FINAL TECHNICAL REPORT

Award: G21AC10478

Oklahoma Water Resources Board

USGS National Groundwater Monitoring Network Oklahoma 2021: Final Report”

Term: 2021-2023

Final Report: 06/03/2024

Chris Adams

405-530-8998

Oklahoma Water Resources Board

3800 N Classen Blvd

Oklahoma City, OK 73118

Chris.adams@owrb.ok.gov

Background

The Oklahoma Water Resources Board (OWRB) has historically maintained an annual groundwater level measurement program that began in the 1950s and expanded in the 1970s. This annual measurement program has varied in size but has continued uninterrupted since its inception, primarily informing the allocation of water rights, and enabling basic post-drought monitoring. USGS Principal Aquifers that have been historically monitored include the Ada-Vamoosa (since 1995), Arbuckle Simpson (since 1994), Blaine (since 1950), Central Oklahoma (since 1977), High Plains (since 1966), Rush Springs (since 1976), and Trinity (since 1981) aquifers. The Principal Aquifers within Oklahoma are shown in Figure 1.

In 2013, OWRB established the Groundwater Monitoring and Assessment Program (GMAP) to quantify the state's groundwater resources, characterize the ambient water quality, expand the water level network, and determine quality and quantity trends and conditions. GMAP is Oklahoma's primary contributor to the National Groundwater Monitoring Network (NGWMN).

Descriptions of Oklahoma's networks, their recent evolution, and interactions with the NGWMN are provided in the following sections ('Network Descriptions – Water Levels', 'Network Descriptions – Water Quality'). A summary of relevant grants and the history of OWRB as a data provider is included in the 'History & Status of Data Flows' section. To provide a comprehensive and accurate picture of OWRB's programs, the network and grants sections will include work undertaken through this and other projects. Work specifically done for this project is discussed in the Project Summary section, with a breakout by objective. The final two sections will discuss problems encountered and the future of Oklahoma's networks.

Network Descriptions - Water Levels

To accomplish the GMAP goals, the spatial density in the annual water level network was significantly improved (one discrete quantity site per 50-100 km^2) with a total of about 842 sites, including 568 in Principal Aquifers. A smaller seasonal (triannual) discrete water level sub-network of about 251 sites (148 in Principal Aquifers) was implemented to recognize seasonality and changes due to climatic and water use drivers.

The combined annual and seasonal networks met the minimum spatial and temporal density recommendations of the NGWMN for a surveillance network in most aquifers but suffered from data gaps in more spatially variable aquifers, such as the Arbuckle-Simpson aquifer (karst, high-use aquifer), or in aquifers where landowner access has been limited (e.g., Ada-Vamoosa, Edwards-Trinity System, Arbuckle-Simpson, and Rush Springs aquifers). The High Plains aquifer has always had relatively good landowner-mediated access but has mostly been limited to annual water level measurements due to the prevalence of irrigation wells with high seasonal use in the network.

The seasonal water level network did not meet the frequency recommendations of the NGWMN for a trend network of at least quarterly measurements and needed improvement. This was especially true in aquifers such as the Arbuckle Simpson, where seasonal sampling is not representative of the large variations inherent in a karst aquifer with heavy usage; the Edwards-Trinity system, which only had one long-term continuous water level monitoring site; the Rush Springs aquifer, which has both very high use and recharge; and the High Plains aquifer, with intense and seasonally variable usage. Year-to-year differences in the timing and extent of rainfall, recharge, and peak water use demands can severely bias measurements made only 1-3 times per year and miss the impacts of seasonal drawdowns.

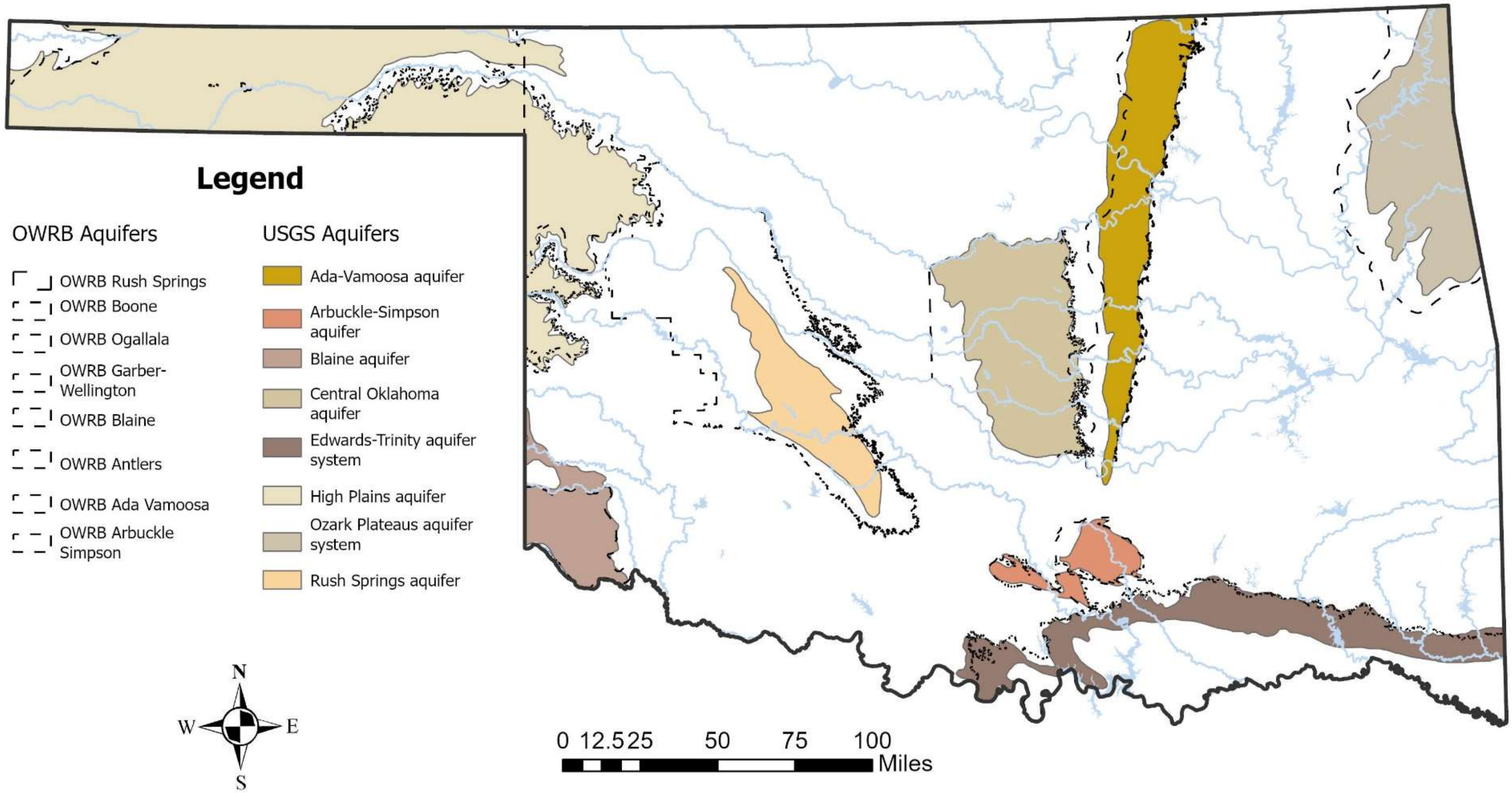

Figure 1: Principal Aquifer boundaries within Oklahoma shown with USGS Aquifers (colored shapes with solid lines) and OWRB Aquifers boundaries (dashed lines). These differ significantly in some areas due to the USGS boundaries being limited to outcropped areas of each aquifer e.g., Rush Springs aquifer, and some of the OWRB boundaries being heavily influenced by political boundaries, e.g. the western edge of the Central Oklahoma aquifer which currently exhibits an unnaturally straight nature.

To meet the temporal requirements of a trend network, the state's existing continuous recorder network was expanded in 2013 across the state's major aquifers (20 sites), except for the Edwards-Trinity System, where landowner participation remained limited. These sites were all equipped with hourly recording data loggers with data transferred through manual download. Despite this expansion, the continuous network did not meet the density goals of a trend network for either the NGWMN or Oklahoma's GMAP, especially in the High Plains, where the NGWMN suggested a minimum density of 20 wells for the Oklahoma portion of the High Plains.

In 2020 (during the 2018 project), it was discovered that three of the water level trend wells, which were old 2" steel USGS monitoring wells, had degraded to the point that they no longer communicated properly with the aquifer and had to be decommissioned. All three of these wells were in the Oklahoma Panhandle region of the High Plains aquifer (one in each of Cimmaron, Texas, and Beaver counties), leaving that part of Oklahoma without a water level trend network that met both the spatial and temporal requirements of the NGWMN. This created a critical data gap in Oklahoma and regionally for the NGWMN, where the High Plains were otherwise better represented by other NGWMN partners. More importantly, it highlighted some of the major weaknesses of the historical OWRB water level networks, which have always hindered the inclusion of wells in long-term trend networks. These weaknesses included:

- An almost exclusive reliance upon private wells or land access with fluctuating landowner permissions and no regulatory framework to enforce monitoring.
- Most of the wells in Oklahoma, and many in these networks, lack construction and/or lithology information.
- Many of the wells have seasonally heavy uses which has also limited their inclusion in the trend network.
- Many more wells are unused/abandoned and, even if they have been long-term wells in our annual measurement programs, have mostly not been tested for connectivity to their aquifers until recently, as was the case of all the initial continuous sites in the OWRB networks.

OWRB began a new expansion of the water level trend network with a more systematic approach to how wells are included, incorporating upfront aquifer testing, a much wider effort at stakeholder engagement, and securing long-term access. This initiative began with the FY20 grant and continued with all additional state and NGWMN-funded work.

In 2021, the OWRB performed a 20-year aquifer study update of the High Plains, which included a large water level synoptic measurement (~430 wells) instead of its annual measurement (196 wells). This involved extensive outreach to landowners, irrigators, and other stakeholders to identify temporary wells for the study and new wells for incorporation into the water level network as discrete or continuous sites. Initially, forty-two sites were identified (including 8 wells new to the network) that could serve as new continuous sites, and additional wells have since been found.

Through this FY21 NGWMN grant, 18 sites have been outfitted with continuous water level recorders and telemetry equipment. With additional state-funded work, all these sites have been fully surveyed, undergone camera inspections, and completed slug tests before inclusion in the network. The same work will be done with any other continuous data wells added to the OWRB network or NGWMN in the future.

Over the next few years, OWRB plans to evaluate coverage in each major aquifer and add continuous sites as needed, working with local stakeholders to improve long-term participation in our programs. The current coverage of the water level networks is shown in Figure 2, which includes all OWRB wells and those already included in the NGWMN.

Network Descriptions - Water Quality

As part of GMAP, a statewide ambient water quality monitoring network was added in 2013 with a well-density goal of one quality site per 100-150 km^2, depending on the spatial extent of the aquifer. This expansion occurred during a baseline assessment period (2013-2018) where each aquifer was characterized. These baseline evaluations were completed for the Ada-Vamoosa (2014), the Arbuckle Simpson (2015), Central Oklahoma (2014), the southern non-Panhandle portion of the High Plains (2013), the Rush Springs (2013), the Trinity (2015), the High Plains Ogallala-Panhandle Region (2016), the Ozarks Plateaus (2017), and the Blaine (2019) aquifers.

In the spring of 2019, OWRB began implementing a trend water quality network composed of around 300 wells, approximately 190 of which were located within Principal Aquifers. Many of these wells originated from the baseline network. The GMAP sampling frequency was set at once every three years except for the High Plains aquifer, which was to be sampled once every five years, and the Arbuckle-Simpson aquifer, which was to be sampled annually. Each of the larger bedrock aquifers was split, with half of the wells for each aquifer being sampled one year and the remaining half the following year. All major alluvial and terrace aquifers were also to be sampled annually. This network design led to a variation in the exact number of wells sampled each year in the rotation, but it usually involved 190-260 wells.

During early 2020, when sampling was temporarily put on hold due to COVID-19, the water quality networks were reassessed. It was determined that, along with maintaining the ongoing water level networks, the existing schedule was not feasible in the long term. The limited temporal density of data and the practice of splitting each bedrock aquifer over two different years, with no way to determine if changes occurred between sites or years, would also preclude the development of water quality trends.

The network is currently being redesigned with both surveillance and trend components in a similar fashion to the NGWMN. The surveillance component resembles the original trend design but with a lower monitoring frequency, which is still being determined but is likely to be every 4-10 years. This component will provide a conditional assessment and guide the trend network in spatial and parametric coverage. Wherever possible, sites already in existing networks will be maintained. The trend component is under development and will involve a much smaller number of sites (using continuous water level sites wherever possible) with aquifer-specific parametric coverage.

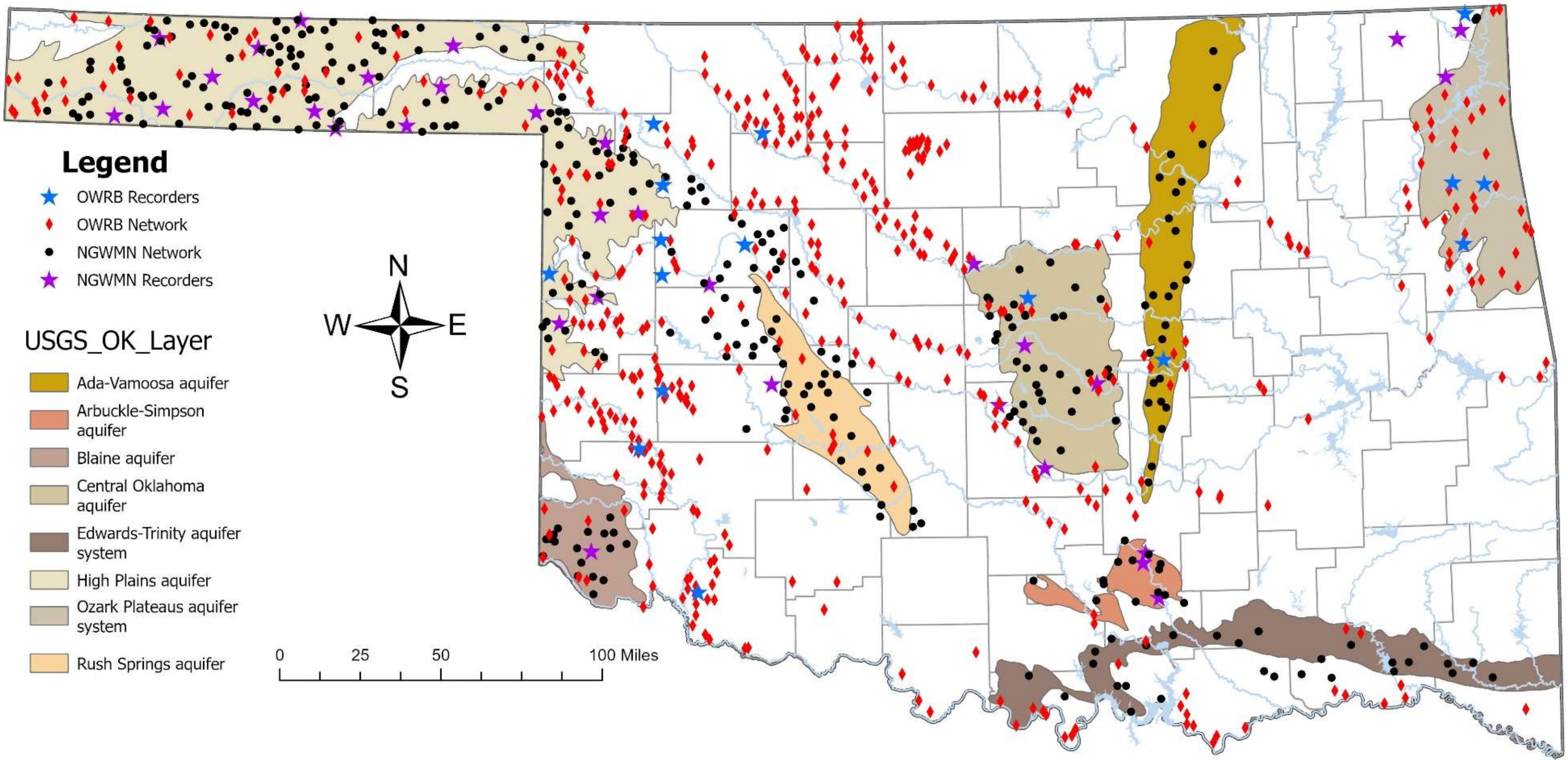

Figure 2: Map of Oklahoma showing principal aquifers and all water level wells currently in the OWRB networks including alluvial ad terrace systems. The alluvial and terrace aquifers boundaries are not shown. Purple and blue stars indicate continuous water level sites in the NGWMN and OWRB networks respectively. Black circles and red diamonds indicate sites in the NGWMN and OWRB discrete water level networks respectively.

History & Status of Data Flows

The OWRB has been an NGWMN data provider since 2016, with six grants to date. These are summarized below and in Table 1. Additional details can be found in relevant project final reports available upon request from OWRB or the NGWMN.

OWRB became a data provider to the NGWMN in January 2016 with a one-year grant to provide data from the continuous water level network. Through a Round II grant (2017-2018), the OWRB established a connection with the USGS data portal via web services, with continuous recorder water-level data housed and managed in Aquatic Informatics' Aquarius Time-Series software (Aquarius) and lithologic and well construction data housed in the OWRB's Oracle Well Drillers database.

Table 1: Summary of Oklahoma's NGWMN Grants

Year	Main Goals	Status
2016	New Data Provider to provide data from the continuous water level network	Completed
2017-2018	Add sites to the NGWMN and create web services to connect continuous water level, construction, and lithology data from Aquarius and the Oklahoma Well Drillers Database.	Completed
2018-2019	Perform slug tests to ensure sites are properly connected to their aquifers and conduct camera surveys to fill well-construction data gaps. Expand and improve the AWQMS database to facilitate groundwater data management and create web services for discrete water levels, water quality, construction, and lithology data.	Completed
2019-2020	Add 93 water level sites (55 in the High Plains) and 22 water quality sites (10 in the High Plains). Perform slug tests on 20 High Plains sites to ensure wells are properly connected to their aquifers and 9 camera surveys to fill well construction data gaps.	Completed
2020-2021	Perform quality control and add new discrete water level and water quality sites to the well registry. Conduct slug tests to ensure sites are properly connected to their aquifers and perform camera surveys to fill well-construction data gaps. Drill three new wells to fill network gaps in the Rush Springs aquifer.	Completed
2021	This project seeks to fill critical gaps in the Trend Water Level Network in the Oklahoma portion of the High Plains aquifer by adding 19 new continuous water level sites.	Completed – This Project
2022	No grant.	N/A

In 2018 OWRB received a third grant, which initiated our use of camera surveys and aquifer tests to fill data gaps and ensure sites were properly connected to their aquifers. This grant also allowed for a significant expansion of our capabilities as a data provider, including curating web services to begin providing discrete water levels and water quality data to the network. Discrete water-level and water quality data were housed in the Ambient Water Quality Monitoring System (AWQMS), which was utilized by at least seven other states and roughly seventy tribes. AWQMS enforced WQX schema and data requirements that sufficiently met the minimum data requirements of the NGWMN for water level and water quality data.

However, the scope of construction and lithology information that AWQMS could store required expansion, and web services needed to be developed/improved to provide these data to the network. Additionally, although the database could store groundwater data, it was missing domains and domain values that made it feasible to manage groundwater data at the programmatic level, including information such as local and national aquifer designations and landowner information. These issues left users requiring additional databases and spreadsheets to operate programs.

Through the 2018 project, AWQMS underwent significant development to improve its ability to manage groundwater-related data. Development goals included creating or expanding numerous monitoring location (well/spring) data domains to provide storage for construction, lithology, and general informational data. Specific examples include new tables for screen information (depths, materials, sizes, etc.) and lithology (depths, material, descriptions, and observation method). These tables are accessible from each Monitoring Location page in the system and, to maintain system functioning, have been integrated with all data import and export tools.

The goals also included developing web services for water level, water quality, construction, and lithology data so that these can flow to the NGWMN. The USGS staff completed a crosswalk of web service domains in early December 2020. The improvements were released with versions 8.0 and 9.0 of AWQMS in 2021 and 2022, respectively. The initial release was to all states, tribes, and other users utilizing the cloud-based version of AWQMS. Shortly after, a second release was made available to all states maintaining individual state-hosted versions of AWQMS. In April 2020, OWRB successfully migrated its data to the cloud version of AWQMS and was thus part of the initial release in 2021. This migration was mainly done to eliminate our reliance on state information technology services, which had previously caused large delays and poor resolution of problems with data flows to the NGWMN and database maintenance in general.

An additional benefit of working with Gold Systems (the developers of AWQMS and contractors with the EPA for WQX development) is that we were able to advise on other groundwater-related development of AWQMS as it was being performed through other projects. This included work done by other states and tribes and some funds from an OWRB-managed Exchange Network grant. As a result, we were able to make general improvements to groundwater data management within AWQMS. These improvements included integrating various domains into query tools, such as screen intervals, well depths, and, well formation types, all of which are now searchable within AWQMS. Other metadata, such as landowner information, were also included in this process.

Hopefully, these improvements will make AWQMS an all-around better tool for groundwater data management, potentially increasing its utilization in this capacity with more states and tribes gaining access to this off-the-shelf mechanism of flowing data to the NGWMN.

With the releases of AWQMS 8 and 9, all OWRB sites in the NGWMN Well Registry were made visible, and discrete water quality and water level data began flowing to the network. AWQMS now serves to provide all lithologic and construction information for all water level and water quality sites in Oklahoma's network. These services are also available to all other states, tribes, and data networks that utilize AWQMS at no additional cost beyond their regular AWQMS maintenance fees.

Work continues to further improve AWQMS concerning groundwater data management through the review of the system and requests for improvements to Gold Systems, which tie the work into other projects as they are able. Additional domain values for the new groundwater-related domains can be freely added at the request of OWRB or any other users since the full expanse of these could not be determined by any one program during development. For instance, construction materials and lithology types may need to be expanded as the system comes into use in different areas or as new technologies are developed. Also, although the current list of local aquifers is extensive for each state, they may need further additions from relevant state and tribal users. OWRB was recently awarded a new Exchange Network grant where one of the goals is to include the water level measurement point height as its domain and to allow that data to be published via API, significantly improving AWQMS as a tool for maintaining a groundwater program and utilizing the stored data in data collection apps such as Esri Survey123. This work has not yet been started but is expected to be completed early in 2025.

The 2019 grant prioritized work in the High Plains aquifer, but also involved work across the state. Specifically, new wells were added to both the water level (93 wells) and water quality (22 wells) networks; camera surveys were performed to fill gaps in construction details, and slug tests were performed to ensure wells were connected to their aquifers and determine hydraulic conductivities.

The 2020 grant prioritized adding new wells to the NGWMN, filling in metadata gaps, ensuring well-aquifer connectivity in various aquifers, and drilling a small number of wells in the Rush Springs aquifer, which has suffered from poor coverage in its central and northwestern sections.

The 2021 grant (discussed more fully in later sections), describes the work done to expand the continuous water level trend network in the High Plains aquifer, including purchasing and installing water level and telemetry equipment at 19 sites.

All grants are completed with this report closing out the FY21 grants.

Project Summary

The scope of work for this round of potential funding was limited to Objective 2, Part A (Support persistent data services from existing data providers), and Objective 6 (Purchase equipment to support continuous water-level data collection). Work includes maintaining Oklahoma's current contribution to the NGWMN under Objective 2, Part A, including site and metadata updates, and maintenance of web services for our continuous water level data.

Through Objective 6, we sought to close the coverage gap in both Oklahoma's and the NGWMN Water Level networks by converting 19 High Plains aquifer Surveillance sites to Trend sites throughout Oklahoma's portion of the aquifer. Federal funds were for the water level measurement equipment costs with related costs, installs, telemetry equipment, and annual water level measurements at High Plains sites being used as in-kind match.

Objectives and Tasks:

Objective 2: Support persistent data services from existing data providers

> **Task I-III:** Maintain data services and data

Objective 6: Purchase equipment to support continuous water-level data collection

> **Task I-III:** Purchase & install continuous water level equipment
>
> **Task IV-V:** Measurement of water levels in the High Plains aquifer
>
> **Task VI:** Final report

Project Objectives

Objective 2: Support persistent data services from existing data providers

Under Part A of Objective 2, all of Oklahoma's wells already in the NGWMN were reviewed, with updates made to well construction and lithology data as needed. Maintenance of the web services for continuous data consisted of paying for one year of a license for Aquarius Time-Series software, which has been dedicated to web services for the NGWMN. Although no in-kind match was required for this objective, we included one additional Aquarius license as an in-kind match. This license was used exclusively for editing and QA'ing data provided to the network. All additional licenses for this software, which were also used for data processing and management, were paid for through state resources. Discrete data web services were maintained as part of OWRB's routine use of the AWQMS database since the web services do not consume a license.

Additional maintenance work (already reported in the 2019 and 2020 final reports) was performed during this period to ensure ongoing connectivity of the continuous data to the NGWMN. This included code fixes to the web services to remedy an issue where hourly water level values were reported instead of daily mean values.

Objective 6: Purchase equipment to support continuous water-level data collection

Work for this objective focused on converting existing water level surveillance sites into continuous recorder trend sites. OWRB performed a large synoptic water level measurement of the aquifer in early 2021 with 409 wells visited and 295 individual water levels collected. During that study, we reviewed each well for suitability to become a recorder well based on various criteria including construction, well use, and access. Photos and GPS data were collected at every site. OWRB identified 42 unused wells (predominantly water supply wells originally serving oil and gas operations) distributed across the aquifer that were suitable for the installation of continuous water level sensors. Thirty-four sites were already part of the annual or seasonal surveillance network and eight more were added to the network to begin collecting water level data.

The goal of the project was to install Insitu brand Level Troll 500 water level sensors and cables at 19 wells using federal funds. As part of the cost share, Insitu brand Vusitu cellular telemetry systems were to be installed at the 19 new trend wells and one existing water level trend well.

During the 2021 seasonal water level surveillance measurements, OWRB staff revisited many wells not originally shortlisted and identified another 35 potential recorder sites. Of the original 42 potential wells, 14 were chosen as priority sites with another 5 sites being added from the additional potential sites.

OWRB originally planned for this to be a one-year project given its straightforward nature. Unfortunately, there were delays with purchasing on the state administrative side with ongoing discussions between agency and central purchasing as to whether the water level equipment consisted of information technology equipment that would require separate approvals and a different purchasing route. This occurred near the completion of the original open bid process and seriously delayed purchasing.

OWRB had made a similar purchase using state funds in early 2022 and had equipment that could be redirected for installation at 18 of the sites. The purchase of telemetry equipment had gone relatively smoothly, and that equipment was also available for installation.

Initially, it was not intended to slug test and camera survey all these wells. However, given the history of issues with poor construction information and poor connectivity in some trend wells, this was reconsidered. It was decided to survey and test every potential trend well before installing a continuous recorder. Some of the 2021 project wells had already been tested during the 2019 project or were due to be tested as part of this 2020 project. Camera surveys and slug tests were performed at 15 additional wells, all of which have been reported on in the 2020 grant. For ease of reference, the results of these surveys are also included in this report (Table 2).

Nineteen sites were finally chosen with some additional sites being rejected due to obstructions or poor camera surveys. Eighteen sites were then installed with existing equipment including water level sensors, telemetry, and locking well caps. When the water level equipment purchase was finalized the last well was installed and existing sensors were swapped for newer models.

Despite the intent to analyze slug test data before installation, a decision was made in the field to install several sites during testing to ease the travel burden. One of these wells, well 2066, was later found to be poorly connected to the aquifer, with indications of possible blockages on the screen openings. This well could be a candidate for remedial work/cleaning in the future if other more suitable wells become unavailable but has been discontinued for now. With the loss of well 2066, OWRB is evaluating replacements from the possible backup sites.

Another four wells (3270, 23628, 120969, and 143209) had good camera surveys and completed field components of the slug tests. Unfortunately, hydraulic conductivities could not be estimated due to data loss before the final analysis. However, preliminary inspection of the data and historic water levels indicated good connections with the aquifer. Each of these sites currently has telemetered water level recorders installed and is part of the trend water level network. Wells 120969 and 143209 are also water quality surveillance sites and are likely to become water quality trend sites. Each of these wells will undergo re-slug testing during a future maintenance trip.

The rest of the camera surveys and slug tests results are summarized in Table 2 with additional details in the FY20 project report. All construction data has been updated to AWQMS and is available to the NGWMN through web services. The estimated hydraulic conductivities for all High Plains wells were 3.9-323 ft day^{-1} (Table 2). Continuing efforts, previously reported in the 2019 and 2020 final reports, aimed at enhancing OWRB's expertise in aquifer testing and confidence in these results, will involve revisiting and reanalyzing 25% of all these wells over the next two years. Utilizing state funds, OWRB has also contracted the local USGS office to perform technical work and modeling of the Oklahoma portion of the High Plains aquifer. As part of that work, the USGS has performed additional slug tests and nuclear magnetic resonance testing (NMR) at 7 and 6 sites respectively (Table 2). These data are not yet available but will be reported on and compared to OWRB data when available.

The final distribution of trend water level sites and backup sites can be seen in Figures 3 and 4. Details of the backup sites can be found in the Appendix in Table A1.

With the completion of this work, OWRB has almost met the minimum recommended density of 20 wells for the Oklahoma portion of the High Plains based on area extent. However, given the rapid but very variable declines in water levels, and increasing climatic and land use stressors we will continue to evaluate backup sites and, where possible, add additional trend sites to the network. With increasing tensions between stakeholders over water availability and water rights, OWRB also hopes to increase the resiliency of the network to potential attrition due to loss of landowner permissions.

As part of the cost share for this project, OWRB proposed to monitor water levels in the High Plains during the annual and two seasonal surveillance measurements in 2022. These measurements occurred, and the data is available to the NGWMN through web services. However, it should be noted that OWRB has now discontinued seasonal water level measurements with efforts being focused on the annual surveillance network and the expanding continuous trend network. The water level surveillance sites can be seen in Figure 4 but no distinction is made between annual and seasonal sites since they are all now annual.

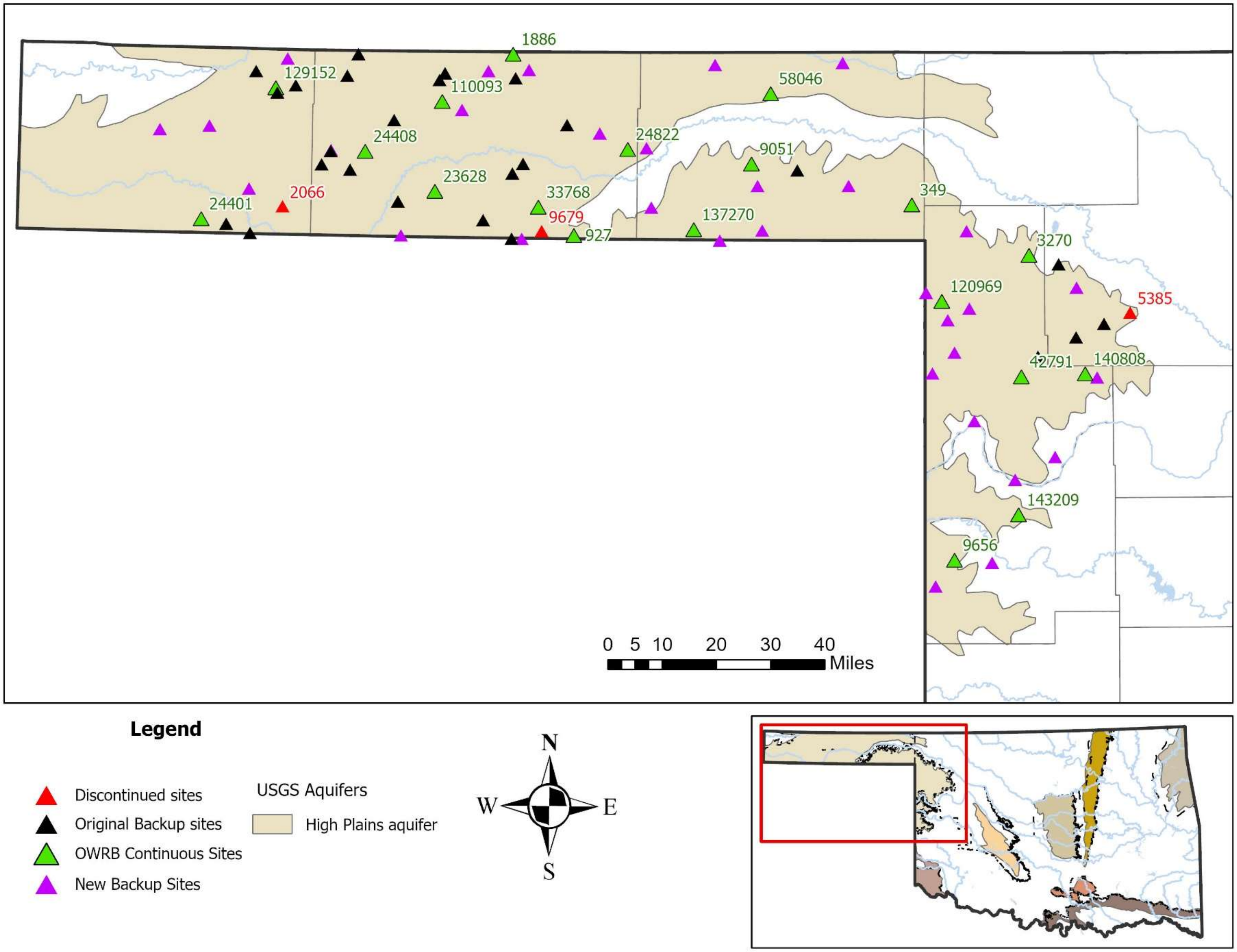

Figure 3: Map showing 19 OWRB continuous recorder sites (green triangle) and 3 sites that were discontinued for various reasons (red triangles). 25 wells are remaining from the original proposed backup sites (black triangles) and 30 additional backup sites have since been found (purple triangles). Further details of the backup water level trend sites can be found in the Appendix, Table A1.

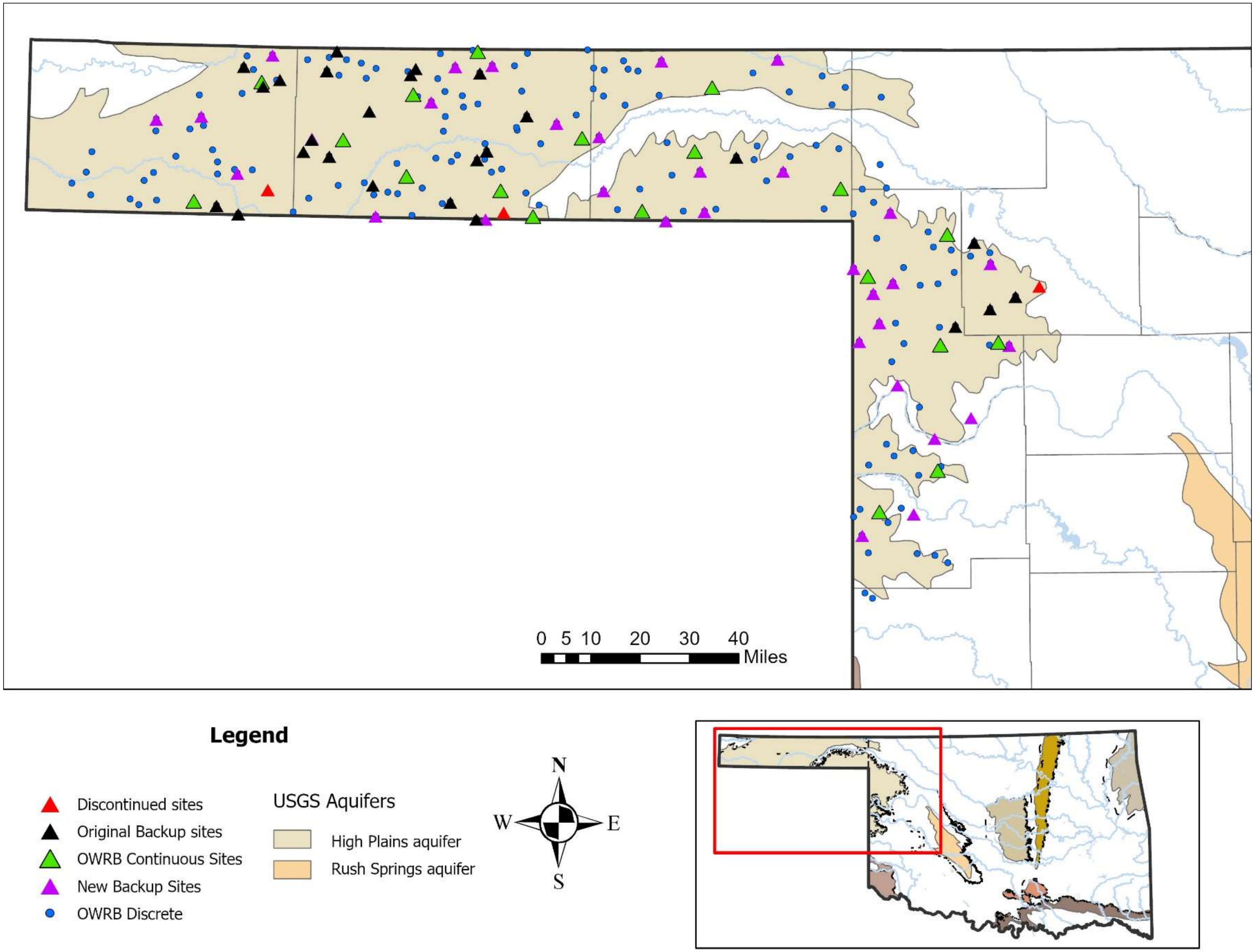

Figure 4: Map showing the same area and wells as Figure 3 but including 196 NGWMN High Plains water level surveillance wells. For reference: 19 OWRB continuous recorder sites (green triangle), 3 discontinued wells (red triangles), 25 wells remaining from the originally proposed backup sites (black triangles), and 30 additional backup sites that have since been found (purple triangles).

Table 2: Locations, well depths, networks, slug test, and camera survey results of water level trend wells from the High Plains aquifer. Work completed is either "Slug" for just slug tests, "Camera" for just a camera survey, or "Both" for both camera surveys and slug tests. Estimated hydraulic conductivities (K) are given where available. Wells having additional slug test and NMR work completed by the USGS are marked "X" in the final two columns. All wells listed as "Surveillance" under the water quality network are also potential trend water quality sites.

Site ID	Well Name	Latitude	Longitude	Principal Aquifer	Well Depth (ft)	WL Network	WL Surveillance Start	WL Trend Start	WQ Network	Work Completed	Test Date	K-Value Range (ft/day)	USGS Slug	NMR
9656	Reydon	35.64928252	-99.90401956	High Plains	80	Trend	01/05/2015			Both		221.3		
58046	Forgan	36.89332094	-100.51297804	High Plains	160	Trend	05/23/2016		Surveillance	Both		38.22		X
927	Schultz WMA	36.51111749	-101.1616275	High Plains	240	Trend	09/21/2016			Both		5.5	X	X
129152	Keyes	36.89319123	-102.15650206	High Plains	320	Trend	06/07/2016			Both		16.7		
33768	Hardesty	36.58564342	-101.28034778	High Plains	280	Trend	01/05/2015		Surveillance	Both		1.1	X	
24822	Adams	36.74199281	-100.985944	High Plains	260	Trend	8/15/2016	9/14/2022		Both	8/2/2022	18.49-23.77		
140808	Harmon	36.14596487	-99.4732699	High Plains	200	Trend	1/11/2012	11/21/2013		Both	8/25/2021	2.7-3.0		
349	Slapout	36.59763799	-100.0443163	High Plains	260	Trend	1/5/2015	11/28/2022		Both	8/2/2022	44.34-63.17		
1886	Straight	36.99251545	-101.3697063	High Plains	300	Trend	5/24/2016	9/27/2022		Both	7/26/2022	3.922-14.42		
3270	Fargo	36.46273715	-99.65699054	High Plains	258	Trend	1/12/2015	11/28/2022		Both	Revisit			X
9051	Elmwood	36.705586	-100.575557	High Plains	180	Trend	3/29/2021	1/19/2023		Both	8/30/2022	5.342-10.17	X	X
23628	Goodwell	36.62430676	-101.6233784	High Plains	370	Trend	1/7/2015	8/22/2023		Both	Reanalyze			
24401	Conrad	36.53984808	-102.3947428	High Plains	140	Trend	8/10/2016	9/13/2022		Both	7/19/2022	37.66-47.86		X
24408	Eva	36.72797578	-101.8561648	High Plains	140	Trend	6/28/2016	8/29/2022		Both	8/2/2022	114.8-323		X
42791	Arnett	36.13864343	-99.68332698	High Plains	280	Trend	1/7/2015	9/12/2022	Surveillance	Both	8/31/2022	30.16-45.78	X	
110093	Hough	36.86401465	-101.6031569	High Plains	380	Trend	3/30/2016	8/30/2022	Surveillance	Both	8/2/2022	44.34-63.17		
120969	Shattuck	36.34029831	-99.94521124	High Plains	235	Trend	1/12/2015	7/25/2023	Surveillance	Both	Reanalyze		X	
137270	Gray	36.52954748	-100.7653787	High Plains	420	Trend	3/9/2016	11/29/2022	Surveillance	Both	8/30/2022	21.15-25.58	X	
143209	Roll	35.77029349	-99.6937825	High Plains	200	Trend	7/31/2013	11/28/2022	Surveillance	Both	Revisit			
2066	Griggs	36.57737621	-102.1266013	High Plains	395	Discontinued	6/14/2016			Both	7/19/2022			
5385	X5385	36.30844249	-99.32381965	High Plains	70	Discontinued	1/31/1980			Camera	8/31/2022			

Additional Information & Problems Encountered

As previously reported in the Final Report for the 2018 and 2019 grants there have been significant changes in OWRB project and administrative staff during this project. Numerous positions have been filled and refilled since this project began in 2021 resulting in staff shortages for extended periods. However, OWRB is currently fully staffed with excellent field and data management capabilities. The current structure of the group can be seen in the Appendix in Figure A1.

This project was not as directly impacted by the COVID-19 pandemic as other recent projects, but a significant period of work was still impacted by the COVID-19 pandemic with reductions in fieldwork capacity through 2020 and 2021. These included periods of complete shutdown during the early part of 2020 while OWRB developed procedures to allow field work to take place with reasonable precautions. Once field work could resume, staffing shortages were encountered when staff became infected or exposed with several periods where all field staff were quarantined. Although this project was not as directly impacted as earlier projects, those earlier delays pushed all projects back.

At various times, there have been supply chain issues that impacted this project, resulting in delayed delivery of water level sensors and increased costs.

One final issue that occurred after the end of this project was a total of 16 telemetered sites across the entire network experiencing connectivity issues on 01/01/2024 (New Year's Day). The cause was identified as a processing error related to 2024 being a leap year. Each unit had to be updated on site and the un-telemetered data retrieved from the data loggers. Once updated, all units reported as scheduled and there have been no more reporting issues.

Summary & Future

The Oklahoma networks have been changing over recent years but also becoming more in line with the design of the NGWMN itself. The number of continuous water level data sites has been expanded, particularly through this project in the High Plains aquifer with additional state-funded expansions planned during 2024 and 2025. Additional wells will be sought in the High Plains to future proof the network against increasing tensions between stakeholders and risks to landowner-approved access. An emphasis has been placed on data quality with an improved review of all data and a detailed upfront investigation of all sites before they are added to the networks. Fifty percent of all continuous data is now being telemetered leaving more time for review and analysis. The remaining sites are planned to move to telemetry during the summer and fall of 2024.

Many staffing changes have occurred at OWRB over the last five years and, although this has provided many challenges, we are hopeful that it can provide new opportunities as well. Specifically, we are working closely with other Oklahoma institutions to coordinate groundwater and surface water data flows, stakeholder engagement, collaborate on technical work, and make our data as available as possible. We are seeking partnerships and input into our water quality network as we redesign to become both a conditional and trend program.

OWRB has no current NGWMN grants but we plan to seek additional funding to help maintain and improve the network as needed. An emphasis will likely be placed on maintaining and improving the current network which is vulnerable to attrition from loss of landowner access and wells being poorly maintained and/or losing connection to their aquifers.

Appendix

Table A1: Well IDs, names, locations, networks and water level surveillance start dates for 55 backup High Plains water level trend sites

Site ID	Well Name	Latitude	Longitude	Principal Aquifer	Well Depth (ft)	WL Network	WL Surveillance Start	WQ Network
45	MM45	36.5004093	-100.6790807	High Plains	328	Surveillance	1/12/1977	
76	OGLLP-045	36.52782658	-100.5390646	High Plains	340	Surveillance	3/30/2016	Surveillance
356	MM356	36.74571279	-100.9238588	High Plains	240	Surveillance	1/22/1991	
428	MM428	36.68856822	-100.4236176	High Plains	100	Surveillance	1/24/1991	
727	OGLLP-042	36.96878675	-100.6983459	High Plains	340	Surveillance	5/23/2016	Surveillance
873	MM873	36.54878368	-101.462553	High Plains	358	Surveillance	3/11/2021	
1102	1102	36.67440501	-101.367425	High Plains	410	Surveillance	3/30/2021	
1172	DAKD-150	36.72709169	-101.9703641	High Plains	340	Surveillance	5/24/2016	Surveillance
1316	MM1316	36.84211196	-101.5372298	High Plains	363	Surveillance	3/2/1966	
1488	MM1488	36.92866807	-101.9195822	High Plains	355	Surveillance	3/10/2021	
1638	MM1638	36.92840176	-101.3606227	High Plains	615	Surveillance	2/23/2000	
1866	1866	36.9393495	-101.5952072	High Plains	460	Surveillance	3/30/2021	
2063	2063	36.50431684	-102.2323957	High Plains	280	Surveillance	1/11/2017	
2137	MM2137	36.62297996	-102.2384288	High Plains	325	Surveillance	1/25/1967	
2325	MM2325	36.78844413	-102.3740446	High Plains	198	Surveillance	1/25/1967	
2644	2644	35.57902713	-99.96649179	High Plains	205	Surveillance	3/27/1980	
2923	MM2923	36.02039712	-99.83832841	High Plains	91	Surveillance	2/6/1980	
3257	3257	36.3624803	-99.99704004	High Plains	383	Surveillance	3/25/1980	
4256	OGLLP-001	36.64726506	-100.2530721	High Plains	120	Surveillance	5/23/2016	Surveillance
5554	OGLA-033	36.43836937	-99.55929811	High Plains	60	Surveillance	6/12/2013	Surveillance
9192	MM9192	36.52771081	-102.3119044	High Plains	221	Surveillance	1/15/1968	
9242	MM9242	36.77625651	-102.5379841	High Plains	280	Surveillance	1/24/1967	
9314	MM9314	36.14780782	-99.97615322	High Plains	290	Surveillance	2/5/1981	
9322	MM9322	36.19198363	-99.62872482	High Plains	UNK.	Surveillance	1/29/1980	
9386	MM9386	36.50043385	-101.3676176	High Plains	UNK.	Surveillance	1/11/1977	
9399	MM9399	36.52716643	-99.86329121	High Plains	260	Surveillance	3/25/1980	
9726	MM9726	36.70059205	-101.3325439	High Plains	148	Surveillance	2/24/1966	
9736	MM9736	36.78358513	-101.0793306	High Plains	355	Surveillance	3/2/1966	
9786	9786	36.94650811	-101.4509407	High Plains	412	Surveillance	4/23/1980	
9869	MM9869	36.24303251	-99.50277893	High Plains	295	Surveillance	2/5/1980	
9883	MM9883	36.37577885	-99.50039291	High Plains	340	Surveillance	1/11/1983	
24814	MM24814	36.95079599	-101.316197	High Plains	280	Surveillance	1/23/1991	
24817	MM24817	36.50529304	-101.7334098	High Plains	306	Surveillance	1/22/1991	
24819	MM24819	36.67816582	-101.9052045	High Plains	194	Surveillance	1/21/1991	
30176	MM30176	36.97565295	-100.2742507	High Plains	140	Surveillance	2/9/1998	
31544	MM31544	36.92088256	-101.6131837	High Plains	410	Surveillance	3/30/2021	
38534	38534	36.93653658	-102.2227535	High Plains	400	Surveillance	6/21/2016	
42864	OGLA-077	36.27883761	-99.41037292	High Plains	240	Surveillance	7/10/2013	Surveillance
58052	DAKD-154	36.59545735	-101.7452723	High Plains	360	Surveillance	6/8/2016	Surveillance
73021	OGLA-085	36.13580531	-99.43376958	High Plains	220	Surveillance	6/25/2013	Surveillance
74705	MM74705	36.97164	-102.118679	High Plains	336	Surveillance	1/15/2008	
87392	DAKD-149	36.81242636	-101.7619417	High Plains	400	Surveillance	6/15/2016	Surveillance

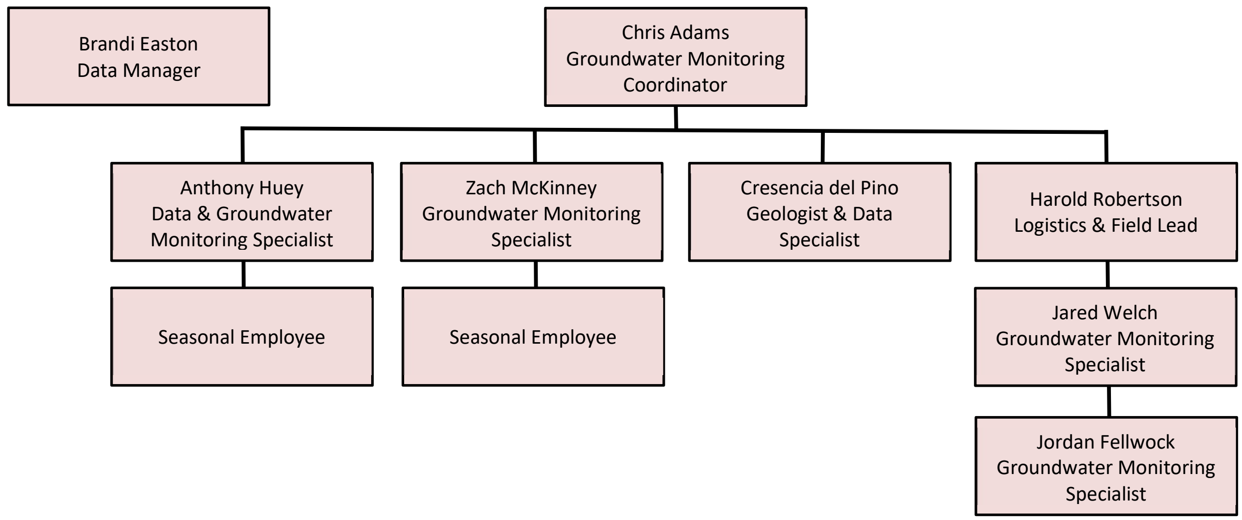

Figure A1: Organizational structure and roles of OWRB Groundwater Monitoring staff 2023-2024