



FINAL TOWNSHIP TESTING NITRATE REPORT:
POPE COUNTY 2015-2016

October 2018

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 2015, private water wells in the Pope 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 303 wells representing an average response rate of 32 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, 6.3 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 58 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 28 wells in 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 20 (seven percent) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of 283 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 0.0 to 3.8 percent. All of the townships tested had less than 5 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 March 2018, 242 townships in 24 counties have completed the initial sampling, for a total of 25, 652 wells.

In 2015, six townships in Pope County were selected to participate in the Township Testing Program (Figure 1). Areas were chosen based on several criteria. Criteria used include: 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 Pope County occurred during the summer of 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 (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, visit the following webpages:

www.mda.state.mn.us/nfmp

www.mda.state.mn.us/townshiptesting

Townships Tested Pope County, Minnesota

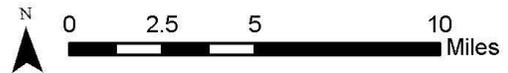
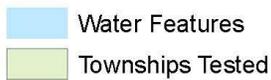
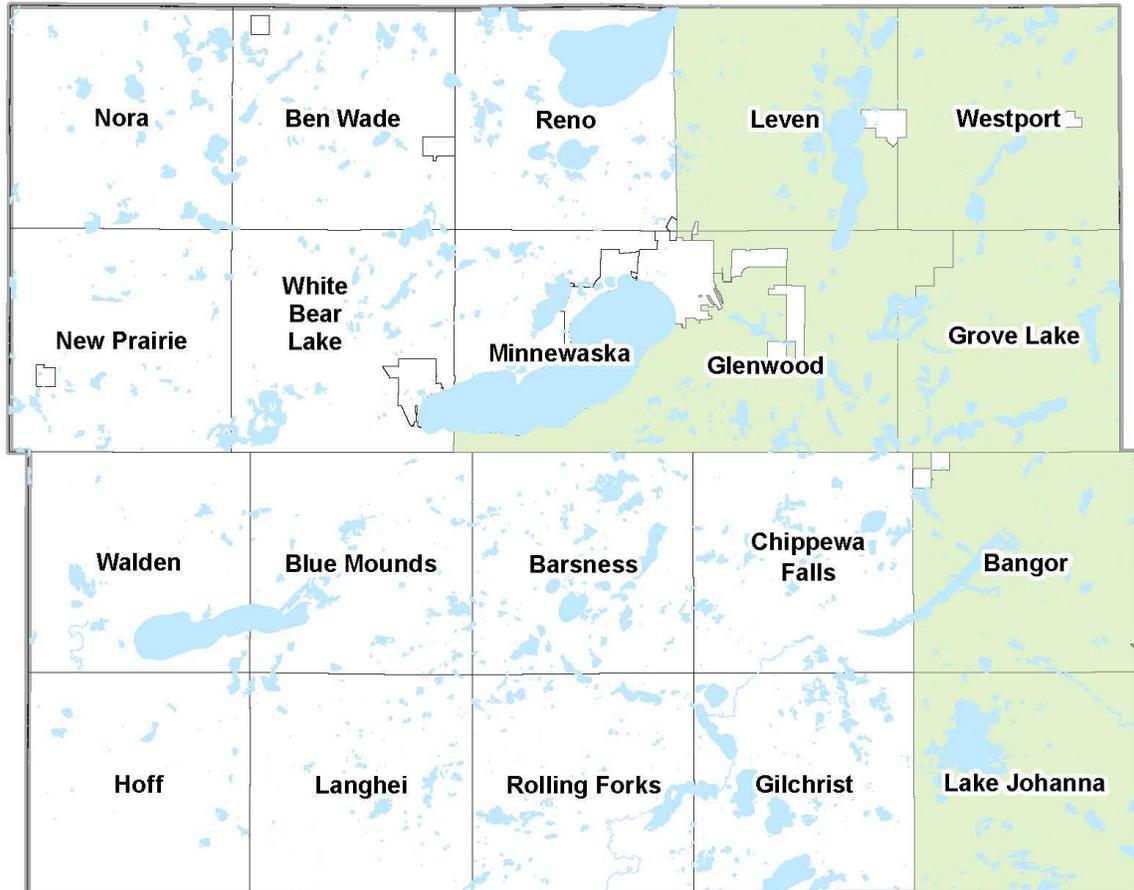


Figure 1. Townships Tested in Pope County

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 shallow coarse-textured groundwater systems. Once in groundwater, nitrate is often considered very stable and can move large distances from its source. However, 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 Pope County with glacial outwash (Harris and Knaeble, 2003) and intensive row crop agriculture, are particularly vulnerable to elevated nitrate concentrations.

GEOLOGY AND HYDROGEOLOGY

The geology in Pope County is heavily influenced by supraglacial drift complex and outwash plains. 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 Pope County as presented in Figure 2.

All of the surface sediments in Pope County were deposited in the Quaternary Period. During this time period there were many advances and retreats from the glacial ice mass (Laurentide ice sheet) that covered much of North America. As ice flowed away from the center glacial ice would reach out in what are known as “lobes”. The Red River and Des Moines lobes were the most influential in shaping the geology in the region. These glacial lobes left behind layers of sediment as they retreated creating modern day aquifers, confining layers and geologic features. (Harris and Knaeble, 2003).

Surficial aquifers are mainly used for irrigation in this region. Pope County boasts one of the largest surficial aquifers of sand and gravel in the state known as the Belgrade-Glenwood sand plain. This aquifer covers much of eastern side of Pope County. The water table depths are variable throughout the aquifer. The depth to the water table is deeper (50-70 feet) in the areas surrounding Lake Johanna and immediately east of Glenwood City compared to the rest of this surficial aquifer. These areas also have

thicker deposits of sand and gravel (Berg, 2006). Another significant surficial aquifer, the Chippewa River, is located to the west of Lake Emily in Walden and Hoff townships. This aquifer is the remnants of a delta from Glacial Lake Benson (Patterson et al., 1998). The water table is shallow within Pope County, with the depth to the water table typically between 0-20 feet (Berg, 2006).

Buried aquifers are typically used for domestic drinking water, industrial, municipal, and public supply wells. There are several layers of buried aquifers that are used for water wells in Pope County. When present the Otter Tail aquifer is the shallowest of the buried aquifers, then Crow Wing, and then Browerville. The Otter Tail buried aquifer is only present in the western part of Pope County. The Crow Wing and Browerville aquifers can be found throughout county. These aquifers are typically between 20 to 40 feet thick, with some portions that are thicker. There are also older sand aquifers that have not been well documented and are not commonly used for wells (Berg, 2006).

Geomorphology-Sediment Association Pope County, Minnesota

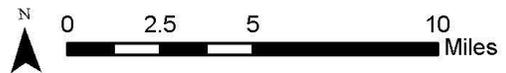
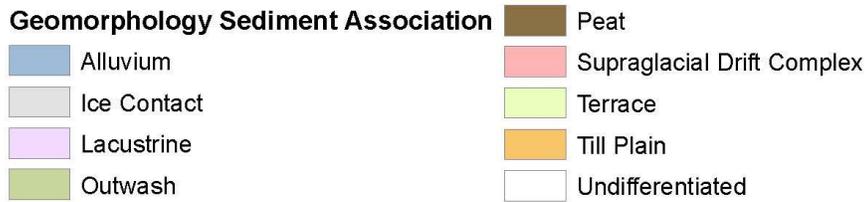
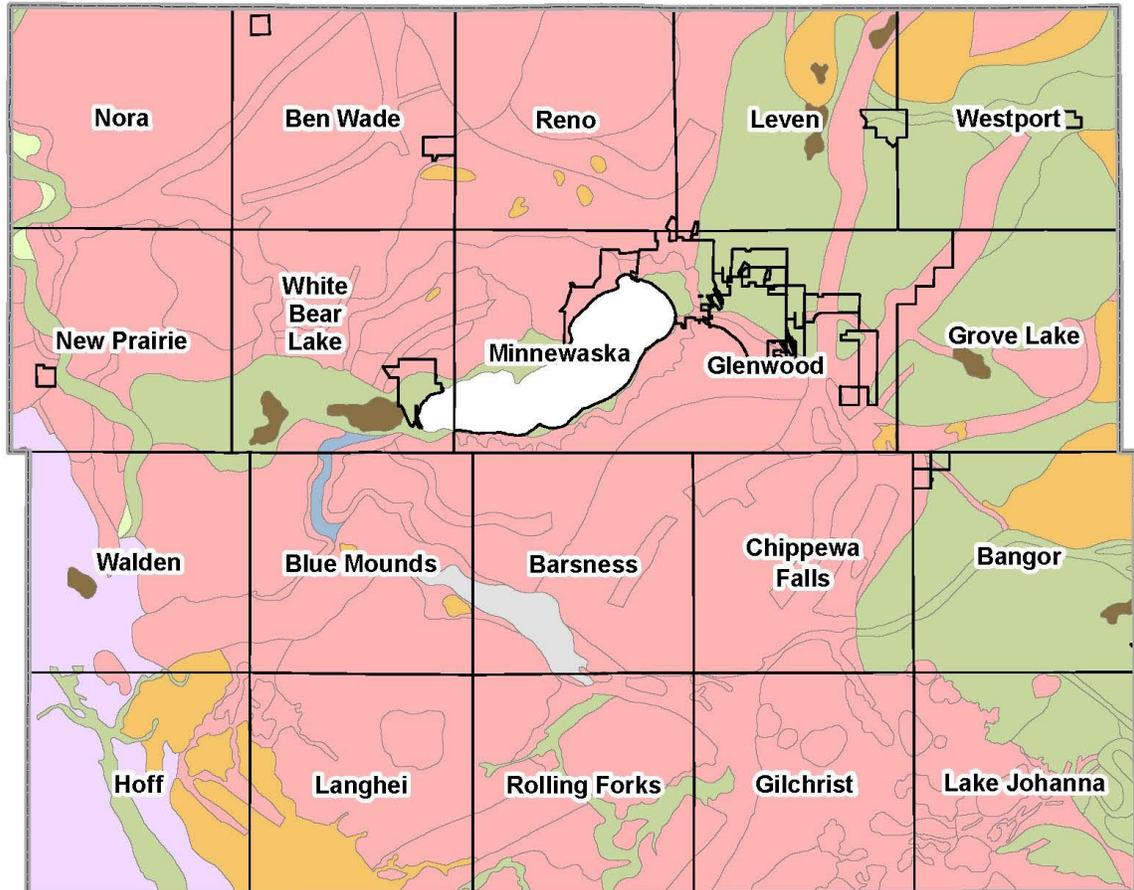


Figure 2. Statewide Geomorphology Layer, Sediment Association in Pope County

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 Pope 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 3,781 SSTS were reported in Pope County for 2016. Over a recent 15 year period (2002-2016), 1,245 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Pope County, 33 percent are newer than 2002 or have been repaired since 2002 (MPCA, 2017a). 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 (Minnesota Rules, part 4725.4450; MDH, 2014).

FEEDLOT

Manure produced on a feedlot can be a potential source of nitrogen pollution if improperly stored or spread. In the Pope County study area there are a total of 117 active feedlots. The majority of the feedlots are permitted to house less than 300 animal units (AU) (Appendix B; Figure 7). Westport Township hosts more than half of the AU in the Pope County study area. Westport also has the most feedlots, the most AU per feedlot, and has the most permitted AU per square mile. (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 Pope County study area has a total of 106 fertilizer storage licenses and 103 of these were chemigation sites. Lake Johanna township overall has the most licenses within the study area (Appendix B; Table 11).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of 7 historic fertilizer spills and investigations, four related to anhydrous ammonia, occurred in the Pope County study area. The majority of these were small spills and investigations (Appendix B; Table 12 and Figure 8)

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.

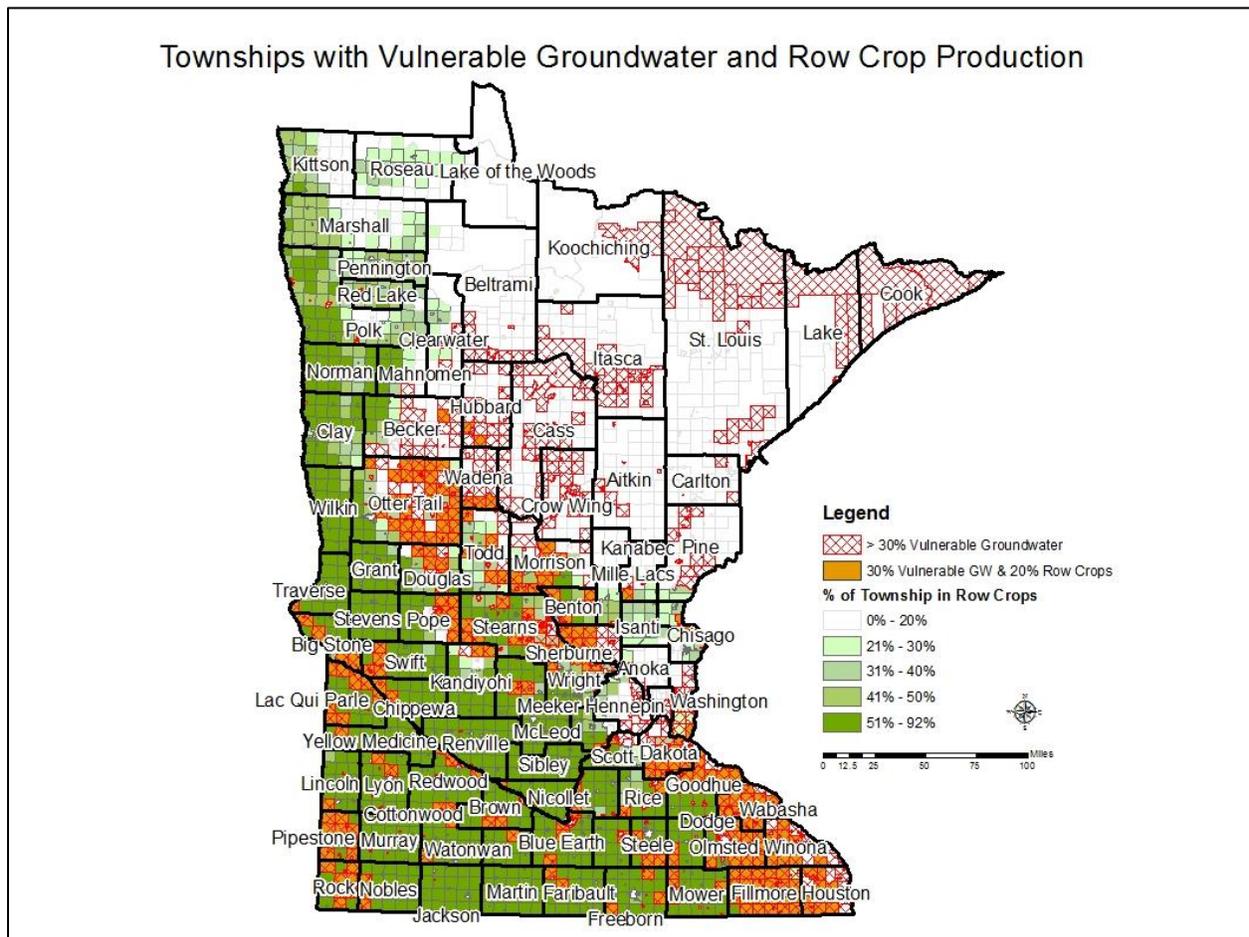


Figure 3. Minnesota Townships with Vulnerable Groundwater and Row Crop Production

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 Pope County depicting the aquifer vulnerabilities is shown below in Figure 4.

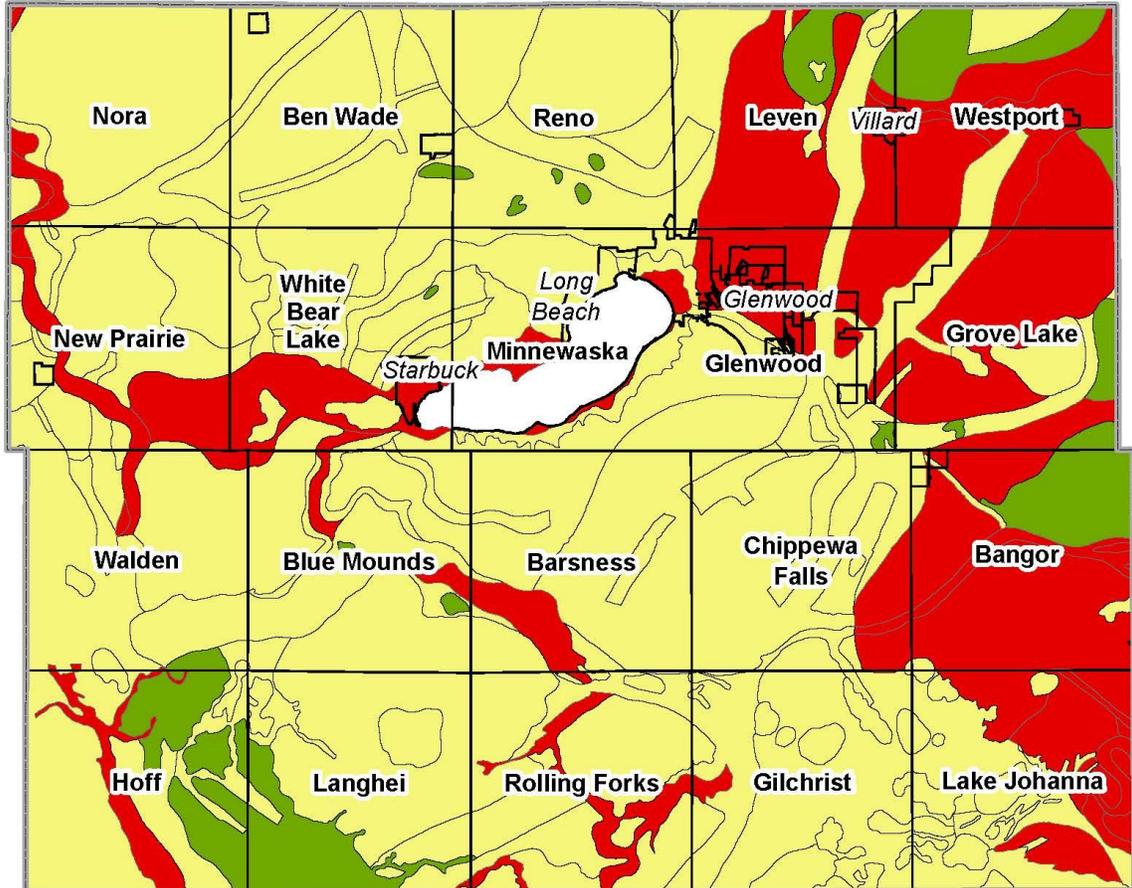
Table 1. Vulnerability Ratings Based on the Geomorphology of Minnesota, Sediment Association Layer

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

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 Pope County can be found in Appendix C (Figure 9, Table 14). On average 41 percent of the land cover was row crop agriculture.

Water Table Aquifer Vulnerability Rating Pope County, Minnesota

Based on Reclassification of Sediment Association Layer (DNR, MGS, and UMD, 1997)



Aquifer Vulnerability Rating

- High
- Medium
- Low
- Undifferentiated

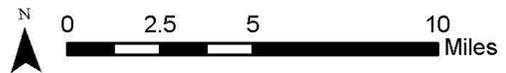


Figure 4. Water Table Aquifer Vulnerability Rating in Pope County

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 2015. 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 303 homeowners using the mail-in kit (Table 2). These 303 samples are considered the “initial well dataset”. On average, 32 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 2016 by MDA staff. A total of 28 follow-up samples were analyzed (Table 2).

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

Township	Kits Sent	Initial Well Dataset	Well Site Visits & Follow-Up Sampling Conducted
Bangor	63	19	0
Glenwood	404	125	10
Grove Lake	109	33	6
Lake Johanna	65	20	4
Leven	209	77	7
Westport	87	29	1
Total	937	303	28

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, 2016b). As part of the follow-up sampling, homeowners were offered a no cost pesticide test. As pesticide results are finalized, they will be posted online in a separate report (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 and 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 20 wells were removed to create the final well dataset. See Appendix E (Tables 17 and 18) 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.

UNSURE OF WATER SOURCE

If the water source of the sample was uncertain, or from an unwanted source, then data pertaining to the sample was removed. For example, these samples include water that may have been collected from an indoor tap with a reverse osmosis system or water from a municipal well were removed from the dataset. This study examines raw well water not treated water or municipal water.

SITE VISIT COMPLETED - WELL NOT FOUND & CONSTRUCTED BEFORE 1975 OR AGE UNKNOWN & 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. Additionally, if the age of the well could not be determined it was assumed to be an older well.

NO SITE VISIT & CONSTRUCTED BEFORE 1975 OR AGE UNKNOWN & NO WELL ID

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. Again, if the age of the well was undetermined the well was assumed to be old.

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.

INITIAL RESULTS

INITIAL WELL DATASET

A total of 303 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 and median values of nitrate-N for all townships were less than the detection limit (<DL) which is 0.03 mg/L. The maximum values ranged from 14.1 to 36.4 mg/L nitrate-N, with Grove Lake Township having the highest result. Mean values range from 0.4 to 3.2 mg/L nitrate-N, with Leven Township having the highest mean value. The 90th percentiles range from 0.2 to 19.3 mg/L nitrate-N, with Leven Township having the highest 90th percentile.

Initial results from the sampling showed that in Grove Lake, Leven, and Westport Townships ten percent or more of the wells were at or over 10 mg/L nitrate. The township testing results for these particular townships 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 Grove Lake, Leven, and Westport Township 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 Pope County, Minnesota

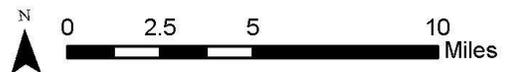
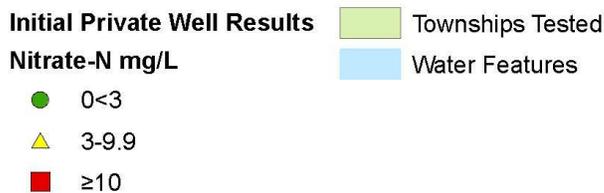
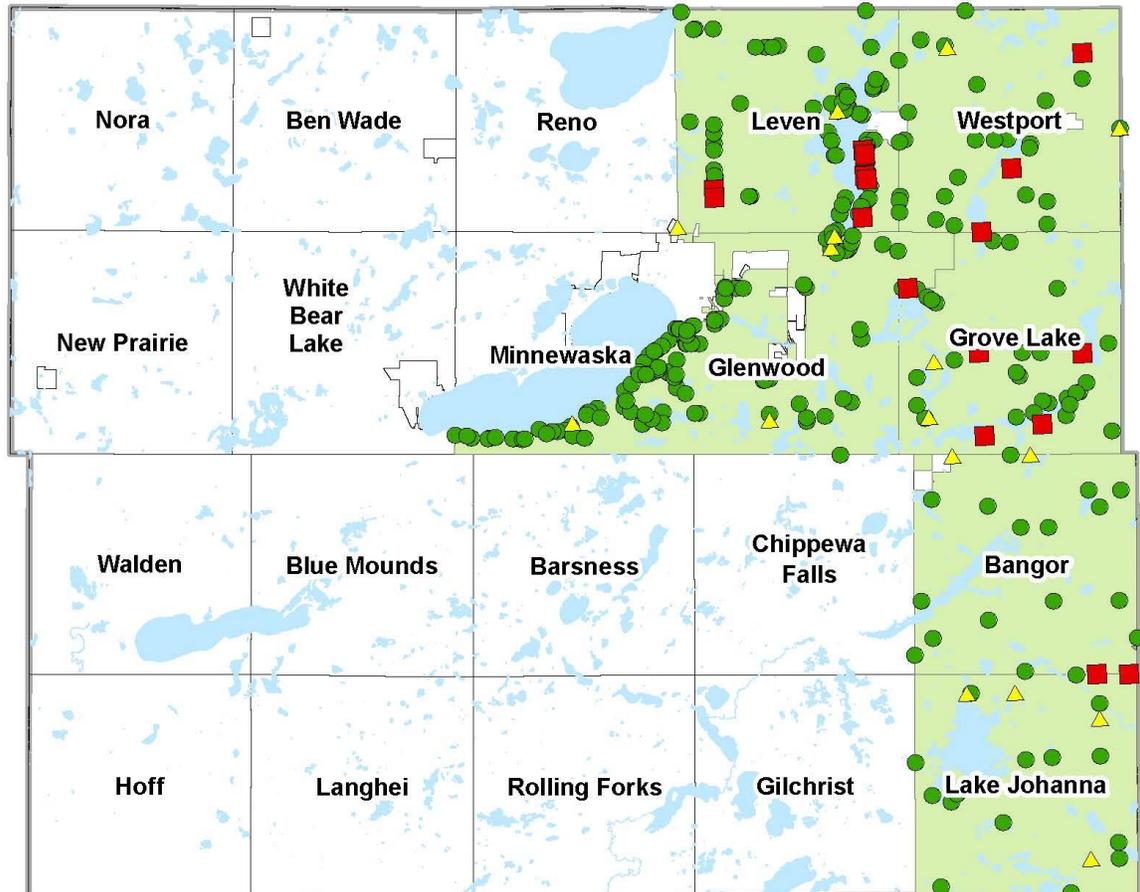


Figure 5. Well Locations and Nitrate Results from Initial Dataset in Pope County

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

Township	Total Wells	Values				Percentiles				Number of Wells					Percent of Wells				
		Min	Max	Mean	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)																	
Bangor	19	<DL	24.0	1.7	<DL	<DL	4.5	15.7	24.0	16	2	2	1	1	84.2%	10.5%	10.5%	5.3%	5.3%
Glenwood	125	<DL	14.1	0.4	<DL	<DL	0.2	1.5	11.0	120	4	5	4	1	96.0%	3.2%	4.0%	3.2%	0.8%
Grove Lake	33	<DL	36.4	2.8	<DL	0.4	11.7	20.8	36.4	27	2	4	4	4	81.8%	6.1%	12.1%	12.1%	12.1%
Lake Johanna	20	<DL	16.5	1.7	<DL	1.9	5.1	11.6	16.5	15	4	2	1	1	75.0%	20.0%	10.0%	5.0%	5.0%
Leven	77	<DL	34.2	3.2	<DL	<DL	19.3	28.5	33.0	66	2	11	11	9	85.7%	2.6%	14.3%	14.3%	11.7%
Westport	29	<DL	34.4	3.1	<DL	<DL	15.2	20.3	34.4	24	2	5	5	3	82.8%	6.9%	17.2%	17.2%	10.3%
Total	303	<DL	36.4	1.8	<DL	<DL	3.6	16.3	31.9	268	16	29	26	19	88.4%	5.3%	9.6%	8.6%	6.3%

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

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 2,406 people in Pope County’s study area have drinking water over the nitrate HRL (Table 4). Additional public awareness and education programming should take place in Pope County.

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

Township	Estimated Households on Private Wells (2015)*	Estimated Population on Private Wells (2015)*	Estimated Population ≥10 mg/L Nitrate-N**
Bangor	64	186	3
Glenwood	440	1,059	4
Grove Lake	117	275	14
Lake Johanna	61	131	3
Leven	211	485	25
Westport	90	270	9
Total	983	2,406	58

* Data collected from the Minnesota State Demographic Center, 2015

** Estimates based off of the 2015 estimated households per township gathered from the 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, 2013).

In some cases, well owners were able to provide Unique Well Identification Numbers for their wells. Additionally, MDA staff were able to find many Unique Well IDs online or on well tags during site visits. 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 94 documented wells (Table 5). Approximately 31 percent of the sampled wells had corresponding well logs. However, most of the well logs did not contain a defined aquifer. Only 26 wells (9 percent) had a defined aquifer, while the rest were undesignated. Thus, the data gathered on aquifers represents a small portion of the total sampled wells.

According to the well log data, the most commonly utilized aquifer in the sampled wells was from the Quaternary buried aquifers. This majority reflects the overall findings for all documented wells in the focus area (Appendix F, Table 19). The wells in these aquifers are relatively shallow, averaging 129 feet deep.

Below is a brief description of the aquifers characterized in Table 5.

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 Unconfined aquifers are similar to the QWTA except that the confining materials are more than 10 feet thick (MPCA, 1998).

The Quaternary Buried Artesian aquifers are confined aquifers that are part of the buried glacial drift aquifers (MPCA, 1998).

Most wells did not have an aquifer identified and therefore are labeled “undesigned”.

Table 5. Nitrate Concentrations within Sampled Groundwater Aquifers

Aquifer	Total Wells	Average Depth (Feet)	Number of wells			Percent of wells		
			<3	3<10	≥10	<3	3<10	≥10
			Nitrate-N mg/L					
Quaternary Water Table	3	61	1	1	1	33%	33%	33%
Quaternary Buried Unconfined	1	132	1	0	0	100%	0%	0%
Quaternary Buried Artesian	22	114	22	0	0	100%	0%	0%
Undesignated	68	137	66	2	0	97%	3%	0%
Total	94	129	90	3	1	96%	3%	1%

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, Tables 20-34).

The wells were mainly located on rural properties in Pope County. There are also a significant number of homes located on lake properties. In Glenwood and Leven more than a quarter of the sampled wells were on lake properties.

Approximately 69 percent of sampled wells are of drilled construction and 10 percent are 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. According to the homeowner survey were no hand dug wells sampled in the townships. However, the MDA follow-up site visit revealed that there was one hand dug well. As mentioned previously, hand dug wells are shallow and more sensitive to local surface runoff contamination than deeper drilled wells.

Most of the wells (61 percent) in the townships were between 50-299 feet deep. Slightly less than 25 percent of homeowners did not know the depth of their well.

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.

It is important to note that in the follow-up site surveys MDA staff was able to gather more information on the construction type, and staff were able to find unique IDs so that an official well depth, and well age could be found. Therefore the information provided by the homeowner survey will not exactly match information provided later in the report for the final well dataset.

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, Tables 20-34).

- On average, farming takes place on 22 percent of the properties.
- Agricultural fields are closer than 300 feet from wells at 28 percent of the properties.
- Less than eight 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 (more than 67 percent) are over 300 feet from an active or inactive feedlot. Less than two percent of homeowners responded that their well is less than 50 feet from a feedlot.
- Very few well owners (one percent) across all townships store more than 500 pounds of fertilizer on their property.
- A small minority of wells (less than four percent) are less than 50 feet away from septic systems. Most wells (67 percent) are between 50-299 feet from a septic system.

FINAL RESULTS

FINAL WELL DATASET

A total of 303 well water samples were collected by homeowners across six townships. A total of 20 (seven percent) wells were found to be unsuitable and were removed to create the final well dataset. The final analysis was conducted on the remaining 283 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-N HRL of 10 mg/L. Table 6 shows the results for all townships sampled. The percent of wells at or over the HRL ranged from 0.0 to 3.8 percent.

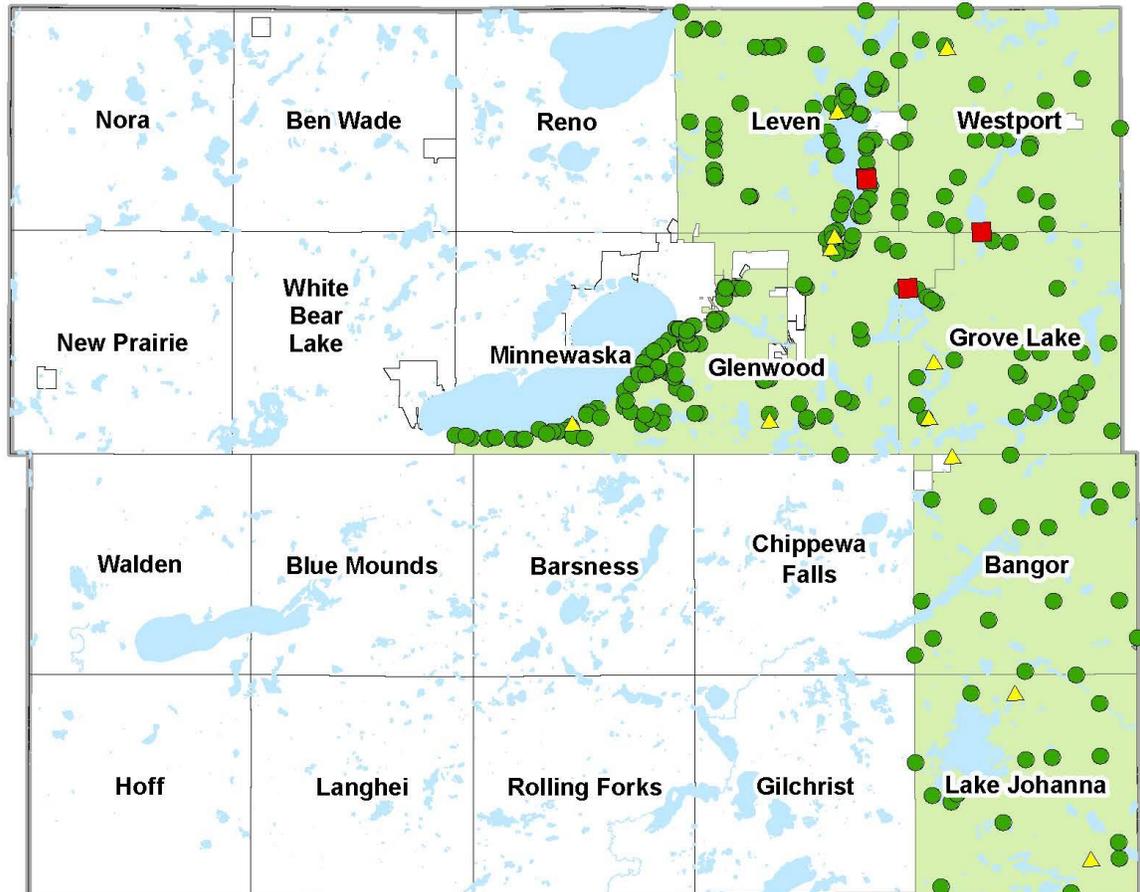
Table 6. Initial and Final Well Dataset Results, Pope County

Township	Initial Well Dataset	Final Well Dataset	Wells \geq 10 mg/L Nitrate-N	
			Count	Percentage
Bangor	19	17	0	0.0%
Glenwood	125	125	1	0.8%
Grove Lake	33	29	0	0.0%
Lake Johanna	20	17	0	0.0%
Leven	77	69	2	2.9%
Westport	29	26	1	3.8%
Total	303	283	4	1.4%

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. There are two wells over 10 mg/L nitrate in Leven, but due to their close proximity it may appear as one on Figure 6.

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 3.0 to 28.6 mg/L nitrate-N, with Leven Township having the highest result. Three townships (Bangor, Grove Lake and Lake Johanna) had maximum nitrate concentrations below the HRL of 10 mg/L. The 90th percentile ranged from <DL to 3.0 mg/L nitrate-N, with Lake Johanna Township having the highest result.

Final Well Dataset Results Pope County, Minnesota



Final Private Well Results

Nitrate-N mg/L

- 0<3
- ▲ 3-9.9
- ≥10

■ Townships Tested

■ Water Features

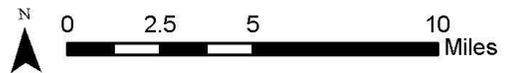


Figure 6. Well Locations and Nitrate Results from Final Well Dataset in Pope County

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

Township	Total Wells	Values			Percentiles					Number of Wells					Percent				
		Min	Max	Mean	(50 th) Median	75 th	90 th	95 th	99 th	<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)																	
Bangor	17	<DL	3.2	0.2	<DL	<DL	<DL	2.1	3.2	16	1	0	0	0	94.1%	5.9%	0.0%	0.0%	0.0%
Glenwood	125	<DL	14.1	0.4	<DL	<DL	0.2	1.5	11.0	120	4	5	4	1	96.0%	3.2%	4.0%	3.2%	0.8%
Grove Lake	29	<DL	3.0	0.3	<DL	0.1	1.2	3.0	3.0	27	2	0	0	0	93.1%	6.9%	0.0%	0.0%	0.0%
Lake Johanna	17	<DL	3.7	0.5	<DL	0.1	3.0	3.6	3.7	15	2	0	0	0	88.2%	11.8%	0.0%	0.0%	0.0%
Leven	69	<DL	28.6	0.9	<DL	<DL	0.2	1.8	27.1	66	1	3	3	2	95.7%	1.4%	4.3%	4.3%	2.9%
Westport	26	<DL	19.6	1.1	<DL	<DL	0.5	11.3	19.6	24	1	2	2	1	92.3%	3.8%	7.7%	7.7%	3.8%
Total	283	<DL	28.6	0.6	<DL	<DL	0.3	3.0	17.8	268	11	0	0	4	94.7%	3.9%	0.0%	0.0%	1.4%

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

As discussed previously, the areas selected were deemed most vulnerable to nitrate contamination of groundwater. Table 8 compares the final results to the percent of vulnerable geology (MDNR, 1991) and row crop production (USDA NASS, 2013) in each township. Westport had 100 percent vulnerable geology however less than 5 percent of the wells were at or over 10 mg/L nitrate-N. 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, Pope County

Township	Final Well Dataset	Percent Vulnerable Geology	Percent Row Crop Production (2013)*	Percent ≥7	Percent ≥10
				Nitrate-N mg/L or parts per million (ppm)	
Bangor	17	75%	41%	0.0%	0.0%
Glenwood	125	31%	41%	3.2%	0.8%
Grove Lake	29	63%	34%	0.0%	0.0%
Lake Johanna	17	44%	26%	0.0%	0.0%
Leven	69	50%	46%	4.3%	2.9%
Westport	26	100%	58%	7.7%	3.8%
Total	283	60%**	41%**	0.0%	1.4%

*Data retrieved from USDA NASS Cropland Data 2013 and grouped into broader categories by MDA

**Represents an average

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Pope 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 35-37).

- The majority of wells were drilled (74 percent) and 6 percent were sand point wells
- The median depth of wells was 109 feet, and the shallowest was 35 feet
- The median year the wells were constructed in was 2002

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.

There were a total of 28 site visits in Pope County, but only 22 of these well sites remained in the final well dataset. The stabilized readings are described below and a more comprehensive view is available in Appendix K (Tables 38-41).

- The temperatures ranged from 9.28 °C to 14.20 °C
- The median specific conductivity was 775 µS/cm, and was as high as 1,550 µS/cm
- The water from the wells had a median pH of 7.32
- The dissolved oxygen readings ranged from 0.06 mg/L to 3.84 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 Pope County. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 41 percent of the land cover is row crop agriculture and there are over 33,000 acres of groundwater irrigation in the study area. In total the Pope County study area covers approximately 138,802 acres.

The initial (homeowner collected) nitrate sampling resulted in 303 samples. The 303 households that participated represent approximately 32 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 28 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 20 (seven percent) wells were found to be unsuitable and were removed to create the final well dataset of 283 wells. The remaining 283 wells were wells believed to be impacted by commercial nitrogen fertilizer.

A majority of wells (74 percent) in the final well dataset were drilled and 6 percent were sand points. The median depth of the wells was 109 and depths ranged from 35 to 357 feet.

In the initial statistics, three townships had over ten percent of their wells at or over the HRL. After wells were removed to create the final statistics, all of the townships had less than five percent of wells at or over the HRL. The percent of wells at or over the nitrate HRL in each township ranged from 0.0 to 3.8 percent.

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APPENDIX A

Private Well Field Log and Survey Form

Site ID _____ Unique ID _____ Date _____

MDA -Private Well Field Log & Well Survey Form

Water Treatment and Testing Information

1. Is this well the primary water supply for the residence? Yes No
2. Is this well used for drinking/cooking water? Yes No
3. Is there an indoor water treatment system? Yes No
 If yes, check system: Softened Distilled Reverse Osmosis
 Activated Carbon Other _____
4. Is there water treatment on the outdoor spigot? Yes No
 If yes, what type? _____
5. List additional samples taken at this site independent of the study _____

Well Construction Information

	HO Survey	HO Verbal	CWI
Construction Type			
Construction Date			
Well Depth			
Well Diameter			
Pump Installer			
Service			

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

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

DIRECTIONS

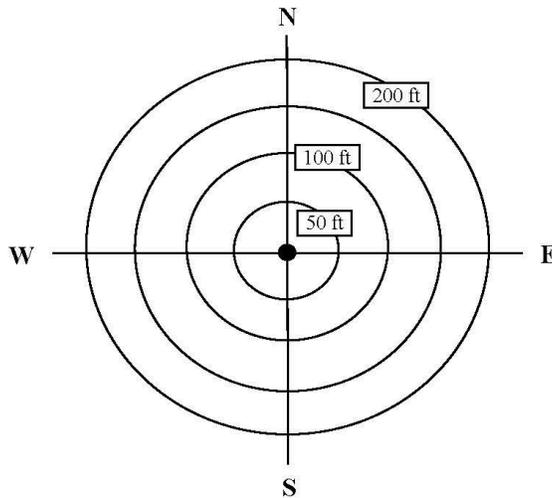
Stand at the well, find north and describe the type, position and distance to potential nitrate sources within 300 feet of the well. Put a dot where nitrate source is relative to the well. Label the dot with the appropriate code and label the distance. Codes are given below.

CODES

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

5. Does water drain toward the well? Yes No
6. Which direction does the landscape slope?(Draw arrow across bull's eye, through well, and label)
7. Is the slope: Steep Shallow Flat
8. Are there any *obvious* problems with the well? Yes No
 If yes, describe the problem _____
9. Source codes, distances, and direction _____

10. Are there potential nitrate sources nearby that are >300 ft. away from the well? If yes, list type direction and approximate distance _____



ADDITIONAL NOTES:

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 (Minnesota Rules, part 4725.4450; 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). Statewide there has been a downward trend in the number of SSTS that are FTPGW or are an ITPHS (MPCA, 2017a).

Inspections at the time of a property transfer are not required by the state, but some local government units like Pope County elect to require this inspection. In 2016, Pope County reported a total of 3,781 SSTS and 76 systems (2.0 percent) were inspected for compliance (MPCA, 2017a).

FEEDLOT

The amount of nitrogen in manure depends on the species of animal. For example, there are 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, 2017b). 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, 2017b)

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, 2015b).

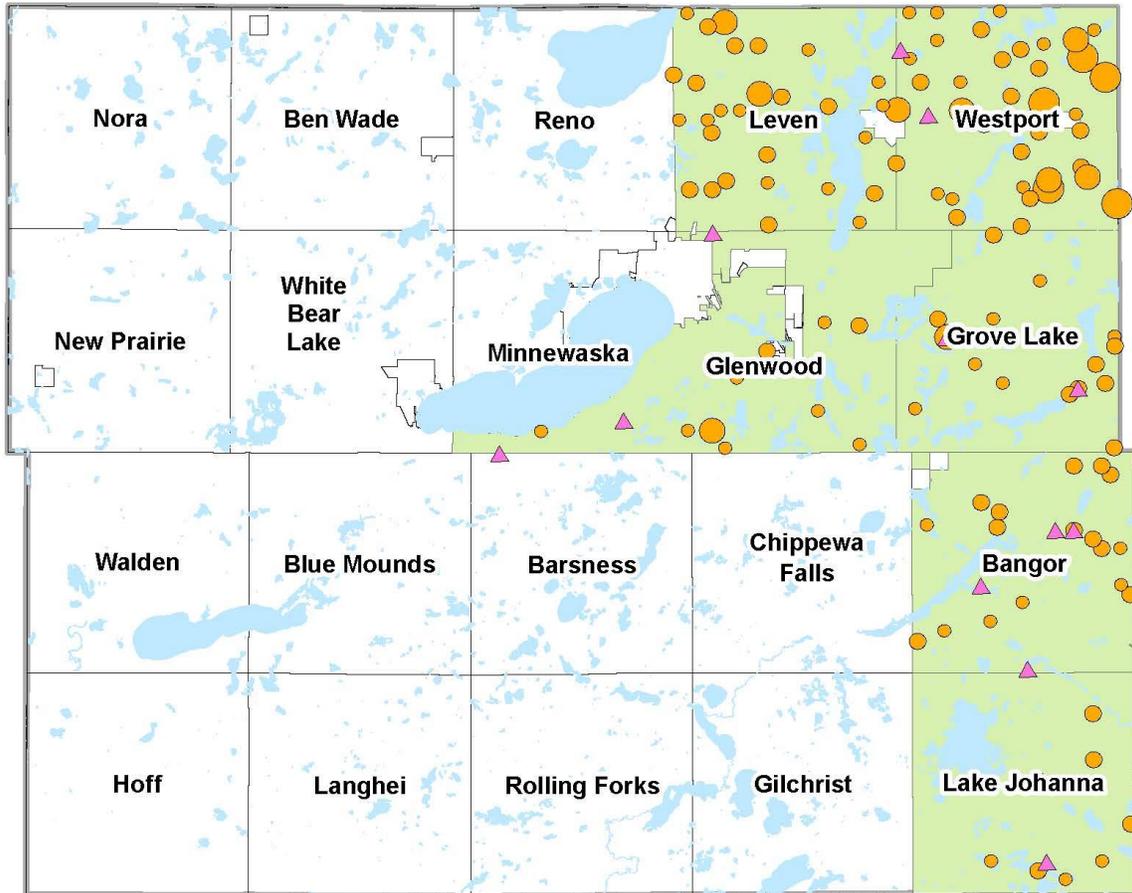
As part of new feedlot construction, an environmental assessment must be completed for feedlots with a proposed capacity of greater than 1,000 AU. If the feedlot is located in a sensitive area the requirement for an environmental assessment is 500 AU (MPCA, 2017b).

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, 2015a). Registration is required to be completed at least once during a set four year period, the most recent period was from 2014 to 2017. Currently, approximately 24,000 feedlots are registered in Minnesota (MPCA, 2017b). A map and table of the feedlots located in the Pope County study area can be found below (Figure 7; Table 10).

Feedlots

Pope County, Minnesota

Data retrieved from Minnesota Pollution Control Agency, updated July, 2016



- Feedlots**
- Townships Tested
 - Water Features
 - 0-99
 - 100-299
 - 300-999
 - $\geq 1,000$
 - Inactive Feedlots

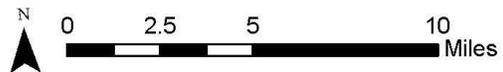


Figure 7. Feedlot Locations in Pope County

On average there are 114 AU per square mile (0.178 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 Pope County study area livestock densities average 0.43 AU per acre of row crops (MPCA, 2016; USDA NASS, 2013).

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

Township	Total Feedlots	Active Feedlots	Inactive feedlots	Average AU Permitted* Per Feedlot	Total Permitted* AU	Total Square Miles	Permitted* AU per Square Mile
Bangor	21	17	4	147	2,507	35	71
Glenwood	13	10	3	137	1,369	41	33
Grove Lake	17	15	2	159	2,383	34	71
Lake Johanna	10	9	1	119	1,070	36	30
Leven	28	28	0	136	3,800	35	108
Westport	40	38	2	357	13,551	35	383
Total	129	117	12	211	24,678	217	114

*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. A total of 106 sites are found in the Pope County study area and 103 of these are 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, Pope County

Township	*Bulk Fertilizer Facility	*Anhydrous Ammonia	*Chemigation Sites	*Abandoned Sites	Total
Bangor	0	0	17	0	17
Glenwood	0	2	16	0	18
Grove Lake	0	0	15	0	15
Lake Johanna	0	0	34	0	34
Leven	0	1	3	0	4
Westport	0	0	18	0	18
Total	0	3	103	0	106

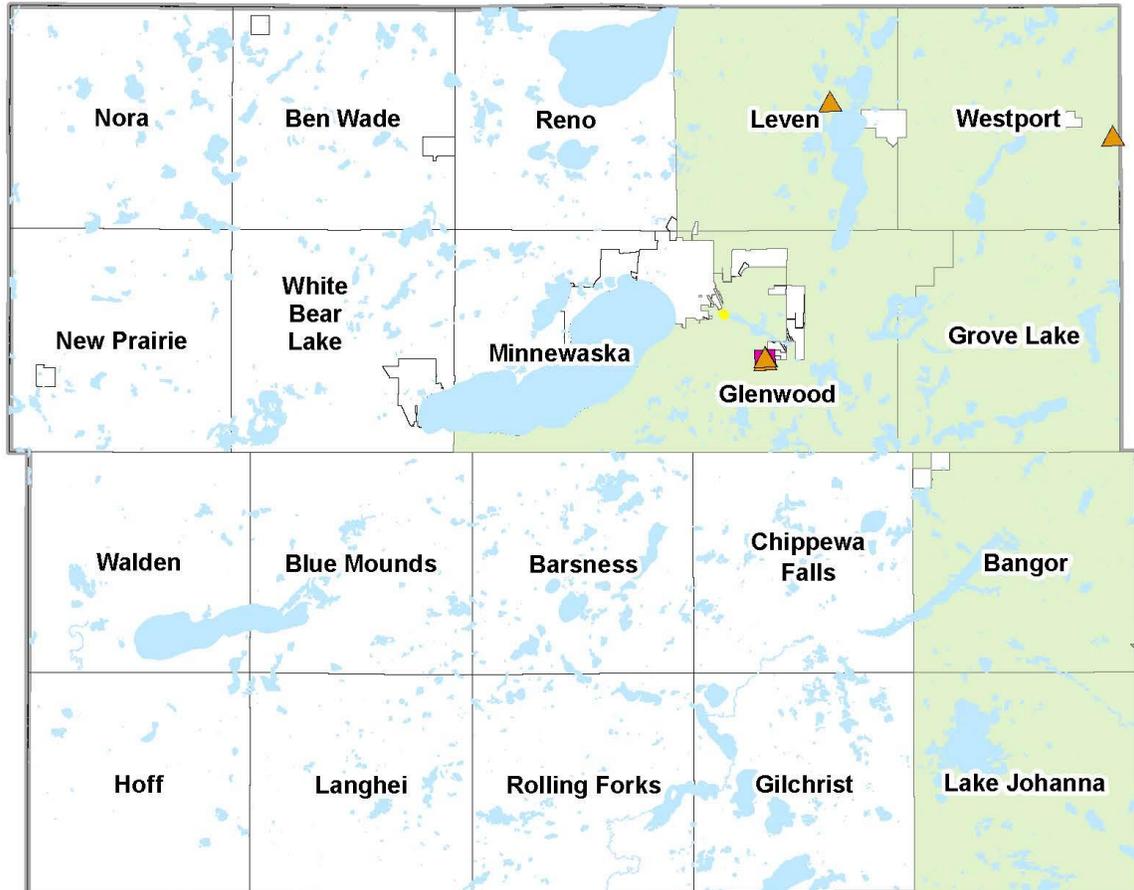
* Data retrieved from MDA Pesticide and Fertilizer Management Division; updated December 2015

SPILLS AND INVESTIGATIONS

The MDA is responsible for investigating any fertilizer spills within Minnesota. Figure 8 shows the locations of mapped historic fertilizer spills within the Pope County study area. While other types of spills are recorded, only sites that are potential point sources of nitrogen to the groundwater are reported here (MDA, 2016a).

The MDA tracks several types of incidents. Incident investigations are typically for larger spills. There is only one 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, 2016a), 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, 2016a). A breakdown of chemical type of these incidents can be found in Table 12. A breakdown of the fertilizer specific spills and investigations, by township, can be found in Table 13.

Spills and Investigations Pope County, Minnesota



- Incident Investigations
- Townships Tested
- Small Spills & Investigations
- Water Features
- Old Emergency Incidents

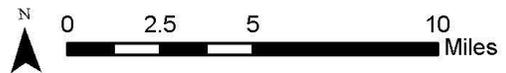


Figure 8. Fertilizer Spills and Investigations in Pope County

Table 12. Spills and Investigations by Chemical Type, Pope County

Contaminant	Incident Investigations	Contingency Areas	Small Spills and Investigations	Old Emergency Incidents	Total
Fertilizer	1	0	2	0	3
Pesticides & Fertilizer	0	0	0	0	0
Anhydrous Ammonia	0	0	3	1	4
Total	1	0	5	1	7

Table 13. Fertilizer Related Spills and Investigations by Township, Pope County

Township	Incidents and Spills
Bangor	0
Glenwood	5
Grove Lake	0
Lake Johanna	0
Leven	1
Westport	1
Total	7

APPENDIX C

LAND AND WATER USE

LAND COVER

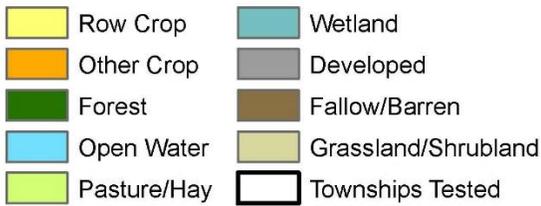
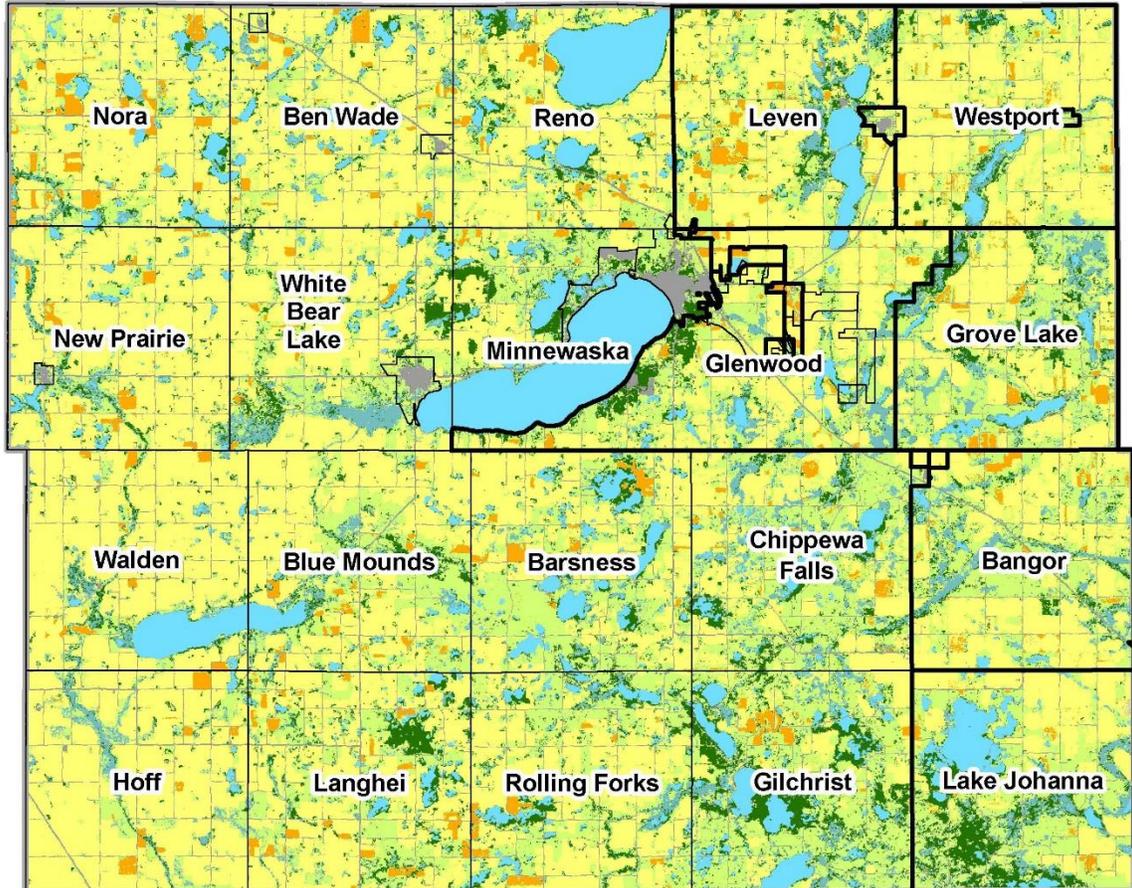
Typically locations were selected for the Township Testing Program if at least 20 percent of the land cover was in row crop production (Figure 9; Table 14). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, dry beans and double crops involving corn and soybeans.

Overall the Pope County study area has 41 percent of its land in row crop production. Westport has the highest percentage with over 50 percent of its land in row crops. The majority of the remaining land is pasture or hay. There is very little development in this area. There are a few lakes, and forested areas scattered in the area. Lake Johanna has the highest percentage of open water (10 percent) and forests (14 percent) (Figure 9 and Table 14).

Land Cover Data 2013

Pope 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



mn DEPARTMENT OF AGRICULTURE

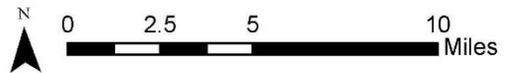


Figure 9. Land Cover in Pope County

Table 14. Land Cover Data (2013) by Township, Pope County

Township	Total Acres	Row Crops	Other Crops	Forest	Open Water	Pasture/Hay	Wetland	Developed	Fallow/Barren	Grassland/Shrubland
Bangor	22,515	41%	3%	5%	1%	34%	10%	4%	0%	1%
Glenwood	26,547	41%	2%	8%	4%	30%	7%	5%	0%	2%
Grove Lake	21,619	34%	4%	8%	4%	34%	12%	3%	0%	1%
Lake Johanna	22,842	26%	1%	14%	10%	33%	8%	3%	0%	3%
Leven	22,628	46%	5%	7%	8%	23%	6%	4%	0%	1%
Westport	22,650	58%	3%	4%	2%	24%	4%	4%	0%	1%
Total	138,802	41%*	3%*	8%*	5%*	30%*	8%*	4%*	0%*	1%*

*Represents an average

Data originated from National Agriculture Statistics Service (NASS), USDA United States Department of Agriculture (USDA NASS, 2013). Data grouped into broad categories by MDA.

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, 2016a). There are a total of 537 active groundwater well permits in the study area and 512 are used for irrigating major crops (Tables 15 and 16; Figure 10). Over 33,000 acres of cropland is permitted for groundwater irrigation in this area (Table 15). Most permitted wells are withdrawing groundwater from the water table aquifer (Table 16; MDNR, 2016b).

Table 15. Active Groundwater Use Permits by Township, Pope County

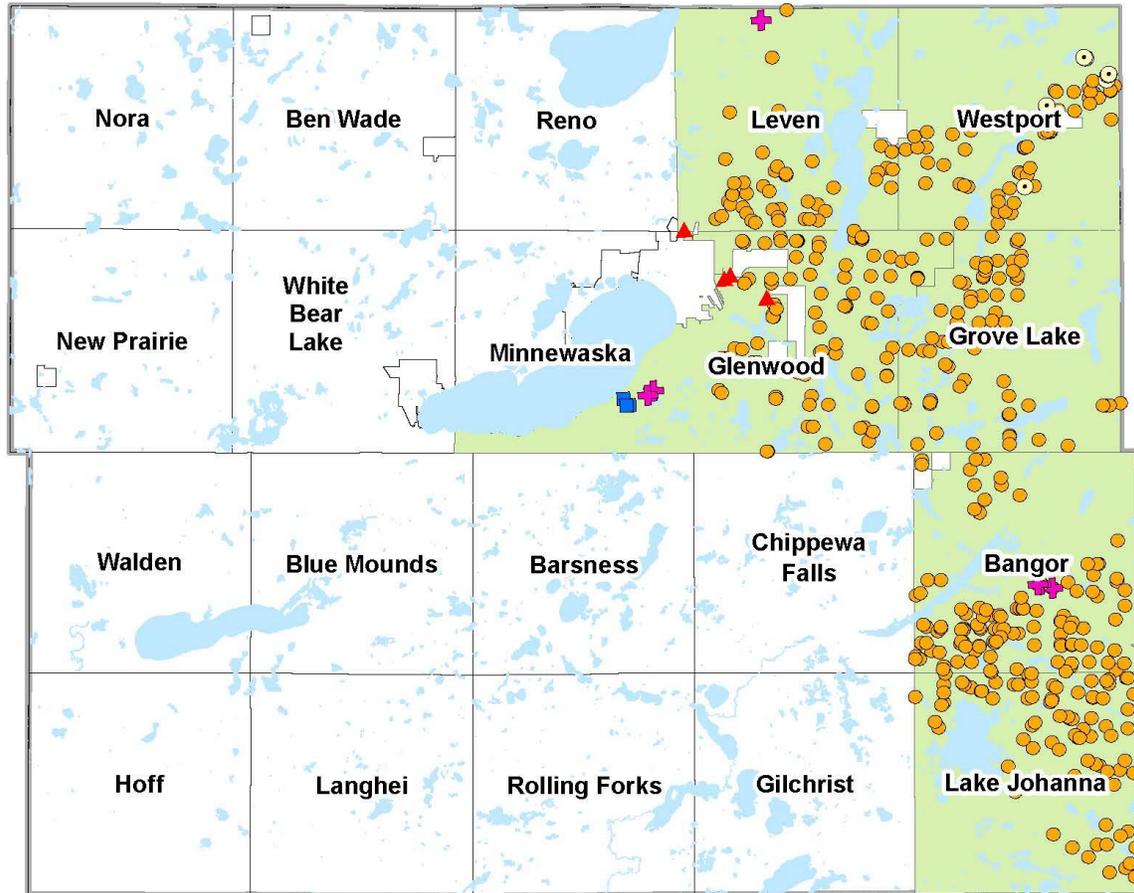
Township	Major Crop Irrigation Well Permits	Average Depth (feet)	Irrigated Acres
Bangor	141	72	7,079
Glenwood	105	70	7,611
Grove Lake	73	85	5,265
Lake Johanna	87	69	6,289
Leven	45	76	3,118
Westport	61	62	4,003
Total	512	72	33,365

Table 16. Active Groundwater Use Permits by Aquifer, Pope County

Water Use Well Permit	Total	Average Depth (feet)	Aquifer		
			Quaternary (Water Table)	Quaternary (Buried)	Not Classified
Major Crop Irrigation	512	72	294	159	59
Non-Crop Irrigation	7	63	2	2	3
Industrial Processing	5	68	2	3	0
Special Categories	10	77	0	10	0
Water Supply	3	154	0	2	1
Total	537	73	298	176	63

Active Groundwater Use Permits Pope County, Minnesota

Data retrieved from Minnesota Department of Natural Resources, updated 6/20/2016



- | | |
|---------------------------------------|-------------------------|
| Active Groundwater Use Permits | Townships Tested |
| ● Major Crop Irrigation | ■ |
| ✚ Non-Crop Irrigation | Water Features |
| ■ Waterworks | ■ |
| ▲ Industrial Processing | |
| ⊙ Special Categories | |

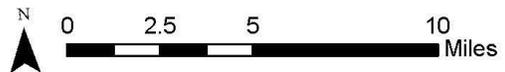


Figure 10. Active Groundwater Use Permits in Pope County

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 17. Reasons Wells Were Removed from the Final Well Dataset by Township, Pope County

Township	Point Source	Well Construction Problem	Hand Dug Well	Unsure of Water Source	Site Visit Completed - Well Not Found & Constructed before 1975 or Age Unknown & No Well ID	No Site Visit & Constructed before 1975 or Age Unknown & No Well ID	No Site Visit & Insufficient Data & No Well ID	Total
Bangor	0	0	0	0	0	2	0	2
Glenwood	0	0	0	0	0	0	0	0
Grove Lake	1	1	0	0	1	1	0	4
Lake Johanna	0	0	1	0	0	1	1	3
Leven	0	1	0	0	2	4	1	8
Westport	0	0	0	0	0	1	2	3
Total	1	2	1	0	3	9	4	20

Table 18. Completed Site Visits for Wells Removed from the Final Well Dataset by Township, Pope County

Township	Site Visit	No Site Visit	Total Wells Removed
Bangor	0	2	2
Glenwood	0	0	0
Grove Lake	2	2	4
Lake Johanna	1	2	3
Leven	3	5	8
Westport	0	3	3
Total	6	14	20

APPENDIX F

MINNESOTA WELL INDEX

The MWI was used to gather information about the six townships in Pope County included in the study. This section includes all domestic drinking water wells in the study area, not just wells MDA sampled. Table 19 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, 2017):

In these townships, there are 414 documented (have a verified location in the MWI) active, drinking water wells:

- Six percent are completed in the shallow Quaternary Water Table Aquifer (QWTA) and are 65 feet deep on average.
- At 77 percent (319 wells), the vast majority are completed in a Quaternary Buried Artesian aquifer and are 117 feet deep on average.

Table 19. Aquifer Type Distribution of Wells in Minnesota Well Index

Township	Quaternary Water Table	Quaternary Buried Unconfined	Quaternary Buried Artesian	Quaternary Undifferentiated	Cretaceous	Undesignated	Other	Total
Number of wells drawing water from an aquifer								
Bangor	0	0	23	0	0	1	0	24
Glenwood	18	4	150	1	1	50	1	225
Grove Lake	1	0	31	0	0	0	0	32
Lake Johanna	1	1	14	0	0	1	0	17
Leven	4	0	63	0	0	7	0	74
Westport	1	1	38	0	0	2	0	42
Total	25	6	319	1	1	61	1	414
Average Well Depth (feet)	65	99	117	15	400	99	270	112

Private Well Survey Questions

1. What setting did the water sample come from? Please choose only one.
Answers choices: Sub-division, Lake Home, River Home, Country, Municipal/city, or Other.
2. Are there livestock on this property? Yes or No
3. Do you mix or store fertilizer (500lbs or more) on this property? Yes or No
4. Does farming take place on this property? Yes or No

Well Information Section

5. Does your well have a Unique Well ID number? Yes or No
6. If yes, what is the Unique ID?
(6 digit number found on a metal tag attached to your well casing)
7. Type of well construction?
Answer choices: Drilled, Sand point, Hand dug, Other, and Don't Know.
8. Approximate age (years) of your well?
Answer choices: 0-10 years, 11-20 years, 21-40 years, and over 40 years old.
9. Approximate depth of your well
Answer choices: 0-49 feet, 50-99 feet, 100-299 feet, and 300 feet or more.
10. Distance to an active or inactive feedlot
Answer choices: 0-49 feet, 50-99 feet, 100-299 feet, and 300 feet or more
11. Distance to a septic system
Answer choices: 0-49 feet, 50-99 feet, 100-299 feet, and 300 feet or more
12. Distance to an agricultural field
Answer choices: 0-49 feet, 50-99 feet, 100-299 feet, and 300 feet or more
13. Is this well currently used for human consumption? Yes or No
14. Please check any water treatment you have other than a water softener.
Answer choices: None, Reverse Osmosis, Distillation, Filtering System and Other.
15. When did you last have your well tested for nitrates?
Answer choices: Never, within the last year, within the last 3 years, the last 10, or 10 or more.
16. What was the result of your last nitrate test?
Answer choices: 0<3, 3<10, 10 or greater, or Don't Know.

APPENDIX H

Table 20. Property Setting for Well Location

Township	Total	Country	Lake	River Home	Sub-division	Municipality/ City	Other	Not available
Bangor	19	84.2%	5.3%	0.0%	0.0%	0.0%	0.0%	10.5%
Glenwood	125	49.6%	29.6%	0.0%	3.2%	0.0%	0.8%	16.8%
Grove Lake	33	72.7%	12.1%	0.0%	0.0%	0.0%	3.0%	12.1%
Lake Johanna	20	70.0%	0.0%	0.0%	0.0%	0.0%	5.0%	25.0%
Leven	77	50.6%	33.8%	0.0%	1.3%	0.0%	1.3%	13.0%
Westport	29	65.5%	3.4%	0.0%	0.0%	0.0%	0.0%	31.0%
Total	303	57.4%	22.8%	0.0%	1.7%	0.0%	1.3%	16.8%

Table 21. Well Construction Type

Township	Total	Drilled	Sand point	Hand Dug	Other	Not Available
Bangor	19	78.9%	10.5%	0.0%	0.0%	10.5%
Glenwood	125	74.4%	3.2%	0.0%	0.8%	21.6%
Grove Lake	33	51.5%	27.3%	0.0%	0.0%	21.2%
Lake Johanna	20	60.0%	15.0%	0.0%	0.0%	25.0%
Leven	77	71.4%	13.0%	0.0%	0.0%	15.6%
Westport	29	62.1%	3.4%	0.0%	0.0%	34.5%
Total	303	69.3%	9.6%	0.0%	0.3%	20.8%

Table 22. Depth of Well

Township	Total	Depth 0-49 ft	Depth 50-99 ft	Depth 100-299 ft	Depth Over 300 ft	Not Available
Bangor	19	10.5%	15.8%	52.6%	5.3%	15.8%
Glenwood	125	7.2%	32.0%	31.2%	3.2%	26.4%
Grove Lake	33	30.3%	21.2%	27.3%	0.0%	21.2%
Lake Johanna	20	30.0%	25.0%	20.0%	0.0%	25.0%
Leven	77	13.0%	36.4%	29.9%	1.3%	19.5%
Westport	29	6.9%	34.5%	24.1%	0.0%	34.5%
Total	303	12.9%	30.7%	30.4%	2.0%	24.1%

Table 23. Age of Well

Township	Total	0-10 years	11-20 years	21-40 years	Over 40 years	Not available
Bangor	19	21.1%	31.6%	21.1%	10.5%	15.8%
Glenwood	125	16.0%	30.4%	24.0%	10.4%	19.2%
Grove Lake	33	6.1%	30.3%	36.4%	12.1%	15.2%
Lake Johanna	20	15.0%	15.0%	35.0%	10.0%	25.0%
Leven	77	15.6%	22.1%	23.4%	23.4%	15.6%
Westport	29	10.3%	27.6%	24.1%	13.8%	24.1%
Total	303	14.5%	27.1%	25.7%	14.2%	18.5%

Table 24. Unique Well ID Known

Township	Total	No Unique Well ID	Yes Unique Well ID	Not Available
Bangor	19	10.5%	26.3%	63.2%
Glenwood	125	19.2%	32.0%	48.8%
Grove Lake	33	42.4%	15.2%	42.4%
Lake Johanna	20	30.0%	10.0%	60.0%
Leven	77	23.4%	24.7%	51.9%
Westport	29	24.1%	10.3%	65.5%
Total	303	23.4%	24.4%	52.1%

Table 25. Livestock Located on Property

Township	Total	No Livestock	Yes Livestock	Not Available
Bangor	19	68.4%	21.1%	10.5%
Glenwood	125	80.0%	4.0%	16.0%
Grove Lake	33	81.8%	6.1%	12.1%
Lake Johanna	20	55.0%	20.0%	25.0%
Leven	77	80.5%	5.2%	14.3%
Westport	29	55.2%	13.8%	31.0%
Total	303	75.6%	7.6%	16.8%

Table 26. Fertilizer (500lbs or more) Stored on Property

Township	Total	No Fertilizer Stored	Yes Fertilizer Stored	Not Available
Bangor	19	84.2%	5.3%	10.5%
Glenwood	125	83.2%	0.0%	16.8%
Grove Lake	33	84.8%	0.0%	15.2%
Lake Johanna	20	70.0%	0.0%	30.0%
Leven	77	85.7%	1.3%	13.0%
Westport	29	65.5%	3.4%	31.0%
Total	303	81.5%	1.0%	17.5%

Table 27. Farming on Property

Township	Total	No Farming	Yes Farming	Not Available
Bangor	19	47.4%	42.1%	10.5%
Glenwood	125	74.4%	9.6%	16.0%
Grove Lake	33	69.7%	18.2%	12.1%
Lake Johanna	20	40.0%	35.0%	25.0%
Leven	77	54.5%	32.5%	13.0%
Westport	29	34.5%	31.0%	34.5%
Total	303	61.1%	22.1%	16.8%

Table 28. Distance to an Active or Inactive Feedlot

Township	Total	Feedlot 0-49 feet	Feedlot 50-99 feet	Feedlot 100-299 feet	Feedlot Over 300 feet	Not Available
Bangor	19	0.0%	5.3%	15.8%	57.9%	21.1%
Glenwood	125	1.6%	0.8%	3.2%	68.8%	25.6%
Grove Lake	33	3.0%	3.0%	3.0%	75.8%	15.2%
Lake Johanna	20	0.0%	5.0%	0.0%	65.0%	30.0%
Leven	77	1.3%	2.6%	6.5%	71.4%	18.2%
Westport	29	0.0%	0.0%	17.2%	51.7%	31.0%
Total	303	1.3%	2.0%	5.9%	67.7%	23.1%

Table 29. Distance to Septic System

Township	Total	Septic 0-49 feet	Septic 50-99 feet	Septic 100-299 feet	Septic Over 300 feet	Not Available
Bangor	19	5.3%	26.3%	47.4%	5.3%	15.8%
Glenwood	125	2.4%	35.2%	33.6%	10.4%	18.4%
Grove Lake	33	9.1%	24.2%	42.4%	12.1%	12.1%
Lake Johanna	20	5.0%	35.0%	30.0%	5.0%	25.0%
Leven	77	3.9%	31.2%	37.7%	9.1%	18.2%
Westport	29	0.0%	24.1%	27.6%	17.2%	31.0%
Total	303	3.6%	31.4%	35.6%	10.2%	19.1%

Table 30. Distance to an Agricultural Field

Township	Total	Field 0-49 feet	Field 50-99 feet	Field 100-299 feet	Field Over 300 feet	Not Available
Bangor	19	0.0%	5.3%	31.6%	47.4%	15.8%
Glenwood	125	0.8%	2.4%	15.2%	62.4%	19.2%
Grove Lake	33	3.0%	0.0%	24.2%	60.6%	12.1%
Lake Johanna	20	5.0%	0.0%	25.0%	40.0%	30.0%
Leven	77	2.6%	7.8%	29.9%	45.5%	14.3%
Westport	29	0.0%	3.4%	24.1%	41.4%	31.0%
Total	303	1.7%	3.6%	22.4%	53.5%	18.8%

Table 31. Drinking Water Well

Township	Total	Not used for drinking	Yes used for drinking	Not available
Bangor	19	5.3%	78.9%	15.8%
Glenwood	125	2.4%	80.8%	16.8%
Grove Lake	33	0.0%	87.9%	12.1%
Lake Johanna	20	0.0%	75.0%	25.0%
Leven	77	3.9%	83.1%	13.0%
Westport	29	0.0%	75.9%	24.1%
Total	303	2.3%	81.2%	16.5%

Table 32. Treatment System Present (Treatment System Used for Drinking Water)

Township	Total	None	Filtering System	Reverse Osmosis	Distillation	Other	Not Available
Bangor	19	63.2%	5.3%	15.8%	0.0%	5.3%	10.5%
Glenwood	125	46.4%	15.2%	16.0%	0.0%	2.4%	20.0%
Grove Lake	33	57.6%	18.2%	12.1%	0.0%	0.0%	12.1%
Lake Johanna	20	50.0%	0.0%	10.0%	0.0%	5.0%	35.0%
Leven	77	44.2%	22.1%	20.8%	0.0%	0.0%	13.0%
Westport	29	44.8%	17.2%	10.3%	0.0%	0.0%	27.6%
Total	303	48.2%	15.8%	15.8%	0.0%	1.7%	18.5%

Table 33. Well Last Tested for Nitrate

Township	Total	Within the past year	Within the last 3 years	Within the last 10 years	Greater than 10 years	Never Tested	Not Sure	Not Available
Bangor	19	0.0%	0.0%	26.3%	21.1%	31.6%	10.5%	10.5%
Glenwood	125	11.2%	5.6%	14.4%	12.0%	22.4%	18.4%	16.0%
Grove Lake	33	0.0%	15.2%	6.1%	12.1%	33.3%	21.2%	12.1%
Lake Johanna	20	0.0%	5.0%	10.0%	20.0%	15.0%	25.0%	25.0%
Leven	77	9.1%	10.4%	15.6%	18.2%	18.2%	15.6%	13.0%
Westport	29	6.9%	3.4%	13.8%	13.8%	27.6%	6.9%	27.6%
Total	303	7.6%	7.3%	14.2%	14.9%	23.1%	16.8%	16.2%

Table 34. Last Nitrate Test Result

Township	Total	<3 mg/L	3<10 mg/L	≥10 mg/L	Not available
Bangor	19	5.3%	5.3%	0.0%	89.5%
Glenwood	125	12.0%	1.6%	2.4%	84.0%
Grove Lake	33	6.1%	0.0%	3.0%	90.9%
Lake Johanna	20	10.0%	5.0%	0.0%	85.0%
Leven	77	15.6%	2.6%	5.2%	76.6%
Westport	29	13.8%	0.0%	0.0%	86.2%
Total	303	11.9%	2.0%	2.6%	83.5%

APPENDIX I

Table 35. Well Construction Type for Final Well Dataset

Township	Samples	Drilled	Sand Point	Not Available
Bangor	17	15	0	2
Glenwood	125	95	4	26
Grove Lake	29	17	6	6
Lake Johanna	17	11	2	4
Leven	69	54	5	10
Westport	26	17	1	8
Total	283	209	18	56

Data compiled from well logs and homeowner responses.

Table 36. Well Depth (feet) for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Bangor	7	35	305	117	168
Glenwood	52	39	357	118	138
Grove Lake	7	50	224	185	158
Lake Johanna	4	58	197	82	105
Leven	18	55	186	104	106
Westport	6	45	93	55	63
Total	94	35	357	109	129

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

Table 37. Year of Well Construction for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Bangor	7	1999	2014	2006	2005
Glenwood	52	1981	2013	2002	2001
Grove Lake	7	1983	2014	2003	2002
Lake Johanna	4	1990	2008	2000	1999
Leven	18	1989	2013	2003	2002
Westport	6	1995	2008	1998	2000
Total	94	1981	2014	2002	2002

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# _____ Lab QA/QC# _____

Well Owner Contact Information

Name _____

Address _____

Phone # _____ Township _____ County _____

Sampling Information

Sampler _____ Time Arrived _____

Pump Start Time _____ Discharge Rate _____ Time Collected _____

Sample Point Location/Notes _____

Well Location/Notes _____

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

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

Nearest Possible Pesticide Source (type, direction, distance) _____

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

Sample Comments/Notes:

APPENDIX K

Table 38. Temperature (°C) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Bangor	0	-	-	-	-
Glenwood	10	9.28	11.22	9.87	9.94
Grove Lake	4	10.85	12.01	11.96	11.70
Lake Johanna	3	9.71	10.38	9.95	10.01
Leven	4	9.66	14.20	12.49	12.21
Westport	1	10.94	10.94	10.94	10.94
Total	22	9.28	14.20	10.17	10.73

Table 39. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Bangor	0	-	-	-	-
Glenwood	10	7.13	7.56	7.20	7.23
Grove Lake	4	7.34	7.56	7.43	7.44
Lake Johanna	3	7.13	7.32	7.31	7.25
Leven	4	7.34	7.51	7.36	7.39
Westport	1	7.36	7.36	7.36	7.36
Total	22	7.13	7.56	7.32	7.31

Table 40. Specific Conductivity ($\mu\text{S}/\text{cm}$) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Bangor	0	-	-	-	-
Glenwood	10	671	1,550	794	861
Grove Lake	4	539	788	665	664
Lake Johanna	3	743	825	773	780
Leven	4	528	1,550	744	891
Westport	1	776	776	776	776
Total	22	528	1,550	775	816

Table 41. Dissolved Oxygen (mg/L) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Bangor	0	-	-	-	-
Glenwood	10	0.06	2.78	1.21	1.12
Grove Lake	4	0.06	3.51	1.20	1.49
Lake Johanna	3	0.06	1.93	1.07	1.02
Leven	4	0.06	3.84	0.61	1.28
Westport	1	3.70	3.70	3.70	3.70
Total	22	0.06	3.84	1.05	1.32