Testimony of the Northwest Kansas Groundwater Management District No. 4 (GMD 4) to Hearing Officer David Barfield, Chief Engineer, Division of Water Resources, Kansas Department of Agriculture.

RE: Written Testimony for Proposed District-Wide Local Enhanced Management Area (LEMA) of November 14, 2017

Presented by: Raymond Luhman

This testimony is from Northwest Kansas Groundwater Management District No. 4 (GMD 4). It was approved by the GMD 4 Board of Directors.

GMD 4 submits this testimony in support of the Chief Engineer finding that the proposed Local Enhanced Management Area (LEMA), with a minor modification, will conserve water and educate water users on further conservation methods to extend the life of the Ogallala aquifer in Northwest Kansas. The GMD 4 provides a short history of the Kansas Water Appropriation Act (KWAA), the Groundwater Management District Act (GMDA), the Local Enhanced Management Area (LEMA) statute, and the previous actions taken in this proceeding. Then, GMD 4 re-states its goal. Last, GMD 4 shows how the corrective control measures should reach the goal in this case.

1. History of the Kansas Water Appropriations Act

In 1944, the Kansas Legislature passed the Kansas Water Appropriation Act (KWAA). K.S.A. 82a-701 et seq. In passing the KWAA, the Kansas Legislature dedicated "All water within the state of Kansas . . . to the use of the people of the state, subject to the control and regulation of the state . . . ." K.S.A. 82a-702.

Then, in 1972, the Kansas Legislature supplemented the KWAA with the Groundwater Management District Act (GMDA). K.S.A. 82a-1020 through 82a-1041. In doing so, the Legislature:

> "recognized that a need exists for the creation of special districts for the proper management of groundwater recourses of the state; for the conservation of groundwater resources; for the prevention of economic deterioration; for associated endeavors within the state of Kansas through the stabilization of agriculture; and to secure of Kansas the benefit of its fertile soils and favorable location." K.S.A. 82a-1020.

Exhibit A
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On December 19, 1974, after a series of informal meetings were held in the GMD 4 area to sense the will of the people relative to forming a GMD, a steering committee filed a declaration of intent and a map of the proposed district boundaries with Kansas' Chief Engineer. After further discussions between the steering committee, the Kansas Department of Agriculture Division of Water Resources (DWR), and the Chief Engineer, the Chief Engineer certified a final description of the district boundaries.

In 1975, the water users voted in favor of creating GMD 4. On May 24, 1976, the initial meeting was held in Colby, Kansas. Eleven board member positions were opened for election and all the positions were filled. GMD 4 was established. Since that time, GMD 4 has undertaken many conservation efforts, including purchasing water rights; monitoring annual usage; sending advisory letters to those who appeared to pump more water than necessary; ending new development; and creating the first LEMA in the Sheridan 6 High Priority Area (SD-6 LEMA). GMD 4 now embarks on a new conservation effort, LEMA using those same boundaries contemplated in 1974 and adopted in 1976 for GMD 4.

In 2012, at GMD 4's request, the Kansas Legislature passed the Local Enhanced Management Area (LEMA) statute. *See* K.S.A. 82a-1041. Any LEMA is a creature of statute. As part of the GMDA, K.S.A. 82a-1041 allows GMDs to address groundwater declines and other conditions of concern through management plans that include specific goals and corrective control procedures while still being consistent with state law. This local autonomy over the management plan distinguishes LEMAs from IGUCAs. The LEMA statute refers to the IGUCA statute to establish the groundwater conditions that may give rise to creating a LEMA. A LEMA must comport with the public interest, a term that figures prominently in both the KWAA and the GMDA, because the Chief Engineer has the statutory duty to regulate the distribution of the state's water resources for the benefit of all of its inhabitants according to the law. K.S.A. 82a-1041(b)(2); K.S.A. 82a-706; K.S.A. 82a-702; K.S.A. 82a-1020. GMD 4 proposed and administered the first LEMA—the SD-6 LEMA. Now, GMD 4 proposes this LEMA.

2. History of these Proceedings

On June 8, 2017, GMD 4 submitted a revised LEMA Proposal (the Proposal) to the Chief Engineer. Before submitting the proposed LEMA, GMD 4 held four public meetings in Colby, Goodland, Hoxie, and St. Francis, Kansas; and, had multiple board meetings, with many interested people attending, over a two and half year period between January 2015 and June 2017 to discuss the Proposal. This represented a significant public involvement in the process that resulted in the locally developed and locally requested plan. Additionally, GMD 4 had previously presented a more restrictive program at an additional 4 meetings. The public acceptance of that program was less positive, and therefore the board rejected that program.

On June 27, 2017, the DWR and Chief Engineer found that "on its face," the Proposal met the threshold requirements of K.S.A. 82a-1041(a) and initiated these proceedings. This determination on whether the Proposal met the K.S.A. 82a-1041 thresholds was not a final determination but an initial determination that the Proposal warranted further review, input, investigation, testimony, and consideration. To begin that review, the Chief Engineer delegated his authority to an independent hearing officer, Constance C. Owen, to conduct the initial public hearing in this matter. Notice was given of that first hearing as required by K.S.A. 82a-1041(b).

On August 23, 2017, Constance C. Owen, Hearing Officer, conducted the initial hearing on whether the Proposal met the statutory requirements of K.S.A. 82a-1041(b) and whether this matter should proceed to a second hearing. Written testimony was allowed to be submitted on this issue until September 13, 2017. *See* Order on Initial Requirements of the Groundwater Management District No. 4 District-Wide Local Enhanced Management Area, 21 (Aug. 23, 2017) (Initial Order).

The testimony GMD 4 presented, both oral and written, for the August 23, 2017 hearing is incorporated and made a part of this testimony. Therefore, this testimony will focus on the goal, the proposed corrective control measures, and the implementation of the proposed corrective control measures.

On September 23, 2017, Ms. Owen issued her Initial Order concluding that the Proposal "satisfied the three initial requirements for approval as set forth in K.S.A. 82a-1041(b)(1)-(3)."

These are excerpts from the GMD #4 Management Program of 9/19/2016, Section IV. Subsection 6 and Subsection 1 b and go further in explaining that the proposed restrictions are in the public interest:

3. The Proposal, as found by Hearing Officer Owen's, is in the public's interest.

K.S.A. 82a-1020 is the Legislative declaration relative to establishing groundwater management districts in Kansas. It declares that in the public interest it is necessary and advisable to permit the establishment of GMDs which allow local water users to determine their own destiny with respect to the use of groundwater—insofar as that destiny does not conflict with the basic laws and policies of the state.

As described by GMD 4's management plan, "Public interest" is a fundamental term used throughout the KWAA and GMDA, and within regulations developed under both statutes. Yet the term is only narrowly defined within state statute and regulation. It has been generally accepted that the complete definition of this term is actually embodied in the full suite of statutes and associated regulations, and therefore must be considered in this total, overarching context. This full context also includes the administrative, executive and judicial systems whose policies and actions also become part of the complete definition. In contrast, it has also been generally accepted that a specific statutory definition of "public interest" would be restrictive and confining, thus having more disadvantages than advantages.

The GMDA made it state policy that the local land owners and water users were to determine their own destiny in regard to groundwater management issues—so long as local decisions were consistent with state law. Since a groundwater management district cannot determine its own destiny without also expressing its own public interest, it seems logical that such authority is inherent in the GMDA.

In this spirit, this LEMA is being proposed by the GMD 4 BOD, because it believes is best for the landowners and water users of GMD 4 and hence best for the state of Kansas. The board also believes it is more clearly within the spirit of the LEMA statute. If in fact the entire suite of statutes and regulations define public interest in concert with the administrative, executive and judicial systems, then the GMDs and LEMAs are clearly a part of these systems and they deserve sufficient consideration. A single expression of public interest exclusively from the state perspective may not serve Kansas as well as a more flexible definition recognizing regional diversity.

When the LEMA process comes from the local board of directors and the corrective control provisions being requested from that process are consistent with state law, then the public interest of K.S.A. 82a-1020 has been satisfied.

In any event, the GMD 4 provided GMD 4 water users information very early in the discussions of the District Wide LEMA. The evidence provided the water users showed that adopting and implementing any corrective control provisions that would reduce water use, would also extend the life of the regional aquifer.

A web page was created to keep the process available to the public and was updated regularly by GMD 4 staff. Beginning in January of 2015, the process was covered by at least 28 board meetings.

4. The corrective controls measures should reach the LEMA goal.

4.1. The Goal for the LEMA is to promote improved management of water and not exceed irrigating 1.7 million acre-feet over a five year period.

The request for a LEMA contained the following goal statement and detail:

To promote improved management of water used district-wide with a goal not to exceed 1.7 million acre-feet (AF) for irrigation over five years within townships displaying an annual decline rate for the period 2004 – 2015 of 0.5% or greater annual decline and promote more efficient use by non-irrigation uses.

This LEMA shall exist only for the five- year period beginning January 1, 2018 and ending December 31, 2022. The proposed LEMA shall include all points of diversion located within the boundaries of GMD 4 excluding vested rights and points of diversion whose source of supply is 100% alluvial.

The total program diversion amount of 1.7 million AF for irrigation use for townships with annual decline rates of 0.5% or greater shall represent five (5) times the sum of designated legally eligible acres times the amount designated for irrigation water rights;

The Northwest Kansas Groundwater Management District No. 4 shall use the procedures herein to determine the 5-year allocation for each water right, and specify said values in Section 3). All allocation values shall be expressed in terms of total acre-feet for the five-year LEMA period. *See* Attachment 1, Request for a District-

Wide LEMA Submitted to the Chief Engineer, Kansas Department of Agriculture, Division of Water Resources (June 8, 2017) (Proposal).

GMD 4 established that goal because many parts of the Ogallala Aquifer within GMD 4 are declining at a rate greater than .05% per year. At the initial hearing, Hearing Officer Owens specifically found that:

> The credible and relevant data provided by the [Kansas Geological Survey] KGS and used to develop this LEMA proposal corroborates GMD 4's conclusion that water levels are declining or have declined excessively and that withdrawals equal or exceed the rate of recharge in the area of the proposed GMD 4 LEMA. Initial Order at 12.

The Hearing Officer based her finding on KGS's measurements of depth-to-water in about 1,400 wells taken from the same year. After taking those depth-to-water measurements, KGS calculated three-year averages (2004, 2009, and 2015) and isolated the data relative to wells within GMD 4. KGS determined that the average saturated thickness for GMD 4 was 76 feet in 2004 and 70 feet in 2015. Parts of Sherman County had an average rate of decline of over 20 feet and much of Sherman County and portions of Thomas and Sheridan County averaged declines of 12 feet over the six year period from 2009-2015. KGS concluded that "The major driver for these water level declines is groundwater pumping as illustrated by published reports (citation omitted), which show statistically significant correlations exist between annual water-level change and annual groundwater use across GMD 4."

4.1.1. The corrective controls measures should reach the LEMA goal as applied to irrigation water use.

The corrective control measures will reach the goal by reducing pumpage. GMD 4 determined the LEMA allocation for each water right using the procedures described below.

To determine a water user's LEMA allocation, GMD 4 first determined what acreage a water users recently irrigated (irrigated acres). To determine irrigated acres, GMD 4 examined annual water use reports from 2009–2015. GMD 4 used the 2009-2015 range because 2009 was the first year that all wells in GMD 4 were metered and 2015 was the last year that water use data was available when the LEMA process through the public meetings was initiated. The maximum reported irrigated acreage during that period was used to set the irrigated acre amount (or eligible acre amount) for each right. GMD 4 checked any discrepancies or inconsistencies against the United States Department of Agriculture aerial photos, the actual water rights, and the water use reports to finally determine irrigated acres (or eligible acres).

GMD 4 derived the LEMA township annual decline percent for the period of 2004-2015 from KGS section level data. A section is an area about one square mile containing 640 acres with 36 sections making up one survey township on a rectangular grid. The KGS compiled data on a section-by-section basis to determine the section-by-section declines. The KGS section level data was averaged for each legal township in the district. KGS section level data was used because it assigns a value for bedrock and water level elevations for each specific section. Then, GMD 4 removed all wells with any alluvial connection from the data set. Additionally, GMD 4 removed any sections that exhibited less than 15 feet of saturated thickness from the analysis; because, removing those sections minimized the depletion status of areas on the fringe of GMD 4. Very small declines in areas of little saturated thickness result in unacceptably high percentage figures, which is why they were removed from the analysis. This section level data GMD 4 relied on to determine the township declines and the LEMA allocations.

Last, GMD 4 examined the Net Irrigation Requirements (NIR) set by the United State Natural Resource Conservation Services. (NCRS). See U.S. Dept. of Agric., Nat. Res. Cons. Serv., Nat'l Eng'r Handbook, Irrigation Guide, KS210-652-H,, Amend. KS31, KS652-4.1 thru 4.25 (2014), https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_030990.pdf. The State of Kansas has used the NIR amounts since at least 1994 and referenced the NIR amounts in K.A.R. 5-5-9, K.A.R. 5-5-10, K.A.R. 5-5-11 and other regulations. The GMD 4 Board used the NRCS NIR 50% and 80% values for corn by county. 50% NIR represents the net irrigation requirement for corn that would be sufficient in 5 out of 10 years (considered to be normal) based on the precipitation that would be expected in 5 out of 10 years. 80% NIR represents the net irrigation requirement for corn that would be sufficient in 8 out of 10 years (considered to be dry) based on the precipitation that would be expected in 8 out of 10 years.

These figures were then interpolated to derive a value at the western edge of each zone. Each township was then assigned a color based on the zone in which it was located," red, yellow, purple, blue and green. Townships exhibiting greater than a 2% annual decline rate were assigned the 50% NIR for corn by zone (red). Townships exhibiting from 1% to 2% annual decline rate were assigned the 80% NIR for corn by zone (yellow). Townships exhibiting 0.5% to 1% were assigned an 18 inch allocation district-wide (purple). Those townships that are below the 0.5% decline rate will not have restrictions on their diversions imposed (blue and green). The tiered system gives due consideration to water users who have already implemented reductions in water use resulting in voluntary conservation measures as evidenced by a slower rate of decline. No township has an allocation less than the 50% NIR for its respective zone.

Last, GMD 4 multiplied the irrigated acre values by the allocation amount on the map attached to the Proposal based on the decline percentage for the township where the point of diversion was located and the corresponding NIR. That NIR number was then divided by 12 (to convert to acre-feet) and then multiplied times the acres times five to determine the five year LEMA allocation. For example, in township 8-42W in Sherman County, the NIR for corn is 16.1 inches per acre. If a water right user irrigated 124 acres in that township, then the LEMA allocation would be 832 acre-feet over five years.

The LEMA allocation will also not reduce water users by greater than 25% except for those being reduced to an 18 inches per acre per year cap. No LEMA allocations within areas of decline greater than .05% will be receive an allocation in excess of 18 inches per acre per year. These amounts apply to those water rights in red, yellow, and purple townships.

The LEMA proposal also contains provisions addressing specific situations. Those provisions include:

> Wells pumping to a common system or systems shall be provided a single allocation for the total system acres, subject to the review process in Sections 5 and 6. The total amount pumped by all of the wells involved must remain within the system allocation.
>
> No water right shall receive more than the currently authorized quantity for that right, times five (5).
>
> No water right within a K.A.R. 5-5-11, 5-year allocation status shall receive an allocation that exceeds its current 5-year allocation limit.

No water right shall be allowed to pump more than its authorized annual quantity in any single year.

In all cases the allocation shall be assigned to the point of diversion and shall apply to all water rights and acres involving that point of diversion. Moreover, in all cases the original water right shall be retained.

For water rights enrolled in EQIP and/or AWEP that will be coming out of either program on or before September 30, 2022, the allocation quantity shall be set at the annual allocation for only the remaining years of the 2018-2022 LEMA period.

If a water right is or has been suspended, or limited for any year of this LEMA, due to penalty issued by the Kansas Department of Agriculture, Division of Water Resources (DWR), then the GMD 4 and DWR will reduce the allocated quantity for such water right accordingly for the 2018-2022 LEMA period.

For water rights enrolled in a KAR 5-5-11 change, MYFA, WCA, or other flexible water plan, the most water restrictive plan will apply.

Each allocation for irrigation will be a total 5-year amount. The Proposal does not contain an acre-inch per acre limitation. The allocation may be used in any fashion and at any time during the LEMA chosen by the right holder, except that water user cannot exceed the annual authorized quantity unless authorized by a Muli-Year Flex Account (MYFA) or Water Conservation Act (WCA) term permit or plan.

After completing these calculations, about 65% of the wells or well-groups slated for a LEMA allocation will have a LEMA allocation that less than their combined diversions from 2009 – 2015.

The base water right will not be altered during the LEMA period. Any order issued under the LEMA will be subject to the additional LEMA terms and conditions for the five years during the LEMA. GMD 4 further requests that any future reiterations of this LEMA that may come into existence or be proposed by the GMD 4 Board take into consideration allowing a maximum 10% carry-over of the LEMA allocated amount. *See* Proposal 1)d)-l). This gives future GMD 4 and LEMA boards an opportunity to continue rewarding those that conserve. It also incentivizes conservation into the future.

4.1.2. The corrective control measures, with modifications, should reach the LEMA goal.

For non-irrigation use type, the GMD 4 Board requests that the following language modify the stockwater portion of the proposed LEMA (Modifications) for two reasons. First, the total acre feet allocated to stockwater use in GMD 4 is less than 0.5 % of total appropriations. Second, animal feeding and dairies represent a significant market for local crops and the GMD 4 Board reasoned that animal feeding and dairies should not be unduly restricted.

The GMD 4 Board still encourages livestock and poultry operations to only use 90% of the amount they are allocated. The proposed Modifications read:

> Part 2)a) Livestock and poultry use will be encouraged to maintain their use at 90% of the said amount provided by K.A.R. 5-3-22 based on the maximum amount supportable by the number of animals authorized by a current facility permit. At no time will a stockwater right be authorized to pump more than its authorized quantity. . . .
>
> Part 2)d) When converting from irrigation to non-irrigation use, the base water right will be converted under the procedures in K.A.R. 5-5-9, 5-5-10, or Groundwater Management District #4 regulations, and the appropriate non-irrigation Local Enhanced Management Area allocation will apply as found in Section 2 for the remainder of the Local Enhanced Management Area period.

Parts 2)b), 2)c), and 2)e) of the Proposal would remain the same. With the acceptance of the above modifications and because of the small fraction of the groundwater used for stock water, dairies, and recreational use, this should not be an impediment to adopting the Proposal. Additionally, stock water and dairies provide a market for crops such that the GMD 4 BOD determined decreasing the stock water and dairy use could negatively impact the agricultural economy in the region and adversely impact implementation of the Proposal.

4.1.3. Appeal Process

If an irrigation user believes they have more irrigated acres or have applied water in a different fashion than reported, an appeal process will be instituted to allow individuals and GMD 4 to review their irrigated acres. Any appeal must begin by March 1, 2019. Only irrigated acres and LEMA allocations may be appealed. The process also allows additional data from 2016 and 2017 to be considered. Again, the information the GMD 4 had when it submitted the proposal was from 2009-2015.

Water users and GMD 4 staff will conference regarding discrepancies in irrigated acres. Any decision made by GMD 4 staff may be brought before the GMD 4 board for a final decision.

This appeal process is an effort by GMD 4 to make sure that the allocations are correctly set.

4.1.4. Violations

Violations under the Proposal will be consistent with the violations in the SD-6 LEMA. These are added fines and/or suspensions to be applied in the case of over-pumping the LEMA quantity. While this does provide penalties for over-pumping the LEMA quantity; it is equally important that accurate data is available regarding water use and these provisions provide additional methods to test the accuracy of the data. In the first five years of the SD-6 LEMA, no violations occurred. There is an additional incentive for those townships not currently being issued a LEMA allocation. That incentive is to maintain or improve on current pumping levels to ensure that their respective townships do not reach decline levels that would require restrictions if a future LEMA were proposed.

An added violation concerns meter tampering. If a preponderance of evidence suggests that actions have been taken to remove or alter the meter's ability to accurately measure flow the offending water right will be suspended for a period of five years and any remaining LEMA allocation will be lost.

There are some added requirements that apply to wells that have a LEMA allocation. These require that the meters be read at least every two weeks and that malfunctioning meters be repaired/replaced as soon as possible. It also requires a back-up system by which the amount of water pumped can be readily determined. If such back-up data is unavailable it will be assumed that the entire appropriated right has been pumped for the purpose of LEMA record keeping.

4.1.5. Economic Viability

Preliminary economic studies done by Dr. Bill Golden on the SD-6 LEMA indicate that cash flow values inside that LEMA very closely resemble those of the immediate surrounding area. Dr. Bill Golden, Monitoring Impacts of Sheridan County 6 Local Enhanced Management Area, Interim Report 2013 – 2015, Nov. 8, 2016 (SD-6 Interim Report). It should be noted that the SD-6 LEMA has a much higher level of restrictions than the ones proposed by this LEMA.

A previous study was done by Golden, Peterson, & O'Brien, Potential Economic Impact of Water Use Changes in Northwest Kansas (2008) (The Golden Report). There, Golden et.al stated that, the least desirable option to institute cutbacks in diversions was to use a system that completely dries up acres—either by a first in time, first in right system, or other programs that take land out of irrigated production. They concluded that less water use on more acres had far less of a negative impact. Instituting reductions by using order of priority would have the effect of drying up many acres and for this reason, the GMD 4 board proposes giving an equal allocation to all non-vested rights based on their location and the decline rate of the Ogallala aquifer.

The Golden Report initially evaluated the potential economic consequences of reduced groundwater us in northwest Kansas. Specifically, the Golden Report evaluated the potential economic impacts of three possible reduction levels: (1) a zero reduction in groundwater pumping; (2) completely eliminating all groundwater pumping; and (3) reducing groundwater pumping by 30%. Regarding the third option, the Golden Report then assessed the respective economic impacts of achieving such a reduction by three scenarios: (a) by limited irrigation; (b) by a buyout of irrigation rights, while allowing dryland farming on dried-up lands; and (c) by a conservation program such as the Conservation Reserve and Enhancement Program (CREP), which requires a 15-year following period, after which dryland farming can resume. The Golden Report employed data that is consistent with the KGS model described above.

In assessing the respective economic impacts of the three possible reduction levels and the three scenarios described above, the Golden Report employed a variety of tools, including input-output impact analysis, and specifically, Impact Analysis for

Planning (IMPLAN). IMPLAN is a commonly accepted method of economic analysis that has been used by agricultural economists in Colorado, Kansas, and Nebraska. IMPLAN has been accepted as a reliable and persuasive method of assessing water-use impacts on agriculture by the Supreme Court of the United State. *See Kansas v. Colorado*, No. 105, Orig., Fifth and Final Report of the Special Master, at 20 (Feb. 4, 2008). *See also Kansas v. Colorado*, No. 105 Orig., 543 U.S. 86, 91 (2004) (accepting the use of IMPLAN to award economic damages).

According to the Golden Report, under the first option, over a 60 year period,—no reduction in groundwater pumping—the irrigated acres of the SD-6 area declined from 16,062 in year one to 8,245 in year 60. Future gross profits tracked this unregulated decline in groundwater levels beginning at about $5,279,829 in Year 1 and dropping to $3,997,627 in Year 60.

Under the other Golden Report extreme—a 30% reducing in groundwater pumping—the decline in water use and profitability is far less precipitous. The irrigated acres of the SD-6 area were projected to decline from 16,062 in year one to 13,327 acres in year 60. Future gross profits track this less aggressive decline in groundwater levels, starting at $4,717,461 in year one and dropping to $4,285,202 in year 60.

The SD-6 LEMA ultimately adopted a 20% reduction. A middle ground between continuing the groundwater mining then occurring and a 30% immediate reduction for all irrigated rights.

In 2016, Golden issued his Interim Report for the SD-6 LEMA. There, Golden found that past efforts (pre-LEMA efforts) to slow decline and ensure the future economic viability of the region have been largely unsuccessful. Golden noted that "LEMAs are proactive, locally designed, and initiated water management strategies for a specific geographic area that are promoted through a GMD and then reviewed and approved by the Chief Engineer." *Id.* at 1. He further notes that the LEMA blueprint may be the future of groundwater management; that it overcomes the problems associated with the 'top-down' Intensive Groundwater Use Control Areal (IGUCA) process; and it "minimizes the common property externality associated with groundwater extraction." *Id.* at 2.

Golden, in his SD-6 Interim Report, then compared those producers inside the SD-6 LEMA with those producers outside the SD-6 LEMA to determine the SD-6 LEMA's economic impact using methods that are consistent with methods used by the Kansas Department of Agriculture. *Id.* at 2-3. On comparing the control and the target group, Golden concluded that producers were able to reduce groundwater use in the SD-6 LEMA area with minimal impacts on cash flow (gross profits less expense equating to net profits). *Id.* at 2-3.

Furthermore, the Proposal does not contain any restrictions below the average water needs for corn; and, most of the wells or groups have allocations at or above the drier 80% chance NIR for corn (see explanation of NIR above). Last, the greatest restriction, 25%, is well within the 0% reduction to 30% reduction ranges contemplated by the Golden Reports (Golden Report and SD-6 Interim Report) to maintain the economic viability of the GMD 4 region.

Conclusion

This concludes the written testimony for GMD 4. In sum, GMD 4 contends that:

1. The Chief Engineer should adopt Hearing Officer Owens' Order on Initial Requirements of the Groundwater Management District No. 4 District-Wide Local Enhanced Management (LEMA) and incorporate it into the Chief Engineer's order.

2. The Chief Engineer should issue an Order of Decision accepting the Proposal with the Modifications and return the Proposal with the Modifications to GMD 4 for approval.

3. On approval by GMD 4, the Chief Engineer should issue an Order of Designation designating all of GMD 4 as a LEMA and implementing the modified corrective controls within the Proposal and described above.

ATTACHMENTS

Attachment 1

Request for a District-Wide LEMA Submitted To the Chief Engineer, Kansas Department of Agriculture, Division of Water Resources

June 9, 2017

In order to reduce decline rates and extend the life of the aquifer in Northwest Kansas Groundwater Management District No. 4 (GMD 4) the Board of Directors of GMD 4 proposes the following five year plan be submitted via the Local Enhanced Management Area (LEMA) process contained in KSA 82a-1041 for the entire area within the boundary of the Northwest Kansas Groundwater Management District No. 4.

Overview and Goal Expression

To promote improved management of water used district-wide with a goal not to exceed 1.7 million acre-feet (AF) for irrigation over five years within townships displaying an annual decline rate for the period 2004 – 2015 of 0.5% or greater annual decline and promote more efficient use by non-irrigation uses.

This LEMA shall exist only for the five- year period beginning January 1, 2018 and ending December 31, 2022. The proposed LEMA shall include all points of diversion located within the boundaries of GMD 4 excluding vested rights and points of diversion whose source of supply is 100% alluvial.

The total program diversion amount of 1.7 million AF for irrigation use for townships with annual decline rates of 0.5% or greater shall represent five (5) times the sum of designated legally eligible acres times the amount designated for irrigation water rights;

The Northwest Kansas Groundwater Management District No. 4 shall use the procedures herein to determine the 5-year allocation for each water right, and specify said values in Section 3). All allocation values shall be expressed in terms of total acrefeet for the five-year LEMA period.

1) Allocations – Irrigation

a) Proposed allocations provided in Sections 3 and 4 were determined based on the maximum reported and/or verified acres for years 2009-2015. Proposed allocations are subject to change in the case where incorrect water use data is verified via the process in Sections 5 and 6.

b) All irrigation water rights, excluding vested rights, shall be limited to the allocation for the water right location on the accompanying map over the 5-year period beginning January 1, 2018 and ending December 31, 2022. If a vested right and an appropriation right have the same place of use or same point of diversion, the vested right will be the vested water right's authorized quantity and the appropriation right will be limited to the total system allocation minus the vested water right's authorized allocation.

c) The base water rights will not be altered by any Order issued under this request, but will be subject to the additional terms and conditions described herein for the duration of the LEMA.

d) Wells pumping to a common system or systems shall be provided a single allocation for the total system acres, subject to the review process in Sections 5 and 6. The total amount pumped by all of the wells involved must remain within the system allocation.

d) No water right shall receive more than the currently authorized quantity for that right, times five (5).

e) No water right within a K.A.R. 5-5-11, 5-year allocation status shall receive an allocation that exceeds its current 5-year allocation limit.

f) No water right shall be allowed to pump more than its authorized annual quantity in any single year.

g) In all cases the allocation shall be assigned to the point of diversion and shall apply to all water rights and acres involving that point of diversion. Moreover, in all cases the original water right shall be retained.

h) For water rights enrolled in EQIP and/or AWEP that will be coming out of either program on or before September 30, 2022, the allocation quantity shall be set at the annual allocation for only the remaining years of the 2018-2022 LEMA period.

i) If a water right is or has been suspended, or limited for any year of this LEMA, due to penalty issued by the Kansas Department of Agriculture, Division of Water Resources (DWR), then the GMD 4 and DWR will reduce the allocated quantity for such water right accordingly for the 2018-2022 LEMA period.

j) For water rights enrolled in a KAR 5-5-11 change, MYFA, WCA, or other flexible water plan, the most water restrictive plan will apply.

k) No water right shall be reduced by more than 25% of their average historical pumping based on years pumped 2009-2015 unless it would allow a quantity over 18 inches per acre to be pumped.

l) Should GMD 4 request a new LEMA beyond the first five-year period, the GMD 4 Board will consider a maximum 10% carry-over of the LEMA allocation for the regions depicted in the purple, yellow, and red on Attachment 1 if a new district-wide LEMA is considered or pursued as a result of the LEMA Order Review discussed in Section 11.

2) Allocations – Non-irrigation

a) Livestock and poultry use will be restricted to 76% of the quantity of water deemed to be reasonable for livestock and poultry provided in K.A.R. 5-3-22 in townships with greater than 2% average annual decline and 85% of said amount in townships with average annual declines between 1% and 2%, based on the maximum head supportable by the feedlot permit in effect on December 31, 2015. At no time will a stockwater right be authorized to pump more than its authorized quantity.

b) Municipal will be encouraged to reduce the amount of unaccounted for water reported annually on the water use report and reduce the gallons per capita per day.

c) All other non-irrigation users will utilize best management practices.

d) When converting irrigation to non-irrigation, then the most restrictive of the LEMA allocation, GMD 4 regulations, or conversion outlined in K.A.R. 5-5-9 will be used to determine the converted allocation amount.

e) The base water rights will not be altered by any Order issued under this request, but will be subject to the additional terms and conditions described herein for the duration of the LEMA.

3) Individual Allocation Amounts

The five-year allocations for every water right per Sections 1.a and 2 above shall be converted to a five-year acre-feet total, with Attachment 1 containing the assigned eligible irrigation restriction for each township. Each water right will be restricted to its total acre-feet allocation within the LEMA order issued through this process, subject to the review processes outlined in Sections 5 and 6.

4) Data Set

The relevant data for this LEMA proposal came from the Water Rights Information System (WRIS) maintained by the Kansas Department of Agriculture, Division of Water Resources (DWR).

If any data errors are discovered, then the GMD 4 Board requests that the person or entity discovering the errors contact GMD 4 to update or correct any alleged errors via the processes outlined in Sections 5 and 6.

Attachment 2 contains pdf files of irrigation and stockwater water right numbers and allocations. Associated spreadsheets will be kept by GMD 4 and DWR; will be available on the GMD 4 and DWR websites; and may be changed with the Chief Engineer's approval or through the processes outline in Section 5 and 6. The GMD 4 and the DWR will document or track any changes made to the irrigation water and stock water right allocations attached hereto.

5) Eligible Acres Process

Based on input from stakeholders, it was agreed that the following procedure would be used to assign eligible acres to every irrigation water right in the District-Wide LEMA and to include in any future LEMA request.

The GMD 4 and DWR determined eligible acres as follows:

a) The GMD 4 and DWR used the maximum reported authorized irrigated acres from 2009-2015 that could be verified as being legally irrigated with the GMD 4 in-house aerial photography and water right file information.

b) If the authorized place of use was not irrigated from January 1, 2009 to December 31, 2015, then earlier years that the water user irrigated the acres may be considered.

c) The DWR will contact every water right owner within 60 days after the Order of Designation and others known to them as operators or interest holders in the water right to inform them of the eligible acres assigned to their water right(s) under the adopted process, allow them the opportunity to appeal the assigned acres under the process described below and allow them the opportunity to provide more information to the GMD 4 Board on the correct acres. The GMD 4 Board's decision is final and the eligible acres determined by the GMD 4 Board will be used to calculate and assign the final allocations.

6) Appeals Process

a) Appeal Process. The following process will govern appeals regarding eligible acres and allocated water:

(1) Any appeal of the eligible acres and allocated water must be filed before March 1, 2019. Failure to file an appeal of the eligible acres and allocated water by March 1, 2019 will cause the assigned eligible acres and allocated water to become final during the LEMA period.

(2) Only eligible acres and allocated water may be appealed through this appeal process. No other issues including, but not limited to, the LEMA boundaries, violations, meter issues, etc., may be appealed through this process.

(3) Any appeal will first be heard by the GMD 4 staff who will determine eligible acres based on the factors above in Section 5) Eligible Acre Process.

(4) Any determination made by the GMD 4 staff may be appealed to the GMD 4 Board.

(5) The GMD 4 and DWR will use the acres and allocated water determined through the processes contained in Sections 5 and 6, as detailed above, to calculate and assign allocations.

b) Factors to be considered by the GMD 4 Board on appeal. The following factors, in order of importance, will be used when reviewing a determination of eligible acres and allocated water on appeal.

(1) First, the reviewer will first consider the location of the well(s) and their township allocations.

(2) Second, the reviewer may consider the authorized place of use.

(3) Third, the reviewer may consider any and all aspects of the water right, use, place of use, point of diversion, or any other factors the reviewer determines appropriate to determine eligible acres and allocated water.

7) Violations

a) The LEMA order of designation shall serve as initial notice of the creation of the LEMA and its terms and conditions to all water right owners within the GMD 4 on its effective date.

b) Upon GMD 4 learning of an alleged violation, GMD 4 will provide DWR with the information GMD 4 believes shows the alleged violation. DWR, under its discretion, may investigate and impose restrictions and fines as described below or allowed by law.

c) DWR will address violations of the authorized quantities as follows:

(1) Exceeding any total allocation quantity of less than 4 AF within the allocation period will result in a $1,000.00 fine for every day the allocation was exceeded.

(2) Exceeding any total allocation quantity of 4 AF or more within the allocation period will result in an automatic two-year suspension of the water right and a $1,000 fine for every day the allocation was exceeded up to a maximum of $10,000.

d) In addition to other authorized enforcement procedures, if the GMD 4 Board finds by a preponderance of evidence that meter tampering, removing the meter while pumping, or any other overt act designed to alter the metered quantity as described in K.A.R. 5-14-10 occurred, then the GMD 4 Board will make a recommendation to the Chief Engineer that a written order be issued which states:

(1) The nature of the violation;

(2) The factual basis for the violation;

(3) That the water right is suspended for 5 years; and

(4) That the water right loses all remaining assigned quantities under the District-Wide Local Enhanced Management Area.

8) Metering

a) All water right owners shall be responsible for ensuring their meters are in compliance with state and local law(s). In addition to being in compliance and reporting annually the quantity of water diverted from each point of diversion, all water right owners shall implement at least one of the following additional well/meter monitoring procedures:

(1) Inspect, read and record the flow meter at least every two weeks the well is operating. The records of this inspection procedure shall be maintained by the well owner and provided to the district upon request. Should the flow meter reported readings be in question and the bi-weekly records not be available and provided upon request of the district, the well shall be assumed to have pumped its full annual authorized quantity for the year in question. Following each year's irrigation season, the person or persons responsible for this data may at their discretion transfer the recorded data to the district for inclusion in the appropriate water right file for future maintenance.

(2) Install and maintain an alternative method of determining the time that the well is operating. This information must be sufficient to be used to determine operating time in the event of a meter failure. Should the alternative method fail or be determined inaccurate the well shall be assumed to have pumped its full annual authorized quantity

for the year in question. Well owners/operators are encouraged to give the details of the alternative method in advance to GMD 4 in order to insure that the data is sufficient.

b) Any water right owner or authorized designee who finds a flow meter that is inoperable or inaccurate shall within 48 hours contact the district office concerning the matter and provide the following information:

(1) water right file number;

(2) legal description of the well;

(3) date the problem was discovered;

(4) flow meter model, make, registering units and serial number;

(5) the meter reading on the date discovered;

(6) description of the problem;

(7) what alternative method is going to be used to track the quantity of water diverted while the inoperable or inaccurate meter is being repaired/replaced; and

(8) the projected date that the meter will be repaired or replaced.

(9) Any other information requested by the GMD 4 staff or Board regarding the inoperable or inaccurate flow meter.

c) Whenever an inoperable or inaccurate meter is repaired or replaced, the owner or authorized designee shall submit form DWR 1-560 Water Flowmeter Repair/Replacement Report to the district within seven days.

d) This metering protocol shall be a specific annual review issue and if discovered to be ineffective, specific adjustments shall be recommended to the chief engineer by the advisory committee.

9) Accounting

a) DWR, in cooperation with GMD 4, shall keep records of the annual diversion amounts for each Water Right within the LEMA area, and the total 5-year quantity balances will make this information available to the Water Right Holder and the GMD 4 on their request.

10) Advisory Committee

a) A District-Wide LEMA Advisory Committee shall be appointed and maintained by the GMD 4 Board consisting of fourteen (14) members as follows: one (1) GMD 4 staff; one (1) GMD 4 Board Member; one (1) representative of the Division of Water Resources, Kansas Department of Agriculture as designated by the chief engineer; and the balance being irrigators with regional distribution identical to GMD 4 board member distribution. One of the District-Wide LEMA members shall chair the committee whose direction shall be set to further organize and meet annually to consider:

(1) water use data;

(2) water table information;

(3) economic data as is available;

(4) violations issues – specifically metered data;

(5) any new and preferable enhanced management authorities become available;

(6) other items deemed pertinent to the advisory committee.

b) The advisory committee in conjunction with DWR shall produce an annual report which shall provide a status for considerations (1) through (6) and any recommended modifications to the current LEMA Order relative to these six items. Said report shall be forwarded to the GMD 4 board and the chief engineer.

11) LEMA Order Reviews

a) In addition to the annual LEMA Order reviews per Section 10 the District-Wide LEMA Advisory Committee shall also conduct a more formal LEMA Order review 1.5 years before the ending date of the LEMA Order. Review items will focus on economic impacts to the LEMA area and the local public interest. Water level data may be reviewed.

b) The committee, in conjunction with DWR and GMD 4, shall also produce a report following this review to the chief engineer and the GMD 4 board which contains specific recommendations regarding future LEMA actions. All recommendations shall be supported by reports, data, testimonials, affidavits or other information of record.

12) Impairment Complaints

While this program is being undertaken, the GMD 4 stakeholders request that any impairment complaint filed in the district while this management plan is in effect, which is based upon either water supply issues or a regional decline impairment cause, be received by the Chief Engineer, and be investigated by the Chief Engineer with consideration to the on-going Local Enhanced Management Area activities.

13) Water Level Monitoring

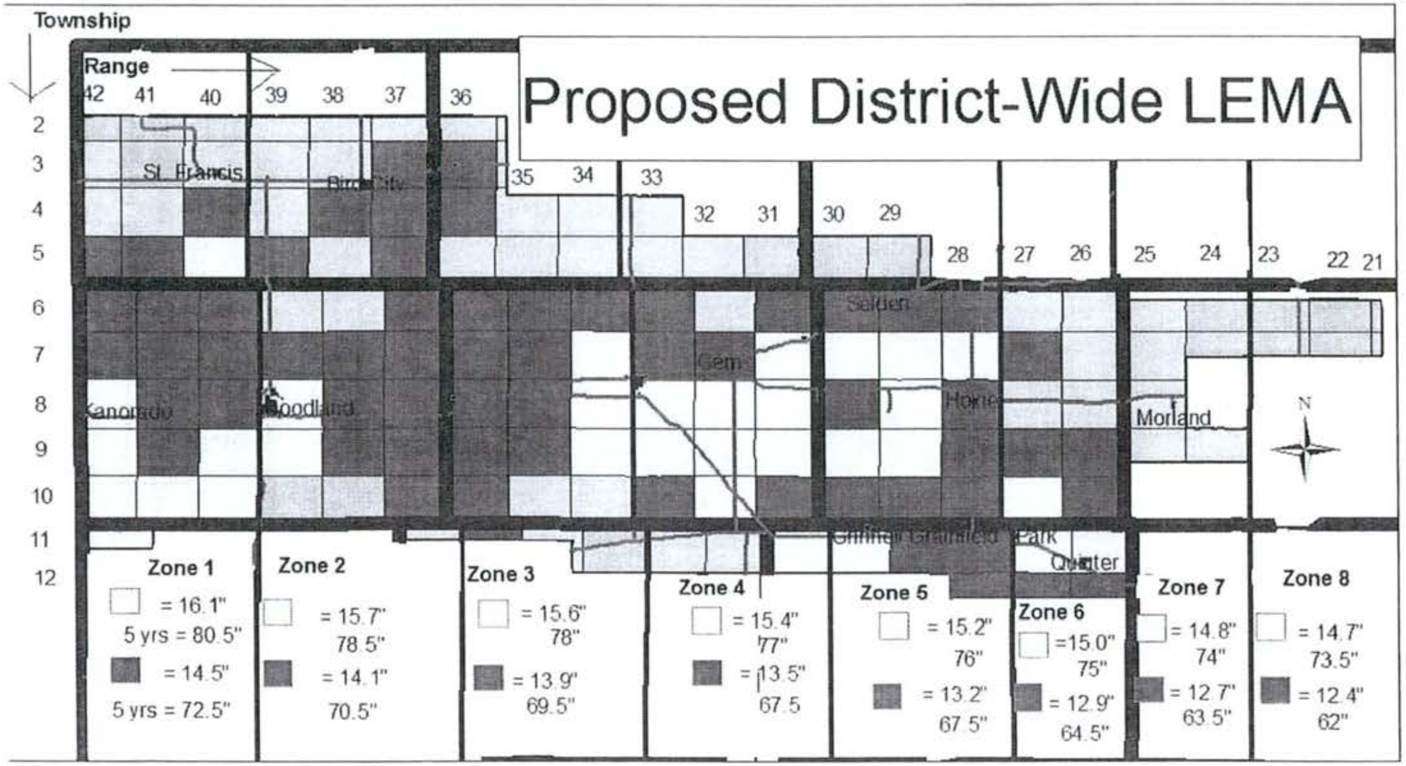
The data used to determine regional aquifer declines in Attachment 1are based on the annual water level monitoring taken by KGS and DWR. Those measurements will continue as the data set used in determining water level declines. In the future, GMD 4 could, but is under no obligation, install additional monitoring wells.

14) Coordination

The GMD 4 stakeholders and the GMD 4 board expect reasonable coordination between the chief engineer's office and the GMD 4 board on at least the following efforts:

a) Development of the LEMA Order resulting from the LEMA process;
b) Accounting for annual pumpage amounts by LEMA water right owners/operators.
c) Compliance and enforcement of the District-Wide LEMA Order.

Attachment 1 to Proposal



Townships with 2%+ Average Annual Decline in 2004-2015

Townships with 1-2% Average Annual Decline in 2004-2015

Townships with 0.5 - 1% Average Annual Decline in 2004-2015 (18 inch max restriction)

Townships with 0-.5% Average Annual Decline in 2004-2015

Townships with no decline 2004-2015

Prepared by Shannon Kenyon GMD 4

Attachment 2 to Proposal

Irrigation and Stockwater Allocation PDF Files

GMD 4 LEMA
Irrigation Water Right

GMD 4 LEMA Stock
Water Rights.pdf

Attachment 3 to Testimony

Public Meeting Notes and Sign-in Sheets

PUBLIC LEMA BOARD MEETINGS QUESTIONS AND COMMENTS

COLBY (97 signed in)

Questions:

Is this a 5 yr. program?

What about restricting dairies?

We used to flood and haven't for a while, how will that affect me?

At the end of 5 years are you going to increase or decrease our allocation?

Why would we do this if we're the only district doing it?

Will we get a letter on what we will get under the plan?

Will we be able to bank the water?

Will there be a vote?

How much water is this going to save?

How is this a LEMA? It looks like an IGUCA

Why cut people that don't have a problem ?

What happens in 5 years?

Can we just "knock off" the new wells?

What happens if we do nothing?

Why the whole district?

Public Comments:

0.5 – 1% should also have a reduction.

This plan is a personal agenda.

You need more measureable goals.

Data other than KGS should be used.

I've lost nine windmills, how here isn't afraid of the water going away.

PLEASE SIGN IN Colby

Brat Rogers
Jerry Bimmy
Norma [illegible]
Kent [illegible]
[illegible]
Phil Keck
Carl Ziegelmeier
Chuck [illegible]
ALAN & Andy Query
Jeff. Youngers
Daniel Schultz
Larry Louws
Jim McKee
Ken Christiansen
Curtis Dopan
Ohm-P. Beamer
[illegible]
Jon Friesen
Jeremy Kersenbrock
Tom Redmond
Eugene Schwarz
[illegible]
Todd Ziegelmeier
[illegible]
[illegible]
Ron Evans
Steve Friesen

Connor Wilson
Steve Wilson
Dan Reitcheck
[illegible]
[illegible]
Mike Stephens
Michael Juenemann
Jon Starns
Dan Antholz
Marvin Albers
Ashley Rohl
[illegible]
[illegible]
Steve Bremenkamp
[illegible]
Mark Myers
Jeremy Myers
[illegible]
Ronald E. Neff
Jamie [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

Harold Murphy Selden Ks

PLEASE SIGN IN Colby 97

[illegible]	DON WOOFTER
Alex ZERR	Chris Soehner
Sarah Jane Barrett	Shawn Diederich
Dave Hubbard	[illegible]
Thad Hahn	Douglas [illegible]
[illegible]	[illegible]
Dale [illegible]	MARSHALL Rhoey
Jon McKee	
Bob Stephens	
Steve Hutton	
Jeff [illegible]	
Robert [illegible]	
[illegible]	
[illegible]	
[illegible]	
John Flanagin	
Richard [illegible]	
[illegible]	
Matt [illegible]	
Travis [illegible]	
Kelly Stewart	
Rick Kuper	
Ian de Haan	
Zach Zweygardt	
Boyd Stewart	
Wayne [illegible]	

Kelly Horinek Farm Credit
Gloria Morgan
Mike Brumbaugh
Jerod Flanagan
Nathan Goetz
Bob Gillen - KSU
Keith Downing (Mary Ann)
Jim Kopriva
Bernard Meyer
[illegible]

GOODLAND: (88 signed in)

Questions:

Is the purple 18" per circle?

What about EQIP acres?

Does this apply to vested rights?

How do you figure out where you are located?

How did you come up with the zones?

Who on the board represents Wallace County?

Is the maximum 25% reduction based on your historical pumping?

Will there be a vote?

Can we do a district-wide WCA instead?

Why was 2009-2015 used?

What is your depletion goal?

Are you going to install more observation wells?

What's the reversal process if there is public outcry?

Is SD6 going to re-up?

Is this going to permanently reduce my water right?

Was there an economic study?

Has the board been advised to wait until the economic study is over?

Is the economic study available?

Can we vote?

What is the time frame for implementation?

Have you contacted the county assessor?

Is there economic impact in SD 6?

How many of the wells in SD 6 get measured?

How did you get the different colors?

When are the observation wells measured?

Comments:

You should do a 20% reduction of all wells and for one year in five you can't pump water.

South of Ruleton I don't have a decline problem, but four miles away they do.

A provision needs to be included to discontinue the plan and make it a reversible process.

This will create a 10% net decrease in economics.

I want to see the scatter plots to determine the % reduction needed in the decline areas.

The longer we extend the aquifer, the longer we benefit.

You need to include a possible drought contingency plan.

Bigger government is not good.

Blue areas should have restrictions if truly a groundwater management district.

Thank you for your efforts.

There should be a 10% reduction in five years for areas that still have a decline. That 10% reduction should continue every five years until no decline.

Thank you to the board for listening to our comments at the last public meetings. The map is proof that you listened to us.

Goodland 80

PLEASE SIGN IN

Craig Boggs
Royce Kohlbeck
Steve Evert
[illegible]
HD House
David Leonard
Joyce Schilling
[illegible] Bellamy
Alan Townsend
Larry [illegible]
Shawna Johnson
Mary Volk
Jace Mosbarger
[illegible] Mosbarger
Barry Guyer
James Fritz
David Dorn
Greg [illegible]
Jane McCarty
Bob + Norma Grangner
Kelly Stewart
[illegible] Armstrong
[illegible]
Leonard [illegible]

24

Goodland

PLEASE SIGN IN

Brent Cook
DICK PETTIBONE
Zach Coryell
Nate Emig
John Rodee
Chris Soehner
Keith Snethen

PLEASE SIGN IN Goodland

David Pedersen
Katie Harness
John Deeds
Darla Deeds
Scott Briney
Frank Van Laeys
KIRK RICE
Elmer & Joyce Purvis
Ken Palmgren
Zach Zweygardt
Ron Robinson
Brady [illegible]
Lonnel Whiteker
GERALD FRANKLIN
LINDA FRANKLIN
Thad Hahn
Neal Thornburg
Joey Sneiken
Scott Harker
DENNIS SHANK
[illegible]
Norman Abuse
Kim Dale
Ryan Dale
Stan Cobada
Gregory E Lure

24

PLEASE SIGN IN Goodland

Ross Townsend

Mike Rogers

Rick Billinger

Tyson Davis

PLEASE SIGN IN Goodland

Ron & Marsha Schilling
Kevin Schmidt
Jan de Waal
Frank Linden
Curtis Dopan
Melvin R. Pamechek
Connie Sigg
Jeff Younger
Tim Frankley
Dan Stephens
David Stephens
Chuck Thomas
Allen Quenzer
Steve Duell
Rich Simon 27
Dillon Traxsel
Jake Golin
John Maney
Kent Williams
Mike Dent
Jeanne Fall Jones
Darrell Owens
Robin Deeds
Dennis Coryell
Darrel Cloyd
Lou Hines
Tom Livengood

ST FRANCIS (49 signed in)

Questions:

How are acres determined?

What happens to water rights still in their perfection period?

What does "encourage" mean in relation to municipalities?

What is depth to water in these areas?

Will it be a reduction in the water right or only what is allowed to be pumped?

If you change tenants in the middle of the five year period, what happens to your remaining allocation?

How much water does this save?

What are the ramifications for going over?

How much is allowed in SD 6?

Can you bank the water if you don't use it?

What are the economic ramifications?

How have the other meetings gone?

Is there any provisions on contiguous acres?

Why is there no flexibility in this plan?

Comments:

I pump 21" per year but was hailed out one year so my average is skewed. That may not trigger the no more than 25% reduction.

St. Francis

PLEASE SIGN IN

(49)

Jeff Younger
Martin Hughes
Tom Hunzell
Craig Busse
Mike Rooney Bird City
Kermit Berg Bird City
Michael Roach
Lonnie Willis
William Gottschall
Dain Stephens
Alex Evert
Dennis Wright
W. Wright
Clayton Janicke
Adam Deeds
John Deeds
David Hendricks
Kale Yonkey
Brooks Brenn

HOXIE (60 signed in)

Questions:

If SD 6 re-ups will they keep their flexibility?

What about restricting the well at the Sheridan Lake?

How many AF do they have?

Who came up with the 12 g/h/d?

Why did you go on a township level instead of individual wells?

How many acres does each observation well cover?

How and when will you know it's working?

How many wells in SD 6?

How do the declines compare to outside of SD 6?

What happens when SD 6 re-ups?

How many townships in SD 6?

Does 5 years give you enough time to readjust if it's not working?

Are you going to get tougher if there is still a decline?

There's not much irrigation in my red township, but there is a huge feedlot and ethanol plant. Have you taken this into account?

How many other hot spots (HPA) are there in the district?

Can you buy water rights like you can in SD 6?

After 5 years what's the plan?

Does the amount I've historically pumped affect me?

If we don't do something now, will the state come in later?

Comments:

The data is inaccurate.

If SD 6 can do it then it should be district-wide.

I want out of the district.

I have issues with tax payers paying for the building and supplying money to the Foundation.

We need to educate the people in town on the water problem.

You can't wait another 20 years to solve this problem.

I testify the LEMA is working. The farm management improves.

The probes, and other technology work.

Please Sign in Hoxie

John Lindenman 100

Shawn Lindeman

Mark Hill

Ginger Pugh KDHD wif

Kelly Stewart

Dan Watkins

Nick Hixon

Dail Bergmeier

Matt Palmquist

Howard J Lockett

Dail Beamer

Randall Youkin

Ray Slipke

Bob Bemster

Nathan [illegible]

Harold Murphy

[illegible]

Jerry McKenna

Kevin Lager

[illegible]

[illegible]

Wade Tremblay

Shane Beckman

Randy Ochs

Paul Bangs

[illegible]

Lenny Petro

Pat Hert Hoxie
Rick Moss Hoxie
Don Moss Hoxie
Harold Foster "
Rick Dillinger Grinnell
Mike McKenny

Northwest Kansas Groundwater Management District No. 4

Revised Management Program

1290 W. 4th Street, PO Box 905, Colby, Kansas 67701-0905
(785) 462-3915

URL: HTTP://www.gmd4.org

2016 Board of Directors:

Brent Rogers, President - Sheridan County
Shane Mann, Vice President - Gove County
Jeff Deeds, Secretary – Sherman/Wallace County
Dave Rietcheck, Treasurer - Sherman/Wallace County

Justin Sloan, Member - Thomas County
Doug David, Member - Graham County
Monty Biggs, Member - Rawlins/Decatur County
Lynn Goossen, Member - Thomas County
Roger Zweygardt, Member - Cheyenne County
Scott Maurath, Member - Logan County
Mitchell Baalman, Member - Sheridan County

DIVISION OF WATER RESOURCES
DAVID W. BARFIELD
CHIEF ENGINEER
KANSAS DEPARTMENT of AGRICULTURE

Approved By: David W. Barfield

Date: 9/19/2016

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TABLE OF CONTENTS

MAPS, TABLES and FIGURES

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I. INTRODUCTION

Northwest Kansas Groundwater Management District No. 4 has been organized to locally manage the groundwater resources within its specified boundaries. This management program is designed to establish the rights of local landowners and water users to determine their destiny regarding the use of groundwater within the district boundaries and within the basic laws and policies of the State of Kansas.

The initial spark which fostered Northwest Kansas Groundwater Management District No. 4 came from a group of concerned citizens in the area who recognized the imminent problems related to a dwindling groundwater supply and increasing rate of development. A series of informational meetings were held in the area to sense the will of the people relative to the formation of a groundwater management district and ultimately a steering committee was formed to execute the formal organization of a district. Under the authority of the Kansas Groundwater Management District Act, the following persons made up that steering committee:

Al Lowenthal, Chairman	Colby, Kansas
Marne Karlin, Secretary/Treasurer	Grinnell, Kansas
Garry Seymour	Bird City, Kansas
John Scott	Brewster, Kansas
Norman Mills	Studley, Kansas
Eugene Hall	Kanorado, Kansas
Willis Hockersmith	Oakley, Kansas

The steering committee filed the declaration of intent and a map of the proposed district boundaries with the Chief Engineer for the State of Kansas on December 19, 1974. After many deliberations between steering committee members, state representatives for the Division of Water Resources and area constituents, the final description of the district boundaries was certified by the Chief Engineer.

A petition outlining the purpose of the district and all other required information was circulated in a timely fashion by the steering committee and was submitted to the Secretary of State on November 13, 1975. Upon the petition approval, the steering committee called for and held an election to determine whether or not the district should be organized. Results of the election were 668 votes in favor and 372 votes against district formation, representing 64% in favor of formation.

A certificate of incorporation was issued by the Secretary of State on March 1, 1976 and was subsequently filed in the offices of the Register of Deeds in each of the ten counties which have land within the district boundaries. An official copy of that certificate may be viewed in the main office of the district.

An organizational meeting to set up and elect the initial board of directors for the district was conducted in Colby, Kansas on May 24, 1976. By resolution, 11 positions were opened for election, with the initial terms staggered as follows:

POSITION	COUNTY REPRESENTATION	INITIAL TERM*
1	Cheyenne	2 years-1978
2	Rawlins/Decatur	3 years-1979
3	Sherman/Wallace	3 years-1979
4	Sherman/Wallace	2 years-1978
5	Thomas	3 years-1979
6	Thomas	2 years-1978
7	Sheridan	3 years-1979
8	Sheridan	1 year -1977
9	Graham	1 year -1977
10	Logan	1 year -1977
11	Gove	1 year -1977

* After initial term is served all positions are then elected for 3 year terms.

Per K.S.A. 82a-1030, expiring directors' positions will be filled by an election to be held during the annual meeting of that year.

III. DESCRIPTION OF THE DISTRICT

1. Location

Northwest Kansas Groundwater Management District No. 4 includes all of Sherman, Thomas and Sheridan Counties and portions of Cheyenne, Rawlins, Decatur, Graham, Gove, Logan and Wallace Counties in northwest Kansas. (see District Boundaries Map page III-2). The district, which covers approximately 3,100,000 acres is located in the High Plains section of the Great Plains Physiographic Province. Elevations range from approximately 3900 feet above sea level at the western district boundary to approximately 2200 feet above sea level at the eastern edge.

2. Climate

Average annual precipitation ranges from seventeen (17) inches in the western tier of counties (Cheyenne, Sherman and Wallace) to twenty-one (21) inches in Graham County on the eastern edge of the district. Rain showers account for the majority of the annual precipitation falling during the growing season from April to September.

Daily and annual temperatures vary significantly with summer days being warm and summer nights generally cool. This is true when the relative humidity is low, even during the hottest periods of the summer. Statistics show that a low relative humidity and frequent cloudless or near cloudless days are typical for the area, as are moderate to strong surface winds most of the year. All of the above typical conditions result in the need for special soil and water management practices.

Overall, the climate is well suited for grassland and certain agricultural crops. This is particularly true if irrigation is developed to supply needed moisture during dry periods. The major climatic drawback is the occasional devastating occurrences of hail and damaging winds associated with severe thunderstorms and/or tornadic activity. These events generally occur in the spring or summer months when the low-pressure storm centers tend to be most intense.

3. Soils

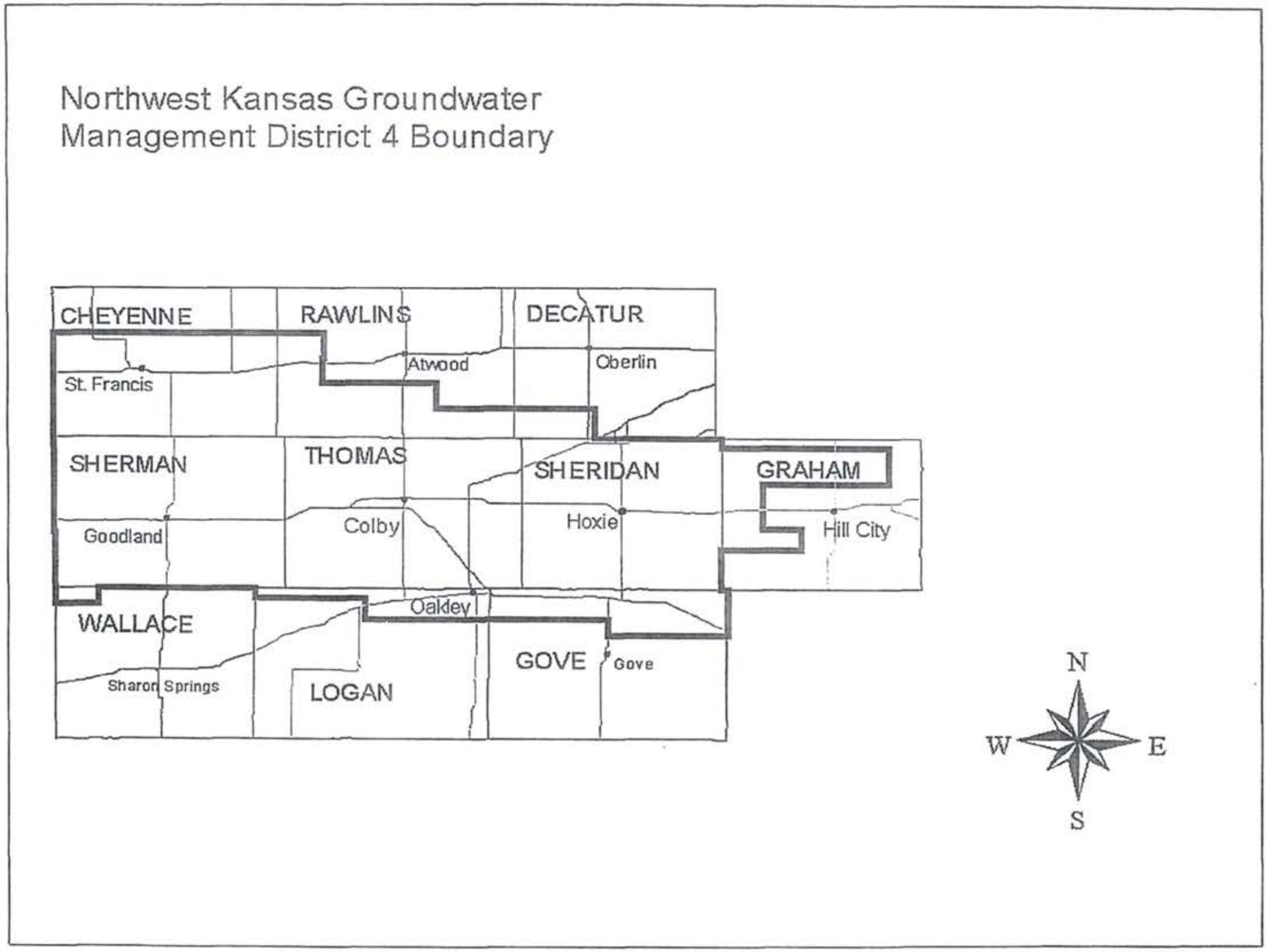
Soils in the district are primarily those resulting from windblown loess deposited during the Pleistocene Age. Most of the river valleys contain a more granular soil type resulting from stream-laid deposits. The primary soils are as follows:

a. *Ulysses-Colby Association.* Deep, grayish-brown to dark grayish-brown silt loams, nearly level to slightly sloping. This soil type is found in the western three-fourths of the district.

b. *Holdrege-Ulysses Association.* Consisting of deep to moderately deep, dark grayish-brown silt loams and moderately deep gray clays that are gently sloping. This type is typically found in the eastern one-fourth of the district.

With today's irrigation equipment and techniques most of the soils in the district are potentially irrigable. This is evidenced by the fact that most of the soils in the district are classified as Class I, II, III with respect to land use capability. It is generally recognized that in many cases these soils do require special management in order to be effectively irrigated.

MAP III-1: DISTRICT BOUNDARIES



II. PURPOSES OF THE DISTRICT

1. To locally organize, develop and administer proper management and conservation practices of the groundwater resource for the benefit of the entire district.

2. To establish a framework by which local landowners and water users can help determine their own policies and programs with respect to the vital management and use of the groundwater resource within the district.

3. To support and participate in research and education relevant to the proper use and management of the limited groundwater resource.

4. To derive optimum social and economic benefits accruing from the wise development, use, and management of the groundwater reserves.

5. To cooperate with all levels of government and all district members in order to accomplish the objectives of the district and the Groundwater Management District Act and amendments thereto.

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4. Surface Drainage

In the geologic past, four drainage basins have established themselves within the present district boundaries. (see Drainage Pattern Map page III-4). These basins are:

a. *The Upper Republican.* Consists of the South Fork Republican, Beaver Creek, Sappa Creek and Prairie Dog Creek. This basin's drainage trends northeastward across the district and ultimately meets the Republican River in southwestern and south central Nebraska.

b. *The Solomon Basin.* Consists of Bow Creek and both the North and South Forks Solomon River which trend primarily eastward across the district.

c. *The Saline Basin.* Consists of the Saline River and its less substantial South Fork. Like the Solomon Basin, it trends eastward and leaves the district essentially in the extreme northeast corner of Gove County.

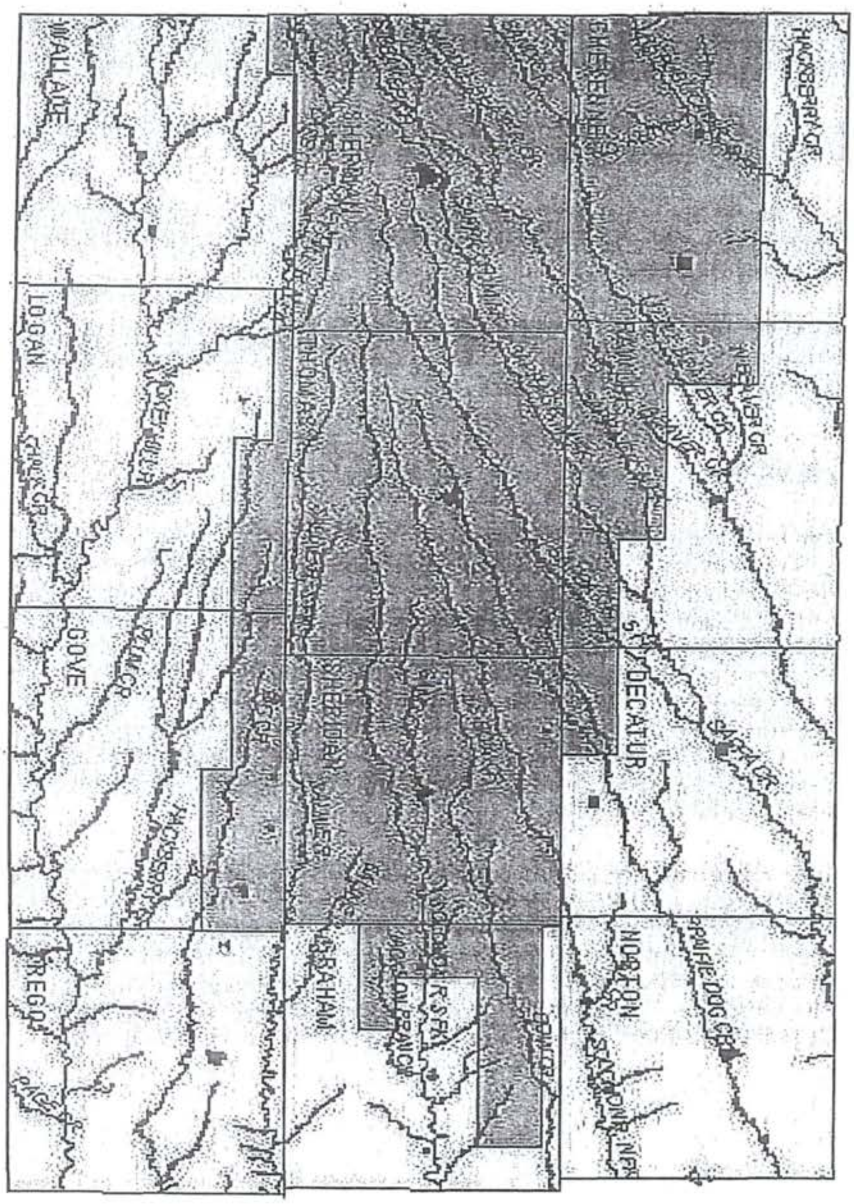
d. *The Smoky Hill Basin.* Consists of the North Fork Smoky Hill and Smoky Hill River, Hackberry Creek and Big Creek. This basin trends east-southeast and leaves the district along the eastern border of Gove County.

5. Water Resources

Surface water within the district is limited to surface runoff during and shortly after periods of moderate to heavy rainfall, and base flows in the South Fork Republican and South Fork Solomon Rivers. Throughout most of the district the surface runoff is rather low and difficult to economically capture due to the nature of the rainfall, the soil characteristics and general topography. Locations where suitable structures could be constructed to capture surface runoff in significant amounts are limited. The value of such large structures at this time is questionable from the standpoints of both groundwater recharge and irrigation use. Studies have shown that the high evaporation rate in the northwest area (as much as 72 inches of pan evaporation per year) would deplete much of the captured water before it could be recharged into the aquifer or used for irrigation purposes. However, future studies are expected to be more detailed in determining the amount of water that could be captured and used versus the cost of the structures.

Groundwater resources in the district supply a large percentage of municipal, industrial, domestic and agricultural needs. All of the district overlies at least the Ogallala aquifer which is a Tertiary aged, fluvially deposited silt, sand and gravel formation. It ranges in thickness from 300 feet in the west to 50 feet or less in the eastern portions of the district. The fact that the Ogallala was deposited on a pre-erosional surface means that the thickness of the deposit can vary significantly within relatively short distances. The January, 2016 saturated thickness of the Ogallala Aquifer in the district ranges from 164 feet to 0 feet (Source: KGS WIZARD section-level data base).

MAP III-2: DRAINAGE PATTERNS OF NORTHWEST KANSAS



North

Using an average 2016 saturated thickness of 79 feet, district size of 3,100,000 acres and an average storage coefficient of .12, the district has an estimated 29,000,000 acre-feet of water in storage. District records as of October 2015 show 3504 non-domestic wells registered with the Division of Water Resources with 850,871.6 acre-feet of water appropriated. This development has resulted in declining water table elevations over most areas of the district.

Alluvial deposits generally 30-80 feet thick along the major streams and creeks supply water of varying amounts to wells. These deposits do not generally exceed 50 feet in saturated thickness, but due to their medium to course texture often yield enough water for limited irrigation.

6. Economy

Northwest Kansas, for the present and future, is largely dependent on the availability of good quality groundwater because a large percentage of the local economy is based on agriculture and agri-related business, which in turn depend heavily on this resource.

Contributing to the economy of NW Kansas are cultivated cropland, both irrigated and dryland, the cattle feeding industry, dairy industry and associated agricultural businesses such as implement dealers, irrigation supply dealers, feed and seed dealers, well drillers and grain elevators and marketing personnel.

Major crops grown from cultivated land are corn, wheat, sorghum, sunflowers, alfalfa, dry beans and soybeans. All of these crops except wheat and sunflowers are predominantly irrigated. Current economic trends reviewed indicate that the marketing potential for these crops remains a stimulus for the higher production achieved by irrigation.

The livestock feeding industry, dairy industry, and a growing ethanol production capacity in the area depends on the production of feed grains and forage crops from irrigated land and are three areas of the present economy which have the best potential for expansion.

7. Table III-1: Assessed Land, Wells and Acre-feet Appropriated (October, 2015 data)

County	Total Assessable Acres+	Assessed Acres	Excluded Acres and % of Total	Wells	Authorized Appropriation in Acre-feet
Cheyenne	445,303	412,335	32,968 (7)	465	105,007
Rawlins	251,796	219,852	31,944 (13)	155	31,436
Decatur	44,576	42,779	1,797 (4)	31	4,358
Sherman	653,090	618,504	34,586 (5)	899	264,294
Thomas	664,387	622,853	41,534 (6)	825	208,791
Sheridan	556,806	518,339	38,467 (7)	731	164,173
Graham	171,197	156,371	14,826 (9)	118	21,952
Wallace	12,650	12,650	0 (0)	8	2,779
Logan	88,844	84,797	4047 (5)	92	17,156
Gove	159,666	145268	14,398 (9)	180	30,926
TOTALS	3,048,315	2,833,748	214,567 (7)	3,504	850,872

+ Land within the county, within the district which is subject to assessment.

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IV. MANAGEMENT PROBLEMS

1. Depletion

Over-appropriation in many areas within the district continues to be a major management problem. Historically, groundwater development was very limited from its introduction into the area until approximately 1950. Since that time the rate of development had increased steadily until the early part of 1980 when the rate of development began to slow significantly mainly due to district policies. By this time however, most of the district had been developed in excess of the rate of recharge or any safe yield criteria. Consequently the groundwater table over most of the district is declining, but at differing rates as shown by figure IV-1. Equally, if not more, concerning is the rate at which the remaining resource is being depleted (see figure IV-2). At current annual depletion rates some areas are facing less than a 50 year supply of water if current pumping levels are maintained. Many other areas face major aquifer loss within 50 to 100 years.

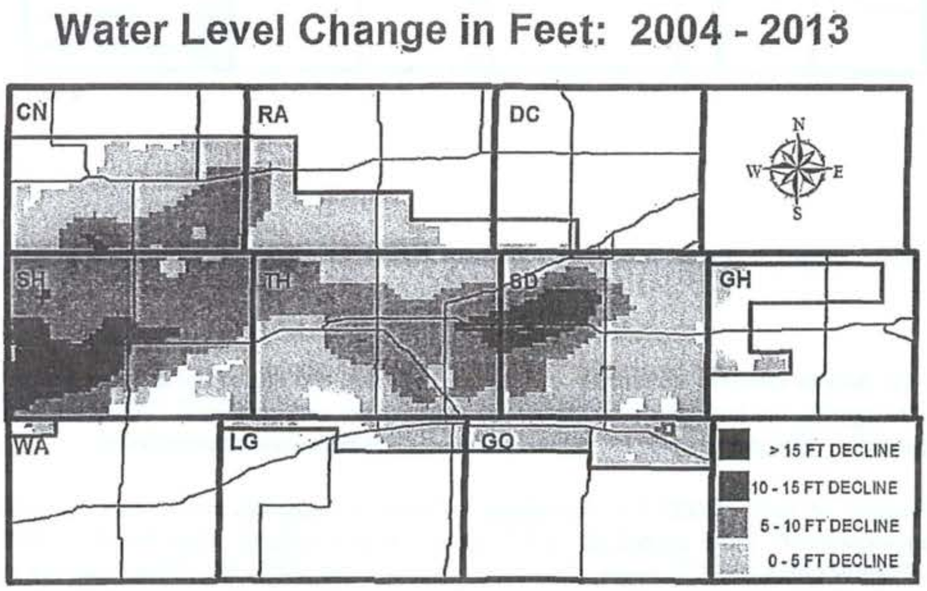

Figure IV-1: Decline areas from 2004 - 2013. Source: KGS section-level data base.

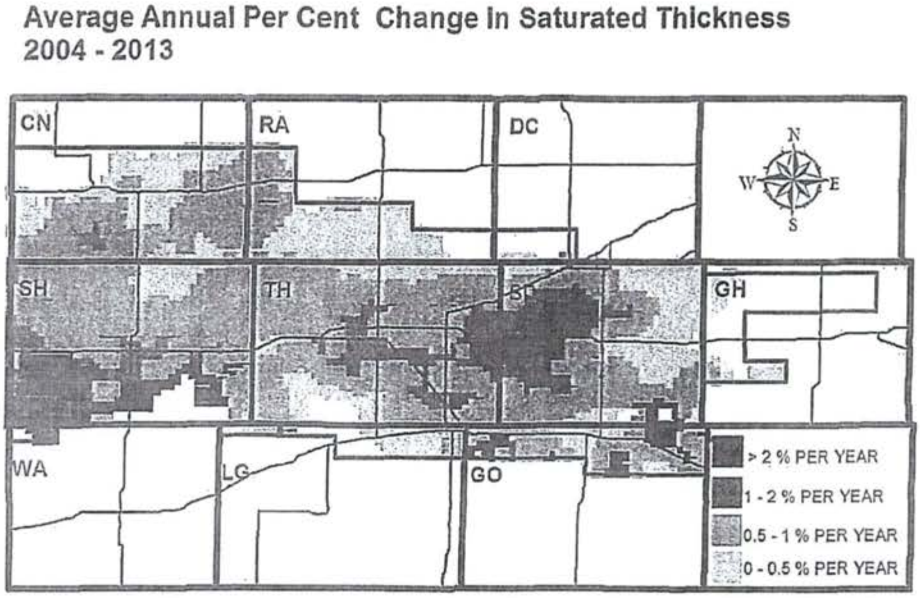

Figure IV-2: Annual % decline in saturated thickness from 2004 - 2013. Source: KGS section-level data base.

Because the decline rates are so variable over space and time, and due to the slow movement of water through the aquifer, the problems associated with declines are very localized. Therefore it is difficult, if not impossible, to make generalized statements on district-wide over-appropriation.

In the broadest of terms, GMD 4 is considered 5.7 times overappropriated, when based on district-wide, *"appropriated"* water quantities, and 3 times overappropriated when based on district-wide, *"pumped"* water quantities. However, there exist smaller areas within the district that are as much as 25 times overappropriated (based on appropriated amounts) and other areas that are completely underappropriated - that is, not yet developed at all. (Source of appropriated water right information is DWR Water Rights Information System (WRIS) data base)

Depletion is also a problem that shares relationships with climate and other influences that are not yet fully understood. One of these better understood relationships is rainfall - particularly in-season rainfall. This climate factor affects both recharge and gross irrigation requirements for the crops grown. Data on water use and rainfall collected in GMD 4 over the past 20 years show a significant inverse relationship between in-season rainfall and groundwater reported pumped. (See Figure IV-3)

1980-2014: Pumped Water, Average Seasonal Rainfall (April-October), and Water Level Declines

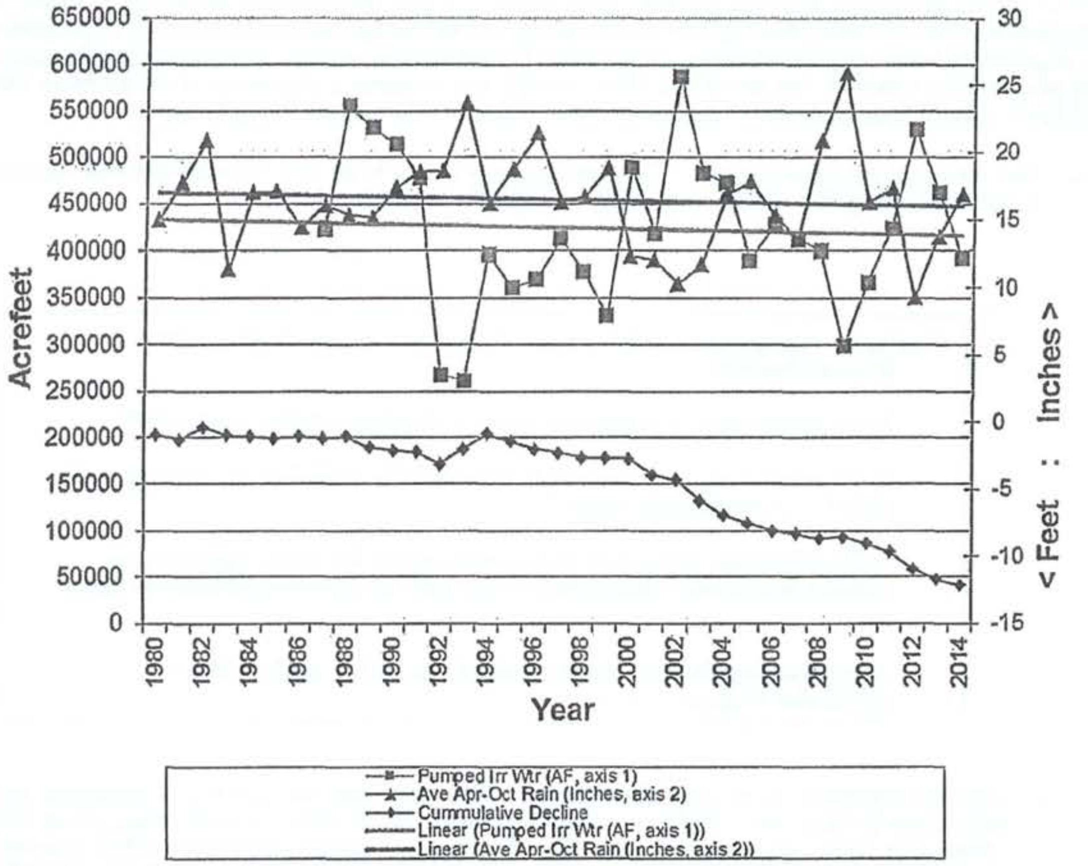

Figure IV-3: Relationships between in-season rainfall, groundwater pumping and water table changes. (Source: GMD 4 rainfall data; DWR water use reporting data; and Kansas Observation well network data.)

However, to fully understand the nature of pumpage and water level declines, all the other relationships need to be identified and further studied.

Stopping or controlling groundwater depletion is a complex problem. A pure resource approach toward a solution will necessitate focusing equally on the control of new development, the ability to direct or influence the use of existing development as necessary, and the design and implementation of programs for augmenting water supplies where possible. Other factors such as social, economic and legal impacts will also require attention, but are at this time actually non-resource components of the problem that will likely require State or Federal cooperation when resource solutions are being designed.

a. *The control of new development.* The district is now closed to all new development that requests a source of supply that wholly or partially includes the Ogallala aquifer.

> Goal(s) for Management Problem 1. a. - The control of new development as it impacts depletion:
>
> 1) To prohibit new development from the Ogallala Aquifer within GMD 4.
>
> 2) To prohibit any new water right from directly impairing any existing water right to an unreasonable degree.
>
> 3) To provide limited access to new water rights for small, legitimate use requests in specified circumstances that does not increase consumptive water use.
>
> Applicable Regulations: KAR 5-24-2; KAR 5-24-3; KAR 5-24-10
> Applicable Programs: V-1-c

b. *Direction/Influence of existing development.* This particular sub-problem of depletion may necessitate policies encouraging or mandating higher efficiencies of water usage along with efforts that reduce consumptive water use. It could also involve additional control measures designed to reduce annual withdrawals within over-appropriated areas to new acceptable limits - including compliance and enforcement, incentive programs or other efforts.

Examples of such efforts would be: multi-year allocations of existing water rights in specified, high priority areas; additional restrictions on adding acres to existing water rights; non-private ownership of existing water rights to explore other conservation/economic uses of the limited supply in specified, high priority areas; and/or incorporating an economic component in decisions regarding changes to existing water rights. Some of these approaches may require the establishment of an Intensive Groundwater Use Control Area (IGUCA) or a Local Enhanced Management Area (LEMA). State supported programs, such as Water Conservation Areas (WCAs) may also be considered.

Finally, it might also entail work on federal or state programs (Kansas Water Plan, federal Farm Program, etc.) as they impact the use and/or conservation of groundwater. This sub-problem potentially could prove to be the most effective way to ease the declines. Its success, however, will hinge on quantifying existing groundwater rights and year-to-year pumpage. The possibility of extensive programs such as metering or resource development planning (irrigation development plans) appears probable.

Goal(s) for Management Problem 1. b - Direction/Influence of existing development as it impacts depletion:

1) Reduce diversions from the aquifer from existing water rights per the Enhanced Management Program process contained in section V-g of this management program. This may include any program mentioned within section 1. b. above or any regulation needed to implement a desired program;

2) Elimination of irrigation on unauthorized places of use;

3) Elimination of over-pumping authorized quantities of water through a State enforcement policy which emphasizes suspensions and, when necessary, revocations of offending water rights;

4) Promoting the enrollment of water rights into WRCP, MYFA, EQIP, WCA or any other such programs;

5) Supporting the creation and proper operation of water banks;

6) Helping to develop and supporting state and federal programs designed to reduce groundwater use, such as the EQIP program in the Farm bill, as long as these programs use financial or other incentives to reduce consumptive water use; and

7) Cooperating with other state and local entities in evaluating other ideas for the regulation or direction of existing development for the purpose of reducing overall diversions. This effort would include the local development and implementation of sub-aquifer management areas designed to identify and address the decline problems in the highest priority areas of the district.

8) Working cooperatively with DWR to ensure that water use is not increased as a result of changes made to existing water rights; and

9) Ensuring that all water use within the district is per the Kansas Water Appropriation Act.

Applicable Regulations: KAR 5-24-2; KAR 5-24-3; KAR 5-24-4; KAR 5-24-5; KAR 5-24-6; KAR 5-24-8; KAR 5-24-9; KAR 5-24-10; KAR 5-24-11
Applicable Programs: V-1-a; V-1-b; V-1-c; V-1-d; V-1-g

c. *Design and implementation of programs augmenting water supplies* as a sub-problem of depletion could require policies regarding artificial recharge, water reuse, weather modification and/or water importation.

Goal(s) for Management Problem 1. c. - Design and implementation of programs augmenting water supplies:

1) Promote new water importation projects as practical;

2) Design and operate artificial recharge structures when non-district funding is available;

3) Promote current water use efficiency to the maximum extent practical.

Applicable Regulations: KAR 5-24-8; KAR 5-24-11
Applicable Programs: V-1-a; V-1-b; V-1-c; V-1-d; V-1-g

2. Public Education and Involvement

The entire concept of local control hinges on public awareness and involvement in the affairs of the district. This is particularly true in the formulation of management policy and in other planning activities. Encouraging public interest and involvement has remained a problem from the start of the district and will require continuing attention from the board. The importance of a well-informed and active membership cannot be over-emphasized.

Areas where a lack of public education has been identified include water rights administration; general water doctrine in Kansas; the role of local districts in managing water, the hydrologic characteristics of the aquifer and awareness of the different responsibilities of various water-related agencies and authorities in Kansas, including the Kansas Geological Survey, United States Geological Survey, Division of Water Resources, Kansas Water Office, Kansas Water Authority, Kansas Department of Health & Environment, Kansas Corporation Commission, Kansas Department of Wildlife and Parks and our own groundwater management district. Without an acceptable knowledge of the areas just mentioned, the effectiveness of public input into district planning and policies will be restricted.

Goal(s) for Management Problem 2. - Public education and Involvement:

1) To develop a public education program that supports all district activities through its ability to inform and educate people about district actions, important non-district activities, water rights and anything else that may affect or assist them. To this end the district shall strive to:

(a) support schools, service clubs, local groups, etc. with presentations or other public information whenever requested;

(b) periodically notify schools of GMD 4 presentation capabilities;

(c) periodically produce a newsletter of general circulation;

(d) use public service announcements or television interviews whenever possible;

(e) periodically conduct a district-wide listening tour for better information transfer between the board and the members;

(f) actively work with all applicable agencies, authorities and the Legislature on water-related issues - both ours and theirs;

(g) maintain a district website that can be used for information dissemination.

Applicable Regulations: None
Applicable Programs: V-1-c

3. Water Quality

The availability of suitable water quality for the needs of GMD members is recognized as a problem within the district. Moreover, human activities are considered to be the major threat to groundwater quality problems, as natural influences on water quality within the district have yet to be identified. Specifically included in the GMD's list of potential groundwater quality degradation problems are:

a. *Unplugged, poorly constructed or improperly maintained wells.* This category would include water wells, oil and gas wells, all test holes, seismic holes, core holes, injection wells, disposal wells and all other drillings and borings having a potential to induce water unnaturally into the subsurface. Wells which do not meet or exceed state and local GMD standards are considered to be potential threats to groundwater contamination or leakage, because they can allow fluid migration either inside or outside the casing(s), either up or down the well or well bore.

Goal(s) for Management Problem 3. a. - Unplugged, poorly constructed or improperly maintained wells:

1) Within 6 months or less cause the plugging, capping or re-construction of every deficient well brought to the attention of the district or found by the district on its own.

Applicable Regulations: KAR 5-24-11
Applicable Programs: V-1-c

b. *Surface activities which require the collection or use of any substance which can possibly influence the quality of the groundwater resource.* This category would include feedlots, landfills and other waste dumps, underground fuel storage facilities, oilfield tank batteries and distribution systems, and all the agricultural-related storage, handling and usage of chemicals including elevators, chemical plants, and chemigation systems. By the very collection of materials, substances or animals, there exists the potential for infiltration and percolation of leachates, chemicals, water soluble by-products, and other organic and inorganic substances into the subsurface and to the water table.

Goal(s) for Management Problem 3. b. - Surface activities which require the collection or use of any substance which can possibly influence the quality of the groundwater resource: 1) Monitor federal and state policy and regulation of all listed surface activities and consider the development of local regulation if any of these are believed to be inadequate to protect district water quality. Applicable Regulations: None Applicable Programs: V-1-e; V-1-f

Specifically identified as surface activities which need additional emphasis are the agricultural practices of chemigation and general nitrate/nitrogen usage, and the salt water handling and disposal practices of the oil and gas industry.

4. Availability of Energy

The availability of economical energy is critical to the availability and use of groundwater within the district. Should energy become too costly, the resulting immediate decline in the area-wide economy would be undesirable at best. It is in the best interest of the district to support and/or assist private efforts aimed at assuring an adequate supply of energy at a reasonable cost for the pumping and diversion of valid water rights within the district.

Goal(s) for Management Problem 4 - Availability of energy: 1) To support and/or assist private efforts aimed at assuring an adequate supply of energy at a reasonable cost for the pumping and diversion of valid water rights within the district. 2) To work on behalf of the energy users of the district in maintaining a cost-effective and reliable source of energy for the production of crops and all other water uses within the district. Applicable Regulations: None Applicable Programs: None

5. Enforcement

Enforcement of locally developed policies could pose problems in the effective management of remaining groundwater reserves. Usually, local enforcement is more effective, more efficient and less expensive than state enforcement. However, anticipating a certain percentage of cases whereby local enforcement is not going to be effective, the district has identified this as a potential problem. Moreover, the district recognizes potential problems concerning the consistency of enforcement when there is not proper coordination between federal, state and local concerns.

It will remain the desire of this district to work at local enforcement as a primary endeavor, yet also be able to quickly coordinate and implement a cooperative enforcement program with the appropriate state agency(s) in those cases where this type of approach is warranted.

Goal(s) for Management Problem 5 - Enforcement:

1) To work on local enforcement as a primary endeavor yet be able to quickly coordinate and implement a cooperative enforcement program with the appropriate state agency(s) when the board deems it necessary.

2) To monitor federal and state enforcement activities and develop our own enforcement capability whenever these efforts are deemed inadequate.

3) To promote responsive state enforcement of local policies and regulations when requested.

Applicable Regulations: All Regulations
Applicable Programs: None

6. Public Interest

"Public interest" is a fundamental term used throughout the Kansas Water Appropriation Act and the Groundwater Management District Act, and within regulations developed under both statutes. Yet the term is only narrowly defined within state statute and regulation. It has been generally accepted that the complete definition of this term is actually embodied in the full suite of statutes and associated regulations, and therefore must be considered in this total, overarching context. This full context also includes the administrative, executive and judicial systems whose policies and actions also become part of the complete definition. In contrast, it has also been generally accepted that a specific statutory definition of "public interest" would be restrictive and confining, thus having more disadvantages than advantages.

The groundwater management district act made it state policy that the local land owners and water users were to determine their own destiny in regard to groundwater management issues - so long as local decisions were consistent with state law. Since a groundwater management district cannot determine its own destiny without also expressing its own public interest, it seems logical that such authority is inherent in the groundwater management district act. Yet, any local expression of public interest must also be consistent with the overarching state expression of public interest, which is subject to eventual change through any administrative, legislative or judicial actions taken.

This issue is identified as a problem because it is not currently known if the existing state expression of "public interest" can be interpreted to accommodate the regional exclusivity being proposed herein.

If so, there is little problem. If not, the state's inability to accommodate local programs and regulations defining a more local expression of public interest, will be considered a local management problem.

In this spirit, this management program is being written to embody a more local definition (expression) of public interest which the board believes is best for the landowners and water users of this GMD and hence best for the state of Kansas. The board also believes it is more clearly within the spirit of the groundwater management district act. If in fact the entire suite of statutes and regulations define public interest in concert with the administrative, executive and judicial systems, then the groundwater management districts are clearly part of these systems and they deserve sufficient consideration. A single expression of public interest exclusively from the state perspective may not serve Kansas as well as a more flexible definition recognizing regional diversity.

Goal(s) for Management Problem 6 - Public interest:

1) To convey through this management program a clear expression of what the local "public interest" is within this GMD relative to groundwater management issues.

2) To insure the district's ability to continue determining the local public interest within the authorities expressed in the groundwater management district act. In order to insure the ability to continue determining the local public interest, the district shall work with the Legislature and all appropriate state agencies insuring that they recognize, support and promote the local public interest expressed herein.

Applicable Regulations: All Regulations
Applicable Programs: All Programs

7. Funding Issues

Funding issues have been discussed often within the district in two contexts. First, the fairness of the existing assessment system, and secondly, does the existing system provide all the conservation support that it might? The Northwest Kansas Groundwater Management District board generally agrees that the current assessment system could be made more fair if variable assessment rates were possible for both the land assessment and/or the water user charge – allowing for differing rates by area; by water use type; or by land use. The new, flexible assessment system should also allow for the rate structure itself to be used as a conservation incentive if necessary in special management areas.

Goal(s) for Management Problem 7 – Funding Issues:

1) Work with Kansas groundwater management districts and the Legislature to consider amendments to the Groundwater Management District Act to accomplish variable assessments. This could be done for all GMD's or only those interested in the amended assessment system.

Applicable Regulations: None
Applicable Programs: None

V. PROGRAMS and RESOLUTIONS

To solve, control or prevent the six management problem areas described in chapter IV, and to address all other aspects of the district's operation, the following programs and resolutions are considered important.

1. Programs

a. Water Use Efficiency Improvement Program: The district shall initially establish a program designed to achieve a district-wide, minimum water application efficiency for irrigation use that places appropriate emphasis on both system design and operator management. Irrigation water use efficiency is considered the percentage of pumped groundwater that enters and remains available for crop production in the effective root zone of the crop being grown. Increased water use efficiency efforts for the other use types will also be undertaken. Increased water use efficiency is deemed important in that it will reduce the demand on the groundwater resource and will also allow the district to more effectively undertake, if necessary, future management alternatives.

The district will also if necessary: 1) require enhanced water use reports from all water users from which reasonable efficiency levels can be determined; 2) develop a method to assess the water application efficiency of all existing irrigation systems; 3) require improved water use measurement for all appropriate water users; and 4) encourage all non-irrigation water users to utilize water as efficiently as possible until similar efficiency improvement programs are specifically established by the district.

b. Water Rights Administration Program: The district shall review all groundwater rights applications filed from within its boundaries to insure compliance with district policies, and shall recommend to the Chief Engineer, Division of Water Resources, any actions or additional requirements deemed necessary.

When consulted, the district will assist in the preparation of applications for a permit to appropriate water for beneficial use and other such water-rights related paperwork, but it shall be the responsibility of the applicant to review all such information and to submit same to the Chief Engineer.

The district shall continue working with the Chief Engineer to establish and maintain reasonable limitations on rates of diversion and total annual quantities for proposed beneficial uses of water within the district for those use types deemed applicable.

The district may also monitor annual water use reports from within the district and work with or assist the Chief Engineer in improving the reporting process and/or correcting any deficiencies found.

Finally, the district shall endeavor to work with the Chief Engineer on any water rights issue which might affect its operation, whether initiated at the federal, state or local level.

c. Public Education Program: This program encompasses all programs to the extent that the district shall provide information concerning all phases of its operation to the members through the use of written publications, news releases, newsletters, public meetings, radio and television announcements, district webpage and other media available. Of particular interest shall be the wide dissemination of information concerning water rights, regulatory policies and specific projects affecting water resources, legislation affecting district operations, and water-related public meetings, hearings, workshops and other gatherings.

Public involvement shall be encouraged at every opportunity, and should be enhanced by an effective public information program. The key to increasing public involvement is to generate interest, provide practical and credible public information, and to instill and reinforce public belief in the merits of decision-making at the local level.

d. Investigations and Research Program: The district shall maintain an active interest in the following topics:

1) Artificial Recharge. The concept of artificial recharge shall be considered in a broadened sense within the district. The board of directors recognize that certain land treatment practices designed to decrease precipitation runoff and soil erosion can increase recharge as well as replenish soil moisture levels. Both these situations can increase water use efficiency and result in the reduction of groundwater pumpage. The district shall continue to study and evaluate more conventional methods of recharge such as injection wells, retention structures and playa lake management. Other such schemes which may be considered include low-head dams, stream channel flow control (gabions) and certain cultivation practices, both irrigated and dryland. Benefits to be expected from any recharge projects undertaken by the district shall relate to soil moisture management or the direct recharge of additional water.

2) Evapotranspiration Research. The district shall cooperate with and encourage research dealing with the impact evapotranspiration has on water management and use. Areas of promise could be: increased use of irrigation scheduling; genetic reduction of crop water requirements; and selection of new hybrids possessing lower water requirements. With increased surface runoff retention and 15% less water required by irrigated crops due to genetic improvements, a reduced number of fully irrigated acres could remain in production for a longer period of time. This combination of conditions might also support the supplemental irrigation of all currently irrigated acres so long as dryland production goals are uniformly established and adhered to.

3) Water Transfers - Importation. Western Kansas and the Great Plains region offers the nation a large food production area which has not yet reached its production potential. The major limiting factor in developing this potential is water. Since presently available water supplies are inadequate to fully develop and maintain the area to its production potential (or even to maintain current development), water from other areas will need to be made available if existing or increased development is desired, or if full production potential is to be realized.

Importation of water from areas of surplus supply seems to be technically feasible if the economic and political aspects of such ventures can be resolved. Some of the problems appear to be legal in nature and deal with inter/intra basin transfers. Any significant importation of water for irrigation use will by necessity be a large scale project and will require the coordination of many water-related entities including local, state, federal and possibly foreign nations. Other smaller-scale transfers will also take considerable coordination and planning.

The district shall encourage the long-range planning and study of projects which are economically feasible or may become economically feasible and which offer potential for the importation of water into northwest Kansas for whatever purposes may be deemed reasonable.

4) Water Transfers - Exportation. The board shall endeavor to involve itself with any exportation of groundwater from within the district boundary to any area or location outside the boundary. Such involvement should be relative to the Water Transfer Act, and all amendments thereto, and should insure that all district policies are met, including those policies which may apply to the receiving entity, such as waste of water and resource development plan policies.

5) Federal Farm Program Refinements. Whenever the federal farm program makes it financially attractive to grow high water-use crops because of the subsidy levels attached to those crops; or provides any other incentives to grow specific, high-water use crops; or provides disincentives to grow low-water use crops; the board should explore ways to alter the farm program so that an equal level of economic incentive can be provided to NW Kansas GMD producers such that they may choose lower water-use crop alternatives without economic or financial penalty or disincentive. All other programs relating to water use or water conservation contained in the farm program (such as EQIP) should also be evaluated and appropriately supported by the district if such programs encourage decreased consumptive water use and achieve district goals.

e. Data Collection Program: The data collection needs of the district are expected to be very broad as its programs are developed and implemented. They will necessarily range from water quantity and water quality issues, to research and investigation needs, to land ownership records, to whatever other data needs may become necessary and important to the board. This could include at any time additional water use, cropping, soils or climate data that would be necessary to support improved water use efficiency efforts.

At very least, the district shall maintain a water well inventory designed to show the location and status of each non-domestic well; mapping and data concerning area groundwater reserves; water quality information that is available or can be collected; a land ownership and mailing list data base for education and enforcement purposes; a water rights data base including authorized points of diversion, places of use and rates and quantities of water; and climate data for the region that is necessary for any irrigation scheduling programs or research.

The district shall also encourage the improvement of the state-wide, water-related data base covering water levels and water level changes in northwest Kansas, and promote the adoption of a state-wide, integrated water data base or geographic information system provided it will have access to such a system.

Finally, coordination and cooperation between the district and any state, federal, or other private or governmental agency shall be a high priority for the board at all times. Such cooperative efforts shall be encouraged whenever district manpower, technical or financial capabilities are not adequate to initiate or complete a study program or other effort approved by the board.

f. Water Quality Protection Program: In reference to the problem stated in Chapter IV-3, the district shall implement and maintain the following water quality protection program(s):

1) Existing Pollution Problems. Any known pollution problems within the district, or outside of district boundaries that pose a direct threat to groundwater within the district, may be researched and evaluated or re-evaluated by staff to determine if present or past clean-up and/or monitoring is sufficient. If staff deems it necessary to take further control measures, whether it be in conjunction with other federal, state or local water-related agencies, or as its sole responsibility, staff will then present its recommendations to the board for consideration of pertinent action.

2) Potential Pollution Problems. The water quality program goal will be to prevent any future degradation of groundwater quality by attempting to identify all potential sources of pollution, and addressing these before they become major problems. Possible programs which satisfy this mission could include, among others:

a) Oil and gas industry monitoring. The district should consider building and maintaining a file on all oil and gas activity in the district. Staff could then review this information to screen for improperly constructed or plugged oil and gas wells. Also to be included under this section could be the implementation of a simple map system for updating well status and/or density within a specific target area, and a computer link with other data bases to obtain information currently not on file.

b) General monitoring. The district could also conduct random visual inspections of oil and gas leases, drilling, completion and plugging operations, feedlots, landfills and other waste dumps, storage facilities for fuels and chemicals, chemigation systems, abandoned or improperly maintained wells and any other agricultural or industrial site that staff considers to have the potential to degrade or contaminate groundwater.

3) Observation well network. The district may set up a network of observation wells in any area that it feels may be threatened by a potential source. This network may contain the following: present irrigation; domestic; stock; or rotary rig supply wells; observation wells drilled either solely by the district or by the district in conjunction with other federal, state or local agency(s); or any combination of these.

4) Water quality testing. The district may establish its own water quality testing unit or coordinate with state, federal or private water quality testing facilities as it deems necessary. All water quality data generated locally shall be made available to cooperating agencies upon their request unless special confidentiality arrangements were made prior to the data collection. All applicable state and federal agencies shall be notified if any district water quality test indicates the existence of a water quality problem.

5) Others. Any other program or effort which the board determines necessary or desirable to prevent groundwater contamination may also fall under this general water quality protection statement.

g. Enhanced Management Program

1) Overview: In general accordance with the Kansas State Water Plan, the district will identify aquifer sub-units of similar hydrology, prioritize these sub-units, and develop an enhanced management program for the high-priority sub-units identified. The goal will be to slow the groundwater table decline rate in all high-priority aquifer sub-units identified and to extend the economic life of the local groundwater resources.

More specifically, the program is outlined as follows:

Task 1) - Cluster aquifer sub-units

Use existing KGS section-level data sets and other data available to cluster or otherwise be used in the determination of aquifer sub-units. This data will be clustered or otherwise considered based upon appropriate hydrologic parameter(s) in order to show reasonable regions of groundwater management need. This task will generate aquifer sub-units of similar groundwater dynamics within the district which can be prioritized for subsequent enhanced management efforts. The entire data set for NW Kansas will be used so as to minimize the boundary effects as much as possible.

The parameter primarily to be used for the designation of aquifer sub-units shall be percent decline of 1996 aquifer saturated thickness between 1996 and 2002 using 3-year averaged values for all data sets. Other hydrologic parameters may also be considered.

Task 2) - Prioritize aquifer sub-units:

The board will set appropriate high, medium, and low threshold triggers based on the Task 1 parameter(s) chosen. The sub-units exceeding the top trigger will be designated as high priority aquifer sub-units for subsequent enhanced management efforts. Additionally, upon request of landowners and/or water users, any high priority area may be expanded to adjacent areas and considered a high priority area provided: the entire area is sufficiently sized to justify the expansion; the landowners and water users within have systematically met and prepared a specific enhanced management plan that meets or exceeds the basic goals and criteria of this protocol; and the board feels it is in the public interest to build upon the local momentum generated by the expansion group.

Task 3) – Verify data for each high priority aquifer sub-unit:

The board will consider KGS/GMD special study findings and other reports and information to more clearly assess if the existing data adequately supports any or all of the high and medium priority aquifer sub-units rendered by task 1. If the data is considered sufficient, the board will continue to task 4. If not, before task 4 is started the board will work with KGS, DWR, KWO, USGS and others who are knowledgeable in data reliability and application to enhance, re-design, find funding for, or whatever else is necessary to obtain or enhance the data considered necessary to scientifically support not only the identification of the sub-units, but also any likely management options for the immediate future.

Task 4) - Establish preliminary water use goals and enhanced management actions for the high priority aquifer sub-units:

The board will conduct at least one public meeting within each high priority aquifer sub-unit in order to: a) inform the land owners and water users of the district's process and findings; b) to discuss the area's future outlook based on the district findings; c) to request input from the attendees about preferred future actions - specifically including preferences for a groundwater budget for the next 20 years; and d) what management policies/actions/strategies should be considered by the board to achieve the preferred groundwater budget.

Following the public meetings, the board will decide what groundwater use goals (groundwater budgets) are appropriate for each high priority aquifer sub-unit and what management approaches should be implemented. These decisions will be incorporated into the management program before being undertaken. If new regulatory authorities are considered necessary or prudent, either by the public or the board, they will be further explored at this step in the process.

(NOTE: In both the public meeting venue and the final board decision process, the following methods for reducing water use will be discussed: 1) targeting funding for water use efficiency improvements, water right set asides, or water right buyouts; 2) mandatory metering; 3) stricter regulation of water rights to include both negative and positive incentives concerning: a) overpumpage; b) tailwater control and reuse; and c) unreasonable pumpage; and 4) IGUCAs or other special management areas. Any other ideas brought up by the district members within either venue will also be considered.)

Task 5) – Assess the management program per board decisions resulting from task 4.

At this point, there may or may not be additional changes required in the management program to implement the enhanced management decisions of task 4. If management program changes are required, there will be no further implementation until the management program is appropriately revised through the prescribed process.

Task 6) - Develop assistance plans to transition to dryland farming.

This issue may or may not be addressed within tasks 4 and 5. If it is, no further specifics need to be included here. If not addressed in tasks 4 and 5, the board will work with the district members and others (state agencies and private groups) to develop a list of economically acceptable transition plans/ideas. All plans/ideas identified through this effort will next be presented to the district members at a public meeting or public meetings if the board decides to pursue such plan(s).

Task 7) - Review, evaluate and reiterate.

On a regular, identified schedule the board will again cluster or otherwise consider each medium and low priority aquifer sub-unit and using the same threshold parameters as originally used and will re-prioritize each. The high priority aquifer sub-units identified through this task will start the process at that time at task 3.

2) Timeframes:

The first timeframe will be to appropriately include the approved protocol into the next management program revision process. The board expects to begin this process in May, 2003, and have the new revised management program approved by the chief engineer by May, 2005. There are, of course, no guarantees to this timeframe. The board would also expect to hold a public hearing on the revised management program shortly after the effective date of the revised program. If approved by the district members, this revised management program, including this protocol, would likely become effective by August, 2005.

Once a protocol is included into the management program and that management program is adopted, the timeframes for the individual tasks are expected to be:

Task 1: Cluster aquifer sub-units: This task should be completed within 3 months of approval of the management program.

Task 2: Prioritize aquifer sub-units: Within 3 months of completion of task 1.

Task 3: Verify data for each high priority aquifer sub-unit: This task will begin by January, 2006, but a completion date is impossible to predict. It should take about 6 months to assess the data originally used in identifying the high priority aquifer sub-units. If the data adequately supports the sub-unit identification, this task would be expected to be completed by July, 2006. However, if the data cannot adequately support the sub-unit identifications, the board believes it could take an additional 4-5 years to design what data sets will be needed, to obtain that data and to re-apply it to tasks 1 and 2.

Task 4: Establish preliminary water use goals and enhanced management actions for the high priority aquifer sub-units: This task should take 6-8 months of time following the completion of task 3. This could be as early as February, 2007 and as late as February, 2012.

Task 5: Assess the management program per board decisions resulting from task 4: Assessment of the management program should take 4 months of time following the completion of task 4. If no revisions are necessary (that is to say that all programs and regulations needed to implement the decisions made in task 4 already exist in the revised management program) the board will be able to begin implementation immediately. Should there be required management program revisions, the implementation process could take up to 2 years while the revised management program process takes place.

Task 6: Develop assistance plans to transition to dryland farming: It is possible that district transition plans can be incorporated in tasks 4 and 5 and that no special plans need to be developed. If so, no timeframe needs to be identified. If district transition plans are not incorporated in tasks 4 and 5, this task would be begun immediately upon the conclusion of task 4. It would be expected to take 2-3 years to develop unique dryland transition plans as proposed.

Task 7: Review, evaluate and reiterate: This task will begin 5 years after the completion of task 2.

3) **Individual Enhanced HPA Management Programs:** On April 12, 2001 the Kansas Water Authority approved the start of an Ogallala Management concept through its water planning process. This action included the creation of two advisory committees to evaluate and recommend management ideas for the Ogallala – the Management Advisory Committee (MAC) and the Technical Advisory Committee (TAC). These committees generated one final report (dated October 16, 2001) containing 5 recommendations and 17 guiding principals – basically supporting local groundwater management toward an aquifer sub-unit approach. June 5, 2003 the GMD 4 board adopted an enhanced management protocol that included 7 tasks. This protocol was incorporated into the Revised Management Program on March 9, 2006. On March 8, 2007 the GMD 4 board completed Task 1 and established 6 high priority areas based on the protocol procedures. The Task 4 process began in November, 2008 when public meetings were called in each of the six areas to discuss the process. The following sections are the individual enhanced management plans for each HPA that has successfully completed Task 4 of the GMD 4 enhanced management protocol.

a) **High Priority Area (HPA) SD-6:**

ORDER

NOW, THEREFORE, it is the decision and order of the Chief Engineer, Division of Water Resources, Kansas Department of Agriculture, that the Sheridan 6 LEMA is hereby designated and established in the Sheridan County and Thomas County, and shall be in full force and effect as of the date of the Order of Decision, January 1, 2013:

BOUNDARIES.

1. That the geographical boundaries of the Sheridan 6 LEMA shall be as follows and shall include all water rights whose points of diversion are located within the following sections in Sheridan County and Thomas County:
Sheridan County:
TWP 7S-28W: Sections 19-21 and 28-33;
TWP 7S-29W: Sections 4-9 and 16-36;
TWP 7S-30W: Sections 19-36;
TWP 8S-29W: Sections 1-18;
TWP 8S-30W: Sections 1-18.
Thomas County:
TWP 8S-R31W: Sections 22-27 and 34-36.

2. This Order shall be in effect as of the date of the Order of Decision, January 1, 2013, and shall govern all irrigation, stockwatering, and recreational rights within the Sheridan 6 LEMA between January 1, 2013, and December 31, 2017. This five-year term shall be known as the "Sheridan 6 LEMA Period."

3. Attached as Attachment 1 is a spreadsheet that lists the water rights affected by this Order of Designation.
ALLOCATIONS.

4. The total amount of diversions of water within the Sheridan 6 LEMA shall be restricted to no more than 114,000 AF during the Sheridan 6 LEMA Period.

5. Each irrigation water right within the Sheridan 6 LEMA shall be limited to a total maximum quantity of 55 inches per designated eligible acre for the Sheridan 6 LEMA Period. This five-year quantity of 55 inches per designated eligible acre shall be known as the "initial irrigation allocation," and shall be applied only to the designated eligible acres for each irrigation water right in the Sheridan 6 LEMA, which have been quantified by GMD4 as described in the Proposal, GMD4 Exh. 1, Appendix 5, p. 35. Somewhat simplified, that procedure for quantifying designated eligible acres is as follows:
i. Where the irrigation water right's water use report for 2010 reports the same irrigated acreage as do the reports for 2007, 2008, and 2009, then the designated eligible acres for that water right shall be the reported acreage for 2010.
ii. Where the irrigation water right's water use report for 2010 reports irrigated acreage that differs from the reports for 2007, 2008, or 2009, then the designated eligible acres for that water right shall be the highest reported acres for any of these four years (2007 to 2010 inclusive) that can be verified by GMD4 as having been legally irrigated under that right.
GMD4 has completed this procedure for every water right within the Sheridan 6 LEMA, and every owner of an irrigation water right within the Sheridan 6 LEMA has received notification of that right's designated eligible acres.

6. The initial irrigation allocation may be increased or decreased subject to the terms and limitations set forth below. In the event of such increase or decrease, that allocation shall be known as the "irrigation allocation."

7. Individual points of diversion pumping to a common irrigation system or systems shall be provided a single allocation for the total system irrigated acres. The total amount of water pumped by all of the points of diversion must remain within that system's allocation.

8. Multiple irrigation allocations may be combined into an irrigation allocation account, which may be apportioned to the irrigation water rights' individual points of diversion within that irrigation allocation account, provided the total allocation account is not exceeded, subject to further limitations set forth below.

9. GMD4 shall administer the combining of multiple irrigation allocations as set forth in Paragraph 8 above, using an "Application to Combine SD-6 LEMA Amounts" form approved by DWR, a version of which is attached to this Order of Designation as Attachment 2. GMD4 shall supply a verified summary of this information to DWR on or before November 1 of each year of the Sheridan 6 LEMA Period.

10. Irrigation allocations may be transferred to a different place of use and/or point of diversion within the Sheridan 6 LEMA, provided that the transferors and transferees of such allocations comply with GMD4 procedures for approving these transfers, subject to the further limitations below.

11. GMD4 shall administer the transfer of irrigation allocations within the Sheridan 6 LEMA, using the "Application for Temporary Transfer of Allocation within the SD-6 Local Enhanced Management Area" form approved by DWR, and attached to this Order of Designation as Attachment 3. GMD4 shall supply a verified summary of all transfers within the Sheridan 6 LEMA to DWR, as set forth more fully at Section VII, ¶¶ 28-30 below. All such transfers shall be limited to the Sheridan 6 LEMA Period.

12. Whether through transfer, purchase, lease, or other conveyance, no irrigation allocation within the Sheridan 6 LEMA shall exceed 5 times the annual quantity of water authorized by the irrigation water right or rights that comprise the irrigation allocation.

13. No irrigation allocation shall be allowed to divert more than the annual quantity of water authorized by its constituent irrigation water right or rights in any single year.

14. Regardless of any irrigation allocation specified pursuant to this Order, any additional restriction or restrictions established pursuant to K.A.R. 5-5-11 shall continue to apply.

15. Each and every irrigation allocation shall be assigned to a specific point or points of diversion, and shall consist of all of the water rights and appurtenant acres related to that point of diversion.

16. Before October 1, 2013, any irrigation allocation may be converted to a Multiyear flex account ("MYFA") pursuant to K.S.A. 82a-736 and its attendant regulations, provided that such allocation is eligible for a MYFA, and provided further that the MYFA quantity or quantities of water do not exceed the irrigation allocation. After October 1, 2013, no conversions to MYFA's shall be allowed.

17. For any irrigation water right enrolled in any state or federal conservation program approved pursuant to K.S.A. 82a-741 and/or K.A.R. 5-7-4, whose term expires on or before September 30, 2017, the initial irrigation allocation for such right shall be limited to 11 acre-inches per acre per year for the remaining years of the Sheridan 6 LEMA Period.

18. Any irrigation water right enrolled into, contracting with, or participating in a reduced water use program (such as the Agricultural Water Enhancement Program, or AWEP, the Environmental Quality Incentives Program, or EQIP, or the Northwest Kansas Groundwater Conservation Foundation) during the Sheridan 6 LEMA Period shall not be allowed to transfer

any part of its initial irrigation allocation.

19. All stockwatering water rights within the Sheridan 6 LEMA shall be granted an allocation for use based on 12 gallons per head per day, according to their licensed lot capacity as of December 31, 2010, for the Sheridan 6 LEMA Period. This quantity of 12 gallons per head per day shall include both drinking water and additional quantities for servicing/flushing, as those terms are used in K.A.R. 5-3-22.

20. All stockwatering water rights within the Sheridan 6 LEMA shall be converted to a five-year allocation, to be known as the "initial stockwatering allocation."

21. The initial stockwatering allocation may be increased or decreased by purchase, sale, transfer, or other conveyance of water rights and water allocations. The KWAA and its attendant regulations shall govern any such modification. In the event of any modification in quantity from the initial stockwatering allocation, that subsequent allocation shall be known as the "stockwatering allocation." No stockwatering allocation shall be allowed to divert more than the annual quantity of water authorized by its constituent water right or rights in any single year.

22. During the Sheridan 6 LEMA Period, recreational water rights shall be limited to five times 90% of their annual authorized quantity as of December 31, 2010. No recreational water right shall be allowed to divert more than its annual quantity of water authorized in any single year.

METERING.

23. All water right owners shall be responsible for ensuring that their meters are in compliance with state law. In addition to the requirements set forth in the KWAA, including K.S.A. 82a-706c, K.A.R. 5-1-4 through 5-1-12, and any other relevant statutes and regulations, all water right owners shall perform one of the following two procedures.

i. Inspect, read, and record the flow meter at least every two weeks during any period in which the pump and well are operating. The owner shall maintain this record and provide it to GMD4 upon request. In the event that reported readings are questioned by either GMD4 or DWR and that the records are not provided to GMD4, the water right shall be presumed to have diverted its full annual authorized quantity for the year in which GMD4 has requested the record of the well.

ii. Install and maintain an alternative method of determining the time that the well is operating. This information must be sufficient to determine the operating time in the event of a meter failure. Should the alternative method fail or be determined inaccurate, the water right shall be presumed to have diverted its full annual authorized quantity for the year or years in which the alternative method was installed. Well and/or water right owners who select this procedure shall submit the details of this alternative method to GMD4 at least 60 days in advance of installation, so that GMD4 can determine whether the method is sufficient. Well owners who select this procedure shall also submit proof of installation to GMD4.

24. Any water right owner or his or her authorized designee who finds a flow meter that is inoperable or inaccurate shall notify GMD4 within 48 hours, and shall provide the following information to GMD4:

i. The water right file number;

ii. The legal description of the location of the point of diversion;

iii. The date the problem was discovered;

iv. The flow meter manufacturer, model, registering units, and serial number;

v. The meter reading on the date the problem was discovered;
vi. A description of the problem;
vii. The alternative method that the owner will use to compute the amount of water diverted while the meter is being repaired or replaced; and
viii. The projected date that the meter will be repaired or replaced.

25. Whenever an inoperable or inaccurate meter is repaired or replaced, the owner or authorized water use correspondent shall notify GMD4 within 7 days and provide the following information:
i. Water right file number;
ii. Date the meter was replaced or repaired;
iii. If the meter was replaced, the make, model, registering units, serial number, and meter reading of the new meter before it records any water use;
iv. If the meter was repaired, the date of repair and confirmation of the meter reading before it records any water use; and
v. A total of the water pumped while the meter was inoperative.

26. These metering provisions and protocol shall be a specific annual review issue pursuant to Section VII, ¶ 45 of this Order, and may be adjusted upon recommendation by the Chief Engineer or the Advisory Committee.

27. Nothing in this Order of Designation shall limit the authority of DWR to require metering or other water measurements in all other respects pursuant to the KWAA and regulations.

ACCOUNTING OF WATER USE.

28. GMD4 shall account for and monitor the use of water within the Sheridan 6 LEMA by keeping complete records of the following on an annual basis:
i. The diversion amounts for each water right, using the annual water use reports filed with DWR;
ii. Any combining of allocations;
iii. Any transfers of allocations;
iv. Any other changes in allocations; and
v. The remaining allocation balance for each water right in the Sheridan 6 LEMA for the Sheridan 6 LEMA Period.

GND4 shall provide DWR and the owner of each water right within the Sheridan 6 LEMA of a summary of the above-described records. GMD4 shall provide the first summary by November 1, 2014 (for 2013 water use) and by November 1 of each successive year (for the previous year's water use), with the final summary to be due by November 1, 2018. GMD4 shall keep copies of each such annual summary in its files.

29. GMD4 shall notify DWR of any combining, transfers, or other changes in allocations within the Sheridan 6 LEMA within 30 days of their approval by GMD4.

30. GMD4 shall develop a system using a commonly accepted electronic spreadsheet program to approve and to track transfers of water within the Sheridan 6 LEMA, and shall make that system and that program accessible to DWR.

VIOLATIONS, ENFORCEMENT, AND CIVIL PENALTIES.

31. Exceeding any total allocation quantity, including any transferred quantities, by an amount less than 4 acre-feet within the allocation period shall result in a $1,000.00 fine for every day that pumping was taking place in excess of the allocation. This penalty shall also apply

to all rights in combined allocation accounts.

32. Exceeding any total allocation quantity, including any transferred quantities, by an amount equal to or more than 4 acre-feet within the allocation period shall result in an automatic two-year suspension of the water right. This penalty shall also apply to all rights in combined allocation accounts.

33. Exceeding the annual authorized quantity of the water right, not including any transferred quantities, shall result in a $1,000.00 fine.

34. These penalties shall not exclude the availability of other civil penalties made available pursuant to K.S.A. 82a-737.

35. If GMD4 learns of any violation of this Order, it shall promptly report any such violation to DWR, request that DWR apply the appropriate civil penalty, and fully assist DWR in any compliance action taken by DWR in response to such violation.
WATER RIGHTS ADMINISTRATION; IMPAIRMENT COMPLAINTS.

36. Nothing in this Order of Designation shall preclude a water right owner from requesting administration of water rights as provided for by the KWAA and its regulations.

37. Nothing in this Order of Designation shall preclude a water right owner from bringing a well-to-well impairment complaint pursuant to K.A.R. 5-4-1.

38. In the event that an impairment investigation produces a determination that the impairment is caused substantially by a regional lowering of the water table, K.A.R. 5-4-1a shall apply; but in such an event, the Chief Engineer may consider the requirements of this Order of Designation in determining the appropriate resolution of such impairment.

WATER LEVEL MONITORING;MONITORING PLAN.

39. The following observation wells, all in Sheridan County, shall be used to monitor changes in depths to water in the SD-6 LEMA, as described by location and well number below:
i. TWP 7S-28W, Section 21, Well No. 07S28W21;
ii. TWP 7S-29W, Section 5, Well No. 07S29W05;
iii. TWP 7S-29W, Section 27, Well No. 07S29W27;
iv. TWP 7S-29W, Section 30, Well No. 07S29W30;
v. TWP 8S-29W, Section 1, Well No. 08S29W01-1;
vi. TWP 8S-29W, Section 1, Well No. 08S29W01-2;
vii. TWP 8S-30W, Section 5, Well No. 08S30W05;
viii. TWP 8S-30W, Section 11, Well No. 08S30W11; and
ix. TWP 8S-30W, Section 13, Well No. 08S30W13.

40. GMD4 shall convert observation Well No. 08S30W13 to an hourly measurement schedule by installing a continuous pressure transducer by January 1, 2013.

41. GMD4 shall drill at least three additional observation wells and equip each of these three wells with pressure transducers that allow the hourly recordation of water levels. These additional wells shall be located in Sheridan County as follows, with parenthetical references to their current landowners:
i. TWP 7S-29W, Section 25, Well No. 07S29W25 (Moss);
ii. TWP 7S-30W, Section 27, Well No. 07S30W27 (Seegmiller);
iii. TWP 8S-31W, Section 26, Well No. 08S31W26 (Steiger); and
These observation wells shall be installed, fully tested, and operational by January 1, 2013. If

GMD4 adds observation wells in addition to these three wells and equips them with instruments subsequent to this order, GMD4 shall notify DWR and KGS upon setting the data logger equipment and collecting data for the first time from those wells. Any such additional observation wells that become operational subsequent to the date of this Order shall be subject to the terms of this Order.

42. GMD4 shall be responsible for maintaining all observation wells that GMD4 has constructed and equipped with instruments, as described in Section VII, ¶¶ 40-41 above, during the Sheridan 6 LEMA Period.

43. DWR and GMD4 shall cooperate in obtaining and analyzing the data obtained from the observation wells.

ADVISORY COMMITTEE; REVIEW.

44. GMD4 shall maintain a Sheridan 6 LEMA Advisory Committee ("Advisory Committee") consisting of nine members. One member shall be an employee of DWR, who shall serve as the designee of the Chief Engineer. One member shall be an at-large member from GMD4. The remaining seven members shall be owners of irrigated land within the Sheridan 6 LEMA, residents of the Sheridan 6 LEMA, or tenant farmer operators of irrigated land within the Sheridan 6 LEMA; and one of these seven Sheridan 6 LEMA members must represent nonirrigation water users. The chair of the Advisory Committee shall be a resident within the Sheridan 6 LEMA.

45. The Advisory Committee shall meet at least annually to consider the following:
i. Water use data;
ii. Water table information;
iii. Economic data;
iv. Whether the combining of allocations and the transfers of allocations have altered the geographic distribution of diversions and/or water use within the Sheridan 6 LEMA;
v. Whether the combining of allocations and the transfers of allocations have produced a concentration of diversions and/or water use within the Sheridan 6 LEMA;
vi. Violations, issues relating to violations, and metered data that relates to violations;
vii. New and preferable enhancement management options; and
viii. Other items deemed pertinent by the Advisory Committee.

46. The Advisory Committee shall produce an annual report providing a summary of its considerations, and shall transmit that report to GMD4 and to the Chief Engineer by December 31 of each year of the Sheridan 6 LEMA Period.

47. The Advisory Committee shall conduct a formal review of this Order of Designation. This formal review shall consider the following:
i. Economic impacts of the Sheridan 6 LEMA;
ii. Changes in water levels;
iii. Whether the flexibility afforded by the use of allocations in the Sheridan 6 LEMA substantially increased water use in any part of the LEMA, or raised other concerns;
iv. Whether the Sheridan 6 LEMA should be extended in time;
v. Whether the geographical boundaries of the Sheridan 6 LEMA should be expanded; and
vi. The impact of the Sheridan 6 LEMA upon the public interest.

Following this formal review, the Advisory Committee shall produce a final report containing specific recommendations regarding future LEMA actions. These recommendations shall be supported by reports, data, testimonials, affidavits, or other documents attesting to their foundation. The Advisory Committee shall submit the final report to GMD4 and to the Chief Engineer on or before December 31, 2016.
RETAINED JURISDICTION.

48. The Chief Engineer specifically retains jurisdiction in this matter to make changes to this Order of Designation to protect the public interest and to prevent the impairment of water rights.

FINAL AGENCY ACTION; DISTRIBUTION OF ORDER.

49. This Order of Designation is final agency action as defined by K.S.A. 77-607(b)(2).

b) [Reserved if future HPA Enhanced Management Plans are generated]

h. Metering:

In response to the division of water resource's announcement that all wells in NW Kansas will be metered, the district will work with the division in developing a mutually acceptable metering program. This effort will be pursued via the adoption of a Memorandum of Understanding with the division of water resources that specifies the obligations and responsibilities of each entity in implementing the MOU.

i. Enhanced Allocation of Water:

In concert with the Northwest Kansas Groundwater Conservation Foundation, and within the established high priority areas determined through the enhanced management program expressed in section V. g, above, it shall be the intent of GMD 4 to obtain water rights in order to immediately reduce consumptive water use while working to lease or re-sell portions of the purchased water rights to maintain or enhance economic returns. The district should work closely with the division of water resources, Kansas department of agriculture and the Kansas department of commerce to respectively facilitate water right transfers and then prepare to market the water rights. It will be the goal of this program to both reduce consumptive water use and to increase economic returns made from the reduced water use.

2. Resolutions:

a. Geographic Distribution of the Board of Directors (PR-76-1)

WHEREAS the Northwest Kansas Groundwater Management District No. 4 was formed for the management and conservation of groundwater resources; for the prevention of economic deterioration; and to secure for Kansas the benefit of its fertile soils and favorable location with respect to national and world markets; and

WHEREAS the Board of Directors of Northwest Kansas Groundwater Management District No. 4 are elected to represent the wishes of the eligible voters of the district; and

WHEREAS the boundaries of the district include all or portions of ten counties;

THEREFORE, BE IT RESOLVED by the eligible voters of the Northwest Kansas Groundwater Management District No. 4 that the board of directors be elected such that all geographic locations within the district will be represented, that one board member be elected from Cheyenne County, hereafter to be considered position No. 1, that one board member be elected from the Rawlins-Decatur County area, hereafter to be considered position No. 2, that two board members be elected from the Sherman-Wallace County area, hereafter to be considered position numbers 3 and 4, and two board members be elected from Thomas County, hereafter to be considered position numbers 5 and 6, that two board members be elected from Sheridan County, hereafter to be considered position numbers 7 and 8, that one board member be elected from Graham County, hereafter to be considered position No. 9, that one board member be elected from Logan County, hereafter to be considered position number 10, and that one board member be elected from Gove County, hereafter to be considered position number 11.

BE IT FURTHER RESOLVED that in order to be eligible as a candidate for a board of directors position, the eligible voter must reside within the boundaries of that respective position as previously described.

b. **Schedule of Annual Meeting Rotation (PR-76-2)**

WHEREAS the Northwest Kansas Groundwater Management District No. 4 was formed for the management and conservation of groundwater resources; for the prevention of economic deterioration; and to secure for Kansas the benefit of its fertile soils and favorable location with respect to national and world markets; and

WHEREAS the board of directors of the Northwest Kansas Groundwater Management District No. 4 are elected to represent the wishes of the eligible voters of the district; and

WHEREAS the boundaries of the district include all or portions of ten counties which constitute a considerable traveling distance for many voters;

THEREFORE, BE IT RESOLVED by the eligible voters of the Northwest Kansas Groundwater Management District No. 4 that after the initial annual meeting, the annual meeting location be in a rotation of Hoxie, Goodland and Colby, respectively, in order to coincide with the geographic election of the board of directors as follows:

1. Hoxie, 1977, Positions 8, 9, 10 and 11
2. Goodland, 1978, Positions 1, 4 and 6
3. Colby, 1979, Positions 2, 3, 5 and 7

c. **Exclusions and Inclusions (PR-84-1)**

WHEREAS the Groundwater Management District Act specifically outlines parameters within which land may be excluded from district assessment, but does not adequately address the assessment status of land transfers; and

WHEREAS Northwest Kansas Groundwater Management District No. 4 now has a landowner data base through which exclusions can more readily be monitored; and

WHEREAS numerous discrepancies in the status of excluded land now exist because of the inability of this district to require landowner updates due to the vagueness of the statutory language regarding same;

BE IT THEREFORE RESOLVED that the Northwest Kansas Groundwater Management District No. 4 shall adopt the following policy with regard to reasonable and equitable administrative actions to prevent persons from unknowingly conflicting with existing statutes concerning land exclusions, or refusing to come into compliance.

1) The term "tract" shall be considered as a portion of land as it is legally described by the county records of the local county clerks office.

2) Any excluded tract of land involved in a change in ownership by any means shall revert to its original included status, as no exclusion form with the current landowner will be on file with the district office.

3) Ownership or acquisition of a water right shall be presumed as intent to use water on or withdraw water from beneath said tract(s) and shall void or prevent the exclusion status of said tract(s).

4) If the assessment status of either the previous owner or the new owner of any transferred tract(s) changes, the district will on its own initiative, administratively correct the situation(s) provided its action is the only legal alternative of that party.

5) When multiple alternatives exist for the seller or buyer because of any transaction involving land resulting in a mixed assessment status which is inconsistent with the Groundwater Management District Act, the owner will be notified and given 45 days from the district's notification date to correct the discrepancy. If no such response and direction is received within that time, the board shall direct staff to implement the district's only option of including all previously excluded land as a result of a voided (outdated) exclusion form on the part of that owner.

6) Sections 1-5 of this policy shall be applied to all land within the district retroactive to March 1, 1976, provided no assessments shall be levied pursuant to this policy prior to January 1, 1985.

d. District Election Procedure (PR-91-2)

WHEREAS KSA 82a-1021 in essence defines an "Eligible voter" as any person who is 18 years old and older if that person either 1) owns 40 or more contiguous acres within the boundaries of the district and outside the corporate limits of a municipality, provided the land has not been voluntarily excluded from district assessments, or 2) withdraws or uses at least 1 acre-foot (325,851 gallons) of groundwater per year from within the district; and

WHEREAS KSA 82a-1021 continues to say that each tract of land and each quantity of water use can only be represented by 1 eligible voter, and if the land is held by lease, contract, or estate, the deed holder is the person or corporation who is presumed to be the eligible voter unless an agreement to the contrary has been reached by the parties involved. Furthermore, if the land is held jointly or in common, the majority of interest determines which person or corporation can vote. If equal interests exist, only 1 voter can be selected; and

WHEREAS KSA 82a-1021 continues to state each eligible voter may cast only one vote except that person who is the duly authorized representative for an estate, a trust, a municipality, or a corporation who may cast an additional vote for each one of these entities that he or she represents; and

WHEREAS KSA 82a-1021(e) strictly prohibits proxy voting; and

WHEREAS some convention or policy is necessary to positively identify the authorized voters so as to insure legal voting during any district event;

BE IT THEREFORE RESOLVED THAT the Northwest Kansas Groundwater Management District No. 4 Board should adopt the following as GMD 4 election policy:

1) The District shall prepare from its records annually an eligible voter list, for use during all voting events, of all known eligible voters based on land ownership and permitted water use.

2) Unless known to or approved by the election officer, any person requesting a ballot(s) on behalf of any estate, trust, municipality, or public or private corporation will be required to furnish written proof of voter status as follows: a) for an estate, the person must be an Executor or Administrator; b) for a trust, the person must be a Trustee; c) for a Municipality, the person must be an Elected Official, or d) for a Public or private corporation, the person must be a Corporate Officer. In each case such approved voter authority shall be construed to be effective for that election only, and pre-arranging such voting status in advance of the voting event is highly recommended.

3) Unless known to or approved by the election officer, any person requesting a ballot for land which is leased, held under and estate for years or held under contract shall furnish written confirmation from the deed holder that a voting agreement has been reached which authorizes the tenant or contract holder to vote, specifying at least one tract of land on which the agreement has been reached. A tenant or contract holder cannot collect more than one such agreement. In each case such written authority shall be construed to be effective for that election only. Pre-arranging such voting status in advance of the voting event is highly recommended.

4) Any person requesting a ballot based on water use in excess of 325,851 gallons of non-permitted water use, shall furnish written confirmation of such use consisting of either; a) water utility receipt(s) showing total calendar year annual use from the previous year; b) energy and pumping records from the previous calendar year substantiating such use; or c) other documentation sufficient to support such use within the previous calendar year. In each case such written authority shall be construed to be effective for that election only. Pre-arranging such voting status in advance of the voting event is highly recommended.

BE IT FINALLY RESOLVED THAT this resolution shall become effective December 12, 1991, and remain in effect until duly amended or rescinded.

VI. District Operation

The district shall operate from a centrally located office established within its boundaries. Staff who are employed with the approval of the board of directors shall run the day-to-day operation and direct the programs heretofore listed. The district shall be run by eleven elected board of director members who shall each represent a certain constituency as has been set out in this program. They shall be responsible for setting policy and insuring the district is working toward the established goals and objectives at all times. They shall meet periodically to review district activities and formulate planning concepts. An annual meeting shall be held each year to allow input and information to flow freely between the district and its members. This is not to say that the district is closed on a day-to-day basis for any individual comments, criticisms or ideas.

The district shall operate on funds resulting from the assessment authority given in K.S.A. 82a-1030. Each year the district's tax rolls shall be re-validated to the appropriate county clerks' and new assessment charges levied. Moreover, the district shall adhere to all laws, regulations and policy statements issued which pertain to the formation and operation of the state's groundwater management districts.

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Testimony of the Northwest Kansas Groundwater Management District No. 4 (GMD 4) to Hearing Officer David Barfield, Chief Engineer, Division of Water Resources, Kansas Department of Agriculture.

RE: Written Testimony for Proposed District-Wide Local Enhanced Management Area (LEMA) of November 14, 2017

Presented by: Raymond Luhman

This testimony is from Northwest Kansas Groundwater Management District No. 4 (GMD 4). It was approved by the GMD 4 Board of Directors.

GMD 4 submits this testimony in support of the Chief Engineer finding that the proposed Local Enhanced Management Area (LEMA), with a minor modification, will conserve water and educate water users on further conservation methods to extend the life of the Ogallala aquifer in Northwest Kansas. The GMD 4 provides a short history of the Kansas Water Appropriation Act (KWAA), the Groundwater Management District Act (GMDA), the Local Enhanced Management Area (LEMA) statute, and the previous actions taken in this proceeding. Then, GMD 4 re-states its goal. Last, GMD 4 shows how the corrective control measures should reach the goal in this case.

1. History of the Kansas Water Appropriations Act

In 1944, the Kansas Legislature passed the Kansas Water Appropriation Act (KWAA). K.S.A. 82a-701 et seq. In passing the KWAA, the Kansas Legislature dedicated "All water within the state of Kansas . . . to the use of the people of the state, subject to the control and regulation of the state . . . ." K.S.A. 82a-702.

Then, in 1972, the Kansas Legislature supplemented the KWAA with the Groundwater Management District Act (GMDA). K.S.A. 82a-1020 through 82a-1041. In doing so, the Legislature:

> "recognized that a need exists for the creation of special districts for the proper management of groundwater recourses of the state; for the conservation of groundwater resources; for the prevention of economic deterioration; for associated endeavors within the state of Kansas through the stabilization of agriculture; and to secure of Kansas the benefit of its fertile soils and favorable location." K.S.A. 82a-1020.

On December 19, 1974, after a series of informal meetings were held in the GMD 4 area to sense the will of the people relative to forming a GMD, a steering committee filed a declaration of intent and a map of the proposed district boundaries with Kansas' Chief Engineer. After further discussions between the steering committee, the Kansas Department of Agriculture Division of Water Resources (DWR), and the Chief Engineer, the Chief Engineer certified a final description of the district boundaries.

In 1975, the water users voted in favor of creating GMD 4. On May 24, 1976, the initial meeting was held in Colby, Kansas. Eleven board member positions were opened for election and all the positions were filled. GMD 4 was established. Since that time, GMD 4 has undertaken many conservation efforts, including purchasing water rights; monitoring annual usage; sending advisory letters to those who appeared to pump more water than necessary; ending new development; and creating the first LEMA in the Sheridan 6 High Priority Area (SD-6 LEMA). GMD 4 now embarks on a new conservation effort, LEMA using those same boundaries contemplated in 1974 and adopted in 1976 for GMD 4.

In 2012, at GMD 4's request, the Kansas Legislature passed the Local Enhanced Management Area (LEMA) statute. *See* K.S.A. 82a-1041. Any LEMA is a creature of statute. As part of the GMDA, K.S.A. 82a-1041 allows GMDs to address groundwater declines and other conditions of concern through management plans that include specific goals and corrective control procedures while still being consistent with state law. This local autonomy over the management plan distinguishes LEMAs from IGUCAs. The LEMA statute refers to the IGUCA statute to establish the groundwater conditions that may give rise to creating a LEMA. A LEMA must comport with the public interest, a term that figures prominently in both the KWAA and the GMDA, because the Chief Engineer has the statutory duty to regulate the distribution of the state's water resources for the benefit of all of its inhabitants according to the law. K.S.A. 82a-1041(b)(2); K.S.A. 82a-706; K.S.A. 82a-702; K.S.A. 82a-1020. GMD 4 proposed and administered the first LEMA—the SD-6 LEMA. Now, GMD 4 proposes this LEMA.

2. History of these Proceedings

On June 8, 2017, GMD 4 submitted a revised LEMA Proposal (the Proposal) to the Chief Engineer. Before submitting the proposed LEMA, GMD 4 held four public meetings in Colby, Goodland, Hoxie, and St. Francis, Kansas; and, had multiple board meetings, with many interested people attending, over a two and half year period between January 2015 and June 2017 to discuss the Proposal. This represented a significant public involvement in the process that resulted in the locally developed and locally requested plan. Additionally, GMD 4 had previously presented a more restrictive program at an additional 4 meetings. The public acceptance of that program was less positive, and therefore the board rejected that program.

On June 27, 2017, the DWR and Chief Engineer found that "on its face," the Proposal met the threshold requirements of K.S.A. 82a-1041(a) and initiated these proceedings. This determination on whether the Proposal met the K.S.A. 82a-1041 thresholds was not a final determination but an initial determination that the Proposal warranted further review, input, investigation, testimony, and consideration. To begin that review, the Chief Engineer delegated his authority to an independent hearing officer, Constance C. Owen, to conduct the initial public hearing in this matter. Notice was given of that first hearing as required by K.S.A. 82a-1041(b).

On August 23, 2017, Constance C. Owen, Hearing Officer, conducted the initial hearing on whether the Proposal met the statutory requirements of K.S.A. 82a-1041(b) and whether this matter should proceed to a second hearing. Written testimony was allowed to be submitted on this issue until September 13, 2017. *See* Order on Initial Requirements of the Groundwater Management District No. 4 District-Wide Local Enhanced Management Area, 21 (Aug. 23, 2017) (Initial Order).

The testimony GMD 4 presented, both oral and written, for the August 23, 2017 hearing is incorporated and made a part of this testimony. Therefore, this testimony will focus on the goal, the proposed corrective control measures, and the implementation of the proposed corrective control measures.

On September 23, 2017, Ms. Owen issued her Initial Order concluding that the Proposal "satisfied the three initial requirements for approval as set forth in K.S.A. 82a-1041(b)(1)-(3)."

These are excerpts from the GMD #4 Management Program of 9/19/2016, Section IV. Subsection 6 and Subsection 1 b and go further in explaining that the proposed restrictions are in the public interest:

3. The Proposal, as found by Hearing Officer Owen's, is in the public's interest.

K.S.A. 82a-1020 is the Legislative declaration relative to establishing groundwater management districts in Kansas. It declares that in the public interest it is necessary and advisable to permit the establishment of GMDs which allow local water users to determine their own destiny with respect to the use of groundwater—insofar as that destiny does not conflict with the basic laws and policies of the state.

As described by GMD 4's management plan, "Public interest" is a fundamental term used throughout the KWAA and GMDA, and within regulations developed under both statutes. Yet the term is only narrowly defined within state statute and regulation. It has been generally accepted that the complete definition of this term is actually embodied in the full suite of statutes and associated regulations, and therefore must be considered in this total, overarching context. This full context also includes the administrative, executive and judicial systems whose policies and actions also become part of the complete definition. In contrast, it has also been generally accepted that a specific statutory definition of "public interest" would be restrictive and confining, thus having more disadvantages than advantages.

The GMDA made it state policy that the local land owners and water users were to determine their own destiny in regard to groundwater management issues—so long as local decisions were consistent with state law. Since a groundwater management district cannot determine its own destiny without also expressing its own public interest, it seems logical that such authority is inherent in the GMDA.

In this spirit, this LEMA is being proposed by the GMD 4 BOD, because it believes is best for the landowners and water users of GMD 4 and hence best for the state of Kansas. The board also believes it is more clearly within the spirit of the LEMA statute. If in fact the entire suite of statutes and regulations define public interest in concert with the administrative, executive and judicial systems, then the GMDs and LEMAs are clearly a part of these systems and they deserve sufficient consideration. A single expression of public interest exclusively from the state perspective may not serve Kansas as well as a more flexible definition recognizing regional diversity.

When the LEMA process comes from the local board of directors and the corrective control provisions being requested from that process are consistent with state law, then the public interest of K.S.A. 82a-1020 has been satisfied.

In any event, the GMD 4 provided GMD 4 water users information very early in the discussions of the District Wide LEMA. The evidence provided the water users showed that adopting and implementing any corrective control provisions that would reduce water use, would also extend the life of the regional aquifer.

A web page was created to keep the process available to the public and was updated regularly by GMD 4 staff. Beginning in January of 2015, the process was covered by at least 28 board meetings.

4. The corrective controls measures should reach the LEMA goal.

4.1. The Goal for the LEMA is to promote improved management of water and not exceed irrigating 1.7 million acre-feet over a five year period.

The request for a LEMA contained the following goal statement and detail:

To promote improved management of water used district-wide with a goal not to exceed 1.7 million acre-feet (AF) for irrigation over five years within townships displaying an annual decline rate for the period 2004 – 2015 of 0.5% or greater annual decline and promote more efficient use by non-irrigation uses.

This LEMA shall exist only for the five- year period beginning January 1, 2018 and ending December 31, 2022. The proposed LEMA shall include all points of diversion located within the boundaries of GMD 4 excluding vested rights and points of diversion whose source of supply is 100% alluvial.

The total program diversion amount of 1.7 million AF for irrigation use for townships with annual decline rates of 0.5% or greater shall represent five (5) times the sum of designated legally eligible acres times the amount designated for irrigation water rights;

The Northwest Kansas Groundwater Management District No. 4 shall use the procedures herein to determine the 5-year allocation for each water right, and specify said values in Section 3). All allocation values shall be expressed in terms of total acre-feet for the five-year LEMA period. *See* Attachment 1, Request for a District-

Wide LEMA Submitted to the Chief Engineer, Kansas Department of Agriculture, Division of Water Resources (June 8, 2017) (Proposal).

GMD 4 established that goal because many parts of the Ogallala Aquifer within GMD 4 are declining at a rate greater than .05% per year. At the initial hearing, Hearing Officer Owens specifically found that:

> The credible and relevant data provided by the [Kansas Geological Survey] KGS and used to develop this LEMA proposal corroborates GMD 4's conclusion that water levels are declining or have declined excessively and that withdrawals equal or exceed the rate of recharge in the area of the proposed GMD 4 LEMA. Initial Order at 12.

The Hearing Officer based her finding on KGS's measurements of depth-to-water in about 1,400 wells taken from the same year. After taking those depth-to-water measurements, KGS calculated three-year averages (2004, 2009, and 2015) and isolated the data relative to wells within GMD 4. KGS determined that the average saturated thickness for GMD 4 was 76 feet in 2004 and 70 feet in 2015. Parts of Sherman County had an average rate of decline of over 20 feet and much of Sherman County and portions of Thomas and Sheridan County averaged declines of 12 feet over the six year period from 2009-2015. KGS concluded that "The major driver for these water level declines is groundwater pumping as illustrated by published reports (citation omitted), which show statistically significant correlations exist between annual water-level change and annual groundwater use across GMD 4."

4.1.1. The corrective controls measures should reach the LEMA goal as applied to irrigation water use.

The corrective control measures will reach the goal by reducing pumpage. GMD 4 determined the LEMA allocation for each water right using the procedures described below.

To determine a water user's LEMA allocation, GMD 4 first determined what acreage a water users recently irrigated (irrigated acres). To determine irrigated acres, GMD 4 examined annual water use reports from 2009–2015. GMD 4 used the 2009-2015 range because 2009 was the first year that all wells in GMD 4 were metered and 2015 was the last year that water use data was available when the LEMA process through the public meetings was initiated. The maximum reported irrigated acreage during that period was used to set the irrigated acre amount (or eligible acre amount) for each right. GMD 4 checked any discrepancies or inconsistencies against the United States Department of Agriculture aerial photos, the actual water rights, and the water use reports to finally determine irrigated acres (or eligible acres).

GMD 4 derived the LEMA township annual decline percent for the period of 2004-2015 from KGS section level data. A section is an area about one square mile containing 640 acres with 36 sections making up one survey township on a rectangular grid. The KGS compiled data on a section-by-section basis to determine the section-by-section declines. The KGS section level data was averaged for each legal township in the district. KGS section level data was used because it assigns a value for bedrock and water level elevations for each specific section. Then, GMD 4 removed all wells with any alluvial connection from the data set. Additionally, GMD 4 removed any sections that exhibited less than 15 feet of saturated thickness from the analysis; because, removing those sections minimized the depletion status of areas on the fringe of GMD 4. Very small declines in areas of little saturated thickness result in unacceptably high percentage figures, which is why they were removed from the analysis. This section level data GMD 4 relied on to determine the township declines and the LEMA allocations.

Last, GMD 4 examined the Net Irrigation Requirements (NIR) set by the United State Natural Resource Conservation Services. (NCRS). See U.S. Dept. of Agric., Nat. Res. Cons. Serv., Nat'l Eng'r Handbook, Irrigation Guide, KS210-652-H,, Amend. KS31, KS652-4.1 thru 4.25 (2014), https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_030990.pdf. The State of Kansas has used the NIR amounts since at least 1994 and referenced the NIR amounts in K.A.R. 5-5-9, K.A.R. 5-5-10, K.A.R. 5-5-11 and other regulations. The GMD 4 Board used the NRCS NIR 50% and 80% values for corn by county. 50% NIR represents the net irrigation requirement for corn that would be sufficient in 5 out of 10 years (considered to be normal) based on the precipitation that would be expected in 5 out of 10 years. 80% NIR represents the net irrigation requirement for corn that would be sufficient in 8 out of 10 years (considered to be dry) based on the precipitation that would be expected in 8 out of 10 years.

These figures were then interpolated to derive a value at the western edge of each zone. Each township was then assigned a color based on the zone in which it was located," red, yellow, purple, blue and green. Townships exhibiting greater than a 2% annual decline rate were assigned the 50% NIR for corn by zone (red). Townships exhibiting from 1% to 2% annual decline rate were assigned the 80% NIR for corn by zone (yellow). Townships exhibiting 0.5% to 1% were assigned an 18 inch allocation district-wide (purple). Those townships that are below the 0.5% decline rate will not have restrictions on their diversions imposed (blue and green). The tiered system gives due consideration to water users who have already implemented reductions in water use resulting in voluntary conservation measures as evidenced by a slower rate of decline. No township has an allocation less than the 50% NIR for its respective zone.

Last, GMD 4 multiplied the irrigated acre values by the allocation amount on the map attached to the Proposal based on the decline percentage for the township where the point of diversion was located and the corresponding NIR. That NIR number was then divided by 12 (to convert to acre-feet) and then multiplied times the acres times five to determine the five year LEMA allocation. For example, in township 8-42W in Sherman County, the NIR for corn is 16.1 inches per acre. If a water right user irrigated 124 acres in that township, then the LEMA allocation would be 832 acre-feet over five years.

The LEMA allocation will also not reduce water users by greater than 25% except for those being reduced to an 18 inches per acre per year cap. No LEMA allocations within areas of decline greater than .05% will be receive an allocation in excess of 18 inches per acre per year. These amounts apply to those water rights in red, yellow, and purple townships.

The LEMA proposal also contains provisions addressing specific situations. Those provisions include:

> Wells pumping to a common system or systems shall be provided a single allocation for the total system acres, subject to the review process in Sections 5 and 6. The total amount pumped by all of the wells involved must remain within the system allocation.
>
> No water right shall receive more than the currently authorized quantity for that right, times five (5).
>
> No water right within a K.A.R. 5-5-11, 5-year allocation status shall receive an allocation that exceeds its current 5-year allocation limit.

No water right shall be allowed to pump more than its authorized annual quantity in any single year.

In all cases the allocation shall be assigned to the point of diversion and shall apply to all water rights and acres involving that point of diversion. Moreover, in all cases the original water right shall be retained.

For water rights enrolled in EQIP and/or AWEP that will be coming out of either program on or before September 30, 2022, the allocation quantity shall be set at the annual allocation for only the remaining years of the 2018-2022 LEMA period.

If a water right is or has been suspended, or limited for any year of this LEMA, due to penalty issued by the Kansas Department of Agriculture, Division of Water Resources (DWR), then the GMD 4 and DWR will reduce the allocated quantity for such water right accordingly for the 2018-2022 LEMA period.

For water rights enrolled in a KAR 5-5-11 change, MYFA, WCA, or other flexible water plan, the most water restrictive plan will apply.

Each allocation for irrigation will be a total 5-year amount. The Proposal does not contain an acre-inch per acre limitation. The allocation may be used in any fashion and at any time during the LEMA chosen by the right holder, except that water user cannot exceed the annual authorized quantity unless authorized by a Muli-Year Flex Account (MYFA) or Water Conservation Act (WCA) term permit or plan.

After completing these calculations, about 65% of the wells or well-groups slated for a LEMA allocation will have a LEMA allocation that less than their combined diversions from 2009 – 2015.

The base water right will not be altered during the LEMA period. Any order issued under the LEMA will be subject to the additional LEMA terms and conditions for the five years during the LEMA. GMD 4 further requests that any future reiterations of this LEMA that may come into existence or be proposed by the GMD 4 Board take into consideration allowing a maximum 10% carry-over of the LEMA allocated amount. *See* Proposal 1)d)-l). This gives future GMD 4 and LEMA boards an opportunity to continue rewarding those that conserve. It also incentivizes conservation into the future.

4.1.2. The corrective control measures, with modifications, should reach the LEMA goal.

For non-irrigation use type, the GMD 4 Board requests that the following language modify the stockwater portion of the proposed LEMA (Modifications) for two reasons. First, the total acre feet allocated to stockwater use in GMD 4 is less than 0.5 % of total appropriations. Second, animal feeding and dairies represent a significant market for local crops and the GMD 4 Board reasoned that animal feeding and dairies should not be unduly restricted.

The GMD 4 Board still encourages livestock and poultry operations to only use 90% of the amount they are allocated. The proposed Modifications read:

> Part 2)a) Livestock and poultry use will be encouraged to maintain their use at 90% of the said amount provided by K.A.R. 5-3-22 based on the maximum amount supportable by the number of animals authorized by a current facility permit. At no time will a stockwater right be authorized to pump more than its authorized quantity. . . .
>
> Part 2)d) When converting from irrigation to non-irrigation use, the base water right will be converted under the procedures in K.A.R. 5-5-9, 5-5-10, or Groundwater Management District #4 regulations, and the appropriate non-irrigation Local Enhanced Management Area allocation will apply as found in Section 2 for the remainder of the Local Enhanced Management Area period.

Parts 2)b), 2)c), and 2)e) of the Proposal would remain the same. With the acceptance of the above modifications and because of the small fraction of the groundwater used for stock water, dairies, and recreational use, this should not be an impediment to adopting the Proposal. Additionally, stock water and dairies provide a market for crops such that the GMD 4 BOD determined decreasing the stock water and dairy use could negatively impact the agricultural economy in the region and adversely impact implementation of the Proposal.

4.1.3. Appeal Process

If an irrigation user believes they have more irrigated acres or have applied water in a different fashion than reported, an appeal process will be instituted to allow individuals and GMD 4 to review their irrigated acres. Any appeal must begin by March 1, 2019. Only irrigated acres and LEMA allocations may be appealed. The process also allows additional data from 2016 and 2017 to be considered. Again, the information the GMD 4 had when it submitted the proposal was from 2009-2015.

Water users and GMD 4 staff will conference regarding discrepancies in irrigated acres. Any decision made by GMD 4 staff may be brought before the GMD 4 board for a final decision.

This appeal process is an effort by GMD 4 to make sure that the allocations are correctly set.

4.1.4. Violations

Violations under the Proposal will be consistent with the violations in the SD-6 LEMA. These are added fines and/or suspensions to be applied in the case of over-pumping the LEMA quantity. While this does provide penalties for over-pumping the LEMA quantity; it is equally important that accurate data is available regarding water use and these provisions provide additional methods to test the accuracy of the data. In the first five years of the SD-6 LEMA, no violations occurred. There is an additional incentive for those townships not currently being issued a LEMA allocation. That incentive is to maintain or improve on current pumping levels to ensure that their respective townships do not reach decline levels that would require restrictions if a future LEMA were proposed.

An added violation concerns meter tampering. If a preponderance of evidence suggests that actions have been taken to remove or alter the meter's ability to accurately measure flow the offending water right will be suspended for a period of five years and any remaining LEMA allocation will be lost.

There are some added requirements that apply to wells that have a LEMA allocation. These require that the meters be read at least every two weeks and that malfunctioning meters be repaired/replaced as soon as possible. It also requires a back-up system by which the amount of water pumped can be readily determined. If such back-up data is unavailable it will be assumed that the entire appropriated right has been pumped for the purpose of LEMA record keeping.

4.1.5. Economic Viability

Preliminary economic studies done by Dr. Bill Golden on the SD-6 LEMA indicate that cash flow values inside that LEMA very closely resemble those of the immediate surrounding area. Dr. Bill Golden, Monitoring Impacts of Sheridan County 6 Local Enhanced Management Area, Interim Report 2013 – 2015, Nov. 8, 2016 (SD-6 Interim Report). It should be noted that the SD-6 LEMA has a much higher level of restrictions than the ones proposed by this LEMA.

A previous study was done by Golden, Peterson, & O'Brien, Potential Economic Impact of Water Use Changes in Northwest Kansas (2008) (The Golden Report). There, Golden et.al stated that, the least desirable option to institute cutbacks in diversions was to use a system that completely dries up acres—either by a first in time, first in right system, or other programs that take land out of irrigated production. They concluded that less water use on more acres had far less of a negative impact. Instituting reductions by using order of priority would have the effect of drying up many acres and for this reason, the GMD 4 board proposes giving an equal allocation to all non-vested rights based on their location and the decline rate of the Ogallala aquifer.

The Golden Report initially evaluated the potential economic consequences of reduced groundwater us in northwest Kansas. Specifically, the Golden Report evaluated the potential economic impacts of three possible reduction levels: (1) a zero reduction in groundwater pumping; (2) completely eliminating all groundwater pumping; and (3) reducing groundwater pumping by 30%. Regarding the third option, the Golden Report then assessed the respective economic impacts of achieving such a reduction by three scenarios: (a) by limited irrigation; (b) by a buyout of irrigation rights, while allowing dryland farming on dried-up lands; and (c) by a conservation program such as the Conservation Reserve and Enhancement Program (CREP), which requires a 15-year following period, after which dryland farming can resume. The Golden Report employed data that is consistent with the KGS model described above.

In assessing the respective economic impacts of the three possible reduction levels and the three scenarios described above, the Golden Report employed a variety of tools, including input-output impact analysis, and specifically, Impact Analysis for

Planning (IMPLAN). IMPLAN is a commonly accepted method of economic analysis that has been used by agricultural economists in Colorado, Kansas, and Nebraska. IMPLAN has been accepted as a reliable and persuasive method of assessing water-use impacts on agriculture by the Supreme Court of the United State. *See Kansas v. Colorado*, No. 105, Orig., Fifth and Final Report of the Special Master, at 20 (Feb. 4, 2008). *See also Kansas v. Colorado*, No. 105 Orig., 543 U.S. 86, 91 (2004) (accepting the use of IMPLAN to award economic damages).

According to the Golden Report, under the first option, over a 60 year period,—no reduction in groundwater pumping—the irrigated acres of the SD-6 area declined from 16,062 in year one to 8,245 in year 60. Future gross profits tracked this unregulated decline in groundwater levels beginning at about $5,279,829 in Year 1 and dropping to $3,997,627 in Year 60.

Under the other Golden Report extreme—a 30% reducing in groundwater pumping—the decline in water use and profitability is far less precipitous. The irrigated acres of the SD-6 area were projected to decline from 16,062 in year one to 13,327 acres in year 60. Future gross profits track this less aggressive decline in groundwater levels, starting at $4,717,461 in year one and dropping to $4,285,202 in year 60.

The SD-6 LEMA ultimately adopted a 20% reduction. A middle ground between continuing the groundwater mining then occurring and a 30% immediate reduction for all irrigated rights.

In 2016, Golden issued his Interim Report for the SD-6 LEMA. There, Golden found that past efforts (pre-LEMA efforts) to slow decline and ensure the future economic viability of the region have been largely unsuccessful. Golden noted that "LEMAs are proactive, locally designed, and initiated water management strategies for a specific geographic area that are promoted through a GMD and then reviewed and approved by the Chief Engineer." *Id.* at 1. He further notes that the LEMA blueprint may be the future of groundwater management; that it overcomes the problems associated with the 'top-down' Intensive Groundwater Use Control Areal (IGUCA) process; and it "minimizes the common property externality associated with groundwater extraction." *Id.* at 2.

Golden, in his SD-6 Interim Report, then compared those producers inside the SD-6 LEMA with those producers outside the SD-6 LEMA to determine the SD-6 LEMA's economic impact using methods that are consistent with methods used by the Kansas Department of Agriculture. *Id.* at 2-3. On comparing the control and the target group, Golden concluded that producers were able to reduce groundwater use in the SD-6 LEMA area with minimal impacts on cash flow (gross profits less expense equating to net profits). *Id.* at 2-3.

Furthermore, the Proposal does not contain any restrictions below the average water needs for corn; and, most of the wells or groups have allocations at or above the drier 80% chance NIR for corn (see explanation of NIR above). Last, the greatest restriction, 25%, is well within the 0% reduction to 30% reduction ranges contemplated by the Golden Reports (Golden Report and SD-6 Interim Report) to maintain the economic viability of the GMD 4 region.

Conclusion

This concludes the written testimony for GMD 4. In sum, GMD 4 contends that:

1. The Chief Engineer should adopt Hearing Officer Owens' Order on Initial Requirements of the Groundwater Management District No. 4 District-Wide Local Enhanced Management (LEMA) and incorporate it into the Chief Engineer's order.

2. The Chief Engineer should issue an Order of Decision accepting the Proposal with the Modifications and return the Proposal with the Modifications to GMD 4 for approval.

3. On approval by GMD 4, the Chief Engineer should issue an Order of Designation designating all of GMD 4 as a LEMA and implementing the modified corrective controls within the Proposal and described above.

ATTACHMENTS

Attachment 1

Request for a District-Wide LEMA Submitted To the Chief Engineer, Kansas Department of Agriculture, Division of Water Resources

June 9, 2017

In order to reduce decline rates and extend the life of the aquifer in Northwest Kansas Groundwater Management District No. 4 (GMD 4) the Board of Directors of GMD 4 proposes the following five year plan be submitted via the Local Enhanced Management Area (LEMA) process contained in KSA 82a-1041 for the entire area within the boundary of the Northwest Kansas Groundwater Management District No. 4.

Overview and Goal Expression

To promote improved management of water used district-wide with a goal not to exceed 1.7 million acre-feet (AF) for irrigation over five years within townships displaying an annual decline rate for the period 2004 – 2015 of 0.5% or greater annual decline and promote more efficient use by non-irrigation uses.

This LEMA shall exist only for the five- year period beginning January 1, 2018 and ending December 31, 2022. The proposed LEMA shall include all points of diversion located within the boundaries of GMD 4 excluding vested rights and points of diversion whose source of supply is 100% alluvial.

The total program diversion amount of 1.7 million AF for irrigation use for townships with annual decline rates of 0.5% or greater shall represent five (5) times the sum of designated legally eligible acres times the amount designated for irrigation water rights;

The Northwest Kansas Groundwater Management District No. 4 shall use the procedures herein to determine the 5-year allocation for each water right, and specify said values in Section 3). All allocation values shall be expressed in terms of total acrefeet for the five-year LEMA period.

1) Allocations – Irrigation

a) Proposed allocations provided in Sections 3 and 4 were determined based on the maximum reported and/or verified acres for years 2009-2015. Proposed allocations are subject to change in the case where incorrect water use data is verified via the process in Sections 5 and 6.

b) All irrigation water rights, excluding vested rights, shall be limited to the allocation for the water right location on the accompanying map over the 5-year period beginning January 1, 2018 and ending December 31, 2022. If a vested right and an appropriation right have the same place of use or same point of diversion, the vested right will be the vested water right's authorized quantity and the appropriation right will be limited to the total system allocation minus the vested water right's authorized allocation.

c) The base water rights will not be altered by any Order issued under this request, but will be subject to the additional terms and conditions described herein for the duration of the LEMA.

d) Wells pumping to a common system or systems shall be provided a single allocation for the total system acres, subject to the review process in Sections 5 and 6. The total amount pumped by all of the wells involved must remain within the system allocation.

d) No water right shall receive more than the currently authorized quantity for that right, times five (5).

e) No water right within a K.A.R. 5-5-11, 5-year allocation status shall receive an allocation that exceeds its current 5-year allocation limit.

f) No water right shall be allowed to pump more than its authorized annual quantity in any single year.

g) In all cases the allocation shall be assigned to the point of diversion and shall apply to all water rights and acres involving that point of diversion. Moreover, in all cases the original water right shall be retained.

h) For water rights enrolled in EQIP and/or AWEP that will be coming out of either program on or before September 30, 2022, the allocation quantity shall be set at the annual allocation for only the remaining years of the 2018-2022 LEMA period.

i) If a water right is or has been suspended, or limited for any year of this LEMA, due to penalty issued by the Kansas Department of Agriculture, Division of Water Resources (DWR), then the GMD 4 and DWR will reduce the allocated quantity for such water right accordingly for the 2018-2022 LEMA period.

j) For water rights enrolled in a KAR 5-5-11 change, MYFA, WCA, or other flexible water plan, the most water restrictive plan will apply.

k) No water right shall be reduced by more than 25% of their average historical pumping based on years pumped 2009-2015 unless it would allow a quantity over 18 inches per acre to be pumped.

l) Should GMD 4 request a new LEMA beyond the first five-year period, the GMD 4 Board will consider a maximum 10% carry-over of the LEMA allocation for the regions depicted in the purple, yellow, and red on Attachment 1 if a new district-wide LEMA is considered or pursued as a result of the LEMA Order Review discussed in Section 11.

2) Allocations – Non-irrigation

a) Livestock and poultry use will be restricted to 76% of the quantity of water deemed to be reasonable for livestock and poultry provided in K.A.R. 5-3-22 in townships with greater than 2% average annual decline and 85% of said amount in townships with average annual declines between 1% and 2%, based on the maximum head supportable by the feedlot permit in effect on December 31, 2015. At no time will a stockwater right be authorized to pump more than its authorized quantity.

b) Municipal will be encouraged to reduce the amount of unaccounted for water reported annually on the water use report and reduce the gallons per capita per day.

c) All other non-irrigation users will utilize best management practices.

d) When converting irrigation to non-irrigation, then the most restrictive of the LEMA allocation, GMD 4 regulations, or conversion outlined in K.A.R. 5-5-9 will be used to determine the converted allocation amount.

e) The base water rights will not be altered by any Order issued under this request, but will be subject to the additional terms and conditions described herein for the duration of the LEMA.

3) Individual Allocation Amounts

The five-year allocations for every water right per Sections 1.a and 2 above shall be converted to a five-year acre-feet total, with Attachment 1 containing the assigned eligible irrigation restriction for each township. Each water right will be restricted to its total acre-feet allocation within the LEMA order issued through this process, subject to the review processes outlined in Sections 5 and 6.

4) Data Set

The relevant data for this LEMA proposal came from the Water Rights Information System (WRIS) maintained by the Kansas Department of Agriculture, Division of Water Resources (DWR).

If any data errors are discovered, then the GMD 4 Board requests that the person or entity discovering the errors contact GMD 4 to update or correct any alleged errors via the processes outlined in Sections 5 and 6.

Attachment 2 contains pdf files of irrigation and stockwater water right numbers and allocations. Associated spreadsheets will be kept by GMD 4 and DWR; will be available on the GMD 4 and DWR websites; and may be changed with the Chief Engineer's approval or through the processes outline in Section 5 and 6. The GMD 4 and the DWR will document or track any changes made to the irrigation water and stock water right allocations attached hereto.

5) Eligible Acres Process

Based on input from stakeholders, it was agreed that the following procedure would be used to assign eligible acres to every irrigation water right in the District-Wide LEMA and to include in any future LEMA request.

The GMD 4 and DWR determined eligible acres as follows:

a) The GMD 4 and DWR used the maximum reported authorized irrigated acres from 2009-2015 that could be verified as being legally irrigated with the GMD 4 in-house aerial photography and water right file information.

b) If the authorized place of use was not irrigated from January 1, 2009 to December 31, 2015, then earlier years that the water user irrigated the acres may be considered.

c) The DWR will contact every water right owner within 60 days after the Order of Designation and others known to them as operators or interest holders in the water right to inform them of the eligible acres assigned to their water right(s) under the adopted process, allow them the opportunity to appeal the assigned acres under the process described below and allow them the opportunity to provide more information to the GMD 4 Board on the correct acres. The GMD 4 Board's decision is final and the eligible acres determined by the GMD 4 Board will be used to calculate and assign the final allocations.

6) Appeals Process

a) Appeal Process. The following process will govern appeals regarding eligible acres and allocated water:

(1) Any appeal of the eligible acres and allocated water must be filed before March 1, 2019. Failure to file an appeal of the eligible acres and allocated water by March 1, 2019 will cause the assigned eligible acres and allocated water to become final during the LEMA period.

(2) Only eligible acres and allocated water may be appealed through this appeal process. No other issues including, but not limited to, the LEMA boundaries, violations, meter issues, etc., may be appealed through this process.

(3) Any appeal will first be heard by the GMD 4 staff who will determine eligible acres based on the factors above in Section 5) Eligible Acre Process.

(4) Any determination made by the GMD 4 staff may be appealed to the GMD 4 Board.

(5) The GMD 4 and DWR will use the acres and allocated water determined through the processes contained in Sections 5 and 6, as detailed above, to calculate and assign allocations.

b) Factors to be considered by the GMD 4 Board on appeal. The following factors, in order of importance, will be used when reviewing a determination of eligible acres and allocated water on appeal.

(1) First, the reviewer will first consider the location of the well(s) and their township allocations.

(2) Second, the reviewer may consider the authorized place of use.

(3) Third, the reviewer may consider any and all aspects of the water right, use, place of use, point of diversion, or any other factors the reviewer determines appropriate to determine eligible acres and allocated water.

7) Violations

a) The LEMA order of designation shall serve as initial notice of the creation of the LEMA and its terms and conditions to all water right owners within the GMD 4 on its effective date.

b) Upon GMD 4 learning of an alleged violation, GMD 4 will provide DWR with the information GMD 4 believes shows the alleged violation. DWR, under its discretion, may investigate and impose restrictions and fines as described below or allowed by law.

c) DWR will address violations of the authorized quantities as follows:

(1) Exceeding any total allocation quantity of less than 4 AF within the allocation period will result in a $1,000.00 fine for every day the allocation was exceeded.

(2) Exceeding any total allocation quantity of 4 AF or more within the allocation period will result in an automatic two-year suspension of the water right and a $1,000 fine for every day the allocation was exceeded up to a maximum of $10,000.

d) In addition to other authorized enforcement procedures, if the GMD 4 Board finds by a preponderance of evidence that meter tampering, removing the meter while pumping, or any other overt act designed to alter the metered quantity as described in K.A.R. 5-14-10 occurred, then the GMD 4 Board will make a recommendation to the Chief Engineer that a written order be issued which states:

(1) The nature of the violation;

(2) The factual basis for the violation;

(3) That the water right is suspended for 5 years; and

(4) That the water right loses all remaining assigned quantities under the District-Wide Local Enhanced Management Area.

8) Metering

a) All water right owners shall be responsible for ensuring their meters are in compliance with state and local law(s). In addition to being in compliance and reporting annually the quantity of water diverted from each point of diversion, all water right owners shall implement at least one of the following additional well/meter monitoring procedures:

(1) Inspect, read and record the flow meter at least every two weeks the well is operating. The records of this inspection procedure shall be maintained by the well owner and provided to the district upon request. Should the flow meter reported readings be in question and the bi-weekly records not be available and provided upon request of the district, the well shall be assumed to have pumped its full annual authorized quantity for the year in question. Following each year's irrigation season, the person or persons responsible for this data may at their discretion transfer the recorded data to the district for inclusion in the appropriate water right file for future maintenance.

(2) Install and maintain an alternative method of determining the time that the well is operating. This information must be sufficient to be used to determine operating time in the event of a meter failure. Should the alternative method fail or be determined inaccurate the well shall be assumed to have pumped its full annual authorized quantity

for the year in question. Well owners/operators are encouraged to give the details of the alternative method in advance to GMD 4 in order to insure that the data is sufficient.

b) Any water right owner or authorized designee who finds a flow meter that is inoperable or inaccurate shall within 48 hours contact the district office concerning the matter and provide the following information:

(1) water right file number;

(2) legal description of the well;

(3) date the problem was discovered;

(4) flow meter model, make, registering units and serial number;

(5) the meter reading on the date discovered;

(6) description of the problem;

(7) what alternative method is going to be used to track the quantity of water diverted while the inoperable or inaccurate meter is being repaired/replaced; and

(8) the projected date that the meter will be repaired or replaced.

(9) Any other information requested by the GMD 4 staff or Board regarding the inoperable or inaccurate flow meter.

c) Whenever an inoperable or inaccurate meter is repaired or replaced, the owner or authorized designee shall submit form DWR 1-560 Water Flowmeter Repair/Replacement Report to the district within seven days.

d) This metering protocol shall be a specific annual review issue and if discovered to be ineffective, specific adjustments shall be recommended to the chief engineer by the advisory committee.

9) Accounting

a) DWR, in cooperation with GMD 4, shall keep records of the annual diversion amounts for each Water Right within the LEMA area, and the total 5-year quantity balances will make this information available to the Water Right Holder and the GMD 4 on their request.

10) Advisory Committee

a) A District-Wide LEMA Advisory Committee shall be appointed and maintained by the GMD 4 Board consisting of fourteen (14) members as follows: one (1) GMD 4 staff; one (1) GMD 4 Board Member; one (1) representative of the Division of Water Resources, Kansas Department of Agriculture as designated by the chief engineer; and the balance being irrigators with regional distribution identical to GMD 4 board member distribution. One of the District-Wide LEMA members shall chair the committee whose direction shall be set to further organize and meet annually to consider:

(1) water use data;

(2) water table information;

(3) economic data as is available;

(4) violations issues – specifically metered data;

(5) any new and preferable enhanced management authorities become available;

(6) other items deemed pertinent to the advisory committee.

b) The advisory committee in conjunction with DWR shall produce an annual report which shall provide a status for considerations (1) through (6) and any recommended modifications to the current LEMA Order relative to these six items. Said report shall be forwarded to the GMD 4 board and the chief engineer.

11) LEMA Order Reviews

a) In addition to the annual LEMA Order reviews per Section 10 the District-Wide LEMA Advisory Committee shall also conduct a more formal LEMA Order review 1.5 years before the ending date of the LEMA Order. Review items will focus on economic impacts to the LEMA area and the local public interest. Water level data may be reviewed.

b) The committee, in conjunction with DWR and GMD 4, shall also produce a report following this review to the chief engineer and the GMD 4 board which contains specific recommendations regarding future LEMA actions. All recommendations shall be supported by reports, data, testimonials, affidavits or other information of record.

12) Impairment Complaints

While this program is being undertaken, the GMD 4 stakeholders request that any impairment complaint filed in the district while this management plan is in effect, which is based upon either water supply issues or a regional decline impairment cause, be received by the Chief Engineer, and be investigated by the Chief Engineer with consideration to the on-going Local Enhanced Management Area activities.

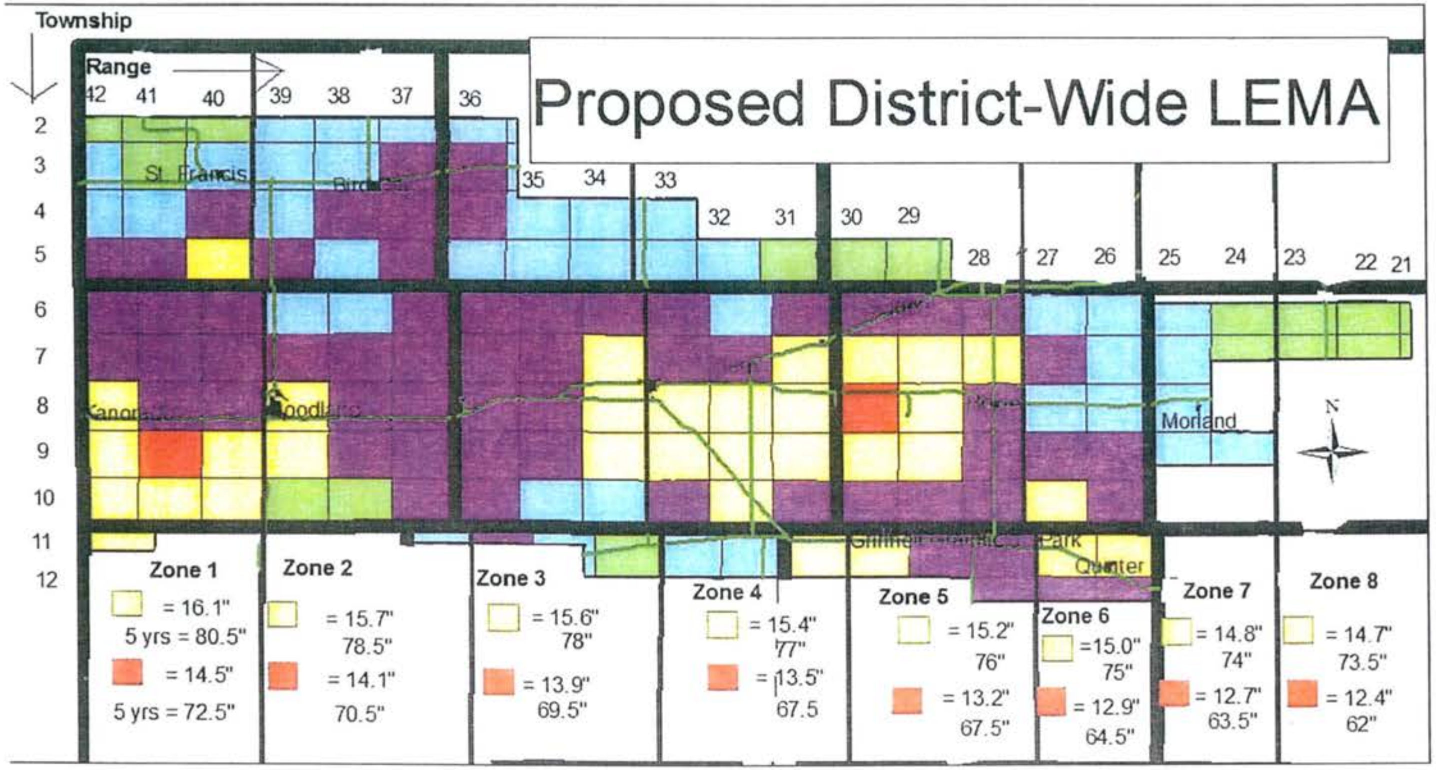
13) Water Level Monitoring

The data used to determine regional aquifer declines in Attachment 1are based on the annual water level monitoring taken by KGS and DWR. Those measurements will continue as the data set used in determining water level declines. In the future, GMD 4 could, but is under no obligation, install additional monitoring wells.

14) Coordination

The GMD 4 stakeholders and the GMD 4 board expect reasonable coordination between the chief engineer's office and the GMD 4 board on at least the following efforts:

a) Development of the LEMA Order resulting from the LEMA process;
b) Accounting for annual pumpage amounts by LEMA water right owners/operators.
c) Compliance and enforcement of the District-Wide LEMA Order.



Townships with 2%+ Average Annual Decline in 2004-2015

Townships with 1-2% Average Annual Decline in 2004-2015

Townships with 0.5 - 1% Average Annual Decline in 2004-2015 (18 inch max restriction)

Townships with 0-.5% Average Annual Decline in 2004-2015

Townships with no decline 2004-2015

Prepared by Shannon Kenyon GMD 4

Attachment 2 to Proposal

Irrigation and Stockwater Allocation PDF Files

GMD 4 LEMA
Irrigation Water Right

GMD 4 LEMA Stock
Water Rights.pdf

Attachment 3 to Testimony

Public Meeting Notes and Sign-in Sheets

PUBLIC LEMA BOARD MEETINGS QUESTIONS AND COMMENTS

COLBY (97 signed in)

Questions:

Is this a 5 yr. program?

What about restricting dairies?

We used to flood and haven't for a while, how will that affect me?

At the end of 5 years are you going to increase or decrease our allocation?

Why would we do this if we're the only district doing it?

Will we get a letter on what we will get under the plan?

Will we be able to bank the water?

Will there be a vote?

How much water is this going to save?

How is this a LEMA? It looks like an IGUCA

Why cut people that don't have a problem ?

What happens in 5 years?

Can we just "knock off" the new wells?

What happens if we do nothing?

Why the whole district?

Public Comments:

0.5 – 1% should also have a reduction.

This plan is a personal agenda.

You need more measureable goals.

Data other than KGS should be used.

I've lost nine windmills, how here isn't afraid of the water going away.

PLEASE SIGN IN

Colby

Brit Rogers	Connor Wilson
Jerry Biney	Steve Wilson
Norma Zerr	Dan Reiterer
Kent [illegible]	Kurt Manrath
Kt [illegible]	Bon Hooting
Phil Keck	Mike Stephens
Carl Ziegelmeier	Michael Juchemann
Chuck [illegible]	Jon Starns
ALAN & Andy Query	Don Antholz
Jeff Younger	Marvin Albers
Daniel Schultz	Ashley Roehl
Larry Louis	Richard Ernil
Jim McKee	Ron Erickson
Ken Christiansen	Steve Brumenkamp
Curtis Dorn	Gary Hall
Chris P. Beamer	Mark Myers
[illegible]	Jeremy Myers
Jon Friesen	Jim Frewey
Jeremy Kersenbrock	Ronald E Neff
Tom Redman	Jamie Dunn
Eugene Schwarz	Daly Dard
Shawn O Burk	Alan Seth
Todd Ziegelmeier	Dale [illegible]
Shirley Harlett	[illegible]
William Rikoff	[illegible]
Ron Evans	R [illegible]
Steve Friesen	

Harold Murphy Selden Ks

PLEASE SIGN IN Colby 97

Doug [illegible]
Alex Zerr
Sarah Jane Barrett
Dave Hubbard
Thad Hahn
[illegible]
Dale [illegible]
Jon McKee
Bob Stephens
Steve [illegible]
Jeff [illegible]
Robert [illegible]
[illegible]
[illegible]
[illegible]
John Flanagin
Richard [illegible]
Ron [illegible]
Matt [illegible]
Travis Towns
Kelly Stewart
Rick Kuper
Jan de Waal
Zach Zweygardt
Brad [illegible]
Wayne [illegible]

Don Woofter
Chris Soehner
Shawn Dietrich
[illegible]
Douglas [illegible]
[illegible]
Marshall Rhea

Kelly Horinek Farm Credit

Gloria Morgan

Mike Baumberger

Jerod Pfortmiller

Nathan Goetz

Bob Gillen - KSU

Keith Downing (May Ann)

Jim Kopriva

Bernard Meyer

[illegible]

[illegible]

GOODLAND: (88 signed in)

Questions:

Is the purple 18" per circle?

What about EQIP acres?

Does this apply to vested rights?

How do you figure out where you are located?

How did you come up with the zones?

Who on the board represents Wallace County?

Is the maximum 25% reduction based on your historical pumping?

Will there be a vote?

Can we do a district-wide WCA instead?

Why was 2009-2015 used?

What is your depletion goal?

Are you going to install more observation wells?

What's the reversal process if there is public outcry?

Is SD6 going to re-up?

Is this going to permanently reduce my water right?

Was there an economic study?

Has the board been advised to wait until the economic study is over?

Is the economic study available?

Can we vote?

What is the time frame for implementation?

Have you contacted the county assessor?

Is there economic impact in SD 6?

How many of the wells in SD 6 get measured?

How did you get the different colors?

When are the observation wells measured?

Comments:

You should do a 20% reduction of all wells and for one year in five you can't pump water.

South of Ruleton I don't have a decline problem, but four miles away they do.

A provision needs to be included to discontinue the plan and make it a reversible process.

This will create a 10% net decrease in economics.

I want to see the scatter plots to determine the % reduction needed in the decline areas.

The longer we extend the aquifer, the longer we benefit.

You need to include a possible drought contingency plan.

Bigger government is not good.

Blue areas should have restrictions if truly a groundwater management district.

Thank you for your efforts.

There should be a 10% reduction in five years for areas that still have a decline. That 10% reduction should continue every five years until no decline.

Thank you to the board for listening to our comments at the last public meetings. The map is proof that you listened to us.

Goodland 80

PLEASE SIGN IN

Craig Boggs
Royce Kohlbeck
Steve Evert
[illegible]
HD House
David Leonard
Joyce Schilling
Terri Bellamy
Alan Townsend
Larry [illegible]
Shawna Johnson
Mary Volk
Jace Mosbarger
[illegible] Mosbarger
Barry Guyer
James Fritz
David Dorn
Greg Sedlacek
Jane McCary
Bob + Norma Grangaard
Kelly Stewart
[illegible] Armstrong
[illegible]
Leonard Kaschka

24

Goodland

PLEASE SIGN IN

Brent Cook
DICK PETTIBONE
Zach Coryell
Nate Emig
John Rode
Chris Soehner
Keith Snethen

PLEASE SIGN IN Goodland

David Pedersen
Katie Harness
John Deeds
Darla Deeds
Scott Briney
Frank Van Laeys
KIRK RICE
Elmer & Joyce Purvis
Ken Palmgren
Zach Zweygardt
Ron Robinson
Brady Ohlbrich
Lonnel Whitaker
GERALD FRANKLIN
LINDA FRANKLIN
Thad Hahn
Neal Thornburg
Joey Snethen
Scott Hooker
DENNIS SHANK
[illegible]
Norman House
Kim Deole
Ryan Deole 24
Stan Cobade
Gregory E Cure

PLEASE SIGN IN Goodland

Ross Jansen

Mike Rogers

Rick Billinger

Tyson Davis

PLEASE SIGN IN Goodland

Ron & Marsha Schilling
Kevin Schmidt
Jan de Waal
Frank Linden
Curtis Dopan
Melvin R. Remechek
Connie Sigs
Jeff Younger
Tim Frankley
Dan Stephens
David Stephens
Chuck Thomas
Allen Quenzer
Steve Duell
Rich Simon
Dillon Troxsel
Jake Bolin
John Namey
Kent Williams
Mike [illegible]
Jeanne Fail Jones
Darrell Owens
Robin Deeds
Dennis Coryell
Darrel Cloyd
Lou Hines
Tom Livengood

27

ST FRANCIS (49 signed in)

Questions:

How are acres determined?

What happens to water rights still in their perfection period?

What does "encourage" mean in relation to municipalities?

What is depth to water in these areas?

Will it be a reduction in the water right or only what is allowed to be pumped?

If you change tenants in the middle of the five year period, what happens to your remaining allocation?

How much water does this save?

What are the ramifications for going over?

How much is allowed in SD 6?

Can you bank the water if you don't use it?

What are the economic ramifications?

How have the other meetings gone?

Is there any provisions on contiguous acres?

Why is there no flexibility in this plan?

Comments:

I pump 21" per year but was hailed out one year so my average is skewed. That may not trigger the no more than 25% reduction.

St. Francis

PLEASE SIGN ~~UP~~ IN

(49)

Jeff Younger
Martin Hupfeld
Tom Hupfeld
Craig Busse
Mike Rooney Bird City
Kermit Bear Bird City
Michael Roach
Lonnie Willis
William [illegible]
Dan Stephens
Alex Evert
Dennis Wright
W m Wright
Clayton Janicke
Adam Deeds
John Deeds
David Hendricks
Kole Yonkey
Brooks Brenn

HOXIE (60 signed in)

Questions:

If SD 6 re-ups will they keep their flexibility?

What about restricting the well at the Sheridan Lake?

How many AF do they have?

Who came up with the 12 g/h/d?

Why did you go on a township level instead of individual wells?

How many acres does each observation well cover?

How and when will you know it's working?

How many wells in SD 6?

How do the declines compare to outside of SD 6?

What happens when SD 6 re-ups?

How many townships in SD 6?

Does 5 years give you enough time to readjust if it's not working?

Are you going to get tougher if there is still a decline?

There's not much irrigation in my red township, but there is a huge feedlot and ethanol plant. Have you taken this into account?

How many other hot spots (HPA) are there in the district?

Can you buy water rights like you can in SD 6?

After 5 years what's the plan?

Does the amount I've historically pumped affect me?

If we don't do something now, will the state come in later?

<u>Comments:</u>

The data is inaccurate.

If SD 6 can do it then it should be district-wide.

I want out of the district.

I have issues with tax payers paying for the building and supplying money to the Foundation.

We need to educate the people in town on the water problem.

You can't wait another 20 years to solve this problem.

I testify the LEMA is working. The farm management improves.

The probes, and other technology work.

Please Sign in Here

John Lindenman

Shawn Lindeman

Mark Hill

Ginger Pugh KDA-DWR

Kelly Stewart

Dan Watkins

Nick Hixon

Dal Bremer

Matt Palmquist

Howard Blockett

Deil Beard

Randall Youkl

Ray Slipke

Bob Brensten

Nathan Lee

Harold Murphy

Jeremy McKenna

Kevin Lager

Ed ...

Ken ...

WADE TREMBLEY

Shane Beckman

Randy Ochs

Paul Bangs

Dan Waldman

Lenny Patton

Pat Herl Hoxie
Rick Moss Hoxie
Don Moss Hoxie
Harold Foster "
Rick Gillespie Brewster
Mike McHenry

Testimony from Brownie Wilson, Kansas Geological Survey.

Submitted to Hearing Officer Connie Owen, Appointed by David Barfield, Chief Engineer, Division of Water Resources, Kansas Department of Agriculture.

RE: Written Testimony, Proposed GMD4 District-Wide LEMA Hearing, August 23, 2017

My name is Brownie Wilson. I am the Geographic Information Systems (GIS) and Support Services Manager for the Geohydrology Section at the Kansas Geological Survey (KGS). The KGS is a research and service division under the University of Kansas and has been directed by the Kansas Water Plan to provide technical assistance to the three western Groundwater Management Districts (GMD), the Kansas Water Office, and the Kansas Department of Agriculture- Division of Water Resources (KDA-DWR) in the assessment, planning, and management of the groundwater resources of western Kansas.

At the request of GMD4 in May of 2016, the KGS looked at the changes in the saturated thickness of the Ogallala/High Plains aquifer (HPA) from 2004 to 2015 within the District boundaries. The saturated thickness is defined as the thickness of the aquifer in which the pore spaces are saturated with water. For the HPA, this is the difference in elevation between the underlying bedrock and the water table for a given year.

In northwest Kansas, the bedrock surface is typically composed of shale layers underlying the unconsolidated aquifer sediments. Because of its impervious nature to groundwater flow, the bedrock represents the bottom of the aquifer. In 2006, the KGS reviewed the lithologic descriptions from tens of thousands of driller's logs and published updated maps of the Ogallala bedrock surface across western Kansas (Macfarlane and Wilson, 2006).

Each year, the KGS and the KDA-DWR measure the depth-to-water from a network of approximately 1,400 water wells, across the HPA, as part of the state's Cooperative Water Level Program. Customized software developed by the KGS, coupled with Global Positioning System (GPS) data, is used to make sure the same wells are visited each year. The majority of water-level measurements are taken in late December and early January using steel or electric tapes with precisions down to the hundredths of a foot. Measurements are field checked on site at the time of the visit to ensure locational accuracy and that the current measurement is within the historical trend of past measurements. Additional statistical and GIS reviews are conducted later to identify abnormal or anomalous measurements. If deemed necessary, well sites will be re-measured the same day or within a month, depending on the circumstances.

Collected water levels from the Cooperative Water Level Program, along with additional measurements from other local, state, and federal sources, are stored and served online through the KGS' Water Information Storage and Retrieval Database (WIZARD). WIZARD evolved from the U.S. Geological Survey's Ground Water Site Inventory in the mid- 1990s, and today represents the largest repository of depth-to-water measurements in Kansas.

Well site locations in the HPA and their associated water-level measurements were downloaded from WIZARD to estimate the water-table elevations for the 2004, 2009, and 2015 calendar years. The well site locations, based on their listed geographic coordinates, were spatially mapped into the ArcGIS software platform, a GIS mapping software. Within GMD4, all of the measured well locations used in this project have been surveyed with hand-held GPS units, which typically have horizontal accuracy ranges of 12 to 40 feet.

The WIZARD database contains codes indicating the status of the site at the time the water level was measured. Most water level measurements across GMD4 were taken in late December and early January and contain blank or null status codes indicating static or near static water level conditions. Past water level measurements that were coded to be "anomalous" from previous statistical and geostatistical reviews were not included in this project along with measurements taken from locations where the well was obstructed, was pumping at the time of the measurement, had recently been pumped, or had nearby sites that were being pumping at the time of the measurements.

The water-level measurements were used to calculate the 3-year average winter depth to water for each well site, centered on the calendar years 2004, 2009, and 2015. For example, a well's 3-year average, winter depth to water for 2004 are based on measurements taken in the months of December 2002, January 2003, February 2003, December 2003, January 2004, February 2004, December 2004, January 2005, and February 2005. Given most wells are only measured once a year, most well site's averages are based on only three measurements, one for each year in the 3-year period, although some could contain over 10 individual measurements depending on the frequency a well was measured. The 3-year average water table elevations for 2004, 2009, and 2015 were then computed by subtracting the averaged depth-to-water values from the land surface elevation listed at each well location.

Three-year winter averaging of water levels helps to smooth out single-year variations in the water table caused by late or early season pumping and allows for more well sites to be used for temporal reviews of water levels over decadal periods. For this project, only wells containing a computed 3-year, winter average water levels centered on the calendar years of 2004, 2009, and 2015 were considered. If a well site was missing a 3-year average value for one of these target years, it was removed from the data set. In addition, only wells in and within 20 miles of the District's boundaries were selected for further analysis. Under these selection criteria, 382 well sites were used with 277 of them located within the boundaries of GMD4.

To estimate the water table elevations across GMD4, the wells sites and their respective 3-year, winter averaged values for 2004, 2009, and 2015 were interpolated into continuous water table surfaces using ArcGIS' "Topo to Raster" interpolation routine. Topo to Raster is an interpolation method specially designed to create digital elevation models. For this project, the interpolated surfaces are composed of uniform grid cells, 250 x 250 meters in size, each containing estimates of the water table elevation for 2004, 2009, and 2015.

Within ArcGIS, a polygon layer representing public land survey system (PLSS) sections were overlain across the interpolated water table surfaces. The mean interpolated water table elevation, based on the cells occurring within each PLSS section, was computed for 2004, 2009, and 2015. In a similar manner, each PLSS section had the mean bedrock elevation assigned from interpolated surfaces used in published KGS reports (MacFarlane and Wilson, 2006) along with the land surface elevation downloaded from the USGS' National Elevation Dataset.

GMD4 was provided a Microsoft Excel spreadsheet and GIS files of the PLSS sections within the District, each coded with their average land surface, bedrock, and 2004, 2009, and 2015 water table elevations. Because the water table elevations are based on interpolated surfaces from wells measured during each time period, the change in the water table between those years and the saturated thickness can be readily computed at the PLSS- section level.

After a review of the data, it was mutually decided by GMD4 and the KGS to remove the well in township 11S, range 27 west, section 13. This well shows a significant water level decline from 2004 to 2015, not seen in any other wells in the region over that same period and was felt to be biasing the overall section-based estimates in the south-east portions of the district. The well was removed the dataset and the interpolation process and assignment of mean values for the overlying PLSS sections was repeated.

A second review of the data centered on the possible influence of alluvial wells. Alluvial aquifer systems are associated with stream deposits, are relatively shallow, close to the land surface and have highly connected ground- and surface-water interactions. In past HPA water level mapping exercises, both alluvial and Ogallala wells were used to estimate water levels as the two systems are in hydrologic connection to each other. However, if the hydrologic connection between alluvial deposits and the underlying Ogallala aquifer is small or impeded by a low-permeable formation between the two systems, the interpolated water-table surfaces could be slightly elevated or there could be a more dynamic temporal change in the water table introduced by including shallower depth-to-water measurements associated with alluvial aquifers.

To remove this possible influence, well sites coded as being screened solely in alluvial deposits were deleted from the data set. If the geologic units were unknown or unlisted, wells that are located spatially within the extent of alluvial aquifer deposits or had drill depths less than 80 feet were individually reviewed relative to their surrounding neighboring wells. In these cases, the wells were coded as being alluvial if their drill depths and past water levels measurements reflected alluvial-type conditions. A total of 60 wells were classified as alluvial with 11 being located within GMD4. All of these wells are found along the northern and eastern edges of the district. With these alluvial wells removed from consideration, the interpolation process and assignment of mean values for the overlying PLSS sections was repeated.

Figure 1 displays the 3-year averaged saturated thickness of the aquifer by PLSS section for the 2004 and 2015 calendar years with the alluvial wells excluded. The average saturated thickness for GMD4 was 76 feet in 2004 and 70 feet in 2015. The greatest areas of change in the water table occurred in southwest portions of Sherman County where the average rate of decline from 2004 to 2015 was over 20 feet. Much of Sherman County and portions of Thomas and Sheridan County averaged declines of 12 feet. The major driver for these water level declines is groundwater pumping as illustrated by published reports (Butler et al., 2016 and Whittemore et al., 2016), which show statistically significant correlations exist between annual water-level change and annual groundwater use across GMD4.

Thank you for your time today and I would be glad to answer questions or provide additional information.

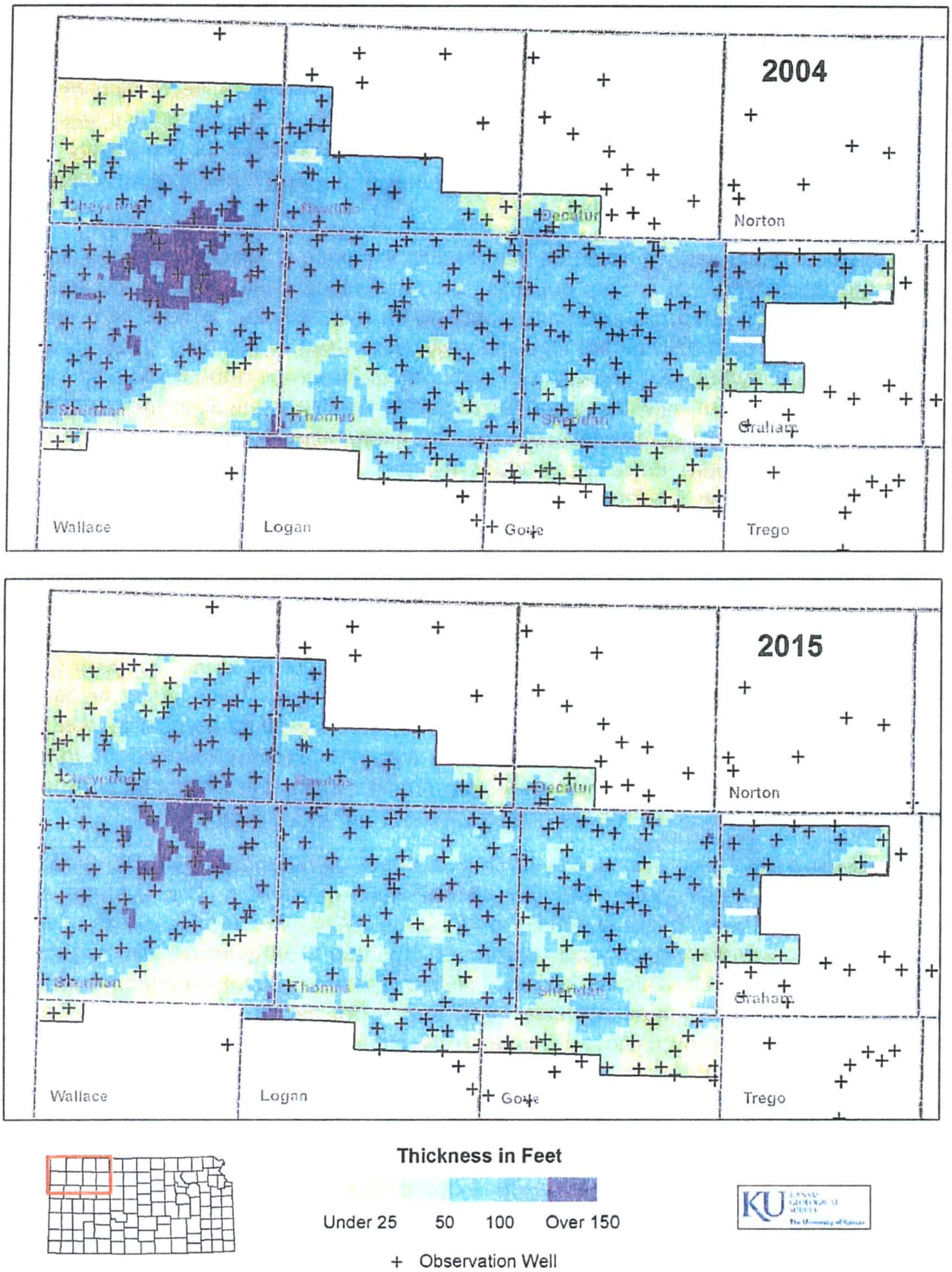


Figure 1. Interpolated 2004 and 2015 three-year averaged saturated thickness of the High Plains Aquifer, by PLSS sections, Northwest Kansas Groundwater Management District no. 4.

References:

Butler, J.J., Jr., D.O. Whittemore, B.B. Wilson, and G.C. Bohling, A new approach for assessing the future of aquifers supporting irrigated agriculture, Geophys. Res. Lett., v. 43, no. 5, pp. 2004-2010, doi:10.1002/2016GL067879, 2016

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Whittemore, D.O, J.J. Butler, Jr., and B.B. Wilson, Assessing the major drivers of water-level declines: New insights into the future of heavily stressed aquifers, Hydrological Sciences Journal, v. 61, no. 1, pp. 134-145, doi:10.1080/02626667.2014.959958, 2016.

KS652.0408 State Supplement–Water Requirements

(a) General information

When crop stress from moisture shortage is eliminated by proper and timely irrigation, other factors become inhibitors to production. These factors include poor soil structure and tilth, low fertility, weeds, insects, and diseases. Much of the water applied through irrigation may be wasted unless the correct combinations of best management practices (BMPs) are followed to combat these factors.

Soil structure and tilth must be favorable in order to have good aeration, good initial water intake, and good soil permeability. Tilth and structure can be maintained or improved by avoiding cultivation of wet fields, addition of manure or plowing under green manure crops, using grass and legumes in rotation, inner-row ripping and/or dammer dikes (furrow dikes), stubble mulching, minimum tillage, and no-till. On irrigated pastures, cattle should be excluded until the surface soil has dried after irrigation.

Low fertility or an imbalance of nutrients is often a major limiting factor on irrigated land. The well-fed plant uses water much more efficiently than a plant that is starved or lacking in some nutrient element. Total water use by a healthy, well-fed plant is greater than for a plant deprived of nutrients, but the production per unit of water is much greater for the well-fed plant. Fertility problems should be corrected by the application of barnyard manure and commercial fertilizer. Soil tests, observations, and field experience help determine the type and amount of fertilizer to use. Crop quality may be more important than crop production in some instances. Quality can usually be improved by proper fertility.

Adequate moisture and fertility and good soil physical condition alone will not ensure optimum production unless the irrigator controls weeds or pests, uses high quality seed of adapted varieties, and uses timely operations. Weeds, insects, and diseases usually are a greater problem on irrigated land than on dryland. Crops and varieties should be selected to fit the soil and the irrigation system. Plant population should be increased in most cases to take advantage of water added by irrigation.

(b) Net irrigation requirements (NIR)

(1) Seasonal NIR values

In developing NIR values for Kansas, there were several agencies and groups that gave input and consultations. Kansas State University (KSU) (through its experiment stations) furnished data to assist in developing crop consumptive use (CU) values. The 1941-1970 rainfall record was used as a basis for rainfall values. (The 1941-1970 records were compared to the 1981-2010 rainfall records, and no significant differences in rainfall amounts were found.) This data, which was furnished by the former Kansas Water Resources Board, included a rainfall record for each county for each month of the 30-year period. Moisture accumulation in the soil profile during the crop dormant or nongrowing season, herein called "carryover," was estimated to be 0 in Zone 1 in the southwest (see Figure KS4-1). It was increased by 0.5 inch for each zone—up to 3.0 inches for Zone 7 on the east border.

With crop CU, carryover, and rainfall values available, the criteria outlined in National Engineering Handbook Part 623, Chapter 2, Appendix A, "Blaney-Criddle Formula (SCS Technical Release No. 21)," was used to develop seasonal NIR for each crop for each county on both the 80% chance and 50% chance rainfall conditions.

Seasonal NIR values based on the 80% chance rainfall were adjusted to seasonal gross irrigation requirements (GIR) assuming 65% irrigation efficiency for all crops except sunflower and cotton. These GIR values were considered representative of maximum seasonal irrigation water demand for the general conditions available at the time of criteria development. Computed GIR values for each county were placed on a state map, and then minor adjustments were made so that lines of equal GIR values progressed smoothly across the state. GIR values (being larger) were used in preference to the NIR values for the smoothing process. Plus and minus adjustments were equalized in each third portion of the state (west, middle, and east) so that adjustments were reasonably balanced.

The Natural Resources Conservation Service (NRCS) did much of the computations and adjustment procedures. However, in addition to the agencies mentioned above, the KSU Biological and Agricultural Engineering Department, Kansas State Research and Extension, U.S. Department of Interior Bureau of Reclamation, and representation from each of the 5 Kansas groundwater management districts made recommendations and contributed to the NIR development process.

NIR is the water need of the specified crop over and above effective rainfall and carryover soil moisture. Table KS4-1 gives the values for seasonal NIR, based on 80% chance rainfall, for each county for each crop named. Likewise, Table KS4-2 gives the values for seasonal NIR based on 50% chance rainfall. The 80% chance rainfall (that which can be expected to be equaled or exceeded in 8 years out of 10) is, of course, a lesser amount of rainfall than the 50% chance rainfall that can be expected to be equaled or exceeded 5 years out of 10. Therefore, irrigation requirements based on the 80% chance rainfall are higher as shown by comparison of values in Table KS4-1 against those in Table KS4-2. Irrigation based on 80% chance rainfall is safer, and there is less risk of drought for the crop than if based on average years. The 80% chance rainfall is normally used to determine crop irrigation requirements.

(2) Monthly NIR values

An analysis was made by grouping certain counties together into irrigation zones as shown in Figure KS4-1, and a monthly composite NIR for each zone was estimated for each of various crops. After due study, however, it was determined that seasonal NIR values by individual counties(instead of zones) would better serve the irrigation need in Kansas so seasonal NIR by zones was not used. The composite zone analysis, however, did give NIR values by months for the various crops. Therefore, monthly NIR values for a crop in any county can be computed by finding the table for the crop, then determining the zone where the county is located, and then multiplying the monthly percentage times the seasonal NIR for the crop and county.

Table KS4-3 gives the monthly NIR distribution by percentage as based on the 80% chance rainfall.

Table KS4-4 gives similar monthly NIR distribution by percentage but based on the 50% chance rainfall.

Computations of monthly NIR for any of the selected crops for any county can be made as shown in the example below.

Example KS4-1 Monthly NIR for 80% chance rainfall

Given: Corn is grown in Ford County which is in Zone 2 (Figure KS4-1).

Ford County seasonal NIR for corn is 15.7 inches (Table KS4-1)

Month	% of Seasonal NIR from Table KS4-3					Monthly NIR	NIR Rounded to Tenths
May	3.9	0.039	x	15.7	=	0.61"	0.6"
June	22.7	0.227	x	15.7	=	3.56"	3.6"
July	40.9	0.409	x	15.7	=	6.42"	6.4"
August	32.5	0.325	x	15.7	=	5.10"	5.1"
Total	100.0						15.7"

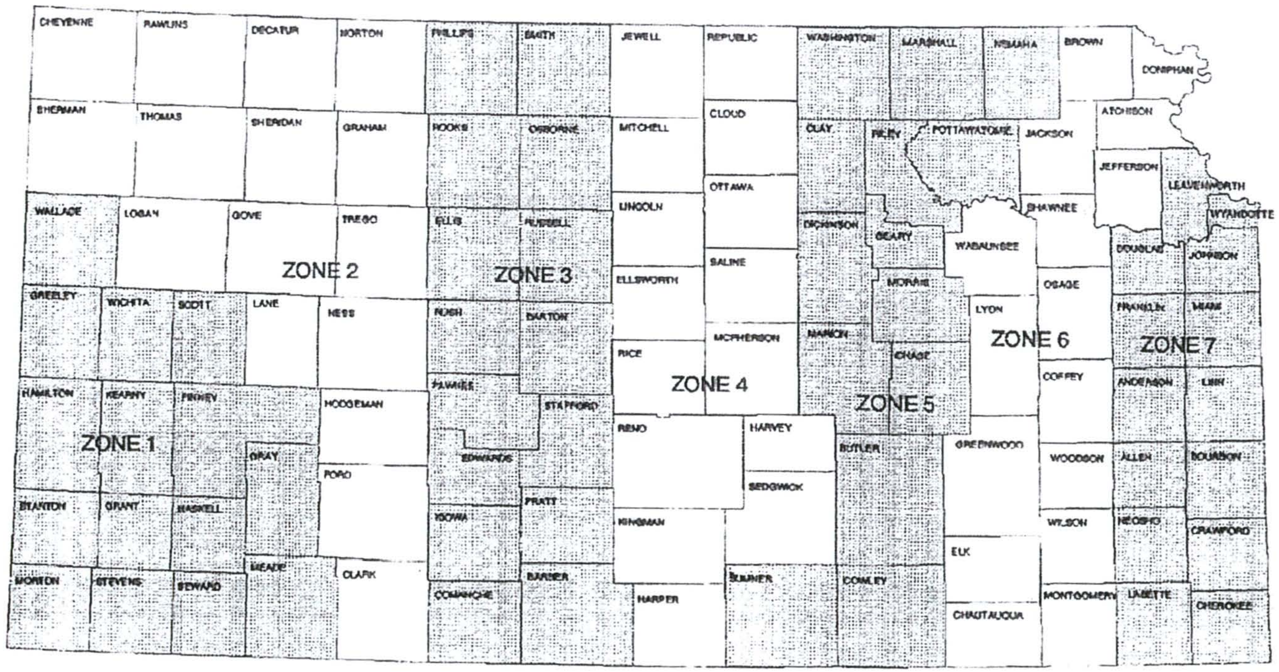
In this example, the sum of the monthly NIR values equals the seasonal value so no adjustment is needed. (In some cases, an adjustment is required.)

Each field office should compute monthly NIR values for the major crops in their county using the worksheets in Figures KS4-2 and KS4-3 to record the data. Assistance from the area engineer should be requested as needed.

Monthly NIR values are important in irrigation water management in making determinations for pumping hours, irrigation timing, frequency of irrigation, and other management elements; however, monthly NIR values can vary. Variation in planting and harvesting dates, length of growing season (for different crop varieties), off-season irrigation, and rainfall distribution for a particular year all impact irrigation requirements during the cropping season, so while monthly NIR values can be developed for typical conditions, they do fluctuate year to year and this should be considered.

Monthly NIR values may be used to determine frequency of irrigation.

Figure KS4-1 Irrigation zones



Zone 1 = 0.0" carryover
Zone 2 = 0.5" carryover
Zone 3 = 1.0" carryover
Zone 4 = 1.5" carryover
Zone 5 = 2.0" carryover
Zone 6 = 2.5" carryover
Zone 7 = 3.0" carryover

Table KS4-1 Seasonal **NIR** (inches)
80% chance rainfall

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Cotton	Sunflowers
Allen	15.5	9.9	6.7	13.5	4.4	6.1	--	--
Anderson	14.7	9.4	6.3	12.8	3.9	5.5	--	--
Atchison	16.6	10.3	7.3	14.8	5.5	6.7	--	--
Barber	23.3	14.6	12.3	21.2	10.3	11.6	13.5	12.3
Barton	22.7	14.4	11.8	20.8	10.1	11.3	--	11.8
Bourbon	15.0	9.6	6.6	12.9	4.0	5.8	--	--
Brown	17.2	10.6	7.7	15.3	6.0	7.2	--	--
Butler	18.7	12.0	9.0	16.8	6.8	8.2	--	--
Chase	17.8	11.4	8.3	15.8	6.4	7.5	--	--
Chautauqua	17.5	11.4	8.5	15.6	5.7	7.8	--	--
Cherokee	15.2	9.9	7.0	13.2	3.6	6.3	--	--
Cheyenne	24.5	15.4	13.3	22.4	11.3	12.7	--	13.3
Clark	24.9	15.7	13.3	22.7	11.6	12.9	14.5	13.3
Clay	19.2	12.2	9.4	17.2	7.6	8.6	--	--
Cloud	20.3	12.7	10.1	18.3	8.5	9.4	--	10.1
Coffey	15.6	9.9	6.8	13.7	4.6	6.0	--	--
Comanche	24.2	15.1	12.8	22.0	11.0	12.4	14.0	12.8
Cowley	18.8	12.3	9.2	17.0	6.8	8.5	--	--
Crawford	15.3	9.8	7.0	13.2	3.8	6.2	--	--
Decatur	23.4	14.8	12.5	21.5	10.7	11.9	--	12.5
Dickinson	19.2	12.3	9.4	17.2	7.5	8.6	--	--
Doniphan	16.9	10.3	7.5	15.0	5.6	6.9	--	--
Douglas	15.7	9.8	6.7	13.8	4.6	6.0	--	--
Edwards	23.9	15.1	12.7	21.8	10.9	12.2	13.9	12.7
Elk	17.4	11.3	8.4	15.5	5.7	7.6	--	--
Ellis	23.1	14.6	12.2	21.2	10.3	11.6	--	12.2
Ellsworth	21.6	13.7	11.2	19.8	9.4	10.5	--	11.2
Finney	25.6	16.3	13.9	23.5	12.3	13.4	15.1	13.9
Ford	24.8	15.7	13.3	22.6	11.6	12.8	14.5	13.3
Franklin	15.0	9.1	6.3	13.0	4.0	5.5	--	--
Geary	18.2	11.5	8.7	16.1	6.8	7.9	--	--
Gove	24.3	15.3	13.1	22.3	11.4	12.5	--	13.1
Graham	23.3	14.7	12.4	21.3	10.6	11.8	--	12.4
Grant	26.5	16.7	14.6	24.2	13.0	14.0	15.7	14.6
Gray	25.4	16.1	13.8	23.3	12.1	13.3	15.0	13.8
Greeley	26.0	16.5	14.3	23.9	12.6	13.8	--	14.3
Greenwood	17.0	11.1	7.9	15.1	5.7	7.2	--	--
Hamilton	26.6	16.9	14.6	24.4	13.1	14.2	15.8	14.6
Harper	22.0	14.0	11.2	20.0	9.2	10.5	12.6	11.2

Table KS4-1 (continued) Seasonal **NIR** (inches)
80% chance rainfall

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Cotton	Sunflowers
Harvey	20.2	12.9	9.9	18.2	8.0	9.2	11.4	9.9
Haskell	26.0	16.4	14.2	23.9	12.6	13.7	15.3	14.2
Hodgeman	24.5	15.5	13.2	22.4	11.4	12.7	--	13.2
Jackson	17.0	10.5	7.6	15.1	5.9	7.0	--	--
Jefferson	16.3	10.1	7.2	14.5	5.3	6.5	--	--
Jewell	20.9	13.1	10.7	19.0	9.0	9.9	--	10.7
Johnson	15.5	9.5	6.4	13.3	4.2	5.7	--	--
Kearny	26.1	16.6	14.4	24.1	12.7	13.8	15.5	14.4
Kingman	22.2	14.0	11.3	20.1	9.4	10.7	12.7	11.3
Kiowa	24.1	15.1	12.8	22.0	11.0	12.3	14.0	12.8
Labette	15.9	10.3	7.5	13.9	4.2	6.8	--	--
Lane	24.8	15.7	13.5	22.7	11.6	12.9	--	13.5
Leavenworth	16.1	9.9	6.9	14.1	4.9	6.2	--	--
Lincoln	21.5	13.6	11.1	19.6	9.2	10.4	--	11.1
Linn	14.2	9.0	5.8	12.1	3.6	5.0	--	--
Logan	25.0	15.8	13.7	22.9	11.8	13.1	--	13.7
Lyon	16.8	10.5	7.4	14.8	5.4	6.7	--	--
Marion	19.2	12.2	9.2	17.1	7.3	8.5	--	--
Marshall	18.3	11.4	8.6	16.3	7.0	7.9	--	--
McPherson	20.7	13.1	10.4	18.8	8.5	9.8	11.8	10.4
Meade	25.5	16.1	13.8	23.4	12.2	13.3	15.0	13.8
Miami	14.6	9.0	6.0	12.3	3.7	5.2	--	--
Mitchell	21.3	13.3	10.9	19.4	9.2	10.2	--	10.9
Montgomery	16.7	10.9	8.0	14.6	4.9	7.3	--	--
Morris	17.9	11.4	8.5	15.9	6.5	7.7	--	--
Morton	27.3	17.1	15.0	24.8	13.7	14.4	16.1	15.0
Nemaha	17.6	10.9	8.1	15.7	6.4	7.5	--	--
Neosho	15.9	10.2	7.3	13.8	4.5	6.6	--	--
Ness	24.2	15.3	13.0	22.1	11.2	12.4	--	13.0
Norton	22.8	14.4	12.1	21.0	10.3	11.5	--	12.1
Osage	15.9	9.9	6.9	14.0	4.9	6.2	--	--
Osborne	22.0	13.8	11.4	20.2	9.7	10.8	--	11.4
Ottawa	20.5	12.9	10.3	18.5	8.5	9.6	--	10.3
Pawnee	23.6	14.9	12.5	21.6	10.7	12.0	13.7	12.5
Phillips	22.2	14.0	11.6	20.5	9.9	11.1	--	11.6
Pottawatomie	17.7	11.1	8.3	15.7	6.5	7.5	--	--
Pratt	23.3	14.6	12.2	21.2	10.3	11.6	13.4	12.2
Rawlins	24.0	15.1	12.9	21.9	11.1	12.4	--	12.9
Reno	21.8	13.8	11.1	19.8	9.2	10.4	12.5	11.1

Table KS4-1 (continued) Seasonal **NIR** (inches)
80% chance rainfall

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Cotton	Sunflowers
Republic	20.0	12.6	9.9	18.1	8.3	9.2	--	9.9
Rice	21.9	13.8	11.2	20.0	9.4	10.6	12.5	11.2
Riley	18.2	11.4	8.7	16.2	6.8	8.0	--	--
Rooks	22.6	14.3	12.0	20.8	10.1	11.3	--	12.0
Rush	23.5	14.8	12.4	21.5	10.7	11.9	--	12.4
Russell	22.2	14.1	11.6	20.5	9.9	11.1	--	11.6
Saline	20.7	13.1	10.5	18.7	8.6	9.6	--	10.5
Scott	25.2	15.9	13.8	23.1	12.0	13.2	--	13.8
Sedgwick	20.3	13.1	10.1	18.4	8.1	9.3	11.6	10.1
Seward	26.1	16.4	14.2	23.9	12.7	13.7	15.3	14.2
Shawnee	16.4	10.2	7.3	14.6	5.4	6.6	--	--
Sheridan	23.9	15.0	12.8	21.8	11.0	12.2	--	12.8
Sherman	25.0	15.7	13.7	22.9	11.8	13.1	--	13.7
Smith	21.6	13.6	11.2	19.9	9.5	10.5	--	11.2
Stafford	22.9	14.5	12.0	21.0	10.2	11.5	13.3	12.0
Stanton	27.2	17.2	15.0	24.9	13.5	14.4	16.1	15.0
Stevens	26.7	16.8	14.6	24.4	13.1	14.0	15.7	14.6
Sumner	20.4	13.2	10.2	18.5	8.1	9.4	--	--
Thomas	24.4	15.4	13.3	22.3	11.4	12.7	--	13.3
Trego	23.7	15.0	12.7	21.7	10.9	12.1	--	12.7
Wabaunsee	17.0	10.7	7.8	15.2	5.9	7.1	--	--
Wallace	25.5	16.1	14.0	23.3	12.2	13.5	--	14.0
Washington	19.1	12.0	9.3	17.2	7.7	8.6	--	--
Wichita	25.6	16.3	14.0	23.5	12.3	13.5	--	14.0
Wilson	16.4	10.7	7.7	14.5	5.1	6.9	--	--
Woodson	16.1	10.4	7.3	14.2	4.9	6.5	--	--
Wyandotte	15.8	9.8	6.7	13.8	4.6	6.0	--	--

Table KS4-2 Seasonal **NIR** (inches)
50% chance rainfall

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Cotton	Sunflowers
Allen	10.8	7.1	4.1	8.8	1.3	3.0	--	--
Anderson	9.2	6.1	3.1	7.3	0.2	1.8	--	--
Atchison	11.9	7.2	4.5	10.0	2.1	3.4	--	--
Barber	20.1	12.6	10.5	18.0	8.1	9.6	11.6	10.5
Barton	19.3	12.0	9.7	17.4	7.8	8.9	--	9.7
Bourbon	10.3	6.8	4.1	8.2	0.4	2.9	--	--
Brown	11.6	7.1	4.1	9.7	1.6	2.9	--	--
Butler	14.2	9.2	6.3	12.0	3.8	5.2	--	--
Chase	13.4	8.7	5.7	11.4	3.6	4.6	--	--
Chautauqua	12.7	8.6	6.0	10.8	1.8	4.8	--	--
Cherokee	10.2	7.0	4.3	8.2	0.0	3.1	--	--
Cheyenne	22.1	13.7	12.0	20.0	9.6	11.2	--	12.0
Clark	22.0	13.7	11.7	19.8	9.7	10.8	12.7	11.7
Clay	15.0	9.2	6.7	12.9	4.5	5.6	--	--
Cloud	16.7	10.3	8.0	14.8	5.9	7.0	--	8.0
Coffey	10.4	6.8	3.7	8.4	0.4	2.4	--	--
Comanche	21.0	13.0	10.9	18.8	8.8	10.1	12.0	10.9
Cowley	14.6	9.7	6.8	12.8	4.0	5.7	--	--
Crawford	10.5	7.0	4.5	8.4	0.0	3.2	--	--
Decatur	20.5	12.7	10.7	18.5	8.7	9.8	--	10.7
Dickinson	14.9	9.4	6.9	12.9	4.5	5.8	--	--
Doniphan	12.3	7.3	4.8	10.3	2.3	3.8	--	--
Douglas	11.1	6.8	4.1	9.2	1.2	3.1	--	--
Edwards	20.9	13.0	11.0	18.8	8.7	10.2	12.0	11.0
Elk	12.9	8.7	5.8	10.9	2.5	4.7	--	--
Ellis	19.8	12.2	10.2	17.9	8.1	9.2	--	10.2
Ellsworth	18.1	11.5	9.0	16.2	6.9	8.1	--	9.0
Finney	23.1	14.5	12.4	21.0	10.6	11.7	13.5	12.4
Ford	21.8	13.7	11.6	19.7	9.5	10.8	12.7	11.6
Franklin	9.7	5.8	3.2	7.8	0.5	2.0	--	--
Geary	13.5	8.4	6.0	11.4	3.3	4.8	--	--
Gove	21.3	13.1	11.2	19.3	9.2	10.4	--	11.2
Graham	20.7	12.4	10.5	18.4	8.3	9.6	--	10.5
Grant	24.0	14.9	13.1	21.8	11.3	12.3	14.0	13.1
Gray	22.3	13.8	11.8	20.0	9.9	11.0	12.8	11.8
Greeley	23.6	14.7	12.9	21.5	11.0	12.1	--	12.9
Greenwood	12.3	8.1	5.1	10.3	2.0	3.9	--	--
Hamilton	24.2	15.2	13.2	22.1	11.6	12.5	14.2	13.2
Harper	18.5	11.7	9.3	16.5	6.5	8.3	10.5	9.3

Table KS4-2 (continued) Seasonal **NIR** (inches)
50% chance rainfall

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Cotton	Sunflowers
Harvey	15.8	10.2	7.2	13.8	5.0	6.1	8.7	7.2
Haskell	23.3	14.5	12.6	21.2	10.8	11.8	13.6	12.6
Hodgeman	21.6	13.4	11.5	19.5	9.4	10.7	--	11.5
Jackson	12.3	7.4	4.7	10.4	2.4	3.7	--	--
Jefferson	11.5	7.0	4.2	9.7	2.0	3.2	--	--
Jewell	17.3	10.6	8.3	15.4	6.5	7.3		8.3
Johnson	11.5	6.6	3.7	9.4	0.7	2.6	--	--
Kearny	23.8	14.9	12.9	21.7	11.2	12.1	13.9	12.9
Kingman	18.5	11.7	9.2	16.4	6.8	8.2	10.5	9.2
Kiowa	21.1	13.2	11.2	19.1	8.8	10.4	12.2	11.2
Labette	10.7	7.3	4.8	8.7	0.4	3.5	--	--
Lane	21.9	13.7	11.7	19.8	9.8	10.9	--	11.7
Leavenworth	11.5	7.0	4.3	9.5	1.6	3.3	--	--
Lincoln	17.9	11.3	8.9	16.0	6.9	7.9	--	8.9
Linn	8.7	5.6	2.6	6.4	0.0	1.4	--	--
Logan	22.4	13.9	12.1	20.3	10.1	11.3	--	12.1
Lyon	11.4	7.5	4.4	9.9	2.0	3.4	--	--
Marion	14.9	9.6	6.4	12.8	4.5	5.5	--	--
Marshall	14.2	8.7	6.1	12.3	4.3	5.0	--	--
McPherson	17.0	10.8	8.3	15.1	5.9	7.3	9.6	8.3
Meade	22.8	14.3	12.2	20.7	10.2	11.4	13.3	12.2
Miami	9.2	5.0	3.0	7.1	0.0	1.8	--	--
Mitchell	17.7	10.8	8.8	15.9	6.7	7.8	--	8.8
Montgomery	12.1	8.1	5.5	10.0	1.2	4.3	--	--
Morris	13.4	8.5	5.9	11.4	3.3	4.7	--	--
Morton	24.9	15.4	13.5	22.5	12.1	12.7	14.5	13.5
Nemaha	12.9	7.8	5.3	11.0	3.2	4.6	--	--
Neosho	10.8	7.1	4.5	8.7	0.5	3.2	--	--
Ness	20.5	13.3	11.3	19.3	9.3	10.4	--	11.3
Norton	19.8	12.3	10.3	18.0	8.3	9.4	--	10.3
Osage	11.2	7.0	4.2	9.4	1.8	3.2	--	--
Osborne	18.8	11.7	9.5	17.0	7.5	8.6	--	9.5
Ottawa	16.7	10.5	8.0	14.7	6.0	6.7	--	8.0
Pawnee	20.5	12.7	10.6	18.5	8.6	9.7	11.7	10.6
Phillips	19.0	11.7	9.7	17.3	7.8	8.8	--	9.7
Pottawatomie	13.4	8.1	5.6	11.5	3.5	4.6	--	--
Pratt	20.2	12.6	10.5	18.1	8.0	9.6	11.6	10.5
Rawlins	21.2	13.2	11.3	19.1	9.1	10.5	--	11.3
Reno	18.1	11.4	8.9	16.1	6.6	7.9	10.2	8.9

Table KS4-2 (continued) Seasonal **NIR** (inches)
50% chance rainfall

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybean	Cotton	Sunflowers
Republic	16.1	10.0	7.4	14.2	5.7	6.4	--	7.4
Rice	18.4	11.5	9.1	16.5	7.0	8.2	10.3	9.1
Riley	13.7	8.5	6.0	11.7	3.8	4.9	--	--
Rooks	19.5	12.0	10.0	17.6	7.9	9.1	--	10.0
Rush	20.3	12.6	10.4	18.3	8.5	9.6	--	10.4
Russell	18.6	11.3	9.4	16.9	7.5	8.5	--	9.4
Saline	17.1	10.8	8.3	15.1	6.1	7.3	--	8.3
Scott	22.5	14.0	12.2	20.5	10.1	11.3	--	12.2
Sedgwick	16.3	10.7	7.7	14.4	5.4	6.6	9.2	7.7
Seward	23.5	14.5	12.8	21.3	10.9	11.9	13.7	12.8
Shawnee	12.2	7.4	4.9	10.4	2.4	4.0	--	--
Sheridan	21.0	12.9	11.0	19.0	9.1	10.2	--	11.0
Sherman	22.8	14.1	12.3	20.7	10.4	11.6	--	12.3
Smith	18.4	11.4	9.2	16.6	7.3	8.2	--	9.2
Stafford	19.7	12.3	10.2	17.7	7.8	9.3	11.3	10.2
Stanton	25.0	15.6	13.7	22.7	12.1	12.9	14.7	13.7
Stevens	23.9	14.8	12.9	21.7	11.4	12.1	13.9	12.9
Sumner	15.9	10.3	7.4	13.8	4.8	6.3	--	--
Thomas	21.9	13.5	11.7	19.7	9.6	10.9	--	11.7
Trego	20.8	12.9	11.0	18.8	8.8	10.1	--	11.0
Wabaunsee	12.3	7.8	5.0	10.5	2.5	3.9	--	--
Wallace	23.0	14.3	12.5	20.8	10.4	11.8	--	12.5
Washington	15.1	9.2	6.8	13.1	5.0	5.7	--	--
Wichita	23.1	14.4	12.5	21.0	10.5	11.8	--	12.5
Wilson	12.0	8.0	5.1	10.1	1.9	3.9	--	--
Woodson	11.3	7.4	4.5	9.4	1.4	3.3	--	--
Wyandotte	11.1	7.0	4.1	9.2	1.3	3.1	--	--

Table KS4-3 Monthly distribution of **NIR** in percent of seasonal total based on **80%** chance rainfall

Zone	April	May	June	July	Aug.	Sept.	Oct.	Total
				Alfalfa				
1	6.5	11.5	18.5	23.5	20.4	13.5	6.1	100
2	6.1	11:3	18.2	24.3	21.0	13.0	6.1	100
3	5.1	12.7	17.8	24.6	21.6	13.1	5.1	100
4	3.7	11.6	19.1	26.5	23.3	12.1	3.7	100
5	1.6	12.2	19.2	28.2	25.0	12.2	1.6	100
6	--	11.7	19.9	30.4	26.3	11.7	--	100
7	--	10.3	21.1	31.4	28.2	9.0	--	100
				Corn				
1	--	6.7	23.6	38.2	31.5	--	--	100
2	--	3.9	22.7	40.9	32.5	--	--	100
3	--	1.4	22.9	43.1	32.6	--	--	100
4	--	--	21.8	45.1	33.1	--	--	100
5	--	--	19.0	49.1	31.9	--	--	100
6	--	--	15.3	53.3	31.4	--	--	100
7	--	--	14.2	54.5	31.3	--	--	100
				Sorghum				
1	--	--	8.4	38.4	36.4	16.8	--	100
2	--	--	4.6	42.0	38.9	14.5	--	100
3	--	--	1.7	44.6	41.3	12.4	--	100
4	--	--	--	45.8	46.7	7.5	--	100
5	--	--	--	46.7	51.1	2.2	--	100
6	--	--	--	46.8	53.2	--	--	100
7	--	--	--	44.1	55.9	--	--	100
				Tame Grass				
1	6.7	11.3	17.9	22.9	20.8	14.2	6.2	100
2	6.1	11.0	17.6	23.7	21.5	14.0	6.1	100
3	5.1	12.5	16.7	24.1	22.2	13.9	5.5	100
4	3.6	11.8	17.9	26.2	24.6	12.3	3.6	100
5	1.2	12.3	17.5	28.1	25.7	12.9	2.3	100
6	--	11.2	18.4	30.9	27.6	11.9	--	100
7	--	8.0	19.7	32.1	30.7	9.5	--	100

Table KS4-3 (continued) Monthly distribution of **NIR** in percent of seasonal total based on **80%** chance rainfall

Zone	April	May	June	July	Aug.	Sept.	Oct.	Total
				Soybeans				
1	--	--	5.6	22.9	45.1	26.4	--	100
2	--	--	1.6	24.6	49.2	24.6	--	100
3	--	--	--	24.4	52.0	23.6	--	100
4	--	--	--	20.6	58.8	20.6	--	100
5	--	--	--	20.6	62.0	17.4	--	100
6	--	--	--	21.0	64.2	14.8	--	100
7	--	--	--	18.1	70.8	11.1	--	100
				Sunflowers				
1	--	--	14.7	41.3	35.7	8.3	--	100
2	--	--	10.3	41.8	39.1	8.8	--	100
3	--	--	7.1	45.1	39.3	8.5	--	100
4	--	--	--	49.7	42.0	8.3	--	100
				Cotton				
1	--	--	5.6	32.0	38.4	19.1	4.9	100
2	--	--	2.0	31.5	41.0	20.5	5.0	100
3	--	--	--	30.7	44.4	20.6	4.3	100
4	--	--	--	26.0	49.6	20.6	3.8	100

Zone	Oct.	Nov.	--	Mar.	Apr.	May	--	Total
				Wheat				
1	12.6	10.2	--	15.3	26.3	35.6	--	100
2	11.7	10.0	--	13.3	28.3	36.7	--	100
3	8.2	10.9	--	13.6	30.0	37.3	--	100
4	5.4	13.1	--	14.1	33.7	33.7	--	100
5	--	13.2	--	11.8	38.2	36.8	--	100
6	--	5.0	--	13.3	41.7	40.0	--	100
7	--	--	--	14.6	43.7	41.7	--	100

Table KS4-4 Monthly distribution of **NIR** in percent of seasonal total based on **50%** chance rainfall

Zone	April	May	June	July	Aug.	Sept.	Oct.	Total
				Alfalfa				
1	6.1	10.9	18.3	23.6	21.0	14.0	6.1	100
2	5.6	10.7	17.7	24.8	22.0	13.1	6.1	100
3	4.4	12.3	17.3	25.6	22.2	13.3	4.9	100
4	2.8	11.3	18.4	27.9	25.1	11.7	2.8	100
5	--	11.3	18.7	30.7	27.3	12.0	--	100
6	--	7.6	19.8	34.4	29.8	8.4	--	100
7	--	4.3	21.6	36.2	33.6	4:3	--	100
				Corn				
1	--	4.3	23.4	39.7	32.6	--	--	100
2	--	1.5	21.5	43.1	33.9	--	--	100
3	--	--	19.8	46.3	33.9	--	--	100
4	--	--	15.6	49.5	34.9	--	--	100
5	--	--	9.9	54.9	35.2	--	--	100
6	--	--	5.0	61.2	33.8	--	--	100
7	--	--	4.0	62.7	33.3	--	--	100
				Sorghum				
1	--	--	4.9	39.8	37.4	17.9	--	100
2	--	--	1.0	43.6	40.9	14.5	--	100
3	--	--	--	44.0	45.0	11.0	--	100
4	--	--	--	44.7	51.8	3.5	--	100
5	--	--	--	45.7	54.3	--	--	100
6	--	--	--	48.3	51.7	--	--	100
7	--	--	--	47.0	53.0	--	--	100
				Tame Grass				
1	6.2	10.5	17.2	23.5	21.5	14.9	6.2	100
2	5.6	10.2	16.8	24.5	22.5	14.3	6.1	100
3	4.3	12.0	16.3	25.0	23.4	14.1	4.9	100
4	2.5	10.6	17.5	28.1	26.9	11.9	2.5	100
5	--	10.5	17.3	30.8	28.6	12.8	--	100
6	--	5.3	17.7	35.4	32.7	8.9	--	100
7	--	1.0	20.4	38.8	36.7	3.1	--	100

Table KS4-4 (continued) Monthly distribution of **NIR** in percent of seasonal total based on **50%** chance rainfall

Zone	April	May	June	July	Aug.	Sept.	Oct.	Total
				Soybeans				
1	--	--	1.6	22.1	48.4	27.9	--	100
2	--	--	--	21.6	52.3	26.1	--	100
3	--	--	--	21.7	54.7	23.6	--	100
4	--	--	--	17.8	63.3	18.9	--	100
5	--	--	--	17.6	67.6	14.8	--	100
6	--	--	--	18.7	71.9	9.4	--	100
7	--	--	--	14.6	81.8	3.6	--	100
				Sunflowers				
1	--	--	13.2	42.3	36.5	8.0	--	100
2	--	--	7.9	42.4	41.0	8.7	--	100
3	--	--	4.4	46.9	40.7	8.0	--	100
4	--	--	--	48.9	43.6	7.5	--	100
				Cotton				
1	--	--	2.2	33.2	40.3	19.5	4.8	100
2	--	--	--	30.3	43.3	21.5	4.9	100
3	--	--	--	26.9	48.2	21.2	3.7	100
4	--	--	--	20.6	55.3	21.2	2.9	100

Zone	Oct.	Nov.	--	Mar.	Apr.	May	--	Total
				Wheat				
1	9.3	10.2	--	16.1	28.0	36.4	--	100
2	7.0	11.0	--	13.0	31.0	38.0	--	100
3	6.6	12.1	--	14.3	33.0	34.0	--	100
4	4.0	13.1	--	13.1	35.6	34.2	--	100
5	--	10.3	--	12.1	41.4	36.2	--	100
6	--	--	--	9.8	51.2	39.0	--	100
7	--	--	--	--	60.0	40.0	--	100

Example KS4-2 Frequency of irrigation

Given: Corn is being grown in Ford County. The net irrigation application during the month of July is 3 inches.

From Example KS4-1, NIR for corn in July in Ford County is 6.4 inches (based on 80% chance rainfall).

Average July NIR is 6.4 inches.

Average daily NIR is 6.4 inch / 31 days = 0.206 inch per day

Net irrigation application (inches) / Average crop daily use (inches/day) = Average irrigation frequency (days)

OR

3 inches application / .206 inch per day = 14.5 days (use 14)

This irrigation frequency represents the average for July but **does not represent the irrigation frequency required to meet the peak CU rate of the crop.**

(c) Peak CU

The daily CU of the crops was calculated when the NIR numbers were determined. Comparison of the peak CU numbers by county found that there were only minor variations in peak CU across the state for a given crop so only one table on peak CU rate (inches per day) was developed for the state (see Table KS4-5).

Example KS4-3 Peak CU irrigation frequency

Given: Corn is being grown in Ford County. The net irrigation application is typically 3 inches.

Corn with 3 inches net application has a peak CU of 0.31 inch per day (Table KS4-5).

Irrigation frequency = 3.0 inch / 0.31 inch per day = 9.7 days (use 10) (Table KS4-6)

The peak CU period for corn might be a 7- to 10-day period in late July or early August; however, stage of crop growth and temperature variations can vary the timing and span of the peak use period by several days.

For the peak CU period of corn, the irrigation frequency in the example is 10 days (no rainfall considered). But based on general conditions for the July period (with 80% chance rainfall), the irrigation frequency is 14 days (Example KS4-2). This information then should give the irrigator a good basis for judging irrigation frequency to fit the current conditions.

Table KS4-5 Peak CU rate (inches/day)

	Net Irrigation Application (inches)				
Crop	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**
Alfalfa, corn	0.34	0.32	0.31	0.30	0.29
Grass, cotton	0.32	0.30	0.29	0.28	0.27
Sorghum, sunflowers, potatoes	0.31	0.29	0.28	0.27	0.26
Dry beans, soybeans	0.29	0.28	0.27	0.26	0.25
Small grain	0.23	0.22	0.21	0.20	0.20
Melons	0.28	0.27	0.26	0.25	0.25
Orchard with cover	0.26	0.25	0.25	0.23	0.23

Table KS4-6 Irrigation frequency during period of maximum CU (days)

	Net Irrigation Application (inches)				
Crop	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**
Alfalfa, corn	3	6	10	13	17
Grass, cotton	3	7	10	14	18
Sorghum, sunflowers, potatoes	3	7	11	15	19
Dry beans, soybeans	3	7	11	15	20
Small grain	4	9	14	20	25
Melons	4	7	12	16	20
Orchard with cover	4	8	12	17	22

(d) Water Requirement

Land developed for irrigation should have the ability to accommodate more than one irrigation method adaptable to the area to enhance efficiency and flexibility of the system. Total water requirements will be contingent upon the crops grown, the acres involved, and the system efficiency. The crop rotations should be consistent with good agronomic management, and the irrigation system must be designed within limitations imposed by CU requirements of the planned cropping system.

Example KS4-4 Monthly NIR values

Given: A farm near Garden City has 320 acres of cropland. The soil is a Ulysses silt loam. The water supply is from a well delivering 600 gallons per minute (gpm). Two center pivot sprinkler systems provide water to the crops, and they have an estimated application efficiency of 85%. Crops being grown are 125.7 acres of corn and 125.7 acres of wheat. Full irrigation is planned for both crops. One inch of net irrigation will be applied with each pass of the sprinkler.

Determine the monthly NIR for the fields of corn and wheat. Base the NIR on 80 percent chance rainfall for Finney County.

Finney County is in Zone 1 (Figure KS4-1). Seasonal NIR for corn is 16.3 inches and 12.3 inches for wheat (Table KS4-1). Using the procedure shown in Example KS4-1 and Table KS4-3, monthly NIR values for corn and wheat were calculated as follows:

Crop	March	April	May	June	July	Aug	Sept	Oct	Nov	Total
Corn	0.00	0.00	1.09	3.85	6.23	5.13	0.00	0.00	0.00	16.30
Wheat	1.88	3.23	4.38	0.00	0.00	0.00	0.00	1.55	1.25	12.30

NIR requirements for the farm can also be estimated using the Irrigation Water Management–449 (Planned Crop and Water Requirement) Spreadsheet. This spreadsheet can be used to analyze irrigation water requirements by crop by month and for the total season. It is also used to compute pumping hours to make certain the pumping rate will meet the water needs of the planned crops.

The following analysis for the same farm relates to periods of peak CU and without rainfall, which is the most demanding water requirement condition.

For a 1-inch net irrigation application, corn has a peak CU of 0.34 inch per day (Table KS4-5).

Irrigation frequency for peak CU =
1.0 inch / 0.34 inch/day = 3 days

Average gross application (water pumped) =
1.0 inch / 0.85 (efficiency) = 1.18 inches

Total gross water required = 125.7 acres x 1.18 inches = 148 acre-inches

Well discharge = 600 gpm = 1.33 cubic feet second (cfs) = 1.33 acre-inches/hour

Gross pumping time = 148 acre-inches /
1.33 acre-inches/hour = 111 hours

111 hours / 3 days = 37 hours pumping per day during peak CU

During the period of peak CU, the flow available from the well will not meet the peak CU needs of the corn. This deficit can be addressed by having available water stored in the soil. The corn can then use some of the soil water to make up the difference between peak CU and the amount of irrigation water applied. This shows the importance of rainfall and filling the root zone with water.

The wheat would also be affected during peak CU as its peak CU is 0.23 inch per day which is a 4-day irrigation frequency for a 1-inch net irrigation. The well would have to be pumped 28 hours per day to supply the required water during peak CU. Although this situation is not as extreme as the corn, available soil water would be needed to make up the difference.

(e) Critical growth period and moisture stress

To produce maximum crop yields, plants must have ample moisture throughout the growing season. Some irrigators, however, may elect to use selective irrigations at critical crop growth periods rather than full irrigation. In some cases, they have more land available for irrigation than they have water so it is more economically feasible to use deficit irrigation. The additional acres, while yielding less than if fully irrigated, still return more in overall yields than a smaller area under full irrigation.

Regardless of what system of irrigation is being used, plants indicate moisture stress by various symptoms. Usually yields will be reduced (depending on the severity and duration of the moisture stress) by the time the plant shows these symptoms. Time of irrigation should be determined by examination of the soil for moisture content. Also, under deficit irrigation, the irrigator must be aware of what crop growth stage the plant is in. The feel and appearance of the soil at various moisture contents are given in Section 652.0902(b)(1)(i). Symptoms of serious moisture stress, critical water requirement periods, and other irrigation considerations are listed in Table KS4-7.

Table KS4-7 Moisture stress symptoms and critical growth period for irrigated crops

Crop	Serious Moisture Stress	Critical Growth Period	Other Considerations
Alfalfa	Bluish green color, then wilting	Seedling and immediately after cuttings	Keep upper 5 feet of soil moist. Avoid over-irrigation. Fall irrigation is desirable.
Corn	Leaf curl by 10:00 a.m.	Tasseling, silk stage until grain becomes firm	Sensitive to over-irrigation. Adequate moisture is needed from germination to dent stage.
Sorghum	Leaf curl by 10:00 a.m.	Boot, bloom, and milk-dough stages	Adequate moisture is needed from germination through dough stage. Yields reduced when moisture is short during heading and seed development.
Grass pasture	Dull green color, then wilting	Seedling stage, for seed production boot to head formation	Late fall irrigation is necessary. Use frequent, light applications. Irrigate at end of grazing period in a rotation system.
Sunflowers	Leaves wilting during mid-day	Prior to flowering through seed development	Apply deep irrigations. Avoid over-irrigation during the vegetative stage. Roots will grow deep so late irrigation is not needed.
Small grain	Dull green color, then firing of lower leaves	Boot, bloom, and early head stage	For fall grain, irrigate top 4 feet before planting. Apply last irrigation at milk stage. When using spring small grain as a nurse crop, irrigate for needs of grass seedlings.
Dry beans and soybeans	Dull color, then wilting	Early bloom, seed-forming	Very sensitive to over-irrigation. Last irrigation should be when the first pod reaches maturity.
Cotton	Leaves wilting during mid-day	Flowering and boil development	Avoid water stress early in the season. The last irrigation should be timed to allow the last boils to develop.

Figure KS4-2 NIR worksheet (80% chance)

_________________ County

NIR (Inches)

For Rainfall 8 Years out of 10 (80% Chance–Dry Years)

	Crop							
Month	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Sunflowers	Cotton
March								
April								
May								
June								
July								
August								
Sept.								
Oct.								
Nov.								
Total[1/]								

[1/] From Table KS4-1

Figure KS4-3 NIR worksheet (50% chance)

_________________ County

NIR (Inches)

For Rainfall 5 Years out of 10 (50% Chance–Normal Years)

	Crop							
Month	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Sunflowers	Cotton
March								
April								
May								
June								
July								
August								
Sept.								
Oct.								
Nov.								
Total[1/]								

[1/] From Table KS4-2

(f) Center pivot systems

(1) Irrigation requirement
As shown earlier, center pivot systems frequently do not provide sufficient water to satisfy peak daily CU of the crop without relying on major withdrawal of soil water from the root zone. Another concern is allowing application rates to exceed soil intake rates (particularly on the lower intake rate soil) thus allowing the irrigation water to run off and not infiltrate into the soil. This is addressed in Chapter 6.

To adjust to this situation, center pivot irrigation designs are calculated to provide only sufficient irrigation water to satisfy average daily CU (rather than peak) for the 62-day period of July and August (April and May for wheat). In addition, the less conservative designs assume a 50% chance monthly rainfall (rather than, for example, 80% chance) and also assume that there is water stored in the soil that is available to the plant. For the dryer-than-average years, the use of this less conservative design criteria will likely result in crop moisture stress and reduced yields unless stored soil water is adequate to make up all of the deficiency.

Tables KS4-9 and KS4-10 (85% system efficiency) and Tables KS4-11 and KS4-12 (90% system efficiency) have been developed for 13 scattered Kansas locations to determine GIR values suitable for sprinklers. Tables KS4-13 and KS4-14 provide GIR values for dry beans, sunflowers, and cotton. Irrigation requirements are given in inches per day and in gallons per minute per acre under continuous application. GIR values for the July to August period were developed as follows:

$$\frac{\text{Seasonal NIR x } [\{(\text{July} + \text{August}) / 100\} / 62]}{(\text{Percent system efficiency} / 100)}$$

Where:

Seasonal NIR is from Tables KS4-1 and KS4-2.

July + August percentages are from Tables KS4-3 and KS4-4.

Percent system efficiency is from Table KS6-1.

Similar calculations were done for wheat using the months of April and May.

Both 80% chance rainfall and 50% chance rainfall considerations are included in the tables. Rainfall at 80% chance should be used for conservative sprinkler irrigation design, but use of the 50% chance design is acceptable. It should be recognized that the 50% chance design might result in substantially reduced yields in the dryer years, and this needs to be clearly conveyed to the irrigator.

The data in Tables KS4-9, KS4-10, KS4-11, and KS4-12 for soybeans is adjusted to the period July 15 to September 15 to better fit the irrigation demand period for that crop.

Rainfall normally occurs in one or two events during each of the months of July and August. The monthly allowance for rainfall should not exceed 50% of the available water-holding capacity in the top 3 feet of the soil profile. Therefore, Tables KS4-9, KS4-10, KS4-11, and KS4-12 are generally applicable to soils in Irrigation Groups 1 through 9. Adjustment is needed for Irrigation Groups 10, 11, and 12 due to low water-holding capacity. Table KS4-8 gives the values for this adjustment.

Table KS4-8 Amount of increase in "gpm per acre"

This is above the value in Tables KS4-9, KS4-10, KS4-11, and KS4-12 that is required to offset low available water-holding capacity.

Irrigation Group	Dry Years 80% Chance	Normal Years 50% Chance
1 through 9	No change	No change
10	No change	+0.2 gpm
11	+0.1 gpm	+0.3 gpm
12	+0.2 gpm	+0.5 gpm

Table KS4-9 Minimum GIR for sprinkler for July to August (62-day) period at 85% efficiency based on 80% chance rainfall

Location	Crop					
	Alfalfa	Corn	Sorghum	Tame Grass	Soybeans [1/]	Wheat [2/]
Tribune	0.22 4.1	0.22 4.1	0.20 3.8	0.20 3.7	0.20 3.8	0.15 2.8
Colby	0.21 3.9	0.21 4.0	0.20 3.8	0.19 3.6	0.20 3.7	0.14 2.7
Ulysses	0.22 4.1	0.22 4.1	0.21 3.9	0.20 3.8	0.20 3.8	0.16 2.9
Ness City	0.21 3.9	0.21 4.0	0.20 3.7	0.19 3.6	0.19 3.6	0.14 2.6
Stockton	0.20 3.7	0.21 3.8	0.20 3.7	0.18 3.4	0.18 3.4	0.13 2.5
Greensburg	0.21 4.0	0.22 4.1	0.21 3.9	0.19 3.6	0.20 3.7	0.14 2.7
Ellsworth	0.20 3.8	0.20 3.8	0.20 3.7	0.19 3.5	0.19 3.5	0.11 2.0
Concordia	0.19 3.6	0.19 3.5	0.18 3.3	0.18 3.3	0.17 3.1	0.11 2.1
Wichita	0.20 3.7	0.20 3.7	0.18 3.4	0.18 3.4	0.17 3.1	0.11 2.0
Council Grove	0.18 3.4	0.18 3.3	0.16 3.0	0.17 3.1	0.15 2.7	0.09 1.8
Holton	0.18 3.4	0.17 3.2	0.14 2.7	0.17 3.2	0.13 2.5	0.09 1.7
Chanute	0.18 3.4	0.17 3.1	0.14 2.6	0.16 3.0	0.13 2.3	0.07 1.4
Paola	0.17 3.1	0.15 2.8	0.11 2.1	0.15 2.8	0.10 1.9	0.06 1.4

[1/] Soybeans are for July 15 to September 15
[2/] Wheat is for April and May

Notes:
Top figure = inches per day. Bottom figure = gpm per acre (continuous application).
For Irrigation Groups 10, 11, and 12, refer to Table KS4-8 for adjustment factors.
Use 80% chance tables for most center pivot sprinkler designs.
Using 50% chance tables may result in substantially reduced yields during dryer years.

Table KS4-10 Minimum GIR for sprinkler for July to August (62-day) period at 85% efficiency based on 50% chance rainfall

Location	Crop					
	Alfalfa	**Corn**	**Sorghum**	**Tame Grass**	**Soybeans [1/]**	**Wheat [2/]**
Tribune	0.20 3.8	0.20 3.8	0.19 3.6	0.18 3.5	0.18 3.5	0.14 2.6
Colby	0.19 3.6	0.20 3.7	0.19 3.5	0.18 3.3	0.18 3.3	0.13 2.4
Ulysses	0.20 3.8	0.20 3.8	0.19 3.6	0.19 3.5	0.19 3.5	0.14 2.6
Ness City	0.18 3.4	0.19 3.6	0.18 3.4	0.17 3.2	0.17 3.2	0.12 2.3
Stockton	0.18 3.3	0.18 3.4	0.17 3.2	0.16 3.0	0.15 2.9	0.10 1.9
Greensburg	0.19 3.6	0.20 3.8	0.19 3.5	0.18 3.3	0.18 3.3	0.11 2.1
Ellsworth	0.18 3.4	0.18 3.5	0.17 3.1	0.17 3.2	0.15 2.9	0.09 1.7
Concordia	0.17 3.2	0.17 3.1	0.15 3.3	0.16 2.9	0.13 2.5	0.08 1.5
Wichita	0.17 3.2	0.18 3.3	0.14 3.2	0.15 2.9	0.12 2.3	0.07 1.4
Council Grove	0.15 3.3	0.15 2.7	0.11 2.1	0.13 2.4	0.09 1.7	0.05 0.9
Holton	0.15 2.8	0.13 2.4	0.09 1.6	0.12 2.3	0.06 1.1	0.01 0.2
Chanute	0.14 2.7	0.13 2.4	0.09 1.6	0.12 2.3	0.06 1.1	0.01 0.2
Paola	0.12 2.3	0.09 1.7	0.06 1.1	0.10 1.9	0.03 0.6	0.00 0.0

[1/] Soybeans are for July 15 to September 15
[2/] Wheat is for April and May

Notes:
Top figure = inches per day. Bottom figure = gpm per acre (continuous application).
For Irrigation Groups 10, 11, and 12, refer to Table KS4-8 for adjustment factors.
Use 80% chance tables for most center pivot sprinkler designs.
Using 50% chance tables may result in substantially reduced yields during dryer years.

Table KS4-11 Minimum GIR for sprinkler for July to August (62-day) period at 90% efficiency based on 80% chance rainfall

Location	Crop					
	Alfalfa	Corn	Sorghum	Tame Grass	Soybeans 1/	Wheat 2/
Tribune	0.20 3.8	0.20 3.8	0.19 3.6	0.18 3.5	0.18 3.5	0.14 2.6
Colby	0.19 3.6	0.20 3.7	0.19 3.5	0.18 3.3	0.18 3.3	0.13 2.4
Ulysses	0.20 3.8	0.20 3.8	0.19 3.6	0.19 3.5	0.19 3.5	0.14 2.6
Ness City	0.18 3.4	0.19 3.6	0.18 3.4	0.17 3.2	0.17 3.2	0.12 2.3
Stockton	0.18 3.3	0.18 3.4	0.17 3.2	0.16 3.0	0.15 2.9	0.10 1.9
Greensburg	0.19 3.6	0.20 3.8	0.19 3.5	0.18 3.3	0.18 3.3	0.11 2.1
Ellsworth	0.18 3.2	0.18 3.1	0.17 3.3	0.17 2.9	0.15 2.5	0.09 1.7
Concordia	0.17 3.2	0.17 3.1	0.15 3.3	0.16 2.9	0.13 2.5	0.08 1.5
Wichita	0.17 3.2	0.18 3.3	0.14 3.2	0.15 2.9	0.12 2.3	0.07 1.4
Council Grove	0.15 3.3	0.15 2.7	0.11 2.1	0.13 2.4	0.09 1.7	0.05 0.9
Holton	0.14 2.7	0.13 2.4	0.09 1.6	0.12 2.3	0.06 1.1	0.01 0.2
Chanute	0.14 2.7	0.13 2.4	0.09 1.6	0.12 2.3	0.06 1.1	0.01 0.2
Paola	0.12 2.3	0.09 1.7	0.06 1.1	0.10 1.9	0.03 0.6	0.00 0.0

1/ Soybeans are for July 15 to September 15
2/ Wheat is for April and May

Notes:
Top figure = inches per day. Bottom figure = gpm per acre (continuous application).
For Irrigation Groups 10, 11, and 12, refer to Table KS4-8 for adjustment factors.
Use 80% chance tables for most center pivot sprinkler designs.
Using 50% chance tables may result in substantially reduced yields during dryer years.

Table KS4-12 Minimum GIR for sprinkler for July to August (62-day) period at 90% efficiency based on 50% chance rainfall

Location	Crop					
	Alfalfa	Corn	Sorghum	Tame Grass	Soybeans [1/]	Wheat [2/]
Tribune	0.19 3.6	0.19 3.6	0.18 3.4	0.17 3.3	0.17 3.3	0.13 2.5
Colby	0.18 3.4	0.19 3.5	0.18 3.3	0.17 3.1	0.17 3.1	0.12 2.3
Ulysses	0.19 3.6	0.19 3.6	0.18 3.4	0.18 3.3	0.18 3.3	0.13 2.5
Ness City	0.17 3.2	0.18 3.4	0.17 3.2	0.16 3.0	0.16 3.0	0.11 2.2
Stockton	0.17 3.1	0.17 3.2	0.16 3.0	0.15 2.8	0.14 2.7	0.09 1.8
Greensburg	0.18 3.4	0.19 3.6	0.18 3.3	0.17 3.1	0.17 3.1	0.10 2.0
Ellsworth	0.17 3.0	0.17 2.9	0.16 3.1	0.16 2.7	0.14 2.4	0.09 1.6
Concordia	0.16 3.0	0.16 2.9	0.14 3.1	0.15 2.7	0.12 2.4	0.08 1.4
Wichita	0.16 3.0	0.17 3.1	0.13 3.0	0.14 2.7	0.11 2.2	0.07 1.3
Council Grove	0.14 3.1	0.14 2.6	0.10 2.0	0.12 2.3	0.09 1.6	0.05 0.9
Holton	0.13 2.6	0.12 2.3	0.09 1.5	0.11 2.2	0.06 1.0	0.01 0.2
Chanute	0.13 2.6	0.12 2.3	0.09 1.5	0.11 2.2	0.06 1.0	0.01 0.2
Paola	0.11 2.2	0.09 1.6	0.06 1.0	0.09 1.8	0.03 0.6	0.00 0.0

[1/] Soybeans are for July 15 to September 15
[2/] Wheat is for April and May

Notes:
Top figure = inches per day. Bottom figure = gpm per acre (continuous application).
For Irrigation Groups 10, 11, and 12, refer to Table KS4-8 for adjustment factors.
Use 80% chance tables for most center pivot sprinkler designs.
Using 50% chance tables may result in substantially reduced yields during dryer years.

Table KS4-13 Minimum GIR for sprinkler based on 85% efficiency

Location	80% Chance Rainfall			50% Chance Rainfall		
	Dry Beans [1/]	Sunflowers [2/]	Cotton [2/]	Dry Beans [1/]	Sunflowers [2/]	Cotton [2/]
Tribune	0.22 4.1	0.21 3.9	-- --	0.20 3.8	0.19 3.6	-- --
Ulysses	0.22 4.1	0.21 4.0	0.21 3.9	0.2 3.8	0.20 3.7	0.20 3.7
Colby	0.2 3.8	0.20 3.8	-- --	0.18 3.5	0.19 3.5	-- --
Pratt	-- --	0.20 3.7	0.19 3.6	-- --	0.17 3.3	0.17 3.1
McPherson	-- --	0.18 3.4	0.17 3.2	-- --	0.15 2.7	0.14 2.6

Table KS4-14 Minimum GIR for sprinkler based on 90% efficiency

Location	80% Chance Rainfall			50% Chance Rainfall		
	Dry Beans [1/]	Sunflowers [2/]	Cotton [2/]	Dry Beans [1/]	Sunflowers [2/]	Cotton [2/]
Tribune	0.20 4.0	0.2 3.7	-- --	0.18 3.8	0.18 3.4	-- --
Ulysses	0.20 4.5	0.2 3.8	0.2 3.7	1.18 4.1	0.18 3.5	0.18 3.4
Colby	0.18 3.6	0.19 3.6	-- --	0.16 3.4	0.17 3.3	-- --
Pratt	-- --	0.18 3.5	0.18 3.4	-- --	0.16 3.1	0.16 2.9
McPherson	-- --	0.17 3.2	0.16 3	-- --	0.14 2.6	0.13 2.4

[1/] Dry beans are for June and July
[2/] Sunflowers and cotton are for July and August

Notes:
Top figure = inches per day. Bottom figure = gpm per acre (continuous application).
For irrigation groups 10, 11, and 12, refer to Table KS4-8 for adjustment factors.
Use 80% chance tables for most center pivot sprinkler designs.
Using 50% chance tables may result in substantially reduced yields during dryer years.

Report on the Formal Review of the SD-6 LEMA Order
December 15, 2016

This review of the SD-6 LEMA order is required in part 47 of the SD-6 LEMA order, dated April 17, 2013. Following are the specific requirements as listed in that order.

Economic impacts.

The interim study being conducted by Bill Golden indicates that there have been shifts in crop mixes and water use amounts. Dr. Golden's interim analysis indicates little, if any, reduction in farm net income from within SD-6 as compared to the surrounding area.

Changes in water levels.

WATER TABLE DATA

	2009	2010	2011	2012	2013	2014	2015	2016
07S29W05	-1.30	-0.46	-0.90	-0.70	-1.70	-0.70	-0.98	-0.52
07S29W27	-1.58	-1.56	-1.51	-1.70	-1.95	-0.50	-0.75	+1.02
07S29W30	-1.76	-0.90	2.66	-4.90	-2.85	0.55	-1.45	+0.56
08S29W01	-3.06	-0.80	-1.55	-0.95	-1.95	-0.89	-1.15	-0.35
08S30W05	-1.42	-1.37	-2.56	-0.60	-3.05	0.55	-1.30	+0.01
08S30W11	-2.40	-1.08	-1.87	-1.20	-1.65	-0.99	+0.58	+0.66
08S30W13	-1.29	-1.20	-1.01	-2.00	-0.88	-1.33	-3.11	-0.80

Additional data from the GMD 4 observation wells attached.

Whether flexibility has substantially increased water use in any part of the LEMA

The SD-6 LEMA currently has 15 combination accounts covering 48 wells. As of the end of the 2016 irrigation season no adverse impacts have been noted. It is the expectation of the committee that there will be no adverse impacts in 2017. The flexibility afforded is one of the major positive issues of SD-6.

Whether the SD-6 LEMA should be re-constituted.

The committee recommends that the GMD #4 Board of Directors take the appropriate action to begin the process of re-formation for the SD-6 LEMA. The time period should be 2018 – 2022. They further recommend that well owners be allowed to carry-over an amount not to exceed 5 inches per program acre, if available, from the current LEMA into the new LEMA. No other changes or modifications are recommended.

Geographical Boundaries

The committee recommends that the boundaries remain unchanged for the new LEMA.

Public Interest

The current SD-6 LEMA has had no appreciable negative impact on the public interest. Conversely, it can be stated that the conservation of water, along with the extension of the aquifer life, has positively impacted the public interest of the area. Committee members have not seen a negative impact to Hoxie or surrounding area.

SD 6 Advisory Public Meeting Notes
December 12, 2016 1:30 pm, Hoxie Elks Lodge

Questions

What kind of time schedule?

What about going to 12" instead of 11"?

If there is a severe drought would the state allow an extra inch?

Can we borrow from a future LEMA?

Would wells outside of SD 6 be in the district wide LEMA?

Do you think the District-Wide LEMA would add more teeth in five years?

How much carry-over are we talking?

Can you do umbrellas when you want it or preseason only?

What is the penalty for going over?

Can I have the ability to develop more acres?

Comments

We should go on with what we are doing.

I think we should go with the District-Wide LEMA instead.

We've got the worst problem and need to do more.

We're barely doing enough.

Concern for alluvial wells irrigating pasture.

Advisory committee should be elected, not appointed.

Most of the people that don't like it aren't here.

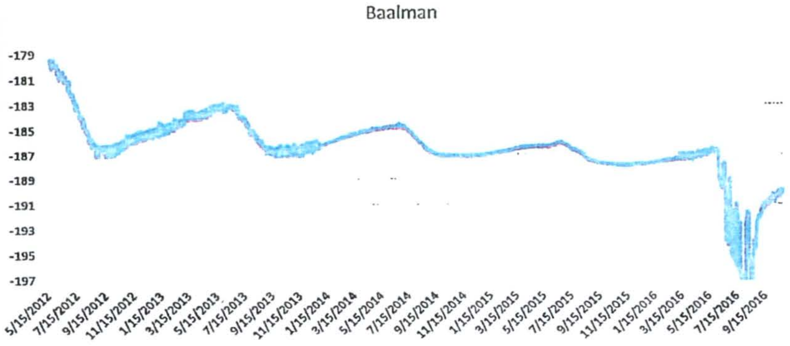
We need to plan if there is going to be a carry-over.

Make a list of water that is for sale.

Limited irrigation insurance concern

Needs to incorporate a drought contingency clause

The place of use is stuck when the LEMA was formed.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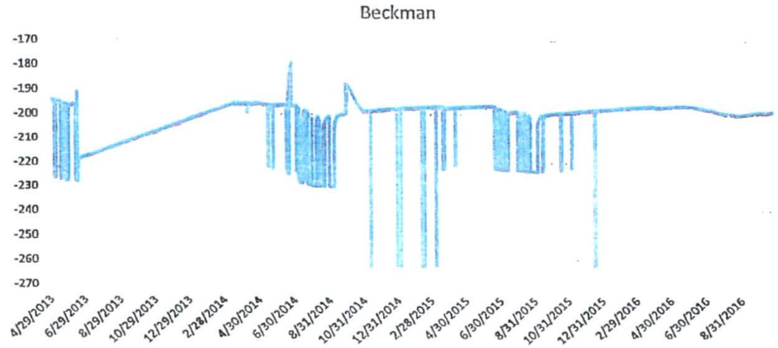
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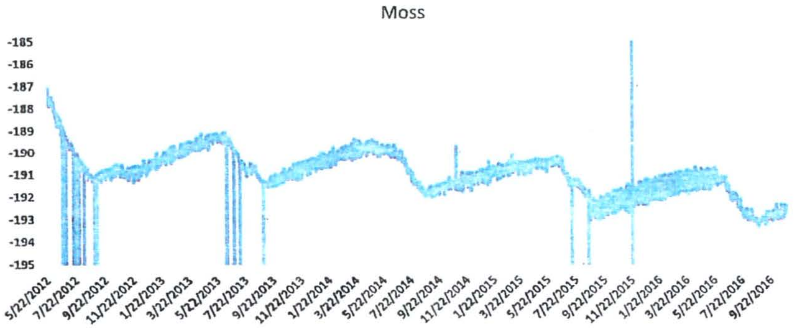
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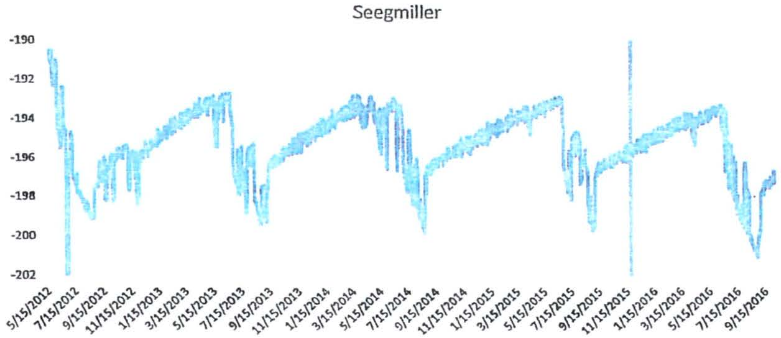
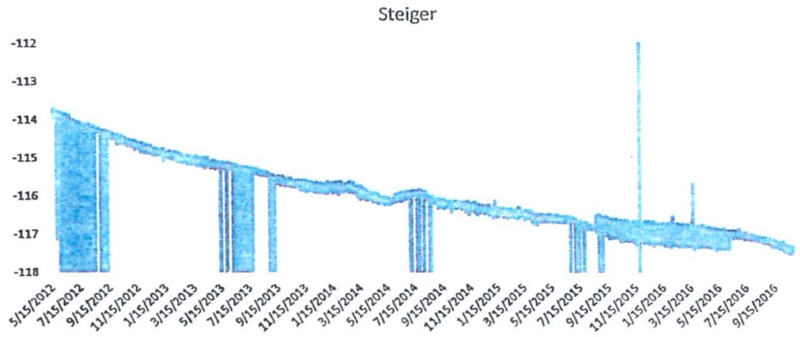

Seegmiller


Steiger

Phone Call Comments from Absent Advisory Committee Members

We should continue with a carryover and possibly go to 12".

We should continue with a carryover.

We should continue.

We should continue with a carryover.

Advisory Committee Post Meeting

11" carry-over may be too much

Should have a 5" carry-over so 12" could be applied if needed.

With a 5" carry-over, 60" would be the maximum you could ever begin a LEMA with.

The final report should be completed with a recommendation to the GMD 4 board that they take action to re-form the SD-6 LEMA for 5 years (2018-2022). A maximum of a 5 inch carry-over from the current LEMA into the new one should be worked into the new LEMA request.

Monitoring the Impacts of Sheridan County 6 Local Enhanced Management Area

Interim Report for 2013 – 2015

11/8/2016

Dr. Bill Golden

Golden is an assistant professor in the Department of Agricultural Economics at Kansas State University. This research was funded in part by the Kansas Water Office under Contract # 15-0112, and in part by the U.S.D.A. Ogallala Aquifer Program

TABLE OF CONTENTS

Monitoring the Impacts of Sheridan County 6 Local Enhanced Management Area

I. Introduction

Study Objectives

Current levels of groundwater consumption in northwest Kansas raise concerns relative to the long-term feasibility of irrigated agriculture in the area. In order to extend the economic life of the aquifer and maintain the economic base of the region, groundwater water use reductions may need to be considered. Past economic studies differ in the calculated economic impact associated with groundwater use reductions. One high priority subarea in northwest Kansas has recently mandated a reduction in groundwater use. Monitoring the Sheridan #6 Local Enhanced Management Area (LEMA) in real time will allow us to observe producer innovation aimed at maintaining revenues and disseminate these data to producers and stakeholders in other areas. The knowledge of how irrigated crop producers react to conservation policies will provide guidance on what is expected to happen in the future as groundwater supplies are diminished and/or conservation policies are implemented.

The purpose of this report is to provide the methods, assumptions, and estimates of the likely economic impacts associated with a groundwater use reduction in the Sheridan #6 LEMA. The reader should note that this is an 'Interim Report' which provides information on the first three years (2013 – 2015) of a five-year study. This research will compare water usage, cropping practices, and economic outcomes for the Sheridan #6 LEMA and surrounding irrigated acreage not located within the LEMA boundaries. This will be accomplished by:

1. Developing annual 'partial budgets' from data obtained from irrigated crop producers (current and historic) (Table 1). The partial budgets will generate measures of 'Cash Flow'.
   a. Each year, aggregated cash flow will be compared for land parcels within the LEMA boundaries and outside LEMA boundaries.
   b. After 5 years, historic cash flow and partial budgets will be compared and across boundaries (comparing LEMA and non-LEMA producers).
2. Developing measures of land-use changes for land parcels within the LEMA boundaries and outside LEMA boundaries from data obtained from irrigated producers and/or the Kansas Water Right Information System (WRIS).
   a. Each year, aggregated land-use will be compared for land parcels within the LEMA boundaries and outside LEMA boundaries.
   b. After 5 years, historic land-use will be compared both across time (comparing LEMA producers before and after) and across boundaries (comparing LEMA and non-LEMA producers).
3. Developing measures of water-use changes for land parcels within the LEMA boundaries and outside LEMA boundaries from data obtained from irrigated producers and/or WRIS.
   a. Each year, aggregated water-use will be compared for land parcels within the LEMA boundaries and outside LEMA boundaries.
   b. After 5 years, historic water-use will be compared both across time (comparing LEMA producers before and after) and across boundaries (comparing LEMA and non-LEMA producers).

Background on Sheridan County 6 LEMA

The Ogallala Aquifer is significantly over-appropriated. The aquifer has declined in some areas more than 60% since predevelopment. Past efforts to slow the decline and insure the future economic viability of the region have been largely unsuccessful. The 2012 Legislature passed SB 310 making LEMAs a part of Kansas water law. This law gives groundwater management districts (GMDs) the authority to initiate a voluntary public hearing process to consider a specific conservation plan to meet local goals. LEMAs are proactive, locally designed, and initiated water management strategies for a specific geographic area that are promoted through a GMD and then reviewed and approved by the Chief Engineer. Once approved by the Chief Engineer the LEMA plan becomes law, effectively modifying prior appropriation regulations. The stated purpose of the LEMA legislation was to reduce groundwater consumption in order to conserve the state's water supply and extend the life of the Ogallala Aquifer.

On December 31, 2012, the chief engineer issued his Order of Decision accepting the LEMA proposed by GMD#4 producers for the Sheridan #6 high priority area. This voluntary LEMA imposed a fixed-quantity-per-right groundwater use restriction on local irrigators, which on average is approximately 20% less than historic use. Producers within the boundaries of the LEMA were assigned a 5-year allocation of 55 inches per acre. The LEMA blueprint may well be the future of groundwater management in Kansas. The LEMA process overcomes the problems associated with the 'top-down' Intensive Groundwater Use Control Area (IGUCA) process. To an extent, the new process also minimizes the common property externality associated with groundwater extraction.

Golden, Peterson, and O'Brien (2008) provided the initial economic analysis associated with the LEMA water use restriction. This static analysis yielded net economic losses associated with reduced groundwater use. Applying dynamic case study techniques, Golden and Leatherman (2010) suggested that, in the Wet Walnut Creek IGUCA, producers were able to mitigate the initial economic losses through innovation. This was accomplished by maintaining/expanding the production of higher valued crops and by adopting efficient irrigation technologies and practices. With these alternate research results in mind it is important that we monitor the economic outcomes associated with the water use restriction and disseminate the information to stakeholders. At present there are additional LEMAs planned for GMD 1, GMD 2, and GMD 4, however there is some hesitancy as local producers want to 'wait and see what happens in Sheridan #6 LEMA'.

When water-use is restricted irrigated producers develop and implement strategies to mitigate potential revenue losses. Buller (1988) and Wu, Bernardo, and Mapp (1996) suggest that producers will change crop mix by shifting from high water-use crops, such as corn, into crops with lower consumptive use, possibly even converting to nonirrigated production. Burness and Brill (2001) and Williams et al. (1996) suggest that in such cases producers will adopt more efficient irrigation technology. Harris and Mapp (1986) and Klocke et al. (2004) suggest that computer-aided technologies and improved irrigation scheduling might provide a solution. Schlegel, Stone, and Dumler (2005) report significant water savings with the adoption of limited irrigation management strategy. This research will provide insights into the management strategies adopted by irrigated producers in the Sheridan #6 LEMA.

II. Agronomic Model Overview

The agronomic portion of this research relies heavily on the quasi-experimental control group analysis method. This method defines an agronomic parameter of interest, a target area, a control area, and a treatment. Preferably, the only difference between the target area and the control area is that the target area received the treatment and the control area did not receive the treatment. For our case, the treatment is the implementation of the LEMA, as depicted in Figure 1, the target area is the Sheridan #6 high priority area, the control area is comprised of irrigated cropland within a three mile boundary around the Sheridan #6 high priority area, and the agronomic parameters of interest are crop mix and groundwater use. If the agronomic parameters in the target and control areas are comparable before the treatment occurs, then any statistically significance difference in the agronomic parameters of interest after the treatment occurs represents the effect of the treatment. As an example, if the target area and control area had comparable irrigated acreage before the LEMA was implemented, and the target area had statistically fewer acres than the control area after the LEMA was implemented then it is assumed that the LEMA caused a reduction in the number of irrigated acres in the target area.

A strong association between the target and control counties will simplify the statistical modeling by comparing parameters in a similar framework. By minimizing the effects of other factors such as commodity prices, rainfall, and soil types, the effects of the LEMA should be easier to identify. The benefits of this approach are its intuitive appeal, transparency, and the fact that it is less dependent on assumptions regarding functional forms of structural models and reduced-form relationships. Since the target and control areas are similar, the use of a linear model to control for potentially convoluting factors should give a good approximation (ERS, 2004). The quasi-experimental control group analysis has been used extensively in impact analysis (ERS, 2004; Bohm and Lind, 1993; Reed and Rogers, 2003; Eklund, Jawa, and Rajala, 1999; Huff et al., 1985; Golden and Leatherman, 2010).

Broder, Taylor, and McNamara (1992) define a time-series linear regression discontinuity model that is suitable for this analysis. The model is estimated using binary variables (dummy variables) to test impacts associated with a treatment for significant intercept shifts or discontinuities. Golden and Leatherman, (2010) applied a similar model to their analysis of the Wet Walnut IGUCA, and a more detailed description of the model can be found there.

In the following sections models for each agronomic variable of interest will be developed and the results reported and discussed. In most cases, data from the target and control areas will be graphed to provide a visual depiction of the data being discussed. Making direct comparisons of agronomic variable across the target and control area is problematic. While the data are statistically similar the magnitude will not be identical. Indexed values will be used to make relative comparisons. When applied to a time series, indexed values are obtained by dividing each annual value by the starting value. When multiplied by 100, an indexed value represents the percent of staring values that occurs in each year.

The regression model used to analyze the indexed values can be defined as

$$\Delta AV = \quad AV_T - AV_C = \beta_0 + \beta_1 * D$$

where ΔAV is the difference in the indexed value of the agronomic variable of interest, T indexes the target area, C indexes the control area, and D is a binary variable that takes the value of zero for the years 2003 through 2012, and a value of one for the years 2013 and 2014. β_0 is the estimated intercept and β_1 is the estimated intercept shift which defines the impact of the LEMA.

III. Agronomic Results

The following results are based on data obtained from the Kansas Water Right Information System (WRIS) for the years 2003 through 2015. The WRIS dataset provides time series data on each point of diversion (PDIV), typically a single water well, in the target area and control area. Producer generated annual water use reports provide the basis for the WRIS dataset. For each PDIV the dataset includes total annual acre-foot groundwater usage, total acres irrigated, and crop type. The crop type is listed as a code number, as example the crop code for a field that is 100% corn is '2' and the crop code for a field that that has both corn and grain sorghum (a mixed crop field) is '23'. When crop specific acres are discussed below a 'Mixed Crop Allocation Table' was used to allocate acres to individual crops, as an example, if the crop code was '23' it was assumed that the reported irrigated acres was comprised of 50% corn and 50% grain sorghum. As a result, when crop specific acreage is discussed below, all fields that were comprised of a either a single crop or mixed crop were included in the calculation.[1] Unfortunately, for a mixed crop field, producer's only report total acre-foot groundwater usage, and no reasonable method has been developed to allocate the total acre-foot groundwater usage to individual crops. As a result, when crop specific groundwater usage is discussed below, only fields that were comprised of a single crop were included in the calculation.[2]

[1] This method is consistent with methods used by the Kansas Department of Agriculture.

[2] The average groundwater use for alfalfa, grain sorghum, and wheat are not reported as there were insufficient numbers of single crop fields to generate valid results.

Total Irrigated Acres

Figure 2, illustrates the indexed values for total irrigated acreage within the target and control areas and Table 2 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 1.7% fewer irrigated acres than the control area and after the LEMA the target area averaged an additional statistically significant 8.5% fewer irrigated acres than the control area. This implies that the LEMA generated an average 8.5% reduction in irrigated acreage relative to the control area.

Total Groundwater Use

Figure 3, illustrates the indexed values for total groundwater use within the target and control areas and Table 3 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 1.3% greater groundwater use than the control area and after the LEMA the target area averaged an additional statistically significant 25.3% less groundwater use than the control area. This implies that the LEMA generated an average 25.3% reduction in total groundwater use relative to the control area.

Average Groundwater Use per Acre

Figure 4, illustrates the indexed values for the average groundwater use per acre within the target and control areas and Table 4 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 2.6% greater average groundwater use per acre than the control area and after the LEMA the target area averaged an additional statistically significant 19.0% less average groundwater use per acre than the control area. This implies that the LEMA generated an average 19.0% reduction in average groundwater use per acre relative to the control area.

Total Irrigated Corn Acres

Figure 5, illustrates the indexed values for the total irrigated corn acres within the target and control areas and Table 5 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 9.2% less total irrigated corn acres than the control area and after the LEMA the target area averaged an additional statistically significant 22.8% less total irrigated corn acres than the control area. This implies that the LEMA generated an average 22.8% reduction in total irrigated corn acres relative to the control area. The percentage change amounts to an average of approximately 2,990 acres of decreased corn acreage within the target area.

Total Irrigated Alfalfa Acres

Figure 6, illustrates the indexed values for the total irrigated alfalfa acres within the target and control areas and Table 6 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 28.3% less total irrigated alfalfa acres than the control area and after the LEMA the target area averaged an additional statistically insignificant 4.9% less total irrigated alfalfa acres than the control area. This implies that the LEMA had no statistically significant impact on total irrigated alfalfa acres relative to the control area.

Total Irrigated Grain Sorghum Acres

Figure 7, illustrates the indexed values for the total irrigated grain sorghum acres within the target and control areas and Table 7 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 33.8% more total irrigated grain sorghum acres than the control area and after the LEMA the target area averaged an additional statistically significant 406.2% more total irrigated grain sorghum acres than the control area. This implies that the LEMA generated an average 406.2% increase in total irrigated grain sorghum acres relative to the control area. The percentage change amounts to an average of approximately 900 acres of increased grain sorghum acreage within the target area.

Total Irrigated Soybean Acres
Figure 8, illustrates the indexed values for the total irrigated soybean acres within the target and control areas and Table 8 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 1.0% more total irrigated soybean acres than the control area and after the LEMA the target area averaged an additional statistically insignificant 13.5% less total irrigated soybean acres than the control area. This implies that the LEMA had no statistically significant impact on total irrigated soybean acres relative to the control area.

Total Irrigated Wheat Acres
Figure 9, illustrates the indexed values for the total irrigated wheat acres within the target and control areas and Table 9 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 20.1% more total irrigated wheat acres than the control area and after the LEMA the target area averaged a statistically significant 95.0% more total irrigated wheat acres than the control area. This implies that the LEMA generated an average 95.0% increase in total irrigated wheat acres relative to the control area. The percentage change amounts to an average of approximately 700 acres of increased wheat acreage within the target area.

Total Irrigated Mixed Crop Acres
Figure 10, illustrates the indexed values for the total irrigated mixed crop acres within the target and control areas and Table 10 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 17.1% less total irrigated mixed crop acres than the control area and after the LEMA the target area averaged a statistically significant 18.3% less total irrigated mixed crop acres than the control area. This implies that the LEMA generated an average 18.3% decrease in total irrigated mixed crop acres relative to the control area. The percentage change amounts to an average of approximately 1,300 acres of decreased mixed crop acreage within the target area.

Average Groundwater Use per Irrigated Corn Acre
Figure 11, illustrates the indexed values for the average groundwater use per irrigated corn acre within the target and control areas and Table 11 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 0.9% less average groundwater use per acres than the control area and after the LEMA the target area averaged a statistically significant 20.2% less average groundwater use per acres than the control area. This implies that the LEMA generated a statistically significant 20.2% reduction in the average groundwater use per irrigated corn acre relative to the control area.

Average Groundwater Use per Irrigated Soybean Acre
Figure 12, illustrates the indexed values for the average groundwater use per irrigated corn acre within the target and control areas and Table 12 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 9.9% more average groundwater use per acres than the control area and after the LEMA the target area averaged a statistically significant 19.4% less average groundwater use per acres than the control area. This implies that the LEMA generated a statistically significant 19.4% reduction in the average groundwater use per irrigated soybean acre relative to the control area.

IV. Economic Results

As we move into the 21st century, goals for our water resources are gradually changing. Concerns over aquifer decline rates call into question the current allocation of water resources. With increasing frequency, producers and policy makers are asked to decide how to reduce groundwater consumption. Policy makers, producers, and other stakeholders are concerned about the likely negative economic impacts that the agricultural producers might incur as crop water use is reduced. Unfortunately, there is little economic literature and less empirical data that is capable of providing guidance on the likely impacts.

This section of the report reviews economic data collected from irrigated crop producers. These producers generally have irrigated cropland within the boundaries of the LEMA as well as irrigated cropland outside the boundaries of the LEMA. Producer involvement is strictly voluntary; they report data directly to GMD #4 who passes the data to the author for analysis. Due to the limited number of participants reporting economic data, the results cannot be considered statistically valid, never the less they are informative. Additional, rainfall and soil type were not reported by the producers and these variables are important determinants of crop yield. In the following tables 'Cash Flow' is the economic metric reported. Cash Flow is defined as gross revenue (crop price x crop yield) less variable costs of production (fertilizer, seed, herbicide, hired labor etc.). While each producer reported their own crop price, for this analysis, the average crop price reported by all producers was used in the cash flow calculation. Land rent and fixed equipment costs were not included in the analysis.

Table 13 summarizes the producer reported data for the 2013 crop year. Irrigated corn producers within the LEMA boundary reported using 19.8% less groundwater and yielding 6.5% less corn as compared to irrigated corn producers outside the LEMA boundary. These data are relatively consistent with irrigated crop production functions developed by Kansas State University Research and Extension which exhibit diminish marginal returns. Somewhat surprisingly, irrigated corn producers within the LEMA boundary reported 1.5% more cash flow than their higher yielding counterparts outside the LEMA. Irrigated soybean producers within the LEMA boundary reported using 9.3% less groundwater and yielding 6.2% less soybeans as compared to irrigated soybean producers outside the LEMA boundary. These data are relatively consistent with irrigated crop production functions developed by Kansas State University Research and Extension. Somewhat surprisingly, irrigated soybean producers within the LEMA boundary reported 1.5% more cash flow than their higher yielding counterparts outside the LEMA. There was no irrigated grain sorghum reported from outside the LEMA boundary. The producers that grew irrigated grain sorghum inside the LEMA boundary applied an average of 4.1 inches per acre (63.3% less than irrigated corn producers inside the LEMA boundary) and generated the largest reported cash flow of any irrigated crop.

Table 14 summarizes the producer reported data for the 2014 crop year. Irrigated corn producers within the LEMA boundary reported using 49.0% less groundwater and yielding 15.6% less corn as compared to irrigated corn producers outside the LEMA boundary. Irrigated corn producers within the LEMA boundary reported 11.5% less cash flow than their higher yielding counterparts outside the LEMA. It should be noted that there was only one observation of irrigated corn produced outside the LEMA boundary. Irrigated soybean producers within the LEMA boundary reported using 34.3% more groundwater and yielding 13.3% less soybeans as compared to irrigated soybean producers outside the LEMA boundary. Irrigated soybean producers within the LEMA boundary reported 32.6% less cash flow than their counterparts outside the LEMA. In this case producers within the LEMA boundary used more groundwater but this evidence suggests that higher levels of groundwater use do not necessarily imply higher returns. It should be noted that there was only one observation of irrigated soybeans produced outside the LEMA boundary. There was no irrigated grain sorghum reported from outside the LEMA boundary. The producers that grew irrigated grain sorghum inside the LEMA boundary applied an average of 6.0 inches per acre (40.0% less than irrigated corn producers inside the LEMA boundary) and generated comparable cash.

As of this interim report, there is insufficient data necessary to publish economic information for the 2015 crop year.

V. Rainfall Data

As previously mentioned, rainfall is a major determinant of groundwater use and crop yield. Figure 13 illustrates the historic annual rainfall for Sheridan County for the years 2000 through 2015. The average for this period was 19.81 inches per year. The 2013 through 2015 annual rainfall amounts were 17.55, 14.83, and 24.23 inches, respectively. Both 1023 and 2014 were dryer than normal years, while 2015 was a wetter than normal year.

VI. Conclusions

The purpose of this report was to provide the methods, assumptions, and estimates of the agronomic and economic impacts associated with groundwater use reductions in the Sheridan #6 LEMA. The reader should note that this is an 'Interim Report' and only provides information on the first three years of a five-year study and should be considered a preliminary analysis. As additional data is collected in the future the results will be more robust.

Relative to their neighbors outside the LEMA boundary, irrigated crop producers within the boundary of the LEMA: reduced total groundwater use by a statistically significant 25.3%, reduced average groundwater use per acre by a statistically significant 19.0%, reduced irrigated crop acreage by a statistically significant 8.5%, reduced irrigated corn acreage by a statistically significant 22.8%, increased irrigated grain sorghum acreage by a statistically significant 406.2%, and increased irrigated wheat acreage by a statistically significant 95.0%.

The economic result, to date, are consistent with Golden and Leatherman (2010) and suggests that, given the certainty of groundwater use reductions, producers are able to implement strategies to maintain returns and apply less groundwater. Additional research on the risk associated with reduced groundwater use is needed. The producer supplied data suggests that producers within the LEMA boundary have been able to reduce groundwater use with minimal impacts on cash flow. While we can observe the changes in crop mix and water use we cannot discern, at this point, exact strategies producers are using to reduce variable expenses and/or adjust cultural practices. Moving forward, we need to increase the number of producers reporting their economic data.

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VIII. Tables

Table 1. Example of Partial Budgets

Name of Operator ______________________ **Due October 1, 2014**

Phone # ______________________ Return to: Manager, GMD4

Email: ______________________ (Electronic copy preferred)

Crop Year 2013

Parcels *(land handled as a single parcel; can be 1/2 circle, can be multiple circles); add parcel columns as needed*

Operator Designated Farm Identifier (name or number)	1	2	3	4	5	6
Is This Farm in the LEMA (yes or no)						
Total Groundwater Pumped per crop*						
Well Capacity (GPM/Acre)						
Total Irrigated Acres						
Crops						
INCOME PER ACRE						
A. Yield per acre						
B. Price per bushel**						
C. Miscellaneous Income *(if due to LEMA)*						
D. Returns/acre ((A x B) + C) *(auto filled)*						
E. COSTS PER ACRE						
1. Seed						
2. Herbicide						
3. Insecticide / Fungicide						
4. Fertilizer and Lime						
5. Crop Consulting						
6. Drying						
7. Miscellaneous						
8. Custom Hire						
9. Labor						
a. Planting						
b. Tilling						
c. Spraying						
d. Disking						
e. Harvesting						
f. Harvest Hauling						
g.						
10. Irrigation						
a. Labor (own time or hired)						
b. Fuel and Oil						
c. Repairs and Maintenance						
11. Land Charge / Rent***						
F. TOTAL COSTS						
G. RETURNS OVER COSTS (D - F) *(auto filled)*						

* If growing wheat, total spring & fall water; if following wheat with another crop, separate out water per crop type

** If not yet sold, give best estimate of price

***Any leases re-negotiated due to LEMA? If a % arrangement, give totals; write in crop shares

Table 2. Regression Results for the Difference in Total Irrigated Acreage

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.017*
D	Impact of LEMA	-0.085*
R^2	Degree of Fit	0.557

* Statistically significant at the 10% level

Table 3. Regression Results for the Difference in Total Groundwater Use

Variable	Description	Parameter Estimate
Intercept	Intercept	0.013
D	Impact of LEMA	-0.253*
R^2	Degree of Fit	0.892

* Statistically significant at the 10% level

Table 4. Regression Results for the Difference in Average Groundwater Use per Acre

Variable	Description	Parameter Estimate
Intercept	Intercept	0.026*
D	Impact of LEMA	-0.190*
R^2	Degree of Fit	0.865

* Statistically significant at the 10% level

Table 5. Regression Results for the Difference in Total Irrigated Corn Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.092*
D	Impact of LEMA	-0.228*
R^2	Degree of Fit	0.715

* Statistically significant at the 10% level

Table 6. Regression Results for the Difference in Total Irrigated Alfalfa Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.283*
D	Impact of LEMA	-0.049
R^2	Degree of Fit	0.004

* Statistically significant at the 10% level

Table 7. Regression Results for the Difference in Total Irrigated Grain Sorghum Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	0.338
D	Impact of LEMA	4.062*
R^2	Degree of Fit	0.839

* Statistically significant at the 10% level

Table 8. Regression Results for the Difference in Total Irrigated Soybean Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	0.010
D	Impact of LEMA	-0.135
R^2	Degree of Fit	0.096

* Statistically significant at the 10% level

Table 9. Regression Results for the Difference in Total Irrigated Wheat Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	0.112
D	Impact of LEMA	0.950*
R^2	Degree of Fit	0.600

* Statistically significant at the 10% level

Table 10. Regression Results for the Difference in Total Irrigated Mixed Crop Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.171*
D	Impact of LEMA	-0.183*
R^2	Degree of Fit	0.237

* Statistically significant at the 10% level

Table 11. Regression Results for the Difference in Total Average Groundwater Use per Irrigated Corn Acre

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.009
D	Impact of LEMA	-0.202*
R^2	Degree of Fit	0.841

* Statistically significant at the 10% level

Table 12. Regression Results for the Difference in Total Average Groundwater Use per Irrigated Soybean Acre

Variable	Description	Parameter Estimate
Intercept	Intercept	0.099*
D	Impact of LEMA	-0.194*
R^2	Degree of Fit	0.412

* Statistically significant at the 10% level

Table 13. 2013 Producer Reported Economic Data

Item	Observations	Water Use (in/ac)	Yield (bu/ac)	Cash Flow ($/ac)	Cash Flow ($/in)
Corn Weighted Average - Inside LEMA	6	11.1	198.0	$403	$36
Corn Weighted Average - Outside LEMA	4	13.8	211.6	$397	$29
Sorghum Weighted Average - Inside LEMA	2	4.1	152	$434	$107
Sorghum Weighted Average - Outside LEMA	0	NA	NA	NA	NA
Soybeans Weighted Average - Inside LEMA	2	10.3	63.8	$418	$41
Soybeans Weighted Average - Outside LEMA	2	11.3	68	$412	$36

Table 14. 2014 Producer Reported Economic Data

Item	Observations	Water Use (in/ac)	Yield (bu/ac)	Cash Flow ($/ac)	Cash Flow ($/in)
Corn Weighted Average - Inside LEMA	5	10.0	229.5	$449	$45
Corn Weighted Average - Outside LEMA	1	19.7	272.0	$507	$26
Sorghum Weighted Average - Inside LEMA	1	6.0	152	$438	$73
Sorghum Weighted Average - Outside LEMA	0	NA	NA	NA	NA
Soybeans Weighted Average - Inside LEMA	2	9.0	60.7	$262	$29
Soybeans Weighted Average - Outside LEMA	1	6.7	70	$388	$58
Sunflowers Weighted Average - Outside LEMA	1	6.0	88.1	$788	$131

IX. Figures

Figure 1. Target and Control Area

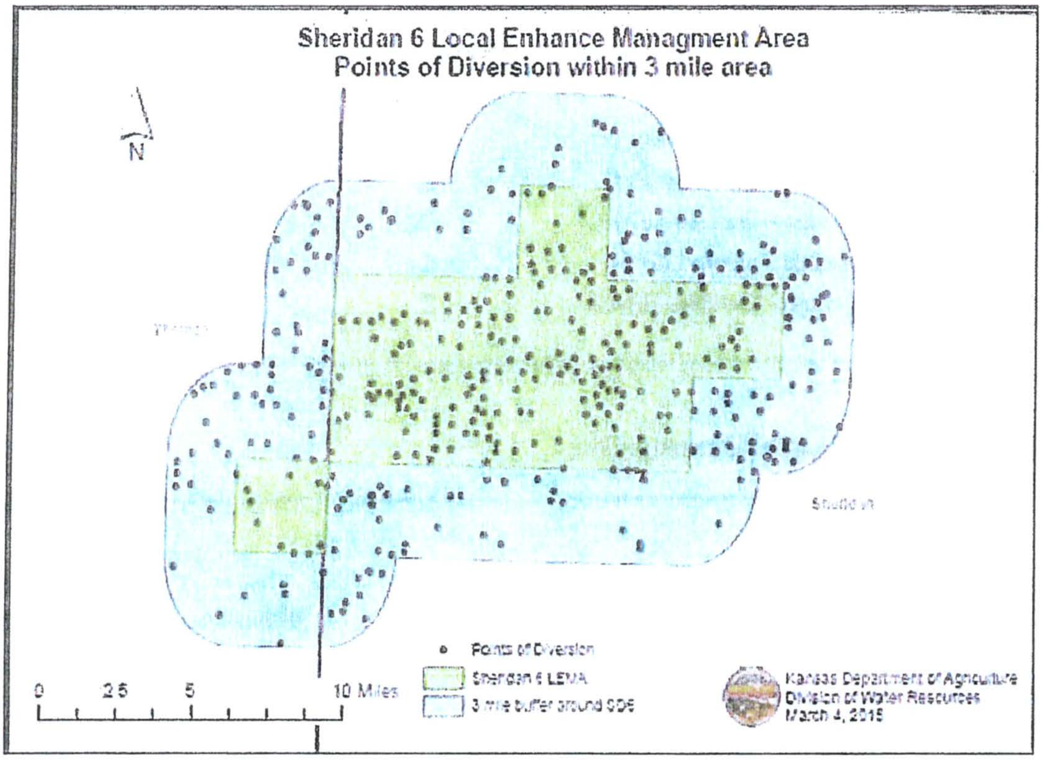


Figure 2. Total Irrigated Acres

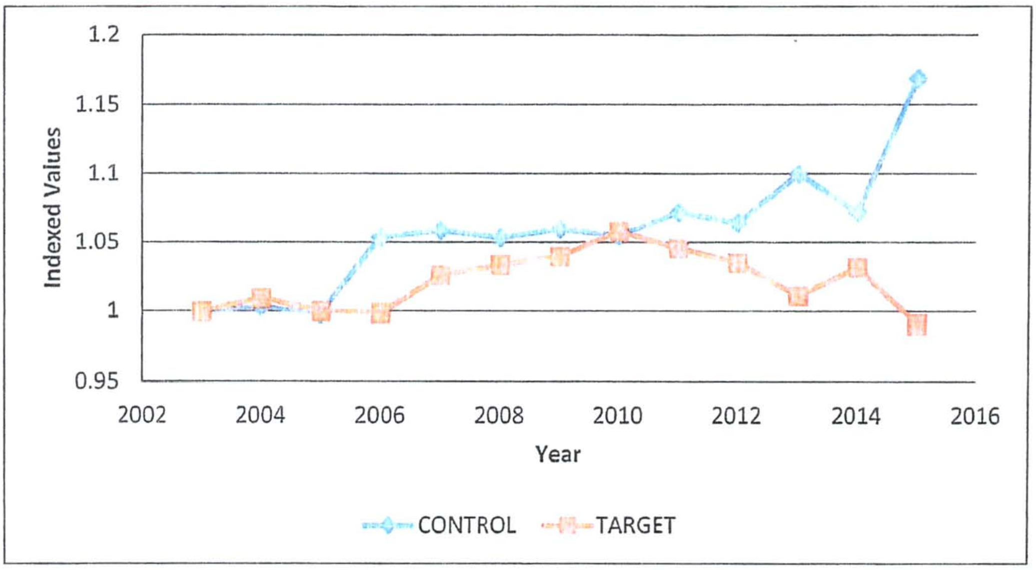


Figure 3. Total Groundwater Use

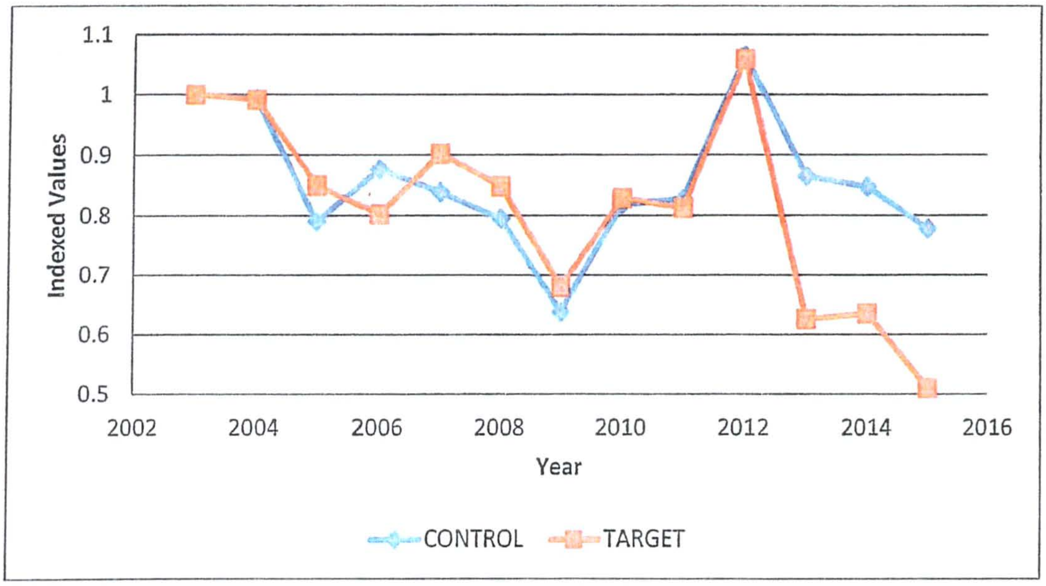


Figure 4. Average Groundwater Use per Acre

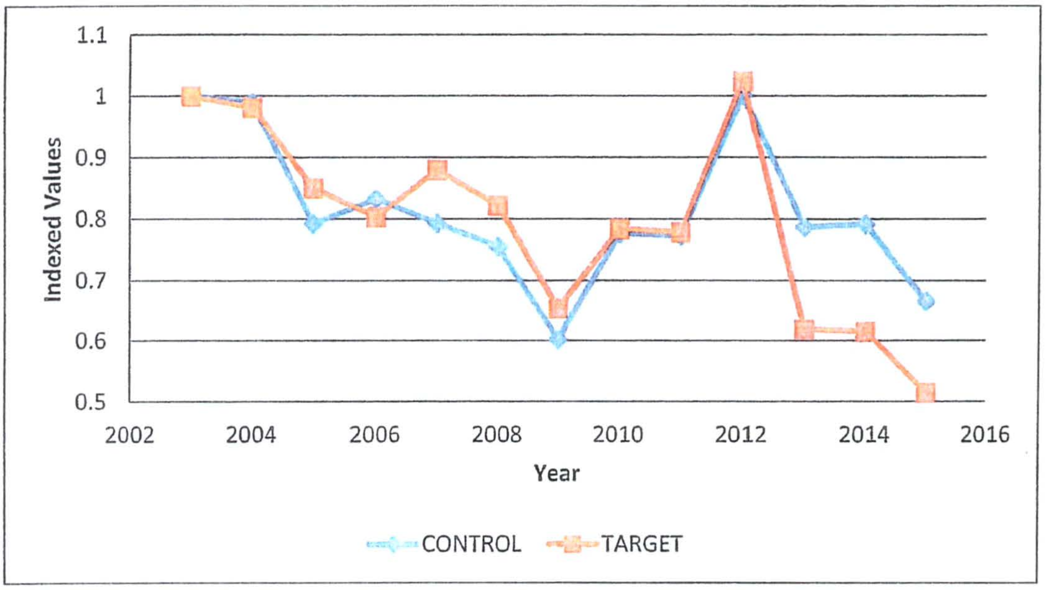


Figure 5. Total Irrigated Corn Acres

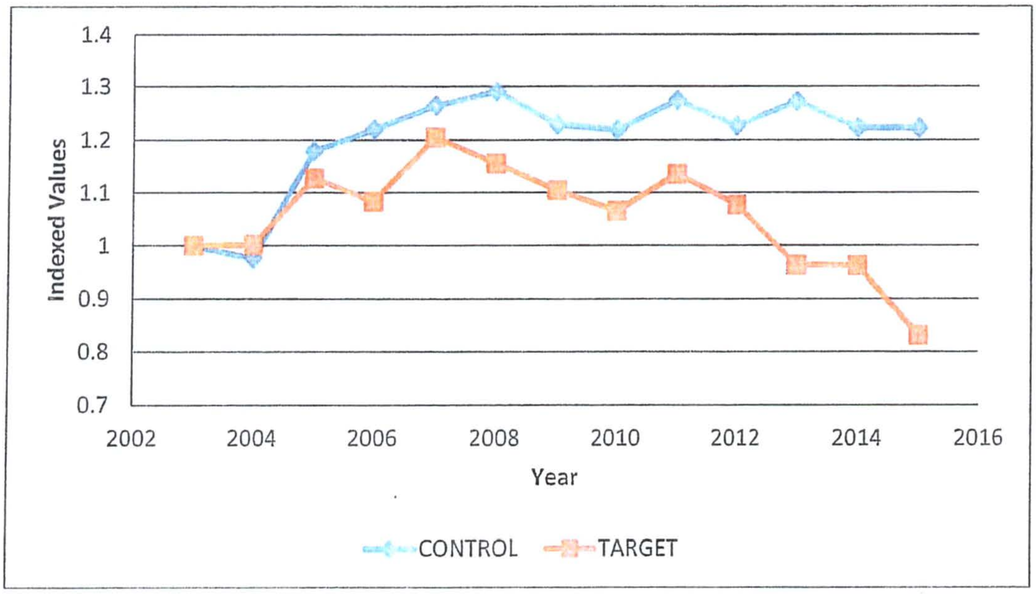


Figure 6. Total Irrigated Alfalfa Acres

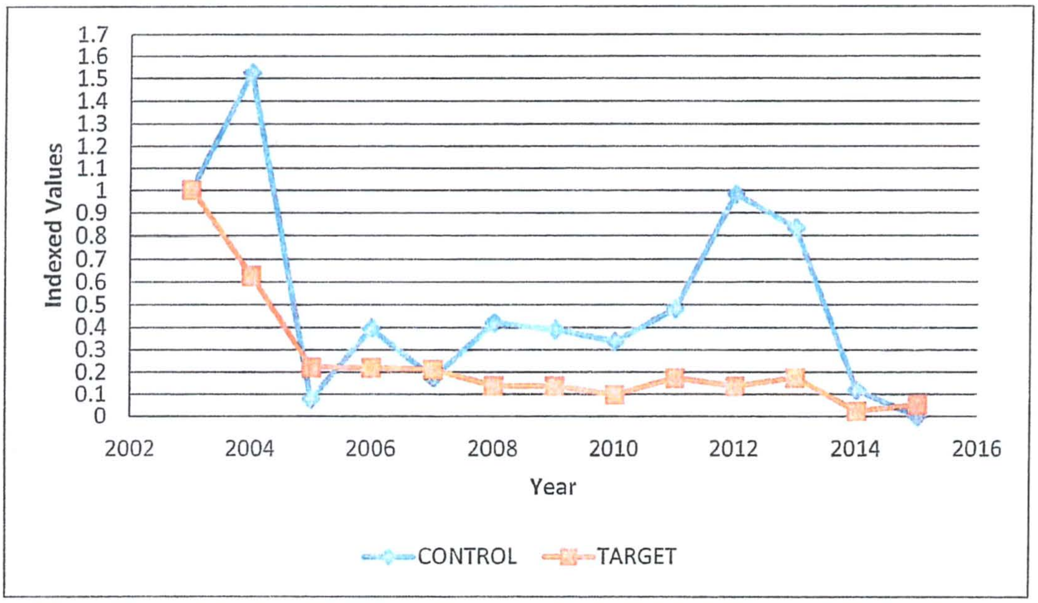


Figure 7. Total Irrigated Grain Sorghum Acres

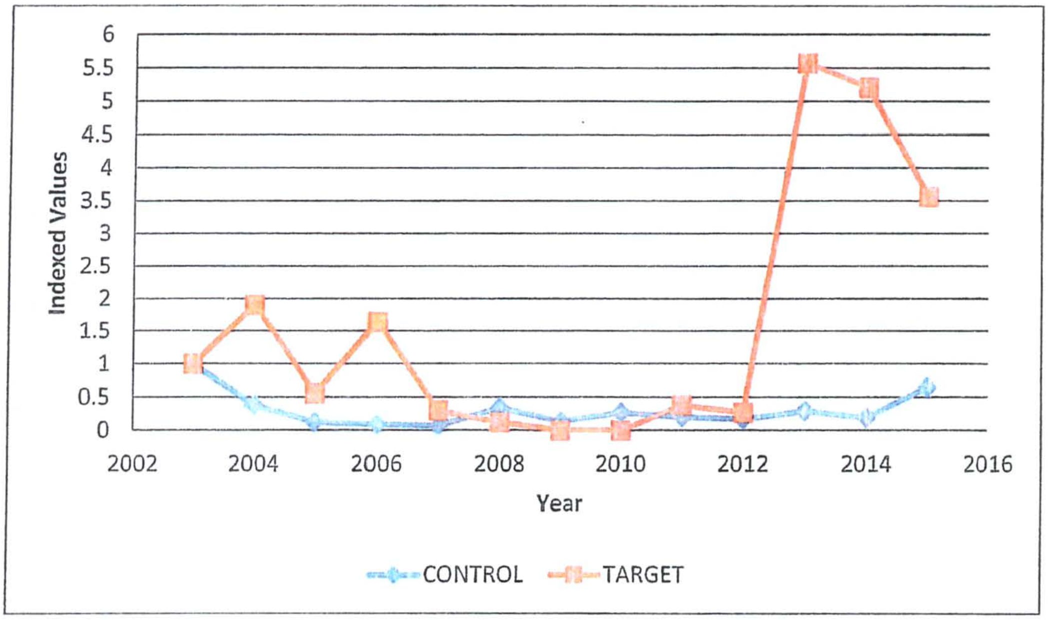


Figure 8. Total Irrigated Soybean Acres

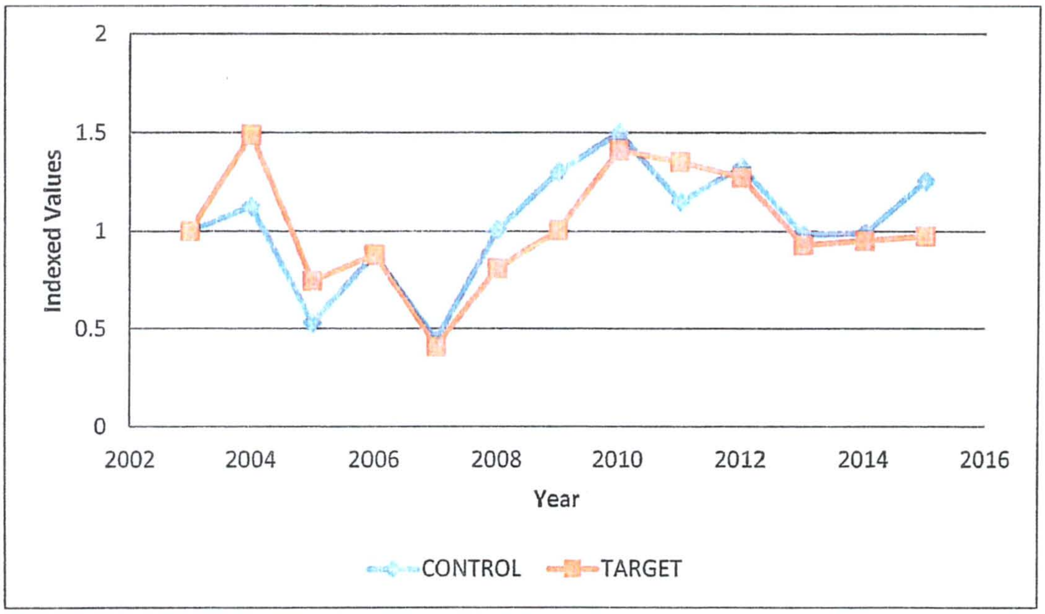


Figure 9. Total Irrigated Wheat Acres

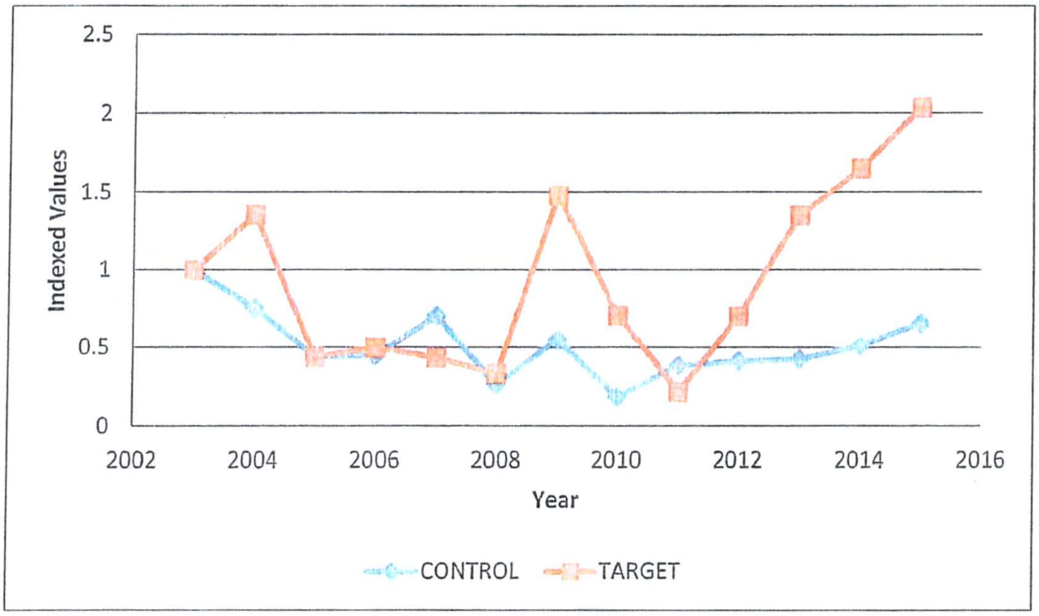


Figure 10. Total Irrigated Mixed Crop Acres

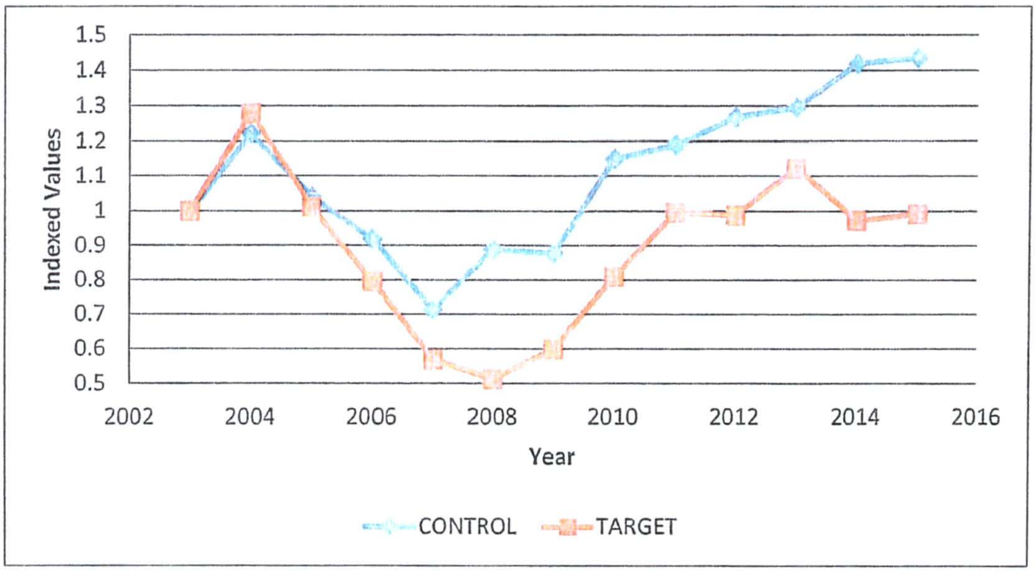


Figure 11. Average Groundwater Use per Irrigated Corn Acre

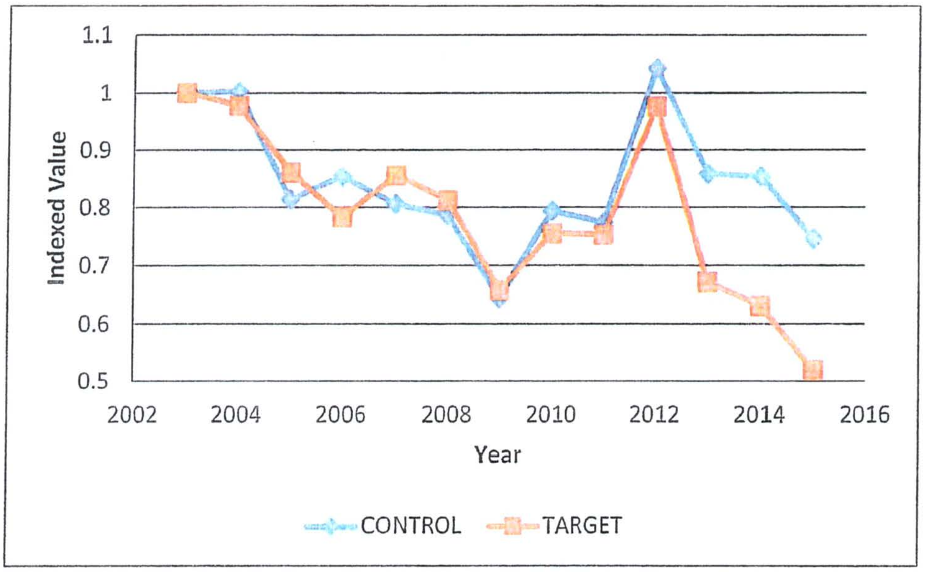


Figure 12. Average Groundwater Use per Irrigated Soybean Acre

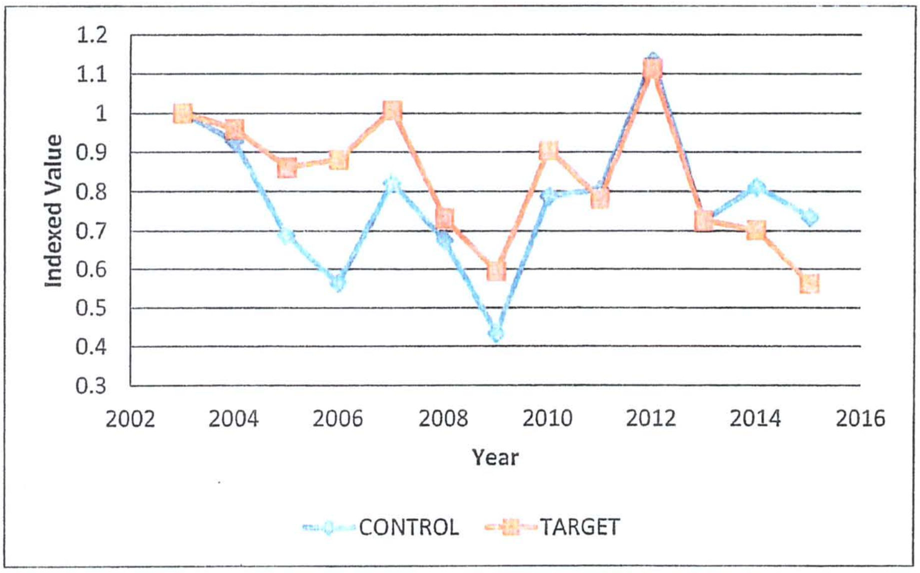
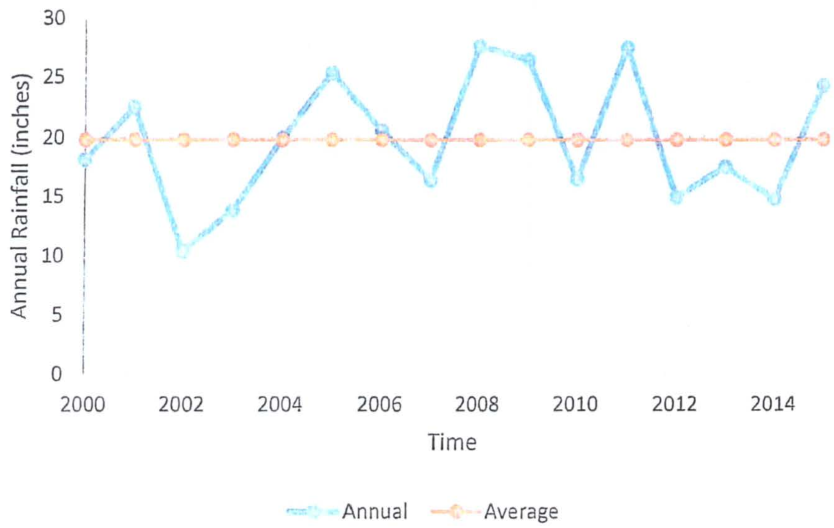


Figure 13. Historic Annual Rainfall for Sheridan County



Source: http://mesonet.k-state.edu/data/20002016+Monthly+Precipitation+by+County.txt

Potential Economic Impact of Water Use Changes in Northwest Kansas

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TABLE OF CONTENTS

Executive Summary

Current levels of groundwater consumption in northwest Kansas raise concerns relative to the long-term feasibility of irrigated agriculture in the area. In order to extend the economic life of the aquifer and maintain the economic base of the region, water conservation alternatives need to be evaluated. The purpose of this research is to estimate the likely economic impacts to producers and the regional economy and hydrologic impacts to the Ogallala aquifer associated with a variety of water conservation policies.

This research focuses on 98,143 irrigated acres in six subareas located in Cheyenne, Thomas, Sheridan, and Sherman counties within the jurisdiction of Groundwater Management District number four. Three policy scenarios were evaluated: a status-quo scenario where water-use continues at current levels; an immediate conversion to nonirrigated production where all water-use for irrigation is immediately stopped, and; a 30% reduction in groundwater withdrawals relative to the status-quo scenario. Three options for achieving a 30% reduction were considered: an immediate shift to a limited irrigation management strategy; a water rights buyout program, and; a Conservation Reserve Enhancement Program. The impact of policy alternatives were measured relative to the status-quo scenario.

Economic models of production and temporal allocation were developed and used to estimate producer and hydrologic impacts over a 60 year time horizon. A nine-county, 140-sector IMPLAN model was developed and used to estimate the regional economic impacts to value-added. Value-added is closely related to the sum of proprietary and property income, employee wages, and indirect business taxes.

The IMPLAN model is a static model that provides probable instantaneous impacts. The literature suggests that after an economic shock regional economies recover in a dynamic fashion. In the absence of empirical information, a consensus forecast was generated by the research team which was used to parameterize an ad hoc decay function that diminished the IMPLAN forecast over time. Net present values were calculated for the 60 year forecast period based on a 5% discount rate.

Results suggest that from the regional economy perspective: if 98,143 irrigated acres were converted to nonirrigated production the net present value of lost value-added would be $172,381,183; if 98,143 irrigated acres shifted from fully irrigated production to limited irrigation production the net present value of lost value-added would be $28,214,016; if 29,443 irrigated acres were converted to nonirrigated production via a water rights buyout program the net present value of lost value-added would be $24,208,710, and ; if 29,443 irrigated acres were enrolled in a Conservation Reserve Enhancement Program the net present value of lost value-added would be $66,132,000. This implies that the water rights buyout program may be the least cost method of conserving groundwater. The water rights buyout has the least impact on value-added because of the relatively high payments producers received for the water rights. The Conservation Reserve Enhancement Program has a relatively high cost because enrolled acreage is prohibited from producing nonirrigated crops during the first 15 years.

Expressing impacts as net present values can sometimes be misleading. As an example, few laymen can readily place the $28 million dollar lost value-added

associated with a shift to limited irrigation production in a relative perspective. The regional economy generates a total annual value-added of approximately $973,387,000. The $28 million dollar lost value-added associated with a shift to limited irrigation production is the 60 year cumulative loss after the annual values have been discounted by 5% annually and diminished by the decay function. The cumulative lost value-added represents 2.8% of a single year's total regional value-added. In the first year, a conversion to limited irrigation would result in a lost value-added of $3,569,328 or 0.37% of the total annual regional value-added. The first year's lost value-added is assumed to diminish over time.

From a producer's perspective the water rights buyout is also the preferred policy option. It has the least impact on gross profits because of the relatively high payments producers received for the water right and nonirrigated production is allowed on the enrolled acreage. Additionally, a producer might oppose a shift to limited irrigation because of the unknown risk associated with production and the lack of incentive payments.

From an input supplier's perspective, a shift from fully irrigated production to limited irrigation production is the preferred policy option as it has the least negative impact on his annual value-added ($869,391). An input supplier may oppose a Conservation Reserve Enhancement Program because it generates relatively large reductions in the sector's annual value-added ($2,838,582) because crop inputs are not required on the enrolled acreage.

From the state's perspective a Conservation Reserve Enhancement Program is attractive because the majority of monies required for incentive payments are provided by the federal government. The water rights buyout program, on a scale this large, may be unattractive as funding would have to be raised within the state. A shift to limited irrigation, which could be viewed as a mandatory water-use restriction, may require changes in current statutes to modify water allocations.

All water conservation policies extend the usable life of the Ogallala aquifer. As an example, a shift to limited irrigation extends the time that producer revenues are stable by 24 years to more than 49 years, depending on the subarea. Since the benefits of water conservation depend, to an extent, on current hydrologic conditions that vary across subareas, targeting available funding to specific subareas will maximize benefits. While all policies considered extend the economic life of the aquifer, no policy stabilizes the aquifer at current levels.

This research estimates measures of producer gross profits and regional value-added in an endeavor to define the least costly water conservation policy. While individual policy alternatives have been compared to a 'Status Quo' scenario, this research does not attempt to place a monetary value on the saved water or place monetary value on other benefits of water conservation and should not be viewed as a cost-benefit analysis of water conservation.

Potential Economic Impact of Water Use Changes in Northwest Kansas

I. Study Objectives

Current levels of groundwater consumption in northwest Kansas raise concerns relative to the long-term feasibility of irrigated agriculture in the area. In order to extend the economic life of the aquifer and maintain the economic base of the region both voluntary and mandated policy intervention may need to be considered.

The purpose of this report is to provide the methods, assumptions, and estimates of the likely economic impacts associated with a variety of groundwater conservation policies aimed at extending the economic life of the Ogallala aquifer in northwest Kansas. This research considers three policy scenarios for six subareas located in Cheyenne, Thomas, Sheridan, and Sherman counties. These counties are located in northwest Kansas, as illustrated in Figure 1, within the jurisdiction of Groundwater Management District number four. The three policy scenarios include 1) a status-quo scenario where water-use continues at current levels, 2) an immediate conversion to nonirrigated production where all water-use for irrigation is immediately stopped, and 3) a 30% reduction in groundwater withdrawals relative to the status-quo scenario. The impact of the two policy alternatives will be measured relative to the baseline (status-quo) scenario.

II. Model Overview

In order to accomplish the goals of this research a variety of economic and hydrological models will be required. The study will require the development of three broad classes of economic models. For simplicity, they will be referred to as models of 'production', models of 'temporal allocation', and models of 'regional economic impact'. The models of production are necessary to provide the required input for the model of temporal allocation. The models of temporal allocation will provide the required time series forecast on water-use, irrigated acreage, and economic productivity for the baseline and alternative scenarios. The models of regional economic impact will utilize the output from the temporal allocation models to predict the baseline economic scenario and the economic impacts associated with the policy options. The models will be discussed in more detail below.

The development of economic models that predict the future are, by their very nature, subject to error, and the results are most appropriately viewed as a 'best guess'. From a policy analysis perspective, it is not imperative that the predictions be perfectly accurate. It is important to focus on the 'difference' between scenarios and not the scenario itself. So long as consistency is maintained between methodology and assumptions, and all stakeholders are comfortable with the methodology and assumptions, comparisons of different scenarios are appropriate to evaluate water management options.

Models of Production

Past research has shown that irrigated agriculture is best viewed in a dynamic framework. As an example, choices of technology, crop choice, crop yields, and water-use per acre may change over time. Future trends in these variables will impact the status quo and alternative scenarios. Data from the Kansas Agricultural Statistics Service (KASS), the Water Right Information System (WRIS), Extension and water management professionals, and other stakeholders will be used to quantify these trends.

Each factor associated with these models will be discussed in detail in the 'Data and Assumptions' section of this report.[1]

Models of Temporal Allocation

The models of temporal allocation will provide a 60-year time-series representation of water-use, aquifer levels, irrigated acreage, and economic productivity. For a unconfined aquifer, the economic community typically uses the concept of a 'single cell aquifer' as the hydrological model that is incorporated into the temporal allocation model. Within this framework, the aquifer is viewed as being strictly homogeneous on the spatial scale being analyzed. In other words, if analysis is performed on a subarea level then the aquifer is assumed to be uniform across that subarea.

There are two methods of generating the temporal allocation solution 1) the competitive market solution and 2) the optimal temporal allocation solution.[2] Gisser and Mercado (1973) were among the first to integrate economic theory and the hydrological theory of groundwater flow into a single model. They conceptualized the single cell aquifer, defined the appropriate equations of motion, and provided the theoretical basis for evaluating the competitive market solution. Within the competitive market framework, a producer maximizes profit by choosing the optimal allocation of water on an annual basis. While a producer may realize that the choice of water-use today impacts the aquifer decline and thus the future value of water, this factor is not taken into consideration due to the common property characteristic of the aquifer. Typically, the producer's decisions are simulated on a yearly basis without regard for the future. Comparable models have been developed and applied to groundwater policy management scenarios by Gisser and Sanchez (1980), Gisser (1983), Ding (2005), and Feinerman and Knapp (1983).

Within the optimal temporal allocation framework, a single 'social planner' determines both current and future water-use. The social planner is forward-looking and chooses the optimal time path of water-use based on the discounted value of future profits considering the marginal benefit of future water consumption. The optimal temporal allocation solution yields an optimal time path for water-use. Burt (1967) is often credited with developing the decision rules for the optimal temporal allocation of groundwater stocks. Comparable models have been developed and applied to groundwater policy management scenarios by Gisser and Sanchez (1980), Gisser (1983), Wheeler (2005), and Johnson (2003 & 2005).

Gisser and Sanchez (1980), Gisser (1983), Feinerman and Knapp (1983), and Nieswiadomy (1985) evaluated both models and suggest there is very little difference between the competitive market solution and the optimal temporal allocation solution. As such, the competitive market framework, based on its intuitive appeal and ability to mimic real-world water allocations, is used in this study. The model will mimic the crop choice, land allocation and water-use decisions of a typical producer in northwest Kansas.

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[1] The WRIS database is maintained by the Kansas Department of Agriculture's Division of Water Resources (DWR).

[2] The competitive market solution is often referred to as the no-control solution in the economic literature. The optimal temporal allocation solution is often referred to as the social planner's solution, the optimal control solution, or the dynamic optimization solution in the economic literature.

Models of Regional Economic Impact

When agricultural water-use is restricted, crop production will, in all likelihood, be reduced in the near term and producers and local communities will incur negative economic impacts. These direct economic impacts will ripple through the economy, creating additional indirect and induced impacts. The short-term magnitude of these impacts will depend upon the magnitude of the water-use reductions and the relative economic importance of agriculture to the affected communities. The results of the temporal allocation models, for various scenarios, will be used as input for the regional economic impact models. Impact Analysis for Planning (IMPLAN) software will be used for these models.

III. Models of Production and Temporal Allocation

Definition of Economic Impact

A reduction in agricultural output results in a direct negative economic impact to the regional economy. For this analysis, the magnitude of the reduction in agricultural gross profits defines the farm-level economic impact (*EI*) and is simply the difference between the gross profits that are calculated for the status-quo scenario (GP_S) and the gross profits that are calculated for an alternative scenario (GP_A). Gross profit (GP) is defined as returns to land, management, and equipment, and calculated as the difference between crop revenue and variable expenses. The economic impact (*EI*) can be defined as

$$EI = GP_A - GP_S .$$

The magnitude of the economic impact, depends on several factors: 1) the magnitude of the water-use reduction; 2) the current level of water-use efficiency in the production process; 3) the number of acres involved; 4) the crop mix for the area; 5) crop yields that depend on the shape of the crop-specific production functions which are impacted by localized growing season characteristics such as precipitation and temperature; and 6) prices and costs. The data and assumptions associated with these factors, as well as their impact on the final estimate, are documented in the 'Data and Assumptions' section of this report.

Data and Assumptions

A. Subareas

This research considers six subareas located in Cheyenne, Thomas, Sheridan, and Sherman counties as reported in Table 1. The subarea acreage was determined based on ARCGIS data provided by the Kansas Water Office (KWO). The number of points of diversion, average annual water-use, and the irrigated acreage are based on 1996 to 2005 averages derived from WRIS data and are consistent with values used in the Republican River Compact Administration (RRCA) model.

B. Assumptions on Hydrology

The Kansas Geological Survey High Plains Aquifer Section-Level Database, accessed through the WIZARD system, was used to obtain the saturated thickness information. The recharge, hydraulic conductivity, specific yield, and average decline in saturated thickness are consistent with the RRCA model. These data are used to estimate the current average well capacity as well as provide the parameter estimates for the single cell aquifer model. Mathematical functions relating well capacity to saturated thickness were derived based on Hecox, Macfarland, and Wilson (2002).[3] These data are reported in Table 2.

C. Assumptions on Irrigated Crop Production

1. Crop Mix

The irrigated crop mix in a subarea impacts two factors. First, the choice of the irrigated crop mix determines the annual water-use and thus the rate at which the aquifer declines. The assumed crop mix also determines the annual gross profits derived from irrigated production. Table 3 reports the irrigated crop mix used in this study. These data are consistent with the 1999 to 2006 average of WRIS data. Within the WRIS data some acres are reported as a mixture of the major crops in the area. As a result these 'mixed' acres were prorated among the major crops. One of the goals of this project is to maintain consistency between the economic/hydrological model and the RRCA hydrological model. To insure that the initial total water-use balanced between the two models, minor adjustments were made to the initial crop mix derived from the WRIS data. The crop mix data are reported in Table 3. These data are applied to the total irrigated acres reported in Table 1, to determine the initial acres irrigated of each crop.

Predicting future crop mix is difficult because it requires predicting future technology and other market impacts (two examples of recent such impacts are Roundup Ready soybeans, and the ethanol industry affecting crop prices and acreages). As a result a producer's crop choice is assumed fixed for this analysis and changes only as water availability limits the production of individual crops and those acres convert to nonirrigated production.

2. Yield-Water Relationship with Full Irrigation

A production function is a mathematical equation that relates the quantity of output produced to the quantity of inputs used in the production process. As an example, the production function for irrigated corn would quantify the relationship between the bushels of corn produced per acre to the acre-inches of irrigation water applied. There is extensive literature on the shape of crop production functions. Research by Frank, Beattie, and Embleton (1990), Paris (1992), Moore, Gollehon and Negri (1992), Llewelyn and Featherstone (1997), and Kastens, Schmidt, and Dhuyvetter (2003) suggest that crop production functions are curvilinear in nature As a result, most economic research assumes a polynomial or other curvilinear functional form. The relevance of the shape of production functions is that curvilinear production functions imply diminishing marginal returns to the quantity of irrigation water applied. Simply stated, the yield increase per acre-inch of water applied diminishes as the amount of water applied increases.

This report applies production functions developed by Stone et al. (2006).[4] Average annual (1996 to 2005) water-use was derived for the major crops from the WRIS data. These data represent gross water-use for the technology mix (flood and center pivot) in the subarea. Based on the technology mix and assumed irrigation efficiencies (discussed at a later point in this report) the crop specific gross water-use data were converted to net water-use requirements. Given the net water-use, irrigated crop yields were estimated from the production function. One of the goals of this project is to

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[3] A detailed explanation of the single cell aquifer as well as the derivation of the mathematical functions relating well capacity to saturated thickness is available upon request.

[4] These production functions were reported for unit increments of annual precipitation. The production functions were adjusted to reflect an average annual rainfall of 19.5 inches by interpolating between the 19 inch function and the 20 inch function.

maintain consistency between the economic/hydrological model and the RRCA hydrological model. To insure that the initial total water-use balanced between the two models, minor adjustments were made to the water-use data derived from the WRIS data. Table 4 reports the net water-use requirements used in this report. Table 5 reports the estimated crop yield. The temporal allocation model assumes that technological advances in crop yield and water-use efficiency remain constant during the simulation period.

3. Yield-Water Relationship with Limited Irrigation
One of the scenarios to be considered is a 30% reduction in groundwater withdrawals based on the status-quo scenario. This scenario can be generated under several assumptions. One possibility is that crop mix and total irrigated acreage stay fixed and producers adopt a limited irrigation strategy and reduce gross water by 30%. Table 6 represents a 30% reduction in net water requirements relative to the data presented in Table 4. Table 7 provides the corresponding yield expectations.

4. Irrigation Efficiency
Rogers et al. (1997) defines irrigation efficiency (E_I) as the percent of water pumped that is used beneficially in crop production. Irrigation efficiency (E_I) can be defined as

$$E_C = 100(W_B / W_P),$$

where W_P is the gross groundwater withdrawal, and W_B is the amount of irrigation water that is beneficially used in crop production. Season-long irrigation efficiency depends upon the coefficient of uniformity, application rate, system capacity and length, sprinkler package, soil type, field slope, irrigation timing, and individual management practices. Due to the variability in observed irrigation efficiencies, ranges of efficiencies are often reported. Several ranges are presented in Table 8.

For this report it is assumed that flood irrigation technology has a season-long irrigation efficiency of 70%. It is assumed that center pivot technology has a season-long irrigation efficiency of 95%. The temporal allocation model assumes that season-long irrigation efficiency remain constant during the simulation period.

5. Technology Mix
Center pivot technology has a higher irrigation efficiency than flood technology. As such, an acre-inch of water-used in the production of an irrigated crop may have a higher value when applied with center pivot technology as compared to application with flood technology. Based on 2005 WRISS data, Table 9 reports the current technology mix for the subareas. Over time, this technology mix has shifted from flood technology to center pivot technology. While there is little flood technology left in the area, these acres need to be accounted for. The model requires that we make assumptions as to the rate at which the remaining acres irrigated with flood technology will be converted to center pivot technology. For the purpose of this report, it is assumed that 15% of the remaining flood irrigated acres will be converted to center pivot technology on an annual basis.

6. Revenue, Costs, and Returns
The magnitude of economic impacts associated with a conversion from irrigated production to dryland production will be determined, to an extent, by the associated

revenue and profit differentials. Table 10 reports the prices, and costs used in this analysis. These data represent a modification to the 2006 Cost-Return Budgets published by the Kansas State University Agricultural Experiment Station and Cooperative Extension Service. The budgets have been modified to reflect long-run average returns to land, management, and equipment. Revenues used in this analysis are based on the prices reported in Table 10, and yields reported in Table 5 and Table 10. Scenarios that simulate a limited irrigation strategy both reduce gross water-use by 30% as well as reduce yields. As yield changes, fertilizer, repairs and maintenance, and fuel expenses are adjusted appropriately.

Once the producer has made the choice of what crop to produce he is faced with the choice of how much irrigation water to use in the production process. Production theory implies that a profit maximizing producer will use water to the point where the value marginal product of water, which is the additional revenue generated by the use of one more unit of water, is equal to the marginal cost of the additional unit of water. As a result, the demand curve for irrigation water is downward sloping, indicating that, as the price of water (which is positively correlated with fuel price and the depth to water) increases, the amount of irrigation water-used in crop production decreases. Extensive economic research has focused on the demand for irrigation water. Allen and Gisser (1984); Nieswiadomy (1985); Kim, Hanchar, and Moore (1987); Ogg and Gollehon (1989); Moore and Negri (1992); Moore, Gollehon, and Carey (1994); Schaible (1997); Peterson and Ding (2005); and Golden (2005) have all estimated the demand for irrigation water. The research consensus is that the demand is highly price inelastic, meaning that the quantity demanded is relatively unresponsive to price. The implication is that, once the crop choice is made, producers essentially apply water based on a fixed land-water ratio. Based on past research, the temporal allocation model implicitly assumes that irrigation fuel prices do not impact the quantity of water applied during the simulation period.

7. Producer Reaction to Diminishing Water Supplies

When water-use is restricted irrigated producers develop and implement strategies to mitigate potential revenue losses. Buller (1988) and Wu, Bernardo, and Mapp (1996) suggest that producers will change crop mix by shifting from high water-use crops, such as corn, into crops with lower consumptive use. Burness and Brill (2001) and Williams et al. (1996) suggest that in such cases producers will adopt more efficient irrigation technology. Harris and Mapp (1986) and Klocke (2004) suggest that computer-aided technologies and improved irrigation scheduling might provide a solution. Schlegel, Stone, and Dumler (2005) report significant water savings with the adoption of limited irrigation management strategy.

In order to develop a temporal allocation model the producer's reaction to diminishing water supplies needs to be defined. It should be mentioned that each of the possible reactions noted in the preceding paragraph lead to different time paths of water-use, crop choices, and economic impacts. For this study it is assumed that 1) a typical producer maintains the current crop choice (typically corn), 2) maintains the current water-use preferences, which is necessary to achieve optimal yields, and 3) converts irrigated acres to dryland acres as water availability becomes a limiting factor.

The assumed producer reaction to diminishing water supplies is based on stakeholder input. Economists would characterize this mode of operation as 'yield maximizing' behavior. An alternative to this assumption would be to assume 'profit maximizing' behavior. Under the profit maximizing assumption a producer might find it more profitable to reduce per acre water-use, obtain lower yields, and maintain irrigation on all acres as opposed to reducing acres and maximizing yield on the remaining acres. Assuming profit maximizing behavior implicitly assumes producers are 'risk neutral', while a yield maximizing behavior may implicitly assume 'risk aversion'.[5]

In order to parameterize the behavioral assumption it is necessary to develop 'trigger-points' for each crop that define when water availability becomes a limiting factor. For informational purposes Table 11 provides data on gross daily application rates for various well capacities.

The 'trigger-points' or the required minimum daily application rate necessary to maintain 100% of the crop acres are reported in Table 12. As an example, if declining saturated thickness results in a well capacity of 475 gallons per minute and the trigger-point for corn is set at 0.20 inches per acre per day, then the typical producer is capable of watering 100% of his corn acreage. If the well capacity diminishes to 450 gallons per minute then the producer can only irrigate 95.5% of his acreage, and maintain a 0.20 inches per acre per day gross daily application rate, and the remaining 4.5% of the acres would be converted to dryland production. An individual producer may not strictly adhere to fractionally reducing irrigated acres in a continuous manner; rather he might reduce acres in larger increments creating a 'stair-step' decline. However, when considering that all producers will not make the acreage reduction at the same point in time, the resulting aggregate average acre reduction for the subarea will reflect a smooth continuous decline.

D. Assumptions on Nonirrigated Crop Production

1. Crop Mix

The model assumes that as saturated thickness declines, well capacity diminishes and irrigated acres are converted to dryland production. The assumed nonirrigated crop mix determines the annual revenue and profits derived from dryland production. Table 13 reports the nonirrigated crop mix used in this study. These data are based on the 1999 to 2006 average of county level KASS data.

2. Crop Yield

The assumed nonirrigated crop yield determines the annual revenue and profits derived from dryland production. Table 14 reports the nonirrigated crop yield used in this study. These data are based on the 1999 to 2006 average of county level KASS data.

3. Revenue, Costs, and Returns

The magnitude of economic impacts associated with a conversion from irrigated production to dryland production will be determined, to an extent, by the associated revenue and profit differentials. Table 15 reports the prices and costs used in this analysis. These data represent a modification to the 2006 Cost-Return Budgets published by the Kansas State University Agricultural Experiment Station and Cooperative Extension Service. The budgets have been modified to reflect long-run average returns to land, management, and equipment. Nonirrigated revenues used in this analysis are based on the prices illustrated in Table 15 and yields reported in Table

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[5] Given all assumptions, there is less than a 1.5% difference in acre allocation between the two behavioral assumptions. A more detailed discussion and comparison of the two behavioral assumptions is available upon request.

14 and the crop mix reported in Table 13. Implicitly, the temporal allocation model assumes that nonirrigated crop yield, crop mix and crop price remain constant during the simulation period.

Model Details: Temporal Allocation Models

The temporal allocation model, based on the competitive market framework, has been discussed in broad generalities and a great deal of data and assumptions have been presented. To insure that stakeholders understand the relevance of the data and assumptions as well as their impact on model output, in this section the model will be discussed in more detail. As an aid to understanding, this discussion will be based on the policy scenarios for subarea number six in Sheridan County.[6]

A. Scenario 1: Status Quo

The output of a temporal allocation model is a time series representation (also referred to as a time path) of the aquifer hydrology, crop mix, water-use, and economic output. Table 16 illustrates this time path for the hydrology, crop mix, and water-use portions of the model. Due to size constraints, the only crop reported in this table is corn.

In time period one, the aquifer has a saturated thickness (ST) of 89.8 feet (Table 2). Based on the saturated thickness and hydraulic conductivity (Table 2) the estimated well capacity was 587 gallons per minute, which has a gross daily application rate (GDAR) of 0.25 inches per day per acre. Table 1 indicates that there are 24,855.0 irrigated acres in subarea six, of which 71.3% are corn acres (Table 3) and 90.6% are irrigated with center pivot technology (Table 9). Assuming equal distribution, this implies that there are 16,062 acres irrigated with center pivot technology and 1667 acres irrigated with flood technology.[7] Table 4 suggests that the net water requirement for corn is 12.7 inches per year. We also have assumed that flood irrigation is 70% efficient and center pivots are 95% efficient. Taken together, these assumptions imply a gross annual water-use (GWU) on the 1667 flood irrigated acres of 28,220 inches and on the 16,062 center pivot irrigated acres of 214,728 inches. Total water-use (TWU) for the year is 26,723.6 acre-feet, which also includes the water-use on other irrigated crop acres. This compares rather well to the average observed water-use of 26,595 acre-feet listed in Table 1. Across all irrigated crop acres, the average acre-foot water usage (AAFWU) was estimated as 1.08 acre-feet during the time period. This is within a small tolerance of the average acre-foot listed in Table 1 of 1.07 acre feet per acre. Based on the hydrological parameters presented in Table 2 the model predicts that the total water-use during the period resulted in a 1.15 foot change in the saturated thickness (ΔST). This compares to the average decline rate of 1.15 feet listed in Table 2.

In time period two, the saturated thickness declines to 72.5 feet ($ST_{T=2} = ST_{T=1} - \Delta ST_{T=1}$). The model then makes comparable calculations to those discussed in the preceding paragraph. Of interest during this time period is the change in the quantity of flood and center pivot irrigated acres. It has been assumed that 15 % of the flood acres are converted to center pivot technology each period. In the second time period 250 (15% of 1667) acres irrigated with flood technology are converted to center pivot technology (ConvCP).[8] As a result of this calculation flood irrigated acreage declines to 1417 acres

[6] An EXCEL spreadsheet with model results for all subareas is available upon request.

[7] The tabular data has been rounded off and mathematical calculations based on the rounded data will not match the results displayed.

[8] To avoid confusion the ConvCP column in Table 15 represents the total cumulative acres converted to center pivot technology and not the annual amount.

and center pivot irrigated acres increase to 16312. Since center pivot technology has higher application efficiency, total water usage (TWU) declines slightly.

A trigger-point is reached in time period 12, based on our assumptions regarding a producer's reaction to diminishing water supplies. In time period 12, saturated thickness has been reduced and well capacity diminished so that the gross daily application rate (GDAR) is slightly below 0.197 inches per day per acre. Since this is lower than the required minimum daily application rate of 0.20 inches per day per acre, as reported in Table 12, producers are forced to reduce irrigated acres. Irrigated acres are reduced, and converted to dryland production (ConvDL), by 279 acres (approximately 1.6%) so that a 464 gallon per minute irrigation well is capable of meeting the 0.20 inches per day per acre minimum requirement on the remaining acres. While this reduction in total irrigated acres reduces total water usage (TWU) it does not change the average acre-foot water usage (AAFWU) for center pivots because our assumption is that a producer may reduce acres but will maintain the per acre water-use necessary to achieve optimal yields on the remaining acres. The reduction in AAFWU is the result of converting flood irrigated acreage to center pivot technology.

By time period 60, saturated thickness has declined to 40 feet, well capacity has diminished to 270 gallons per minute, all flood irrigated acres have been converted to center pivot irrigation, and 15,073 acres (approximately 41.8% of the starting irrigated corn acres) have been converted to dryland production.

Figure 2 illustrates the time path for saturated thickness and well capacity. These curves are a function of hydrological, crop mix, crop acre, and water-use assumptions and the equations of motion that have been previously discussed. Different assumptions on hydrological, crop mix, crop acre, and water-use will lead to different time paths. Figure 3 illustrates the time path for irrigated corn acres. The shape of this curve is determined by the relationship between well capacity and saturated thickness and the assumed producer reaction to diminishing water supplies. The 'kinked' convex nature of the curve is the result of the implicit assumption that producers 'follow' the well capacity curve by reducing acres. Different assumptions regarding a producer's reaction to diminishing water supplies will lead to different shapes and time paths. Figure 4 illustrates the time path for total irrigated and nonirrigated acres. The slope of the total irrigated acreage curve is less severe than the irrigate corn acreage curve illustrated in Figure 3. This is the result of different trigger-point for different crops as reported in Table 12. Essentially, irrigated crops with different water requirements convert to nonirrigated production at different points in time.

The time path for the economic portions of the temporal allocation model is reported in Table 17. In time period number one the model predicts that irrigated corn generates total gross profits of $4,003,719. The revenue portion of this number is calculated by multiplying the crop price of $2.99 per bushel (Table 10), by a crop yield of 198.2 bushels per acre (Table 5), by a crop mix percentage of 71.3% (Table 3), by the irrigated acres in the subarea of 24,855 (Table 1). [9] The base variable costs are reported in Table 15. The gross profits for alfalfa, sorghum, soybeans, sunflowers, and wheat are calculated in a similar manner.

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[9] The tabular data has been rounded off and mathematical calculations based on the rounded data will not match the results displayed.

In time period 12 irrigated alfalfa and corn gross profits start to diminish as irrigated acres are converted due to a lack of well capacity. Nonirrigated crop revenue is calculated based on a weighted average per acre revenue calculated from crop price (Table 15), nonirrigated crop mix (Table 13), and nonirrigated crop yields (Table 14). The weighted average per acre revenue is then multiplied by the number of acres converted to dryland production.

In time period 22, irrigated sorghum, soybean, and sunflower gross profit start to diminish. At this point well capacity has diminished to the point that not all soybean acres can be fully irrigated and producers are forced to reduce irrigated acres, based on our assumptions regarding a producer's reaction to diminishing water supplies. Notice that gross profits generated from irrigated wheat production never decline. This is because well capacity never diminishes to the point that gross daily application rate (GDAR) is below the required minimum daily application rate reported in Table 12.

By time period 60, total irrigated acreage declined from 24,855 acres to 12,901. The remaining 11,954 acres have been converted to dryland production, as illustrated in Figure 4. As reported in Table 12, total gross profits have declined from approximately $5.28 million to approximately $4.0 million.

B. Scenario 2: Immediate Conversion to Dryland Production

If the 24,855 irrigated acres in subarea six were immediately converted to dryland production, there would be no water-use on those acres and those acres would generate revenues based on nonirrigated production. Nonirrigated crop gross profit is calculated base on a weighted average per acre gross profit calculated from crop price and costs (Table 15), nonirrigated crop mix (Table 13), and nonirrigated crop yields (Table 14). The weighted average per acre revenue for subarea six in Sheridan County is $112.23 per acre. As a result, total annual gross profits for the subarea are projected at $2,789,420. The gross profit estimate is constant over the time horizon.

C. Scenario 3: 30% Reduction in Groundwater Withdrawals

A 30% reduction in groundwater withdrawals can be achieved in several ways. While all methods have similar impacts on the aquifer, the impacts on the economy are significantly different. This report will analyze three methods to achieve a 30% reduction in groundwater withdrawals: 1) a limited irrigation scenario where all producers, regardless of crop choice, reduce groundwater consumption by 30%, 2) a water right buy-out program impacting 30% of the crop acreage (equally distributed across crop choices) where producers are allowed to immediately produce nonirrigated crops, and 3) a Conservation Reserve Enhancement Program (CREP) impacting 30% of the crop acreage (equally distributed across crop choices) where producers are required to fallow the impacted acres and allowed to resume production of nonirrigated crops in 15 years.

Scenario 3a, the 'Limited Irrigation, scenario, evaluates a limited irrigation scenario where all producers, regardless of crop choice, reduce groundwater consumption by 30%. Crop water-use parameters are reported in Table 6 and crop yield expectations are reported in Table 7. All other parameters and assumptions are the same as the status quo scenario. Table 18 illustrates this time path for the hydrology, crop mix, and water-use portions of the model. Due to size constraints, the only crop reported in this table is corn.

In this scenario aquifer decline rates are reduced to approximately 0.61 feet per year which slows the decline in well capacity. As a result irrigated corn and alfalfa acres start declining in time period 37, as opposed to time period 12 for the status quo scenario. Sorghum and soybean acres start to decline in time period 55 and sunflower and wheat acres never reach the threshold that requires a reduction in irrigated acres.

Table 19 reports the impacts on gross revenues. In time period one, gross revenues are reduced by approximately 10.7% relative to the status quo scenario. The reduction in gross revenue is less than the reduction in groundwater consumption due to the curvilinear nature of the assumed production functions.

Scenario 3b, the 'Water Rights Buyout' scenario evaluates a water right buy-out program impacting 30% of the crop acreage (equally distributed across crop choices) where producers are allowed to immediately produce nonirrigated crops. The reduction in acreage occurs over 6 years (5% per year) and producers receive $800 per acre for their water right. All other parameters and assumptions are the same as the status quo scenario. The initial total irrigated acres are 5% less than those used in the status quo scenario and total irrigated acres declines by 5% through the sixth year. Additionally, landowners receive revenues during the first six years as compensation for their water right. Table 20 illustrates this time path for the hydrology, crop mix, and water-use portions of the model. Due to size constraints, the only crop reported in this table is corn. Table 21 reports the impacts on gross revenues

Scenario 3c, the 'CREP' scenario, evaluates a CREP impacting 30% of the crop acreage (equally distributed across crop choices) where producers must wait till year 15 to resume production of nonirrigated crops. All acreage is enrolled the first year and producers receive an annual payment of $112 per acre for 15 years. All other parameters and assumptions are the same as the status quo scenario except that the nonirrigated crop revenues for the 30% impacted acres do not start until year 15. Table 22 illustrates this time path for the hydrology, crop mix, and water-use portions of the model. Due to size constraints, the only crop reported in this table is corn. Table 23 reports the impacts on gross revenues.

Analysis of the Net Present Value of Gross Profit

The time paths for gross profits for all scenarios are illustrated in Figure 5. The net present values of gross revenue for the different scenarios are reported in Table 24. The difference in net present values, by scenario 2 and scenario 3, relative to the status quo scenario are reported in Table 25.

Net present value comparison is a standard method used to compare long-term projects. The calculation discounts future cash flows to present values and sums the resulting income stream. The use of net present value is a reasonable method for long-lived entities to use when comparing investments and/or project costs. However, it often has been argued that measures welfare based on the discounted value of the future benefit stream, are inappropriate.[10] Ferejohn and Page (1978) argued that the use of the discounted present value metric is inappropriate when dealing with welfare maximization over an infinite horizon because it implies that the underlying social preference ranking remains constant over time. Gisser (1983) indicates that there is a philosophical

[10] In economics, welfare is a synonym for the overall well being of an individual or society. Welfare is often measured in monetary terms.

problem of the inappropriateness of welfare maximization over an infinite horizon. He argues that the only justification for the application of net present value theory is the assumption that the present generation feels altruistic toward future generations and will represent their best interest.

An additional concern raised by the economic literature is the reliance on net present value as a metric of comparison, and the failure to include measures of social welfare loss in analyses. There probably is no justification for excluding social welfare losses due to the social cost of water in economic analysis. The existence value which society places on the remaining stock of water in the Ogallala should not be neglected. [11]

Net present value calculations require a 'discount rate' that transforms future values into present values. The use of a positive discount rate would imply the conventional view that profits today are more valuable than profits in the future. A positive discount rate might be chosen by a producer that focuses on the near term cash flows necessary to meet current obligations such as land and equipment payments. A zero percent discount rate would imply neutrality as to the timing of cash flows. The use of a negative discount rate would imply that profits, and by extension water, is valued more highly in the future than it is today. Such a stance might be taken by a producer that wants to insure that water resources are conserved today so that his children might enjoy the stability of irrigated production in the future.

For this research, it is appropriate to use net present value analysis to compare and choose between policy alternatives, since all polices were developed to yield similar short-run water savings. Amosson et al. (2006) suggests that the cost of generating water savings must be weighed against the benefit of doing so and to accomplish this, a 'price tag' needs to be given to the water that is conserved. Since this research does not attempt to place a value on the conserved water, it is not appropriate to use net present value analysis to make the decision on whether or not water-use restrictions should be implemented.

Analysis of Water Savings

The time paths for saturated thickness and total water used, for all scenarios, are illustrated in Figure 6 and Figure 7, respectively. While economists have the tools and ability to conduct the net present value analysis on the future revenue streams generated by different scenarios, we are probably no better than anyone else at placing a value on the water conserved by the different scenarios. Total water-use is reported in Table 26. The amounts of water conserved by scenario 2 and scenario 3, relative to the status quo scenario are reported in Table 27.

IV. Models of Regional Economic Impact

Background

Input-output (I-O) analysis is often used to estimate the impacts that changes in policy have on regional economies. Given estimates of direct economic impacts, software

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[11] Existence value can be an important component of non-market value associated with nature. Sources of non-market or non-use values might include the existence of rare or diverse species of animals, unique natural environments, or even a way of life, such as family farms. These values are less tangible and thus more difficult to quantify because they are derived from the satisfaction an individual gets from knowing that such aspects of nature exist, and/or will continue to exist, without actually experiencing them and/or intending to experience them.

such as Impact Analysis for Planning (IMPLAN) estimates endogenous linkages between production, labor and capital income, trade, and household expenditures providing estimated effects on sector output, value-added, household income, and employment (MIG, 1999). The process captures not only the direct and indirect effects in production, but induced effects, as well. Direct effects represent the initial impacts of an outside shock on a particular sector. Indirect effects refer to the economic impacts on a particular sector's demands for intermediate goods. Induced effects refer to changes in those demands for goods and services made by households spending their altered income.

IMPLAN is often used to analyze water-use impacts on agriculture. Pritchett et al. (2005) used IMPLAN to model the economic impacts of reduced irrigation water-use in the Republican River Basin of Colorado. Leatherman et al. (2006) evaluated the proposed CREP program in southwest Kansas with input-output analysis and IMPLAN software. Lamphear (2005) applied IMPLAN analysis to valuing the importance of irrigated agriculture to the Nebraska economy. Supalla, Buell, and McMullen (2006) applied multipliers developed by Lamphear (2005) in their evaluation of economic impacts associated with various policy scenarios aimed at reducing consumptive use of irrigation water in the Platte and Republican Basins of Nebraska.

I-O impact analysis is a valuable tool for evaluating the economic consequences of policy decisions. The method provides a static snap-shot in time of probable impacts, but does not estimate the dynamic adjustment process. However, implicit in economic theory is the notion that policy implementation influences individual and market behavior creating dynamic reactions. Recognizing this factor, several researchers have applied ad-hoc (best guess for the case at hand) correction factors to conventional I-O impact analysis. Pritchett et al (2005) applied impact analysis to the case of water rights retirement in Colorado. He noted that this type of analysis has limitations; in particular, the analysis does not capture the dynamic adjustments of businesses that pursue new activities in lieu of the business traditionally used to support irrigated cropping. He suggested that, in spite of this limitation, the analysis does provide a basis for policy discussion. Supalla, Buell, and McMullen (2006) applied I-O analysis to various water conservation policy scenarios in Nebraska. Recognizing that rural economies make dynamic adjustments, the authors diminished a portion of the economic impacts in an ad-hoc linear fashion over 10 years. Leatherman et al. (2006) evaluated the proposed CREP program in southwest Kansas with I-O analysis. The research team assumed that people generally are innovative in their response to economic change, and that an economy is never static in the way it responds to change. They suggested that it is likely that the negative impacts associated with the program would in fact diminish over time and developed an ad-hoc non-linear response function.

The Descriptive Model

I-O model development is often conceptualized as having two components; the descriptive model and the predictive model. The descriptive model contains the social accounts and I-O accounts and describes the transfer of money between industries and institutions (MIG, 1999). The descriptive model is for a specified geographic area for a selected time period. Multipliers, which will be discussed later, generate the predictive model.

IMPLAN analysis uses published government economic data to account for financial transactions which occur in a region at a specific point in time. The method generates multipliers that reflect how industry sectors, households, and other institutions are financially linked one to another and to the overall economy, and how they are impacted by an exogenous economic shock. These multipliers can be used to determine the size and direction of the secondary economic impacts.

The appropriate geographic scope used in the analysis should reflect the researcher's belief in where the reduction in agricultural output, associated with reduced water-use, impacts the economy. The intent of this analysis is to identify those impacts that affect market participants and households within that area. It is assumed that stakeholders are not concerned with economic impacts that may affect the state or US economy. MIG (1999) suggest the use of the concept of a 'functional economic area' to define the study area. This area is semi self-sufficient economic unit that includes the places where people live, work, and shop, and accounts for the locations of buyers and sellers of goods and services important to the analysis. According to the Thorvaldson and Prichett (2007) in order to isolate the effects of an economic impact it is desirable to make the study area as small as possible while still including areas necessary to capture all important effects. While the six subareas are located in Cheyenne, Thomas, Sheridan, and Sherman counties, the I-O study area includes Cheyenne, Thomas, Sheridan, Sherman, Decatur, Gove, Logan, Rawlins, and Wallace Counties. Table 28 reports the basic demographic information for the study region. Within the study region there are 143 industries. Table 29 reports economic demographic information on select industries.

This research uses 2004 data (the most recent data available) obtained from MIG. IMPLAN uses a single year's data to create the structural matrices, production functions, and multipliers that describe the regional economy. Thorvaldson and Prichett (2007) suggest that it is important to select the appropriate annual IMPLAN dataset to ensure that anomalies do not exist. By selecting 2004 data, this research assumes that the overall structure of the economy, industry linkages, and multipliers that described the 2004 regional economy are reasonable approximations for the 2007 regional economy. All results are reported in 2007 dollars.

Types of Economic Impacts

Purchases for final use (final demand), for an industry, drive an I-O model. Changes in final demand represent a direct economic impact to the affected industry. 'Direct effects' are the changes in the industries to which the final demand change was made (MIG, 1999). For our case, the direct impacts are those that directly impact the producer's revenues and impact the grain farming sector.

Accurately identifying and quantifying the direct economic impact is critical to I-O analysis. The researcher defines the magnitude of the direct economic impact and typically, IMPLAN then estimates the indirect and induced impacts. If the direct impacts are erroneous then the indirect and induced impacts will also be erroneous. When water resources are shifted from agricultural production a variety of direct economic impacts may occur. Reduced revenues from irrigated crop production will negatively impact the community through both backwards and forwards industry linkage. In most cases, the lost revenues from irrigated crop production will be offset, to some extent, by the increased revenues generated from dryland crop production. In some cases, previously irrigated cropland may be converted to a permanent pasture which might enhance revenues from haying, grazing, and recreation. Many of the water right transfer policies compensate the landowner which in turn generates a positive direct economic impact.

This research considers four policy alternatives/scenarios. Table 30 reports the type of direct impacts associated with each scenario. As in the previous section, this discussion will be based on subarea number six in Sheridan County. Since the CREP scenario involves all the types of direct impacts it will serve as the example scenario.[12]
In all likelihood, an industry that experiences a direct economic impact, purchases goods and services from other industries which may indirectly experience economic impacts. 'Indirect effects' are the changes in inter-industry purchases as they respond to the new demands of the directly affected industries (MIG, 1999). When irrigated land is retired, the demand for goods and services will diminish. Major inputs for agricultural production (equipment, replacement parts, fuel, seed, fertilizer, herbicides, and insecticides) are purchased from local suppliers. The reduction in demand experienced by these local suppliers is referred to as the first-round indirect impacts. The firms that experience first-round indirect impacts will in-turn reduce their demand for goods and services which will create subsequent rounds of indirect impacts.

As the direct and indirect economic impacts ripple through the economy household consumer income may be affected. 'Induced effects' typically reflect changes in spending from households as income increases or decreases due to the changes in industry production (MIG, 1999), resulting from the direct and indirect impacts. Indirect and induced effects are often referenced in the literature as secondary impacts and/or third party costs.

Types of Multipliers

Given a direct economic impact, the goal of I-O analysis is to estimate the indirect and induced effects so that total effects (total economic impact) can be determined. The total impact can be expressed as a multiplier which is defined as

$$Multiplier = \frac{Total\ Impacts}{Direct\ Impacts}.$$

A multiplier is simply the ratio of total impacts to direct impacts and will always be expressed as a number greater than one.

I-O multipliers measure the strength of backward linkages; that is the financial impact that an increase or decrease in output by given local industry causes to its input supply chain. This financial impact is the result of changes in purchases from local industries and local resource providers (Hughes, 2003).

Final demand changes in one industry (direct impacts) creates final demand changes in related industries (indirect impacts), which in turn may generate a second round of final demand changes, and so forth. The combined effects of these multiple iterations are described by multipliers. There are three types of multipliers developed for predictive modeling: the Type I, the Type II, and the Type SAM (MIG, 1999). The 'Type I multiplier' measures the direct and indirect effects of the change in economic activity. It captures only the inter-industry effects (MIG, 1999). The 'Type II multiplier' captures the effects of direct and indirect impacts as well as the induced impacts on household incomes and expenditure (MIG, 1999).

[12] An EXCEL spreadsheet with model results for all subareas is available upon request.

Traditionally, I-O analysis has focused on impacts to industries and households. By adding social accounting data researchers can examine non-industrial transactions such as payment of taxes by business and households and other institutional transactions. These institutional transactions are accounted for when social accounting matrices (SAMs) are included in the analysis. The 'Type SAM multiplier' captures the effect of direct, indirect, and induced impacts on industries, households, and institutions (MIG, 1999). Many researchers have used SAM type multipliers; however, Thorvaldson and Prichett (2007) used Type II multipliers as they felt the focus should be on industries and not on institutions. They suggest that while Type SAM multipliers can result in more information and detail the additional information is often more complicated and harder to interpret and explain. This research will be based on Type SAM multipliers.[13]

Reporting Economic Impacts

The IMPLAN software generates several types of outputs that quantify the total economic impact (all of which are broken down into the direct, indirect, and induced effects). 'Total Industry Output' (TIO) is the total value of industry output for a given time frame (MIG, 1999). It can be loosely interpreted as the value of sales. Norvell and Kluge (2005) suggest that TIO is not a good measurement of economic impacts as it double count sales to other industries. As an example, within the study region there is a manufacturer of phosphate fertilizer that may sell his output to a fertilizer mixer. The fertilizer mixer in-turn may sell his output to a local cooperative, which then sells the blended fertilizer to the producer. If, as the result of retiring irrigated farm land, a producer reduces his phosphate fertilizer demand, then the measure of TIO would count the manufacturer's sale three times and the mixer's margin twice. To be consistent with the literature, this study will report TIO but the metric will not be used in policy comparison.

A more accurate measure of the local economic impact may be 'Value-added' (VA). VA consist of four components: 1) employment compensation (wage, salary, and benefits paid by the employers), 2) proprietor income (payments received by self-employed individuals as income), 3) other property income (payments to individuals in the form of rents), and 4) indirect business taxes (basically all taxes with the exception of income tax). Thorvaldson and Prichett (2007) and BBC Research & Consulting et al. (1996) suggest that VA is the most appropriate measure of community economic impact. This research reports the measure of VA and uses the metric to compare policy options.

Researchers often report 'Employment' impacts generated by IMPLAN. Thorvaldson and Prichett (2007), (Hughes, 2003), and Norvell and Kluge (2005) suggest that IMPLAN may over estimate employment impacts. There are several reasons why IMPLAN may overstate employment impacts associated with agricultural production: 1) the employment calculation counts both full and part time workers as employees. Part time workers, necessary during peak labor periods such as harvesting and planting may not be eliminated in reality, even though IMPLAN will predict such a change. 2) IMPLAN assumes fixed proportion production. While this is a reasonable assumption for most inputs, it is probably not a reasonable assumption for labor and capital expenditures. Mann (2002) suggest that if farmers expect to continue farming in the future they maintain machinery, other capital expenditures, and that labor expenses are maintained because experienced labor is scarce and a skilled person might not be available in the future. Norvell and Kluge (2005) suggest that employers may not lay off workers given

[13] Based on a discussion with Doug Olson from the Minnesota IMPLAN Group.

that experienced labor is sometime scarce and not readily available and lost jobs might find employment in other sectors. 3) As much as 69% of agriculture labor, both paid and unpaid, is provided by family members.[14] It may be unlikely that family members would be impacted by land retirement programs. Additional research is needed to quantify the impact of land retirement programs have on family labor in northwest Kansas.

IMPLAN uses the concept of 'sales-per-worker' to estimate employment impacts; where sales and total industry output are equivalent. For the nine county study area, IMPLAN estimates that the grain farming sector (#2) has a total industry output of $265 million and an employment of 2,663 workers, which equates to $99,566 in sales-per-worker. Under the assumption of a linear production function, this implies that a reduction in the sale of agricultural commodities totaling $99,566 would result in one lost job. As will be discussed later, an average irrigated acre generates approximately $563 in sales, which implies one job will be lost for every 177 acres of irrigated land retired. A review of Langemeier and Dhuyvetter (2005) and an informal survey of extension professionals suggests a better estimate might be that one job will be lost for every 2000 acres or $1,126,000 in sales. This sales-per-worker estimate will be used in calculating the employment change resulting form the direct economic impact associated with lost agriculture revenues. This implies that the employment impacts reported in this research are approximately 8.8% of the employment impacts initially generated by IMPLAN. In the absence of better information, the indirect employment changes (associated with input suppliers) will also be based on the 8.8% factor.[15] This study will report employment impacts but the metric will not be used in policy comparison.

A final note on reporting economic impacts; while total industry output, value-added, and employment impacts are reported, the reader is cautioned that the impacts are not additive. The wages associated with any employment change are included in the estimated value-added, which is itself a portion of the total industry output.

Modeling Economic Impacts Using Analysis by Parts

The reduced revenues from irrigated production are often difficult to conceptualize, estimate, and model. There are four areas that need attention: first, which irrigated crop acres are retired; second, which backward linked industries are affected; third, of the crop revenues paid to backward linked industries, what percent is purchased from local suppliers; and fourth, of crop revenues paid to backward linked industries in the region, what proportion (wholesaler margin) remains in the regional economy.

Many researchers assume that the crops grown on retired irrigated acres have cropping patterns similar to the regional average. Thorvaldson and Prichett (2007), BBC Research & Consulting et al. (1996), and Norvell and Kluge (2005) applied this technique. However, BOR (1999) suggest that in a willing-seller market, water would tend to be purchased in locations with crop patterns that cost the least, in terms of foregone crop revenue; Thorvaldson and Prichett (2007) suggest that while their study assumed that crops were taken out of production in proportion to the observed crop mix, it was more likely that some crops would be taken out of production in greater proportion than others based on relative profitability; Taylor and Young (1995), BBC Research &

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[14] Source: http://www.usda.gov/news/pubs/fbook98/ch3a.htm

[15] The change in the sales-per-worker factor only affects the reported employment impacts. It does not affect calculations for TIO or VA.

Consulting et al. (1996) suggest that lower valued crops on marginal land will be the first to be retired; based on crop profitability, soil characteristics, and aquifer profiles; Leatherman et al (2006) developed a model to predict which acreage would be retired first. Since the crop mix in the subareas is predominantly corn, and to maintain consistency with the temporal allocation model, this study assumes that crop acreage is taken out of production in proportion to the observed crop mix in the subarea, as reported in Table 3.

I-O analysis is a means of examining relationships within an economy both between businesses and between businesses and final consumers. It captures all monetary market transactions for consumption in a given time period (MIG, 1999). The method generates mathematical formulas (also referred to as production functions) that can be used to estimate how changes in the final demand for one industry affect both other industries and consumers. The technical coefficients (also called multipliers) on these production functions are based on national averages, and should be modified if they are not representative of the region (MIG, 1999). Norvell and Kluge (2005) suggest that since the national average for agricultural production is an aggregation of irrigated and dryland production and also includes crops that and may not be present in the region, modification of the production functions may be appropriate. BBC Research & Consulting et al. (1996), Thorvaldson and Prichett (2007), and Mann (2002) also suggest the national production functions may not naturally reflect local production methods and may need to be adjusted. Thorvaldson and Prichett (2007) suggest that state extension crop budgets, which describe how producers allocate monies to various crop inputs, can be used to develop appropriate IMPLAN production function. Crop budgets, reported in Table 10, and cash flow budgets developed by the Kansas Farm Management Association are the basis for the crop specific production functions used in this analysis. These production functions also define the backward linked industries that are affected in the first-round of indirect impacts.

The concept of a functional economic area has been previously discussed, however the notion of keeping a study region relatively small while at the same time defining an area sufficiently large enough to capture all industry linkages is problematic for agriculture. Some of the inputs necessary for agricultural production will be purchased from suppliers that are not in the defined area. Additionally, a portion of household income may be spent in adjoining states. Regional Purchase Coefficients (RPC) are calculated by IMPLAN and used to correct for these issues. A RPC is the estimated fraction of the region's commodity demand met by using locally produced commodities. It is the result of an econometric equation which predicts local purchases based on the regions characteristics (MIG, 1999).

Agricultural production can be characterized as generating large input demands and subsequent cash flows, much of which flows outside of the regional economies. The major inputs for agricultural production (equipment, replacement parts, fuel, seed, fertilizer, herbicides, and insecticides), while purchased locally on a retail basis and may have a 100% RPC, are produced by major manufacturers, and sold to local suppliers on a wholesale basis. These major manufacturers are typically not located within the study region. The value-added to these inputs by these local merchandising activities is typically only a small fraction of total purchase costs. If these out-of-region cash flows are not appropriately accounted for, I-O analysis may significantly overestimate regional economic impacts. Thorvaldson and Prichett (2007) suggest that I-O analysis may overstate indirect impacts because if the direct impact results in a demand change for a particular good the entire purchase price of that good is counted as an indirect impact. If the good is produced outside the region, but sold through a local retailer only the retailer markup, as opposed the full purchase price, will be lost to the local economy. Only if the good is produced entirely in the local economy will the entire purchase price be lost to that local economy. If an industry within an area purchases goods or services from an industry outside of the area it would be necessary to include both areas in the study region to capture the effects of all linkage (MIG, 1999). To correct for this factor, margins derived by IMPLAN and from informal surveys of extension professionals will be incorporated into the analysis. Margins define the difference between what an input supplier pays for an item and what he sells it for.

Typically, a researcher defines the magnitude of a direct impact and the sector which is impacted (referred to as an 'event' in IMPLAN). As an example, if we anticipate the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6) with average revenue of $563.73 per acre, then the direct impact would be $4,203,453. We might specify the grain farming sector (#2) as the impacted sector. IMPLAN then uses the sector's production function to define the magnitude of the indirect impact and the distribution of the indirect impact across the supply chain. As has been previously noted, production functions based on the national average may not be appropriate. Researchers at Minnesota IMPLAN Group have developed a protocol, referred to as Analysis By Parts (ABP), to accommodate this situation and tailor I-O modeling to local conditions.

ABP is an IMPLAN protocol that allows a researcher to incorporate project-specific information into the analysis. It is accomplished by dividing the direct economic impact into the two parts: 1) the indirect impacts to the supply chain and 2) the direct impact to the payroll sector (which also is equivalent to the direct impact on VA). When using ABP the researcher manually calculates the direct impacts on Total Industry Output, Value-added, and Employment and actually models the first-round indirect impacts. Two caveats need to be noted when using ABP: first, since the indirect impacts are being modeled the IMPLAN generated output listing direct, indirect, and induced impacts are mislabeled and need to be re-aggregated; and second, since margins and RPC are incorporated the IMPLAN generated output includes impacts on domestic and foreign trade which need to be removed from the totals.[16]

The literature suggests that IMPLAN production functions, based on national averages, may not be appropriate. Additionally, MIG (1999) suggests that since their agriculture data is entirely derived, researchers with better data should incorporate it when building their IMPLAN models. ABP is a means of incorporating local information by creating a production function that specifies the first-round indirect impacts and is used in this research.

Modeling the Impact of Irrigated Crop Revenue

Since IMPLAN is driven by cash flow accounting, the KSU budgets, used in the temporal allocation model, are not entirely suitable for our purposes and were supplemented with information from cash flow budgets developed by the Kansas Farm Management

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[16] For a more detailed explanation of required modifications when using ABP, the reader is refereed to IMPLANS protocol documentation.

Association.[17] These crop specific budgets were then weighted by the irrigated crop mix reported in Table 3. Table 31 reports the IMPLAN coding and impacts to the different sectors. These data suggest that the total direct impact on total industry output resulting from the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6) is $4,203,455. The total direct impact to value-added is $1,561,891. The total first-round indirect impact is $2,641,564. However, this is the total indirect impact to all areas of the country and includes both domestic and foreign trade. That is, it does not account for local input supplier's margins or the RPC. Table 32 reports the first-round indirect impact to local suppliers as $762,261 or approximately 28.8% of the total. Based on these data, Table 33 reports the impacts on total industry output, value-added, and employment due to revenue losses associated with a reduction in irrigated crop acreage.

Stakeholders are often concerned about the magnitude of land payments and USDA farm program payments that leave the regional economy. ERS (2004) suggests that approximately 23% of USDA farm program payments, associated with farm production in northwest Kansas, may be paid to absentee landowners outside the region. Event 10 in Table 32 reflects that 23% of the estimated farmland rental and lease value leave the local economy and have a zero percent effective local impact.

Modeling the Impact of Nonirrigated Crop Revenue
As with the previous analysis, the KSU budgets were supplemented with information from cash flow budgets developed by the Kansas Farm Management Association. These crop specific budgets were then weighted by the nonirrigated crop mix reported in Table 13.[18] Table 34 reports the IMPLAN coding and impacts to the different sectors. These data suggest that the total direct impact on total industry output resulting from an increase of 7,456.5 nonirrigated acres (30% of the 24,855 irrigated acres in subarea 6) is $1,696,637. The total direct impact to value-added is $843,636. The total first-round indirect impact is $853,000. However, this is the total indirect impact to all areas of the country and includes both domestic and foreign trade. That is, it does not account for the local input supplier's margins or the RPC. Table 35 reports the first-round indirect impact to local suppliers as $261,782 or approximately 30.7% of the total. Based on these data, Table 36 reports the impacts on total industry output, value-added, and employment due to revenue gains associated with an increase in nonirrigated crop acreage.

When landowners enroll in the CREP, they are allowed the option of enrolling the corners associated with center pivot irrigation and receiving a payment for those acres based on nonirrigated rental rates. These corners are currently producing a combination of nonirrigated crops and pasture, or are being fallowed. It is assumed that for every irrigated acre enrolled in the CREP that 0.231 acres of nonirrigated crop land will be retired at an average CREP rate of $40 per acre.

Modeling the Impact of Haying, Grazing, and Recreation Revenues
The CREP program requires landowners to idle their land for 15 years. A portion of the idled land enrolled in the CREP would be eligible to be used for haying and grazing. Up

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[17] In the section titled 'Models of Production and Temporal Allocation' producer gross profit was the metric of comparison as the focus was on producer impacts. In this section value-added is the metric of comparison as the focus is on community impacts. Producer gross profits will generally be larger than value-added.
[18] Weighting the revenues by the nonirrigated crop mix implicitly assumes that all retired irrigated land resumes production of nonirrigated crops.

to one-third of the acreage could be used for haying and grazing on a rotational basis each year. Dhuyvetter and Kastens (2006), suggest that the cash rent per acre for pasture land in the Northwest Kansas was $9.60, which is used as a proxy for the value of haying and grazing. The annual contribution to the local economy is estimated as $3.20 (one third of $9.60) per acre, of which 23% is estimated to be paid to absentee landowners as reported in Table 36.

The land idled by the CREP program may increase local recreation opportunities and generate additional economic activity. ERS (2004) estimated the national value of recreation benefits associated with CRP. Leatherman et al. (2006), based on ERS (2004), estimated that each acre of CRP land annually generates $1.20 of access lease income for the landowner and $2.85 additional economic activity for the local community.[19] It is assumed that 100% of the land lease income stays in the local economy (since the absentee landowner's portion may be accounted for as haying and grazing rental) and the additional economic activity ($2.85 per acre) is distributed as reported in Table 37.

Based on these data, Table 38 reports the impacts on total industry output, value-added, and employment due to revenue gains associated with an increase in haying, grazing and recreational activity.

Modeling the Impact of Program Payments

Landowner participation in the CREP (or water rights buyout program) generates incentive payments to the landowner. A landowner participating in the CREP is assumed to receive $112 per enrolled irrigated acre. It is assumed that 23% of these payments are made to absentee landowners.

Based on these data, Table 39 reports the IMPLAN coding and Table 40 reports the impacts on value-added, and employment due to revenue gains associated with the CREP incentive payments.

One caveat, to maintain consistency between scenarios and between the individual types of impacts within a scenario, it is assumed that 23% of proprietary income associated with land is paid to absentee landowners and 100% of the remainder is spent locally. BBC Research & Consulting et al. (1996) suggests that whether or not compensation received by the farmers are reinvested in the local community will have an important influence on nature magnitude is secondary impacts.

Impacts Not Modeled with IMPLAN

IMPLAN multipliers only trace backward linkages and do not capture the impacts on forward linked industries (MIG, 1999). Industries such as fuel, machinery, and fertilizer provide inputs to the irrigated crop sectors. These industries are referred to as backward linked industries or upstream industries. Other industries in the region use irrigated crops as an input to their production process. These industries are often referred to as forward linked industries or downstream industries. For our case, feedlots, dairies, and ethanol plants represent the forward linked industries of interest.

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[19] Leatherman et al. (2006) focused in southwest Kansas, it is assumed that these data are a proxy for northwest Kansas.

BBC Research & Consulting et al. (1996) suggest that the downstream impacts of a water-use change in the Edwards aquifer region of Texas would be severe. This is due to the fact that the region produces vegetables and other high-value crops that are further process in the region. Howe et al. (1990) suggested that water-use changes in southern Colorado did not appear to impact the expansion of feed lots, and that high valued vegetable and specialty crops moved to new irrigated lands so there was no impact on processors. Thorvaldson and Prichett (2007) suggested that since Colorado is a grain-deficit state (net importer of grain), a reduction in irrigated acres would not require a substantial shift in grain flows and thus have little downstream impact. Additionally, Thorvaldson and Prichett (2007) suggested that since Colorado's corn production is small relative to national levels, large price changes were not expected.

The economic 'Law of One Price' suggests that in an efficient market all identical goods must have only one price. This suggests that in an efficient market the factor price of corn (as an industry input) will be the same for corn purchased locally and corn imported. Since northwest Kansas is already a net corn importer and since local production is small relative to national levels, this research assumes that there will be no downstream impacts or price effects.

When irrigated cropland is converted to nonirrigated cropland there will be a change in land values which may in turn impact local property tax revenues and/or personal income tax. This research does not estimate the impacts to the landowner resulting from a reduction in his asset valuation. It is assumed that a producer would not participate in a voluntary water rights retirement program if the benefits did not equal or exceed the costs. This research does not address personal income tax issues.

This research does not provide a separate analysis of the institutional impacts generated from changes in local property tax revenues. However, the IMPLAN model implicitly captures this impact. By using the ABP methodology, applying SAM type multipliers, and incorporating cash flow budgets from KFMA, the change in indirect business taxes (IMPLAN sector 8001) is captured. Referencing the difference in values reported in Table 31 and Table 34, a change of $2.86 per acre has been included in the impact analysis.

Farmers adopted irrigation technology to enhance profits and reduce risk relative to nonirrigated production. There is little research that focuses on the increased risk associated with such practices as limited irrigation. This research quantifies the impacts on profits but does not address the impacts of increased production risk.

Duration of the Economic Impacts

The most difficult aspect of a regional economic impact analysis is estimating the duration of the impacts. All policy scenarios, relative to the status quo scenario, reduce producer output, input usage, revenues, and profits and as such have negative direct, indirect, and induced impacts. When faced with declining incomes producers develop strategies (adopt new technology, shift cropping patterns, increase inputs on the remaining acreage, etc.) to reduce the loss and return to previous income levels. Similarly, when faced with negative impacts local businesses develop strategies to reduce the impact. As time passes, the direct, indirect and induced negative impacts diminish and the economy recovers.

ERS (2004) suggested that I-O models are useful for predicting the local economic response to policy shocks ex ante (before the fact), but they do not reflect actual ex post (after the fact) adjustments. Supalla (2006) suggested that the secondary impacts are transitory in nature because the resources involved eventually find alternative employment. He noted that principles and guidelines used by federal agencies for evaluating water projects do not allow project applications to include secondary costs (US Water Resource Council, 1983) based on the assumption that labor and other resources which become unemployed move on to alternative employment and earn as much or more than they earned before the policy. Anderson and Settle (1977) suggests that secondary costs should be ignored in economic analysis because they are both transitory and difficult to estimate. Adams (2004) suggests that the CRP program negatively impacted elevator merchandising margins, but the elevators adjusted rather quickly, making most of the adjustment within one year. Pritchett et al (2005) applied impact analysis to the case of water rights retirement in Colorado. He noted that this type of analysis has limitations; in particular, the analysis does not capture the dynamic adjustments of businesses that pursue new activities in lieu of the business traditionally used to support irrigated cropping. He suggested that, in spite of this limitation, the analysis does provide a basis for policy discussion. Bangsund et al. (2002) performed an ex post analysis of the CRP program in North Dakota and suggested that the net economic effects in several areas of the state were not as economically severe as previous research had suggested. In summary, based on the literature, past research, and empirical evidence, an IMPLAN analysis is a short-run static analysis, which implicitly assumes that the impacted firms do not react. As such it is inappropriate to project the impacts generated with IMPLAN analysis into the future without accounting for the dynamic adjustment process. Unfortunately, there is little empirical research on the dynamic adjustment process.

Several ad-hoc methods have been applied to dynamically adjust estimates of direct and indirect impacts. Supalla, Buell, and McMullen (2006) applied I-O analysis to various water conservation policy scenarios in Nebraska. Recognizing that rural economies make dynamic adjustments, the authors diminished a portion of the economic impacts in an ad-hoc linear fashion over 10 years. Leatherman et al. (2006) evaluated the proposed CREP program in southwest Kansas with I-O analysis. The team assumed that people generally are innovative in their response to economic change, and that an economy is never static in the way it responds to change. They suggested that it is likely that the negative impacts associated with the program would in fact diminish over time and developed an ad-hoc non-linear response function. Similar to Leatherman et al. (2006) this research applies an ad-hoc non-linear 'S-curve' response function to estimate the duration of impacts. [20]

Once the duration of the impacts are estimated, net present values can be calculated as a metric of comparison. As discussed in Section II net present value analysis can be ambiguous. For this research, it is appropriate to use net present value analysis to compare and choose between policy alternatives, since all polices were developed to yield similar water savings. However, Amosson et al. (2006) suggests that the cost of generating water savings must be weighed against the benefit of doing so. In order to accomplish this, a 'price tag' needs to be given to the water that is conserved. Since this research does not attempt to place a value on the conserved water, it is not appropriate

[20] Reference Leatherman et al. (2006) for a complete description of the S-curve used in this analysis.

to use this net present value analysis to make the decision on whether or not water-use restrictions should be implemented.

Economic Impacts of a Conversion to Dryland Production

The 'Immediate Conversion to Dryland Production Scenario' (scenario 2) assumes all irrigated production is immediately converted to dryland production, and producers are not compensated for the change. Subarea 6 in Sheridan County has 24,855 irrigated acres, as reported in Table 1. Table 31 indicates that the average irrigated acre contributes $209.47 in direct value-added, which accrues primarily to the benefit of the landowner, operator, and hired labor. Table 33 reports a value-added multiplier of 1.64, implying that each irrigated acre contributes $343.53 in total value-added to the community. The 24,855 irrigated acres is estimated to contribute $8,538,438 in total value-added to the regional economy.

Table 34 suggests that the average nonirrigated acre contributes $113.14 in direct value-added and has a value-added multiplier of 1.51, implying that each nonirrigated acre contributes $170.84 in total value-added to the community. If the entire 24,855 irrigated acres were converted to nonirrigated production they would generate $4,246,228 in total value-added to the regional economy. The total loss in value-added for the first year would be $4,292,201.

Figure 8 illustrates the time path for value-added for this scenario. The data series labeled 'Status Quo' projects the time path of the value-added to the regional economy from irrigated production. In year 11 the value-added contribution begins to decline as aquifer depletion forces some irrigated acreage to convert to nonirrigated production. The data series labeled 'Conversion to Dryland' projects the time path of the value-added to the regional economy from dryland production. The data series labeled 'Difference' represents the difference between the 'Status Quo' scenario and the 'Conversion to Dryland' scenario. For convenience and figure clarity the difference is illustrated as positive value, even though it represents a negative impact. Over time producers and input suppliers develop strategies to mitigate the negative impact and this impact diminishes. Cash flows that occur in the future may need to be discounted to reflect current values. The data series labeled 'Diminished and Discounted Difference' represents the 'Difference' curve after it has been diminished by the previously discussed S-curve and discounted based on a 5% annual discount rate. Based on these adjustments, the net present value, over the 60 year planning horizon, of the lost value-added is $43,815,439.

Economic Impacts of a Shift to Limited Irrigation

The 'Immediate Shift to Limited Irrigation Scenario' (scenario 3a) assumes all producers of irrigated crops immediately adopt a limited irrigation management strategy. A 30% reduction in water-use is achieved and producers are not compensated for the change. Subarea 6 in Sheridan County has 24,855 irrigated acres, as reported in Table 1. Table 31 indicates that the average irrigated acre contributes $209.47 in direct value-added, which accrues primarily to the benefit of the landowner, operator, and hired labor. Table 33 reports a value-added multiplier of 1.64, implying that each irrigated acre contributes $343.53 in total value-added to the community. The 24,855 irrigated acres is estimated to contribute $8,538,438 in total value-added to the regional economy.

The average limited irrigated acre contributes $183.12 in direct value-added and has a value-added multiplier of 1.64, implying that each limited irrigated acre contributes

$300.31 in total value-added to the community. If the entire 24,855 irrigated acres were converted to limited irrigated production they would generate $7,464,205 in total value-added to the regional economy. The total loss in value-added, for the first year, would be $1,074,233.

Figure 9 illustrates the time path for value-added for this scenario. The data series labeled 'Status Quo' projects the time path of the value-added to the regional economy from irrigated production. In year 11 the value-added contribution begins to decline as aquifer depletion forces some irrigated acreage to convert to nonirrigated production. The data series labeled 'Conversion to Limited Irrigation' projects the time path of the value-added to the regional economy from limited irrigation production. Under this scenario the value-added form limited irrigation does not start to diminish until year 37. The data series labeled 'Difference' represents the difference between the 'Status Quo' scenario and the 'Conversion to Dryland' scenario. For convenience and figure clarity the difference is illustrated as positive values, even though it represents a negative impact. Over time producers and input suppliers develop strategies to mitigate the negative impact and this impact diminishes. Cash flows that occur in the future may need to be discounted to reflect current values. The data series labeled 'Diminished and Discounted Difference' represents the 'Difference' curve after it has been diminished by the previously discussed S-curve and discounted based on a 5% annual discount rate. Based on these adjustments, the net present value, over the 60 year planning horizon, of the lost value-added is $7,943,605.

Economic Impacts of a Water Rights Buyout Program

The 'Water Rights Buyout Scenario' (scenario 3b) assumes that water rights are purchased and permanently retired. A 30% reduction in water-use is achieved, participating producers can immediately start producing nonirrigated crops, and producers are compensated at a rate of $800 per acre. The water rights would be purchased over a 6 year period. Subarea 6 in Sheridan County has 24,855 irrigated acres that currently contribute $8,538,438 in total value-added to the regional economy.

In this scenario 5% of the irrigated acreage (1243 acres) would be converted to dryland production in the first year. These dryland acres would yield a total value-added of $170.84 per acre, or $212,354 in total. The remaining 23612 irrigated acres would generate $343.53 per acre, or $8,111,430 in total value-added. The landowner would receive $800 per acre, of which 23% stays in the local economy, with a value-added multiplier of 1.29 (Table 39). These producer payments would yield $987,773 in total value-added to the regional economy, and would continue for six years. The cumulative value-added under this scenario is $9,311,557. Since the value-added gained from the landowner payments exceeds the reduction in value-added due to converting irrigated land to dryland this scenario increases regional total value-added in the first year. The total gain in value-added, for the first year, would be $773,119.

Figure 10 illustrates the time path for value-added for this scenario. The data series labeled 'Status Quo' projects the time path of the value-added to the regional economy from irrigated production. In year 11 the value-added contribution begins to decline as aquifer depletion forces some irrigated acreage to convert to nonirrigated production. The data series labeled 'Water Rights Buyout' projects the time path of the value-added to the regional economy. The data series labeled 'Difference' represents the difference between the 'Status Quo' scenario and the 'Water Rights Buyout' scenario. The data series labeled 'Diminished and Discounted Difference' represents the 'Difference' curve after it has been diminished by the previously discussed S-curve and discounted based on a 5% annual discount rate. Based on these adjustments, the net present value, over the 60 year planning horizon, of the lost value-added is $5,080,542.

Economic Impacts of a CREP Program

The 'CREP' (scenario 3c) assumes that water rights are purchased and permanently retired. A 30% reduction in water-use is achieved, participating producers cannot start producing nonirrigated crops until year 15, and producers are compensated at a rate of $112 per acre per year for the 15 year enrollment period. Subarea 6 in Sheridan County has 24,855 irrigated acres that currently contribute $8,538,438 in total value-added to the regional economy.

In this scenario 30% of the irrigated acreage (7456.5 acres) would be idled in the first year. Table 38 suggests that the haying, grazing, and recreational benefits from these acres would yield a total value-added to the regional economy of $51,862 ($6.96 per acre). The remaining 17398.5 irrigated acres would generate $343.53 per acre, or $5,976,907 in total value-added. The landowner would receive $112 per acre, of which 23% stays in the local economy, with a value-added multiplier of 1.29 (Table 40). These producer payments would yield $832,501 in total value-added to the regional economy, and would continue for 15 years.

The cumulative value-added, thus far, under this scenario is $6,858,301. Since the value-added gained from the landowner payments plus the haying, grazing, and recreation income does not exceed the reduction in value-added due to idling previously irrigated land this scenario decreases regional total value-added in the first year. The total loss in value-added (due to the retirement of irrigated cropland), for the first year, would be $1,680,137.

In addition to this amount, there will be a loss in value-added associated with the enrollment of the center pivot corners in the CRP program. It is estimated that 1721 acres (23.1% of 7456.5 acres) of nonirrigated cropland will be enrolled. These acres will cause a reduction in value-added of $294,016 (1721 acres X $170.84), which will be offset by $88,805 (1721 acres X $40 X 1.29) in value-added gained from the CRP payments and $11,978 (1721 acres X $6.96) in value-added gained from haying, grazing, and recreation. The total loss in value-added (due to the retirement of nonirrigated cropland), for the first year, would be $193,233. The total loss in value-added, for the first year, would be $1,873,370.

Figure 11 illustrates the time path for value-added for this scenario. The data series labeled 'Status Quo' projects the time path of the value-added to the regional economy from irrigated production. In year 11 the value-added contribution begins to decline as aquifer depletion forces some irrigated acreage to convert to nonirrigated production. The data series labeled 'CREP' projects the time path of the value-added to the regional economy. The data series labeled 'Difference' represents the difference between the 'Status Quo' scenario and the 'CREP' scenario. The data series labeled 'Diminished and Discounted Difference' represents the 'Difference' curve after it has been diminished by the previously discussed S-curve and discounted based on a 5% annual discount rate. Based on these adjustments, the net present value, over the 60 year planning horizon, of the lost value-added is $17,182,693.

V. Summary

The previous sections have concentrated on subarea number 6 in Sheridan County. In This section, the most relevant results for all subareas will be discussed.[21] In some cases, making direct comparisons across subareas is problematic since the magnitude of irrigated acres varies considerably. Indexed values will be used to make relative comparisons. When applied to a time series, indexed values are obtained by dividing each annual value by the starting value. When multiplied by 100, an indexed value represents the percent of staring values that occurs in each year.

Based on the 'Status Quo' scenario, Figure 12 illustrates the relative time trends in gross profit (associated with the acreage that was initially irrigated) for all subareas. All subareas start the series with 100% of the acreage irrigated. As water resources are diminished irrigated acreage is converted to nonirrigated production, gross profits diminish, and the indexed values start to decline. As an example, irrigated acres start to decline and gross profits diminish in year 11 in subarea number 6, in year 19 in subarea number 3, and in year 1 in subarea number 4. By year 60, revenues in subarea number 6 are reduced to approximately 76% of the initial value, revenues in subarea number 3 are reduced to approximately 84% of the initial value, and revenues in subarea number 4 are reduced to approximately 82% of the initial value. The shapes of these curves are dependent upon the subarea specific hydrological parameter, crop mix and water-use. In the absence of groundwater conservation programs, if water-use continues at current levels the model predicts that subarea numbers 2 and 4 will experience reduced gross revenues in the next few years. On the other hand, subarea number 3 will not experience gross revenue losses in the near term.

Based on the 'Limited Irrigation' scenario, Figure 13 illustrates the relative time trends in gross profit for all subareas. If producers reduce current groundwater consumption by 30%, irrigated acres and gross profits do not decline over the 60 year planning period in subareas number 3 and 6. The remaining subareas are capable of maintain their current irrigated acres in production for approximately 30 to 35 years before they start to decline. The shapes of these curves are also dependent upon the subarea specific hydrological parameter, crop mix and water-use.

Relative to the 'Status Quo' scenario, Table 41 reports the total net present value of lost producer gross profits associated with each policy option. Table 42 reports the per acre net present value of lost producer gross profits associated with each policy option. Both tables are based on a 5% discount rate. A 5% discount rate assumes current losses are worth more than future gains. As an example, a 5% discount rate implies that a dollar received or lost 60 years from now is only worth $0.05. The use of a 5% discount rate can be useful in determining the relative short-run costs borne by the producers. Table 41 and Table 42 suggest that the 'Water Rights Buyout' scenario is the least-cost method of conserving groundwater, while the 'CREP' scenario is the most expensive.[22] A CREP program tends to be more expensive because the enrolled acreage does not produce crop revenues for the first 15 years. Table 42 suggests that the short-run costs are most severe for subarea 3 in Cheyenne County. Referencing Figure 12, subarea 3

[21] An EXCEL spreadsheet with additional summary tables and figures including all subareas is available upon request.
[22] The 'Immediate Conversion to Dryland' scenario is not considered in this discussion. It is important to note that the 'Water Rights Buyout' scenario is superior to the 'Limited Irrigation' scenario because of the payments to producers.

in Cheyenne County has the 'best' water and is not expected to experience irrigated acreage reductions within the next 20 years.[23]

Relative to the 'Status Quo' scenario, Table 43 reports the total net present value of lost producer gross profits associated with each policy option. Table 44 reports the per acre net present value of lost producer gross profits associated with each policy option. Both tables are based on a -5% discount rate. A -5% discount rate assumes current losses are worth less than future gains. As an example, a -5% discount rate implies that a dollar received 60 years from now is worth $21.71 in today's value. The use of a -5% discount rate can be useful in determining the relative producer long-run gains of water conservation today. Table 43 and Table 44 suggest that the 'Limited Irrigation' scenario generates the largest future gains to conserving groundwater, while the 'Water Rights Buyout' scenario is the most expensive.[24] Table 44 suggests that subarea 3 in Cheyenne County has the least the long-run benefits. Referencing Figure 12, subarea 3 in Cheyenne County has the 'best' water and thus derives fewer benefits from conservation.

Figure 14 and Figure 15 illustrate the relative temporal changes in saturated thickness for the 'Limited Irrigation' and 'Status Quo' scenario. Of particular interest is the difference in these two graphs, as illustrated in Figure 16, which depicts to some extent the impact of water conservation on the aquifer and by extension gross profits. If subarea 3 in Cheyenne County can be categorized as having the 'best' water then subarea 2 in Sherman County and subarea 4 in Thomas County might be categorized as having the 'worst' water.[25] Notice that, in the first 20 years, there is little difference in impacts between subareas with the 'best' water and subareas with the 'worst' water. At the extremes this can be generalized as: if water resources are stable there is little economic need for water conservation and after the well has run dry water conservation can not restore the water resource. On the other hand, Figure 16 illustrate that subarea 1 in Sherman County and subarea 6 in Sherman County receive the greatest short-run benefits of water conservation. These subareas currently have sufficient saturated thickness to maintain status quo irrigation practices but can be expected to experience difficulties maintaining revenues from irrigated production in the short run. This implies that in the presence of scarce financial resources necessary to fund water conservation, economic benefits may be maximized by targeting subarea 1 in Sherman County and subarea 6 in Sherman County. Additional research is needed to quantify the relationship between the temporal changes in saturated thickness and the optimal targeting of water conservation funds across subareas.

Relative to the 'Status Quo' scenario, Table 45 reports the net present value of lost value-added to the regional economy. These data have been discounted and diminished as previously discussed. This analysis is based on a 5% discount rate. While landowners may value future profits more than current profits, and consider negative discount rates, it may be unlikely that input suppliers will feel altruistic toward future generations. These data suggest that the 'Water Rights Buyout' scenario is the

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[23] In so far as the largest saturated thickness typically implies the largest well capacity, which implies the largest revenues, then 'best' can be used as a qualitative descriptor.
[24] Relative to the 'CREP' scenario, the 'Water Rights Buyout' scenario reduces water-use over a 6 year period so there is relatively less water available for future use. The 'Immediate Conversion to Dryland' scenario is not considered in this discussion.
[25] The model implies that subarea 2 in Sherman County and subarea 4 in Thomas County currently have diminishing well capacity that is reducing revenues from irrigated production.

least-cost method of conserving groundwater, while the 'CREP' scenario is the most expensive.[26] A CREP program tends to be more expensive because the enrolled acreage does not produce crop revenues for the first 15 years.

When a researcher expresses costs as net present value the numbers can become staggering. As an example, few laymen can readily place the $66 million dollar lost value-added associated with a CREP program, as reported in Table 45, in a relevant context. Howe and Goemans (2003) suggest reporting impacts on a per capita basis. Leatherman et al. (2006) reported impacts as a percent of total regional values. Table 46 reports the first year impacts, relative to the 'Status Quo' scenario, on both a per capita and percent basis. During the first year, the 'Water Rights Buyout' scenario generates positive values due to landowner payments. The 'CREP' scenario is the most costly. Based on previously discussed assumptions, these impacts would be expected to diminish over time.

Prichett et al. (2003), Howe and Goemans (2003), and Wahl (1993) suggest, that while landowners may benefits by selling their water, third party costs are generally not fully accounted for. However, Wahl (1993) points out that this cost is simply one price that society incurs for changes in water-use and that a similar impact occurs when industries of other types relocate. The IMPLAN ABP protocol allows us to partially disaggregate impacts and approximate third party costs. More precisely, ABP allows the estimation of indirect and induced impacts to the input suppliers. Induced impacts resulting from changes in proprietary income, property income, employee compensation, and indirect business taxes are not accounted for. Table 47 reports estimates of lost value-added to input supplier sectors. Comparing Table 46 and Table 47: the 'Limited Irrigation' scenario reflects modest impacts on input suppliers, approximately 24% of the total, implying that producers bear the majority of the costs associated with the policy; the 'Water Rights Buyout' scenario has a negative impact on input suppliers indicating that the positive first year impact reported in Table 46 is the result of the relatively large payments made to landowners and; the 'CREP' scenario is the most costly to input suppliers as there is no crop production on the enrolled acreage.

VI. Conclusions

The purpose of this research was to provide input into the water planning process for relatively small sub-basins in northwest Kansas. The study considered a variety of water conservation policies aimed at achieving a 30% reduction in current groundwater consumption levels. Stakeholder input suggests that a reduction in water-use is desirable in order to preserve the Ogallala aquifer and extend its economic contribution to both the producer and the regional economy. This research estimates measures of producer gross profits and regional value-added in an endeavor to define the least costly water conservation policy. While individual policy alternatives have been compared to a 'Status Quo' scenario, this research does not attempt to place a monetary value on the saved water or place monetary value on other benefits of water conservation and should not be viewed as a cost-benefit analysis of water conservation,

[26] The 'Immediate Conversion to Dryland' scenario is not considered in this discussion. It is important to note that the 'Water Rights Buyout' scenario is superior to the 'Limited Irrigation' scenario because of the payments to producers.

In order to accomplish the goals of this research, models of 'production', models of 'temporal allocation', and models of 'regional economic impact' were developed and used to estimate impacts over a 60 year time horizon. The development of economic models that predict the future are, by their very nature, subject to error, and the results are most appropriately viewed as a 'best guess'. The estimated impacts were based on a variety of assumptions. A different set of assumptions will alter the magnitude of impacts. So long as consistency of assumptions is maintained across policy options, different assumptions may not impact the relative order of policy choices.

Of the policy options considered, the Conservation Reserve Enhancement Program is the most costly method of conserving water. While producers are compensated, based on a fair market value of land rent, this payment does not fully compensate the average producer for current losses in gross profit or the value-added contribution of crop production to the regional economy. This scenario also has the largest impact to the input supply sectors. The magnitude of these losses is the result of the programs requirement that enrolled irrigated acreage be idled, and also the assumption that additional nonirrigated acreage will be enrolled and idled. The CREP program may be the easiest water conservation policy to implement. The program has wide spread support of environmental groups and will generate additional recreational benefits. Importantly, the majority of monies necessary to fund this program will come from the federal government as opposed to Kansas taxpayers.

The Water Rights Buyout Program has short-run positive impacts and long run-negative impacts to the producer and regional economy as a whole. The program has both short-run and long-run negative impacts to the input supply sectors. While input suppliers have negative impacts, they are not as severe as those that occur with the CREP program as enrolled acreage maintains nonirrigated production. The Water Rights Buyout Program may be the most difficult water conservation policy to implement. The majority of monies necessary to fund this program will come from Kansas taxpayers.

Of the policy options considered, the 'Limited Irrigation' scenario is the least costly method of conserving water. All irrigated cropland remains in production so the impact to the input supply sector is minimized. The annual negative impact on value-added for the input supply sector was estimated as 0.09% of the total value-added for regional economy ($869,391). Producers will also incur losses as crop output will decline and producers will not be compensated. The total annual negative impact on value-added was estimated as 0.37% of the regional economy ($3,569,328). The 'Limited Irrigation' scenario may be a difficult water conservation policy to implement. While no monies will be necessary from Kansas taxpayers, producers may hesitate to voluntarily assume the risk of limited irrigation without compensation. Additional research is required to quantify this risk. Additionally, changes in current statutes may be required to modify water allocations.

The analysis was conducted based on an either-or assumption (either policy A or policy B is implemented) and the assumption that implementation is rapid. In all reality, a combination of these policies may be required to achieve the goal of a 30% reduction in groundwater consumption and it may take more time than assumed to reach the goal. If timing or funding becomes an issue, this research suggests that economic benefits may be maximized by targeting subarea 1 in Sherman County and subarea 6 in Sherman County. This is not to imply that the other subareas do not receive economic benefits from water conservation.

The adoption of a water conservation policy, similar to the technology adoption process, may reduce groundwater consumption in the short-run but will not reduce groundwater consumption over an infinite horizon. The water saved today will eventually be used and the water resource exhausted. This research suggests that a 30% reduction in groundwater consumption is not sufficient to stabilize the groundwater resource.

The reported water savings are potential water savings. The study area was chosen because of current concerns over aquifer decline rates and diminishing well capacities. Average well capacity and average water-use were the basis for this analysis. Undoubtedly, there are producers in the area that are currently incapable of fully irrigated production. If the aquifer is stabilized their water-use could increase. From an equitability and administrative standpoint, Kansas water appropriation regulations may need to be modified to ensure that water-use is constrained.

It should be noted that the long-run impact estimates of value-added are subject to a degree of uncertainty. While they have been calculated based on the stated assumptions and reported accurately, they are based on an ad hoc decay function that has not been substantiated by empirical research. However, the notion that these impacts diminish over time is firmly established by the literature. The estimates of long-run impacts to value-added should be considered tentative and subject to change based on additional empirical evidence. While the exact magnitude may be in question, since all scenarios apply the same decay function policy comparison is appropriate.

Producers in the semi-arid region of northwest Kansas adopted irrigation technologies to increase profits and reduce risk. This research estimates the impact on profits associated with the adoption of a limited irrigation management practice, but does not address the potential for increased risk exposure. Local producers have suggested that increased risk exposure is their primary concern associated with the adoption of a limited irrigation. Additional research is needed to identify and quantify the risks associated with limited irrigation.

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Tables

Table 1. Subarea Designations and Size

Item	Subarea Number 1	2	3	4	5	6
State Name	Kansas	Kansas	Kansas	Kansas	Kansas	Kansas
County Name	Sherman	Sherman	Cheyenne	Thomas	Thomas	Sheridan
Average Annual Water Use (acre feet)	23593.0	9684.0	7008.0	1054.0	35766.0	26595.0
Total Irrigated Acres	21888.0	8775.0	6211.0	1202.0	35212.0	24855.0
Average Water Use per Acre	1.08	1.10	1.13	0.88	1.02	1.07

These data are based on 1996 – 2005 averages and are consistent with the Water Rights Information System (WRIS) and data used in the Republican River Compact Administration (RRCA) model.

Table 2. Subarea Hydrological Parameters

Item	Subarea Number 1	2	3	4	5	6
Recharge (inches/year) (RRCA 1996 – 2005)	1.01	0.96	0.71	0.62	0.76	1.20
Depth to Water (feet)	162.8	167.5	208.0	159.6	146.3	164.7
Saturated Thickness (feet) (KGS)	105.5	107.4	116.1	93.3	73.3	89.8
Hydraulic Conductivity (ft/day)	25.1	20.4	23.0	27.6	46.7	40.4
Specific Yield (RRCA)	0.175	0.175	0.175	0.175	0.175	0.175
Average Well Capacity (gallons per minute)	531	473	593	461	480	587
Average Decline in Saturated Thickness (feet)	1.08	0.83	0.79	0.60	0.76	1.15

These data are consistent with the Republican River Compact Administration (RRCA) model. Average well capacity has been calculated based on methods described in Appendix 1.

Table 3. Subarea Irrigated Crop Mix

Subarea	County	Alfalfa	Corn	Sorghum	Crop Soybeans	Sunflowers	Wheat
1	Sherman	4.5%	60.0%	4.0%	7.6%	9.1%	14.8%
2	Sherman	2.3%	63.9%	4.9%	7.3%	5.5%	16.1%
3	Cheyenne	0.1%	65.4%	2.2%	18.8%	4.1%	9.5%
4	Thomas	3.7%	64.1%	5.7%	11.0%	6.7%	8.8%
5	Thomas	2.4%	60.6%	3.0%	22.0%	4.7%	7.3%
6	Sheridan	1.1%	71.3%	3.5%	16.0%	3.8%	4.2%

Table 4. Subarea Net Water Requirements Assuming Full Irrigation (inches)

Subarea	County	Crop Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
1	Sherman	15.5	14.3	9.9	12.5	6.7	6.9
2	Sherman	15.9	14.4	9.8	12.3	6.4	6.7
3	Cheyenne	14.1	13.9	10.3	12.5	6.4	7.2
4	Thomas	11.9	11.9	7.5	11.7	6.1	6.7
5	Thomas	12.8	12.6	9.2	11.9	6.1	6.8
6	Sheridan	13.8	12.7	7.8	12.1	6.3	6.9

Table 5. Subarea Crop Yields Assuming Full Irrigation

Subarea	County	Crop Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
1	Sherman	9.0	204.1	145.7	64.3	94.9	64.2
2	Sherman	9.1	204.3	145.3	63.9	93.5	63.7
3	Cheyenne	8.7	202.9	147.4	64.3	93.0	65.1
4	Thomas	8.1	194.1	133.5	62.8	91.6	63.6
5	Thomas	8.3	197.7	142.6	63.2	91.8	64.0
6	Sheridan	8.6	198.2	135.3	63.5	92.7	64.2

All yields are in bushel except alfalfa which is in tons.

Table 6. Subarea Net Water Requirements Assuming Limited Irrigation (inches)

Subarea	County	Crop Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
1	Sherman	10.9	10.0	6.9	8.8	4.7	4.8
2	Sherman	11.1	10.1	6.9	8.6	4.5	4.7
3	Cheyenne	9.9	9.7	7.2	8.8	4.5	5.0
4	Thomas	8.3	8.3	5.3	8.2	4.3	4.7
5	Thomas	9.0	8.8	6.4	8.3	4.3	4.8
6	Sheridan	9.7	8.9	5.5	8.5	4.4	4.8

Table 7. Subarea Crop Yields Assuming Limited Irrigation

		Crop					
Subarea	County	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
1	Sherman	6.7	187.7	134.0	59.1	87.3	59.1
2	Sherman	6.8	188.0	133.7	58.8	86.0	58.6
3	Cheyenne	6.5	186.7	135.6	59.1	85.6	59.9
4	Thomas	6.1	178.5	122.8	57.8	84.3	58.5
5	Thomas	6.2	181.9	131.2	58.1	84.4	58.9
6	Sheridan	6.5	182.4	124.5	58.5	85.3	59.1

All yields are in bushel except alfalfa which is in tons.

Table 8. Ranges of Irrigation Efficiency for Center Pivot and Flood Technology.

	Irrigation Efficiency		
Source	Flood	Center Pivot	SDI
Rogers et al. (1997)	50% - 90%	70% - 95%	70% - 95%
KSU - CWA	50% - 80%	85% - 90%	95%
UNL - WO	50% - 75%	70% - 80%	NR

KSU - CWA: Kansas State University's Crop Water Allocator
UNL – WO: University of Nebraska at Lincoln's Water Optimizer
SDI: Subsurface Drip Irrigation
NR: Not reported

Table 9. Subarea Percent of Acres Irrigated with Center Pivot Technology

Subarea Number					
1	2	3	4	5	6
Sherman	Sherman	Cheyenne	Thomas	Thomas	Sheridan
97.9%	92.7%	89.6%	100.0%	98.2%	90.6%

These data are based on 2005 WRISS data. Due to comparable efficiencies, these percentages include acres irrigated with center pivots, center pivots with drops, and subsurface drip irrigation technology.

Table 10. Example of a Crop Budget for Irrigated Production in Northwest Kansas

	Crop					
	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
Income per Acre						
A. Yield per acre	7.5	215	120	65	2,800	75
B. Price per unit	$101.00	$2.99	$2.65	$5.68	$11.82	$4.33
C. Net government payment	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
D. Indemnity payments	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
E. Miscellaneous income	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
F. Revenue per Acre	$757.50	$642.85	$318.00	$369.20	$330.96	$324.75
Costs per Acre						
1. Seed	$10.17	$57.46	$17.75	$33.00	$17.32	$13.20
2. Herbicide	$16.20	$30.96	$28.04	$13.44	$20.42	$4.60
3. Insecticide / Fungicide	$9.06	$37.43	$0.00	$0.00	$15.10	$0.00
4. Fertilizer and Lime	$32.38	$100.39	$53.33	$14.50	$50.17	$45.46
5. Crop Consulting	$6.50	$6.50	$6.25	$6.25	$6.50	$6.00
6. Crop Insurance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
7. Drying	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
8. Miscellaneous	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
9. Custom Hire / Machinery Expense	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10. Non-machinery Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
11. Irrigation						
a. Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b. Fuel and Oil	$97.73	$81.44	$65.15	$73.30	$48.86	$40.72
c. Repairs and Maintenance	$7.92	$6.60	$5.28	$5.94	$3.96	$3.30
d. Depreciation on Equipment and Well	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
e. Interest on Equipment	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
12. Land Charge / Rent	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
13. Interest	$5.70	$9.92	$5.57	$4.69	$5.17	$3.70
H. Total Cost per Acre	$195.65	$340.70	$191.37	$161.12	$177.50	$126.98
I. Returns per Acre	$561.85	$302.15	$126.63	$208.08	$153.46	$197.77

Table 11. Gross Daily Application Rates at Various Well Capacities

Well Capacity (gallons per minute)	Acres	Gross Daily Application Rate (inches per day per acre)
1200	125	0.51
1150	125	0.49
1100	125	0.47
1050	125	0.45
1000	125	0.42
950	125	0.40
900	125	0.38
850	125	0.36
800	125	0.34
750	125	0.32
700	125	0.30
650	125	0.28
600	125	0.25
550	125	0.23
500	125	0.21
475	125	0.20
450	125	0.19
400	125	0.17
350	125	0.15

Table 12. Required Minimum Daily Application Rate (inches per acre per day)

Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
0.2	0.2	0.16	0.16	0.12	0.08

Table 13. Subarea Non-Irrigated Crop Mix

					Crop		
Subarea	County	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
1	Sherman	0.0%	10.9%	7.2%	0.0%	12.9%	69.0%
2	Sherman	0.0%	10.9%	7.2%	0.0%	12.9%	69.0%
3	Cheyenne	0.0%	0.0%	3.9%	0.0%	0.0%	96.1%
4	Thomas	0.0%	14.4%	14.8%	0.0%	0.0%	70.8%
5	Thomas	0.0%	14.4%	14.8%	0.0%	0.0%	70.8%
6	Sheridan	0.0%	20.1%	17.5%	0.0%	0.0%	62.4%

Table 14. Subarea Non-Irrigated Crop Yield

		Crop					
Subarea	County	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
1	Sherman	4.8	46.4	40.2	14.9	36.3	29.6
2	Sherman	4.8	46.4	40.2	14.9	36.3	29.6
3	Cheyenne	4.7	44.2	31.1	13.1	34.4	29.2
4	Thomas	4.4	55.8	51.3	15.6	32.6	32.6
5	Thomas	4.4	55.8	51.3	15.6	32.6	32.6
6	Sheridan	4.7	63.8	55.9	13.8	26.8	36.9

Table 15. Crop Budgets for Non-Irrigated Production in Northwest Kansas

	Crop					
	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat
Income per Acre						
A. Yield per acre	5.5	95	85	35	1,800	50
B. Price per unit	$101.00	$2.99	$2.65	$5.68	$11.82	$4.33
C. Net government payment	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
D. Indemnity payments	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
E. Miscellaneous income	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
F. Revenue per Acre	$555.50	$284.05	$225.25	$198.80	$212.76	$216.50
Costs per Acre						
1. Seed	$10.17	$33.80	$7.92	$26.40	$14.80	$8.80
2. Herbicide	$3.03	$34.38	$34.38	$24.40	$37.10	$9.48
3. Insecticide / Fungicide	$10.02	$1.00	$0.00	$0.00	$15.10	$0.00
4. Fertilizer and Lime	$22.13	$55.80	$47.52	$8.03	$40.32	$30.48
5. Crop Consulting	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
6. Crop Insurance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
7. Drying	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
8. Miscellaneous	$5.50	$5.50	$5.50	$5.50	$5.50	$5.50
9. Custom Hire / Machinery Expense	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10. Non-machinery Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
11. Irrigation						
a. Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b. Fuel and Oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
c. Repairs and Maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
d. Depreciation on Equipment and Well	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
e. Interest on Equipment	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
12. Land Charge / Rent	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
13. Interest	$1.53	$3.91	$2.86	$1.93	$3.38	$1.63
H. Total Cost per Acre	$52.38	$134.40	$98.18	$66.26	$116.21	$55.90
I. Returns per Acre	$503.12	$149.65	$127.07	$132.54	$96.55	$160.60

Table 16. Status Quo Projected Impacts on Future Hydrology, Crop Mix, and Water-Use in Subarea 6 of Sheridan County

						Corn						
		Hydrology			Flood Technology			Center Pivot Technology			Total	
Time	ST	GPM	GDAR	Acres	ConvCP	GWU	Acres	ConvDL	GWU	TWU	AAFWU	ΔST
1	89.8	587.4	0.249	1667	0	28220	16062	0	214728	26723.6	1.08	1.15
2	88.6	575.4	0.244	1417	250	23987	16312	0	218070	26474.1	1.07	1.14
3	87.5	563.7	0.239	1204	462	20389	16525	0	220910	26406.1	1.06	1.13
4	86.4	552.1	0.234	1023	643	17330	16705	0	223325	26348.3	1.06	1.13
5	85.2	540.6	0.229	870	797	14731	16859	0	225377	26299.2	1.06	1.13
6	84.1	529.3	0.225	739	927	12521	16989	0	227121	26257.5	1.06	1.12
7	83.0	518.1	0.220	629	1038	10643	17100	0	228604	26222.0	1.06	1.12
8	81.9	507.1	0.215	534	1132	9047	17195	0	229864	26191.9	1.06	1.12
9	80.7	496.1	0.210	454	1212	7690	17275	0	230936	26166.2	1.06	1.12
10	79.6	485.2	0.206	386	1281	6536	17343	0	231846	26144.4	1.05	1.12
11	78.5	474.5	0.201	328	1338	5556	17401	0	232620	26125.9	1.05	1.12
12	77.4	463.9	0.197	274	1392	4647	17175	279	229603	25792.1	1.05	1.09
13	76.3	453.5	0.192	228	1438	3862	16837	664	225079	25341.2	1.05	1.07
14	75.2	443.5	0.188	190	1477	3210	16502	1037	220608	24906.2	1.05	1.04
15	74.2	433.9	0.184	158	1509	2669	16173	1398	216207	24486.7	1.05	1.01
16	73.2	424.6	0.180	131	1535	2220	15850	1748	211888	24081.9	1.05	0.98
17	72.2	415.6	0.176	109	1557	1847	15534	2086	207659	23691.3	1.05	0.96
18	71.2	406.9	0.173	91	1576	1537	15224	2414	203526	23314.3	1.04	0.93
19	70.3	398.5	0.169	76	1591	1280	14923	2731	199494	22950.2	1.04	0.91
20	69.4	390.4	0.166	63	1604	1066	14629	3037	195563	22598.5	1.04	0.89
21	68.5	382.5	0.162	52	1614	887	14342	3334	191734	22258.6	1.04	0.87
22	67.6	374.9	0.159	44	1623	739	14064	3622	188009	21901.2	1.04	0.84
23	66.8	367.5	0.156	36	1630	616	13793	3899	184393	21490.1	1.04	0.82
24	66.0	360.4	0.153	30	1636	514	13532	4166	180904	21095.1	1.04	0.79
25	65.2	353.6	0.150	25	1641	428	13280	4423	177537	20715.2	1.04	0.77
26	64.4	347.1	0.147	21	1645	357	13037	4670	174288	20349.8	1.04	0.74
27	63.7	340.8	0.145	18	1649	298	12803	4908	171154	19998.2	1.04	0.72
28	63.0	334.7	0.142	15	1652	249	12577	5138	168129	19659.8	1.03	0.70
29	62.3	328.8	0.140	12	1654	208	12358	5358	165210	19333.8	1.03	0.68
30	61.6	323.2	0.137	10	1656	174	12148	5571	162393	19019.7	1.03	0.66
31	60.9	317.7	0.135	9	1658	145	11944	5776	159674	18717.0	1.03	0.64
32	60.3	312.5	0.133	7	1659	121	11748	5974	157049	18425.2	1.03	0.62
33	59.7	307.4	0.130	6	1661	101	11558	6165	154514	18143.6	1.03	0.60
34	59.1	302.5	0.128	5	1661	85	11375	6349	152065	17872.0	1.03	0.58
35	58.5	297.8	0.126	4	1662	71	11198	6527	149700	17609.8	1.03	0.57
36	57.9	293.3	0.124	4	1663	59	11027	6698	147414	17356.7	1.03	0.55
37	57.4	288.9	0.123	3	1664	50	10862	6864	145205	17112.1	1.03	0.53
38	56.8	284.6	0.121	2	1664	42	10702	7024	143070	16875.9	1.03	0.52
39	56.3	280.5	0.119	2	1664	35	10548	7179	141005	16643.7	1.03	0.50
41	55.3	272.7	0.116	1	1665	25	10254	7473	137081	16196.8	1.03	0.47
43	54.4	265.4	0.113	1	1665	17	9980	7748	133413	15779.5	1.02	0.45
45	53.5	258.5	0.110	1	1666	12	9723	8005	129983	15389.4	1.02	0.42
47	52.7	252.1	0.107	1	1666	9	9483	8245	126771	15024.3	1.02	0.40
49	51.9	246.2	0.104	0	1666	6	9258	8471	123762	14682.2	1.02	0.38
51	51.1	240.5	0.102	0	1666	4	9047	8682	120940	14361.6	1.02	0.36
52	50.8	237.9	0.101	0	1666	4	8946	8783	119595	14208.7	1.02	0.35
53	50.4	235.3	0.100	0	1666	3	8849	8880	118292	14060.7	1.02	0.34
54	50.1	232.8	0.099	0	1666	3	8754	8975	117029	13917.2	1.02	0.33
55	49.8	230.3	0.098	0	1666	2	8663	9066	115805	13778.1	1.02	0.32
56	49.5	228.0	0.097	0	1666	2	8574	9155	114618	13643.3	1.02	0.31
57	49.1	225.7	0.096	0	1666	2	8488	9241	113467	13512.6	1.02	0.30
58	48.8	223.5	0.095	0	1666	1	8404	9325	112351	13385.8	1.02	0.29
59	48.6	221.3	0.094	0	1666	1	8323	9405	111269	13262.9	1.02	0.29
60	48.3	219.2	0.093	0	1666	1	8245	9484	110219	13143.6	1.02	0.28

Time is time measured in years; ST is saturated thickness measured in feet; GPM is gallons per minute; GDAR is the gross daily application of the well measured in inches; ConvCP is the number of flood irrigated acreage converted to center pivot technology; GWU is the gross water use measured in inches; ConvDL is the number of center pivot acres converted to dryland production; TWU is the total water use measured in acre-feet; AAFWU is the average acre foot water usage per acre measured in feet; ΔST is the change in saturated thickness measured in feet..

Table 17. Status Quo Projected Impacts on Future Gross Profits in Subarea 6 of Sheridan County

Time	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat	Non Irrigated	Program Payments	Total
1	$168,344	$4,003,719	$137,510	$720,320	$109,884	$140,051	$0	$0	$5,279,829
2	$168,344	$4,003,719	$137,510	$720,320	$109,884	$140,051	$0	$0	$5,279,829
3	$168,344	$4,003,719	$137,510	$720,320	$108,335	$140,051	$1,497	$0	$5,279,776
4	$168,344	$4,003,719	$137,510	$720,320	$107,018	$140,051	$2,769	$0	$5,279,731
5	$168,344	$4,003,719	$137,510	$720,320	$105,899	$140,051	$3,850	$0	$5,279,693
6	$168,344	$4,003,719	$137,510	$720,320	$104,947	$140,051	$4,769	$0	$5,279,661
7	$168,344	$4,003,719	$137,510	$720,320	$104,138	$140,051	$5,550	$0	$5,279,633
8	$168,344	$4,003,719	$137,510	$720,320	$103,451	$140,051	$6,214	$0	$5,279,610
9	$168,344	$4,003,719	$137,510	$720,320	$102,867	$140,051	$6,779	$0	$5,279,590
10	$168,344	$4,003,719	$137,510	$720,320	$102,370	$140,051	$7,258	$0	$5,279,573
11	$168,344	$4,003,719	$137,510	$720,320	$101,948	$140,051	$7,666	$0	$5,279,558
12	$165,691	$3,940,626	$137,510	$720,320	$101,589	$140,051	$39,872	$0	$5,245,659
13	$162,038	$3,853,729	$137,510	$720,320	$101,284	$140,051	$84,046	$0	$5,198,977
14	$158,497	$3,769,517	$137,510	$720,320	$101,024	$140,051	$126,819	$0	$5,153,738
15	$155,067	$3,687,960	$137,510	$720,320	$100,804	$140,051	$168,214	$0	$5,109,927
16	$151,748	$3,609,008	$137,510	$720,320	$100,617	$140,051	$208,262	$0	$5,067,516
17	$148,535	$3,532,596	$137,510	$720,320	$100,458	$140,051	$247,001	$0	$5,026,470
18	$145,426	$3,458,648	$137,510	$720,320	$100,322	$140,051	$284,471	$0	$4,986,749
19	$142,417	$3,387,085	$137,510	$720,320	$100,207	$140,051	$320,718	$0	$4,948,309
20	$139,504	$3,317,824	$137,510	$720,320	$100,109	$140,051	$355,786	$0	$4,911,105
21	$136,685	$3,250,781	$137,510	$720,320	$100,026	$140,051	$389,720	$0	$4,875,094
22	$133,956	$3,185,871	$136,691	$716,033	$99,956	$140,051	$425,812	$0	$4,838,370
23	$131,319	$3,123,149	$134,014	$702,008	$99,896	$140,051	$468,164	$0	$4,798,600
24	$128,783	$3,062,837	$131,437	$688,510	$99,845	$140,051	$508,891	$0	$4,760,354
25	$126,344	$3,004,822	$128,957	$675,517	$99,801	$140,051	$548,069	$0	$4,723,560
26	$123,996	$2,948,996	$126,568	$663,005	$99,764	$140,051	$585,770	$0	$4,688,151
27	$121,737	$2,895,256	$124,268	$650,955	$99,733	$140,051	$622,063	$0	$4,654,062
28	$119,561	$2,843,505	$122,052	$639,346	$99,706	$140,051	$657,013	$0	$4,621,233
29	$117,464	$2,793,651	$119,916	$628,158	$99,684	$140,051	$690,682	$0	$4,589,606
30	$115,444	$2,745,606	$117,857	$617,373	$99,664	$140,051	$723,130	$0	$4,559,125
31	$113,497	$2,699,290	$115,872	$606,973	$99,648	$140,051	$754,410	$0	$4,529,740
32	$111,619	$2,654,623	$113,957	$596,940	$99,634	$140,051	$784,576	$0	$4,501,400
33	$109,807	$2,611,532	$112,109	$587,260	$99,622	$140,051	$813,678	$0	$4,474,059
34	$108,058	$2,569,948	$110,325	$577,917	$99,612	$140,051	$841,761	$0	$4,447,674
35	$106,371	$2,529,806	$108,603	$568,897	$99,604	$140,051	$868,872	$0	$4,422,203
36	$104,741	$2,491,042	$106,940	$560,185	$99,596	$140,051	$895,051	$0	$4,397,606
37	$103,166	$2,453,599	$105,333	$551,769	$99,590	$140,051	$920,338	$0	$4,373,847
38	$101,645	$2,417,420	$103,781	$543,637	$99,585	$140,051	$944,771	$0	$4,350,890
39	$100,175	$2,382,453	$102,280	$535,777	$98,753	$140,051	$969,185	$0	$4,328,673
40	$98,754	$2,348,664	$100,830	$528,180	$97,350	$140,051	$993,355	$0	$4,307,184
41	$97,381	$2,316,017	$99,429	$520,841	$95,994	$140,051	$1,016,708	$0	$4,286,422
42	$96,055	$2,284,465	$98,075	$513,747	$94,685	$140,051	$1,039,278	$0	$4,266,356
43	$94,772	$2,253,964	$96,766	$506,889	$93,419	$140,051	$1,061,096	$0	$4,246,957
44	$93,532	$2,224,470	$95,500	$500,257	$92,195	$140,051	$1,082,194	$0	$4,228,200
45	$92,333	$2,195,944	$94,275	$493,843	$91,012	$140,051	$1,102,599	$0	$4,210,057
46	$91,172	$2,168,347	$93,091	$487,638	$89,867	$140,051	$1,122,340	$0	$4,192,506
47	$90,050	$2,141,643	$91,944	$481,633	$88,760	$140,051	$1,141,442	$0	$4,175,522
48	$88,963	$2,115,796	$90,835	$475,821	$87,688	$140,051	$1,159,931	$0	$4,159,084
49	$87,911	$2,090,774	$89,761	$470,194	$86,650	$140,051	$1,177,830	$0	$4,143,170
50	$86,892	$2,066,546	$88,720	$464,746	$85,646	$140,051	$1,195,160	$0	$4,127,761
51	$85,905	$2,043,081	$87,713	$459,469	$84,673	$140,051	$1,211,945	$0	$4,112,838
52	$84,950	$2,020,351	$86,737	$454,357	$83,731	$140,051	$1,228,204	$0	$4,098,381
53	$84,024	$1,998,329	$85,792	$449,405	$82,818	$140,051	$1,243,957	$0	$4,084,375
54	$83,126	$1,976,987	$84,876	$444,606	$81,933	$140,051	$1,259,223	$0	$4,070,802
55	$82,257	$1,956,303	$83,988	$439,954	$81,076	$140,051	$1,274,019	$0	$4,057,647
56	$81,413	$1,936,251	$83,127	$435,445	$80,244	$140,051	$1,288,362	$0	$4,044,894
57	$80,596	$1,916,809	$82,292	$431,073	$79,439	$140,051	$1,302,269	$0	$4,032,529
58	$79,803	$1,897,956	$81,483	$426,833	$78,657	$140,051	$1,315,755	$0	$4,020,538
59	$79,034	$1,879,670	$80,698	$422,720	$77,899	$140,051	$1,328,835	$0	$4,008,908
60	$78,289	$1,861,932	$79,936	$418,731	$77,164	$140,051	$1,341,524	$0	$3,997,627

Table 18. Impacts on Future Hydrology, Crop Mix, and Water-Use in Subarea 6 of Sheridan County, Based on a Limited Irrigation Scenario.

							Corn					
		Hydrology			Flood Technology			Center Pivot Technology			Total	
Time	ST	GPM	GDAR	Acres	ConvCP	GWU	Acres	ConvDL	GWU	TWU	AAFWU	ΔST
1	89.8	587.4	0.249	1667	0	19754	16062	0	150310	18706.5	0.75	0.64
2	89.2	580.8	0.246	1417	250	16791	16312	0	152649	18531.8	0.75	0.63
3	88.5	574.3	0.244	1204	462	14272	16525	0	154637	18484.3	0.74	0.62
4	87.9	567.9	0.241	1023	643	12131	16705	0	156327	18443.8	0.74	0.62
5	87.3	561.5	0.238	870	797	10312	16859	0	157764	18409.5	0.74	0.62
6	86.7	555.2	0.236	739	927	8765	16989	0	158985	18380.2	0.74	0.62
7	86.1	548.9	0.233	629	1038	7450	17100	0	160023	18355.4	0.74	0.61
8	85.4	542.7	0.230	534	1132	6333	17195	0	160905	18334.3	0.74	0.61
9	84.8	536.5	0.228	454	1212	5383	17275	0	161655	18316.4	0.74	0.61
10	84.2	530.4	0.225	386	1281	4575	17343	0	162292	18301.1	0.74	0.61
11	83.6	524.3	0.222	328	1338	3889	17401	0	162834	18288.1	0.74	0.61
12	83.0	518.2	0.220	279	1388	3306	17450	0	163295	18277.1	0.74	0.61
13	82.4	512.2	0.217	237	1429	2810	17492	0	163686	18267.8	0.74	0.61
14	81.8	506.2	0.215	201	1465	2388	17527	0	164019	18259.8	0.74	0.61
15	81.2	500.3	0.212	171	1495	2030	17558	0	164302	18253.0	0.74	0.61
16	80.6	494.3	0.210	146	1521	1726	17583	0	164542	18247.3	0.74	0.61
17	80.0	488.4	0.207	124	1543	1467	17605	0	164747	18242.4	0.74	0.61
18	79.4	482.6	0.205	105	1561	1247	17624	0	164920	18238.2	0.74	0.61
19	78.7	476.7	0.202	89	1577	1060	17639	0	165068	18234.7	0.74	0.61
20	78.1	470.9	0.200	76	1591	901	17653	0	165193	18231.7	0.74	0.61
21	77.5	465.2	0.197	65	1602	766	17664	0	165300	18229.1	0.74	0.61
22	76.9	459.4	0.195	55	1612	651	17674	0	165391	18227.0	0.74	0.61
23	76.3	453.7	0.192	47	1620	553	17682	0	165468	18225.1	0.74	0.61
24	75.7	448.0	0.190	40	1627	470	17689	0	165533	18223.6	0.74	0.61
25	75.1	442.3	0.188	34	1633	400	17695	0	165589	18222.2	0.74	0.61
26	74.5	436.7	0.185	29	1638	340	17700	0	165636	18221.1	0.74	0.61
27	73.9	431.1	0.183	24	1642	289	17704	0	165677	18220.1	0.74	0.61
28	73.3	425.5	0.181	21	1646	245	17708	0	165711	18219.3	0.74	0.61
29	72.7	420.0	0.178	18	1649	209	17711	0	165740	18218.6	0.74	0.61
30	72.1	414.5	0.176	15	1652	177	17714	0	165765	18218.0	0.74	0.61
31	71.5	409.0	0.174	13	1654	151	17716	0	165786	18217.5	0.74	0.61
32	70.9	403.5	0.171	11	1656	128	17718	0	165803	18217.1	0.74	0.61
33	70.3	398.1	0.169	9	1657	109	17720	0	165819	18216.7	0.74	0.61
34	69.7	392.7	0.167	8	1659	93	17721	0	165831	18216.4	0.74	0.61
35	69.1	387.3	0.164	7	1660	79	17722	0	165842	18216.2	0.74	0.61
36	68.4	381.9	0.162	6	1661	67	17723	0	165852	18215.9	0.74	0.61
37	67.8	376.6	0.160	5	1662	57	17700	24	165634	18196.6	0.74	0.60
38	67.2	371.3	0.158	4	1662	48	17452	273	163316	17999.3	0.73	0.59
39	66.6	366.2	0.155	3	1663	40	17211	515	161057	17807.1	0.73	0.58
41	65.5	356.3	0.151	2	1664	28	16746	980	156711	17437.5	0.73	0.56
43	64.4	346.9	0.147	2	1665	20	16305	1422	152582	17086.7	0.73	0.53
45	63.4	337.9	0.143	1	1665	14	15886	1842	148656	16753.3	0.73	0.51
47	62.3	329.4	0.140	1	1666	10	15487	2241	144922	16436.3	0.73	0.49
49	61.4	321.4	0.136	1	1666	7	15107	2621	141368	16134.7	0.73	0.47
51	60.4	313.7	0.133	0	1666	5	14745	2983	137984	15847.6	0.73	0.45
52	60.0	309.9	0.132	0	1666	4	14571	3158	136352	15709.2	0.73	0.44
53	59.5	306.3	0.130	0	1666	3	14401	3328	134759	15574.0	0.73	0.43
54	59.1	302.8	0.128	0	1666	3	14234	3494	133204	15442.1	0.73	0.43
55	58.7	299.3	0.127	0	1666	2	14072	3657	131685	15286.9	0.73	0.42
56	58.3	296.0	0.126	0	1666	2	13914	3814	130207	15124.0	0.73	0.41
57	57.9	292.7	0.124	0	1666	2	13761	3968	128773	14965.8	0.73	0.40
58	57.5	289.5	0.123	0	1666	1	13612	4117	127379	14812.2	0.73	0.39
59	57.1	286.5	0.122	0	1666	1	13467	4261	126026	14662.9	0.73	0.38
60	56.7	283.5	0.120	0	1666	1	13327	4402	124711	14518.0	0.73	0.37

Time is time measured in years; ST is saturated thickness measured in feet; GPM is gallons per minute; GDAR is the gross daily application of the well measured in inches; ConvCP is the number of flood irrigated acreage converted to center pivot technology; GWU is the gross water use measured in inches; ConvDL is the number of center pivot acres converted to dryland production; TWU is the total water use measured in acre-feet; AAFWU is the average acre foot water usage per acre measured in feet; ΔST is the change in saturated thickness measured in feet..

Table 19. Impacts on Future on Crop Revenues in Subarea 6 of Sheridan County, Based on a Limited Irrigation Scenario

Time	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat	Non Irrigated	Program Payments	Total
1	$124,402	$3,583,519	$124,473	$658,287	$98,325	$128,455	$0	$0	$4,717,461
2	$124,402	$3,583,519	$124,473	$658,287	$98,325	$128,455	$0	$0	$4,717,461
3	$124,402	$3,583,519	$124,473	$658,287	$96,939	$128,455	$1,497	$0	$4,717,571
4	$124,402	$3,583,519	$124,473	$658,287	$95,760	$128,455	$2,769	$0	$4,717,665
5	$124,402	$3,583,519	$124,473	$658,287	$94,759	$128,455	$3,850	$0	$4,717,745
6	$124,402	$3,583,519	$124,473	$658,287	$93,907	$128,455	$4,769	$0	$4,717,812
7	$124,402	$3,583,519	$124,473	$658,287	$93,184	$128,455	$5,550	$0	$4,717,870
8	$124,402	$3,583,519	$124,473	$658,287	$92,569	$128,455	$6,214	$0	$4,717,919
9	$124,402	$3,583,519	$124,473	$658,287	$92,046	$128,455	$6,779	$0	$4,717,960
10	$124,402	$3,583,519	$124,473	$658,287	$91,601	$128,455	$7,258	$0	$4,717,996
11	$124,402	$3,583,519	$124,473	$658,287	$91,223	$128,455	$7,666	$0	$4,718,026
12	$124,402	$3,583,519	$124,473	$658,287	$90,902	$128,455	$8,013	$0	$4,718,051
13	$124,402	$3,583,519	$124,473	$658,287	$90,629	$128,455	$8,308	$0	$4,718,073
14	$124,402	$3,583,519	$124,473	$658,287	$90,397	$128,455	$8,558	$0	$4,718,091
15	$124,402	$3,583,519	$124,473	$658,287	$90,200	$128,455	$8,771	$0	$4,718,107
16	$124,402	$3,583,519	$124,473	$658,287	$90,033	$128,455	$8,952	$0	$4,718,120
17	$124,402	$3,583,519	$124,473	$658,287	$89,890	$128,455	$9,106	$0	$4,718,132
18	$124,402	$3,583,519	$124,473	$658,287	$89,769	$128,455	$9,236	$0	$4,718,141
19	$124,402	$3,583,519	$124,473	$658,287	$89,666	$128,455	$9,347	$0	$4,718,149
20	$124,402	$3,583,519	$124,473	$658,287	$89,579	$128,455	$9,442	$0	$4,718,156
21	$124,402	$3,583,519	$124,473	$658,287	$89,504	$128,455	$9,522	$0	$4,718,162
22	$124,402	$3,583,519	$124,473	$658,287	$89,441	$128,455	$9,590	$0	$4,718,167
23	$124,402	$3,583,519	$124,473	$658,287	$89,387	$128,455	$9,648	$0	$4,718,172
24	$124,402	$3,583,519	$124,473	$658,287	$89,342	$128,455	$9,698	$0	$4,718,175
25	$124,402	$3,583,519	$124,473	$658,287	$89,303	$128,455	$9,740	$0	$4,718,178
26	$124,402	$3,583,519	$124,473	$658,287	$89,270	$128,455	$9,775	$0	$4,718,181
27	$124,402	$3,583,519	$124,473	$658,287	$89,242	$128,455	$9,806	$0	$4,718,183
28	$124,402	$3,583,519	$124,473	$658,287	$89,218	$128,455	$9,831	$0	$4,718,185
29	$124,402	$3,583,519	$124,473	$658,287	$89,198	$128,455	$9,853	$0	$4,718,187
30	$124,402	$3,583,519	$124,473	$658,287	$89,180	$128,455	$9,872	$0	$4,718,188
31	$124,402	$3,583,519	$124,473	$658,287	$89,166	$128,455	$9,888	$0	$4,718,189
32	$124,402	$3,583,519	$124,473	$658,287	$89,153	$128,455	$9,901	$0	$4,718,190
33	$124,402	$3,583,519	$124,473	$658,287	$89,143	$128,455	$9,912	$0	$4,718,191
34	$124,402	$3,583,519	$124,473	$658,287	$89,134	$128,455	$9,922	$0	$4,718,192
35	$124,402	$3,583,519	$124,473	$658,287	$89,126	$128,455	$9,930	$0	$4,718,192
36	$124,402	$3,583,519	$124,473	$658,287	$89,120	$128,455	$9,937	$0	$4,718,193
37	$124,233	$3,578,647	$124,473	$658,287	$89,114	$128,455	$12,692	$0	$4,715,901
38	$122,489	$3,528,420	$124,473	$658,287	$89,109	$128,455	$41,033	$0	$4,692,267
39	$120,791	$3,479,501	$124,473	$658,287	$89,105	$128,455	$68,636	$0	$4,669,248
40	$119,137	$3,431,847	$124,473	$658,287	$89,102	$128,455	$95,524	$0	$4,646,825
41	$117,525	$3,385,419	$124,473	$658,287	$89,099	$128,455	$121,720	$0	$4,624,978
42	$115,955	$3,340,175	$124,473	$658,287	$89,097	$128,455	$147,247	$0	$4,603,689
43	$114,424	$3,296,079	$124,473	$658,287	$89,094	$128,455	$172,127	$0	$4,582,940
44	$112,932	$3,253,094	$124,473	$658,287	$89,093	$128,455	$196,379	$0	$4,562,713
45	$111,477	$3,211,185	$124,473	$658,287	$89,091	$128,455	$220,025	$0	$4,542,993
46	$110,058	$3,170,318	$124,473	$658,287	$89,090	$128,455	$243,082	$0	$4,523,763
47	$108,674	$3,130,460	$124,473	$658,287	$89,089	$128,455	$265,569	$0	$4,505,008
48	$107,325	$3,091,580	$124,473	$658,287	$89,088	$128,455	$287,505	$0	$4,486,713
49	$106,008	$3,053,648	$124,473	$658,287	$89,087	$128,455	$308,906	$0	$4,468,864
50	$104,723	$3,016,636	$124,473	$658,287	$89,086	$128,455	$329,787	$0	$4,451,447
51	$103,469	$2,980,514	$124,473	$658,287	$89,086	$128,455	$350,167	$0	$4,434,450
52	$102,245	$2,945,257	$124,473	$658,287	$89,085	$128,455	$370,058	$0	$4,417,860
53	$101,050	$2,910,838	$124,473	$658,287	$89,085	$128,455	$389,476	$0	$4,401,664
54	$99,883	$2,877,233	$124,473	$658,287	$89,085	$128,455	$408,435	$0	$4,385,851
55	$98,744	$2,844,417	$123,501	$653,142	$89,084	$128,455	$431,213	$0	$4,368,556
56	$97,636	$2,812,499	$122,115	$645,813	$89,084	$128,455	$455,294	$0	$4,350,896
57	$96,560	$2,781,506	$120,769	$638,697	$89,084	$128,455	$478,677	$0	$4,333,748
58	$95,515	$2,751,407	$119,462	$631,785	$89,084	$128,455	$501,386	$0	$4,317,094
59	$94,500	$2,722,170	$118,193	$625,072	$89,084	$128,455	$523,444	$0	$4,300,918
60	$93,514	$2,693,766	$116,960	$618,550	$89,083	$128,455	$544,874	$0	$4,285,202

Table 20. Impacts on Future Hydrology, and Water-Use in Subarea 6 of Sheridan County, Based on a Water Rights Buyout Scenario.

	Corn											
	Hydrology			Flood Technology			Center Pivot Technology				Total	
Time	ST	GPM	GDAR	Acres	ConvCP	GWU	Acres	ConvDL	GWU	TWU	AAFWU	ΔST
1	89.8	587.4	0.25	1667	0	28220	15176	886	202878	25420.1	1.1	1.07
2	88.7	576.3	0.24	1417	250	23987	14539	1773	194369	23867.1	1.1	0.97
3	87.8	566.3	0.24	1204	212	20389	13865	2659	185359	22503.0	1.1	0.88
4	86.9	557.2	0.24	1023	181	17330	13160	3546	175923	21147.9	1.1	0.79
5	86.1	549.1	0.23	870	154	14731	12427	4432	166125	19800.7	1.1	0.71
6	85.4	542.0	0.23	739	130	12521	11671	5319	156019	18459.9	1.1	0.62
7	84.8	535.7	0.23	629	111	10643	11782	5319	157502	18428.3	1.1	0.62
8	84.1	529.5	0.22	534	94	9047	11876	5319	158763	18401.4	1.1	0.62
9	83.5	523.4	0.22	454	80	7690	11956	5319	159834	18378.6	1.1	0.62
10	82.9	517.3	0.22	386	68	6536	12024	5319	160744	18359.1	1.1	0.61
11	82.3	511.2	0.22	328	58	5556	12082	5319	161518	18342.6	1.1	0.61
12	81.7	505.1	0.21	279	49	4722	12131	5319	162176	18328.6	1.1	0.61
13	81.1	499.1	0.21	237	42	4014	12173	5319	162736	18316.7	1.1	0.61
14	80.4	493.2	0.21	201	36	3412	12209	5319	163211	18306.5	1.1	0.61
15	79.8	487.3	0.21	171	30	2900	12239	5319	163615	18297.9	1.1	0.61
16	79.2	481.4	0.20	146	26	2465	12265	5319	163958	18290.6	1.1	0.61
17	78.6	475.5	0.20	124	22	2095	12286	5319	164250	18284.4	1.1	0.61
18	78.0	469.7	0.20	105	19	1775	12260	5364	163902	18227.9	1.1	0.61
19	77.4	463.9	0.20	88	17	1490	12126	5514	162110	18052.1	1.0	0.59
20	76.8	458.3	0.19	74	14	1251	11993	5662	160325	17880.8	1.0	0.58
21	76.2	452.8	0.19	62	12	1051	11860	5807	158552	17713.6	1.0	0.57
22	75.7	447.4	0.19	52	10	882	11729	5948	156796	17550.6	1.0	0.56
23	75.1	442.1	0.19	44	8	741	11599	6086	155060	17391.6	1.0	0.55
24	74.5	437.0	0.19	37	7	623	11471	6221	153346	17236.3	1.0	0.54
25	74.0	432.0	0.18	31	6	523	11344	6353	151657	17084.8	1.0	0.53
26	73.5	427.1	0.18	26	5	440	11220	6483	149995	16936.8	1.0	0.52
27	72.9	422.3	0.18	22	4	370	11098	6609	148360	16792.3	1.0	0.51
28	72.4	417.6	0.18	18	3	311	10978	6733	146752	16651.1	1.0	0.50
29	71.9	413.0	0.18	15	3	261	10859	6854	145174	16513.1	1.0	0.50
30	71.4	408.5	0.17	13	2	220	10744	6972	143624	16378.2	1.0	0.49
31	70.9	404.1	0.17	11	2	185	10630	7088	142104	16246.4	1.0	0.48
32	70.5	399.8	0.17	9	2	155	10518	7201	140612	16117.4	1.0	0.47
33	70.0	395.6	0.17	8	1	131	10409	7312	139149	15991.3	1.0	0.46
34	69.5	391.5	0.17	6	1	110	10301	7421	137714	15867.9	1.0	0.45
35	69.1	387.5	0.16	5	1	92	10196	7527	136308	15747.2	1.0	0.45
36	68.6	383.5	0.16	5	1	78	10093	7631	134929	15629.0	1.0	0.44
37	68.2	379.7	0.16	4	1	65	9992	7733	133577	15513.4	1.0	0.43
38	67.8	375.9	0.16	3	1	55	9893	7833	132252	15389.0	1.0	0.42
39	67.3	372.2	0.16	3	1	46	9796	7930	130955	15245.2	1.0	0.41
41	66.5	365.1	0.15	2	0	33	9609	8118	128458	14968.6	1.0	0.40
43	65.7	358.3	0.15	1	0	23	9431	8296	126083	14705.7	1.0	0.38
45	65.0	351.9	0.15	1	0	17	9262	8466	123822	14455.9	1.0	0.36
47	64.3	345.7	0.15	1	0	12	9101	8627	121671	14218.3	1.0	0.35
49	63.6	339.9	0.14	0	0	8	8948	8780	119623	13992.1	1.0	0.33
51	62.9	334.4	0.14	0	0	6	8802	8926	117671	13776.8	1.0	0.32
52	62.6	331.7	0.14	0	0	5	8732	8997	116731	13672.9	1.0	0.31
53	62.3	329.1	0.14	0	0	4	8663	9065	115812	13571.6	1.0	0.31
54	62.0	326.5	0.14	0	0	4	8596	9133	114915	13472.7	1.0	0.30
55	61.7	324.0	0.14	0	0	3	8531	9198	114039	13376.1	1.0	0.29
56	61.4	321.6	0.14	0	0	3	8467	9262	113184	13281.7	1.0	0.29
57	61.1	319.2	0.14	0	0	2	8404	9325	112349	13189.6	1.0	0.28
58	60.8	316.9	0.13	0	0	2	8343	9386	111533	13099.7	1.0	0.27
59	60.6	314.6	0.13	0	0	2	8283	9445	110736	13011.8	1.0	0.27
60	60.3	312.4	0.13	0	0	1	8225	9504	109957	12925.9	1.0	0.26

Time is time measured in years; ST is saturated thickness measured in feet; GPM is gallons per minute; GDAR is the gross daily application of the well measured in inches; ConvCP is the number of flood irrigated acreage converted to center pivot technology; GWU is the gross water use measured in inches; ConvDL is the number of center pivot acres converted to dryland production; TWU is the total water use measured in acre-feet; AAFWU is the average acre foot water usage per acre measured in feet; ΔST is the change in saturated thickness measured in feet..

Table 21. Impacts on Future on Crop Revenues in Subarea 6 of Sheridan County, Based on a Water Rights Buyout Scenario

Time	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat	Non Irrigated	Program Payments	Total
1	$159,927	$3,803,533	$130,634	$684,304	$104,390	$133,048	$139,471	$994,200	$6,149,508
2	$151,510	$3,603,347	$123,759	$648,288	$98,896	$126,046	$278,942	$994,200	$6,024,988
3	$143,093	$3,403,161	$116,883	$612,272	$93,402	$119,043	$418,413	$994,200	$5,900,468
4	$134,675	$3,202,975	$110,008	$576,256	$87,908	$112,041	$557,884	$994,200	$5,775,947
5	$126,258	$3,002,789	$103,132	$540,240	$82,413	$105,038	$697,355	$994,200	$5,651,427
6	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$994,200	$5,526,906
7	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
8	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
9	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
10	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
11	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
12	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
13	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
14	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
15	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
16	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
17	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$836,826	$0	$4,532,706
18	$117,413	$2,792,436	$96,257	$504,224	$76,919	$98,036	$841,960	$0	$4,527,245
19	$115,981	$2,758,376	$96,257	$504,224	$76,919	$98,036	$859,159	$0	$4,508,952
20	$114,579	$2,725,037	$96,257	$504,224	$76,919	$98,036	$875,993	$0	$4,491,046
21	$113,208	$2,692,416	$96,257	$504,224	$76,919	$98,036	$892,466	$0	$4,473,525
22	$111,866	$2,660,503	$96,257	$504,224	$76,919	$98,036	$908,580	$0	$4,456,385
23	$110,554	$2,629,289	$96,257	$504,224	$76,919	$98,036	$924,341	$0	$4,439,620
24	$109,270	$2,598,761	$96,257	$504,224	$76,919	$98,036	$939,757	$0	$4,423,224
25	$108,015	$2,568,905	$96,257	$504,224	$76,919	$98,036	$954,833	$0	$4,407,188
26	$106,787	$2,539,705	$96,257	$504,224	$76,919	$98,036	$969,577	$0	$4,391,505
27	$105,586	$2,511,147	$96,257	$504,224	$76,919	$98,036	$983,998	$0	$4,376,166
28	$104,412	$2,483,213	$96,257	$504,224	$76,919	$98,036	$998,103	$0	$4,361,164
29	$103,263	$2,455,889	$96,257	$504,224	$76,919	$98,036	$1,011,901	$0	$4,346,488
30	$102,139	$2,429,158	$96,257	$504,224	$76,919	$98,036	$1,025,399	$0	$4,332,131
31	$101,039	$2,403,004	$96,257	$504,224	$76,919	$98,036	$1,038,605	$0	$4,318,084
32	$99,963	$2,377,413	$96,257	$504,224	$76,919	$98,036	$1,051,527	$0	$4,304,339
33	$98,910	$2,352,368	$96,257	$504,224	$76,919	$98,036	$1,064,173	$0	$4,290,888
34	$97,879	$2,327,856	$96,257	$504,224	$76,919	$98,036	$1,076,551	$0	$4,277,722
35	$96,870	$2,303,862	$96,257	$504,224	$76,919	$98,036	$1,088,667	$0	$4,264,835
36	$95,883	$2,280,372	$96,257	$504,224	$76,919	$98,036	$1,100,528	$0	$4,252,219
37	$94,916	$2,257,373	$96,257	$504,224	$76,919	$98,036	$1,112,142	$0	$4,239,866
38	$93,969	$2,234,851	$95,940	$502,565	$76,919	$98,036	$1,124,771	$0	$4,227,050
39	$93,043	$2,212,832	$94,996	$497,618	$76,919	$98,036	$1,139,636	$0	$4,213,079
40	$92,141	$2,191,375	$94,076	$492,798	$76,919	$98,036	$1,154,122	$0	$4,199,465
41	$91,261	$2,170,462	$93,179	$488,098	$76,919	$98,036	$1,168,241	$0	$4,186,196
42	$90,404	$2,150,078	$92,304	$483,517	$76,919	$98,036	$1,182,003	$0	$4,173,262
43	$89,569	$2,130,206	$91,451	$479,051	$76,919	$98,036	$1,195,421	$0	$4,160,652
44	$88,754	$2,110,830	$90,620	$474,695	$76,919	$98,036	$1,208,504	$0	$4,148,357
45	$87,959	$2,091,934	$89,809	$470,448	$76,919	$98,036	$1,221,262	$0	$4,136,367
46	$87,185	$2,073,505	$89,018	$466,305	$76,919	$98,036	$1,233,705	$0	$4,124,673
47	$86,429	$2,055,529	$88,247	$462,263	$76,919	$98,036	$1,245,843	$0	$4,113,266
48	$85,691	$2,037,992	$87,494	$458,321	$76,919	$98,036	$1,257,685	$0	$4,102,137
49	$84,972	$2,020,880	$86,759	$454,473	$76,919	$98,036	$1,269,239	$0	$4,091,279
50	$84,270	$2,004,183	$86,043	$450,719	$76,919	$98,036	$1,280,514	$0	$4,080,683
51	$83,585	$1,987,887	$85,343	$447,055	$76,919	$98,036	$1,291,518	$0	$4,070,342
52	$82,916	$1,971,981	$84,660	$443,478	$76,919	$98,036	$1,302,259	$0	$4,060,249
53	$82,263	$1,956,454	$83,994	$439,987	$76,919	$98,036	$1,312,744	$0	$4,050,396
54	$81,626	$1,941,295	$83,343	$436,578	$76,919	$98,036	$1,322,980	$0	$4,040,776
55	$81,003	$1,926,494	$82,708	$433,250	$76,919	$98,036	$1,332,975	$0	$4,031,384
56	$80,395	$1,912,040	$82,087	$429,999	$76,919	$98,036	$1,342,735	$0	$4,022,212
57	$79,802	$1,897,925	$81,481	$426,825	$76,919	$98,036	$1,352,266	$0	$4,013,254
58	$79,222	$1,884,138	$80,890	$423,725	$76,919	$98,036	$1,361,576	$0	$4,004,505
59	$78,656	$1,870,671	$80,311	$420,696	$76,919	$98,036	$1,370,670	$0	$3,995,959
60	$78,103	$1,857,514	$79,747	$417,738	$76,919	$98,036	$1,379,555	$0	$3,987,610

Table 22. Impacts on Future Hydrology, Crop Mix, and Water-Use in Subarea 6 of Sheridan County, Based on a CREP Scenario.

	Corn											
	Hydrology			Flood Technology			Center Pivot Technology				Total	
Time	ST	GPM	GDAR	Acres	ConvCP	GWU	Acres	ConvDL	GWU	TWU	AAFWU	ΔST
1	89.8	587.4	0.249	1167	0	19754	11244	0	150310	18706.5	1.08	0.64
2	89.2	580.8	0.246	992	175	16791	11419	0	152649	18531.8	1.07	0.63
3	88.5	574.3	0.244	843	324	14272	11567	0	154637	18484.3	1.06	0.62
4	87.9	567.9	0.241	716	450	12131	11694	0	156327	18443.8	1.06	0.62
5	87.3	561.5	0.238	609	558	10312	11801	0	157764	18409.5	1.06	0.62
6	86.7	555.2	0.236	518	649	8765	11893	0	158985	18380.2	1.06	0.62
7	86.1	548.9	0.233	440	727	7450	11970	0	160023	18355.4	1.06	0.61
8	85.4	542.7	0.230	374	793	6333	12036	0	160905	18334.3	1.06	0.61
9	84.8	536.5	0.228	318	849	5383	12092	0	161655	18316.4	1.06	0.61
10	84.2	530.4	0.225	270	896	4575	12140	0	162292	18301.1	1.05	0.61
11	83.6	524.3	0.222	230	937	3889	12181	0	162834	18288.1	1.05	0.61
12	83.0	518.2	0.220	195	971	3306	12215	0	163295	18277.1	1.05	0.61
13	82.4	512.2	0.217	166	1001	2810	12244	0	163686	18267.8	1.05	0.61
14	81.8	506.2	0.215	141	1026	2388	12269	0	164019	18259.8	1.05	0.61
15	81.2	500.3	0.212	120	1047	2030	12290	0	164302	18253.0	1.05	0.61
16	80.6	494.3	0.210	102	1065	1726	12308	0	164542	18247.3	1.05	0.61
17	80.0	488.4	0.207	87	1080	1467	12324	0	164747	18242.4	1.05	0.61
18	79.4	482.6	0.205	74	1093	1247	12337	0	164920	18238.2	1.05	0.61
19	78.7	476.7	0.202	63	1104	1060	12348	0	165068	18234.7	1.05	0.61
20	78.1	470.9	0.200	53	1113	900	12345	12	165031	18217.9	1.05	0.61
21	77.5	465.2	0.197	45	1122	756	12202	163	163123	18043.6	1.05	0.59
22	76.9	459.5	0.195	37	1129	634	12061	311	161240	17873.7	1.05	0.58
23	76.4	454.0	0.193	31	1135	533	11923	456	159386	17707.7	1.05	0.57
24	75.8	448.6	0.190	26	1140	448	11786	598	157563	17545.8	1.05	0.56
25	75.2	443.4	0.188	22	1144	376	11652	736	155770	17387.7	1.05	0.55
26	74.7	438.3	0.186	19	1148	316	11520	871	154010	17233.2	1.05	0.54
27	74.1	433.2	0.184	16	1151	265	11391	1003	152282	17082.4	1.05	0.53
28	73.6	428.3	0.182	13	1153	223	11264	1133	150586	16935.0	1.05	0.52
29	73.1	423.5	0.180	11	1155	187	11140	1259	148923	16790.9	1.05	0.51
30	72.6	418.8	0.178	9	1157	158	11018	1383	147293	16650.1	1.05	0.50
31	72.1	414.2	0.176	8	1159	132	10898	1504	145695	16512.4	1.04	0.50
32	71.6	409.7	0.174	7	1160	111	10781	1622	144129	16377.8	1.04	0.49
33	71.1	405.3	0.172	6	1161	94	10667	1738	142594	16246.2	1.04	0.48
34	70.6	401.0	0.170	5	1162	79	10554	1852	141091	16117.4	1.04	0.47
35	70.1	396.8	0.168	4	1163	66	10444	1962	139617	15991.4	1.04	0.46
36	69.7	392.7	0.167	3	1163	56	10336	2071	138174	15868.1	1.04	0.45
37	69.2	388.7	0.165	3	1164	47	10230	2177	136760	15747.4	1.04	0.45
38	68.8	384.7	0.163	2	1164	39	10126	2281	135374	15629.3	1.04	0.44
39	68.3	380.9	0.162	2	1165	33	10025	2383	134017	15513.7	1.04	0.43
41	67.5	373.4	0.158	1	1165	24	9828	2581	131384	15255.8	1.04	0.41
43	66.7	366.2	0.155	1	1166	17	9640	2769	128875	14978.6	1.04	0.40
45	65.9	359.4	0.152	1	1166	12	9462	2948	126490	14715.1	1.04	0.38
47	65.1	353.0	0.150	0	1166	8	9292	3118	124221	14464.7	1.04	0.36
49	64.4	346.8	0.147	0	1166	6	9131	3279	122063	14226.5	1.04	0.35
51	63.7	341.0	0.145	0	1166	4	8977	3433	120008	13999.8	1.04	0.33
52	63.4	338.2	0.143	0	1166	4	8903	3507	119017	13890.5	1.03	0.33
53	63.1	335.4	0.142	0	1166	3	8831	3579	118051	13783.9	1.03	0.32
54	62.7	332.7	0.141	0	1166	3	8760	3650	117107	13679.8	1.03	0.31
55	62.4	330.1	0.140	0	1166	2	8691	3719	116186	13578.2	1.03	0.31
56	62.1	327.6	0.139	0	1166	2	8624	3786	115287	13479.1	1.03	0.30
57	61.8	325.1	0.138	0	1166	2	8558	3852	114409	13382.2	1.03	0.29
58	61.5	322.6	0.137	0	1166	1	8494	3916	113551	13287.7	1.03	0.29
59	61.2	320.3	0.136	0	1166	1	8431	3979	112714	13195.3	1.03	0.28
60	61.0	317.9	0.135	0	1167	1	8370	4040	111896	13105.2	1.03	0.28

Time is time measured in years; ST is saturated thickness measured in feet; GPM is gallons per minute; GDAR is the gross daily application of the well measured in inches; ConvCP is the number of flood irrigated acreage converted to center pivot technology; GWU is the gross water use measured in inches; ConvDL is the number of center pivot acres converted to dryland production; TWU is the total water use measured in acre-feet; AAFWU is the average acre foot water usage per acre measured in feet; ΔST is the change in saturated thickness measured in feet..

Table 23. Impacts on Future on Crop Revenues in Subarea 6 of Sheridan County, Based on a CREP Scenario

Time	Alfalfa	Corn	Sorghum	Soybeans	Sunflowers	Wheat	Non Irrigated	Program Payments	Total
1	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$0	$835,128	$4,531,008
2	$117,841	$2,802,603	$96,257	$504,224	$76,919	$98,036	$0	$835,128	$4,531,008
3	$117,841	$2,802,603	$96,257	$504,224	$75,835	$98,036	$1,048	$835,128	$4,530,971
4	$117,841	$2,802,603	$96,257	$504,224	$74,913	$98,036	$1,938	$835,128	$4,530,940
5	$117,841	$2,802,603	$96,257	$504,224	$74,129	$98,036	$2,695	$835,128	$4,530,913
6	$117,841	$2,802,603	$96,257	$504,224	$73,463	$98,036	$3,338	$835,128	$4,530,890
7	$117,841	$2,802,603	$96,257	$504,224	$72,897	$98,036	$3,885	$835,128	$4,530,871
8	$117,841	$2,802,603	$96,257	$504,224	$72,416	$98,036	$4,350	$835,128	$4,530,855
9	$117,841	$2,802,603	$96,257	$504,224	$72,007	$98,036	$4,745	$835,128	$4,530,841
10	$117,841	$2,802,603	$96,257	$504,224	$71,659	$98,036	$5,081	$835,128	$4,530,829
11	$117,841	$2,802,603	$96,257	$504,224	$71,363	$98,036	$5,366	$835,128	$4,530,819
12	$117,841	$2,802,603	$96,257	$504,224	$71,112	$98,036	$5,609	$835,128	$4,530,810
13	$117,841	$2,802,603	$96,257	$504,224	$70,899	$98,036	$5,815	$835,128	$4,530,803
14	$117,841	$2,802,603	$96,257	$504,224	$70,717	$98,036	$5,991	$835,128	$4,530,797
15	$117,841	$2,802,603	$96,257	$504,224	$70,563	$98,036	$6,140	$835,128	$4,530,792
16	$117,841	$2,802,603	$96,257	$504,224	$70,432	$98,036	$843,092	$0	$4,532,485
17	$117,841	$2,802,603	$96,257	$504,224	$70,320	$98,036	$843,200	$0	$4,532,481
18	$117,841	$2,802,603	$96,257	$504,224	$70,226	$98,036	$843,292	$0	$4,532,478
19	$117,841	$2,802,603	$96,257	$504,224	$70,145	$98,036	$843,369	$0	$4,532,476
20	$117,725	$2,799,850	$96,257	$504,224	$70,077	$98,036	$844,826	$0	$4,530,994
21	$116,289	$2,765,683	$96,257	$504,224	$70,018	$98,036	$862,135	$0	$4,512,642
22	$114,884	$2,732,271	$96,257	$504,224	$69,969	$98,036	$879,054	$0	$4,494,694
23	$113,510	$2,699,600	$96,257	$504,224	$69,927	$98,036	$895,592	$0	$4,477,146
24	$112,167	$2,667,655	$96,257	$504,224	$69,891	$98,036	$911,757	$0	$4,459,987
25	$110,853	$2,636,421	$96,257	$504,224	$69,861	$98,036	$927,558	$0	$4,443,210
26	$109,569	$2,605,879	$96,257	$504,224	$69,835	$98,036	$943,005	$0	$4,426,806
27	$108,314	$2,576,014	$96,257	$504,224	$69,813	$98,036	$958,107	$0	$4,410,765
28	$107,086	$2,546,809	$96,257	$504,224	$69,794	$98,036	$972,872	$0	$4,395,078
29	$105,885	$2,518,245	$96,257	$504,224	$69,779	$98,036	$987,311	$0	$4,379,736
30	$104,710	$2,490,306	$96,257	$504,224	$69,765	$98,036	$1,001,432	$0	$4,364,730
31	$103,561	$2,462,976	$96,257	$504,224	$69,754	$98,036	$1,015,243	$0	$4,350,050
32	$102,436	$2,436,238	$96,257	$504,224	$69,744	$98,036	$1,028,754	$0	$4,335,689
33	$101,336	$2,410,077	$96,257	$504,224	$69,736	$98,036	$1,041,972	$0	$4,321,638
34	$100,260	$2,384,476	$96,257	$504,224	$69,729	$98,036	$1,054,906	$0	$4,307,887
35	$99,206	$2,359,420	$96,257	$504,224	$69,723	$98,036	$1,067,564	$0	$4,294,430
36	$98,175	$2,334,896	$96,257	$504,224	$69,717	$98,036	$1,079,952	$0	$4,281,258
37	$97,166	$2,310,889	$96,257	$504,224	$69,713	$98,036	$1,092,079	$0	$4,268,363
38	$96,178	$2,287,384	$96,257	$504,224	$69,709	$98,036	$1,103,951	$0	$4,255,739
39	$95,210	$2,264,369	$96,257	$504,224	$69,706	$98,036	$1,115,576	$0	$4,243,378
40	$94,262	$2,241,831	$96,243	$504,151	$69,704	$98,036	$1,127,015	$0	$4,231,241
41	$93,334	$2,219,759	$95,296	$499,190	$69,701	$98,036	$1,141,920	$0	$4,217,235
42	$92,430	$2,198,250	$94,373	$494,355	$69,700	$98,036	$1,156,444	$0	$4,203,587
43	$91,548	$2,177,286	$93,473	$489,642	$69,698	$98,036	$1,170,601	$0	$4,190,284
44	$90,689	$2,156,852	$92,596	$485,049	$69,697	$98,036	$1,184,400	$0	$4,177,318
45	$89,851	$2,136,930	$91,741	$480,570	$69,695	$98,036	$1,197,852	$0	$4,164,676
46	$89,035	$2,117,506	$90,908	$476,202	$69,694	$98,036	$1,210,970	$0	$4,152,350
47	$88,238	$2,098,563	$90,094	$471,943	$69,693	$98,036	$1,223,761	$0	$4,140,330
48	$87,461	$2,080,088	$89,301	$467,789	$69,693	$98,036	$1,236,237	$0	$4,128,606
49	$86,704	$2,062,066	$88,528	$463,737	$69,692	$98,036	$1,248,407	$0	$4,117,170
50	$85,964	$2,044,485	$87,773	$459,784	$69,692	$98,036	$1,260,280	$0	$4,106,013
51	$85,243	$2,027,331	$87,037	$455,926	$69,691	$98,036	$1,271,863	$0	$4,095,127
52	$84,539	$2,010,592	$86,318	$452,162	$69,691	$98,036	$1,283,167	$0	$4,084,505
53	$83,852	$1,994,255	$85,617	$448,488	$69,690	$98,036	$1,294,199	$0	$4,074,138
54	$83,182	$1,978,310	$84,932	$444,903	$69,690	$98,036	$1,304,967	$0	$4,064,019
55	$82,527	$1,962,744	$84,264	$441,402	$69,690	$98,036	$1,315,478	$0	$4,054,142
56	$81,888	$1,947,548	$83,612	$437,985	$69,690	$98,036	$1,325,740	$0	$4,044,498
57	$81,265	$1,932,711	$82,975	$434,648	$69,690	$98,036	$1,335,759	$0	$4,035,083
58	$80,655	$1,918,222	$82,353	$431,390	$69,689	$98,036	$1,345,543	$0	$4,025,888
59	$80,060	$1,904,072	$81,745	$428,208	$69,689	$98,036	$1,355,098	$0	$4,016,909
60	$79,479	$1,890,252	$81,152	$425,100	$69,689	$98,036	$1,364,431	$0	$4,008,139

Table 24. Net Present Value of All Scenarios for Subarea 6 of Sheridan County

Discount Rate	Scenario: Status Quo	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
-5.0%	$1,776,655,690	$1,155,165,605	$1,868,000,813	$1,742,659,126	$1,732,817,846
-2.5%	$633,322,787	$398,102,515	$651,905,014	$617,034,606	$606,997,137
0.0%	$277,433,415	$167,365,224	$277,417,462	$269,097,175	$259,924,585
2.5%	$148,725,231	$86,217,237	$144,246,112	$144,385,706	$136,125,050
5.0%	$93,979,870	$52,801,746	$88,840,809	$91,836,868	$84,362,187

Table 25. Difference in Net Present Value Relative to the Status Quo Scenario for Subarea 6 of Sheridan County

Discount Rate	Scenario: Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
-5.0%	-$621,490,085	$91,345,123	-$33,996,564	-$43,837,844
-2.5%	-$235,220,272	$18,582,227	-$16,288,181	-$26,325,650
0.0%	-$110,068,191	-$15,953	-$8,336,240	-$17,508,829
2.5%	-$62,507,995	-$4,479,119	-$4,339,526	-$12,600,182
5.0%	-$41,178,124	-$5,139,062	-$2,143,003	-$9,617,683

Table 26. Total Water Use for All Scenarios for Subarea 6 of Sheridan County (acre-feet)

Scenario: Status Quo	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
1,179,241	0.0	1,050,008	1,021,174	982,605

Table 27. Water Conserved Relative to the Status Quo Scenario for Subarea 6 of Sheridan County (acre-feet)

Scenario: Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
1,179,241	129,233	158,067	196,636

Table 28. Input-Output Study Region: Basic Demographics

County	Area (square miles)	Population	Households	Household Income	Average Household Income
Cheyenne	1,020	2,979	1,386	$51,887,000	$37,434
Decatur	894	3,274	1,518	$74,763,000	$49,247
Gove	1,072	2,845	1,282	$66,671,000	$52,002
Logan	1,073	2,827	1,243	$61,213,000	$49,243
Rawlins	1,070	2,765	1,315	$61,863,000	$47,041
Sheridan	896	2,614	1,171	$87,008,000	$74,297
Sherman	1,056	6,218	2,826	$150,256,992	$53,166
Thomas	1,075	7,801	3,245	$198,064,992	$61,032
Wallace	914	1,579	694	$38,720,000	$55,788
Total	9,069	32,902	14,681	$790,446,984	$53,841

Based on 2004 IMPLAN Data

Table 29. Input-Output Study Region: Select Industry Economic Demographics

Sector	Sector Description	Industry Output*	Employment	Value Added*
11	Cattle ranching and farming	$422.542	2,110	$70.037
52	Soybean processing	$270.354	106	$7.561
2	Grain farming	$265.105	2,663	$164.330
390	Wholesale trade	$106.332	1,052	$72.684
503	State & Local Education	$81.972	2,875	$81.972
509	Owner-occupied dwellings	$78.249	0	$64.205
430	Monetary authorities and depository credit in	$63.157	427	$48.281
394	Truck transportation	$48.522	469	$19.716
18	Agriculture and forestry support activities	$42.009	1,101	$27.485
481	Food services and drinking places	$40.727	1,098	$15.535
468	Nursing and residential care facilities	$40.370	1,190	$20.114
504	State & Local Non-Education	$38.134	1,271	$38.134
483	Automotive repair and maintenance- except car	$34.685	594	$16.469
13	Animal production- except cattle and poultry	$28.229	464	$3.810
422	Telecommunications	$28.164	111	$12.356
465	Offices of physicians- dentists- and other he	$27.000	460	$18.203
30	Power generation and supply	$23.748	71	$16.095
10	All other crop farming	$23.070	61	$14.277
1	Oilseed farming	$22.654	108	$16.056
467	Hospitals	$21.385	269	$8.573
401	Motor vehicle and parts dealers	$21.065	292	$12.214
19	Oil and gas extraction	$19.982	105	$11.215
428	Insurance agencies- brokerages- and related	$19.850	366	$15.132
499	Other State and local government enterprises	$18.806	124	$6.266
407	Gasoline stations	$18.712	278	$12.217
405	Food and beverage stores	$17.537	351	$10.275
410	General merchandise stores	$17.518	364	$9.892
47	Other animal food manufacturing	$16.906	26	$0.679
67	Animal- except poultry- slaughtering	$16.217	45	$1.849
33	New residential 1-unit structures- all	$16.043	151	$5.097
257	Farm machinery and equipment manufacturing	$14.213	49	$2.196
431	Real estate	$11.747	138	$8.223
157	Phosphate fertilizer manufacturing	$9.567	11	$1.117
485	Commercial machinery repair and maintenance	$4.875	102	$3.013
142	Petroleum refineries	$0.000	0	$0.000
156	Nitrogenous fertilizer manufacturing	$0.000	0	$0.000
159	Pesticide and other agricultural chemical man	$0.000	0	$0.000
	All Other	$287.185	5901	$138.107
	Total	$2,216.630	24,804	$973.387

* Millions of dollars
Based on 2004 IMPLAN Data

Table 30. Types of Direct Economic Impacts Included in Analysis

Direct Impact	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
	Scenario			
Loss of Irrigated Crop Revenue	Yes	Yes	Yes	Yes
Gain of Non-Irrigated Crop Revenue	Yes	No	Yes	Yes
Gain in Haying, Grazing, and Recreational Revenues	No	No	No	Yes
Gain Due to Producer Compensation	No	No	Yes	Yes

Table 31. IMPLAN Coding for the Revenues Lost Due to a Reduction in Irrigated Crop Acreage and Total Sector Impacts

Event	IMPLAN Sector[6]	Sector Name	Input	Impact Per Acre	Impact Total[7]
1	2	Grain Farming	Seed[1]	$48.22	$359,581
2	159	Pesticide & chemical manufacturing	Herbicide & insecticide[1]	$53.76	$400,853
3	156	Nitrogen fertilizer manufacturing	Nitrogen fertilizer[1]	$62.39	$465,230
4	157	Phosphate fertilizer manufacturing	Phosphate fertilizer[1]	$17.60	$131,219
5	428	Insurance agencies, brokerages, & related	Crop & other insurance[2]	$17.00	$126,737
6	142	Petroleum refineries	Fuel & oil[2]	$72.60	$541,327
7	390	Farm machinery wholesalers	Parts[2]	$11.47	$85,544
8	485	Farm machinery repair and maintenance	Repairs[2]	$11.47	$85,544
9	430	Commercial Banking	Interest[2]	$23.08	$172,101
10	431	Farmland rental or leasing (absentee owner)	Land Charge[2]	$11.28	$84,114
11	390	Farm machinery wholesalers	Equipment payments[2]	$25.39	$189,315
		Total Indirect Impact (all regions)		**$354.26**	**$2,641,564**
12	5001	Employee compensation	Labor[3]	$30.21	$225,284
13	7001	Other property income	Land Charge[2]	$37.77	$281,598
14	8001	Indirect business taxes	Taxes[2]	$6.64	$49,505
15	6001	Proprietary income	Profits[4]	$134.85	$1,005,503
		Total Direct Impact on Payroll Sectors[5]		**$209.47**	**$1,561,891**
		Total Direct Impact		**$563.73**	**$4,203,455**

1: The total weighted average expense is based on KSU extension budgets.
2: The total weighted average expense is based on KFMA budgets
3: The total weighted average expense is based on KSU and KFMA budgets. The number 1ncludes labor, consulting, and machine hire.
4: Proprietary income is the remainder after all other categories have been deducted from gross revenues.
5: This is equivalent to the total direct impact on Value Added
6: The IMPLAN sectors were chosen based on local ES-202 data. ES-202 data is based on annual county-level establishment data from the U.S. Department of Labor, Bureau of Labor Statistics' Quarterly Census of Employment and Wages program. These data tracks all employers with employees who are eligible for unemployment compensation insurance. The North American Industry Classification System (NAICS) codes for local input suppliers were obtained from the ES-202 data. IMPLAN's cross reference guide was then used to match NAICS codes to the correct IMPLAN sector.
7: Based on the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6) with a weighted average revenue of $563.73 per acre.

Table 32. IMPLAN Coding for the Revenues Lost Due to a Reduction in Irrigated Crop Acreage and Regional Sector Impacts

Event	IMPLAN Sector	Sector Name	Input	Effective Local Impact (%)[3]	Impact Local
1	2	Grain Farming	Seed	14.2%	$51,060
2	159	Pesticide & chemical manufacturing	Herbicide & insecticide	19.5%	$78,166
3	156	Nitrogen fertilizer manufacturing	Nitrogen fertilizer	15.4%	$71,645
4	157	Phosphate fertilizer manufacturing	Phosphate fertilizer	45.2%[1]	$59,311
5	428	Insurance agencies, brokerages, & related	Crop & other insurance	55.9%	$70,846
6	142	Petroleum refineries	Fuel & oil	20.5%	$110,972
7	390	Farm machinery wholesalers	Parts	40.0%	$34,218
8	485	Farm machinery repair and maintenance	Repairs	100.0%	$85,544
9	430	Commercial Banking	Interest	100.0%	$172,101
10	431	Farmland rental or leasing (absentee owner)	Land Charge	0.0%[2]	$0
11	390	Farm machinery wholesalers	Equipment payments	15.0%	$28,397
		Total Indirect Impact (Local region)			**$762,261**
12	5001	Employee compensation	Labor	100.0%	$225,284
13	7001	Other property income	Land Charge	100.0%	$281,598
14	8001	Indirect business taxes	Taxes	100.0%	$49,505
15	6001	Proprietary income	Profits	100.0%	$1,005,503
		Total Direct Impact on Payroll Sectors[5]			**$1,561,891**

1: IMPLAN assumes that 100% of local demand is met by a local supplier, if there is a supplier in the region. The IMPLAN data suggests that there is a phosphate fertilizer manufacturer in the region. The margin includes the manufacturer's margin as well as the local wholesaler's margin. In the absence of better information, IMPLAN's suggested impacts were used. This may overstate the local impact due to the reduced demand for phosphate fertilizer.
2: ERS (2004) suggests that approximately 23% of USDA farm program payments may be made to individuals outside the target region. It is assumed that 23% of payments that accrue to land also are made to individuals outside the target region and have no regional impact. The remaining 77% of payments that accrue to land are included in value added.
3: The effective local impact was derived by modeling each event separately. The effective local impact percent captures the combined affect of input supplier margins and the RPC.

Table 33. Total Impacts Due to Revenues Losses from a Reduction in Irrigated Crop Acreage

Metric	Direct	Indirect	Induced	Total	Multiplier
Total Industry Output	$4,203,455	$866,240[1]	$777,043	$5,846,738	1.39
Value Added	$1,561,891	$542,849	$453,784	$2,558,524[3]	1.64
Employment[2]	3.7	0.8	0.5	5.0	1.36

1: The indirect impacts to total industry output includes the first-round impact of $762,261 reported in Table 30 plus indirect impacts generated by subsequent rounds of input supplier spending.
2: These data represent 8.8% of the employment impacts calculated by IMPLAN.
3: Based on the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6).

Table 34. IMPLAN Coding for the Revenues Gained Due to an Increase in Nonirrigated Crop Acreage and Total Sector Impacts

Event	IMPLAN Sector[6]	Sector Name	Input	Impact Per Acre	Impact Total[7]
1	2	Grain Farming	Seed[1]	$12.28	$91,542
2	159	Pesticide & chemical manufacturing	Herbicide & insecticide[1]	$16.90	$125,984
3	156	Nitrogen fertilizer manufacturing	Nitrogen fertilizer[1]	$28.59	$213,176
4	157	Phosphate fertilizer manufacturing	Phosphate fertilizer[1]	$8.06	$60,126
5	428	Insurance agencies, brokerages, & related	Crop & other insurance[2]	$7.56	$56,406
6	142	Petroleum refineries	Fuel & oil[2]	$8.09	$60,357
7	390	Farm machinery wholesalers	Parts[2]	$5.05	$37,672
8	485	Farm machinery repair and maintenance	Repairs[2]	$5.05	$37,672
9	430	Commercial Banking	Interest[2]	$7.19	$53,626
10	431	Farmland rental or leasing (absentee owner)	Land Charge[2]	$3.15	$23,510
11	390	Farm machinery wholesalers	Equipment payments[2]	$12.46	$92,930
		Total Indirect Impact (all regions)		**$114.40**	**$853,000**
12	5001	Employee compensation	Labor[3]	$13.60	$101,439
13	7001	Other property income	Land Charge[2]	$10.56	$78,709
14	8001	Indirect business taxes	Taxes[2]	$3.78	$28,155
15	6001	Proprietary income	Profits[4]	$85.21	$635,334
		Total Direct Impact on Payroll Sectors[5]		**$113.14**	**$843,636**
		Total Direct Impact		**$227.54**	**$1,696,637**

1: The total weighted average expense is based on KSU extension budgets.
2: The total weighted average expense is based on KFMA budgets
3: The total weighted average expense is based on KSU and KFMA budgets. The number 1ncludes labor, consulting, and machine hire.
4: Proprietary income is the remainder after all other categories have been deducted from gross revenues.
5: This is equivalent to the total direct impact on Value Added
6: The IMPLAN sectors were chosen based on local ES-202 data. ES-202 data is based on annual county-level establishment data from the U.S. Department of Labor, Bureau of Labor Statistics' Quarterly Census of Employment and Wages program. These data tracks all employers with employees who are eligible for unemployment compensation insurance. The North American Industry Classification System (NAICS) codes for local input suppliers were obtained from the ES-202 data. IMPLAN's cross reference guide was then used to match NAICS codes to the correct IMPLAN sector.
7: Based on the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6) with average revenue of $563.73 per acre.

Table 35. IMPLAN Coding for the Revenues Gained Due to an Increase in Nonirrigated Crop Acreage and Regional Sector Impacts

Event	IMPLAN Sector	Sector Name	Input	Effective Local Impact (%)[3]	Impact Local
1	2	Grain Farming	Seed	14.2%	$12,999
2	159	Pesticide & chemical manufacturing	Herbicide & insecticide	19.5%	$24,567
3	156	Nitrogen fertilizer manufacturing	Nitrogen fertilizer	15.4%	$32,829
4	157	Phosphate fertilizer manufacturing	Phosphate fertilizer	45.2%[1]	$27,177
5	428	Insurance agencies, brokerages, & related	Crop & other insurance	55.9%	$31,531
6	142	Petroleum refineries	Fuel & oil	20.5%	$12,373
7	390	Farm machinery wholesalers	Parts	40.0%	$15,069
8	485	Farm machinery repair and maintenance	Repairs	100.0%	$37,672
9	430	Commercial Banking	Interest	100.0%	$53,626
10	431	Farmland rental or leasing (absentee owner)	Land Charge	0.0%[2]	$0
11	390	Farm machinery wholesalers	Equipment payments	15.0%	$13,939
		Total Indirect Impact (Local region)			**$261,782**
12	5001	Employee compensation	Labor	100.0%	$101,439
13	7001	Other property income	Land Charge	100.0%	$78,709
14	8001	Indirect business taxes	Taxes	100.0%	$28,155
15	6001	Proprietary income	Profits	100.0%	$635,334
		Total Direct Impact on Payroll Sectors[5]			**$843,636**

1: IMPLAN assumes that 100% of local demand is met by a local supplier, if there is a supplier in the region. The IMPLAN data suggests that there is a phosphate fertilizer manufacturer in the region. The margin includes the manufacturer's margin as well as the local wholesaler's margin. In the absence of better information, IMPLAN's suggested impacts were used. This may overstate the local impact due to the demand change for phosphate fertilizer.
2: ERS (2004) suggests that approximately 23% of USDA farm program payments may be made to individuals outside the target region. It is assumed that 23% of payments that accrue to land also are made to individuals outside the target region and have no regional impact. The remaining 77% of payments that accrue to land are included in value added.
3: The effective local impact was derived by modeling each event separately. The effective local impact percent captures the combined affect of input supplier margins and the RPC.

Table 36. Total Impacts Due to Revenues Gained from an Increase in Nonirrigated Crop Acreage

Metric	Direct	Indirect	Induced	Total	Multiplier
Total Industry Output	$1,696,637	$297,875[1]	$422,176	$2,416,688	1.42
Value Added	$843,636	$183,449	$246,569	$1,273,654	1.51
Employment[2]	1.5	0.3	0.2	2.0	1.36

1: The indirect impacts to total industry output includes the first-round impact of $261,782 reported in Table 34 plus indirect impacts generated by subsequent rounds of input supplier spending.
2: These data represent 8.8% of the employment impacts calculated by IMPLAN.
Based on the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6).

Table 37. IMPLAN Coding for the Revenues Gained Due to an Increase in Haying, Grazing, and Recreation and Sector Impacts

Event	IMPLAN Sector[6]	Sector Name	Impact Per Acre	Impact Total	RPC
1	405	Food and beverage stores	$0.27	$2,036	100.0%
2	407	Gasoline stations	$0.30	$2,269	100.0%
3	409	Sporting goods stores	$1.28	$9,565	100.0%
4	410	General merchandise stores	$0.07	$488	100.0%
5	411	Miscellaneous retail stores	$0.07	$551	100.0%
6	432	Automotive rental and leasing	$0.30	$2,269	100.0%
7	479	Hotels and motels	$0.27	$2,036	100.0%
8	481	Food services and drinking places	$0.27	$2,036	100.0%
		Total Direct Recreational Impact	**$2.85**	**$21,251.03**	**100.0%**
9	6001	Proprietary income (Recreation)[3]	$1.20	$8,947.80	100.0%
10	6001	Proprietary income (Haying & Grazing -Absentee)[1]	$0.74	$5,487.98	0.0%
11	6001	Proprietary income (Haying & Grazing -Local)[1]	$2.46	$18,372.82	100.0%
		Total Direct Impact on Payroll Sectors [2]	**$9.36**	**$69,822.67**	**100.00%**

1: The total annual proprietary income from haying and grazing is estimated as $3.20 per acre, of which 23% ($0.74) is estimated to be paid to absentee landowners.
2: The proprietary income associated with absentee landowners has been removed from the total.
3: All proprietary income associated with recreation is assumed to be paid to the local operator.
Based on the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6).

Table 38. Total Impacts Due to Revenues Gained from an Increase in Haying, Grazing and Recreational Activities

Metric	Direct	Indirect	Induced	Total	Multiplier
Total Industry Output	$48,571	$19,376	$6,035	$73,982	1.52
Value Added	$39,668	$1,582	$10,612	$51,862	1.31
Employment[1]	0.1	0.0	0.0	0.1	1.11

1: These data represent 8.8% of the employment impacts calculated by IMPLAN.
Based on the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6).

Table 39. IMPLAN Coding for the CREP Incentives Paid to Landowners and Sector Impacts

Event	IMPLAN Sector[6]	Sector Name	Impact Per Acre	Impact Total	RPC
1	6001	Proprietary income (Incentive -Absentee)	$25.76	$192,079	0.00%
2	6001	Proprietary income (Incentive -Local)	$86.24	$643,049	100.00%
		Total Direct Impact on Payroll Sectors[1]	**$86.24**	**$643,049**	

1: The proprietary income associated with absentee landowners has been removed from the total. These data are based on a $112 per acre incentive paid to landowners.
Based on the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6).

Table 40. Total Impacts Due to CREP Incentives Paid to Landowners

Metric	Direct	Indirect	Induced	Total	Multiplier
Total Industry Output	NA	NA	NA	NA	NA
Value Added	$643,049	$0	$189,452	$832,501	1.29
Employment[1]	0.3	0.0	0.1	0.4	1.31

1: These data represent 8.8% of the employment impacts calculated by IMPLAN.
NA: Not Applicable; payroll sector impacts have only a value added impact.
Based on the retirement of 7,456.5 irrigated acres (30% of the 24,855 irrigated acres in subarea 6).

Table 41. Total Net Present Value of Producer Gross Profits, at a 5% Discount Rate

		Scenario			
Subarea	County	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
1	Sherman	-$40,598,443	-$5,044,516	-$5,811,092	-$9,298,043
2	Sherman	-$15,152,883	-$1,395,309	-$2,865,160	-$3,558,114
3	Cheyenne	-$11,398,450	-$1,877,773	-$1,561,732	-$2,997,437
4	Thomas	-$1,917,431	-$253,201	-$311,225	-$486,814
5	Thomas	-$54,788,294	-$5,472,980	-$5,829,657	-$12,817,581
6	Sheridan	-$41,178,124	-$5,139,062	-$2,143,003	-$9,617,683
	Total	-165,033,625	-19,182,841	-18,521,869	-38,775,671

All impacts are measured relative to the 'Status Quo' scenario.
These data are based on a total retirement of 30% of the 98,143 irrigated acres in the six subareas.

Table 42. Per Acre Net Present Value of Producer Gross Profits, at a 5% Discount Rate

		Scenario			
Subarea	County	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
1	Sherman	-$1,855	-$230	-$265	-$425
2	Sherman	-$1,727	-$159	-$327	-$405
3	Cheyenne	-$1,835	-$302	-$251	-$483
4	Thomas	-$1,595	-$211	-$259	-$405
5	Thomas	-$1,556	-$155	-$166	-$364
6	Sheridan	-$1,657	-$207	-$86	-$387
	Average	-$1,682	-$195	-$189	-$395

All impacts are measured relative to the 'Status Quo' scenario.
These data are based on a total retirement of 30% of the 98,143 irrigated acres in the six subareas.

Table 43. Total Net Present Value of Impacts on Producer Gross Profits, at a -5% Discount Rate

		Scenario			
Subarea	County	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
1	Sherman	-$637,347,240	$56,619,633	-$109,641,180	-$74,540,292
2	Sherman	-$258,433,163	$17,733,301	-$65,178,654	-$39,650,466
3	Cheyenne	-$204,041,718	$4,253,400	-$35,802,255	-$33,705,710
4	Thomas	-$33,814,427	$295,755	-$8,605,519	-$6,093,770
5	Thomas	-$871,556,743	$73,900,115	-$133,143,973	-$104,743,324
6	Sheridan	-$621,490,085	$91,345,123	-$33,996,564	-$43,837,844
	Total	-$2,626,683,377	$244,147,327	-$386,368,144	-$302,571,405

All impacts are measured relative to the 'Status Quo' scenario.
These data are based on a total retirement of 30% of the 98,143 irrigated acres in the six subareas.

Table 44. Per Acre Net Present Value of Impacts on Producer Gross Profits, at a -5% Discount Rate

		Scenario			
Subarea	County	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
1	Sherman	-$29,119	$2,587	-$5,009	-$3,406
2	Sherman	-$29,451	$2,021	-$7,428	-$4,519
3	Cheyenne	-$32,852	$685	-$5,764	-$5,427
4	Thomas	-$28,132	$246	-$7,159	-$5,070
5	Thomas	-$24,752	$2,099	-$3,781	-$2,975
6	Sheridan	-$25,005	$3,675	-$1,368	-$1,764
	Average	-$26,764	$2,488	-$3,937	-$3,083

All impacts are measured relative to the 'Status Quo' scenario.
These data are based on a total retirement of 98,143 irrigated acres in the six subareas.

Table 45. Total Net Present Value of Impacts on Regional Value Added, at a 5% Discount Rate

		Scenario			
Subarea	County	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
1	Sherman	-$41,631,687	-$7,191,179	-$6,918,724	-$15,205,286
2	Sherman	-$15,901,577	-$2,121,068	-$3,257,611	-$5,896,617
3	Cheyenne	-$11,821,392	-$2,222,283	-$1,853,606	-$4,603,317
4	Thomas	-$1,915,764	-$317,538	-$326,013	-$776,064
5	Thomas	-$57,295,324	-$8,418,343	-$7,742,513	-$22,468,024
6	Sheridan	-$43,815,439	-$7,943,605	-$4,110,243	-$17,182,693
	Total	-172,381,183	-28,214,016	-24,208,710	-66,132,000

All impacts are measured relative to the 'Status Quo' scenario.
These data are based on a total retirement of 98,143 irrigated acres in the six subareas.

Table 46. First Year Economic Impact on Total Value Added on a Per Capita basis and as a Percent of Total Regional Value Added

	Scenario			
Item	Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
First Year Lost Value Added	-$16,509,509	-$3,569,328	$2,751,298	-$7,117,582
Impact per Capita	-$502	-$108	$84	-$216
Percent Impact	-1.70%	-0.37%	0.28%	-0.73%

All impacts are measured relative to the 'Status Quo' scenario.
These data are based on a total retirement of 98,143 irrigated acres in the six subareas.
As reported in Table 28, the nine-county regional economy produces $973,387,000 in value added annually.
As reported in Table 27, the nine-county region has a population of 32,902.

Table 47. First Year Economic Impact on Input Suppliers Value added on a Per Capita basis and as a Percent of Total Regional Value Added

Item	Scenario: Conversion to Dryland	Limited Irrigation	Water Rights Buyout	CREP
First Year Lost Value Added	-$5,398,503	-$869,391	-$1,619,551	-$2,383,582
Impact per Capita	-$164	-$26	-$49	-$72
Percent Impact	-0.55%	-0.09%	-0.17%	-0.24%

All impacts are measured relative to the 'Status Quo' scenario.
These data do not include impacts associated with producer proprietary income, employee compensation, producer property income, or indirect business tax.
These data are based on a total retirement of 98,143 irrigated acres in the six subareas.
As reported in Table 28, the nine-county regional economy produces $973,387,000 in value added annually.
As reported in Table 27, the nine-county region has a population of 32,902.

Figures

Figure 1. Subareas in Cheyenne, Sheridan, and Sherman Counties

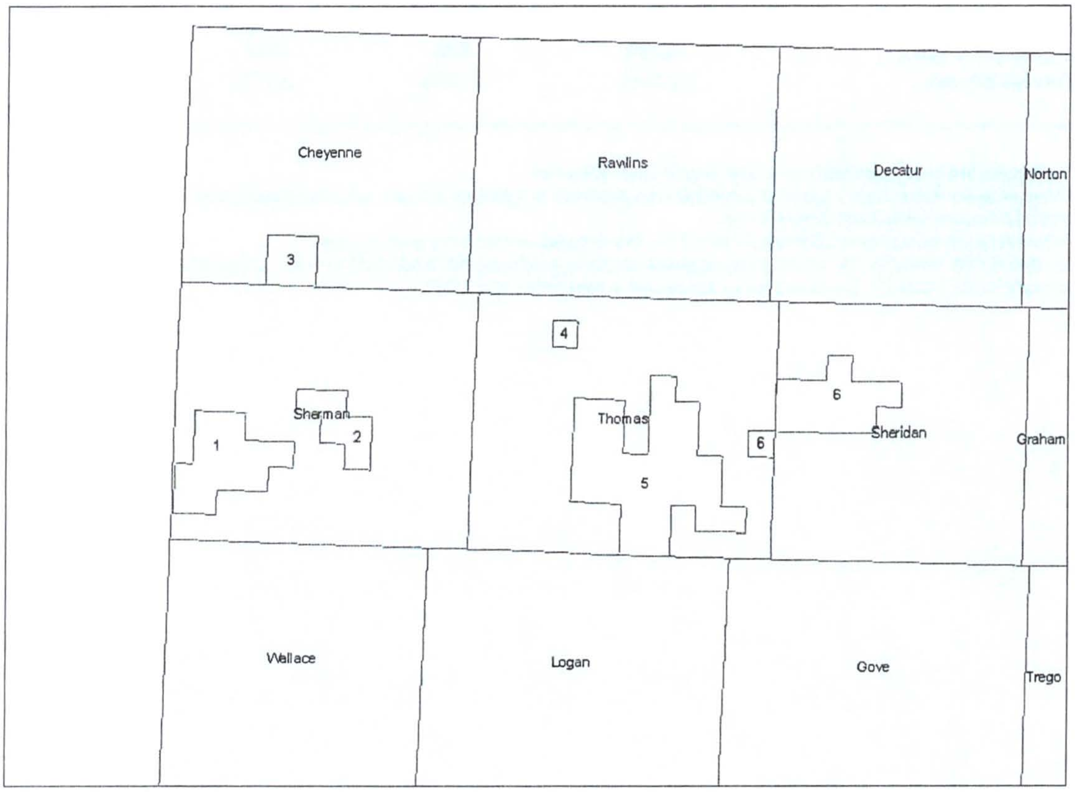

Figure 2. Scenario 1: Status Quo Projected Time Path for Saturated Thickness and Well Capacity in Subarea 6 of Sheridan County

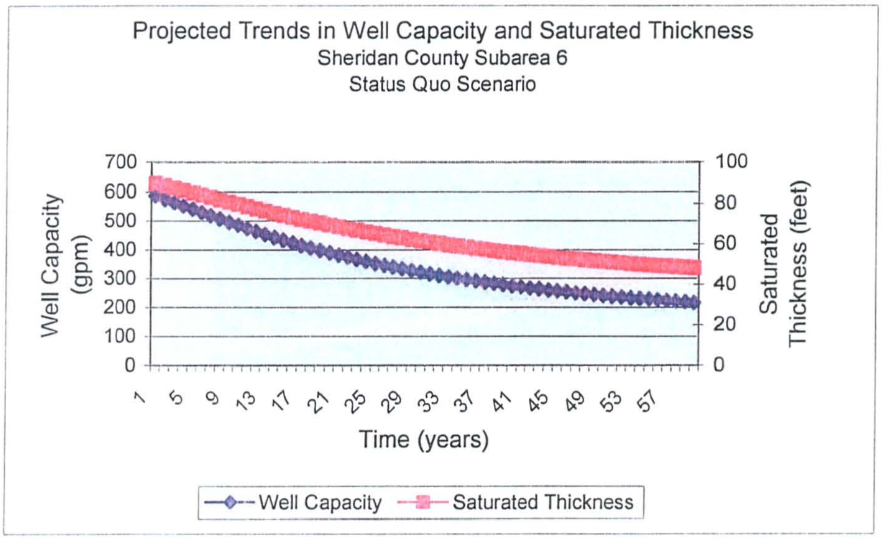

Figure 3. Scenario 1: Status Quo Projected Time Path for Irrigated Corn Acreage in Subarea 6 of Sheridan County

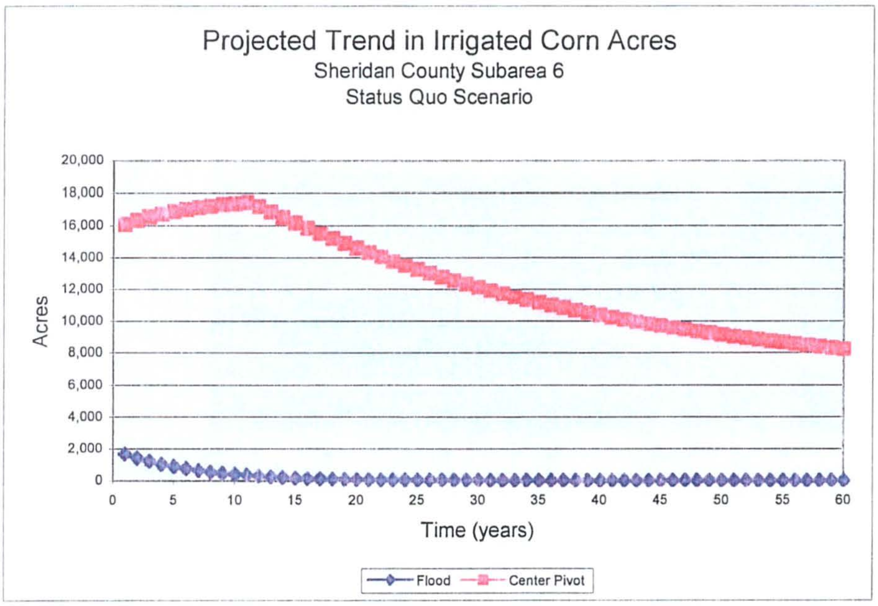

Figure 4. Scenario 1: Status Quo Projected Time Path for Total Irrigated and Non-Irrigated Acreage in Subarea 6 of Sheridan County

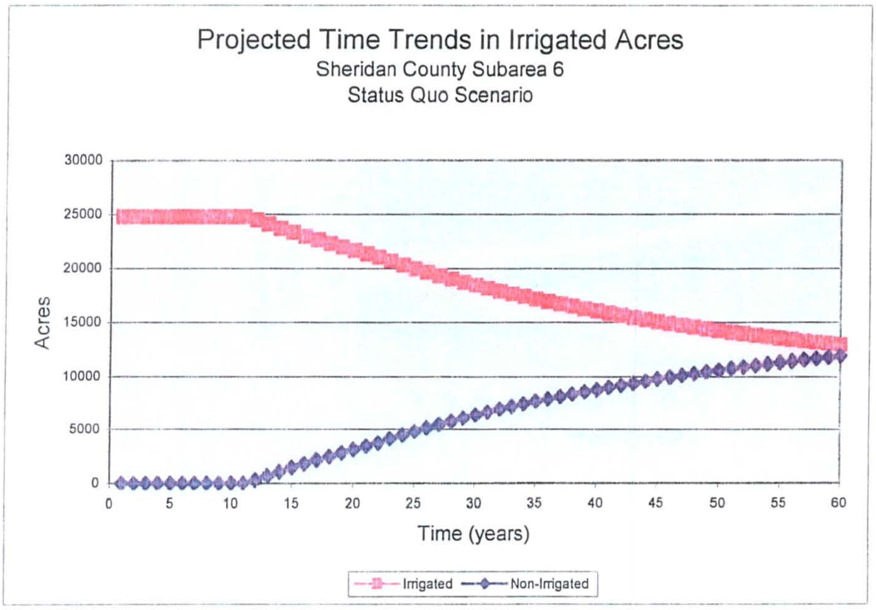

Figure 5. Time Path for Gross Profits in Subarea 6 of Sheridan County for all Scenarios.

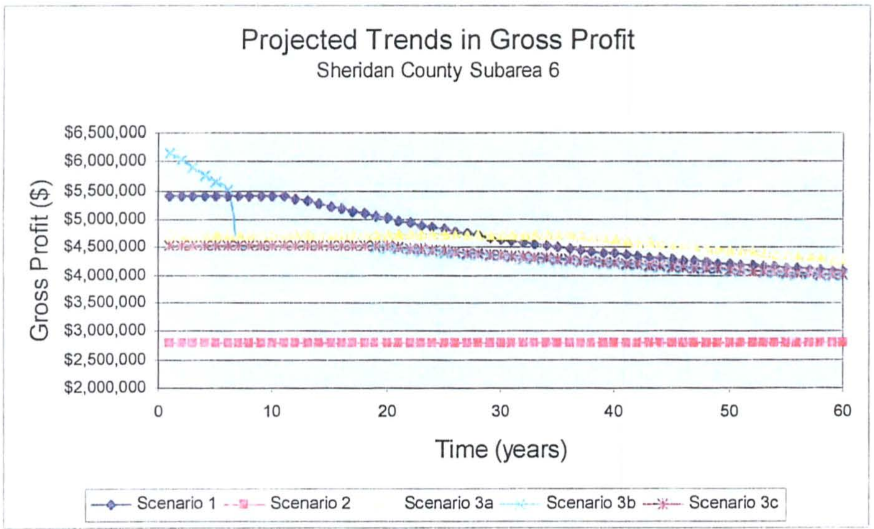

Figure 6. Time Path for Saturated Thickness in Subarea 6 of Sheridan County for all Scenarios

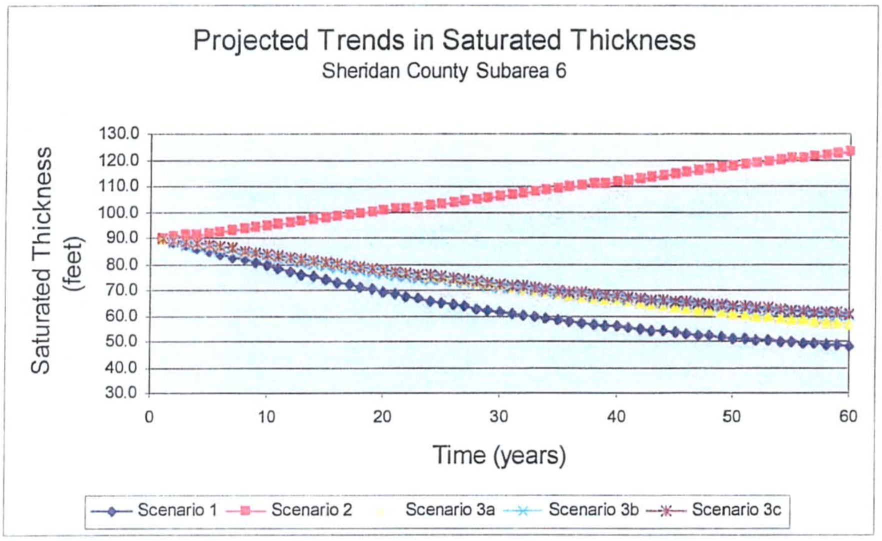

Figure 7. Time Path for Gross Water Used in Subarea 6 of Sheridan County for all Scenarios

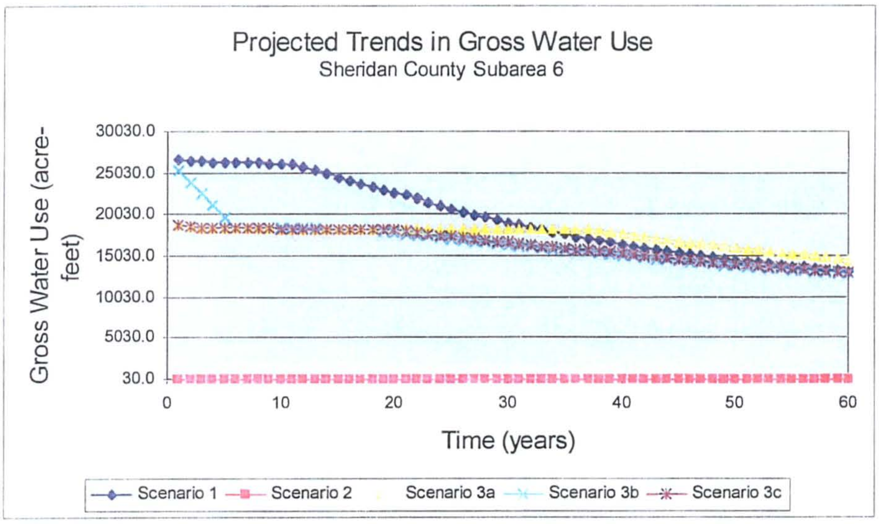

Figure 8. Time Path for Total Value Added for the Immediate Conversion to Dryland Scenario for Subarea 6 of Sheridan County

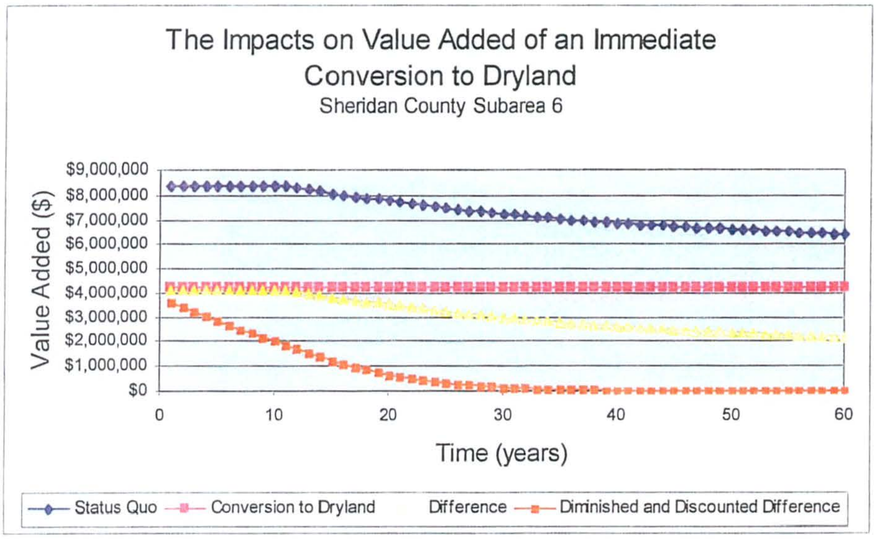

Figure 9. Time Path for Total Value Added for the Immediate Conversion to Limited Irrigation Scenario for Subarea 6 of Sheridan County

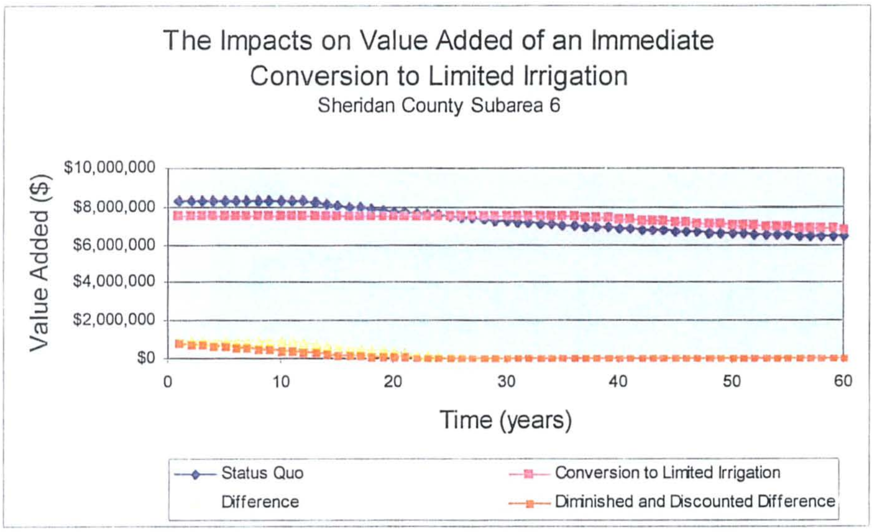

Figure 10. Time Path for Total Value Added for a Water Rights Buyout Scenario for Subarea 6 of Sheridan County

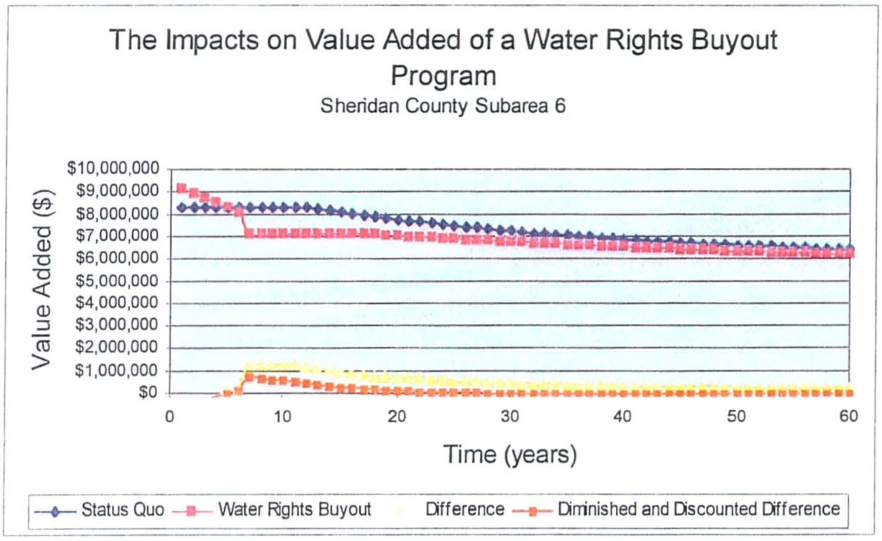

Figure 11. Time Path for Total Value Added for a CREP Scenario for Subarea 6 of Sheridan County

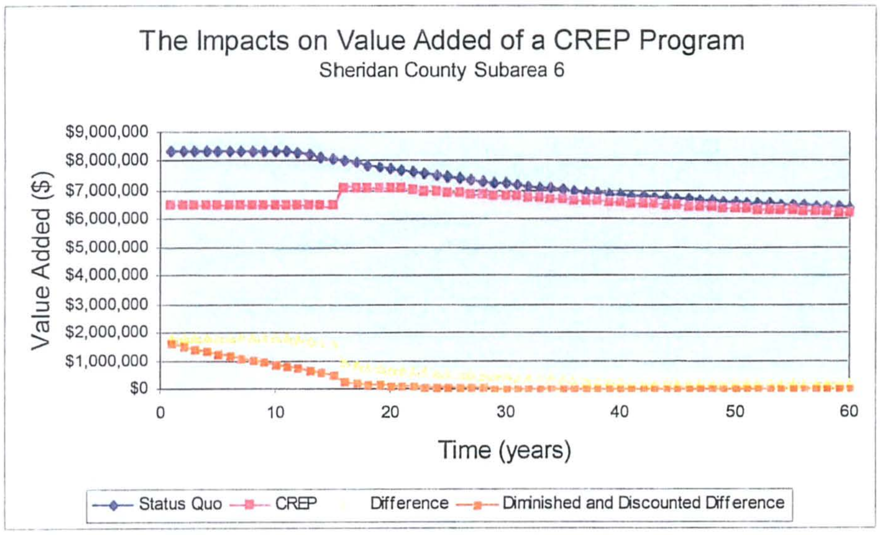

Figure 12. Relative Time Trends in Gross Profit for the Status Quo Scenario

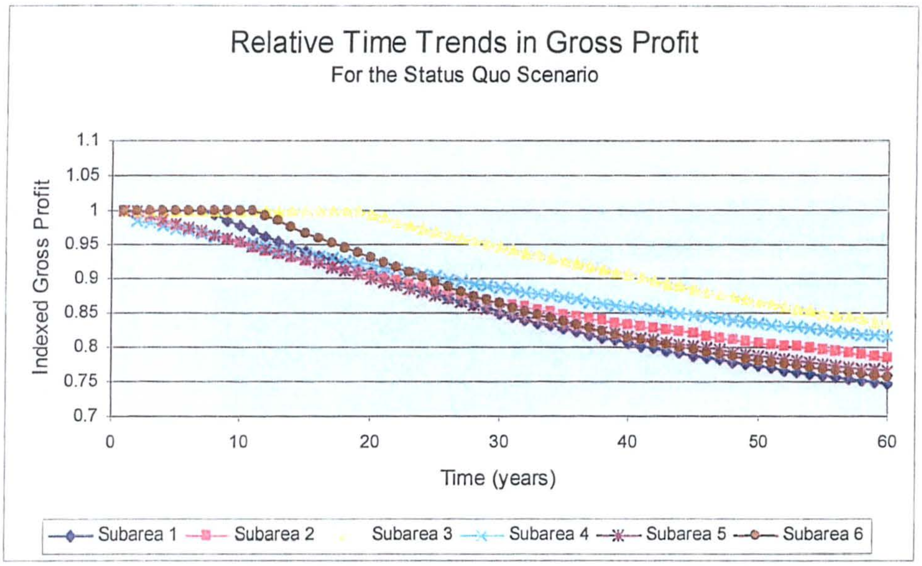

Figure 13. Relative Time Trends in Gross Profit for the Limited Irrigation Scenario

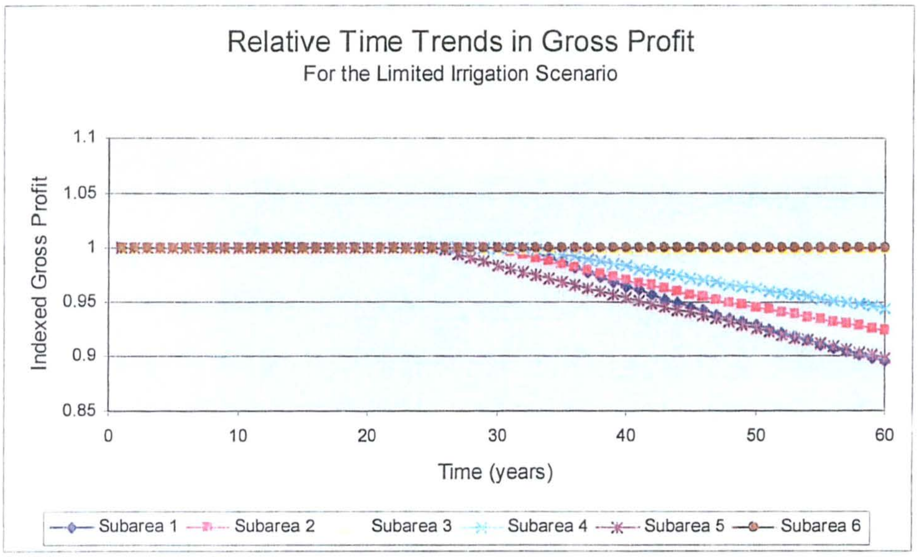

Figure 14. Relative Time Trends in Saturated Thickness for the Status Quo Scenario

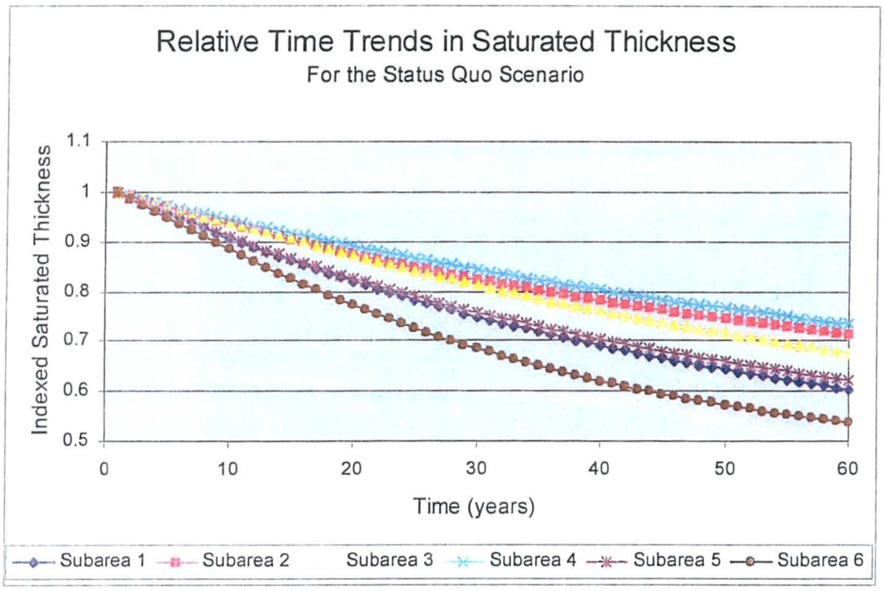

Figure 15. Relative Time Trends in Saturated Thickness for the Status Quo Scenario

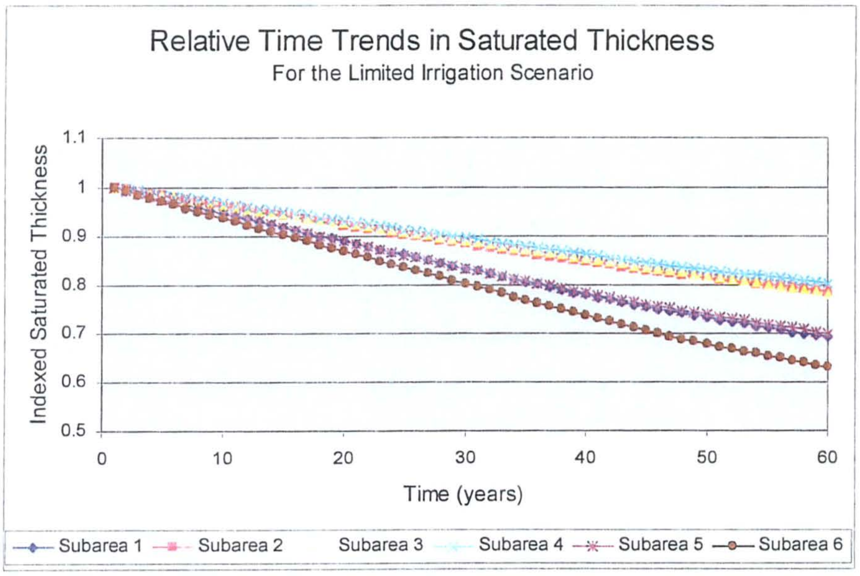

Figure 16. Relative Difference Time Trends in Saturated Thickness between the Limited Irrigation and Status Quo Scenario