Economic Impacts of Groundwater Management Standards

In the Panhandle Groundwater Conservation District of Texas

Final Report

Submitted February 28, 2012

Photo Courtesy of Allison Purviance, PGCD

Prepared by:

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EXECUTIVE SUMMARY

The Ogallala Aquifer serves as the primary source of irrigation water for agricultural production throughout the Texas Panhandle. With current pumping rates exceeding the natural recharge of the aquifer, the state of Texas has passed legislation in an attempt to conserve water from the Ogallala Aquifer for future generations. In 1998 the Panhandle Groundwater Conservation District (PGCD) implemented 50 year management goals to ensure that at least 50% of the current water supply will be available in 50 years, more commonly referred to as the 50/50 management standard.

The objective of this study was to conduct an economic analysis of how the 50/50 management standard would impact irrigated producers in the region and the overall agricultural economy. Specifically this analysis was conducted on three levels: county, hydrologic area, and representative farm. The study focused on the dynamic changes in agricultural production, saturated thickness, farm revenue, and the capacity to irrigate. A socioeconomic model was subsequently used to estimate changes in the regional economy due to changes in gross farm income that may occur under the 50/50 management standard.

Task results indicate that the 50/50 management standard will not have significant aggregate impacts on the county, hydrologic study area, or farm level analyses. Thus, there were no estimated socioeconomic impacts to the regional economy (industry output, income, and employment). However, in the case of the Donley County High Drawdown Farm which represented an extreme case of drawdown in saturated thickness, the analysis did indicate a decline in the present value of net returns of $350 per acre over a fifty year period. This value represents the loss in total net returns per acre over the 50 year planning horizon discounted to present day values in comparison to a status quo scenario where no 50/50 management plan was implemented.

The overall results of this study indicate that economic impacts of the 50/50 management standard to agriculture at the county, hydrologic area, or representative farm level were insignificant. However, areas of extremely high decline in saturated thickness, such as in the Donley County High Drawdown Farm scenario, could be impacted by such standards and should be monitored closely. The 50/50 management standard as currently designed allows for continued irrigated agricultural production and economic activity to occur in the region while addressing water supply concerns.

I. INTRODUCTION

Agricultural producers within the Panhandle Groundwater Conservation District (PGCD) rely on the Ogallala Aquifer as their primary source of water for irrigated crop production. However, the sustainability of this irrigated production is a concern due to current withdrawals of water from the aquifer exceeding the recharge which could lead to the depletion of the water resource.

Recent developments in Texas water planning efforts began with the passage of Senate Bill 1 (SB1) in 1997 which put in place a regional water planning process that has evolved toward comprehensive groundwater management. This process was further developed with the passage of SB2 in 2001 and HB 1763 in 2005 by the Texas Legislature. This legislative process dictated that Desired Future Conditions (DFCs) within each Groundwater Management Area (GMA) must be determined and submitted to the Texas Water Development Board (TWDB). GMAs were given the primary responsibility by SB2 to plan for groundwater management in conjunction with the local water conservation districts within each GMA. DFCs are the desired, quantified conditions of groundwater resources and represent a management goal that addresses how an aquifer will be managed (Mace et al., 2008). The groundwater management districts within a GMA must implement rules and/or regulations to reach the specified management goal of meeting the DFC for a GMA.

The District has implemented management standards or goals, approved in 1998, to formulate a 50 year water plan (Panhandle Groundwater Conservation District, 2008). The District's chosen 50 year management plan, which can be updated every five years, is to have 50 percent of the current water supplies or saturated thickness available in 50 years, more commonly referred to as the 50/50 management standard.

The objective of this study was to conduct an economic analysis of how the 50/50 management standard would impact agricultural producers and the overall economy within the region. Specifically, this study was conducted for the following tasks:

1. TASK I. Evaluation of the 50/50 management standard at the county level for Carson and Donley Counties. The 50 year projections analyzed the change in farm profitability, irrigated acres, and hydrologic conditions for each county. Any changes in crop production that occurred within these two counties were included in a regional analysis to determine how the 50/50 management standard in Carson and Donley Counties impacted the regional economy of the PGCD (eight county area).

2. TASK II. Evaluation of the 50/50 management standard for four representative farms, two in Carson County and two in Donley County. These representative farm analyses capture detailed changes that could occur to a typical farming operation within the region, specifically in the farms ability to generate net cash income.

3. TASK III. Evaluation of the 50/50 management standard for two specific hydrologic areas within Carson and Donley Counties. These 20,480 acre blocks represented areas within the counties that have similar hydrologic conditions and farming practices.

The study region used to capture the regional economic impacts was defined as the eight counties within the PGCD which include Armstrong, Carson, Donley, Gray, Hutchinson, Potter, Roberts, and Wheeler, Figure 1. The total value of agricultural crop production in the eight county study region is estimated to be $191.9 million and the value of livestock production is estimated at $236.8 million. The regional economy has a population of 185,979 with total economic output of $30 billion and employment of 135,765 (MIG, 2008).

Carson and Donley Counties were specifically chosen for more detailed analysis due to the higher concentration of irrigated acres relative to the remainder of the PGCD, Figure 2. These counties contained both the representative farms and the study areas addressed in Tasks II and III. The total economic output is $1.1 billion in these counties and employment is estimated at 9,925 jobs (MIG, 2008).

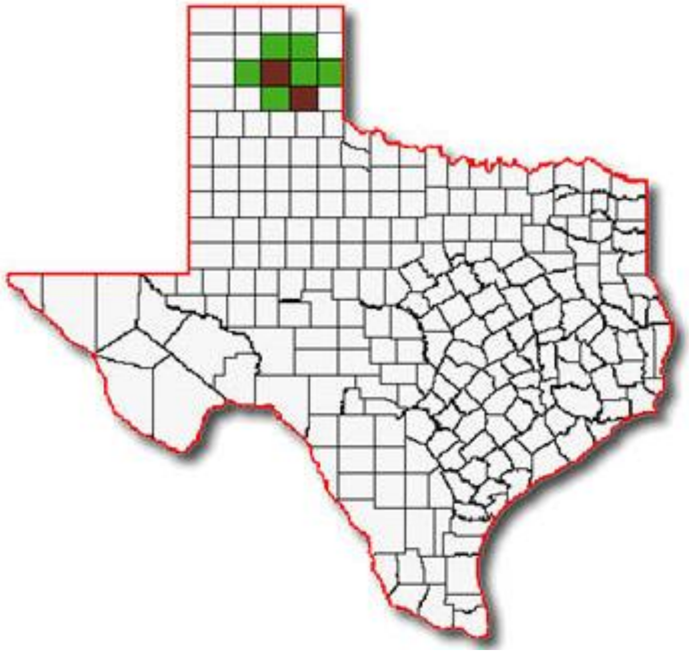

Figure 1. Counties partially or completely within the Panhandle Groundwater Conservation District study region (Carson and Donley Counties in brown)

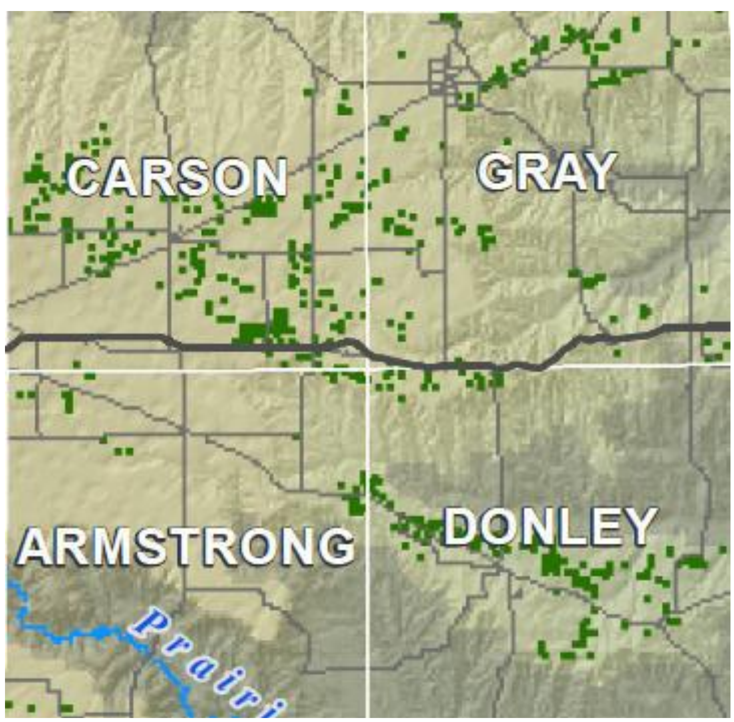

Figure 2. Center pivot irrigation systems in Carson, Gray, Armstrong, and Donley Counties (center pivots represented by green dots)
Source: Texas Tech University Center for Geospatial Technology

II. GENERAL DATA AND METHODS

The modeling procedure utilized in this project is unique in that the demand portion for irrigation water is dependent upon the per acre profitability of irrigation. Changes in irrigation capacities due to aquifer drawdown or changes in the regulatory environment, such as the policy implications evaluated in this project, can potentially impact the farm level profitability and gross receipts of irrigated operations. *It should be noted that the mathematical methods used in this study are derived from a mathematical model developed in the General Algebraic Modeling System (GAMS). This should not be confused with any reference to the Groundwater Availability Model (GAM) that is utilized within water planning and consulting processes at the TWDB to estimate groundwater and hydrologic interactions. Within this study, the Groundwater Availability Models are used for reference and comparison, however, were not used to estimate any of the results within this study.*

To capture the impacts of the 50/50 management standard, two scenarios were modeled for each task. First, a baseline estimate was determined for the years 2010 to 2060 which represented the status quo where no irrigation management standards were implemented. The baseline scenario projects the economic, agronomic, and hydrologic variables under the assumption that no management techniques are employed and farmers irrigate under an environment with no pumping restrictions. The baseline scenario was then compared to a constrained scenario, in which the 50/50 management standard was implemented from 2010 to 2060. The difference between these two scenarios represents the potential impacts to agricultural production within the region resulting from the implementation of the 50/50 management standards. Three primary measures were used to determine these impacts: changes in the producers' gross margin ($/acre), changes in saturated thickness, and changes in the percentage of acres irrigated. The producer gross receipts generated under each scenario were used to estimate impacts to the overall regional economy of the PGCD.

Methodology and Data for County Level and Hydrologic Area Models

The county level and hydrologic area analysis employed two types of economic models, economic optimization models and a socioeconomic model (IMPLAN). Economic optimization models (Brooke et al., 1998) were developed for both Carson and Donley Counties and the hydrologic areas. The optimization models estimated changes in the aquifer and per acre gross margin over a 50 year planning period under the baseline (status quo) scenario and the 50/50 management standard scenario. Socioeconomic models were then used to evaluate impacts on the regional economy resulting from changes in aggregate gross revenues from crop production over the 50 year planning horizon under the baseline scenario and the 50/50 management standard (MIG, 2009).

The county optimization models begin with the initial county or area values (assumed to represent 2010) for crop acreage, irrigated acreage, average saturated thickness, and depth to water. Given the initial conditions, the models estimate the level of crop production and water use that optimizes farm net income over a 50 year planning period. The results of the model include changes in crop acres, irrigated acres, and farm profitability over the planning horizon. The model also estimates the value of gross receipts from agricultural production for each irrigated and dryland crop by year. These values are the input to the socioeconomic model which estimates the impact of agricultural production to other sectors of the economy including agricultural input suppliers and other non-agriculture related sectors such as department stores and home repair services.

The underlying assumptions for the model include county, aquifer, and crop parameters. Baseline parameters are illustrated in Table 1. The parameters for each county include the number of acres planted in each crop, the number of irrigated acres (Farm Service Agency, 2006-2010), and the percentage of the county overlying the Ogallala Aquifer. The aquifer characteristics for each county include the average saturated thickness, depth to water, specific yield, and recharge (Panhandle Groundwater Conservation District, 2010). The crop parameters for each crop include crop price, cost of production, and crop yield (Amosson et al., 2007; Amosson et al., 2008; 2009). Crop yield was determined by a production function which estimates yield as a response to irrigation water applied. As irrigation water application rates change, the crop yield per acre adjusts accordingly. The production functions were estimated with the aid of Leon New (2010). Dr. New is a local crop consultant and agricultural engineer with exceptional knowledge and familiarity of the area, having 40 years of experience working in the region. The production functions are based on field-level observations of the relationships between crop yield and irrigation water applied. The water response functions are different for each crop and county within the analysis. Cost of pumping for natural gas powered pumping plants was estimated using the energy price and energy requirements in accordance with pumping lift. The pumping costs changed as depth to water increased over the planning period. One of the unique aspects of this model is that water demand incorporates costs of pumping, changes in depth to water, and changing yields and crop mix as they respond to changing water availability over time. Water demand is driven by economic forces in conjunction with the ability of the underlying hydrology to provide irrigation water.

Table 1. Carson and Donley county baseline data summary

County Characteristic	**Carson**	**Donley**
Cultivated acres	229,710	71,787
Irrigated acres	67,488	23,842
Dryland acres	162,222	47,945
Irrigated Crop Allocation (acres)		
Alfalfa	-	2,499
Cotton	18,285	5,902
Corn	14,100	1,475
Peanuts	-	5,103
Sorghum	6,168	1,476
Wheat	50,589	3,442
Dryland Crop Allocation (acres)		
Cotton	37,844	5,496
Sorghum	24,222	3,650
Wheat	99,555	10,455
Average Dryland Yields		
Cotton (lbs)	467	467
Sorghum (lbs)	2,260	2,260
Wheat (bu)	25	25
2010 Saturated Thickness (ft)	163	116
Specific Yield	0.17	0.16
Recharge (inches/year)	0.30	0.50
Number of wells	810	195
Average Well Yield (GPM)	550	350
Pumping Lift (ft)	400	175
Pumping Season (Days)	83	83
Acres/well	110	102

Many studies that have quantified the economic impacts of a change in a region have utilized IMPLAN (Impact Analysis for PLANning) which is an input-output model building system. This computer-based system was originally developed by the United States Department of Agriculture's Forest Service to assist in land and resource management planning. IMPLAN was developed by MIG (formerly the Minnesota IMPLAN Group) (2009) and provides access to comprehensive and detailed data coverage of the entire U.S. by county. IMPLAN datasets are compiled from a wide variety of sources including the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor, and the U.S. Census Bureau. One advantage of the IMPLAN model is that it allows the incorporation of user-supplied data throughout the model building process. This aspect makes the model flexible and enhances the accuracy of impact results (MIG, 2004).

The IMPLAN model was used in this study for the socioeconomic analyses to forecast the effects of the 50/50 management standard on the overall economic activity in the study region (eight county PGCD study area) in comparison to the baseline scenario. The aggregate regional results of gross crop receipts from the optimization models for Carson and Donley Counties served as the input into the socioeconomic model. Particular crop production costs for each crop were input into the model to generate more detailed and region-specific results (Amosson et al., 2007; Amosson et al., 2008; 2009).

The model captures the often-cited "spillover effects" of changes in water availability on other economic sectors linked directly and indirectly to irrigated crop production. This method is used to understand the linkages between elements of an economy and estimate the impacts of changes in the region. To measure impacts, the IMPLAN model produces multipliers which estimate the total economic impact of expenditures within an economy. These impacts are referred to as direct, indirect, and induced effects. An example is a producer paying for custom crop harvesting (direct effect). Then, the custom harvester purchases additional equipment (indirect effect). As a result of profits received, the producer and the custom harvester can spend money at the local grocery store (induced effect).

Multipliers are created for the study region that estimates the total economic impact of expenditures within an economy. Three measures of economic activity that can be estimated through IMPLAN are industry output, value added, and employment. Industry output is the value of total production of an economy or the total economic activity that occurs in a region. Value added is the income or wealth portion of industry output that includes employee compensation, proprietary income, other property income, and indirect business taxes. Finally, employment is simply the number of jobs in an economy (MIG, 2004). These are the measures reported in this study.

Methodology and Data for the Representative Farms

The modeling of the representative farms was a two stage process. The first utilizes the optimization procedure previously discussed with data specific to the individual representative farm. The output from the optimization model was then transferred to a simulation model (Simetar, 2008), which captures the risk associated with changes to the farming operation due to yield and price risk. The representative farms were designed to represent a typical farming operation within the areas of interest. Two farms, one in Carson County and one in Donley County, were designed based upon personal correspondence with producers in each of the regions (Bowers et al., 2010) and projected to a maximum of 20 years or 2030. These farms were evaluated for two separate rates of drawdown with one representing average values observed within the district and the High Drawdown farm which represents an extreme case of drawdown in saturated thickness. Each rate of drawdown was provided by PGCD.

Results for the farm level analysis are presented for two separate time horizons. The simulation model (Simetar) utilizes a 20 year time horizon because of the compatibility with available projected commodity prices and changes in production costs. The output of this procedure provides an outlook for how an irrigated farm's risk profile changes under the scenarios evaluated. The second set of results project farm level net returns, saturated thickness, and percent cropland irrigated over a 50 year time horizon. These results are derived from the optimization procedure and are similar in nature to the county level 50 year projections.

Data received from the interviews included total farm acres, enterprise mix, debt owed for land, and equipment expense, as well as cash rent values for rented farmland as summarized in Table 2. Other characteristics included well capacity, depth to water, number of irrigation wells, and any crop insurance enrollment characteristics. Farm program payments were considered in the analysis and are based on enrolled acres in the 2010 and 2008 Farm Bill programs. Projected commodity prices and costs were incorporated into the modeling process based upon the Food and Agricultural Policy Research Institutes (FAPRI) 2010 Baseline estimates (Food and Agricultural Policy Research Institute (FAPRI), 2010). Each representative farm was subjected to two rates of drawdown and saturated thickness to simulate a normal (expected) and an extreme level of water use (high drawdown). *The high drawdown scenarios for the representative farms were analyzed to assess the impacts of pumping levels greater than those estimated from the optimization models.* All cropping characteristics and enterprise acreages remained the same for the High Drawdown scenarios. The results for the representative farms focused on how the 50/50 management standard would impact the farm's ability to generate net cash income over two different time horizons.

Table 2. Carson and Donley County representative farm data summary

Farm Characteristic	Carson	Donley
Cultivated acres	2500	1500
Irrigated acres	825	1125
Dryland acres	1675	375
Irrigated Crop Allocation (acres)		
Corn	495	0
Peanuts	0	333
Cotton	248	333
Wheat	83	333
Alfalfa	0	125
Dryland Crop Allocation (acres)		
Wheat	553	188
Sorghum	553	0
Cotton	553	188
Rented Acres	1875	750
Owned acres	625	375
Dryland Rent ($/acre)	18	30
Irrigated Rent ($/acre)	90	200
Equipment Expense ($/acre)	25	25
Land Debt ($1000)	375	170
2010 Saturated Thickness (ft)	190	150
Specific Yield	0.17	0.16
Recharge (inches/year)	0.30	0.50
Number of wells	7	11
Average Well Yield (GPM)	550	300
Pumping Lift (ft)	400	175
Pumping Season (Days)	83	83
Acres/well	118	102

Validation

The validation procedure used for the optimization model was developed to verify that the drawdown in saturated thickness through time was accurately represented at all levels of analysis. This was accomplished through two separate procedures. First the optimization model was run from 2000 to 2050 to verify that the predictor of saturated thickness projected for 2010 matched the current estimates at the county, hydrologic area, and representative farm levels. Once these estimates were verified, the model was calibrated to represent the projected drawdown in water availability. Second, comparisons were made between the saturated thickness estimates generated in the optimization models and GAM runs completed by the TWDB (INTERA, 2010). While the economic optimization model's primary water storage output is presented in saturated thickness, the GAM runs are generally presented in acre-feet of water in storage by county. Assuming that saturated thickness and the GAM values for acre-feet of water in storage are synonymous, percentage changes from 2010 to 2060 were compared for the optimization model and the most recent baseline GAM run for the Panhandle Water Planning Group (PWPG) prepared by INTERA. These percentage changes (2010 to 2060) in water storage/saturated thickness indicated that the optimization models used in this study were within 3% of the baseline GAM projections made for the PWPG. However, it must be noted that the optimization models used within this study estimate water demand through an economic process which differs from the methods reported in the regional water plans GAM runs. The economic process utilized within this model allocates water to land based upon if it is economical to irrigate or not. This "allocation" of water differs from projections made by groups such as INTERA, as their projections utilize only hydrologic parameters to estimate water in storage or pumping volumes.

The farm level simulation models were validated to verify the process for completeness, accuracy, and forecasting ability. Verification ensured that variables predicted and calculated within the model were arithmetically accurate and linkages between models or cells were properly calculating. Validation was used to insure that the random variables being simulated were correct and demonstrated characteristics of the parent distribution. In the case of the simulation model, the variables being simulated were stochastic yield and price. While the financial position of the farm was the end goal, all prior calculations are based on the yield and price draws within the model. Thus validation of yield and price was achieved in two phases. First, visual inspection of the simulated and historical prices and yields was evaluated in a Cumulative Distribution Function format to ensure that the model was associating proper probability to the draw of a particular stochastic variable. Second, simulated and historical yield and price were evaluated to ensure that the mean vectors and covariance matrices were statistically equivalent.

III. RESULTS

Task I Results - Carson and Donley Counties

The results presented below summarize the estimates for the county level and corresponding regional level economic impacts of the 50/50 management standard in two specific counties, Carson and Donley, within the PGCD. Figures 3 and 4 and Tables 3 through 5 present the estimates for saturated thickness, gross margin per acre, and percent irrigated land for Carson and Donley Counties over the 50 year planning horizon. Table 6 presents the socioeconomic estimates for the impact of producer gross revenue from Carson and Donley Counties on the PGCD eight county study region.

Initial saturated thickness in Carson County begins at 163 feet and declines to 138 feet by year 50 under the baseline scenario. The desired future condition for Carson County under the 50/50 management standard requires a minimum saturated thickness of 85 feet remaining by the end of the planning horizon in 2060. Results indicate that the water management strategy is not binding for area producers as there is almost 53 feet of saturated thickness above the stated 50/50 standard requirement under the baseline scenario. Graphical results for Carson County are presented in Figure 3 with estimates provided in Table 3. Donley County has a comparatively lower initial saturated thickness of 116 feet which declines to 97 feet by year 50 under the baseline scenario. Donley County must have 61 feet of saturated thickness remaining in year 50 under the 50/50 management standard. However, with 97 feet of saturated thickness remaining in year 50, Donley County is 36 feet above the stated management goal (Figure 4 and Table 3).

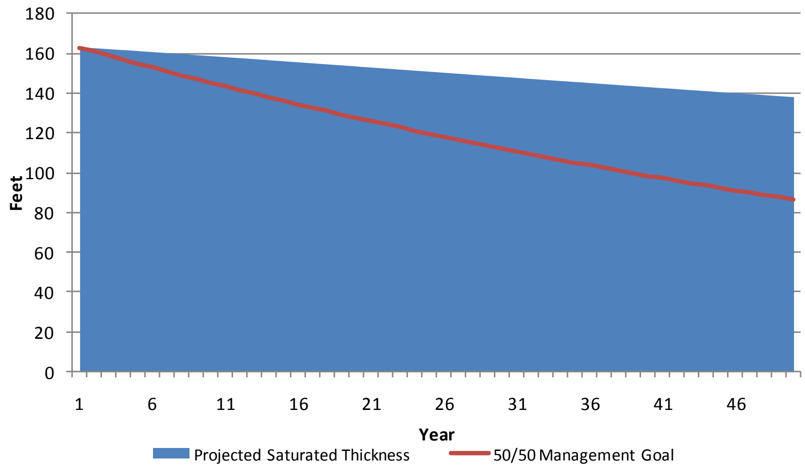

Figure 3. Carson County saturated thickness

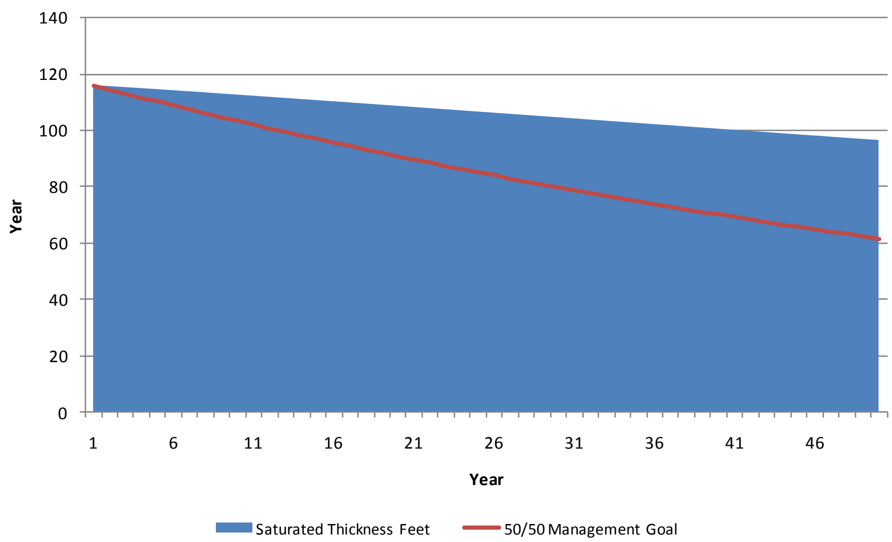

Figure 4. Donley County saturated thickness

Table 3. Carson and Donley County saturated thickness (ft) [1]

Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Baseline Year 1 = 163	159.07	153.36	148.14	143.00	137.99
Desired Future Conditions[2]	143.26	125.91	110.67	97.27	85.49
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Baseline Year 1 = 116	112.63	108.65	104.61	100.56	96.52
Desired Future Conditions[2]	101.95	89.61	78.76	73.83	60.84
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

[1] Averages are weighted by the area overlying the aquifer in each county.
[2] Desired Future Condition based on the 50/50 management standard.
[3] Changes from baseline are 0.00% if baseline is above desired future condition.

Gross margin per acre was not impacted as a result of the 50/50 standard as seen in Table 4. For Carson County, gross margin per acre was estimated to increase from an initial $153 per acre to $217 per acre in year 2060. Gross margin per acre for Donley County was slightly higher since the county produces some alfalfa, with initial gross margin estimates at $219 per acre increasing to $312 per acre by 2060. The increase in profitability through time in each county is due to the optimization process within the model choosing the crop mix which maximizes profit over the 50 year planning horizon.

Table 4. Carson and Donley County average gross margin per acre ($/acre) [1]

Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Baseline Year 1 = $153.47	$189.57	$205.09	$211.30	$214.43	$216.63
Desired Future Conditions[2]	$189.57	$205.09	$211.30	$214.43	$216.63
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Baseline Year 1 = $219.16	$275.86	$294.52	$302.87	$307.87	$311.96
Desired Future Conditions[2]	$275.86	$294.52	$302.87	$307.87	$311.96
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

[1] Gross margin is defined as gross revenue less cash field expenses. The average is based on the total irrigated and nonirrigated gross margin (at time = t) divided by total irrigated and non-irrigated cropland acres.
[2] Desired Future Condition based on the 50/50 management standard.
[3] Changes from baseline are 0.00% if baseline is above desired future condition.

Irrigated acres within each county were not impacted by the management standard as seen in Table 5. These irrigated acres represent the percentage of cropland acres within the county which are irrigated. Carson County exhibits a slightly lower percentage of irrigated acres with 29.4% of cropland irrigated while Donley County has 33.2% irrigated cropland. Projections indicate that the implementation of the management standard will not impact the aggregated amount of irrigated cropland through year 2060.

Table 5. Projected irrigated acres as a percentage of total cropland acres for Carson and Donley County

Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Baseline Year 1 = 29.38%	29.38%	29.38%	29.38%	29.38%	29.38%
Desired Future Conditions[1]	29.38%	29.38%	29.38%	29.38%	29.38%
Change from Baseline[2]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Baseline Year 1 = 33.21%	33.21%	33.21%	33.21%	33.21%	33.21%
Desired Future Conditions[1]	33.21%	33.21%	33.21%	33.21%	33.21%
Change from Baseline[2]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

[1] Desired Future Condition based on the 50/50 management standard.
[2] Changes from baseline are 0.00% if baseline is above desired future condition.

The regional impacts presented in Table 6 represent the cumulative net present value of regional economic impacts from 2010 through 2060. Specific results of the IMPLAN analysis, which capture the combined impacts of Carson and Donley Counties indicate that the value of the irrigated and dryland crops to the PGCD economy is $8.37 billion in industry output, $1.91 billion in value added, and 1,074 average annual employment over the 50 year time period under the baseline scenario. In addition, since the 50/50 management standard is not binding for area producers, there is no reduction in producer income and thus, no impacts on the local economy.

Table 6. 50 year economic impacts of agricultural production in Carson and Donley Counties on the PGCD Region.

	Direct[1]	Indirect[2]	Induced[3]	Total
		Baseline ($ Million)		
Output[4]	$4,476	$3,480	$411	$8,367
Value Added[4]	$1,230	$441	$236	$1,907
Employment (Number)	864	136	75	1,074

[1] Direct impacts represent the economic impact to agricultural producers.
[2] Indirect impacts represent the economic effects of industries buying from other industries to supply inputs to agricultural producers.
[3] Induced impacts result from changes in household income caused by direct and indirect effects.
[4] Millions of dollars – discounted at 3% over the 50 year time horizon.

Conclusions: At the aggregate county level, no impacts were detected from the implementation of the 50/50. Since the baseline results for both Carson and Donley Counties did not exceed the 50/50 management standard, the management standard was not a binding restriction, thus having no significant impacts on saturated thickness drawdown, farm profitability, irrigated acres or the regional economy. Gross margin per cropland acre shows no impact from the implementation of the 50/50 management standard. Additionally, no change in the percentage of irrigated cropland is expected holding current infrastructure constant. While there is no change in the regional economy under the management standard, the IMPLAN results provide an estimate of the economic contribution of agricultural crop production over the planning horizon.

Task II **Results – Representative Farms**

The results for the three representative farms are presented in Tables 7 through 9 and Figures 5 through 16. Figures 5, 6, 7, and 8 illustrate the farm level projected baseline saturated thickness in comparison to the 50/50 management standard. Figures 9, 11, 13, and 15 indicate the likelihood of the representative farm achieving a specified net return per acre of $100 for the first 20 years of the 50 year projection. Figures 10, 12, 14, and 16 indicate the projected gross margin per acre for the entire 50 year planning horizon.

Saturated thickness for the Carson County Farm was 190 feet in 2010, dropping to 152 feet by end of the planning horizon (Figure 5 and Table 7). Under the 50/50 management standard requirements for the minimum saturated thickness in 2060 is 100 feet, thus the baseline projections were 52 feet above the standard. The Carson County High Drawdown Farm had the highest initial saturated thickness of the farms evaluated at 320 feet which declined to 237 feet by 2060 as seen in Figure 6 and Table 7. The Donley County Farm has a comparatively lower saturated thickness in 2010 of 150 feet which declined to 121 feet by 2060 as seen in Figure 7 and Table 7. As with the Carson County Farm, the 50/50 management standard was not binding as the baseline was projected to be 41 feet above the minimum saturated thickness by the end of the planning horizon. The Donley County High Drawdown Farm was the only farm analyzed in this study for which the 50/50 management standard was binding. With a baseline saturated thickness of 150 feet in 2010 the high drawdown farm declines to 80.51 feet by year 2060, Figure 8 and Table 7.

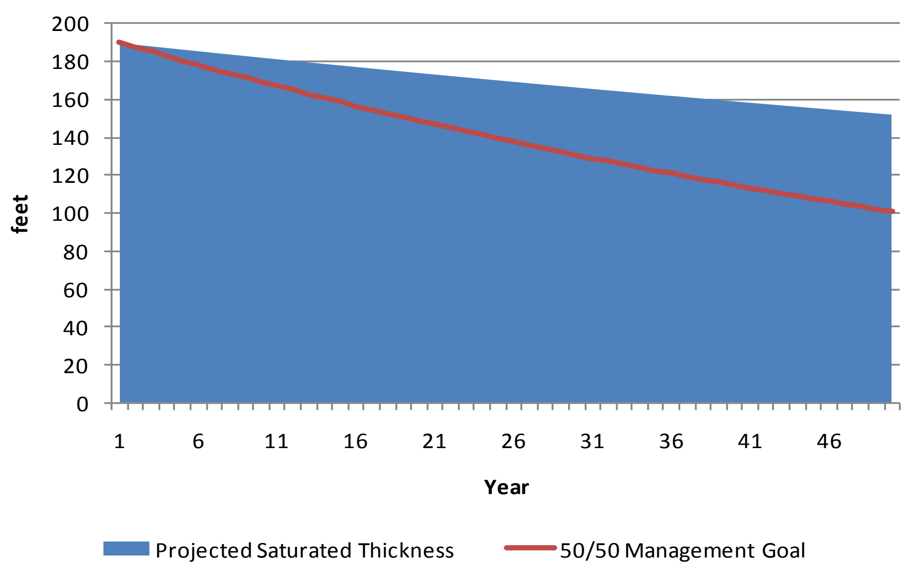

Figure 5. Carson County representative farm saturated thickness

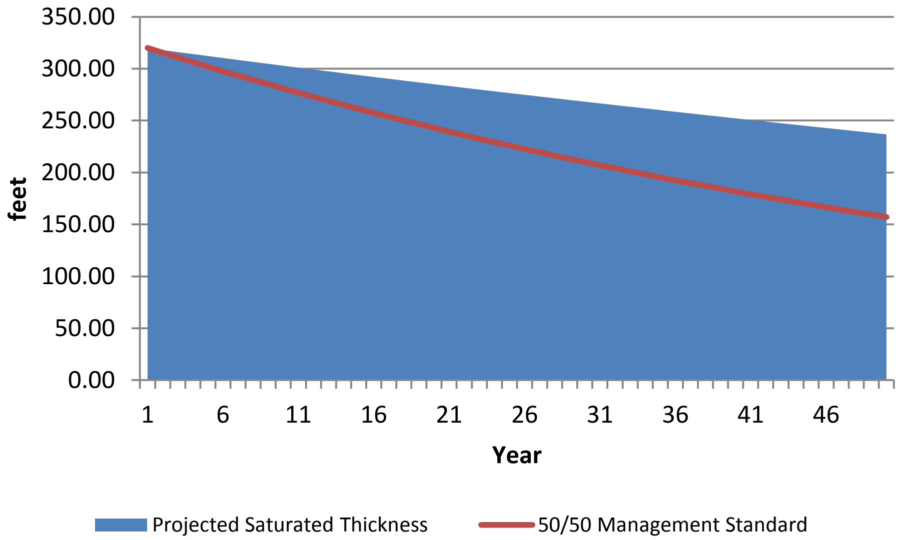

Figure 6. Carson County High Drawdown representative farm saturated thickness

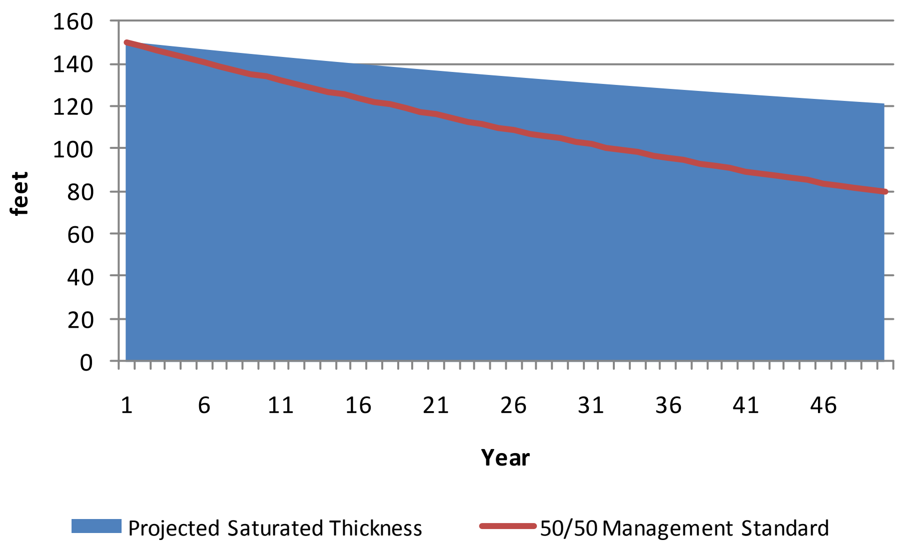

Figure 7. Donley County representative farm saturated thickness

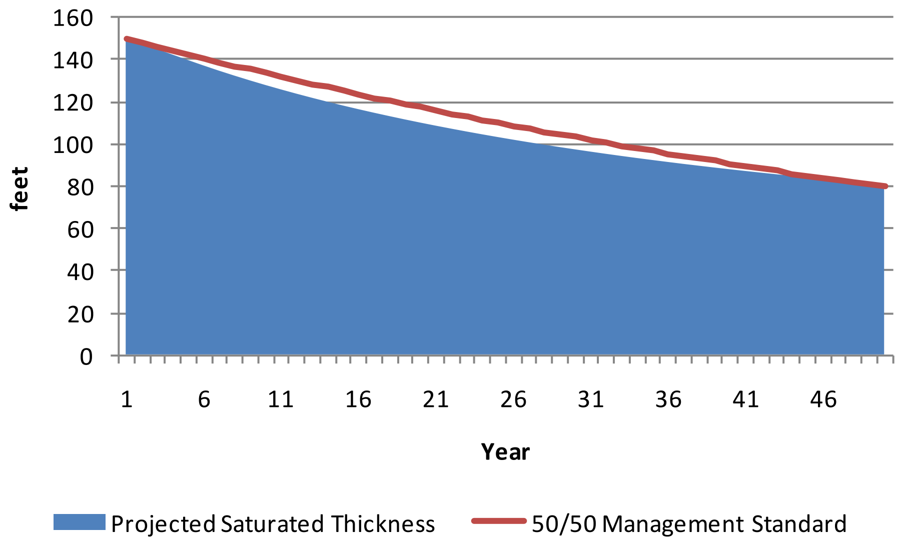

Figure 8. Donley County High Drawdown representative farm saturated thickness.

Table 7. Carson and Donley County representative farms: saturated thickness (ft) [1]

Farm Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Farm Baseline Year 1 = 190	182.24	174.13	166.46	159.15	152.13
Desired Future Conditions[2]	166.90	146.77	129.00	113.38	99.65
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Carson Farm – High Drawdown Baseline Year 1 = 320	302.97	285.16	268.33	252.29	236.89
Desired Future Conditions[2]	276.77	239.38	207.04	179.07	154.87
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Farm Baseline Year 1 = 150	143.51	136.99	131.11	125.79	120.94
Desired Future Conditions[2]	131.84	115.87	101.84	89.51	78.67
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*		*0.00%*
Donley Farm - High Drawdown Baseline Year 1 = 150	127.69	109.88	97.17	87.73	80.51
Desired Future Conditions[2]	131.84	115.87	101.84	89.51	78.67
Change from Baseline[3]	***3.26%***	***5.45%***	***4.93%***	***2.03%***	***-2.29%***

[1] Averages are weighted by the area overlying the aquifer in each county.
[2] The minimum saturated thickness for the Desired Future Condition based on the 50/50 management standard.
[3] Changes from baseline are 0.00% if baseline is above desired future condition.

The Carson County Farm indicated gross margins of $144 per acre in 2010 which increased to $161 per acre in year 2060 with no change from the desired future condition (Table 8). Similar results were seen for the Carson County High Drawdown Farm. The Donley County Farm, which has irrigated alfalfa, was comparatively more profitable with a gross margin of $293 per acre in 2010 which increases through year 30 of the projection to $291 per acre (Table 8). However, as water supplies decrease and conversion to dryland from irrigated acres is projected by year 50 (Table 9), the farm shows a decline in per acre gross margin to $274 by 2060. As in Task I, any increase in profitability was due to the optimal economic choices that occurred over the planning horizon within the modeling process.

Table 8. Carson and Donley County representative farms: gross margin per acre ($/acre) [1]

Farm Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Farm Baseline Year 1 = $144.13	$136.40	$144.60	$151.26	$156.64	$160.98
Desired Future Conditions[2]	$136.40	$144.60	$151.26	$156.64	$160.98
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Carson Farm – High Drawdown Baseline Year 1 = $144.11	$135.38	$142.60	$148.47	$153.12	$156.78
Desired Future Conditions[2]	$135.38	$142.60	$148.47	$153.12	$156.78
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Farm Baseline Year 1 = $293.71	$278.33	$288.90	$290.84	$285.86	$274.22
Desired Future Conditions[2]	$278.33	$288.90	$290.84	$285.86	$274.22
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Farm - High Drawdown Baseline Year 1 =$277.57	$223.17	$159.19	$120.43	$98.96	$86.90
Desired Future Conditions[2]	$196.72	$161.65	$143.02	$114.19	$97.27
Change from Baseline[3]	***-11.85%***	***1.54%***	***18.75%***	***15.39%***	***11.93%***

[1] Gross margin is defined as gross revenue less cash field expenses. The average is based on the total irrigated and non-irrigated gross margin (at time = t) divided by total irrigated and non-irrigated cropland acres.
[2] Desired Future Condition based on the 50/50 management standard.
[3] Changes from baseline are 0.00% if baseline is above desired future condition.

The Donley County High Drawdown Farm was modeled such that the drawdown in saturated thickness was at extreme levels of 1.42 feet per year which did show changes in net returns per acre as indicated in Table 8. Gross margins were initially $278 per acre for this farm and steadily declined to $87 per acre by 2060. This relatively dramatic drop in revenue is due to the high rate of drawdown experienced by the farm which is reflected in gross margin estimates. This drop in profitability was not reflected in the likelihood of success of producing net income per acre but rather in the loss of overall profitability through the 50 year planning horizon. The net present value of net returns in the optimization model dropped from the baseline of $4,727 to $4,405 over the planning horizon. This was the only scenario within the study which was impacted by the 50/50 management standard; however, these impacts will likely only affect a small percentage of the farmers within Donley County.

The percentage of irrigated acres presented in Table 9, shows what percentage of cropland the representative farms were able to irrigate through time. The Carson County Farms, which have relatively fewer irrigated acres at 33% compared to the Donley County Farms at 75%, can continue to produce on these acres without any transition to dryland alternatives. The Donley County Farm is mostly irrigated at 75% and can continue to irrigate at this level through most of the planning horizon with only a reduction between year 40 and 50 of the planning horizon in which irrigated acres drop slightly to 72%. The Donley County High Drawdown Farm experiences major changes in irrigated acres from the initial 75% declining to 34% by year 2060. This is due to the high rate of drawdown that was assumed for this farm. The 50/50 management standard impacts this farm by reducing water use to sustain irrigated acres through time increasing acres in 2060 to 35.5% of cropland.

Table 9. Projected irrigated acres as a percentage of total acres cropland acres for representative farms

Farm Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Farm Baseline Year 1 = 33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Desired Future Conditions[1]	33.33%	33.33%	33.33%	33.33%	33.33%
Change from Baseline[2]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Carson Farm – High Drawdown Baseline Year 1 = 33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Desired Future Conditions[1]	33.33%	33.33%	33.33%	33.33%	33.33%
Change from Baseline[2]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Farm Baseline Year 1 = 75%	75%	75%	75%	75%	71.96%
Desired Future Conditions[1]	75%	75%	75%	75%	71.96%
Change from Baseline[2]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Farm - High Drawdown Baseline Year 1 = 75%	75%	61.87%	50.55%	41.30%	33.75%
Desired Future Conditions[1]	75%	62.36%	53.03%	43.33%	35.47%
Change from Baseline[2]	***0.00%***	***0.79%***	***4.91%***	***4.92%***	***5.10%***

[1] Desired Future Condition based on the 50/50 management standard.
[2] Changes from baseline are 0.00% if baseline is above desired future condition.

Farm Level Financial Simulation Results

When comparing the likelihood of profitability for the three farms (Figures 9, 11, 13 and 15), the Carson County High Drawdown Farm indicated the highest chance of producing a positive net cash income of the four farms evaluated (Figure 11). The Donley County Farm indicated greater probability of negative net cash income which peaked to 26% in years 2015 to 2020, mainly due to a dramatic increase in projected production costs (Figure 13). The overall increase in the probability of negative cash income for the Donley County Farm is mainly driven by the comparatively high cost of cash rent for both dryland and irrigated acres which are more than double that in the Carson County Farms. Additionally the Donley County Farms are predominately irrigated, thus making the weighted average costs of rent per cropland acre relatively more expensive. The Donley County High Drawdown Farm illustrated the greatest probability of negative cash flows peaking at 44% by the end of the 20 year projection. This relative increase in the probability of negative cash flow is due to the conversion of irrigated cropland to dryland enterprises as previously discussed. As the conversion of irrigated to dryland occurs, the likelihood of being subjected to weather related yield downfalls increases, thus increasing the overall probability of negative net cash income per acre.

Carson County Farm (Saturated thickness drawdown of 0.75 feet/year)

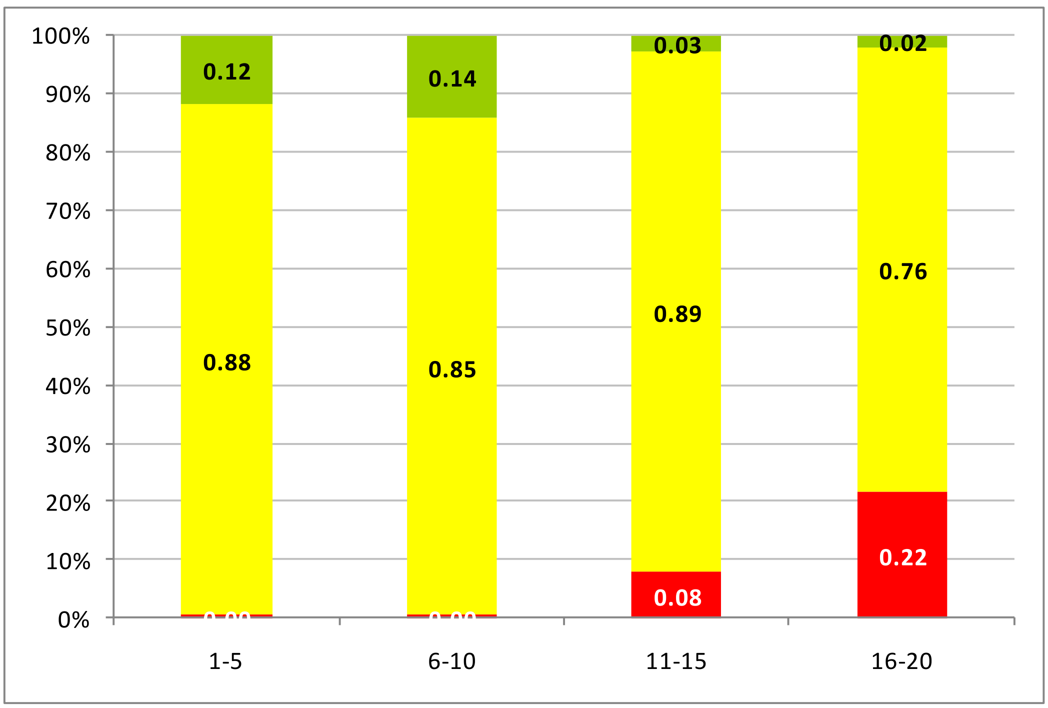

Figure 9. Probabilities of net income per acre between $0 and $100 (yellow), greater than $100 per acre (green), and less than $0 per acre (red) for the Carson County representative farm.

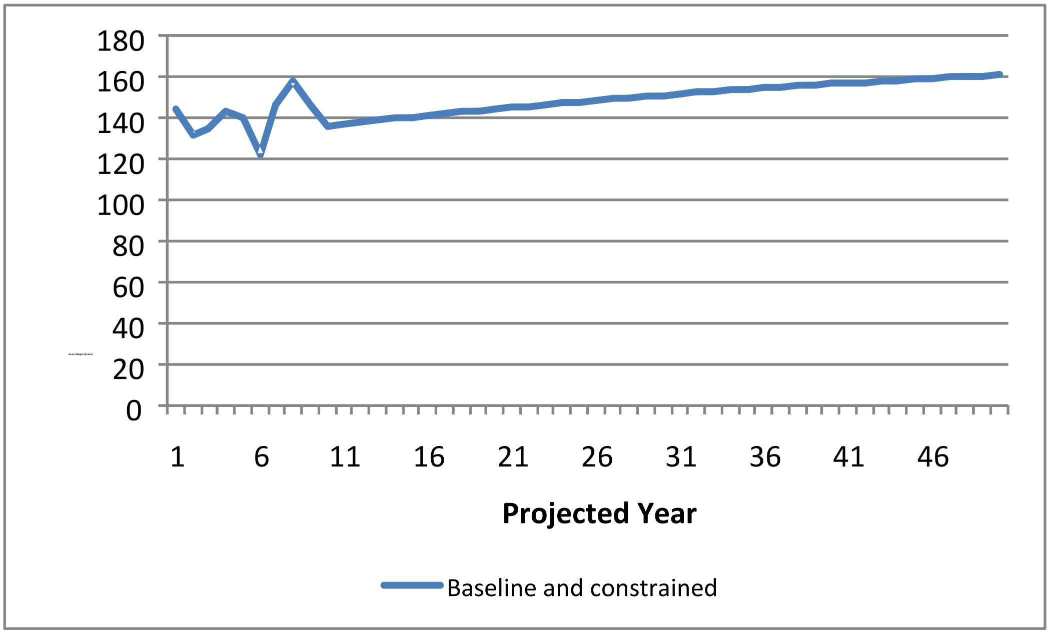

Figure 10. Projected gross margin per acre for the Carson County representative farm for the time horizon of 2010-2060 (does not include land, equipment, or interest expenses)

Carson County High Drawdown Farm (Saturated thickness drawdown of 1.6 feet/year)

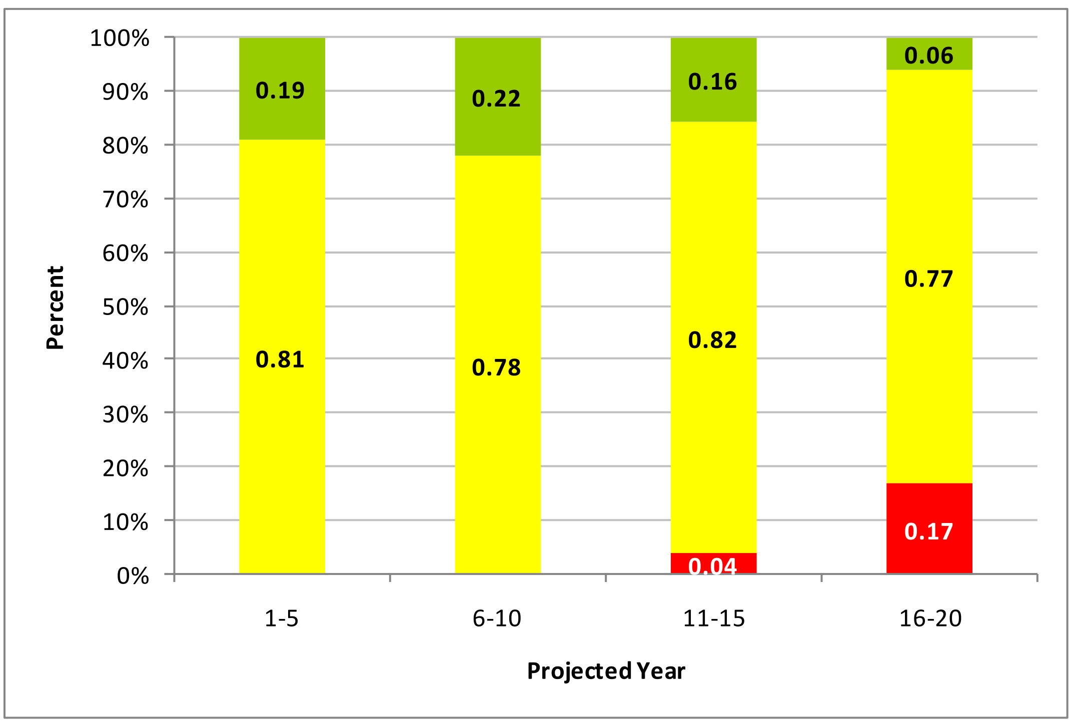

Figure 11. Probabilities of net income per acre between $0 and $100 (yellow), greater than $100 per acre (green), and less than $0 per acre (red) for the Carson County High Drawdown representative farm.

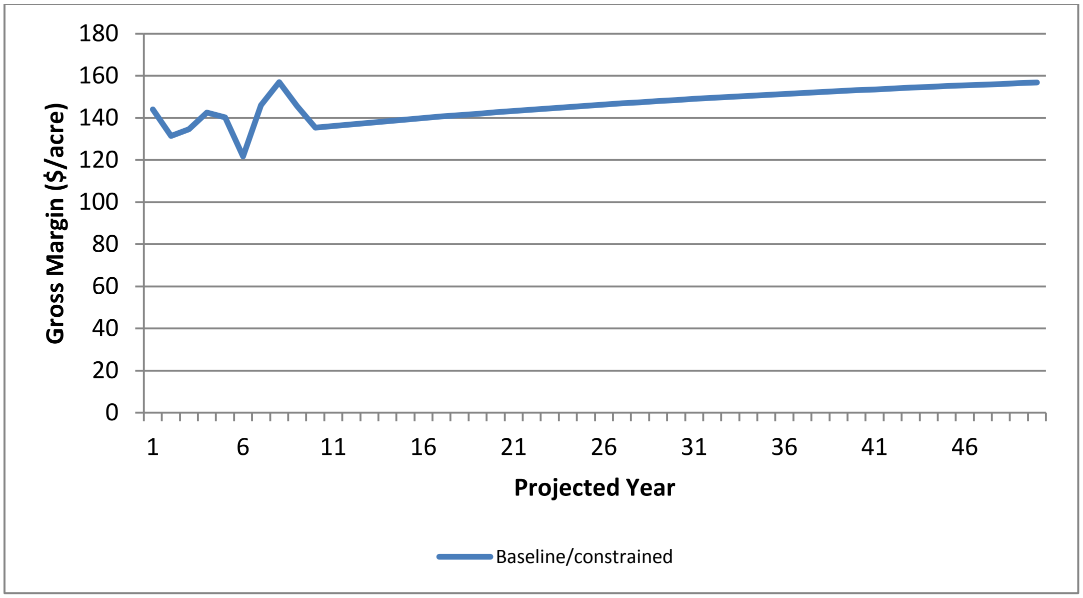

Figure 12. Projected gross margin per acre for the Carson County High Drawdown representative farm for the time horizon of 2010-2060 (does not include land, equipment, or interest expenses)

Donley County Farm (Saturated thickness drawdown of 0.60 ft/year)

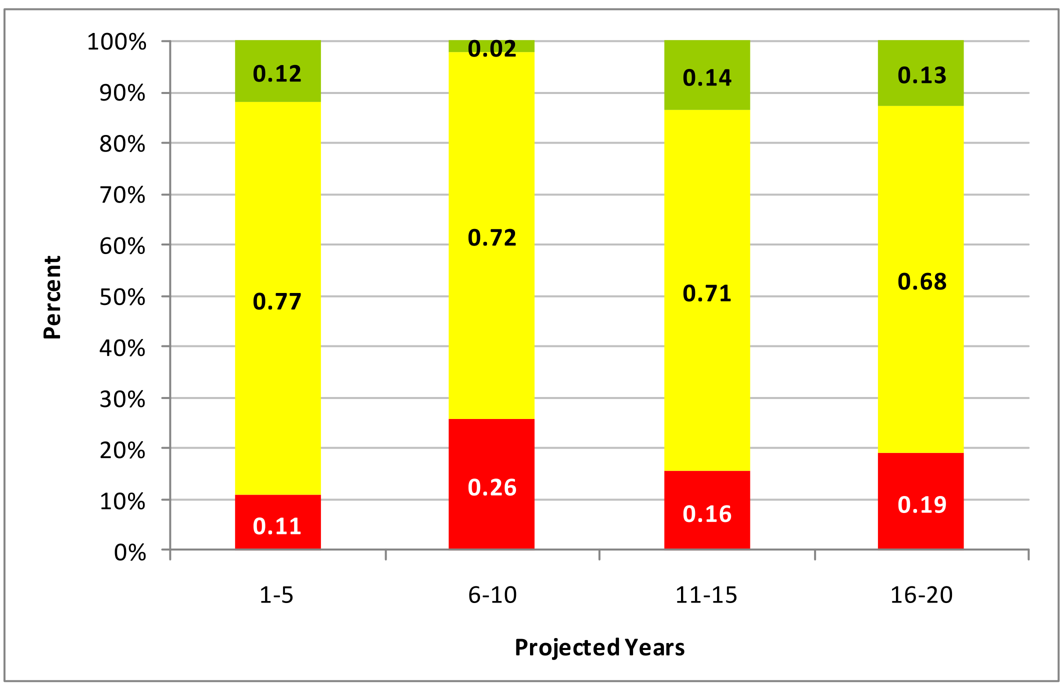

Figure 13. Probabilities of net returns per acre between $0 and $100 (yellow), greater than $100 per acre (green), and less than $0 per Acre (red) for the Donley County representative farm.

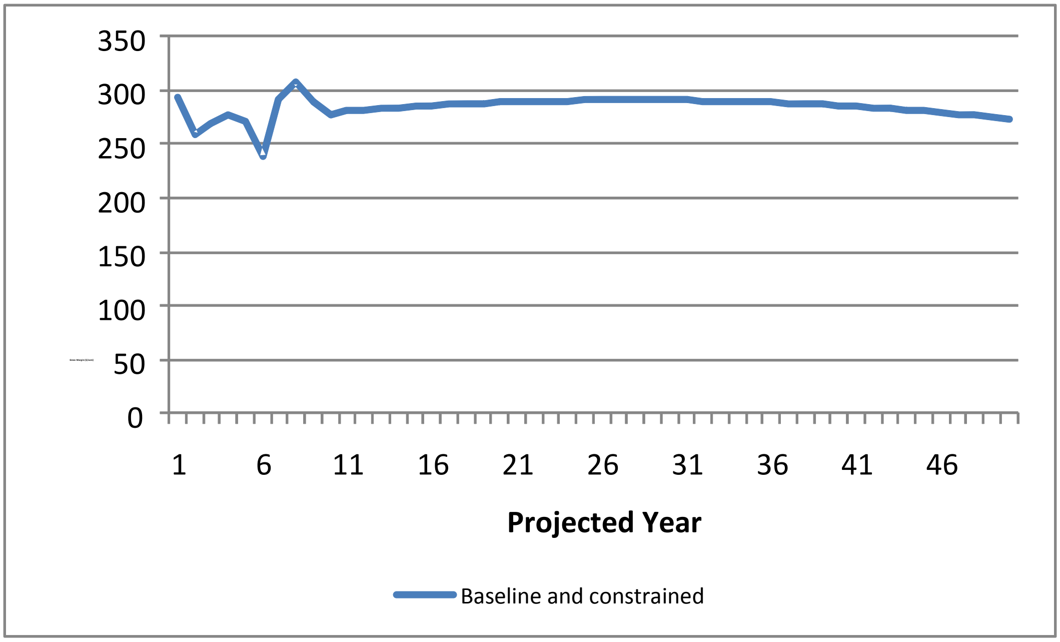

Figure 14. Projected gross margin per acre for the Donley County representative farm for the time horizon of 2010-2060 (does not include land, equipment, or interest expenses)

Donley County High Drawdown Farm (Saturated thickness drawdown of 1.4 ft/year)

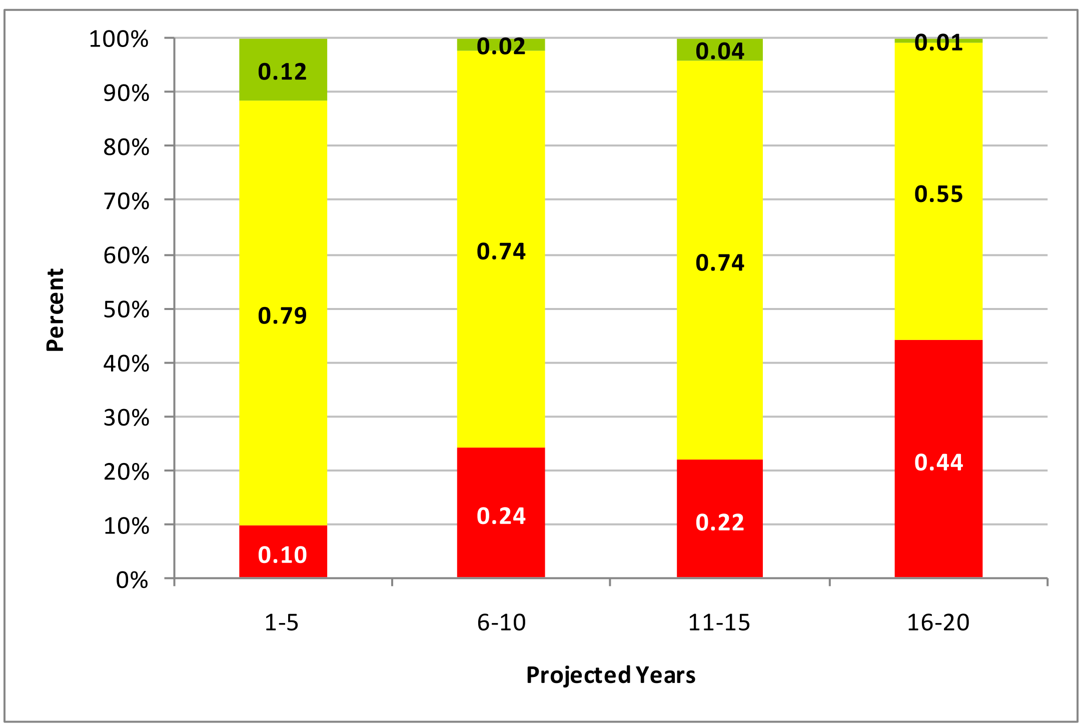

Figure 15. Probabilities of net returns per acre between $0 and $100 (yellow), greater than $100 per Acre (green), and less than $0 per acre (red) for the Donley County High Drawdown representative farm.

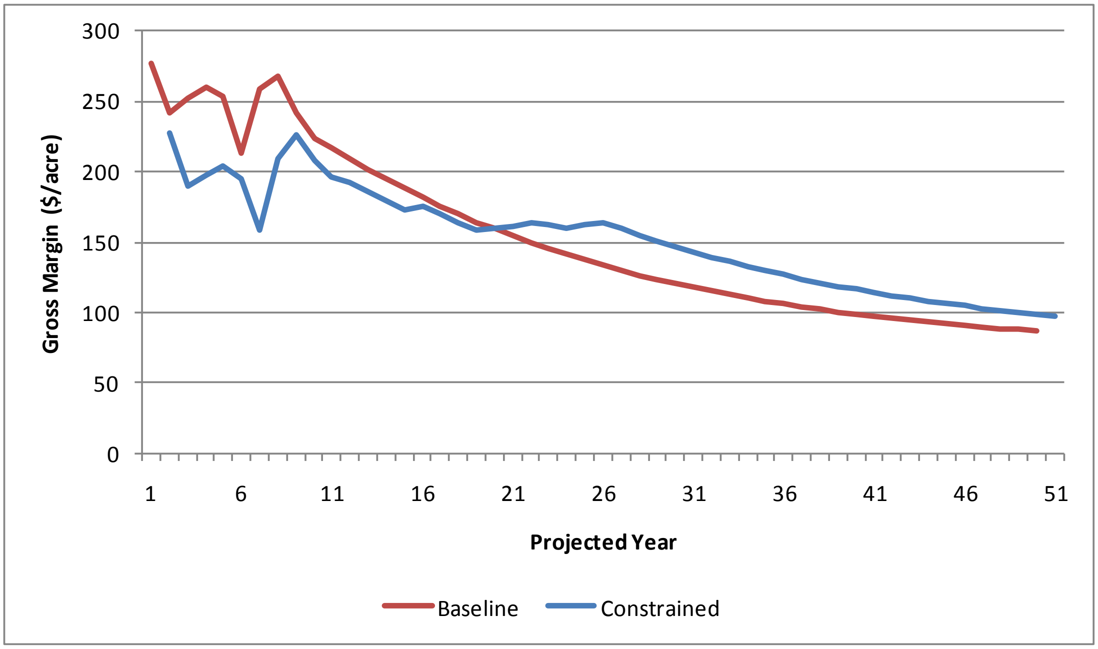

Figure 16. Projected gross margin per acre for the Donley County High Drawdown representative farm for the time horizon of 2010-2060 (does not include land, equipment, or interest expenses)

Conclusions: The overall results indicate that the 50/50 management standard will not significantly impact typical farms within Carson and Donley Counties. However, in areas of extreme drawdown, such as the Donley County High Drawdown Farm, where the saturated thickness is declining at rates of 1.4 feet or more per year, producers could face changes to their operations as they attempt to reduce the rates of decline. Based on average observed drawdown numbers, only a small percentage of farmers in Carson and Donley Counties will have to make any significant changes to their operations.

Task III <u>Results – Hydrologic Study Areas</u>

The purpose of Task III was to conduct economic projections for specific areas of the county (smaller than a county and larger than a farm) in which the underlying hydrologic conditions and farming practices were similar. The areas were defined as 20,480 acre blocks within both Carson and Donley County. These blocks were not specific to any location but rather scaled up versions of the representative farms. As with Task I, the changes in each of these study areas were aggregated and projected through the region.

Initial saturated thickness in the Carson County Hydrologic Area begins at 190 feet and declines to 152 feet by year 50 under the baseline scenario, Figure 17 and Table 10. The desired future condition for the Carson County Hydrologic Area under the 50/50 management standard requires a minimum saturated thickness of 100 feet remaining by the end of the planning horizon in 2060. Results indicate that the water management strategy is not binding for area producers as there is almost 53 feet of saturated thickness above the stated 50/50 management standard. Graphical results are presented in Figure 17 with point estimates provided in Table 10. The Donley County Hydrologic Area has a comparatively lower initial saturated thickness of 150 feet which declines to 112 feet by year 50 under the baseline. The Donley County Hydrologic Area must have 79 feet of saturated thickness remaining in year

50 according to the 50/50 management standard. However, with 112 feet of saturated thickness remaining in year 50, the Donley County Hydrologic Area is 33 feet above the stated management goal (Figure 18 and Table 10).

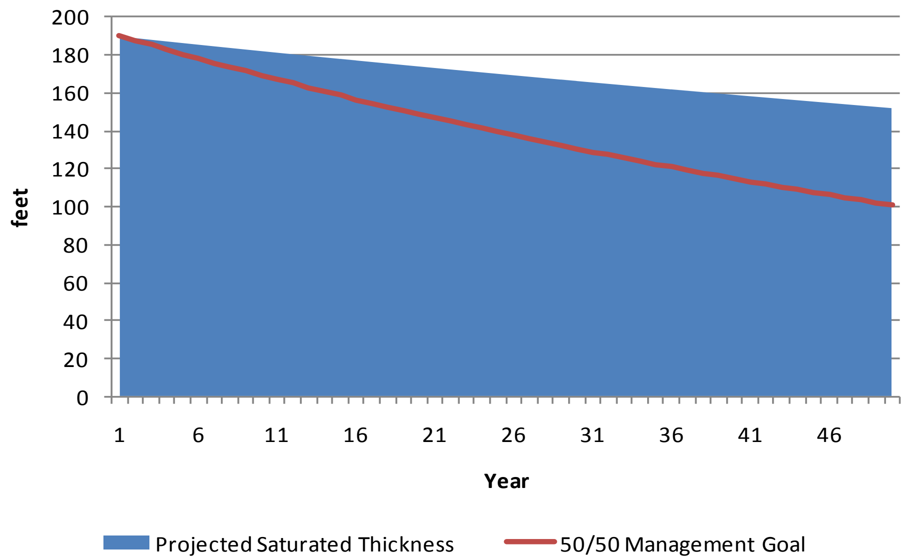

Figure 17. Carson County Area saturated thickness

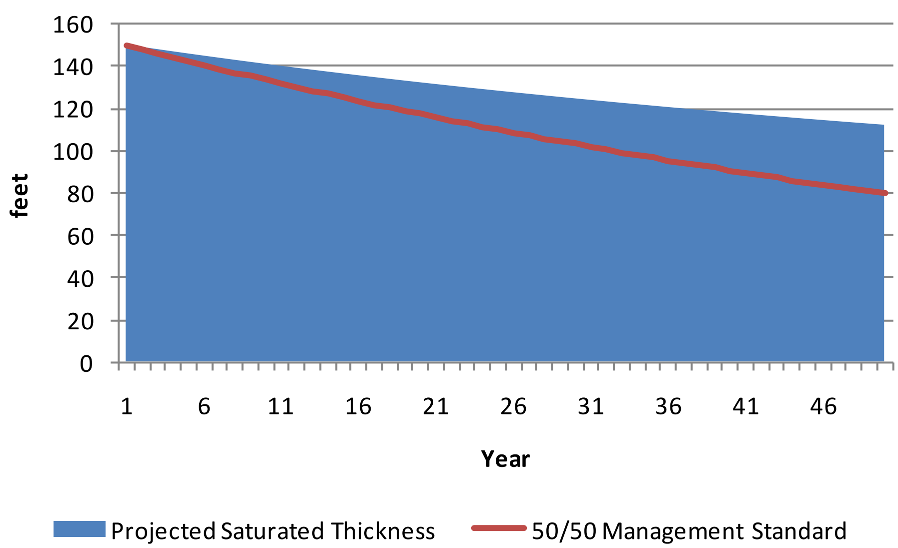

Figure 18. Donley County Area saturated thickness

Table 10. Carson and Donley County Areas: saturated thickness (ft)[1]

Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Area Baseline Year 1 = 190	182.24	174.13	166.46	159.15	152.13
Desired Future Conditions[2]	166.90	146.77	129.00	113.38	99.65
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Area Baseline Year 1 = 150	140.89	132.13	124.52	117.88	112.02
Desired Future Conditions[2]	131.84	115.87	101.84	89.51	78.67
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

[1] Averages are weighted by the area overlying the aquifer in each county.
[2] The minimum saturated thickness for the Desired Future Condition based on the 50/50 management standard.
[3] Changes from baseline are 0.00% if baseline is above desired future condition.

The Carson County Hydrologic Area indicated gross margins per acre of $144 in 2010 which increased to $161 per acre in year 2060 with no change from the desired future condition. The Donley County Area, which contained irrigated alfalfa, was comparatively more profitable per acre producing a gross margin of $293 per acre in 2010 and increasing through year 30 of the projection to $291 per acre. However, as water supplies decrease and conversion to dryland from irrigated acres is projected (Table 11), gross margin declines to $274 per acre by 2060. As in the Task I, any increase in profitability was due to the optimal economic choices that occurred over the planning horizon with the modeling process.

Table 11. Carson and Donley County Areas: gross margin per acre ($/acre) [1]

Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Area Baseline Year 1 = $144.13	$136.40	$144.60	$151.26	$156.64	$160.98
Desired Future Conditions[2]	$136.40	$144.60	$151.26	$156.64	$160.98
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Area Baseline Year 1 = $293.71	$278.33	$288.90	$290.84	$285.86	$274.22
Desired Future Conditions[2]	$278.33	$288.90	$290.84	$285.86	$274.22
Change from Baseline[3]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

[1] Gross margin is defined as gross revenue less cash field expenses. The average is based on the total irrigated and non-irrigated gross margin (at time = t) divided by total irrigated and non-irrigated cropland acres.
[2] Desired Future Condition based on the 50/50 management standard.
[3] Changes from baseline are 0.00% if baseline is above desired future condition.

Table 12 shows the percentage of irrigated cropland through time in the hydrologic areas. The Carson County Hydrologic Area, which has relatively fewer irrigated acres than the Donley County Hydrologic Area, at 33%, can continue to produce on these acres without any transition to dryland alternatives. The Donley County Hydrologic Area is mostly irrigated at 75% and would continue to irrigate at this level through most of the planning horizon with only a slight reduction between year 40 and 50 of the planning horizon in which irrigated acres drop slightly to 72%.

Table 12. Projected irrigated acres as a percentage of total cropland acres for the Carson and Donley Study Areas

Scenario	Year 10	Year 20	Year 30	Year 40	Year 50
Carson Area Baseline Year 1 = 33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Desired Future Conditions[1]	33.33%	33.33%	33.33%	33.33%	33.33%
Change from Baseline[2]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Donley Area Baseline Year 1 = 75%	75%	75%	75%	75%	71.96%
Desired Future Conditions[1]	75%	75%	75%	75%	71.96%
Change from Baseline[2]	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

[1] Desired Future Condition based on the 50/50 management standard.
[2] Changes from baseline are 0.00% if baseline is above desired future condition.

Results of the regional IMPLAN analysis shown in Table 13, illustrate that the value of the irrigated and dryland crops from the Carson and Donley County Hydrologic Areas to the PGCD eight county economy is $1.48 billion in industry output, $307 million in value added, and 178 jobs over the 50 year time period under the baseline scenario. In addition, since the 50/50 management standard is not binding for area producers, there is no reduction in producer income and thus, no effect on the local economy.

Table13. 50 year economic impacts of agricultural production in Carson and Donley County Areas on the PGCD region.

	Direct[1]	Indirect[2]	Induced[3]	Total
		Baseline ($ Million)		
Output[4]	$784	$630	$67	$1,480
Value Added[4]	$198	$71	$38	$307
Employment (Number)	142	24	12	178

[1] Direct impacts represent the economic impact to agricultural producers.
[2] Indirect impacts represent the economic effects of industries buying from other industries to supply inputs to agricultural producers.
[3] Induced impacts result from changes in household income caused by direct and indirect effects.
[4] Millions of dollars – discounted at 3% over the 50 year time horizon

Conclusions: Since the baseline results for both Carson and Donley County Hydrologic Areas did not exceed the 50/50 management standard, the standard was not a binding restriction, thus having no significant impacts on saturated thickness drawdown, farm profitability, or irrigated acres. Additionally, no change was expected in the percentage of irrigated cropland if the current irrigation infrastructure is held constant (Table 12). As a result of the 50/50 management standard not being a binding restriction, there was no change to the regional economic contribution made by these areas. While there is no change in the regional economy under the management standard, the IMPLAN results provide an estimate of the economic contribution of agricultural crop production over the planning horizon.

IV. CONCLUSIONS

The objective of the study was to evaluate the 50/50 management standard for the Panhandle Groundwater Conservation District on three specific yet linked levels. County level, specific study area, and farm level analyses were conducted to estimate the economic impacts of the 50/50 management standard on the economic viability of agriculture in the region. The county level and hydrologic study area optimization analyses were transferred into economic projections using IMPLAN which estimated any spillover effects that the management standard would have to the region. In this case the region was defined as all of the counties in which PGCD has jurisdiction to impose the 50/50 management standard.

The overall results indicate that the 50/50 management standard will have no significant effects on the region at all average levels of analysis including the county, hydrologic study area, and representative farm level. The only case in which the management standard impacted agricultural production practices was illustrated in an extreme case of drawdown on the Donley County High Drawdown Farm, where drawdown levels of the aquifer were simulated to be double the average for farms in the region. Even at these high rates of decline, the farm only indicated slight changes in economic viability as a result of the 50/50 management standard and this scenario is only likely to affect a very small percentage of farmers within the region.

The baseline projections for drawdown in saturated thickness in Carson and Donley Counties were projected to have nearly 80% of the 2010 saturated thickness remaining in the aquifer in 2060. Thus, for a county wide management restriction to have significant aggregate economic impacts on both Carson and Donley Counties the management standard would have to be as follows:

Saturated thickness remaining in 50 years:

- Greater than 80% in Carson County or (80/50)
- Greater than 80% in Donley County or (80/50)

This study did not evaluate the economic impacts of an alternative water market where irrigated producers could sell their water in lieu of irrigated crop production. Had this “market” been included in this study, the economic projections would vary from what is presented. Potential impacts of this market sell off could include; reduced commodity production within PGCD and reduced economic activity from agricultural input suppliers. Typically, agricultural producers receive a greater value for sold water in comparison to what can be generated on the farm. Hence, it is possible that farm level revenue would increase or at least be maintained under the addition of an external water market.

The management plan proposed by PGCD allows production agriculture to continue to be profitable while setting a goal (50/50) which prevents excessive decline in groundwater resources. It is important to note that even with water conservation strategies such as the 50/50 in place, the economic activity of the region will change and in some cases decline as irrigation water availability is reduced through the mining of the Ogallala Aquifer.

V. LIMITATIONS

The results and projections in this study are based upon a given set of data points and assumptions. As with any projection analysis there are limitations to the results based on the assumptions, data, and time frame used in the modeling process. Through the course of this study the input data and assumptions utilized were considered accurate to the best ability of the parties involved in its collection. This study was only able to make projections from an aggregated or representative level, relying heavily on average values for input data. Regional economic projections were based on current economic linkages and structures and no attempt was made to project how the economy would change through time. In addition, no attempt was made to project changes in land value through time. In order to capture the impacts of the policy evaluated (50/50) certain variables had to be held constant. Sensitivity or distribution analysis was not conducted due to the length of the planning horizon and the ad hoc approach that would be necessary to include additional projected or random data.

Agricultural water use was the focus of the study and other uses such as municipal, industrial, or other uses were not included in the projections. No attempt was made to capture potential impacts of water quality issues, as this was beyond the scope of the project. Crop production and irrigation requirements were based on average annual weather patterns for the region and annual rainfall was not simulated separately in the modeling process. Farm program enrollments were based on the 2008 farm bill criteria for direct and countercyclical payments for a farmer and a spouse. No payment limits were included. Crop insurance was based upon 65% coverage of Actual Production History (APH). Typical farming practices were assumed with irrigation pumping capacity based on a 2000 hour or 84 day pumping season. The hydrologic calculations within the models were calibrated to the observed decline in saturated thickness for the previous 12 year period in the PGCD.

The objective of this project was to estimate the economic impacts resulting from the implementation of water management strategies employed by the Panhandle Groundwater Conservation District. The procedure used in this study did not include any estimation of changes in farm land values. In addition, estimates made did not include any projections of changes in climate, drought, population growth, or expansions in regional industries such as confined livestock operations. Changes in these parameters were beyond the evaluation focus of the study.

Section II, Article III, Item III within the contract indicates that any datasets, computer models or programs developed with funding should be provided. No datasets, computer programs, or models were developed utilizing the granting funds.

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GLOSSARY

Desired Future Condition – the projected, quantified condition of a groundwater resource (such as water levels, water quality, springflows, or volumes) at a specified time or times in the future determined by groundwater conservation districts that is used to calculate managed available groundwater values. These conditions are used for regional water plans and permitting.

Employment - the total number of jobs (both full-time and part-time) throughout the economy that are needed, directly and indirectly, to deliver final demand for a specific commodity.

General Algebraic Modeling System (GAMS) – The General Algebraic Modeling System (GAMS) is specifically designed for modeling linear, nonlinear and mixed integer optimization problems. The system is especially useful with large, complex problems.

Groundwater Availability Model (GAM) – a computer model that includes comprehensive information on an aquifer, such as recharge (amount of water entering the aquifer); geology and how that conveys into the framework of the model; rivers, lakes, and springs; water levels; aquifer properties; and pumping.

Groundwater Management Area (GMA) – an area designated and delineated by the Texas Water Development Board as suitable for the management of groundwater resources.

Gross Margin – an estimate of farm profitability most commonly used on per acre basis and represents the gross revenue less cash expenses not including fixed expenses.

Impact Analysis for Planning (IMPLAN) – a complete input-output economic assessment package including data, software, and an external hard drive, providing economic resolution from the National level down to the ZIP code level. This tool is used to assess the economic impacts resulting from a change in one or several economic activities.

Industry Output - the value of total production of an economy or the total economic activity that occurs in a region.

Panhandle Groundwater Conservation District (PGCD) – consists of Carson, Donley, Gray, Roberts and Wheeler Counties, along with parts of Armstrong, Hutchinson and Potter Counties for a total of 6,309 square miles. The mission is to develop, promote, and implement water conservation, augmentation, and management strategies, to protect water resources for the benefit of the citizens, economy, and environment of the District.

Saturated Thickness – the vertical thickness of the hydrogeologically defined aquifer in which the pore spaces of the rock forming the aquifer are filled (saturated) with water.

Simulation and Econometrics to Analyze Risk (SIMETAR) – a software program designed to simulate risk as an addition within Microsoft Excel.

Value Added - the income or wealth portion of industry output that includes employee compensation, proprietary income, other property income, and indirect business taxes.

Addendum to Final Report for TWDB Contract #0903580958

TWDB Comments on Economic Impacts of Groundwater Management Standards in the Panhandle Groundwater Conservation District of Texas

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1. Please provide an electronic copy of the datasets, computer programs, and models developed under the terms of this contract (as outlined in Section II. Article III. Item III.)

   Response: No datasets, computer programs, or models were developed utilizing the granting funds.

2. Please include a table of contents, list of figures, and list of tables. Also include a glossary or index of terms *I* acronym definitions (IMPLAN, GAMs, DFCs, etc.). Distinguish throughout the report the two different "GAMs" - Groundwater Availability Models vs. General Algebraic Modeling System.

   Response: A table of contents, list of figures, list of tables, and glossary have been provided. Groundwater Availability Model is referenced as GAM. General Algebraic Modeling System is referenced as GAMS. An explanation of the differentiation is noted on page 8.

3. All TWDB Agricultural Water Conservation Grants are required to report actual water savings.
   - Please include an estimation of actual water savings resulting through implementation of this project, and an explanation of the methodology used for calculation.

     Response: This number is not easy to estimate over a long period of time. Water savings early in a planning horizon is available for use later in time and thus the "net" over fifty years can be very insignificant.

     For the "High Drawdown Farm" the numbers are as follows:

     Total Water savings the first 20 years on the high drawdown farm as a result of the policy evaluated – 3097 acre-feet or 2.75 acre-feet/irrigated acre or 0.16 acre-feet/irrigated acre/year

     Total Water savings over the 50 year planning horizon on the high drawdown farm - 1399 acre-feet or 1.25 acre-feet/irrigated acre or 0.025 acre-feet/irrigated acre/year.

     These numbers can be scaled but it is important to note that this will only be realized on acres with characteristics that match the hydrology of the "high drawdown farm".

4. In the Executive Summary, Senate Bill One is explained as being the underlying reason for the *50/50* management standard. Additional explanation about the subsequent HB 1763 desired future conditions process is also relevant to this project and should be explained.

    Response: The explanation of several pieces of applicable legislation, including Senate Bill One and HB1763, is now in Paragraph 2 of the Introduction.

5. Page 2. Paragraph 1. Please revise this sentence, "... as required by the TWDB, the PGCD implemented a 50 year management goal to ensure that at least 50% of supply will be available in 50 years."
    - While TWDB does require the DFCs to match the planning horizon (e.g., 50-year management goals), this statement incorrectly infers that TWDB required that 50% of supply be available in 50 years. Clarify that the PGCD *50/50* management standard was determined through working with the other districts in the Groundwater Management Area (GMA 1).

    Response: The statement was corrected.

6. Page 2. Paragraph 3. " ... the analysis did indicate a decline in the present value of net returns of $350 over a ten year period."
    - Please clarify whether the $350 figure is a 'per-acre' figure or the sum-total economic impact of the *50/50* management standard over the period on the Donley County High Drawdown Farm.
    - Please also correct this to correlate with the '20-year period' used in the farm-level analyses instead of the 'ten-year period' as stated here; or, to correlate with the 50-year planning horizon.

    Response: The $350 figure was clarified as net returns per acre over the 50-year planning horizon.

7. Page 2. Paragraph 4. "Further research should be conducted to better understand high impact areas and the associated irrigated operations."
    - Please explain why the "High Drawdown" farms are not representative of these "high impact areas". Include a map showing the proximity of potential high impact areas to the study areas and representative farms.

    Response: The sentence referencing “Further research…high impact areas” has been deleted.

8. Page 3. Paragraph 7. "Minnesota IMPLAN Group" is now "MIG, Inc.".
    - Please change references throughout text to MIG, Inc.

- First occurrence here (and on Page 6 where the explanation of the model is given) should mention that Minnesota IMPLAN Group is now MIG, Inc.

  Response: MIG,Inc. references have been changed.

9. Page 5. Methodology - general suggestions:
   - Please clarify which model inputs are random variables.

     Response: "Validation was used to insure that the random variables being simulated were correct and demonstrated characteristics of the parent distribution. In the case of the simulation model, the variables being simulated were stochastic yield and price. " as referenced on page 13.

   - Please provide additional detail including error bounds, confidence intervals, and sensitivity analysis.
     Response: Sensitivity or distribution analysis was not conducted due to the length of the planning horizon and the ad hoc approach that would be necessary to include additional projected or random data. – See Limitations on page 31

   - Please explain the level of model prediction error for 2010 saturated thickness and the certainty of projections.

     Response: "Assuming that saturated thickness and the GAM values for acre-feet of water in storage are synonymous, percentage changes from 2010 to 2060 were compared for the optimization model and the most recent baseline GAM run for the Panhandle Water Planning Group (PWPG) prepared by INTERA. These percentage changes (2010 to 2060) in water storage/saturated thickness indicated that the optimization models used in this study were within 3% of the baseline GAM projections made for the PWPG." – page 13

10. Page 5. Paragraph 3. Please explain in greater detail what comes out of the GAMS model and what goes into the IMPLAN model.

    Response: The results of the model include changes in crop acres, irrigated acres, and farm profitability over the planning horizon. The model also estimates the value of gross receipts from agricultural production for each irrigated and dryland crop by year.

11. Page 5. Paragraph 4. "The production functions were estimated with the aid of Leon New ... "

- Please explain that Leon New is a local crop consultant and agricultural engineer with exceptional knowledge and familiarity of the area, having _ years of experience working in the region.

  Response: "Dr. New is a local crop consultant and agricultural engineer with exceptional knowledge and familiarity of the area, having 40 years of experience working in the region." – page 9

12. Page 6. Paragraph 2. Please explain what is meant by the "baseline scenario."

    Response: "The baseline scenario projects the economic, agronomic, and hydrologic variables under the assumption that no management techniques are employed and farmers irrigate under an environment with no pumping restrictions." – page 8

13. Page 7. Paragraph 4. "20 year time horizon"
    - Please explain whether or not the twenty-year horizon used for the representative farms creates limitations on the applicability of this analysis over the 50-year planning horizon in determining the economic impacts of the PGCD *50/50* management standard. Include a brief mention of the level of uncertainty in the subsequent 30 years by those not being included in the scope of work for this project and how that ultimately may affect the accuracy and usability of this study in determining 50-year economic [and water resource] impacts to the region.

      Response: Explanation of analysis for two separate time horizons is offered on pages 10-11.

14. Page 7. Paragraph 4. "High Drawdown"
    - Please explain how rates of drawdown were determined. Include tables, figures, and discussion of correlation between groundwater withdrawals and the effects on saturated thickness. Include an explanation of how the irrigation water use demand projections were created.

      Response: " Each rate of drawdown was provided by PGCD." – page 10.

      Explanation of groundwater withdrawal effects on saturated thickness is on page 11.

15. Page 9. Paragraph 1. " ... the optimization models used in this study estimate water demand through an economic process which differs from the methods reported in the regional water plans GAM runs."
    - Please explain how the economic process used in the optimization models differs from the methods used in regional plans/GAM runs. Give a brief analysis and

comparison between the two. Add a table or figure showing how the water storage, saturated thickness, and groundwater withdrawals correlate over the study horizon with the projected irrigation demands developed by the Panhandle Regional Planning Group.

Response: Explanation and comparative analysis of optimization models and GAM runs is presented under the Validation section on page 13.

16. Page 9. Paragraph 1. " ... comparisons were made between the saturated thickness estimates ... and GAM runs completed by the TWDB (Intera 2010)."
  - Please explain what comparisons were made to the Intera models. Also consider including comparative analysis with the Region A 2007 water plan, work by Freese and Nichols Inc., and/or Dutton, Reedy, and Mace (2000).

  Response: "Assuming that saturated thickness and the GAM values for acre-feet of water in storage are synonymous, percentage changes from 2010 to 2060 were compared for the optimization model and the most recent baseline GAM run for the Panhandle Water Planning Group (PWPG) prepared by INTERA. These percentage changes (2010 to 2060) in water storage/saturated thickness indicated that the optimization models used in this study were within 3% of the baseline GAM projections made for the PWPG." – page 13

17. Page 9. Although the GAM model was used in the *50/50* scenario at the regional level and in this report's analysis, it might be more relevant to look at the GAM model results from the Groundwater Management Area 1 runs from the desired future condition process.

  Response: "…it must be noted that the optimization models used within this study estimate water demand through an economic process which differs from the methods reported in the regional water plans GAM runs. The economic process utilized within this model allocates water to land based upon if it is economical to irrigate or not. This "allocation" of water differs from projections made by groups such as INTERA, as their projections utilize only hydrologic parameters to estimate water in storage or pumping volumes." – As found in Validation on page 13

18. Page 9. Paragraph 4. Please explain the conditions of the "baseline scenario" for Carson and Donley counties.
  Response: Please see paragraph 2 under III. Results – Task I Results – Carson and Donley Counties.

19. Page 10. In the conclusions, although this study did not address the value of water it might be helpful to explain briefly if someone chose not to irrigate and chose to sell their

water instead to a water market, how that might or might not change the outcome of the impacts. In addition, although the *50/50* management strategy is not strictly a binding restriction, it might be helpful to elaborate in much more detail on what it is from the regional planning standpoint and the groundwater conservation district standpoint. Another factor that might be worth mentioning and could be better explained in this report is how the water quality changes as the aquifer is being pumped down and how that affects the economic impacts.

Response: The “water market” scenario is mentioned in the Conclusions section of the study on page 30.

“No attempt was made to capture potential impacts of water quality issues, as this was beyond the scope of the project.” – Limitations on page 31

20. Page 23. Please include a map showing the location of the two "hydrologic study areas".

Response: “These blocks were not specific to any location but rather scaled up versions of the representative farms. As with Task I, the changes in each of these study areas were aggregated and projected through the region.” – As stated in Results – Hydrologic Study Areas on page 26

21. Page 23. Paragraph 6. Given that the standard was not a binding restriction, please explain the function of IMPLAN in this analysis.

Response: “While there is no change in the regional economy under the management standard, the IMPLAN results provide an estimate of the economic contribution of agricultural crop production over the planning horizon.” – pages 29-30

22. Page 26. Table 13. Consider moving the description of Table 13 from page 23.

Response: The description was moved to the paragraph preceding Table 13 – page 29

23. Page 27. Paragraph 1. "Regional economic projections were based on current economic linkages ... no attempt was made to project how the economy would change through time. In addition, no attempt was made to project changes in land value through time."

- According to Task 3, the scope involves analysis of changes in enterprise levels, irrigated acres, and farm net income. Please explain why certain variables were not included in the analysis; for example, changes in farm land values that have increased over time, especially in recent years (i.e., from 2002 to 2007 respectively, $444 to $816 per acre in Carson County and $360 to $642 per acre in Donley County, according to the 2007 USDA-NASS Ag Census).

Response: “In order to capture the impacts of the policy evaluated (50/50) certain variables had to be held constant. Sensitivity or distribution analysis was not conducted due to the length of the planning horizon and the ad hoc approach that would be necessary to include additional projected or random data.” – Limitations on page 31

- Please include a brief discussion/disclaimer of regional and farm-level economic impacts that could be caused by other factors not included for analysis in this study (changes in national farm policy, land-use changes due to dairies and ethanol industries entering the region, global food shortages, population growth, climate variability, etc.).

  Response: “The procedure used in this study did not include any estimation of changes in farm land values.” – Limitations on page 31

24. Page 27. Paragraph 2. "Agricultural water use ... was based on average annual weather patterns."
    - Please mention the potential economic impacts and uncertainty due to changing weather patterns, climate change, etc.

      Response: “…estimates made did not include any projections of changes in climate, drought, population growth, or expansions in regional industries such as confined livestock operations. Changes in these parameters were beyond the evaluation focus of the study.” – Limitations on page 31

    - Consider updating the analysis by incorporating 2011 drought conditions and 2011 pumping data from PGCD. (TWDB acknowledges this would likely require a no-cost, one-year, time-extension amendment to the contract.)

      Response: Given the lengthy time horizon evaluated in this project (20 to 50 years) including a single outlying drought into a 50 year average weather pattern would not produce significantly different results or change long run pumping estimates for irrigation. To accurately estimate the long term impacts of drought the weather patterns within the modeling process must be adjusted in a manner which would represent a long term change in weather i.e. extreme drought expected 4 out of 5 years. Additionally, to conduct such a change in weather patterns under the current modeling process would require additional funds and was beyond the scope and objective of the original study.