



FINAL TOWNSHIP TESTING NITRATE REPORT: HUBBARD COUNTY 2016-2017

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Minnesota Department of Agriculture

Pesticide and Fertilizer Management Division

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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 2016, private wells in the Hubbard County study area (six 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 1,106 wells representing an average response rate of 38 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, 10.5 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 516 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 278 wells in 2017. 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 58 (5 percent) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of 1,048 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 percentage of wells at or over the HRL ranged from 2.4 to 15.2 percent. One third (2 of 6) of the townships sampled in Hubbard 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 April 2018, 242 townships in 24 counties have completed the initial sampling with the goal of providing nitrate testing in approximately 300 vulnerable townships by 2019.

In 2016, six townships in Hubbard 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 Hubbard County occurred during the summer of 2017. 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 B).

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

Townships Tested Hubbard County, Minnesota

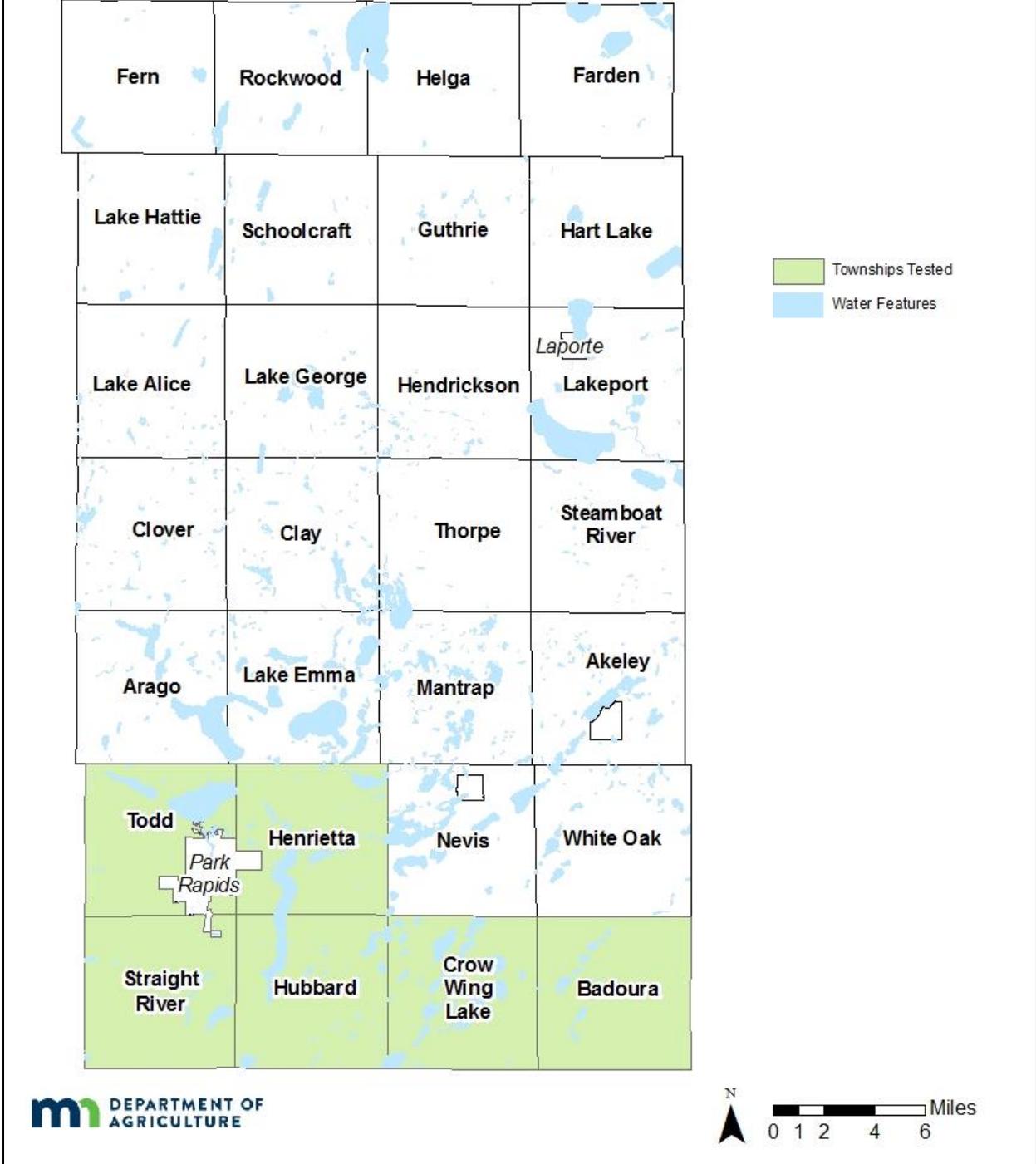


Figure 1. Townships Tested in Hubbard County

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-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 Hubbard County with glacial outwash (Lusardi, 2013) 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, 1999).

GEOLOGY AND HYDROGEOLOGY

The geology in Hubbard County is heavily influenced by glacial outwash, glacial till, and supraglacial drift complex (DNR, MGS, UMD, 1997).

The southern part of Hubbard County is dominated by glacial outwash. There are two distinct glacial outwash areas. West of the Crow Wing chain of lakes, calcareous sandy and gravelly materials are common and were formed from the meltwaters of the Itasca Moraine. East of the Crow Wing chain of lakes, acidic sandy and gravelly materials are common and were formed from the meltwaters of the St.

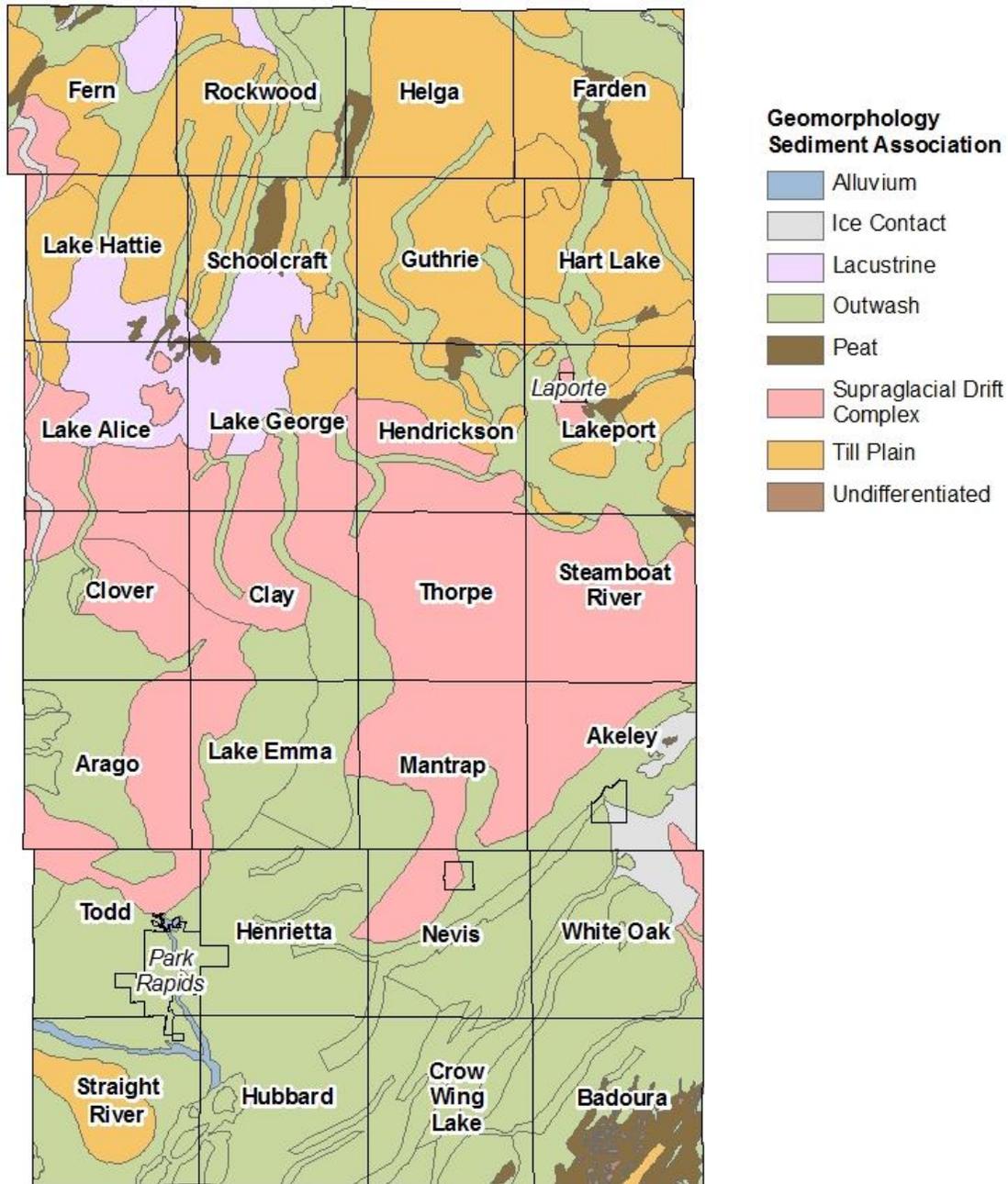
Croix Moraine. Due to the sand and gravel composition of the surficial geology in these two areas, groundwater is more susceptible to contamination (USDA NRCS, 2003).

The northern part of Hubbard County is dominated by compacted glacial till, deposited by advancing and retreating glaciers. This area has many small and large rocks and mostly calcareous sandy loam and loam is common (USDA NRCS, 2003).

The middle of Hubbard County consists of the Itasca Moraine complex which is made up of steep, rugged hills. Calcareous sandy loam and loam glacial till are common in this area, however there are also smaller, less common deposits of sand, gravel, and stratified materials (USDA NRCS, 2003).

Statewide geomorphological mapping conducted by the Minnesota Department of Natural Resources (MDNR), the Minnesota Geological Survey (MGS) and the University of Minnesota at Duluth (MDNR, MGS and UMD, 1997) indicates the extent of glacial deposits in Hubbard County as presented in Figure 2.

Hubbard County Geomorphology-Sediment Association



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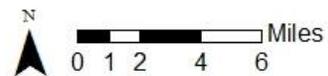


Figure 2. Statewide Geomorphology Layer, Sediment Association in Hubbard County (DNR, MGS, and UMD, 1997)

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, and bulk storage of fertilizer are considered in this section. Below is a brief overview of these sources in Hubbard County. Further details are in Appendix B.

SUBSURFACE SEWAGE TREATMENT SYSTEM

Subsurface Sewage treatment systems (SSTS) can be a potential source for contaminants in groundwater such as nitrate and fecal material (MDH, 2014). A total of 17,570 SSTS were reported in Hubbard County for 2016. Over a recent 15 year period (2002-2016), 4,145 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Hubbard County, 24 percent are newer than 2002 or have been repaired since 2002 (MPCA, 2017a). When new SSTS 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 Hubbard County study area there is a total of 1 active feedlot. The one active feedlot is permitted to house 300-999 animal units (AU). (Appendix B; Figure 7). It is located in Hubbard Township which also has 5 inactive feedlots. Straight River Township has the most inactive feedlots with a total of 7. (Appendix B; Table 10).

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 Hubbard County study area has a total of 173 fertilizer storage licenses, with Hubbard Township having the greatest number (72). (Appendix B; Table 11).

FERTILIZER SPILLS AND INVESTIGATIONS

There are no historic fertilizer spills and investigations that occurred in the Hubbard County Study area.

TOWNSHIP TESTING METHODS

VULNERABLE TOWNSHIPS

Well water sampling is focused on areas that are considered vulnerable to groundwater contamination by commercial nitrogen fertilizer. Typically townships and cities are selected for sampling if more than 30 percent of the underlying geology is considered vulnerable and more than 20 percent 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 is shown in Figure 3. Additional factors such as previous nitrate results and local knowledge of groundwater conditions were, and continue to be, used to prioritize townships for testing.

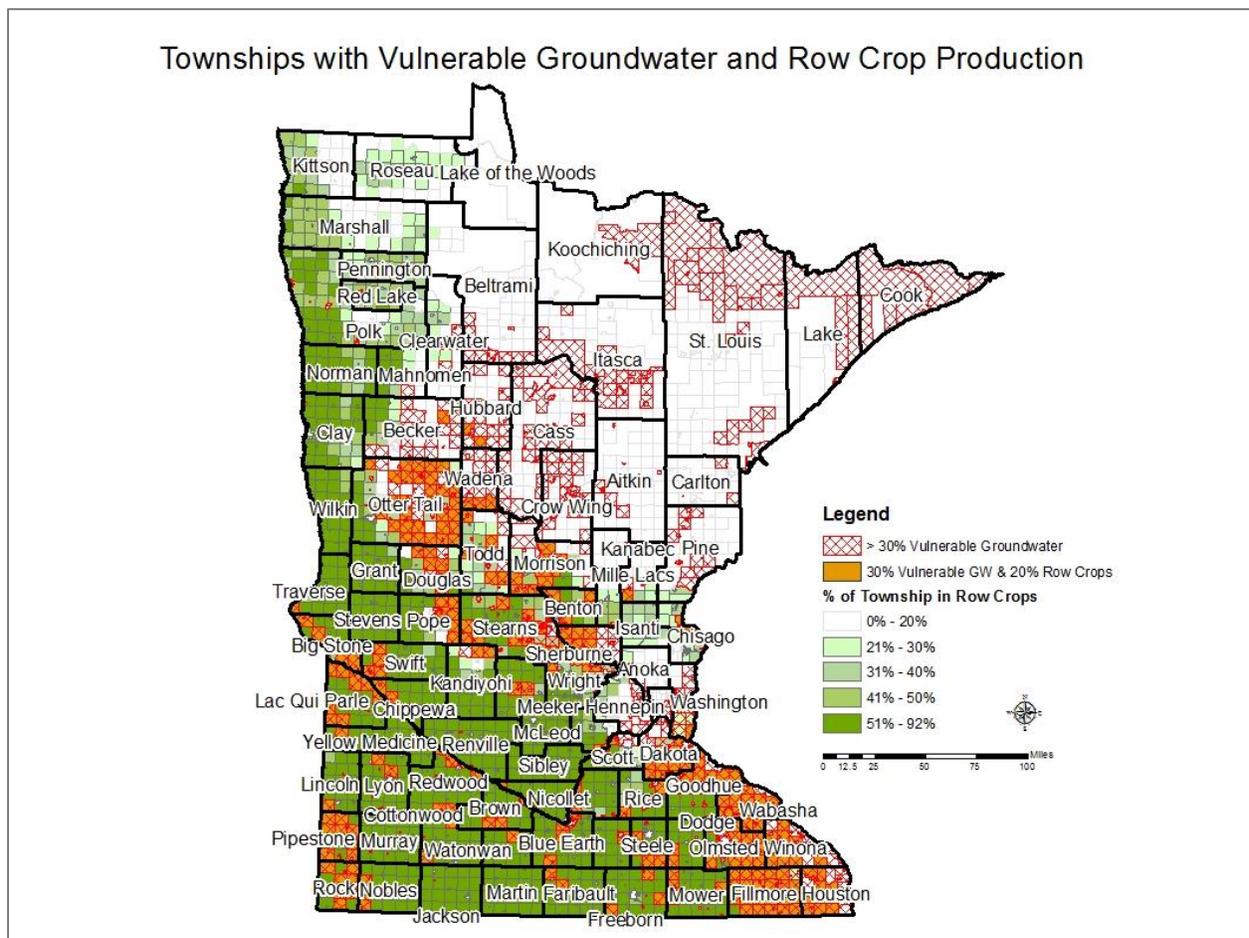


Figure 3. Minnesota Townships with Vulnerable Groundwater and Row Crop Production

Aquifer sensitivity ratings from the Minnesota Department of Natural Resources were used to estimate the percentage of geology vulnerable to groundwater contamination. The same geologic mapping project presented in Figure 2 was used to classify the state into aquifer sensitivity ratings. There are three ratings for aquifer sensitivity: low, medium and high. Sensitivity ratings are described in Table

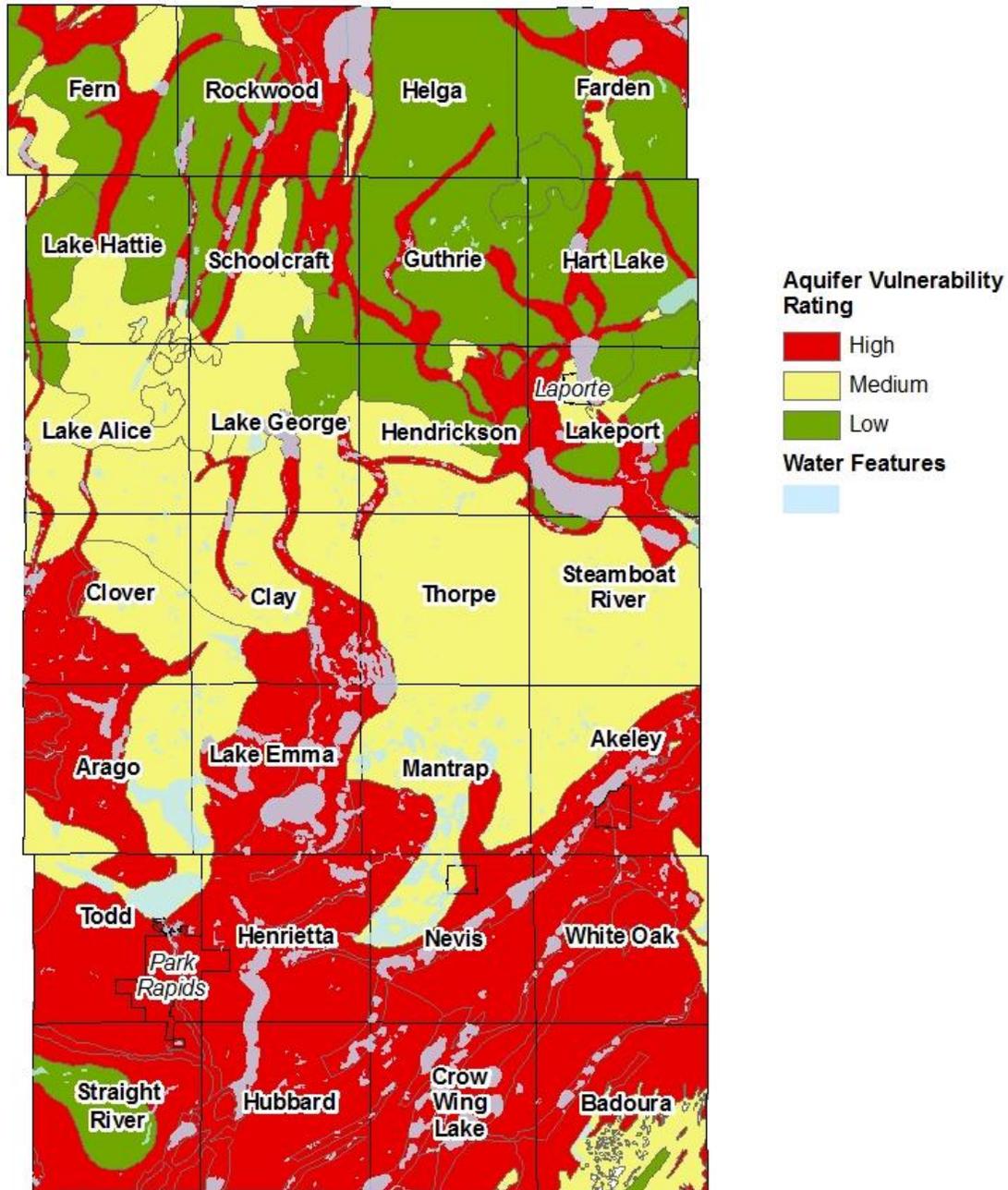
1. The ratings are based upon guidance from the Geologic Sensitivity Project Workshop’s report “Criteria and Guidelines for Assessing Geologic Sensitivity in Ground Water Resources in Minnesota” (MDNR, 1991). A map of Hubbard County depicting the aquifer vulnerabilities is shown below in Figure 4.

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

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

Water Table Aquifer Vulnerability Rating Hubbard County

Reclassification of Geomorphology of Minnesota Sediment Association Layer (MGS and UMD, 1997)



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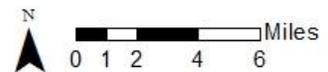


Figure 4. Water Table Aquifer Vulnerability Rating in Hubbard County

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 Hubbard County can be found in Appendix C (Figure 8, Table 12). On average 13 percent of the land cover was row crop agriculture.

PRIVATE WELL SAMPLING - NITRATE

The testing is done in two steps in each township: “initial” sampling and “follow-up” sampling. The initial nitrate sampling was conducted in 2017. In the initial sampling, all private well owners in the selected townships 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 nitrate brochure (Appendix D). Well water samples were collected by 1,106 homeowners using the mail-in kit (Table 2). These 1,106 samples are considered the “initial well dataset”. On average, 38 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 2017 by MDA staff. A total of 278 follow-up samples were analyzed (Table 2).

Table 2. Homeowner Participation in Initial and Follow-Up Well Water Sampling, Hubbard County

Township	Kits Sent	Return Rate for Kits	Initial Well Dataset	Well Site Visits & Follow-up Sampling Conducted
Badoura	103	39.8%	41	9
Crow Wing Lake	498	41.8%	208	39
Henrietta	764	33.9%	259	60
Hubbard	618	39.0%	241	77
Straight River	324	42.3%	137	35
Todd	592	37.2%	220	58
Total	2,899	38.2%	1,106	278

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](http://www.mda.state.mn.us/pwps)).

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 Private Well Field Log & Well Survey 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 58 wells were removed to create the final well dataset. See Appendix E (Table 15 and 16) for a summary of the removed wells.

HAND DUG

All hand dug wells were excluded from the dataset, regardless of the nitrate concentration. 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.

DUPLICATE / EXTRA KIT

Wells that were later found to be duplicates were removed from the final well dataset.

INITIAL RESULTS

INITIAL WELL DATASET

Approximately 1,106 well owners returned water samples for analysis across the six townships (Figure 5). These wells represent the initial well dataset.

The following paragraphs provide a brief discussion of the statistics presented in Table 3.

The minimum values of nitrate for all townships were less than the detection limit (<DL) which is 0.03 mg/L. The maximum values ranged from 20.2 to 46.3 mg/L, with Hubbard Township having the highest result. Median values range from <0.03 to 0.3 mg/L, with Hubbard Township having the highest median value. The 90th percentiles range from 4.2 to 17.8 mg/L, with Hubbard Township having the highest 90th percentile.

Initial results from the sampling showed that in Badoura, Hubbard, and Straight River Townships, ten percent or more of the wells were at or over 10 mg/L nitrate-N. The township testing results contrast findings from a 2010 USGS report on nitrate concentrations in private wells in the glacial aquifer systems across the upper United States (US) in which less than five percent of sampled private wells had nitrate concentrations greater than 10 mg/L (Warner and Arnold, 2010). Data from the township testing program suggests that private well water in Badoura, Hubbard, and Straight River Townships is more heavily impacted by nitrate than other areas of the upper United States. Both the USGS and the township testing studies indicate that nitrate concentrations can vary considerably over short distances.

Initial Well Dataset Results Hubbard County, Minnesota

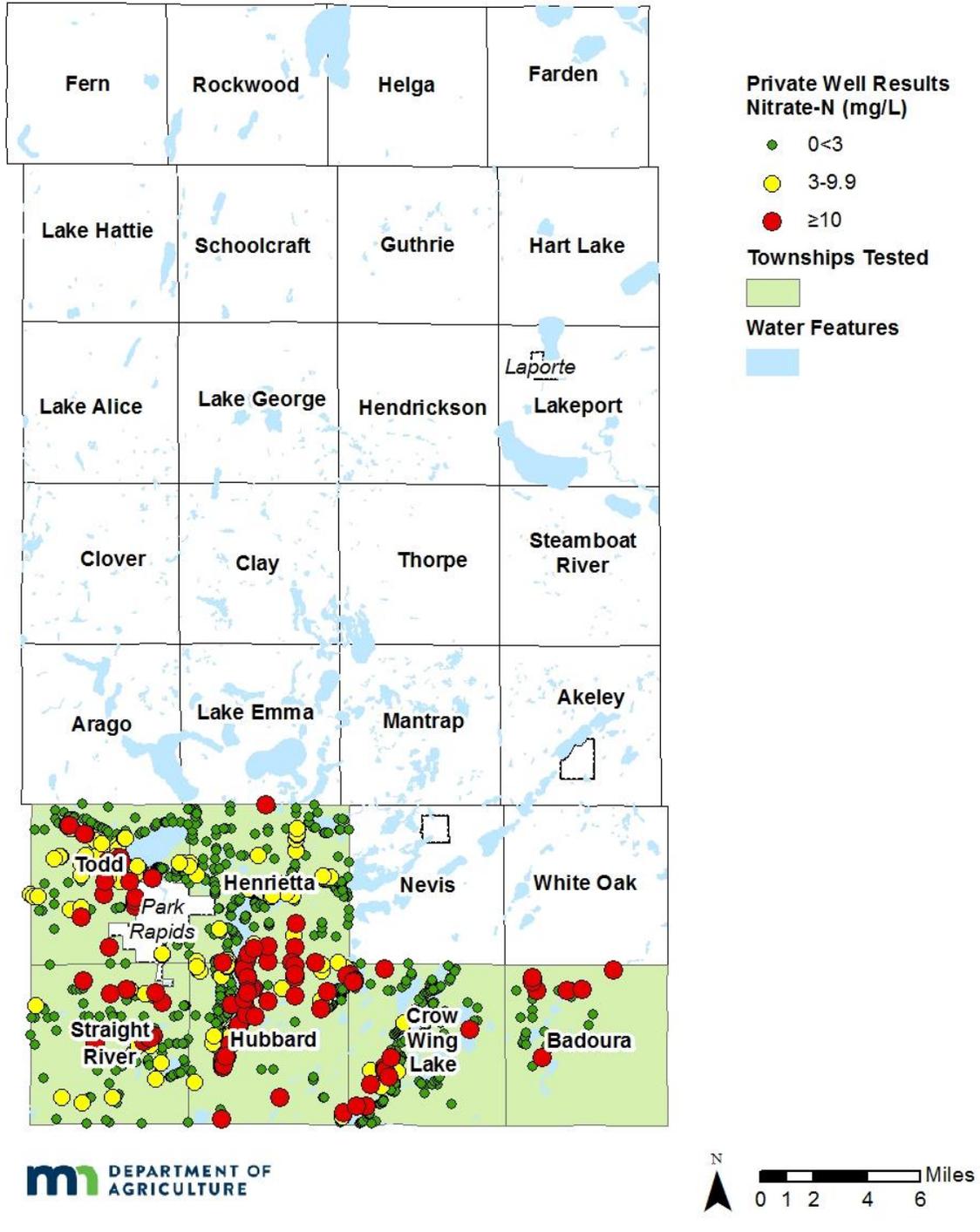


Figure 5. Well Locations and Nitrate Results from Initial Dataset in Hubbard County

Table 3. Hubbard County Township Testing Summary Statistics for Initial Well Dataset

Township	Total Wells	Values			Percentiles					Number of Wells					Percent of Wells				
		Min	Max	Mean	50 th (Median)	75 th	90 th	95 th	99 th	<3	3<10	≥5	≥7	≥10	<3	3<10	≥5	≥7	≥10
		Nitrate-N mg/L or parts per million (ppm)																	
Badoura	41	<0.03	32.8	3.8	<0.03	2.0	17.8	23.1	32.8	33	1	7	7	7	80.5%	2.4%	17.1%	17.1%	17.1%
Crow Wing	208	<0.03	32.6	2.0	<0.03	0.1	7.0	17.6	29.7	183	7	22	21	18	88.0%	3.4%	10.6%	10.1%	8.7%
Henrietta	259	<0.03	20.2	1.5	0.1	1.7	4.2	7.0	17.6	221	29	22	14	9	85.3%	11.2%	8.5%	5.4%	3.5%
Hubbard	241	<0.03	46.3	5.2	0.3	6.7	17.8	27.0	40.6	159	35	63	59	47	66.0%	14.5%	26.1%	24.5%	19.5%
Straight River	137	<0.03	26.1	2.6	<0.03	2.3	10.0	16.0	23.1	107	16	23	16	14	78.1%	11.7%	16.8%	11.7%	10.2%
Todd	220	<0.03	26.9	2.7	<0.03	3.1	9.6	14.0	25.0	164	35	40	29	21	74.5%	15.9%	18.2%	13.2%	9.5%
Total	1,106	<0.03	46.3	2.9	<0.03	2.3	10.4	17.4	29.5	867	123	177	146	116	78.4%	11.1%	16.0%	13.2%	10.5%

The 50th percentile (75th, 90th, 95th, and 99th) is the value below which 50 percent (75%, 90%, 95%, and 99%) of the observed values fall

ESTIMATES OF POPULATION AT RISK

The human population at risk of consuming well water at or over the HRL of 10 mg/L nitrate was estimated based on the sampled wells. An estimated 516 people in Hubbard County's study area have drinking water over the nitrate HRL (Table 4). Nitrate contamination is a significant problem across much of Hubbard County. Additional public awareness and education programming will need to take place in many of the townships.

Table 4. Estimated Population with Water Wells Over 10mg/L Nitrate-N, Hubbard County

Township	Estimated Households on Private Wells*	Estimated Population on Private Wells*	Estimated Population ≥ 10 mg/L Nitrate-N**
Badoura	58	133	23
Crow Wing Lake	167	335	29
Henrietta	614	1,550	54
Hubbard	329	781	152
Straight River	302	736	75
Todd	571	1,384	131
Total	2,041	4,919	516

* Data collected from the Minnesota State Demographic Center, 2017

** Estimates based off of the 2016 estimated households per township gathered Minnesota State Demographic Center and percentage of wells at or over the HRL from the initial well dataset

WELL SETTING AND CONSTRUCTION

MINNESOTA WELL INDEX AND WELL LOGS

The Minnesota Well Index (MWI) (formerly known as the "County Well Index") is a database system developed by the Minnesota Geological Survey and the Minnesota Department of Health (MDH) for the storage, retrieval, and editing of water-well information. The database contains basic information on well records (e.g. location, depth, static water level) for wells drilled in Minnesota.

The database also contains information on the well log and the well construction for many private drinking water wells. The MWI is the most comprehensive Minnesota well database available, but contains only information for wells in which a well log is available. Most of the records in MWI are for wells drilled after 1974, when water-well construction code required well drillers to submit records to the MDH. The MWI does contain data for some records obtained by the MGS through the cooperation of drillers and local government agencies for wells drilled before 1974 (MGS, n.d., b)

In some cases, well owners were able to provide Unique Well Identification Numbers for their wells. When the correct Unique IDs are provided, a well log can be used to identify the aquifer that the well withdraws water from. The well logs were obtained from the MWI for 485 documented wells (Table 5).

Approximately 44 percent of the sampled wells had corresponding well logs. Thus, the data gathered on aquifers represents a portion of the total sampled wells. Below is a brief description of the aquifers characterized in Table 5.

The Quaternary aquifers represent the youngest geological aquifer formation identified in Hubbard County. The Quaternary Water Table (QWTA) wells are defined as having less than ten feet of confining material (clay) between the land surface and the well screen (MPCA, 1998). When there is less than ten feet of clay, it allows surface contaminants to travel more quickly to the water table aquifers. In general, shallower wells completed in the QWTA may be more susceptible to nitrate contamination. The Quaternary Buried aquifer wells have more than ten feet of confining material (typically clay) between the land surface and the well screen (MPCA, 1998).

According to the well log data, the most commonly utilized aquifer in the sampled wells was split between the water table aquifer and the Quaternary buried aquifers. This majority reflects the overall findings for all documented wells in the focus area (Appendix F, Table 17). The wells in these aquifers are relatively shallow, averaging between 60 and 90 feet deep.

Table 5. Nitrate Concentrations within Sampled Groundwater Aquifers

Aquifer Group	Average Depth	Total Wells	Values				Percentile	Number of Wells			Percent of Wells		
			Min	Max	Mean	Median	90th	<3	3<10	≥10	<3	3<10	≥10
Nitrate-N mg/L or parts per million (ppm)													
QWTA	60.6	292	<0.03	37.4	2.9	0.0	11.3	223	36	33	76.4%	12.3%	11.3%
QBUA	66.0	22	<0.03	7.0	1.5	0.0	6.6	18	4	0	81.8%	18.2%	0.0%
QBAA	90.4	170	<0.03	25.6	1.3	0.0	3.2	153	10	7	90.0%	5.9%	4.1%
QUUU	58	1	10.6	10.6	10.6	10.6	<0.03	0	0	1	0.0%	0.0%	100.0%
Not Available	70.9	621	<0.03	46.3	3.3	0.1	12.2	473	73	75	76.2%	11.8%	12.1%
Total	69.2*	1,106	<0.03	46.3	2.9	<0.03	10.4	867	123	116	78.4%	11.1%	10.5%

* Represents an average value.

WELL OWNER SURVEY

The private well owner survey, sent out with the sampling kit, provided additional information about private wells that were sampled. The survey included questions about the well construction, depth and age, and questions about nearby land use. A blank survey can be found in Appendix G. It is important to note that well information was provided by the well owners and may be approximate or potentially erroneous. The following section is a summary of information gathered from the well owner survey (complete well survey results are located in Appendix H at the end of this document, Tables 18-32).

The majority of wells in each township are located on lake home property. In Crow Wing Lake Township 70 percent were a lake property.

Just over half of the wells were drilled construction (57 percent), and 22 percent were sand point wells. Sand point (drive-point) wells are typically completed at shallower depths than drilled wells. Sand point

wells are also usually installed in areas where sand is the dominant geologic material and where there are no thick confining units such as clay. This makes sand point wells more vulnerable to contamination from the surface. There were only two hand dug wells sampled in the townships. As mentioned previously hand dug wells are shallow and more sensitive to local surface runoff contamination than deeper drilled wells.

Approximately 24 percent of the wells in the townships are less than 50 feet deep. Henrietta Township has the lowest percentage of wells less than 58 feet deep (14 percent) and Todd has the highest percent of wells less than 50 feet deep (30 percent).

Most of the wells had not been tested for nitrate within the last ten years or homeowners were unsure if they had been tested. Therefore, the results most homeowners receive from this study will provide new information.

POTENTIAL NITRATE SOURCE DISTANCES

The following response summary relates to isolation distances of potential point sources of nitrate that may contaminate wells. This information was obtained from the well surveys completed by the homeowner (complete well survey results are located in Appendix H at the end of this document, Tables 18-32).

- On average, farming takes place on less than five percent of the properties.
- Agricultural fields are greater than 300 feet from wells at 67 percent of the properties.
- One percent of the well owners across all the townships responded that they have livestock (greater than ten head of cattle or other equivalent) on their property.
- The majority of wells (66 percent) are over 300 feet from an active or inactive feedlot.
- Very few well owners (less than one percent) across all townships store more than 500 pounds of fertilizer on their property.
- A small minority of wells (less than five percent) are less than 50 feet away from septic systems.

FINAL RESULTS

FINAL WELL DATASET

A total of 1,106 well water samples were collected by homeowners across six townships. A total of 58 (5 percent) wells were found to be unsuitable and were removed to create the final well dataset. The final analysis was conducted on the remaining 1,048 wells (Table 6). 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 at or over the nitrate HRL of 10 mg/L. Table 6 shows the initial results compared to the final results for all townships sampled. The percent of wells at or over the HRL ranged from 2.4 to 15.2 percent.

Table 6. Initial and Final Well Dataset Results, Hubbard County

Township	Initial Well Dataset	Final Well Dataset	Final Number of Wells ≥10 mg/L Nitrate-N	Final Percentage of Wells ≥10 mg/L Nitrate-N
Badoura	41	38	5	13.2%
Crow Wing Lake	208	202	15	7.4%
Henrietta	259	254	6	2.4%
Hubbard	241	223	34	15.2%
Straight River	137	128	9	7.0%
Todd	220	203	11	5.4%
Total	1,106	1,048	80	7.6%

* Represents an average value

The individual nitrate results from this final well dataset are displayed spatially in Figure 6. 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 7. The minimum values were all below the detection limit. The maximum values ranged from 20.2 to 46.3 mg/L nitrate, with Hubbard Township having the highest result. The 90th percentile ranged from 2.5 to 15.0 mg/L nitrate-N, with Crow Wing Lake? Township having the lowest result and Hubbard Township having the highest result.

Final Well Dataset Results Hubbard County, Minnesota

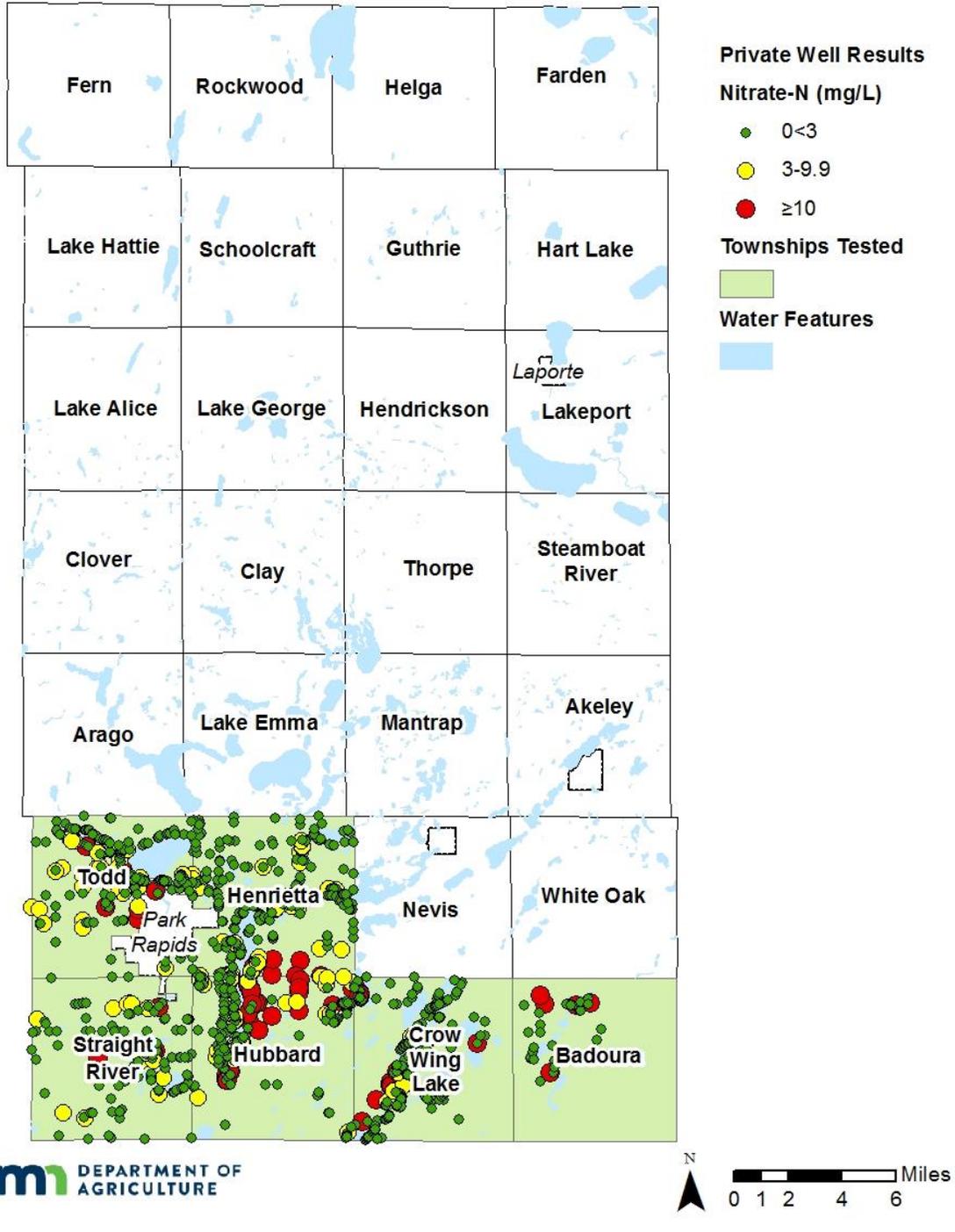


Figure 6. Well Locations and Nitrate Results from Well Dataset in Hubbard County

Table 7. Hubbard County Township Testing Summary Statistics for Final Well Dataset

Township	Total Wells	Values			Percentiles					Number of Wells					Percent of Wells				
		Min	Max	Mean	50 th (Median)	75th	90th	95th	99th	<3	3<10	≥5	≥7	≥10	<3	3<10	≥5	≥7	≥10
		Nitrate-N mg/L or parts per million (ppm)																	
Badoura	38	<0.03	32.8	3.0	<0.03	1.2	11.1	22.7	32.8	32	1	5	5	5	84.2%	2.6%	13.2%	13.2%	13.2%
Crow Wing Lake	202	<0.03	28.1	1.6	<0.03	0.1	2.5	13.6	27.6	182	5	18	18	15	90.1%	2.5%	8.9%	8.9%	7.4%
Henrietta	254	<0.03	20.2	1.3	0.07	1.6	3.6	6.0	16.8	221	27	18	10	6	87.0%	10.6%	7.1%	3.9%	2.4%
Hubbard	223	<0.03	46.3	4.1	0.17	4.0	15.0	21.8	40.3	159	30	45	41	34	71.3%	13.5%	20.2%	18.4%	15.2%
Straight River	128	<0.03	26.1	2.0	<0.03	1.4	6.4	11.7	23.4	106	13	15	10	9	82.8%	10.2%	11.7%	7.8%	7.0%
Todd	203	<0.03	26.9	1.9	<0.03	2.0	6.5	10.4	24.1	163	29	24	17	11	80.3%	14.3%	11.8%	8.4%	5.4%
Total	1048	<0.03	46.3	2.2	<0.03	1.5	6.6	13.8	27.4	863	105	125	101	80	82.3%	10.0%	11.9%	9.6%	7.6%

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 8 compares the final results to the percent of vulnerable geology (MDNR, 1991) and row crop production (USDA NASS, 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 8. Township Nitrate Results Related to Vulnerable Geology and Row Crop Production, Hubbard County

Township	Final Well Dataset	Percent in Row Crop Production*	Percent in Vulnerable Geology	Percent ≥7 mg/L	Percent ≥10 mg/L
				Nitrate-N mg/L or parts per million (ppm)	
Badoura	38	5%	62%	13.2%	13.2%
Crow Wing Lake	202	7%	99%	8.9%	7.4%
Henrietta	254	9%	98%	3.9%	2.4%
Hubbard	223	34%	100%	18.4%	15.2%
Straight River	128	11%	72%	7.8%	7.0%
Todd	203	19%	78%	8.4%	5.4%
Total	1048	14%	85%	9.6%	7.6%

* Represents an average value

** Data retrieved from USDA NASS Cropland Data Layer, 2013

WELL AND WATER CHARACTERISTICS OF FINAL WELL DATASET

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Hubbard County final well dataset. The well logs provided information on the well age, depth, and construction type (MDH Minnesota Well Index 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 I (Tables 33-35).

- Just over a majority of wells were drilled (62 percent), and 22 percent were sand point wells
- The median depth of wells was 54 feet, and the shallowest was 13 feet
- The median year the wells were constructed in was 1998

WELL WATER PARAMETERS

MDA staff conducted the follow-up sampling. Field measurements of the well water parameters were recorded on the first page of the Private Well Field Log & Well Survey Form (Appendix J). 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 K (Tables 36-39).

- The temperatures ranged from 7.04 °C to 13.88 °C
- The median specific conductivity was 525 µS/cm, and was as high as 1,338 µS/cm
- The water from the wells had a median pH of 7.56
- The dissolved oxygen readings ranged from 0.16 mg/L to 12.63 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, 2016).

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 (N₂). 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 Hubbard County. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 14 percent of the land cover is row crop agriculture and there are over 22,000 acres of groundwater irrigation in the study area.

Six townships were sampled covering over 132,000 acres. The initial (homeowner collected) nitrate sampling resulted in 1,106 samples. The 1,106 households that participated represent approximately 38 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 278 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 58 (5 percent) wells were found to be unsuitable and were removed from the initial well dataset of 1,106 wells. The remaining 1,048 wells were wells believed to be impacted by nitrogen fertilizer and were included in the final well dataset.

The majority of the wells from the final data set (62 percent) were drilled; 21 percent were sand points. The median depth of the wells was 54 and depths ranged from 13 to 137 feet.

In two of the six townships tested in Hubbard County, more than 10 percent of the wells were at or over the nitrate Health Risk Limit of 10 mg/L. The percent of wells at or over the nitrate Health Risk Limit in each township ranged 2.4 to 15.2 percent.

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APPENDIX A

Well information and Potential Nitrate Source Inventory Form

Site ID _____ Unique ID _____ Date _____
MDA -Private Well Field Log & Well Survey Form

Water Treatment Information

1. Is this well used for drinking water? Yes No
2. Is there an indoor water treatment system? Yes No
 If yes, check system: Activated Carbon Distilled Iron Filter
 Reverse Osmosis Sediment Filter Softened
 Other _____
3. Is there water treatment on the outdoor spigot? Yes No
 If yes, what type? _____

Well Construction Information

	HO Survey	Homeowner or Observation (circle one or both)	Well Log
Construction Type			
Construction Date			
Well Depth			
Well Diameter			
Well/Pump Installer			

1. Have you made any changes to your well in the last year? Yes No
 If yes, what type? Upgraded Well Casing Raised Well Replaced Piping
 Replaced Pump Replaced Well Other _____

Field Survey Information

1. Are there any other wells on this property? Yes No
 If yes, list well type, use, and UID if available _____
2. Is fertilizer stored on this property? Yes No
 If yes, what is the distance and direction from the well? _____
3. Historical fertilizer storage? Yes No
 If yes, what is the distance and direction from the well? _____
4. Historic/Abandoned septic system? Yes No
 If yes, what is the distance and direction from the well? _____
5. Have pesticides been used in the last month? Yes No
 If yes, what type/brand name, when, and location _____

Updated: March, 2017

Site ID _____ Unique ID _____ Date _____
MDA -Private Well Field Log & Well Survey Form

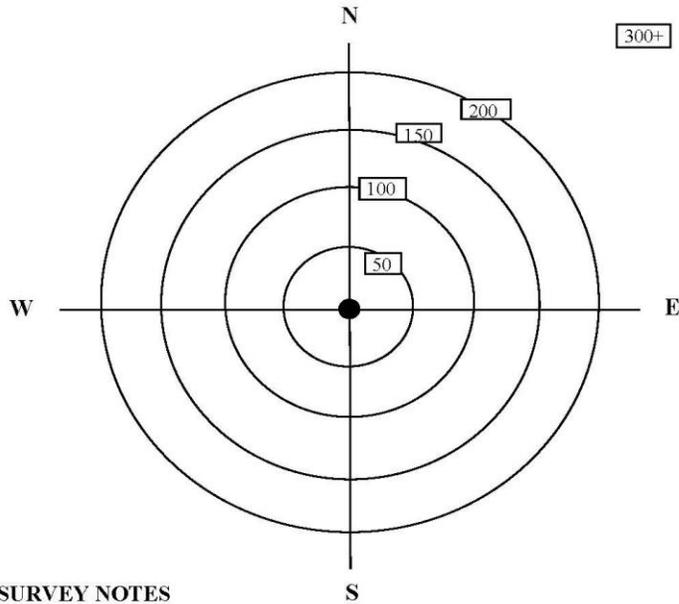
DIRECTIONS

Describe the type, position and distance to potential nitrate sources within 300 feet of the well. Use the bullseye to draw in and label nitrate sources relative to the well (center dot). Indicate house location when applicable.

- | | |
|---|--|
| AFL: Animal Feedlot | FWP: Feeding or Watering Area |
| AGG: Dry Well, Leaching Pit, Seepage Pit,
Injection Well, Ag Drainage Well | GOLF: Golf Course |
| APB: Animal/Poultry Building | LAP: Land Application of Manure, Septage, Sewage |
| DRA: Drain field - Above or Below Grade | MSA: Manure Storage Area |
| FIELD: Agricultural Field | PRV: Privy (Old Outhouse) |
| FSA: Fertilizer Storage Area | SAA: Small Animal Area (chicken coop, rabbit pen, etc) |
| | SET: Septic Tank |

6. Does water drain toward the well? Yes No
7. Which direction does the landscape slope? (Draw arrow across bullseye through well)
8. Is the slope: Steep Shallow Flat
9. Are there any *obvious* problems with the well? Yes No No Access Not Found
 Describe any well issues seen _____
10. Distance from ground surface to bottom of well cap (round to nearest inch) _____
11. Source codes, distances, and direction (<300ft) _____

12. Source codes, distances, and direction (>300ft) _____



ADDITIONAL SURVEY NOTES

Updated: March, 2017

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 contaminants such as nitrate, and fecal material. To protect drinking water supplies in Minnesota, SSTS septic 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).

Hubbard County has the authority to inspect SSTS for all townships within the county. The city of Park Rapids is only other authority in Hubbard County with SSTS programs. In 2016 Hubbard County reported a total of 17,570 SSTS and 1.6 percent were inspected for compliance (MPCA, 2017a). Compliance inspections are conducted in Hubbard County when building permits are applied for, upon completion of new or replacement SSTS, whenever a bedroom is added to a residence, whenever the use of a property is being changed or expanded, and anytime the county deems appropriate (Hubbard County, 2018). Hubbard County performs soil verification after system construction which only 6% of the local governmental units do in Minnesota. The majority of counties verify the soil before the construction (MPCA, 2017a).

FEEDLOT

The amount of nitrogen in manure depends on the species of animal. For example, there is approximately 31 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 9) (MPCA, 2017b).

Table 9. 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 Pollutant Discharge Elimination (NPDES) permits (MPCA, 2011) and must submit an annual manure management plan as part of their permit (MPCA, 2017b).

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 2018 to December 2021. From 2014 to 2017, approximately 24,000 feedlots were registered in Minnesota (MPCA, 2017b). A map and table of the feedlots located in the Hubbard County study area can be found below (Figure 7; Table 10)

Feedlots Hubbard County, Minnesota

Data retrieved from Minnesota Pollution Control Agency, updated February, 2018

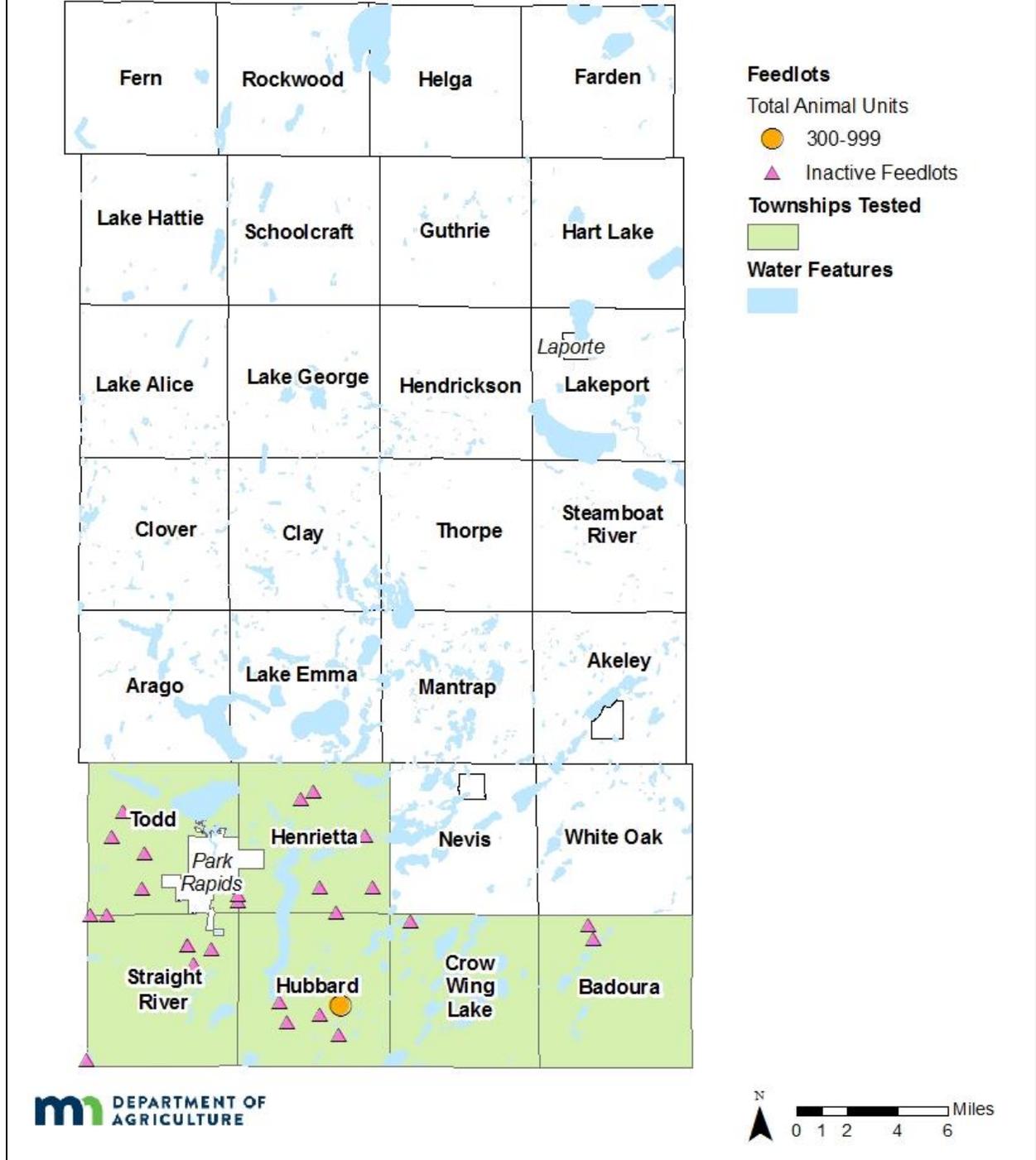


Figure 7. Feedlot Locations in Hubbard County (MPCA, 2018)

Table 10. Feedlots and Permitted Animal Unit Capacity, Hubbard County

Township	Total Feedlots	Active Feedlots	Inactive Feedlots	Average AU Permitted** Per Feedlot	Total Permitted** AU	Total Square Miles	Permitted** AU per Square Mile
Badoura	2	0	2	0	0	36	0
Crow Wing Lake	1	0	1	0	0	35	0
Henrietta	6	0	6	0	0	35	0
Hubbard	6	1	5	464	464	36	13
Straight River	7	0	7	0	0	35	0
Todd	6	0	6	0	0	29	0
Total	28	1	27	464*	464	207	2*

* Represents an average value

**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 have less livestock than permitted.

On average there are 2 AU per square mile (0.0035 AU/acre) over the entire study area (Table 10). Manure is often applied to cropland so it is pertinent to look at the AU per cropland acre. In the Hubbard County study area livestock densities average 0.025 AU per acre of row crops (MPCA, 2018; USDA NASS, 2013).

FERTILIZER STORAGE LOCATION

MDA tracks licenses for bulk fertilizer storage facilities, anhydrous ammonia, and chemigation sites (Table 11). Abandoned sites are facilities that once housed fertilizer chemicals. These sites are also noted and tracked by the MDA as they are potential contamination sources.

Table 11. Fertilizer Storage Facility Licenses and Abandoned Sites, Hubbard County

Township	*Bulk Fertilizer Storage	*Anhydrous Ammonia	*Chemigation Sites	*Abandoned Sites	Total
Badoura	0	0	7	0	7
Crow Wing Lake	0	0	15	0	15
Henrietta	0	0	10	0	10
Hubbard	0	0	72	0	72
Straight River	1	0	28	0	29
Todd	0	0	40	0	40
Total	1	0	172	0	173

* Data retrieved from MDA Pesticide and Fertilizer Management Division, 2018; updated March 2018

SPILLS AND INVESTIGATIONS

The MDA is responsible for investigating any fertilizer spills within Minnesota. Figure 8 shows the locations of mapped historic spills within the Hubbard County study area from fertilizer. While other types of spills are recorded, only sites that are potential point sources of nitrogen to the groundwater are reported here (MDA, 2017). There are no spills or investigations in the Hubbard County study area.

APPENDIX C

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. With its close proximity to the north woods, much of Hubbard County is dominated by forest, but it has areas with agricultural activities, especially in the south part of the county (Figure 8; Table 12). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, wheat, dry beans and double crops involving corn and soybeans.

Hubbard County is situated south of Bemidji and west of Walker and Leech Lake. Hubbard Township has the most row crops in the study area at 34% coverage. More than 60 percent of the land area in the townships of Crow Wing Lake and Badoura is classified as forest (Figure 8; Table 12).

Land Cover Data 2013 Hubbard County, Minnesota

Data originated from National Agricultural Statistics Service (NASS), United States Department of Agriculture (USDA).
Data grouped into broad categories by MN Department of Agriculture.

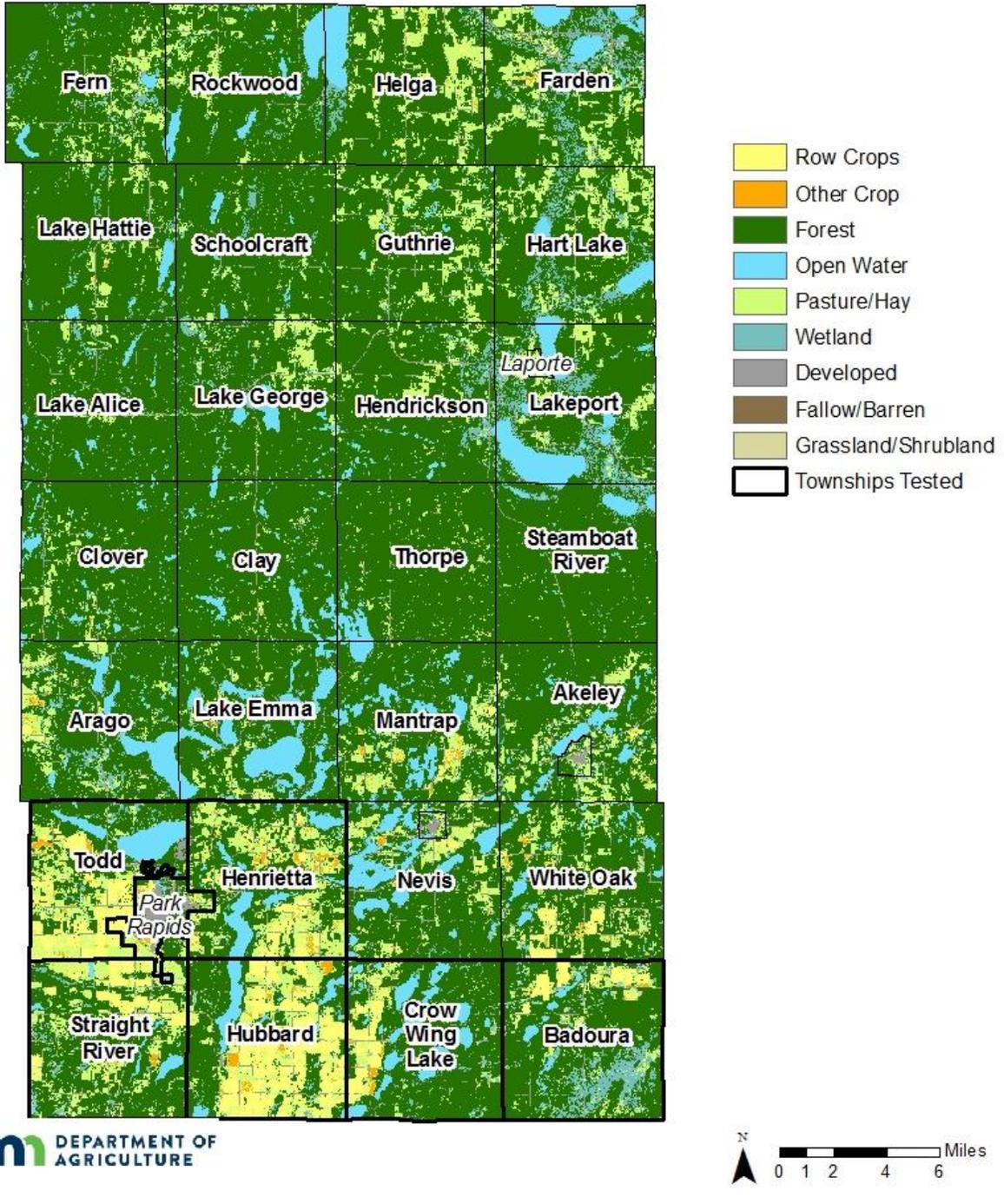


Figure 8. Land Cover in Hubbard County (USDA NASS, 2013)

Table 12. Land Cover Data (2013) by Township, Hubbard County (USDA NASS, 2013)

Township	Total Acres	Row Crop	Other Crops	Forest	Open Water	Pasture/Hay	Wetland	Developed	Fallow/Barren	Grassland/Shrubland
Badoura	23,273	5%	1%	66%	3%	7%	15%	2%	0%	2%
Crow Wing Lake	22,622	7%	1%	64%	14%	6%	4%	2%	0%	1%
Henrietta	22,398	9%	3%	45%	9%	26%	2%	5%	0%	1%
Hubbard	23,080	34%	3%	33%	7%	17%	2%	4%	0%	0%
Straight River	22,610	11%	1%	54%	3%	20%	5%	4%	0%	2%
Todd	18,799	19%	2%	37%	11%	21%	3%	5%	0%	1%
Average	22,131	14%	2%	50%	8%	16%	5%	4%	0%	1%

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 223 active groundwater well permits in the study area and 209 are used for irrigating major crops (Figure 9). Over 22,000 acres of cropland is permitted for groundwater irrigation in this area (Table 13). Most permitted wells are withdrawing groundwater from quaternary aquifer (Table 14; MDNR, 2017).

Table 13. Active Groundwater Use Permits by Township, Hubbard County

Township	Major Crop Irrigation Well Permits	Average Depth (feet)	Acres Permitted
Badoura	22	163	1,603
Crow Wing Lake	17	154	2,019
Henrietta	13	119	1,405
Hubbard	90	117	9,618
Straight River	26	129	3,086
Todd	41	113	4,383
Total	209	126*	22,114

* Represents an average value

Table 14. Active Groundwater Use Permits by Aquifer, Hubbard County

Water Use Well Permits	Total Wells	Average Depth (feet)	Aquifer System			
			Quaternary (Water Table)	Quaternary (Buried)	Paleozoic	Not Classified
Major Crop Irrigation	209	126	47	140	0	22
Non-Crop Irrigation	5	110	0	4	0	1
Industrial Processing	6	173	1	5	0	0
Special Categories**	3	109	0	3	0	0
Total	223	127*	48	152	0	23

* Represents an average value.

** Livestock watering.

Active Groundwater Use Permits Hubbard County, Minnesota

Data retrieved from Minnesota Department of Natural Resources, updated 8/4/2017

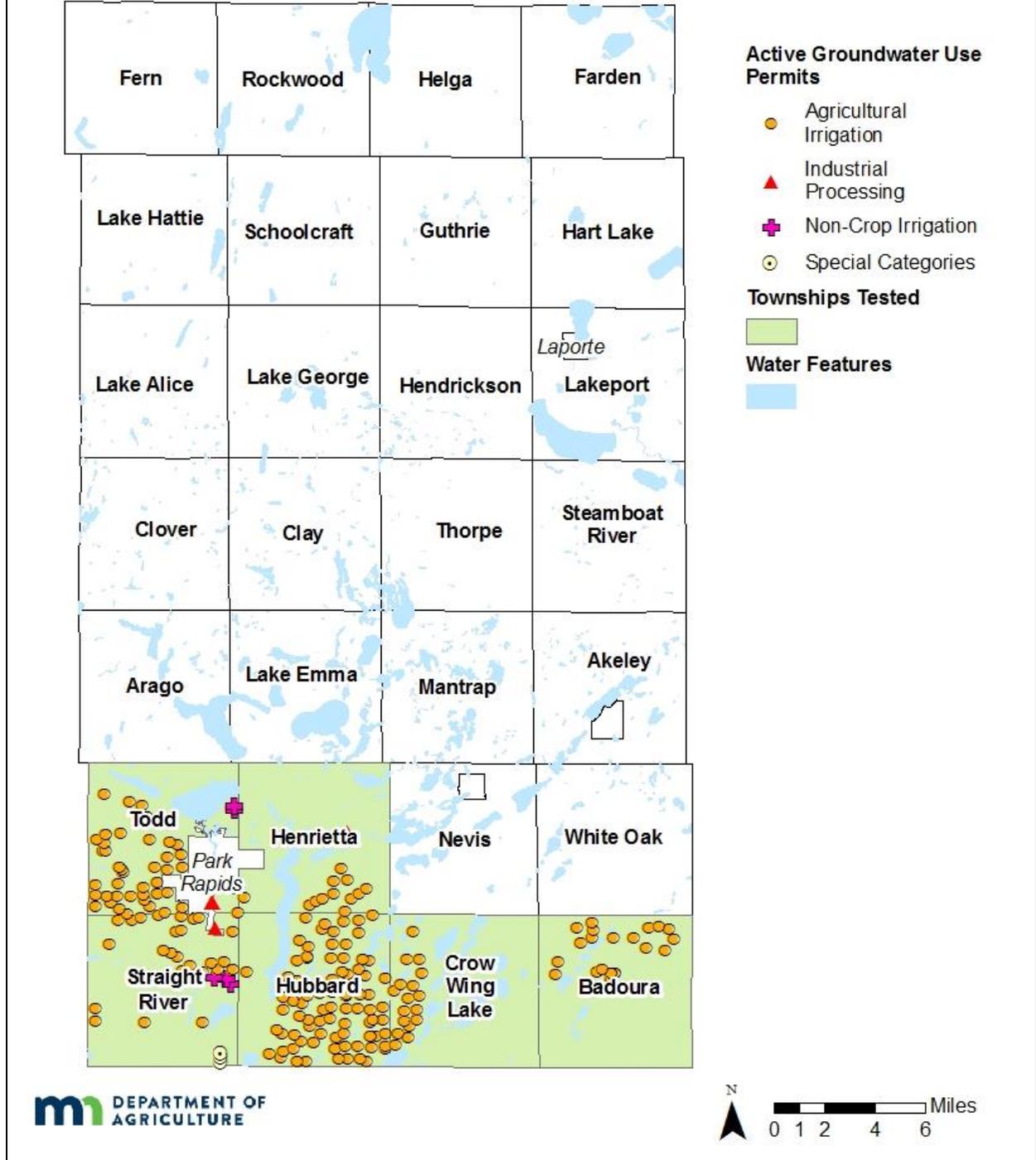


Figure 9. Active Groundwater Use Permits in Hubbard County (MDNR, 2017)

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 15. Reasons Wells Were Removed from the Final Well Dataset by Township, Hubbard County

Township	Point Source	Well Construction Problem	Hand Dug Well	Unsure of water source	Wrong Township-Out of Study Area	Site Visit Completed - Well Not Found & Constructed before 1975 & No Well ID	No Site Visit & Constructed before 1975 or Unknown & No Well ID	No Site Visit & Insufficient Data & No Well ID	Total
Badoura	1	0	0	1	0	0	1	0	3
Crow Wing Lake	1	0	1	1	0	1	1	1	6
Henrietta	1	1	0	1	0	0	2	0	5
Hubbard	7	2	0	0	0	0	6	3	18
Straight River	3	1	0	1	0	0	2	2	9
Todd	7	1	0	0	1	2	3	3	17
Total	20	5	1	4	1	3	15	9	58

Table 16. Completed Site Visits for Wells Removed from the Final Well Dataset by Township, Hubbard County

Township	Site Visit	No Site Visit	Total Wells Removed
Badoura	1	2	3
Crow Wing Lake	3	3	6
Henrietta	3	2	5
Hubbard	9	9	18
Straight River	3	6	9
Todd	7	10	17
Total	26	32	58

APPENDIX F

MINNESOTA WELL INDEX

The MWI was used to gather information about the six townships in Hubbard County included in the study. This section includes all drinking water wells in the study area, not just wells MDA sampled. Table 17 summarizes the general aquifer types, while the following is a brief summary of the major aquifer types with the average well depth. According to the information from the MWI (MDH, 2018):

In these townships, there are 1,858 documented (have a verified location in the MWI) wells:

- At Fifty-five percent, the majority of wells are completed in the shallow Quaternary Water Table Aquifer (QWTA) and are 61 feet deep on average.
- Forty-two percent are completed in a Quaternary buried aquifer and are 90 feet deep on average.
- Quaternary undifferentiated aquifers are utilized in only one percent of the wells, with a majority of these wells found in Badoura and Todd Townships. The average depth is 47 feet deep.
- Only two percent of wells were completed in the undesignated aquifers, with a majority of these well completed in Badoura Township.

Table 17. Aquifer Type Distribution of Wells in Minnesota Well Index

Township	Badoura	Crow Wing Lake	Henrietta	Hubbard	Straight River	Todd	Total	
Wells	56	280	492	395	269	366	1,858	
Aquifer Type	Quaternary Water Table	41%	61%	71%	57%	25%	52%	55%
	Quaternary Buried	52%	35%	26%	41%	74%	45%	42%
	Quaternary Undifferentiated	2%	1%	0%	1%	1%	2%	1%
	Undesignated	5%	3%	2%	2%	0%	1%	2%

Example – “Participation Letter and Well Survey”

Private Well Survey for Township Testing Program

The Minnesota Department of Agriculture appreciates you taking the time to answer a few questions about your well. These questions are voluntary, but will help in the analysis of your nitrate results and provide information as to nitrate concentrations across Minnesota. Your name, addresses, telephone numbers, and e-mail addresses are considered private under Minnesota Statutes Chapter 13. Only data from sample results, general location data and unique well number are considered public. Only people with a need to access your data in support of the private well nitrate sampling program will have authority to access your data unless you provide MDA with an informed consent to release the data, upon court order or provided to the state or legislative auditor to review the data. If you don't know an answer to a question, skip it and go on to the next question. Please make corrections to contact information if needed.

First name _____ **Last name** _____

Parcel Number _____ **Township** _____

Physical address _____ **City** _____ **State** _____ **Zip** _____

Mailing address _____ **City** _____ **State** _____ **Zip** _____

Phone number _____ **(in case we have questions about your survey)** **Email** _____

1. What setting did the water sample come from? Please choose only one.
 Sub-division Lake Home River Home Country Municipal/City* Other

*** If municipal/City well, stop here, your well will not be included in the private well sampling.**

2. Are there livestock on this property?
 (more than 10 head of cattle, 30 head of hogs or an equivalent number of other livestock)
 Yes No

3. Do you mix or store fertilizer (500 lb. or more) on the farm site? Yes No

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

WELL INFORMATION
It is extremely helpful if you can go to your well and look for the Unique Well Number
- this is a 6 digit number found on a metal tag attached to your well casing.

5. Does your well have a Unique Well ID number? Yes No Don't Know

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

7. Type of **well construction**? Drilled Sand point Hand Dug Well Don't Know Other

8. Approximate **age** of your well? 0 - 10 years 11 - 20 years 21 - 40 years over 40 years

9. Approximate **depth** of your well? 0 - 49 Feet 50 -99 feet 100 - 299 feet >=300 feet

10. Distance to an active or inactive feedlot? 0 - 49 Feet 50 -99 feet 100 - 299 feet >=300 feet

11. Distance to a septic system? 0 - 49 Feet 50 -99 feet 100 - 299 feet >=300 feet

12. Distance to an agricultural field? 0 - 49 Feet 50 -99 feet 100 - 299 feet >=300 feet

13. Is this well currently used for human consumption (Drinking or Cooking)? Yes No

14. Please check any water treatment you have **other than a water softener**.
 None Reverse Osmosis Distillation Filtering system Other

15. When did you last have your well tested for nitrates?
 Never tested Within the last year Within the last 3 years
 Within the last 10 years Greater than 10 years Not sure

16. What was the result of your **last** nitrate test?
 <3 mg/L (ppm) 3<10 mg/L(ppm) >=10 mg/L (ppm) Don't Know

APPENDIX H

Table 18. Property Setting for Well Location

Township	Total	Country	Lake Home	River Home	Other	Sub-division	Not Available
Badoura	41	36.6%	51.2%	0.0%	0.0%	0.0%	12.2%
Crow Wing Lake	208	8.7%	69.7%	4.3%	1.4%	0.0%	15.9%
Henrietta	259	43.2%	39.4%	0.0%	1.5%	0.4%	15.4%
Hubbard	241	29.9%	55.2%	1.2%	1.2%	0.4%	12.0%
Straight River	137	53.3%	25.5%	9.5%	0.0%	0.0%	11.7%
Todd	220	47.7%	33.2%	2.3%	1.4%	2.7%	12.7%
Total	1,106	35.7%	46.0%	2.7%	1.2%	0.7%	13.7%

Table 19. Well Construction Type

Township	Total	Drilled	Hand Dug Well	Other	Sand Point	Don't Know	Not Available
Badoura	41	56.10%	0.00%	0.00%	24.39%	7.32%	12.20%
Crow Wing Lake	208	49.52%	0.48%	0.00%	27.40%	6.25%	16.35%
Henrietta	259	58.30%	0.39%	0.00%	16.22%	9.27%	15.83%
Hubbard	241	55.19%	0.00%	0.83%	25.31%	7.47%	11.20%
Straight River	137	72.26%	0.00%	0.00%	13.87%	1.46%	12.41%
Todd	220	54.09%	0.00%	0.00%	24.09%	7.27%	14.55%
Total	1,106	56.78%	0.18%	0.18%	21.88%	6.87%	14.10%

Table 20. Age of Well

Township	Total	Before 1975	1975 to 1984	1985 to 1993	1994-Present	Don't Know	Not Available
Badoura	41	4.88%	7.32%	12.20%	53.66%	7.32%	14.63%
Crow Wing Lake	208	14.90%	9.13%	8.65%	43.75%	7.69%	15.87%
Henrietta	259	10.42%	10.42%	11.58%	42.86%	9.27%	15.44%
Hubbard	241	13.69%	10.37%	12.45%	40.66%	10.37%	12.45%
Straight River	137	9.49%	9.49%	13.14%	45.26%	10.22%	12.41%
Todd	220	11.82%	16.36%	14.09%	33.64%	9.55%	14.55%
Total	1,106	11.93%	11.12%	11.93%	41.41%	9.31%	14.29%

Table 21. Well Depth

Township	Total	Depth 0-15 feet	Depth 16-49 feet	Depth 50-99 feet	Depth 100-299 feet	Depth ≥300 feet	Not Available
Badoura	41	4.9%	22.0%	39.0%	12.2%	0.0%	22.0%
Crow Wing Lake	208	5.3%	23.6%	38.5%	6.7%	0.5%	25.5%
Henrietta	259	0.8%	13.1%	46.3%	9.3%	0.4%	30.1%
Hubbard	241	6.2%	20.7%	34.9%	12.4%	0.0%	25.7%
Straight River	137	0.7%	18.2%	39.4%	19.7%	0.0%	21.9%
Todd	220	2.3%	27.7%	34.1%	10.0%	0.5%	25.5%
Total	1,106	3.3%	20.6%	38.8%	11.0%	0.3%	26.0%

Table 22. Unique Well ID Known

Township	Total	No	Yes	Don't Know	Not Available
Badoura	41	34.1%	29.3%	14.6%	22.0%
Crow Wing Lake	208	23.6%	29.3%	28.8%	18.3%
Henrietta	259	18.1%	25.1%	36.3%	20.5%
Hubbard	241	22.8%	28.2%	34.0%	14.9%
Straight River	137	27.7%	31.4%	28.5%	12.4%
Todd	220	21.8%	21.4%	37.3%	19.5%
Total	1,106	22.7%	26.8%	32.8%	17.7%

Table 23. Livestock Located on Property

Township	Total	No Livestock	Yes Livestock	Not Available
Badoura	41	87.8%	0.0%	12.2%
Crow Wing Lake	208	82.7%	0.0%	17.3%
Henrietta	259	81.9%	1.5%	16.6%
Hubbard	241	88.0%	0.4%	11.6%
Straight River	137	84.7%	3.6%	11.7%
Todd	220	84.5%	2.3%	13.2%
Total	1,106	84.4%	1.4%	14.2%

Table 24. Fertilizer Stored on Property

Township	Total	No Fertilizer	Yes Fertilizer	Not Available
Badoura	41	87.8%	0.0%	12.2%
Crow Wing Lake	208	82.7%	0.0%	17.3%
Henrietta	259	82.2%	0.4%	17.4%
Hubbard	241	86.7%	0.4%	12.9%
Straight River	137	87.6%	0.0%	12.4%
Todd	220	85.9%	0.5%	13.6%
Total	1,106	84.9%	0.3%	14.8%

Table 25. Farming on Property

Township	Total	No Farming	Yes Farming	Not Available
Badoura	41	78.0%	9.8%	12.2%
Crow Wing Lake	208	81.3%	1.4%	17.3%
Henrietta	259	76.4%	6.9%	16.6%
Hubbard	241	85.1%	2.5%	12.4%
Straight River	137	78.1%	10.2%	11.7%
Todd	220	83.2%	3.2%	13.6%
Total	1,106	80.8%	4.7%	14.5%

Table 26. Distance to an Active or Inactive Feedlot

Township	Total	0-49 feet	50-99 feet	100-299 feet	≥300 feet	Not Available
Badoura	41	2.4%	0.0%	4.9%	65.9%	26.8%
Crow Wing Lake	208	5.8%	0.5%	0.0%	65.9%	27.9%
Henrietta	259	4.6%	1.5%	1.9%	61.4%	30.5%
Hubbard	241	3.3%	1.2%	0.0%	74.3%	21.2%
Straight River	137	2.9%	0.0%	3.6%	65.7%	27.7%
Todd	220	6.8%	0.0%	0.9%	61.4%	30.9%
Total	1,106	4.7%	0.7%	1.3%	65.7%	27.6%

Table 27. Distance to Septic System

Township	Total	Septic 0-49 feet	Septic 50-99 feet	Septic 100-299 feet	Septic ≥300 feet	Not Available
Badoura	41	9.8%	36.6%	39.0%	2.4%	12.2%
Crow Wing Lake	208	4.3%	38.5%	34.1%	3.8%	19.2%
Henrietta	259	3.1%	36.7%	36.7%	4.6%	18.9%
Hubbard	241	5.4%	39.4%	35.7%	4.6%	14.9%
Straight River	137	2.2%	36.5%	41.6%	3.6%	16.1%
Todd	220	4.5%	33.2%	37.3%	6.8%	18.2%
Total	1,106	4.2%	36.9%	36.8%	4.7%	17.4%

Table 28. Distance to an Agricultural Field

Township	Total	Field 0-49 feet	Field 50-99 feet	Field 100-299 feet	Field ≥300 feet	Not Available
Badoura	41	2.4%	2.4%	12.2%	63.4%	19.5%
Crow Wing Lake	208	4.3%	0.5%	1.4%	69.2%	24.5%
Henrietta	259	2.7%	1.9%	6.2%	64.5%	24.7%
Hubbard	241	2.5%	1.2%	4.6%	73.4%	18.3%
Straight River	137	2.2%	2.9%	8.8%	65.7%	20.4%
Todd	220	4.5%	1.8%	5.9%	63.2%	24.5%
Total	1,106	3.3%	1.6%	5.4%	67.2%	22.5%

Table 29. Drinking Water Well

Township	Total	No, Drinking Water	Yes, Drinking Water	Not Available
Badoura	41	2.4%	85.4%	12.2%
Crow Wing Lake	208	5.3%	78.4%	16.3%
Henrietta	259	1.2%	82.6%	16.2%
Hubbard	241	2.1%	86.3%	11.6%
Straight River	137	3.6%	83.9%	12.4%
Todd	220	1.8%	85.5%	12.7%
Total	1,106	2.6%	83.5%	13.9%

Table 30. Treatment System Present (Treatment System Used for Drinking Water)

Township	Total	Distillation	Reverse Osmosis	Filtering system	None	Other	Not Available
Badoura	41	0.0%	9.8%	12.2%	61.0%	0.0%	17.1%
Crow Wing Lake	208	0.0%	2.9%	11.1%	65.4%	1.0%	19.7%
Henrietta	259	0.0%	3.5%	7.7%	66.0%	0.8%	22.0%
Hubbard	241	0.0%	6.2%	9.1%	65.6%	0.0%	19.1%
Straight River	137	0.0%	5.8%	10.2%	65.7%	0.7%	17.5%
Todd	220	0.5%	6.8%	11.8%	60.0%	1.4%	19.5%
Total	1,106	0.1%	5.2%	9.9%	64.4%	0.7%	19.7%

Table 31. Last Tested for Nitrate

Township	Total	Within the last year	Within the last 3 years	Within the last 10 years	Greater than 10 years	Never Tested	Not sure	Not Available
Badoura	41	12.2%	7.3%	14.6%	7.3%	26.8%	19.5%	12.2%
Crow Wing Lake	208	7.7%	10.6%	14.4%	15.9%	22.6%	13.0%	15.9%
Henrietta	259	5.0%	10.8%	13.9%	15.4%	22.4%	17.8%	14.7%
Hubbard	241	7.1%	12.0%	19.1%	9.1%	21.6%	19.5%	11.6%
Straight River	137	9.5%	11.7%	13.9%	11.7%	26.3%	14.6%	12.4%
Todd	220	7.7%	10.9%	16.4%	13.2%	18.2%	20.9%	12.7%
Total	1,106	7.3%	11.0%	15.6%	12.9%	22.1%	17.5%	13.5%

Table 32. Last Nitrate Test Result

Township	Total	<3 mg/L (ppm)	3<10 mg/L (ppm)	≥10 mg/L (ppm)	Don't Know	Not Available
Badoura	41	19.5%	2.4%	4.9%	41.5%	31.7%
Crow Wing Lake	208	10.1%	1.9%	1.9%	50.5%	35.6%
Henrietta	259	12.4%	5.0%	1.2%	45.9%	35.5%
Hubbard	241	7.9%	6.2%	7.9%	46.1%	32.0%
Straight River	137	11.7%	6.6%	2.9%	46.0%	32.8%
Todd	220	9.1%	5.5%	2.3%	52.7%	30.5%
Total	1106	10.5%	4.9%	3.3%	48.0%	33.3%

APPENDIX I

Table 33. Well Construction Type for Final Well Dataset

Township	Drilled	Sand Point	Don't Know	NA	Other	Total
Badoura	22	11	1	4	0	38
Crow Wing Lake	110	55	12	25	0	202
Henrietta	158	43	20	33	0	254
Hubbard	140	51	13	17	2	223
Straight River	101	13	2	12	0	128
Todd	121	52	13	17	0	203
Total	652	225	61	108	2	1,048

Data compiled from well logs and homeowner responses.

Table 34. Well Depth for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Badoura	7	15	80	54	48
Crow Wing Lake	34	14	87	54	50
Henrietta	45	20	126	63	66
Hubbard	62	14	118	54	54
Straight River	31	20	137	50	58
Todd	38	13	72	50	43
Total	217	13	137	54	54

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

Table 35. Year of Well Construction for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Badoura	7	1981	2012	1998	1999
Crow Wing Lake	35	1960	2017	1999	1996
Henrietta	51	1976	2017	1998	1997
Hubbard	70	1969	2016	1999	1997
Straight River	31	1969	2012	1998	1996
Todd	44	1955	2015	1994	1992
Total	238	1955	2017	1998	1996

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 J

Private Well Field Log

Site ID _____ Unique ID _____ Date _____

MDA -Private Well Field Log & Well Survey Form

Sample# _____

Duplicate# _____ Field Blank# _____

Additional Samples _____

Well Owner Contact Information

Name _____

Address _____

Phone # _____ Township _____ County _____

Sampling Information

Sampler _____ Time Arrived _____

Pump Start Time _____ Discharge Rate _____ Time Collected _____

Sample Point Location _____

Well Location _____

GPS Location _____ UTM Easting (X) _____ UTM Northing (Y) _____

Weather _____ Wind Speed/Direction (mph) _____ Air Temp (°F) _____

Nearest possible pesticide source (type, dist., dir.) _____ None noticeable

Time	Temp °C (1.0)	Specific Cond µs/cm (10%)	DO mg/L (10%)	pH (0.1)	Appearance/Odor/Notes

Field Comments - sample specific notes

Updated: March, 2017

APPENDIX K

Table 36. Temperature (°C) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Badoura	9	8.39	10.92	9.47	9.66
Crow Wing Lake	39	7.65	13.88	9.60	9.87
Henrietta	60	7.57	13.42	9.06	9.30
Hubbard	77	7.20	11.64	9.09	9.12
Straight River	35	7.97	11.50	9.17	9.32
Todd	57	7.04	11.36	9.04	9.01
Total	277	7.04	13.88	9.15	9.28

Table 37. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Badoura	9	6.54	8.03	7.55	7.51
Crow Wing Lake	39	7.16	7.93	7.60	7.57
Henrietta	60	7.30	8.30	7.62	7.64
Hubbard	77	7.10	7.87	7.56	7.56
Straight River	35	7.28	7.77	7.48	7.51
Todd	57	7.27	7.78	7.51	7.50
Total	277	6.54	8.3	7.56	7.56

Table 38. Specific Conductivity (µS/cm) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Badoura	9	185	906	336	437
Crow Wing Lake	39	215	802	534	524
Henrietta	60	291	771	500	516
Hubbard	77	325	1,338	548	573
Straight River	35	387	888	552	562
Todd	57	395	866	523	532
Total	277	185	1,338	525	539

Table 39. Dissolved Oxygen (mg/L) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Badoura	9	0.18	3.86	1.70	1.75
Crow Wing Lake	38	0.19	12.63	2.86	4.14
Henrietta	60	0.36	11.67	6.45	5.90
Hubbard	76	0.16	11.03	5.52	4.91
Straight River	34	0.24	11.66	2.79	3.56
Todd	56	0.32	9.43	4.16	4.24
Total	273	0.16	12.63	4.05	4.61