



Central Sands Private Well Network 2011 Current Nitrate Conditions Summary

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1.0 Introduction

1.1. Executive Summary

In the spring of 2011, the Minnesota Department of Agriculture (MDA) began the Central Sands Private Well Monitoring Network. During the first year, MDA coordinated the random sampling of 1,555 private drinking water wells throughout Central Minnesota and samples were analyzed for nitrate nitrogen. Home owners from 14 counties participated in this project which was supported by the Clean Water Fund. Over 88.6 percent of the wells sampled had nitrate concentrations less than 3 mg/L, 6.8 percent of the wells ranged from 3 < 10 mg/L of nitrate and 4.6 percent were greater than 10 mg/L of nitrate as nitrogen. Older, shallower wells tended to have a higher percentage of nitrate results at or above 10 mg/L. The data collected in 2011 was used to determine current nitrate concentrations that were at or above 10 mg/L, prioritize areas of concern, and to develop a long-term trend network.

1.2. Background

The MDA has been monitoring nitrate concentrations in observation wells since 1986 through the pesticide groundwater monitoring program. Sixty-two percent of the MDA observation well data shows that nitrate levels in the most vulnerable portion of the aquifer, near the edge of fields, exceeds the drinking water standards in the Central Sands counties. The Central Sands counties include: Becker, Benton, Cass, Crow Wing, Douglas, Hubbard, Kandiyohi, Morrison, Otter Tail, Pope, Sherburne, Stearns, Todd, and Wadena (Figure 1). Wadena County Soil and Water Conservation District (SWCD) is the lead local project coordinator.

The Central Sands counties make up the MDA's Pesticide Management Region (PMR) 4. PMRs are based on areas of similar agricultural practices and hydrologic characteristics. PMR 4 is characterized by glacial outwash sand plains that are highly sensitive to surface activities. The observation/monitoring wells in the MDA PMR network are designed to monitor pesticides at the edge of fields in the most vulnerable portion of the aquifers. MDA includes nitrate sampling in its pesticide sampling program.

The MDA has determined that high levels of nitrate have been measured in PMR 4 observation wells, it was important to expand nitrate monitoring to private drinking water wells in order to determine if the concentrations in such wells are similar. Using Clean Water Funds, MDA developed the Central Sands Private Well Network (CSPWN) project, which is comprised of two phases and includes all 14 counties Central Sands region. Phase 1 of the project determined current nitrate concentrations in private wells throughout the Central Sands region of Minnesota. The data collected in Phase 1 will be used to determine areas of concern, and to develop a long-term trend monitoring network as part of Phase 2. Long-term trend monitoring will answer the question: "Are nitrate concentrations in private drinking water wells increasing, decreasing or remaining the same?"

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 man-made sources such as fertilizer,

animal manure and human waste. Because nitrate can have a negative effect on human health at elevated levels, the U.S. Environmental Protection Agency (USEPA) has established a drinking water Maximum Contaminant Level (MCL) of 10 mg/L for nitrate as nitrogen (U.S. EPA, 2009). Depending on location, nitrates are among the most common contaminants in Minnesota's groundwater, and in some areas of the state (e.g., the Central Sands), a significant number of wells have high nitrate levels that have exceeded the MCL standards.

Nitrogen present in groundwater is in the forms of nitrite and nitrate. Nitrite concentration is commonly less than the reporting level of 0.01 mg/L as nitrogen in groundwater, resulting in negligible contribution to the nitrate plus nitrite concentration (Nolan and Stoner, 2000). In the environment, nitrite generally converts to nitrate, which means nitrite occurs very rarely in groundwater. Measurements of nitrate plus nitrite as nitrogen will hereafter be referred to as "nitrate." Nitrate in groundwater may be converted to nitrogen gas in the absence of oxygen and the presence of organic carbon, during denitrification. Denitrification occurs when oxygen levels are depleted and nitrate becomes the primary oxygen source for microorganisms. Shallow groundwater in coarse textured soils has low concentrations of organic carbon and contains oxygen, so denitrification is limited in these conditions. These conditions are highly variable over time and space (MPCA, 1998).

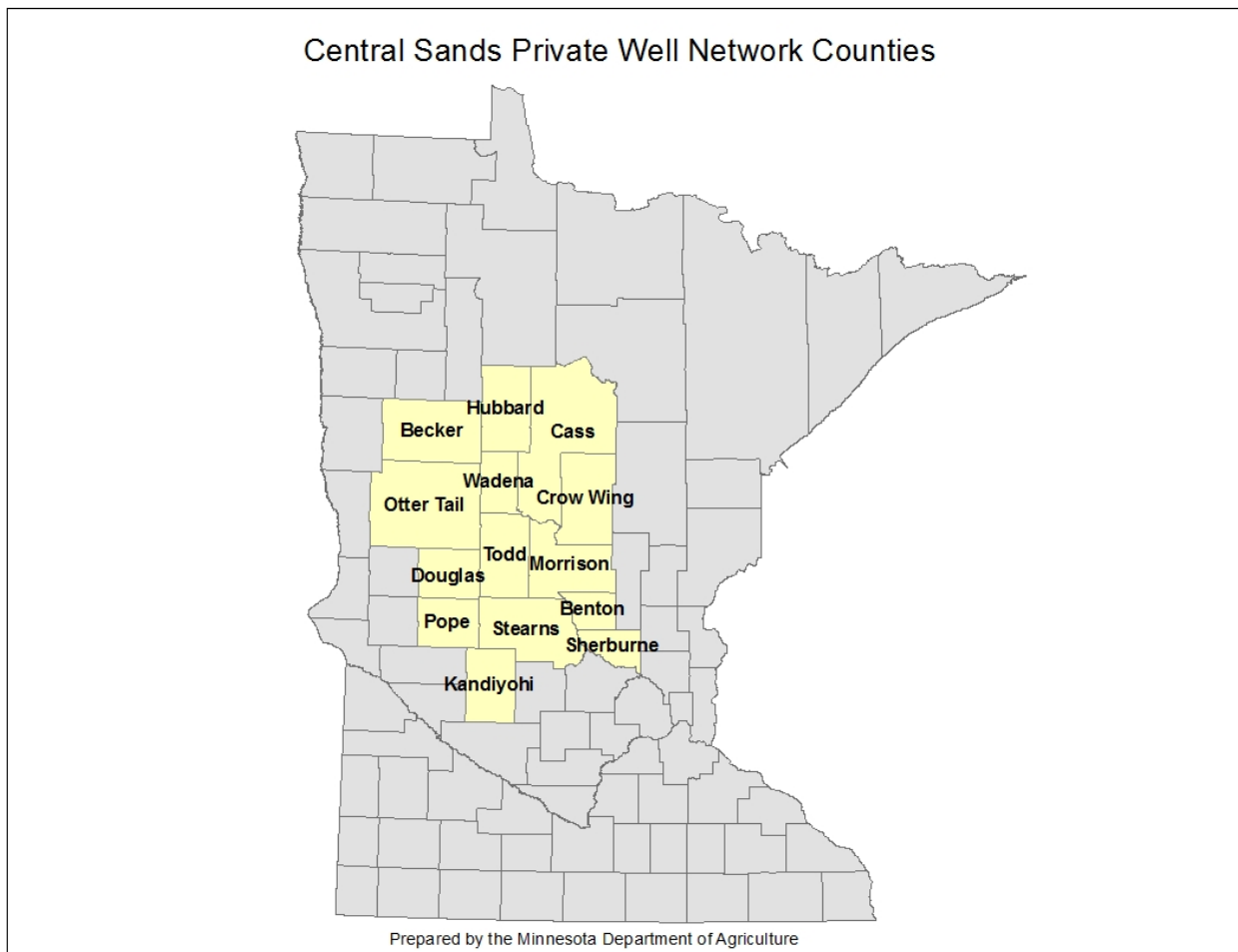


Figure 1. Counties participating in the Central Sands Private Well Network.

2.0 Methods

Phase 1: Current Nitrate Concentrations

All counties in the Central Sands region were invited to participate in the CSPWN. The MDA developed a Joint Powers Agreement with the Wadena County SWCD to accomplish the goals of the first phase of the CSPWN project. The MDA based the sampling on a systematic, multi-stage approach. To ensure unbiased sampling and to obtain a uniform spatial distribution, a randomly-started grid was superimposed over the Central Sands region. A 1.5 mile circular buffer was created around each point (node) in the grid, and the distance between grid nodes was 2.15 miles. Within each 1.5 mile circular buffer three land parcel owners were randomly selected (Figure 2). The University of Minnesota's Minnesota Center for Survey Research (MCSR) was given a list of the randomly chosen parcel owners. The MCSR sent each of the three parcel owners within each buffer a letter and survey about their well. The letter explained the nature of the project and invited the parcel owner to participate. The first parcel owner from each buffer to reply was chosen as the participant. If no parcel owners replied the buffer was left empty.

Once a well owner agreed to participate, they filled out a survey about their well and returned it to MCSR. The survey answers were compiled into a database with well owner information. In March 2011, the final list of participants was sent to the RMB Environmental Laboratories (RMB Lab). Each participant received a sample kit from RMB Lab with instructions on how to take the sample and where to send it for analysis. The lab analyzed the samples and compiled all results in a spreadsheet. Sample results were sent to the well owner and to the MDA.

Phase 2: Long-term Trend Network Planning

Phase 2 of the CSPWN study is to develop a long-term trend monitoring network. The MDA has developed another Joint Powers Agreement with the Wadena County SWCD to accomplish the goals of the second phase of the CSPWN project. Approximately 600-800 wells will be included in the long-term network. Enrollment in the long-term network is based on volunteer willingness to participate. All of the volunteers from the first round of sampling have been given the chance to participate in the long-term network, and as many as 800 wells may be enrolled.

Each well enrolled in the long-term network will be evaluated during a site visit. During the visit, information will be collected about the well by a well network coordinator. The well network coordinators will be trained to perform the visits and will record the information on three forms (GPS Waypoint Log, Well Information Form, and Potential Nitrate Source Inventory Form) provided by MDA.

Each participant will then receive a sample kit from Wadena SWCD with instructions on how to take the sample and where to send it for analysis. Wadena SWCD will analyze the samples using a spectrophotometer (provided by MDA) and enter results into a database. Individual results will be sent by letter to the well owners. The MDA will receive a copy of the database annually. Sample results will be summarized and reported by the MDA to all participating counties.

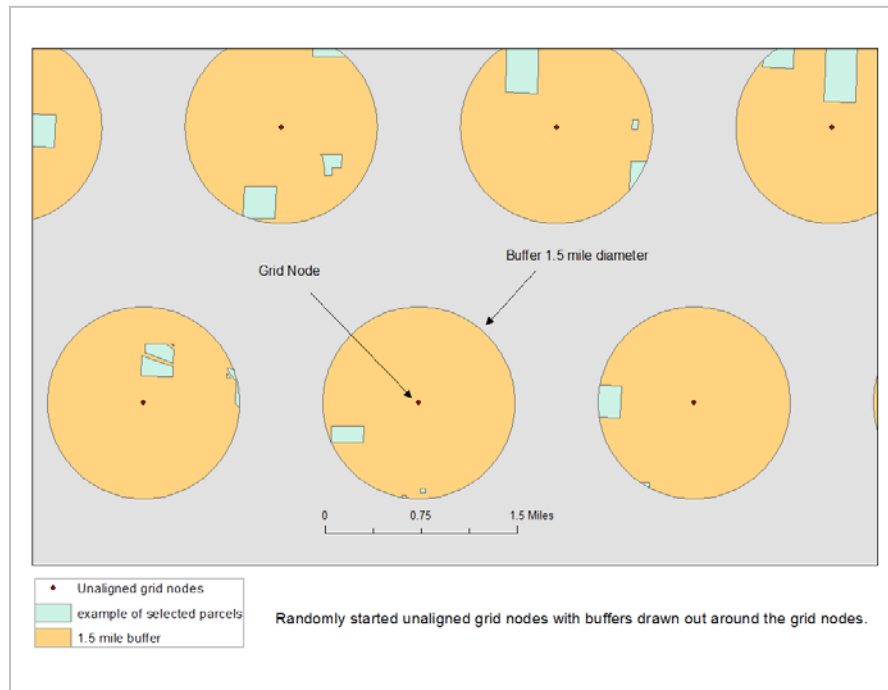


Figure 2. Unaligned grid nodes and buffer example.

3.0 Results

A total of 1,555 well owners returned their well survey and water sample for analysis. Over 88.6 percent of the wells sampled had nitrate concentrations less than 3 mg/L, 6.8 percent of the wells ranged from 3 < 10 mg/L of nitrate and 4.6 percent were greater than the nitrate MCL of 10 mg/L (Figure 3). These results are similar to findings from a 2010 USGS report on nitrate concentrations in private wells in the glacial aquifer systems across the upper US (Warner and Arnold, 2010). The USGS report found that less than 5 percent of sampled private wells had nitrate concentrations equal to or greater than 10 mg/L. Nitrate concentrations from the CSPWN 2011 results varied widely over short distances (Figure 4.). This was also the case in the USGS report on glacial aquifer systems (Warner and Arnold, 2010). In contrast, nitrate concentrations from MDA PMR 4 observation wells had only 14 percent of samples below 3 mg/L and 62 percent of samples above 10 mg/L (Table 2). The median concentration for the MDA observation wells is 14.4 mg/L while the CSPWN median concentration is 0 mg/L. The high nitrate concentrations seen in the MDA PMR 4 observation wells are not being seen in the private drinking water wells.

Nitrate concentrations varied between counties. Morrison County had the highest percentage of wells (10.5 percent) with nitrate concentrations over 10 mg/L (Table 1, Figure 3). Benton and Wadena County both had approximately 8 percent of wells over 10mg/L. Cass, Crow Wing, and Douglas counties did not have any results above 10 mg/L. Although Stearns County only had 4.2 percent of wells with concentrations over 10 mg/L, it had 13.2 percent of the wells with concentrations in the 3-10 mg/L range. The 3 to 10 mg/L range is important because although

there is not an immediate health risk, nitrate is above background levels and therefore the groundwater is being impacted by external sources.

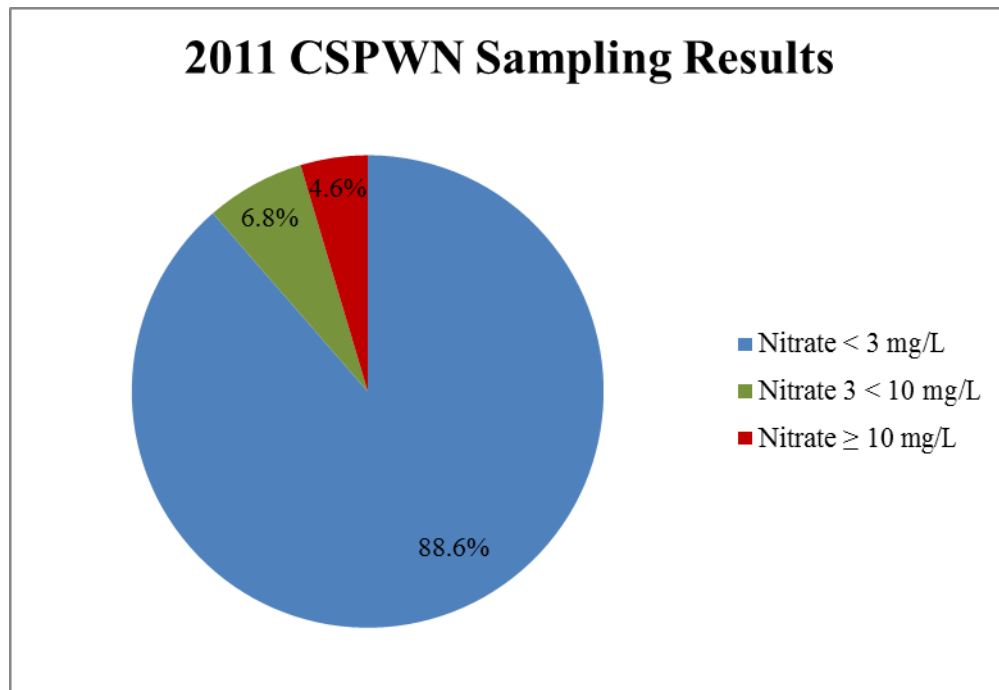


Figure 3. 2011 CSPWN sampling results

Central Sands Private Well Network Distribution of 2011 Nitrate(mg/L) Results

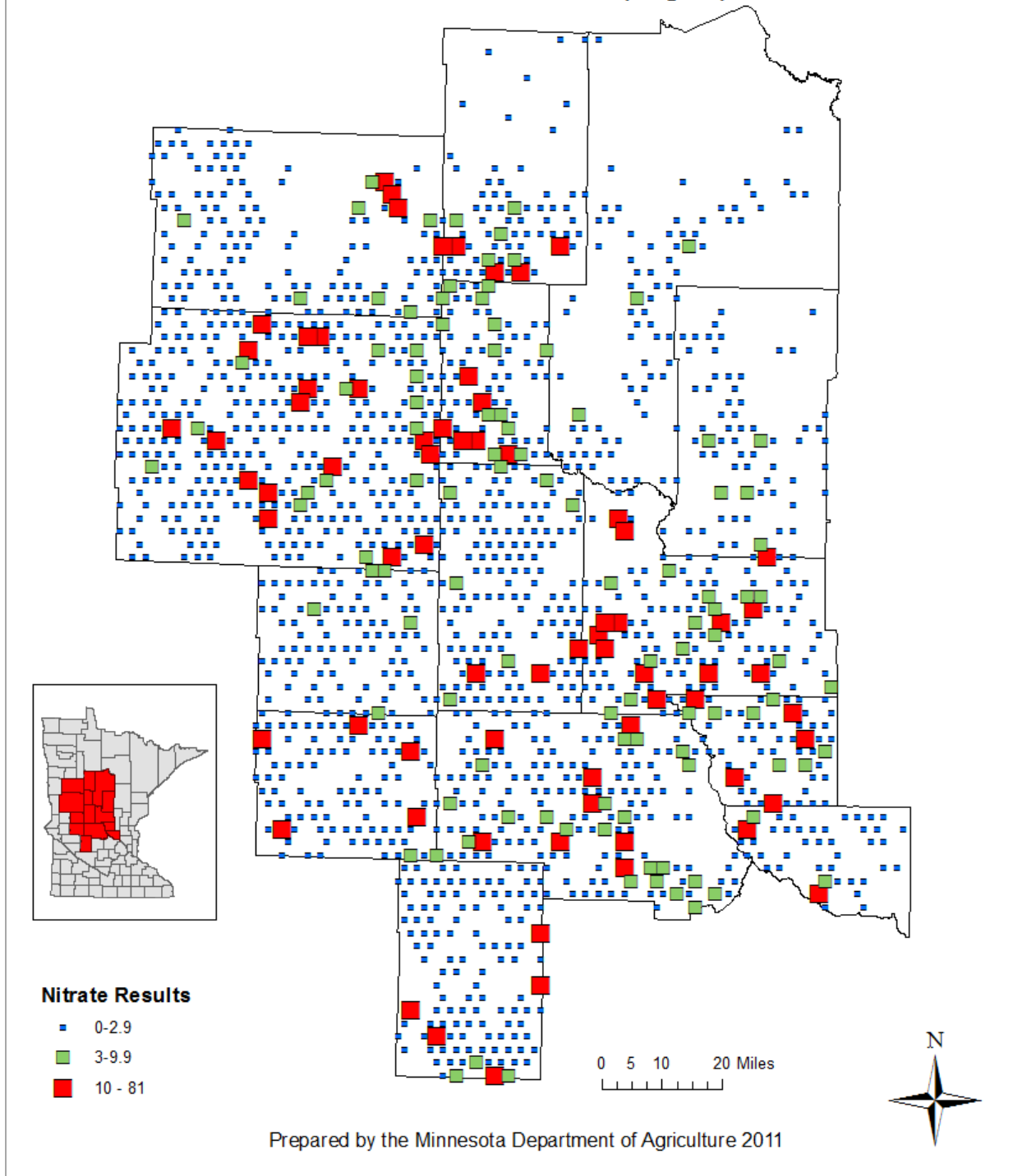


Figure 4. Nitrate concentration distribution.

Table 1. 2011 Summary of Nitrate Concentrations for the Central Sands Private Well Network.

County	Number of Samples	Min	Median	75th Percentile	90th Percentile	Max	% at or Below 3 (mg/L)	% Between 3 < 10 (mg/L)	% at or Above 10 (mg/L)
Becker	123	0.0	0.00	0.00	1.96	15.4	92.7%	4.9%	2.4%
Benton	57	0.0	0.00	0.77	8.98	15.6	78.9%	12.3%	8.8%
Cass	82	0.0	0.00	0.03	1.37	9.46	96.3%	3.7%	0.0%
Crow Wing	66	0.0	0.00	0.27	2.14	8.31	92.4%	7.6%	0.0%
Douglas	90	0.0	0.00	0.00	0.69	8.78	94.4%	5.6%	0.0%
Hubbard	65	0.0	0.00	1.67	6.87	29.3	84.6%	7.7%	7.7%
Kandiyohi	117	0.0	0.00	0.00	0.35	38.7	93.2%	2.6%	4.3%
Morrison	124	0.0	0.00	2.53	10.34	33.9	78.2%	11.3%	10.5%
Ottertail	320	0.0	0.00	0.03	2.47	32.7	90.3%	4.4%	5.3%
Pope	93	0.0	0.00	0.00	1.02	35	93.5%	1.1%	5.4%
Sherburne	42	0.0	0.00	0.06	3.16	40	90.5%	4.8%	4.8%
Stearns	167	0.0	0.00	0.75	7.57	49.8	82.0%	13.2%	4.2%
Todd	137	0.0	0.00	0.04	2.24	81	92.7%	5.1%	2.2%
Wadena	72	0.0	0.09	3.07	8.93	49.2	75.0%	16.7%	8.3%
Average	1,555 total samples	0.0	0.01	0.66	4.15	31.9	88.6%	6.8%	4.6%

Table 2. 2000-2010 Nitrate Concentrations summary table for the MDA PMR 4 observation wells.

MDA PMR 4 Observation Wells	Number of Samples	Average						
		Min	Median	75th Percentile	90th Percentile	Max	% at or below 3 (mg/L)	% at or above 10 (mg/L)
Years 2000-2010	1,378	0	14.4	23.1	33.1	77.5	14%	62%

The well owner survey provided additional information about sampled wells. The survey included questions about the well construction, depth and age, as well as questions about nearby land use. Well information was provided by the well owners and may be approximate or erroneous. Following is a brief summary of well information gathered from the survey (complete well survey results are located in Appendix 1):

- The majority of well owners reported the wells to be of drilled construction, the well age ranges from 21-50 years old, and the wells are over 100 feet deep.
- Most wells are on rural property with no livestock or farming.
- Few well owners store more than 500 pounds of fertilizer on their property.
- Most wells are greater than 300 feet from an active or inactive feedlot or an agricultural field.
- Septic systems are greater than 50 feet away from wells in 96 percent of cases.
- Water treatment is used by 30 percent of the well owners.

In the following discussion wells are grouped by nitrate concentrations into one of three categories: less than 3mg/L, 3-10mg/L, and greater than 10mg/L. The nitrate categories are then compared by well construction, well depth and well age.

In the less than 3 mg/L category, 87 percent of the wells are of drilled construction, while only 8 percent are of sand point and hand dug construction (Figure 5 and Table 3). In the greater than 10 mg/L category the percentage of drilled wells drops to 57 percent, while the sand point and hand dug wells increase to 37 percent. Wells with sand point and hand dug construction generally intersect the aquifer at shallow depths and, as such, may tend to have higher nitrate concentrations than deeper wells. Shallow wells (0-50ft) comprise 46 percent of the results over 10 mg/L, while wells that are deeper (101-300ft) only make up 7 percent (Figure 6 and Table 4). As nitrate concentrations increase the proportion of wells that are greater than 50 years old also increases from 7 percent to 26 percent (Figure 7 and Table 5). Wells that are greater than 50 years old were installed before the Minnesota Well Code in 1974.

Well construction, age and depth seem to be important factors affecting the quality of water in private drinking water wells. However, because well information was provided by the well owners, it may be approximate or erroneous. In Phase 2 of the CSPWN project, well information will be verified in the field on a smaller set of wells for the long-term network.

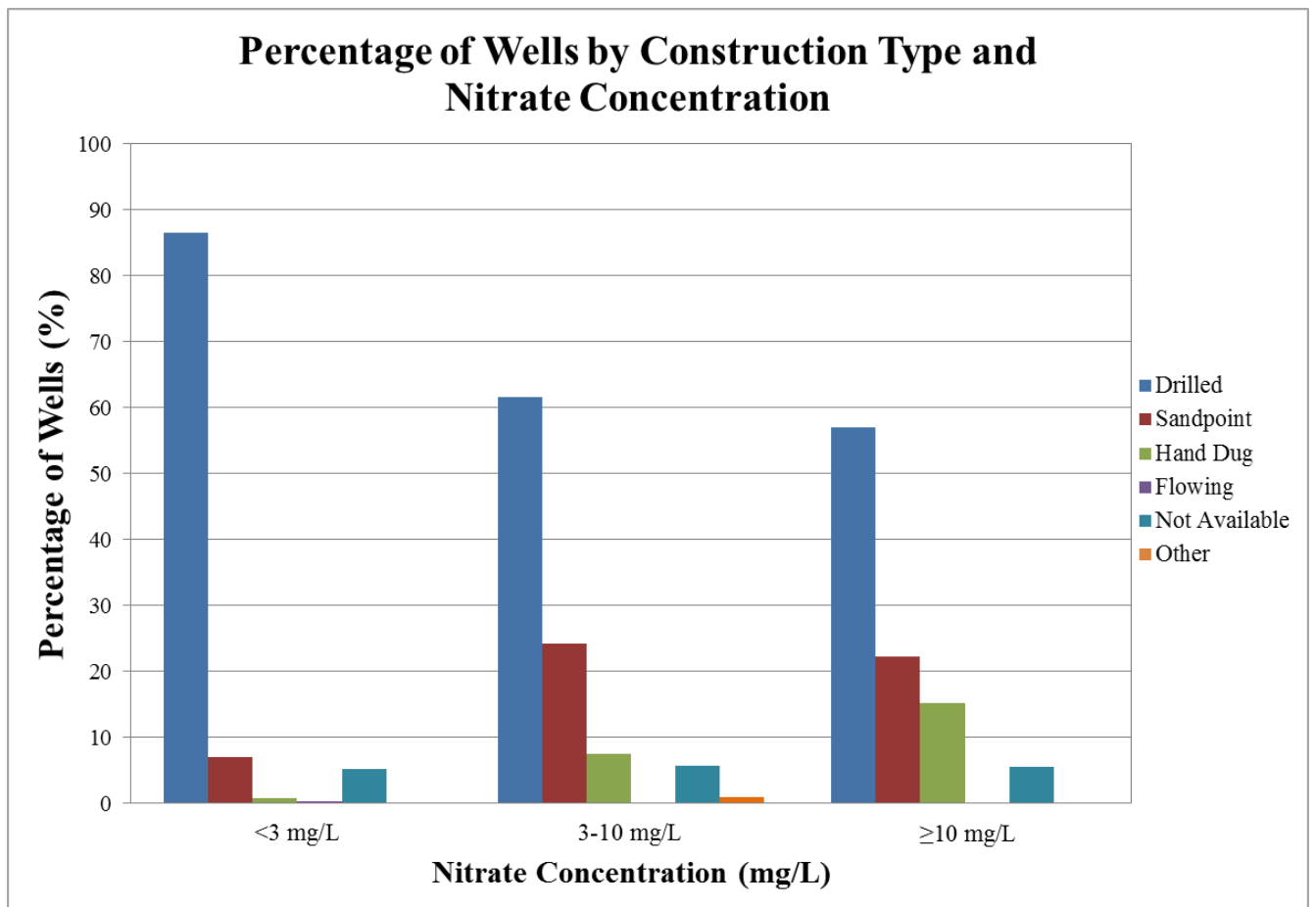


Figure 5. Percentage of wells by construction type and nitrate concentration.

Table 3. Well construction type and nitrate concentration.

Well Construction Type	Nitrate < 3mg/L		Nitrate 3 < 10mg/L		Nitrate ≥ 10mg/L	
	Number	Percent	Number	Percent	Number	Percent
Drilled	1,191	87	66	62	41	57
Sandpoint	97	7	26	24	16	22
Hand Dug	11	1	8	7	11	15
Flowing	4	0	0	0	0	0
Not Available	72	5	6	6	4	6
Other	1	0	1	1	0	0
Totals	1,376	100	107	100	72	100

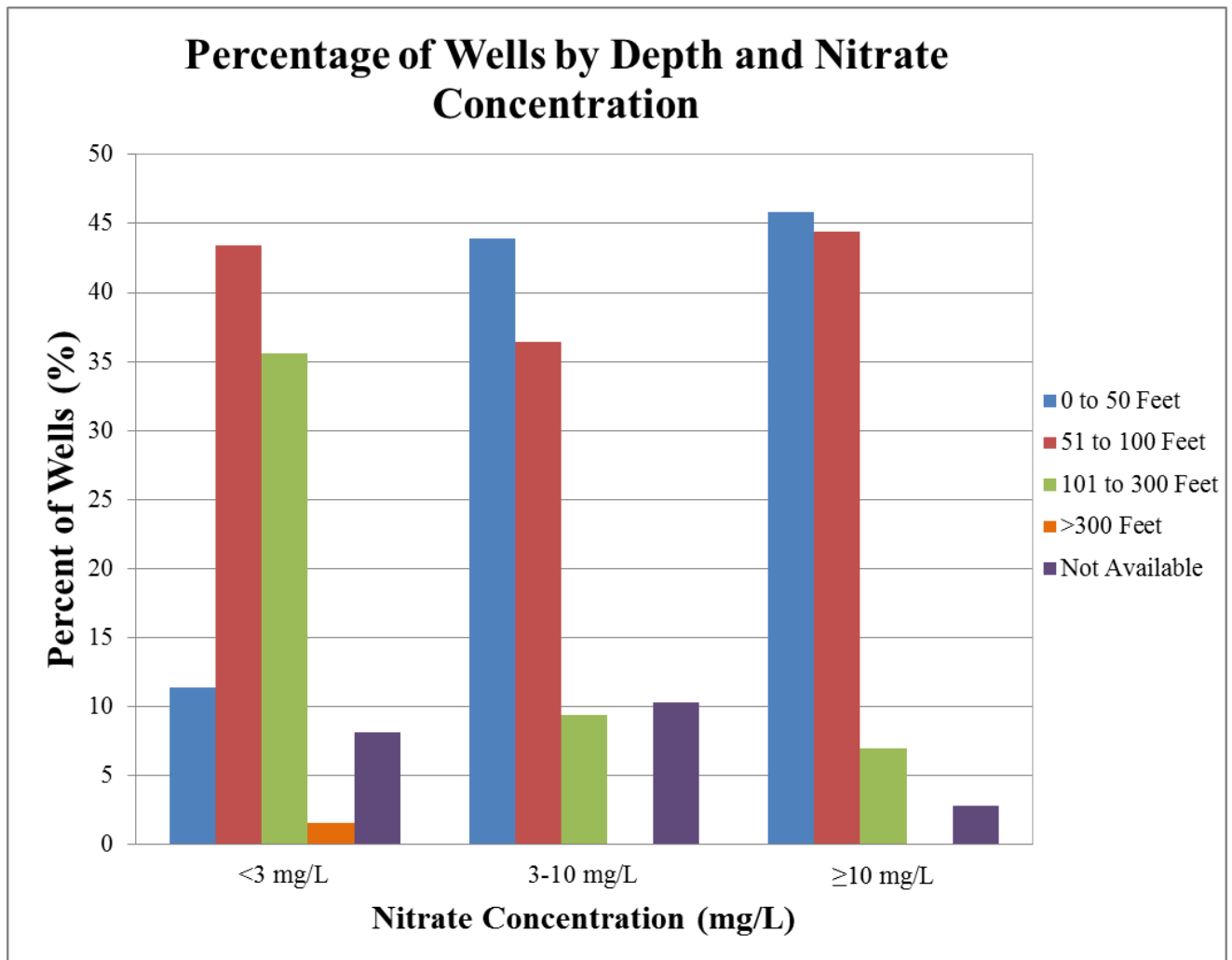


Figure 6. Percentage of wells by depth and nitrate concentration.

Table 4. Well depth and nitrate concentration

Well Depth (feet)	Nitrate < 3 mg/L		Nitrate 3 < 10 mg/L		Nitrate ≥ 10 mg/L	
	Number	Percent	Number	Percent	Number	Percent
0 to 50 ft	156	11	47	44	33	46
51 to 100 ft	597	43	39	36	32	44
101 to 300 ft	490	36	10	9	5	7
>300 ft	21	2	0	0	0	0
Not Available	112	8	11	10	2	3
Totals	1,376	100	107	100	72	100

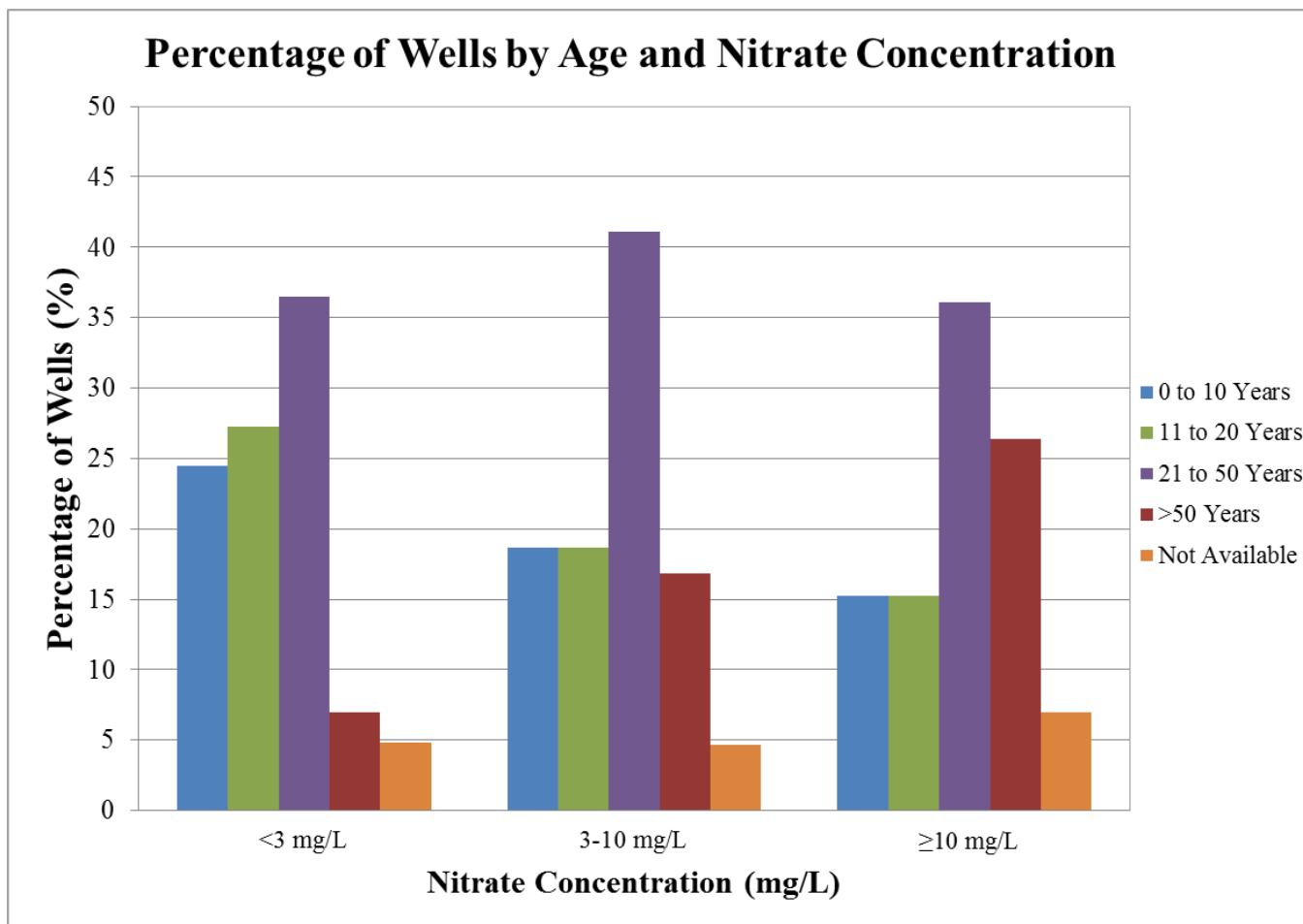


Figure 7. Percentage of wells by age and nitrate concentration.

Table 5. Well age and nitrate concentration.

Well Age (Years)	Nitrate < 3mg/L		Nitrate 3 < 10mg/L		Nitrate ≥ 10mg/L	
	Number	Percent	Number	Percent	Number	Percent
0 to 10 years	337	24	20	19	11	15
11 to 20 years	375	27	20	19	11	15
21 to 50 years	502	36	44	41	26	36
>50 years	96	7	18	17	19	26
Not Available	66	5	5	5	5	7
Totals	1,376	100	107	100	72	100

4.0 Conclusions

The CSPWN has very good well owner participation. Volunteers were the backbone of this project collecting samples from their own wells which saved time and money. Each county has a sufficient sample size of wells and spatial coverage, which allows for detecting areas of concern.

Overall nitrate concentrations are lower in the CSPWN than in MDA PMR 4 observation wells. Analysis of the well owner surveys demonstrate that well construction, age and depth may be important factors affecting the quality of water in private wells. Finally, the development of the long-term private well network will establish long-term nitrate concentration trends.

5.0 References

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