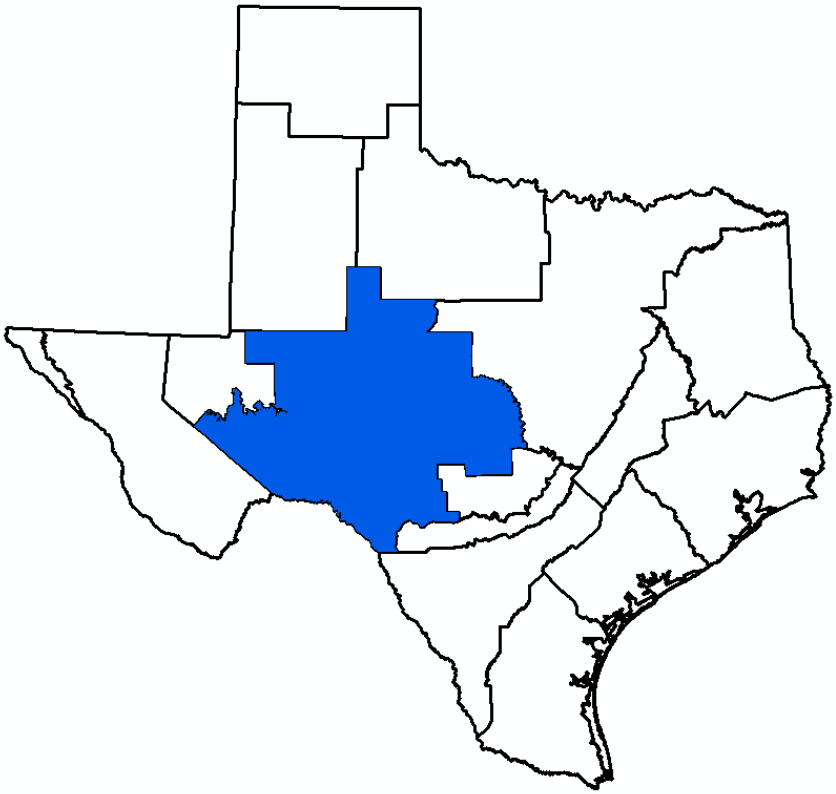
GMA 7 Technical Memorandum 16-01
Final

Dockum and Ogallala Aquifers: Initial Predictive Simulations with HPAS



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Groundwater Management Area 7

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November 18, 2016

GMA 7 Technical Memorandum 16-01, Final
Dockum and Ogallala Aquifer: Initial Predictive Simulations with HPAS

Geoscientist and Engineering Seal

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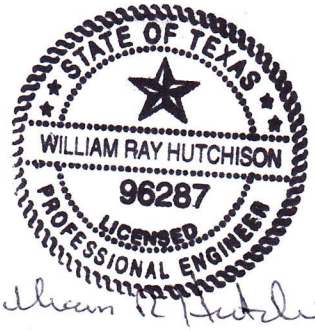

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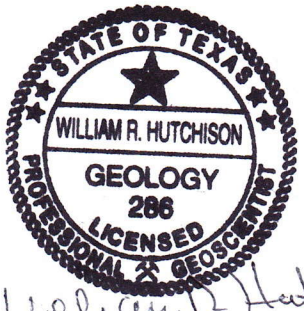

William R Hutchison
11/18/2016

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1.0 Introduction and Objective

This technical memorandum documents initial simulations using the recently released High Plains Aquifer System Groundwater Availability Model (Deeds and Jigmond, 2015). The model is also known as the HPAS GAM, or simply the GAM. The GAM includes the Ogallala, Edwards-Trinity (High Plains), and Dockum aquifers. This technical memorandum covers the results of 15 initial predictive simulations of the Ogallala and Dockum aquifers in GMA 7 (Scenarios 1 to 15), and a final scenario that was completed after GMA 7 reviewed the initial results (Scenario 17). The scenario numbering is not consecutive since Scenario 16 using this GAM was completed for GMA 2, and the results were not relevant to GMA 7.

The objective of these simulations was to take advantage of a feature in the recently released model that differs from the previous version of the GAM. Earlier versions of the GAM required external adjustment of input groundwater pumping rates to avoid dry cells. The new version of the GAM uses the Newton Formulation and the upstream weighting package which automatically reduces pumping as heads drop in a particular cell as defined by the user (Niswonger and others, 2011). This feature provides a means to simulate the declining production of a well as saturated thickness decreases.

Deeds and Jigmond (2015) further enhanced the utility of this new feature by changing the threshold specification of saturated thickness when pumping reductions occur during a simulation. Niswonger and others (2011) used a fraction of cell thickness. As explained by Deeds and Jigmond (2015, pg. 2-27), a disadvantage of this approach is that cells that have an initially high saturated thickness, pumping reduction would occur to rapidly as compared to cells with less saturated thickness. Deeds and Jigmond (2015) modified the code to include a specification of an absolute value of saturated thickness at which pumping would be reduced. During development and calibration of the GAM, Deeds and Jigmond (2015) used a value of 30 feet as the threshold value of saturated thickness.

Scenarios 1 to 15 described in this technical memorandum considered two sets of basic alternatives: 1) varying the value of saturated thickness threshold, and 2) varying the initial pumping for each cell. Scenario 17 represented modifications to initial pumping in Reagan County, Pecos County, and all of GMA 3 in the Dockum Aquifer.

Scenarios 1 to 15 provided a means to understand the sensitivity of increasing and decreasing the saturated thickness threshold value used in the development and calibration of the model (30 feet). For these simulations, the three threshold values were used: 20 feet, 30 feet, and 40 feet. Scenario 17 used a threshold value of 30 feet.

Scenarios 1 to 15 also provided a means to understand the effect of increasing current pumping and, alternatively, reducing current amounts of pumping on long term well production and groundwater level declines. Because the groundwater levels in the Ogallala Aquifer have been declining over recent decades, and because it is recognized that current levels of pumping are likely to decline in future decades due to decreased saturated thickness, these simulations are useful as part of understanding the balance of groundwater conservation and development over a long period of time (58 years). This new version of the GAM represents the first time that a modeling tool can simulate

the declining production rates associated with decreasing saturated thickness without user intervention and multiple iterations to avoid dry cells.

2.0 Description of Simulations

Simulations were run for 58 years (2013 to 2070). Model files for the scenarios were taken from INTERA's deliverable to the TWDB for predictive runs in GMA 1. The only modification to these files for these simulations were the WEL file (input pumping amounts) as described below.

A base case was developed using a saturated thickness threshold of 30 feet (as was used during the development and calibration of the GAM), and pumping equal to 2012 amounts (the last year of model calibration). Other threshold values for saturated thickness (PHIRAMP) that would result in decreased pumping were 20 feet and 40 feet. Other values of initial pumping were 50 percent of 2012 pumping (on a cell by cell basis), 75 percent of 2012 pumping, 125 percent of 2012 pumping and 150 percent of 2012 pumping.

As a result, 15 simulations were run as shown in Table 1.

Table 1. Summary of Simulations

Scenario	Initial Pumping Rate (as a percentage of 2012 pumping)	Saturated Thickness Threshold (PHIRAMP)
1	0.50	20
2	0.75	20
3	1.00	20
4	1.25	20
5	1.50	20
6	0.50	30
7	0.75	30
8 (Base Case)	1.00	30
9	1.25	30
10	1.50	30
11	0.50	40
12	0.75	40
13	1.00	40
14	1.25	40
15	1.50	40

Scenario 17 modified the input pumping for the Dockum Aquifer in Pecos County and all of GMA 3 by setting the pumping to the current values of modeled available groundwater adopted in 2010. Scenario 17 pumping for the Dockum Aquifer in Reagan County was set to 2,000 AF/yr.

3.0 Scenario 1 to 15 Results - Dockum Aquifer

Results for the 15 simulations are summarized by county in appendices and summary tables. Section 3.1 covers the Dockum Aquifer, and Section 3.2 covers the Ogallala Aquifer.

3.1 Summary of Pumping and Drawdown Results

Table 2 summarizes the drawdown in 2070 for all 15 simulations. Please note that the choice of saturated thickness threshold resulted in only minor differences in results.

Appendix A presents graphs of pumping and drawdown, and is organized as follows:

- The cover sheet includes a map of GMA 7 counties for reference purposes.
- Each subsequent page summarizes results for a particular county.
- The upper graph shows the pumping from 1930 to 2012 (from the calibrated GAM), the pumping from Scenarios 6 to 10 (the pumping simulations associated with a saturated thickness threshold of 30 feet) for the years 2013 to 2070. The current modeled available groundwater (MAG) is also shown for reference purposes for the years 2010 to 2060.
- The lower graph shows the county-average drawdown from 2013 to 2070 of Scenarios 5 to 9 (the pumping simulations associated with a saturated thickness threshold of 30 feet). The current DFC in terms of drawdown from 2010 to 2060 is also shown for reference purposes.

3.2 Discussion of Results

The county-by-county discussion is limited to those counties that had DFCs adopted in 2010. As seen in Table 2, there are six counties in which the Dockum Aquifer is present but no DFCs were established as they were designated not relevant for purposes of joint planning.

3.2.1 Ector County

Please note that pumping in Scenario 8 (initial pumping is equal to 2012 pumping) is about the same as the current MAG. However, all drawdown is less than the current DFC. From this, it can be concluded that the HPAS is predicting less drawdown for the same amount of pumping. In fact, the HPAS predicts that drawdown in 2070 would be less than one foot even under increased pumping (up to 1.5 times the 2012 pumping).

3.2.2 Midland County

Please note that there is no historic pumping from the Dockum Aquifer in Midland County. The HPAS simulations show some drawdown in all scenarios despite no pumping in Midland County due to pumping in the surrounding area.

Table 2. Summary of Drawdown for Dockum Aquifer

Dockum Aquifer
Simulated Drawdown (ft) from 2012 to 2070
Average Drawdown by County - GMA 7

Scenario	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Saturated Thickness Threshold (ft)	20					30					40				
Initial Pumping Factor (applied to 2012 pumping in HPAS GAM)	0.50	0.75	1.00	1.25	1.50	0.50	0.75	1.00	1.25	1.50	0.50	0.75	1.00	1.25	1.50
Counties with DFC in 2010															
Ector	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1
Midland	2	2	2	2	3	2	2	2	2	3	2	2	2	2	2
Mitchell	0	2	3	3	4	0	2	3	3	4	0	2	3	3	4
Nolan	7	7	8	8	8	6	7	7	8	8	6	7	7	7	8
Pecos	11	12	12	13	14	11	12	12	13	14	11	12	12	13	14
Scurry	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Upton	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Counties without DFC in 2010															
Coke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crockett	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Glasscock	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Irion	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Reagan	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
TomGreen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Based on this finding, it is recommended that the Dockum Aquifer in Midland County be designated as not relevant for purposes of joint planning.

3.3.3 Mitchell County

Please note that pumping in Scenarios 8, 9 and 10 (initial pumping set to 1.0, 1.25, and 1.5 of 2012 pumping, respectively) declines over time. By 2070, the pumping would decline to about 11,000 AF/yr. In this area, the lower Dockum Aquifer (Layer 4 of the HPAS) is the surficial layer, and this is a result of declining heads and declining saturated thickness.

Thus, if the HPAS is used as the basis for a DFC, the MAG will decline over the planning period as a result of the declining saturated thickness.

3.3.4 Nolan County

Similar to Nolan County, the simulations show that pumping will decline over time as a result of decreased saturated thickness. The decline is projected to be more rapid than in Mitchell County,

Thus, if the HPAS is used as the basis for a DFC, the MAG will decline over the planning period as a result of the declining saturated thickness.

3.3.5 Pecos County

The existing MAG is about the same as the pumping in Scenario 8, which is about the same as the 2012 historic pumping.

However, the existing DFC is zero drawdown, and the drawdown for the five scenarios presented ranges from about 10 feet to about 14 feet.

3.3.6 Scurry County

Please note that the current MAG is well below the historic pumping. The MAG is low enough that there is essentially no drawdown (DFC of zero).

The HPAS simulations have pumping ranging from about 4,000 AF/yr to about 12,000 AF/yr, and drawdowns range from about a foot to about 5 feet.

3.3.7 Upton County

The drawdown in Upton County from the HPAS is less than the drawdown from the old Dockum model as seen in the graphs. The current DFC is about 4 feet with about pumping about 200 AF/yr. The HPAS simulations show drawdown of a little more than a foot with pumping ranging from about 150 AF/yr to about 500 AF/yr.

4.0 Scenario 1 to 15 Results - Ogallala Aquifer

4.1 Summary of Pumping, Drawdown and Storage Remaining Results

Table 3 summarizes the drawdown and storage remaining in 2070 for all 15 simulations. Please note that the choice of saturated thickness threshold resulted in only minor differences in results.

Appendix B presents graphs of pumping and drawdown, and is organized as follows:

- The cover sheet includes a map of GMA 7 counties for reference purposes.
- Each subsequent page summarizes results for a particular county.
- The upper graph shows the pumping from 1930 to 2012 (from the calibrated GAM), the pumping from Scenarios 6 to 10 (the pumping simulations associated with a saturated thickness threshold of 30 feet) for the years 2013 to 2070. The current modeled available groundwater (MAG) is also shown for reference purposes for the years 2010 to 2060.
- The lower graph shows the county-average drawdown from 2013 to 2070 of Scenarios 5 to 9 (the pumping simulations associated with a saturated thickness threshold of 30 feet). The current DFC in terms of drawdown from 2010 to 2060 is also shown for reference purposes.

Appendix C presents graphs of pumping and remaining storage volume, and is organized as follows:

- The cover sheet includes a map of GMA 7 counties for reference purposes.
- Each subsequent page summarizes results for a particular county.
- The upper graph shows the pumping from 1930 to 2012 (from the calibrated GAM), the pumping from Scenarios 6 to 10 (the pumping simulations associated with a saturated thickness threshold of 30 feet) for the years 2013 to 2070. The current modeled available groundwater (MAG) is also shown for reference purposes for the years 2010 to 2060.
- The lower graph shows the storage remaining in each year (2013 to 2070) as a percentage of the initial storage (2012) for Scenarios 5 to 9 (the pumping simulations associated with a saturated thickness threshold of 30 feet). The current DFC in terms of storage remaining from 2010 to 2060 is also shown for reference purposes.

4.2 Discussion of Results

4.2.1 Ector County

Please note that the historic pumping from about 2003 to 2012 is much lower than pumping from 1960 to about 2000. Since future pumping is tied to the 2012 pumping, simulated future pumping is very low, and the HPAS simulates a small recovery that would continue through 2070 that is directly related to this reduction in pumping.

Table 3. Summary of Drawdown and Storage Remaining for Ogallala Aquifer

Ogallala Aquifer
Simulated Drawdown (ft) and Storage Volume Remaining from 2012 to 2070
Average Drawdown by County - GMA 7

Scenario	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Saturated Thickness Threshold (ft)	20					30					40				
Initial Pumping Factor (applied to 2012 pumping in HPAS GAM)	0.50	0.75	1.00	1.25	1.50	0.50	0.75	1.00	1.25	1.50	0.50	0.75	1.00	1.25	1.50
Average Drawdown by County - GMA 7															
Ector	-2	-2	-2	-2	-1	-2	-2	-2	-2	-1	-2	-2	-2	-2	-2
Glasscock	-3	0	2	5	7	-3	0	2	5	6	-3	0	2	4	6
Midland	1	4	5	7	8	1	3	5	7	8	1	3	5	7	8
Storage Volume Remaining in 2070 (as a percentage of 2012 storage) - GMA 7															
Ector	105	104	104	104	104	105	104	104	104	104	105	105	104	104	104
Glasscock	104	100	96	92	89	104	100	96	93	90	104	100	96	93	91
Midland	98	92	88	84	81	98	92	88	85	82	98	93	89	85	82

The current MAG is set for a level of pumping that reflects pumping during the 1970s. For purposes of joint planning, it may be reasonable to set the pumping at a higher rate to reflect the historic pumping (i.e. pumping in the 8,000 to 10,000 AF/yr range).

4.2.2 Glasscock County

The historic pumping from the Ogallala Aquifer has been relatively consistent in Glasscock County since the 1980s. The DFC that was adopted in 2010 called for 50 percent of the volume to remain in 2060. Thus, there was a large increase in pumping that was reduced from 2010 to 2060 (the black line that represents the current MAG).

The HPAS simulation simply used the 2012 pumping as a starting point. Given the low rate of simulated pumping compared to the MAG, it is not surprising that the drawdown is lower and the remaining storage is higher than the DFC condition.

Scenario 10 in Glasscock County results in initial pumping of 8,019 AF/yr in 2013 and reduces to 6,577 AF/yr in 2070. By comparison, pumping in 2012 was estimated to be 5,346 AF/yr. Average drawdown from 2012 to 2070 in Scenario 10 is 6 feet.

4.2.3 Midland County

The simulation results in Ector and Glasscock counties suggest that the model simulations can be updated with pumping rates to match the policy choices of the GMA 7 representatives (i.e. increasing the simulated pumping to more closely match the existing MAG). The simulation results in Midland County, however, suggest that similar adjustments may not be possible.

Please note that the simulated pumping in Midland County in Scenarios 8, 9 and 10 (1.0, 1.25 and 1.50 of 2012 pumping, respectively), decrease over time as a result of decreasing saturated thickness. Storage remaining in 2070, however, is greater than 80 percent. The current DFC calls for 50 percent remaining in 2060.

Based on these results with the new HPAS GAM, it appears that the only way to achieve 50 percent remaining would be to increase pumping to extraordinarily high rates as compared to historic pumping. However, this pumping would not remain at the high rates, and would decrease in time to levels of between 10,000 and 15,000 AF/yr after a few years. Essentially, meeting a 50/50 type objective would simply be an exercise in increasing pumping for a few years and observing sharp declines to a lower and nearly sustainable rate of around 10,000 to 15,000 AF/yr.

The new GAM (the HPAS) is an updated tool that replaces the old Ogallala GAM that was the basis for the current DFC and MAG. However, use of this new tool and the updated information that it yields will likely result in a reduced MAG in Midland County. It would be reflective of the updated model. However, this reduction in the MAG could be easily misinterpreted and misused.

An example of this is the recently released report by TWDB (Hermitte and others, 2015). This report summarizes differences between 2012 State Water Plan groundwater availability numbers

and the MAGs developed from the DFCs that were adopted in 2010. There are many reasons for the noted differences, but Hermitte and others (2015) provided no context to the changes. In fact, there was no opportunity for stakeholders to provide comments to this report, it simply was published. In many cases, the differences are directly attributable to updates in models, and the improved understanding that is the result of updating a model. However, the data and comparisons in this report provide opportunities to mischaracterize these differences as simple policy choices to reduce groundwater availability. It is unfortunate that Hermitte and others (2015) chose not to provide context to their comparisons, and leave so much room for misinterpretation of a complex process that relies on imperfect models.

In this case, it is likely that the available groundwater in Midland County from 2050 to 2070 will be about one-third of the previous availability (from the 2010 MAG). Simply increasing the pumping over the next few years to achieve an arbitrary 50/50 standard will not change the pumping rates from 2050 to 2070, and pumping in those years would be lower than the current MAG.

Scenario 10 yields an initial pumping higher than historic pumping and would result in pumping rates that are about 15,000 AF/yr by the end of the planning period (2070).

5.0 Scenario 17 Results

The initial 15 scenarios were reviewed at the GMA 7 meeting on January 14, 2016. As a result of this review, Scenario 17 was developed in response to two specific requests. In Pecos County and all of GMA 3, Middle Pecos GCD requested that pumping in the Dockum Aquifer be set to the modeled available groundwater that was established in 2010. These values were considerably higher than the pumping in Scenarios 1 to 15, which relied on historic pumping.

In addition, Santa Rita GCD requested that pumping from the Dockum Aquifer in Reagan County be set at 2000 AF/yr, which is the approximate pumping in 1999. Pumping from the Dockum Aquifer in Reagan County has been considerably less than the historic maximum from 2000 to 2012. The Dockum Aquifer had been classified as not relevant for purposes of joint planning in Reagan County by GMA 7 in 2010.

Decadal pumping and drawdown results are summarized in Table 4.

Table 4. Summary of Scenario 17 Results - Dockum Aquifer

Year	Pecos County		Reagan County	
	Pumping (AF/yr)	Drawdown (ft from 2012)	Pumping (AF/yr)	Drawdown (ft from 2012)
2020	17,976	20	2,138	5
2030	17,976	32	2,138	9
2040	17,976	39	2,138	11
2050	17,976	44	2,138	12
2060	17,976	48	2,138	13
2070	17,888	52	2,138	14

6.0 References

Deeds, N.E. and Jigmond, M., 2015. Numerical Model Report for the High Plains Aquifer System Groundwater Availability Model. Prepared by INTERA Incorporated for Texas Water Development Board, 640p.

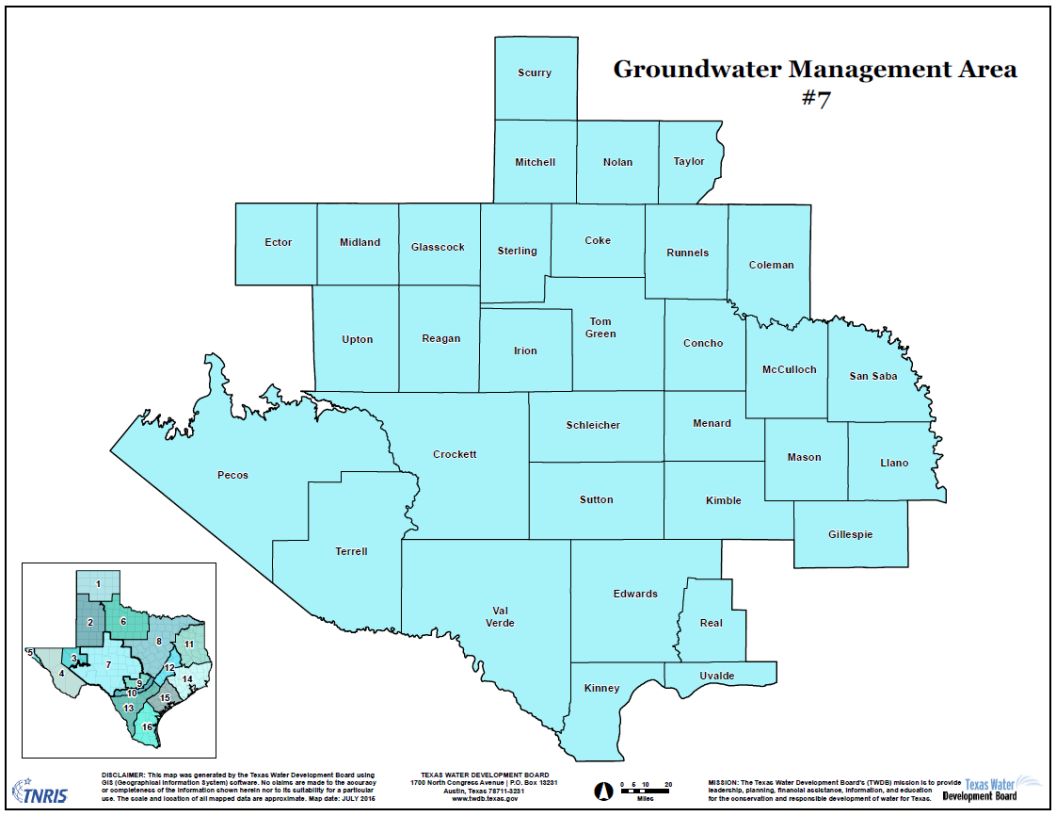
Hermitte, S.M., Backhouse S., Kalaswad, S., and Mace, R.E., 2015. Groundwater Availability in Texas: Comparing Estimates from the 2012 State Water Plan and Desired Future Conditions. Texas Water Development Board Technical Note 15-05. August 2015, 102p.

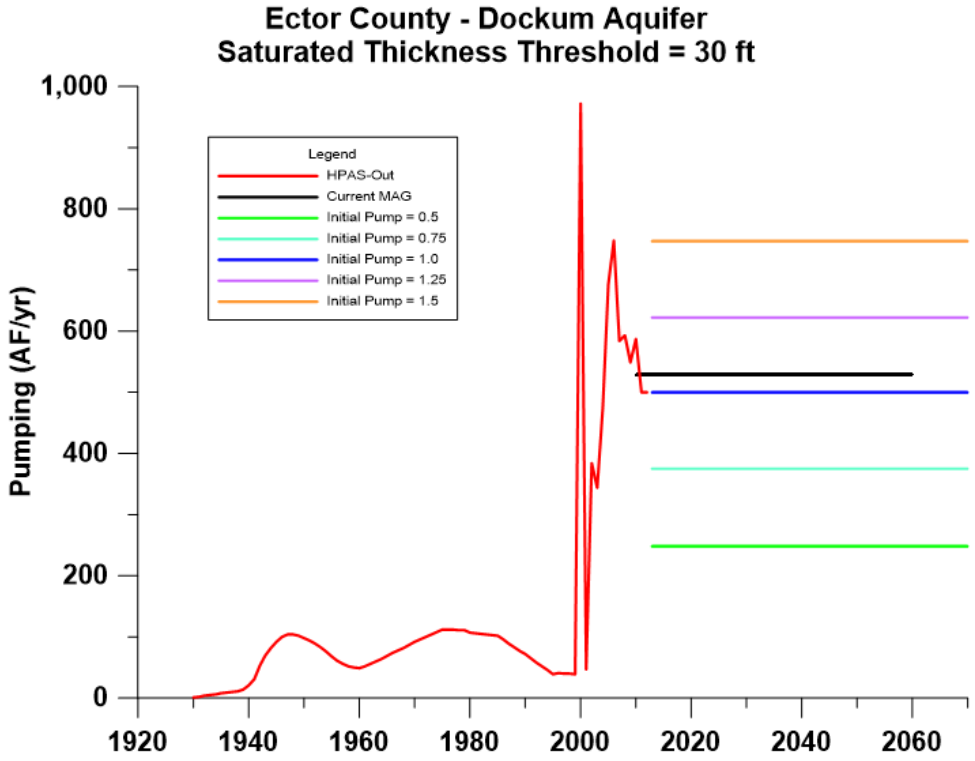
Niswonger, R.G., Panday, S., and Ibaraki, M., 2011. MODFLOW-NWT, A Newton Formulation for MODFLOW-2005.

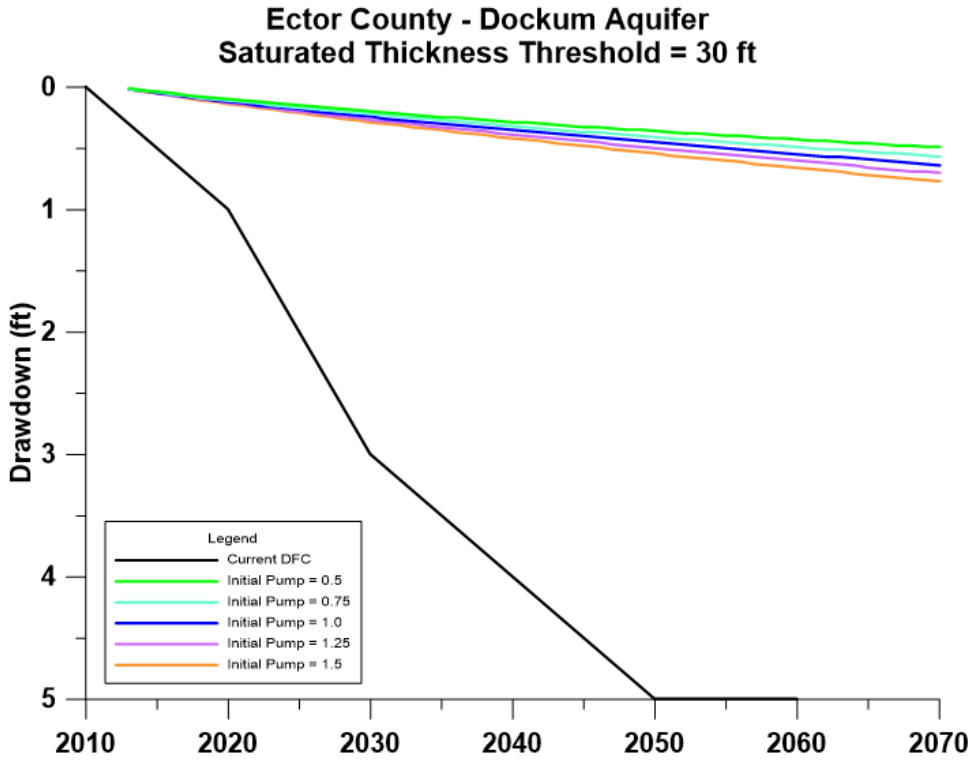
Appendix A

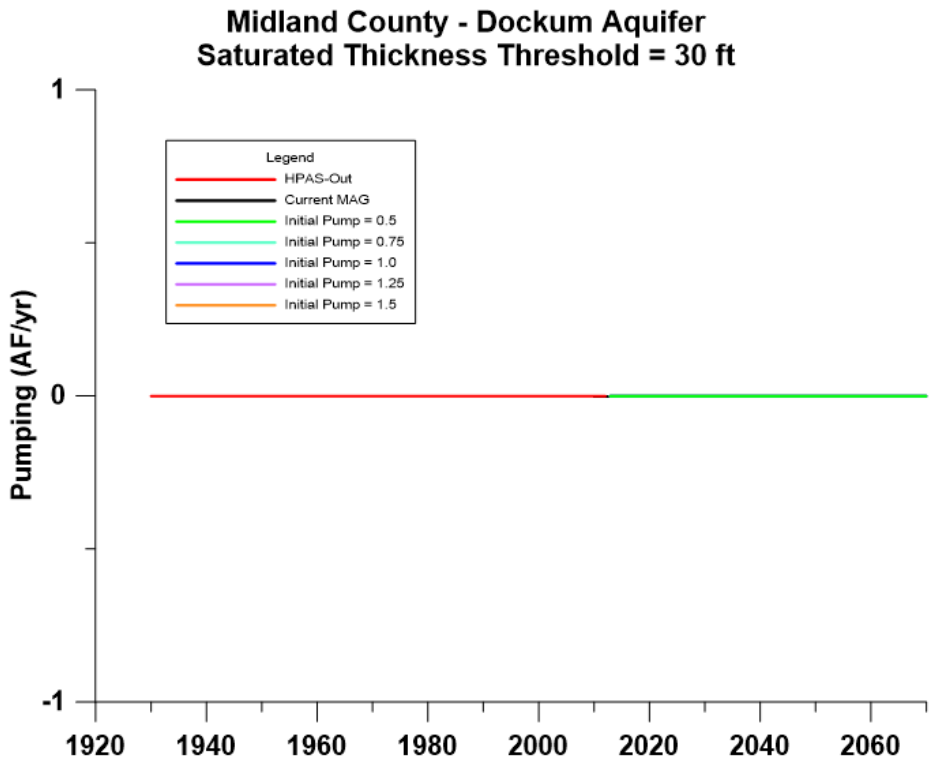
Dockum Aquifer

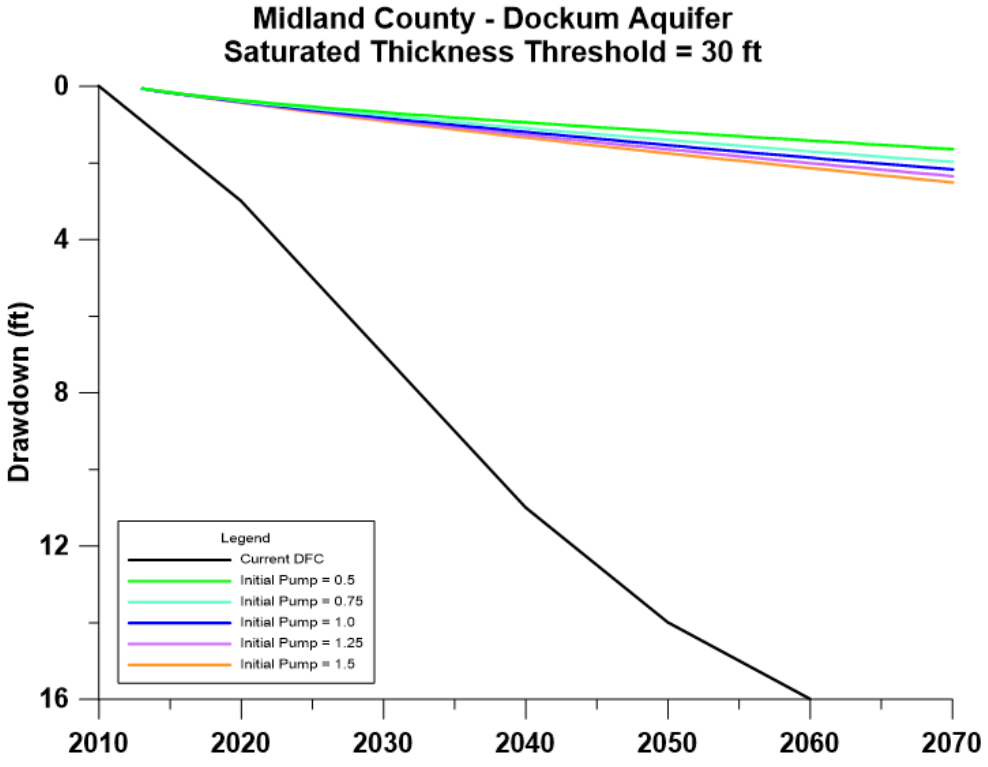
Hydrographs of Pumping and Drawdown for Each County in GMA 7

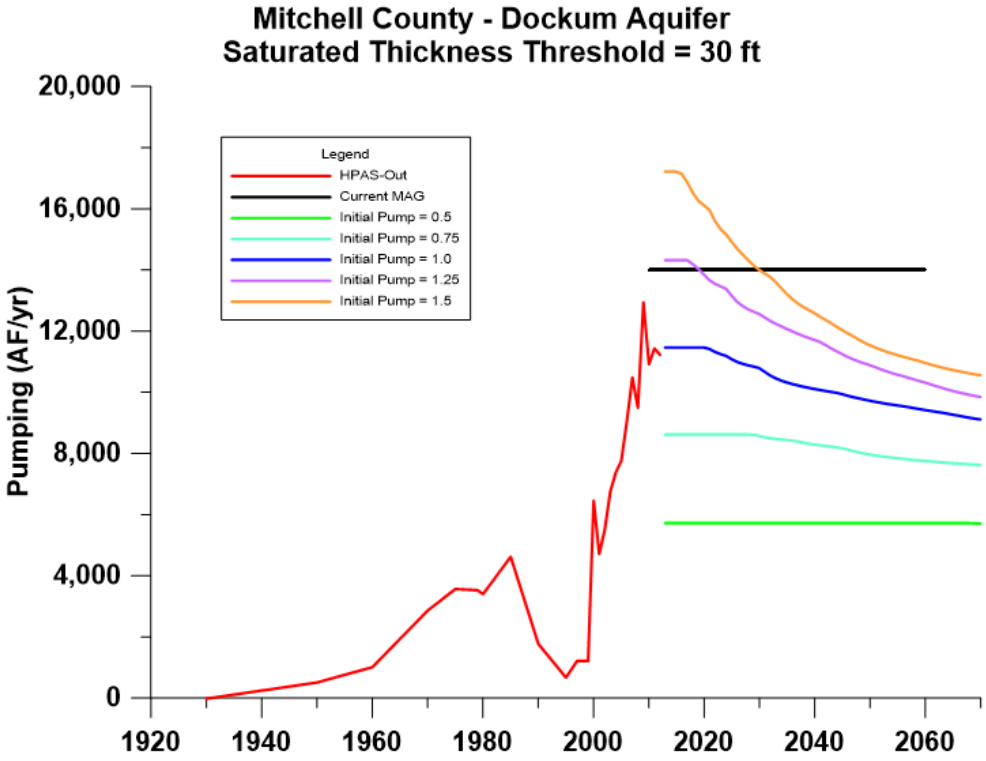


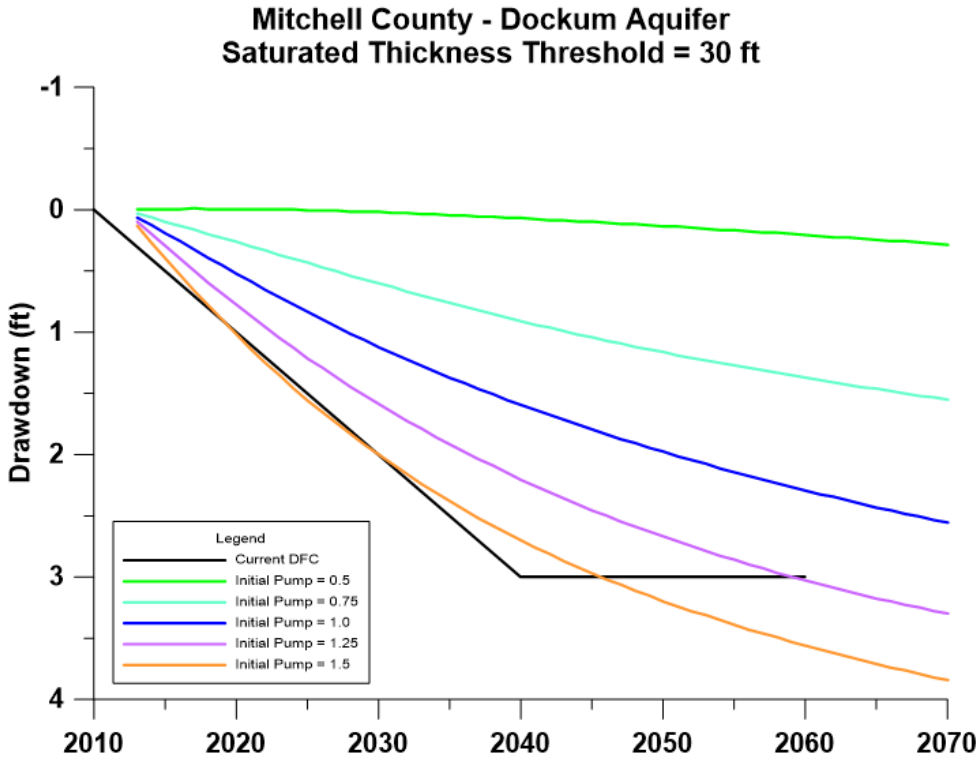

Ector County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
1,000
800
600
400
200
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

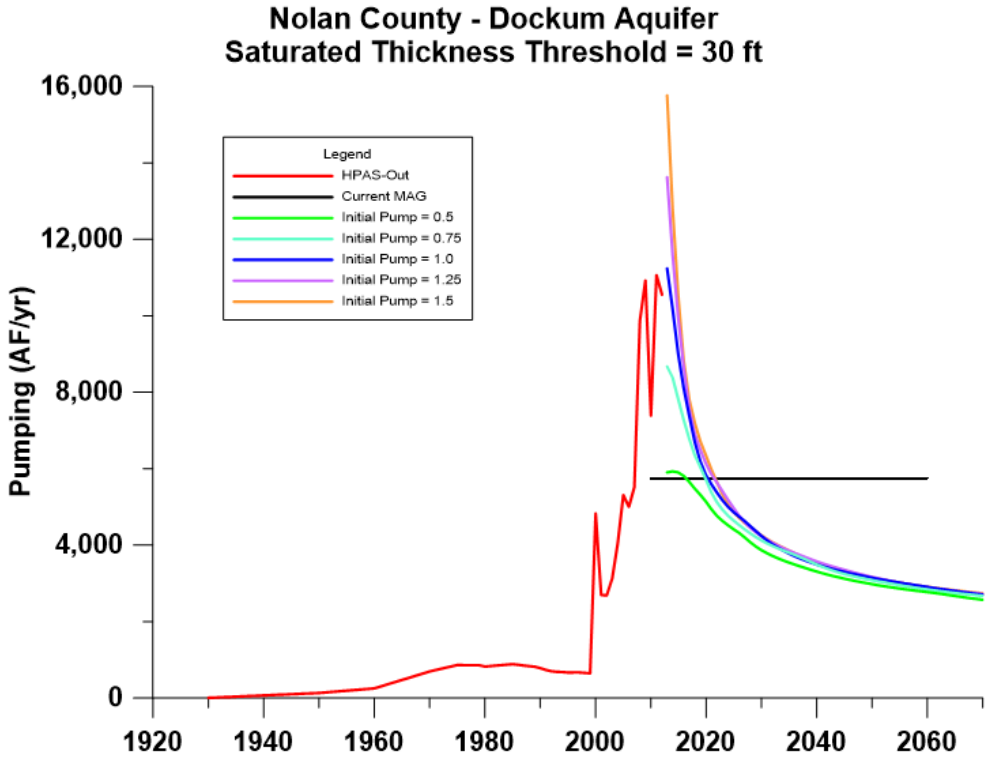

Ector County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
0
1
2
3
4
5
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

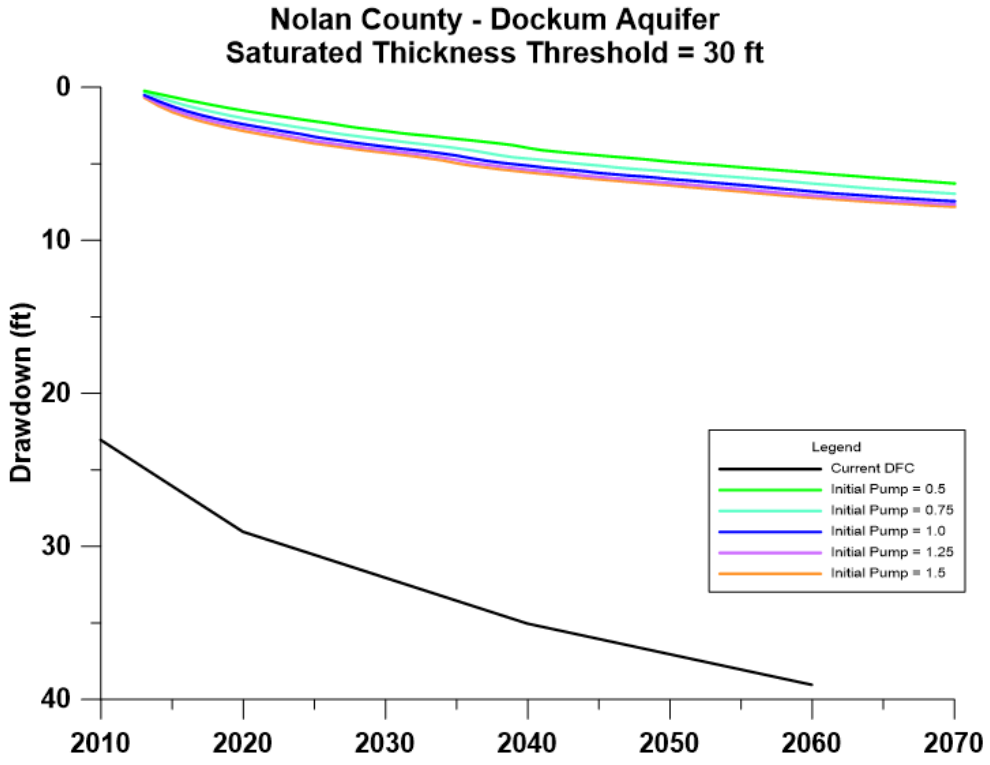

Midland County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
1
0
-1
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

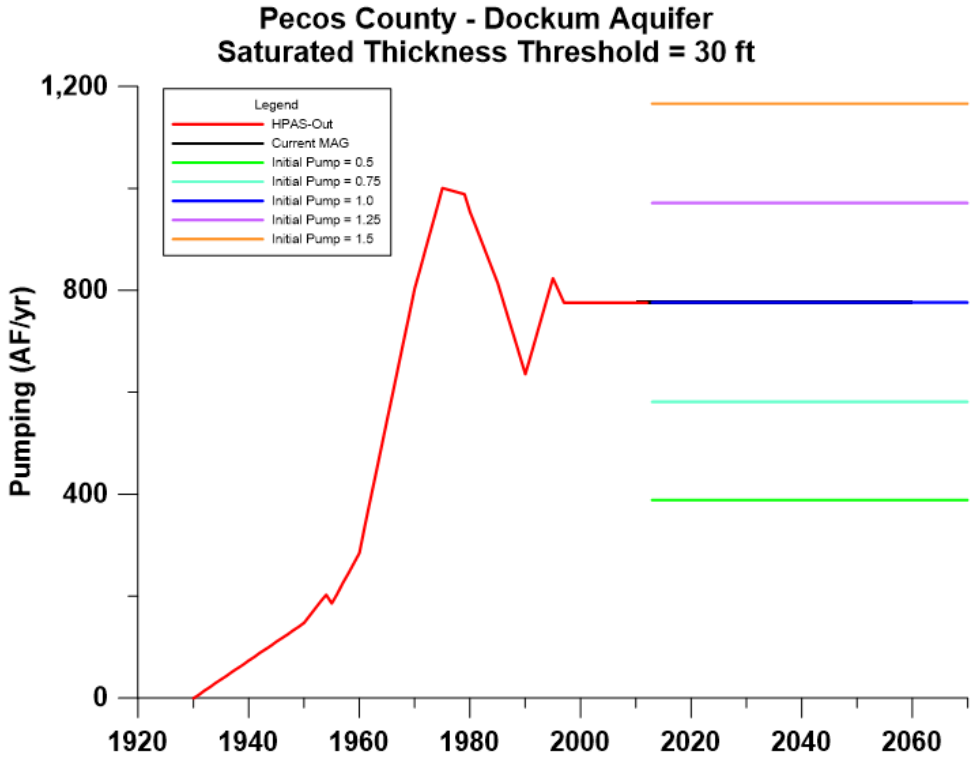

Midland County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
0
4
8
12
16
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

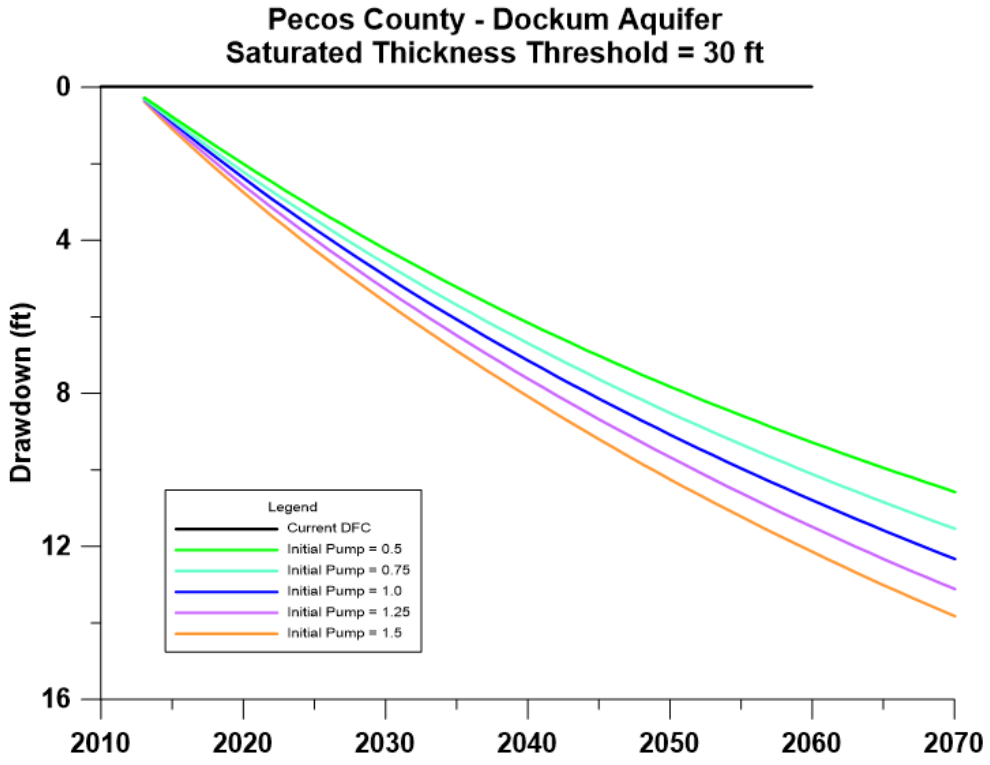

Mitchell County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
20,000
16,000
12,000
8,000
4,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

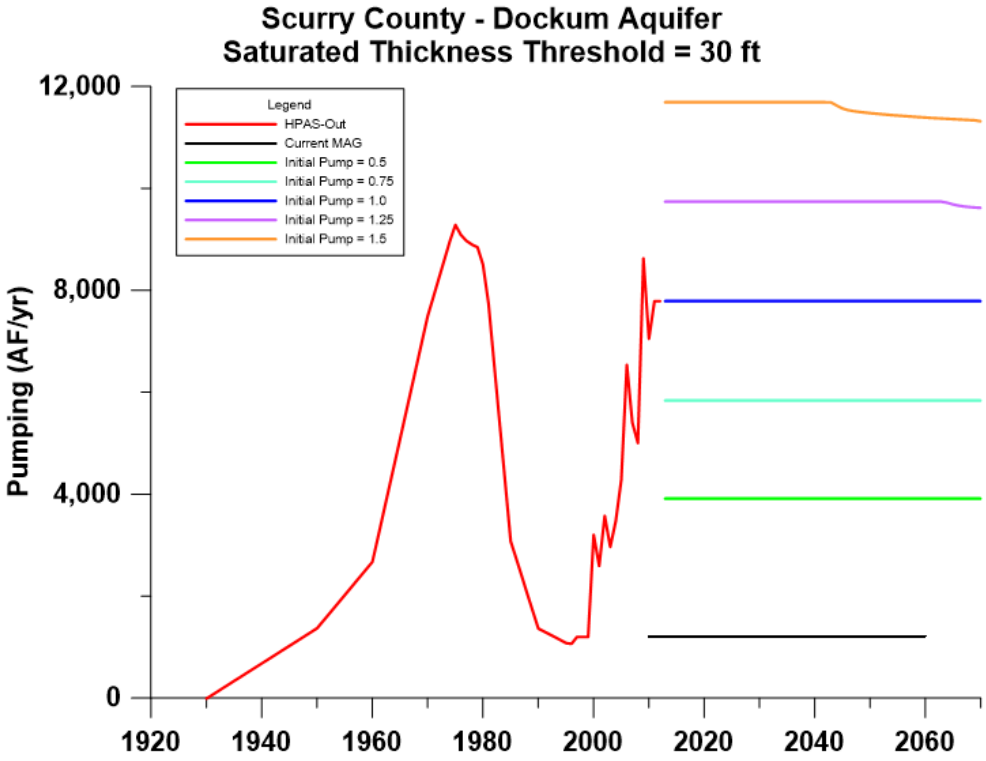

Mitchell County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
-1
0
1
2
3
4
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

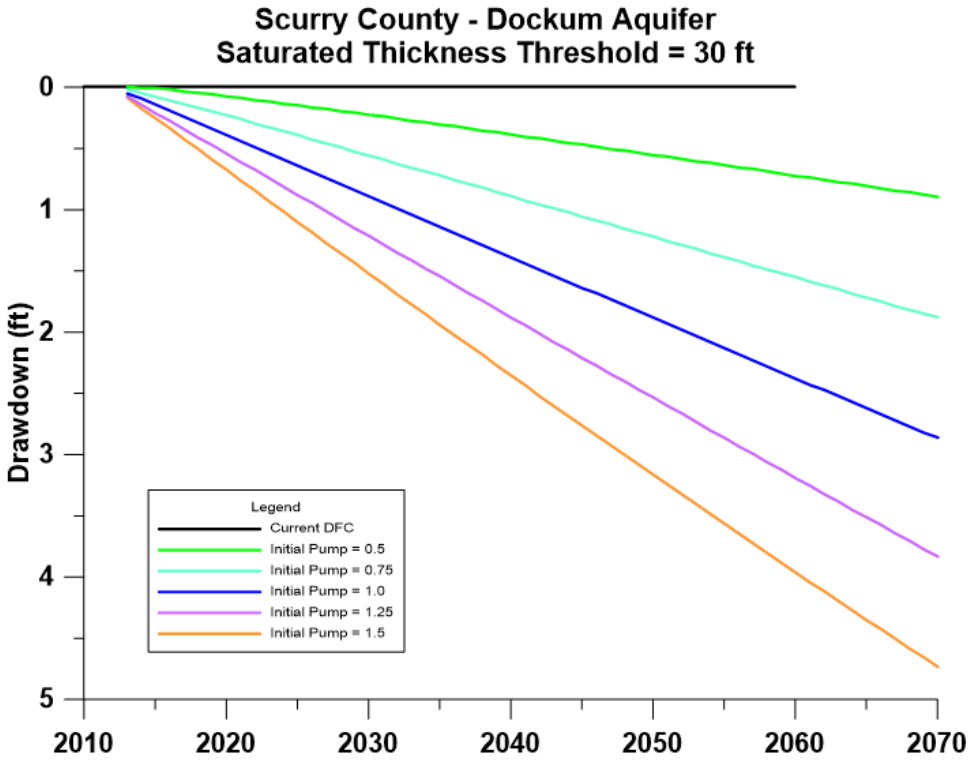

Nolan County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
16,000
12,000
8,000
4,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

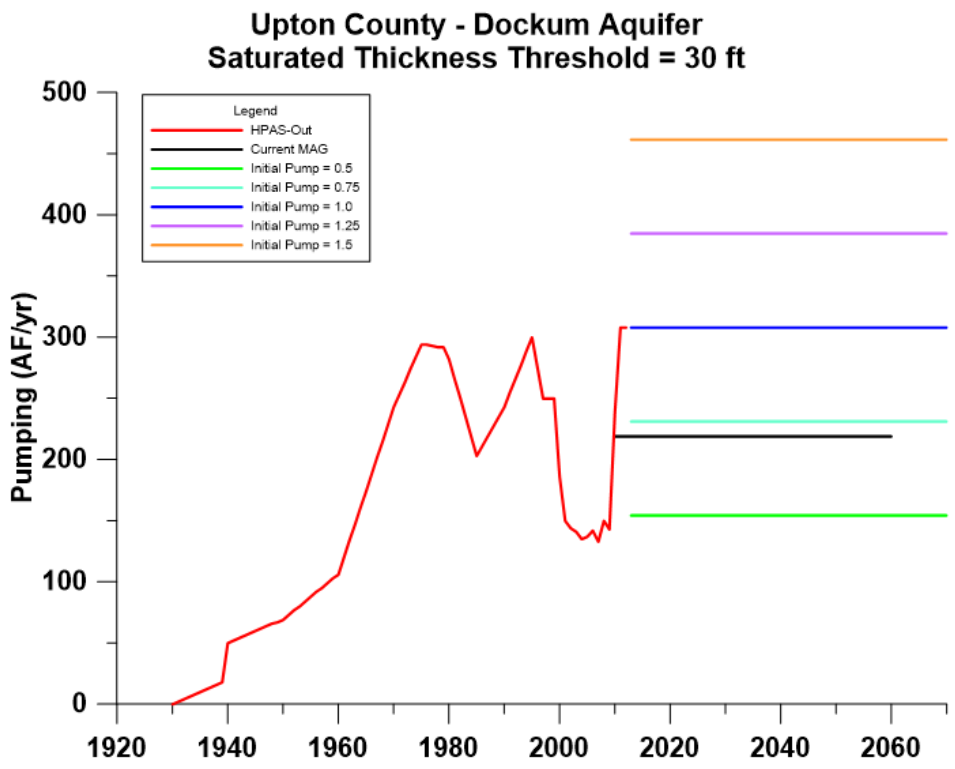

Nolan County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
0
10
20
30
40
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

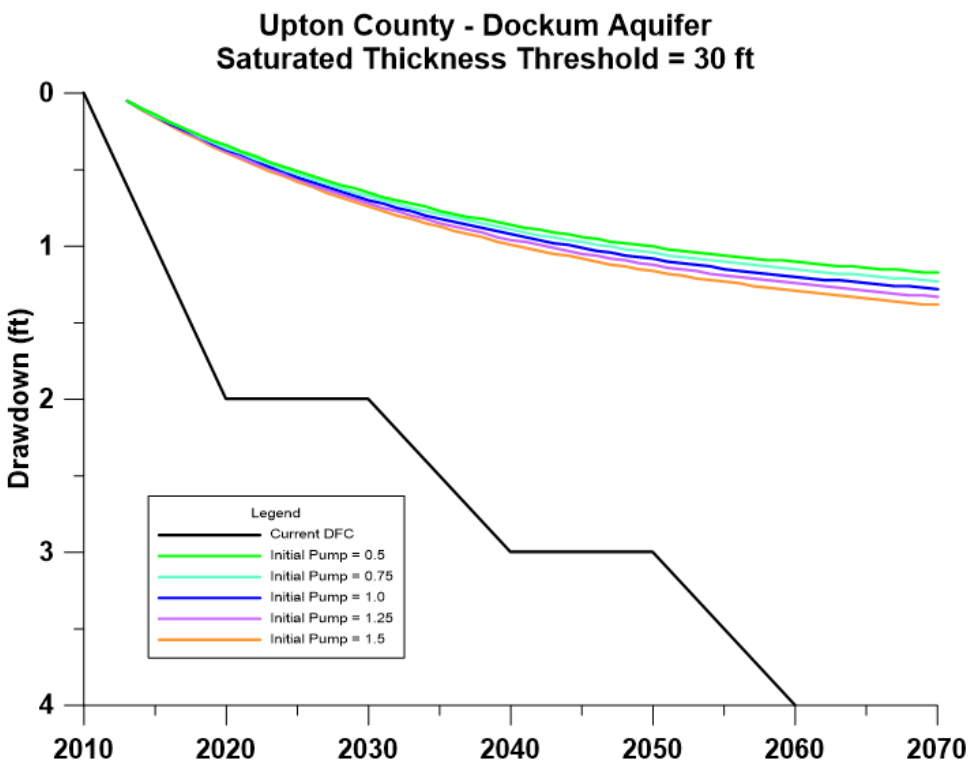

Pecos County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
1,200
800
400
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Pecos County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
0
4
8
12
16
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Scurry County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
12,000
8,000
4,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Scurry County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
0
1
2
3
4
5
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

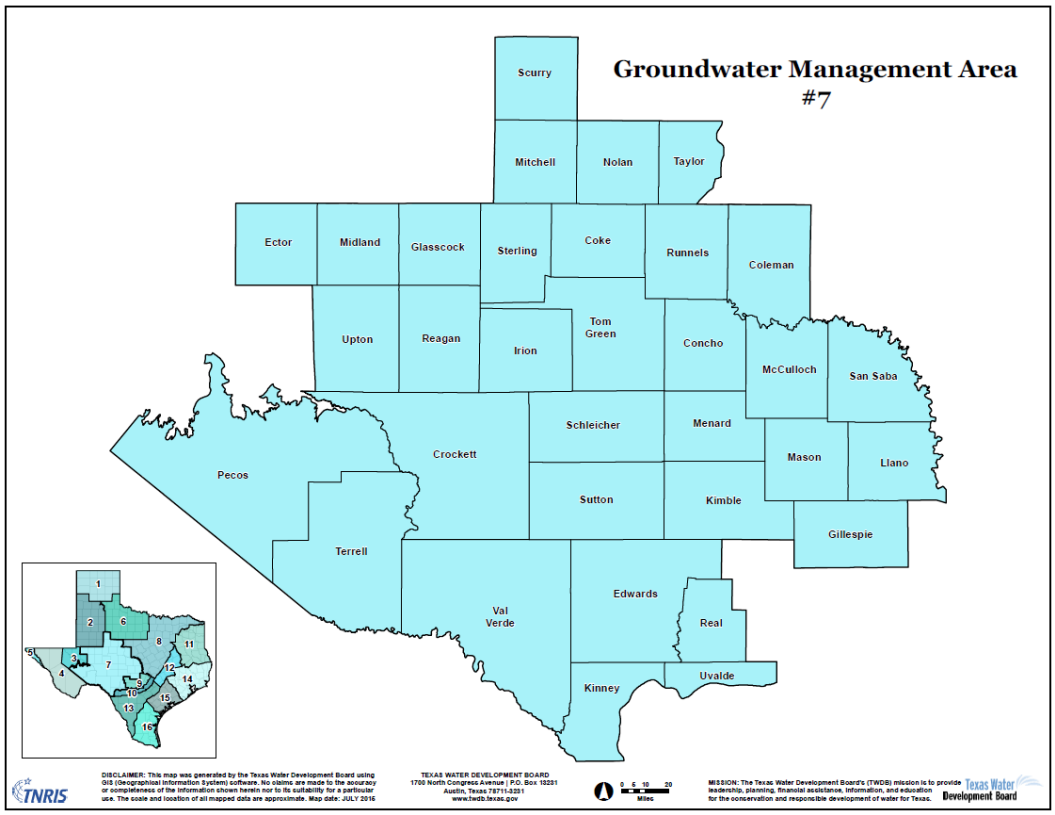

Upton County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
500
400
300
200
100
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

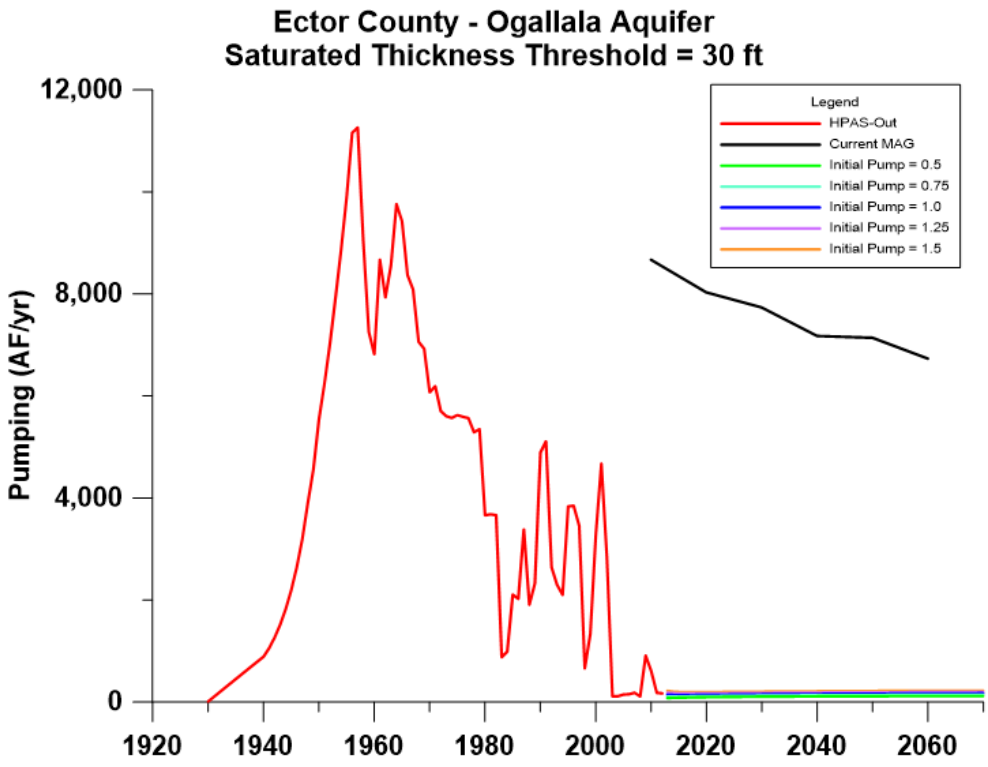

Upton County - Dockum Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
0
1
2
3
4
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

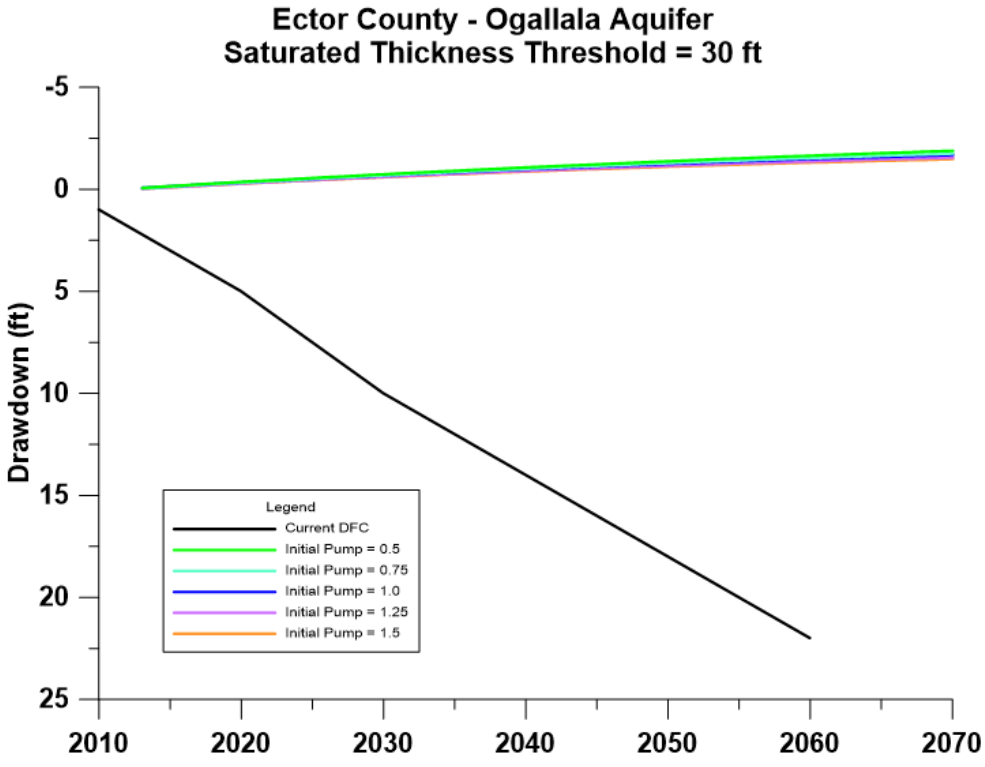
Appendix B

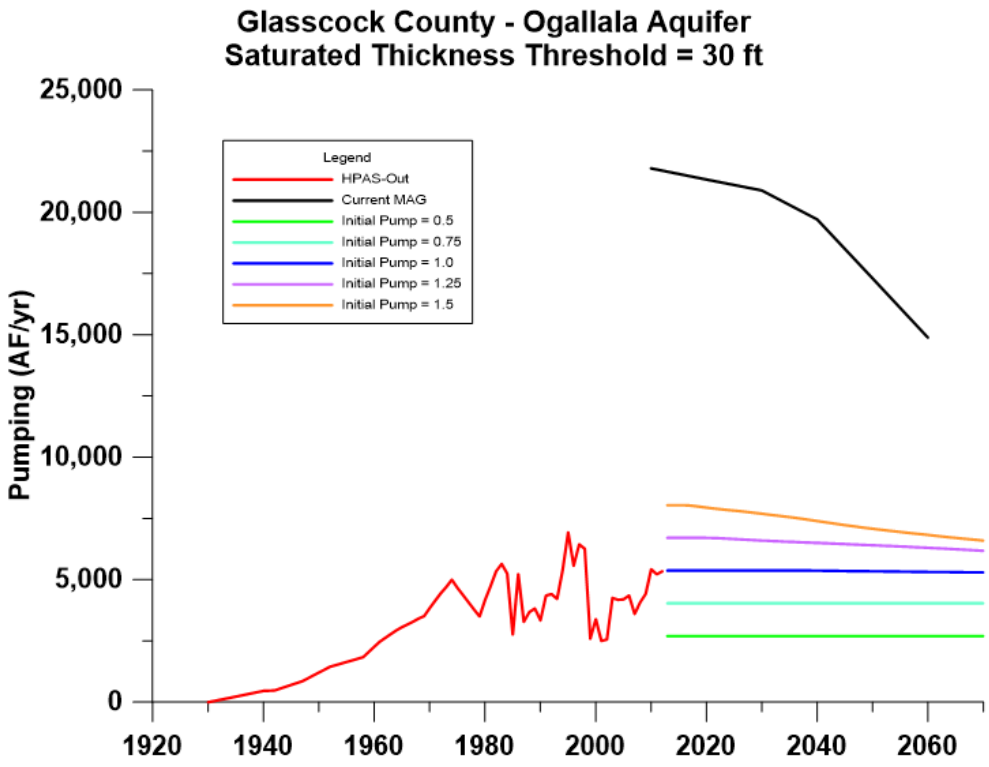
Ogallala Aquifer

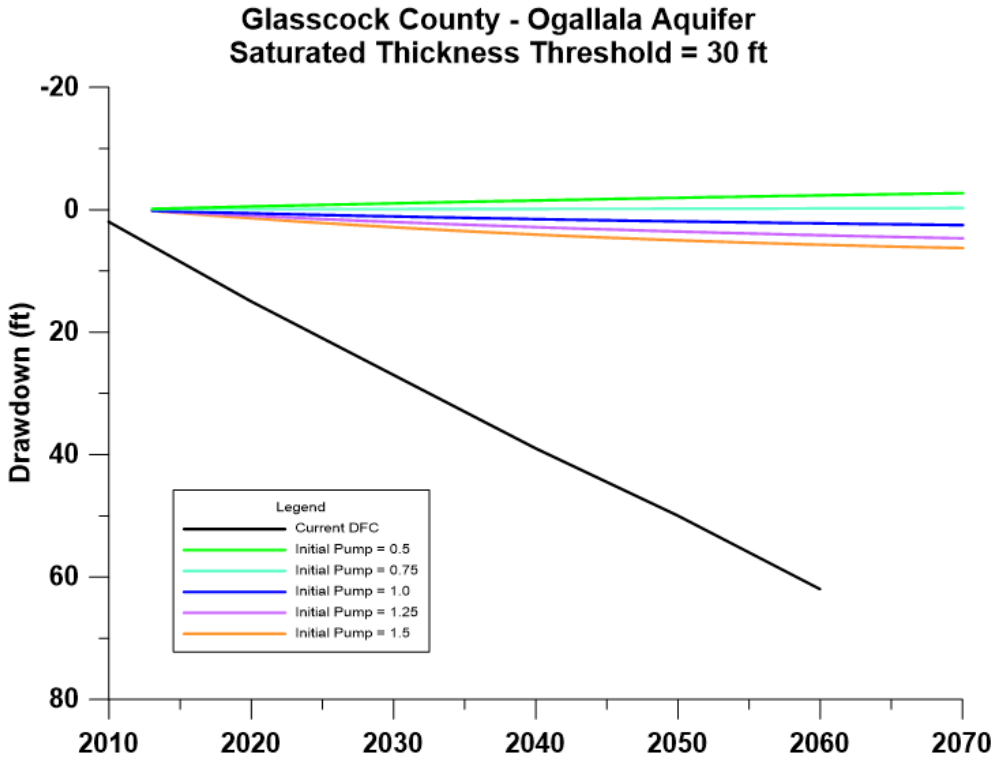
Hydrographs of Pumping and Drawdown for Each County in GMA 7

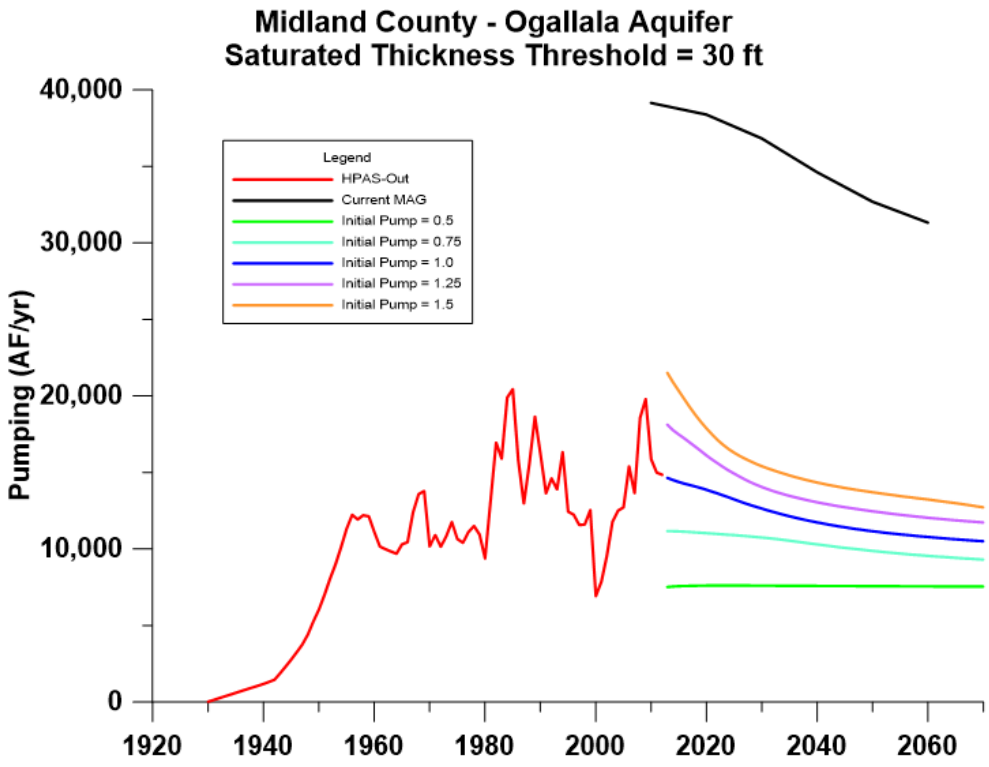


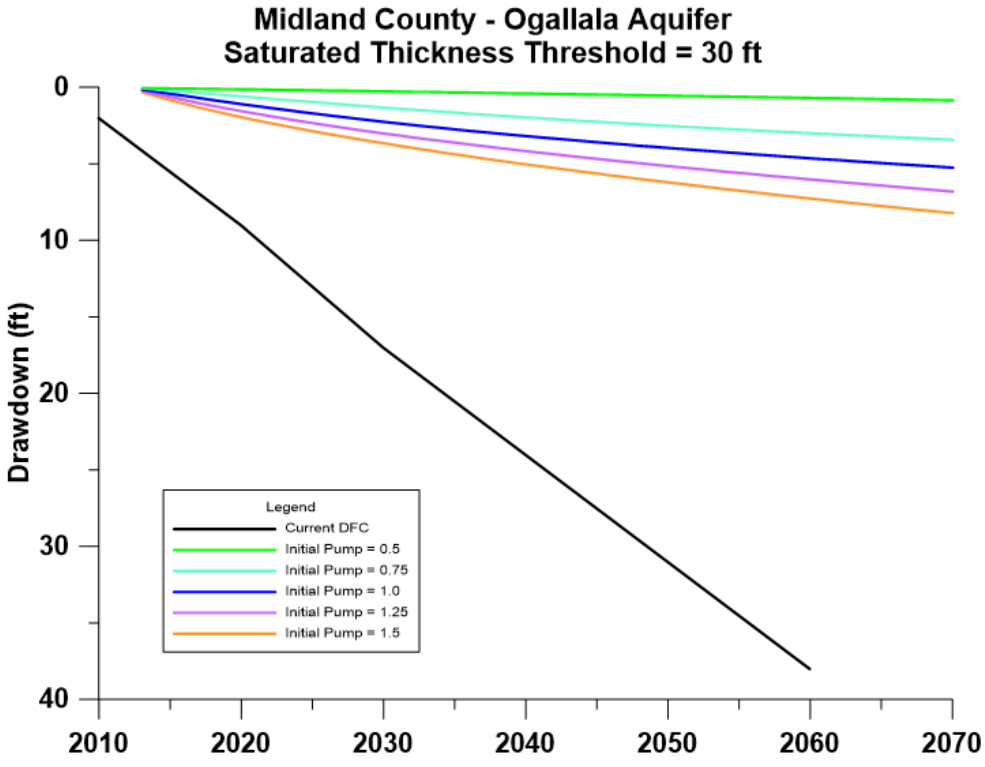

Ector County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
12,000
8,000
4,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Ector County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
-5
0
5
10
15
20
25
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Glasscock County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
25,000
20,000
15,000
10,000
5,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Glasscock County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
-20
0
20
40
60
80
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

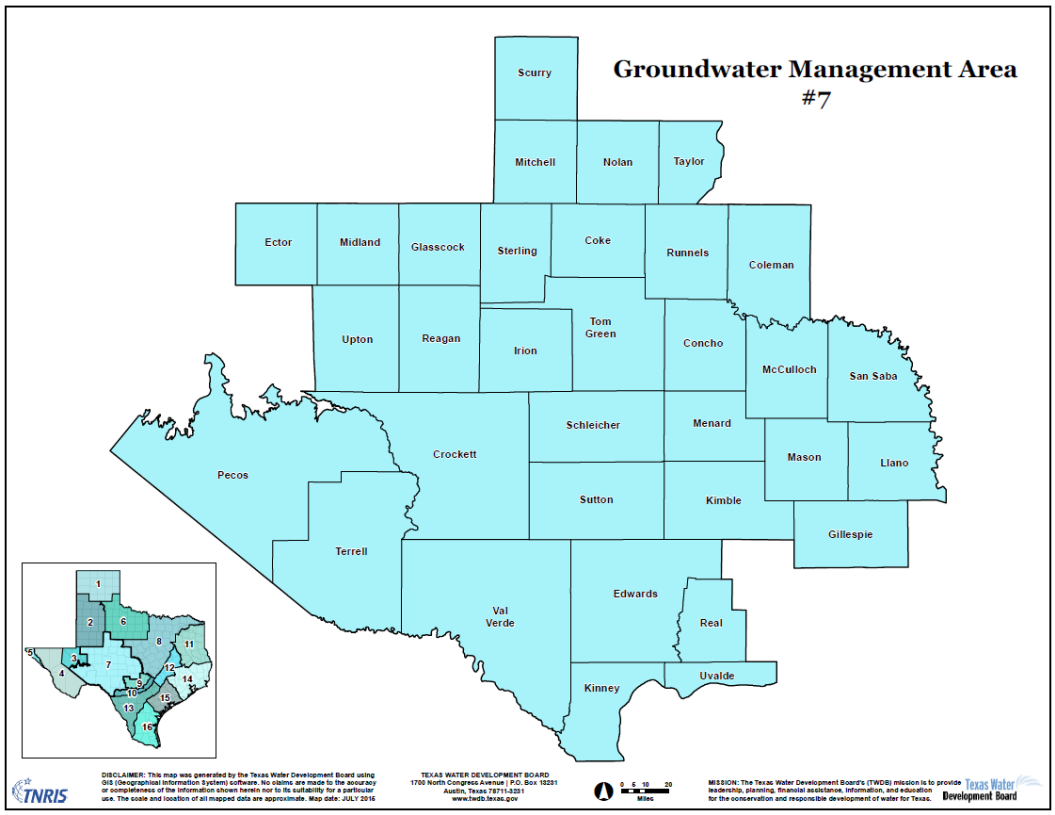

Midland County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
40,000
30,000
20,000
10,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

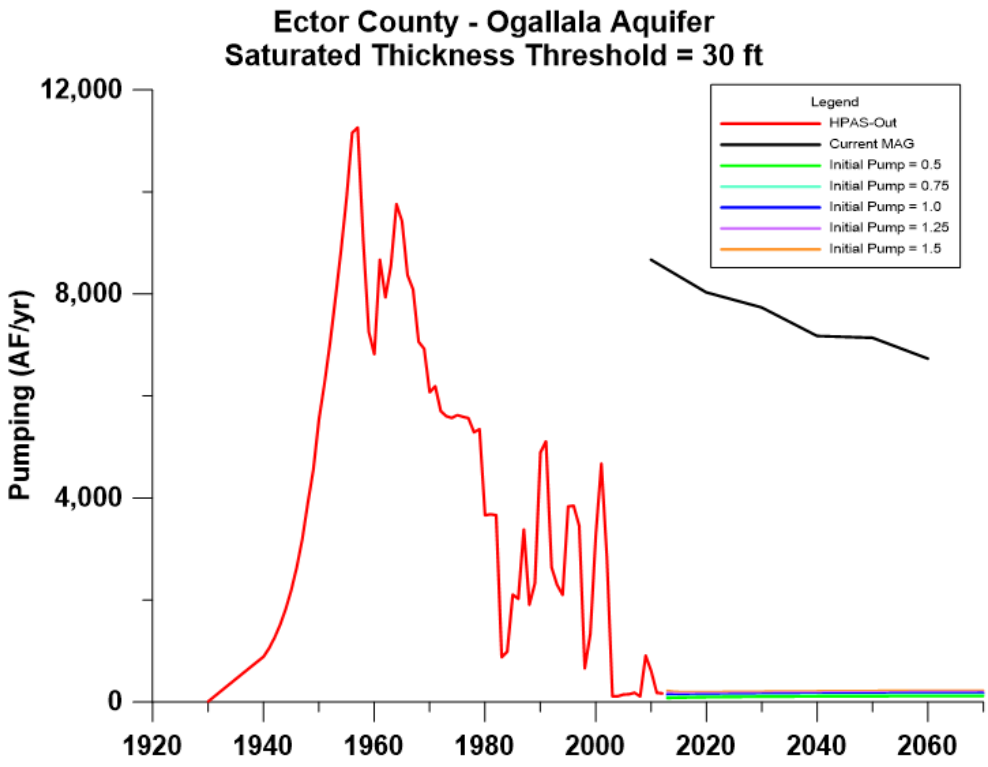

Midland County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Drawdown (ft)
0
10
20
30
40
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5

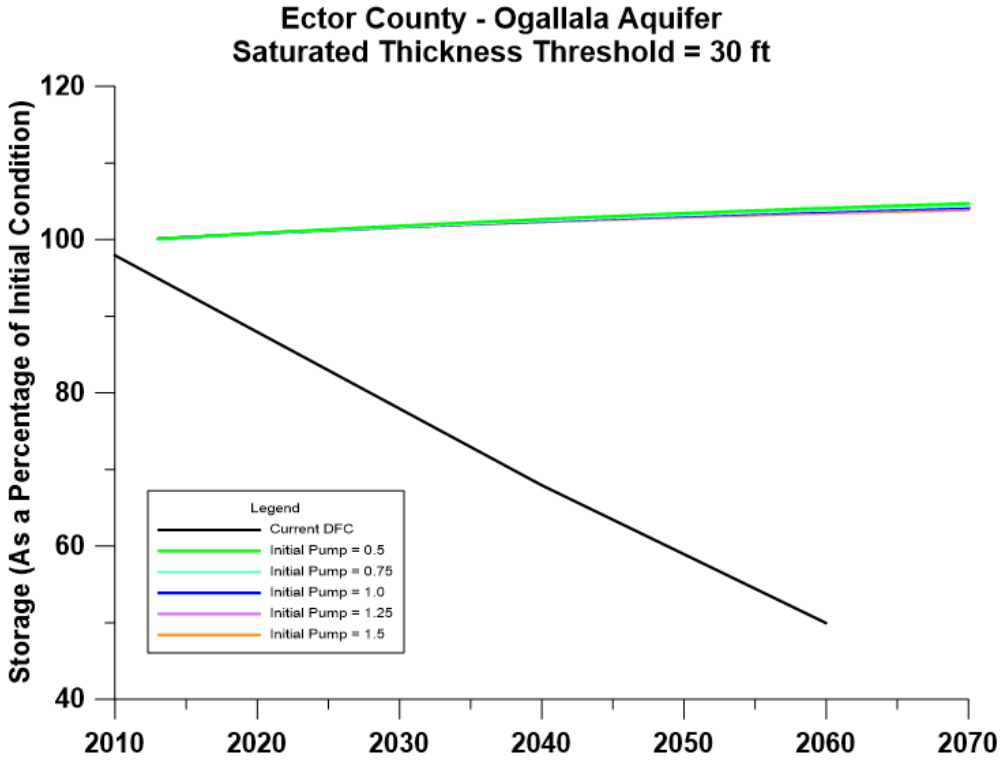
Appendix C

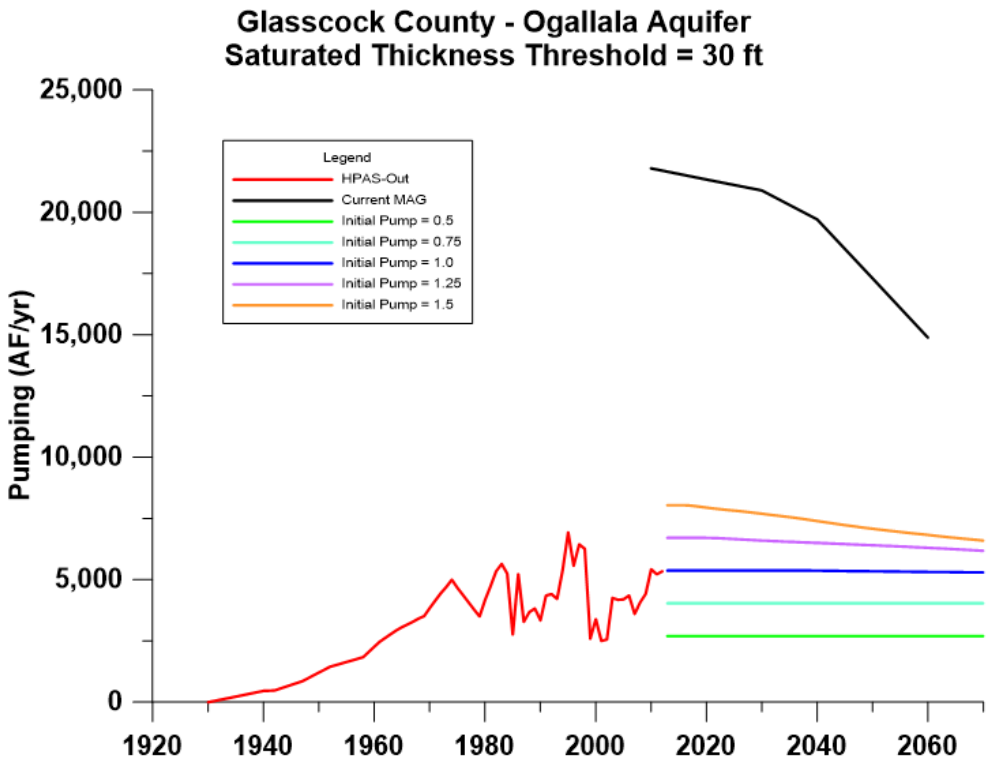
Ogallala Aquifer

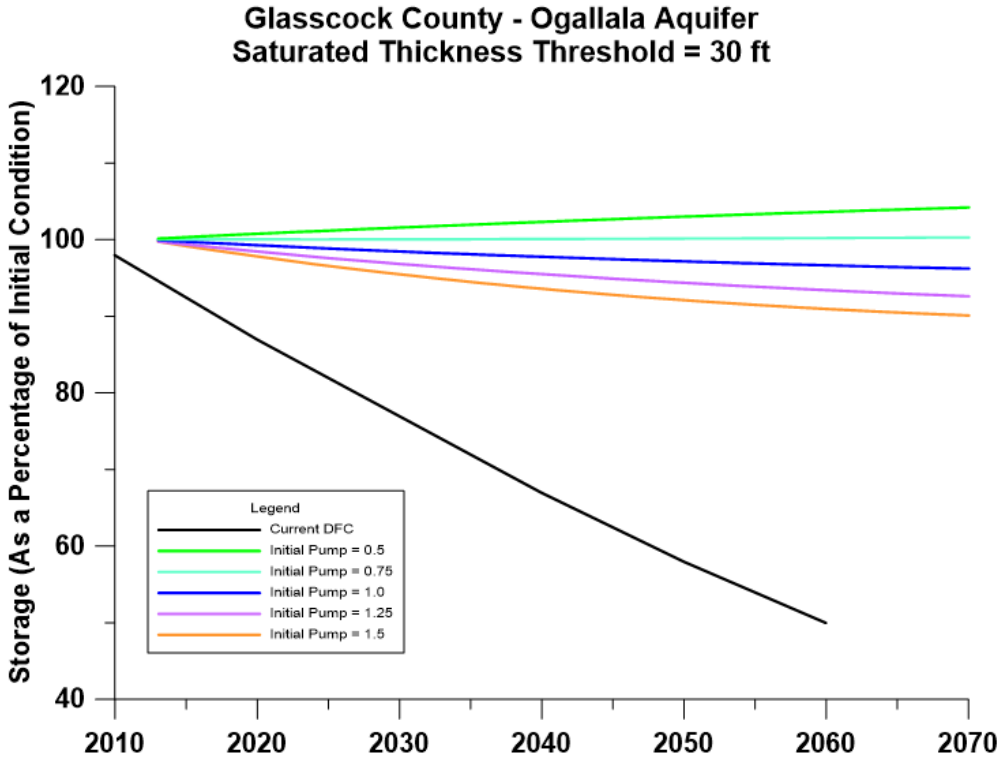
Hydrographs of Pumping and Storage Reamaining for Each County in GMA 7

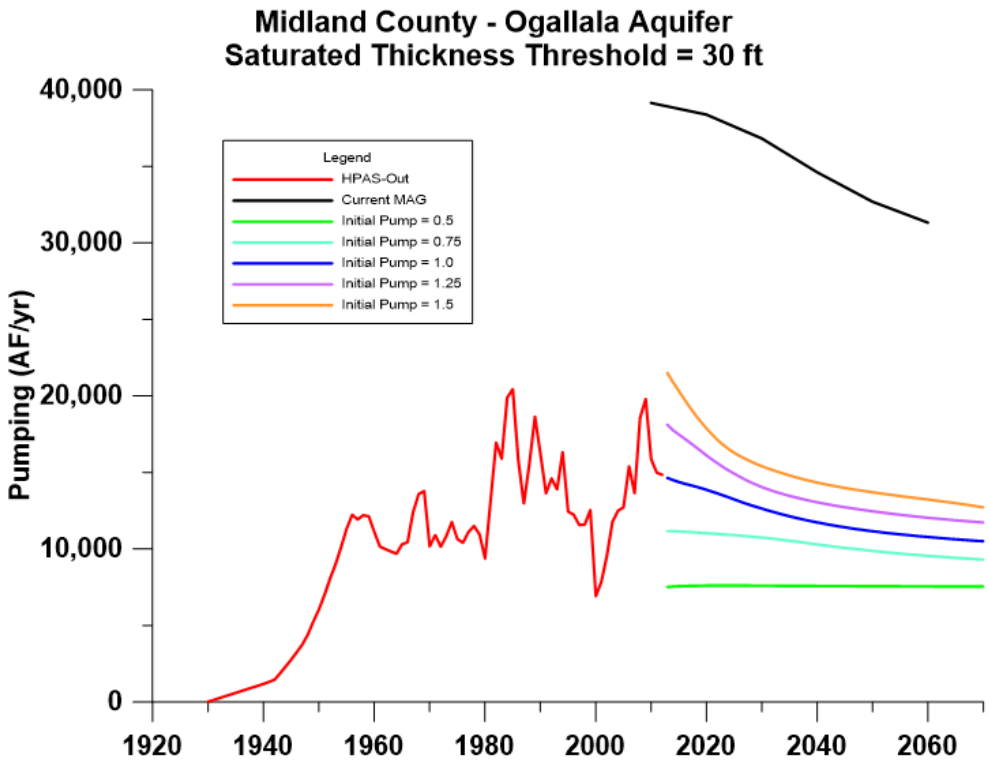


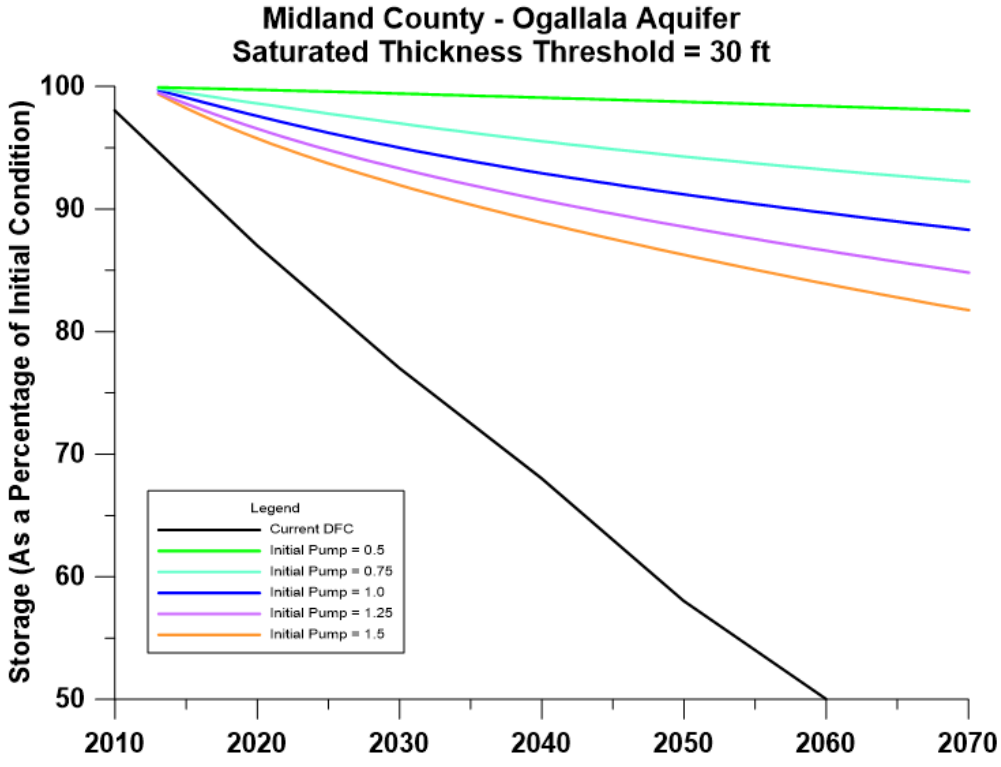

Ector County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
12,000
8,000
4,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Ector County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Storage (As a Percentage of Initial Condition)
120
100
80
60
40
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Glasscock County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
25,000
20,000
15,000
10,000
5,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Glasscock County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Storage (As a Percentage of Initial Condition)
120
100
80
60
40
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Midland County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Pumping (AF/yr)
40,000
30,000
20,000
10,000
0
1920
1940
1960
1980
2000
2020
2040
2060
Legend
HPAS-Out
Current MAG
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5


Midland County - Ogallala Aquifer
Saturated Thickness Threshold = 30 ft
Storage (As a Percentage of Initial Condition)
100
90
80
70
60
50
2010
2020
2030
2040
2050
2060
2070
Legend
Current DFC
Initial Pump = 0.5
Initial Pump = 0.75
Initial Pump = 1.0
Initial Pump = 1.25
Initial Pump = 1.5