INITIAL TOWNSHIP TESTING OF NITRATE IN PRIVATE WELLS

DAKOTA COUNTY 2013-2014 SUMMARY

March 2016

Minnesota Department of Agriculture

Pesticide and Fertilizer Management Division

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

The testing conducted in Dakota County is part of a statewide assessment of vulnerable areas as the Minnesota Department of Agriculture plans to offer nitrate tests to approximately 70,000 private well owners (within 250-300 townships) between 2014 and 2019.

In 2013 and 2014, 13 townships and 5 cities located in Dakota County were selected for private well nitrate sampling. This selection was based on historically elevated nitrate conditions, aquifer vulnerability and row crop production. Samples were collected from private wells using homeowner collection and mail-in methods. These initial samples were collected from 1,395 wells representing a 27 percent response rate from homeowners. For this initial report, no wells were eliminated due to potential point source problems other than hand dug wells. Well log information was obtained when available and correlated with nitrate results. Information collected indicated approximately 80 percent of wells in the study area were finished in the Paleozoic sedimentary deposits.

Results showed that across the study area, 27 percent of private wells sampled were above the health standard of 10 mg/L for nitrate as nitrogen (nitrate-N.) Results from the sampling revealed that in 12 communities, 10 percent or more of the wells were over 10 mg/L nitrate-N. In Marshan Township, 53 percent were over the health standard in contrast to Farmington Township where no wells were found in excess of the standard.

This initial homeowner collected sampling was followed by a second sampling offered to homeowners with wells that had a “detectable” nitrate result. The second sampling, collected by the Minnesota Department of Agriculture staff, will be discussed further in a follow-up report which should be available in the latter part of 2016.

INTRODUCTION

The Minnesota Department of Agriculture (MDA) has recently updated the 1990 Nitrogen Fertilizer Management Plan (NFMP), which is the state’s blueprint for prevention or minimization of the impacts of nitrogen fertilizer on groundwater. To effectively manage nitrate contamination of water resources, it is appropriate to focus on areas of greatest risk. Testing for nitrate in private wells is one method for identifying areas and wells at greatest risk. For this, the MDA has developed the “Township Testing Program”. In the Township Testing Program (TTP), the MDA works with local partners (counties and SWCDs) to collect and analyze water samples from private drinking water wells within townships that either had high nitrate results previously or exist in an area with high aquifer vulnerability and a high percentage of row crop production.

This testing conducted in Dakota County is part of a statewide assessment as the MDA plans to offer nitrate tests to approximately 70,000 private well owners (within 250-300 townships) between 2014 and 2019. As of February 2016, 104 townships in 10 counties have been completed. For further information on this program, please visit the project webpage at:
http://www.mda.state.mn.us/protecting/cleanwaterfund/gwdwprotection/townshiptesting.aspx

BACKGROUND

In many rural areas of the state, nitrate is one of the most common contaminants in Minnesota's groundwater, and in some areas of the state, a significant number of wells have high nitrate levels.

Nitrate is a naturally occurring, water soluble molecule that is made up of nitrogen and oxygen. Although nitrate occurs naturally, it can also originate from man-made sources such as fertilizer, animal manure, and human waste. Nitrate is a concern because it can have a negative effect on human health at elevated levels. The U.S. Environmental Protection Agency (USEPA) has established a drinking water Maximum Contaminant Level (MCL) of 10 mg/L for nitrate as nitrogen (nitrate-N) (U.S. EPA, 2009) in municipal water systems. Minnesota Department of Health (MDH) has also established a Health Risk Limit (HRL) of 10 mg/L nitrate-N for private drinking water wells in Minnesota.

Nitrogen present in groundwater can be found in the forms of nitrite and nitrate. Nitrite concentration is commonly less than the reporting level of 0.01 mg/L, resulting in negligible contribution to the nitrate plus nitrite concentration (Nolan and Stoner, 2000). In the environment, nitrite generally converts to nitrate, which means nitrite occurs very rarely in groundwater. Analytical methods generally combine nitrate plus nitrate together. Measurements of nitrate plus nitrite as nitrogen and measurements of nitrate as nitrogen will hereafter be referred to as “nitrate”.

NITRATE FATE AND TRANSPORT

Nitrate is considered a conservative anion and is highly mobile in many shallow coarse-textured groundwater systems. Once in groundwater nitrate is often considered very stable and can move large distances from its source. However, in some settings nitrate in groundwater may be converted to nitrogen gas in the absence of oxygen and the presence of organic carbon, through a natural process called denitrification. Denitrification occurs when oxygen levels are depleted and nitrate becomes the primary oxygen source for microorganisms. Shallow groundwater in coarse-textured soils (glacial outwash) generally has low concentrations of organic carbon and is well oxygenated, so denitrification is often limited in these conditions. As a result areas like Dakota County, with glacial outwash aquifers and intensive row crop agriculture, are particularly vulnerable to elevated nitrate concentrations. However, geochemical

conditions can be highly variable within an aquifer or region and can also change over-time (MPCA, 1998).

GEOLOGY AND HYDROGEOLOGY

The geology in Dakota County is influenced by outwash plains, supraglacial drift complex, and plain till. Glacial outwash is relatively coarse-textured compared to other glacial deposits such as till and supraglacial drift deposits. Outwash is material consisting primarily of sand and gravel that was deposited by running water that flowed from melting ice during the last glacial period. The outwash sand and gravel is typically deposited in a stratified (layered) fashion as the glacial melt conditions change. The coarse-textured deposits associated with glacial outwash often allow contaminants from the surface to travel rapidly to the water table aquifers. Statewide geomorphological mapping conducted by the Minnesota Department of Natural Resources, Minnesota Geological Survey (MGS) and the University of Minnesota at Duluth (DNR, MGS and UMD, 1997) indicates the extent of glacial deposits in Dakota County as presented in Figure 1.

The Quaternary Water Table Aquifer (QWTA) does not underlie all of Dakota County and is only used for domestic wells and irrigation wells. The QWTA in this county is not generally used for public water supplies because there is little protection from contaminants entering the water table (Palen, 1990).

The Prairie Du Chien-Jordan Aquifer underlies nearly all of Dakota County and is the most frequently utilized aquifer in the region. The Prairie du Chien-Jordon Aquifer is composed of the Prairie du Chien Group and Jordon Sandstone. These two bedrock aquifers have distinctly different compositions, the Prairie du Chien is a composed primarily of dolostone and the Jordan is sandstone. The bottom member of the Prairie du Chien is the Oneota Formation which is a moderate confining unit. At a local scale (1 to 3 miles or less) the Prairie du Chien and Jordan behave as hydrologically disconnected, while at a larger scale (more than 3 miles) they behave as hydrologically connected. This aquifer has higher yield capacity than the water table and other bedrock aquifers. The water is hard to very hard and can have an iron taste. Concentrations of nitrate-n above the 10 mg/L HRL were found in some wells completed in the Prairie Du Chien (Balaban and Hobbs, 1990).

Other bedrock aquifers in Dakota County include Platteville formation, St. Peter, St. Lawrence-Franconia, and the Ironton-Galesville. The Platteville and St. Lawrence-Franconia have unreliable and limited water yields. The Mt. Simon-Hinckley is the deepest of these aquifers and has a high yield. In the northern part of the county, the St. Peter is used for domestic water supply (Balaban and Hobbs, 1990).

The same geologic mapping project presented in Figure 1 was used to classify the state into aquifer sensitivity ratings. There are three ratings for aquifer sensitivity: low, medium, and high. Sensitivity ratings are described in Table 1. The ratings are based upon guidance from the Geologic Sensitivity Project Workgroup's report "Criteria and Guidelines for Assessing Geologic Sensitivity in Ground Water Resources in Minnesota" (DNR, 1991) (Figure 2).

Table 1. Vulnerability Ratings Based on the Geomorphology of Minnesota, Sediment Association Layer.

Sediment Association	Sensitivity/Vulnerability Rating
Alluvium, Outwash, Ice Contact, Terrace, Bedrock: Igneous, Metamorphic, and Sedimentary	High
Supraglacial Drift Complex, Peat, Lacustrine	Medium
Till Plain	Low

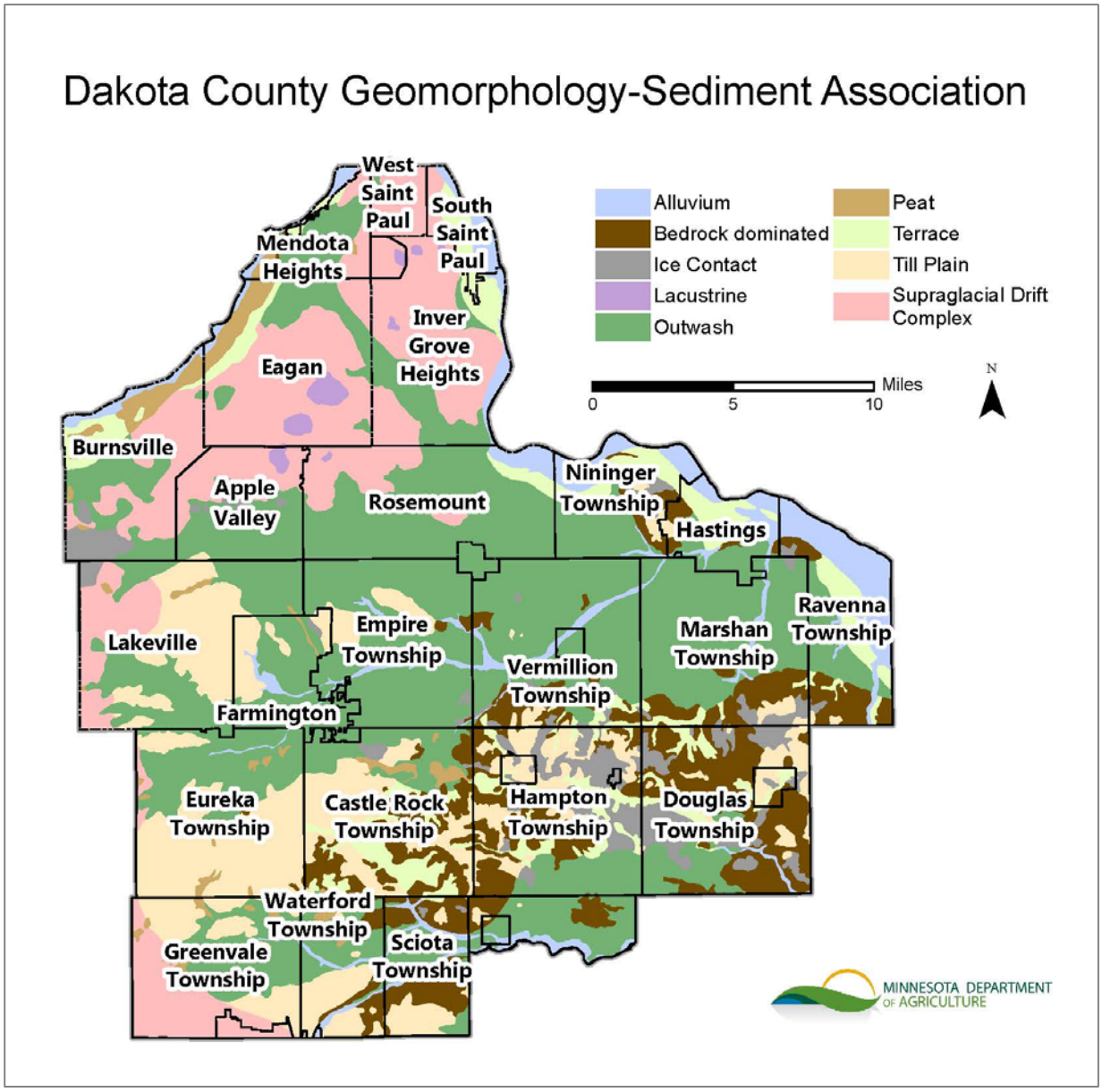

Figure 1. Statewide Geomorphology Layer, Sediment Association, Dakota County (DNR, MGS and UMD, 1997).

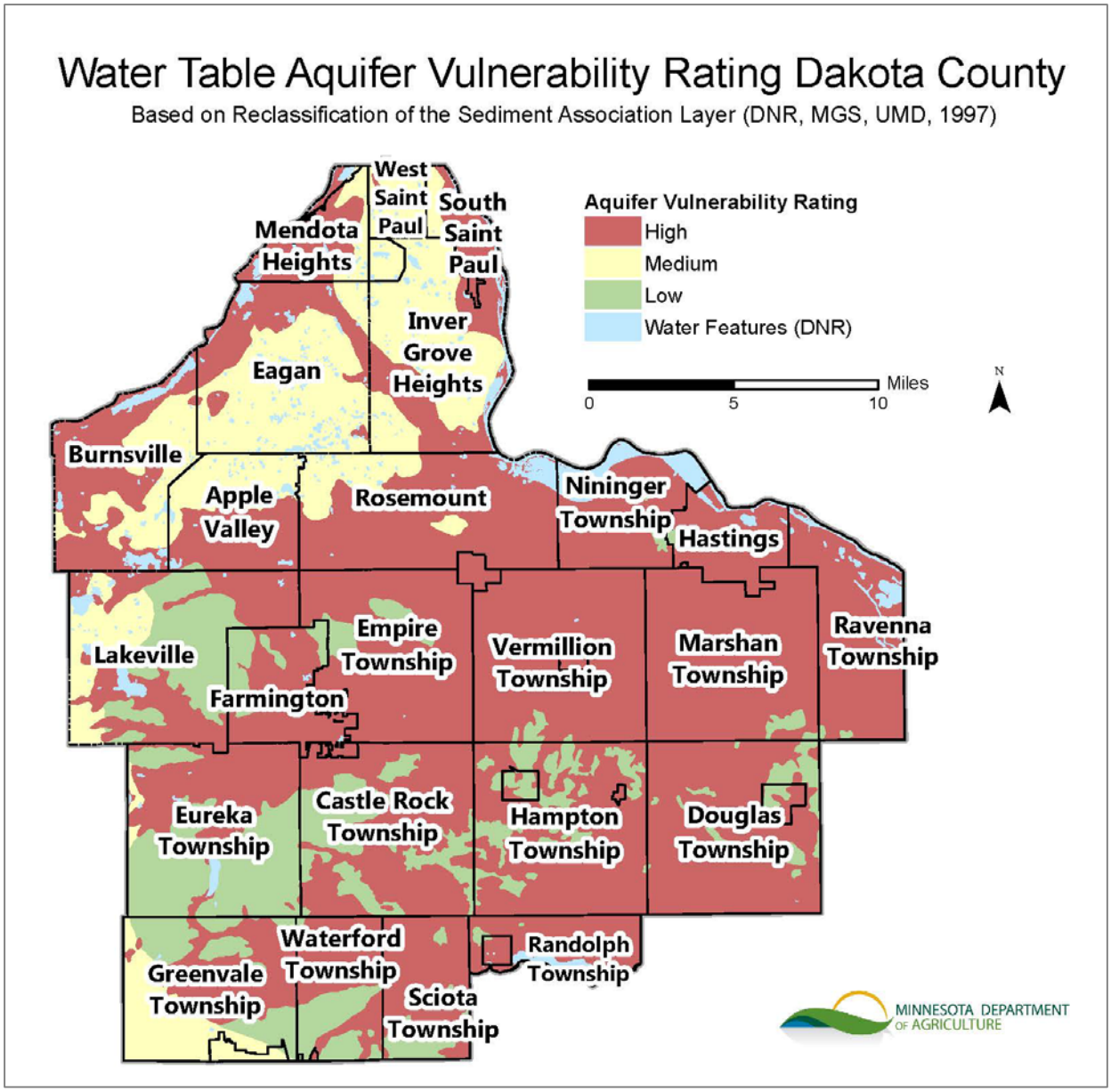

Figure 2. Water Table Aquifer Vulnerability Rating Dakota County.

GEOLOGIC ATLAS

A County Geologic Atlas is a systematic study of a county's geologic and groundwater resources. The atlas defines aquifer properties and boundaries, as well as the connection of aquifers to the land surface and to surface water resources (MGS, 2015). This information is essential to sustainable management of groundwater resources and can help with activities such as monitoring, appropriation, permitting, remediation, and well construction.

A complete geologic atlas typically consists of two parts:

- Part A (prepared by MGS), which includes the water well database and 1:100,000 scale geologic maps showing properties and distribution of sediments and rocks in the subsurface, and
- Part B (developed by the Department of Natural Resources (DNR) Division of Waters) which includes maps of water levels in aquifers, direction of groundwater flow, water chemistry, and sensitivity to pollution.

The geologic atlas for Dakota County was completed in 1990 and was not divided into these two parts. However, this county still contains much of the data that can typically be found in Parts A and B. An important analysis completed is called the Sensitivity of Prairie Du Chien-Jordan Aquifer to Pollution. This map has a rating system based on the time for water to travel from the land surface to the Prairie Du Chien-Jordan Aquifer or the shallowest aquifer if the Prairie Du Chien-Jordan Aquifer has been eroded (Figure 3). The "Very High" ratings occur where it is estimated that water can travel to the aquifer in hours to days, while the "Very Low" ratings the travel time could be more than a century. The estimated travel times were based on the bedrock confining layer(s) above the aquifer, and the composition and thickness of material overlying the bedrock.

The water table aquifer vulnerability map (Figure 2) is similar to the pollution sensitivity map when comparing at a one-dimensional level, however, the pollution sensitivity map has a higher level of detail and is based on slightly different data.

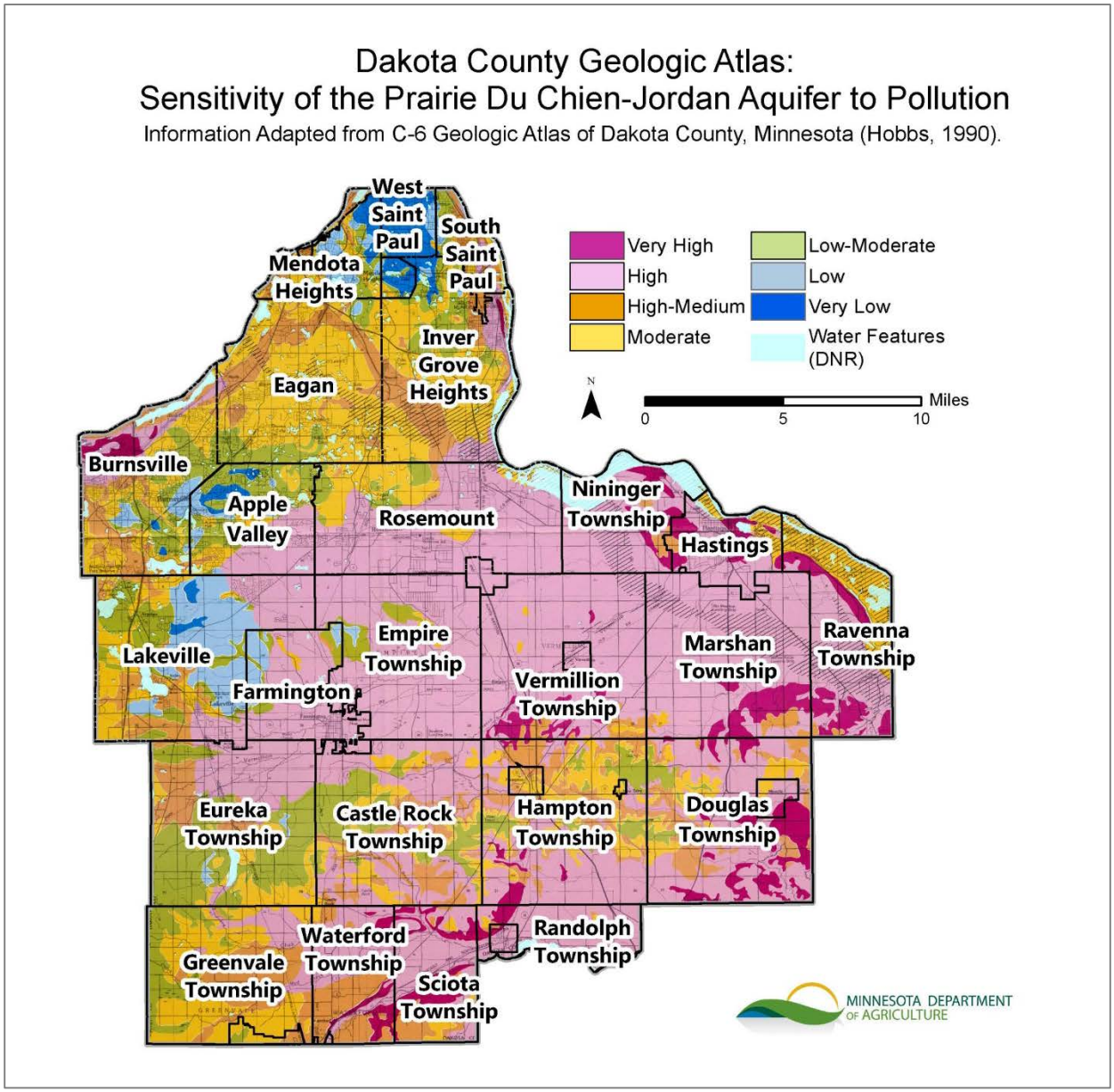

Figure 3. Dakota County Geologic Atlas: Pollution Sensitivity Rating.

COUNTY WELL INDEX

The County Well Index (CWI) is a database system developed by Minnesota Geological Survey and Minnesota Department of Health (MDH) for the storage, retrieval, and editing of water-well information. The database contains basic information on well records (e.g. location, depth, static water level) for wells drilled in Minnesota. The database also contains information on the well log and the well construction for many private drinking water wells. The CWI is instrumental in the development of the Geologic Atlas described in the previous section. The CWI is the most comprehensive Minnesota well database available, but contains only information for wells in which a well log is available. Most of the records in CWI are for wells drilled after 1974, when water-well construction code required well drillers to submit records to the MDH. The CWI does contain data for some records obtained by the MGS through the cooperation of drillers and local government agencies for wells drilled before 1974 (MGS, 2014).

The CWI and the Dakota County well database was used to gather information about the selected townships in Dakota County included in this study. Table 2 summarizes the aquifer types, while the following section is a brief summary of the major aquifer types with the average well depth. According to the information from the CWI (MDH, 2015):

In these townships, there are 2,132 documented (have a verified location in the CWI) wells:

- Approximately 16 percent of wells are completed in a Quaternary aquifer and are 158 feet deep on average.
- The Paleozoic aquifers (80 percent) are utilized the most frequently in the Dakota County study area. Wells in the Prairie du Chien Group average 185 feet deep and the Jordan Sandstone wells average 326 feet deep.

Table 2. General Aquifer Designations According to the County Well Index (CWI).

General Aquifer Designation	Number of Wells in General Aquifers	Percent of Wells in General Aquifers	Specific Aquifer	Aquifer Description	Number of Wells in Specific Aquifers	Percent in Specific Aquifers	Average Depth Completed (Feet)
Undesignated	81	4%	Undesignated	Undesignated	81	4%	139
Multiple	17	<1%	MTPL	Multiple Aquifers	17	1%	212
Quaternary	339	16%				0%	158
			QWTA	Quaternary Water Table	241	11%	171
			QBAA	Quaternary Buried Artesian	68	3%	177
			QBUA	Quaternary Buried Unconfined	27	1%	186
			QUUU	Quaternary Undifferentiated	3	0%	97
Paleozoic	1695	80%					301
			OSTP	St. Peter Sandstone	37	2%	164
			OSPC	St. Peter-Prairie Du Chien	9	0%	224
			OPCJ	Prairie du Chien-Jordan	13	1%	313
			OPDC	Prairie du Chien Group	483	23%	185
			CJDN	Jordan Sandstone	818	38%	326
			CJSL	Jordan-St. Lawrence	30	1%	335
			CSLT	St. Lawrence-Tunnel City	32	2%	330
			CSTL	St. Lawrence	48	2%	316
			CTLR	Tunnel City/Lone Rock Formation	222	10%	334
			CTCW	Tunnel City-Mt. Simon	3	0%	482
Total	2132	100%	Total		2132	100%	202

NITRATE PROBABILITY MAPPING

Minnesota Department of Health (MDH) has developed nitrate probability maps to assist in local water quality planning efforts. These maps identify areas of a county with relatively high, moderate, and low probability of having elevated nitrate concentrations in groundwater. The goal of nitrate probability mapping is to help protect public and private drinking water supplies, help prevent further contamination by raising awareness, and assist in local planning and prevention. The nitrate probability map is similar in appearance compared to the updated aquifer vulnerability map (Figure 2); however in the northern part of Dakota County it shows more area categorized in the low rating. The nitrate probability map MDH produced utilized more data inputs (land use, land slope, surface geology, bedrock geology, and depth to water table) and these account for the differences between the two maps. Dakota County's report was published in 2012 and can be accessed here:

http://www.health.state.mn.us/divs/eh/water/swp/nitrate/reports/2011method/dakota.pdf

TOWNSHIP TESTING

The MDA has updated the 1990 Nitrogen Fertilizer Management Plan (NFMP). The NFMP is the state's blueprint for prevention or minimization of the impacts of nitrogen fertilizer on groundwater. Updating of the NFMP provided an opportunity to restructure county and the state strategies for reducing nitrate contamination of groundwater, with more specific, localized accountability for nitrate contamination from agriculture. In order to effectively reduce nitrate contamination of groundwater resources, it is necessary to identify areas of concern. Areas of concern tend to be fairly localized and therefore township and city boundaries were selected for nitrate testing. Factors such as aquifer vulnerability, row crop production, and previous nitrate results will be used to prioritize townships for sampling. Townships with at least 30 percent of the area characterized with vulnerable groundwater and at least 20 percent of the area in row crop production are shown in Figure 4. This map serves as a starting point for planning sample locations and is modified based on local expertise.

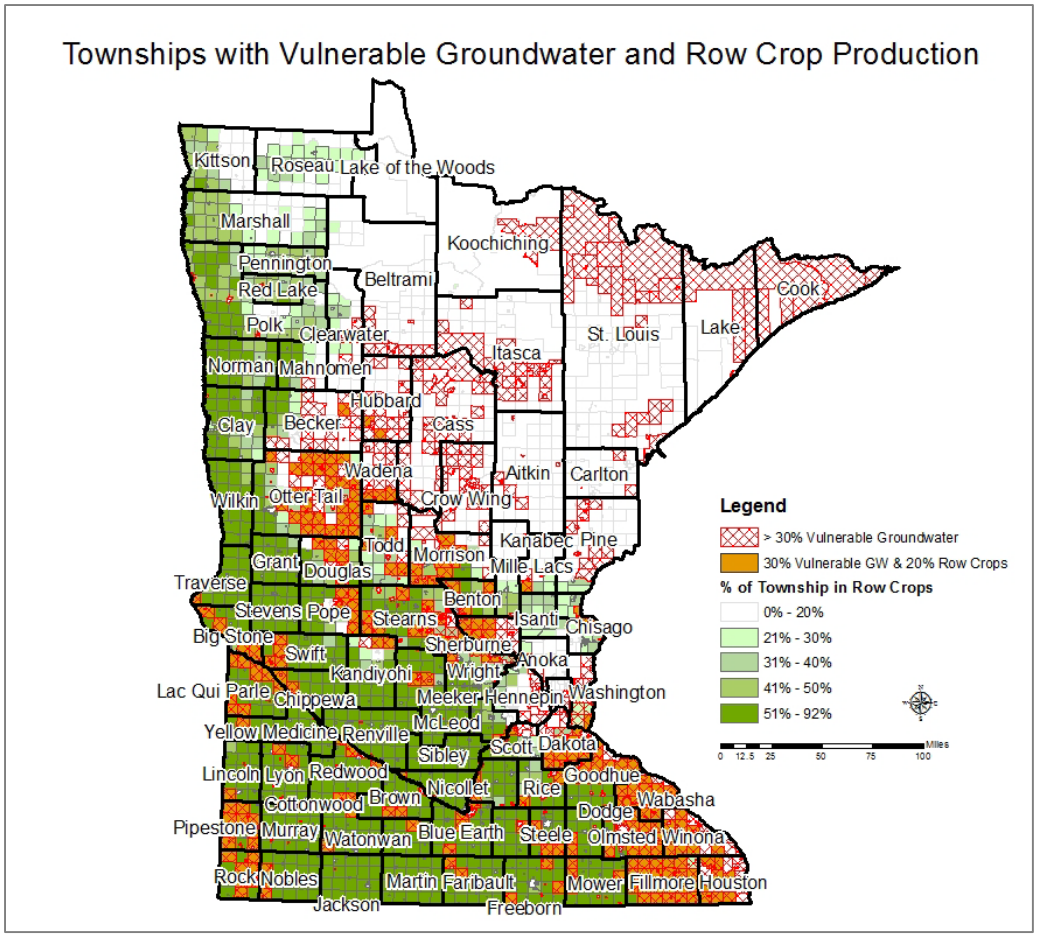

Figure 4. Townships with Vulnerable Groundwater and Row Crop Production.

METHODS

These 18 communities (13 townships and 5 cities) were chosen for sampling based on the following criteria: local expertise from Dakota County, past high nitrate results, vulnerable groundwater, and row crop production. In 2013 and 2014, households in the study area with private wells received an invitation letter from Dakota County to participate in the free nitrate testing supported by MDA. Homeowners with private wells were sent a water sample kit (by a certified lab) which included a survey about their well, sample bottle, sample instructions, and a pre-paid return mailer. All costs of the kit are paid by the MDA using Clean Water Funds. Homeowners were asked to complete the well survey, fill the sample bottle with untreated water, and mail the sample to the certified lab in the prepaid mailer. Once the sample was analyzed, the lab sent homeowners their results in the mail. Table 3 presents the responses received from the homeowners.

Table 3. Responses Received from Homeowners.

Township	Estimated Number of Households on Private Wells	Number of Samples Returned	Return Rate of Sample Kits
Castle Rock	473	101	21%
Coates City	55	11	20%
Douglas	250	68	27%
Empire	220	58	26%
Eureka	525	123	23%
Farmington City	80	18	23%
Greenvale	283	58	20%
Hampton	326	80	25%
Hampton City	NA	2*	NA
Hastings City	40	2*	5%
Marshan	401	115	29%
Nininger	301	88	29%
Randolph	231	55	24%
Ravenna	804	298	37%
Rosemount City	528	165	31%
Sciota	121	29	24%
Vermillion	417	83	20%
Waterford	202	41	20%
Total	5257	1395	27%
*Not included in final summary due to low return rate			

RESULTS

Homeowners returned 1,391 water samples for analysis across the selected townships (Figure 6). Two samples were also collected from the City of Hampton and another two from the City of Hastings, these are not included in the summary due to the low response rate. Most homeowners in both the City of Hastings and the City of Hampton are on a public water supply. On average, 27 percent of households responded to the free nitrate test offered by the MDA (Table 3). The results of the township nitrate sampling are displayed in Figure 5.

The summary statistics for all well construction types *except* known hand dug wells are shown in Table 4. Hand dug wells are often very shallow, typically just intercepting the water table, and therefore are much more sensitive to local surface runoff contamination (feedlot runoff), point source pollution (septic system effluent), or chemical spills. The following paragraphs provide a brief discussion of the statistics presented in Table 4,

which does ***not*** include hand dug wells. There were only two samples submitted from hand dug wells.

The minimum values of nitrate-N were <DL (less than the detection limit), with one exception, the City of Coates (7.6 mg/L). The detection limit for the 2013 samples was 0.023 mg/L and in 2014 it was 0.2 mg/L. The maximum values ranged from to 9.1 to 68.6 mg/L, with Douglas Township having the highest result. The 90th percentiles ranged from <DL to 23.3 mg/L, with Marshan having the higher 90th percentile. The mean nitrate-N values found were 0.8 to 11.7 mg/L with the City of Coates having the highest mean. Results from the sampling revealed that in 12 communities 10 percent or more of the wells were over 10 mg/L nitrate-N. Overall, 27 percent of the wells were greater than or equal to 10 mg/L.

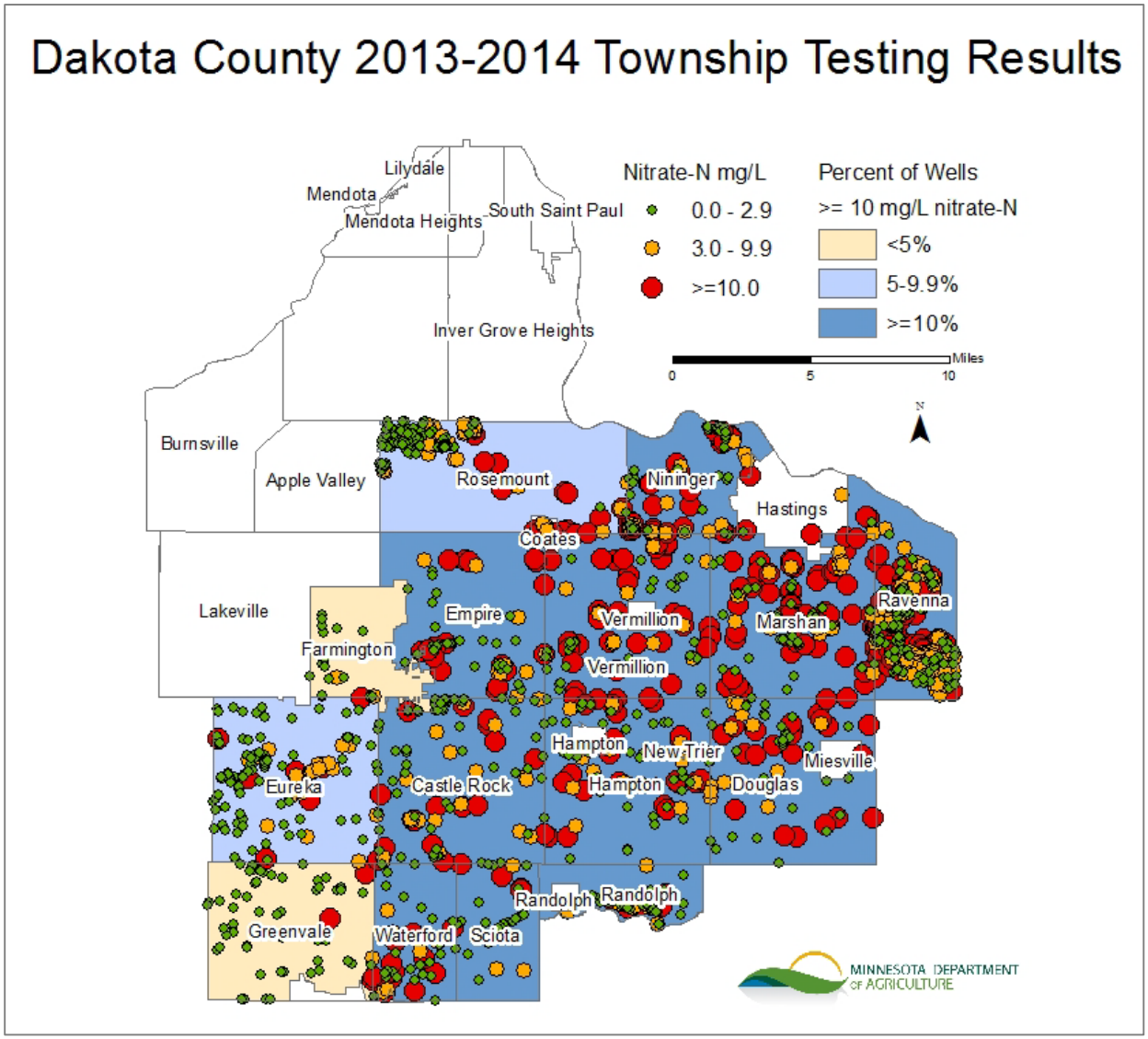

Figure 5. Dakota County 2013-2014 Township Testing Initial Results.

Table 4. Dakota County Township Testing Initial Summary Statistics, Does Not Include Known Hand Dug Wells.

Townships	Total Wells	Values			Percentiles					Number of Wells					Percent				
		Min	Max	Mean	50th (Median)	75th	90th	95th	99th	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L
		Nitrate-N mg/L or parts per million (ppm)																	
Castle Rock	101	<DL	59.8	4.0	<DL	5.8	14.3	15.1	39.2	65	21	28	24	15	64%	21%	28%	24%	15%
Coates City	11	7.6	15.9	11.7	10.5	15.3	15.8	15.9	15.9	0	5	11	11	6	0%	45%	100%	100%	55%
Douglas	68	<DL	68.6	8.3	3.1	12.9	21.8	33.0	62.4	33	11	31	27	24	49%	16%	46%	40%	35%
Empire	58	<DL	30.2	5.9	1.7	11.4	17.9	19.5	29.5	30	10	26	20	18	52%	17%	45%	34%	31%
Eureka	123	<DL	27.4	2.5	<DL	2.7	8.2	13.3	26.8	95	20	24	14	8	77%	16%	20%	11%	7%
Farmington City	18	<DL	9.1	0.9	<DL	<DL	3.8	7.2	9.1	16	2	1	1	0	89%	11%	6%	6%	0%
Greenvale	58	<DL	20.9	0.8	<DL	<DL	<DL	4.4	20.4	55	1	3	2	2	95%	2%	5%	3%	3%
Hampton	80	<DL	28.9	5.9	2.3	10.4	15.9	18.4	26.9	42	14	36	30	24	53%	18%	45%	38%	30%
Marshan	115	<DL	32.7	10.4	11.2	17.2	23.3	27.1	32.1	38	16	72	69	61	33%	14%	63%	60%	53%
Nininger	88	<DL	29.8	7.7	5.0	14.4	21.4	22.6	27.5	39	18	44	42	31	44%	20%	50%	48%	35%
Randolph	55	<DL	18.7	3.0	<DL	5.4	11.0	13.9	18.7	39	10	15	12	6	71%	18%	27%	22%	11%
Ravenna	298	<DL	22.8	7.3	7.1	12.1	15.7	17.5	19.0	94	91	179	151	113	32%	31%	60%	51%	38%
Rosemount City	165	<DL	21.9	2.8	1.1	4.2	6.4	11.5	18.4	107	48	27	16	10	65%	29%	16%	10%	6%
Sciota	29	<DL	21.2	3.3	<DL	2.6	14.5	19.7	21.2	22	3	6	5	4	76%	10%	21%	17%	14%
Vermillion	83	<DL	27.1	8.1	9.3	13.6	19.7	23.5	26.0	30	16	48	43	37	36%	19%	58%	52%	45%
Waterford	41	<DL	33.2	5.8	1.0	10.4	13.5	26.0	33.2	24	6	17	16	11	59%	15%	41%	39%	27%
Total	1391	<DL	29.3*	5.5*	3.3*	8.7*	13.9*	18.0*	26.6*	729	292	568	483	370	52%	21%	41%	35%	27%

* Represents an average value

< DL stands for less than a detectable limit. The detection limit for the 2013 samples was 0.023 mg/L and in 2014 it was 0.2 mg/L. The 50th percentile (75th, 90th, 95th, and 99th) is the value below which 50 percent (75%, 90%, 95%, and 99%) of the observed values fall

WELL SETTING AND CONSTRUCTION

WELL OWNER SURVEY

The well owner survey, sent out with the sampling kit, provided additional information about private wells that were sampled. The survey included questions about the well construction, depth and age, and questions about nearby land use. A blank survey can be found in Appendix A. It is important to note that well information was provided by the well owners and may be approximate or potentially erroneous. The following section is a summary of information gathered from the well owner survey (complete well survey results are located in Appendix B at the end of this document, Tables 6-21).

The majority of wells in each township are located on “rural” property. Approximately 85.7 percent of sampled wells are of drilled construction and 3.1 percent are sand-point wells. There were 2 known hand dug wells sampled which, they are not included in the summary.

The majority (70.1%) of sampled wells are more than 100 feet deep. Most of the wells (58.2%) had not been tested for nitrate within the last ten years or homeowners were unsure if they had ever been tested. Therefore, the results most homeowners receive from this study will provide new information. Overall, less than half (43.8%) of the tested wells are treated with a filter (24.7%) or with a reverse osmosis system (19.1%).

POTENTIAL NITRATE SOURCE DISTANCES

The following response summary relates to isolation distances of potential point sources of nitrate that may contaminate wells. This information was obtained from the well surveys completed by the homeowner (complete well survey results are located at the end of this document, Tables 6-21).

- On average farming takes place on 19.5 percent of the properties.
- Agricultural fields are greater than 300 feet from wells at 49 percent of the properties.
- Only 3.4 percent of the well owners across the communities responded that they have livestock (greater than ten head of cattle or other equivalent) on their property.
- Most wells (72.5 %) are more than 300 feet from an active or inactive feedlot.
- Very few well owners (<1 %) store more than 500 pounds of fertilizer on their property.
- A small minority of wells (3.4 %) are less than 50 feet away from septic systems.

WELL LOGS

In some cases, well owners were able to provide Unique Well Identification Numbers for their wells. When the correct Unique IDs are provided, a well log can be used to identify the aquifer that the well withdraws water from. In this case, 774 wells were identified in the CWI or with the help of the Dakota County Environmental Resources (Table 5). Approximately 56 percent of the sampled wells had corresponding well logs. Thus, the data gathered is only a portion of the total sampled wells.

According to the well logs, the most commonly utilized aquifers in the sampled wells were from the Paleozoic era specifically the Prairie du Chien and Jordan Aquifers. The highest percent of wells over the HRL (17%), are from unknown aquifers, followed by the Quaternary aquifers (4%) Prairie du Chien (3%) and Jordan (3%) aquifers.

Table 5. Aquifer Designation and Nitrate-N Results.

	Number of Wells				Percent of Wells			
	DL<3	3<10	≥10	Total	DL<3	3<10	≥10	Total
Aquifers	Nitrate-N mg/L							
All Quaternary	26	35	54	115	2%	3%	4%	8%
St. Peter Sandstone	16	2	1	19	1%	<1%	<1%	1%
Prairie du Chien Group	169	35	37	241	12%	3%	3%	17%
Prairie du Chien -Jordan	2	0	1	3	<1%	0%	<1%	<1%
Jordan Sandstone	215	50	40	305	15%	4%	3%	22%
Jordan-St. Lawrence	5	0	0	5	<1%	0%	0%	<1%
St. Lawrence	7	0	0	7	<1%	0%	0%	<1%
St. Lawrence - Tunnel City	6	0	2	8	<1%	0%	<1%	<1%
Tunnel City - Mt. Simon	1	0	0	1	<1%	0%	0%	<1%
Tunnel City -Lone Rock	49	6	5	60	4%	<1%	<1%	4%
Tunnel City Group	3	0	0	3	<1%	0%	0%	<1%
Multiple	6	1	0	7	<1%	<1%%	0%	1%
Unknown	224	163	230	617	16%	12%	17%	44%
Total	729	292	370	1391	52%	21%	27%	100%

SUMMARY

In 2013 and 2014, 13 townships and 5 cities were chosen for sampling based on criteria such as past high nitrate results, vulnerable groundwater, and row crop production. Samples were collected in the study area at 1,395 private wells using homeowner collection and mail-in methods. This represents a 27 percent response rate from homeowners. According to the County Well Index (CWI) the Paleozoic aquifers are the most readily used in the selected townships.

Results showed that across the study area, 27 percent of private wells sampled were above the health standard of 10 mg/L for nitrate as nitrogen (nitrate-N.) Results from the sampling revealed that in 12 communities, 10 percent or more of the wells were over 10 mg/L nitrate-N. In Marshan Township, 53 percent were over the health standard in contrast to Farmington Township where no wells were found in excess of the standard.

FUTURE WORK

Well owners with detectable nitrate results from the 2013 and 2014 township testing were offered a free pesticide sample and a follow-up nitrate sample taken by MDA staff. At the time of this resampling a well site visit was performed (when possible) in order to rule out well construction issues and likely point sources of nitrogen. The follow-up nitrate sampling in Dakota County occurred during the fall of 2014 and the summer of 2015, results from this effort will be available in 2016.

The testing conducted in Dakota County is part of a statewide assessment of vulnerable areas as the MDA plans to offer nitrate tests to approximately 70,000 private well owners (within 250-300 townships) between 2014 and 2019. As of February 2016, 104 townships in 10 counties have been completed.

REFERENCES

Balaban, N.H.; Hobbs, H.C. 1990. C-06 Geologic atlas of Dakota County, Minnesota. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy, http://purl.umn.edu/58494.

Minnesota Department of Health. 2012. Nitrate-Nitrogen Probability Ranking Map for the Water Table Aquifer, Dakota County, Minnesota, on-line PDF accessed on 8/04/15 at: http://www.health.state.mn.us/divs/eh/water/swp/nitrate/reports/2011method/dakota.pdf

Minnesota Department of Health, County Well Index website accessed on 3/11/2015 at: http://www.health.state.mn.us/divs/eh/cwi/

Minnesota Department of Natural Resources, 1991. Geologic Sensitivity Project Workgroup. Criteria and guidelines for assessing geologic sensitivity of ground water resources in Minnesota, Minnesota Department of Natural Resources, Division of Waters, St. Paul, Minn., 122 p.

Minnesota Department of Natural Resources, Minnesota Geological Survey, and University of Minnesota –Duluth (1997). Geomorphology of Minnesota, geomorphology data describing a wide variety of conditions related to surficial geology within a hierarchical classification scheme that was devised for use within Minnesota, Scale 1:100,000.

Minnesota Pollution Control Agency, 1998. Baseline Water Quality of Minnesota's Principal Aquifers, Region 2, North Central Minnesota.

Minnesota Geologic Survey, County Atlas Website accessed on 3/17/2015 at: http://www.mngs.umn.edu/county_atlas/countyatlas.htm

Nolan, BT., and Stoner, J.D., 2000. Nutrients in Groundwaters of the Conterminous United States, 1992-95: Environmental Science and Technology, v. 34, no. 7, p. 1156-1165.

Ruhl, J.F. 1987. Hydrogeologic and water-quality characteristics of glacial-drift aquifer in Minnesota: U.S. Geological Survey Water-Resources Investigations Report 87-4224, 3 pls.

U.S. Environmental Protection Agency, 2009. National Primary Drinking Water Regulations list, on-line PDF file accessed on 2/17/2015 at http://water.epa.gov/drink/contaminants/upload/mcl-2.pdf

Warner, K.L., and Arnold, T.L., 2010. Relations that Affect the Probability and Prediction of Nitrate Concentration in Private Wells in the Glacial Aquifer System in the United States, A USGS National Water-Quality Assessment Program Scientific Investigations Report 2010

Dakota County Department of Public Health & Environment [PHE]. 2014. The Dakota County Groundwater Plan 2014-2024, on-line PDF accessed on 3/27/2015 at: http://www.co.Dakota.mn.us/DocumentCenter/View/794

APPENDIX A

Private Well Survey Questions

1. What setting did the water sample come from? Please choose only one.
   Answers choices: Sub-division, Lake Home, River Home, Country, Municipal/city, or Other.

2. Are there livestock on this property? Yes or No

3. Do you mix or store fertilizer (500lbs or more) on this property? Yes or No

4. Does farming take place on this property? Yes or No

Well Information Section

5. Does your well have a Unique Well ID number? Yes or No

6. If yes, what is the Unique ID?
   (6 digit number found on a metal tag attached to your well casing)

7. Type of well construction?
   Answer choices: Drilled, Sandpoint, Hand dug, other, and don't know.

8. Approximate age (years) of your well?
   Answer choices: 0-10 years, 11-20 years, 21-40 years, and over 40 years old.

9. Approximate depth of your well
   Answer choices: 0-50 feet, 51-99 feet, 100-299 feet, and 300 or more feet.

10. Distance to an active or inactive feedlot
    Answer choices: 0-50 feet, 51-99 feet, 100-299 feet, and 300 or more feet.

11. Distance to a septic system
    Answer choices: 0-50 feet, 51-99 feet, 100-299 feet, and 300 or more feet.

12. Distance to an agricultural field
    Answer choices: 0-50 feet, 51-99 feet, 100-299 feet, and 300 or more feet.

13. Is this well currently used for human consumption? Yes or No

14. Please check any water treatment you have other than a water softener.
    Answer choices: None, Reverse osmosis, distillation, filtering system and other.

15. When did you last have your well tested for nitrates?
    Answer choices: Never, within the last year, within the last 3 years, the last 10, or 10 or more.

16. What was the result of your last nitrate test?
    Answer choices: 0<3, 3<10, 10 or greater, or don't know.

APPENDIX B

Table 6. Property Setting.

Property Setting					
Township	Total	Country	Lake	Sub-division	Not Available (NA)
		Percent			
Castle Rock	101	74.3%	0.0%	19.8%	5.9%
Coates City	11	90.9%	0.0%	0.0%	9.1%
Douglas	68	88.2%	0.0%	2.9%	8.8%
Empire	58	91.4%	0.0%	0.0%	8.6%
Eureka	123	85.4%	1.6%	8.1%	4.9%
Farmington City	18	88.9%	0.0%	0.0%	11.1%
Greenvale	58	91.4%	0.0%	5.2%	3.4%
Hampton	80	95.0%	0.0%	0.0%	5.0%
Marshan	115	91.3%	0.0%	0.0%	8.7%
Nininger	88	86.4%	0.0%	5.7%	8.0%
Randolph	55	30.9%	47.3%	12.7%	9.1%
Ravenna	298	85.2%	0.0%	7.7%	7.0%
Rosemount City	165	48.5%	0.6%	40.6%	10.3%
Sciota	29	89.7%	0.0%	0.0%	10.3%
Vermillion	83	81.9%	0.0%	3.6%	14.5%
Waterford	41	85.4%	0.0%	0.0%	14.6%
Total	1391	79.7%	2.1%	10.1%	8.1%

Table 7. Well Construction Type.

Well Construction Type					
Township	Total	Drilled	Sand point	Other	NA
		Percent			
Castle Rock	101	91.1%	3.0%	0.0%	5.9%
Coates City	11	100.0%	0.0%	0.0%	0.0%
Douglas	68	88.2%	1.5%	0.0%	10.3%
Empire	58	63.8%	19.0%	0.0%	17.2%
Eureka	123	81.3%	4.1%	0.0%	14.6%
Farmington City	18	66.7%	5.6%	0.0%	27.8%
Greenvale	58	91.4%	1.7%	1.7%	5.2%
Hampton	80	95.0%	1.3%	0.0%	3.8%
Marshan	115	89.6%	0.9%	0.0%	9.6%
Nininger	88	92.0%	0.0%	0.0%	8.0%
Randolph	55	72.7%	9.1%	0.0%	18.2%
Ravenna	298	86.2%	2.0%	1.0%	10.7%
Rosemount City	165	89.1%	1.2%	0.0%	9.7%
Sciota	29	82.8%	3.4%	0.0%	13.8%
Vermillion	83	80.7%	3.6%	0.0%	15.7%
Waterford	41	78.0%	4.9%	0.0%	17.1%
Total	1391	85.7%	3.1%	0.3%	10.9%

Table 8. Well Age.

Well Age						
Township	Total	0-10 years	11-20 years	21-40 years	Over 40 years	NA
		Percent				
Castle Rock	101	5.0%	19.8%	50.5%	21.8%	3.0%
Coates City	11	18.2%	9.1%	27.3%	36.4%	9.1%
Douglas	68	5.9%	22.1%	33.8%	26.5%	11.8%
Empire	58	20.7%	13.8%	31.0%	24.1%	10.3%
Eureka	123	8.1%	14.6%	42.3%	21.1%	13.8%
Farmington City	18	0.0%	27.8%	33.3%	16.7%	22.2%
Greenvale	58	15.5%	27.6%	20.7%	27.6%	8.6%
Hampton	80	7.5%	25.0%	42.5%	22.5%	2.5%
Marshan	115	7.0%	21.7%	42.6%	21.7%	7.0%
Nininger	88	6.8%	22.7%	43.2%	19.3%	8.0%
Randolph	55	9.1%	29.1%	34.5%	16.4%	10.9%
Ravenna	298	3.0%	19.1%	52.7%	20.5%	4.7%
Rosemount City	165	5.5%	17.6%	56.4%	18.2%	2.4%
Sciota	29	17.2%	27.6%	20.7%	27.6%	6.9%
Vermillion	83	8.4%	16.9%	42.2%	19.3%	13.3%
Waterford	41	7.3%	19.5%	36.6%	26.8%	9.8%
Total	1391	7.2%	20.1%	43.9%	21.4%	7.3%

Table 9. Well Depth.

Well Depth						
Township	Total	0-50 feet	51-100 feet	101-300 feet	Over 300 feet	NA
		Percent				
Castle Rock	101	5.0%	11.9%	51.5%	19.8%	11.9%
Coates City	11	0.0%	0.0%	63.6%	18.2%	18.2%
Douglas	68	0.0%	7.4%	48.5%	27.9%	16.2%
Empire	58	13.8%	15.5%	46.6%	6.9%	17.2%
Eureka	123	3.3%	13.0%	62.6%	0.8%	20.3%
Farmington City	18	5.6%	16.7%	50.0%	0.0%	27.8%
Greenvale	58	6.9%	29.3%	41.4%	5.2%	17.2%
Hampton	80	0.0%	5.0%	47.5%	32.5%	15.0%
Marshan	115	1.7%	4.3%	54.8%	24.3%	14.8%
Nininger	88	1.1%	1.1%	62.5%	17.0%	18.2%
Randolph	55	7.3%	27.3%	20.0%	23.6%	21.8%
Ravenna	298	0.0%	3.0%	60.7%	18.1%	18.1%
Rosemount City	165	0.0%	3.6%	70.9%	9.1%	16.4%
Sciota	29	6.9%	24.1%	17.2%	31.0%	20.7%
Vermillion	83	3.6%	13.3%	45.8%	12.0%	25.3%
Waterford	41	7.3%	19.5%	34.1%	12.2%	26.8%
Total	1391	2.7%	9.2%	54.0%	16.1%	18.0%

Table 10. Does the Well Have a Unique ID.

Does the Well Have a Unique ID				
		No	Yes	NA
Township	Total	Percent		
Castle Rock	101	34.7%	17.8%	47.5%
Coates City	11	9.1%	0.0%	90.9%
Douglas	68	19.1%	19.1%	61.8%
Empire	58	29.3%	15.5%	55.2%
Eureka	123	26.8%	13.0%	60.2%
Farmington City	18	22.2%	5.6%	72.2%
Greenvale	58	25.9%	20.7%	53.4%
Hampton	80	22.5%	21.3%	56.3%
Marshan	115	20.9%	15.7%	63.5%
Nininger	88	23.9%	22.7%	53.4%
Randolph	55	16.4%	30.9%	52.7%
Ravenna	298	29.2%	14.8%	56.0%
Rosemount City	165	18.2%	15.8%	66.1%
Sciota	29	10.3%	17.2%	72.4%
Vermillion	83	26.5%	6.0%	67.5%
Waterford	41	24.4%	9.8%	65.9%
Total	1391	24.6%	16.2%	59.2%

Table 11. Livestock on Property.

Livestock on Property				
		No	Yes	NA
Township	Total	Percent		
Castle Rock	101	85.1%	5.9%	8.9%
Coates City	11	81.8%	9.1%	9.1%
Douglas	68	82.4%	8.8%	8.8%
Empire	58	84.5%	5.2%	10.3%
Eureka	123	90.2%	4.1%	5.7%
Farmington City	18	77.8%	11.1%	11.1%
Greenvale	58	87.9%	5.2%	6.9%
Hampton	80	81.3%	15.0%	3.8%
Marshan	115	85.2%	1.7%	13.0%
Nininger	88	90.9%	0.0%	9.1%
Randolph	55	92.7%	0.0%	7.3%
Ravenna	298	92.3%	0.3%	7.4%
Rosemount City	165	95.2%	0.6%	4.2%
Sciota	29	82.8%	3.4%	13.8%
Vermillion	83	88.0%	1.2%	10.8%
Waterford	41	80.5%	7.3%	12.2%
Total	1391	88.6%	3.4%	8.1%

Table 12. Fertilizer Stored on Property.

Fertilizer Stored On Property				
		No	Yes	NA
Township	Total	Percent		
Castle Rock	101	97.0%	1.0%	2.0%
Coates City	11	100.0%	0.0%	0.0%
Douglas	68	88.2%	2.9%	8.8%
Empire	58	91.4%	1.7%	6.9%
Eureka	123	96.7%	0.8%	2.4%
Farmington City	18	77.8%	11.1%	11.1%
Greenvale	58	94.8%	1.7%	3.4%
Hampton	80	93.8%	2.5%	3.8%
Marshan	115	95.7%	0.0%	4.3%
Nininger	88	93.2%	0.0%	6.8%
Randolph	55	90.9%	0.0%	9.1%
Ravenna	298	94.3%	0.0%	5.7%
Rosemount City	165	95.2%	0.6%	4.2%
Sciota	29	93.1%	0.0%	6.9%
Vermillion	83	89.2%	1.2%	9.6%
Waterford	41	90.2%	0.0%	9.8%
Total	1391	93.7%	0.9%	5.5%

Table 13. Does Farming Take Place on Property.

Does Farming Take Place on Property				
		No	Yes	NA
Township	Total	Percent		
Castle Rock	101	71.3%	26.7%	2.0%
Coates City	11	90.9%	9.1%	0.0%
Douglas	68	42.6%	48.5%	8.8%
Empire	58	70.7%	22.4%	6.9%
Eureka	123	60.2%	36.6%	3.3%
Farmington City	18	66.7%	22.2%	11.1%
Greenvale	58	62.1%	34.5%	3.4%
Hampton	80	58.8%	38.8%	2.5%
Marshan	115	67.0%	27.8%	5.2%
Nininger	88	84.1%	10.2%	5.7%
Randolph	55	87.3%	3.6%	9.1%
Ravenna	298	91.3%	3.4%	5.4%
Rosemount City	165	92.1%	4.2%	3.6%
Sciota	29	72.4%	20.7%	6.9%
Vermillion	83	67.5%	24.1%	8.4%
Waterford	41	63.4%	26.8%	9.8%
Total	1391	75.3%	19.5%	5.2%

Table 14. Distance to an Active Feedlot.

Distance to an Active Feedlot						
Township	Total	0-50 feet	51-100 feet	101-300 feet	Over 300 feet	NA
		Percent				
Castle Rock	101	3.0%	3.0%	8.9%	74.3%	10.9%
Coates City	11	18.2%	0.0%	0.0%	81.8%	0.0%
Douglas	68	1.5%	10.3%	13.2%	63.2%	11.8%
Empire	58	1.7%	3.4%	1.7%	72.4%	20.7%
Eureka	123	7.3%	2.4%	6.5%	71.5%	12.2%
Farmington City	18	0.0%	11.1%	0.0%	61.1%	27.8%
Greenvale	58	3.4%	5.2%	3.4%	69.0%	19.0%
Hampton	80	5.0%	0.0%	7.5%	72.5%	15.0%
Marshan	115	6.1%	3.5%	2.6%	64.3%	23.5%
Nininger	88	2.3%	2.3%	0.0%	76.1%	19.3%
Randolph	55	3.6%	1.8%	1.8%	83.6%	9.1%
Ravenna	298	4.7%	0.7%	2.0%	76.8%	15.8%
Rosemount City	165	8.5%	1.2%	0.6%	73.9%	15.8%
Sciota	29	6.9%	3.4%	3.4%	72.4%	13.8%
Vermillion	83	2.4%	3.6%	2.4%	69.9%	21.7%
Waterford	41	2.4%	4.9%	7.3%	63.4%	22.0%
Total	1391	4.7%	2.7%	3.7%	72.5%	16.3%

Table 15. Distance to Septic System.

Distance to Septic System						
Township	Total	0-50 feet	51-100 feet	101-300 feet	Over 300 feet	NA
		Percent				
Castle Rock	101	3.0%	28.7%	57.4%	5.9%	5.0%
Coates City	11	9.1%	45.5%	27.3%	9.1%	9.1%
Douglas	68	1.5%	19.1%	52.9%	16.2%	10.3%
Empire	58	8.6%	41.4%	34.5%	6.9%	8.6%
Eureka	123	2.4%	32.5%	46.3%	12.2%	6.5%
Farmington City	18	11.1%	38.9%	33.3%	0.0%	16.7%
Greenvale	58	3.4%	25.9%	51.7%	12.1%	6.9%
Hampton	80	2.5%	37.5%	42.5%	15.0%	2.5%
Marshan	115	4.3%	21.7%	58.3%	7.8%	7.8%
Nininger	88	1.1%	44.3%	45.5%	2.3%	6.8%
Randolph	55	5.5%	34.5%	43.6%	9.1%	7.3%
Ravenna	298	2.7%	32.2%	47.7%	9.7%	7.7%
Rosemount City	165	5.5%	27.3%	51.5%	11.5%	4.2%
Sciota	29	0.0%	31.0%	37.9%	17.2%	13.8%
Vermillion	83	2.4%	34.9%	44.6%	8.4%	9.6%
Waterford	41	0.0%	22.0%	53.7%	14.6%	9.8%
Total	1391	3.4%	31.2%	48.3%	9.9%	7.2%

Table 16. Distance to an Agricultural Field.

Distance to an Agricultural Field						
Township	Total	0-50 feet	51-100 feet	101-300 feet	Over 300 feet	NA
		Percent				
Castle Rock	101	7.9%	9.9%	29.7%	49.5%	3.0%
Coates City	11	18.2%	18.2%	54.5%	9.1%	0.0%
Douglas	68	7.4%	14.7%	32.4%	36.8%	8.8%
Empire	58	5.2%	25.9%	29.3%	29.3%	10.3%
Eureka	123	5.7%	13.8%	30.9%	42.3%	7.3%
Farmington City	18	5.6%	27.8%	38.9%	11.1%	16.7%
Greenvale	58	12.1%	20.7%	34.5%	27.6%	5.2%
Hampton	80	8.8%	20.0%	25.0%	42.5%	3.8%
Marshan	115	4.3%	13.9%	40.0%	33.9%	7.8%
Nininger	88	2.3%	10.2%	26.1%	53.4%	8.0%
Randolph	55	3.6%	3.6%	25.5%	58.2%	9.1%
Ravenna	298	2.7%	6.4%	14.4%	67.4%	9.1%
Rosemount City	165	3.6%	1.8%	10.3%	74.5%	9.7%
Sciota	29	6.9%	17.2%	27.6%	37.9%	10.3%
Vermillion	83	3.6%	12.0%	44.6%	25.3%	14.5%
Waterford	41	7.3%	19.5%	39.0%	24.4%	9.8%
Total	1391	5.1%	11.4%	26.2%	49.0%	8.3%

Table 17. Is the Well Used for Human Consumption?

Is the Well Used for Drinking Water				
Township	Total	No	Yes	NA
		Percent		
Castle Rock	101	3.0%	95.0%	2.0%
Coates City	11	0.0%	100.0%	0.0%
Douglas	68	0.0%	91.2%	8.8%
Empire	58	1.7%	91.4%	6.9%
Eureka	123	2.4%	93.5%	4.1%
Farmington City	18	5.6%	83.3%	11.1%
Greenvale	58	1.7%	96.6%	1.7%
Hampton	80	1.3%	95.0%	3.8%
Marshan	115	2.6%	91.3%	6.1%
Nininger	88	2.3%	90.9%	6.8%
Randolph	55	0.0%	89.1%	10.9%
Ravenna	298	0.3%	95.3%	4.4%
Rosemount City	165	0.6%	96.4%	3.0%
Sciota	29	0.0%	93.1%	6.9%
Vermillion	83	1.2%	90.4%	8.4%
Waterford	41	2.4%	85.4%	12.2%
Total	1391	1.4%	93.3%	5.3%

Table 18. Treatment System for Drinking Water.

Treatment System Used for Drinking Water					
Township	Total	Filtering System	Reverse Osmosis	None	NA
Castle Rock	101	27.7%	20.8%	41.6%	9.9%
Coates City	11	27.3%	0.0%	54.5%	18.2%
Douglas	68	20.6%	14.7%	52.9%	11.8%
Empire	58	22.4%	25.9%	36.2%	15.5%
Eureka	123	23.6%	21.1%	43.1%	12.2%
Farmington City	18	38.9%	27.8%	5.6%	27.8%
Greenvale	58	22.4%	22.4%	50.0%	5.2%
Hampton	80	25.0%	12.5%	56.3%	6.3%
Marshan	115	19.1%	26.1%	44.3%	10.4%
Nininger	88	29.5%	13.6%	42.0%	14.8%
Randolph	55	30.9%	25.5%	27.3%	16.4%
Ravenna	298	24.5%	16.8%	48.0%	10.7%
Rosemount City	165	27.3%	11.5%	50.3%	10.9%
Sciota	29	27.6%	20.7%	37.9%	13.8%
Vermillion	83	24.1%	27.7%	37.3%	10.8%
Waterford	41	14.6%	26.8%	34.1%	24.4%
Total	1391	24.7%	19.1%	44.4%	11.8%

Table 19. Last Tested for Nitrate.

When was the Well Last Tested for Nitrate								
Township	Total	Within the past year	Within the last 3 years	Within the last 10 years	Greater than 10 years	Not Sure	Never Tested	NA
		Percent						
Castle Rock	101	5.9%	14.9%	19.8%	14.9%	19.8%	22.8%	2.0%
Coates City	11	9.1%	18.2%	18.2%	18.2%	27.3%	9.1%	0.0%
Douglas	68	5.9%	7.4%	27.9%	16.2%	23.5%	11.8%	7.4%
Empire	58	6.9%	20.7%	17.2%	13.8%	19.0%	13.8%	8.6%
Eureka	123	4.1%	8.1%	13.0%	18.7%	28.5%	22.0%	5.7%
Farmington City	18	5.6%	5.6%	5.6%	22.2%	11.1%	38.9%	11.1%
Greenvale	58	8.6%	13.8%	20.7%	17.2%	22.4%	15.5%	1.7%
Hampton	80	7.5%	13.8%	31.3%	17.5%	16.3%	12.5%	1.3%
Marshan	115	6.1%	18.3%	27.8%	13.9%	12.2%	13.9%	7.8%
Nininger	88	4.5%	19.3%	29.5%	12.5%	17.0%	10.2%	6.8%
Randolph	55	1.8%	20.0%	7.3%	14.5%	34.5%	16.4%	5.5%
Ravenna	298	4.4%	11.4%	29.2%	16.1%	17.4%	17.8%	3.7%
Rosemount City	165	2.4%	14.5%	13.3%	16.4%	24.8%	24.8%	3.6%
Sciota	29	0.0%	20.7%	24.1%	10.3%	24.1%	13.8%	6.9%
Vermillion	83	9.6%	22.9%	22.9%	10.8%	18.1%	8.4%	7.2%
Waterford	41	9.8%	7.3%	14.6%	14.6%	29.3%	14.6%	9.8%
Total	1391	5.2%	14.3%	22.1%	15.5%	20.7%	17.1%	5.0%

Table 20. Last Nitrate Result.

What was the Last Nitrate Result					
Township	Total	<3 mg/L	3<10 mg/L	>= 10 mg/L	NA
		Percent			
Castle Rock	101	14.9%	5.9%	4.0%	75.2%
Coates City	11	0.0%	9.1%	27.3%	63.6%
Douglas	68	8.8%	13.2%	4.4%	73.5%
Empire	58	8.6%	10.3%	6.9%	74.1%
Eureka	123	12.2%	6.5%	0.8%	80.5%
Farmington City	18	5.6%	0.0%	0.0%	94.4%
Greenvale	58	13.8%	3.4%	1.7%	81.0%
Hampton	80	18.8%	10.0%	6.3%	65.0%
Marshan	115	17.4%	13.9%	13.9%	54.8%
Nininger	88	19.3%	17.0%	11.4%	52.3%
Randolph	55	18.2%	5.5%	0.0%	76.4%
Ravenna	298	12.1%	17.8%	5.4%	64.8%
Rosemount City	165	15.2%	4.2%	0.6%	80.0%
Sciota	29	3.4%	3.4%	0.0%	93.1%
Vermillion	83	15.7%	12.0%	12.0%	60.2%
Waterford	41	4.9%	4.9%	4.9%	85.4%
Total	1391	13.6%	10.6%	5.5%	70.4%