FINAL TOWNSHIP TESTING NITRATE REPORT: DAKOTA COUNTY 2013-2015

March 2017

Updated: February 2018

Minnesota Department of Agriculture

Pesticide and Fertilizer Management Division

ACKNOWLEDGEMENTS

MDA PRIMARY AUTHOR

Nikol Ross

MDA CONTRIBUTORS AND REVIEWERS

Kimberly Kaiser, Larry Gunderson, Annie Felix-Gerth, and Bruce Montgomery

DAKOTA COUNTY ENVIRONMENTAL RESOURCES PARTNERS

Jill Trescott, Steve Scott, and Vanessa Demuth

FUNDING

Project dollars provided by the Clean Water Fund (from the Clean Water, Land and Legacy Amendment).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

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 sources such as fertilizer, animal manure, and human waste. Nitrate is a concern because it can be a risk to human health at elevated levels. The Minnesota Department of Health (MDH) has established a Health Risk Limit (HRL) of 10 mg/L nitrate as nitrogen (nitrate-N) for private drinking water wells in Minnesota.

In response to health concerns over nitrate-N in drinking water the Minnesota Department of Agriculture (MDA) developed the Nitrogen Fertilizer Management Plan (NFMP). The NFMP outlines a statewide plan to assess vulnerable areas for nitrate in groundwater known as the Township Testing Program.

The goal of the Township Testing Program is to identify areas that have high nitrate concentrations in their groundwater. Areas were selected based on historically elevated nitrate conditions, aquifer vulnerability and row crop production. The MDA plans to offer nitrate tests to approximately 70,000 private well owners (within 250-300 townships) between 2014 and 2019. This will be one of the largest nitrate testing efforts ever conducted and completed.

In 2013 and 2014, private wells in the Dakota County study area (thirteen townships and five cities) were sampled for nitrate. Samples were collected from private wells using homeowner collection and mail-in methods. These initial samples were collected from 1,393 wells representing an average response rate of 27 percent of homeowners. Well log information was obtained when available and correlated with nitrate results.

The MDA completed follow-up sampling and well site visits at 487 wells in 2014 and 2015. A follow-up sampling was offered to all homeowners with wells that had a detectable nitrate result.

A well site visit was conducted to identify wells that were unsuitable for analysis. Wells with construction issues or nearby potential point sources of nitrogen were removed from the final well dataset. Point sources of nitrogen include: feedlots, subsurface sewage treatment systems, fertilizer spills, bulk storage of fertilizer, and wastewater treatment plants. A total of 205 (15%) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of 1,184 wells.

The final well dataset was analyzed to determine the percentage of wells over the HRL of 10 mg/L nitrate-N. When analyzed at the township or city scale the percent of wells over the HRL ranged from 0 to 44.2 percent. In the Dakota County study area, it is estimated that 3,919 residents could have well water with nitrate-N over the Health Risk Limit.

Although it is early in the Township Testing Program, it was quite apparent that there are wide spread nitrate problems in Dakota County. Over half of the townships and cities in Dakota County are showing significant problems with 10% of wells over the HRL.

INTRODUCTION

The Minnesota Department of Agriculture (MDA) is the lead agency for nitrogen fertilizer use and management. The NFMP is the state's blueprint for prevention or minimization of the impacts of nitrogen fertilizer on groundwater. The MDA revised the Nitrogen Fertilizer Management Plan (NFMP) in 2015. Updating the NFMP provided an opportunity to restructure county and state strategies for reducing nitrate contamination of groundwater, with more specific, localized accountability for nitrate contamination from agriculture. The NFMP outlines how the MDA addresses elevated nitrate levels in groundwater. The NFMP has four components: prevention, monitoring, assessment and mitigation.

The goal of nitrate monitoring and assessment is to develop a comprehensive understanding of the severity, magnitude, and long term trends of nitrate in groundwater as measured in public and private wells. The MDA established the Township Testing Program to determine current nitrate concentrations in private wells on a township scale. This program is designed to quickly assess a township in a short time window. Monitoring focuses on areas of the state where groundwater nitrate contamination is more likely to occur. This is based initially on hydrogeologically vulnerable areas where appreciable acres of agricultural crops are grown. Statewide the MDA plans to offer nitrate tests to up to 70,000 private well owners (within 250-300 townships) between 2014 and 2019.

In 2013 and 2014, thirteen townships and five cities in Dakota County were selected to participate in the Township Testing Program (Figure 1). Areas were chosen based on several criteria. Criteria used includes: professional knowledge shared by the local soil and water conservation district (SWCD) or county environmental departments, past high nitrate as nitrogen (nitrate-N) results, vulnerable groundwater, and the amount of row crop production. Initial water samples were collected from private wells by homeowners and mailed to a laboratory. Sample results were mailed by the lab to the participating homeowners. The sampling, analysis, and results were provided at no cost to participating homeowners and paid for by the Clean Water Fund.

Well owners with detectable nitrate-N results were offered a no cost pesticide sample and a follow-up nitrate-N sample collected by MDA staff. The MDA began evaluating pesticide presence and concentrations in private water wells at the direction of the Minnesota Legislature. The follow-up pesticide and nitrate-N sampling in Dakota County occurred during the summers of 2014 and 2015. The follow-up included a well site visit (when possible) in order to rule out well construction issues and to identify potential point sources of nitrogen (Appendix A). Wells that had questionable construction integrity or are near a point source of nitrogen were removed from the final well dataset. After the unsuitable wells were removed, the nitrate-N concentrations of well water were assessed for each area.

For further information on the NFMP and Township Testing Program, please visit the following webpages:

www.mda.state.mn.us/nfmp
www.mda.state.mn.us/townshiptesting

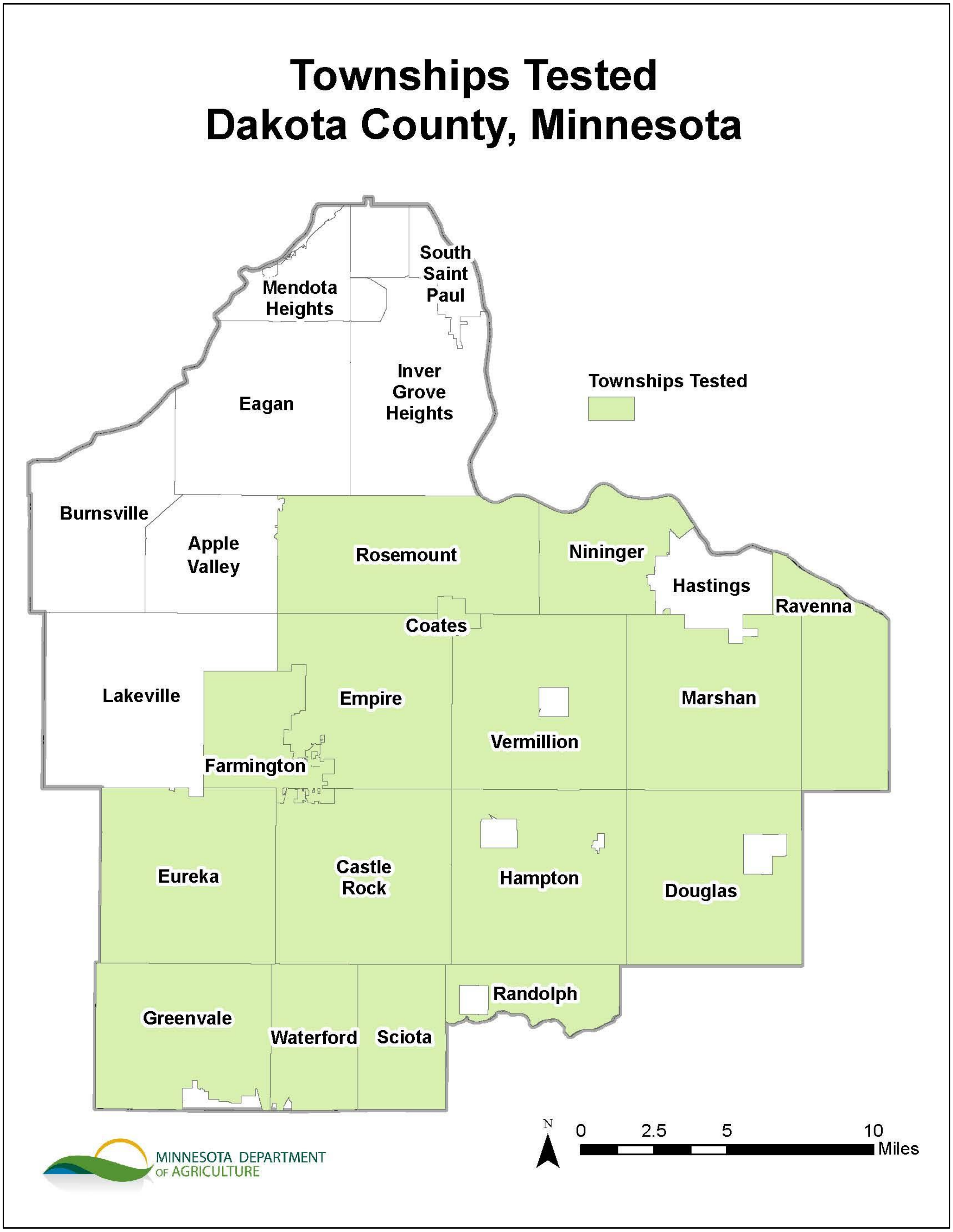


Figure 1. Townships Tested in Dakota County

BACKGROUND

In many rural areas of Minnesota, nitrate is one of the most common contaminants in groundwater, and in some localized areas, 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 other 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 United States Environmental Protection Agency has established a drinking water Maximum Contaminant Level (MCL) of 10 mg/L for nitrate as nitrogen (nitrate-N) (US EPA, 2009) in municipal water systems. The 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. In the environment, nitrite generally converts to nitrate, which means nitrite occurs very rarely in groundwater. The nitrite concentration is commonly less than the reporting level of 0.01 mg/L, resulting in a negligible contribution to the nitrate plus nitrite concentration (Nolan and Stoner, 2000). Therefore, analytical methods generally combine nitrate plus nitrite 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).

NITROGEN POINT SOURCES

The focus of the Township Testing Program is to assess nitrogen contamination in groundwater as a result of commercial nitrogen fertilizer applied to cropland. Any wells potentially impacted by point sources were removed from the final well dataset. Potential point sources such as subsurface sewage treatment systems (more commonly known as septic systems), feedlots, fertilizer spills, bulk storage of fertilizer, and wastewater treatment plants are considered in this section. Below is a brief overview of these sources in Dakota County. Further details are in Appendix B.

SUBSURFACE SEWAGE TREATMENT SYSTEM

Subsurface Sewage treatment systems (SSTS) can be a potential source for contaminates in groundwater such as nitrate and fecal material (MDH, 2014). In Dakota County, over a recent 13 year period (2002-2014), a total of 2,409 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Dakota County, 33% are newer than 2002 (MPCA, 2015a). When new SSTS's are installed they are required to be in compliance with the rules at the time of installation. Newer systems meet modern SSTS regulations and must comply with the current well code; which requires a 50 foot horizontal separation from the well (MDH, 2014).

FEEDLOT

Manure produced on a feedlot can be a potential source of nitrogen pollution if improperly stored or spread. In the Dakota County study area there are a total of 322 feedlots. The majority of the feedlots are permitted to house less than 300 animal units (AU) (Appendix B; Figure 3). Douglas and Sciota Townships have the most permitted AU per square mile (Appendix B; Table 7).

FERTILIZER STORAGE LOCATION

Bulk fertilizer storage locations are potential point sources of nitrogen because they store large concentrations of nitrogen based chemicals. Licenses are required for individuals and companies that store large quantities of fertilizer. The Dakota County study area has a total of 94 fertilizer storage licenses with the vast majority registered in Marshan and Vermillion Townships (Appendix B; Table 8).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of 22 historic fertilizer spills and investigations occurred in the Dakota County study area. The majority of these were located in the City of Rosemount and Marshan Township (Appendix B; Table 10).

WASTEWATER

There are three active wastewater treatment plants and two abandoned wastewater treatment plants in the study area. The treated water from these plants discharges into surface water. These discharges are not considered a groundwater point source to private wells in the Dakota County Study area.

TOWNSHIP TESTING METHODS

VULNERABLE TOWNSHIPS

Well water sampling is focused on areas that are considered vulnerable to groundwater contamination by nitrogen fertilizer. Typically townships and cities are selected for sampling if more than 30% of the underlying geology is considered vulnerable and more than 20% of the land cover is row crop agriculture. These are not rigid criteria, but are instead used as a starting point for creating an initial plan. A map depicting the areas that meet this preliminary criteria can be found in the initial Dakota County report (MDA, 2016a). Additional factors such as previous nitrate results and local knowledge of groundwater conditions were, and continue to be, used to prioritize townships for testing.

Aquifer sensitivity ratings from the Minnesota Department of Natural Resources were used to estimate the percentage of geology vulnerable to groundwater contamination. The ratings are based upon guidance from the Geologic Sensitivity Project Workshop's report "Criteria and Guidelines for Assessing Geologic Sensitivity in Ground Water Resources in Minnesota" (MDNR, 1991). A map depicting these sensitivities and a more detailed description can be found in the initial Dakota County report (MDA, 2016a). The National Agriculture Statistics Service data (USDA NASS, 2016) on cropland was used to determine the percentage of row crop agriculture. A map and table depicting the extent of the cropland in Dakota County can be found in Appendix C (Figure 5, Table 11).

PRIVATE WELL SAMPLING - NITRATE

The testing is done in two steps in each township: "initial" sampling and "follow-up" sampling. The initial sampling for nitrate-N was conducted in 2013 and 2014. In the initial sampling, all private well owners in the selected townships or cities are sent a nitrate test kit. These kits include instructions on how to collect a water sample, a sample bottle, a voluntary survey, and a prepaid mailer. Each homeowner was mailed the nitrate result for their well along with an explanatory brochure (Appendix D). Well water samples were collected by 1,393 homeowners using the mail-in kit (Table 1). These 1,393 samples are considered the "initial well dataset". The four samples collected in the City of Hampton and Hastings are not evaluated in this study.

All of the homeowners with a nitrate-N detection from the initial sampling were asked to participate in a follow-up well site visit and sampling. The well site visit and follow-up sampling was conducted in 2014 and 2015 by MDA staff. A total of 487 follow-up samples were analyzed (Table 1).

Each follow-up visit was conducted at the well site by a trained MDA hydrologist. Well water was purged from the well for 15 minutes before a sample was collected to ensure a fresh water sample. Additionally, precautions were taken to ensure no cross-contaminate occurred. A more thorough explanation of the sampling process is described in the sampling and analysis plan (MDA, 2016b). As part of the follow-up sampling, homeowners were offered a no cost pesticide test. As pesticide results are finalized they will be posted online in a separate report (http://www.mda.state.mn.us/pwps.aspx).

Table 1. Homeowner Participation in Initial and Follow-Up Well Water Sampling, Dakota County

Township	Estimated Households on Private Wells	Initial Well Dataset**	Well Site Visits & Follow-Up Sampling Conducted
Castle Rock	473	101	32
Coates (city)	55	11	7
Douglas	250	68	26
Empire	220	58	14
Eureka	525	123	29
Farmington (city)	80	18	1
Greenvale	283	58	2
Hampton	326	80	31
Hampton (city)*	NA	2*	NA
Hastings (city)*	40	2*	NA
Marshan	401	115	53
Nininger	301	88	33
Randolph	231	55	15
Ravenna	804	297	137
Rosemount (city)	528	165	52
Sciota	121	29	5
Vermillion	417	82	39
Waterford	202	41	11
Total	5,257	1,393	487

* These cities were not included in the final study due to their low sample numbers.
** Due to township and address discrepancies, the values presented in this report may not match the initial Dakota County report (MDA, 2016a)

The well site visit was used to collect information on potential nitrogen point sources, well characteristics (construction type, depth, and age) and the integrity of the well construction. Well site visit information was recorded on the Well Information and Potential Nitrate Source Inventory Form (Appendix A).

WELL ASSESSMENT

All wells testing higher than 5 mg/L were carefully examined for well construction, potential point sources and other potential concerns.

Using the following criteria, a total of 205 wells were removed to create the final well dataset. See Appendix E (Table 14 and 15) for a summary of the removed wells.

HAND DUG

All hand dug wells were removed from the dataset, even if the nitrate-N result was less than 5 mg/L. Hand dug wells do not meet well code and are more susceptible to local surface runoff contamination. 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.

POINT SOURCE

Well code in Minnesota requires wells to be at least 50 feet away from most possible nitrogen point sources such as SSTS (septic tanks and drain fields), animal feedlots, etc. High nitrate-N wells that did not maintain the proper distance from these point sources were removed from the final well dataset. Information gathered from well site visits was used to assess these distances. If a well was not visited by MDA staff, the well survey information provided by the homeowner and aerial imagery was reviewed.

WELL CONSTRUCTION PROBLEM

The well site visits allowed the MDA staff to note the well construction of each well. Some wells had noticeable well construction problems. For instance, a few wells were missing bolts from the cap, making the groundwater susceptible to pollution. Other examples include wells buried underground or wells with cracked casing. Wells with significant problems such as these were excluded from the final well dataset.

IRRIGATION WELL

If the water sample from the initial homeowner sample was likely collected from an irrigation well, it was removed from the dataset. This study is focused on wells that supply drinking water.

UNSURE OF WATER SOURCE

Also, if the water source of the sample was uncertain, then data pertaining to this sample was removed.

SITE VISIT COMPLETED - WELL NOT FOUND & CONSTRUCTED BEFORE 1975 & NO WELL ID

Old wells with no validation on the condition of well construction were removed from the dataset. These wells were installed before the well code was developed in Minnesota (mid-1975), did not have a well log, and MDA staff could not locate the well during a site visit.

NO SITE VISIT & CONSTRUCTED BEFORE 1975 & NO WELL ID

Additionally if there was no site visit conducted, and the well is an older well (pre-1975) the well would not be used in the final analysis.

NO SITE VISIT & INSUFFICIENT DATA & NO WELL ID

Wells that were clearly lacking necessary background information were also removed from the dataset. These wells did not have an associated well log, were not visited by MDA staff, and the homeowner did not fill out the initial well survey or the address could not be found.

RESULTS

FINAL WELL DATASET

A total of 1,393 well water samples were collected by homeowners across thirteen townships and five cities. The initial published report shows 1,395 wells, but two wells were found to be duplicates and were removed. The City of Hastings and Hampton were not included in the final study due to low sample number, therefore these four samples were removed creating an initial well dataset of 1,389 wells. A total of 205 (15%) wells were found to be unsuitable and were removed to create the final well dataset. The final analysis was conducted on the remaining 1,184 wells (Table 2). The wells in the final well dataset represent ambient groundwater conditions.

WELL WATER NITROGEN ANALYSIS

The final analysis was based on the number of wells over the nitrate-N Health Risk Limit of 10 mg/L. A minimum of 30 wells was determined to be an adequate sample size for analysis. There were less than 30 wells in the City of Coates, City of Farmington, Sciota Township, and Waterford Township.

Table 2 shows the results for all townships and cities sampled. The percent of wells over the Health Risk Limit ranged from 0 to 44.2 (excluding the City of Coates, which is 1.4 square miles and was considered too small to be evaluated individually).

Table 2. Initial and Final Well Dataset Results, Dakota County

Township	Initial Well Dataset	Final well Dataset	Wells ≥10 mg/L Nitrate-N	
			Count	Percentage
Castle Rock	101	93	10	10.8%
Coates (city)	11	5*	3	60.0%
Douglas	68	50	8	16.0%
Empire	58	49	11	22.4%
Eureka	123	110	2	1.8%
Farmington (city)	18	18*	0	0.0%
Greenvale	58	56	1	1.8%
Hampton	80	67	16	23.9%
Marshan	115	95	42	44.2%
Nininger	88	72	19	26.4%
Randolph	55	47	4	8.5%
Ravenna	297	243	77	31.7%
Rosemount (city)	165	154	5	3.2%
Sciota	29	26*	2	7.7%
Vermillion	82	70	27	38.6%
Waterford	41	29*	2	6.9%
Total	1,389	1,184	229	19.3%**

* Insufficient sample size
** Represents a weighted average

The individual nitrate-N results from this final well dataset are displayed spatially in Figure 2. Due to the inconsistencies with geocoding the locations, the accuracy of the points is variable and thirteen wells are not depicted.

The final well dataset summary statistics are shown in Table 3. The minimum values were all below the detection limit; except for Coates. The maximum values ranged from 9.1 to 32.7 mg/L nitrate-N, with Marshan Township having the highest result. The 90th percentile ranged from below the detection limit to 18.9 mg/L nitrate-N, with Greenvale Township having the lowest result and Marshan Township having the highest result.

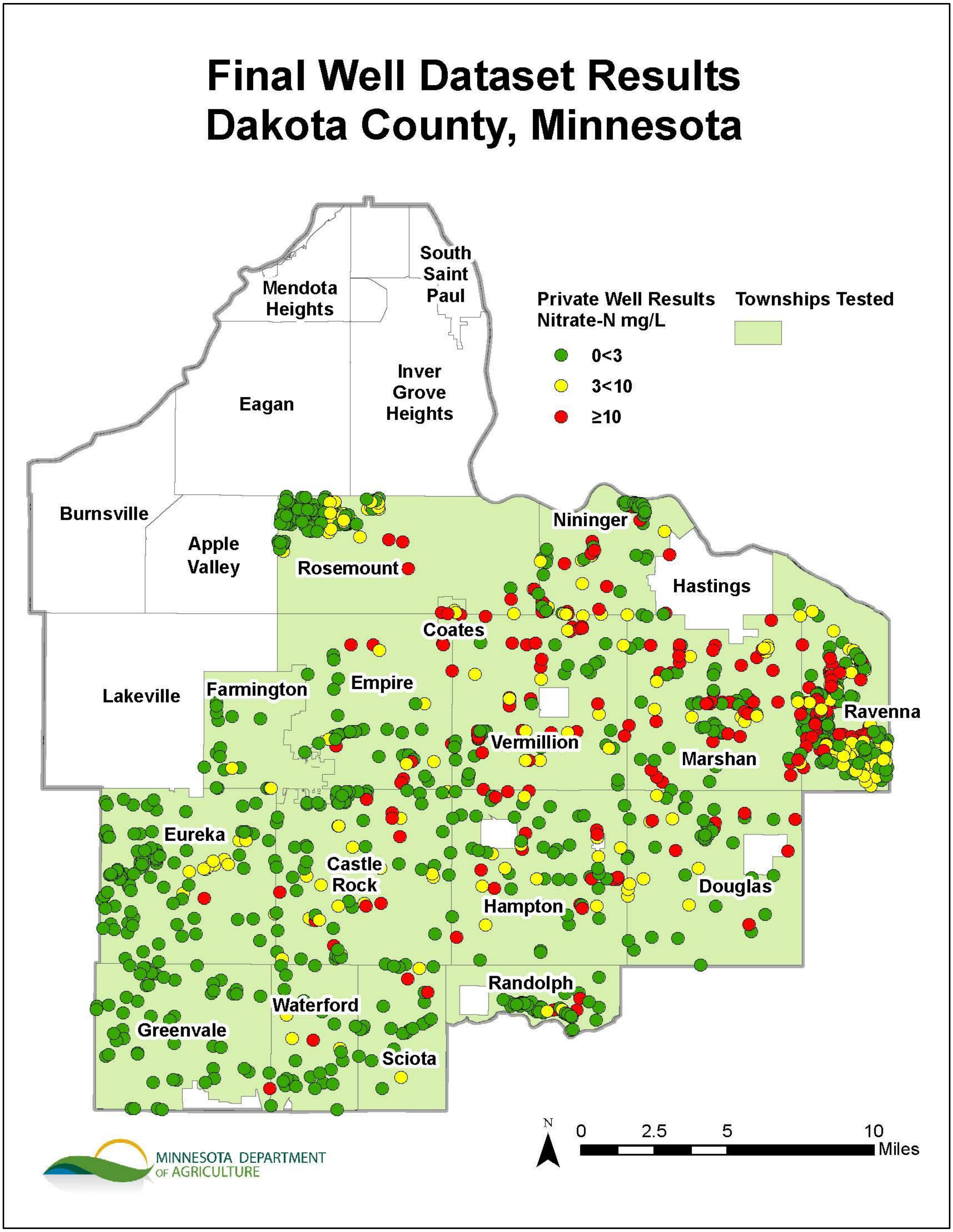


Figure 2. Well Locations and Nitrate Results from Final Well Dataset in Dakota County

Table 3. Dakota County Township Testing Summary Statistics for Final Well Dataset

Township	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	93	<DL	19.4	2.8	<DL	4.3	11.0	14.7	18.3	65	18	20	17	10	70%	19%	22%	18%	11%
Coates (city)	5	7.6	15.6	10.8	10.5	12.2	15.6	15.6	15.6	0	2	5	5	3	0%	40%	100%	100%	60%
Douglas	50	<DL	18.1	3.5	<DL	5.3	13.9	17.1	18.1	33	9	13	9	8	66%	18%	26%	18%	16%
Empire	49	<DL	20.9	4.0	<DL	8.4	12.0	13.5	20.9	30	8	17	13	11	61%	16%	35%	27%	22%
Eureka	110	<DL	21.3	1.3	<DL	0.8	5.1	8.1	19.4	94	14	12	6	2	85%	13%	11%	5%	2%
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	56	<DL	14.3	0.3	<DL	<DL	<DL	0.8	13.5	55	0	1	1	1	98%	0%	2%	2%	2%
Hampton	67	<DL	21.9	4.7	0.1	9.4	14.9	17.5	21.4	40	11	25	21	16	60%	16%	37%	31%	24%
Marshan	95	<DL	32.7	8.5	7.8	14.9	18.9	23.0	31.0	38	15	52	50	42	40%	16%	55%	53%	44%
Nininger	72	<DL	29.8	6.1	1.6	10.1	17.2	22.5	28.5	39	14	29	28	19	54%	19%	40%	39%	26%
Randolph	47	<DL	18.7	1.9	<DL	0.3	9.3	12.3	18.7	39	4	7	6	4	83%	9%	15%	13%	9%
Ravenna	243	<DL	22.8	6.4	5.2	11.5	14.5	17.2	18.5	94	72	124	109	77	39%	30%	51%	45%	32%
Rosemount (city)	154	<DL	18.7	2.2	0.8	4.0	5.1	7.0	15.6	107	42	16	8	5	69%	27%	10%	5%	3%
Sciota\	26	<DL	21.2	2.1	<DL	1.6	5.2	17.8	21.2	22	2	3	2	2	85%	8%	12%	8%	8%
Vermillion	70	<DL	23.9	6.7	5.0	10.9	16.1	19.9	23.7	30	13	35	31	27	43%	19%	50%	44%	39%
Waterford	29	<DL	22.1	2.4	<DL	2.1	9.5	13.7	22.1	24	3	5	5	2	83%	10%	17%	17%	7%
Total	1,184	<DL	32.7	4.2*	0.2*	7.5*	13.8*	17.0*	22.5*	726	229	365	312	229	61%*	19%*	31%*	26%*	19%*

* Represents an average value
<DL stands for less than detectable limit. The detectable limit ranges from <0.03 to <0.5 mg/L nitrate-N. The 50th percentile (75th, 90th, 95th, and 99th respectively) is the value below which 50 percent (75%, 90%, 95% and 99%) of the observed values fall

As discussed previously, the areas selected were deemed most vulnerable to nitrate contamination of groundwater. Table 4 compares the final results to the percent of vulnerable geology (MDNR, 1991) and row crop production (USDA NASS Cropland Data Layer, 2013) in each township and city. The percent land area considered vulnerable geology and in row crop production was estimated using a geographic information system known as ArcGIS.

Table 4. Township Nitrate Results Related to Vulnerable Geology and Row Crop Production, Dakota County

Township	Total Wells	Percent Vulnerable Geology	Percent Row Crop Production	Percent ≥7 mg/L	Percent ≥10 mg/L
				Nitrate-N mg/L or parts per million (ppm)	
Castle Rock	93	63%	65%	18%	11%
Coates (city)	5	100%	57%	100%	60%
Douglas	50	90%	68%	18%	16%
Empire	49	91%	55%	27%	22%
Eureka	110	38%	55%	5%	2%
Farmington (city)	18	75%	30%	6%	0%
Greenvale	56	36%	62%	2%	2%
Hampton	67	79%	68%	31%	24%
Marshan	95	98%	60%	53%	44%
Nininger	72	96%	41%	39%	26%
Randolph	47	98%	46%	13%	9%
Ravenna	243	99%	17%	45%	32%
Rosemount (city)	154	81%	30%	5%	3%
Sciota	26	79%	69%	8%	8%
Vermillion	70	98%	64%	44%	39%
Waterford	29	59%	59%	17%	7%
Total	1,184	78%*	55%*	26%	19%

* Represents a weighted average

ESTIMATES OF POPULATION AT RISK

The human population at risk of consuming well water over the HRL of 10 mg/L nitrate-N was estimated based on the sampled wells. An estimated 3,919 people in Dakota County's study area have drinking water over the nitrate-N Health Risk Limit (Table 5). Nitrate contamination is a significant problem across much of Dakota County. Additional public awareness and education programming will need to take place in many of the townships.

Table 5. Estimated Population with Water Wells Over 10 mg/L Nitrate-N, Dakota County

Township	Estimated Households on Private Wells[1]	Estimated Population on Private Wells[2]	Estimated Population ≥10 mg/L Nitrate-N
Castle Rock	473	1,272	189
Coates (city)	55	128	70
Douglas	250	695	245
Empire	220	684	212
Eureka	525	1,444	94
Farmington (city)	80	234	0
Greenvale	283	818	28
Hampton	326	919	276
Marshan	401	1,075	570
Nininger	301	804	283
Randolph	231	628	69
Ravenna	804	2,420	921
Rosemount (city)	528	1,521	92
Sciota	121	358	49
Vermillion	417	1,193	538
Waterford	202	519	139
Total	5,217	14,712	3,919

[1] Data obtained from Dakota County

[2] Estimates based off of the estimated households on private wells and the 2013 persons per household data gathered from Minnesota State Demographic Center (http://mn.gov/admin/demography/)

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells within the Dakota County final well dataset. The well logs provided information on the well age, depth, and construction type. These well characteristics were also provided by some homeowners. The well characteristics are described below and a more comprehensive view is provided in Appendix F (Table 16-18).

- The majority of wells were drilled (89%), and only 27 (2%) were sand point wells
- The median depth of wells was 280 feet, and the shallowest was 64 feet
- The median year the wells were constructed in was 1991

WELL WATER PARAMETERS

MDA staff conducted the follow-up sampling. Field measurements of the well water parameters were recorded on a field log (Appendix G). The measurements included temperature, pH, specific conductivity, and dissolved oxygen. The well was purged for 15 minutes, so that the measurements stabilized, ensuring a fresh sample of water was collected. The stabilized readings are described below and a more comprehensive view is available in Appendix H (Table 19-22).

- The temperatures ranged from 8.72 °C to 18.50 °C
- The median specific conductivity was 554 µS/cm, and was as high as 1,535 µS/cm
- The water from the wells had a median pH of 7.75
- The dissolved oxygen readings ranged from 0.05 mg/L to 12.82 mg/L

Water temperature can affect many aspects of water chemistry. Warmer water can facilitate quicker chemical reactions, and dissolve surrounding rocks faster; while cooler water can hold more dissolved gases such as oxygen (USGS, 2015).

Specific conductance is the measure of the ability of a material to conduct an electrical current at 25°C. Thus the more ions present in the water, the higher the specific conductance measurement (Hem, 1985). Rainwater and freshwater range between 2 to 100 µS/cm. Groundwater is between 50 to 50,000 µS/cm (Sanders, 1998).

The United States Environmental Protection Agency has set a secondary pH standard of 6.5-8.5 in drinking water. These are non-mandatory standards that are set for reasons not related to health, such as taste and color (40 C.F.R. §143).

Dissolved oxygen concentrations are important for understanding the fate of nitrate in groundwater. When dissolved oxygen concentrations are low (<0.5 mg/L) (Dubrovsky, 2010), bacteria will use electrons on the nitrate molecule to convert nitrate into nitrogen gas (N_2). Thus nitrate can be removed from groundwater through the process known as bacterial denitrification (Knowles, 1982).

SUMMARY

The focus of this study is to assess nitrate-N concentrations in groundwater impacted by row crop production. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 55% of the land cover is row crop agriculture and there are over 55,000 acres of groundwater irrigation in the study area.

Thirteen townships and five cities were sampled covering over 254,000 acres. The initial (homeowner collected) nitrate sampling resulted in 1,393 samples. Approximately 1,400 households participated which was 27% of the population on private wells. Well owners with measureable nitrate results were offered a follow-up nitrate sample and a pesticide sample. The MDA resampled and visited 487 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 205 (15%) wells were found to be unsuitable and were removed from the final well dataset of 1,184 wells. The remaining wells were wells believed to be impacted by nitrogen fertilizer and were included in the final well dataset.

A majority of wells (89%) were drilled; less than 2% were sand points. The median depth of the wells was 280 and depths ranged from 64 – 520 feet.

In over half of the townships tested, more than 10% of the wells were over the Health Risk Limit of 10 mg/L. The percent of wells over the Health Risk Limit in each township ranged from 0% to 44.2%.

REFERENCES

Title 40 Code of Federal Regulations Part §143: National Secondary Drinking Water Regulations – US EPA

Balaban, N.H. and Hobbs, H.C. (1990). C-06 Geologic atlas of Dakota County, Minnesota. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital

Dubrovsky, N., Burow, K.R., Clark, G.M., Gronberg, J.M., Hamilton, P.A.., Hitt, K.J., Mueller, D.K., Munn, M.D., Nolan, B.T., Puckett, L.J., Rupert, M.G., Short, T.M., Spahr, N.E., Sprague, L.A., and Wilber, W.G. (2010). The Quality of Our Nation's Water: Nutrients in the Nation's Streams and Groundwater, 1992-2004. U. G. S. US Dept. of the Interior. Circular 1350.

Helsel, D.R. and R. M. Hirsch. (2002). Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. U.S. Geological Survey. 522 pages.

Hem, J.D. (1985). Study and interpretation of the chemical characteristics of natural water. Water Supply Paper 2254. Alexandria, VA: U.S. Department of the Interior, Geological Survey.

Hernandez, J.A., Schmitt, M.A. (2012). Manure Management in Minnesota. Online PDF retrieved on January 28, 2016, from http://www.extension.umn.edu/agriculture/manure-management-and-air-quality/manure-management-basics/manure-management-in-minnesota/doc/manure-management-in-minnesota.pdf

Knowles, R. (1982). Denitrification. Microbiol. Rev. 46 (1), 43–70.

Metropolitan Council. (2015a). 2040, Water Resources Policy Plan. On-line PDF retrieved January 28, 2016, from http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Resources-Management-Policy-Plan/WATER-RESOURCES-POLICIES/Water-Resources-Policy-Plan.aspx

Metropolitan Council. (2015b). Wastewater Treatment Plants. Geospatial Information System, updated 2015.

Minnesota Department of Agriculture [MDA]. (2016a). Initial Township Testing of Nitrate in Private Wells Dakota County 2013-2014 Summary. On-line PDF retrieved November 14, 2016, from https://www.mda.state.mn.us/protecting/cleanwaterfund/gwdwprotection/~/media/Files/chemicals/nfmp/dakota13-14nitrasum.pdf

Minnesota Department of Agriculture [MDA]. (2016b). Township Testing Program Sampling and Analysis Plan. Available Upon Request.

Minnesota Department of Agriculture [MDA]. (2015a). Agricultural Chemical Incidents. Geospatial Metadata. Online database accessed on September 24, 2015, from ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_mda/env_agchem_incidents/metadata/metadata.html

Minnesota Department of Agriculture [MDA]. (2015b). What's in My Neighborhood? – Agriculture. Online Map accessed December, 2015, from http://www.mda.state.mn.us/chemicals/spills/incidentresponse/neighborhood.aspx

Minnesota Department of Health [MDH], Well Management Section. (2014). Well Owner's Handbook – A Consumer's Guide to Water Wells in Minnesota. On-line PDF Retrieved January 11, 2016, from http://www.health.state.mn.us/divs/eh/wells/construction/handbook.pdf

Minnesota Department of Health [MDH]. (2012). Nitrate-Nitrogen Probability Ranking Map for the Water Table Aquifer, Dakota County, Minnesota. On-line PDF Retrieved August 4, 2015, from, http://www.health.state.mn.us/divs/eh/water/swp/nitrate/reports/2011method/dakota.pdf

Minnesota Department of Health [MDH], County Well Index website, accessed on March 11, 2015, from, http://www.health.state.mn.us/divs/eh/cwi/

Minnesota Department of Natural Resources [MDNR]. (2016). DNR Water Permits. Online webpage retrieved on January 12, 2016, from http://www.dnr.state.mn.us/permits/water/index.html

Minnesota Department of Natural Resources [MDNR]. (2013). Minnesota Water Use Data. Online database accessed on February, 2016, from http://dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

Minnesota Department of Natural Resources [MDNR]. (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 [MDNR. MGS and UMD]. (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 Geologic Survey, County Atlas. Website accessed on March 17, 2015, from, http://www.mngs.umn.edu/county_atlas/countyatlas.htm

Minnesota Pollution Control Agency [MPCA]. (2015a). 2014 SSTS Annual Report, Subsurface Sewage Treatment Systems in Minnesota. Online PDF retrieved January 29, 2016, from https://www.pca.state.mn.us/sites/default/files/wq-wwists1-53.pdf

Minnesota Pollution Control Agency [MPCA]. (2015b). Feedlot Registration Form. Online PDF retrieved December 7, 2015 from https://www.pca.state.mn.us/sites/default/files/wq-f4-12.pdf

Minnesota Pollution Control Agency [MPCA]. (2015c). Spatial Data. Online database accessed on December, 2015, https://www.pca.state.mn.us/data/spatial-data#current-b6e91034

Minnesota Pollution Control Agency [MPCA]. (2015d). State of Minnesota General Animal Feedlots NPDES Permit. Online PDF retrieved December 8, 2015, from https://www.pca.state.mn.us/sites/default/files/wq-f3-53.pdf

Minnesota Pollution Control Agency [MPCA]. (2014). Livestock and the Environment: MPCA Feedlot Program Overview. Online PDF retrieved December 7, 2015, from https://www.pca.state.mn.us/sites/default/files/wq-f1-01.pdf

Minnesota Pollution Control Agency [MPCA]. (2013a). Compliance Inspections for Subsurface Sewage Treatment Systems (SSTS). On-line PDF retrieved January 11, 2016, from https://www.pca.state.mn.us/sites/default/files/wq-wwists4-39.pdf

Minnesota Pollution Control Agency [MPCA]. (2013b). Nitrogen in Minnesota Surface Waters. Online PDF retrieved January 29, 2016, from https://www.mcknight.org/system/asset/document/529/MPCA-NitrogenInMNSurfaceWaters.pdf

Minnesota Pollution Control Agency [MPCA]. (2011). Land Application of Manure: Minimum State Requirements. Online PDF retrieved December 16, 2015, from https://www.pca.state.mn.us/sites/default/files/wq-f8-11.pdf

Minnesota Pollution Control Agency [MPCA]. (1998). Baseline Water Quality of Minnesota's Principal Aquifers, Region 2, North Central Minnesota.

Minnesota Statutes 2015, section 115.55, subdivision 5

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.

Sanders, L.L. (1998). A Manual of Field Hydrogeology: Prentice-Hall, NJ, 381p.

United States Environmental Protection Agency (US EPA). (2009). National Primary Drinking Water Regulations list. On-line PDF retrieved February 17, 2015, from, http://water.epa.gov/drink/contaminants/upload/mcl-2.pdf

United States Geological Survey. (2015). Water Properties: Temperature. On-line website accessed January 20, 2016, from http://water.usgs.gov/edu/temperature.html

United States Department of Agriculture National Statistics Service (USDA NASS) (2016). https://gisdata.mn.gov/dataset/agri-cropland-data-layer-2013.

WSB & Associates Inc. (2007). Comprehensive Sanitary Sewer System Plan. City of Rosemount. Online PDF retrieved January 13, 2016, from http://ci.rosemount.mn.us/DocumentCenter/View/11

APPENDIX A

Well information and Potential Nitrate Source Inventory Form

UNIQUE NUMBER:________________ or SITE ID:______________________

Well Information and Potential Nitrate Source Inventory Form

General Information

Date of Visit: ________________County: ____________________ Township______________

Well Unique Number (6 digits): ______________ Parcel Number: ______________________

Site ID (from township sampling if no Unique ID):_____________________________________

GPS location of well: Latitude:________________ Longitude:________________________

Owner Name: ____

Owner Phone: ____

Owner Address: ____

e-mail:_____________________________

Inspector Name:___________________________Inspector Phone: ____________________

Well Construction Information

1. Is this well used for drinking water? (Circle One) a) YES or b) NO
2. Is the outdoor water raw or filtered? (softened, distilled, reverse osmosis, activated carbon, etc.)

   ____

3. Well Information collected from (Circle One):
   - a) Well Log (**Attach**) or b) Verbal (Indicate Person): ________________
4. Well Construction Type: ______________________ (Drilled, Sand point, Hand-dug, other)
5. Well Construction Date: _________________________
6. Well Depth (Feet): _________________
7. Well Diameter (Inches): _________
8. Pump Installer (Sticker):__________________________
9. Who services the well (if available)? ______________________________
10. Is there more than one well on this property?_____________________________________
    - If yes, list well type and Unique No. if available:___________________________

1

UNIQUE NUMBER:________________ or SITE ID:______________________

11. Is Fertilizer stored on this property(Circle One) a) YES or b) NO
    - If yes, what is the distance to the well?______________________
12. Historical fertilizer storage? a) YES or b) NO
    - If yes, what is the distance to the well? ______________________
13. Historic/Abandoned septic system? a) YES or b) NO
    - If yes, what is the distance to the well?______________________
14. List sample types collected at this site:____
15. Have you made any changes to your well in the last year? ____________________________

    (added filtration system, raised well, replaced pump, upgraded well casing, replaced well, etc.)

16. Are there potential nitrate sources nearby that are >300 ft. away from the well, if so list type and

    approximate distance____

Go to last page for Source Codes and well drawing.

ADDITIONAL NOTES:

____

____

____

____

UNIQUE NUMBER:________________ or SITE ID:______________________

DIRECTIONS: Stand at the well, find north and describe the type, position and distance to potential nitrate sources with 300 feet of the well. Put a dot where nitrate source is relative to the well. Label the dot with the appropriate code and label the distance. Codes are given below:

CODES

AFL: Animal Feedlot
APB: Animal/Poultry Building
MSA: Manure Storage Area
FSA: Fertilizer Storage Area
LAP: Land Application of Manure, Septage, Sewage Sludge, Waste
FWP: Feeding or Watering Area
DRA: Drain field - Above or Below Grade
PRV: Privy (Old Outhouse)
SET: Septic Tank
AGG: Dry Well, Leaching Pit, Seepage Pit, Injection Well, Agricultural Drainage Well
FIELD: Agricultural Field

17. Does water drain toward the well? a) YES or b) NO

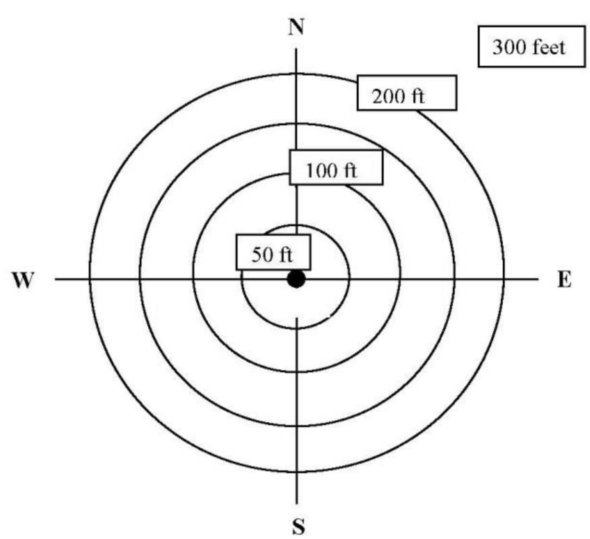
18. Which direction does the landscape slope? (Draw arrow across bull's eye, through well, and label)

19. Is the slope: a) Steep or b) Shallow

20. Are there any *obvious* problems with the well? a) YES or b) NO

21. If yes, describe the problem:____

20. Source Codes and Distances:____



3

APPENDIX B

SUBSURFACE SEWAGE TREATMENT SYSTEM

Most homes that have private wells also have private subsurface sewage treatment systems (SSTS). These treatment systems can be a potential point source for contaminates such as nitrate, and fecal material. To protect drinking water supplies in Minnesota, SSTS holding tanks and the associated drain fields are required to be at least 50 feet away from private drinking water wells. The minimum required distance doubles for wells that have less than ten feet of a confining layer or if the well has less than 50 feet of watertight casing (MDH, 2014).

Technical and design standards for SSTS systems are described in Minnesota Rules Chapter 7080 and 7081. Some local government units (LGU) have their own statutes that may be more restrictive or differ from these standards.

Many LGUs collect information on the condition of SSTS in their jurisdiction. Often information is collected when a property is transferred, but inspections can occur at other times as well. A SSTS inspection determines if a system is compliant or non-compliant. A non-compliant treatment system can be further categorized as “failing to protect groundwater (FTPGW)” or “imminent threat to public health and safety (ITPHS)”. A system is considered FTPGW if it is a seepage pit, cesspool, the septic tanks are leaking below their operating depth, or if there is not enough vertical separation to the water table or bedrock. A system is considered ITPHS if the sewage is discharging to the surface water or groundwater, there is sewage backup, or any other condition where the SSTS would harm the health or safety of the public (Minnesota Statutes, section 335.01 and MPCA, 2013a).

Dakota County delegates the authority to inspect SSTS to the township or city government. While most have maintenance programs and require inspections at the point of sale of a property, there are very few electronic records of SSTS condition. In 2014 Dakota County and the LGUs reported a total of 7,300 SSTS. Of these 133 (1.8%) were inspected for compliance (MPCA, 2015a).

FEEDLOT

The amount of nitrogen in manure depends on the species of animal. For example, there is approximately 31-32 pounds of nitrogen in 1,000 gallons of liquid dairy cow manure, and 53-63 pounds in 1,000 gallons of liquid poultry manure. Most of the nitrogen in manure is in organic nitrogen or in ammonium (NH_4^+) forms (Hernandez and Schmitt, 2012).

Under the right conditions organic nitrogen can be converted into ammonium and then eventually transformed into nitrate. Nitrate is a highly mobile form of nitrogen that can move into groundwater and become a contamination concern (MPCA, 2013b).

Government agencies regulate feedlots to reduce the risk of contamination to water resources. Rules pertaining to feedlots have been in place since the 1970’s; they were revised in 2000 and

2014 (MPCA, 2014). The degree of regulation of a feedlot is dependent on the amount of manure that is produced; measured in animal units (AU) (MPCA, 2011). One AU is equal to the amount of manure produced by one beef cow (Table 6) (MPCA, 2014).

Table 6. Animal Unit Calculations (MPCA, 2014)

Animal Type	Number of Animal Units (AU)
Mature dairy cow (over 1,000 lbs.)	1.4
Cow/calf pair	1.2
Stock cow/steer	1.0
Horse	1.0
Dairy heifer	0.7
Swine (55-300 lbs.)	0.3
Sheep	0.1
Broiler (over 5 lbs., dry manure)	0.005
Turkey (over 5 lbs.)	0.018

Animal feedlots with 1-300 AU require a 50 foot setback from private water wells. Larger feedlots (≥300 AU) must be at least 100 feet away from private water wells. The minimum required distance doubles for wells that have less than ten feet of a confining layer or if the well has less than 50 feet of watertight casing (MDH, 2014).

Farmers must register a feedlot through the Minnesota Pollution Control Agency (MPCA) if they have at least 50 AU, or 10 AU if the feedlot is located near shoreline. Larger feedlots must follow additional regulations. Feedlots with more than 300 AU must submit a manure management plan if they do not use a licensed commercial applicator (MPCA, 2014). Feedlots with more than 1,000 AU are regulated through federal National Pollution Discharge Elimination (NPDES) permits (MPCA, 2011) and must submit an annual manure management plan as part of their permit (MPCA, 2015d).

As part of new feedlot construction, an environmental assessment must be completed for feedlots with a proposed capacity of greater than 1,000 AU. If the feedlot is located in a sensitive area the requirement for an environmental assessment is 500 AU (MPCA, 2014).

Farmers must register their feedlot if it is in active status. Feedlots are considered active until no animals have been present on the feedlot for five years. To register, farmers fill out paperwork which includes a chart with the type and maximum number of animals on the feedlot. Registration is required to be completed at least once during a set four year period, the most recent period ran from January 2014 to December 2017 (MPCA, 2015b). From 2010 to 2014, approximately 18,000 feedlots were registered in Minnesota (MPCA, 2014). A map and table of the feedlots located in the Dakota County study area can be found below (Figure 3; Table 7).

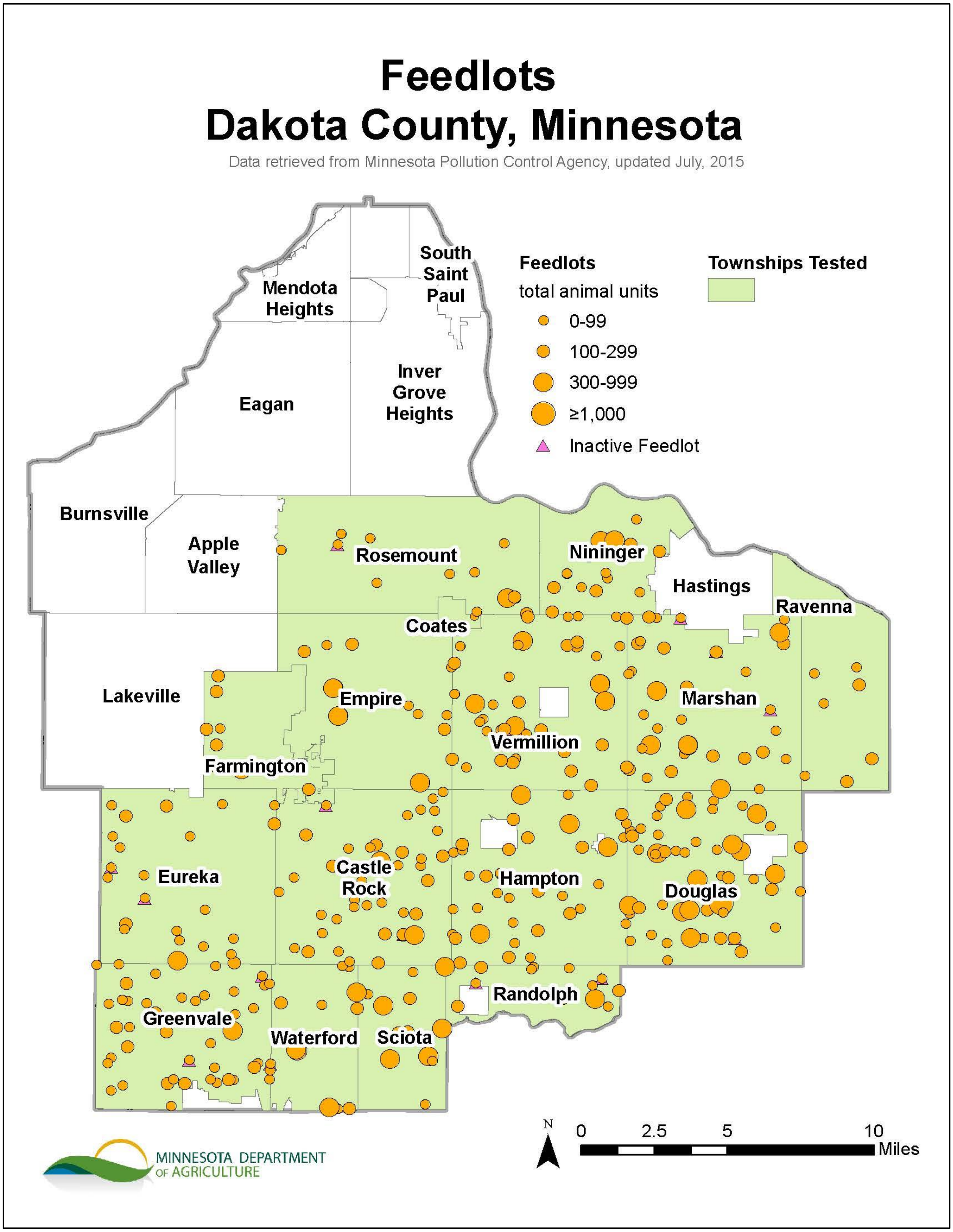


Figure 3. Feedlot Locations in Dakota County (MPCA, 2015c)

Table 7. Feedlots and Permitted Animal Unit Capacity, Dakota County

Township	Total Feedlots	Inactive Feedlots	Average AU Permitted** Per Feedlot	Total Permitted** AU	Total Square Miles	Permitted** AU per Square Mile
Castle Rock	33	2	91	2,835	35	80
Coates (city)	1	0	43	43	1	43
Douglas	47	3	192	8,444	34	248
Empire	11	0	181	1,990	32	63
Eureka	23	2	92	1,923	36	54
Farmington (city)	7	0	240	1,677	15	113
Greenvale	33	3	82	2,464	29	86
Hampton	37	0	175	6,459	34	188
Marshan	32	5	111	2,991	34	87
Nininger	13	0	180	2,335	17	137
Randolph	11	2	123	1,110	11	106
Ravenna	7	0	113	790	22	36
Rosemount (city)	12	1	99	1,087	35	31
Sciota	13	0	280	3,642	15	245
Vermillion	31	1	167	5,019	34	147
Waterford	11	0	290	3,192	15	217
Total	322	19	*152	46,001	398	*152

* Represents an average
**Animals permitted may not be the actual animals on site. The total animals permitted is the maximum number of animals that are permitted for a registered feedlot. It is common for feedlots to be have less livestock than permitted.

On average there are 152 AU per square mile (0.24 AU/acre) over the entire study area (Table 7). Manure from AU is often applied to cropland so it is pertinent to look at the AU per cropland acre. In the Dakota County study area livestock densities average 0.34 AU per acre of row crops (MPCA, 2015c; USDA NASS, 2016).

FERTILIZER STORAGE LOCATION

MDA tracks licenses for bulk fertilizer storage facilities, anhydrous ammonia, and chemigation sites (Table 8). Abandoned sites are facilities that once housed fertilizer chemicals. These sites are also noted and tracked by MDA as they are potential contamination sources.

Table 8. Fertilizer Storage Facility Licenses and Abandoned Sites, Dakota County

Township	*Bulk Fertilizer Storage	*Anhydrous Ammonia	*Chemigation Sites	*Abandoned Sites	Total
Castle Rock	1	1	1	0	3
Coates (city)	0	0	0	0	0
Douglas	0	0	9	0	9
Empire	0	0	1	0	1
Eureka	0	0	0	0	0
Farmington (city)	0	0	4	0	4
Greenvale	0	0	1	0	1
Hampton	2	1	2	0	5
Marshan	0	0	32	0	32
Nininger	0	0	3	0	3
Randolph	2	1	1	1	5
Ravenna	0	0	3	0	3
Rosemount (city)	3	1	1	1	6
Sciota	0	0	5	0	5
Vermillion	0	0	19	0	19
Waterford	0	0	0	0	0
Total	8	4	82	2	96

* Data retrieved from MDA Pesticide and Fertilizer Management Division, 2015; updated December 2015

SPILLS AND INVESTIGATIONS

MDA is responsible for investigating any fertilizer spills within Minnesota. Figure 4 shows the locations of mapped historic spills within the Dakota County study area. These sites are potential point sources of nitrogen to the groundwater (MDA, 2015b).

MDA tracks several types of incidents. Incident investigations are typically for larger spills. There are eight in the study area. Contingency areas are locations that have not been remediated because they were inaccessible or the contaminant could not be removed for some other reason. They are often a part of an incident investigation. There are no contingency areas in this study area. Old emergency incidents were closed prior to March 1st, 2004 (MDA, 2015a), but they can still be a point source. At most of these older sites, the contaminants are unknown and their location may not be precise. Small spills and investigations are typically smaller emergency spills such as a truck spilling chemicals. It is important to note that while the locations of the incidents described are as accurate as possible, it is an incomplete dataset (MDA, 2015a). Many types of spills are reported to the MDA, however only spills that potentially contain nitrogen are reported here. A breakdown of chemical type of these incidents can be found in Table 9. A breakdown of the fertilizer specific spills and investigations, by township, can be found in Table 10.

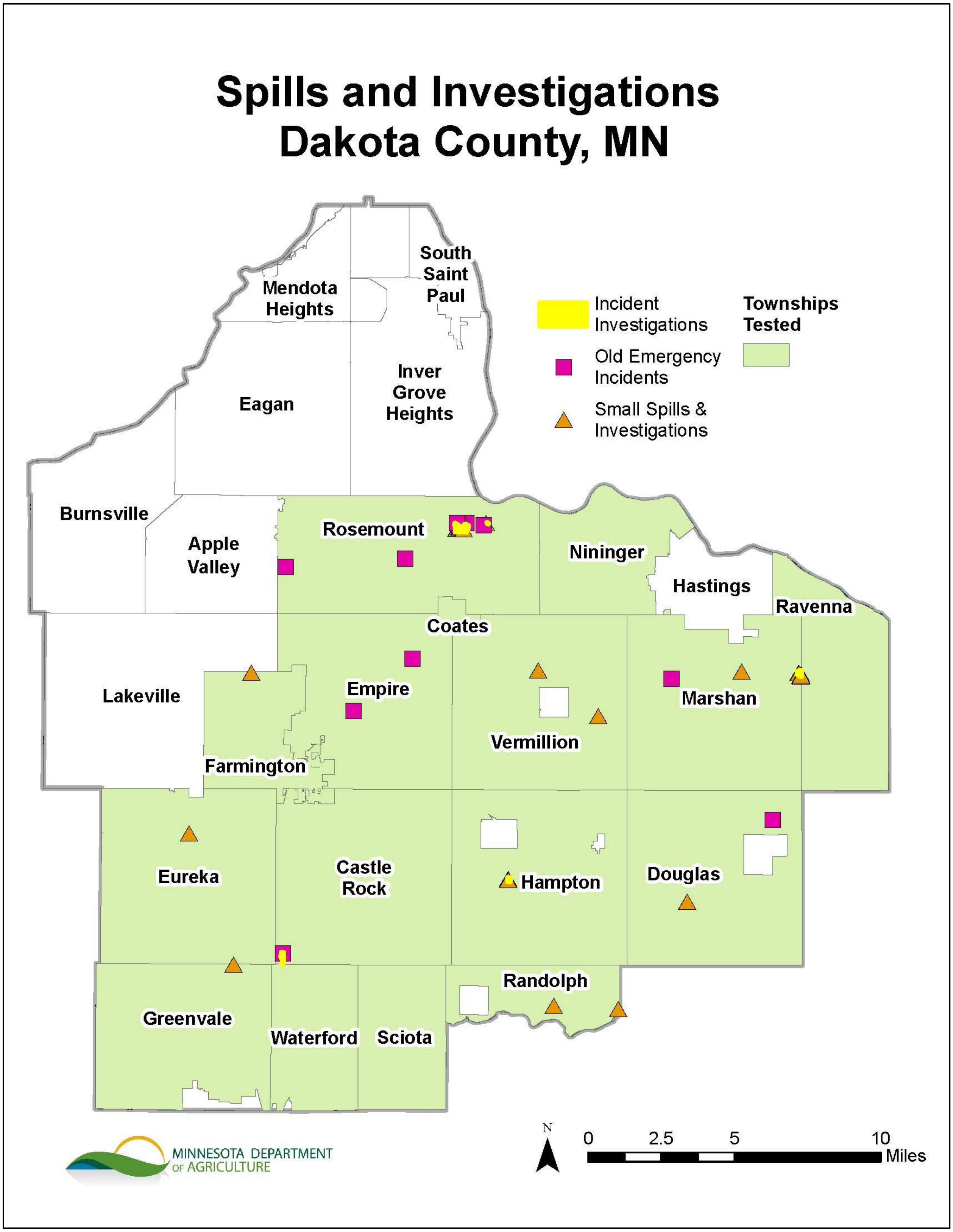


Figure 4. Fertilizer Spills and Investigations in Dakota County (MDA, 2015a)

Table 9. Spills and Investigations by Chemical Type, Dakota County

Contaminant	Incident Investigations	Contingency Areas	Small Spills and Investigations	Old Emergency Incidents
Fertilizer	4	0	6	3
Pesticides & Fertilizer	4	0	1	4
Anhydrous Ammonia	0	0	39	9
Total	8	0	46	16

Table 10. Fertilizer Related Spills and Investigations by Township, Dakota County

Township	Incidents and Spills
Castle Rock	4
Coates (city)	0
Douglas	2
Empire	2
Eureka	1
Farmington (city)	1
Greenvale	1
Hampton	7
Marshan	26
Nininger	0
Randolph	2
Ravenna	0
Rosemount (city)	22
Sciota	0
Vermillion	2
Waterford	0
Total	70

WASTEWATER

Wastewater treatment plants are required to meet effluent limits for ammonia (NH_3). To meet this standard, treatment plants convert ammonia to nitrate before discharging the treated wastewater. The average nitrate-N discharge concentration is 15 to 20 mg/L (METC, 2015a). These concentrations are above the Minnesota Health Risk Limit of 10 mg/L nitrate-N.

There are three active wastewater treatment plants and two abandoned wastewater treatment plants in the study area.

The abandoned plants are located in Rosemount and Farmington. The Rosemount wastewater treatment plant was closed in 2008 when the population exceeded the plant's capacity (WSB & Associates Inc., 2007). The Farmington wastewater treatment plant was closed in 1975 (METC, 2015b). Wastewater from Rosemount and Farmington is currently routed to the Empire treatment plant (METC, 2015a)

The Empire plant is an active facility designed to reduce ammonia and phosphorus. The treated wastewater discharges to the Mississippi River at a rate of 10 million gallons per day. This plant treats water from Apple Valley, Elko, New Market, Empire, Farmington, Lakeville, and Rosemount (METC, 2015a). With the large volume of water and the high concentration of nitrate-N this wastewater treatment is considered a point source of nitrogen to surface water. This surface discharge is not considered a groundwater point source to wells within the study area.

The Hampton and Vermillion plants are both much smaller facilities that only have the capacity to discharge 101,000 and 54,000 gallons per day, respectively. They are designed to meet effluent limits for biochemical oxygen demand and suspended solids. Both plants discharge into ditches which flow into the Vermillion River, and eventually the discharge reaches the Mississippi River in Hastings (METC, 2015a).

APPENDIX C

LAND COVER

Typically locations were selected for the Township Testing Program if at least 20 percent of the land cover was in row crop production. Despite its close proximity to the Twin Cities, much of Dakota County remains dominated by agricultural activities (Figure 5; Table 11). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, durum wheat, dry beans and double crops involving corn and soybeans.

Dakota County is located just south of a large metropolitan area and abuts the Mississippi River on the south and east boundaries. More than 25 percent of the land area in the Cities of Farmington and Rosemount is developed. Nininger and Ravenna Townships are influenced by the Mississippi River to their south; over 20 percent of the terrain is open water or wetlands (Figure 5; Table 11).

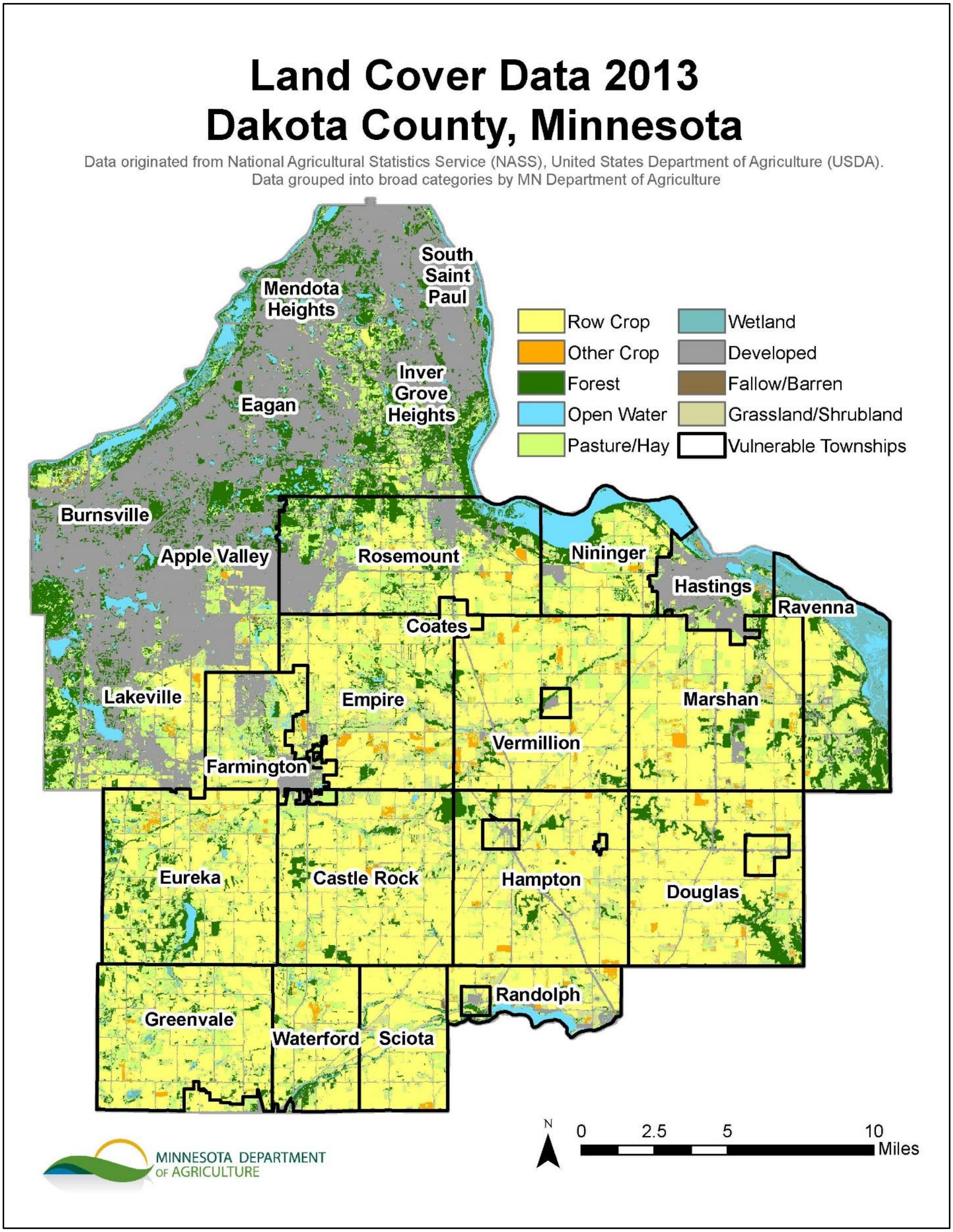


Figure 5. Land Cover in Dakota County (USDA NASS Cropland Data Layer, 2013)

Table 11. Land Cover Data (2013) by Township, Dakota County (USDA NASS Cropland Data Layer, 2013)

Township	Total Acres	Row Crop	Other Crops	Forest	Open Water	Pasture/ Hay	Wetland	Developed	Fallow/ Barren	Grassland/ Shrubland
Castle Rock	22,614	63%	1%	7%	0%	16%	1%	5%	0%	7%
Coates (city)	882	67%	0%	1%	0%	19%	0%	12%	0%	1%
Douglas	21,776	67%	2%	9%	0%	9%	0%	5%	0%	8%
Empire	20,178	50%	3%	7%	0%	23%	1%	5%	0%	10%
Eureka	22,805	51%	1%	11%	1%	23%	1%	4%	0%	6%
Farmington (city)	9,500	33%	0%	5%	2%	23%	1%	27%	0%	9%
Greenvale	18,267	56%	1%	6%	0%	24%	2%	4%	0%	7%
Hampton	22,044	68%	2%	5%	0%	11%	0%	5%	0%	9%
Marshan	21,998	62%	3%	7%	0%	15%	0%	6%	0%	7%
Nininger	10,944	33%	1%	13%	23%	21%	0%	6%	0%	2%
Randolph	6,730	45%	5%	4%	10%	12%	2%	11%	0%	11%
Ravenna	13,969	19%	0%	20%	9%	16%	23%	6%	0%	6%
Rosemount (city)	22,543	27%	1%	16%	4%	25%	1%	23%	0%	3%
Sciota	9,512	70%	1%	2%	0%	13%	1%	4%	0%	8%
Vermillion	21,896	64%	3%	4%	0%	16%	0%	6%	0%	6%
Waterford	9,426	57%	1%	7%	1%	20%	2%	5%	0%	7%
Average	15,943	53%	2%	9%	2%	18%	2%	8%	0%	7%

WATER USE

Water use permits are required for wells withdrawing more than 10,000 gallons of water per day or 1,000,000 gallons of water per year (MDNR, 2016). There are a total of 463 active groundwater permits in the study area and 364 are used for irrigating major crops (Table 12; Figure 6). Over 55,000 acres of cropland is permitted for groundwater irrigation. Most permitted wells are withdrawing groundwater from Paleozoic aquifers (Table13). The Jordon formation and the Prairie du Chien group are the most heavily utilized aquifers (MDNR, 2013).

Table 12. Active Groundwater Use Permits by Township, Dakota County

Township	Major Crop Irrigation Permits	Average Depth (feet)
Castle Rock	20	260
Coates (city)	0	-
Douglas	43	357
Empire	19	231
Eureka	9	235
Farmington (city)	5	102
Greenvale	1	270
Hampton	39	243
Marshan	75	349
Nininger	11	295
Randolph	24	261
Ravenna	8	429
Rosemount (city)	10	376
Sciota	22	310
Vermillion	67	321
Waterford	11	285
Total	364	305

Table 13. Active Groundwater Use Permits by Aquifer, Dakota County

Water Use Permits	Total	Average Depth (feet)	Aquifer System			
			Quaternary (Water Table)	Quaternary (Buried)	Paleozoic	Not Classified
Major Crop Irrigation	364	305	36	4	311	13
Non-Crop Irrigation	30	297	6	1	21	2
Waterworks	24	461	0	0	24	0
Industrial Processing	23	476	0	0	19	4
Water Level Maintenance	8	35	8	0	0	0
Special Categories	14	325	8	0	4	2
Total	463	318	58	5	379	21

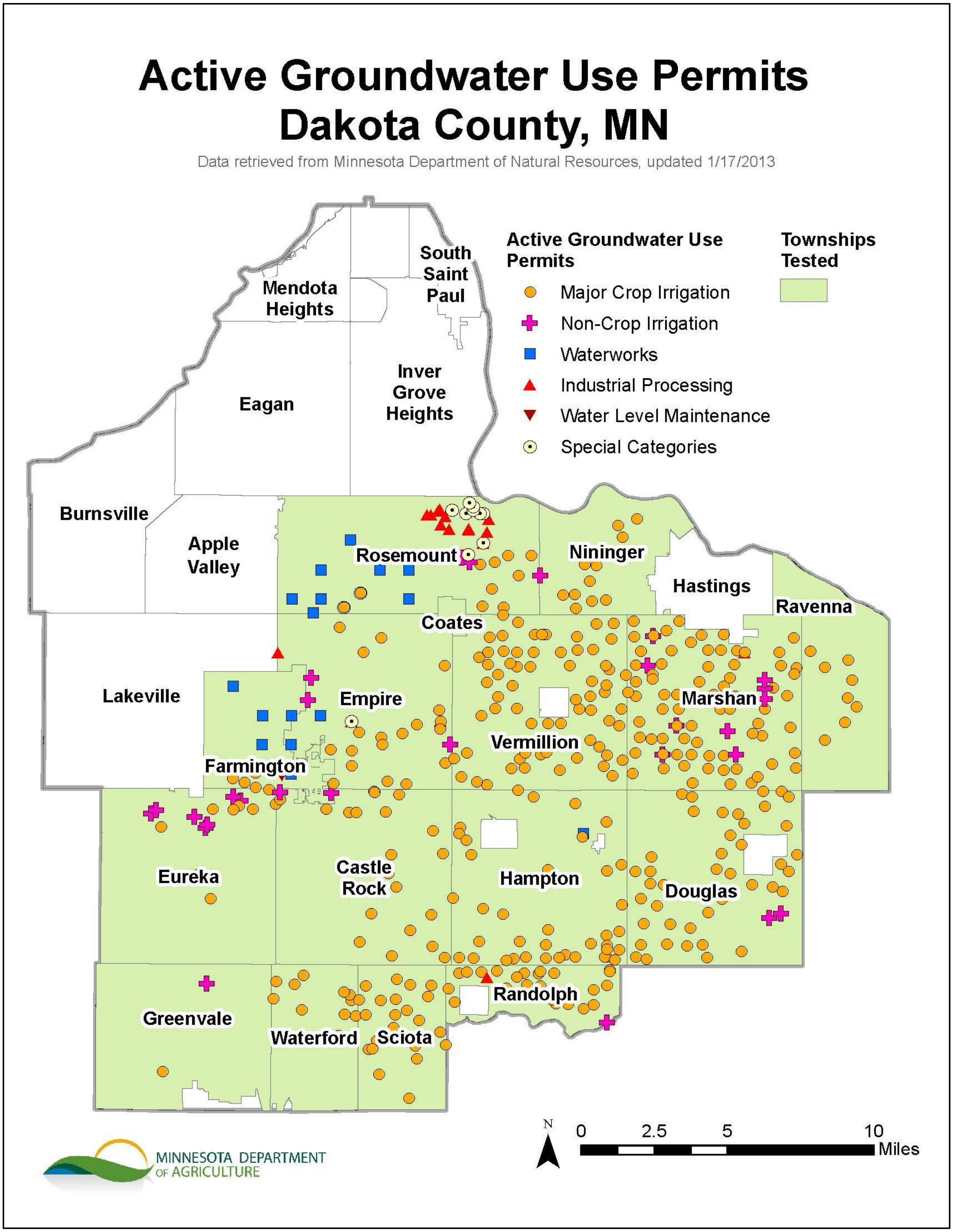


Figure 6. Active Groundwater Use Permits in Dakota County (MDNR, 2013)

APPENDIX D

Nitrate Brochure

The Minnesota Department of Agriculture and the _ County SWCD would like to **thank you** for participating in the private well volunteer nitrate monitoring. The results of your water sample are enclosed. Results from this sampling event will be reviewed and summarized and a summary report will be issued to the counties. In addition, the data will be used to determine the need and the design of a long-term monitoring network. Below is general information regarding nitrate result ranges.

If the Nitrate result is between 0 to 4.9 mg/L:

- Continue to test your water for nitrate every year or every other year.
- Properly manage nitrogen sources when used near your well.
- Continue to monitor your septic tank. Sewage from improperly maintained septic tanks may contaminate your water.
- Private wells should be tested for bacteria at least once a year. A Minnesota Department of Health (MDH) certified water testing lab can provide nitrate and bacteria testing services. Search for the lab nearest you at www.health.state.mn.us/labsearch.

If the Nitrate result is between 5 to 9.9 mg/L:

- Presently the nitrate nitrogen level in your water is below the nitrate health standard for drinking water. However, you have a source of contamination which may include: contributions from fertilized lawns or fields, septic tanks, animal wastes, and decaying plants.
- Test annually for both nitrate and bacteria. As nitrate levels increase, especially in wells near cropped fields, the probability of detecting pesticides also increases. MDA monitoring data indicates that pesticide levels are usually below state and federal drinking water guidelines. For more information on testing and health risks from pesticides and other contaminants in groundwater go to: http://www.mda.state.mn.us/protecting/waterprotection/pesticides.aspx
- In addition to pesticides, high nitrate levels may suggest an increased risk for other contaminants. For more information go to: http://www.health.state.mn.us/divs/eh/wells/waterquality/test.html

If the Nitrate result is above 10 mg/L:

- **Do not allow this water to be consumed by infants**, Over 10 mg/L is not safe for infants younger than 6 months of age
- **Pregnant women** also may be at risk along with **other people with specific metabolic conditions.** Find a safe alternative water supply.
- Consider various options including upgrading the well if it was constructed before the mid 1970's.
- Be sure to retest your water prior to making any significant financial investment in your existing well system. See link to MDH certified labs listed above.
- ***Boiling your water increases the nitrate concentration in the remaining water.***

Infants consuming high amounts of nitrates may develop Blue Baby Syndrome (Methemoglobinemia). This disease is potentially fatal and first appears as blue coloration of the fingers, lips, ears, etc. Seek medical assistance immediately if detected

If you have additional questions about wells or well water quality in Minnesota, contact your local Minnesota Department of Health office and ask to talk with a well specialist or contact the Well Management Section Central Office at health.wells@state.mn.us or at 651-201-4600 or 800-383-9808. If you have questions regarding the private well monitoring contact Nikol Ross at 651-201-6443 or Nikol.Ross@state.mn.us.

APPENDIX E

Table 14. Reasons Wells Were Removed from the Final Well Dataset by Township, Dakota County

Township	Point Source	Well Construction Problem	Hand Dug well	Irrigation Well	Unsure of water source	Site Visit Completed – Well Not Found & Constructed before 1975 & No Well ID	No Site Visit & Constructed before 1975 & No Well ID	No Site Visit & Insufficient Data & No Well ID	Total
Castle Rock	0	0	0	0	1	1	6	0	8
Coates (city)	0	0	0	0	0	2	4	0	6
Douglas	1	1	3	0	0	2	8	3	18
Empire	2	0	0	1	1	2	2	1	9
Eureka	5	1	0	0	3	2	2	0	13
Farmington	0	0	0	0	0	0	0	0	0
Greenvale	0	0	0	0	0	1	1	0	2
Hampton	1	0	0	0	3	1	8	0	13
Marshan	1	0	2	0	0	1	13	3	20
Nininger	0	0	0	0	2	1	11	2	16
Randolph	0	0	0	0	1	3	4	0	8
Ravenna	8	1	0	1	1	9	34	0	54
Rosemount (city)	5	0	0	0	0	2	4	0	11
Sciota	0	0	0	0	1	0	2	0	3
Vermillion	2	0	1	0	0	2	5	2	12
Waterford	0	0	1	0	1	1	6	3	12
Total	25	3	7	2	14	30	110	14	205

Table 15. Site Visits Completed for Wells Removed from the Final Well Dataset by Township, Dakota County

Township	Site Visit	No Site Visit	Total Wells Removed
Castle Rock	2	6	8
Coates (city)	2	4	6
Douglas	7	11	18
Empire	4	5	9
Eureka	8	5	13
Greenvale	1	1	2
Farmington (city)	0	0	0
Hampton	5	8	13
Marshan	4	16	20
Nininger	3	13	16
Randolph	4	4	8
Ravenna	13	41	54
Rosemount (city)	4	7	11
Sciota	1	2	3
Vermillion	4	8	12
Waterford	3	9	12
Total	65	140	205

APPENDIX F

Table 16. Well Construction Type for Final Well Dataset

Township	Samples	Drilled	Sand Point	Not Available
Castle Rock	93	85	3	5
Coates (city)	5	5	0	0
Douglas	50	46	0	4
Empire	49	37	6	6
Eureka	110	92	3	15
Farmington (city)	18	13	1	4
Greenvale	56	52	1	3
Hampton	67	63	1	3
Marshan	95	91	0	4
Nininger	72	69	0	3
Randolph	47	36	3	8
Ravenna	243	223	3	17
Rosemount (city)	154	143	1	10
Sciota	26	21	1	4
Vermillion	70	58	2	10
Waterford	29	22	2	5
Total	1,184	1,056	27	101

Data compiled from well logs and homeowner responses.

Table 17. Well Depth for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Castle Rock	53	75	460	205	236
Coates (city)	4	158	300	280	255
Douglas	39	215	480	360	362
Empire	18	98	360	120	165
Eureka	22	90	240	160	167
Farmington (city)	1	200	200	200	200
Greenvale	12	120	320	180	197
Hampton	41	180	520	340	347
Marshan	66	147	380	320	290
Nininger	45	140	500	280	292
Randolph	30	64	400	320	286
Ravenna	110	124	400	280	264
Rosemount (city)	45	137	360	240	244
Sciota	17	70	380	300	287
Vermillion	41	120	500	260	269
Waterford	12	89	350	310	293
Total	556	64	520	280	272

Data compiled from well logs only; homeowner responses are not included.

Table 18. Year of Well Construction for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Castle Rock	53	1972	2012	1987	1988
Coates (city)	4	1976	2007	1999	1995
Douglas	38	1972	2007	1992	1991
Empire	18	1974	2011	1998	1994
Eureka	22	1976	2011	1993	1993
Farmington (city)	1	1993	1993	1993	1993
Greenvale	12	1995	2007	1999	2001
Hampton	41	1972	2005	1993	1991
Marshan	66	1972	2010	1989	1990
Nininger	45	1972	2011	1995	1992
Randolph	30	1977	2007	1997	1994
Ravenna	110	1972	2005	1988	1988
Rosemount (city)	45	1960	2011	1990	1990
Sciota	16	1971	2010	1997	1995
Vermillion	41	1974	2012	1987	1989
Waterford	12	1984	2009	1992	1993
Total	554	1960	2012	1991	1990

Data compiled from well logs only; homeowner responses are not included. Most wells do not have a well log if they were constructed before 1974.

APPENDIX G

Private Well Field Log

Minnesota Department of Agriculture -Private Well Field Log

<table>
<tr><th>Well Unique#</th><th>Site ID</th><th>Sample #'s</th><th>Date</th><th>Time</th><th>Well Depth (units)</th></tr>
<tr><td></td><td rowspan="2"></td><td>Nitrate:</td><td rowspan="2"></td><td rowspan="2"></td><td></td></tr>
<tr><td>Sampler:</td><td>Pesticide:</td><td>Well Type:</td></tr>
<tr><td colspan="6">Well Owner Name:</td></tr>
<tr><td colspan="6">Well Owner Address:</td></tr>
<tr><td colspan="6">GPS: Latitude: Longitude:</td></tr>
</table>

Duplicates collected? Yes or No

Duplicate #'s: nitrate: ______________________ pesticide:____________________________

Sample point location (for example: outside tap on south side of home)_________________________

Pump start time: _____________ Discharge rate: __________ Time sample collected:_____________

Stabilization Measurements

Time	Temp (units) (1.0°)	pH (0.1)	Specific Cond. (units) (10%)	DO (units) (10%)	Appearance/Notes

Wind (units)	Air temp (units)	Weather	Nearest possible pesticide source (type and distance)

COMMENTS/Notes:

Updated 5/18/2015

APPENDIX H

Table 19. Temperature (°C) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Castle Rock	30	8.72	11.39	9.92	9.85
Coates (city)	5	9.53	11.10	10.78	10.57
Douglas	19	8.78	12.10	10.28	10.34
Empire	10	9.84	11.26	10.37	10.45
Eureka	21	9.18	11.16	10.09	10.13
Farmington (city)	1	10.06	10.06	10.06	10.06
Greenvale	1	9.84	9.84	9.84	9.84
Hampton	26	8.89	12.10	10.80	10.66
Marshan	49	8.72	18.50	10.11	10.43
Nininger	30	8.78	11.56	10.14	10.14
Randolph	11	10.44	12.39	11.61	11.46
Ravenna	123	9.85	12.55	10.82	10.86
Rosemount (city)	48	9.62	14.01	10.26	10.42
Sciota	4	9.80	11.39	10.25	10.42
Vermillion	35	8.72	12.80	10.39	10.37
Waterford	8	9.40	13.47	10.31	10.57
Total	421	8.72	18.50	10.44	10.51

Table 20. Specific Conductivity (µS/cm) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Castle Rock	30	356	956	528	531
Coates (city)	5	576	1535	712	829
Douglas	19	273	1167	552	569
Empire	10	519	1029	652	672
Eureka	21	520	761	608	618
Farmington (city)	1	472	472	472	472
Greenvale	1	713	713	713	713
Hampton	26	296	804	471	492
Marshan	49	342	837	610	596
Nininger	30	381	867	620	630
Randolph	11	473	787	613	628
Ravenna	123	296	830	476	479
Rosemount (city)	48	457	913	724	723
Sciota	4	558	738	571	610
Vermillion	35	353	810	574	570
Waterford	8	534	1140	661	699
Total	421	273	1535	554	573

Table 21. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Castle Rock	30	6.23	8.36	7.74	7.65
Coates (city)	5	7.26	7.71	7.68	7.59
Douglas	19	7.34	8.47	7.89	7.88
Empire	10	7.28	8.29	8.10	7.90
Eureka	21	7.20	8.25	7.56	7.64
Farmington (city)	1	7.56	7.56	7.56	7.56
Greenvale	1	8.07	8.07	8.07	8.07
Hampton	26	7.18	8.45	7.87	7.88
Marshan	49	7.27	8.31	7.79	7.82
Nininger	30	7.49	7.98	7.72	7.73
Randolph	11	7.52	7.84	7.65	7.66
Ravenna	123	7.19	8.72	7.78	7.85
Rosemount (city)	48	7.15	8.30	7.58	7.68
Sciota	4	7.50	7.86	7.60	7.64
Vermillion	35	7.47	8.25	7.72	7.79
Waterford	8	7.38	7.78	7.62	7.59
Total	421	6.23	8.72	7.75	7.78

Table 22. Dissolved Oxygen* (mg/L) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Castle Rock	2	1.81	7.63	4.72	4.72
Coates (city)	1	9.13	9.13	9.13	9.13
Douglas	0	--	--	--	--
Empire	10	0.18	7.98	5.45	4.80
Eureka	20	0.14	5.56	3.73	2.71
Farmington (city)	1	2.14	2.14	2.14	2.14
Greenvale	1	5.51	5.51	5.51	5.51
Hampton	1	10.46	10.46	10.46	10.46
Marshan	3	4.77	10.67	10.05	8.50
Nininger	3	9.75	12.50	11.56	11.27
Randolph	0	--	--	--	--
Ravenna	123	0.21	12.82	9.21	7.66
Rosemount (city)	48	0.05	12.03	2.70	2.97
Sciota	0	--	--	--	--
Vermillion	3	9.33	12.11	9.59	10.34
Waterford	1	5.48	5.48	5.48	5.48
Total	217	0.05	12.82	5.72	6.08

** Dissolved oxygen was only measured in 2015 follow-up sampling.*