Hydraulic testing of Mississippian and Devonian NGWMN wells by the Iowa Geological Survey

5 November 2020

Funded by the
U.S. Geological Survey – Award #G19AC00186
01 July 2018 – 30 June 2019

Submitted by:
Rick Langel
Iowa Geological Survey
University of Iowa
300 Trowbridge Hall
Iowa City, IA 52242-1319
richard-langel@uiowa.edu
319-335-1575

INTRODUCTION

The National Ground-Water Monitoring Network (NGWMN), which was established to assess long-term water-level and water-quality trends at a national scale, provides a unique opportunity to collect and share date from different states, agencies, and others. The Iowa Geological Survey (IGS) at the University of Iowa joined the NGWMN in 2017. The IGS contributes 40 wells, completed in the Cambrian-Ordovician (USGS national code S300CAMORD), Cretaceous (N300lLCRTCS), Mississippian (N500MSSPPI), and Silurian-Devonian (N400SLRDVN) aquifers, where quarterly static water level measurements are made to the NGWMN.

Many of the IGS wells are decades old and lack documentation of when (or if) water was last purged or if hydraulic tests were ever conducted. Through U.S. Geological Survey (USGS) Award # G19AC00186 the IGS received funding to pump water and conduct hydraulic tests on thirteen (13) selected NGWMN sites. This report describes the work performed and results obtained under this award.

WELL

The IGS received funding to pump water and conduct hydraulic tests on thirteen (13) selected NGWMN sites. Figure 1 shows the locations of the selected wells. Appendix A contains more detailed information on the wells. The wells are completed in the Devonian and Mississippian aquifers.

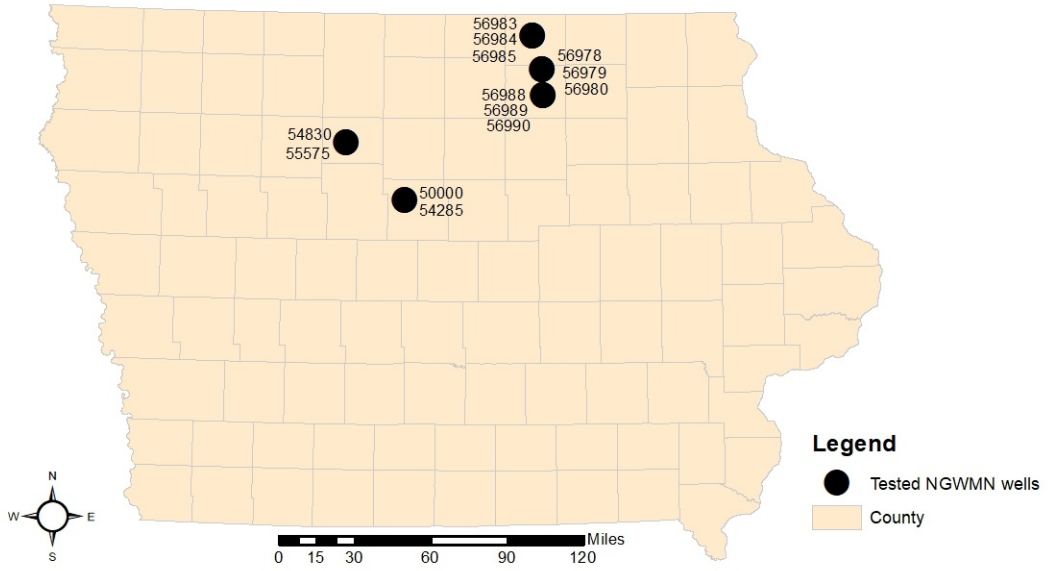

Figure 1. Location of wells selected for pumping and hydraulic testing.

WELL PUMPING

Water was purged from the wells in the fall 2019. Four sites were pumped using a 3" submersible pump. The remaining nine sites are cased with 1.5" PVC casing. Because of the

small casing and the depth to water in each well, airlifting water from these wells was the only method available to purge water. Appendix A documents the method that was used to purge water. Water was purged from most sites until either the water's specific conductance readings stabilized or three well volumes of water had been removed. Briggs Woods 3, NGWMN ID 50000, was the exception to this procedure. Pumping this particular well in the past has been problematic because of the well's low hydraulic conductivity. The IGS' pumping procedure for this well is to lower the pump to the maximum depth (130' at the time) and pump the well until pumps air. The water level was allowed to recover. The pump was again lower to maximum depth and the well was pumped until the well pumped air.

Most well pumped clear water for the entire pumping cycle. The exception were the wells at the FM1 wellnest (NGWMN IDs 56978, 56979, and 56990). Inside the protective casing at this site, a mouse nest was found on top of these wells and removed several years prior to pumping. Grass and seeds were observed early as these wells were airlifted. But, the water was clear by the end of the purging.

HYDRAULIC TESTING

Mechanical slug tests were conducted at all sites. The slug tests followed procedures established in the USGS' groundwater technical procedure document (GWPD) 17 (Cunningham and Schalk, 2011). A 2½ inch diameter, 3½ foot long slug was used at Rutland Marsh wellnets and for 1 test in Briggs Woods #2. A 2½ inch diameter, 2 foot long slug wells was used at the Briggs Woods wellnest. A 3/4 inch diameter, 2 foot long slug was used at the FM wellnests. A minimum of four slug tests were conducted at each site (two slug in and two slug out tests). Additional slug in or slug out tests were conducted at sites if any of the original tests seemed anomalous.

Water levels during the slug tests were collected using a pressure transducer with a built-in data logger (In-Situ Level TROLL 700). The data collection interval varied from 0.25 to 5 seconds depending on the anticipated response of the aquifer to the slug's introduction and removal. Data from the slug tests was processed in Microsoft Excel and analyzed using the AquiferTest 7.0 software (Waterloo Hydrogeologic). Two separate test methods were used to analyze the slug tests and determine hydraulic conductivity (K): Hvorslev (1951) and Bulter et al. (2003). The Hvorslev method was used in wells where the water level response to the introduction/removal of the slug had minimal oscillations. The Butler method was used in wells where the water level response to the introduction/removal of the slug produced significant oscillations.

Slug test results are presented in Table 1. Hydraulic conductivities varied considerably between wells with average K ranging from 0.03 to 63 feet/day. Analysis of the FM wellnests data was challenging. The wells penetrate permeable carbonate formations. The introduction and removal of a slug in the FM wells caused noise for the first few seconds of the test. The IGS altered its slug introduction procedures to see if this noise could be eliminated to no avail. The conclusion is the slug is not be introduced 'instantaneously' relative to the formations response. To obtain results for the conducted tests, the IGS used the translation method outlined in Butler (1998). The time and initial displacement of the analysis was set to either the crest or trough where the data began a normal oscillatory pattern (not influenced by early noise). The IGS is exploring

alternative for conducting slug tests in highly permeable formations. The IGS believe a pneumatic slug may eliminate the noise early in the tests. The IGS has constructed a device for pneumatic slugs. However, problems with establishing an airtight seal with the FM wells have prevented a successful pneumatic test from occurring to date.

Table 1. Results from slug tests conducted on the NGWMN wells.

Location (NGWMN ID)	Hydraulic Conductivity (feet/day)		Method
	Average	Range	
Briggs Woods 2 (54285)	0.2	0.1 to 0.2	Horslev
Briggs Woods 3 (50000)	0.2	0.1 to 0.2	Horslev
FM1-2 (56978)	0.1	0.03 to 0.2	Horslev
FM1-3 (56979)	23.3	18 to 30	Butler
FM1-4 (56980)	16.8	16 to 17	Butler
FM2-2 (56983)	3.8	0.2 to 7	Butler
FM2-3 (56984)	19.0	18 to 21	Butler
FM2-4 (56985)	12.3	7 to 17	Butler
FM3-2 (56988)	59.8	55 to 63	Butler
FM3-3 (56989)	45.8	42 to 48	Butler
FM3-4 (56990)	62.3	60 to 67	Butler
Rutland Marsh 3 (55576)	1.0	0.5 to 1.5	Horslev
Rutland Marsh 5 (54830)	0.6	0.2 to 0.9	Horslev

Unfortunately, no previous estimates of hydraulic conductivity exists to compare the current results. The current results will be used as the baseline to compare future hydraulic conductivities against.

The raw data and analysis results of the slug tests have been entered into IGS Pump Test (https://www.iihr.uiowa.edu/igs/pump-test/) to allow public access. Entries into IGS Pump Test are screened randomly to ensure data standards are maintained.

WEBSERVICE AND DATABASES

The IGS did not encounter any problems with its web services transferring data to the NGWMN data portal in this contract period.

Under USGS award #G19AC00275, the IGS is modify web services using WaterML2 and GWML2 data standards to transfer data to the NGWMN data portal. The IGS' water-level web service is currently being modified to use WaterML2 data standards. The goal is to have an updated water-level web service operational and in use by December 2020.

SUMMARY

The IGS has achieved all of the project goals. Specifically, we pumped water from thirteen NGWMN wells located at five sites to ensure the wells were still in connection with the aquifer. Mechanical slug tests were conducted at all sites to establish baseline hydraulic conductivity for future comparison. The raw data and analysis results of the slug tests have been entered into IGS Pump Test for public access.

References

Butler Jr, J. J, 1998, The Design, Performance, and Analysis of Slug Tests, Lewis Publishers.

Butler Jr, J. J., Garnett, E. J., and Healey, J. M., 2003, Analysis of Slug Tests in Formations of High Hydraulic Conductivity, Groundwater, 41(5), 620-631.

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater Technical Procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 p.

Hvorslev, M. J., 1951, Time Lag and Soil Permeability in Ground-Water Observations, Vicksburg, MS: U.S. Army Waterways Experiment Station.

APPENDIX A
DETAILED WELL INFORMATION

NGWMN ID	Name	County	Latitude	Longitude	Accuracy	Drill Date	Well Depth	Aquifer	Purge Method
50000	Briggs Woods #3	Hamilton	42.436284	-93.795223	GPS +/- 10 m.	5/30/2001	410	Mississippian	Pump
54285	Briggs Woods #2	Hamilton	42.436274	-93.795220	GPS +/- 10 m.	7/6/2001	110	Mississippian	Pump
54830	Rutland Marsh #5	Humboldt	42.760957	-94.256656	GPS +/- 10 m.	10/30/2001	280	Mississippian	Pump
55575	Rutland Marsh #3	Humboldt	42.760967	-94.256615	GPS +/- 10 m.	1/30/2002	150	Mississippian	Pump
56978	FM1-2	Floyd	43.181920	-92.732670	GPS +/- 10 m.	9/20/1984	138	Devonian	Airlift
56979	FM1-3	Floyd	43.181920	-92.732670	GPS +/- 10 m.	9/20/1984	240	Devonian	Airlift
56980	FM1-4	Floyd	43.181920	-92.732670	GPS +/- 10 m.	9/19/1984	357	Devonian	Airlift
56983	FM2-2	Mitchell	43.377240	-92.811850	GPS +/- 10 m.	9/19/1984	150	Devonian	Airlift
56984	FM2-3	Mitchell	43.377240	-92.811850	GPS +/- 10 m.	9/18/1984	250	Devonian	Airlift
56985	FM2-4	Mitchell	43.377240	-92.811850	GPS +/- 10 m.	9/18/1984	348	Devonian	Airlift
56988	FM3-2	Floyd	43.033150	-92.732000	GPS +/- 10 m.	9/25/1984	207	Devonian	Airlift
56989	FM3-3	Floyd	43.033150	-92.732000	GPS +/- 10 m.	9/25/1984	297	Devonian	Airlift
56990	FM3-4	Floyd	43.033150	-92.732000	GPS +/- 10 m.	9/24/1984	360	Devonian	Airlift

NGWMN ID	Hyperlink
50000	https://www.iihr.uiowa.edu/igs/geosam/well/50000/general-information
54285	https://www.iihr.uiowa.edu/igs/geosam/well/54285/general-information
54830	https://www.iihr.uiowa.edu/igs/geosam/well/54830/general-information
55575	https://www.iihr.uiowa.edu/igs/geosam/well/55575/general-information
56978	https://www.iihr.uiowa.edu/igs/geosam/well/56978/general-information
56979	https://www.iihr.uiowa.edu/igs/geosam/well/56979/general-information
56980	https://www.iihr.uiowa.edu/igs/geosam/well/56980/general-information
56983	https://www.iihr.uiowa.edu/igs/geosam/well/56983/general-information
56984	https://www.iihr.uiowa.edu/igs/geosam/well/56984/general-information
56985	https://www.iihr.uiowa.edu/igs/geosam/well/56985/general-information
56988	https://www.iihr.uiowa.edu/igs/geosam/well/56988/general-information
56989	https://www.iihr.uiowa.edu/igs/geosam/well/56989/general-information
56990	https://www.iihr.uiowa.edu/igs/geosam/well/56990/general-information