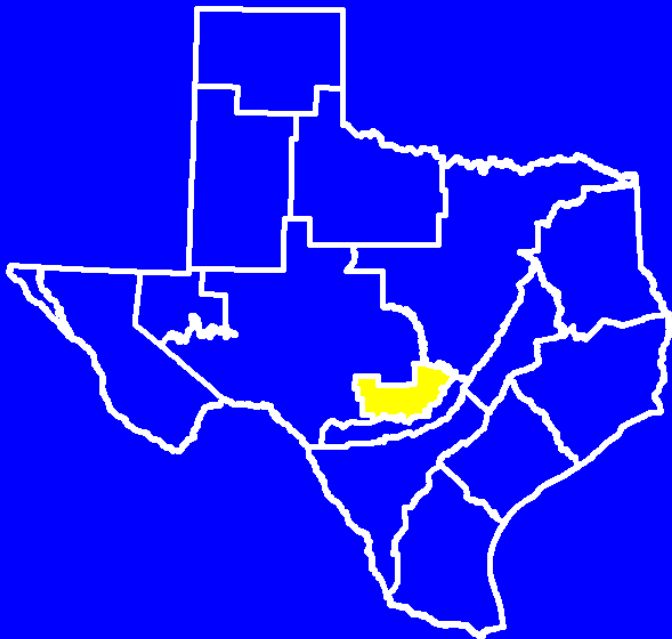


GMA 9

Comparison of Groundwater Monitoring Data with Groundwater Model Results



Bill Hutchison, Ph.D., P.E., P.G.

GMA 9 Meeting

February 11, 2013

Overview

- Brief history of DFC development
- Comparison of monitoring data with groundwater model results
 - Hydrographs
 - Maps
 - Histograms

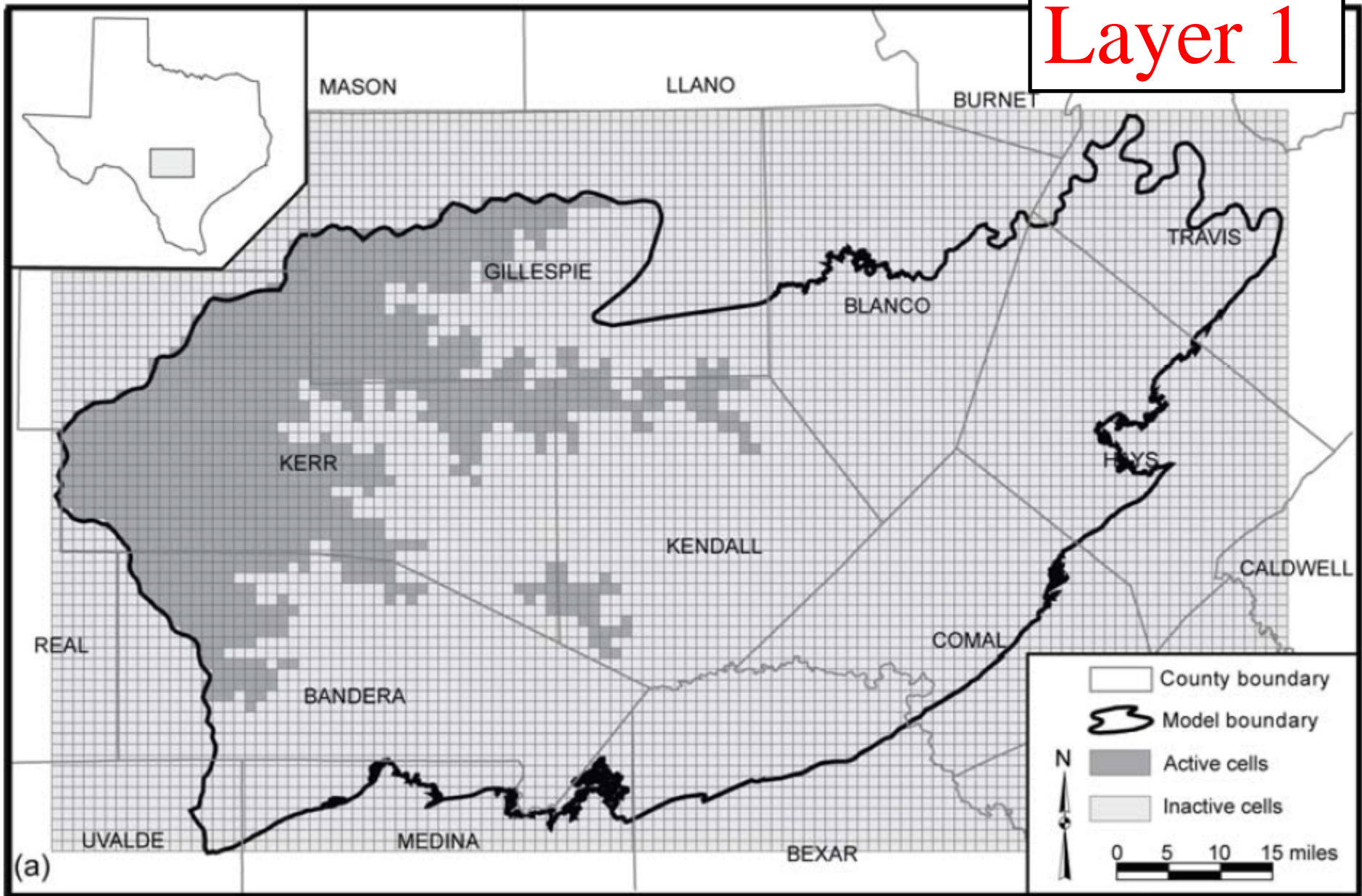
GMA 9 DFC for Trinity Aquifer

- GMA 9 adopted a Desired Future Condition (DFC) for the Trinity Aquifer on July 26, 2010
- DFC establishment relied on results from several model simulations
 - DFC expressed as GMA-wide average (30 ft)
 - Based on Scenario 6 of GAM Task 10-005
 - Relied on Groundwater Availability Model (GAM)

GAM for GMA 9

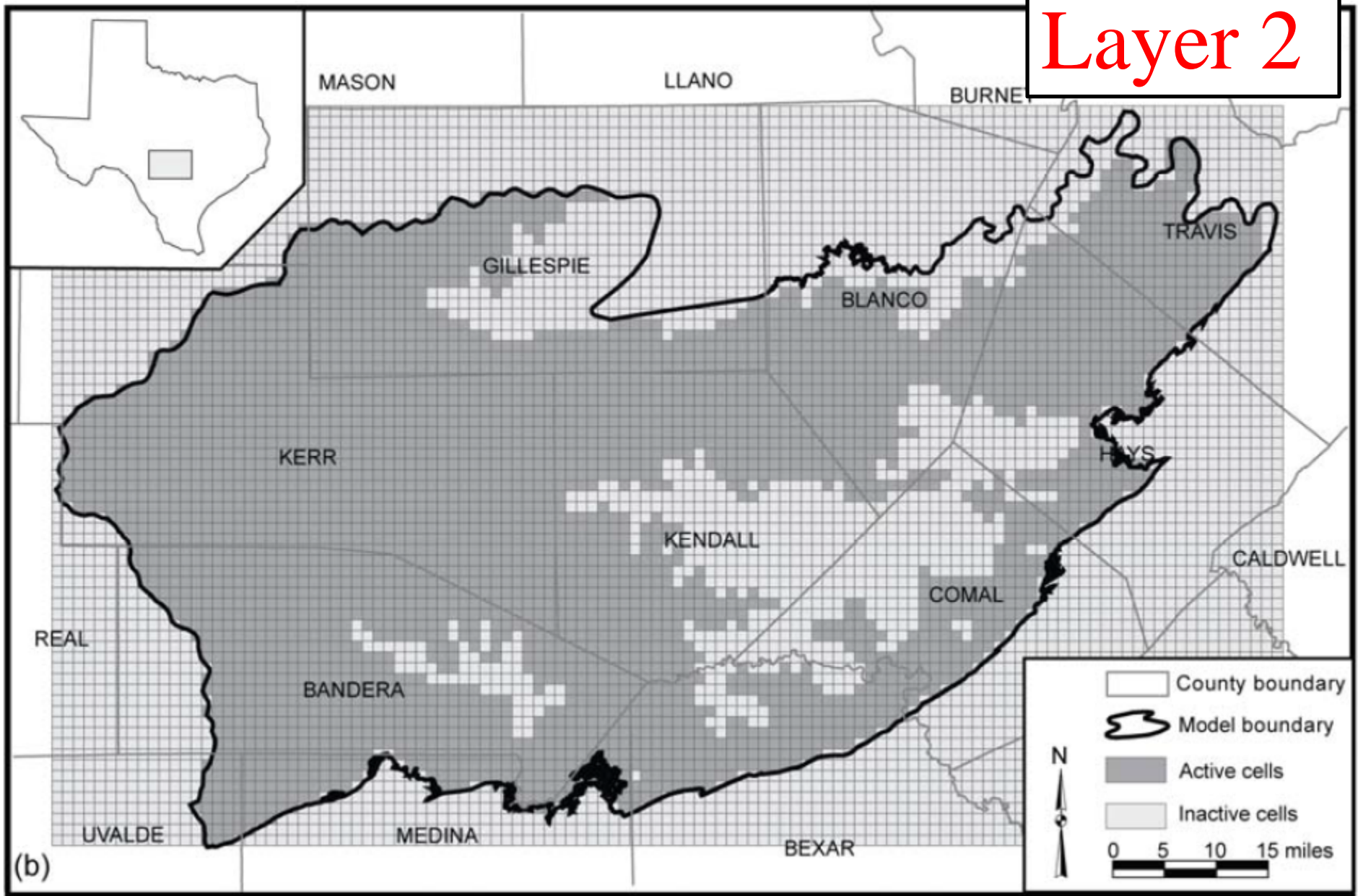
- Edwards and Trinity Aquifers
- One square mile grid cells
 - 69 Rows
 - 115 Columns
 - 4 Layers

Layer 1



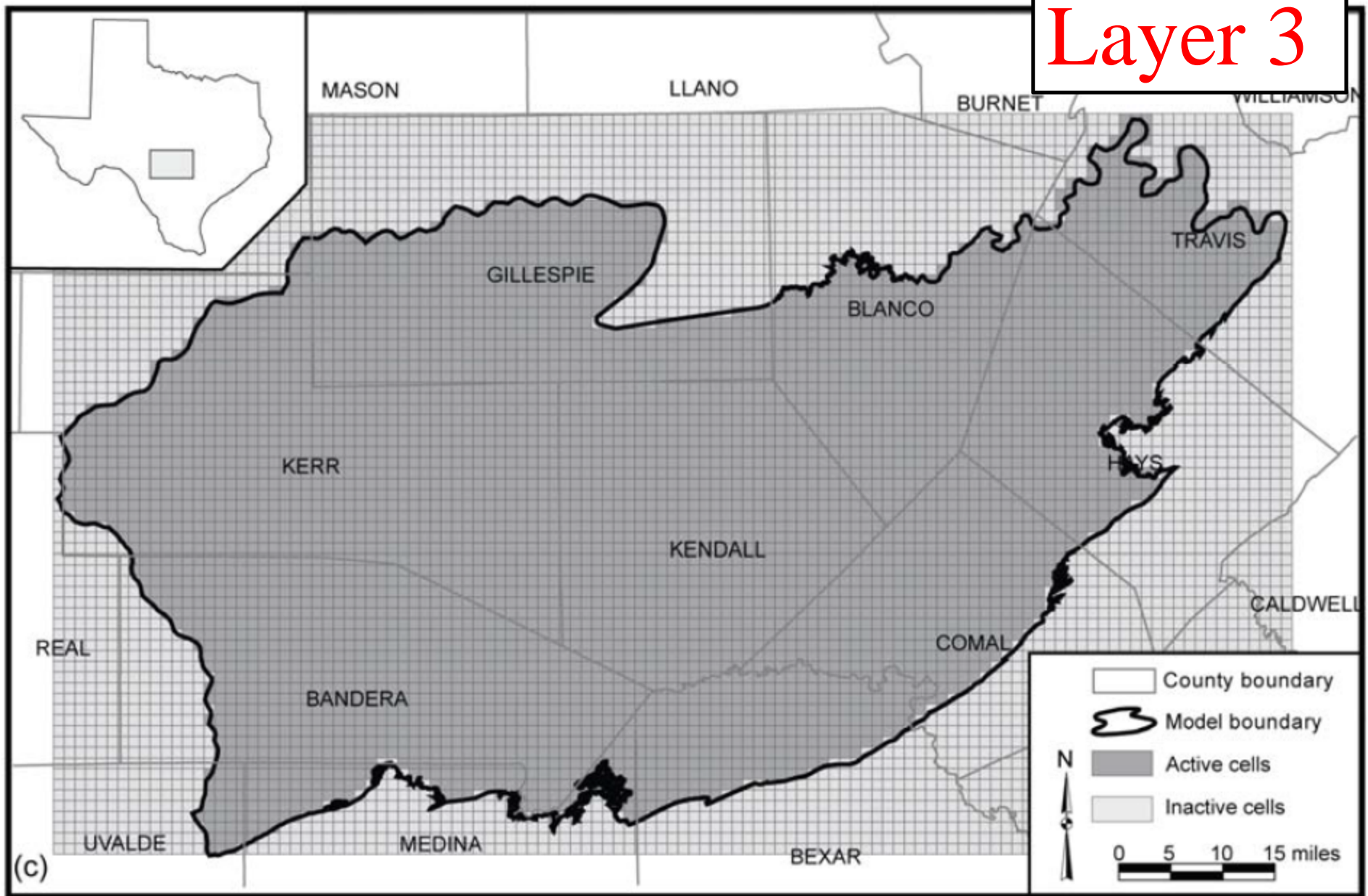
From Jones and others (2009)

Layer 2



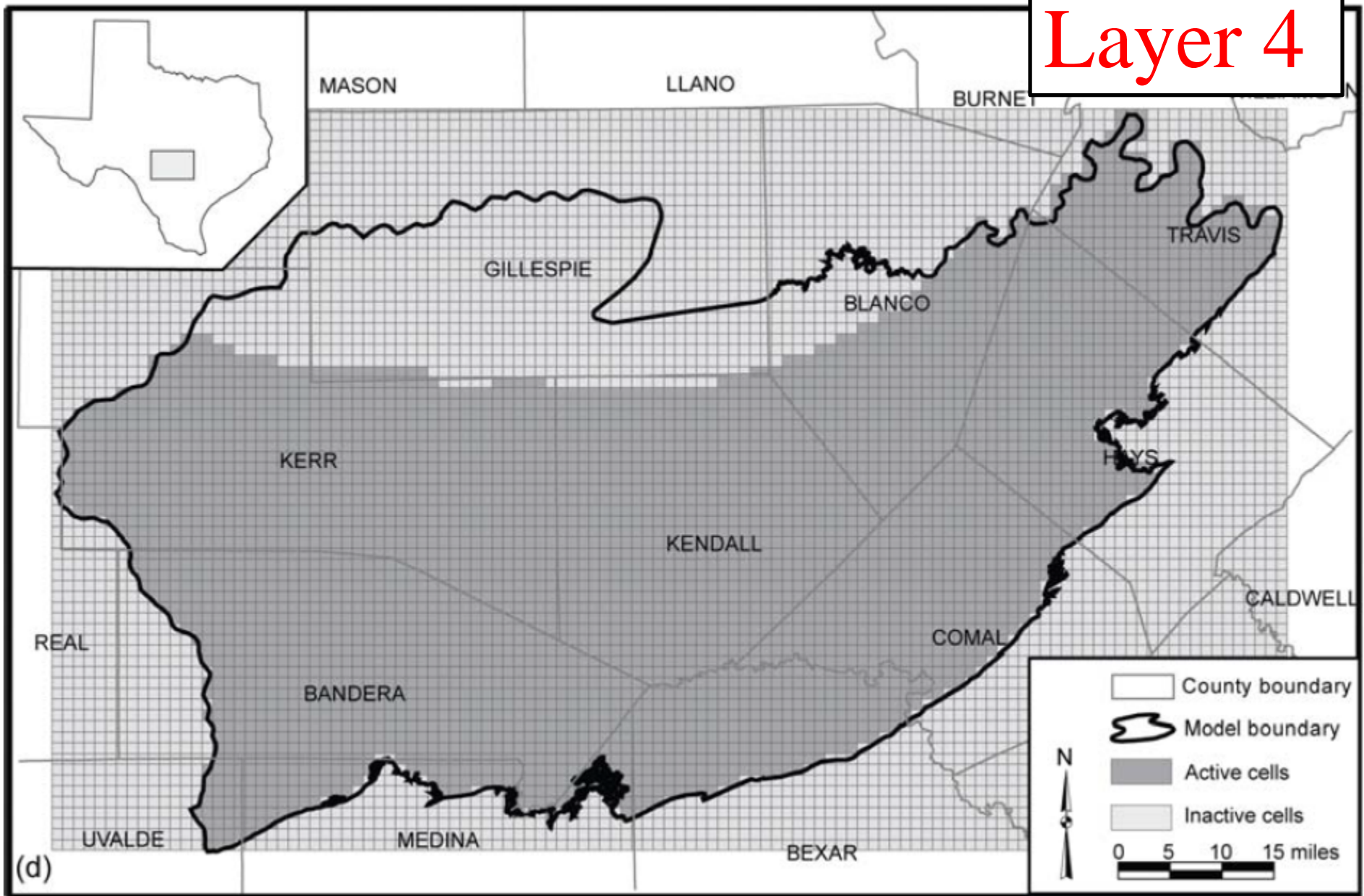
From Jones and others (2009)

Layer 3



From Jones and others (2009)

Layer 4



From Jones and others (2009)

Active Model Cells in GMA 9

County	Layer 1	Layer 2	Layer 3	Layer 4	GMA 9
Bandera	152	620	684	684	2,140
Bexar	0	228	243	243	714
Blanco	0	253	383	294	930
Comal	0	168	338	338	844
Hays	0	294	358	358	1,010
Kendall	88	441	660	645	1,834
Kerr	596	881	881	809	3,167
Medina	0	105	105	105	315
Travis	0	166	212	212	590
GMA 9	836	3,156	3,864	3,688	11,544

“Early” Model Runs

- Recharge:
 - 53 years of average recharge
 - 46 years of average recharge and 7 years drought
- Pumping:
 - 2008 pumping
 - 1.5 x 2008 pumping
 - With and without drought reductions in pumping

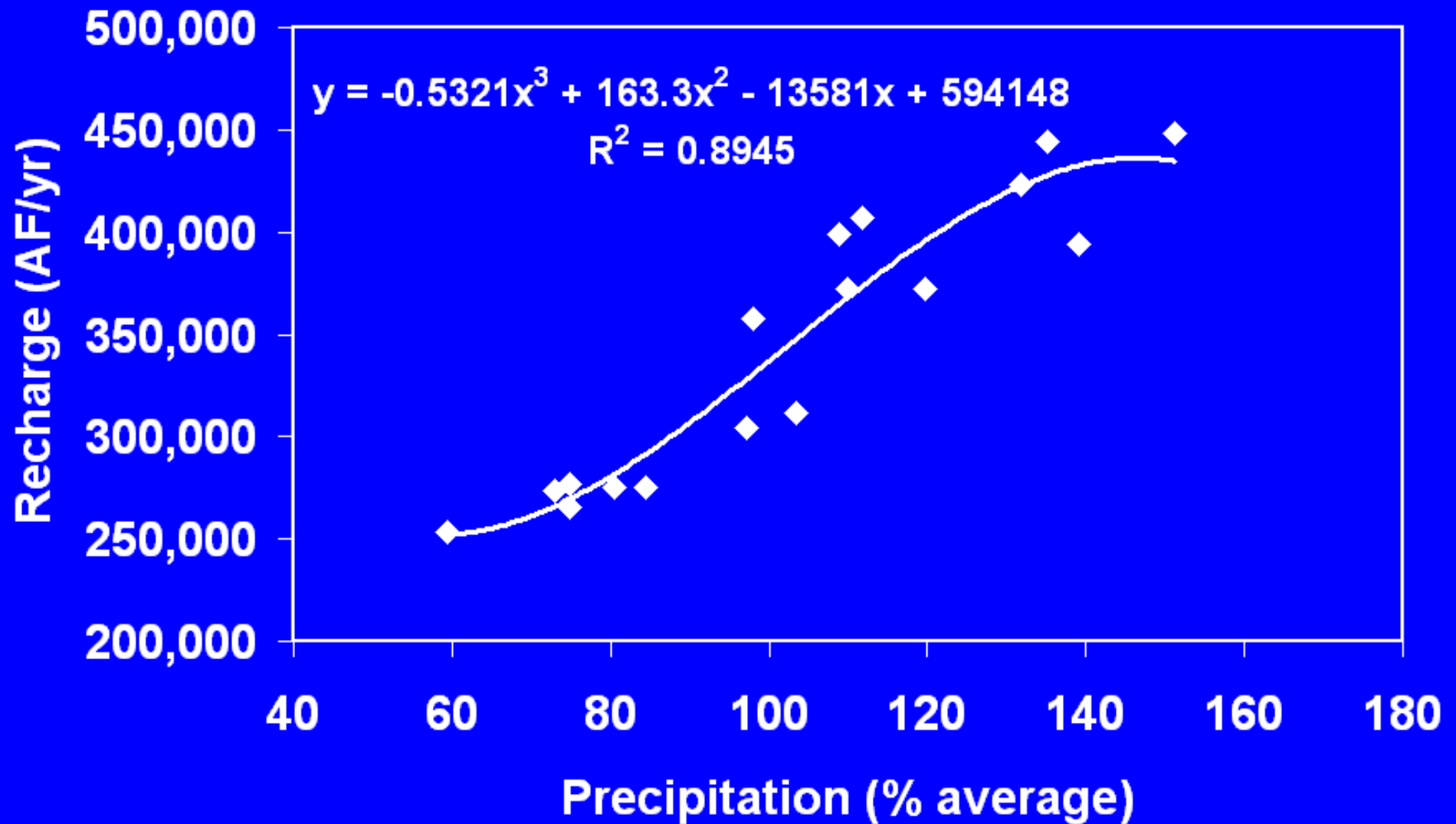
Task 10-005

- Considered variations in pumping
- Considered variations in precipitation/recharge

Precipitation vs. Recharge

- Precipitation from San Marcos and Austin Airport
- Recharge from Hill Country model (1981-1997)

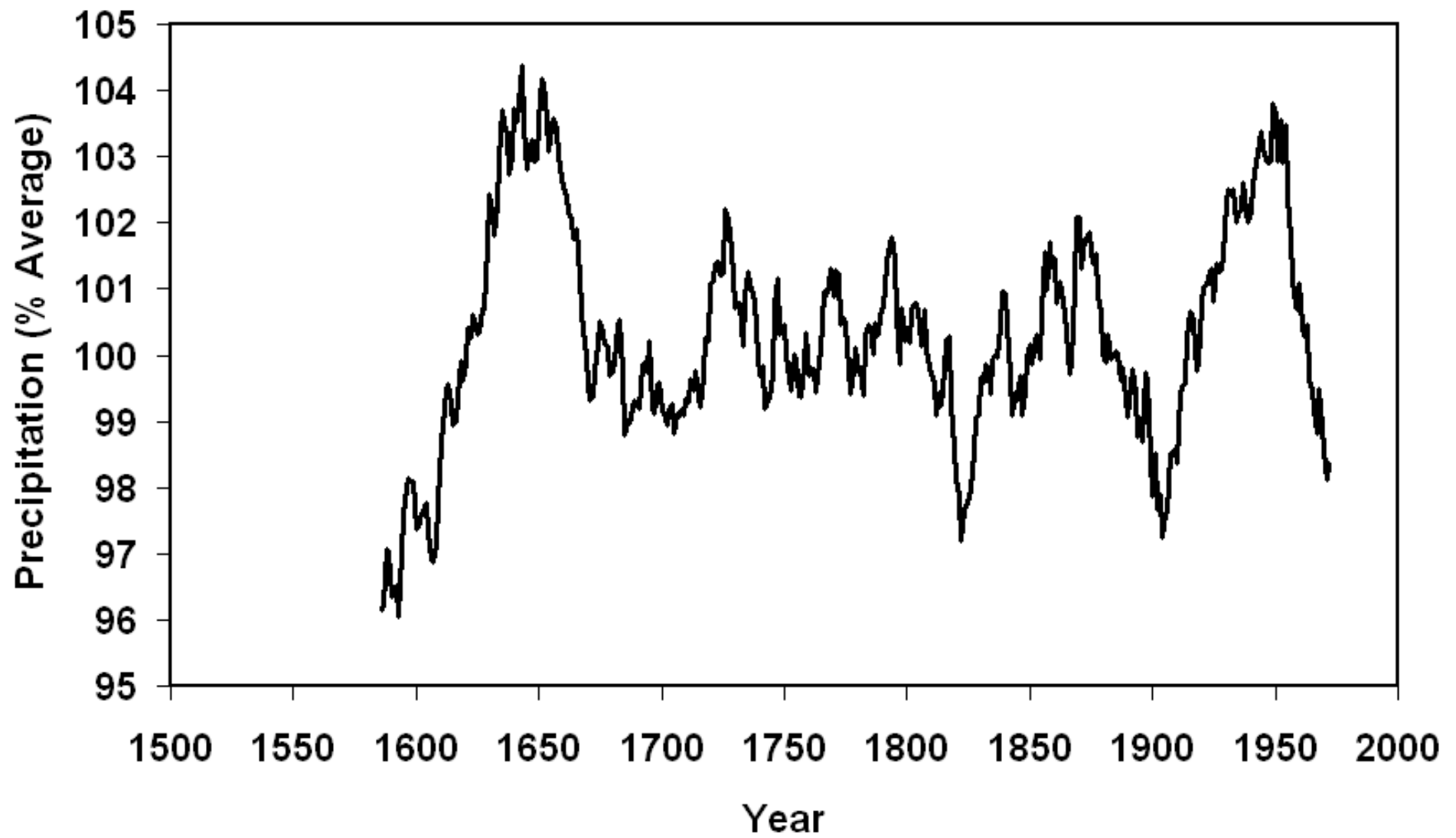
Precipitation vs. Recharge



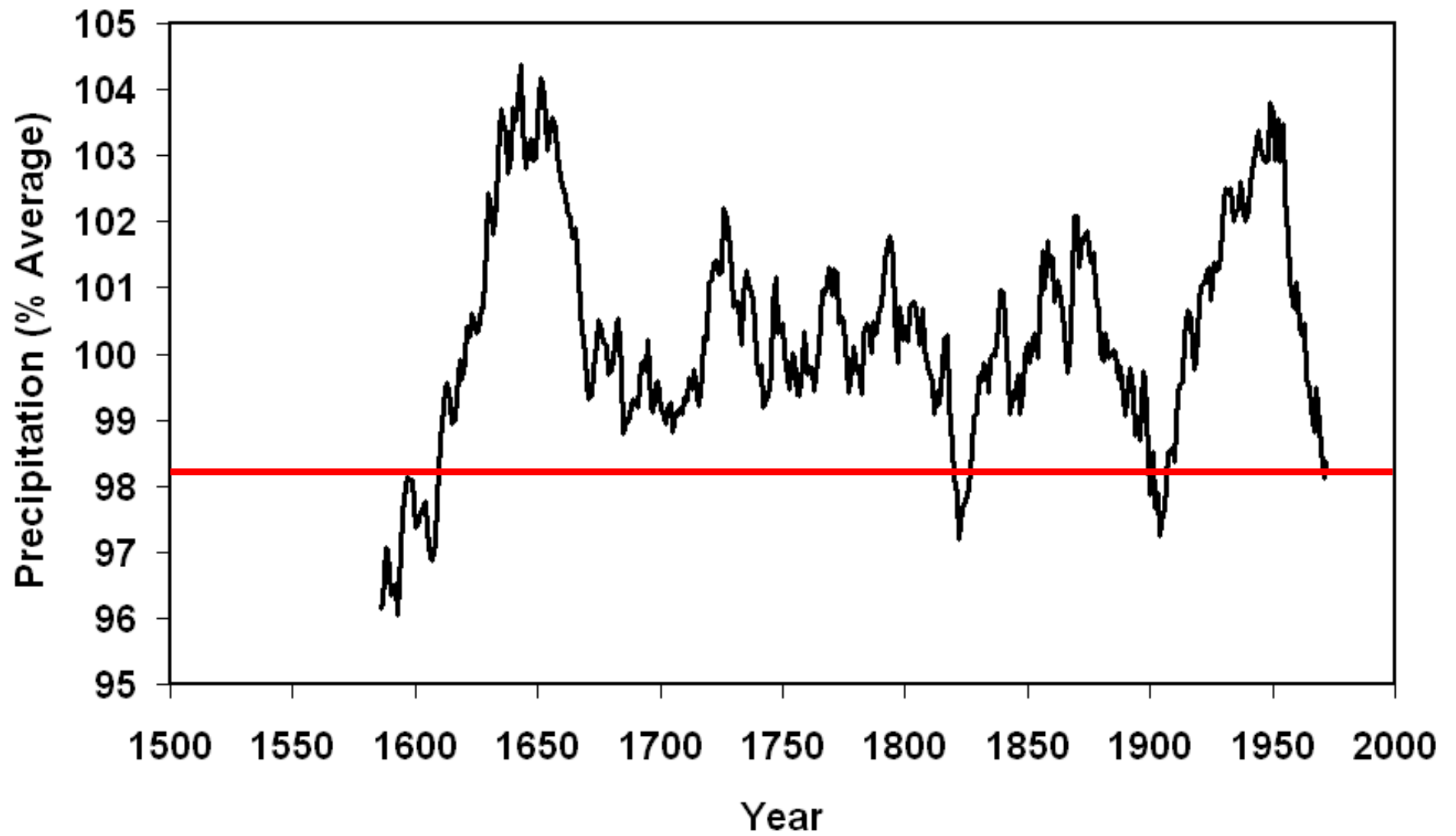
Extending Historic Record of Precipitation

- University of Arkansas study (GBRA)
- Tree ring Record: 1537 – 1972
- Is “drought-of-record” in the 1950s the worst?
- 50-year running averages

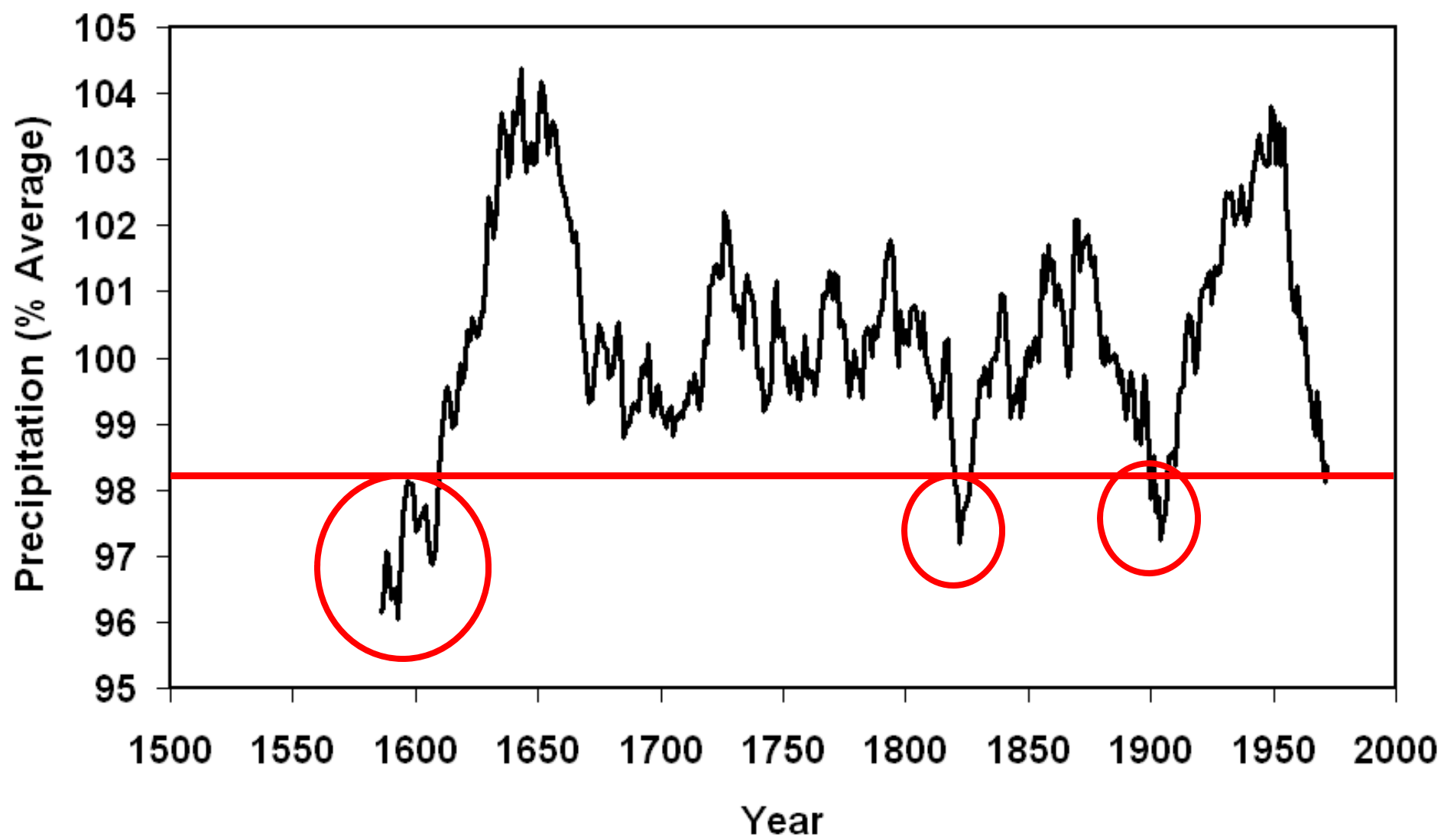
Plateau Region



Plateau Region



Plateau Region



2008 Pumping

- County-by-County Estimates
- Provided by GCDs
- Used as starting point for 7 scenarios

County	Edwards Group of the Edwards- Trinity (Plateau) Aquifer	Upper Trinity Aquifer	Middle Trinity Aquifer	Lower Trinity Aquifer	Total Pumping (County)
Bandera	631	288	3567	515	5,000
Bexar	0	693	14110	197	15,000
Blanco	0	77	1,477	0	1,554
Comal	0	398	5,788	0	6,186
Hays	0	416	4,800	449	5,665
Kendall	315	300	6,060	325	7,000
Kerr	1,035	213	6,263	5,534	13,045
Medina	0	0	500	1000	1,500
Total pumping (aquifer)	1,981	2,936	47,532	8,020	60,468

Pumping Scenarios

- Scenario 1 – 0 AF/yr
- Scenario 2 – 20,000 AF/yr
- Scenario 3 – 40,000 AF/yr
- Scenario 4 – 60,000 AF/yr (2008 pumping)
- Scenario 5 – 80,000 AF/yr
- Scenario 6 – 100,000 AF/yr
- Scenario 7 – 120,000 AF/yr

Tree Ring Record: 1537 – 1972

387 50-year simulations

1. 1537 – 1586
2. 1538 – 1587
3. 1539 – 1588
- ⋮
- ⋮
386. 1922 - 1971
387. 1923 - 1972

Scenario 6 of GAM Task 10-005

- 387 50-year simulations
 - Alternative precipitation and recharge conditions (tree-ring data)
- Specific spatial distribution of pumping
 - About 100,000 AF/yr for all 387 simulations

Calculation of “Average” Drawdown

- Each active cell (one square mile) groundwater elevation calculated at end of each “stress period” (one year)
 - Drawdown in each cell = groundwater elevation at the end of the year of interest minus the groundwater elevation at the initial time (2008)
 - Sum the drawdowns for an area of interest (e.g. county, layer, county-layer, entire GMA)
 - Divide sum of drawdowns by the number of cells

Hypothetical Example of Average Drawdown

2	4	6	4	2
4	6	8	6	4
6	8	10	8	6
4	6	8	6	4
2	4	6	4	2

$$\text{Avg} = 5.2 \text{ ft}$$

Concepts

- 387 drawdown calculations
 - Minimum = lowest
 - 95% Level = more drawdown 95% of the time
 - Average = Average of 387 simulations
 - 5% Level = more drawdown 5% of the time
 - Maximum = highest

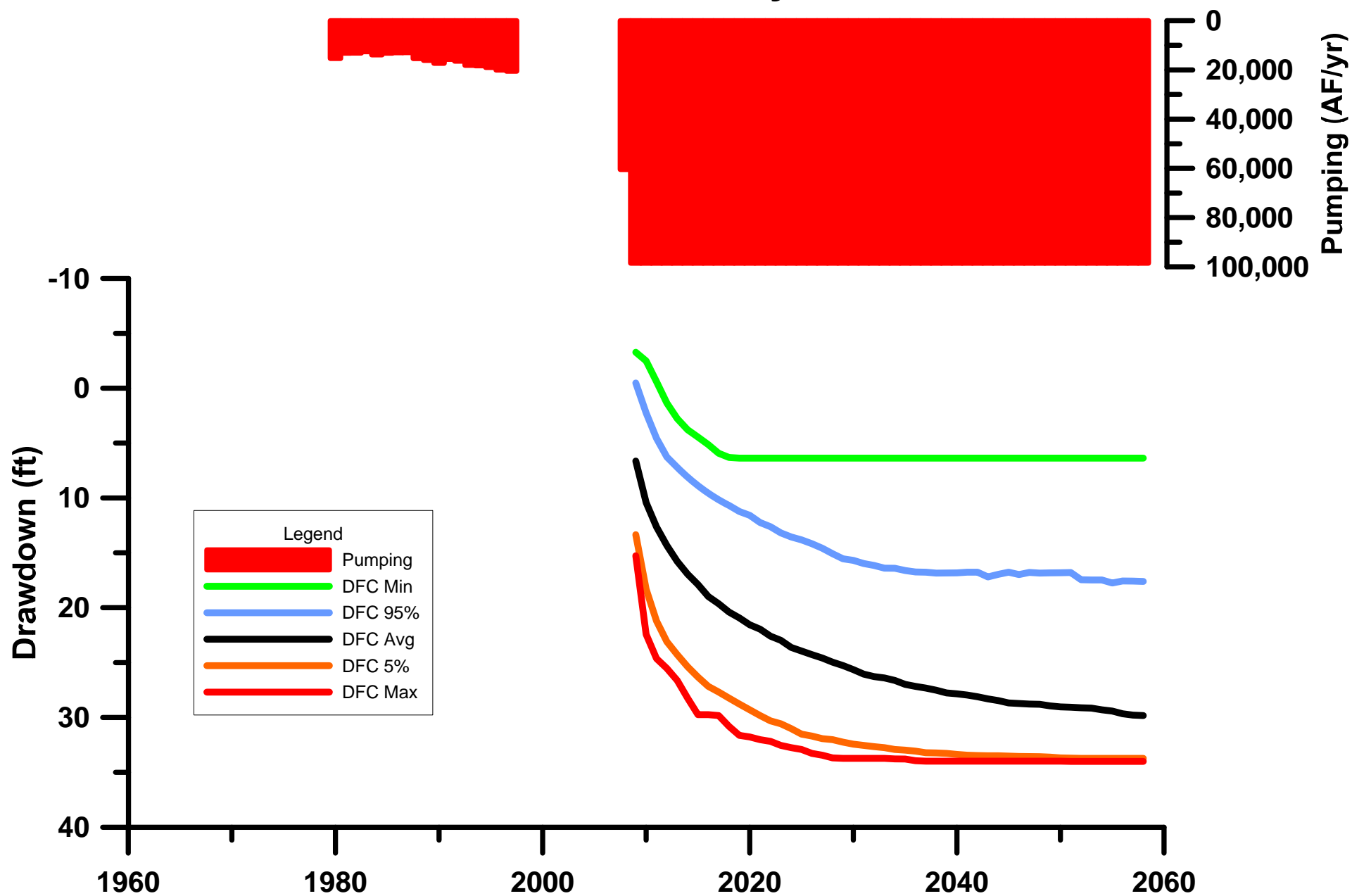
Average Drawdown in Scenario 6

County	Trinity Aquifer		
	Min	Avg	Max
Bandera	4.5	29.3	35.0
Bexar	4.7	46.0	49.4
Blanco	-1.4	19.2	22.1
Comal	-1.3	23.9	25.7
Hays	5.4	19.2	20.8
Kendall	-0.2	28.6	32.5
Kerr	5.6	39.2	47.5
Medina	5.0	16.1	17.9
Travis	11.1	27.6	29.4
GMA 9	6.4	29.8	34.0

Average Drawdown in Scenario 6

County	Trinity Aquifer		
	Min	Avg	Max
Bandera	4.5	29.3	35.0
Bexar	4.7	46.0	49.4
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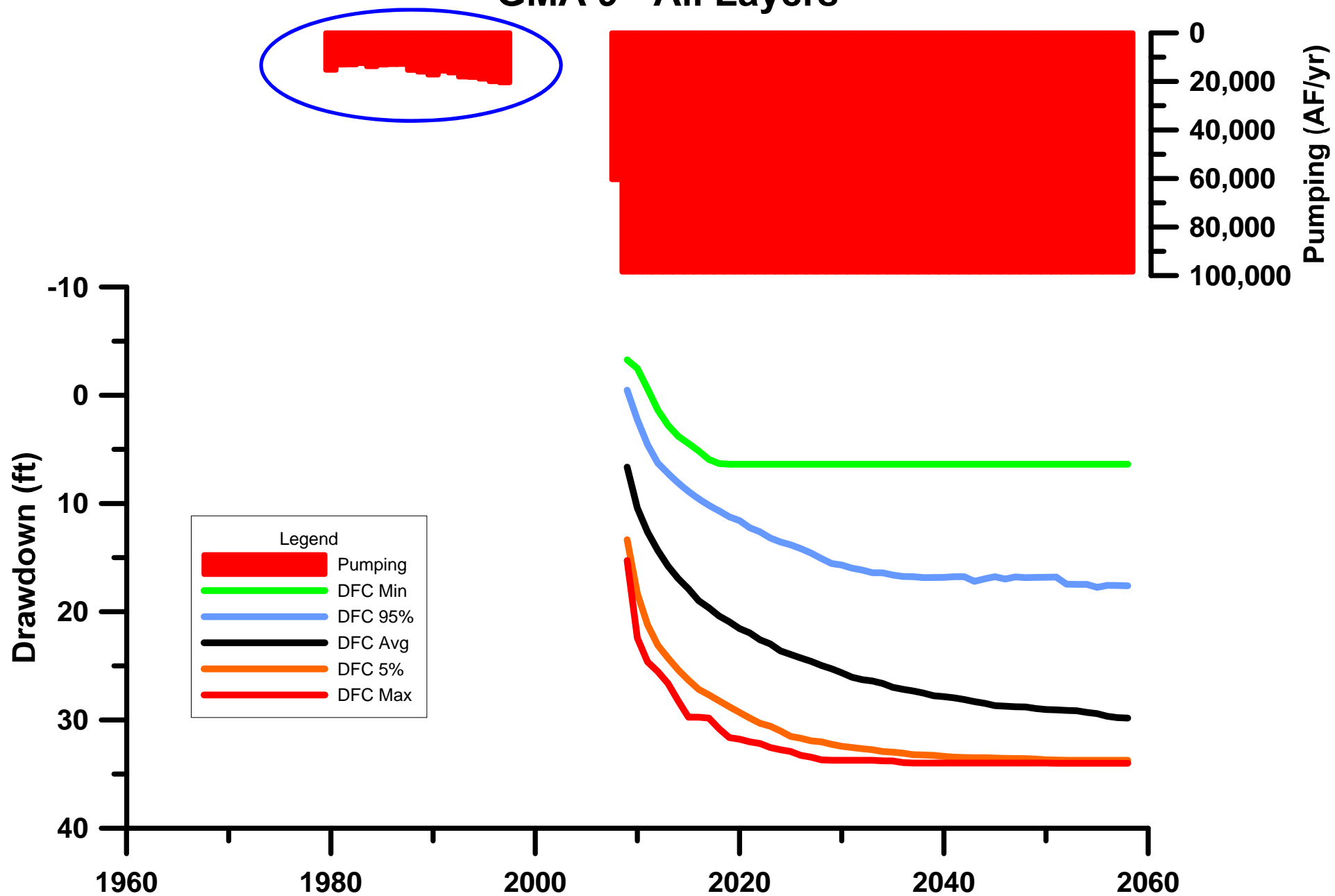
GMA 9 - All Layers



Observations

- Pumping from 1980 to 1997
 - 15,000 to 20,000 AF/yr

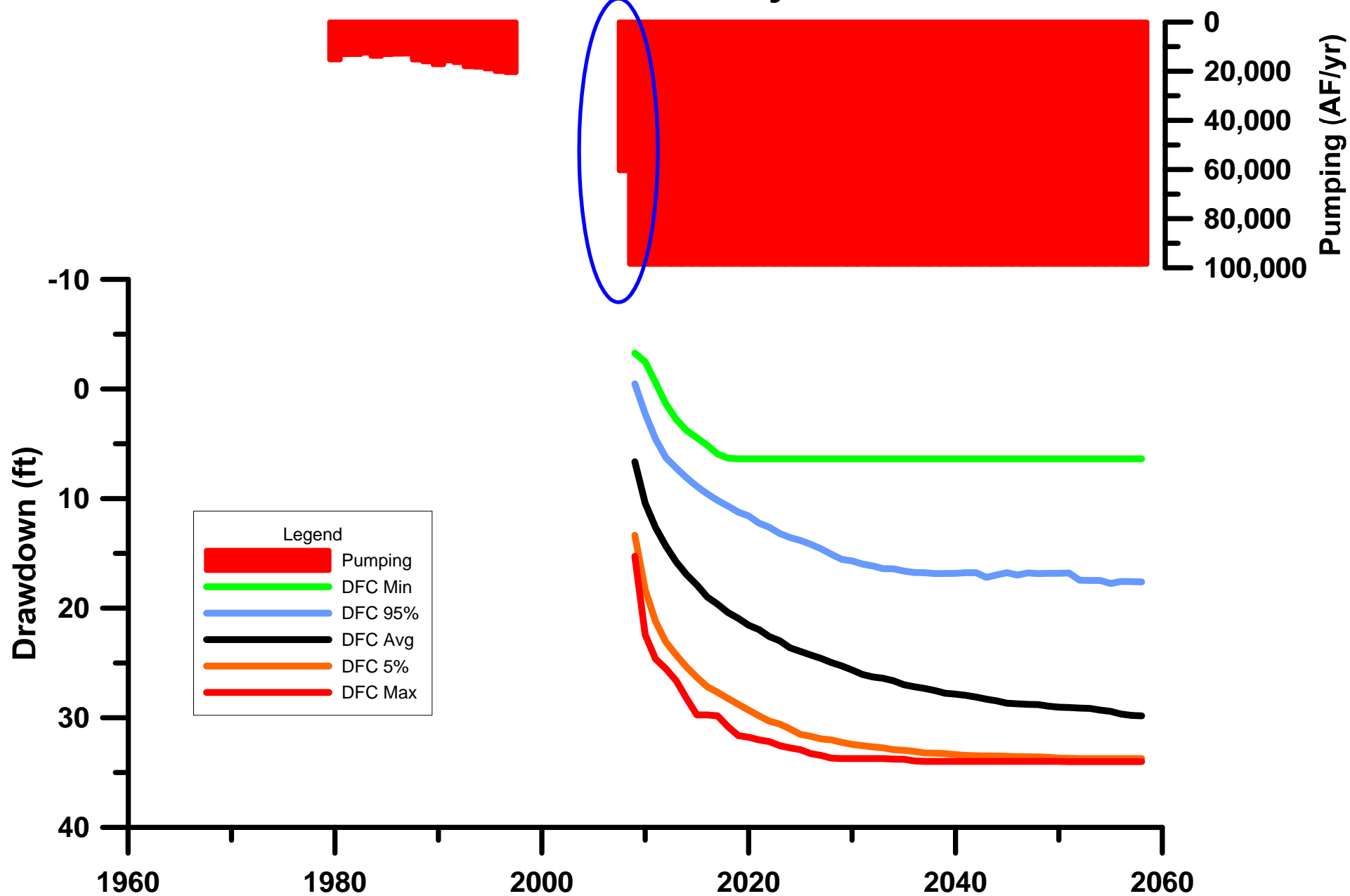
GMA 9 - All Layers



Observations

- Pumping from 1980 to 1997
 - 15,000 to 20,000 AF/yr
- 2008 Pumping
 - 60,000 AF/yr

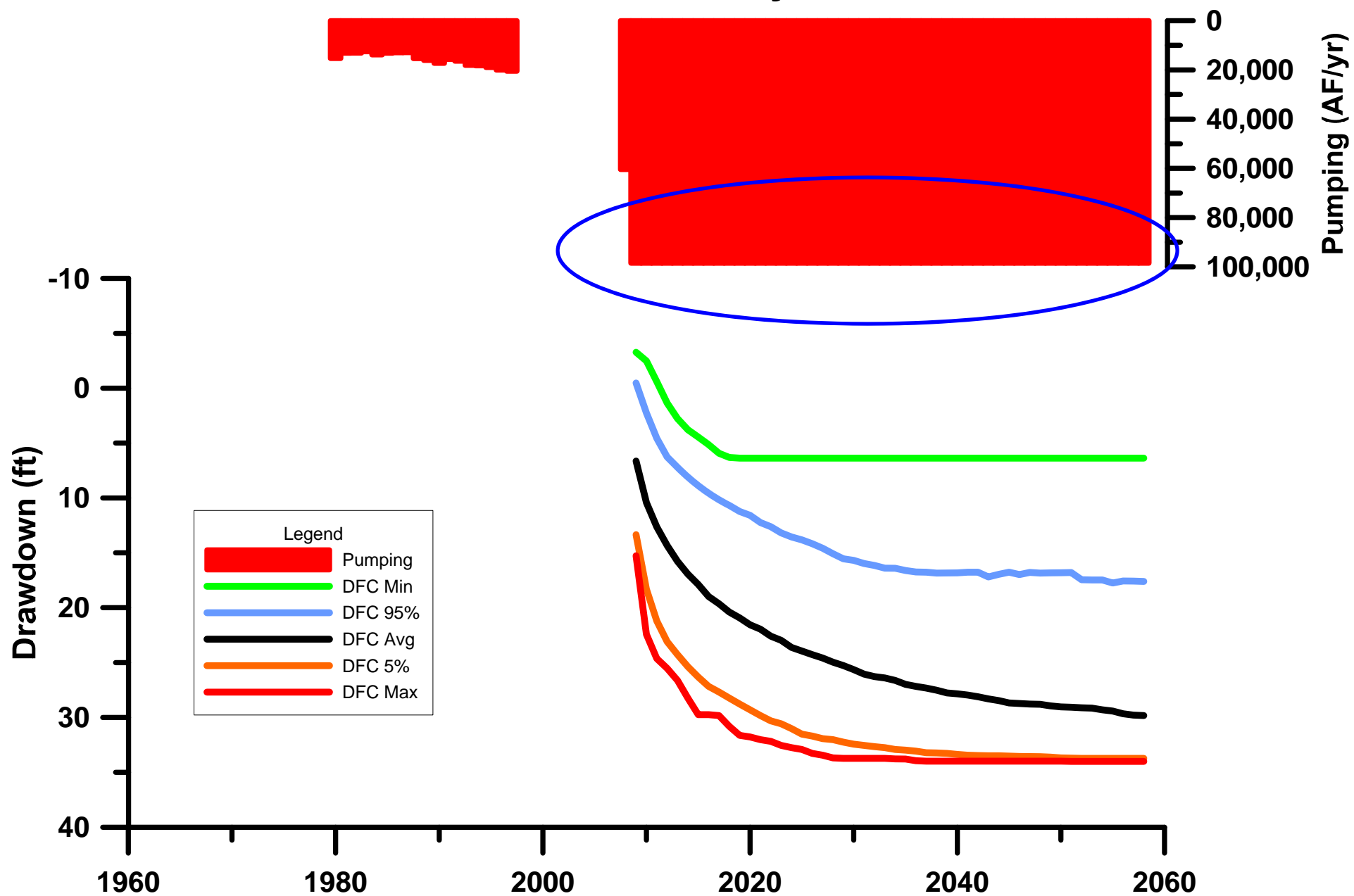
GMA 9 - All Layers



Observations

- Pumping from 1980 to 1997
 - 15,000 to 20,000 AF/yr
- 2008 Pumping
 - 60,000 AF/yr
- Future Pumping (Scenario 6)
 - 100,000 AF/yr

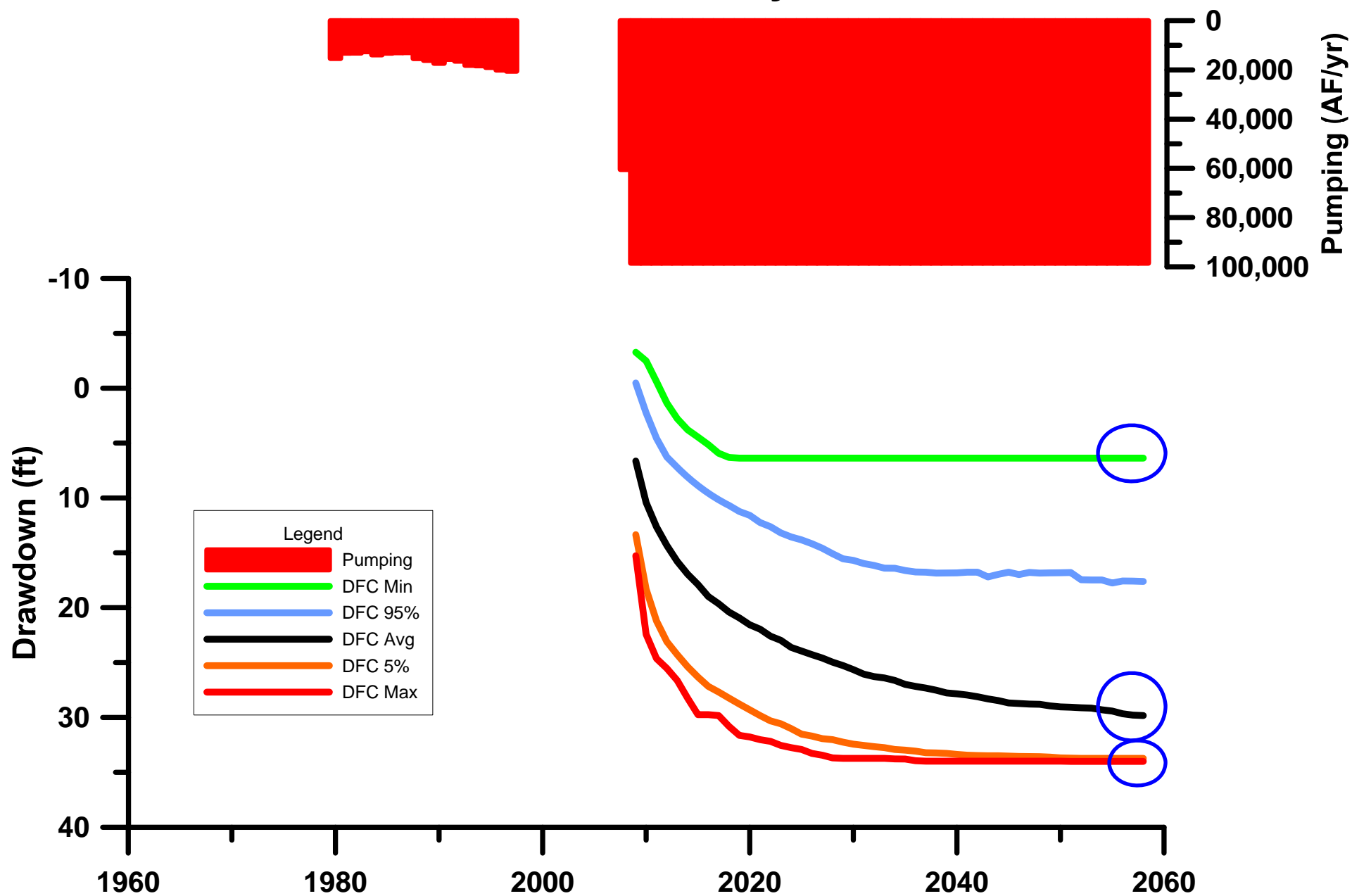
GMA 9 - All Layers



Observations

- Pumping from 1980 to 1997
 - 15,000 to 20,000 AF/yr
- 2008 Pumping
 - 60,000 AF/yr
- Future Pumping (Scenario 6)
 - 100,000 AF/yr
- 30 ft of drawdown after 50 years
 - Average of 387 simulations
 - Range = 6 to 34 ft

GMA 9 - All Layers



Similar Plots for Each County

- Contained in report

Current Effort

- Evaluate “DFC Assumptions”
 - Pumping amounts and locations
 - Adequacy of GAM to predict drawdown
 - Appropriateness of recharge assumptions in light of recent drought

Point-by-Point Comparison

- Extract predicted groundwater levels/
drawdown from model files
- Compare to actual monitoring data
- Comparisons at discrete locations

Hypothetical Example of Average Drawdown

2	4	6	4	2
4	6	8	6	4
6	8	10	8	6
4	6	8	6	4
2	4	6	4	2

$$\text{Avg} = 5.2 \text{ ft}$$

Hypothetical Example of Average Drawdown

	4			
4			6	
	8	10	8	6

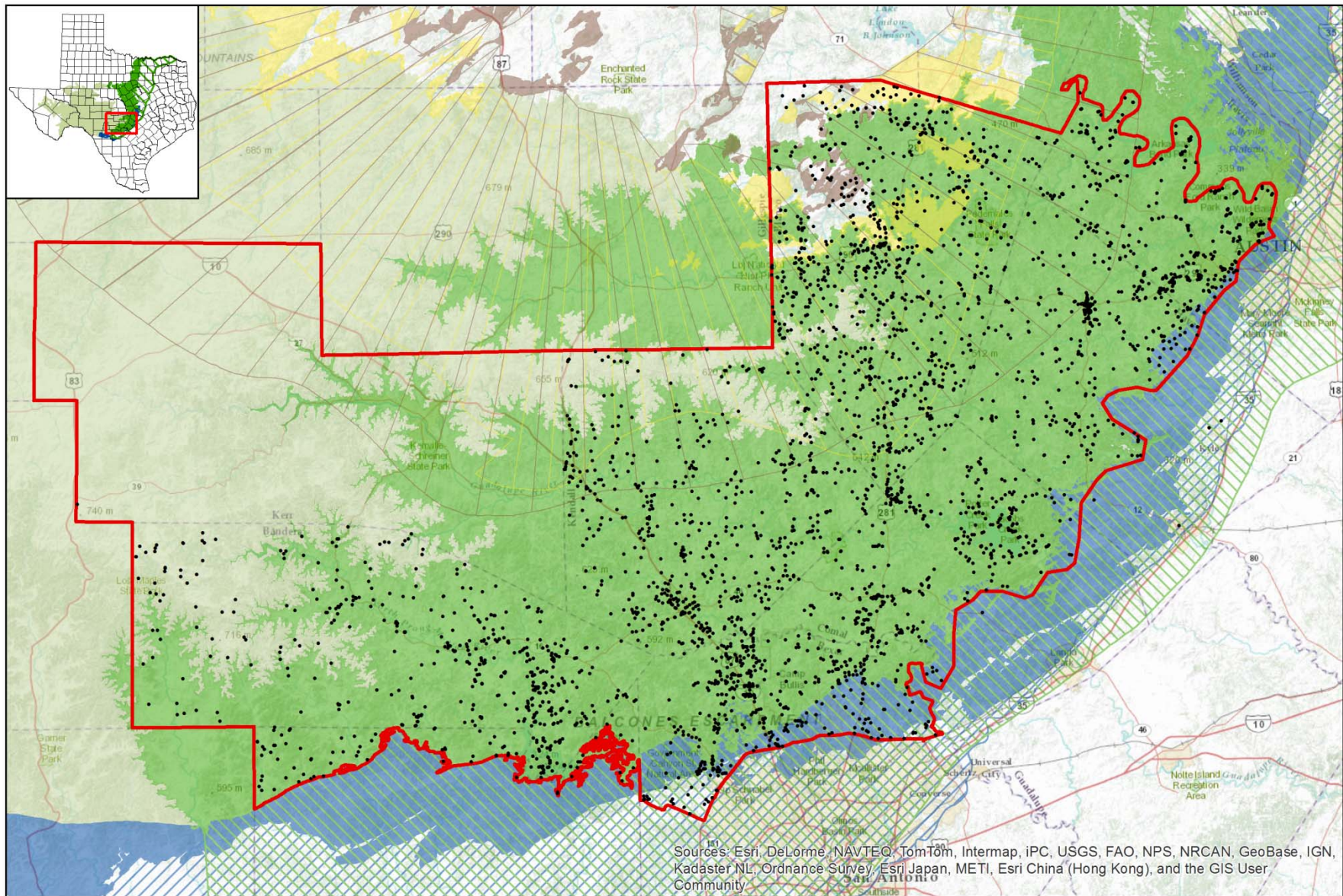
$$\text{Avg} = 6.6 \text{ ft}$$

GAM Data and Results

- For each active cell (one square mile)
 - Top and bottom elevations of 4 layers
 - Aquifer parameters
 - Historic pumping (calibrated model)
 - Future pumping (DFC run)
 - Groundwater elevations (annual)

TWDB Database

- Well location (latitude and longitude)
- Well depth
- Completion data (screen top and bottom)
- Groundwater elevation data



GMA 9 Wells

And Aquifer Extents

Updated: 9/12/2012

Minor Aquifers

- Ellenburger - San Saba (outcrop)
- Ellenburger - San Saba (confined)
- Hickory (outcrop)
- Hickory (confined)

Major Aquifers

- Edwards - Trinity Plateau (outcrop)
- Edwards - Trinity Plateau (confined)
- Edwards BFZ (outcrop)

- Edwards BFZ (confined)
- Trinity (outcrop)
- Trinity (confined)
- GMA 9 Extent
- GMA 9 Wells

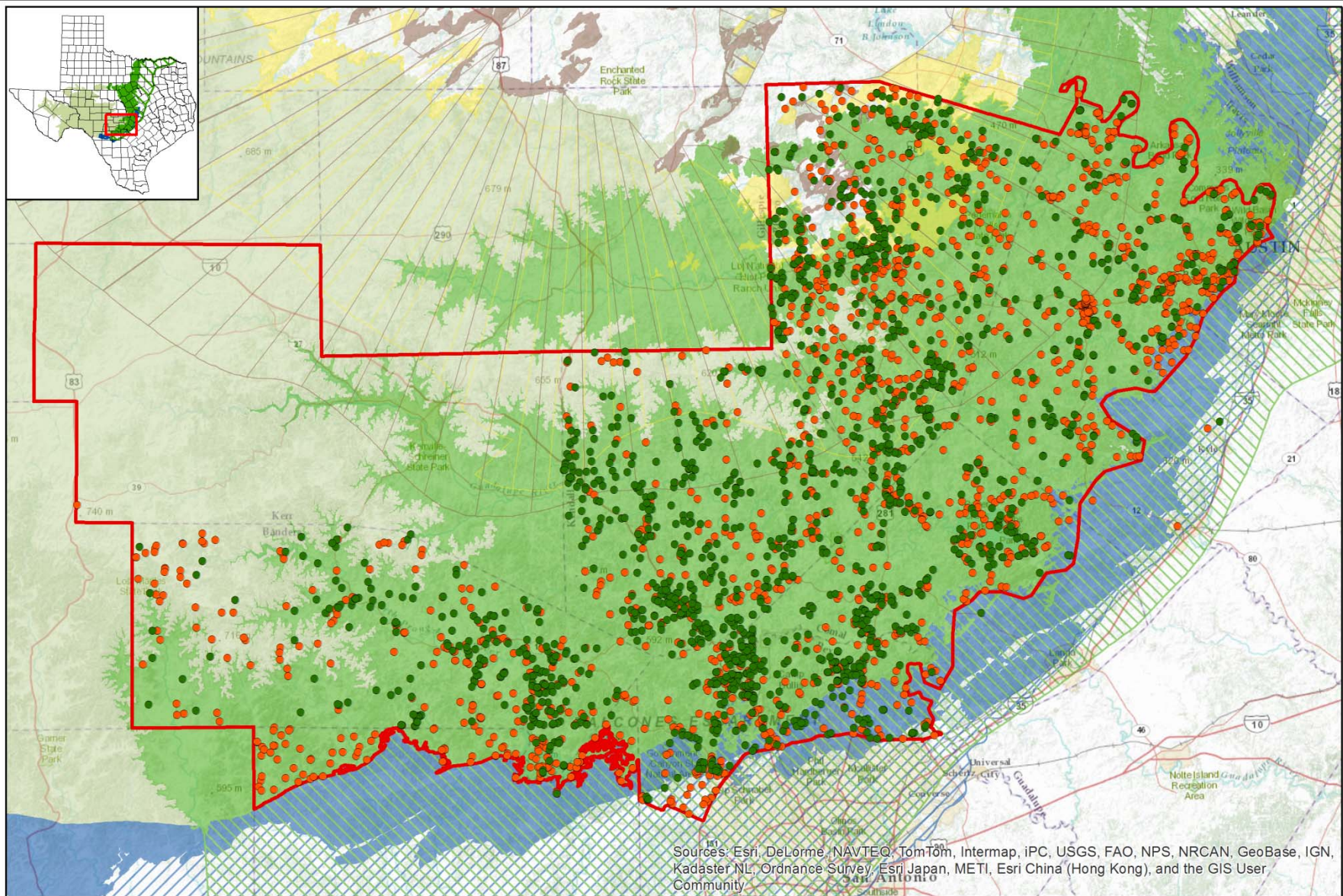


LBG GUYTON ASSOCIATES

0 4 8 12
Miles

GMA 9 Wells in TWDB Database

- 4,203 wells
 - 2,210 have no details of screened interval
 - Most of these have an aquifer designation
 - 1,993 have screen top and bottom



GMA 9 Wells by Completion Data Available And Aquifer Extents

Updated: 9/12/2012

Minor Aquifers

- Ellenburger - San Saba (outcrop)
- Ellenburger - San Saba (confined)
- Hickory (outcrop)
- Hickory (confined)

Explanation

- GMA 9 Extent
- Wells with completion data
- Wells not containing completion data

Major Aquifers

- Edwards - Trinity Plateau (outcrop)

- Edwards - Trinity Plateau (confined)
- Edwards BFZ (outcrop)
- Edwards BFZ (confined)
- Trinity (outcrop)
- Trinity (confined)



LBG GUYTON ASSOCIATES

0 4 8 12
Miles

Wells with Completion Data

- 1,993 Wells
 - 242 have no groundwater level data
 - 1,031 have exactly one groundwater level measurement
 - 720 have 2 or more groundwater level measurements

Find Row and Column from GAM

- 4,203 wells
 - 15 outside of model grid
 - 4,188 in model grid
 - 2,200 – no completion data
 - 1,988 – with completion data
 - 242 no groundwater level data
 - 1,746 with at least one groundwater level measurement

In Model Grid, Completion and Groundwater Level Data

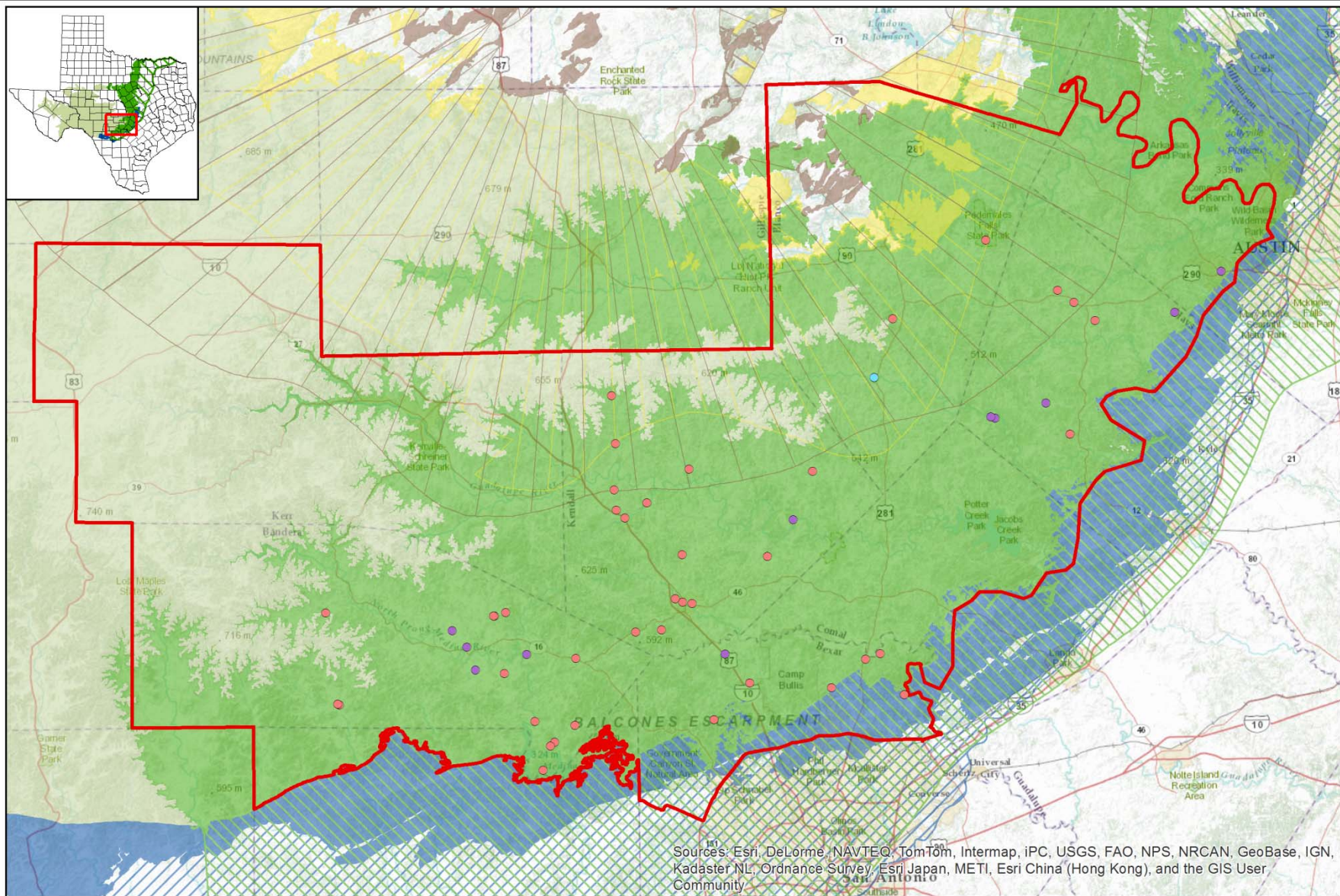
- 1,746 wells
 - 239 outside active grid
 - 348 extend below bottom of model
 - 59 extend above top of model
 - 450 completed in multiple layers
 - 650 completed in one layer

650 completed in one layer

- 4 located in inactive layer
- 297 have most recent groundwater level before 1980
- 76 have most recent groundwater in 2008 or later
 - Hydrographs of 63 wells in report (no Kerr County)

63 Hydrograph Wells

- Bandera County = 21 wells
- Bexar County = 10 wells
- Blanco County = 6 wells
- Comal County = 1 well
- Hays County = 13 wells
- Kendall County = 11 wells
- Travis County = 1 well



GMA 9 Wells with Hydrographs by Model Layer

(Excludes Headwaters GCD Wells)

Updated: 9/13/2012

- Layer 2
- Layer 3
- Layer 4

Minor Aquifers

- Ellenburger - San Saba (outcrop)
- Ellenburger - San Saba (confined)
- Hickory (outcrop)
- Hickory (confined)

Explanation

Major Aquifers

- Edwards - Trinity Plateau (outcrop)
- Edwards - Trinity Plateau (confined)
- Edwards BFZ (outcrop)

- Edwards BFZ (confined)
- Trinity (outcrop)
- Trinity (confined)
- GMA 9 Extent



LBG-GUYTON ASSOCIATES

0 4 8 12
Miles

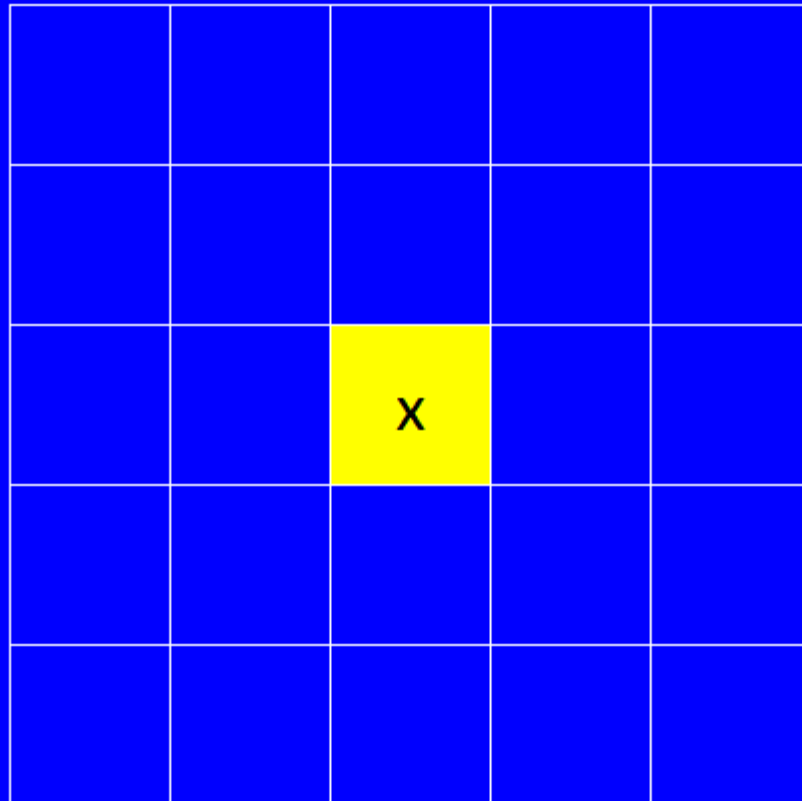
Hydrographs

- Pumping (3 zones)
- Land Surface Elevation
- Screen Elevations (Top and Bottom)
- Calibrated Model Groundwater Elevations
- Measured Groundwater Elevations
- DFC Run Groundwater Elevations
 - Average
 - Lowest (minimum)

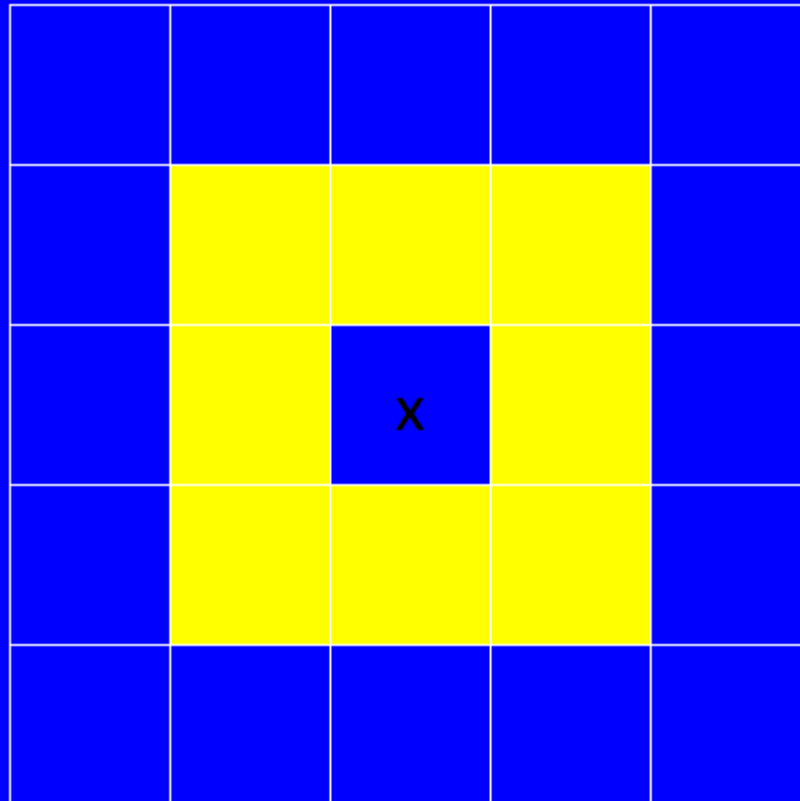
Pumping Zones

1. Cell where well is located
2. Cells immediately surrounding Zone 1
3. Cells immediately surrounding Zone 2

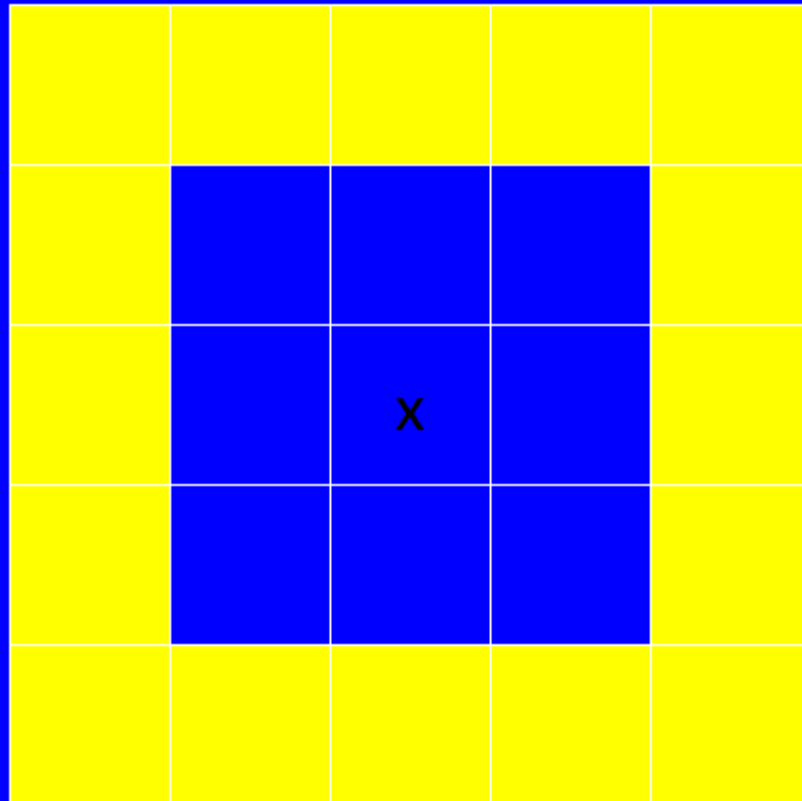
Zone 1



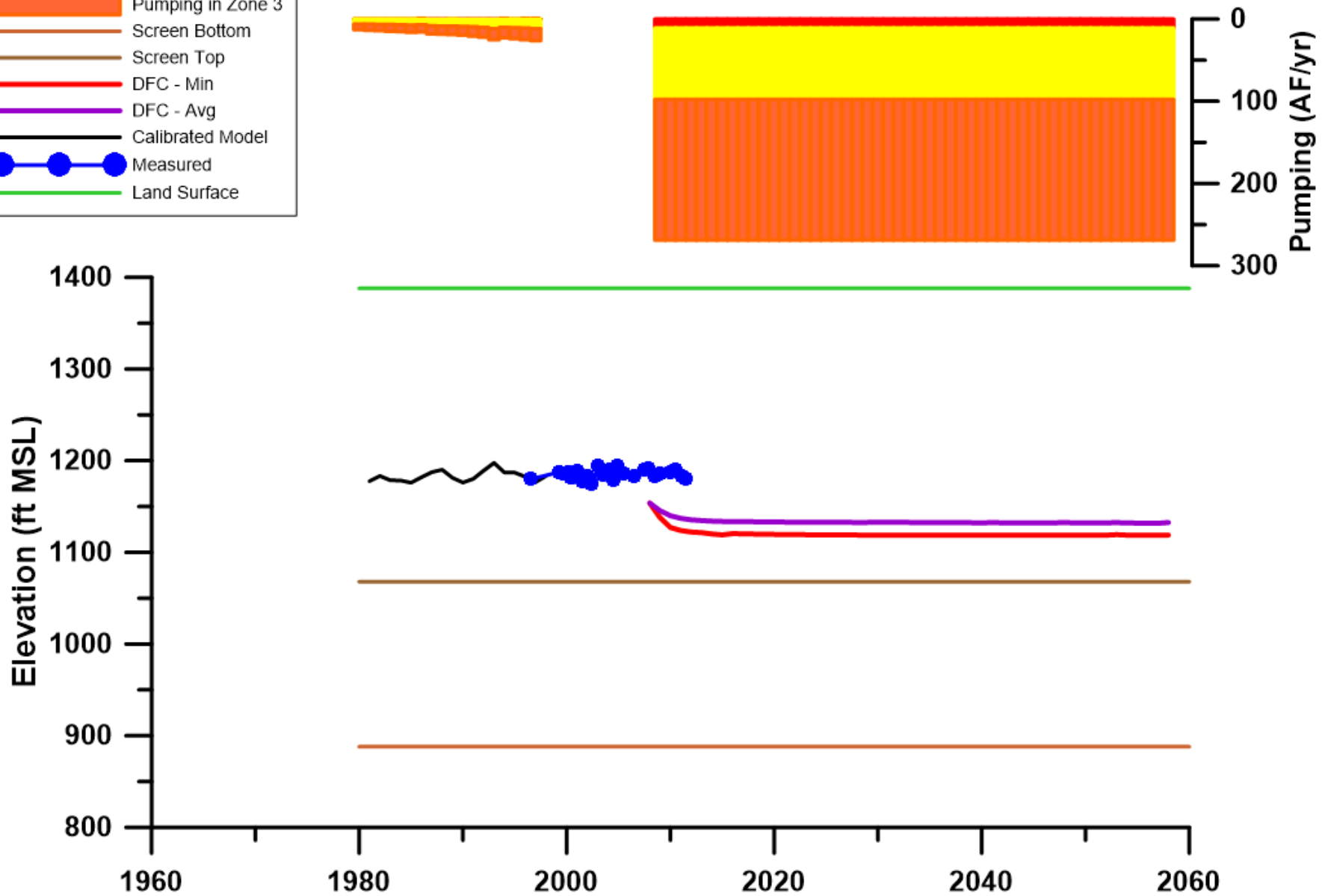
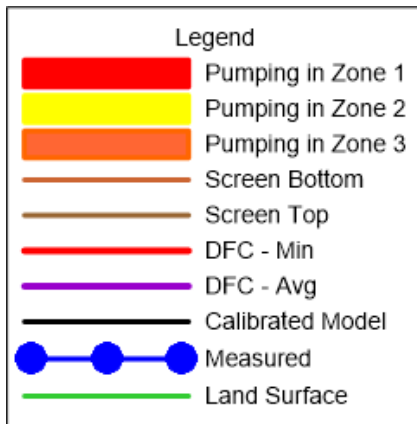
Zone 2

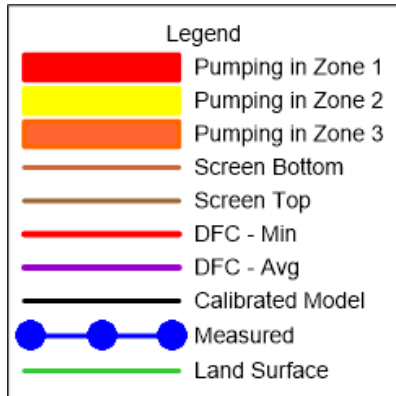


Zone 3

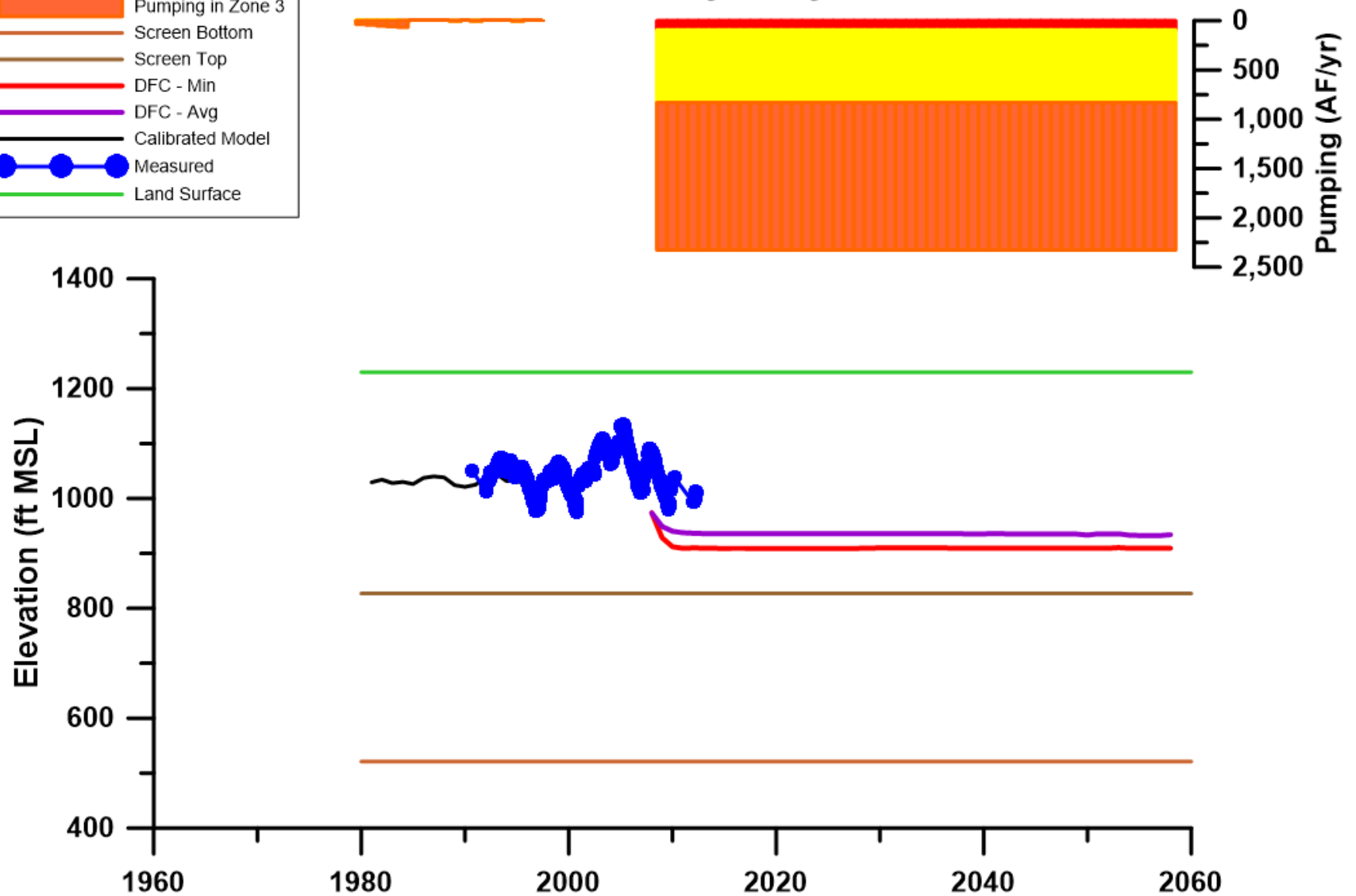


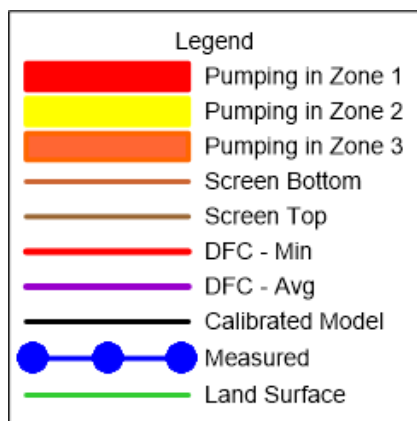
Well 6817302 Bandera County - Layer 3



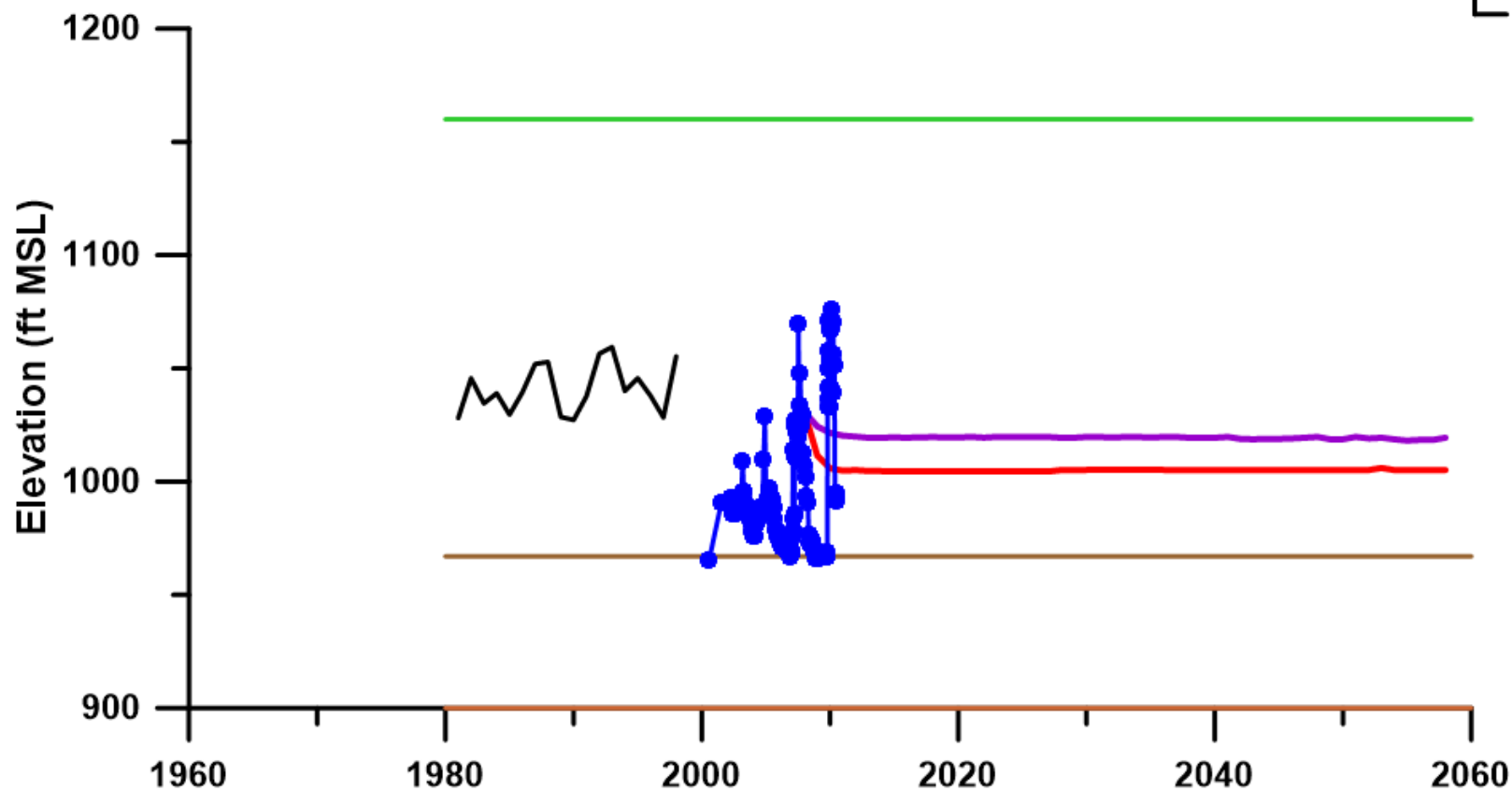
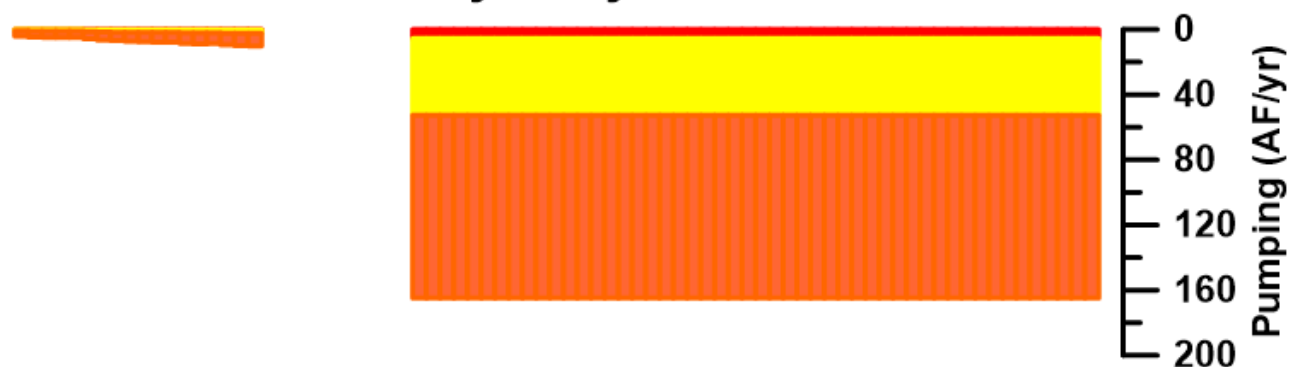


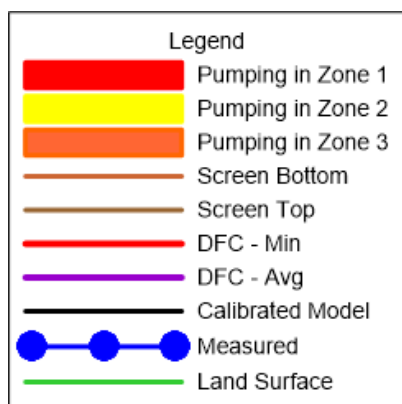
Well 6819806 Bexar County - Layer 3





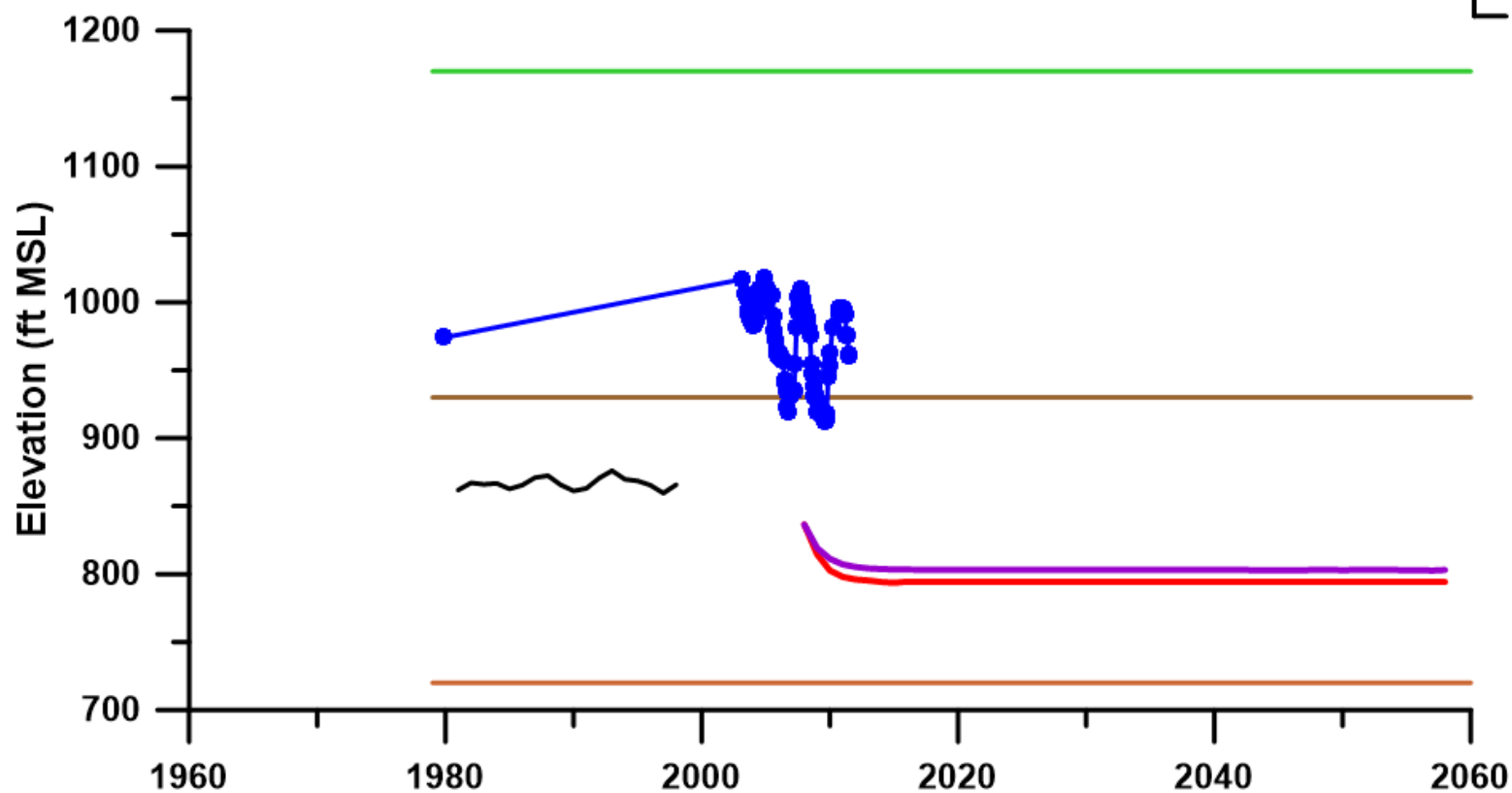
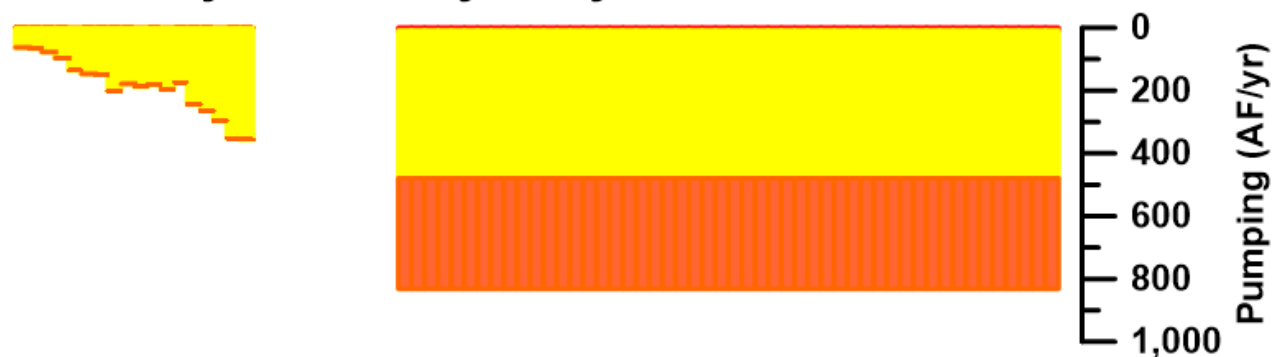
Well 5747705 Blanco County - Layer 3



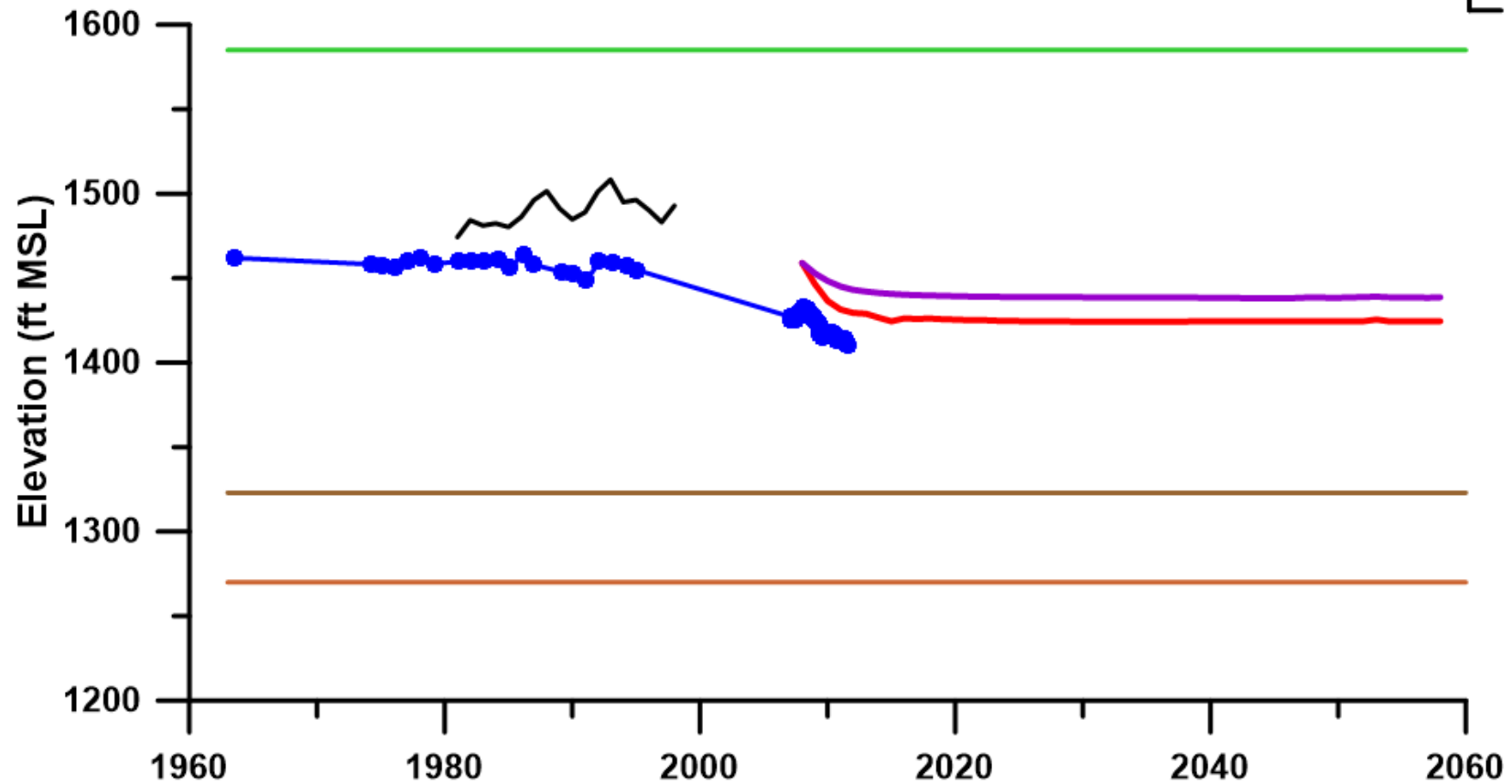
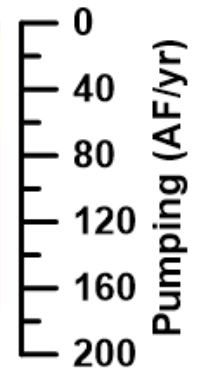
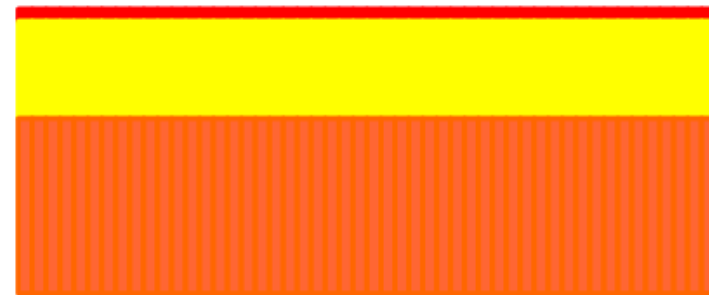
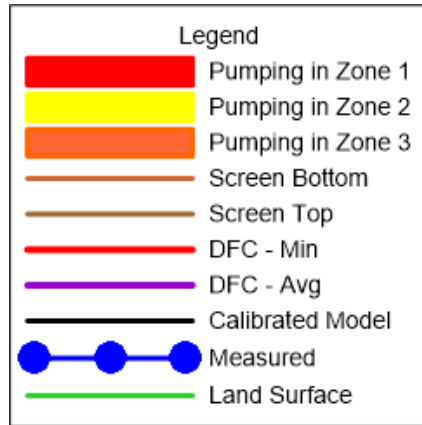


Well 5756513

Hays County - Layer 3



Well 5758402 Kendall County - Layer 3



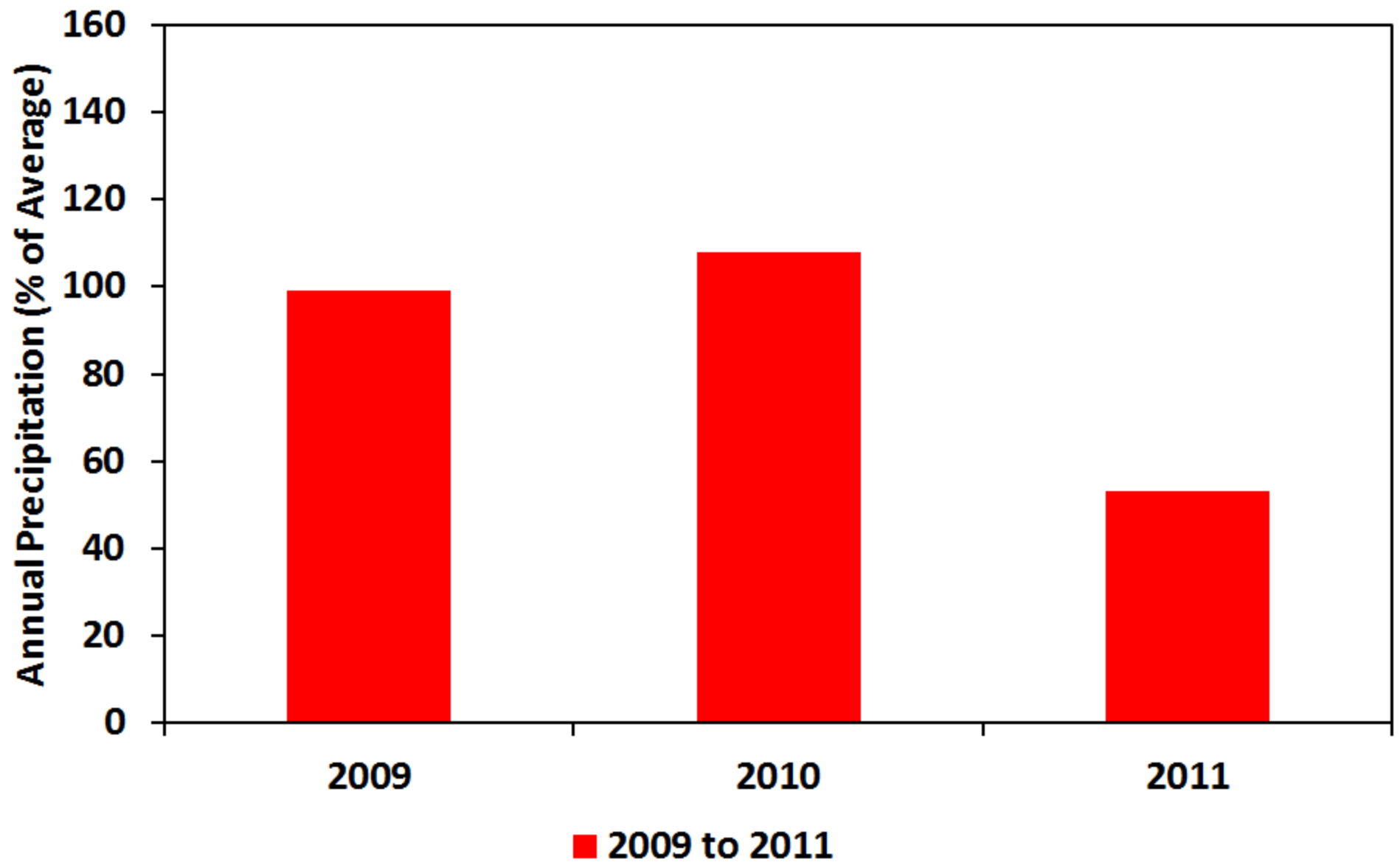
Observations

- Model calibration
 - Good on some
 - Not as good on others
- Pumping Issues
 - Estimated 1980-1997 pumping
 - Estimated 2008 pumping
 - Scenario 6 pumping

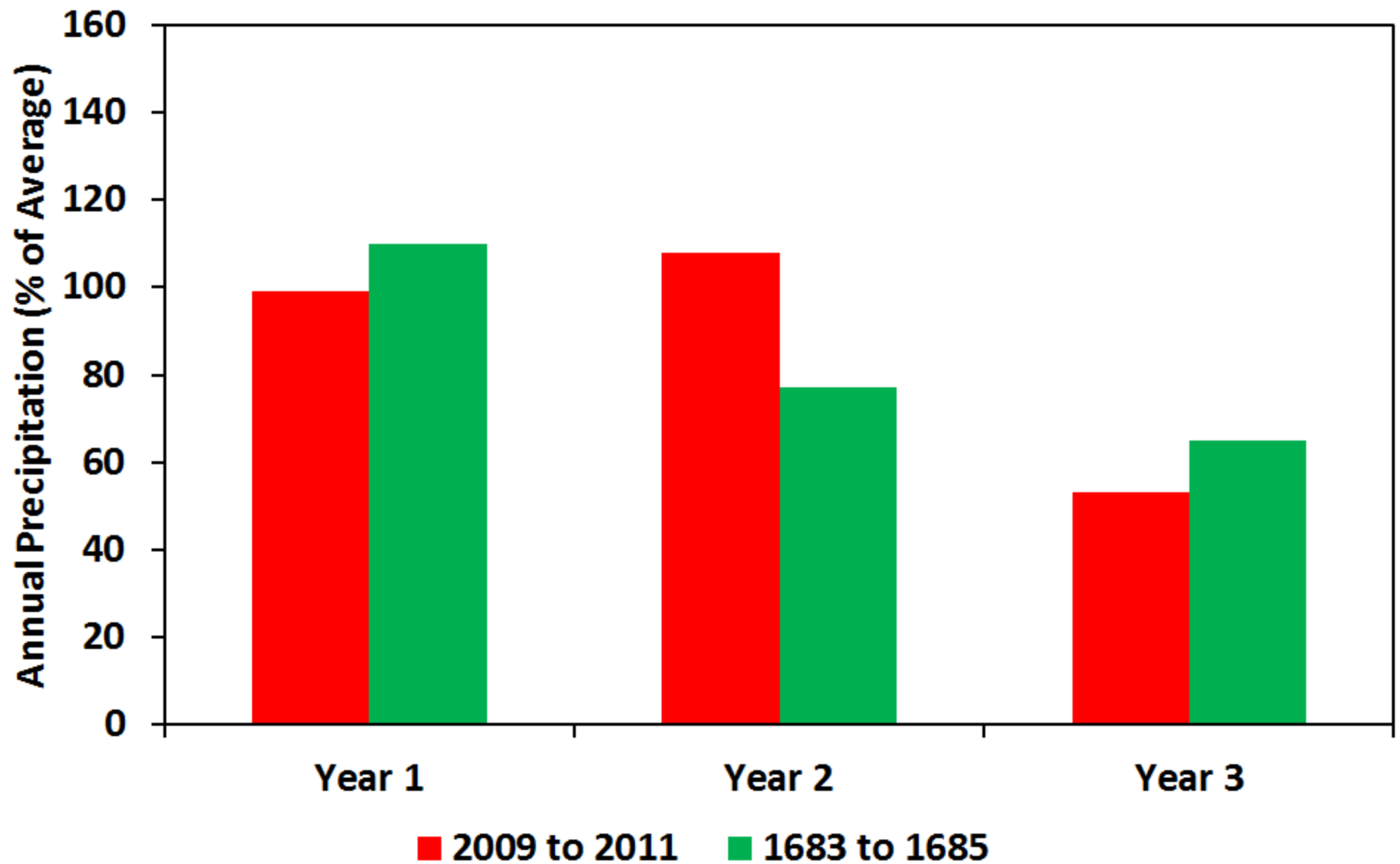
DFC is Drawdown Based

- Stated as a 50-year drawdown
 - Model files contain annual estimates for each cell and for each simulation
- Start at end of 2008
- 3 years to compare (2009 to 2011)
- Point by point comparison
 - “Average” DFC drawdown
 - Specific simulations

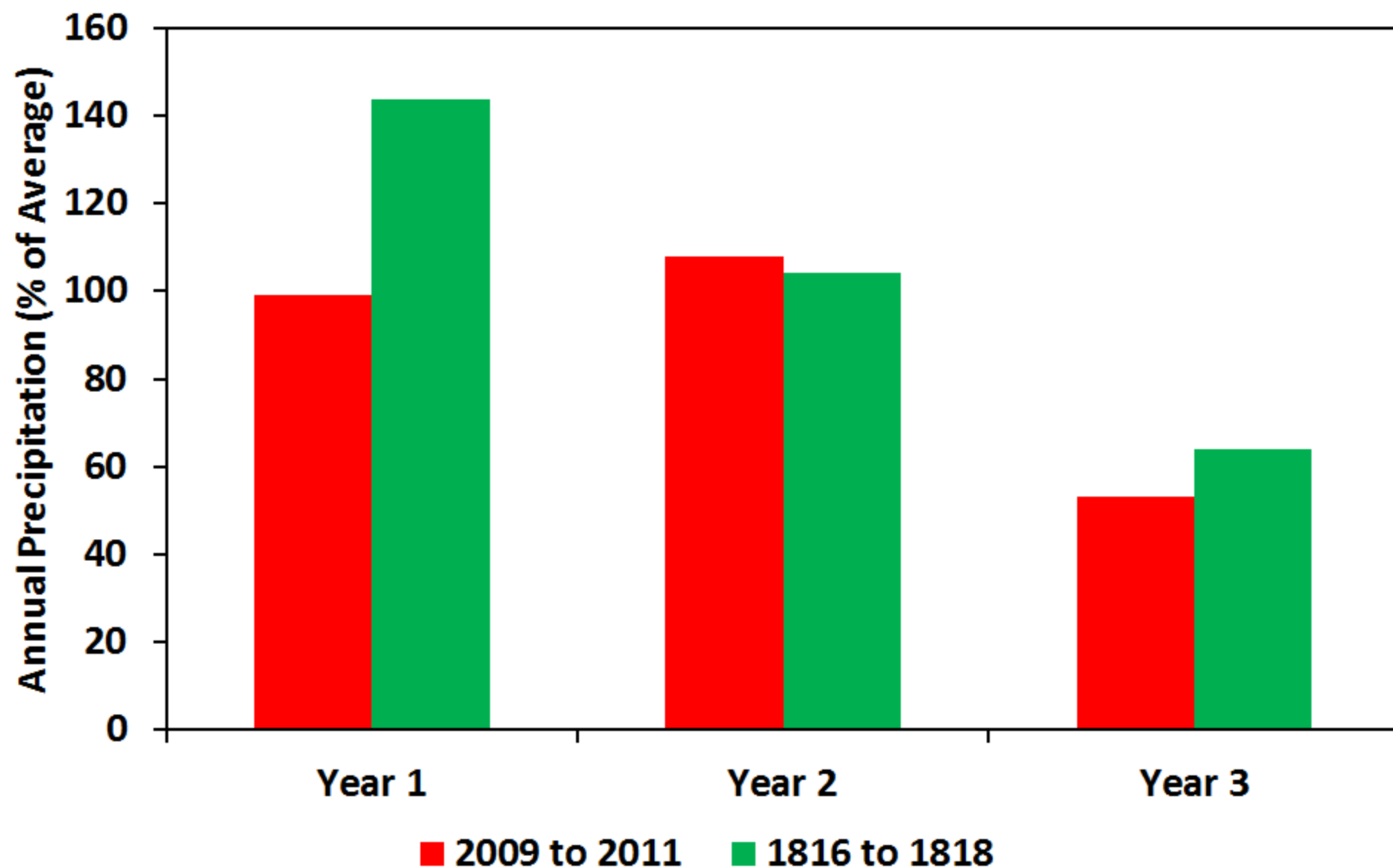
Precipitation 2009 - 2011



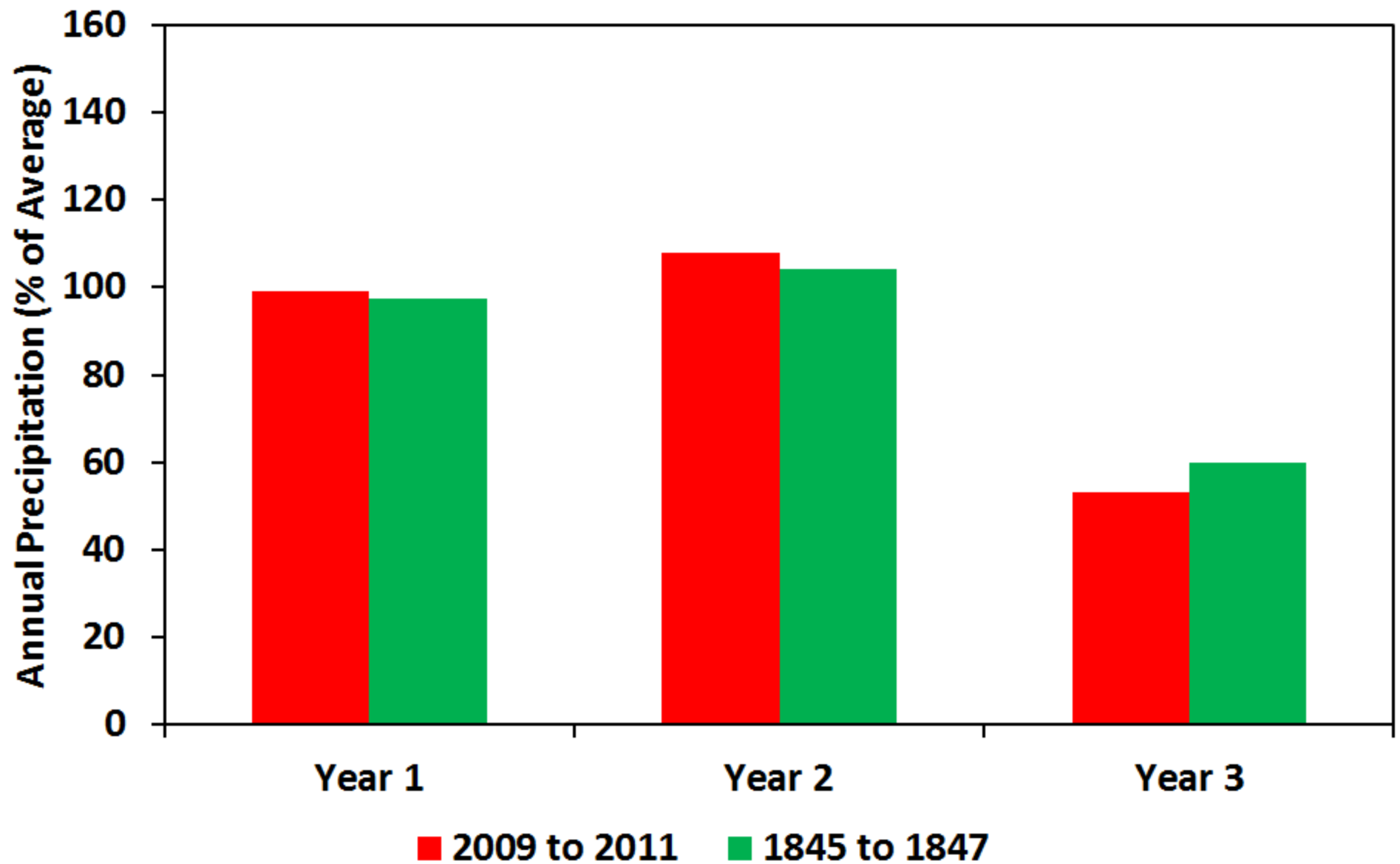
Comparison of Precipitation 1683 - 1685 (Scenario 149) to 2009 - 2011



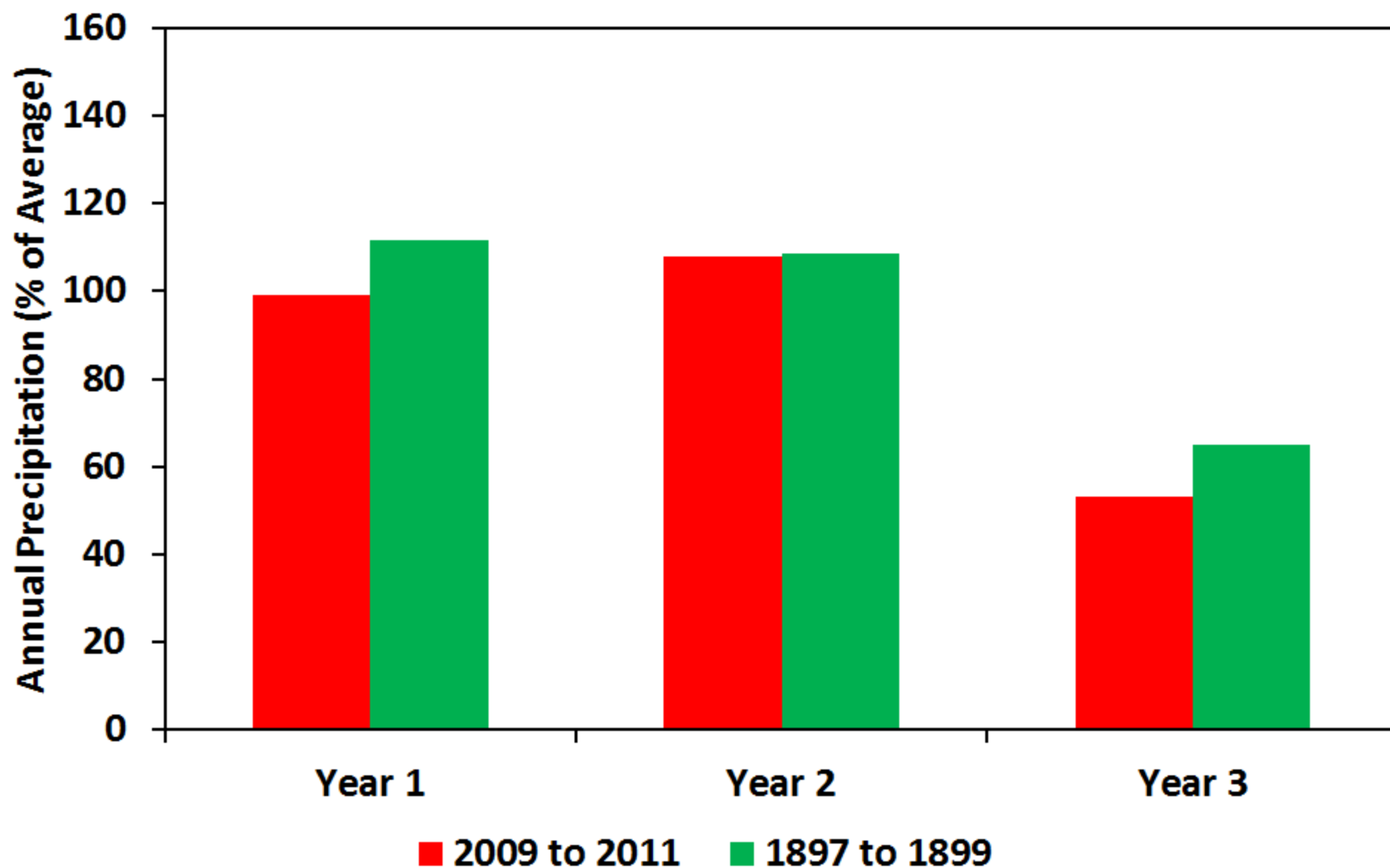
Comparison of Precipitation 1816 - 1818 (Scenario 282) to 2009 - 2011



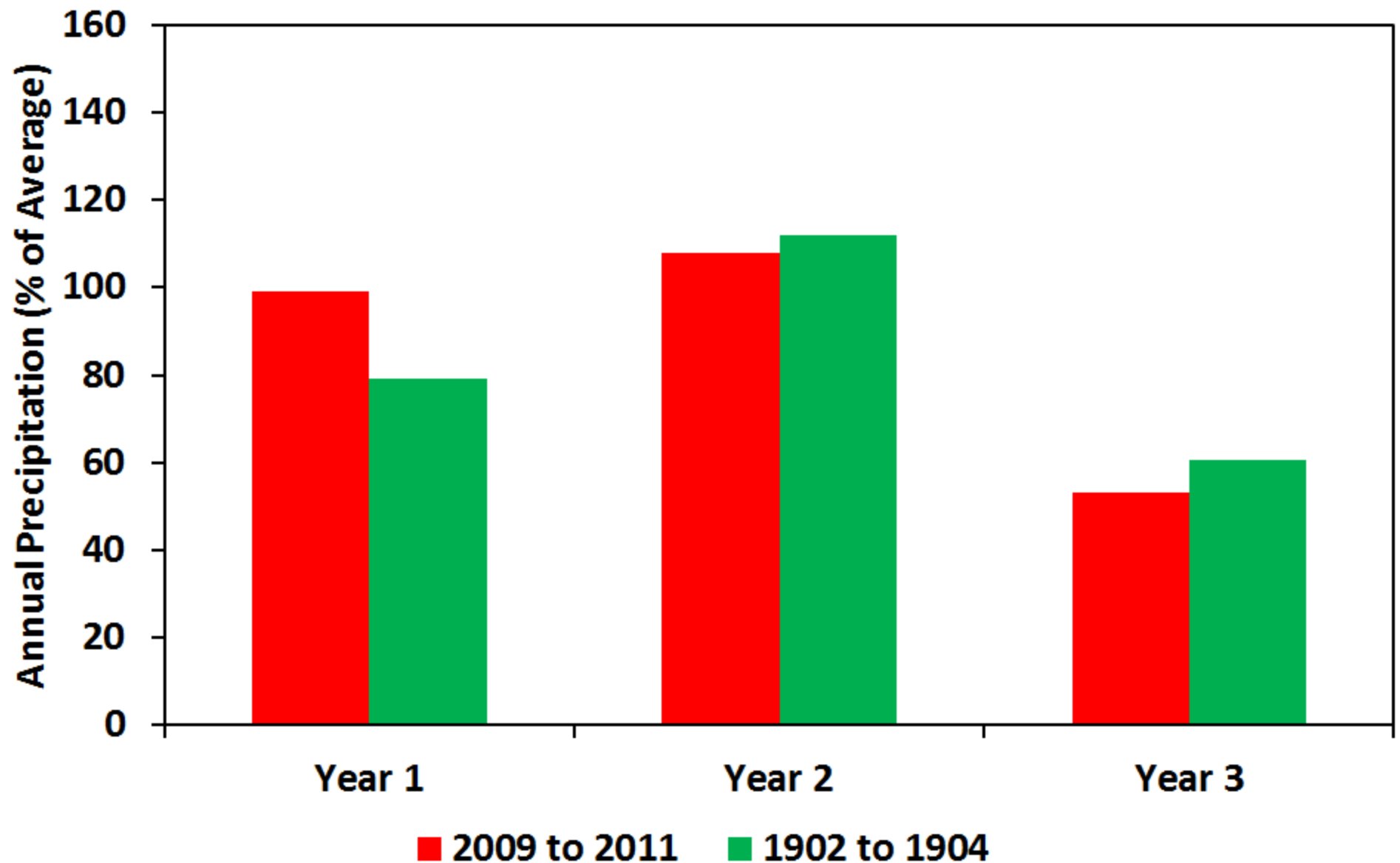
Comparison of Precipitation 1845 - 1847 (Scenario 309) to 2009 - 2011



Comparison of Precipitation 1897 - 1899 (Scenario 363) to 2009 - 2011



Comparison of Precipitation 1902 - 1904 (Scenario 366) to 2009 - 2011



Drawdown Comparison Wells

- 52 Wells with a measurement in late 2008
- Plotted comparison hydrographs for 42 wells (No Kerr County wells)
- Summaries of results in histograms

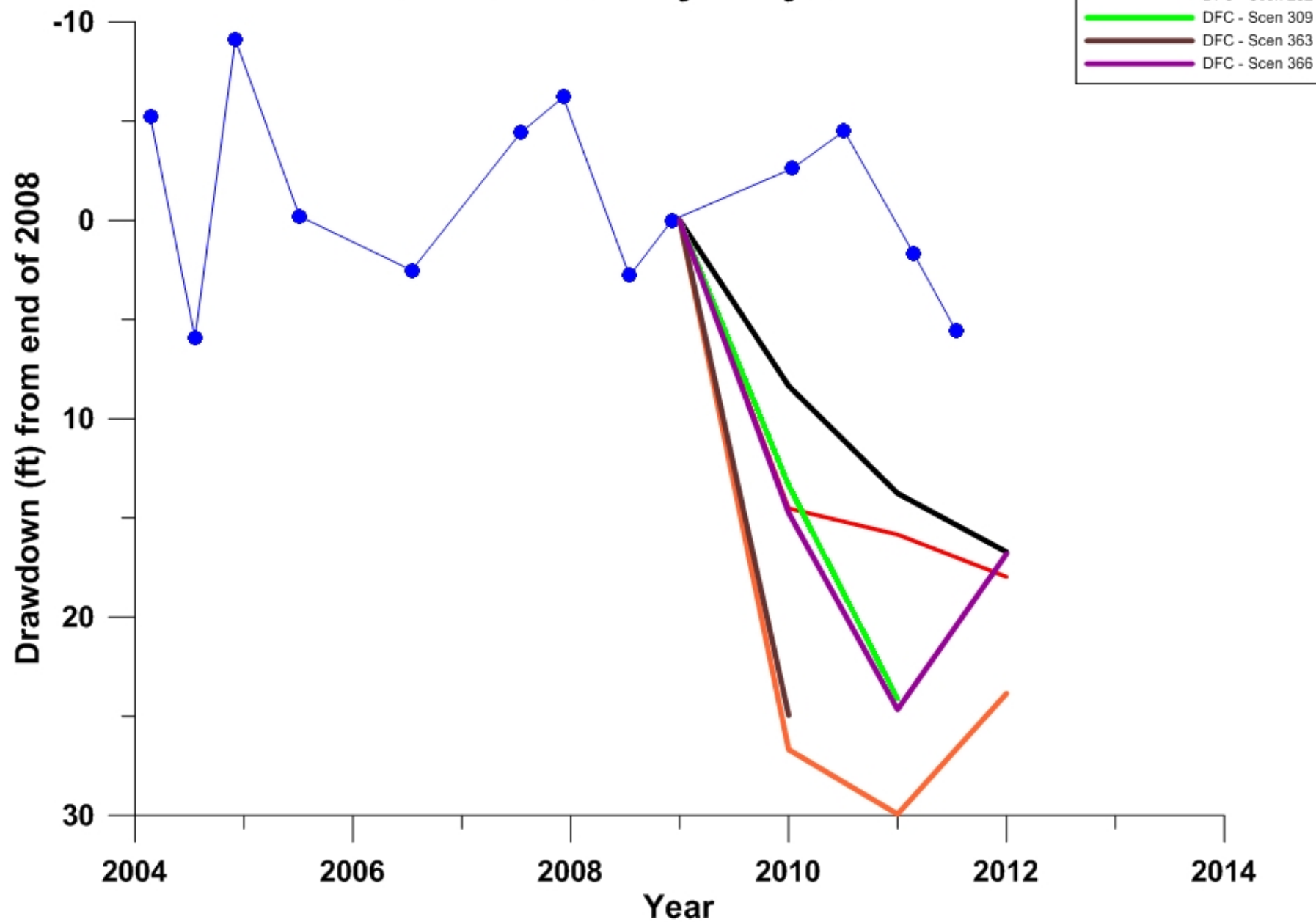
42 Drawdown Wells

- Bandera County = 18 Wells
- Bexar County = 3 Wells
- Blanco County = 3 Wells
- Hays County = 7 Wells
- Kendall County = 10 Wells
- Travis County = 1 Well

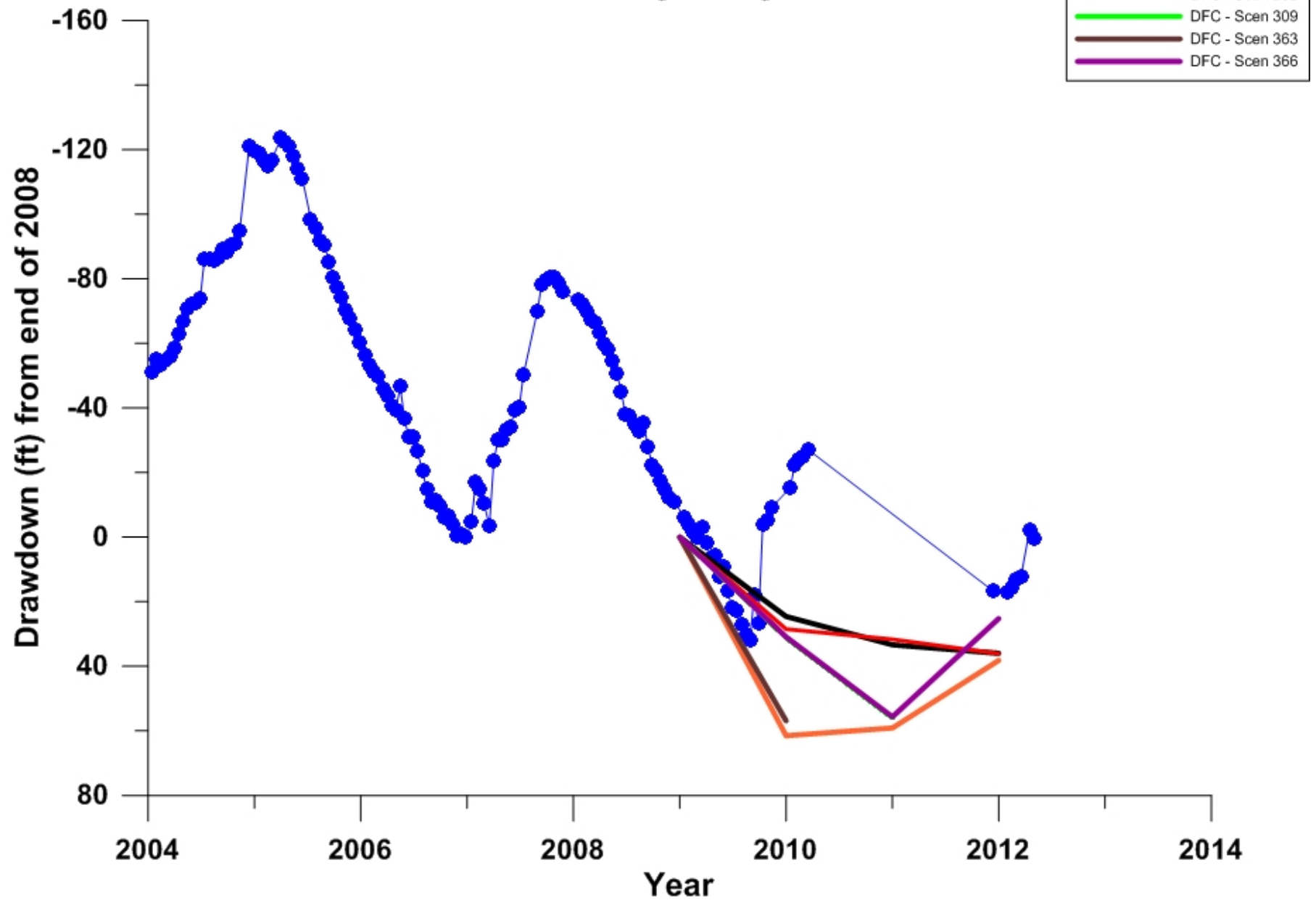
Drawdown Hydrographs

- End of 2008 = zero point
- End of 2008 Elevation minus elevation at time of interest
- Relative to end of 2008
 - positive number = drawdown (lower elevation)
 - negative number = recovery (higher elevation)

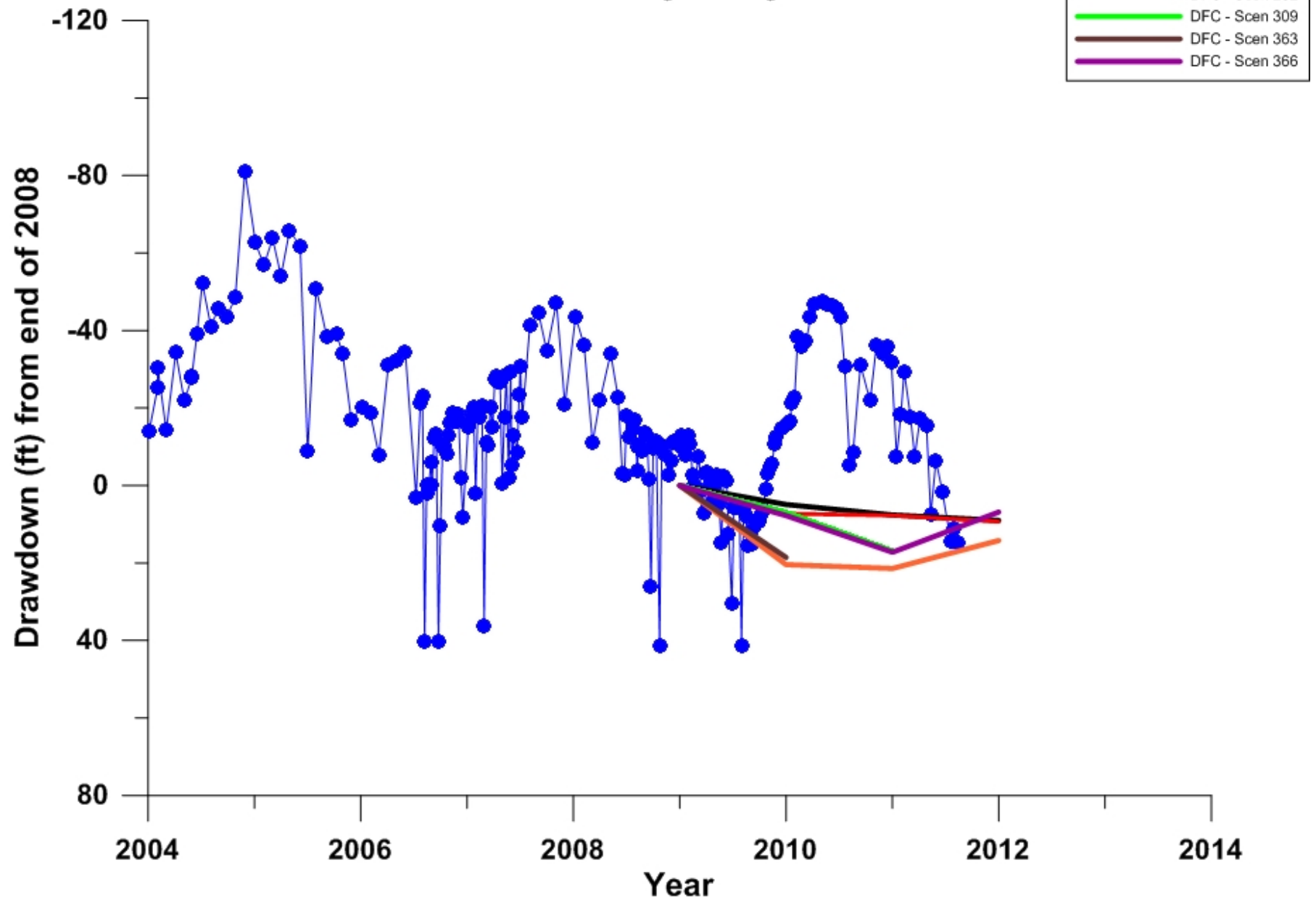
Well 6817302 Bandera County - Layer 3



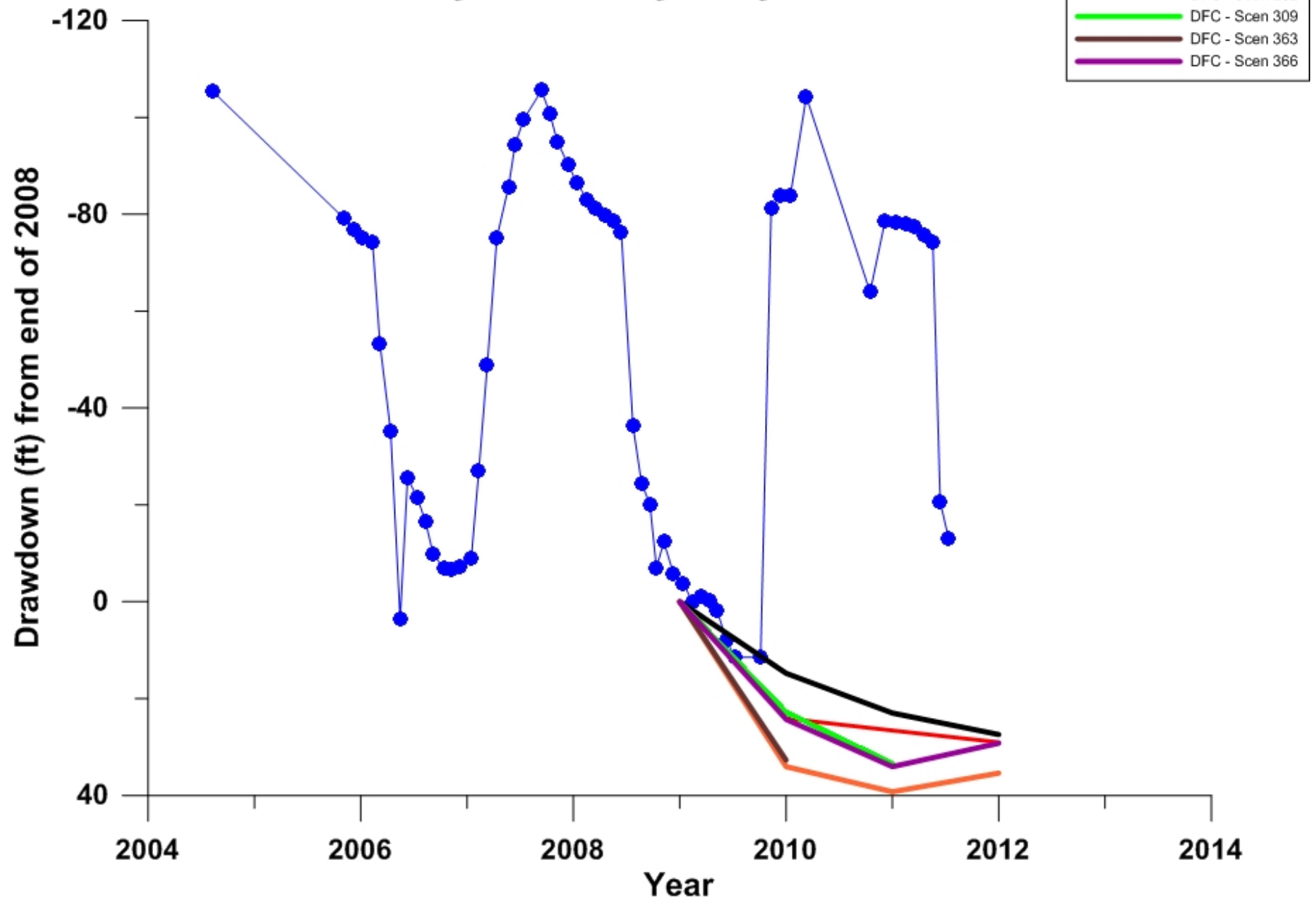
Well 6819806 Bexar County - Layer 3



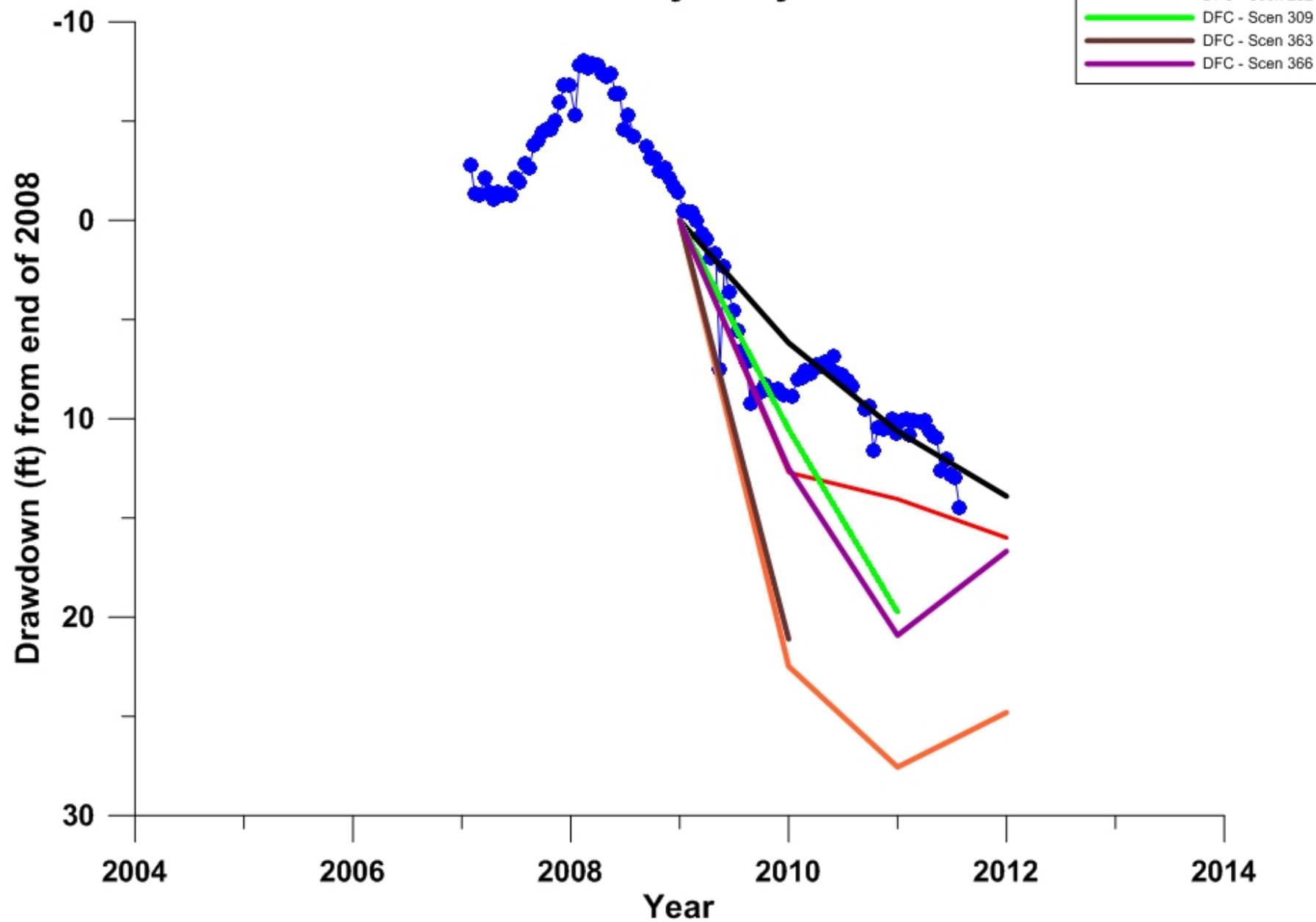
Well 5753614 Blanco County - Layer 3



Well 5756480 Hays County - Layer 3



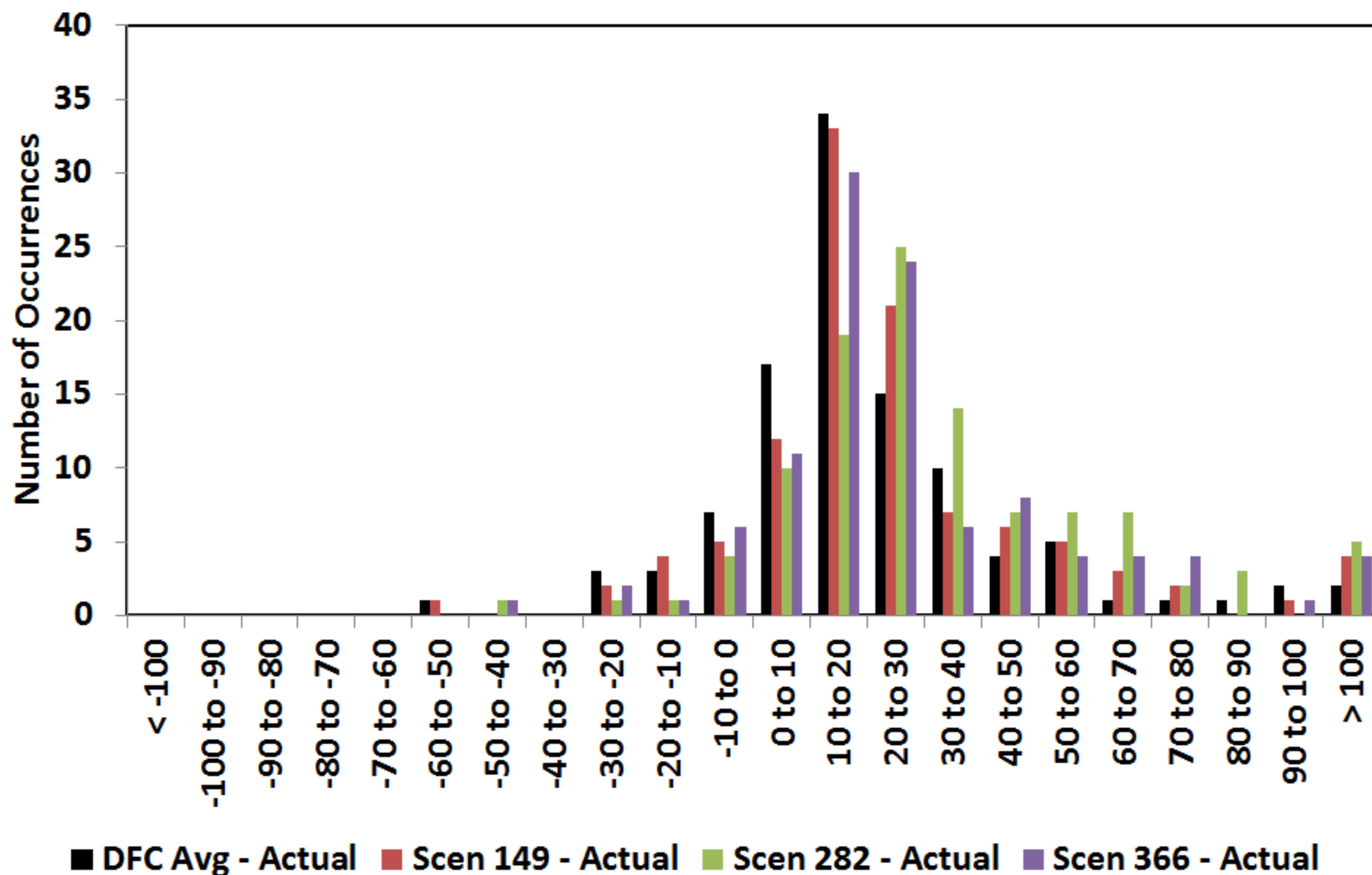
Well 5758402 Kendall County - Layer 3



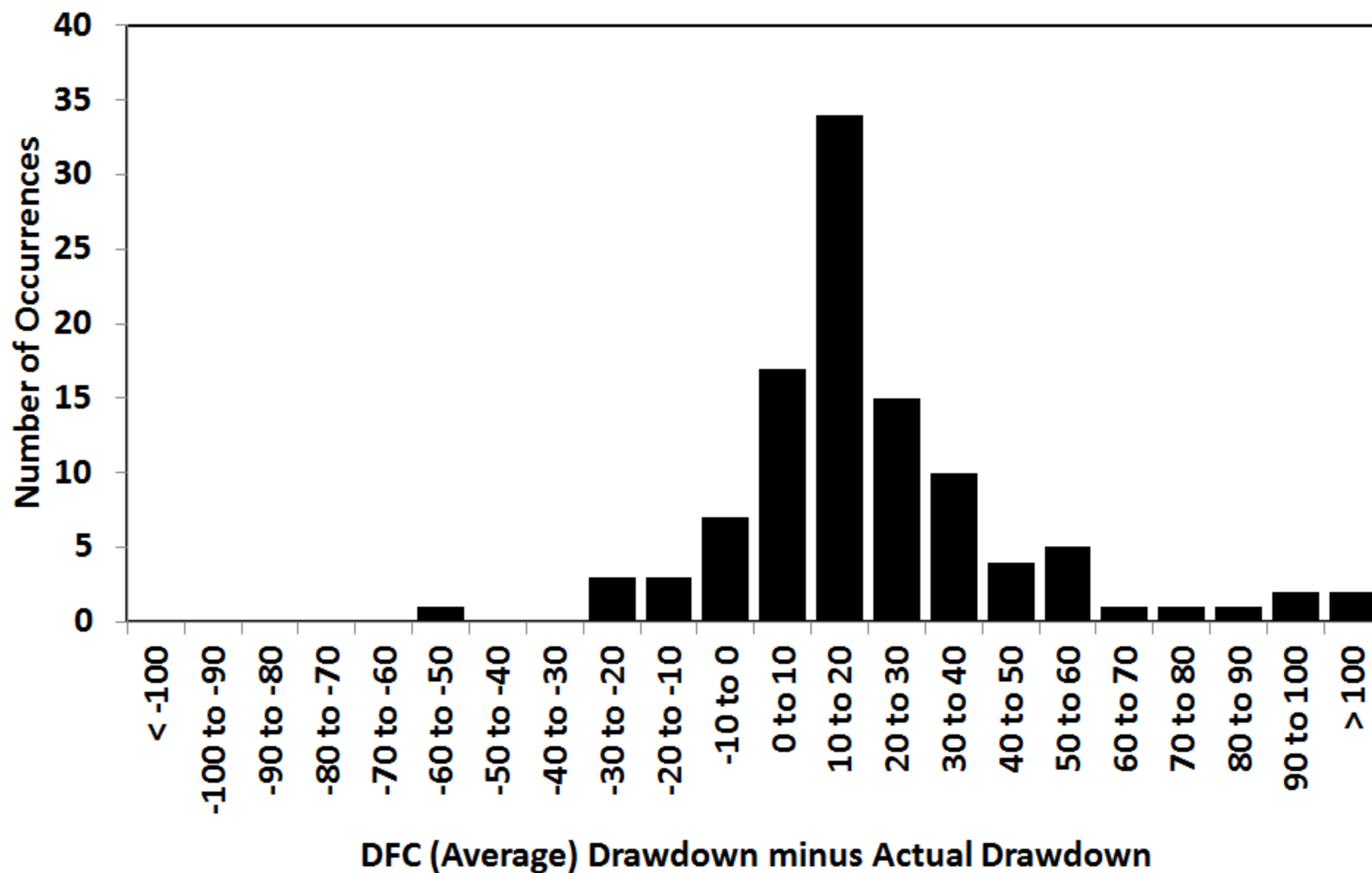
Comparison Method

- DFC Drawdown minus Actual Drawdown
 - Positive number means that actual groundwater level is higher than DFC groundwater level
 - DFC drawdown = 10 ft
 - Actual drawdown = 8 ft
 - Difference = 2 ft
 - Negative number means that actual groundwater level is lower than DFC groundwater level

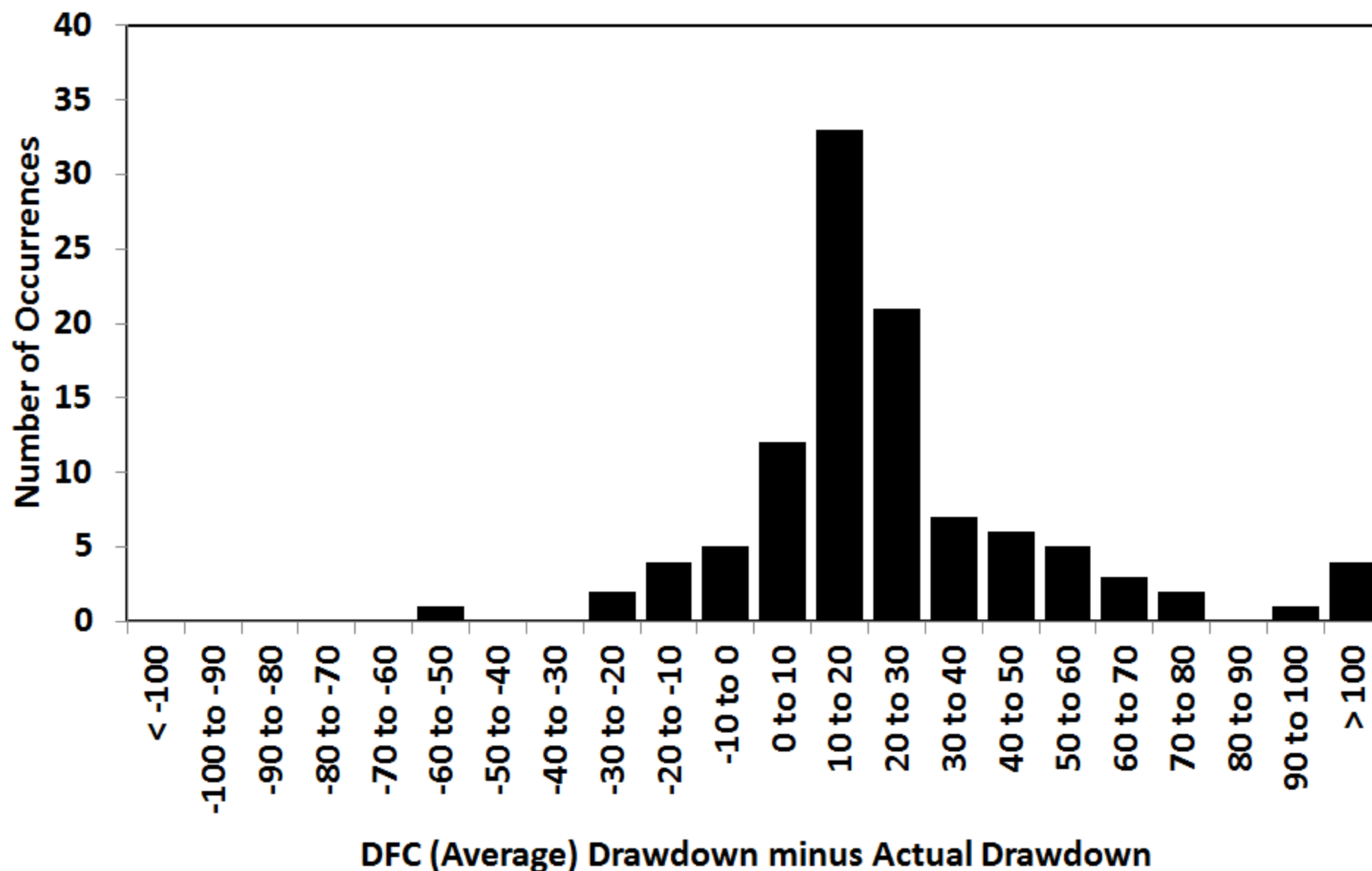
Comparison of DFC and Actual Drawdown 2009, 2010 and 2011



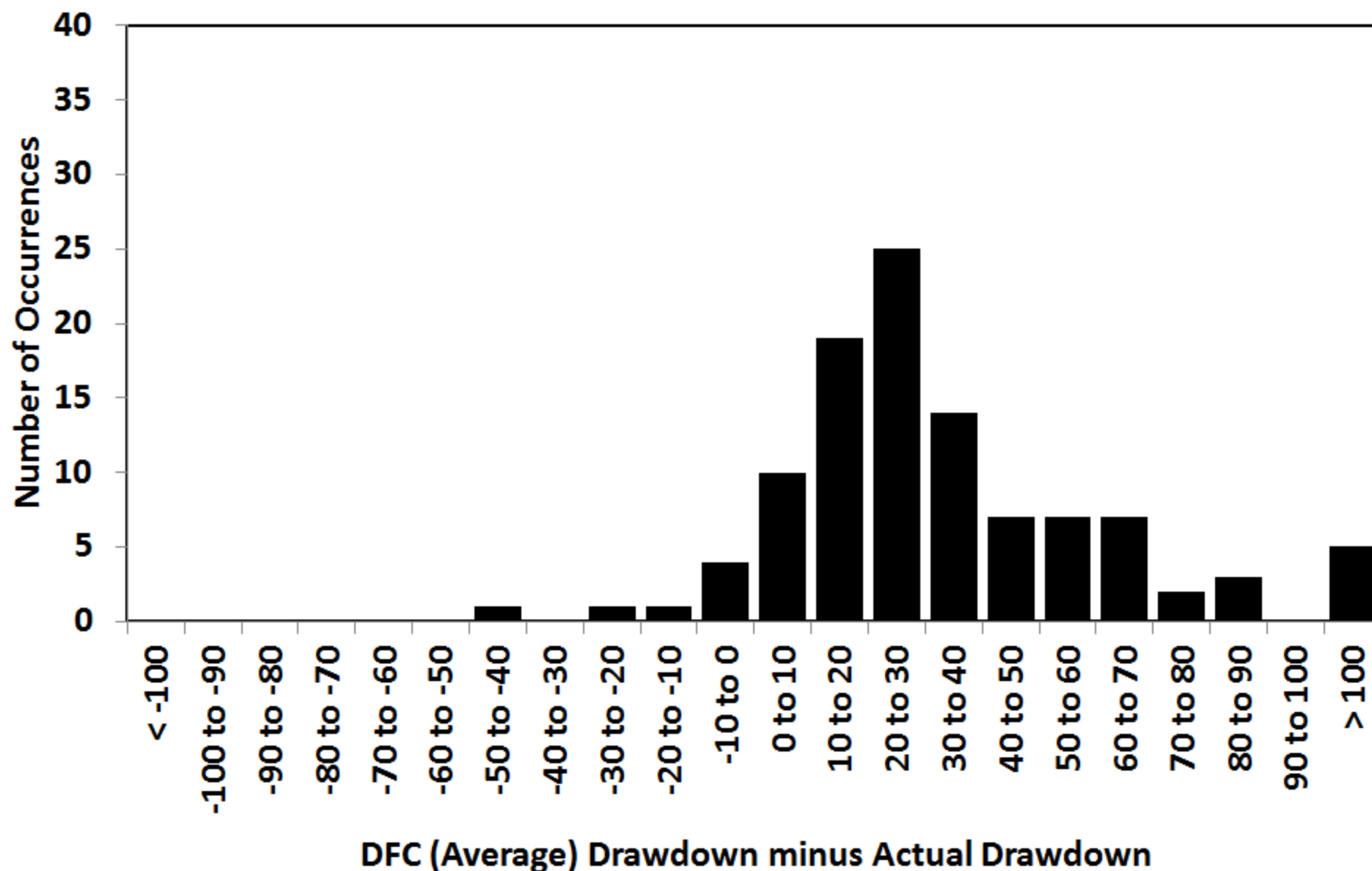
Comparison of DFC (Average) and Actual Drawdown 2009, 2010 and 2011



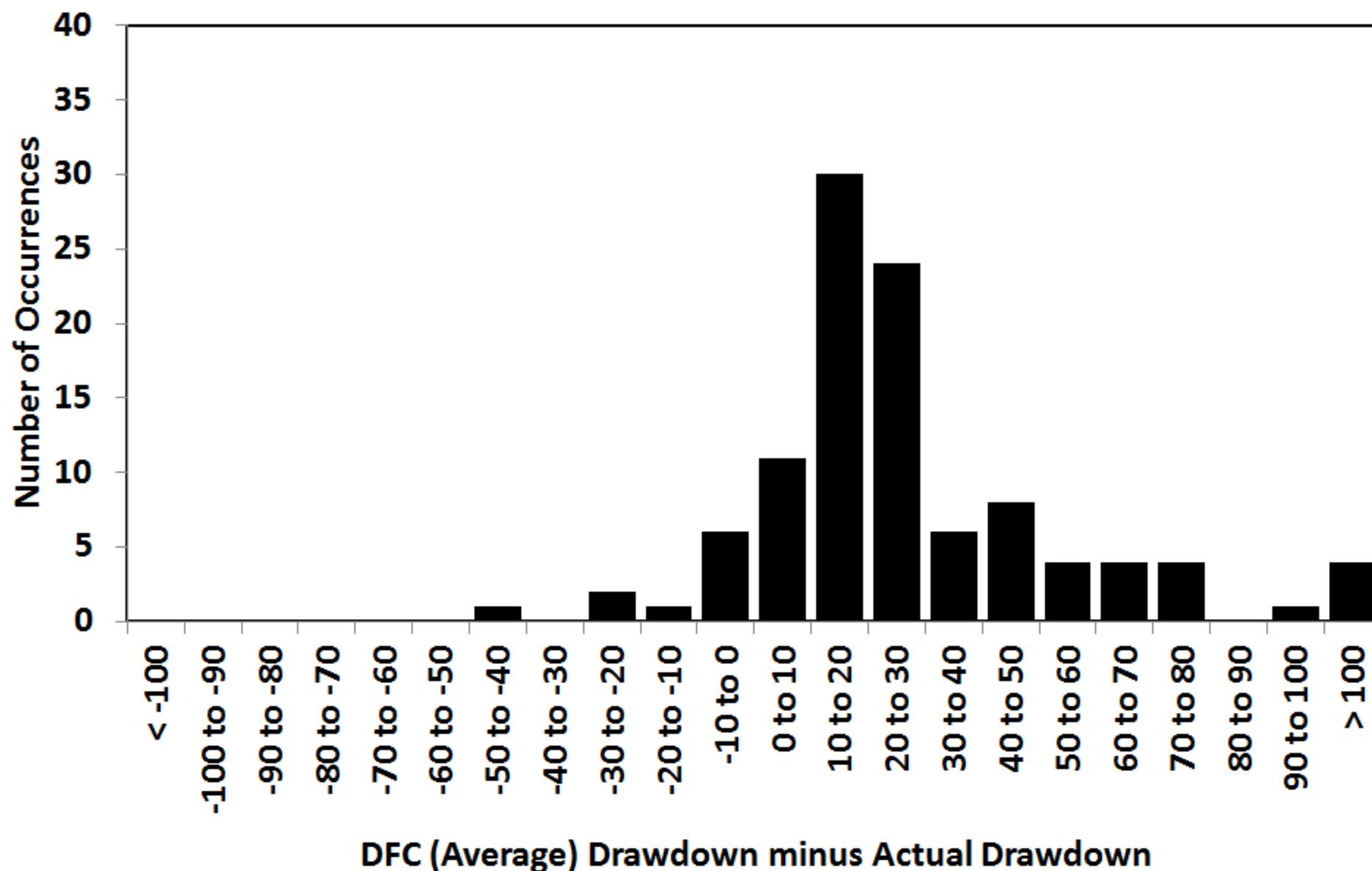
Comparison of DFC (Scenario 149) and Actual Drawdown 2009, 2010 and 2011



Comparison of DFC (Scenario 282) and Actual Drawdown 2009, 2010 and 2011

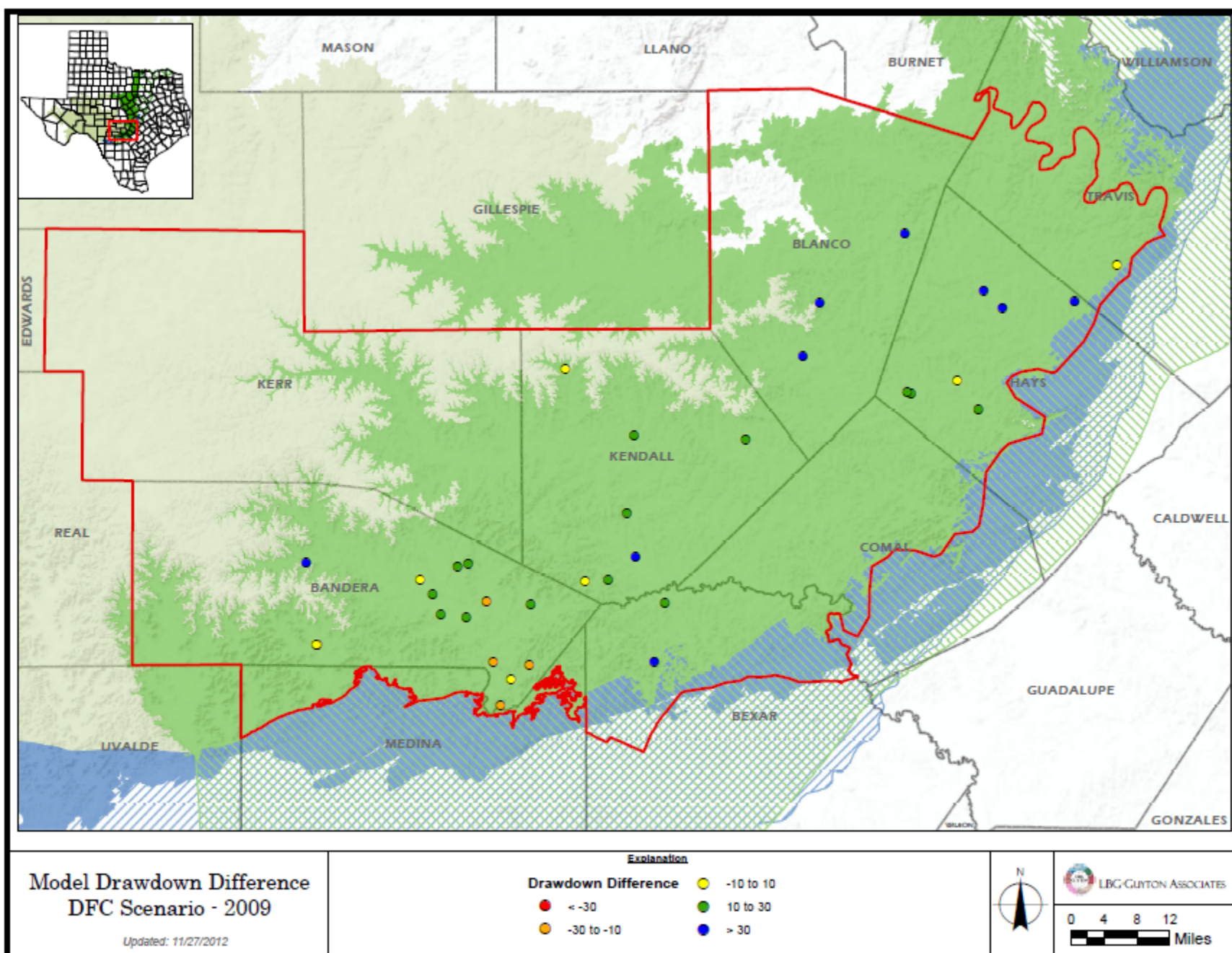


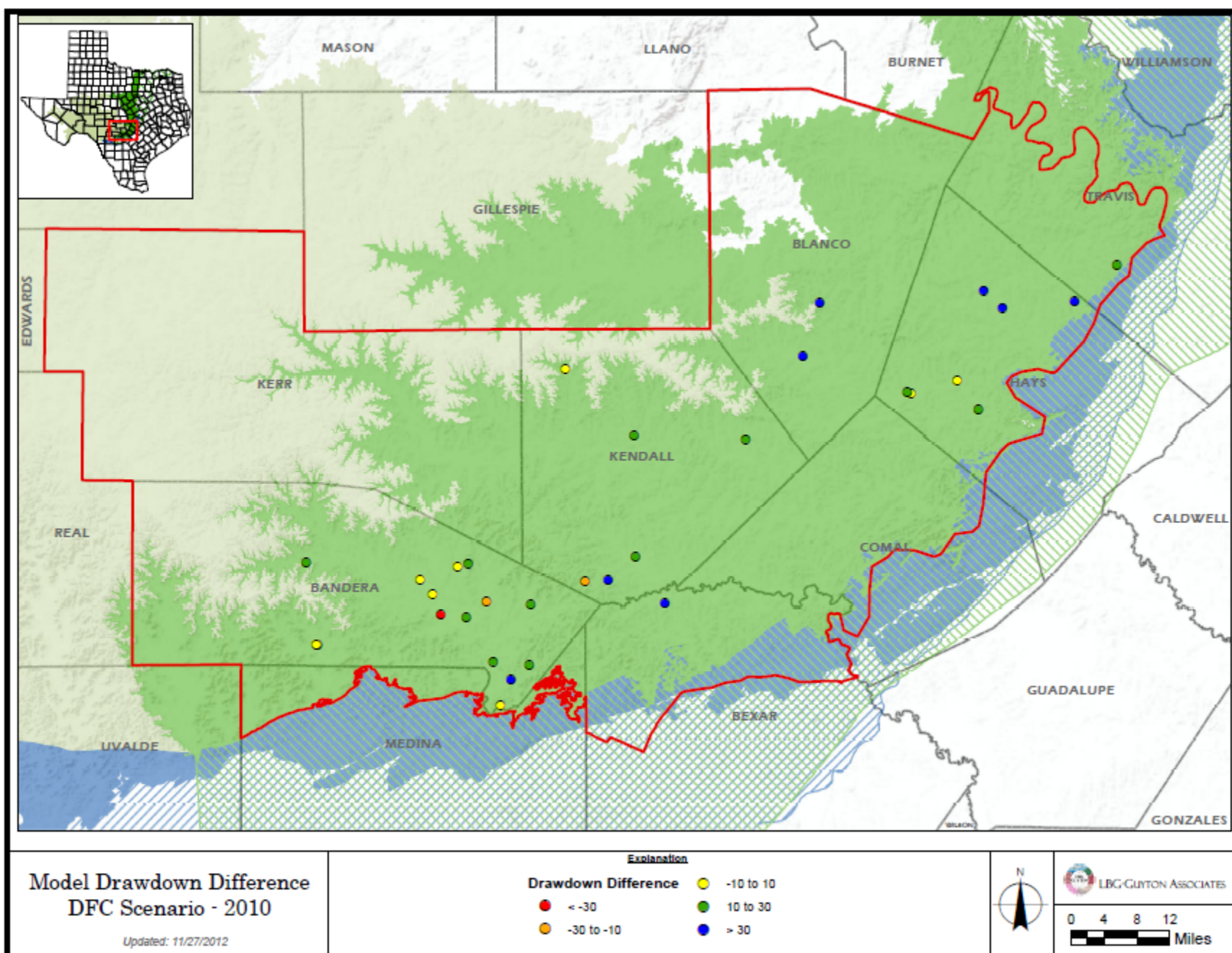
Comparison of DFC (Scenario 366) and Actual Drawdown 2009, 2010 and 2011

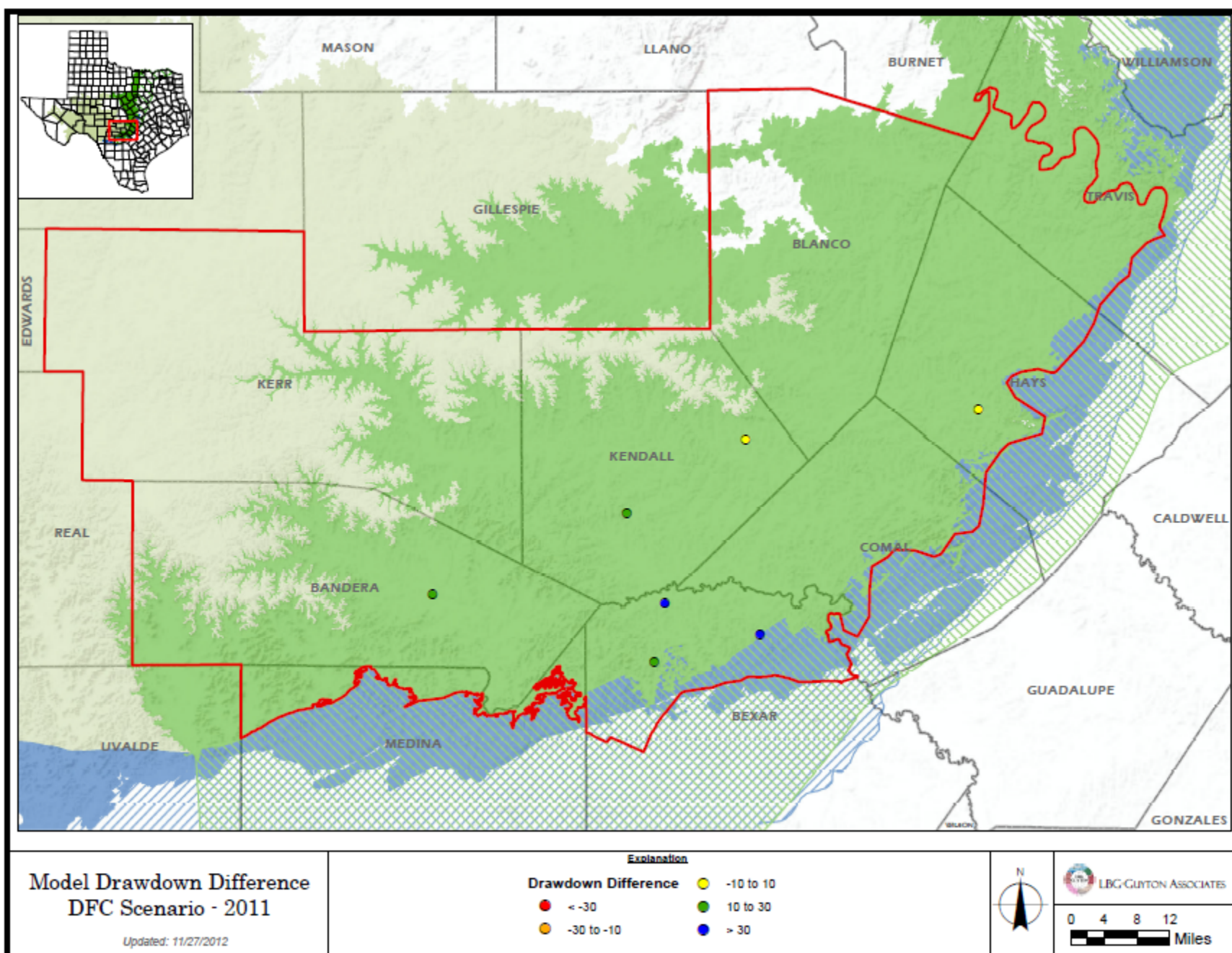


Maps of Comparison

- 2009, 2010, 2011
- Average DFC Condition







Observations

- In general, drawdown is less than DFC drawdown
 - Average condition
 - Specific scenarios
- Specific scenarios
 - Pumping assumptions (assumed high pumping) has not occurred
 - Larger difference in drawdown

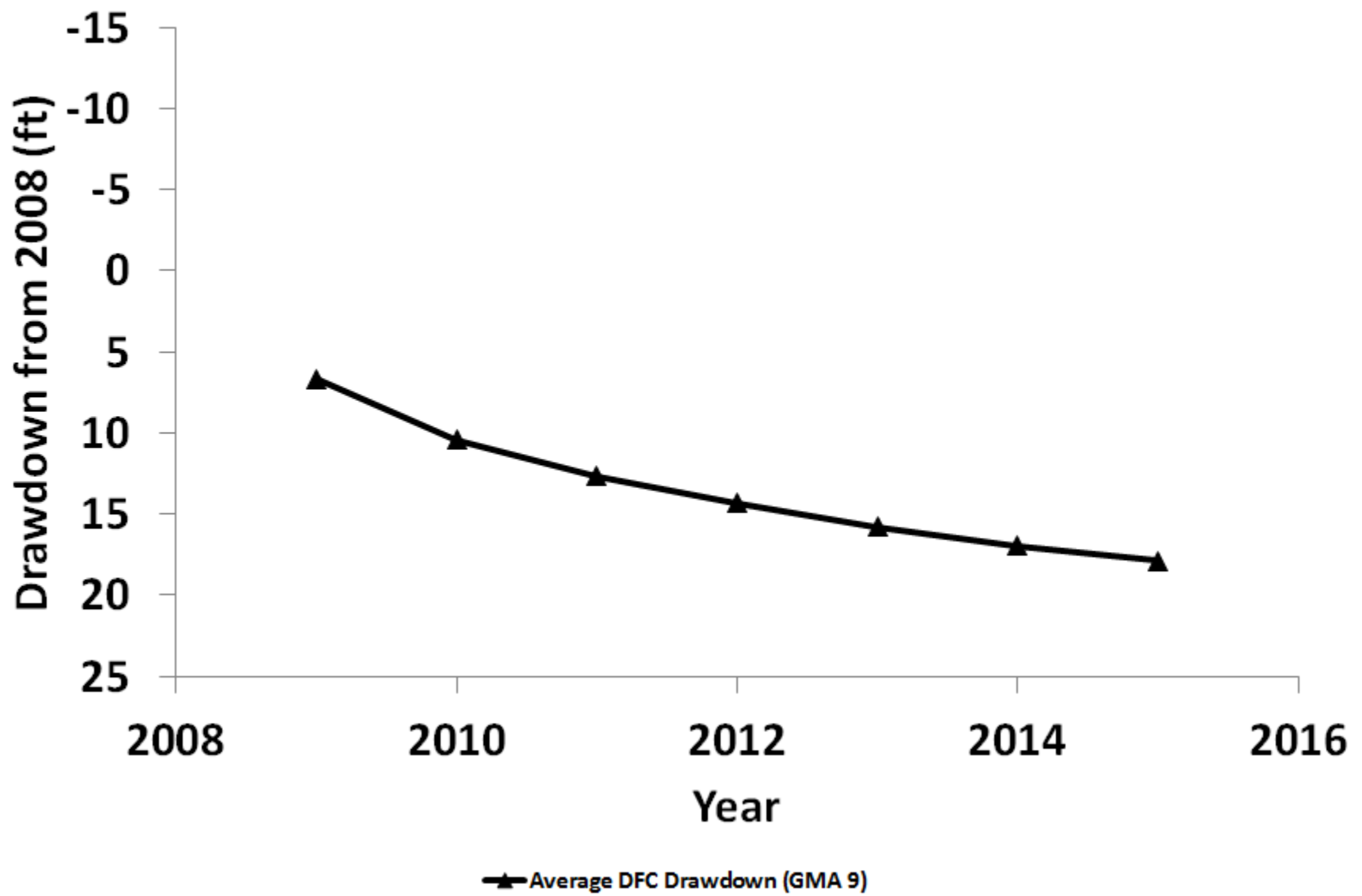
Observations

- Spatial distribution in pumping
 - Most areas: pumping has not increased as assumed in the simulations
 - Some instances where simulated pumping is less than apparent actual pumping

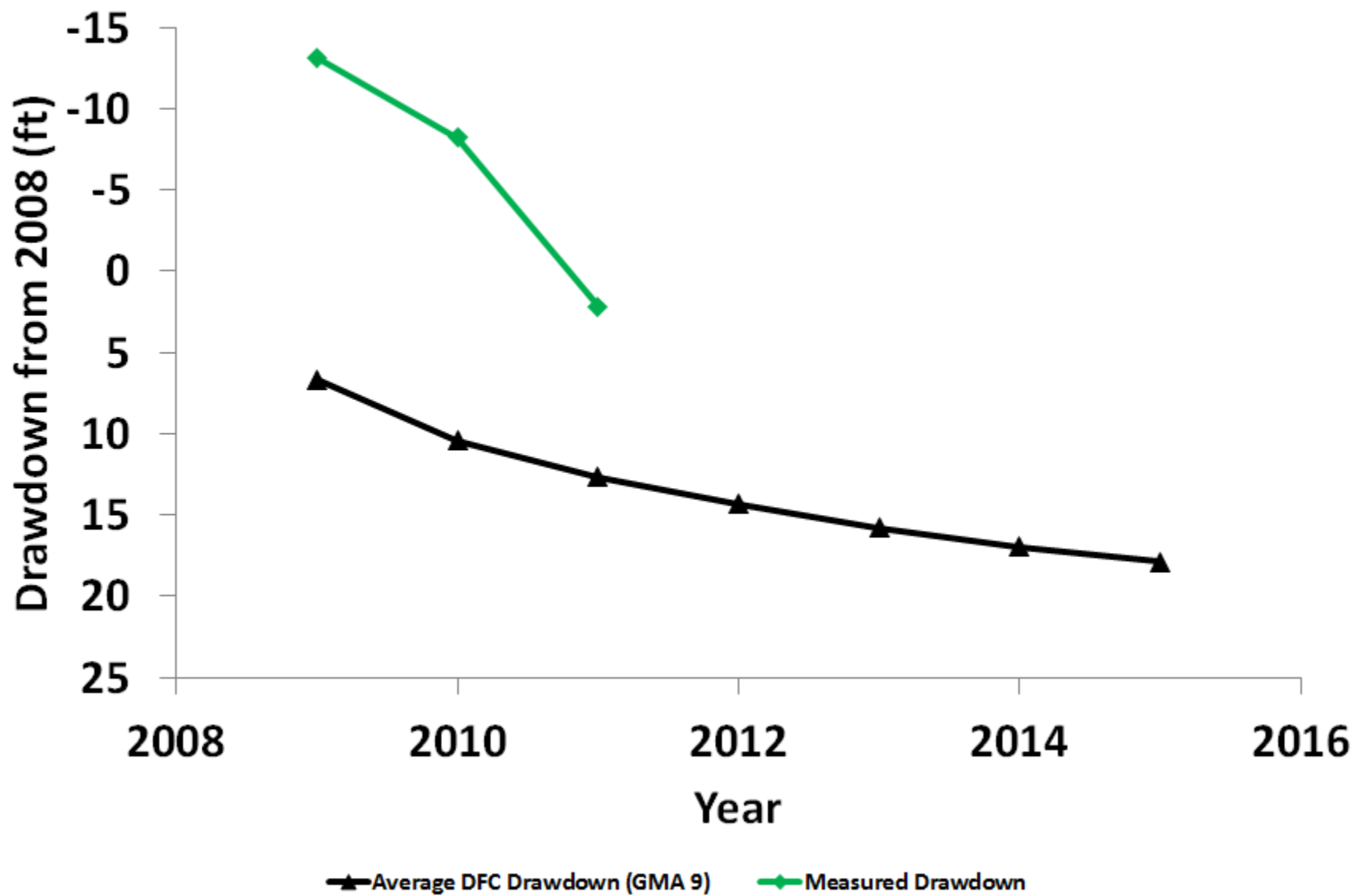
Overall “Compliance”

- Compare actual groundwater elevations with model drawdown for 2009, 2010 and 2011 at those points
 - 2009: 35 wells
 - 2010: 32 wells
 - 2011: 9 wells
- Plot for GMA 9
 - Plots on a county level in report

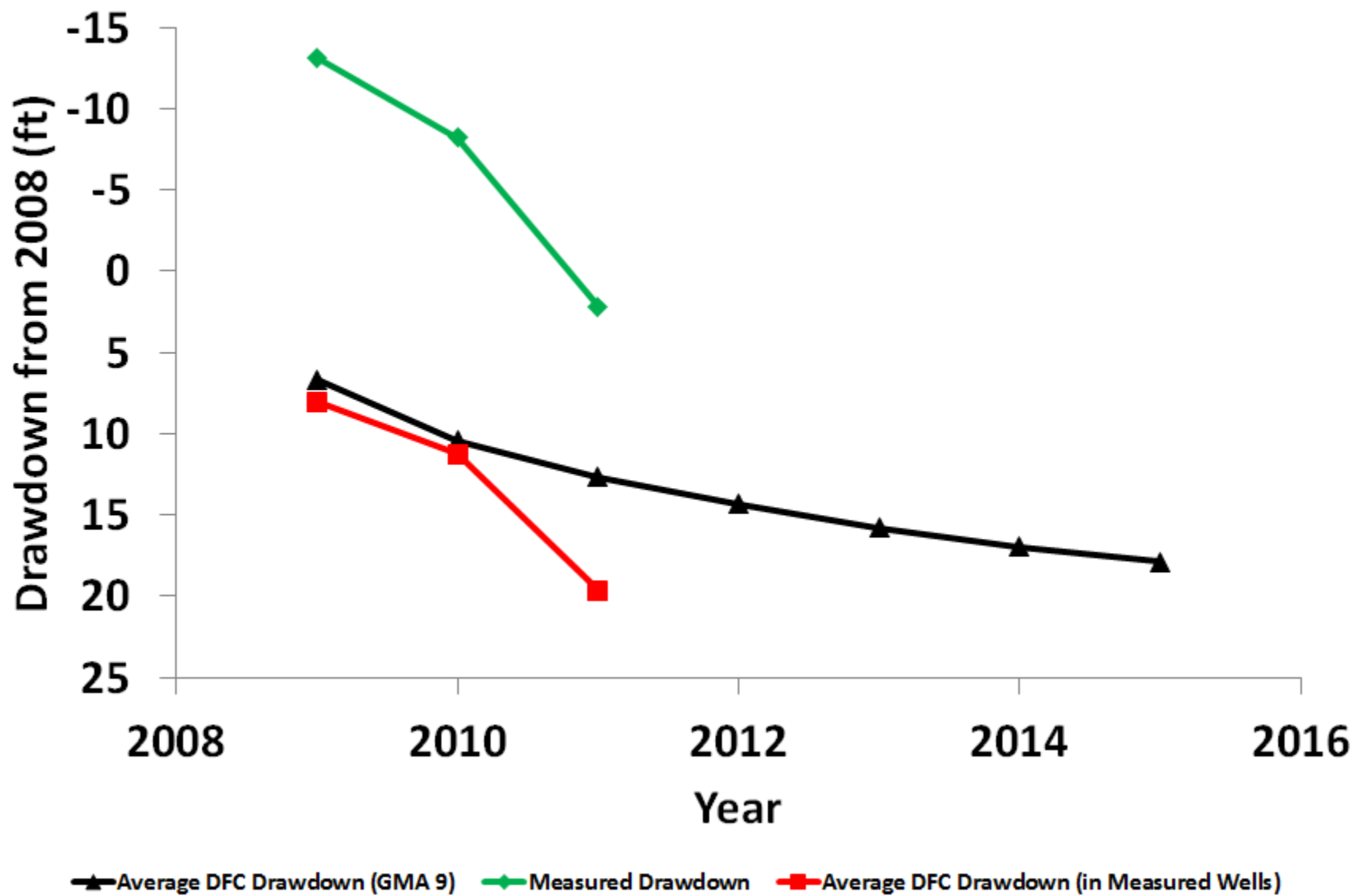
GMA 9 DFC "Compliance"



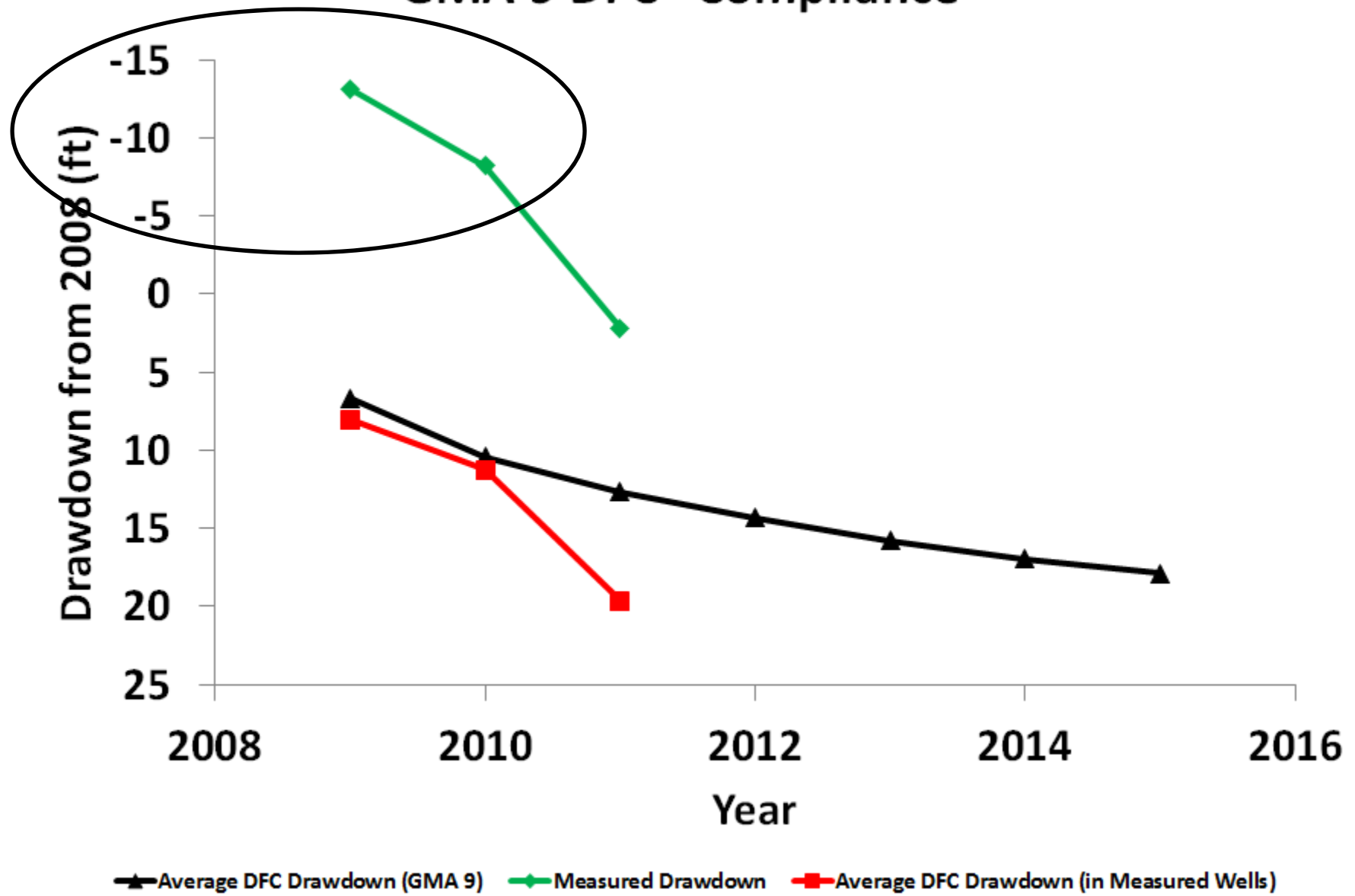
GMA 9 DFC "Compliance"



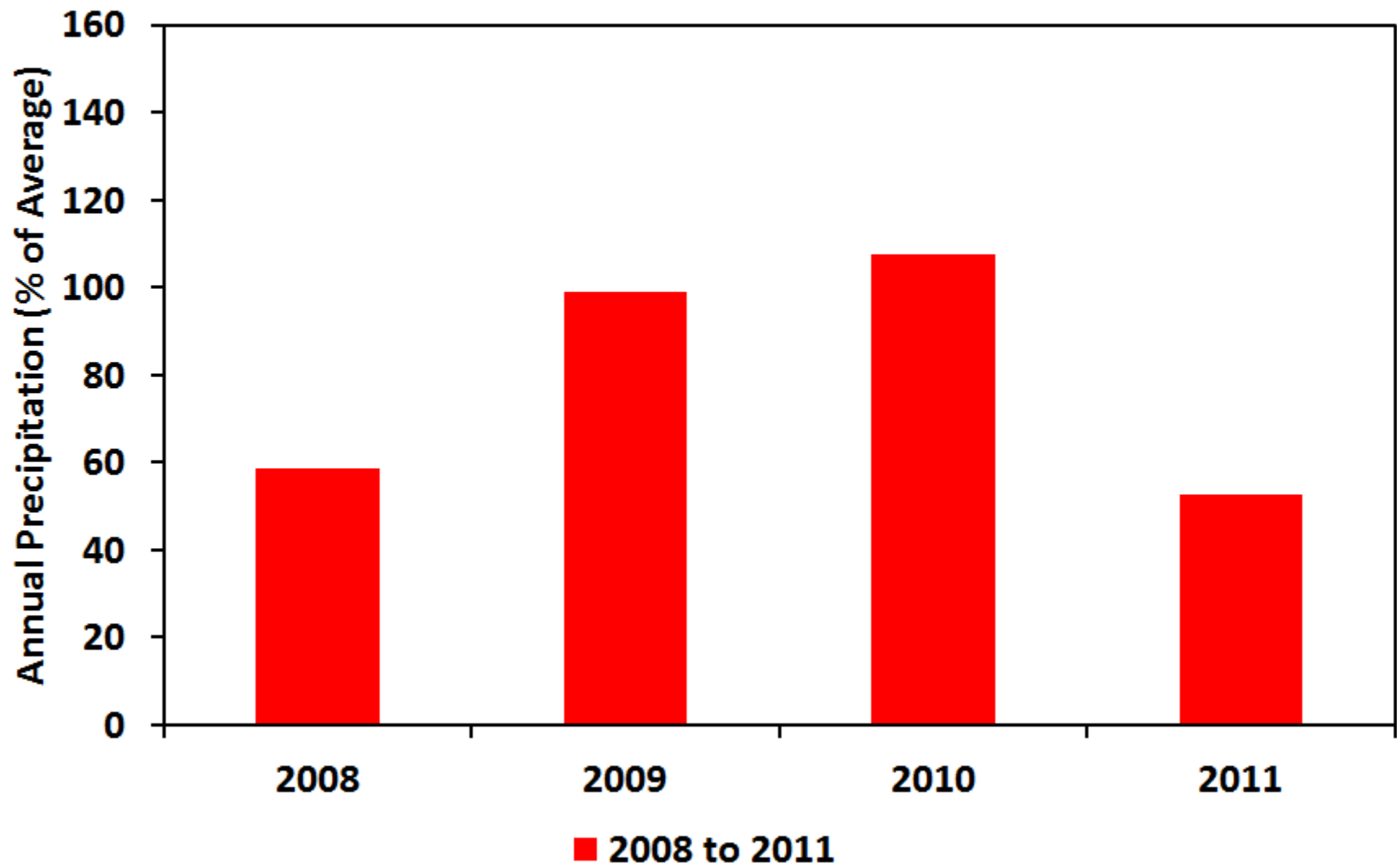
GMA 9 DFC "Compliance"



GMA 9 DFC "Compliance"



Precipitation 2008 - 2011



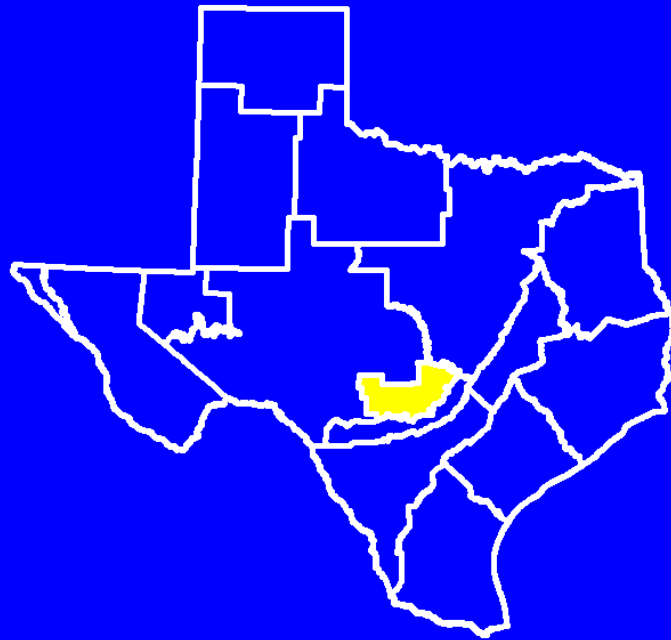
Recovery in First Two Years

- 2008 was severe drought year
 - End of 2008 groundwater elevations were generally low
- End of 2009 was wet
 - End of 2009 groundwater elevations were recovering due to recharge
- 2010 was slightly higher than average
 - September rainfall (TS Hermine)
 - 9.37 in (San Antonio)
 - 13.2 in (Austin)

Conclusions

- Pumping issues
 - 1980 to 1997 (calibrated model)
 - 2008 (previously estimated by GCDs)
 - Simulated (post 2009)
- 2008 as starting point needs to be reviewed
- Actual drawdown from 2009 to 2011 is less than DFC drawdown from 2009 to 2011
 - Considered precipitation conditions

Questions?



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