FINAL REPORT

Potential Economic Impacts from Groundwater Regulation in the Republican Valley

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with

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In 1998 Kansas sued Nebraska alleging that Nebraska had violated the Republican River Compact "by allowing the proliferation and use of thousands of wells hydraulically connected to the Republican River and its tributaries . . ." In 1999 the Special Master appointed by the U.S. Supreme Court ruled that groundwater which depleted stream flow was covered by the Compact. The states of Colorado, Kansas and Nebraska negotiated how to account for groundwater and settled this lawsuit in December 2002. The Settlement Agreement: 1) counts all groundwater use that is determined to deplete stream flow as part of the States consumptive use; 2) waives and forever bars all past claims for damages; 3) gives Nebraska the flexibility to use its allocations where ever it sees fit; and 4) increases flexibility further by measuring Compact compliance on a five-year running average, as opposed to annually, except in dry years when compliance is measured on a two or three year running average basis. The Republican Basin NRD's and the Nebraska Department of Natural Resources are currently developing policies for implementing the Settlement, with the first regulations expected to go into effect during the 2005 crop year.

In April of 2004 we contracted with a consortium of public power districts, bankers and farm supply firms, led by Southwest Public Power District, to study the economic implications of alternative policies for complying with the Settlement. The primary purpose of this study was to determine the effects on the Republican Basin of these alternatives, including both the on-farm and off-farm effects. The policy or policies most likely to be implemented were unknown, so the charge was to consider a range of policies that were plausible and representative of the potential range of outcomes. The specific objectives were:

1. Estimate the affect of alternative water allocation policies on irrigation water use, agricultural production and farm income in the Nebraska Republican Basin.
2. Estimate the effect of changes in agriculture on other sectors of the Republican Valley economy.
3. Discuss the potential long-term impacts of water policy options on land values, local property tax revenues and related issues.

The study began in early May 2000 and preliminary empirical results were presented to the Consortium and to the Republican Basin Management Association in late July. This report documents, interprets and expands on the results presented earlier.

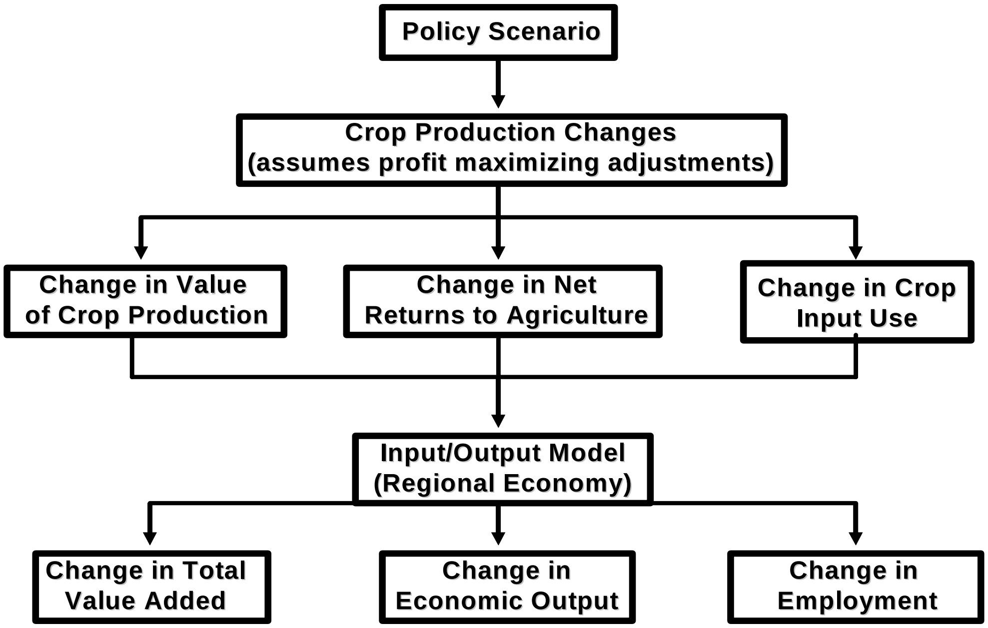
Methods and Procedures

The impacts of reduced irrigation on the Republican Valley depend on: 1) the magnitude of the water use reductions that will be required under the terms of the Republican River Compact; 2) the policies which the State and the NRD's choose to use to meet Compact requirements; 3) how farmers respond to the policies; and 4) the economic linkages between agriculture and the total Republican Valley economy. These components of the problem and how they are linked together are depicted in Figure 1, which describes the general methodology used in the study.

The analysis begins with the selection of a policy scenario. A policy scenario essentially defines the amount of water available to irrigators and any other constraints which they must meet. Irrigators were assumed to respond to these constraints in a profit maximizing manner, i.e., they choose the profit maximizing crops and apply the profit maximizing amount of water to each crop. The method used to determine these profit maximizing choices was a non-linear optimization model which computes the profit maximizing management strategy for average annual conditions. The farm level optimization model was used to produce estimates of how each policy scenario would effect the value of crop production, net returns to agriculture and crop input use. These farm level effects are the driving forces which determine the impacts on the total Basin economy. The changes in net returns to agriculture also represent the direct cost of the policy for irrigators.

An input-output model was used to estimate the indirect effects of the farm level impacts on the remainder of the Basin economy. This methodology allows one to compute how other sectors of the economy, such as retail trade, ag services, etc., are impacted as expenditures from agriculture are spent and re-spent within the regional economy. This model was used as the basis for computing changes in economic output, value added and employment. Economic output is a measure of total sales or business volume, while value added is a measure of wages and salaries and net income to businesses.

Figure 1. General Methodology



Baseline Acreage and Pumpage Data

The agricultural model was used to compute optimum irrigation management strategies for nine different land areas in the Basin. First, the Basin was subdivided into the three Natural Resources Districts (NRD's) which encompass the lands which will be impacted: Upper Republican, Middle Republican and Lower Republican. Secondly, a distinction was made between wells which irrigate land located near the river, called quick response wells and wells located in the uplands, because it was expected that different policies would apply to these groups. Wells within one mile of the river were considered quick response[1]. The quick response and upland land areas in each NRD were further subdivided by type of irrigation system, sprinkler or gravity, for those cases where there was a significant amount of acres irrigated by both system types.

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[1] Since this analysis was done, the NDNR estimate of quick response lands has been refined to include some land irrigated by wells which are more than one mile from the river. This increased quick response acreage by 1.7 percent (Ann Bleed, personal communication).

The total number of acres in each NRD, subdivided into quick response and upland, were based on certified acres provided by the NRD's to the State (Table 1). These acreage estimates were provided by The Flatwater Group and reflect a best estimate of what the State is most likely to use in administering the Settlement.

Table 1. Baseline Irrigated Acres and Water Pumped

	Certified	Baseline	Average
	Acres	**Pumping (acre-feet)**	**Application (In./acre)**
Upper Republican NRD[a]			
Upland Sprinkler	368,970	428,896	13.95
Quick Response Sprinkler	51,301	66537	15.56
Quick Response Gravity	28,446	36,340	15.69*
Total	448,717	531,773	
Middle Republican NRD			
Upland Sprinkler	135,169	134,816	11.97
Upland Gravity	64,243	64,074	11.97
Quick Response Gravity	112,588	110,620	14.82*
Total	312,000	309,510	
Lower Republican NRD			
Upland Sprinkler	132,185	101,713	9.23
Upland Gravity	36,562	28,133	9.23
Quick Response Gravity	161,253	112,502	9.79[b]
Total	330,000	242,348	

[a] Categories with a minor number of acres were combined specifically, upland gravity was combined with upland sprinkler in the URNRD; quick response sprinkler was combined with quick response gravity in the MRNRD and in the LRNRD.

[b] The total baseline water supply for the quick response gravity irrigated areas in each NRD includes groundwater pumped plus surface water deliveries of 850 acre-feet in the URNRD; 28,425 acre-feet for the MRNRD; and 19,000 acre-feet for the LRNRD.

The classification of irrigated acres in each area by irrigation system type was also done by the Flatwater Group, using maps of total irrigated land with distinguishable center pivots that were available from the NDNR. Essentially all sprinkler irrigation was assumed to be pivots and the remaining land gravity irrigated. In geographic areas where there was only a small number of acres irrigated by a given system type, these “minor” acres were included with the dominant system type in order to keep the number of situations to be analyzed manageable. It is also important to note that this analysis included all irrigated land that was groundwater irrigated, or irrigated with a combination of ground and surface water (co-mingled), but did not include land that was supplied by surface water only.

Because irrigation requirements depend to some extent on soil characteristics, it was necessary to select a soil to represent each land area. A weighted average soil was defined for the upland and quick response areas of each NRD by the Flatwater Group, and used to represent both sprinkler and gravity irrigation.

The amount of water pumped historically in each land area was another important input to the analysis, because historical pumping from 1998 through 2002 is being used by the state to define pumping entitlements for the future. The Nebraska DNR estimated average annual pumping by NRD for 1998-2002, using electric power records. Their estimates were: URNRD, 531,773 acre-feet; MRNRD, 309,510 acre-feet; and the LRNRD, 242,348 acre-feet. These baseline pumping estimates were divided into quick response and upland values by the Flatwater Group based also on well location and electric power records (Table 1).

The total amount of water applied in the baseline consists of what was pumped historically, plus the amount of surface water applied to co-mingled acres. Historical average surface water deliveries of 850 acre-feet for the URNRD, 28,425 acre-feet for the MRNRD and 19,000 acre-feet for the LRNRD were added to the pumpage estimates for the quick response gravity irrigated area of NRD’s. This approach assumed that all surface irrigated land was located near the river and gravity irrigated.

Co-mingled lands were not analyzed separately from quick response gravity land because we did not know the number of co-mingled acres, nor did we have the time to add another set of circumstances to the analysis. This simplification does not materially affect the economic impact results as long as it is reasonable to assume that those irrigators using a combination of surface and groundwater have historically applied about the same amount of water as gravity irrigators who were dependent on groundwater only. The analysis assumed that irrigators with co-mingled systems would be able to adjust groundwater pumping if future surface water deliveries were more or less.

Selection of Crops

The irrigated crops included in the analysis were corn, alfalfa, soybeans, grain sorghum and wheat. At the present time there is very little irrigation of grain sorghum or wheat in the Basin, but these crops were included because of the possibility that they would emerge as more attractive alternatives under limited water conditions.

The dryland sector was not modeled, but it was still necessary to include a dryland activity to capture the fact that there may be a water supply situation where the most profitable option is to convert some irrigated acreage to dryland. The dryland option included for each of the three NRD's was a composite acre that reflected average returns to the major dryland crops produced in the NRD.

Crop Prices

Crop prices for corn, wheat, grain sorghum and soybeans were obtained from the Food and Agricultural Policy Research Institute (FAPRI). FAPRI is a joint venture between Iowa State University and the University of Missouri that provides analyses of agricultural markets and farm programs for Congress and other decision makers. FAPRI prices were not used for alfalfa because local market conditions are the primary factor influencing alfalfa prices. Alfalfa prices were determined on a basis of average price received from years 2000, 2001 and 2002 in Southwest Nebraska.

This analysis used FAPRI revenue estimates for crop year 2005 to 2006. This time period was chosen because of when the first regulations imposed on the Republican River would most likely be implemented. Two components of the FAPRI revenue estimates were used in this analysis: the on-farm market price and the projected direct government payment. This resulted in estimated average total prices (market + payment) of $2.60, $3.75, $2.52 and $5.50 for corn, wheat, grain sorghum and soybeans respectively. The average alfalfa price used in the analysis was $74.14. Readers interested in the basis for the FAPRI forecast can get detailed information from their website: http://www.fapri.missouri.edu/Publications/2004Publications/04BriefingBook/BriefingBk2004.pdf.

Irrigated Production Costs

Crop production costs were estimated using the 2004 Nebraska Crop Budgets produced by the Nebraska Cooperative Extension. The costs for each crop included yield dependent costs and other variable production costs. *Yield dependent costs* include all costs that vary with crop yield. Hauling, drying grain and nitrogen fertilizer (for corn only) were the main yield dependent costs. *Other production costs* included those costs associated with producing a crop which were variable in the sense that they could be avoided if the crop was not produced, such as seed, chemicals, fertilizer and field operations. Costs which are unaffected by how the land is managed, such as overhead and management charges, insurance, taxes and some depreciation were not considered. Irrigation costs were addressed as a separate category.

Production costs depend to some extent on what production practices are used, such as ridge-till, conventional-till, no-till, etc. Because no data were available regarding the distribution of production practices, we used representative averages for each crop. Results are summarized in Table 2.

Table 2. Crop Production Costs

	Yield Dependent Costs[a] ($/bushel)	Other Variable Costs Except Irrigation[b] ($/acre)
Corn	**0.28**	**132.79**
Wheat	**0.06**	**118.48**
Grain Sorghum	**0.08**	**100.41**
Alfalfa	**7.95**	**24.22**
Soybeans	**0.06**	**87.83**

[a] Includes all costs that vary with yield such as grain handling and grain drying. In the case of corn it also includes nitrogen fertilizer that is applied based on a yield goal.

[b] Includes costs for seed, chemicals, fertilizer, labor, field operations and use related depreciation. Costs which are not affected by what crop is produced, such as overhead and management charges, insurance or taxes are excluded.

Estimated corn production costs were based on four different Nebraska Crop Budgets: ridge till, continuous corn (both gravity and pivot-irrigated); conventional tillage, continuous corn (pivot irrigated); and no-till after soybeans (pivot irrigated). Costs which varied with yield were estimated as the average of these budgets, except for nitrogen costs which were estimated separately based on UNL fertilizer recommendations.[2] This resulted in a total yield dependent cost estimate of $0.28 per bushel. Other production costs, which included seed, starter fertilizer and field operations were estimated at $132.79 per acre.

Irrigated wheat production costs were based on the Cooperative Extension budget for conventional tillage, pivot irrigated wheat. Yield dependent costs were estimated at $0.06 per bushel, and other production costs at $118.48 per acre.

Production costs for irrigated grain sorghum were based on the pivot-irrigated conventional budget developed by Cooperative Extension. Yield dependent costs were estimated at $0.08 per bushel, and other production costs at $100.41 per acre.

Alfalfa production costs assumed large square bales and re-establishment every five years. Yield dependent costs were estimated at $7.95 per ton and other production costs at $24.22 per acre per year.

Irrigated soybean production costs were estimated as an average of four budgets: pivot-irrigated ridge-till, after corn; pivot-irrigated conventional tillage, roundup ready, after corn; pivot-irrigated, no-till narrow row, roundup ready, after corn; and pivot-irrigated no-till drilled, roundup ready after corn. Yield dependent costs were estimated at $0.06 while other production costs were estimated at $87.83 per acre.

The Cooperative Extension budgets used for all crops can be accessed at: http://agecon.unl.edu/prices/Crop%20Budgets04.pdf

Irrigation Costs

Variable irrigation costs were estimated for sprinkler and gravity systems located in the upland and quick response areas of each NRD (Table 3). These estimates include all energy costs at $.07 per kWh, all labor costs, all repairs and maintenance and use related depreciation. Unavoidable costs such as well depreciation changes, taxes and insurance were not considered, because they do not change, irrespective of what crops are produced and how much water is applied. Use related depreciation was assumed to be 75 percent of total depreciation for the irrigation pump and center pivot system, and 100 percent of total depreciation for the electric motor.

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[2] Nitrogen fertilizer costs were calculated by assuming 1.1 pounds of N per bushel at $0.20 per pound, which is consistent with UNL fertilizer recommendations.

Table 3. Irrigation Costs

Land Area	Feet of Head[a]	Hook-up Cost[b]	Variable Irrigation Costs[c]
		($/Acre)	($/acre-inch)
Upper NRD			
Upland Sprinkler	**321**	**5.77**	**6.11**
Quick Response Sprinkler	**203**	**5.77**	**5.00**
Quick Response Gravity	**87**	**7.81**	**3.02**
Middle NRD			
Upland Sprinkler	**369**	**5.77**	**6.57**
Upland Gravity	**254**	**7.81**	**4.58**
Quick Response Gravity	**124**	**7.81**	**2.52**
Lower NRD			
Upland Sprinkler	**304**	**5.77**	**5.96**
Upland Gravity	**186**	**7.81**	**3.97**
Quick Response Gravity	**84**	**7.81**	**2.98**

[a] Assume average feet of lift in each land area, plus a pressure requirement of 55 psi for sprinklers and 5 psi for gravity systems.

[b] Hook-up charges in $/acre vary by power district, horsepower requirements, acres/per system and load management plan. Such data were not available for each land area, so this analysis assumed hook-up charges of $750 and $625 for pivot and gravity systems, respectively. It further assumed 130 acres per pivot and 80 acres per gravity system, resulting in per acre charges of $5.77 for pivot and $7.81 for gravity.

[C] Includes energy costs at $.07 per kwh, labor costs, repairs and maintenance and use related depreciation. Unavoidable costs such as well depreciation changes are excluded.

To minimize the number of calculations required, all pumps were assumed to be electric, with center pivot systems irrigating an average of 130 acres and gravity systems an average of 80 acres. Pressure requirements were assumed to be 55 psi for all center pivot sprinklers and 5 psi for all gravity systems. Hook-up charges expressed in dollars per acre vary by power district, horsepower requirements, acres per system and load management plans. Such data were not available for each land area, so this analysis assumed one-half hook-up charges of $750 for pivot systems ($5.17/acre) and $625 for gravity systems ($7.28/acre). Total irrigation cost varies between NRD's as a function of average well depth. Readers interested in the base data for the irrigation cost calculations can find it at: http://lancaster.unl.edu/ag/crops/irrigate.htm#CPISC

Crop Water Requirements

The estimated production functions which define the relationship between water applied and grain yields are probably the most important inputs to this analysis. Most of the economic effects stem directly from how crop yields change as the amount of water applied is reduced. Production functions were estimated separately for each NRD, for five irrigated crops (corn, soybeans, wheat, grain sorghum and alfalfa), two irrigation system types (center pivot sprinklers and gravity), assuming average soil characteristics.

Estimating the water applied versus crop yield production functions required five critical inputs for each case: dryland yield, dryland evapotranspiration (ET), maximum irrigated yield, ET required for the maximum irrigated yield and the amount of irrigation water required for the maximum irrigated yield. The dryland yields used for estimating the production functions were the same yields as we used for estimating the economic returns to dryland production (Table 4). Dryland ET, maximum irrigated ET and the amounts of irrigation water required for maximum yield were based on simulations run by the Flatwater Group, using a model called CROPSIM developed by Derrel Martin, Professor of Biological Systems Engineering at UNL (Table 4).

Each of the production functions used in this analysis were defined mathematically as

$$Y = Yd + (Ym - Yd)\,[1 - (1 - I/Imax)\hat{}(1/B)] \qquad [1]$$

where: $B = (Etmax - Etdry)/Imax;$ [2]

Y = Crop yield;
Yd = Dryland yield;
Ym = Maximum irrigated yield;
I = Irrigation level; and
Imax = Maximum irrigation requirement

B represents the portion of the irrigation that is used by the crop as evapotranspiration when producing maximum yield. The value of B depends on the application efficiency of the system, irrigation scheduling, soil characteristics and other management factors. In general, B values close to 1.0 represent efficient irrigation and low B values represent less efficient irrigation. The B values used in this analysis ranged from 0.84 for sprinkler irrigated alfalfa to 0.39 for gravity irrigated wheat. Interested readers can calculate the B value for each case using Equation [2] and the data in Table 4.

The production functions describing how crop yields respond to water applied have been plotted in Appendix A, Figures A1 - A15 for all crops and situations. Note that water requirements are always about 25 percent higher for gravity systems when compared with center pivot sprinklers. Note also that irrigation requirements are substantially higher for all crops as you move from the LRNRD in the east to the URNRD in the west, due primarily to differences in rainfall. Finally, note the diminishing returns to irrigation water, i.e., how crop response to water declines as increased amounts of irrigation water are applied. This is evident from the plotted functions and is also described in numeric terms in Table 5.

This concept of diminishing returns to water is of crucial importance for understanding the economic effects from reduced irrigation. The profit maximizing irrigator logically continues to apply successive amounts of water to a crop as long as the additional water will produce a net economic gain. The first inch of water applied to a crop produces a large economic gain, whereas the last inch applied may cost more than it produces. This is illustrated in Table 6 for generalized cases using the yield response data from Table 5, the crop prices described earlier and an average variable irrigation cost of $5.00 per inch. The fact that the last water applied to a crop produces only a small net increase in income also means that regulations which force only small reductions in the amount of water applied will not be very costly.

Table 4. Crop Water Requirements

	URNRD		MRNRD		LRNRD	
Crop and Irrigation System	**Upland**	**Quick Response**	**Upland**	**Quick Response**	**Upland**	**Quick Response**
Corn						
Dry Yield	54.00	52.50	70l20	68.48	105.16	106.55
Max Irr Yield	202.00	202.00	200.00	200.00	195.00	195.00
Dry ET	18.89	18.89	20.29	20.29	22.09	22.09
Max Irrigated ET	31.02	31.15	30.93	31.07	29.45	29.34
Irr Needed for Max Yield						
Sprinkler	17.18	17.08	15.17	X	11.03	X
Gravity						
Wheat						
Dry Yield	36.98	37.66	38.78	39.94	43.42	42.24
Max Irr Yield	69.34	69.34	63.00	63.00	57.85	57.85
Dry ET	18.83	19.15	21.00	21.45	22.49	22.12
Max Irrigated ET	26.35	26.52	26.63	26.81	25.85	25.74
Irr Needed for Max Yield						
Sprinkler	10.73	10.74	9.32	X	6.63	X
Grain Sorghum						
Dry Yield	57.21	57.34	64.05	64.35	79.98	84.17
Max Irr Yield	115.34	115.34	114.06	114.06	114.07	114.07
Dry ET	17.29	17.48	19.15	19.41	21.32	18.20
Max Irrigated ET	29.66	29.83	29.79	29.99	28.57	24.56
Irr Needed for Max Yield						
Sprinkler	15.15	15.08	13.13	X	9.39	X
Alfalfa						
Dry Yield	3.00	2.96	3.40	3.36	3.63	3.65
Max Irr Yield	7.30	7.30	7.40	7.40	6.80	6.80
Dry ET	18.72	18.71	20.40	20.40	23.69	23.65
Max Irrigated ET	44.32	44.52	44.19	44.42	42.57	42.41
Irr Needed for Max Yield						
Sprinkler	30.36	30.57	28.18	X	22.59	X
Soybeans						
Dry Yield	16.82	17.00	18.97	19.25	32.08	31.75
Max Irr Yield	64.91	64.91	61.10	61.10	61.66	61.66
Dry ET	16.67	16.88	18.38	18.65	20.43	20.18
Max Irrigated ET	29.33	29.49	29.46	29.67	28.22	28.05
Irr Needed for Max Yield						
Sprinkler	15.62	15.53	13.81	X	9.94	X
Gravity	X	20.31	18.06	17.90	13.01	13.16

Table 5. Crop Yield Responses to Irrigation Water

	URNRD		MRNRD		LRNRD	
Crop/Water	**Pivot**	**Gravity**	**Pivot**	**Gravity**	**Pivot**	**Gravity**
Corn						
First inch	12.05	11.97	12.03	11.93	11.93	11.80
Fifth inch	10.81	10.14	10.50	9.78	9.40	8.52
Tenth inch	8.86	7.73	8.02	6.96	4.54	4.35
Fifteenth inch	5.79	5.15	3.15	3.92	0	0
Twentieth inch	0	2.24	0	0	0	0
Wheat						
First inch	4.21	4.16	4.15	4.10	3.98	3.91
Fifth inch	3.35	3.03	2.79	2.52	1.42	1.35
Tenth inch	1.59	1.55	0	0.74	0	0
Fifteenth inch	0	0	0	0	0	0
Twentieth inch	0	0	0	0	0	0
Grain Sorghum						
First inch	4.66	4.62	4.66	4.62	4.63	4.57
Fifth inch	4.34	4.02	4.26	3.90	3.88	3.43
Tenth inch	3.77	3.17	3.48	2.87	0	1.68
Fifteenth inch	2.22	2.12	0	1.50	0	0
Twentieth inch	0	0	0	0	0	0
Alfalfa						
First inch	0.17	0.17	0.17	0.17	0.17	0.17
Fifth inch	0.16	0.16	0.16	0.16	0.16	0.15
Tenth inch	0.16	0.14	0.16	0.14	0.15	0.13
Fifteenth inch	0.15	0.13	0.15	0.13	0.14	0.11
Twentieth inch	0.14	0.12	0.14	0.11	0.11	0.09
Soybeans						
First inch	3.77	3.74	3.77	3.74	3.74	3.70
Fifth inch	3.51	3.26	3.45	3.17	3.21	2.86
Tenth inch	3.05	2.58	2.85	2.38	0	1.58
Fifteenth inch	2.01	1.77	0	1.37	0	0
Twentieth inch	0	0.52	0	0	0	0

* Yield response values were calculated from the quick response area of the URNRD and the upland areas in the MRNRD and LRNRD.

Table 6. Net Economic Returns from Incremental Applications of Irrigation Water[a]

	URNRD		MRNRD		LRNRD	
Crop/Water	**Pivot**	**Gravity**	**Pivot**	**Gravity**	**Pivot**	**Gravity**
	------------------------------------- **Dollars per Acre-Inch** ---------------------------------------					
Corn						
First inch	26.34	26.12	26.28	26.02	26.02	25.68
Fifth inch	23.11	21.36	22.30	20.43	19.44	17.15
Tenth inch	18.04	15.10	15.85	13.10	6.80	6.31
Fifteenth inch	10.05	8.39	3.19	5.19	-5.00	-5.00
Twentieth inch	-5.00	0.82	-5.00	-5.00	-5.00	-5.00
Wheat						
First inch	10.77	10.60	10.56	10.38	9.93	9.66
Fifth inch	7.56	6.36	5.46	4.45	0.32	0.06
Tenth inch	0.96	0.81	-5.00	-2.23	-5.00	-5.00
Fifteenth inch	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
Twentieth inch	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
Grain Sorghum						
First inch	6.75	6.64	6.74	6.64	6.67	6.52
Fifth inch	5.94	5.13	5.74	4.83	4.78	3.64
Tenth inch	4.50	2.99	3.77	2.23	-5.00	-0.77
Fifteenth inch	0.59	0.34	-5.00	-1.22	-5.00	-5.00
Twentieth inch	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
Alfalfa						
First inch	7.60	7.60	7.60	7.60	7.60	7.60
Fifth inch	6.86	6.86	6.86	6.86	6.86	6.12
Tenth inch	6.86	5.38	6.86	5.38	6.12	4.64
Fifteenth inch	6.12	4.64	6.12	4.64	5.38	3.16
Twentieth inch	5.38	3.90	5.38	3.16	3.16	1.67
Soybeans						
First inch	15.74	15.57	15.74	15.57	15.57	15.35
Fifth inch	14.31	12.93	13.98	12.44	12.66	16.23
Tenth inch	11.78	9.19	10.68	8.09	-5.00	3.69
Fifteenth inch	6.06	4.74	-5.00	2.54	-5.00	-5.00
Twentieth inch	-5.00	-2.14	-5.00	-5.00	-5.00	-5.00

[a] Analysis uses the yield response numbers from Table 5; crop prices of $2.60, $3.75, $2.52, $5.50 and $74.14 for corn, wheat, grain sorghum, soybeans and alfalfa, respectively; and an illustrated irrigation cost of $5.00/inch.

Economic Returns to Dryland Production

A dryland alternative was included in this analysis because of the fact that there may be a water supply situation where the most profitable option is to convert some irrigated acreage to dryland. The dryland alternative is comprised of weighted average economic returns to a composite acre of corn, soybeans, wheat, grain sorghum and summer fallow. The percentage distribution of crops which compose the composite acre was based on what was produced in each NRD from 1994 to 2003, as reported by the Nebraska Agricultural Statistics Service (NASS). The number of summer fallow acres was estimated using the 2002 Census of Agriculture. The resulting crop mix for each NRD is described in Table 7.

Dryland yields were also estimated using NASS data for 1994-2003. The yield estimates used were the average for 1994-2003 after excluding the two highest and two lowest yield values, with each NRD considered separately (Table 8).

Costs of production for dryland crops were estimated in the same way and from the same sources as the irrigated crops. Average production costs for each crop were derived from selected farming practices using the 2004 Nebraska Crop Budgets produced by the Nebraska Cooperative Extension Service. The crop mix percentages in Table 7 were then multiplied times the production cost for each crop and the results summed to determine the weighted average production costs for the composite acre.

Dryland corn production costs were estimated from four budgets: conventional-continuous; no-till continuous; no-till after wheat; and eco-fallow after wheat. Total production costs per acre were $151.94, $154.96 and $160.55 for the URNRD, MRNRD and LRNRD, respectively.

Dryland grain sorghum production costs were also estimated from four budgets: eco-fallow after wheat; conventional; no-till; and ridge-till farming practices. Total production costs per acre were $99.38 in the URNRD; $99.93 in the MRNRD; and $101.20 in the LRNRD.

Soybean production costs were estimated from two budgets: conventional round-up ready and no-till round-up ready, both in rotation with corn. Total production costs per acre were $88.38 for the URNRD; $88.51 for the MRNRD; and $89.29 for the LRNRD.

Wheat production costs were estimated from three budgets provided in the 2004 Nebraska Crop Budgets: no-till after row crop; stubble mulch fallow; and clean-till fallow. Total production costs per acre were $80.27, $80.38 and $80.65 for the UPRNRD, MRNRD and LRNRD, respectively.

Summer fallow costs were also estimated at $13.00 per acre to account for weed control on fallow ground.

Composite acre revenues were also estimated as a weighted average using the percentages in Table 7. Composite acre percentages were multiplied by dryland yields to find yield per composite acre. Yields were then multiplied by price and summed to find total revenue per composite acre. A $5.00 an acre grazing value was also figured in for dryland corn production.

The weighted production costs and revenues were combined to determine net returns to dryland for each NRD. Lower Republican dryland production costs (operating cost and use related depreciation) were estimated at $90.74 per composite acre, with net revenue over operating cost and use related depreciation of $77.49 per composite acre. Middle Republican production costs were estimated at $70.98 with net revenue of $33.71 per composite acre. The Upper Republican composite acre production costs were $65.10 with net revenue of $20.63.

Table 7. Dryland Crop Mix by NRD

Crop	Upper	Middle	Lower
	-------------------------- Percent of Cropping Pattern		------------------------------
Corn	15.5	15.9	20.7
Soybeans	0	0	6.9
Wheat	45.4	45.0	34.5
Grain Sorghum	0	6.0	21.1
Summer Fallow	39.1	33.2	16.8
Total	100	100	100

Off-Farm Economic Impacts

Limiting water for irrigation also impacts the off-farm economy. Those off-farm firms and individuals who supply agricultural inputs, handle and process agricultural commodities and provide consumer services can also be significantly affected. The effect of changes in agricultural production and income on the off-farm regional economy were estimated using an

Table 8. Economic Returns to Dryland

Crop	URNRD	MRNRD	LRNRD
Corn			
Yield (bu/ac)	54.4	70.1	105.0
Cost ($/ac)	$151.94	$154.96	$160.55
Net	-$10.50	$27.30	$112.45
Soybeans			
Yield (bu/ac)	16.8	19.0	32.1
Cost ($/ac)	$88.38	$88.51	$89.29
Net	$4.02	$16.10	$87.26
Wheat			
Yield (bu/ac)	37.0	38.8	43.4
Cost ($/ac)	$80.27	$80.38	$80.65
Net	$58.48	$65.12	$82.10
Grain Sorghum			
Yield (bu/ac)	57.2	64.1	79.7
Cost ($/ac)	$99.38	$99.93	$101.20
Net	$44.84	$61.60	$99.64
Alfalfa			
Yield (bu/ac)	3.0	3.4	3.6
Cost ($/ac)	$28.83	$31.13	$31.99
Net	$195.81	$220.95	$234.91
Summer Fallow Cost	$12.98	$12.98	$12.98
Composite Acre			
Revenue	$85.73	$104.69	$168.23
Cost	$65.10	$70.98	$90.74
Net	$20.63	$33.71	$77.49

**Crop Net is obtained from (crop price * crop yield)-crop cost

***Yield dependent costs are considered in crop costs.

****A grazing value of $5.00/acre for corn was considered in the analysis but is not reflected here.

input-output framework. Input-output models allow one to estimate how changes in one sector of the economy affects all other sectors.

The first step in applying this input-output methodology was to define the boundaries of the regional economy. Although there are no clearly defined rules for doing this, the usual approach is to define a region as a contiguous set of counties that includes a trade center or centers (larger city), plus the area served. This was especially difficult for the Republican Valley because there is no dominant trade center that serves all or even most of the region. McCook and Holdredge are located within the Republican Basin and do serve as trade centers for a significant part of the Basin's agricultural sector, but significant trade also occurs in North Platte and other communities that lie north of the River Basin boundaries. The dilemma this presents is that if we define the economic region to include only those counties that lie within the river basin boundaries, we will underestimate the total off-farm effects because of the trade which occurs with nearby trade centers such as North Platte. On the other hand, if the region is defined to include all major trade centers that are linked to the affected agricultural producers in the Republican Basin, then the estimated off-farm impacts will be larger in total, but smaller as a proportion of all economic activity within the region.

For this analysis we chose to define the region to include all of the significant trade centers in Nebraska that were economically linked to agricultural production in the Republican Basin, including the following 15 counties: Chase, Frontier, Franklin, Dundy, Furnas, Hitchcock, Hayes, Harlan, Gosper, Red Willow, Phelps, Nuckols, Lincoln, Kearney and Webster. This approach insured that all significant off-farm economic effects would be identified. But users of the estimated off-farm impacts must consider that it is not just the magnitude of the off-farm impacts that is important for policy purposes, but also the distribution of the impacts. Impacts which in total constitute only a small portion of the total regional economy may never-the-less be very important and very serious if they are concentrated in just a few locations within the region. Unfortunately input-output analysis does not address how impacts are spatially distributed within a region. This requires detailed knowledge of where major farm input suppliers are located, where grain is marketed and where people live and shop, a task that was well outside the scope of this analysis.

The second major step in analyzing the off-farm economic effects was to construct the input-output model for the 15 county region, hereafter called the Republican Basin Economy. This was done using IMPLAN, which is a software and data package that is widely used to analyze regional economic impacts. The IMPLAN data base contains a total of 508 economic sectors for describing the national economy. These were aggregated into just 11 sectors to describe the Republican Basin economy: crop farming, livestock production, agricultural support services, other services, utilities, construction, manufacturing, wholesale and retail trade, transportation, government and other. IMPLAN estimates of the coefficients which describe the buying and selling between sectors, reflect national technology and are averages based on total production levels. These coefficients required some modification to reflect local conditions.

The only direct change made to the IMPLAN coefficients was to adjust the estimate of farm household income per dollar of crop production to better reflect how farm household income was likely to change when irrigation water use was restricted. The original IMPLAN coefficient reflected all crop production, both irrigated and dryland, and reflected household income per unit of total production. What was needed for this study was a value that approximated how the income of irrigators would change as production changed in response to a 10 to 20 percent reduction in irrigation water. The estimate used was $0.39 in farm household income per dollar of reduced crop production based on the results of the on-farm LP model. This value is relatively high because at the margin as the amount of irrigation water applied to an acre of land is reduced, cost savings tend to offset much of the reduction in production.

The modified IMPLAN model was used to produce multipliers for how regional economic output, value added and employment would change with changes in agricultural production. It was estimated that each one dollar reduction in crop production which occurs as a result of groundwater pumping restrictions would reduce total regional economic output by $1.35 and regional value added by $0.65. Regional employment decreased by about one job for every $100,000 in output, or 2 jobs per $100,000 in value added.

These regional impact coefficients are believed to be reasonable for the policy scenarios considered in this analysis where irrigation water use is limited by regulation and the primary farm level outcome is to produce similar crop mixes with lower yields and less net farm income, but very little change in the purchase of agricultural inputs. If one were evaluating land retirement scenarios, however, the economic effects per dollar change in crop production would be much greater. This is because with a land retirement program net farm income is higher than if you used a regulatory approach only (assuming farmers are paid for land retirement), but there is a much larger effect on the amount of farm inputs purchased and the amount of grain handled by other economic entities in the region.

Study Results

Three policy scenarios were evaluated: a 10 and 20 percent reduction in pumping, and a drought scenario consisting of a 13 percent reduction in pumping for everyone, plus an additional 120,000 acre-foot reduction for quick response wells. These scenarios were selected in early June 2004 to represent the plausible range of possibilities that were then being discussed by the NDNR. Subsequently, the NDNR found that an across the board five percent basin wide reduction in pumping during all years, plus an additional 120,000 acre-feet reduction during drought periods, might be sufficient. Unfortunately, there was not sufficient time to analyze these less draconian scenarios.

The analysis for all three scenarios assumed that the NRD's and the NDNR would differentiate between quick response and upland wells and between sprinkler and gravity irrigation. For the 10 and 20 percent scenarios the assumption was that each land group would be given an allocation equal to 90 and 80 percent, respectively, of the average volume pumped from 1998 to 2002[3]. For the 13% + 120k drought scenario the assumption was that everyone would be reduced by 13 percent and that the additional 120 kaf reduction in pumping by quick response wells would be allocated to each NRD in proportion to their total contribution to consumptive use. This results in different allocations to each land group in each NRD for each scenario (Table 9).

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[3] 1998 to 2002 is the five year period which is being used by Kansas and Nebraska in implementing the terms of the Settlement in Kansas v. Nebraska.

Allocation Levels, by Scenario

A key step in the analysis consisted of determining what allocation level would be required to reduce irrigation pumping by the desired percentages. This was done using historical well pumping distributions. Such distributions show what percentage of the wells pumped less than particular amounts, expressed in inches per acre (Figure 2). These distributions are usually log-normal (S -shaped), which means that there are a few wells that pump relatively few inches per acre and a few that pump at very high levels, with all others pumping at levels close to the average. Log normal distributions were estimated for each land area. Each distribution was estimated by inputting the mean historical pumping level and then varying the standard deviation until the total area under the distribution curve matched the total average annual volume pumped by all wells from 1998 to 2002 (See Figure 2 for an illustration of this procedure).

Once the pumping distributions were estimated, the required allocation levels for each scenario were estimated by moving down the distributions just far enough to achieve the desired percentage reductions in volume pumped. In practical terms this means that you reduce the wells pumping the highest number of inches first, and move downward until the cumulative reduction is equal to the desired percentage. For the illustrative case shown in Figure 2, which closely corresponds to upland sprinklers in the MRNRD, the desired 10 percent reduction is reached at an allocation level of 13.2 inches per acre. This means that an allocation level of 13.2 inches should produce a reduction in pumping of 10 percent.

It is important to note that the historical average pumping (unregulated) was only 12 inches, yet we have estimated that you can get a 10 percent reduction by allowing irrigators to pump 13.2 inches. How can this be? This happens whenever there are enough very high volume pumpers to account for the desired reduction. To illustrate, consider the following hypothetical example. Suppose you had 5 wells which historically pumped 4, 6, 8, 10 and 12 inches, respectively, for an average of 8 inches (4+6+8+10+12 = 40; 40/5 = 8). In this case an allocation of 9 inches would result in 36 total inches, which is a 10 percent reduction in pumping, because the first three wells would continue at historical levels, while well 4 would decrease from 10 to 9 inches and well 5 from 12 to 9 inches; thus the total would be 4+6+8+9+9 = 36.

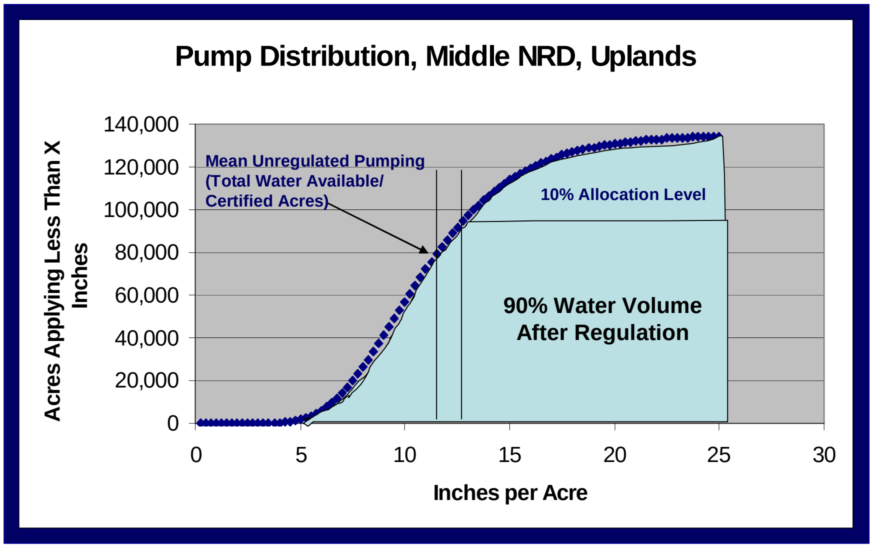


Figure 2. Ilustrative Pumping Distribution & Allocation Determination

Allocation levels for each land area and each scenario are depicted in Table 9. These allocation levels were used as constraints for the farm level analysis of economic impacts. The analysis assumes that producers are allowed to adjust their actual applications to account for year-to-year variations in rainfall, as long as their multi-year average is equal to the allocation. This methodology will understate the economic impacts of regulations if the allocation time period is too short and there is an unusual number of dry years in succession, or will overstate them in the event that there is an unusual number of wet years.

Farm Level Results

Farmers faced with limited water have several management options. They can reduce the amount of water applied to each crop (deficit irrigation), grow different crops, reduce the number of acres irrigated or invest in irrigation system improvements. In some cases there may also be land retirement, insurance or other government programs to consider. This analysis incorporates only the first three options: deficit irrigation, different crops or fewer acres.

Table 9. Allocation Levels for Each Policy Scenario

	Baseline	10%	20%	13% +120 kaf
Upper NRD				
Upland-Sprinkler	13.95	13.83	11.43	12.92
Quick Response-Sprinkler	15.56	15.24	12.87	5.38
Quick Response-Gravity	15.69	15.29	12.97	5.97
Middle NRD				
Upland-Sprinkler	11.97	13.17	10.8	12.41
Upland-Gravity	11.97	13.17	10.8	13.12
Quick Response-Gravity	14.82	15.86	13.38	9.56
Lower NRD				
Upland-Sprinkler	9.23	10.32	8.32	9.5
Upland- Gravity	9.23	10.32	8.32	9.5
Quick Response-Gravity	9.79	10.54	8.32	6.38

The results of this analysis suggests that if one starts with the current cropping pattern the optimum response to increasingly limited water is to: first, reduce the amount applied to wheat, grain sorghum and alfalfa significantly; second, reduce water applied to corn and soybeans slightly; third, convert wheat and sorghum acres to a dryland rotation; and fourth, reduce water applied to corn and soybeans still further. Producers who grow only corn, however, will generally find it more profitable to deficit irrigate corn, rather than reducing irrigated acres or going to alternative crops. This is because an inch of water applied to corn when supplies are limited usually produces more revenue than an inch of water applied to any other crop. The fact that alternative crops, such as wheat and grain sorghum, take less water than corn to produce a full yield does not mean that they are the preferred option when water is short.

10 Percent Scenario. It was estimated that a 10 percent reduction in pumping would decrease the value of crop production in the Republican Basin by $12.1 million, and decrease the net returns to agriculture by $3.4 million (Table 10). About 63 percent of the impact occurs in the URNRD, 28 percent in the MRNRD and only 9 percent in the LRNRD. Net returns to agriculture basin-wide were estimated to decrease by $32.41 per acre-foot pumped. If the on-farm cost was spread across all acres in the Basin, it would cost irrigators an average of $3.13 per acre per year to reduce pumping by 10 percent. However, some irrigators are unaffected by the regulations, because when not regulated they pumped less than they are allowed to pump under the 10 percent scenario. When the total change in net returns was divided by only the number of acres affected, the average cost was nearly double at $5.81 per acre, ranging from $1.68 per affected acre for quick response gravity acres in the MRNRD, to $11.33 for upland gravity acres in the MRNRD. These differences between land areas are due primarily to variations in the adequacy of their historical water supply.

20 Percent Scenario. A 20 percent reduction in pumping was estimated to reduce the value of agricultural production by $42.4 million, which is 3.5 times as much as the 10 percent reduction, and to reduce net returns to agriculture by $16.2 million, which is nearly five times the cost of the 10 percent case. Net returns to agriculture basin-wide were estimated to decrease by $74 per acre-foot pumped. If the on-farm cost was spread across all acres in the Basin it would cost irrigators an average of $14.83 per acre per year to reduce pumping by 20 percent. When the total change in net returns was divided by only the number of acres affected, the average cost was 50 percent higher at $21.18 per acre, ranging from $27.00 for upland sprinklers in the URNRD to $11.23 for quick response gravity acres in the LRNRD. For this scenario, the affects across the Basin are generally higher as you go from east to west because the same percentage reductions in pumping amount to larger reductions in inches per acre for land areas which historically pumped more water.

Drought Scenario. The drought scenario was defined as a 13 percent reduction in pumping for everyone, plus another 120 thousand acre-feet reduction from the quick response wells. The 120 kaf that was distributed across the NRD’s according to their respective contributions to total consumptive use. Under this policy, allocations for quick response wells fall to very low levels, especially in the URNRD where there is only a few quick response wells and a large amount of consumptive use. This scenario would cause the value of agricultural production to decrease by over $50 million and net returns to agriculture to fall by over $23 million. Net returns to agriculture basin-wide were estimated to decrease by $90 per acre-foot change in pumping. If the on-farm cost was spread across all acres in the Basin it would cost irrigators an average of $21.44 per acre per year to reduce pumping by 20 percent. When the total change in net returns was divided by only the number of acres affected, the average cost was again about 50 percent higher at $30.71 per acre, ranging from about $100 per acre for quick response wells in the URNRD to less than $5.00 for upland sprinkler wells in the LRNRD.

Table 10. Farm Level Results for 10 Percent Scenario

Area	Allocation Level	Value of Prod.	Change in Net Returns	Cost/ All Acres	Cost/ Affected Acres	Cost of Change in Pumping
	(In Acre)	(Thous. $)	(Thous. $)	($/Acre)	($/Acre)	($/AF)
URNRD						
Upland Spk	13.83	6,770	1,566	4.25	7.25	39.16
Quick Spk	15.24	702	237	4.62	7.72	35.37
Quick Gravity	15.53	394	200	7.02	11.60	55.44
Total		7,566	2,003	4.46	7.59	39.82
MRNRD						
Upland Spk	13.17	2,016	486	3.59	7.36	35.70
Upland Gravity	13.12	946	359	5.59	11.33	55.06
Quick Gravity	17.77	375	99	0.88	1.68	8.81
Total		3,337	944	3.03	6.02	30.09
LRNRD						
Upland Spk	10.42	138	44	0.33	0.69	5.16
Upland Gravity	10.12	303	108	2.96	6.25	36.06
Quick Gravity	11.41	738	310	1.92	3.65	25.83
Total		1,041	462	1.40	2.78	19.66
Total Basin		12,082	$3,409	$3.13	$5.81	$32.41

Table 11. Farm Level Results for 20 Percent Scenario

Area	Allocation Level	Value of Prod.	Change in Net Returns	Cost/ All Acres	Cost/ Affected Acres	Cost of Change in Pumping
	(In Acre)	(Thous. $)	(Thous. $)	($/Acre)	($/Acre)	($/AF)
URNRD						
Upland Spk	11.43	21,326	7,806	21.16	27.01	88.91
Quick Spk	12.87	2,521	1,004	19.57	25.22	76.62
Quick Gravity	13.07	1,073	577	20.30	25.93	79.09
Total		24,020	9,387	20.92	26.74	86.76
MRNRD						
Upland Spk	10.80	5,910	1,954	14.45	23.26	68.55
Upland Gravity	10.78	2,268	951	14.80	23.77	75.48
Quick Gravity	14.08	2,885	1,064	9.45	14.00	48.14
Total		11,063	3,968	12.72	19.84	62.79
LRNRD						
Upland Spk	8.28	3,849	1,278	9.66	15.36	62.62
Upland Gravity	8.36	712	328	8.96	15.24	59.03
Quick Gravity	9.30	2,789	1,213	7.52	11.23	56.43
Total		7,350	2,818	8.54	13.25	59.40
Total Basin		42,433	$16,174	$14.83	$21.18	$73.91

Table 12. Farm Level Results 13 Percent to 120K Scenario

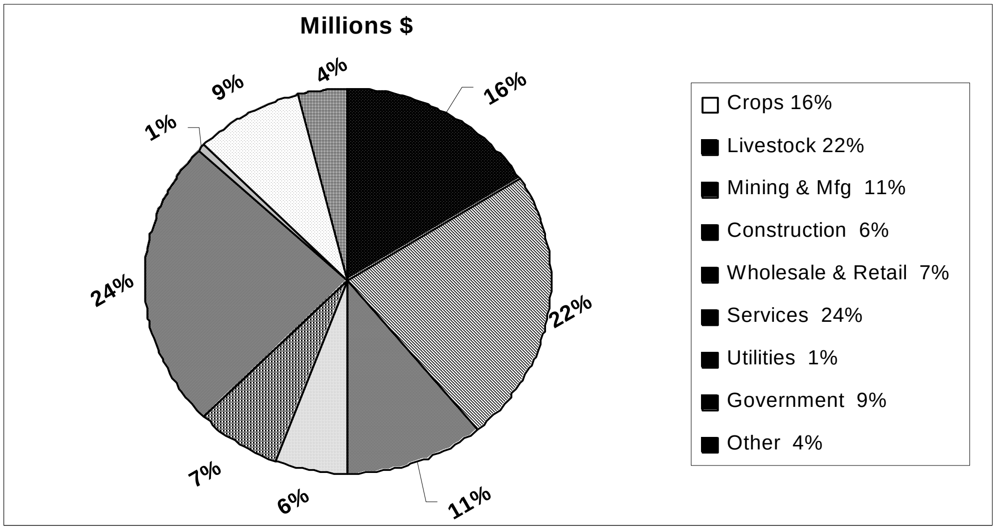
Area	Allocation Level	Value of Prod.	Change in Net Returns	Cost/ All Acres	Cost/ Affected Acres	Cost of Change in Pumping
	(In Acre)	(Thous. $)	(Thous. $)	($/Acre)	($/Acre)	($/AF)
URNRD						
Upland Spk	12.92	12,197	4,258	11.54	17.60	75.36
Quick Spk	5.38	10,458	5,335	104.00	104.00	122.55
Quick Gravity	5.97	4,854	2,791	98.10	98.10	121.17
Total		27,509	12,384	27.60	38.49	100.63
MRNRD						
Upland Spk	12.41	2,731	734.835	5.44	10.28	41.99
Upland Gravity	13.12	946	360,000	5.60	10.57	55.06
Quick Gravity	9.58	9,484	4,871	43.26	47.29	98.20
Total		13,161	5,965	19.12	28.75	81.01
LRNRD						
Upland Spk	9.50	1,260	328	2.48	4.64	25.27
Upland Gravity	9.50	401	150	4.11	7.91	42.93
Quick Gravity	6.40	8,210	4,556	28.25	31.96	98.61
Total		9,871	5,034	15.26	21.67	80.30
Total Basin		50,541	$23,383	$21.44	$30.71	$90.15

Impacts on the Regional Economy

The brief review of the structure of the Republican Basin economy suggests that agriculture, especially livestock production, is an important part of the economic base. Crop production account accounts for 16 percent and livestock production 22 percent of total economic output (Figure 3).Mining and manufacturing, the other basic sector, accounts for only 11 percent. The remaining 51 percent of output is produced by those sectors of the economy which are primarily service sectors, i.e., they service the region rather than produce for sale to entities outside the region.

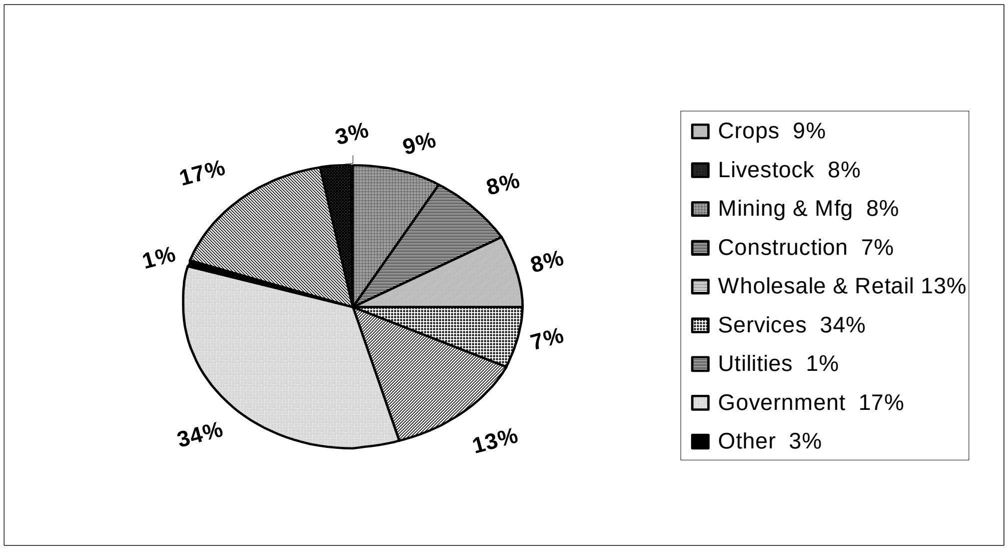
The sources of employment in the region reveal a somewhat different picture. Crop production accounts for only 9 percent, and livestock production 8 percent of total regional employment (Figure 4). This is because economic output per unit employee is much higher in agriculture than in most other sectors of the economy.

If Lincoln and Kearney Counties were excluded, the structure of the region would look quite different. Lincoln and Kearney Counties account for about 33 percent of the economic output and 36 percent of total employment in the Republican Basin economy, as it was defined for this study. Lincoln and Kearney also account for 49 percent of the services and 60 percent of the retail trade.



Total Industry output = $4,425,000,000

Figure 3. Republican Valley Industry Output



Total Employment = 54,887

Figure 4. Republican Valley Employment

Regional Effects from 10% Scenario. The effect of reductions in agricultural production and net farm income on the regional economy were estimated for each of the scenarios. It was found that the 10 percent scenario would reduce total pumping by 105,175 acre-feet, decrease total economic output by $16.3 million, reduce value added by $5.6 million and reduce employment by 150 jobs (Table 13). Each one-acre foot reduction in irrigation water applied reduced economic output by $155 and cost the region $53 in value added. Value added includes wages and salaries, proprietors income and other payments that can be used eventually to meet personal consumer needs, and is thus the preferred measure of how the welfare of people is affected.

Regional Effects from 20% Scenario. The effects from the 20 percent scenario were much larger, both in total and on a per acre-foot basis. It was found that the 20 percent scenario would decrease total economic output by $58.3 million, reduce value added by $24.0 million and reduce employment by 540 jobs (Table 13). This means that the second 10 percent decrease in pumping reduced economic output by $370 per acre-foot and cost the region $162 in value added, compared to $155 and $53, respectively, for the first 10 percent. Adding the effects of the first and second 10 percent reductions together results in an output effect of $266 per acre-foot and a value added cost of $110 per acre-foot. Note that doubling the reduction in pumping from 10 to 20 percent increased total welfare cost by 430 percent.

Regional Effects from 13 Percent + 120 kaf Drought Scenario. The drought scenario reduced total pumping by about 17 percent more than the 20 percent scenario, and had about the same impact on economic output per acre-foot change in pumping. The impact on value added, however, increased from $110 in the 20 percent case to $125 per acre-foot of change for the drought scenario. The estimated total impacts for the drought scenario were a $68 million reduction in economic output, a $32.5 million reduction in value added and a decrease of 630 jobs.

Distribution of Economic Impacts by Industry.

The most significantly affected industries are those which supply inputs and services to irrigators and/or process and handle agricultural outputs. Those retail firms which sell generally to households will also be significantly affected. On the other hand, the policy scenarios considered are not likely to have much impact on manufacturing firms, construction companies or govern- ment agencies, including schools.

The effects of each scenario on the purchase of fuel (including electricity), lubricants and agricultural chemicals were calculated within the agricultural model, whereas other less important and/or more difficult to compute impacts were considered only as a part of more generalized input-output effects. It was estimated that the 20 percent scenario and the 13% plus 120 kaf drought scenario would directly reduce sales of fuel (including electricity)and lubricants by about $10 million per year and agricultural chemicals by about $4.5 million.

Geographic Distribution of Economic Impacts

All of the estimated regional impacts, even those for the most severe scenarios, amounted to a very small part of the total regional economy. In an economy that produces $4.4 billion in output and employs 55,000 people, a $68 million reduction in output and a decrease of 630 would hardly be noticed as long as the consequences were evenly distributed across the region. On the other hand, if the impacts were concentrated in certain parts of the region the consequences would be much more significant.

Unfortunately it is difficult to determine where within the region the impacts will most likely be located. This depends on where the farm impacts occur, where irrigators purchase farm inputs and market their production, and where the directly affected households go to shop. The farm level impacts are concentrated in the west end of the Basin, with the URNRD accounting for 55 to 65 percent, the MRNRD 25 percent and the LRNRD 10 to 20 percent of the reductions (Figure 5). This suggests that the communities of Imperial and McCook will be affected to a greater extent than other similar sized trade centers within the region. Another factor to consider is that Lincoln and Kearney Counties account for about 35 percent of the economic activity in the region as it was originally defined. Because these counties are located on the edge of the region, it is unlikely that they will suffer a percentage impact from agricultural reductions in the Republican Basin that is as large as what will be experienced by communities that are locally closer to where the on-farm effect occurs.

Table 13. Regional Economic Impacts

		Policy Scenarios		
		10%	**20%**	**13% + 120 kaf**
Economic Output				
Farm Sector		12,083	43,332	50,541
Off-farm Sectors		4,169	14,950	17,436
	Total	16,252	58,252	67,977
Value Added				
Farm Sector		3,409	16,174	23,383
Off-farm Sector		2,177	7,807	9,106
	Total	5,586	23,981	32,489
Employment		150	537	627

Table 14. Effects on the Purchase of Fuel, Lubricants and Ag Chemicals

Scenario	Fuel & Lubricants	Ag Chemicals	Total
	-------------- Reduction in Purchases, Thousands of $ ------------		
10 Percent	2,646	891	3.537
20 Percent	6,485	4,024	10,509
Drought, 13% +120 kaf	5,794	4,466	10,260

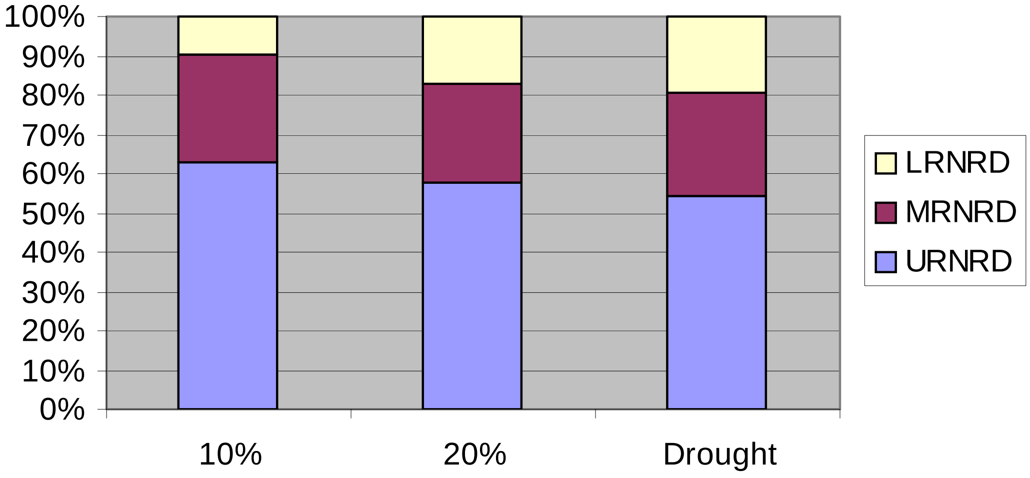


Figure 5. Geographic Distribution of the Impacts on Value of Ag Production

Table 15 shows how each scenario affects the regional economy as a proportion of economic output and employment, with and without the inclusion of Lincoln and Kearney Counties. What these percentage calculations indicate is that even if one assumes that none of the estimated impacts actually occurred in Lincoln or Kearney County they will still constitute just a small part (1 to 3 percent) of total economic output and employment. What this means from a policy perspective is that the region should be able to absorb the consequences of these policy scenarios without much disruption. It does not mean, however, that the results are insignificant or should be ignored by policy makers.

Table 15. Regional Economic Impacts as a Proportion of the Total Regional Economy, with and without the Inclusion of Lincoln and Kearney Counties

Scenario	Economic Output with Lincoln and Kearney	Economic Output without Lincoln and Kearney	Employment with Lincoln and Kearney	Employment without Lincoln and Kearney
	----------------- Percent of Total Output or Employment -----------------			
10 Percent	0.37	0.56	0.03	0.04
20 Percent	1.31	2.02	0.96	1.50
Drought (13% + 120 kaf	1.53	2.36	1.14	1.75

Land Value Impacts

Another important economic impact is the potential effect on agricultural land values. Agricultural land values in the Southwest Region have risen steadily over the past 20 years**,** although not quite as fast as they have on a statewide basis (Figure 7). Given the size of the on-farm economic effects it seems reasonable to suggest that this trend will continue, i.e., most irrigated land values will continue to increase, but at a slower rate than would have been the case without water supply changes. In the case of quick response lands and dryland with irrigation potential, however, we may see some absolute declines at least in the short-run.

What happens to the value of quick response lands over the long-term will depend on what kind of land retirement or compensation programs emerge in the future, and on the frequency of drought. If we were to get a few successive years of drought that resulted in severe regulation of quick response lands without compensation, we could very well see a drop in market value of several hundred dollars per acre. On the other hand, if attractive compensation programs emerge and it starts raining consistently, we may see a slower rate of increase, but not an absolute decline.

Over the long-term one would expect the effects of regulations on irrigated land values to approximate the capitalized value of changes in net economic returns, but it is important to remember that in the short-term the market is driven more by psychology than by economics. Certainly, if buyers and sellers become anxious and pessimistic about the future of agriculture in the region, market values could dip well below current levels until market participants get a better sense of what water regulations are going to do to the economic returns to land.

Effects on the value of dryland with irrigation potential are a little more certain. Historically, dryland with irrigation potential has been worth about $400 per acre more than dryland without irrigation potential (Figure 6). With well drilling moratoria in place this distinction will disappear, resulting in somewhat lower average dryland values. Without knowing how much of the land in the region has been regarded by the market in recent years as having irrigation potential, however, it is not possible to say whether there will be a noticeable impact on aggregate land values in the region.

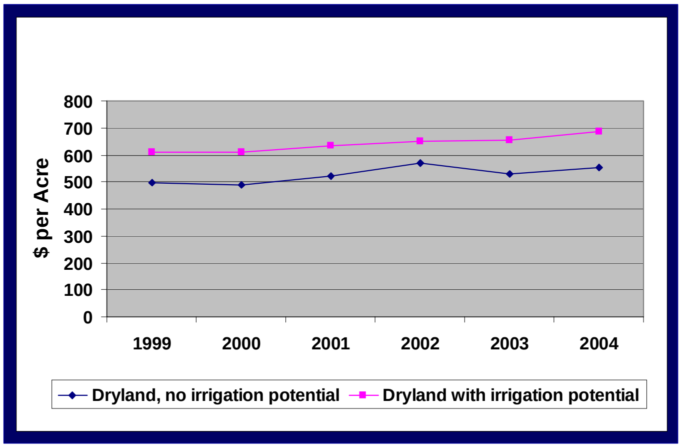


Figure 6. Land Value Trends, Southwest Nebraska

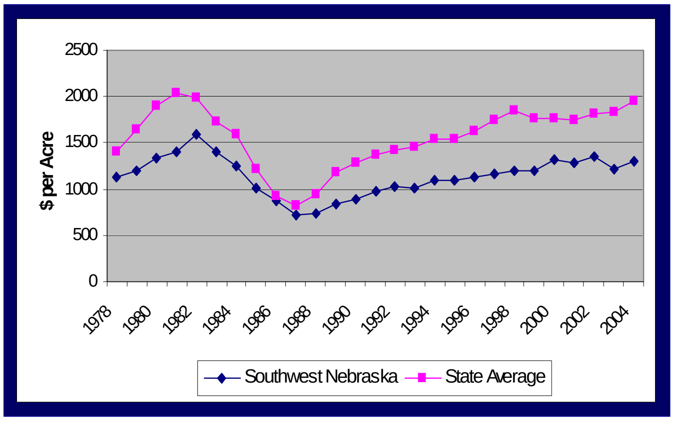


Figure 7. Irrigated Land Value Trends

Summary, Conclusions, Qualifications and Policy Implications

Th State of Nebraska is required by law to limit consumptive use of water in the Republican Basin to 49 percent of the available supply. This may require reductions in pumping during normal years of 5 to 10 percent, with additional reductions during drought periods. This analysis examines the potential economic impact of such reductions on irrigators and on the Republican Valley economy.

The study used a linear programming methodology to analyze the on-farm effects and an input-output model to estimate off-farm effects. The on-farm effects were estimated by positing a change in water supply and then computing how a profit maximizing irrigator would respond. The method incorporates five irrigated crops (corn, soybeans, wheat, grain sorghum and alfalfa) and a dryland rotation, and solves for the optimum crops to produce and the optimum amount of water to apply to each crop. Other outputs from the on-farm model include the effect of water supply changes on the total value of crop production, net economic returns and farm input purchases. These results were then fed into an input-output model which computes how the farm level changes affect economic output, value added and employment for the total regional economy.

In this study three policy options for reducing irrigation were evaluated, including basin-wide pumping reductions of 10 and 20 percent, and a worst case drought period scenario.[1] The drought scenario consisted of a 13 percent basin-wide reduction in pumping, plus an additional 120,000 acre-feet of pumping reductions (40,000 at the river) that was proportionally distributed across the NRD’s based on their respective share of depletions to the river. On-farm economic effects from these scenarios were estimated separately for the Lower, Middle and Upper NRD’s and for the upland and quick response wells within each NRD. Off-farm impacts were estimated for a single fifteen county Republican Valley economy that includes the three NRDs and their respective primary trade areas.

Summary of Results.

It was estimated that a 10 percent reduction in pumping would reduce pumping by 110,000

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[1] Since this analysis was done the Nebraska Department of Natural Resources has lowered their estimate of the pumping reductions that may be required in drought years from 13 percent basin-wide plus 120,000 acre-feet (40,000 at the river), to a 5 percent basin-wide plus 120,000 acre-feet reduction.

acre-feet, reduce net farm income by $3.00 per certified acre per year ($6.00 per affected acre)[2], and cost the Republican Valley $5.6 million in value added receipts. This total cost is equivalent to $53 for each one acre-foot change in pumping and to $196 for each one acre-foot change in consumptive use.

It was estimated that a 20 percent reduction in pumping would reduce pumping by 220,000 acre-feet, reduce net farm income by $15.00 per certified acre per year ($21.00 per affected acre), and cost the Republican Valley $24.0 million per year in value added. This total cost is equivalent to $110 for each one acre-foot change in pumping and to $254 for each one acre-foot change in consumptive use.

The worst case drought scenario reduced pumping by 260,000 acre-feet, reduced net farm income by $21.00 per certified acre per year ($31.00 per affected acre), and cost the Republican Valley $32.5 million per year in value added. This total cost is equivalent to $125 for each one acre-foot change in pumping and to $287 for each one acre-foot change in consumptive use.

Study Qualifications and Limitations

Like all studies this analysis has a number of important limitations which users should keep in mind. They include:

1. **Assumptions concerning producer responses to pumping regulations.**

   This analysis assumed that producers will respond to regulations in an optimum manner which maximizes profits. If some producers choose to adjust by growing dryland crops on part of their historically irrigated land, or by producing drought tolerant crops such as wheat or grain sorghum under irrigation, the economic consequences from each of the policy scenarios will be much larger than what was estimated. The consequences will also be more severe than what was estimated if mistakes are made in the implementation of deficit irrigation practices, i.e., if the limited water available is applied at the wrong time or in the wrong way. Although mistakes will inevitably be made during the first year or two as producers transition to a new management environment, we believe that our estimates are still reasonable, because most producers will quickly discover what works best.

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[2] The cost per certified acre was computed by dividing the total on-farm effects on net income by the total number of certified acres, whereas cost per affected acre was computed by dividing the same total change in net income by the number of acres affected by the regulation. Not all irrigated acres are affected by a regulation because not all of them have historically used more than the regulated amount.

2. Uncertain historical pumping data.

The historical pumping data used in this analysis are estimates developed by the NDNR using electric utility data for the LRNRD and MRNRD. Comprehensive metered data exists only for the URNRD. Although the data used were the best available and contain no obvious discrepancies, we still do not know for certain how much producers have pumped historically. There could be errors, for example, due to differences in the average volume from electric powered wells compared to wells where diesel or natural gas pumps are used. There could also be errors in the statistical procedures for extrapolating from a sample of wells to all wells when computing total pumping. The significance of these possibilities is unknown. Actual historical pumping could have been higher or lower than what was estimated.

3. Uncertain irrigated acreage estimates.

Reaching agreement on what constitutes an irrigated acre would be difficult to do from a technical perspective, even if no one had a vested interest in the outcome. Should the land that receives very little water because it lies at the end of a center pivot's reach be considered irrigated, for example, or when should center pivot corners be included? Because of these complications and the obvious opportunities for bias when reporting acreage, it is not surprising that there is much disagreement over acreage estimates. The number of acres used in this analysis were the "certified acres" estimates submitted by the NRD's to the NDNR. Some people believe these estimates are high and others believe they are low, and at this point we do not know who is correct. Hence, a sensitivity analysis was conducted to determine how much different the economic results might be if different estimates of irrigated acreage had been used.

The effects from a + or - 10 percent error in irrigated acreage were estimated for the MRNRD as an illustrative case. First, we assumed that the historical pumping estimates and required reductions in pumping under each scenario would be the same irrespective of the acreage estimate. This is consistent with the fact that historical pumping was estimated based on well data rather than acreage data and reflects NDNR's policy that NRD's could not change the amount of water which they would be able to pump under any of the scenarios by changing their acreage estimates. Second, net economic returns at the farm level were estimated at the historical water use level using three different acreage estimates: certified and + or - 10 percent of certified. Third, net economic returns were estimated at the same three acreage levels with water use limited to 90 percent of historical (the 10 percent policy scenario). Finally, the results were compared and found to be very sensitive to errors in acreage. The total cost to irrigators in the MRNRD was estimated at $944,000 using certified acres; $3,327,000 if the number of acres was actually 10 percent higher than certified; and $172,000 if 10 percent lower.

The economic impact results are very sensitive to what is used as an estimate of irrigated acres, because the lower the number of acres the higher the estimate of historical water use on a per acre basis. If historical pumping is high, a given percentage cutback costs less because it has less impact on agricultural production.

4. Mitigation possibilities.

This analysis did not consider many of the opportunities available to producers for mitigating or reducing the economic consequences from reduced water. Some possibilities that could make a significant difference include: investment in center pivot systems; improved management of tail water; or field leveling and other practices to improve irrigation uniformity. Although most of these possibilities would probably reduce the economic losses, there is no way of knowing how much mitigation will occur and what the total economic effect will be.

5. Crop price uncertainty.

Crop prices have a large impact on the on-farm cost of water restrictions. If future prices are 20 percent higher than those used in this analysis, for example, then the cost to irrigators of water reductions will be much higher than what was estimated in this analysis. Of course, if prices are lower the reverse is true. Although the prices used in this analysis are believed to be a middle range best guess, the actual future could be very different and cannot be predicted. It is perhaps somewhat comforting, however, to note that when prices are high the economic cost is high, but so also is the ability to pay. Most producers would probably be quite willing to trade a $0.25 hike in the price of corn for a 10 percent reduction in water, if it was possible to choose.

6. Regional economic linkages.

The effect of changes at the farm level on the rest of the regional economy are very hard to estimate, especially for small regions and for agricultural adjustments which occur at the margin. We know very little about where agricultural inputs are purchased, where grain is sold or where consumers spend household income. All of these factors create a great deal of uncertainty regarding the effects on the regional economy. We believe that our estimates are a reasonable best guess, but it is certainly possible that in reality the off-farm impacts could be double what we have estimated. It is also possible that they could be less, especially if the business community aggressively pursues other economic development opportunities in the wake of changes in agriculture.

Relevance of Study Results.

What can we conclude about the results of this study, given the associated study limitations? If used carefully, these results have relevance for both business planning and public policy decisions. From a business planning perspective, these results provide irrigators with ideas about which irrigation management strategies to use if water use is restricted and gives them at least a rough idea of how their net income may be affected. The off-farm impact results provide main street businesses with a general idea of what to expect in terms of reduced business activity. From a policy perspective, the results provide information which can help decide how the burden of reduced pumping should be shared. In particular, the estimated differences in per acre costs between NRD’s and between land areas within an NRD offers at least some indication of which policies are practical and equitable.

Optimum Irrigation Management Strategies. The economic effects from restricting the use of irrigation water depend most importantly on how irrigators respond to the restrictions. This analysis assumed that irrigators will respond in an economically optimum, profit maximizing manner. The optimum way of managing limited water is almost always to deficit irrigate corn, although in some cases deficit irrigation of soybeans and alfalfa can also be profit maximizing. In none of the average cases which we considered was it ever most profitable to grow irrigated wheat or grain sorghum**,** or shift some irrigated land to dryland. However, there are special circumstances where one or more of these options may be appropriate, such as shifting previously irrigated corner areas to dryland when converting from gravity to sprinkler irrigation.

Implications for Main Street Businesses. Our estimates of off-farm impacts suggest that most main street businesses will find the effects on their business to be well within the variations in business volume which they have experienced historically. This is because crop price variability and weather impacts on grain yields often have larger effects than was estimated herein for even the most severe water supply reductions. The average price received for corn, for example, has varied between about $2.10 and $3.25 per bushel over the past fifteen years; wheat has varied between $2.25 and $4.50 per bushel. Each $0.25 reduction in the price of grain reduces the revenue from a 200 bushel corn crop by $50 per acre and a 50 bushel wheat crop by $25 per acre; hence, it is likely that most firms in the region have probably frequently experienced economic downturns which were much larger than those that may occur from a 10 to 20 percent reduction in irrigation water. In years when prices or yields are low reduced irrigation will make a bad situation worse, but in years when prices are just slightly above average the effects of reduced irrigation are likely to be small enough to go unnoticed by most businesses.

Farm supply and grain handling firms in the region will probably experience the largest impacts from irrigation reductions. Those selling fuel for irrigation and some agricultural chemicals will certainly be adversely affected, with some experiencing the continuation of a downward trend. Irrigation energy use has already declined in some cases due to conversion from high pressure to low pressure machines and perhaps from pumping regulations in the URNRD. In other areas these energy reducing factors have been offset by new irrigation development and conversion from gravity to center pivot systems.

Reduced irrigation may also contribute to a downward trend in the amount of grain handled by some firms in the Basin. Shifts to more direct marketing of grain and increased soybean production has caused a reduction in grain handling revenues for some firms, a situation which will only get worse due to reduced irrigation. The growing attractiveness of soybean production is of particular significance because the amount of grain handled from an acre of irrigated soybeans is about one-third of what is produced from an acre of irrigated corn. If pumping limitations accelerate the evolution from continuous corn to a corn-soybean rotation, as could happen, it will only worsen an already depressed situation.

Policy Implications. Perhaps the most important policy implication to keep in mind is the distinction between regulatory policies and subsidized land retirement policies. With regulatory policies such as those considered in this analysis, the irrigator bears most of the cost of reduced pumping, with very little adverse impact on other parts of the regional economy. Land retirement options, on the other hand, are likely to cost irrigators less and the off-farm economy more. Subsequent to the start of this study there has been serious discussion of the use of voluntary land retirement programs to achieve part of the required reductions in pumping and consumptive use, most notably EQIP and CREP. Under EQIP, irrigators would be paid with federal funds to not irrigate, but they could grow dryland crops on the land. Under CREP, irrigators would be paid with federal funds to convert their irrigated land to conservation uses (grass) and dryland crops would not be allowed.

EQIP and CREP would be a very helpful way of more equitably getting the needed reductions from quick response wells during drought periods, because the irrigators involved receive compensation. The downside is that the impact on the off-farm economy would be very high per acre-foot reduction in pumping. This is because paying irrigators to take land out of production substantially reduces the amount of inputs they purchase from the regional economy. The first round effect of the CREP option would be to reduce the amount of income flowing into the region by over $375 for every acre of fully irrigated corn that is removed from production. Instead of producing an acre of corn which brings $500 in the region ($2.50 per bushel x 200 bushels = $500), the irrigator produces nothing and receives a payment from the government of about $125, for a net difference of $375. Although this option has not been studied in detail, the total impact would be still larger as this income ripples through the region.

Another policy implication suggested by this study concerns the equity aspects of using the same percentage reduction across NRD’s and across different land areas within an NRD. When using the same percentage reduction in pumping, costs per acre increased significantly going from east to west. The estimated cost to irrigators in the Upper Republican NRD of a 20 percent reduction, for example, was more than double the cost of the same percentage change in the Lower Republican NRD. Decision makers may wish to consider alternative policies which spread the burden more evenly across NRD’s.

Another equity issue that may be of interest to policy makers is equity between sprinkler and gravity irrigation systems within an NRD. If gravity irrigators are allocated the same amount of water as sprinkler irrigators, then usually the cost per acre will be higher for gravity systems. Some observers regard this as inequitable, while others believe equivalent allocations create a proper incentive for producers to invest in more efficient systems.

General Conclusions

Although we can draw certain rather broad conclusions from these results, it would be presumptuous to suggest that these results are the final answer for either business planning or policy decision making. We offer the following general conclusions only as interpretations of what we believe the results mean in a policy context. We hope they are helpful to decision makers and residents of the Republican Basin, but fully recognize that other well informed and sincere observers may reach different conclusions.

1. A 10 percent across the board reduction in pumping was estimated to cost affected producers between $2 and $12 per acre. When study limitations are considered, we believe there is a reasonable possibility that actual costs could be double this amount, $4 to $24 per acre depending on location and irrigation system type. A 5 percent across the board reduction, as currently proposed by the NDNR, would cost less that one-half of what the10 percent scenario would cost because of the principle of diminishing returns. The bottom line is that in our opinion if policy makers choose to reduce pumping by 5 to 10 percent most producers could probably absorb the costs without major consequences such as bankruptcies, loan defaults, etc.

2. The drought scenario, which was defined as a reduction of 13 percent across the board, plus an additional 120 kaf from quick response wells, was estimated to cost producers from $5 per acre (upland sprinklers in the LRNRD) to $100 per acre (quick response wells in the URNRD). Here we have more confidence in the estimates because there is less room for error, especially at the higher cost levels, and the bottom line is quite clear. This scenario reduces the allocation to quick response wells to about 35 percent of historical levels in the URNRD, and to 65 percent in the MRNRD and LRNRD. In our opinion many producers with quick response wells would find the corresponding costs unmanageable, especially in the URNRD ($100/acre) and the MRNRD ($47/acre), but perhaps also in the LRNRD ($32/acre). Since this analysis was done, the NDNR has proposed a drought scenario of 5 percent across the board, plus 120 kaf, which would be much less costly, but how much less is unknown. Policy makers may wish to pursue other options during drought periods, such as subsidized voluntary land retirement programs, public purchase of irrigation rights or direct compensation payments to quick response well operators.

3. Common definitions of economic equity call for equalizing the on-farm cost burden, perhaps defined in terms of cost per affected acre. If this is a desirable political objective, then the on-farm economic results suggest that one should not implement policies which reduce pumping by the same percentage across NRD’s and irrigation system types. This is because percentage reductions favor those cases where historical pumping has been relatively low because of rainfall differences or type of irrigation system. An alternative approach would be to implement differential allocations where historical pumping is reduced by the same number of inches per acre in every case, rather than by the same percentage. In our opinion, this option merits further evaluation.

4. Our estimates of off-farm economic impacts are certainly significant in an absolute context and clearly merit consideration in the on-going policy debate, because impacts totaling in the tens of millions of dollars should not be ignored. From a business planning perspective, however, the results suggest a different conclusion. Even if one doubles or triples our estimated effects on economic output, value added and employment, the conclusion remains the same, i.e., the effects are not large enough to significantly disrupt most main street businesses. It is important to recognize that averages can mask a lot of sins, however, so this finding should not be interpreted to mean that there will not be some exceptions. Imperial, for example, is likely to be affected much more than other communities in the Basin because of its location relative to where the largest agricultural changes will occur. Some businesses are likely to flourish, such as agronomic consultants and center pivot dealers, as producers search for improved management options, while others decline, such as the firms who will be handling less grain.

Appendix A.

Relationships Between Crop Yield and Water Applied

Figure 1. Yield - Water Functions for Corn, URNRD

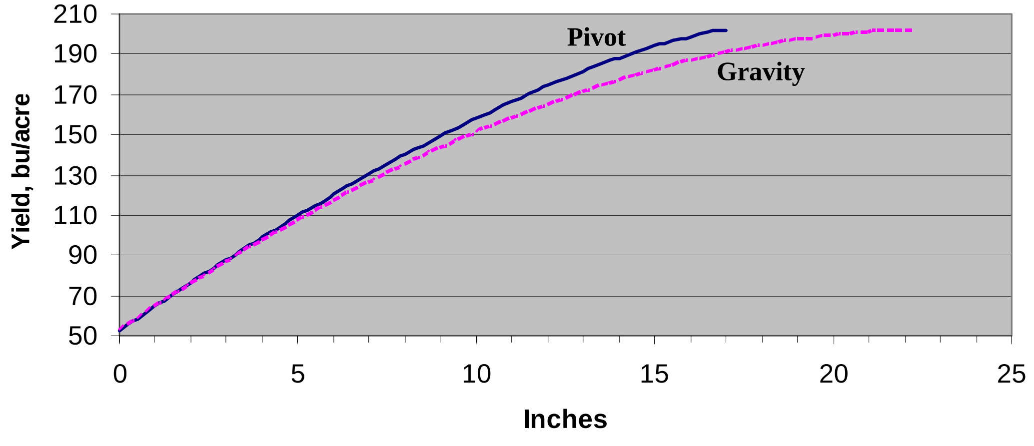
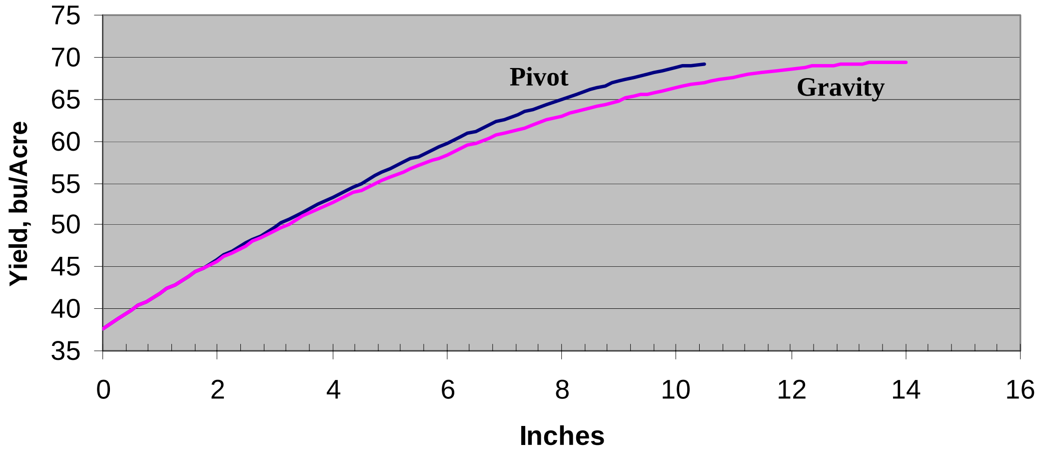


Figure A2. Yield - Water Functions for Wheat, URNRD



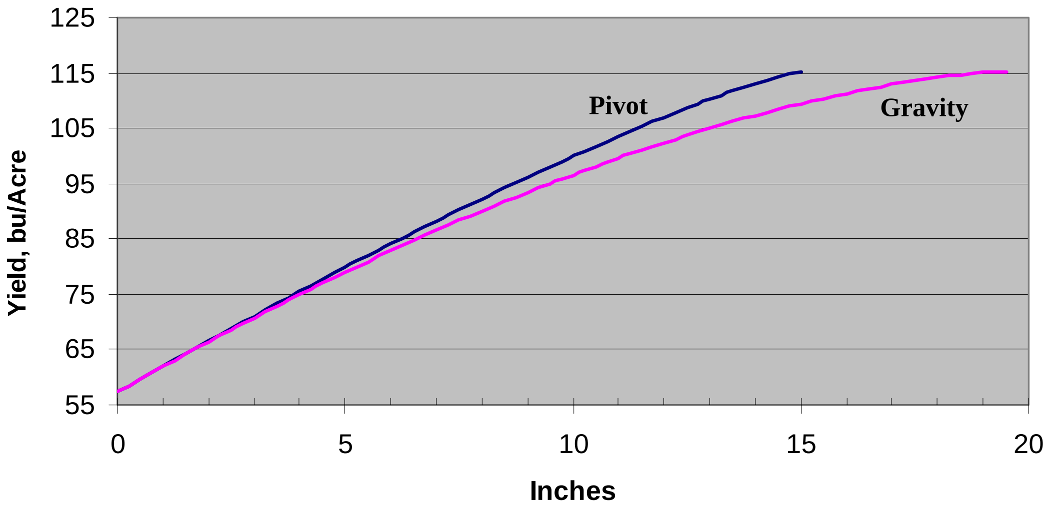


Figure A3. Yield - Water Functions for Sorghum, URNRD

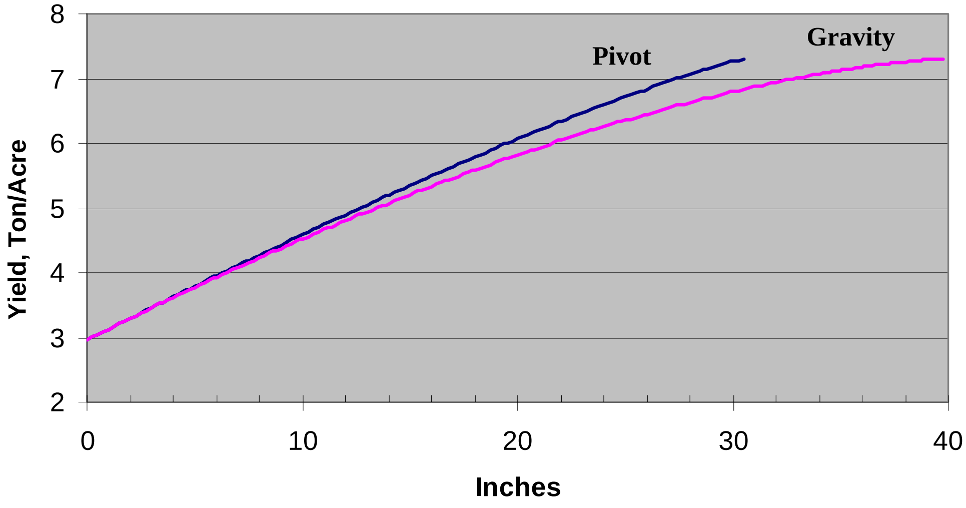


Figure A4. Yield - Water Functions for Alfalfa, URNRD

Figure A5. Yield - Water Functions for Soybeans, URNRD

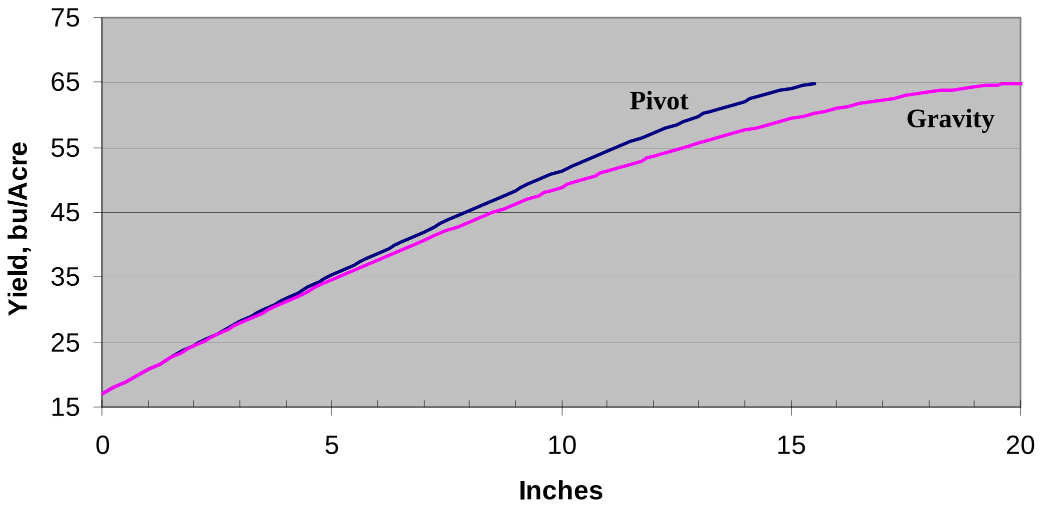


Figure A6. Yield - Water Functions for Corn, MRNRD

Figure A7. Yield - Water Functions for Wheat, MRNRD

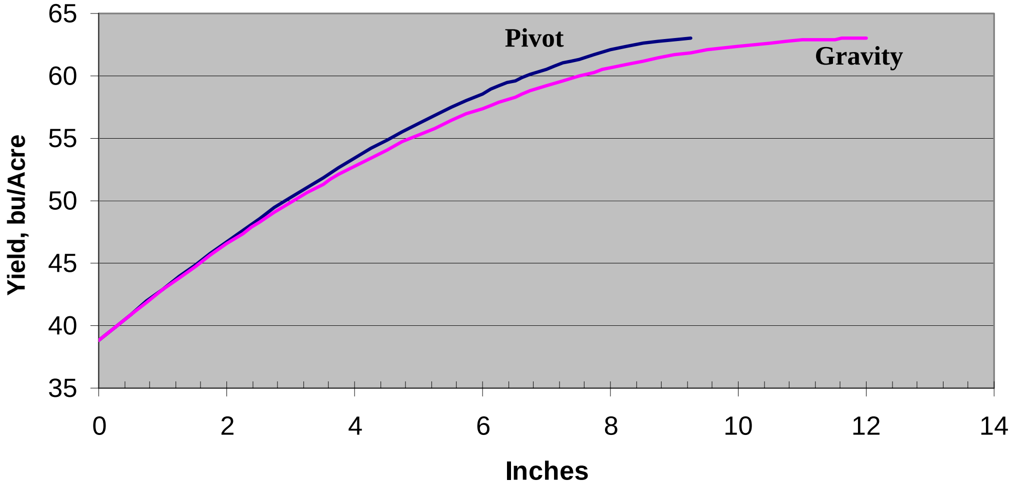


Figure A8. Yield - Water Functions for Sorghum, MRNRD

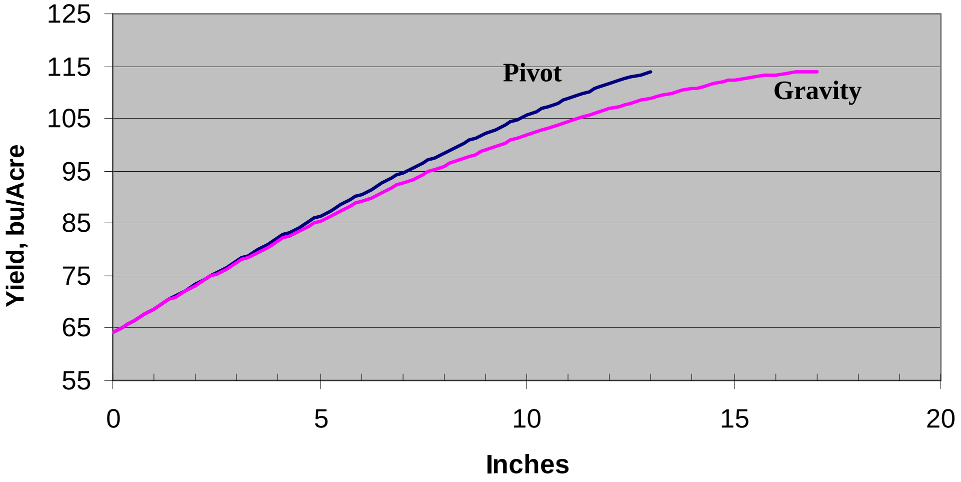


Figure A9. Yield - Water Functions for Alfalfa, MRNRD

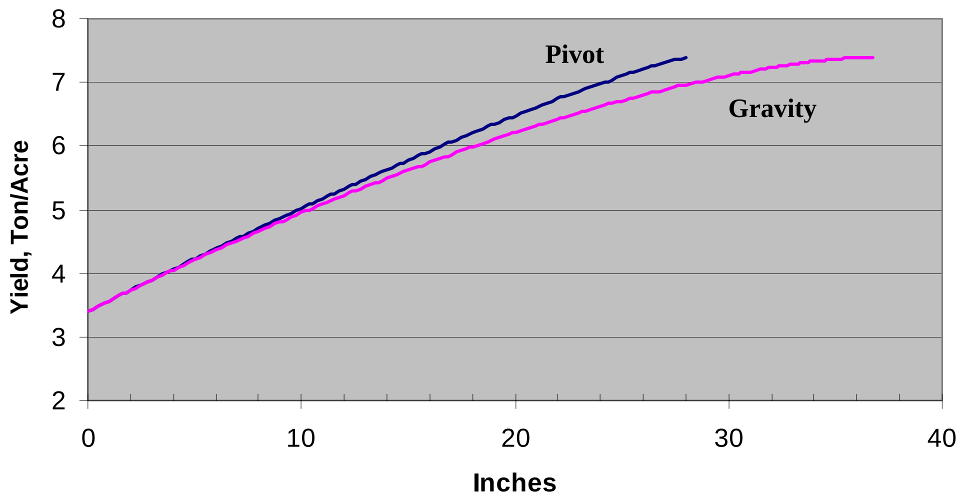


Figure A10. Yield - Water Functions for Soybeans, MRNRD

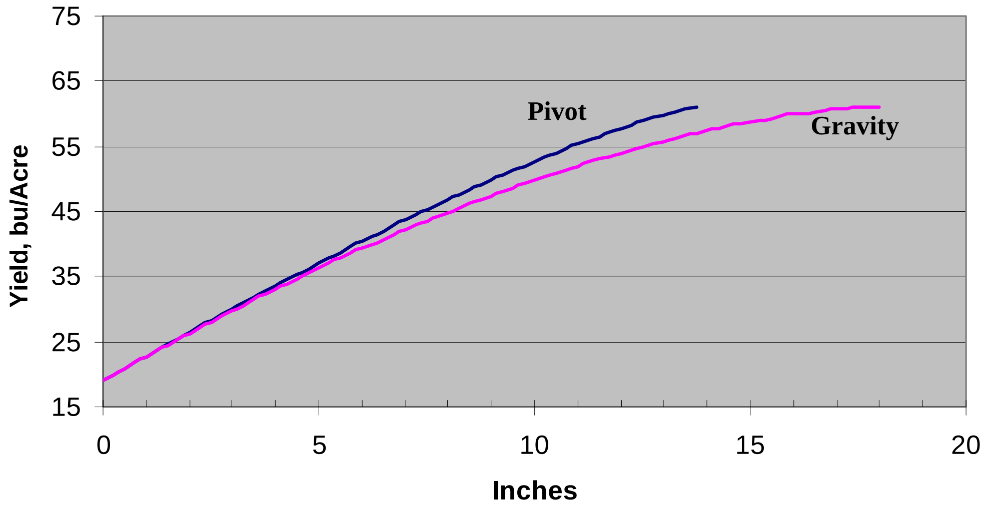


Figure A11. Yield - Water Functions for Corn, LRNRD

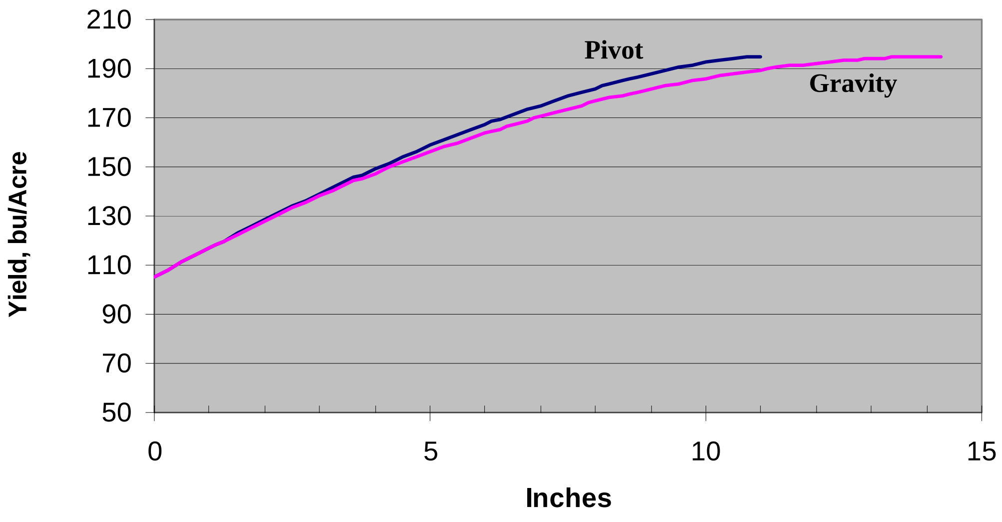
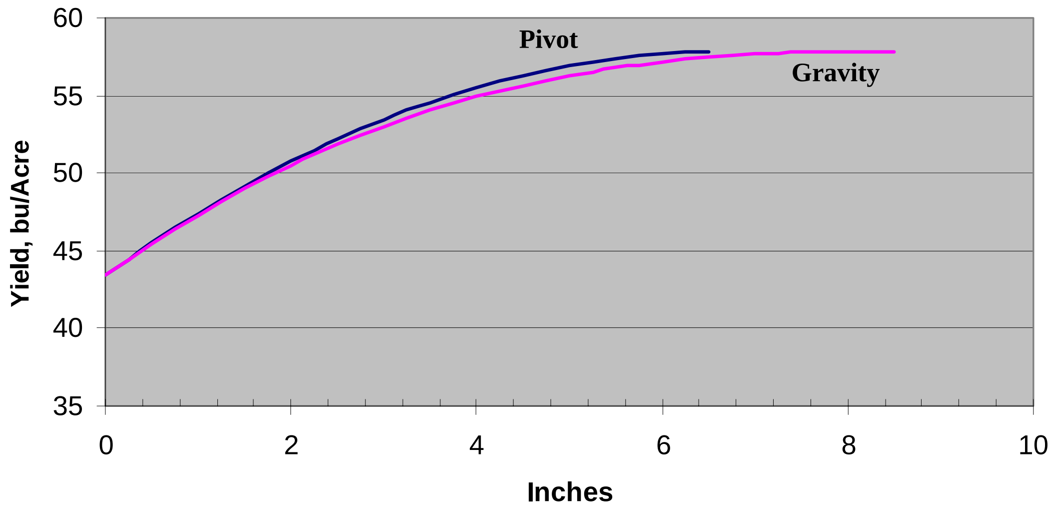


Figure A12. Yield - Water Functions for Wheat, LRNRD



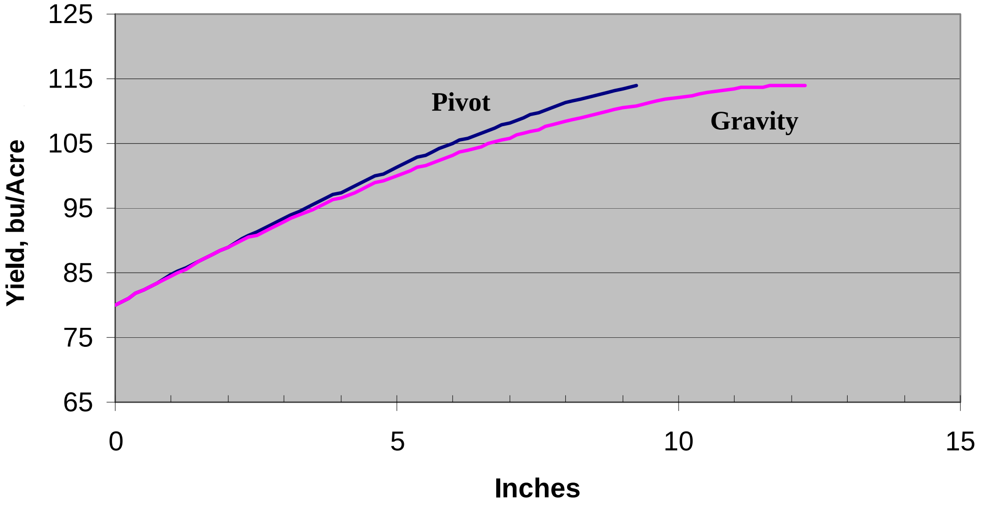


Figure A13. Yield - Water Functions for Sorghum, LRNRD

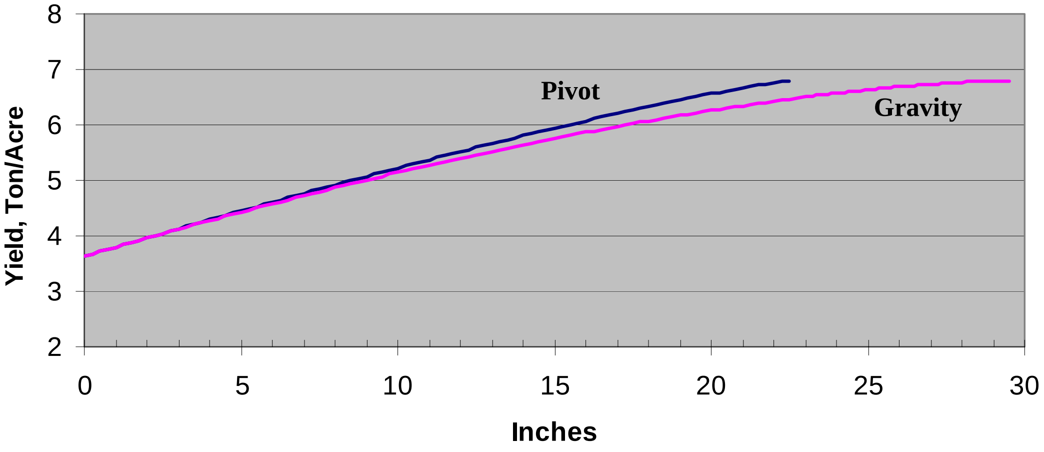


Figure A14. Yield - Water Functions for Alfalfa, LRNRD

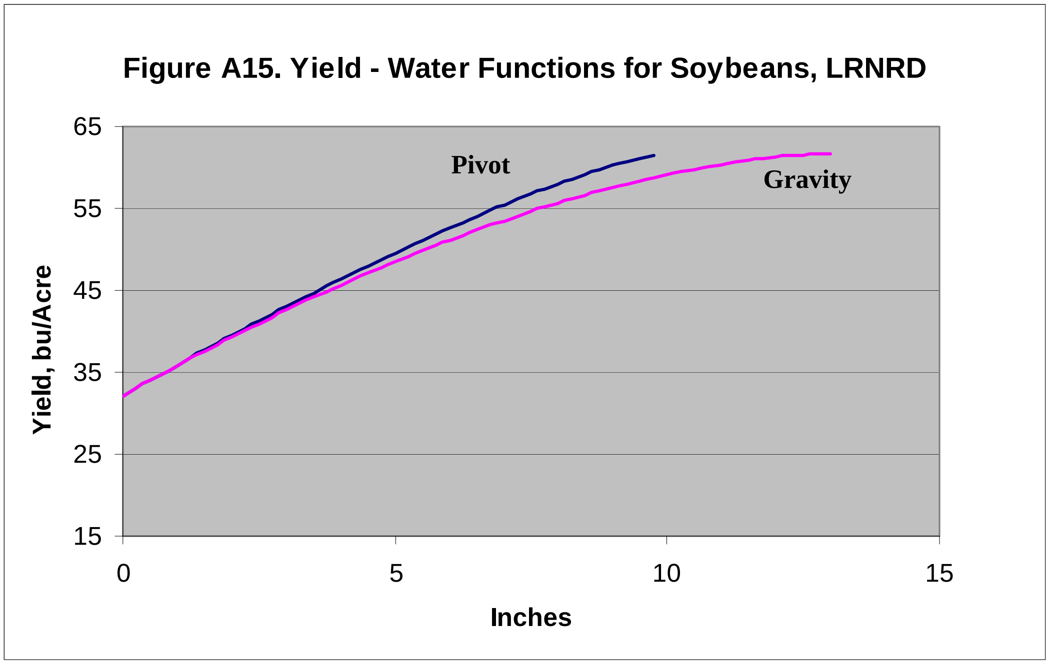


Figure A15. Yield - Water Functions for Soybeans, LRNRD
65
55
45
35
25
15
Yield, bu/Acre
0
5
10
15
Inches
Pivot
Gravity

Appendix B.

Responses to Questions from the Public and Reviewers

Responses to Questions from the Public and Reviewers

The results of this study were presented at a public meeting at Arapahoe, Nebraska on July 26 and the power point slides from that presentation have been widely distributed electronically. This generated a great deal of public comment and numerous requests for more information and explanation. In this appendix we have summarized the most frequent and important questions and attempted to address them in as much detail as practical. Several of the comments helped us improve our interpretations and explanations of the results. Others raised important study limitations which we did not recognize earlier. All were helpful to us as we search for an improved understanding of the economics of water limiting policies.

1. Why are the on-farm economic effects so small?

In our view, many of the economic effects are not "small." We estimated, for example, that the 13 percent + 120 kaf drought scenario would cost those with quick response wells in the Upper Republican NRD $104 per acre. Impacts of this magnitude are very large indeed! On the other hand, there were many situations where the economic effects were quite small, and certainly small relative to the expectations of some people in the Basin. Why was this the case?

We think that a major reason why the results surprised many people is that it is common practice to think in terms of the average value of water, rather than the incremental value. Let us consider the irrigation of corn, for example. The first inch of water applied to a corn crop probably produces about 12 bushels of corn and costs about $5.00 to apply, for a net gain of $25, if corn sells for $2.50 per bushel (12 x $2.50 - $5.00 = $25/inch). The 12th inch, on the other hand, may produce perhaps 3 bushels, for a net value of only $2.50 (3 x $2.50 - $5.00 = $2.50). In this case the average value of all irrigation water applied to corn may be about $10 per inch, with the first one inch being worth $25 and the last inch only $2.50. When irrigation is reduced by regulating pumping, the cost to the irrigator is the lost net income from the last inches used, which is much less than the average value for all irrigation water.

Another reason why some observers disagree with our estimate of on-farm costs is that they believe we may have over-estimated the ability of producers to respond optimally to the expected regulations. We share this concern. If irrigators respond by shifting some irrigated corn acres to drought tolerant crops such as wheat and grain sorghum, rather than choosing to deficit irrigate corn, for example, the economic costs will be much higher than we have estimated. Anecdotal evidence certainly suggests that this could happen, but we are cautiously optimistic that an aggressive education program will lead quickly to optimum management practices.

2. Why was the Republican Basin economy defined to include counties which lie outside the watershed boundaries of the Basin?

Although there are no clearly defined rules for defining a region, the usual approach is to define regions based on trade areas. The data are only available on a county basis, so what this usually means is that you define a region as consisting of a contiguous set of counties that includes a trade center or centers (larger city), plus the area they serve. This was especially difficult for the Republican Valley, because there is no dominant trade center that serves all or even most of the region. Imperial and McCook are located within the Republican Basin and do serve as trade centers for a significant part of the Basin’s agricultural sector, but significant trade also occurs in North Platte and other cities that lie north of the River Basin boundaries. The dilemma this presents is that if we define the economic region to include only those counties that lie within the river basin boundaries, we will underestimate the total off-farm effects because of the trade which occurs with nearby trade centers such as North Platte. On the other hand, if the region is defined to include all major trade centers that are linked to the affected agricultural producers in the Republican Basin, then the estimated off-farm impacts will be larger in total, but smaller as a proportion of all economic activity within the region.

For this analysis we chose to define the region to include all of the significant trade centers in Nebraska that were economically linked to agricultural production in the Republican Basin, including the following 15 counties: Chase, Frontier, Franklin, Dundy, Furnas, Hitchcock, Hayes, Harlan, Gosper, Red Willow, Phelps, Nuckols, Lincoln, Kearney and Webster. This approach insured that all significant off-farm economic effects would be identified. However, users of the estimated off-farm impacts must consider that it is not just the magnitude of the off-farm impacts that is important for policy purposes, but also the distribution of the impacts. Impacts which in total constitute only a small proportion of the total regional economy may never-the-less be very important and very serious if they are concentrated in just a few locations within the region. Unfortunately input-output analysis does not address how impacts are spatially distributed within a region. This requires detailed knowledge of where major farm input suppliers are located, where grain is marketed and where people live and shop, a task that was well outside the scope of this analysis.

The regional economic impacts section of this report now includes a description of the Republican Basin economy that excludes Lincoln and Kearney Counties, for those who may want to look more closely at how the regional economy might be affected.

3. Why are the off-farm economic effects so small?

In our view most of the off-farm economic effects are not small and some are very substantial. The 20 percent pumping reduction scenario, for example, was estimated to decrease economic output in the region by $58 million and value added by $24 million, with about 25 percent of the output impact and one-third of the value added impact occurring off-farm. Impacts of this size are certainly significant, but public feedback suggests that our estimates are still much smaller than many people expected. Why is this the case?

We hypothesize that a major reason why some people believe the off-farm impacts will be much larger than we have estimated, perhaps 3 or 4 times larger, is that they are accustomed to thinking in terms of an average impact from removing an acre of irrigation. If we were evaluating policy scenarios which retired irrigated land, especially if it goes from irrigated production to conservation grasses, the off-farm effects on the region might well be 3 to 4 times what we have estimated. This is because removing an acre of land from production, rather than merely cutting back the amount of water applied to the land, as was done under the policy scenarios we evaluated, has a much larger effect on gross agricultural sales from the region and on the amount of agricultural inputs purchased.

4. Water use differences between gravity and sprinkler systems.

Some reviewers have suggested that the roughly 15 percent difference in water applied between sprinkler and gravity systems which emerged from our analysis is too small; that the actual difference is between 40 and 60 percent. Although there are certainly some gravity systems where water application levels are 50 percent higher than a good pivot, usually this is only the case when surface water is used and the tail water can be allowed to run off the field and move downstream. Our analysis includes only lands which are groundwater irrigated (although some have a little bit of co-mingled surface water) and thus we assumed that everyone had or will soon have some kind of control over tail water, as required by state law. Under these circumstances a 15 to 20 percent difference is reasonable. It is also important to keep in mind that when water use is restricted application efficiencies go up, which tends to narrow the difference between sprinkler and gravity systems.

5. Method of computing consumptive use.

One reviewer commented that our method of computing yields as a function of water applied (Cobb/Douglas production functions) was inconsistent with what the NDNR used when suggesting that 120,000 acre-feet pumped produced 40,000 acre-feet of consumptive use saving at the river, a 3 to 1 ratio. We concur that this appears to be the case. Even the most inefficient irrigation systems produce more than 1 unit of consumptive use for every 3 units of pumping.

We are not sure why the NDNR is using or at least did use 3 to 1 when considering drought scenarios. Our best guess is that they had to consider time to the river as well as the field level relationship between water applied and consumptive use at the field. In other words, not all of the consumptive use which occurs from quick response wells will show up at the river in the required time frame. You might need 120,000 acre-feet of pumping to get 40,000 at the river when you need it, even though the longer term effect is certainly greater.

6. Targeted impacts.

One reviewer expressed concern about targeted impacts getting lost in the averages, especially in the case of quick response wells which must absorb a big part of the hit during drought periods. We concur that this is a very critical issue. Our analysis showed that a 13 percent, 120 kaf drought scenario would cost users of quick response wells in the URNRD about $100 per acre, which is more than 5 times the impact on upland well operators in the same NRD. For the MRNRD the cost for quick response wells was about $50 per acre compared to $10 per acre for upland sprinklers, and for the LRNRD the quick response cost was $32 compared to less than $5 for upland sprinklers. These differences are due to several factors, but the most significant one is the ratio of quick response acres to all acres in each NRD. Only 19 percent of the acreage in the URNRD is irrigated with quick response wells compared to 36 percent in the MRNRD, and 46 percent in the LRNRD. A lower percentage of quick response acres means a larger per acre reduction in pumping to meet quick response obligations, because the current policy proposal is to allocate quick response obligations to each NRD based on the NRD's total contribution to consumptive use.

7. Irrigated acreage and historical pumping data.

A lot of concern has been expressed about the accuracy of the irrigated acreage and historical pumping estimates used in the analysis. We used the numbers which we believed would most likely be used by the NDNR in administering regulations, because this leads to the most realistic estimate of what will most likely happen when regulations are implemented. However, we certainly share the concern of other observers that in time we may discover that the best estimates of pumping provided by the NDNR were wrong and/or that the acreage estimates provided by the NRD's were wrong. The economic impact results are very sensitive to what is used as an estimate of irrigated acres, because the lower the number of acres the higher the estimate of historical water use on a per acre basis (see the limitations section of this report for details). If historical average pumping on a per acre basis was higher than we estimated, either because we underestimated acres or over estimated total pumping, then a given percentage cutback costs less than what we calculated because it has less impact on agricultural production. Of course, the reverse is also true. If actual acres are lower or historical pumping higher, then our calculated costs for a given cutback in water are underestimated.