FINAL TECHNICAL REPORT

OBSERVATION WELL INTEGRITY TESTING

Grant/Cooperative Agreement Number G20AC00181

Ohio Department of Natural Resources

Division of Geological Survey

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The Groundwater Program of the Ohio Department of Natural Resources, Division of Geological Survey (DGS) is responsible for collecting, researching, interpreting, and disseminating hydrologic and groundwater resource information for the State of Ohio. An important component of this program is to characterize Ohio's groundwater resources through monitoring and evaluating long-term trends in groundwater level fluctuations throughout the state's various aquifer systems.

This grant project conducted 60 well integrity tests (slug tests) over the two-year grant period. See Table 1 or Appendix A for a list of observation wells that were assessed.

Project Description

Well Maintenance

Under Objective 4 – Well Maintenance, integrity tests (slug tests) were conducted on 60 existing observation wells. The last time any of these observation wells were slug tested was in the late 1990s. The USGS recommends an integrity test cycle of every 5 years. With existing staffing levels, the DGS can test all 141 existing observation wells in six years. Slug test procedures outlined in USGS document *GWPD 17 – Conducting an Instantaneous Change in Head (Slug) Test with a Mechanical Slug and Submersible Pressure Transducer* were followed. Appendix A contains a list of the wells that were tested along with the results of each test.

In addition to the 60 observation wells tested for the grant, three wells (BU-8, MD-7, and MR-2) were tested shortly before or after the grant period started/ended. None of the work on these three wells was billed as part of this grant. Table 1 shows the list of wells planned to be tested as part of this grant and the list of total wells drilled, including these three.

Wells Projected to be Tested	Total Wells Tested
AL-5	AL-5
AS-2	AS-2
AS-3	AS-3
	BU-8
C-1	C-1
CL-9	CL-9
CO-27	CO-27
CS-2A	CS-2A
CS-3	CS-3
D-2	D-2
DL-3	DL-3
FA-1	FA-1
G-2	G-2
GE-3A	GE-3A
GR-1	GR-1
GR-10	GR-10
GR-12	GR-12

GR-13	GR-13
H-1	H-1
H-11	H-11
H-3	H-3
H-8	H-8
HA-3	HA-3
HN-2A	HN-2A
HY-2	HY-2
K-1	K-1
K-4	K-4
LI-4	LI-4
LU-1	LU-1
MA-1	MA-1
MD-6	MD-6
	MD-7
MI-3A	MI-3A
MN-1	MN-1
	MR-2
MT-49	MT-49
MT-6	MT-6
O-2	O-2
PI-3	PI-3
PO-123	PO-123
PO-124	PO-124
PR-2A	PR-2A
PU-1	PU-1
S-3	S-3
S-4	S-4
SE-2	SE-2
SH-5	SH-5
ST-27A	ST-27A
ST-33	ST-33
ST-5A	ST-5A
SU-7	SU-7
T-7	T-7
TU-1	TU-1
TU-5	TU-5
TU-9	TU-9
U-4	U-4
U-5	U-5
VW-1	VW-1
WA-2	WA-2

WM-12	WM-12
WM-1A	WM-1A
WM-3	WM-3
WN-8	WN-8

Table 1. List of wells tested

Figure 1 shows the current status of slug testing:

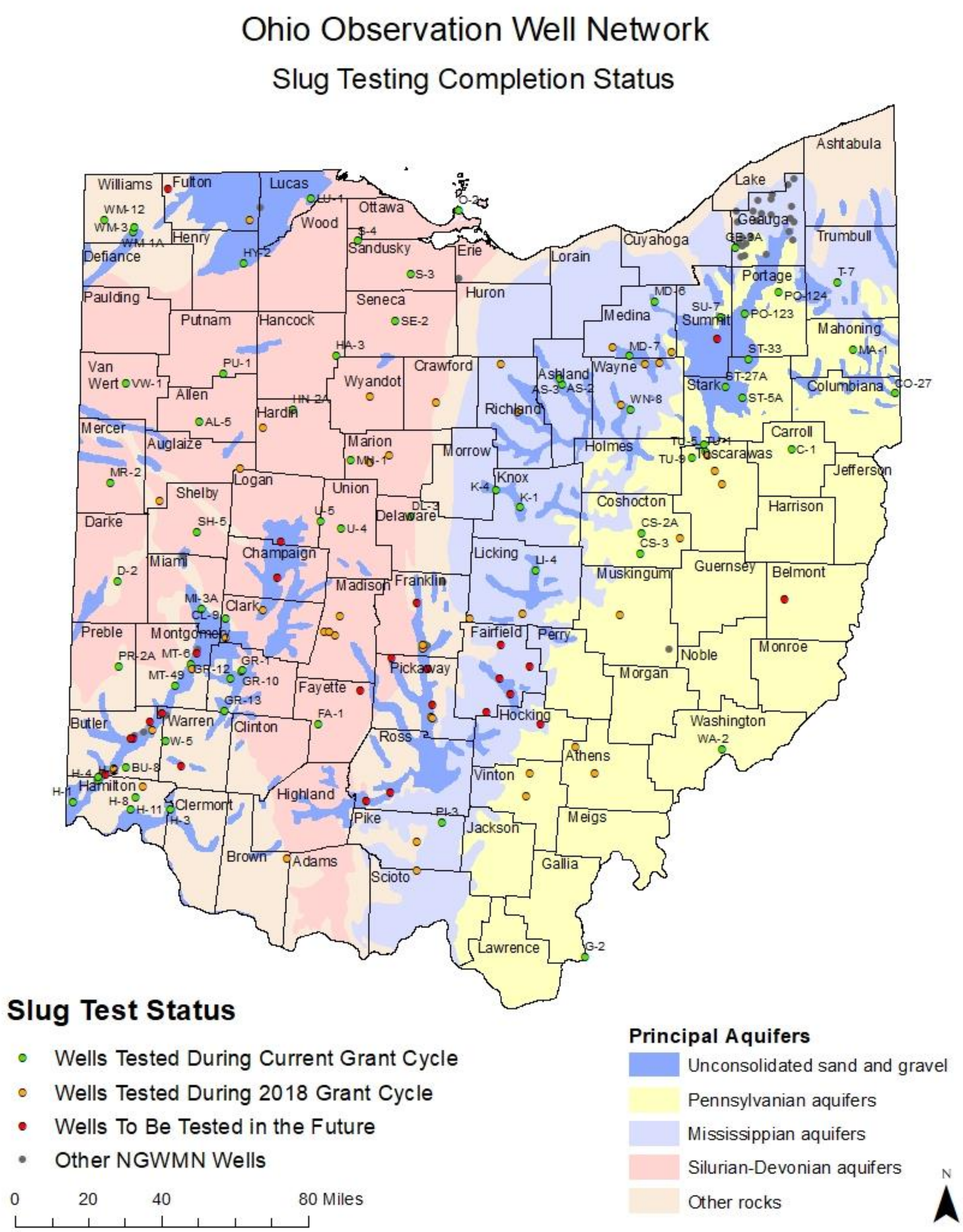

Figure 1. Status of slug testing

Since the project started, there has been several staffing changes. Krista Hardin has left the DGS. Current staff (Scott Kirk, Devon Goeller, Curtis Coe, and Tom Valachovics) conducted most of the slug tests. The general tasks that were followed for slug testing included:

- Removal of the existing observation well equipment that is in the well
- Installation of the temporary pressure transducer
- Conducting the slug test
- Re-installation of the observation well equipment
- Analyzing the slug test data

Staff had four types of slug tests they could perform: water in, physical slug in, physical slug out, and pneumatic. Depending on the well diameter and physical site conditions, one or more of the methods were used for each well. The type of test(s) conducted on each well is listed in the table in Appendix A. The pneumatic technique could only be used on wells that were 5 to 8 inches in diameter and did not have any abrasions near the top of the casing that would damage the packer.

Most of the wells responded rapidly to the slug tests (see Appendix A for a table of the wells that were slug tested and the resulting aquifer properties). However, there were some wells that were slow to respond. This could be due to a clogging of the well screen or a degradation of the formation. The following wells listed in Table 2 did not respond quick enough to calculate aquifer properties and will be evaluated for either a cleanout or redrill in a subsequent project.

Well ID	**County**
G-2	Gallia
H-11	Hamilton
MD-7	Medina
SH-5	Shelby
TU-5	Tuscarawas
TU-9	Tuscarawas
WN-8	Wayne

Table 2. Observation wells that were slow to respond to testing

As part of the DGS's analysis, staff looked at the data from the previous slug tests conducted in the late 1990s. Table 3 is a list of the wells that were tested in the 1990s and during this grant:

Well ID	Aquifer Type	Hydraulic Conductivity 1996–1998 (ft/day)	Hydraulic Conductivity 2021–2022 (ft/day)	Change
AS-3	Sand and Gravel	138.9	151.6	+12.7
C-1	Sandstone	229.6	255	+25.4
CL-9	Sand and Gravel	73.7	6.5	-67.2
D-2	Sand and Gravel	39.7	138.4	+98.7
DL-3	Limestone	7.9	96.8	+88.9
GE-3A	Sandstone	56.7	85.4	+28.7
HA-3	Limestone	4.3	2.4	-1.9
HN-2A	Limestone	11.1	76.4	+65.3
HY-2	Limestone	5.1	5.4	+0.3
K-4	Sand and Gravel	87.9	99.1	+11.2
LI-4	Sand and Gravel	566.9	465.5	-101.4
LU-1	Limestone	9.1	8.9	-0.2
MA-1	Sandstone	1.8	1.3	-0.5
MN-1	Limestone	6.8	5.4	-1.4
O-2	Limestone	38.6	40.8	+2.2
PU-1	Limestone	9.6	6.3	-3.3
S-3	Limestone	121.9	357	+235.1
SE-2	Limestone	0.28	27.6	+27.32
SH-5	Limestone	0.16	0.21	+0.05
ST-5A	Sand and Gravel	368.5	412	+43.5
U-4	Limestone	10.2	39.2	+29
U-5	Limestone	2.1	3.8	+1.7
VW-1	Limestone	27.8	53.2	+25.4
WM-12	Sand and Gravel	311.8	530	+218.2
WM-3	Sand and Gravel	19	44.1	+25.1

Table 3. Observation wells that were slow to respond to slug test.

Most hydraulic conductivities were similar or higher between the two rounds of slug tests. Two of the wells, CL- 9, and LI-4, showed significant decreases in the hydraulic conductivity. For these two wells, we examined the last 10-year hydrograph for that well to see if response times and magnitude of response had changed. For LI-4 (Licking County), there does appear to be small changes in the hydrograph since when the well returned to monitoring in 2018. The yearly high and low values have not changed. See Figure 2:

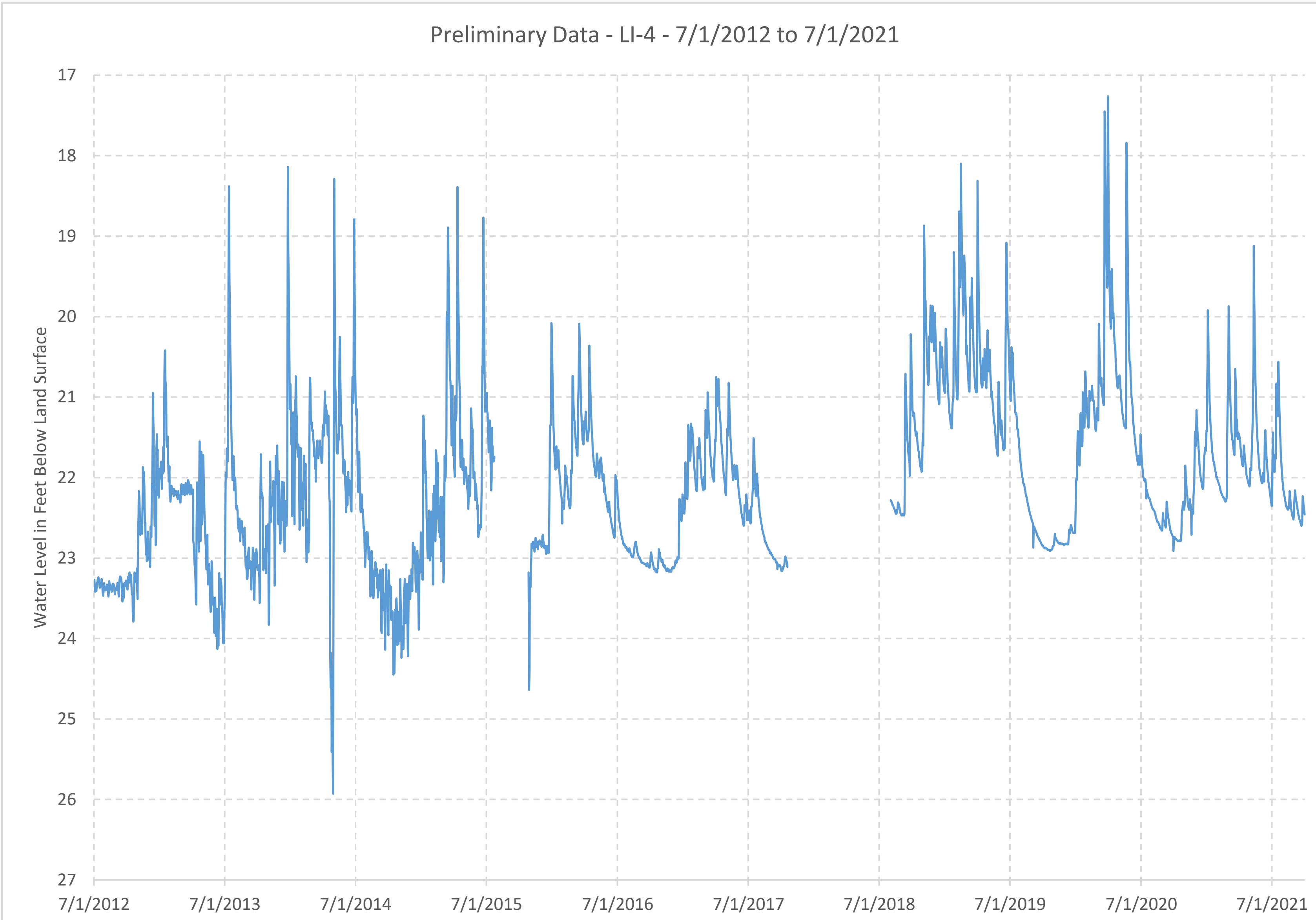

Figure 2. LI-4 water level data

There are no discernable changes in the hydrograph for CL-9. It still appears to be responding to changes:

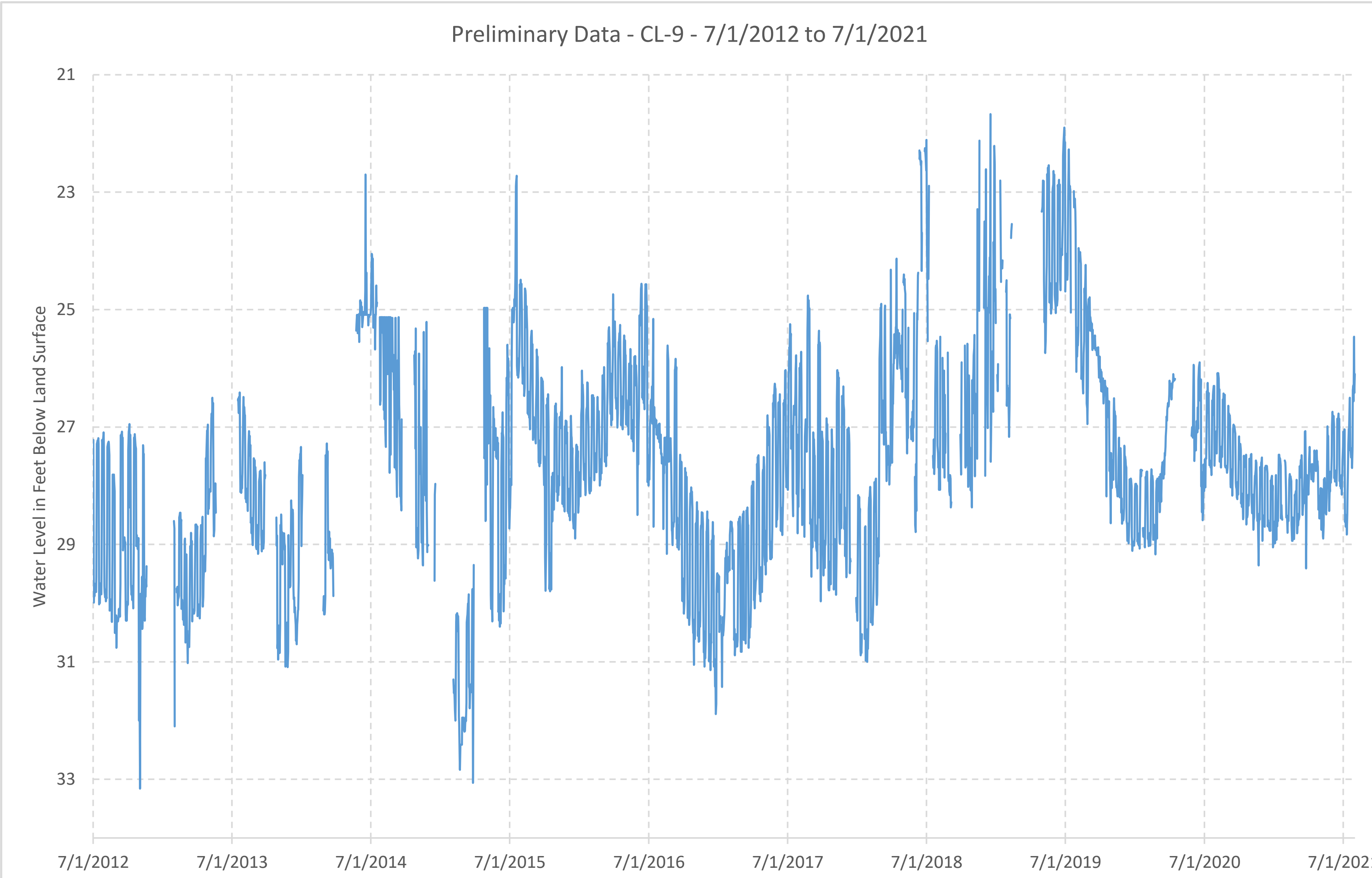

Figure 3. CL-9 water level data

DGS did not receive funding to perform slug testing as part of the 2022 NGWMN grant cycle. Nevertheless, five wells are slated for testing in 2022, including F-1, F-5, F-6, F-7, and F-8. It is the intent of the DGS to apply for additional funding in 2023 to complete the slug testing of the remaining wells.

Appendix A

Table of Slug Test Data

Well ID	Date of Test	Test Type	Conclusion	Solution Method	Dampening Determination	Aquifer Hydraulic Conductivity (Kr)	Aquifer Specific Storage (Ss)	Anisotropy Ratio (Kv/Kr)
AL-5	8/9/2021	Water In	Pass	Bouwer-Rice		0.522		
AL-5	8/9/2021	Slug In	Pass	Bouwer-Rice		0.5883		
AL-5	8/9/2021	Slug Out	Pass	Bouwer-Rice		0.5229		
AS-2	6/29/2021	Water In	Pass	KGS Model w/skin		83.05	0.0000252	1
AS-2	6/29/2021	Slug Out	Pass	KGS Model w/skin		79.96	2.221E-12	1
AS-2	6/29/2021	Slug In	Pass	KGS Model w/skin		89.58	0.0000252	1
AS-3	6/29/2021	Slug Out	Pass	Butler	Critically Dampened	429.1		
AS-3	6/29/2021	Water In	Pass	Butler	Critically Dampened	338.1		
AS-3	6/29/2021	Slug In	Pass	Butler	Critically Dampened	338.1		
BU-8	7/21/2020	Water In	Pass	Butler	Overdampened	0.2483		
C-1	6/9/2021	Water In	Pass	Springer-Gelhar	Underdampened	346.7		
C-1	6/9/2021	Water In	Pass	Springer-Gelhar	Underdampened	426		
CL-9	9/23/2020	Water In	Pass	Butler	Overdampened	9.058		
CL-9	9/23/2020	Water In	Pass	Butler	Overdampened	9.967		
CO-27	6/9/2021	Slug In	Pass	Springer-Gelhar	Critically Dampened	347.1		
CO-27	6/9/2021	Slug Out	Pass	Springer-Gelhar	Critically Dampened	342.2		
CO-27	6/9/2021	Water In	Pass	Springer-Gelhar	Critically Dampened	277.6		
CS-2A	5/19/2021	Water In	Pass	Butler	Underdampened	657.3		
CS-2A	5/19/2021	Slug In	Pass	Butler	Underdampened	707		
CS-2A	5/19/2021	Slug Out	Pass	Butler	Underdampened	718.4		
CS-3	5/19/2021	Slug Out	Pass	Bouwer-Rice		759.4		

Well ID	Date of Test	Test Type	Conclusion	Solution Method	Dampening Determination	Aquifer Hydraulic Conductivity (Kr)	Aquifer Specific Storage (Ss)	Anisotropy Ratio (Kv/Kr)
CS-3	5/19/2021	Water In	Pass	Bouwer-Rice		834.5		
D-2	8/3/2021	Water In	Pass	Springer-Gelhar	Overdampened	42.57		
D-2	8/3/2021	Slug Out	Pass	Springer-Gelhar	Critically Dampened	81.91		
D-2	8/3/2021	Slug In	Pass	Springer-Gelhar	Critically Dampened	284.6		
DL-3	9/30/2021	Water In	Pass	KGS Model w/skin		101	0.000000034	0.03055
FA-1	9/10/2020	Slug Out	Pass	KGS Model w/skin		3.203	0.0004262	1
FA-1	9/10/2020	Water In	Pass	KGS Model w/skin		5.227	0.0000625	0.4365
FA-1	9/10/2020	Slug In	Pass	KGS Model w/skin		11.93	0.0000625	1
G-2	9/22/2020	Water In	Fail (Analyzed)	KGS Model w/skin		0.8415	0.0009072	1
GE-3A	8/27/2020	Slug In	Pass	KGS Model w/skin		46.66	0.0007546	1
GE-3A	8/27/2020	Slug Out	Pass	KGS Model		52.28	0.001156	1
GE-3A	8/27/2020	Water In	Pass	KGS Model w/skin		46.66	0.0001815	1
GR-1	9/9/2020	Water In	Pass	KGS Model w/skin		7.282	0.0003154	1
GR-10	9/9/2020	Water In	Pass	Springer-Gelhar	Overdampened	54.65		
GR-10	9/9/2020	Slug In	Pass	Springer-Gelhar	Overdampened	133.1		
GR-10	9/9/2020	Slug Out	Pass	Springer-Gelhar	Overdampened	77.66		
GR-12	9/9/2020	Water In	Pass	KGS Model w/skin		53.52	3.267E-12	0.7079
GR-12	9/9/2020	Water In	Pass	KGS Model w/skin		49.19	0.00003226	1
GR-13	9/9/2020	Water In	Pass	Butler	Overdampened	41.23		
GR-13	9/9/2020	Slug In	Pass	Butler	Overdampened	80.05		
GR-13	9/9/2020	Slug Out	Pass	Butler	Overdampened	83.82		
H-1	6/24/2021	Water In	Pass	Springer-Gelhar	Critically Dampened	72400		
H-1	6/24/2021	Water In	Pass	Springer-Gelhar	Overdampened	19990		
H-11	6/24/2021	Water In	Fail (Field)					
H-3	6/10/2021	Water In	Pass	KGS Model w/skin		4.838	2.764E-12	1
H-3	6/10/2021	Water In	Pass	KGS Model w/skin		2.646	2.764E-12	1
H-8	6/10/2021	Water In	Pass	Springer-Gelhar	Overdampened	1.44		
H-8	6/10/2021	Water In	Pass	Springer-Gelhar	Overdampened	2.448		

Well ID	Date of Test	Test Type	Conclusion	Solution Method	Dampening Determination	Aquifer Hydraulic Conductivity (Kr)	Aquifer Specific Storage (Ss)	Anisotropy Ratio (Kv/Kr)
HA-3	6/16/2021	Water In	Pass	Butler	Overdampened	3.494		
HN-2A	8/18/2021	Slug Out	Pass	Butler	Critically Dampened	84.62		
HN-2A	8/18/2021	Slug In	Pass	Butler	Underdampened	642.1		
HY-2	9/16/2021	Water In	Pass	Butler	Overdampened	10.86		
HY-2	9/16/2021	Water In	Pass	Butler	Overdampened	10		
K-1	8/26/2020	Slug Out	Pass	Springer-Gelhar	Overdampened	586.3		
K-1	8/26/2020	Water In	Pass	Springer-Gelhar	Underdampened	397.2		
K-1	8/26/2020	Slug In	Pass	Springer-Gelhar	Overdampened	612.6		
K-4	8/26/2020	Slug In	Pass	Springer-Gelhar	Overdampened	105.2		
K-4	8/26/2020	Water In	Pass	Springer-Gelhar	Overdampened	94.97		
K-4	8/26/2020	Slug Out	Pass	Springer-Gelhar	Overdampened	97.02		
LI-4	8/26/2020	Slug Out	Pass	Springer-Gelhar	Critically Dampened	657		
LI-4	8/26/2020	Slug In	Pass	Springer-Gelhar	Critically Dampened	522		
LI-4	8/26/2020	Water In	Pass	Springer-Gelhar	Critically Dampened	432.9		
LU-1	9/16/2021	Water In	Pass	Butler	Overdampened	11.75		
LU-1	9/16/2021	Water In	Pass	Butler	Critically Dampened	8.26		
MA-1	9/17/2020	Water In	Pass	Springer-Gelhar	Overdampened	1.302		
MD-6	6/23/2022	Slug Out	Pass	Butler	Underdampened	4.151		
MD-6	6/23/2022	Slug In	Pass	Butler	Underdampened	2.668		
MD-6	6/23/2022	Water In	Pass	Butler	Underdampened	2.57		
MD-7	6/23/2022	Slug In	Fail (Analyzed)	KGS Model w/skin		0.1156	6.094E-08	1
MD-7	6/23/2022	Water In	Fail (Analyzed)	KGS Model w/skin		0.06885	0.000002794	1
MD-7	6/23/2022	Slug Out	Fail (Analyzed)	KGS Model w/skin		0.01936	0.0008112	1
MI-3A	9/23/2020	Water In	Pass	Butler	Overdampened	20.86		
MI-3A	9/23/2020	Slug In	Pass	Butler	Overdampened	26.48		
MI-3A	9/23/2020	Slug Out	Pass	Butler	Overdampened	24.21		
MN-1	8/18/2021	Slug In	Pass	Butler	Overdampened	7.873		
MN-1	8/18/2021	Water In	Pass	Butler	Overdampened	7.919		

Well ID	Date of Test	Test Type	Conclusion	Solution Method	Dampening Determination	Aquifer Hydraulic Conductivity (Kr)	Aquifer Specific Storage (Ss)	Anisotropy Ratio (Kv/Kr)
MR-2	7/23/2020	Water In	Pass	KGS Model		0.1461	0.000529	1
MT-49	7/21/2020	Slug Out	Pass	KGS Model w/skin		11.45	5.03E-13	1
MT-49	7/21/2020	Slug In	Pass	KGS Model w/skin		12.46	0.000000697	1
MT-6	11/9/2021	Water In	Pass	Butler		32.47		
MT-6	11/9/2021	Water In	Pass	Butler	Overdampened	44.48		
O-2	9/1/2020	Slug Out	Pass	Springer-Gelhar	Critically Dampened	44.02		
O-2	9/1/2020	Water In	Pass	Springer-Gelhar	Overdampened	40.21		
O-2	9/1/2020	Slug In	Pass	Springer-Gelhar	Overdampened	42.04		
PI-3	9/10/2020	Slug Out	Pass	Springer-Gelhar	Critically Dampened	214.7		
PI-3	9/10/2020	Water In	Pass	Springer-Gelhar	Critically Dampened	153.9		
PI-3	9/10/2020	Slug Out	Pass	Springer-Gelhar	Critically Dampened	165.8		
PO-123	6/28/2022	Slug In	Pass	Springer-Gelhar	Overdampened	1.12		
PO-123	6/28/2022	Slug Out	Pass	Springer-Gelhar		0.8653		
PO-123	6/28/2022	Water In	Pass	Springer-Gelhar	Overdampened	1.12		
PO-124	8/27/2020	Slug In	Pass	Butler	Overdampened	2.986		
PO-124	8/27/2020	Water In	Pass	Butler	Overdampened	1.616		
PO-124	8/27/2020	Slug Out	Pass	Butler		1.999		
PR-2A	8/10/2021	Slug Out	Pass	Butler	Underdampened	896.3		
PR-2A	8/10/2021	Slug In	Pass	Butler	Overdampened	1408.6		
PR-2A	8/10/2021	Water In	Pass	Butler		993.9		
PU-1	8/18/2021	Water In	Pass	Butler	Overdampened	7.628		
PU-1	8/18/2021	Slug Out	Pass	Butler	Overdampened	9.421		
PU-1	8/18/2021	Slug In	Pass	Butler	Overdampened	10.06		
S-3	6/16/2021	Water In	Pass	Butler	Underdampened	563.9		
S-3	6/16/2021	Water In	Pass	Butler	Underdampened	564.1		
S-4	9/1/2020	Slug Out	Pass	Butler	Underdampened	517		
S-4	9/1/2020	Water In	Pass	Butler	Underdampened	1274		
S-4	9/1/2020	Water In	Pass	Butler	Underdampened	352.9		

Well ID	Date of Test	Test Type	Conclusion	Solution Method	Dampening Determination	Aquifer Hydraulic Conductivity (Kr)	Aquifer Specific Storage (Ss)	Anisotropy Ratio (Kv/Kr)
SE-2	6/16/2021	Slug In	Pass	Springer-Gelhar	Overdampened	54.57		
SE-2	6/16/2021	Water In	Pass	Springer-Gelhar	Overdampened	1.254		
SH-5	8/3/2021	Water In	Fail (Analyzed)	Bouwer-Rice		0.2486		
SH-5	8/3/2021	Water In	Fail (Analyzed)	Bouwer-Rice		0.1584		
ST-27A	9/16/2020	Slug In	Pass	Bouwer-Rice		209.8		
ST-27A	9/16/2020	Slug Out	Pass	Bouwer-Rice		213.5		
ST-27A	9/16/2020	Water In	Pass	Bouwer-Rice		181.3		
ST-33	6/28/2022	Water In	Pass	Bouwer-Rice		5.084		
ST-33	6/28/2022	Slug In	Pass	Bouwer-Rice		6.666		
ST-33	6/28/2022	Slug Out	Pass	Bouwer-Rice		6.6666		
ST-5A	9/16/2020	Water In	Pass	Bouwer-Rice		485.8		
ST-5A	9/16/2020	Slug Out	Pass	Bouwer-Rice		477.6		
ST-5A	9/16/2020	Water In	Pass	Bouwer-Rice		263.8		
ST-5A	9/16/2020	Slug In	Pass	Bouwer-Rice		485.8		
SU-7	8/25/2021	Slug Out	Pass	Springer-Gelhar	Overdampened	40.68		
SU-7	8/25/2021	Slug In	Pass	Springer-Gelhar	Overdampened	40.41		
SU-7	8/25/2021	Water In	Pass	Springer-Gelhar	Overdampened	19.66		
T-7	9/17/2020	Slug Out	Pass	KGS Model w/skin		4.671	9.932E-08	1
T-7	9/17/2020	Water In	Pass	KGS Model w/skin		5.161	7.686E-07	1
T-7	9/17/2020	Slug In	Pass	KGS Model		5.161	7.694E-07	1
TU-1	9/9/2021	Water In	Pass	KGS Model w/skin		4.123	2.259E-07	0.6095
TU-1	9/9/2021	Water In	Pass	KGS Model w/skin		2.728	9.671E-12	1
TU-5	9/9/2021	Water In	Fail (Analyzed)	KGS Model w/skin		0.8491	0.00008749	0.6166
TU-9	8/9/2021	Water In	Fail (Analyzed)	KGS Model w/skin		0.01528	8.087E-09	0.871
U-4	9/30/2021	Water In	Pass	Bouwer-Rice		34.96		
U-4	9/30/2021	Water In	Pass	Bouwer-Rice		43.36		
U-5	9/30/2021	Water In	Pass	Butler		4.468		
U-5	9/30/2021	Water In	Pass	Butler		4.769		

Well ID	Date of Test	Test Type	Conclusion	Solution Method	Dampening Determination	Aquifer Hydraulic Conductivity (Kr)	Aquifer Specific Storage (Ss)	Anisotropy Ratio (Kv/Kr)
VW-1	8/9/2021	Water In	Pass	Springer-Gelhar	Underdampened	93.55		
WA-2	9/22/2020	Slug In	Pass	Springer-Gelhar	Critically Dampened	584.1		
WA-2	9/22/2020	Water In	Pass	Springer-Gelhar	Critically Dampened	354.6		
WM-12	8/19/2020	Water In	Pass	Butler	Underdampened	352.8		
WM-12	8/19/2020	Water In	Pass	Butler	Underdampened	417.1		
WM-1A	8/19/2020	Slug In	Pass	Butler	Overdampened	224		
WM-1A	8/19/2020	Slug Out	Pass	Butler	Overdampened	253.4		
WM-3	8/19/2020	Water In	Pass	Butler	Overdampened	28.15		
WM-3	8/19/2020	Slug In	Pass	Butler	Overdampened	29.34		
WM-3	8/19/2020	Slug Out	Pass	Butler	Overdampened	29.34		
WN-8	6/29/2021	Water In	Fail (Analyzed)	Butler	Overdampened	0.8157		
WN-8	6/29/2021	Water In	Fail (Analyzed)	Butler	Overdampened	1.527		