FINAL TECHNICAL REPORT

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Oklahoma Water Resources Board

The Oklahoma Water Resources Board providing Oklahoma Data to the USGS National Groundwater Monitoring Network. High Plains 2019 Funding Opportunity: Final Report"

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Background

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

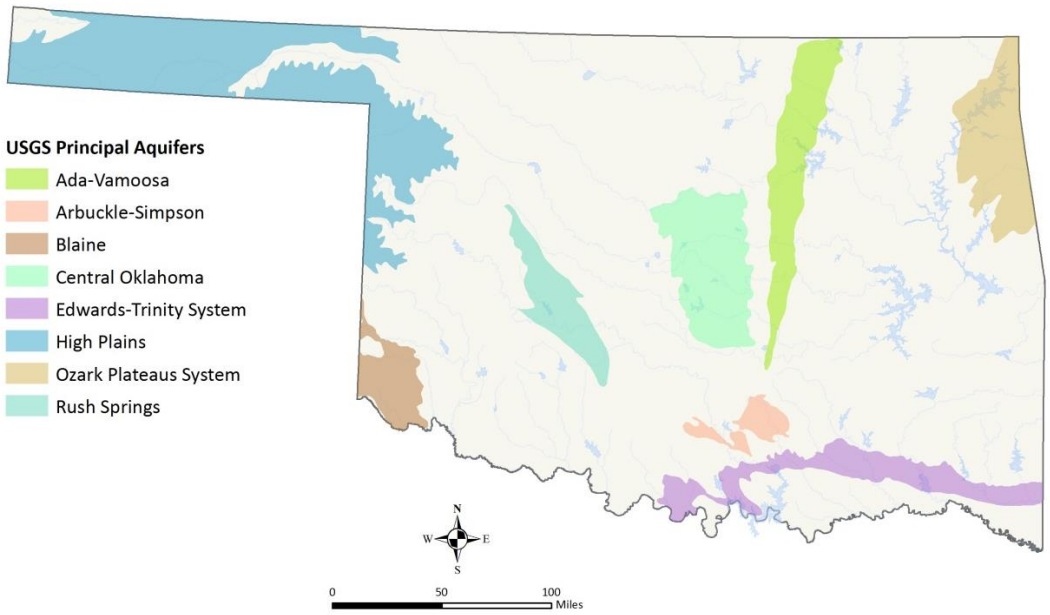

Figure 1: Principal Aquifer boundaries within Oklahoma.

In 2013, OWRB established the Groundwater Monitoring and Assessment Program (GMAP) with the aim of fully quantifying the states groundwater resources, characterizing the ambient water quality, expanding the water level network, and aiming to determine quality and quantity trends and conditions.

It is the GMAP program that acts as Oklahoma's primary contributor to the National Groundwater Monitoring Network program (NGWMN). Descriptions of Oklahoma's networks and how they have evolved over their recent history, interactions with and implications for, the NGWMN are given in the following sections ('Network Descriptions – Water Levels', 'Network Descriptions – Water Quality'). A summary of the relevant grants and history as a data provider is given in the 'History & Status of Data Flows' section. For completeness and to provide and an accurate picture of OWRB's programs both the network and grants sections will include work that has been undertaken since the 2019 project was completed. Work directly 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 size of about 842 sites with 197 in the

High Plains aquifer. A smaller seasonal (triannual) discrete water level sub-network of about 251 sites with 40 in the High Plains aquifer was implemented to recognize seasonality as well as changes due to climatic and water use drivers.

The combined annual and seasonal networks meet the minimum spatial and temporal density recommendations of the NGWMN for a surveillance network in most aquifers but still suffers from data gaps in more spatially variable aquifers such as the Arbuckle-Simpson aquifer (karst, high use aquifer) or in aquifers where landowner allowed access has been limited (e.g. Ada-Vamoosa and Arbuckle-Simpson 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. Also, areas with higher spatial variability such as the High Plains within Texas County, OK, have always been sampled at the same density as less variable areas.

The seasonal water level network did not meet the frequency recommendations of the NGWMN for a trend network of at least quarterly measurement and needed to be improved. This was especially true in aquifers such the High Plains aquifer with such intense and variable usage and the Arbuckle Simpson, where the seasonal sampling is not representative of the large variations inherent in a karst aquifer with heavy usage. Year to year differences on the timing and extent of rainfall, recharge and peak water use demands, have the potential to severely bias measurements made only 3 times per year and miss the impacts of seasonal drawdowns.

To meet the temporal requirements of a trend network, the state's existing continuous recorder network was expanded in 2014 across the state's major aquifers including all the Principal Aquifers (20 sites). These were all equipped with hourly recording data loggers with data mostly transferred through manual download. Despite this expansion, the continuous network did not currently meet the density goals of a trend network for the NGWMN or Oklahoma. For example, at the time this project began (2019), the Oklahoma portion of the High Plains aquifer only had 5 continuous sites (including a USGS site) which gave a spatial density of roughly 0.6 wells per 1,000 mi^2, below the minimum spatial requirements. The specific NGWMN density guidance for the Oklahoma portion of the High Plains is a minimum of 20 wells with some heavily developed areas likely requiring a higher density.

In 2020 (during the 2018 project), it was further discovered that three of these wells, which were old 2" steel USGS monitoring wells, had degraded to the point they were no longer communicating properly with the aquifer and have 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) and so that part of Oklahoma no longer had a water level trend network that met both the spatial and temporal requirements of the NGWMN. This was a critical data gap both in Oklahoma and regionally for the NGWMN where the High Plains was otherwise better represented by other NGWMN partners.

However, this data gap was not easily filled and initially existed due to some of the major weaknesses of the historical OWRB water level networks which have always hindered inclusion of wells in long-term trend networks. These included:

- An almost exclusive reliance upon private wells 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.

In 2021, OWRB performed a 20-year aquifer study update of the High Plains which included a large water level synoptic measurement (~430 wells) in place of its annual measurement (196 wells). This involved a large outreach effort with landowners, irrigators, and other stakeholders to both find temporary wells for the study and new wells for incorporation into the water level network as either discrete or continuous sites. Forty-two sites were initially identified (including 8 wells new to the network) which could serve as new continuous sites and additional wells have since been found. Through a NGWMN grant, 19 of these sites have been outfitted with continuous water level recorders and telemetry equipment. Through additional state funded work, all these sites have been fully surveyed, undergone camera inspections and slug tests prior to 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.

The work in the High Plains is the first part of a new expansion of the water level trend network with a more systematic approach to both how wells are included in the network, with upfront aquifer testing, and a much wider effort at stakeholder engagement. Over the next few years OWRB plan 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 can be seen in Figure 2 which shows 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 where the well density goal was one quality site per 100-150 km^2 depending on the spatial extent of the aquifer. This expansion occurred throughout a baseline assessment period (2013-2018) where each aquifer was characterized in turn. These baseline evaluations were completed for the Ada-Vamoosa (2014), the Arbuckle Simpson (2015), the 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 spring 2019 OWRB began implementing a trend water quality network composed of around 300 wells, of which approximately 190 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 would be split, with half of the wells for each aquifer being sampled one year and the remaining half of that aquifer 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 would usually be 190-260 wells.

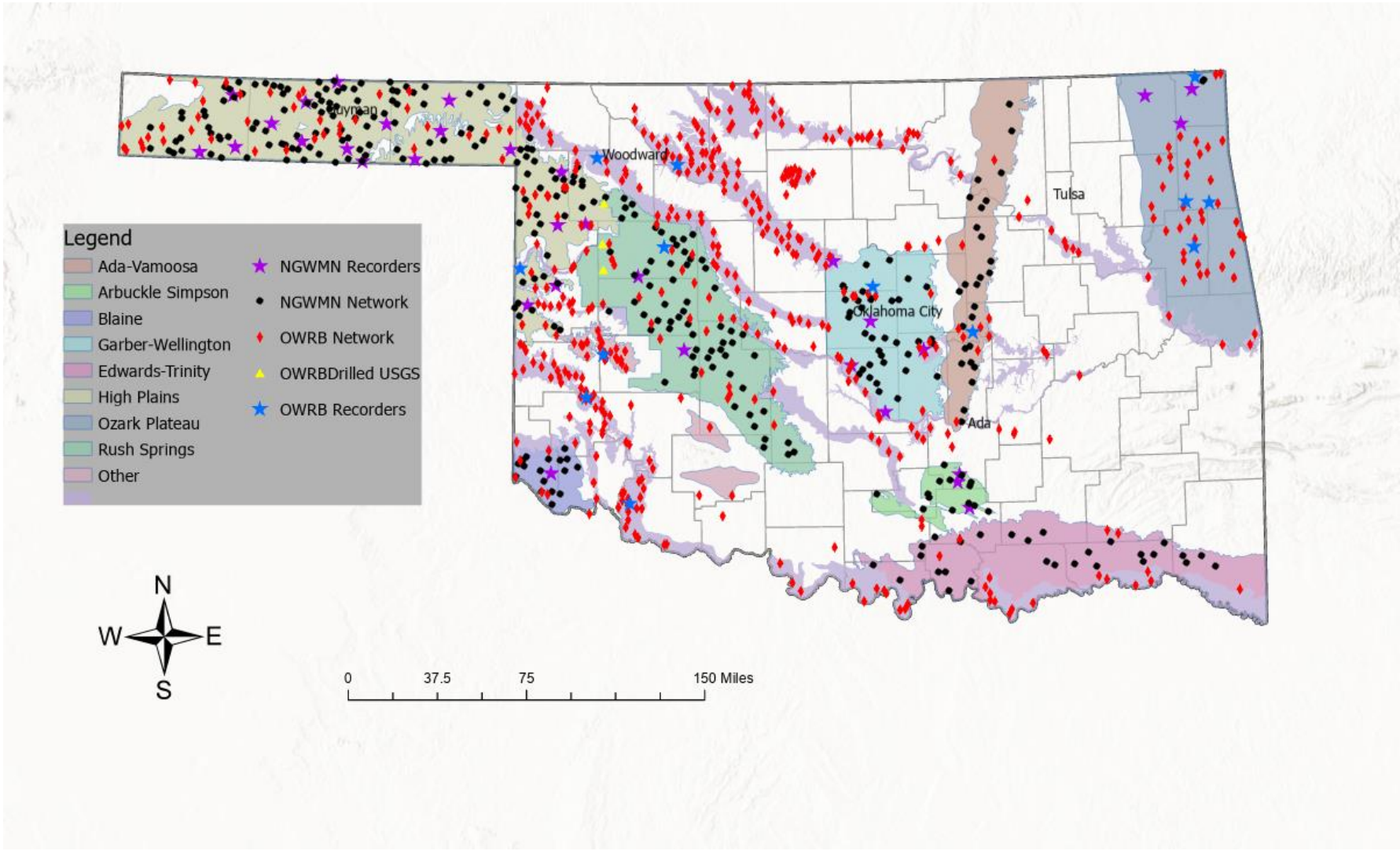

Figure 2 Map of Oklahoma showing principal aquifers and all water level wells currently in the OWRB networks. Purple and blue stars indicate continuous water level sites in the NGWMN and OWRB networks respectively. Black circles and red diamonds indicate sites in the NGWMN and OWRB discrete water level networks respectively. Yellow triangles indicate sites currently being drilled through the 2020 project.

During early 2020, when sampling was temporarily put on hold due to COVID-19, the water quality networks were reassessed and it was determined that along with maintaining the ongoing water level networks, this schedule was not feasible in the long term. The limited temporal density of data and splitting each bedrock aquifer over two different years with no way to determine if change occurred between sites or years would also preclude 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 is like the original trend design but with a lower monitoring frequency that is still being determined (potentially every 3-5 years). It will serve to both provide a conditional assessment and to 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 (continuous water level sites wherever possible) potentially with aquifer specific parametric coverage.

History & Status of Data Flows

The OWRB has been a 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 began the process of becoming 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 housed and managed in Aquatic Informatics' Aquarius Time-Series software (Aquarius) and lithologic and well construction data housed in the OWRBs 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 webservices 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 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 - This Project
2020-2021	Quality control and add to the well registry many new discrete water level and water quality sites, perform slug tests to ensure sites are properly connected to their aquifers and camera surveys to fill well construction data gaps. Drill three new wells to fill network gaps in the Rush Springs aquifer.	Ongoing - Extended
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.	Ongoing - Extended
2022	No grant.	N/A

In 2018 OWRB received a third grant which began 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 significant expansion of our capabilities as a data provider including the development of 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 also in use 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 towards improving its ability to manage groundwater related data. Development goals included creating or expanding numerous monitoring location (well/spring) data domains providing storage for construction, lithology, and general informational data. A few 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.

Goals also included development of webservices for water level & quality, construction, and lithology data so that these can flow to the NGWMN. A crosswalk of webservice domains was completed by the USGS staff in early December 2020. Release of the improvements occurred 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 who utilized 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 so was part of the initial release in 2021. This was mainly done to remove 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. These are all now searchable within AWQMS. Other metadata such as landowner information were also included through this process. It is hoped that these improvements will make AWQMS an all-round 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 who utilize AWQMS at no additional cost to them other than their regular AWQMS maintenance fees.

Work continues to further improve AWQMS with respect to groundwater data management through review of the system and requests for improvements to Gold Systems who 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 was to include the water level measurement point height as its own domain and to allow that data to be published via API.

The 2019 grant (discussed more fully in later sections) prioritized work in the High Plains aquifer but did also involve 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.

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

In 2021, OWRB received a 1-year grant to expand the continuous water level trend network in the High Plains aquifer, purchasing and installing water level and telemetry equipment at 19 sites. Both the 2020 and 2021 grants are still active and each has received extensions.

Project Summary

This grant prioritized work in the High Plains aquifer but did also involve adding new wells to the network from across the state. The scope of work included work under four objectives with the overall intent of expanding the number of sites in the NGWMN, maintaining OWRB's data flows, providing missing metadata at key long-term High Plains water level sites, and ensuring High Plains wells were connected to the aquifer. A summary of the objectives and associated tasks is given below with each task then expanded upon.

Objectives and Tasks:

Objective 1: Support to become a new data provider or to expand services/sites by existing data providers

Task I: Addition of new sites to the NGWMN

Objective 2: Support persistent data services from existing data providers

Task II: Migration of historical well records to the AWQMS database and maintenance of webservices for the Aquarius database

Objective 3: Filling gaps in information at NGWMN sites

Task III: Downhole camera evaluation of 9 High Plains well

Objective 4: Well Maintenance

Task IV: Slug testing to assess well connectivity

Task 1: Addition of New Sites to the NGWMN

A major goal of this project was to add 93 new water level (55 High Plains) and 22 new water quality (10 High Plains) sites into the well registry with corresponding metadata. The planned number of new wells by principal aquifer is shown in Table 2. Selected sites were reviewed for metadata completeness (relative to minimum data element requirements) and then classified by sub-network prior to well registration. The selection and designation of sites was performed by Mark Belden prior to his retirement in March 2020 utilizing his experience of both the NGWMN requirements and over 40 years' experience with Oklahoma's groundwater. All methods for site selection, field techniques, data quality assurance processes, and data storage outlined in OWRB's initial new data provider document (G16AC00020, submitted 3/2017) were adhered to while selecting and providing all additional sites for this grant.

Eight additional High Plains wells were added to the OWRB water level network following a synoptic survey in 2021 which facilitated new wells to be found. These additional wells had a high potential as possible long-term continuous water level sites and so were included as discrete sites to allow continued data collection and site evaluation with the hope of enabling future expansion of the continuous network.

*Table 2: Planned additions to the NGWMN during this project. *An additional 8 water level sites were added to the High Plains aquifer for a total of 63.*

Principal Aquifer	Proposed Water Level Sites	Proposed Water Quality Sites
High Plains	55*	10
Rush Springs	15	5
Central Oklahoma	15	7
Ada-Vamoosa	8	0
Totals	93	22

All minimum data elements were met for all new wells. However, some water level wells were identified as having incomplete records for well construction details and/or lithology records. Some of the wells underwent camera surveys under Task 3 of this project and have updated construction records.

The remaining wells lacking metadata have been included in the Well Registry under the 'Special' well types until additional manual work can be done to complete the well records. In many cases, these well records are incomplete due to the incomplete filing of a well record by the well driller themselves, or

because the well predates the requirement for a well log to be submitted for new well construction. In the case that a complete well log does not exist, long term water level data predating the implementation of GMAP, has previously been used to confirm the connectivity and representativeness of this well to the aquifer of interest. All water quality sites are required to have this information to be in the GMAP network and have also been sampled during the statewide baseline period and shown to be representative of the aquifer specific water quality.

Since the end of the 2019 project, additional work to fill these metadata gaps has been completed through the 2020 NGWMN grant (G20AC00385) and additional state funded work related to the sites being instrumented through the 2021 (G21AC10478) grant. No matter its source, all data updated to AWQMS for NGWMN wells will become available to the network through webservices. As these data are updated in AWQMS the sites will be moved to the Surveillance or Trend well types in the NGWMN Well Registry.

Task 2: Support Persistent Data Services Through Migration of Historical Data and Maintenance of Webservices

Historical water level data and well metadata (construction and lithology) was migrated from OWRB's "Well Drillers" oracle database. All water level data pertaining to any wells that have ever been in the OWRB water level programs was downloaded, checked for gross data errors, and imported into AWQMS. Following the migration, data in AWQMS was checked for comparability to the original database. Data had previously been quality controlled by comparison to hardcopy field records during each year of data collection, so the focus of this task was on ensuring the migration process did not create new errors.

Water quality data had previously been migrated from an Access database but all incoming water quality data flows were improved and moved to AWQMS.

Well metadata for all NGWMN sites, including all construction and lithologic information requested by the NGWMN was downloaded, and checked for gross data errors. Any data represented by codes, e.g. screen and casing materials, was transformed into fully worded values for ease of review. Data was then checked, well by well, against all available records including the electronic version in the Well Drillers database, scans of the original hardcopy well completion reports, and field notebooks from annual water level collections where some metadata had previously been updated. Any new updates or corrections were tracked, and the final data was then imported to AWQMS. Following the migration, data in AWQMS was checked for comparability to the corrected data files.

Once the well metadata was available in AWQMS it was intended that construction and lithology data would flow from it to the NGWMN. However, due to some issues with assigning the correct webservices to each well, data continued to flow from the Well Drillers database via OMES created webservices until early 2023.

The final part of this task was to continue the existing relationship with OMES-IT to maintain the Aquarius database and support data services associated with continuous water level sites. As previously reported in the 2018 project final report, there have been many ongoing issues with OMES-IT including long downtimes of both the Aquarius database and the webservices created by OMES to provide construction, lithology, and daily mean water levels. During the 2018 and 2019 projects, in an attempt to limit these

issues, the OWRB instance of Aquarius was migrated to Amazon Web Services and is now hosted and maintained directly by Aquatic Informatics (the creators of Aquarius). OMES was required to perform additional work to alter the continuous data webservices to pull data from a new domain. Also, as previously reported, OWRB staff identified another issue with the continuous water level webservices where hourly data was being sent to the network instead of daily mean data. Moreover, all the data for each day was labeled with the same hourly timestamp. The original web services were constructed to pull the hourly water level data from Aquarius, calculate daily mean, and then provide that to the network when called. To the knowledge of staff currently working on the project, it is unclear why the OMES developers constructed them in that way when such a calculation is easily achieved in Aquarius and the Aquarius calculated daily mean data could have been pulled directly. OWRB now has calculated daily mean data series in Aquarius for each well and the technicians working on the problem altered the webservices to directly use the daily mean data. At the time of the 2018 final report, the code fixes had not been deployed due to OMES staff being unable to obtain permissions to the relevant OMES servers and the issue was being escalated through the senior administration of both OMES and OWRB. This has now been resolved and all continuous water level data is flowing through the corrected webservices.

Task 3: Provide Missing Metadata Through Camera Surveys

It was intended to perform downhole camera surveys at nine High Plains sites that lack construction information but possessed long period of record water level measurements. All nine wells are also part of Task 4. Seven of the wells were successfully surveyed but wells 9679 and 9081 were not due to issues discussed below. Table 3 gives additional details of all wells investigated through either Task 3 or Task 4.

Wells 9679 and 9081 were scheduled for camera surveys and were slug tested through Task 4. However, during the field visits well 9081 had obstructions preventing the survey and there were technical issues with the camera during the 9679 survey. Both wells demonstrated poor or no connectivity to the aquifer and were dropped from the networks.

Although well 9242 was surveyed, it was found the well had collapsed at 221 ft below ground level. The well has steel casing with screen starting at 169 ft and continuing to the collapsed portion. Only about 5 ft of water remains above the collapse. The well has exhibited a relatively stable downward trend since 1967 and is likely still connected to the aquifer, either in the small remaining portion of the well or below the collapsed portion. The well is still in the network but is being evaluated for either remediation work or removal from the network.

The remaining six surveys all provided clear construction details of the wells. Data has been updated to AWQMS and is available to the NGWMN.

During the early stages of this project, it was decided that whenever possible, camera surveys would be performed on all wells due to be slug tested to ensure the accuracy of the original well completion reports and the accuracy of the slug test interpretations. To that end, eight more wells due to be slug tested under Task 4 were surveyed along with an additional two wells added to the network during this project (wells 9243 and 24881). In total nineteen wells surveyed. No additional construction or maintenance issues were discovered through the surveys.

Table 3: Hydraulic conductivities and slug test outcomes for 2018 and 2019 project wells.

NGWMN Site ID	Well ID	Site Name	Project Year	Slug test K values (ft/d)	Camera Survey	Date Slugged	Aquifer
OWRB:86267	86267	Bromide	2018	11.70	Y	12/10/2019	Arbuckle-Simpson
OWRB:97451	97451	Fittstown Mesonet	2018	1.70	Y	4/8/2019	Arbuckle-Simpson
OWRB:85192	85192	Fittstown2	2018	1.00	Y	4/3/2019	Arbuckle-Simpson
OWRB:33464	33464	El Dorado	2018	1.40	Y	12/10/2019	Blaine
OWRB:127559	127559	Spencer Mesonet	2018	Revisit	Y	4/9/2019	Central Oklahoma
OWRB:94941	94941	Lexington	2018	0.60	Y	4/2/2019	Central Oklahoma
OWRB:127446	127446	Arcadia	2018	Revisit	Y	4/9/2019	Central Oklahoma
OWRB:128507	128507	Norman2	2018	0.14	Y	12/9/2019	Central Oklahoma
OWRB:9202	9202	Texoma	2018	Not Connected	Y	12/17/2017	High Plains
OWRB:9708	9708	Guymon	2018	Not Connected	Y	12/17/2017	High Plains
OWRB:9074	9074	Knowles	2018	Not Connected	Y	4/8/2019	High Plains
OWRB:140033	140033	Putnam	2018	0.20	Y	12/11/2019	Rush Springs
OWRB:27650	27650	Corn	2018	3.90	Y	12/11/2019	Rush Springs
OWRB:15597	15597	Welch	2018	0.70	Y	4/16/2019	Ozark Plateau
OWRB:41483	41483	Miami	2018	Screen Not Determined-Connected	Y	4/16/2019	Ozark Plateau
OWRB:181101	181101	Afton	2018	Screen Not Determined-Connected	Y	4/17/2019	Ozark Plateau
OWRB:9034	9034	MM9034	2019	Revisit due to data loss	N	N/A	High Plains
OWRB:9679	9679	MM9679	2019	Not Connected	N	11/28/2022	High Plains
OWRB:9243	9243	MM9243	2019	1.70	Y	7/14/2021	Rush Springs
OWRB:24881	24881	X24881	2019	1.50	Y	7/28/2021	Rush Springs
OWRB:9242	9242	MM9242	2019	Well Collapsed-No Slug Test	Y	8/3/2021	High Plains
OWRB:9869	9869	MM9869	2019	66.97	Y	3/23/2020	High Plains
OWRB:9656	9656	9656	2019	221.30	Y	3/25/2020	High Plains
OWRB:9081	9081	MM9081	2019	Not Connected	Y	8/16/2021	High Plains
OWRB:9883	9883	MM9883	2019	15.21	Y	3/23/2020	High Plains
OWRB:9387	9387	9387	2019	6.35	Y	3/24/2020	High Plains
OWRB:9653	9653	9653	2019	9.00	Y	3/25/2020	High Plains
OWRB:9399	9399	MM9399	2019	107.80	Y	3/25/2020	High Plains
OWRB:2063	2063	2063	2019	1.30	Y	8/3/2021	High Plains
OWRB:356	356	MM356	2019	55.38	Y	11/22/2022	High Plains
OWRB:58046	58046	OGLLP-022	2019	38.22	Y	8/3/2022	High Plains
OWRB:1721	1721	MM1721	2019	6.90	Y	8/4/2021	High Plains
OWRB:24817	24817	MM24817	2019	11.70	Y	8/17/2021	High Plains
OWRB:927	927	MM927	2019	5.50	Y	8/2/2022	High Plains
OWRB:129152	129152	X129152	2019	16.70	Y	8/17/2021	High Plains
OWRB:727	727	OGLLP-042	2019	35.39	Y	11/21/2022	High Plains
OWRB:14	14	OGLLP-044	2019	6.90	Y	8/4/2021	High Plains
OWRB:33768	33768	OGLLP-468	2019	1.10	Y	8/18/2021	High Plains
OWRB:140952	140952	140952	2019	Dropped	N	N/A	High Plains
OWRB:49463	49463	MM49463	2019	Not tested	N	N/A	High Plains

Task 4: Well Maintenance – Slug Testing to Determine Well Connectivity

During the previous 2018 project, three members of staff were sent for training in slug test methodology and trained in the use of Aqtesolv. Single well slug tests were performed on all continuous water level sites in the network during 2018-2020 to evaluate connectivity between well screens/boreholes with the adjacent aquifer for the existing sites. The estimated hydraulic conductivities were not presented in the previous final report and so have been included in this report (Table 3). At the time, 3 of the 16 sites were shown to be poorly connected and they were temporarily removed from the network. Since that time, the 3 wells (9202, 9708, 9074), which were all in the Oklahoma Panhandle portion of the High Plains aquifer have been completely removed from the network with replacement wells sought through the 2021 grant. Wells 41483 and 181101 were tested and although both the slug test and continuous water level data suggested good connections between the wells and the aquifer (Ozark Plateau) the construction information could not be determined, and the slug test data could not be fully analyzed.

The aquifer testing work continued in 2019-2021 under Task 4 of this project with 20-22 discrete water level sites proposed to be slug tested. Sixteen of the originally proposed wells were successfully tested and analyzed. An additional two wells were added to the network and analyzed but were from the Rush Springs aquifer. The remaining wells are discussed below.

As discussed under Task 3, wells 9679 and 9081 could not be surveyed and, although they were slug tested, the data suggested poor to no connections with the aquifer. Lack of accurate construction information prevented a full analysis of the data. Well 9242 was visited but could not be tested due to the short water column remaining above the collapsed portion of the well (see Task 3).

Well 140952 was dropped from the network due to a change in landowner permissions.

Well 49463 could not be tested during the first two attempts due to various issues including weather and access. The well has continued to be visited for annual discrete water level measurements every January. However, a pump was installed sometime between January 2022 and January 2023. During the last visit the pump was pumping and the measured water level was not representative of the aquifer. The well will be further investigated as to the potential for future unbiased measurements and if needed, dropped from the network.

Well 9034 needs to be revisited due to data loss.

The remaining 16 wells had estimated hydraulic conductivities of 1.1-221.3 ft/day (Table 3) with a mean of 37.9 and a median of 13.5 ft/day. These values are wide ranging with both higher and lower values than expected. To improve the reliability of future data and to quality control existing data, a series of steps have been initiated with additional steps still underway including:

- Additional training in theoretical aquifer testing has been completed by the majority of the staff with new staff members training throughout 2023
- Standardized slug test field data forms were created and then improved upon with Survey123 versions now being utilized vastly improving the recording of required field data
- Training three additional employees at the in-person Midwest geosciences aquifer testing course in 2023 followed by internal training trips for all remaining employees

- Reanalyzing all data collected to date with improved recording and standardization of analytical decisions
- Revisiting and retesting at least 25% of the sites from the 2018 and 2019 projects with a higher % (up to 100%) revisited as needed
- Comparison of independently analyzed data by different staff and independent review of every analysis

All validated or corrected data will be provided to the NGWMN through reports and data provider pages. Additional wells have been tested through the 2020 grant and state funded work to test all the wells included in the 2021 grant (all High Plains wells) to ensure they are fully connected to the aquifer. Data for these wells will be reported in the 2020 final report.

Additional Information & Problems Encountered

As previously reported in the Final Report for the 2018-2020 grant (G18AC00071) there have been significant changes in OWRB project and administrative staff during this project with some additional changes to be reported.

Mark Belden left OWRB with Chris Adams replacing him as Groundwater Monitoring Coordinator. Kyle Mattingly also left with his project and data administrative duties moving to Margarita Mendivelso and his field duties being taken up by Zachary McKinney.

Additional project staff changes include Jet Stine replacing Chris Adams as OWRB Data and Quality Assurance Manager. LeAnna Kilhoffer moved internally from being the NGWMN projects GIS specialist and being replaced by Anthony Huey. Kevin Kilhoffer, one of our Field and Continuous Data Leads was replaced by Zachary Tomlinson.

Administrative staff changes included the OWRB Financial Manager, Leslie Nance, who oversaw all project finances and billing. Jessica Billingsley replaced her as Financial Manager with Kelly Marsh taking over billing responsibilities for all USGS grants.

A significant period of work was impacted by the COVID-19 pandemic with reductions in field work 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.

Work on USGS projects was prioritized so all project work was completed. Additionally, state data generating programs related to the NGWMN were given a secondary priority and so data intended to be collected for inclusion in the network was also generated. Statewide water levels were collected annually with all continuous water level data flows maintained. Water Quality work was focused on the High Plains aquifer with additional sites added to the original baseline characterization.

For informational purposes it should be noted that since the end of the 2019 project additional staff changes include Margarita Mendivelso leaving OWRB; Jason Shiever and Zachary Tomlinson moving to new positions internally. Anthony Huey has taken on more data management work with additional data

related duties being moved to all staff. Neal Jones has joined the group as a geologist and field specialist and Jared Welch as a field specialist.

Summary & Future

Under Task 1, Oklahoma successfully added 101 new sites to the NGWMN. Historical water level data and well metadata for all sites in the network was migrated to the AWQMS database and is now available to the NGWMN via webservices. The previously reported issues with continuous water level data being provided as hourly data with a daily timestamp have been resolved and all data flows are occurring as intended. Field data recording has been improved with most data flows originated through Esri Field Maps and Survey123 before flowing data to the AWQMS and Aquarius databases. Camera surveys and slug tests were performed to fill metadata gaps and check longer term wells are properly connected to the aquifers. Despite overall success of that work, some wells were shown to be in poor condition or poorly connected to the aquifer of interest. This highlights the importance of performing those types of checks upfront.

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 in the High Plains aquifer with additional state funded expansions planned during 2023 and 2024. An emphasis has been placed on data quality with improved review of all data and detailed upfront investigation of all sites before they are added to the networks. Continuous data flows are beginning to be telemetered leaving more time for review and analysis.

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

OWRB's remaining NGWMN grants (FY20 and FY21) come to an end in 2023 (after extensions) and we plan to seek additional funding to help maintain and improve the network as needed.