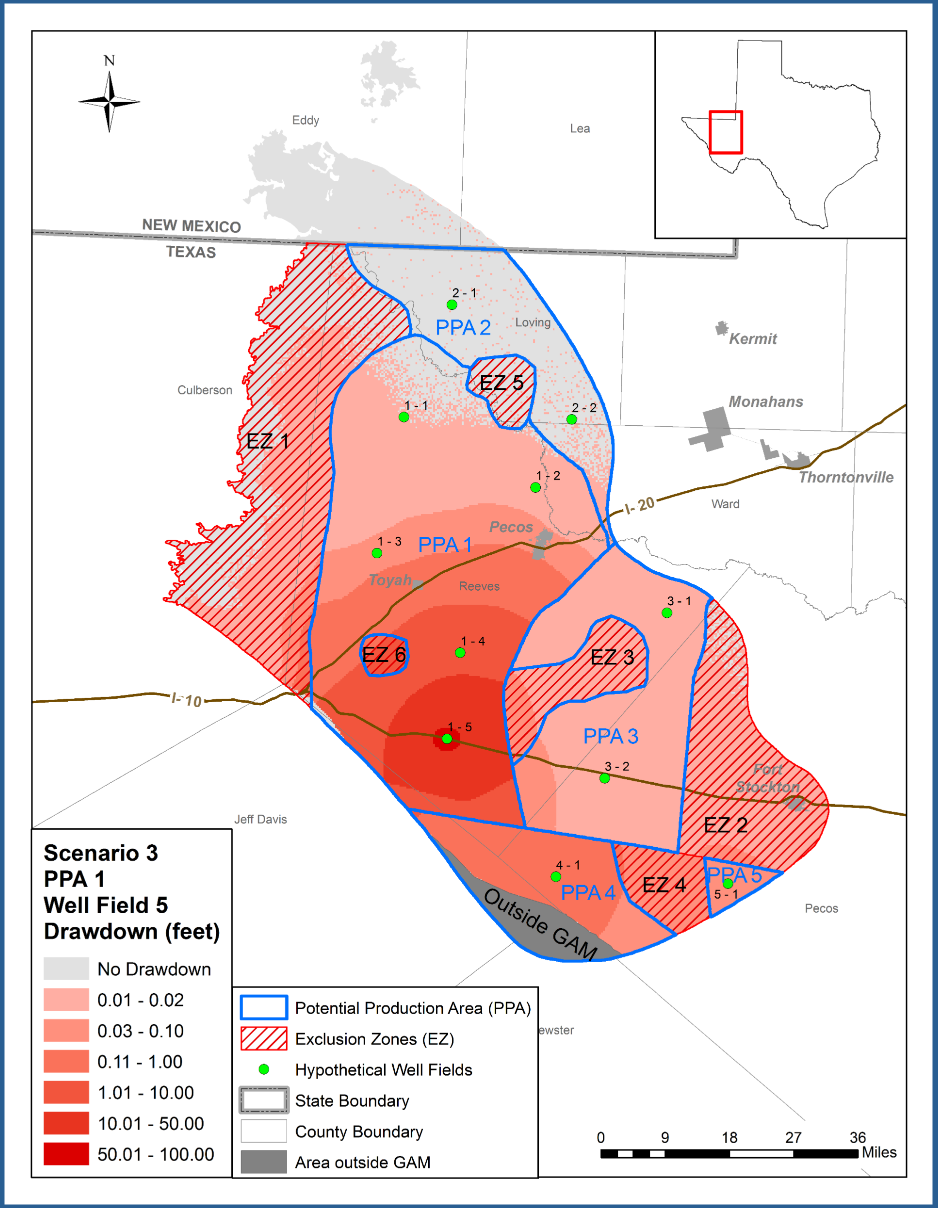
- Well fields were modeled for twelve (12) scenarios including the base-case scenario
- Sensitivity parameters considered include:
    - Horizontal hydraulic conductivity
    - Vertical hydraulic conductivity
    - Specific storage
    - Fault conductance
  - Also looked at the sensitivity of production potential to a three (3) well field array versus a nine(9) well field array

Potential Production Area Number	Number of Well Fields
1	5
2	2
3	2
4	1
5	1
Total number of well fields	11



Modeling of Impacts - Metrics

- Metrics used to measure impacts:
  - Drawdown from baseline conditions measured:
    - Maximum drawdown at protected wells and the location (exclusion zone)
    - Maximum drawdown and location at the boundary between a potential production area and an exclusion zone
  - Calculated production rate for the each well field



Conclusions

- The Rustler Aquifer is an extremely complex assemblage of lithologies further complicated by post-depositional processes such as cementation, collapse as a result of karstification and regional to local faulting
- This study provided a framework for the analysis of water quality from geophysical logs. This framework incorporates the complex geologic and petrophysical scenarios inherent to the Rustler Aquifer
- Volumes of groundwater in place were calculated by salinity classes (Winslow and Kister, 1956)
- Based upon the criteria in House Bill 30, five potential production areas were defined as part of this study.
- Groundwater modeling was performed in each of the potential brackish production areas to determine potential production rates (a proxy to groundwater availability) and to assess impacts within excluded zones and at protected wells.
- This study provides a good basis for the TWDB staff to make recommendations to the Board regarding brackish resources and brackish groundwater production areas in the Rustler Aquifer.

Next Steps

- TWDB staff:
  - review the reports and potential production areas
  - consider stakeholder comments
  - recommend brackish groundwater production zones to the Executive Administrator (EA)
- The EA will review and propose brackish groundwater productions zones to the Board
- The Board will consider designating brackish groundwater production zones in a Board Meeting this fall

- TWDB staff:
  - prepare biennial desalination report including:
    - seawater or brackish groundwater activities in Texas
    - results of TWDB desalination studies
    - impediments to desalination in Texas (regulatory, financial, …)
    - evaluate state's role in development of desalination projects
    - anticipated general revenue appropriation to continue investigating desalination activities
    - identification and designation of brackish groundwater production zones

- TWDB Board will consider the report in a Board Meeting this fall

- Biennial desalination report due December 1, 2016

Public Comments

- Verbal comments:
  - One question/comment at a time
  - Please raise your hand or submit written comment card
  - TWDB staff will prepare written comment/answers
  - These will be posted to TWDB website

- Written comments:
  - due September 16, 2016
  - Send to: Dr. Sanjeev Kalaswad
    Sanjeev.kalaswad@twdb.texas.gov

- Written comments will be posted to TWDB website

Closing Remarks

We sincerely appreciate your patience and comments during this bill implementation.

We look forward to working with you during the next steps in the process