FINAL TOWNSHIP TESTING NITRATE REPORT: MORRISON COUNTY 2013-2016

August 2017

Updated June 2018

Minnesota Department of Agriculture

Pesticide and Fertilizer Management Division

ACKNOWLEDGEMENTS

MDA PRIMARY AUTHOR

Nikol Ross

MDA CONTRIBUTORS AND REVIEWERS

Kimberly Kaiser, Larry Gunderson, and Bruce Montgomery

FUNDING

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

DEPARTMENT OF AGRICULTURE

CLEAN WATER LAND & 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 primary goal of the Township Testing Program is to identify areas that have high nitrate concentrations in their groundwater. The program also informs residents about the health risk of their well water. Areas were selected based on historically elevated nitrate conditions, aquifer vulnerability and row crop production. The MDA plans to offer nitrate-N tests to more than 70,000 private well owners in over 300 townships by 2019. This will be one of the largest nitrate testing efforts ever conducted and completed.

In 2013 and 2015, private wells in the Morrison County study area (11 townships) were sampled for nitrate-N. Samples were collected from private wells using homeowner collection and mail-in methods. These initial samples were collected from 1,222 wells representing an average response rate of 33 percent of homeowners. Well log information was obtained when available and correlated with nitrate-N results. Initial well dataset results showed that across the study area, 10.8 percent of private wells sampled were at or above the health standard of 10 mg/L for nitrate-N. Based on the initial results, it is estimated that over 1,278 residents could be consuming well water with nitrate-N at or over the HRL.

The MDA completed follow-up sampling and well site visits at 324 wells in 2015 and 2016. A follow-up sampling was offered to all homeowners with wells that had a detectable nitrate-N result.

A well site visit was conducted to identify wells that were unsuitable for final analysis. The final well dataset is intended to only include private drinking water wells potentially impacted by applied commercial agricultural fertilizer. Therefore, wells with construction issues or nearby potential point sources of nitrogen were removed from the final well dataset. Point sources of nitrogen can include: feedlots, subsurface sewage treatment systems, fertilizer spills, and bulk storage of fertilizer. A total of 117 (10 percent) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of 1,105 wells.

The final well dataset was analyzed to determine the percentage of wells at or over the HRL of 10 mg/L nitrate-N. When analyzed at the township scale the percent of wells at or over the HRL ranged from 3.1 to 47.3 percent. Three of the eleven townships sampled in Morrison County are showing significant problems with 10 percent of wells at or over the HRL.

INTRODUCTION

The Minnesota Department of Agriculture (MDA) is the lead agency for nitrogen fertilizer use and management. The Nitrogen Fertilizer Management Plan (NFMP) is the state's blueprint for prevention or minimization of the impacts of nitrogen fertilizer on groundwater. The MDA revised the 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-N tests to more than 70,000 private well owners in over 300 townships by 2019. As of January 2017, 167 townships in 19 counties have completed the initial sampling. A total of 20,042 wells have been sampled.

In 2013 and 2015, eleven townships in Morrison 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 laboratory 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 Morrison County occurred during the summers of 2015 and 2016. 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. 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

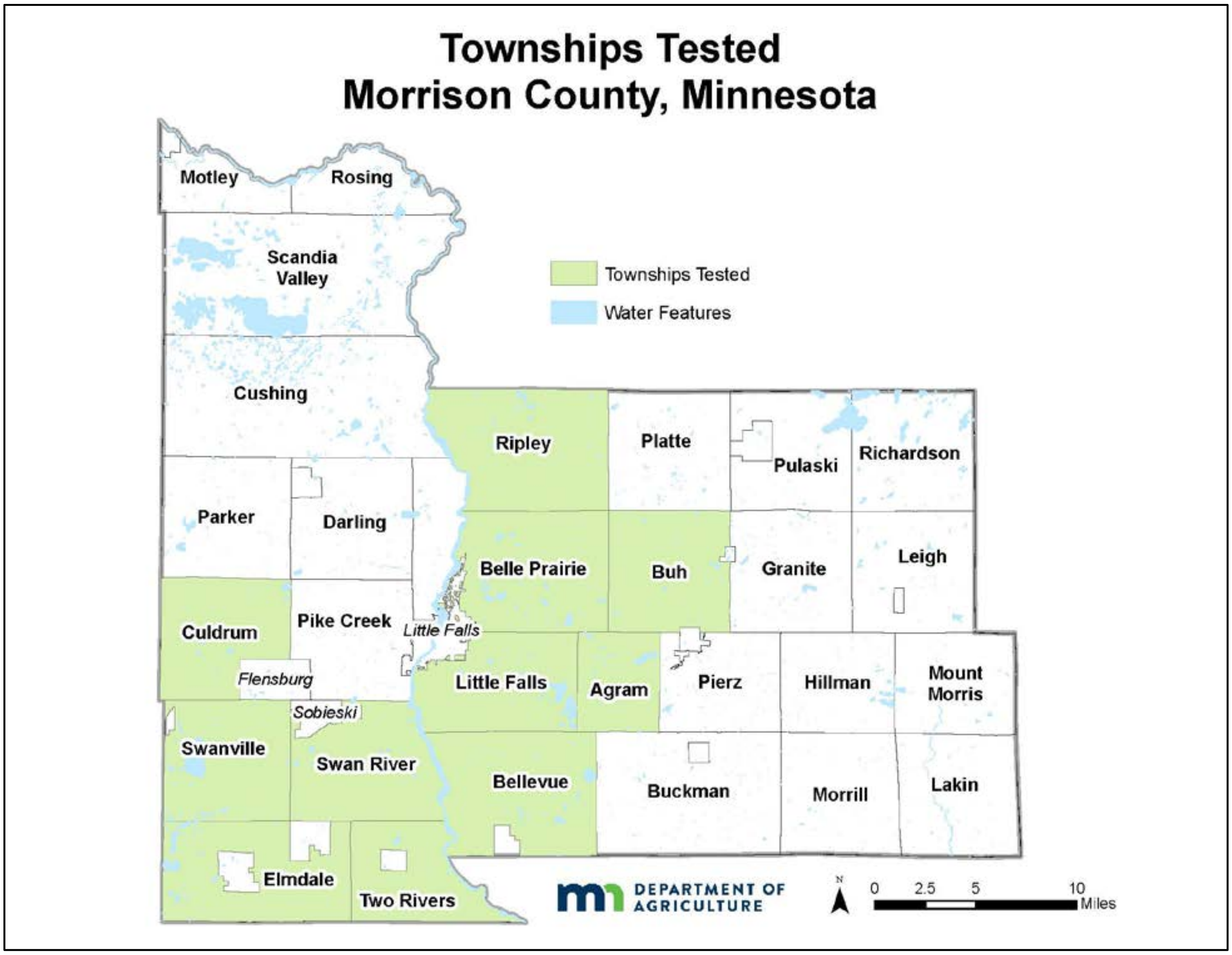


Figure 1. Townships Tested in Morrison County

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 Morrison County with extensive 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, bulk storage of fertilizer, and fertilizer spills are considered in this section. Below is a brief overview of these sources in Morrison County. Further details are in Appendix A.

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 Morrison County, over a recent 13 year period (2002-2014), a total of 3,941 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Morrison County, 40% 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 Morrison County study area there are a total of 321 feedlots. The majority of the feedlots are permitted to house less than 300 animal units (AU) (Appendix A; Figure 3). Buh and Culdrum Townships have the most permitted AU per square mile (Appendix A; 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 Morrison County study area has a total of 118 fertilizer storage licenses and 1 abandoned fertilizer storage site. The vast majority are chemigation sites that are registered in Belle Prairie, Bellevue and Ripley Townships (Appendix A; Table 8).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of 2 historic fertilizer spills and investigations occurred in the Morrison County study area. Both of these were small spills and investigations (Appendix A; Table 9).

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 Morrison County report (MDA, 2015). 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 Morrison County report (MDA, 2015). The National Agriculture Statistics Service data (USDA NASS, 2013) on cropland was used to determine the percentage of row crop agriculture. A map and table depicting the extent of the cropland in Morrison County can be found in Appendix B (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 was conducted in 2013 and 2015. In the initial sampling, all private well owners in the selected townships were 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 nitrate brochure (Appendix C). Well water samples were collected by 1,222 homeowners using the mail-in kit. These 1,222 samples are considered the "initial well dataset". On average, 33 percent of the homeowners in these townships responded to the free nitrate test offered by MDA.

All of the homeowners with a nitrate 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 2015 and 2016 by MDA staff. A total of 324 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-contamination occurred. A more thorough explanation of the sampling process is described in the sampling and analysis plan (MDA, 2016). 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 (www.mda.state.mn.us/pwps.).

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

Township	Kits Sent	Initial Well Dataset	Well Site Visits & Follow-Up Sampling Conducted
Agram	188	109	45
Belle Prairie	449	101	30
Bellevue	406	135	29
Buh	227	52	7
Culdrum	172	58	6
Elmdale	445	148	27
Little Falls	687	281	92
Ripley	330	106	31
Swan River	261	70	17
Swanville	227	49	5
Two Rivers	288	113	35
Total	3,680	1,222	324

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 D).

WELL ASSESSMENT

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

Using the following criteria, a total of 117 wells were removed to create the final well dataset. See Appendix E (Tables 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 1,222 well water samples were collected by homeowners across 11 townships. A total of 117 (10%) wells were found to be unsuitable and were removed to create the final well dataset. The final analysis was conducted on the remaining 1,105 wells (Table 2). The wells in the final well dataset represent drinking water wells potentially impacted by applied commercial agricultural fertilizer.

WELL WATER NITROGEN ANALYSIS

The final analysis was based on the number of wells over the nitrate HRL of 10 mg/L. Table 2 shows the results for all townships sampled. The percent of wells over the HRL ranged from 3.1 to 47.3 percent.

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

Township	Initial Well Dataset	Final well Dataset	Wells ≥10 mg/L Nitrate-N	
			Count	Percentage
Agram	109	93	44	47.3%
Belle Prairie	101	87	10	11.5%
Bellevue	135	126	9	7.1%
Buh	52	44	3	6.8%
Culdrum	58	55	5	9.1%
Elmdale	148	131	4	3.1%
Little Falls	281	266	15	5.6%
Ripley	106	94	12	12.8%
Swan River	70	61	5	8.2%
Swanville	49	44	2	4.5%
Two Rivers	113	104	10	9.6%
Total	1,222	1,105	119	10.8%*

* Represents an average value

The individual nitrate 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.

The final well dataset summary statistics are shown in Table 3. The minimum values were all below the detection limit. The maximum values ranged from 13.3 to 48.5 mg/L nitrate, with Little Falls Township having the highest result. The 90th percentile ranged from 1.9 to 20.1 mg/L nitrate, with Elmdale Township having the lowest result and Agram Township having the highest result.

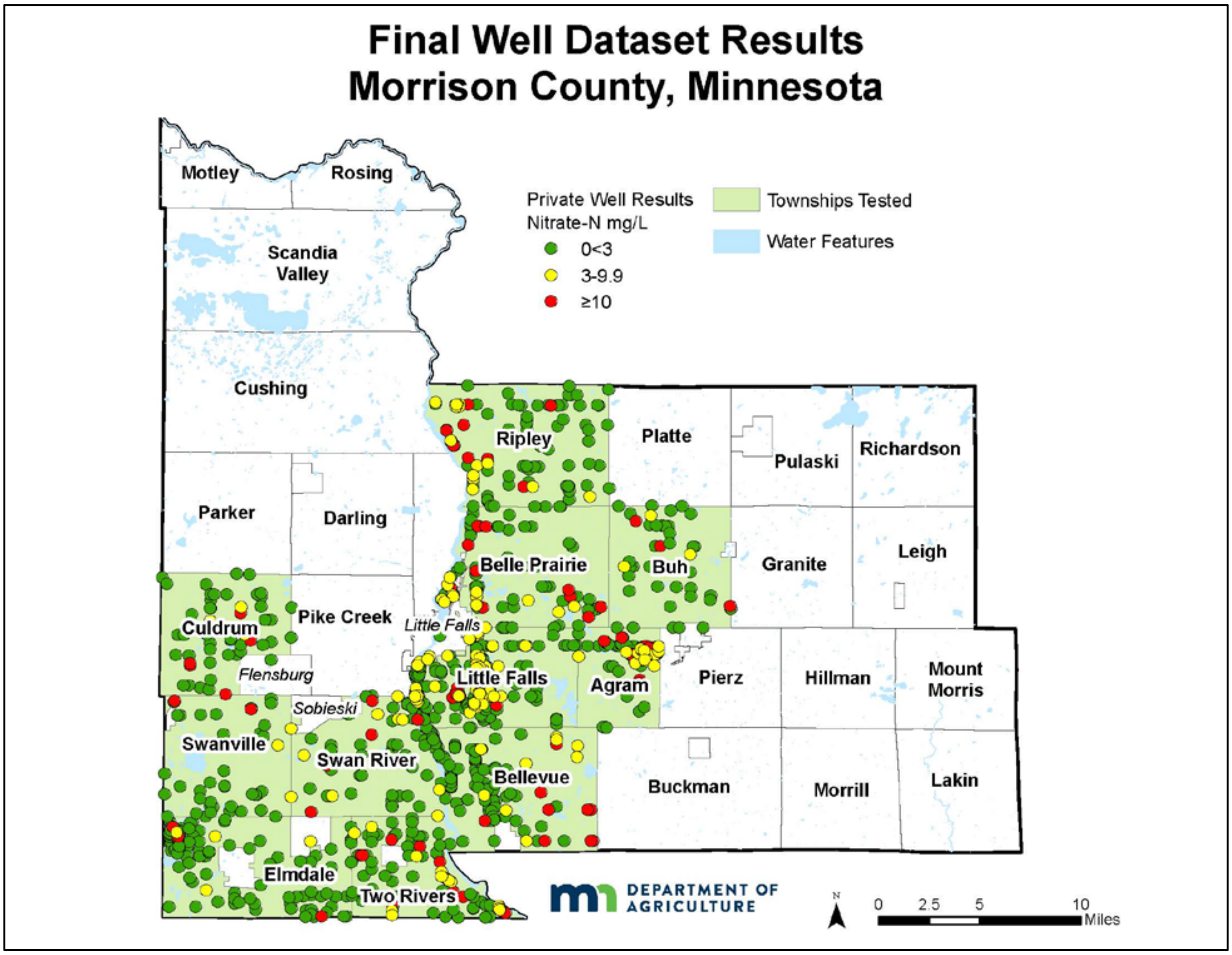


Figure 2. Well Locations and Nitrate Results from Final Well Dataset in Morrison County

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

Township	Total Wells	Values			Percentiles					Number of Wells					Percent of Wells				
		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)																	
Agram	93	<DL	40.8	8.8	7.2	15.7	20.1	22.8	35.6	36	13	49	47	44	38.7%	14.0%	52.7%	50.5%	47.3%
Belle Prairie	87	<DL	39.0	3.2	<DL	2.8	11.1	15.4	35.5	65	12	16	14	10	74.7%	13.8%	18.4%	16.1%	11.5%
Bellevue	126	<DL	43.7	2.8	<DL	0.7	7.2	24.2	39.8	107	10	15	13	9	84.9%	7.9%	11.9%	10.3%	7.1%
Buh	44	<DL	13.3	1.4	<DL	0.5	5.6	12.6	13.3	38	3	5	4	3	86.4%	6.8%	11.4%	9.1%	6.8%
Culdrum	55	<DL	18.5	1.9	<DL	0.7	7.4	13.6	18.4	46	4	8	6	5	83.6%	7.3%	14.5%	10.9%	9.1%
Elmdale	131	<DL	44.1	1.1	<DL	0.1	1.9	5.1	21.2	121	6	8	5	4	92.4%	4.6%	6.1%	3.8%	3.1%
Little Falls	266	<DL	48.5	3.1	0.4	3.6	6.7	14.8	40.2	188	63	43	26	15	70.7%	23.7%	16.2%	9.8%	5.6%
Ripley	94	<DL	15.9	2.9	0.2	4.3	11.6	12.3	15.6	67	15	22	18	12	71.3%	16.0%	23.4%	19.1%	12.8%
Swan River	61	<DL	20.6	2.2	<DL	1.7	7.4	14.5	20.3	48	8	10	6	5	78.7%	13.1%	16.4%	9.8%	8.2%
Swanville	44	<DL	25.8	1.4	<DL	0.0	2.6	11.5	25.8	40	2	3	3	2	90.9%	4.5%	6.8%	6.8%	4.5%
Two Rivers	104	<DL	37.8	3.1	0.05	4.3	10.1	15.8	28.1	74	20	24	18	10	71.2%	19.2%	23.1%	17.3%	9.6%
Total	1,105	<DL	48.5	3.1	<DL	2.9	11.1	17.2	32.2	830	156	203	160	119	75.1%	1105	<DL	48.5	3.1

<DL stands for less than detectable limit. The detectable limit is <0.03 mg/L nitrate. 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 land area of vulnerable geology (MDNR. MGS and UMD, 1997) and row crop production (USDA NASS Cropland Data Layer, 2013) in each township. 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, Morrison County

Township	Total Wells	Percent Vulnerable Geology	Percent Row Crop Production (2013)	Percent ≥7 mg/L	Percent ≥10 mg/L
				Nitrate-N mg/L or parts per million (ppm)	
Agram	93	76%	32%	50.5%	47.3%
Belle Prairie	87	53%	25%	16.1%	11.5%
Bellevue	126	55%	41%	10.3%	7.1%
Buh	44	39%	33%	9.1%	6.8%
Culdrum	55	10%	23%	10.9%	9.1%
Elmdale	131	38%	28%	3.8%	3.1%
Little Falls	266	89%	19%	9.8%	5.6%
Ripley	94	33%	20%	19.1%	12.8%
Swan River	61	14%	30%	9.8%	8.2%
Swanville	44	58%	19%	6.8%	4.5%
Two Rivers	104	42%	32%	17.3%	9.6%
Total	1,105	46%*	27%*	14.5%*	10.8%*

* Represents an average value

ESTIMATES OF POPULATION AT RISK

The human population at risk of consuming well water over the HRL of 10 mg/L nitrate was estimated based on the sampled wells. An estimated 467 people in Morrison County's study area have drinking water over the nitrate HRL (Table 5). Nitrate contamination is a significant problem across much of Morrison County. Additional public awareness and education programming will need to take place in many of the townships.

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

Township	Estimated Households on Private Wells*	Estimated Population on Private Wells*	Estimated Population ≥10 mg/L Nitrate-N**
Agram	199	575	104
Belle Prairie	242	586	43
Bellevue	389	1,092	43
Buh	201	527	23
Culdrum	173	479	24
Elmdale	347	1,002	30
Little Falls	611	1,653	46
Ripley	272	713	44
Swan River	271	754	31
Swanville	183	527	22
Two Rivers	250	675	29
Total	3,138	8,583	467

* Data collected from the Minnesota State Demographic Center, 2013

** Estimates based off of the 2013 estimated households per township gathered Minnesota State Demographic Center and percentage of wells at or over the HRL from the initial well dataset

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Morrison County final well dataset. The well logs provided information on the well age, depth, and construction type (MDH Minnesota Well Index (MWI) Database; https://apps.health.state.mn.us/cwi/). 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 (Tables 16-18).

- The majority of wells were drilled (81 percent), and 79 (7 percent) were sand point wells
- For wells with a well log the median depth of wells was 67 feet, and the shallowest was 20 feet
- For wells with a well log the median year the wells were constructed in was 1999

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 (Tables 19-22).

- The water temperatures ranged from 8.29 °C to 16.46 °C
- The median specific conductivity was 497 µS/cm, and was as high as 1,660 µS/cm
- The water from the wells had a median pH of 7.67
- The dissolved oxygen readings ranged from 0.09 mg/L to 11.26 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 et al., 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 was to assess nitrate concentrations in groundwater impacted by row crop production in selected townships in Morrison County. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 27 percent of the land cover is row crop agriculture and there are over 25,000 acres of groundwater irrigation in the study area.

Eleven townships were sampled covering over 260,000 acres. The initial (homeowner collected) nitrate sampling resulted in 1,222 samples. The 1,222 households that participated represent approximately 33 percent 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 324 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 117 (10 percent) wells were found to be unsuitable and were removed to create the final well dataset of 1,105 wells. The remaining 1,105 wells were wells believed to be impacted by commercial nitrogen fertilizer and were included in the final well dataset.

A majority of wells (81 percent) were drilled; and seven percent were sand point wells. The median depth of the wells was 67 and depths ranged from 20 to 504 feet.

In three of the 11 townships tested in Morrison County, more than 10 percent of the wells were at or over the nitrate HRL of 10 mg/L. The percent of wells at or over the nitrate HRL in each township ranged from 3.1 to 47.3 percent.

REFERENCES

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.

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 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.

Minnesota Department of Agriculture [MDA]. (2017). Agricultural Chemical Incidents. Geospatial Metadata. Online database accessed on May 23, 2017, from https://gisdata.mn.gov/dataset/env-agchem-incidents

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

Minnesota Department of Agriculture [MDA]. (2015). Initial Township Testing of Nitrate in Private Wells Morrison County 2013 Summary. On-line PDF retrieved August 14, 2017, from www.mda.state.mn.us/protecting/cleanwaterfund/gwdwprotection/~/media/Files/chemicals/nfmp/morrison2013summary.pdf

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 www.health.state.mn.us/divs/eh/wells/construction/handbook.pdf

Minnesota Department of Natural Resources [MDNR]. (2017). Minnesota Water Use Data. Online database accessed on April, 2017, from http://dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

Minnesota Department of Natural Resources [MDNR]. (2016). DNR Water Permits. Online webpage retrieved on January 12, 2016, from www.dnr.state.mn.us/permits/water/index.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 Pollution Control Agency [MPCA]. (2017). Feedlots in Minnesota. Online database accessed on February, 2017, from https://gisdata.mn.gov/dataset/env-feedlots

Minnesota Pollution Control Agency [MPCA]. (2015a). 2014 SSTS Annual Report, Subsurface Sewage Treatment Systems in Minnesota. Online PDF retrieved January 29, 2016, from 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 www.pca.state.mn.us/sites/default/files/wq-f4-12.pdf

Minnesota Pollution Control Agency [MPCA]. (2015c). State of Minnesota General Animal Feedlots NPDES Permit. Online PDF retrieved December 8, 2015, from 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 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 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 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 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 Rules, part 4725.4450 (2014).

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.

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

United States Environmental Protection Agency (US EPA). (2009). National Primary Drinking Water Regulations list. On-line PDF retrieved February 17, 2015, from, www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.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]. (2013). Online database accessed November 10, 2017, from, https://gisdata.mn.gov/dataset/agri-cropland-data-layer-2013

APPENDIX A

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 115.55.05 and MPCA, 2013a).

In 2014 Morrison County reported a total of 9,916 SSTS. Of these 593 (6.0%) were inspected for compliance; which was the 5th highest of any county in Minnesota (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. 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, 2015c).

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 (MPCA, 2015b). Registration is required to be completed at least once during a set four year period, the current period runs from January 2014 to December 2017. During the previous period, from 2010 to 2014, approximately 18,000 feedlots were registered in Minnesota (MPCA, 2014). A map and table of the feedlots located in the Morrison County study area can be found below (Figure 3; Table 7).

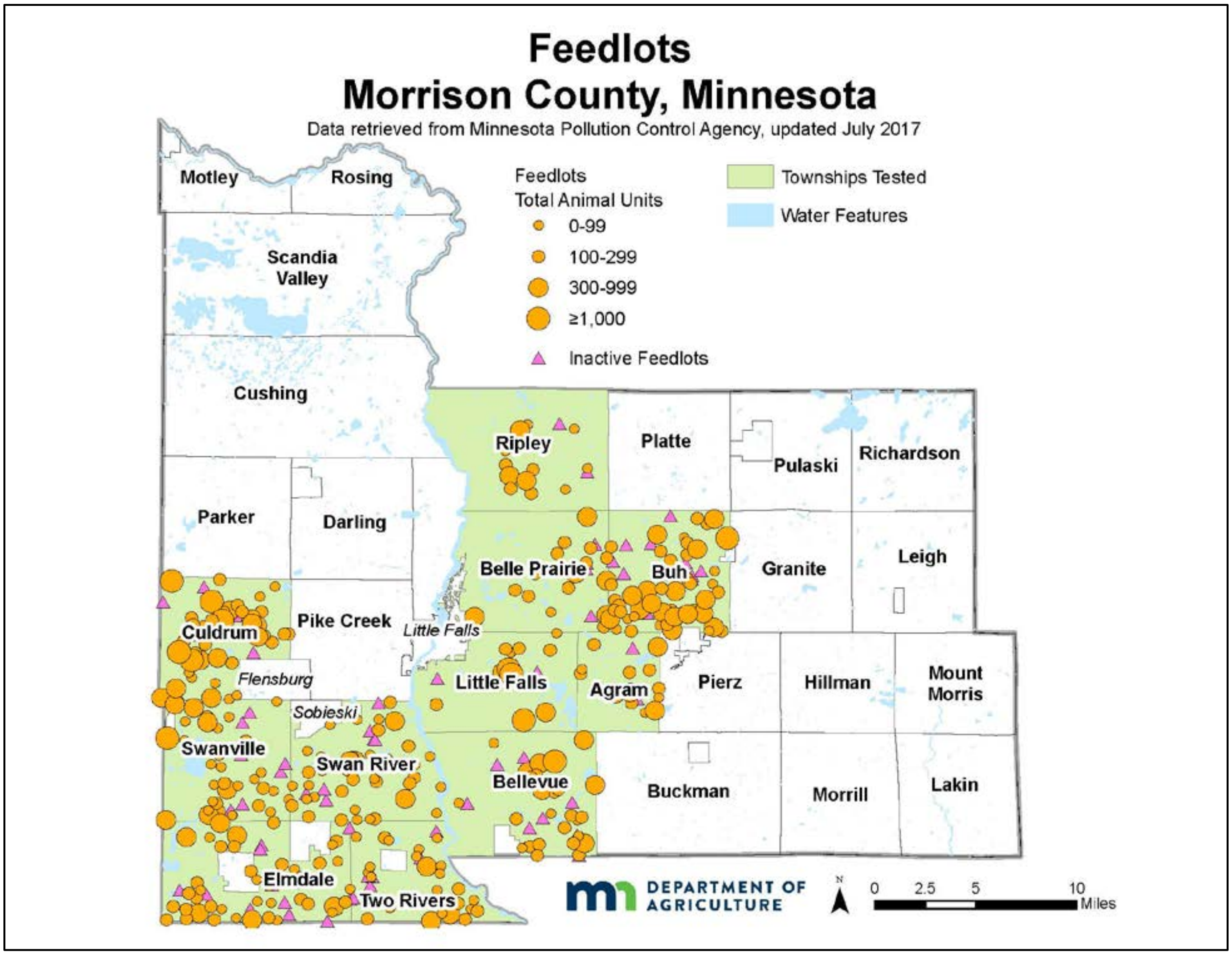


Figure 3. Feedlot Locations in Morrison County (MPCA, 2017)

On average there are 215 AU per square mile (0.34 AU/acre) over the entire study area (Table 7). Manure is often applied to cropland so it is pertinent to look at the AU per cropland acre. In the Morrison County study area livestock densities average 1.23 AU per acre of row crops (MPCA, 2017; USDA NASS, 2013).

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

Township	Total Feedlots	Active Feedlots	Inactive Feedlots	Average AU Permitted** Per Feedlot	Total Permitted** AU	Total Square Miles	Permitted** AU per Square Mile
Agram	14	12	2	272	3,802	20	190
Belle Prairie	18	14	4	287	5,172	44	116
Bellevue	27	19	8	320	8,653	46	189
Buh	49	38	11	313	15,338	36	427
Culdrum	42	36	6	434	18,238	34	539
Elmdale	44	31	13	160	7,040	40	178
Little Falls	11	8	3	676	7,433	36	206
Ripley	13	11	2	262	3,412	48	71
Swan River	39	32	7	174	6,791	38	179
Swanville	34	26	8	231	7,851	37	212
Two Rivers	30	24	6	123	3,689	28	134
Total	321	251	70	272*	87,419	407	215*

* 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.

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, Morrison County

Township	*Bulk Fertilizer Storage	*Anhydrous Ammonia	*Chemigation Sites	*Abandoned Sites	Total
Agram	0	0	7	0	7
Belle Prairie	1	0	31	0	32
Bellevue	0	0	31	1	32
Buh	0	0	2	0	2
Culdrum	0	0	0	0	0
Elmdale	0	1	0	0	1
Little Falls	1	0	1	0	2
Ripley	0	0	41	0	41
Swan River	0	0	0	0	0
Swanville	0	0	1	0	1
Two Rivers	0	0	1	0	1
Total	2	1	115	1	119

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

SPILLS AND INVESTIGATIONS

The MDA is responsible for investigating any fertilizer spills within Minnesota. Figure 4 shows the locations of mapped historic spills within the Morrison County study area. These sites are potential point sources of nitrogen to the groundwater (MDA, 2017).

The MDA tracks several types of incidents. Incident investigations are typically for larger spills. There are none 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, 2017), 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, 2017). 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.

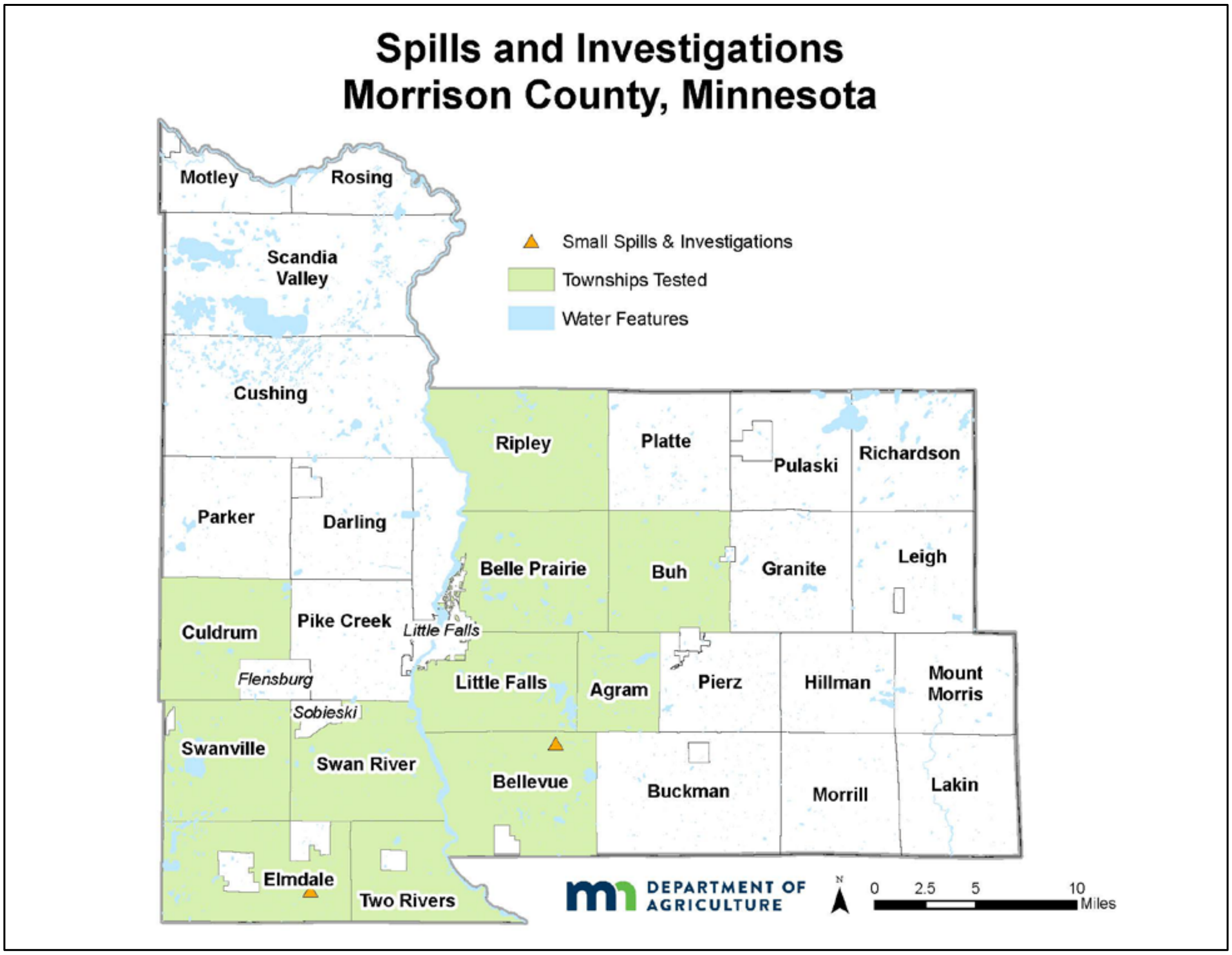


Figure 4. Fertilizer Spills and Investigations in Morrison County (MDA, 2017)

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

Contaminant	Incident Investigations	Contingency Areas	Small Spills and Investigations	Old Emergency Incidents
Fertilizer	0	0	1	0
Pesticides & Fertilizer	0	0	0	0
Anhydrous Ammonia	0	0	1	0
Total	0	0	2	0

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

Township	Incidents and Spills
Agram	0
Belle Prairie	0
Bellevue	1
Buh	0
Culdrum	0
Elmdale	1
Little Falls	0
Ripley	0
Swan River	0
Swanville	0
Two Rivers	0
Total	2

APPENDIX B

LAND AND WATER USE

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. Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, wheat, dry beans and double crops involving corn and soybeans.

Morrison County is located in central Minnesota and is north of the Twin Cities. The Mississippi River flows through the center of the county. More than 10 percent of the land area in the Townships of Agram and Little Falls is Wetland. The Morrison study area is mainly dominated by agricultural activities. Approximately 27 percent of the land area in the study area is considered row crops and 38 percent is used for pasture or hay (Figure 5, Table 11).

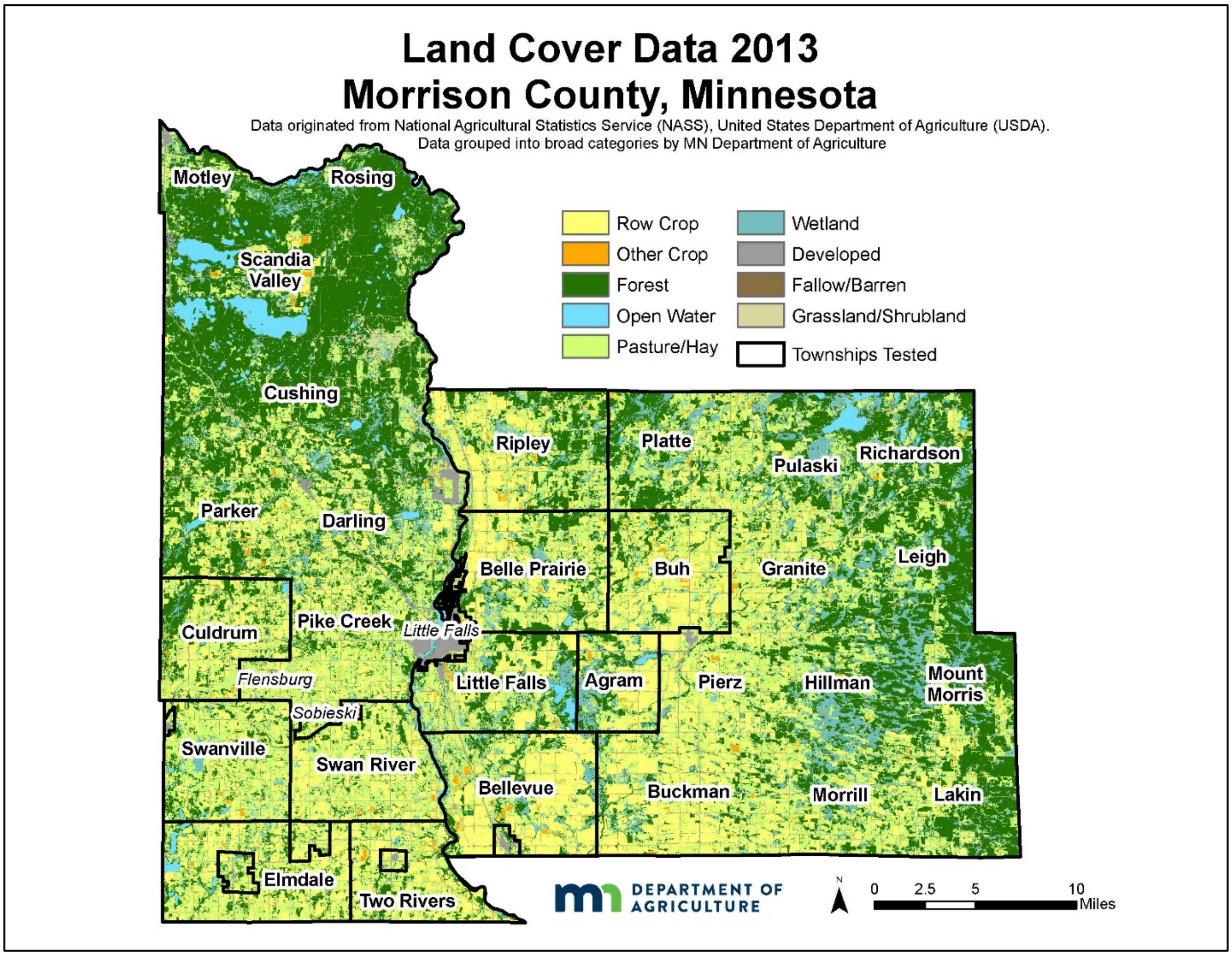


Figure 5. Land Cover in Morrison County (USDA NASS Cropland Data Layer, 2013)

Table 11. Land Cover Data (2013) by Township, Morrison 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
Agram	12,829	32%	2%	18%	2%	24%	19%	3%	0%	1%
Belle Prairie	28,513	25%	2%	22%	2%	35%	9%	4%	0%	1%
Bellevue	29,292	41%	3%	14%	2%	28%	8%	4%	0%	1%
Buh	22,964	33%	3%	13%	0%	39%	6%	4%	0%	1%
Culdrum	21,669	23%	2%	25%	1%	41%	3%	5%	0%	1%
Elmdale	25,376	28%	1%	15%	3%	45%	3%	4%	0%	1%
Little Falls	23,116	19%	2%	24%	4%	32%	12%	5%	0%	1%
Ripley	30,938	20%	3%	28%	1%	35%	8%	3%	0%	1%
Swan River	24,307	30%	2%	10%	2%	48%	3%	4%	0%	1%
Swanville	23,742	19%	2%	16%	1%	52%	5%	4%	0%	1%
Two Rivers	17,608	32%	3%	17%	1%	39%	3%	4%	0%	1%
Average	260,354*	27%	2%	18%	2%	38%	7%	4%	0%	1%

*Represents a total value

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 279 active groundwater permits in the study area and 266 are used for irrigating major crops (Table 12; Figure 6). Approximately 27,167 acres of cropland is permitted for groundwater irrigation. This is 10% of the total cropland acres in the study area. Most permitted wells are withdrawing groundwater from Quaternary aquifers (Table 13). The Quaternary Buried Artesian the most heavily utilized aquifers (MDNR, 2017).

Table 12. Major Crop Active Groundwater Use Permits by Township, Morrison County

Township	Major Crop Irrigation Well Permits	Average Depth (feet)	Acres Permitted
Agram	26	99	3,233
Belle Prairie	29	93	3,430
Bellevue	75	93	8,387
Buh	20	79	1,726
Culdrum	13	84	1,160
Elmdale	8	67	541
Little Falls	17	116	2,053
Ripley	37	99	4,141
Swan River	14	52	852
Swanville	4	82	247
Two Rivers	23	73	1,397
Total	266	90	27,167

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

Water Use Permits	Total	Average Depth (feet)	Aquifer System			
			Quaternary (Water Table)	Quaternary (Buried)	Paleozoic	Not Classified
Major Crop Irrigation	266	90	91	144	0	31
Non-Crop Irrigation	2	85	1	1	0	0
Waterworks	0	--	--	--	--	--
Industrial Processing	2	109	0	2	0	0
Special Categories	9	91	2	6	0	1
Total	279	90	94	153	0	32

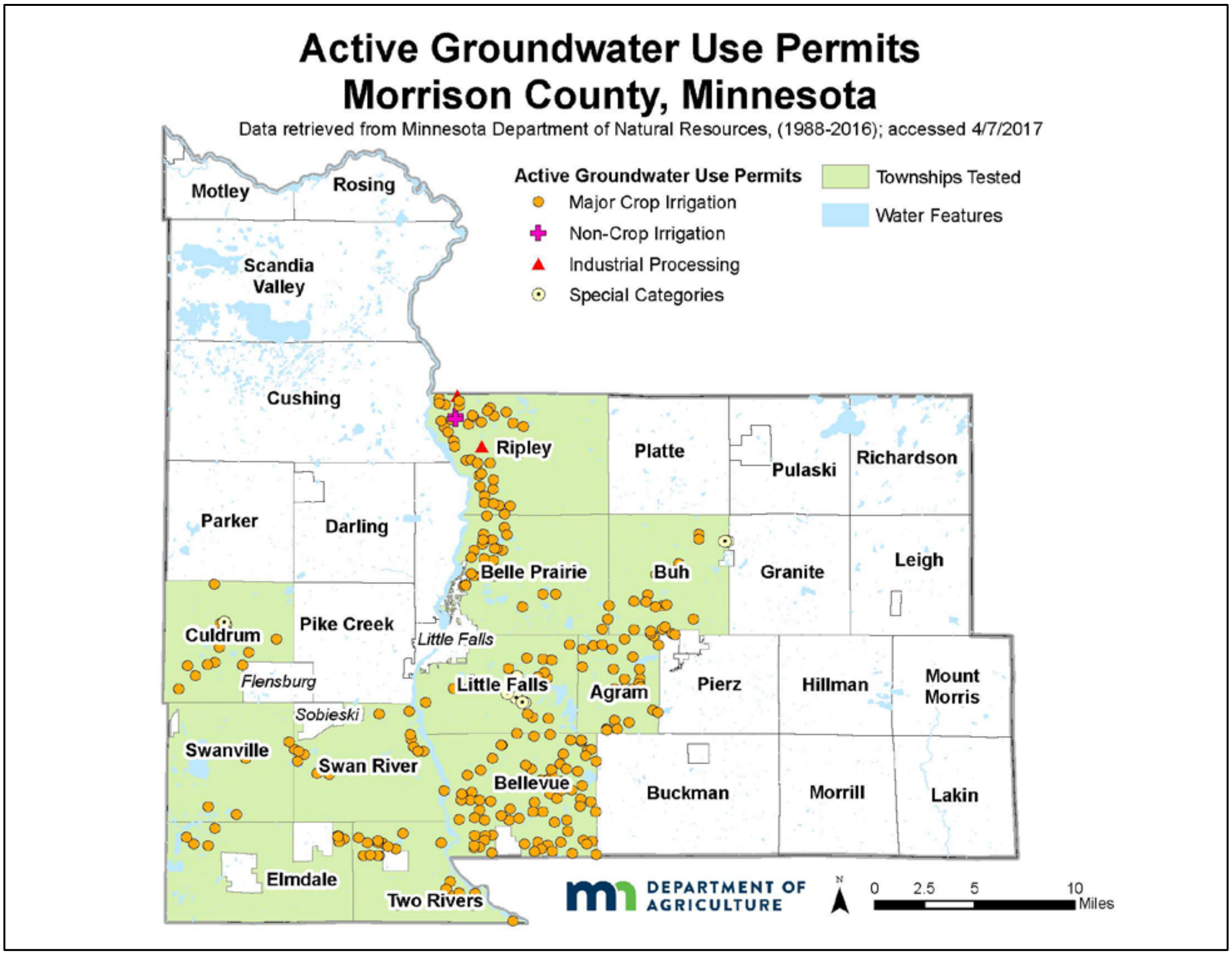


Figure 6. Active Groundwater Use Permits in Morrison County (MDNR, 2017)

APPENDIX C

Nitrate Brochure

The Minnesota Department of Agriculture and the Morrison 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: www.mda.state.mn.us/protecting/waterprotection/pesticides
- In addition to pesticides, high nitrate levels may suggest an increased risk for other contaminants. For more information go to: www.health.state.mn.us/divs/eh/wells/waterquality/test

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 Kimberly Kaiser at 651-201-6280 or Kimberly.kaiser@state.mn.us.

Minnesota Department of Agriculture

CLEAN WATER LAND & LEGACY AMENDMENT

APPENDIX D

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:

____
____
____
____

2

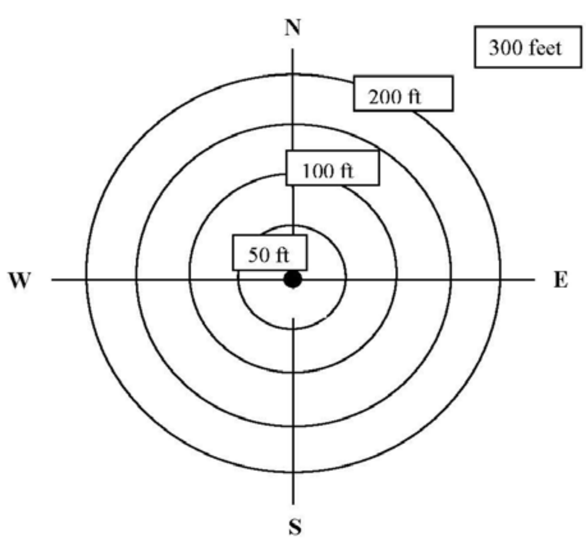
UNIQUE NUMBER:________________ or SITE ID:_______________________

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 E

Table 14. Reasons Wells Were Removed from the Final Well Dataset by Township, Morrison 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
Agram	6	2	0	0	1	0	5	2	16
Belle Prairie	6	0	3	0	0	1	3	1	14
Bellevue	1	1	2	0	1	1	2	1	9
Buh	1	0	4	0	0	1	2	0	8
Culdrum	1	0	1	0	0	0	1	0	3
Elmdale	3	0	5	0	0	1	4	4	17
Little Falls	1	1	1	0	0	3	5	4	15
Ripley	0	0	6	0	1	0	4	1	12
Swan River	0	0	5	0	0	1	3	0	9
Swanville	0	0	3	0	0	0	2	0	5
Two Rivers	2	1	2	0	0	1	3	0	9
Total	21	5	32	0	3	9	34	13	117

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

Township	Site Visit	No Site Visit	Total Wells Removed
Agram	5	11	16
Belle Prairie	5	9	14
Bellevue	4	5	9
Buh	1	7	8
Culdrum	2	1	3
Elmdale	4	13	17
Little Falls	5	10	15
Ripley	4	8	12
Swan River	4	5	9
Swanville	0	5	5
Two Rivers	3	6	9
Total	37	80	117

APPENDIX F

Table 16. Well Construction Type for Final Well Dataset

Township	Samples*	Drilled	Sand Point	Not Available
Agram	93	77	12	4
Belle Prairie	87	69	13	5
Bellevue	126	99	25	2
Buh	44	41	1	2
Culdrum	55	51	2	2
Elmdale	131	93	3	35
Little Falls	266	205	12	49
Ripley	94	81	3	10
Swan River	61	57	3	1
Swanville	44	34	3	7
Two Rivers	104	91	2	11
Total	1,105	898	79	128

*Data compiled from well logs and homeowner responses.

Table 17. Well Depth for Final Well Dataset

Township	Samples*	Min	Max	Median	Mean
Agram	64	23	205	64	67
Belle Prairie	47	30	185	74	84
Bellevue	73	20	147	63	66
Buh	25	44	127	73	72
Culdrum	32	41	192	75	85
Elmdale	68	24	156	73	80
Little Falls	127	22	270	66	76
Ripley	52	28	302	65	78
Swan River	34	26	504	56	76
Swanville	16	32	201	69	79
Two Rivers	55	35	241	73	84
Total	593	20	504	67	76

*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
Agram	64	1977	2016	1999	1997
Belle Prairie	47	1980	2012	1997	1996
Bellevue	73	1976	2012	1998	1996
Buh	25	1976	2009	2002	1997
Culdrum	32	1976	2009	1995	1995
Elmdale	68	1976	2014	2000	1999
Little Falls	127	1977	2013	1998	1996
Ripley	52	1975	2013	2000	2000
Swan River	34	1980	2010	1996	1996
Swanville	16	1987	2013	2001	2001
Two Rivers	55	1975	2015	1999	1999
Total	593	1975	2016	1999	1997

*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

Well Unique#	**Site ID**	**Sample #'s**	**Date**	**Time**	**Well Depth (units)**
		Nitrate:			
Sampler:		**Pesticide:**			**Well Type:**
Well Owner Name:					
Well Owner Address:					
GPS: Latitude:			Longitude:		

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
Agram	40	8.39	12.48	10.00	10.15
Belle Prairie	25	8.55	11.69	10.01	10.00
Bellevue	25	8.64	16.46	10.32	10.59
Buh	6	8.95	11.25	10.11	10.14
Culdrum	4	9.23	10.91	9.59	9.83
Elmdale	23	8.42	13.48	10.16	10.37
Little Falls	87	8.29	13.57	10.19	10.35
Ripley	26	9.03	11.80	10.30	10.28
Swan River	13	9.32	12.98	10.48	10.54
Swanville	5	9.50	11.87	10.15	10.47
Two Rivers	32	9.19	14.15	10.55	10.81
Total	286	8.29	16.46	10.22	10.36

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

Township	Samples	Min	Max	Median	Mean
Agram	40	315	633	502	488
Belle Prairie	25	285	956	514	517
Bellevue	25	235	992	411	463
Buh	6	277	960	513	544
Culdrum	4	616	893	777	766
Elmdale	23	405	880	674	677
Little Falls	87	193	1660	399	442
Ripley	26	294	754	444	452
Swan River	13	176	897	615	569
Swanville	5	536	881	621	661
Two Rivers	32	433	908	577	601
Total	286	176	1660	497	511

Table 21. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Agram	40	6.42	8.13	7.44	7.40
Belle Prairie	25	6.90	8.78	8.18	8.08
Bellevue	25	7.29	8.63	8.01	8.01
Buh	6	7.52	8.46	8.04	7.98
Culdrum	4	7.07	8.22	7.78	7.71
Elmdale	23	7.02	7.72	7.29	7.30
Little Falls	87	6.70	8.28	7.84	7.78
Ripley	26	6.66	7.87	7.65	7.59
Swan River	13	7.21	8.28	7.99	7.84
Swanville	5	7.23	7.50	7.31	7.34
Two Rivers	32	7.00	7.64	7.45	7.44
Total	286	6.42	8.78	7.67	7.68

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

Township	Samples	Min	Max	Median	Mean
Agram	40	0.14	9.57	3.37	3.25
Belle Prairie	25	0.58	8.61	1.95	3.09
Bellevue	25	0.38	10.44	1.97	3.69
Buh	6	0.33	11.26	3.13	4.04
Culdrum	4	0.41	1.14	1.08	0.93
Elmdale	23	0.14	8.31	1.06	2.76
Little Falls	87	0.09	6.66	2.08	2.17
Ripley	26	0.51	9.13	4.01	4.09
Swan River	13	0.30	9.75	2.12	3.44
Swanville	5	0.49	9.20	4.67	4.39
Two Rivers	32	0.11	5.46	1.29	2.02
Total	286	0.09	11.26	2.08	2.86