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**MINNESOTA DEPARTMENT OF
NATURAL RESOURCES**

2018 NGWMN Grant Final Report

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The Minnesota Department of Natural Resources (MN DNR) has been contributing to the NGWMN monitoring of principal aquifers since 2017. The DNR established a connection so that water level data from 363 DNR observation wells would be served to the NGWMN portal. Of those 363 wells, the DNR has transducers in 253 of them that are taking hourly water level measurements that are then verified by quarterly hand measurements. The remaining 110 wells are measured approximately 8 times a year by hand. For this grant request, we wanted to improve some of the already-existing wells and add 5 new wells in principal aquifers where there are large gaps in Minnesota.

i) **Objectives**

a. **Objective 4**

1. Conduct maintenance on 25 existing wells in Otter Tail County. Maintenance to include measuring the well depths, performing slug tests to determine specific capacity, video logging, well development to clean out the wells and then a final slug test to determine if the well condition has been improved.

b. **Objective 5**

1. Tri Cooperative WMA: Install a Galena Group Limestone/Dolostone well at approximately 210' and a St. Peter Sandstone well at approximately 410' at an estimated cost of \$69,500.
2. Pheasants Forever WMA: Install a Galena Group Limestone/Dolostone well at approximately 140' and a St. Peter Sandstone well at approximately 380' at an estimated cost of \$58,500.
3. Dilworth: Install a Quaternary Buried Artesian (QBAA) well at approximately 155' at an estimated cost of \$15,000.

ii) **Completed Work**

- a. The DNR maintained 18 wells in Otter Tail County where staff measured the total depth, conducted a slug test to determine the hydraulic conductivity and then re-developed the well. After re-development, another slug test was performed and a final depth was confirmed. The other 7 wells turned out to be privately-owned irrigation wells, so access to the inside of these wells was not available.
- b. The DNR completed 5 new wells at the proposed sites to monitor principal aquifers in NGWMN gaps. The DNR contracted with Midwestern Drilling LLC to complete these wells using the mud rotary drilling method.
 - i. The total cost for the wells in Steele County was \$88,753.20. The DNR covered \$44,376.60 and the USGS matched that amount.
 1. Tri Cooperative WMA: Completed a Galena well at 180' and a St. Peter well at 380'.
 2. Pheasants forever WMA: Completed a Galena well at 158' and a St. Peter well at 385'.
 - a. A Galena well was installed at the proposed location and ended up flowing at 30 gallons per minute at the surface which would not have allowed the DNR to monitor this well accurately. Therefore, this well was sealed and the contractor mobilized approximately 1,000' southeast to the south edge of the WMA on top of the hill where we successfully installed the Galena and St. Peter well. The static water

levels for local Galena wells was 10' below the elevation of the first drill location. Because of the local static water levels, the DNR did not expect to encounter a flowing well. There were extra costs and quantities incurred by having to seal the original well, mobilize, drill, and install a new well, but it did not require extra funding over the original budget.

- ii. QBAA at Dilworth: Completed this well at 118' using Midwestern Drilling LLC as the contractor at a total cost of \$10,454.40. The DNR covered \$5,227.20 and the USGS matched that amount.

iii) Data collection and quality

a. Well Maintenance

- i. The DNR used a tag line to measure the total well depths prior to pumping and/or flushing the well. A calibrated e-tape was used to measure an initial static water level before the slug test. For the slug test, a pressure transducer was installed in the well and then a cylindrical slug of known volume was lowered and raised to monitor falling and rising head. Multiple slug tests were conducted to ensure results were repeatable. After pumping/flushing the wells, the hydraulic conductivities for many of them were improved (see table 1 below). This raised the question of whether we are actually measuring hydraulic conductivities of the aquifer, or the efficiency of the well screen (all of the wells that were maintained were built into unconsolidated materials, and therefore had well screens at the bottom).

b. Well Installations

- i. During the well installation process, we required the drillers to take cuttings samples every 5 feet for an onsite DNR hydrologist to identify the formations encountered (see figures 1-5 below). Based on the depths that formations were encountered, the DNR hydrologist established well specifications (see table 2 below) to ensure they monitored the targeted principal aquifers. After the wells were installed, the DNR surveyed the wells and measured the static water levels with calibrated e-tapes. After at least 2 hand measurements, data loggers were installed and programmed to the observed water level. These sites will be visited quarterly by the DNR or their partners to measure the water levels, download the data, and maintain the loggers. Once the logger data is uploaded to our database, we use WISKI software to analyze the data and make necessary adjustments to logger data using the hand measurements as control points. Once the data is adjusted it is then ready for review and final distribution. Water level data will then be uploaded to the NGWMN portal.

iv) Tables

Well	FH Mean Pre Development (ft/day)	FH Mean Post Development (ft/day)	n (pre)	n (post)	GPM (final)	Future Monitoring Plans
56000	133.6252	253.9843	3	3	20	continue
56006	0.346677	0.55048	1	1	0.04	seal & replace nearby
56009	0.002587	0.002702	1	1	0	seal & replace nearby
56010	8.7288	33.54336	2	2	0.7	seal & replace nearby
56022	0.3016	77.3953	1	3	0.06	seal & replace nearby
56024	0.3855	0.4149	1	1	0.13	seal & replace nearby
56026	0.2888	7.524	1	3	0.04	seal & replace nearby
56031	27.255	27.958	3	3	0.25	continue
56032	0.09703	44.3	1	3	0.16	continue
56034	2.758	5.5209	3	3	0.01	seal / consolidate
56039	0.079937	2.712	1	3	0.52	continue
56045		234.878	0	2	8	continue
56046	109.6725	118.9512	3	3	5	continue
56047	74.834	74.248	3	3	7	continue
56049	0.043143	0.025512	1	1	0.3	seal
56050	239.8299	320.5512	3	3	7	continue
56051	73.034	121.474	2	3	7	continue
56052	42.76536	112.1953	3	3	1	continue

Table 1: These are the wells that were maintained in Otter Tail County and the slug test results prior to re-developing the well and after re-developing the well.

Site	DNR Obwell #	MDH Unique #	Formation	Principal Aquifer	Completed Depth (ft)	Open Hole or Screened Interval (ft)	Ground Elevation (ft AMSL)	Well Log
Pheasants Forever WMA	20007	843404	Galena	Upper Carbonate	158	80-158	1250.2	Figure 1
Pheasants Forever WMA	20008	843405	St. Peter	Cambrian-Ordovician	385	325-385	1250.2	Figure 2
Tri Cooperative WMA	20009	843406	Galena	Upper Carbonate	180	132-180	1264.4	Figure 3
Tri Cooperative WMA	20010	843407	St. Peter	Cambrian-Ordovician	380	310-380	1264.4	Figure 4
Dillworth	14055	841555	Quaternary Buried	Glacial and Alluvial	118	108-118	918.8	Figure 5

Table 2: New well specifications.

v) **Figures**

Figure 1: Well 20007 specifications and lithology.

Geologist's Mud Log - Minnesota Department of Natural Resources									
				UTM: easting 514623.64 northing 4876833.15		instrument used: GPS			
DNR OB #:	20007	MN Unique	843404	UTM: easting 514623.64 northing 4876833.15					
Start Date:		Driller:	Traut - Perry & Phil	PLS:					
End Date:	9/20/2018	Method:	Mud Rotary	County:		Dodge			
		Geologist:	Nic Borchardt	Site :		Pheasants Forever WMA			
				Ground Elev.:		1250.2			
				Total Depth:		158			
				Completed Depth:		158			
				Screen Length/Open Hole:		78			
Depth (ft)		Color	Description	Hardness	Thickness (ft)	Top Elevation (ft)	Bottom Elevation (ft)	Field Interpretation	Additional Observations & Notes
From	To								
0	30	tan-yellow	clay		30	1250.2	1220.2		
30	40	brown-tan	sandy clay		10	1220.2	1210.2		
40	45	tan-yellow	sandy clay		5	1210.2	1205.2		
45	50	bluish gray	sandy clay		5	1205.2	1200.2		
50	56	yellowish gray	mod sorted, sub rd-sub ang, coarse-fine sand		6	1200.2	1194.2		
56	75	bluish gray	sandy clay		19	1194.2	1175.2		
75	77	gray	mod sorted, sub ang-sub rd, med-coarse sand		2	1175.2	1173.2		trace clay
77	80	yellowish white	dolomite		3	1173.2	1170.2	OGAL	
80	90	yellow	dolomite		10	1170.2	1160.2	OGAL	
90	120	brownish tan	dolomite		30	1160.2	1130.2	OGAL	
120	158	brownish gray	limestone		38	1130.2	1092.2	OGAL	traces of white shale

Figure 2: Well 20008 specifications and lithology.

Geologist's Mud Log - Minnesota Department of Natural Resources									
				UTM: easting 514619.64 northing 4876833.12		instrument used: GPS			
DNR OB #:	20008	MN Unique	843405	UTM: easting 514619.64 northing 4876833.12					
Start Date:		Driller:	Traut - Perry & Phil	PLS:					
End Date:	9/18/2019	Method:	Mud Rotary	County:		Dodge			
		Geologist:	Nic Borchardt	Site :		Pheasants Forever WMA			
				Ground Elev.:		1250.2			
				Total Depth:		385			
				Completed Depth:		385			
				Screen Length/Open Hole:		60			
Depth (ft)		Color	Description	Hardness	Thickness (ft)	Top Elevation (ft)	Bottom Elevation (ft)	Field Interpretation	Additional Observations & Notes
From	To								
0	30	tan-yellow	clay		30	1250.2	1220.2		
30	40	brown-tan	sandy clay		10	1220.2	1210.2		
40	45	tan-yellow	sandy clay		5	1210.2	1205.2		
45	50	bluish gray	sandy clay		5	1205.2	1200.2		
50	56	yellowish gray	mod sorted, sub rd-sub ang, coarse-fine sand		6	1200.2	1194.2		
56	75	bluish gray	sandy clay		19	1194.2	1175.2		
75	77	gray	mod sorted, sub ang-sub rd, med-coarse sand		2	1175.2	1173.2		trace clay
77	80	yellowish white	dolomite		3	1173.2	1170.2	OGAL	
80	90	yellow	dolomite		10	1170.2	1160.2	OGAL	
90	120	brownish tan	dolomite		30	1160.2	1130.2	OGAL	
120	170	brownish gray	limestone		50	1130.2	1080.2	OGAL	traces of white shale
170	175	gray	limestone		5	1080.2	1075.2	OGAL	increase in shale
175	180	gray	limestone	very hard	5	1075.2	1070.2	OGAL	little shale
180	185	greenish gray	shaley limestone		5	1070.2	1065.2	OGAL	
185	195	greenish gray	limy shale		10	1065.2	1055.2	OGAL	very reactive to acid, very calcareous
195	200	brownish gray	shaley limestone		5	1055.2	1050.2	OGAL	
200	205	greenish gray	limy shale		5	1050.2	1045.2	OGAL	calcareous/fossiliferous
205	230	greenish gray	shale w/ some white and minor LS chunks		25	1045.2	1020.2	OGAL	very calcareous
230	237	med green	shale w/ some white and minor LS chunks		7	1020.2	1013.2	OGAL	very calcareous, lost circulation
237	285	med-dark gray	silty shale		48	1013.2	965.2	ODCR	
285	290	med gray	silty shale		5	965.2	960.2	OPVL	
290	300	light-med gray	very sandy shale		10	960.2	950.2	OPVL	
300	306	light-med gray	sandy silt		6	950.2	944.2	OGWD	
306	325	gray	very fine, sub rd, lithic qz sandstone		19	944.2	925.2	OSTP	
325	350	white/clear	well sorted, well rounded, quartz arenite		25	925.2	900.2	OSTP	
350	385	white-tan	well sorted, well rounded, lithic quartz arenite		35	900.2	865.2	OSTP	

Figure 3: Well 20009 specifications and lithology.

Geologist's Mud Log - Minnesota Department of Natural Resources										
				UTM:	easting	northing	instrument used: GPS			
				PLS:	524662.74	4866386.04				
DNR OB #:	20009	MN Unique	843406	Driller:	Traut - Perry & Phil		County:	Dodge		
Start Date:		Method:	Mud Rotary		Site :		Tri-Cooperative WMA			
End Date:	10/17/2019	Geologist:	Nic Borchardt		Ground Elev.:		1264.4			
				Total Depth:		180				
				Completed Depth:		180				
				Screen Length/Open Hole:						132
Depth (ft)		Color	Description	Hardness	Thickness (ft)	Top Elevation (ft)	Bottom Elevation (ft)	Field Interpretation	Additional Observations & Notes	
From	To									
0	5	dark brown-black	top soil		5	1264.4	1259.4			
5	15	yellow	clay		10	1259.4	1249.4			
15	20	yellow, some white	poorly sorted, sub rd, coarse sand w/ clay		5	1249.4	1244.4		lost circulation at 20'	
20	48	n/a	n/a		28	1244.4	1216.4		drilled blind, no returns and not in bedrock yet. Feels like bedrock was hit at 35'	
48	50	golden yellow	dolomite		2	1216.4	1214.4	OGAL		
50	85	yellowish tan	dolomite		35	1214.4	1179.4	OGAL		
85	110	tannish light gray	dolomite		25	1179.4	1154.4	OGAL	very dirty	
110	180	tannish gray	limestone		70	1154.4	1084.4	OGAL	with some yellow	

Figure 3: Well 20010 specifications and lithology.

Geologist's Mud Log - Minnesota Department of Natural Resources										
				UTM:	easting	northing	instrument used: GPS			
				PLS:	524665.67	4866387.92				
DNR OB #:	20010	MN Unique	843407	Driller:	Traut - Perry & Phil		County:	Dodge		
Start Date:		Method:	Mud Rotary		Site :		Tri-Cooperative WMA			
End Date:	10/14/2019	Geologist:	Nic Borchardt		Ground Elev.:		1264.4			
				Total Depth:		380				
				Completed Depth:		380				
				Screen Length/Open Hole:						70
Depth (ft)		Color	Description	Hardness	Thickness (ft)	Top Elevation (ft)	Bottom Elevation (ft)	Field Interpretation	Additional Observations & Notes	
From	To									
0	5	dark brown-black	top soil		5	1264.4	1259.4			
5	15	yellow	clay		10	1259.4	1249.4			
15	20	yellow, some white	poorly sorted, sub rd, coarse sand w/ clay		5	1249.4	1244.4		lost circulation at 20'	
20	48	n/a	n/a		28	1244.4	1216.4		drilled blind, no returns and not in bedrock yet. Feels like bedrock was hit at 35'	
48	50	golden yellow	dolomite		2	1216.4	1214.4	OGAL		
50	85	yellowish tan	dolomite		35	1214.4	1179.4	OGAL		
85	110	tannish light gray	dolomite		25	1179.4	1154.4	OGAL	very dirty	
110	204	tannish gray	limestone		94	1154.4	1060.4	OGAL	with some yellow	
204	277	grayish olive green	sandy shale		73	1060.4	987.4	ODCR		
277	295	med gray	sandy limestone		18	987.4	969.4	OPVL		
295	303	gray	shale		8	969.4	961.4	OGWD		
303	380	white/clear	well sorted, well rounded, lithic qz arenite		77	961.4	884.4	OSTP		

Figure 5: Well 14055 specifications and lithology.

Geologist's Mud Log - Minnesota Department of Natural Resources									
				UTM:	easting	northing	instrument used: Survey-grade GPS		
				PLS:	222341	5197956			
DNR OB #:	14055	MN Unique	841555	Driller:	Traut - Perry and Phil		County:	Clay	
Start Date:	3/18/2019	Method:	mud rotary		Site :		Moorhead Public Service		
End Date:	3/19/2019	Geologist:	Matthew Meyer		Ground Elev.:		918.8		
				Total Depth:		120			
Depth (ft)		Color	Description	Hardness	Thickness (ft)	Top Elevation (ft)	Bottom Elevation (ft)	Field Interpretation	Additional Observations & Notes
From	To								
0	3	black	silty topsoil	soft	3	918.8	915.8		
3	5	gray-brown	silty clay, trace fine sand	soft	2	915	913.8		
5	20	brown	clay, trace silt, trace fine sand	soft-med	15	913	898.8		
20	25	gray	silty clay, trace fine sand	soft	5	898	893.8		
25	30	gray	fine sand	soft	5	893	888.8		seemed to be clean sand drilled very easy; seemed to be clean sand
30	37	gray	fine sand	very soft	7	888	881.8		
37	65	gray	silty clay, trace fine sand, trace coal	soft to soft-med	28	881	853.8		
65	75	brown	fine-coarse sand, trace coal	soft	10	853	843.8		
75	80	brown	fine-coarse sand, trace coal, trace gray clay	soft-med	5	843	838.8		
80	118	brown/multi	fine-very coarse sand, trace-some gravel (more with depth), trace coal	soft-med	38	838	800.8		took drilling mud
118	120	n/a	no sample, but drilled slower/harder (like a sandy/silty clay)	soft-med to med	2	800	798.8		
				Screened from 108-118 feet					
				Produced ~100gpm during development					
				Static WL: 19.5ft (grd)					