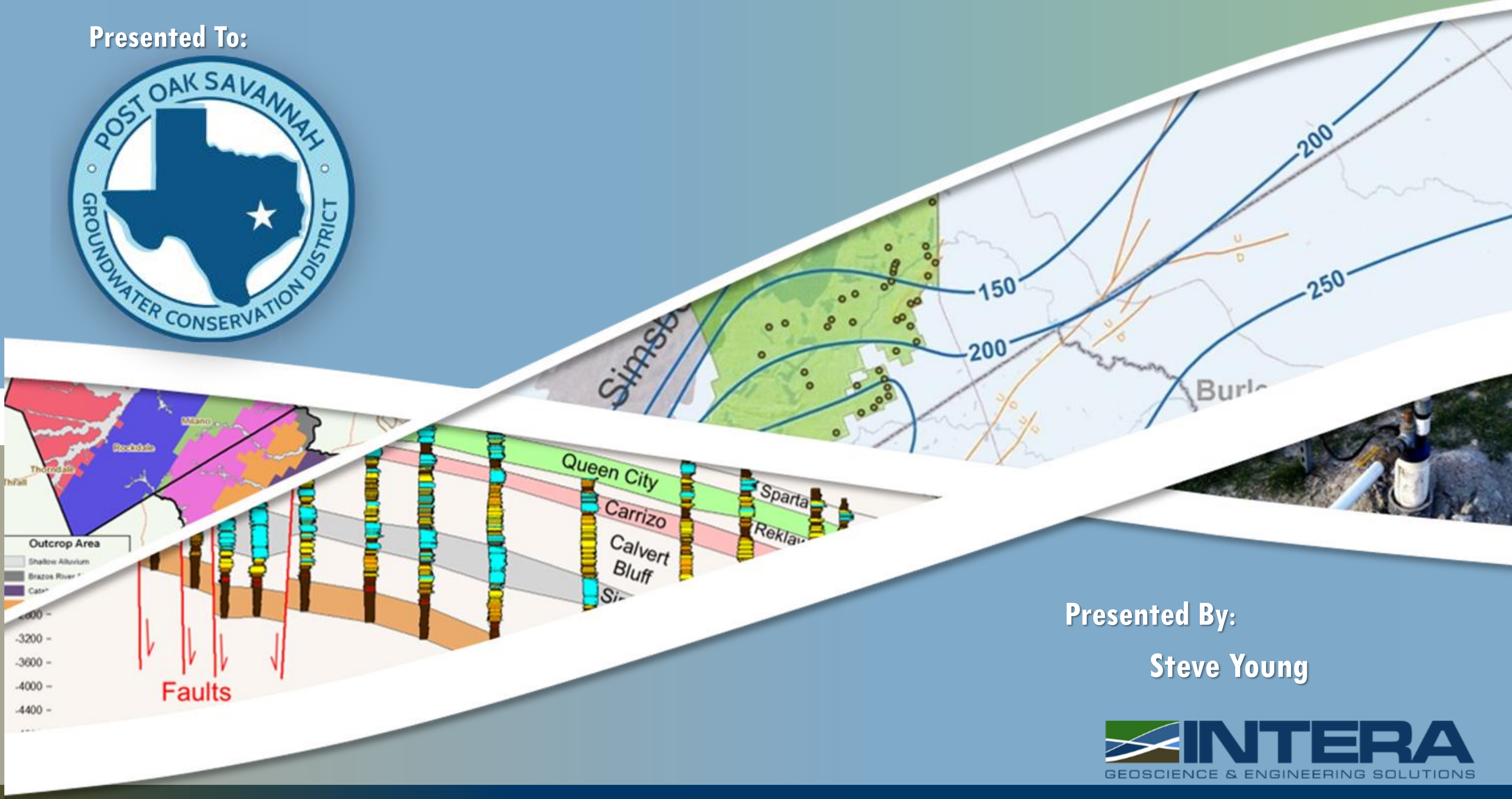
Update on Activities Related to DFC Compliance, PDLs, Monitoring, Impact Assessment & MS Report

Presented To:

POST OAK SAVANNAH GROUNDWATER CONSERVATION DISTRICT



Presented By:

Steve Young

INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS

August 10, 2021

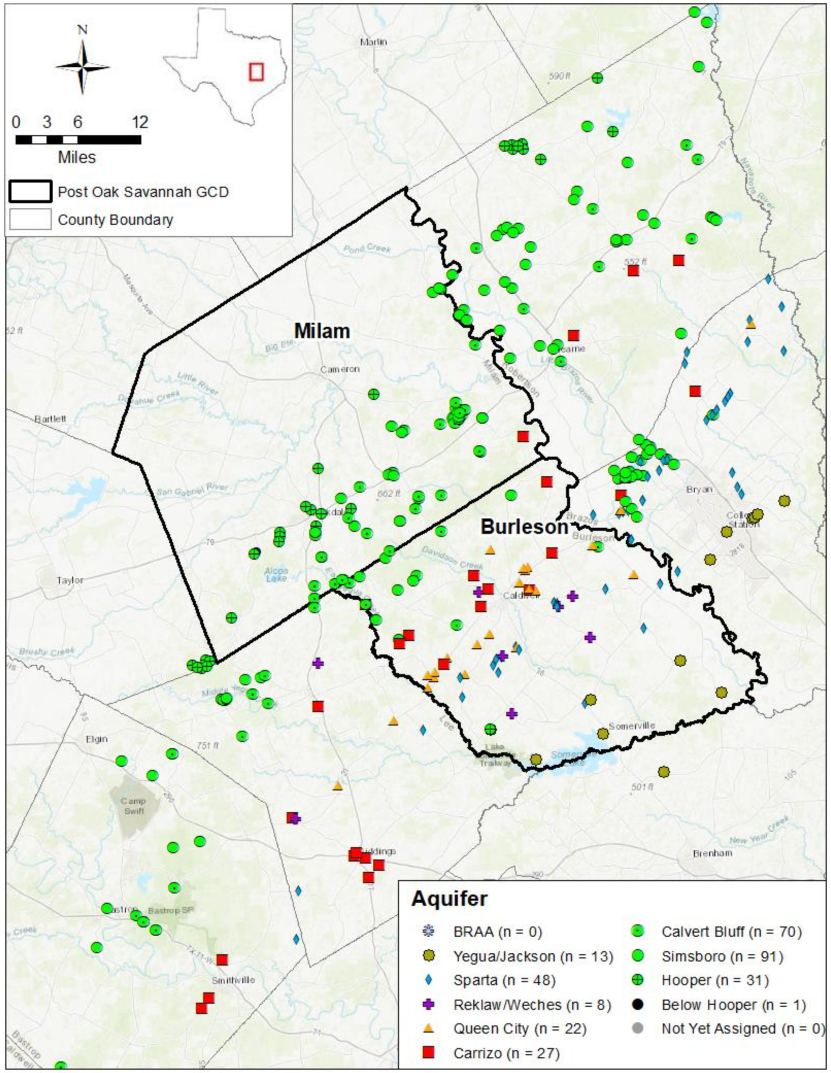
Agenda

- Compliance Assessment
  - DFCs
  - PDLs
- Guidance Documents
  - On-going Updates
  - Expanded Analysis
- GAM Improvements
  - Technical Approach
  - Revised Model Results
  - Suggest for Future Work
- Management Strategy Report
  - Comments
  - Next Steps

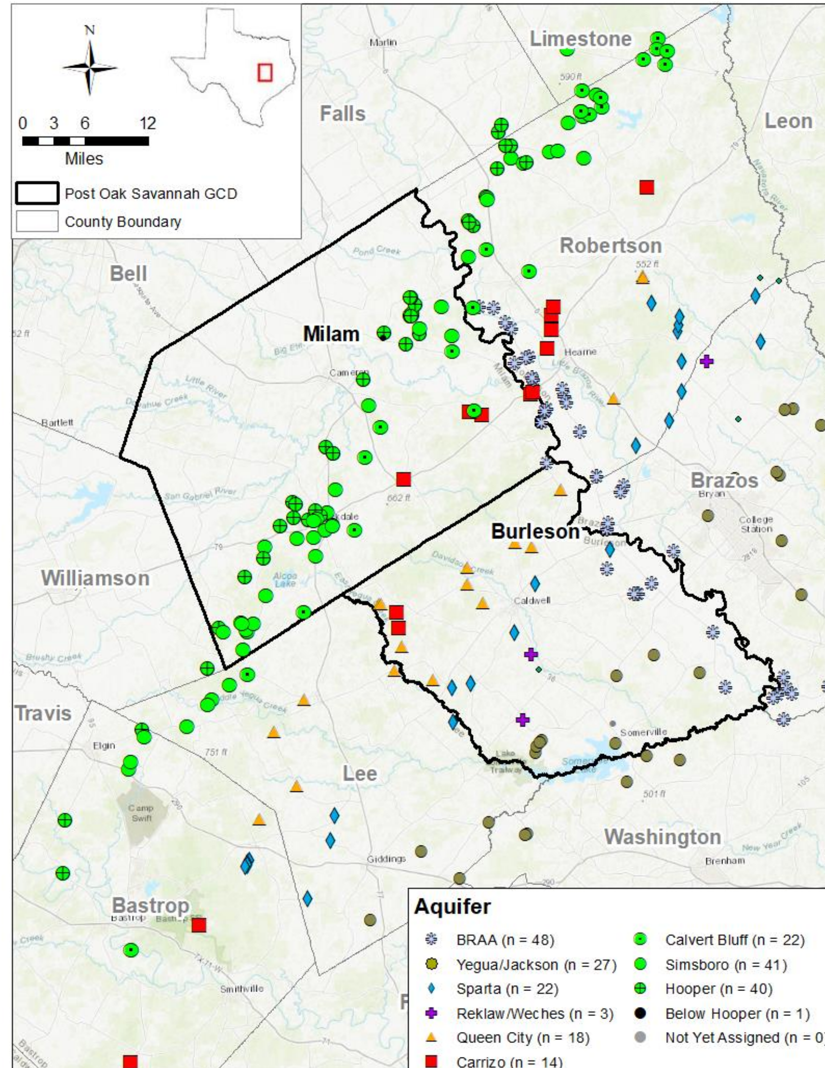
Compliance Assessment

Monitoring Wells

DFCs



PDLs

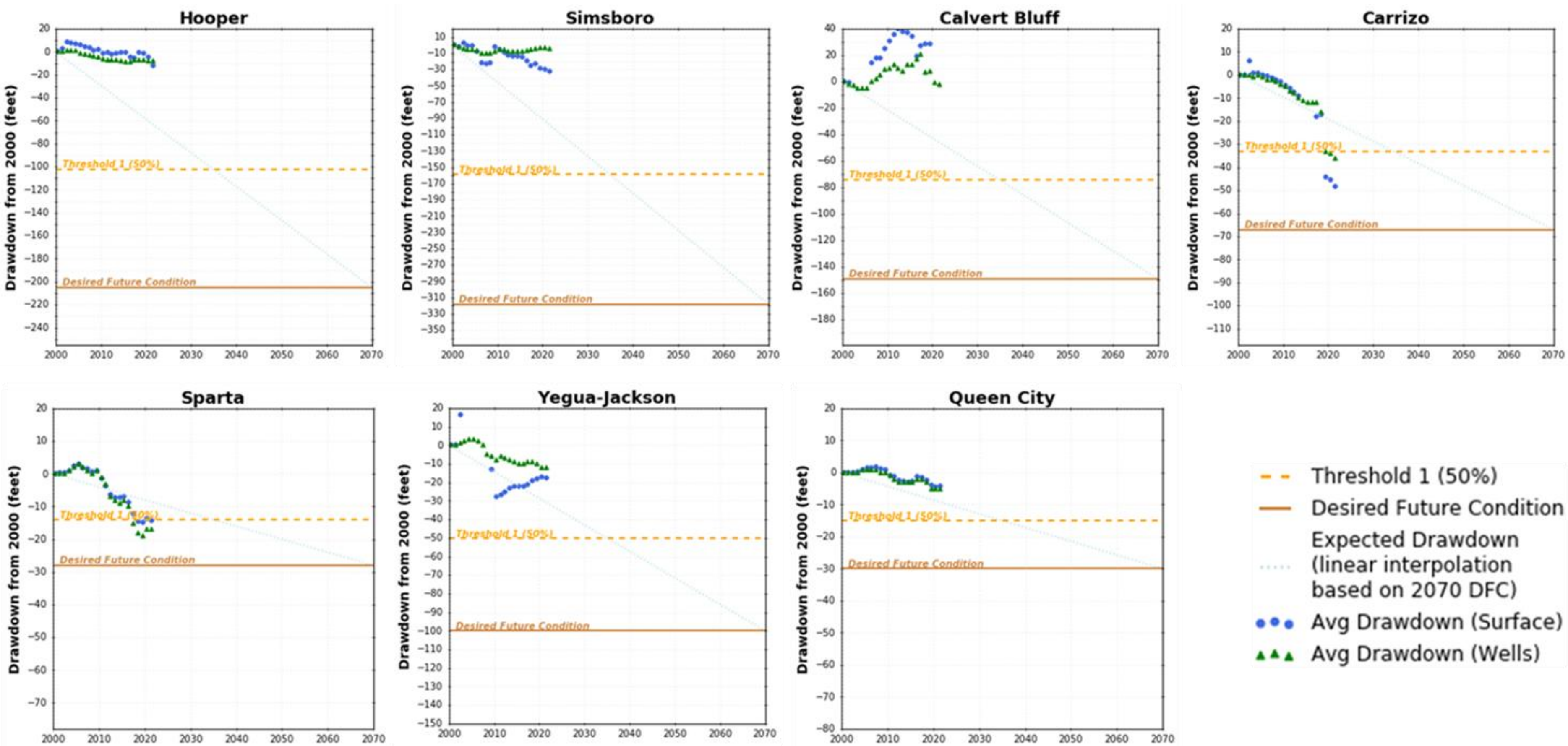


Calculated Compliance with DFCs: Tables

Management Zone	DFC	Drawdown from 2000 to 2010	Drawdown from 2000 to 2015	Drawdown from 2000 to 2016	Drawdown from 2000 to 2017	Drawdown from 2000 to 2018	Drawdown from 2000 to 2019	Drawdown from 2000 to 2020	Drawdown from 2000 to 2021
		Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)
Yegua Jackson	100	27.5	22.3	22.2	21.0	19.2	18.1	17.1	17.8
		27.5%	**22.3%**	**22.2%**	**21.0%**	**19.2%**	**18.1%**	**17.1%**	**17.80%**
Sparta	28	1.4	6.9	8.6	12.3	**14.5**	**15.0**	13.8	**14.3**
		5.0%	**24.8%**	**30.6%**	**43.8%**	**51.8%**	**53.4%**	**49.3%**	**51.20%**
Queen City	30	0.9	2.7	1.3	1.6	2.4	3.9	4.4	4.2
		3.0%	**8.9%**	**4.4%**	**5.5%**	**8.0%**	**13.0%**	**14.6%**	**14.10%**
Carrizo	67	-11.1	-4.3	-3.8	18.1	17.3	**44.1**	**45.5**	**48.2**
		-16.6%	**-6.4%**	**-5.7%**	**27.0%**	**25.8%**	**65.9%**	**67.9%**	**71.90%**
Calvert Bluff (Upper Wilcox)	149	-29.9	-34.6	-19.0	-27.0	-28.3	-28.4	-57.8	-56.5
		-20.1%	**-23.2%**	**-12.7%**	**-18.1%**	**-19.0%**	**-19.1%**	**-38.8%**	**-37.90%**
Simsboro (Middle Wilcox)	318	5.0	14.9	19.0	24.7	22.4	28.3	30.3	32
		1.6%	**4.7%**	**6.0%**	**7.8%**	**7.0%**	**8.9%**	**9.5%**	**10.10%**
Hooper (Lower Wilcox)	205	5.4	-1.3	2.2	3.6	-0.7	-0.5	3.0	10.7
		2.6%	**-0.6%**	**1.0%**	**1.8%**	**-0.3%**	**-0.2%**	**1.5%**	**5.20%**

Threshold 1 = 50% of DFC
Threshold 2 = 60% of DFC
Threshold 3 = 75% of DFC

Calculated Compliance with DFCs: Graphs



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Calculated Compliance with PDLs: Tables

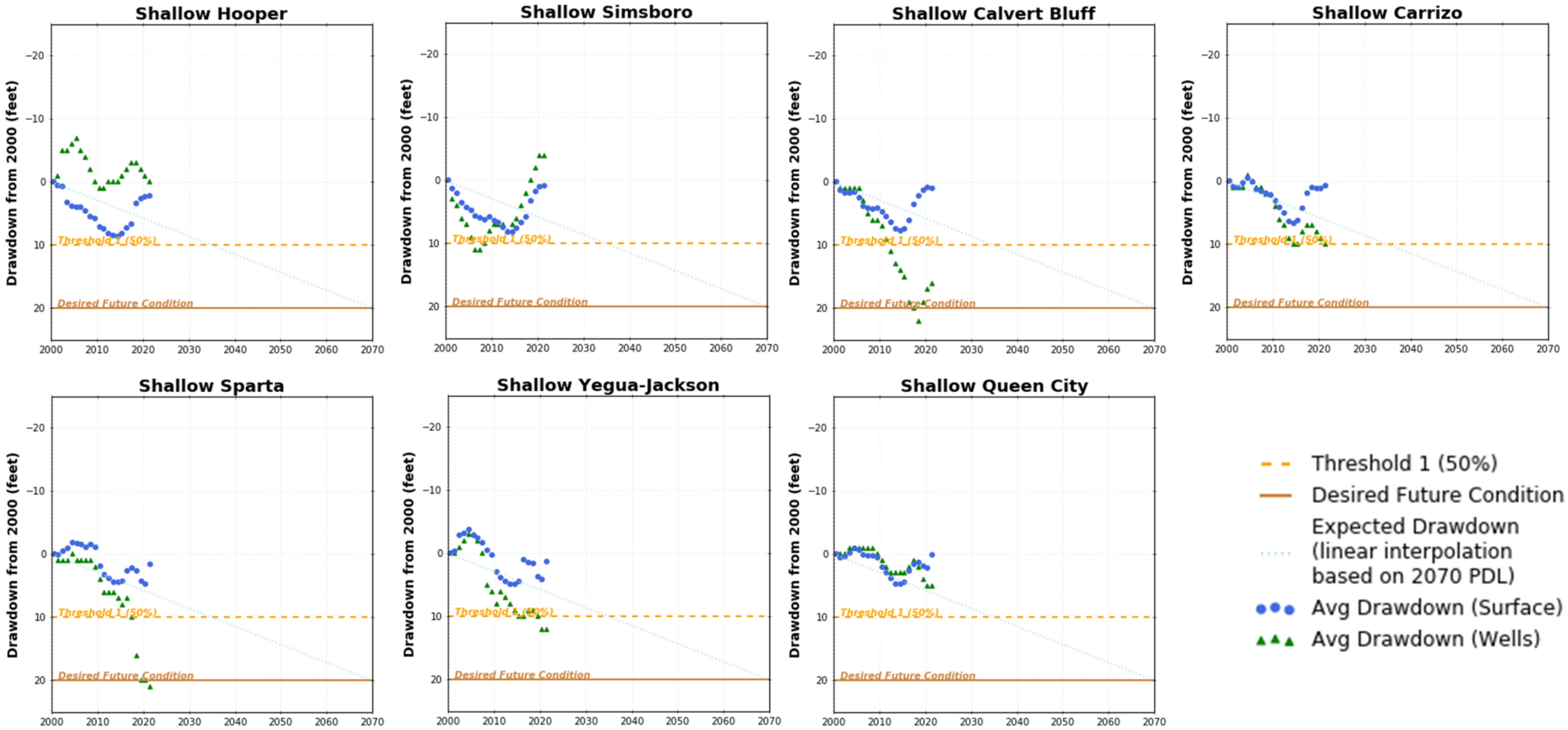
Management Zone	PDL	Drawdown from 2000 to 2015	Drawdown from 2000 to 2016	Drawdown from 2000 to 2017	Drawdown from 2000 to 2018	Drawdown from 2000 to 2019	Drawdown from 2001 to 2020	Drawdown from 2000 to 2021
		Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)
Yegua Jackson	20	4.40	0.93	1.46	1.60	3.63	4.07	1.2
		22%	**5%**	**7%**	**8%**	**18%**	**20%**	**6%**
Sparta	20	4.3	2.6	2.1	2.7	4.2	4.7	1.6
		21%	**13%**	**11%**	**13%**	**21%**	**24%**	**8%**
Queen City	20	4.4	2.6	1.6	1.2	1.9	2.2	0.03
		22%	**13%**	**8%**	**6%**	**10%**	**11%**	**0%**
Carrizo	20	6.1	4.3	1.9	1.0	1.1	1.1	0.66
		31%	**21%**	**10%**	**5%**	**6%**	**6%**	**3%**
Calvert Bluff (Upper Wilcox)	20	7.3	6.1	3.5	2.3	1.4	0.8	0.96
		37%	**30%**	**18%**	**11%**	**7%**	**4%**	**5%**
Simsboro (Middle Wilcox)	20	7.6	6.6	5.8	3.2	1.8	1.0	0.87
		38%	**33%**	**29%**	**16%**	**9%**	**5%**	**4%**
Hooper (Lower Wilcox)	20	8.1	7.3	6.7	3.3	2.6	2.3	2.2
		40%	**37%**	**33%**	**17%**	**13%**	**12%**	**11%**

Threshold 1 = 50% of DFC

Threshold 2 = 60% of DFC

Threshold 3 = 75% of DFC

Calculated Compliance with PDLs: Graphs



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Guidance Document

- Monitoring Network
  - New Wells
  - Location
  - Aquifer Assignment
  - Map
  - Well Diagrams
- Compliance Calculations
  - Evaluations updated through 2021
  - Additional explanations & discussions
  - Added two options that involve geostastistics because:
    - Desired to have a defendable basis as practicable, use of several viable approaches improves our understanding of the groundwater system
    - Additional monitoring data supports more advanced techniques
    - Account for limitation of topo2raster

Geostatistics: Overview

Geostatistics is a collection of numerical techniques for the characterization of spatial attributes

- **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

Tobler's 1st Law of Geography

"Everything is related to everything else, but near things are more related than distant things. (1970)"

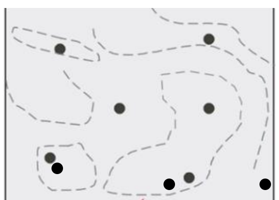
Geostatistical Options

- Interpolate Water Levels using Kriging
  - Similar to Topo2raster
  - Accounts for coorelations
  - Probably the most used approach for Water Levels
- Interpolate Water Levels using Kriging after Detrending Using GAM
  - Improves on Kriging by accounting for trends and effects of pumping, SW-GW interaction, and regional hydraulic gradients
  - Provides stability to calculations in areas with sparse well coverage or changes or where wells are added

Application of Geostastics for Interpolating Water Levels

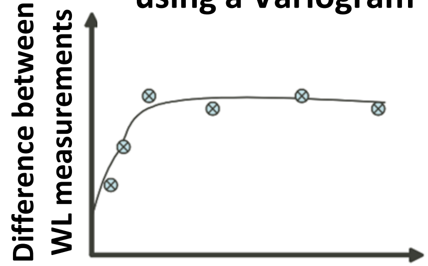
Goal: predict the possible spatial distribution water levels

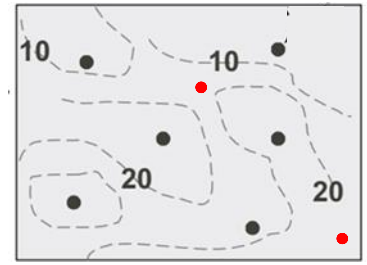
Measured Water Level Data Set



"reality (unknown)!"

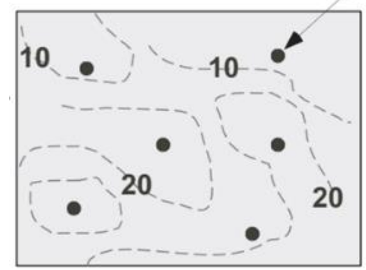
Model the Spatial Pattern in the Data using a Variogram



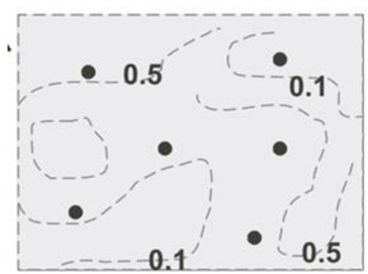


Improved Monitoring Network

Kriging is an exact interpolator (at sampled locations, known data values are exactly preserved)



Kriged Water Levels



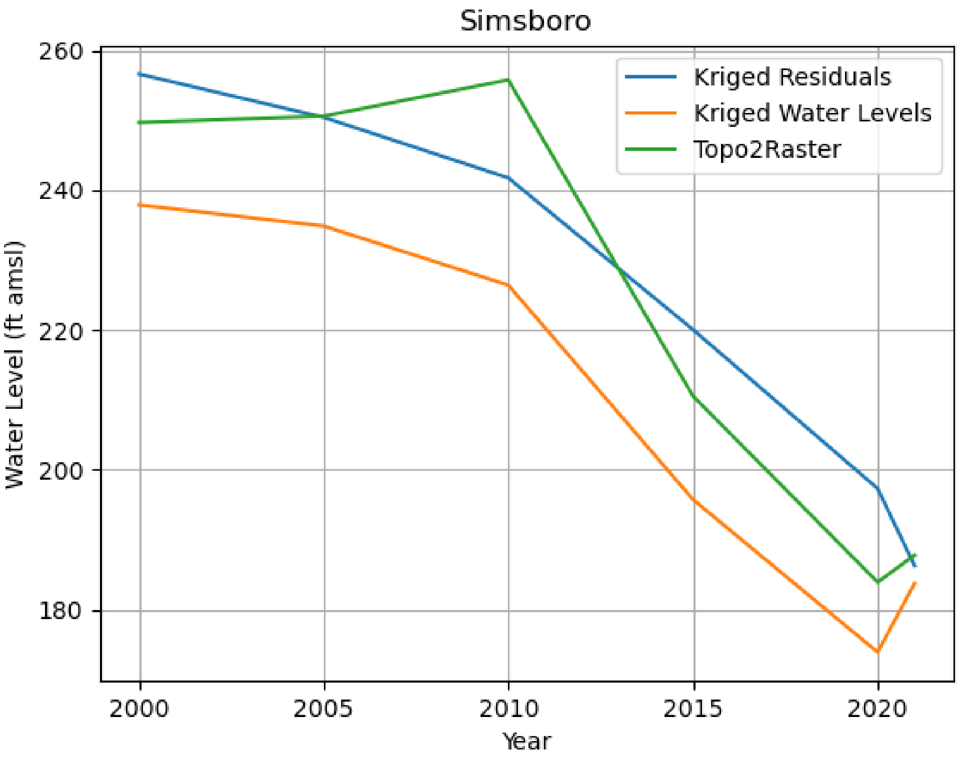
Estimated Uncertainty

Project Tasks →

Possible Future Tasks - - - →

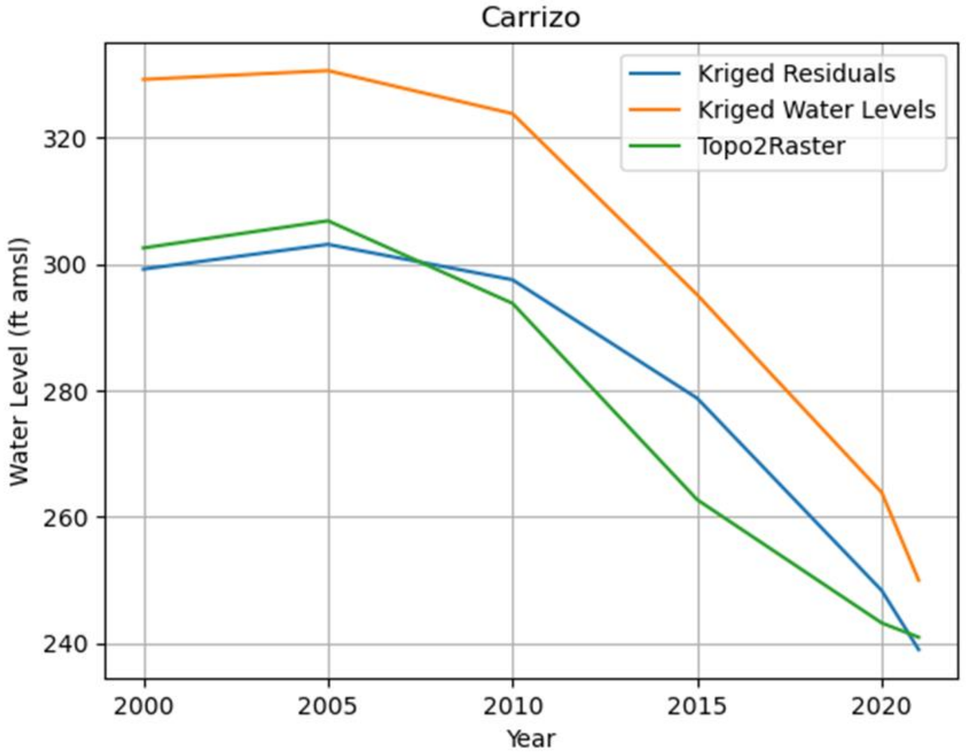
Comparison of Three Options: Simsboro

Simsboro			
Method	Year	Avg. Water Level (ft amsl)	Drawdown (ft) Since 2000
Kriged Residuals	2000	257	0
	2005	250	6
	2010	242	15
	2015	220	37
	2020	197	59
	2021	186	70
Kriged Water Levels	2000	238	0
	2005	235	3
	2010	226	11
	2015	196	42
	2020	174	64
	2021	184	54
Topo2Raster	2000	250	0
	2005	251	-1
	2010	256	-6
	2015	211	39
	2020	184	66
	2021	188	62



Comparison of Three Options: Carrizo

Carrizo			
Method	Year	Avg. Water Level (ft amsl)	Drawdown (ft) Since 2000
Kriged Residuals	2000	299	0
	2005	303	-4
	2010	298	2
	2015	279	20
	2020	248	51
	2021	239	60
Kriged Water Levels	2000	329	0
	2005	331	-1
	2010	324	5
	2015	295	34
	2020	264	65
	2021	250	79
Topo2Raster	2000	303	0
	2005	307	-4
	2010	294	9
	2015	263	40
	2020	243	59
	2021	241	62



GAM Improvements

Important Questions about Models that Should be Addressed before Using their Results for Decision-Making

- How reliable are the model predictions?
- Is there sufficient data to develop a reliable model?
- How can you evaluate uncertainty in a model? Does uncertainty change with location and over time?
- How far into the future can you reliably forecast water levels?
- What are the unknowns that are important to predictions?
- Where there is sparse data, can you get a reliable prediction?
- Are some model predictions better than others?
- **How should POSGCD use modeling to help manage groundwater resources wisely?**

Traditional Approach for Developing a Groundwater Model

- Goal is to generate a single computer model
- Calibrate Model
  - A modeler select best set of aquifer parameters and historical water levels
  - A modeler or a computer continually adjusts model parameters until an acceptable match is made to water levels
- Result is a single model that often fits selected data points relatively well

Key Points Regarding Calibration of SP/QC/CW GAM

- Given
  - Less than 0.05% of aquifer has been characterized
  - Aquifer 500+ thick and are considered be uniform not vertical variation
  - No measurements of vertical hydraulic conductivity at scale of aquifer layers
  - Aquifer boundaries have not been properly documented
  - Historical pumping has large uncertainty and location are often estimated
  - Water levels are spotty, are measured in wells that are pumping, and in wells that often intersect about 50 feet of the aquifer thickness

- If seems reasonable that the reliability of a model prediction is as important

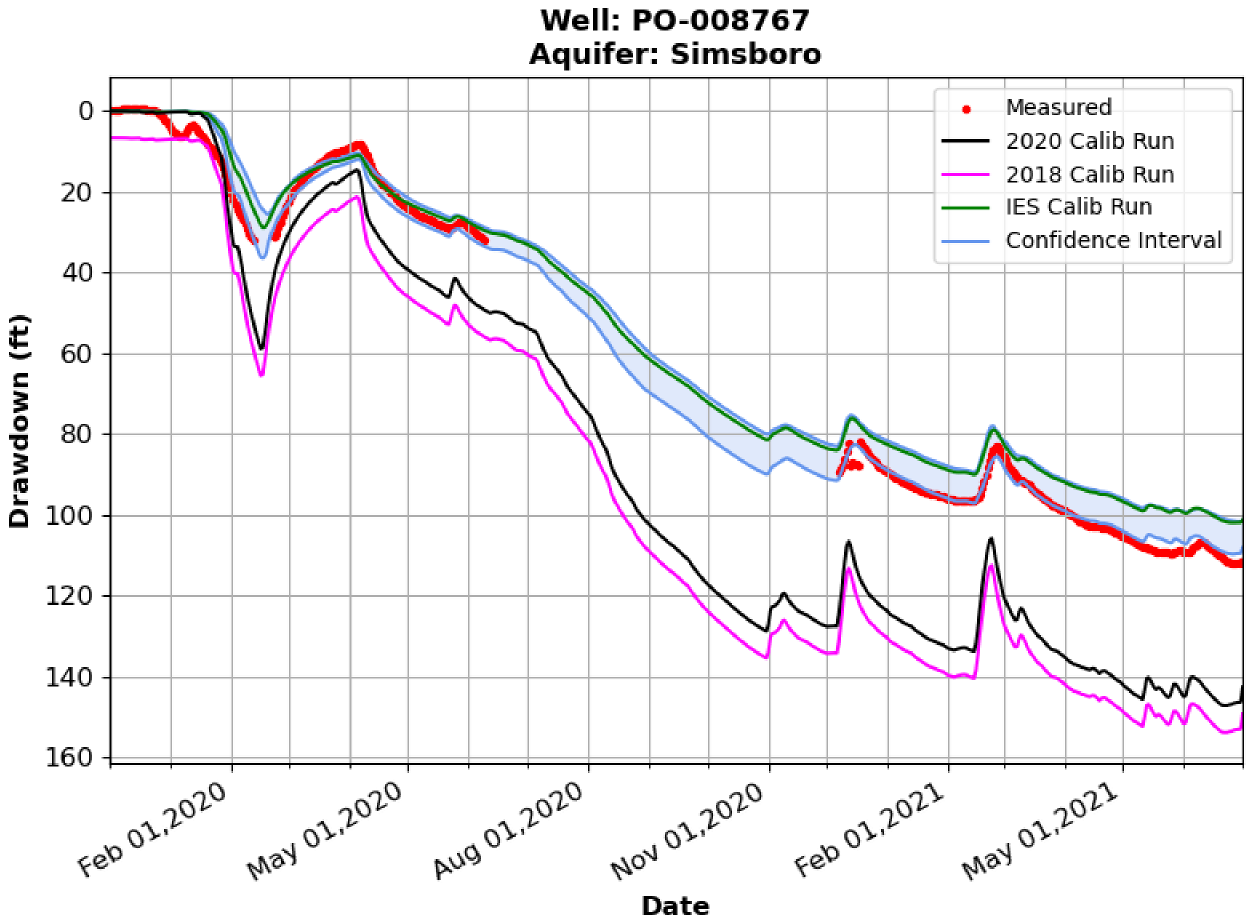
Revised Approach for Developing a Groundwater Model For POSGCD: Multiple Models (or IES)

- Goal is to generate as many models that fit the data reasonably well (100s to 1000s of models)
- Modeler sets the best estimate and ranges for aquifer properties in model areas and ranges for acceptable fits to water levels
  - Computer generates the initial properties of the different models
  - Computer adjusts model parameters and rerun model until an acceptable match is made to water levels or model is dropped
- Multiple models are generated

GAM Recalibration Criteria

- Same historical data used to calibrate the 2018 GAM from 1929 to 2010
- Aquifer test data from Vista Ridge Simsboro wells used in 2020 GAM Update Plus Vista Ridge Carrizo Wells
- Predictions of drawdown from Vista Ridge Wells from December 2019 to June 2021
  - ignores pumping from other wells
  - monthly time steps with constant pumping

Example Hydrograph Used For "Vista Ridge" Calibration



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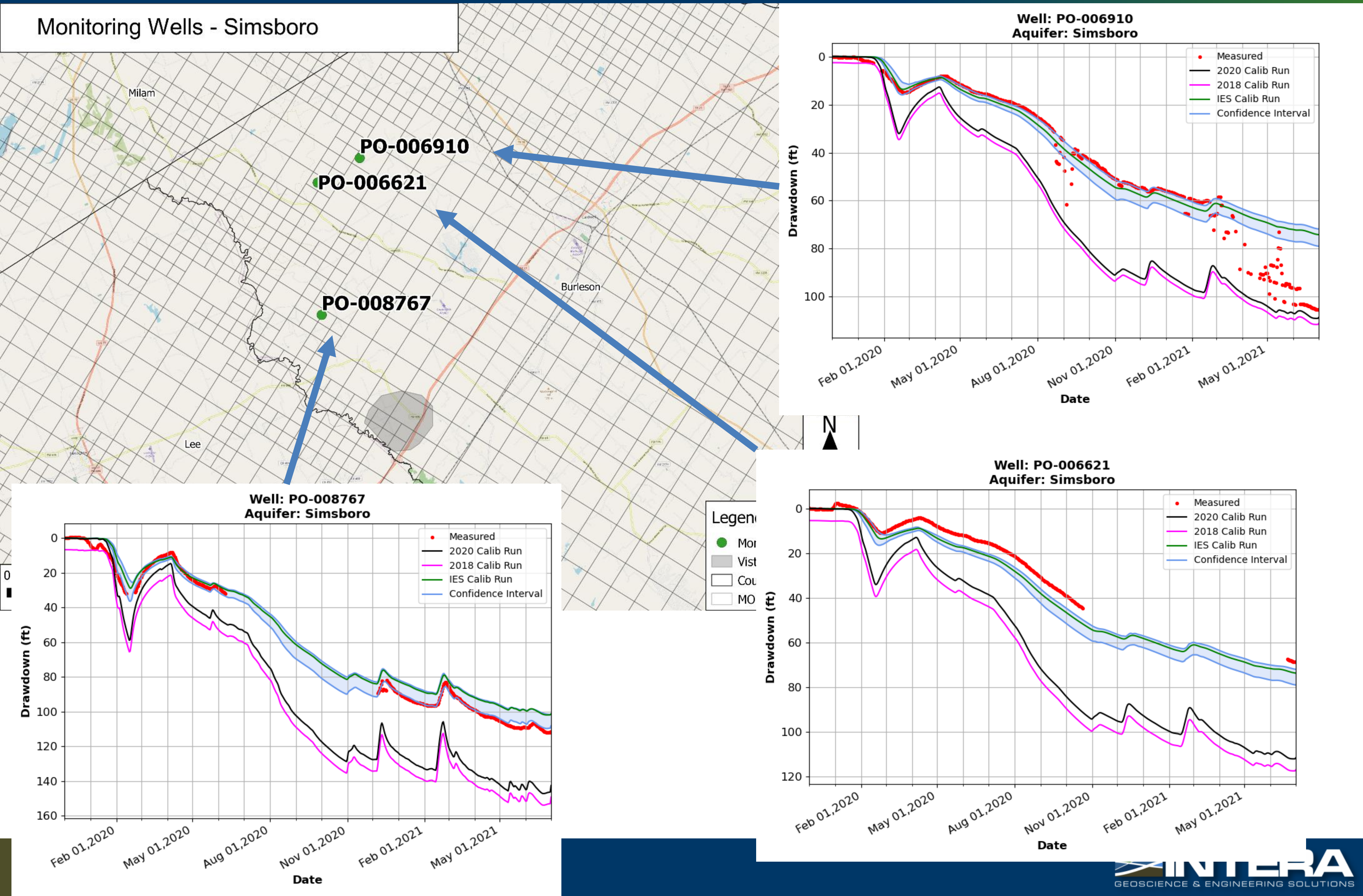
Simsboro Monitoring Wells



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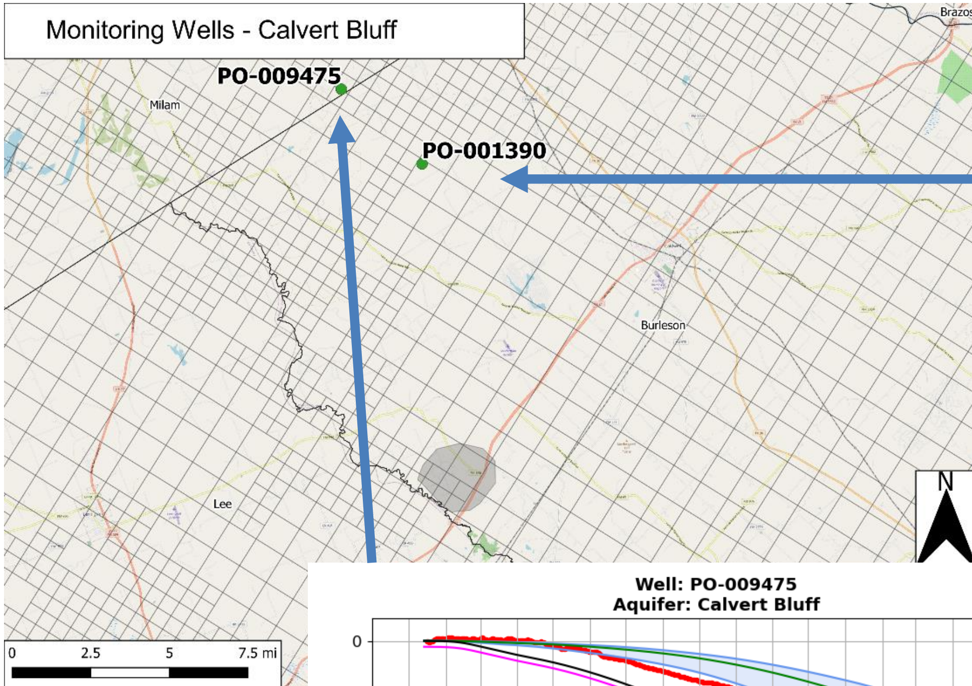
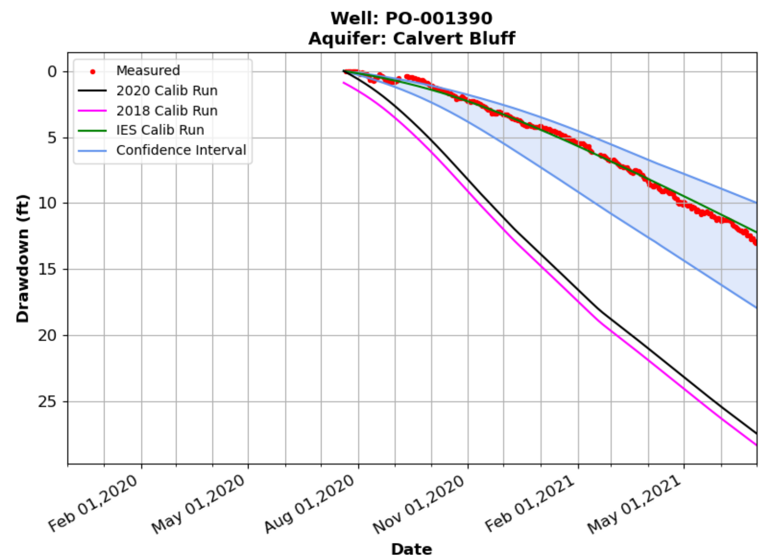
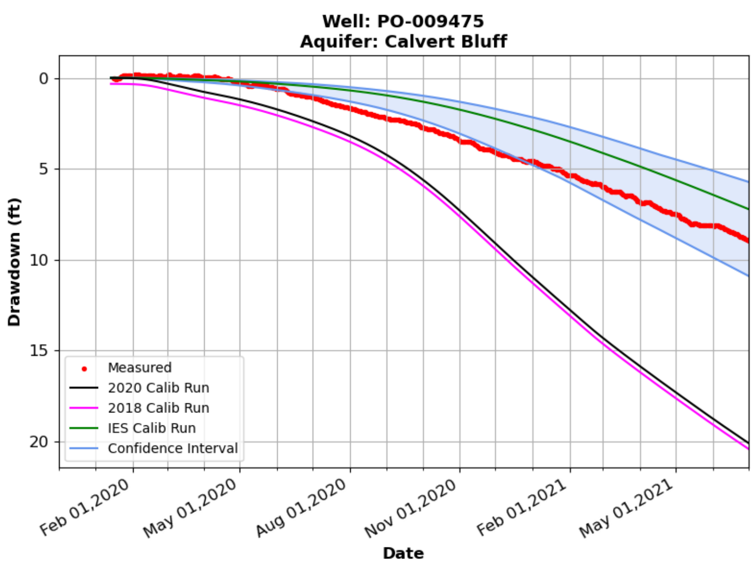
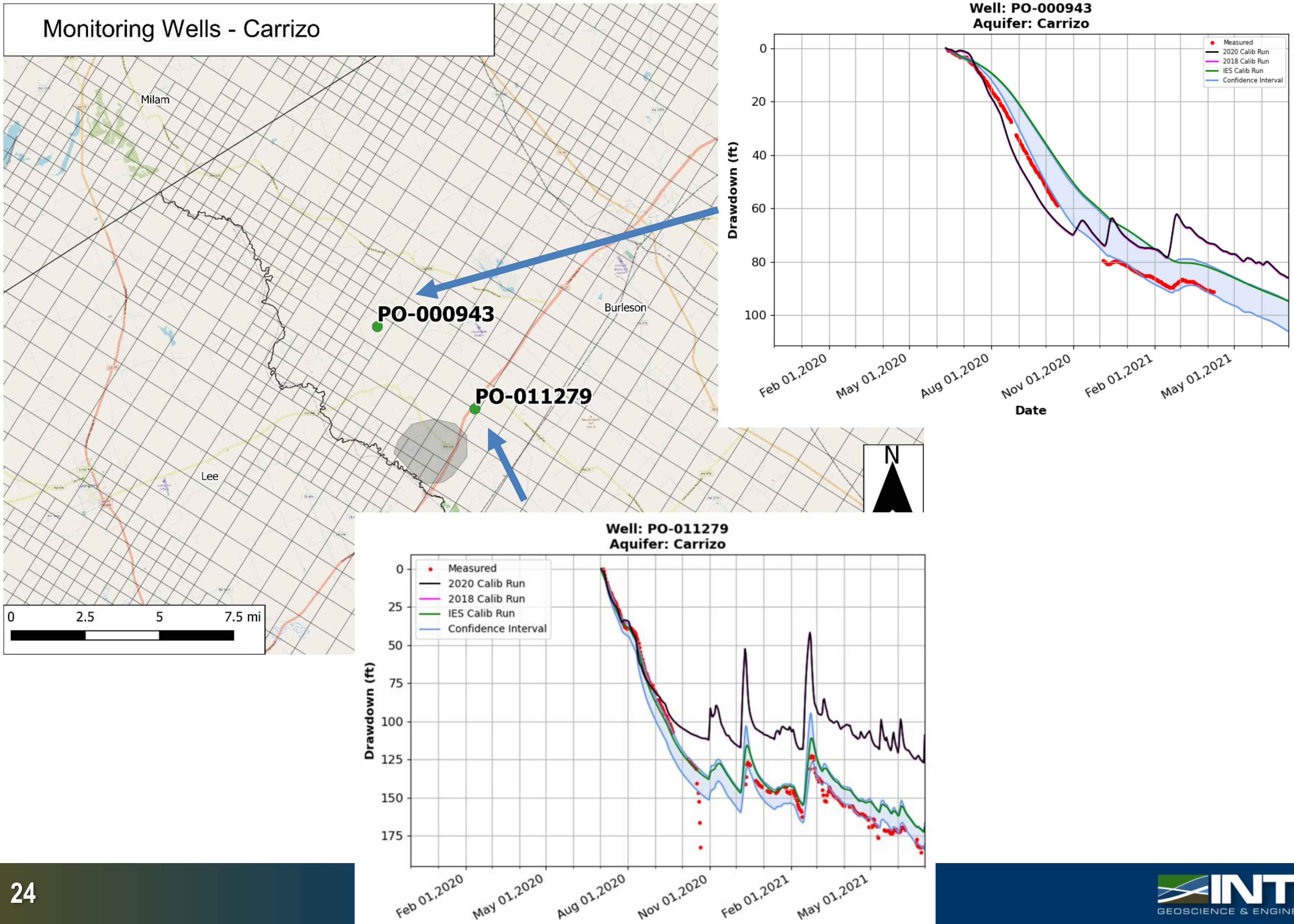
Calvert Bluff Monitoring Wells







Carrizo Monitoring Wells



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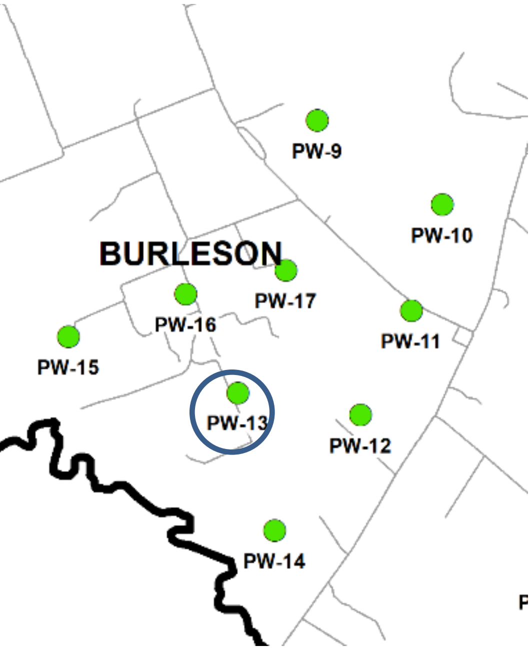
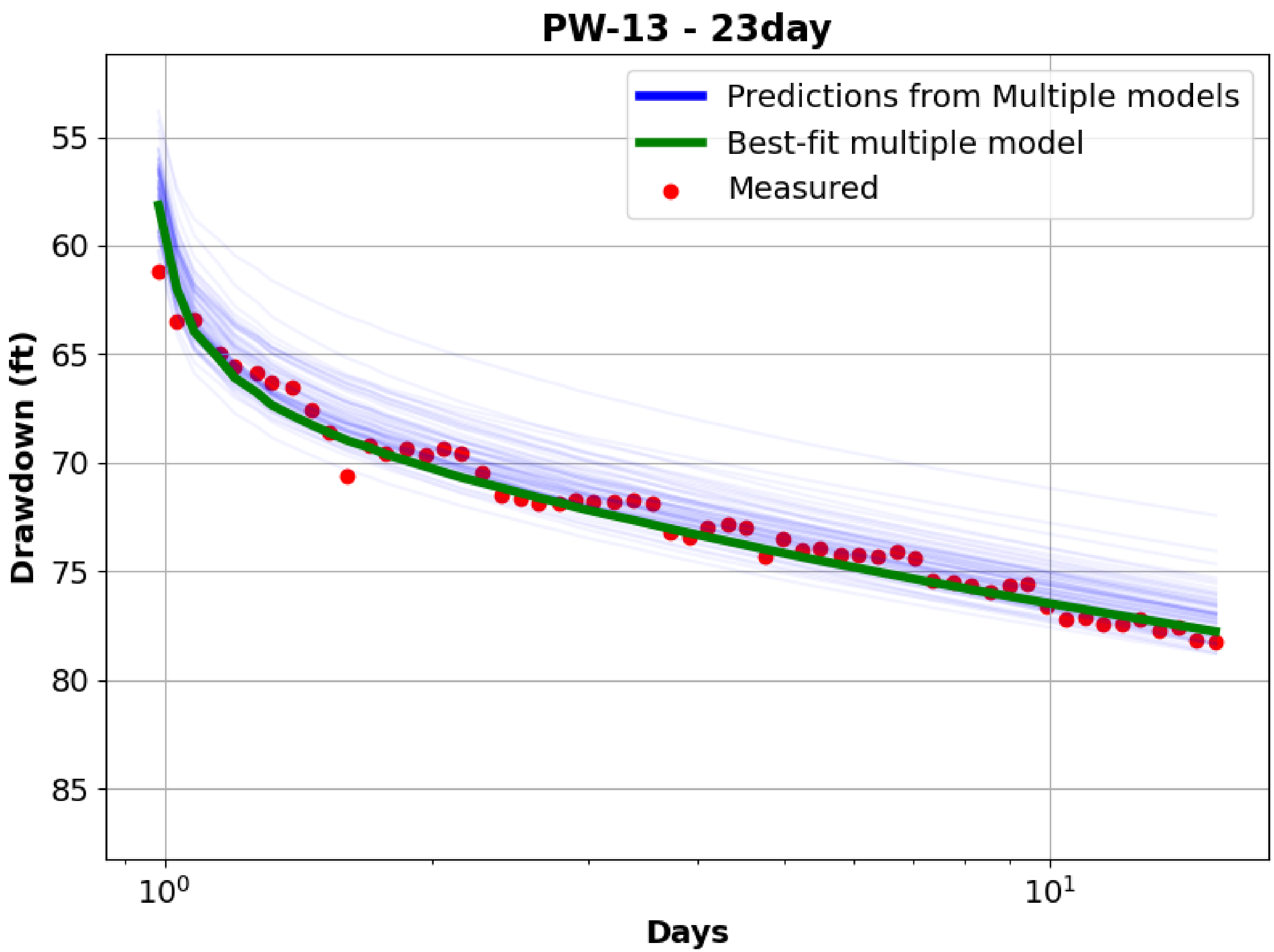
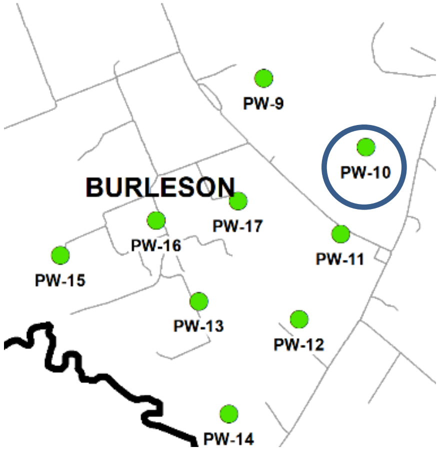
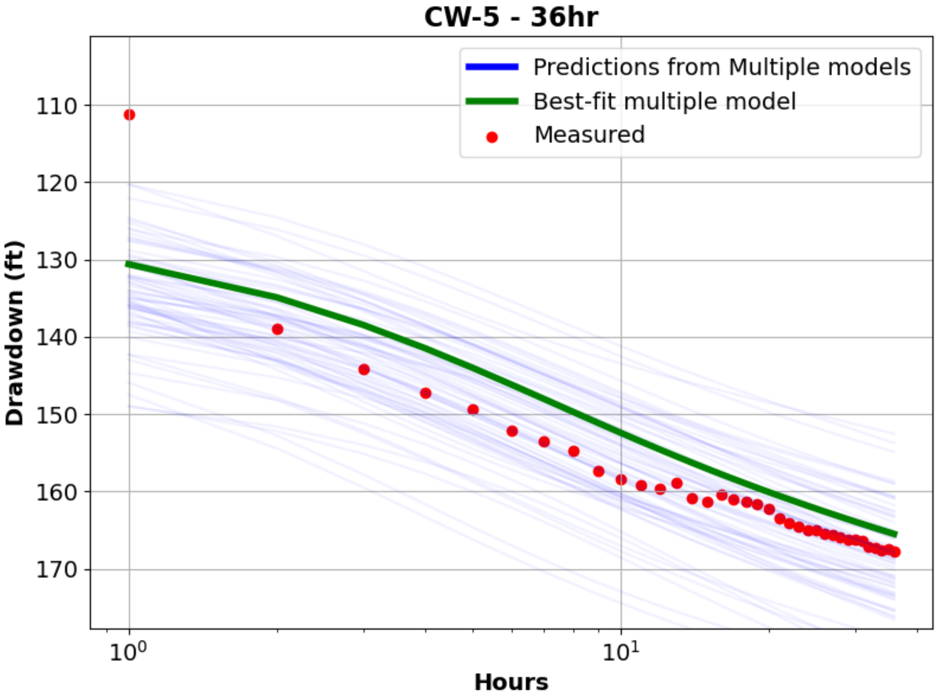
Measured & Simulated Drawdown for 23-day Aquifer Pumping Test at Vista Ridge Pumping Well PW-13:

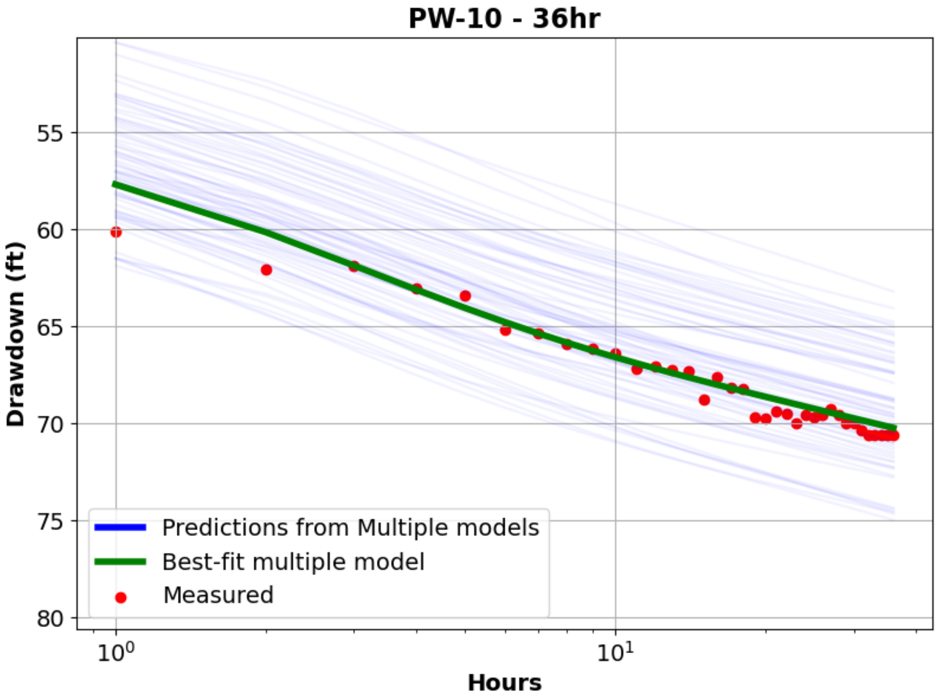




Measured & Simulated Drawdown for 36-hour Aquifer Pumping Tests at VR Pumping Wells CW-5 and CW-9







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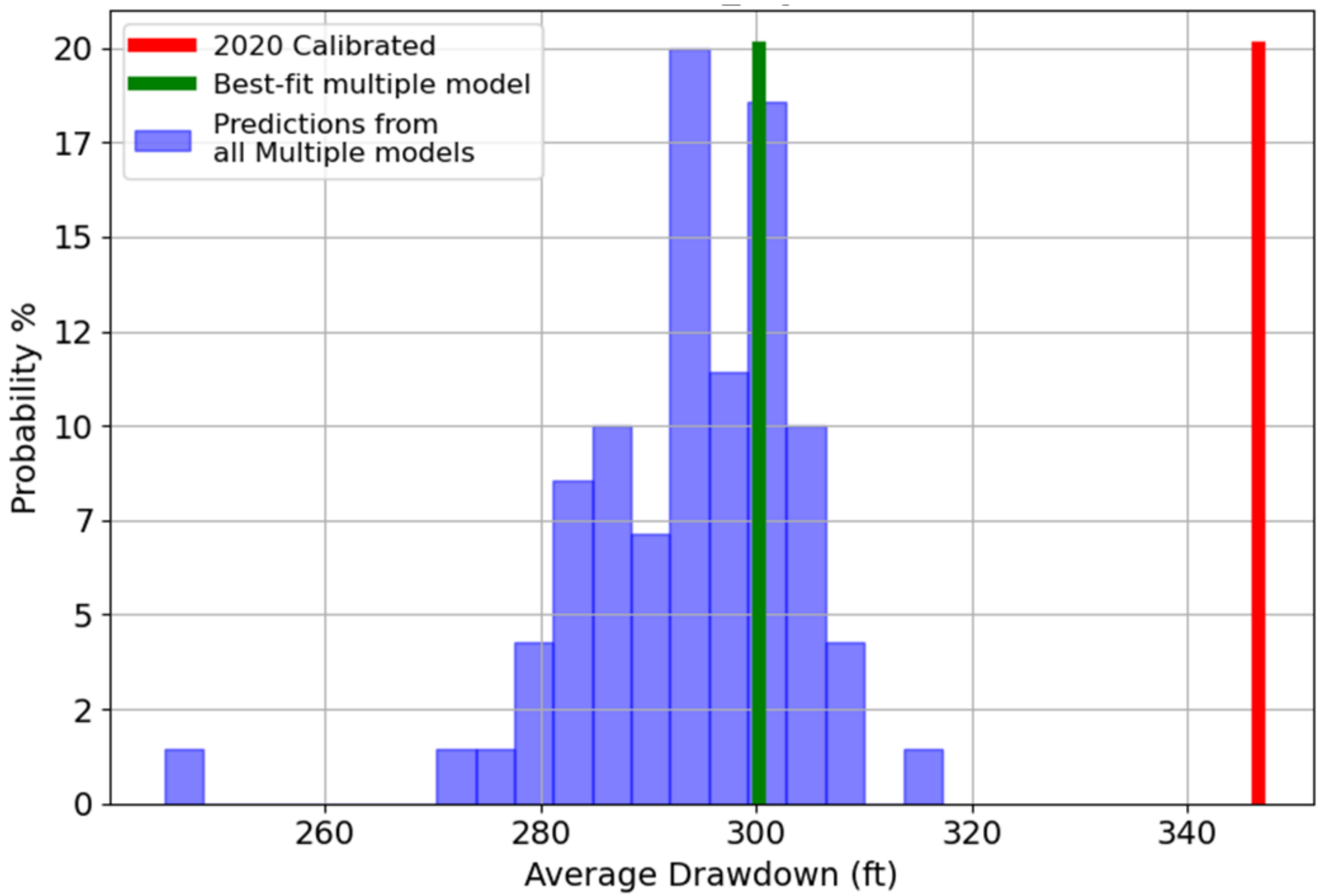
Simsboro DFC: Preliminary Results



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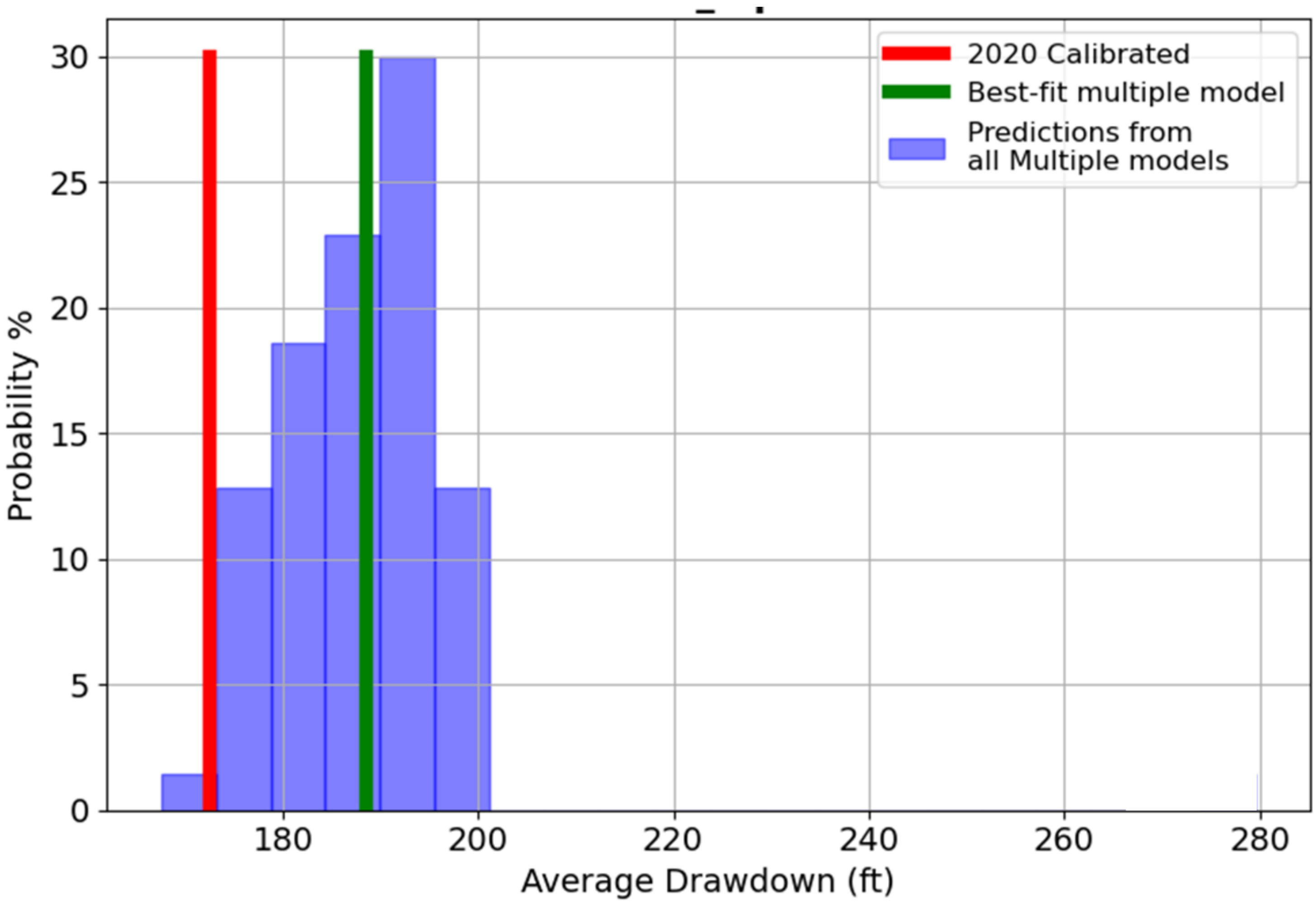
Carrizo DFC: Preliminary Results



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Proposal for Continuing GAM Update/Improvements

- Collaborative Funding and Partners
- Groundwater Management Policy/Science Issues
- Technical Issues Related to POSGCD and GMA 12
- Local-scale issues and data acquisition

Benefits include a well vetted model data, modeling approach, modeling results, and analysis of model results.

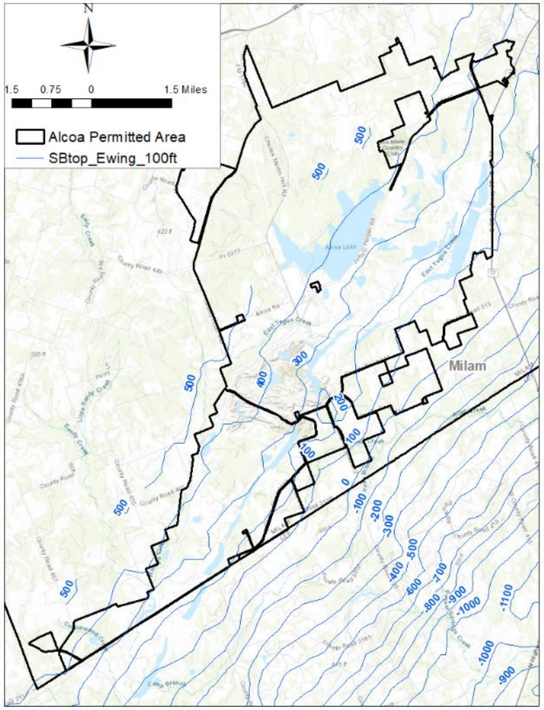
Groundwater Management Science/Policy Issues

- Improve reliability and quantifying uncertainty in model predictions
- Improve defining sustainable pumping and total estimated recoverable storage
- Establish protocols for forecasting/prediction of water levels
- Develop guidelines for expanding GAMs from tools primary for regional planning tools to also tools for GCDs to assess local-scale issues
- Incorporate relational information in GAM to improve interpretation of water levels for assessing DFC compliance
- Improve overall utility, useability, and transparency o f models

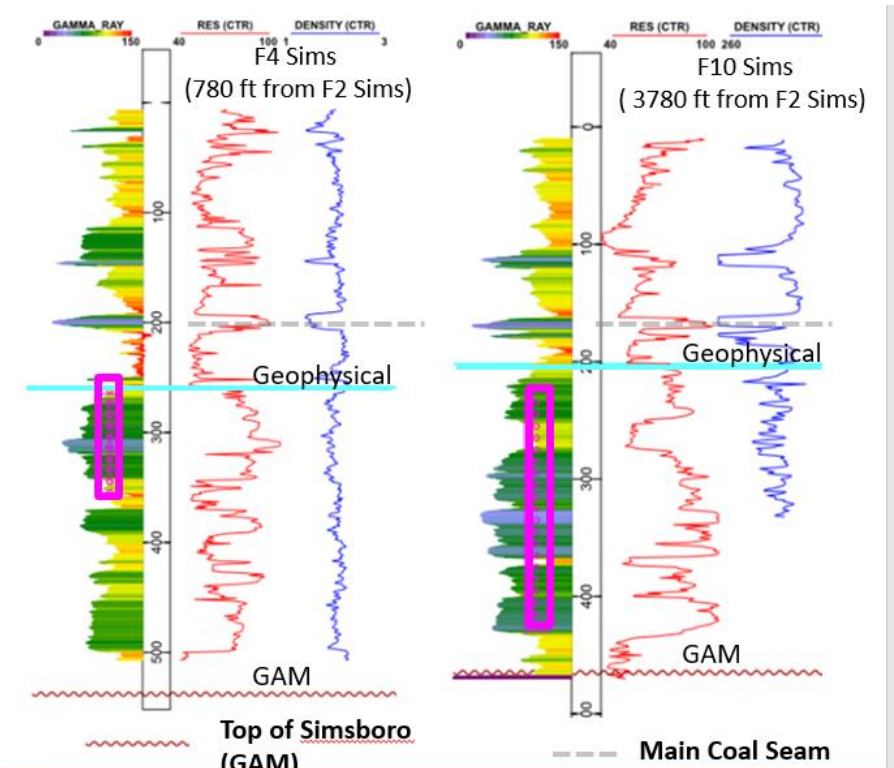
Technical Issues Related to POSGCD & GMA 12

- Aquifer Surfaces
  - GAM uses original surfaces show surfaces are not properly documented
  - Surfaces developed by INTERA using geophysical logs
  - 11 of ALCOA "Simsboro" wells were 100% in the Calvert Bluff

Top of Simboro based on Geophysical Log Analysis

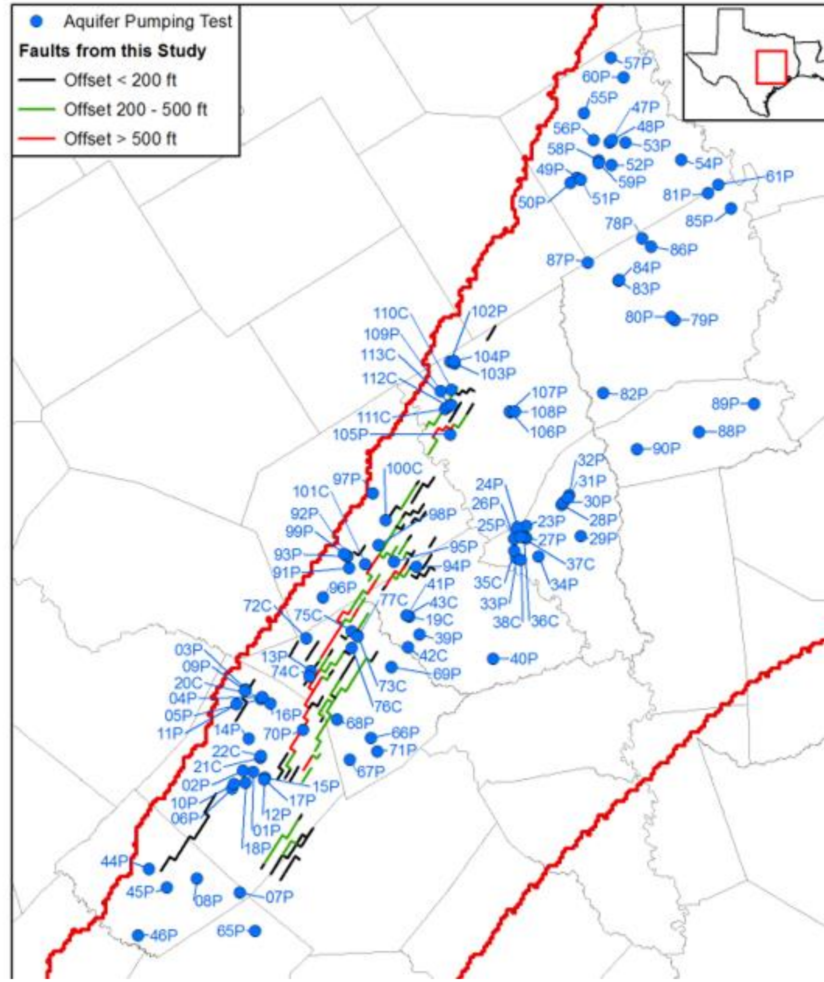


Comparison of GAM-based and Geophysical-based Top of Simsboro



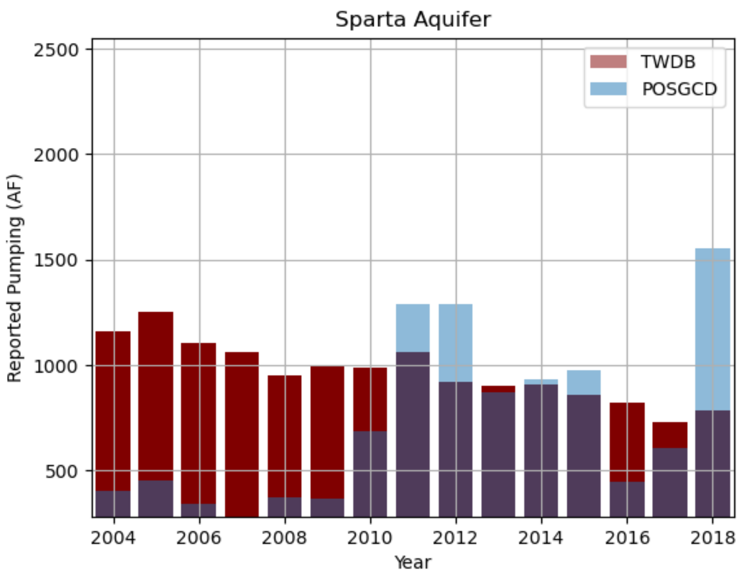
Technical Issues Related to Modeling (con't)

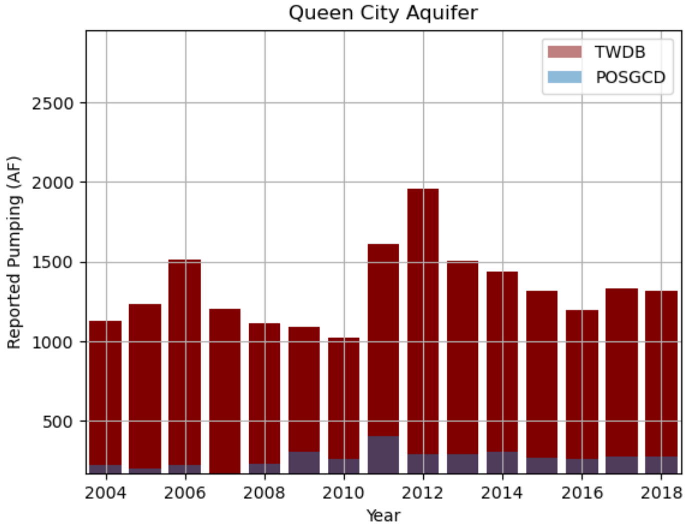
- Constraining Aquifer Properties at Local Scale
  - Simulate aquifer pumping tests as part of calibration
  - Numerous tests available – additional results coming with ALCOA and other future permits



Technical Issues Related to POSGCD & GMA 12

- Transition from only "Vista-Ridge" Pumping to All Pumping
  - Expand historical pumping for GAM from 2010 to present Resolve discrepancies between TWDB pumping estimates and POSGCD reported pumping
  - Options for receiving more timely updates of monthly estimates of pumping in POSGCD





Management Strategies Report

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Table of Contents (con't)

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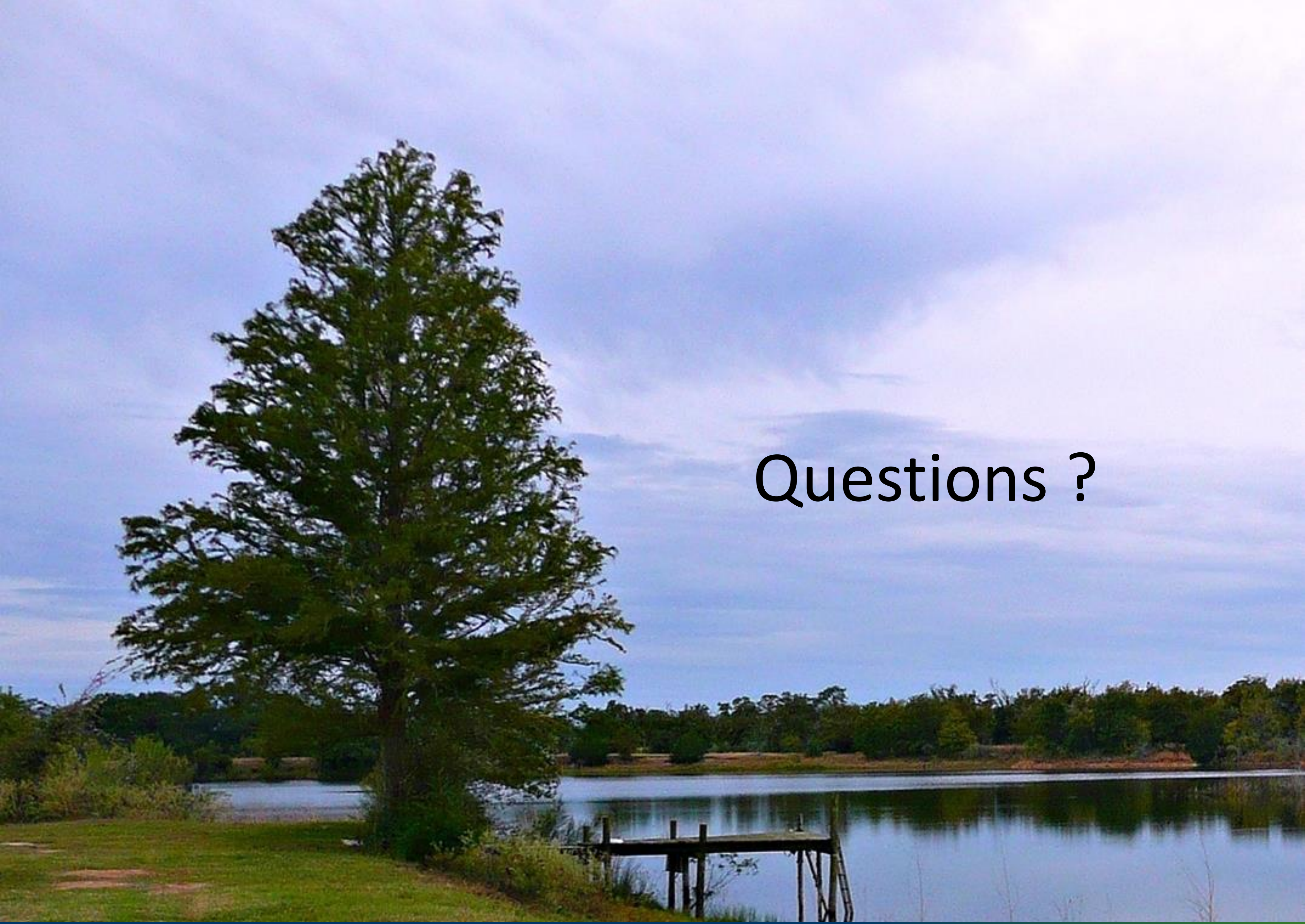
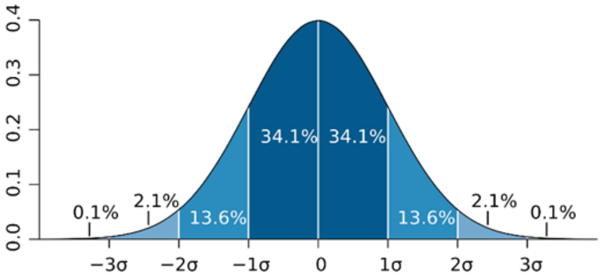

Questions ?

Kriging Application: General Requirements

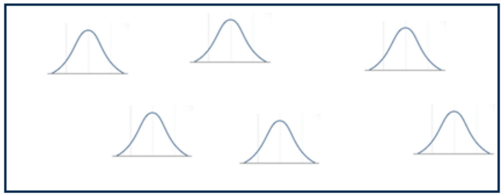
- **Normally distributed (or nearly so)**



Normal (Bell shaped) distribution can be defined by;

- mean (μ)
- standard deviation (σ)

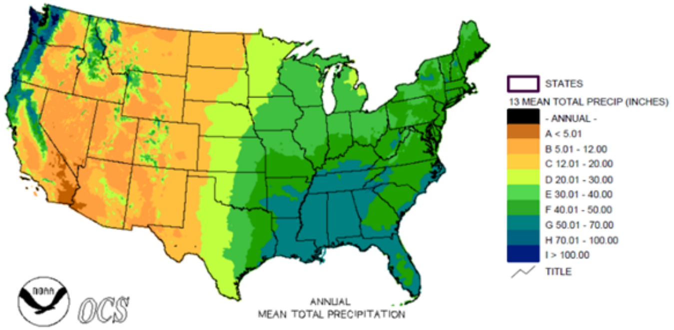
- **Stationarity (or nearly so)**



The statistics/metrics of interested do not change with location. It is a decision and not a hypothesis. Stationarity is a function of scale and dimensions.

- affects how data is pooled & analyzed
- affects how kriging is applied

- **No trends (or nearly so)**



Spatial trends should be removed from the data prior to developing the variogram. Models used to detrend the data should not over fit the data. Options for detrending data:

- groundwater model
- fitted two-dimensional surfaces

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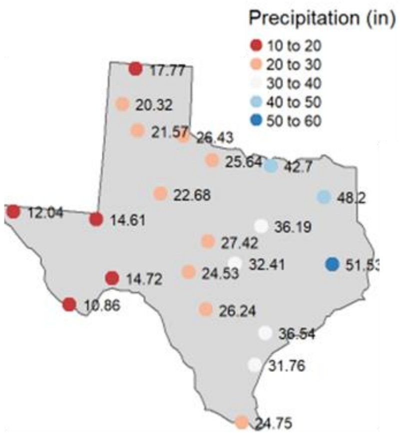
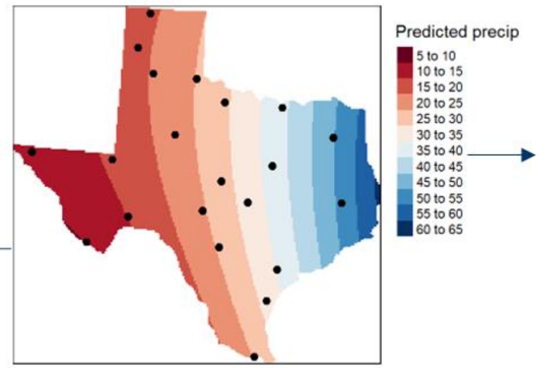
Ordinary Kriging – Six-Step Process for Interpolation Rainfall in Texas

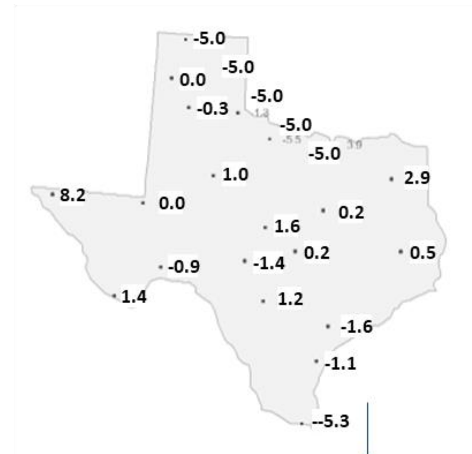
#1 -Data Precipitation Data



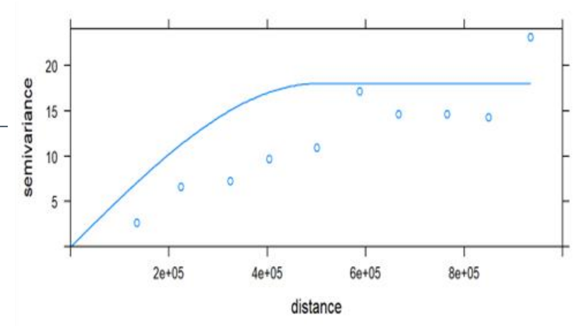
#2- Trend Surface develop from Data



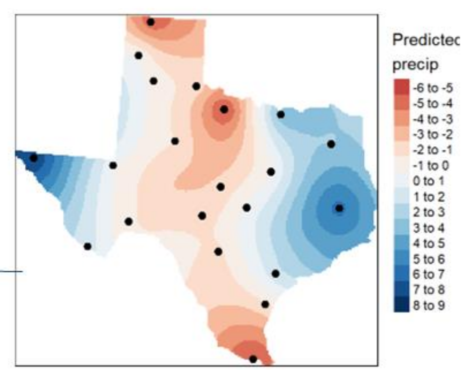
#3-Calculate Residuals at each Data Location



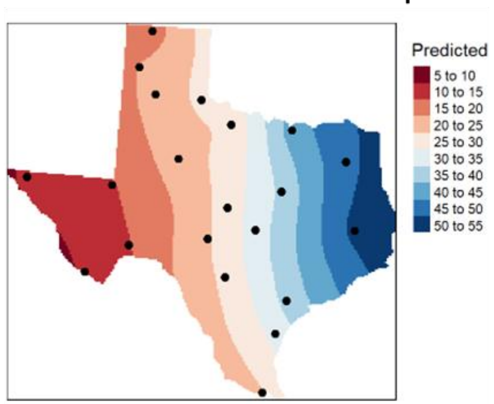
#4- Construct Variogram Using Residuals



#5-Map of Kriged Residuals



#6-Combine Trend and Kriged Results for Final Map



https://mgimond.github.io/Spatial/spatial-interpolation.html

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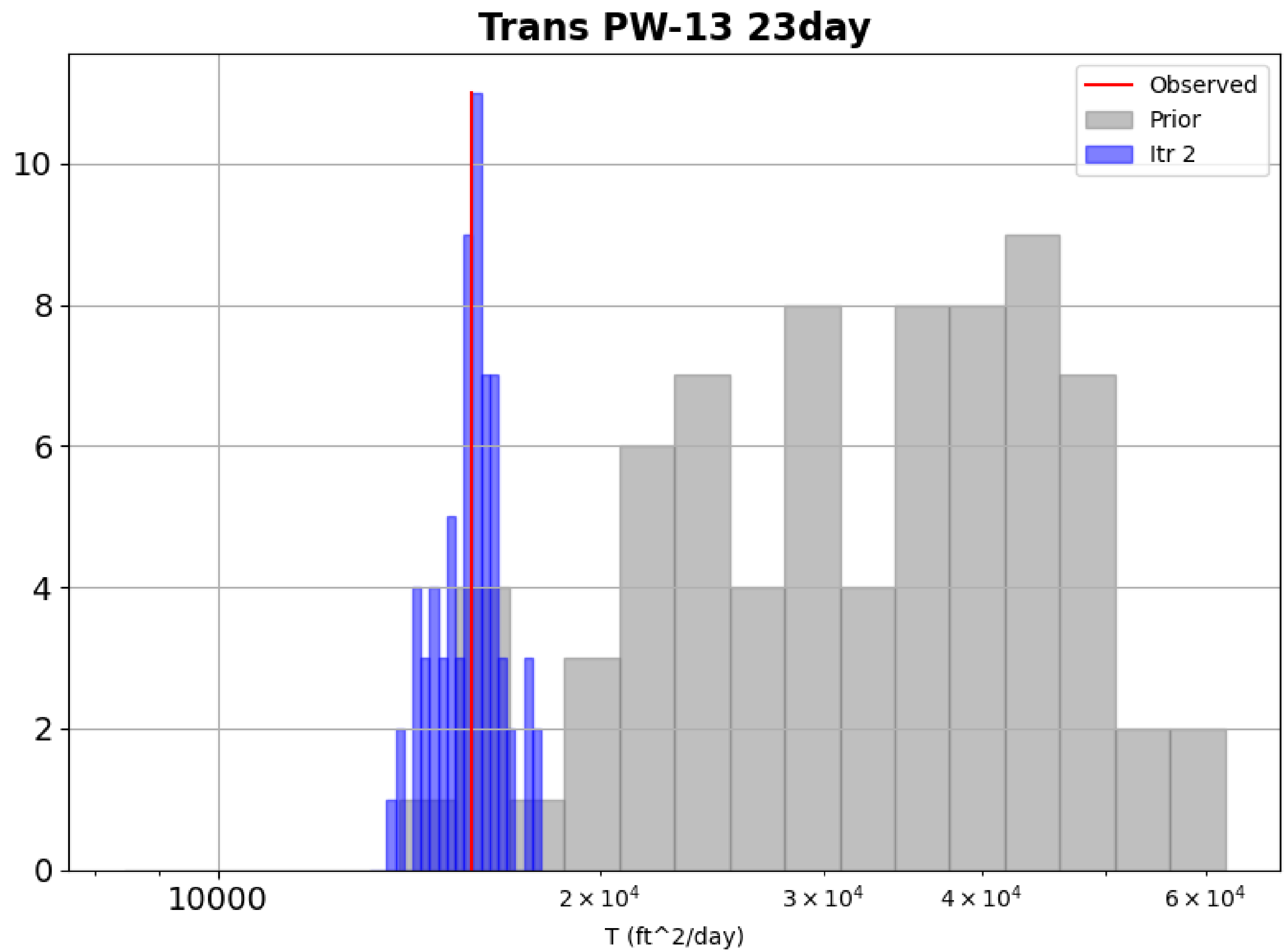

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