Maintain Existing and Expand Kansas-Based Data Services to the National Groundwater Monitoring Network

January 14, 2022

Funded by the

U.S. Geological Survey-Grant G19AC00191
07/15/2019 to 07/14/2022

Submitted by:
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Kansas Geological Survey Open-File Report 2022-1

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Introduction

The National Groundwater Monitoring Network (NGWMN) is an effort led by the U.S. Geological Survey (USGS) to establish a network of selected monitoring wells across the country to facilitate the planning and management of groundwater resources. The NGWMN serves as a single data portal that retrieves, in real time, construction, lithology, depth-to-water measurements, and water-quality data that are maintained and served to the portal from a variety of participating local, state, and federal sources. The NGWMN can be accessed at the following URL: http://cida.usgs.gov/ngwmn/.

In 2016 (federal fiscal year 2016), the USGS provided funding support through Cooperative Agreement G16AC00017 to the Kansas Geological Survey (KGS) to become a data provider to the NGWMN (Wilson, 2016). The project period started January 1, 2016, and ended December 31, 2016. Under this agreement, the KGS evaluated monitoring sites for inclusion in the NGWMN, worked with USGS staff to populate the data portal with monitoring well sites that met a set of minimum data standards, and then developed a series of web services that allowed the NGWMN real-time data access to the state's well construction, lithology, and depth-to-water measurements records.

In 2017 (FY2016), the USGS provided funding support to the KGS through Cooperative Agreement G16AC00363 to maintain persistent data services to the NGWMN (Wilson, 2017). This included preserving existing web services and applying routine updates to existing network sites, which included removing well sites that were no longer viable and uploading replacement and new well site locations. The project period started October 10, 2016, and ended September 30, 2017.

In 2018 (FY2017), the KGS was awarded funding from the USGS under Cooperative Agreement G17AC00170 to update the Kansas portion of the well registry, maintain the persistent data services to the NGWMN, and install a network of trend wells in the Kansas River alluvial aquifer, which underlies a river valley in Kansas with major population growth and economic activity but without an active water-level observation network at the state level (Wilson, 2019). This two-year project started July 1, 2017, and was completed June 4, 2019.

In the summer of 2019 (FY2019), USGS Cooperative Agreement G19AC00191 was awarded to the KGS to continue updates and maintenance of the Kansas portion of the well registry and persistent data services but also to expand the number of wells participating in the NGWMN by including all the annually measured wells from the Kansas Cooperative Water-Level Network. Additionally, the project calls for well maintenance on four selected trend wells by redeveloping the sites to ensure a continued good hydraulic connection with the High Plains aquifer. This two-year project started on July 15, 2019, and was delayed by travel restrictions related to the COVID-19 pandemic. After receiving a no-cost extension, the project was completed on December 23, 2021.

Existing Kansas NGWMN Well Sites

The NGWMN started serving Kansas-based groundwater data in September 2016 from 133 surveillance wells — those that are measured annually during the winter months — and 4 trend wells, which are true observation wells that record water levels in real time throughout the year (Wilson, 2016). Through each subsequent NGWMN contract, the registry was updated by removing wells no longer measurable and adding new additional well sites that met the NGWMN data requirements. At the start of this project (summer 2019), there were 210 Kansas wells in the NGWMN network (fig. 1).

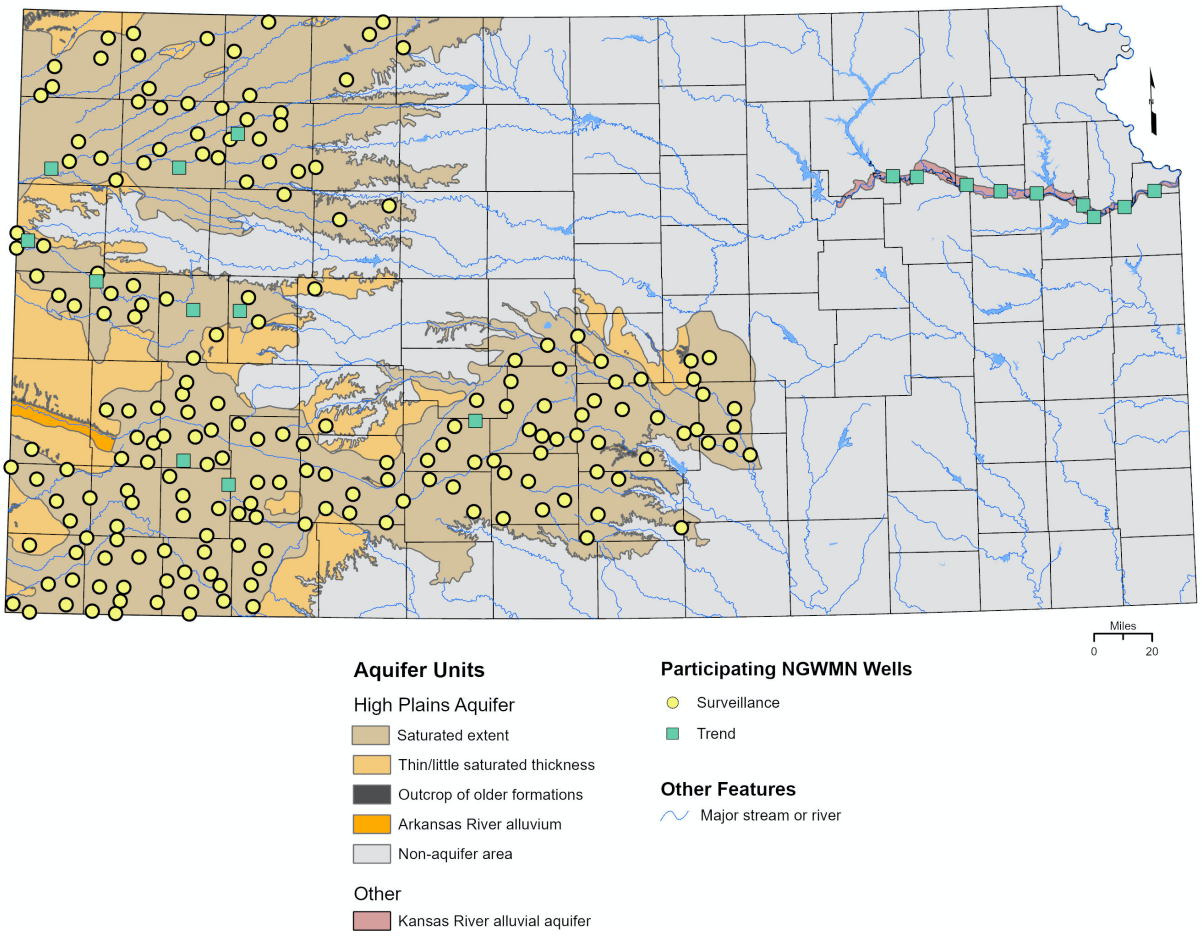

Figure 1. Participating 2019 NGWMN sites in the Kansas High Plains aquifer and the Kansas River alluvial aquifer.

All well sites in the High Plains aquifer are part of the larger Kansas Cooperative Water-Level Network, a collection of approximately 1,400 wells measured annually by the KGS in cooperation with the Kansas Department of Agriculture, Division of Water Resources (Miller et al., 1998). The vast majority of measurements take place in the month of January, typically from irrigation wells using steel or electric tapes, which have precisions down to hundredths of a foot. Customized software developed by the KGS combined with global positioning systems is used to ensure the same wells are measured each year and to conduct on-site data validations of depth-to-water

measurements. The KGS further randomly selects 7% of the wells each year to be re-measured by a second person within 24 hours of the initial visit. Referred to as “QA” wells, these extra measurements serve to provide quality assurance of the collected data. Additional statistical and GIS reviews are conducted later on the entire data set to identify abnormal or anomalous measurements. If necessary, well sites are re-measured the same day or within a month, depending on the circumstances.

The Kansas Cooperative Water-Level Network also consists of a growing collection of continuously monitored wells. Referred to as “index wells,” these sites are equipped with pressure transducers that record water levels every hour and, through the use of telemetry systems, provide real-time access to water-level data throughout the year (Butler et al., 2020b). The index program was expanded into the Kansas River alluvial aquifer to better understand the dynamics of the aquifer and its interactions with the river (Butler et al., 2020a; Wilson, 2019). Index wells are also manually measured throughout the calendar year, typically every three to four months.

Depth-to-water measurements, both manually and electronically recorded, are stored in an Oracle-based enterprise-level relational database (RDMS) called the Water Information Storage and Retrieval Database (WIZARD). WIZARD evolved from the U.S. Geological Survey’s Ground Water Site Inventory in the mid-1990s (Hausberger et al., 1998) and today represents the largest repository of depth-to-water measurements in Kansas. Measured well sites are used to track temporal changes in water-table elevations and estimates of water availability. WIZARD currently consists of more than 57,000 well sites with more than 650,000 water-level measurements. Data can be accessed at the following URL:

http://www.kgs.ku.edu/Magellan/WaterLevels/index.html

A key feature of the NGWMN data framework is that participating wells must have associated construction and lithology descriptions. In Kansas, this information can be obtained from the Water Well Completion Records Database (WWC5). Since the mid-1970s, water well drilling companies have been required to provide location, type, use, casing, lithology, and other information to the Kansas Department of Health and Environment any time a well is constructed, reconstructed, or plugged. The KGS stores more than 280,000 WWC5 records (fig. 2) in an Oracle RDMS and serves these data to the public through the following URL:

http://www.kgs.ku.edu/Magellan/WaterWell/index.html

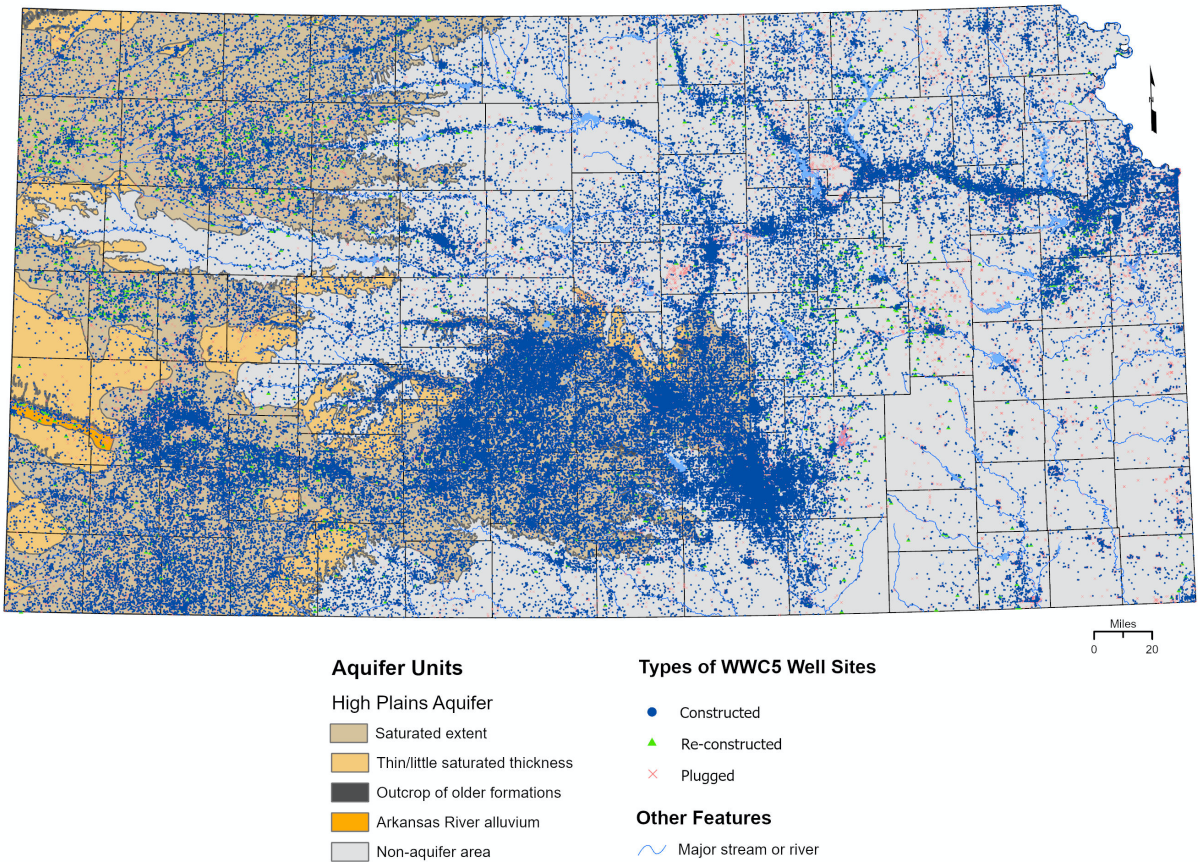

Figure 2. WWC5 well sites.

Existing Kansas NGWMN Data Streams

Data are streamed to the NGWMN through a series of web services, standardized protocols by which data are transmitted and shared across the internet. The Kansas web services were developed as a single Adobe ColdFusion component, stored on a Linux web server running Apache software. The ColdFusion component has four methods (one representing each service [e.g., water levels, lithology, screens, and casings]), supports REST protocol, and returns XML-formatted web documents.

Each of the four methods provided under the Kansas web service is called using a URL-based variable along with a list of one or more site IDs for NGWMN wells. A list of the methods for an example well/site number is shown below.

- Water Levels Method
  - http://maps.kgs.ku.edu/geohydro/wizard/services/data.cfc?**method=WaterLevels**&sites=371237100455301
- Lithology Method
  - http://maps.kgs.ku.edu/geohydro/wizard/services/data.cfc?**method=Lithology**&sites=371237100455301
- Casing Method
  - http://maps.kgs.ku.edu/geohydro/wizard/services/data.cfc?**method=Casing**&sites=371237100455301
- Screens Method
  - http://maps.kgs.ku.edu/geohydro/wizard/services/data.cfc?**method=Screens**&sites=371237100455301

A more detailed description of each process can be found in the report “Establishing Kansas as a Data Provider to the National Groundwater Monitoring Network” (Wilson, 2016).

Kansas 2019 and 2020 Updates to the NGWMN

At the conclusion of the 2020 and 2021 water-level collection campaigns and subsequent data review and follow-up, the KGS assessed the participating NGWMN wells to make sure the sites were still measurable and to determine whether the annual changes in the water table were representative of aquifer conditions for given areas. Table 1 lists wells that were dropped from the NGWMN data portal and the reason for removal. All of these actions occurred after the 2021 measurement runs with the exception of 35S 37W 16BCC 02, which happened after the 2020 season.

Table 1
Kansas Wells Removed in 2020 and 2021 From the NGWMN Data Portal

Site Number	Legal Description	Reason for Removal
394814100505201	03S 31W 07CBD 01	Well plugged.
394013101155301	04S 35W 29DDD 01	Water table at bottom of well.
391339100151101	09S 26W 32BCD 01	Tape blocked downhole.
383405101363901*	17S 39W 22ABB 01	Measuring point filled with foam.
381734098372501	20S 12W 23CCA 01	Well plugged.
380810100400301	22S 31W 13DDB 01	Well plugged.
375607100185701	24S 27W 29BCC 01	Well converted to stockwater use.
374126098411501*	27S 13W 13DDC 01	Measuring point blocked.
374215101222301	27S 37W 16AAD 01	Casing collapsed downhole.
373940101521101	27S 42W 36BCB 01	Only access is through pump column.
373609098494301	28S 14W 14CCC 01	Well plugged.
373607101121001	28S 36W 24AAD 01	Well plugged.
373731101255901	28S 38W 12CBD 01	Water table at bottom of well.
372109101174101	31S 37W 13BDD 01	Tape blocked downhole.
371211101122202	33S 36W 02CCC 01	Well gives extremely spotty cuts.
371246101290701	33S 38W 06AAB 01	Well plugged.
370014101211602	35S 37W 16BCC 02	Tape blocked downhole.

* Well record is still in the NGWMN but display option has been turned off.

The display options for surveillance wells 383405101363901 and 374126098411501 were turned off in the NGWMN data portal. This leaves the well in the data registry but effectively removes the site from public queries through the NGWMN interface. The measuring points for both wells were blocked at the surface in 2021; however, after revisiting the sites, the KGS determined simple modifications may allow future measurements to continue. The KGS is in the process of obtaining landowner permissions to make these adjustments. If successful, the wells' display options will be turned back on.

Another objective, to be completed in year 1 of this contract, was to include the annually measured wells from the Kansas Cooperative Water-Level Network that are wholly or partially screened in the HPA to help support the USGS High Plains Assessment project. In August of 2019, the NGWMN High Plains data providers met with the USGS to discuss how to best complete this task. It was decided that sites with well depths and construction information could be included as surveillance sites even if they were missing lithology data. Sites that did not contain well depths or well construction information should be included as special studies sites.

For sites missing well depths and construction information, any associated drillers' logs and, in some cases, self-reported water-use information records were reviewed to identify the missing information. During this review, three wells were found to have consolidated well histories from multiple well sites. This typically happens when a new well is drilled and measured in close approximation to an older site. Water-level measurements from these sites were split, assigned to their appropriate well locations, and added to the NGWMN.

In May of 2020, 1,115 wells from the Kansas Cooperative Water-Level Network determined to be screened wholly or partially in the HPA were loaded into the NGWMN. Of those, 234 of them have the required well depth and construction information to be classified as surveillance wells, 3 sites are equipped with downhole sensors and telemetry units along with construction and lithology descriptions allowing them to be classified as trend wells, and the remaining 878 are assigned to special studies. In May of 2021, an additional 17 HPA well sites were added based on results of the 2021 measurement campaign. Of those, three meet the minimum data requirements to be surveillance wells, one is equipped with telemetry equipment and has a measurement frequency to allow it to be listed as a trend site, and the rest are assigned to special studies. All of these sites are located in areas that have active groundwater pumping (Fross et al., 2012; Whittemore et al., 2016) and therefore have been designated as part of the "Documented Changes" subnetwork of the NGWMN.

Several other data updates to the NGWMN data portal took place over this contract period. Trend well 391244101501901 in Sherman County (SH) in northwest Kansas was added to the registry in 2017 but the display option to show the data record through the NGWMN public data portal was turned off in 2018 after collected water-level data indicated the well had a poor hydraulic connection to the aquifer. The well was developed in the fall of 2018 and the water levels now show representative responses to both barometric pressure and pumping influences, allowing the well record's display option to be turned back on.

Surveillance well 370033100534202 in Seward County (SW) in southwest Kansas was changed to a trend well after the site was equipped with a pressure transducer and telemetry equipment to provide real-time, hourly water-level measurements. This particular well was originally drilled as a true observation well by the USGS in 1999 and used in the 2001 Water-Resources Investigations Report 01-4028 by P.B. McMahon to assess vertical gradients in water chemistry in the central High Plains aquifer.

Trend well 390843096381401 in Riley County (RL) in northeast Kansas was added to the NGWMN data registry. Although drilled as part of the original trend well network in the Kansas River alluvial aquifer, this well's addition to the NGWMN was delayed as the KGS worked with vendors to explore different telemetry options.

Lastly, site 375847101081801 in Kearny County (KE) in southwest Kansas, which was added with the HPA wells in 2020, was updated from special studies to surveillance with the inclusion of related well construction, screening, casing, and lithologic information. This observation well was drilled in 1998 to study water quality and stream-aquifer interactions between the Arkansas River, its alluvial deposits, and the underlying HPA.

The associated web services for all the new trend wells (391244101501901, 370033100534202, 390843096381401, and 391921100444601) were updated so they served daily average values.

As of the date of this report, a total of 1,327 wells (not including 2 with their display options turned off) are being served from the KGS to the NGWMN system; of those, 423 are surveillance wells, 15 are trend wells, and 879 are special study wells in the Kansas HPA with the remaining 10 as trend wells in the Kansas River alluvial aquifer (fig. 3).

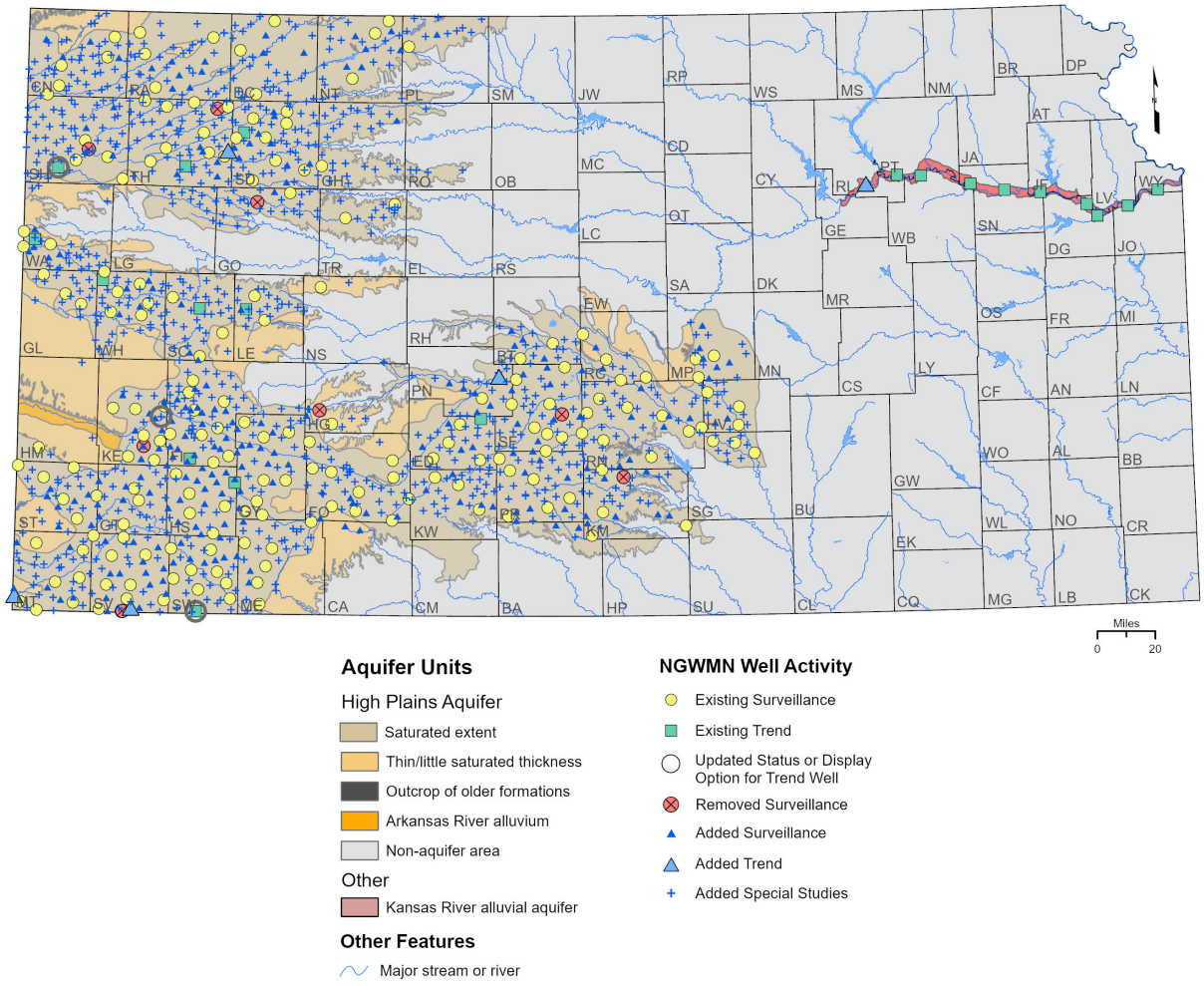

Figure 3. Status and 2020–2021 update activities of KGS-based NGWMN wells.

Well Maintenance

The last objective, to be completed in year 2 of this contract, was to conduct maintenance work on four trend wells in the HPA. The three most western of these selected sites (fig. 4) were some of the first observations wells drilled under the state's Index Well Program in 2007 and have been instrumental in providing insights and characterizations of the water-level responses occurring in the aquifer throughout the year. The easternmost well of the four selected sites, in Edwards County, Kansas, is an observation well completed by the KGS for Big Bend Groundwater Management District #5 and has a measurement history going back to the late 1980s.

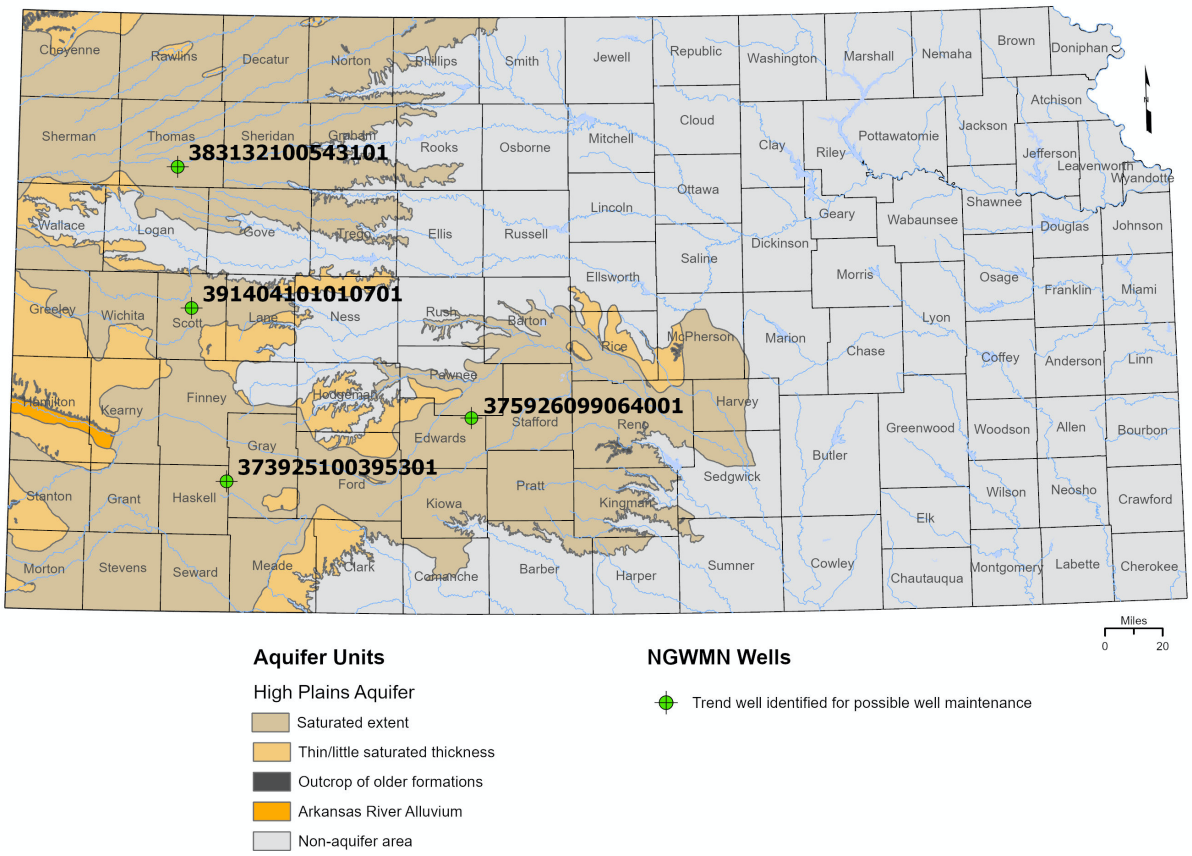

Figure 4. Selected trend well sites for well redevelopment.

At each site, the KGS conducted a downhole camera survey before the wells were redeveloped by air-lift pumping each site to remove sediment. Redevelopment work was subcontracted to the Kansas office of Hydro Resources, a drilling company out of Garden City, Kansas. After redevelopment, KGS staff conducted slug tests and a second downhole camera survey. The initial camera survey and well redevelopment at the three northern well sites (383132100543101, 391404101010701, and 375926099064001) occurred September 21–22, 2021, while work at the southernmost well, 373925100395301, was delayed until December 7, 2021, to allow the landowner time to complete the harvest of crops surrounding the site. Slug tests at the two northernmost wells (383132100543101 and 391404101010701) were completed November 9 and 10, respectively, while tests at the two southernmost wells (373925100395301 and

375926099064001) were completed December 14 and 15, respectively. The tests were conducted using solid slugs following the Kansas Geological Survey slug-test guidelines (Butler et al., 1996; Butler, 2019). The tests were analyzed using the analysis guidelines described in Chapter 12 of Butler (2019). The final parameter estimates were obtained with the KGS Model (Hyder et al., 1994; Butler, 2019). Results from each site are listed below.

383132100543101- Thomas County, Kansas

https://geoportal.kgs.ku.edu/geohydro/wizard/wizardwelldetail.cfm?usgs_id=383132100543101

Located in northwest Kansas, the 2.5-inch diameter Thomas County index/trend well was completed on July 3, 2007, drilled to the base of the Ogallala/High Plains aquifer (284 ft below land surface), with the bottom 10 ft screened. Estimated one-well volume is 14 gallons. The initial camera survey on September 21, 2021, identified the water level at 222.80 ft and tagged the bottom of the well at 280.17 ft, both below the top of the casing (BTOC). The actual bottom of the well could not be reached due to blockage from accumulated material within the bottom 6 ft of the screen interval (fig. 5).

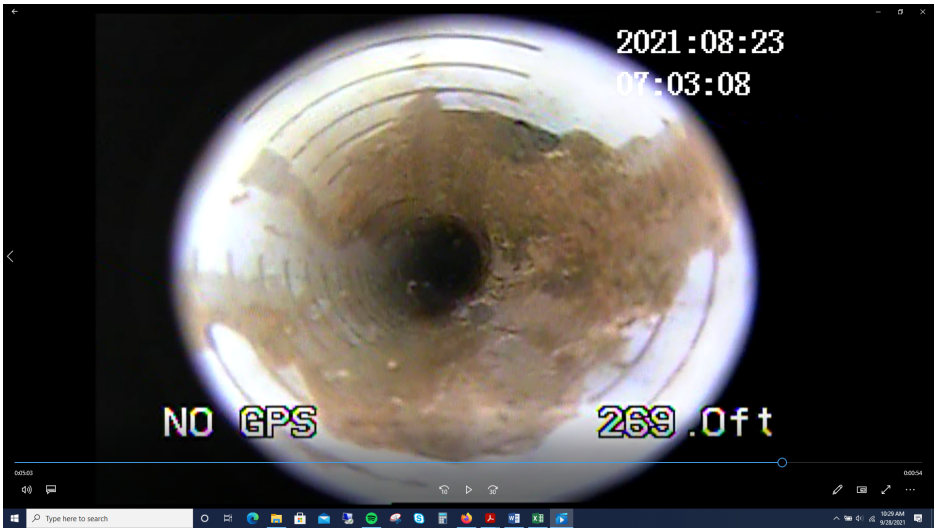

Figure 5. Image of well blockage within the bottom of the screen interval for index/trend well 383132100543101 during the initial camera survey, prior to redevelopment. Depth corrected for interval adjustment is 277 ft from top of casing.

After the camera survey, a ½-inch steel air line was installed to approximately 280 feet BTOC with a measured bucket flow of roughly 4 gpm. Air lifting lasted 35 minutes, after which time KGS staff took a water-quality sample. The water level after redevelopment was 222.72 ft BTOC and the well bottom was tagged at 286.4 ft BTOC.

A series of slug tests using 2 ft and 4 ft slugs for a total of eight tests were completed on November 9, 2021. Results indicated that the well has a good hydraulic connection to the aquifer with water levels recovering within 30 seconds (fig. 6). The estimated hydraulic conductivity was 36.8 ft/day, which was 16% greater than the estimate obtained from slug tests performed in August 2014. After testing, a second downhole camera survey showed that the heavy scaling was reduced but still prevalent in parts of the screen. The bottom of the well was soft and tagged at 281.5 ft BTOC,

an indication that since late September, fine material had moved through the slots into the well with additional sediment accumulation from settling after the development (fig.7).

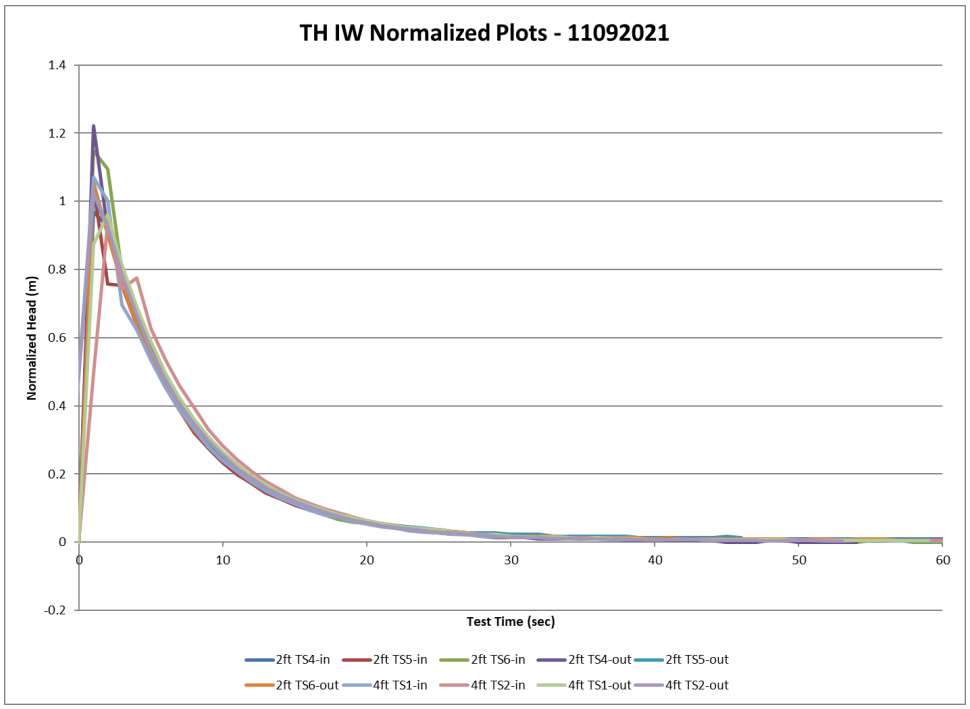

Figure 6. Normalized head (H(t)/H0) from test initiation for a series of slug tests performed at index/trend well 383132100543101 on November 9, 2021; H0 is the initial water-level change at the start of the slug test, H(t) is the deviation from static at time t. Slug tests were performed in both slug-in (solid slug introduced into the water column) and slug-out (solid slug removed from the water column) modes.

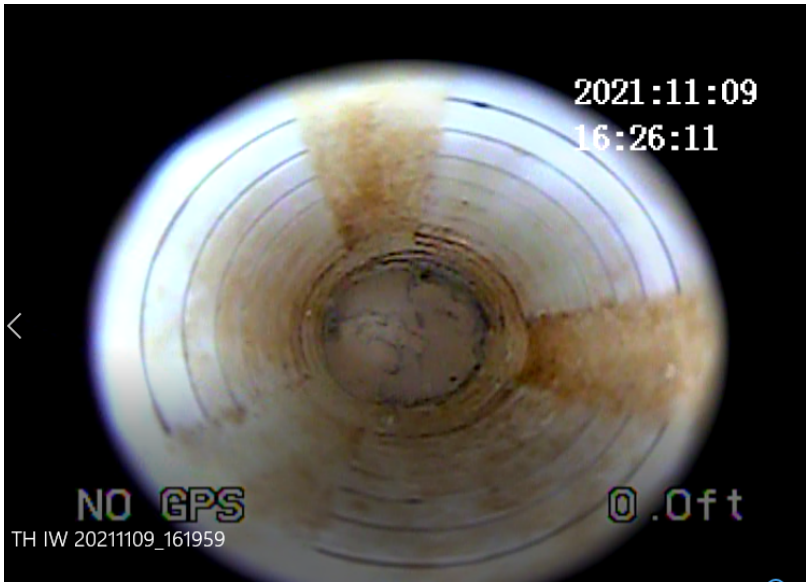

Figure 7. Image of bottom of well for index/trend well 383132100543101 after redevelopment on November 9, 2021.

391404101010701- Scott County, Kansas

https://geoportal.kgs.ku.edu/geohydro/wizard/wizardwelldetail.cfm?usgs_id=391404101010701

Located in west-central Kansas, the 2.5-inch diameter Scott County index/trend well was completed on July 10, 2007, drilled to the base of the Ogallala/High Plains aquifer (227 ft below land surface), with the bottom 10 ft of the well screened. An initial camera survey on September 21, 2021, identified the water level at 145.11 ft and tagged the bottom of the well at 225.32 ft, both BTOC. Estimated one-well volume is 20 gallons. The pre-redevelopment video log shows the bottom 2.25 ft of the screen filled with sediment. In addition, the top 5 ft of the screen interval shows varying amounts of blockage from the neat cement that migrated during well construction (fig. 8).

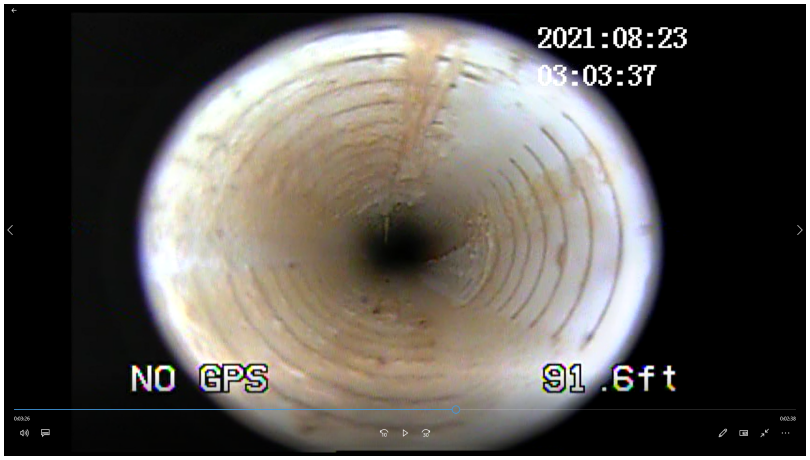

Figure 8. Image of some well blockage within the screened interval for index/trend well 391404101010701 during the initial camera survey, prior to redevelopment. Depth corrected for interval adjustment is 220 ft from top of casing.

After the camera survey, a ½-inch steel air line was installed to approximately 224 feet BTOC with a measured bucket flow of roughly 5 gpm. Air lifting lasted 35 minutes, after which time KGS staff took a water-quality sample. The water level after redevelopment was 145.4 ft BTOC and the tagged bottom of the well was 226.40 ft BTOC.

A series of slug tests using 2 ft and 4 ft slugs for a total of eight tests were completed on November 10, 2021. Results indicate the well has a reasonable hydraulic connection to the aquifer with water levels recovering within 400 seconds (fig. 9). The estimated hydraulic conductivity was 3.5 ft/day, which was 7% less than the estimate obtained from slug tests performed in August 2014. After testing, a second downhole camera survey was completed and the bottom tagged at 225.3 ft BTOC, an indication that since September, fine material had moved through the slots into the well with additional sediment accumulation from settling after the development (fig.10). The original driller's log indicates the screen extends 2 ft below this point followed by a 2 ft sump. As such, it is unlikely that any amount of redevelopment will completely and permanently clear the screen.

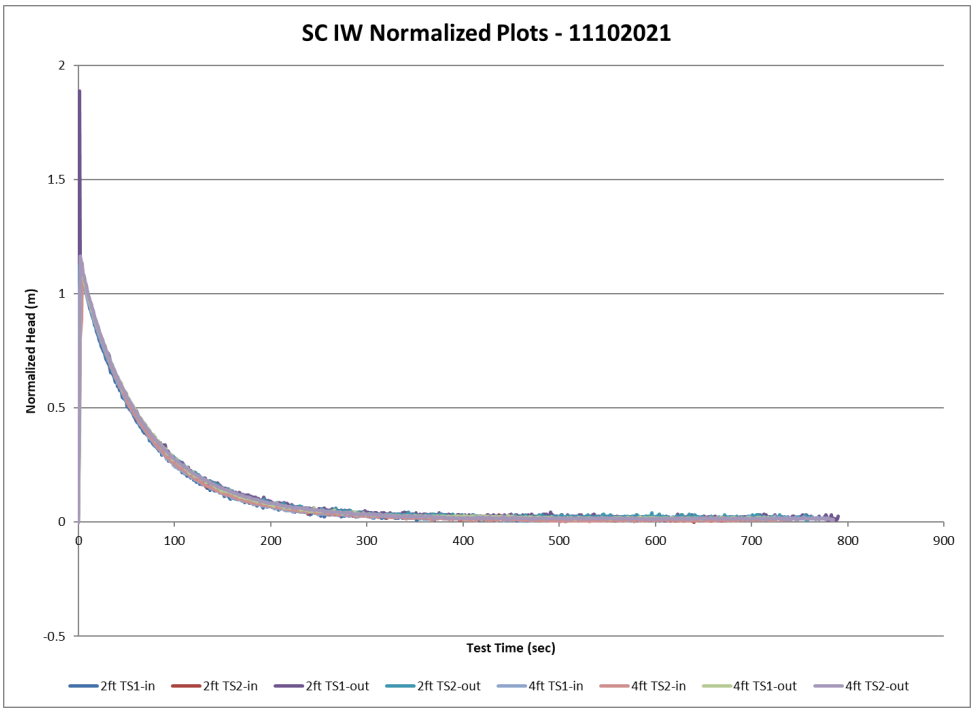

Figure 9. Normalized head (H(t)/H0) from test initiation for a series of slug tests performed at index/trend well 391404101010701 on November 10, 2021; H0 is the initial water-level change at the start of the slug test, H(t) is the deviation from static at time t. Slug tests were performed in both slug-in (solid slug introduced into the water column) and slug-out (solid slug removed from the water column) modes.

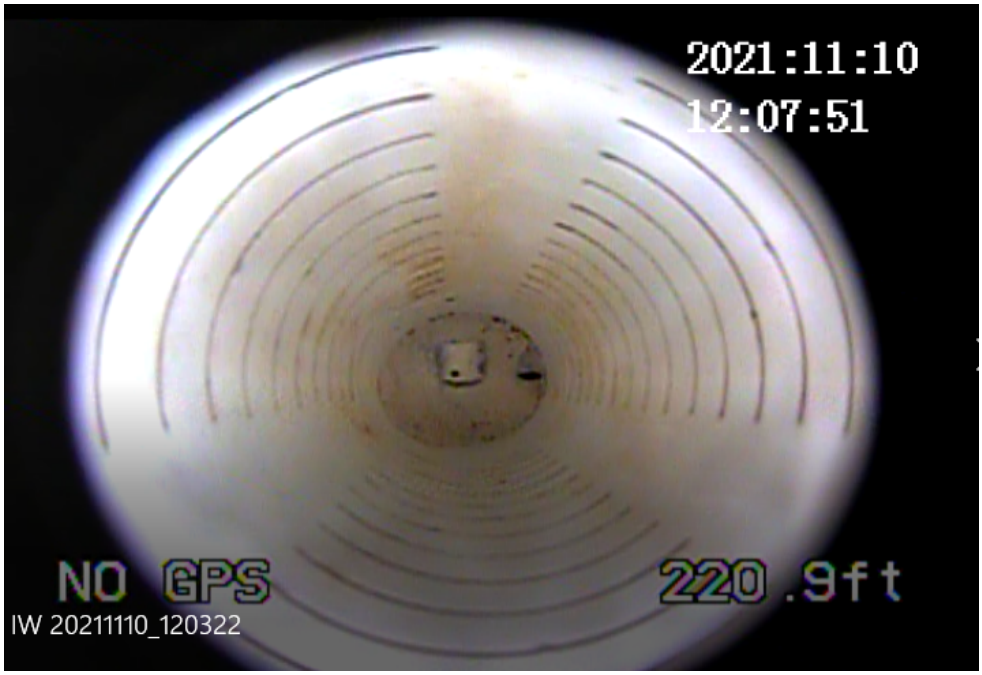

Figure 10. Image of bottom of well for index/trend well 391404101010701 after redevelopment on November 10, 2021.

373925100395301- Haskell County, Kansas

https://geoportal.kgs.ku.edu/geohydro/wizard/wizardwelldetail.cfm?usgs_id=373925100395301

Located in southwest Kansas, the 2.5-inch diameter Haskell index/trend well was completed on June 20, 2007, drilled to the base of the Ogallala/High Plains aquifer (432 ft below land surface), with the bottom 10 ft of the well screened. An initial camera survey on December 7, 2021, identified the water table at 330.89 ft BTOC and tagged the bottom of the well at 425.43 ft BTOC. Estimated one-well volume is 21 gallons. The pre-redevelopment video of the well was not saved due to the SD memory card reaching its storage capacity. Based on hand measurements and looking at the screen view of the camera, there appeared to be roughly 4 ft of open screen before the top of the sediment.

After the camera survey, a ½-inch steel air line was installed to approximately 422 feet BTOC with a measured bucket flow of roughly 4 gpm. Air lifting lasted 67 minutes, after which time KGS staff took a water-quality sample. The water level after redevelopment was 330.99 ft BTOC and the tagged bottom of the well was 425 ft BTOC.

A series of slug tests using a series of 2 ft and 4 ft slugs for a total of 12 tests were completed on December 14, 2021. Results indicate the well has a good hydraulic connection to the aquifer with water levels recovering within 30 seconds (fig. 11). The slug-test data could not be matched by any existing models. There appear to be additional mechanisms affecting the tests, likely related to the filter pack extending 95 ft above the top of the screen, so no defensible hydraulic conductivity estimates could be obtained. No previous slug tests had been performed at this well. After testing, a second downhole camera survey was murky, making it difficult to identify the screen slots. The bottom of the well was soft and tagged at 426.74 ft BTOC (fig.12).

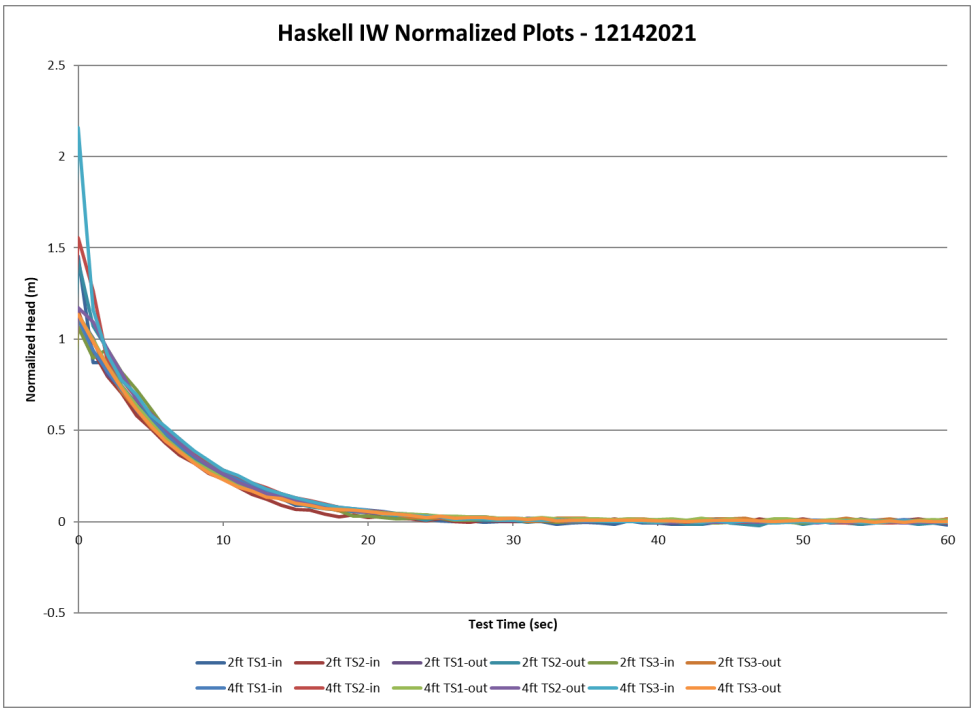

Figure 11. Normalized head (H(t)/H0) from test initiation for a series of slug tests performed at index/trend well 373925100395301 on December 14, 2021; H0 is the initial water-level change at the start of the slug test, H(t) is the deviation from static at time t. Slug tests were performed in both slug-in (solid slug introduced into the water column) and slug-out (solid slug removed from the water column) modes.

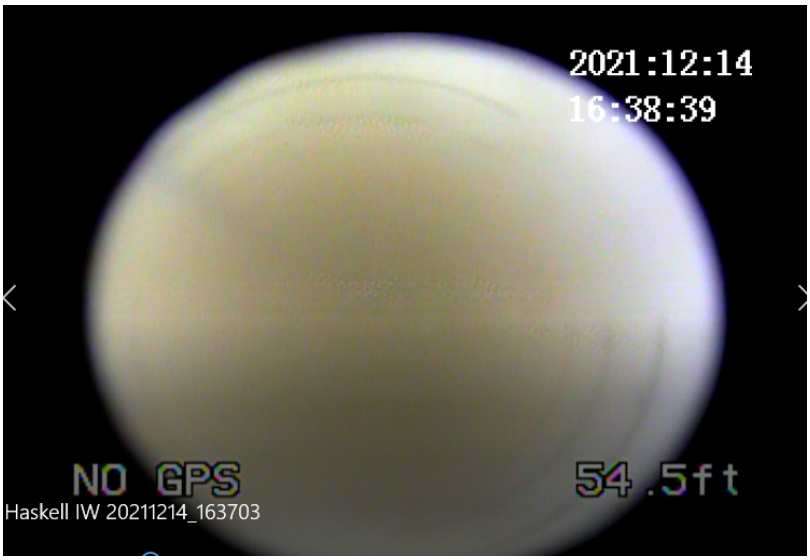

Figure 12. Image of screen slots for index/trend well 373925100395301 after redevelopment on December 14, 2021.

375926099064001- Edwards County, Kansas

https://geoportal.kgs.ku.edu/geohydro/wizard/wizardwelldetail.cfm?usgs_id=375926099064001

Located in south-central Kansas, the 5-inch diameter Belpre index/trend well in Edwards County was completed on May 20, 1987, drilled to the base of the Great Bend Prairie/High Plains aquifer (109 ft below land surface), with the bottom 20 ft of the well screened. Estimated one-well volume is 75 gallons. An initial camera survey on September 22, 2021, identified the water level at 39.39 ft and tagged the bottom of the well at 113.25 ft, both BTOC. The pre-redevelopment video log shows the bottom of the well to be fairly clear with a pipe at the bottom of the hole (fig. 13).

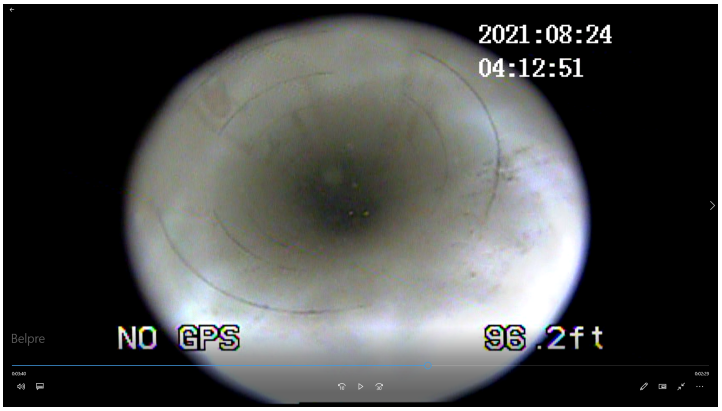

Figure 13. Image of bottom screen interval for index/trend well 375926099064001 during the initial camera survey, prior to redevelopment. Depth corrected for interval adjustment is 99 ft from top of casing.

After the camera survey, a ½-inch steel air line was installed to approximately 113 feet BTOC. Measured bucket flow could not be obtained due to harder water surge but was estimated to be double that of the other wells (~8 to 10 gpm). Air lifting lasted 30 minutes, after which time KGS staff took a water-quality sample. The water level after redevelopment was 40.61 ft BTOC and the bottom of the well was tagged at 113.62 ft BTOC.

A series of mechanical slug tests using a series of 2 ft and 4 ft slugs for a total of eight tests were completed on December 15, 2021. Given the larger diameter of the well, the slugs were doubled (e.g., two 2 ft slugs and two 4 ft slugs per test) to get better head response. Results indicate the well has a reasonable hydraulic connection to the aquifer with water levels recovering within 600 seconds (fig. 14). The estimated hydraulic conductivity was 2.5 ft/day. However, analyses using multiple models found that the tests were affected by a thin zone (skin) of low hydraulic conductivity in the immediate vicinity of the well. This well “skin” effect could have been produced by the more widely spaced screen slots than at the other wells (compare figs. 10 and 15). No slug tests had previously been performed at this well. After testing, a second downhole camera survey identified the well bottom at 113.93 ft BTOC (fig.15).

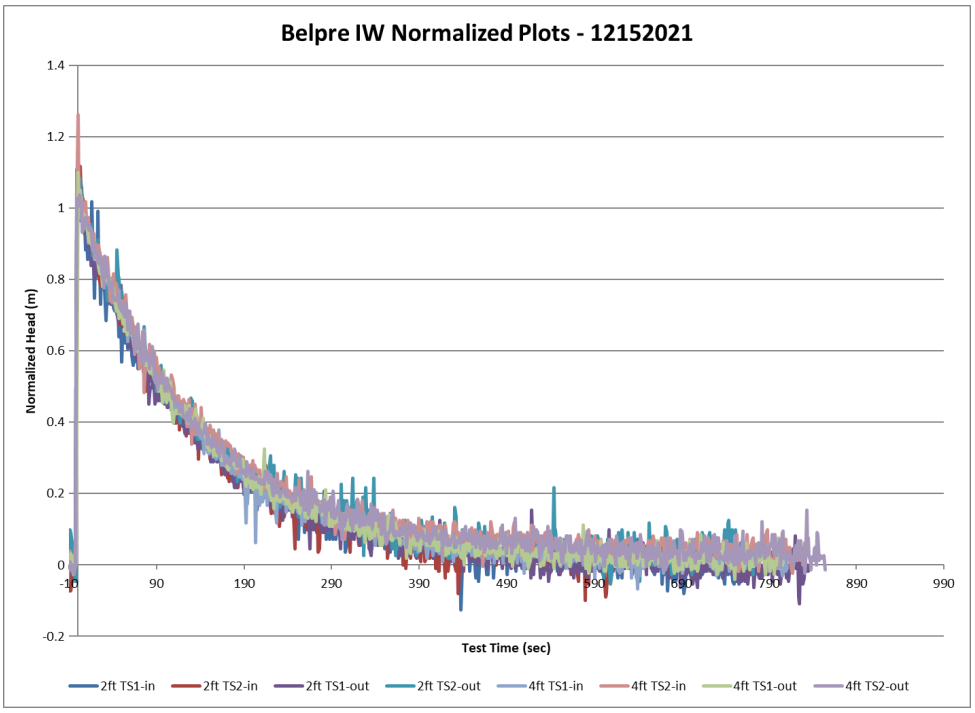

Figure 14. Normalized head (H(t)/H0) from test initiation for a series of slug tests performed at index/trend well 375926099064001 on December 15, 2021; H0 is the initial water-level change at the start of the slug test, H(t) is the deviation from static at time t. Slug tests were performed in both slug-in (solid slug introduced into the water column) and slug-out (solid slug removed from the water column) modes.

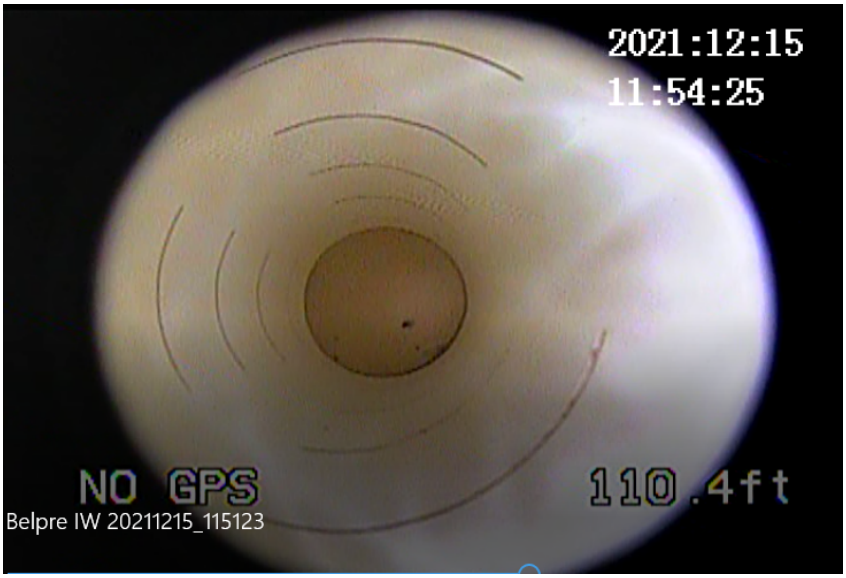

Figure 15. Image of bottom of well for index/trend well 375926099064001 after redevelopment on December 15, 2021.

Future Developments

The KGS has entered into a fifth grant and cooperative agreement with the USGS. This two-year project, which started July 15, 2021, will work to continue to maintain the Kansas-based web services to the NGWMN and make any needed changes and well additions after the Kansas Cooperative Water-Level Network measurements are acquired in the winters of 2022 and 2023. In addition, this new project will install two trend well nests, each site consisting of one well drilled in the Ogallala/High Plains aquifer and a second well drilled into the underlying and hydraulically connected Dakota aquifer. These nests will help to expand the trend/index well network in Kansas and provide insights into the interactions between the HPA and Dakota aquifer systems.

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