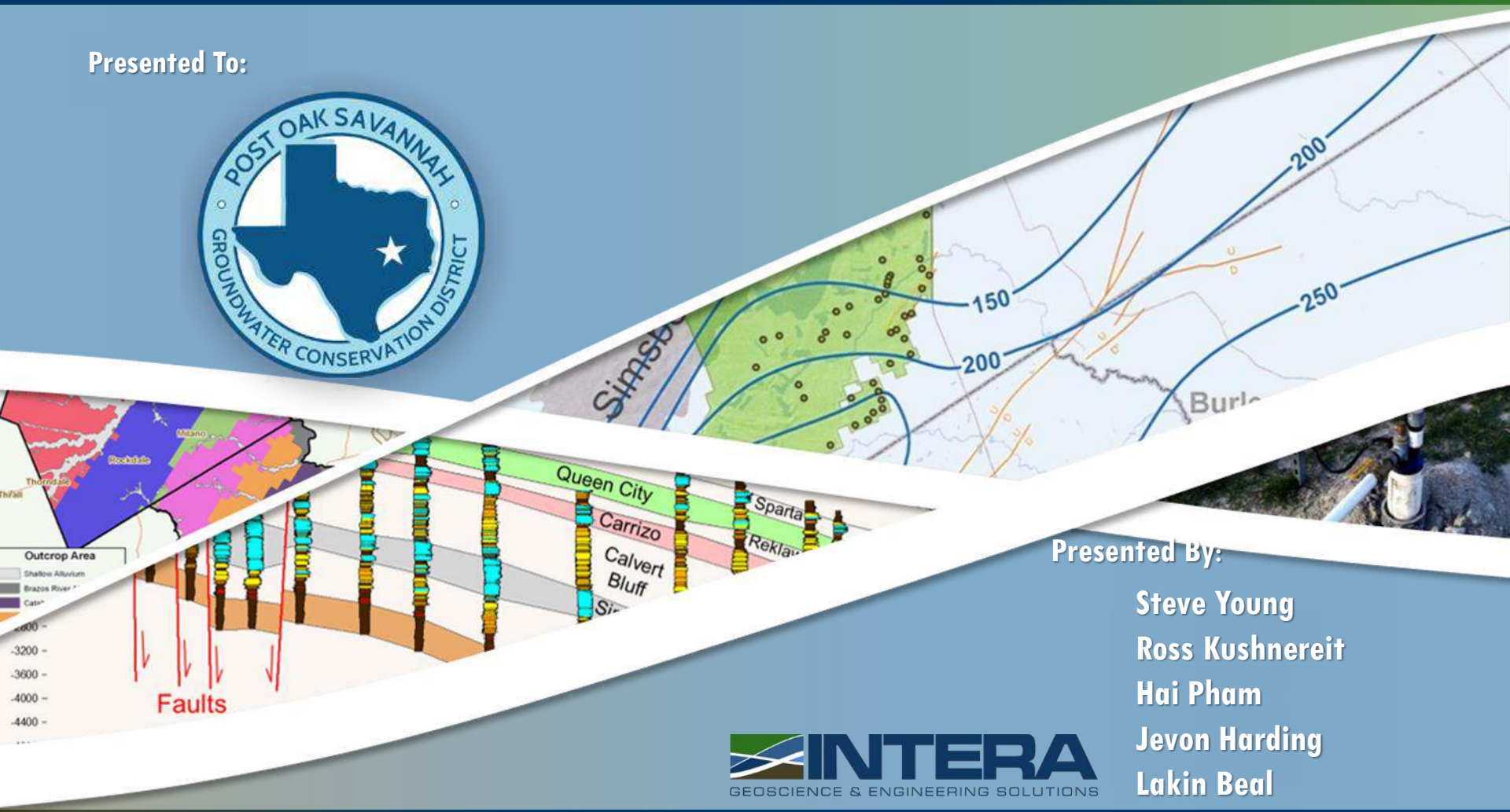
Workshop to DFC Committee: Collection, Management, Evaluation, and Reporting of Monitoring Data

Presented To:

POST OAK SAVANNAH GROUNDWATER CONSERVATION DISTRICT



Presented By:

Steve Young
Ross Kushnereit
Hai Pham
Jevon Harding
Lakin Beal

INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS

October 8, 2020

Agenda

- Simulations from Modified SP/QC/CW GAM
  - Simulated and Measured Impacts from Vista Ridge Pumping
  - Results from PS-7 DFC Simulation
- Desired Future Conditions
  - Review Existing and PS-7 DFCs and MAGs
  - Considerations for Changing DFCs
  - Recommendations for GMA-12 and GANA Scenarios
- Highlights of Monitoring & Pumping Dashboards
  - Comparison of TWDB and POSGCD Well Assignments
  - Comparison of TWDB and POSGCD Pumping Rates

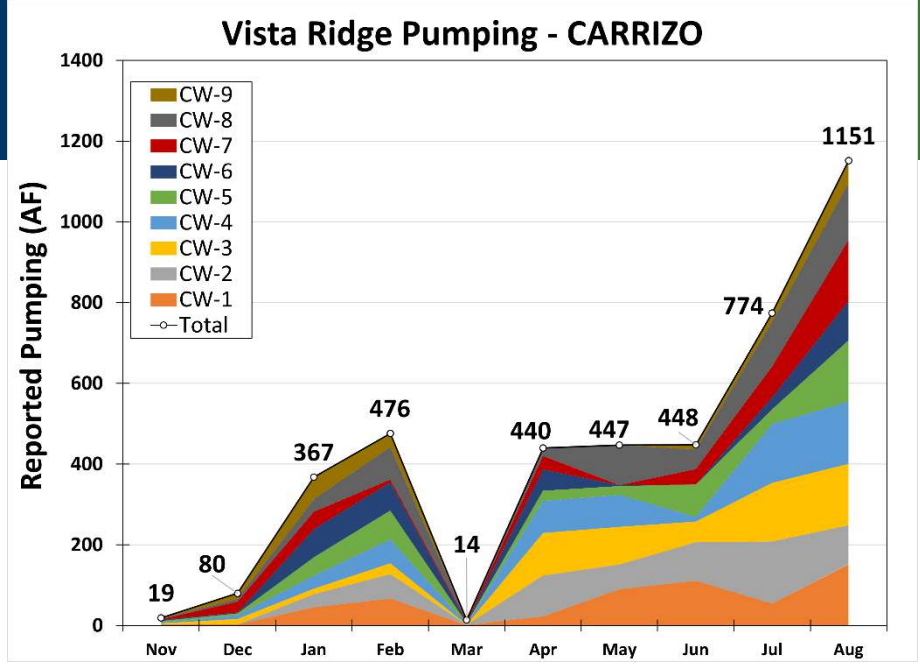
Agenda (con't)

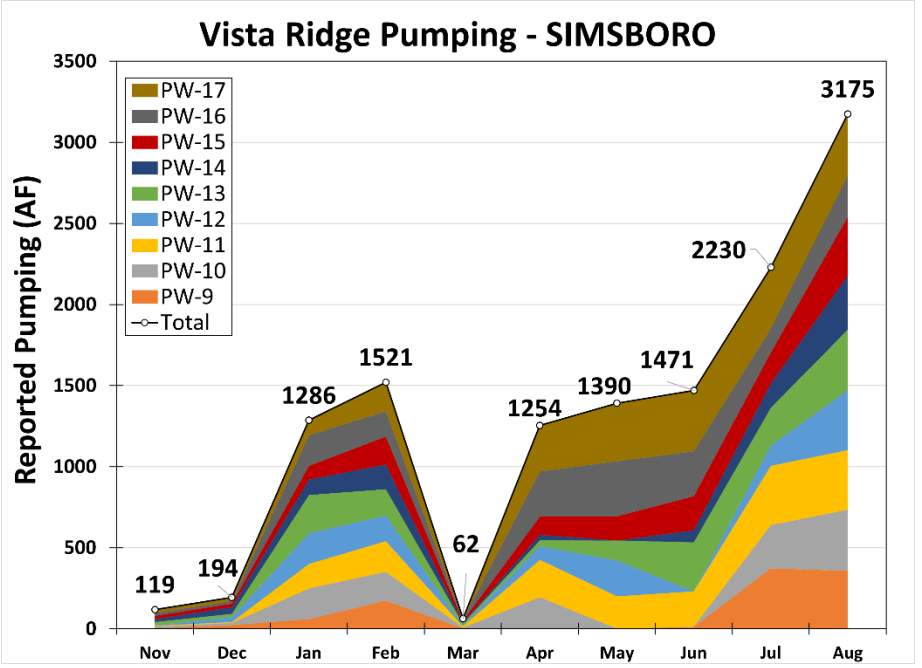
- Water Level Analyses for DFC and PDL Compliance
  - Analysis Methods
  - Comparison of Analysis Methods
  - Recommendations for CR Report
- GWAP Annual Needs Assessment Report and Compliance Report Report
- Suggestions for 2021 Hydrological Studies
  - Improvement on Analysis Methods
  - Improvement to SP/QC/CW GAM

Simulations from Modified SP/QC/CW GAM

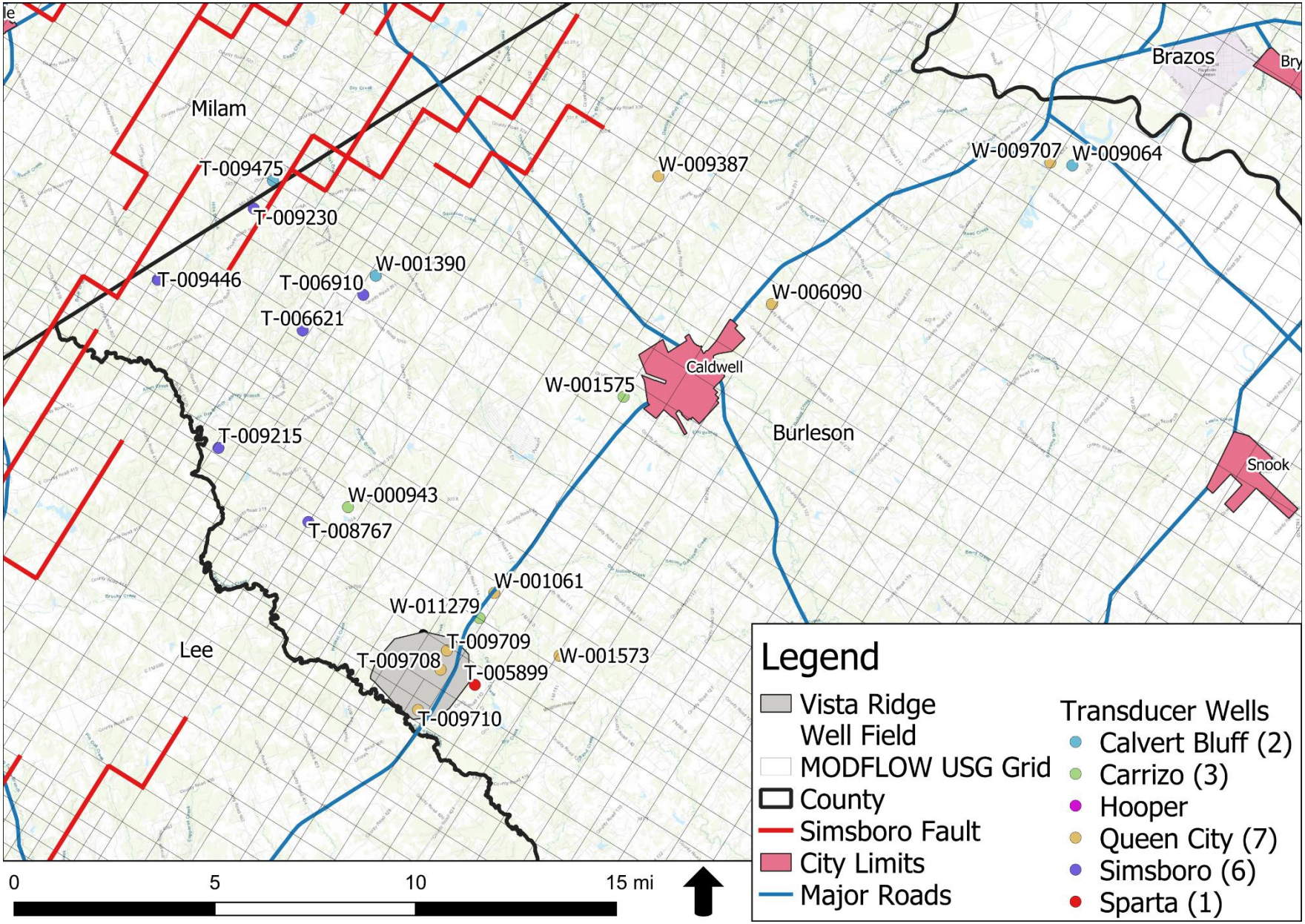
Vista Ridge Pumping Through August 2020

Month	Monthly acre-feet		
	Carrizo	Simsboro	Total
Nov 2019	19	119	138
Dec 2019	80	194	274
Jan 2020	367	1,286	1,653
Feb 2020	476	1,521	1,997
Mar 2020	14	62	76
Apr 2020	440	1,254	1,694
May 2020	447	1,390	1,837
Jun 2020	448	1,471	1,919
Jul 2020	774	2,230	3,004
Aug 2020	1,151	3,175	4,326
Avg. Monthly Permit	1,250	2,994	4,244

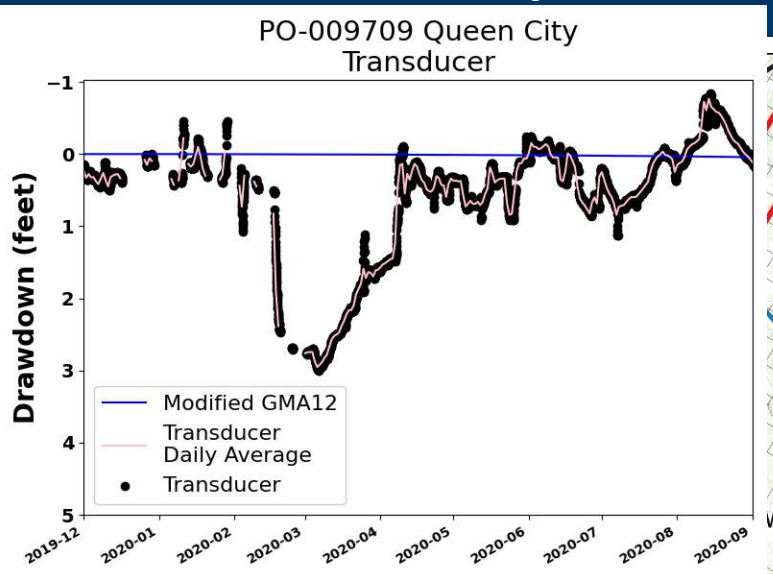


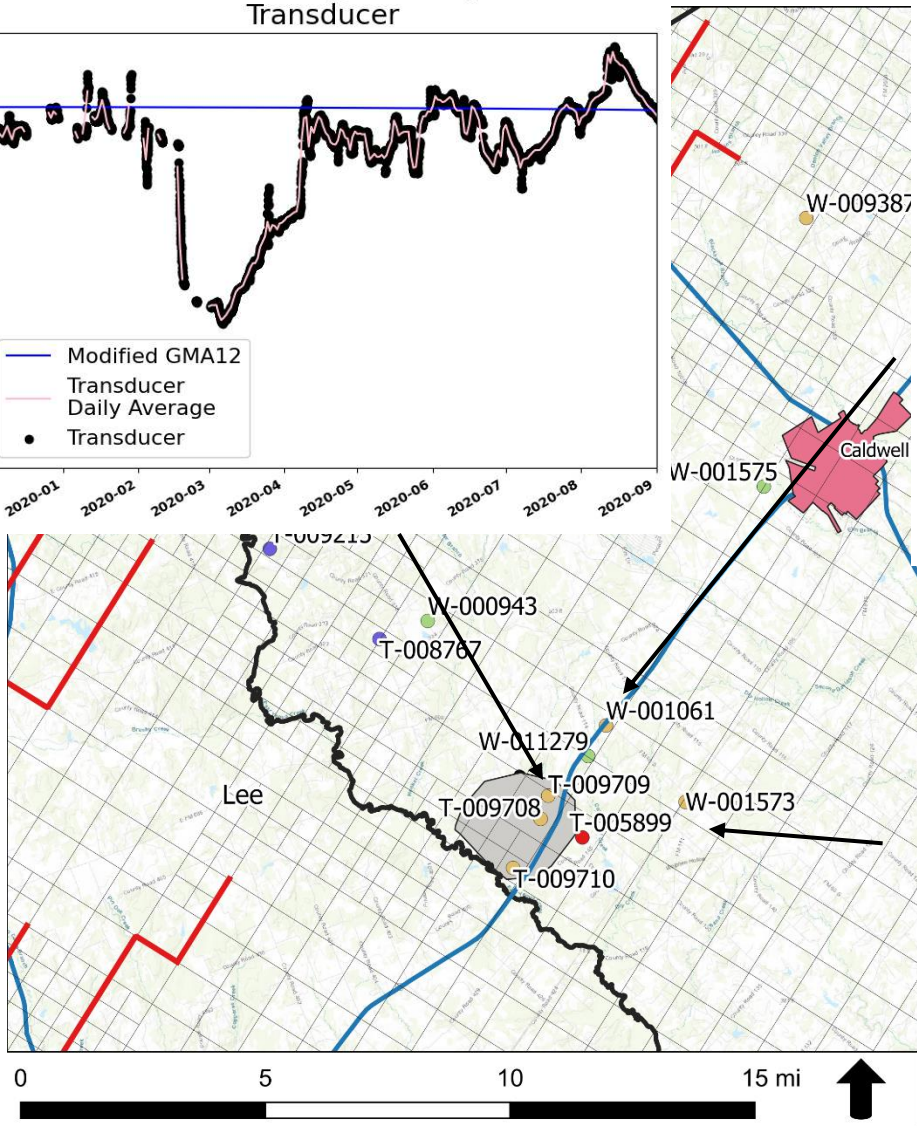


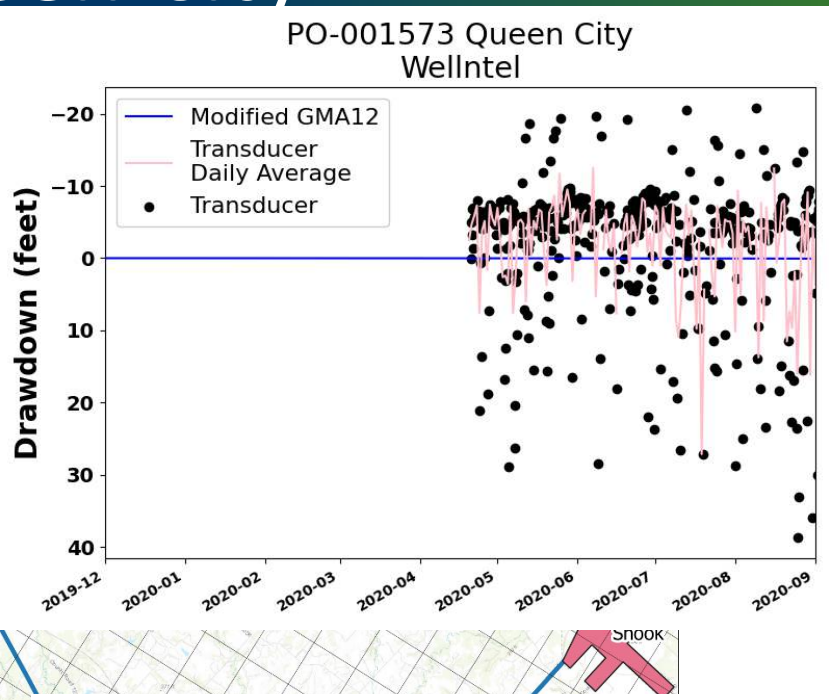
Location of Transducers

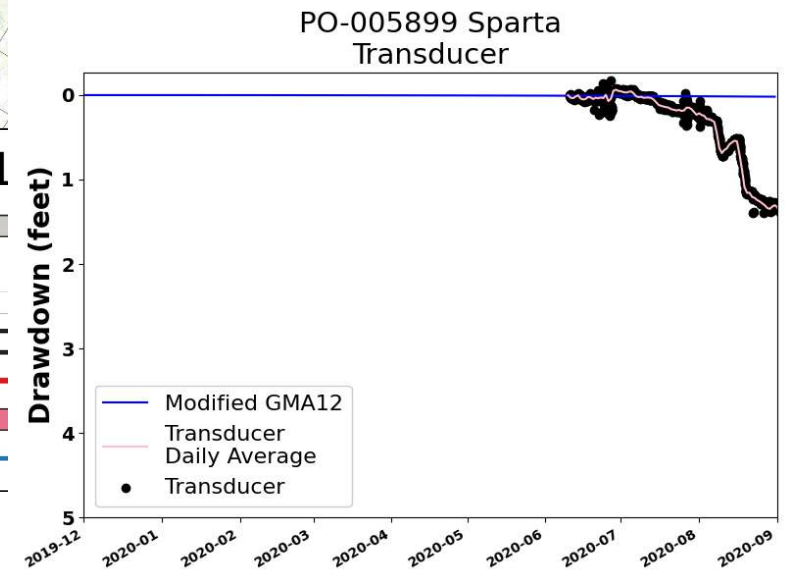


Sparta & Queen City

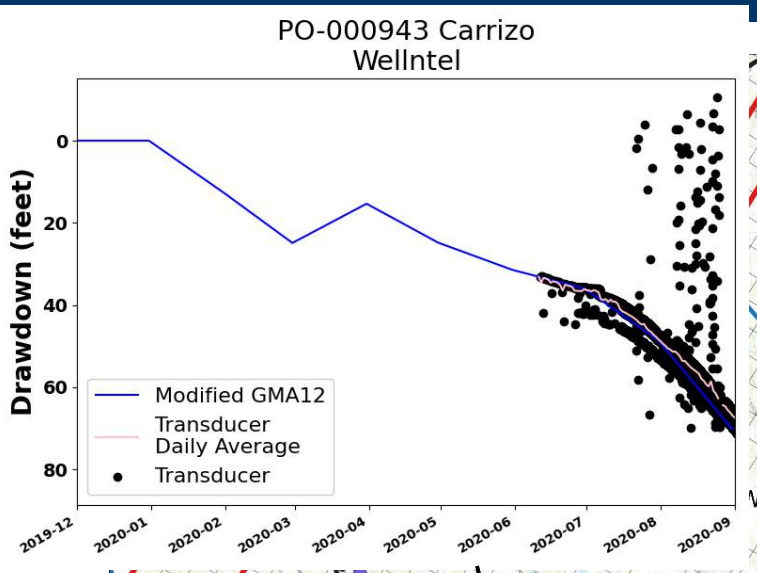


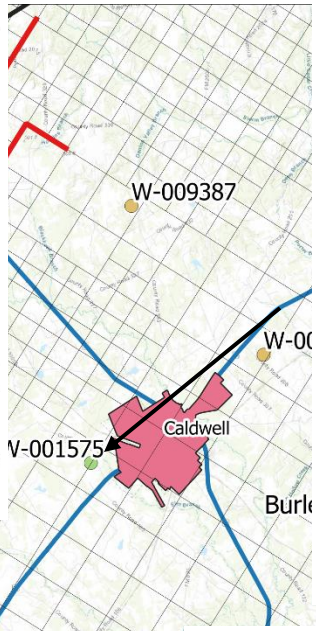






Carrizo


PO-000943 Carrizo
Wellntel
Drawdown (feet)
0
20
40
60
80
Modified GMA12
Transducer
Daily Average
Transducer
2019-12
2020-01
2020-02
2020-03
2020-04
2020-05
2020-06
2020-07
2020-08
2020-09


W-009387
W-00
Caldwell
W-001575
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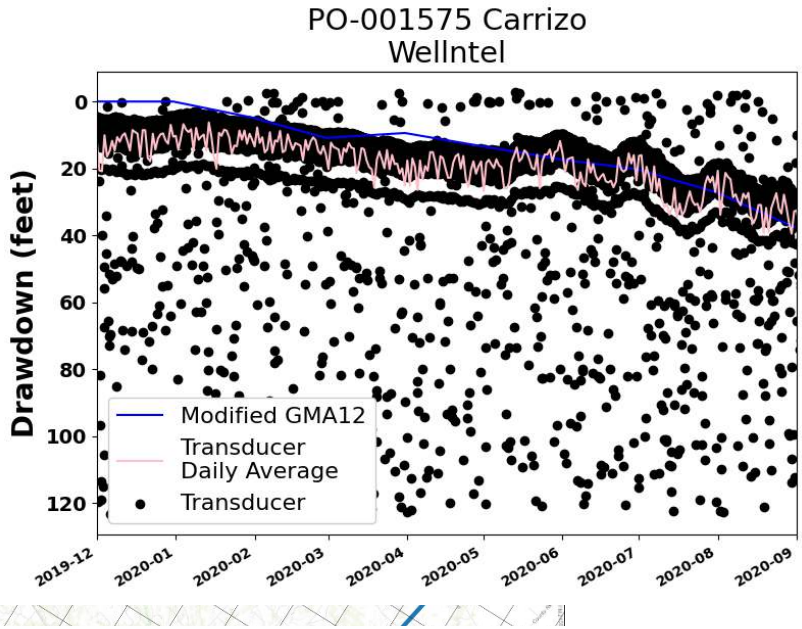
PO-001575 Carrizo
Wellntel
Drawdown (feet)
0
20
40
60
80
100
120
Modified GMA12
Transducer
Daily Average
Transducer
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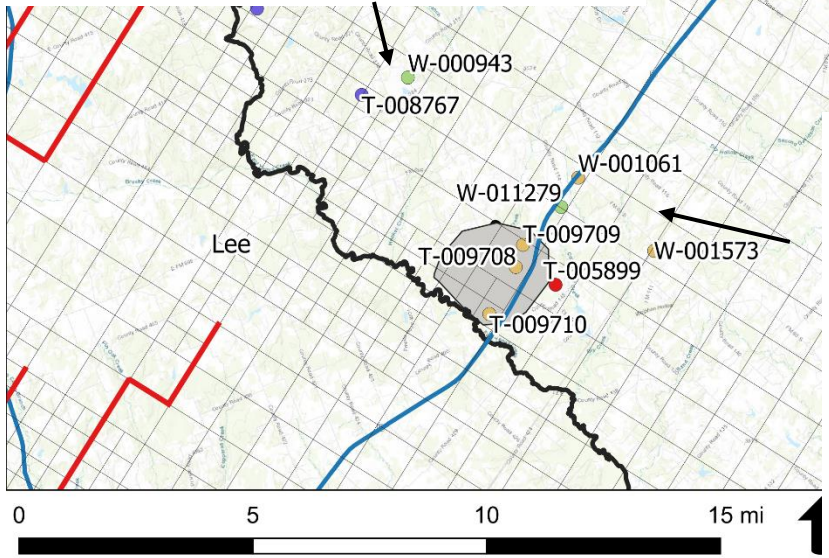
2020-01
2020-02
2020-03
2020-04
2020-05
2020-06
2020-07
2020-08
2020-09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T-008767
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T-009709
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W-001573
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5
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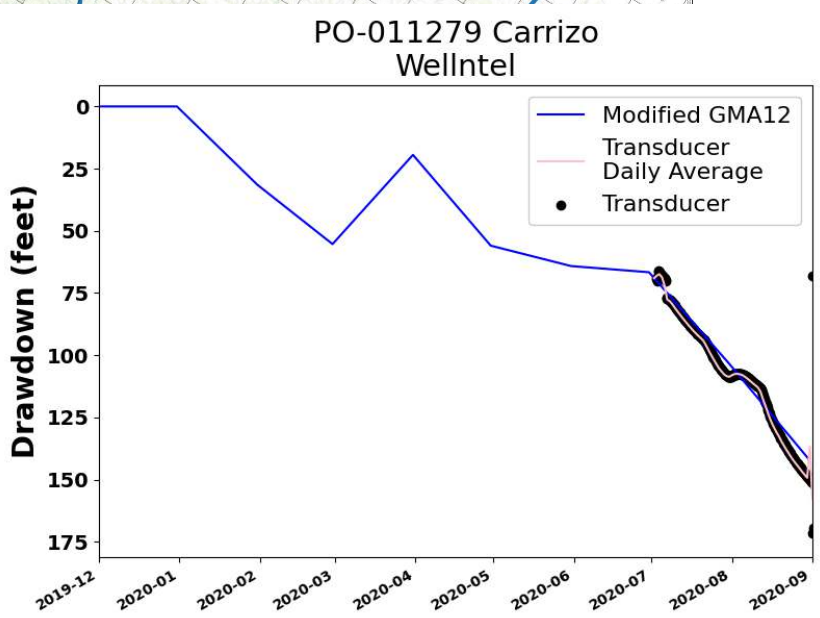
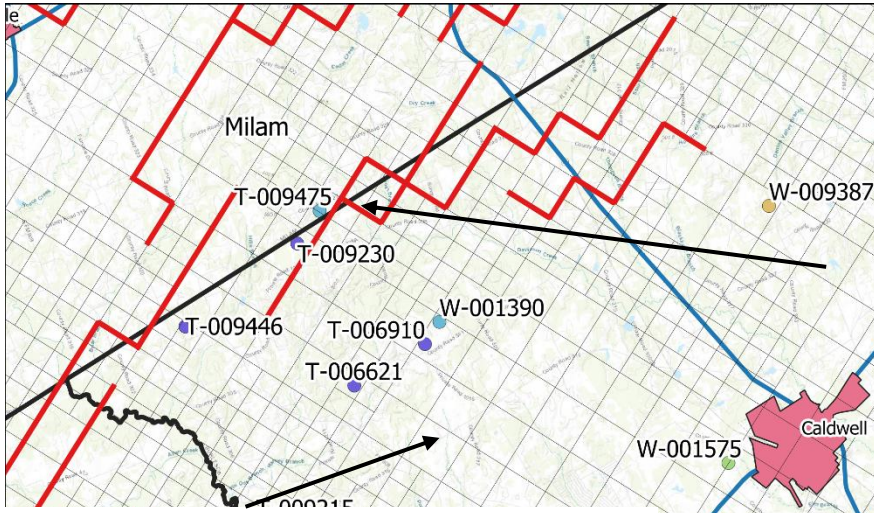
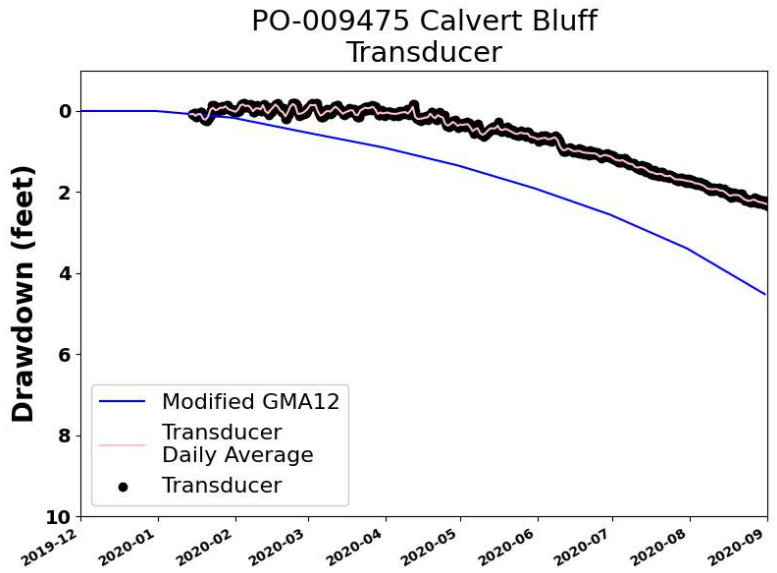
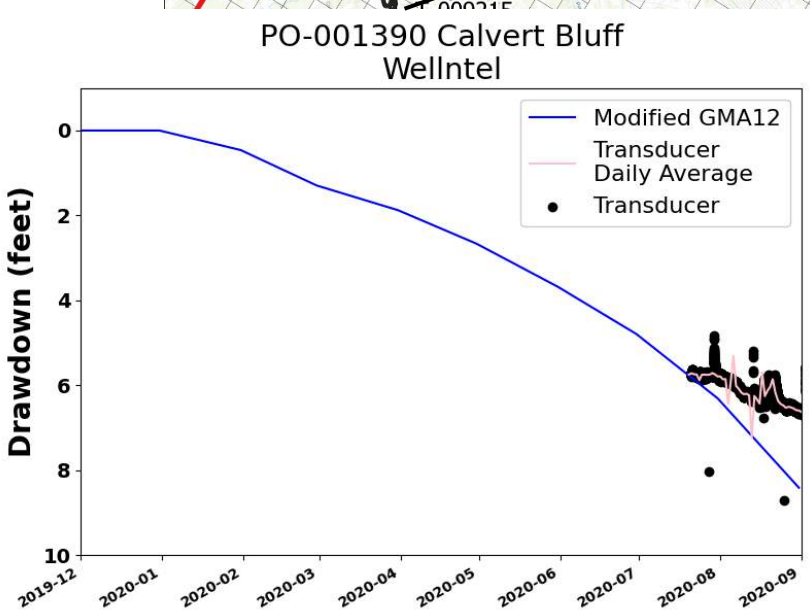
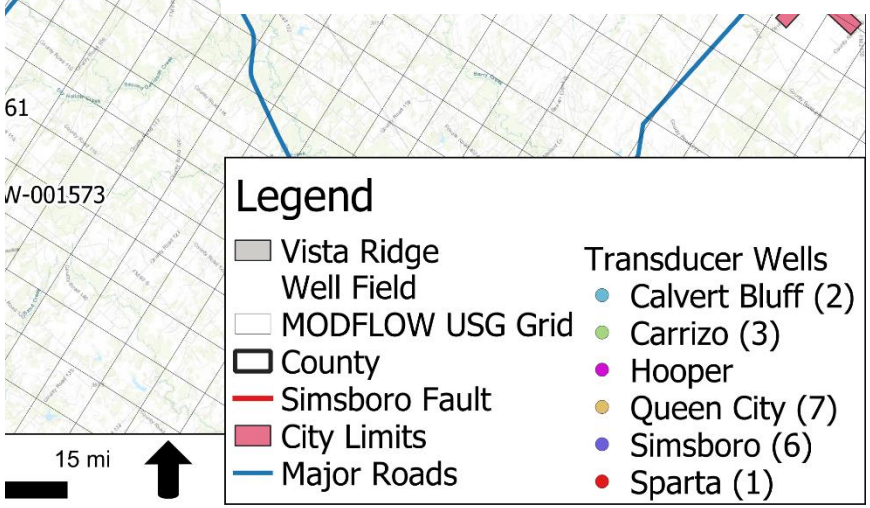

PO-011279 Carrizo
Wellntel
Drawdown (feet)
0
25
50
75
100
125
150
175
Modified GMA12
Transducer
Daily Average
Transducer
2019-12
2020-01
2020-02
2020-03
2020-04
2020-05
2020-06
2020-07
2020-08
2020-09

Calvert Bluff

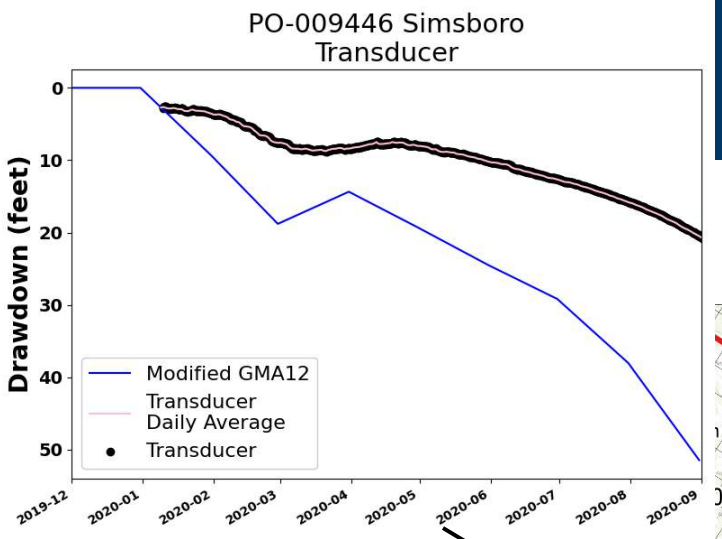


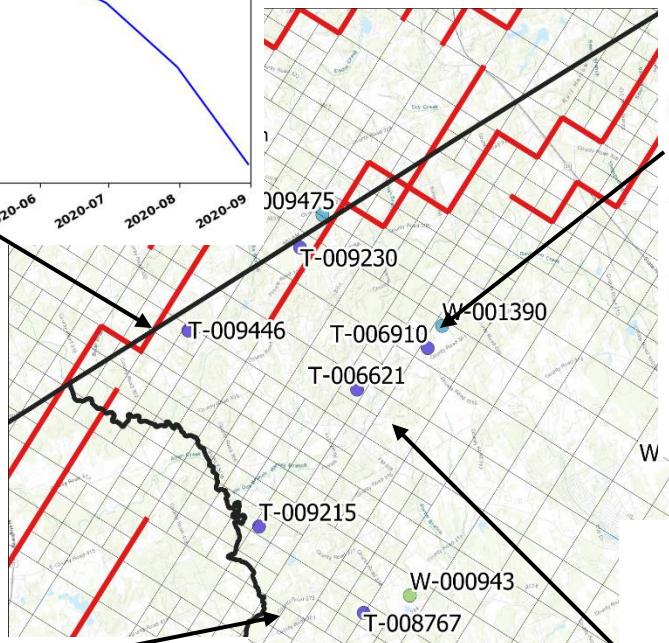






Simsboro


PO-009446 Simsboro
Transducer
Drawdown (feet)
Modified GMA12
Transducer
Daily Average
Transducer


009475
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W-001390
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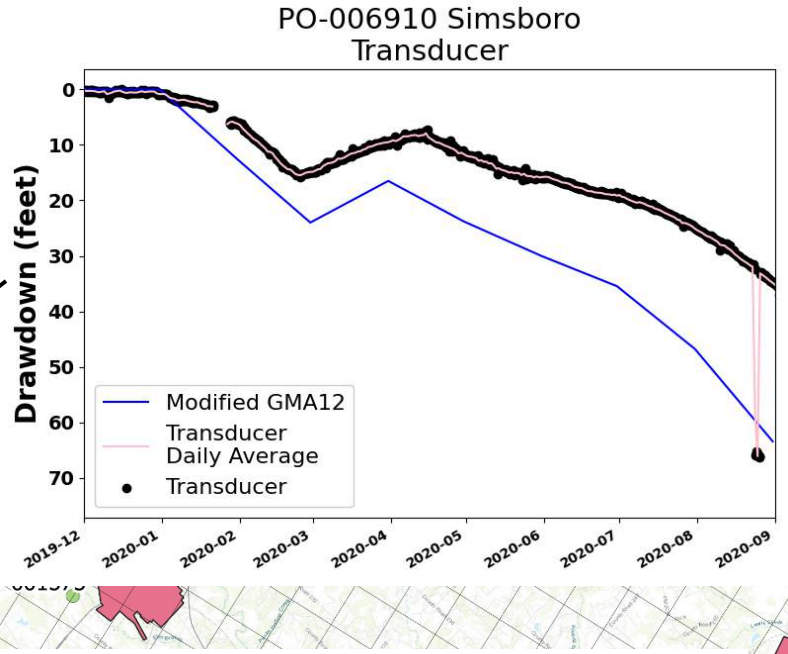
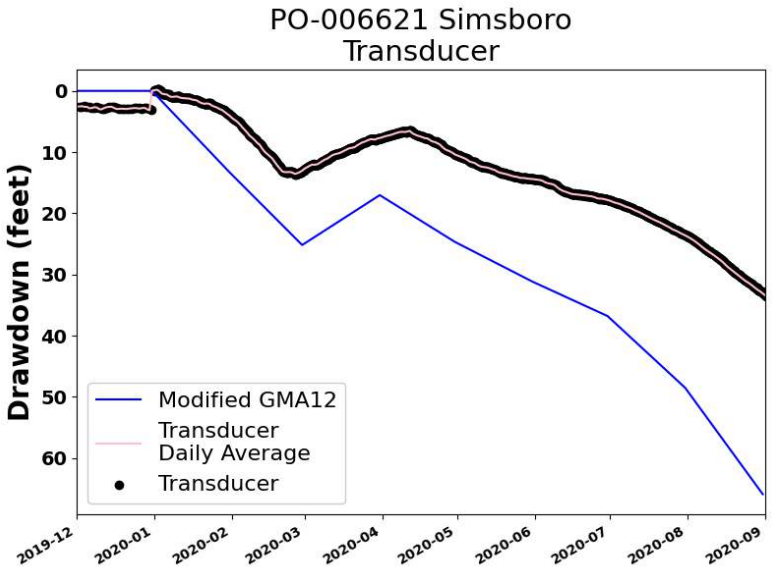
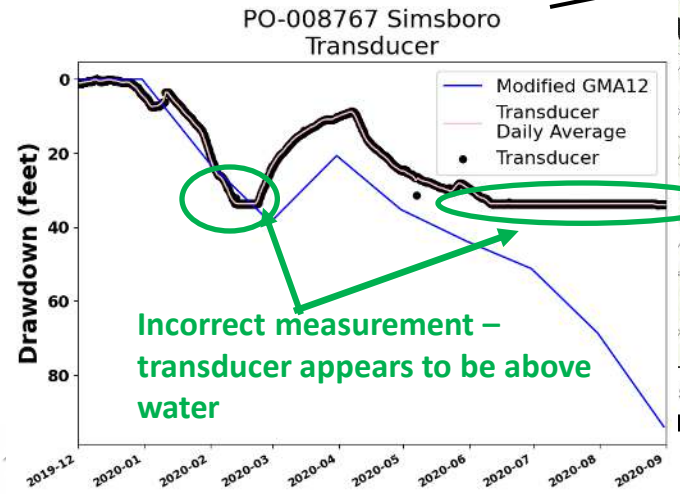
W-000943
T-008767
W-011279
T-009709
T-009708
T-009710
5
10


PO-006910 Simsboro
Transducer
Drawdown (feet)
Modified GMA12
Transducer
Daily Average
Transducer


PO-006621 Simsboro
Transducer
Drawdown (feet)
Modified GMA12
Transducer
Daily Average
Transducer


PO-008767 Simsboro
Transducer
Drawdown (feet)
Modified GMA12
Transducer
Daily Average
Transducer
Incorrect measurement – transducer appears to be above water

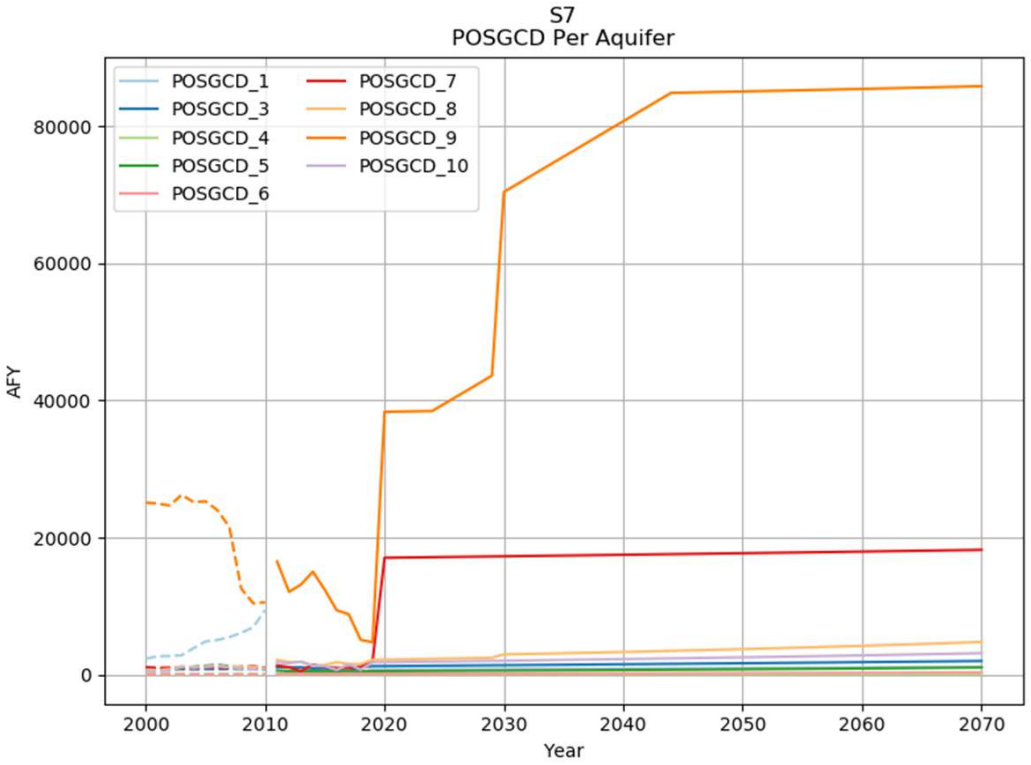
Observations: First 8 months

- All measured drawdowns are about the same or less than simulated by groundwater model– no surprises
- No distinguishable impacts in Sparta or Queen City
- Measurable impacts in all formations in the Carrizo, Calvert Bluff, and Simsboro
- Revised GAM is over estimating drawdown in the Simsboro

Desired Future Conditions

POSGCD Pumping for PS-7

	Current DFC (feet)	Current MAG in 2070	S-7 Drawdown from 2010 to 2070 (feet)	S-7 Pumpage in 2070 (acre-feet)
Sparta	28	6,735	17	1,983
Queen City	30	504	19	1,045
Carrizo	67	7,058	177	18,205
Calvert Bluff	149	1,036	183	4,761
Simsboro	318	48,503	355	85,855
Hooper	205	4,422	222	3,126

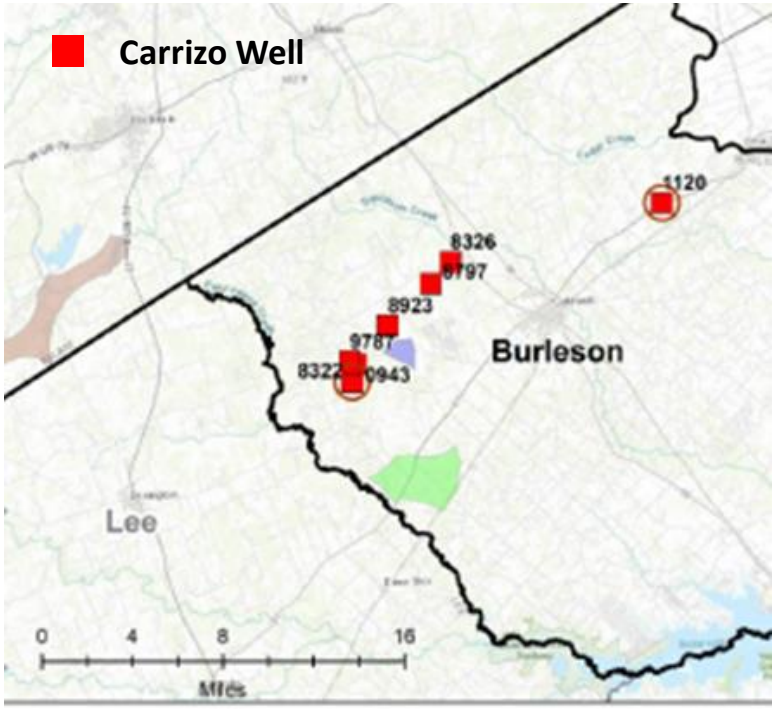


Consideration for Evaluating DFCs

- Permitted Pumping
- Impact of Pumping on Water Levels at Existing Wells
- Compliance with existing DFCs and PDLs
- Existing Water Column above the Top of the Aquifer (Available drawdown)
- Impact on Pumping in Adjacent GCDs on DFCs in POSGCD
- Reported Pumping is Less than the Permitted Pumping
- Addition of Management Zones and Changes in DFC
- Uncertainty in model predictions (± 10%)

Carrizo Issues of Concern

Impacts of Simulated Drawdown on Existing Wells



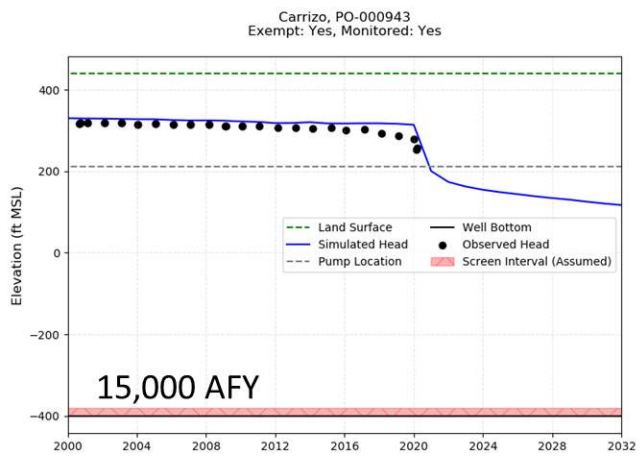
GANA Perform Using PS-9

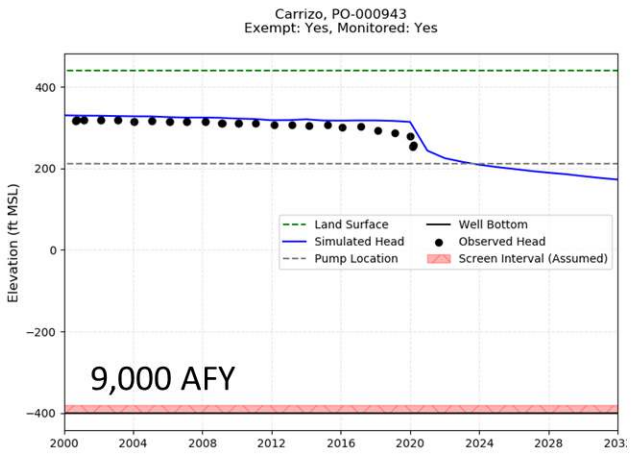
Impact of Non-POSGCD Wells on POSGCD DFCs

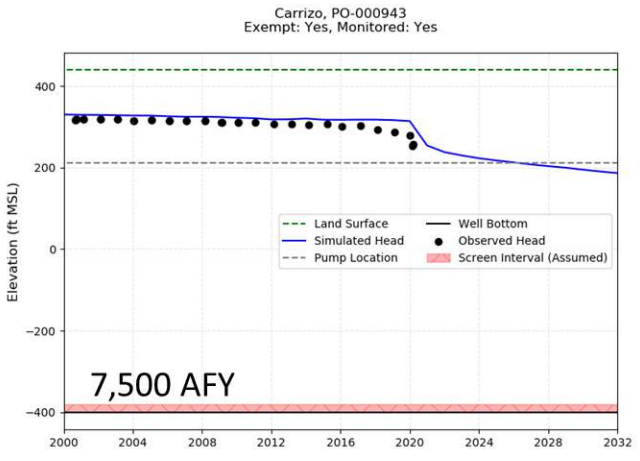
Vista Ridge Pumping (AFY)	DFC (2010 - 2070)		
	Carrizo	Calvert Bluff	Simsboro
0	105	157	347
5,000	127	165	349
6,000	132	166	349
7,500	139	169	349
9,000	145	171	350
15,000	172	181	351

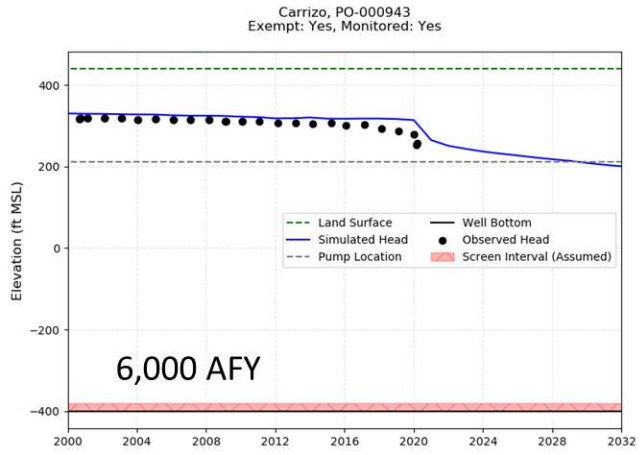
	Current DFC (feet)	Current MAG in 2070	S-7 Drawdown from 2010 to 2070 (feet)	S-7 Pumpage in 2070 (acre-feet)
Carrizo	67	7,058	177	18,205

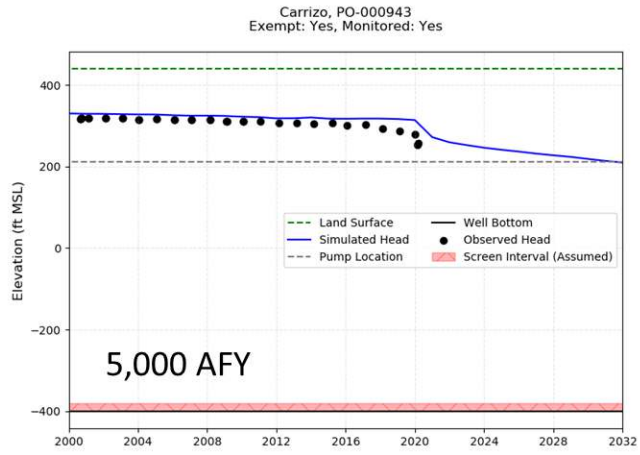
PO-0943 Hydrograph using Modified PS-7

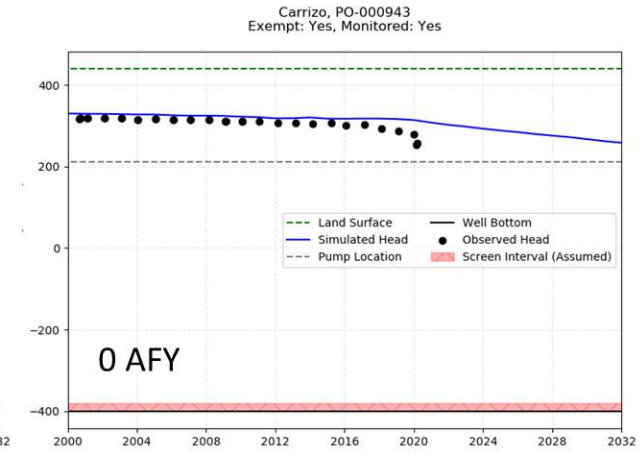






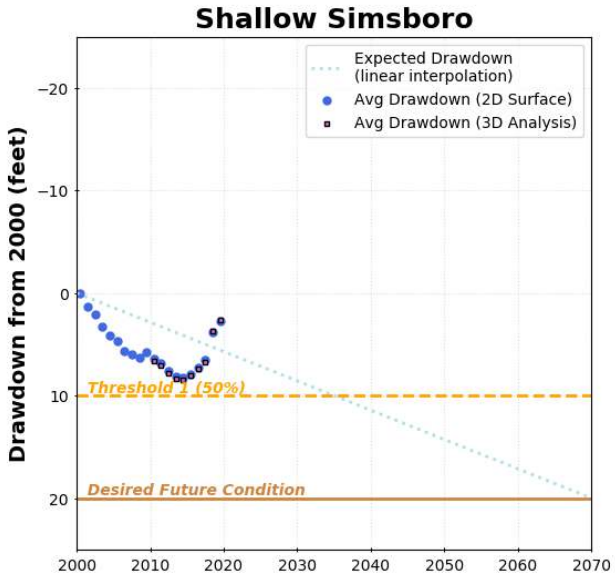


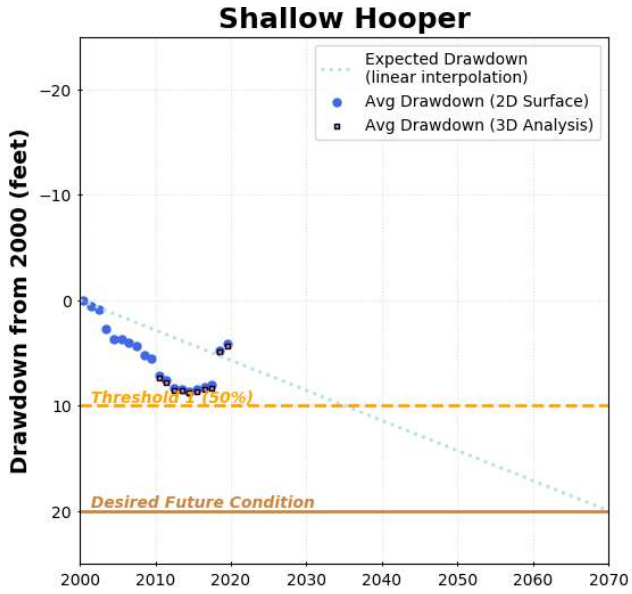




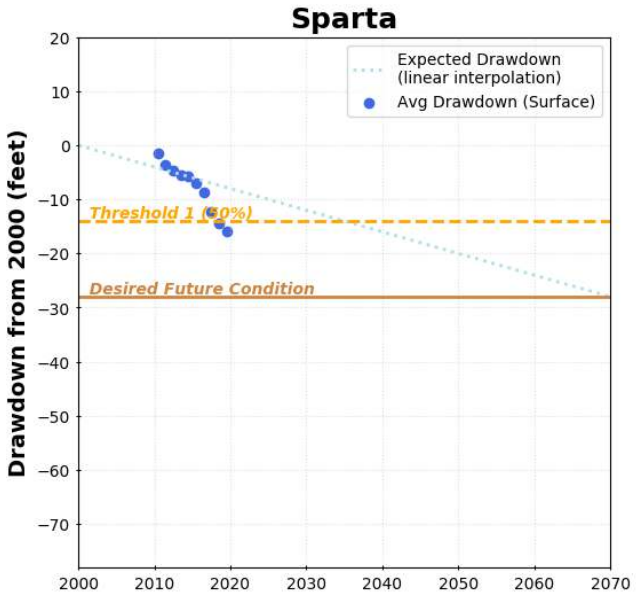
DFC and PDLs Issues of Concern

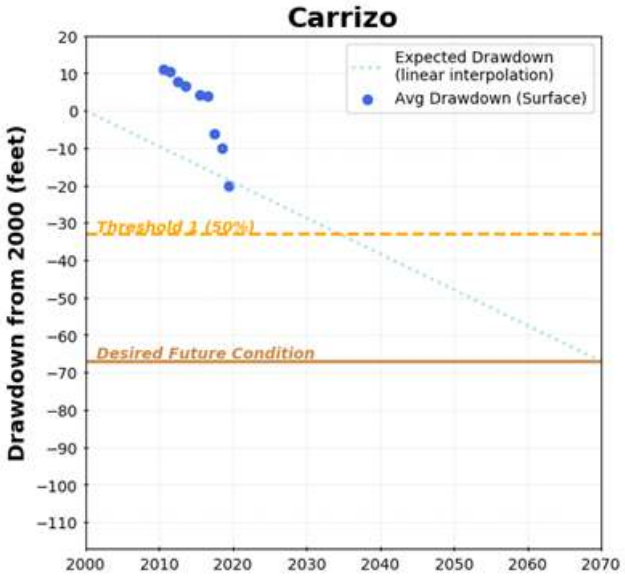
PDLs





DFCs





	Current DFC (feet)	Current MAG in 2070	S-7 Drawdown from 2010 to 2070 (feet)	S-7 Pumpage in 2070 (acre-feet)
Sparta	28	6,735	17	1,983
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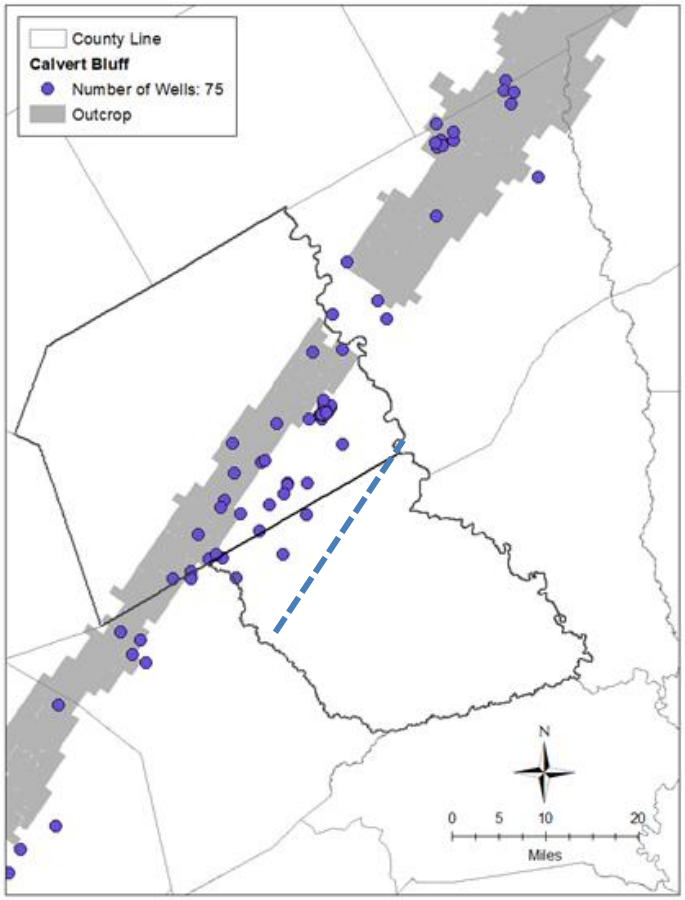
Carrizo	67	7,058	177	18,205
Calvert Bluff	149	1,036	183	4,761
Simsboro	318	48,503	355	85,855
Hooper	205	4,422	222	3,126

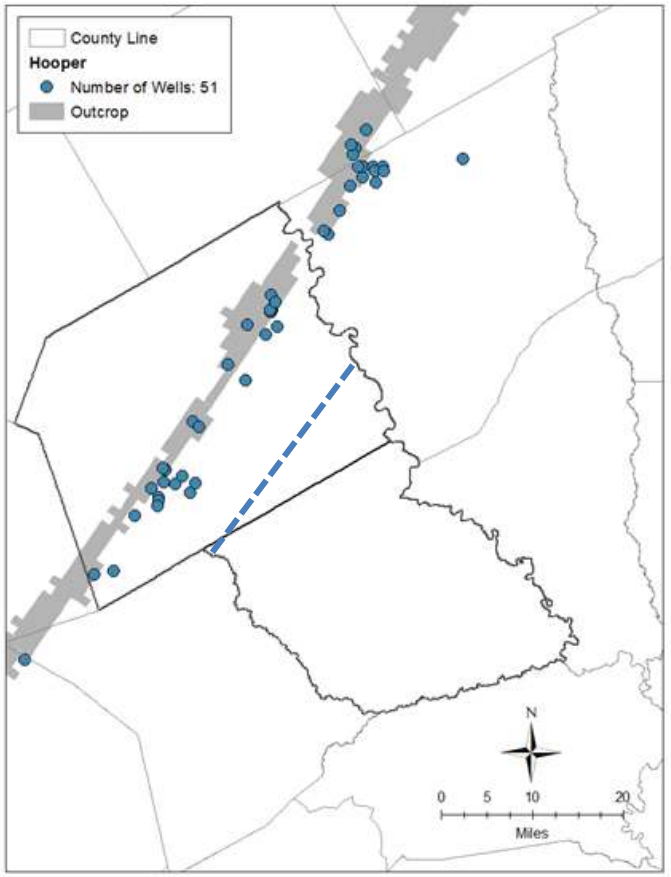
Sparta Permitted Pumping < 2,600 AFY

Addition of Management Zones and Possible Change of DFCs

Calvert Bluff



Hooper

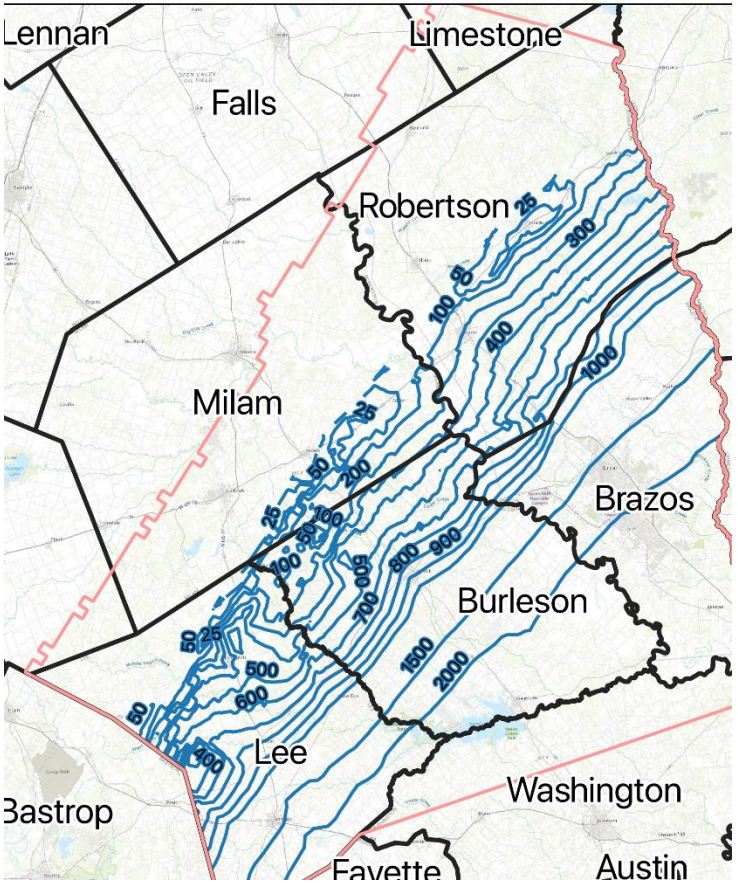


Available Drawdown
(water column above top of aquifer)

Available Water Column above the Top of the Aquifer

Aquifer	Water Column (ft) Above Top of Aquifer	
	Average	Median
Sparta	851	806
Queen City	892	708
Carrizo	1,213	975
Calvert Bluff	1,322	1,012
Simsboro	2,000	1,729
Hooper	2,287	2,114

Contours of Available Water Column above the Top of Carrizo (2020)



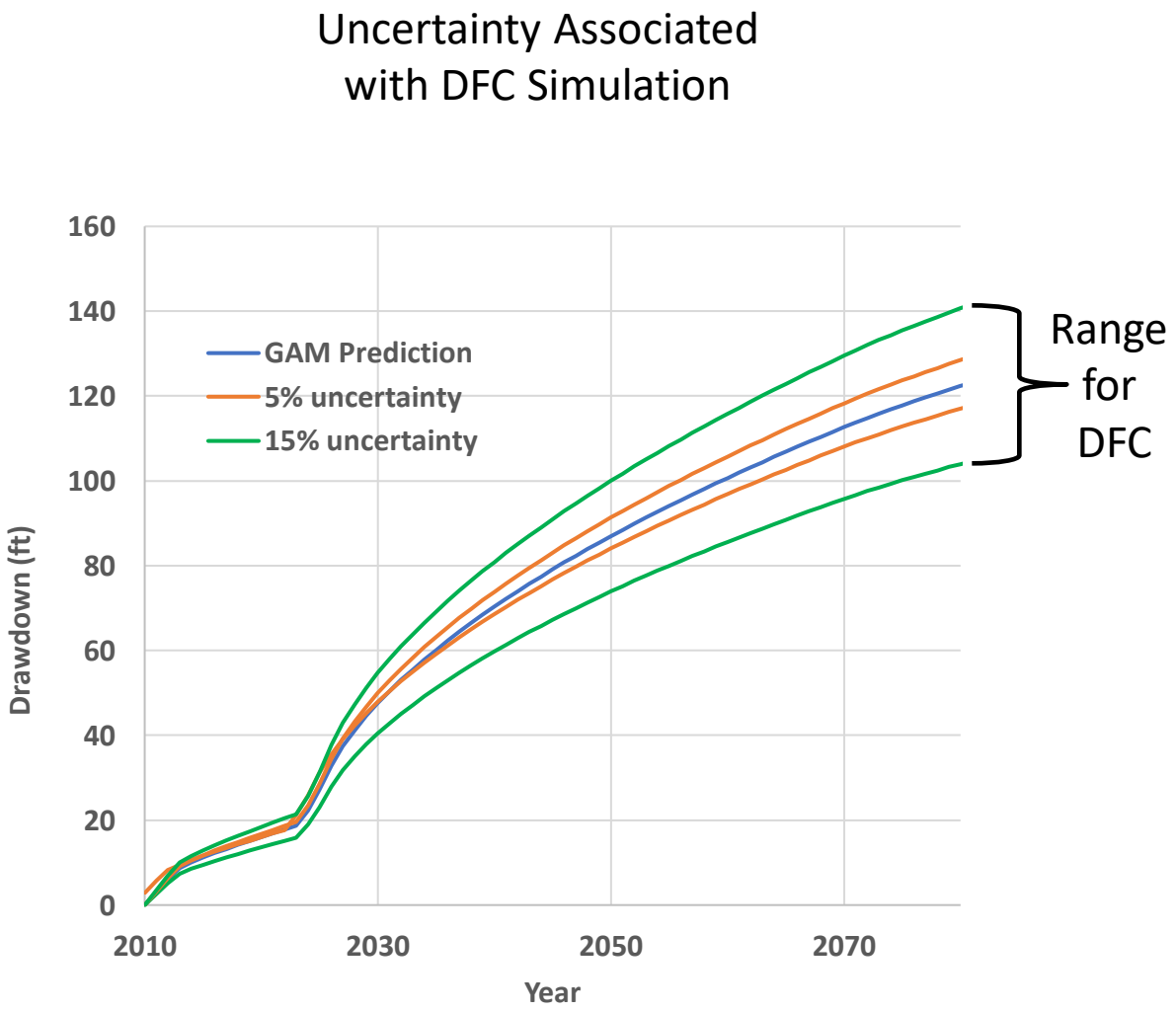
Maps of Available Drawdown can be used to help understand the vulnerability of an aquifer to pumping impacts is spatially dependent

Permitted Amounts

Comparison of Pumping Versus Permitted

Aquifer	Permited Amount (AFY)	PS-7 Pumping (AFY)
Sparta	2,586	1,983
Queen City	1,414	1,045
Carrizo	18,690	18,205
Calvert Bluff	4,366	4,761
Simsboro	103,398	85,855
Hooper	2,618	3,126
Total	133,072	114,975

Uncertainty Associated with GAM Prediction



DFCs Discussion

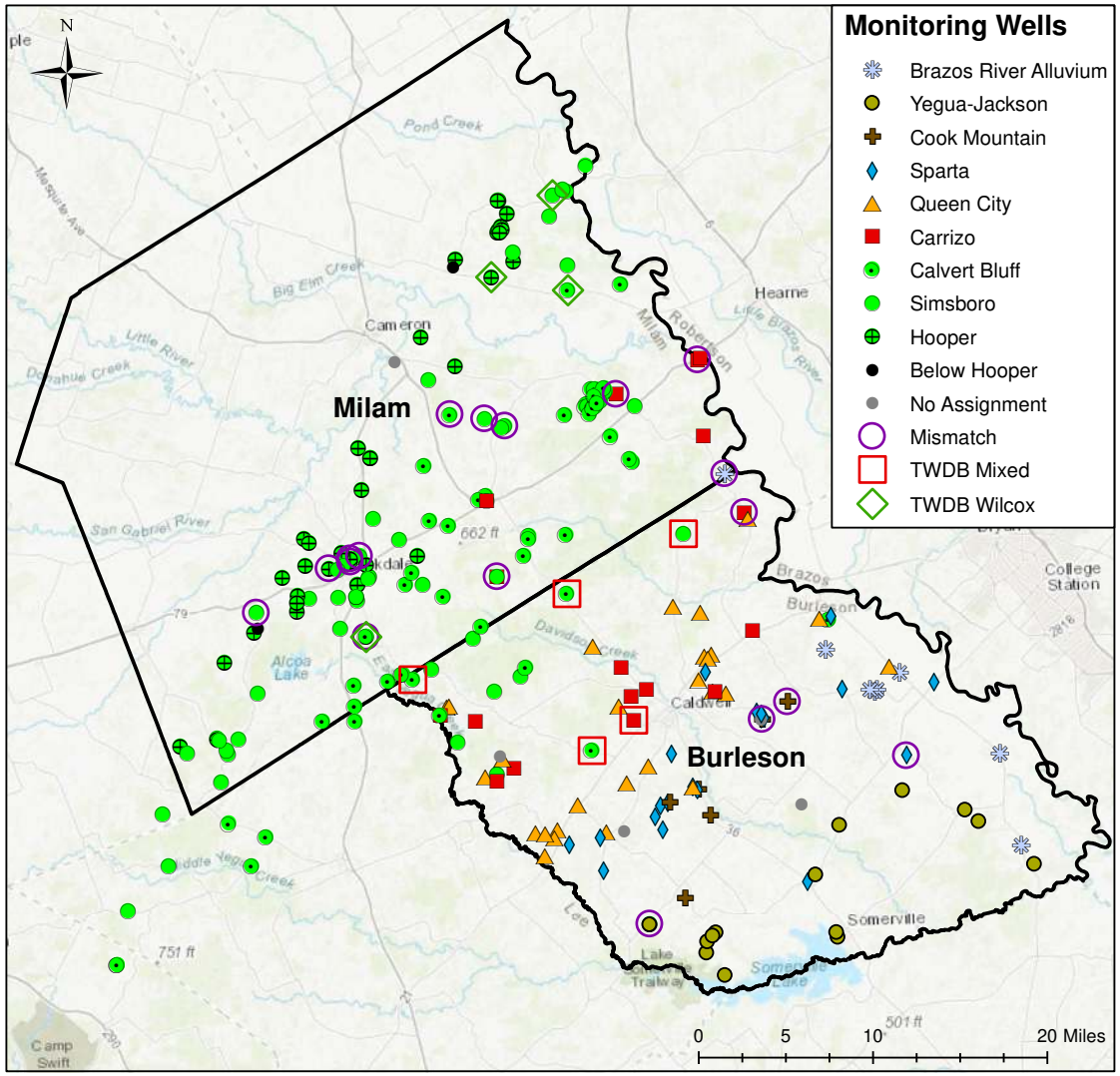
- Considerations
  - drawdown (available, existing DFC, GANA report, DFC and PDL compliance)
  - production (permit, existing MAG, percentage of TERS)
  - Assessment of Water Levels above bottom of wells
  - Sensitivity Analyses of Well Impacts based Modifications to PS-7
- Uncertainty
  - Upper limit (15% - 20%)
  - Lower Limit (0 -5%)
- DFCs
  - Areas Based on new Management Area2

Highlights of Monitoring & Pumping Dashboards

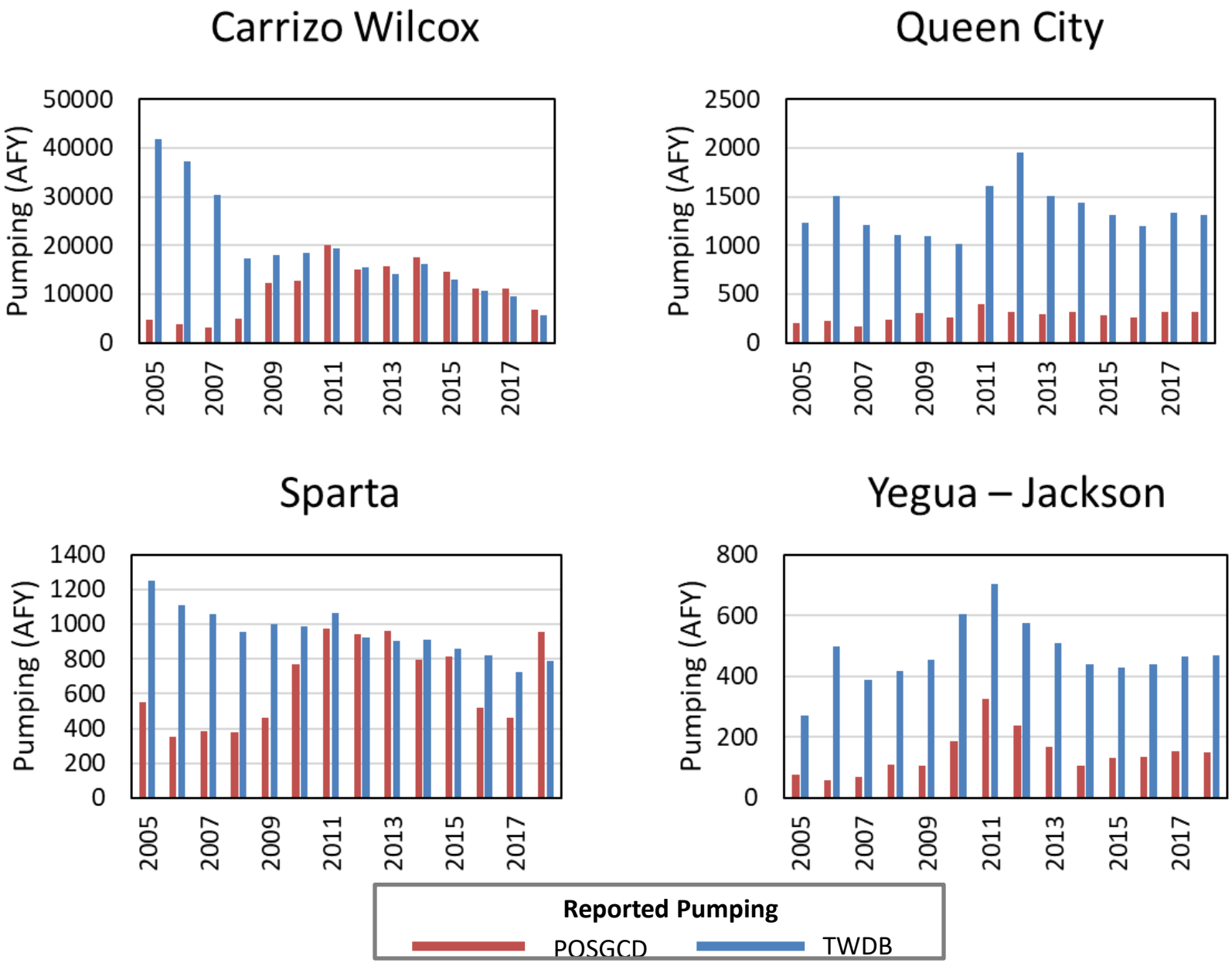
Aquifer Assignment: TWDB Assignments Differ from INTERA Assignments*

18 wells – difference between TWDB and INTERA assignments

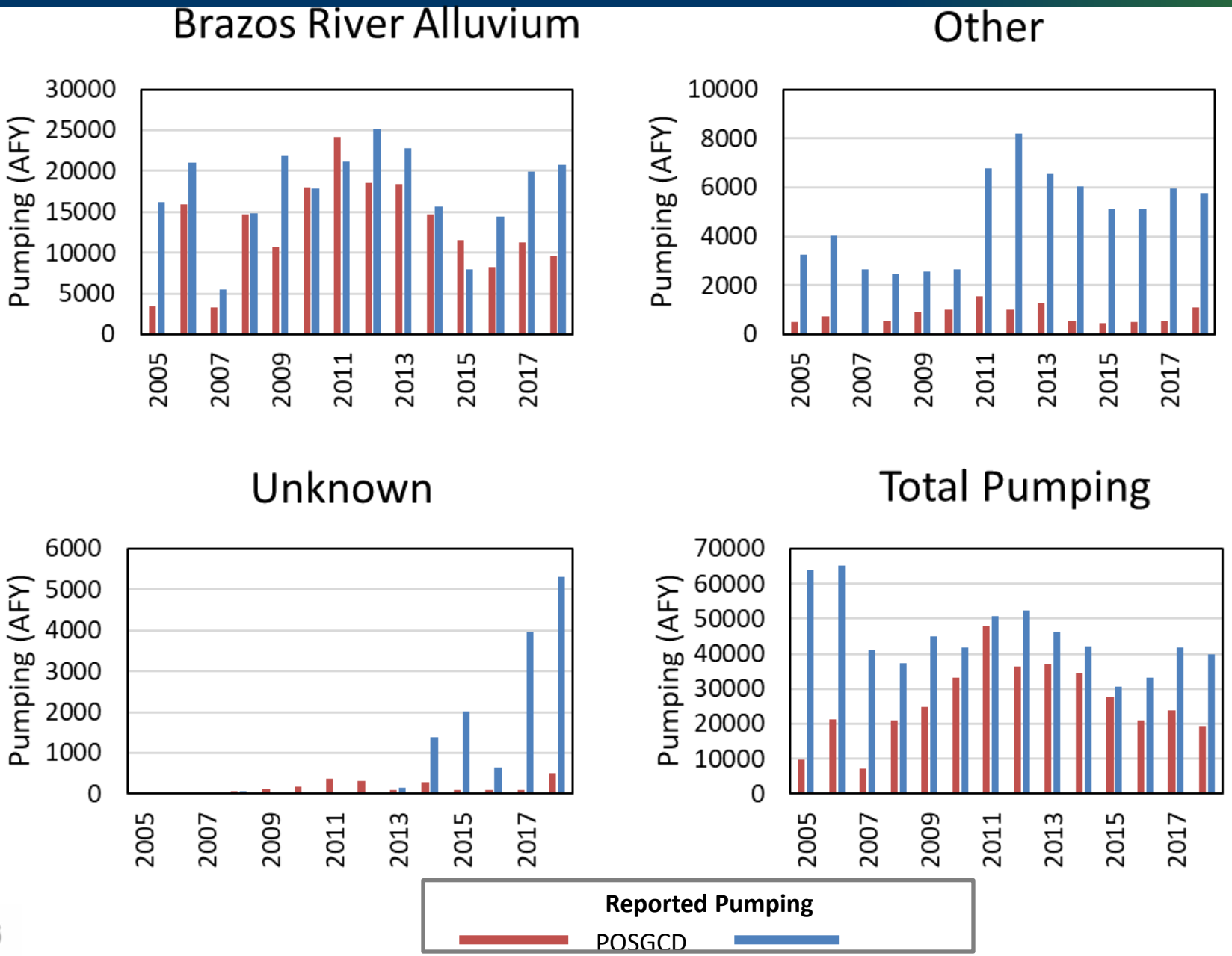
TWDB dB does not match INTERA assignment



Estimates of Reported Pumping



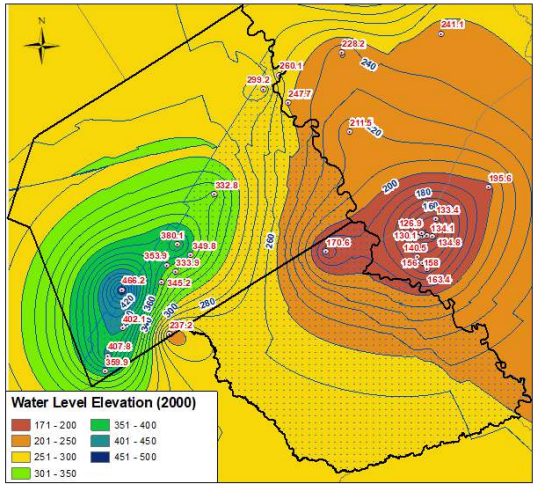
Estimates of Reported Pumping (con't)



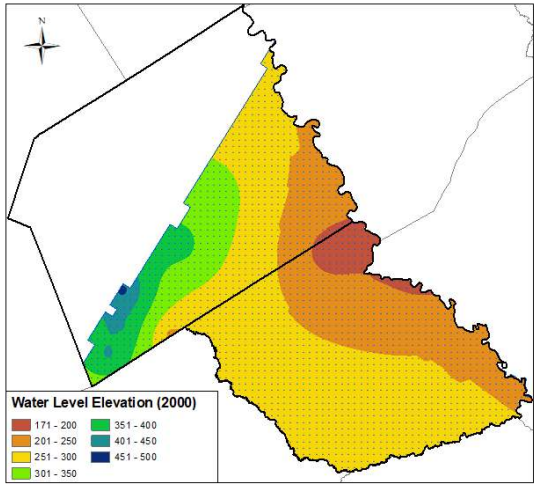
Water Level Analyses for DFC and PDL Compliance

Review of Drawdown Calculation

Interpolate Baseline (2000) Simsboro Water Level Surface

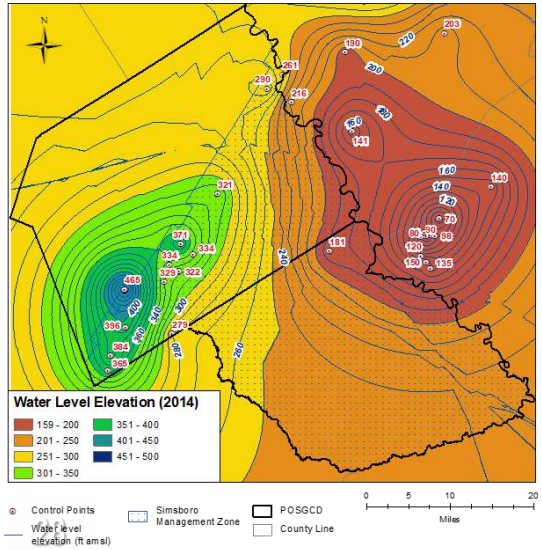


Clip Baseline (2000) Water Level Surface to Simsboro Zone

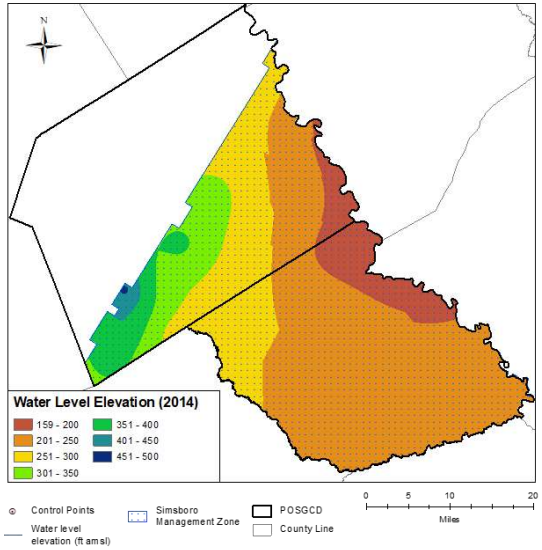


Calculate Average Baseline (2000) Water Level Elevation

Interpolate Evaluation Year (2014) Simsboro Water Level Surface



Clip Evaluation Year (2014) Water Level Surface to Simsboro Zone



Calculate Average Evaluation Year (2014) Water Level Elevation

Average Drawdown =
Baseline WL (2000) – Evaluation Year WL (2014)

Current Interpolation Routine: Benefits

- No objective method for assessing uncertainty
  - Provides coverage across entire area of interest
  - Allows integration of monitoring data from adjacent GCDs
  - Prevents bias associated with clustered data points
  - Minimizes subjectivity associated with how to weight individual measurements
  - Well documented methodology that is publicly available

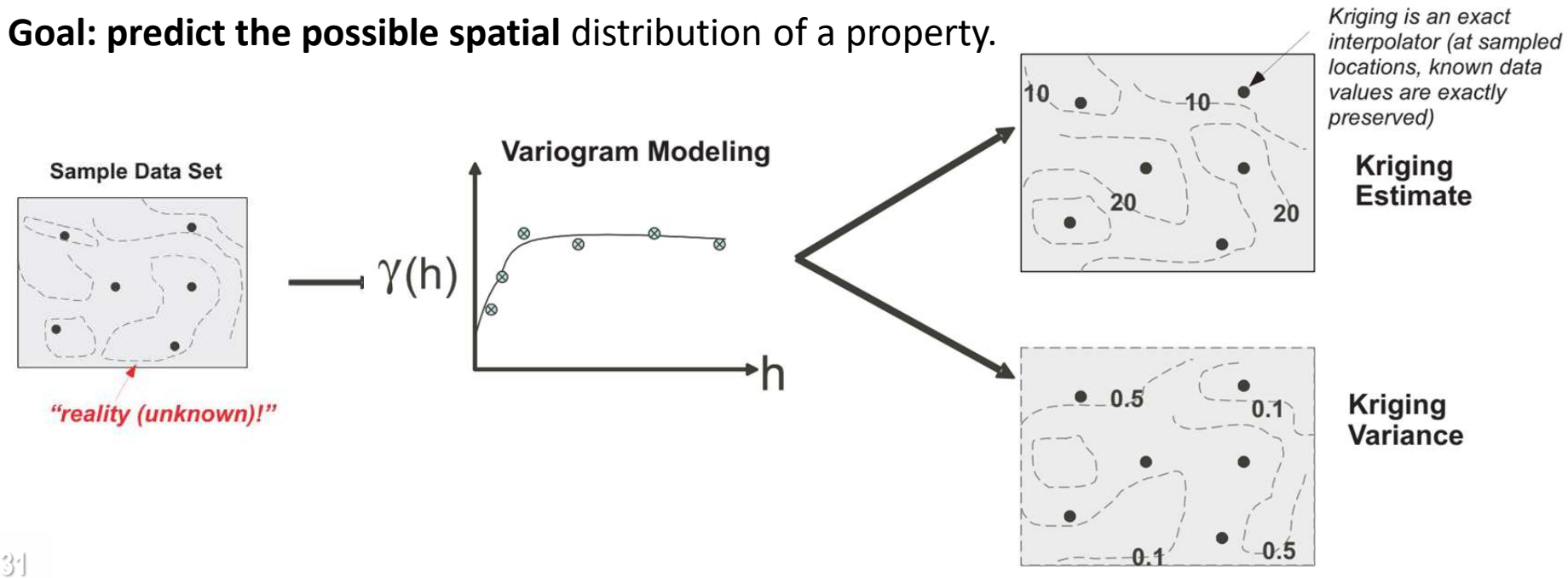
Current Interpolation Routine: Limitations

- Designed to generated delineate maps of watersheds from topographic
- Avoids creating depressions (like those around pumping wells)
- Underlying mathematic does not provide options to estimate uncertainty

Geostatistics for Predicting Water Levels

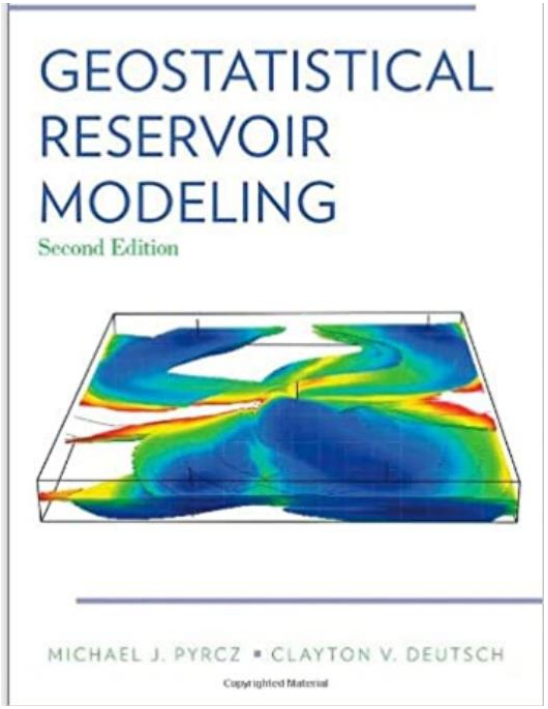
- **Defensibility**: Best-science estimates (BSEs), industry-leading techniques
- **Robust Analysis**: Allows inclusion of secondary data that is correlated to water level data
- **Software**: Algorithms are known and code is available for review (not a blackbox)
- **Reproducibility/transparency**: Remove any guesswork from annual drawdown maps
- **Risk reduction** (no surprises): any uncertainty in estimates are known and predictable

Goal: predict the possible spatial distribution of a property.



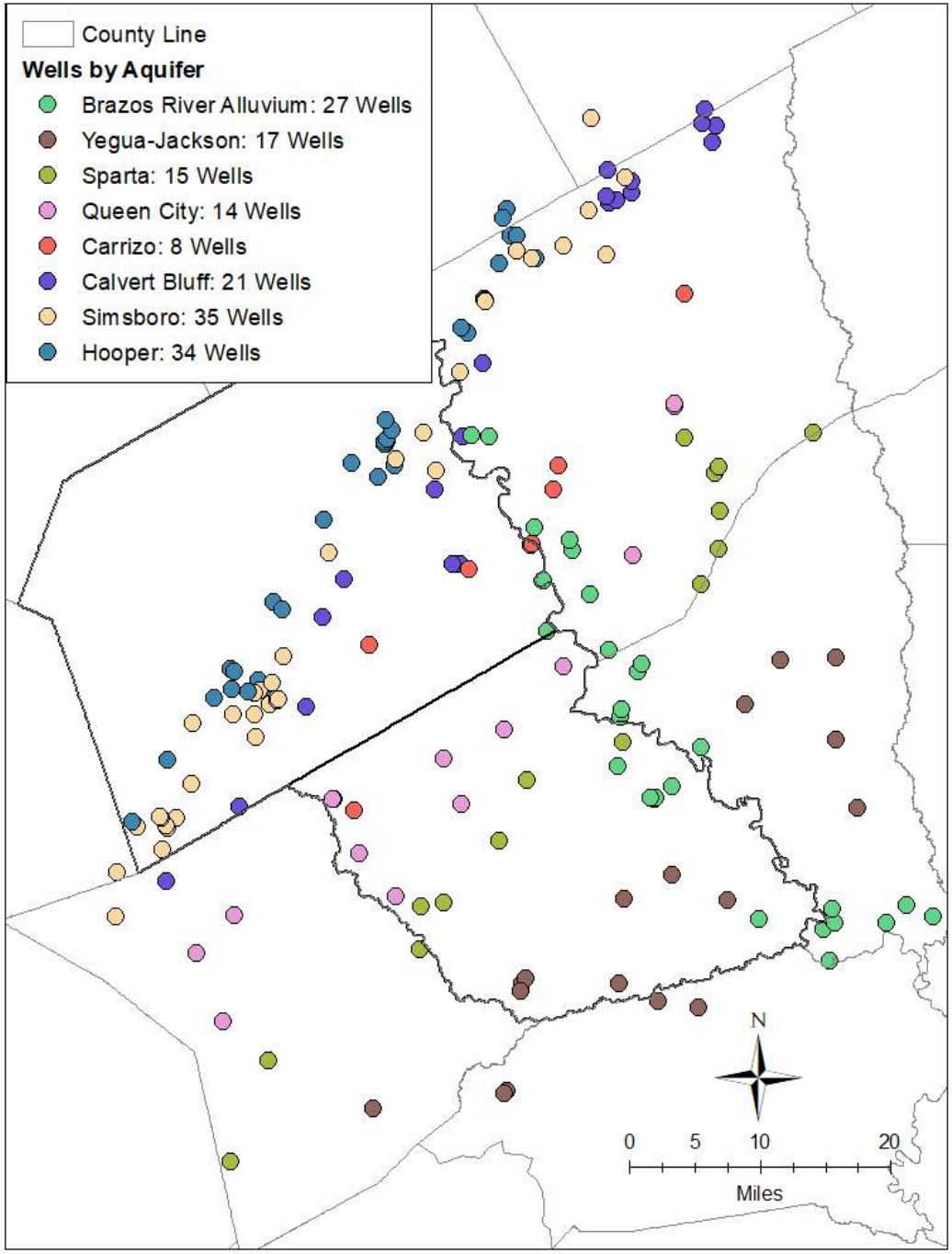
Development of Geostatiscal Programs

- QA/QC water level measurements for 2019 and 2020
- Work with Dr. Michael Pyrcz at UT Austin on developing and applying geostatistical methods
  - Dr. Pyrcz has developed software that is publicly available
  - Tenured Professor with distinguished publication record and 14 years with industry



Location of Shallow Monitoring Wells

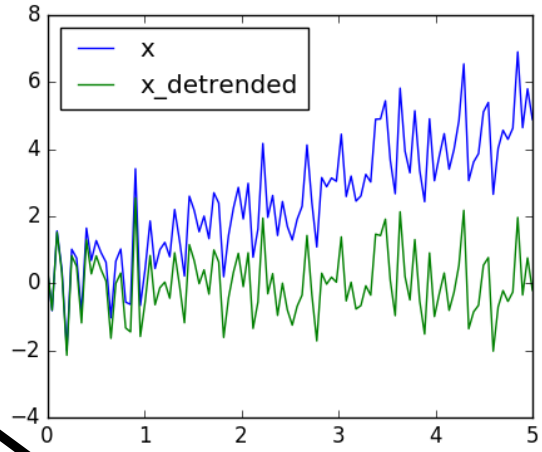
- No major gaps in coverage
- One notable gap in coverage near Milam-Burleson County line
- Depth of wells range between 30 and 370 feet
- Notable changes in water levels (>10 ft) occur at some wells during 3-month sampling period
- Several outcrop zones are relatively thin and wide
- Excellent correlation between topography and water levels



2018, 2019, & 2020 Water levels

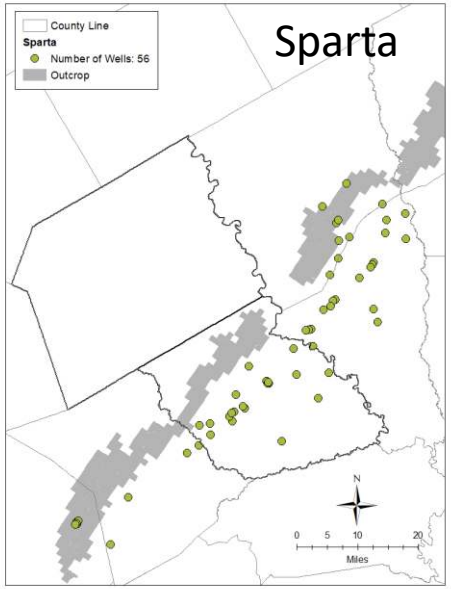
Approaches for Interpreting Shallow Water Levels

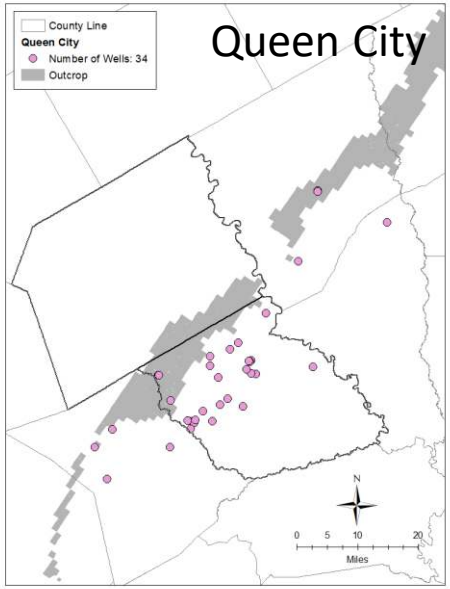
- Topo2raster *(baseline)*
- Topo2rasters *(baseline + stream elevations)*
- Kriging *(BSE, no secondary data)*
- Kriging Detrended Water Levels
  (BSE, use model to "detrend" data)
- CoKriging using Topography
  (BSE, use model to "detrend" data)
- CoKriging using Topography
  & Stream
- CoKriging using Topography
  & Stream & Pumping

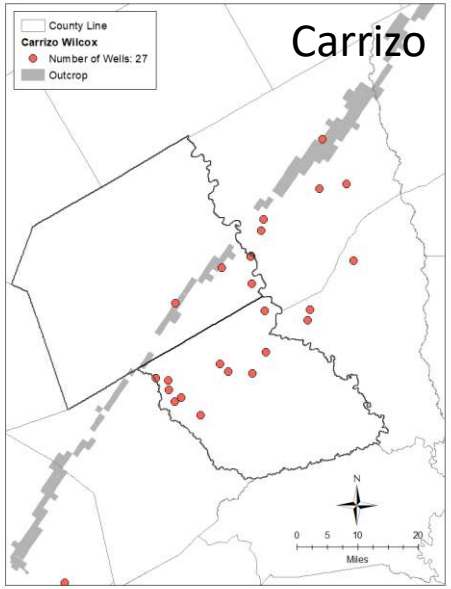


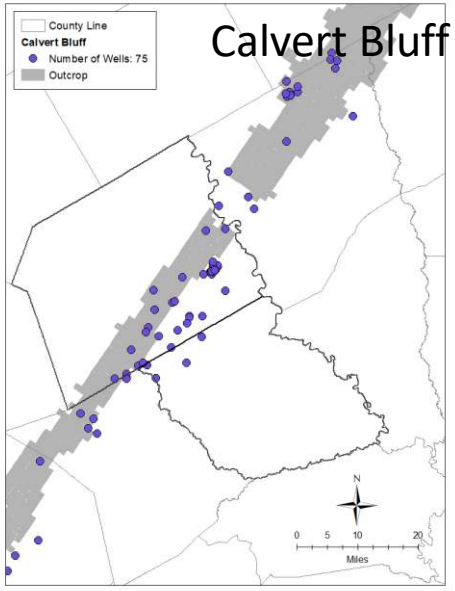
Location of Aquifer Monitoring Wells

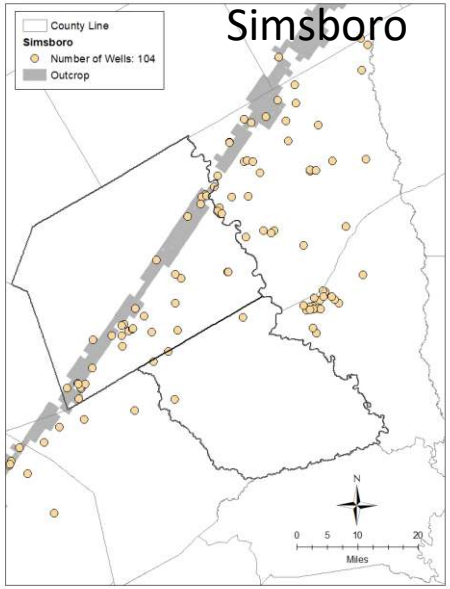
- major gaps in coverage
- water levels change more sensitive than zone zones

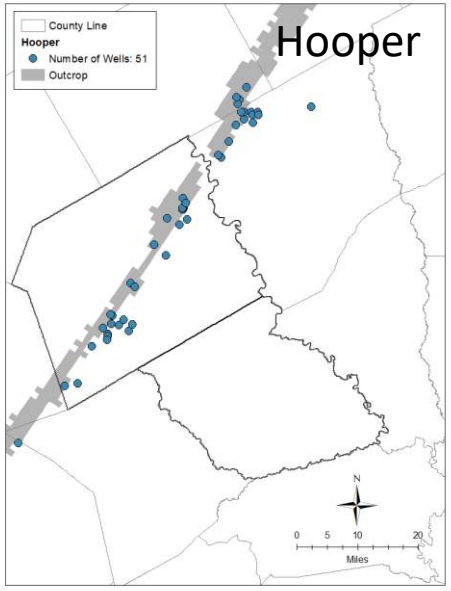












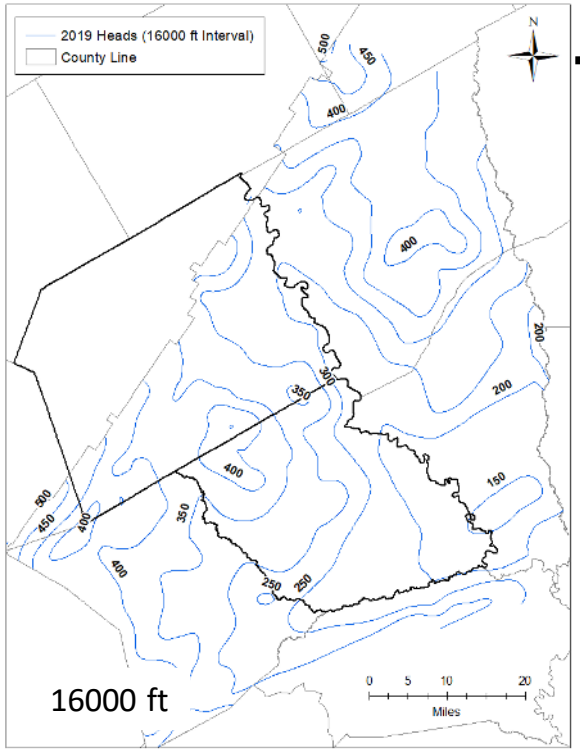
2018, 2019, & 2020 Water levels

Approaches for Interpreting Aquifer Water Levels

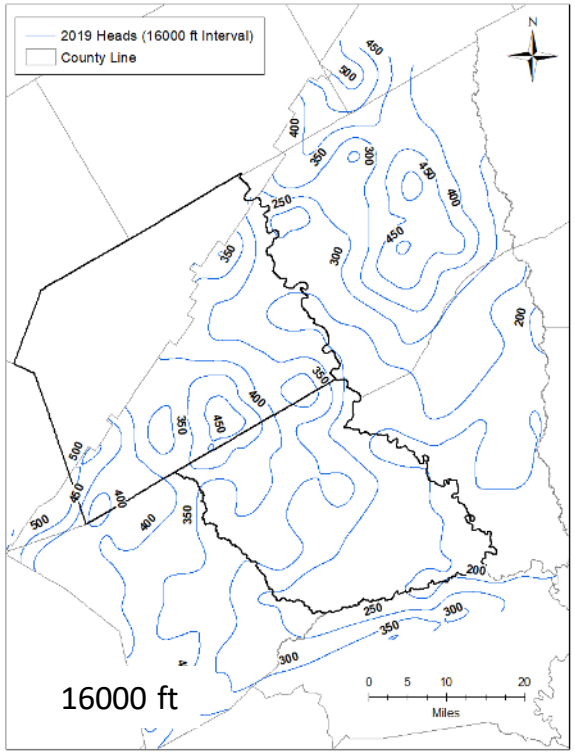
- Topo2raster *(baseline)*
- Kriging *(BSE, no secondary data)*
- Kriging Detrended Water Levels
  (BSE, use model to "detrend" data)

Process for Generating Water Level Maps for Detrending Water Levles

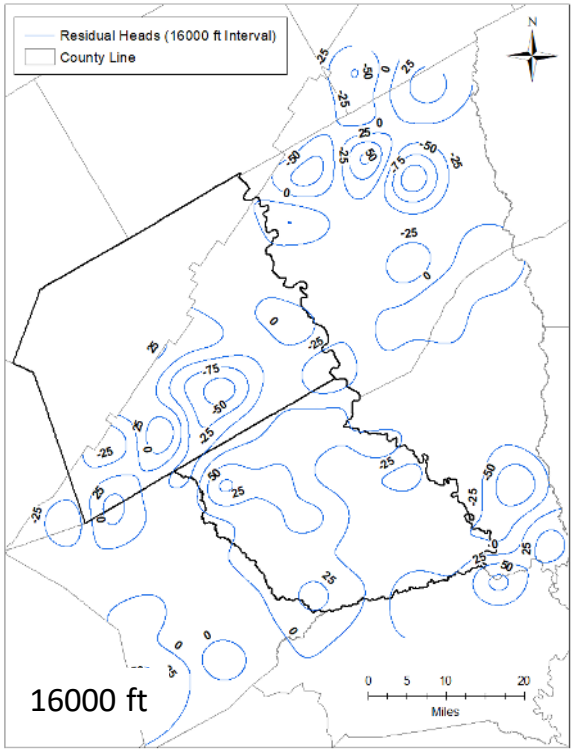
Water Level Trend Generated from the Model



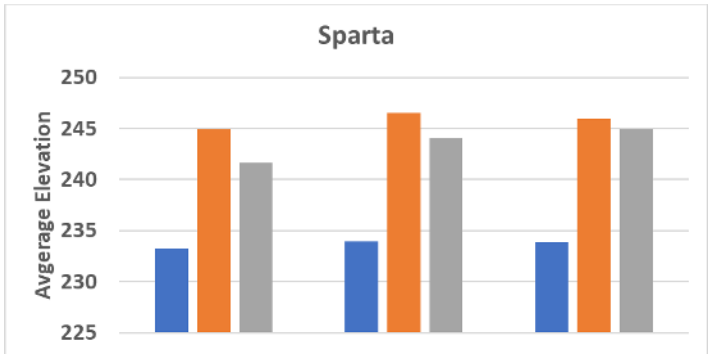
Map of Water Level Contours

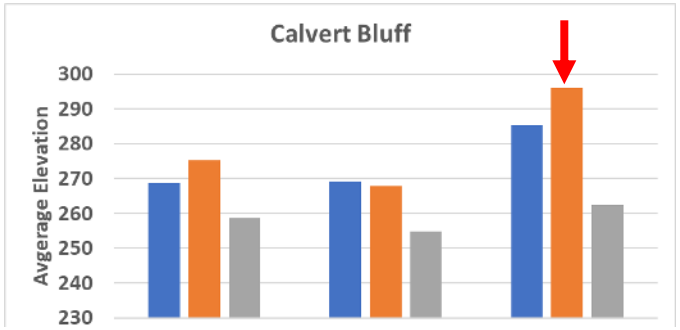


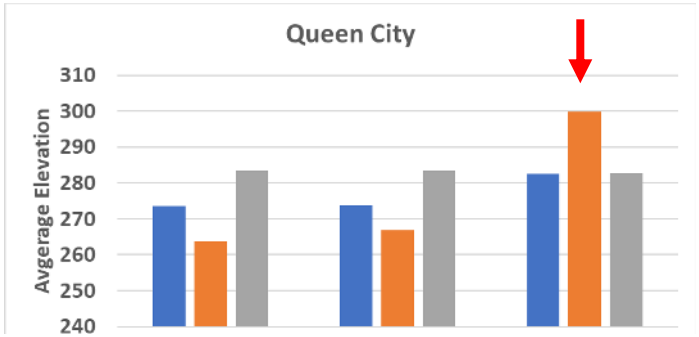
Kriged "residual" Generated From Measured Water Levels

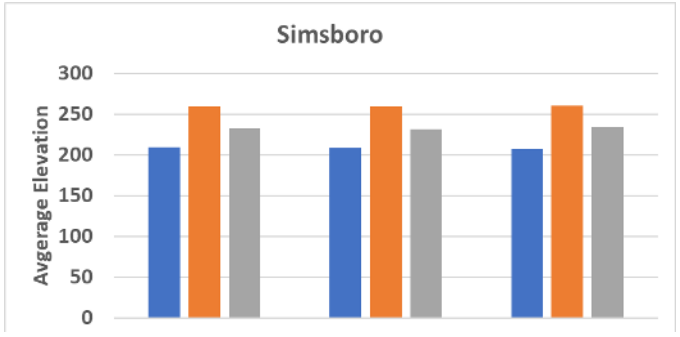


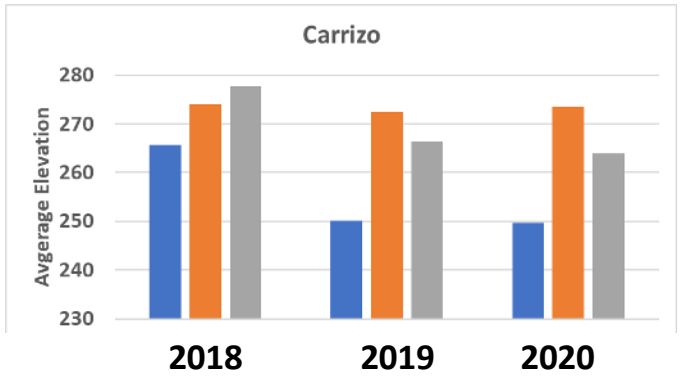
Comparison of Methods For Entire Aquifer

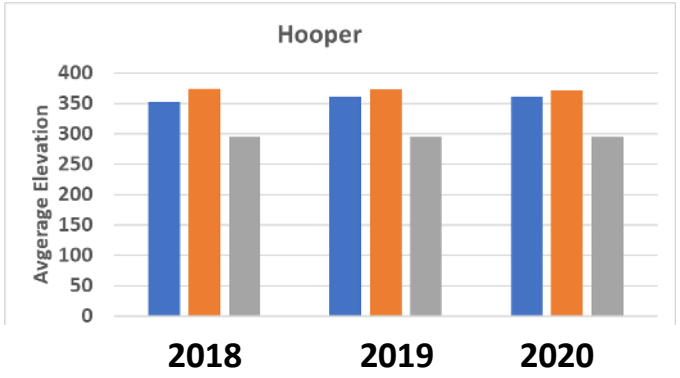






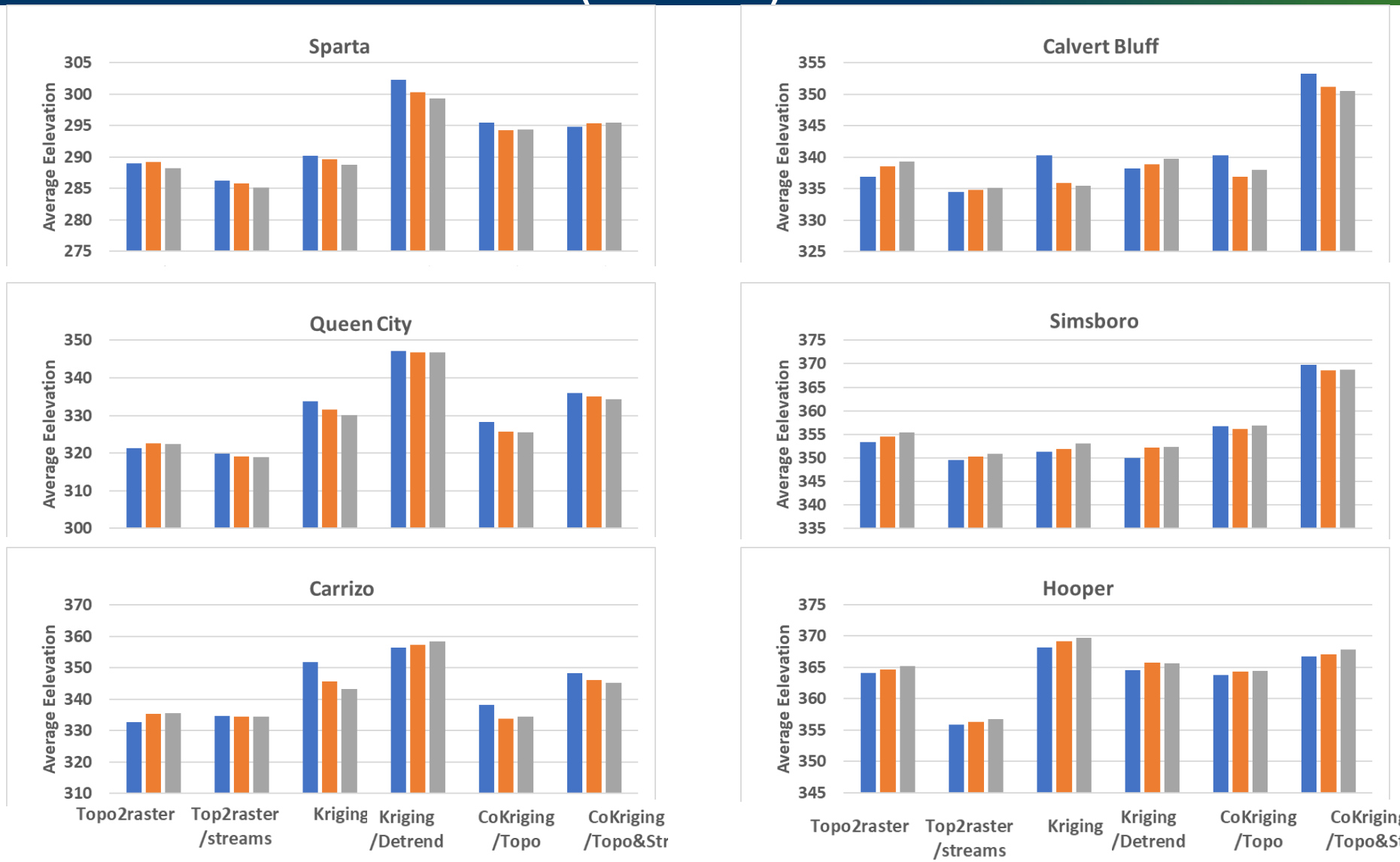




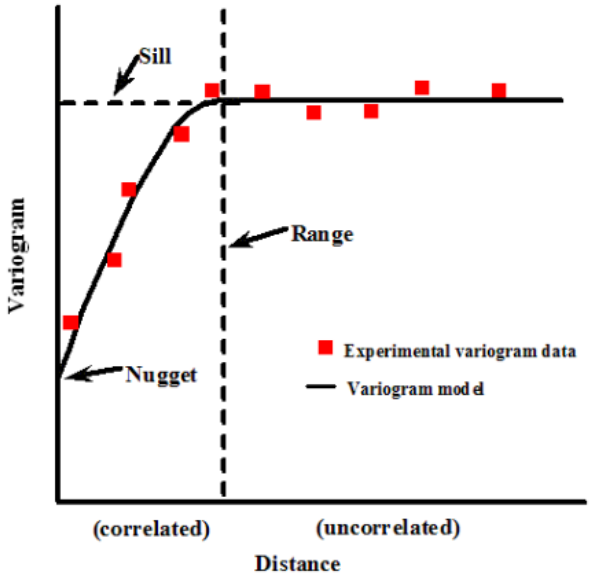


Topo2raster Kriging Kriging /Detrend

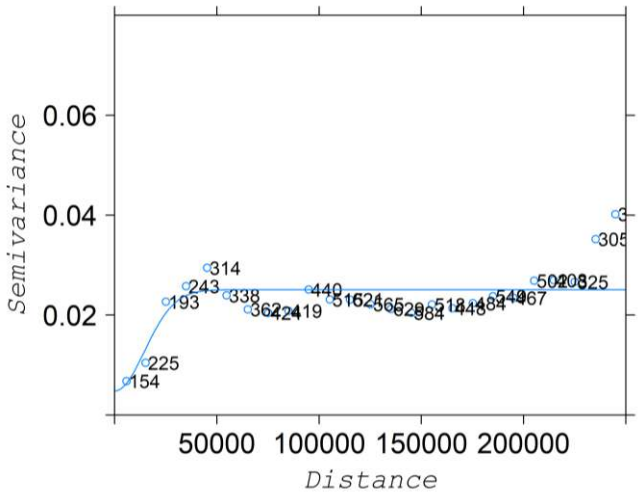
Comparison of Methods for Shallow Aquifer Zone (<400 ft)



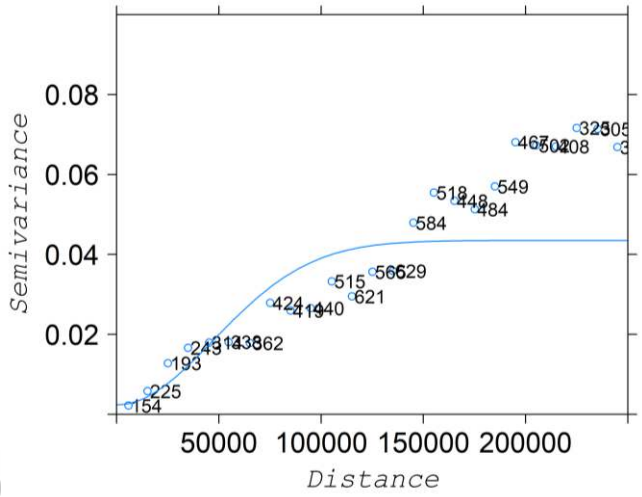
Comparison of Variograms (2020 data)



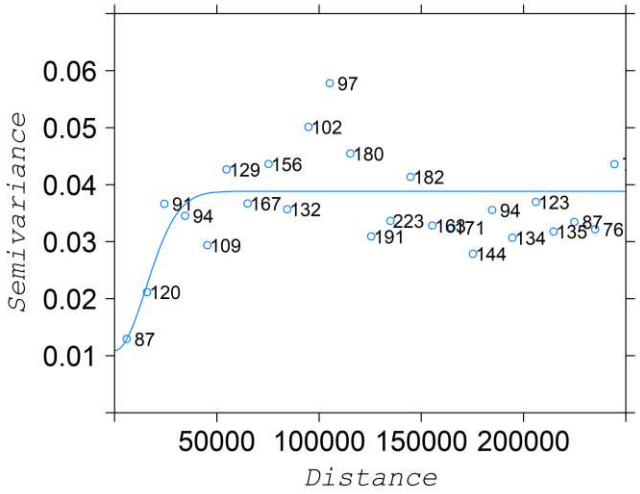
Kriging\Detrending (shallow)



Kriging (shallow)



Kriging\Detrending (Simsboro)



Assessment

- Criteria
  - Conceptual assumptions
  - Mathematical foundation
  - Capability to support uncertainty analysis
  - Scientific literature
  - Consistency in predicted values
  - Opportunity for continued improvement
- Evaluation
  - Kriging/Detrending is best
  - Kriging is too sensitivity to moderate perturbations in data
  - Topo2raster is a viable option for validation

Potential Applications

- Shallow Zone
  - Average Water Level Elevation with Kriging/Detrending
  - Average Water Level Drawdown with Kriging/Detrending and possibility Topo2raster
  - Data limitations in small outcrops
  - Yegua/Jackson zone is least reliable
  - Additional work recommended (uncertainty, starting year)
- Evaluation
  - Kriging/Detrending is best
  - Data limitation are significant in down dip regions of some aquifers
  - Quality checks on measured data is very important
  - Yegua/Jackson zone is least reliable because of GAM
  - Recommendation is to use average drawdown as primary and average water levels as secondary criteria
  - Additional work recommended (uncertainty, GAM)

GWAP Annual Needs Assessment Report and Compliance Report Report

Reports

GANA Report
Groundwater Assistance Program Annual Needs Assessment

Objective: Evaluate the potential of *water wells* going "dry" based on *simulated water levels* from GMA 12 DFC simulations

CR Report
Evaluation of Compliance Goals Based on Monitored Water Levels

Objective: Evaluate compliance to *DFC's and PDL's* based on interpretation of *measured water levels*

MS Report
Assessment of Management Strategies for Water Availability and Production

Objective: Using best science to:
1) predict year that Rule 16 thresholds may occur
2) evaluate timing for production cutbacks to achieve management goals
3) assess the need for adjusting maximum allowable production of 2 ac-ft/ac
4) assess effectiveness of current management strategies for achieving management goals
5) identify possible changes in management strategies to help achieve management goals

GANA = Groundwater Assistance Program Annual Needs Assessment
CR = Compliance Report
MS = Management Strategies

GWAP Annual Needs Assessment Report

- INTERA submit list of changes in GWAP discussed in Aug DFC Committee Meeting that address report on Oct 12
- INTERA submit proposed model runs on Oct 23
- Complete draft report by November 17th

Compliance Report

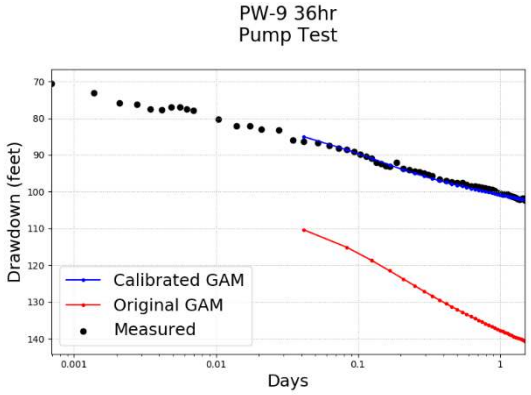
- Document analyzes presented on April 30 to DFC committee
- Include chapter on recommended changes to data collections and data analysis protocols
- Complete draft report by November 30^{h}

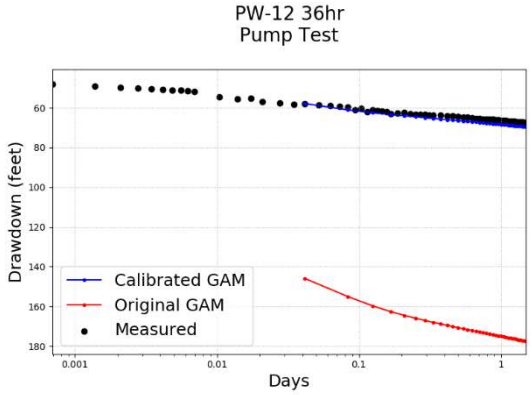
Suggestions for 2021 Hydrological Studies

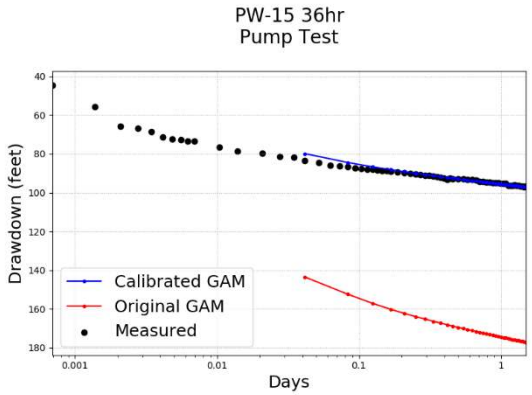
Aquifer Research

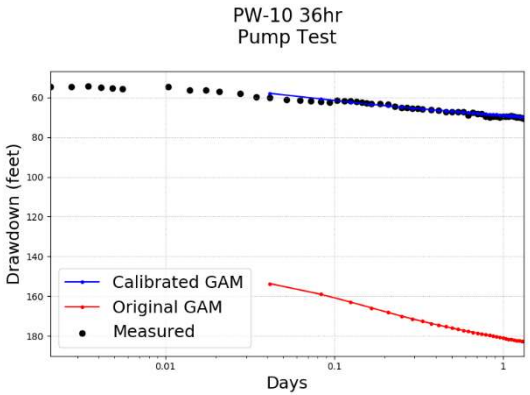
- Continued Improvements to GAM
  - Pumping rates for permitted wells
  - Additional pumping tests
  - Calibration
    - POSGCD monitoring data
    - Vista Ridge monitoring data
- Kriging/Detrend Application
  - Improved Coupling between modeled and measured water levels
  - Quantity uncertainty

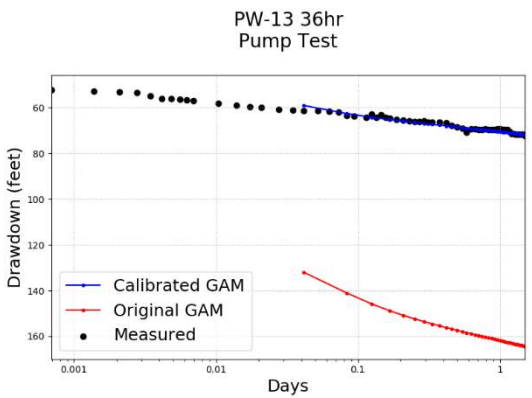
Evidence for Potential Improvement in the GAM

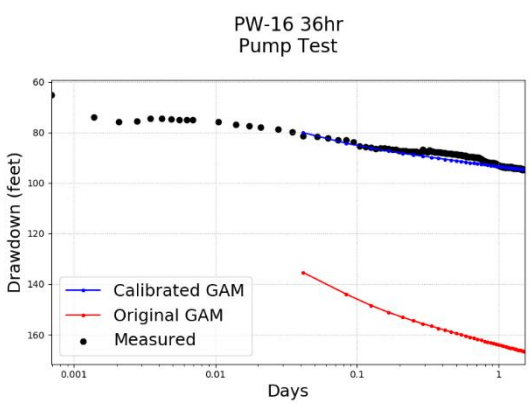


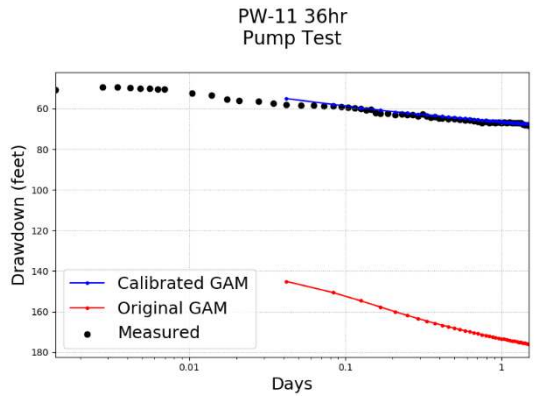


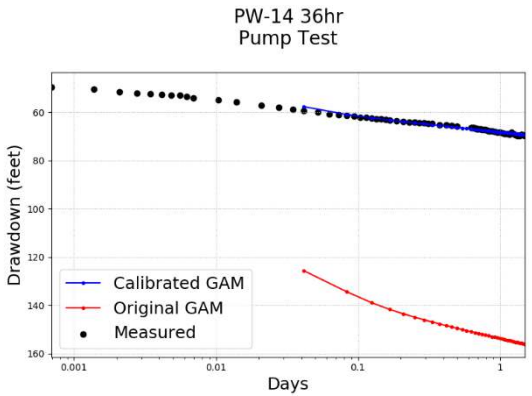


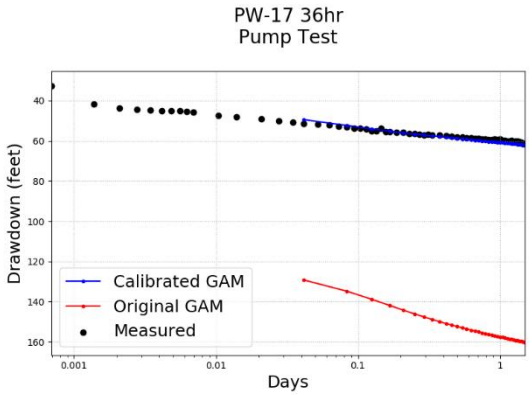


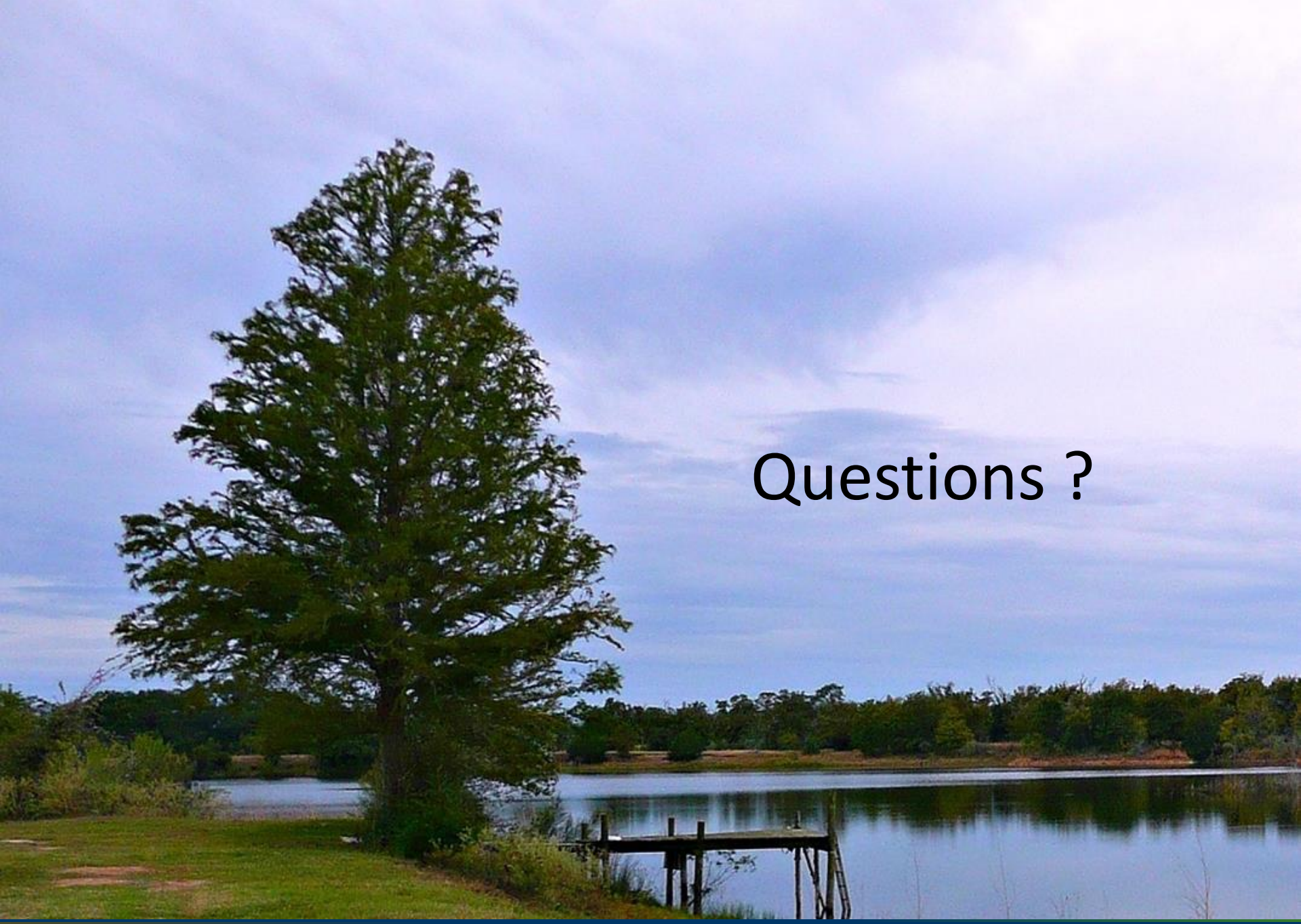











Questions ?