FINAL TOWNSHIP TESTING NITRATE REPORT: OLMSTED COUNTY 2014-2016

August 2017

Minnesota Department of Agriculture

Pesticide and Fertilizer Management Division

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ACKNOWLEDGEMENTS

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FUNDING

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

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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 2014, private wells in the Olmsted County study area (11 townships) were sampled for nitrate-N. Samples were collected from private wells using homeowner collection and mail-in methods. These initial samples were collected from 1,057 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, 4.7 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 437 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 182 wells in 2015. A follow-up sample 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 134 (13 percent) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of 923 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 13.9 percent. One township, Farmington, has more than 10% of the sampled wells at or over the HRL. The other 10 townships sampled in Olmsted County have less than 5% of their wells at or over the HRL.

INTRODUCTION

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

The goal of nitrate monitoring and assessment is to develop a comprehensive understanding of the severity, magnitude, and long term trends of nitrate in groundwater as measured in public and private wells. The MDA established the Township Testing Program to determine current nitrate concentrations in private wells on a township scale. This program is designed to quickly assess a township in a short time window. Monitoring focuses on areas of the state where groundwater nitrate contamination is more likely to occur. This is based initially on hydrogeologically vulnerable areas where appreciable acres of agricultural crops are grown. Statewide the MDA plans to offer nitrate-N tests to more than 70,000 private well owners in over 300 townships by 2019. As of January 2017, 167 townships in 19 counties have completed the initial sampling. A total of 20,042 wells have been sampled.

In 2014, eleven townships in Olmsted 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 Olmsted County occurred in 2015. The follow-up included a well site visit (when possible) in order to rule out well construction issues and to identify potential point sources of nitrogen (Appendix A).

Wells that had questionable construction integrity or are near a point source of nitrogen were removed from the final well dataset. After the unsuitable wells were removed, the nitrate-N concentrations of well water were assessed for each area.

For further information on the NFMP and Township Testing Program, please visit the following webpages:
www.mda.state.mn.us/nfmp
www.mda.state.mn.us/townshiptesting

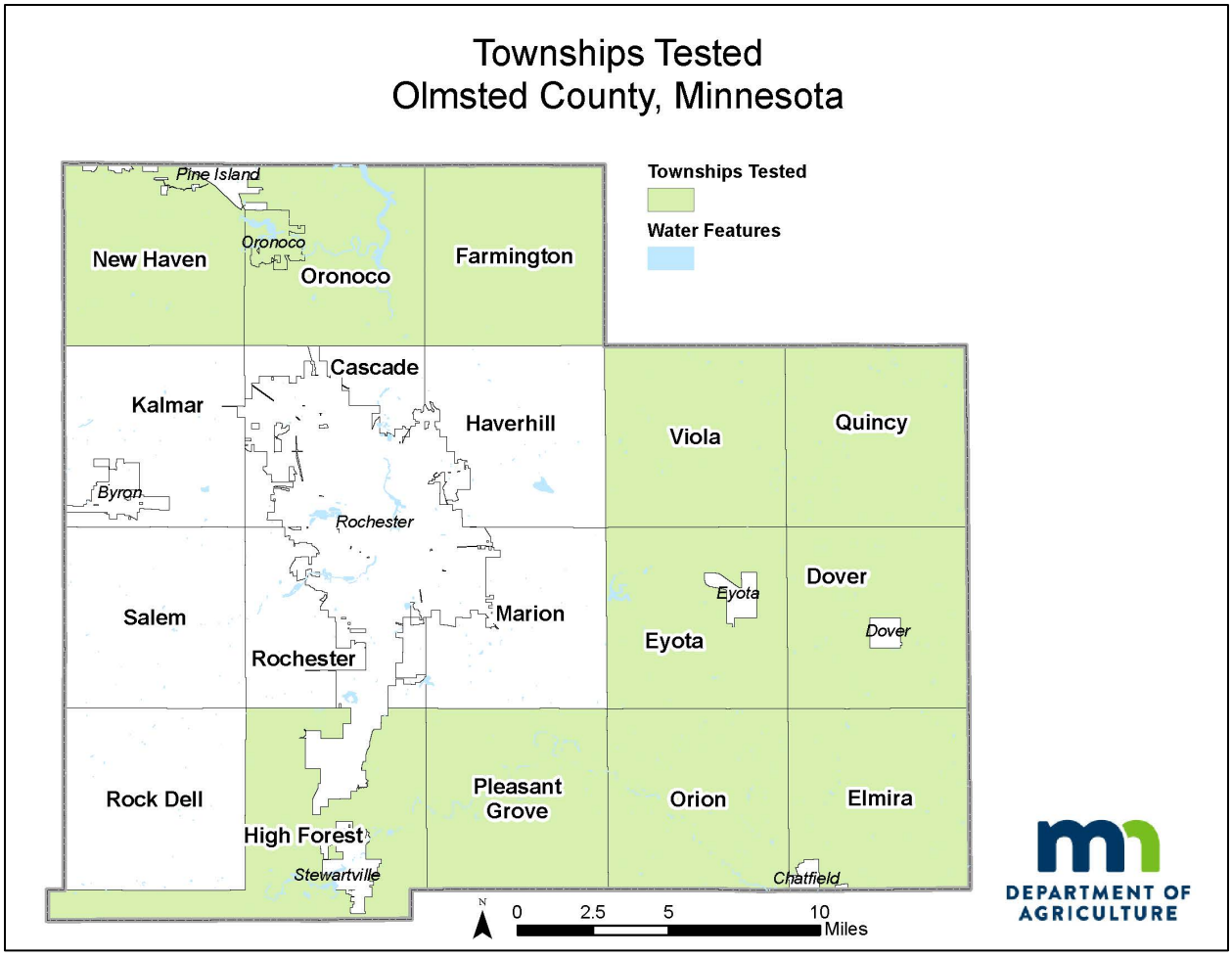

Figure 1. Townships Tested in Olmsted County

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 generally has low concentrations of organic carbon and is well oxygenated, so denitrification is often limited in these conditions (MPCA, 1998). Also areas like those in Olmsted County with karst bedrock, (Balaban, 1988) 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 surficial geology in Olmsted County is dominated by bedrock and till. Bedrock outcrops within five feet of the surface are common in the county. The uppermost bedrock in the region has karst geology. Karst is where water solutions have dissolved the bedrock resulting in enlarged fractures. These fractures can serve as conduits for surface water to rapidly flow into the ground. In certain locations, the bedrock is covered by a layer of loess sediment. Loess is windblown silt (mixed with some clay and fine sand) that was deposited about 25,000 years ago. Loess can provide some protection to the groundwater, however it is not considered impermeable (Balaban, 1988).

Till is the most prominent in western Olmsted County. It is an unsorted material that was deposited by glacial activity. It consists primarily of sand, silt, and clay. It is often classified as a loam to a clay-loam soil texture. This unsorted material is a relatively protective barrier to groundwater contamination. The finer sediments fill in any empty spaces around larger particles, making the till somewhat impermeable (Balaban, 1988). However the till in this area is thin (MPCA, 1999).

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 bedrock and till in Olmsted County as presented in Figure 2.

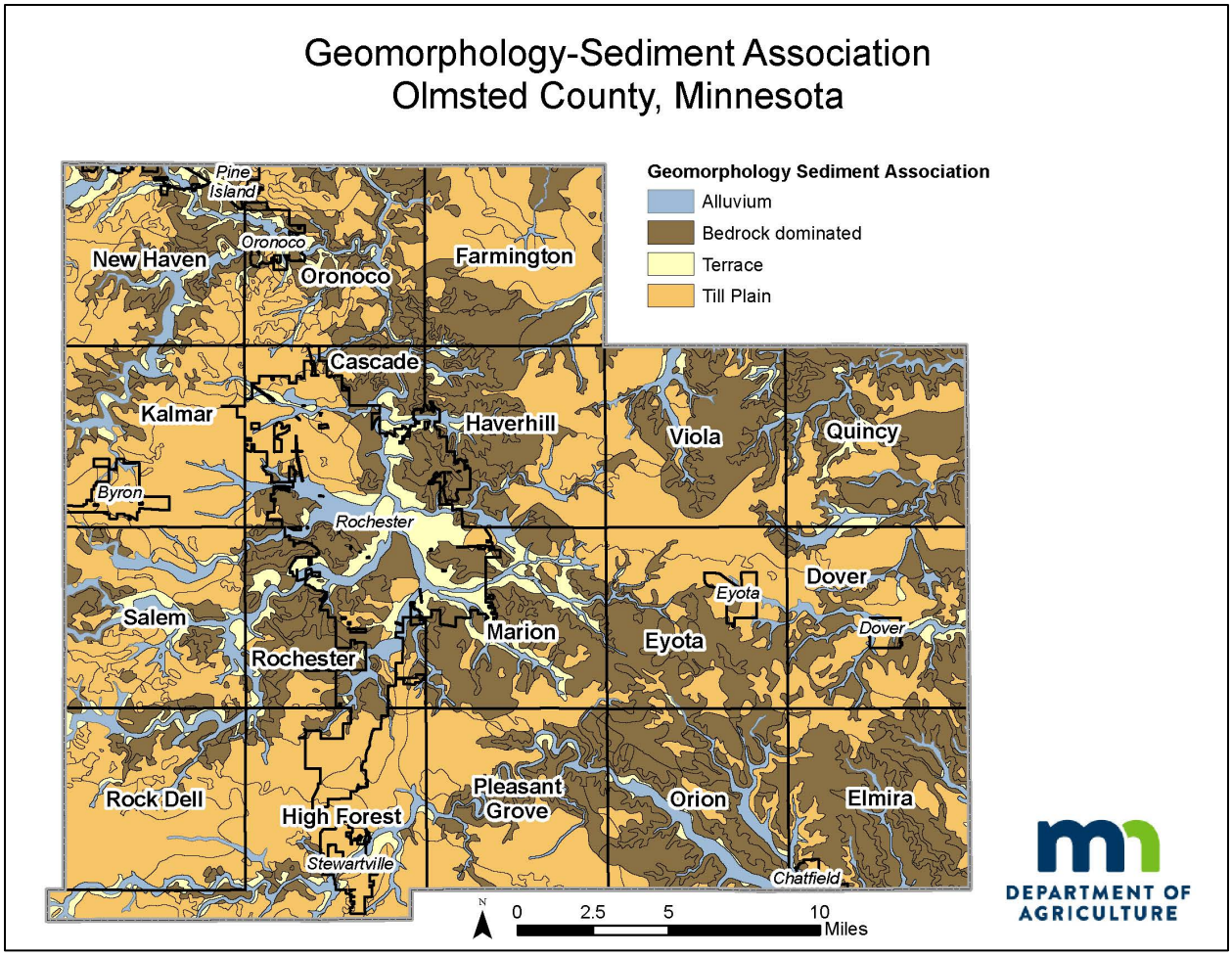

Figure 2. Statewide Geomorphology Layer, Sediment Association in Olmsted County (MDNR, MGS, UMD, 1997)

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 Olmsted 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 3,494 SSTS were reported in Olmsted County for 2014. Over a recent 13 year period (2002-2014), 1,464 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Olmsted County, 42 percent are newer than 2002 or have been repaired since

2002 (MPCA, 2015a). When new SSTS's are installed they are required to be in compliance with the rules at the time of installation. Newer systems meet modern SSTS regulations and must comply with the current well code; which requires a 50 foot horizontal separation from the well (MDH, 2014).

FEEDLOT

Manure produced on a feedlot can be a potential source of nitrogen pollution if improperly stored or spread. In the Olmsted County study area there are a total of 89 active feedlots. The majority of the feedlots are permitted to house less than 300 animal units (AU) (Appendix B; Figure 7). Eyota Township houses the largest feedlots, 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 Olmsted County study area has a total of 7 fertilizer storage licenses with majority located in Farmington and High Forest Townships (Appendix B; Table 11).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of 10 historic fertilizer spills and investigations occurred in the Olmsted County study area. The majority of these were old emergency incidents (Appendix B; Table 12).

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.

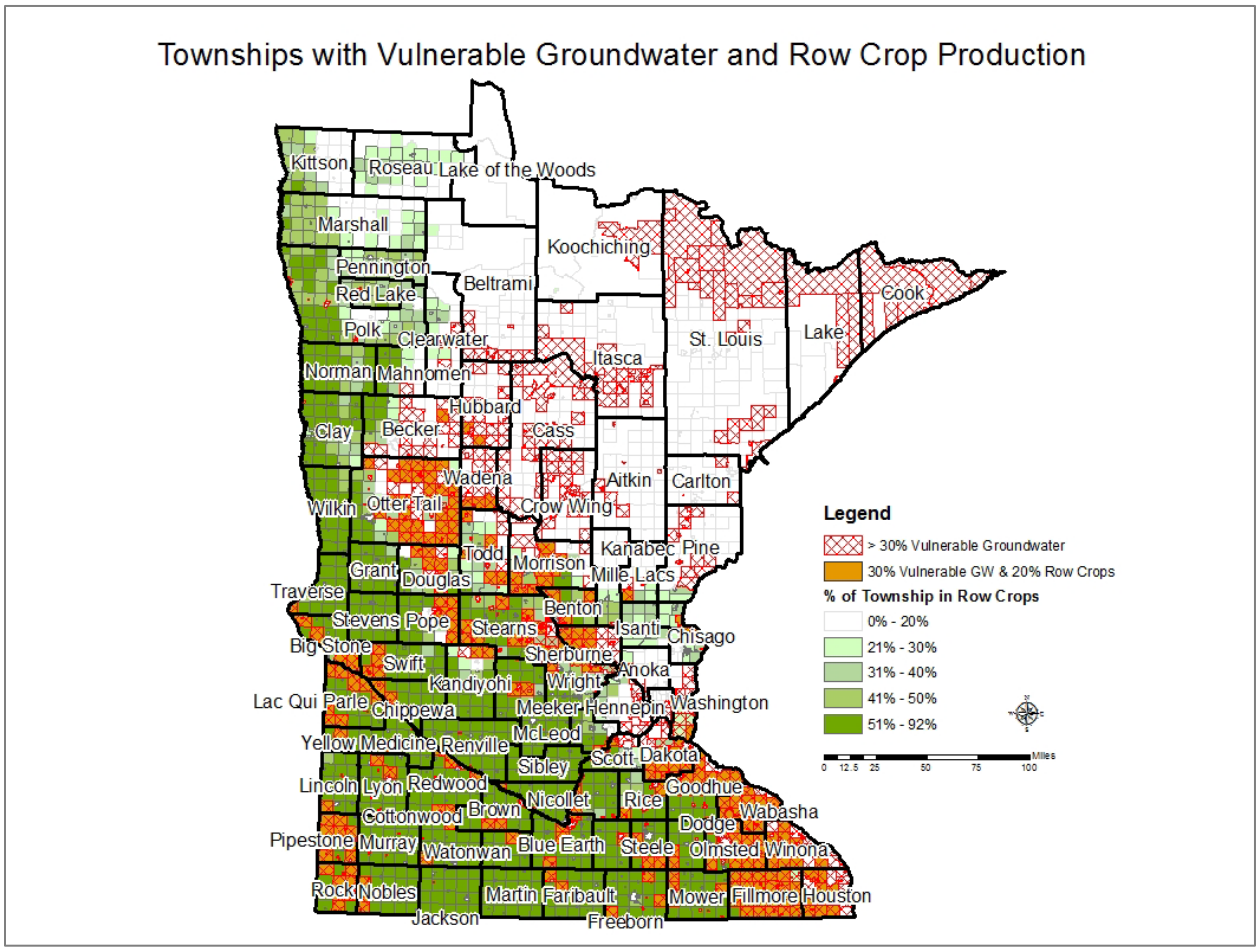

Figure 3. Minnesota Townships with Vulnerable Groundwater and Row Crop Production

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 Olmsted 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

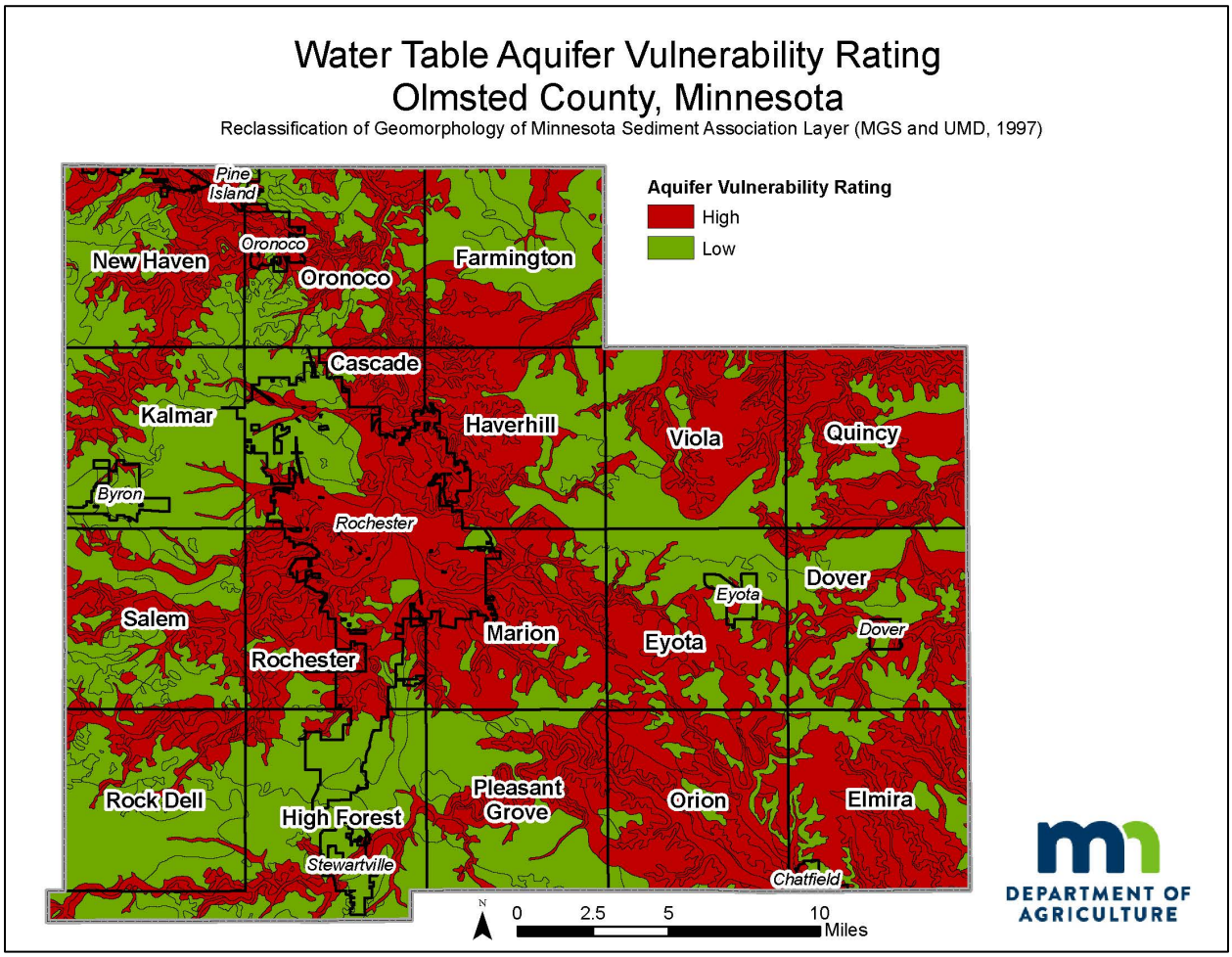

Figure 4. Water Table Aquifer Vulnerability Rating in Olmsted County

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 Olmsted County can be found in Appendix C (Figure 9, Table 14). On average 50% 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 2014. In the initial sampling, all private well owners in the selected townships are sent a nitrate test kit. Additionally any of the households on private wells located in the small towns/cities within the townships were also offered kits. 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 1,057 homeowners using the mail-in kit (Table 2). These 1,057 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 2015 by MDA staff. A total of 182 follow-up samples were analyzed (Table 2).

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

Township	Kits Sent	Initial Well Dataset*	Well Site Visits & Follow-Up Sampling Conducted
Dover	163	49	16
Elmira	160	50	13
Eyota	207	54	4
Farmington	207	56	16
High Forest	425	143	18
New Haven	457	169	26
Orion	229	73	9
Oronoco**	745	255	51
Pleasant Grove	338	100	7
Quincy	143	35	11
Viola	236	73	11
Total	3,308	1,057	182

*Includes all well types
**Includes Oronoco City

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 Well Information and Potential Nitrate Source Inventory Form (Appendix A).

WELL ASSESSMENT

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

To create the final well dataset, 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.

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. (MINN. R. 4725.4450 (2014)). High nitrate 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.

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 well may have a completely loose 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.

This study is focused on wells that supply drinking water and if the water source of the sample was uncertain, then data pertaining to this sample was removed.

Sometimes multiple homeowners share one well. If multiple samples were collected from the same well only one sample was kept and the subsequent samples were removed from the final well dataset.

Old wells with no validation on the condition of well construction were also removed from the dataset. These wells were installed before the well code was developed in Minnesota, (mid-1974 (MDH, 2014)) they did not have a well log, and MDA staff did not visually examine these wells.

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.

Using these criteria, a total of 134 wells were removed to create the final well dataset. See Appendix E (Table 16) for a summary of the removed wells.

INITIAL RESULTS

INITIAL WELL DATASET

Approximately 1,057 well owners returned water samples for analysis across the 11 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 0.25 mg/L or 0.10 mg/L. The maximum values ranged from 13.6 to 32.0 mg/L, with Elmira Township having the highest result. Median values range from <DL to 8.1 mg/L, with Farmington Township having the highest median value. The 90th percentiles range from 3.5 to 14.8 mg/L, with Farmington Township having the highest 90th percentile.

Initial results from the sampling showed that in Dover and Farmington Townships, ten percent or more of the wells were at or over 10 mg/L nitrate. 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 Dover and Farmington Townships are 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.

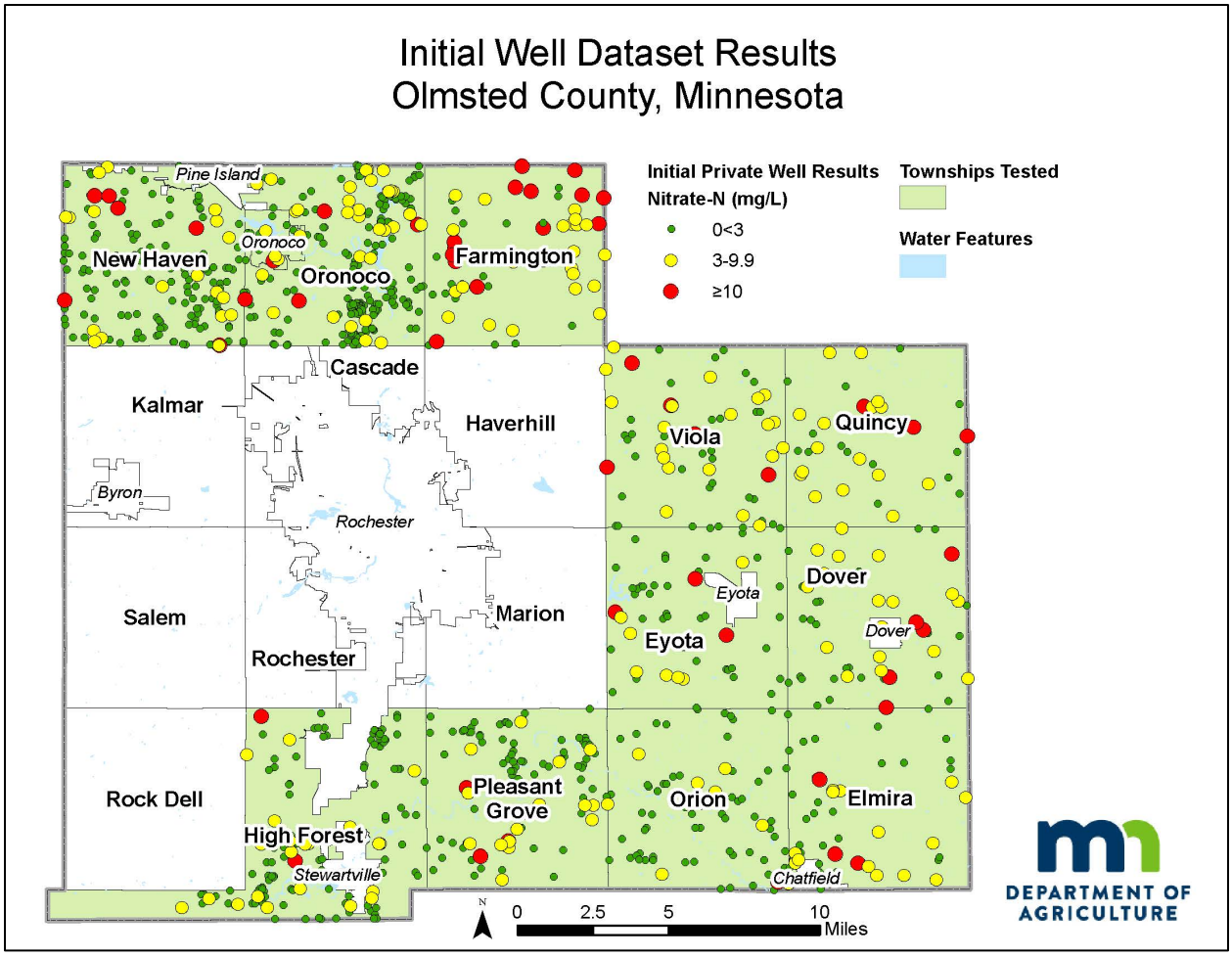

Figure 5. Well Locations and Nitrate Results from Initial Well Dataset in Olmsted County

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

Township	Total Wells	Values				Percentile				Number of Wells					Percentage of Wells				
		Min	Max	Mean	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)																	
Dover	49	<DL	18.2	3.8	2.1	7.0	9.8	11.7	18.2	27	17	16	12	5	55.1%	34.7%	32.7%	24.5%	10.2%
Elmira	50	<DL	32.0	3.5	1.2	5.2	8.7	13.3	32.0	31	16	13	8	3	62.0%	32.0%	26.0%	16.0%	6.0%
Eyota	54	<DL	14.5	1.6	<DL	1.0	7.9	9.9	14.4	44	7	7	6	3	81.5%	13.0%	13.0%	11.1%	5.6%
Farmington	56	<DL	22.4	7.1	8.1	10.2	14.8	20.8	22.3	19	23	32	30	14	33.9%	41.1%	57.1%	53.6%	25.0%
High Forest	143	<DL	13.6	1.1	<DL	0.4	5.0	7.1	10.8	118	23	15	8	2	82.5%	16.1%	10.5%	5.6%	1.4%
New Haven	169	<DL	21.5	1.4	<DL	1.1	4.6	8.6	19.0	144	19	16	11	6	85.2%	11.2%	9.5%	6.5%	3.6%
Orion	73	<DL	14.7	1.1	<DL	1.1	3.5	5.5	13.5	64	8	6	3	1	87.7%	11.0%	8.2%	4.1%	1.4%
Oronoco	255	<DL	16.1	1.3	<DL	0.9	5.3	8.0	13.8	216	34	28	16	5	84.7%	13.3%	11.0%	6.3%	2.0%
Pleasant Grove	100	<DL	16.2	1.4	<DL	<DL	6.3	8.4	13.8	81	16	15	8	3	81.0%	16.0%	15.0%	8.0%	3.0%
Quincy	35	<DL	22.7	5.3	5.4	8.9	9.7	14.6	22.7	16	16	18	15	3	45.7%	45.7%	51.4%	15.3%	8.6%
Viola	73	<DL	19.6	3.5	0.3	6.2	9.6	12.3	19.2	42	26	25	18	5	57.5%	35.6%	34.2%	24.7%	6.8%
Total	1057	<DL	32.0	2.1*	<DL*	2.6*	8.1*	9.9*	18.2*	802	205	191	135	50	75.9%*	19.4%*	18.1%*	12.8%*	4.7%*

* Represents an average value

< DL stands for less than a detectable limit. This means results are less than 0.25 mg/L or 0.10 mg/L. The 50th percentile (75th, 90th, 95th, and 99th) is the value below which 50 percent (75%, 90%, 95%, and 99%) of the observed values fall.

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 437 people in Olmsted County's study area have drinking water over the nitrate HRL (Table 4). Nitrate contamination is a significant problem across much of Olmsted 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, Olmsted County

Township	2013 Estimated Households on Private Wells*	2013 Estimated Population on Private Wells*	Estimated Population ≥10 mg/L Nitrate-N**
Dover	149	400	41
Elmira	136	367	22
Eyota	176	497	28
Farmington	188	449	112
High Forest	391	1,003	14
New Haven	473	1,213	43
Orion	242	618	8
Oronoco* **	1,306	3,624	71
Pleasant Grove	328	832	25
Quincy	131	356	31
Viola	227	613	42
Total	3,747	9,972	437

* Data collected from the Minnesota State Demographic Center, 2013

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

*** Includes Oronoco City

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 (MDH, 2015).

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 (MDH, 2015).

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 245 documented wells (Table 5). Approximately 23 percent of the sampled wells had corresponding well logs. Thus, the data gathered on aquifers represents only a portion of the total sampled wells.

According to the well log data, the most commonly utilized aquifer in the sampled wells was from the Paleozoic era, specifically the Prairie Du Chien Group and the Jordon Sandstone aquifers. This majority reflects the overall findings for all documented wells in the focus area (Appendix F, Table 17). The wells in these Paleozoic aquifers are relatively deep, averaging 415 feet deep.

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

The Quaternary aquifers are not present in Olmsted County. The earliest aquifer formations are from the Paleozoic time period,

The first group of Paleozoic aquifers are known as the Upper Carbonate Group. The Upper Carbonate Aquifer is comprised of the Maquoketa, Debuque, Stewartville, Prosser, and Cummingsville formations. However, no wells were found in these formations. Olmsted has set more restrictive well regulations than the Minnesota Well Code. Current Olmsted regulations require potable water wells to have 50 feet of protective cover for a one mile radius. This means that new wells cannot withdraw from the Upper Carbonate aquifer in Olmsted County (Rochester-Olmsted Planning Department, 2013; Balaban, 1988).

Typically found below the Upper Carbonate Group is the Decorah-Platteville-Glenwood confining layer. This layer has eroded in northern parts of Olmsted County (Balaban, 1988).

There are three hydrologically connected aquifers typically found under the confining layer. The first is the St. Peter Sandstone and it is absent in much of the County. The Prairie du Chien Group is a karsted dolomite found below the St. Peter Sandstone. A majority of wells are completed in this group, but, in certain locations it is prohibited to drill potable wells since it has less than 50 feet of protective cover. Lastly the Jordan Sandston aquifer also frequently utilized and is more heavily utilized in the north where the upper confining layers have eroded. (Rochester-Olmsted Planning Department, 2013; Balaban, 1988).

The St. Lawrence layer has very low permeability and is considered a confining layer. Very few wells are completed in this aquifer or beneath (Balaban, 1988).

Table 5. Nitrate Concentrations within Sampled Groundwater Aquifers, Olmsted County

Aquifer (Era)	Aquifer (Period)	Aquifer (Group/Formation)**	Total Wells	Ave Depth (Feet)	Number			Percent		
					<3	3<10	≥10	<3	3<10	≥10
					Nitrate-N mg/L					
Undesignated			122	392	106	14	2	87%	11%	2%
Multiple			1	380	1	0	0	100%	0%	0%
Paleozoic	Devonian	Lower Cedar Valley	1	140	1	0	0	100%	0%	0%
	Ordovician	St. Peter Sandstone	10	297	10	0	0	100%	0%	0%
		St. Peter-Prairie Du Chien	1	360	1	0	0	100%	0%	0%
		Prairie Du Chien Group	53	386	46	6	1	87%	11%	2%
		Prairie Du Chien/Shakopee Fm	2	436	2	0	0	100%	0%	0%
		Prairie Du Chien/Oneota Fm	5	368	4	1	0	80%	20%	0%
	Cambrian	Jordon Sandstone	41	454	38	3	0	93%	7%	0%
		Jordon-St. Lawrence	2	613	2	0	0	100%	0%	0%
		Tunnel City/Lone Rock Fm	5	622	5	0	0	100%	0%	0%
		Wonewoc Sandstone	1	592	1	0	0	100%	0%	0%
Paleozoic (sub-total)			122	415	111	10	1	91%	8%	1%
Total			245	404*	218	24	3	89%*	10%*	1%*

* Represents a weighted average value.
** Data obtained from Minnesota Well Index (http://www.health.state.mn.us/divs/eh/cwi/) in 2015

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 18-31).

The majority of wells in each township are located on “rural” property. In Oronoco a significant number of wells were located in a subdivision (21%) or on lake home properties (7.5%).

Approximately 76 percent of sampled wells are of drilled construction and less than one percent are sand point wells. Sand point (drive-point) wells are typically completed at shallower depths than drilled wells. These 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. Olmsted County Health Department regulates well construction in the county. One of the current regulations includes that sand point wells are not permitted to be constructed for potable water use (Balaban, 1988; Chapter 3200 Water Well and Water Supply Ordinance).

There were only three 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.

Over half of the wells in the townships are deeper than 100 feet. However, 29 percent of homeowner were either unsure of the depth or did not provide a depth on their survey.

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 18-31).

- On average, farming takes place on 33 percent of the properties.
- Agricultural fields are closer than 300 feet from wells at 42 percent of the properties.
- Over 10 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.

- Less than two percent of homeowners across all townships store bulk fertilizer (more than 500 pounds) on their property.
- Few wells (less than four percent) are less than 50 feet away from septic systems.

FINAL RESULTS

FINAL WELL DATASET

A total of 1,057 well water samples were collected by homeowners across 11 townships. A total of 134 (13 percent) wells were found to be unsuitable and were removed to create the final well dataset. The final analysis was conducted on the remaining 923 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 results for all townships sampled. The percent of wells at or over the HRL ranged from 0.0 to 13.9 percent.

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

Township	Initial Well Dataset	Final well Dataset	Final Wells ≥10 mg/L Nitrate-N	
			Count	Percentage
Dover	49	41	1	2.4%
Elmira	50	43	2	4.7%
Eyota	54	48	1	2.1%
Farmington	56	36	5	13.9%
High Forest	143	131	0	0.0%
New Haven	169	159	3	1.9%
Orion	73	70	0	0.0%
Oronoco**	255	228	1	0.4%
Pleasant Grove	100	88	0	0.0%
Quincy	35	23	1	4.3%
Viola	73	56	2	3.6%
Total	1,057	923	16	1.7%*

* Represents an average value

** Included Oronoco City

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 5.6 to 32.0 mg/L nitrate, with Elmira Township having the highest result. The 90th percentile ranged from 1.5 to 11.8 mg/L nitrate-N, with Pleasant Grove Township having the lowest result and Farmington Township having the highest result.

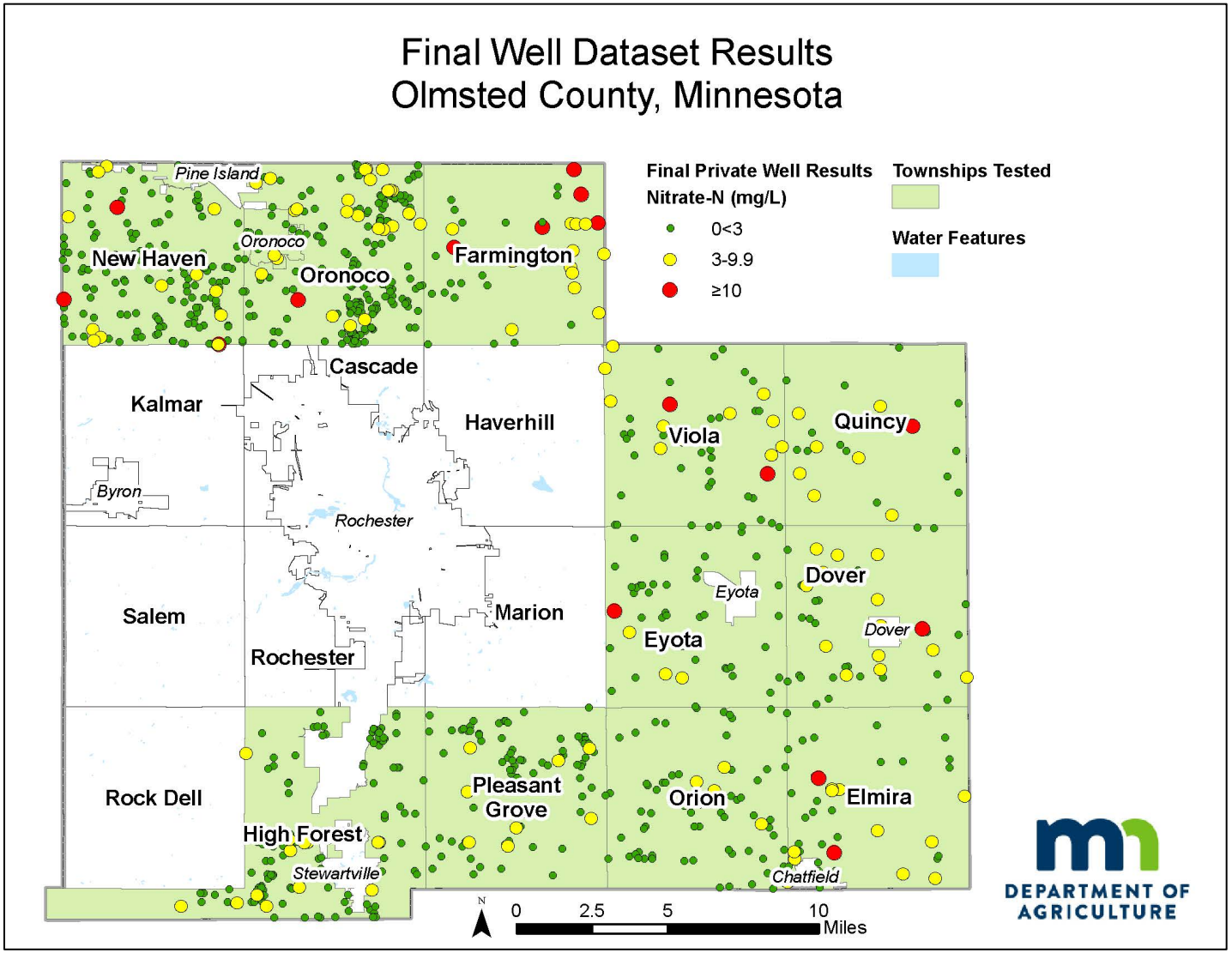

Figure 6. Well Locations and Nitrate Results from Final Well Dataset in Olmsted County

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

Township	Total Wells	Values			Percentiles					Number of Wells					Percent of Wells				
		Min	Max	Mean	(50th) Median	75th	90th	95th	99th	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L
		Nitrate-N mg/L or parts per million (ppm)																	
Dover	41	<DL	10.3	2.4	0.9	4.4	7.1	8.4	10.3	27	13	8	4	1	65.9%	31.7%	19.5%	9.8%	2.4%
Elmira	43	<DL	32.0	2.7	0.7	3.4	7.3	11.1	32.0	31	10	6	4	2	72.1%	23.3%	14.0%	9.3%	4.7%
Eyota	48	<DL	10.0	0.6	<DL	<DL	2.3	4.3	10.0	44	3	1	1	1	91.7%	6.3%	2.1%	2.1%	2.1%
Farmington	36	<DL	21.0	4.8	2.7	8.6	11.8	19.0	21.0	19	12	13	12	5	52.8%	33.3%	36.1%	33.3%	13.9%
High Forest	131	<DL	9.5	0.6	<DL	<DL	3.1	4.6	7.7	117	14	4	2	0	89.3%	10.7%	3.1%	1.5%	0.0%
New Haven	159	<DL	13.1	0.9	<DL	<DL	2.9	4.3	12.0	144	12	6	5	3	90.6%	7.5%	3.8%	3.1%	1.9%
Orion	70	<DL	5.6	0.7	<DL	0.9	2.4	4.6	5.5	64	6	3	0	0	91.4%	8.6%	4.3%	0.0%	0.0%
Oronoco	228	<DL	14.0	0.9	<DL	0.6	3.5	5.8	9.6	202	25	15	8	1	88.6%	11.0%	6.6%	3.5%	0.4%
Pleasant Grove	88	<DL	7.6	0.5	<DL	<DL	1.5	4.8	7.6	80	8	4	2	0	90.9%	9.1%	4.5%	2.3%	0.0%
Quincy	23	<DL	22.7	3.6	1.5	5.4	9.5	14.3	22.7	15	7	7	5	1	65.2%	30.4%	30.4%	21.7%	4.3%
Viola	56	<DL	12.6	1.8	<DL	2.9	5.9	8.5	12.5	42	12	8	5	2	75.0%	21.4%	14.3%	8.9%	3.6%
Total	923	<DL	32.0	1.8	1.4*	2.4*	5.2*	8.1*	13.7*	785	122	75	48	16	85.0%*	13.2%*	8.1%*	5.2%*	1.7%*

* Represents an average value

<DL stands for less than detectable limit. The detectable limit ranges from <0.1 to <0.25 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, 1997) and row crop production (USDA NASS Cropland Data Layer, 2013) in each township. The percent land area considered vulnerable geology and in row crop production was estimated using a geographic information system known as ArcGIS.

Table 8. Township Nitrate Results Related to Vulnerable Geology and Row Crop Production, Olmsted County

Township	Final Well Dataset	Percent Vulnerable Geology	Percent Row Crop Production (2013)**	Percent ≥7 mg/L	Percent ≥10 mg/L
				Nitrate-N mg/L or parts per million (ppm)	
Dover	41	51%	60%	9.8%	2.4%
Elmira	43	80%	48%	9.3%	4.7%
Eyota	48	53%	62%	2.1%	2.1%
Farmington	36	41%	70%	33.3%	13.9%
High Forest	131	25%	58%	1.5%	0.0%
New Haven	159	52%	40%	3.1%	1.9%
Orion	70	86%	33%	0.0%	0.0%
Oronoco	228	54%	31%	3.5%	0.4%
Pleasant Grove	88	42%	48%	2.3%	0.0%
Quincy	23	76%	47%	21.7%	4.3%
Viola	56	62%	59%	8.9%	3.6%
Total	923	56%*	51%*	5.2%*	1.7%*

* Represents an average value

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

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Olmsted 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 32-34).

- The majority of wells were drilled (79 percent), and less than one percent were sand point wells
- The median depth of wells was 396 feet, and the shallowest was 140 feet
- The median year the wells were constructed was 1997

WELL WATER PARAMETERS

MDA staff conducted the follow-up sampling. Field measurements of the well water parameters were recorded on a field log (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 (Table 35-38).

- The temperatures ranged from 9.32 °C to 16.07 °C
- The median specific conductivity was 590 µS/cm, and was as high as 1,422 µS/cm
- The water from the wells had a median pH of 7.89
- The dissolved oxygen readings ranged from 0.12 mg/L to 12.66 mg/L

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

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

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

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

SUMMARY

The focus of this study was to assess nitrate concentrations in groundwater impacted by row crop production in selected townships in Olmsted County. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 50 percent of the land cover is row crop agriculture, but none of the land in the study area is permitted for groundwater irrigation.

Eleven townships were sampled covering over 290,864 acres. The initial (homeowner collected) nitrate sampling resulted in 1,057 samples. The 1,057 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 182 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 134 (13 percent) wells were found to be unsuitable and were removed to form the final well dataset of 923 wells. The remaining 923 wells were believed to be impacted by nitrogen fertilizer and were included in the final well dataset.

A majority of wells (79 percent) were drilled; less than one percent were sand points. The median depth of the wells was 396 and depths ranged from 140 - 694 feet.

In one of the 11 townships tested in Olmsted County, more than 10 percent of the wells were at or over the nitrate HRL of 10 mg/L. The percent of wells at or over the nitrate HRL in each township ranged from 0.0 to 13.9 percent.

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APPENDIX A

Well information and Potential Nitrate Source Inventory Form

UNIQUE NUMBER:_____ or SITE ID:_____

Well Information and Potential Nitrate Source Inventory Form

General Information

Date of Visit: _____County: _____ Township_____

Well Unique Number (6 digits): _____ Parcel Number: _____

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

GPS location of well: Latitude:_____ Longitude:_____

Owner Name: _____

Owner Phone: _____

Owner Address: _____

e-mail:_____

Inspector Name:_____Inspector Phone: _____

Well Construction Information

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

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

1

UNIQUE NUMBER:_____ or SITE ID:_____

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

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

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

Go to last page for Source Codes and well drawing.

ADDITIONAL NOTES:

_____
_____
_____
_____

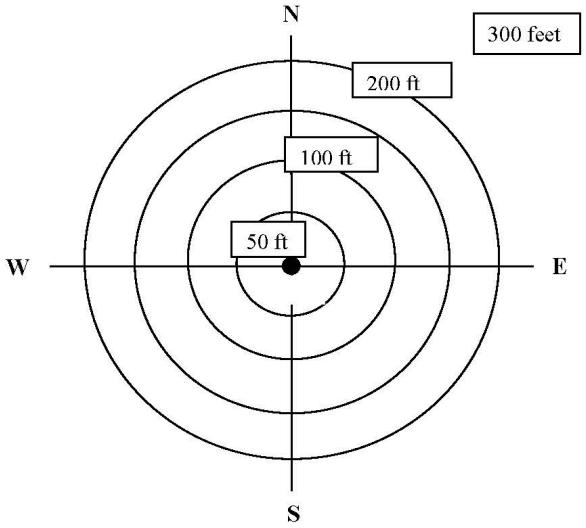
UNIQUE NUMBER:_____ or SITE ID:_____

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

CODES

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

17. Does water drain toward the well? a) YES or b) NO
18. Which direction does the landscape slope? (Draw arrow across bull's eye, through well, and label)
19. Is the slope: a) Steep or b) Shallow
20. Are there any *obvious* problems with the well? a) YES or b) NO
21. If yes, describe the problem:_____
20. Source Codes and Distances:_____



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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).

In Olmsted County septic system compliance administered by either Olmsted County Environmental Safety Division or the Township Cooperative Planning Association (TCPA). In 2014 Olmsted did not require compliance inspections at the point of sale. In 2014 Olmsted County and TCPA reported a total of 3,494 SSTS. Of these 51 (1.4%) were inspected for compliance (MPCA, 2015a).

FEEDLOT

The amount of nitrogen in manure depends on the species of animal. For example, there is approximately 31 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, 2014).

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, 2014).

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

Farmers must register their feedlot if it is in active status. Feedlots are considered active until no animals have been present on the feedlot for five years. To register, farmers fill out paperwork which includes a chart with the type and maximum number of animals on the feedlot (MPCA, 2015b). Registration is required to be completed at least once during a set four year period, the current period runs from January 2014 to December 2017. During the previous period, from 2010 to 2014, approximately 18,000 feedlots were registered in Minnesota (MPCA, 2014). A map and table of the feedlots located in the Olmsted County study area can be found below (Figure 7; Table 10).

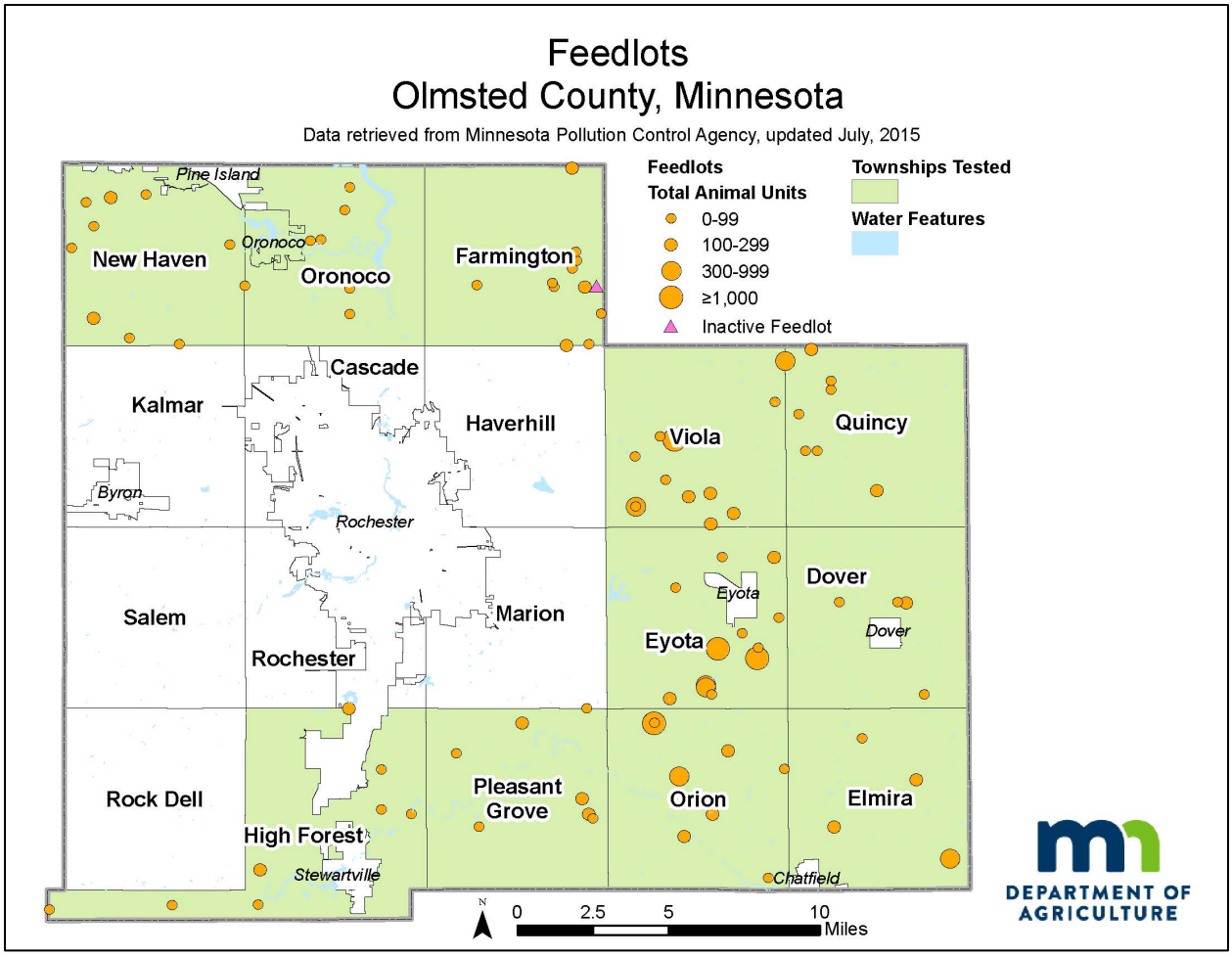

Figure 7. Feedlot Locations in Olmsted County (MPCA, 2015c)

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

Township	Total Feedlots	Active Feedlots	Inactive Feedlots	Average AU Permitted* Per Feedlot	Total Permitted* AU	Total Square Miles	Permitted* AU per Square Mile
Dover	4	0	0	97	292	35	8
Elmira	4	0	0	256	1,025	35	29
Eyota	12	0	0	613	6,133	34	180
Farmington	12	1	1	111	776	35	22
High Forest	8	0	0	69	556	40	14
New Haven	10	0	0	78	699	34	21
Orion	8	0	0	352	2,814	36	79
Oronoco* **	6	0	0	23	136	35	4
Pleasant Grove	7	0	0	97	581	36	16
Quincy	7	0	0	89	535	36	15
Viola	12	0	0	328	3,606	36	101
Total	89	1	1	1,559**	17,154	390	44**

* 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.

**Represents an average value

***Includes Oronoco City

On average there are 44 AU per square mile (0.069 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 Olmsted County study area livestock densities average 0.135 AU per acre of row crops (MPCA, 2017; 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, Olmsted County

Township	*Bulk Fertilizer	*Anhydrous Ammonia	*Chemigation Sites	*Abandoned Sites	Total
Dover	0	0	0	1	1
Elmira	0	0	0	0	0
Eyota	0	1	0	0	1
Farmington	2	1	0	0	3
High Forest	1	1	0	0	2
New Haven	0	0	0	0	0
Orion	0	0	0	0	0
Oronoco	0	0	0	0	0
Pleasant Grove	0	0	0	0	0
Quincy	0	0	0	0	0
Viola	0	0	0	0	0
Total	3	3	0	1	7

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

SPILLS AND INVESTIGATIONS

The MDA is responsible for investigating any fertilizer spills within Minnesota. Figure 8 shows the locations of mapped historic spills within the Olmsted 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, 2016).

The MDA tracks several types of spills and investigations. Incident investigations are typically for larger spills. There are none in the study area. Contingency areas are locations that have not been remediated because they were inaccessible or the contaminant could not be removed for some other reason. They are often a part of an incident investigation. There are no contingency areas in this study area. Old emergency incidents were closed prior to March 1st, 2004 (MDA, 2016), 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, 2016). 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.

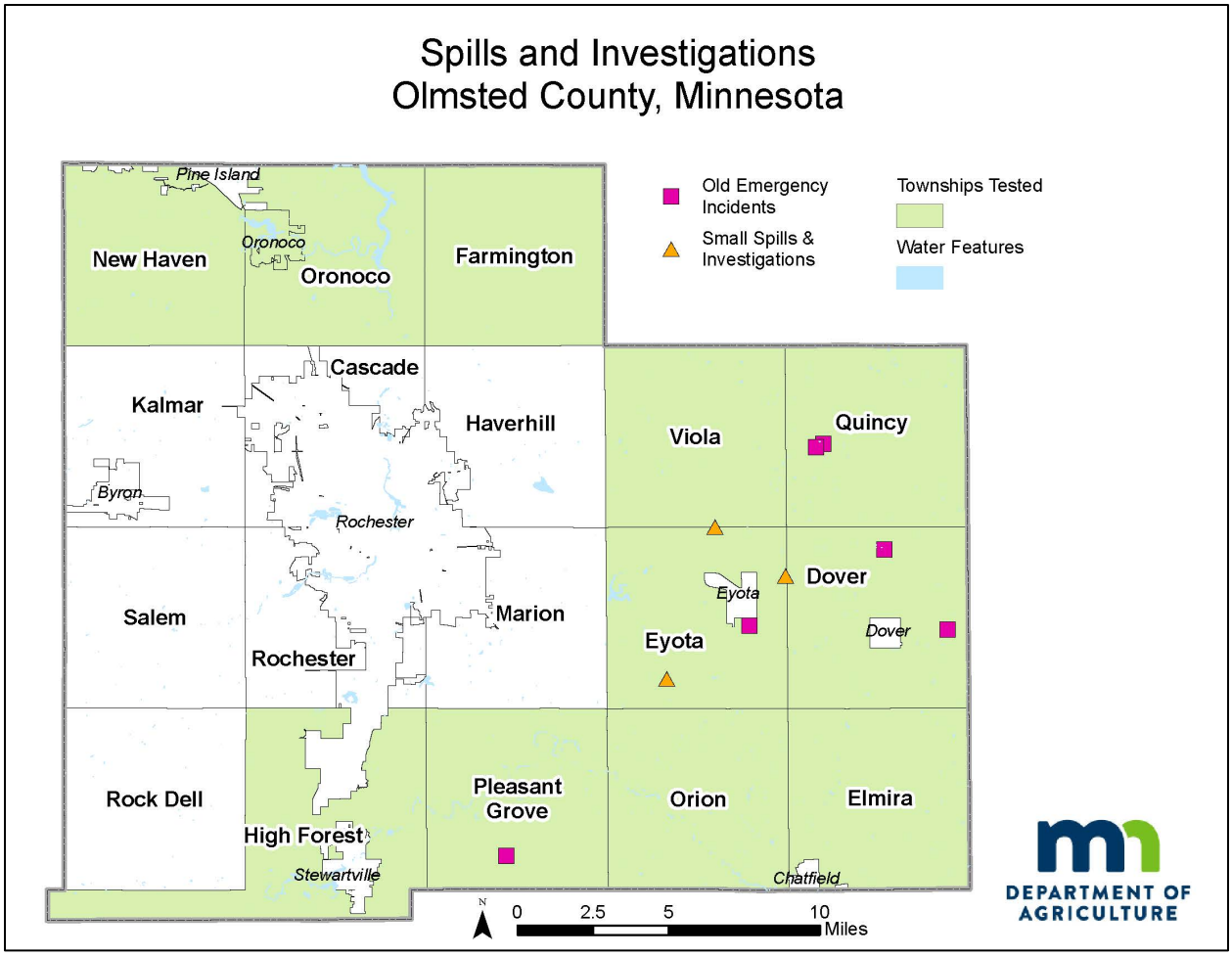

Figure 8. Fertilizer Spills and Investigations in Olmsted County (MDA, 2016)

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

Contaminant	Incident Investigations	Contingency Areas	Small Spills and Investigations	Old Emergency Incidents	Total
Fertilizer	0	0	2	4	6
Pesticides & Fertilizer	0	0	0	1	1
Anhydrous Ammonia	0	0	1	2	3
Total	0	0	3	7	10

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

Township	Investigations and Spills
Dover	2
Elmira	0
Eyota	4
Farmington	0
High Forest	0
New Haven	0
Orion	0
Oronoco	0
Pleasant Grove	2
Quincy	2
Viola	0
Total	10

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

Olmsted County is located in the southeast part of Minnesota, near the Wisconsin and Iowa boarders. Besides Rochester there are few developed areas in Olmsted County. Wetlands and open water are also sparse within the study area. The Olmsted study area is mainly dominated by agricultural activities. Approximately 50 percent of the land area in the study area is considered row crops and 19 percent is used for pasture or hay (Figure 9; Table 14).

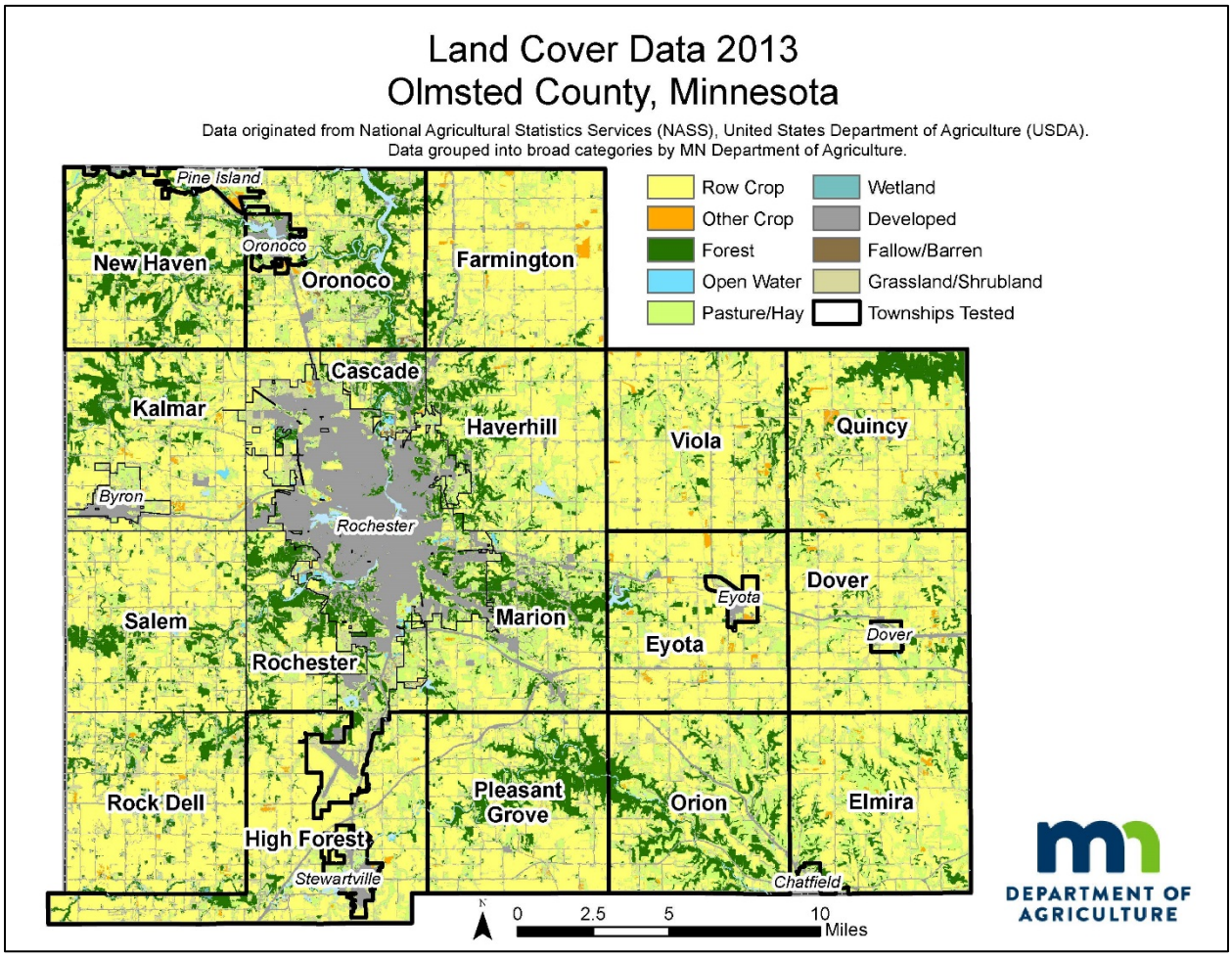

Figure 9. Land Cover in Olmsted County (USDA NASS Cropland Data Layer, 2013)

Table 14. Land Cover Data (2013) by Township, Olmsted County (USDA NASS Cropland Data Layer, 2013)

Township	Total Acres	Row Crop	Other Crops	Forest	Open Water	Pasture/ Hay	Wetland	Developed	Fallow/ Barren	Grassland/ Shrubland
Dover	22,284	60%	1%	5%	0%	18%	0%	7%	0%	10%
Elmira	22,281	48%	1%	9%	0%	28%	0%	3%	0%	10%
Eyota	21,783	62%	2%	4%	1%	14%	0%	7%	0%	11%
Farmington	22,689	70%	2%	3%	0%	10%	0%	4%	0%	10%
Haverhill	20,639	44%	0%	14%	1%	23%	0%	5%	0%	13%
High Forest	25,467	58%	1%	6%	0%	13%	0%	7%	0%	15%
New Haven	21,673	40%	0%	21%	0%	17%	1%	5%	0%	15%
Orion	22,807	33%	1%	21%	0%	28%	0%	4%	0%	13%
Oronoco**	22,231	29%	1%	21%	2%	19%	1%	9%	0%	18%
Pleasant Grove	22,878	48%	0%	20%	0%	16%	0%	5%	0%	11%
Quincy	22,870	47%	2%	17%	0%	20%	0%	3%	0%	11%
Viola	22,826	59%	1%	6%	0%	19%	0%	4%	0%	11%
Average	290,864*	50%	1%	12%	0%	19%	0%	5%	0%	12%

*Represents a total value

**Includes Oronoco City

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 15 active groundwater well permits in the study area and none are used for irrigating major crops (Table 15 and Figure 10). Most permitted wells are withdrawing water for non-crop irrigation (such as nurseries and golf courses) or public waterworks (MDNR, 2013).

Table 15. Active Groundwater Use Permits by Aquifer, Olmsted County

Water Use Well Permits	Total Wells	Average Depth (feet)	Aquifer System			
			Quaternary (Water Table)	Quaternary (Buried)	Paleozoic	Not Classified
Major Crop Irrigation	0	NA	NA	NA	NA	NA
Non-Crop Irrigation	6	355	0	0	6	0
Waterworks	4	421	0	0	4	0
Industrial Processing	1	300	0	0	0	1
Water Level Maintenance	1	NA**	0	0	0	1
Special Categories	3	435	0	0	3	0
Air Conditioning	0	NA	NA	NA	NA	NA
Power Generation	0	NA	NA	NA	NA	NA
Total	15	387*	0	0	13	2

* Represents an average value
** No depth recorded

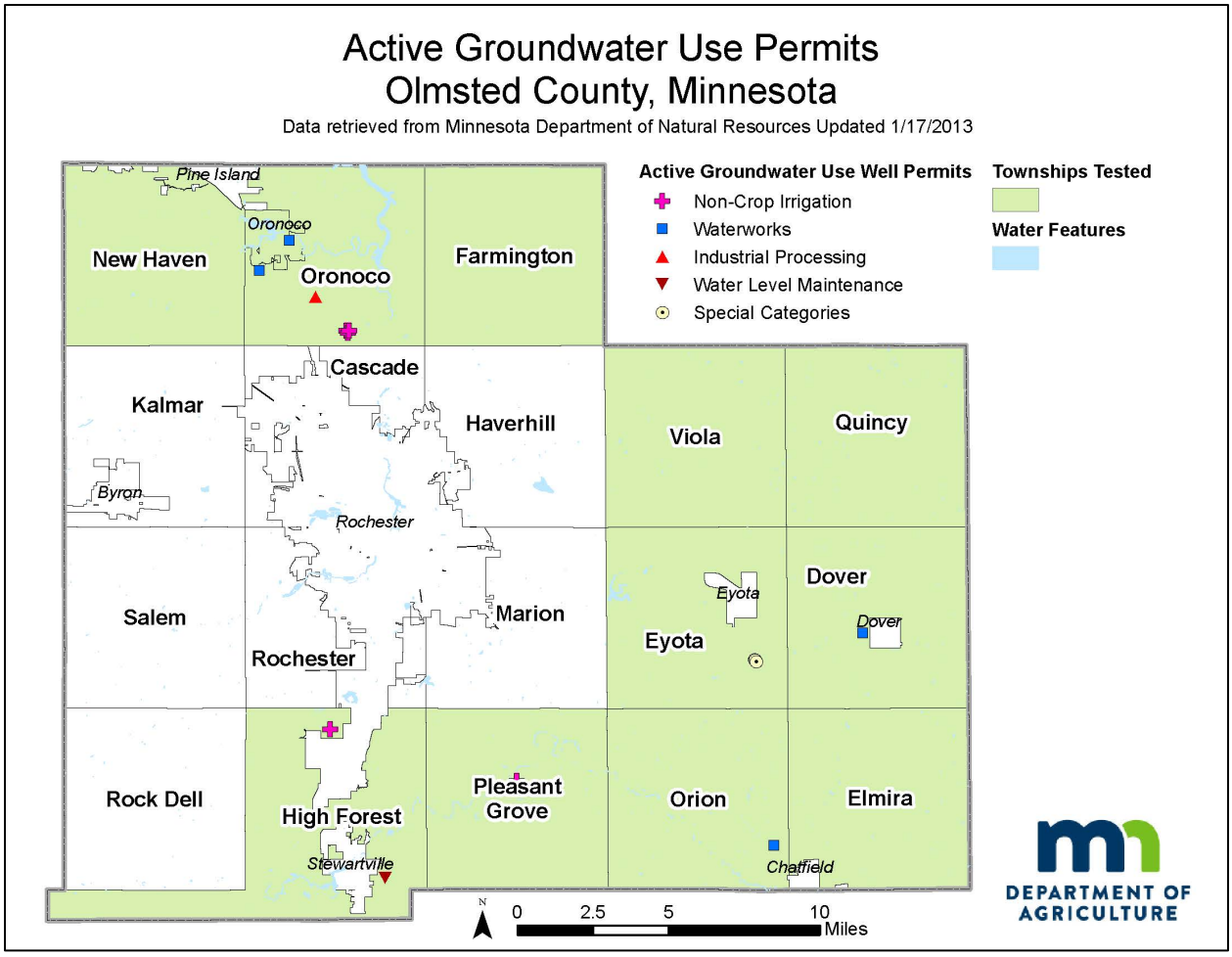

Figure 10. Active Groundwater Use Permits in Olmsted County (MDNR, 2013)

APPENDIX D

Nitrate Brochure

The Minnesota Department of Agriculture and the Olmsted County Environmental Services 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.

MINNESOTA DEPARTMENT OF AGRICULTURE

CLEAN WATER LAND & LEGACY AMENDMENT

APPENDIX E

Table 16. Reasons Wells Were Removed from the Final Well Dataset by Township, Olmsted County

Township	Point Source	Well Construction Problem	Hand Dug Wells	Shared Wells	Unsure of Water Source	No Unique ID & Well Not Seen & Constructed Before 1975	No Unique ID & No Site Visit & Insufficient Information	Total
Dover	1	0	0	0	0	6	1	8
Elmira	0	0	0	0	0	4	3	7
Eyota	0	0	0	0	0	5	1	6
Farmington	2	0	0	0	1	13	4	20
High Forest	1	0	1	1	1	7	1	12
New Haven	3	0	0	0	0	5	2	10
Orion	0	0	0	0	0	1	2	3
Oronoco	0	1	0	14	1	10	1	27
Pleasant Grove	3	0	1	0	0	7	1	12
Quincy	0	0	0	0	1	8	3	12
Viola	2	0	0	0	0	13	2	17
Total	12	1	2	15	4	79	21	134

APPENDIX F

MINNESOTA WELL INDEX

The MWI was used to gather information about the 11 townships in Olmsted County included in the study. This section includes all 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, 2015):

In these townships, there are 1,356 documented (have a verified location in the MWI) wells:

- Less than one percent are completed in the shallow Quaternary Water Table Aquifer (QWTA) and are 50 feet deep on average.
- At 87 percent, the vast majority of wells were completed in the Paleozoic Era aquifers and are 312 feet deep on average.
    - There are two relevant geologic time periods in the Paleozoic Era. The more recent period is known as the Ordovician and the older period is the Cambrian.
    - At 34 percent overall, the Prairie Du Chien Group was the most heavily utilized aquifer from the Ordovician period. The wells drilled in this aquifer were 280 feet deep on average.
    - The Jordon Sandston was utilized the most from the Cambrian period. This aquifer was drilled into 25 percent of the time. The wells drilled in this aquifer were 409 feet deep on average.

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

Aquifer (Era)	Aquifer (Period)	Aquifer (Group/Formation)**	Total Wells	Percentage Wells	Ave Depth (feet)
Undesignated			129	9.5%	137
Multiple			31	2.3%	355
Cenozoic	Quaternary	Quaternary Water Table	12	0.9%	50
Paleozoic	Ordovician	Stewartville-Cummingsville	110	8.1%	110
		Stewartville-Decorah	2	0.1%	155
		Gelena/Prosser Fm	1	0.1%	107
		Galena/Cummingsville Fm	1	0.1%	140
		Decorah Shale	4	0.3%	105
		Decorah-Plattville	1	0.1%	60
		Platteville Formation	3	0.2%	90
		Platteville-St. Peter	2	0.1%	289
		St. Peter Sandstone	178	13.1%	297
		St. Peter-Prairie Du Chien	16	1.2%	311
		Prairie Du Chien Group	466	34.4%	280
		Prairie Du Chien/Shakopee Fm	10	0.7%	402
		Shakopee/Willow River Mbr	3	0.2%	408
		Prairie Du Chien/Oneota Fm	11	0.8%	408
		Prairie Du Chien-Jordan	5	0.4%	418
	Ordovician (subtotal)		813	60.0%	263
	Cambrian	Jordan Sandstone	344	25.4%	409
		Jordan-St. Lawrence	10	0.7%	522
		St. Lawrence Formation	1	0.1%	520
		St. Lawrence-Tunnel City	2	0.1%	501
		Tunnel City/Lone Rock Fm	14	1.0%	549
	Cambrian (subtotal)		371	27.4%	418
	Paleozoic (subtotal)		1,184	87.3%	312
Total			1,356	100%	294

* Represents a weighted average value.

** Data obtained from Minnesota Well Index (http://www.health.state.mn.us/divs/eh/cwi/) in 2016

APPENDIX G

Private Well Survey Questions

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

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

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

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

Well Information Section

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

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

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

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

9. Approximate depth of your well
   Answer choices: 0-50 feet, 51-100 feet, 101-300 feet, and 300 or more feet.

10. Distance to an active or inactive feedlot
    Answer choices: 0-50 feet, 51-100 feet, 101-300 feet, and 300 or more feet.

11. Distance to a septic system
    Answer choices: 0-50 feet, 51-100 feet, 101-300 feet, and 300 or more feet.

12. Distance to an agricultural field
    Answer choices: 0-50 feet, 51-100 feet, 101-300 feet, and 300 or more feet.

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

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

15. When did you last have your well tested for nitrates?
    Answer choices: Never, with 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 18. Property Setting for Well Location

Township	Total	Property Setting						
		Rural	Lake	River Home	Sub-division	Municipal /City	Other	Not available
		Percent						
Dover	49	83.7%	0.0%	0.0%	0.0%	0.0%	0.0%	14.3%
Elmira	50	80.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%
Eyota	54	83.3%	0.0%	0.0%	0.0%	0.0%	0.0%	14.8%
Farmington	56	82.1%	0.0%	0.0%	0.0%	0.0%	0.0%	16.1%
High Forest	143	81.8%	0.0%	0.0%	7.0%	0.0%	0.0%	9.8%
New Haven	169	89.3%	0.0%	0.0%	0.0%	0.0%	0.0%	10.7%
Orion	73	83.6%	0.0%	0.0%	0.0%	0.0%	0.0%	16.4%
Oronoco	255	53.7%	7.5%	3.9%	21.2%	0.4%	0.0%	12.2%
Pleasant Grove	100	82.0%	0.0%	1.0%	0.0%	0.0%	1.0%	15.0%
Quincy	35	77.1%	0.0%	0.0%	0.0%	0.0%	0.0%	22.9%
Viola	73	79.5%	0.0%	0.0%	1.4%	0.0%	0.0%	16.4%
Average	1057*	76.2%	1.8%	1.0%	6.1%	0.1%	0.1%	13.6%

Table 19. Well Construction Type

Township	Total	Well Construction Type				
		Drilled	Sand point	Hand Dug	Other	Not available
		Percent				
Dover	49	75.5%	2.0%	0.0%	0.0%	22.4%
Elmira	50	76.0%	2.0%	0.0%	0.0%	22.0%
Eyota	54	72.2%	0.0%	0.0%	0.0%	27.8%
Farmington	56	83.9%	0.0%	0.0%	1.8%	14.3%
High Forest	143	79.0%	0.7%	0.7%	0.0%	19.6%
New Haven	169	78.1%	1.2%	0.0%	0.6%	20.1%
Orion	73	83.6%	0.0%	0.0%	0.0%	16.4%
Oronoco	255	72.5%	0.4%	0.0%	0.8%	26.3%
Pleasant Grove	100	74.0%	1.0%	1.0%	1.0%	23.0%
Quincy	35	77.1%	0.0%	0.0%	0.0%	22.9%
Viola	73	75.3%	0.0%	0.0%	0.0%	24.7%
Average	1057*	76.4%	0.7%	0.2%	0.5%	22.2%

Table 20. Age of Well

Well Age						
Township	Total	0-10 years	11-20 years	21-40 years	Over 40 years	Not available
		Percent				
Dover	49	4.1%	8.2%	26.5%	36.7%	24.5%
Elmira	50	12.0%	14.0%	22.0%	24.0%	28.0%
Eyota	54	14.8%	13.0%	22.2%	25.9%	24.1%
Farmington	56	10.7%	3.6%	19.6%	51.8%	14.3%
High Forest	143	7.7%	14.0%	30.8%	31.5%	16.1%
New Haven	169	7.1%	16.6%	38.5%	20.7%	17.2%
Orion	73	12.3%	19.2%	31.5%	23.3%	13.7%
Oronoco	255	7.8%	27.5%	35.3%	13.3%	16.1%
Pleasant Grove	100	9.0%	13.0%	34.0%	21.0%	23.0%
Quincy	35	8.6%	14.3%	25.7%	28.6%	22.9%
Viola	73	11.0%	11.0%	30.1%	21.9%	26.0%
Average	1057*	9%	17%	32%	24%	19%

Table 21. Depth of Well

Well Depth						
Township	Total	0-50 feet	51-100 feet	101-300 feet	Over 300 feet	Not available
		Percent				
Dover	49	4.1%	4.1%	42.9%	22.4%	26.5%
Elmira	50	2.0%	4.0%	14.0%	46.0%	34.0%
Eyota	54	1.9%	3.7%	29.6%	29.6%	35.2%
Farmington	56	1.8%	1.8%	46.4%	28.6%	21.4%
High Forest	143	2.8%	11.2%	19.6%	39.9%	26.6%
New Haven	169	3.0%	5.9%	27.2%	43.2%	20.7%
Orion	73	1.4%	4.1%	20.5%	52.1%	21.9%
Oronoco	255	0.4%	5.1%	20.8%	36.9%	36.9%
Pleasant Grove	100	1.0%	8.0%	20.0%	44.0%	27.0%
Quincy	35	0.0%	11.4%	25.7%	34.3%	28.6%
Viola	73	2.7%	8.2%	20.5%	32.9%	35.6%
Average	1057*	1.8%	6.3%	24.2%	38.6%	29.0%

Table 22. Livestock Located on Property

Livestock on Property			
Township	Total	No	Yes
		Percent	
Dover	49	79.6%	20.4%
Elmira	50	80.0%	20.0%
Eyota	54	88.9%	11.1%
Farmington	56	83.9%	16.1%
High Forest	143	89.5%	10.5%
New Haven	169	91.7%	8.3%
Orion	73	78.1%	21.9%
Oronoco	255	98.4%	1.6%
Pleasant Grove	100	86.0%	14.0%
Quincy	35	74.3%	25.7%
Viola	73	93.2%	6.8%
Average	1057*	89.4%	10.6%

Table 23. Fertilizer Stored on Property

Fertilizer Stored on Property			
Township	Total	No	Yes
		Percent	
Dover	49	98.0%	2.0%
Elmira	50	98.0%	2.0%
Eyota	54	96.3%	3.7%
Farmington	56	96.4%	3.6%
High Forest	143	98.6%	1.4%
New Haven	169	99.4%	0.6%
Orion	73	100.0%	0.0%
Oronoco	255	98.8%	1.2%
Pleasant Grove	100	99.0%	1.0%
Quincy	35	97.1%	2.9%
Viola	73	98.6%	1.4%
Average	1057*	98.6%	1.4%

Table 24. Farming on Property

Does Farming Take Place on Property			
Township	Total	No	Yes
		Percent	
Dover	49	44.9%	55.1%
Elmira	50	50.0%	50.0%
Eyota	54	68.5%	31.5%
Farmington	56	33.9%	66.1%
High Forest	143	67.1%	32.9%
New Haven	169	72.2%	27.8%
Orion	73	54.8%	45.2%
Oronoco	255	84.3%	15.7%
Pleasant Grove	100	62.0%	38.0%
Quincy	35	51.4%	48.6%
Viola	73	67.1%	32.9%
Average	1057*	66.7%	33.3%

Table 25. Distance to an Active or Inactive Feedlot

Distance to a Feedlot						
Township	Total	0-50 feet	51-100 feet	101-300 feet	Over 300 feet	Not available
		Percent				
Dover	49	4.1%	4.1%	16.3%	55.1%	20.4%
Elmira	50	4.0%	4.0%	12.0%	54.0%	26.0%
Eyota	54	0.0%	0.0%	11.1%	61.1%	27.8%
Farmington	56	7.1%	10.7%	10.7%	55.4%	16.1%
High Forest	143	2.1%	2.1%	8.4%	70.6%	16.8%
New Haven	169	4.7%	1.2%	8.9%	69.8%	15.4%
Orion	73	2.7%	5.5%	11.0%	63.0%	17.8%
Oronoco	255	3.5%	0.0%	2.7%	72.2%	21.6%
Pleasant Grove	100	2.0%	2.0%	12.0%	64.0%	20.0%
Quincy	35	0.0%	8.6%	28.6%	42.9%	20.0%
Viola	73	5.5%	2.7%	4.1%	65.8%	21.9%
Average	1057*	3.4%	2.5%	8.8%	65.7%	19.7%

Table 26. Distance to Septic System

Distance to Septic System						
Township	Total	0-50 feet	51-100 feet	101-300 feet	Over 300 feet	Not available
		Percent				
Dover	49	2.0%	18.4%	42.9%	16.3%	20.4%
Elmira	50	0.0%	8.0%	50.0%	20.0%	22.0%
Eyota	54	7.4%	18.5%	44.4%	13.0%	16.7%
Farmington	56	1.8%	16.1%	41.1%	25.0%	16.1%
High Forest	143	2.8%	21.0%	44.8%	16.1%	15.4%
New Haven	169	1.8%	22.5%	47.3%	14.2%	14.2%
Orion	73	1.4%	28.8%	38.4%	16.4%	15.1%
Oronoco	255	2.7%	18.0%	37.3%	20.8%	21.2%
Pleasant Grove	100	8.0%	14.0%	44.0%	15.0%	19.0%
Quincy	35	11.4%	5.7%	45.7%	14.3%	22.9%
Viola	73	1.4%	15.1%	39.7%	26.0%	17.8%
Average	1057*	3.2%	18.4%	42.5%	18.0%	18.0%

Table 27. Distance to an Agricultural Field

Distance to an Agricultural Field						
Township	Total	0-50 feet	51-100 feet	101-300 feet	Over 300 feet	Not available
		Percent				
Dover	49	8.2%	20.4%	30.6%	24.5%	16.3%
Elmira	50	6.0%	14.0%	28.0%	28.0%	24.0%
Eyota	54	13.0%	9.3%	27.8%	31.5%	18.5%
Farmington	56	12.5%	14.3%	30.4%	28.6%	14.3%
High Forest	143	2.8%	9.8%	28.0%	46.9%	12.6%
New Haven	169	7.7%	10.7%	28.4%	40.8%	12.4%
Orion	73	4.1%	9.6%	24.7%	47.9%	13.7%
Oronoco	255	2.4%	7.1%	16.9%	56.5%	17.3%
Pleasant Grove	100	1.0%	10.0%	26.0%	45.0%	18.0%
Quincy	35	17.1%	14.3%	34.3%	14.3%	20.0%
Viola	73	13.7%	8.2%	30.1%	30.1%	17.8%
Average	1057*	6.1%	10.2%	25.5%	42.2%	16.0%

Table 28. Drinking Water Well

Is the Well Used for Drinking Water			
Township	Total	No	Yes
		Percent	
Dover	49	14.3%	85.7%
Elmira	50	24.0%	76.0%
Eyota	54	14.8%	85.2%
Farmington	56	16.1%	83.9%
High Forest	143	10.5%	89.5%
New Haven	169	10.7%	89.3%
Orion	73	15.1%	84.9%
Oronoco	255	11.4%	88.6%
Pleasant Grove	100	15.0%	85.0%
Quincy	35	20.0%	80.0%
Viola	73	13.7%	86.3%
Average	1057*	13.3%	86.7%

Table 29. Treatment System for Drinking Water

Treatment System Used for Drinking Water							
Township	Total	None	Filtering system	Reverse osmosis	Distillation	Other	Not available
		Percent					
Dover	49	55.1%	16.3%	6.1%	0.0%	0.0%	22.4%
Elmira	50	34.0%	22.0%	12.0%	0.0%	4.0%	28.0%
Eyota	54	38.9%	37.0%	3.7%	0.0%	0.0%	20.4%
Farmington	56	60.7%	14.3%	7.1%	0.0%	0.0%	17.9%
High Forest	143	43.4%	37.1%	4.9%	0.0%	1.4%	13.3%
New Haven	169	45.0%	32.5%	6.5%	0.0%	0.6%	15.4%
Orion	73	34.2%	35.6%	4.1%	1.4%	0.0%	24.7%
Oronoco	255	34.5%	38.8%	10.6%	0.0%	0.8%	15.3%
Pleasant Grove	100	44.0%	27.0%	4.0%	0.0%	4.0%	21.0%
Quincy	35	45.7%	31.4%	2.9%	0.0%	0.0%	20.0%
Viola	73	42.5%	27.4%	12.3%	0.0%	0.0%	17.8%
Average	1057*	41.7%	32.0%	7.3%	0.1%	1.0%	17.9%

Table 30. Last Tested for Nitrate

When was the Well Last Tested for Nitrate								
Township	Total	<1 year	<3 years	<10 years	>10 years	Never tested	Not sure	Not available
		Percent						
Dover	49	8.2%	4.1%	16.3%	26.5%	4.1%	26.5%	14.3%
Elmira	50	8.0%	10.0%	20.0%	26.0%	8.0%	6.0%	22.0%
Eyota	54	3.7%	9.3%	20.4%	9.3%	18.5%	24.1%	14.8%
Farmington	56	7.1%	8.9%	10.7%	33.9%	5.4%	21.4%	12.5%
High Forest	143	3.5%	4.2%	18.2%	25.9%	10.5%	27.3%	10.5%
New Haven	169	2.4%	7.7%	18.9%	25.4%	16.0%	19.5%	10.1%
Orion	73	6.8%	5.5%	15.1%	28.8%	11.0%	19.2%	13.7%
Oronoco	255	3.1%	5.5%	19.2%	21.2%	12.5%	27.8%	10.6%
Pleasant Grove	100	5.0%	4.0%	24.0%	21.0%	8.0%	22.0%	16.0%
Quincy	35	5.7%	8.6%	8.6%	20.0%	14.3%	22.9%	20.0%
Viola	73	5.5%	13.7%	16.4%	17.8%	12.3%	23.3%	11.0%
Average	1057*	4.4%	6.7%	18.2%	23.3%	11.6%	23.2%	12.6%

Table 31. Last Nitrate Test Result

What was the Last Nitrate Result					
Township	Total	<3 mg/L	3<10 mg/L	≥ 10 mg/L	Not available
		Percent			
Dover	49	18.4%	10.2%	2.0%	69.4%
Elmira	50	20.0%	4.0%	2.0%	74.0%
Eyota	54	13.0%	1.9%	1.9%	83.3%
Farmington	56	5.4%	14.3%	8.9%	71.4%
High Forest	143	7.7%	2.1%	1.4%	88.8%
New Haven	169	10.1%	1.8%	1.8%	86.4%
Orion	73	19.2%	0.0%	2.7%	78.1%
Oronoco	255	11.0%	3.9%	2.7%	82.4%
Pleasant Grove	100	11.0%	3.0%	6.0%	80.0%
Quincy	35	14.3%	2.9%	5.7%	77.1%
Viola	73	9.6%	4.1%	5.5%	80.8%
Average	1057*	11.5%	3.7%	3.2%	81.6%

* Represents a total

APPENDIX I

Table 32. Well Construction Type for Final Well Dataset

Township	Samples	Drilled	Sand Point	Not Available
Dover	41	32	1	8
Elmira	43	35	1	7
Eyota	48	36	0	12
Farmington	36	33	0	3
High Forest	131	108	0	23
New Haven	159	127	1	31
Orion	70	61	0	9
Oronoco	228	169	1	58
Pleasant Grove	88	66	1	21
Quincy	23	21	0	2
Viola	56	44	0	12
Total	923	732	5	186

Data compiled from well logs and homeowner responses.

Table 33. Well Depth for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Dover	13	295	635	420	438
Elmira	14	285	616	549	509
Eyota	14	225	460	376	368
Farmington	9	180	640	398	389
High Forest	24	300	665	384	397
New Haven	39	160	545	387	392
Orion	27	140	665	440	436
Oronoco	50	172	592	380	370
Pleasant Grove	22	208	480	378	381
Quincy	9	342	580	375	393
Viola	15	295	694	480	479
Total	236	140	694	396	405

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

Table 34. Year of Well Construction for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Dover	13	1969	2005	1989	1986
Elmira	14	1972	2011	1999	1995
Eyota	14	1976	2011	2002	1998
Farmington	10	1914	2013	1988	1981
High Forest	24	1973	2011	1998	1997
New Haven	39	1976	2013	1997	1996
Orion	27	1968	2013	1997	1997
Oronoco	50	1963	2014	1999	1995
Pleasant Grove	22	1968	2013	1995	1995
Quincy	9	1966	2015	1998	1996
Viola	16	1920	2013	1995	1991
Total	238	1914	2015	1997	1994

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

Minnesota Department of Agriculture -Private Well Field Log

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

Duplicates collected? Yes or No

Duplicate #'s: nitrate: _____ pesticide:_____

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

Pump start time: _____ Discharge rate: _____ Time sample collected:_____

Stabilization Measurements

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

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

COMMENTS/Notes:

Updated 5/18/2015

APPENDIX K

Table 35. Temperature (°C) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Dover	14	9.55	13.42	10.64	10.79
Elmira	11	9.68	11.07	10.67	10.52
Eyota	3	9.32	11.52	11.16	10.67
Farmington	13	9.68	11.46	10.55	10.55
High Forest	15	10.47	16.07	11.66	11.86
New Haven	23	9.57	15.84	10.78	11.03
Orion	9	9.99	12.37	11.30	11.30
Oronoco	37	9.83	13.48	10.88	10.97
Pleasant Grove	4	9.45	11.19	9.99	10.15
Quincy	9	9.89	11.25	10.48	10.63
Viola	10	9.89	11.83	10.39	10.69
Total	148	9.32	16.07	10.75	10.93

Table 36. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Dover	14	7.28	8.57	8.14	8.09
Elmira	11	7.52	8.44	8.19	8.11
Eyota	3	7.26	7.55	7.41	7.41
Farmington	13	8.17	8.48	8.36	8.34
High Forest	15	7.35	7.9	7.72	7.71
New Haven	23	7.44	8.38	7.70	7.74
Orion	9	7.17	7.92	7.62	7.63
Oronoco	37	7.31	8.39	7.93	7.93
Pleasant Grove	4	7.35	7.7	7.40	7.46
Quincy	9	7.29	8.49	8.28	8.14
Viola	10	7.35	8.49	8.19	8.01
Total	148	7.17	8.57	7.89	7.92

Table 37. Specific Conductivity (µS/cm) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Dover	14	448	849	563	567
Elmira	11	478	688	523	554
Eyota	3	454	731	652	612
Farmington	13	514	839	628	652
High Forest	15	468	1422	619	695
New Haven	23	422	823	628	616
Orion	9	439	1001	540	580
Oronoco	37	439	825	509	547
Pleasant Grove	4	667	1016	716	779
Quincy	9	419	788	610	596
Viola	10	523	1170	647	734
Total	148	419	1422	590	610

Table 38. Dissolved Oxygen (mg/L) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Dover	14	1.65	10.43	6.51	6.02
Elmira	11	1.09	10.89	6.11	6.12
Eyota	3	4.91	6.71	6.48	6.03
Farmington	13	3.74	10.14	8.23	7.70
High Forest	15	0.39	8.11	4.02	3.88
New Haven	23	0.68	10.75	4.49	5.24
Orion	9	0.17	8.07	3.99	4.27
Oronoco	37	0.12	10.24	4.43	5.22
Pleasant Grove	4	4.3	8.46	5.40	5.89
Quincy	9	3.56	12.66	5.79	6.88
Viola	10	3.81	10.37	6.83	6.82
Total	148	0.12	12.66	5.52	5.64