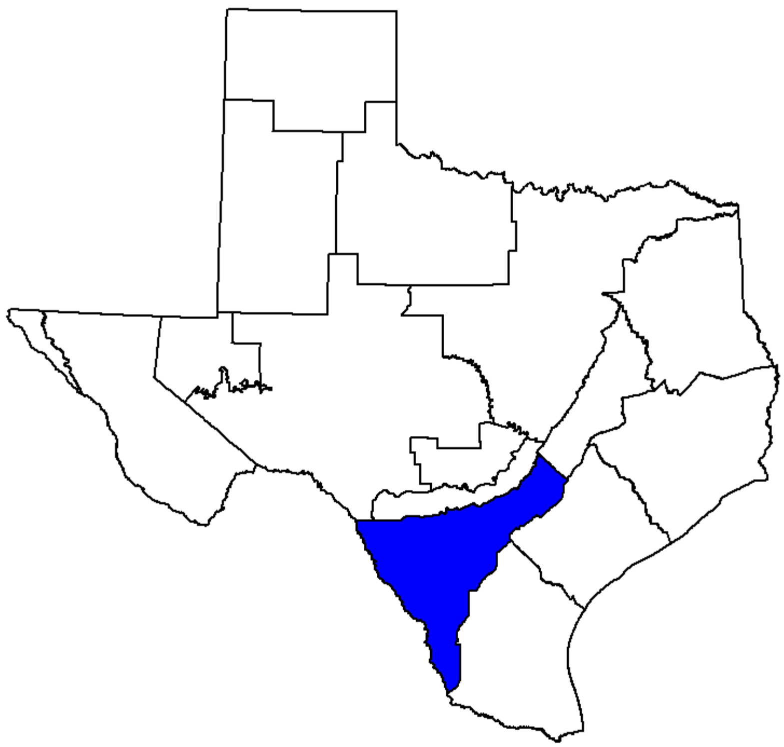
Final Report

Comparison of Groundwater Monitoring Data with Groundwater Model Results

Groundwater Management Area 13



March 20, 2013

William R. Hutchison, Ph.D., P.E., P.G.
Independent Groundwater Consultant
9802 Murmuring Creek Drive
Austin, TX 78736
512-745-0599
billhutch@texasgw.com

Executive Summary

This effort was authorized by the groundwater conservation districts of GMA 13 as the initial step of the current round of joint planning. The objectives were:

1. Compare model results from desired future condition simulations with actual data, and identify areas where comparisons were favorable and unfavorable. In areas where comparisons were unfavorable, the objective was to assess how the accuracy of various assumptions made in the process.
2. Summarize these findings in a report suitable for use by the groundwater conservation districts in updates to their management plans.
3. Use the findings in the next round of joint planning (i.e. desired future condition development) to make the process more efficient, less costly, and more defendable.

This report represents a resource document for use in the current round of joint planning, and contains the results of analyses completed to meet the objectives:

- Plotting hydrographs of actual groundwater elevations for 92 wells and comparing the data to estimates of historic and future pumping and estimates of groundwater elevations at those points from the model simulation of the initial desired future condition statement.
- Comparing actual drawdowns (from 1999 conditions) and drawdowns estimated from the model simulation at those points of the initial desired future condition statement for 70 wells.

In general, the comparisons of actual drawdowns and estimated drawdowns from the desired future condition simulation were favorable. Differences appear to be attributable to pumping increases or decreases assumed to occur from 2000 to 2011 that did not occur, increased groundwater use associated with hydraulic fracturing operations, and drought conditions.

The establishment of the initial desired future conditions for the Carrizo-Wilcox, Queen City and Sparta aquifers relied heavily on simulations using the groundwater availability model of the area. Comparisons of these model results with actual data provide a foundation for future discussions related to the current round of joint planning. The major areas for discussion include:

- Improvement in 2000 to 2011 pumping estimates
- Timing of future pumping increases and decreases
- Evaluate the “average” recharge assumption for the entire DFC simulation
- Evaluate the assumption that future pumping does not vary between wet years and droughts
- Review model assumptions and implementation for recharge and stream flow
- Assess county-to-county impacts more explicitly
- The use of actual well data as part of the statement of desired future conditions

Table of Contents

List of Figures and Tables

1.0 Introduction

Groundwater Management Area 13 is one of sixteen groundwater management areas in Texas, and covers a large portion of the southwest part of the state (Figure 1).

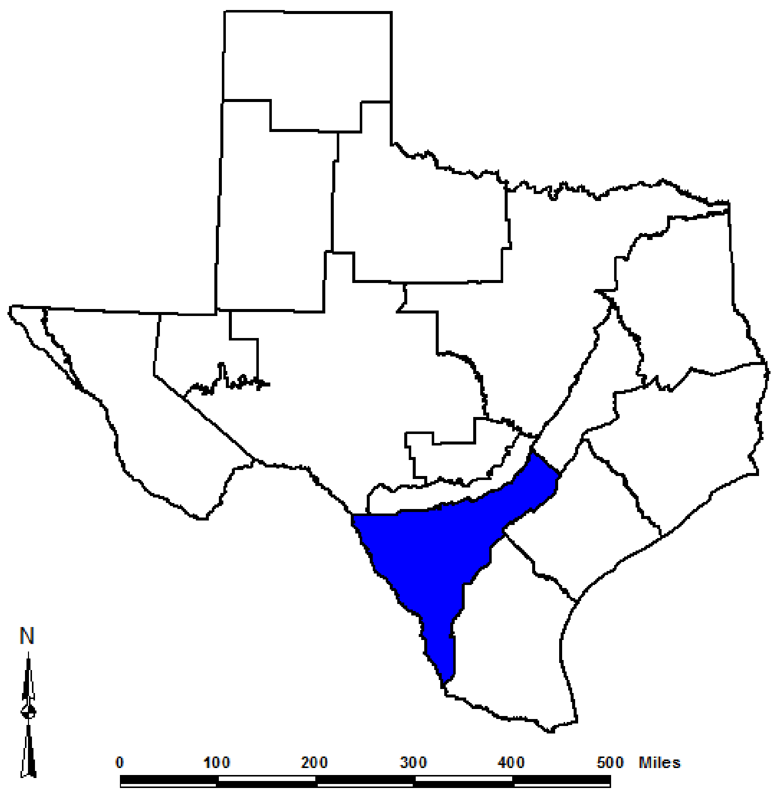


Figure 1. Groundwater Management Area 13

Groundwater Management Area 13 covers all or portions of the following counties: Atascosa, Bexar, Caldwell, Dimmit, Frio, Gonzales, Guadalupe, Karnes, La Salle, Maverick, McMullen, Medina, Uvalde, Webb, Wilson, Zapata, and Zavala (Figure 2).

There are nine groundwater conservation districts in Groundwater Management Area 13: Evergreen Underground Water Conservation District, Gonzales County Underground Water Conservation District, Guadalupe County Groundwater Conservation District, Edwards Aquifer Authority, McMullen Groundwater Conservation District, Medina County Groundwater Conservation District, Plum Creek Conservation District, Uvalde County Underground Water Conservation District, and Wintergarden Groundwater Conservation District (Figure 3). Please note that as shown in Figure 3, the Edwards Aquifer Authority overlaps other groundwater conservation districts in a small portion of Atascosa County, and larger parts of Caldwell, Guadalupe, Medina, and Uvalde counties.

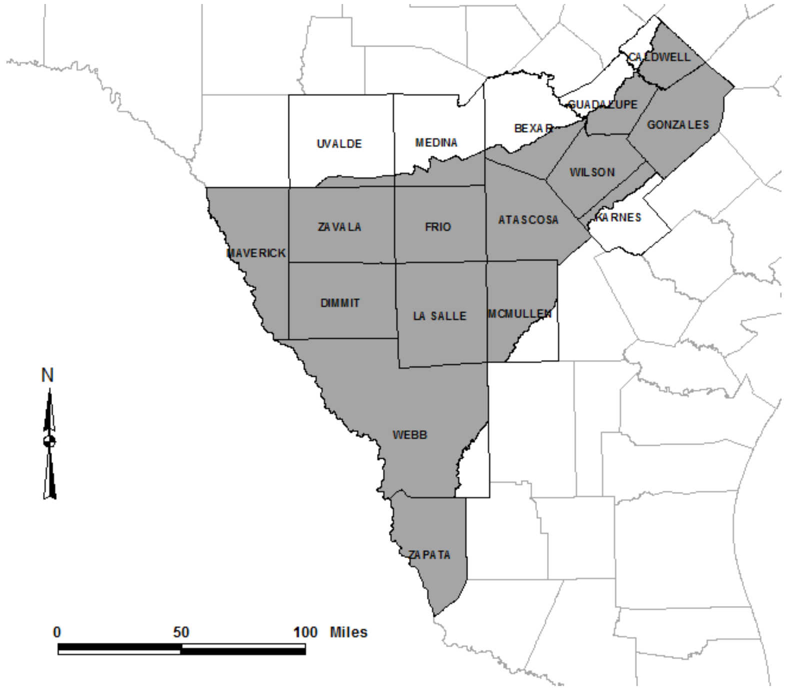


Figure 2. Counties Entirely or Partially in GMA 13

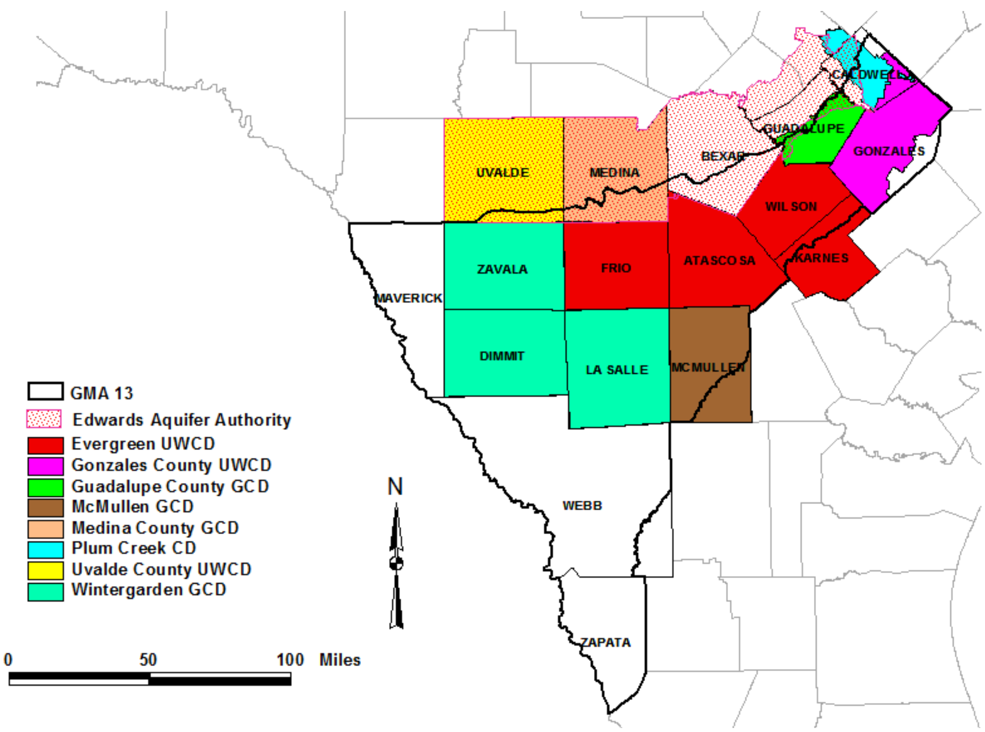


Figure 3. Groundwater Conservation Districts in GMA 13

1.1 Background and Objectives

On May 24, 2012, the groundwater conservation districts in GMA 13 issued a request for qualifications for technical services associated with the development of the next round of desired future conditions. On June 4, 2012, GMA 13 issued a request for proposals that specifically outlined seven tasks that GMA 13 identified relative to assistance in developing and defending desired future conditions. William R. Hutchison, Ph.D., P.E., P.G., an independent groundwater consultant, was selected at the GMA 13 meeting of July 25, 2012 to assist GMA 13 on these tasks. Dr. Hutchison recommended that an additional task be completed prior to beginning any of the tasks listed in the June 4, 2012 request for proposal. Known as Task 0, this task consisted of comparing actual groundwater elevation and drawdown data with model results that were used in the establishment of the initial desired future condition. Authorization to proceed with Task 0 was made at the September 7, 2012 GMA 13 meeting, and was based on two proposals dated August 10, 2012 and August 31, 2012.

The objectives of Task 0 were:

1. Compare model results from desired future condition simulations with actual data, and identify areas where comparisons were favorable and unfavorable. In areas where comparisons were unfavorable, the objective was to assess the accuracy of various assumptions made in the process.
2. Summarize these findings in a report suitable for use by the groundwater conservation districts in updates to their management plans.
3. Use the findings in the next round of joint planning (i.e. desired future condition development) to make the process more efficient, less costly, and more defendable.

It should be noted that there is no formal requirement in statute to report findings from this effort. In contrast, statutes do require that district management plans and desired future condition adoptions be approved as administratively complete by the Texas Water Development Board. However, statute does provide for a petition process if a desired future condition is not being met or if a district is not managing to meet a desired future condition. Such a petition would be filed with the Texas Commission on Environmental Quality. If such a petition were filed, the findings in this report could be used to respond to claims made. Most importantly, this effort represents good practice in evaluating groundwater levels measured in wells, and comparing these data with model results to place model results into appropriate context during the next round of joint planning.

1.2 Initial Desired Future Conditions for GMA 13

Groundwater Management Area 13 (GMA 13) adopted a desired future condition (DFC) for the Carrizo-Wilcox, Queen City, and Sparta aquifers on April 9, 2010. This initial DFC was established with a heavy reliance on results from simulations using the Groundwater Availability Model (GAM) for the Southern Carrizo-Wilcox, Queen City and Sparta aquifers. The adopted DFC is expressed as a GMA-wide average drawdown of 23 feet, and is based on Scenario 4 of GAM Run 09-034 as reported by the Texas Water Development Board. Scenario 4 of GAM Run 09-034 was a 61-year simulation with a starting point in the year 2000. Thus, the 23 feet of drawdown is an average drawdown over the entire GMA in these aquifers, and is estimated to occur in the year 2060.

It is important to note the assumptions associated with Scenario 4 of GAM Run 09-034. These assumptions include a specific distribution of recharge and that the "average" recharge occurs each year of the 61-year simulation. Also, there is an assumed spatial distribution of pumping, and a specific pattern of pumping increases and decreases assumed as part of GAM Run 09-034. Using 1999 pumping as a baseline (the last year of the calibration period of the model), there are some areas where pumping increases, some areas where pumping is about the same as 1999, and some areas where pumping decreases from 1999 amounts.

1.3 Comparing Model Results with Monitoring Data

The emphasis of using model results and averaging the estimated drawdown from the model results over the entire GMA was a topic of a fair degree of discussion at GMA meetings, and was a significant aspect of objections to the DFC articulated in two petitions filed with the Texas Water Development Board in 2011 challenging the reasonableness of the DFC.

Because the DFC is expressed as a GMA-wide average, questions have been raised on how to compare the actual data with idealized and heavily averaged model results to evaluate consistency with the DFC. Monitoring data can be used to track the groundwater level changes and can be compared to the DFC, either on a well-by-well basis, a county basis, a district basis, or on a GMA level.

It is possible to use synoptic groundwater level data (i.e. groundwater level data over many wells collected at the same time) to create contour maps of groundwater levels or drawdown, and then compare the resulting synoptic data with a similar map of model results. However, it is possible that the resulting contours would not be representative of aquifer conditions in the non-monitored areas and the "averaging" associated with the contouring process may lead to erroneous conclusions.

Conversely, it is possible to extract predicted groundwater levels from the model files (which are stored in the model files based on the one-square mile grid cells and for each year of the simulation) at the same locations as the wells that are used in a monitoring program. If the model is well calibrated at these points, this approach would provide some advantage in that comparisons of model results and monitoring data would be consistent, and averaging would be limited, if not eliminated. Conclusions could then be drawn based on the comparison of actual data with model results at discrete locations.

Results of the comparison will provide the districts the ability to evaluate various assumptions that are embedded in the desired future condition. Among these are assumed pumping locations in areas where pumping is expected to increase, the timing and amount of pumping increases and decreases, the adequacy of the selected groundwater availability model to predict drawdown, and the appropriateness of assuming that recharge is average each year for the next 61 years.

2.0 Review of GAM Run 09-034

Scenario 4 of GAM Run 09-034 was used as the basis for establishing the desired future condition in GMA 13. It relied on the groundwater availability model of the Southern Carrizo-Wilcox, Queen City, and Sparta aquifers. This model discretized the flow system into 112 row and 217 columns of one-square mile cells. The groundwater flow system is further discretized into 8 layers of cells to represent various aquifers and aquitards of varying thickness. Thus, there are 194,432 cells in the model, 100,883 of which are active in the flow system. GMA 13 is represented by 82,029 of these active cells, or 81% of all active cells in the model grid. Table 1 summarizes the active cells in each county and layer in the GMA 13 portion of the model.

Table 1. Active Model Cell County by County and Model Layer

County	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	GMA 13
Atascosa	820	853	1,033	1,073	1,189	1,189	1,216	1,216	8,589
Bexar	0	0	0	8	67	73	193	345	686
Caldwell	0	0	20	61	101	102	241	360	885
Dimmit	145	210	988	1,049	1,203	1,232	1,293	1,311	7,431
Frio	389	460	1,031	1,102	1,129	1,129	1,129	1,129	7,498
Gonzales	787	833	977	1,051	1,065	1,065	1,071	1,071	7,920
Guadalupe	0	0	1	28	102	102	273	383	889
Karnes	186	186	186	186	186	186	186	186	1,488
LaSalle	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	12,024
Maverick	0	0	0	8	64	69	115	206	462
McMullen	853	853	853	853	853	853	853	853	6,824
Medina	0	0	0	2	138	138	259	329	866
Uvalde	0	0	0	0	27	1	90	108	226
Webb	1,087	1,158	1,885	1,933	1,948	1,955	1,962	1,963	13,891
Wilson	316	370	595	662	772	772	805	807	5,099
Zavala	169	230	918	1,026	1,178	1,185	1,257	1,288	7,251
GMA13	6,255	6,656	9,990	10,545	11,525	11,554	12,446	13,058	82,029

The desired future condition was expressed as an average drawdown over the entire area of GMA 13, and was based on the results of Scenario 4 of GAM Run 09-034. Groundwater elevations are calculated for each active cell at the end of each stress period (one year). The drawdown in each cell was calculated as the groundwater elevation at the beginning of the simulation (end of 1999) minus the groundwater elevation at the end of the year of interest. These drawdowns are then summed for an area of interest (e.g. county, layer, county-layer, entire GMA). The average drawdown for an area of interest is then calculated as the sum of the drawdowns divided by the number of cells in the area of interest. Thus, the desired future condition of 23 feet in GMA 13 in 2060 is the average of 82,029 individual drawdown estimates. Also note that this calculation can be completed for any geographic area of interest for any of the 61 stress periods in the simulation (2000 to 2060). There are over 5 million individual drawdown estimates contained in the model files of Scenario 4 of GAM Run 09-034 to make these calculations.

The drawdown estimates by county and layer for 2060 from Scenario 4 of GAM Run 09-034 are summarized in Table 2. Note that blanks in Table 2 correspond to areas where specific layers do not exist (e.g. Layers 1, 2 and 3 do not exist as active cells in Bexar County). By tying a particular model run to the desired future condition, it is possible to extract specific drawdown values for specific areas, down to a one square mile area (a model cell) for any year.

Table 2. Summary of Estimated Drawdowns in 2060 by County and Model Layer

County	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	GMA 13
Atascosa	10	13	15	43	74	74	85	145	62
Bexar				8	64	48	37	136	90
Caldwell			5	16	96	92	51	65	63
Dimmit	-2	3	-4	-14	-17	-17	-22	-18	-15
Frio	4	3	-3	19	39	38	31	35	24
Gonzales	21	26	32	60	94	94	88	81	65
Guadalupe			-13	5	52	50	20	31	31
Karnes	17	27	34	60	86	85	61	88	57
LaSalle	7	8	9	11	12	12	-1	-9	6
Maverick				1	-8	-12	-11	-3	-7
McMullen	25	29	32	39	45	44	12	9	29
Medina				-1	29	29	28	28	28
Uvalde					1	3	12	30	19
Webb	-7	-4	-9	-5	-4	-3	-1	-3	-4
Wilson	7	13	13	43	75	75	78	153	68
Zavala	-7	-5	-13	-14	2	0	-5	-3	-5
GMA13	9	11	7	17	31	31	25	38	23

It is also possible to extract pumping data from each model cell, both from the calibrated groundwater model (to evaluate estimates of historic pumping) and from Scenario 4 of GAM Run 09-034 (to evaluate assumptions of future pumping). Increases in pumping would be expected to result in higher drawdown, and decreases in pumping would be expected to result groundwater level stabilization or recovery. This relationship for all of GMA 13 is summarized in Figure 4.

The upper part of Figure 4 contains estimates of historic pumping (1975 to 1999) which were extracted from the calibrated groundwater availability model, and estimates of assumed future pumping (2000 to 2060) which were extracted from Scenario 4 of GAM Run 09-034. Note that "future" pumping included the period 2000 to 2010 (when the DFC was adopted). It can be seen that historic pumping is about 300,000 AF/yr and pumping is assumed to increase to about 420,000 AF/yr in the future. The lower part of Figure 4 shows the annual estimate of average drawdown over all of GMA 13. Note that drawdown estimates begin in the year 2000 and extend to 2060, and the 23 ft of average drawdown in 2060 can be seen. Because the "future" pumping began in 2000 and extends to 2060, it is possible to compare drawdown estimates from 2000 to 2011 with actual monitoring data to advance the objectives of this investigation.

Figures 5 to 20 are similar plots of individual counties. Plots of individual county-layer combinations are not presented, but were developed for later use in the joint planning process, and are available on request.

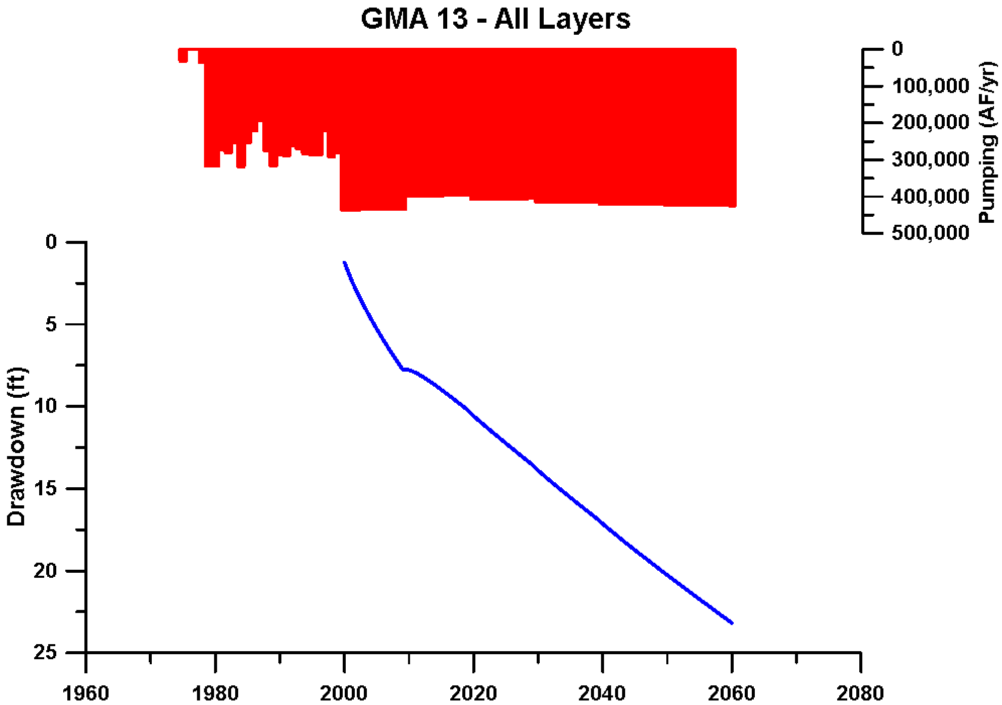


Figure 4. Summary of Pumping and Drawdown - GMA 13

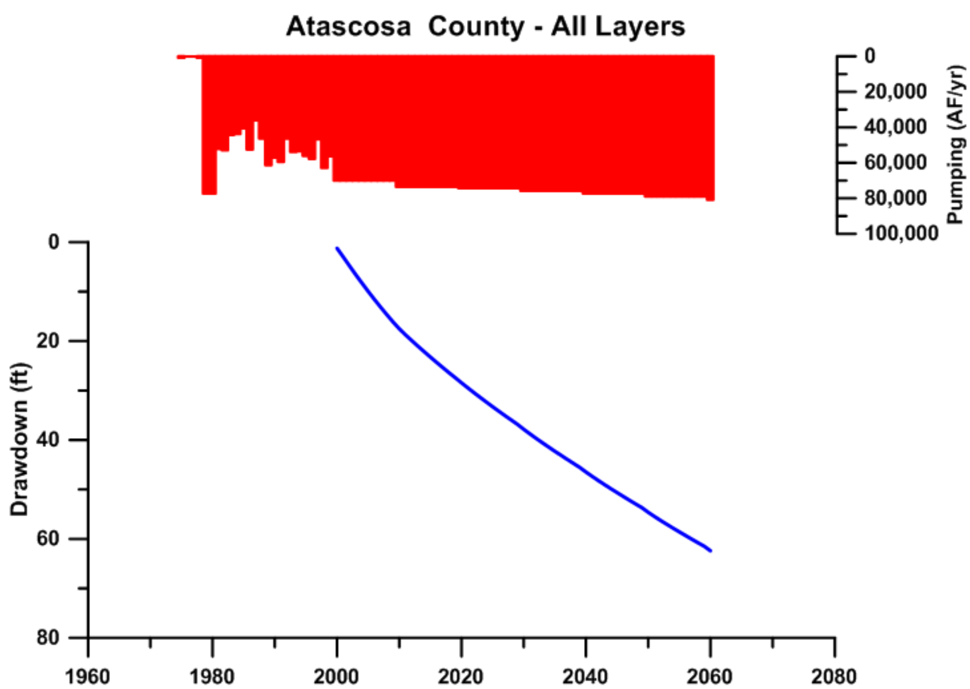


Figure 5. Summary of Pumping and Drawdown - Atascosa County

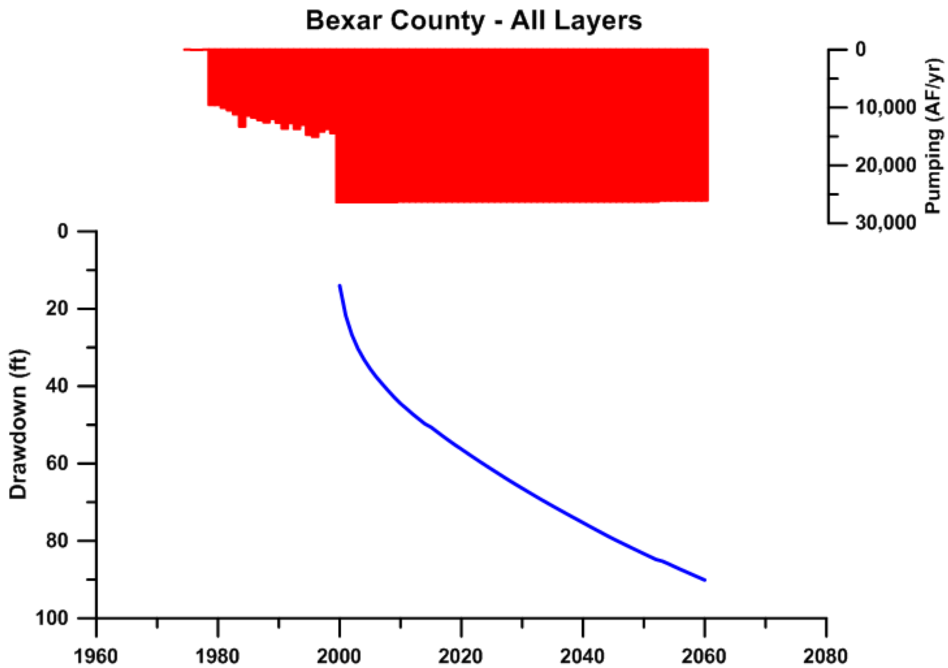


Figure 6. Summary of Pumping and Drawdown - Bexar County

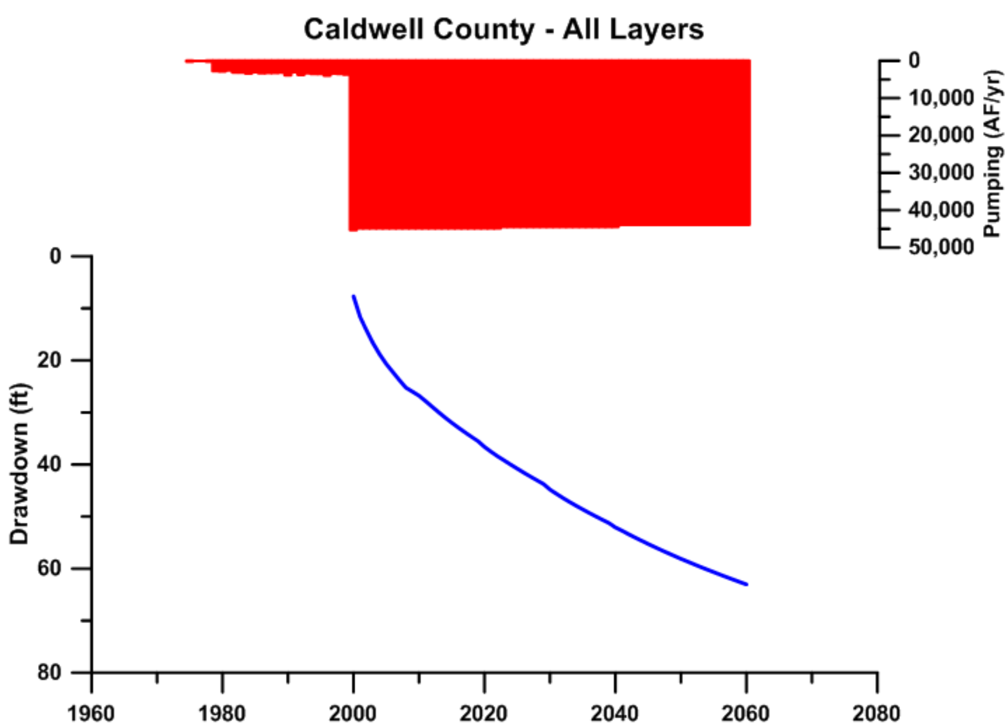


Figure 7. Summary of Pumping and Drawdown - Caldwell County

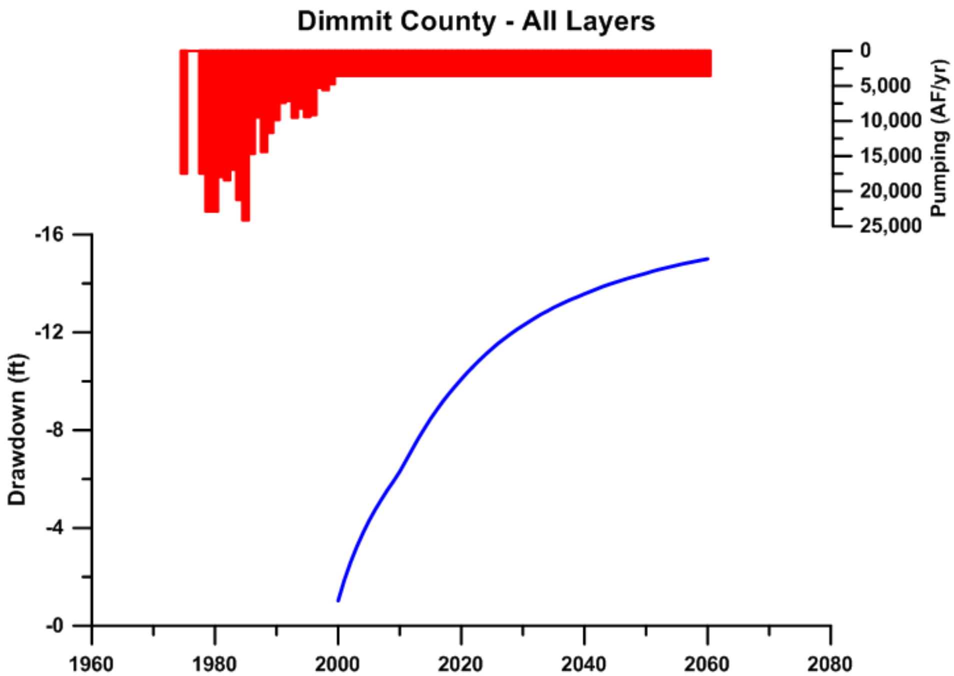


Figure 8. Summary of Pumping and Drawdown - Dimmit County

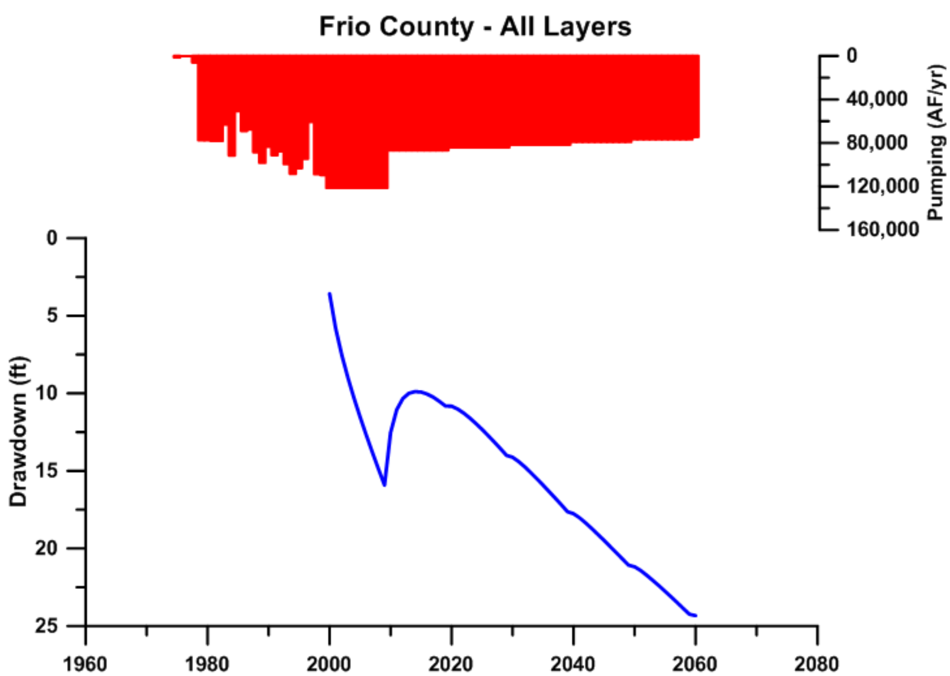


Figure 9. Summary of Pumping and Drawdown - Frio County

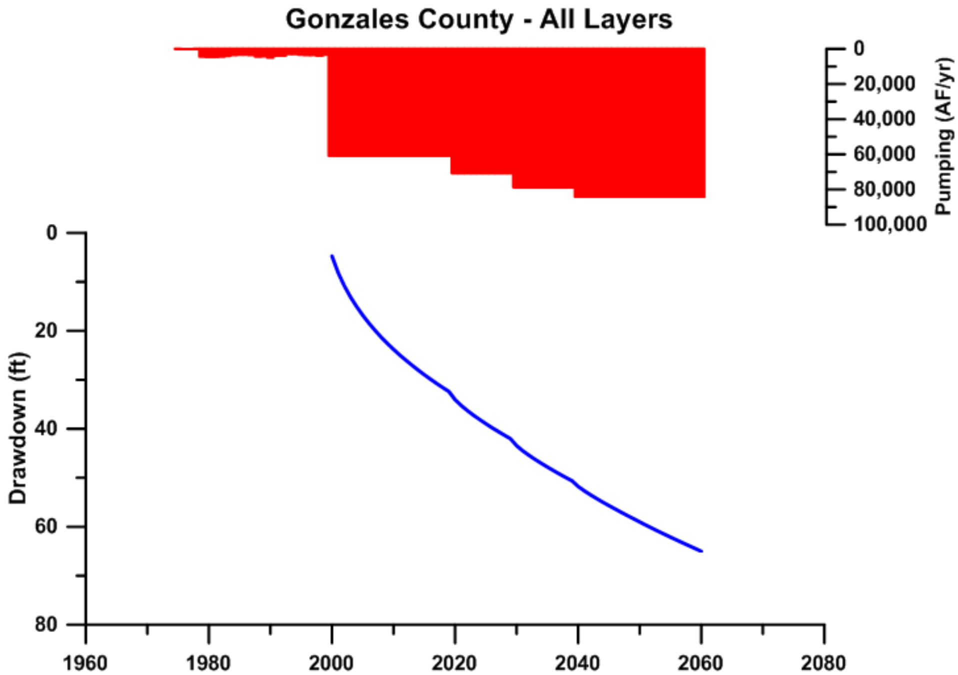


Figure 10. Summary of Pumping and Drawdown - Gonzales County

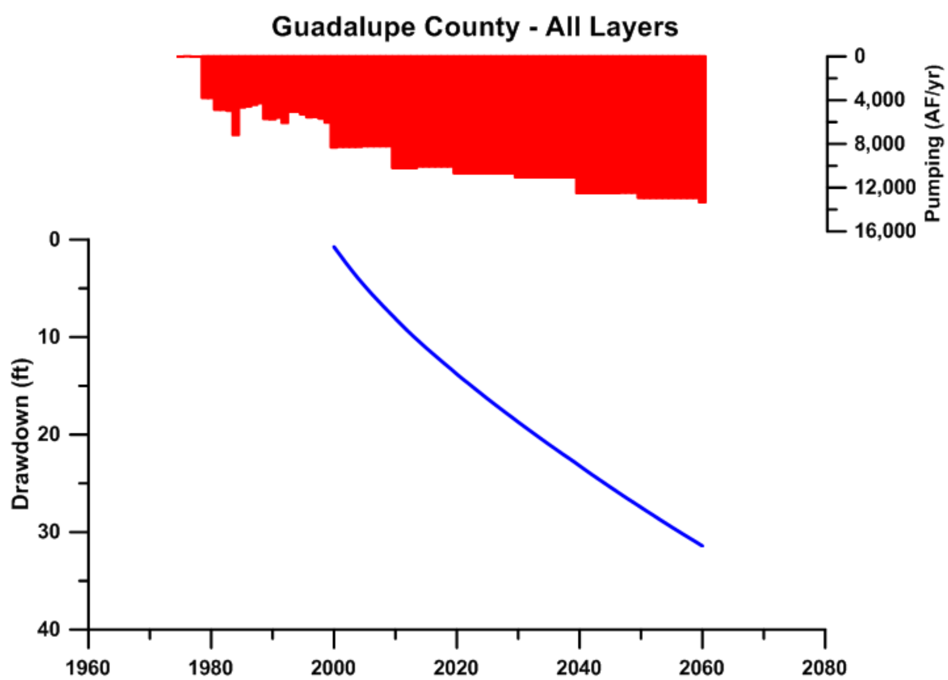


Figure 11. Summary of Pumping and Drawdown - Guadalupe County

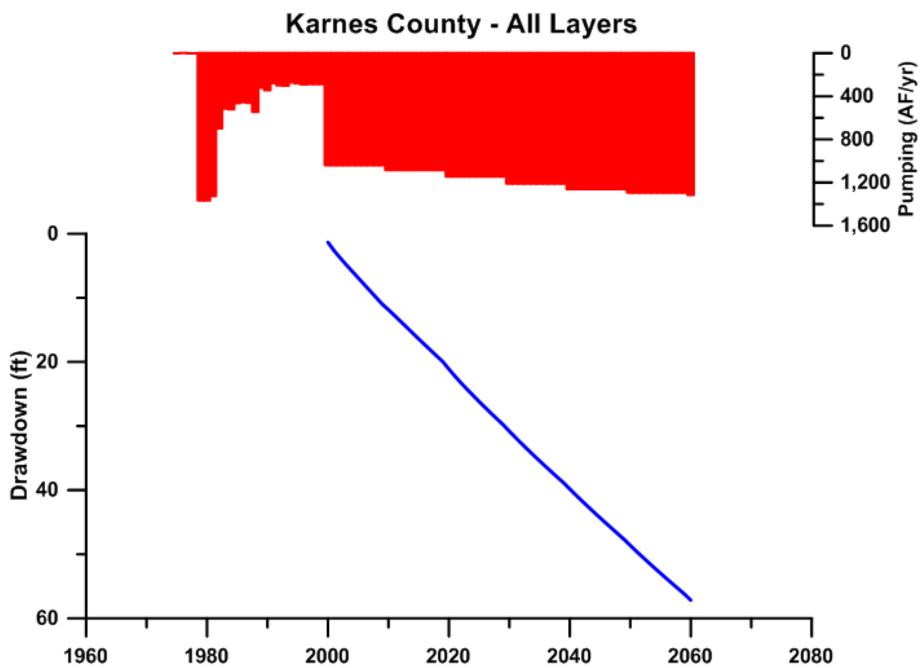


Figure 12. Summary of Pumping and Drawdown - Karnes County

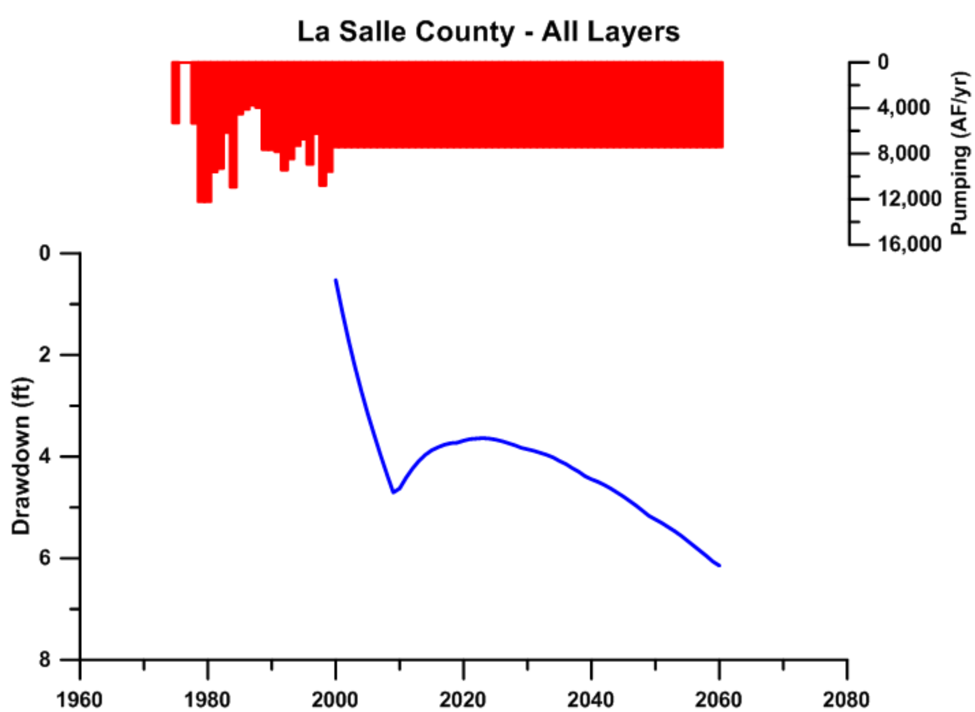


Figure 13. Summary of Pumping and Drawdown - La Salle County

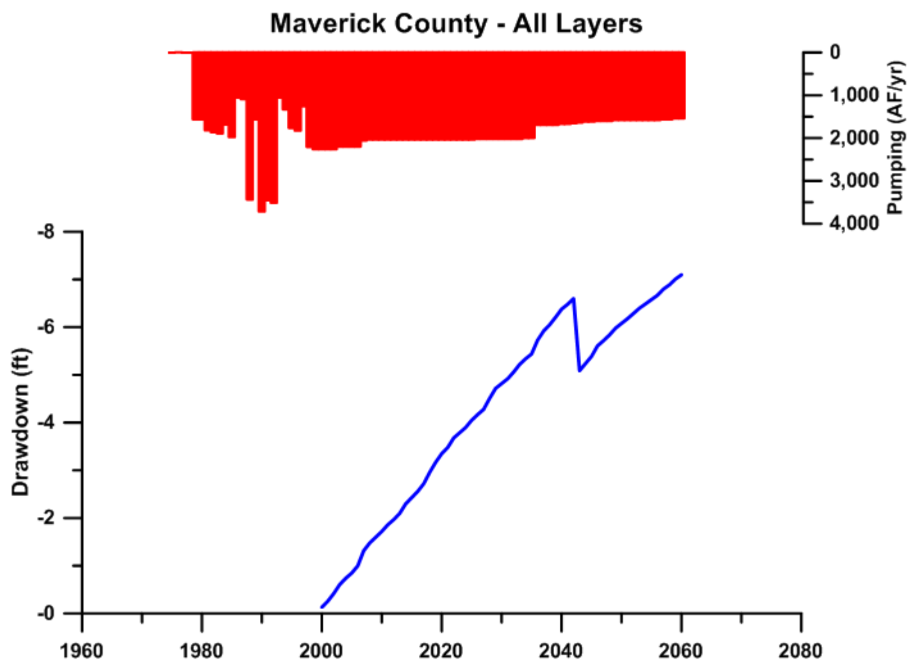


Figure 14. Summary of Pumping and Drawdown - Maverick County

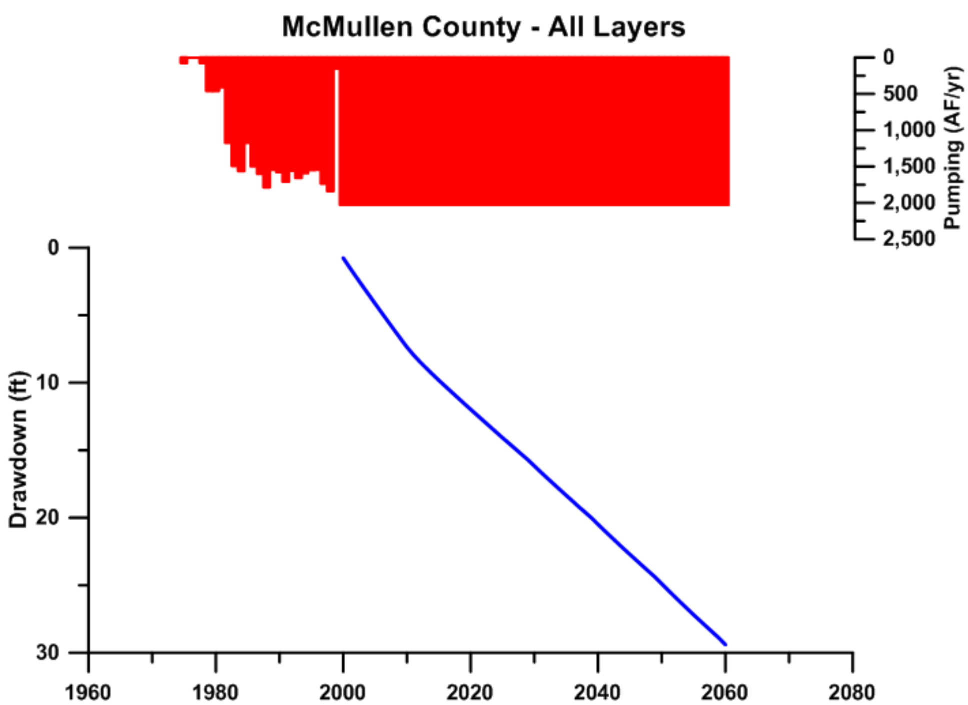


Figure 15. Summary of Pumping and Drawdown - McMullen County

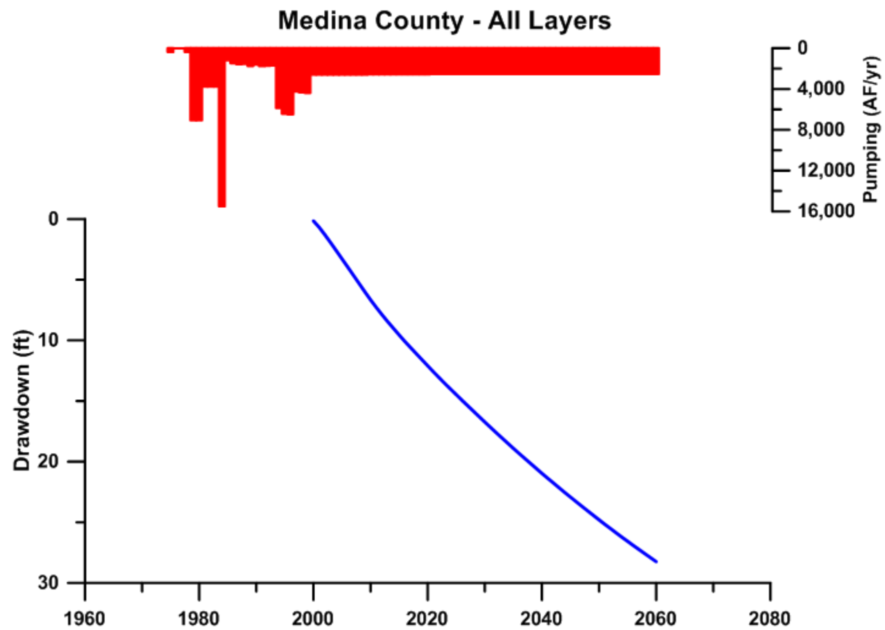


Figure 16. Summary of Pumping and Drawdown - Medina County

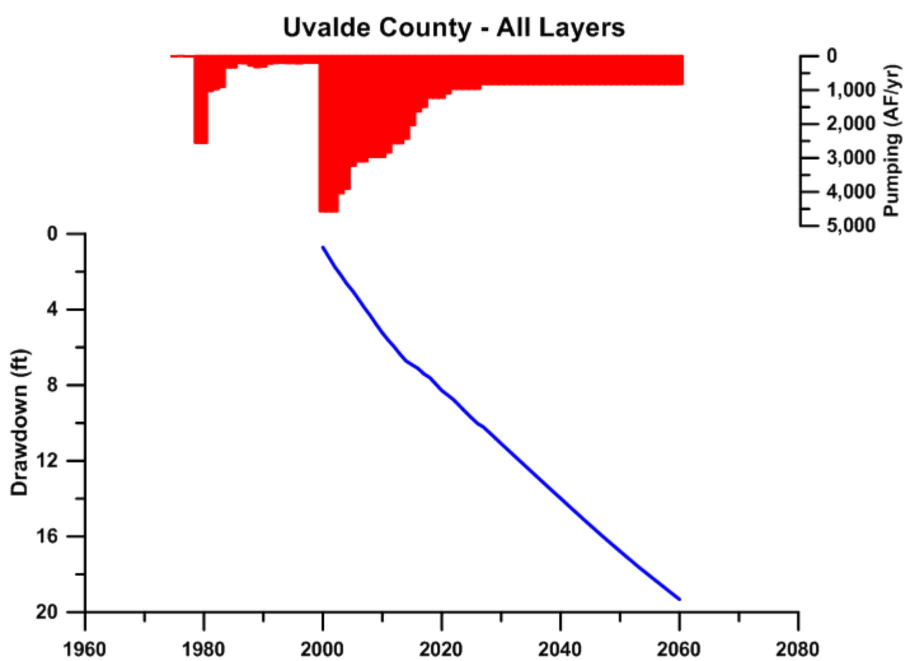


Figure 17. Summary of Pumping and Drawdown - Uvalde County

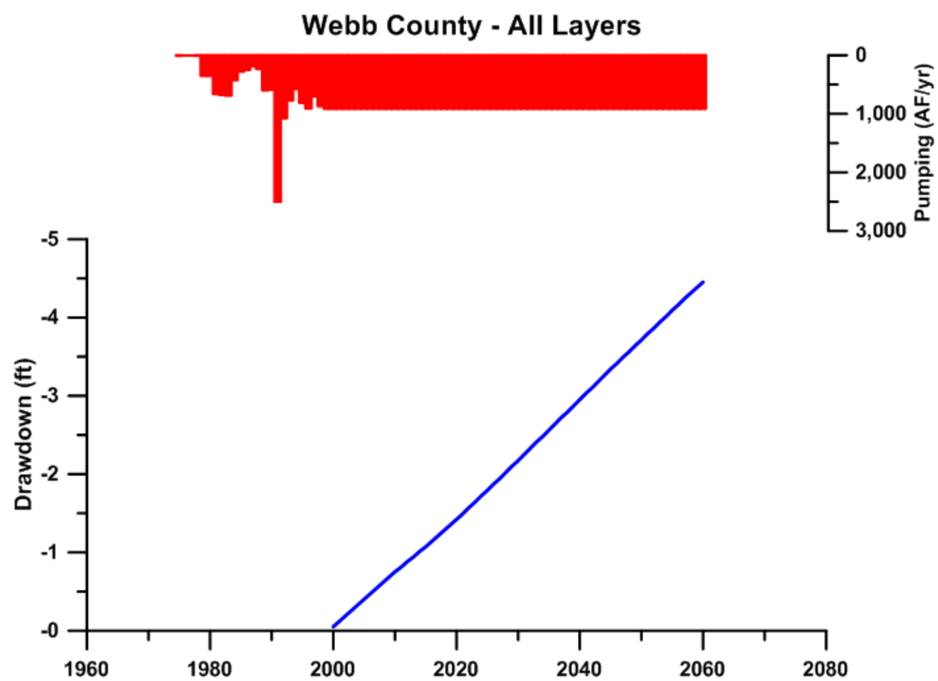


Figure 18. Summary of Pumping and Drawdown - Webb County

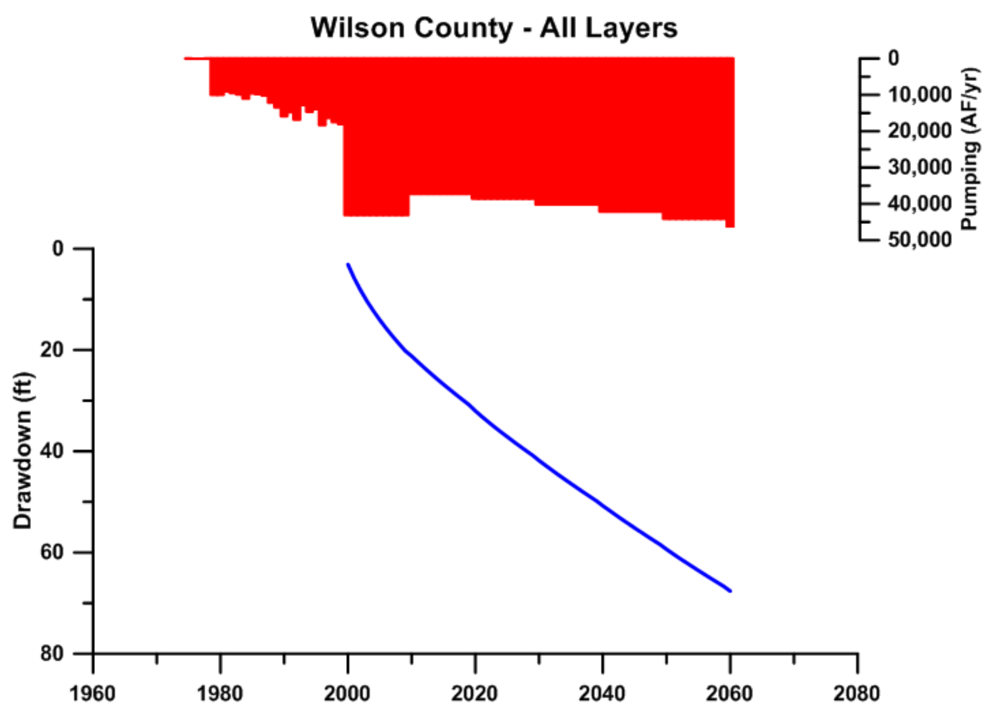


Figure 19. Summary of Pumping and Drawdown - Wilson County

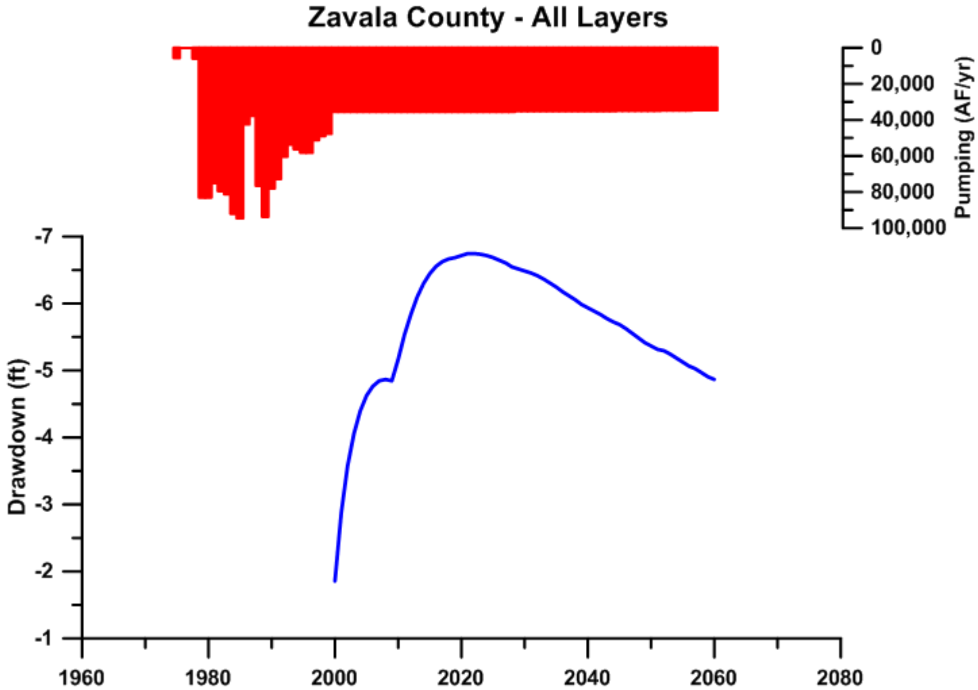


Figure 20. Summary of Pumping and Drawdown - Zavala County

Inspection of Figures 5 to 20 shows that, in some counties, groundwater pumping is expected to increase. Some of these increases were assumed to occur in 2000. Groundwater pumping is expected to be about the same as 1999 pumping in some counties. Finally, groundwater pumping is expected to decrease in some counties, and these decreases were assumed to begin in 2000. Also note the general correlation between pumping increases/decreases and groundwater elevation drawdown/recovery. There is also some observation of drawdown/recovery impacts of pumping changes across county lines. This is of particular interest in the joint planning process.

3.0 Point-by-Point Comparison of Groundwater Elevations

Historic groundwater elevation data were obtained from the Texas Water Development Board for use in this analysis. Data maintained in this database include well location (latitude and longitude), well depth, completion data (screen top and bottom depth), and groundwater elevation data. In GMA 13, the database contains 31,247 groundwater elevation measurements from 1906 to 2012 in 6,956 wells. However, in 5,112 wells there are no details of screened intervals, but many of these have an aquifer code. Of the 1,844 wells that have screened interval data, 574 wells have no groundwater elevation data, 695 have exactly one groundwater elevation data point, and 575 have two or more groundwater elevation measurements.

The wells with screened interval data were used in conjunction with the Groundwater Availability Model (GAM) for the Southern Carrizo-Wilcox, Queen City and Sparta aquifers. Each well was located in the model grid (i.e. row and column), and the completion interval was compared to the model layering data. Model data were then extracted for each cell with a well (e.g. aquifer parameters, historic and future pumping, and simulated groundwater elevations).

Based on this analysis, 748 wells in GMA 13 were selected as being completed in a single model layer. 412 wells had exactly one groundwater level measurement. 207 wells had five or more groundwater elevation measurements. 92 wells had 10 or more groundwater elevation measurements with at least one data point collected after the year 2000.

3.1 Hydrographs of Groundwater Elevations and Pumping

These 92 wells were used to construct hydrographs of groundwater elevation and pumping. The locations of these 92 wells are shown in Figure 21, and details of these 92 wells are presented in Table 3. Please note that Table 3 is sorted by county and well number, and includes details of screen elevation, period of available groundwater elevation measurements, and data on aquifer parameters from the GAM.

Hydrographs of these 92 wells are presented in individual appendices organized by county. These hydrographs include historic groundwater elevations data, future groundwater elevation data from the results of GAM Run 09-034, land surface elevation, screened intervals and historic and future pumping in three zones: 1) pumping within the cell where the well is located, 2) pumping in the cells immediately surrounding zone 1, and 3) pumping in cells immediately surrounding zone 2. Thus, pumping (both historic and projected) in a 25 square mile area surrounding the well of interest is presented in aid interpretation of the groundwater elevation changes. The appendices also present the locations of these wells, and contain data, maps and graphs from other analyses described later in this report.

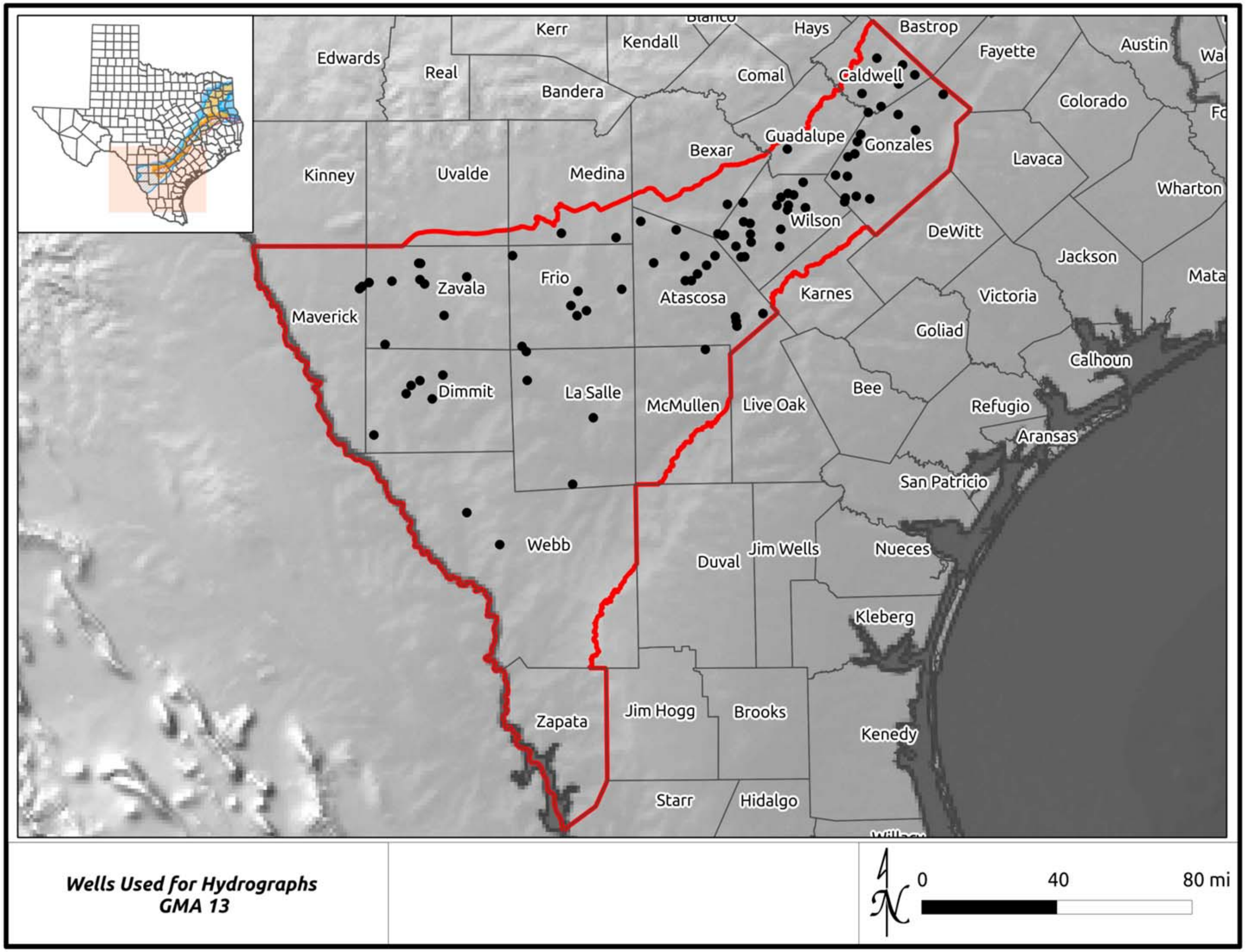


Figure 21. Map of Hydrograph Well Locations

Table 3. Summary Data for 92 Wells used in Hydrograph Construction

TWDB Well Number	County	TWDB Aquifer Code	Land Surface Elevation (ft MSL)	Well Depth (ft)	Elevation of Screen Top (ft MSL)	Elevation of Screen Bottom (ft MSL)	Model Row	Model Column	Model Layer	Well Use (TWDB Code)	Number of Groundwater Elevation Measurements	Ealiest Year with Measurement	Latest Year with Measrement	Hydraulic Conductivity (ft/day)	Storativity (dimensionless)	Specific Yield (ft^{-1})	Elevation of Layer Top (ft MSL)	Elevation of Layer Bottom (ft MSL)
6850603	Atascosa	124WLCX	655	249	504	406	42	113	7	H	19	1969	2004	5.43	1.06E-03	0.1	628	276
6852713	Atascosa	124CRRZ	665	393	498	330	50	120	5	U	81	1970	2009	3.27	1.00E+00	0.15	691	296
6859804	Atascosa	124CRRZ	487	740	-56	-213	54	109	5	I	31	1964	2010	31.32	3.62E-03	0.15	5	-827
6860852	Atascosa	124CRRZ	470	1130	-460	-650	58	117	5	I	11	2000	2009	46.95	1.91E-03	0.15	-303	-810
6861905	Atascosa	124CRRZ	482	1413	-718	-931	63	125	5	I	40	1965	2010	20.75	3.11E-03	0.15	-433	-1268
7804508	Atascosa	124CRRZ	466	1850	-1234	-1344	64	113	5	U	89	2008	2012	13.51	1.92E-03	0.15	-967	-1586
7804612	Atascosa	124CRRZ	420	2125	-1286	-1518	65	115	5	P	15	1991	2010	14.06	2.39E-03	0.15	-1098	-1870
7805212	Atascosa	124CRRZ	405	1637	-957	-1232	64	121	5	I	13	1994	2010	27.04	3.10E-03	0.15	-706	-1562
7805409	Atascosa	124QNCT	380	800	-260	-420	64	117	3	P	31	1963	2010	4.53	5.17E-03	0.15	287	-698
7814801	Atascosa	124CRRZ	241	3992	-3239	-3319	82	118	5	U	20	1951	2010	14.78	2.03E-03	0.15	-2960	-4079
7814802	Atascosa	124CRRZ	233	3663	-3382	-3428	81	119	5	U	19	1951	2010	14.9	2.19E-03	0.15	-2825	-3982
7815805	Atascosa	124CRRZ	469	4359	-3851	-3888	85	126	5	P	27	1969	2010	40.44	1.36E-03	0.15	-3405	-4354
7822201	Atascosa	124CRRZ	228	4015	-3722	-3782	84	117	5	U	21	1951	2010	12.6	1.70E-03	0.15	-3240	-4258
6846702	Bexar	124WLCX	499	500	269	199	53	137	7	U	28	1970	2011	5.21	9.77E-04	0.1	522	197
6712111	Caldwell	124WLCX	472	175	332	312	45	198	8	S	48	1964	2011	8.12	9.76E-04	0.1	445	120
6713102	Caldwell	124WLCX	599	450	199	149	51	203	7	S	25	1964	2010	1	2.40E-03	0.1	444	-358
6713605	Caldwell	124CRRZ	490	470	60	40	55	204	5	H	24	1964	2009	24.52	2.02E-03	0.15	238	-198
6713702	Caldwell	124CRRZ	566	270	366	346	55	199	5	H	12	1963	2010	19.19	1.00E+00	0.15	502	139
6719306	Caldwell	124WLCX	475	330	292	145	51	188	8	U	49	1964	2011	6.23	1.71E-03	0.1	298	-273
6720802	Caldwell	124WLCX	410	200	241	221	57	191	7	S	50	1963	2010	1	2.68E-03	0.1	362	-531
7648801	Dimmit	124CRRZ	680	55	672	625	45	12	5	H	44	1965	2012	0.54	1.00E+00	0.15	690	613
7726708	Dimmit	124CRRZ	602	315	522	287	40	33	5	H	36	1969	2012	1.46	2.05E-03	0.15	550	256
7727709	Dimmit	124BGDF	525	99	459	445	43	39	3	U	32	1974	2012	2.28	1.00E+00	0.15	530	244
7733322	Dimmit	124CRRZ	665	263	560	518	40	30	5	G	61	1971	2004	2.86	1.00E+00	0.15	636	460
7733611	Dimmit	124CRRZ	690	360	650	330	41	27	5	H	39	1944	2012	5.94	1.00E+00	0.15	671	316
7734607	Dimmit	124CRRZ	565	601	215	-36	47	32	5	S	42	1957	2009	2.84	1.73E-03	0.15	217	-132
6961606	Frio	124CZWX	687	338	557	349	27	77	5	I	16	1981	2010	35.56	2.13E-03	0.15	589	266
7708803	Frio	124CRRZ	652	1352	-468	-548	47	86	5	U	254	1963	2011	50.82	2.60E-03	0.15	-415	-1118
7716409	Frio	124CRRZ	589	1392	-705	-800	49	82	5	I	19	1997	2006	31.67	1.54E-03	0.15	-696	-1155
7716603	Frio	124CRRZ	640	1785	-945	-1145	53	84	5	I	35	1963	2010	31.68	1.45E-03	0.15	-895	-1378
7716801	Frio	124CRRZ	521	1828	-1107	-1307	53	81	5	U	141	1952	2010	48.2	1.13E-03	0.15	-1037	-1404
7722703	Frio	124CRRZ	575	2000	-1185	-1425	50	63	5	I	10	2001	2010	20.1	1.01E-03	0.15	-1179	-1526
7802701	Frio	124CRRZ	553	1588	-647	-1035	54	97	5	H	17	1965	2002	30.78	1.89E-03	0.15	-638	-1214
6719901	Gonzales	124WLCX	360	230	150	130	56	186	7	U	37	1959	2010	20.5	2.06E-03	0.1	373	-312
6721703	Gonzales	124CRRZ	420	520	-54	-75	62	193	5	S	34	1967	2010	36.72	2.75E-03	0.15	-30	-713
6722301	Gonzales	124SPRT	366	600	-137	-234	65	207	1	H	36	1959	2010	1.79	1.14E-03	0.15	-130	-351
6727502	Gonzales	124CRRZ	435	180	280	259	60	181	5	U	29	1970	2010	18.43	1.90E-03	0.15	354	14
6727503	Gonzales	124WLCX	433	323	133	110	60	181	5	H	17	1979	2010	18.43	1.90E-03	0.15	354	14
6727805	Gonzales	124CRRZ	370	700	104	-148	61	179	5	U	99	1981	2010	21.82	2.19E-03	0.15	286	-149
6729602	Gonzales	124CRRZ	375	1685	-1245	-1310	69	195	4	S	29	1969	2010	1	1.52E-03	0.1	-1121	-1407
6735201	Gonzales	124CRRZ	493	800	-107	-307	64	176	5	I	20	1959	2010	55.81	2.38E-03	0.15	110	-451
6735401	Gonzales	124CRRZ	398	732	154	-174	63	174	5	I	25	1959	2010	23.67	2.41E-03	0.15	271	-235
6742202	Gonzales	124CRRZ	409	600	-91	-191	65	168	5	S	35	1963	2010	20.92	2.54E-03	0.15	98	-506
6742905	Gonzales	124CRRZ	375	1525	-1050	-1150	73	165	5	H	23	1959	2010	71.2	2.31E-03	0.15	-849	-1565
6742906	Gonzales	124CRRZ	390	1645	-1032	-1215	72	166	5	P	10	1968	2002	71.56	2.36E-03	0.15	-773	-1493
6743103	Gonzales	124CRRZ	380	1000	-420	-620	68	170	5	I	28	2000	2010	53.08	2.52E-03	0.15	-357	-1033
6743805	Gonzales	124CRRZ	365	1950	-1485	-1585	74	169	5	S	12	1959	2010	31.56	2.20E-03	0.15	-1032	-1748
6743903	Gonzales	124CRRZ	312	2530	-2018	-2218	77	172	5	P	13	2001	2005	17.56	2.13E-03	0.15	-1850	-2745
6840310	Guadalupe	124WLCX	585	130	475	455	50	161	8	U	40	1970	2011	7.37	5.27E-04	0.1	604	428
7722801	LaSalle	124LRDO	583	252	383	331	52	63	1	H	35	1962	2012	5.17	7.46E-04	0.15	512	289
7730801	LaSalle	124CRRZ	516	2051	-1284	-1535	59	58	5	H	44	1955	2007	11.26	9.80E-04	0.15	-1258	-1554
7748301	LaSalle	124CRRZ	420	3483	-2914	-3063	80	67	5	H	54	1956	2012	7.82	1.64E-03	0.15	-2541	-3278
7764401	LaSalle	124CRRZ	395	4280	-3535	-3885	92	50	5	H	45	1959	2012	2.7	1.41E-03	0.15	-3286	-4072
7607901	Maverick	124CRRZ	703	100	623	603	8	34	5	U	48	1955	2012	2.28	1.00E+00	0.15	715	602

Table 3. Summary Data for 92 Wells used in Hydrograph Construction

TWDB Well Number	County	TWDB Aquifer Code	Land Surface Elevation (ft MSL)	Well Depth (ft)	Elevation of Screen Top (ft MSL)	Elevation of Screen Bottom (ft MSL)	Model Row	Model Column	Model Layer	Well Use (TWDB Code)	Number of Groundwater Elevation Measurements	Ealiest Year with Measurement	Latest Year with Measrement	Hydraulic Conductivity (ft/day)	Storativity (dimensionless)	Specific Yield (ft^{-1})	Elevation of Layer Top (ft MSL)	Elevation of Layer Bottom (ft MSL)
7607919	Maverick	124CRRZ	700	115	616	595	8	36	5	U	68	1971	2012	2.38	1.00E+00	0.15	697	560
7821801	McMullen	124CZWX	378	3600	-3122	-3212	83	106	5	H	42	1959	2012	10.98	1.27E-03	0.15	-3030	-3749
6857307	Medina	124CRRZ	643	409	517	329	41	104	5	U	71	1971	2011	15.51	1.00E+00	0.15	654	236
6955901	Medina	124WLCX	665	225	565	440	30	92	8	U	44	1952	2011	7.56	5.10E-04	0.1	572	402
8504401	Webb	124CRRZ	620	2000	-1222	-1272	80	20	5	H	33	1965	2012	0.79	7.07E-04	0.15	-1121	-1328
8513402	Webb	124LRDO	720	505	245	220	93	22	3	U	39	1965	2012	0.61	7.71E-03	0.15	255	-1365
6741102	Wilson	124CRRZ	590	272	340	318	61	159	5	U	141	1964	2010	23.1	2.49E-03	0.15	524	42
6749201	Wilson	124CRRZ	470	916	-341	-431	68	155	5	U	51	1963	2010	29.51	2.35E-03	0.15	-257	-890
6749202	Wilson	124QNCT	472	460	142	12	68	155	3	Z	33	1969	2010	1.74	1.00E+00	0.15	493	-93
6749206	Wilson	124CRRZ	467	972	-385	-485	68	155	5	P	10	2000	2010	29.51	2.35E-03	0.15	-257	-890
6846902	Wilson	124WLCX	517	692	-95	-175	55	141	8	U	17	1994	2010	5.57	1.57E-03	0.1	29	-495
6848601	Wilson	124CRRZ	490	202	438	288	61	153	5	H	39	1964	2010	11.38	1.00E+00	0.15	487	-78
6848812	Wilson	124CRRZ	426	533	239	134	61	151	5	U	73	1970	2010	25.99	2.11E-03	0.15	344	-84
6848907	Wilson	124CRRZ	502	340	312	162	62	154	5	I	30	1969	2010	13.22	3.24E-03	0.15	386	-227
6853902	Wilson	124CRRZ	533	754	-86	-221	58	129	5	I	13	1994	2010	40.9	3.43E-03	0.15	270	-491
6854602	Wilson	124CRRZ	525	200	367	325	60	137	4	U	40	1964	2010	1	1.00E+00	0.1	468	324
6855407	Wilson	124CRRZ	456	417	136	39	61	139	5	I	35	1969	2010	38.87	2.72E-03	0.15	224	-336
6855704	Wilson	124CRRZ	430	920	-190	-490	64	137	5	I	37	1969	2010	29.13	3.24E-03	0.15	-155	-896
6856101	Wilson	124CRRZ	490	280	233	211	62	148	5	U	44	1955	2010	41.07	2.61E-03	0.15	328	-217
6856201	Wilson	124CRRZ	428	800	-252	-372	65	150	5	I	36	1970	2010	76.86	2.23E-03	0.15	-69	-621
6856302	Wilson	124CRRZ	431	520	-27	-89	64	151	5	I	44	1964	2010	77.96	1.99E-03	0.15	22	-451
6856804	Wilson	124QNCT	489	460	251	29	68	145	3	I	37	1969	2010	2.05	3.70E-03	0.15	464	-184
6862104	Wilson	124CRRZ	590	925	-176	-330	60	130	5	U	198	1966	2012	56.07	3.23E-03	0.15	19	-753
6862108	Wilson	124CRRZ	572	938	-266	-366	60	131	5	H	14	1993	2010	42.25	3.06E-03	0.15	24	-693
6862503	Wilson	124QNCT	487	600	17	-113	64	131	3	H	36	1969	2010	2.28	3.55E-03	0.15	444	-272
6862902	Wilson	124CRRZ	437	1600	-1023	-1163	68	131	5	I	105	1955	2010	32.21	2.08E-03	0.15	-1001	-1691
6862906	Wilson	124CRRZ	422	1924	-1387	-1497	68	132	5	I	18	1991	2010	29.27	2.06E-03	0.15	-956	-1634
6863101	Wilson	124CRRZ	448	1210	-602	-762	66	136	5	U	43	1952	2010	33.2	2.46E-03	0.15	-482	-1190
6864402	Wilson	124CRRZ	403	2032	-1376	-1628	72	142	5	P	23	1954	2010	21.32	2.17E-03	0.15	-1206	-1978
6958701	Zavala	124CRRZ	772	182	671	604	13	53	5	U	147	1954	2012	2.12	1.00E+00	0.15	767	415
6958707	Zavala	124CRRZ	789	244	651	589	12	53	5	I	39	1958	2012	4.85	1.00E+00	0.15	785	542
7608406	Zavala	124CRRZ	712	102	647	610	8	38	5	U	23	1970	2012	2.04	1.00E+00	0.15	716	569
7624906	Zavala	124CRRZ	631	438	349	210	26	31	5	U	69	1971	2012	3.97	1.66E-03	0.15	451	174
7701404	Zavala	124CRRZ	735	189	581	550	12	43	5	S	26	1970	2003	5.7	8.82E-04	0.15	586	422
7702403	Zavala	124CRRZ	748	575	323	173	16	50	5	P	87	1964	2007	8.28	9.44E-04	0.15	326	111
7702509	Zavala	124CRRZ	735	734	121	1	18	51	5	U	209	2002	2012	10.45	1.32E-03	0.15	232	-61
7704431	Zavala	124CRRZ	708	807	41	-99	24	62	5	P	68	1968	2011	48.08	7.26E-04	0.15	47	-132
7711719	Zavala	124BGDF	640	865	-210	-220	29	50	4	U	41	1975	2012	1	2.04E-03	0.1	-32	-339

The hydrographs are useful to compare model calibration by comparing pre-1999 historic groundwater elevations to the estimates of groundwater elevation at that point (the black line). In many cases the comparison is favorable, in other areas it is not. The estimates of historic pumping in the vicinity of the well are sometimes a useful guide to interpret the comparisons. In general, the recovering future groundwater elevations are well correlated with assumed decreases in pumping, and declining future groundwater elevations are well correlated with assumed increases in pumping.

3.2 Well-by-Well Drawdown Comparison

In order to compare drawdown estimates from GAM Run 09-034 with drawdown data from specific wells, the group of wells used in hydrograph construction were filtered further to include wells that had a late 1999/early 2000 groundwater elevation measurement and at least one measurement at the end of the year/beginning of the year from late 2000/early 2001 to late 2011/early 2012. As a result of this additional filtering 70 wells with 628 groundwater drawdown measurements were identified that met these criteria. Locations of these wells are presented in Figure 22 and the selected details of the wells and the 628 actual drawdown measurements from 2000 to 2011 are presented in Table 4. Please note that blank entries in Table 4 represent years where no data were collected.

The comparison of actual drawdown and model-estimated drawdown was completed by calculating the difference between the model-estimated drawdown and actual drawdown. A positive number means that the actual groundwater elevation is higher than the groundwater elevation projected by GAM Run 09-034 in that cell of the model. For example, if the drawdown from GAM Run 09-034 is 10 feet, and the actual drawdown is 8 feet, the difference is 2 feet, which means that the groundwater elevation is two feet higher than projected in GAM Run 09-034. Conversely, a negative number from this calculation means that actual groundwater elevations are lower than the estimated groundwater elevation from GAM Run 09-034. Results were summarized by GMA, year, and county.

The overall summary of the analysis for GMA 13 is shown in Figure 23, which is a histogram of the difference between DFC drawdown and actual drawdown for all years evaluated (2000 to 2011). Maps showing this analysis for each year for GMA 13 are presented in Appendix 1. More detailed maps for 2001, 2006 and 2011 which include well numbers for each county are presented in the county-specific appendices.

Please note that a difference of greater than 3 feet (actual groundwater elevation is 3 feet or more higher than the DFC simulation elevation) is shown in green, differences of between -3 and 3 feet are shown in yellow (actual groundwater elevation and DFC simulation elevation is within 3 feet), and differences less than -3 feet are shown in red (actual groundwater elevation is 3 feet or lower than the DFC simulation elevation). From this plot, it can be seen that about 18 percent of all groundwater elevation measurements are below the projected groundwater elevation from the DFC condition, about 25 percent are within 3 feet of the DFC condition, and about 57 percent are 3 feet or higher than the DFC condition.

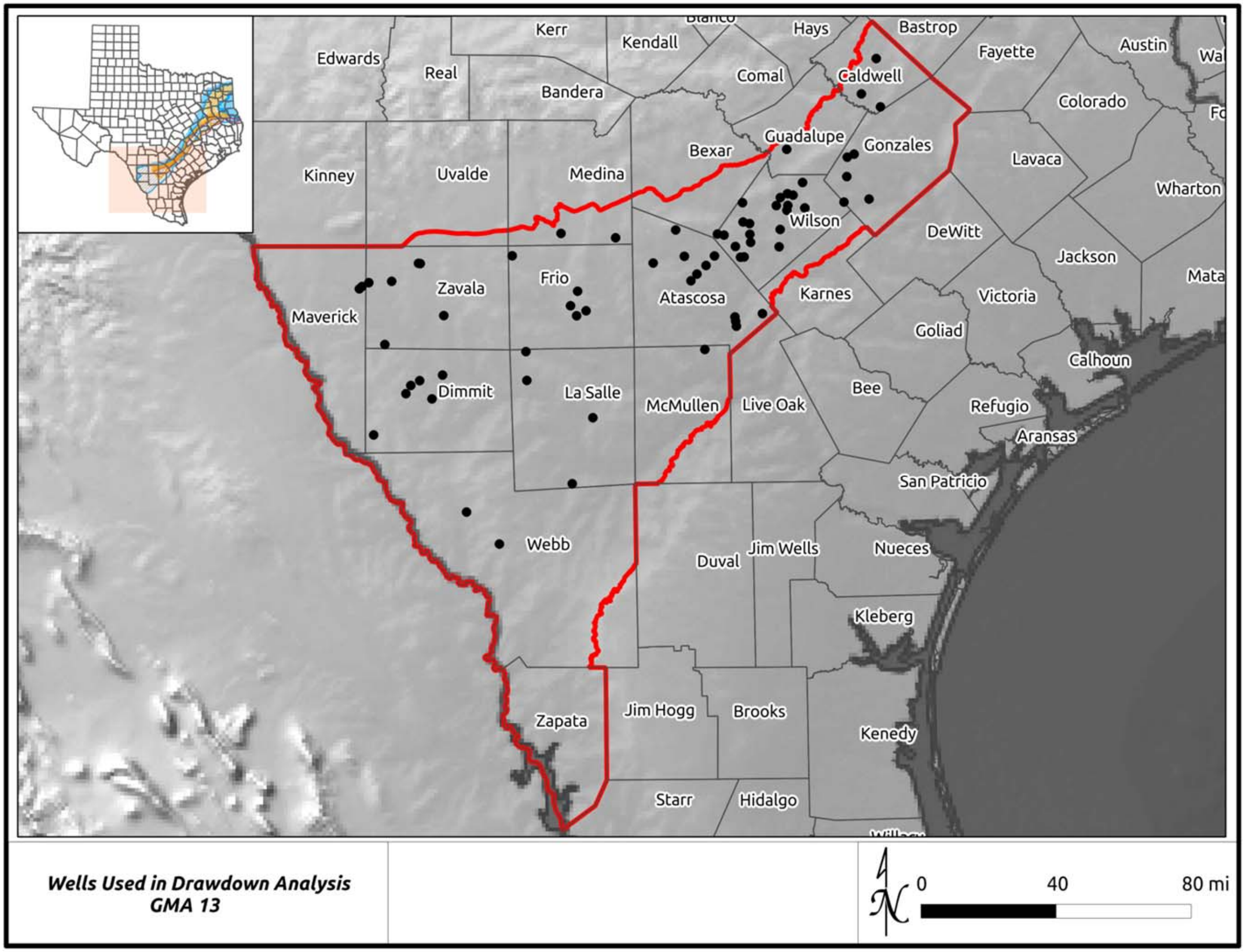


Figure 22. Locations of Wells Used in Drawdown Comparison

Table 4. Wells Used in Drawdown Comparison

Well Number	County	Model Row	Model Column	Model Layer	Measured Drawdown from 1999 Groundwater Level (ft) by Year											
					2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
6852713	Atascosa	50	120	5	0.50	0.10	-2.20	-2.80	-3.50	-0.90	-2.30	-2.90	-4.30	-6.00		
6859804	Atascosa	54	109	5	3.20	4.00	3.00	0.50	0.75	2.50	3.60	1.60	2.50			
6860852	Atascosa	58	117	5		-5.15	-11.95	-9.45	-20.35	-22.15	-22.05	-30.35	-34.65	-40.05		
6861905	Atascosa	63	125	5	-2.70	11.40	-1.00	-1.50	-23.00	-6.00	-9.00	-7.40	-2.00			
7804612	Atascosa	65	115	5	-0.90	10.80	6.20	4.40	4.80	7.40	9.20	6.40	7.80	5.80		
7805212	Atascosa	64	121	5		2.10	0.90	1.70	1.50	3.90	5.80	5.20	5.70	4.70		
7805409	Atascosa	64	117	3		2.00	0.10	0.50	4.40	5.70	10.40	5.90	7.30	5.60		
7814801	Atascosa	82	118	5	16.15	22.85	-4.18	-0.72	-0.72	1.59	10.83	9.68	15.50	10.80		
7814802	Atascosa	81	119	5	11.55	17.33	11.55	13.90	11.55	12.71	17.33	15.02	13.90	13.90		
7815805	Atascosa	85	126	5	14.00	12.30	11.60	10.30	9.30	10.60	6.10	9.10	10.00			
7822201	Atascosa	84	117	5	0.42	5.04	5.04	3.88	-0.74	0.42	2.04	-2.12	-0.70	0.20		
6712111	Caldwell	45	198	8	-0.10	-0.90	-2.47	-3.15	-3.83	-1.95	-1.50	-0.60	-0.30	0.60	1.62	0.75
6719306	Caldwell	51	188	8	-3.44	-3.16	-4.16	-3.84	-6.31	-3.24	-8.71	-3.44	-3.16	-2.66	-0.82	-0.04
6720802	Caldwell	57	191	7	0.93	-0.93	-1.95	2.48	-0.52	-2.27	-1.15	0.18	0.75	-0.01		
7648801	Dimmit	45	12	5	0.20	0.48			-0.53	0.03	0.28	0.70	-0.40	0.23	0.66	10.75
7726708	Dimmit	40	33	5	1.40	1.34	2.11	0.43	1.39	13.65	4.00	5.50		8.08	7.71	10.94
7727709	Dimmit	43	39	3	0.60	1.20	0.68	0.80	0.03	1.65	2.80	0.70	2.71	6.36	5.01	4.75
7733322	Dimmit	40	30	5	0.00	0.78	-5.96	2.00								
7733611	Dimmit	41	27	5	-3.20	-1.46	-2.93	6.40	-0.83	0.82	1.59		5.53		3.87	6.03
7734607	Dimmit	47	32	5		10.10	6.95	-12.90					-10.00			
6961606	Frio	27	77	5	1.50	6.60	-8.00	-5.50	-9.00	-0.20	11.00	0.60	0.60			
7708803	Frio	47	86	5	-13.20	47.82	-10.61	-16.97	-31.81	46.55	32.35	49.32	68.22	15.31	85.85	
7716409	Frio	49	82	5	-33.00	-28.00										
7716603	Frio	53	84	5		31.00	18.10	12.00	11.40	16.60	21.30	17.04	32.50	24.50		
7716801	Frio	53	81	5		35.90	-8.80	-1.70	-12.28	23.40	37.60	16.40	61.00	25.20		
6735201	Gonzales	64	176	5		2.17		5.94	4.54	7.94		6.77		14.75		
6735401	Gonzales	63	174	5		2.42		5.55	6.62	7.70		7.33		10.19		
6742905	Gonzales	73	165	5		7.86		12.58	11.39	13.82		13.45		16.94		
6743103	Gonzales	68	170	5	0.19	5.65		17.58	16.90	21.39		23.27		23.51		
6743903	Gonzales	77	172	5	0.00	50.40										
6840310	Guadalupe	50	161	8	-0.65	-0.30	-0.52	0.00	-0.82	0.00	-0.62	-0.15	-0.30		1.36	0.41
7722801	LaSalle	52	63	1	1.70	1.05	0.80	0.90	-0.62	12.70	2.70	2.40	4.77	2.12	-1.76	-3.70
7730801	LaSalle	59	58	5	-0.20	5.80	-8.60	-1.80								
7748301	LaSalle	80	67	5	10.70	6.14	8.22	6.30	-14.85	-6.53	12.00	10.90	19.56	38.44	45.22	95.89
7764401	LaSalle	92	50	5	15.15	0.40	8.32			10.65	5.95		11.28		58.59	78.21
7607901	Maverick	8	34	5		-7.73	-7.25	-6.45	-2.54	-1.58	-3.05	-4.70	-1.32	-1.07	-7.94	-7.34
7607919	Maverick	8	36	5		-1.90	-1.35	-1.94	-2.35	-1.35	-1.70	-0.52	0.21	0.40	-0.03	-0.69
7821801	McMullen	83	106	5	8.55	7.17				-0.95	12.70	0.08	8.40	8.42	9.56	54.48
6857307	Medina	41	104	5		1.82	3.40	4.40	4.28	6.09	7.22	8.18	9.73	8.38	9.06	9.55
6955901	Medina	30	92	8	-0.07	0.27	-4.32	-3.41	-5.13	-0.17	6.46	6.73	6.75	4.81	10.74	3.63
8504401	Webb	80	20	5		7.74	9.38		12.90		28.40					71.80
8513402	Webb	93	22	3	3.94	1.37		4.04	-3.00	-0.60	4.05	3.84		19.19	21.27	25.79

Table 4. Wells Used in Drawdown Comparison

Well Number	County	Model Row	Model Column	Model Layer	Measured Drawdown from 1999 Groundwater Level (ft) by Year											
					2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
6741102	Wilson	61	159	5	0.00	-0.20	0.40	-0.80	1.40	1.80	2.50	2.20	0.70	3.10		
6749201	Wilson	68	155	5	0.00	-2.80	-1.60	0.20	-1.10	6.40	7.10	3.50	5.50	5.00		
6749202	Wilson	68	155	3	0.00	-0.20	5.90	3.30	1.40	-0.20	2.70	4.40	4.80	3.39		
6749206	Wilson	68	155	5		0.10	5.40	1.00	-0.80	0.00	4.00	1.20	3.80	3.25		
6846902	Wilson	55	141	8	-1.30	-1.70	-6.00	-6.70	-6.50	-3.20	-2.40	-3.90	-3.00			
6848601	Wilson	61	153	5	0.10	1.60	0.80	1.20	0.40	1.60	2.60	1.40	2.50			
6848812	Wilson	61	151	5	0.20	2.00	-0.80	1.50	-0.70	2.70	4.00	3.10	3.50			
6848907	Wilson	62	154	5	-3.40	-8.80	-4.50	-15.50	-17.40	-17.80	-16.00	-16.80	-16.20			
6853902	Wilson	58	129	5	-0.70	4.10	-10.00	-7.70	-32.60	-22.00	-4.30	-49.30	-3.90			
6854602	Wilson	60	137	4	0.10	2.40	0.60	0.80	-1.40	0.20	-0.20	-7.60	-10.70			
6855407	Wilson	61	139	5	0.90	2.80	1.20	1.90	-0.70	2.50	3.50	-0.20	0.20			
6855704	Wilson	64	137	5	-1.60	0.50	-0.90	-1.20	-2.80	-0.90	0.60	-1.40	0.10			
6856101	Wilson	62	148	5	0.20	4.80	3.50	3.80	1.60	2.40	3.30	0.80	2.10			
6856201	Wilson	65	150	5	-2.20	3.00	3.00	3.20	2.20	12.00	6.25	5.60	6.30			
6856302	Wilson	64	151	5	0.10	0.10	-0.40	-0.20	-2.20	-0.40	0.35	-0.50	0.20			
6856804	Wilson	68	145	3	0.10	2.85	8.00	7.10	0.60	6.40	8.10	6.80	8.10			
6862108	Wilson	60	131	5	-2.30	3.20	5.20	4.70	-7.00	-3.20	0.00	-18.20	-9.70			
6862503	Wilson	64	131	3	0.00	2.00	1.40	-2.50	-10.00	-7.50	-0.50	-2.70	0.50			
6862902	Wilson	68	131	5	0.80	3.50	0.40	-1.20	-9.00	-3.00	3.00	-1.20	1.60			
6862906	Wilson	68	132	5	3.00	5.75	1.50	-0.10	-8.30	3.50	7.00	4.60	6.69			
6863101	Wilson	66	136	5	0.05	3.00	1.60	2.00	1.20	2.40	3.00	1.90	3.60			
6864402	Wilson	72	142	5	0.25	-2.00	-5.00	-3.70	-7.20	-1.50	5.40	2.60	4.10			
6958701	Zavala	13	53	5	-8.95	-8.80	-3.40	-8.55	-8.53	-8.43	-8.01	-6.85	-5.28	-6.08	-5.13	-4.34
6958707	Zavala	12	53	5	-1.45	-1.00	-2.00	-2.56	-2.86	-2.57	-1.76	-1.30	-0.95	4.25	2.24	0.12
7608406	Zavala	8	38	5	5.10	1.00	1.90	1.05			1.65	6.55		14.58	9.16	8.90
7624906	Zavala	26	31	5	0.90	3.40	0.60	5.30	3.57	5.87	6.90	8.22	8.10	14.59	11.44	13.50
7701404	Zavala	12	43	5			-12.95									
7711719	Zavala	29	50	4	7.40	36.30	18.35	-0.90	-21.20	-0.42	17.80				-15.55	88.33

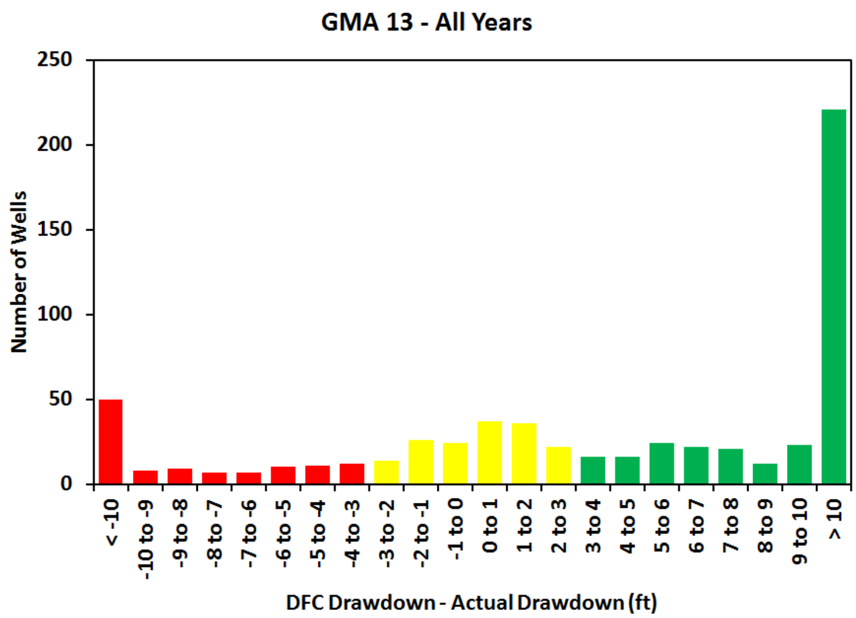


Figure 23. Summary of Differences between DFC Drawdown and Actual Drawdown for All Years

Figure 24 summarizes the data for all of GMA 13 for each year. Note that most in the early years (2000 and 2001), the majority of actual drawdowns are within 3 feet of the DFC condition. From 2002 to 2008, the majority of readings are more than 3 feet above the DFC conditions. From 2009 to 2011, the number of readings decreases significantly, and by 2011, the majority of actual drawdowns are greater than the DFC condition.

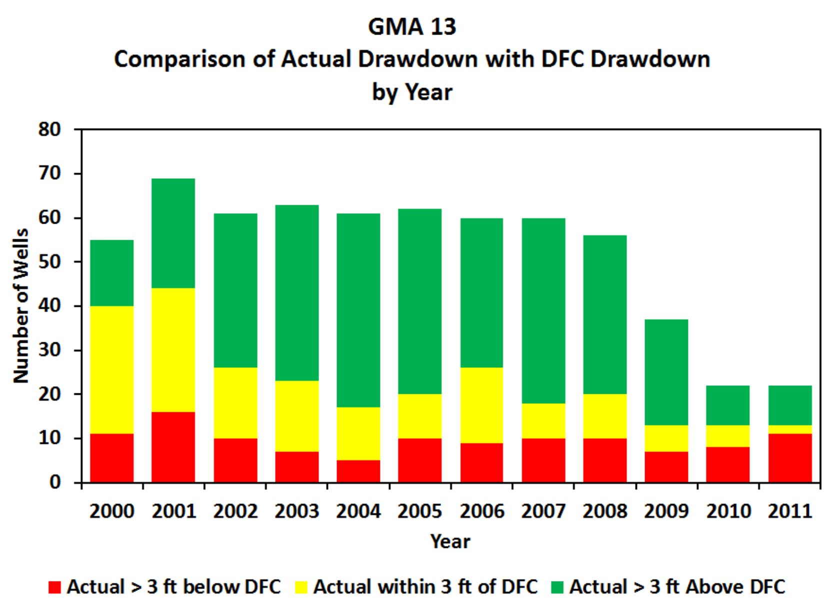


Figure 24. Comparison of Actual Drawdown with DFC Drawdown by Year – GMA 13

3.3 Average Drawdown Comparison

The analysis was extended by averaging all actual drawdowns in a particular year, all DFC condition drawdowns at wells with data for a particular year, the difference between the DFC condition and the actual drawdown, and comparing the results with county-wide average drawdown from GMA Run 09-034 and rainfall data. These results are summarized in Table 5 for GMA 13. Similar tables for each county are presented in the appendices.

Table 5. Summary of GMA 13 Drawdown Comparisons

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**GMA-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	1.22	55	0.55	3.06	2.50
2001	101	2.23	69	4.79	6.25	1.46
2002	113	3.09	61	0.37	5.75	5.38
2003	96	3.87	63	0.47	9.02	8.55
2004	132	4.59	61	-2.77	10.78	13.55
2005	75	5.28	62	2.53	12.30	9.77
2006	86	5.93	60	4.37	11.33	6.96
2007	142	6.56	60	1.95	15.59	13.64
2008	74	7.16	56	4.47	14.81	10.34
2009	76	7.74	37	7.05	18.43	11.38
2010	132	7.78	22	11.46	7.87	-3.59
2011	45	7.93	22	21.26	7.03	-14.23

Figure 25 presents the data from Table 5 in histogram form, and includes the average annual precipitation. Similar histograms are presented for each county in the appendices. Note that in 2001 and 2002, the difference is less than 3 feet, and the color bar is yellow. From 2002 to 2009, the differences are all great than 3 feet (actual drawdown is less than DFC drawdown) and the bars are green. In 2010 and 2011, the differences are less than -3 feet (actual drawdown is less than DFC drawdown) and the bars are red.

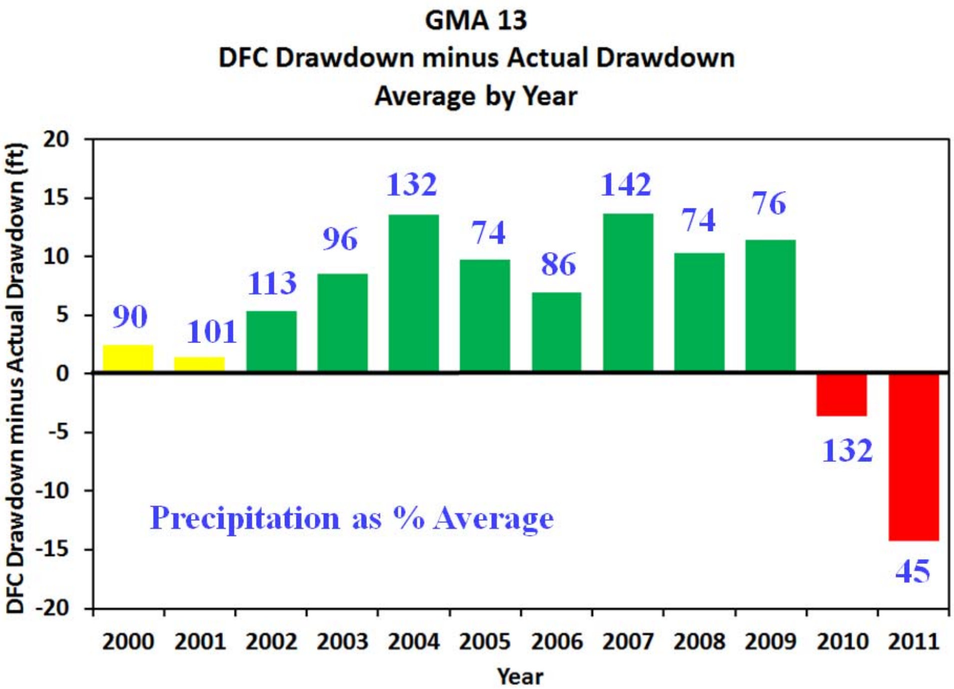


Figure 25. DFC Drawdown minus Actual Drawdown, Average by Year - GMA 13

The close agreement between actual drawdown and DFC drawdown in 2000 and 2001 is not surprising given the short time from the initial condition (1999) and the near-average precipitation. From 2002 to 2004, there is a general increase in actual groundwater elevations relative to the simulated DFC condition. This is partly due to the assumed pumping increases in much of GMA 13 that did not occur, and the relatively high precipitation conditions. This trend is interrupted in 2005 and 2006 when low precipitation occurred. The low precipitation conditions likely result in increased pumping due to the lack of rainfall as well as decreased recharge. In 2007, high precipitation again caused an increase in groundwater elevations, likely due to increased recharge and lower pumping. In 2008 and 2009, a return of low precipitation condition causes groundwater levels to fall relative to the DFC condition, again likely due to the combined effects of decreased recharge and increased pumping. Finally, in 2010 and 2011, groundwater levels drop to below that of the DFC condition. In both of these years, please recall that the number of readings is substantially lower than in previous years (see Table 5). This may affect the data, but other factors also need to be considered. 2010 is interesting because it was a relatively wet year, but it was also one of the first years of increased pumping due to hydraulic fracturing operations in the region. The large difference in 2011 appears to be explainable by considering the continuation/expansion of hydraulic fracturing operations and the severe drought year.

Figure 26 presents the actual drawdown data and the two sets of DFC data (full GMA average and estimated drawdown at the wells used in the analysis) from Table 5 in hydrograph form. Similar graphs for each county are presented in the appendices.

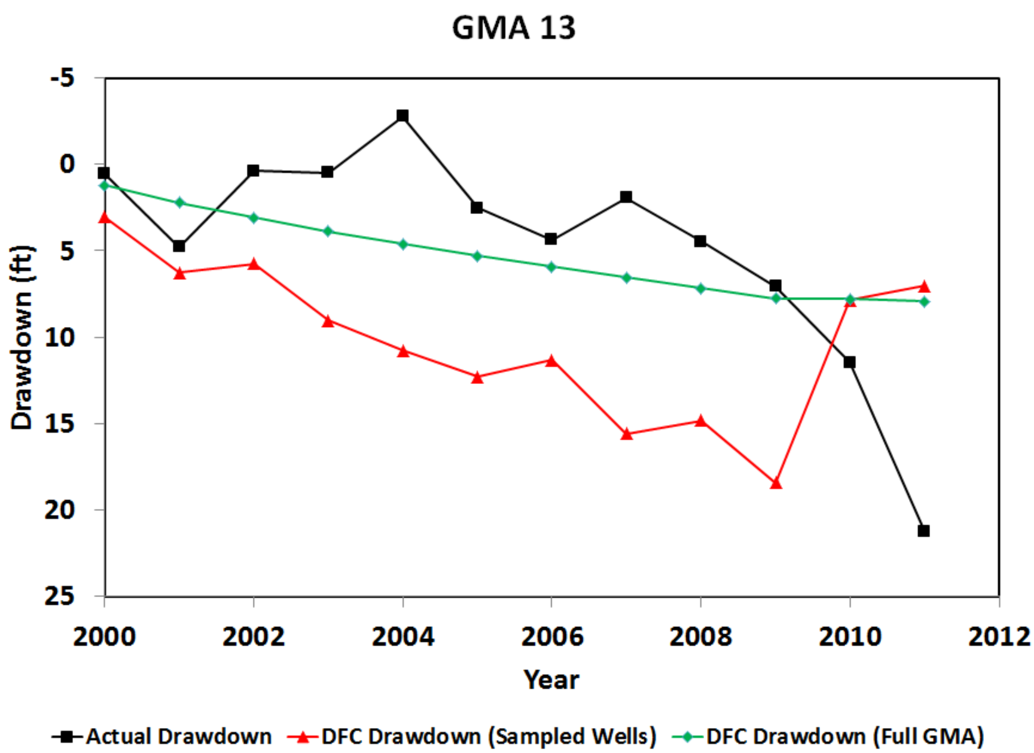


Figure 26. Hydrograph of Average Actual Drawdown and Average DFC Drawdown

Note that the actual drawdown in the wells with data is less than the drawdown estimated from the DFC simulation (Scenario 4 of GAM Run 09-034). The exception to this generalization is in 2010 and 2011. As discussed above, this is due to a combination of increased pumping during drought conditions, increased pumping due to hydraulic fracturing operations, decreased recharge due to drought (in 2011) and skewed results due to a smaller dataset. For future planning efforts, it appears that simulations of "constant" recharge and "constant" pumping may not be appropriate.

Also, please note that the DFC drawdown for the entire GMA (the green line) is generally larger than the DFC drawdown for the wells used in the analysis (the red line) until 2010 and 2011. Recall that fewer wells had measurements in 2010 and 2011 than the period 2000 to 2009. The fact that the DFC drawdowns for the wells used in the analysis (the red line) are lower than the overall GMA-wide average drawdown (green line) suggests that the wells used in the analysis are in areas where pumping increases were planned. It appears that data were not collected in many of these wells in 2010 and 2011, and the drawdown estimates are closer together.

4.0 County-Level Data Suitable for use in Management Plan Updates

One of the objectives of this effort was to develop data and information useful for the districts in their updates to groundwater management plans. One of the required elements of those plans is to address desired future conditions. The main body of the report focused on GMA-level analyses with various tables, maps and graphs.

Pertinent tables, maps and graphs were also developed for each county in GMA 13 for which suitable well data were available. These data are presented in the appendices (one for each county).

In general, the appendices contain:

- A map of the location of wells used in the hydrograph analysis
- The hydrographs of all wells that met the criteria previously described,
- A table analogous to Table 5 in the text summarizing annual average drawdown (actual and DFC)
- A figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions
- A figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

5.0 Recommendations for Current Round of Joint Planning

This effort was authorized by the groundwater conservation districts of GMA 13 as the initial step of the current round of joint planning. The establishment of the initial desired future conditions for the Carrizo-Wilcox, Queen City and Sparta aquifers relied heavily on simulations using the groundwater availability model of the area. Comparisons of these model results with actual data provide a foundation for future discussions related to the current round of joint planning. The major areas for discussion include:

- Improvement in 2000 to 2011 pumping estimates
- Timing of future pumping increases and decreases
- Evaluate the "average" recharge assumption for the entire DFC simulation
- Evaluate the assumption that future pumping does not vary between wet years and droughts
- Review model assumptions and implementation for recharge and stream flow
- Assess county-to-county impacts more explicitly
- The use of actual well data as part of the statement of desired future conditions

In reviewing the results of the comparisons between groundwater elevations and pumping in general, and between actual groundwater elevations and groundwater elevations estimated through the joint planning process, it is evident that the future pumping assumptions used in Scenario 4 of GAM Run 09-034 from 2000 to 2011 need updating for the current round of joint planning. Projected increases and decreases are envisioned and the timing of those changes needs to be better incorporated into the planning process.

The comparison analysis also yielded interesting observations regarding the variation in groundwater elevations from wet years to dry years. Sharp declines in dry years appear to be the result of the combined effect of decreased recharge and increased pumping during drought periods. Scenario 4 of GAM Run 09-034 included an assumption that recharge was constant and "average" each year of the 61 year simulation. Also, there was no assumption of pumping variation as a result of dry years. For a long-term planning process, this may be the most cost-effective means of simulating future conditions. However, it is a point that should be discussed in the context of how much detail the desired future condition statement will contain.

In reviewing the results of the analysis, there were a few examples where the model results identified some county-to-county impacts of pumping changes that seemed to be consistent with the conceptual model and others that may have been a result of model implementation. These should to be investigated further as part of the joint planning process to assure that the model simulations of the desired future condition are rational and defendable.

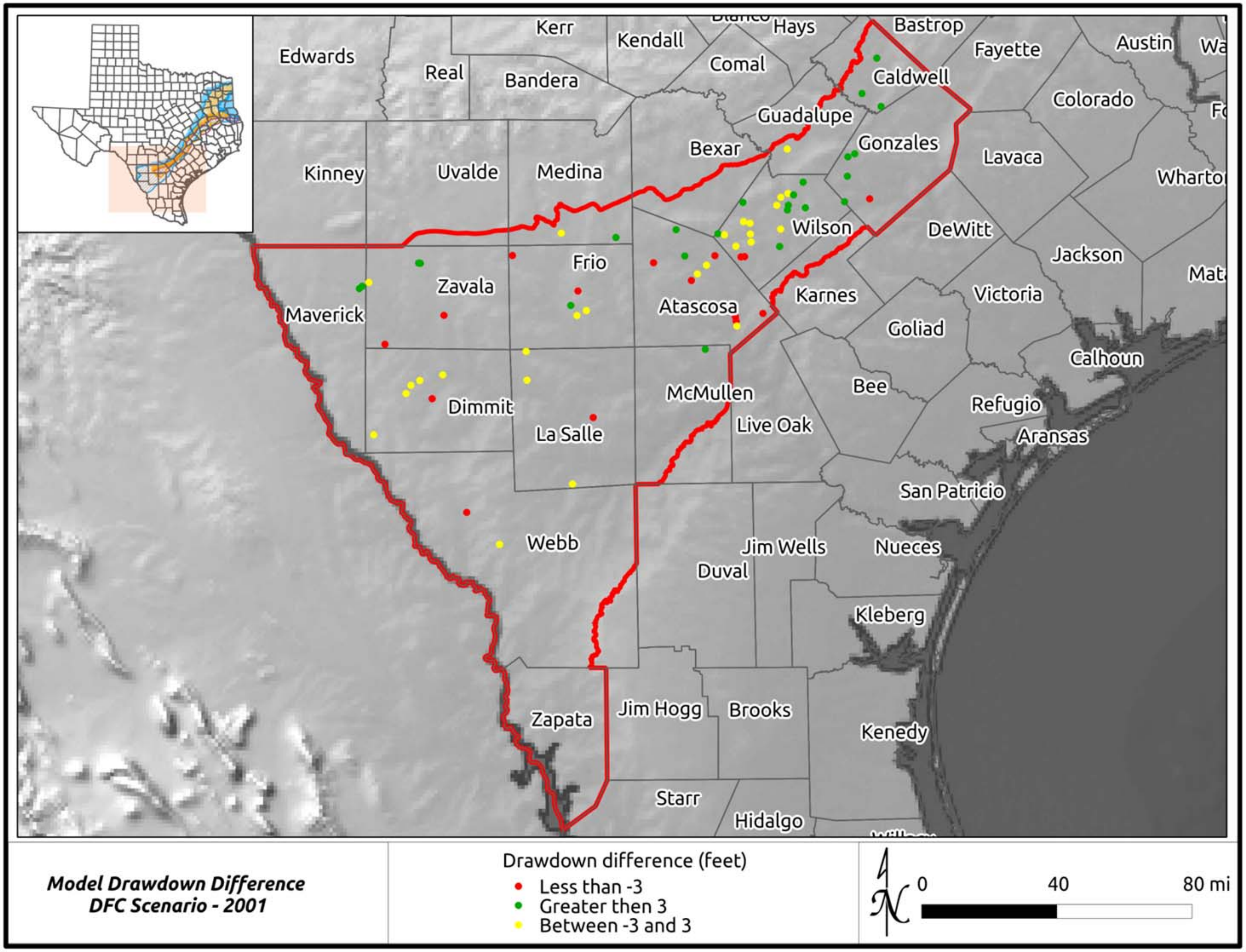
A discussion that needs to occur is how actual well data could be incorporated into the desired future condition statement and the role of the model in the process. It needs to be recognized that a model run, while not an absolute requirement, is certainly going to be made by the TWDB in the development of the Modeled Available Groundwater. Therefore, the groundwater conservation districts should realize that the GAM will continue to be an important aspect of the process. By linking the model run results to the desired future condition statement, however, the issues of whether to describe the DFC as a single GMA-wide average or as county-averaged DFCs, or as county-layer averaged DFCs is somewhat irrelevant since all describe the same set of assumptions that are explicitly and implicitly tied to the DFC. The decision on how to express the DFC statement in terms of averaging and the decision to include or not include actual data will be policy decisions by the groundwater conservation districts of GMA 13. The data and results in this analysis will assist the districts in those decisions.

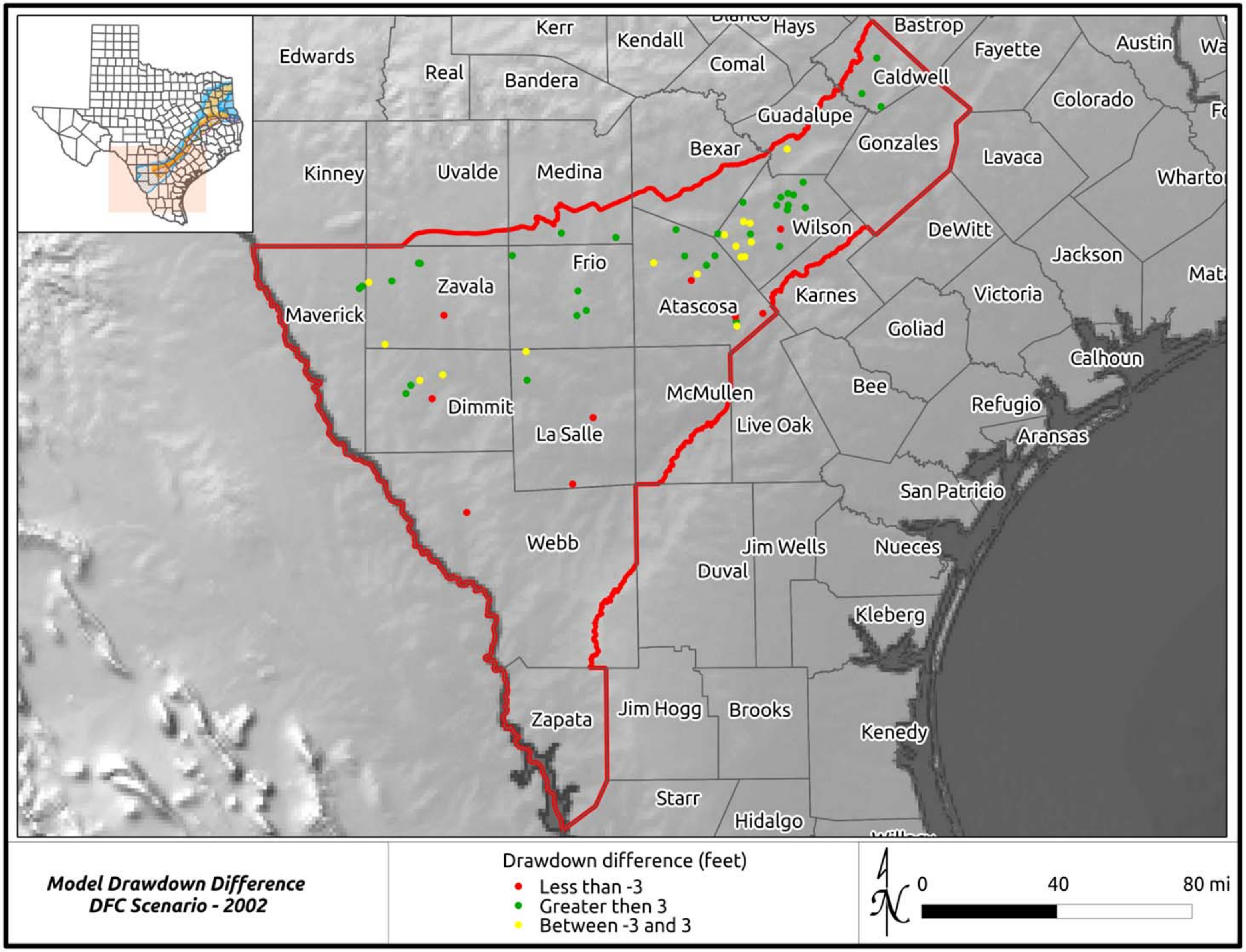
Appendix 1 – GMA 13 Drawdown Maps for All Years

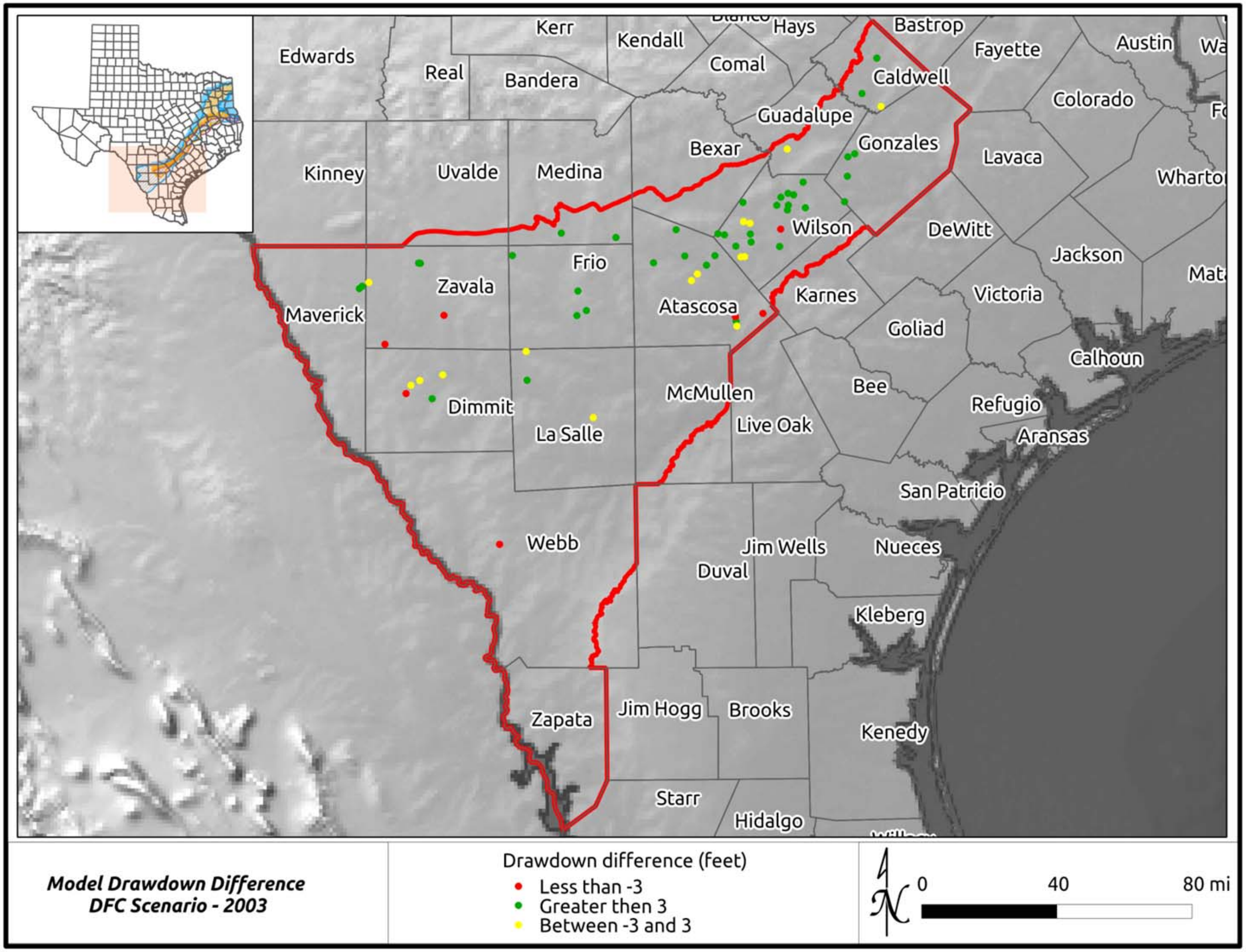
This appendix presents GMA-wide maps of the point-by-point year-by-year drawdown analysis. These maps provide a GMA-wide perspective of the drawdown comparison. Each well on these maps is color coded to show the difference between actual drawdown and the estimated drawdown at that point in that year.

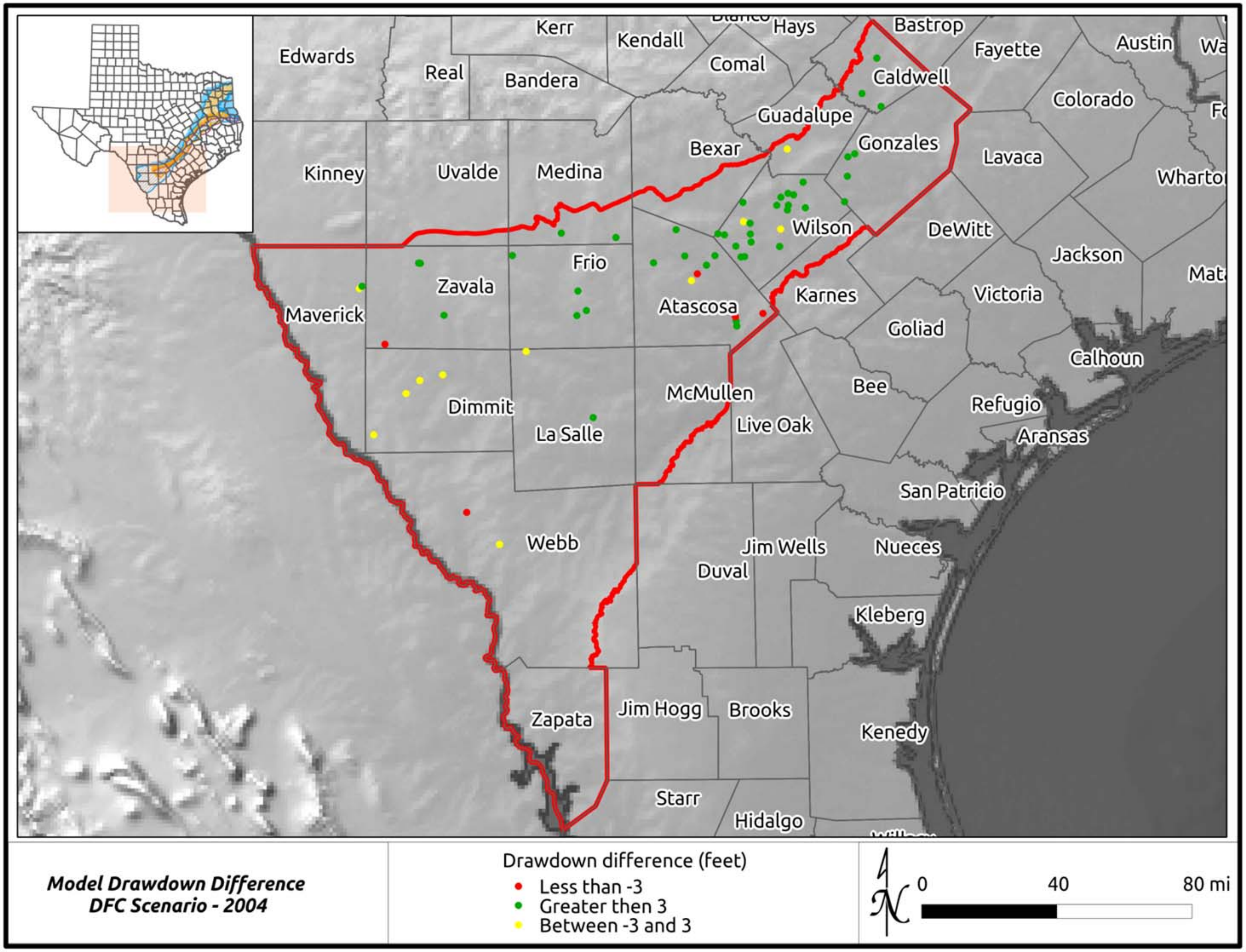
- A difference of greater than 3 feet (actual groundwater elevation is 3 feet or more higher than the DFC simulation elevation) is shown in green
- Differences of between -3 and 3 feet are shown in yellow (actual groundwater elevation and DFC simulation elevation is within 3 feet)
- Differences less than -3 feet are shown in red (actual groundwater elevation is 3 feet or lower than the DFC simulation elevation).

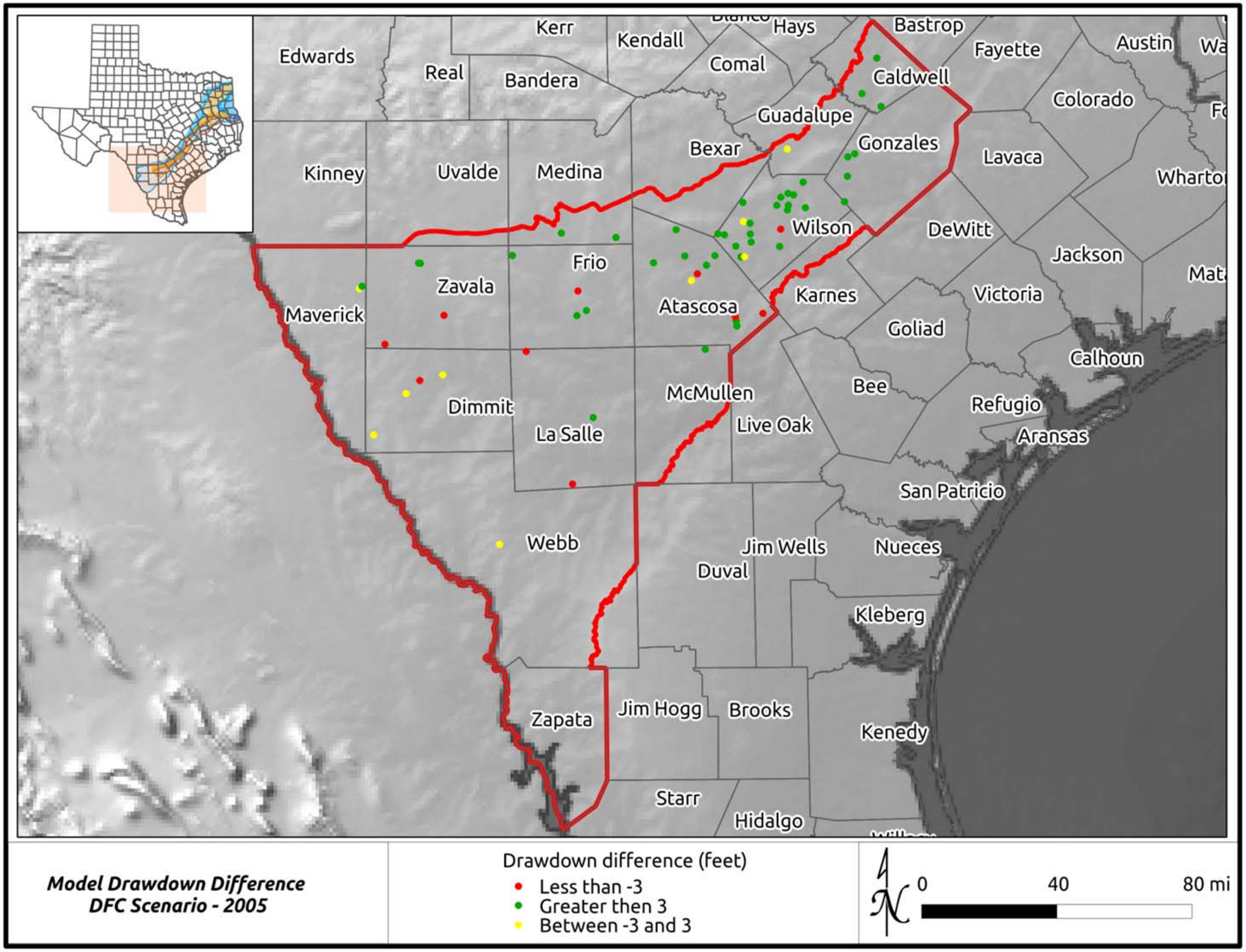
Detailed maps for each county using the same color coding for 2001, 2006 and 2011 (with well numbers) are presented in the appropriate county appendix.

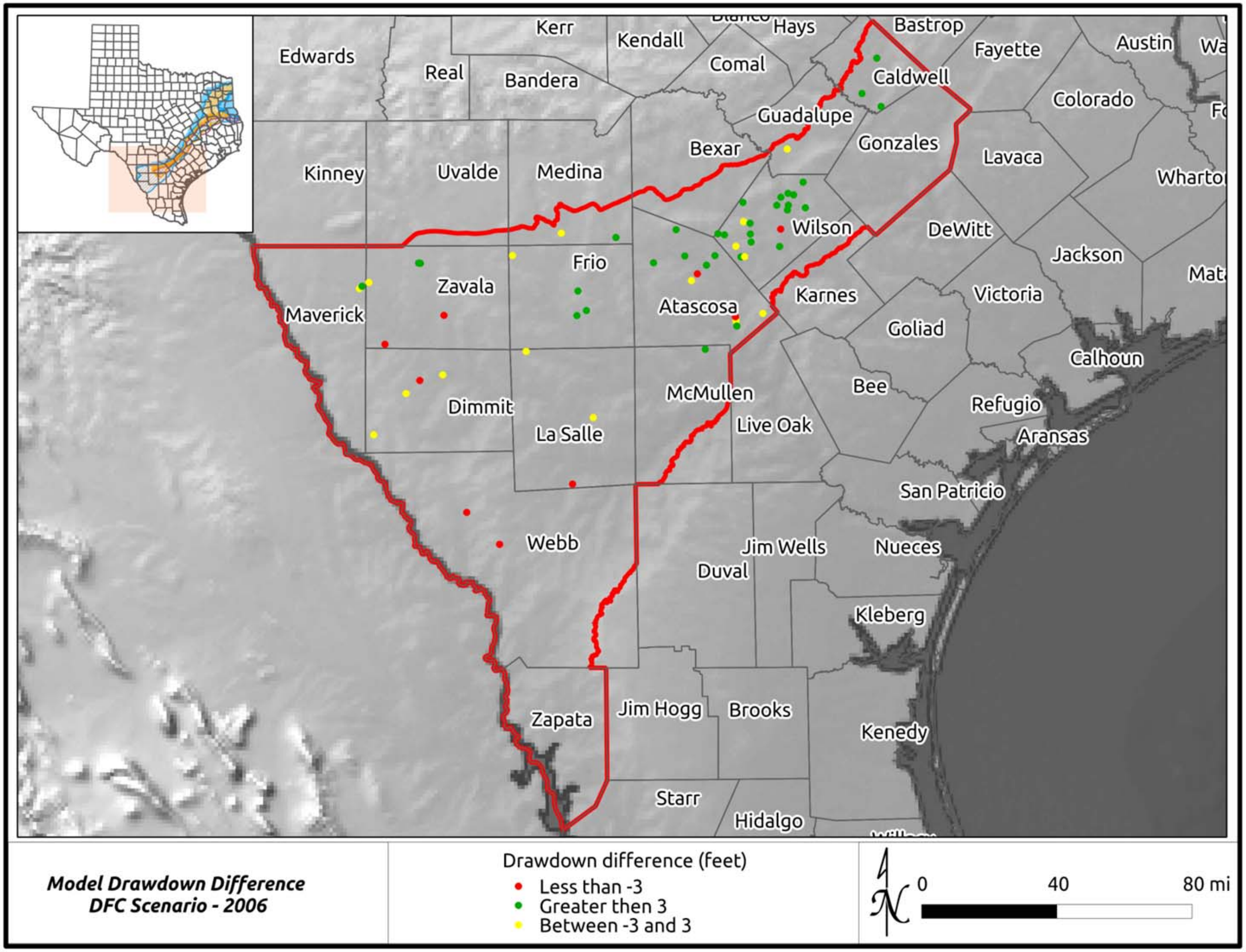

Kerr
Kendall
Hays
Bastrop
Edwards
Real
Bandera
Comal
Fayette
Austin
Caldwell
Colorado
Guadalupe
Bexar
Gonzales
Lavaca
Kinney
Uvalde
Medina
Wharton
Wilson
DeWitt
Jackson
Frio
Zavala
Atascosa
Karnes
Victoria
Maverick
Goliad
Calhoun
Bee
McMullen
Refugio
Dimmit
Live Oak
La Salle
Aransas
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2001
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
40
80 mi


Edwards
Kerr
Kendall
Hays
Bastrop
Real
Bandera
Comal
Caldwell
Fayette
Austin
Colorado
Guadalupe
Bexar
Gonzales
Lavaca
Kinney
Uvalde
Medina
Wharton
Wilson
DeWitt
Jackson
Frio
Zavala
Atascosa
Karnes
Victoria
Maverick
Goliad
Calhoun
McMullen
Bee
Dimmit
Live Oak
Refugio
La Salle
Aransas
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2002
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
40
80 mi

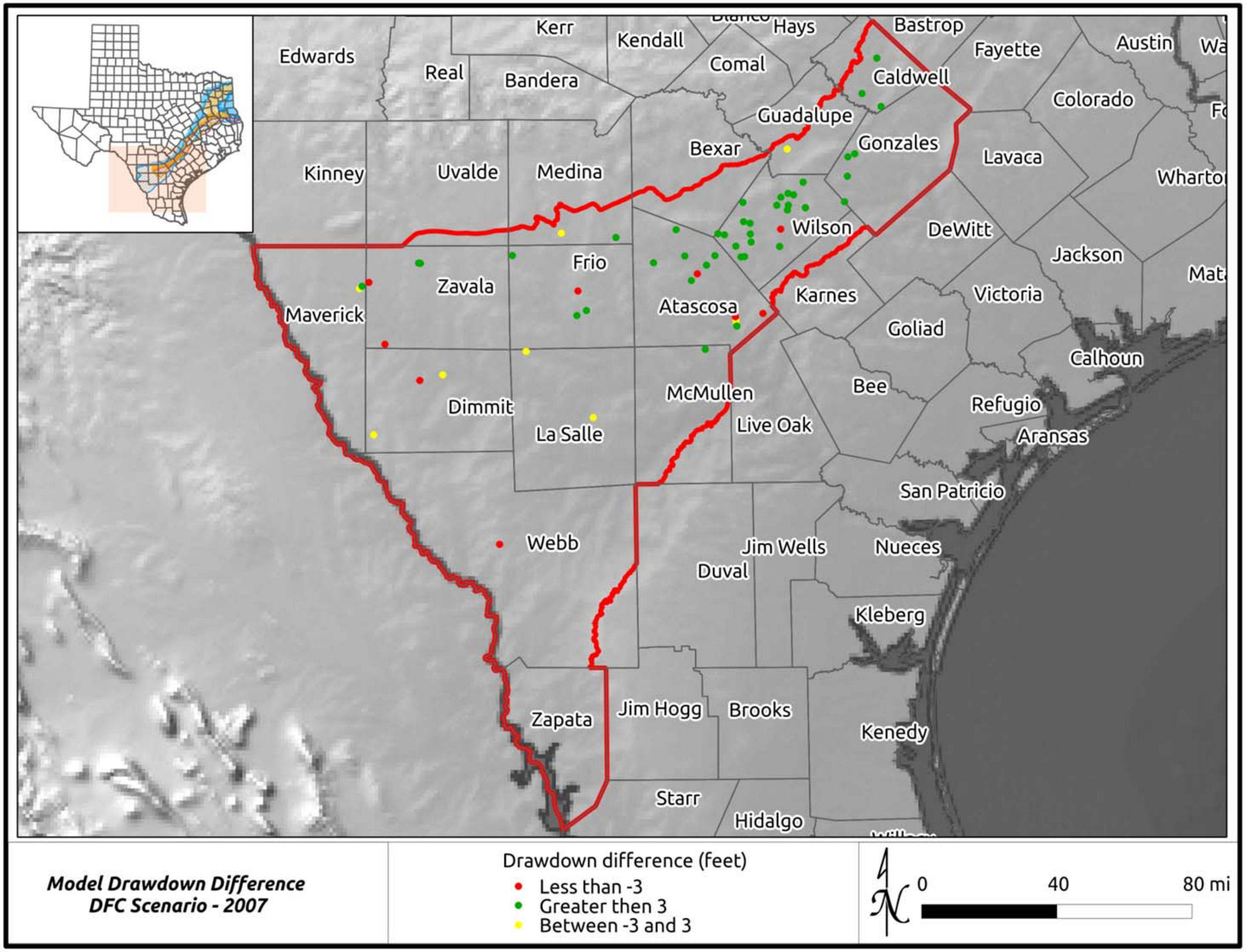

Edwards
Real
Kerr
Bandera
Kendall
Comal
Hays
Bastrop
Fayette
Austin
Caldwell
Guadalupe
Colorado
Bexar
Gonzales
Lavaca
Kinney
Uvalde
Medina
Wilson
DeWitt
Jackson
Frio
Zavala
Maverick
Atascosa
Karnes
Victoria
Goliad
Calhoun
Dimmit
La Salle
McMullen
Live Oak
Bee
Refugio
Aransas
San Patricio
Webb
Jim Wells
Duval
Nueces
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2003
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
40
80 mi


Edwards
Kerr
Kendall
Hays
Bastrop
Real
Bandera
Comal
Caldwell
Fayette
Austin
Guadalupe
Colorado
Bexar
Gonzales
Kinney
Uvalde
Medina
Lavaca
Wilson
DeWitt
Jackson
Frio
Zavala
Maverick
Atascosa
Karnes
Victoria
Goliad
Calhoun
Dimmit
McMullen
Bee
Refugio
La Salle
Live Oak
Aransas
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2004
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
40
80 mi

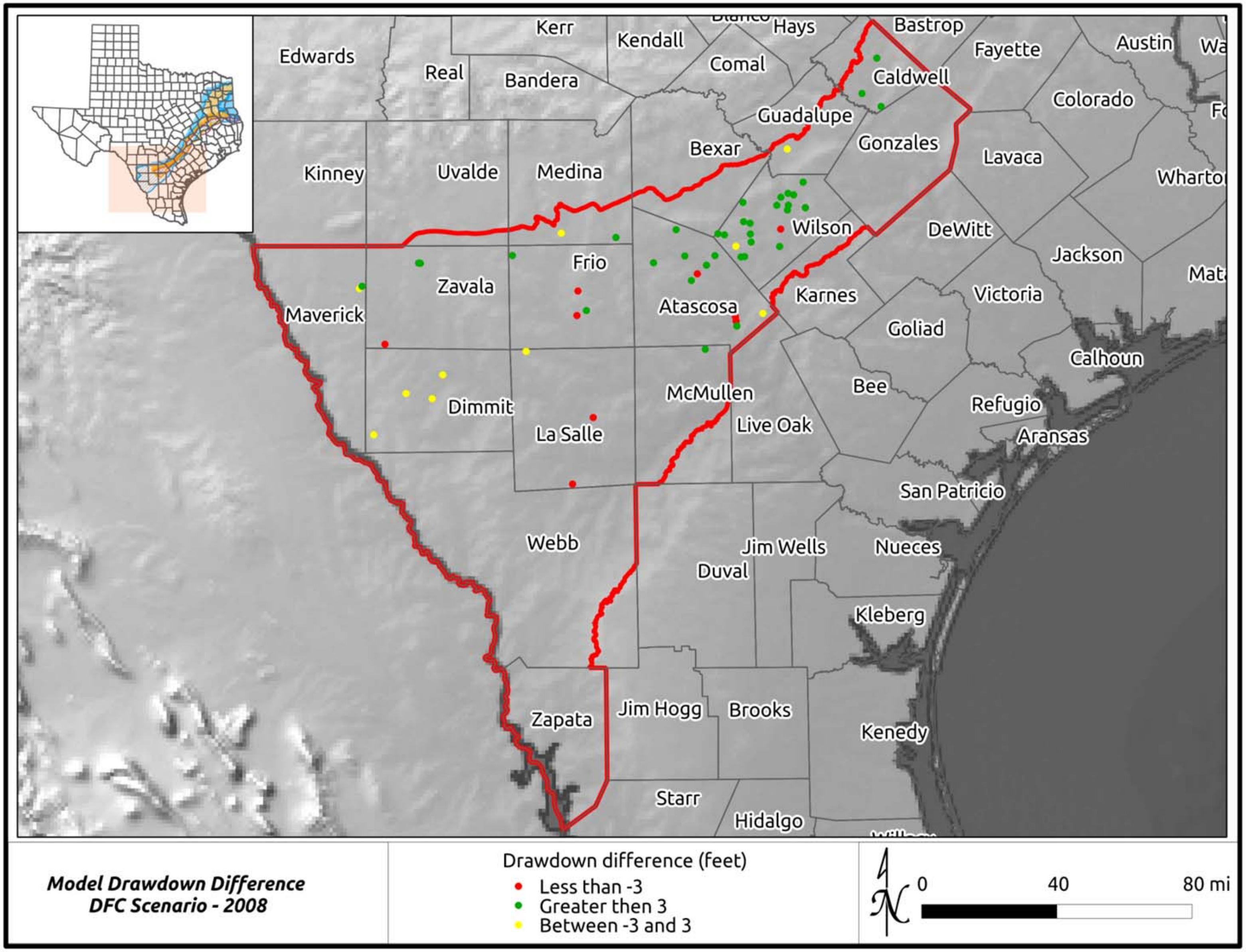

Edwards
Real
Kerr
Bandera
Kendall
Comal
Hays
Bastrop
Caldwell
Fayette
Austin
Colorado
Guadalupe
Bexar
Gonzales
Lavaca
Wharton
Kinney
Uvalde
Medina
Wilson
DeWitt
Jackson
Frio
Zavala
Maverick
Atascosa
Karnes
Victoria
Goliad
Calhoun
McMullen
Bee
Refugio
Dimmit
La Salle
Live Oak
Aransas
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2005
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
40
80 mi

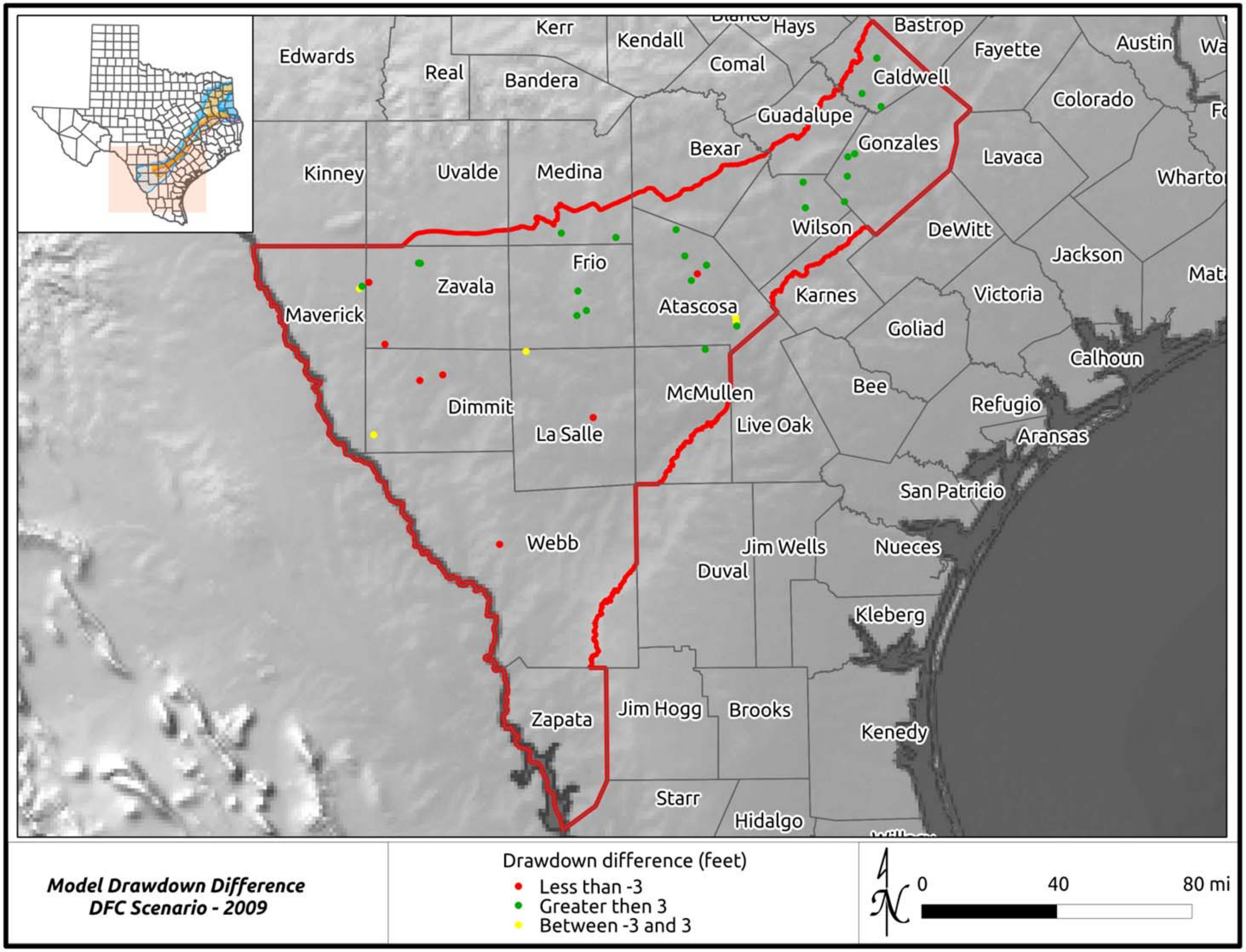


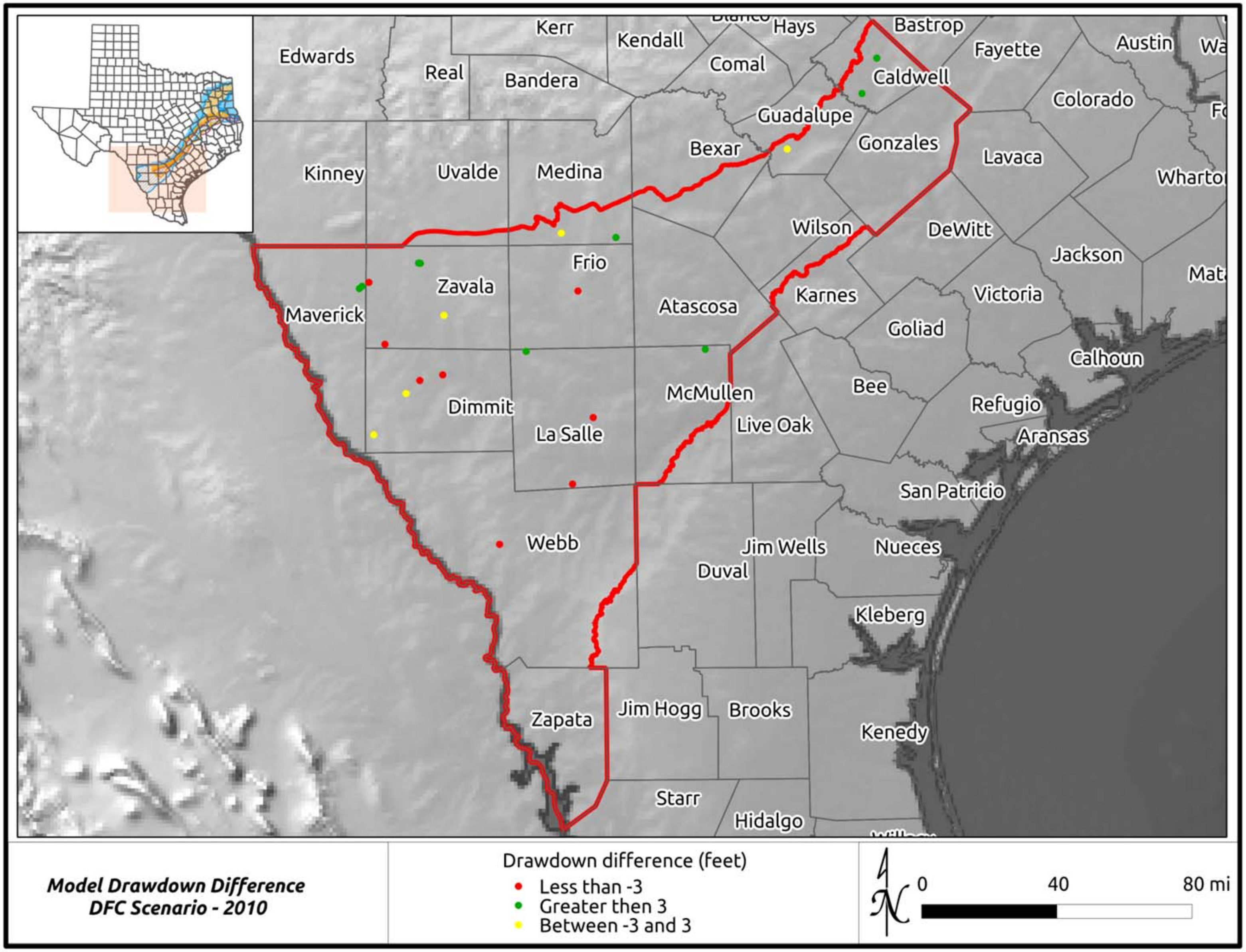
Edwards
Real
Kerr
Bandera
Kendall
Hays
Comal
Bastrop
Caldwell
Fayette
Austin
Guadalupe
Colorado
Bexar
Gonzales
Lavaca
Kinney
Uvalde
Medina
Wharton
Wilson
DeWitt
Jackson
Frio
Zavala
Atascosa
Karnes
Victoria
Maverick
Goliad
Calhoun
Bee
McMullen
Dimmit
Refugio
La Salle
Live Oak
Aransas
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2006
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
40
80 mi
N



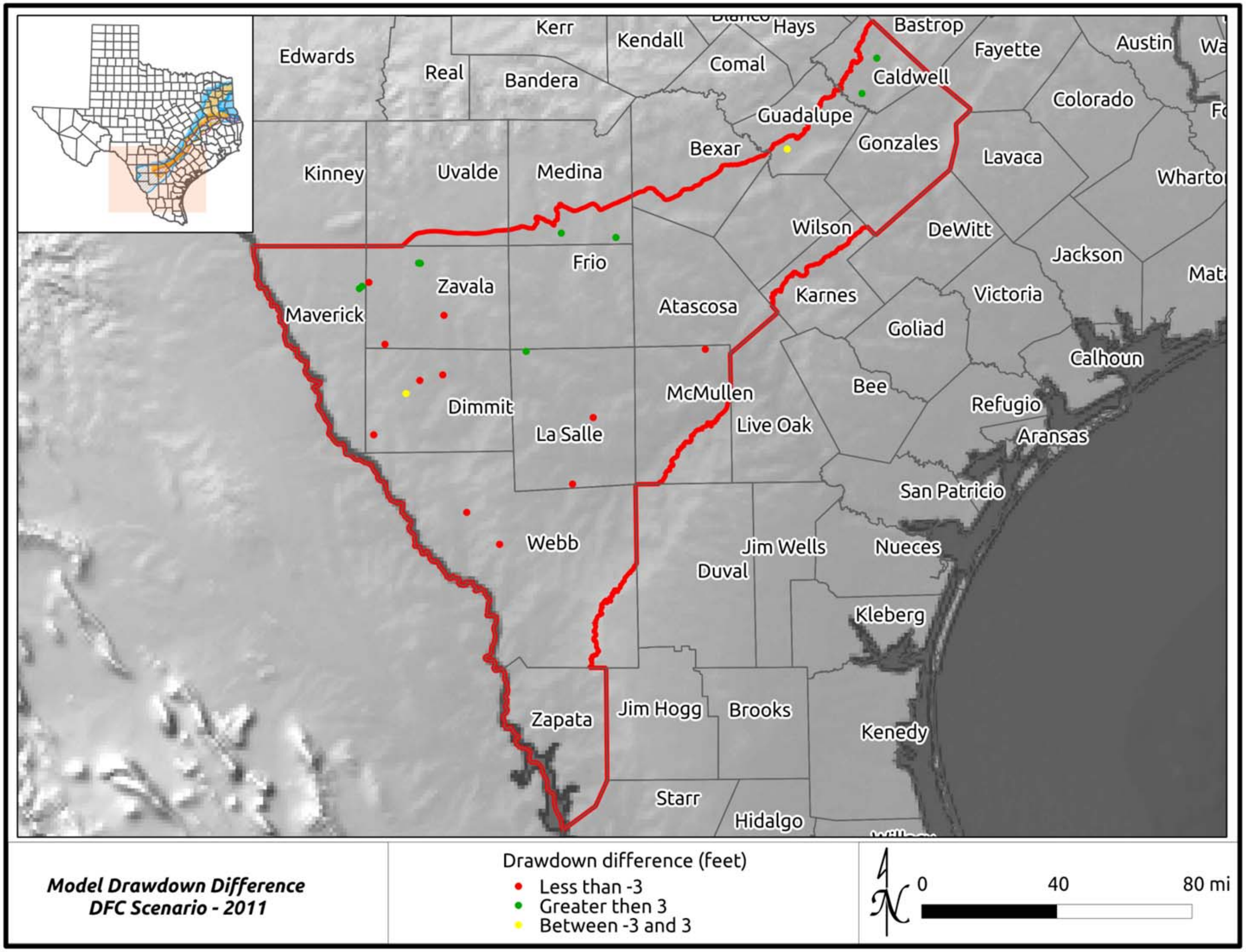
Model Drawdown Difference
DFC Scenario - 2007


Edwards
Real
Kerr
Bandera
Kendall
Hays
Bastrop
Comal
Caldwell
Fayette
Austin
Guadalupe
Colorado
Bexar
Gonzales
Lavaca
Kinney
Uvalde
Medina
Wharton
Wilson
DeWitt
Jackson
Frio
Zavala
Atascosa
Karnes
Victoria
Maverick
Goliad
Calhoun
Bee
McMullen
Refugio
Dimmit
La Salle
Live Oak
Aransas
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2008
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
40
80 mi


Edwards
Kerr
Kendall
Hays
Bastrop
Fayette
Austin
Real
Bandera
Comal
Caldwell
Colorado
Guadalupe
Bexar
Gonzales
Lavaca
Kinney
Uvalde
Medina
Wharton
Wilson
DeWitt
Jackson
Frio
Zavala
Maverick
Atascosa
Karnes
Victoria
Goliad
Calhoun
Bee
McMullen
Dimmit
Refugio
Live Oak
La Salle
Aransas
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2009
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
40
80 mi



Edwards
Real
Kerr
Kendall
Bandera
Hays
Comal
Bastrop
Caldwell
Fayette
Austin
Colorado
Guadalupe
Bexar
Gonzales
Lavaca
Kinney
Uvalde
Medina
Wilson
DeWitt
Jackson
Frio
Zavala
Karnes
Victoria
Maverick
Atascosa
Goliad
Calhoun
McMullen
Bee
Dimmit
Refugio
Live Oak
La Salle
Aransas
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2010
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
40
80 mi


Kerr
Kendall
Hays
Bastrop
Edwards
Real
Bandera
Comal
Fayette
Austin
Caldwell
Colorado
Guadalupe
Bexar
Gonzales
Lavaca
Kinney
Uvalde
Medina
Wilson
DeWitt
Jackson
Frio
Zavala
Karnes
Victoria
Maverick
Atascosa
Goliad
Calhoun
McMullen
Bee
Refugio
Dimmit
Live Oak
Aransas
La Salle
San Patricio
Webb
Jim Wells
Nueces
Duval
Kleberg
Zapata
Jim Hogg
Brooks
Kenedy
Starr
Hidalgo
Model Drawdown Difference
DFC Scenario - 2011
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
40
80 mi

Appendix 2 – Atascosa County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001 and 2006

Summary of Drawdown Comparisons

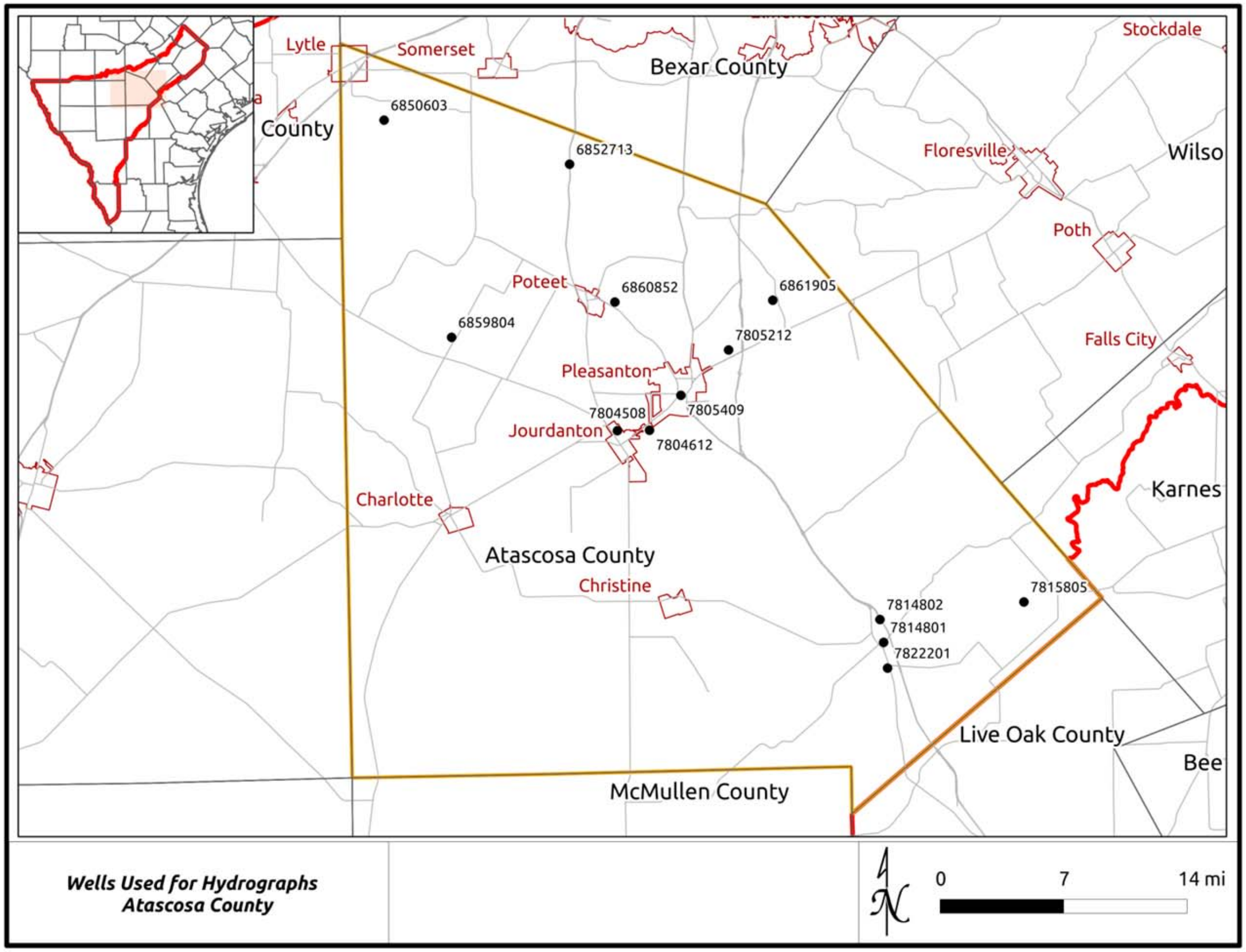
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

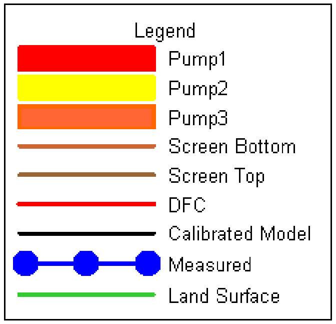
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

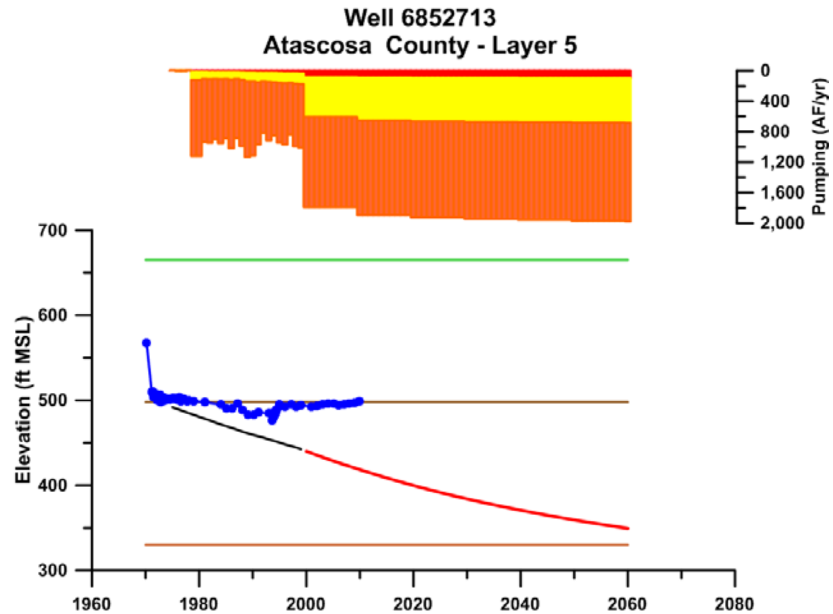
Hydrograph of Actual Drawdown and DFC Drawdown

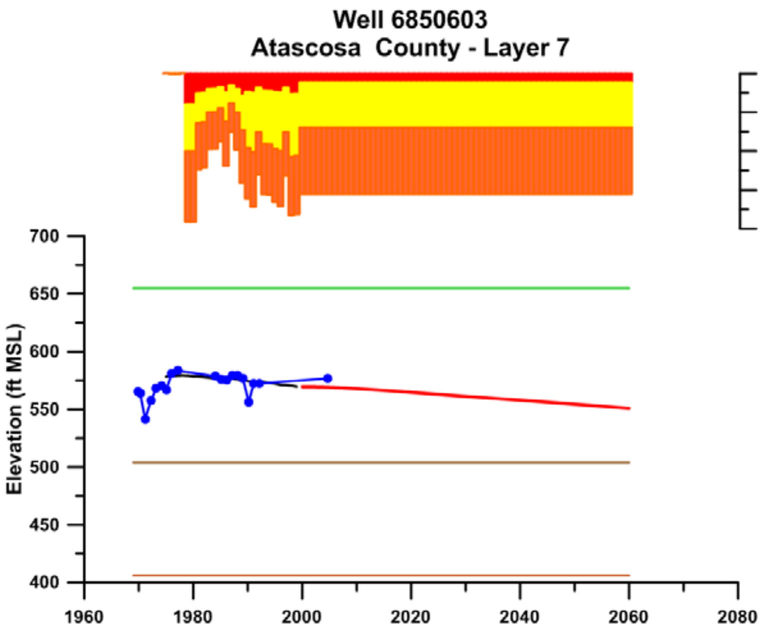
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

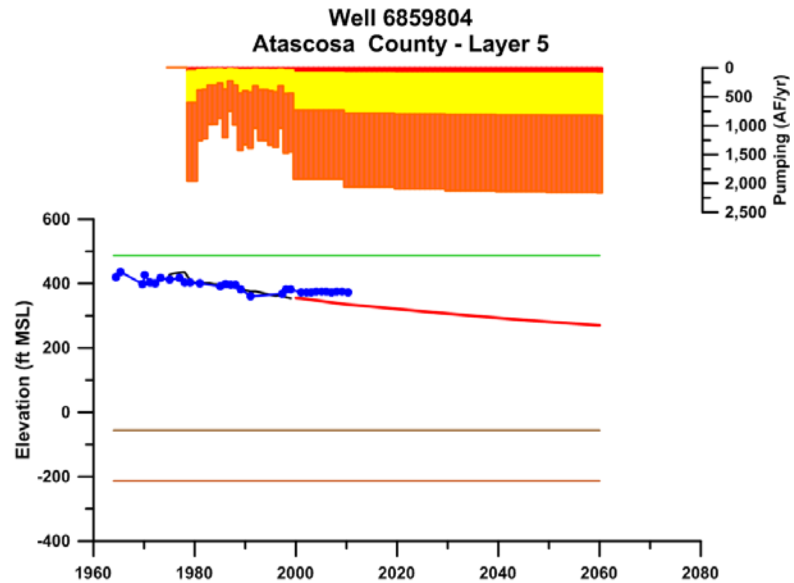


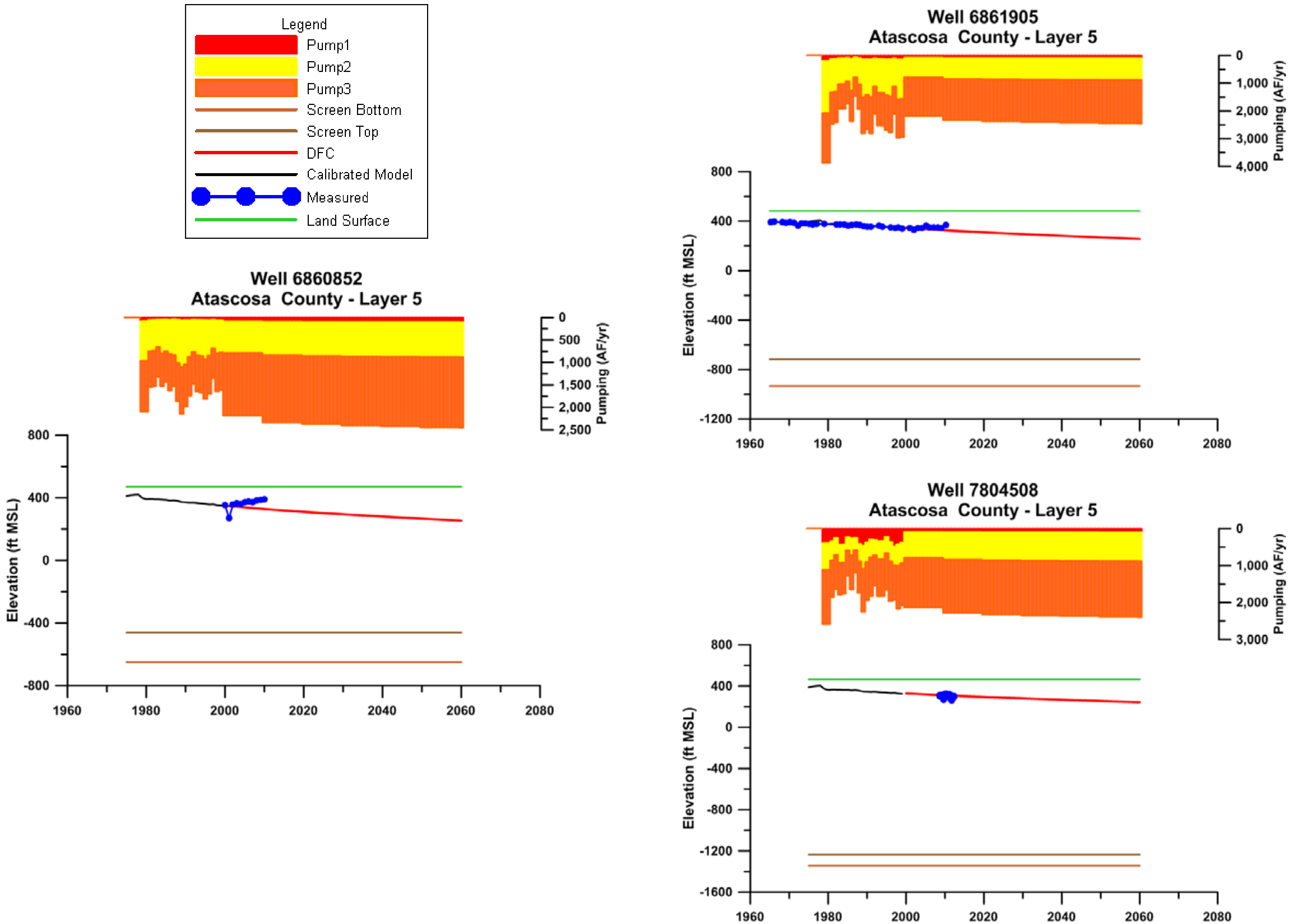
Location Map of Wells with Hydrographs – Atascosa County


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface

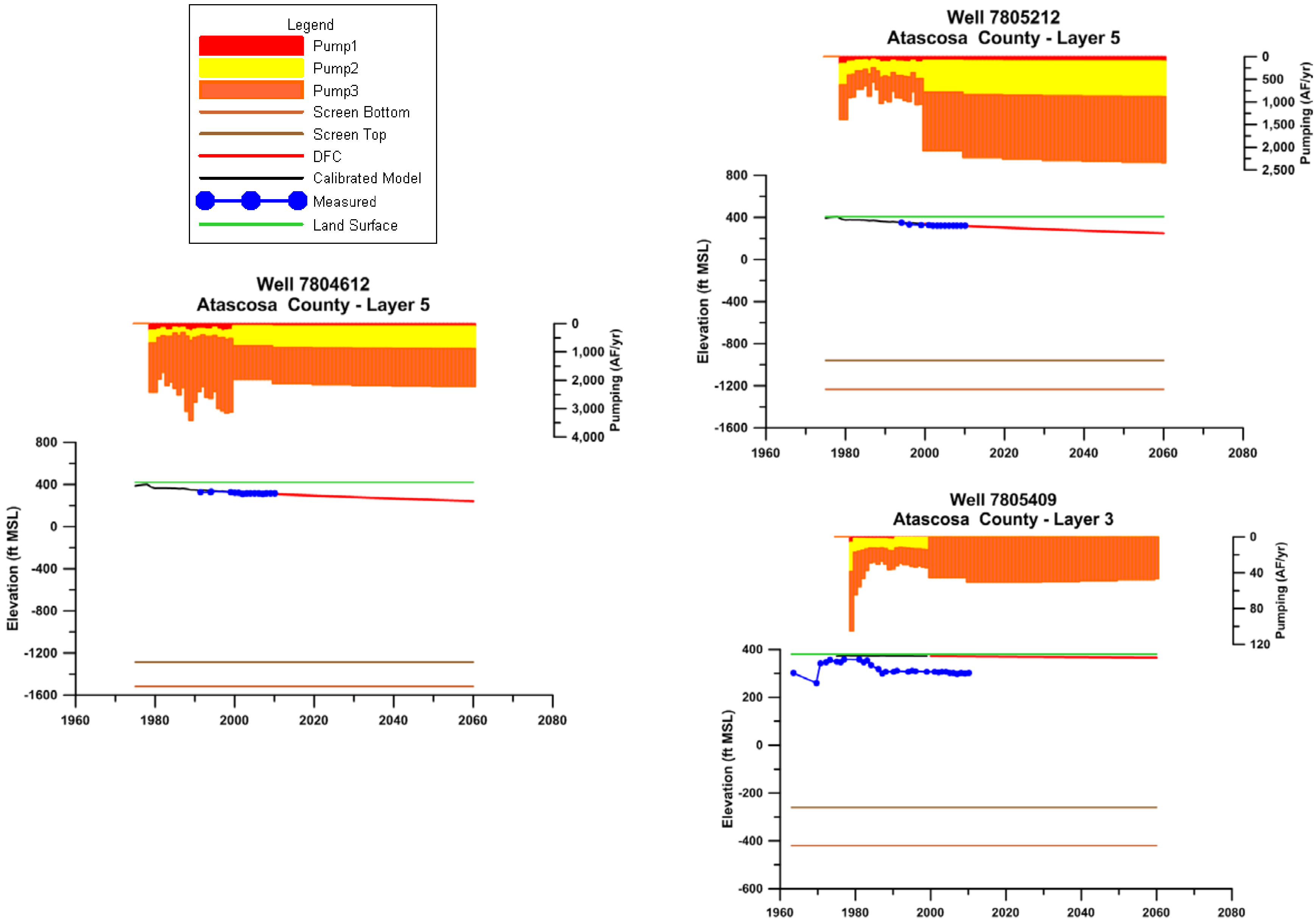

Well 6852713
Atascosa County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
400
800
1,200
1,600
2,000
700
600
500
400
300
1960
1980
2000
2020
2040
2060
2080

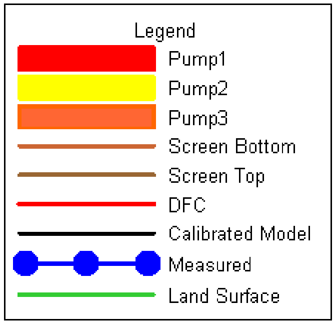

Well 6850603
Atascosa County - Layer 7
Elevation (ft MSL)
Pumping (AF/yr)
0
40
80
120
160
700
650
600
550
500
450
400
1960
1980
2000
2020
2040
2060
2080

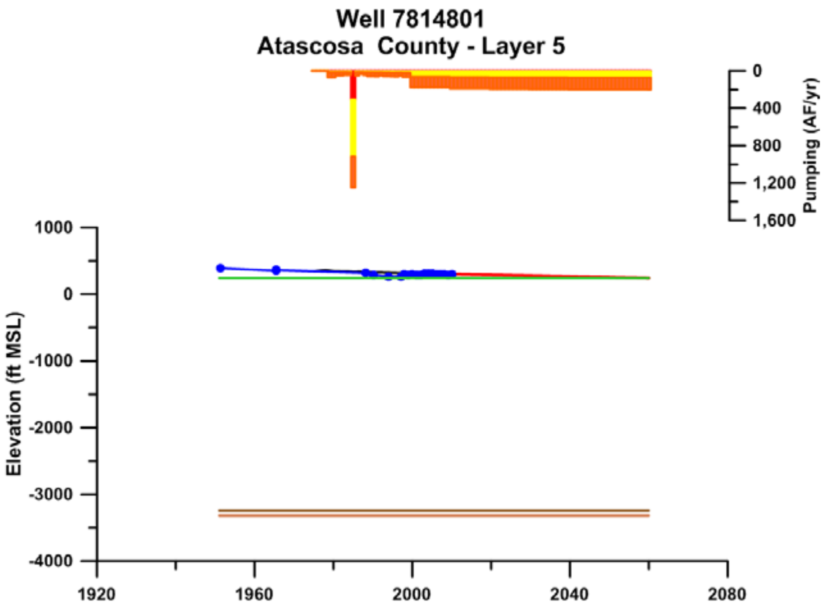

Well 6859804
Atascosa County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
500
1,000
1,500
2,000
2,500
600
400
200
0
-200
-400
1960
1980
2000
2020
2040
2060
2080

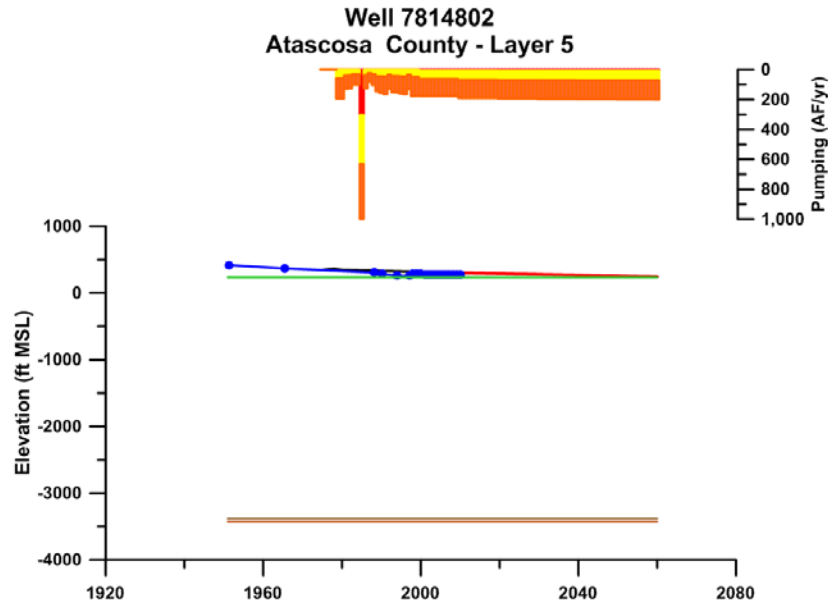


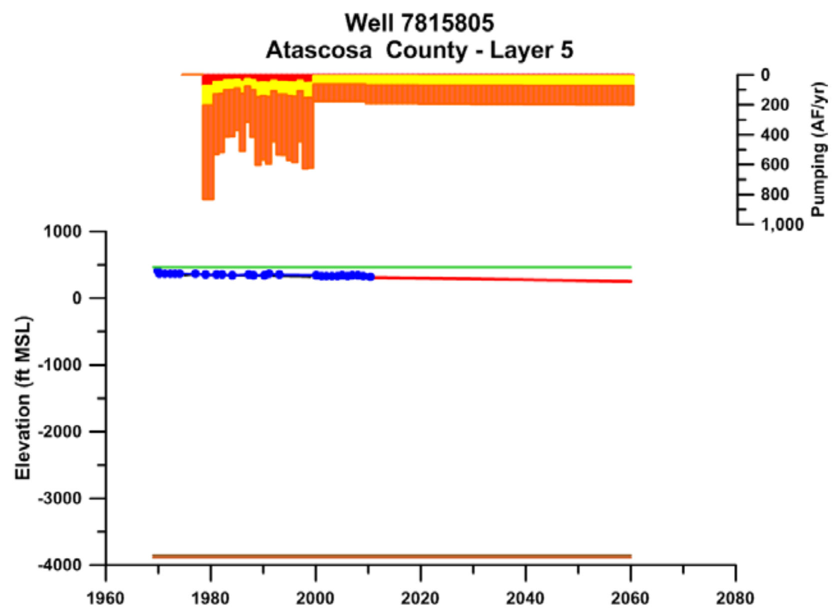
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6860852
Atascosa County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
500
1,000
1,500
2,000
2,500
800
400
0
-400
-800
1960
1980
2000
2020
2040
2060
2080
Well 6861905
Atascosa County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
1,000
2,000
3,000
4,000
800
400
0
-400
-800
-1200
1960
1980
2000
2020
2040
2060
2080
Well 7804508
Atascosa County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
1,000
2,000
3,000
800
400
0
-400
-800
-1200
-1600
1960
1980
2000
2020
2040
2060
2080

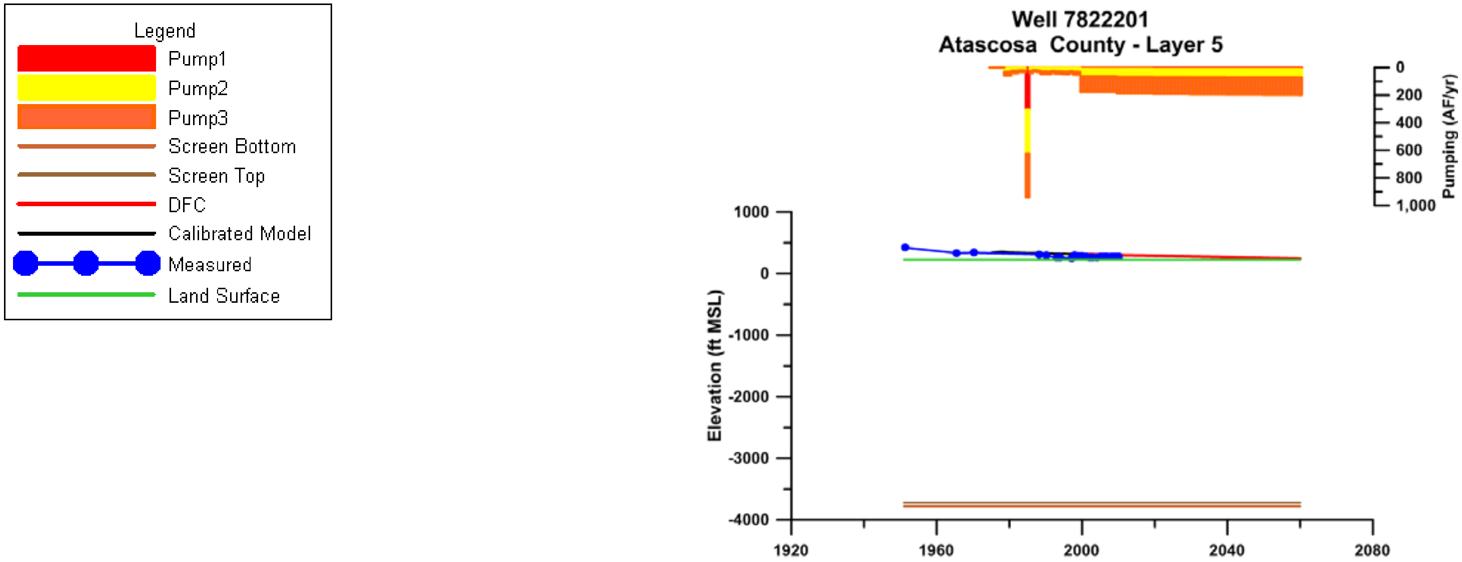

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 7804612
Atascosa County - Layer 5
Pumping (AF/yr)
0
1,000
2,000
3,000
4,000
Elevation (ft MSL)
800
400
0
-400
-800
-1200
-1600
1960
1980
2000
2020
2040
2060
2080
Well 7805212
Atascosa County - Layer 5
Pumping (AF/yr)
0
500
1,000
1,500
2,000
2,500
Elevation (ft MSL)
800
400
0
-400
-800
-1200
-1600
1960
1980
2000
2020
2040
2060
2080
Well 7805409
Atascosa County - Layer 3
Pumping (AF/yr)
0
40
80
120
Elevation (ft MSL)
400
200
0
-200
-400
-600
1960
1980
2000
2020
2040
2060
2080

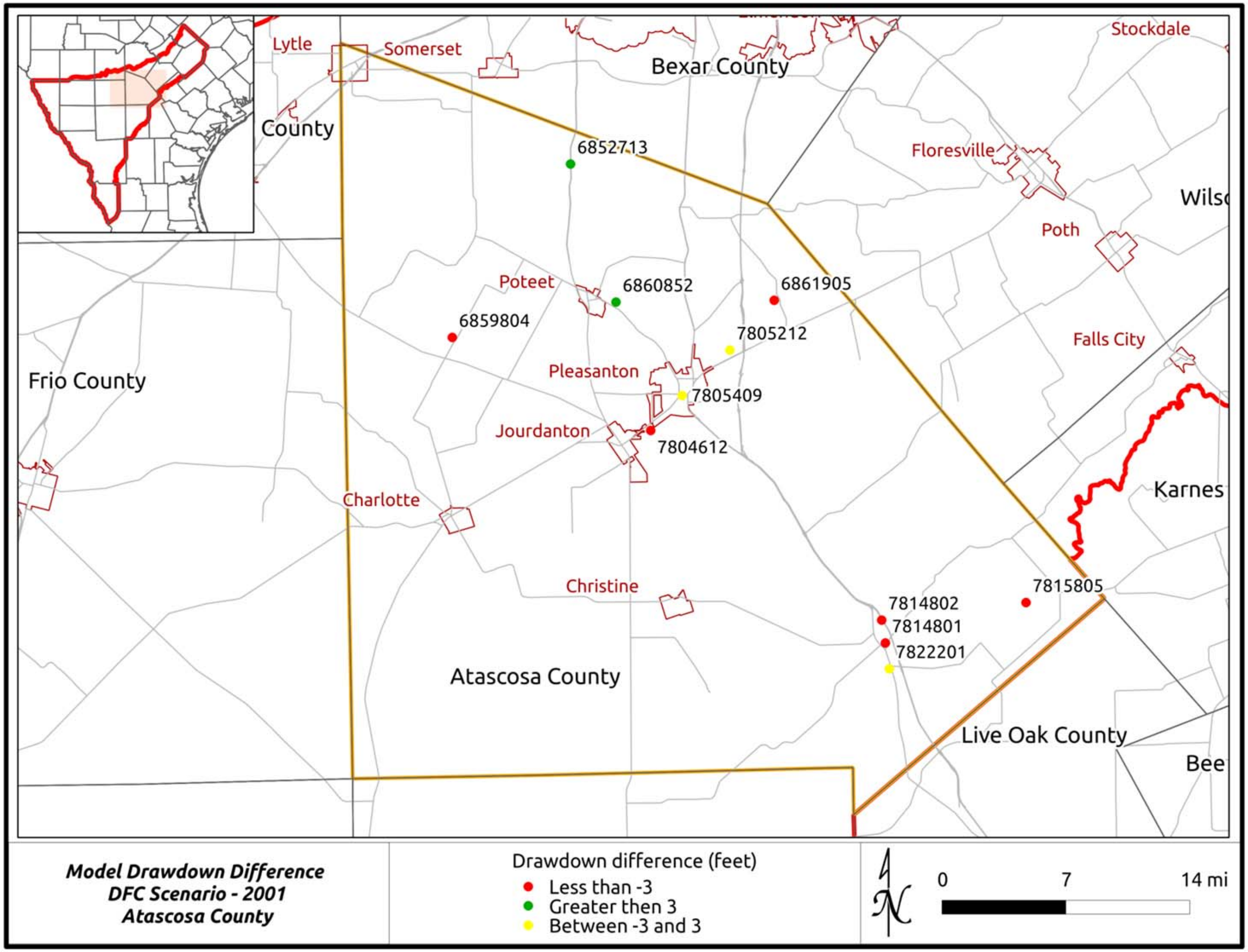

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface

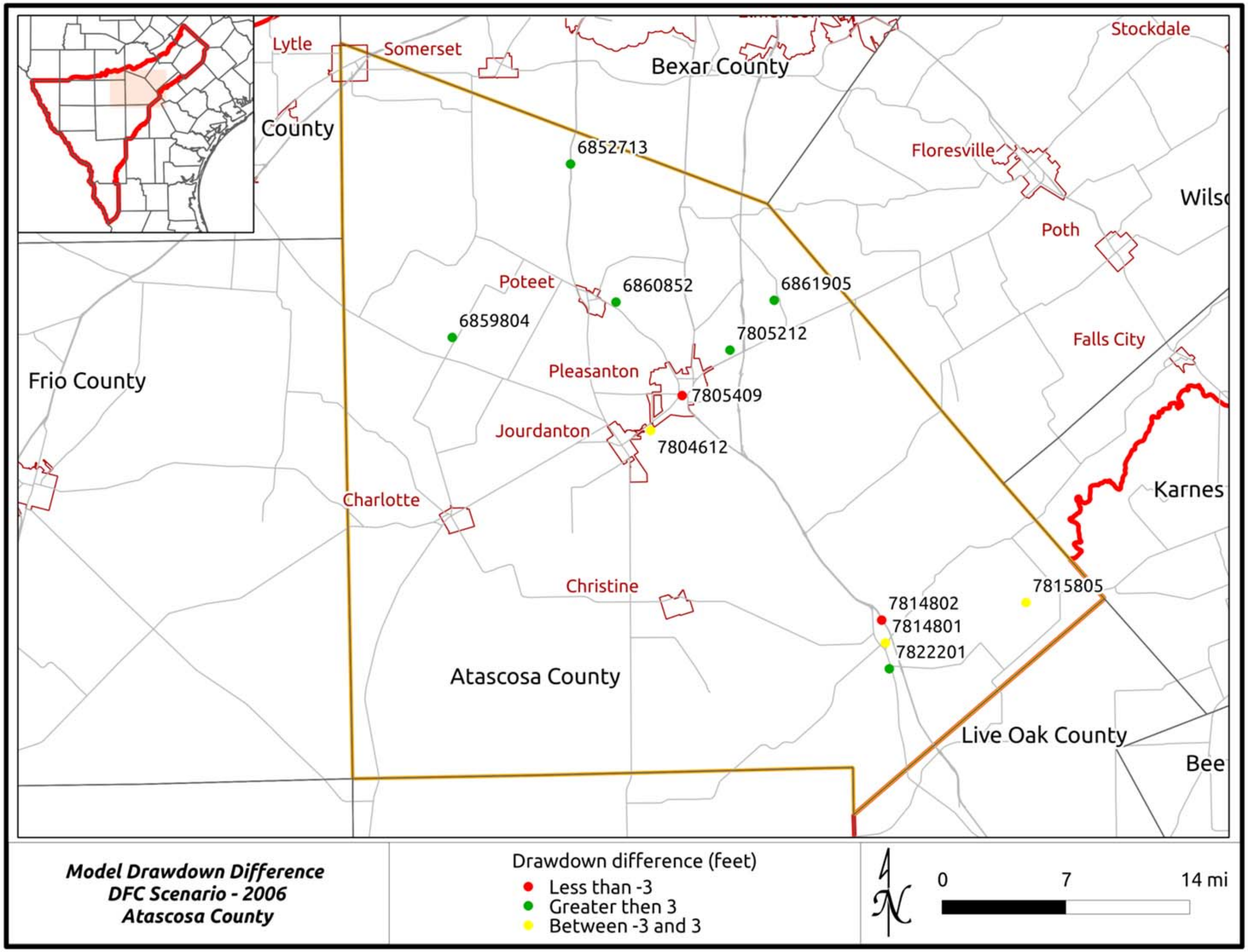

Well 7814801
Atascosa County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
1000
0
-1000
-2000
-3000
-4000
0
400
800
1,200
1,600
1920
1960
2000
2040
2080


Well 7814802
Atascosa County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
1000
0
-1000
-2000
-3000
-4000
0
200
400
600
800
1,000
1920
1960
2000
2040
2080


Well 7815805
Atascosa County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
1000
0
-1000
-2000
-3000
-4000
0
200
400
600
800
1,000
1960
1980
2000
2020
2040
2060
2080

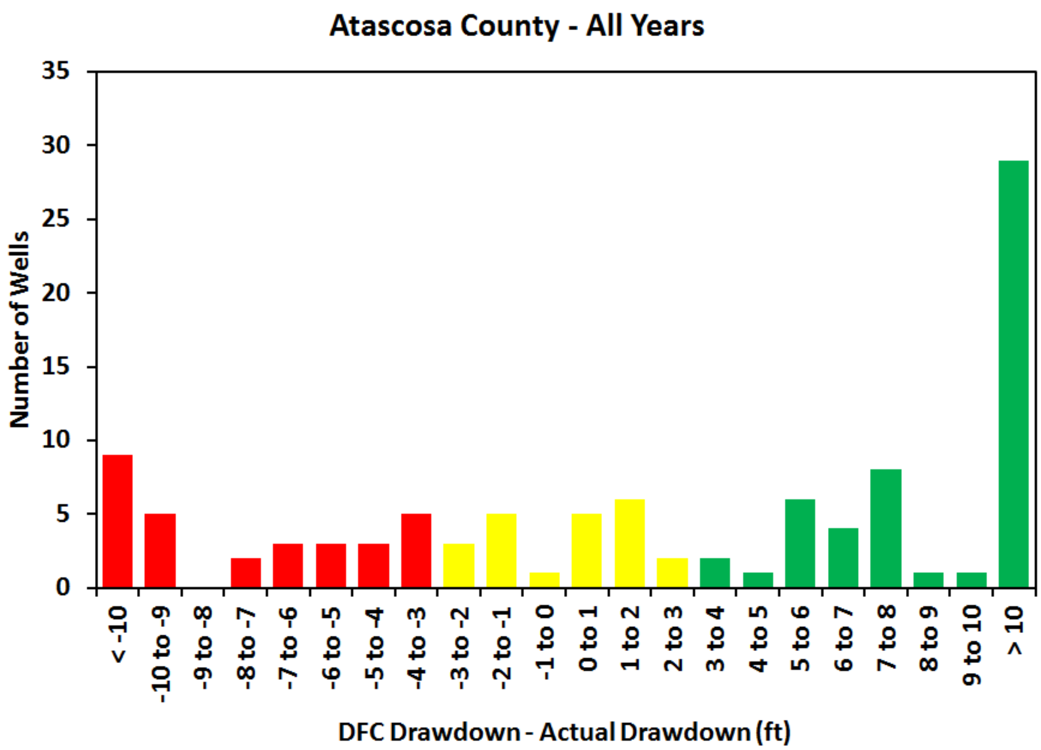

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 7822201
Atascosa County - Layer 5
Elevation (ft MSL)
1000
0
-1000
-2000
-3000
-4000
1920
1960
2000
2040
2080
Pumping (AF/yr)
0
200
400
600
800
1,000

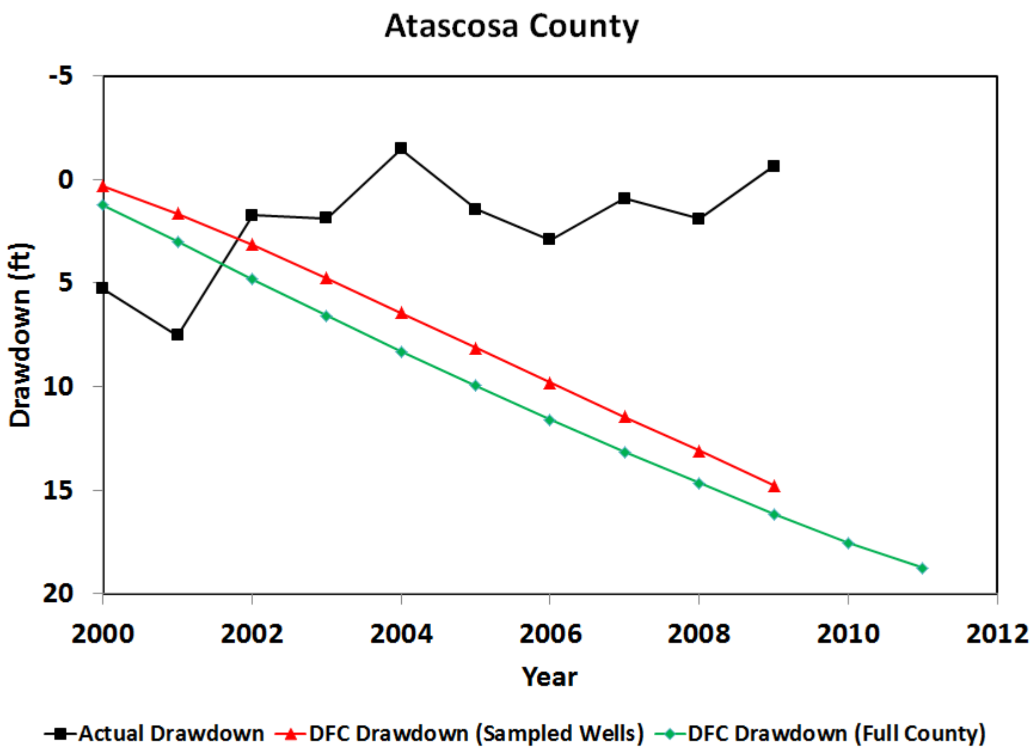

Lytle
Somerset
Stockdale
Bexar County
County
6852713
Floresville
Wilso
Poth
Poteet
6860852
6861905
6859804
7805212
Falls City
Frio County
Pleasanton
7805409
Jourdanton
7804612
Karnes
Charlotte
Christine
7815805
7814802
7814801
7822201
Atascosa County
Live Oak County
Bee
Model Drawdown Difference
DFC Scenario - 2001
Atascosa County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
7
14 mi


Lytle
Somerset
Bexar County
Stockdale
County
Floresville
Wilso
Poth
Frio County
Poteet
Pleasanton
Jourdanton
Charlotte
Falls City
Karnes
Christine
Atascosa County
Live Oak County
Bee
6852713
6860852
6861905
6859804
7805212
7805409
7804612
7815805
7814802
7814801
7822201
Model Drawdown Difference
DFC Scenario - 2006
Atascosa County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
7
14 mi

Summary of Drawdown Comparisons - Atascosa County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	1.25	8	5.28	0.31	-4.97
2001	101	3.01	11	7.52	1.66	-5.87
2002	113	4.81	11	1.73	3.15	1.42
2003	96	6.58	11	1.88	4.78	2.89
2004	132	8.30	11	-1.46	6.45	7.91
2005	75	9.97	11	1.43	8.14	6.70
2006	86	11.59	11	2.90	9.81	6.91
2007	142	13.15	11	0.92	11.46	10.54
2008	74	14.67	11	1.91	13.09	11.18
2009	76	16.15	8	-0.63	14.76	15.39
2010	132	17.53				
2011	45	18.75				





Atascosa County
-5
0
5
10
15
20
Drawdown (ft)
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 3 – Bexar County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

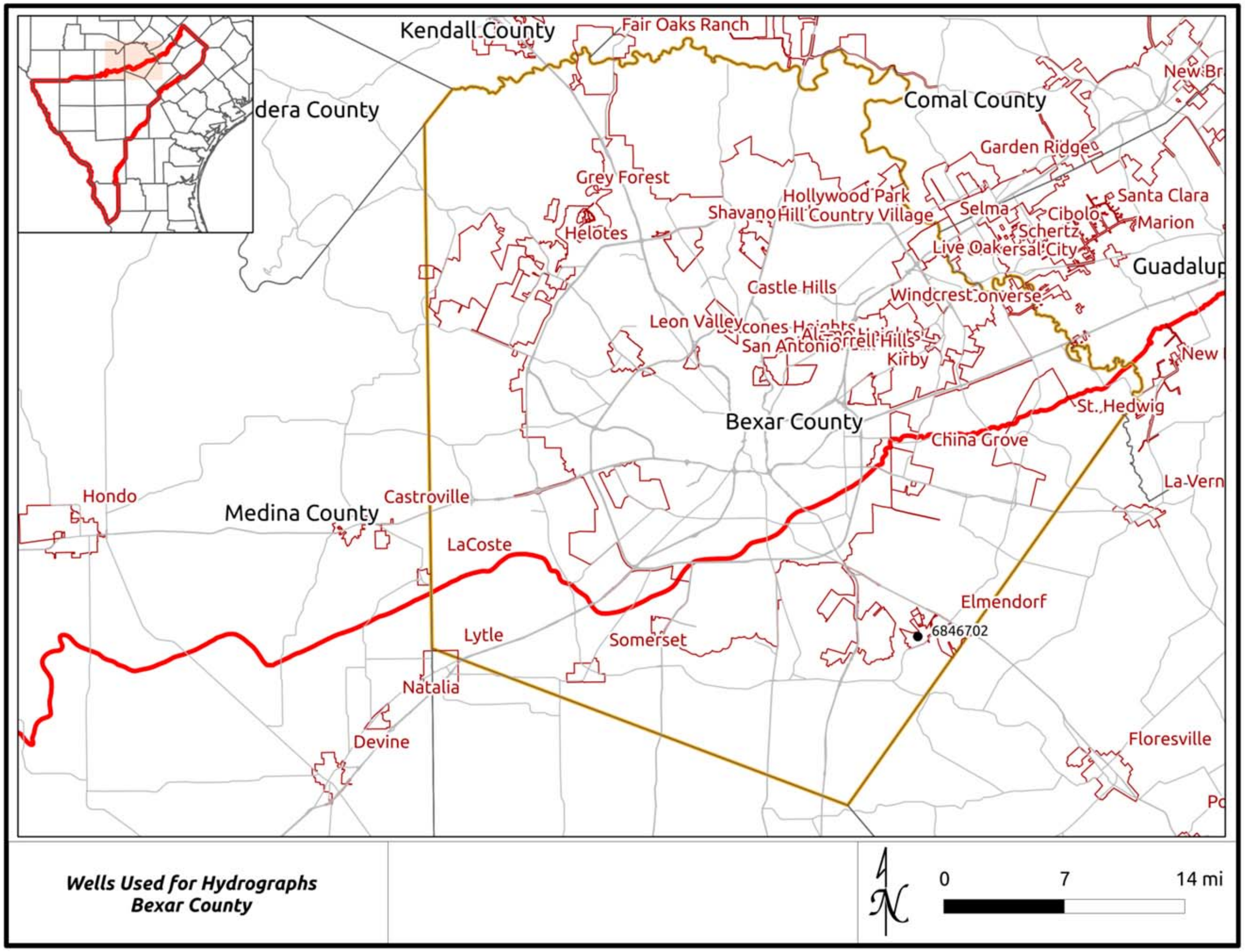
- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

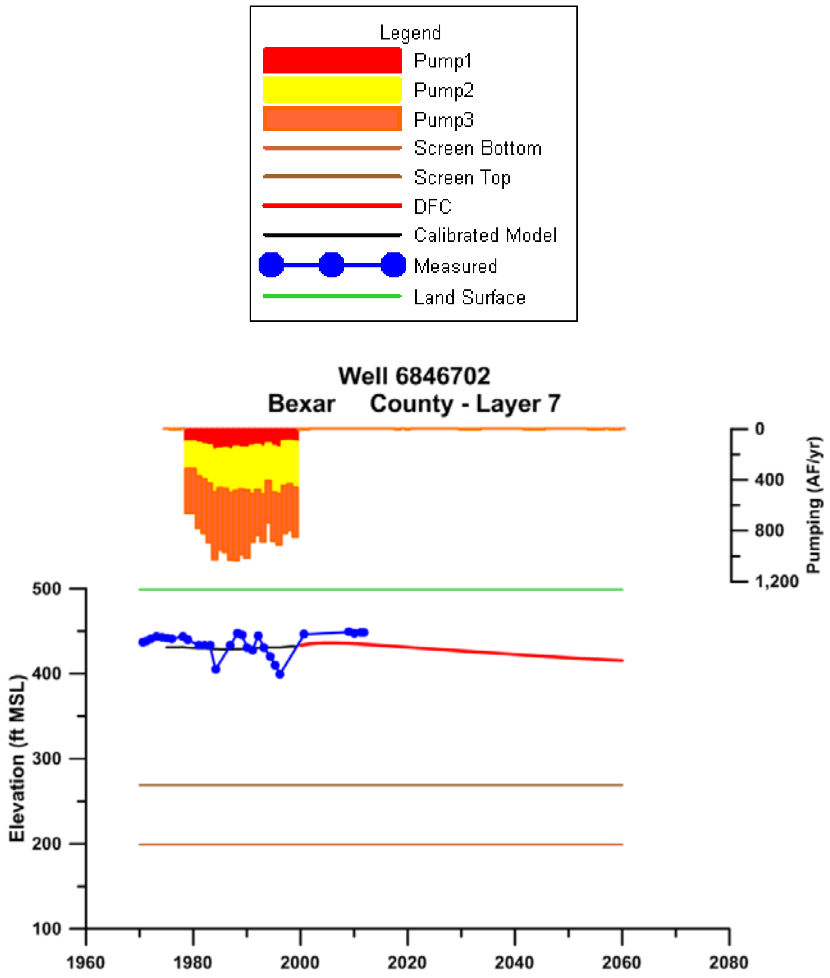
Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034



Location Map of Wells with Hydrographs – Bexar County


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6846702
Bexar County - Layer 7
0
400
800
1,200
Pumping (AF/yr)
500
400
300
200
100
Elevation (ft MSL)
1960
1980
2000
2020
2040
2060
2080

Appendix 4 – Caldwell County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

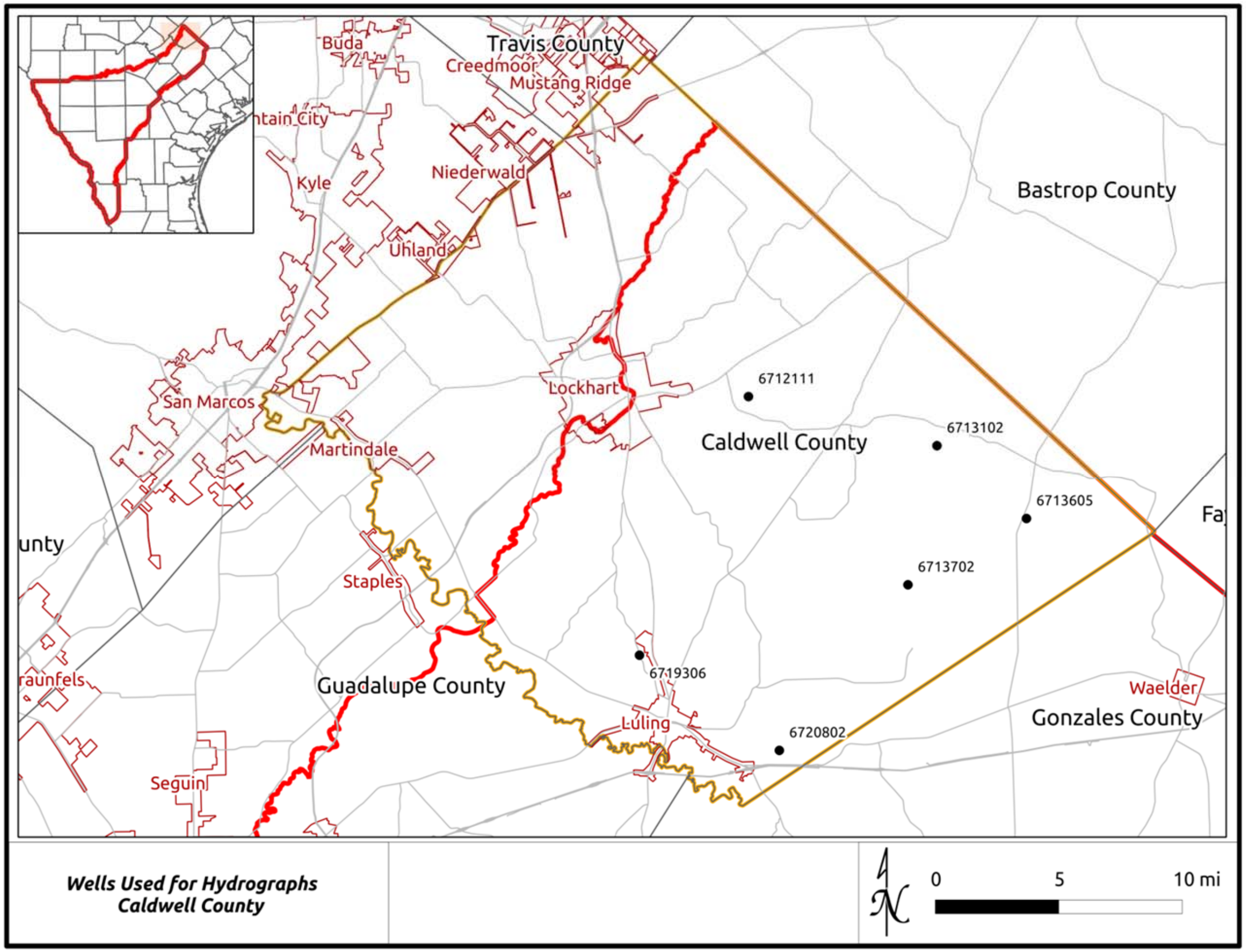
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

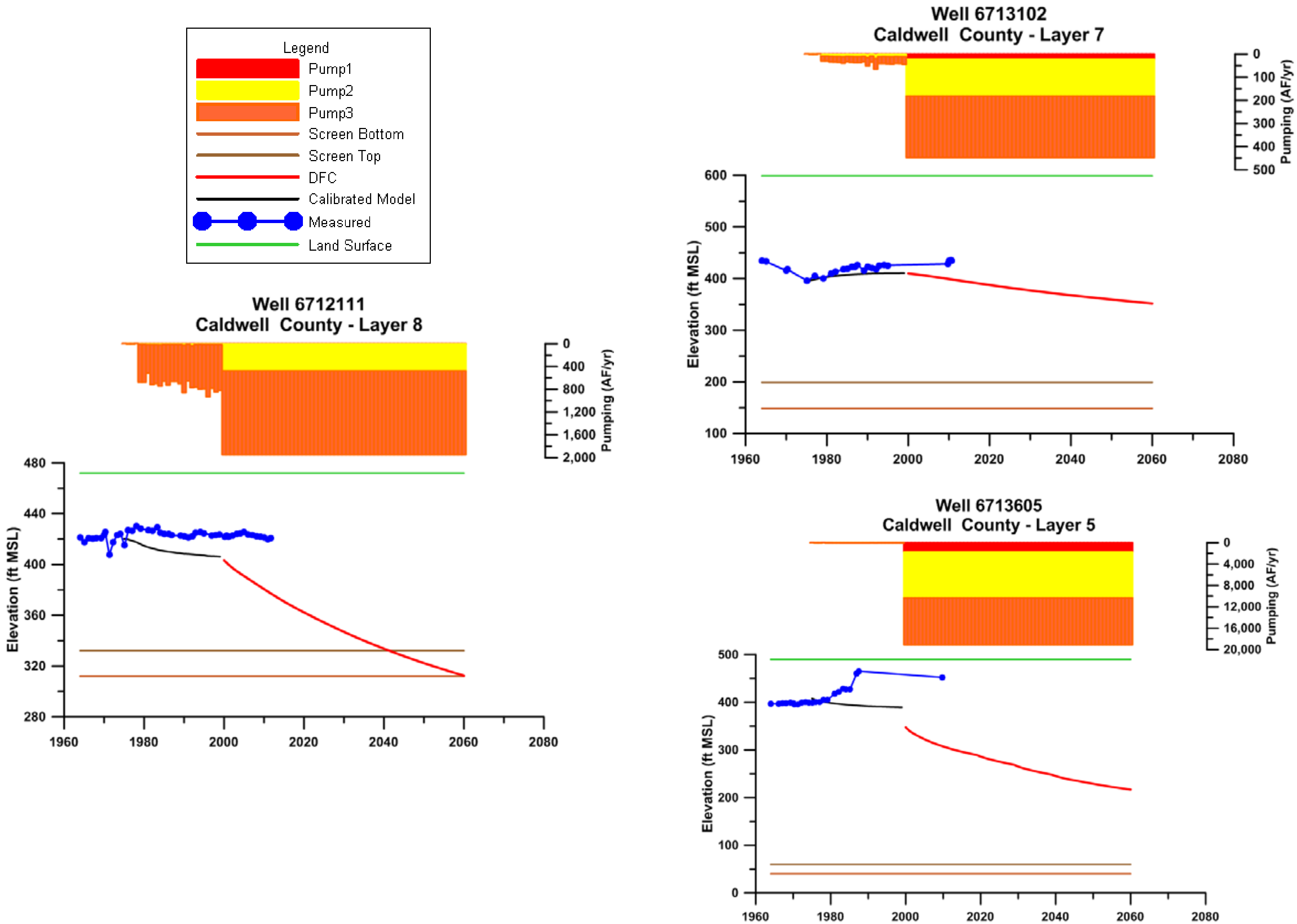
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

Hydrograph of Actual Drawdown and DFC Drawdown

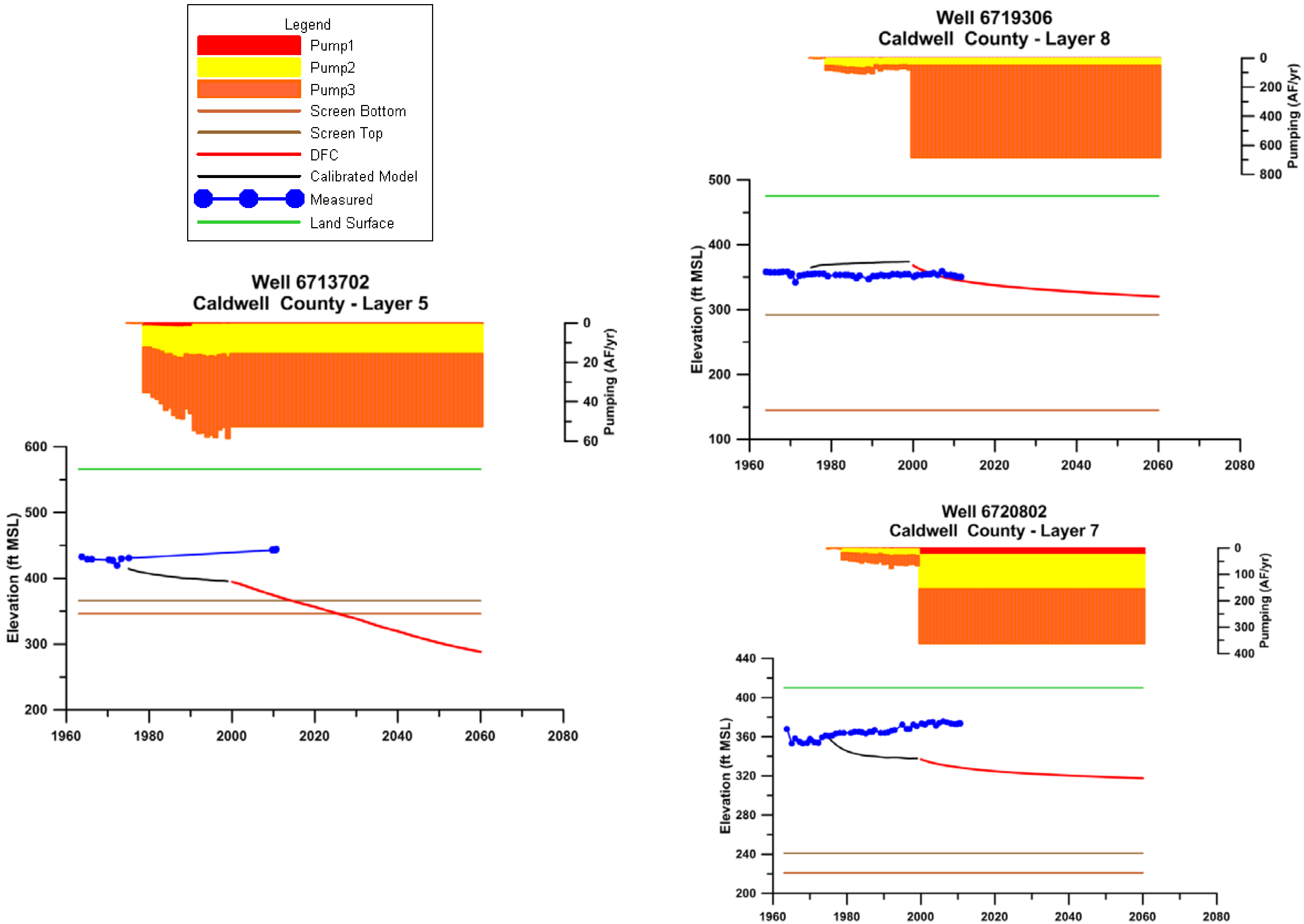
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011



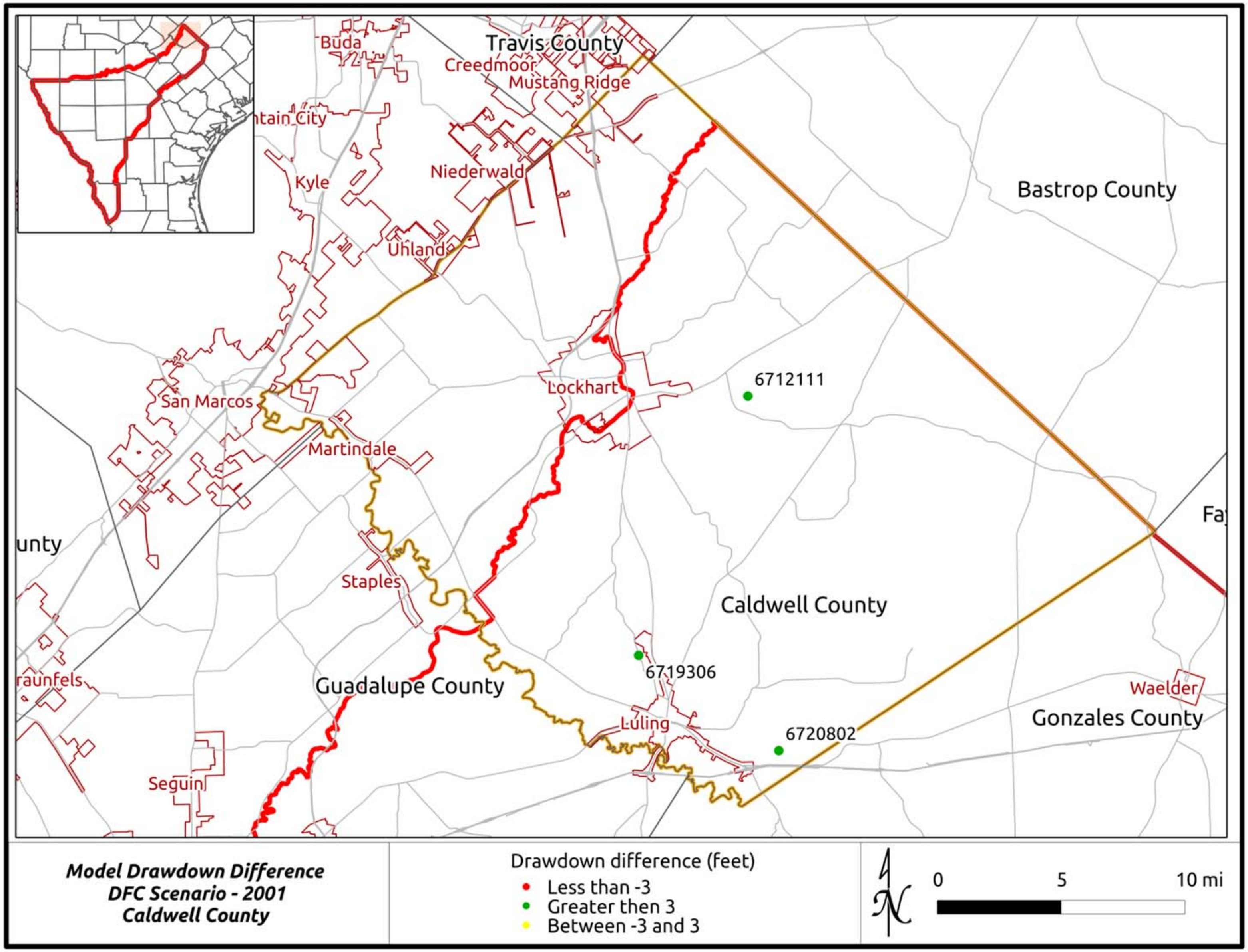
Location Map of Wells with Hydrographs – Caldwell County



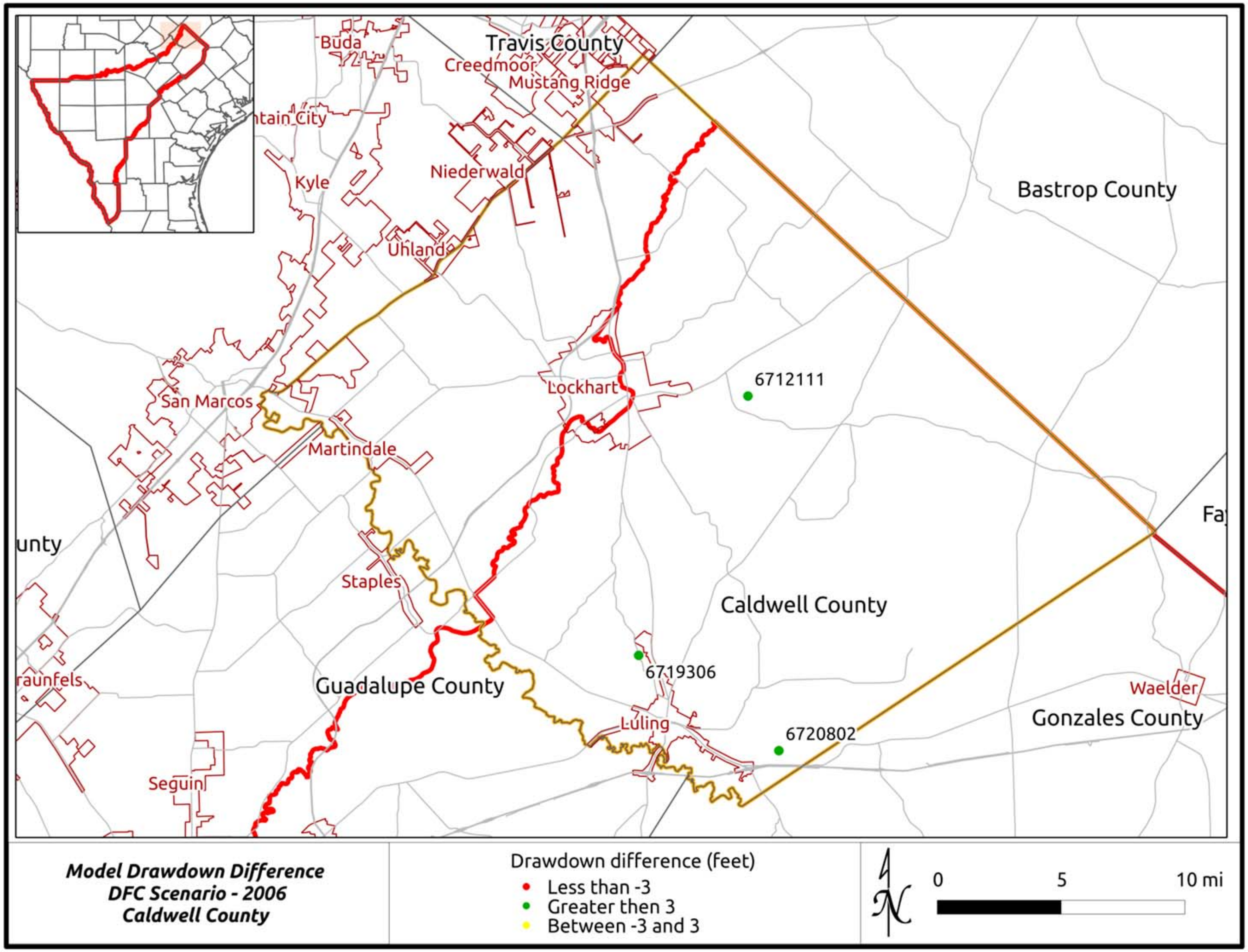
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6713102
Caldwell County - Layer 7
Pumping (AF/yr)
0
100
200
300
400
500
Elevation (ft MSL)
600
500
400
300
200
100
1960
1980
2000
2020
2040
2060
2080
Well 6712111
Caldwell County - Layer 8
Pumping (AF/yr)
0
400
800
1,200
1,600
2,000
Elevation (ft MSL)
480
440
400
360
320
280
1960
1980
2000
2020
2040
2060
2080
Well 6713605
Caldwell County - Layer 5
Pumping (AF/yr)
0
4,000
8,000
12,000
16,000
20,000
Elevation (ft MSL)
500
400
300
200
100
0
1960
1980
2000
2020
2040
2060
2080



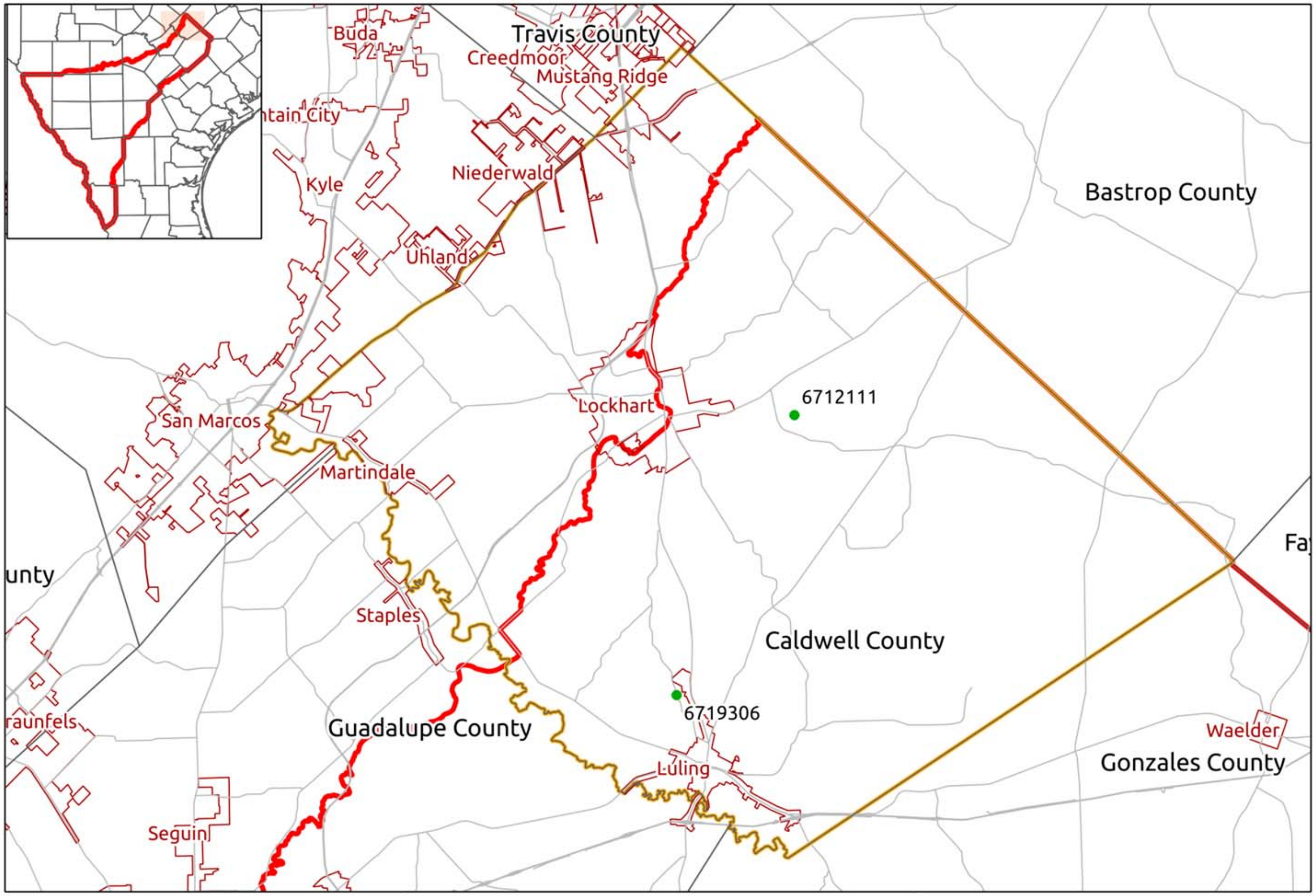
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6713702
Caldwell County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
20
40
60
600
500
400
300
200
1960
1980
2000
2020
2040
2060
2080
Well 6719306
Caldwell County - Layer 8
Elevation (ft MSL)
Pumping (AF/yr)
0
200
400
600
800
500
400
300
200
100
1960
1980
2000
2020
2040
2060
2080
Well 6720802
Caldwell County - Layer 7
Elevation (ft MSL)
Pumping (AF/yr)
0
100
200
300
400
440
400
360
320
280
240
200
1960
1980
2000
2020
2040
2060
2080



Buda
Travis County
Creedmoor
Mustang Ridge
ntain City
Kyle
Niederwald
Uhland
Bastrop County
San Marcos
Lockhart
6712111
Martindale
Fa
unty
Staples
Caldwell County
6719306
raunfels
Guadalupe County
Waelder
Luling
Gonzales County
6720802
Seguin
Model Drawdown Difference
DFC Scenario - 2001
Caldwell County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
5
10 mi



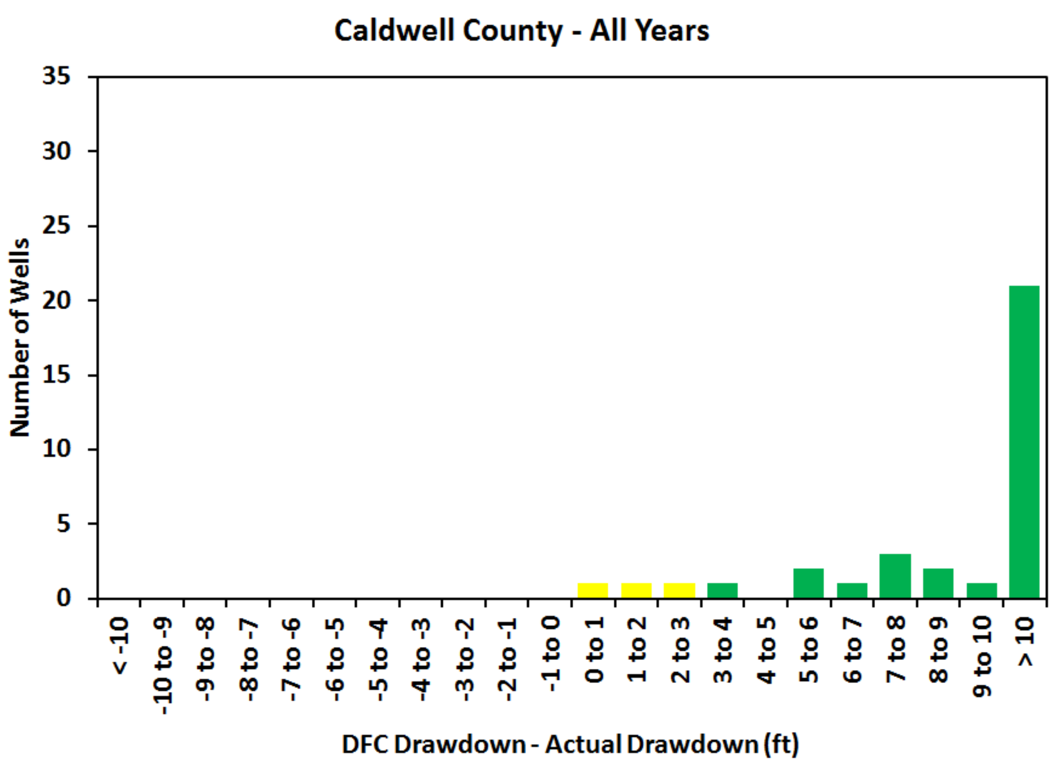
Travis County
Buda
Creedmoor
Mustang Ridge
ntain City
Kyle
Niederwald
Uhland
Bastrop County
San Marcos
Lockhart
6712111
Martindale
unty
Fa
Staples
Caldwell County
6719306
raunfels
Guadalupe County
Waelder
Luling
Gonzales County
6720802
Seguin
Model Drawdown Difference
DFC Scenario - 2006
Caldwell County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
5
10 mi

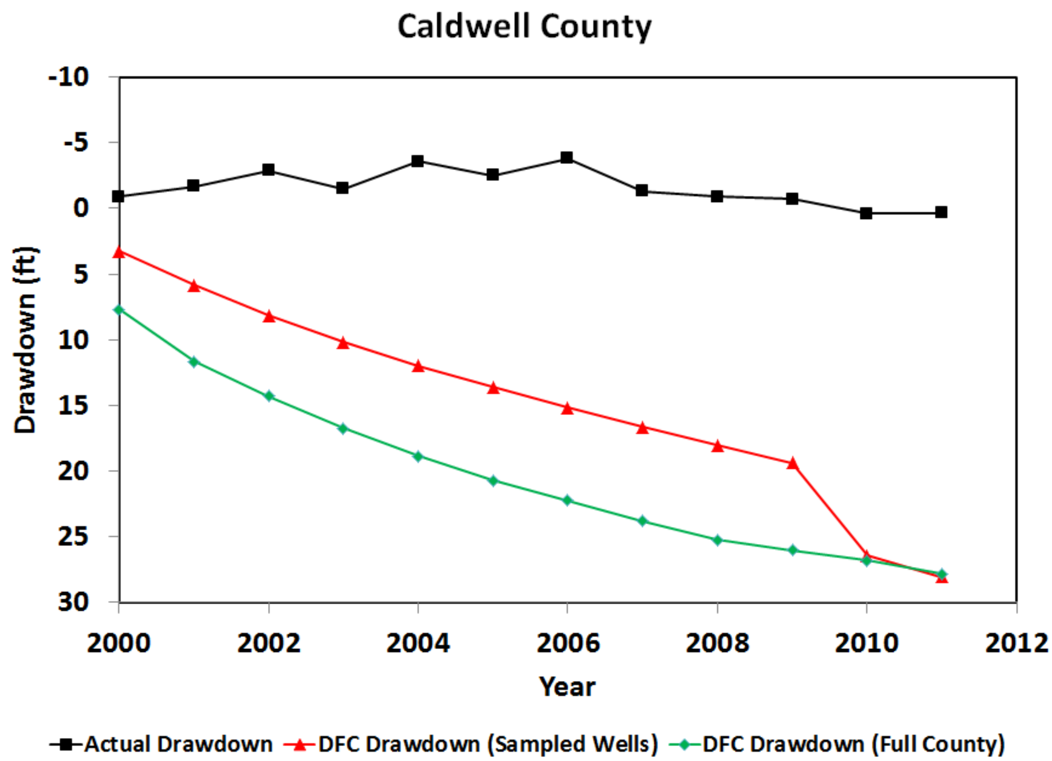


Model Drawdown Difference
DFC Scenario - 2011
Caldwell County

Summary of Drawdown Comparisons - Caldwell County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	7.71	3	-0.87	3.25	4.12
2001	101	11.65	3	-1.66	5.85	7.51
2002	113	14.31	3	-2.86	8.17	11.03
2003	96	16.77	3	-1.50	10.20	11.71
2004	132	18.88	3	-3.55	11.99	15.54
2005	75	20.71	3	-2.49	13.63	16.11
2006	86	22.26	3	-3.79	15.17	18.96
2007	142	23.80	3	-1.29	16.64	17.92
2008	74	25.26	3	-0.90	18.04	18.94
2009	76	26.02	3	-0.69	19.38	20.07
2010	132	26.80	2	0.40	26.43	26.03
2011	45	27.84	2	0.36	28.04	27.68





Caldwell County
Drawdown (ft)
-10
-5
0
5
10
15
20
25
30
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 5 – Dimmit County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

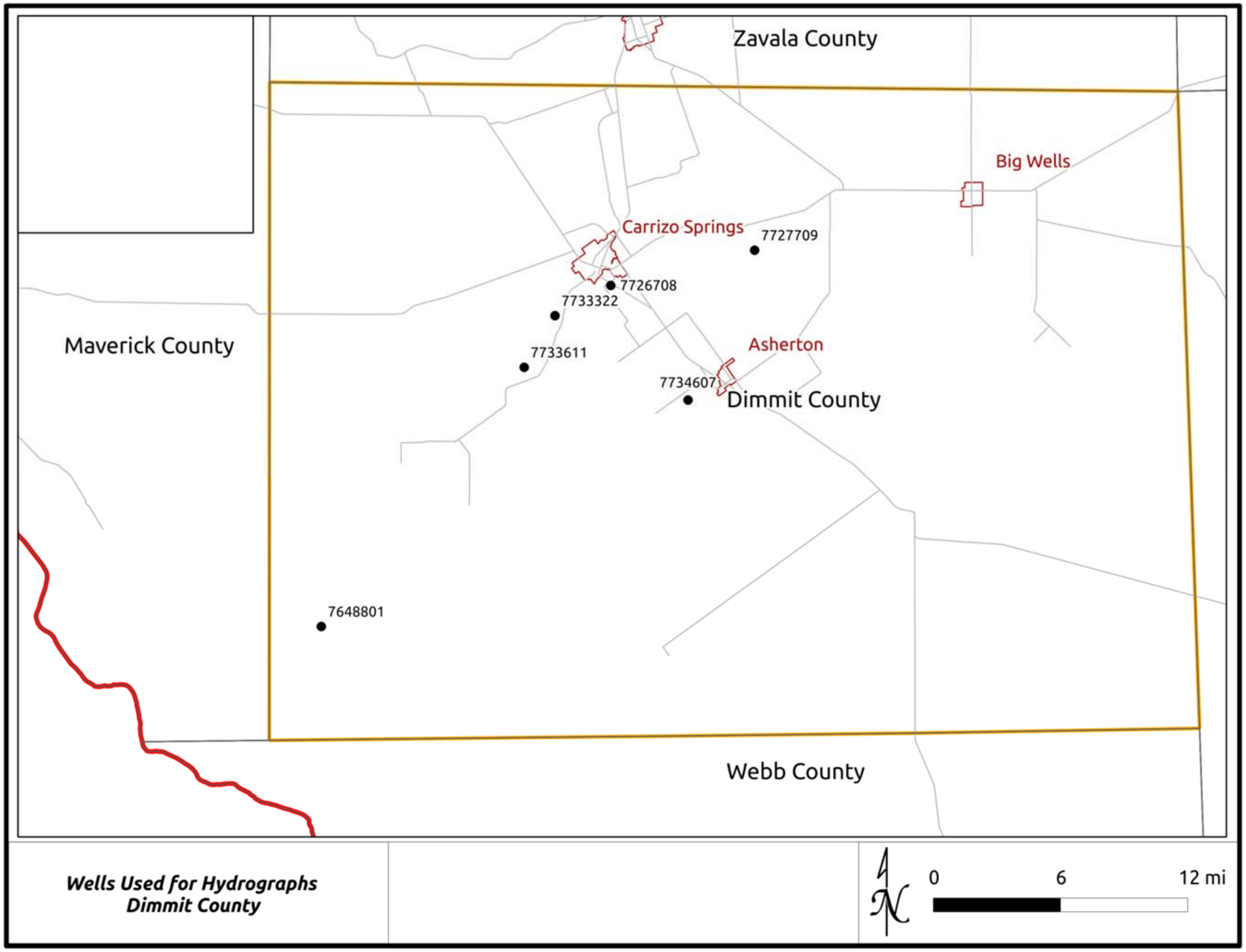
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

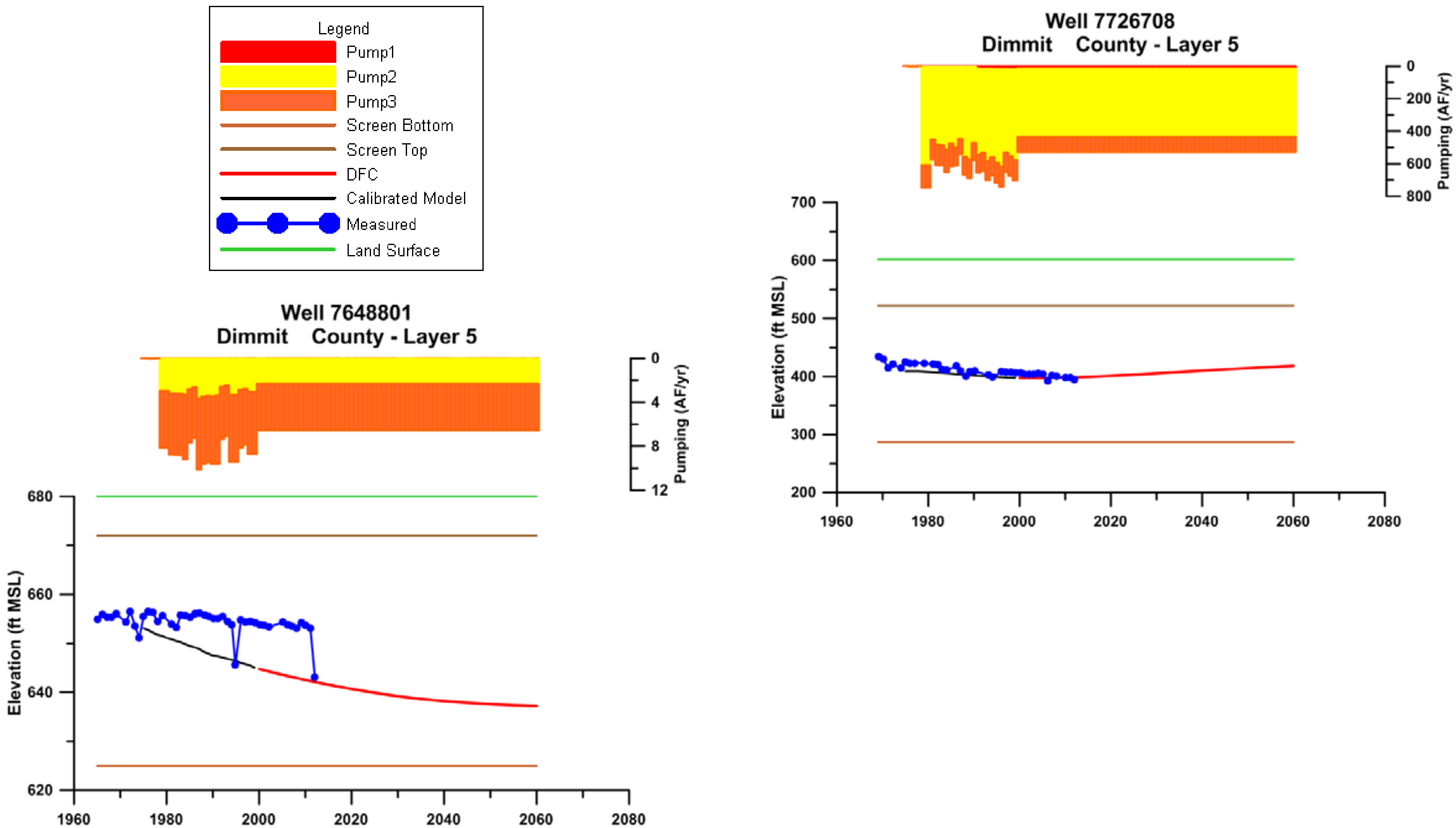
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

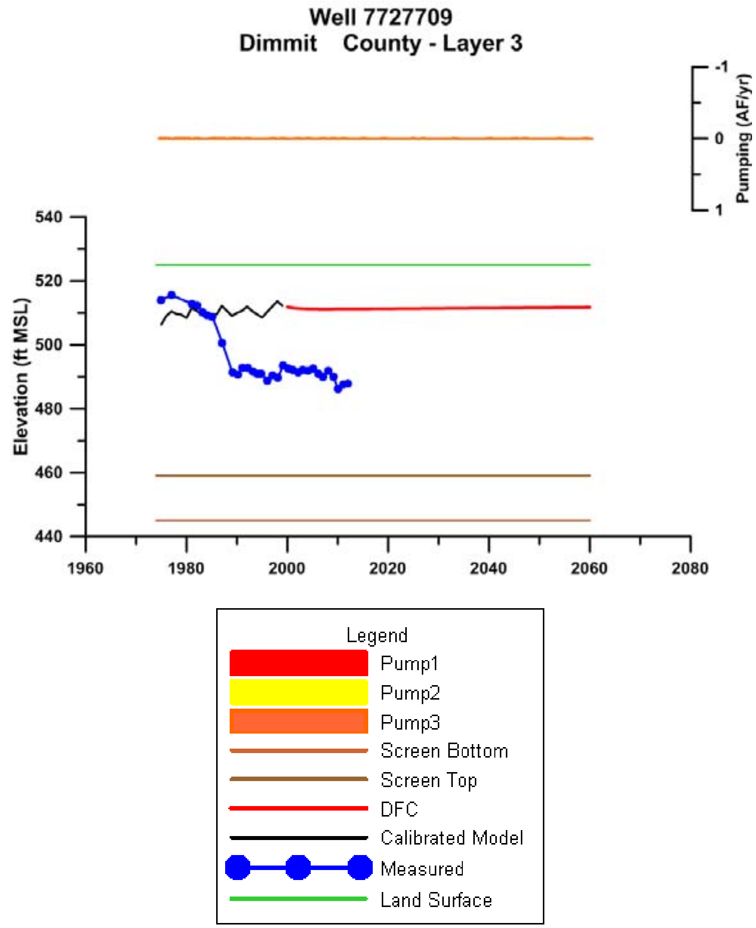
Hydrograph of Actual Drawdown and DFC Drawdown

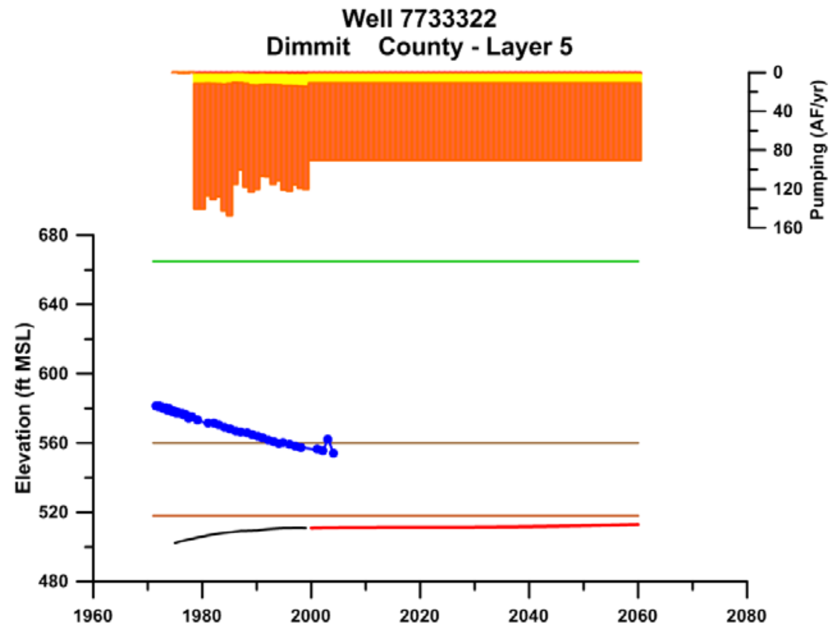
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

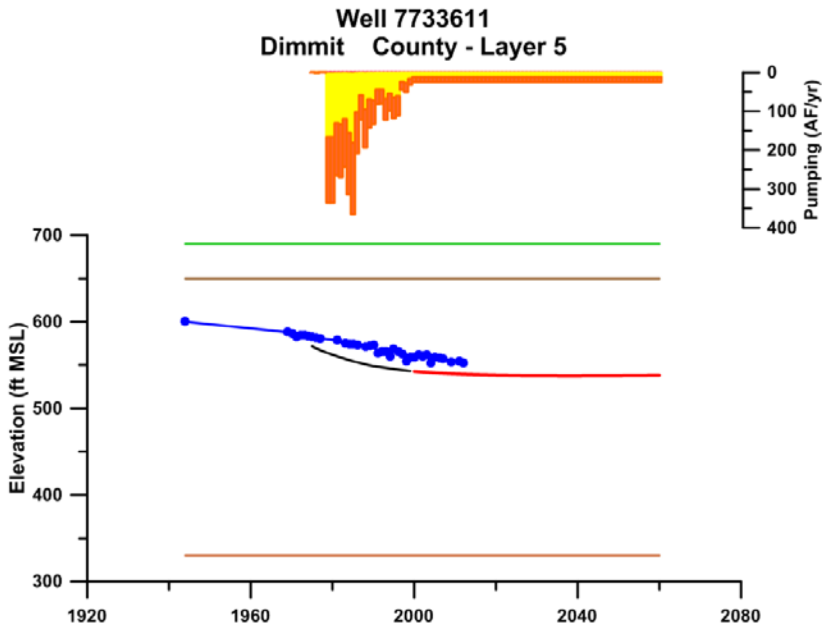


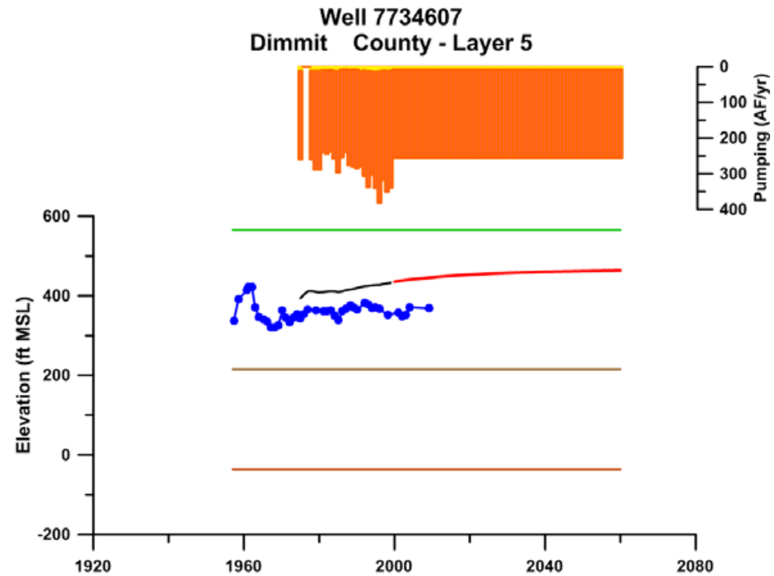
Location Map of Wells with Hydrographs – Dimmit County

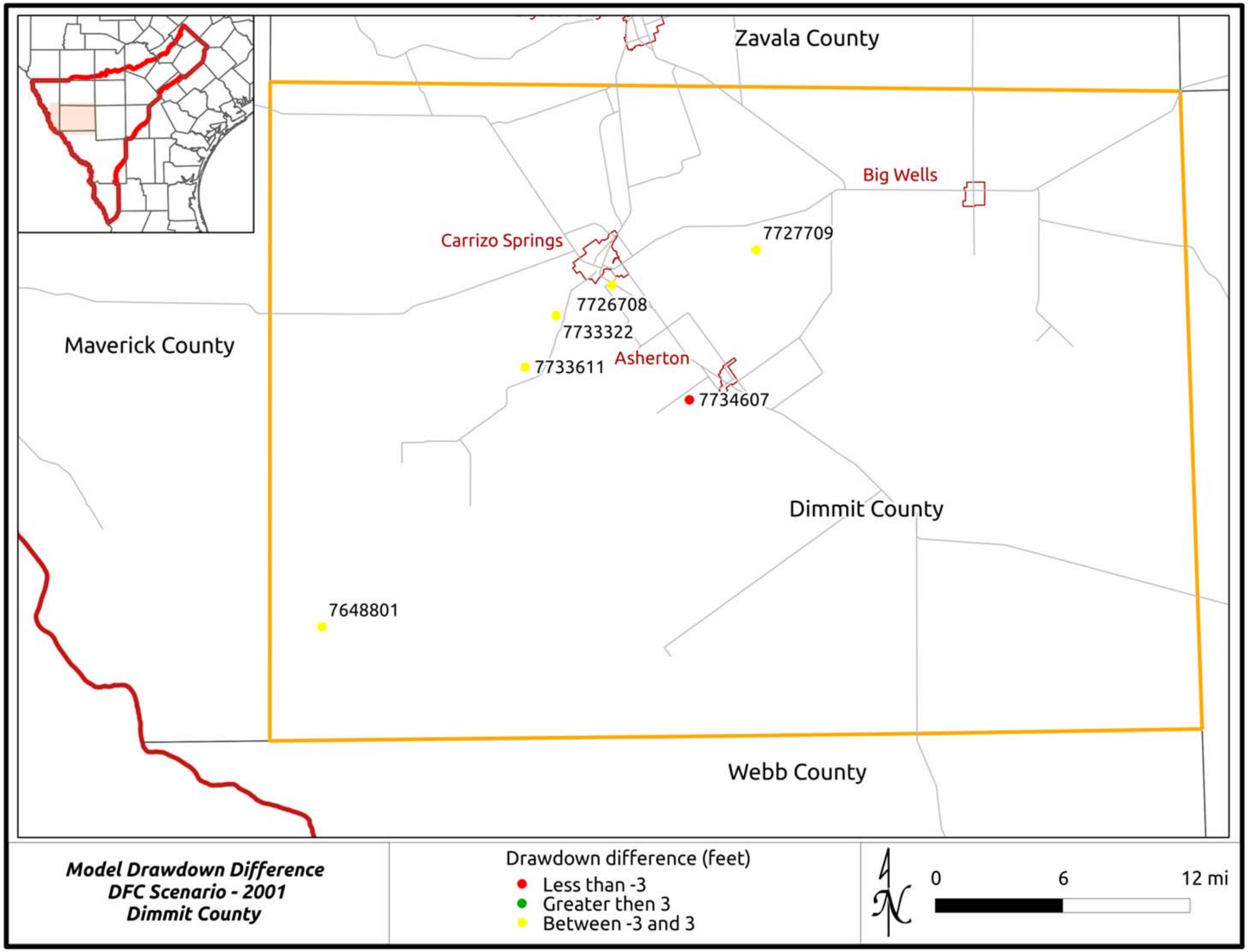

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 7648801
Dimmit County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 7726708
Dimmit County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)


Well 7727709
Dimmit County - Layer 3
Pumping (AF/yr)
-1
0
1
Elevation (ft MSL)
540
520
500
480
460
440
1960
1980
2000
2020
2040
2060
2080
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface

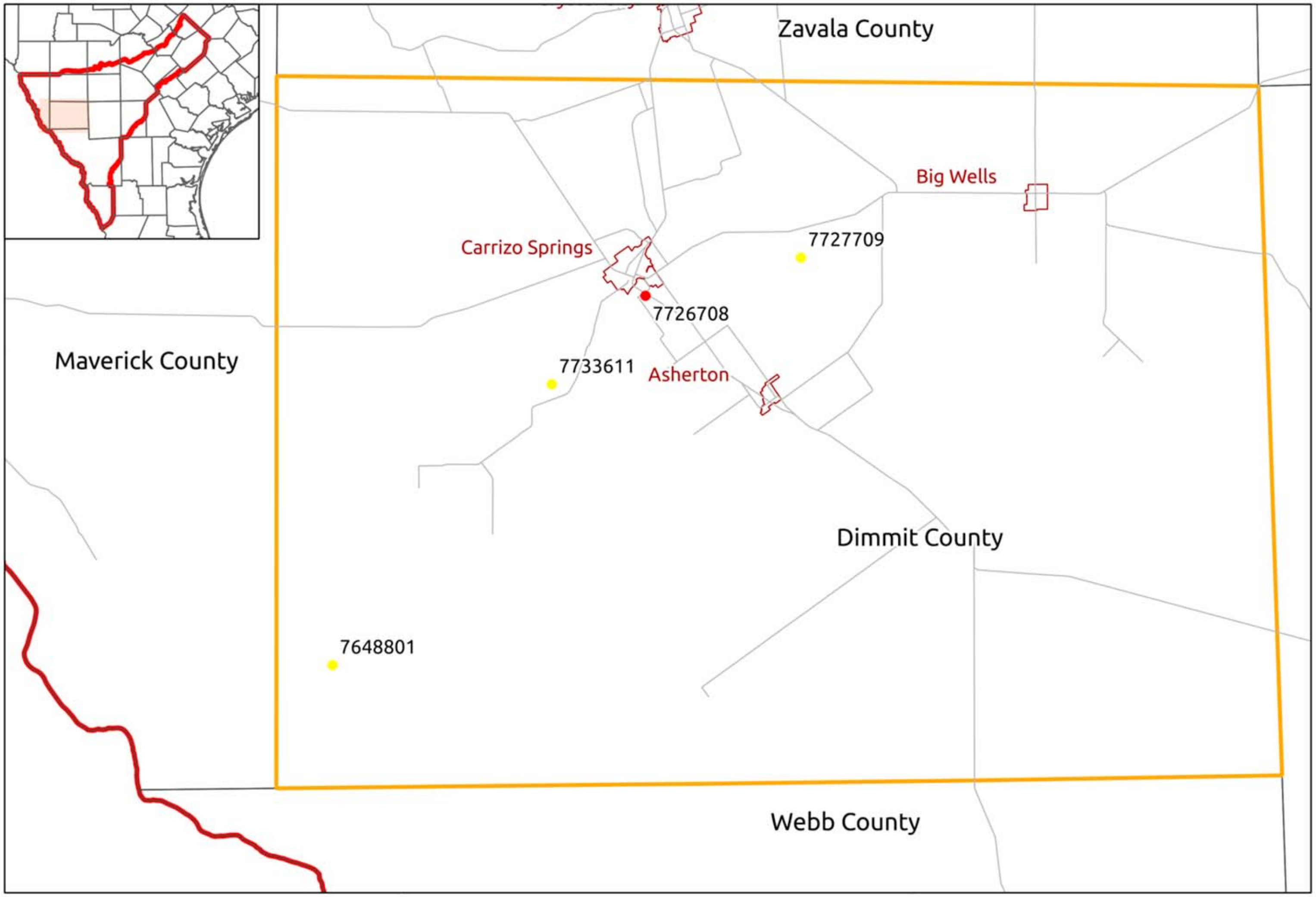

Well 7733322
Dimmit County - Layer 5
Pumping (AF/yr)
0
40
80
120
160
Elevation (ft MSL)
680
640
600
560
520
480
1960
1980
2000
2020
2040
2060
2080


Well 7733611
Dimmit County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
700
600
500
400
300
0
100
200
300
400
1920
1960
2000
2040
2080


Well 7734607
Dimmit County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
600
400
200
0
-200
0
100
200
300
400
1920
1960
2000
2040
2080



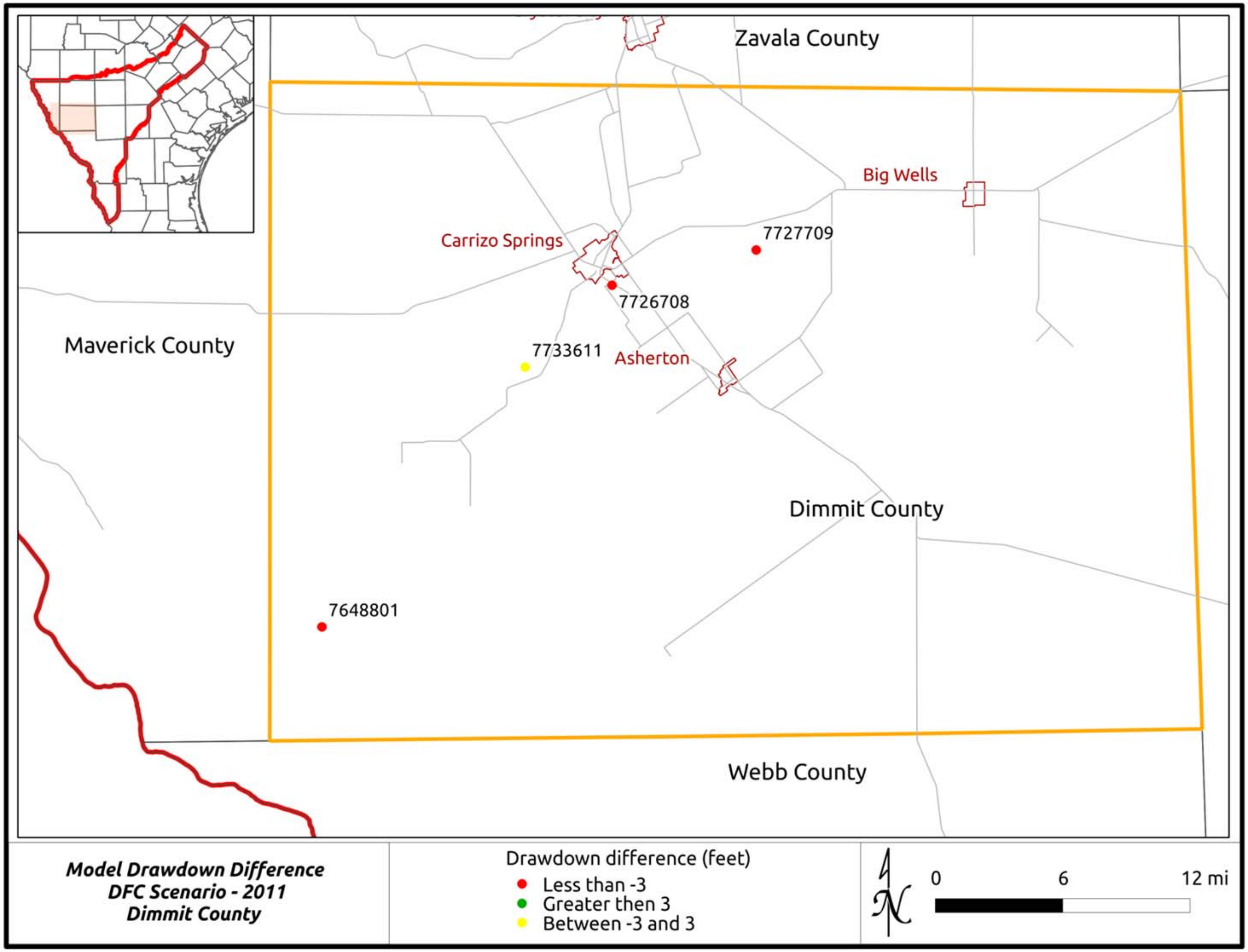
Zavala County
Big Wells
Carrizo Springs
7727709
7726708
7733322
Maverick County
Asherton
7733611
7734607
Dimmit County
7648801
Webb County
Model Drawdown Difference
DFC Scenario - 2001
Dimmit County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
6
12 mi



Model Drawdown Difference
DFC Scenario - 2006
Dimmit County

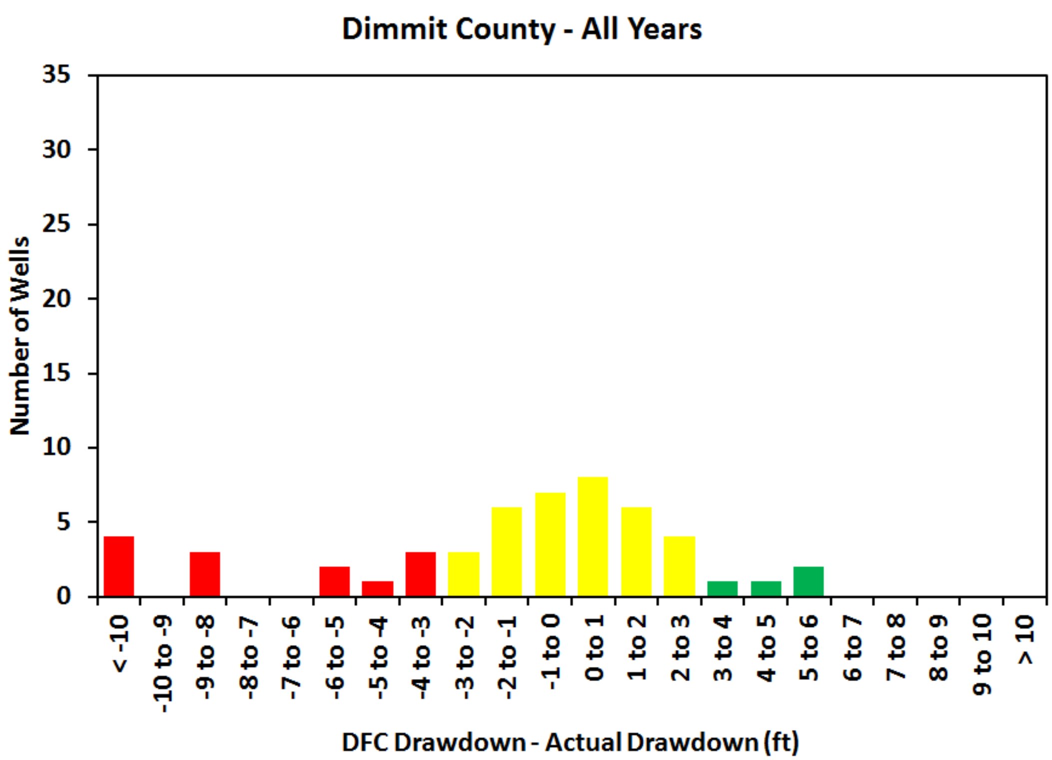
Drawdown difference (feet)
- Less than -3
- Greater then 3
- Between -3 and 3

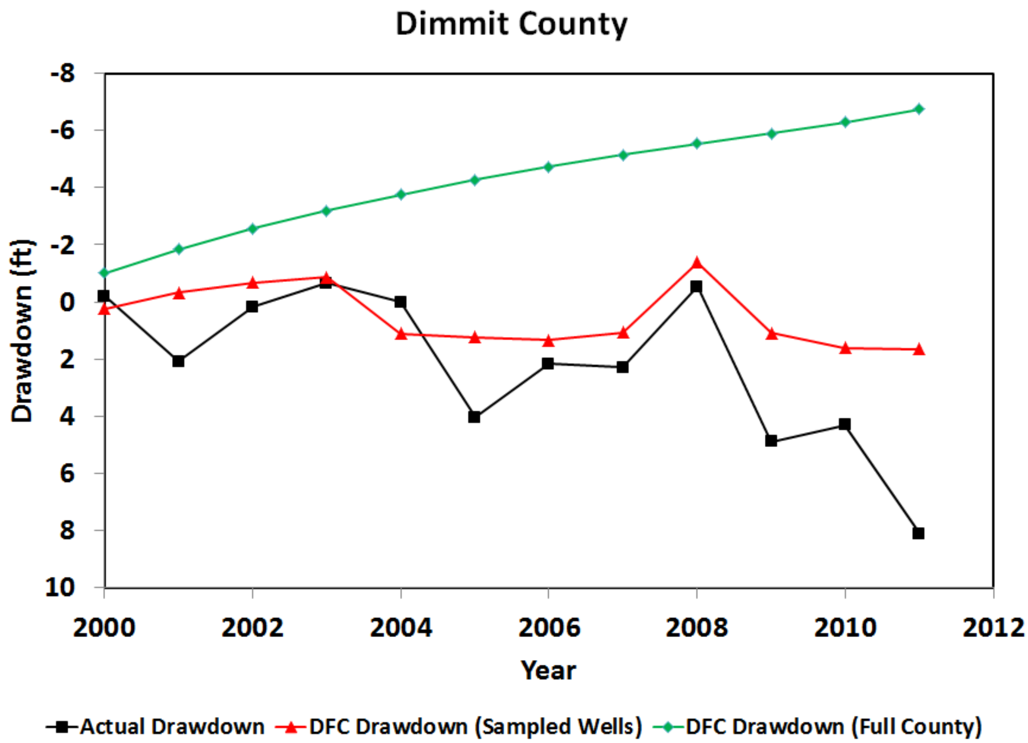
0 6 12 mi


Zavala County
Big Wells
Carrizo Springs
7727709
7726708
Maverick County
7733611
Asherton
Dimmit County
7648801
Webb County
Model Drawdown Difference
DFC Scenario - 2011
Dimmit County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
6
12 mi

Summary of Drawdown Comparisons - Dimmit County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	-1.01	5	-0.20	0.24	0.44
2001	101	-1.85	6	2.07	-0.32	-2.39
2002	113	-2.57	5	0.17	-0.69	-0.86
2003	96	-3.2	5	-0.65	-0.86	-0.21
2004	132	-3.76	4	0.02	1.11	1.09
2005	75	-4.27	4	4.04	1.23	-2.81
2006	86	-4.73	4	2.17	1.34	-0.83
2007	142	-5.14	3	2.30	1.06	-1.24
2008	74	-5.54	4	-0.54	-1.39	-0.85
2009	76	-5.9	3	4.89	1.09	-3.80
2010	132	-6.29	4	4.31	1.62	-2.70
2011	45	-6.74	4	8.12	1.66	-6.46




Dimmit County
-8
-6
-4
-2
0
2
4
6
8
10
Drawdown (ft)
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 6 – Frio County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001 and 2006

Summary of Drawdown Comparisons

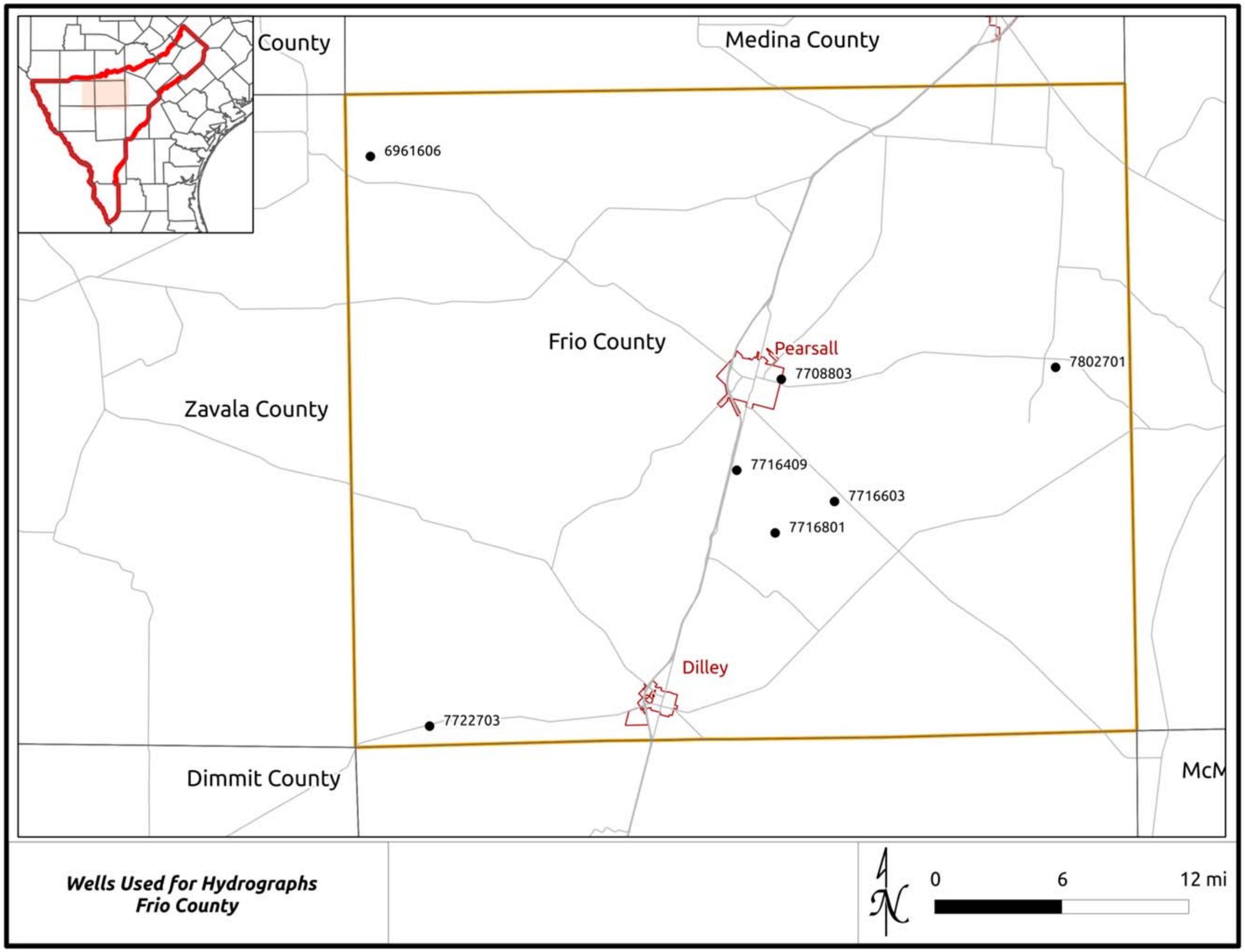
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

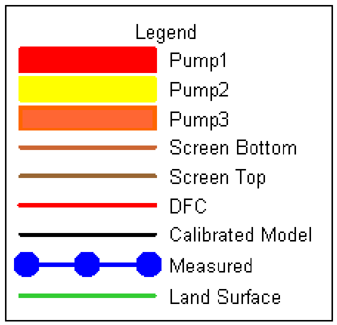
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

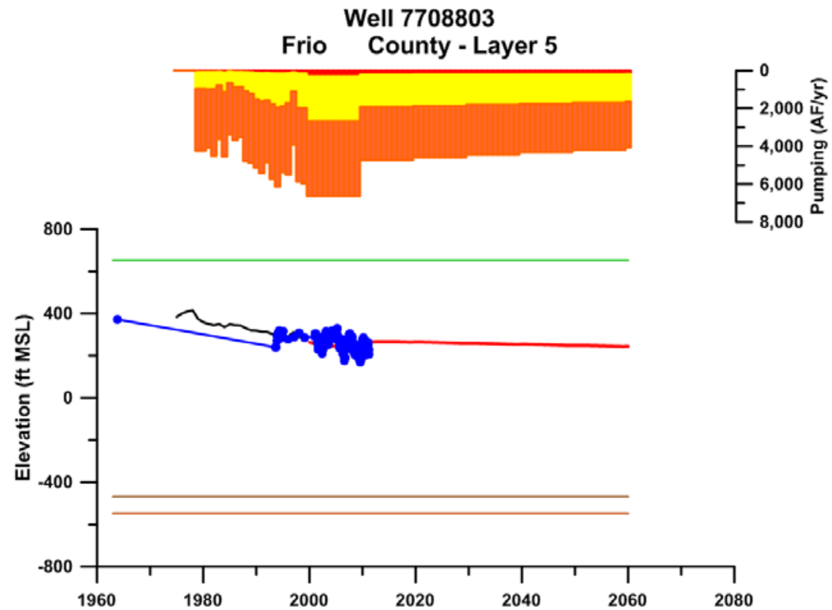
Hydrograph of Actual Drawdown and DFC Drawdown

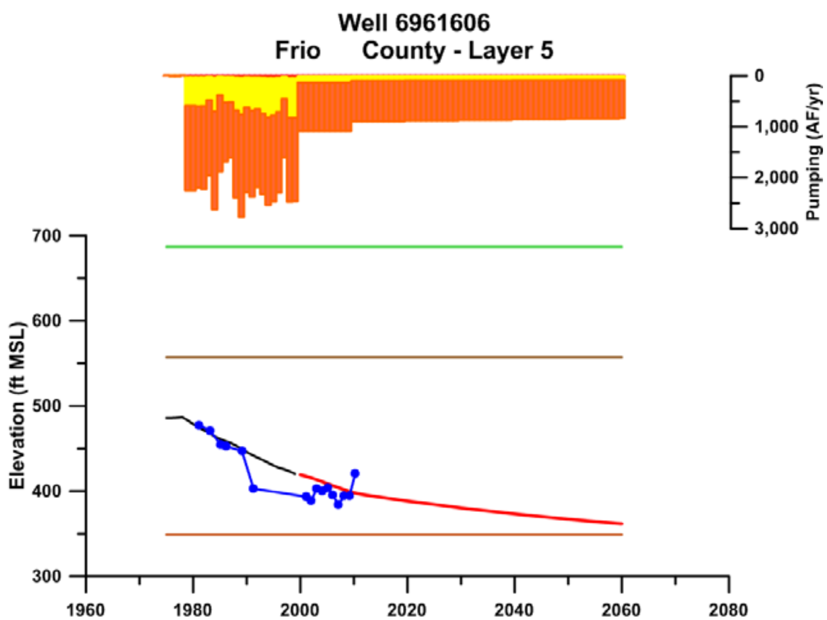
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

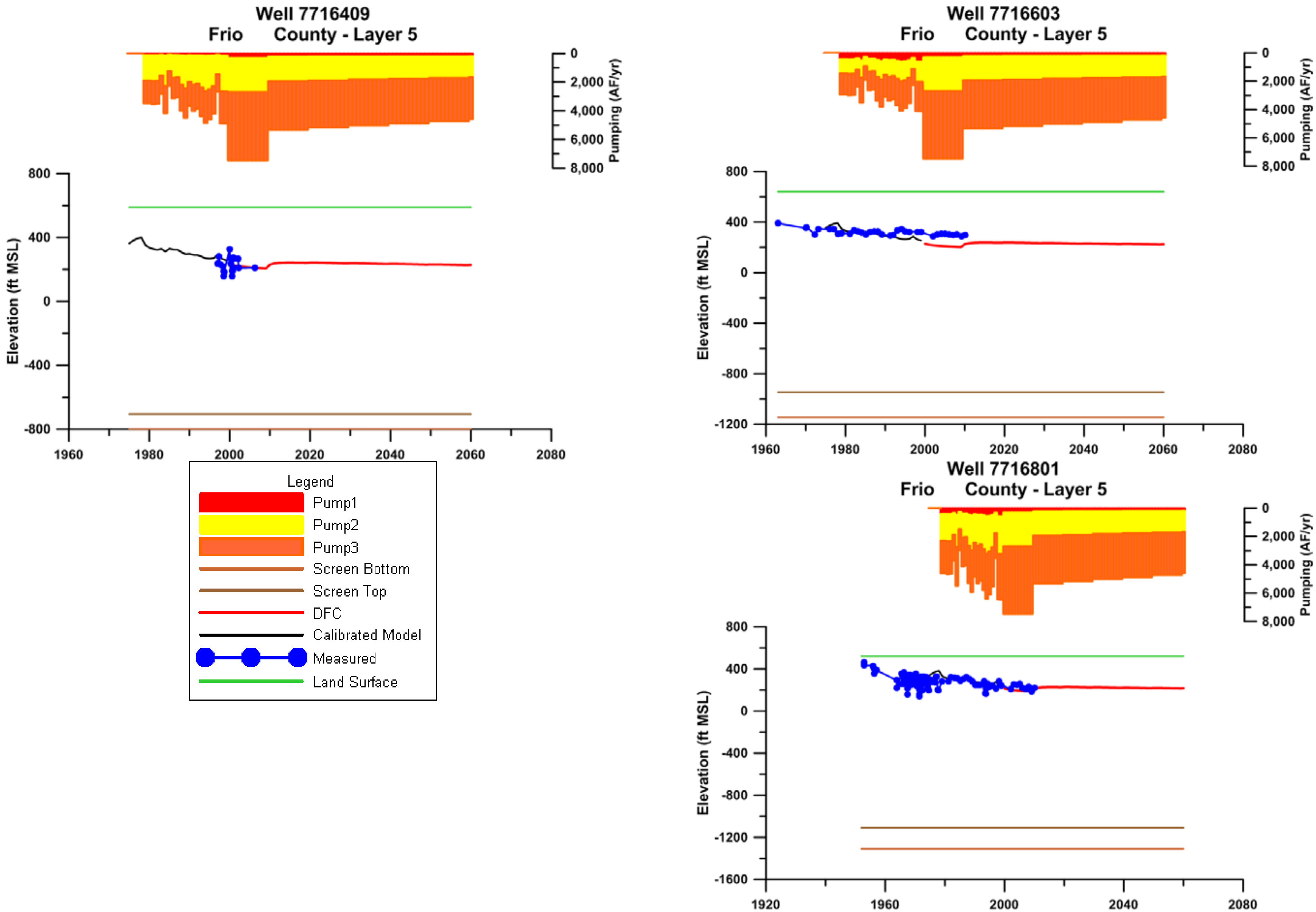


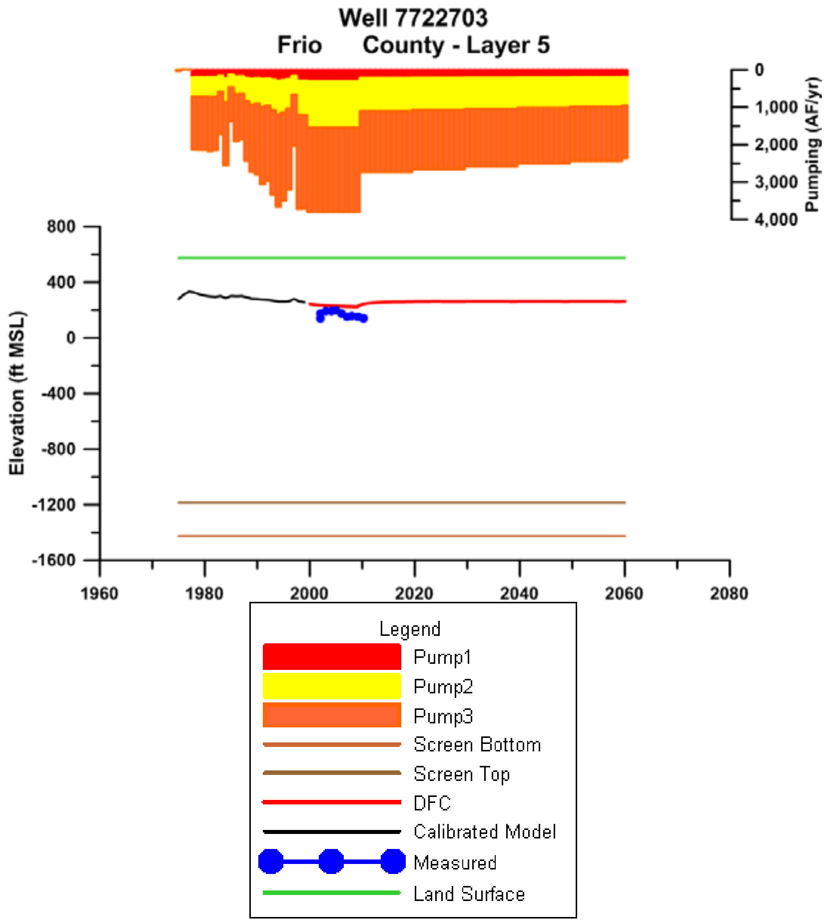
Location Map of Wells with Hydrographs – Frio County


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface

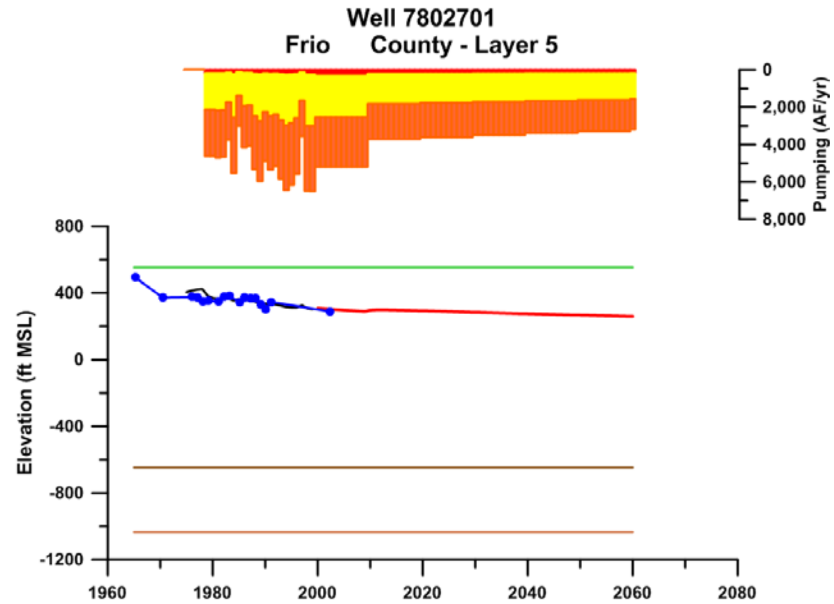

Well 7708803
Frio County - Layer 5
Elevation (ft MSL)
800
400
0
-400
-800
1960
1980
2000
2020
2040
2060
2080
Pumping (AF/yr)
0
2,000
4,000
6,000
8,000


Well 6961606
Frio County - Layer 5
Elevation (ft MSL)
700
600
500
400
300
1960
1980
2000
2020
2040
2060
2080
Pumping (AF/yr)
0
1,000
2,000
3,000

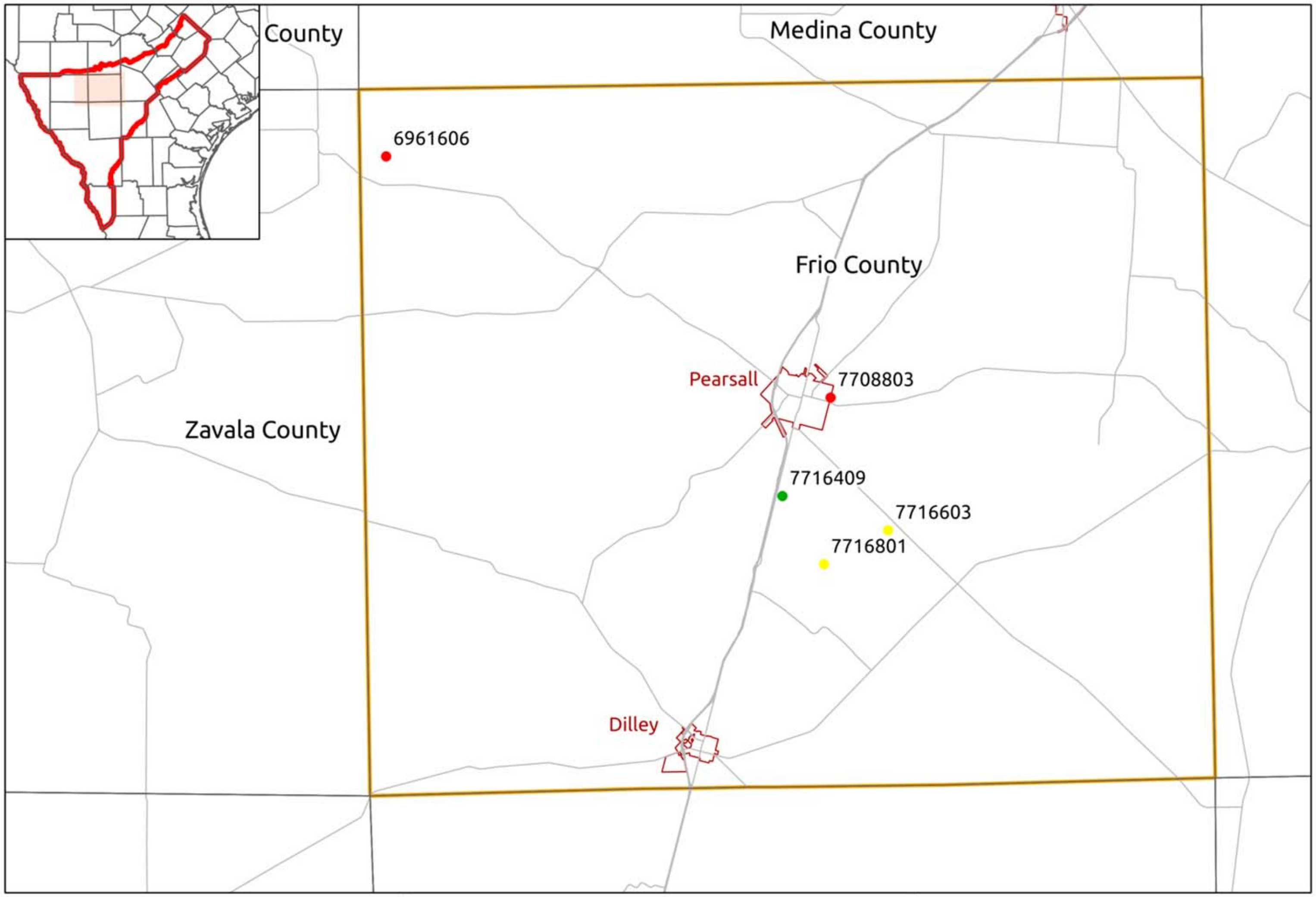

Well 7716409
Frio County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 7716603
Frio County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 7716801
Frio County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)



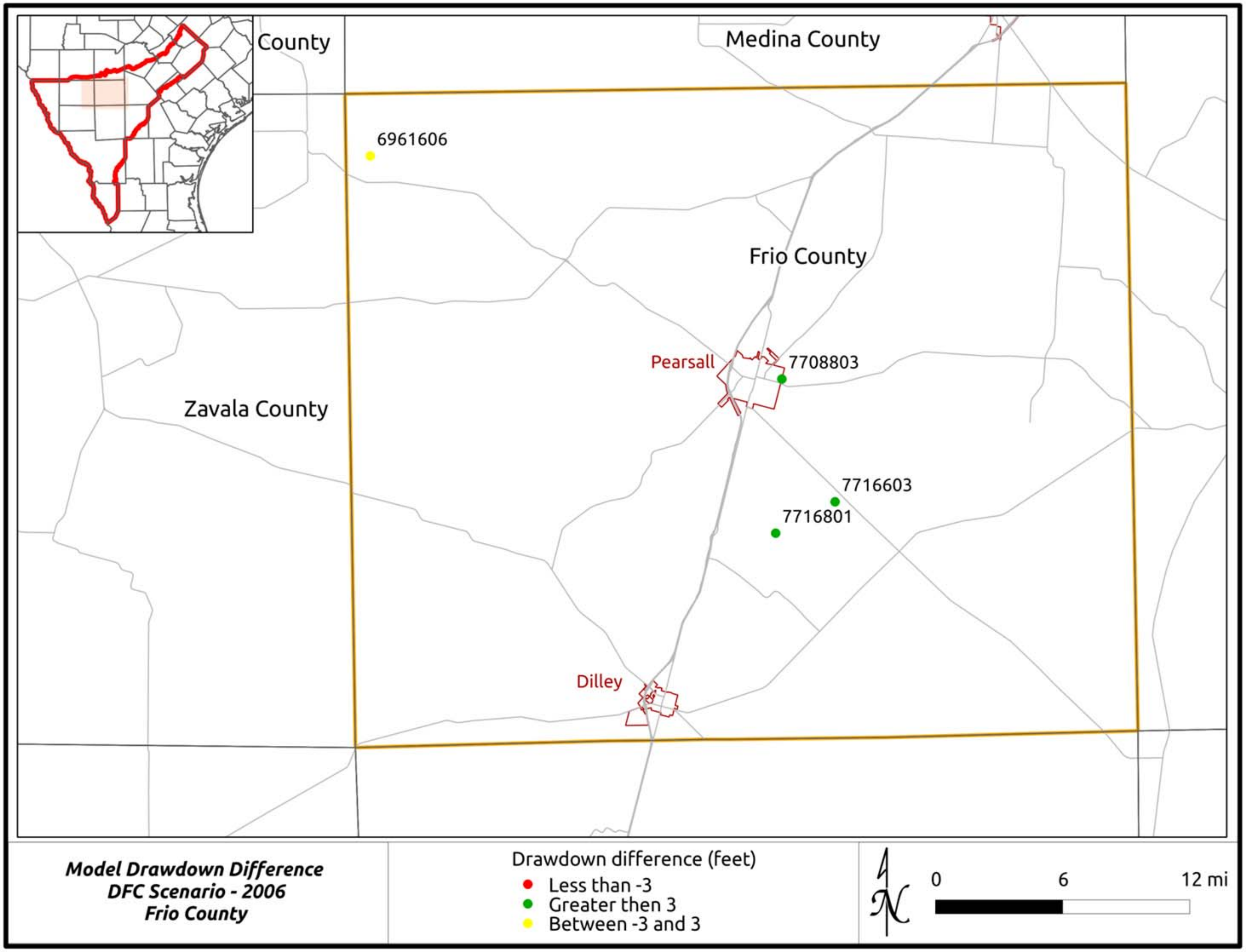
Well 7722703
Frio County - Layer 5
Pumping (AF/yr)
0
1,000
2,000
3,000
4,000
Elevation (ft MSL)
800
400
0
-400
-800
-1200
-1600
1960
1980
2000
2020
2040
2060
2080
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface



Well 7802701
Frio County - Layer 5
Pumping (AF/yr)
0
2,000
4,000
6,000
8,000
Elevation (ft MSL)
800
400
0
-400
-800
-1200
1960
1980
2000
2020
2040
2060
2080



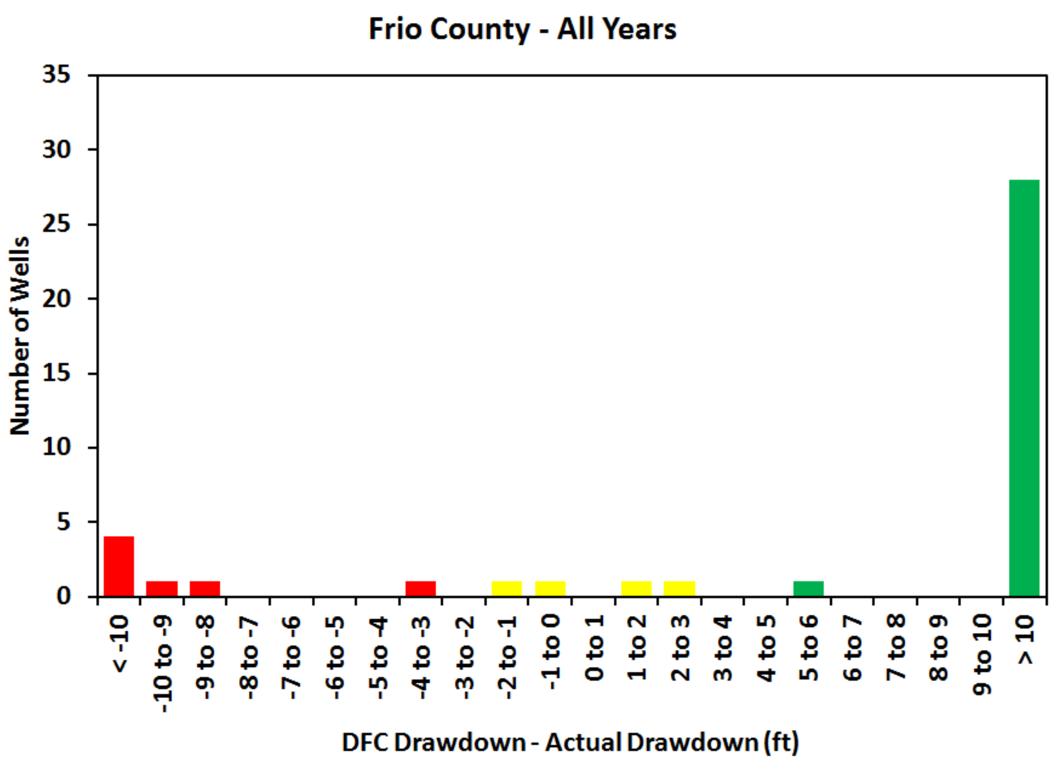
Model Drawdown Difference
DFC Scenario - 2001
Frio County

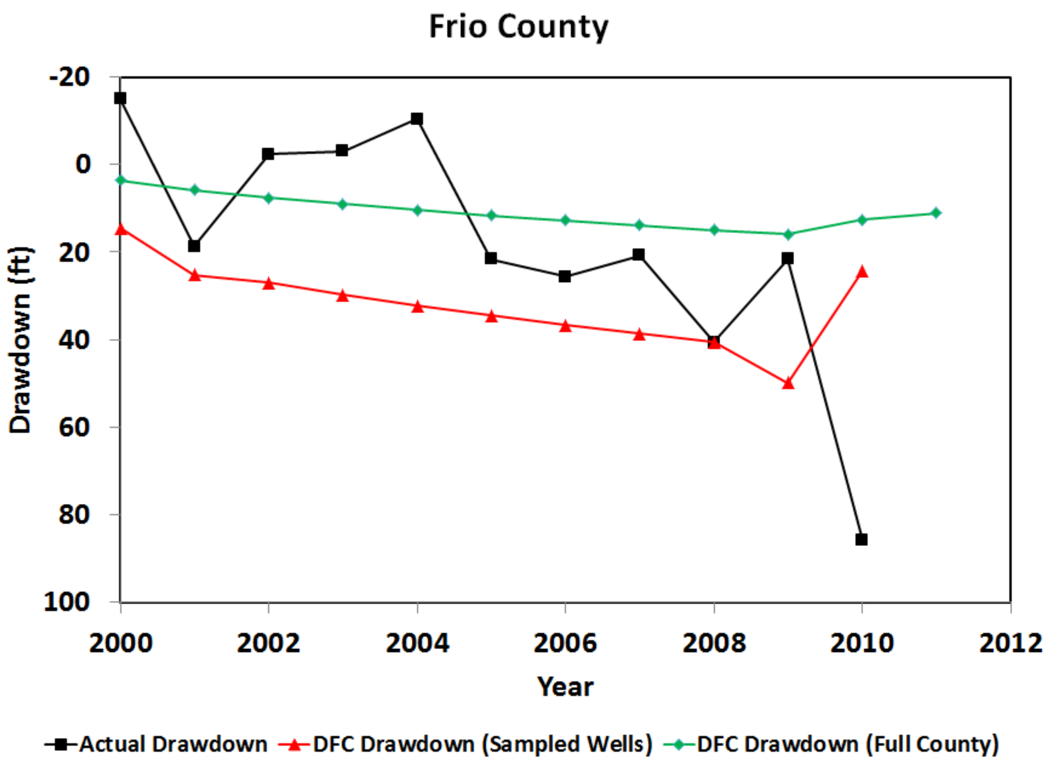


Model Drawdown Difference
DFC Scenario - 2006
Frio County

Summary of Drawdown Comparisons - Frio County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	3.62	3	-14.90	14.52	29.42
2001	101	5.87	5	18.66	25.16	6.50
2002	113	7.58	4	-2.33	26.98	29.31
2003	96	9.03	4	-3.04	29.82	32.86
2004	132	10.35	4	-10.42	32.29	42.71
2005	75	11.57	4	21.59	34.55	12.96
2006	86	12.72	4	25.56	36.67	11.11
2007	142	13.83	4	20.84	38.68	17.84
2008	74	14.91	4	40.58	40.61	0.03
2009	76	15.96	3	21.67	49.80	28.13
2010	132	12.57	1	85.85	24.21	-61.64
2011	45	11.1				





Frio County
Drawdown (ft)
-20
0
20
40
60
80
100
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 7 – Gonzales County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Map for 2001

Summary of Drawdown Comparisons

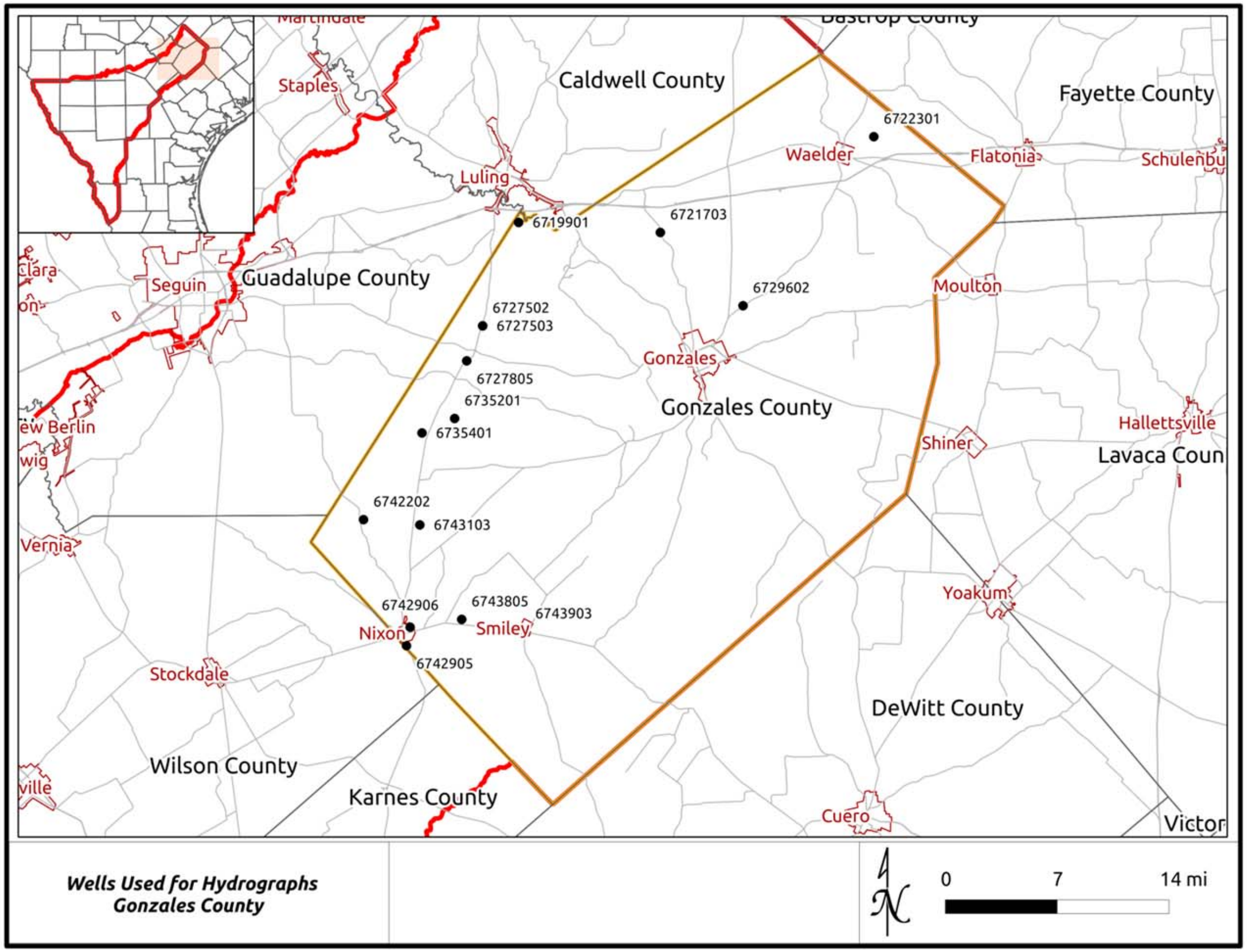
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

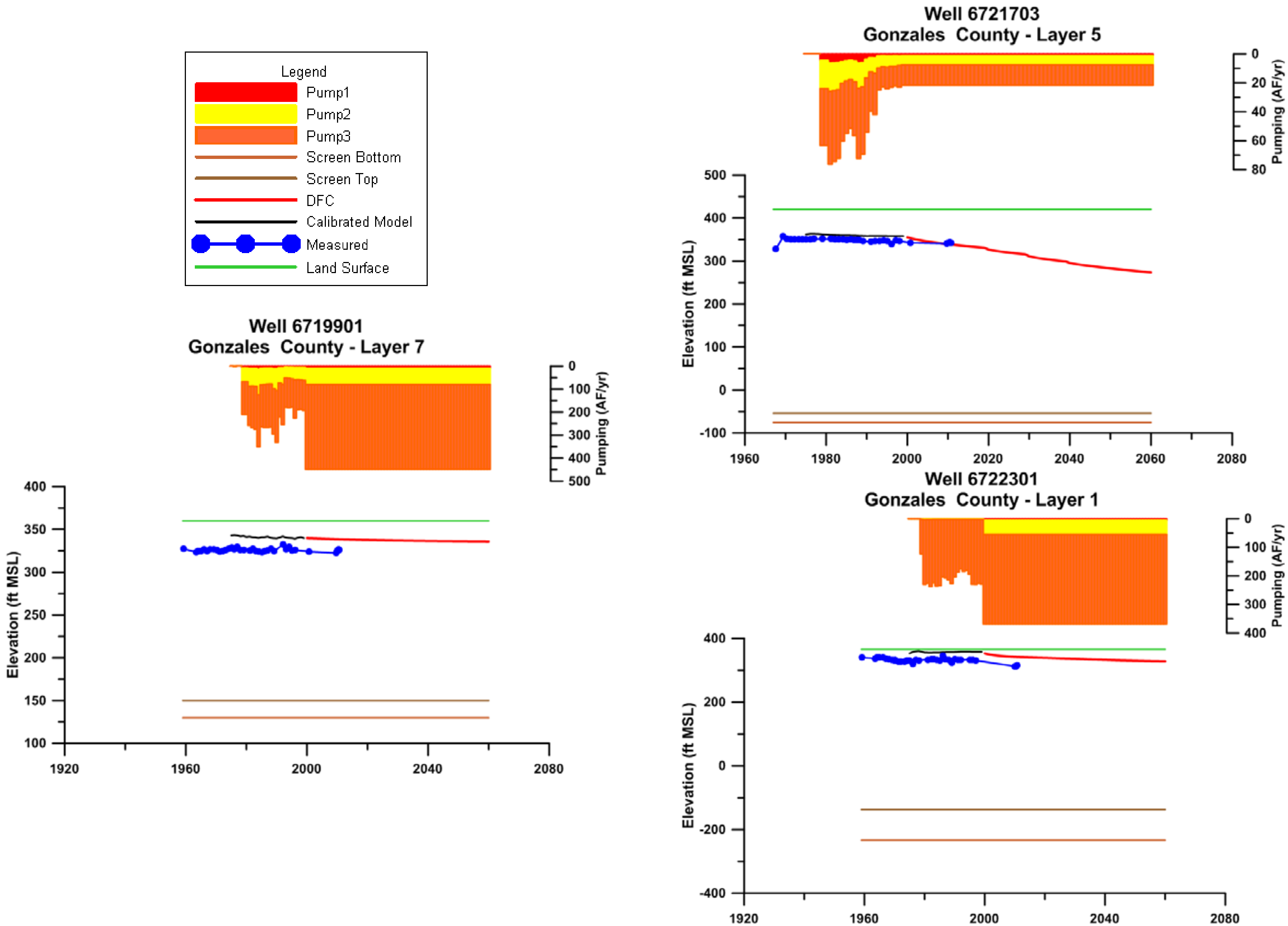
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

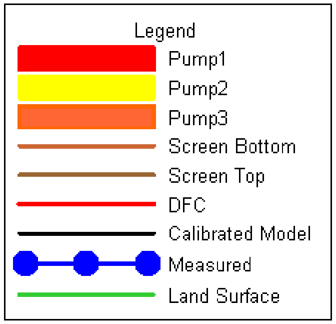
Hydrograph of Actual Drawdown and DFC Drawdown

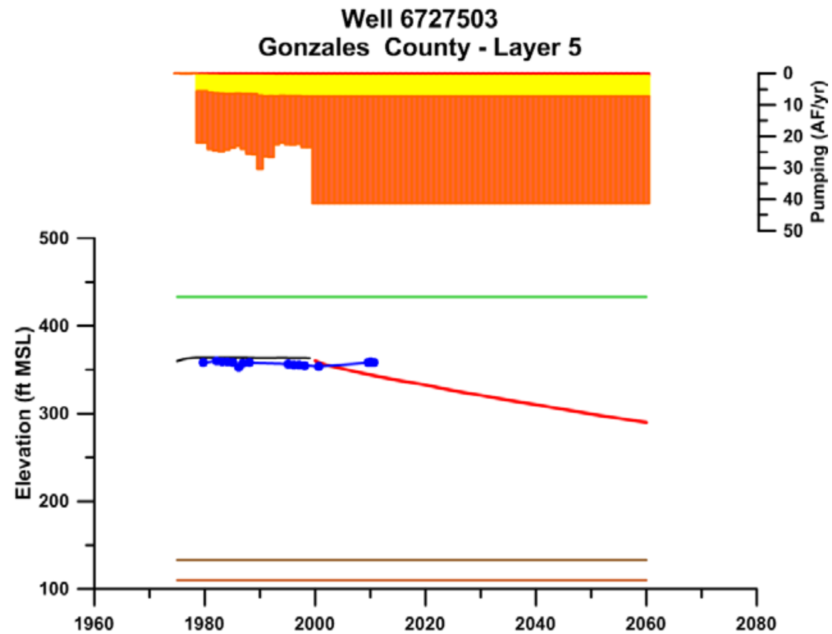
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

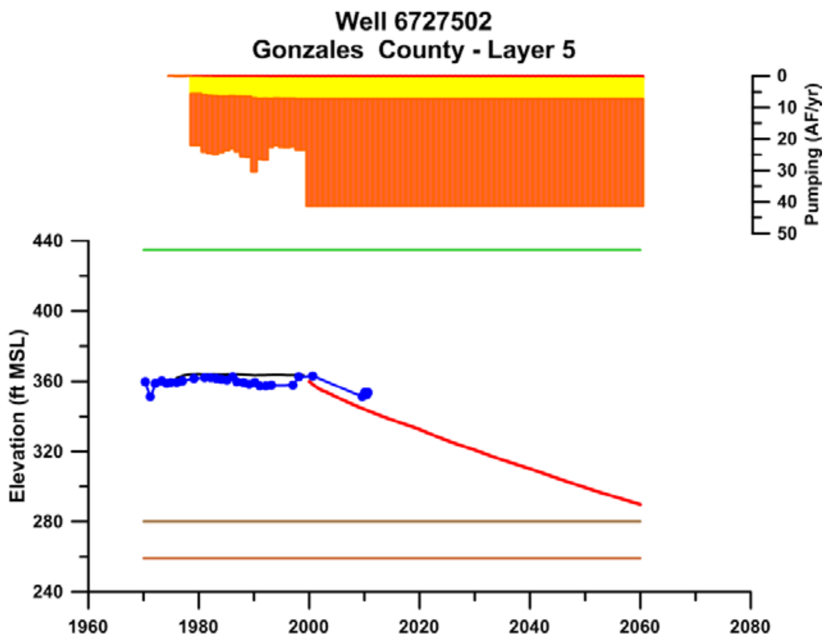


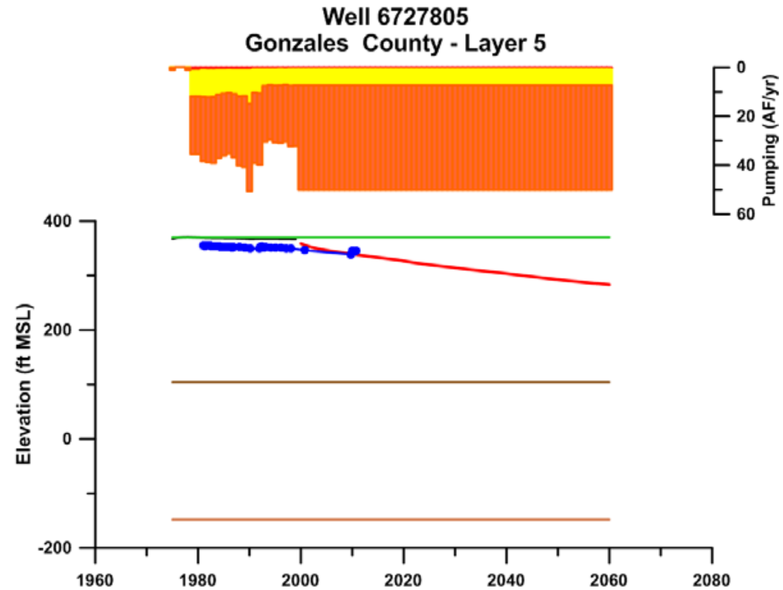
Location Map of Wells with Hydrographs – Gonzales County

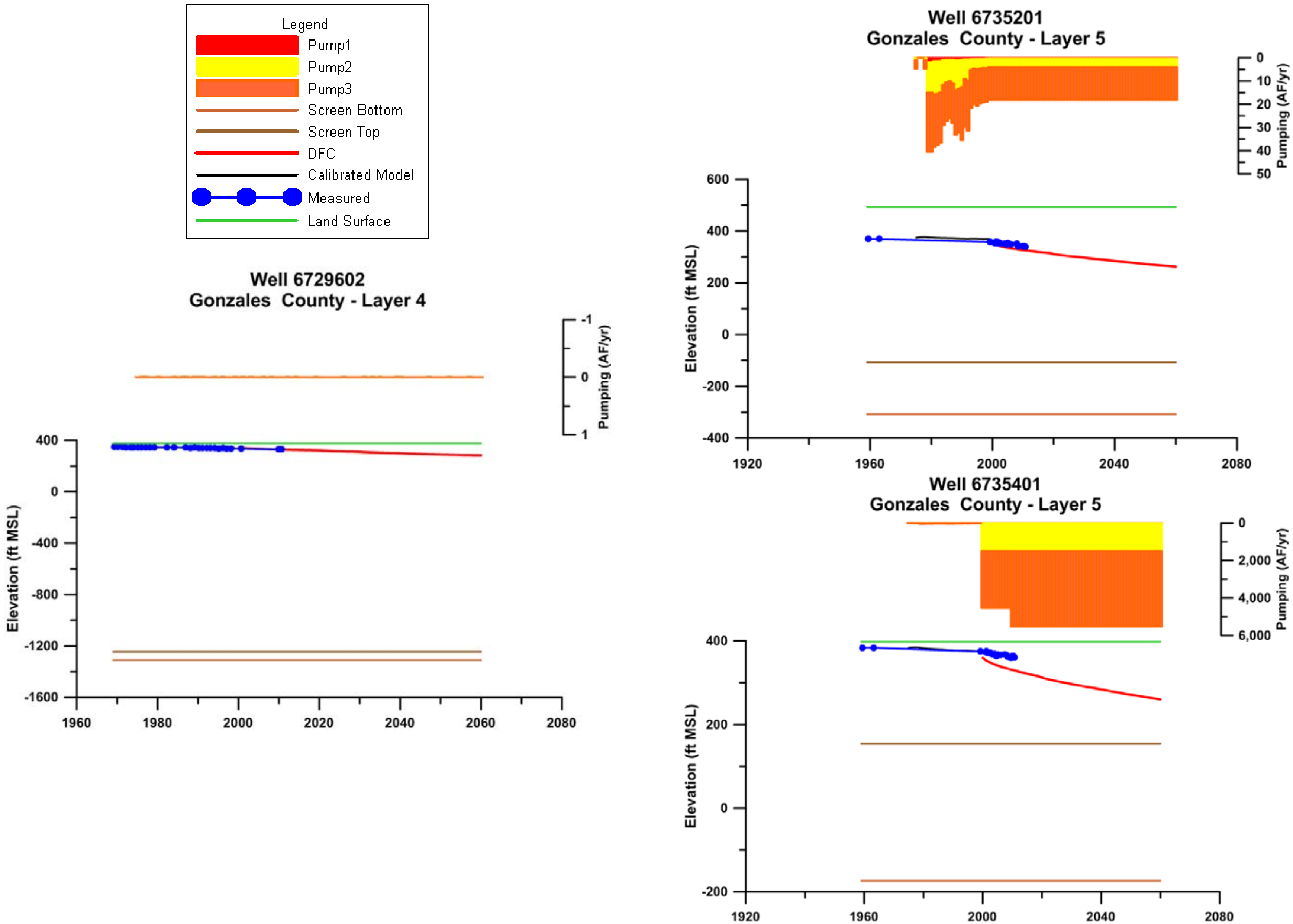

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6721703
Gonzales County - Layer 5
Pumping (AF/yr)
0
20
40
60
80
Elevation (ft MSL)
500
400
300
200
100
0
-100
1960
1980
2000
2020
2040
2060
2080
Well 6719901
Gonzales County - Layer 7
Pumping (AF/yr)
0
100
200
300
400
500
Elevation (ft MSL)
400
350
300
250
200
150
100
1920
1960
2000
2040
2080
Well 6722301
Gonzales County - Layer 1
Pumping (AF/yr)
0
100
200
300
400
Elevation (ft MSL)
400
200
0
-200
-400
1920
1960
2000
2040
2080

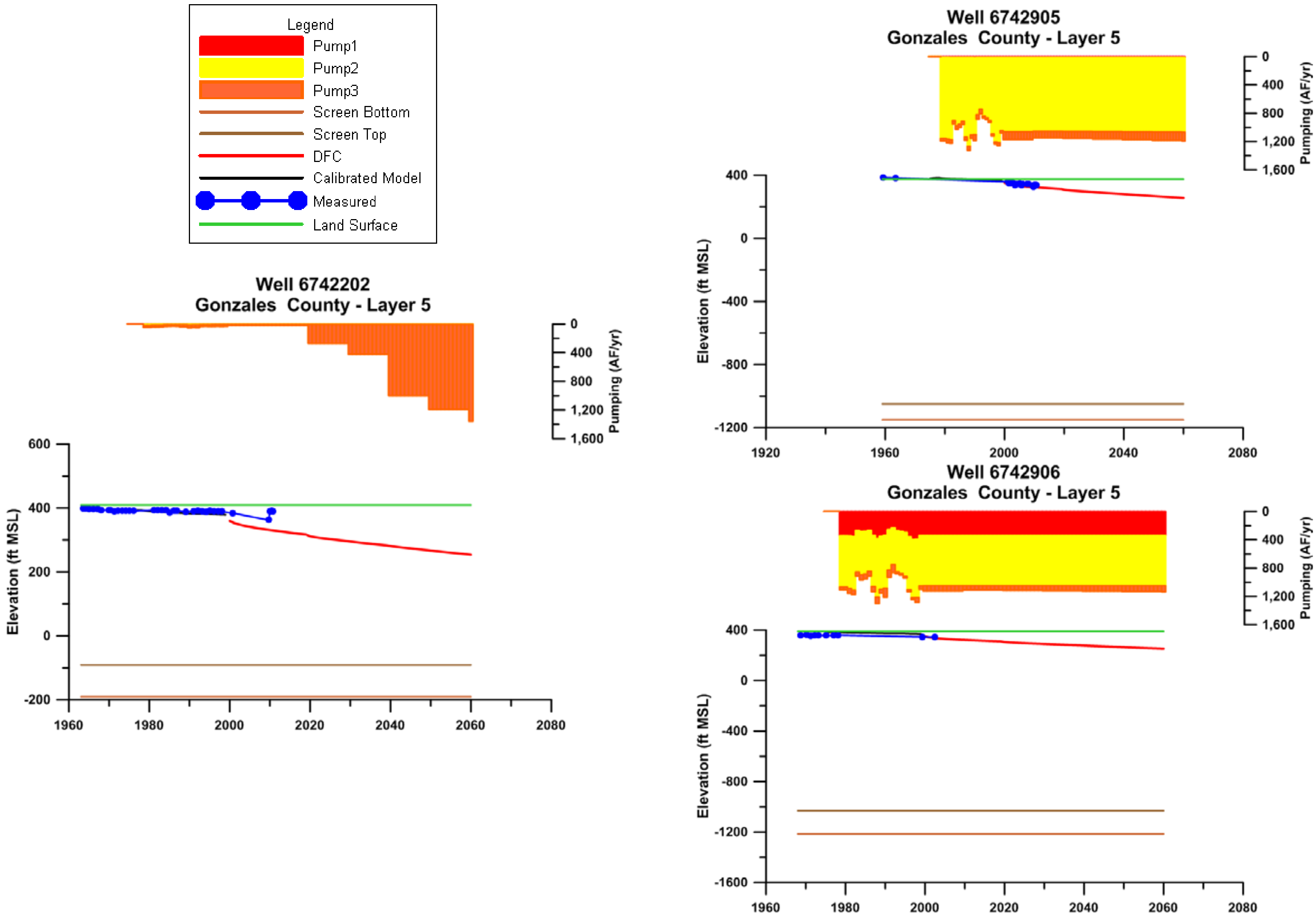

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface

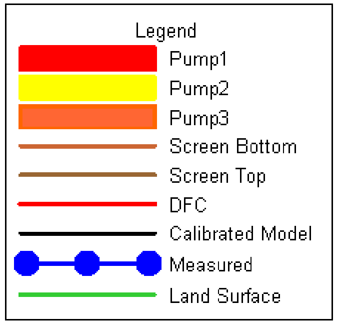

Well 6727503
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
10
20
30
40
50
100
200
300
400
500
1960
1980
2000
2020
2040
2060
2080

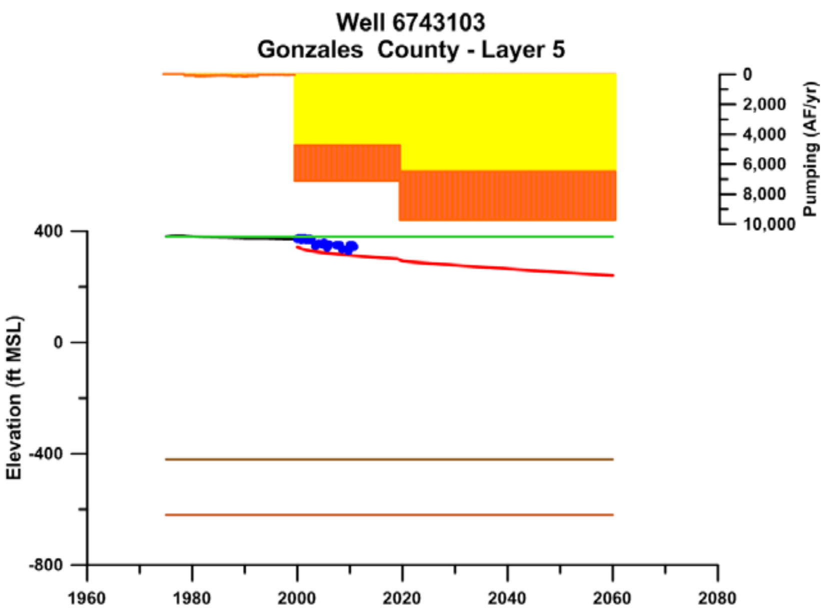

Well 6727502
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
10
20
30
40
50
240
280
320
360
400
440
1960
1980
2000
2020
2040
2060
2080

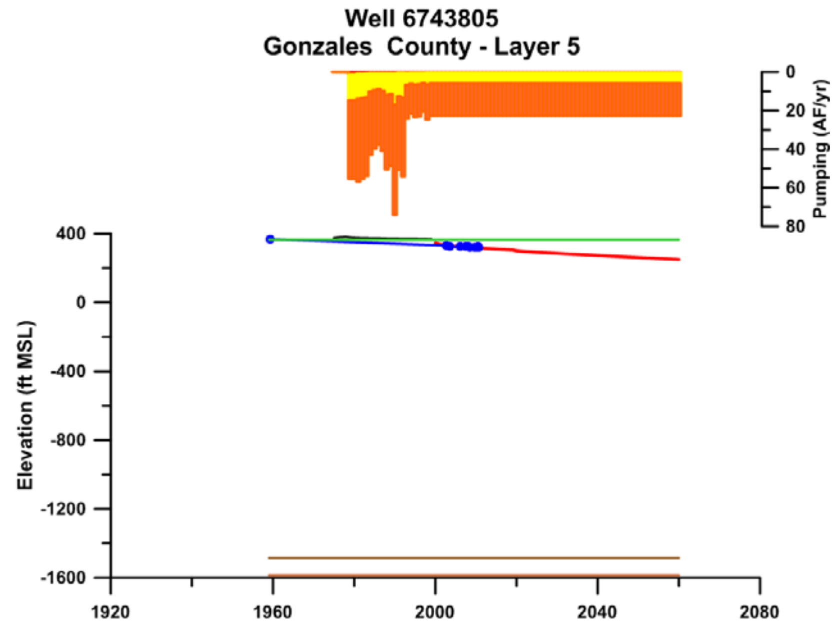

Well 6727805
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
20
40
60
-200
0
200
400
1960
1980
2000
2020
2040
2060
2080

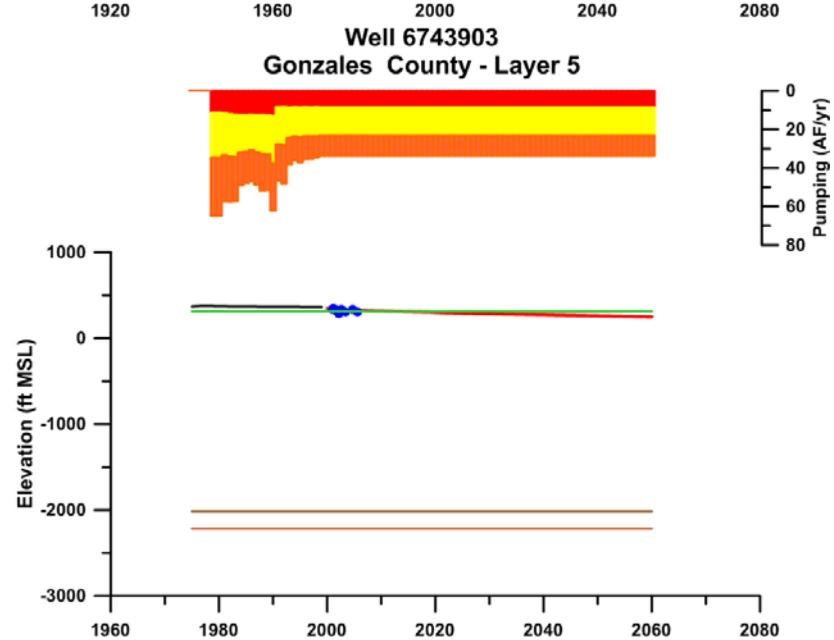

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6729602
Gonzales County - Layer 4
Elevation (ft MSL)
Pumping (AF/yr)
Well 6735201
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 6735401
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)

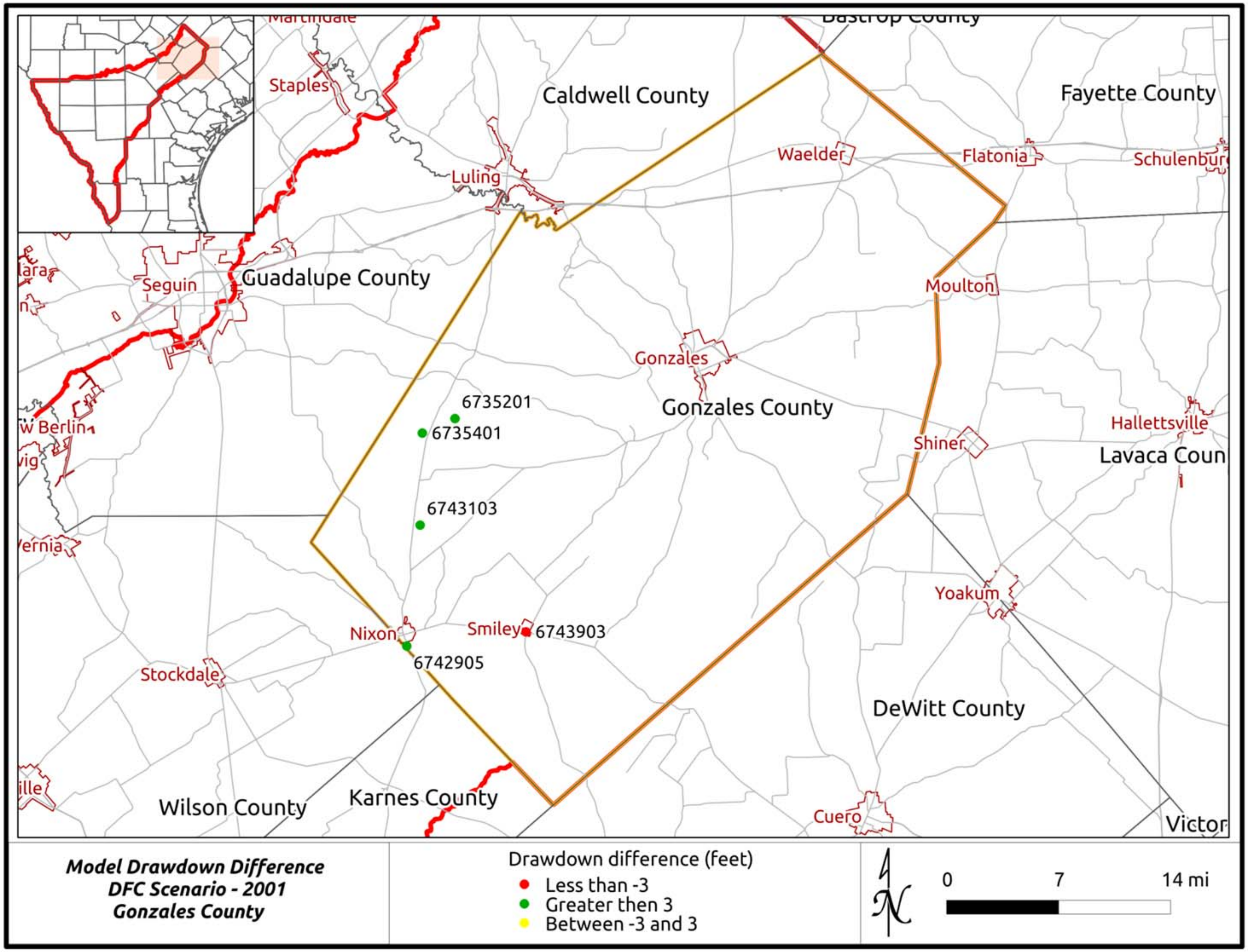

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6742202
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 6742905
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 6742906
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface


Well 6743103
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
2,000
4,000
6,000
8,000
10,000
400
0
-400
-800
1960
1980
2000
2020
2040
2060
2080


Well 6743805
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
20
40
60
80
400
0
-400
-800
-1200
-1600
1920
1960
2000
2040
2080

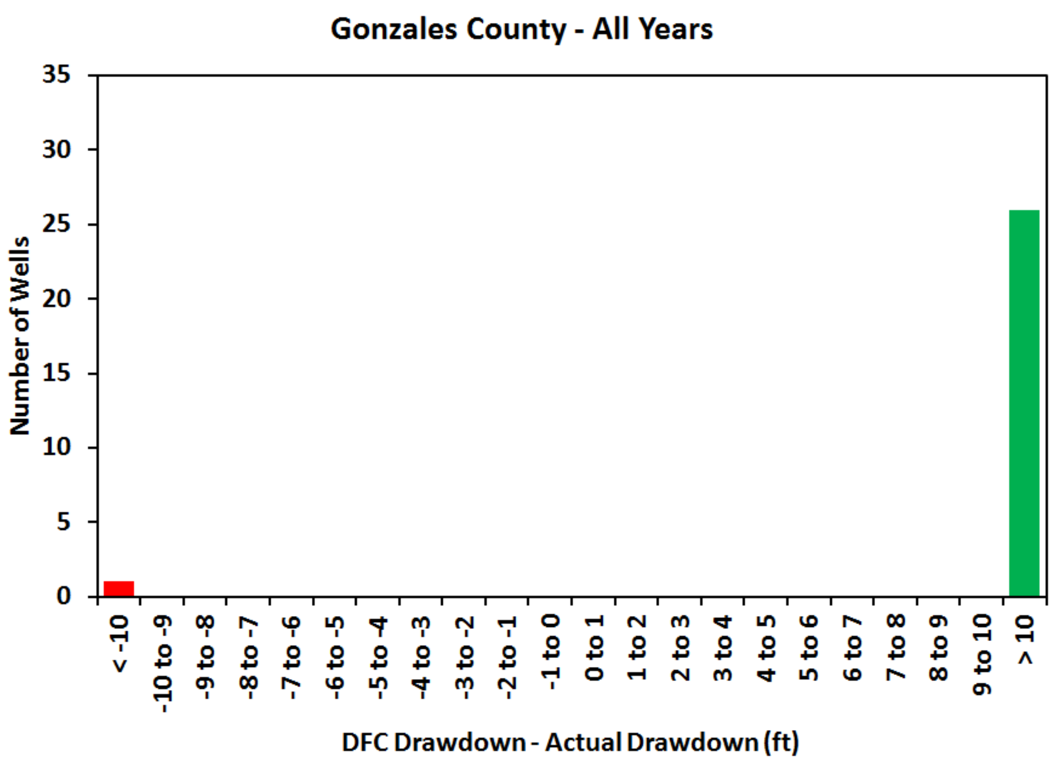

Well 6743903
Gonzales County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
20
40
60
80
1000
0
-1000
-2000
-3000
1960
1980
2000
2020
2040
2060
2080

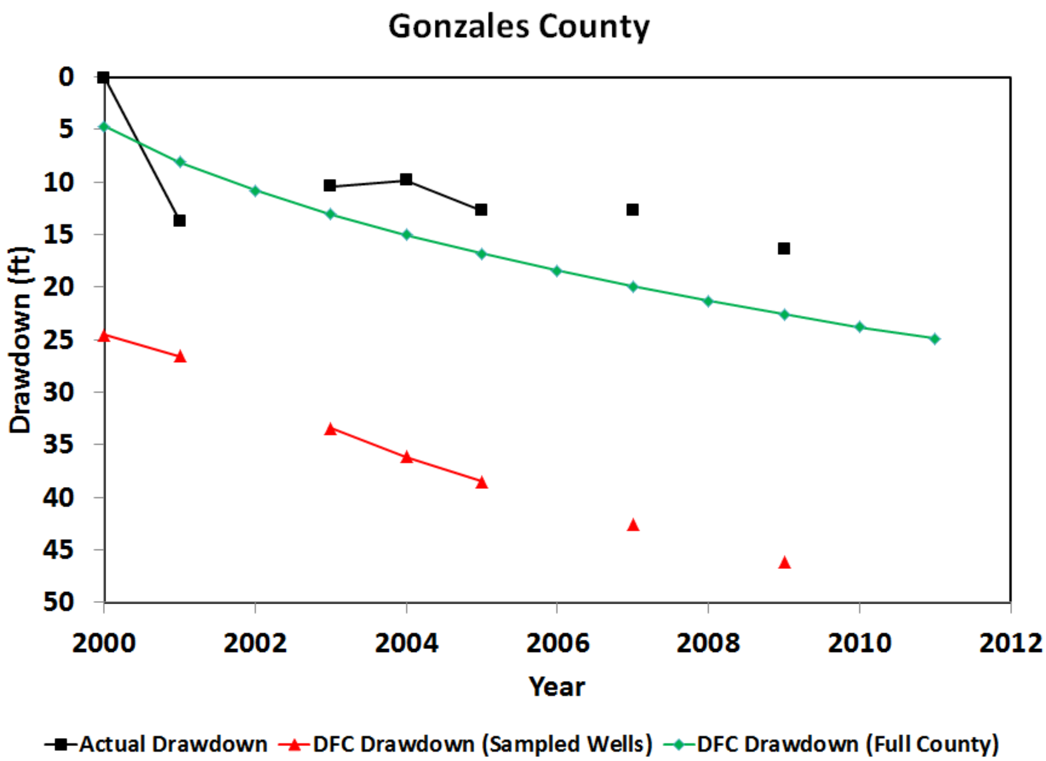


Martindale
Bastrop County
Staples
Caldwell County
Fayette County
Waelder
Flatonia
Schulenburg
Luling
Seguin
Guadalupe County
Moulton
Gonzales
6735201
Gonzales County
6735401
Hallettsville
Shiner
Lavaca Coun
6743103
Yoakum
Nixon
Smiley
6743903
6742905
Stockdale
DeWitt County
Wilson County
Karnes County
Cuero
Victor
Model Drawdown Difference
DFC Scenario - 2001
Gonzales County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
7
14 mi

Summary of Drawdown Comparisons - Gonzales County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	4.72	2	0.10	24.52	24.43
2001	101	8.11	5	13.70	26.59	12.89
2002	113	10.8				
2003	96	13.06	4	10.41	33.43	23.02
2004	132	15.04	4	9.86	36.14	26.28
2005	75	16.82	4	12.71	38.52	25.81
2006	86	18.43				
2007	142	19.91	4	12.71	42.61	29.91
2008	74	21.29				
2009	76	22.58	4	16.35	46.21	29.86
2010	132	23.77				
2011	45	24.91				




Gonzales County
Drawdown (ft)
0
5
10
15
20
25
30
35
40
45
50
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 8 – Guadalupe County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

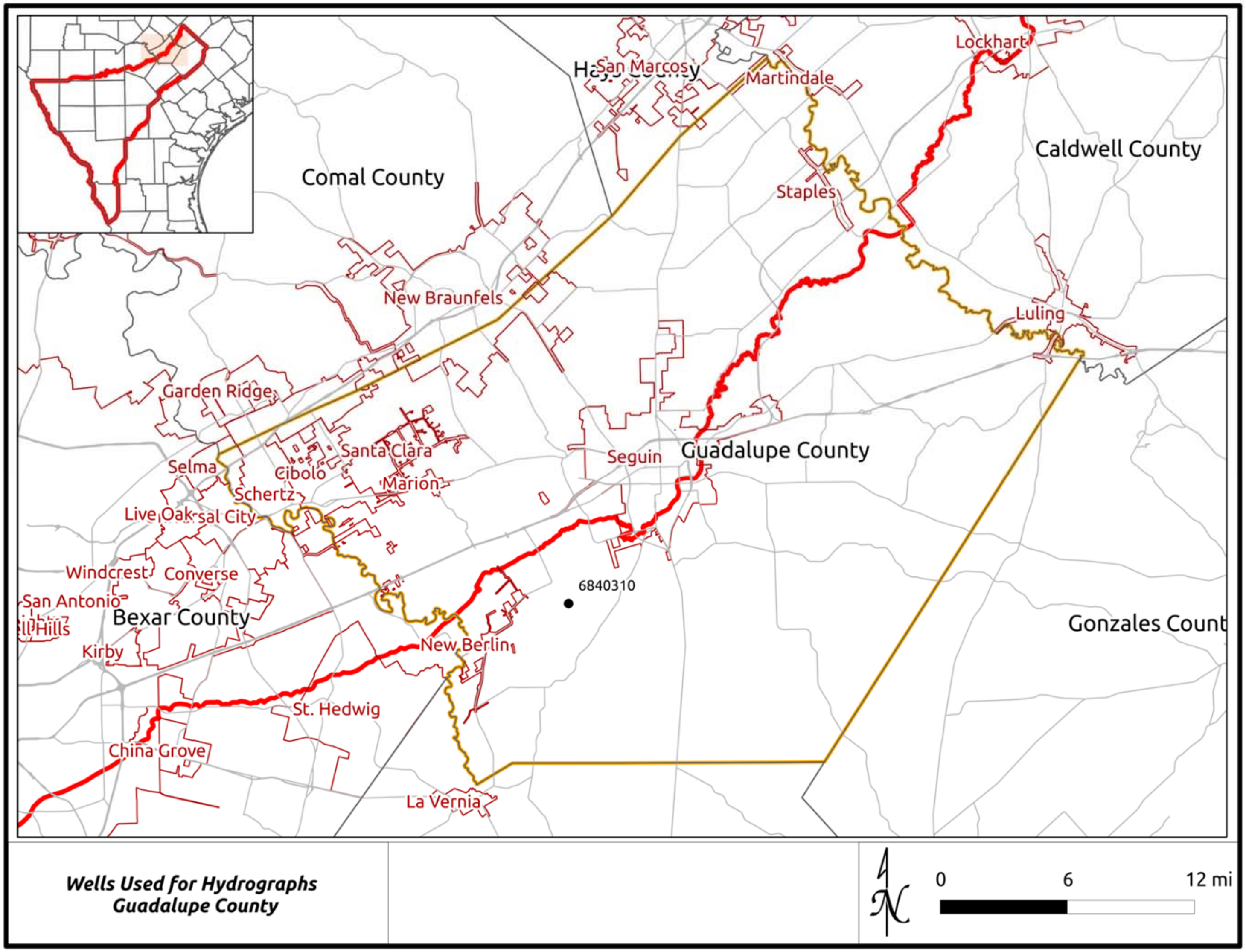
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

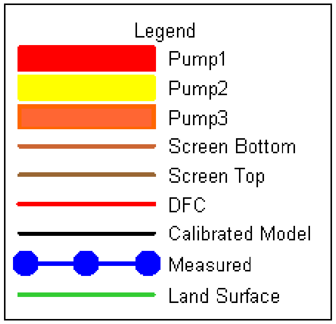
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

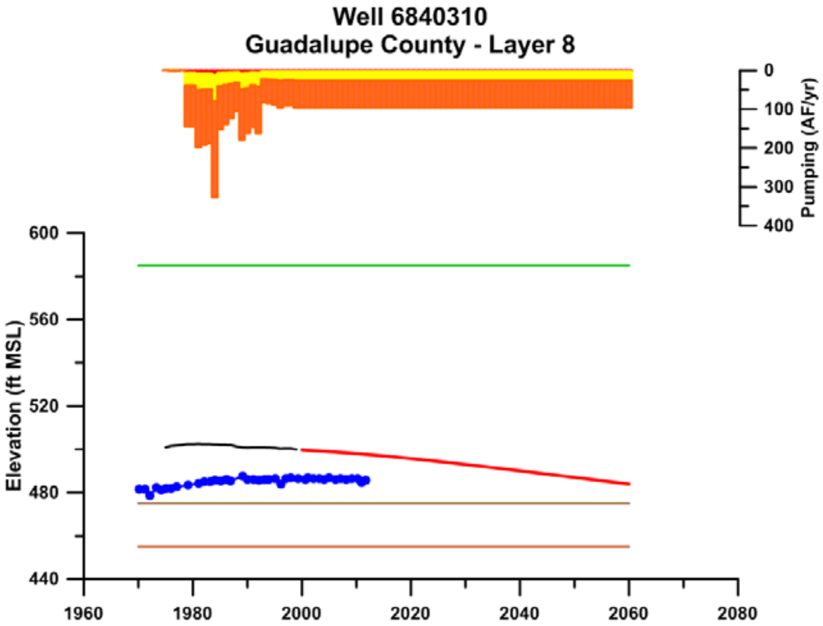
Hydrograph of Actual Drawdown and DFC Drawdown

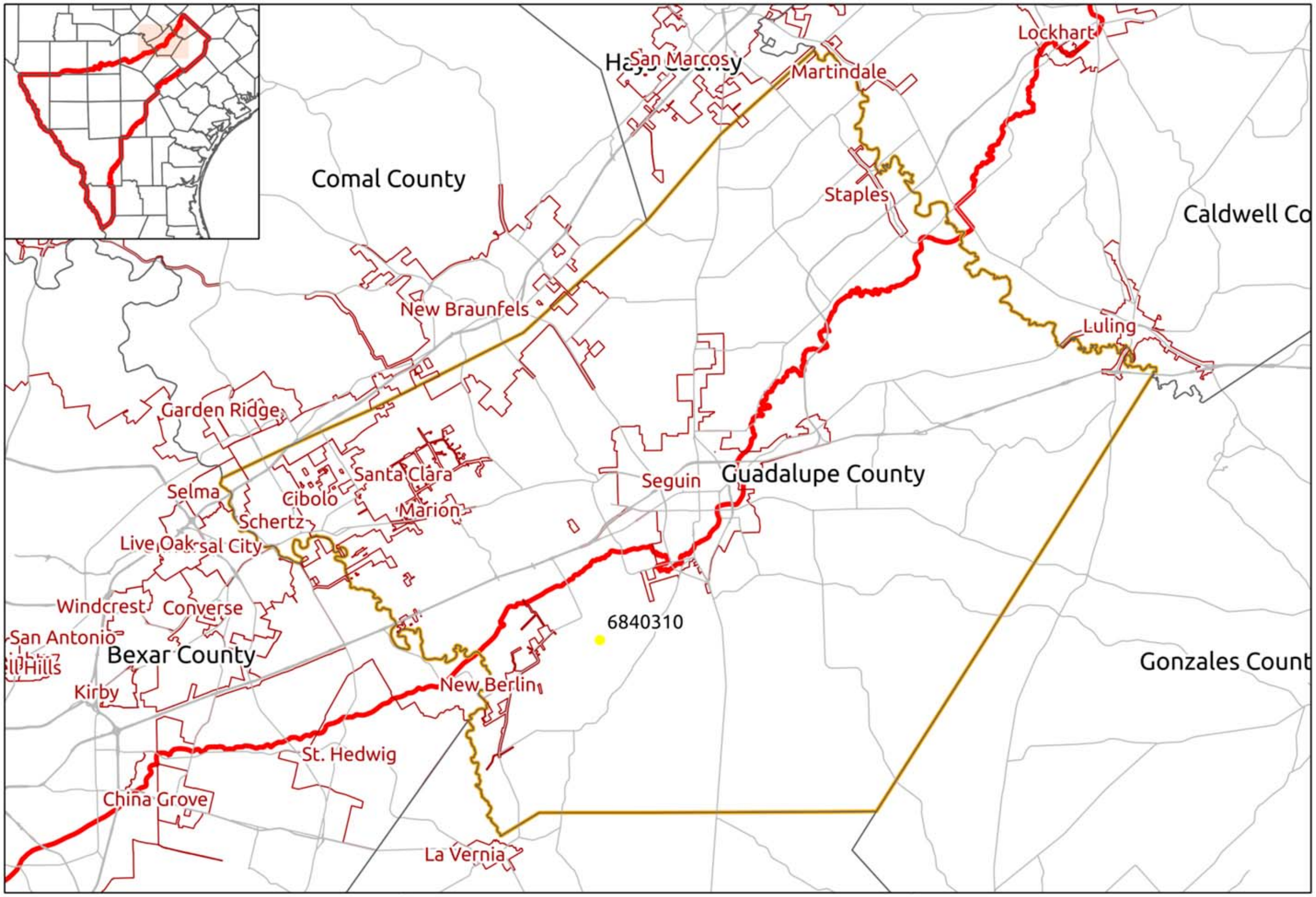
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011



Location Map of Wells with Hydrographs – Guadalupe County


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface

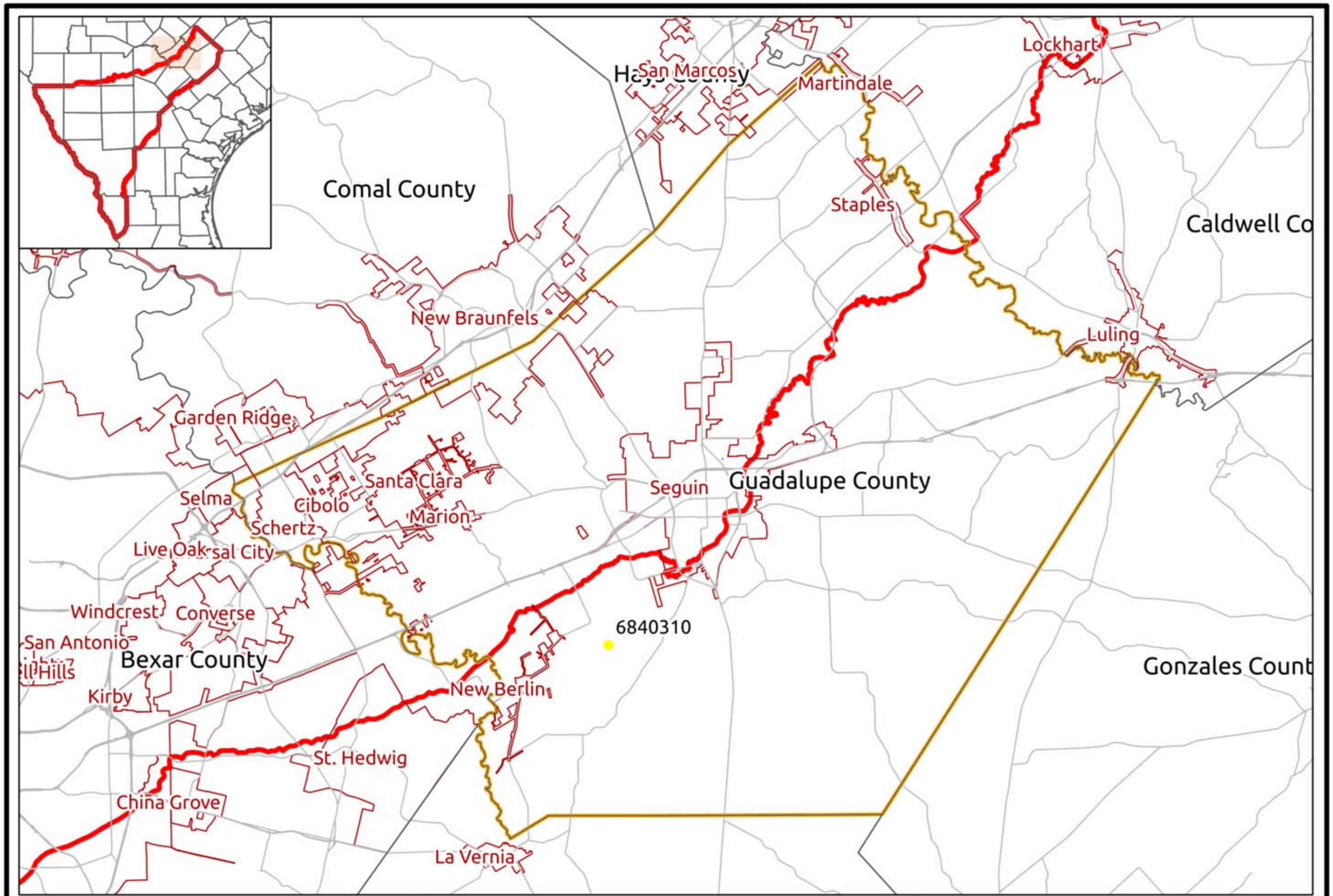

Well 6840310
Guadalupe County - Layer 8
Elevation (ft MSL)
Pumping (AF/yr)
600
560
520
480
440
0
100
200
300
400
1960
1980
2000
2020
2040
2060
2080



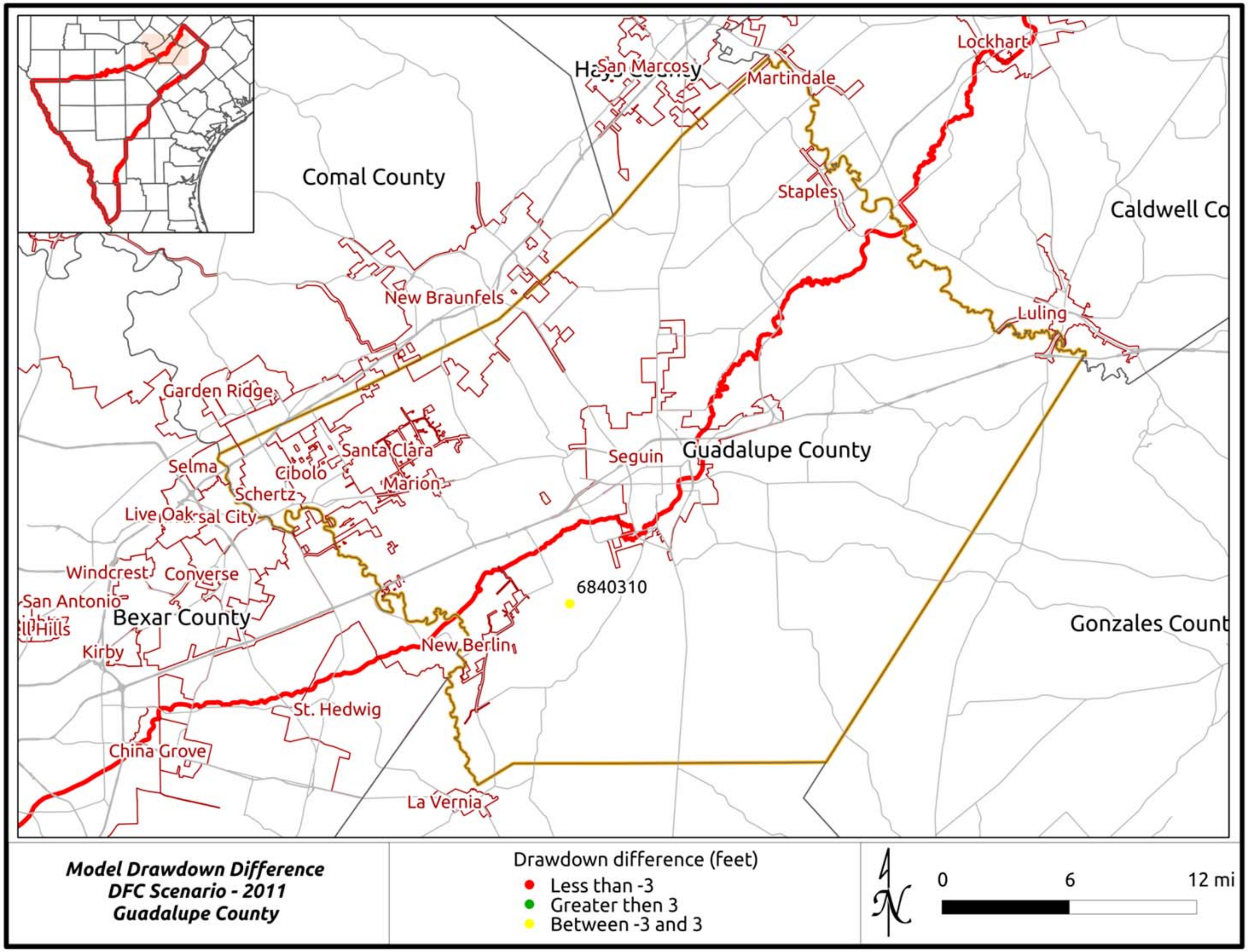
Model Drawdown Difference
DFC Scenario - 2001
Guadalupe County

Drawdown difference (feet)
- Less than -3
- Greater then 3
- Between -3 and 3

0 6 12 mi

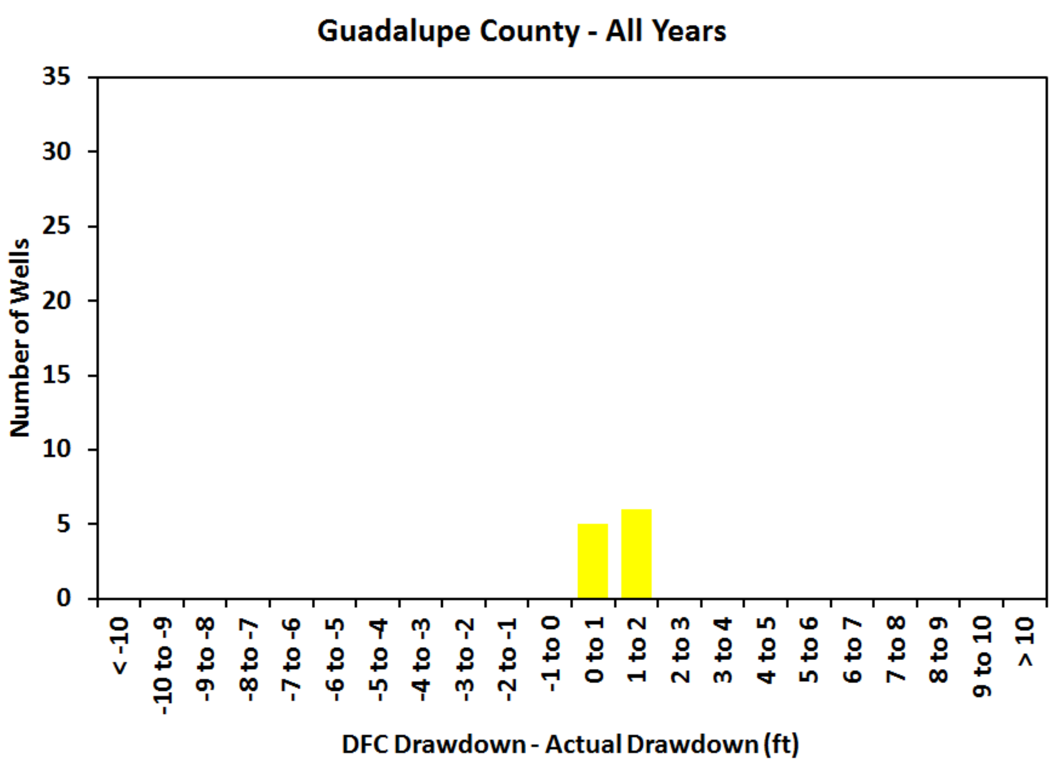


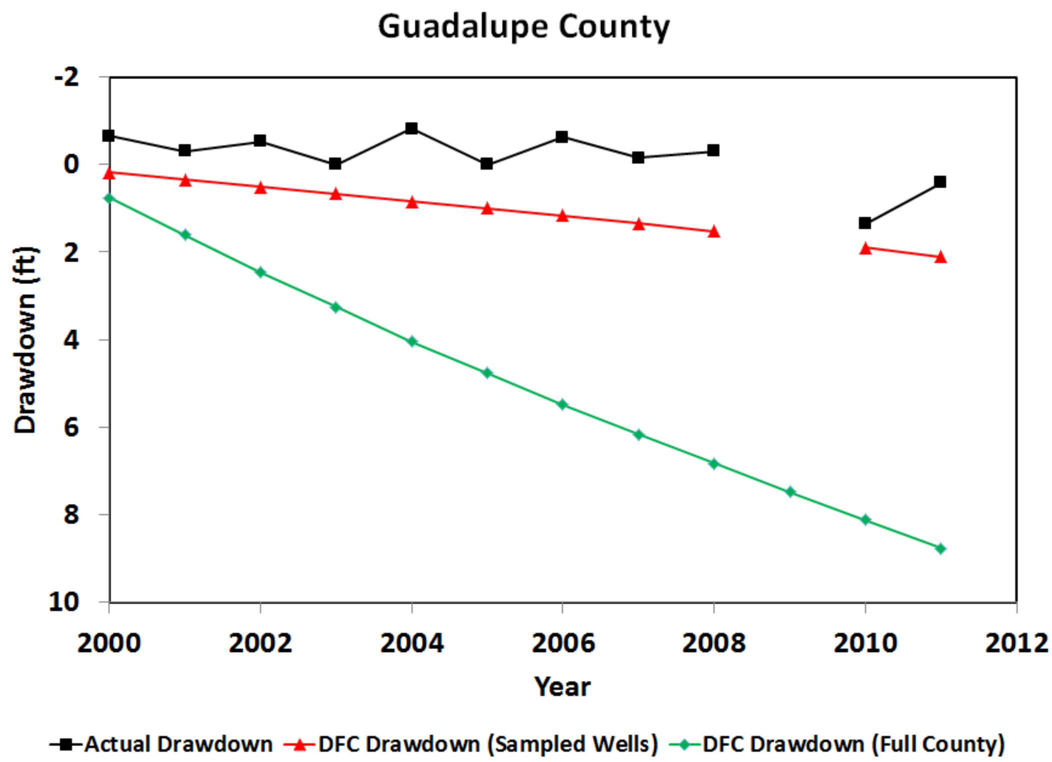
Model Drawdown Difference
DFC Scenario - 2006
Guadalupe County


Comal County
Hays County
San Marcos
Martindale
Lockhart
Staples
Caldwell Co
New Braunfels
Luling
Garden Ridge
Santa Clara
Selma
Cibolo
Seguin
Guadalupe County
Marion
Schertz
Live Oak
Universal City
Windcrest
Converse
6840310
San Antonio
Bexar County
Gonzales Count
Kirby
New Berlin
St. Hedwig
China Grove
La Vernia
Model Drawdown Difference
DFC Scenario - 2011
Guadalupe County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
6
12 mi

Summary of Drawdown Comparisons - Guadalupe County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	0.76	1	-0.65	0.18	0.83
2001	101	1.61	1	-0.3	0.35	0.65
2002	113	2.46	1	-0.52	0.51	1.03
2003	96	3.26	1	0	0.67	0.67
2004	132	4.04	1	-0.82	0.84	1.66
2005	75	4.77	1	0	1	1
2006	86	5.49	1	-0.62	1.17	1.79
2007	142	6.16	1	-0.15	1.34	1.49
2008	74	6.83	1	-0.3	1.52	1.82
2009	76	7.48				
2010	132	8.12	1	1.36	1.9	0.54
2011	45	8.76	1	0.41	2.1	1.69





Guadalupe County
Drawdown (ft)
-2
0
2
4
6
8
10
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 9 – La Salle County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

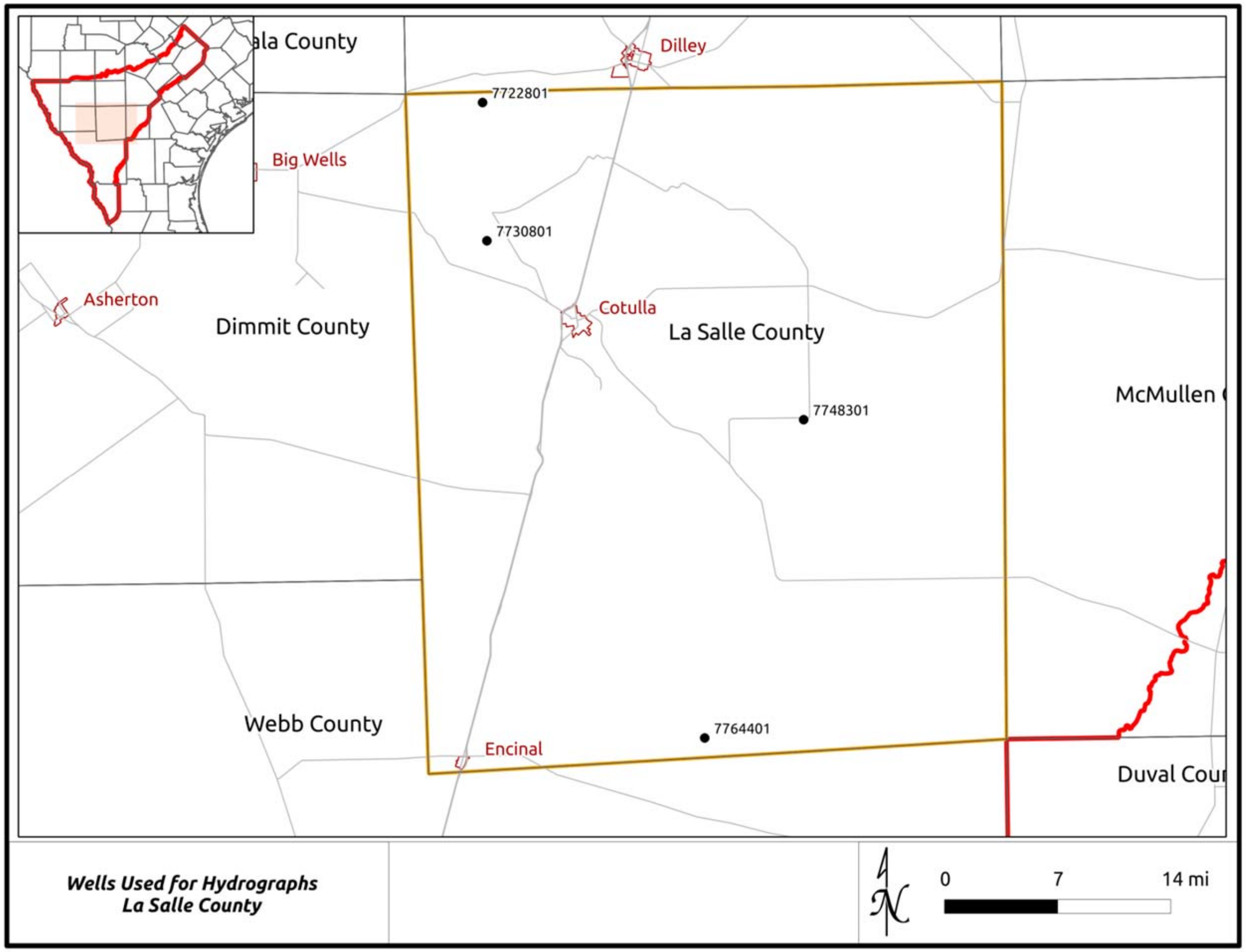
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

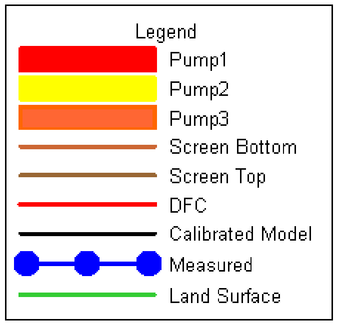
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

Hydrograph of Actual Drawdown and DFC Drawdown

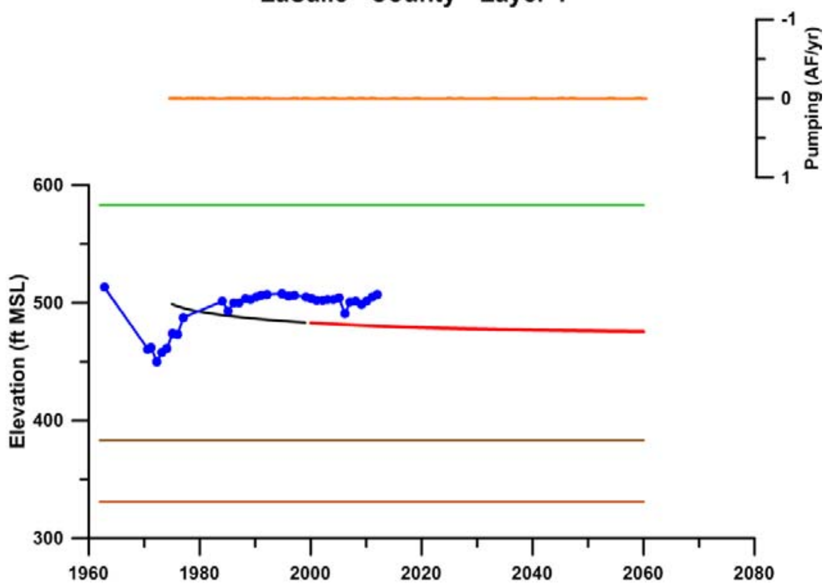
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011



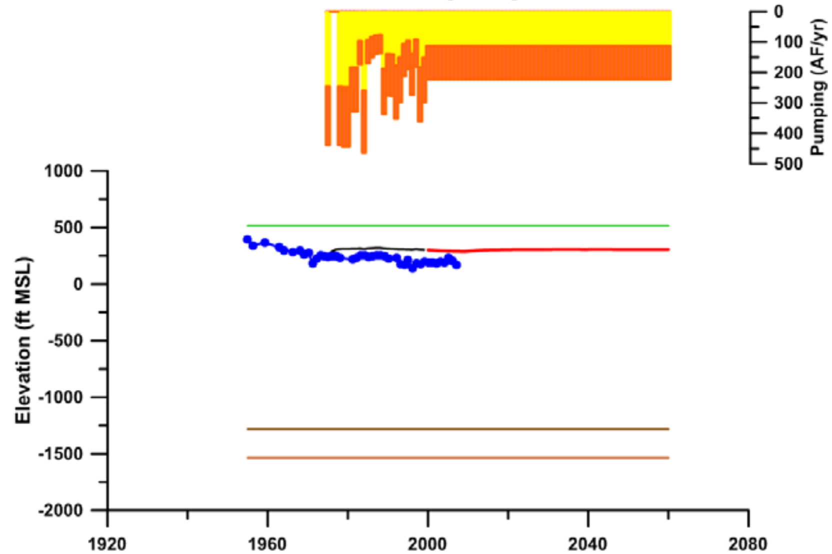
Location Map of Wells with Hydrographs – La Salle County



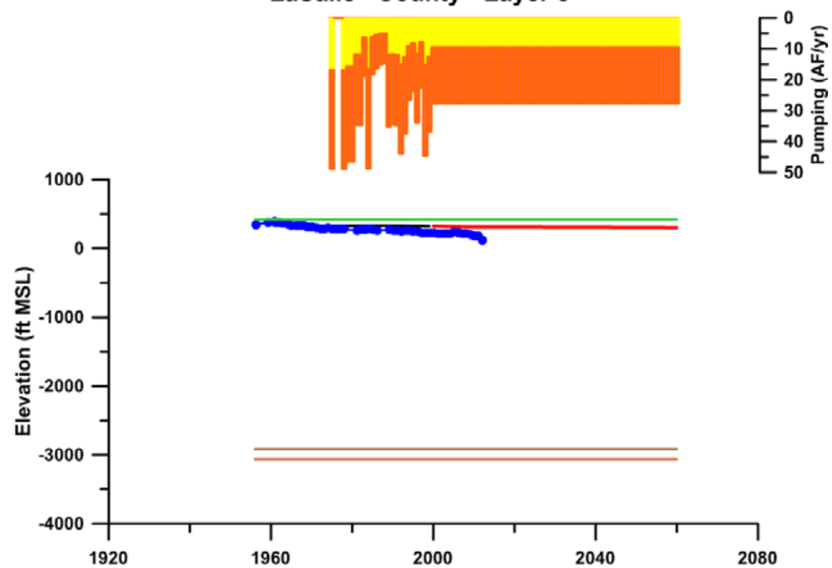
Well 7722801
LaSalle County - Layer 1

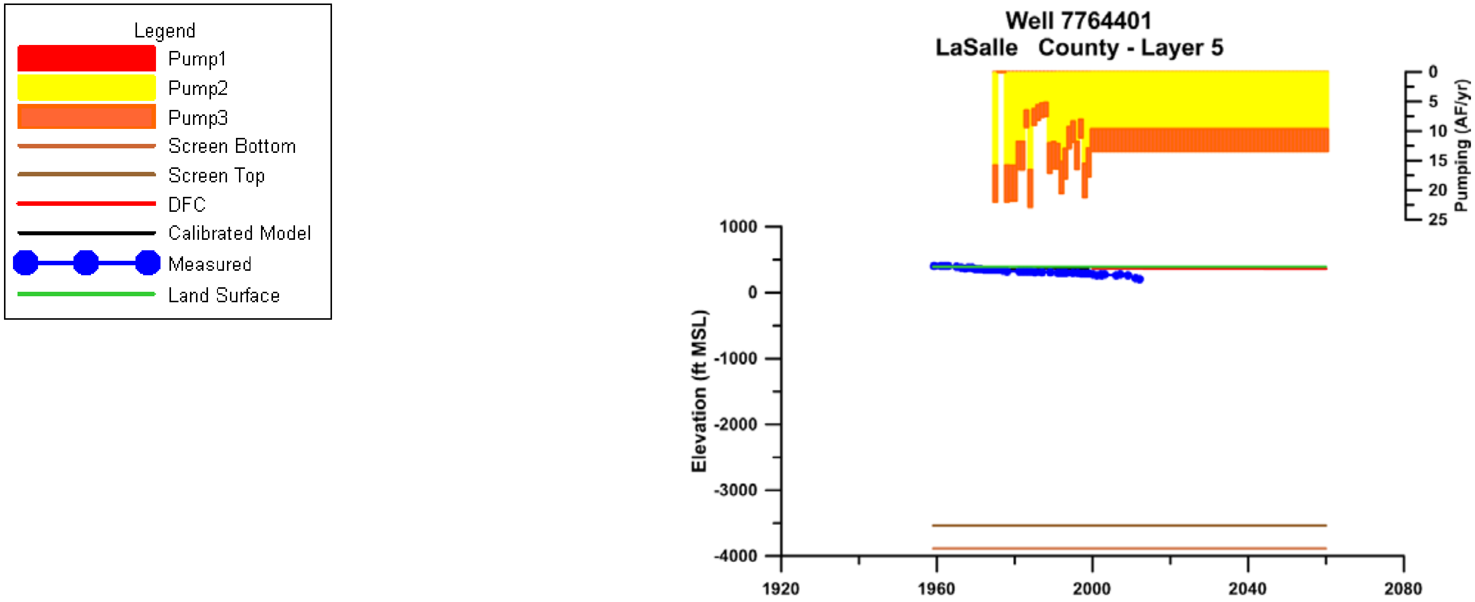


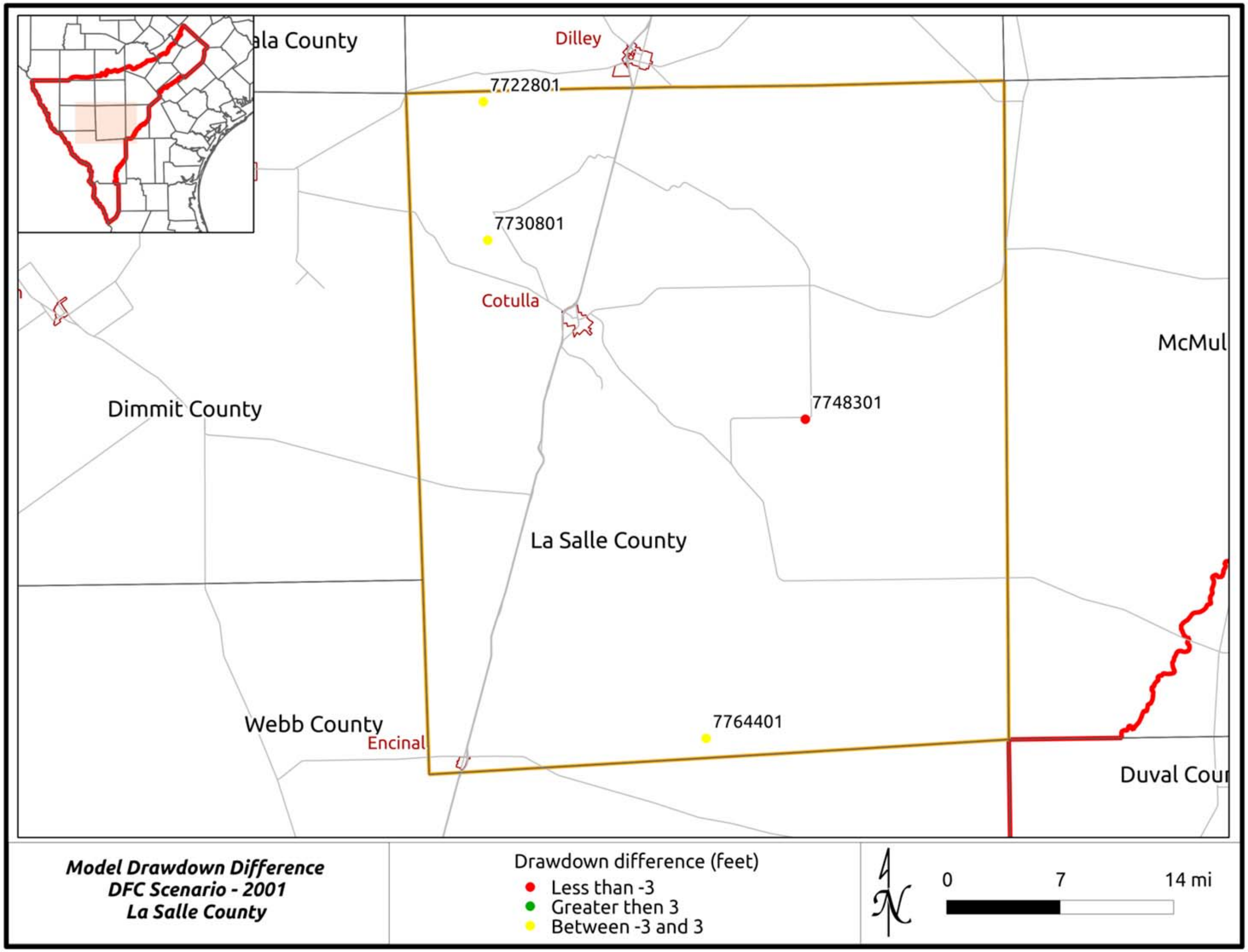
Well 7730801
LaSalle County - Layer 5



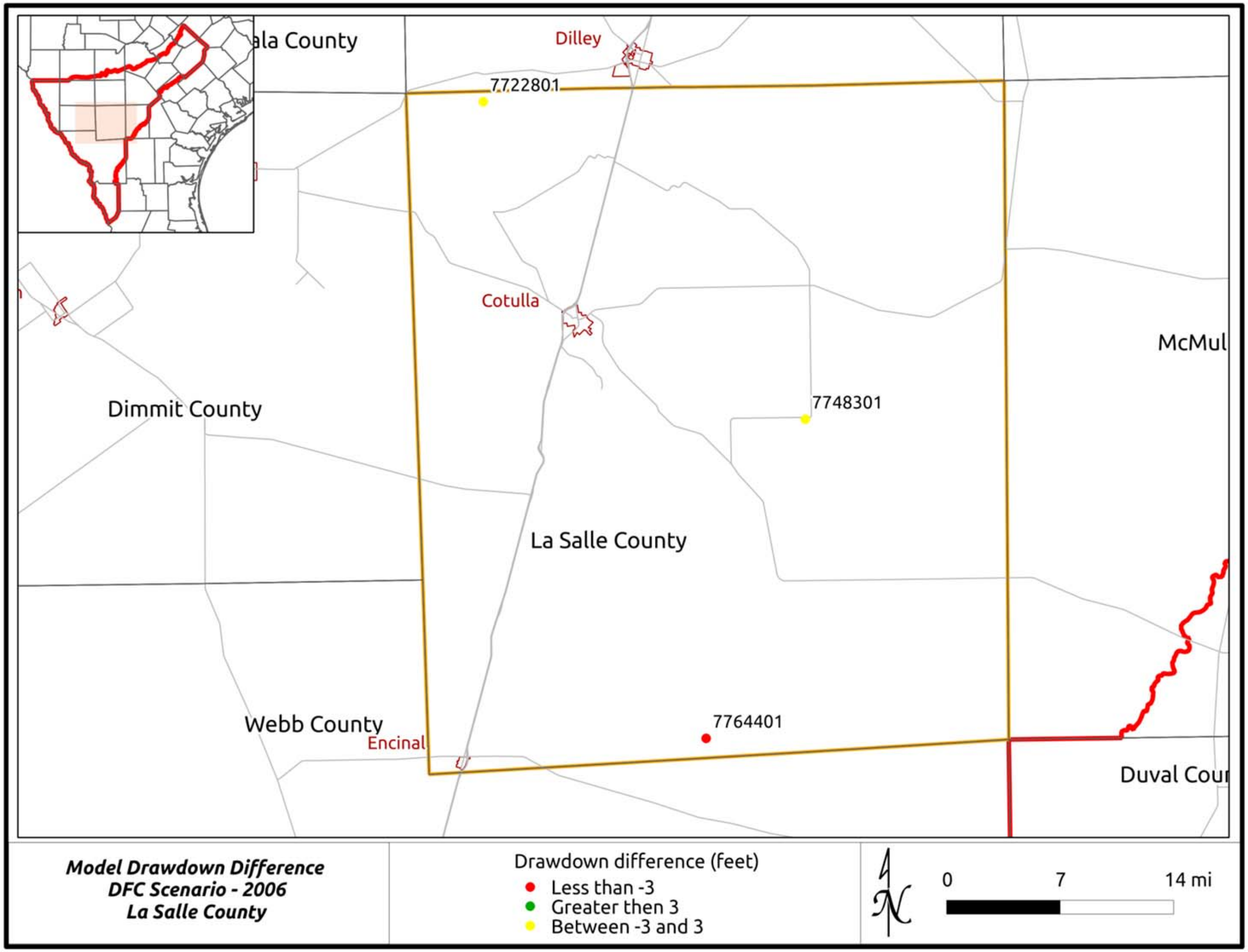
Well 7748301
LaSalle County - Layer 5

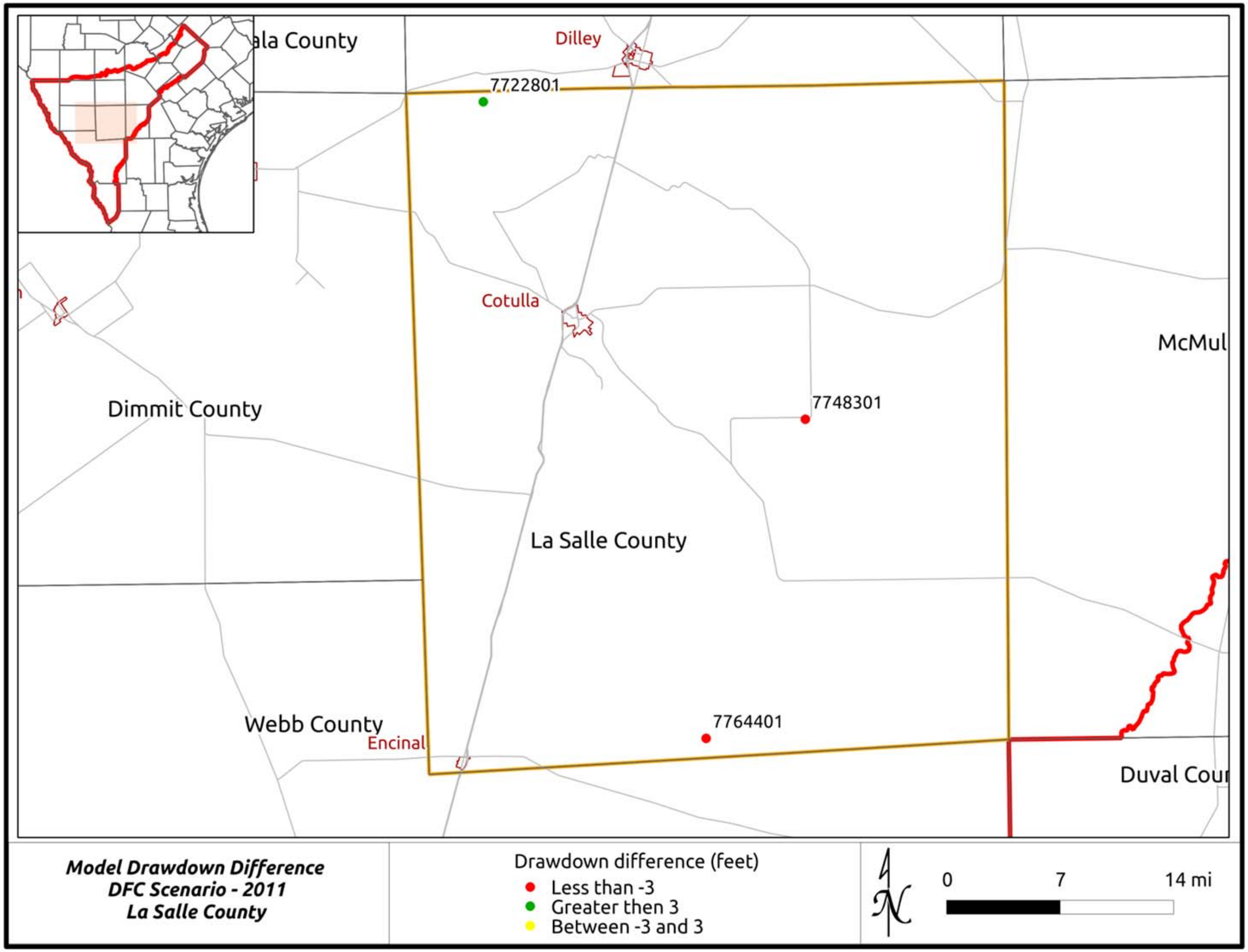



Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 7764401
LaSalle County - Layer 5
Elevation (ft MSL)
1000
0
-1000
-2000
-3000
-4000
1920
1960
2000
2040
2080
Pumping (AF/yr)
0
5
10
15
20
25



Zavala County
Dilley
7722801
7730801
Cotulla
McMul
Dimmit County
7748301
La Salle County
Webb County
Encinal
7764401
Duval Cou
Model Drawdown Difference
DFC Scenario - 2001
La Salle County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
7
14 mi

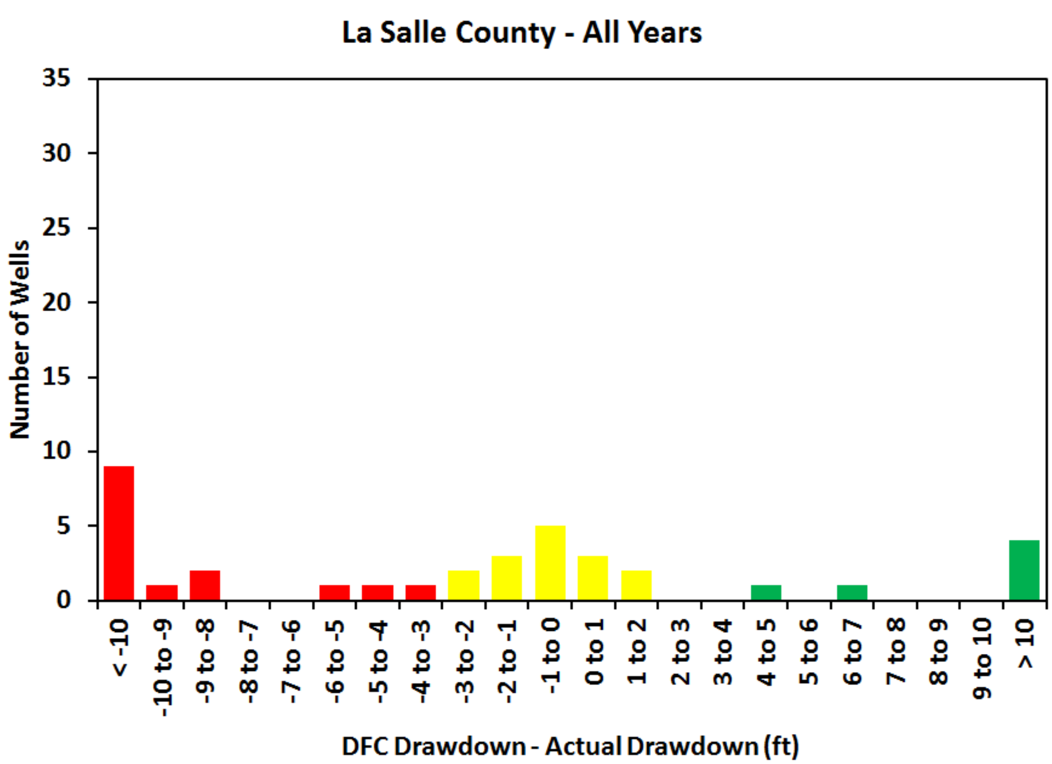

ala County
Dilley
7722801
Cotulla
McMul
Dimmit County
7748301
La Salle County
Webb County
Encinal
7764401
Duval Cou
Model Drawdown Difference
DFC Scenario - 2006
La Salle County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
7
14 mi

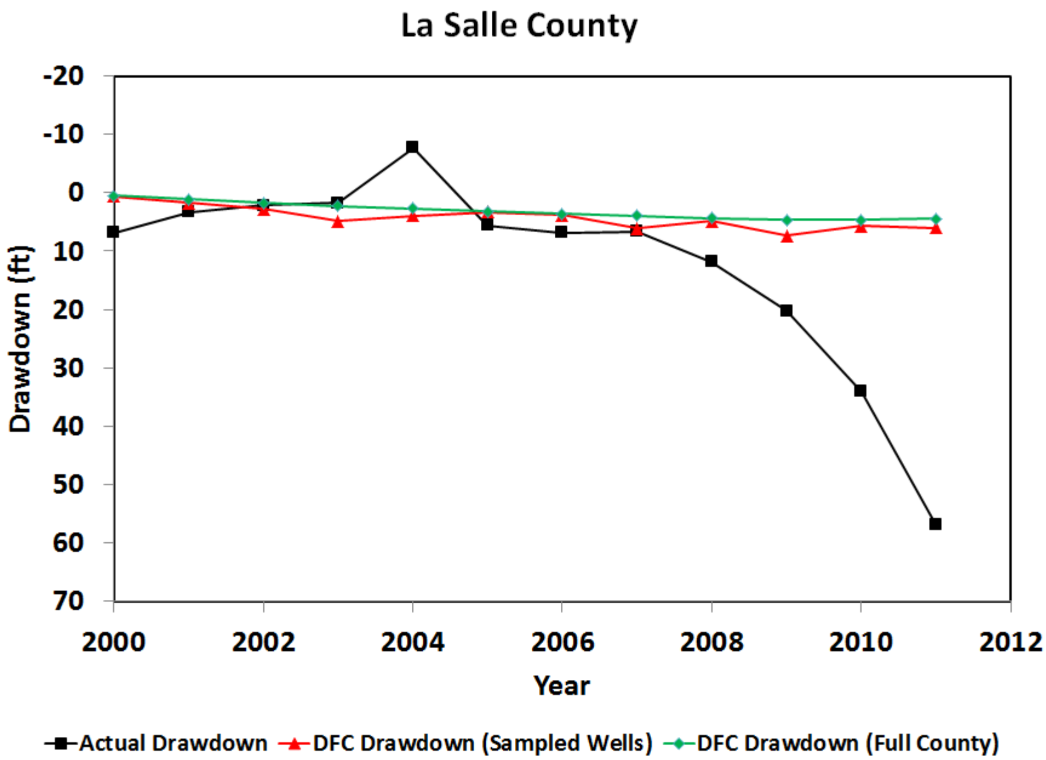


ala County
Dilley
7722801
Cotulla
McMul
7748301
Dimmit County
La Salle County
Webb County
Encinal
7764401
Duval Cou
Model Drawdown Difference
DFC Scenario - 2011
La Salle County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
7
14 mi

Summary of Drawdown Comparisons - La Salle County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	0.53	4	6.84	0.65	-6.19
2001	101	1.14	4	3.35	1.74	-1.61
2002	113	1.71	4	2.19	2.77	0.59
2003	96	2.23	3	1.80	4.91	3.11
2004	132	2.71	2	-7.74	3.97	11.71
2005	75	3.16	3	5.61	3.27	-2.33
2006	86	3.57	3	6.88	3.82	-3.07
2007	142	3.97	2	6.65	6.15	-0.51
2008	74	4.35	3	11.87	4.84	-7.03
2009	76	4.71	2	20.28	7.39	-12.89
2010	132	4.63	3	34.02	5.74	-28.28
2011	45	4.42	3	56.80	5.98	-50.82




La Salle County
Drawdown (ft)
-20
-10
0
10
20
30
40
50
60
70
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 10 – Maverick County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

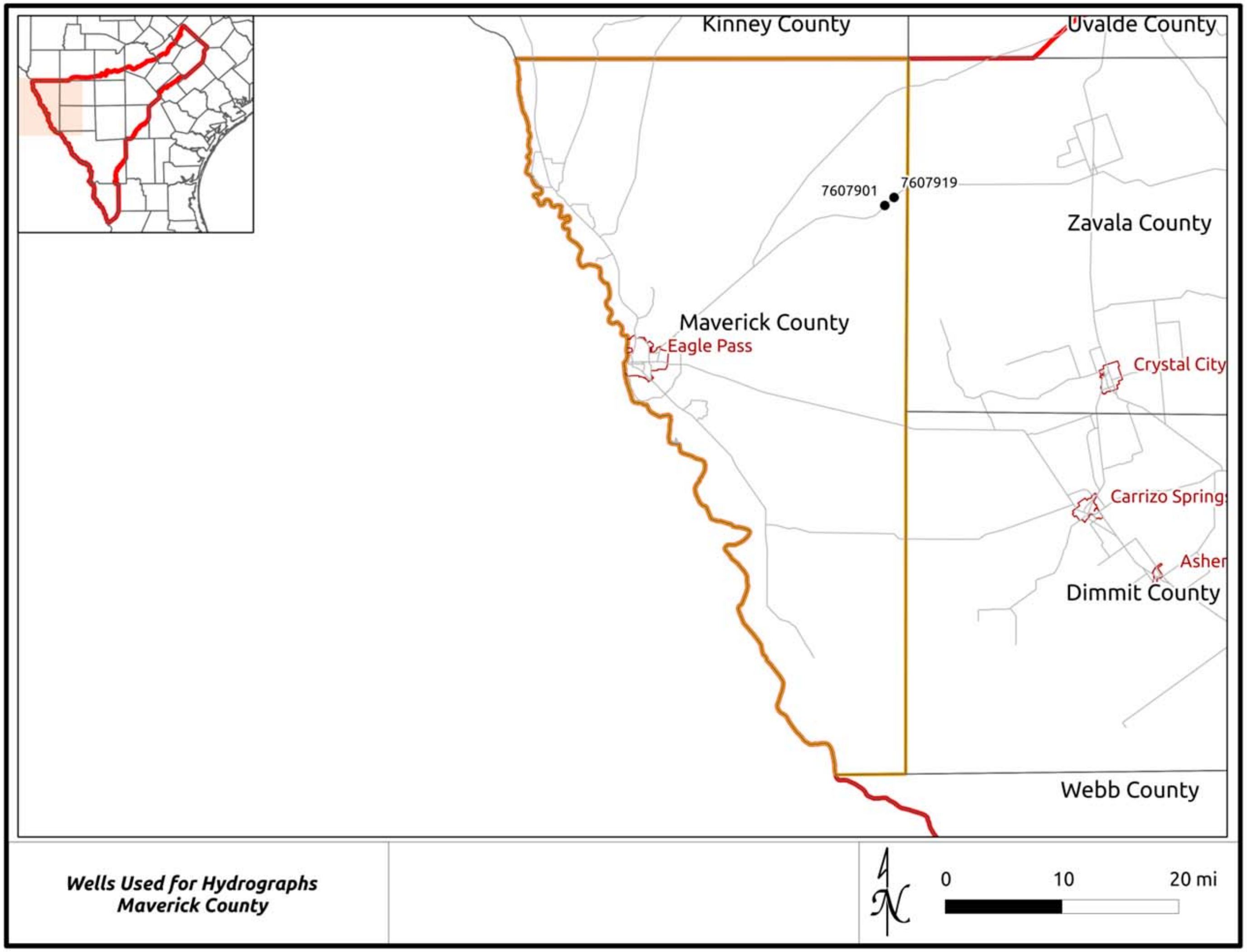
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

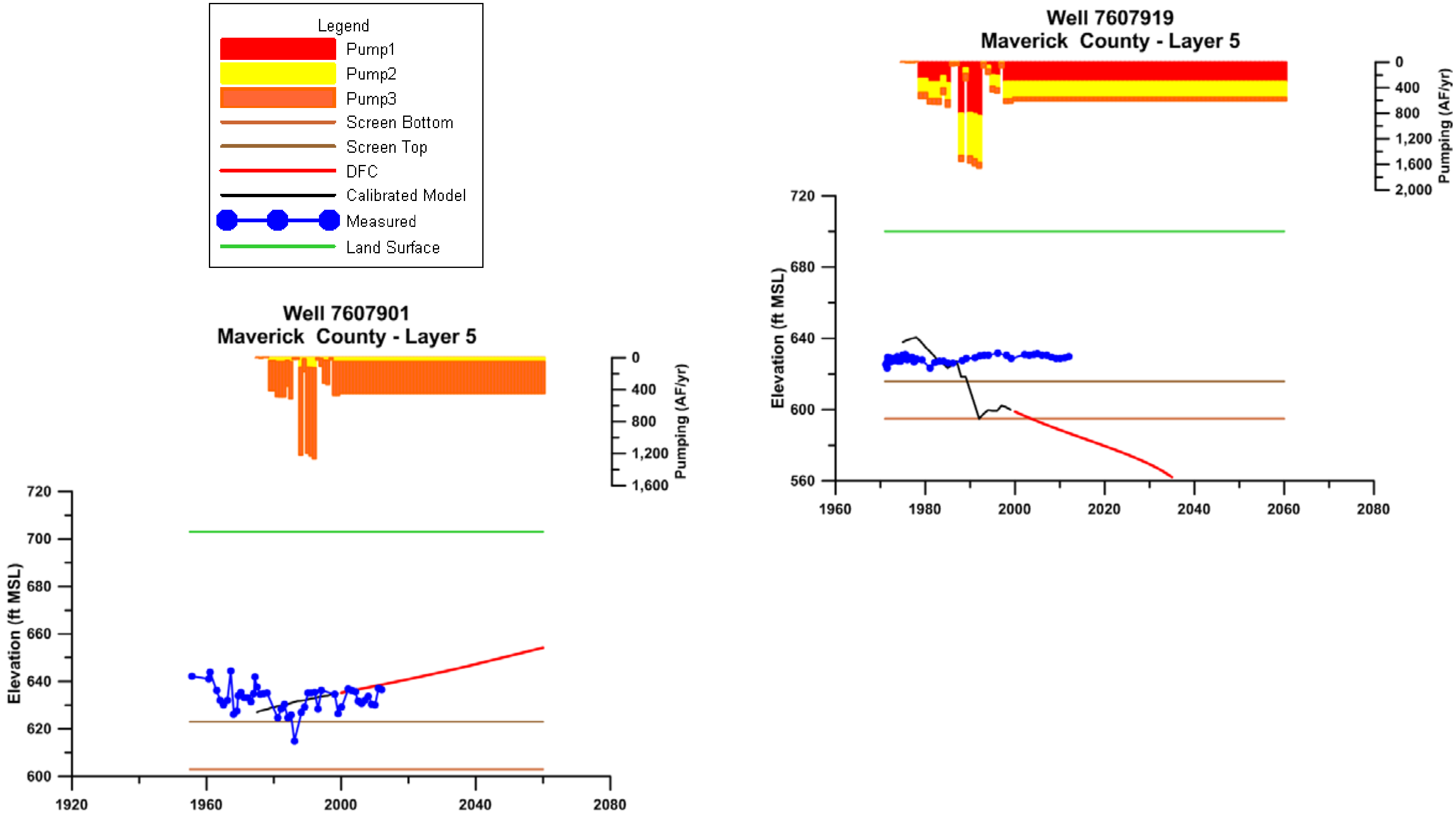
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

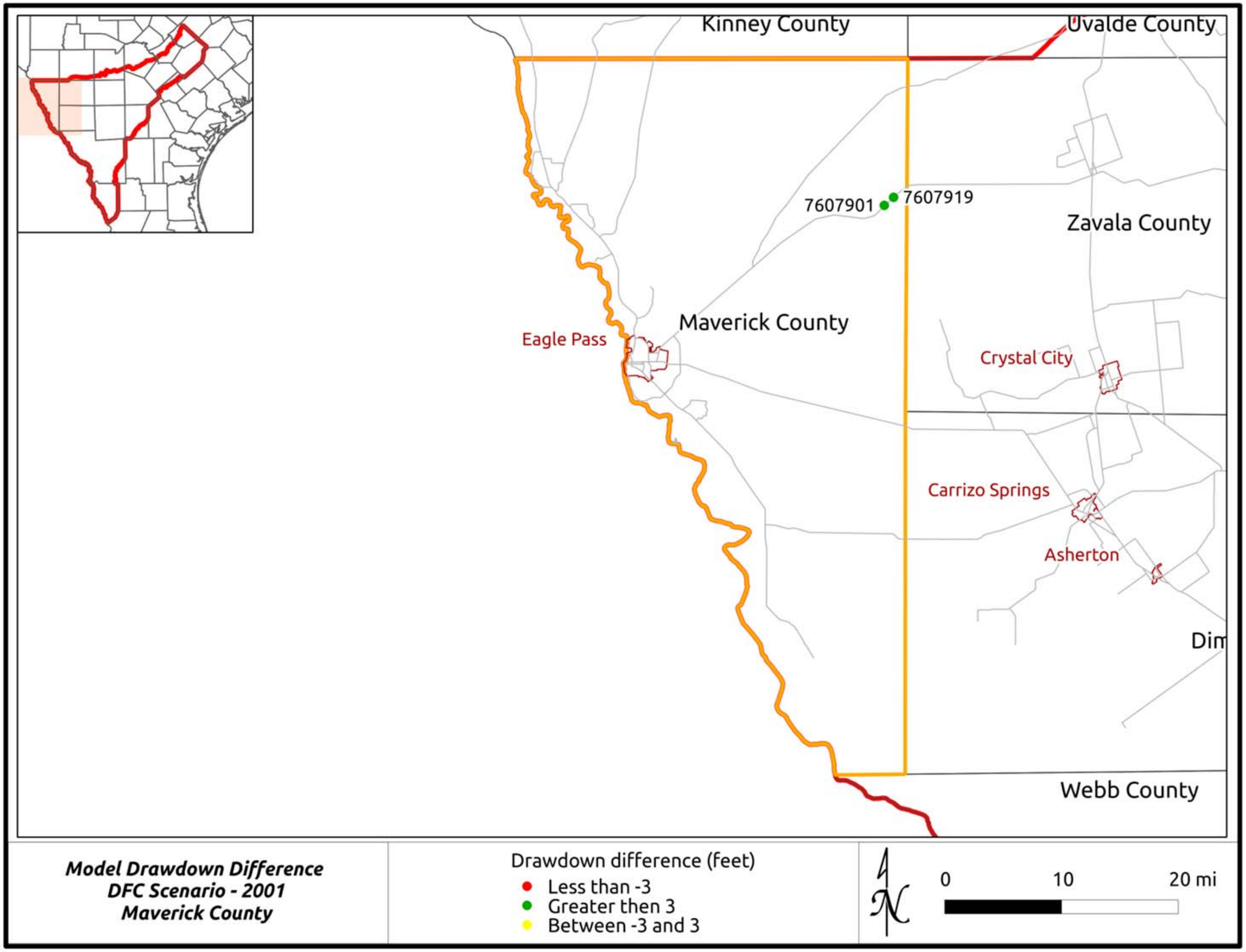
Hydrograph of Actual Drawdown and DFC Drawdown

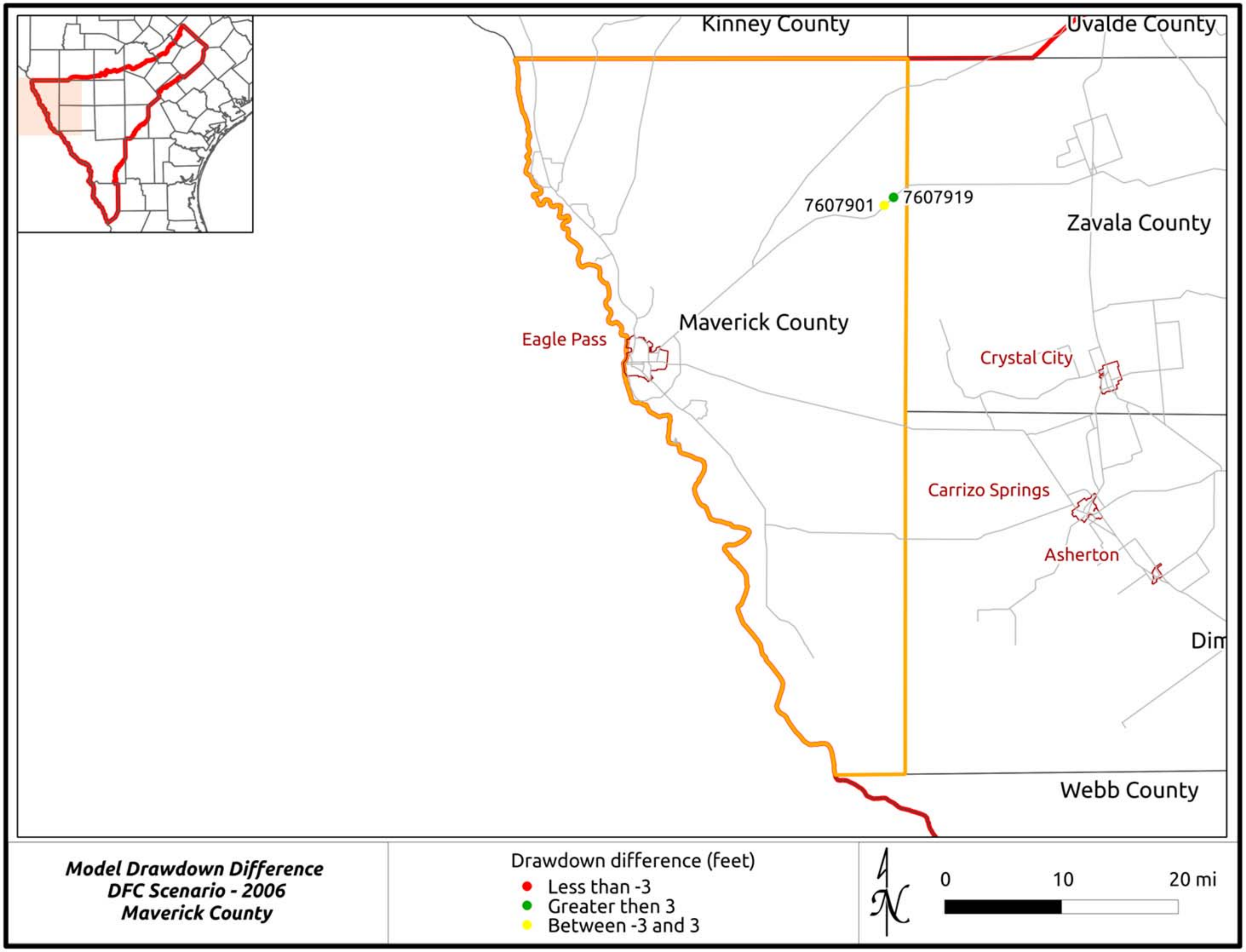
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

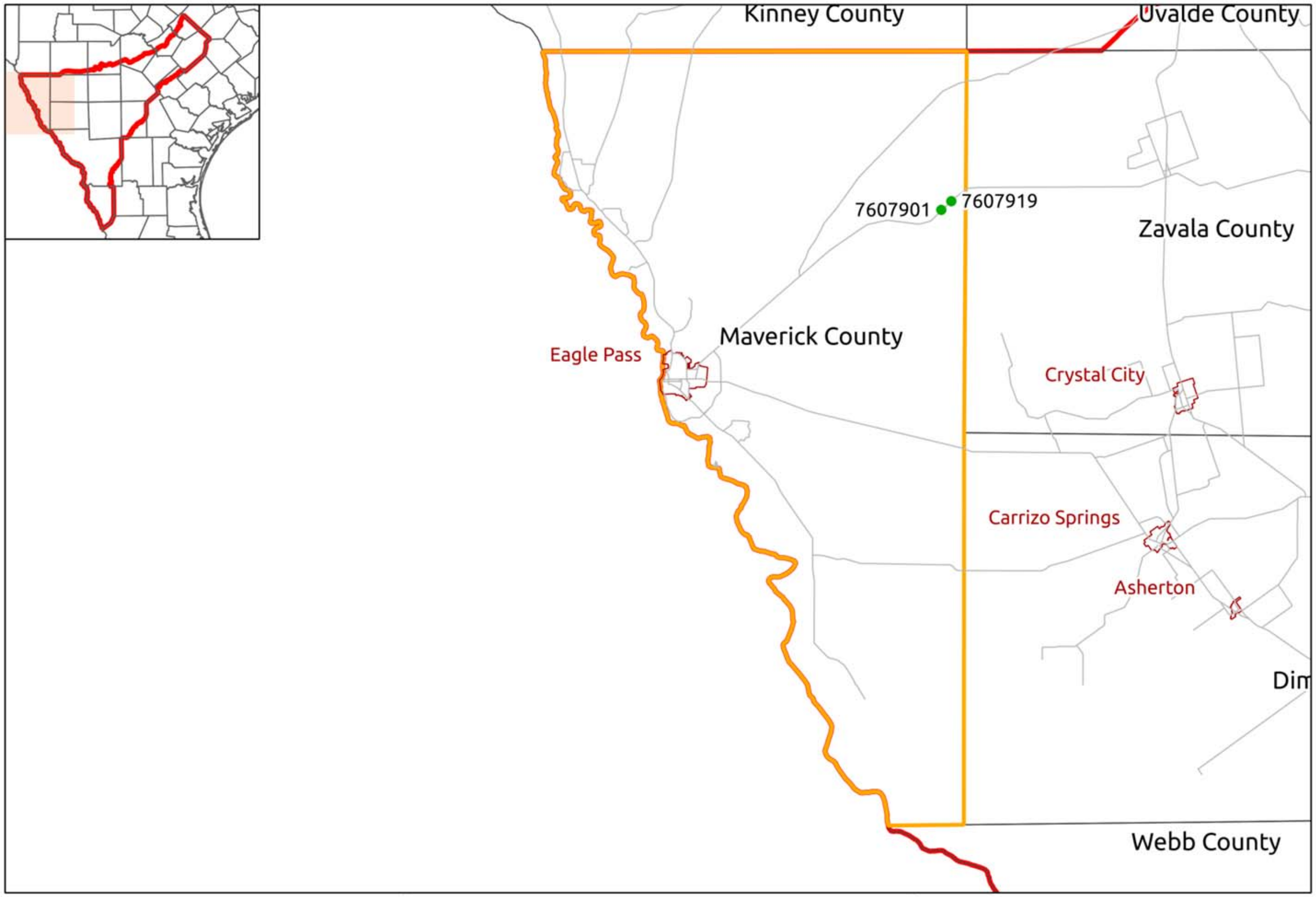


Location Map of Wells with Hydrographs – Maverick County


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 7607901
Maverick County - Layer 5
Pumping (AF/yr)
0
400
800
1,200
1,600
Elevation (ft MSL)
720
700
680
660
640
620
600
1920
1960
2000
2040
2080
Well 7607919
Maverick County - Layer 5
Pumping (AF/yr)
0
400
800
1,200
1,600
2,000
Elevation (ft MSL)
720
680
640
600
560
1960
1980
2000
2020
2040
2060
2080


Kinney County
Uvalde County
7607901
7607919
Zavala County
Maverick County
Eagle Pass
Crystal City
Carrizo Springs
Asherton
Dim
Webb County
Model Drawdown Difference
DFC Scenario - 2001
Maverick County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
10
20 mi


Kinney County
Uvalde County
7607901
7607919
Zavala County
Maverick County
Eagle Pass
Crystal City
Carrizo Springs
Asherton
Dim
Webb County
Model Drawdown Difference
DFC Scenario - 2006
Maverick County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
10
20 mi



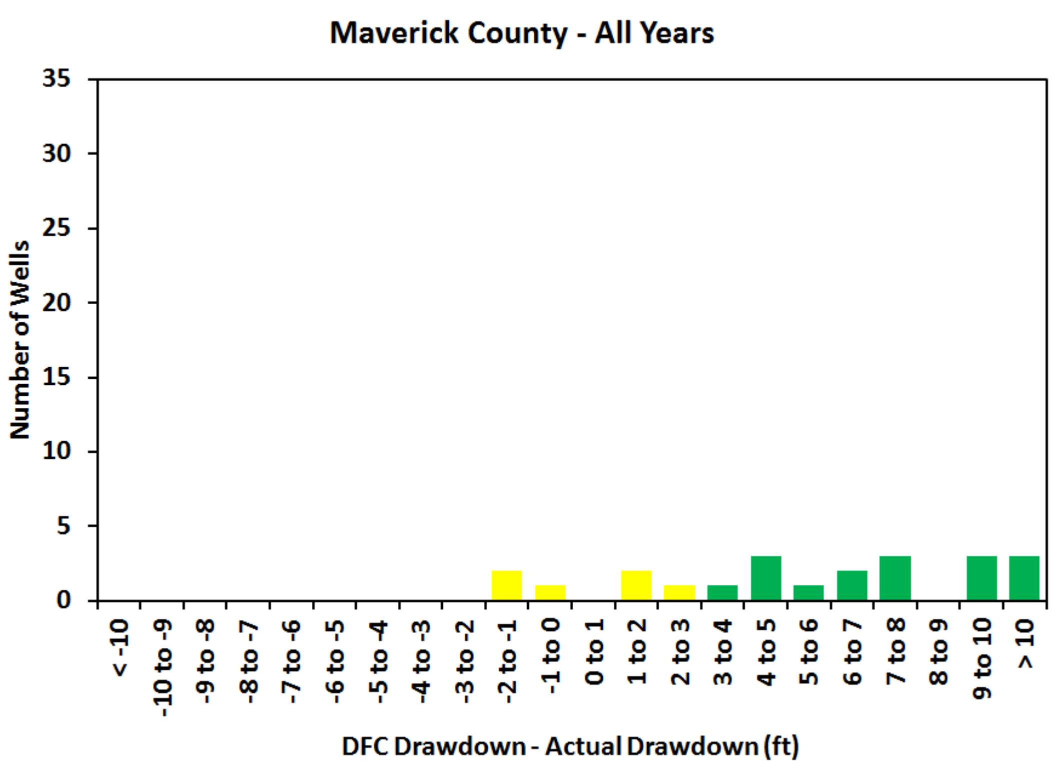
Model Drawdown Difference
DFC Scenario - 2011
Maverick County

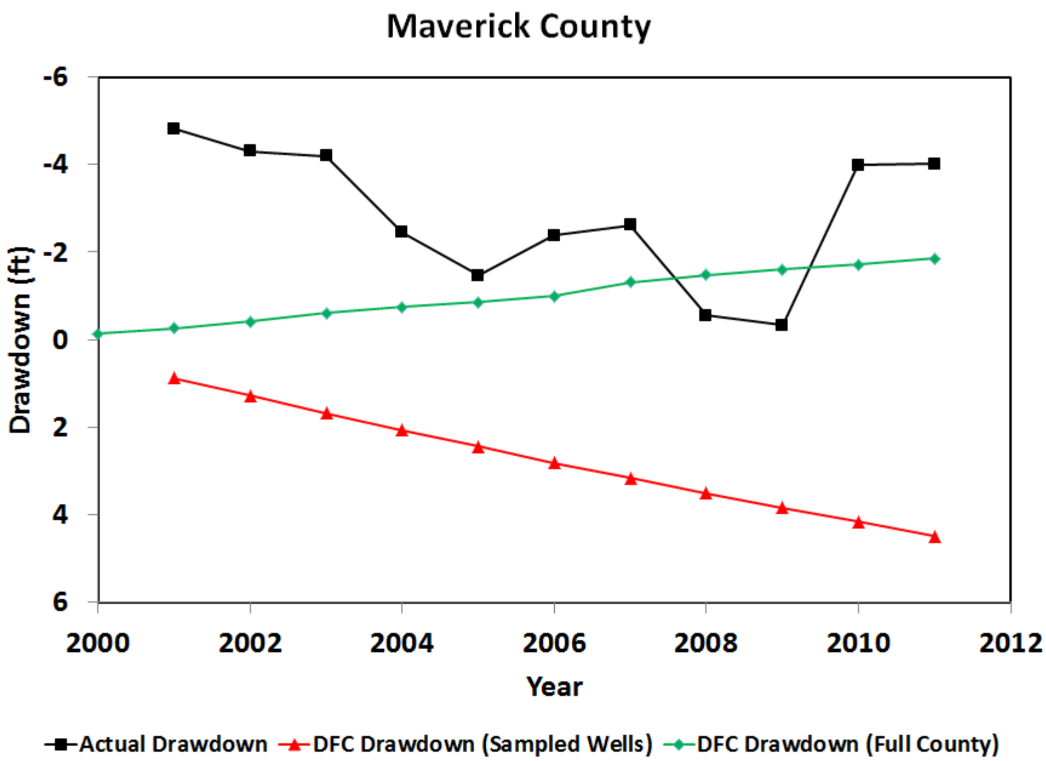
Drawdown difference (feet)
- Less than -3
- Greater then 3
- Between -3 and 3

0 10 20 mi

Summary of Drawdown Comparisons - Maverick County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	-0.13				
2001	101	-0.26	2	-4.82	0.87	5.69
2002	113	-0.42	2	-4.30	1.28	5.58
2003	96	-0.61	2	-4.20	1.68	5.88
2004	132	-0.74	2	-2.45	2.07	4.52
2005	75	-0.85	2	-1.47	2.45	3.91
2006	86	-1.00	2	-2.38	2.81	5.19
2007	142	-1.32	2	-2.61	3.17	5.78
2008	74	-1.48	2	-0.56	3.51	4.06
2009	76	-1.60	2	-0.34	3.84	4.18
2010	132	-1.72	2	-3.99	4.16	8.15
2011	45	-1.86	2	-4.02	4.49	8.50




Maverick County
-6
-4
-2
0
2
4
6
Drawdown (ft)
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 11 – McMullen County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

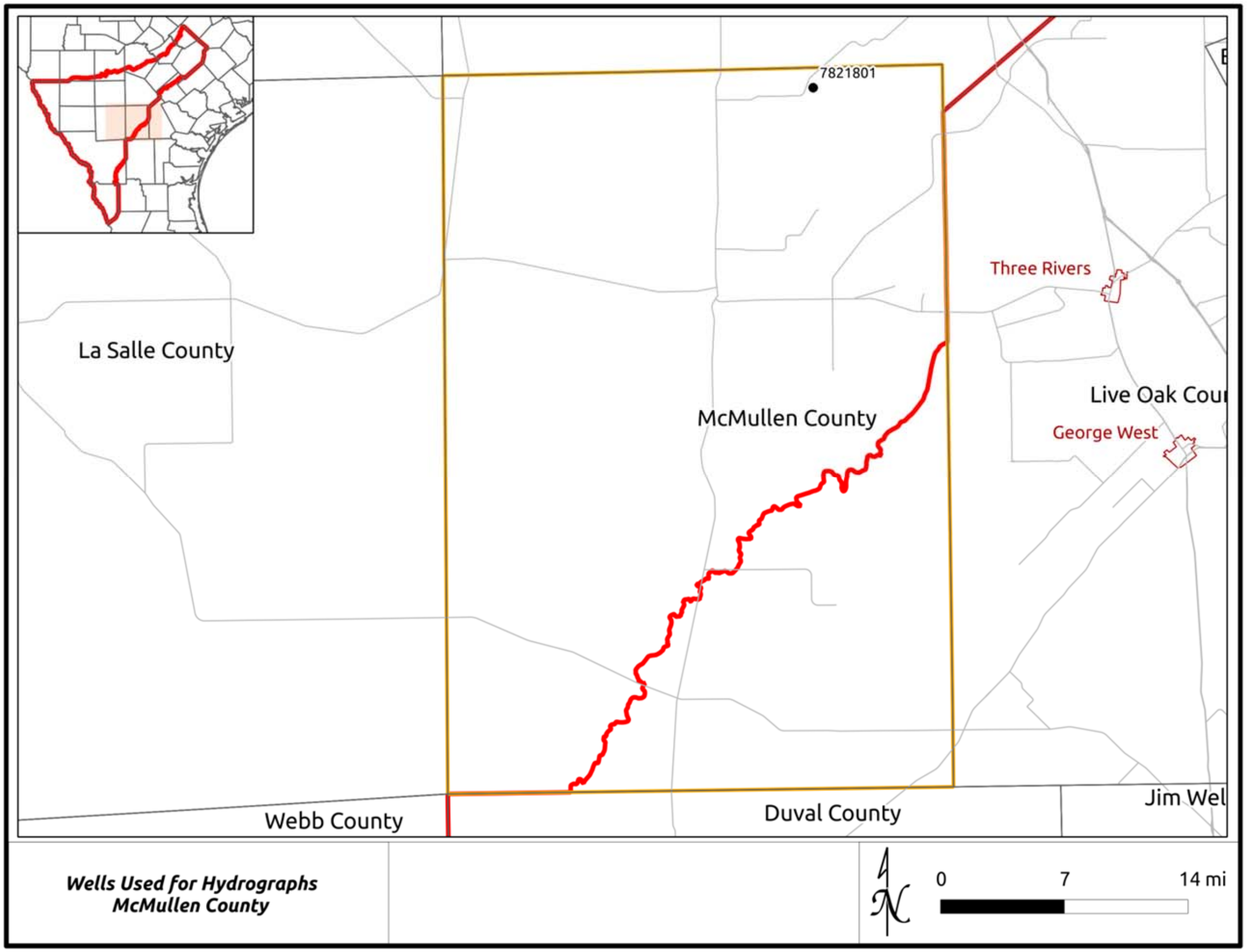
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

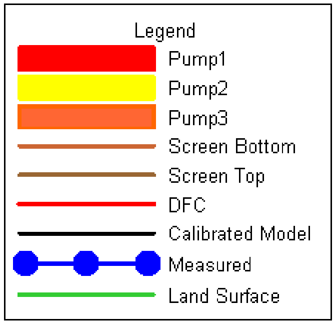
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

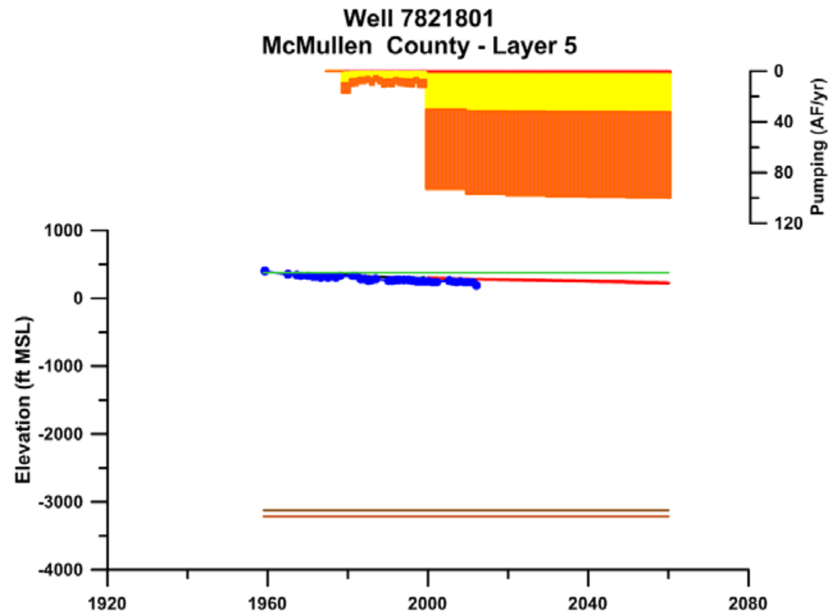
Hydrograph of Actual Drawdown and DFC Drawdown

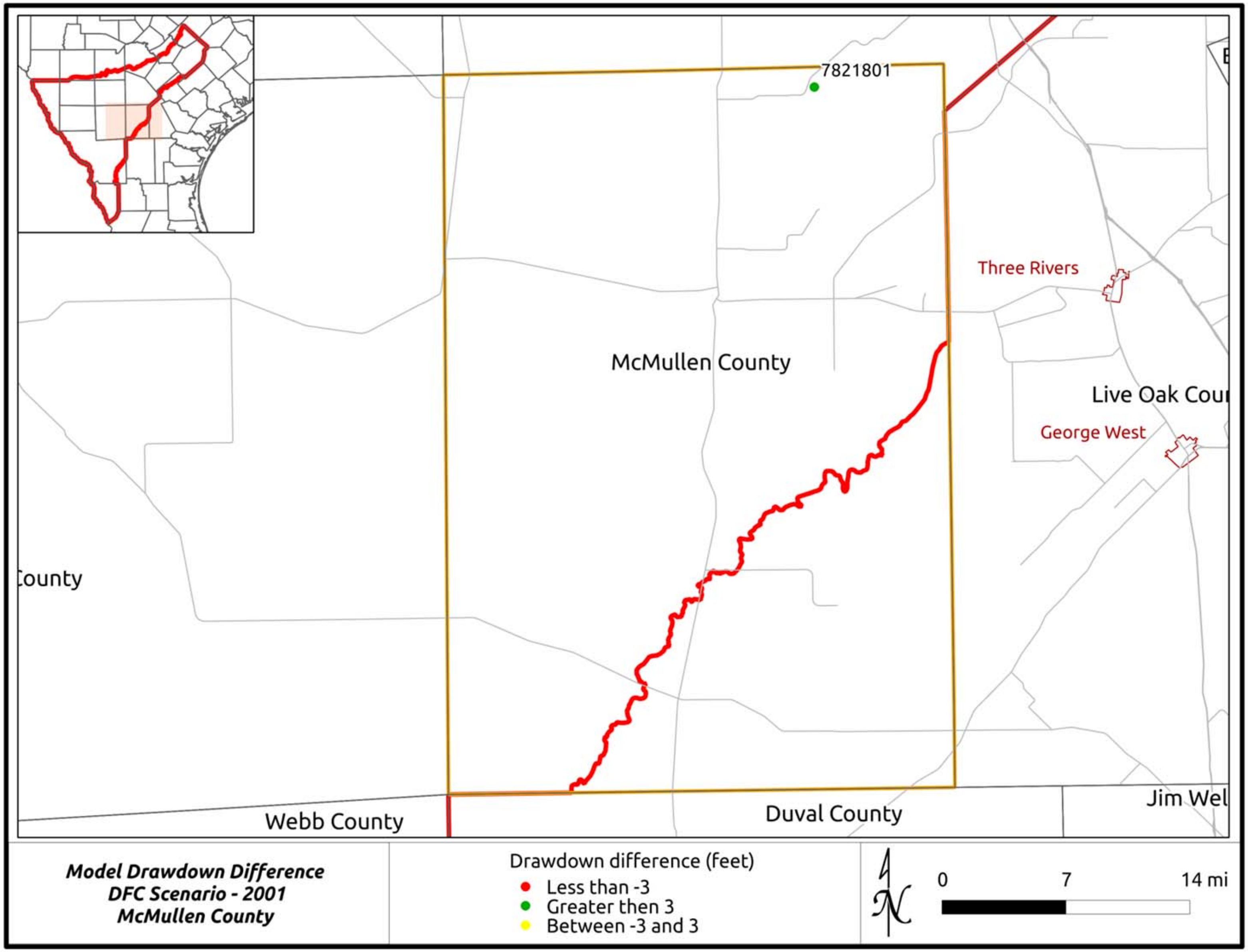
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

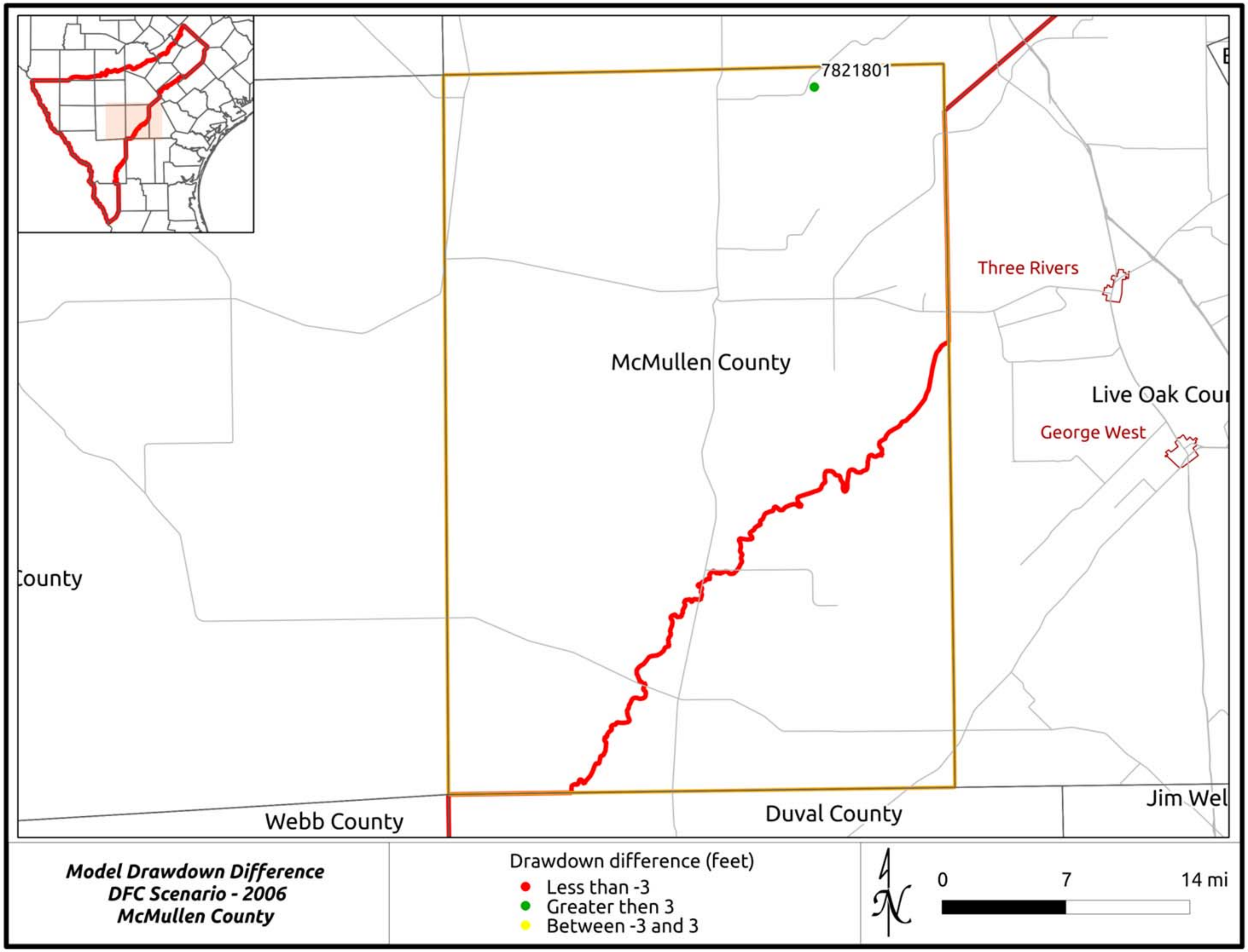


Location Map of Wells with Hydrographs – McMullen County

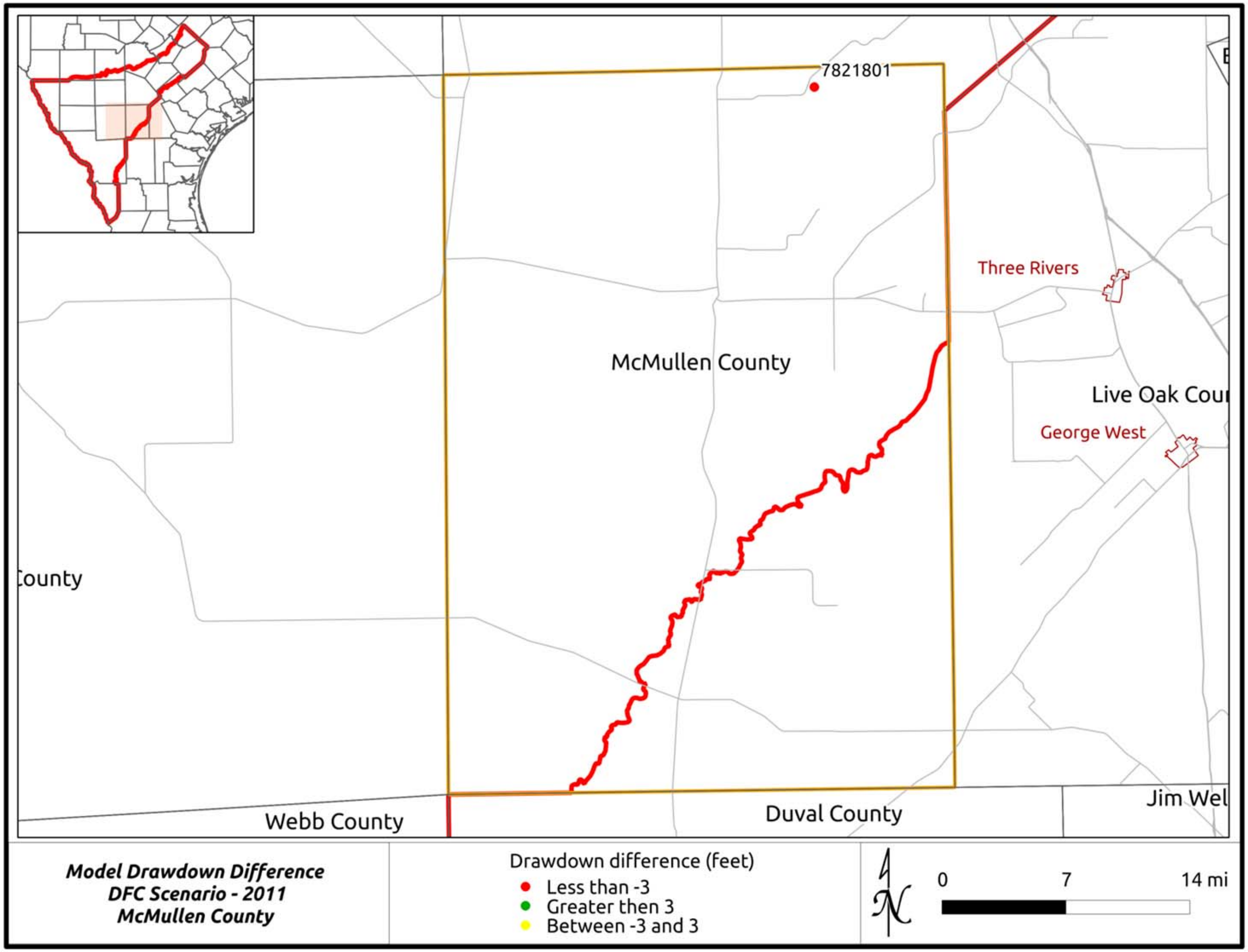

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface


Well 7821801
McMullen County - Layer 5
Elevation (ft MSL)
1000
0
-1000
-2000
-3000
-4000
1920
1960
2000
2040
2080
Pumping (AF/yr)
0
40
80
120


7821801
Three Rivers
McMullen County
Live Oak Cou
George West
ounty
Webb County
Duval County
Jim Wel
Model Drawdown Difference
DFC Scenario - 2001
McMullen County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
7
14 mi

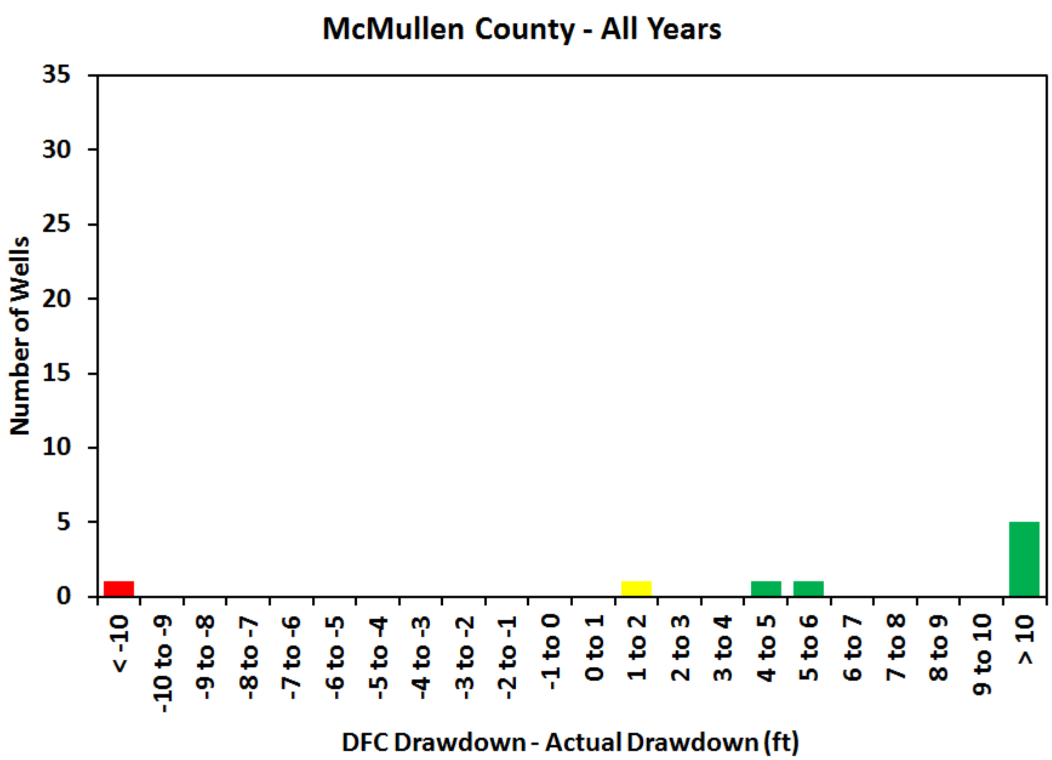


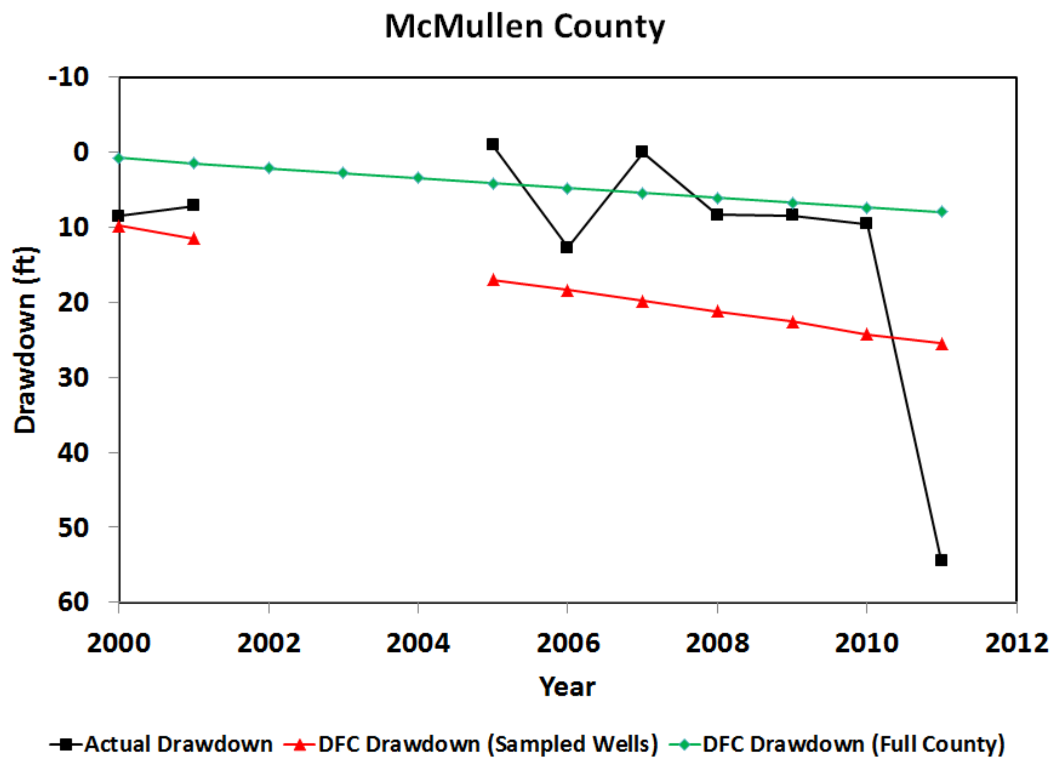
7821801
Three Rivers
McMullen County
Live Oak Cou
George West
ounty
Webb County
Duval County
Jim Wel
Model Drawdown Difference
DFC Scenario - 2006
McMullen County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
7
14 mi


7821801
Three Rivers
McMullen County
Live Oak Cou
George West
County
Webb County
Duval County
Jim Wel
Model Drawdown Difference
DFC Scenario - 2011
McMullen County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
7
14 mi

Summary of Drawdown Comparisons - McMullen County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	0.77	1	8.55	9.84	1.29
2001	101	1.47	1	7.17	11.55	4.38
2002	113	2.15				
2003	96	2.82				
2004	132	3.48				
2005	75	4.14	1	-0.95	16.99	17.94
2006	86	4.80	1	12.70	18.40	5.70
2007	142	5.45	1	0.08	19.81	19.73
2008	74	6.10	1	8.40	21.21	12.81
2009	76	6.74	1	8.42	22.59	14.17
2010	132	7.37	1	9.56	24.25	14.69
2011	45	7.93	1	54.48	25.49	-28.99




McMullen County
Drawdown (ft)
-10
0
10
20
30
40
50
60
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 12 – Medina County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

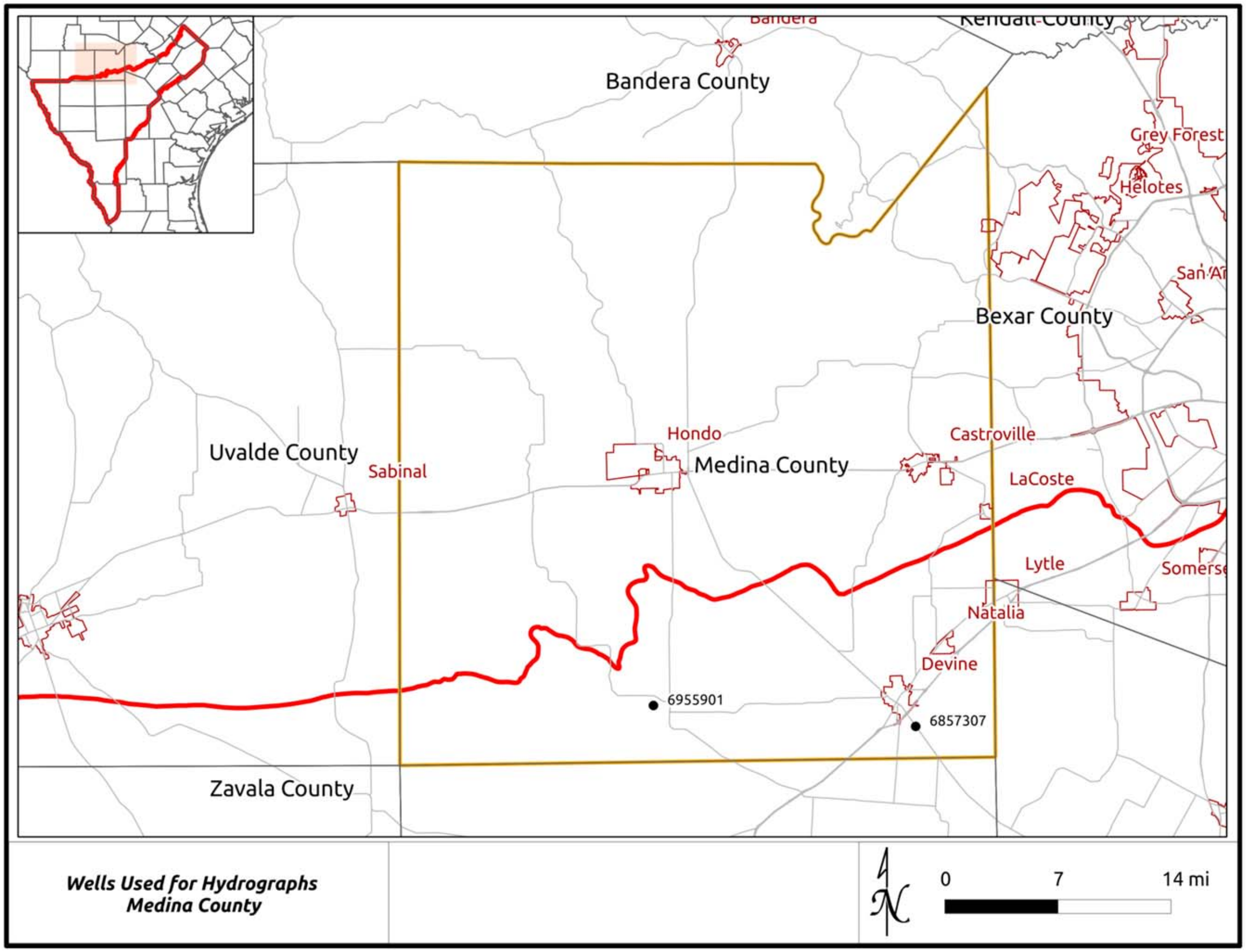
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

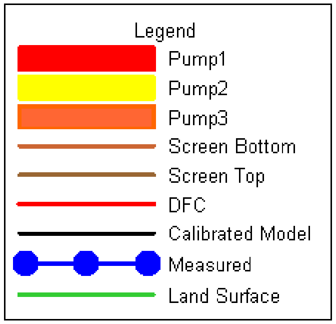
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

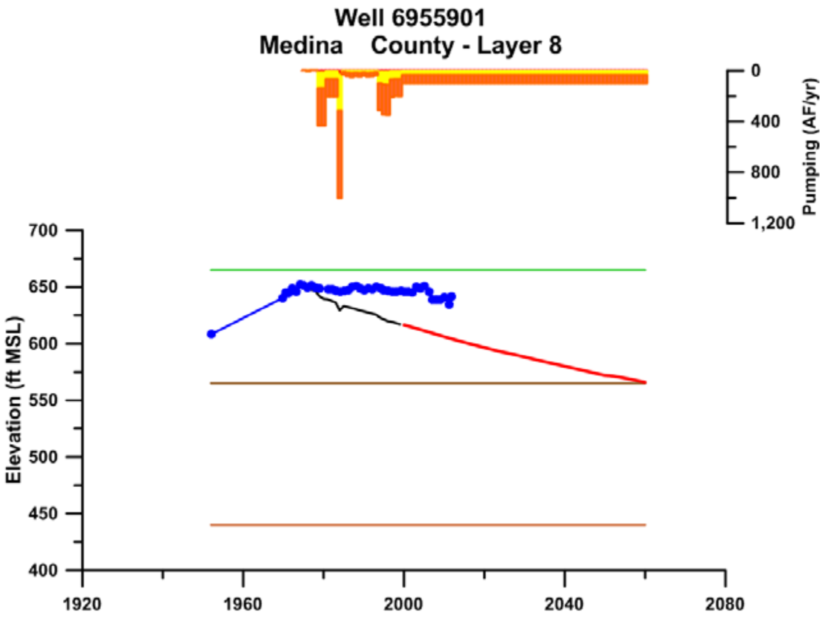
Hydrograph of Actual Drawdown and DFC Drawdown

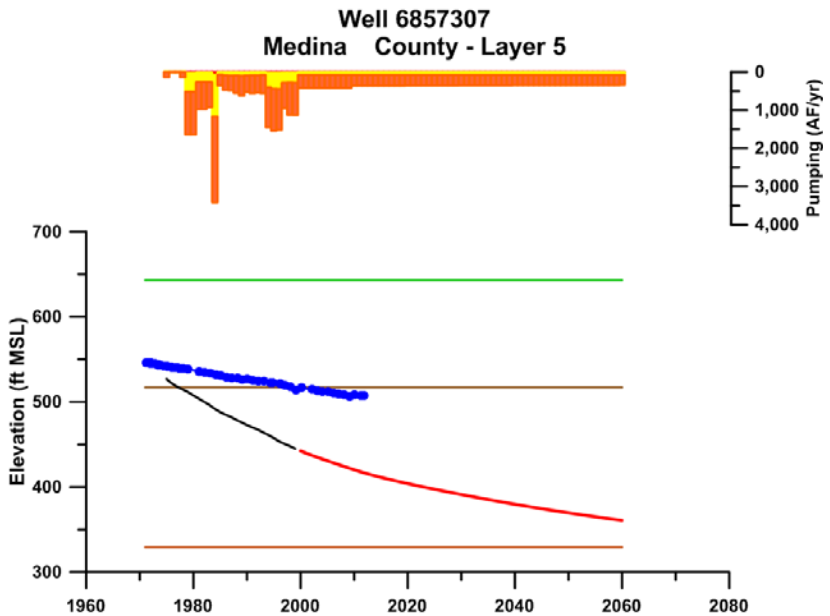
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

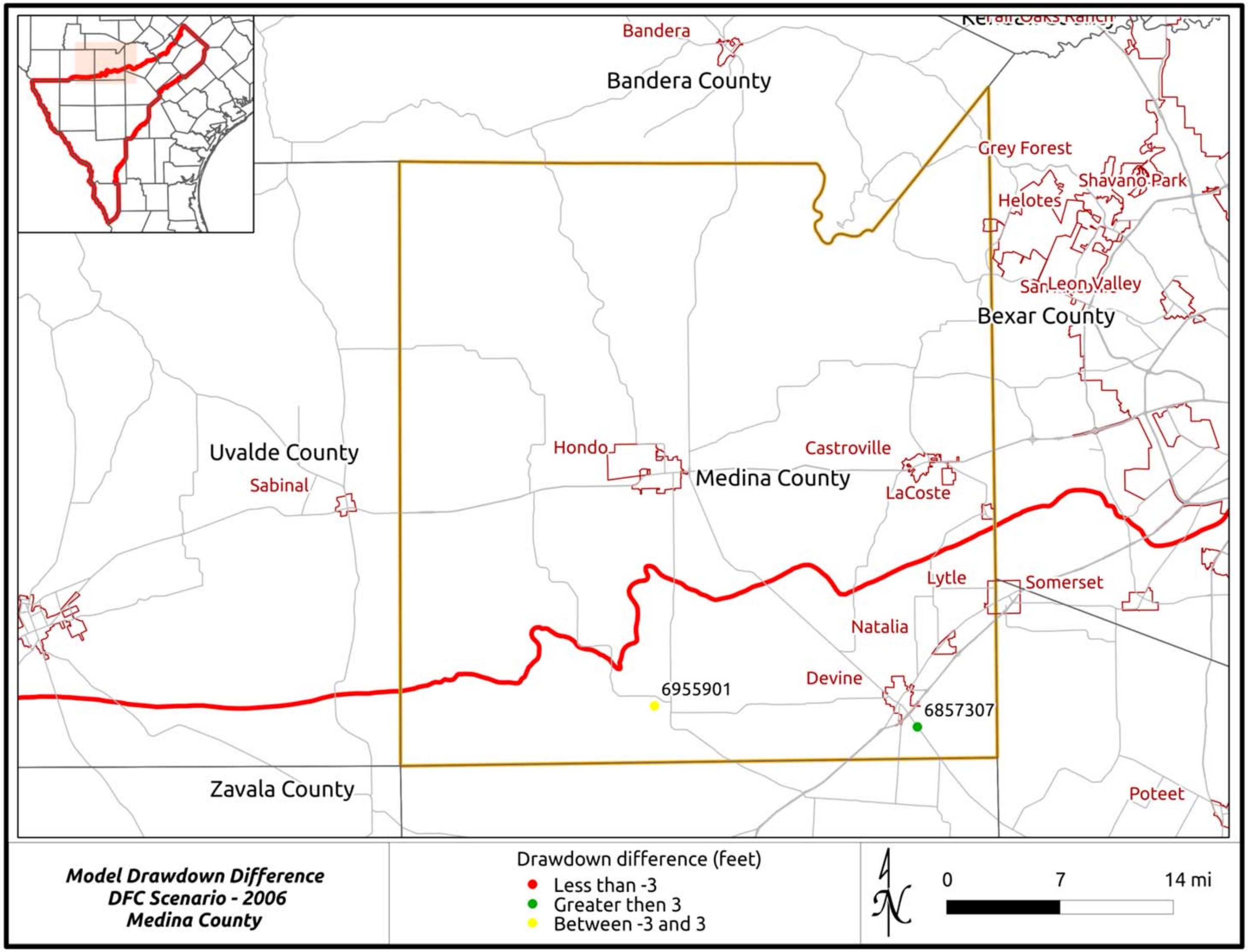


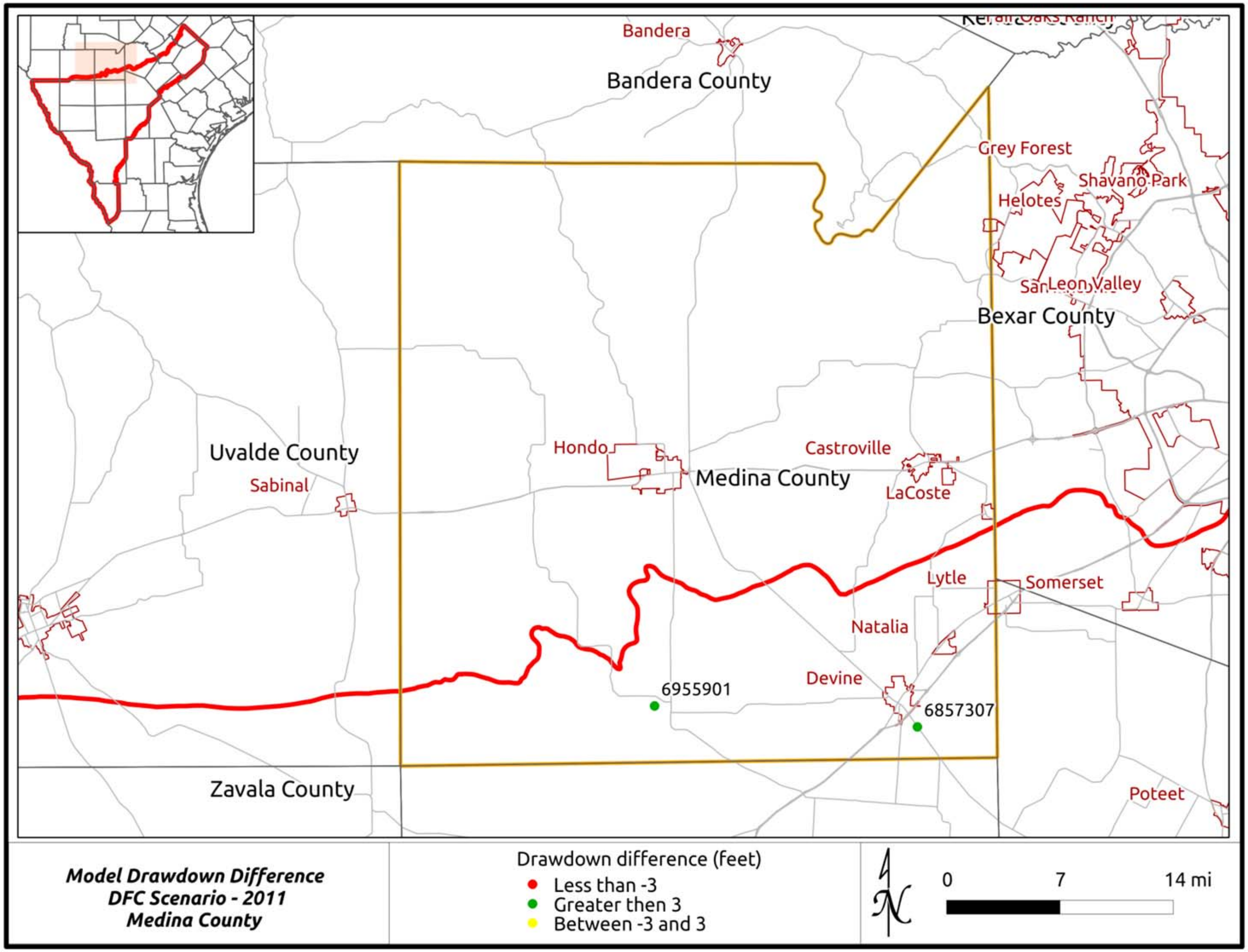
Location Map of Wells with Hydrographs – Medina County


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface


Well 6955901
Medina County - Layer 8
0
400
800
1,200
Pumping (AF/yr)
700
650
600
550
500
450
400
Elevation (ft MSL)
1920
1960
2000
2040
2080

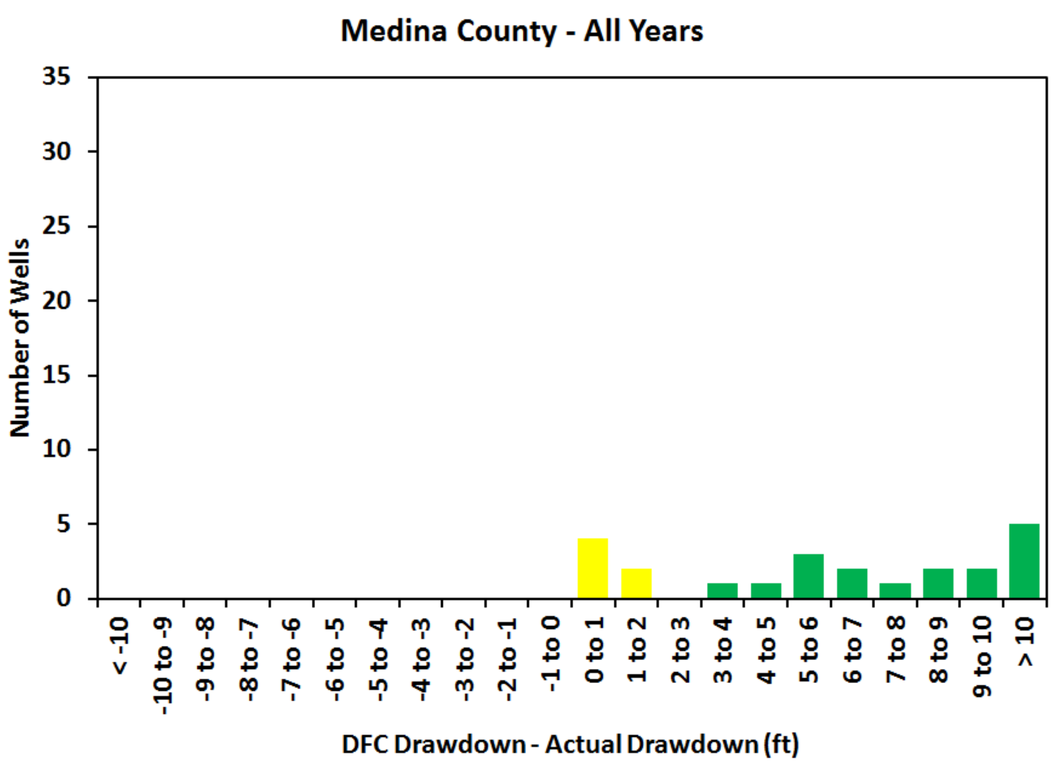

Well 6857307
Medina County - Layer 5
0
1,000
2,000
3,000
4,000
Pumping (AF/yr)
700
600
500
400
300
Elevation (ft MSL)
1960
1980
2000
2020
2040
2060
2080

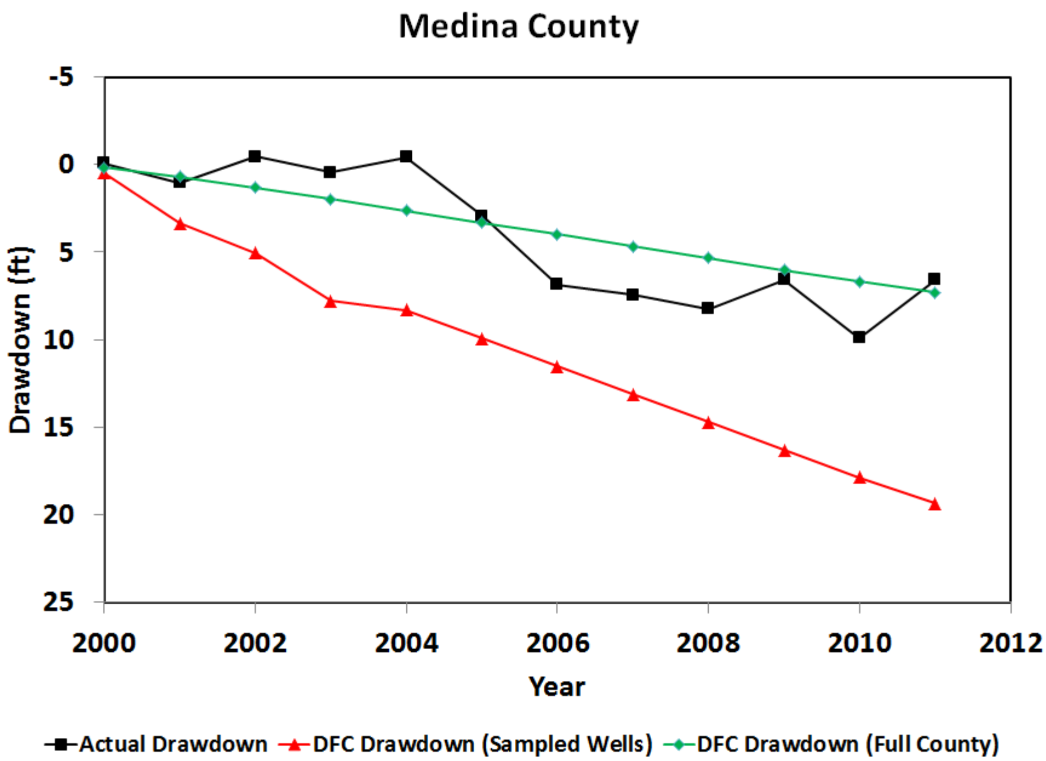

Bandera
Bandera County
Fair Oaks Ranch
Grey Forest
Shavano Park
Helotes
Leon Valley
Bexar County
Uvalde County
Sabinal
Hondo
Medina County
Castroville
LaCoste
Lytle
Somerset
Natalia
Devine
6955901
6857307
Zavala County
Poteet
Model Drawdown Difference
DFC Scenario - 2006
Medina County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
7
14 mi


Bandera
Bandera County
Grey Forest
Shavano Park
Helotes
Leon Valley
Bexar County
Uvalde County
Sabinal
Hondo
Medina County
Castroville
LaCoste
Lytle
Somerset
Natalia
Devine
6955901
6857307
Zavala County
Poteet
Model Drawdown Difference
DFC Scenario - 2011
Medina County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
7
14 mi

Summary of Drawdown Comparisons - Medina County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	0.18	1	-0.07	0.50	0.57
2001	101	0.70	2	1.05	3.35	2.30
2002	113	1.32	2	-0.46	5.04	5.50
2003	96	1.97	2	0.44	7.80	7.37
2004	132	2.63	2	-0.43	8.32	8.75
2005	75	3.31	2	2.96	9.94	6.98
2006	86	3.98	2	6.84	11.54	4.70
2007	142	4.66	2	7.46	13.13	5.68
2008	74	5.34	2	8.24	14.72	6.48
2009	76	6.02	2	6.60	16.29	9.70
2010	132	6.68	2	9.90	17.86	7.96
2011	45	7.31	2	6.59	19.36	12.77





Medina County
-5
0
5
10
15
20
25
Drawdown (ft)
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 13 – Webb County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

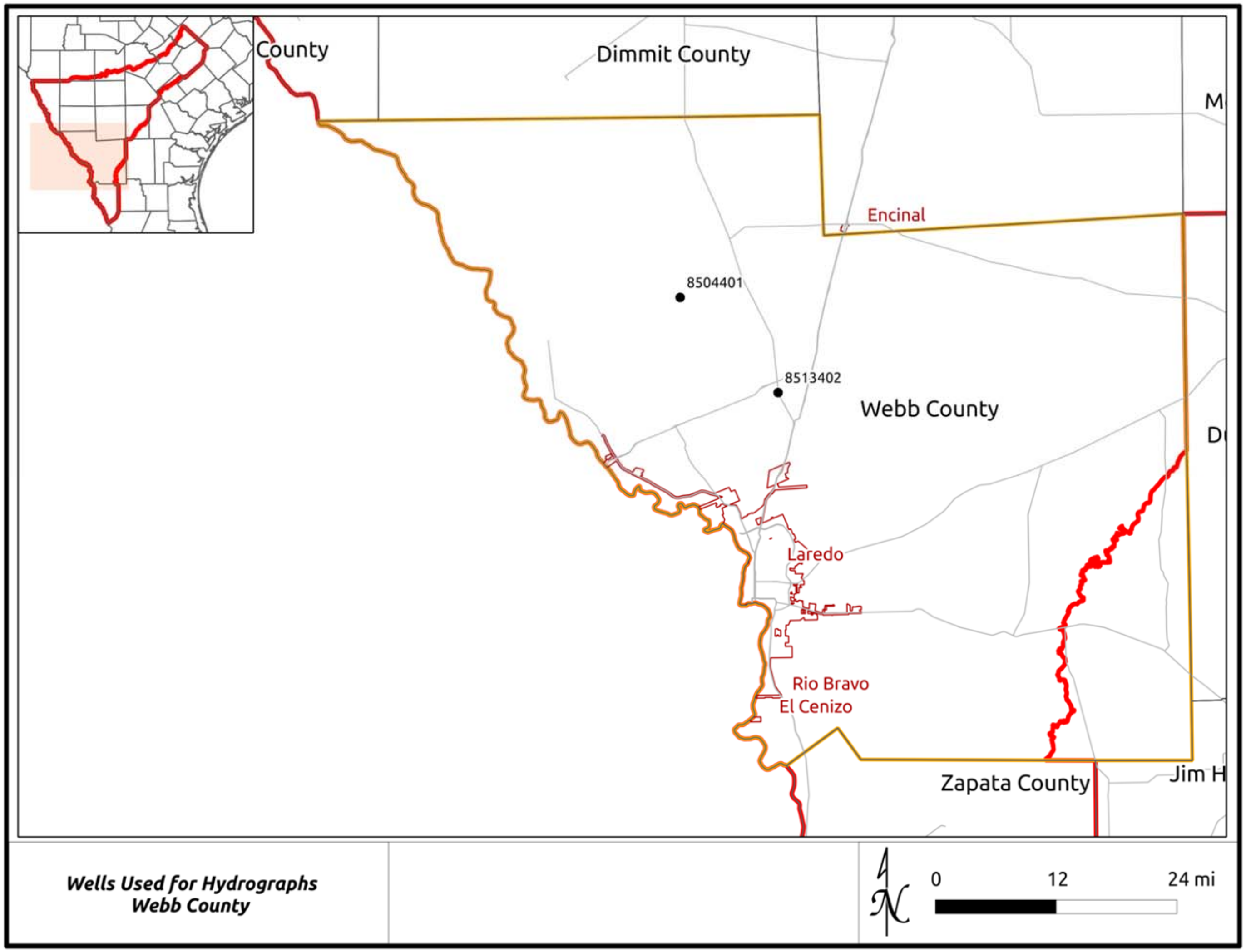
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

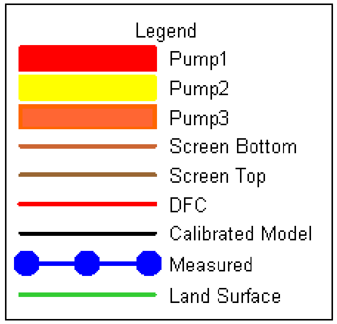
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

Hydrograph of Actual Drawdown and DFC Drawdown

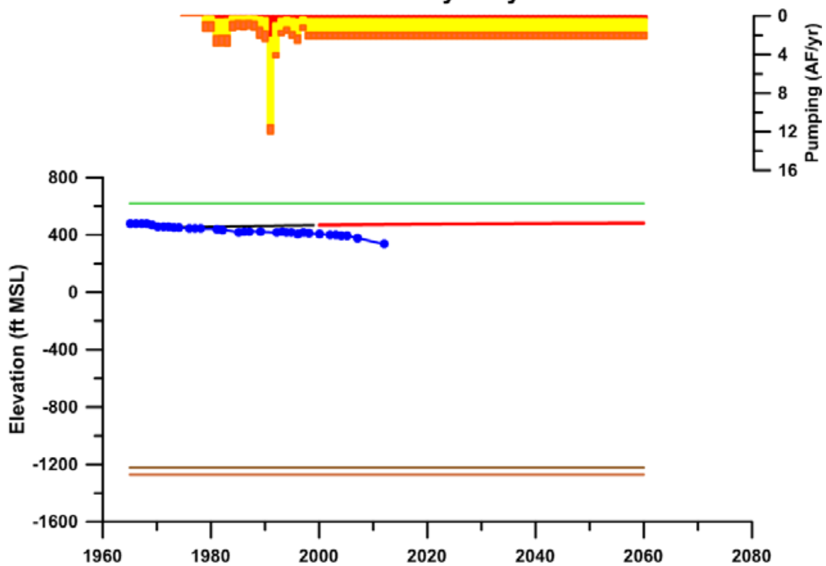
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011



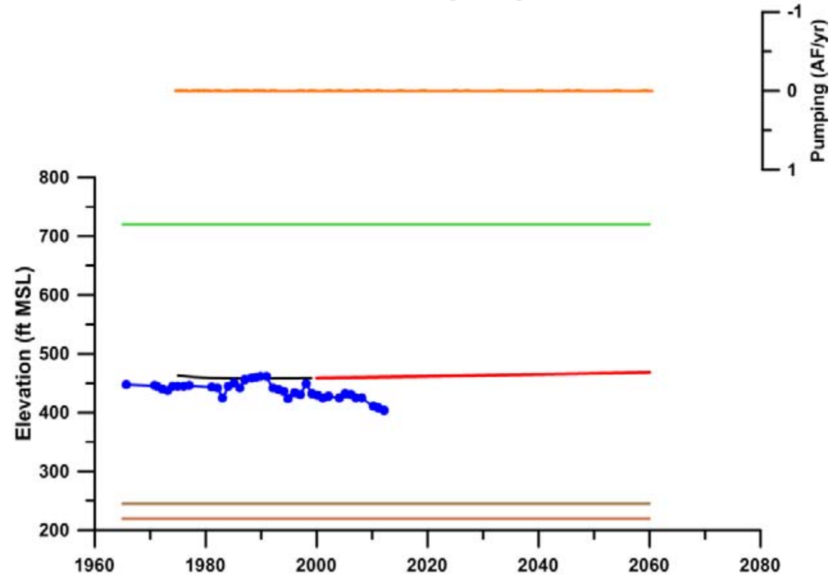
Location Map of Wells with Hydrographs – Webb County

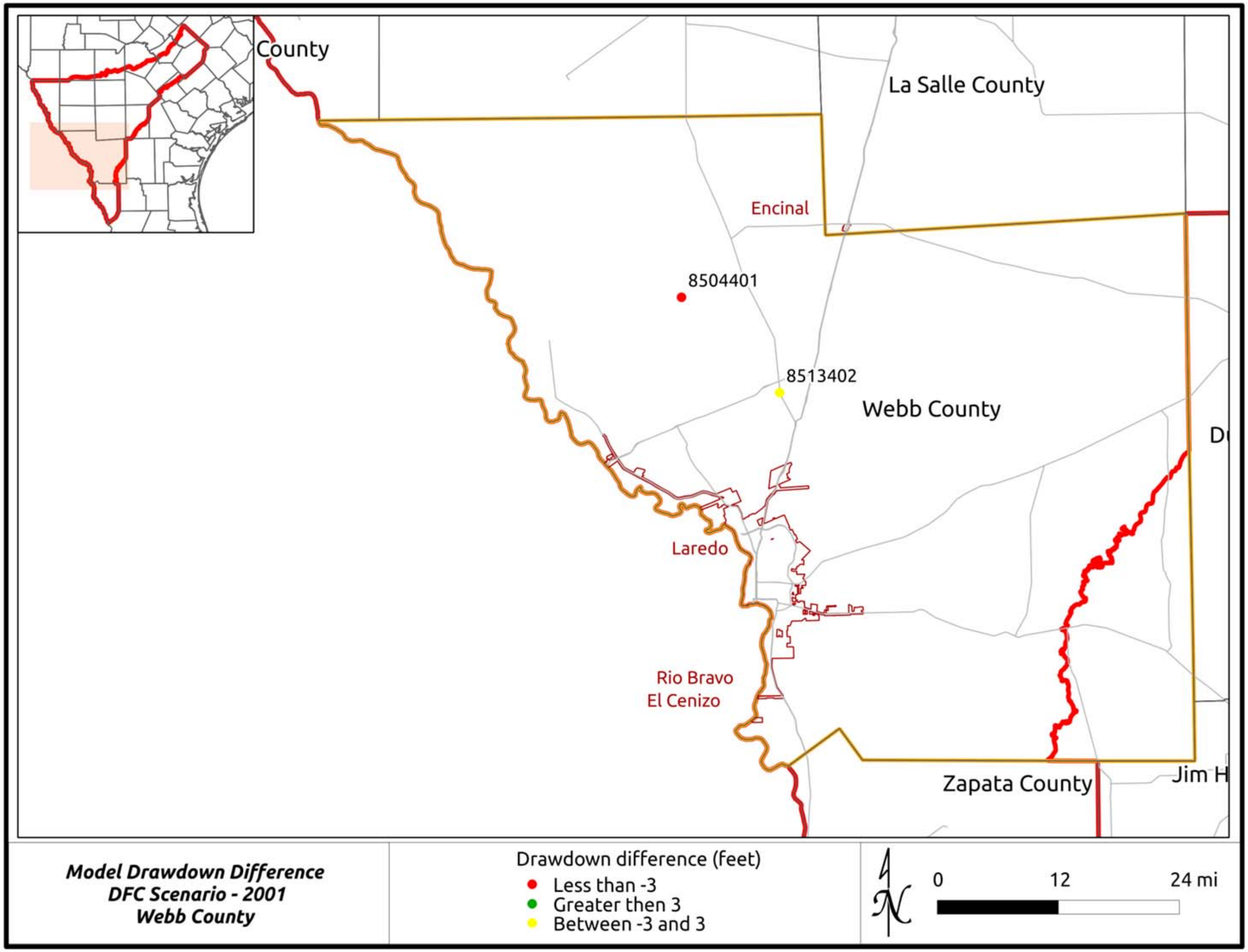


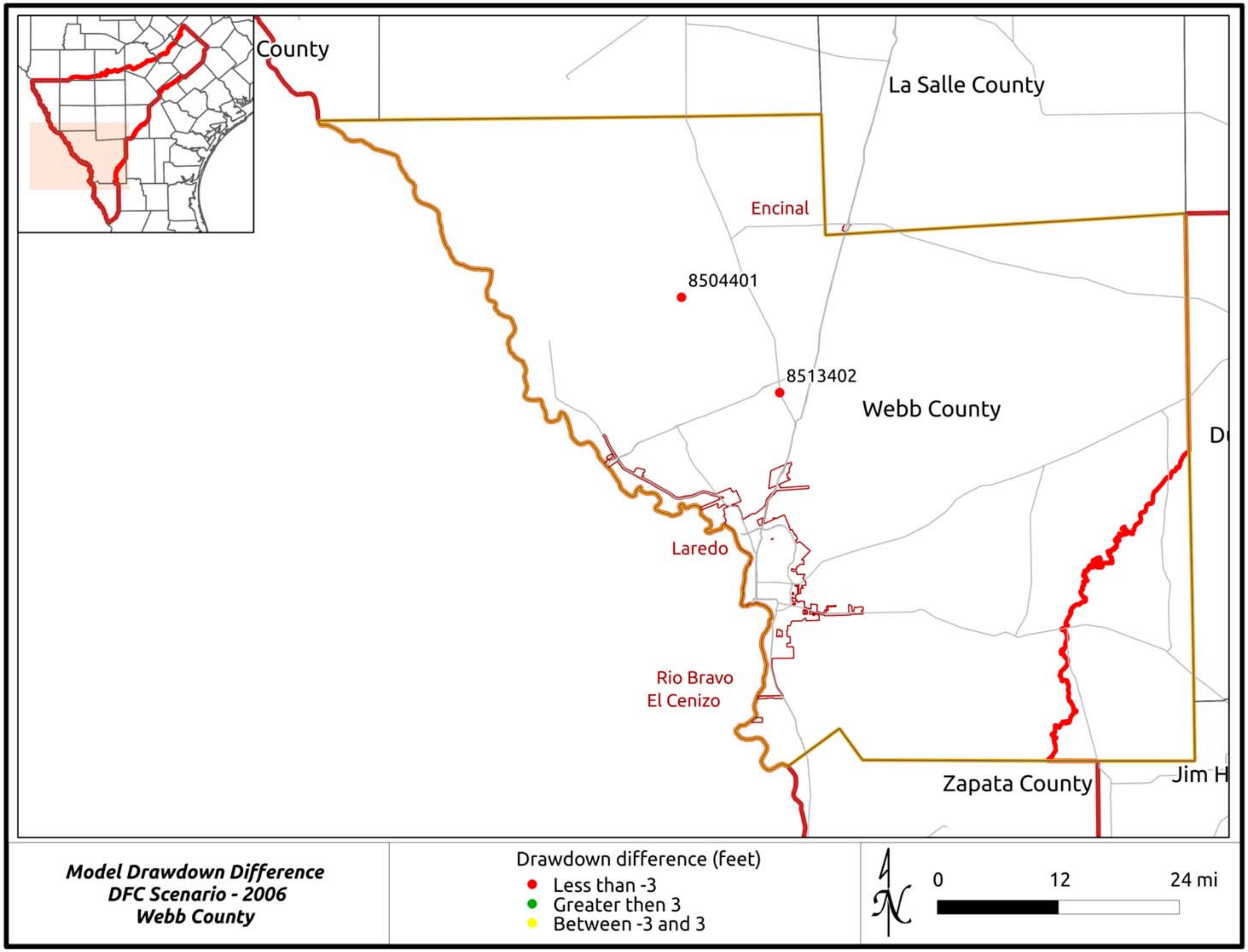
Well 8504401
Webb County - Layer 5

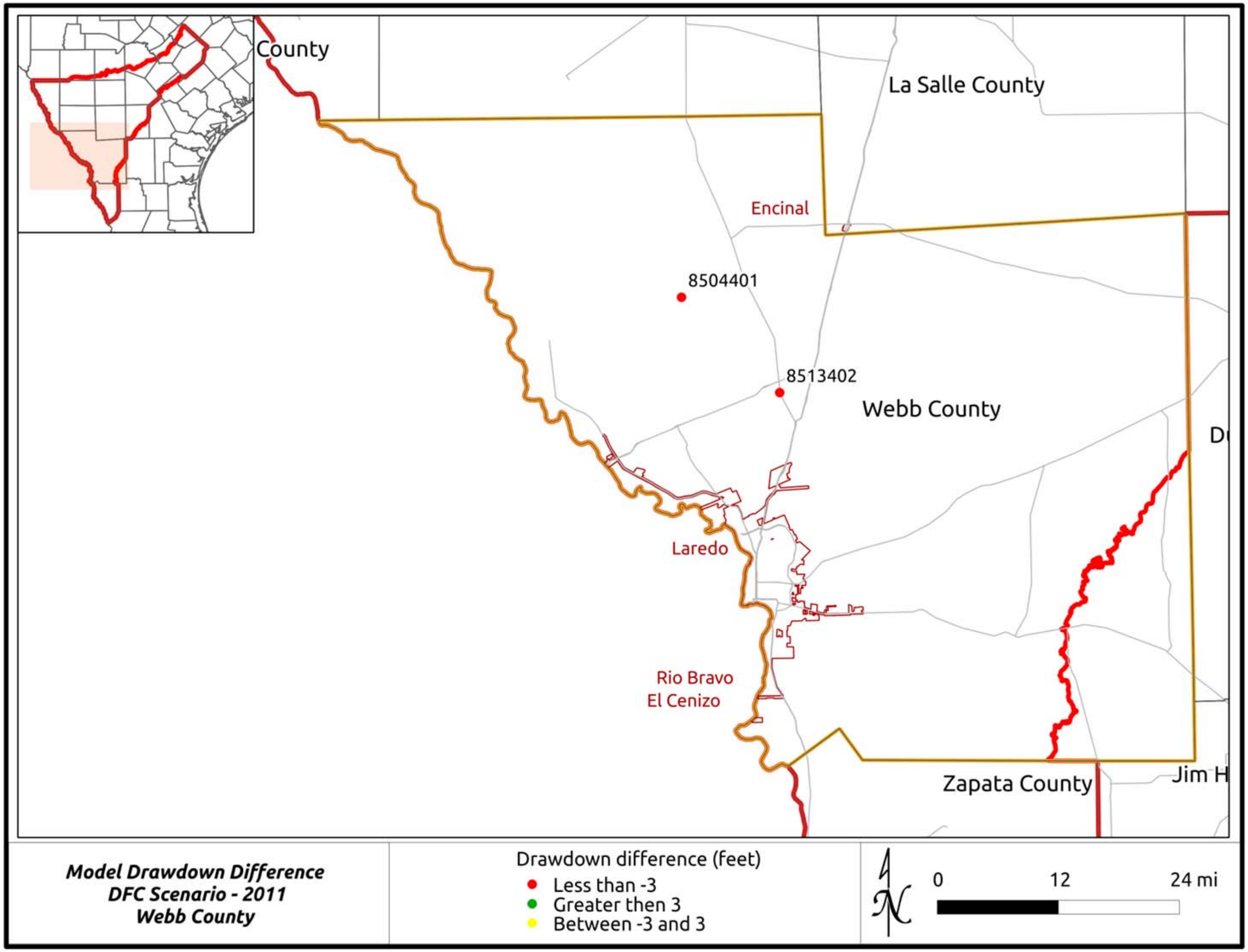


Well 8513402
Webb County - Layer 3



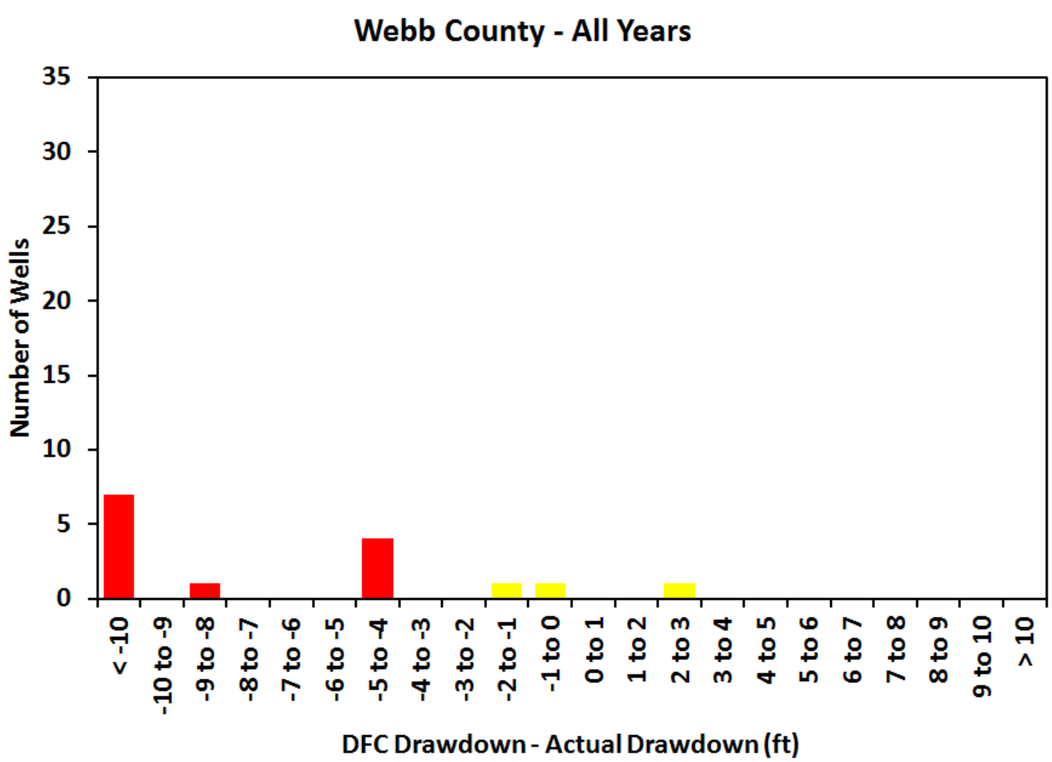

County
La Salle County
Encinal
8504401
8513402
Webb County
Laredo
Rio Bravo
El Cenizo
Zapata County
Jim H
Model Drawdown Difference
DFC Scenario - 2001
Webb County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
12
24 mi

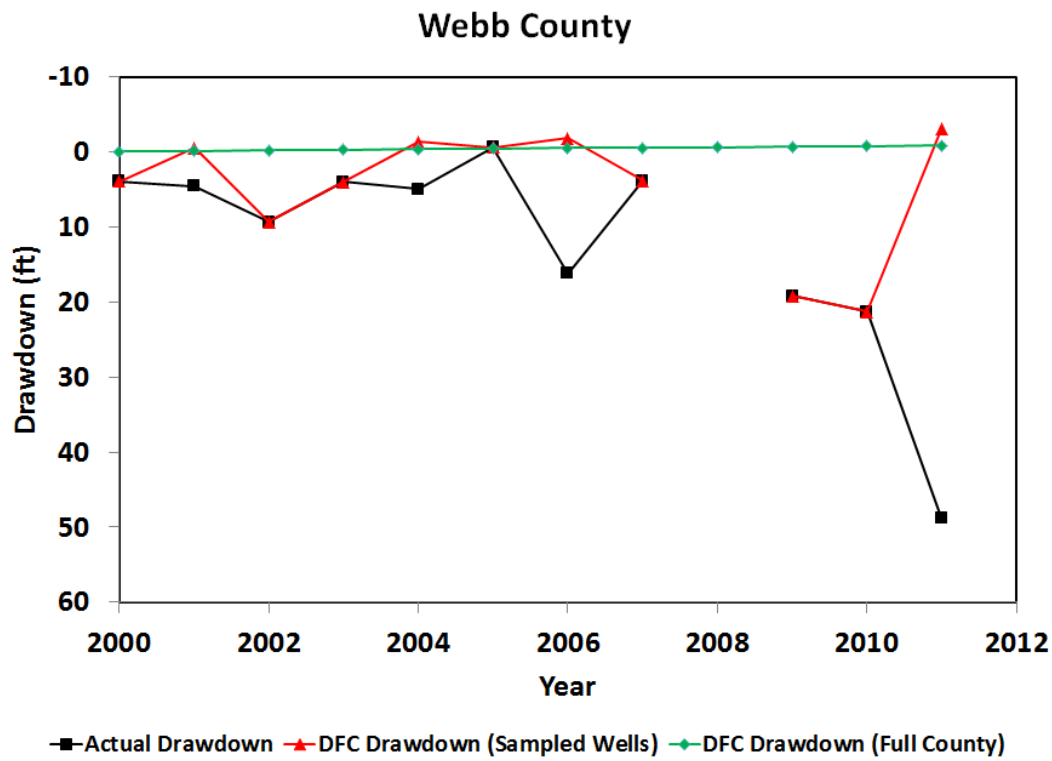

County
La Salle County
Encinal
8504401
8513402
Webb County
Laredo
Rio Bravo
El Cenizo
Zapata County
Jim H
Model Drawdown Difference
DFC Scenario - 2006
Webb County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
12
24 mi


County
La Salle County
Encinal
8504401
8513402
Webb County
D
Laredo
Rio Bravo
El Cenizo
Zapata County
Jim H
Model Drawdown Difference
DFC Scenario - 2011
Webb County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
12
24 mi

Summary of Drawdown Comparisons - Webb County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	-0.06	1	3.94	3.94	3.94
2001	101	-0.13	2	4.56	-0.52	-5.07
2002	113	-0.20	1	9.38	9.38	9.38
2003	96	-0.27	1	4.04	4.04	4.04
2004	132	-0.34	2	4.95	-1.29	-6.24
2005	75	-0.41	1	-0.60	-0.60	-0.60
2006	86	-0.48	2	16.23	-1.78	-18.01
2007	142	-0.55	1	3.84	3.84	3.84
2008	74	-0.62				
2009	76	-0.69	1	19.19	19.19	19.19
2010	132	-0.76	1	21.27	21.27	21.27
2011	45	-0.82	2	48.80	-2.99	-51.79




Webb County
-10
0
10
20
30
40
50
60
Drawdown (ft)
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 14 – Wilson County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001 and 2006

Summary of Drawdown Comparisons

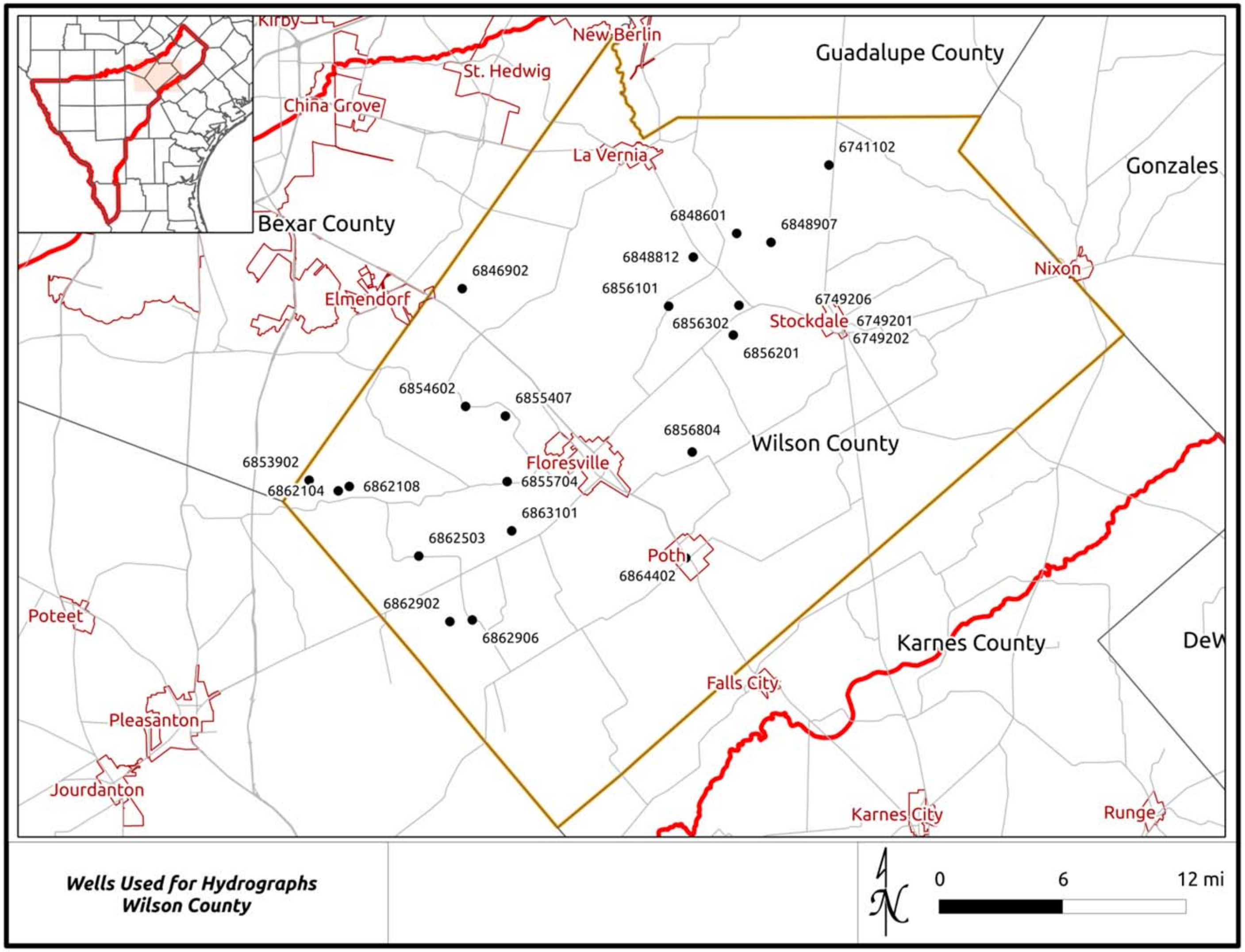
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

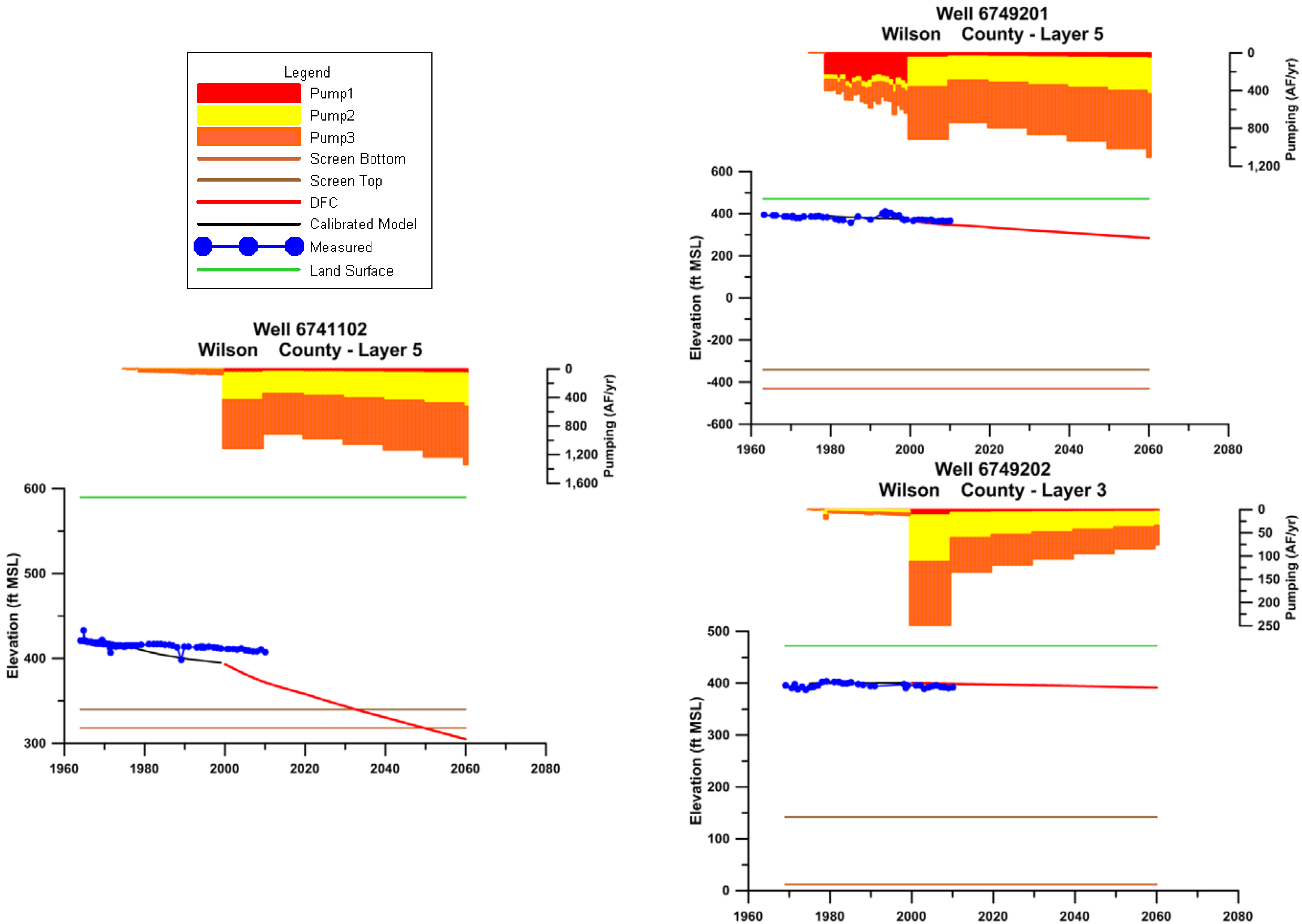
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

Hydrograph of Actual Drawdown and DFC Drawdown

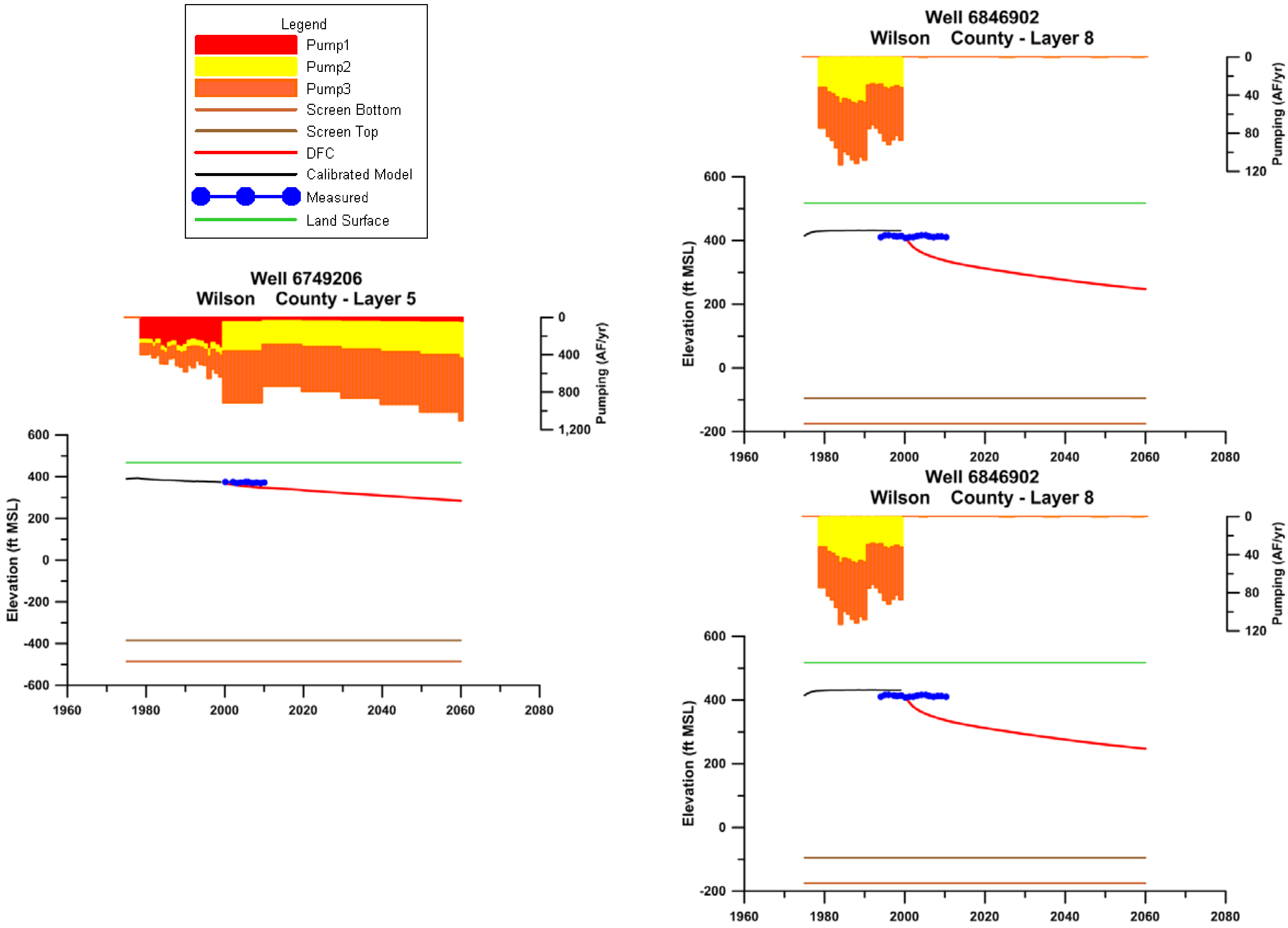
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011



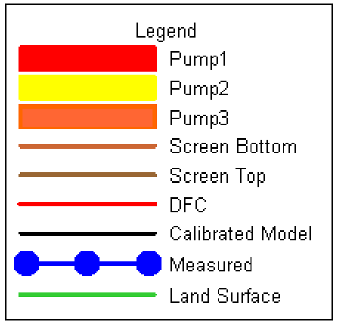
Location Map of Wells with Hydrographs – Webb County

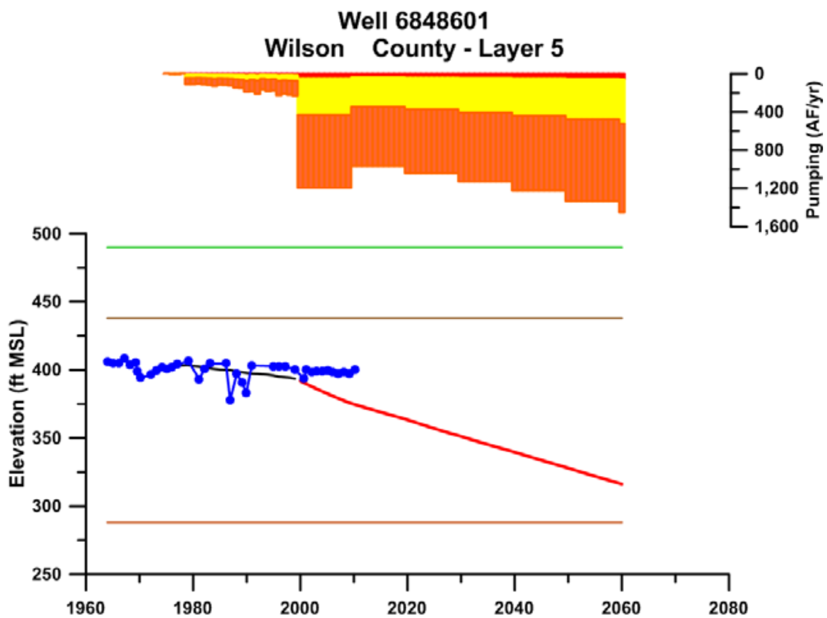


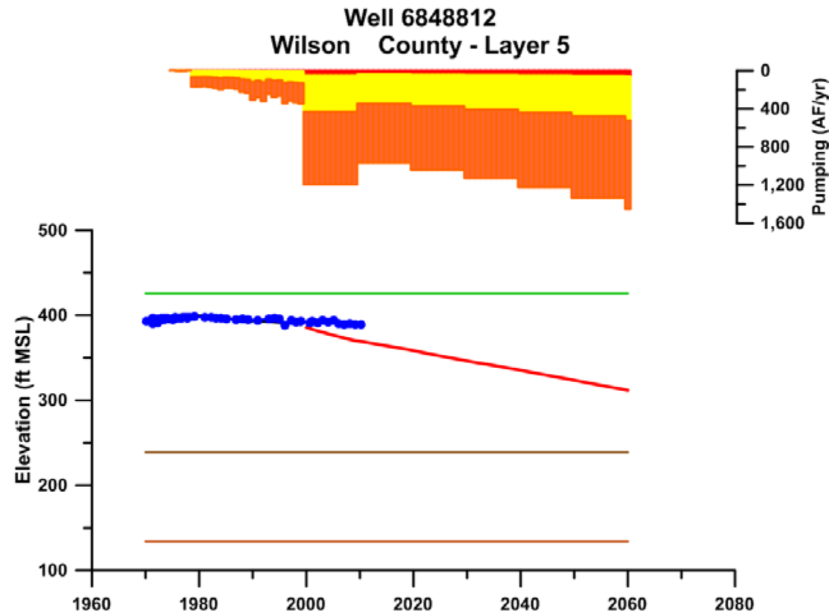
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6741102
Wilson County - Layer 5
Well 6749201
Wilson County - Layer 5
Well 6749202
Wilson County - Layer 3
Elevation (ft MSL)
Pumping (AF/yr)

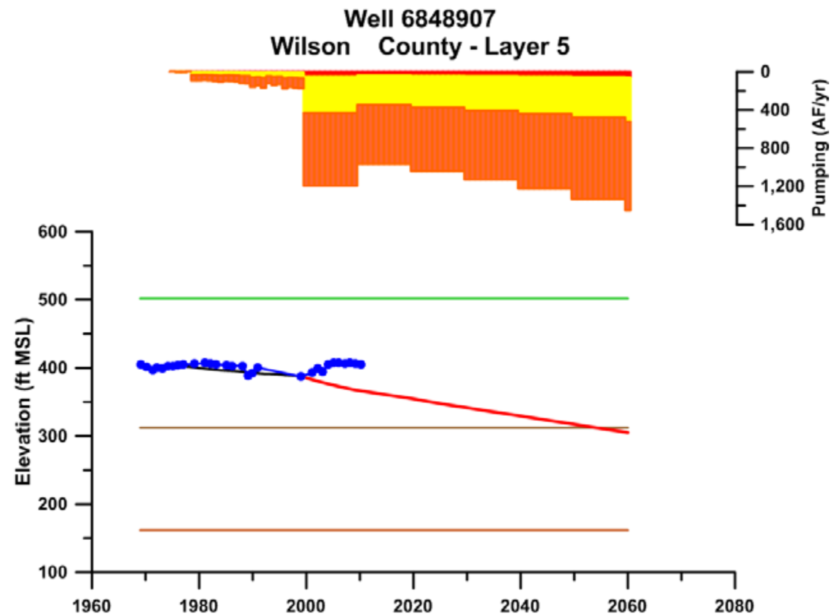


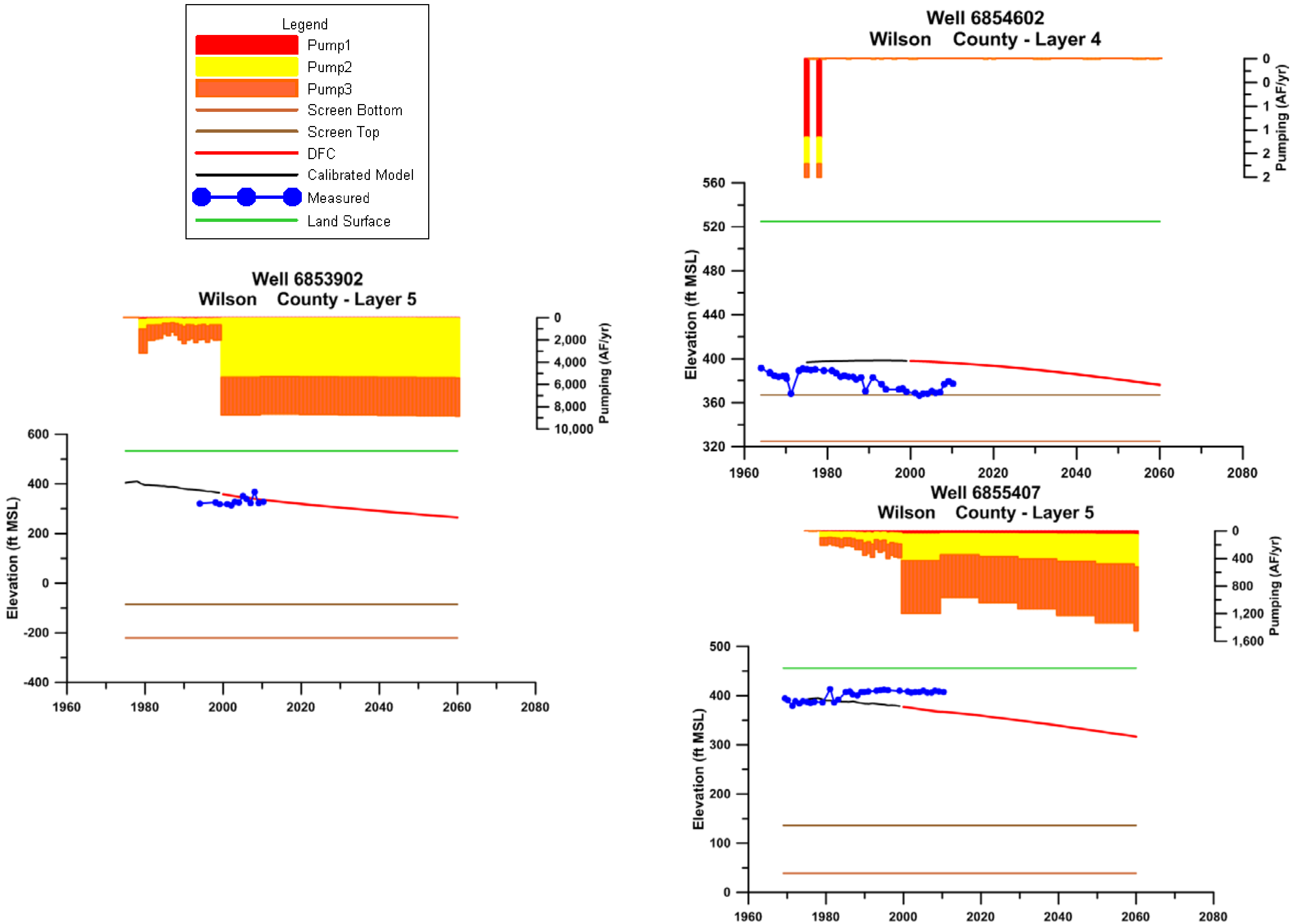
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6749206
Wilson County - Layer 5
Pumping (AF/yr)
Elevation (ft MSL)
Well 6846902
Wilson County - Layer 8
Pumping (AF/yr)
Elevation (ft MSL)
Well 6846902
Wilson County - Layer 8
Pumping (AF/yr)
Elevation (ft MSL)


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface

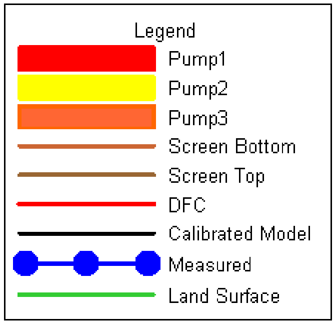

Well 6848601
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
400
800
1,200
1,600
500
450
400
350
300
250
1960
1980
2000
2020
2040
2060
2080

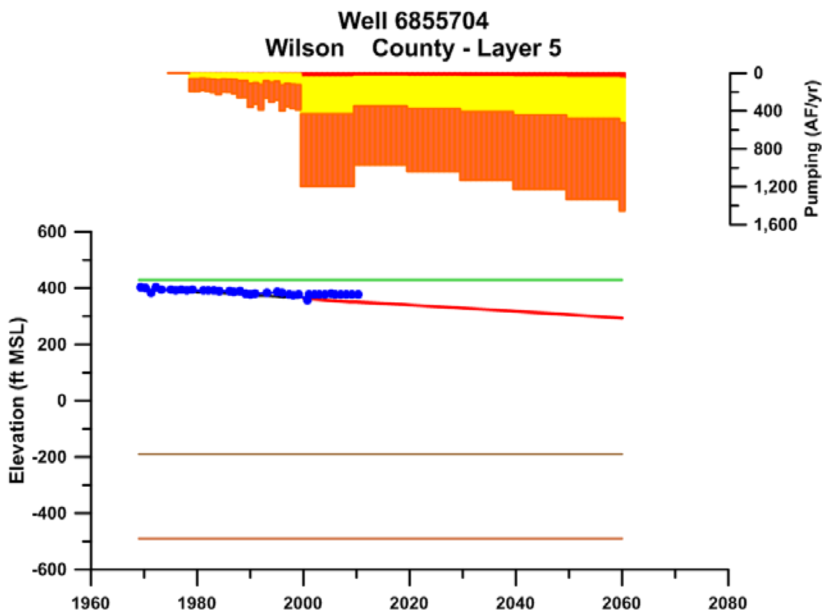

Well 6848812
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
400
800
1,200
1,600
500
400
300
200
100
1960
1980
2000
2020
2040
2060
2080

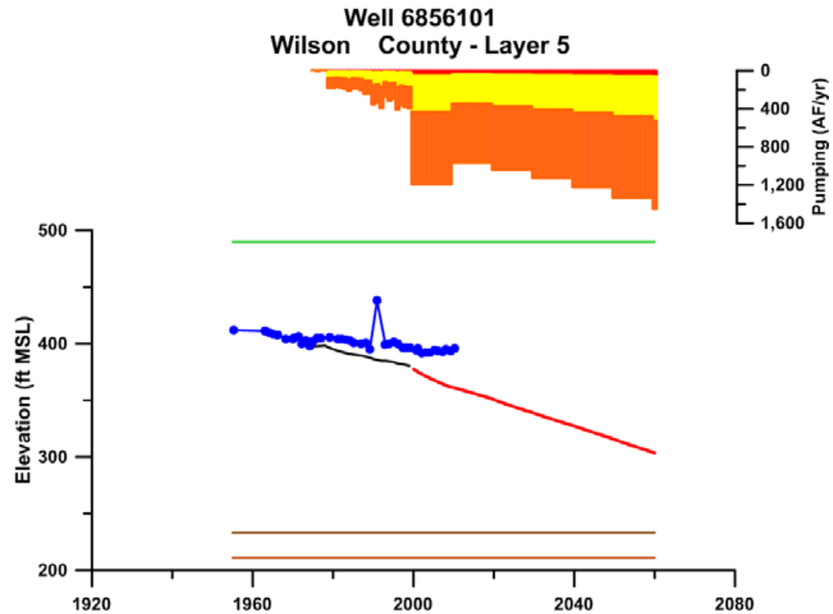

Well 6848907
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
400
800
1,200
1,600
600
500
400
300
200
100
1960
1980
2000
2020
2040
2060
2080

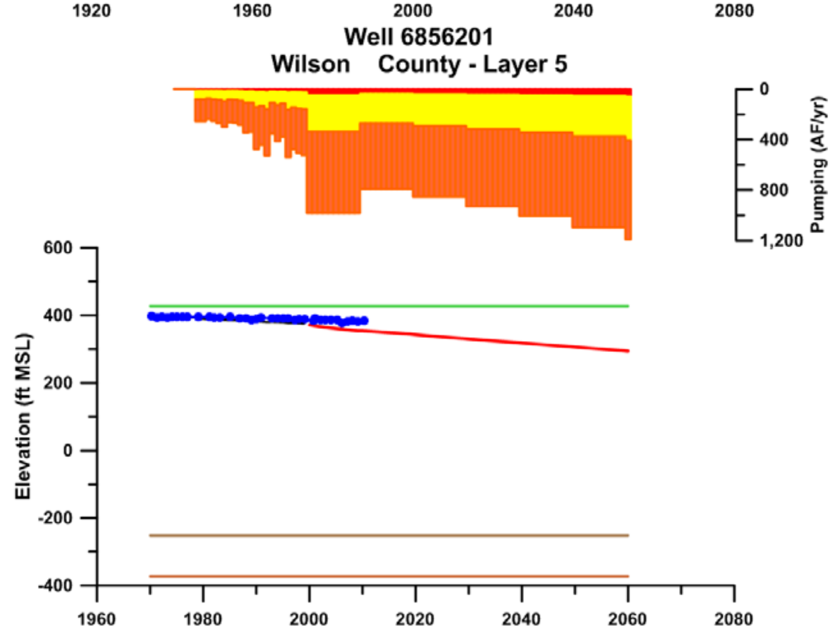


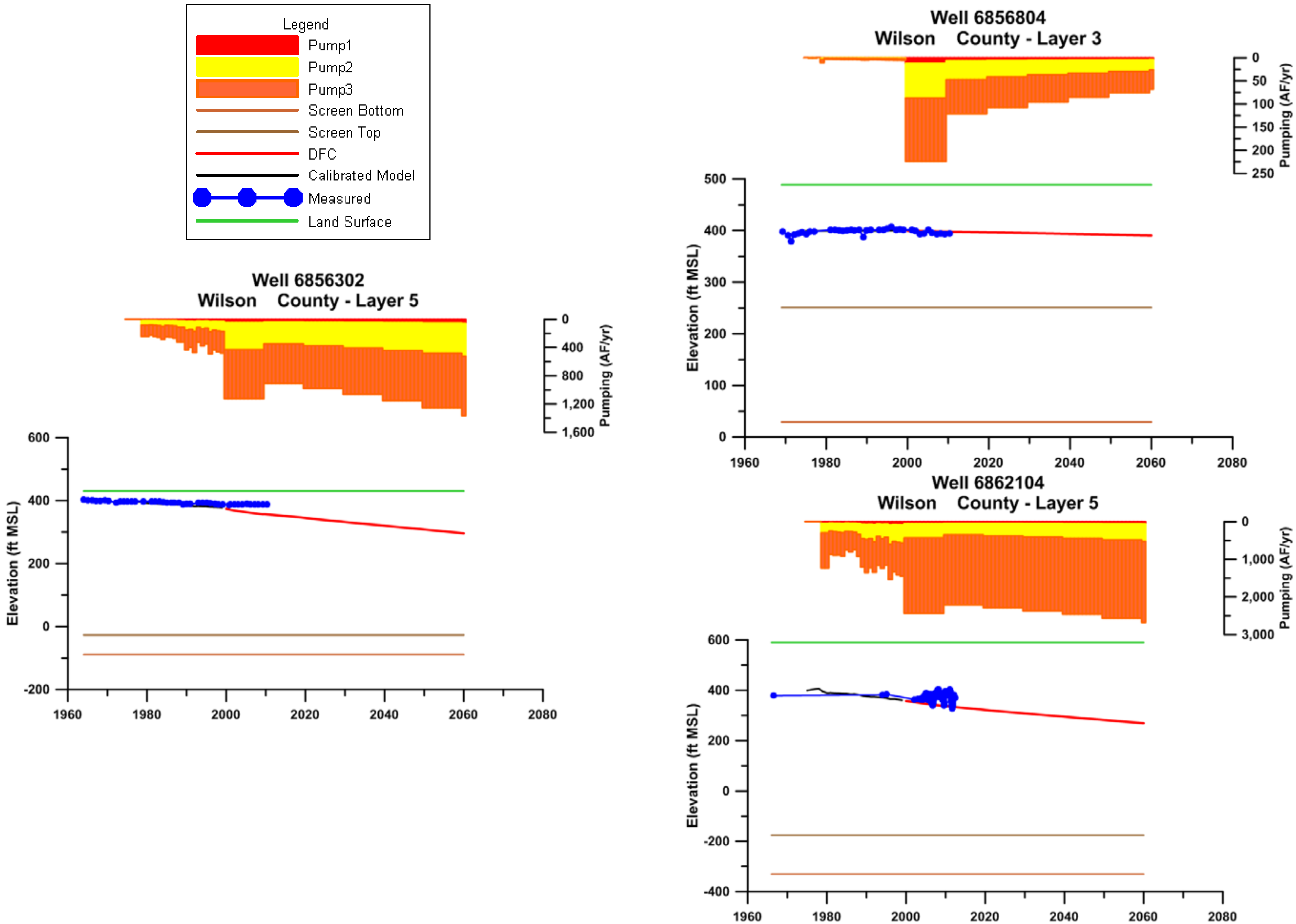
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6853902
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 6854602
Wilson County - Layer 4
Elevation (ft MSL)
Pumping (AF/yr)
Well 6855407
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)

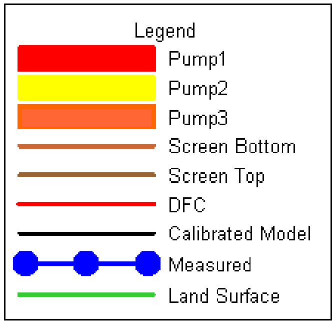

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface


Well 6855704
Wilson County - Layer 5
Pumping (AF/yr)
0
400
800
1,200
1,600
Elevation (ft MSL)
600
400
200
0
-200
-400
-600
1960
1980
2000
2020
2040
2060
2080

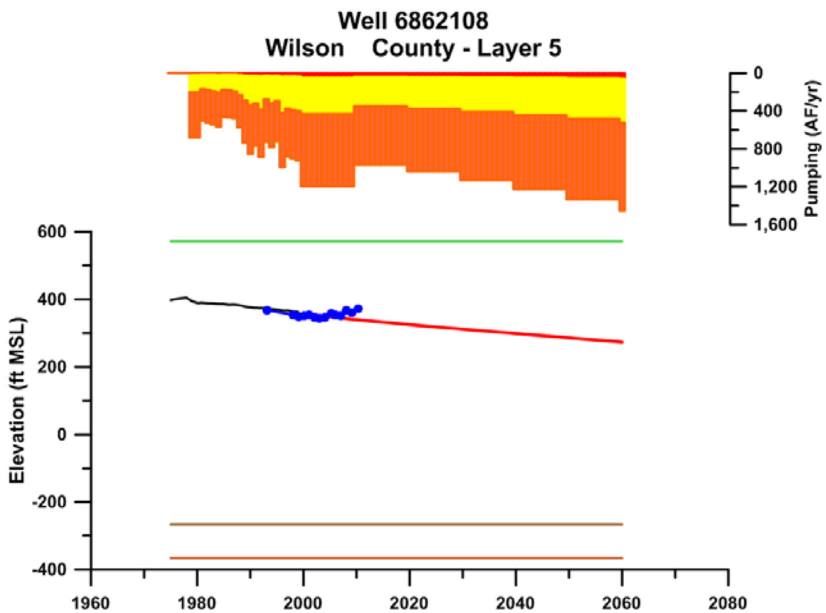

Well 6856101
Wilson County - Layer 5
Pumping (AF/yr)
0
400
800
1,200
1,600
Elevation (ft MSL)
500
400
300
200
1920
1960
2000
2040
2080


Well 6856201
Wilson County - Layer 5
Pumping (AF/yr)
0
400
800
1,200
Elevation (ft MSL)
600
400
200
0
-200
-400
1960
1980
2000
2020
2040
2060
2080

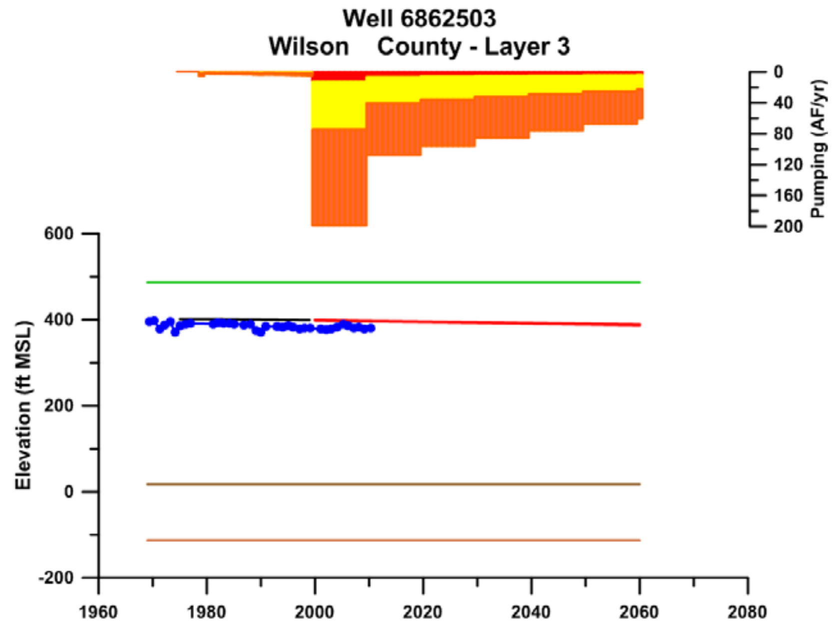

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6856302
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 6856804
Wilson County - Layer 3
Elevation (ft MSL)
Pumping (AF/yr)
Well 6862104
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)



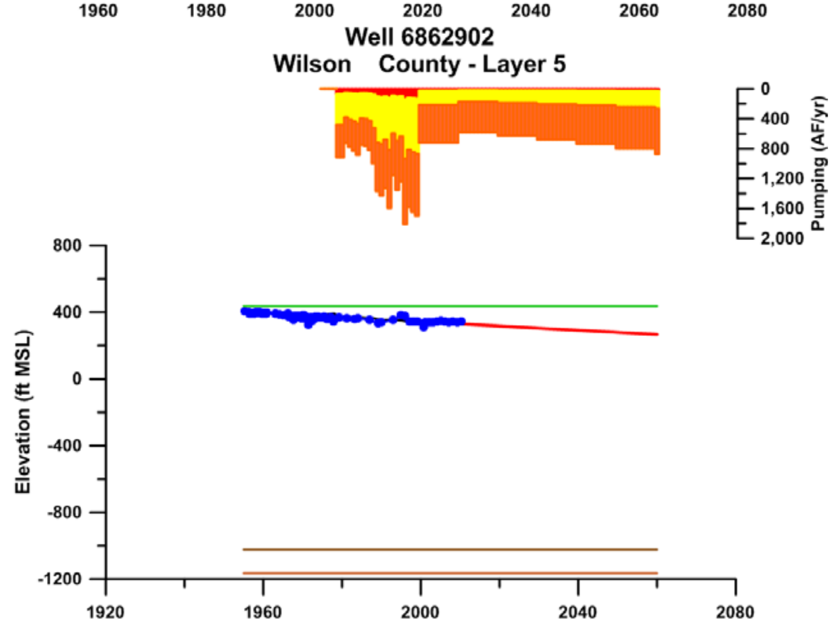
Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface



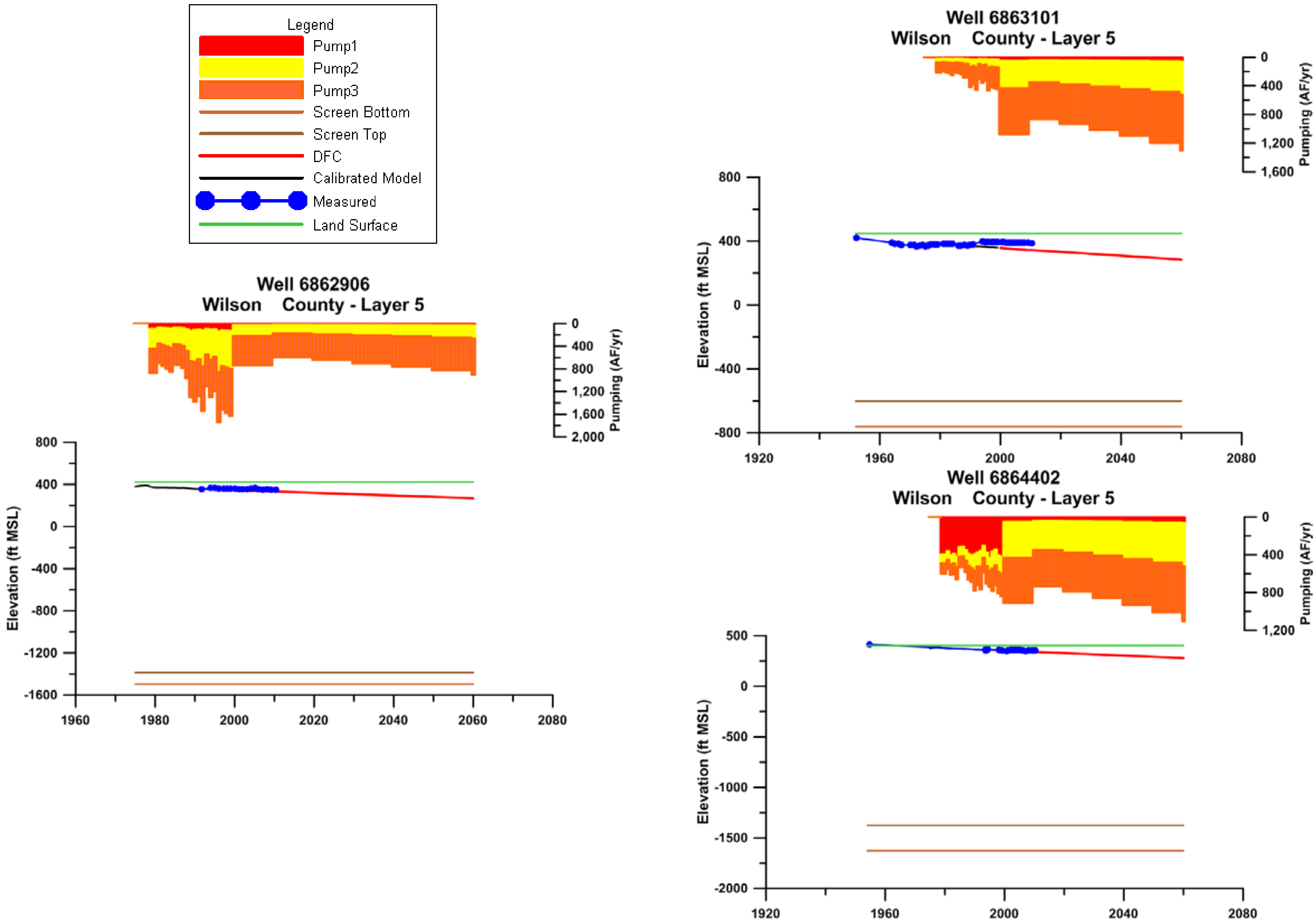
Well 6862108
Wilson County - Layer 5
Elevation (ft MSL)
600
400
200
0
-200
-400
1960
1980
2000
2020
2040
2060
2080
Pumping (AF/yr)
0
400
800
1,200
1,600

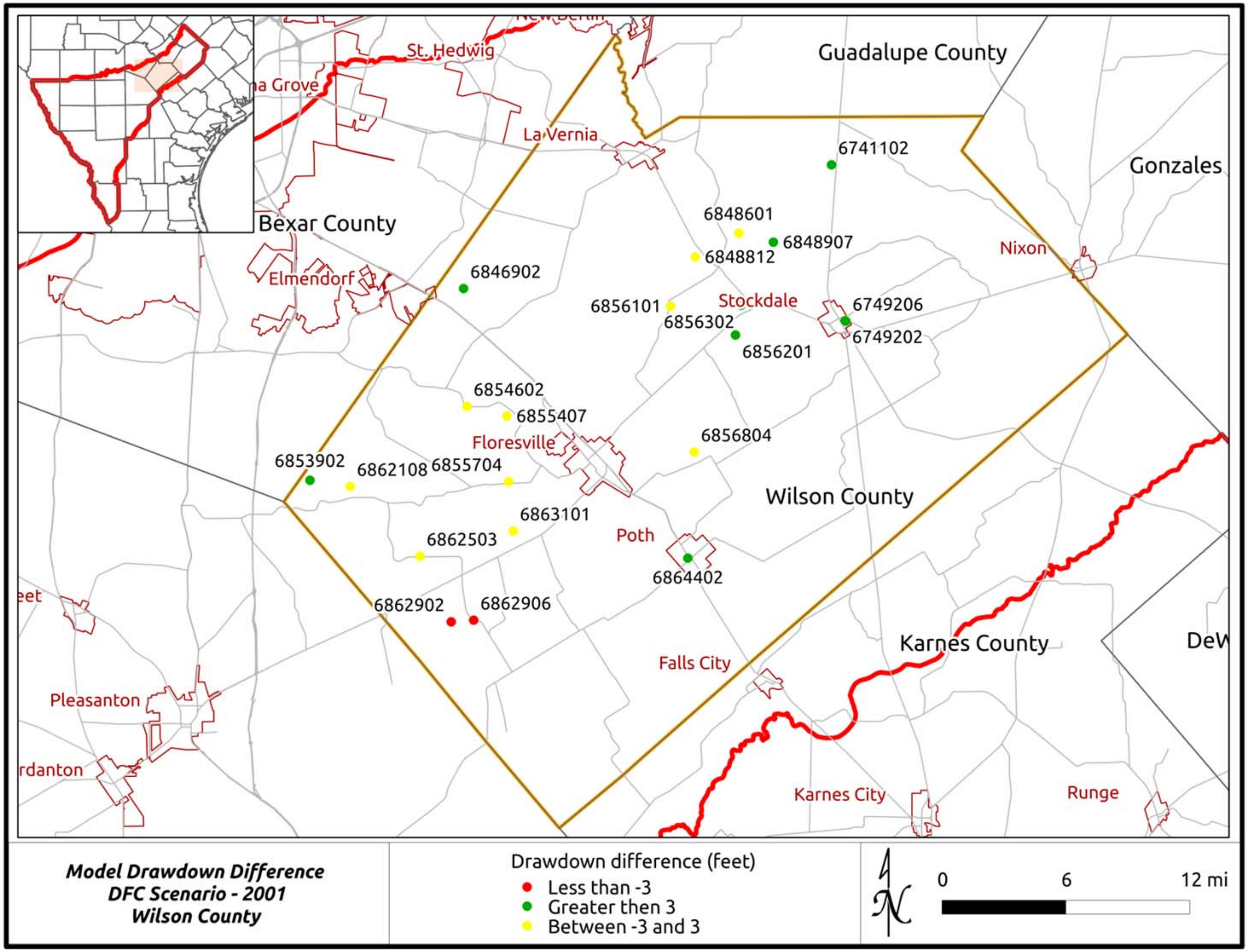


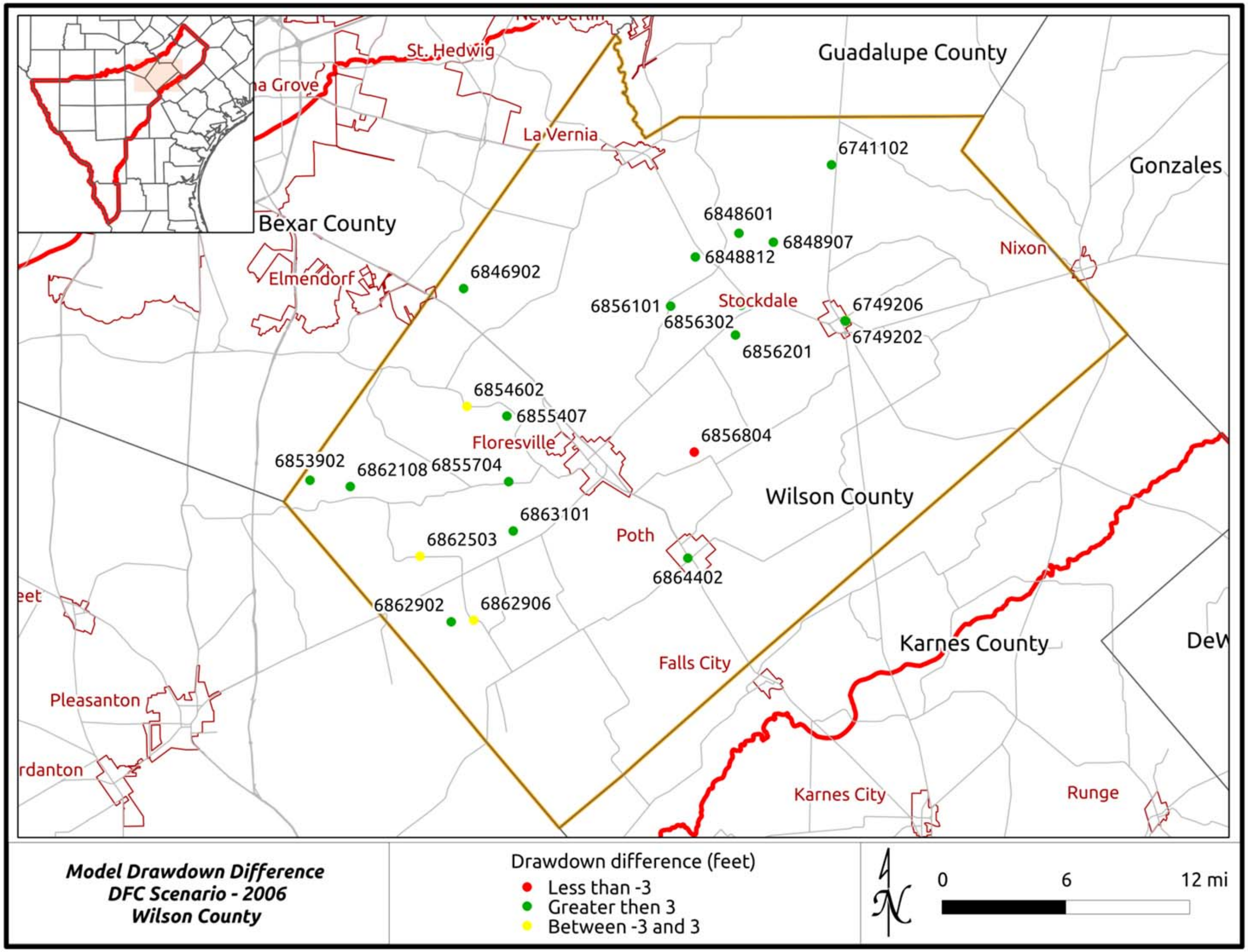
Well 6862503
Wilson County - Layer 3
Elevation (ft MSL)
600
400
200
0
-200
1960
1980
2000
2020
2040
2060
2080
Pumping (AF/yr)
0
40
80
120
160
200



Well 6862902
Wilson County - Layer 5
Elevation (ft MSL)
800
400
0
-400
-800
-1200
1920
1960
2000
2040
2080
Pumping (AF/yr)
0
400
800
1,200
1,600
2,000

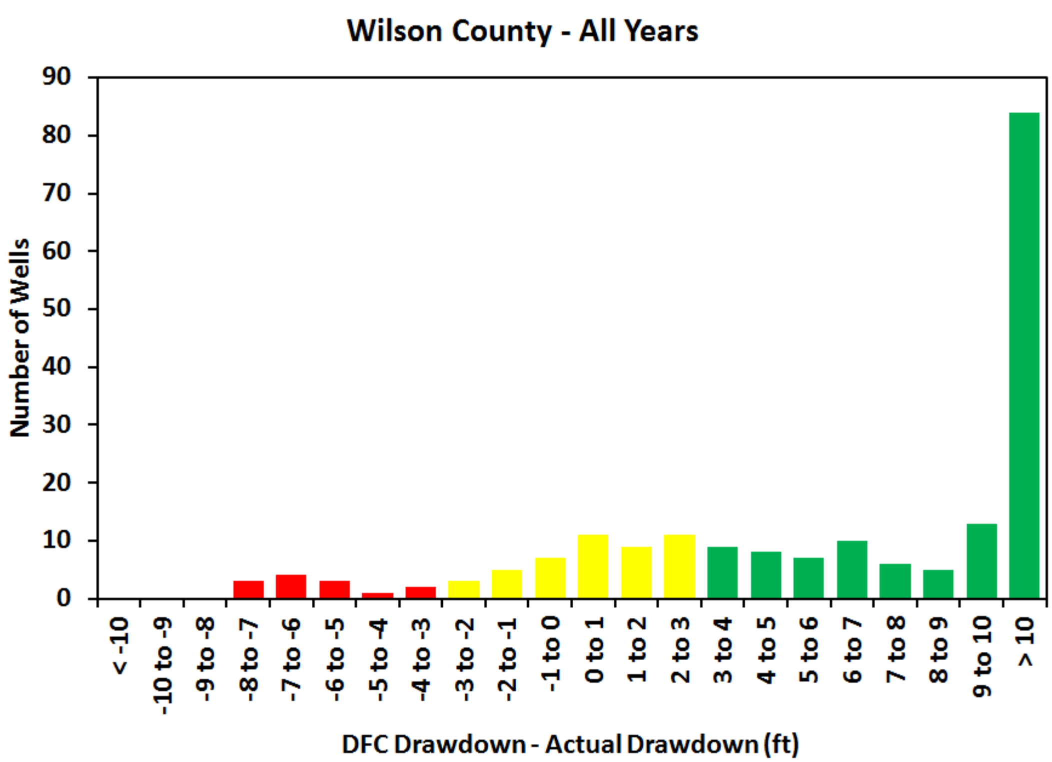

Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 6862906
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 6863101
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 6864402
Wilson County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)

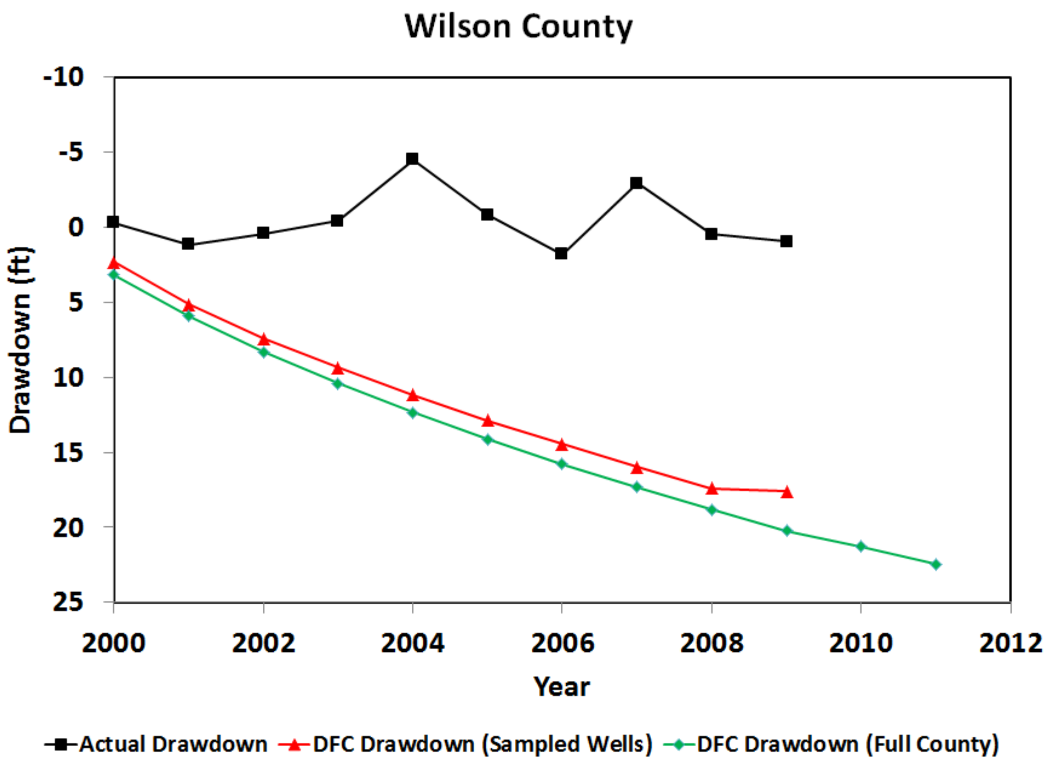

Guadalupe County
Gonzales
Bexar County
Wilson County
Karnes County
DeW
St. Hedwig
La Vernia
Elmendorf
Nixon
Stockdale
Floresville
Poth
Falls City
Pleasanton
Karnes City
Runge
6741102
6848601
6848907
6848812
6846902
6856101
6856302
6749206
6749202
6856201
6854602
6855407
6856804
6853902
6862108
6855704
6863101
6862503
6864402
6862902
6862906
Model Drawdown Difference
DFC Scenario - 2001
Wilson County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
6
12 mi


Guadalupe County
Gonzales
Bexar County
Wilson County
Karnes County
DeW
St. Hedwig
La Vernia
Elmendorf
Nixon
Stockdale
Floresville
Poth
Falls City
Pleasanton
Karnes City
Runge
6741102
6848601
6848907
6848812
6846902
6856101
6856302
6856201
6749206
6749202
6854602
6855407
6856804
6853902
6862108
6855704
6863101
6862503
6864402
6862902
6862906
Model Drawdown Difference
DFC Scenario - 2006
Wilson County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
6
12 mi

Summary of Drawdown Comparisons - Wilson County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	3.17	21	-0.27	2.35	2.62
2001	101	5.93	22	1.18	5.16	3.98
2002	113	8.31	22	0.44	7.42	6.98
2003	96	10.43	22	-0.40	9.38	9.79
2004	132	12.35	22	-4.50	11.18	15.68
2005	75	14.13	22	-0.81	12.87	13.68
2006	86	15.79	22	1.82	14.46	12.64
2007	142	17.34	22	-2.90	15.97	18.87
2008	74	18.82	22	0.49	17.42	16.93
2009	76	20.23	4	0.98	17.59	16.60
2010	132	21.28				
2011	45	22.44				





Wilson County
-10
-5
0
5
10
15
20
25
Drawdown (ft)
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 15 – Zavala County

Location Map of Hydrograph Wells

Hydrographs

Note that pumping data are expressed in three zones:

- Pump 1 = pumping from cell where well is located
- Pump 2 = pumping in cells adjacent to Zone 1
- Pump 3 = pumping in cells adjacent to Zone 2

Screen Bottom and Screen Top = Elevation of Well Completion Interval

Land Surface = Elevation of Land Surface at Well

Groundwater Elevations

- Measured = Actual data from TWDB database
- Calibrated Model = Results for cell defined by well from calibrated model
- DFC = Results for cell defined by well from Scenario 4 of GAM Run 09-034

Drawdown Comparison Maps for 2001, 2006 and 2011

Summary of Drawdown Comparisons

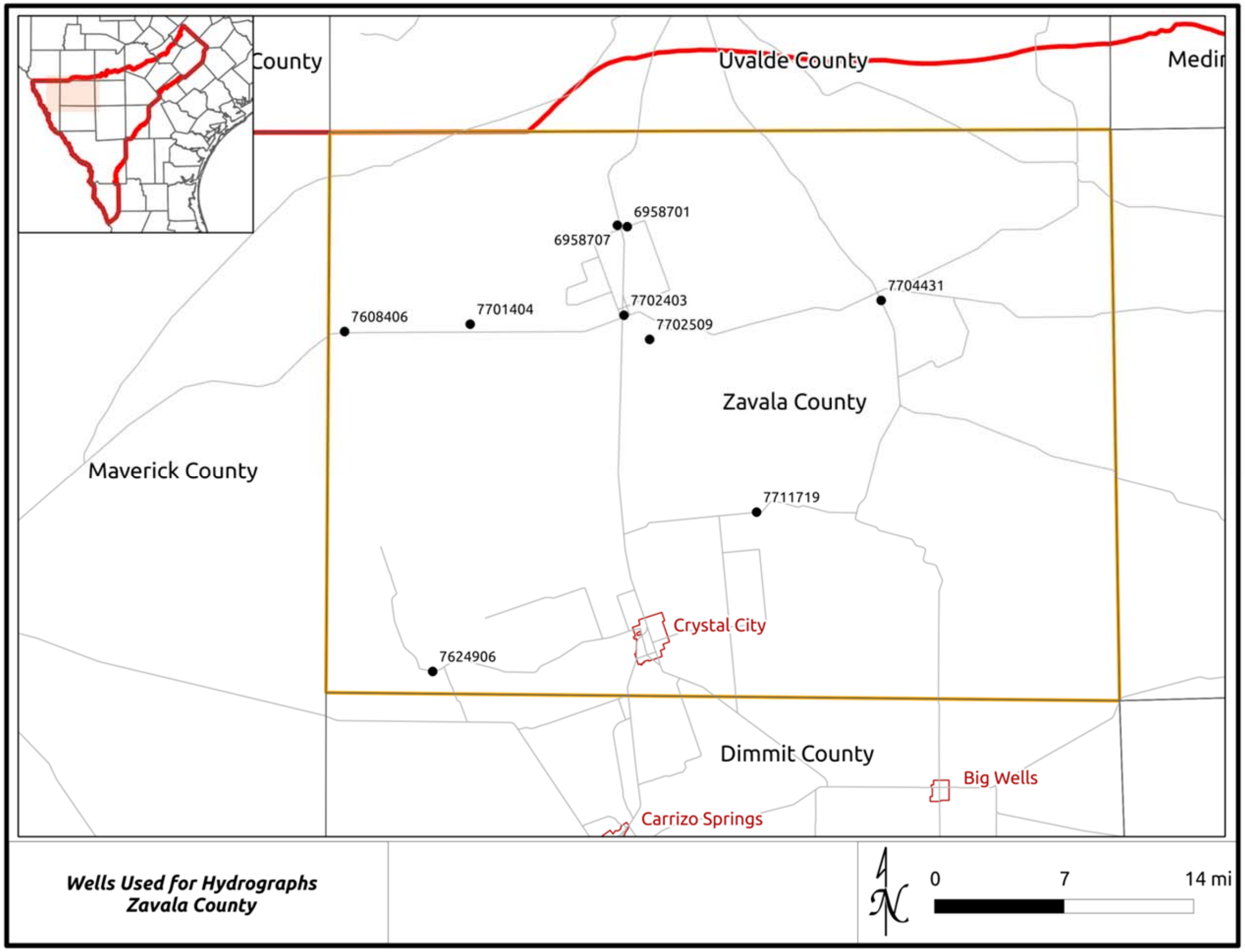
Table analogous to Table 5 in text summarizing annual average drawdown (actual and DFC)

Histogram of Differences between DFC Drawdown and Actual Drawdown for All Years

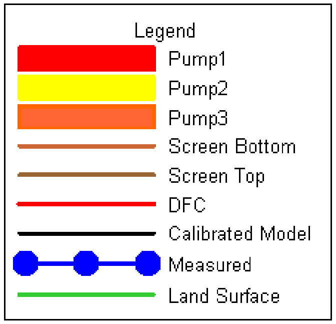
Figure analogous to Figure 23 in text showing differences between actual drawdown and DFC conditions

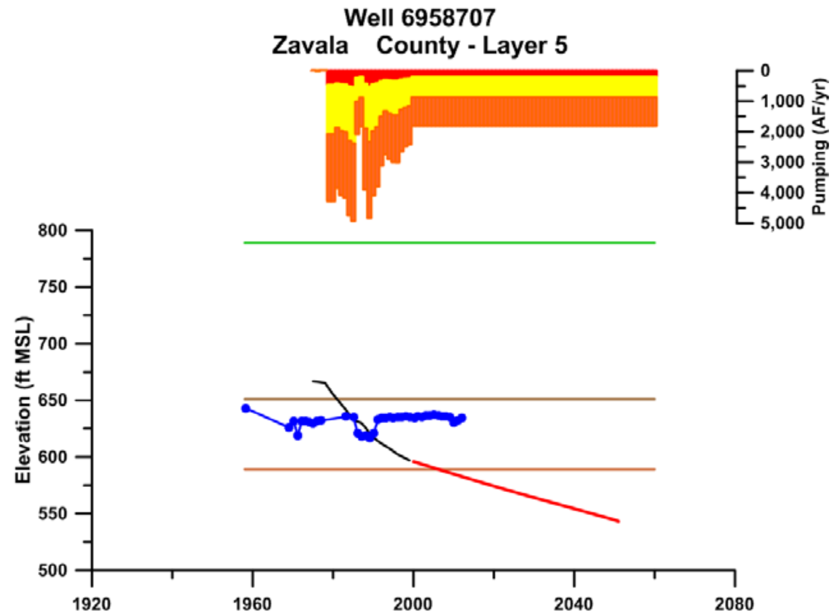
Hydrograph of Actual Drawdown and DFC Drawdown

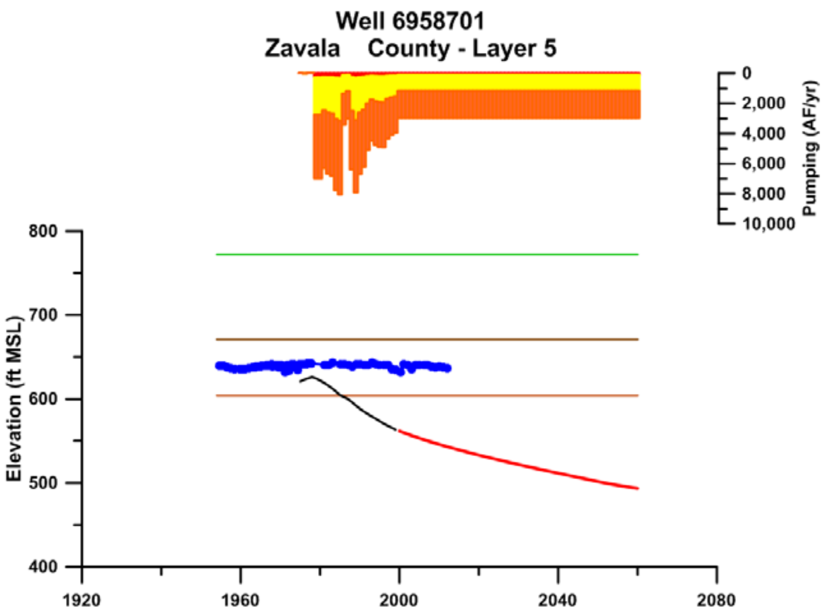
Figure analogous to Figure 26 in text showing time history of drawdown (actual and DFC) from 2000 to 2011

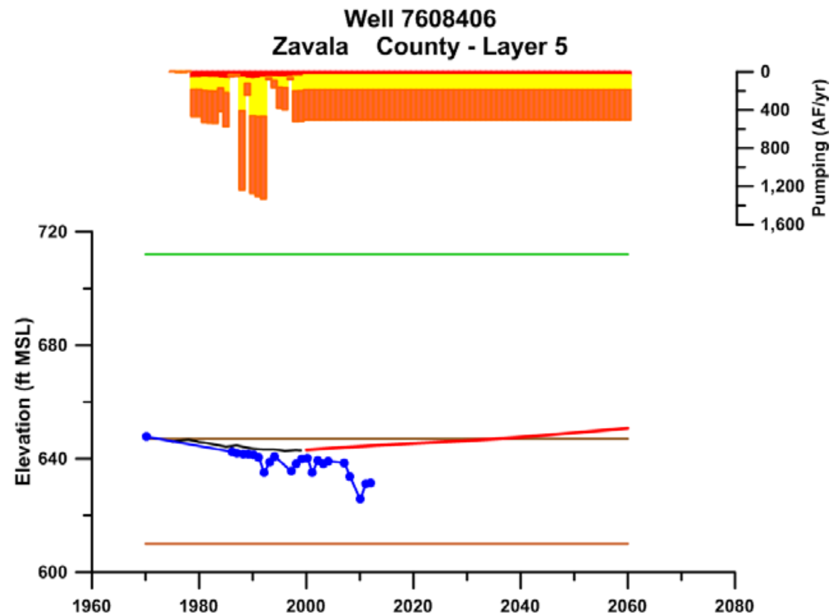


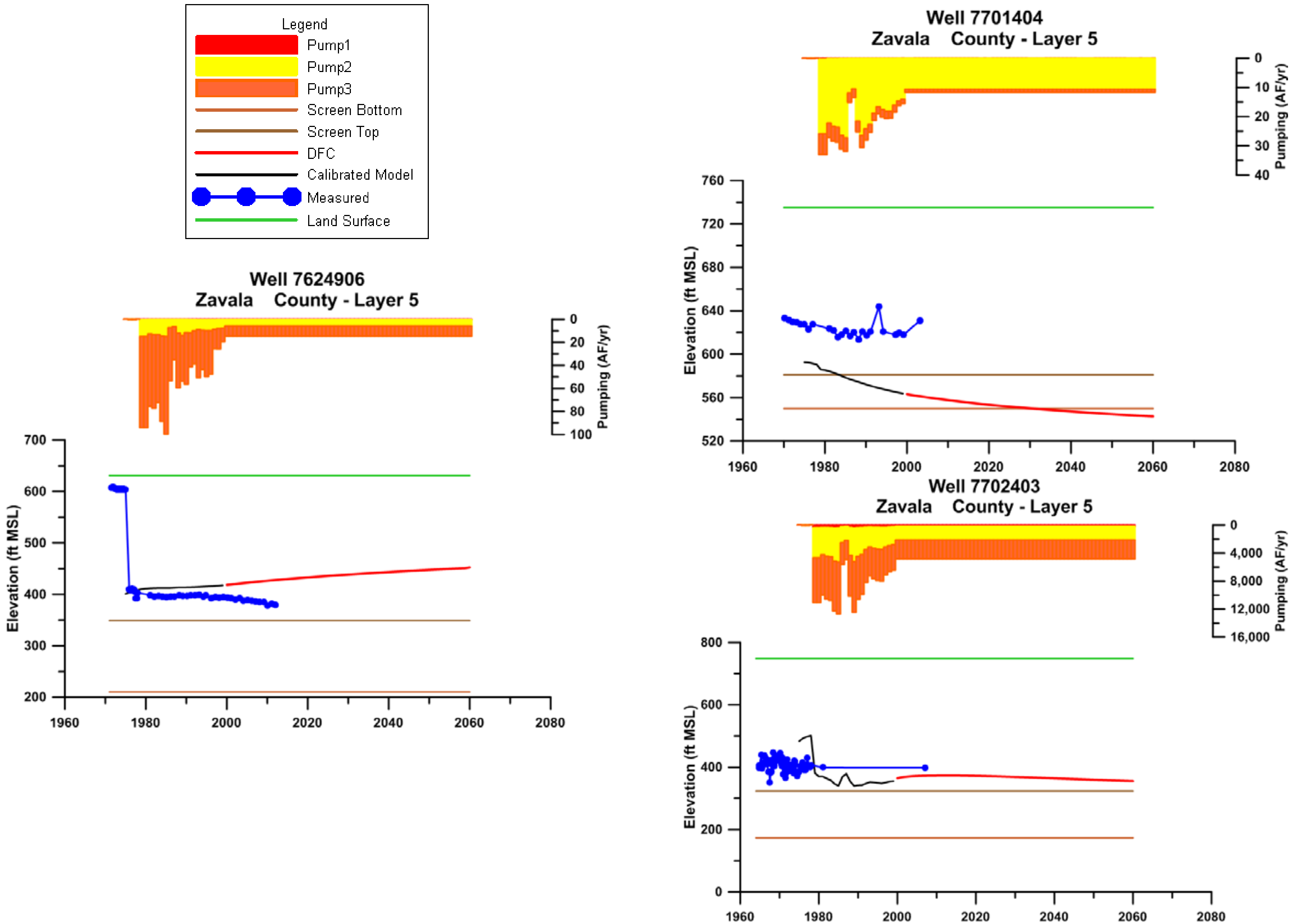
Location Map of Wells with Hydrographs – Zavala County


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface

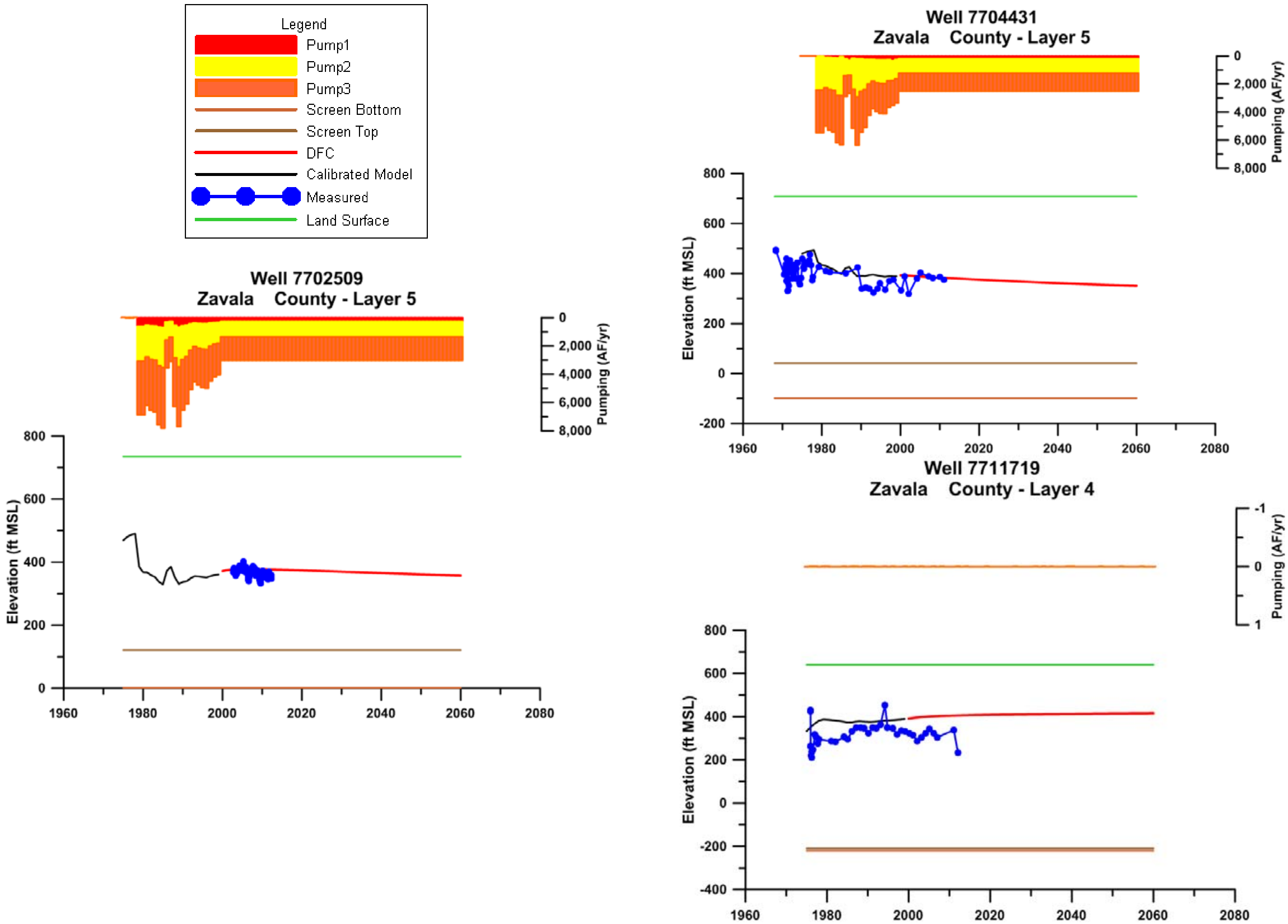

Well 6958707
Zavala County - Layer 5
Pumping (AF/yr)
0
1,000
2,000
3,000
4,000
5,000
Elevation (ft MSL)
800
750
700
650
600
550
500
1920
1960
2000
2040
2080

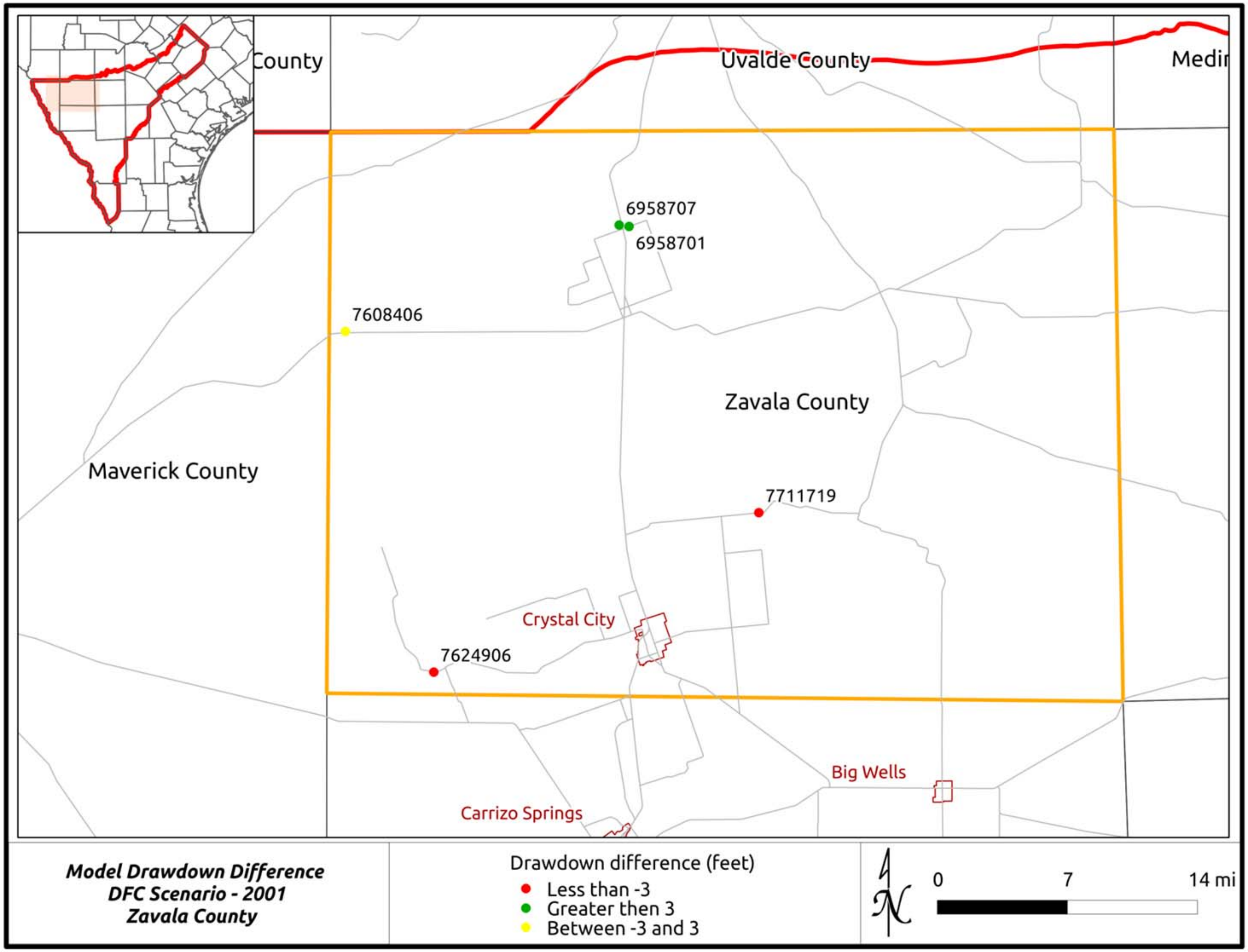

Well 6958701
Zavala County - Layer 5
Pumping (AF/yr)
0
2,000
4,000
6,000
8,000
10,000
Elevation (ft MSL)
800
700
600
500
400
1920
1960
2000
2040
2080

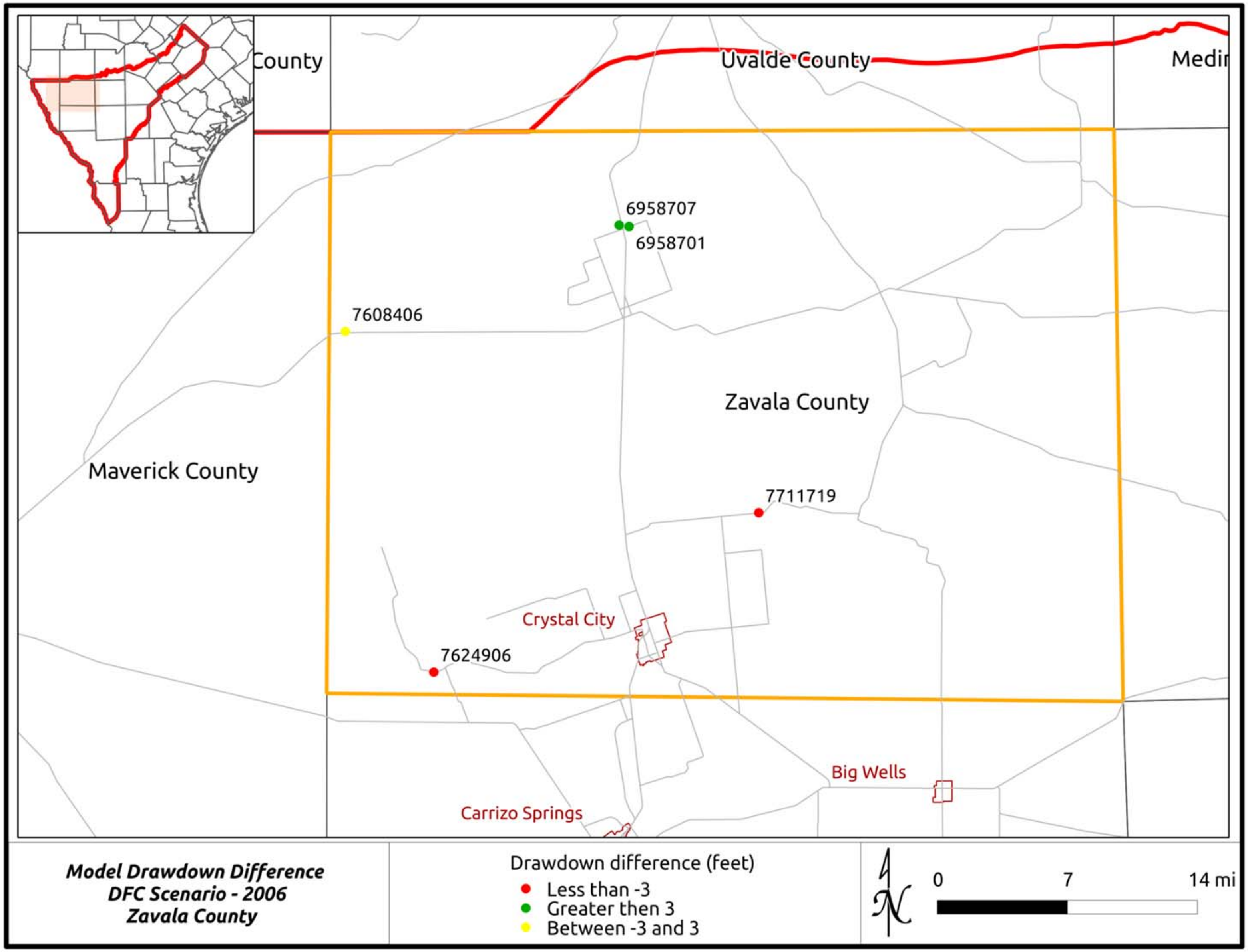

Well 7608406
Zavala County - Layer 5
Pumping (AF/yr)
0
400
800
1,200
1,600
Elevation (ft MSL)
720
680
640
600
1960
1980
2000
2020
2040
2060
2080

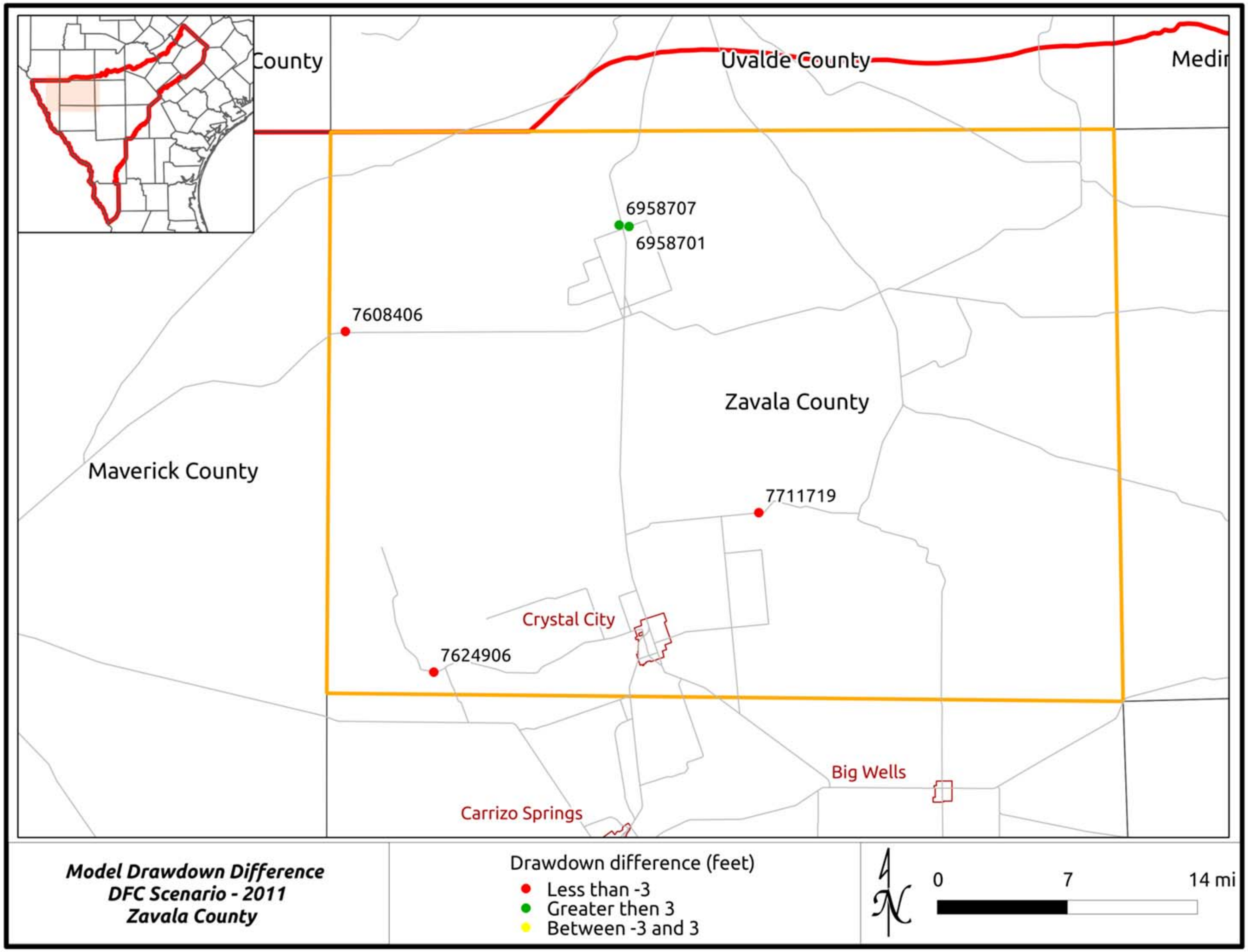


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 7624906
Zavala County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 7701404
Zavala County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
Well 7702403
Zavala County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)


Legend
Pump1
Pump2
Pump3
Screen Bottom
Screen Top
DFC
Calibrated Model
Measured
Land Surface
Well 7702509
Zavala County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
2,000
4,000
6,000
8,000
800
600
400
200
0
1960
1980
2000
2020
2040
2060
2080
Well 7704431
Zavala County - Layer 5
Elevation (ft MSL)
Pumping (AF/yr)
0
2,000
4,000
6,000
8,000
800
600
400
200
0
-200
1960
1980
2000
2020
2040
2060
2080
Well 7711719
Zavala County - Layer 4
Elevation (ft MSL)
Pumping (AF/yr)
-1
0
1
800
600
400
200
0
-200
-400
1960
1980
2000
2020
2040
2060
2080


County
Uvalde County
Medir
6958707
6958701
7608406
Zavala County
Maverick County
7711719
Crystal City
7624906
Big Wells
Carrizo Springs
Model Drawdown Difference
DFC Scenario - 2001
Zavala County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
7
14 mi

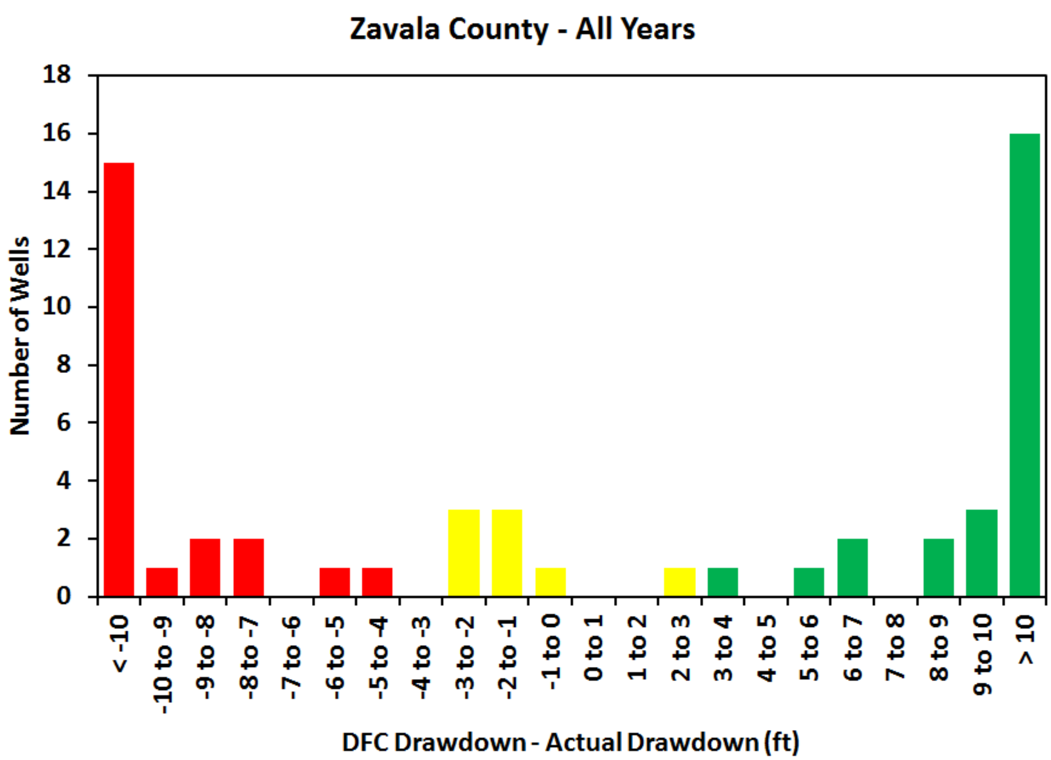

County
Uvalde County
Medir
6958707
6958701
7608406
Zavala County
Maverick County
7711719
Crystal City
7624906
Big Wells
Carrizo Springs
Model Drawdown Difference
DFC Scenario - 2006
Zavala County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
0
7
14 mi

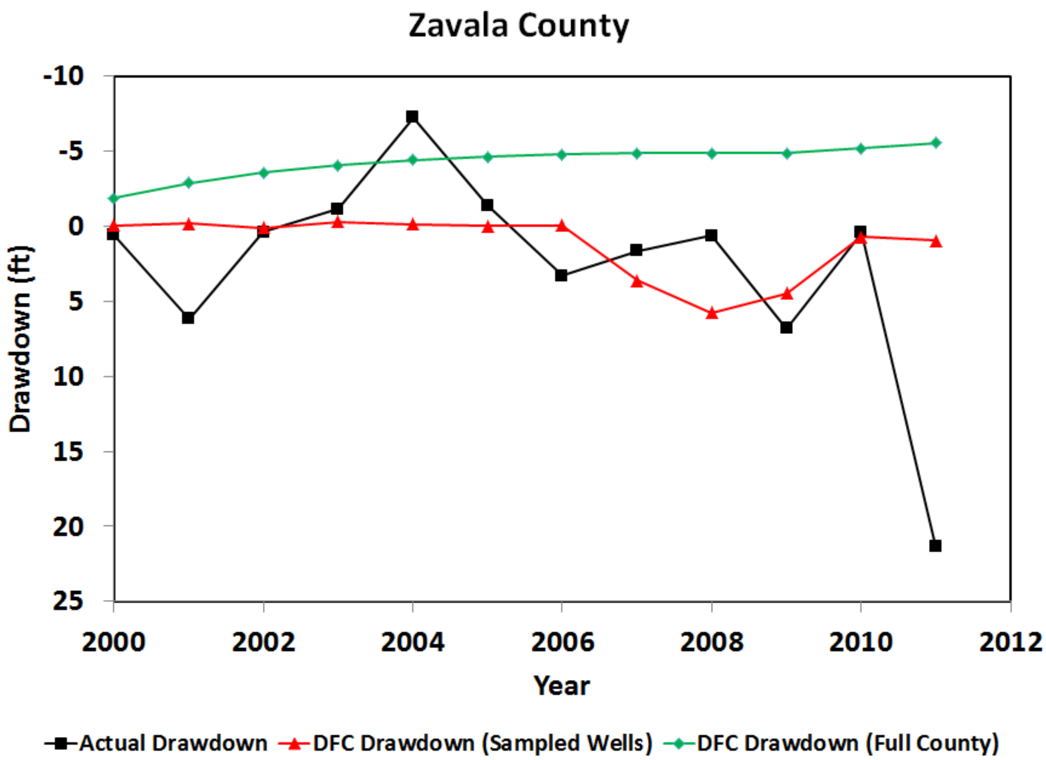


County
Uvalde County
Medir
6958707
6958701
7608406
Zavala County
Maverick County
7711719
Crystal City
7624906
Big Wells
Carrizo Springs
Model Drawdown Difference
DFC Scenario - 2011
Zavala County
Drawdown difference (feet)
Less than -3
Greater then 3
Between -3 and 3
N
0
7
14 mi

Summary of Drawdown Comparisons - Zavala County

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Year	**Precipitation (% Avg)**	**County-Wide Average DFC**	**Number of Actual Drawdown Data Points**	**Average Actual Drawdown for Wells with Data**	**Average DFC for Wells with Data**	**Column 6 minus Column 5**
2000	90	-1.86	5	0.60	-0.05	-0.65
2001	101	-2.88	5	6.18	-0.17	-6.35
2002	113	-3.58	6	0.42	0.11	-0.31
2003	96	-4.06	5	-1.13	-0.29	0.85
2004	132	-4.40	4	-7.26	-0.15	7.11
2005	75	-4.63	4	-1.39	-0.01	1.38
2006	86	-4.77	5	3.32	-0.05	-3.36
2007	142	-4.85	4	1.66	3.62	1.97
2008	74	-4.87	3	0.62	5.78	5.15
2009	76	-4.85	4	6.84	4.46	-2.38
2010	132	-5.17	5	0.43	0.73	0.30
2011	45	-5.54	5	21.30	0.96	-20.34




Zavala County
-10
-5
0
5
10
15
20
25
Drawdown (ft)
2000
2002
2004
2006
2008
2010
2012
Year
Actual Drawdown
DFC Drawdown (Sampled Wells)
DFC Drawdown (Full County)

Appendix 16 – Responses to Comments from Draft Report dated December 21, 2012

Email from Jay Troell on February 13, 2013 containing 11 numbered comments.

Forwarded email from Louis Rosenberg on February 14, 2013 with comments from James Bene and a summary of the comment from Mr. Rosenberg.

Comments from Jay Troell, Larry Fox and Arthur Troell

1. Why do the numbers on Table 2, page 9 differ from Scenario 4 of GAM Run 09-034 since Table 2 is supposedly from Scenario 4 of GAM Run 09-034?

Table 5 from GAM Run 09-034 that summarized the drawdowns from Scenario 4 is presented below:

	Groundwater Management Area 13 drawdowns in feet - scenario 4									
County	Sparta	Weches	Queen City	Reklaw	Carrizo	Layer 6	Layer 7	Layer 8	Wilcox Overall	Overall
Atascosa	10	13	15	43	74	74	85	145	102	62
Bexar	0	0	0	8	64	48	37	136	94	90
Caldwell	0	0	5	16	97	93	52	65	64	63
Dimmit	-2	3	-4	-14	-17	-17	-22	-18	-19	-15
Frio	4	3	-3	19	39	38	31	35	35	24
Gonzales	21	26	32	60	94	94	88	82	88	65
Guadalupe	0	0	-11	5	54	52	20	31	30	32
Karnes	17	27	34	60	85	85	61	88	78	57
La Salle	7	8	9	11	12	12	-1	-9	1	6
Maverick	0	0	0	1	-8	-12	-11	-3	-7	-7
McMullen	25	29	32	39	45	44	12	9	22	29
Medina	0	0	0	-1	29	29	28	28	28	28
Uvalde	0	0	0	0	1	0	12	30	22	19
Webb	-7	-4	-9	-5	-4	-3	-1	-3	-2	-4
Wilson	7	13	13	43	75	75	78	153	102	68
Zavala	-7	-5	-13	-14	2	0	-5	-3	-3	-5
Overall	9	11	7	17	31	31	25	38	31	23

Table 2, page 9 from this report is presented below:

County	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	GMA 13
Atascosa	10	13	15	43	74	74	85	145	62
Bexar				8	64	48	37	136	90
Caldwell			5	16	96	92	51	65	63
Dimmit	-2	3	-4	-14	-17	-17	-22	-18	-15
Frio	4	3	-3	19	39	38	31	35	24
Gonzales	21	26	32	60	94	94	88	81	65
Guadalupe			-13	5	52	50	20	31	31
Karnes	17	27	34	60	86	85	61	88	57
LaSalle	7	8	9	11	12	12	-1	-9	6
Maverick				1	-8	-12	-11	-3	-7
McMullen	25	29	32	39	45	44	12	9	29
Medina				-1	29	29	28	28	28
Uvalde					1	3	12	30	19
Webb	-7	-4	-9	-5	-4	-3	-1	-3	-4
Wilson	7	13	13	43	75	75	78	153	68
Zavala	-7	-5	-13	-14	2	0	-5	-3	-5
GMA13	9	11	7	17	31	31	25	38	23

The biggest difference in these tables is that GAM Run 09-034 did not account for county-layer splits that had no active cells in the model (please see discussion in the report on page 8 and Table 1). GAM Run 09-034 used a default value of zero drawdown and this report simply reported blank values when there were no active cells.

Individual differences in the tables are summarized below, with the drawdown value from GAM Run 09-034 reported first, and the drawdown value from this report presented second:

- Caldwell County, Layer 5 (97 vs. 96)
- Guadalupe County, Layer 5 (54 vs. 52)
- Karnes County, Layer 5 (85 vs. 86)
- Caldwell County, Layer 6 (93 vs. 92)
- Guadalupe County, Layer 6 (52 vs. 50)
- Uvalde County, Layer 6 (0 vs. 3)
- Caldwell County, Layer 7 (52 vs. 51)
- Gonzales County, Layer 8 (82 vs. 81)
- Guadalupe County, GMA 13 (32 vs. 31)

In most cases, the difference is a foot. Two of the differences are two feet, and one is three feet. The method used to develop the estimates in GAM Run 09-034 was different than that used to develop the table in this report. Rounding error and the fact that different methods were used are the reasons for these slight differences.

It would be helpful for the reader to define/label the "Layers" in Table 1 and Table 2, i.e. Layer 1 (Sparta Aquifer), Layer 2 (Weches Formation), Layer 3 (Queen City Aquifer), Layer 4 (Reklaw Formation), Layer 5 (Carrizo Aquifer), Layer 6 (upper Wilcox Aquifer), Layer 7 (middle Wilcox Aquifer), Layer 8 (lower Wilcox Aquifer).

The reason that I simply reported the layer number and did not attach a name to the layer was addressed at the November 15, 2012 GMA 13 meeting. I presented a series of slides at that meeting that compared the well completions (screen top and bottom elevation) that defined what layer the wells were located in with the TWDB assignment of aquifer units. Assuming that the TWDB aquifer designations are accurate, this analysis suggests that the model layering did not always honor the stratigraphy. Alternatively, if the model layers are assumed accurate, then the TWDB aquifer designations have errors. Although the possibility of some errors in the TWDB aquifer designations are likely, it is more likely that the model layers do not always accurately honor the stratigraphy.

2. Figure 5, page 10 shows pumping of about 70,000 AF/yr for Atascosa County in 2000 and 80,000 AF/yr in 2060. Please explain why the increase will be only 10,000 AF/yr.

All pumping changes were specified by the groundwater conservation districts in GMA 13 during the development of the DFC.

3. The largest draw-down will occur in northern Atascosa of 110 ft. From 2000 to 2060 northern Atascosa County and Bexar County will be highly pumped areas so why are Carrizo well data on either side of SAWS ASR unit not being used? The

only monitor well in Bexar County is a Wilcox well at Elmendorf.

4. Utilizing only 11 monitor wells in Atascosa County which covers over 1200 sq. miles seems way too few. Aren't more wells available? The Evergreen is monitoring at least 83 wells in the district, and should have more than 11 in Atascosa County.

Monitoring well data at San Miguel Electric Power Plant should be included.

These comments all involve the omission of specific wells or the number of wells in general. This effort was limited to data contained within the TWDB database in order to provide a consistent, reliable, and publically available set of data to evaluate DFCs. Moreover, in order to complete the task of comparing monitoring data to DFC drawdowns, it was necessary to further constrain the data set to wells that had a measurement in late 1999 or early 2000 to provide a basis for a drawdown calculation that were consistent with the DFC.

There are other wells that could be used by individual groundwater conservation districts to advance their own groundwater management objectives. However, the scope of this effort was specific to TWDB database wells with the constraint on the existence of a measurement in late 1999 or early 2000. The overall approach was designed to use data that were available. Future efforts to expand the monitoring network to include more wells are needed and should be developed by individual districts.

5. Map scale: rather than use 1-inch ~= 10 miles in your maps why not use a scale of 1:16000 (1-inch ~= 3 miles) for better readability for those who need to drill wells, etc.

The maps were intended to show the distribution of wells used in the analysis and summarize the results. The maps and this analysis are not suitable for identifying new well locations.

6. For evaluation of your model runs please show the pumping volume input data and assumptions, an example table is included on the last two pages. Input data for Carrizo and Wilcox should be shown separately.

The model runs were completed as part of the DFC development process, not as part of this effort. Table 5 in GAM Run 09-034 (shown below) has a breakdown of the pumping in 2060 by county and model layer. Decadal totals for each county can be seen in Figure 4 to 20 of this report. The detail that is suggested is beyond the scope of this effort, and the ability to breakdown pumping by type of use is generally not possible from the data in GAM Run 09-034. Future efforts may well include this level of detail, if the committee members decide to break the pumping down in this manner.

Table 5. Groundwater Management Area 13 pumpage in acre-feet per year used in model - scenario 4

County	Sparta	Queen City	Carrizo	Layer 6	Layer 7	Layer 8	Total
Atascosa	994	4,202	58,308	250	250	17,000	81,004
Bexar	0	0	9,107	0	0	17,000	26,107
Caldwell	0	307	22,809	0	7,372	13,441	43,929
Dimmit	0	0	2,188	991	142	38	3,359
Frio	601	3,983	70,030	0	0	0	74,614
Gonzales	3,552	5,065	50,121	0	9,577	16,272	84,587
Guadalupe	0	0	9,500	0	2,994	1,549	14,043
Karnes (GMA 13)	0	0	1,280	0	0	0	1,280
Karnes (GMA 15)	0	0	601	0	0	0	601
La Salle	987	1	4,263	1,952	189	50	7,442
Maverick	0	0	143	136	259	992	1,530
McMullen (GMA 13)	90	136	1,819	0	0	0	2,045
McMullen (GMA 16)	10	14	181	0	0	0	205
Medina	0	0	400	0	1,248	886	2,534
Uvalde	0	0	828	0	0	0	828
Webb	0	0	896	13	6	1	916
Wilson	140	845	27,549	125	121	17,000	45,780
Zavala	0	0	24,649	6,316	3,676	328	34,969
Total (GMA 13)	6,364	14,539	283,890	9,783	25,834	84,557	424,967

7. Recharge water. What is the basis for recharge: average value over what period? average value during the drought of record (worst case - i.e. 1950's)? last 10-years average? please explain how the "average" recharge is determined and if this is to be varied by year/decade or held constant over next 50 years?

What are the recharge values based on? When was the analysis done, how and by whom?

The first full paragraph in the Methods and Results section of GAM Run 09-034 referenced previous GAM runs for the DFC process for "details on parameters and assumptions". One of those referenced documents is GAM Run 08-43, which stated that the recharge rate is an average of historic estimates from 1981 to 1999. This is the calibration period of the model, and the "average" recharge that was used was the average of the recharge estimates from the calibrated model. This average recharge was held constant for the entire simulation on which the DFC is based, and that assumption was the subject of discussion at the GMA 13 meeting and in this report.

8. We need synoptic water level maps through time in addition to the 1935 Lonsdale map, 1965 USGS map, 2000, 2010, and modeled maps for 2020, 2030, 2040, 2050 and 2060.

This request is beyond the scope of this analysis. A map of Scenario 4 drawdown in layer 5 in

2060 was presented as Figure 1 in TWDB GAM Run 11-007 Addendum and is reproduced below:

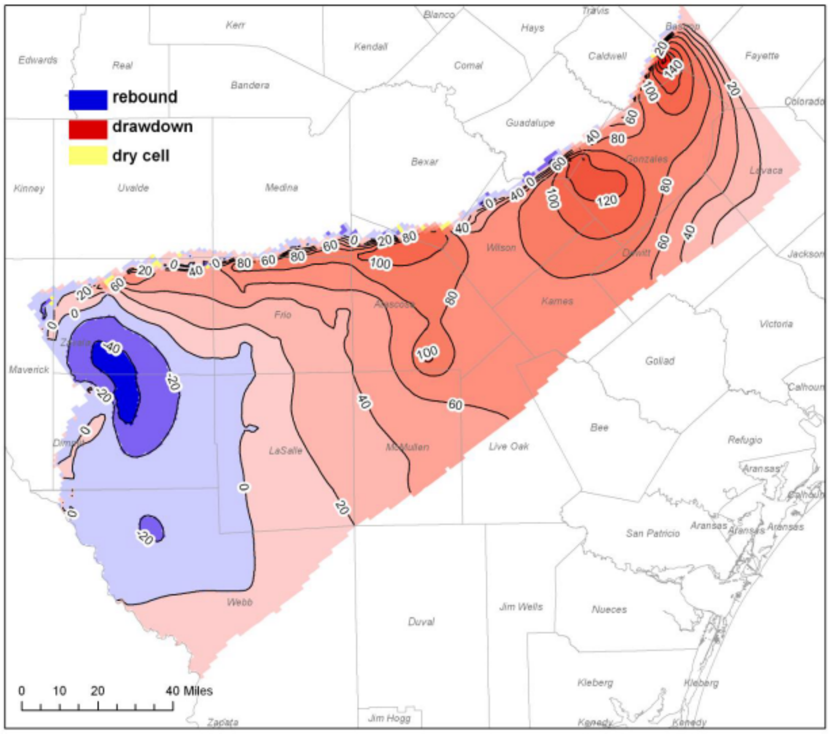
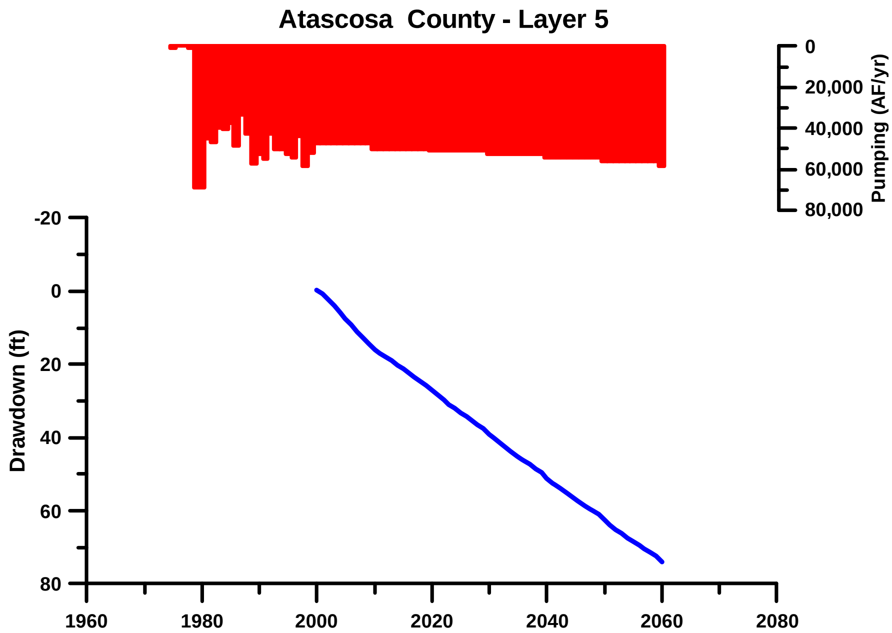


FIGURE 1: ESTIMATED CARRIZO AQUIFER WATER LEVEL DRAWDOWN IN FEET FROM 2000 TO 2060 FOR SCENARIO 4. CONTOUR INTERVAL IS 20 FEET.

9. Figure 5 summary of pumping and draw-down for Atascosa County is misleading because the largest draw-down will occur in the Carrizo, i.e. Carrizo is the most critical source for Atascosa County and its separate draw-down line should be superimposed on Figure 5.

The intent of this series of figures (4 to 20) is to show the range of pumping increases and decreases from 2000 to 2060 that were assumed in the model run and the resulting drawdown and recovery on a county-by-county basis. Similar figures were developed for each county-aquifer split (e.g. Layer 5 in Atascosa County). However, given the scope and objectives of this effort, and at the request at the GMA 13 meeting on November 15, 2012 to present summary level information, a complete set of these figures was not included in the report. The specific graph mentioned in this comment is provided below:



10. Does this report show where withdrawal of hydraulic fracturing water has increased draw-down more than originally predicted by GAM 09-034?

This report covers the model simulations that were completed in 2010 as part of the DFC process, and does not represent the recent increases to pumping for hydraulic fracturing operations. This has been a point of discussion at the GMA 13 meetings and has been identified as something that needs to be addressed in the current joint planning process.

11. More monitor wells need to be included for south Atascosa County (and other counties) where oil companies are drilling water wells for "fracking" operations.

Please see the response above regarding monitoring wells (comments 3 and 4).

Comments from Lou Rosenberg and James Bene

Mr. Rosenberg's comments summarizing Mr. Bene's comment:
DEVELOPING details, but not necessarily completed and sufficient upon which to make major, life defining decisions.

In polite terms, we have a distance to travel for greater courtroom reliability. But progress is in motion, however it is incomplete.

Mr. Bene's comments:
The general consensus is that generating written comments on the report wouldn't be meaningful or helpful at this time because the Board is going to ignore it anyway. My primary beef with the report is that it attempts to draw meaningful conclusions by comparing real-world water level measurements to DFC Scenario 4 model outputs, which is absurd because the pumpage in the model doesn't correspond to real-world pumpage. However, it sounded to me during the last meeting that Bill and everyone else now understands that in order to gage the model's performance over the last decade then real pumpage numbers need to be input. That's what they're working on now: the districts are compiling pumpage records and Bill will decipher their data, insert it into the model, and then make another report.

One of the objectives stated in the report was to "use the findings in the next round of joint planning (i.e. desired future condition development) to make the process more efficient, less costly, and more defendable." This effort identified specific areas where the model simulations that will be used in the current round of joint planning can be improved (e.g. pumping from 2000 to present), and, thus, advance the stated objective.