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

RE: Supplement to the Preceding Written Testimony and Record for SD-6 Proposed Local Enhanced Management Area (LEMA) of November 28, 2012 & May 31st, 2017

Presented by: Shannon Kenyon

This written testimony is from the Northwest Kansas Groundwater Management District No. 4. It supplements the Testimony of the Northwest Kansas Groundwater Management District No. 4 to Hearing Officer David Barfield, Chief Engineer, Division of Water Resources, Kansas Department of Agriculture, RE: SD-6 Proposed Local Enhanced Management Area (SD-6 LEMA) Proposal of 2012 & 2017, Wayne Bossert and Raymond Luhman. This previous testimony is in the records of the Kansas Department of Agriculture, Division of Water Resources and will not be provided again here. See https://www.agriculture.ks.gov/divisions-programs/dwr/managing-kansas-water-resources/local-enhanced-management-areas/sheridan-county-6-lema.

Request

To continue reducing the local decline rate and extend the economic life of the aquifer within the SD-6 LEMA, the Northwest Kansas Groundwater Management District No. 4 (GMD 4) board submitted a SD-6 LEMA proposal to the chief engineer on behalf of the stakeholders of HPA SD-6 on July 16, 2012. On December 31, 2012, the Chief Engineer signed an Initial LEMA Order of Decision approving the SD-6 LEMA. On April 17, 2013, the Chief Engineer signed a FINAL LEMA Order of Designation. On February 2, 2017, GMD 4 requested the Chief Engineer re-formulate the SD-6 LEMA for a period from 2018 to 2022. On November 7, 2017, the Chief Engineer renewed the SD-6 LEMA with the Order of Designation for 2018 – 2022.

On October 21, 2021, the GMD 4 board submitted a request to renew the LEMA to the Chief Engineer. See attached Exhibit 1. The LEMA period would be from January 1, 2023, through December 31, 2027.

Process

The 2021 request to re-formulate the SD-6 LEMA will be heard in one consolidated hearing to take place on July 26th, 2022, The hearings will determine:

- Whether one of more of the following circumstances continues to exists:

  - o Groundwater levels in the area in question are declining or have declined excessively.
  - o The rate of withdrawal of groundwater within the area in question equals or exceeds the rate of recharge in such area.
  - o Preventable waste of water is occurring or may occur within the area in question.
  - o Unreasonable deterioration of the quality of water is occurring or may occur within the area in question.

- Whether the public interest requires one or more corrective control provision be adopted

- Whether the geographic boundaries are reasonable.

- And whether the Chief Engineer should accept, reject, or suggest modifications to the proposed LEMA.

GMD 4 requests the Chief Engineer accept the proposed 2022 SD-6 LEMA for the following reasons.

Status of the Aquifer in the SD-6 LEMA

The previous SD-6 LEMAs have reduced groundwater decline. However, the rate of withdrawal of groundwater within the proposed SD-6 LEMA area continues exceeding the rate of recharge in that area. See Exhibit 2. Therefore, the SD-6 Advisory Committee advised the GMD 4 Board that corrective controls should be continued and that it is in the public's interest to continue with the controls currently in place.

Evidence Showing SD-6 LEMA Corrective Control Success

The 2022 SD-6 LEMA proposal submitted by the GMD 4 Board of Directors consists of:

- a substantially similar goal expression from the 2012 & 2017 SD-6 LEMA proposals;
- the twelve implementable elements designed to achieve that goal;
- and adds the ability for water rights to be enrolled in a Multi-Year Flex Account during the LEMA period.

The 2022 SD-6 LEMA proposal is the product of annual review of the SD-6 Advisory Committee, their recommendations to the GMD 4 Board of Directors, and a stakeholder meeting to discuss the renewal of the SD-6 LEMA

Pursuant to LEMA Plan, the SD-6 Advisory Committee continues to meet annually to discuss the six points as outlined in the Plan. The most recent report is attached as Exhibit 2.

The 2022 SD-6 LEMA request adopts the goal statement and justifications from the goal statement of the 2012 & 2017 SD-6 LEMA request. The empirical evidence used to justify that goal remains the same, and is supplemented with data collected and analyzed from 2013 to 2022 regarding reduced pumpage and aquifer decline. *See* Testimony of the Northwest Kansas Groundwater Management District No. 4 to Hearing Officer David Barfield, Division of Water Resources, Kansas Department of Agriculture, RE: SD-6 Proposed Local Enhanced Management Area (LEMA) Proposal November 28, 2012, Wayne Bossert and Raymond Luhman, pg. 2. This 2022 SD-6 LEMA proposal continues the approach of requiring every water type within the SD-6 LEMA to be part of the solution while still requiring the predominate water-use type – irrigation - as considered desirable by the stakeholders in 2012, 2017, and now in 2022, to bear the most water use reduction.

Even though rate of withdrawal of groundwater from the aquifer continues to decline, during the implementation of the 2012 & 2017 SD-6 LEMAs, GMD 4's observation wells showed a marked decrease in the aquifer's water level decline. the proposed LEMA boundaries contain six annually measured observation wells. The observation wells are located at:

SD	7	29W	5	07S29W05
SD	7	29W	27	07S29W27
SD	7	29W	30	07S29W30
SD	8	29W	1	08S29W01
SD	8	30W	5	08S30W05
SD	8	30W	11	08S30W11
SD	8	30W	13	08S30W13

From 2008 till 2013, the observation wells averaged 1.5 feet per year declines in the water table. From 2013 till 2017, the observation wells averaged 0.68 feet per year declines. From 2017 to 2022, the observation wells average 0.30 feet. See Attached Exhibit 3.

The Kansas Geological Survey (KGS) now monitors GMD 4's installed transducer wells. The data shows that most of the index wells within SD 6 area are not declining as quickly, or not at all, as compared to the index well outside of the SD 6 area. Exhibit 4.

Attached is an updated analysis by the KGS of the SD-6 area, reviewing relationships between pumping and precipitation and water level declines. See Exhibit 5.

The left-hand graph of Exhibit 5 evidences the same conclusion presented at the 2017 hearing that when pumpage throughout the SD-6 LEMA is about 15,000 acre feet, then decline reaches about zero and may encourage recharge. As pumpage in the SD-6 LEMA increases, the rate of decline increases, too.. Therefore, the SD-6 LEMA is achieving its goals of reducing the declination of the aquifer and extending the aquifer's life.

The extension of the aquifer's life comes while maintaining the economic viability of the area. According to the Golden Final Report on November 15, 2018:

> 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 23.1%, reduced average groundwater use per acre by a statistically significant 16.0%, reduced irrigated crop acreage by a statistically significant 10.9%, reduced irrigated corn acreage by a statistically significant 23.3%, increased irrigated grain sorghum acreage by a statistically significant 335.4%, and increased irrigated wheat acreage by a statistically significant 60.3%. Monitoring the Impacts of Sheridan County 6 Local Enhanced Management Area, Final Report for 2013-2017, Dr. Bill Golden, November 15, 2018 attached as Exhibit 6.

Flexibility remains key to water right user success under the SD-6 LEMA limitations. GMD 4 proposes that the flexibility contained in the original SD-6 LEMA be continued in the 2023 re-formation of the SD-6 LEMA. GMD 4 will update the combination forms with new dates. All the approved "umbrella accounts" must re-submit the updated forms. GMD 4 has seen no evidence that this flexibility was detrimental in reaching the goal. GMD 4 and the Advisory Committee will continue monitoring this flexibility for potential abuses and other unanticipated concerns.

The metering and enforcement policies have worked because they allow for a swift response to meter failures and contain a penalty sufficient to encourage compliance. GMD-4 requests the enforcement and metering policies be continued.. The GMD 4 checked all of the wells within SD-6 during the 2018 LEMA period. Several well meters failed and the water users and GMD 4 worked together under normal procedures to see that the meters were replaced. Most, if not all, water users adopted alternate means to monitor their meters. This allowed quick compliance and an attainment of the five-year goal.

The Advisory Committee should be continued in its current form. The advisory committee meets yearly, has produced yearly reports (see attached Exhibit 2), and has encouraged GMD 4 and stakeholders to work towards communication regarding the SD-6 LEMA status. The request for re-formation was done at the Advisory Committee's recommendation to the GMD 4 Board of Directors.

Conclusion

In closing, the GMD 4 Board offers a proposal to re-form the SD-6 LEMA for 2023-2027 and the re-formation:

1. Reduces the historical water use by a significant amount and will achieve the LEMA goal of no more than 122,400 acre-feet pumped during the LEMA period.

2. Does not disadvantage the less used water rights or benefit the highest used water rights.

3. Allows maximum economic use of the total goal quantity chosen.

4. Includes a monitoring and enforcement element that is sufficient to thwart violations.

5. Is consistent with Kansas water law.

6. Is an accurate representation of the specific desires of the consensus of the SD-6 stakeholders, who developed the plan.

7. Meets all the requirements of K.S.A. 82a-1040 et seq.

Therefore, this re-formation should be approved and implemented as requested.

Request for Renewal of Sheridan 6 LEMA Submitted To the Chief Engineer, Kansas Department of Agriculture, Division of Water Resources

October 20, 2021

This request represents a re-constitution of the current SD-6 LEMA (2018 – 2022). It is essentially the same request as was previously filed.

In order to reduce decline rates and extend the life of the aquifer SD 6 HPA proposes the following five year plan be submitted via the LEMA process contained in KSA 82a-1041. This proposal has been recommended by the SD-6 Advisory Committee. A public meeting on this proposal was held on August 25, 2021. A copy of the meeting notes are attached.

Goal Expression

All water diversions within the SD-6 area are to be collectively restricted per this proposal between the period January 1, 2023 through December 31, 2027 to no more than 117,600 AF total.

This LEMA shall exist only for the five year period beginning January 1, 2023 and ending December 31, 2027. The SD-6 HPA shall include all points of diversion that are located in the following sections:

- 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
- TWP 8S-31W: Sections 22-27 and 34-36

These sections represent a LEMA boundary that is both clearly identifiable and entirely within the boundaries of the Northwest Kansas Groundwater Management District No. 4.

The total program diversion amount of 117,600 AF, plus carryover, shall represent five (5) times the sum of:

a) Designated legally eligible acres (per section 1) x 11/12 for irrigation water rights plus carryover;

b) Maximum permitted head of livestock on December 31, 2020 x 12 GPH/D for stockwater rights; and

c) Ninety percent (90%) of the December 31, 2020 authorized recreational water quantity for recreation rights.

The Northwest Kansas Groundwater Management District No. 4 shall use the following procedures 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 AF for the 5-year LEMA period. Any notes or remarks necessary to explain the individual allocations shall also be included.

1) Allocations – Irrigation

a) All irrigation water rights shall be limited to no more than 55 acre inches per irrigated acre for the period of 2007 – 2010 or any acreage adjustments due to appeal, covered by the water right over the 5-year period beginning January 1, 2023 and ending December 31, 2027.

b) Carry-Over Amount. The carry-over amount will be determined as of December 31, 2022 for IRR use only. The carry-over amount cannot exceed 5 inches per program acre and is the lesser of: 1) 5 inches per program acre or; 2) a water users unused acre inches per program acre.

c) Wells pumping to a common system or systems shall be provided a single allocation for the total system acres. The total amount pumped by all of the wells involved must remain within the system allocation.

d) For additional producer flexibility, water rights may at the discretion of the owners be combined into a single allocation account with flexibility of pumping the multiple wells within the account as directed by the owner, provided the total account allocation is not exceeded.

e) Temporary transfers of allocations between water rights may be made anywhere within the boundaries of SD-6. Said transfers shall be in effect for the balance of the current allocation time period. An Application for Transfer form shall be developed and must be signed by all owners involved in the transfer. No transfer shall result in an allocation that exceeds the authorized amount for the water right receiving the transfer.

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

g) 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.

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

i) 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.

j) A irrigation water right owner will have the option of converting to a Multi-year Flex Account (MYFA) provided the MYFA quantity does not exceed the established 5-year allocation quantit.

For a MYFA with less than five years, the MYFA quantity shall be less or equal than 11" multiplied by the number of years applied for, less than five years. In all instances, the most water restrictive plan will apply.

k) For water rights enrolled in EQIP and/or AWEP that will be coming out of either program on or before September 30, 2027, the allocation quantity shall be set at 11 acre-inches per acre for only the remaining years of the 2023-2027 LEMA period.

l) Any water right enrolling into, contracting with, or officially participating in a reduced water use program (AWEP, EQIP, Northwest Kansas Groundwater Conservation Foundation, WCA, etc.) during the period January 1, 2023 through December 31, 2027 shall not be allowed to trade or market any allocation balance.

2) Allocations – Non-irrigation

a) Livestock uses will be limited to 12 gallons per head per day based on the maximum head supportable by the feedlot permit in effect on December 31, 2020. Each water right shall have the option of having this limited quantity as an annual limit or converted to a 5-year water right at 5 times the assigned allocation. The original water right will be retained.

b) Recreation water rights will be limited to 90% of the December 31, 2020 annual authorized water right quantity. Each water right shall have the option of having this limited quantity as an annual limit or converted to a 5-year water right at 5 times the assigned allocation. The original water right will be retained.

3) Individual Allocation Amounts

The 5-year allocations for every water right per Sections 1) a) and 2) above shall be converted to a 5-year acrefeet total, with Attachment 2 containing the assigned eligible allocations for each water right within the SD-6 HPA. Each water right is to be restricted to its total acrefeet allocation within any LEMA order issued through this process.

4) Violations

The LEMA order shall serve as initial notice to all water right owners within HPA SD-6 on its effective date. Violations of the authorized quantities shall be addressed as follows:

(1) Exceeding any total allocation quantity (which shall include any transferred quantities) of less than 4 AF within any allocation period shall result in a $1,000.00 fine for every day the allocation was exceeded. This penalty shall apply to all rights in combined allocation accounts described in sections 1) b) (1) and 1) b) (2).

(2) Exceeding any total allocation quantity (which shall include any transferred quantities) of 4 AF or more within any allocation period shall result in an automatic two year suspension

of the water right. This penalty shall apply to all rights in combined allocation accounts described in sections 1) b) (1) and 1) b) (2).

(3) Exceeding the annual authorized quantity of the water right (not to include any transferred quantities) shall result in a $1,000.00 fine.

5) 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.

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.

6) Accounting

a) 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. Annual status reports shall be mailed to each water right owner and provided to DWR.

b) DWR shall provide GMD 4 with as timely as possible copies of annual water use reports received in the office of the chief engineer. GMD 4 and DWR shall cooperate on reconciliation and correction of any WUR found to be in error.

c) A form similar to the Wet Walnut IGUCA temporary transfer of allocations shall be developed by the chief engineer with input from GMD 4 for the SD-6 LEMA and shall be used to approve and track transfers of water within the SD-6 HPA per Section 1) d) above.

7) Advisory Committee

a) A SD-6 LEMA Advisory Committee shall be appointed and maintained by the GMD 4 Board consisting of an odd number of members between five (5) and nine (9) members as follows: one (1) GMD 4 representative; one (1) representative of the Division of Water Resources, Kansas Department of Agriculture as designated by the chief engineer; and the balance being SD-6 HPA residents/owners/operators – one (1) of which must represent non-irrigation users. One of the SD-6 HPA 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 shall produce a report after every meeting 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.

8) LEMA Order Reviews

a) In addition to the annual LEMA Order reviews per section 7), the SD-6 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 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.

9) Impairment Complaints

While this program is being undertaken it is the desire of the SD-6 stakeholders that any impairment complaint filed in the HPA 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 either: deferred for investigation until the management program is no longer valid; or, be investigated by the chief engineer in consideration to the on-going management activities.

10) Water Level Monitoring

Prior to the 2013 SD-6 LEMA proposal there were seven recognized observation wells within the SD-6 HPA that have been measured annually by either Division of Water Resources (DWR) or Kansas Geological Survey (KGS) personnel. These wells are located:

SD	7	29W	5	07S29W05
SD	7	29W	16	07S29W16
SD	7	29W	25	07S29W25
SD	7	29W	27	07S29W27
SD	7	29W	30	07S29W30
SD	7	30W	27	07S30W27
SD	8	29W	1	08S29W01
SD	8	30W	5	08S30W05
SD	8	30W	11	08S30W11
SD	8	30W	13	08S30W13
SD	8	31W	26	08S31W26

For each of these wells there is a long history of annual water level measurements. The stakeholders of HPA SD-6 expressed a desire to increase the number of monitoring wells in support of this proposal.

The Kansas Geological Survey collects data from five wells within the SD-6 boundaries. These wells record water levels hourly with the installation of a continuous pressure transducer. These locations are:

07S29W16
07S29W25
07S30W27
08S30W13
08S31W26

11) Coordination

The SD-6 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 four efforts:

a) Development of the LEMA Order resulting from the LEMA process;

b) Setting and accounting for the umbrella accounts authorized by Section 1) c);

c) Authorizing and accounting of water right transfers and bookkeeping authorized by Section 1) d); and

d) Accounting for annual pumpage amounts by LEMA water right owners/operators.

12) General

The core concern of this LEMA is to remain within the allocation quantity after five years of pumping. Any future decisions within this LEMA period which intend to incorporate new or overlooked issues shall be made in deference to this total allocation limit.

In the case of multiple allocation programs (WCAs, KAR 5-5-11 changes, other LEMAs, MYFAs, etc) the requirements of the most restrictive program will apply.

All combination applications or temporary transfers must be re-done for the LEMA period 2023-2027.

Attachment 1

SD 6 LEMA Renewal Public Meeting Notes
August 25th, 2021 3:00 pm, Hoxie Elks Lodge

When we were having those first meetings. I feel that they are connected. If someone accumulates a large area, could they be pumping out from under their neighbor?
Then the overall usage could come up.

What happens in dry years?

Where that usage comes from?

If converted to livestock could be a lot more.

It could be kept track of - - needs to be looked at. I know there's one sprinkler that runs all the time.

We see what happens in full blown drought back west.

Some people are giving up more than others.

Pooling wells – umbrellaing could take more.

The water rights that Harold is talking about are all umbrellaed anyway?

You wind up with more usage.

We should be aware of where increased usage comes from.

I think people are trying to use it wisely (altogether).

Tracking it?

I think it is doing what it's supposed to do.

Some are trying to adjust with different crops.

Pumping more than should be because of umbrellas?

It comes down to management decisions.

Track it.

I agree.

What are we gonna have for carryover?

That's in the new one?

Looks like we've made progress.

Until we get a 5-year drought.

It needs noted that if we get into a serious drought.

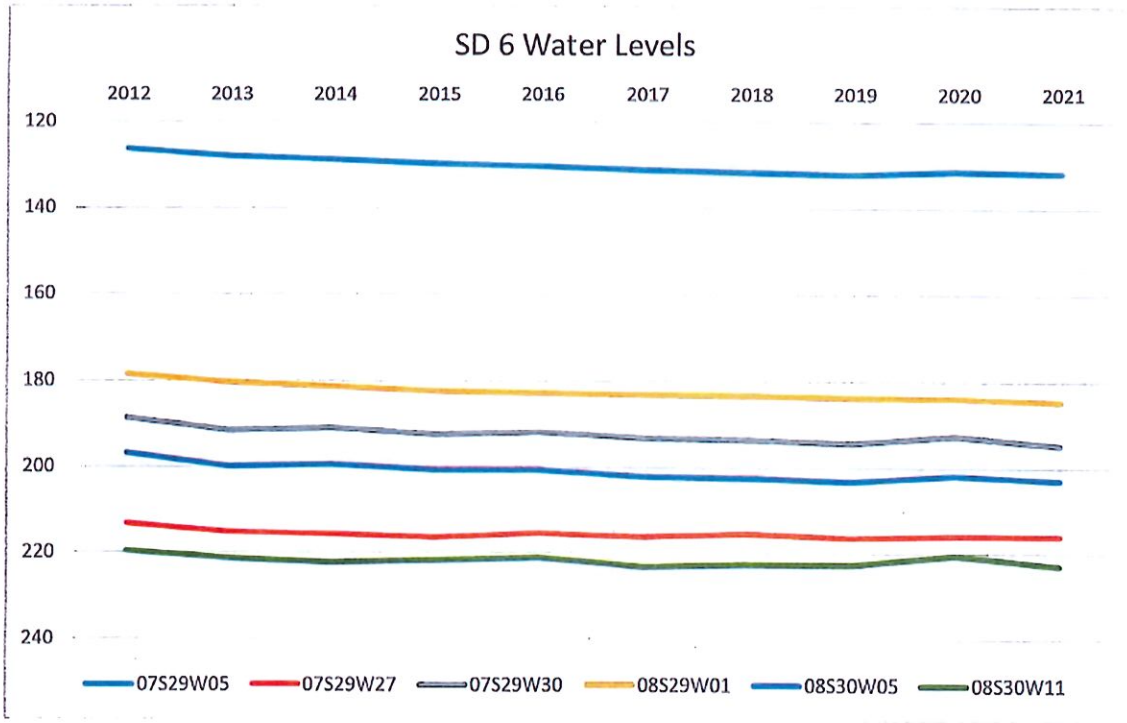
It started how far south of the highway?

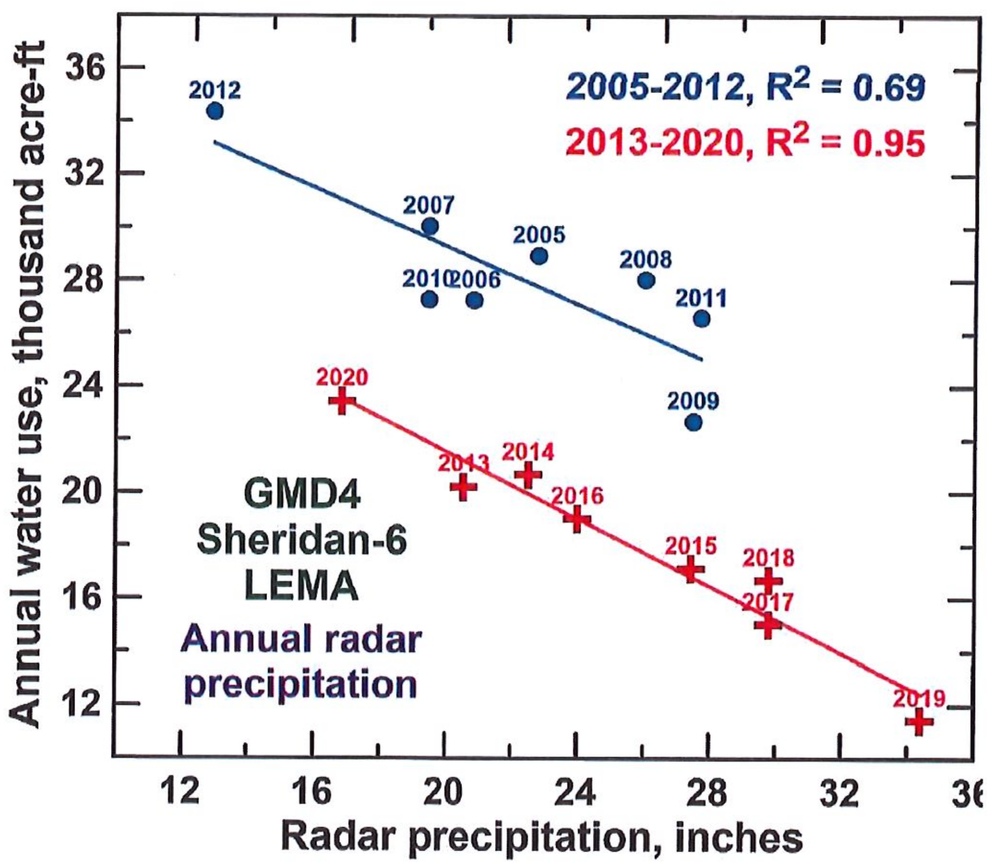
Being able to pump any water on grass is okay - - but when there's runoff when moisture comes isn't.

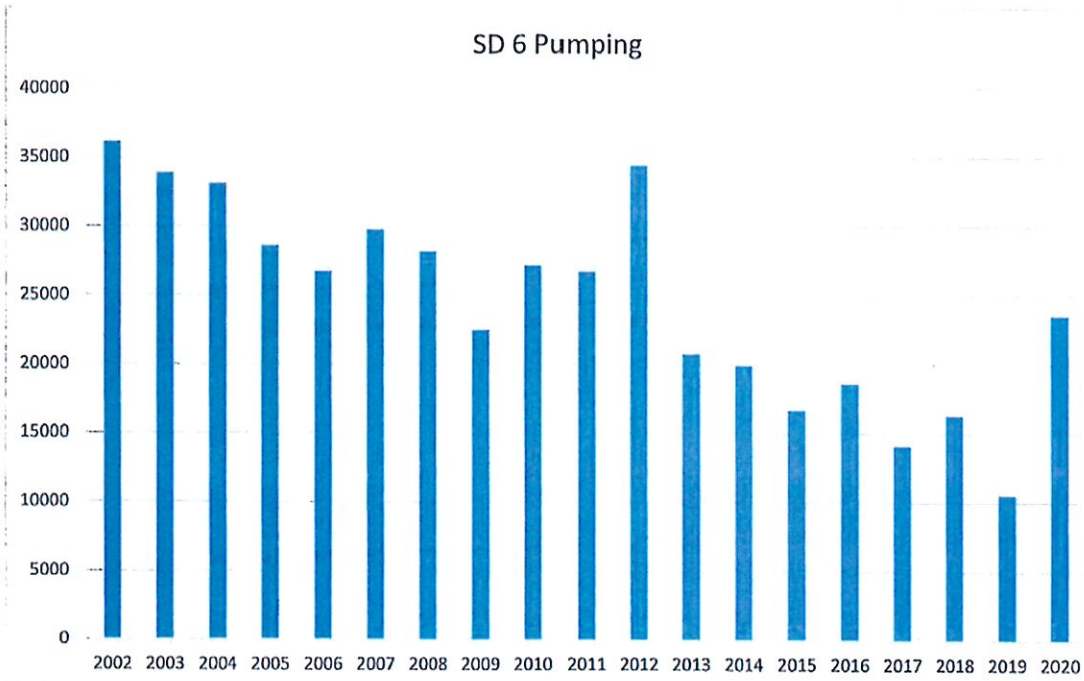
Going into creeks – runoff areas were supposed to be monitored. Because the state was trying to make it look better – doesn't make it right, its pollution. Areas need to be monitored. There's a bigger chance of not having pure water. There are large areas where other farmers are being monitored for nitrates. I don't want to see it here.

Scott Foote shouldn't be able to mix stock water with irrigation to further livestock expansion.

Attachment 2






SD 6 Pumping
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2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Exhibit 2

Sheridan 6 LEMA

Local Enhanced Management Area-LEMA

Sheridan 6 LEMA concludes its fourth year of the 5 year allocation program set to continue through December 31st of 2022. The 99 square mile area included 185 irrigation wells and 10 non-irrigation wells.

As required in the Order of Designation Approving the Sheridan 6 Local Enhanced Management Area Within Groundwater Management District No. 4 the "Advisory committee shall produce a report after every meeting which shall provide for considerations…"

The following report will include summaries of the April 19th, 2022 Sheridan 6 Advisory Committee Meeting, and will provide additional information fulfilling all requirements as stated in the Order including the final 2021 water use data for the LEMA.

SD-6

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

TWP 8S-31W: Sections 22-27 and 34-36

ANNUAL SD-6 ADVISORY COMMITTEE MEETING

Tuesday, April 19th @ 11 am– The First State Bank, Hoxie, KS

Those in attendance: Shannon Kenyon & Colter Stoll (GMD 4), Gary Moss, Dennis Rogers, Brett Oelke, Jeff Munk, Stuart Beckman and Rebecca Hageman (DWR)

i. Water use data
Shannon Kenyon distributed a graph showing the historical pumping from 2003 – 2021 within the SD 6 LEMA boundaries. As 2021 seemed to be much drier than 2020 discussion was had on reasons why and it was thought that being the fourth year of the LEMA, many wanted to make sure they had enough for year five.

Colter Stoll plans to visit SD 6 wells during the irrigation season to make sure meters are working accurately and then again at the end of the irrigation season to determine how much is left in their SD 6 LEMA account and if any water needed to be transferred.

Letters were sent to all SD 6 landowners or tenants indicating how much water they can pump in 2022. The new format was favorable and will be continued. Many were surprised they had that much left but made them feel more comfortable going into the fifth year.

ii. Water table information
Shannon then pointed to the information in the meeting packets on the SD 6 water levels provided to her by KGS. The first is a map of the entire cooperative network. It was noted that GMD 4 wasn't in near the decline as the southwest.

Another document showing the six index wells and what their water levels were and the progression from 2012 to current. There is also a chart included showing those water levels and the 5 year, 10 year, and 1 year declines. Committee members were pleased the declines weren't worse considering the lack of rainfall.

Shannon then pointed them to each of the index wells and their respective graphs. Each well has historical data, but also data for the current recovery period. Not much discussion was had on this data other than questions were raised about the Steiger well as it had come up almost 8 feet last year to drop back down again. Shannon will follow up with KGS and get back to the group.

iii. Economic data
No ongoing economic studies at this time.

iv. Violations, issues relating to violations, and metered data that relates to violations
Colter will be in the SD 6 region this summer keeping everyone in compliance as this

ANNUAL SD-6 ADVISORY COMMITTEE MEETING
11 am CDT
Tuesday, April 19th, 2022

First State Bank, Hoxie Basement

i. Water use data

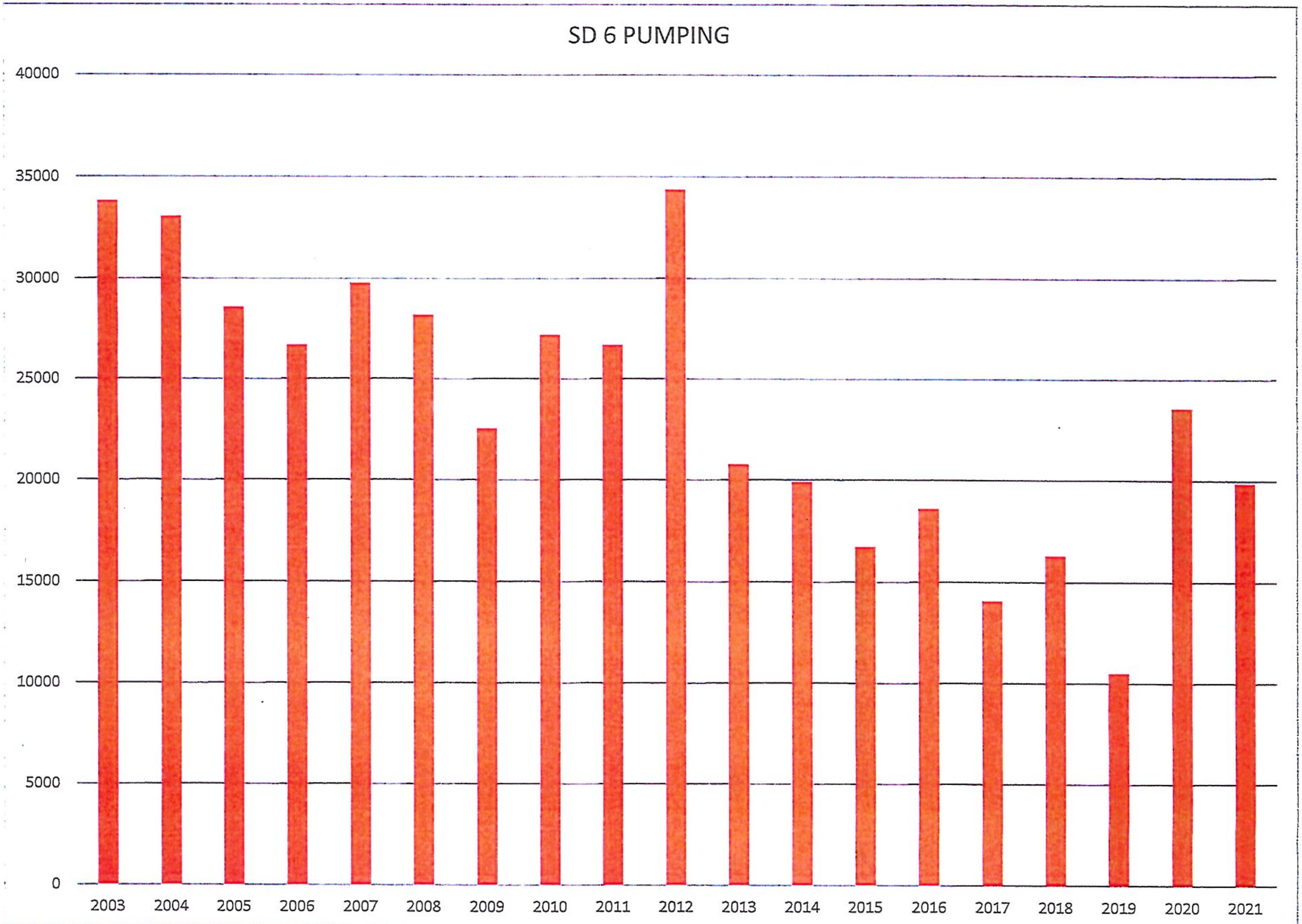
ii. Water table information

iii. Economic data

iv. Violations, issues relating to violations, and metered data that relates to violations

v. New and preferable enhancement management options

vi. Other items (meter alternative discussion)


SD 6 PUMPING
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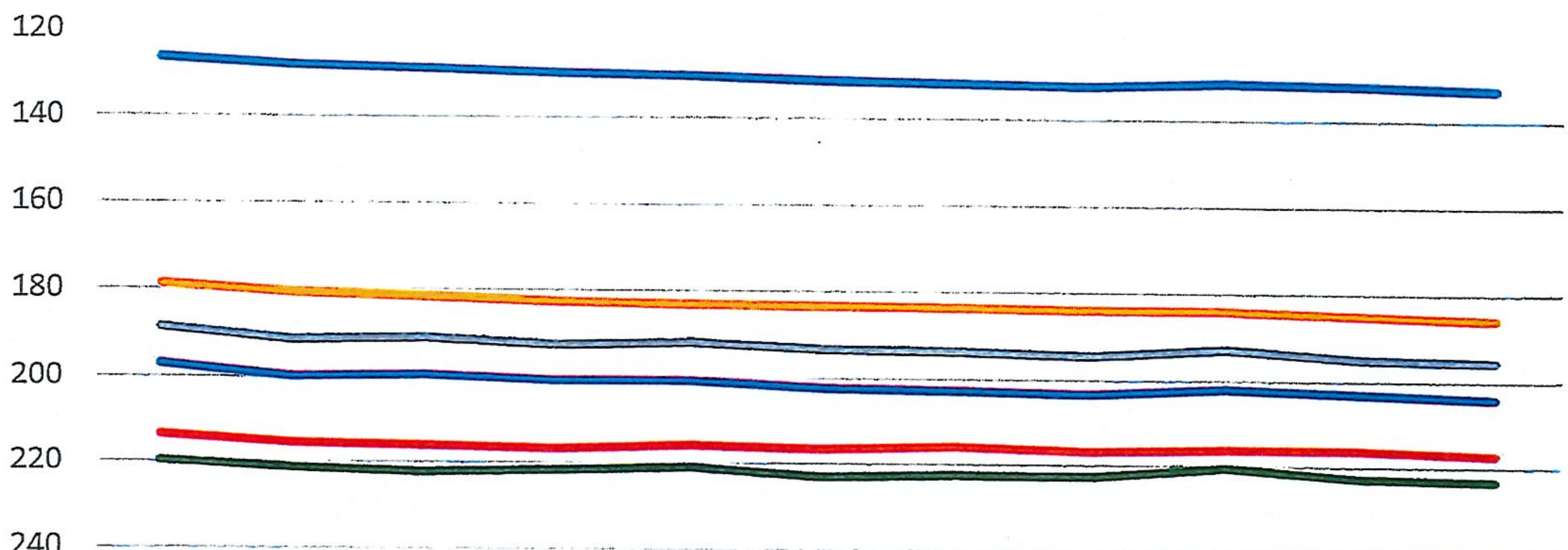
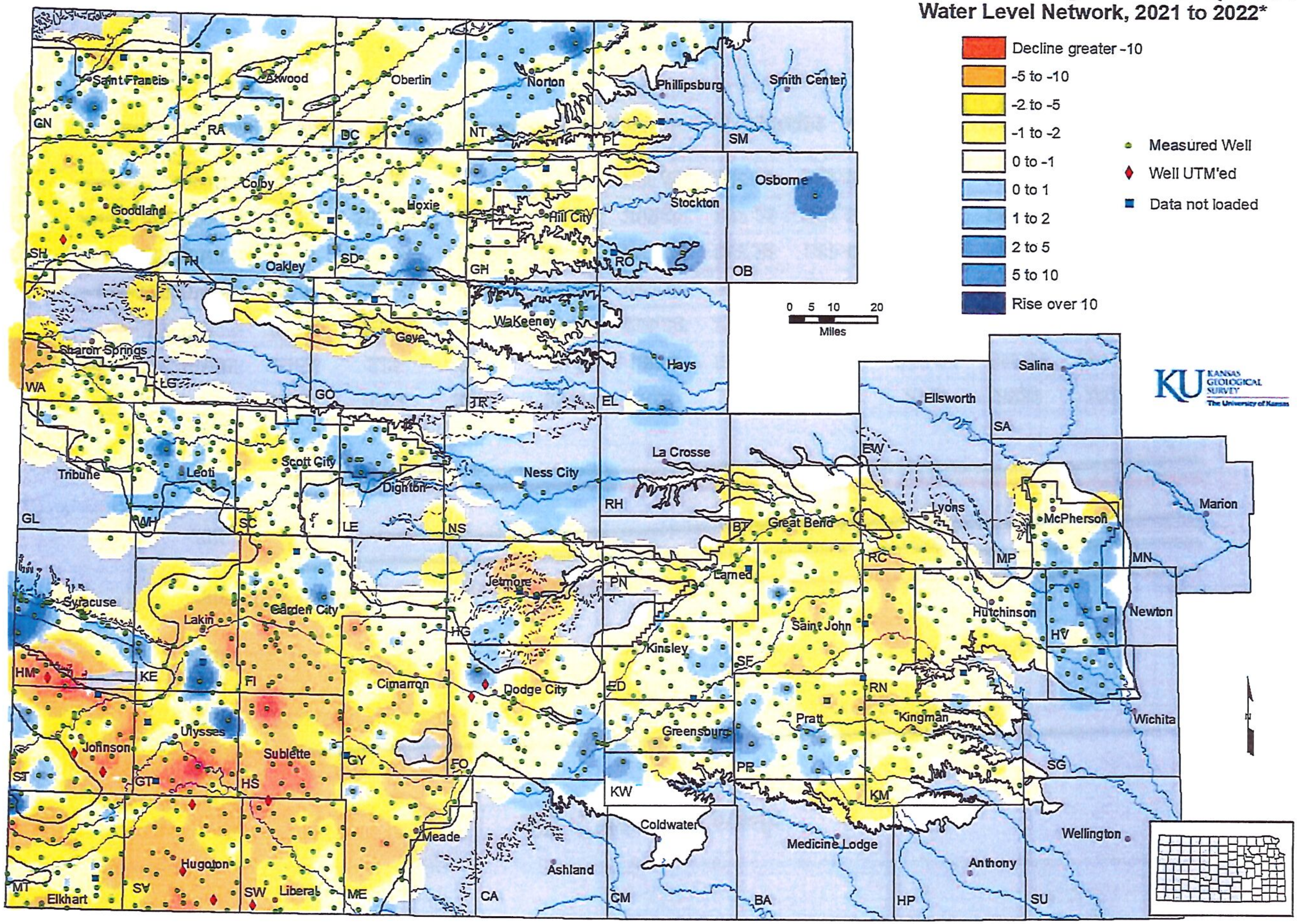
SD 6 Water Levels



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
07S29W05	126.3	128	128.7	129.68	130.2	131.07	131.6	132.14	131.33	131.75	132.55
07S29W27	213.4	215.35	215.85	216.60	215.58	216.45	215.7	216.63	216.09	216.06	217.04
07S29W30	188.65	191.5	190.95	192.40	191.84	193.16	193.53	194.31	192.655	194.76	195.32
08S29W01	178.6	180.55	181.44	182.59	182.94	183.28	183.47	183.96	183.97	184.74	185.63
08S30W05	196.9	199.95	199.4	200.70	200.69	202.19	202.58	203.26	201.91	202.93	203.91
08S30W11	219.65	221.3	222.29	221.71	221.05	223.11	222.53	222.7	220.45	222.79	223.34

07S29W05 07S29W27 07S29W30 08S29W01 08S30W05 08S30W11

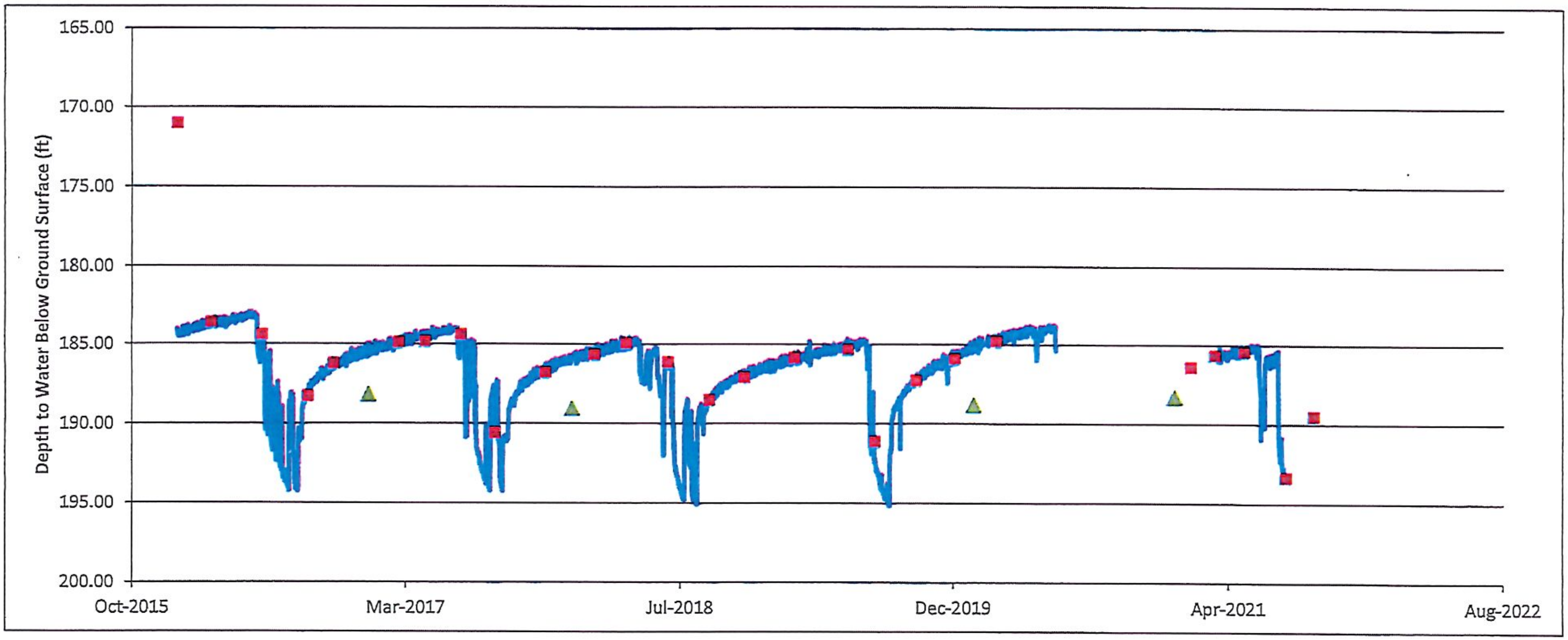
Interpolated Change in Feet, Cooperative Water Level Network, 2021 to 2022*



*Results are based only on the cooperative network (KGS and KDA-DWR) and do not include sub-regional networks from the KGS, KDA-DWR or local GMDs.

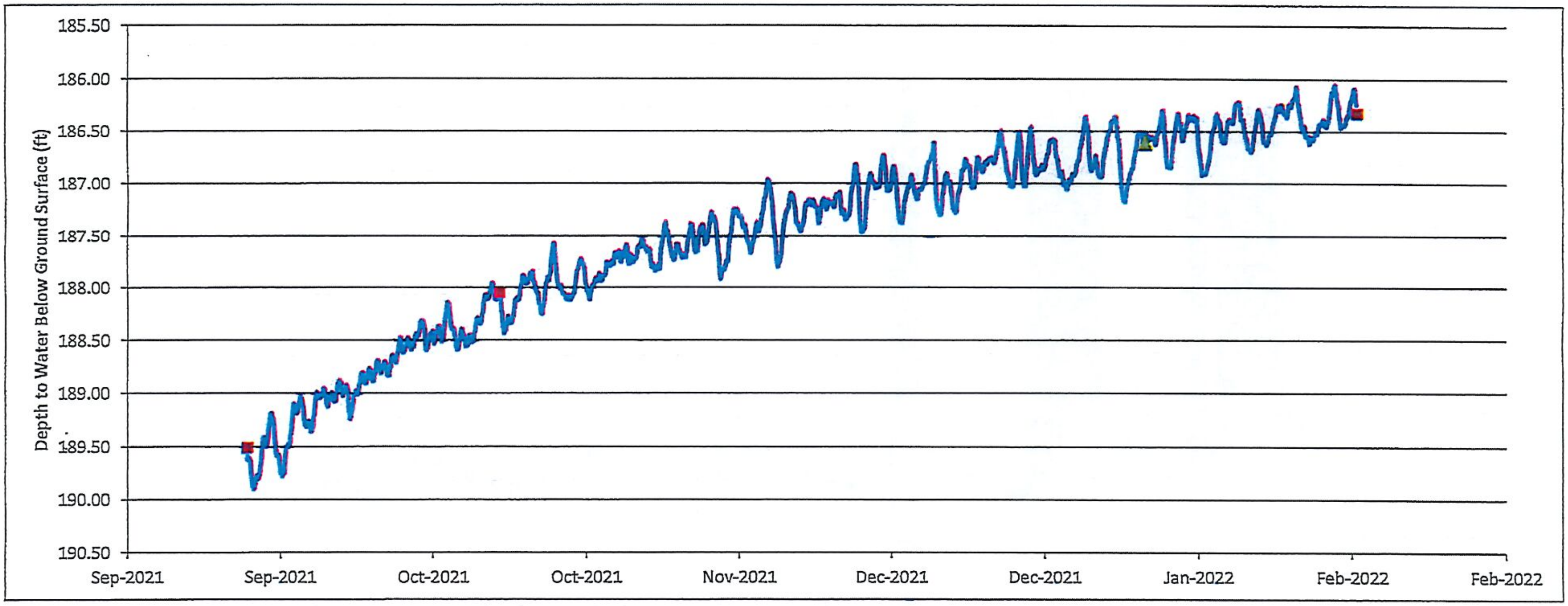
egal	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	5 Yr.	10 Yr.	1 Year
'S29W05	126.3	128	128.7	129.68	130.2	131.07	131.6	132.14	131.33	131.75	132.55	-0.95	-4.55	-0.8
'S29W27	213.4	215.35	215.85	216.60	215.58	216.45	215.7	216.63	216.09	216.06	217.04	-1.34	-1.69	-0.98
'S29W30	188.65	191.5	190.95	192.40	191.84	193.16	193.53	194.31	192.655	194.76	195.32	-1.79	-3.82	-0.56
S29W01	178.6	180.55	181.44	182.59	182.94	183.28	183.47	183.96	183.97	184.74	185.63	-2.16	-5.08	-0.89
S30W05	196.9	199.95	199.4	200.70	200.69	202.19	202.58	203.26	201.91	202.93	203.91	-1.33	-3.96	-0.98
S30W11	219.65	221.3	222.29	221.71	221.05	223.11	222.53	222.7	220.45	222.79	223.34	-0.81	-2.04	-0.55

Baalman



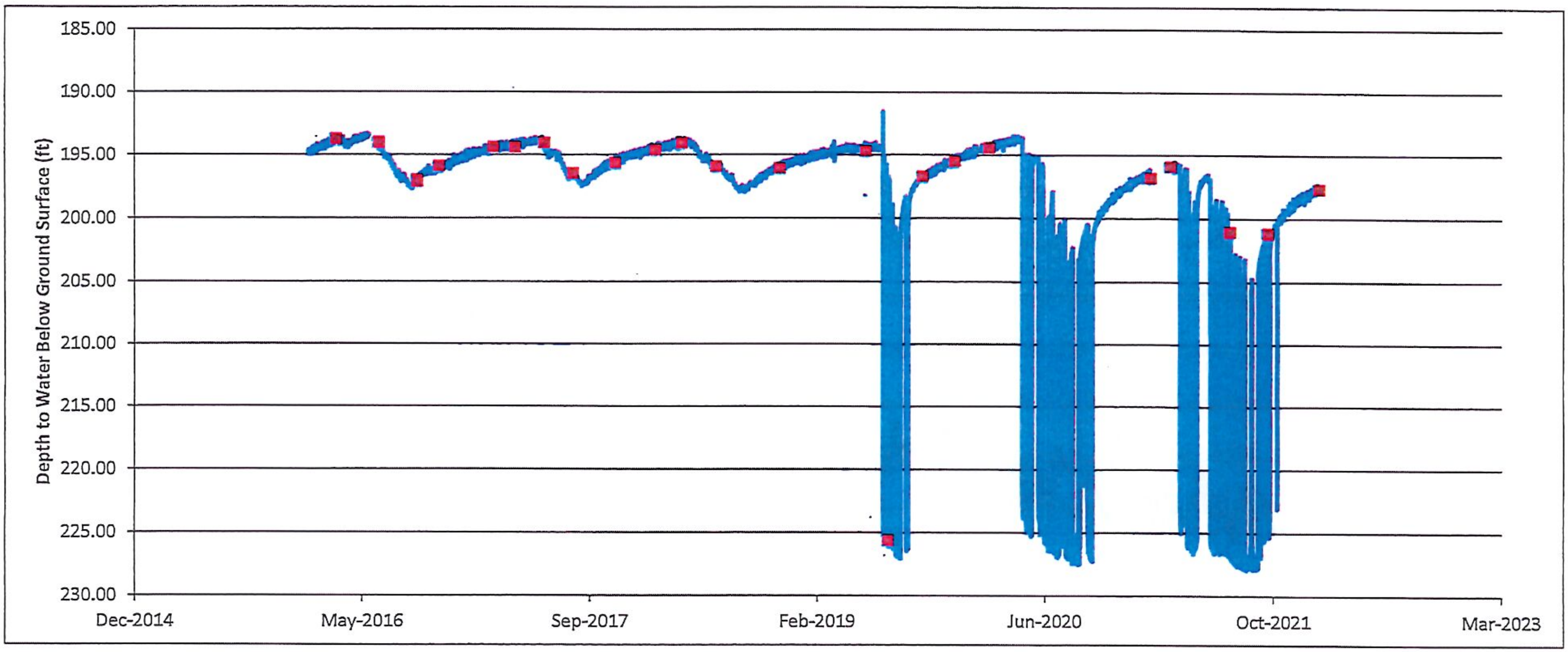
Depth to Water Below Ground Surface (ft)
165.00
170.00
175.00
180.00
185.00
190.00
195.00
200.00
Oct-2015
Mar-2017
Jul-2018
Dec-2019
Apr-2021
Aug-2022

Baalman



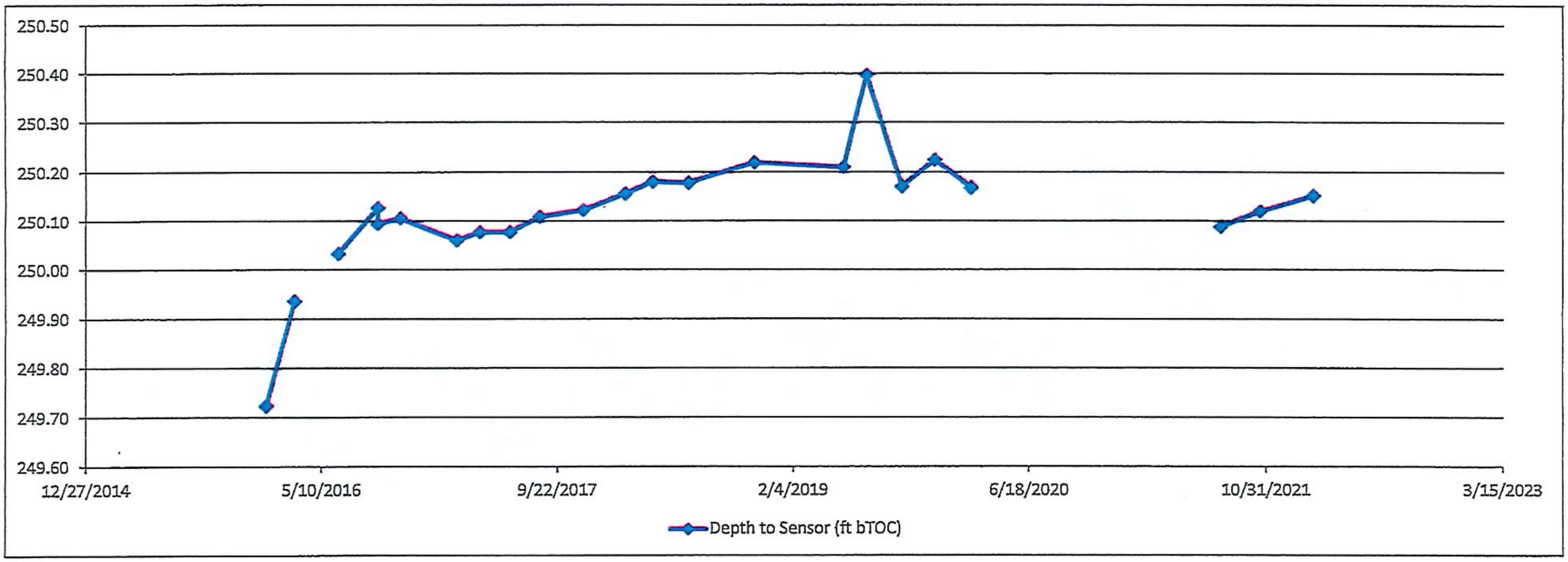
Depth to Water Below Ground Surface (ft)
185.50
186.00
186.50
187.00
187.50
188.00
188.50
189.00
189.50
190.00
190.50
Sep-2021
Sep-2021
Oct-2021
Oct-2021
Nov-2021
Dec-2021
Dec-2021
Jan-2022
Feb-2022
Feb-2022

Beckman

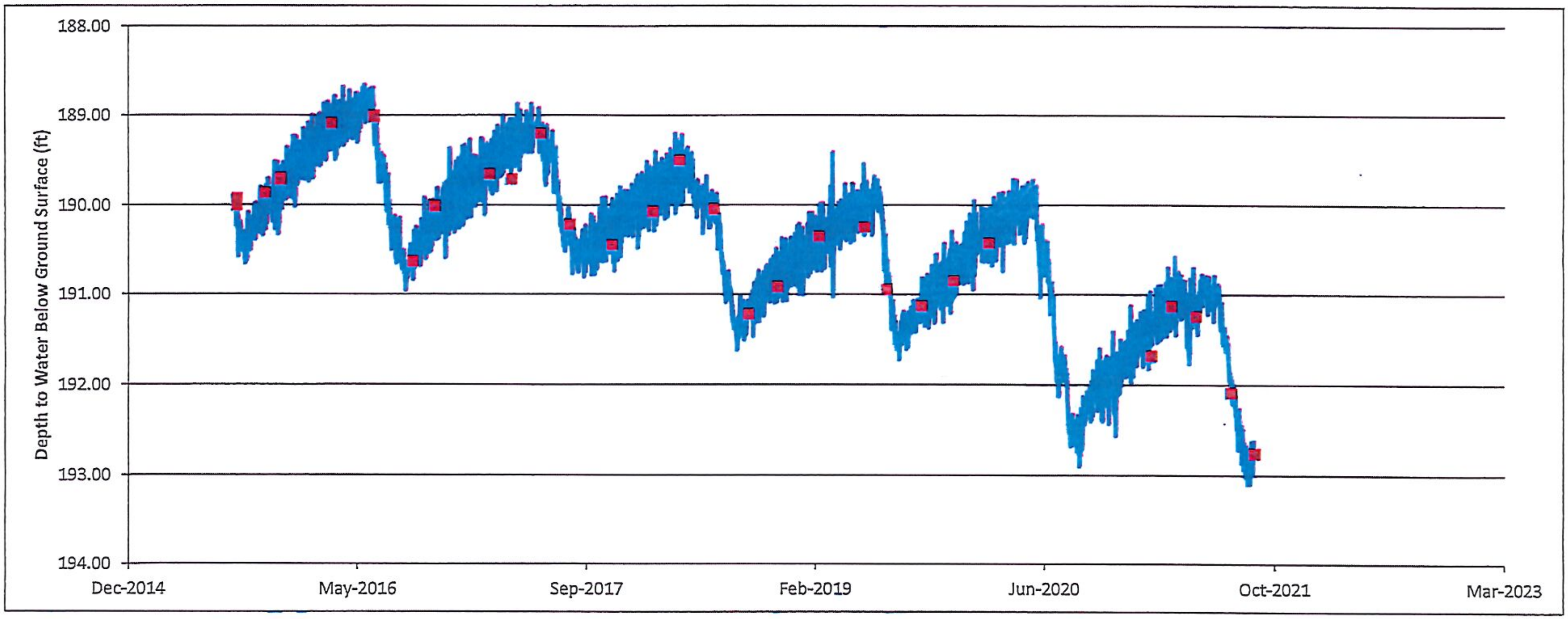


185.00
190.00
195.00
200.00
205.00
210.00
215.00
220.00
225.00
230.00
Depth to Water Below Ground Surface (ft)
Dec-2014
May-2016
Sep-2017
Feb-2019
Jun-2020
Oct-2021
Mar-2023

Beckman

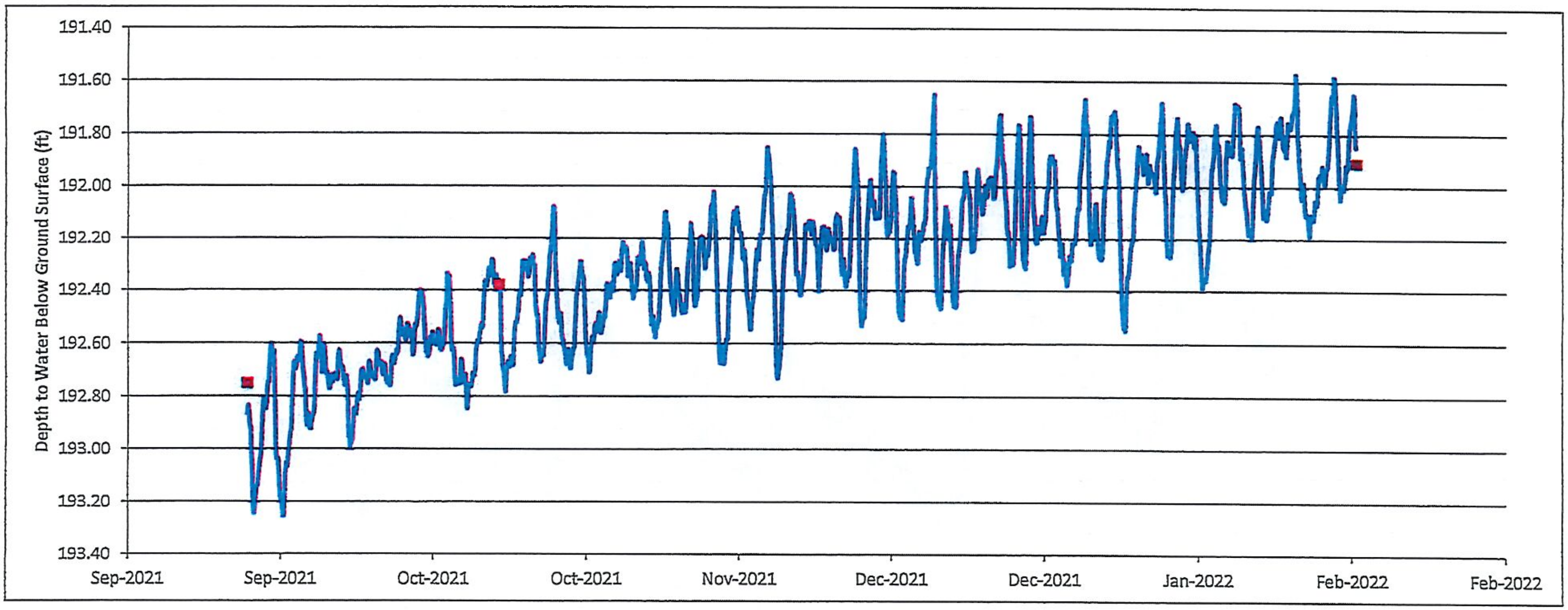

250.50
250.40
250.30
250.20
250.10
250.00
249.90
249.80
249.70
249.60
12/27/2014
5/10/2016
9/22/2017
2/4/2019
6/18/2020
10/31/2021
3/15/2023
Depth to Sensor (ft bTOC)

Moss



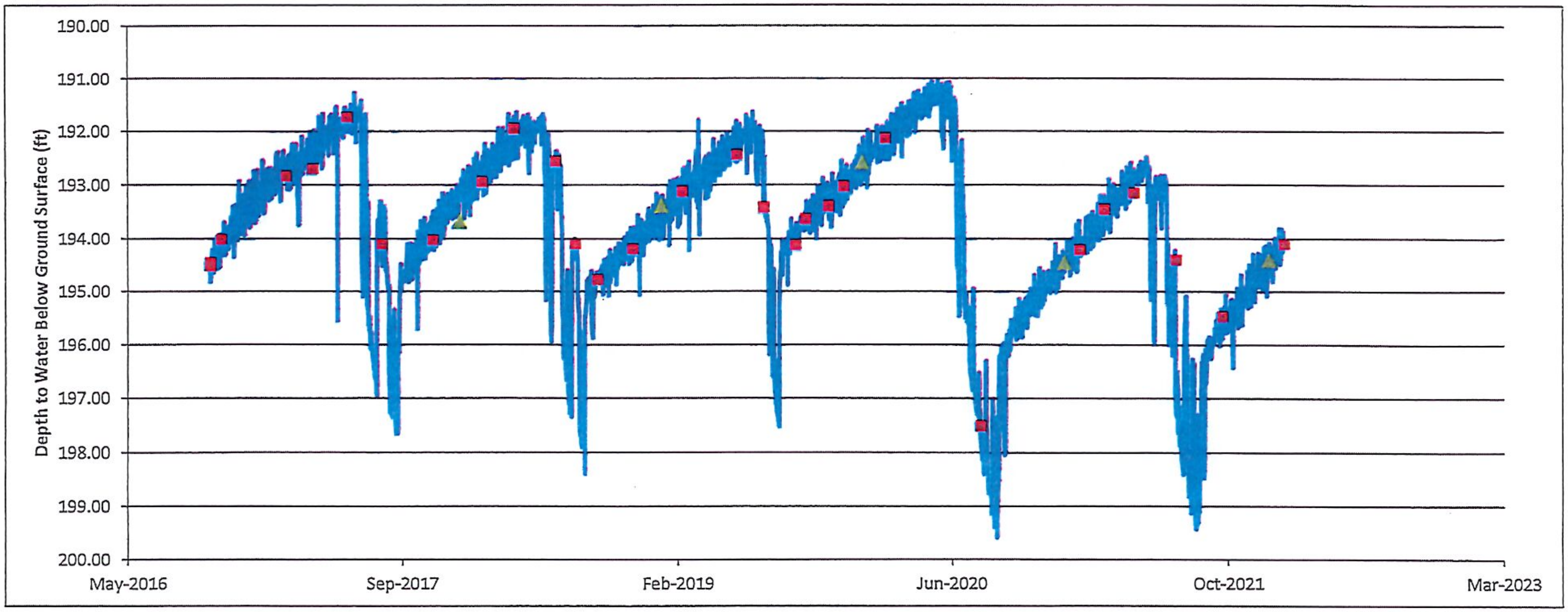
188.00
189.00
190.00
191.00
192.00
193.00
194.00
Depth to Water Below Ground Surface (ft)
Dec-2014
May-2016
Sep-2017
Feb-2019
Jun-2020
Oct-2021
Mar-2023

Moss



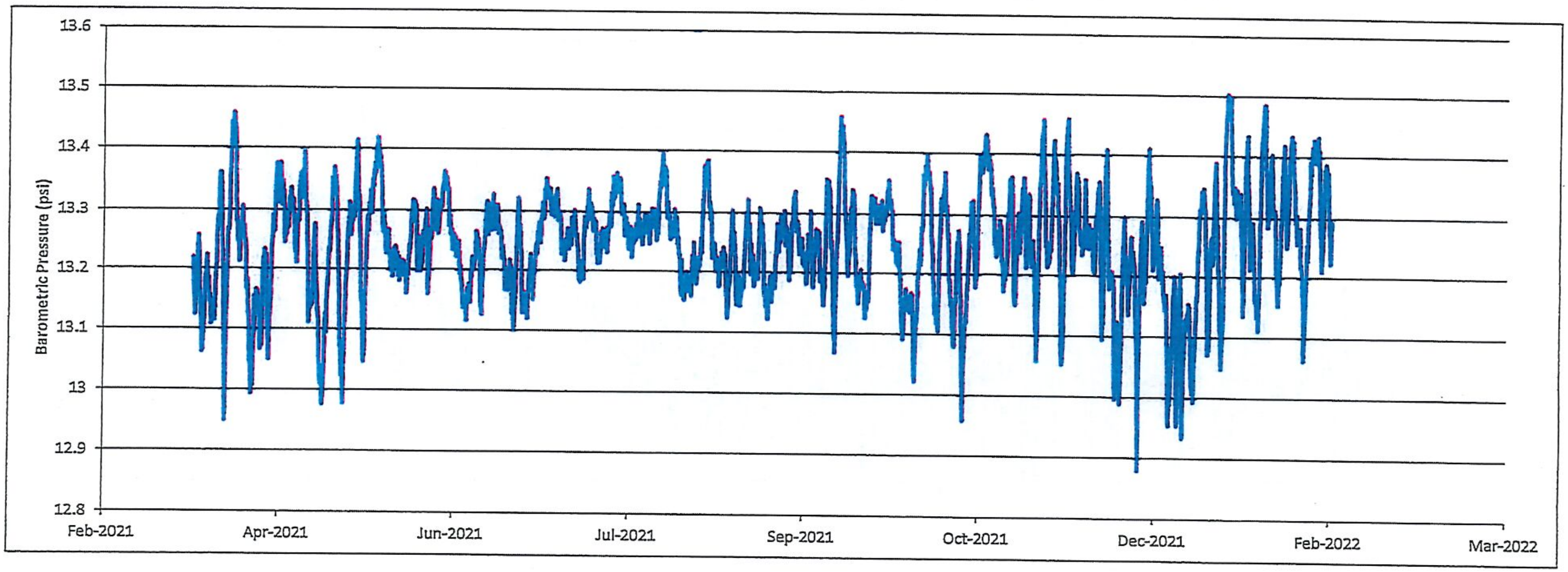
Depth to Water Below Ground Surface (ft)
191.40
191.60
191.80
192.00
192.20
192.40
192.60
192.80
193.00
193.20
193.40
Sep-2021
Sep-2021
Oct-2021
Oct-2021
Nov-2021
Dec-2021
Dec-2021
Jan-2022
Feb-2022
Feb-2022

Seegmiller



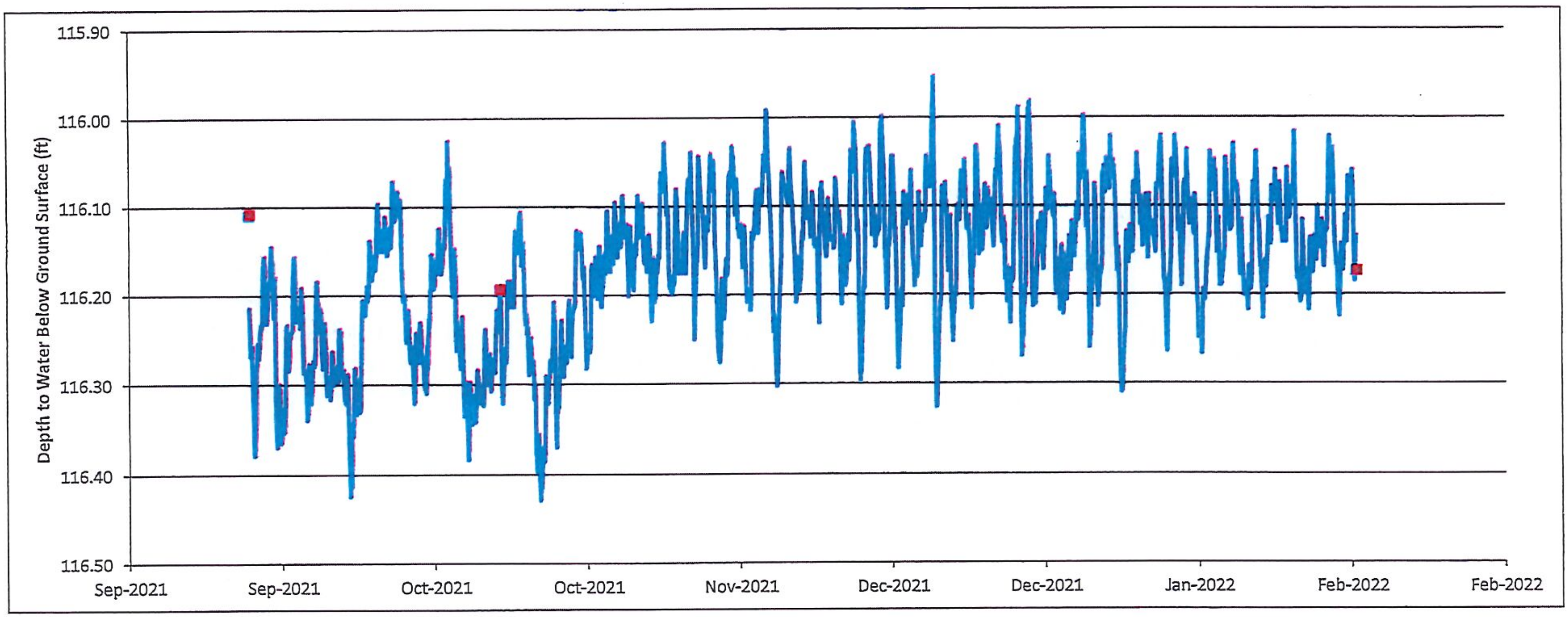
Depth to Water Below Ground Surface (ft)
190.00
191.00
192.00
193.00
194.00
195.00
196.00
197.00
198.00
199.00
200.00
May-2016
Sep-2017
Feb-2019
Jun-2020
Oct-2021
Mar-2023

Seegmiller



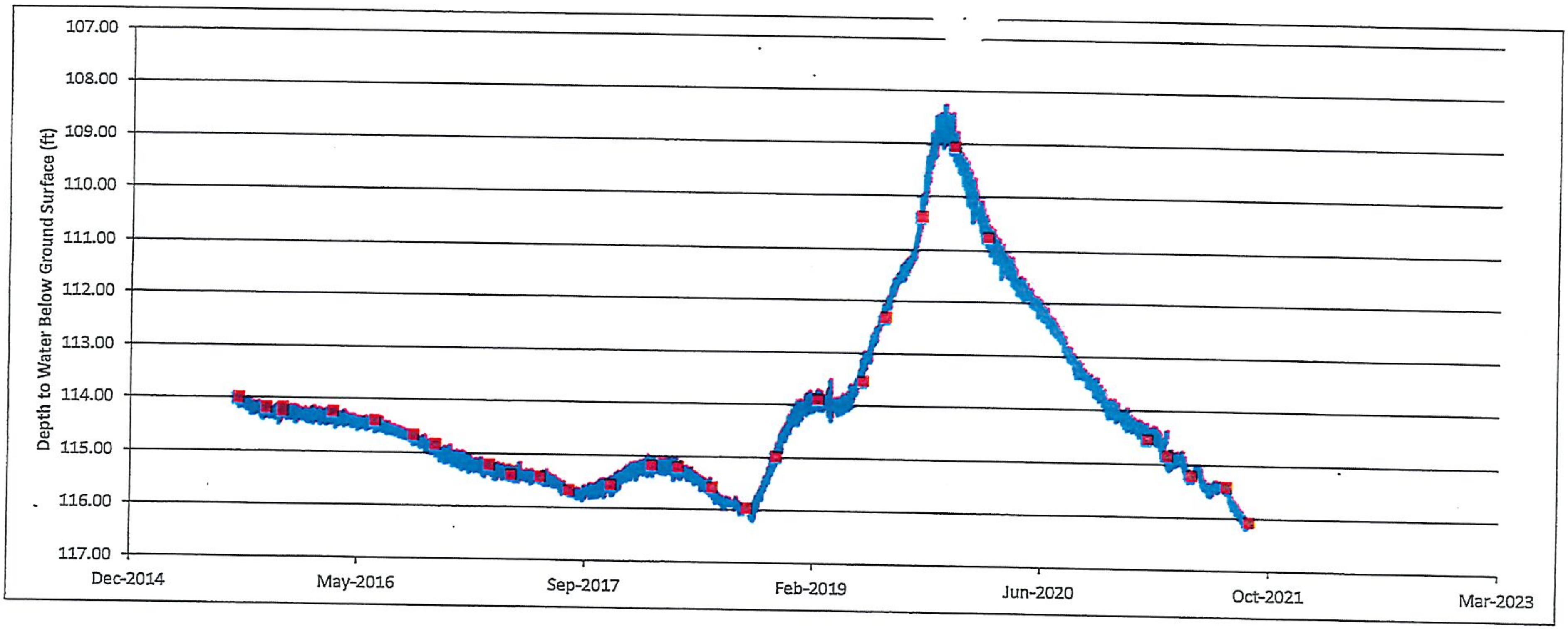
Barometric Pressure (psi)
13.6
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
Feb-2021
Apr-2021
Jun-2021
Jul-2021
Sep-2021
Oct-2021
Dec-2021
Feb-2022
Mar-2022

Steiger



Depth to Water Below Ground Surface (ft)
115.90
116.00
116.10
116.20
116.30
116.40
116.50
Sep-2021
Sep-2021
Oct-2021
Oct-2021
Nov-2021
Dec-2021
Dec-2021
Jan-2022
Feb-2022
Feb-2022

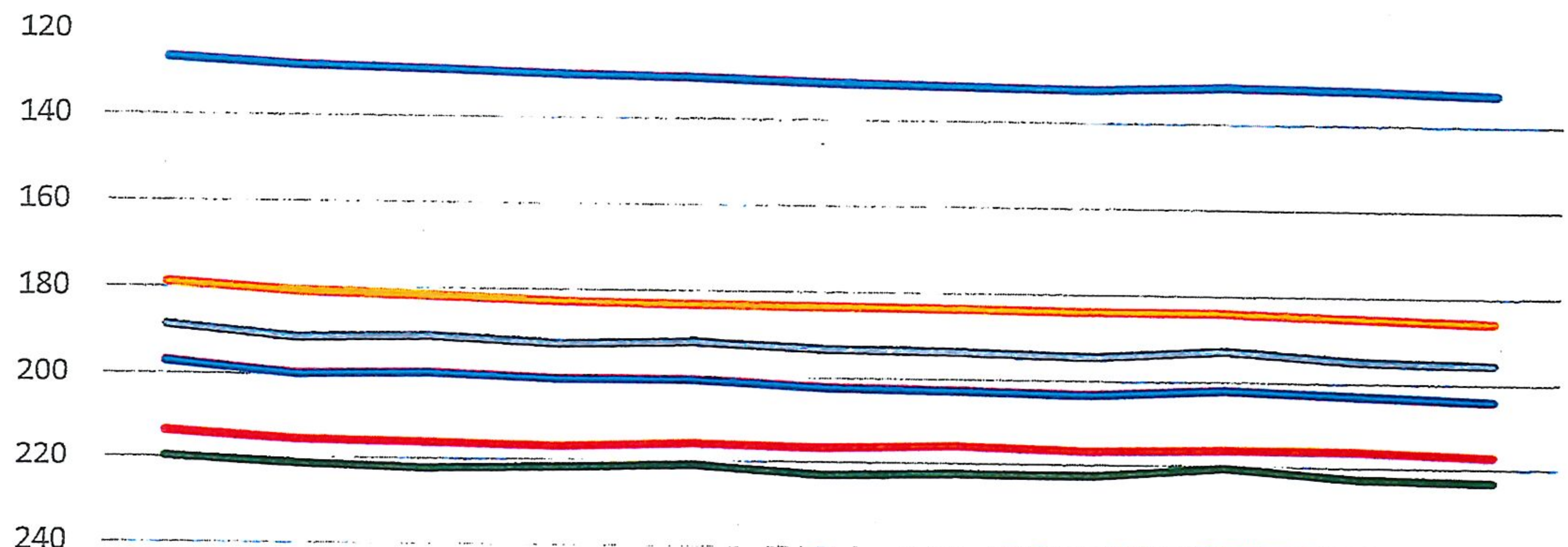
Steiger



Depth to Water Below Ground Surface (ft)
107.00
108.00
109.00
110.00
111.00
112.00
113.00
114.00
115.00
116.00
117.00
Dec-2014
May-2016
Sep-2017
Feb-2019
Jun-2020
Oct-2021
Mar-2023

Exhibit 3

SD 6 Water Levels



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
07S29W05	126.3	128	128.7	129.68	130.2	131.07	131.6	132.14	131.33	131.75	132.55
07S29W27	213.4	215.35	215.85	216.60	215.58	216.45	215.7	216.63	216.09	216.06	217.04
07S29W30	188.65	191.5	190.95	192.40	191.84	193.16	193.53	194.31	192.655	194.76	195.32
08S29W01	178.6	180.55	181.44	182.59	182.94	183.28	183.47	183.96	183.97	184.74	185.63
08S30W05	196.9	199.95	199.4	200.70	200.69	202.19	202.58	203.26	201.91	202.93	203.91
08S30W11	219.65	221.3	222.29	221.71	221.05	223.11	222.53	222.7	220.45	222.79	223.34

07S29W05 07S29W27 07S29W30 08S29W01 08S30W05 08S30W11

3.4 GMD4 Index Wells

Eight index wells are located in GMD4, five of which have telemetry equipment that allows real-time viewing of data (fig. 22). The Thomas index well was one of the original 2007 index wells and had telemetry capabilities from the start. Monitoring with telemetry began at the Colby, Seegmiller Sheridan-6 (SD-6) LEMA, Sherman, and Steiger SD-6 LEMA index wells in 2015, 2016, 2017, and 2021, respectively. Table 4 summarizes characteristics of these eight wells. Further details concerning these wells are given in the 2016 annual report (Butler, Whittemore et al., 2017) and the online appendices for this report (www.kgs.ku.edu/HighPlains/OHP/index_program/index.shtml).

Table 4—Characteristics of the GMD4 index well sites.

Site	2021 WL elev. (ft)[a]	2021 saturated thickness (ft)	Bedrock depth (estimated ft below land surface)	Screened interval (ft below land surface)	2019 water use (ac-ft) 1 mi radius	2 mi radius	5 mi radius
Colby	3,024.4	97.4[b]	250–300	156–175	399[c]	1,708[d]	7,227[e]
SD-6 Baalman	NA[f]	NA	262	260–270	388	1,170	8,308[g]
SD-6 Beckman[h,i]	2,679.9[h]				489	1,817[j]	8,077[k]
SD-6 Moss[h]	2,624.4[h]	51.4	243	205–245	168	1,445	8,891[l]
SD-6 Seegmiller	2,738.5	70.5	265	225–265	425	1,674	8,593[m]
SD-6 Steiger[h]	2,850.7[h]	62.7	177	145–185	146	670[n]	5,293[o]
Sherman	3,614.5	143.5	323	310–320	1,263	2,543	8,656
Thomas	2,969.8	66.4	284	274–284	572	1,536	6,405

[a] 2021 annual tape water-level measurements from WIZARD database (http://www.kgs.ku.edu/Magellan/WaterLevels/index.html).
[b] Based on bedrock depth of 250 ft below lsf.
[c] Includes 212 ac-ft of municipal water.
[d] Includes 1,002 ac-ft of municipal water and 220 ac-ft of other water.
[e] Includes 1,158 ac-ft of municipal water, 220 ac-ft of other water, 1 ac-ft of industrial water, and 17 ac-ft of non-irrigation stock water.
[f] Annual measurement on 01/07/2021 is likely in error. Transducer measurements not available as sensor failed after 6/5/2020 and wasn't replaced until 3/20/2021.
[g] Includes 766 ac-ft of non-irrigation stock water.
[h] Not an annually measured index well; 2021 water-level measurements from hand measurements taken 01/7/2021 at Moss and Steiger.
[i] Well construction information not available.
[j] Includes 438 ac-ft of non-irrigation stock water.
[k] Includes 691 ac-ft of non-irrigation stock water.
[l] Includes 659 ac-ft of non-irrigation stock water, 1 ac-ft of industrial water, and 278 ac-ft of municipal water.
[m] Includes 691 ac-ft of non-irrigation stock water.
[n] Includes 30 ac-ft of non-irrigation stock water.
[o] Includes 50 ac-ft of non-irrigation stock water and 2 ac-ft of recreation water.

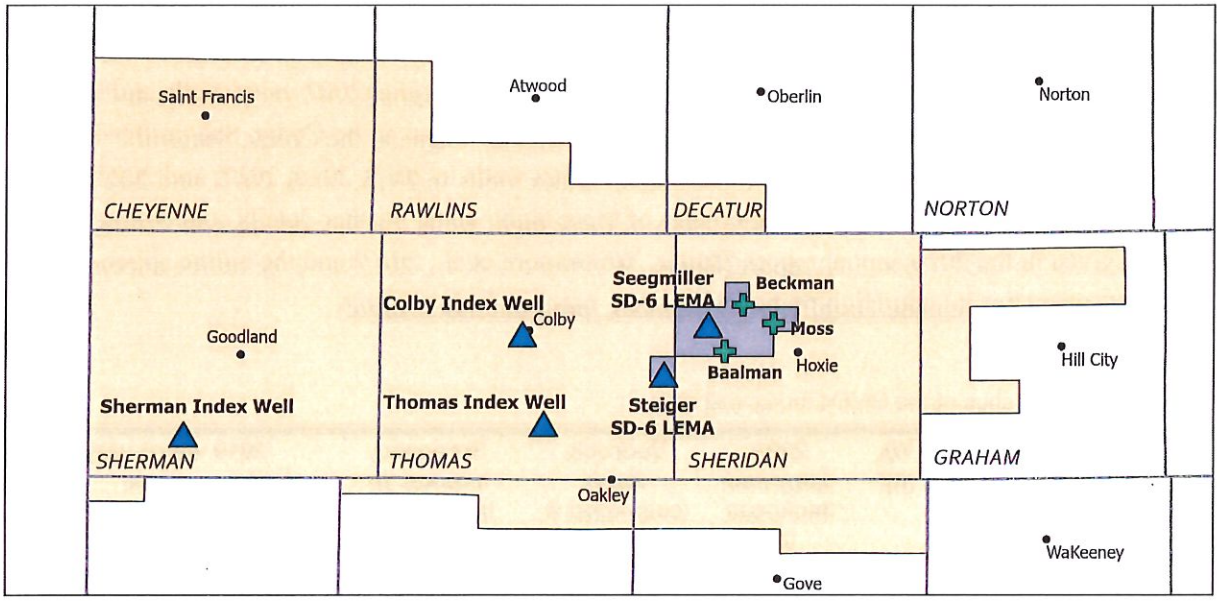


Figure 22—Map of index wells in GMD4. Triangles designate wells with telemetry equipment, whereas plus signs designate wells without telemetry equipment. Data from wells with telemetry equipment can be viewed in real time on the KGS website (www.kgs.ku.edu/HighPlains/OHP/index_program/index.shtml); data from wells without telemetry equipment are periodically downloaded (typically quarterly) and posted on the KGS website. Shaded area is the Sheridan-6 LEMA.

3.4.1 Colby Index Well

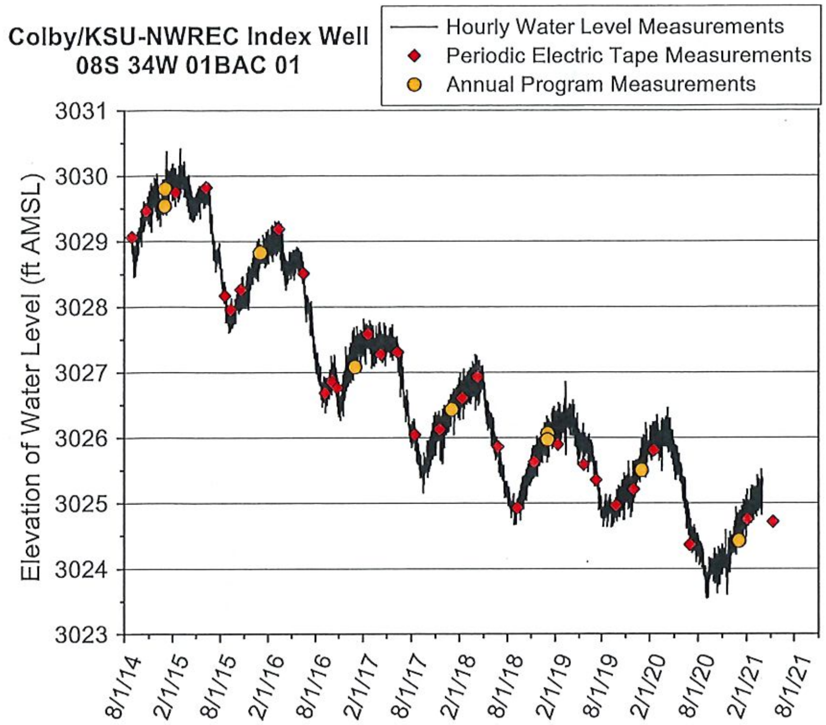


Figure 23—Colby index well hydrograph—total data run to 5/12/21. A water-level elevation of 3,029 ft corresponds to a depth to water of 148 ft below lsf. Total depth of the well is 175 ft below lsf (elevation of 3,002 ft). The screened interval extends from 156 to 175 ft below lsf. The base of the aquifer is estimated to be 250–300 ft below lsf (Butler, Whittemore et al., 2017). Sensor failed on 4/1/21 and was replaced on 5/12/21.

Major Points

- The relatively large amplitude fluctuations superimposed on the water-level record indicate unconfined conditions.
- After the end of the irrigation season, water levels continue to recover until the start of the next season; apparent stabilization of water levels in late winter and early spring of 2017 appears to be a product of nearby pumping.
- The maximum recovered water level has declined each year during the monitoring period, giving a distinct stair-step character to the hydrograph.
- Based on annual water-level measurements, the water level has declined approximately 0.88 ft/yr over the monitoring period and a total of 38.5 ft since January 1948.
- Transducer readings are in good agreement with manual measurements.

3.4.2 SD-6 Baalman Index Well

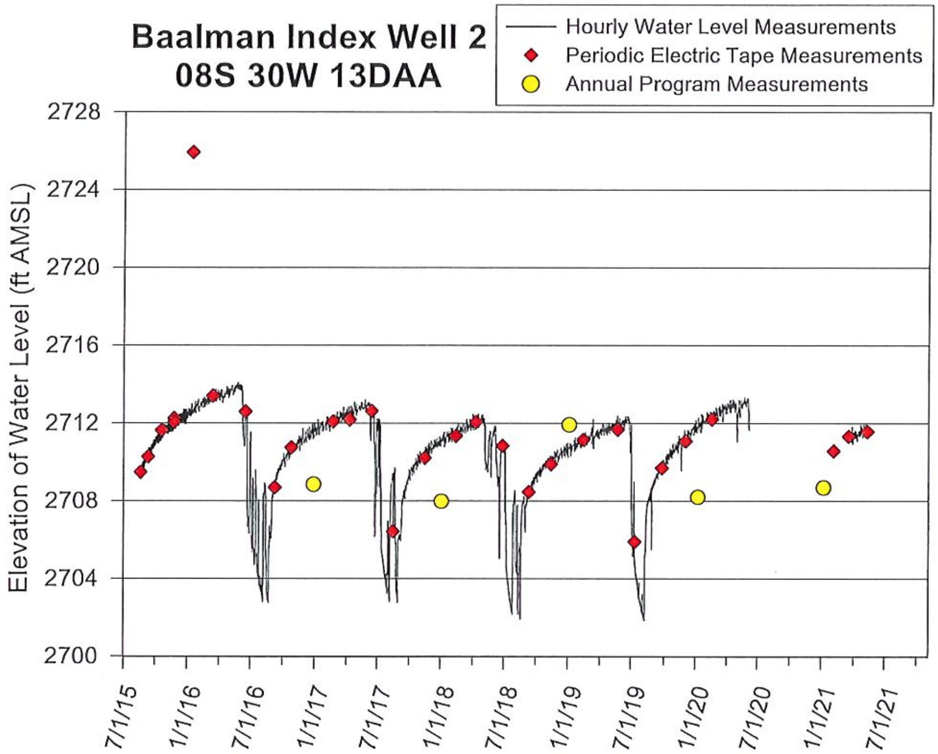


Figure 24—Baalman index well hydrograph—total data run to 5/12/21. A water-level elevation of 2,712 ft corresponds to a depth to water of 185 ft below lsf. The top of the 10 ft screen is 260 ft below lsf (elevation of 2,637 ft), and the bottom of the aquifer is 262 ft below lsf (elevation of 2,635 ft). The difference between the electric-tape and transducer measurements in January 2016 was caused by a malfunctioning electric tape.

Major Points

- The hydrograph form and the relatively large amplitude fluctuations superimposed on the water levels, particularly evident during the recovery period, are an indication of unconfined conditions.
- The effect of individual wells turning on and off is clearly visible, indicating pumping wells are in relatively close proximity to and in good hydraulic connection with the index well.
- The maximum water level in 2020 was above the previous three years as a result of the relatively small amount of pumping in 2019 (lowest pumping total and shortest pumping season [44 days] in the vicinity of the Baalman well [2 mi radius] since the establishment of the SD-6 LEMA).
- Since the establishment of the SD-6 LEMA, the water use per irrigated acre has been approximately 0.69 ft (8.3 inches)/acre in the vicinity of the Baalman index well (2 mi radius).
- Sensor failed on 6/5/20 but, because of the pandemic and the lack of telemetry, the failure was not recognized until 2/4/21; a new sensor was installed on 3/20/21.
- Transducer readings are in good agreement with periodic electric-tape measurements, except for the January 2016 measurement, but in poor agreement with annual program measurements.

3.4.3 SD-6 Beckman Index Well

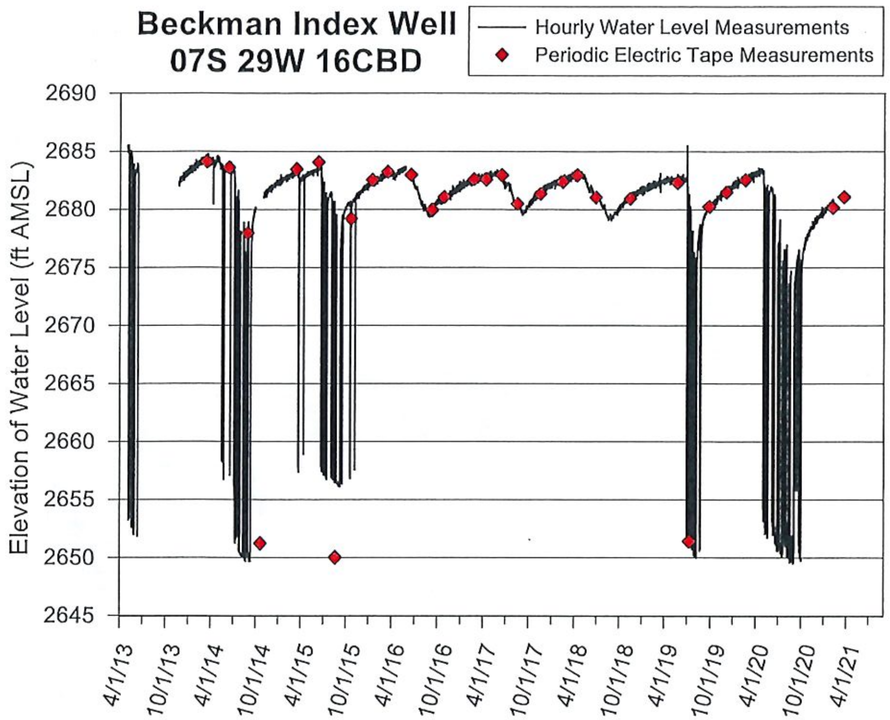


Figure 25—Beckman index well hydrograph—total data run to 3/20/21. A water-level elevation of 2,680 ft corresponds to a depth to water of 200.15 ft below lsf. The data gaps in 2013 and 2014 were caused by datalogger battery problems. The difference between the electric-tape measurement in the summer of 2015 and the hourly measurements from the transducer is thought to be caused by a change in transducer calibration specifications associated with the resumption of monitoring in late October 2014.

Major Points

- The irrigation well adjacent to the Beckman index well was pumped for the second time in the last five irrigation seasons and the fifth time since the establishment of the SD-6 LEMA.
- The hydrograph form and the relatively large amplitude fluctuations superimposed on the water levels, particularly evident during the recovery period, are an indication of unconfined conditions.
- After the end of the irrigation season, water levels continue to recover until the start of the next season (water levels never stabilize).
- Since the establishment of the SD-6 LEMA, the water use per irrigated acre has been approximately 0.69 ft (8.3 in)/acre in the vicinity of the Beckman index well (2 mi radius).
- Sensor failed on 2/4/21 and was replaced during site visit on 3/20/21. However, the sensor could not be downloaded during the 5/12/21 visit because the site could not be accessed without damaging the winter wheat crop.
- Transducer readings are in good agreement with manual measurements in the latter half of the monitoring period.

3.4.4 SD-6 Moss Index Well

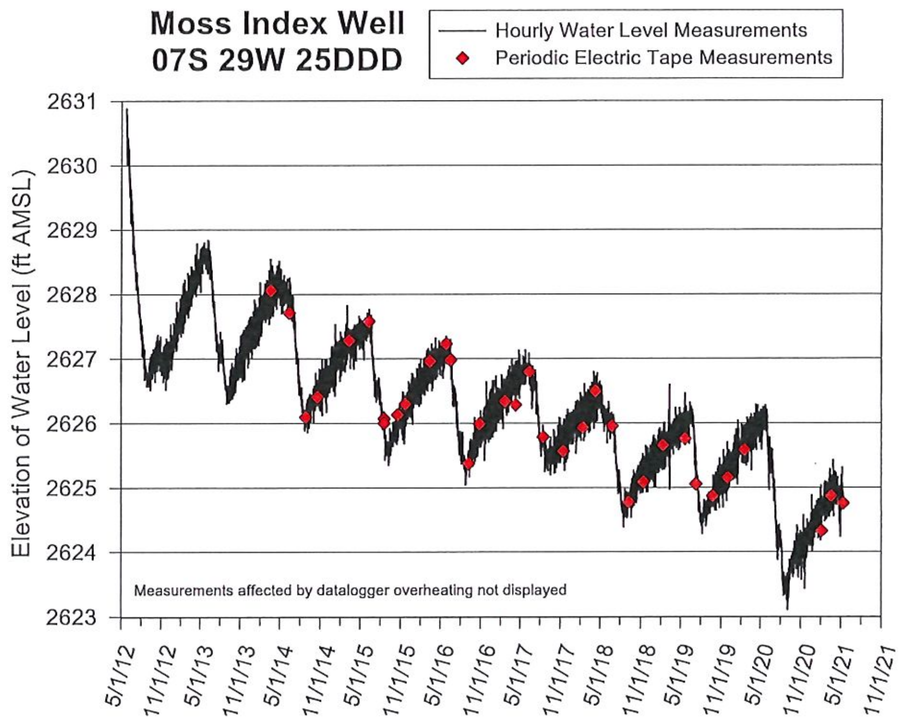


Figure 26—Moss index well hydrograph—total data run to 5/12/21. A water-level elevation of 2,627 ft corresponds to a depth to water of 189.0 ft below lsf. The top of the 40 ft screen is 205 ft below lsf (elevation of 2,611.0 ft), and the bottom of the aquifer is 243 ft below lsf (elevation of 2,573.0 ft).

Major Points

- The relatively large amplitude fluctuations superimposed on the water levels, particularly evident during the recovery period, are an indication of unconfined conditions.
- After the end of the irrigation season, water levels continue to recover until the start of the next season (water levels never stabilize).
- The minimum water-level elevation has been above that of the preceding year once (2017, a wet year). Otherwise, the hydrograph displays a downward stepping pattern.
- Since the establishment of the SD-6 LEMA, the water use per irrigated acre has been approximately 0.79 ft (9.5 in)/acre in the vicinity of the Moss index well (2 mi radius).
- Transducer readings are in good agreement with manual measurements.

3.4.5 SD-6 Seegmiller Index Well

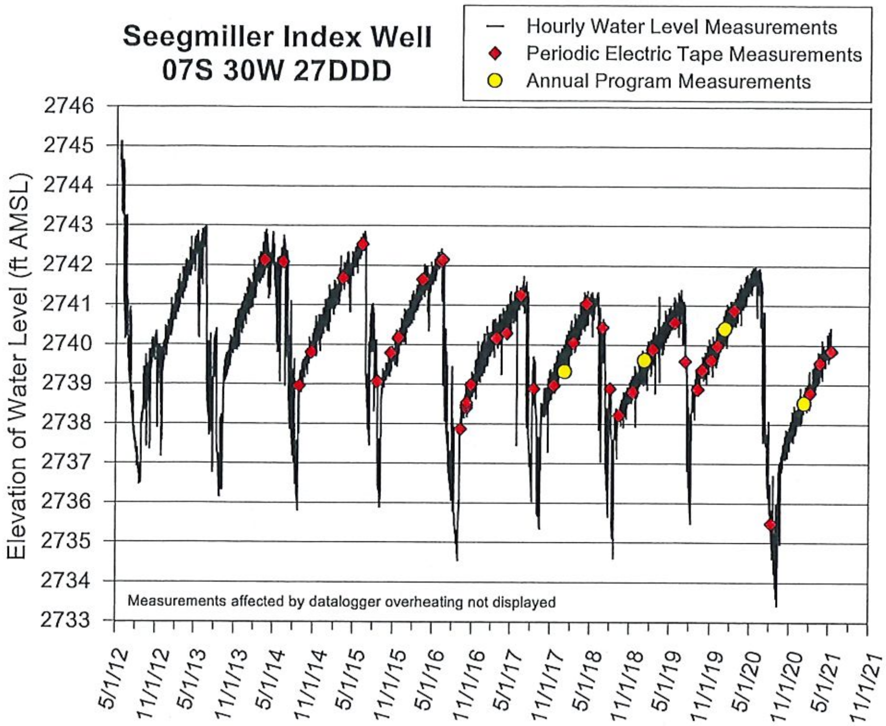


Figure 27—Seegmiller index well hydrograph—total data run to 5/12/21. A water-level elevation of 2,740 ft corresponds to a depth to water of 193.0 ft below lsf. The top of the 40 ft screen is 225 ft below lsf (elevation of 2,708.0 ft), and the bottom of the aquifer is 265 ft below lsf (elevation of 2,668.0 ft).

Major Points

- The hydrograph form and the relatively large amplitude fluctuations superimposed on the water levels, particularly evident during the recovery period, indicate unconfined conditions.
- The effect of individual wells turning on and off is clearly visible on the hydrograph, indicating pumping wells in relatively close proximity to and in good hydraulic connection with the index well.
- After the end of the irrigation season, water levels continue to recover until the start of the next season (water levels never stabilize).
- The minimum water-level elevation for 2020 was 2.1 ft below that of 2019 and 1.2 ft below that of 2018, which was the previous lowest level observed during the monitoring period. The increase in maximum water-level elevations between 2019 and 2020 was the largest (0.6 ft) observed during the monitoring period because of the small amount of pumping in 2019 (lowest during the monitoring period and about 24% lower than the previous low [2017]).
- Since the establishment of the SD-6 LEMA, the water use per irrigated acre has been approximately 0.71 ft (8.5 in)/acre in the vicinity of the Seegmiller index well (2 mi radius).
- Transducer readings are in good agreement with manual measurements.

3.4.6 SD-6 Steiger Index Well

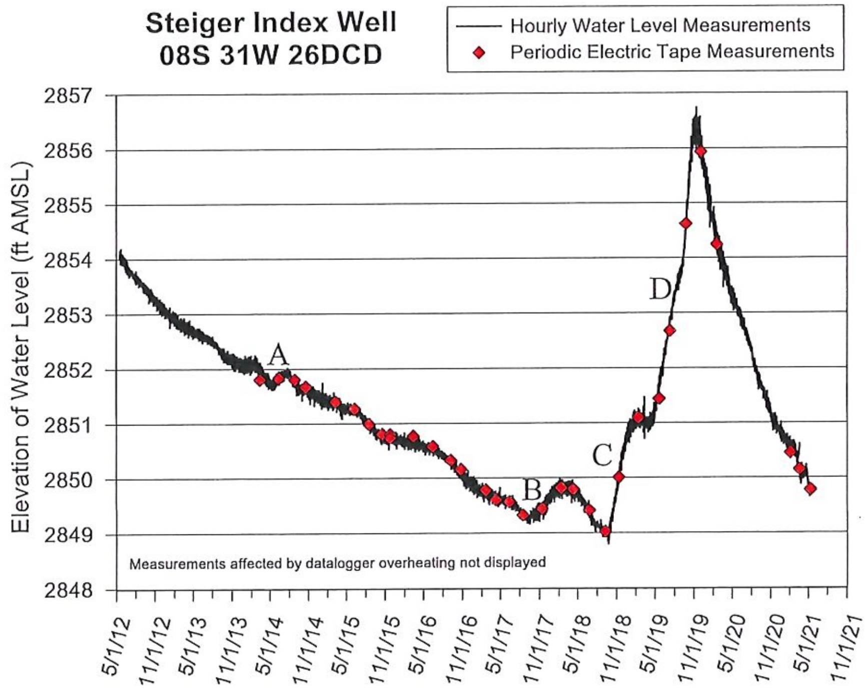


Figure 28—Steiger index well hydrograph—total data run to 5/12/21. A water-level elevation of 2,851 ft corresponds to a depth to water of 114.0 ft below lsf. The top of the 40 ft screen is 145 ft below lsf (elevation of 2,820.0 ft), and the bottom of the aquifer is 177 ft below lsf (elevation of 2,788.0 ft). A–D defined in text.

Major Points

- The fluctuations superimposed on the water levels are an indication of unconfined conditions but are of smaller magnitude than the other index wells in GMD4; this small magnitude typically indicates a relatively shallow depth to water.
- It is difficult to discern individual pumping seasons. The humps and troughs observed in the hydrograph at points marked A–D are likely related to a series of episodic recharge events and not pumping. The Steiger index well is located near an impoundment behind a small dam over an ephemeral stream channel; the impoundment appears to serve as a site of focused recharge.
- The effect of individual wells cutting on and off cannot be discerned.
- Except for a short decline early in the 2019 irrigation season, water levels rose continuously from the end of the 2018 pumping season to November 2019. This rise (>7.5 ft) is the only definitive example of episodic recharge that we have observed in the index wells in western Kansas. The sharp decline since the peak in November of 2019 indicates that the recharge was likely a localized event (i.e. water flows laterally to areas that did not receive the recharge) associated with the nearby impoundment (Butler, Knobbe et al., 2021). Comparison of the rise in water level with area rainfall indicates that the recharge pulse appears to have taken a little over a year to reach the water table.
- Since the establishment of the SD-6 LEMA, the water use per irrigated acre has been approximately 0.78 ft (9.3 in)/acre in the vicinity of the Steiger index well (2 mi radius).
- Transducer readings are in good agreement with manual measurements.

3.4.7 Sherman County Index Well

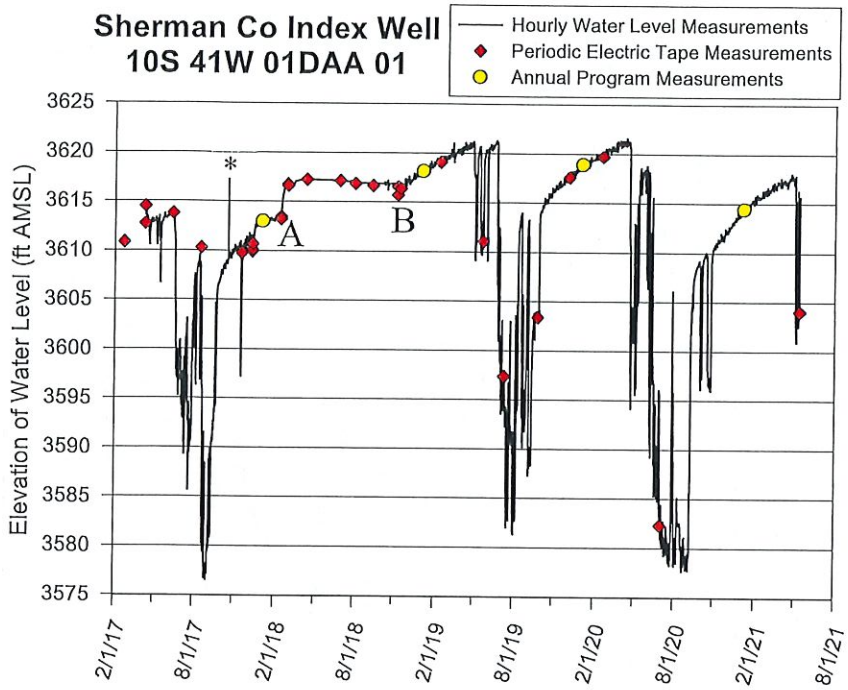


Figure 29—Sherman County index well hydrograph—total data run to 5/13/21. A water-level elevation of 3,617 ft corresponds to a depth to water of 177 ft below lsf. The top of the 10 ft screen is 310 ft below lsf (elevation of 3,484 ft), and the bottom of the aquifer is 323 ft below lsf (elevation of 3,471 ft). The well has a 10 ft sump that extends to 330 ft below lsf. The asterisk indicates a single spurious reading; A and B defined in text.

Major Points

- The hydrograph form and the relatively large amplitude fluctuations superimposed on the water levels, particularly evident during the recovery period, indicate unconfined conditions.
- The effect of individual wells turning on and off is clearly visible on the hydrograph, indicating pumping wells in relatively close proximity to and in good hydraulic connection with the index well.
- The well was not developed immediately after installation because of extreme cold. As a result, the screened interval gradually filled with fine-grained sediments. During the period from 2/13/18 (A on plot) to 11/7/18 (B on plot), the screened interval appears to have been in very poor hydraulic connection with the aquifer. Well development on 11/7/18 (B) reestablished the hydraulic connections between the well and the aquifer (Butler, Knobbe et al., 2021).
- After the end of the irrigation season, water levels continue to recover until the start of the next season (water levels never stabilize).
- Agreement between transducer readings and manual measurements varied over the monitoring period; agreement appears good after a new sensor was installed on 2/13/18 (A).

3.4.8 Thomas County Index Well

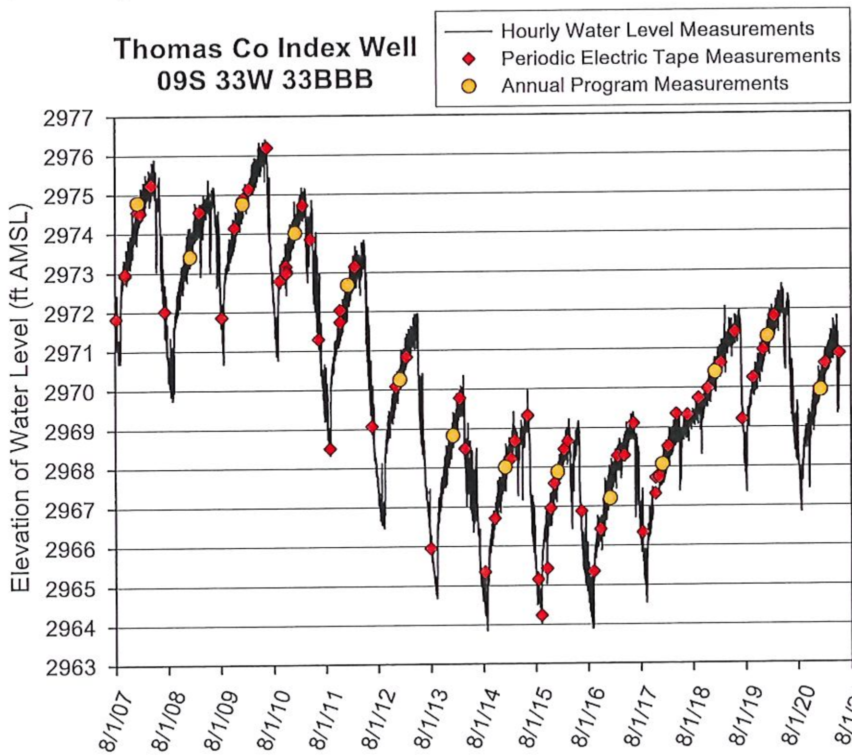
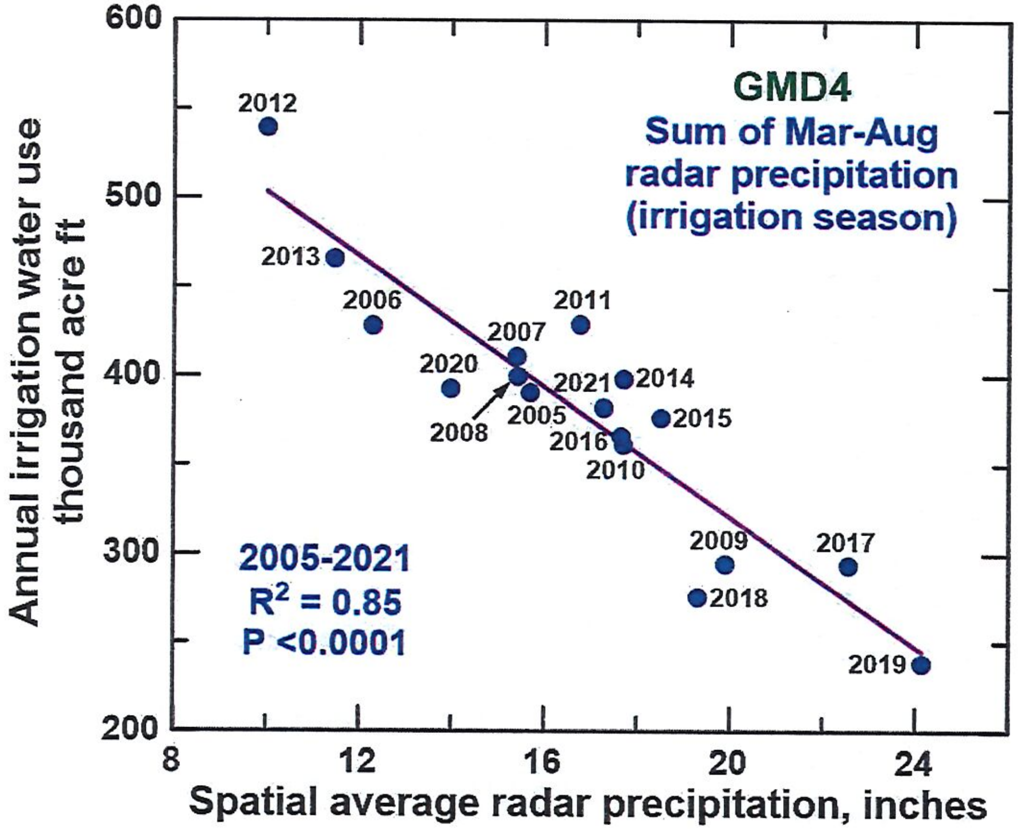


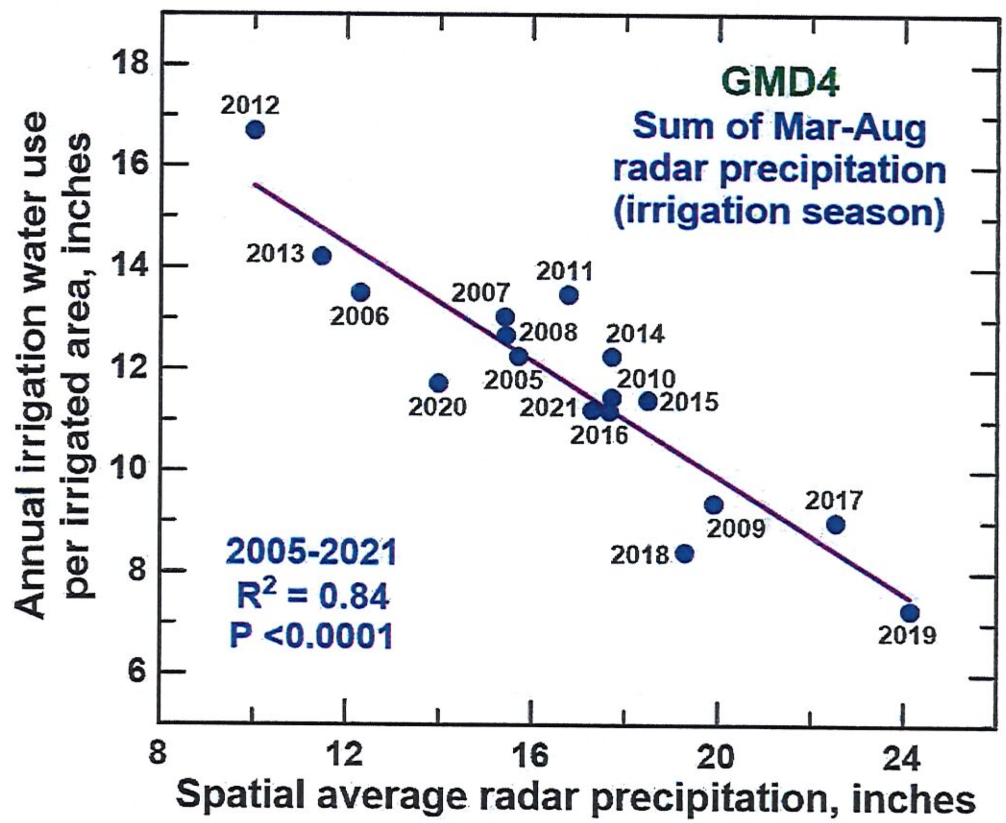
Figure 30—Thomas County index well hydrograph—total data run to 5/12/21. A water-level elevation of 2,968 ft corresponds to a depth to water of 219.56 ft below lsf. The top of the screen is 274 ft below lsf (elevation of 2,913.6 ft), and the bottom of the aquifer is 284 ft below lsf (elevation of 2,903.6 ft). The screen terminates at the bottom of the aquifer. No water-level data are available from 10/28/17 to 12/11/17 because of sensor failure.

Major Points

- The hydrograph form, the relatively small change and rate of change in water level during each pumping and recovery season (despite eight high-capacity pumping wells within a mile of the index well), and the relatively large amplitude fluctuations superimposed on water levels indicate unconfined conditions.
- The effect of individual wells turning on and off is clearly visible on the hydrograph, indicating pumping wells in relatively close proximity to and in good hydraulic connection with the index well.
- After the end of the irrigation season, water levels continue to recover until the start of the next season (water levels never stabilize).
- The maximum water level in 2020 was 0.5 ft above that in 2019 and the highest since 2012.
- 2018 water use was the lowest for the monitoring period because of cessation of pumping after a hail storm in late spring 2018 that destroyed the crops in the vicinity of the index well. 2019 water use was the second lowest for the monitoring period and 1.9 times greater than that in 2018.
- Transducer readings are in good agreement with manual measurements.

Northwest Kansas Groundwater Management District No. 4





Kansas Geological Survey

Exhibit 5

Annual irrigation water use,

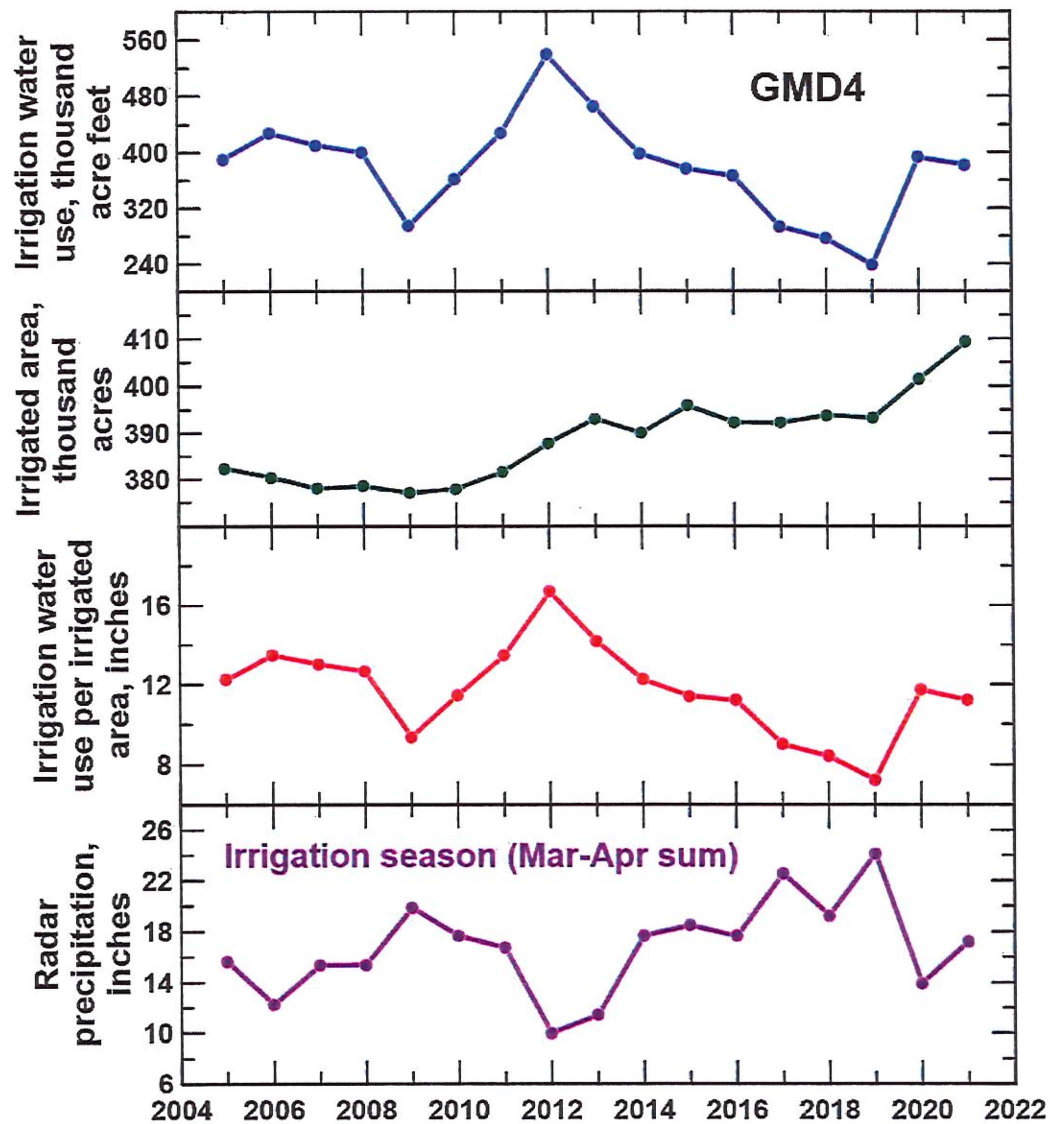
Irrigated area,

Annual irrigation water use per irrigated area,

and

Spatial average radar precipitation

during 2005-2021



Kansas Geological Survey

Exhibit 6

Monitoring the Impacts of Sheridan County 6 Local Enhanced Management Area

Final Report for 2013 – 2017

11/15/2018

Dr. Bill Golden

Golden is an assistant professor in the Department of Agricultural Economics at Kansas State University. Liebsch is a graduate student 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, in part by the U.S.D.A. Ogallala Aquifer Program, and in part by the U.S.D.A. – N.I.F.A. Ogallala Water CAP Project.

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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 a 'Final Report' which provides information on the five years (2013 – 2017) 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 (2017) 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 a 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, 2017).

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 (2017) 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 thru 2017. 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 2017. 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- for 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, all fields that were comprised of 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. Therefore, when crop specific groundwater usage is discussed below, only fields that were comprised of a single crop were included in the calculation.[2]

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[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 insignificant 1.7% fewer irrigated acres than the control area and after the LEMA the target area averaged an additional statistically significant 10.9% fewer irrigated acres than the control area. This implies that the LEMA generated an average 10.9% reduction in irrigated acreage relative to the control area. However, referencing Figure 2, it should be noted that the control area significantly increased their irrigated acres after 2013.

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 23.1% less groundwater use than the control area. This implies that the LEMA generated an average 23.1% 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 16.0% less average groundwater use per acre than the control area. This implies that the LEMA generated an average 16.0% 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 23.3% less total irrigated corn acres than the control area. This implies that the LEMA generated an average 23.3% reduction in total irrigated corn acres relative to the control area. The percentage change amounts to an average of approximately 3,000 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 13.5% 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 33.7% more total irrigated grain sorghum acres than the control area and after the LEMA the target area averaged an additional statistically significant 335.4% more total irrigated grain sorghum acres than the control area. This implies that the LEMA generated an average 335.4% increase in total irrigated grain sorghum acres relative to the control area. The percentage change amounts to an average of approximately 750 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 6.19% 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 20.0% more total irrigated wheat acres than the control area and after the LEMA the target area averaged a statistically significant 60.3% more total irrigated wheat acres than the control area. This implies that the LEMA generated an average 60.3% increase in total irrigated wheat acres relative to the control area. The percentage change amounts to an average of approximately 500 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 30.8% less total irrigated mixed crop acres than the control area. This implies that the LEMA generated an average 30.8% decrease in total irrigated mixed crop acres relative to the control area. The percentage change amounts to an average of approximately 2,600 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 17.8% less average groundwater use per acres than the control area. This implies that the LEMA generated a statistically significant 17.8% reduction in the average groundwater use per irrigated corn acre relative to the control area. Between 2003 and 2012 producers in the target area used an average of 1.24 acre-feet per acre on irrigated corn. During the first 5 years of the LEMA (2013 – 2017) producers in the target area used an average of 0.85 acre-feet per acre on irrigated corn, or a decrease of 31.2%.

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. Between 2003 and 2012 producers in the target area used an average of 1.12 acre-feet per acre on irrigated corn. During the first 5 years of the LEMA (2013 – 2017) producers in the target area used an average of 0.78 acre-feet per acre on irrigated corn, or a decrease of 30.4%.

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 was strictly voluntary; they reported data directly to GMD #4 who passed 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. Additionally, 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' was the economic metric reported. Cash Flow was 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 annual 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 through 2017 crop year. Irrigated corn producers within the LEMA boundary reported using 23.1% less groundwater and yielding 1.2% 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 diminishing marginal returns, from the standpoint that using less groundwater typically generates less yield. However, if producers are efficiently using groundwater, outside the LEMA area we would expect a slightly larger yield loss. Somewhat surprisingly, irrigated corn producers within the LEMA boundary reported 4.3% more cash flow than their higher yielding counterparts outside the LEMA. Irrigated soybean producers within the LEMA boundary reported using 1.3% less groundwater and yielding14.9% 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. Soybean producers within the LEMA boundary reported 12.4% less cash flow than their higher yielding counterparts outside the LEMA. There was only one field of 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, 60.5% less groundwater than their counterpart, yielded 13.8% less grain, but 59.9% more cash flow.

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 2017. The average for this period was 20.3 inches per year. Both 2013 and 2014 were dryer than normal years, while 2015, 2016, and 2017 were wetter than normal years.

VI. Hydrology Response

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. While the purpose of this research was to document the observed economic and agronomic changes, it is certainly relevant to comment on the hydrology response to the LEMA. After analyzing the data, Jim Butler, Kansas Geological Survey senior scientist and geohydrology section chief stated that the results indicate that the decline rate within the LEMA has gone from about two feet per year to about 5 inches per year.[3]

VII. 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 the 'Final Report' and provides information from the five-year study

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 23.1%, reduced average groundwater use per acre by a statistically significant 16.0%, reduced irrigated crop acreage by a statistically significant 10.9%, reduced irrigated corn acreage by a statistically significant 23.3%, increased irrigated grain sorghum acreage by a statistically significant 335.4%, and increased irrigated wheat acreage by a statistically significant 60.3%.

The economic results are consistent with Golden and Leatherman (2017) 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 impact 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.

On February 17, 2017, GMD 4, at the request of producers in the Sheridan #6 LEMA, submitted a request to the Division of Water Resources to extend the Sheridan #6 LEMA. On August 24, 2017, the Chief Engineer accepted the extension proposal for the period 2018-2022. This suggests that producers within the Sheridan #6 LEMA believe they can mitigate any negative economic consequences associated with reduced groundwater use and that the benefits of groundwater conservation outweigh the costs.

[3] Source: http://www.kgs.ku.edu/General/News/2017/stabilize.html

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IX. 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	-0.109*
R^2	Degree of Fit	0.692

* 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	-0.231*
R^2	Degree of Fit	0.848

* 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	-0.160*
R^2	Degree of Fit	0.768

* 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	-0.233*
R^2	Degree of Fit	0.789

* 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	0.136
R^2	Degree of Fit	0.041

* 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	3.354*
R^2	Degree of Fit	0.679

* 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	-0.061
R^2	Degree of Fit	0.021

* Statistically significant at the 10% level

Table 9. Regression Results for the Difference in Total Irrigated Wheat Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	0.200
D	Impact of LEMA	0.603*
R^2	Degree of Fit	0.294

* 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	-0.308*
R^2	Degree of Fit	0.444

* 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	-0.178*
R^2	Degree of Fit	0.788

* 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	0.500

* Statistically significant at the 10% level

Table 13. 2013-2017 Producer Reported Economic Data

Item	Observations	Water Use (in/ac)	Yield (bu/ac)	Cash Flow ($/ac)	Cash Flow ($/in)
Corn Weighted Average - Inside LEMA	20	10.3	218.0	$375	$36
Corn Weighted Average - Outside LEMA	11	13.4	220.6	$360	$27
Sorghum Weighted Average - Inside LEMA	4	4.3	152.6	$361	$83
Sorghum Weighted Average - Outside LEMA	1	11.0	177.0	$226	$21
Soybeans Weighted Average - Inside LEMA	5	9.5	59.6	$315	$33
Soybeans Weighted Average - Outside LEMA	4	9.7	70.0	$358	$37
Sunflowers Weighted Average - Inside LEMA	0	NA	NA	NA	NA
Sunflowers Weighted Average - Outside LEMA	1	6.0	2818	$788	$131
Wheat Weighted Average - Inside LEMA	5	5.7	76.3	$219	$38
Wheat Weighted Average - Outside LEMA	3	7.4	81.8	$178	$24

X. Figures

Figure 1. Target and Control Area

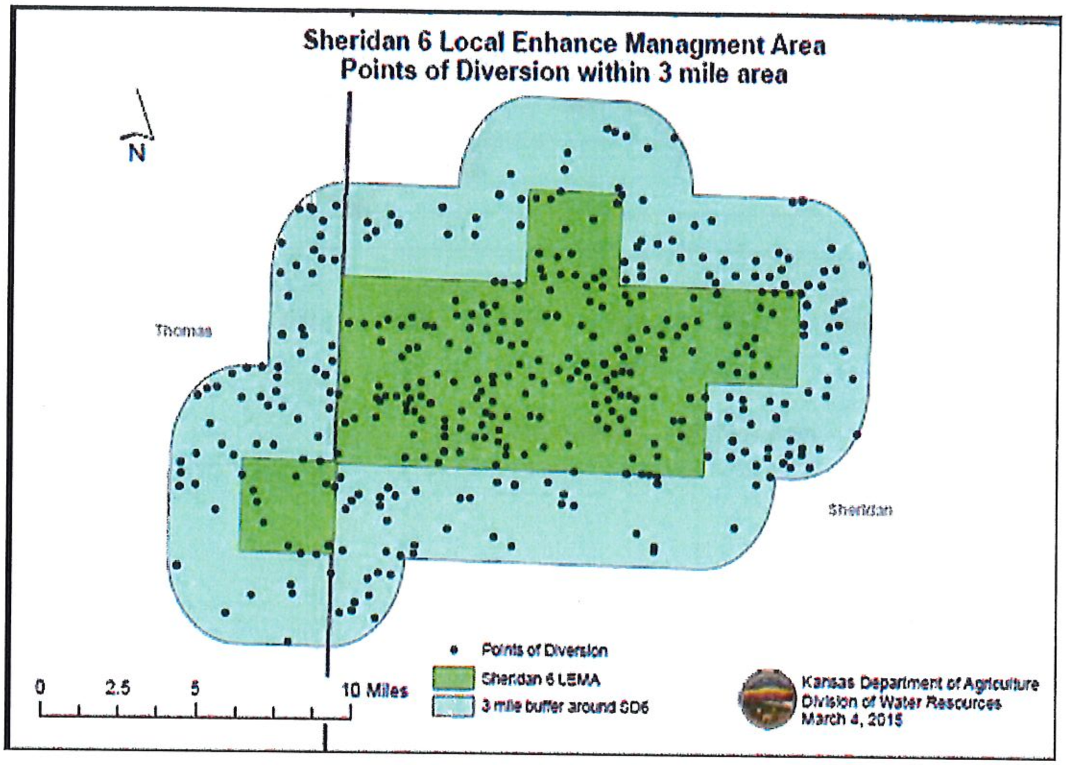


Figure 2. Total Irrigated Acres

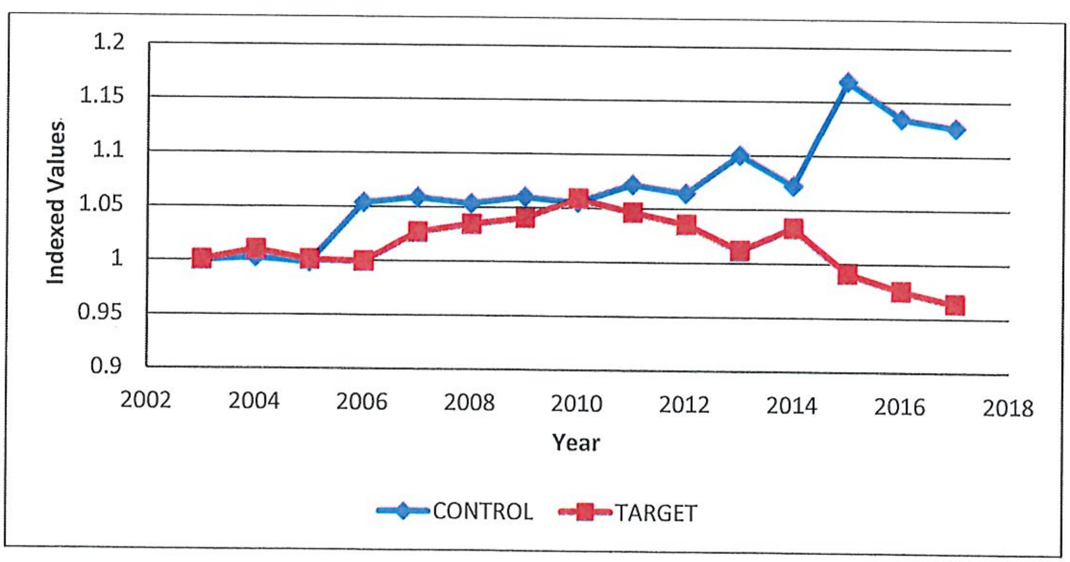


Figure 3. Total Groundwater Use

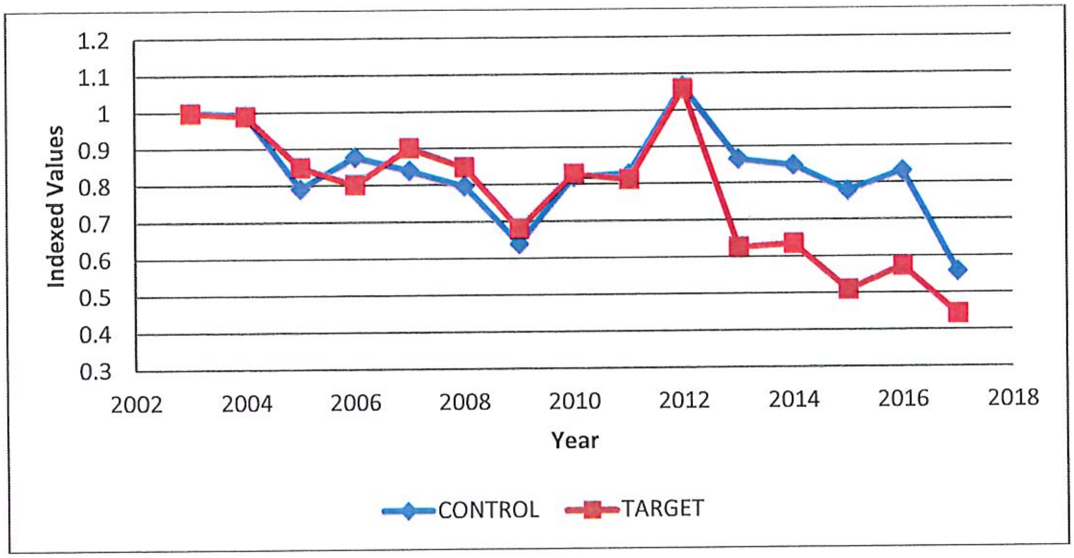


Figure 4. Average Groundwater Use per Acre

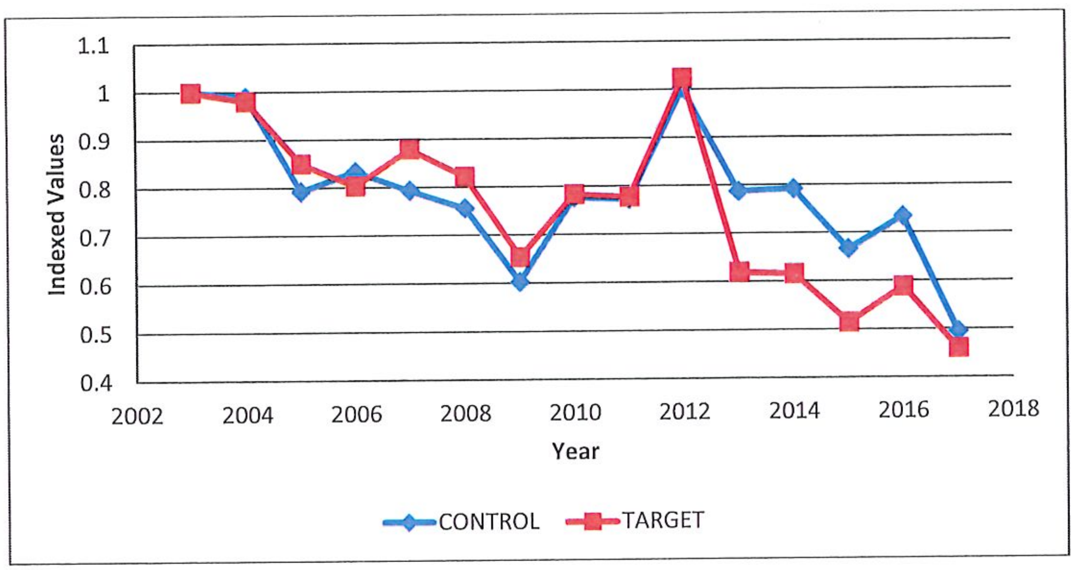


Figure 5. Total Irrigated Corn Acres

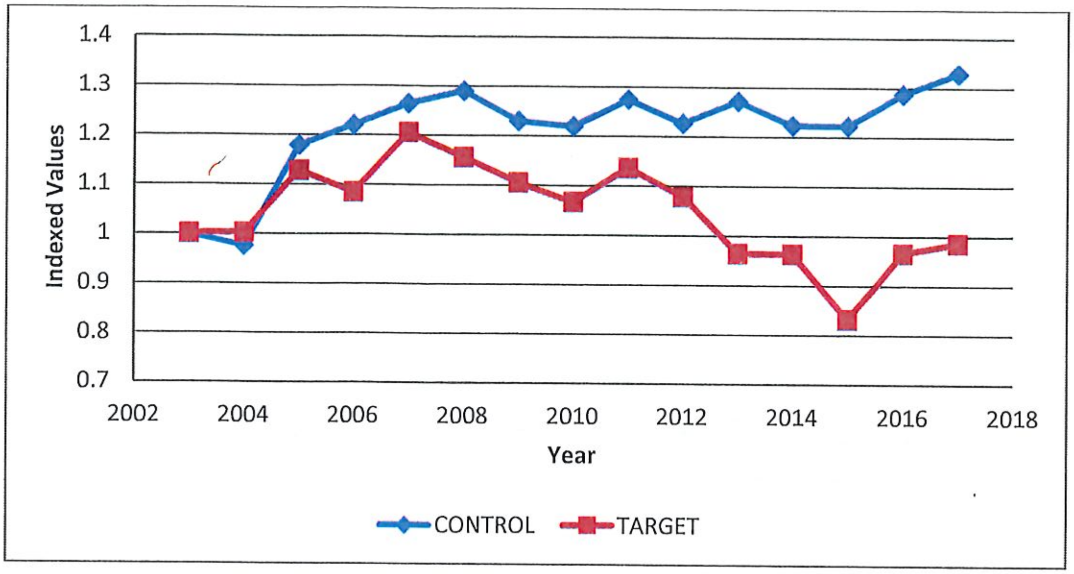


Figure 6. Total Irrigated Alfalfa Acres

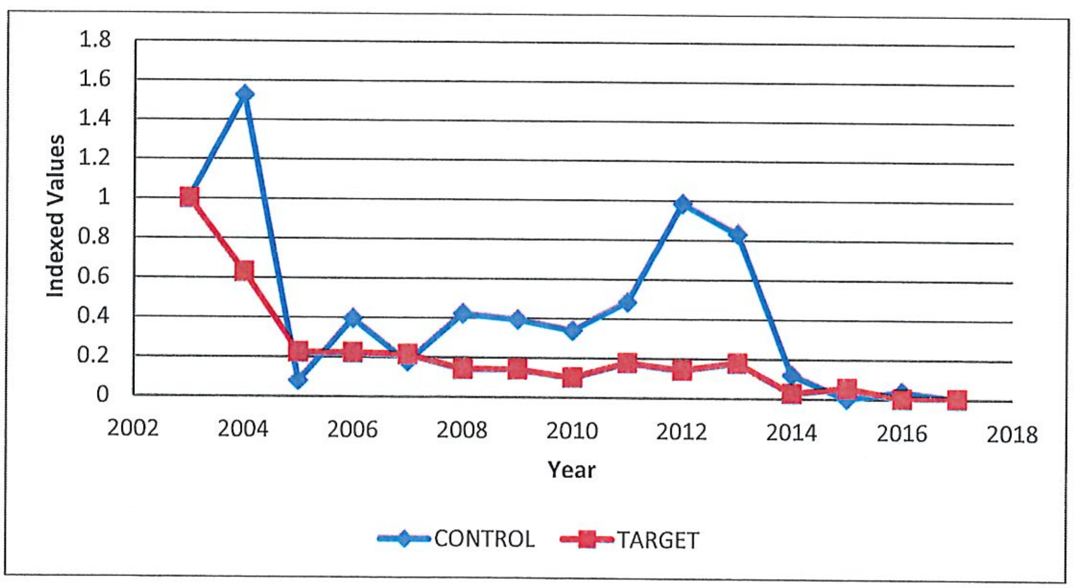


Figure 7. Total Irrigated Grain Sorghum Acres

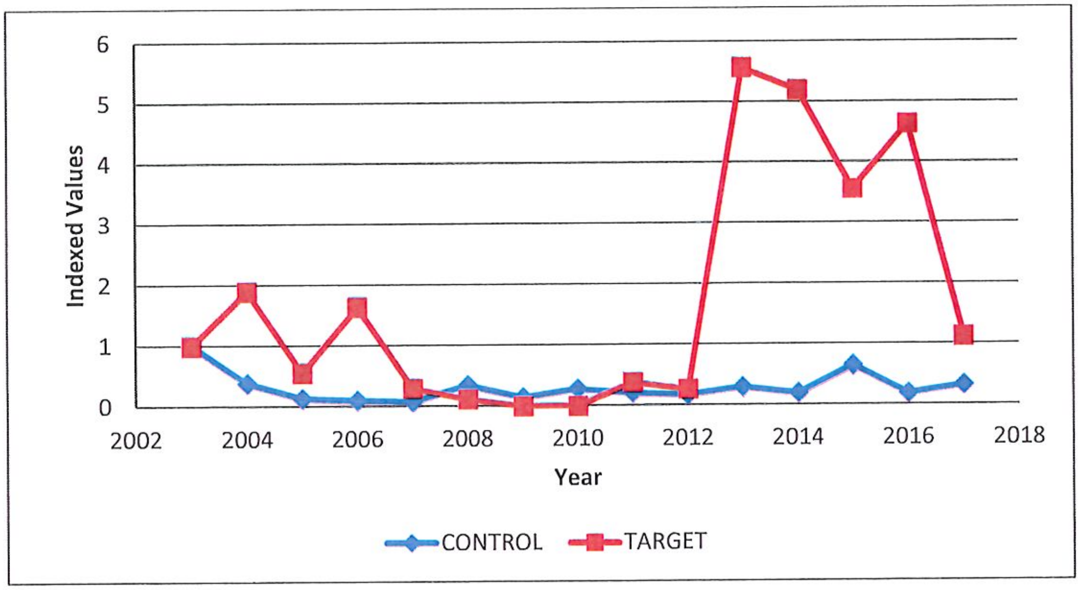


Figure 8. Total Irrigated Soybean Acres

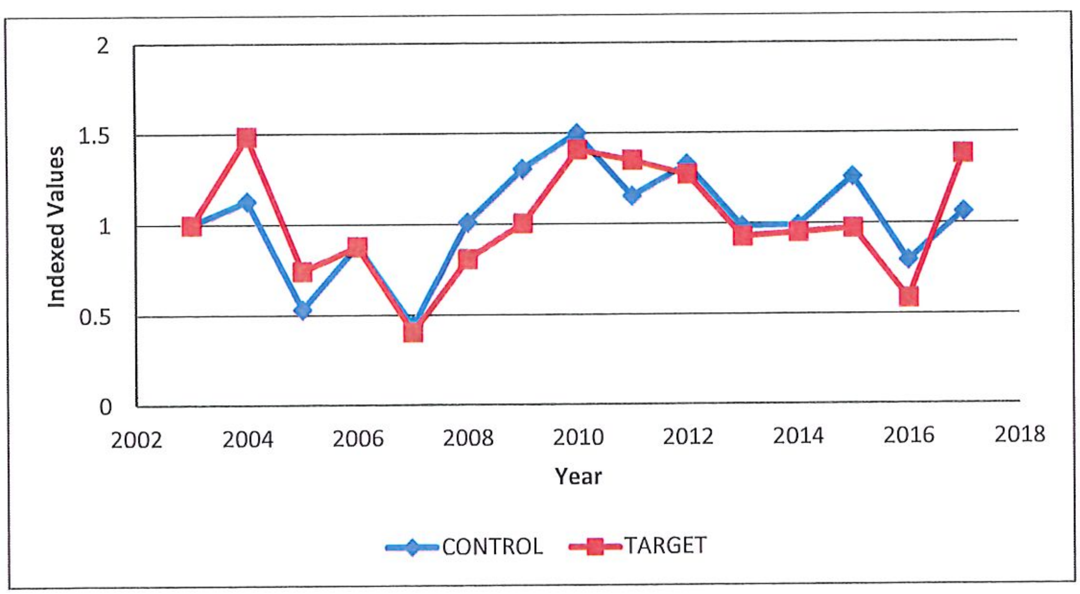


Figure 9. Total Irrigated Wheat Acres

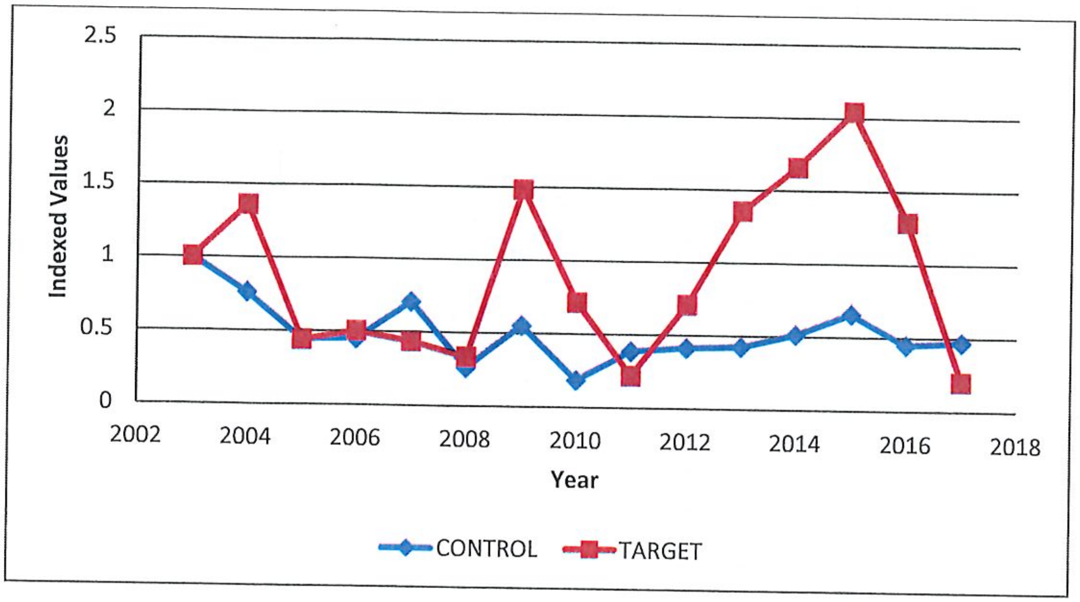


Figure 10. Total Irrigated Mixed Crop Acres

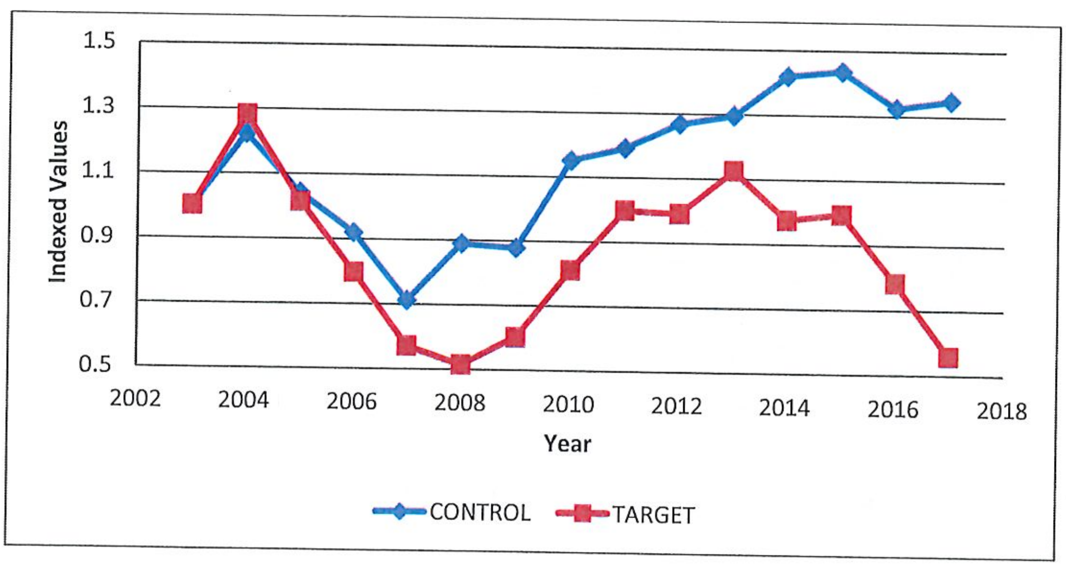


Figure 11. Average Groundwater Use per Irrigated Corn Acre

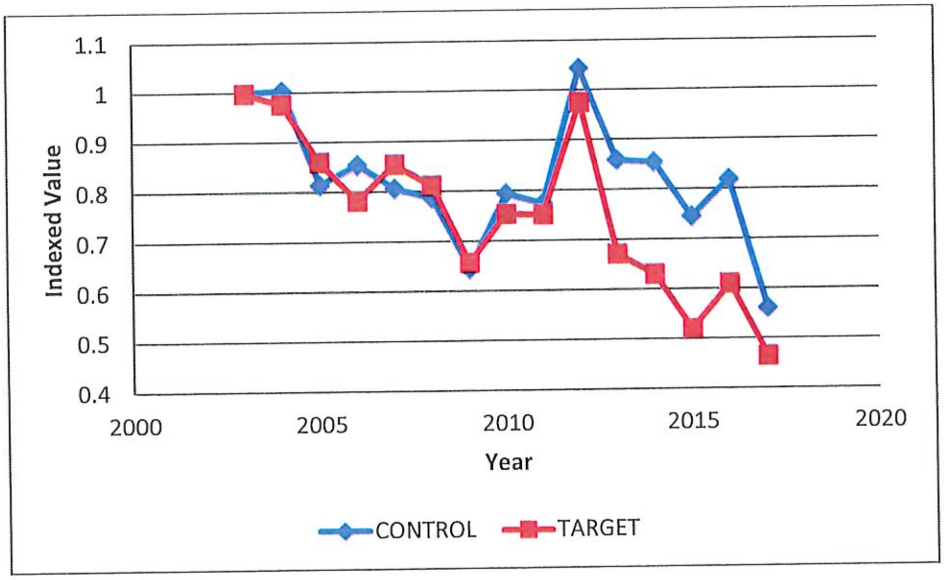


Figure 12. Average Groundwater Use per Irrigated Soybean Acre

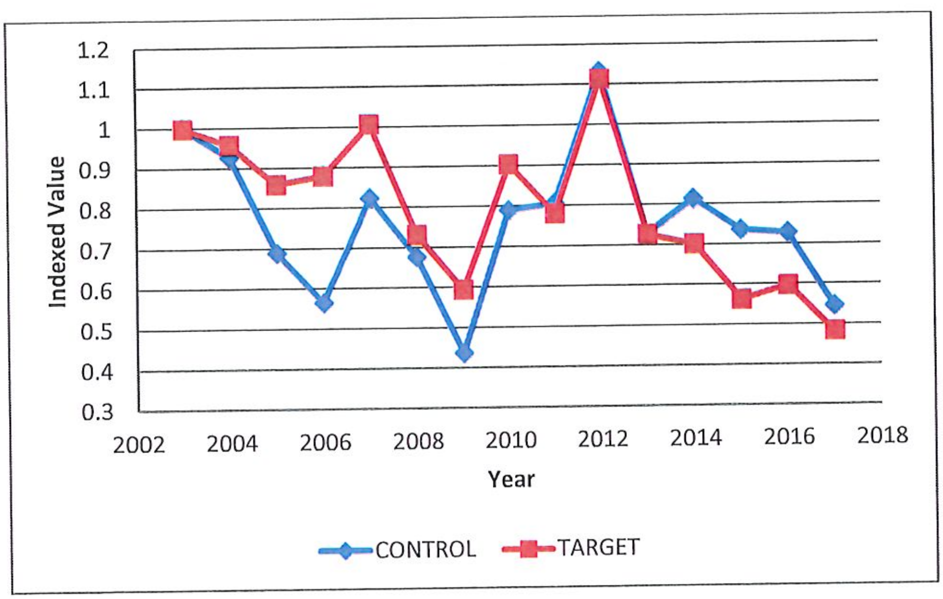
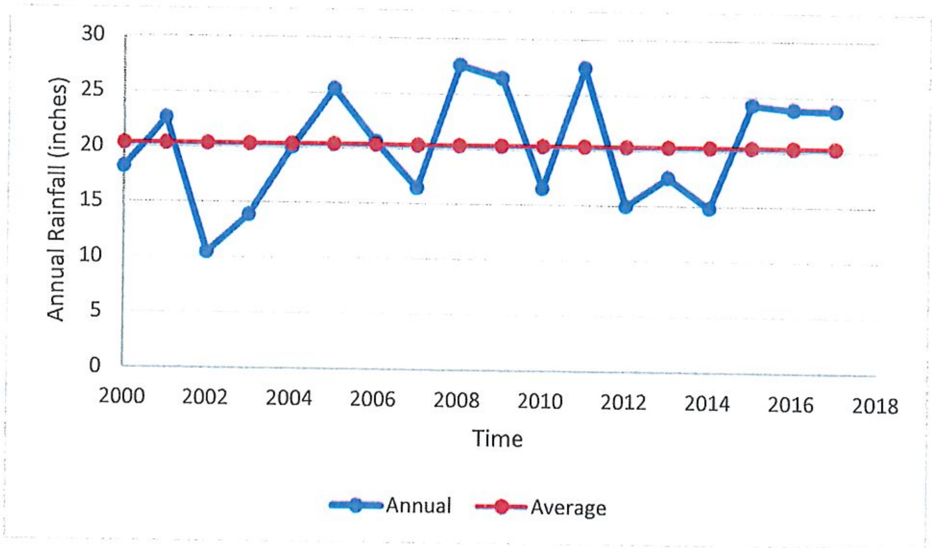


Figure 13. Historic Annual Rainfall for Sheridan County



Source: http://mesonet.k-state.edu