Review of Desired Future Conditions and Protective Drawdown Limits for Sparta, Queen City and Carrizo-Wilcox Aquifer

Presented To:

Post Oak Savannah Groundwater Conservation District

Presented By:

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November 6, 2018

Topics

- Definition: Desired Future Condition (DFCs)
- Current DFCs and PDLs
- Review of Methodology used by POSGCD in 2009 to develop and evaluate alternative DFCs
- Predicted Average Drawdowns by Revised GAM
- Consideration(s) for updating/revising DFCs
- Discussion and Possible Decisions for Moving Forward

Desired Future Condition

- Title 31, Part 10, §356.10 (7) of Texas Administrative Code:

"the desired, quantified condition of groundwater resources (such as water levels, spring flows, or volumes) within a management area at one or more specified future times as defined by participating groundwater conservation districts within a groundwater management area as part of the joint planning process."

Desired Future Condition: Points to Consider

- DFCs are an expression of local groundwater management.
- DFCs can be modified by districts to address improvements in data/science/technology and changing groundwater usage.
- Districts are responsible for managing the groundwater resource to achieve the DFCs.
- Development of DFCs requires blending policy and science.

Desired Future Condition: Points to Consider

- DFCs need to be measurable to be enforceable
- With respect to drawdown-based DFCs, the most important aspect of enforcing and monitoring DFCs is measured water levels
- Groundwater models are developed to help predict pumping impacts to help interpret monitoring data

Current Desired Future Conditions (DFCs) and Protective Drawdown Limits (PDLs)

Average Drawdown from Jan. 2000 to Dec. 2069

DFC for Entire Aquifer	Drawdown (ft)
Sparta	28
Queen City	30
Carrizo	67
Upper Wilcox (Calvert Bluff Fm)	149
Middle Wilcox (Simsboro Fm)	318
Lower Wilcox (Hooper Fm)	205

Average Drawdown from Jan. 2010 to Dec. 2069

DFC for Entire Aquifer	Drawdown (ft)
Yegua-Jackson	100

Average Drawdown from Jan. 2010 to Dec. 2070

DFC for Entire Aquifer	Drawdown (ft)
Paluxy	--
Glen Rose	212
Travis Peak	345
Hensell	229
Hosston	345

Decrease in Average Saturated Thickness from Jan. 2010 to Dec. 2069

Aquifer	DFC for County	Average Decrease in Saturated Thickness (ft)
Brazos River Alluvium Aquifer	Milam in GMA 12	5
	Burleson in GMA 12	6

Average Drawdown in Shallow Management Zones (upper 400 feet measured from land surface)

Aquifer	Average Drawdown (ft) that Occurs between January 2000 and December 2069 in the Shallow Management Zone
Sparta	20 ft
Queen City	20 ft
Carrizo	20 ft
Upper Wilcox (Calvert Bluff Fm)	20 ft
Middle Wilcox (Simsboro Fm)	20 ft
Lower Wilcox (Hooper Fm)	20 ft
Yegua	20 ft
Jackson	20 ft

Consideration(s) for Updating/Revising DFCs (and PDLs where applicable)

- 2009-2010 POSGCD method for generating possible DFCs (this is the primary basis for current DFCs)
- Method used to calculate average drawdowns
- Use of average water level elevation in place of average drawdown
- Use of aquifer zone(s) based on active/anticipate area of pumping and aquifer extent covered by monitoring network in place of entire aquifer
- Reassess protocols for assigning wells to aquifers
- Revisit monitoring wells for determining compliance with Upper Wilcox, Middle Wilcox, and Lower Wilcox

Methodology Used by POSGCD to Set DFC For First Joint Planning Cycle

- Developed preliminary DFCs based on:
  - Average drawdown in unconfined portion of aquifer
  - Allow percent decline in artesian pressure in the confined portion o the aquifer
  - Maximum allowable drawdown in the confined portion of the aquifer
  - Area of the unconfined portion of the aquifer
  - Area of the confined portion of the aquifer
- Adjusted preliminary DFCs based on GAM simulations and preliminary DFCs from other districts

Conceptualization of Unconfined and Confined Regions of Aquifer

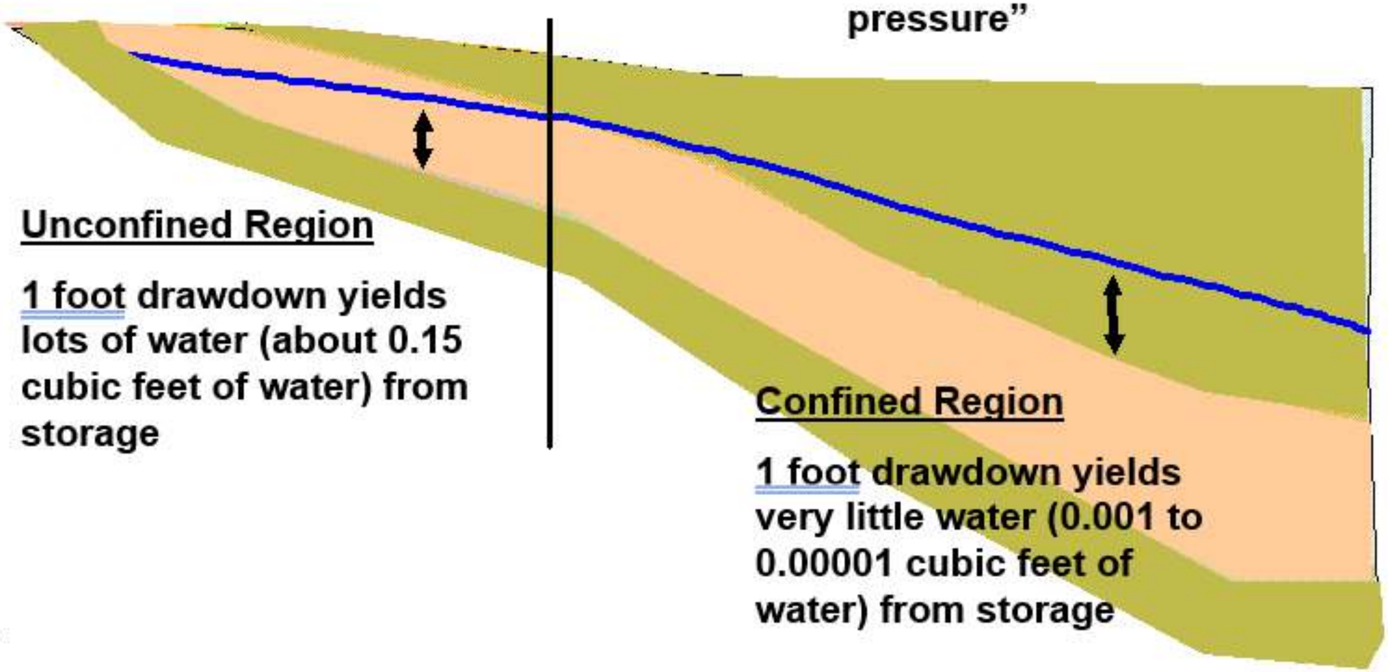
DFCs Should Consider Different Impact of Pumping has on Confined and Unconfined Aquifer

Unconfined Region

Water level usually associated with saturated thickness

Confined Region

Water level usually often associated with "artesian pressure"



Unconfined Region

1 foot drawdown yields lots of water (about 0.15 cubic feet of water) from storage

Confined Region

1 foot drawdown yields very little water (0.001 to 0.00001 cubic feet of water) from storage

From 2/10/2009 DFC Committee Mtg

Example DFC Calculations Used by POSGCD to Establish Preliminary DFC for Simsboro in 2009

Example DFC Calculations: Simsboro

Conditions			Desired Future Conditions - Drawdown
			Aquifer
DD in Unconfined Area	% Decline in artesian pressure	Max DD in Confined Area	Simsboro
10	0.25	450	312
15	0.25	450	313
20	0.25	450	313
25	0.25	450	314
20	0.25	350	260
20	0.25	400	288
20	0.25	450	313
20	0.25	500	336
20	0.25	550	357
20	0.33	350	273
20	0.33	400	305
20	0.33	450	335
20	0.33	500	364
20	0.33	550	390

Selected by DFC Committee

From 2/10/2009 DFC Committee Mtg

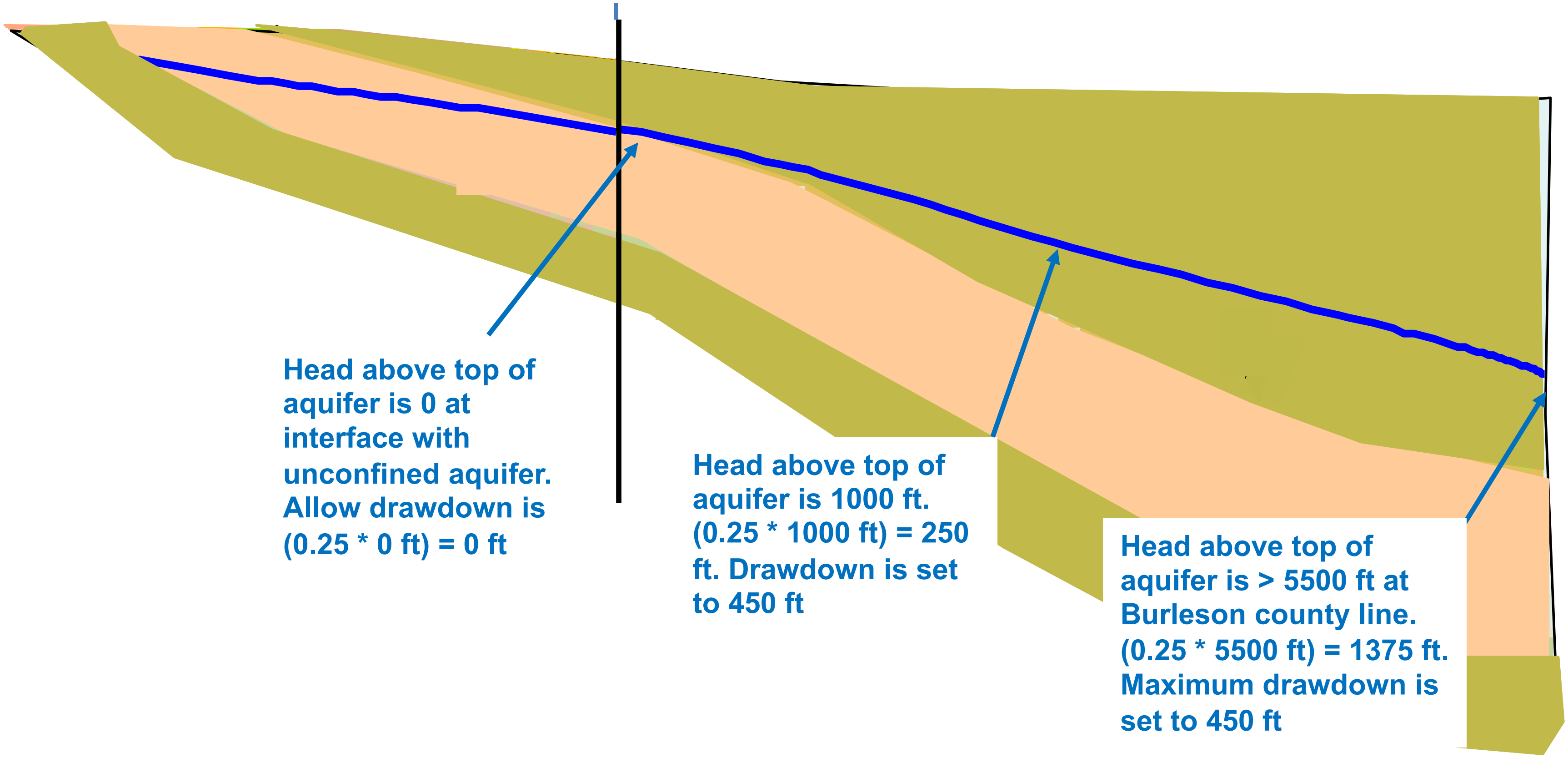
Drawdowns Used to Establish the Preliminary DFC for the Simsboro Aquifer in 2009

Unconfined Region

Drawdown is 20 ft across the entire unconfined region (139 sq miles)

Confined Region

Drawdown is 25% of the head above top of the Simsboro but no more than 450 ft across the entire confined regions (996 sq miles)



Letter Documenting Preliminary DFCs and Recommendation for Final DFCs

URS

February 09, 2010

Mr. Gary Westbrook, Manager
Post Oak Savannah Groundwater Conservation District
P.O. Box 92
Milano, Texas 76556

Re: → Evaluation of Preliminary DFCs for GMA-12 Meeting on February 11, 2010

Dear Mr. Westbrook,

On February 10, 2009 the POSGCD adopted the preliminary DFCs in Table 1 (Attachment A). During the last year, GMA-12 has applied the QCSCW GAM help evaluate the compatibility of the member district's DFCs. On February 11, 2010 GMA-12 will considered amending the preliminary DFCs prior to interacting with the TWDB with future GMA-12 GAM simulations. Before the up-coming GAM meeting we suggest that POSGCD review the appropriateness of their preliminary DFCs.

A finding from these model simulations is that there may be a problem with the compatibility among the GMA-12 districts' DFCs for the Carrizo Aquifer. The GMA-12 consultants are currently working on resolving this issue. As shown in Table 2 (Attachment A), a recent GMA model simulation by URS suggests that if POSGCD lowered their Carrizo DFC from 120 ft to 70 ft then model predicts drawdowns that are below or close to other districts' preliminary DFCs. In order to help facilitate the joint planning process, we recommend that that POSGCD consider revising the Carrizo DFC prior to the GMA-12 meeting on February 11, 2010.

The POGCD DFC committee developed the original preliminary DFCs based on the presumed aquifer conditions in Table 3 (Attachment B). In order to achieve a DFC of 70 feet in the Carrizo Aquifer, the maximum drawdown in the confined area of the Carrizo would need to be changed from 150 ft to 93 ft.

For your consideration, Figure 1 (Attachment C) and Figure 2 (Attachment D) provide the simulated drawdowns and pumping rates associated with the recent GAM run cited above. These results are intended provide POSGCD with the most recent information for evaluating the status of their preliminary DFCs.

We appreciate the opportunity to serve POSGCD and we gladly address any questions regarding above information.

Sincerely,

Steven C. Young, P.G., P.E.
Senior Hydrogeologist and Project Manager

Section Break (Next Page)

Attachment B:

Table 3. Assumed Aquifer Conditions Used to Develop Preliminary DFCs in February 2009

Aquifer	Assumed Aquifer Conditions		
	Average Drawdown in Unconfined Area	% Decline in Artesian Pressure in Confined Area	Maximum Drawdown in Confine Area
Sparta	10	0.25	35
Queen City	10	0.25	55
Carrizo	20	0.25	150
Calvert Bluff	20	0.25	200 to 250
Simsboro	20	0.25	400 to 450
Hooper	20	0.25	200 to 250

Attachment A:

Table 1. Preliminary POSGCDs DFCs for Five Aquifers

Aquifer	Average Drawdown (ft) Across the District from 2000 to 2060	
	DFC's Adopted by POGCD Board on February 10, 2009	Suggested Revised DFC Based on GAM runs performed by GMA-12
Sparta	30	30
Queen City	40	40
Carrizo	120	70
Calvert Bluff	150	150
Simsboro	300	300
Hooper	180	180

Additional Information Used to Establish DFCs in 2009

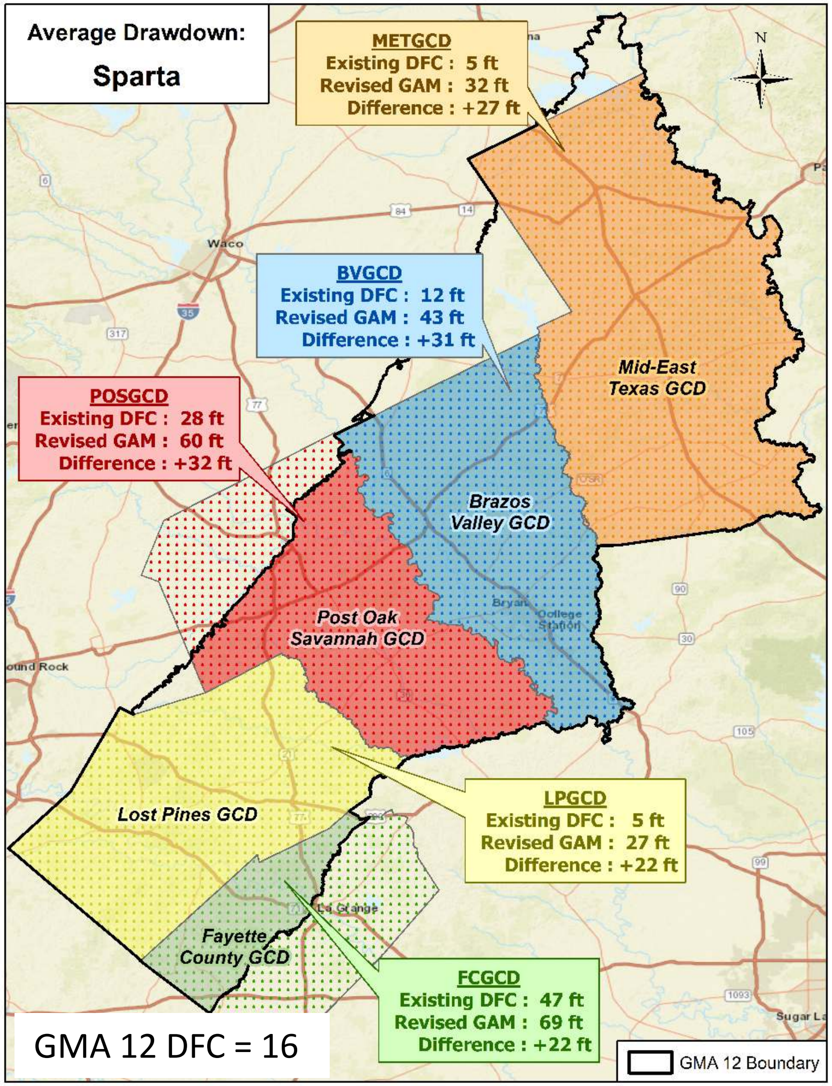
Aquifer parameters used to calculate preliminary DFCs

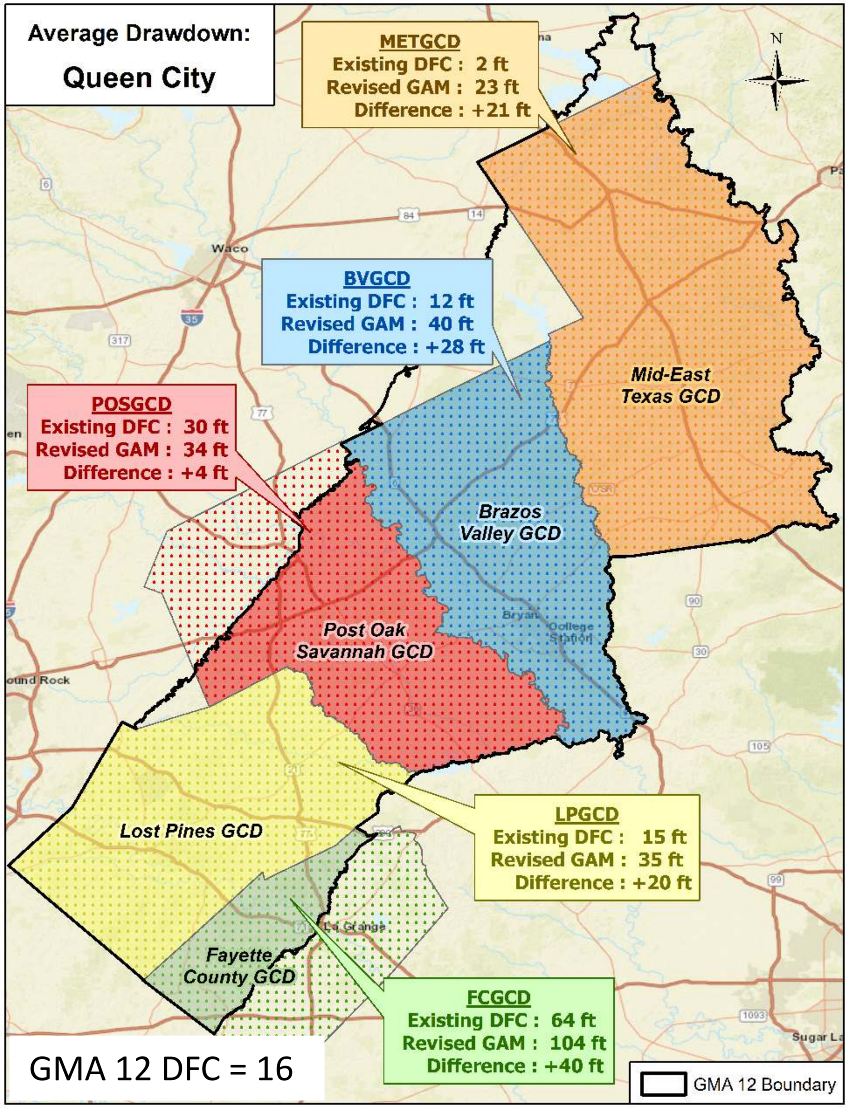
		Aquifer					
		Sparta	Queen City	Carrizo	Calvert Bluff	Simsboro	Hooper
Area (sq. miles) based on 2000 heads	Confined	466	579	797	823	996	1116
	Unconfined	109	173	39	204	139	124
Average head (ft) 2000	Confined	248	268	294	286	248	312
	Unconfined	330	354	397	364	359	370
Storage Volume (1000 acre-ft) in 2000	Confined	15,585	26,985	28,501	58,070	51,114	53,444
	Unconfined	814	2,971	597	4,962	2,408	1,401

Table 2. Comparison of Preliminary DFC's and GAM Results

District	Aquifer	Preliminary DFC Statements	Simulated Result From URS Run 745 for GMA12_6a Model
Fayette County	Sparta	50	50
	Queen City	50	48
	Carrizo	150	60
	Calvert Bluff	-	168
	Simsboro	-	222
	Hooper	-	182
Lost Pines	Sparta	10	5
	Queen City	13	15
	Carrizo	47	52
	Calvert Bluff	99	135
	Simsboro	212	221
	Hooper	129	133
Brazos Valley	Sparta	12	14
	Queen City	12	13
	Carrizo	44	52
	Calvert Bluff	-	116
	Simsboro	268	273
	Hooper	-	183
Mid-East	Sparta	12	-2
	Queen City	25	-3
	Carrizo	55	54
	Calvert Bluff	70	84
	Simsboro	115	109
	Hooper	95	93
Post Oak	Sparta	30	29
	Queen City	40	31
	Carrizo	120	70
	Calvert Bluff	150	160
	Simsboro	300	292
	Hooper	180	178

Predicted Average Drawdown(ft) and Current DFCs GMA 12: Sparta and Queen City





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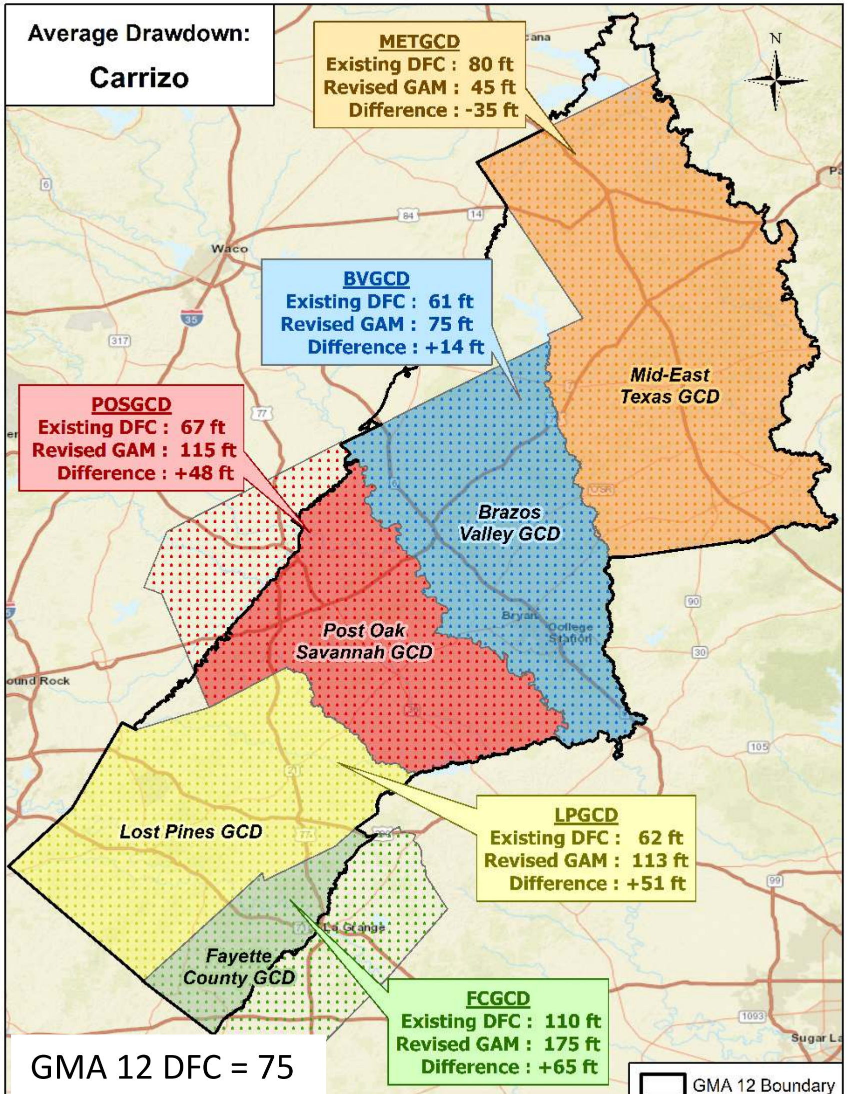
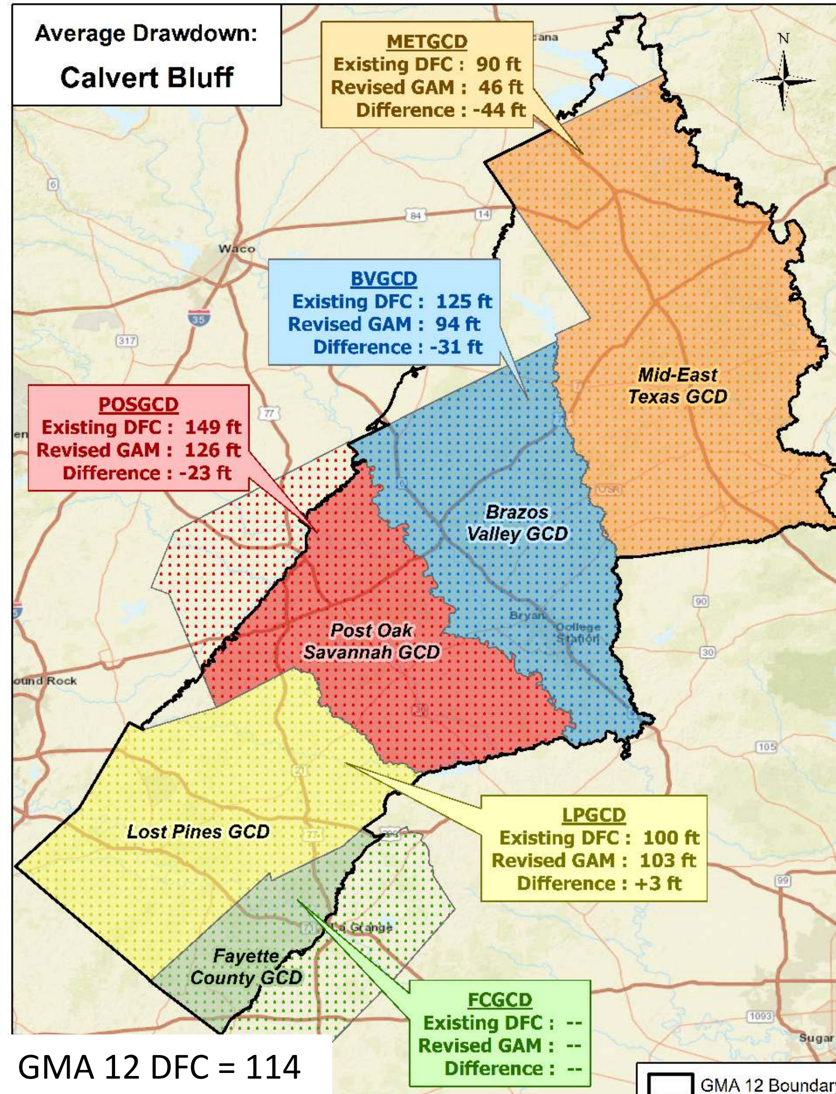
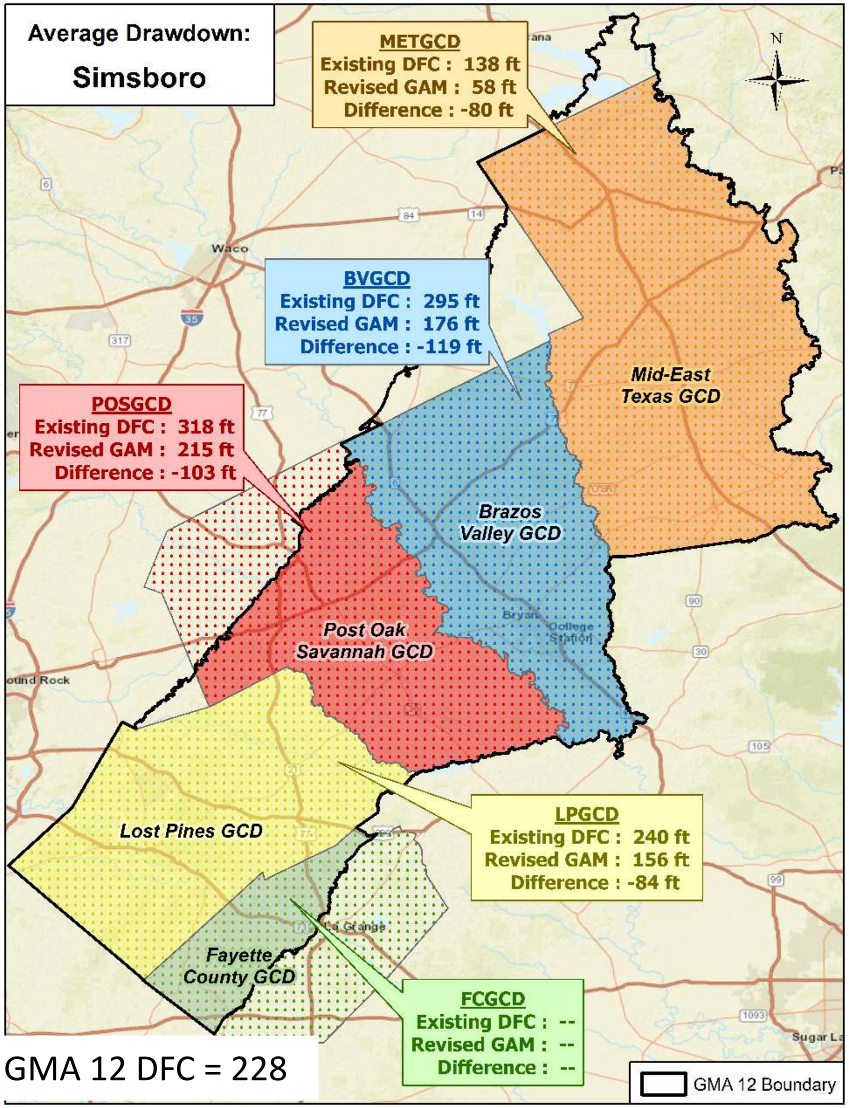
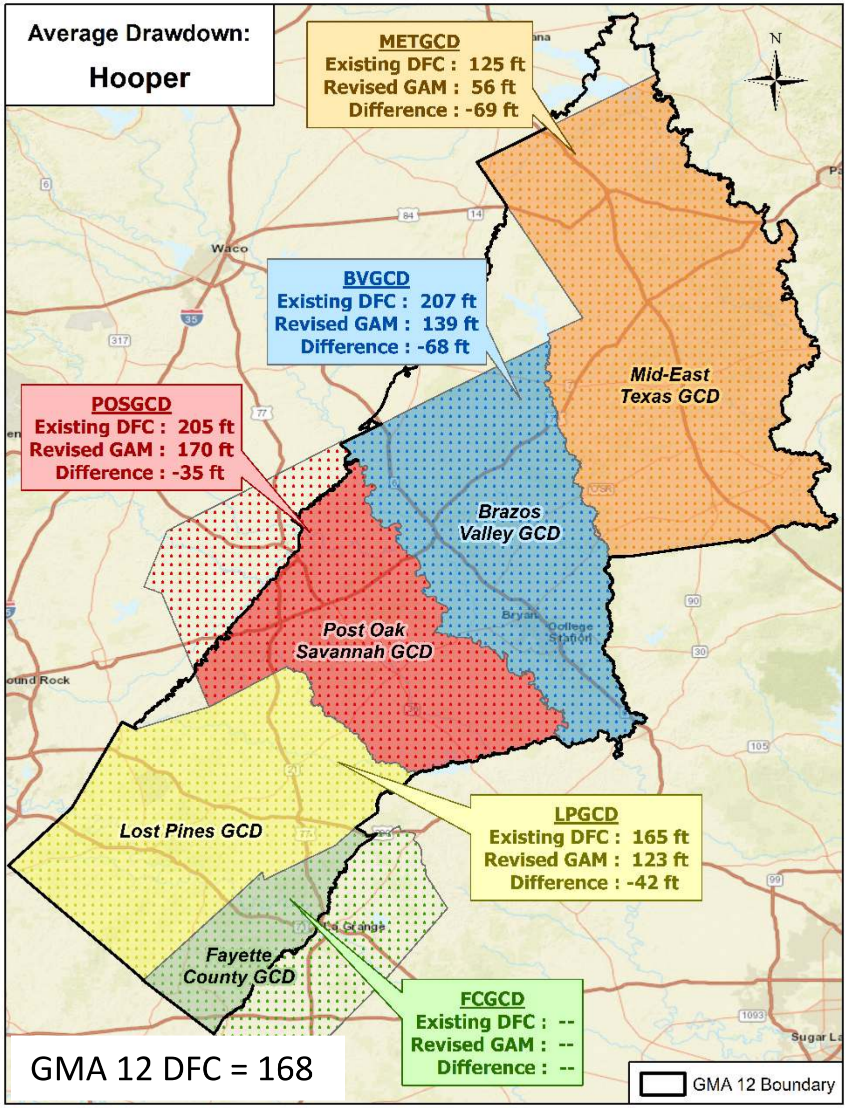
Predicted Average Drawdown(ft) and Current DFCs GMA 12: Carrizo and Calvert Bluff





Predicted Average Drawdown(ft) and Current DFCs GMA 12: Simsboro and Hooper





Predicted Average Drawdown(ft) and Current DFCs for POSGCD

Drawdown Average Weighted by Area

Aquifer	Entire Aquifer			
	2000-2069 Average Drawdown (ft)			2010-2069 Averge Drawdown (ft)
	Current DFC	Revised GAM	Difference	Revised GAM
Brazos Aluvium	4 to 5	4	1	3
Sparta	28	60	-32	56
Queen City	30	34	-4	32
Carrizo	67	115	-48	109
Calvert Bluff	149	126	23	116
Simsboro	318	215	103	198
Hooper	205	170	35	158

Example DFC Calculations: Carrizo and Sparta

Carrizo Aquifer

Conditions			Desired Future Conditions - Drawdown Aquifer
DD in Unconfined Area	% Decline in artesian pressure	Max DD in Confined Area	Carrizo
5	0.25	150	119
10	0.25	150	119
15	0.25	150	119
20	0.25	150	120
15	0.25	100	85
15	0.25	125	103
15	0.25	150	119
15	0.25	175	135
15	0.25	200	149
15	0.33	100	88
15	0.33	125	107
15	0.33	150	125
15	0.33	175	142
15	0.33	200	159

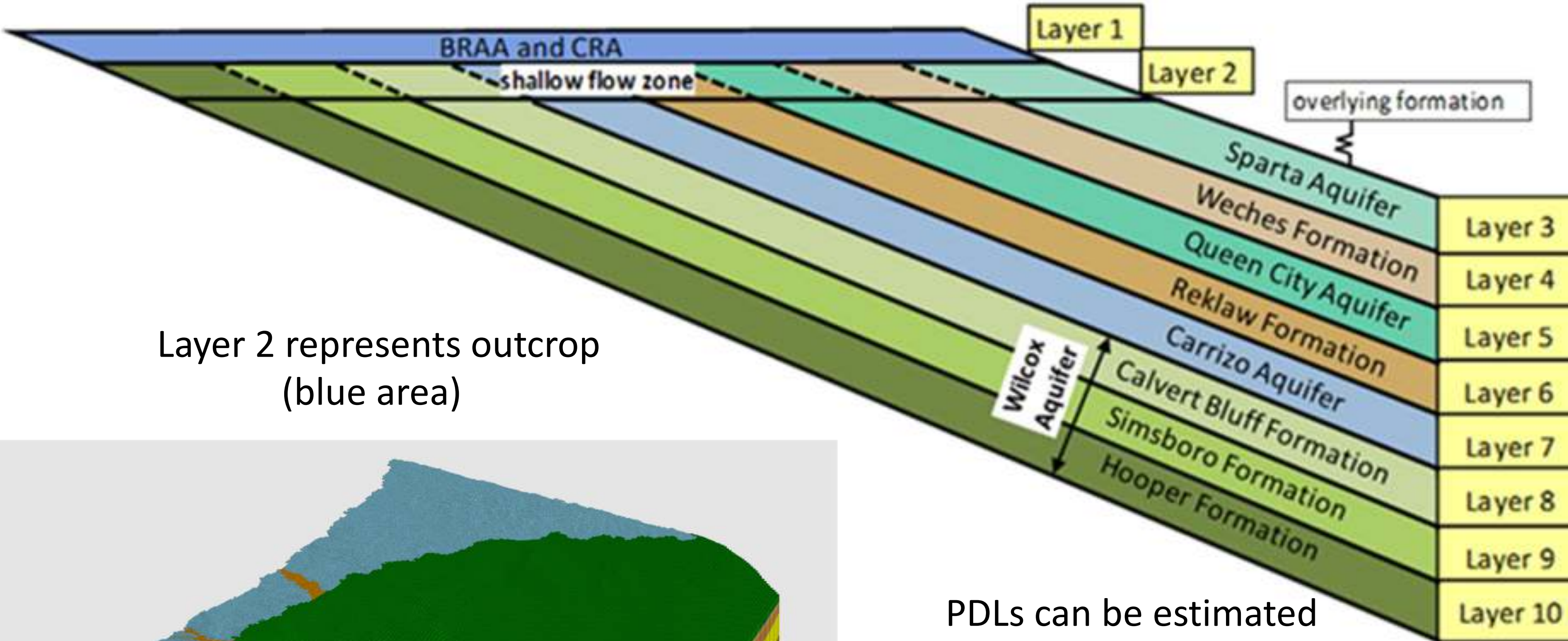
Sparta Aquifer

Conditions			Desired Future Conditions - Drawdown Aquifer
DD in Unconfined Area	% Decline in artesian pressure	Max DD in Confined Area	Sparta
5	0.25	35	28
10	0.25	35	29
15	0.25	35	30
20	0.25	35	31
10	0.25	15	14
10	0.25	25	21
10	0.25	35	29
10	0.25	45	36
10	0.25	55	43
10	0.33	15	14
10	0.33	25	21
10	0.33	35	29
10	0.33	45	37
10	0.33	55	44

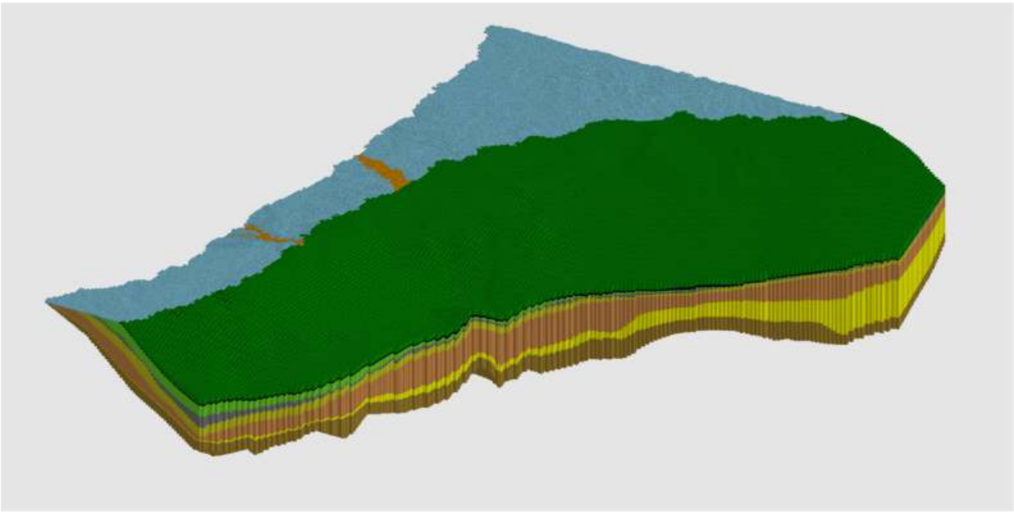
Selected by DFC Committee in 2009

From 2/10/2009 DFC Committee Mtg

Approach for Estimating PDLs Using Revised GAM



Layer 2 represents outcrop (blue area)



PDLs can be estimated by using drawdown in Layer 2 and up-dip portion of model layer

Predicted Average Drawdown(ft) and Current PDLs

Drawdown Average Weighted by Area

Aquifer	Shallow Aquifer (Upper 400 ft) PDL	GAM Layer 2		Average GAM Layer 2 Thickness (ft)
		2000-2069	2010-2069	
Sparta	20	3	3	112
Queen City	20	2	2	112
Carrizo	20	22	21	133
Calvert Bluff*	20	40	38	113
Simsboro*	20	35	31	122
Hooper *	20	15	15	110

Drawdown Average Weighted by Area

Aquifer	Shallow Aquifer (Upper 400 ft) PDL	GAM Shallow Aquifer		Average GAM Shallow Aquifer Thickness (ft)
		2000-2069	2010-2069	
Sparta	20	3	3	171
Queen City	20	2	2	229
Carrizo	20	22	21	166
Calvert Bluff	20	40	38	319
Simsboro	20	35	31	199
Hooper	20	15	15	252

* May consider combining

Considerations: Method Used to Average Drawdowns Across an Aquifer ?

- Current method is two-dimensional approach– it uses only the area of the aquifer and ignores the thickness (call this method “area-based”

- Another option is a a three-dimensional approach – it use both the area and thickness of the aquifer – see article on Guadalupe County GCD*

Texas Water Resources Institute
Texas Water Journal
Volume 7, Number 1, Pages 69-81

Implementing three-dimensional groundwater management in a Texas groundwater conservation district

Hilmar Blumberg[1] and Gabriel Collins[2*]

Abstract: The Guadalupe County Groundwater Conservation District has implemented a 3-dimensional water management solution that allocates pumping rights based on actual volumes in place under a tract. This new regime treats the aquifer as a "constant level lake" where rights holders are awarded the right to a percentage of the inflow (recharge) based on the volume of saturated sands underneath their property.

Three-dimensional management can improve Texas groundwater governance by strengthening property rights, promoting conservation, and unlocking economic value by promoting water trading and collateralization. It is also cost-effective and can be rapidly implemented: the Guadalupe County Groundwater Conservation District created its initial 3-dimensional ruleset in approximately 4 months at a cost of roughly $15,000. Larger districts or districts that could not benefit from an existing property parcel map created by an appraisal district would face higher costs. Creating the type of property ownership maps used by local tax appraisal districts can cost as much as $100,000. Yet the intensive property tax regime in Texas means that even the least-populous counties typically already have such information available in digital form.

Quantifying the available water volume beneath each property and making pumping rights transferrable between wells profoundly transforms groundwater management and confers clear vested rights to water in place. As such, it can provide economic recourse to smaller water holders even in areas where municipalities and other large pumpers enter the district. In short, this forward-looking, conservation-oriented new ruleset provides a way for Texas groundwater stewards to move past flat surface acreage-based allocations and move into an era where a handful of large pumpers in a district do not erode the property rights of smaller holders. Quantifying water in place involves averaging and making certain approximations and generalizations because of the inevitably complex nature of geologic formations. Over time, groundwater conservation districts and their constituent members will determine how deeply to engage that complexity. The bottom line is that 3-dimensional management offers an exponential degree of improvement over existing Texas groundwater management models. The Guadalupe County Groundwater Conservation District's ruleset embraces a philosophy of iterative learning and improvement and acknowledges that employing models as tools of governance always involves approximations. It handles this by including the capacity to rapidly update and revise its approach as the district obtains additional data points and insights through operational implementation of its rules.

Keywords: rule of capture, groundwater governance, conservation, dormant rights, collateralization, water market, cap and trade

[1] Director, District 2 and Secretary, Guadalupe County Groundwater Conservation District, Seguin, Texas.
[2] Baker Botts Fellow in Energy and Environmental Regulatory Affairs at Rice University's Baker Institute for Public Policy, Houston, Texas.
Please note that in this analysis, Mr. Blumberg and Mr. Collins are expressing their respective personal ideas and opinions and that these do not necessarily reflect the views of the Guadalupe County Groundwater Conservation District or the Baker Institute for Public Policy.
*Corresponding author: gabe.collins@rice.edu

* Discussed in November 2016 and December 2016 DFC Committee Meetings

Considerations: Area-based versus Volume-based?

- Area-based (ignores aquifer thickness)
  - 1 acre of 150-foot thick unconfined Simsboro weighted same as 1 acre of 750-foot thick of confined Simsboro
- Volume-based (accounts for aquifer thickness)
  - 1 acre of 150-foot thick unconfined Simsboro weighted 20% (1/5) as much as 1 acre of 750-foot thick of confined Simsboro

Aquifer Consists of Two Zones	Drawdown (ft)	Area (mi2)	Thickness (ft)	Average Drawdown	
				Area-based	Volume-based
A	10	1	150	20 ft	26.6 ft
B	30	1	750		

Additional Consideration for Calculating a Volume-based Drawdown

- Volume-based is more complicated because you need to define an aquifer thickness across entire county
- Volume-based will weight the drawdown in the confined zone more than it will drawdown in the unconfined zone
- Calculating changes in the volume of groundwater stored in an aquifer may be useful metric for District

Comparison of Average Drawdown (ft) from 2010 to 2069 Based on Area versus Volume

Average drawdowns calculated using the standard area-based method (method currently use by GMA 12) and a volume-based method

Aquifer	Entire Aquifer			Shallow Aquifer		
	Volume	Area	Difference	Volume	Area	Difference
Sparta	74	56	18	3	3	0
Queen City	42	32	11	2	2	-1
Carrizo	124	109	15	23	21	2
Calvert Bluff	147	116	31	44	38	7
Simsboro	238	198	40	37	31	6
Hooper	207	158	49	23	15	9

Considerations for Establishing DFCs and PDLs: Water Level Instead of Drawdown

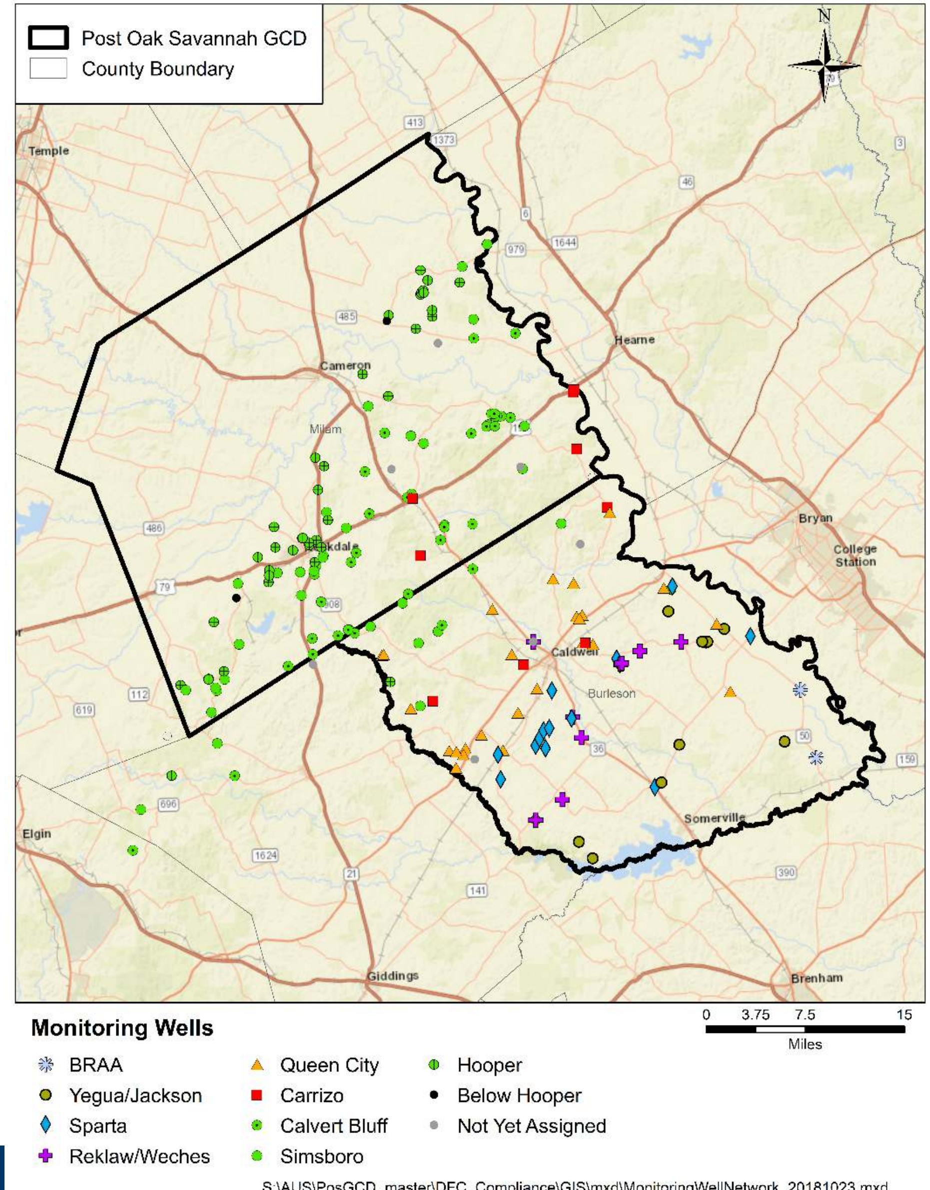
- Considerations for using average drawdowns for DFCs
  - requires average water level for both the initial and ending time period to develop a DFCs
  - **requires average water level for both the initial and current time period to evaluate compliance**
  - Problems and biases can be introduced into the drawdown value if the same wells are not used for calculating the water levels for both the time periods

Considerations for Establishing DFCs and PDLs: Water Level Instead of Drawdown

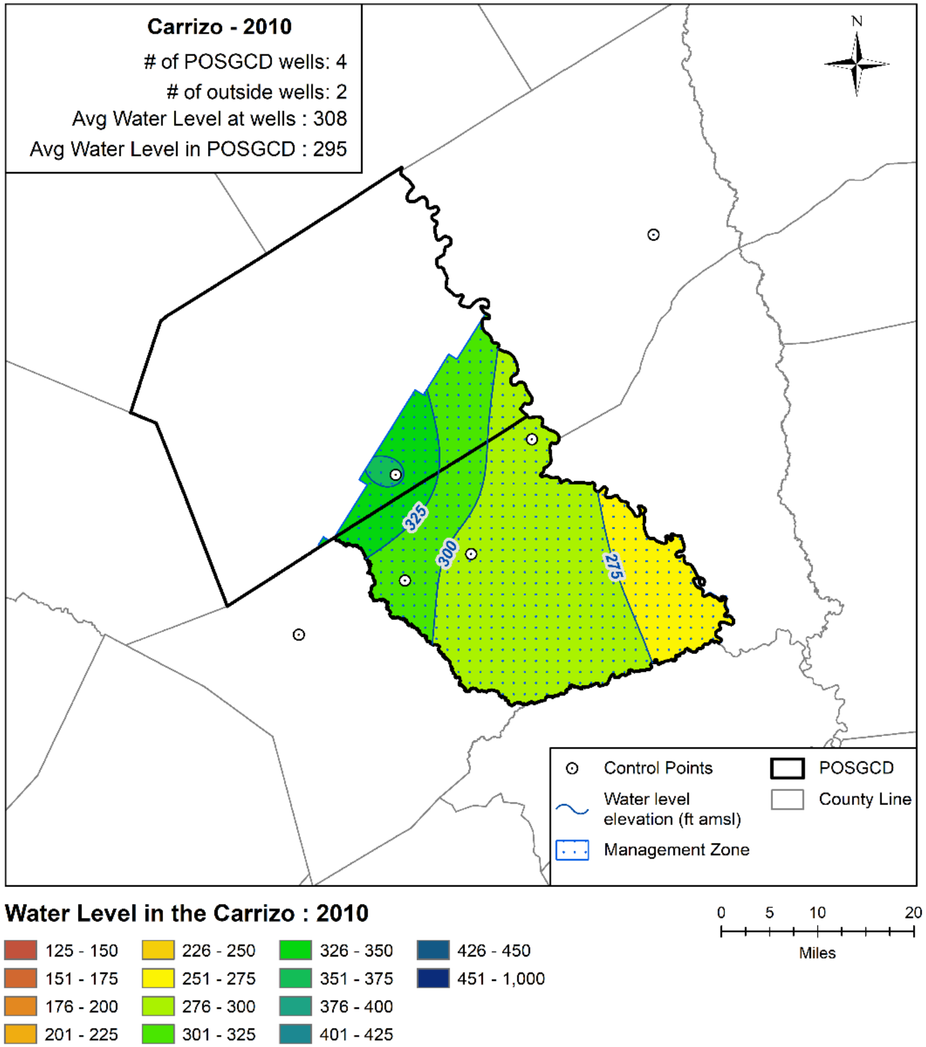
- Considerations for using average elevation of water levels for DFC
  - requires estimate of average water level for both the initial and ending time period to calculate (like drawdown method)
  - **<u>requires only average water level for only current time period to evaluate compliance (unlike drawdown method)</u>**
  - a two-year or three-year average water level would be recommended
  - the need for only recent water levels to check DFC compliances allows districts to use data from a monitoring well to check DFC compliance so after it is installed
  - use of several methods for calculating drawdown recommended

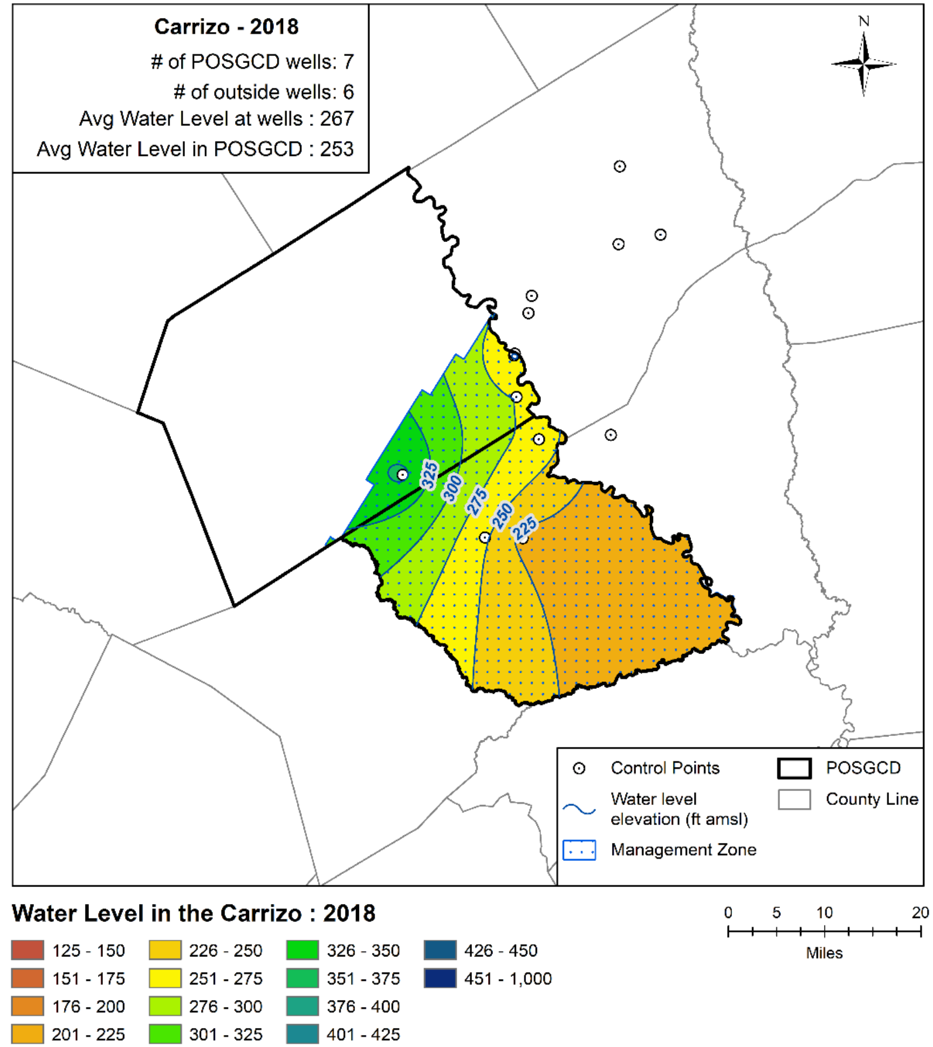
Monitoring Well Network

- Coverage significantly improved last two years.
- Future additions need to focus on more identify and filling gaps in coverage for specific aquifers
- Additional work needed on assigning aquifers to wells.
- BVGCD cooperation with data very good
- LPGCD cooperation has been hampered by problems with their water level database – no values used in subsequent plots

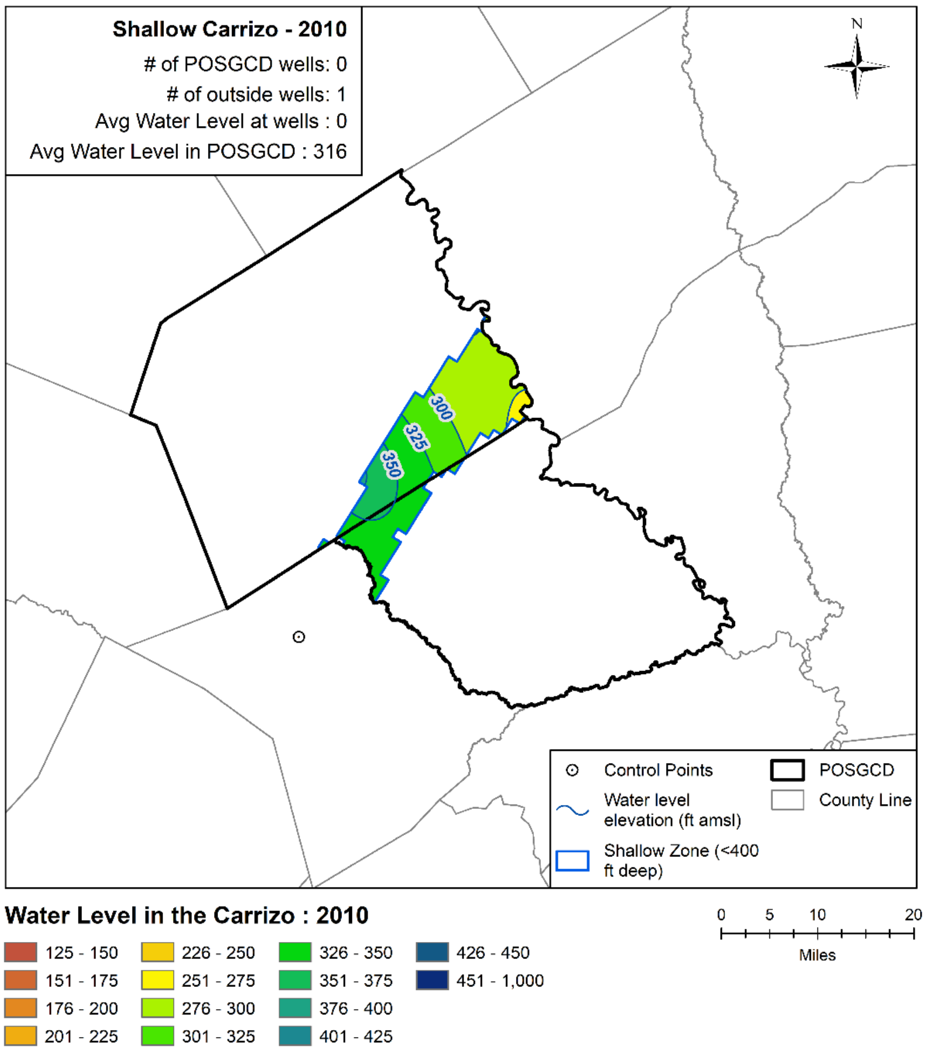


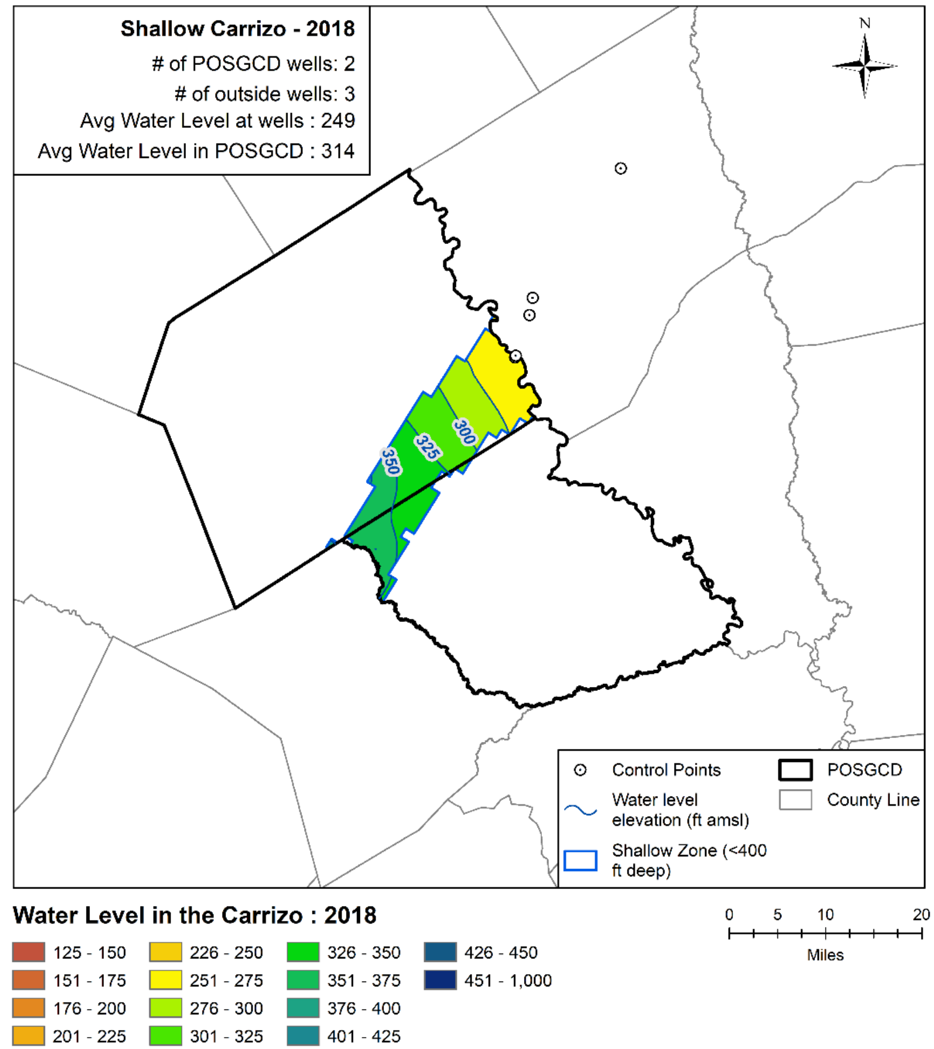
Carrizo Water Levels (ft msl)



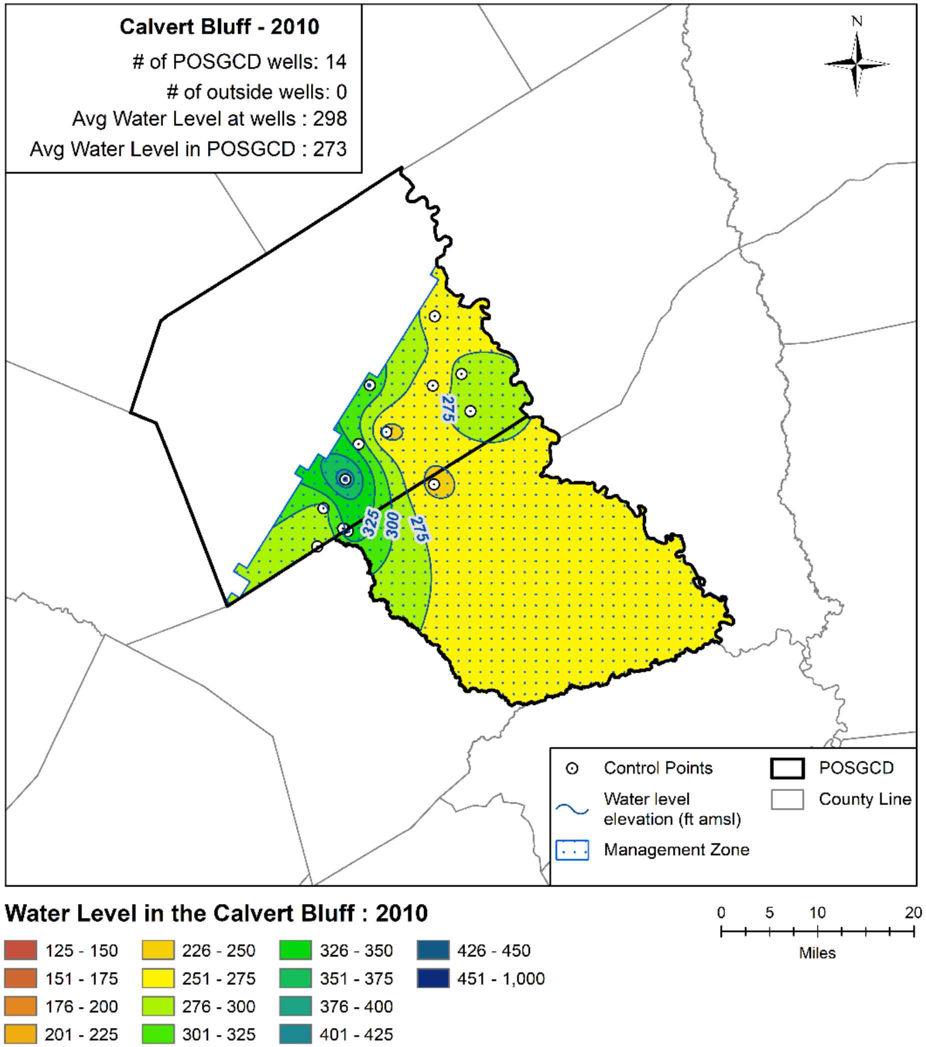


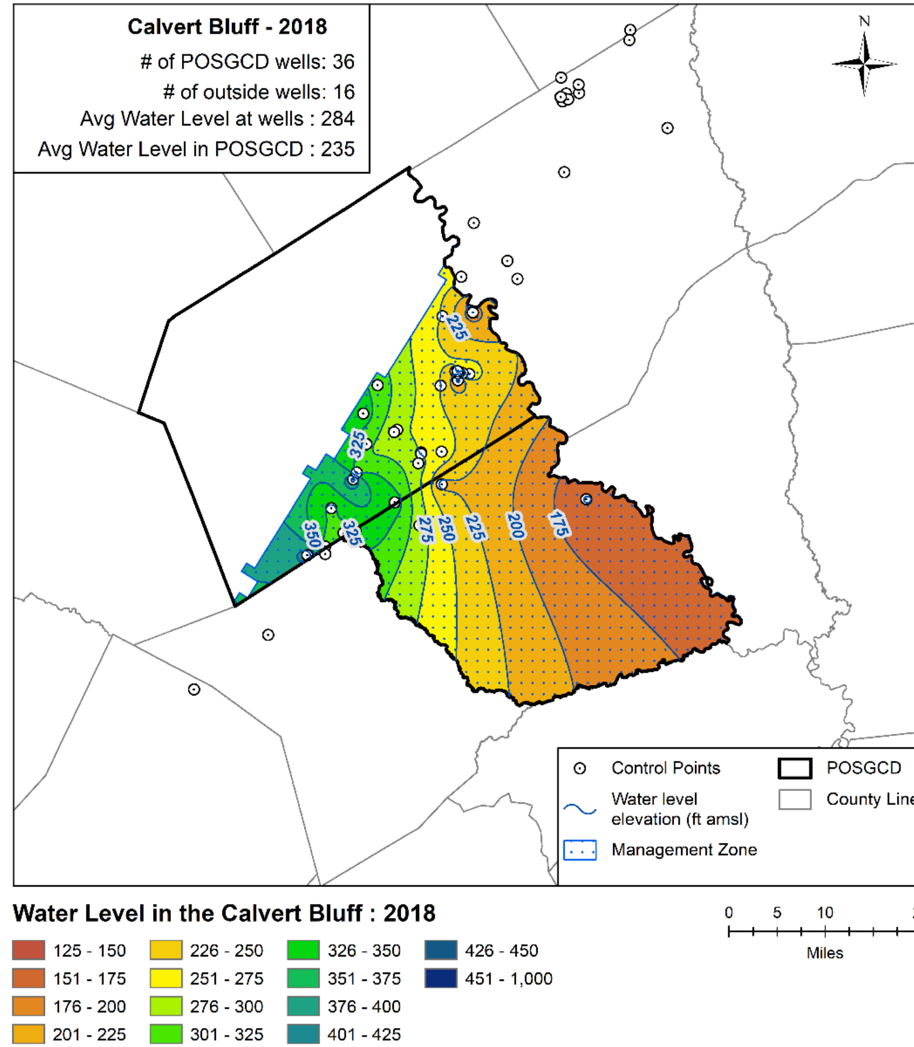
Shallow Carrizo Water Levels (ft msl)



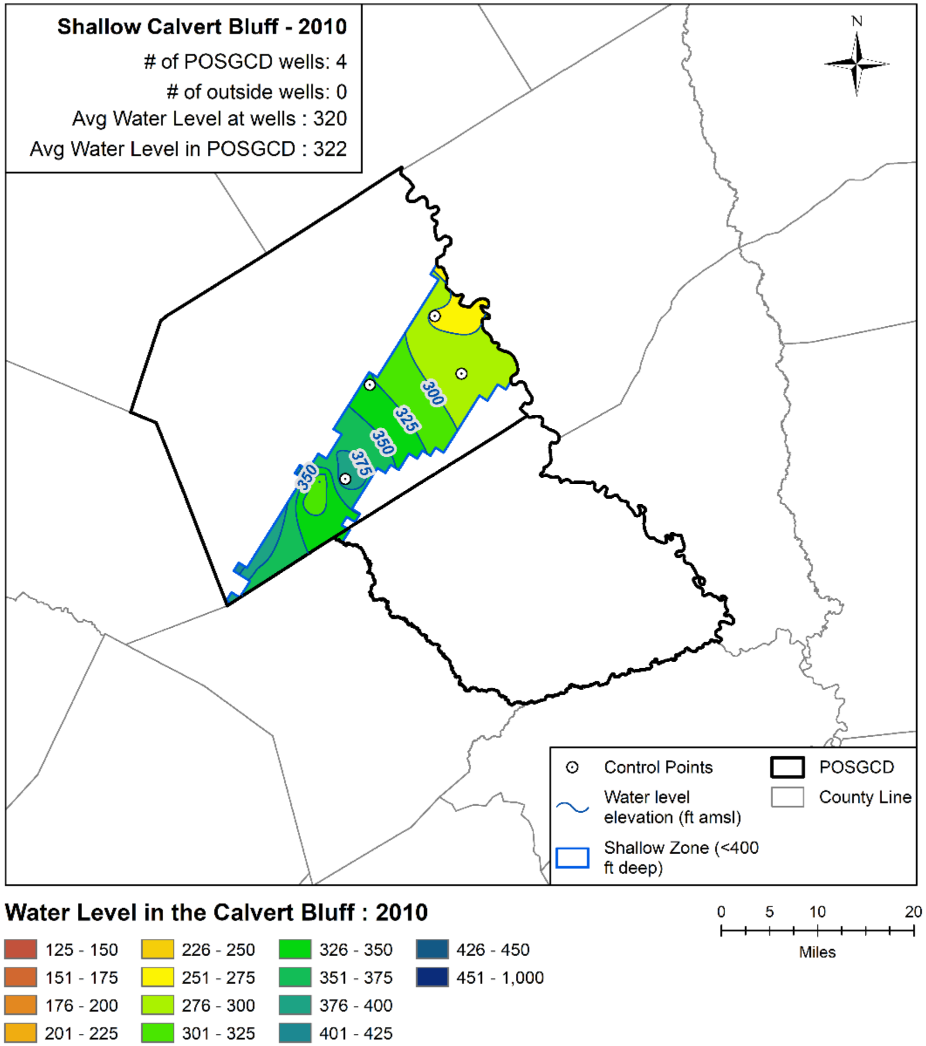


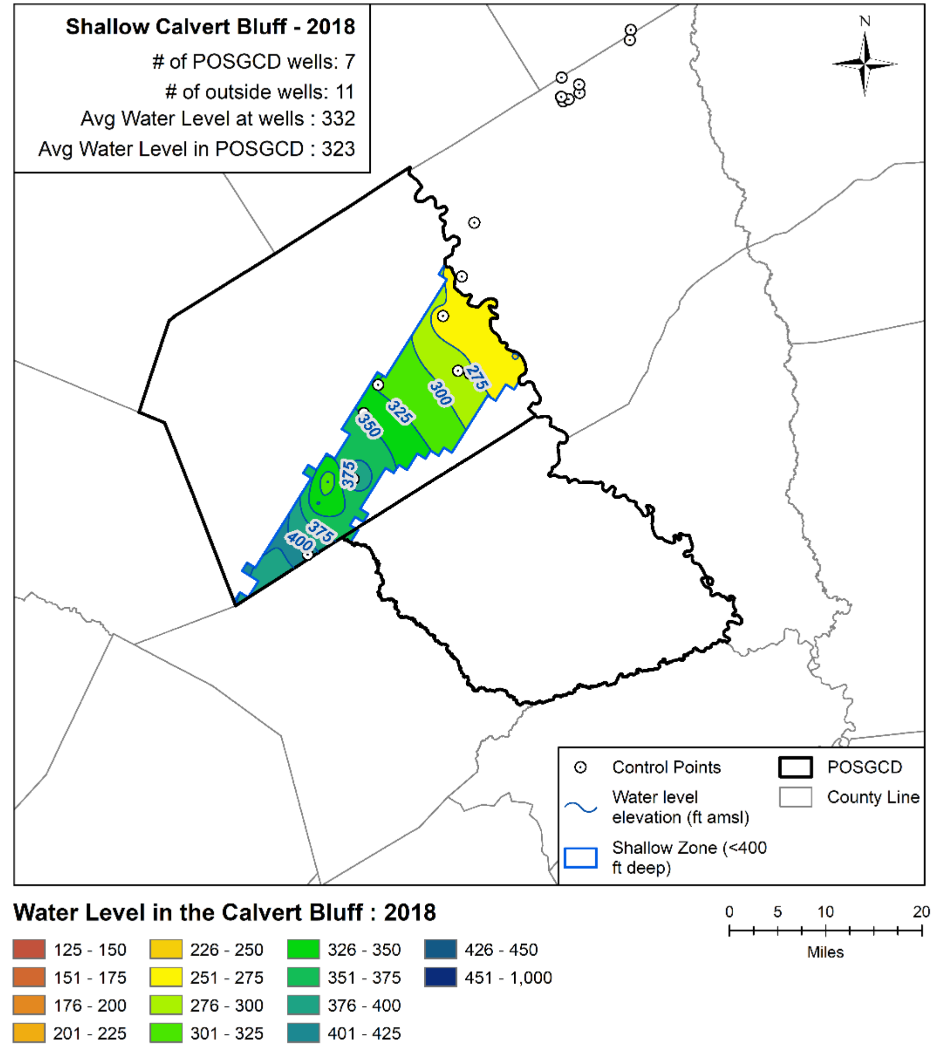
Calvert Bluff Water Levels (ft msl)





Shallow Calvert Bluff Water Levels





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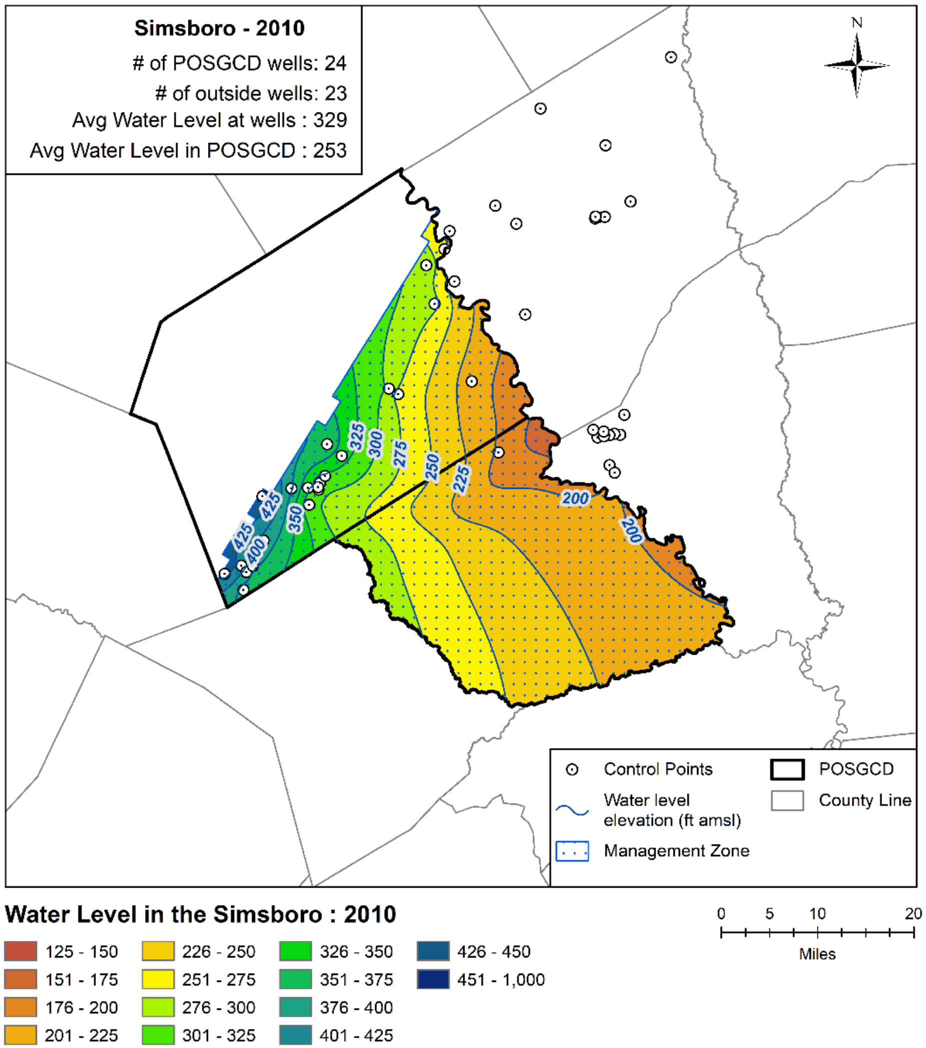
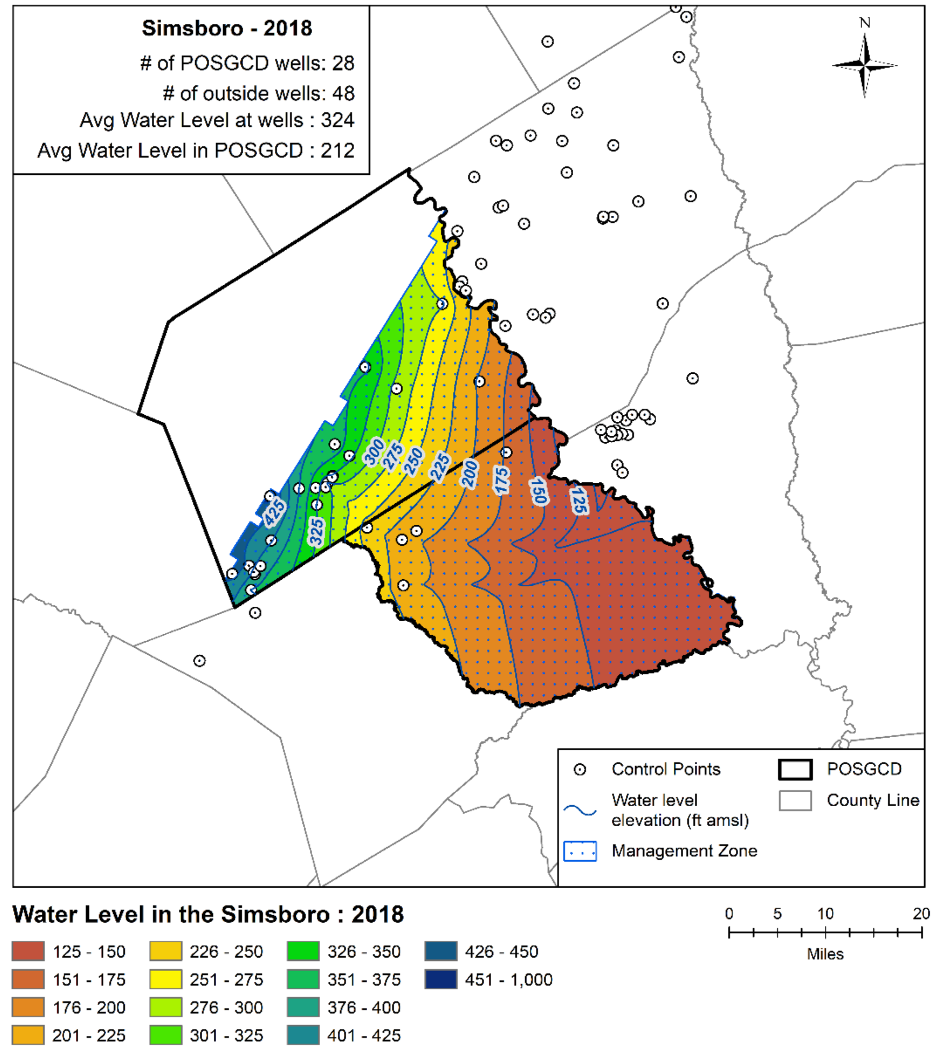
Simsboro Water Levels (ft msl)





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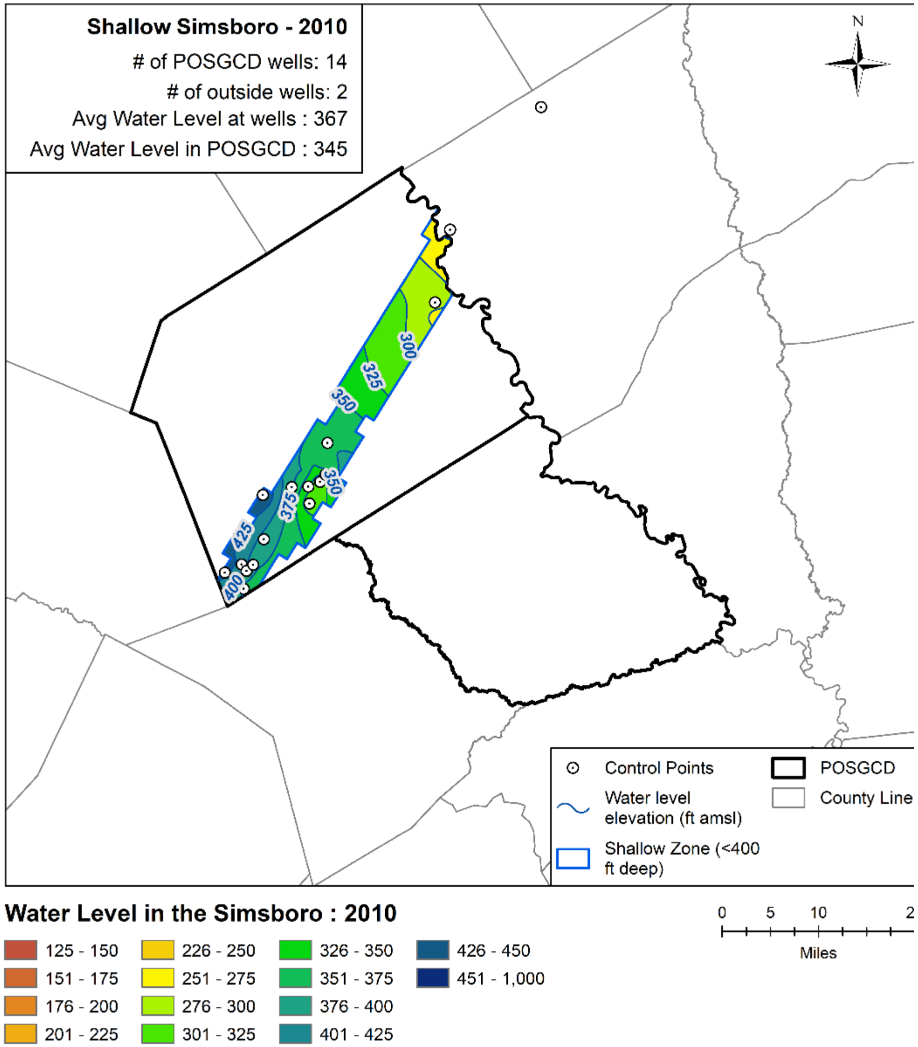
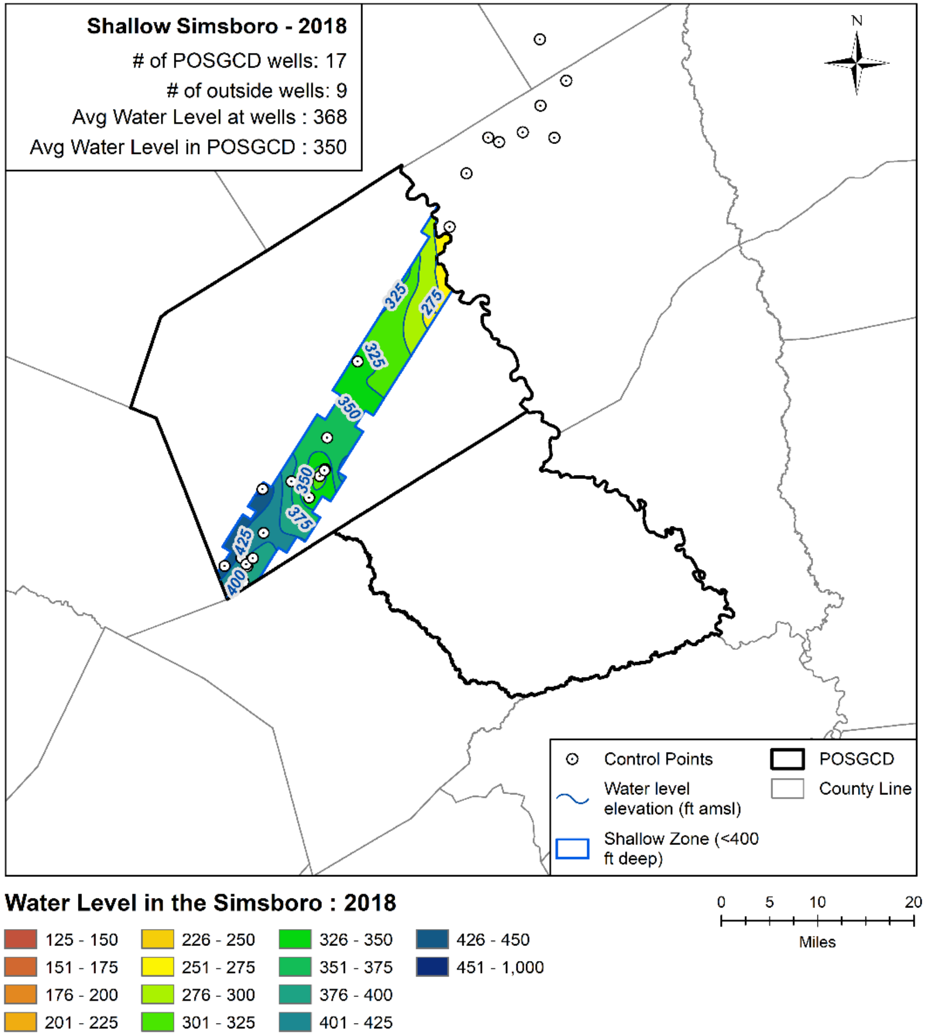
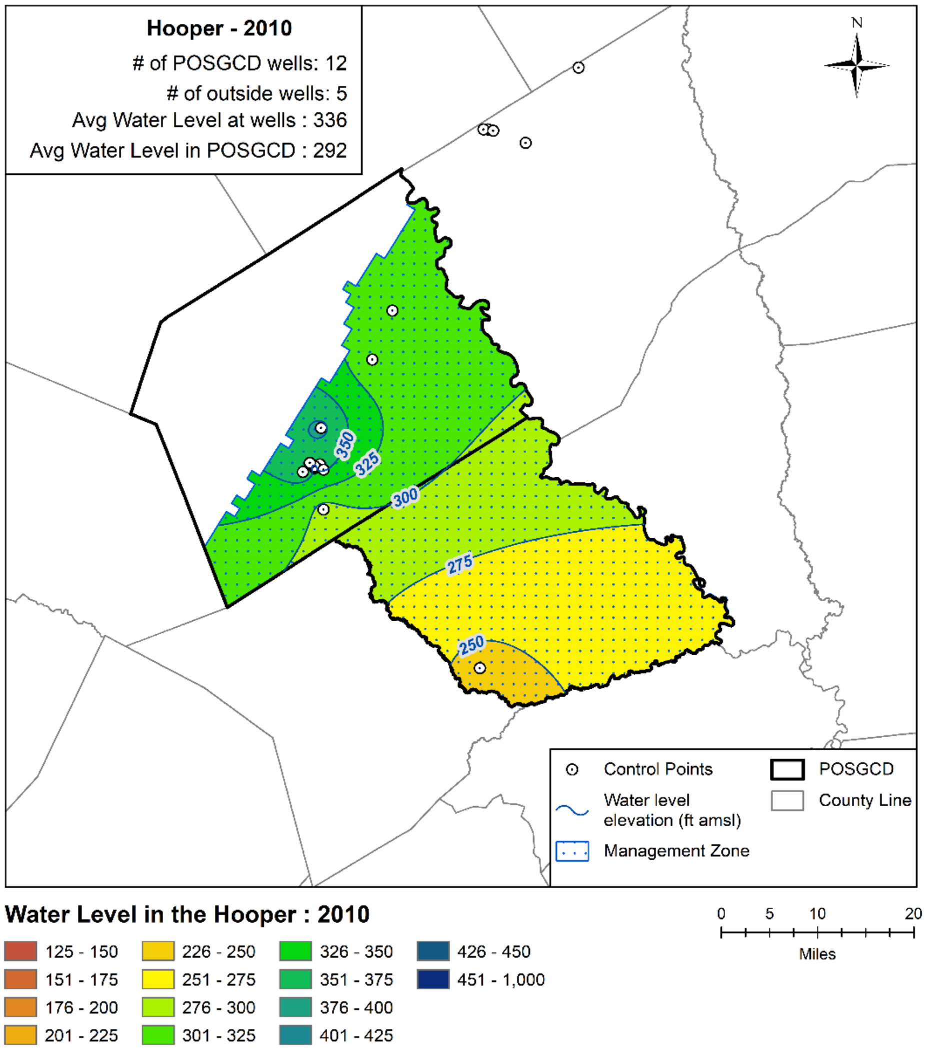
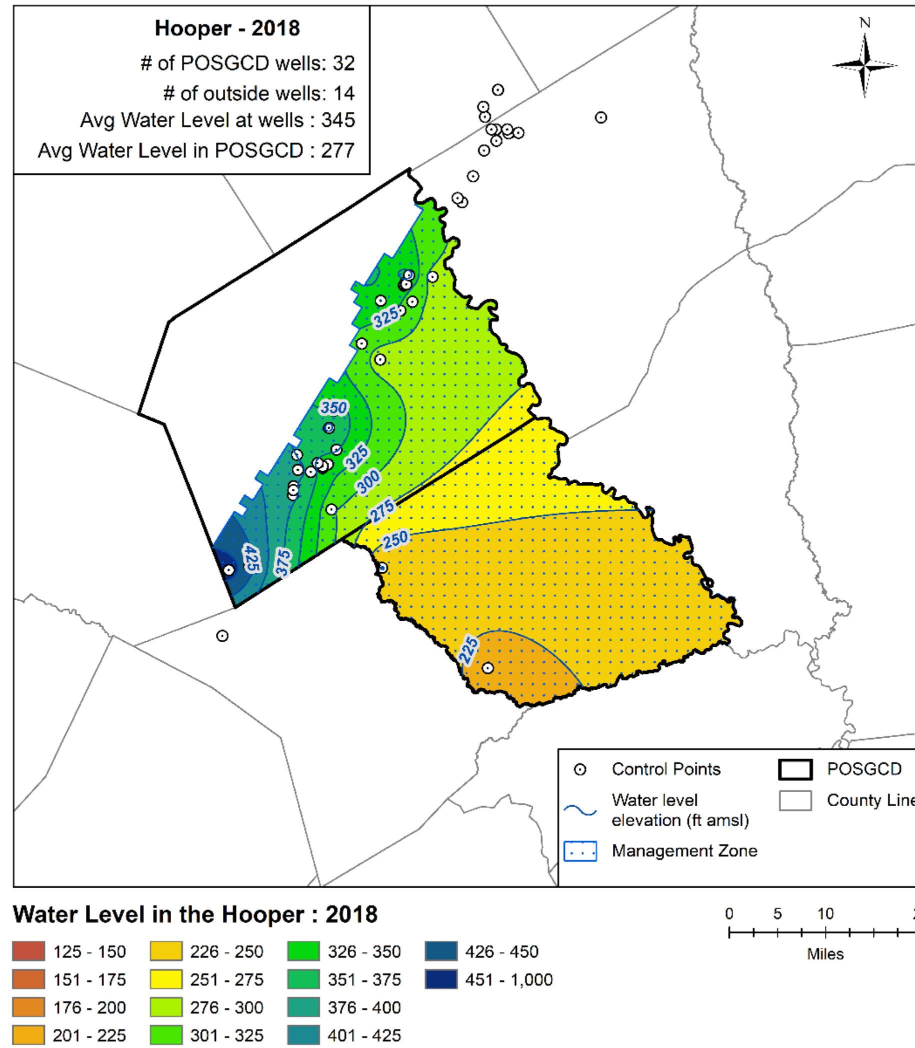
Shallow Simsboro Water Levels (ft msl)





Hooper Water Levels





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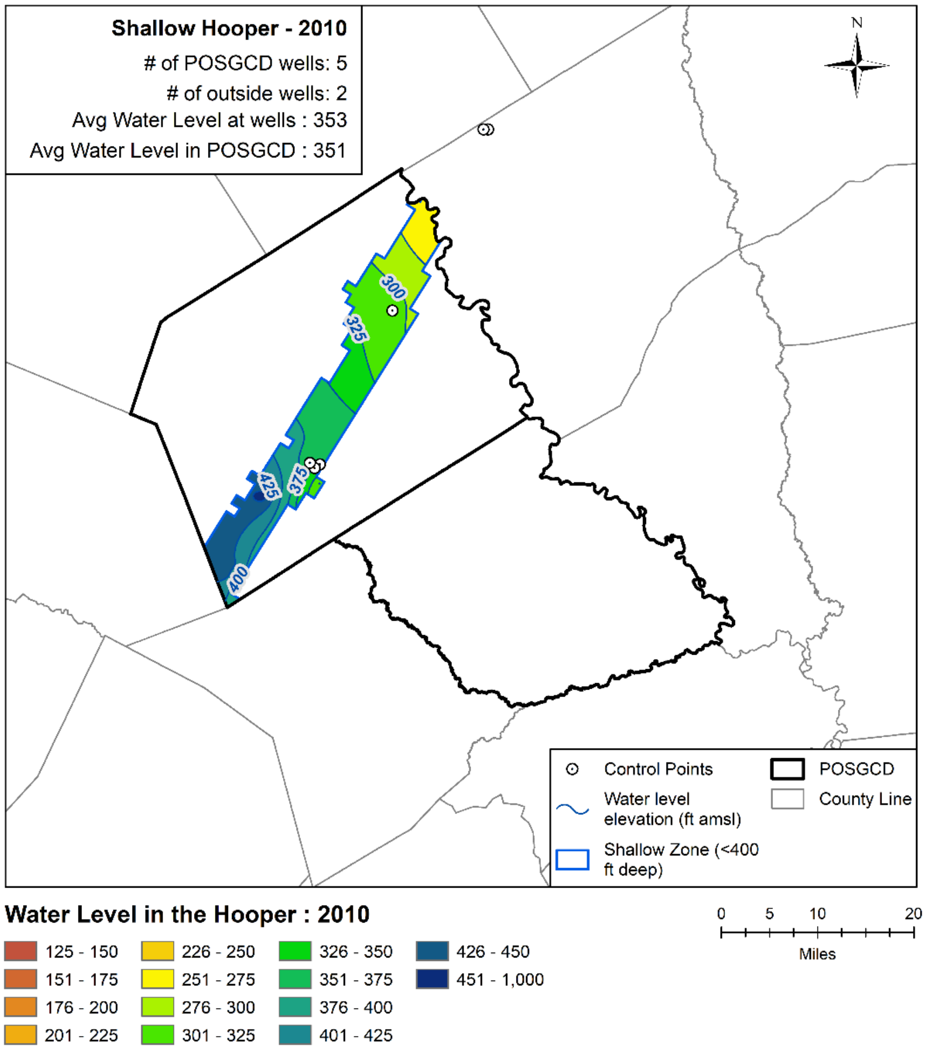
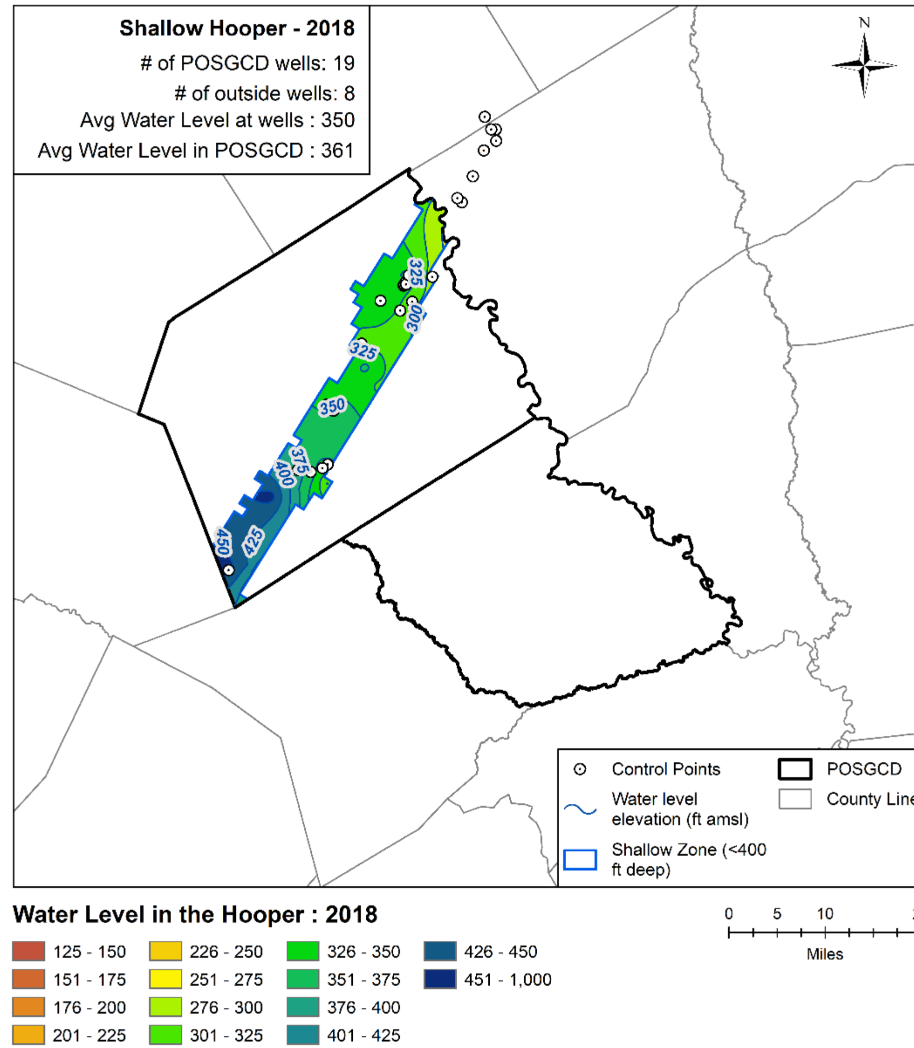
Shallow Hooper Water Levels (ft msl)





Comparison of Interpolation Methods for Determining an Average Water Level (ft, msl)

- POSGCD wells –average all wells in POSGCD
- Three methods used to interpolate points in between POSGCD and then average all of the points
  - Kriging – often used by geologists
  - Topo2raster – often used by geographers
  - Artificial Intelligence – new type of program that looks for patterns
- GAM
  - Area – thickness of model cell is ignored
  - Volume – thickness of model cell is considered

Aquifer	2010					
		Interpolated			GAM	
	POSGCD wells	Kriging	Topo 2 Raster	AI Method	Area	Volume
Yegua-Jackson	214	215	207	210	NA	NA
Sparta	263	**264**	**260**	**252**	**259**	**241**
Queen City	304	312	**295**	**312**	**293**	276
Carrizo	308	318	**295**	325	**296**	**292**
Calvert Bluff	298	**290**	273	282	300	**290**
Simsboro	329	264	**253**	**255**	**256**	242
Hooper	336	311	**292**	319	**303**	293

Aquifer	2018					
		Interpolated			GAM	
	POSGCD wells	Kriging	Topo 2 Raster	AI Method	Area	Volume
Yegua-Jackson	215	**215**	**214**	**216**	NA	NA
Sparta	259	**238**	**239**	223	**243**	**244**
Queen City	299	**289**	**270**	**284**	**282**	**262**
Carrizo	267	289	253	264	233	225
Calvert Bluff	284	264	**235**	263	**244**	**226**
Simsboro	324	230	**212**	**215**	173	152
Hooper	345	308	277	310	234	212

The differences among the values for an aquifer reflects the amount of uncertainty there exists - solution is better interpolation approach

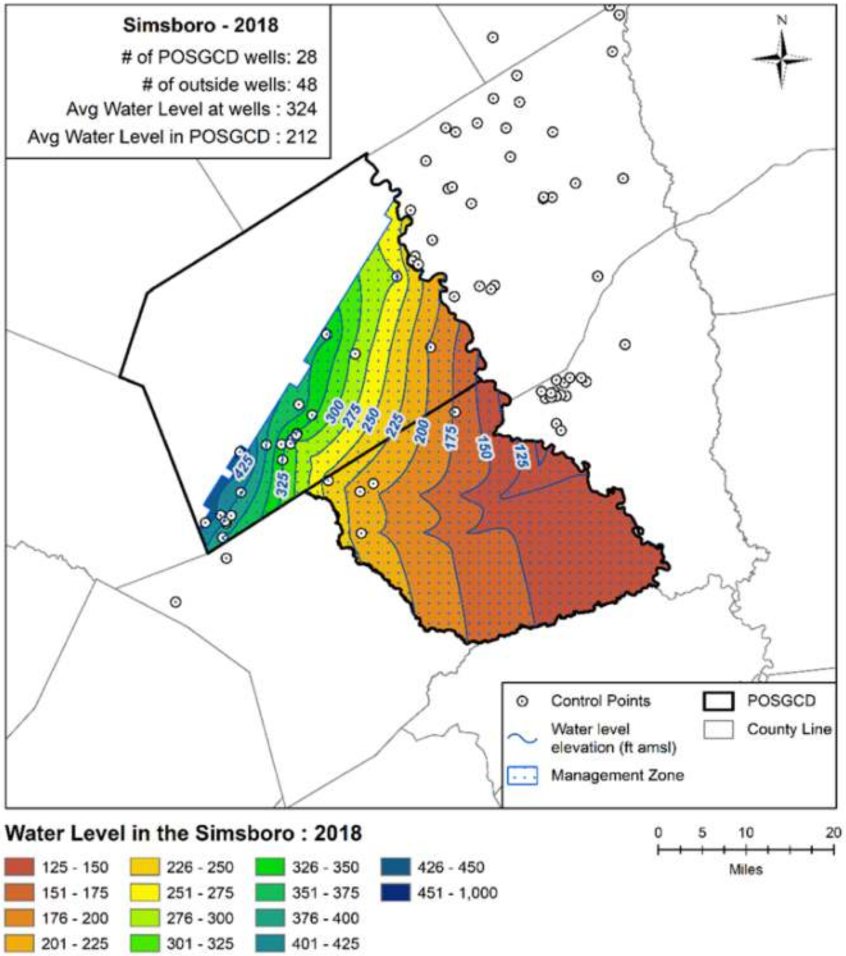
Considerations for Establishing DFCs and PDLs: Water Level Instead of Drawdown (con't)

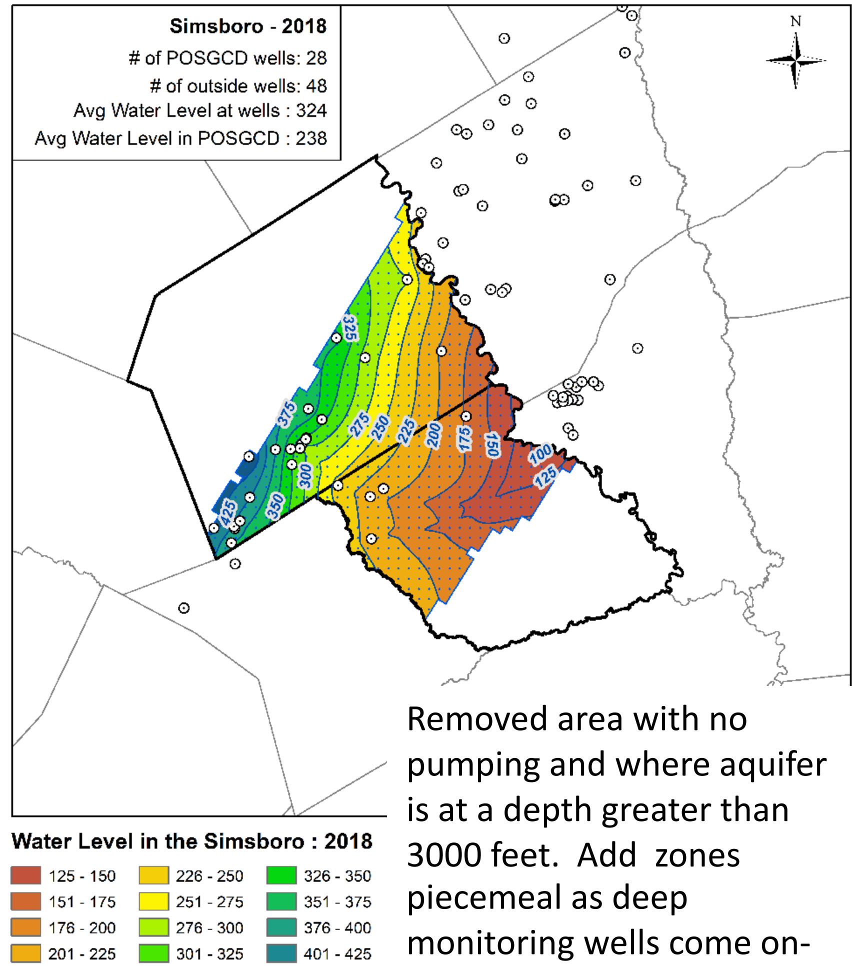
- Options Evaluation of Water Levels
  - at POSGCD wells
  - areas selected to be represented of aquifer
  - entire aquifer
- Routine for Interpolating Monitoring Data Is Important Component of Method
  - Interpolation is difficult because of sparseness of data and impacts of pumping, faults, and differences in aquifer properties
  - Need an interpolation method can extract a pattern from simulated GAM water levels and used that pattern to interpolate between the measured water levels
  - One such routine is co-kriging. INTERA has successfully used co-kriging water levels with topographic data to help map elevation surfaces of water tables

Considerations for Establishing DFCs: Restricting Aquifer Area Used for DFCs

- Monitoring data where aquifers are deep will be non-existence to sparse
- Large areas of down-dip region of aquifers will not be pumped for next 30 years
- Remove portions of the aquifer that are deep and expensive to monitor and that have not pumping
- Focus on area of aquifer where pumping is occurring and there are adequate number of monitoring wells

Examples of Trimming Aquifer Area for DFC: Calvert Bluff and Simsboro





Removed area with no pumping and where aquifer is at a depth greater than 3000 feet. Add zones piecemeal as deep monitoring wells come on-line

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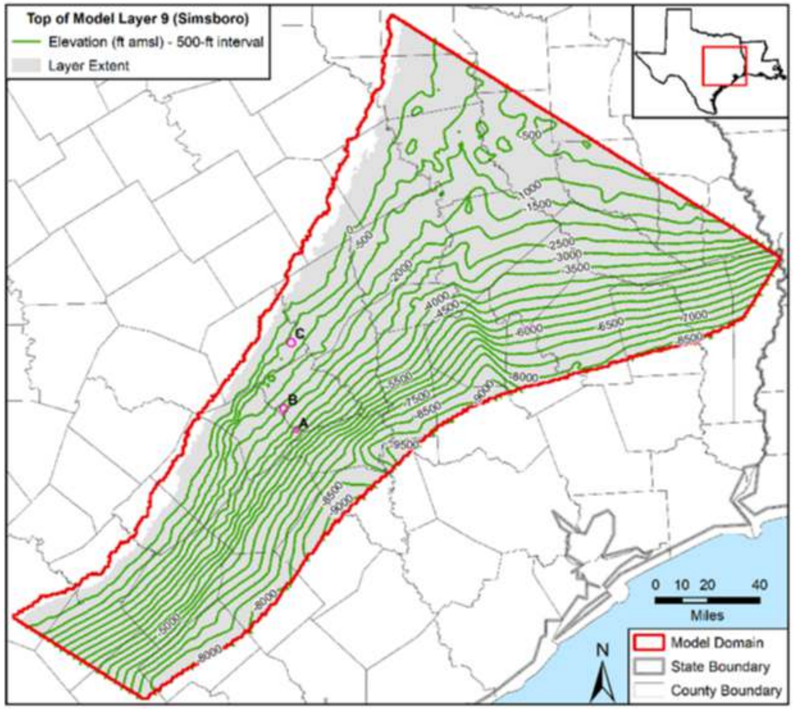
Considerations for Establishing DFCs: Wilcox Aquifer

- Top of the Simsboro Aquifer can be a difficult to distinguish from bottom of Calvert Bluff
- Faults complicate the assignment of wells to upper, middle, and lower Wilcox
- A, B, and C locations shown in map is where current Simsboro tops and bottoms did not align with geophysical logs and changes were made in revised GAM
- Need to evaluate criteria used to assign wells to Wilcox Aquifer – GAM data may not be reliable



Discussion Topics

- Additional POSGCD Example DFC calculation using in unconfined and confined aquifer using "2009 approach"
- Develop improved predicted 2010 to 2069 GAM simulation using better pumping data from 2010 to 2019 and better well placement
- Investigate option of an average water level for DFC
- Aquifer areas other than, or in addition to, the entire aquifer for DFCs
- Identify data gaps and sensitive area in monitoring well network
- Improved stratigraphy for POSGCD
- Coordination with GMA 12