Effect of Faults on Groundwater Flow in the Carrizo-Wilcox Aquifer in Central Texas: Update the Central GAM for Sparta, Queen City, Carrizo-Wilcox Aquifers

Stakeholder Meeting #1
November 20, 2015

Milano Civic Center

Presented by:
Steve Young, INTERA
Bob Harden, Harden & Associates

Agenda

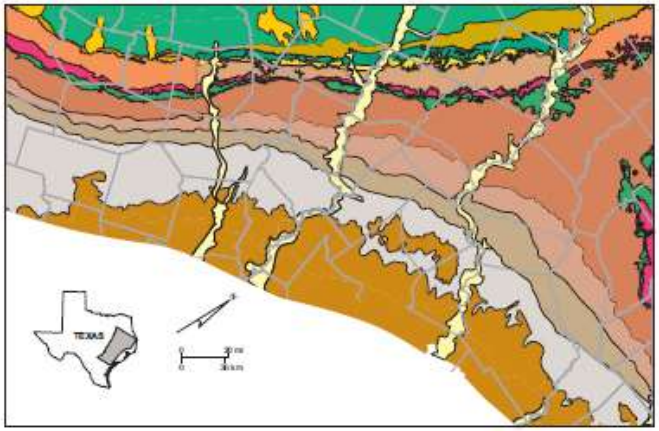
- Central SP, QC, Carrizo-Wilcox GAM
- Fault Analysis
- Current Tasks and Schedule
- Team Members
- Data Sets for Improved Aquifer Characterization
- Proposed Contract Expansion to Improve Simulation of GW-SW Interaction
- Call for Data
- Questions

Groundwater Availability Models (GAMs) for Carrizo-Wilcox Aquifer

Central Carrizo-Wilcox GAM

FINAL TECHNICAL REPORT

GROUNDWATER AVAILABILITY MODEL FOR THE CENTRAL PART OF THE CARRIZO-WILCOX AQUIFER IN TEXAS



Prepared for
Texas Water Development Board

By Alan R. Dutton, Bob Harden[1], Jean-Philippe Nicot, and David O'Rourke[2]

Bureau of Economic Geology
Scott W. Tinker, Director
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

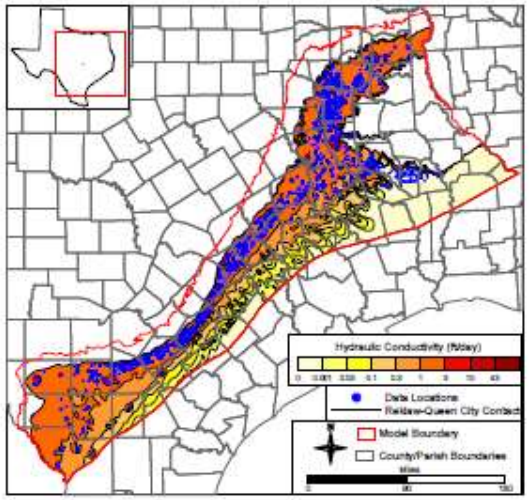
[1] R. W. Harden and Associates, Inc.
[2] HDR Engineering Services, Inc.

FEBRUARY 2003

Central QCSP GAM

FINAL REPORT

Groundwater Availability Models for the Queen City and Sparta Aquifers



Prepared for the:
Texas Water Development Board

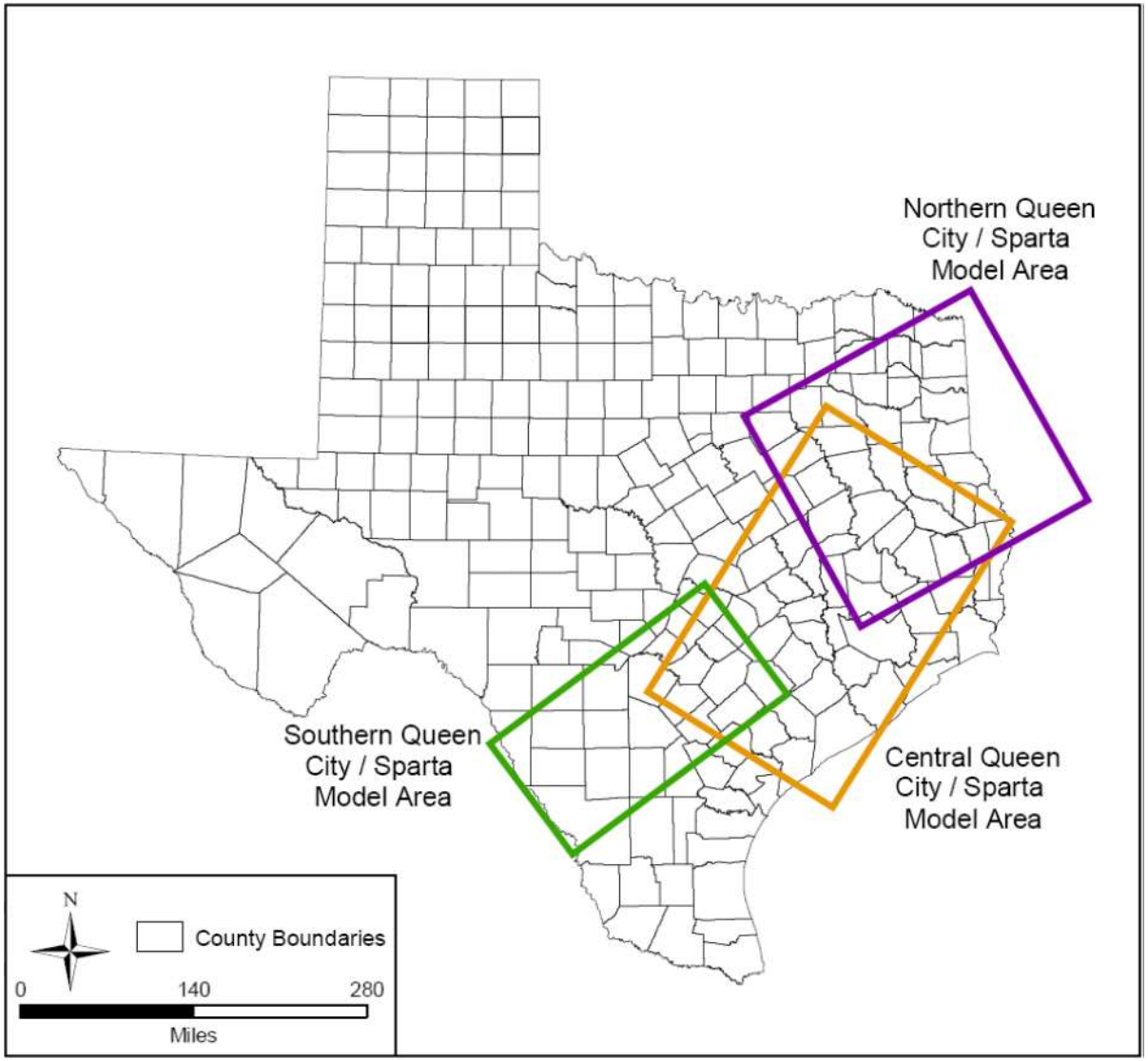
Prepared by:
Van A. Kelley, Neil E. Deeds, Dennis G. Fryar, and Jean-Philippe Nicot[1]
with
Toya L. Jones, Alan R. Dutton[1], Gabe Bruehl[2], Tanya Unger-Holtz, and James L. Machin[2]

INTERA Incorporated
9111A Research Blvd.
Austin, Texas 78758

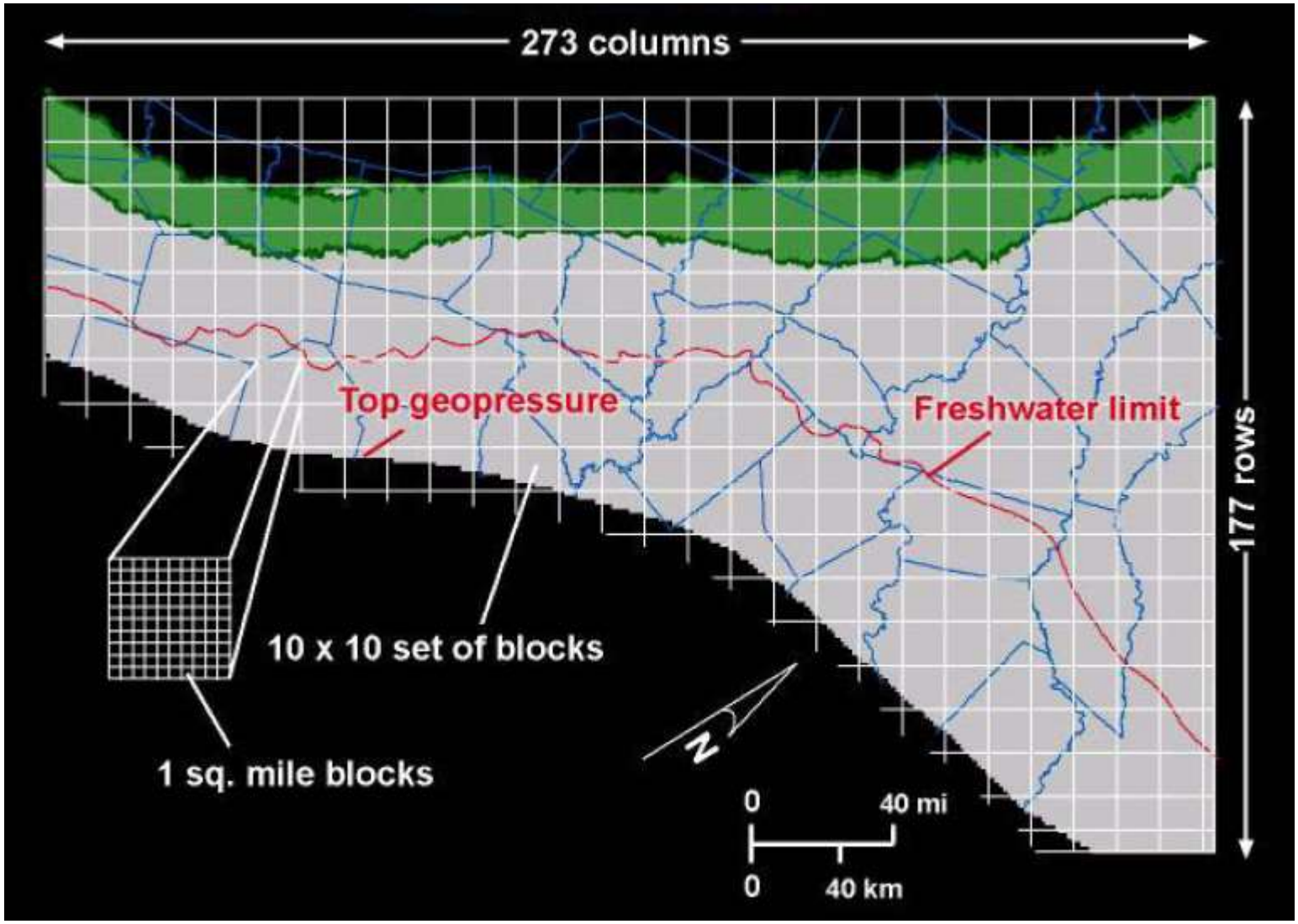
[1] University of Texas Bureau of Economic Geology
[2] R.J. Brandes Company

October, 2004

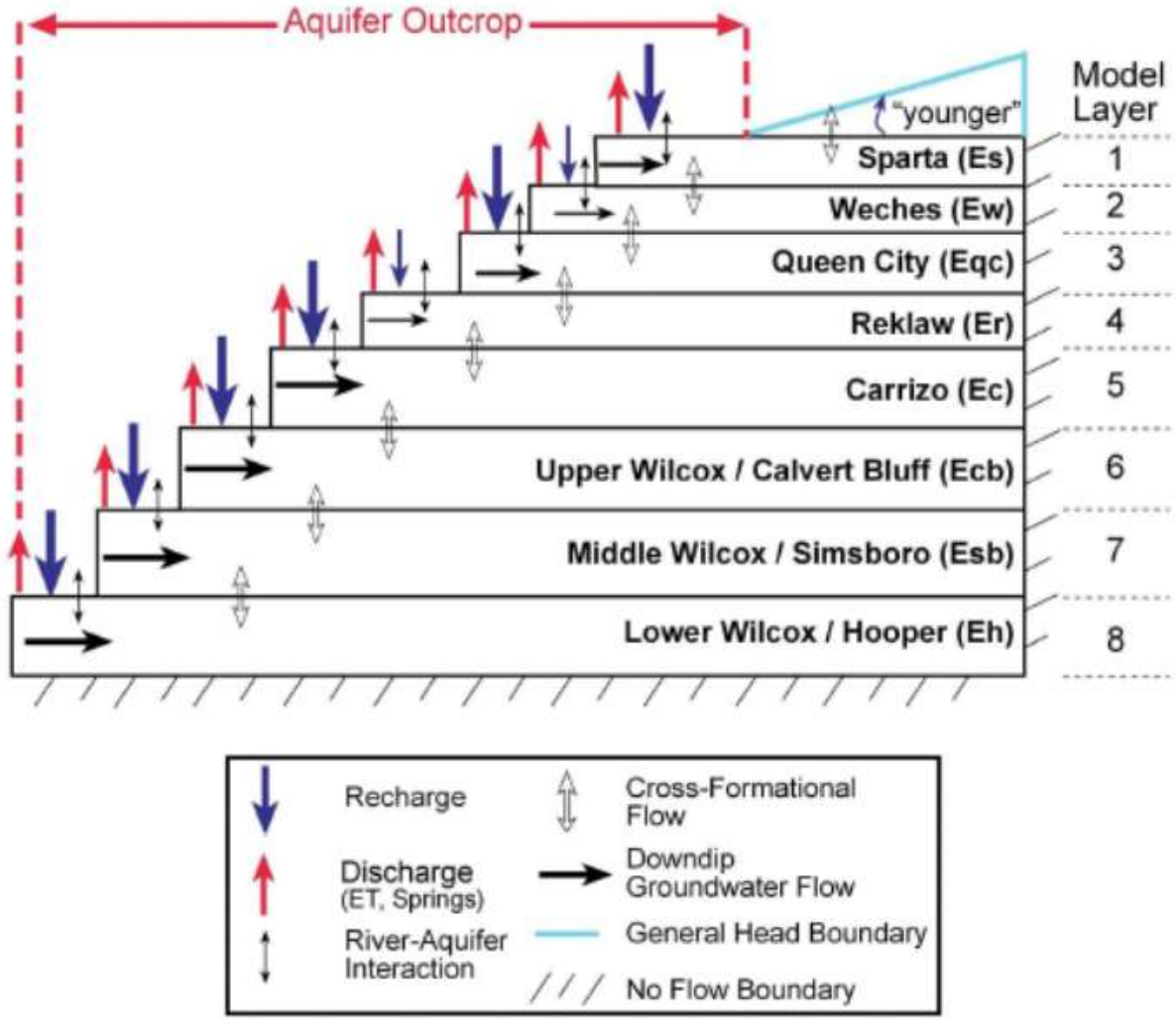
Domains for Southern, Central, and Northern QCSP GAMs



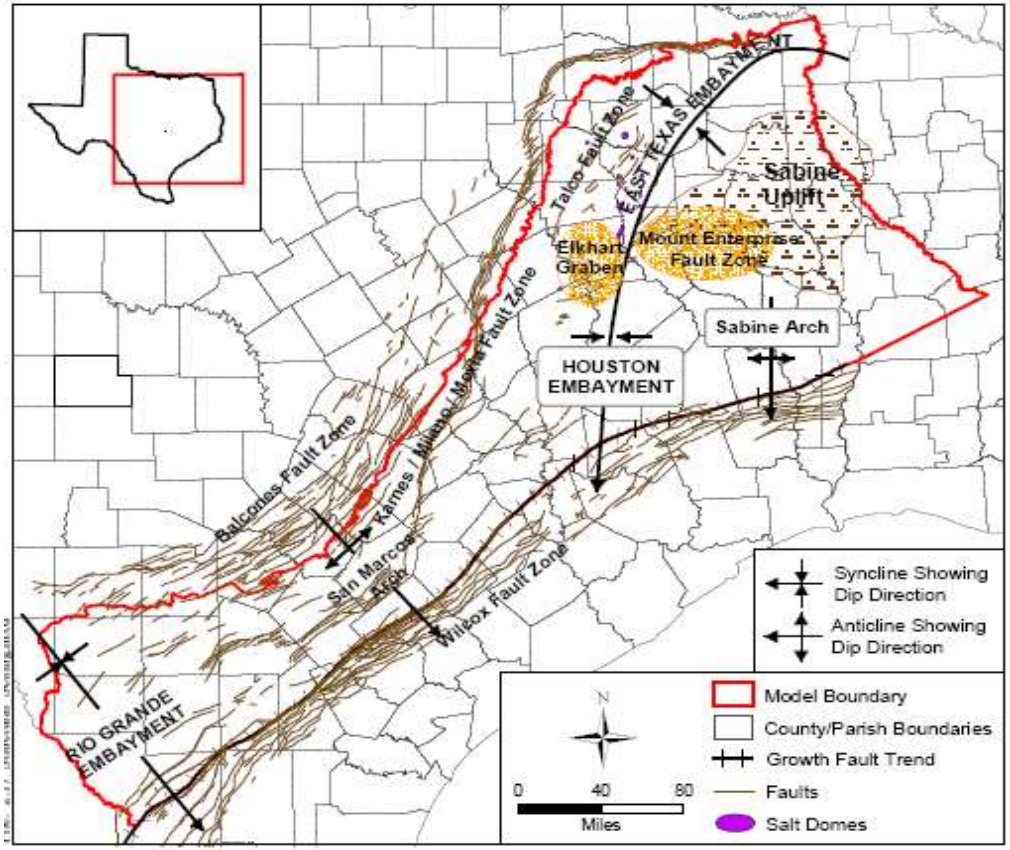
Model Grid for Central QCSP and Carrizo-Wilcox GAM

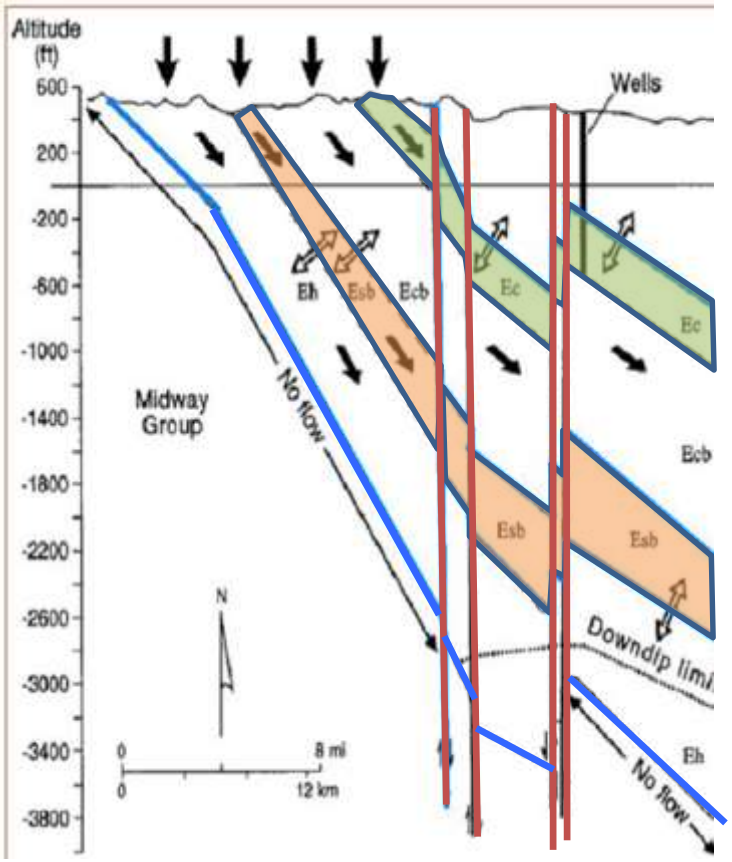


Model Layers in Central QCSP GAM



Fault Zones


EAST TEXAS EMBAYMENT
Talco Fault Zone
Sabine Uplift
Elkhart Graben
Mount Enterprise Fault Zone
Sabine Arch
HOUSTON EMBAYMENT
Balcones Fault Zone
Karnes / Milano / Mexia Fault Zone
San Marcos Arch
Wilcox Fault Zone
RIO GRANDE EMBAYMENT
Syncline Showing Dip Direction
Anticline Showing Dip Direction
Model Boundary
County/Parish Boundaries
Growth Fault Trend
Faults
Salt Domes
N
0 40 80
Miles

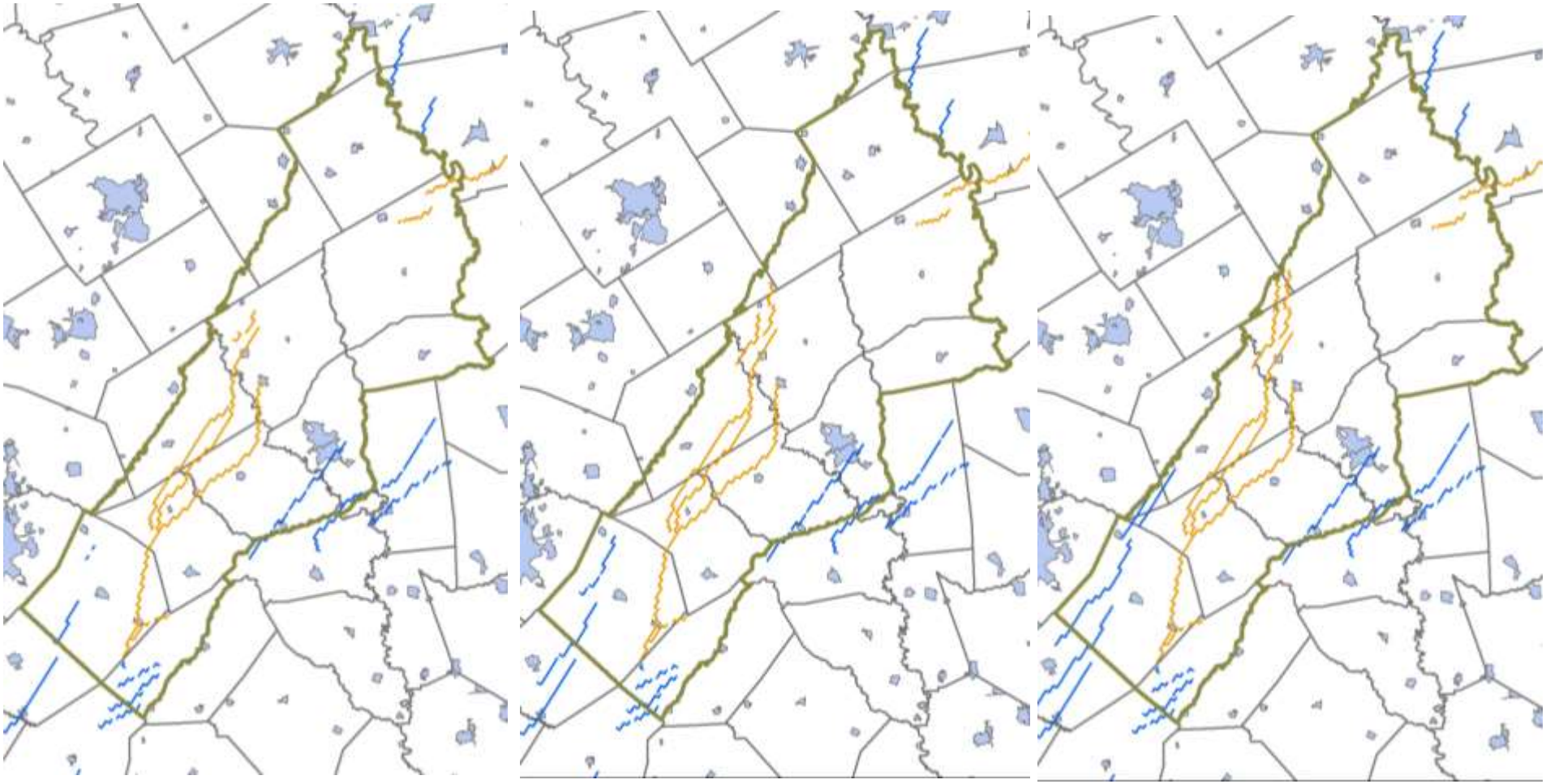

Altitude (ft)
600
200
-200
-600
-1000
-1400
-1800
-2200
-2600
-3000
-3400
-3800
Wells
Eh
Esb
Ecb
Ec
Midway Group
No flow
Downdip limit
N
0 8 mi
0 12 km

Representation Of Faults In Central QCSP GAM

Calvert Bluff

Simsboro

Hooper



Sealing Faults

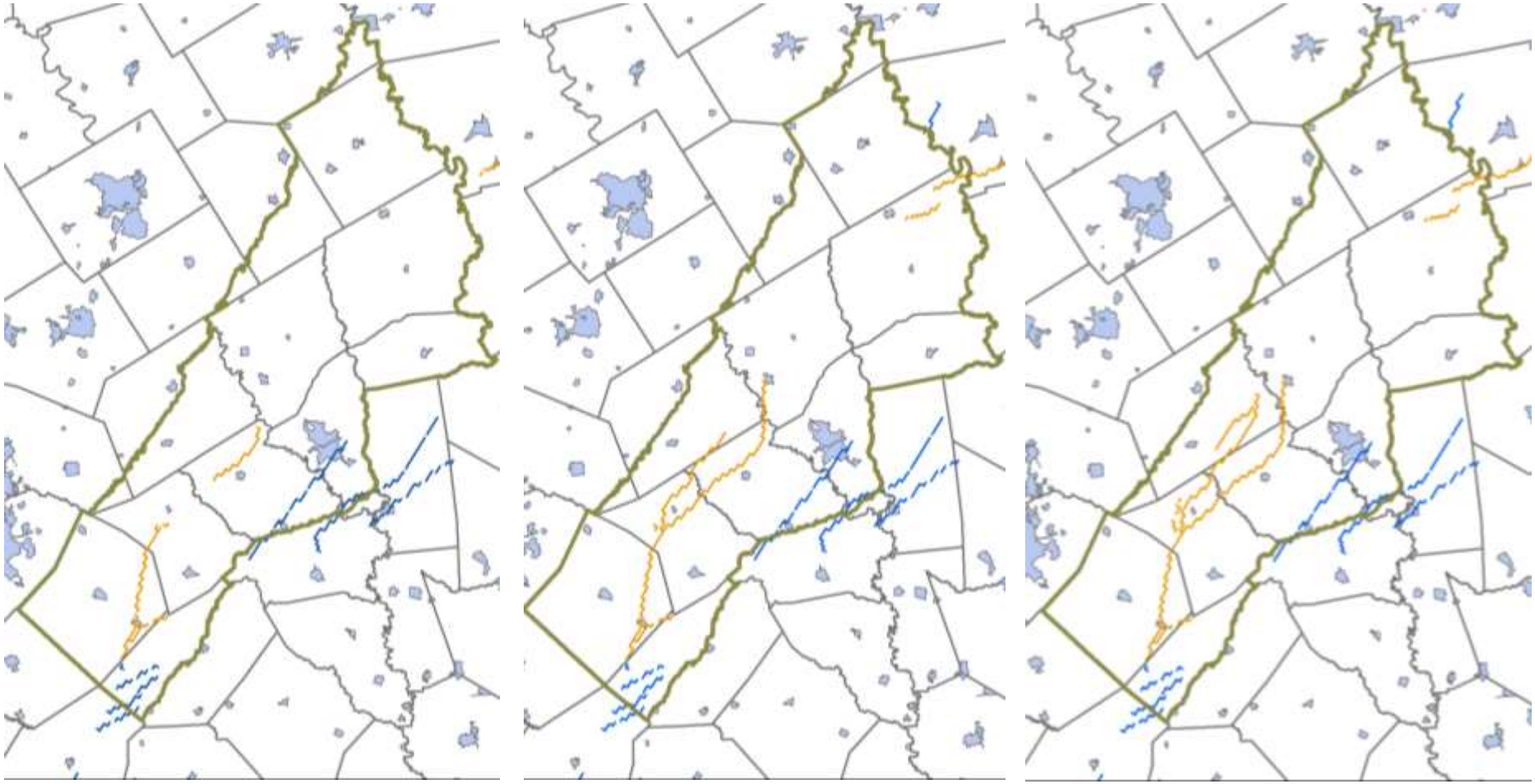
Non-Sealing Faults

Representation Of Faults In Central QCSP GAM (con't)

Sparta

Queen City

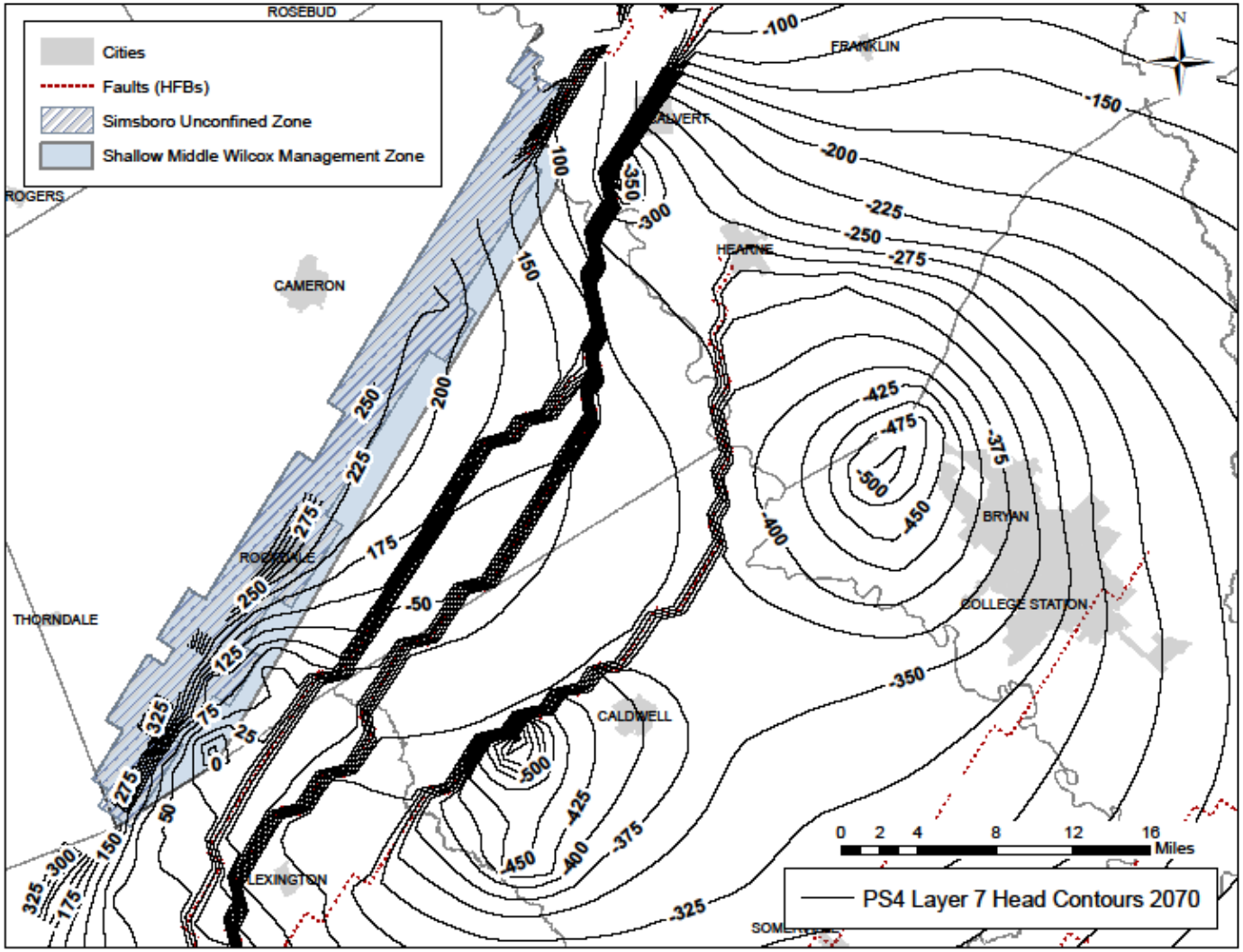
Carrizo



Sealing Faults

Non-Sealing Faults

Simulated Water Levels For GMA-12 Pumping Scenario 4

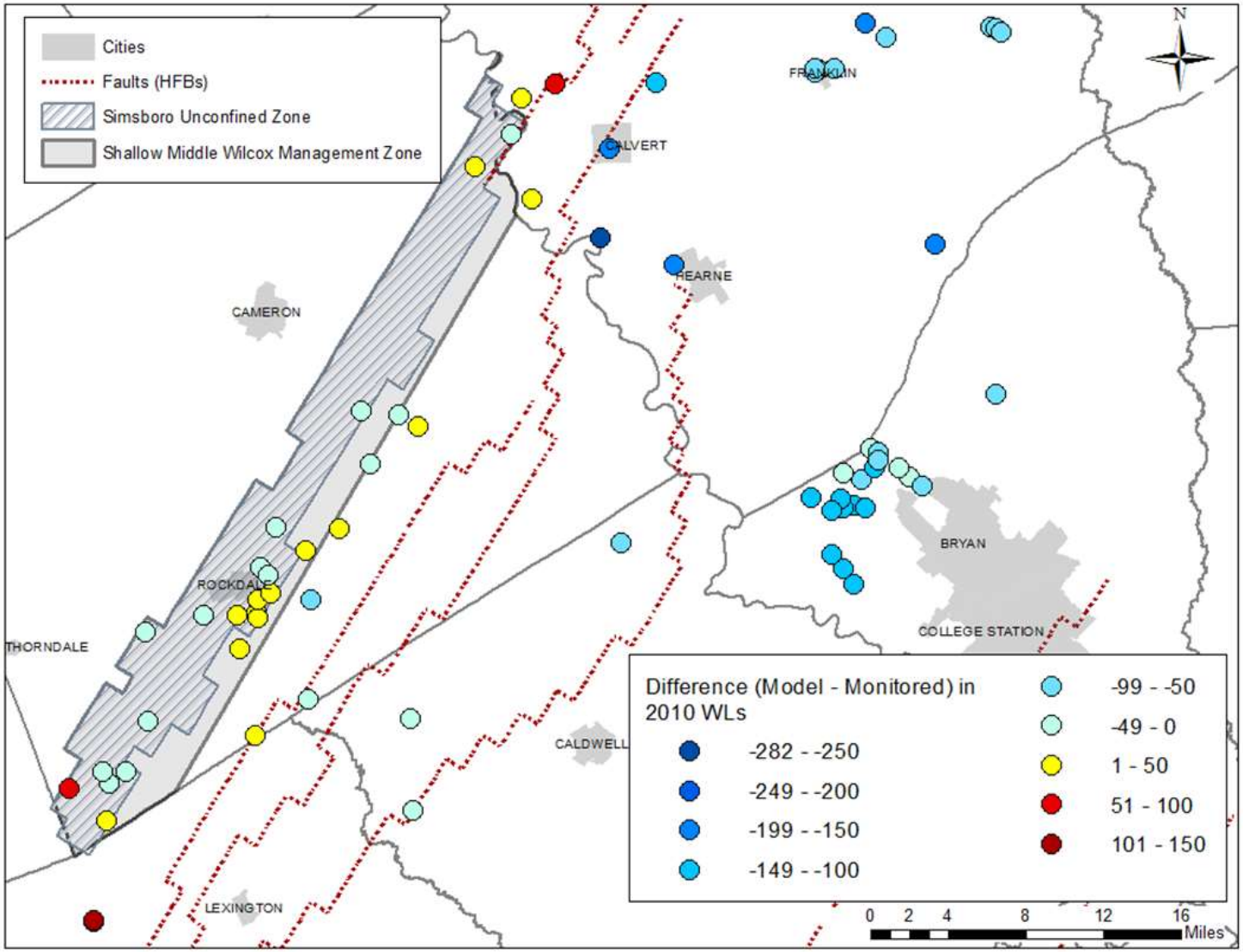


Sensitivity Of Simulated Water Level To Faults

Comparison of Predicted Drawdown between 2000 and 2060 for Run12_7a for the Condition of Inclusion of the Faults and of the Exclusion of the Faults

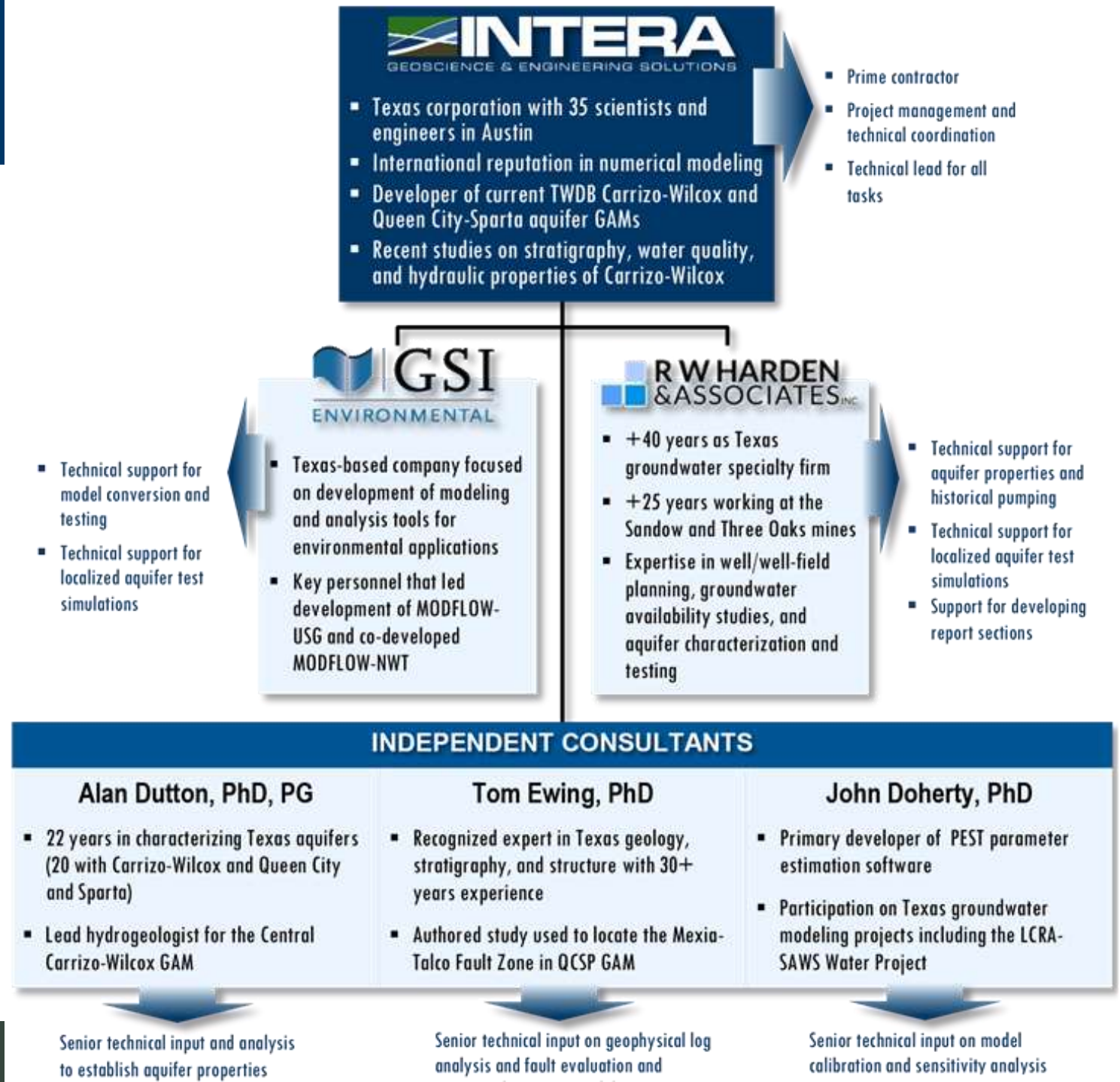
Groundwater Conservation District	Fault Assumption	Sparta	Queen City	Carrizo	Calvert Bluff	Simsboro	Hooper
Brazos Valley	Faults	13.7	12.3	47.9	108.8	269.1	175.6
	No Faults	12.3	10.1	37.1	77.6	188.5	121.0
	Difference	1.4	2.2	10.9	31.2	**80.6**	**54.6**
Fayette County	Faults	58.9	58.7	59.6	126.5	219.6	171.7
	No Faults	52.9	51.3	47.9	92.5	155.8	125.2
	Difference	**6.1**	**7.3**	**11.7**	33.9	63.7	46.5
Lost Pines	Faults	3.7	12.7	47.2	94.4	236.2	133.4
	No Faults	1.3	9.4	41.8	69.4	184.0	102.5
	Difference	2.5	3.2	5.5	25.0	52.2	30.9
Mid-East Texas	Faults	0.4	-3.2	52.5	66.9	113.3	95.4
	No Faults	0.3	-3.4	45.3	52.4	84.7	69.6
	Difference	0.2	0.3	7.3	14.5	28.5	25.8
Post Oak Savannah	Faults	27.5	27.9	60.8	135.9	296.6	177.6
	No Faults	24.2	22.5	53.1	96.3	225.2	132.6
	Difference	3.4	5.4	7.7	**39.6**	71.4	45.0

Comparison Between Modeled and Measured Water Levels for 2010 Based on GMA 12 PS4 Simulation



CURRENT TASKS & SCHEDULE

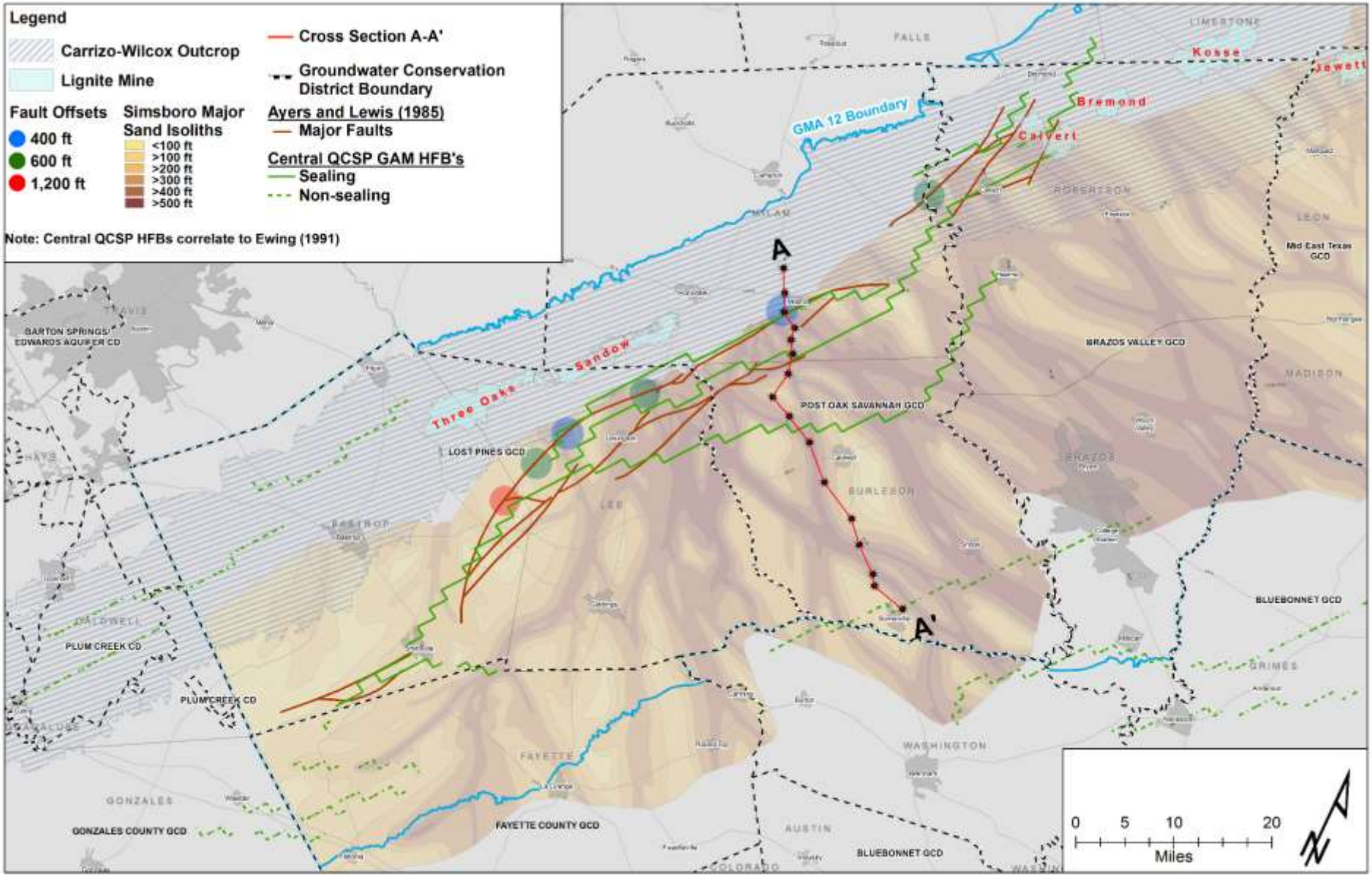
- The Central QCSP GAM will be updated from MODFLOW-96 to MODFLOW-2005 or to more recent MODFLOW codes with pre-approval from the TWDB contract manager.
- The time period of the existing Central QCSP GAM will be extended from 1999 to 2010 or later and historical pumping will be updated.
- The framework from the existing Central QCSP GAM will be compared to the results of a TWDB geophysical log analysis and the model will be updated as applicable.
- Review and update the application of recharge in the model outcrop areas to eliminate anomalies.
- Model sensitivity analyses will be conducted on the existing Central QCSP GAM and compared against measured water levels and aquifer tests to evaluate the effect of faults on the groundwater flow system. The model will be updated depending on the outcome of the sensitivity analyses.
- The Central QCSP GAM will be recalibrated after being updated.
- FAULT STUDY, MODEL SENSITIVITY ANALYSIS, AND UPDATE TO CONCEPTUAL MODEL DEADLINE: September 2016
- Stakeholder meeting will be held September 2017 with opportunity to review draft model deliverables
- Final Model Report: December 2017


INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS
Texas corporation with 35 scientists and engineers in Austin
International reputation in numerical modeling
Developer of current TWDB Carrizo-Wilcox and Queen City-Sparta aquifer GAMs
Recent studies on stratigraphy, water quality, and hydraulic properties of Carrizo-Wilcox
Prime contractor
Project management and technical coordination
Technical lead for all tasks
GSI
ENVIRONMENTAL
Texas-based company focused on development of modeling and analysis tools for environmental applications
Key personnel that led development of MODFLOW-USG and co-developed MODFLOW-NWT
Technical support for model conversion and testing
Technical support for localized aquifer test simulations
R W HARDEN &ASSOCIATES INC
+40 years as Texas groundwater specialty firm
+25 years working at the Sandow and Three Oaks mines
Expertise in well/well-field planning, groundwater availability studies, and aquifer characterization and testing
Technical support for aquifer properties and historical pumping
Technical support for localized aquifer test simulations
Support for developing report sections
INDEPENDENT CONSULTANTS
Alan Dutton, PhD, PG
22 years in characterizing Texas aquifers (20 with Carrizo-Wilcox and Queen City and Sparta)
Lead hydrogeologist for the Central Carrizo-Wilcox GAM
Tom Ewing, PhD
Recognized expert in Texas geology, stratigraphy, and structure with 30+ years experience
Authored study used to locate the Mexia-Talco Fault Zone in QCSP GAM
John Doherty, PhD
Primary developer of PEST parameter estimation software
Participation on Texas groundwater modeling projects including the LCRA-SAWS Water Project
Senior technical input and analysis to establish aquifer properties
Senior technical input on geophysical log analysis and fault evaluation and
Senior technical input on model calibration and sensitivity analysis

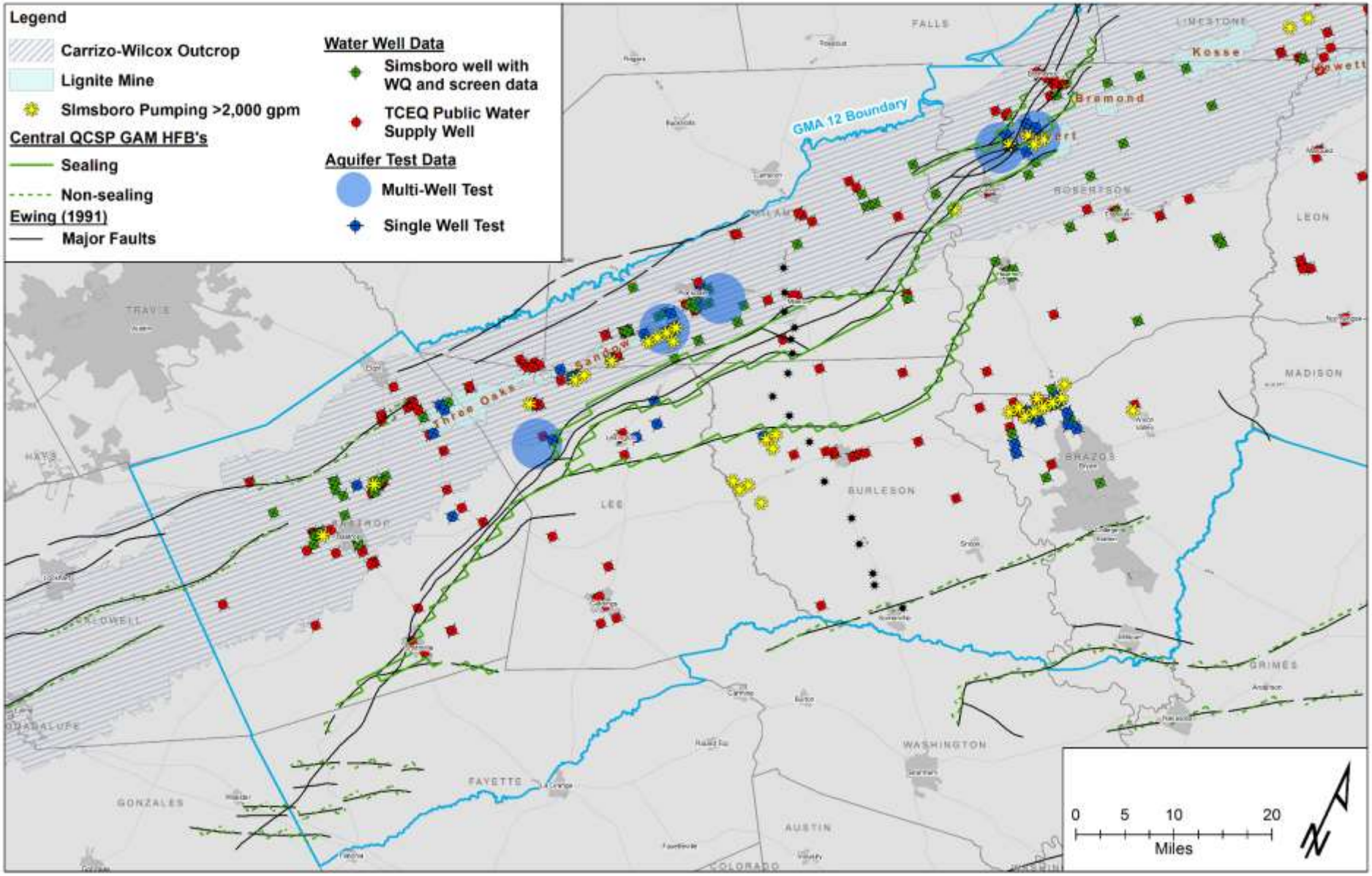
Data Sets for Improved Aquifer Characterization

- Maps and Data of Faults and Faults Zones
- Aquifer Pumping Tests
- Water Levels
- Water Quality
- Geophysical Logs

Comparison from Ayers and Lewis (1985) Fault Zones and from GAM



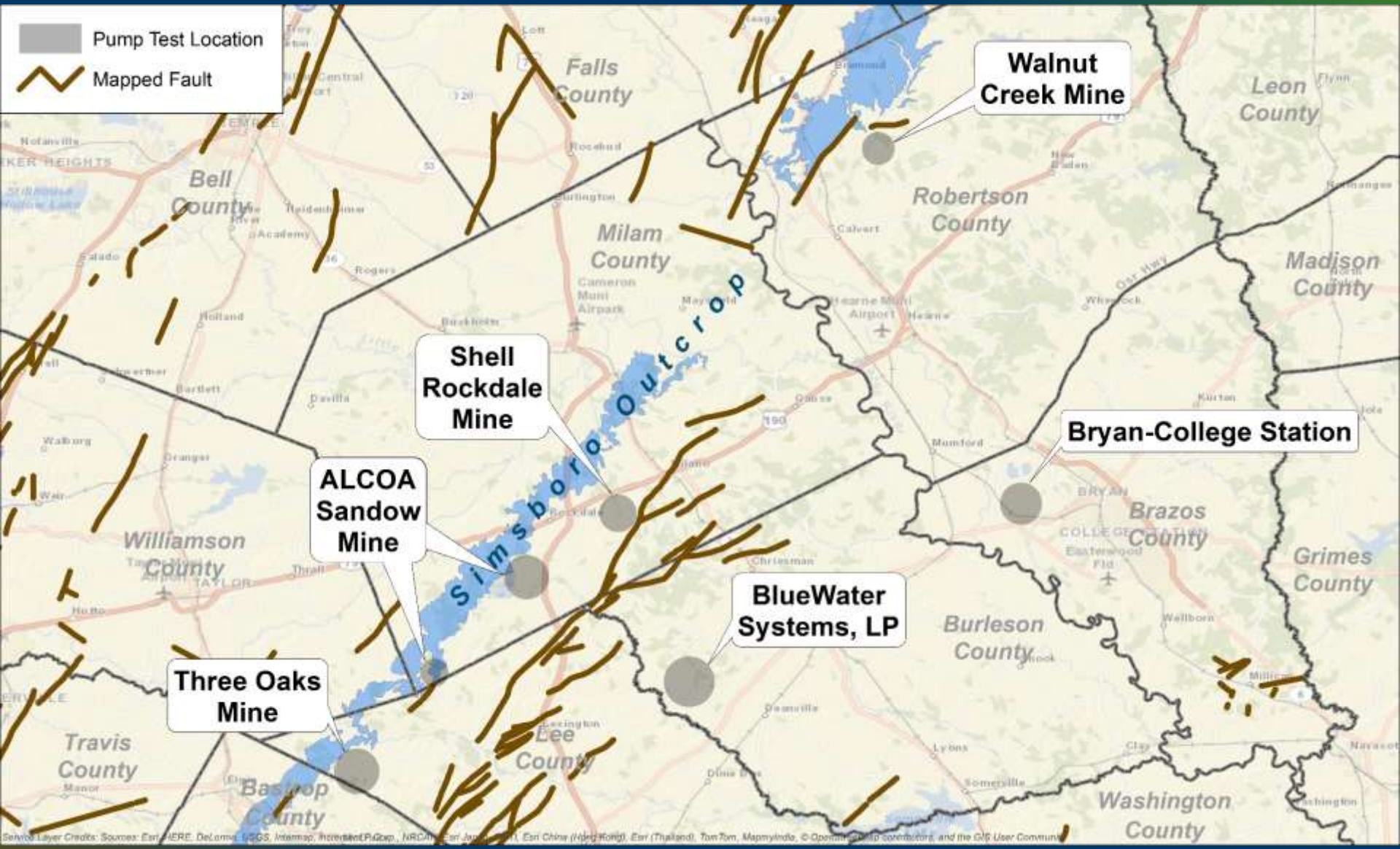
Available Aquifer Pumping Tests



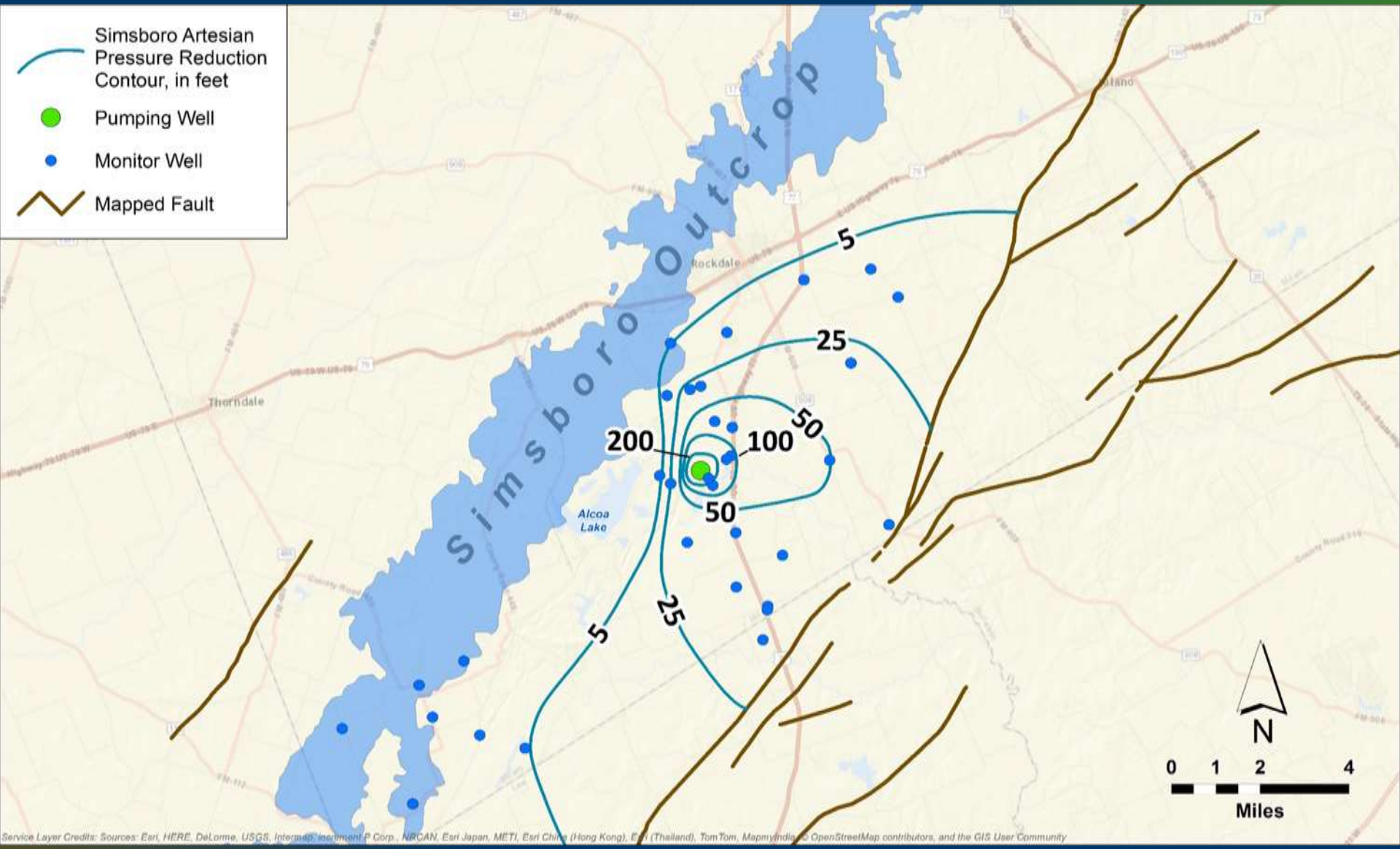
Simsboro Pump Test Data

- Single Well Pump Tests
  - 30+ Tests; Many locations
- Mine Block Pump Tests
  - 10+ Tests; ALCOA Sandow, Walnut Creek, Three Oaks; Shell Rockdale Mine
  - 20-30 day tests
  - Monitor wells distributed near pumping well
- Regional Pump Tests
  - Several Tests; ALCOA Sandow, End Op
  - Longer duration tests, up to three months
  - Monitor wells farther away from pumping well

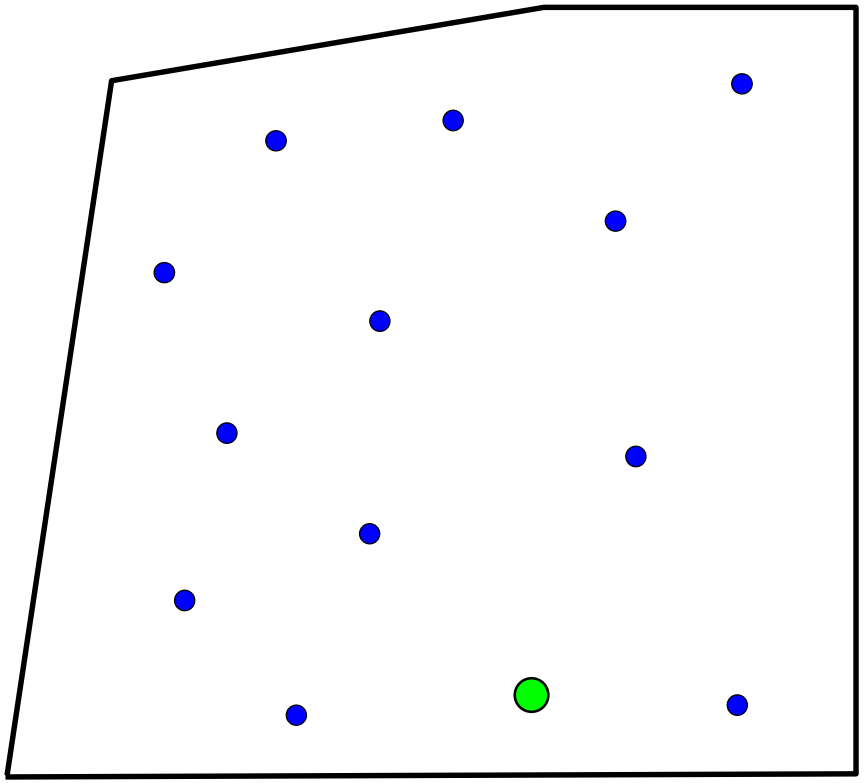
Sample of Aquifer Testing Locations



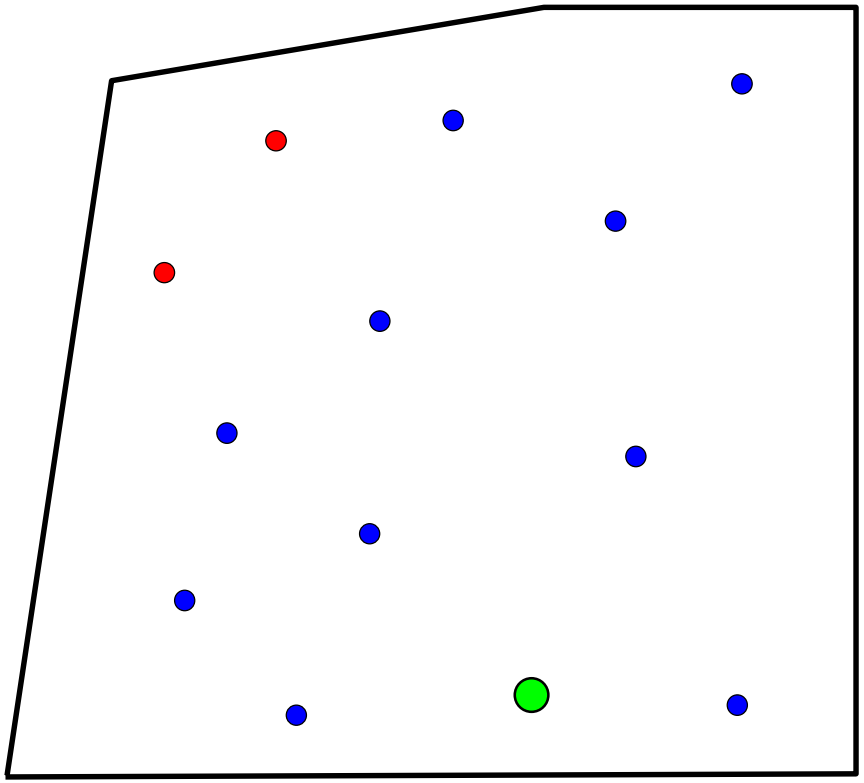
Alcoa 1988 Pumping Test



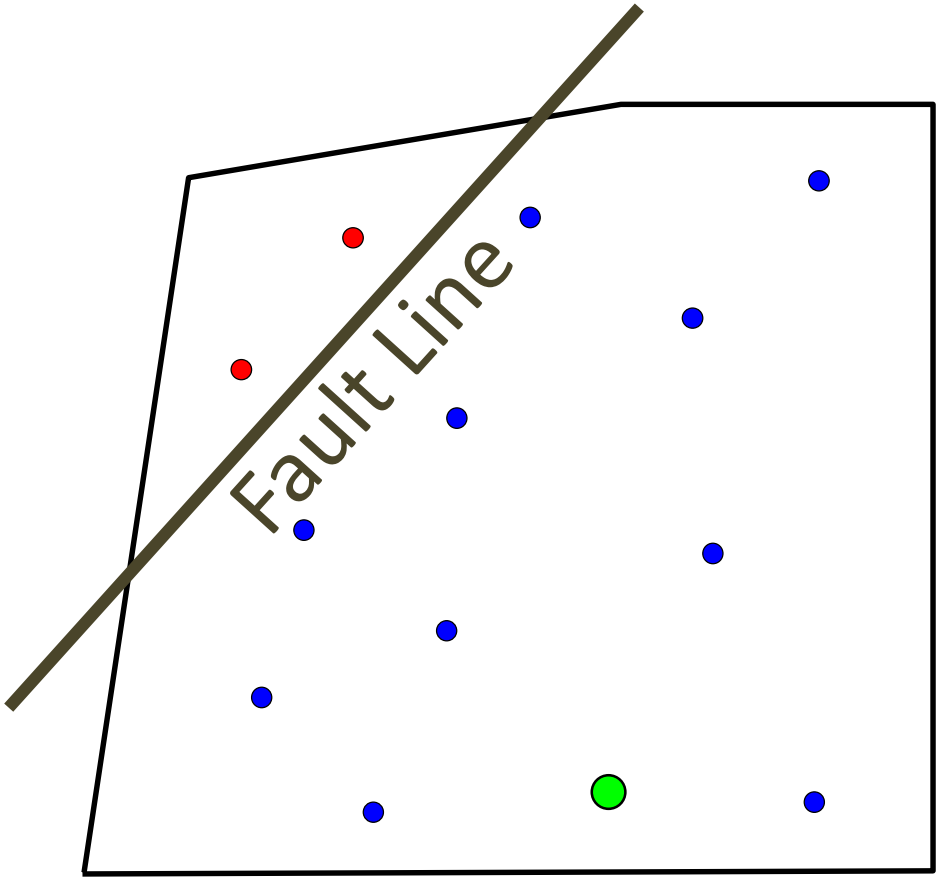
Mining Block Aquifer Test



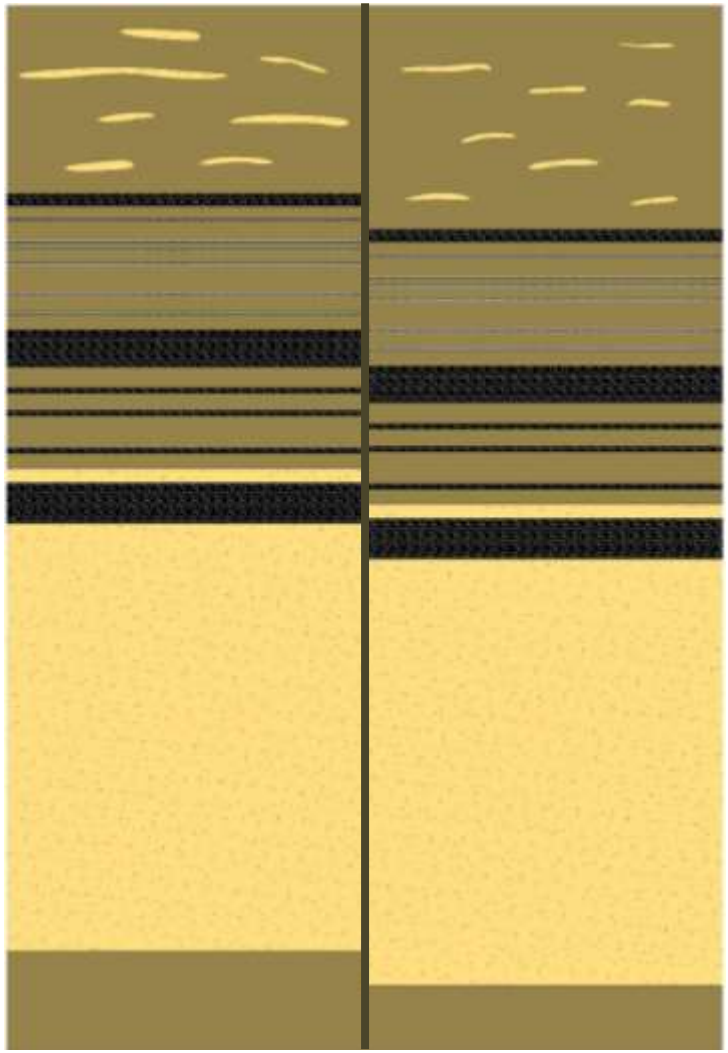
Mining Block Aquifer Test



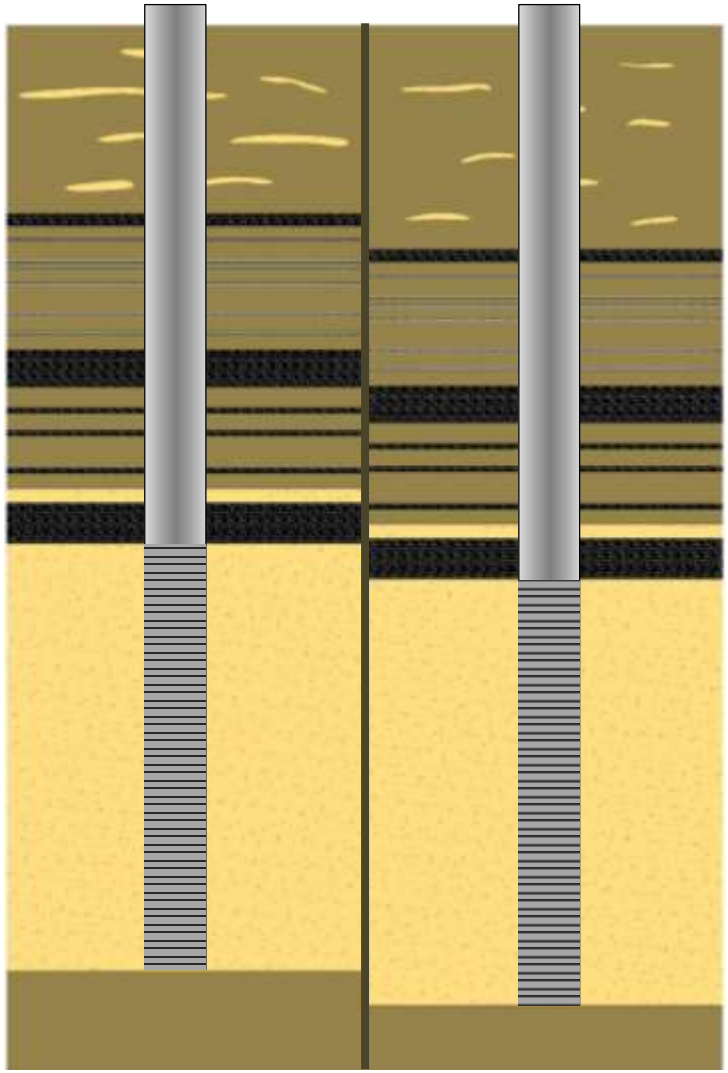
Mining Block Aquifer Test



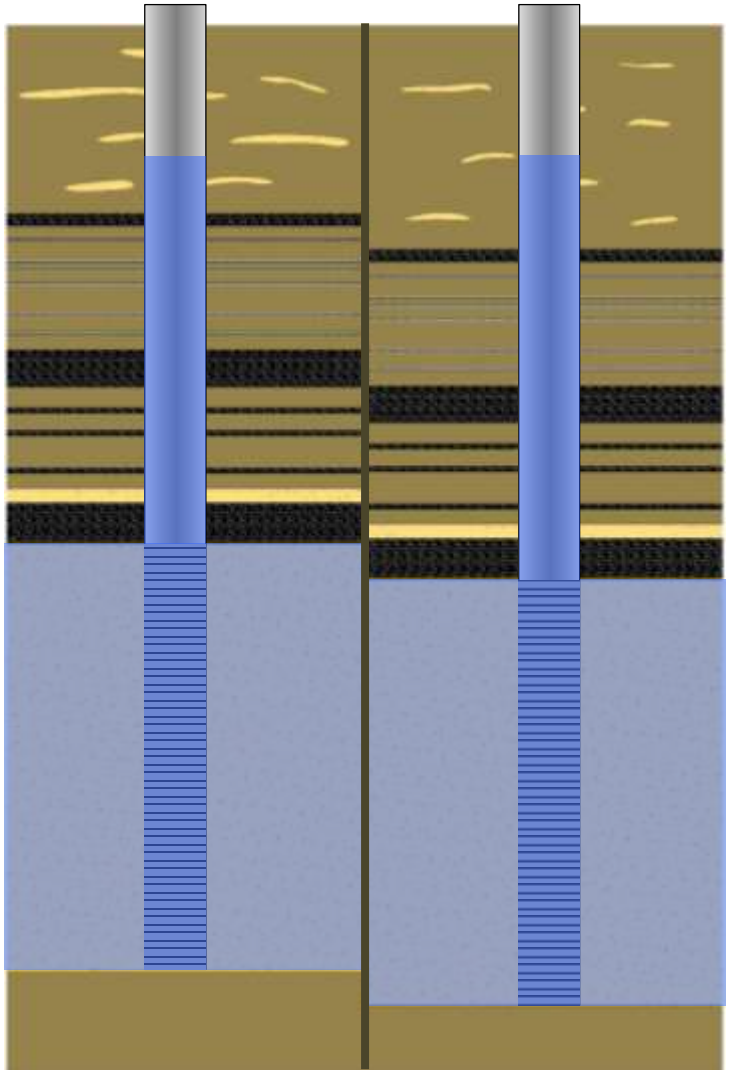
Faulting Example



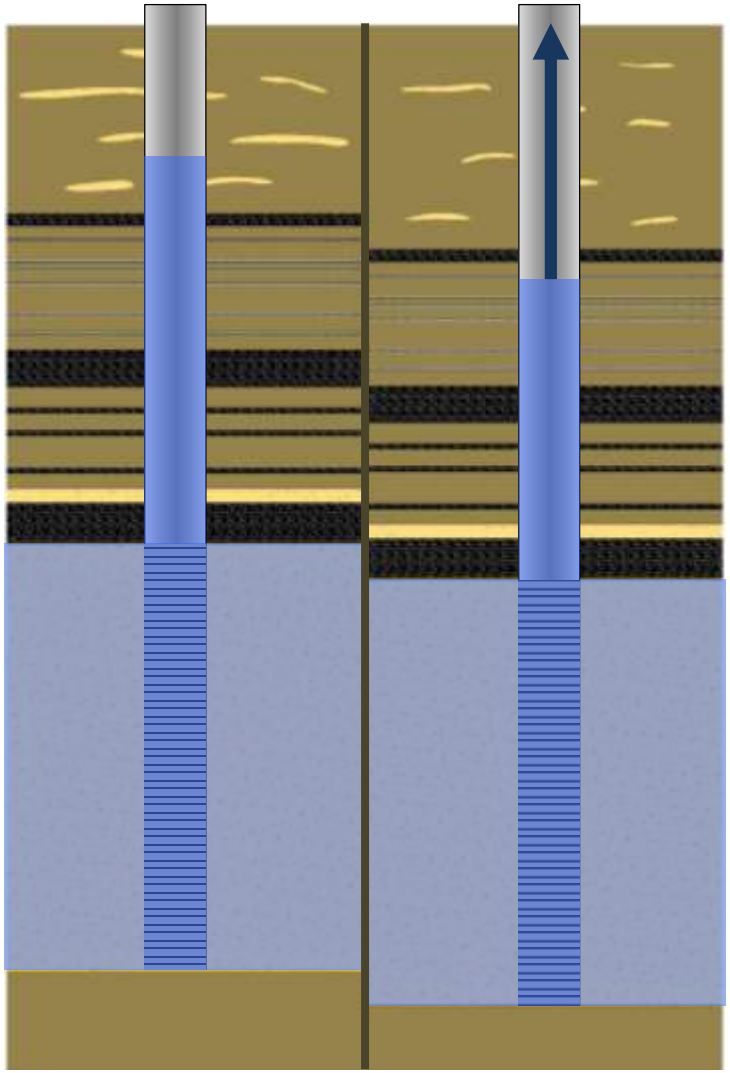
Faulting Example



Faulting Example



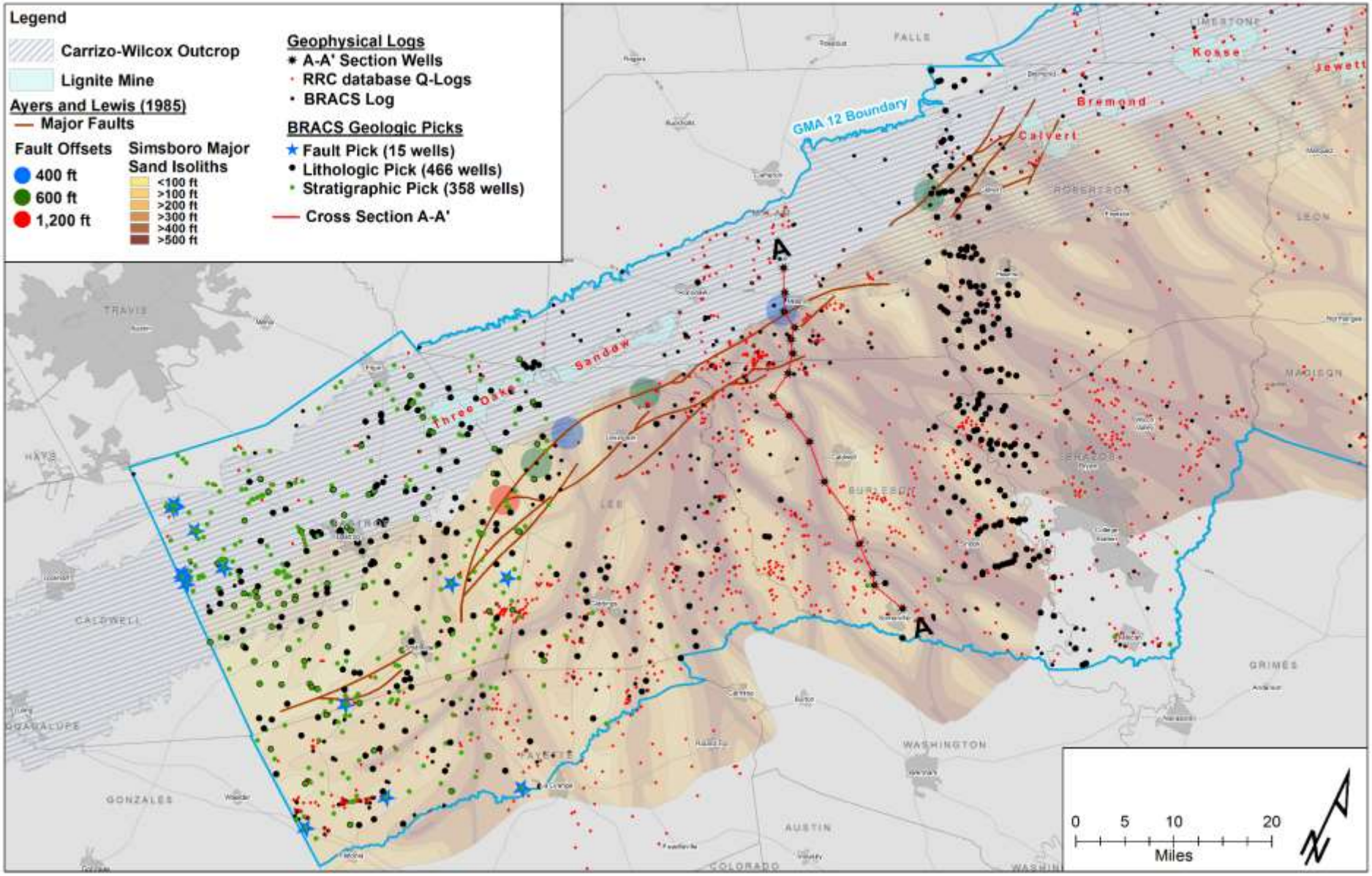
Faulting Example



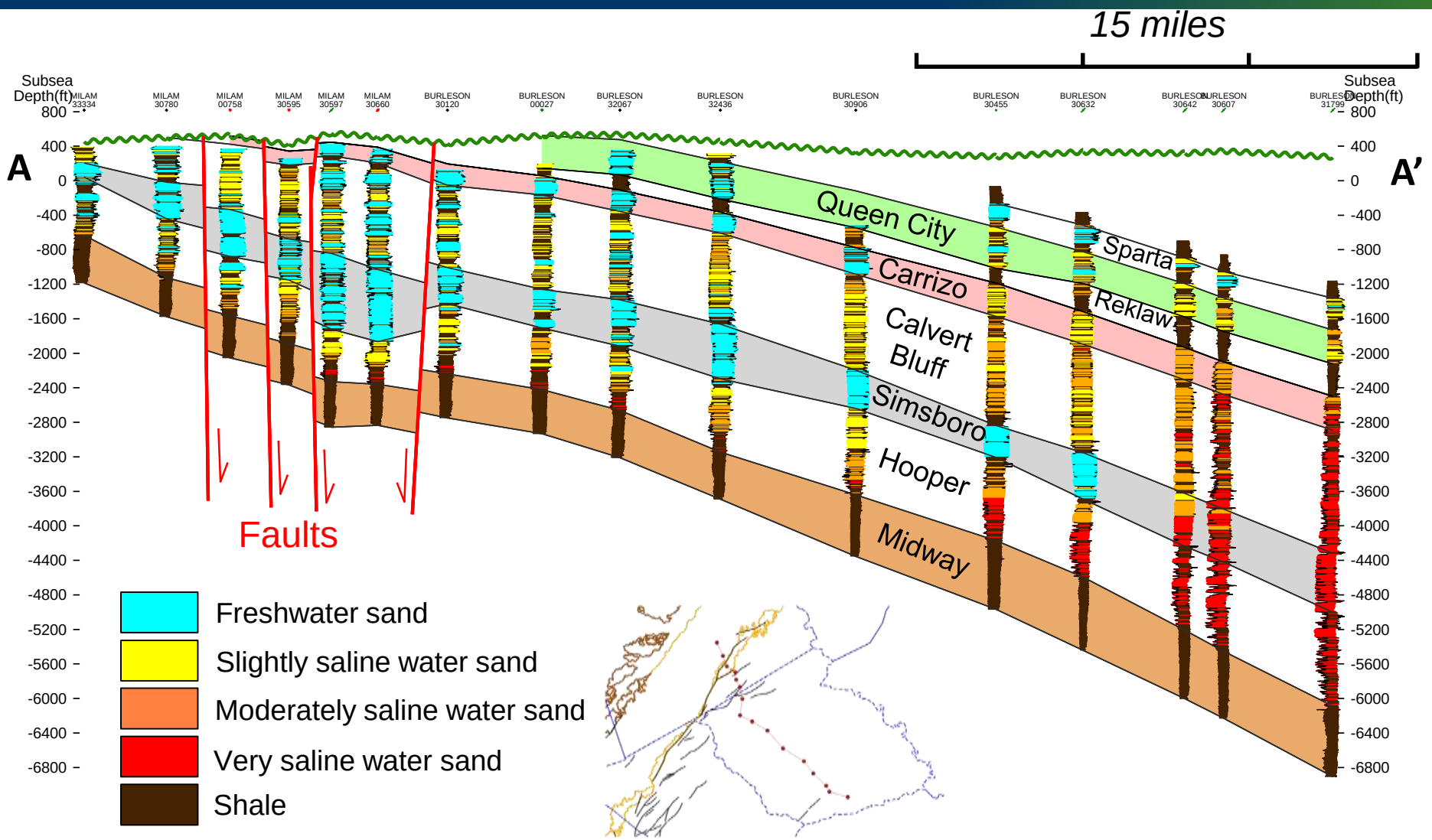
Faulting - Knowns and Unknowns

- Faults affect hydraulic response to pumping
  - "negative boundary"
- Amount of effect is variable
- Location and effects are only partly known
- Highlights the importance of monitoring and refinement

Available Geophysical Logs



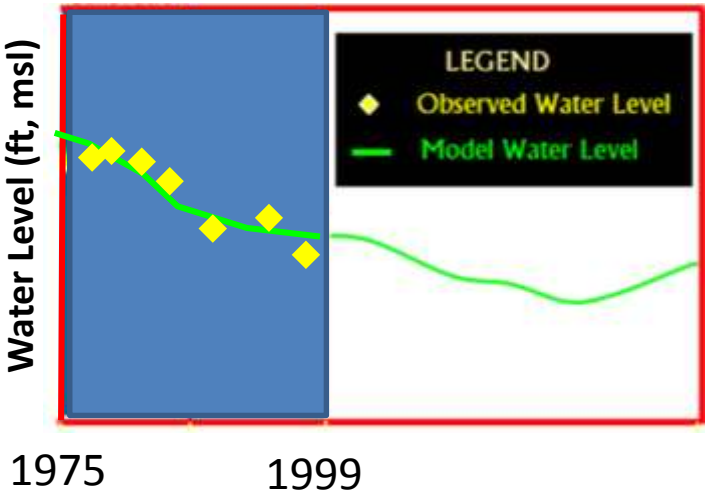
QCSP GAM Vertical Cross Section



Model Calibration

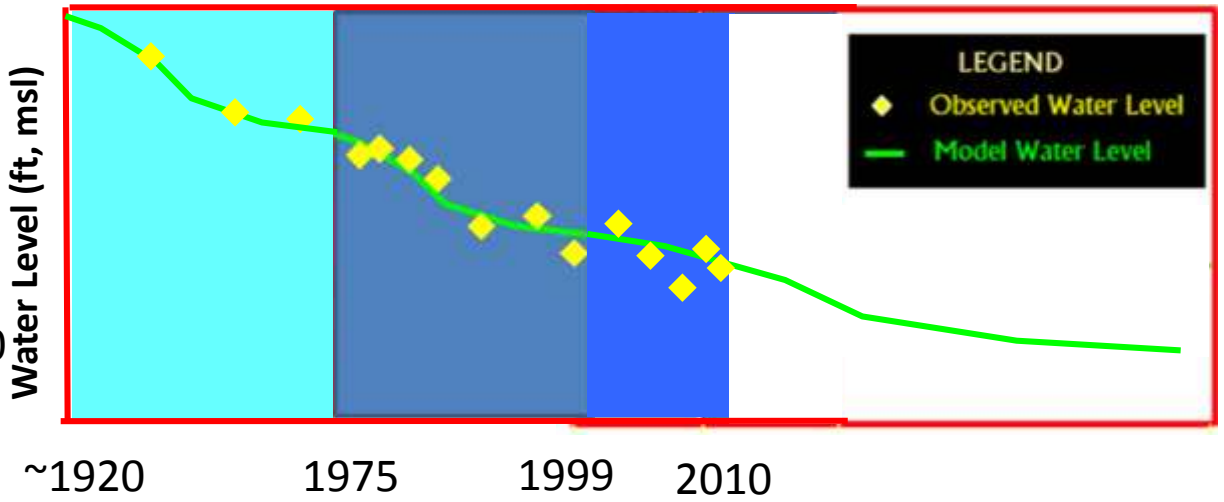
Current GAM

- Calibration Period 1975-1999
- No Pre-development



Updated GAM

- Pre-development ~1920
  - No Pumping
  - Steady-state condition
- Calibration Period 1920-2010



Proposed Contract Expansion to Improve GW-SW Interaction

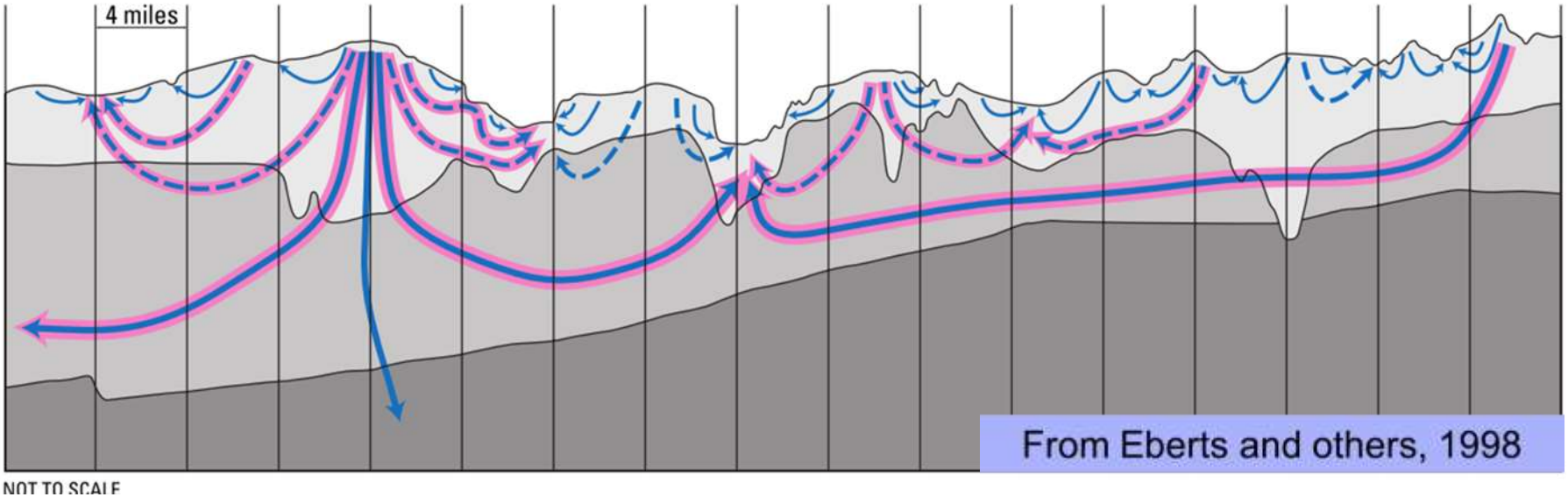
Tasks

- Convert model to MODFLOW-USG to allow for smaller grid cells near rivers
- Decrease grid cell size from 1-mile by 1-mile to 0.5-mile to 0.5-mile or smaller for the main reach of the Colorado River and Brazos River and the tributary streams and creeks for these two rivers
- Create one or more shallow model layers to represent a shallow groundwater flow system
- Where appropriate represent the river alluvium as model layer

Proposed Funding Sources

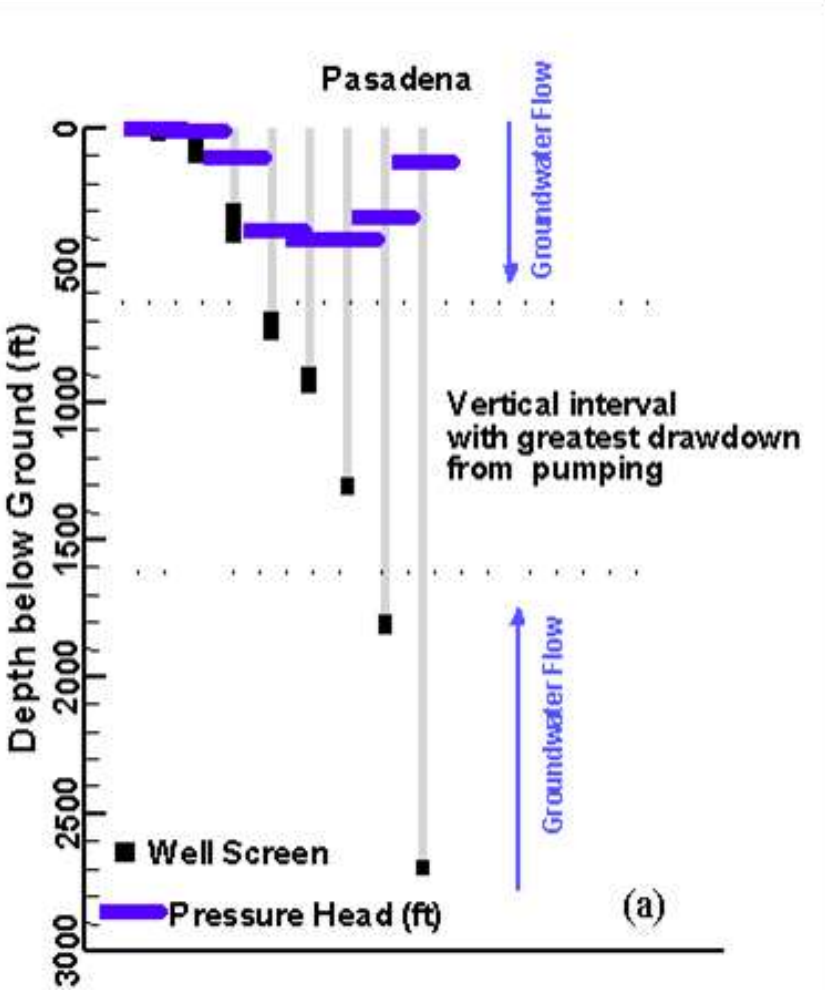
- Post Oak Savannah GCD
- Brazos Valley GCD
- Mid-East Texas GCD
- Lower Colorado River Authority
- Brazos River Authority
- Texas Water Development Board
- Possible in-kind services from Lost Pine GCD

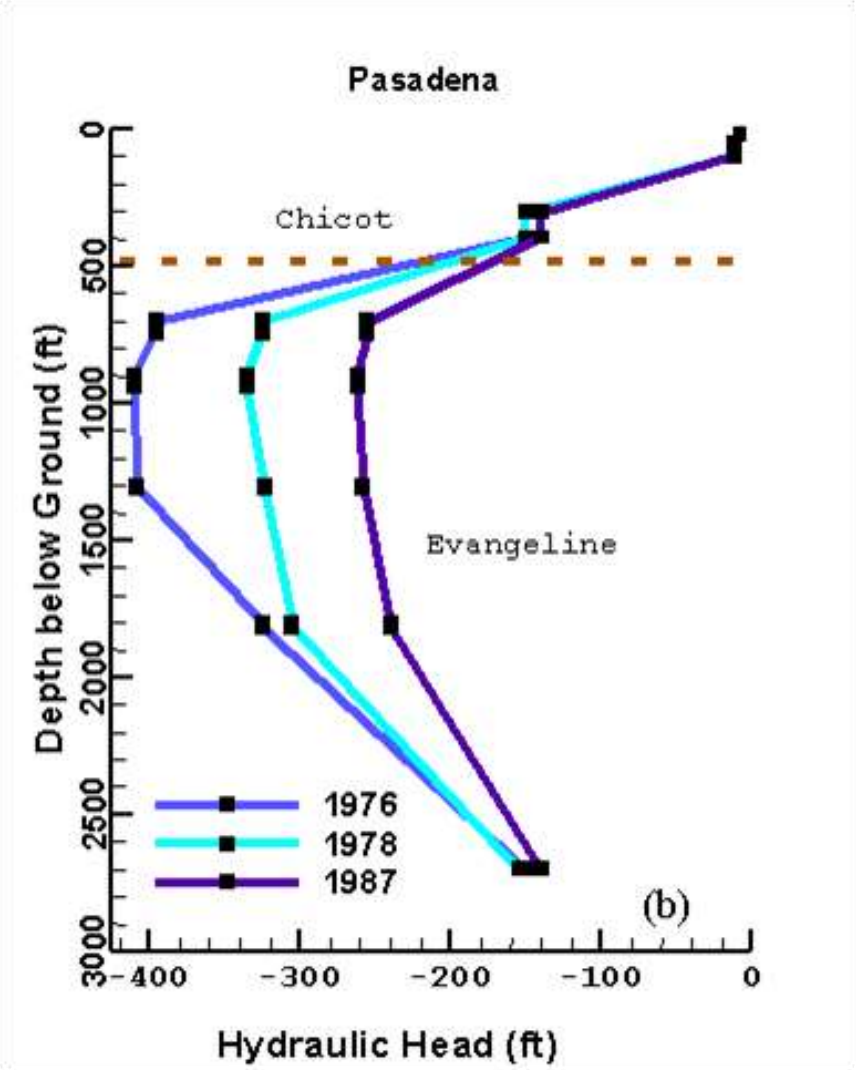
HIERARCHY OF GROUNDWATER FLOW SYSTEMS



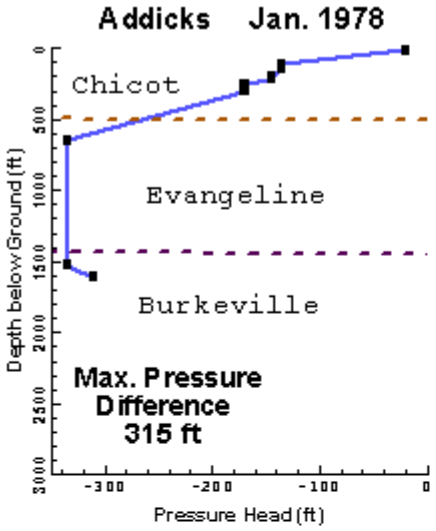
Note: Most GAMs and regional groundwater flow models do not have the vertical resolution in their layering to represent local flow paths.

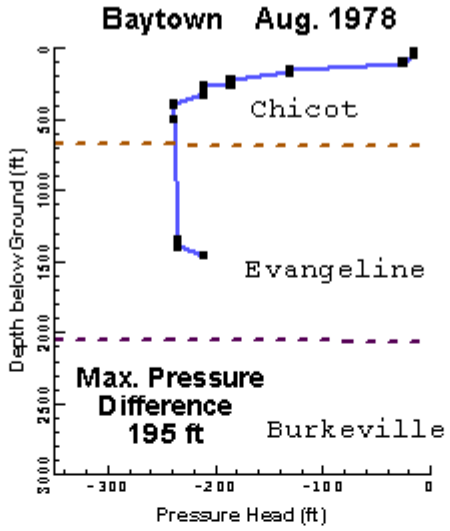
SHALLOW WATER LEVELS MAY BE VERY DIFFERENT FROM DEEP WATER LEVELS

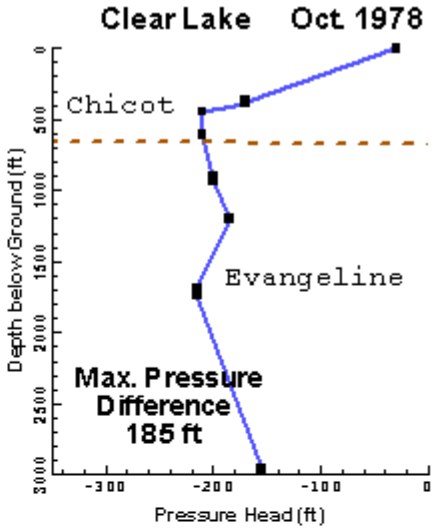


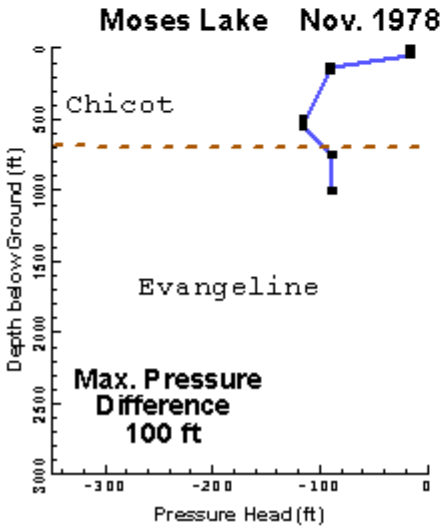


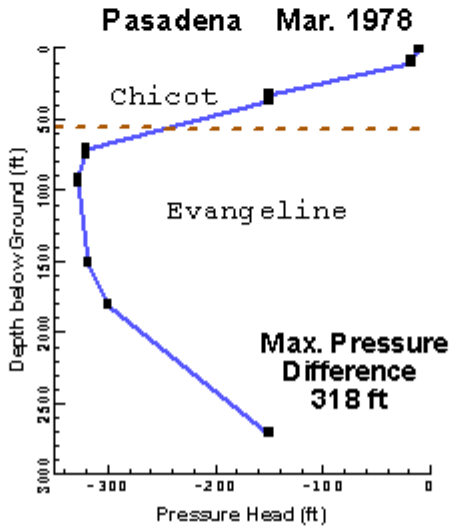
ADDITIONAL WATER LEVELS FROM STAGED MONITORING WELLS IN HARRIS COUNTY

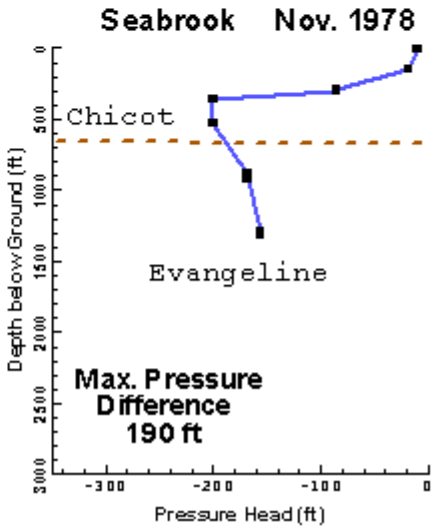




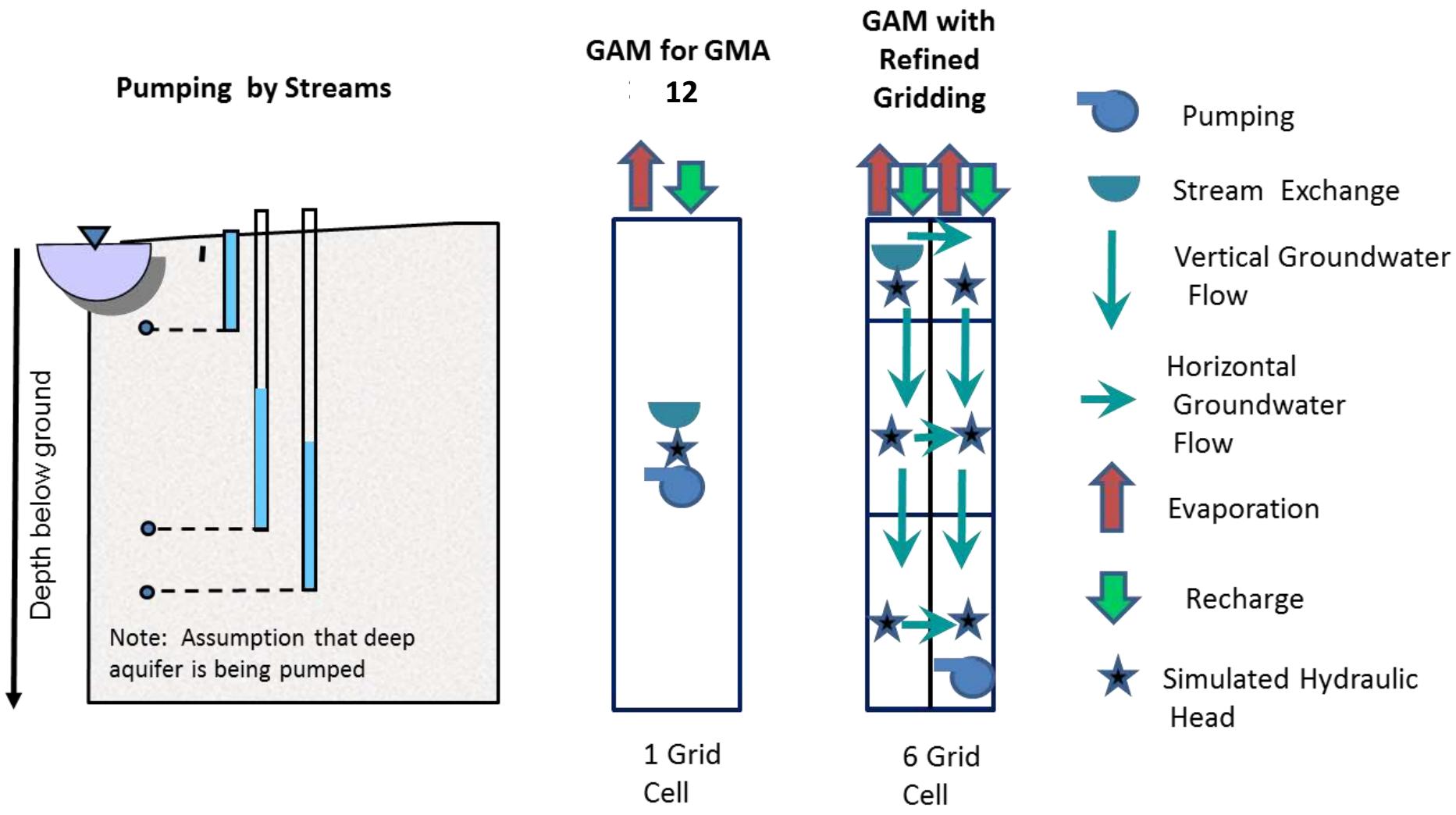






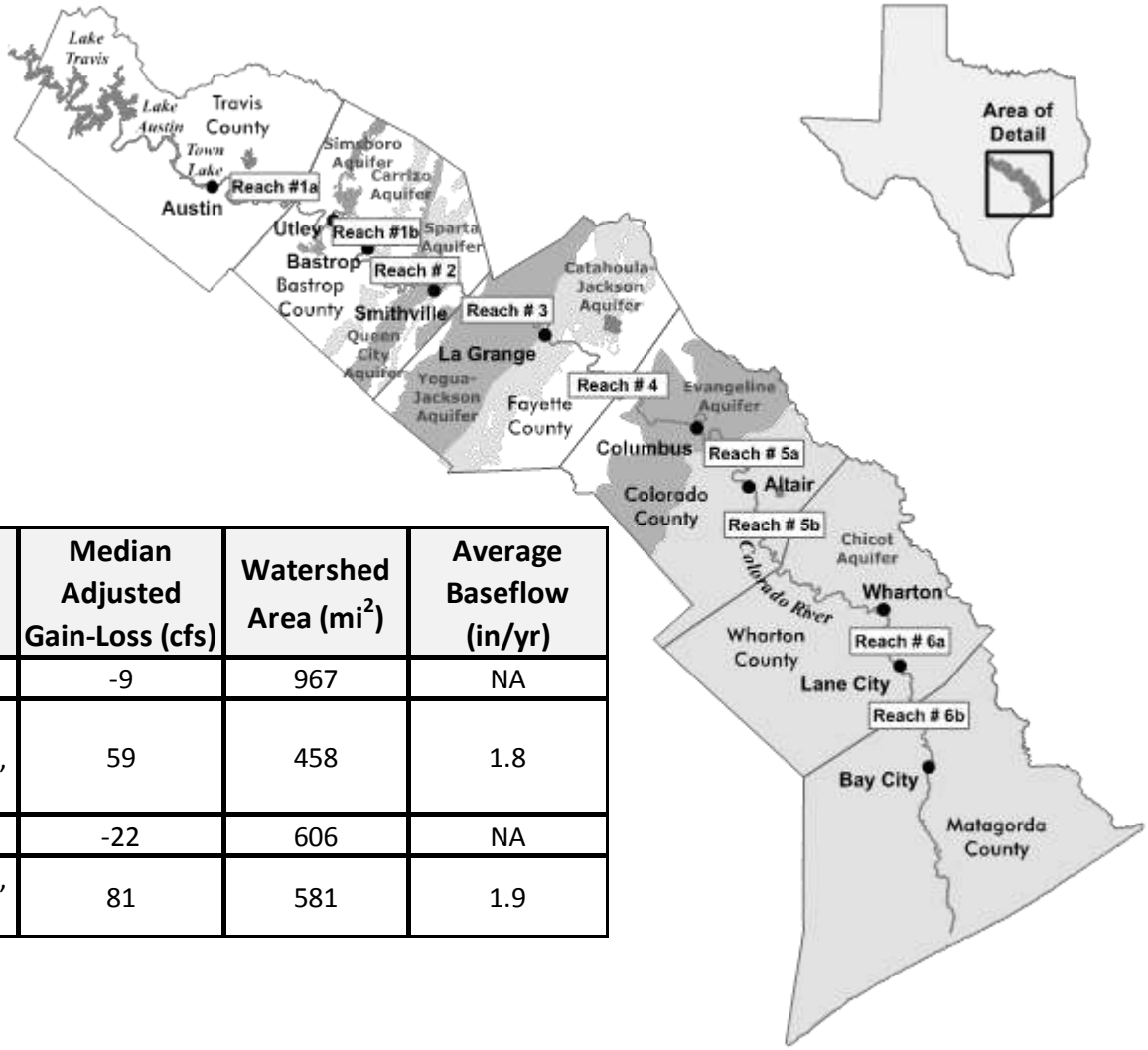


POTENTIAL BENEFITS OF ADDING A SHALLOW MODEL LAYER WHERE MODEL LAYER 1 IS THICK



COLORADO RIVER GAIN-LOSS STUDY (SAUNDERS, 2006)*

Description	River Mile Length (mi)	Water-bearing units	Median Adjusted Gain-Loss (cfs)	Watershed Area (mi^2)	Average Baseflow (in/yr)
Austin-Bastrop	54	Simsboro	-9	967	NA
Bastrop-Smithville	25	Calvert Bluff, Carrizo, Queen City, Sparta	59	458	1.8
Smithville-LaGrange	36	Yegua-Jackson	-22	606	NA
LaGrange-Columbus	41	Catahoula, Oakville, Goliad	81	581	1.9

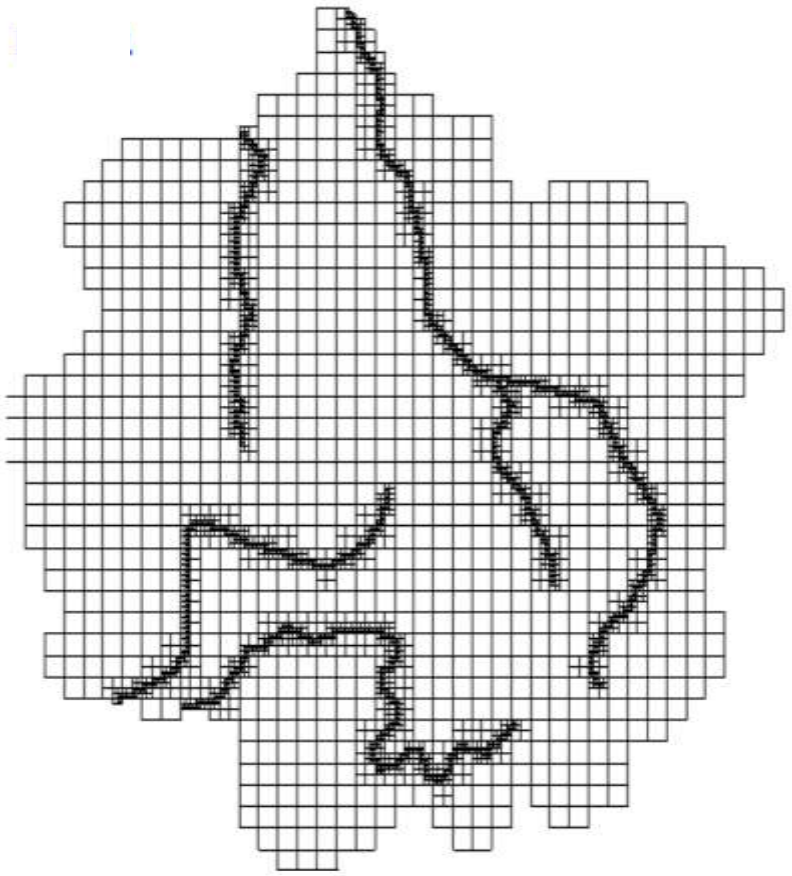


10 CFS = 7,240 AFY

* Based on 1999 and 2005 data

MODFLOW-USG

- Unstructured Grid allows refinement in vertical and in horizontal direction
- Variable spacing promotes shorter run times and increased accuracy
- USGS Publication, 2013, Panday and others



http://www.novametrixgm.com/blog/modflow-usg-layer-dependent-discretization

CALL FOR DATA

- Historical groundwater pumping data
- Historical depth to water data
- Geophysical logs (SP, gamma ray, resistivity, density, etc.) and collocated groundwater quality to calibrate the logs
- Groundwater well locations and construction details
- Historic groundwater pumping data
- Evidence of impacts of faults on groundwater flow


QUESTIONS

List of Stakeholders' Question and Comments
1st SAF: Effect of Faults on Groundwater Flow in the Carrizo-Wilcox Aquifer in Central Texas: Update the Central GAM for Sparta, Queen City, Carrizo-Wilcox Aquifers
November 20, 2015
Milano Civic Center
Milano, Texas

Questions:

1. **Q.** What was the size of the mine block on slide 21?
   A. The area is about 3,000 acres.

2. **Q.** With regard to the experience with performing dewatering at the Sandow mine, were faults discovered at different locations than originally mapped?
   A. We did locate faults where no faults were previously mapped. The existence of the newly mapped faults was discovered only as a result of a pumping test.

3. **Q.** What pumping tests will be used to locate the faults?
   A. Data from existing pumping tests will be used. Vista Ridge is still performing aquifer testing through this summer in Burleson and the results of these tests will be used in the study.

4. **Q.** What is the relationship between the period of pumping at a well and the zone-of-influence of the pumping well on water level change?
   A. The answer depends on the type of aquifer system. In a flat and horizontal aquifer system, the zone of influence from pumping increases with the log of time until a boundary condition is reached. For an aquifer that is dipping, the relationship may be different because the storage in the aquifer increases toward the outcrop. As the cone-of-influence approaches an outcrop the drawdown will approach zero (as shown in Slide 20) because of the unconfined conditions and high storativity values in the outcrop.

5. **Q.** Will the model be better calibrated in the Bryan/College Station area compared to other areas of the model? Will the same amount of model refinement be included in the northern part of the GAM?
   A. The GAM refinement and improvements will focus on the GMA 12 footprint for two reasons. The first reason is that the Mexia-Talco fault zone occurs between Gonzales and Robertson counties and does not exist in the GAM area north of Robertson County. The second reason is that no organization is paying for improving the GW-SW relationships outside of the GMA 12 footprint. Some refinement/improvement will be performed across the entire model. Examples of such improvements is the updating the historical pumping information and the length of the model calibration period.

6. **Q.** Will the GAM update include a task to improve the model's capability to simulate the interaction between surface water and groundwater?
   A. A proposal to modify the INTERA contract to include such a task will be presented to the TWDB Board for their evaluation. The TWDB Board will have final say on whether or not the INTERA contract will be modified. TWDB staff will try to present to the TWDB Board on 12/14/2015.

7. **Q.** Will the gain/loss data be used to calibrate the model?
   A. Yes.

8. **Q.** Will the Colorado/Lavaca BBASC funding be presented to the TWDB board?
   A. The BBASC funding will not be going to the TWDB board at the same time as the work funded by the GCDs and the river authorities. The BBASC work may need to be delayed to another update.

Comments:

1. **Stakeholder:** The numerous faults at the up-dip extent of the geopressured zone shown in Slide 7 could partially account for why the high pressures still exist down-dip of the faults.
   Response: Agreed. There is a very good paper that explains the geopressured zone downgradient of the Wilcox fault zone written by Dutton and Kier. The longevity of the geopressure zone occurs partly because of the clay layers of very low permeability that trap the high pressure.

2. **Stakeholder:** Characterizing faults is hard using just logs because you may not be able to distinguish whether any offset is caused by a single large fault or several smaller faults.
   Response: Agreed.

3. **Stakeholder:** The pumping at the City of Bryan since the 1950s represents a large continuous pumping test that may help with defining the boundaries.
   Response: Agreed. RW Harden and William Guyton worked together on performing and analyzing the first pumping tests at Bryan/College Station. Their work concluded that the transmissivity at the well location was well characterized but the rate of water level decline was greater than expected for that transmissivity value at very late time. The reason for the acceleration in the rate of water level decline may be caused by changes in the aquifer properties away from the Bryan. Two possibilities that account for this change is the Mexia-Talco fault zone or a thinning of the permeable sediments up dip of Bryan.

4. **Stakeholder:** Comment made about the evolution of the GAM to include an improved capability to simulate GW-SW interaction.
   Response: The original GAMs were intended to support regional planning. For this reason they have very large models will large grid cells that focused on regional flow patterns. Because GAM's have the capability to simulate GW-SW interaction, the GAMs will be used to make such predictions whether or not they are adequately calibrated for such predictions. GCDs and river authorities are interested in trying to improve the GAM capability to simulate GW-SW interaction to address their project needs. As a result, the GAM will be modified to include refinement in the model layers and grid cells so that the GAM has an improved capability to simulate shallow groundwater flow at the local scale.

5. **Stakeholder:** The interpretation of gain-lost studies such as the Colorado River study reported by Saunders is not necessarily a straight-forward process. Several processes that affect groundwater-surface interactions are not represented in the GAM. Everyone should be cautious when interpreting gain-loss data.
   Response: Agreed. The confidence bounds and sources of error in the calculated gain-loss

values along river reaches needs to should be accounted for during the model calibration. These include incorrect accounting of return flows, diversions, and the impacts of unsteady river flows caused by pulsed releases at dams. These concerns are more important when using data from the gain-loss study on the Brazos River.

6. **Comment**: The project may not have all the necessary GW-SW data required to do a proper calibration of the SW-GW improvements but the project will develop a better GAM tool and have the capability to be improved or validated when the appropriate GW-SW data becomes available. Gradual improvements in GAMs are part of the evolving and iterative nature of the GAM program.

7. **Stakeholder:** The modeling team should review the work on SW-GW interaction that Fred Odgen at the University of Wyoming as recently written several good papers on GW-SW interaction.
   Response. We will review Dr. Odgen's research.

8. **Stakeholder:** Comment made regarding concerned about the reliability of the GAMs to predict out 50 years.
   Response. The reliability of a GAMs will improve with each GAM update. Updates can proceed only as fast as new information becomes available. Much of the data and tools that will be used in this update were not available 15 to 20 years ago when the GAM was first constructed

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Attendees
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Milano, Texas

	Attendee Name	Affiliation
1	George Rice	GRGwH
2	Philip Price	Brazos River Authority
3	Steve Young	INTERA
4	David Bailey	Mid-East Texas Groundwater Conservation District
5	Cindy Ridgeway	Texas Water Development Board
6	Shirley Wade	Texas Water Development Board
7	Gary Westbrook	Post Oak Savannah Groundwater Conservation District
8	Stephen Allen	Texas Water Development Board
9	Tim Shoglund	San Antonio Water System
10	John Waugh	San Antonio Water System
11	Steve Box	Environmental Stewardship
12	Bob Harden	R.W.Harden & Associates
13	Alan Day	Brazos Valley Groundwater Conservation District
14	John Seifert	LBG Guyton
15	Andy Donnelly	Daniel B. Stephens & Associates
16	Larry French	Texas Water Development Board
17	Amy Muttoni	Brazos River Authority
18	Amanda Malouks	Rusk County Groundwater Conservation District
19	David Alford	Neches and Trinity Valleys Groundwater Conservation District
20	Bob Kier	None
21	Eric Seeger	Thornhill Group
22	David Wheelock	Lower Colorado River Authority