Economic Analysis of Water Conservation Policies in the Texas Panhandle

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Abstract: Due to declining water availability from the Ogallala Aquifer, management policy alternatives for extending the life of the aquifer to sustain rural economies in the Texas Panhandle are evaluated. The study concludes that water conservation policies for the region significantly impact crop mix, resource usage, and net present value of farm profits over a sixty-year planning horizon.

Key Words: Ogallala Aquifer, Groundwater Conservation, Water Management Policy, Texas Panhandle

Introduction:

The availability of water in the Texas Panhandle is a major concern, as is the conservation of the limited supply of water in the region. The Texas High Plains area has a semi-arid climate and average low rainfalls which results in little surface water being available year-round for agriculture. Thus, more than 90% of the water used in agriculture in the High Plains area comes from the Ogallala Aquifer (Stewart, 2003 and Jenson, 2004). The aquifer covers about 36,080 square miles and it currently has a supply of water of approximately 6.1 million acre feet of water, which is expected to decline to 4.8 million acre feet by 2060 (Jenson, 2004). From 1994 to 2004, the aquifer declined at an average of 1.28 feet per year (Jenson, 2004). Adding to the problem is the low recharge rate of the aquifer in the High Plains area (Postel, 1998). In the southern region, the recharge rate has been reported to be as low as 0.024 inches per year from precipitation (Ryder, 1996).

The use of low-energy-application (LEPA) and low-energy-spray-application (LESA) have allowed for more efficient use of water in the region (Howell, 2001). However, producers have had the benefit of increased technology in drilling and installing these systems, which has led to increased irrigation use. In the southern High Plains, which uses intense irrigation, the decline in the water table has been estimated to be between 50 and 100 feet (Ryder, 1996). A contributing factor to the increased use of groundwater comes from the state laws covering the right of capture of ground water beneath the land, by which the land owner may capture the water beneath the land regardless of the effect on nearby or distant users of the water supply (Stewart, 2003). A survey conducted in 2003 showed that of 63,602 operating wells, only 4,530 wells had a meter installed (NASS, 2004). Finally, recent trends in purchasing “water rights” and the potential uses of the water associated with these rights threaten to result in further depletion.

The main goal of any conservation policy is to limit the use of a resource in an effort to preserve the quantity of that resource. Thus the purpose behind a policy to restrict groundwater use is to prevent aquifer depletion in an effort to assure a continued supply of water for many years to come. This is very important when a region is rural in nature and in which the local economy is heavily dependent on agriculture. Such is the case in the Texas Panhandle. In an effort to increase returns, producers have focused heavily on producing irrigated crops, due in large part to low energy costs to apply irrigation water in the earlier years, and more recently the adoption of new technology that improves efficiency and reduces costs. However, continued pumping of groundwater at the present levels will draw the aquifer down to the point where it will no longer be economically feasible to irrigate, which will result in a greater negative economic impact for the region. The implementation of a water conservation policy will ideally prolong the life of the aquifer in an effort to maintain the economy of the rural Texas Panhandle for many years to come. In choosing an appropriate policy, the benefits (in this case decreased drawdown of the aquifer) need to be weighed with the costs (reduced producer and resource supplier revenues due to reduced irrigated crop acres).

Research Objectives:

This study compares a base scenario of no restriction on irrigation for sixty years with three conservation policies: a 10% reduction in the irrigated acreage representing a water conservation reserve program, a 50% reduction in water pumped and used, and a 100% reduction in water use representing a water right buyout program. The objectives of this study are to determine the effectiveness of each policy in conserving water (expressed in terms of saturated thickness of the aquifer), as well as the effect of each policy on the crop mix (irrigated versus dry land), change in major crops, resource usage, and the net present value of producer profits over the sixty year scenario period. The specific crops to be examined are irrigated corn, irrigated soybean, irrigated and dry land sorghum and irrigated and dry land wheat. The specific resources examined include nitrogen fertilizer, labor, gasoline, diesel, and natural gas.

Data and Research Methodology:

This study will utilize optimization models developed for the Ogallala Aquifer Initiative (Almas et al, 2006 and Park, 2005) to compare a base line scenario with no reduction with three policy alternatives, including a water conservation reserve program in which it will be assumed that 10% of the irrigated acreage will be converted to dry land acreage, a policy in which a limit on water use is imposed that reduces the amount of water that can be pumped and is available for use by 50%, and a water right buyout in which 100% of the water is no longer available for irrigation resulting in all irrigated acreage converting to dry land crops. These policies were incorporated into the aquifer models by restricting the amount of water available in the simulating process. The simulations were then run for a period of sixty years to observe the shifts from irrigated to dry land crops. These models provided the saturated thickness, crop mix, resource usage and cost, and profit for each county for each of the sixty years. The results for each policy were then compared to the base scenario to determine the effectiveness of the policy on reducing the drawdown of the aquifer (in terms of saturated thickness of the aquifer for each county in feet), and the changes in the crop mix, resource use, and net present value of profits under the three scenarios during the sixty year period. Results for three counties (Dallam, Castro, and Ochiltree) are also presented to demonstrate the varied results specific to each county due to the diverse nature of agriculture in each county.

Results and Discussion:

The first issue to be addressed is the effectiveness of each policy scenario in conserving water. As Figure 1 shows, the average saturated thickness of the Ogallala Aquifer with no restriction begins at 129.33 feet, and gradually declines to 105.75 feet by year sixty. As Table 1 shows, the saturated thickness in the region is not uniform, and ranges from 20.97 feet in Oldham County to 266.78 feet in Roberts County. However, each county has a different level of usage during the sixty year period. For example, Dallam County starts 124.22 feet of saturated thickness in the base model and each scenario, Castro County begins at 108.77 feet, and Ochiltree County at 194.07. After sixty years, the water level in Dallam County dropped to 67.82 feet, while the level in Castro County dropped 54.76 feet and Oldham County to 151.67 feet. Both Dallam and Castro Counties dropped nearly 50%, while Ochiltree dropped just over 20%. This is due to the fact that agriculture in Ochiltree County is focused more on wheat production which requires less irrigation than corn, which is dominant in Dallam County.

Under the 10% reduction in irrigated acreage policy, the aquifer declines an average of 0.37% per year to reach a level of 111.60 feet after sixty years, which is a loss of 27.69 feet in saturated thickness. With this policy, the ending average saturated thickness is just 80.12% of the original thickness, representing a savings of nearly 5% of the original thickness. Under this conservation policy, the ending level of the aquifer in Dallam County was 67.80 feet, which is nearly the same level under the base line scenario with no restriction. The importance of irrigated crops in this county is such that even though 10% of the irrigated acreage is converted to dry land use, there is not a significant level of conservation occurring in the models. However, the level in Castro County after sixty years 68.30 feet, as compared to 54.76 with no policy, and the level in Ochiltree dropped to 162.30 feet. This shows that those counties less dependent on irrigation will show the greatest conservation under this policy.

Under the 50% reduction policy, the average saturated thickness decreases a mere 0.22% per year average, to reach a final level of 121.88 feet. This is a loss of just 17.41 feet in saturated thickness, and represents a decline of 12.50% of the original level. Under this policy, the level in Dallam County fell to 96.02 feet compared to the 67.82 feet under no policy. This reflects a significant savings of water compared to the 10% acreage reduction policy for that county. In Castro County, the level fell to 81.76 feet, and in Ochiltree County it fell to 172.87 feet, compared to 68.30 and 162.30 feet, respectively, under the 10% acreage reduction policy. Here again it is obvious that the 10% irrigated acreage reduction policy is not as effective as a policy centered on reducing water pumping by 50%. As would be expected, the 100% reduction policy results in there being no irrigated acreage in any county, with all irrigated acres being converted to dry land use, and the saturated thickness for each county remains at the beginning level. This represents the extreme case of water conservation and the most successful in terms of water savings, though as will be shown later, this is at a great cost to producers and resource suppliers.

As producers pump water out of the aquifer and the saturated thickness declines, the cost to pump increases due to the increased lift the irrigation wells have to carry. This increased cost leads to less efficient producers switching to dry land crops as they can no longer afford to irrigate their crops. Over the sixty year scenario in this study, the crop mix changes to reflect more and more producers making the switch as costs continue to increase the more the aquifer is drawn down. As Figure 2 shows, the percentage of irrigated acres to total acres begins at 60%. Under the no policy base scenario, the percentage of irrigated acres declines gradually to just fewer than 9.11% by the sixtieth year. The crop mix under the 10% acreage reduction falls to

7.44% of total acreage, and under the 50% water use reduction it falls to 6.64%. Under the 100% reduction, it is assumed that there will be no irrigation occurring during the sixty year period, and thus there will be no acreage in irrigated crops. This shows that there is very little difference in the ending crop mix between the scenarios, though there is a significant difference in each county. For example, in Dallam County, as Table 2 shows, the amount of acreage in irrigated crops starts at 78.9% and declines to 17.45% in year sixty under the base line scenario. The amount of irrigated crops in that county falls to 12.88% under the 10% acreage reduction scenario, and 7.75% in the 50% water use reduction scenario. In Castro County, it begins at 80.43% and falls to 19.57% under the base scenario, as well as both the 10% acreage and 50% water use reduction scenarios. For Ochiltree County, the beginning amount in irrigated acreage is 29.29%, and this falls to 8.46% in the base model in year sixty, and it falls to 8.91% in the 10% scenario and to 4.88 in the 50% scenario. It is obvious by looking at Figure 1 though that the shift occurs much quicker under the 50% reduction as compared to the 10% acreage reduction.

With no reduction in water use (Table 3), irrigated corn planted drops from 22.4% of the total acreage in the region to 2.33% in year sixty. This is a drop from 670,634 acres to 69,790 acres. Under the same policy, irrigated soybeans drops from 54,713 acres to 116 acres or from 1.83% to nearly 0%. Irrigated sorghum drops from 170,233 acres to 310 acres, or from 5.69% of total acreage to 0.01%, and dry land sorghum drops from 372,338 acres, or 12.44%, to 110,406 acres, or 3.69%. Irrigated wheat falls from 19.51%, which is 19.51 aces, to 0.09%, or 2,815 acres. However, most of this shift is from these crops to dry land wheat, which starts at 26.12% of total crop acreage, or 781,784 acres, to 85.32%, which is 2,553,897 acres.

Under a 10% acreage reduction policy, these shifts occur more rapidly. As Table 4 shows, irrigated corn falls to 1.18%, or 35,210 acres, compared to the 2.33% under no reduction in water use. With restricted use, irrigated soybeans and irrigated sorghum fall to about the same levels as under the no restriction scenario, though not as quickly. Dry land sorghum falls from 372,338 acres to 111,109 acres, or about 3.71% compared to the 3.69% under the no restriction policy. Irrigated wheat acreage drops even slower, from 584,049 acres to 2,815 acres. However, dry land wheat acreage grows and at a higher rate as once again a shift occurs from all crops to dry land wheat. Dry land wheat acreage reaches 2,609,440 acres, or 87.17% of total crop acreage, under the 25% reduction scenario.

Under the 50% water use reduction policy (Table 5) shows, irrigated corn as a percentage of total crops falls to 2.79% in year fifty, compared to 3.89% under the 25% reduction scenario and 5.15% under no reduction in water use. However, it begins to grow slightly in the last ten years under investigation to reach a total of 51,552 acres, or 1.72%. Irrigated soybeans irrigated sorghum, and irrigated wheat all fall about the same under the 50% scenario as they did under the 25% scenario. However, dry land wheat acreage increased even faster under the 50% scenario than it did under the 10% acreage reduction scenario, increasing to 89.55% of total acreage, or 2,680,618 acres. Under the 100% water use reduction scenario (Table 6), all of the irrigated acreage is shifted to dry land acreage. Wheat acreage rose from 26.12% in the base year to 86.48% in year 20, 90.12% in year 40, and 94.62% in year 60. Dry land sorghum acreages fluctuated but generally declined as the model shifted more to dry land wheat production than other dry land crops.

While water conservation is of greatest concern, the effects of any water use reduction policy must be considered. It is important to keep in mind the actual savings gained by the policy and the benefit of that savings, as well as the speed with which the water savings occurs. Water conservation has many negative affects as well that need to be considered though when deciding on a policy. All of the costs both direct and indirect, associated with implementing the policy must be considered. Most of the direct costs can easily be calculated, but the indirect costs are not so obvious without a detailed analysis of the policy and all of its effects. One example of these negative effects is the impact the policy has on resource markets and producer profits. Tables 7, 8, 9, and 10 present the levels of resources in the base line scenario with no restriction, the 10% acreage reduction, and the 50% and 100% water use reduction policies.

In the base line scenario (Table 7), the models showed that 241.2 million pounds of nitrogen fertilizer were used in the base year. That level gradually declined to 87.3 million pounds by the sixtieth year. The annual decline ranged from 5.39% from year one to year two, down to 1.24% from year 59 to year 60, and the average annual decline was 1.68%, and the total nitrogen fertilizer consumed during the entire period was 8.9 billion pounds. Under the 10% acreage reduction scenario (Table 8), the consumption of nitrogen fertilizer fell to 74.8 million pounds by year sixty, which was a reduction of 14.35% from that used under no restriction. Under the 10% policy, a sixty-year total of 7.5 billion pounds of nitrogen fertilizer was consumed, which was a total reduction of 16.3% compared to the total consumed under no reduction. In the 50% water use reduction scenario (Table 9), the consumption fell to 75.2 million pounds in year sixty. This consumption level is higher than under the 10% scenario due to the slight increase in corn production experienced in the last ten years of the study as noted above. Under the 50% scenario, a total of 6.1 billion pounds of nitrogen fertilizer was consumed during the sixty year period, which was a reduction of 31% from that consumed under the base line scenario. In the 100% reduction scenario (Table 10), the use of nitrogen fertilizer fell to

72.1 million ponds in year ten, 64.7 million pounds in year sixty, and the sixty year total was 4.2 billion pounds.

Probably the most important resource to agriculture is labor. As Tables 7, 8, 9, and 10 shows, any reduction policy is going to have a negative impact on the amount of labor demanded by farming operations. In the base year, 4.1 million hours of labor were used. Under the base line scenario (Table 7), this level fell to a low of 2.8 million hours in year sixty. The average annual decline during the period was 0.61%. For the entire sixty year period, a total of 204.0 million hours of labor were consumed in the model. Under the 10% acreage reduction scenario (Table 8), the amount of labor used in the sixtieth year was 2.5 million hours, a decrease of 3.08 million hours compared to no reduction. The total labor consumed under the 10% reduction policy was 176.7 million hours, a decrease of 27.3 million hours. In the 50% reduction policy, labor used in the sixtieth year fell to 2.5 million hours, and the total consumed over the entire period was 158.6 million hours, 22.22% less than without a water conservation policy. In the 100% reduction scenario, labor use fell to 2.2 million hours in year sixty, and the total for all sixty years was 125.4 hours.

As would be expected, the consumption of natural gas declined under all three conservation scenarios. In the base year, 25.8 million MCF of natural gas was consumed. In the base line scenario, this level decreased about 1.84% per year, to reach a level of 8.4 million MCF in year sixty. However, the use of natural gas declined an average of 2.15% per year under the 10% scenario, resulting in a consumption level of 6.5 million MCF in year sixty, and it declined an average 2.53% annually under the 50% scenario to reach a level of 4.3 million MCF in year sixty. Under the 100% reduction policy, natural gas consumption fell 2.2 million MCF in year sixty. Total consumption during the entire period fell from 741.6 million MCF under no restriction to 584.8, 398.4, and 200.9 million MCF in the 10%, 50%, and 100% scenarios, respectively. The consumption of diesel and gasoline also fell in the three policy scenarios. Diesel usage for the base year was 9.1 million gallons and gasoline usage was 6.3 million gallons. In the base line scenario, the consumption of each fell to 6.7 and 6.0 million gallons in year sixty, respectively. Under the 10% scenario, the level of consumption fell to 6.0 and 5.4 million gallons, in the 50% scenario they fell to 5.9 and 5.2 million gallons, and in the 100% scenario they fell to 5.1 and 4.5 million gallons respectively. Total consumption of diesel for the entire period fell from 463.5 million gallons in the base line scenario, to 403.3 million gallons in the 10% acreage reduction policy, 366.4 million gallons under the 50% water use reduction policy, and 294.5 million gallons in the 100% reduction scenario. Total gasoline usage fell from 373.4 million gallons in the base line scenario to 328.7 million gallons in the 10% acreage reduction scenario, and to 305.9 and 251.5 million gallons in the 50% and 100% water reduction scenarios.

The decline in resource usage by the alternative policies represents a loss of income, as well as a loss of jobs, in these resource markets. Without a conservation policy, suppliers can gradually adapt to changes in resource demand, but with a policy designed to reduce water consumption, they have less time to adapt, resulting in economic hardship for those suppliers. There is also an effect on producers in terms of lost revenues accompanying the switch to dry land crops. However, unlike resource suppliers, producers may be compensated for the loss in revenue associated with the implementation of a conservation policy. This loss of producer income needs still needs to be considered though in a policy analysis as any subsidies paid may not fully cover the lost revenue.

Table 11 presents the net present value of producer profits in the base line scenario as well as the three policy alternatives considered in this study for the counties overlying the Ogallala Aquifer in the Texas Panhandle for the sixty year period. As is shown, the difference in net present value of the profits for each county between the three alternatives varies significantly, with the greatest difference in dollar terms occurring in Dallam County. For that county, the NPV under the no restriction policy was $177.5 million, and it was $139.9 million and $116.3 million under the 10% and 50% policy, respectively. This is a 21.21% decrease under 10% acreage reduction and a 34.52% decrease under the 50% water use reduction. In the 100% water reduction scenario, the net present value of producer profits in Dallam County fell to $24.9 million. This is a significant loss to those producers located in Dallam County.   In Castro County, the net present value of producer profits fell from $114.2 million in the base line scenario to $94.6 million in the 10% acreage reduction scenario, $83.2 million in the 50% water use reduction scenario, and $19.3 million in the 100% reduction scenario.

The second and third most significant changes in dollar terms resulting from a 10% acreage reduction policy occurred in Swisher County ($35.9 million) and Moore County ($34.1 million). This was a 36.69% and 28.09% change for each county, respectively. Under the 50% water use reduction policy, the second and third greatest decreases occurred in Hartley County ($31.0 million) and Moore County ($43.9 million). In terms of percentage loss, Swisher County had the greatest decrease under the 10% scenario with a 36.69% decrease in NPV, while Hartley County experienced a 51.47% decrease under the 50% scenario. In fact, the five counties affected by the 25% reduction the most all had a decline in NPV greater than 27%, reflecting their greater reliance on irrigated crops. For the entire region, the NPV in the base line scenario $1,401.1 million dollars, and it was $1,139.2 under the 10% reduction and $1,003.171 million under the 50% reduction. The total percentage decrease for the region was 18.69% and 28.40%, respectively. This clearly shows that any policy aimed at reducing irrigation will have a significant economic impact on the region, with some counties experiencing severe losses in revenues. This is a major concern that must be addressed when considering policy alternatives, as these losses, when combined with the lost resource demand, will have a significant impact on rural economies that rely on agriculture.

Conclusion:

As has been shown, any policy designed to reduce water consumption and irrigation will have significant effects on all areas of agriculture in the Texas Panhandle. It is obvious that water conservation is of greatest importance, and new technology has made agriculture more efficient in the use of water. However, many argue that enough is not being done to save this precious natural resource to assure its availability to agriculture in the future and that policies must be implemented to force producers to decrease their levels of irrigation. Agriculture in the Texas Panhandle is very dependent on irrigation, as are the local communities and businesses in those counties. While arguing for or against any one policy under consideration is outside the scope of this article, we have shown the effects of three policy alternatives on the amount of water conserved, producer profits, and resource usage.

Under a no-reduction scenario, resource suppliers and producers have the full sixty years to absorb the changes caused by the decline in the Ogallala Aquifer level. As the water level draws down, the cost to irrigate rises as more energy is required to lift the water to the surface. This creates a natural decline in irrigation as the most inefficient producers begin to switch to non-irrigated crops. A policy designed to restrict irrigation will cause this change to occur more quickly as all producers are required to comply with the reduction immediately. The result is a sharper and quicker shift away from irrigated crops, as well as a faster decrease in the demand for those resources needed for irrigated crops, with the greatest shift occurring under a 100% water use reduction plan, and the least with a 10% acreage reduction plan. Overall, this causes a loss of income not just for producers, but the resource suppliers and communities where the policies are implemented, with the 100% reduction plan having the greatest economic impact to both producers and resource suppliers. The rural communities where agriculture is most reliant on irrigation will be the most affected by the policy, while urban communities and those communities in counties that are less reliant on irrigation will absorb the change more easily. All of these concerns must be addressed when deciding on any policy designed to restrict water used for irrigation.

Bibliography:

Almas, Lal K., W. Arden Collette, and Seong C. Park. 2006. "Economic Optimization of Groundwater Resources in the Texas Panhandle." Selected Paper presented at the SAEA Annual Meeting, Orlando, Florida, February 5-8, 2006.

Howell, Terry A. 2001. "Enhancing Water Use Efficiency in Irrigated Agriculture." Agronomy Journal, 93, pp 281-289 (2001).

Jensen, R. 2004. Ogallala Aquifer: Using improved irrigation technology and water conservation to meet future needs. Texas Water Resource Institute. http://twri.tamu.edu/newsarticles.php?view=2004-08-05, accessed December 8, 2005.

NASS (National Agricultural Statistical Service). 2004. Farm and Ranch Irrigation Survey (2003). 2002 Census of Agriculture, http://www.nass.usda.gov/census, accessed December 2, 2005.

Park, Seong C. 2005. "Economic Optimization of Groundwater Resources in the Texas Panhandle." M.S. Thesis, West Texas State University, Division of Agriculture, Canyon, Texas.

Postel, Sandra A. 1998. "Water for Food Production: Will There be Enough in 2005." BioScience, 48:8, pp 629-637 (1998).

Ryder, P.D. 1996. (United States Geological Survey). Geological Survey-Ground Water Atlas of the United States, Oklahoma, and Texas. http://capp.water.usgs.gov/gwa/ch_e/E-text5.htnl, accessed December 16, 2005.

Stewart, B.A. 2003. Aquifers, Ogallala. Encyclopedia of Water Science, pp. 43-44 (2003).

Figure 1: Change in Regional Average Saturated Thickness

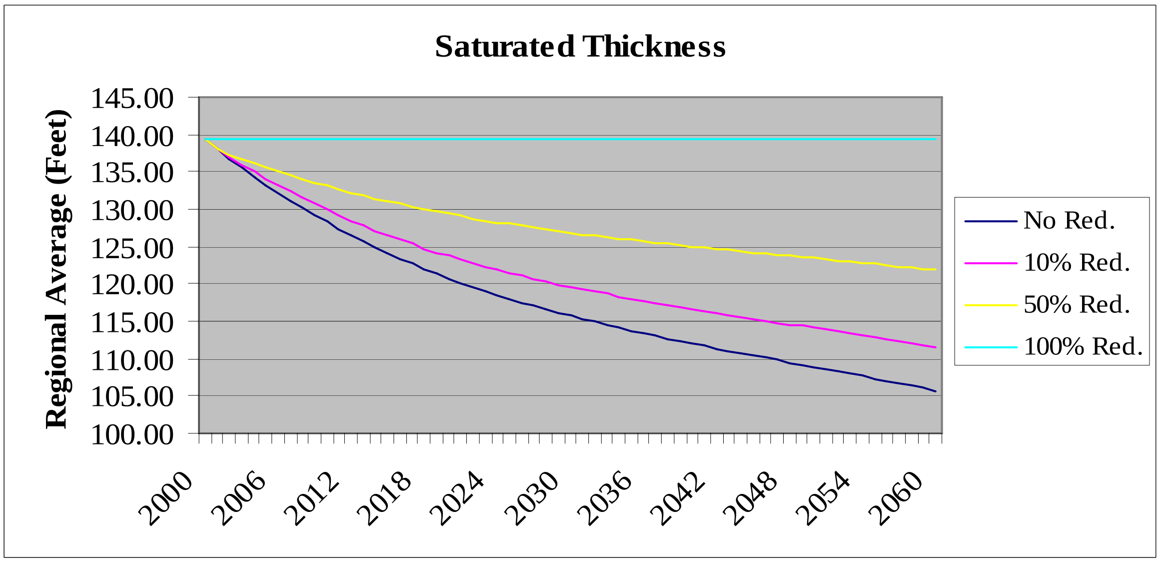

Figure 2: Change in Crop Mix-Percentage of Total Acres Planted in Irrigated Crops

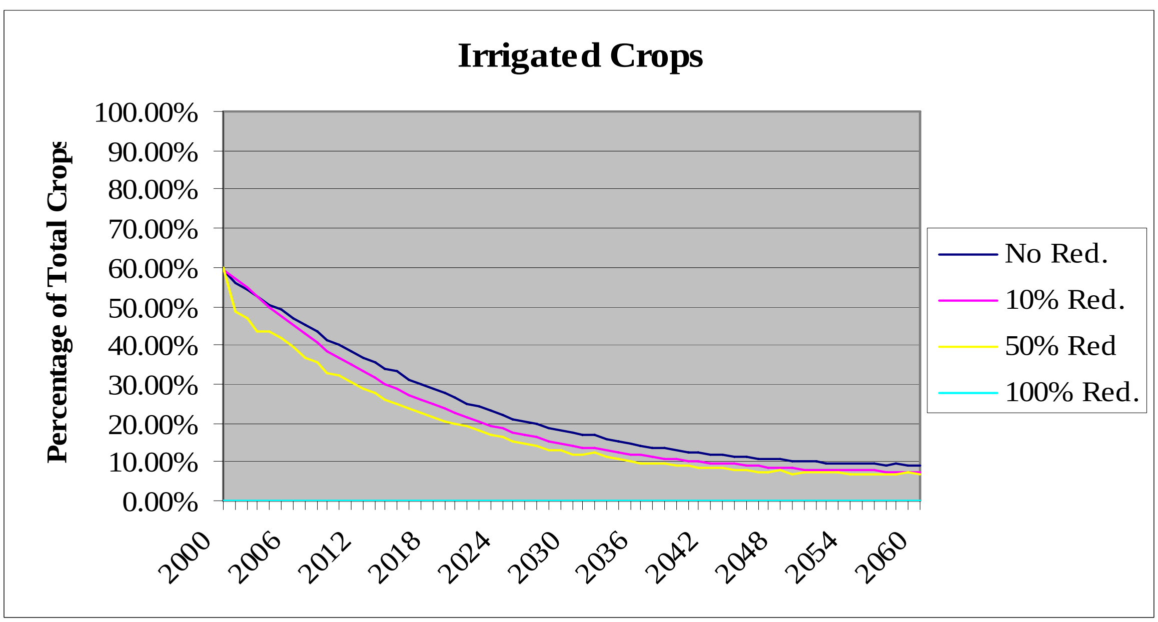

Table 1: Change in Saturated Thickness over 60 years for each county

	No Reduction		10% Reduction		50% Reduction		100% Reduction	
	Beg ST (Ft)	End ST (Ft)	Beg ST (Ft)	End ST (Ft)	Beg ST (Ft)	End ST (Ft)	Beg ST (Ft)	End ST (Ft)
Armstrong	71.86	70.58	71.86	70.90	71.86	71.22	71.86	71.86
Briscoe	63.86	49.25	63.86	53.55	63.86	56.99	63.86	63.86
Carson	145.18	126.16	145.18	130.91	145.18	135.67	145.18	145.18
Castro	108.77	54.76	108.77	68.26	108.77	81.76	108.77	108.77
Dallam	124.22	67.82	124.22	67.82	124.22	96.02	124.22	124.22
Deaf Smith	126.07	75.42	126.07	75.42	126.07	100.75	126.07	126.07
Donley	93.75	81.18	93.75	81.18	93.75	87.47	93.75	93.75
Gray	132.79	121.53	132.79	121.53	132.79	127.16	132.79	132.79
Hansford	207.95	160.55	207.95	172.40	207.95	184.25	207.95	207.95
Hartley	167.47	109.16	167.47	123.73	167.47	138.31	167.47	167.47
Hemphill	169.00	168.78	169.00	168.83	169.00	168.89	169.00	169.00
Hutchinson	155.33	145.80	155.33	148.18	155.33	150.56	155.33	155.33
Lipscomb	194.85	191.49	194.85	192.33	194.85	193.17	194.85	194.85
Moore	166.96	97.64	166.96	114.97	166.96	132.30	166.96	166.96
Ochiltree	194.07	151.67	194.07	162.27	194.07	172.87	194.07	194.07
Oldham	20.97	20.69	20.97	20.76	20.97	20.83	20.97	20.97
Parmer	81.30	34.28	81.30	46.03	81.30	57.79	81.30	81.30
Potter	74.83	67.05	74.83	68.99	74.83	70.94	74.83	74.83
Randall	63.09	49.54	63.09	52.93	63.09	56.31	63.09	63.09
Roberts	266.78	263.91	266.78	264.63	266.78	265.35	266.78	266.78
Sherman	183.57	127.20	183.57	141.29	183.57	155.38	183.57	183.57
Swisher	85.02	35.44	85.02	47.84	85.02	60.23	85.02	85.02
Wheeler	105.91	101.27	105.91	102.43	105.91	103.59	105.91	105.91

Table 2: Irrigated Acreage as a Percent of total Acres for selected counties

	Beginning %	No Red. Ending %	10% Red. Ending %	50% Red. Ending %
Castro	80.43%	19.57%	19.57%	19.57%
Dallam	78.90%	17.45%	12.88%	7.75%
Ochiltree	29.29%	8.46%	5.91%	4.88%

Table 3: Percent of Total Acres Planted in Major Crops with no Reduction, Selected Years

	Irrigated Corn	Irrigated Soybean	Irrigated Sorghum	Dry land Sorghum	Irrigated Wheat	Dry land Wheat
2000	22.40%	1.83%	5.69%	12.44%	19.51%	26.12%
2010	16.96%	0.76%	2.01%	6.77%	13.58%	49.92%
2020	14.07%	0.26%	0.70%	4.22%	6.36%	66.47%
2030	11.57%	0.09%	0.24%	3.45%	2.22%	76.57%
2040	8.87%	0.03%	0.09%	3.32%	0.75%	81.74%
2050	5.15%	0.01%	0.03%	3.51%	0.27%	84.48%
2060	2.33%	0.00%	0.01%	3.69%	0.09%	85.32%

Table 4: Percent of Total Acres Planted in Major Crops with 10% Reduction, Selected Years

	Irrigated Corn	Irrigated Soybean	Irrigated Sorghum	Dry land Sorghum	Irrigated Wheat	Dry land Wheat
2000	22.40%	1.83%	5.69%	12.44%	19.51%	26.12%
2010	12.82%	0.87%	2.35%	7.59%	15.05%	51.49%
2020	11.14%	0.30%	0.74%	4.53%	6.81%	68.77%
2030	9.63%	0.10%	0.28%	3.57%	2.12%	79.11%
2040	7.27%	0.03%	0.10%	3.37%	0.73%	83.90%
2050	3.89%	0.01%	0.03%	3.53%	0.18%	86.43%
2060	1.18%	0.00%	0.01%	3.71%	0.09%	87.17%

Table 5: Percent of Total Acres Planted in Major Crops with 50% Reduction, Selected Years

	Irrigated Corn	Irrigated Soybean	Irrigated Sorghum	Dry land Sorghum	Irrigated Wheat	Dry land Wheat
2000	22.40%	1.83%	5.69%	12.44%	19.51%	26.12%
2010	7.44%	0.72%	2.43%	8.66%	14.20%	58.22%
2020	7.48%	0.24%	0.70%	4.95%	5.79%	75.13%
2030	6.81%	0.11%	0.25%	3.81%	1.44%	84.12%
2040	4.94%	0.04%	0.10%	3.53%	0.51%	87.68%
2050	2.79%	0.01%	0.03%	3.64%	0.31%	89.27%
2060	1.72%	0.00%	0.01%	3.81%	0.11%	89.55%

Table 6: Percent of Total Acres Planted in Major Crops with 100% Reduction, Selected Years

	Irrigated Corn	Irrigated Soybean	Irrigated Sorghum	Dry land Sorghum	Irrigated Wheat	Dry land Wheat
2000	22.40%	1.83%	5.69%	12.44%	19.51%	26.12%
2010	0.00%	0.00%	0.00%	8.87%	0.00%	82.36%
2020	0.00%	0.00%	0.00%	6.18%	0.00%	86.48%
2030	0.00%	0.00%	0.00%	4.33%	0.00%	88.74%
2040	0.00%	0.00%	0.00%	3.88%	0.00%	90.12%
2050	0.00%	0.00%	0.00%	3.92%	0.00%	92.08%
2060	0.00%	0.00%	0.00%	4.08%	0.00%	94.62%

Table 7: Input Usage for Selected Years, No Reduction, Selected Years

	Nitrogen Fertilizer	Labor	Natural Gas	Diesel	Gasoline
	(Mil. Lbs.)	(Mil. Hrs.)	(Mil. MCF)	(Mil. Gals.)	(Mil. Gals.)
2000	241.156	4.126	25.838	9.063	6.306
2010	192.733	3.749	18.084	8.334	6.214
2020	162.564	3.518	13.052	7.919	6.217
2030	138.422	3.274	9.607	7.476	6.134
2040	120.609	3.101	7.953	7.159	6.074
2050	101.326	2.958	7.630	6.892	6.043
2060	87.300	2.849	8.412	6.677	6.025

Table 8: Input Usage for Selected Years, 10% Reduction, Selected Years

	Nitrogen Fertilizer	Labor	Natural Gas	Diesel	Gasoline
	(Mil. Lbs.)	(Mil. Hrs.)	(Mil. MCF)	(Mil. Gals.)	(Mil. Gals.)
2000	241.156	4.126	25.838	9.063	6.306
2010	157.163	3.207	14.167	7.171	5.349
2020	134.451	3.032	10.192	6.853	5.396
2030	116.566	2.846	7.551	6.525	5.393
2040	102.830	2.730	6.248	6.320	5.376
2050	86.981	2.630	5.954	6.134	5.363
2060	74.775	2.541	6.508	5.963	5.359

Table 9: Input Usage for Selected Years, 50% Reduction, Selected Years

	Nitrogen Fertilizer	Labor	Natural Gas	Diesel	Gasoline
	(Mil. Lbs.)	(Mil. Hrs.)	(Mil. MCF)	(Mil. Gals.)	(Mil. Gals.)
2000	241.156	4.126	25.838	9.063	6.306
2010	117.905	2.671	9.378	6.063	4.640
2020	105.991	2.615	6.795	5.998	4.874
2030	95.280	2.531	5.023	5.875	4.982
2040	87.830	2.516	4.159	5.885	5.099
2050	79.993	2.494	3.970	5.864	5.168
2060	75.172	2.491	4.338	5.861	5.197

Table 10: Input Usage for Selected Years, 100% Reduction, Selected Years

	Nitrogen Fertilizer	Labor	Natural Gas	Diesel	Gasoline
	(Mil. Lbs.)	(Mil. Hrs.)	(Mil. MCF)	(Mil. Gals.)	(Mil. Gals.)
2000	241.156	4.126	25.838	9.063	6.306
2010	72.129	1.903	4.863	4.411	3.465
2020	69.105	1.944	3.537	4.543	3.820
2030	65.585	1.956	2.626	4.618	4.047
2040	63.959	2.042	2.175	4.838	4.280
2050	63.151	2.103	2.065	4.990	4.419
2060	64.728	2.178	2.238	5.144	4.484

Table 11: Net Present Value of Profits over 60 Years ($Millions)

County	No Red.	10% Red.	50% Red.	100% Red.
Armstrong	41.254	36.759	36.684	34.960
Briscoe	21.288	18.321	17.614	11.240
Carson	97.317	78.425	76.171	44.050
Castro	114.192	94.554	83.168	19.280
Dallam	177.539	139.890	116.259	24.930
Deaf Smith	85.755	74.064	70.779	37.800
Donley	17.725	12.679	9.803	4.400
Gray	42.330	36.171	29.167	26.170
Hansford	47.201	36.847	27.725	14.200
Hartley	113.197	82.185	54.940	8.160
Hemphill	5.655	5.079	5.026	5.250
Hutchinson	44.603	39.149	38.560	19.530
Lipscomb	24.189	18.117	18.994	18.520
Moore	121.259	87.201	77.396	32.660
Ochiltree	143.230	122.624	113.904	102.450
Oldham	15.431	13.855	13.830	12.480
Parmer	89.043	72.562	67.661	21.360
Potter	9.470	8.660	8.754	8.690
Randall	35.527	29.361	28.146	15.070
Roberts	10.512	9.386	10.490	5.540
Sherman	74.005	56.256	38.508	20.250
Swisher	97.780	61.908	54.596	19.790
Wheeler	7.949	5.172	4.996	7.950
Total Region	**$1,401.138**	**$1,139.226**	**$1,003.171**	**$514.730**