Brush Management in Gonzales County as a Water Management Strategy

Final Report

HDR Project No. 229237

August 20, 2015

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1.1 Introduction

The Texas State Soil and Water Conservation Board's (TSSWCB) Water Supply Enhancement Program (WSEP) seeks to manage brush in all areas of the state where brush is contributing to a substantial water conservation problem. Through this program, TSSWCB prepares and adopts comprehensive strategies for managing brush, and documents the goals and processes for which brush management is to be implemented. The WSEP also entails a competitive grant process and information about how the agency will allocate funding for priority watersheds across the state in order to enhance water supply via brush control.

As part of the WSEP process, the TSSWCB commissioned Texas Tech University to apply the Ecological Dynamics Simulation (EDYS) model to various watersheds in the State of Texas. The EDYS model incorporates precipitation, depth of groundwater, topography, soils, and vegetation in order to complete a water balance tracking rainfall, soil moisture, evapotranspiration, runoff of surface water, and recharge of groundwater.

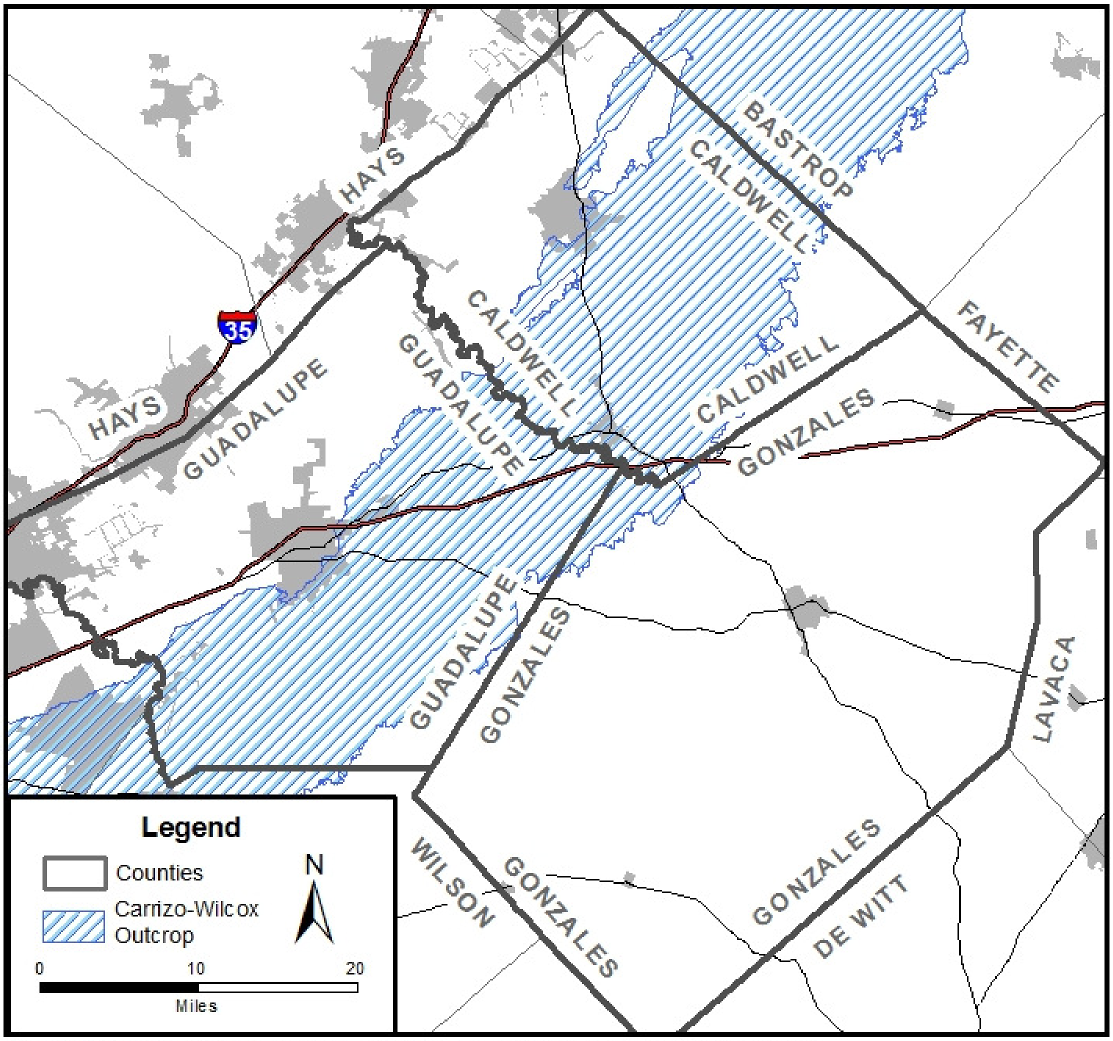
In 2012, Texas Tech completed a study for TSSWCB in Gonzales County, TX[1] investigating target areas for brush control in order to enhance water yield. The study looked at 44 sub-watersheds within the county over a 10-year period from 2002-2011.

As part of the competitive grant process, state law requires that brush management be included in state and regional water plans. After the San Antonio River Authority reached out to TSSWCB in 2013, TSSWCB approached the South Central Texas Regional Planning Group (SCTRWPG) about inclusion of a brush management project in Gonzales County as a water management strategy in the upcoming 2016 South Central Texas Regional Water Plan (2016 Region L Plan). Working with the regional planning group's consultant (HDR) and their regional administrator (San Antonio River Authority), a water management strategy was conceptualized for areas of the Carrizo-Wilcox Aquifer outcrop in Gonzales County. Information from the Texas Tech study was used to approximate recharge to the aquifer in the areas that could potentially increase pumping in the Carrizo-Wilcox Aquifer in Gonzales County. These areas include the Carrizo-Wilcox outcrop in Guadalupe, Gonzales, and Caldwell Counties (Figure 1).

In regional water planning, total pumpage from the Carrizo-Wilcox Aquifer is limited to the Modeled Available Groundwater (MAG) within a given area. In the current planning cycle, the SCTRWPG has determined that the Carrizo-Wilcox Aquifer in Gonzales County is fully allocated, as usage and permitted pumpage are greater than the MAG in at least one decade during the planning period. Increasing the recharge to the Carrizo-Wilcox Aquifer by implementing brush management over the outcrop in Guadalupe, Gonzales, and Caldwell Counties could lead to a larger MAG, while still adhering to the Desired Future Condition (DFC) prescribed by the local Groundwater Management Area (GMA 13).

[1] McLendon, Terry, Cindy R Pappas, Cade L Coldren, Ernest B Fish, Micah J Beierle, Annette E Hernandez, Kenneth A Rainwater, and Richard E Zartman, "Application of the EDYS Decision Tool for Modeling of Target Sites [in Gonzales County] for Water Yield Enhancement Through Brush Control," Texas State Soil and Water Conservation Board, September 2012.

Figure 1. Location of Study Area



TSSWCB, HDR, and SARA laid out a procedure to determine the increase in the MAG due to the enhanced recharge from brush management. The steps include:

1. Using available data, approximate the recharge over the Carrizo-Wilcox outcrop in three counties (Guadalupe, Gonzales, and Caldwell)
2. Estimate the recharge for a 61-year period (including the drought of record) using the 10-year period in the Texas Tech study
3. Incorporate the enhanced recharge estimates into the appropriate Groundwater Availability Model (GAM)
4. Perform iterative simulations of the GAM in order to determine the increase pumpage (above the current MAG estimates) from the Carrizo-Wilcox Aquifer in Gonzales County, while adhering to the DFC (as set be GMA 13) at the end of the simulation period

The calculations and results of this procedure are described herein.

1.2 Recharge Enhancement Estimation

The Texas Tech EDYS study provided good information about the sub-watersheds within Gonzales County over a 10-year period (2002-2011). In order to increase the recharge to the Carrizo-Wilcox Aquifer, it would be necessary to concentrate brush management over the outcrop, where fresh water (via precipitation) enters the aquifer. Furthermore, as shown in Figure 1, the Carrizo-Wilcox Aquifer outcrop covers a small part of the northwestern edge of the county.

For a water management strategy to be viable, the project sponsor would likely wish to implement brush management over the length of the outcrop that affects water availability all across Gonzales County. Additionally, in order to conform with Texas Water Development Board (TWDB) rules and guidance for evaluating water management strategies, one must prove the reliability of the firm supply of the project through a repeat of the drought of record. For this part of Texas, the drought of record is the drought of the 1950s.

Using data and modeling performed for the TSSWCB in the Gonzales County EDYS study by Texas Tech University, linear regression analyses were performed to attempt to correlate the amount of enhanced, recharge that could be expected. In order to extrapolate the results of the Texas Tech study from a 10-year period to the full 61-year period, a common data point was necessary. Measured precipitation for the area (specifically the precipitation associated with the TWDB's Quad 810 data – Figure 2) was used as this correlation data set as precipitation is an independent variable and the force that drives the hydrologic cycle.

Various regressions were analyzed investigating modeled recharge enhancement from the EDYS model to single-month precipitation, multiple-month precipitation, lagged single and multiple-month precipitation, and annual precipitation. Ultimately, annual enhanced recharge for a given area was best correlated with annual precipitation as shown in Figure 3. Note that Figure 3 includes an Enhanced Recharge Ratio, which is simply the ratio of enhanced recharge to the annual precipitation. Therefore, the equation to determine enhanced recharge as a function of annual precipitation can be simplified as shown in Equation 1 below.

$$\boldsymbol{Enhanced\ Recharge\ = Average\ Annual\ Precipitation^{2} \times 0.00117} \qquad \textbf{Eq. 1}$$

This equation was used to calculate enhanced recharge for a 1950-2013 model simulation. Average annual rainfall in the equation is derived from the TWDB quad 810 database[2]. This quad covers most all of the outcrop area of the Carrizo-Wilcox aquifers in the study area. These precipitation data show rainfall ranged from 14.5 to 50.4 in/yr and averaged 34.4 in/yr. Enhanced recharge in the equation is the long-term average annual enhanced recharge amount. These calculations resulted in an enhanced recharge of 2.16 in/yr for the simulation period if 100 percent of landowners participated in brush management program. The enhanced recharge was applied to each of the

[2] http://www.twdb.texas.gov/surfacewater/conditions/evaporation/

model cells in the outcrop of the Carrizo, middle Wilcox, and lower Wilcox model layers. The potential enhanced recharge by landowner participation levels of 10, 30, 50, and 100 percent are shown in Table 1.

Figure 2. Location of TWDB Precipitation Quads in Relation to Gonzales County

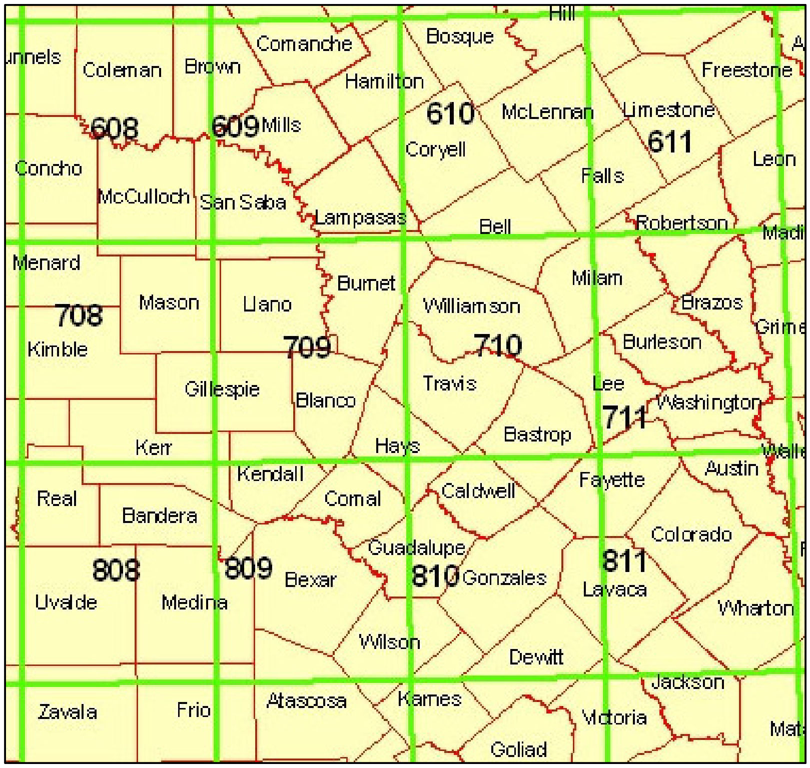
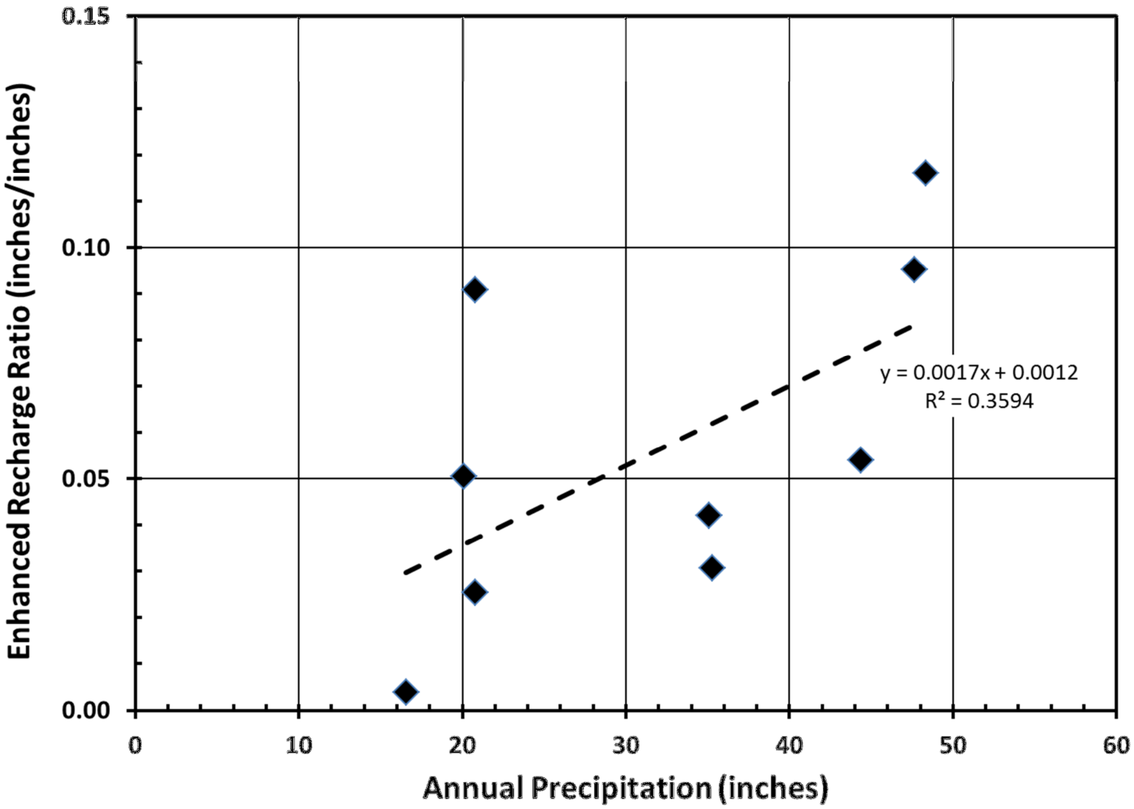


Figure 3. Location of TWDB Precipitation Quads in Relation to Gonzales County



(Units: in/yr)

Table 1. Enhanced Recharge by Landowner Participation

Percent of Landowner Participation	Enhanced Recharge (in/yr)
10%	0.22
30%	0.65
50%	1.08
100%	2.16

The potential enhanced recharge was applied to a series of modeling simulations using the Southern Queen City and Sparta Aquifers[3] Groundwater Availability Model (GAM); this model also includes the Carrizo and Wilcox aquifers. Five simulations were conduced, including: baseline (no enhanced recharge), 10, 30, 50, and 100 percent landowner participation. Specifically, the baseline model run was the GMA 13 adopted Desired Future Condition Scenario 4 of GAM Run 09-034. This model is a 61-year simulation which uses average recharge conditions and historic, calibrated initial heads to year 1999 conditions. The pumping amounts vary throughout the DFC simulation; however the recharge values are constant for each stress period. The potential

[3] Kelley, V., Deeds, N., Fryar, D., Nicot, J. Groundwater Availability Models for Queen City and Sparta Aquifers. Texas Water Development Board. October 2004.

enhanced recharge was applied only to the Carrizo (model layer 5), middle Wilcox (layer 7), and the lower Wilcox (layer 8) of the GAM model in Guadalupe, Caldwell, and Gonzales Counties. The recharge in all other counties and aquifers was unchanged.

1.3 Approach

The conceptual modeling approach to estimate the increase in MAG that can be attributed to brush management included adding enhanced recharge to the selected model layers and running the model in an iterative process of increasing pumping until the water levels from the model run *with* enhanced recharge (scenario) nearly matched the model run *without* enhanced recharge (baseline). The amount of pumping needed to drawdown the water levels to the baseline levels is the potential increase in MAG due to enhanced recharge, i.e. brush management. Pumping wells to capture the enhanced recharge were added in the most productive part of the aquifer.

The specific modeling steps included the following:

1. *Calculate and Add Enhanced Recharge to the Model's Baseline Recharge in Guadalupe, Caldwell, and Gonzales Counties* – Using the *enhanced recharge* equation, the enhanced recharge was calculated and added to the baseline recharge. The enhanced recharge was applied to each aquifer layer and in each county uniformly (recharge was applied at a constant rate to each cell in the Carrizo and Wilcox outcrop, regardless of the aquifer permeability). The combined recharge (baseline plus enhanced) is assumed to represent the total recharge to the aquifer if a brush management program was implemented. Five modeling scenarios representing varying levels of landowner involvement were modeled including:

    1. Baseline (no landowner participation)
    2. Baseline + 10% landowner participation (enhanced 0.22 in/yr of recharge)
    3. Baseline + 30% landowner participation (enhanced 0.65 in/yr of recharge)
    4. Baseline + 50% landowner participation (enhanced 1.08 in/yr of recharge)
    5. Baseline + 100% landowner participation (enhanced 2.16 in/yr of recharge)

    The baseline and modeled recharge by aquifer, county, and scenario is shown in Table 2 and Figures 4-6. The average baseline recharge in the Carrizo aquifer is about 2.5 in/yr in Caldwell County and 1.8 in/yr in Gonzales and Guadalupe Counties. The baseline recharge in the middle and lower Wilcox is significantly less and ranges from 0.58 to 0.76 in/yr in the study area. Using the enhanced recharge equation, the enhanced recharge was calculated and added to the baseline recharge for each scenario. As shown on the graphs, the enhanced recharge in some scenarios is up to 3 times greater than the existing baseline recharge.

    Figures 7-11 show the baseline recharge and the modeled brush management recharge for each scenario. Recharge was only modified in Guadalupe, Caldwell, and Gonzales counties in the Carrizo, middle Wilcox, and lower Wilcox aquifers representing model layers 5, 7, and 8, respectively. There is no recharge in the upper Wilcox aquifer (layer 6) in the study area. The recharge in all other aquifers and counties was unchanged.

Table 2. Average Modeled Recharge by Scenario, County, and Aquifer (in/yr)

Scenario	Aquifer	Caldwell County			Gonzales County			Guadalupe County		
		Baseline	Enhanced Recharge	Total Modeled Recharge	Baseline	Enhanced Recharge	Total Modeled Recharge	Baseline	Enhanced Recharge	Total Modeled Recharge
Baseline (Scenario 4)	Carrizo	2.53	0.00	2.53	1.88	0.00	1.88	1.83	0.00	1.83
	Middle Wilcox	0.58	0.00	0.58	0.57	0.00	0.57	0.61	0.00	0.61
	Lower Wilcox	0.71	0.00	0.71	-	-	-	0.76	0.00	0.76
10% Participation	Carrizo	2.53	0.22	2.74	1.88	0.22	2.10	1.83	0.22	2.04
	Middle Wilcox	0.58	0.22	0.80	0.57	0.22	0.79	0.61	0.22	0.83
	Lower Wilcox	0.71	0.22	0.92	-	-	-	0.76	0.22	0.98
30% Participation	Carrizo	2.53	0.65	3.18	1.88	0.65	2.53	1.83	0.65	2.47
	Middle Wilcox	0.58	0.65	1.23	0.57	0.65	1.22	0.61	0.65	1.26
	Lower Wilcox	0.71	0.65	1.36	-	-	-	0.76	0.65	1.41
50% Participation	Carrizo	2.53	1.08	3.61	1.88	1.08	2.96	1.83	1.08	2.91
	Middle Wilcox	0.58	1.08	1.67	0.57	1.08	1.65	0.61	1.08	1.70
	Lower Wilcox	0.71	1.08	1.79	-	-	-	0.76	1.08	1.85
100% Participation	Carrizo	2.53	2.16	4.69	1.88	2.16	4.05	1.83	2.16	3.99
	Middle Wilcox	0.58	2.16	2.75	0.57	2.16	2.73	0.61	2.16	2.78
	Lower Wilcox	0.71	2.16	2.87	-	-	-	0.76	2.16	2.93

2. *Run the groundwater model for baseline and enhanced recharge scenarios* – A series of monitoring wells were placed in the Carrizo and Wilcox aquifers throughout the study area, shown on Figure 12, to record the model results. Hydrographs of the model results at these monitoring wells were plotted to for a visual presentation of water levels over time. Figure 13 shows three representative hydrographs plotting the modeled scenarios for wells located in the outcrop and downdip sections of the model. The model results comparing the baseline model water levels with no enhanced recharge (blue line) to the enhanced recharge scenario (red line) show that the water levels in the outcrop areas for the scenario runs are considerably higher. The water levels are also higher in the downdip areas; however, the rise was less then in the outcrop.

3. *Layout conceptual well fields across Guadalupe, Caldwell, and Gonzales Counties* – As noted in Step 2, when enhanced recharge is applied to the baseline scenarios, the water levels throughout the model rise. To calculate the potential MAG increase from enhanced recharge, the scenario water levels must nearly match the baseline water levels. In order to lower scenario model water levels from Step 2 to match the baseline model runs, conceptual well fields were added to the model in the Carrizo and Wilcox aquifers. The conceptual well fields, shown in Figure 14, were 5 to 6 miles wide and were located approximately 5 to 6 miles downdip of the outcrop of the Carrizo and Wilcox aquifers in model layers 5 (Carrizo), 7 (Wilcox), and 8 (Wilcox). This area was chosen because it would

be the most probable location for new high capacity wells based on aquifer depth, thickness, and transmissivities. Note that the potential MAG increase calculated in the report is sensitive to the location of the conceptual well fields. If the conceptual well fields were moved closer to the outcrop, the calculated potential MAG is expected to increase. Conversely, if the conceptual well fields were moved further from the outcrop, the calculated potential MAG is expected to decrease.

4. *Adjust Well Pumping to Match Water Levels* – Pumping was added to the conceptual well field and adjusted in an iterative process until the scenario water levels (Figure 13, green line) nearly match the baseline water levels (Figure 13, blue line). The amount of pumping needed to drawdown the water levels is the potential MAG increase due to enhanced recharge, i.e. brush management. The added pumping was constant for each cell and each stress period and was in addition to the existing baseline pumping. If the scenario water levels were higher than the baseline water levels, more pumping was added to the conceptual well field to draw the water levels down. Alternatively, if the scenario water levels were below the baseline water levels, less pumping was added to the conceptual well field to raise the water levels to the baseline water levels. Note that this is a simplified assumption in that it takes considerable time for the recharge to build-up groundwater levels in the outcrop a sufficient amount to increase the groundwater flow into the downdip part of the aquifer. Also, because aquifer properties vary throughout the model, constant pumping in some areas has a different effect on the aquifer water levels than in other parts areas of the model.
5. *Calculate Increase in MAG by Landowner Participation Levels* – After the conceptual well field model pumping was adjusted so that the scenario water levels nearly match the baseline water levels, the additional pumping rate was summed and this result is the potential MAG increase if brush management practices were implemented.

1.4 Modeling Results

Applying the steps above, the modeling results for each of the five scenarios are discussed in the following sections. Model results focus on stress period 61, which is the last year of the simulation.

<u>Baseline (no landowner participation)</u>:

The baseline scenario is the adopted GMA 13 Desired Future Condition Scenario 4. This model run was *not* modified to include a conceptual well field or enhanced recharge. The results of this model were solely used to subtract and compare water levels with all other model scenarios water levels to determine the affects of enhanced recharge and pumping. Baseline water levels are shown on the hydrographs and discussed in the following sections. In general, water levels decline throughout the 61 stress period model run in both the Carrizo and Wilcox aquifers.

Baseline + 10% landowner participation:

In this scenario, an additional 0.22 in/yr of recharge was added to the existing recharge in the Carrizo and Wilcox aquifers, as shown in Figure 8. The water level hydrographs for this scenario are shown in Figures 15-17. The water levels rise slightly from baseline conditions in the outcrop and less so in the downdip areas. Figures 18a-20a show the rise in water levels from baseline conditions in stress period 61 for the Carrizo and Wilcox aquifers, as noted by negative values on the figures. The added recharge increases the water levels in the Carrizo and middle Wilcox outcrops by about 5 ft and by about 1 ft in the downdip areas. The lower Wilcox aquifer outcrop water levels rise by 10 ft in Guadalupe County, up to 20 ft in Caldwell County, and by 1 ft in the downdip areas.

Figures 18b-20b shows the water levels after the conceptual well field pumping was added to the model. Since pumping was added to the model to lower water levels to baseline conditions, the water levels in the conceptual model well field should nearly match the baseline conditions, i.e. the difference in water levels in the conceptual well field should be zero, or very close to zero. The difference in water levels in the Carrizo and middle Wilcox in the conceptual well field area are 0 ft and the water levels in the lower Wilcox are about 1 ft. Water levels between the outcrop area and the conceptual well field will always be higher than baseline conditions because higher water levels are needed to increase the hydraulic gradient that is required to force additional groundwater flow toward the conceptual well field.

The amount of potential MAG increase with 10 percent landowner participation is 758 acft/yr from the Carrizo aquifer, 35 acft/yr from the middle Wilcox, and 576 from the lower Wilcox to total 1,370 acft/yr, as shown in Table 3. For comparison purposes, the enhanced recharge was 1,489 acft/yr, 3,704 acft/yr, and 2,723 acft/yr for the Carrizo, middle Wilcox, and lower Wilcox, respectively. The difference between the increase in MAG and enhanced recharge is largely attributed to an increase in groundwater storage (rise in groundwater levels).

Table 3. MAG increase with 10 percent landowner participation

Aquifer	Number of Conceptual Wells in Well Field	Well Pumping in each Conceptual Well (acft)	Total Conceptual Well Field Pumping (acft)	Enhanced Recharge (acft)	Difference between Well Field Pumping and Enhanced Recharge (acft)
Carrizo	190	3.99	758	1,489	731
Middle Wilcox	214	0.16	35	3,704	3,669
Lower Wilcox	245	2.35	576	2,723	2,147
Total			**1,369**	**7,916**	**6,547**

Baseline + 30% landowner participation:

In this scenario, an additional 0.65 in/yr of recharge was added to the existing recharge in the Carrizo and Wilcox aquifers, as shown in Figure 9. The water level hydrographs for this scenario are shown in Figures 21-23. The water levels rise moderately from baseline conditions in the outcrop and less so in the downdip areas. Figures 24a-26a show the increase in water levels from baseline conditions in stress period 61 for the Carrizo and Wilcox aquifers, as noted by negative values on the figure. The added recharge increases the water levels in the Carrizo aquifer by about 15 ft and by about 5 ft in the downdip areas. The middle Wilcox aquifer water levels increase by 20 to 25 ft in the outcrop and by about 3 ft in the downdip areas. The lower Wilcox aquifer outcrop water levels increase by 25 to 30 ft in Guadalupe County and about 20 ft in Caldwell County with localized areas of increased recharge and by 5 ft in the downdip areas.

Figures 24b-26b shows the water levels after the conceptual well field pumping was added to the model. Since pumping was added to the model to drawdown the water levels to baseline conditions, the water levels in the conceptual model well field should nearly match the baseline conditions. The water levels in the Carrizo in the conceptual well field area are 0 ft and the water levels in the middle and lower Wilcox are about 1 foot.

The amount of potential MAG increase with 30 percent landowner participation is 2,274 acft/yr from the Carrizo aquifer, 105 acft/yr from the middle Wilcox, and 2,251 from the lower Wilcox to total 4,631 acft/yr, as shown in Table 4. For comparison purposes, the enhanced recharge was 4,466 acft/yr, 11,113 acft/yr, and 8,170 acft/yr for the Carrizo, middle Wilcox, and lower Wilcox, respectively.

Table 4. MAG increase with 30 percent landowner participation

Aquifer	Number of Conceptual Wells in Well Field	Well Pumping in each Conceptual Well (acft)	Total Conceptual Well Field Pumping (acft)	Enhanced Recharge (acft)	Difference between Well Field Pumping and Enhanced Recharge (acft)
Carrizo	190	11.97	2,274	4,466	2,192
Middle Wilcox	214	0.49	105	11,113	11,008
Lower Wilcox	245	9.19	2,251	8,170	5,919
Total			**4,630**	**23,749**	**19,119**

<u>Baseline + 50% landowner participation:</u>

In this scenario, an additional 1.08 in/yr of recharge was added to the existing recharge in the Carrizo and Wilcox aquifers, as shown in Figure 10. The water level hydrographs for this scenario are shown in Figures 27-29. The water levels rise moderately from baseline conditions in the outcrop and less so in the downdip areas. Figures 30a-32a show the increase in water levels from baseline conditions in stress period 61 for the Carrizo and Wilcox aquifers, as noted by negative values on the figure. The added recharge increases the water levels in the Carrizo aquifer by about 30 ft in Guadalupe County and 10 ft in Caldwell County and by about 5 ft in the downdip areas. The middle Wilcox aquifer water levels increase by about 40 ft in the outcrop and by about 5 ft in the downdip areas. The lower Wilcox aquifer outcrop water levels increase by 40 to 60 ft in Guadalupe County and about 40 ft in Caldwell County with localized areas of increased recharge and by 10 ft in the downdip areas.

Figures 30b-32b shows the water levels after the conceptual well field pumping was added to the model. Since pumping was added to the model to drawdown the water levels to baseline conditions, the water levels in the conceptual model well field should nearly match the baseline conditions. The water levels in the Carrizo and middle Wilcox in the conceptual well field area are 0 ft and the water levels in the lower Wilcox are about 5 ft.

The amount of potential MAG increase with 50 percent landowner participation is 3,790 acft/yr from the Carrizo aquifer, 280 acft/yr from the middle Wilcox, and 2,855 from the lower Wilcox to total 6,925 acft/yr, as shown in Table 5. For comparison purposes, the enhanced recharge was 7,443 acft/yr, 18,521 acft/yr, and 13,617 acft/yr for the Carrizo, middle Wilcox, and lower Wilcox, respectively.

Table 5. MAG increase with 50 percent landowner participation

Aquifer	Number of Conceptual Wells in Well Field	Well Pumping in each Conceptual Well (acft)	Total Conceptual Well Field Pumping (acft)	Enhanced Recharge (acft)	Difference between Well Field Pumping and Enhanced Recharge (acft)
Carrizo	190	19.95	3,790	7,443	3,653
Middle Wilcox	214	1.31	280	18,521	18,241
Lower Wilcox	245	11.65	2,855	13,617	10,762
Total			**6,925**	**39,581**	**32,656**

Baseline + 100% landowner participation:

In this scenario, an additional 2.16 in/yr of recharge was added to the existing recharge in the Carrizo and Wilcox aquifers, as shown in Figure 11. The water level hydrographs for this scenario are shown in Figures 33-35. The water levels rise significantly from baseline conditions in the outcrop and less so in the downdip areas. Figures 36a-38a show the increase in water levels from baseline conditions in stress period 61 for the Carrizo and Wilcox aquifers, as noted by negative values on the figure. The added recharge increases the water levels in the Carrizo aquifer by about 60 ft in Guadalupe County and 25 ft in Caldwell County and by about 10 ft in the downdip areas. The middle Wilcox aquifer water levels increase by about 70 to 80 ft in the outcrop and by about 10 ft in the downdip areas. The lower Wilcox aquifer outcrop water levels increase by 70 ft in Guadalupe County and about 70 ft in Caldwell County with localized areas of increased recharge and by 20 ft in the downdip areas.

Figures 36b-38b shows the water levels after the conceptual well field pumping was added to the model. Since pumping was added to the model to drawdown the water levels to baseline conditions, the water levels in the conceptual model well field should nearly match the baseline conditions. The water levels in the Carrizo and middle Wilcox in the conceptual well field area are 0 ft and the water levels in the lower Wilcox are about 5 ft.

The amount of potential MAG increase with 100 percent landowner participation is 6,065 acft/yr from the Carrizo aquifer, 641 acft/yr from the middle Wilcox, and 7,204 from the lower Wilcox to total 13,910 acft/yr, as shown in Table 6. For comparison purposes, the enhanced recharge was 7,443 acft/yr, 18,521 acft/yr, and 13,617 acft/yr for the Carrizo, middle Wilcox, and lower Wilcox, respectively.

Table 6. MAG increase with 100 percent landowner participation

Aquifer	Number of Conceptual Wells in Well Field	Well Pumping in each Conceptual Well (acft)	Total Conceptual Well Field Pumping (acft)	Enhanced Recharge (acft)	Difference between Well Field Pumping and Enhanced Recharge (acft)
Carrizo	190	31.92	6,065	14,886	8,821
Middle Wilcox	214	3.0	641	37,043	36,402
Lower Wilcox	245	29.4	7,204	27,234	20,030
Total			**13,910**	**79,163**	**65,253**

1.5 Model Discussion

The enhanced recharge added to the model by scenario that resulted in increased MAG is shown on Figure 39.The enhanced recharge increases the MAG by about 17 to 19 percent for the tested scenarios. To determine why the increase in MAG is much less than the enhanced recharge, mass balances from the model for the last stress period (61) were exported from each recharge scenario and compared to the baseline scenario. The differences in scenario mass balances and the baseline scenario for the entire model are shown in Table 7. As planned, each scenario shows an increase in recharge going *into* the aquifer, as noted by the positive values in Table 7. Also shown in Table 7 is the amount of pumping (negative values) that is needed to cause water levels in the conceptual well field area to remain about the same as during baseline conditions. As the water levels rise in the outcrop area due to increased recharge and stay about the same in the conceptual well field area, the net change in groundwater levels is a rise. The model readjusts the aquifer's inflow and outflow to the boundaries to accommodate the net higher groundwater levels in the outcrop (recharge area). Table 7 shows that water is flowing out of the aquifer to each of the boundaries (ET, rivers, drains, GHB, streams, and storage. The greatest losses are attributed to drains, streams, and storage. The distribution of these losses change somewhat with landowner participation.

Assumptions and modifications were made to the recharge and conceptual well field in this modeling analysis which could potentially affect the model results. For example, recharge was applied at a constant annual rate to each cell in the Carrizo and Wilcox outcrop, regardless of the aquifer permeability. In some instances, the rate applied was 3 times the background recharge. However, this conceptualization is not believed to be an issue because: (1) the background recharge rate is only a few inches per year (between 0.58" in the Wilcox and 2.5" in the Carrizo) and (2) the recharge in the less permeable zones is expected to readily migrate into more permeable zones.

The location of the conceptual well field could also affect the calculated MAG. If the conceptual well fields were moved closer to the outcrop where the recharge occurs, the MAG benefit is expected to increase. Conversely, if the conceptual well fields were moved further from the outcrop where the recharge occurs, the MAG benefit is expected to decrease. Also, the pumping assigned to the conceptual well field could also affect the modeling results. For purposes of this study, a constant amount of pumping was assigned to each model cell to lower the water levels to baseline conditions and calculate the MAG. In reality, there is a time lag for the recharge to migrate into the distant parts of the aquifer system. If the lag was taken into account, the pumping in the conceptual well field would start at a low rate and gradually increase in time.

Table 7. Difference in Mass Balances from Scenario Model Results and the Baseline Scenario Model Results (acft/yr)

Description[1]	10 Percent Participation	30 Percent Participation	50 Percent Participation	100 Percent Participation
	Inflow minus Outflow	Inflow minus Outflow	Inflow minus Outflow	Inflow minus Outflow
Recharge	7,870	23,686	39,450	79,019
ET	-193	-615	-1,049	-2,651
River	0	0	-1	-1
Drain	-220	-1,020	-2,126	-7,372
GHB	-79	-162	-367	-972
Well	-1,423	-5,364	-7,806	-15,199
Stream	-2,936	-8,783	-15,309	-31,120
Storage	-3,018	-7,742	-12,792	-21,703

[1]The Recharge package defines average recharge for each calendar year.
The ET (Evapotranspiration) package calculates evapotranspiration from the water table.
The Drain package is assigned to model cells in low-lying stream valleys where the depth to water was shallow. A drain allows water to only discharge from an aquifer to a stream. Springs are usually represented by the Drain package.
The GHB (General Head Boundary) package indirectly calculates the interaction between: (1) the aquifer and overlying younger sediments that overlie the Sparta aquifer in the downdip portions of the model, and (2) the aquifer inside and outside the perimeter of the model.
The Well package defines the aquifer discharge attributed to well pumping.
The Stream package calculates the interaction between streams and the aquifer, similar to the River package. In the case of the Stream package, there is an accounting of the flow in stream which prevents leakage being greater than the flow in the stream.
Storage calculates the change in water volume in an aquifer during a model simulation. This accounts for rises and declines in groundwater levels.

1.6 Summary

The model scenarios show that implementing a brush management program in Gonzales, Caldwell, and Guadalupe Counties could potentially increase the groundwater levels and the subsequent MAG in these counties by 1,370 acft/yr to 13,910 acft/yr depending on the landowner participation levels. The total increase in year 2060 MAG by landowner participation and county is shown in Table 8 and on Figure 40 and distribution by aquifer is shown in Table 9. The greatest increase in additional MAG is in Guadalupe County. With 100 percent landowner participation, the MAG could increase by 25%. One hundred percent participation is probably impracticable; however, 10 percent or 30 percent landowner participation may be attainable and would increase the MAG by 1,370 acft/yr or 4,631 acft/yr, respectively.

Table 8. MAG Increase by Percent Landowner Participation and by County (acft/yr)

County	County	10 Percent Participation	30 Percent Participation	50 Percent Participation	100 Percent Participation
Caldwell	2060 MAG:	44,544	44,544	44,544	44,544
	Increase in MAG:	242	921	1,215	2,948
	Total 2060 MAG:	**44,786**	**45,465**	**45,759**	**47,492**
	Percent Increase:	**0.5%**	**2%**	**3%**	**7%**
Gonzales	2060 MAG:	75,970	75,970	75,970	75,970
	Increase in MAG:	843	2,601	4,296	7,397
	Total 2060 MAG:	**76,813**	**78,571**	**80,266**	**83,367**
	Percent Increase:	**1%**	**3%**	**6%**	**10%**
Guadalupe	2060 MAG:	14,041	14,041	14,041	14,041
	Increase in MAG:	284	1,109	1,414	3,564
	Total 2060 MAG:	**14,325**	**15,150**	**15,455**	**17,605**
	Percent Increase:	**2%**	**8%**	**10%**	**25%**

Table 9. MAG Increase by Percent Landowner Participation and by Aquifer (acft/yr)

Aquifer	10 Percent Participation	30 Percent Participation	50 Percent Participation	100 Percent Participation
Carrizo	758	2,274	3,790	6,065
Middle Wilcox	35	105	280	641
Lower Wilcox	576	2,251	2,855	7,204
Total	**1,370**	**4,631**	**6,925**	**13,910**

Figures

Figure 4. Carrizo Aquifer Baseline and Enhanced Recharge by County and Scenario

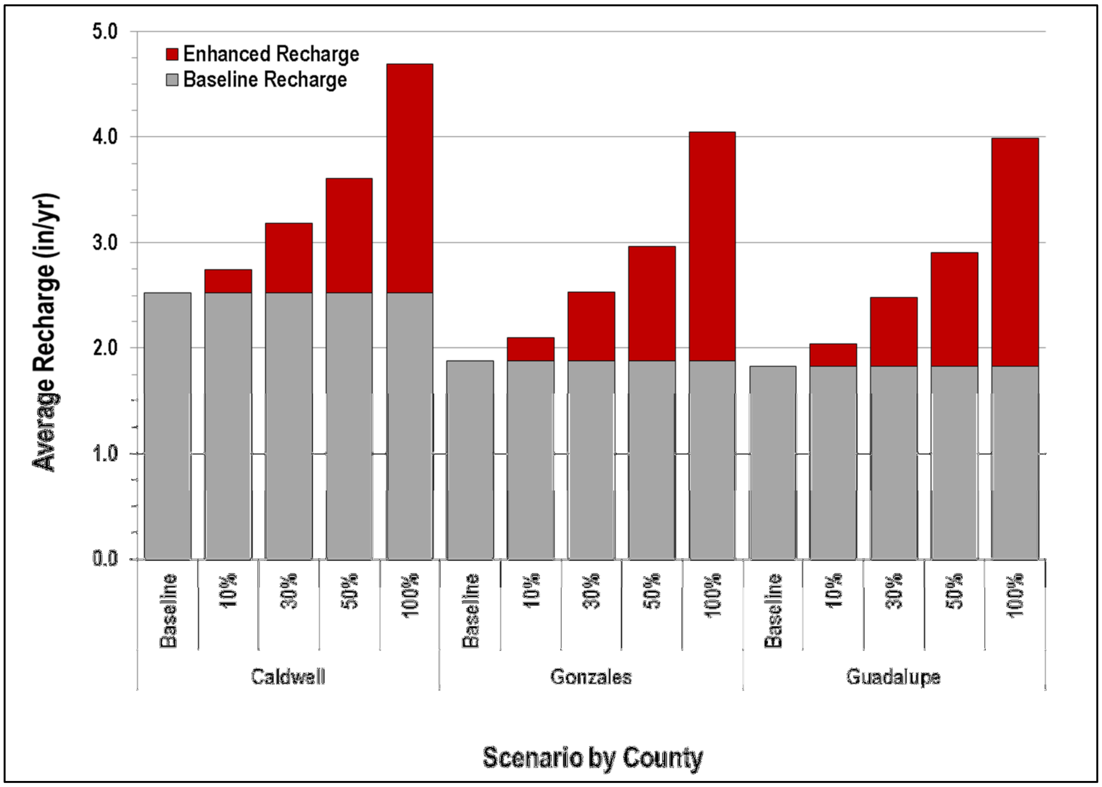


Figure 5. Middle Wilcox Aquifer Baseline and Enhanced Recharge by County and Scenario

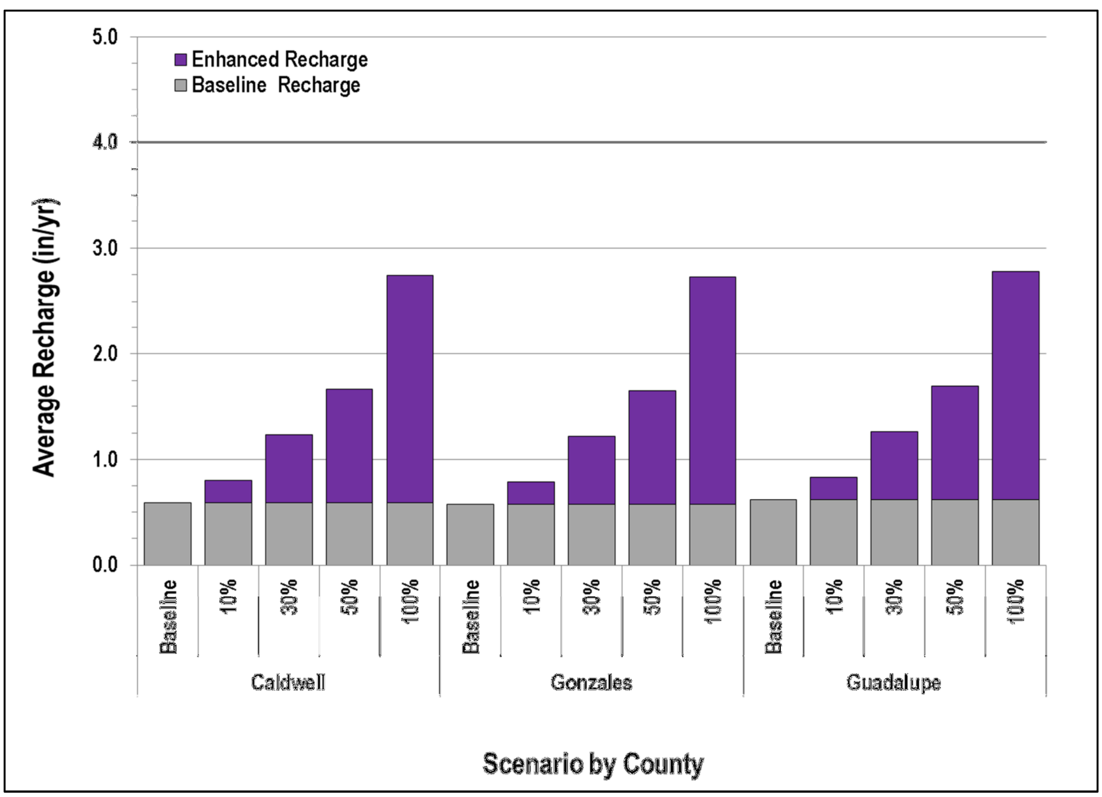


Figure 6. Lower Wilcox Aquifer Baseline and Enhanced Recharge by County and Scenario

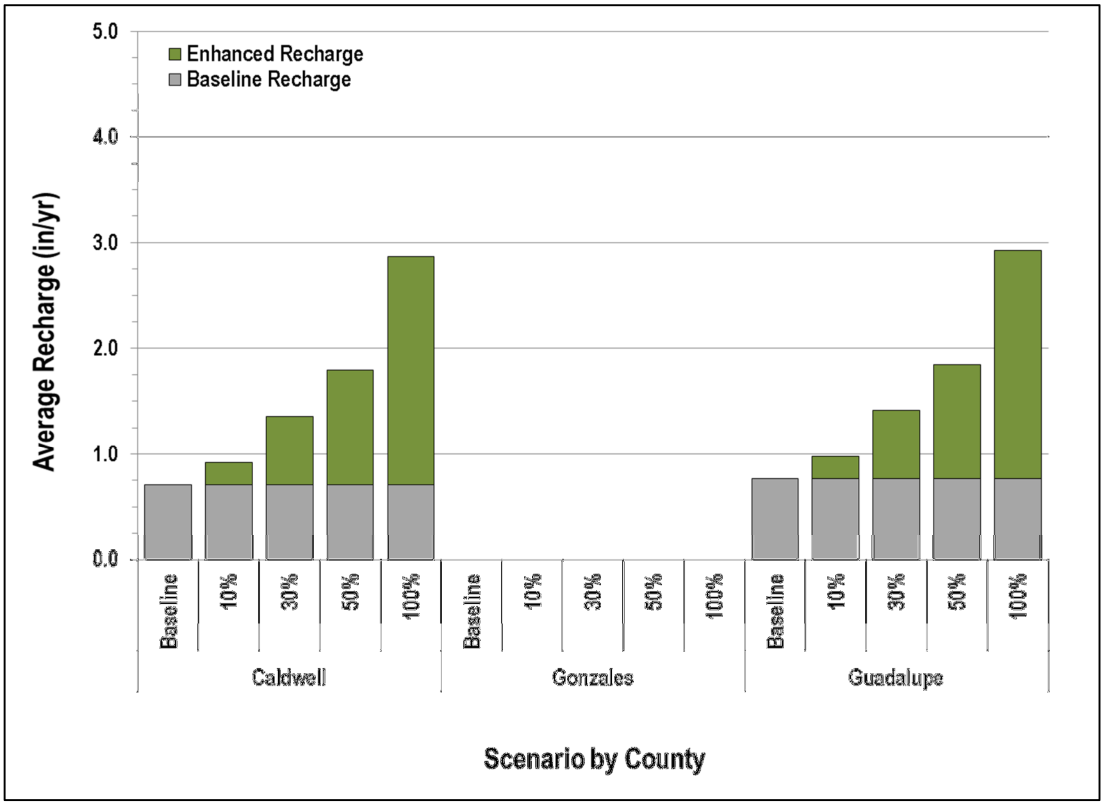


Figure 7. Baseline Recharge (in/yr)

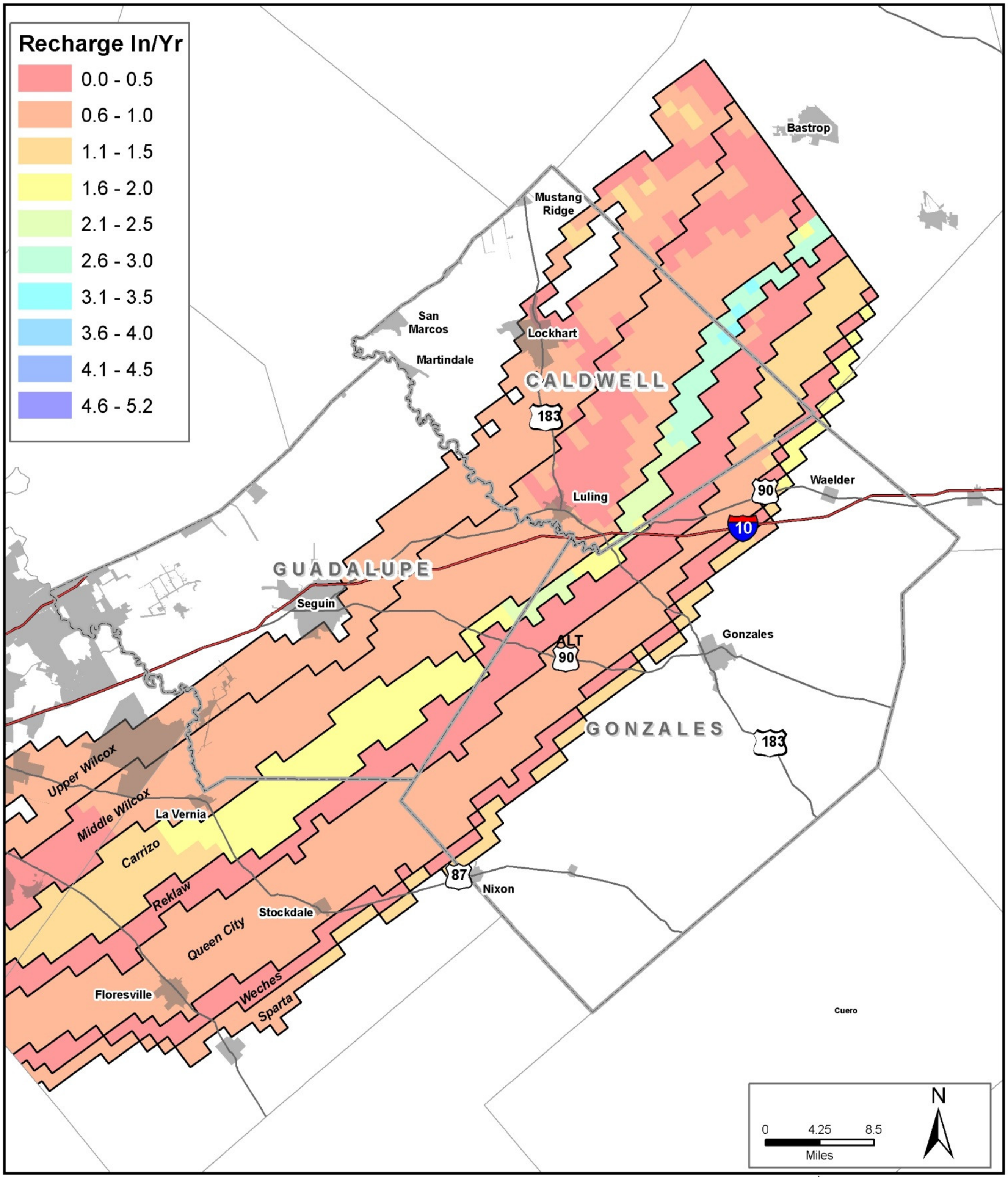


Figure 8. Recharge for Baseline plus 10 Percent Landowner Participation Scenario

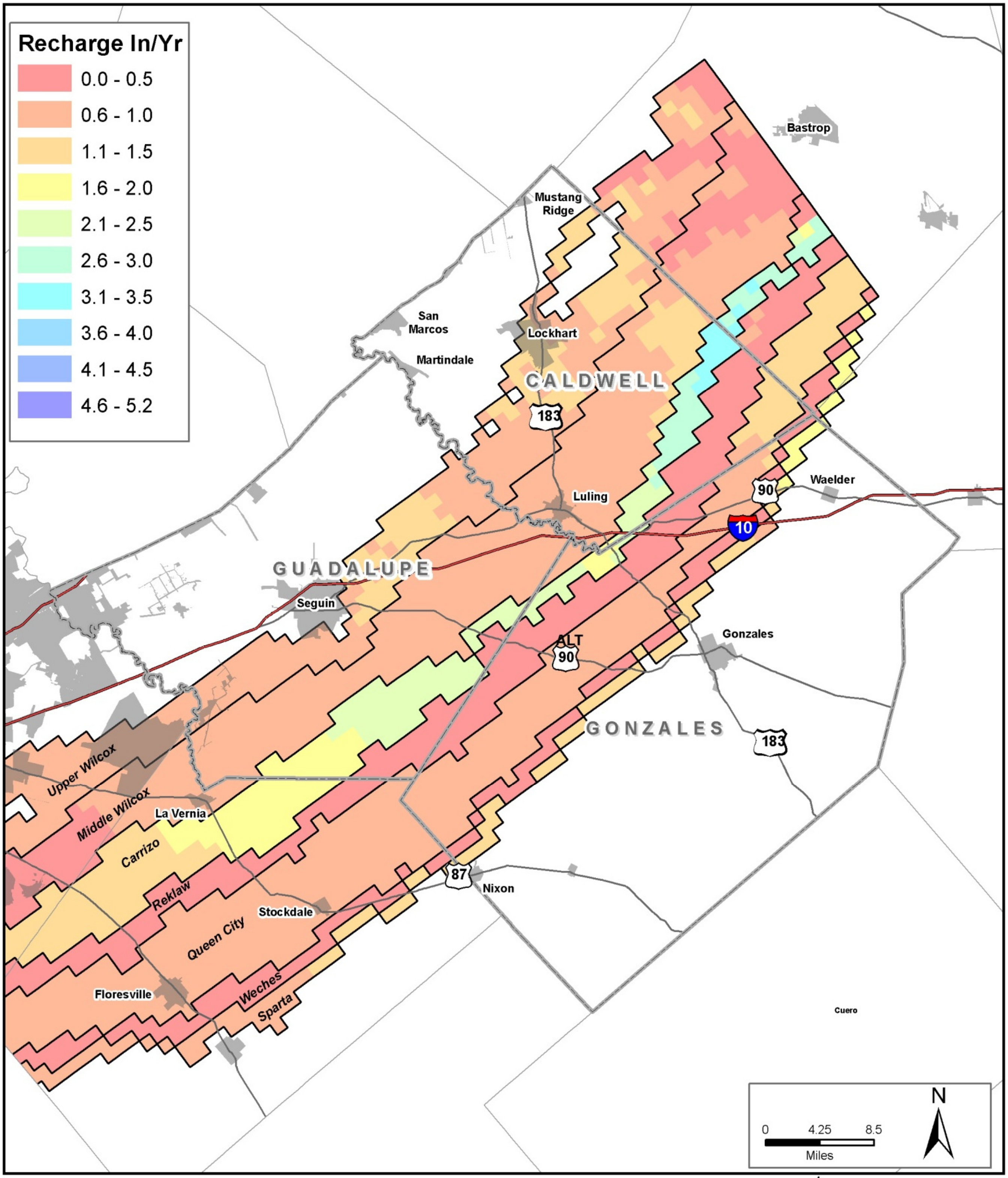


Figure 9. Recharge for Baseline plus 30 Percent Landowner Participation Scenario

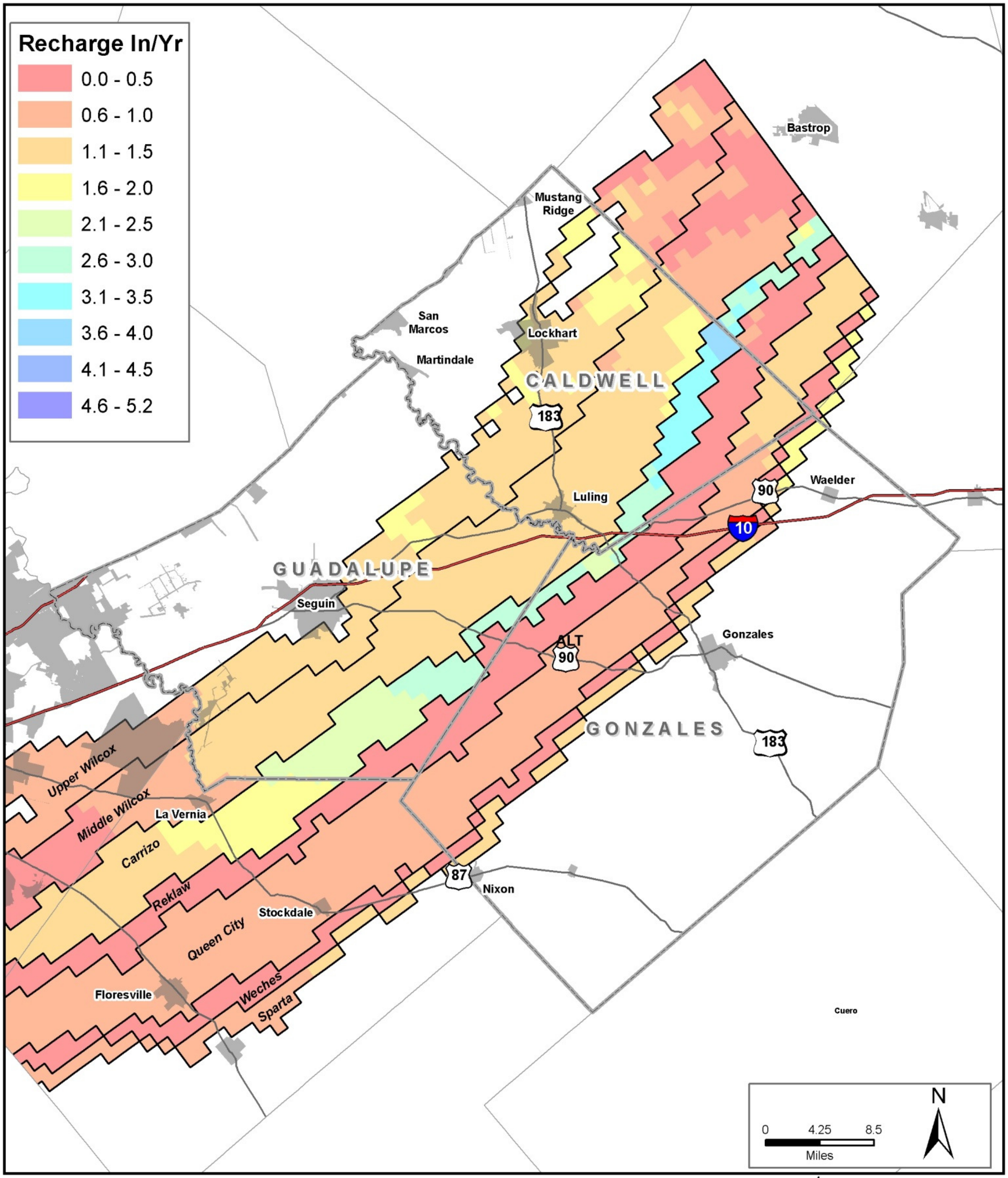


Figure 10. Recharge for Baseline plus 50 Percent Landowner Participation Scenario

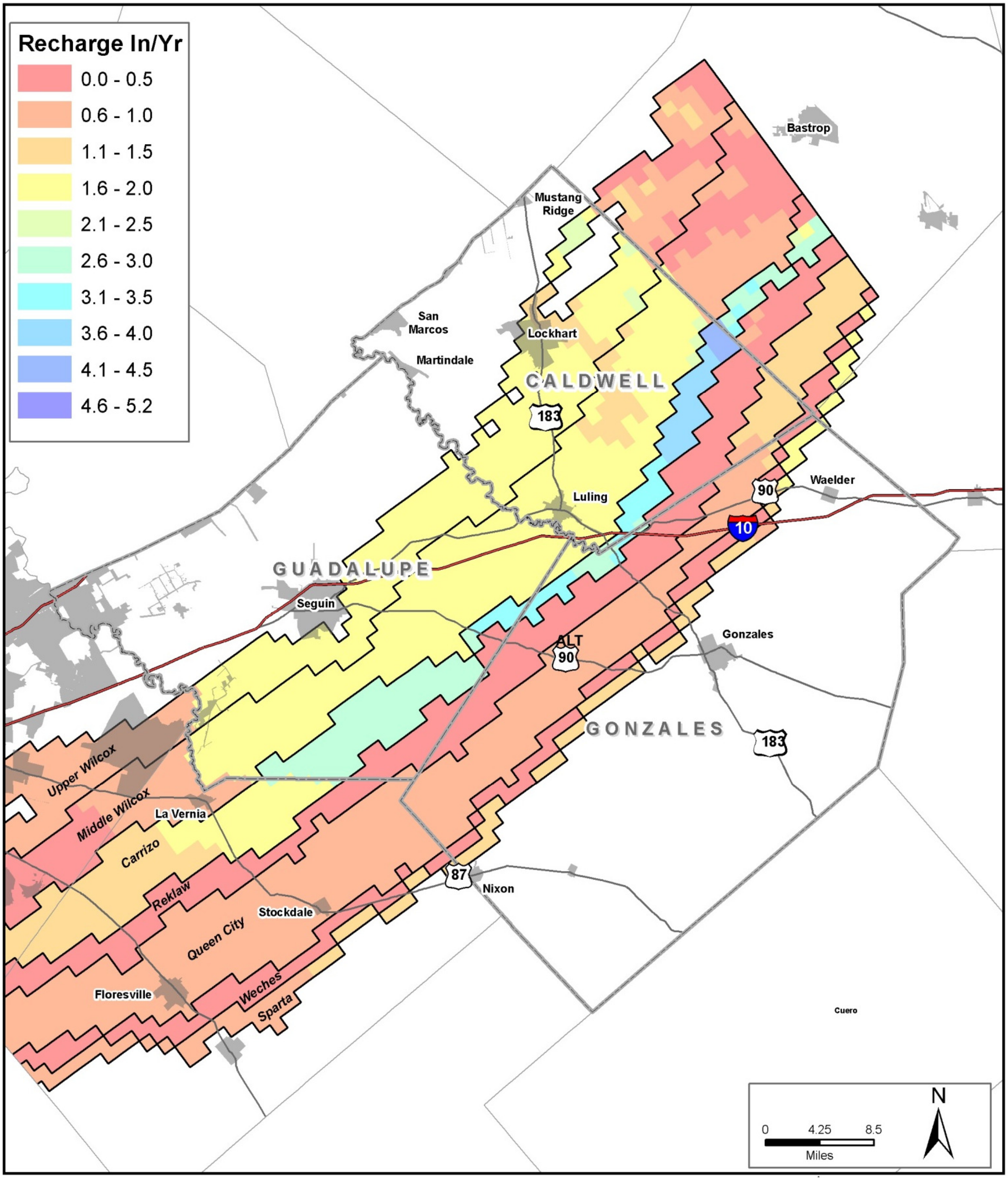


Figure 11. Recharge for Baseline plus 100 Percent Landowner Participation Scenario

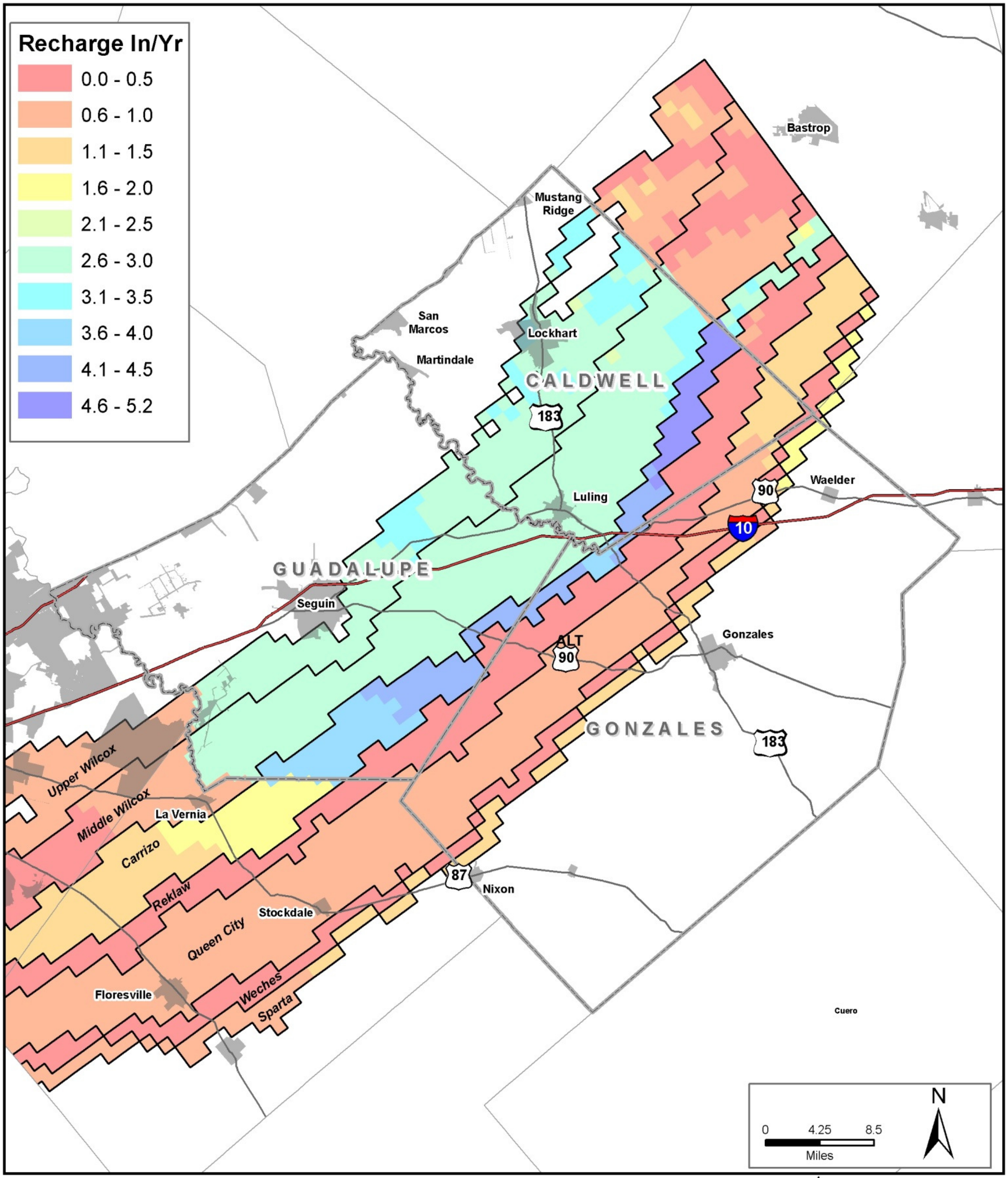


Figure 12. Monitoring Wells

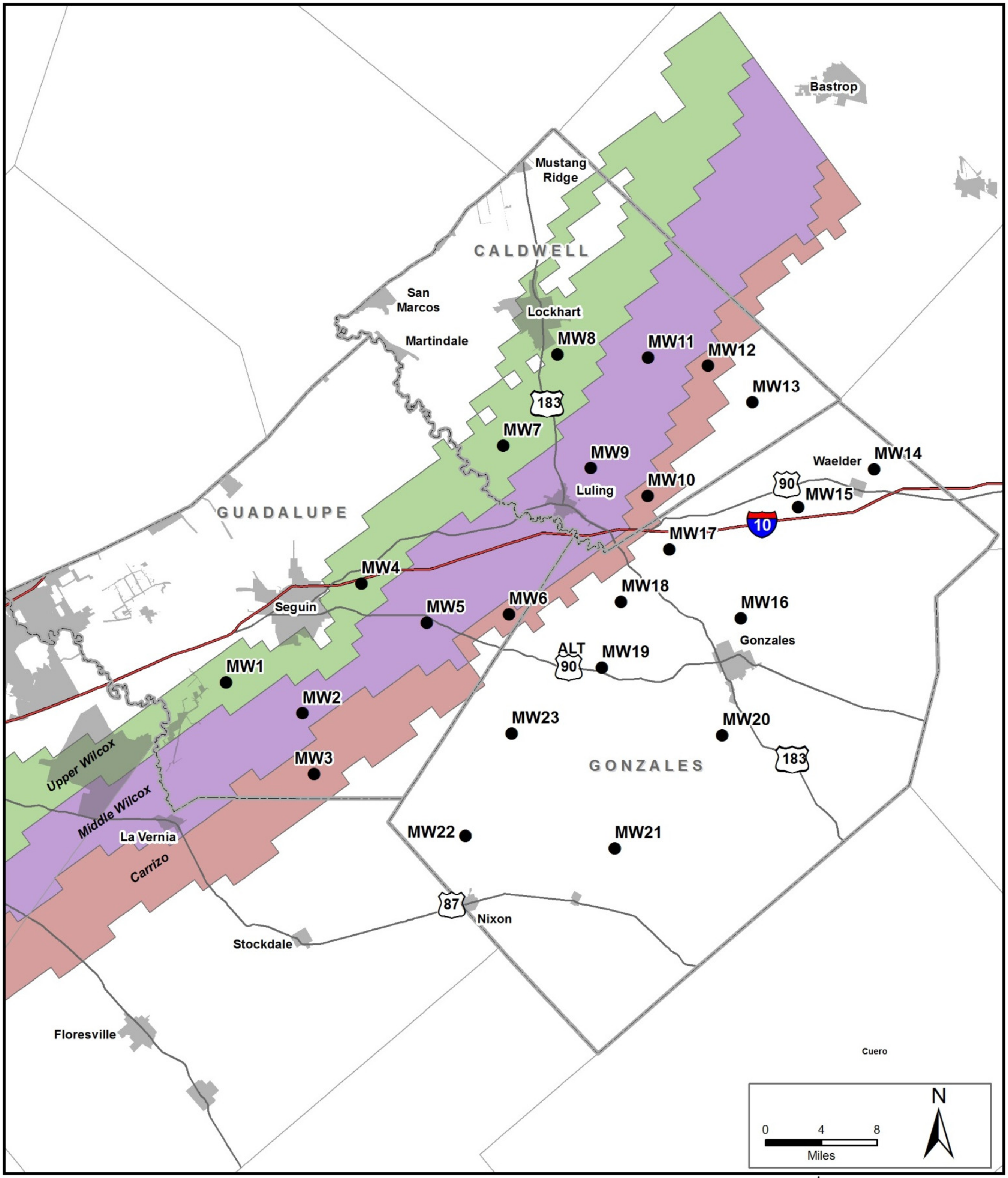


Figure 13. Three Representative Hydrographs illustrating model results in the Outcrop, Downdip, and Conceptual Well Field

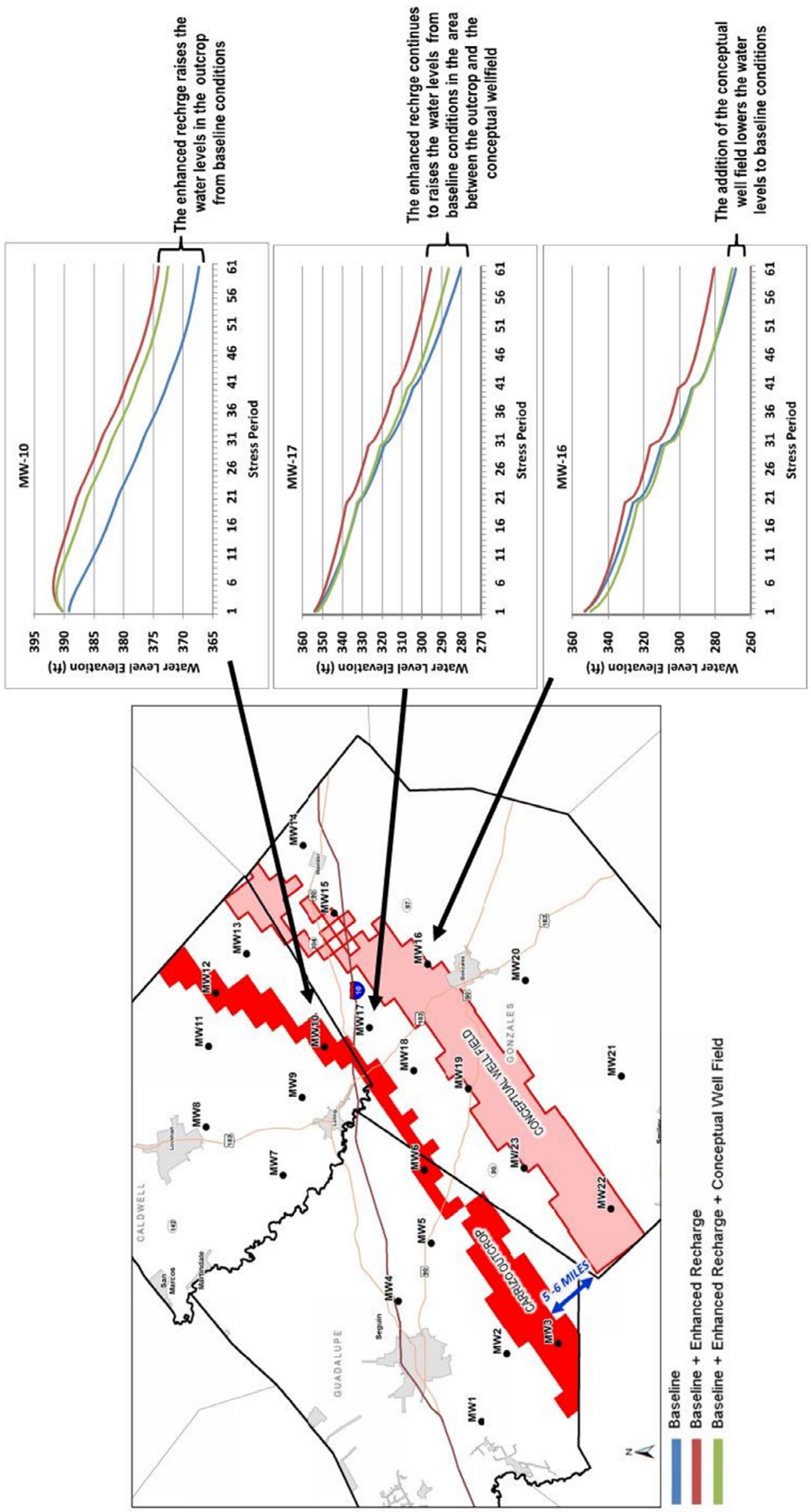


Figure 14. Conceptual Well Fields by Aquifer

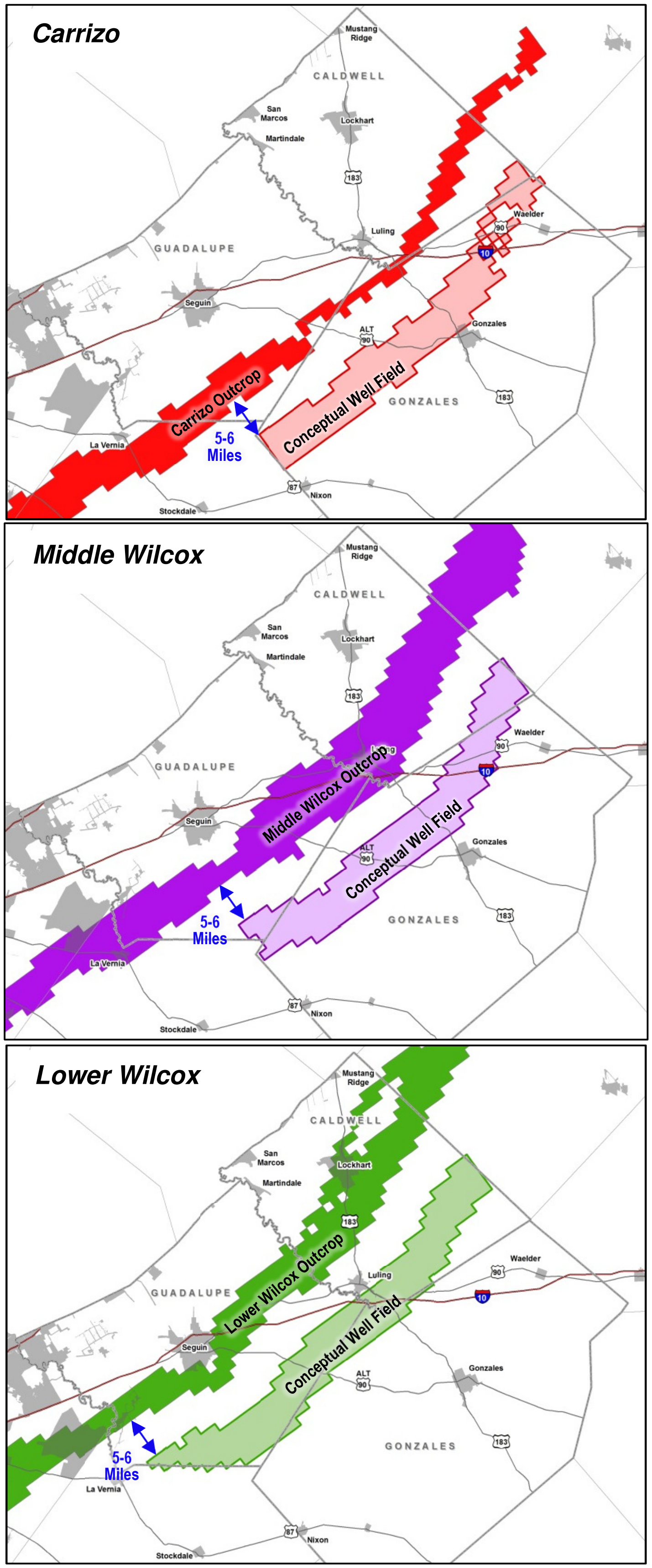
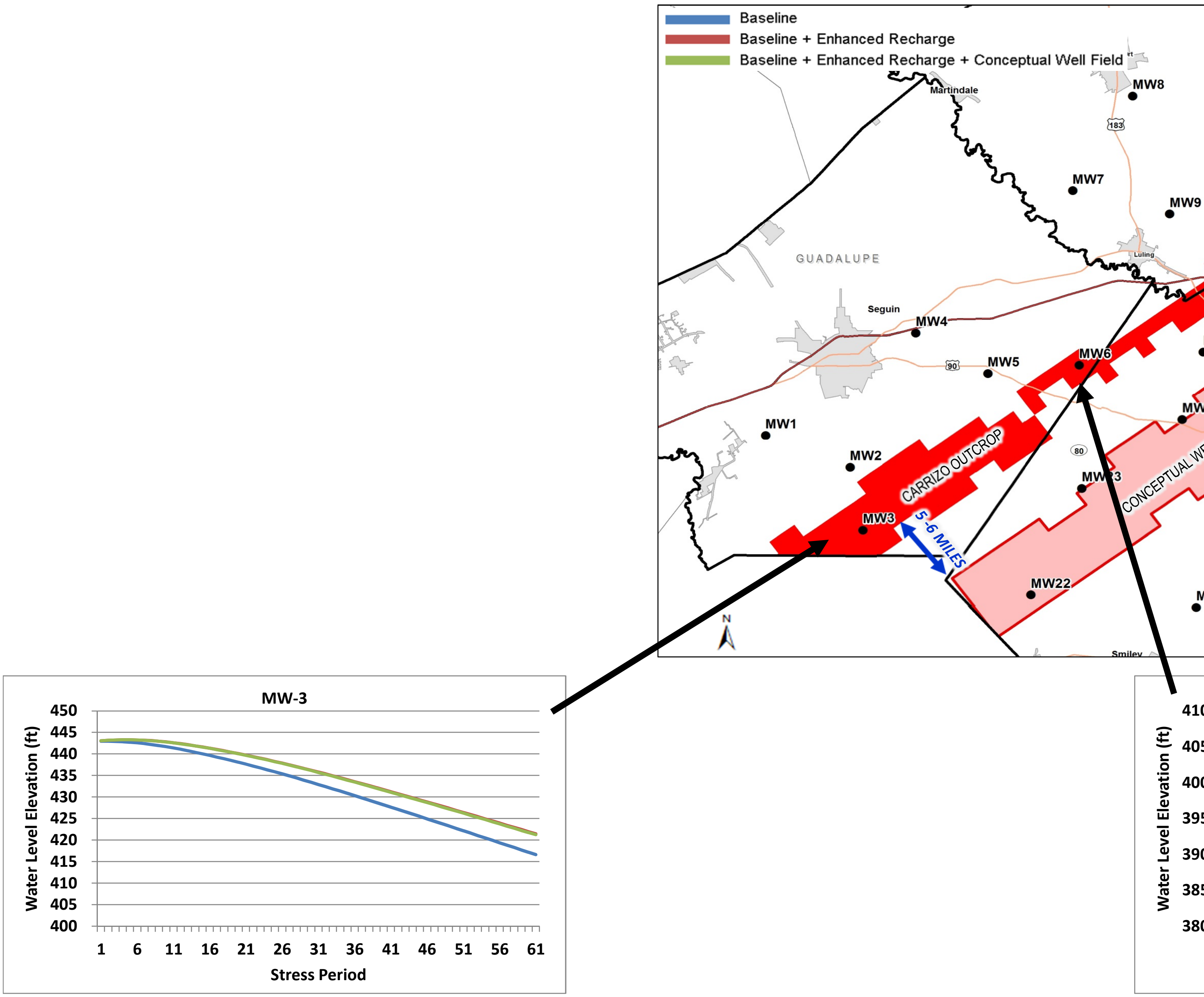
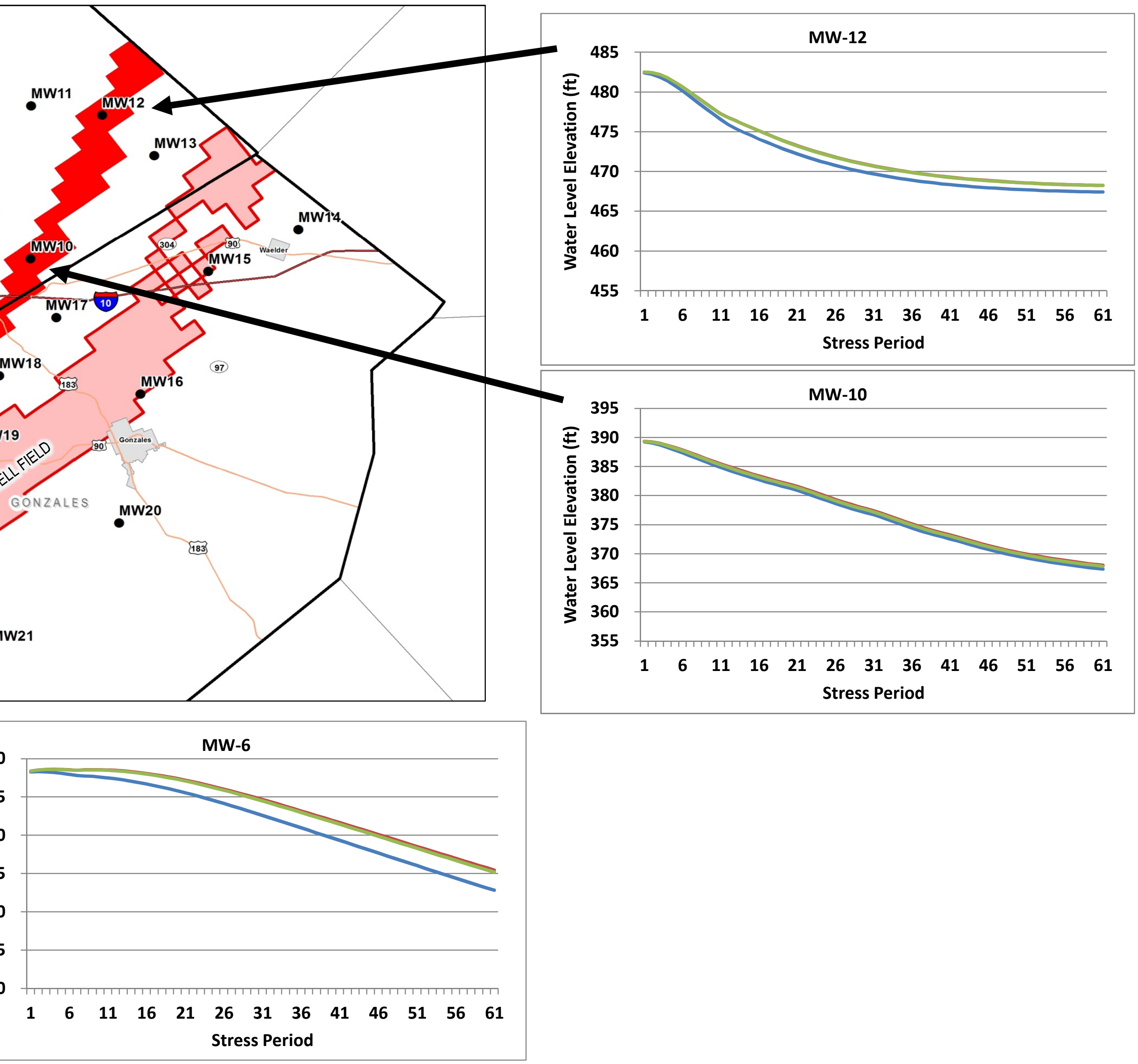


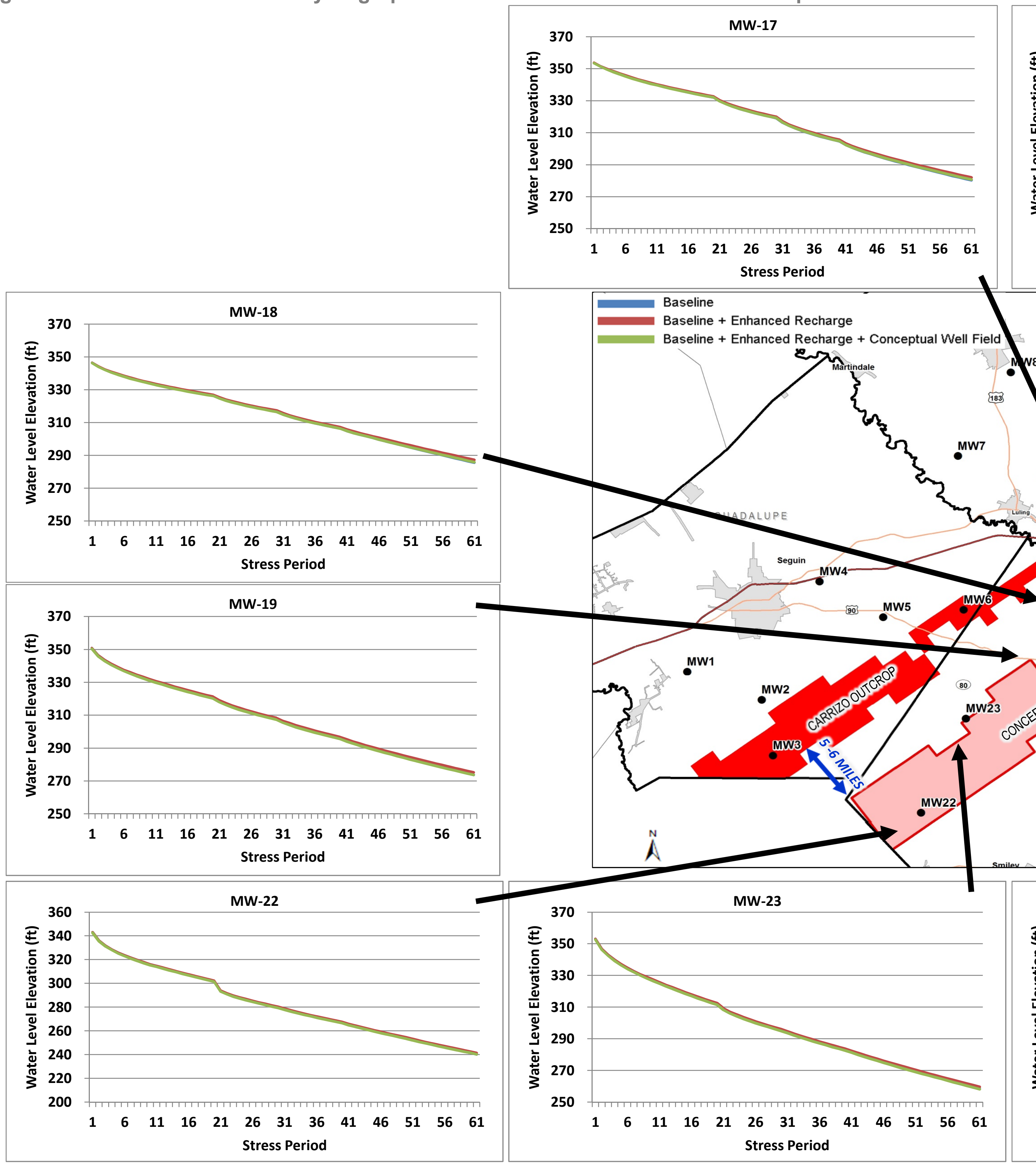
Figure 15: Carrizo Water Level Hydrographs for the 10 Percent Landowner Participation Scenario





MW11
MW12
MW13
MW14
MW10
MW15
Waelder
MW17
MW18
MW16
Gonzales
GONZALES
MW20
MW21
MW-12
Water Level Elevation (ft)
Stress Period
MW-10
Water Level Elevation (ft)
Stress Period
MW-6
Stress Period

Figure 15a: Carrizo Water Level Hydrographs for the 10 Percent Landowner Participation Scenario



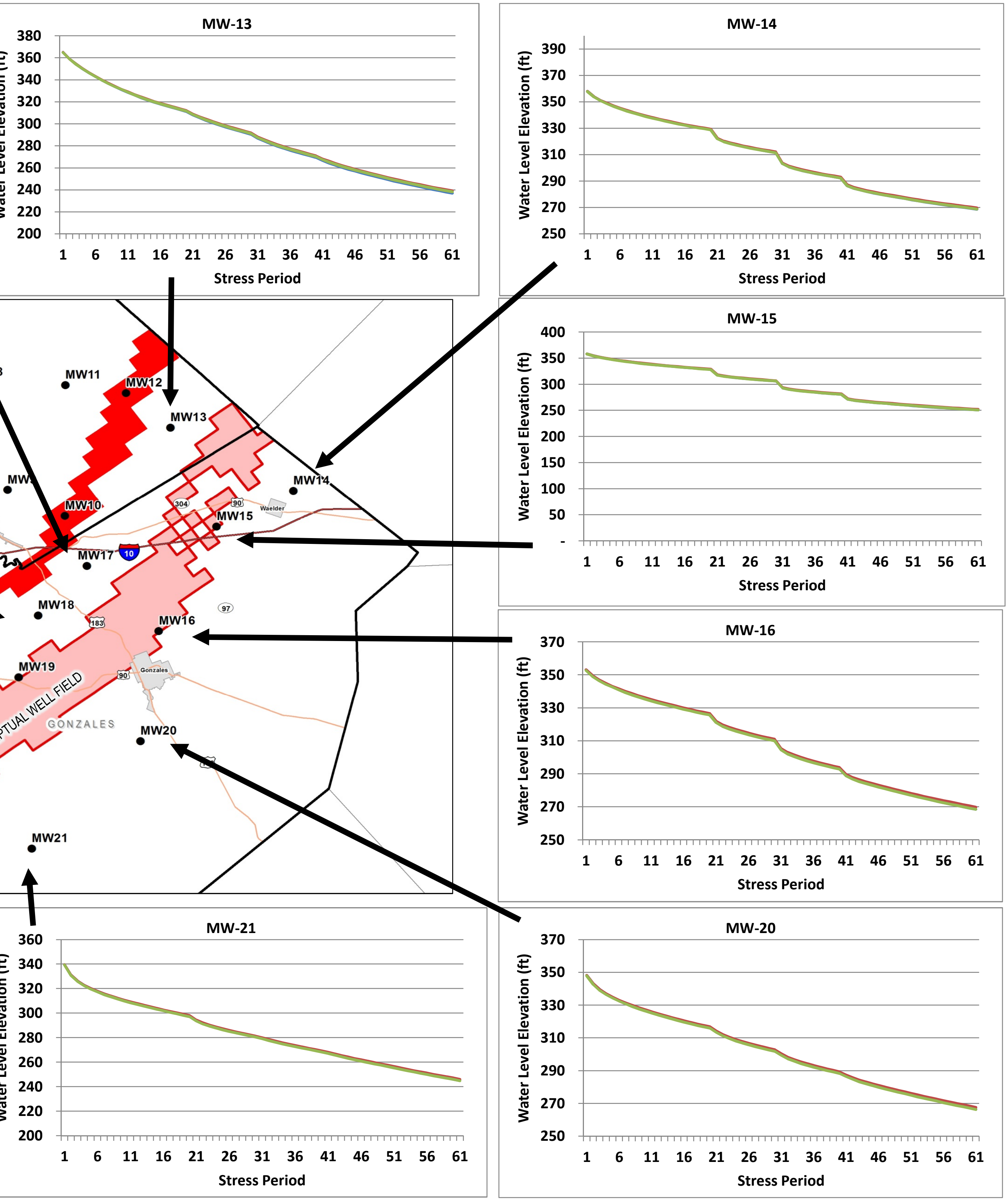
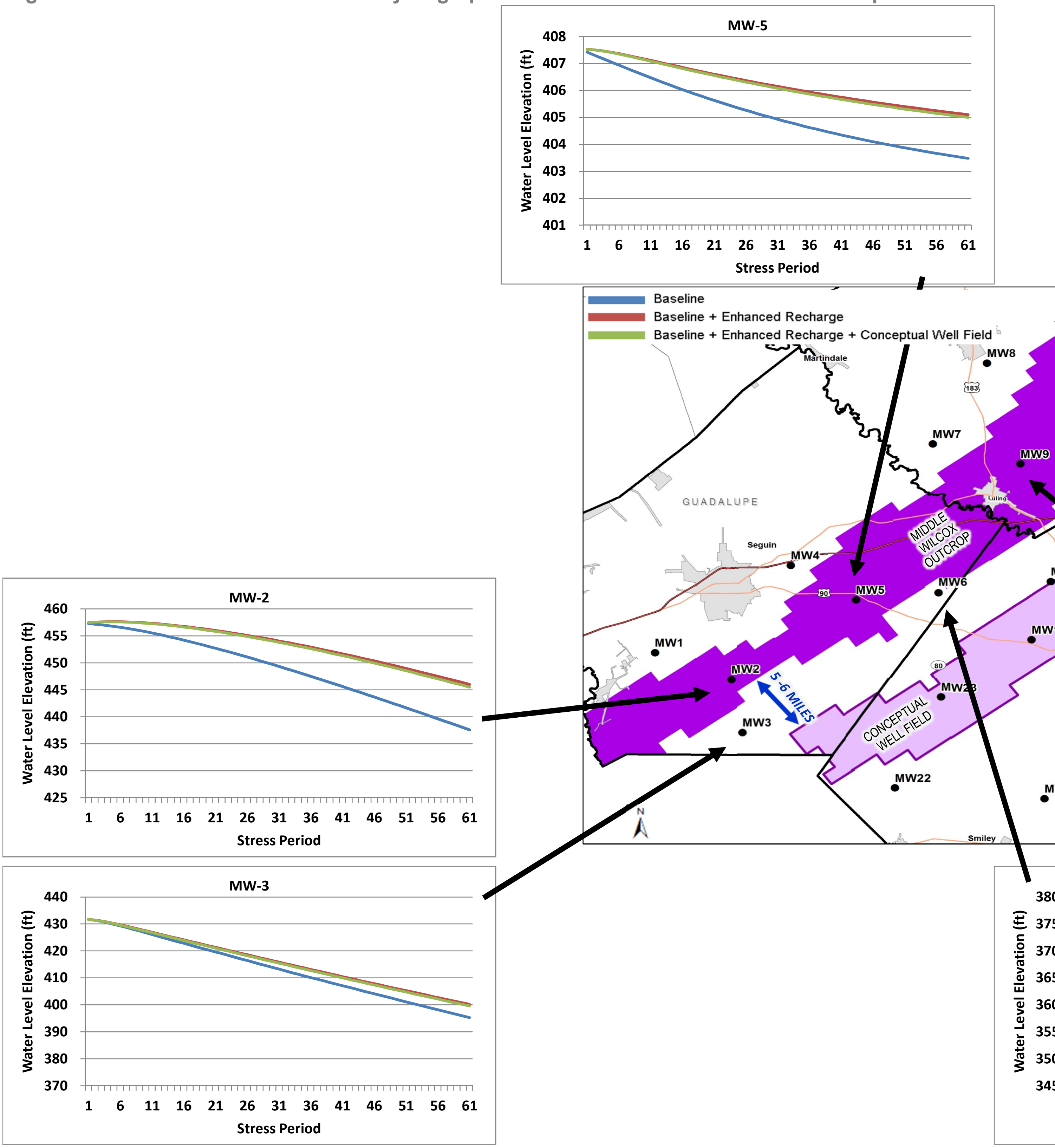

MW-13
MW-14
MW-15
MW-16
MW-21
MW-20
Water Level Elevation (ft)
Stress Period
1 6 11 16 21 26 31 36 41 46 51 56 61
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES
10
90
97
183
304

Figure 16: Middle Wilcox Water Level Hydrographs for the 10 Percent Landowner Participation Scenario



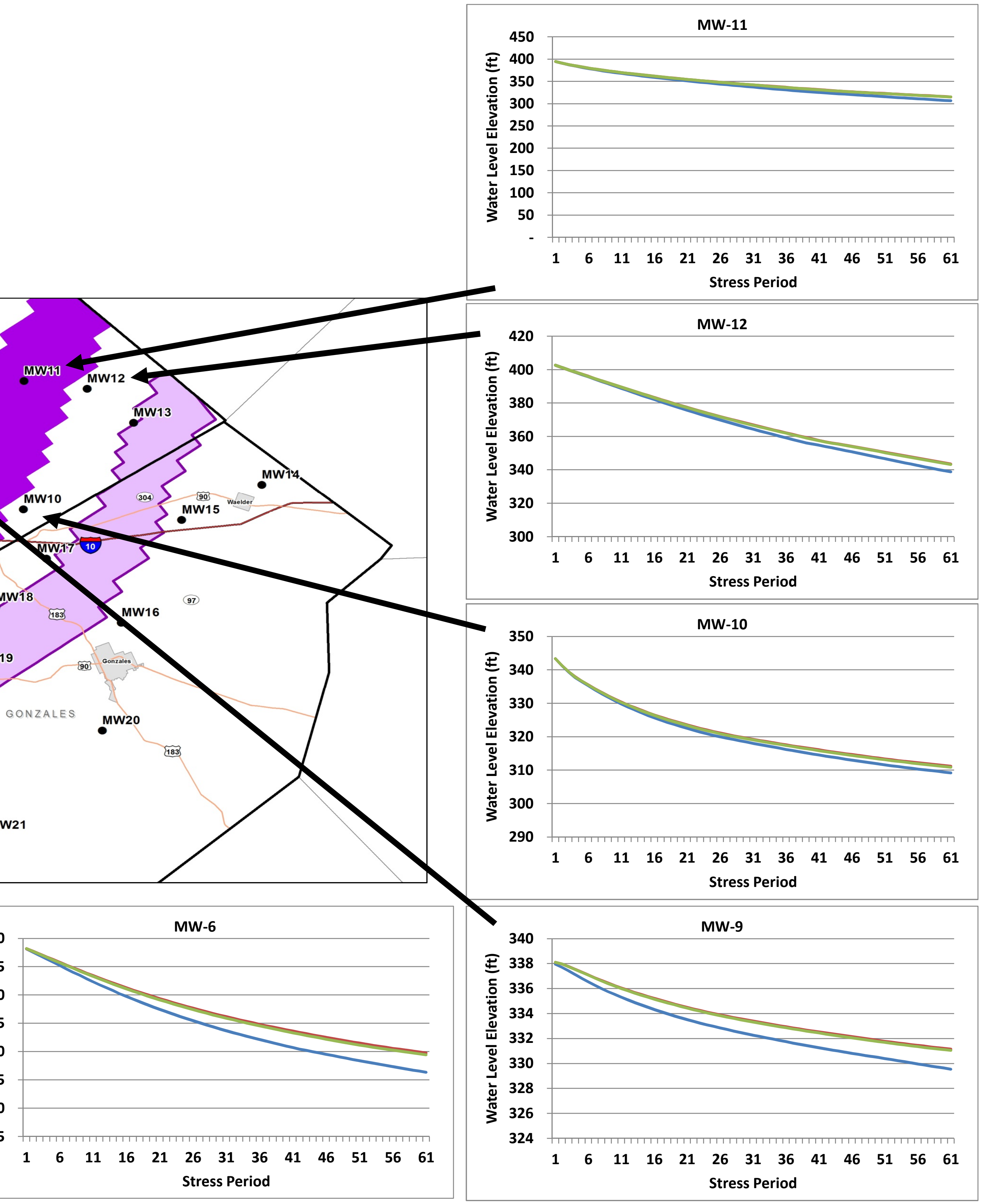
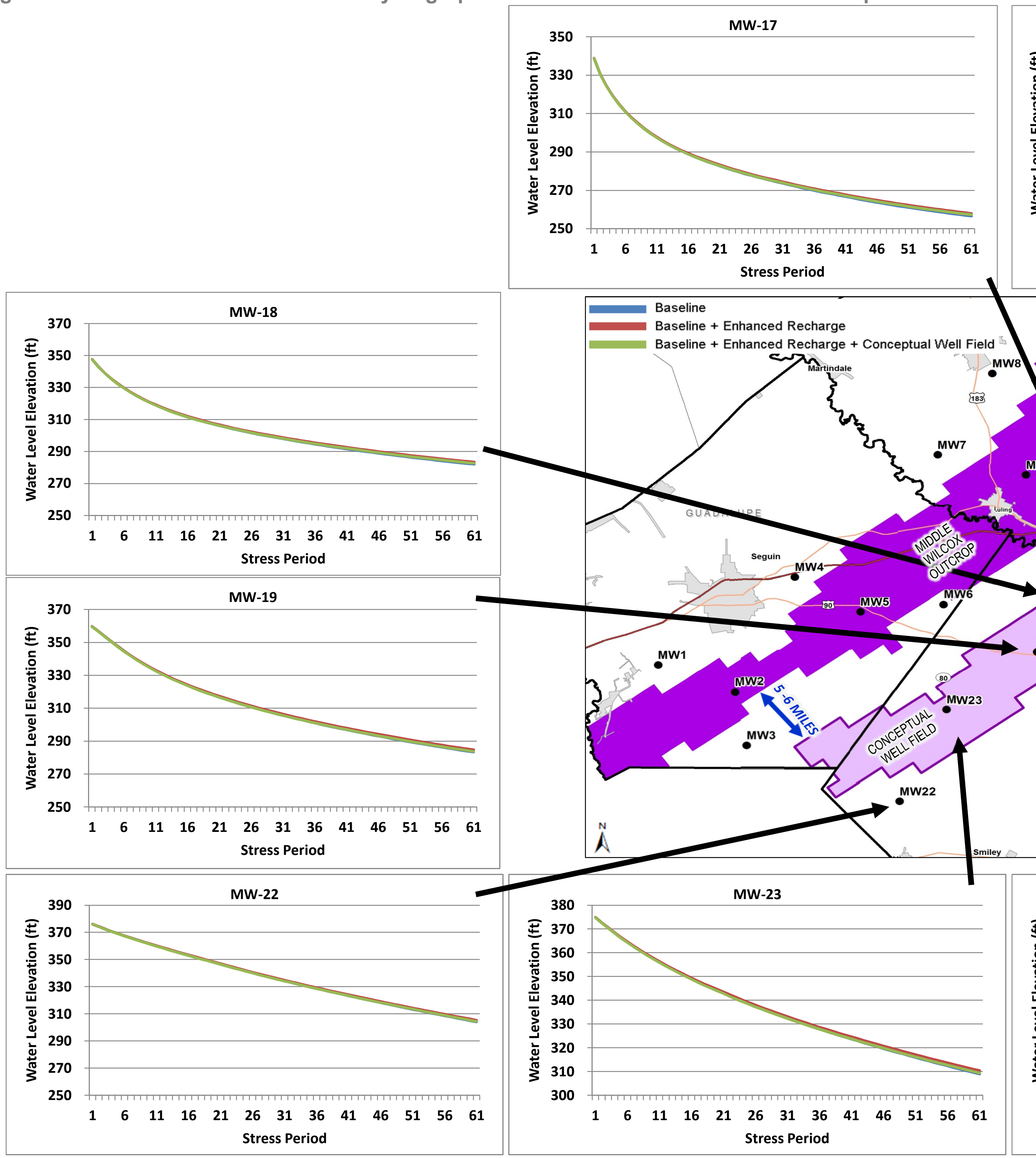

MW-11
Water Level Elevation (ft)
450
400
350
300
250
200
150
100
50
-
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-12
Water Level Elevation (ft)
420
400
380
360
340
320
300
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-10
Water Level Elevation (ft)
350
340
330
320
310
300
290
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-9
Water Level Elevation (ft)
340
338
336
334
332
330
328
326
324
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-6
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW20
GONZALES
Gonzales
Waelder
W21
19
10
90
304
97
183

Figure 16a: Middle Wilcox Water Level Hydrographs for the 10 Percent Landowner Participation Scenario



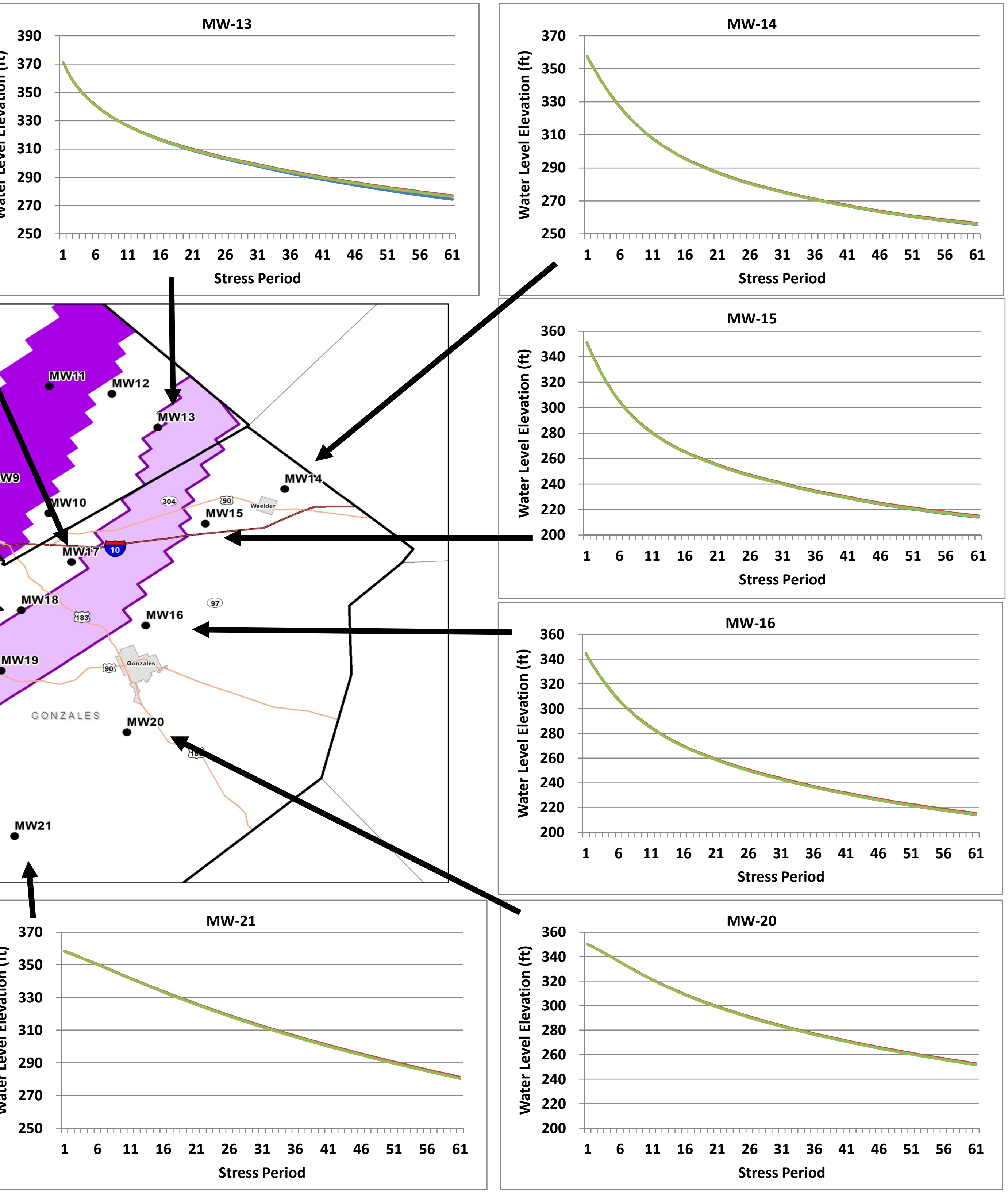
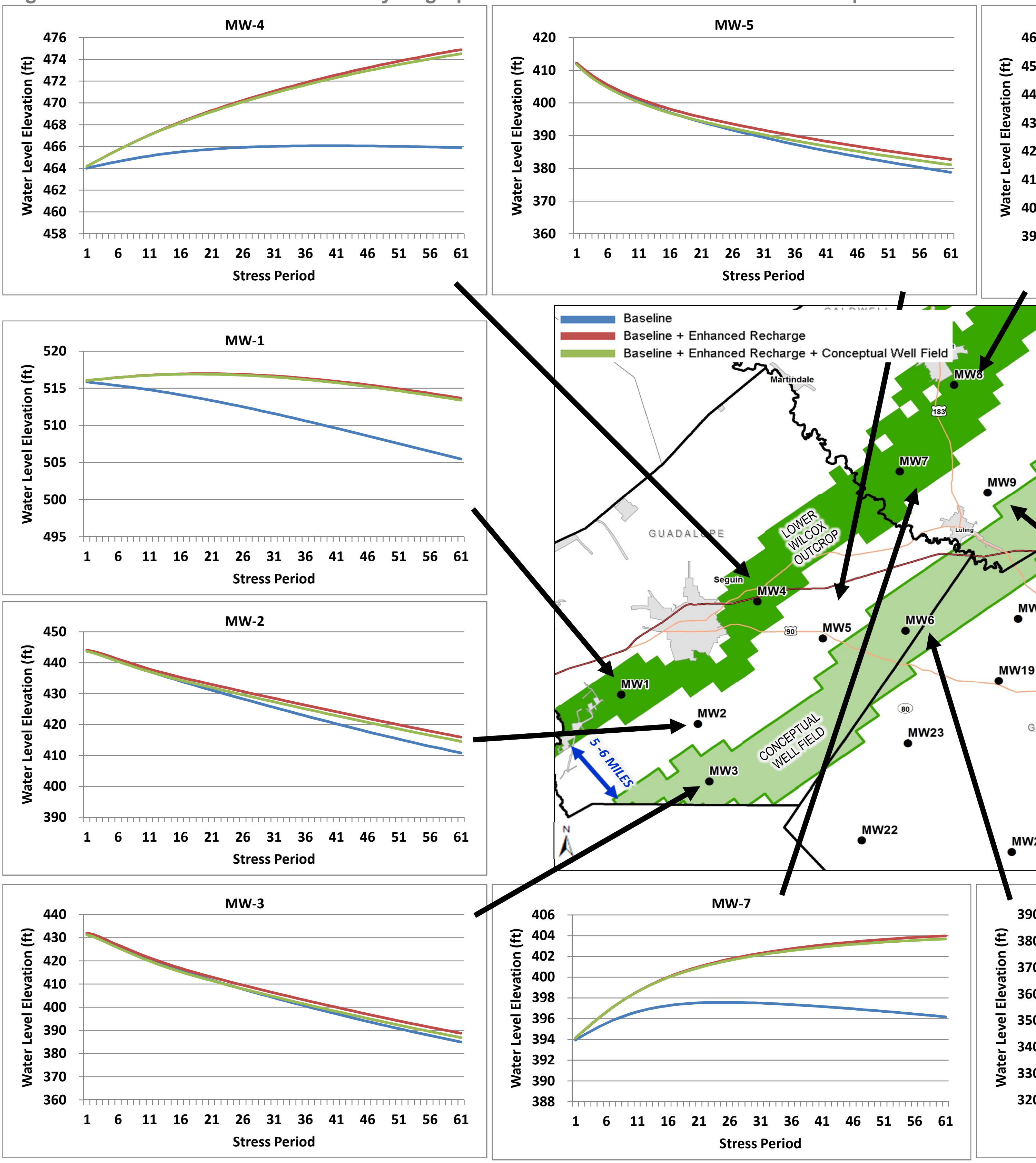
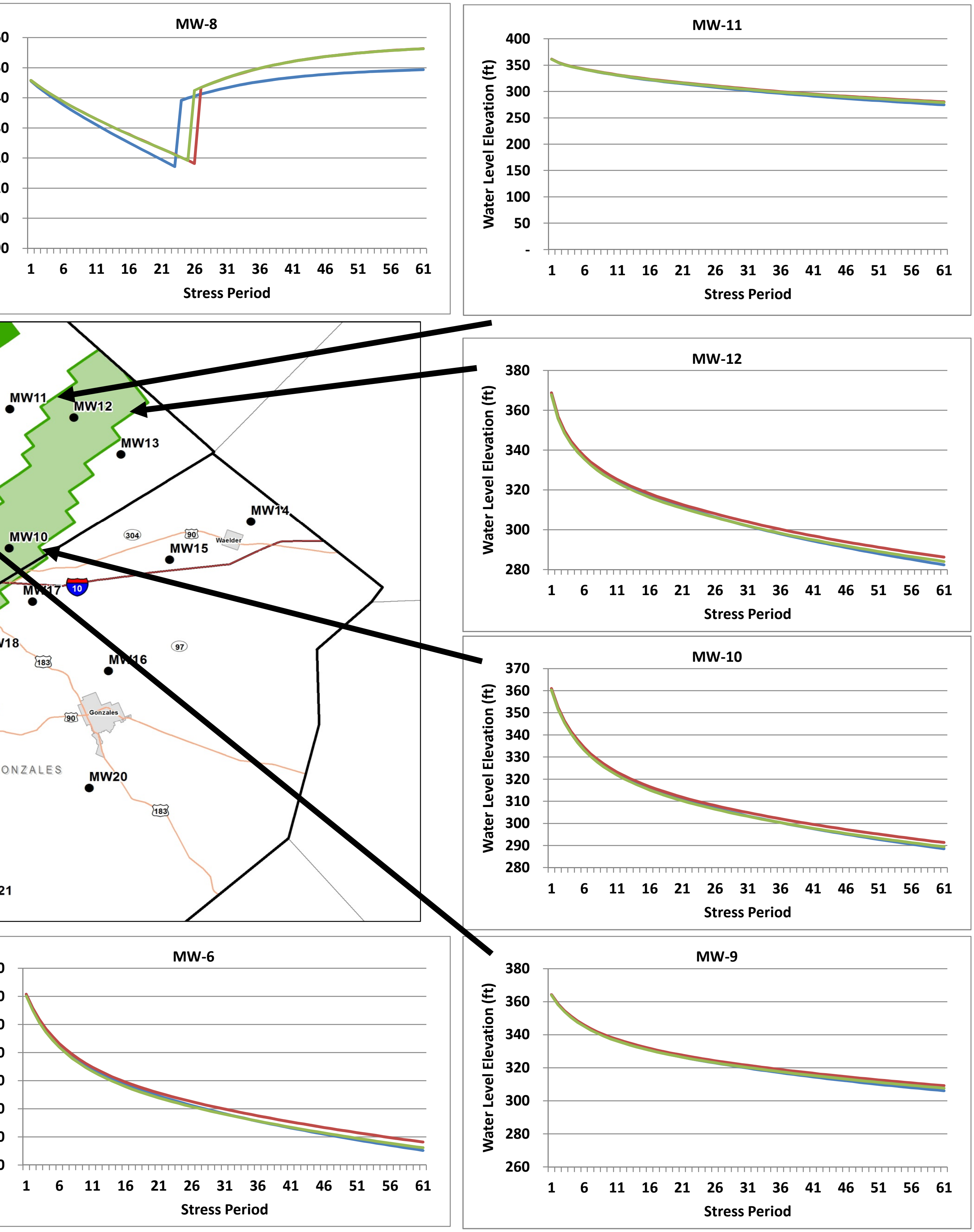

MW-13
MW-14
MW-15
MW-16
MW-21
MW-20
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES

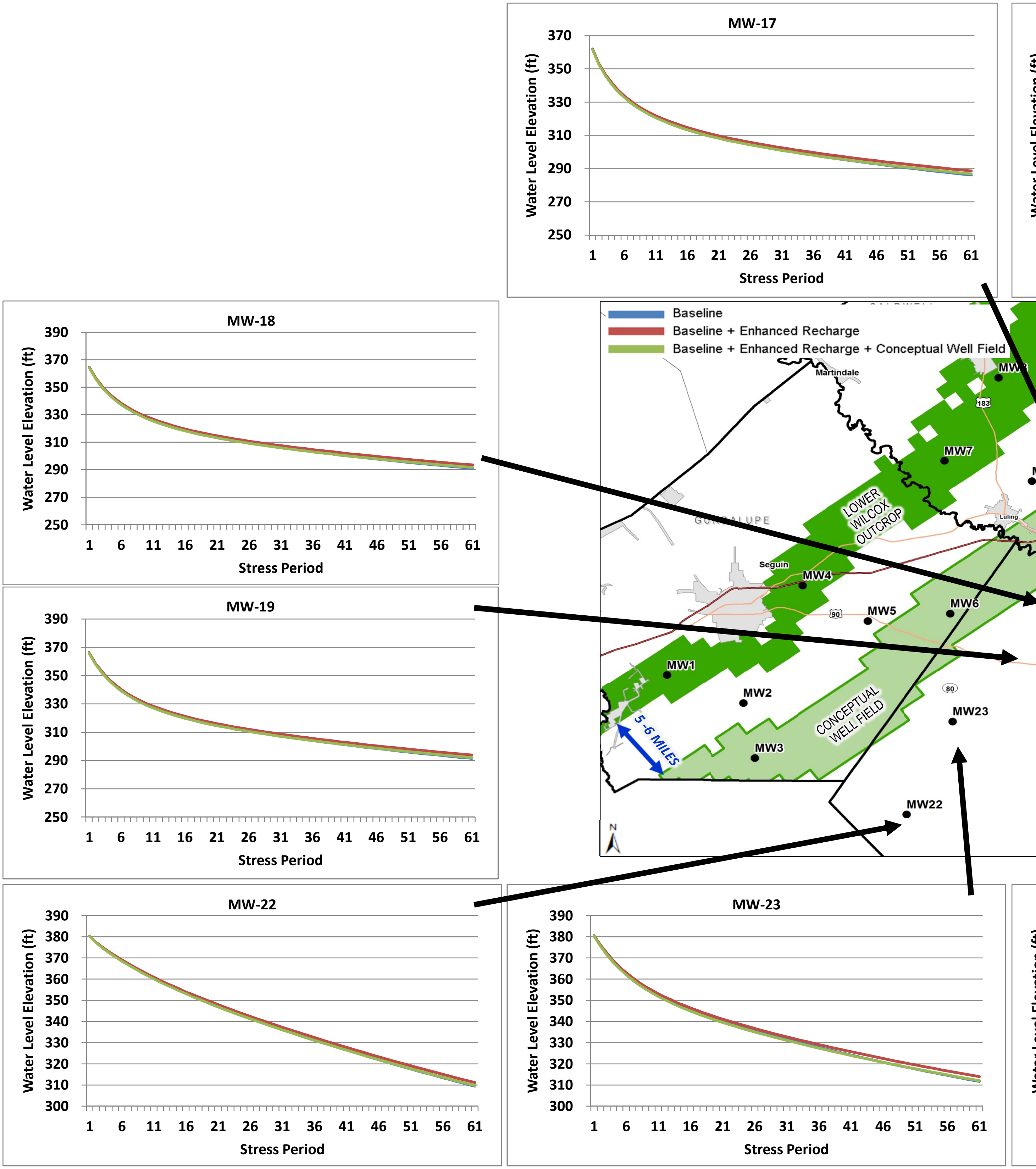
Figure 17: Lower Wilcox Water Level Hydrographs for the 10 Percent Landowner Participation Scenario





MW-8
1
6
11
16
21
26
31
36
41
46
51
56
61
Stress Period
MW-11
400
350
300
250
200
150
100
50
-
Water Level Elevation (ft)
Stress Period
MW-12
380
360
340
320
300
280
Water Level Elevation (ft)
Stress Period
MW-10
370
360
350
340
330
320
310
300
290
280
Water Level Elevation (ft)
Stress Period
MW-6
Stress Period
MW-9
380
360
340
320
300
280
260
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW16
MW20
Waelder
Gonzales
ONZALES
304
90
10
97
183

Figure 17a: Lower Wilcox Water Level Hydrographs for the 10 Percent Landowner Participation Scenario



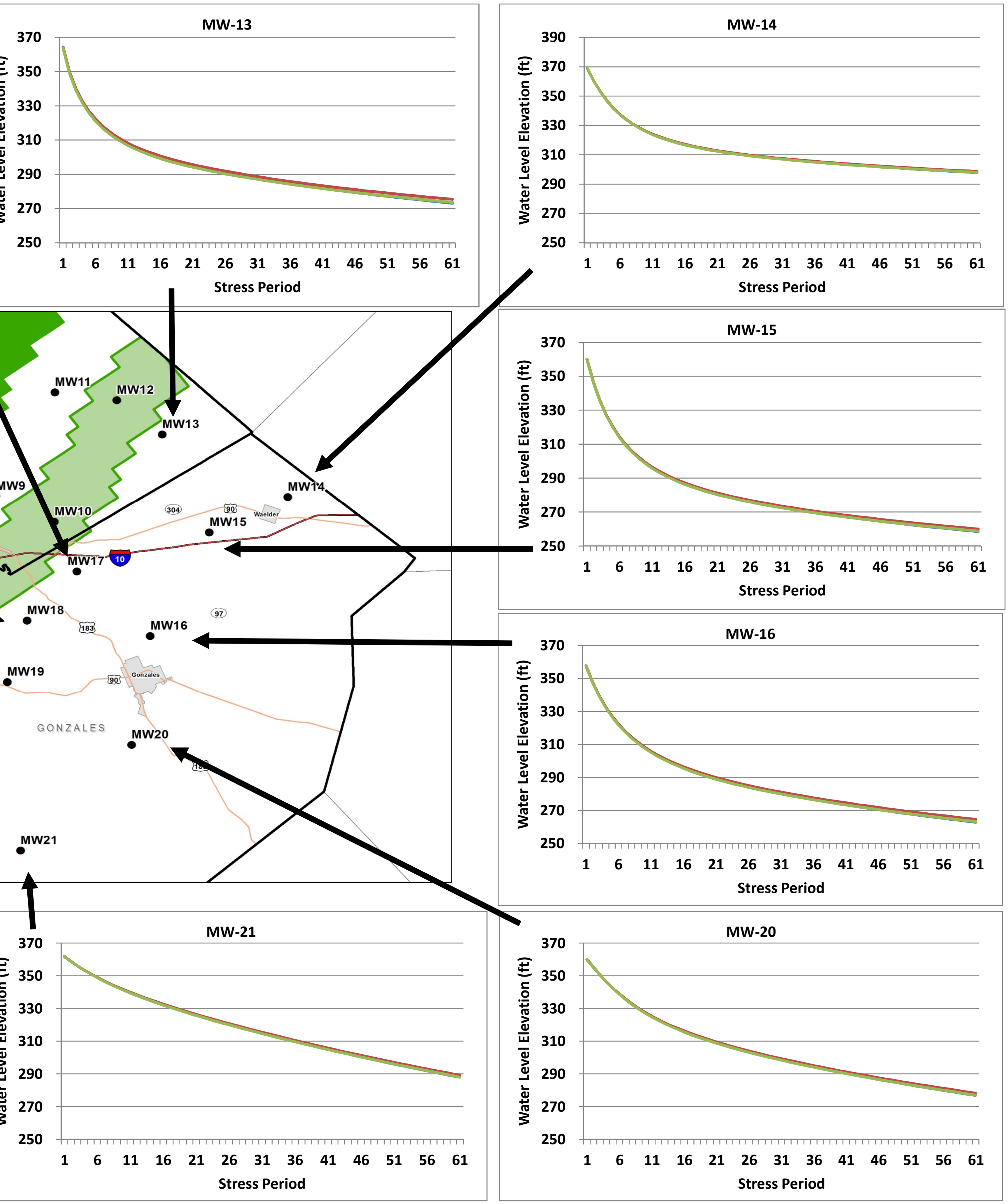

MW-13
MW-14
MW-15
MW-16
MW-20
MW-21
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW14
MW9
MW10
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES

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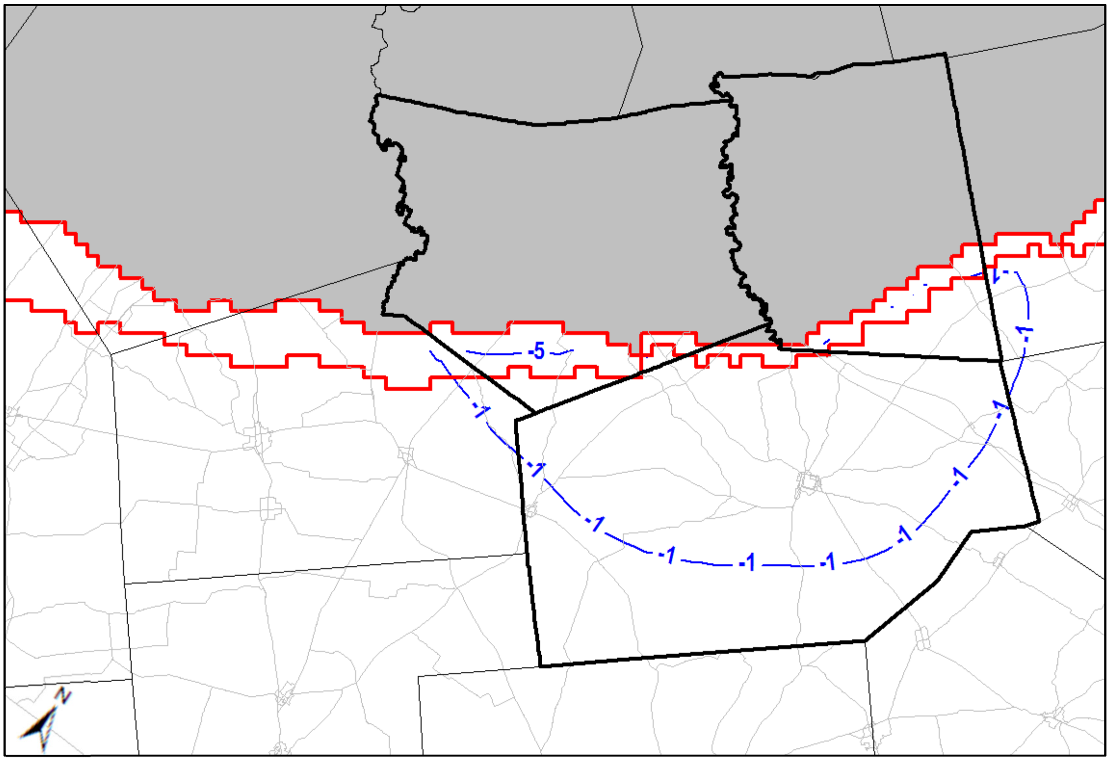
Figure 18. Rise in Water Levels from Baseline Conditions in the Carrizo Aquifer (Layer 5) for the 10 Percent Landowner Participation Scenario in Stress Period 61.

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

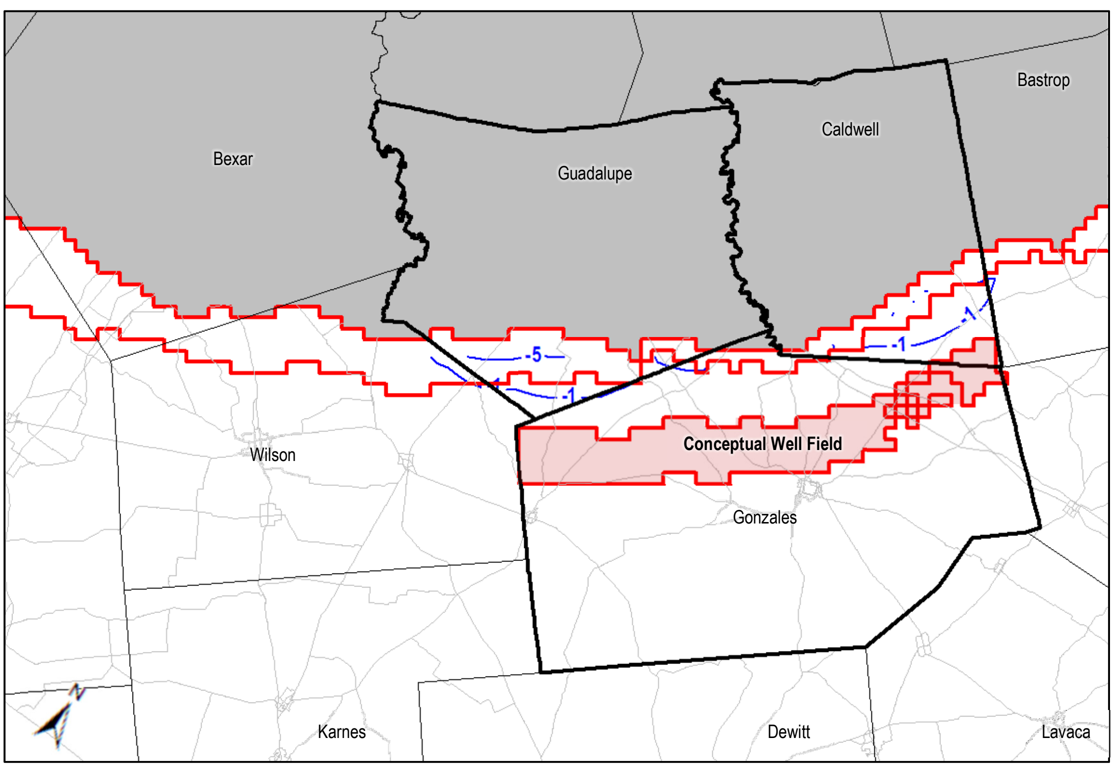
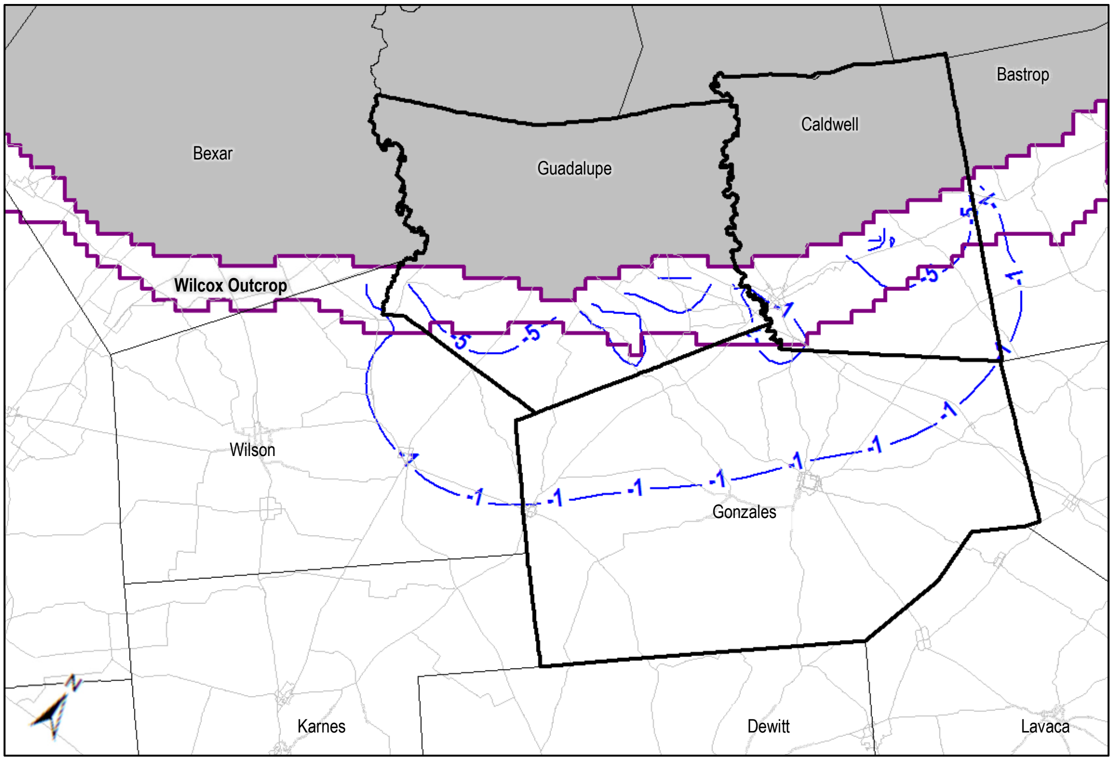


Figure 19. Rise in Water Levels from Baseline Conditions in the Middle Wilcox Aquifer (Layer 7) for the 10 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

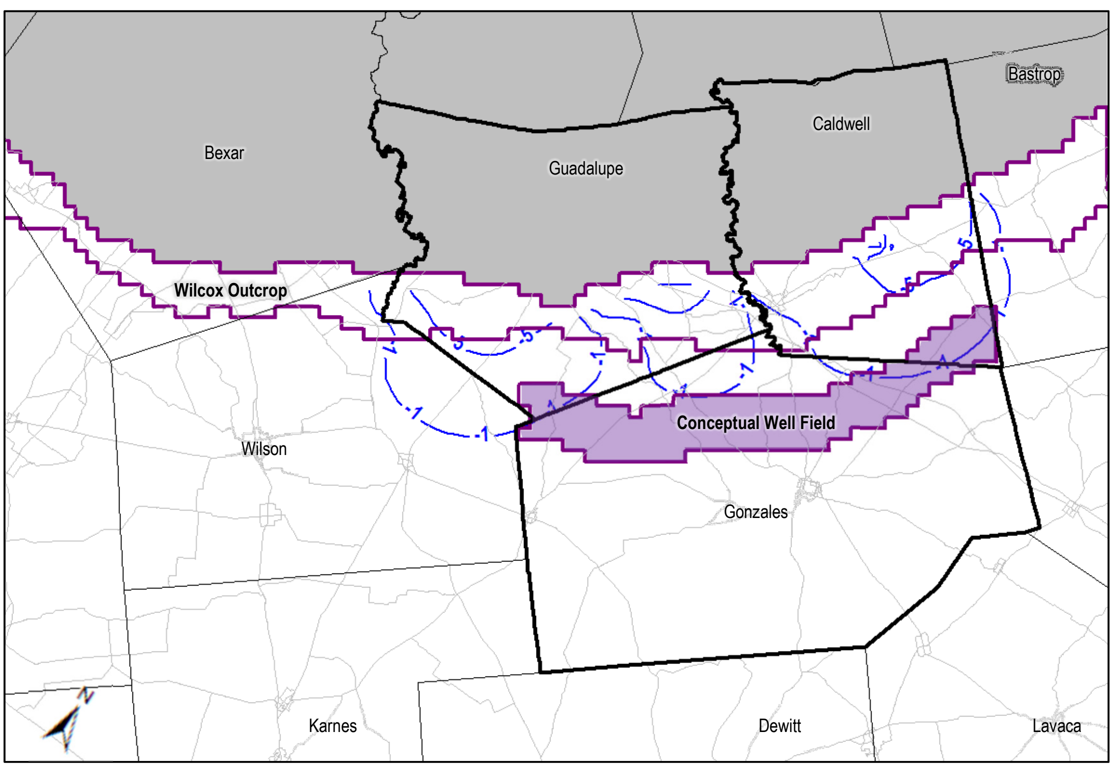
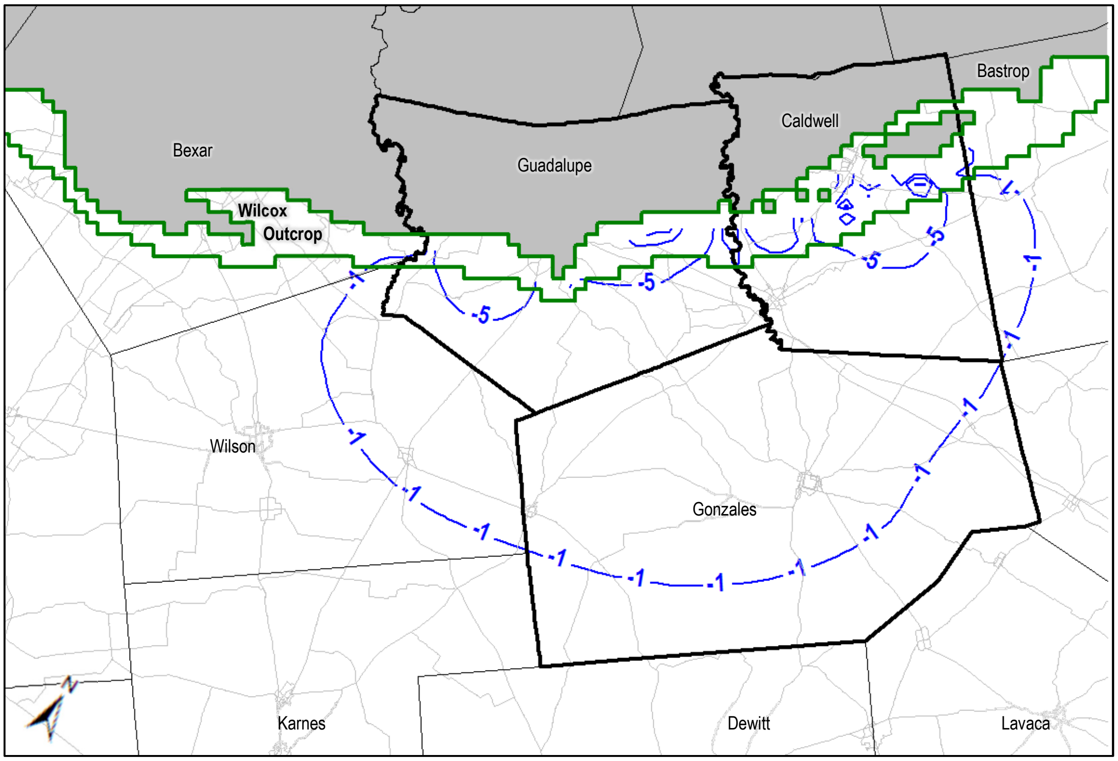


Figure 20. Rise in Water Levels from Baseline Conditions in Lower Wilcox Aquifer (Layer 8) for the 10 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

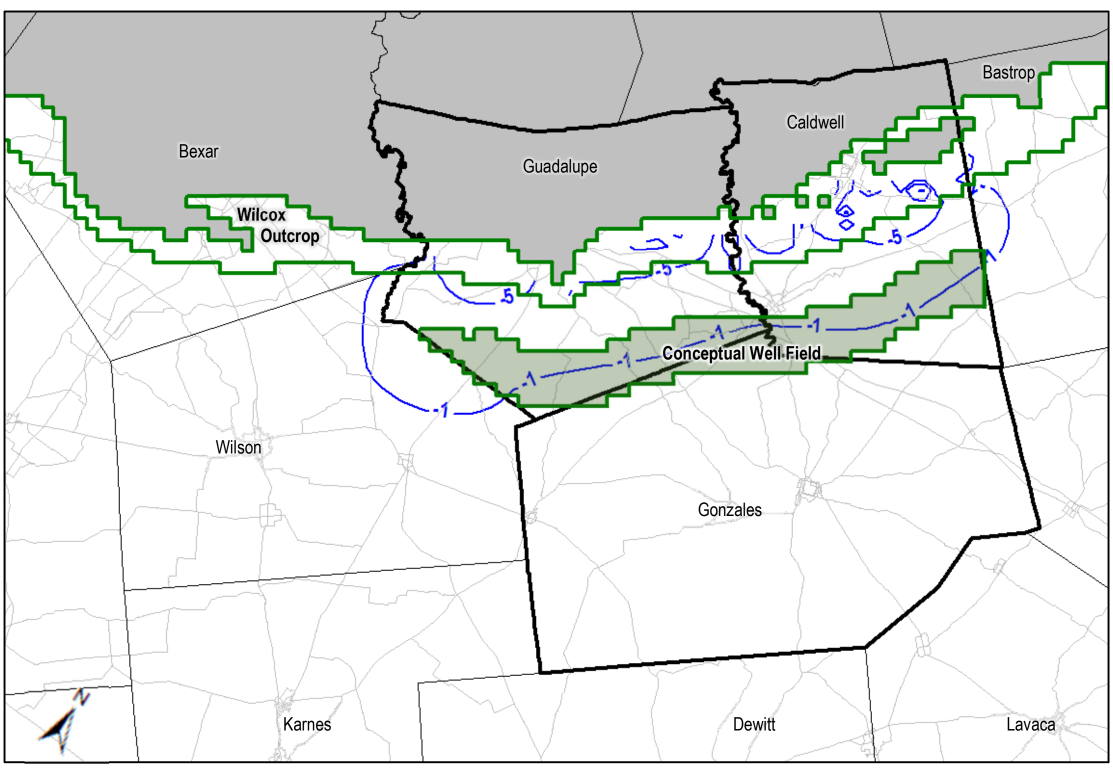
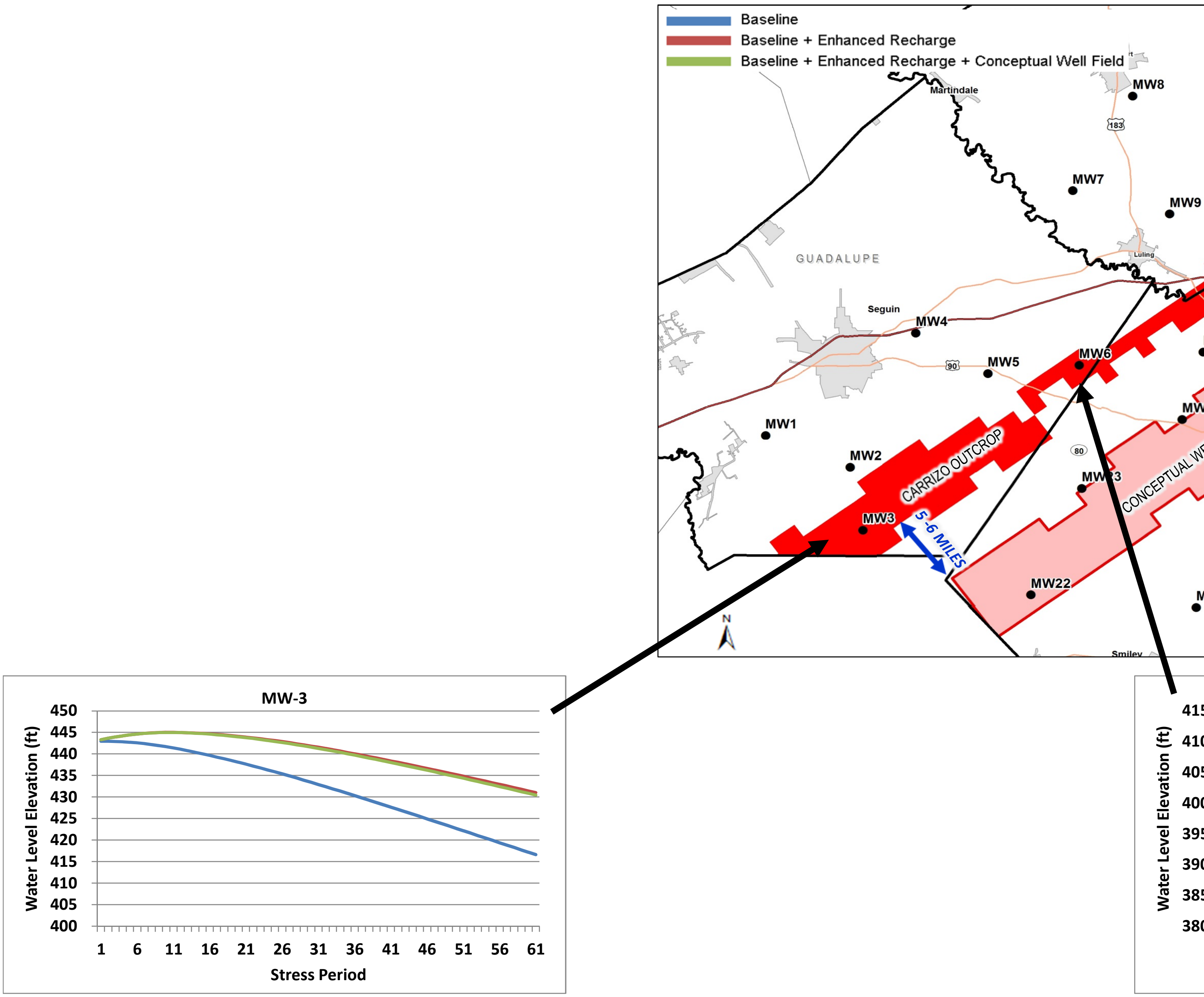


Figure 21: Carrizo Water Level Hydrographs for the 30 Percent Landowner Participation Scenario



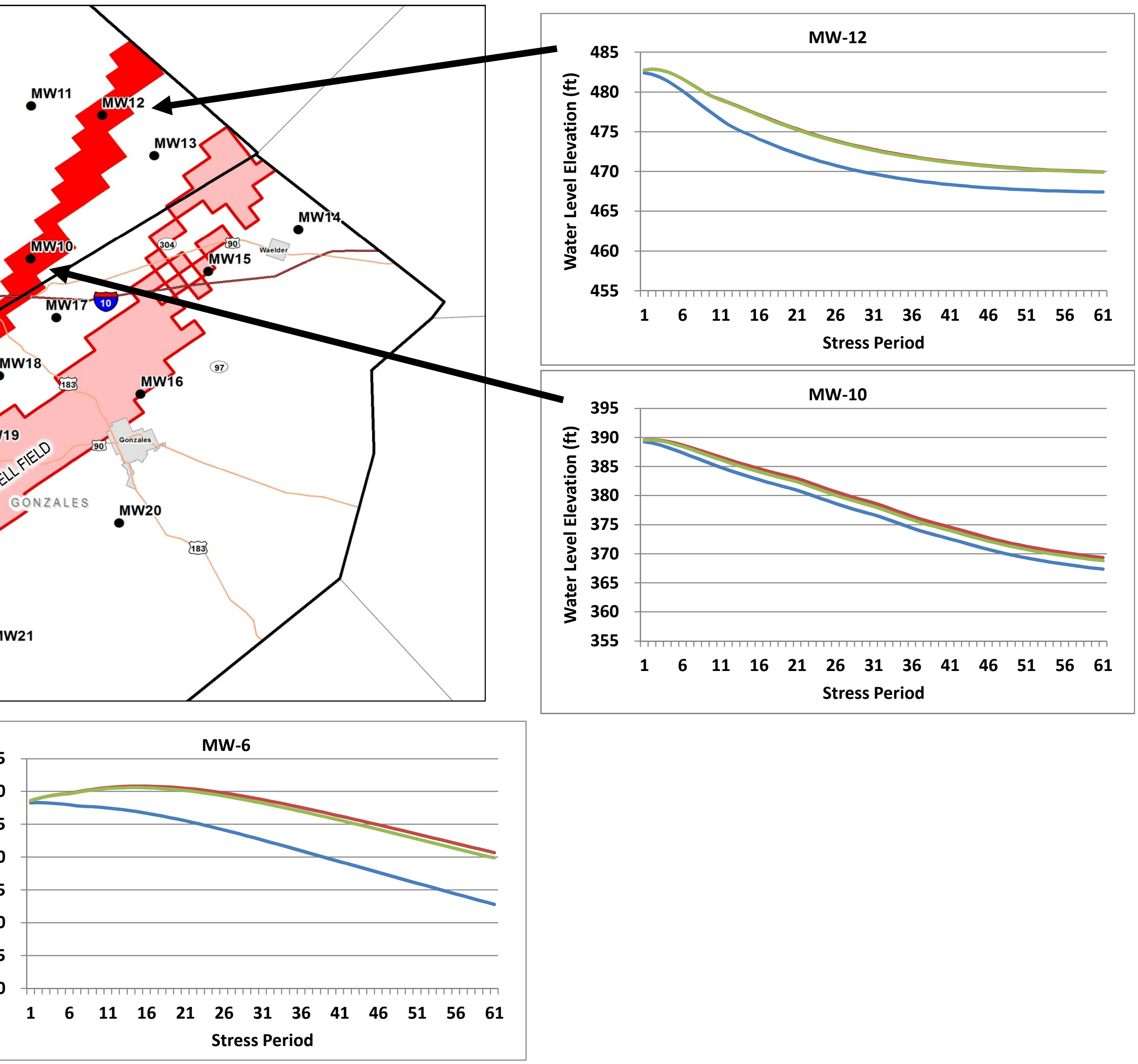
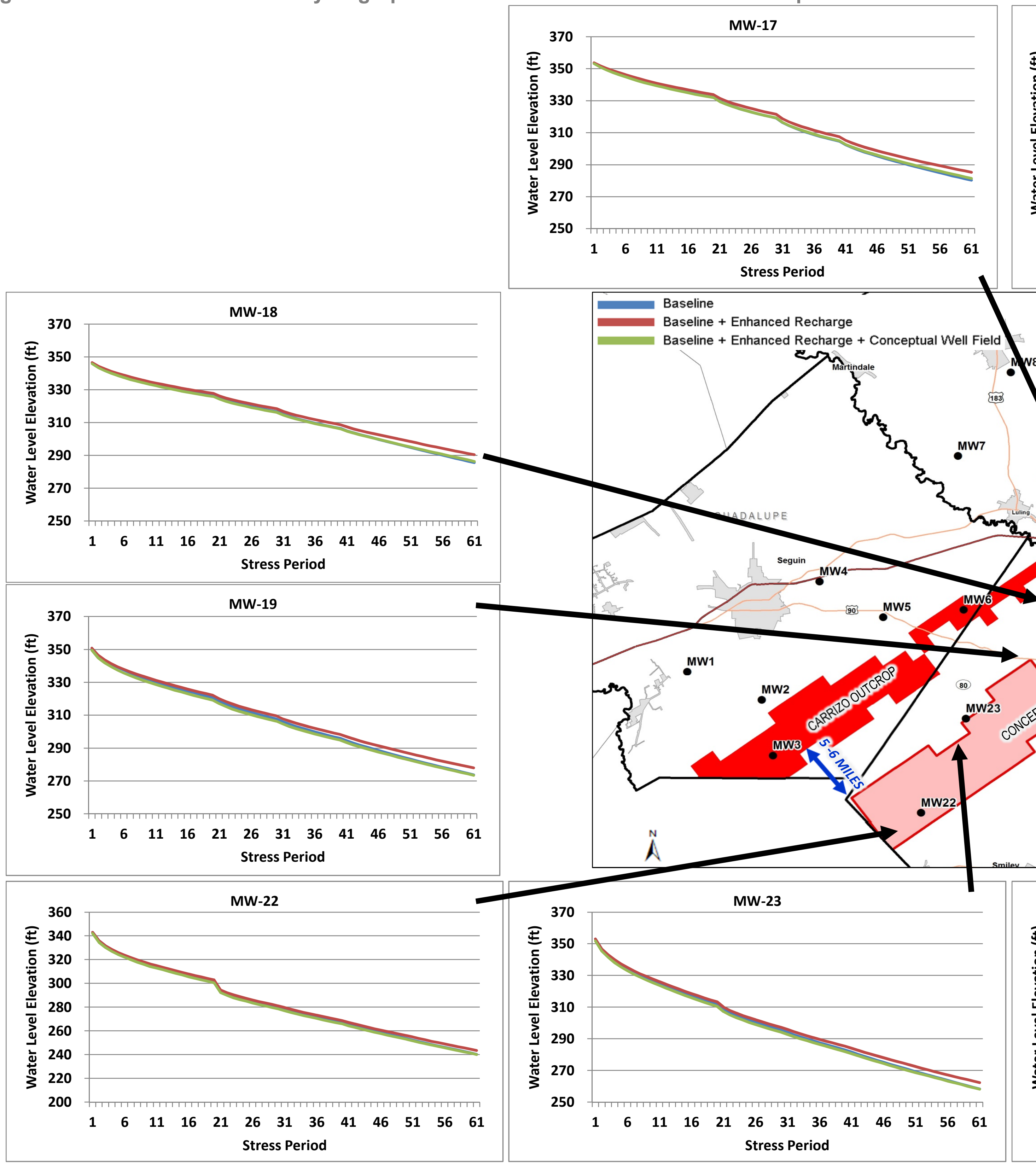

MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
W19
ELL FIELD
GONZALES
MW20
W21
Waelder
Gonzales
10
90
183
304
97
MW-12
Water Level Elevation (ft)
485
480
475
470
465
460
455
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-10
Water Level Elevation (ft)
395
390
385
380
375
370
365
360
355
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-6
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period

Figure 21a: Carrizo Water Level Hydrographs for the 30 Percent Landowner Participation Scenario



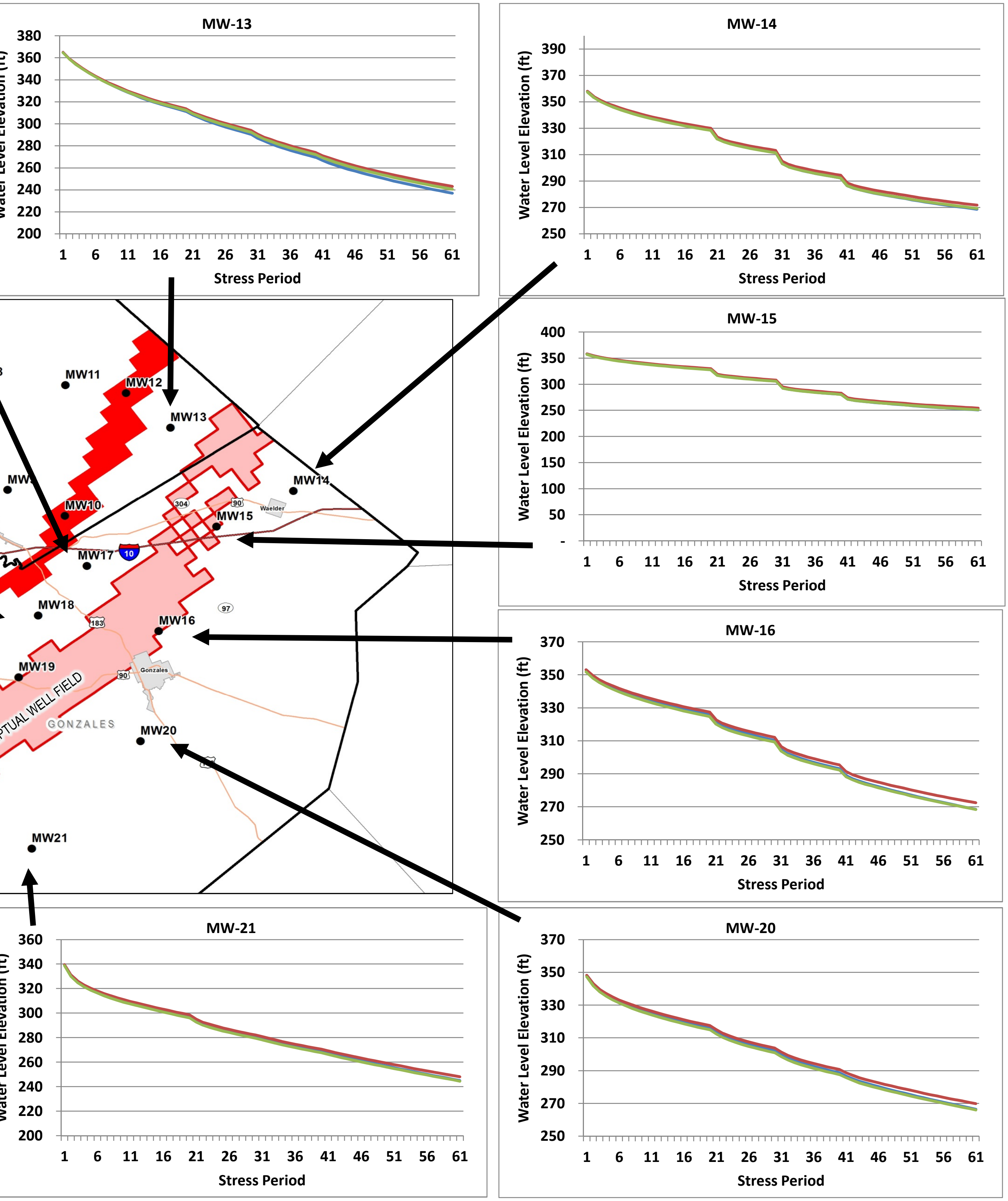
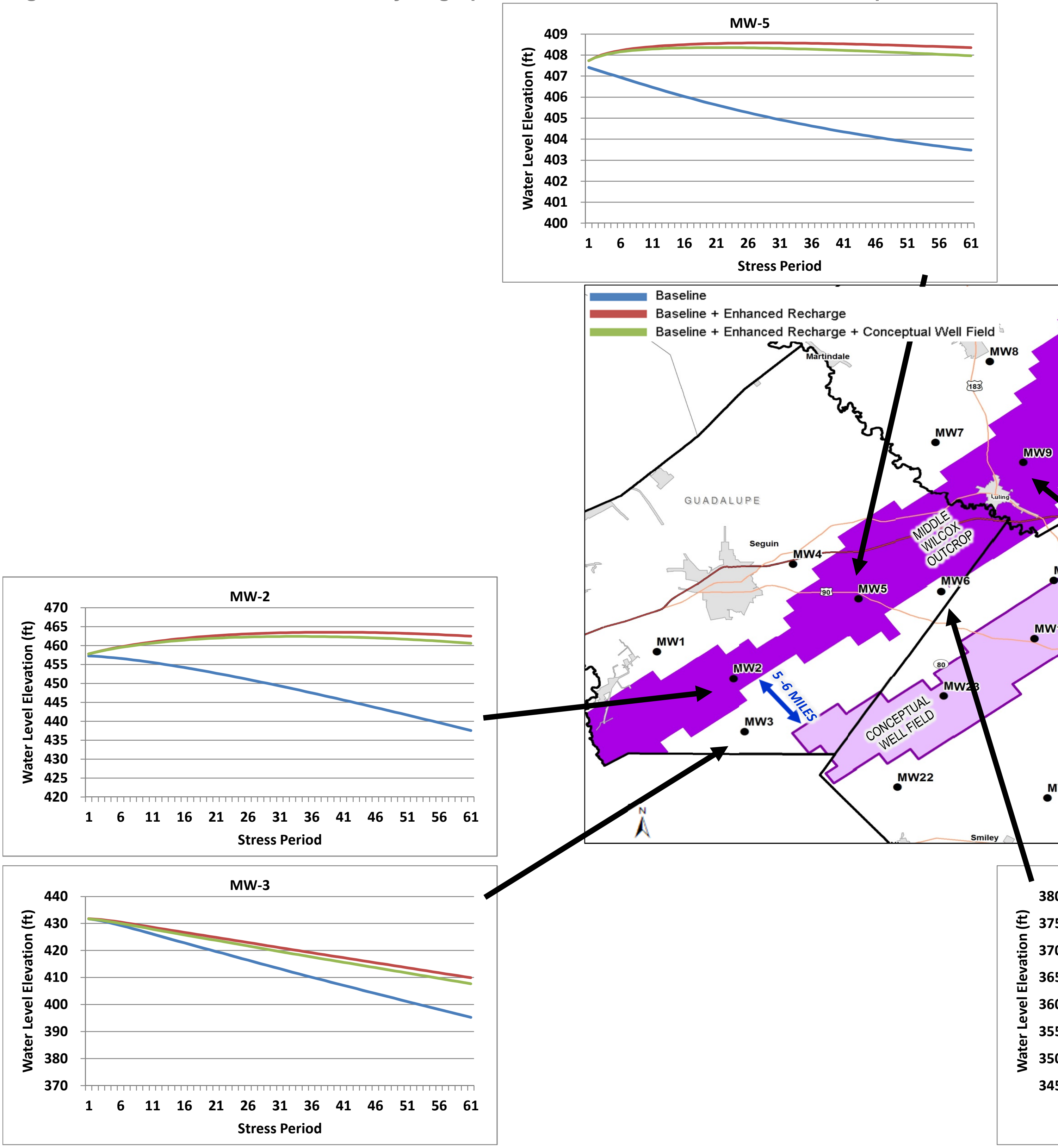

MW-13
Water Level Elevation (ft)
Stress Period
MW-14
Water Level Elevation (ft)
Stress Period
MW-15
Water Level Elevation (ft)
Stress Period
MW-16
Water Level Elevation (ft)
Stress Period
MW-21
Water Level Elevation (ft)
Stress Period
MW-20
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES
PTUAL WELL FIELD

Figure 22: Middle Wilcox Water Level Hydrographs for the 30 Percent Landowner Participation Scenario



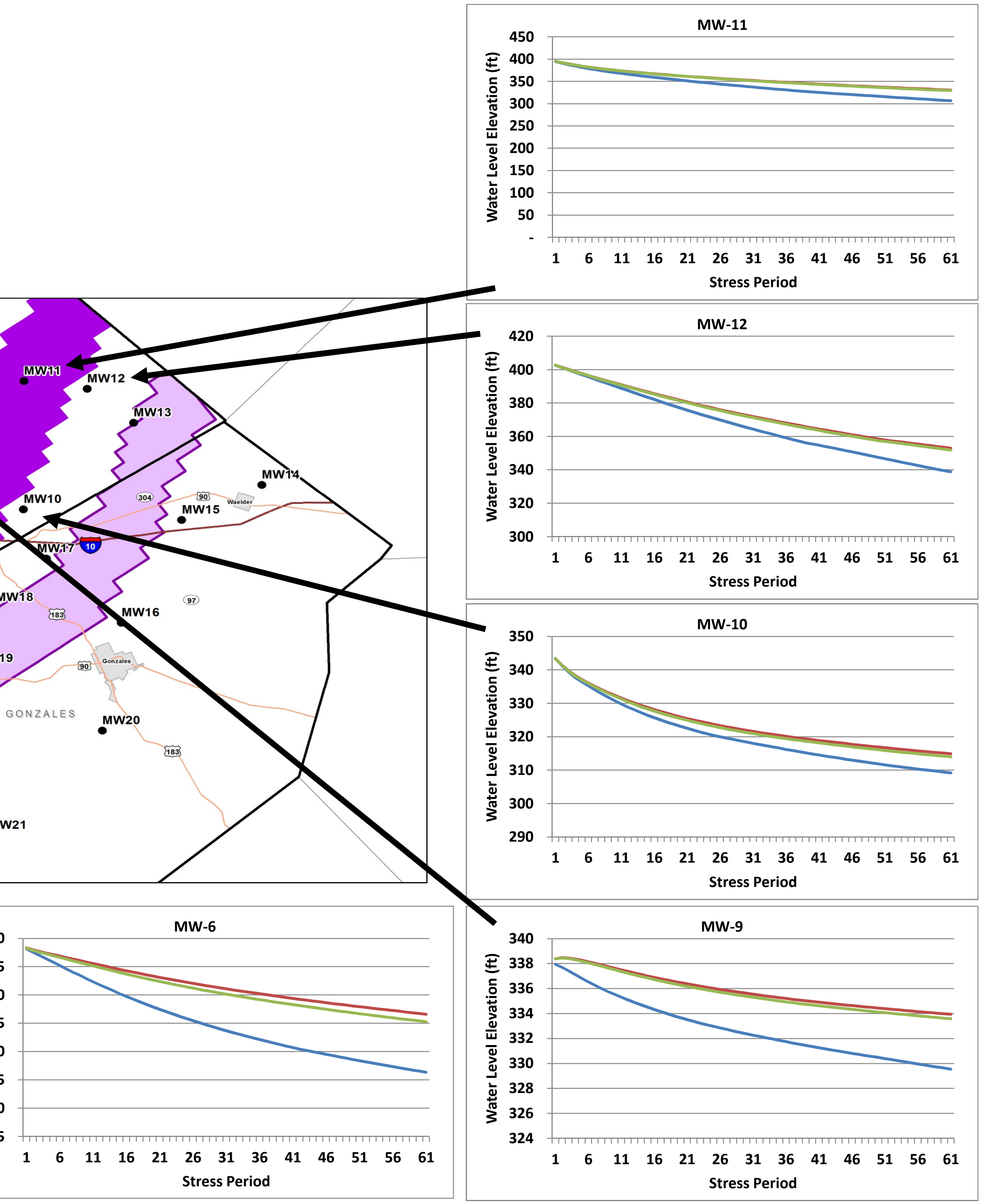
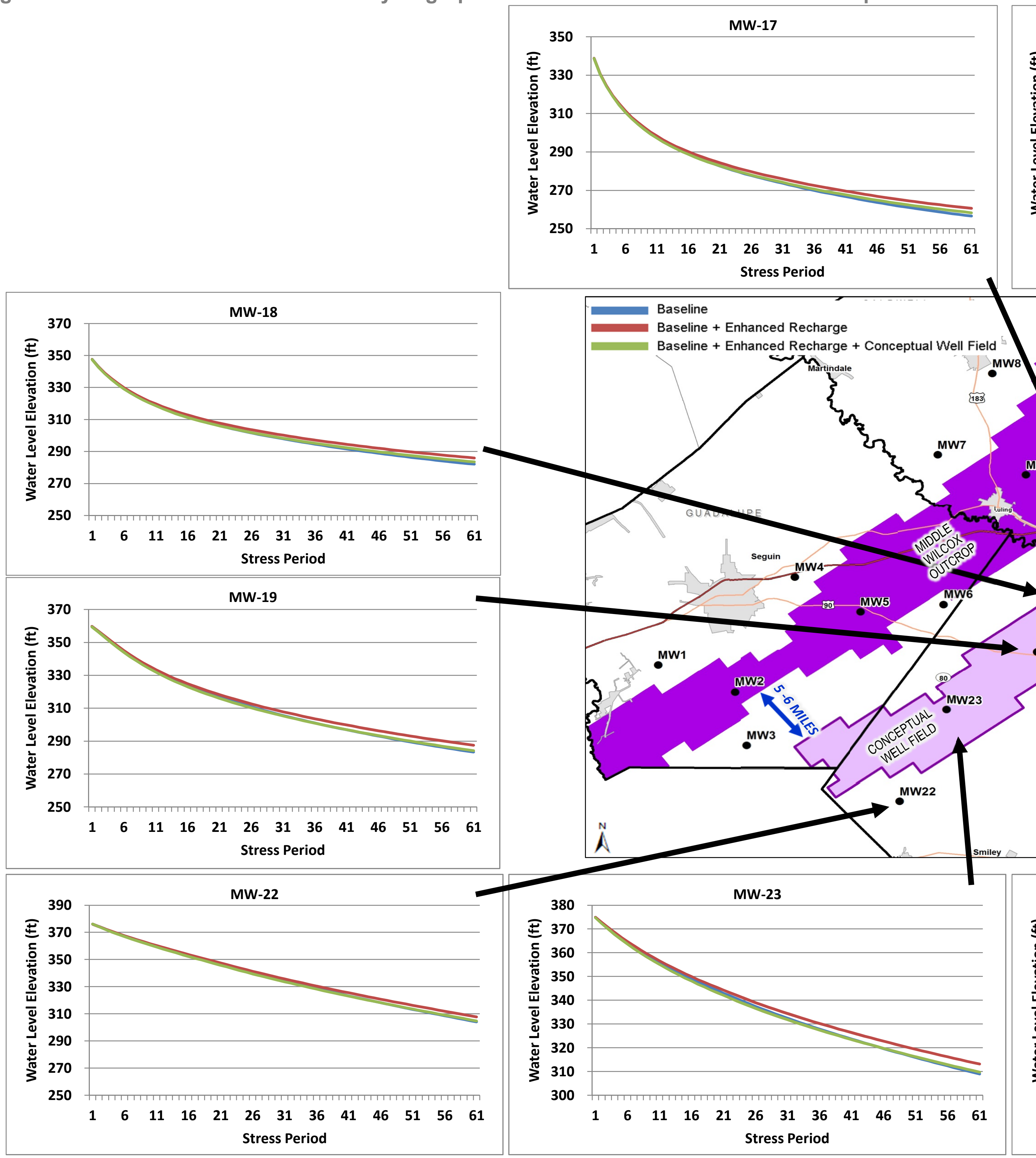

MW-11
Water Level Elevation (ft)
450
400
350
300
250
200
150
100
50
-
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-12
Water Level Elevation (ft)
420
400
380
360
340
320
300
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-10
Water Level Elevation (ft)
350
340
330
320
310
300
290
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-6
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-9
Water Level Elevation (ft)
340
338
336
334
332
330
328
326
324
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW20
W21
Waelder
Gonzales
GONZALES
10
90
304
97
183

Figure 22a: Middle Wilcox Water Level Hydrographs for the 30 Percent Landowner Participation Scenario



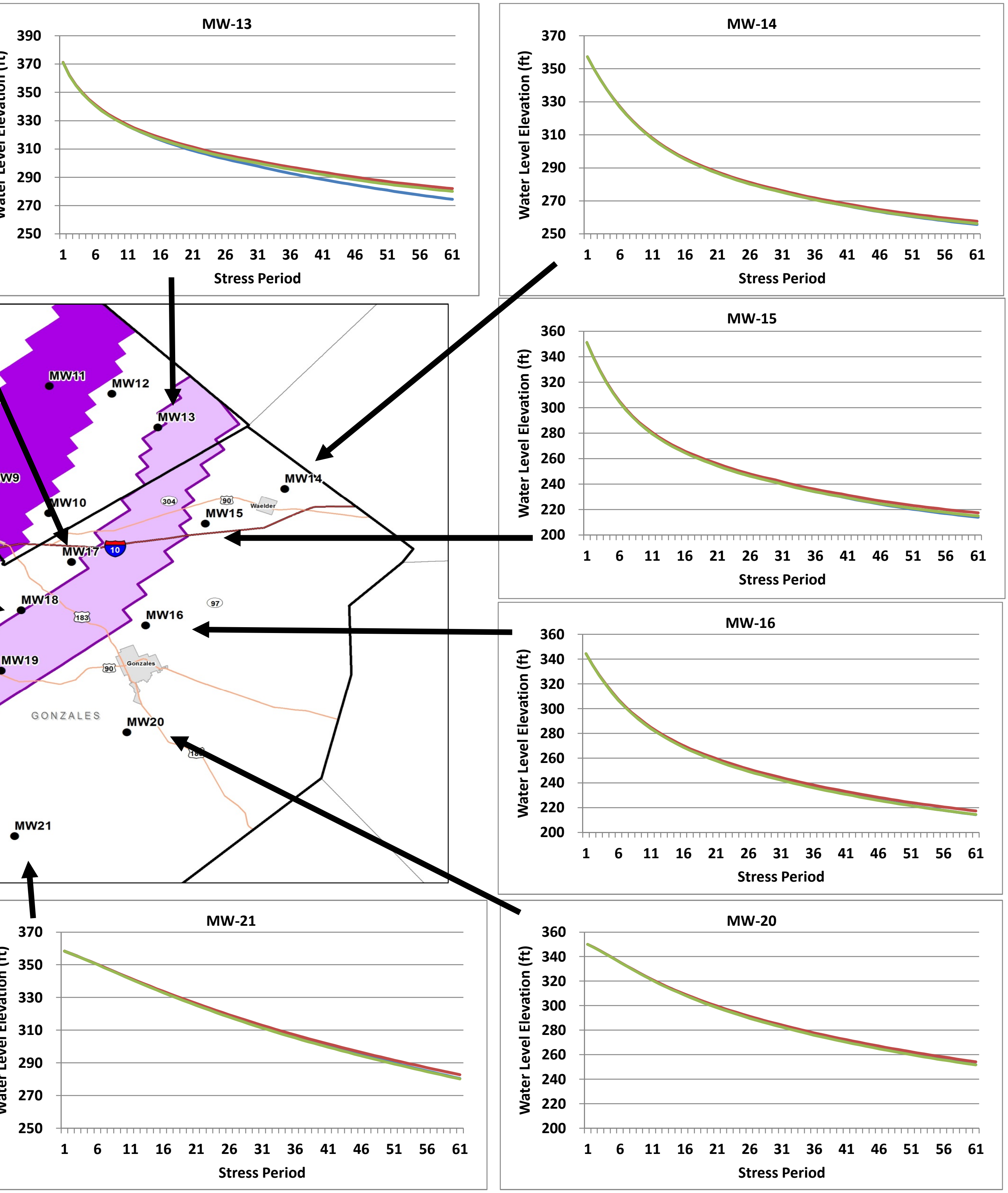
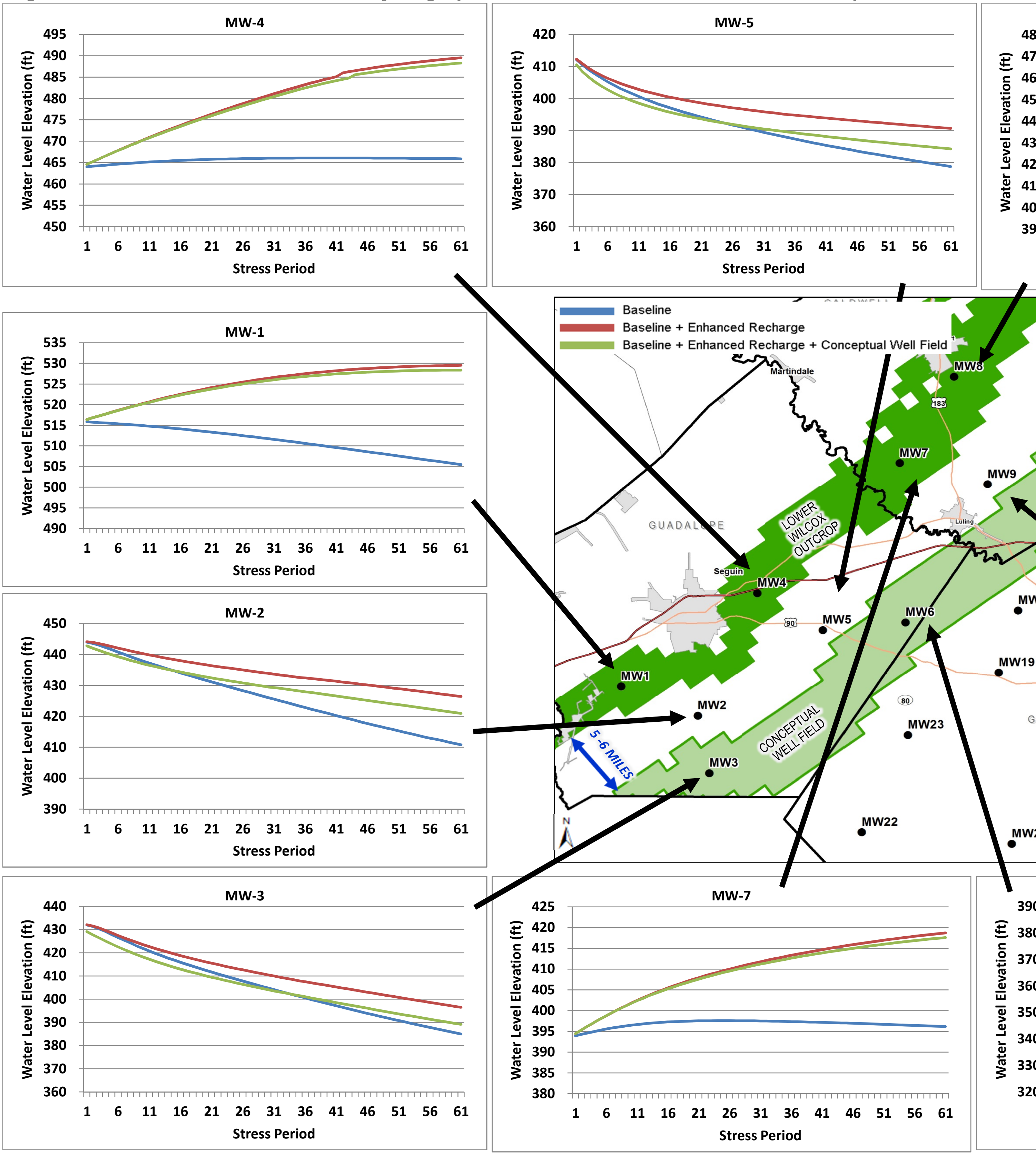

MW-13
Water Level Elevation (ft)
390
370
350
330
310
290
270
250
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-14
Water Level Elevation (ft)
370
350
330
310
290
270
250
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-15
Water Level Elevation (ft)
360
340
320
300
280
260
240
220
200
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-16
Water Level Elevation (ft)
360
340
320
300
280
260
240
220
200
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW11
MW12
MW13
MW9
MW14
MW10
MW15
Waelder
MW17
10
MW18
MW16
MW19
Gonzales
GONZALES
MW20
MW21
MW-21
Water Level Elevation (ft)
370
350
330
310
290
270
250
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-20
Water Level Elevation (ft)
360
340
320
300
280
260
240
220
200
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period

Figure 23: Lower Wilcox Water Level Hydrographs for the 30 Percent Landowner Participation Scenario



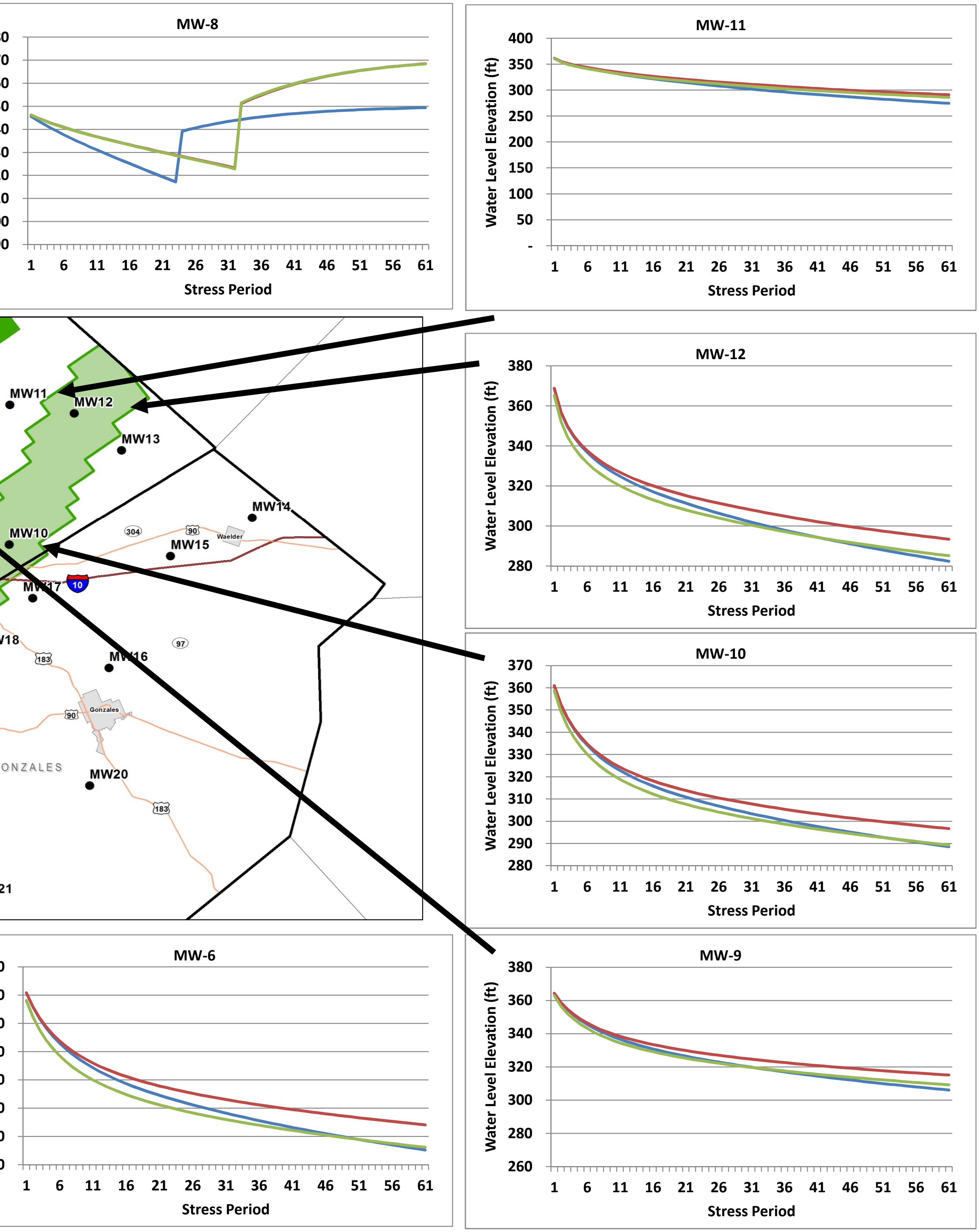
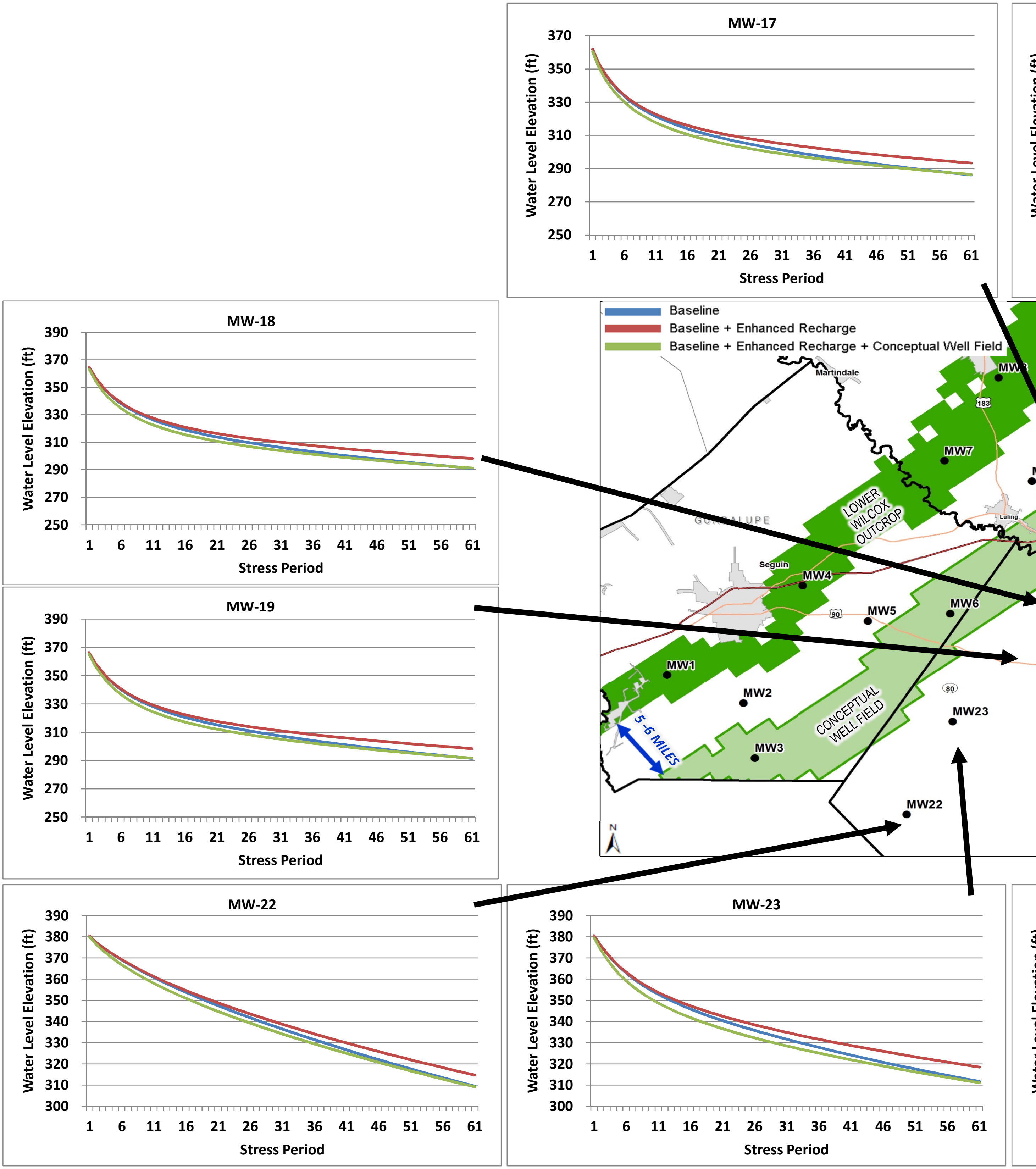

MW-8
Stress Period
MW-11
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW16
MW20
Gonzales
Waelder
MW-12
Water Level Elevation (ft)
Stress Period
MW-10
Water Level Elevation (ft)
Stress Period
MW-6
Stress Period
MW-9
Water Level Elevation (ft)
Stress Period

Figure 23a: Lower Wilcox Water Level Hydrographs for the 30 Percent Landowner Participation Scenario



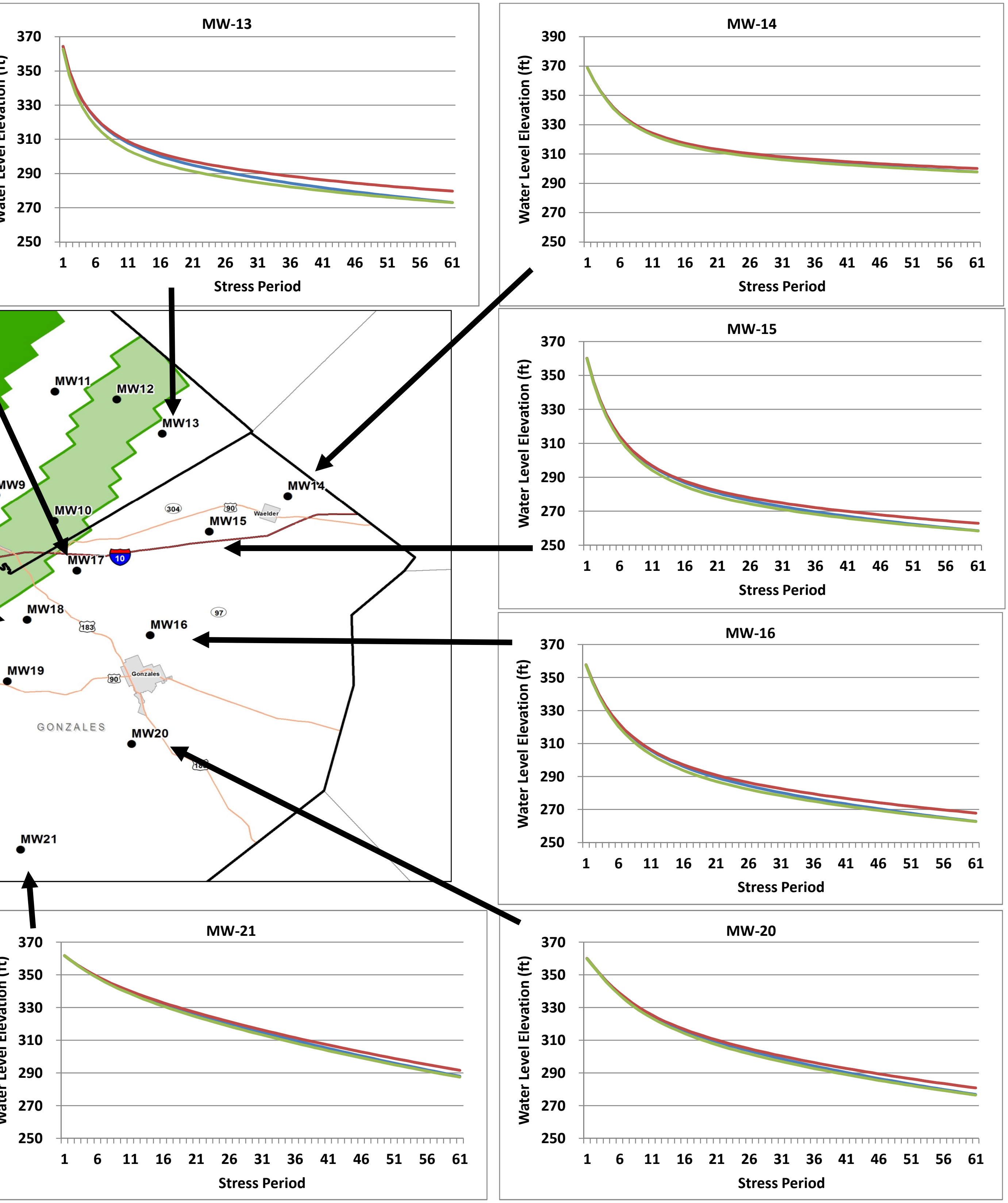

MW-13
MW-14
MW-15
MW-16
MW-20
MW-21
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW9
MW10
MW14
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES

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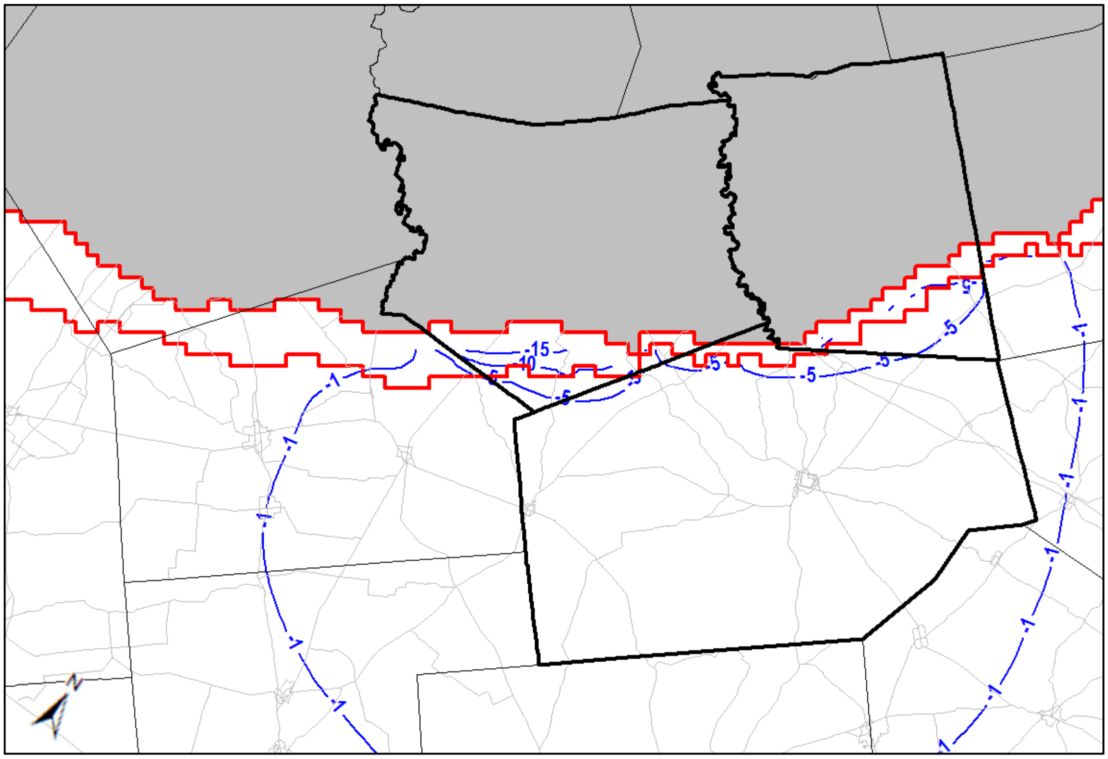
Figure 24. Rise in Water Levels from Baseline Conditions in the Carrizo Aquifer (Layer 5) for the 30 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

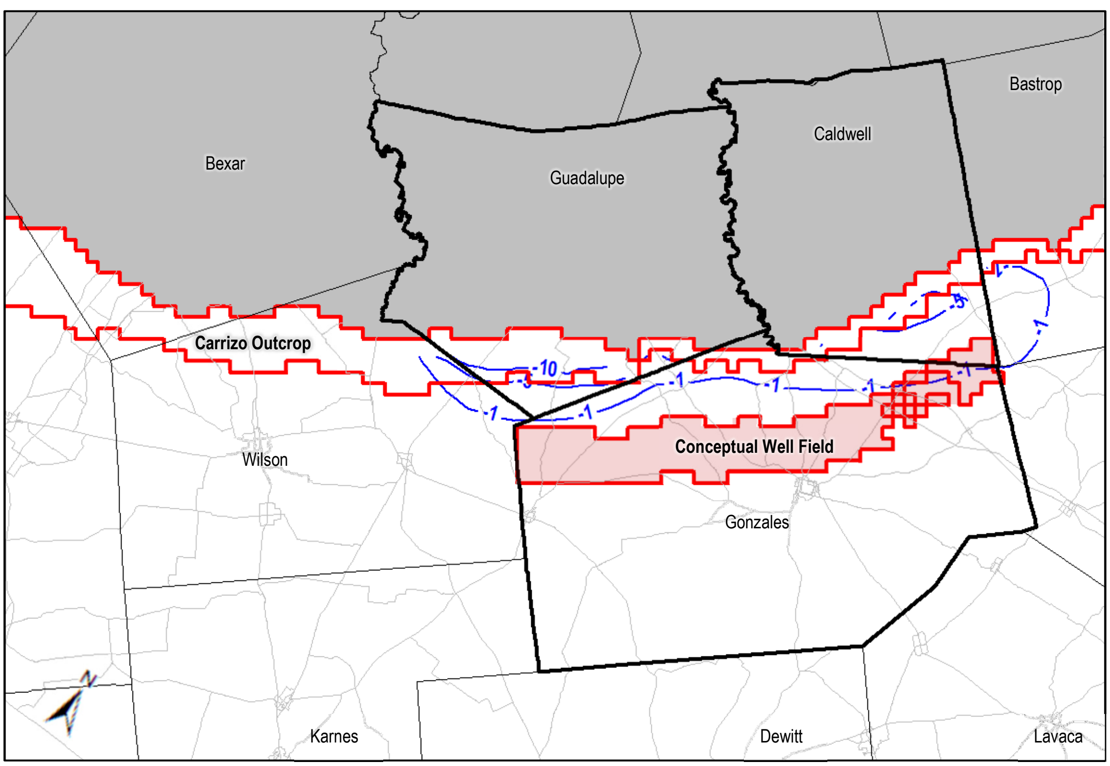
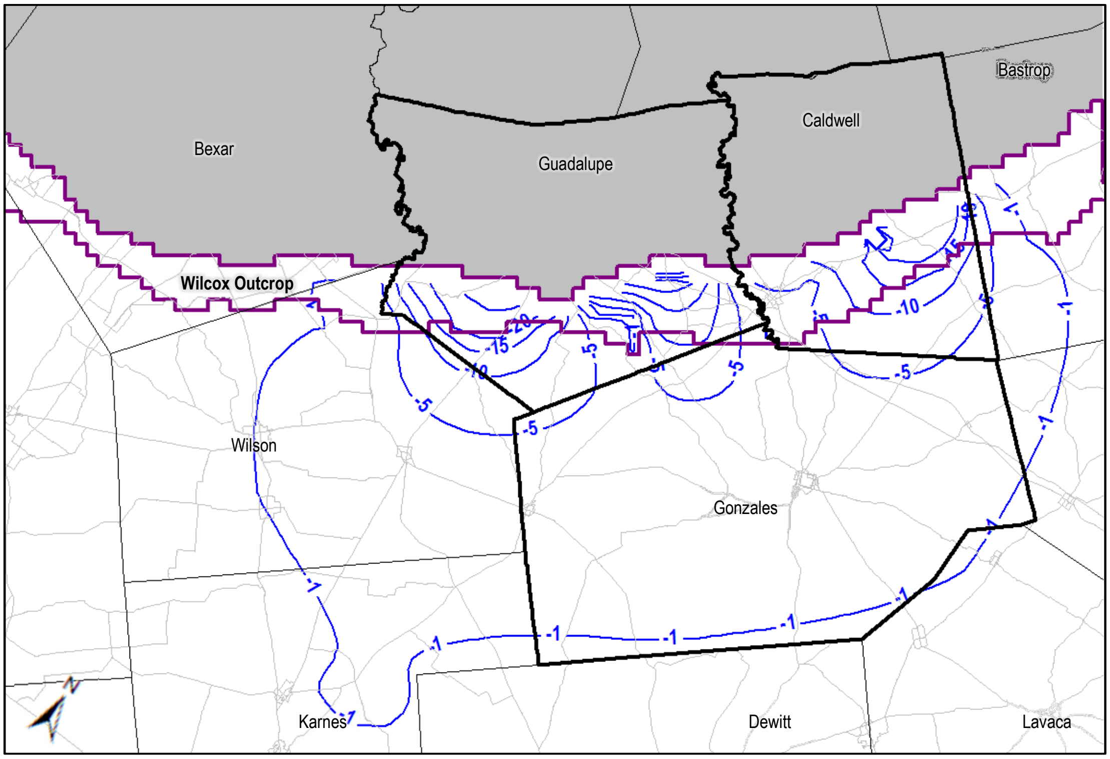


Figure 25. Rise in Water Levels from Baseline Conditions in the Middle Wilcox Aquifer (Layer 7) for the 30 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

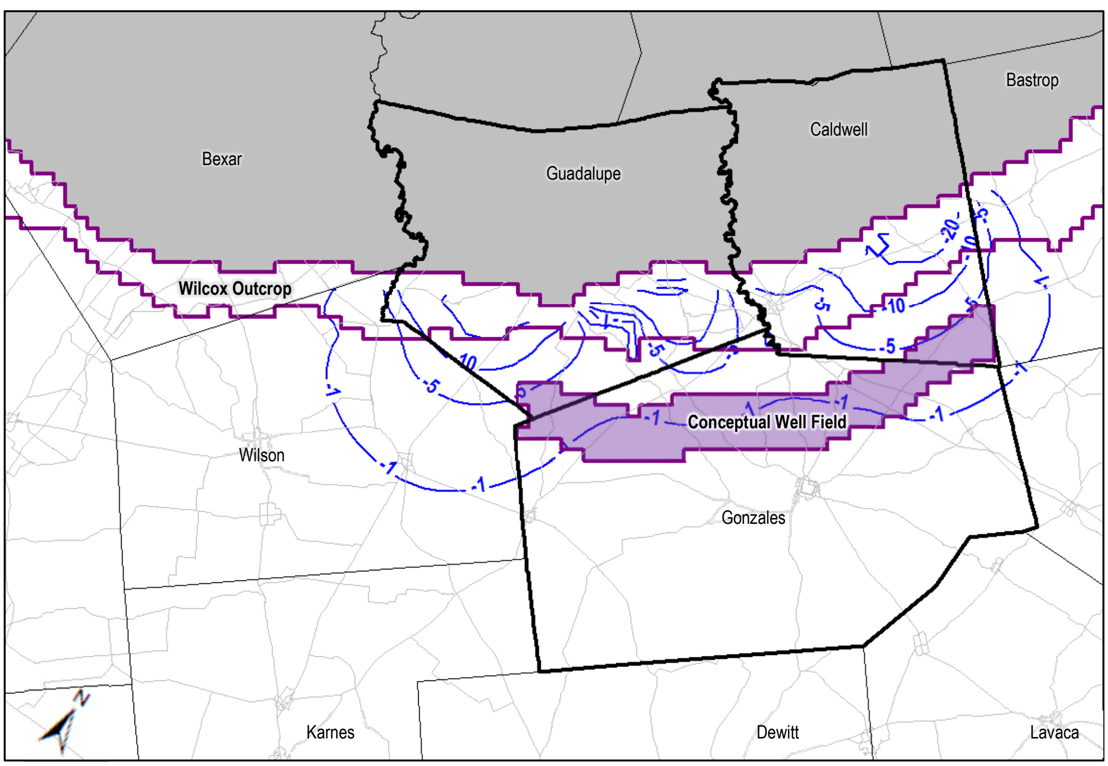
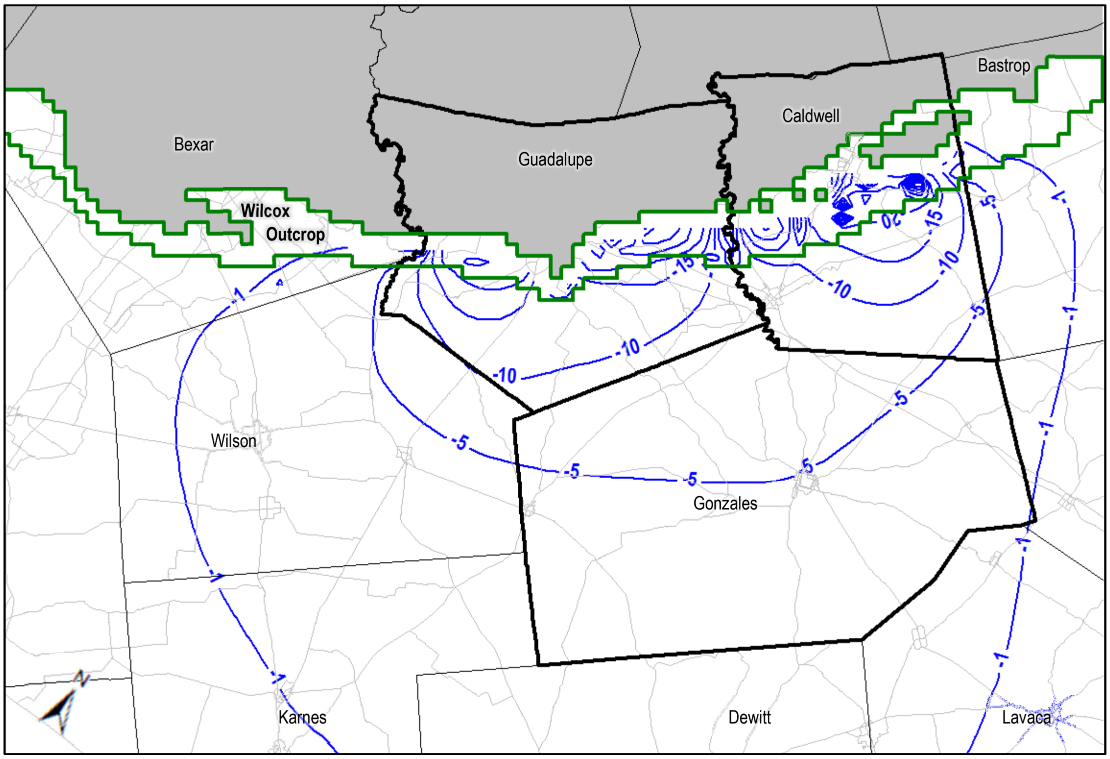


Figure 26. Rise in Water Levels from Baseline Conditions in Lower Wilcox Aquifer (Layer 8) for the 30 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

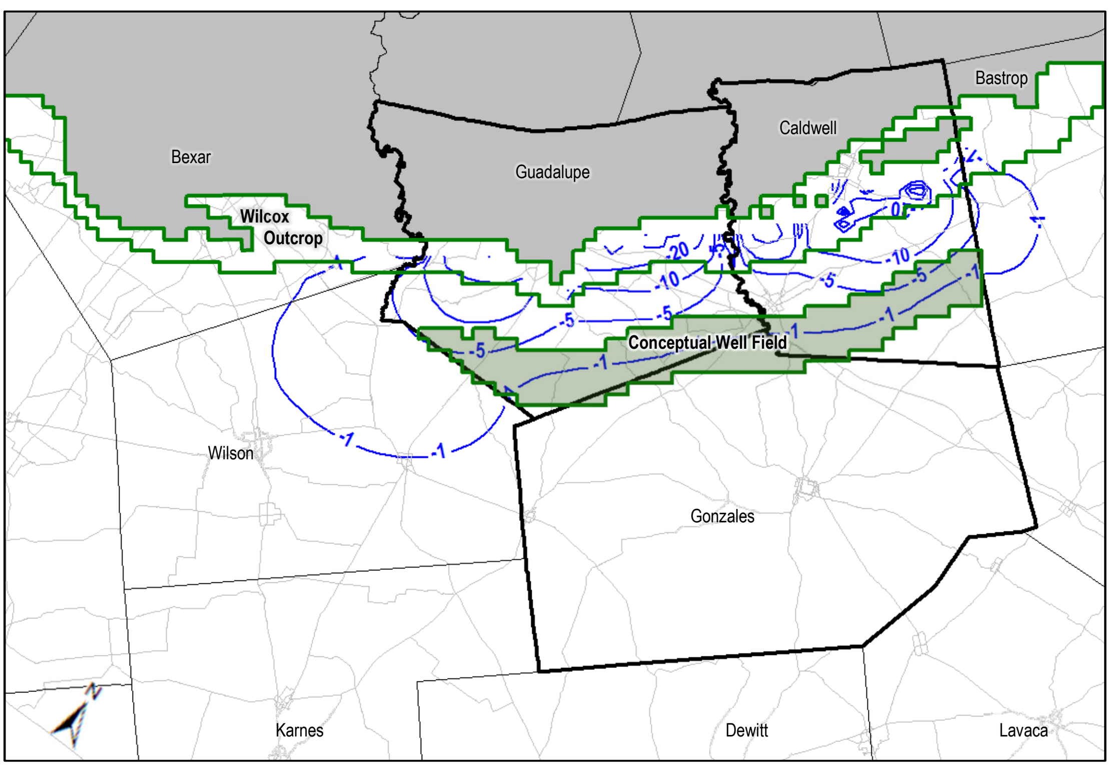
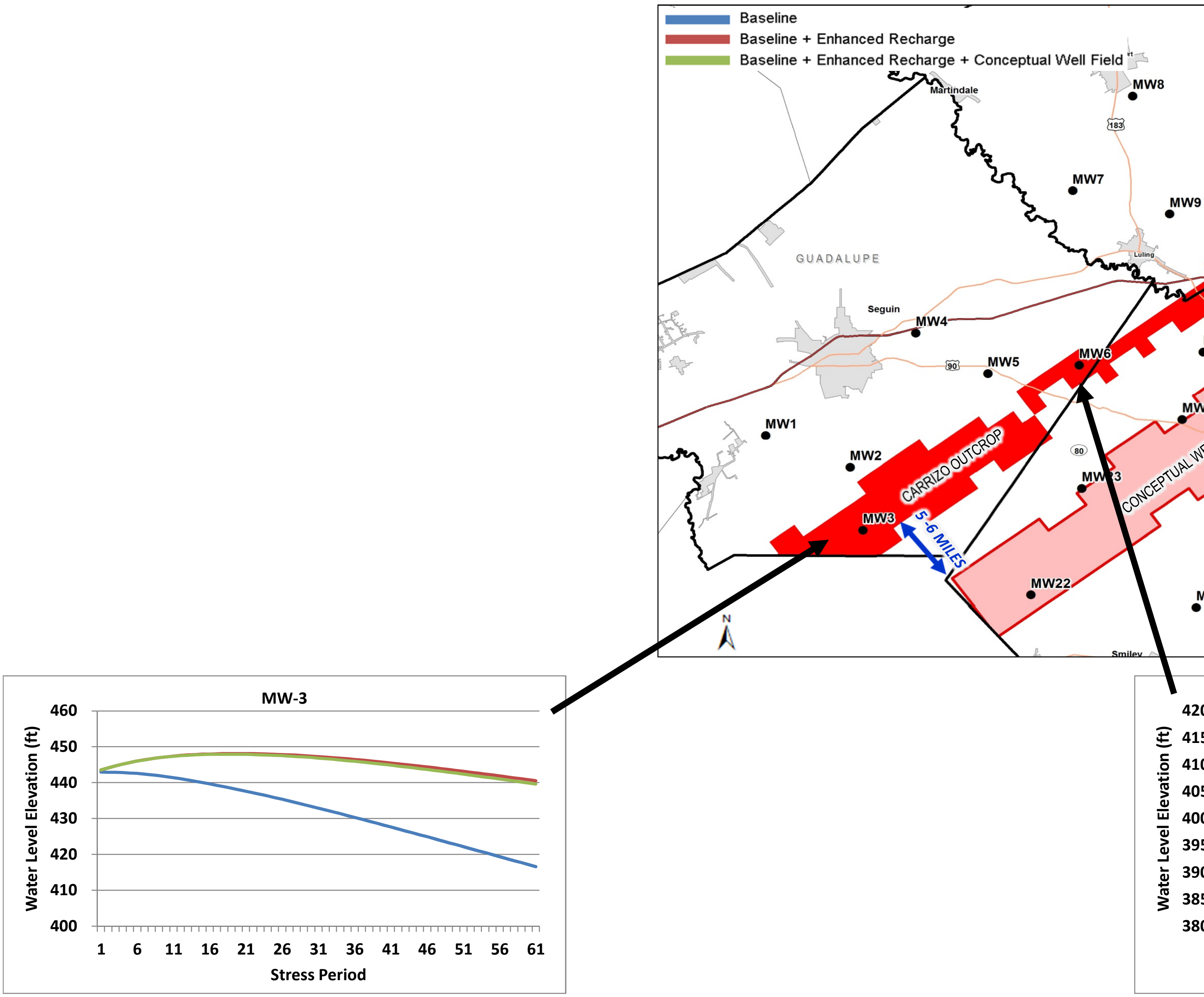


Figure 27: Carrizo Water Level Hydrographs for the 50 Percent Landowner Participation Scenario



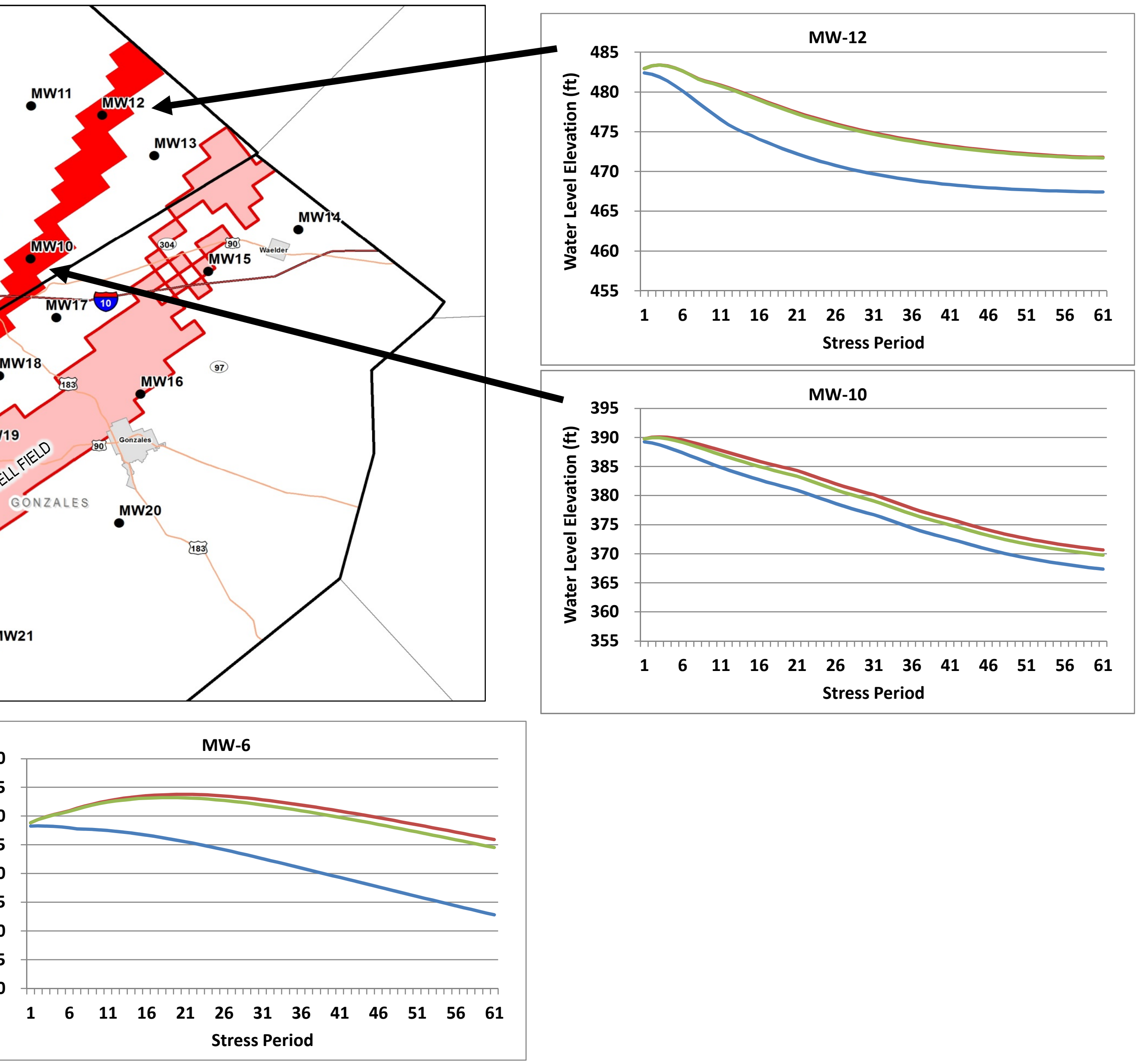
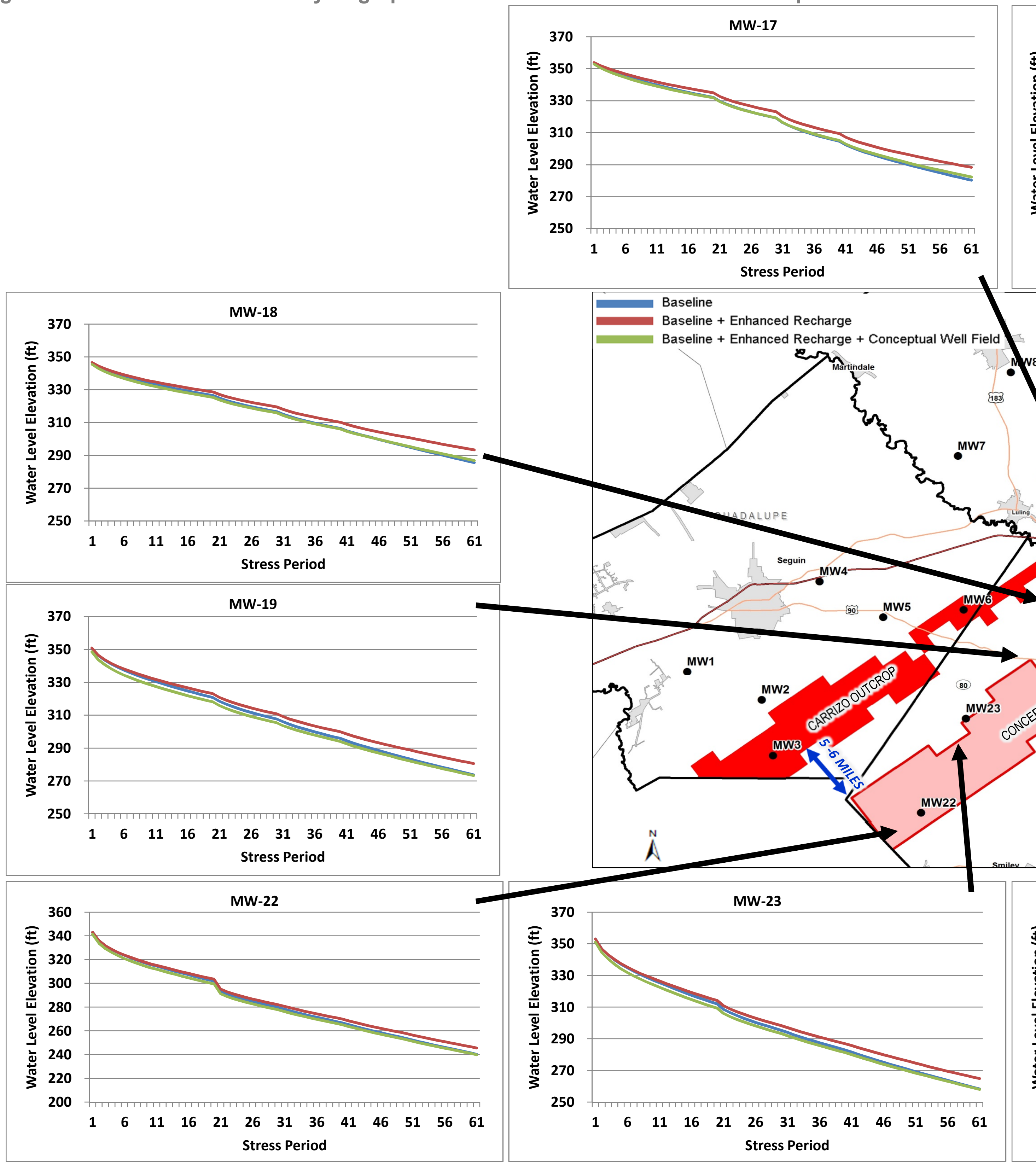

MW11
MW12
MW13
MW14
MW10
MW15
Waelder
MW17
MW18
MW16
Gonzales
GONZALES
MW20
MW-12
Water Level Elevation (ft)
485
480
475
470
465
460
455
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-10
Water Level Elevation (ft)
395
390
385
380
375
370
365
360
355
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-6
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period

Figure 27a: Carrizo Water Level Hydrographs for the 50 Percent Landowner Participation Scenario



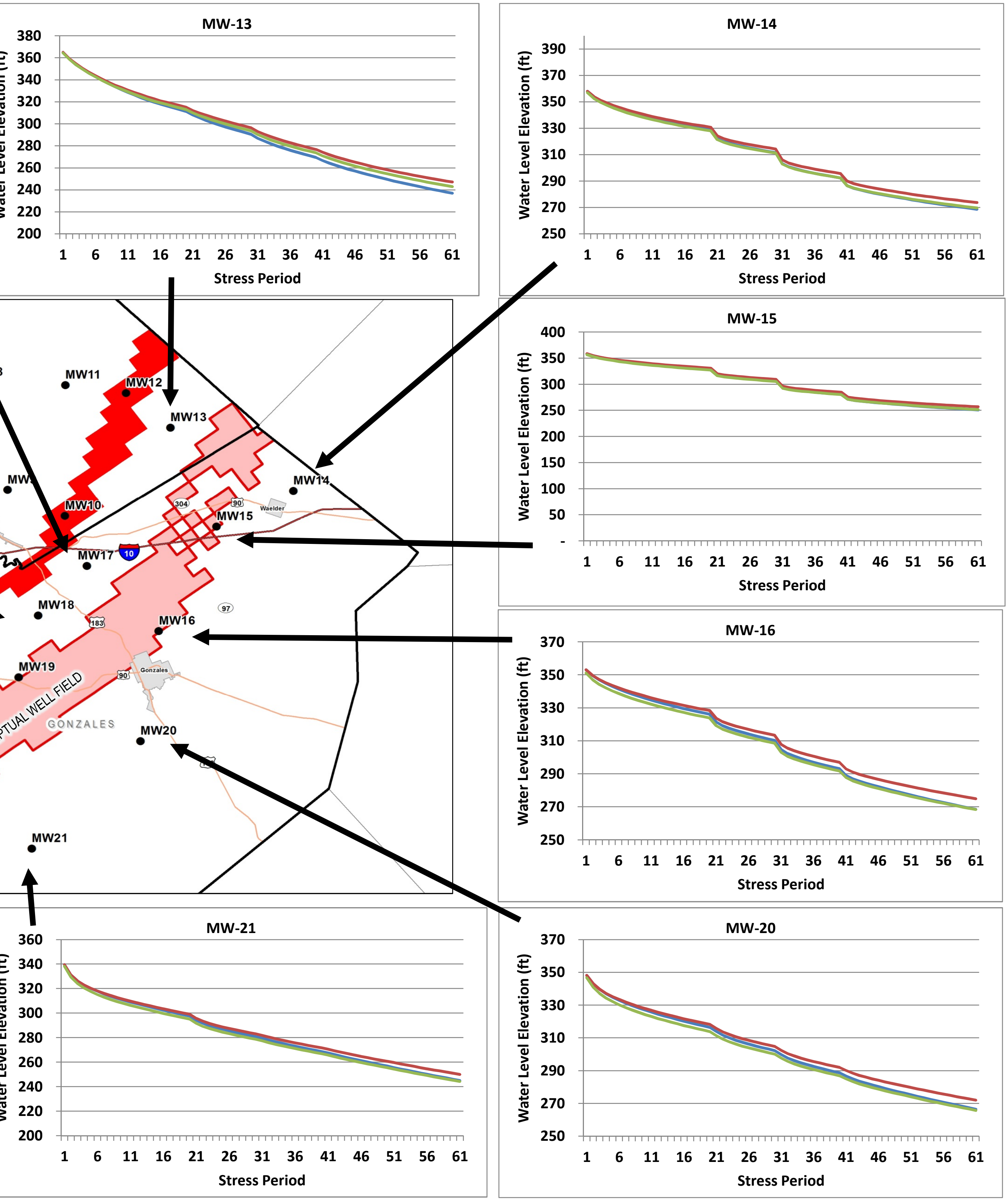
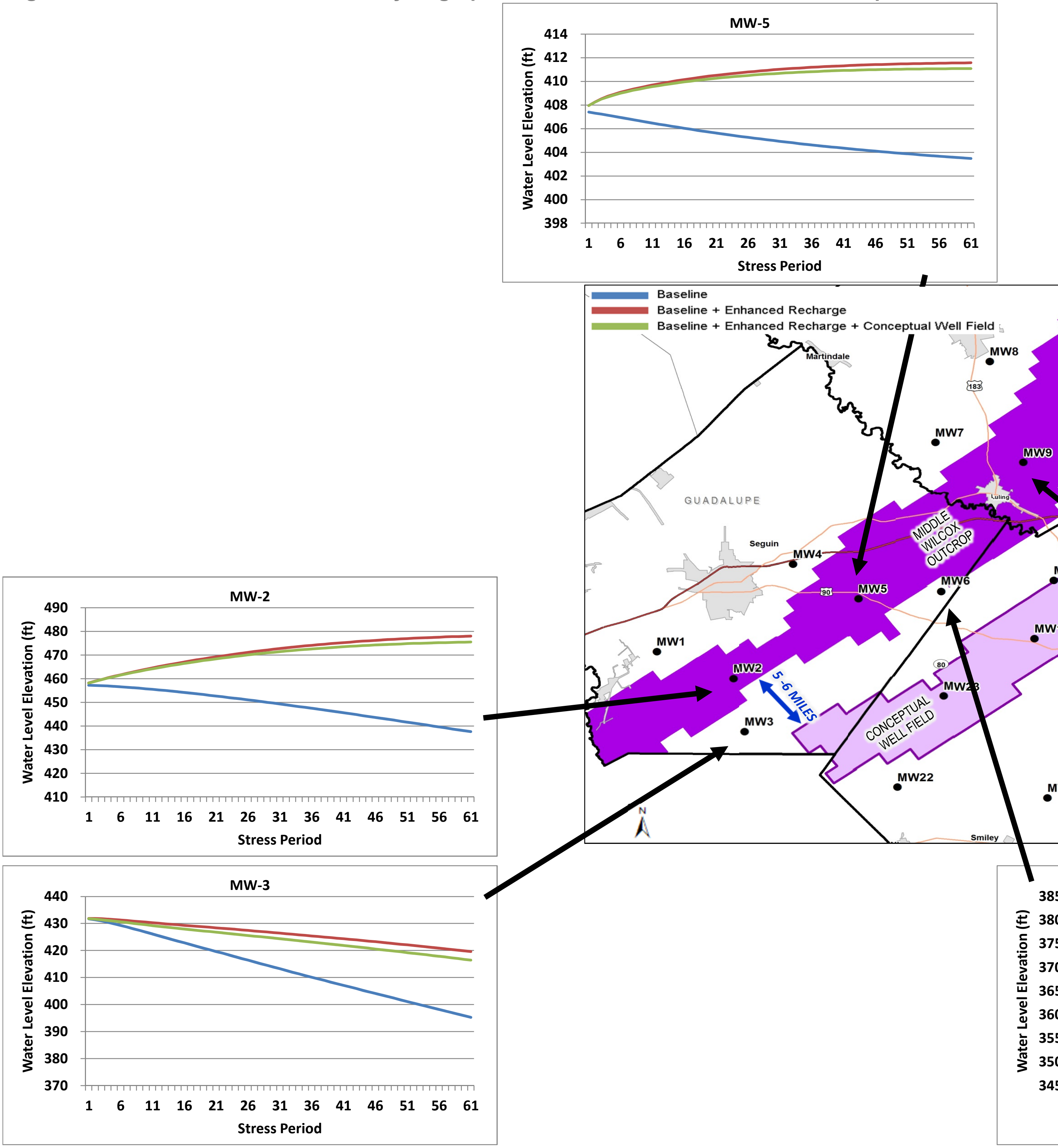

MW-13
Water Level Elevation (ft)
Stress Period
MW-14
Water Level Elevation (ft)
Stress Period
MW-15
Water Level Elevation (ft)
Stress Period
MW-16
Water Level Elevation (ft)
Stress Period
MW-21
Water Level Elevation (ft)
Stress Period
MW-20
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES
PTUAL WELL FIELD

Figure 28: Middle Wilcox Water Level Hydrographs for the 50 Percent Landowner Participation Scenario



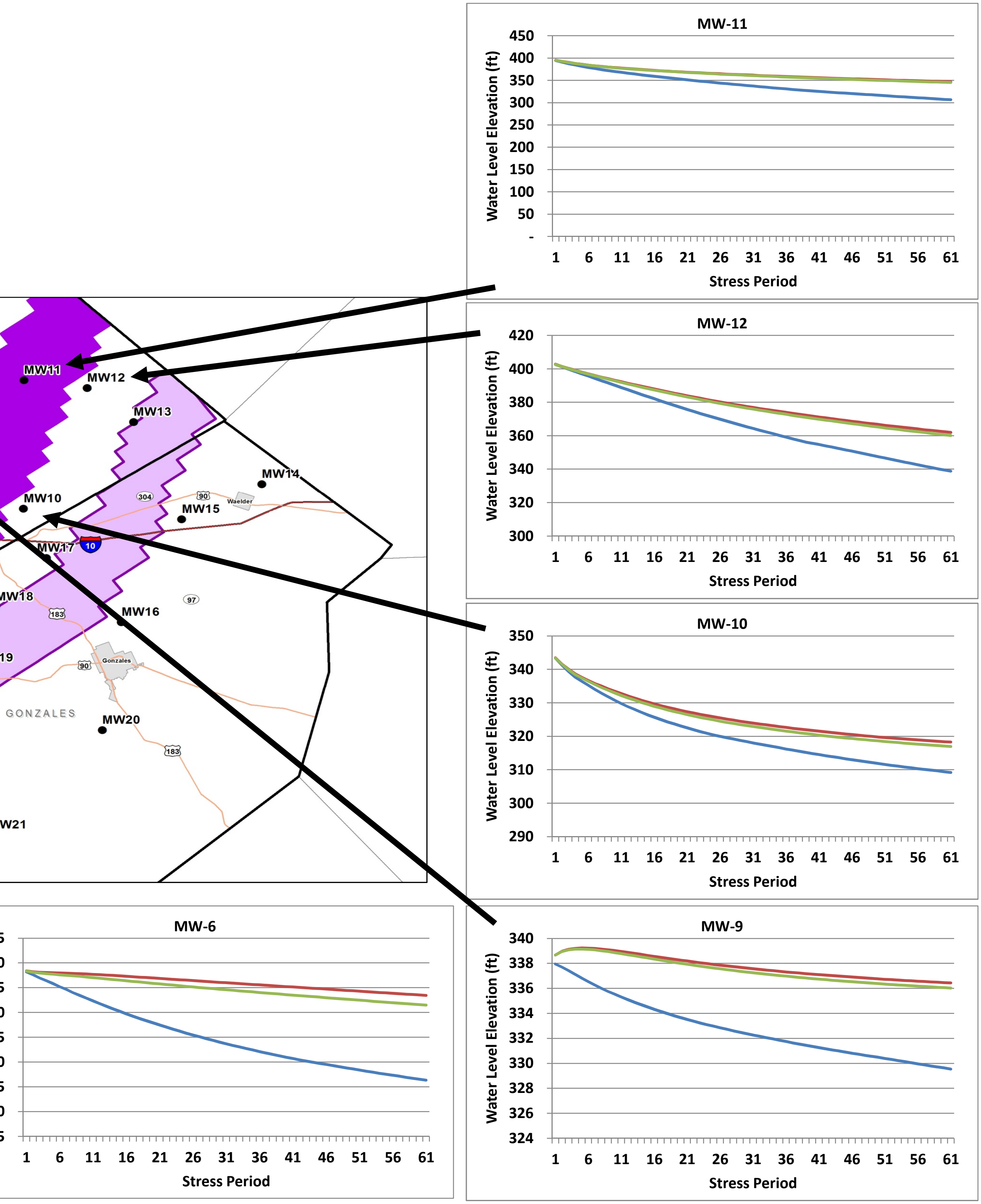
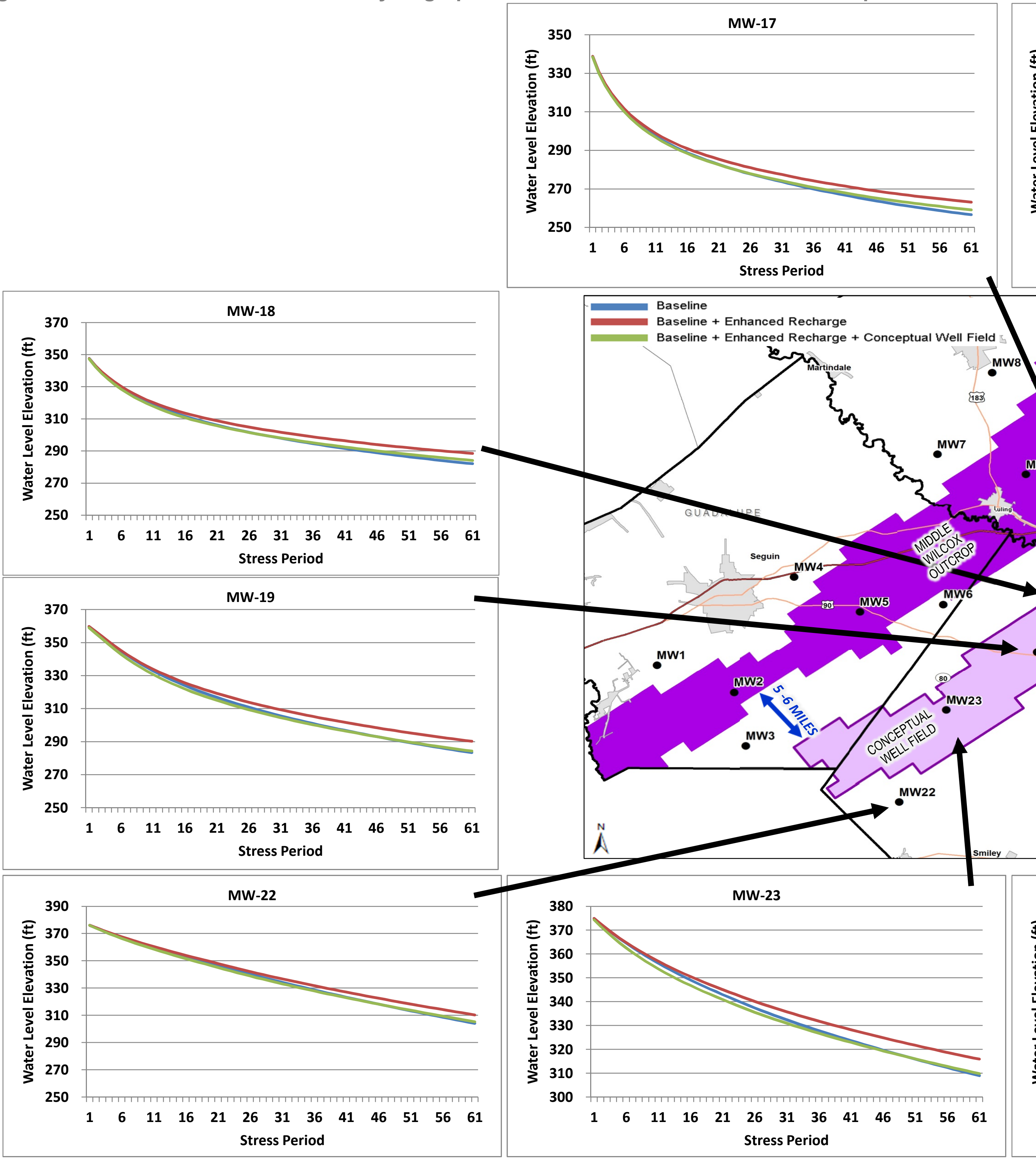
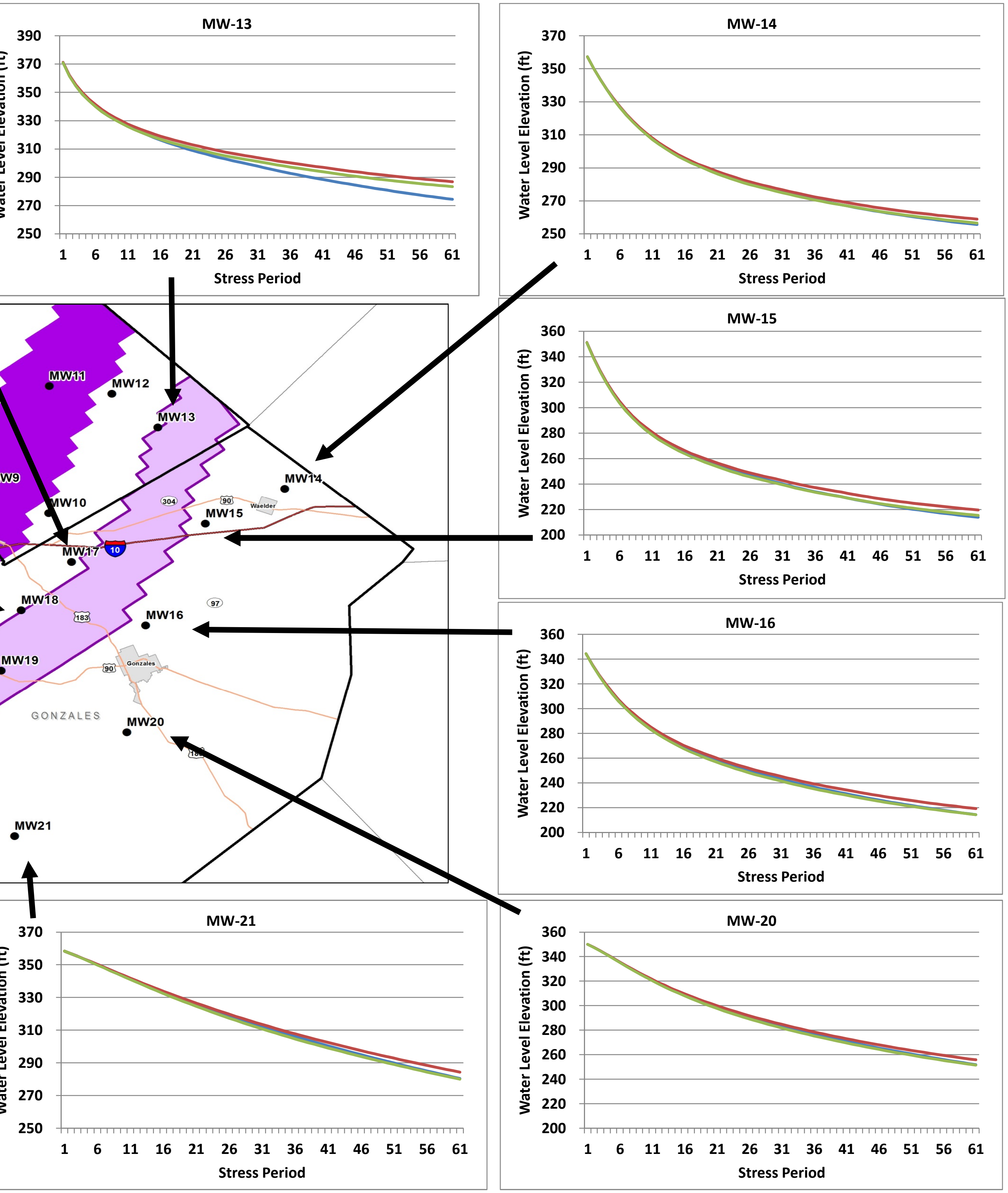

MW-11
Water Level Elevation (ft)
Stress Period
MW-12
Water Level Elevation (ft)
Stress Period
MW-10
Water Level Elevation (ft)
Stress Period
MW-9
Water Level Elevation (ft)
Stress Period
MW-6
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW20
GONZALES
Gonzales
Waelder
W21

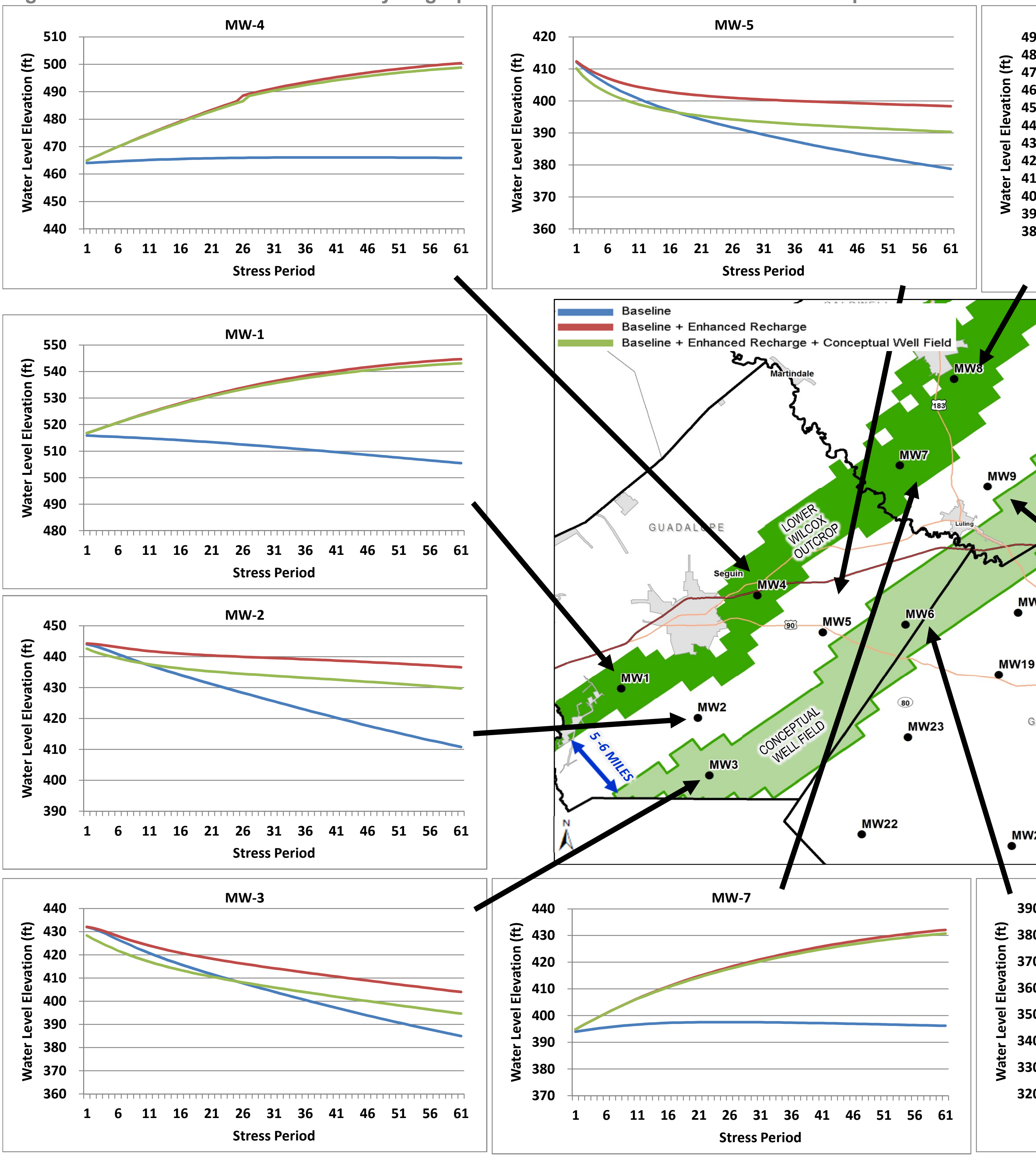
Figure 28a: Middle Wilcox Water Level Hydrographs for the 50 Percent Landowner Participation Scenario





MW-13
MW-14
MW-15
MW-16
MW-21
MW-20
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES

Figure 29: Lower Wilcox Water Level Hydrographs for the 30 Percent Landowner Participation Scenario



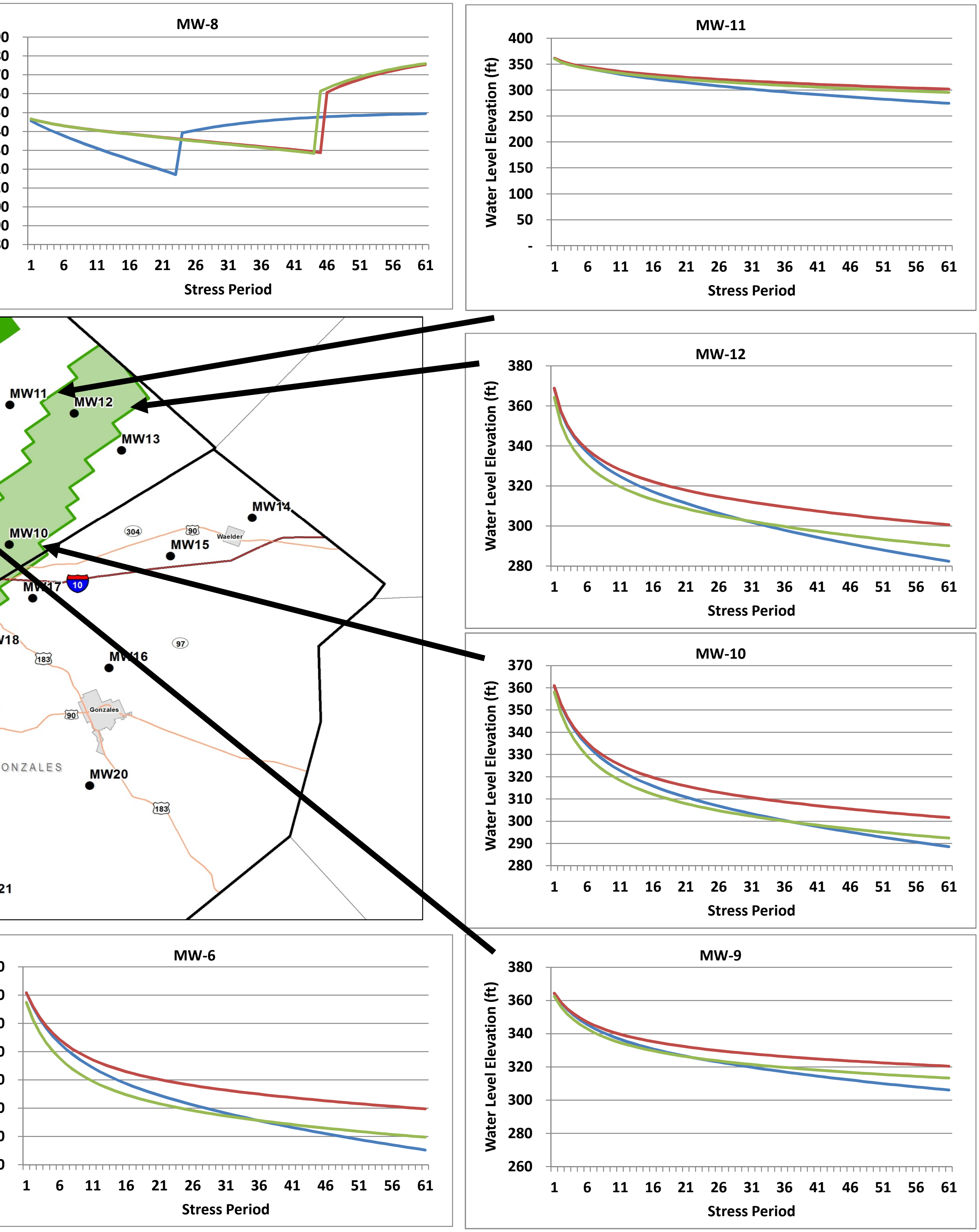
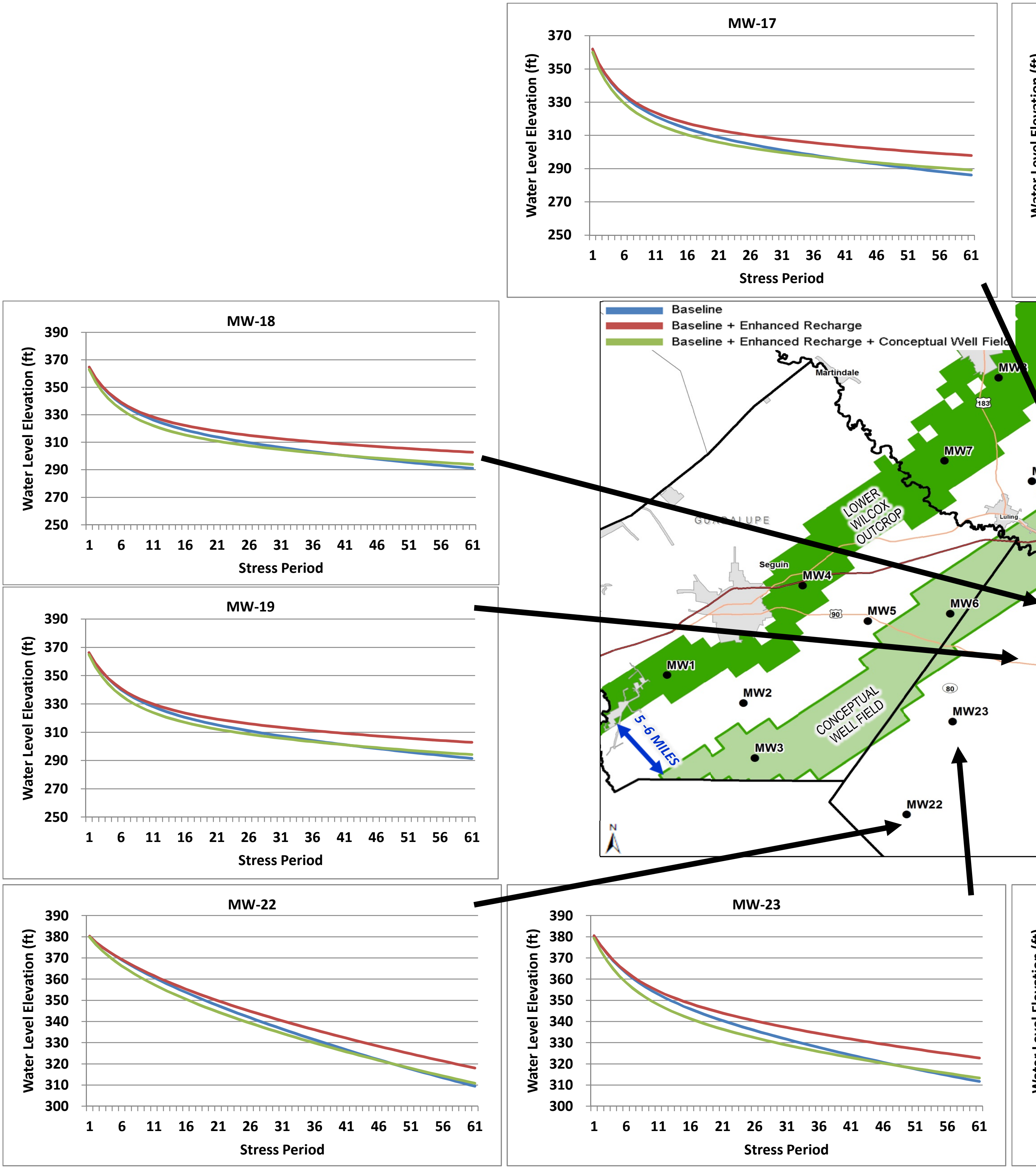

MW-8
1
6
11
16
21
26
31
36
41
46
51
56
61
Stress Period
MW-11
Water Level Elevation (ft)
400
350
300
250
200
150
100
50
-
Stress Period
MW-12
380
360
340
320
300
280
MW-10
370
360
350
340
330
320
310
300
290
280
MW-6
MW-9
260
MW11
MW12
MW13
MW14
MW10
MW15
Waelder
MW17
MW16
MW20
Gonzales
ONZALES
304
90
10
97
183

Figure 29a: Lower Wilcox Water Level Hydrographs for the 30 Percent Landowner Participation Scenario



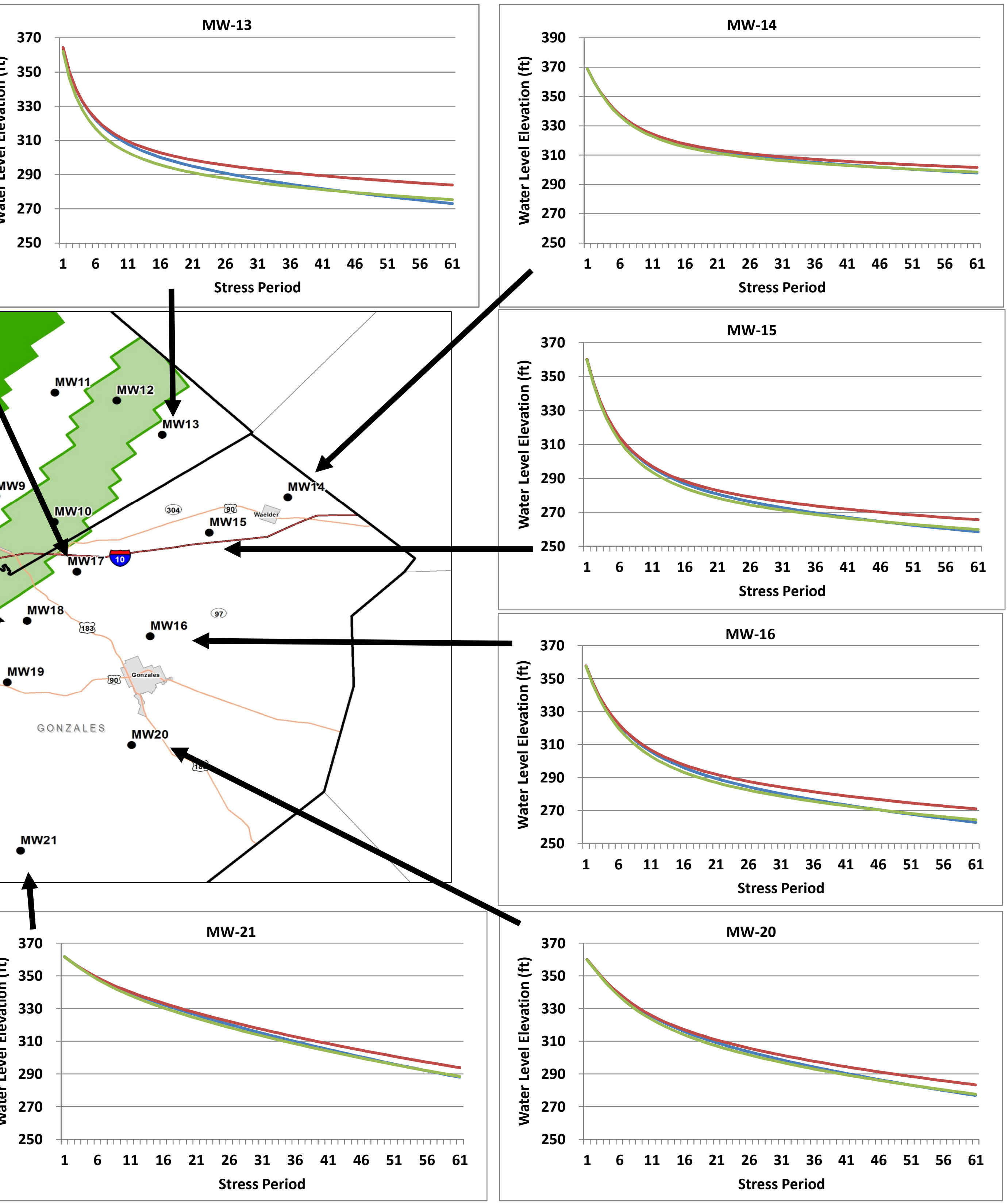

MW-13
MW-14
MW-15
MW-16
MW-20
MW-21
Water Level Elevation (ft)
Stress Period
1 6 11 16 21 26 31 36 41 46 51 56 61
250 270 290 310 330 350 370 390
MW11
MW12
MW13
MW9
MW10
MW14
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES
304
90
10
97
183

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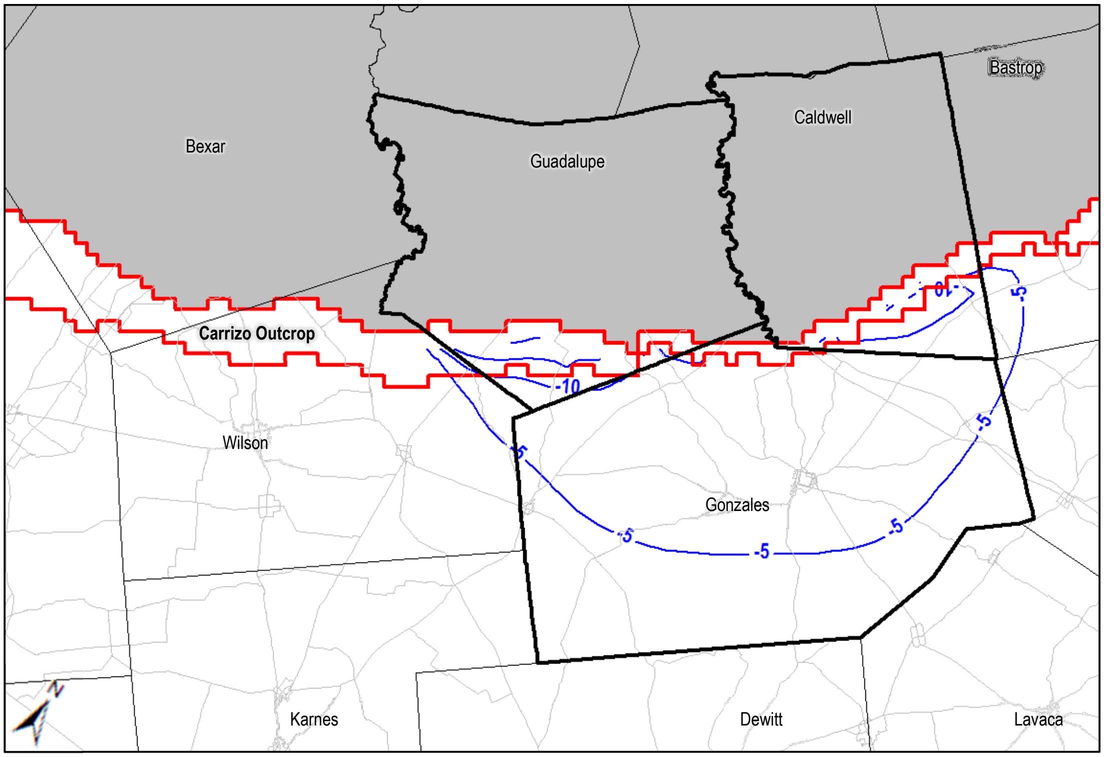
Figure 30. Rise in Water Levels from Baseline Conditions in the Carrizo Aquifer (Layer 5) for the 50 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

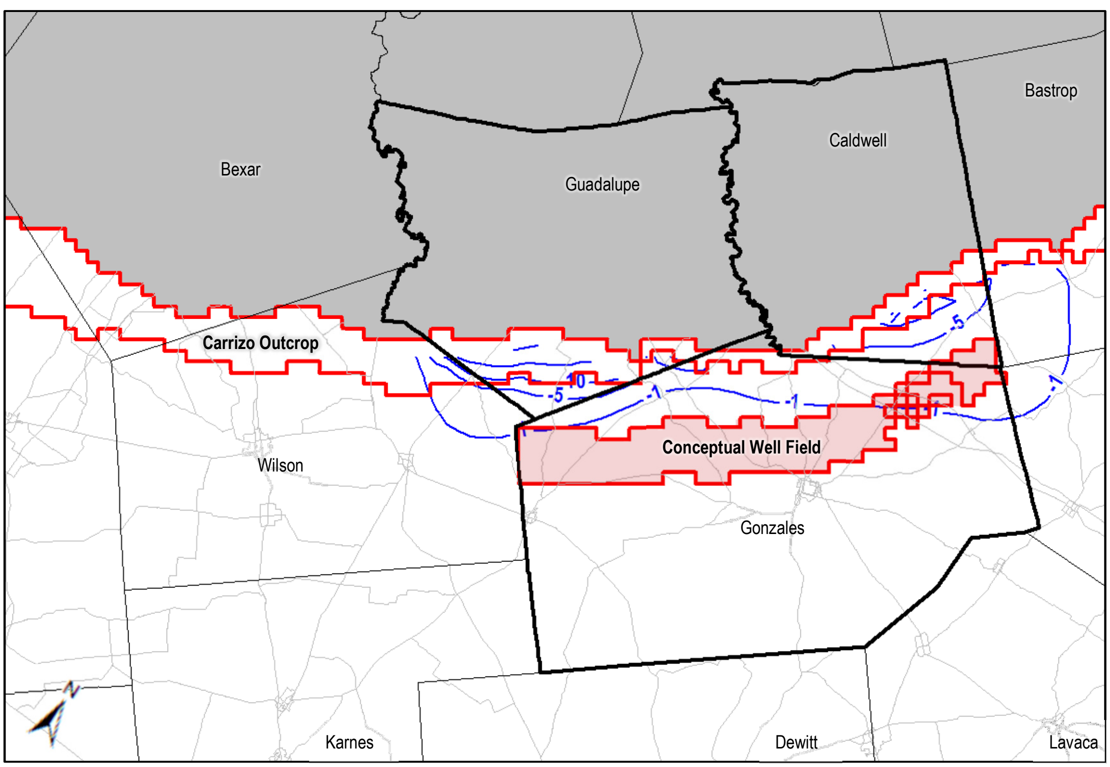
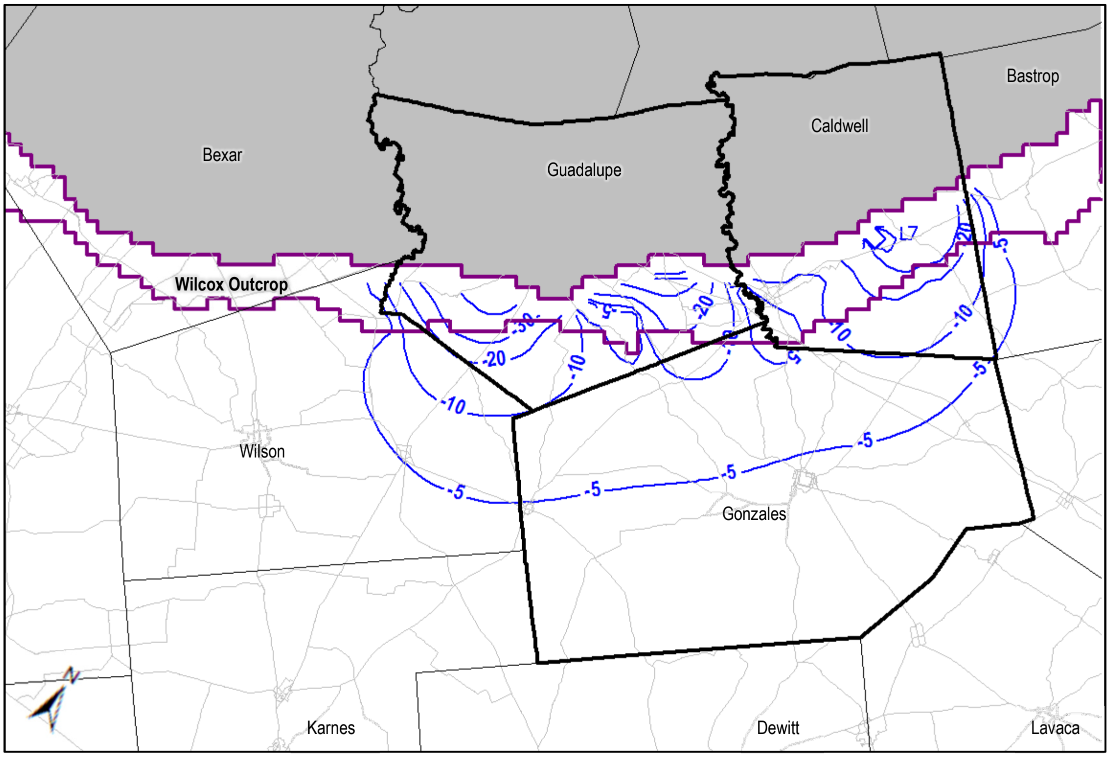


Figure 31. Rise in Water Levels from Baseline Conditions in the Middle Wilcox Aquifer (Layer 7) for the 50 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

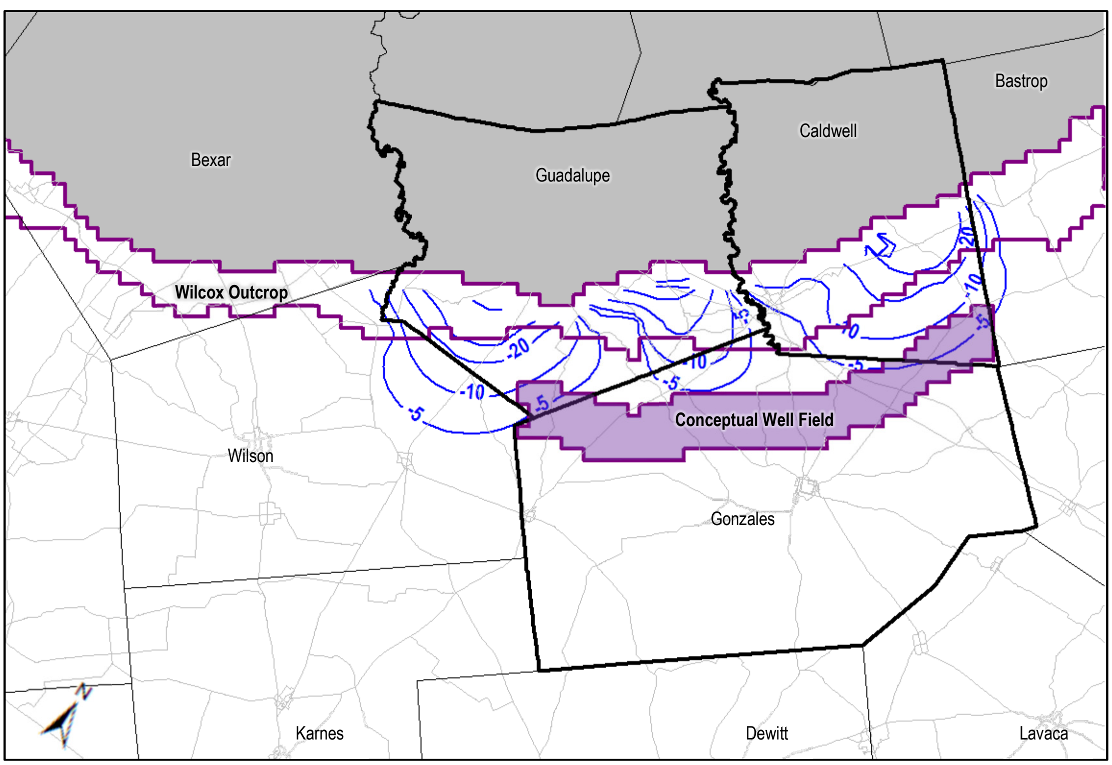
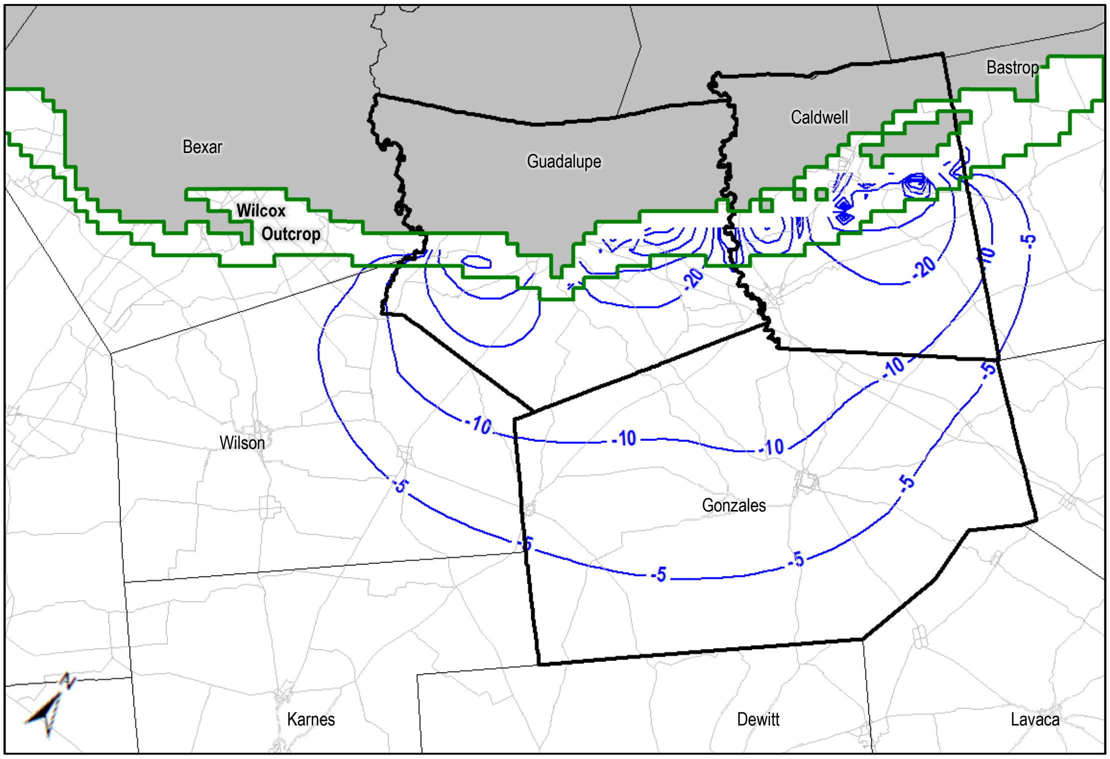


Figure 32. Rise in Water Levels from Baseline Conditions in Lower Wilcox Aquifer (Layer 8) for the 50 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

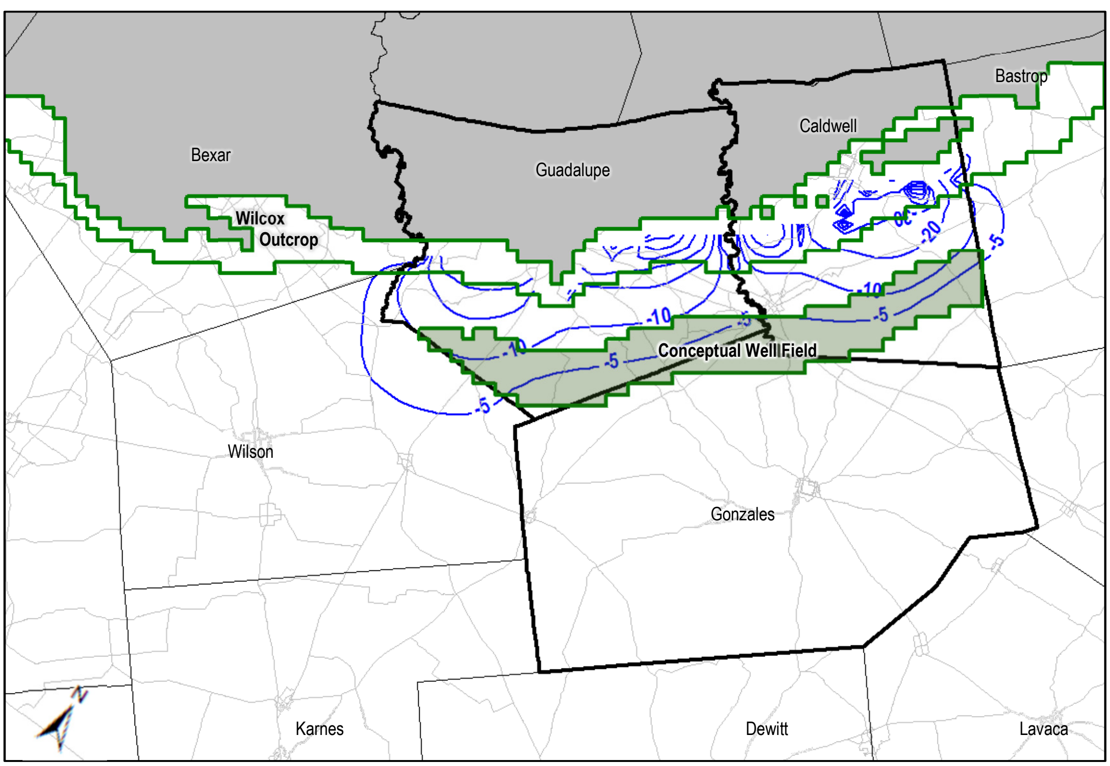
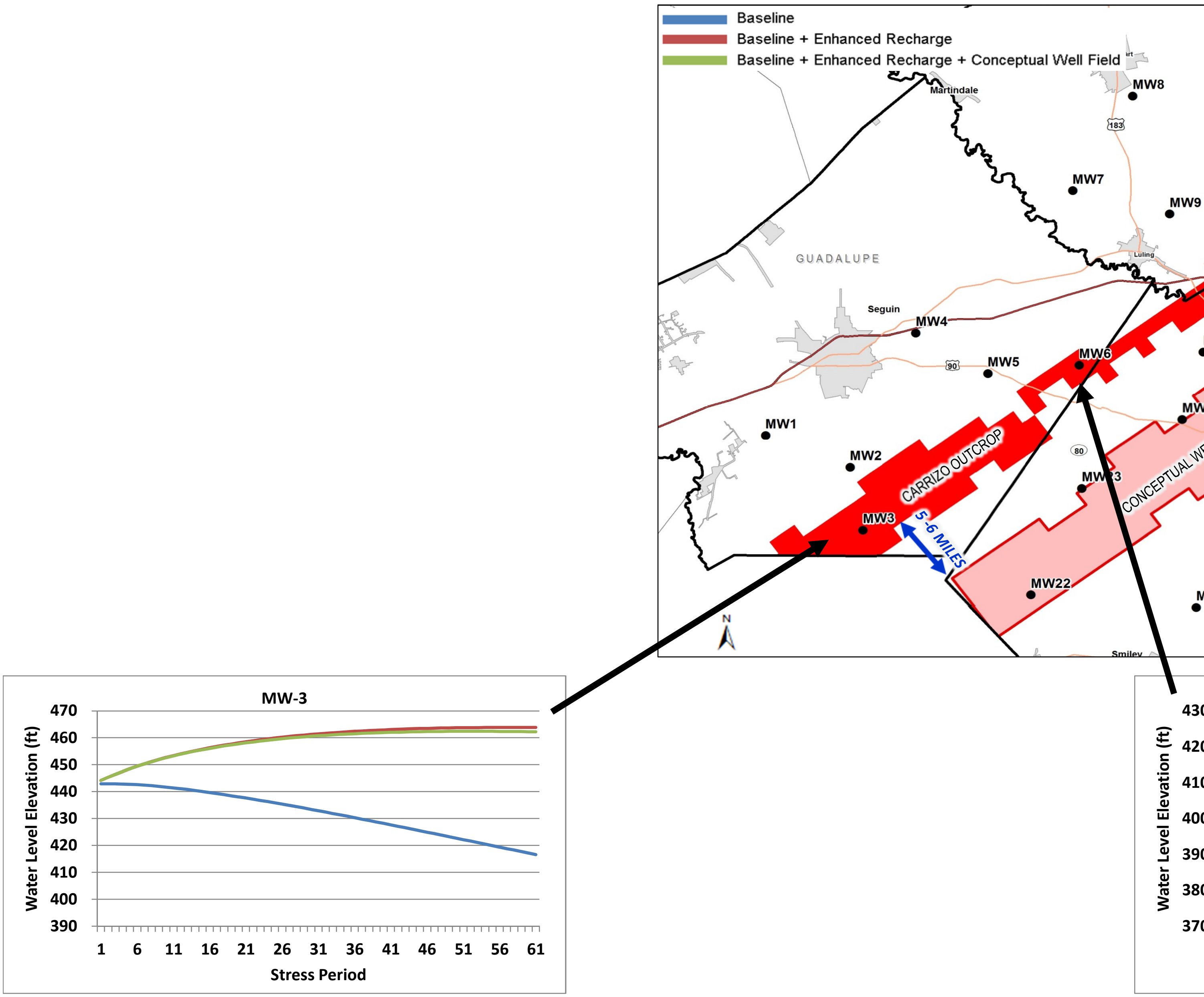


Figure 33: Carrizo Water Level Hydrographs for the 100 Percent Landowner Participation Scenario



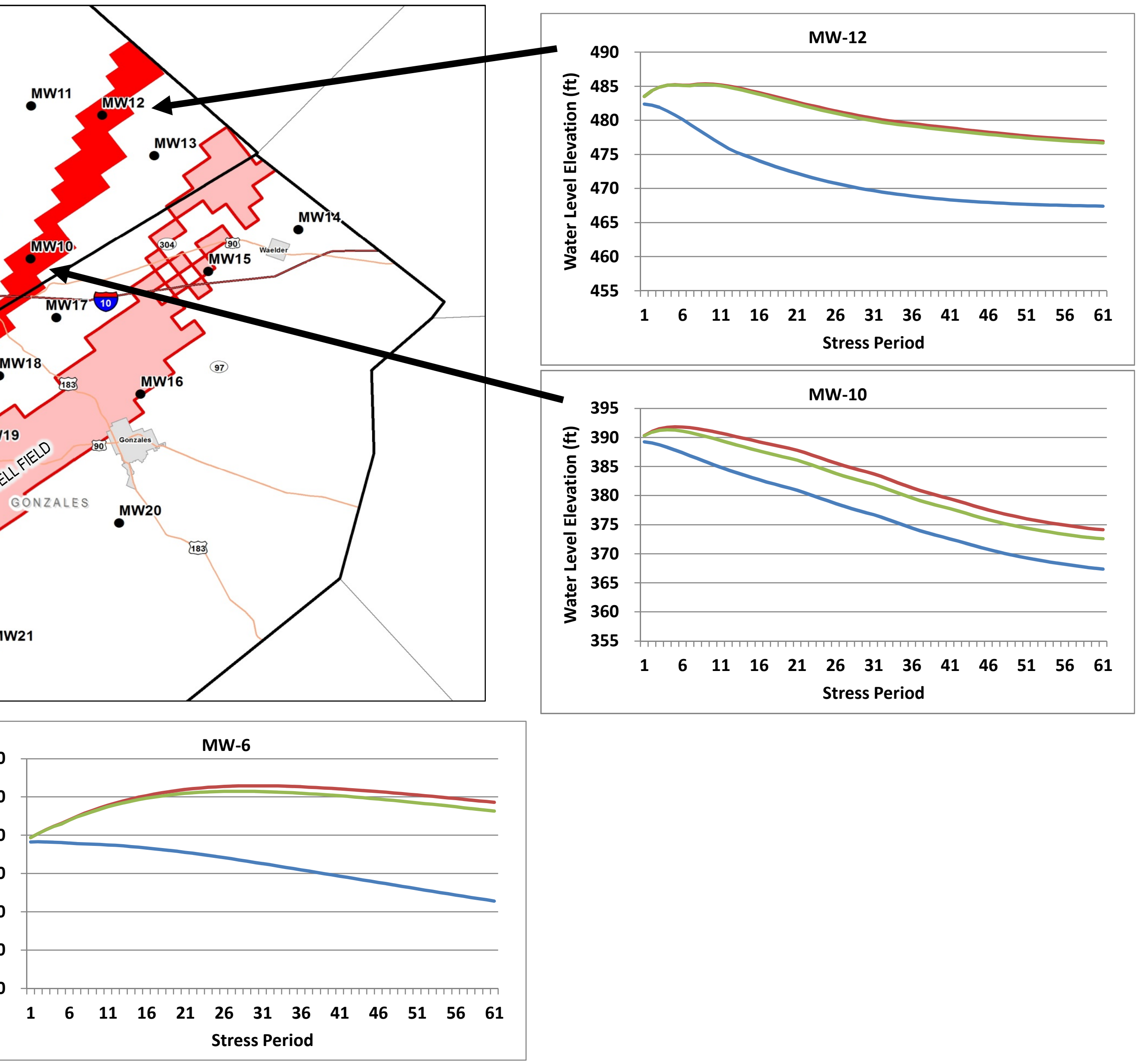
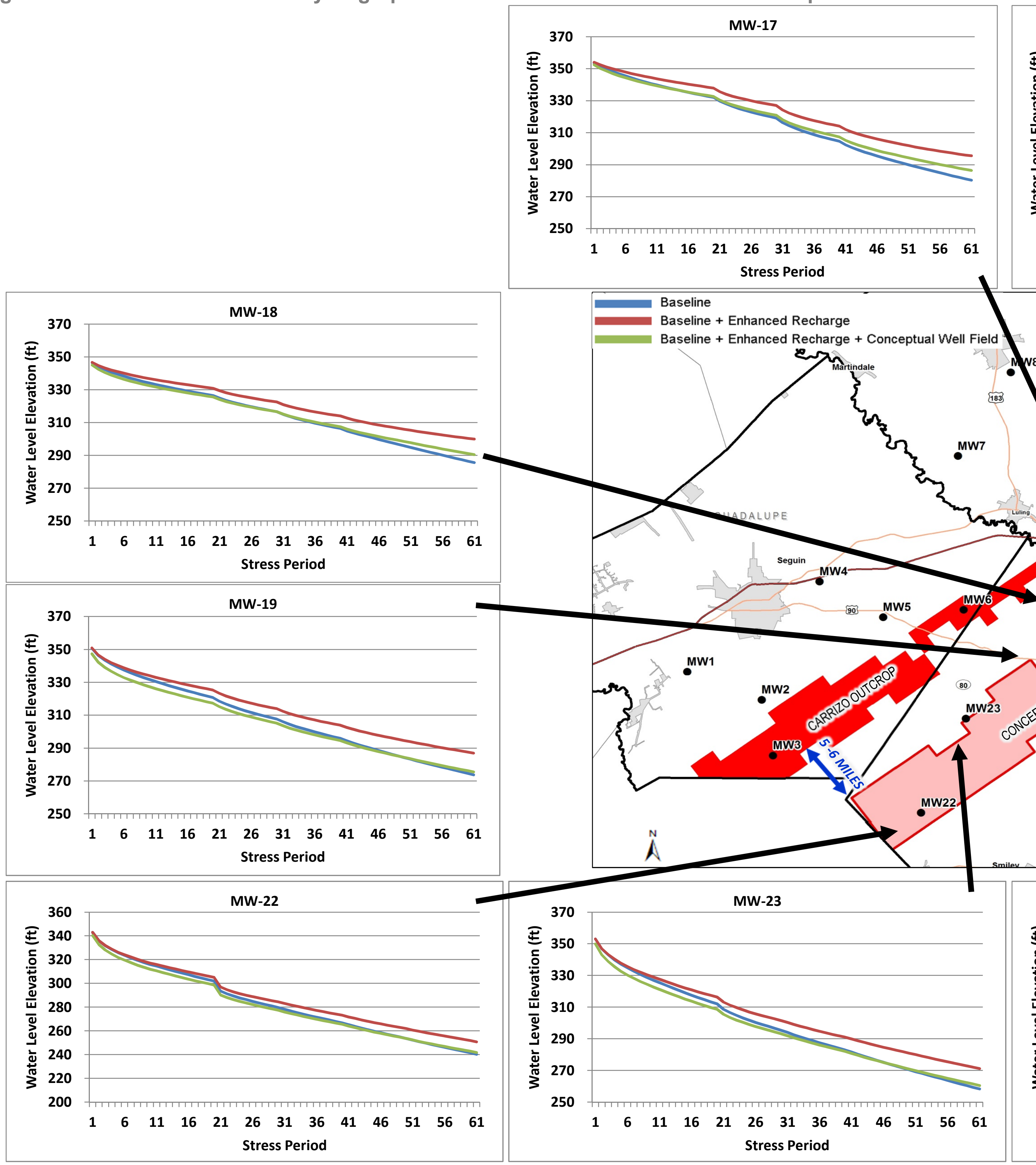

MW11
MW12
MW13
MW14
MW10
MW15
Waelder
MW17
MW18
MW16
Gonzales
GONZALES
MW20
IW21
MW-12
Water Level Elevation (ft)
490
485
480
475
470
465
460
455
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-10
Water Level Elevation (ft)
395
390
385
380
375
370
365
360
355
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-6
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period

Figure 33a: Carrizo Water Level Hydrographs for the 100 Percent Landowner Participation Scenario



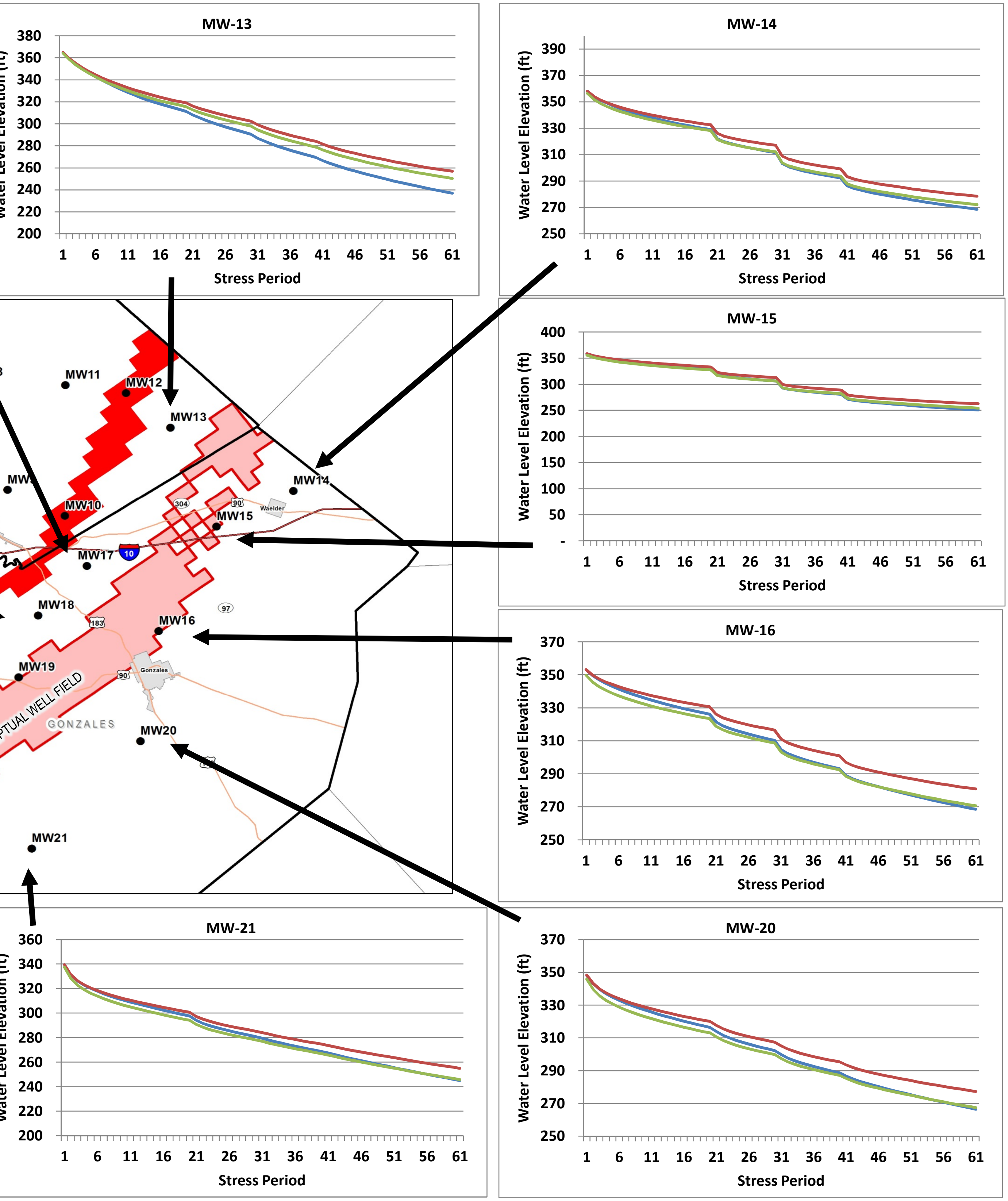
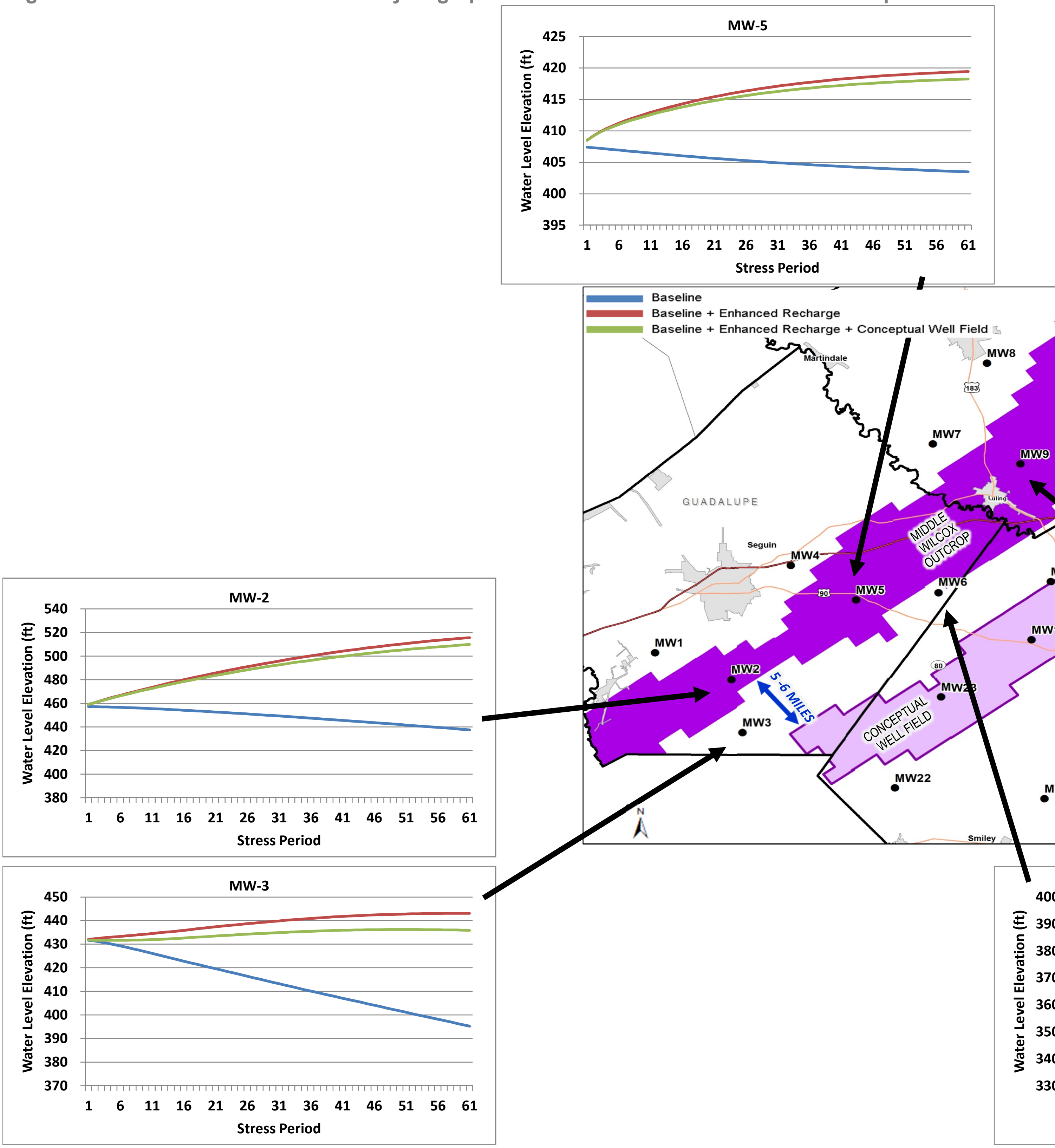

MW-13
Stress Period
MW-14
Water Level Elevation (ft)
Stress Period
MW-15
Water Level Elevation (ft)
Stress Period
MW-16
Water Level Elevation (ft)
Stress Period
MW-21
Stress Period
MW-20
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES
PTUAL WELL FIELD

Figure 34: Middle Wilcox Water Level Hydrographs for the 100 Percent Landowner Participation Scenario



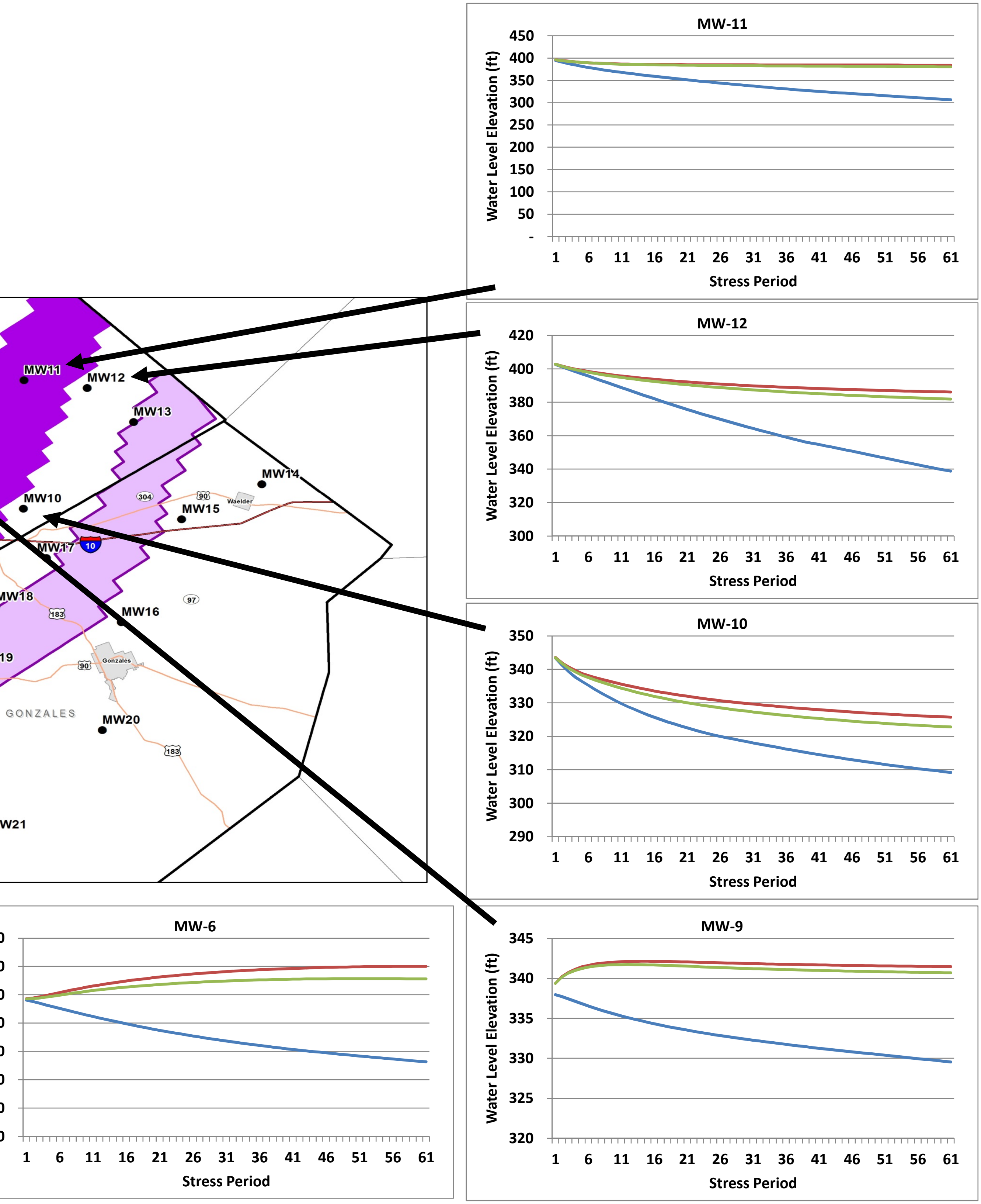
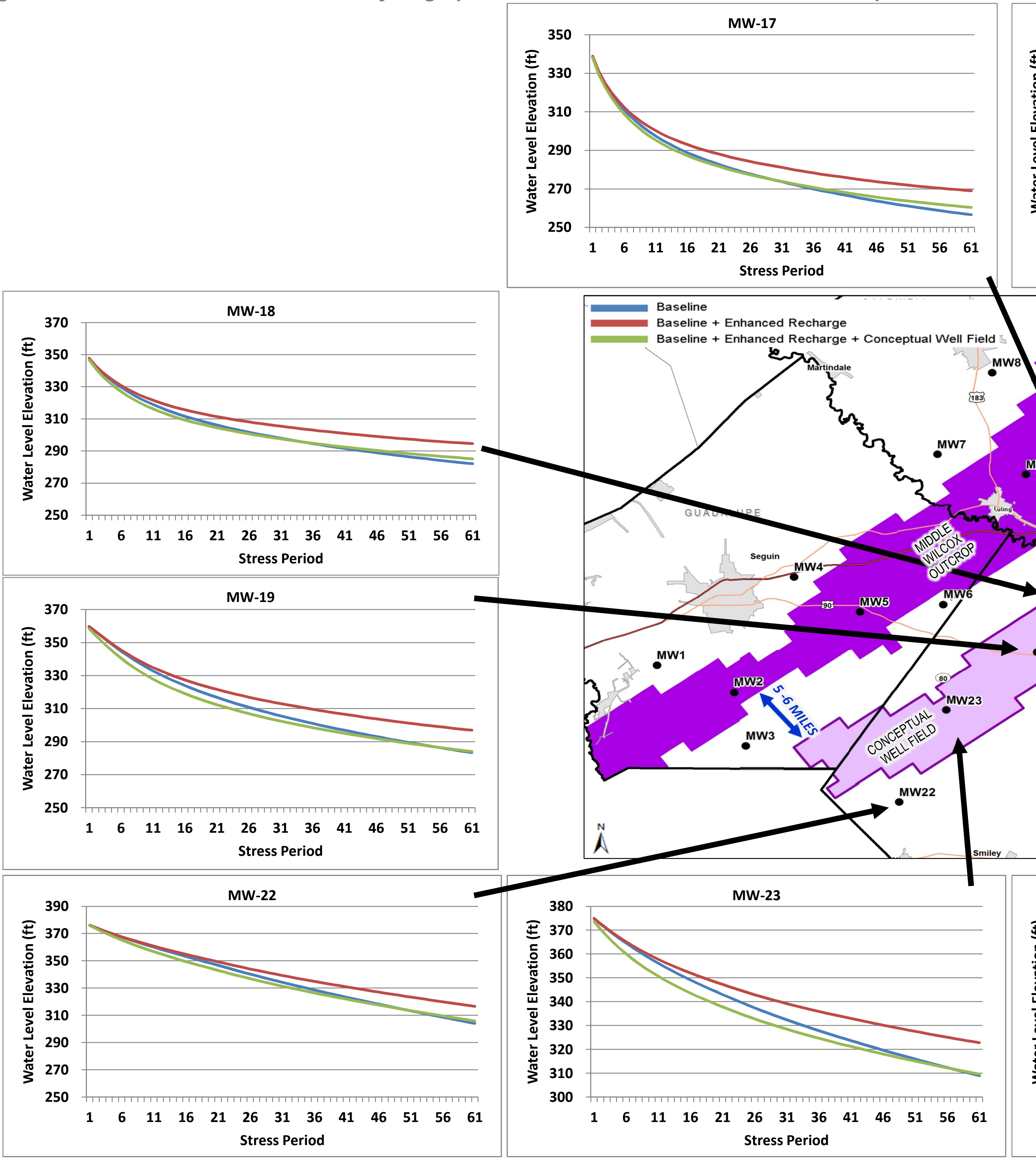

MW-11
Water Level Elevation (ft)
450
400
350
300
250
200
150
100
50
-
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-12
Water Level Elevation (ft)
420
400
380
360
340
320
300
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-10
Water Level Elevation (ft)
350
340
330
320
310
300
290
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-9
Water Level Elevation (ft)
345
340
335
330
325
320
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-6
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
MW17
MW18
MW16
19
GONZALES
MW20
W21
Waelder
Gonzales
10
90
304
97
183

Figure 34a: Middle Wilcox Water Level Hydrographs for the 100 Percent Landowner Participation Scenario



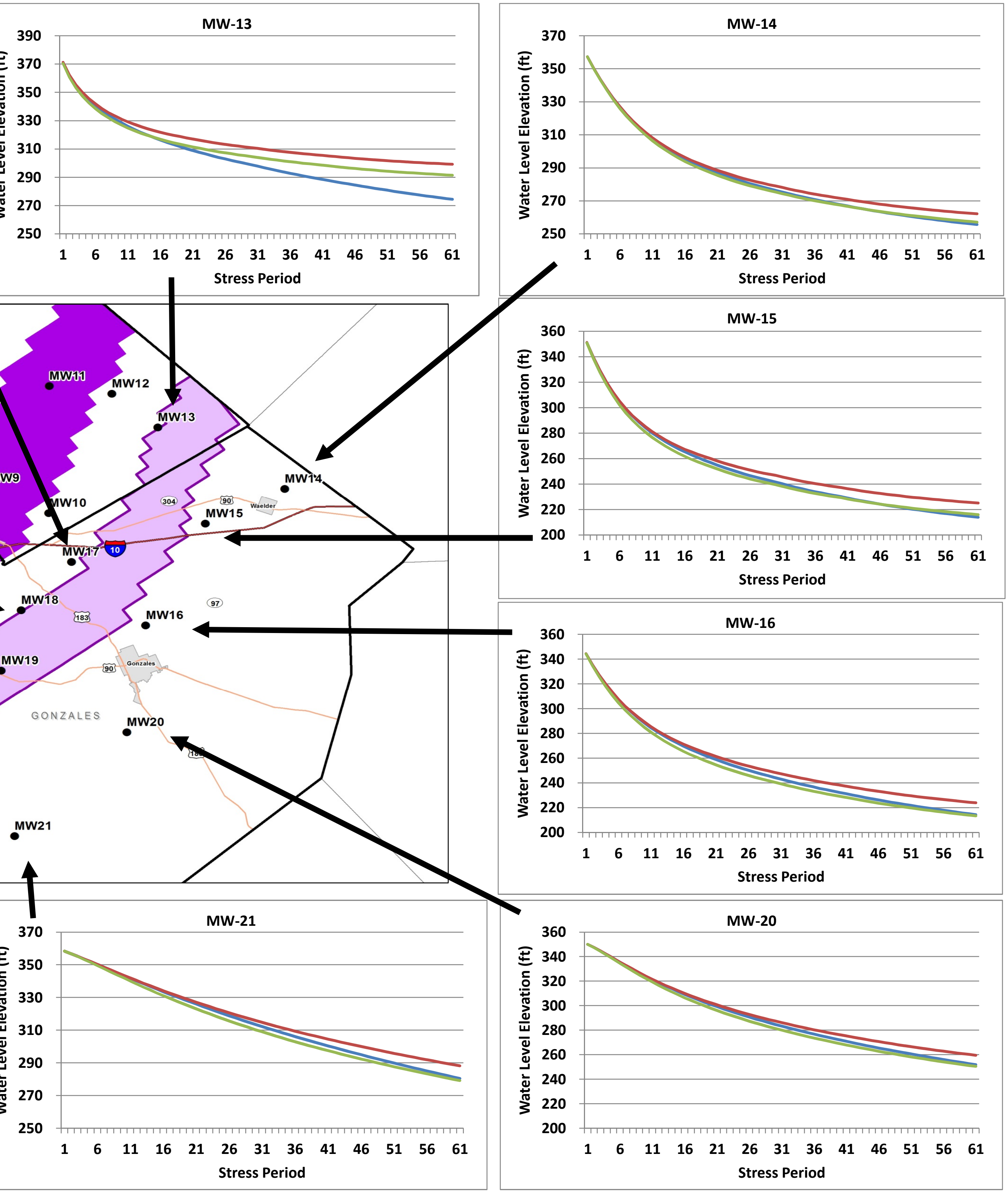
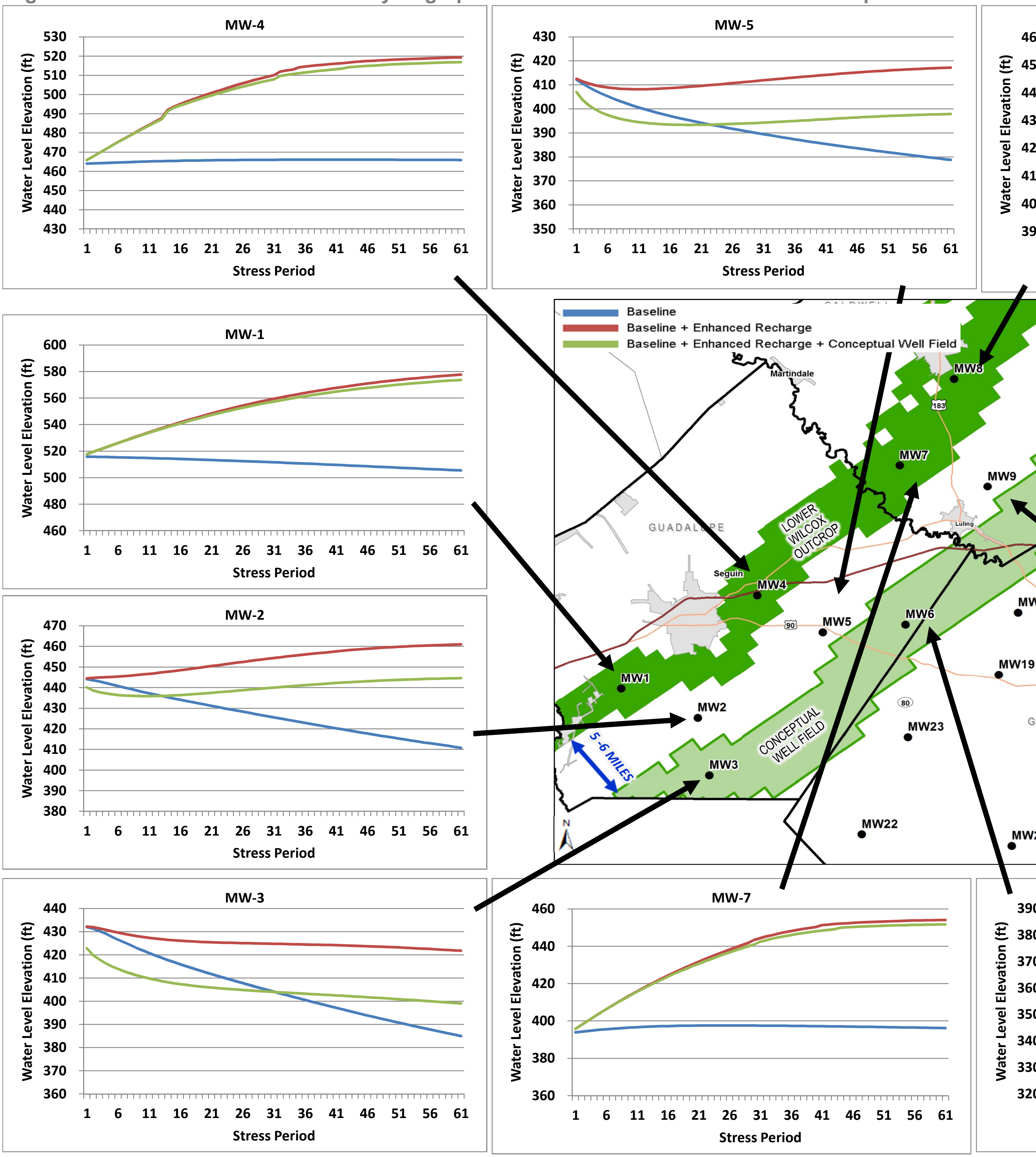

MW-13
Water Level Elevation (ft)
Stress Period
MW-14
Water Level Elevation (ft)
Stress Period
MW-15
Water Level Elevation (ft)
Stress Period
MW-16
Water Level Elevation (ft)
Stress Period
MW-20
Water Level Elevation (ft)
Stress Period
MW-21
Water Level Elevation (ft)
Stress Period
MW11
MW12
MW13
W9
MW10
MW14
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES
304
90
10
97
183

Figure 35: Lower Wilcox Water Level Hydrographs for the 100 Percent Landwoner Participation Scenario



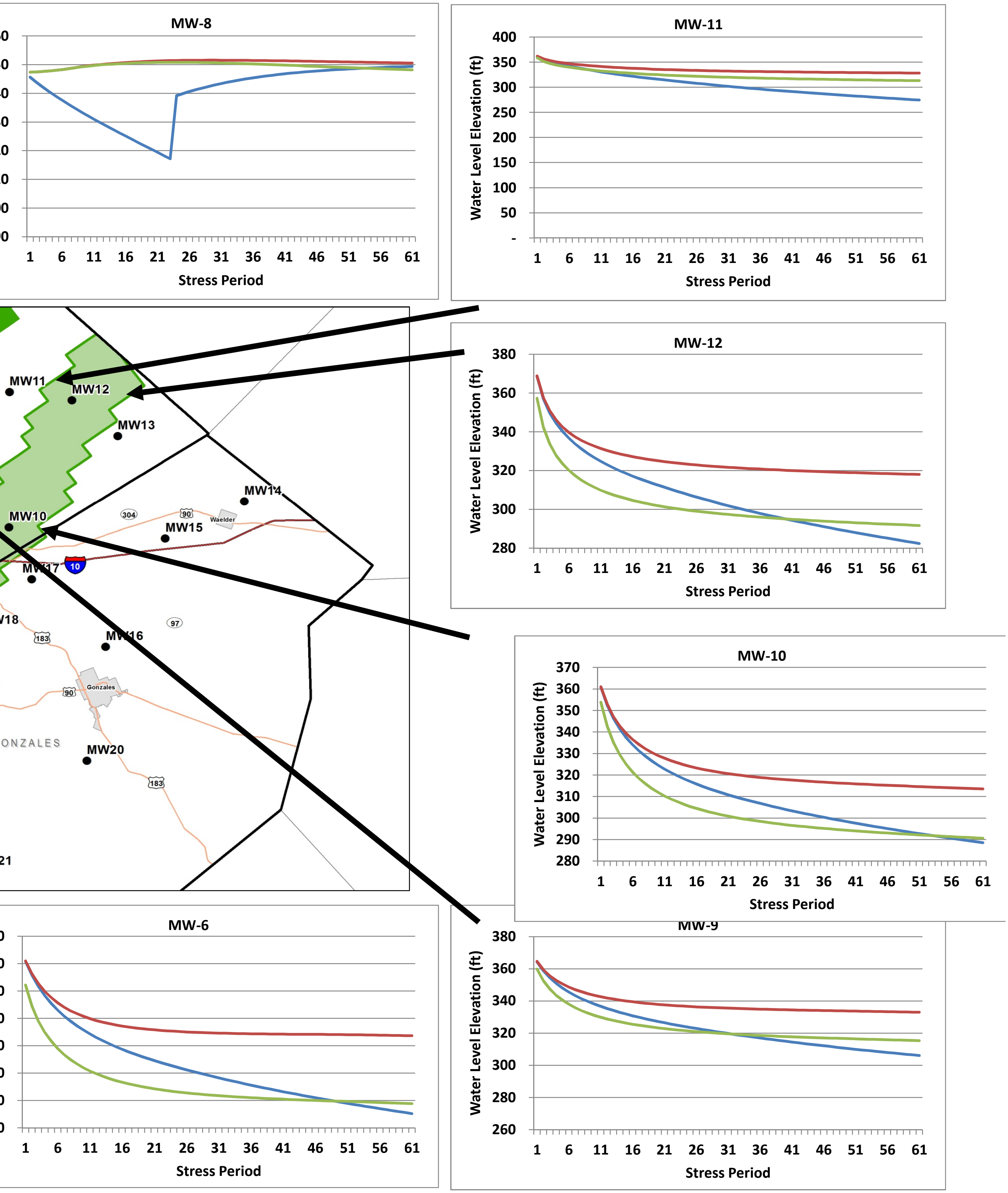
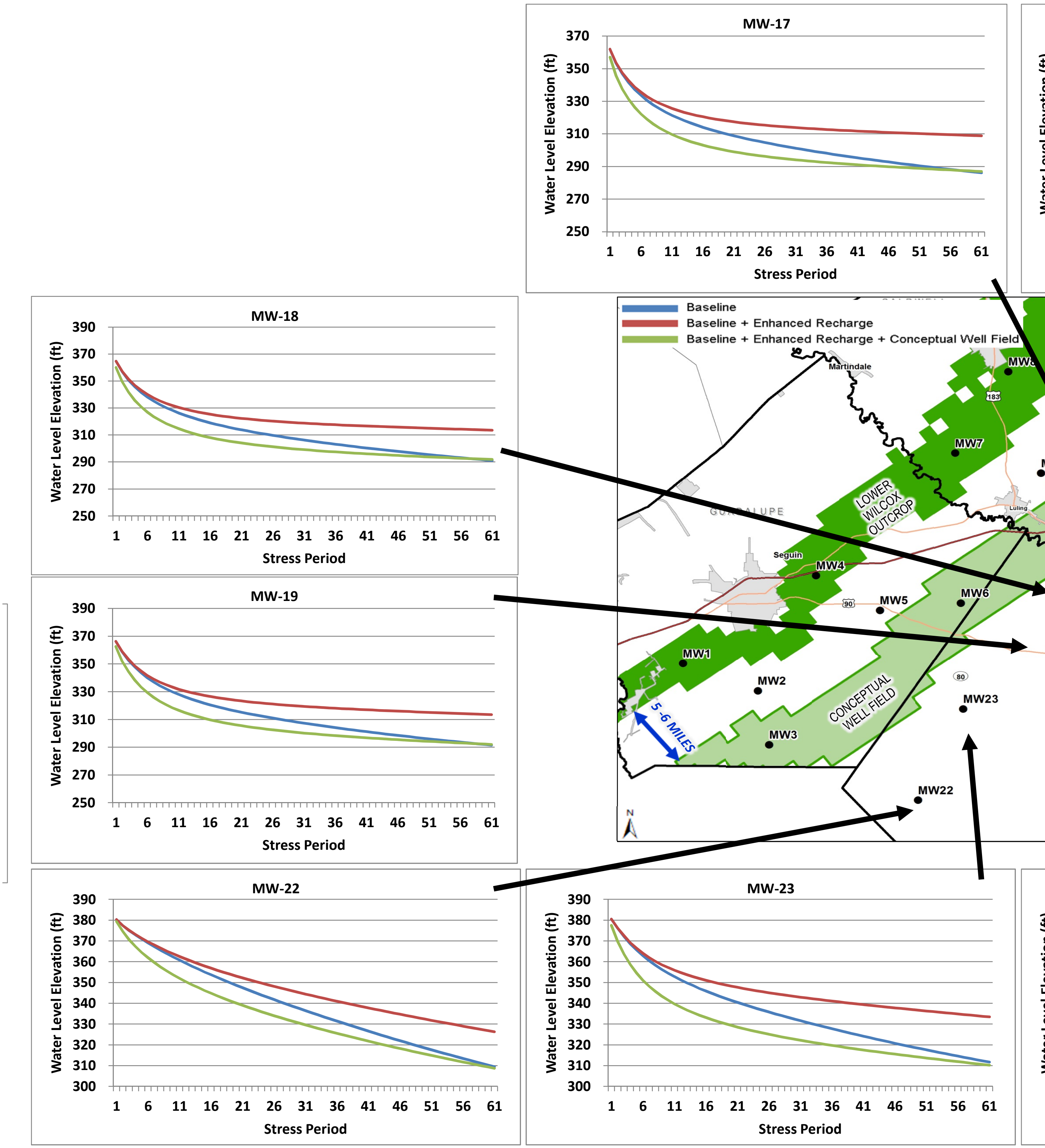

MW-8
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-11
400 350 300 250 200 150 100 50 -
Water Level Elevation (ft)
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-12
380 360 340 320 300 280
Water Level Elevation (ft)
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW11
MW12
MW13
MW14
MW10
MW15
Waelder
MW16
MW20
Gonzales
ONZALES
MW-10
370 360 350 340 330 320 310 300 290 280
Water Level Elevation (ft)
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-6
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period
MW-9
380 360 340 320 300 280 260
Water Level Elevation (ft)
1 6 11 16 21 26 31 36 41 46 51 56 61
Stress Period

Figure 35a: Lower Wilcox Water Level Hydrographs for the 100 Percent Landwoner Participation Scenario



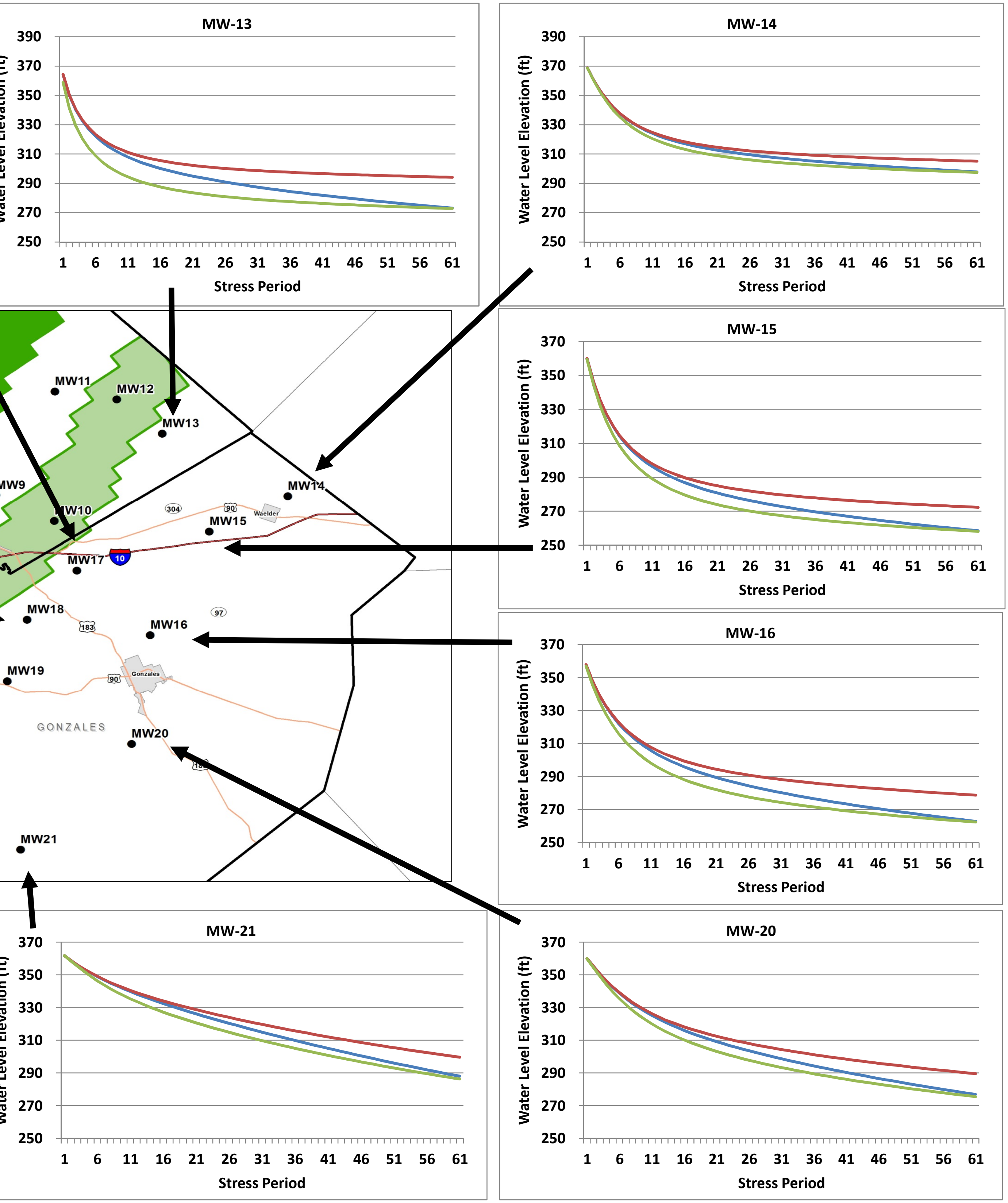

MW-13
MW-14
MW-15
MW-16
MW-21
MW-20
Water Level Elevation (ft)
Stress Period
390
370
350
330
310
290
270
250
1 6 11 16 21 26 31 36 41 46 51 56 61
MW11
MW12
MW13
MW9
MW10
MW14
MW15
MW17
MW18
MW16
MW19
MW20
MW21
Waelder
Gonzales
GONZALES
304
90
10
97
183

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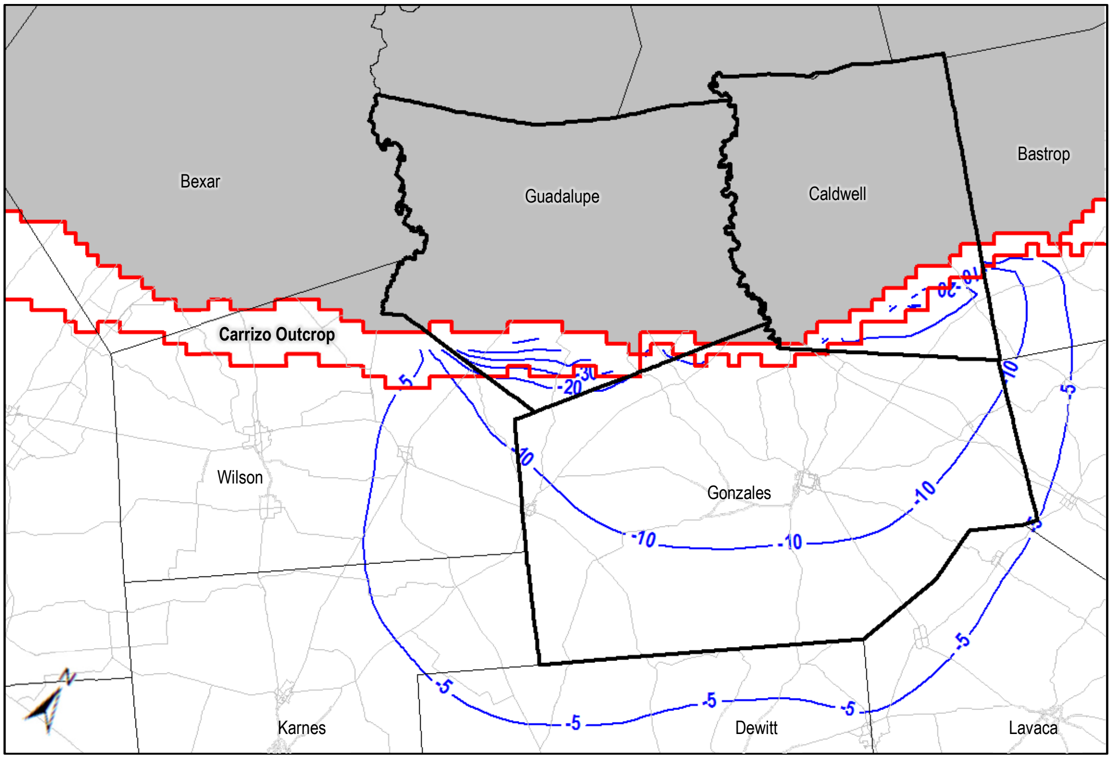
Figure 36. Rise in Water Levels from Baseline Conditions in the Carrizo Aquifer (Layer 5) for the 100 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

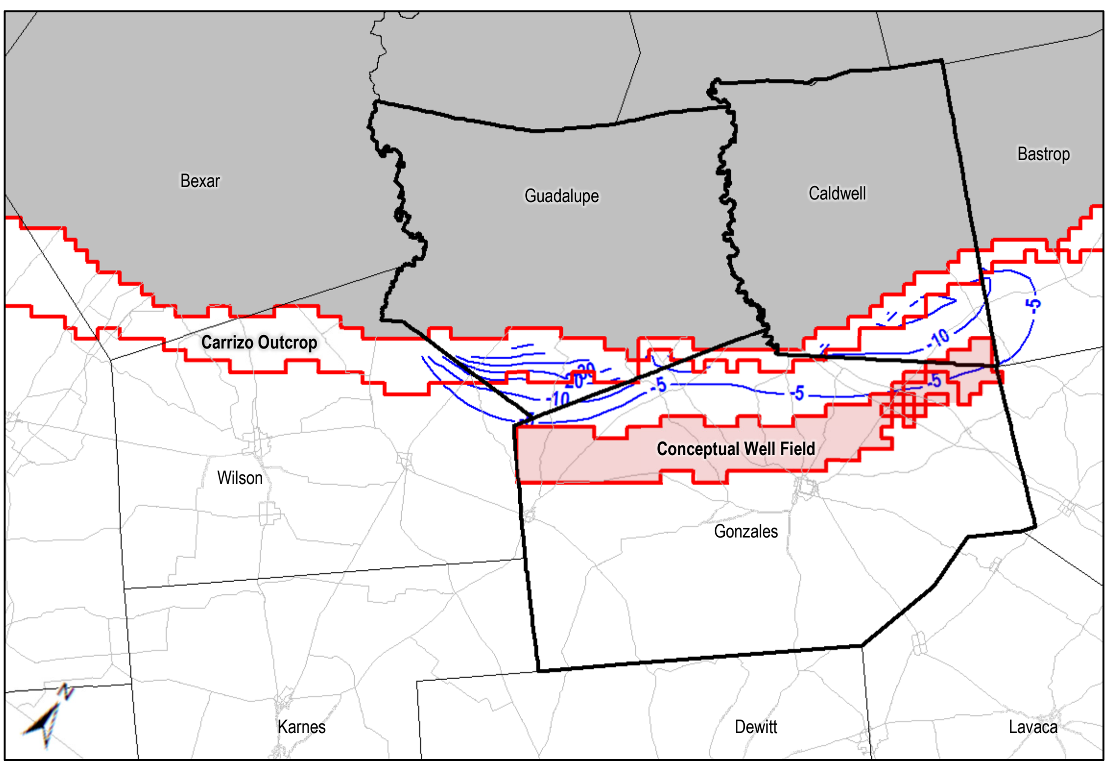
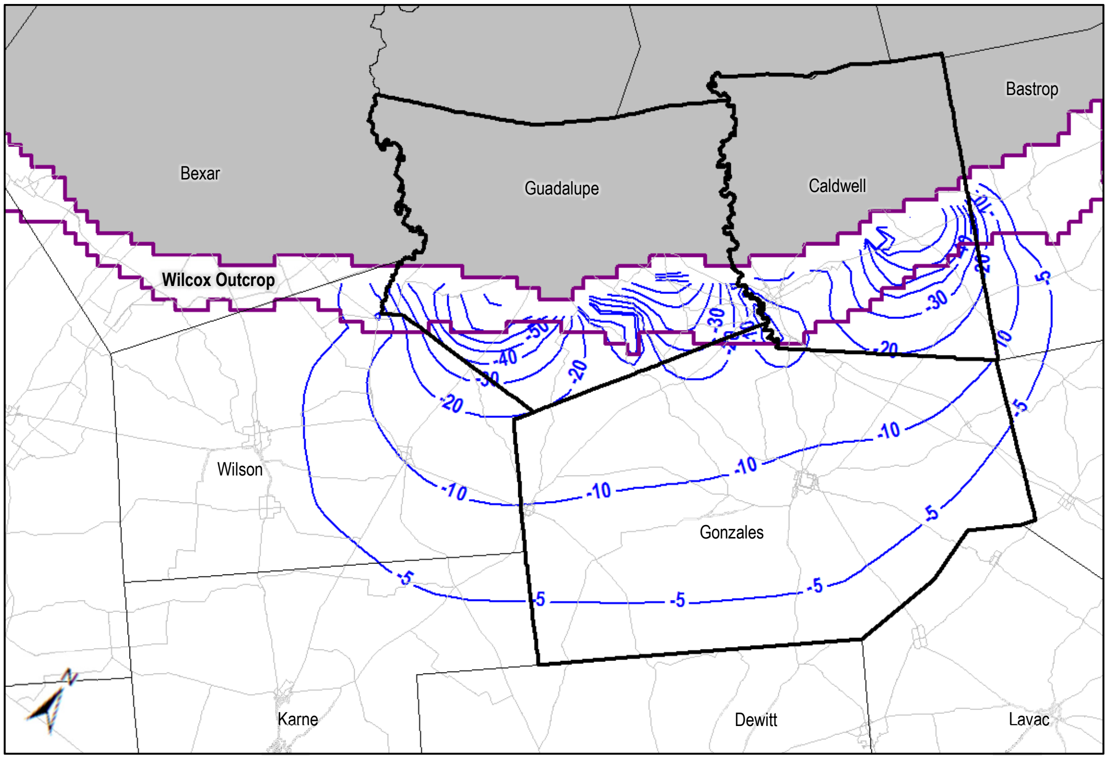


Figure 37. Rise in Water Levels from Baseline Conditions in the Middle Wilcox Aquifer (Layer 7) for the 100 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

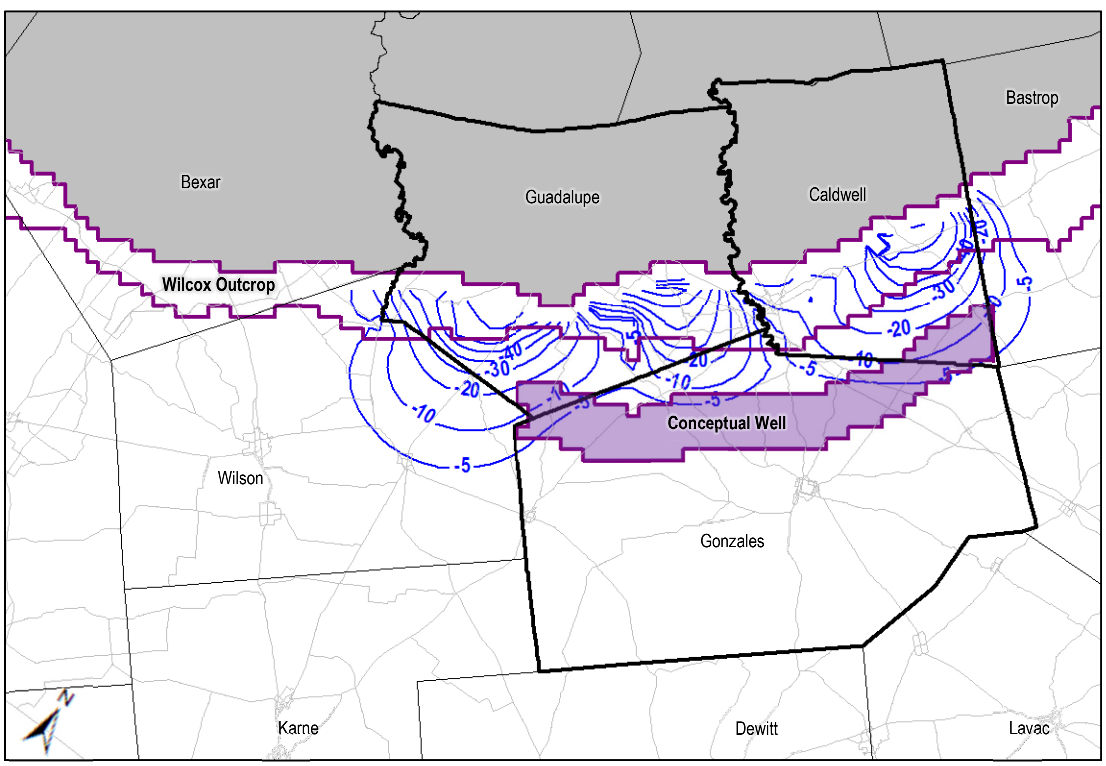
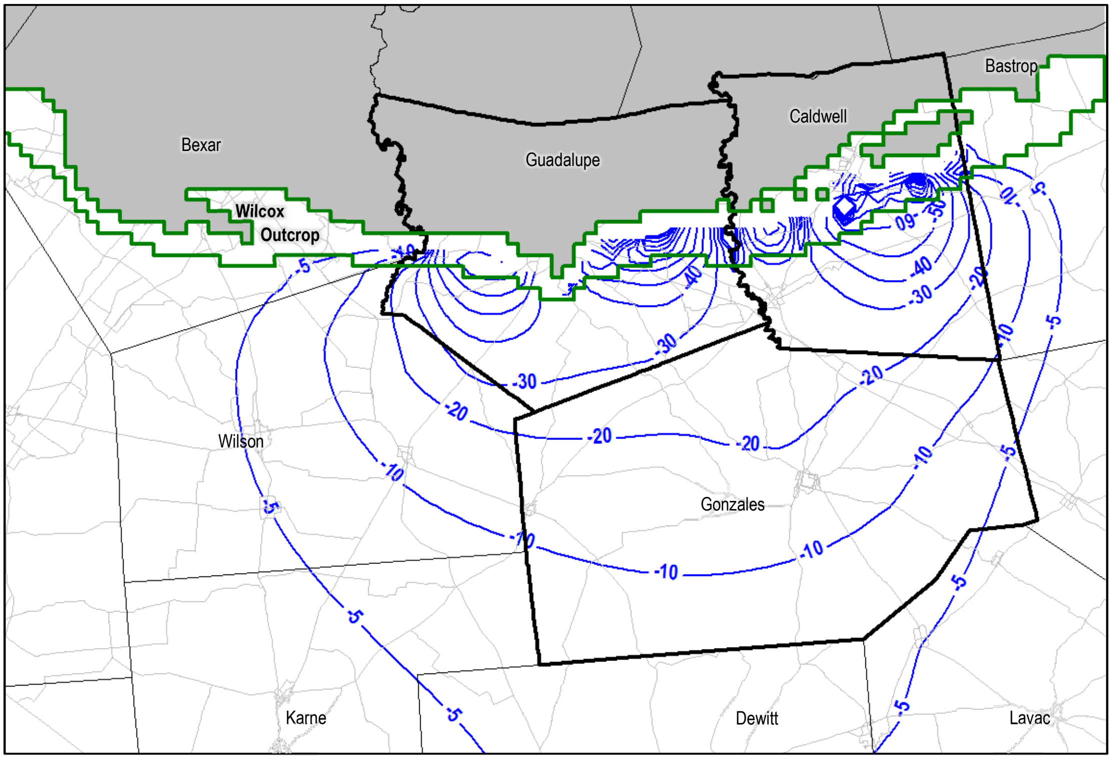


Figure 38. Rise in Water Levels from Baseline Conditions in Lower Wilcox Aquifer (Layer 8) for the 100 Percent Landowner Participation Scenario in Stress Period 61

a. After Enhanced Recharge is Added



b. After the Conceptual Well Field is Turned-On

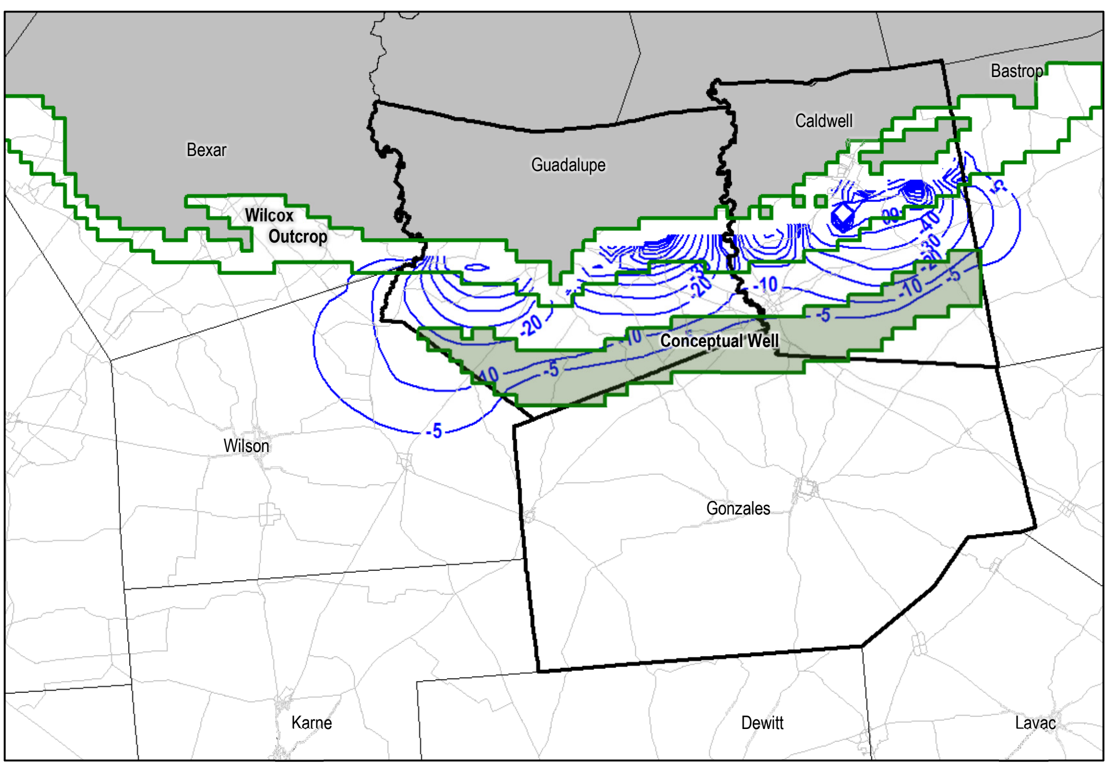


Figure 39. Comparison of Enhanced Recharge Added to the Model and Resulting Enhanced MAG (acft/yr)

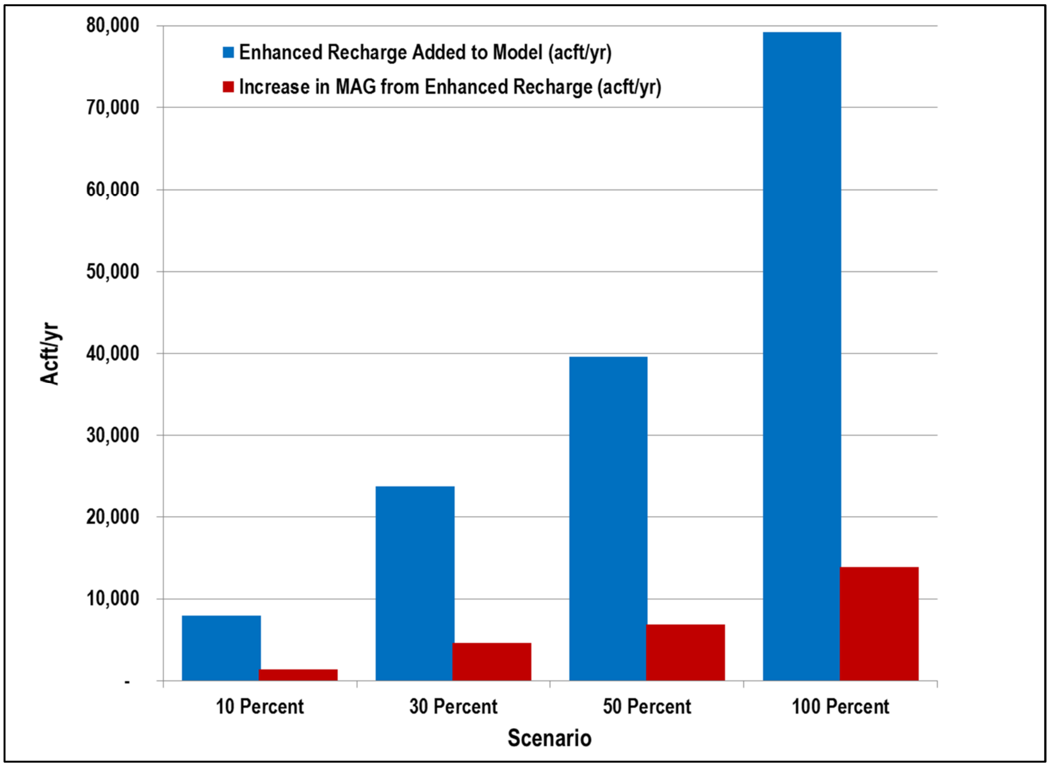
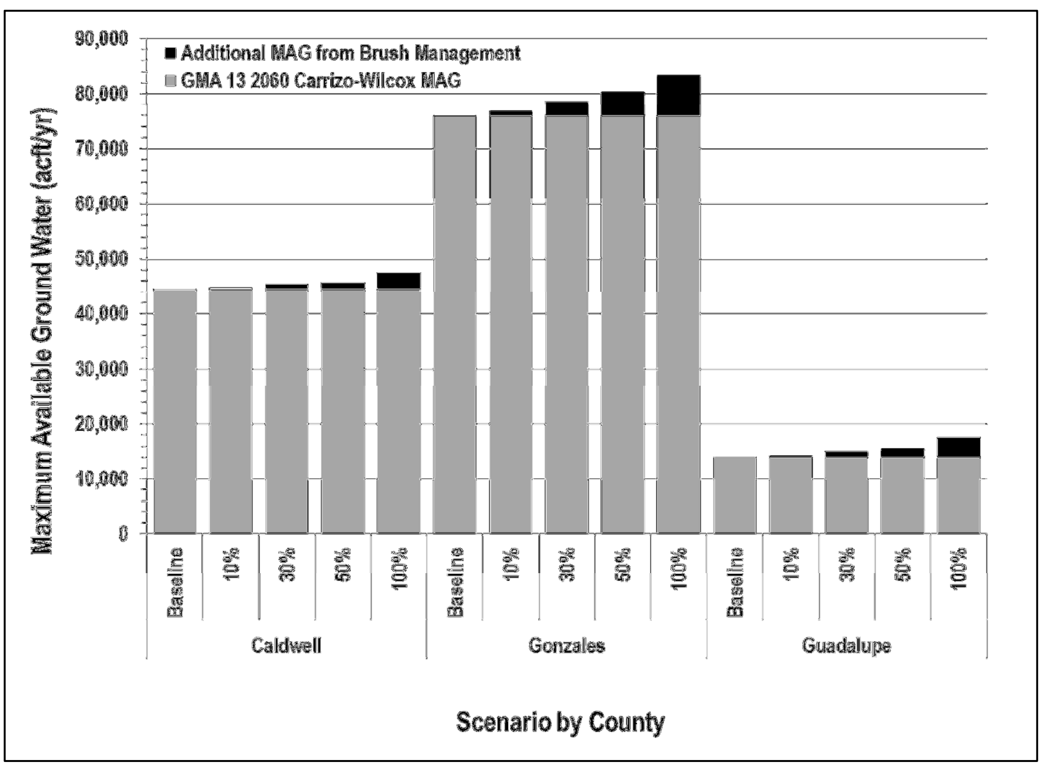


Figure 40. 2060 MAG and Increase in MAG by Landowner Participation Level and County



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