

Source Investigations of Nitrate Contamination for Private Wells in Eau Claire County

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Principal investigator:

Dr. Laura Suppes, PhD, MPH, REHS, Associate Professor, University of Wisconsin - Eau Claire

Co-investigators:

Audrey Boerner, MS, Environmental Specialist/Groundwater Geologist, Eau Claire City-County Health Department,

Shane Sanderson, MS, JD, REHS, Former Director of Environmental Health at the Eau Claire City-County Health Department,

Ted Johnson, Environmental Chemist, Eau Claire City-County Health Department

Student lead:

Dexter Zebro, Bachelor of Science in Environmental Public Health, University of Wisconsin - Eau Claire

Abstract:

This research explores sources and risk factors of nitrate contamination in private wells in Eau Claire County, Wisconsin. Nitrate is a naturally occurring compound found in groundwater, but also has anthropogenic sources. It can be harmful to human health if ingested above 10 mg/L. Nitrogen-containing fertilizers, manure, and septic tank effluent are potential sources of nitrate contamination in groundwater. For this project, 110 private wells in Eau Claire County were tested for seven indicators of agricultural contamination and three indicators of septic contamination. Data on nitrate contamination risk factors (well depth, water level, distance from agricultural fields, etc.) were also collected. Project aims were: 1) To gather and analyze data to determine trends and risk factors associated with nitrate contamination in Eau Claire County, WI; 2) Evaluate the relationship between nitrate and indicators of ag or wastewater impact on groundwater; 3) Create methods to make this study reproducible by other health departments to continue research on high nitrate in private wells in Wisconsin, and 4) Gather and analyze data to provide meaningful information for decision makers. A significantly higher average nitrate concentration in wells with agricultural indicators was found, suggesting agriculture is a source of nitrate contamination in private wells in Eau Claire County. Septic systems were not found to be a significant source of nitrate in Eau Claire County. Using this analysis method, the results suggest atrazine is the most appropriate agricultural indicator of nitrate contamination in corn-dense regions where atrazine use is not prohibited. None of the risk factors hypothesized to have associations with nitrate contamination in private wells did except casing depth. Eau Claire County has 12% more private wells above the USEPA nitrate drinking water MCL than the state of Wisconsin, suggesting there is a nitrate contamination problem in Eau Claire County private wells. Direct action is needed to protect homeowners from the adverse health effects associated with consuming water with nitrate ≥ 10 mg/L.

University of Wisconsin-Eau Claire



Executive Summary

In 2016 the Eau Claire City County Health Department (ECCCHD), in partnership with University of Wisconsin—Eau Claire Environmental Public Health faculty, initiated a two-year study on emerging contaminants in Eau Claire County private wells. Approximately 1 in 4 (25,000) county residents are served by 9,000 private wells. Well water quality records for approximately 4,500 wells are available at ECCCHD. Over 50% of sampled wells contain nitrate above the preventative action limit of 2 mg/L, and 1 in 20 sampled wells exceed the 10 mg/L MCL.

The burden and associated health risks of nitrate contamination in Wisconsin has been widely studied, and nitrate contamination is not unique to Eau Claire County. Wells in which the level of nitrate contamination exceeds 2 mg/L are believed to be influenced by an anthropogenic source of nitrate, rather than purely naturally occurring. The Wisconsin Department of Natural Resources has estimated that 90% of nitrate in groundwater is from agricultural activities, while 9% is from septic systems, and 1% attributable to lawn fertilizer or other sources. These sources may also contribute other contaminants to groundwater, such as agrichemicals, pathogens, and pharmaceuticals. Many of these contaminants were only more recently able to be identified and the health effects of prolonged exposure may be unknown.

The goals of this study were: 1) To gather and analyze data to determine trends and risk factors associated with nitrate contamination in Eau Claire County, WI; 2) Evaluate the relationship between nitrate and indicators of ag or wastewater impact on groundwater; 3) Create methods to make this study reproducible by other health departments to continue research on high nitrate in private wells in Wisconsin, and 4) Gather and analyze data to provide meaningful information for policy makers.

This study was the first of its type in Eau Claire County to better understand the potential sources of nitrate in private wells in the county. The study was designed to identify private wells with a historical high nitrate (≥ 5 mg/L) result in a water test in the ECCCHD database. Participants would then be able to opt in to the study to have their water tested for the target parameters at no cost. UWEC Environmental Public Health students working closely with ECCCHD contacted eligible and interested study participants to schedule a sampling time, collect water samples, and deliver the samples to the certified public health lab at ECCCHD. There was an overall 33% response rate to the initial outreach welcoming up to 399 study participants. Of the respondents, 110 samples were collected and analyzed. All households had a septic system on-site.

Nitrate water samples were collected in clear, sterilized plastic sample bottles. Agricultural and wastewater indicators were collected in 1 L amber glass bottles. During sample collection, property owners were also asked to complete a survey about risk factors of nitrate contamination, like well construction, site history, and proximity to potential nitrate sources such as septic systems, agricultural fields, and fertilizer storage. Nitrate samples were analyzed with a calibrated ion sensitive electrode. Seven agricultural indicators (atrazine, desethyl atrazine,

desisopropyl atrazine, acetochlor, alachlor, metolachlor, cyanazine) and three human waste water indicators (caffeine, carbamazepine, carisoprodol) were analyzed using a gas chromatograph with a nitrogen-phosphorus detector (modified EPA method 507).

Statistical analysis was conducted on 108 samples that contained nitrate or a targeted co-contaminant above the limit of detection. Of these 108 samples with detectable levels, agriculture and human wastewater indicators were identified in samples from three of the ten townships with sample participants. These townships are adjacent to the population center of the city of Eau Claire and have a relatively higher residential density than townships farther from the city limits.

Overall, 15% of sites tested positive for agricultural indicators and 5% of sites tested positive for human waste indicators. Four of seven agricultural indicators and two of three human waste indicators were present at least once. The agricultural indicators detected were desethyl atrazine, desisopropyl atrazine, atrazine, and alachlor. Caffeine and carbamazepine were the human waste indicators detected. Sixteen of the 108 samples (15%) were positive for atrazine and/or an atrazine metabolite. Caffeine was the most frequent human waste indicator (3.7%). The average nitrate concentration in wells with agricultural indicators present was 10.7 mg/L, which is significantly higher at the 95% confidence level than the average nitrate concentration in wells without agricultural indicators present (6.8 mg/L). No statistically significant relationship was found between wells with high nitrate concentrations and presence of the human waste indicators analyzed.

Well construction information was available for 39% of sampled sites and contrary to our hypothesis, there was no correlation between well age or well borehole depth and nitrate concentration. Among these sites, wells with a casing depth <40 ft had significantly more nitrate at the 95% confidence level ($P = 0.032$).

Though the results of this project suggest a significant influence on groundwater from agricultural contamination, it also highlights the potential for contamination of private wells because of private onsite wastewater treatment systems. In the upcoming decade, the expansion of the agricultural industry (primarily through large animal feeding operations) and unsewered subdivisions are anticipated as the county population grows. The results of this study will be used by county planners, land conservation and public health practitioners, and academics to inform decisions regarding land use, zoning, permitting, and regulation of point-source and non-point source pollution to groundwater. We feel that while these actions are an important part of the solution, direct action is needed to protect homeowners from the adverse health effects associated with consuming water with nitrate ≥ 10 mg/L. Since many Wisconsin homeowners do not act on their own to reduce nitrate exposures from drinking contaminated well water, local public health may be able to intervene through promoting and subsidizing point-of-use drinking water treatment systems in homes with nitrate ≥ 10 mg/L. The efficacy of this approach could be studied as a pilot for other counties in Wisconsin experiencing a similar rate of unsafe nitrate contamination in private well water.

Introduction

The burden of nitrate contamination in the upper Midwest has been widely studied (Bundy et al. 1994; Chern, Kraft and Postel, 1999; LeMasters and Baldock, 1997; Shaw, 1994), partly because of nitrate contamination of groundwater and the effects it has on human health. Though nitrate is a naturally-occurring compound, it is often found in groundwater at levels that greatly exceed the United States Environmental Protection Agency's (USEPA) preventive action limit (2 mg/L) or maximum contaminant level (MCL) (10 mg/L) in agricultural and dense unsewered residential areas. The health-based standards for nitrate were established from the risk of methemoglobinemia, a condition in which the blood's ability to transport oxygen is compromised. Pregnant women and infants are at the greatest risk. Some studies also suggest livestock that drink water with elevated nitrate have poorer pregnancy outcomes (Al-Qudah et al., 2009).

Nitrate is a widespread, highly mobile contaminant of groundwater, especially common in dense agricultural areas (Spalding and Exner, 1993). Potential sources of nitrate contamination include agricultural or lawn fertilizer application, onsite wastewater systems, animal feedlots and barnyards, and septage or sludge disposal. The Wisconsin Department of Natural Resources has estimated that 90% of nitrate in groundwater is from agricultural activities, while 9% is from septic systems, and 1% attributable to lawn fertilizer or other sources (Wisconsin Groundwater Coordinating Council Report to the Legislature, 2018).

In Eau Claire County, Wisconsin, over 25,000 people (approximately 1 in 4) rely on private wells as their primary source of drinking water. The quality of private well water is of public health concern because private water supplies are not regularly tested or regulated. Over 4,500 nitrate tests have been analyzed at the Eau Claire City-County Health Department (ECCCHD) since 2005. Though the average concentration of all tests is below the USEPA nitrate MCL of 10 mg/L, it is above the statewide average of 1.5 mg/L. Approximately 4,500 wells remain untested in Eau Claire County. Figure 1 shows the general results of nitrate tests conducted by the ECCCHD since 2010. The majority of nitrate data available is from the western half of the county. The watersheds with the highest nitrate averages are Muddy and Elk Creek and Lower Eau Claire River. The eastern side of the county has only a few nitrate samples, as much of this area is forested and the population is lower density. Approximately 1 in 2 wells sampled have nitrate that exceeds naturally occurring concentrations (generally presumed to be 2 mg/L or less). Nearly 1 in 20 wells that have been sampled exceed the health-based standard for nitrate.

In addition to the health risks from nitrate, there may be additional risks to private well owners in contaminated areas (where nitrate levels exceed the preventative action level) from co-contaminants associated with agriculture and human wastewater. Elevated nitrate is often correlated with pesticides, herbicides, viruses, pharmaceuticals, or other constituents of agrichemicals or human wastewater (Wisconsin Department of Agriculture, Trade and Consumer Protection). A 2002 study estimated that 52% of private drinking water wells in the region of Wisconsin that includes Eau Claire County contained a detectable level of an herbicide or herbicide metabolite (Protecting Wisconsin's Groundwater Through Comprehensive Planning).

The goal of the drinking water protection program of ECCCHD is to assure the public is provided a safe water supply that is protected from organic and inorganic chemical contamination and pathogens. ECCCHD began this project in partnership with University of Wisconsin - Eau Claire (UWEC) Environmental Public Health faculty to better understand

sources of nitrate contamination and better tailor public health interventions in Eau Claire County. Aims of this study were: 1) To gather and analyze data to determine trends and risk factors associated with nitrate contamination in Eau Claire County, WI; 2) Evaluate the practicality of using nitrate indicators as a tool for preventing contamination; 3) Create methods to make this study reproducible by other health departments to continue research on high nitrate in private wells in Wisconsin, and 4) Gather and analyze data to provide meaningful information for policy makers.

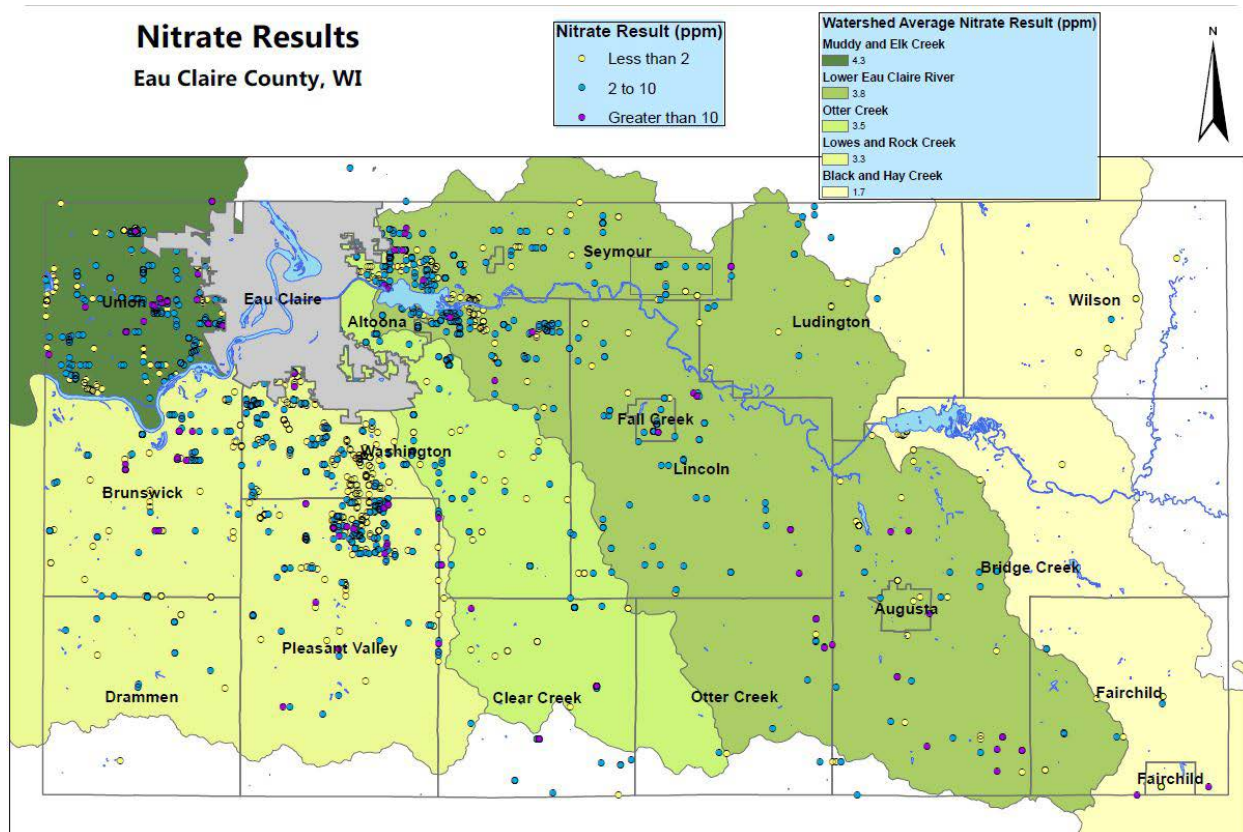


Figure 1. Eau Claire County private well nitrate test results from the Eau Claire City-County Health Department from 2010 to 2017.

Methods

This study took place from July 2016 through June 2018 and was the first of its type in Eau Claire County to better understand the potential sources of nitrate in private wells. The study was reviewed and approved by the UWEC Internal Review Board in September 2016 (Federal Wide Assurance Number FWA00001217). Participants for the study were identified through the water quality database at the ECCHD. All previous nitrate sample locations were filtered for only those with past nitrate tests ≥ 5 mg/L. This level was used because it provided a robust number of sample participants. In addition, at ≥ 5 mg/L, it is likely the nitrate is from an anthropogenic source. This resulted in 399 potential locations to sample. Property owners at each of these locations were mailed a letter describing the study and with information to opt in.

UWEC Environmental Public Health students working closely with ECCCHD contacted study participants to schedule a sampling time, collect water samples, and deliver the samples to the certified public health lab at ECCCHD on ice for analysis within 24 hours of sampling. Samples were collected for nitrate as well as seven agricultural indicators (atrazine, desethyl atrazine, desisopropyl atrazine, acetochlor, alachlor, metolachlor, cyanazine) and three human waste water indicators (caffeine, carbamazepine, carisoprodol). Nitrate water samples were collected in clear, sterilized plastic sample bottles. Agricultural and wastewater indicators were collected in 1 L amber glass bottles. Samples were collected from outside tap or pressure tank taps (after water treatment systems where present) and after running the source for approximately two minutes. Some water samples were also collected from the indoor tap if no water treatment system was present.

During water sample collection, property owners were also asked to complete a survey about risk factors of nitrate contamination, such as well construction, site history, and proximity to potential nitrate sources (septic systems, agricultural fields, fertilizer storage). The survey used is shown in Appendix I. Some survey data, like well construction date, were input before the site visit by student researchers who had access to well logs. The survey was developed in consultation with researchers from the Hastings Area Nitrate Study to create an exhaustive list of potential risk factors of nitrate contamination of well water (Dakota County Environmental Management, 2003).

Sample Analysis

Nitrate samples were treated with an interference suppressor and then analyzed with a calibrated ion-sensitive electrode. Target chemicals for agricultural and human waste indicators were obtained as neat standards from ChemService and prepared as diluted solutions in ethyl acetate. Control spikes were prepared by addition of standard solutions to 1 L of reagent water. Method blanks consisted of 1 L reagent water. One liter of samples was drawn through one C18 and one SPD-RPD extraction disk. The disks were eluted first with 8 mL ethyl acetate and then with 8 mL methylene chloride. The eluant was dried with sodium sulfate powder, then reduced to 5 mL volume by evaporation of the solvent over a hot plate. The extract was injected into a calibrated gas chromatograph with a nitrogen-phosphorus detector to determine the sample concentration (modified EPA method 507). Both the control spikes and method blanks (11 of each per batch) were processed in the same manner as the samples.

Statistical Analysis

A student's t-test at the 95% confidence level was performed on dichotomous questionnaire responses to determine if the average nitrate concentration differed among sites with risk factors identified on the questionnaire or sample analysis. For example, the average nitrate concentration was compared at sites positive and negative for agricultural indicators to determine if herbicides and pesticides are indicators of nitrate contamination in private wells. Pearson's correlation coefficient was used to explore associations between numerical data collected on the questionnaire. Correlation coefficients (r) >0.3 and <0.5 indicate a moderate correlation and $r>0.5$ indicates a strong correlation. STATA data analysis and statistical software was used to perform the statistical analysis.

Results

Three-hundred and ninety-nine households were contacted to participate in this study and 130 households responded (33% response rate). Of the 130 households that responded, 110

participated in the study by completing the questionnaire and submitting a well water sample. One-hundred and eight of 110 samples (98%) were above the nitrate, agricultural, or human waste indicator detection limits and thus included in the statistical analysis. All households had a septic system on-site. Samples were collected from 10 different townships in Eau Claire County, WI (Figure 2, Table 1). Of the 10 townships, Union had the highest percentage of samples positive for agricultural indicators (71%), followed by Pleasant Valley (22%) and Washington (3%) (Table 1). Pleasant Valley had the highest percentage of samples positive for human waste indicators (3%), followed by Washington (2%) and Union (1%). No agricultural or human waste indicators were found in samples from the other seven townships.

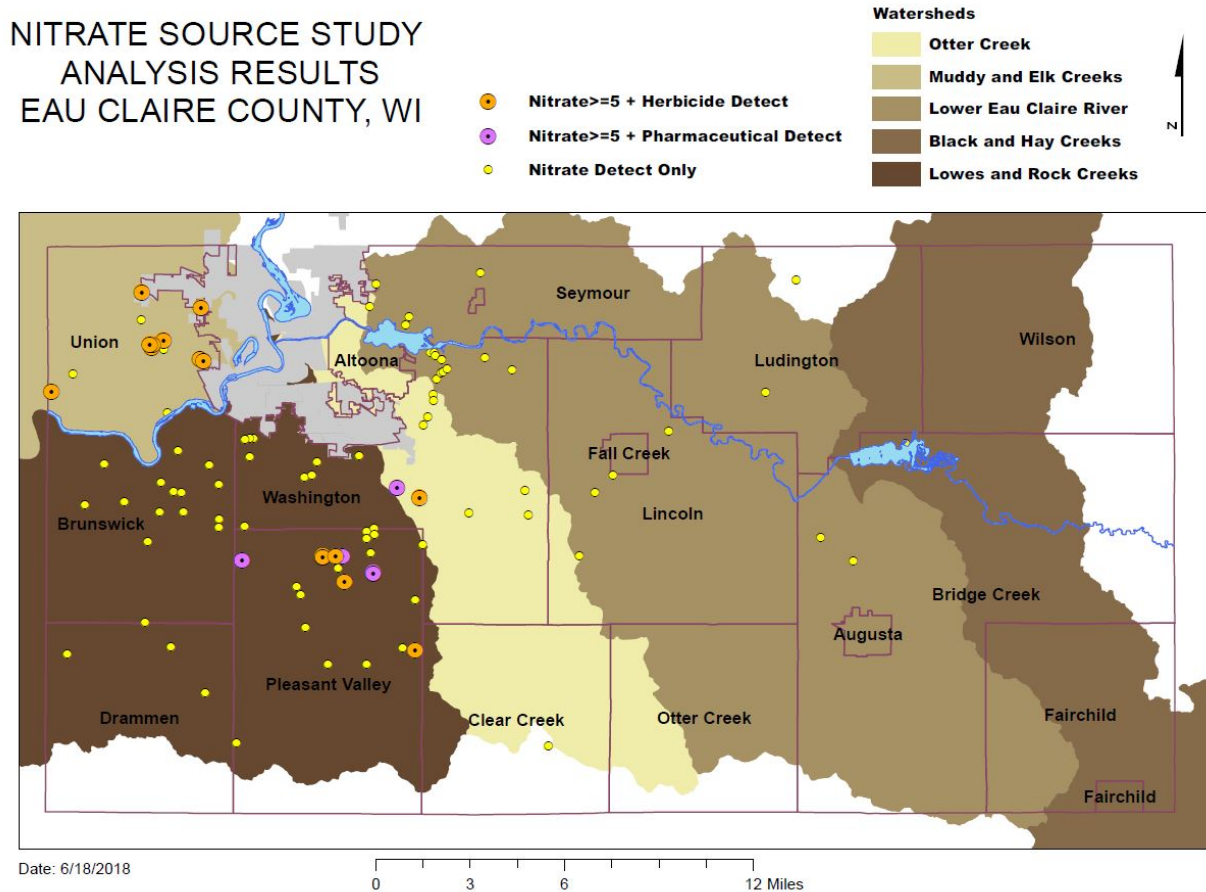


Figure 2. Map of herbicide, pharmaceutical and nitrate detects in the 10 townships sampled in Eau Claire County, WI.

Table 1. Number of samples collected from participating townships and the percentage of samples positive for agricultural and human waste indicators.

*Township	Number of samples collected	Number of samples positive for agricultural indicators (% positive samples)	Number of samples positive for human waste indicators (% positive samples)
Bridge Creek	3	0 (0)	0 (0)
Brunswick	16	0 (0)	0 (0)
Clear Creek	1	0 (0)	0 (0)
Drammen	2	0 (0)	0 (0)
Lincoln	3	0 (0)	0 (0)
Ludington	1	0 (0)	0 (0)
Pleasant Valley	27	6 (22)	3 (11)
Seymour	8	0 (0)	0 (0)
Union	14	10 (71)	1 (7)
Washington	29	1 (3)	2 (7)

**Altoona, Augusta, Eau Claire, Fairchild, Fall Creek, Otter Creek and Wilson were included in the study but no households participated from these townships.*

Fifteen percent of sites tested positive for agricultural indicators and 5% of sites tested positive for human waste indicators. Four of seven agricultural indicators and two of three human waste indicators were present at least once. The agricultural indicators detected were desethyl atrazine, desisopropyl atrazine, atrazine and alachlor. Caffeine and carbamazepine were the human waste indicators detected (Table 2). The maximum concentrations of nitrate and agricultural and human waste indicators are listed in Table 2. Table 2 also shows the frequency of detection of the analyzed chemicals. The most frequent agricultural indicator was desethyl atrazine (13% of samples) followed by atrazine (10% of samples). Sixteen of the 108 samples (15%) were positive for atrazine and/or an atrazine metabolite. Caffeine was the most frequent human waste indicator (3.7%).

Table 2. Maximum concentrations, frequency and limit of detection of nitrate and the agricultural and human waste indicators analyzed.

	Chemical	Chemical purpose	Limit of detection ($\mu\text{g/L}$)	Maximum concentration detected ($\mu\text{g/L}$)	No. of detects
Agricultural Indicators	<i>Desethyl atrazine</i>	<i>Atrazine metabolite</i>	0.2	0.49	14
	<i>desisopropyl atrazine</i>	<i>Atrazine metabolite</i>	0.2	0.42	3
	<i>Atrazine</i>	<i>Herbicide</i>	0.1	0.49	11
	<i>Acetochlor</i>	<i>Herbicide</i>	0.2	0	0
	<i>Alachlor</i>	<i>Herbicide</i>	0.2	0.28	1
	<i>Metolachlor</i>	<i>Herbicide</i>	0.2	0	0
	<i>Cyanazine</i>	<i>Herbicide</i>	0.1	0	0
Human Waste Indicators	<i>Caffeine</i>	<i>Stimulant</i>	0.2	0.36	4
	<i>Carbamazepine</i>	<i>Anti-convulsant</i>	0.3	0.85	2
	<i>Carisoprodol</i>	<i>Muscle relaxant</i>	0.3	0	0
	<i>Nitrate</i>	<i>Fertilizer</i>	0.41 (mg/L)	22 (mg/L)	108

No township's average nitrate concentration exceeded the USEPA nitrate MCL of 10 mg/L in drinking water (Figure 3). Pleasant Valley and Ludington had the highest average nitrate concentrations at 9.8 mg/L and 9.3 mg/L, respectively. Twenty-four of 108 samples (22%) were above the USEPA nitrate MCL. The maximum nitrate concentration detected was more than double the USEPA MCL at 22 mg/L and was detected in a Pleasant Valley sample. None of the agricultural or human waste indicators were above available enforcement standards. The average nitrate concentration in wells with agricultural indicators present was 10.7 mg/L, which is significantly higher at the 95% confidence level than the average nitrate concentration in wells without agricultural indicators present (6.8 mg/L) ($P = 0.0026$). When the average nitrate concentration in wells positive for atrazine but no other agricultural indicators was compared to wells without atrazine, nitrate concentrations were significantly higher in atrazine wells ($P = 0.0025$). No statistically significant relationship was found between wells with high nitrate concentrations and presence of the human waste indicators analyzed.

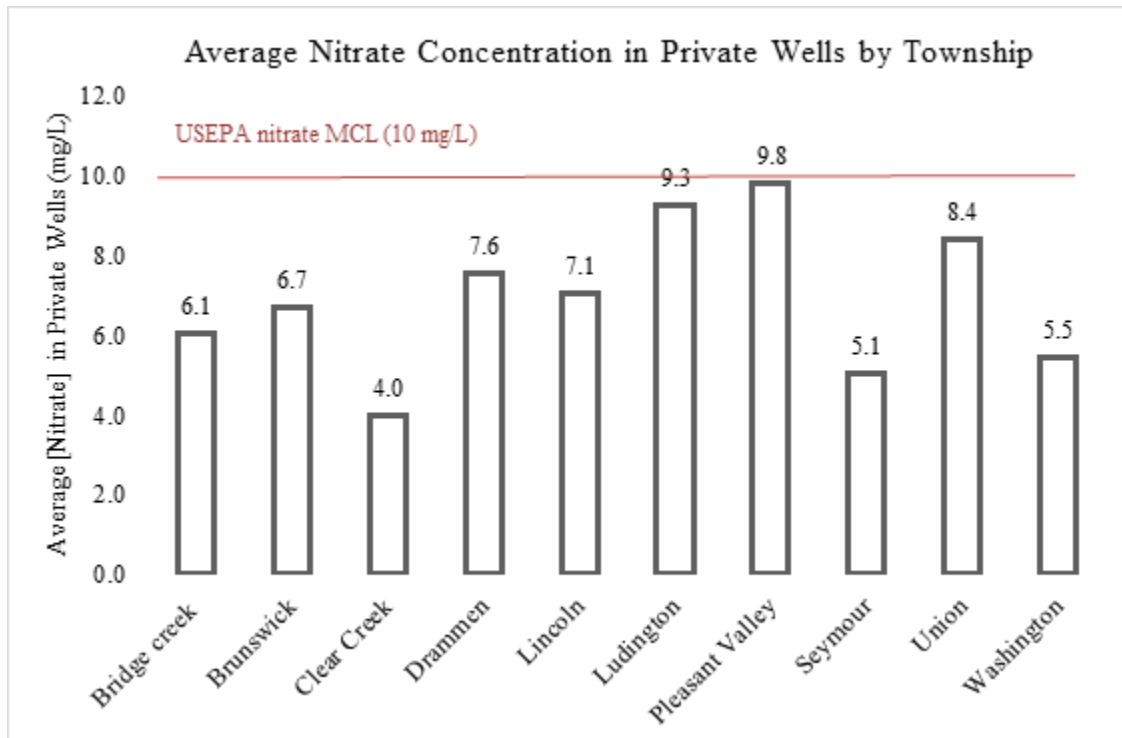


Figure 3. Average nitrate concentrations by township. No township's average nitrate concentration in private wells exceeded the USEPA nitrate MCL.

Contrary to our hypothesis and other research (Dakota County Environmental Management, 2003), there was no correlation between well age or well depth and nitrate concentrations (Figure 4, Figure 5). Figure 4 illustrates the weak correlation between nitrate concentration and well age ($r = 0.08$) and Figure 5 shows the weak correlation between well depth and nitrate concentration ($r = 0.17$). Well construction information was available for 39% of sampled sites. Among these sites, wells with a casing depth <40 ft had significantly more nitrate at the 95% confidence level ($P = 0.032$). Seventy-three percent of households that reported a crop within 300 ft. of their well (52 total households) stated the crop was corn.

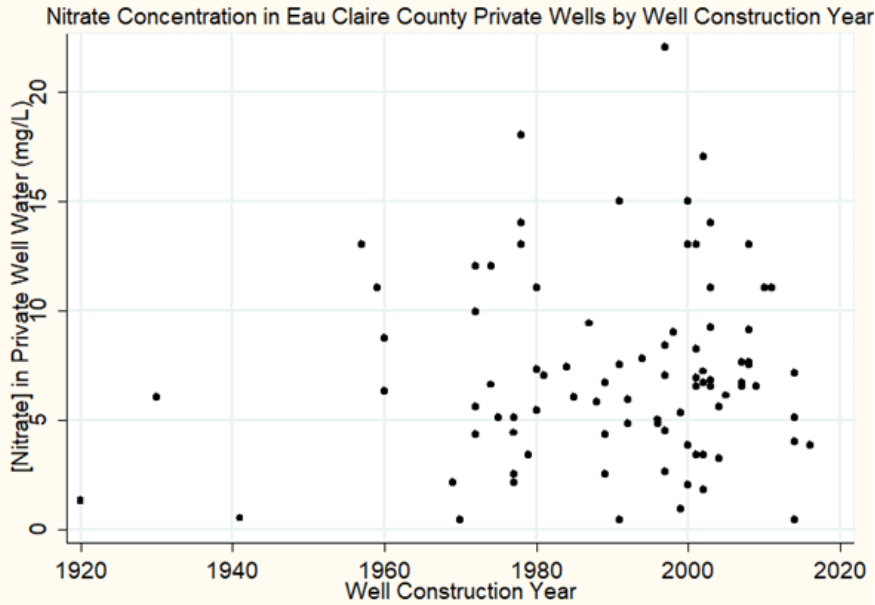


Figure 4. No correlation ($r = 0.08$) was found between well age and the concentration of nitrate, contrary to our hypothesis and results from previous studies. Well construction year was reported by or found for 88 households ($n = 88$).

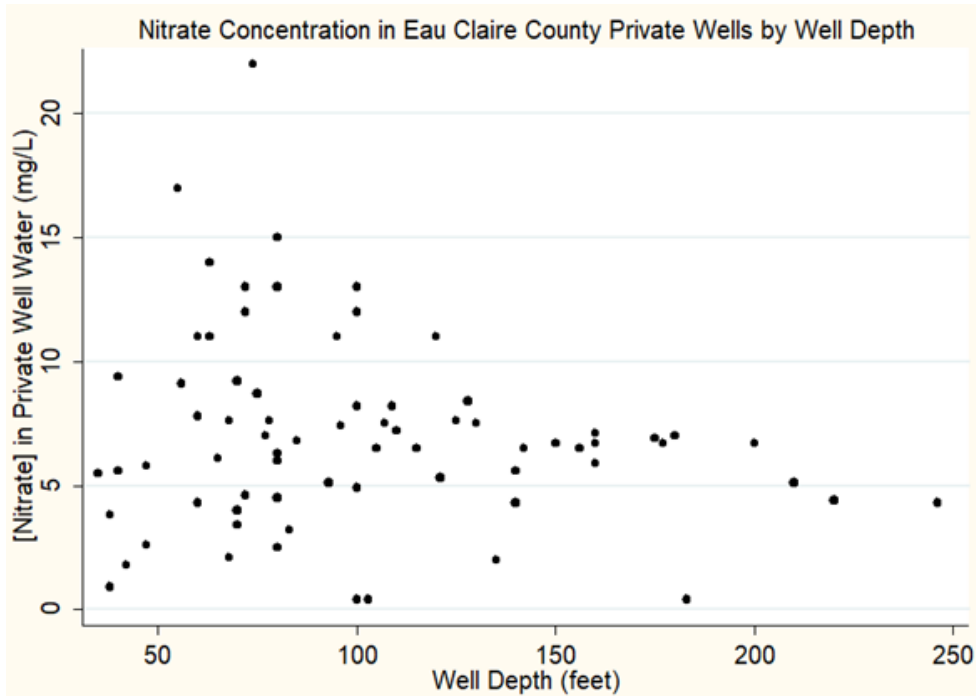


Figure 5. No correlation ($r = 0.17$) was found between well depth and the concentration of nitrate, contrary to our hypothesis and results from previous studies. Well depth was reported by or found for 73 households ($n = 73$).

Discussion

Nitrate contamination is not a new area of investigation for researchers or public health officials in Eau Claire County. However, emerging contaminants such as those associated with agriculture or human wastewater and tested in this study is a relatively new area of investigation county-wide. Though the results of this project suggest a significant influence on groundwater from agricultural contamination, it also highlights the potential for contamination of private wells as a result of private onsite wastewater treatment systems. In the upcoming decade, the expansion of the agricultural industry (primarily through large animal feeding operations) and unsewered subdivisions are anticipated as the county population grows. Aims of this study were: 1) To gather and analyze data to determine trends and risk factors associated with nitrate contamination in Eau Claire County, WI; 2) Evaluate the relationship between nitrate and indicators of ag or wastewater impact on groundwater; 3) Create methods to make this study reproducible by other health departments to continue research on high nitrate in private wells in Wisconsin, and 4) Gather and analyze data to provide meaningful information for decision makers.

Aim 1: Determine trends and risk factors associated with nitrate contamination in Eau Claire County, WI

The significantly higher average nitrate concentration in wells with agricultural indicators present suggests agriculture is a source of nitrate contamination in private wells in Eau Claire County. Although studies have demonstrated that nitrate from septic system effluent is a contributor to poor well water quality (Shaw, 1994), our findings do not suggest septic systems are a significant source of nitrate in Eau Claire County. Other studies have also indicated agriculture is the primary source of nitrate contamination compared to septic systems (Chern et al., 1999).

Surprisingly, none of the risk factors we hypothesized to have associations with nitrate contamination in private wells did except casing depth. Previous research indicates wells with casings less than 40 ft have significantly more nitrate (Bundy et al. 1994), which is consistent with this study. Well age and depth had been previously identified as nitrate contamination risk factors but did not correlate with nitrate contamination in this study (Dakota County Environmental Management, 2003). The sandy soil, heavy agriculture, and thick sandstone aquifers allow for rapid and deep infiltration of water and water-soluble contaminants. This process and the increased likelihood of denitrification or lower nitrate concentrations in older groundwater at depth (Böttcher et al., 1990; Kraft et al., 2004) are the most likely explanation for higher concentrations of nitrate in wells with shallow casing. Many of the wells for which records are available (n=43) are constructed as open boreholes, with highly variable distances between the bottom of the borehole and bottom of the casing (0 ft to 158 ft, median of 17 ft). This may explain the lack of correlation between nitrate concentration and well borehole depth in this study.

Aims 2 and 3: Evaluate the relationship between nitrate and indicators of ag or wastewater impact on groundwater, and create methods to make this study reproducible by other health departments to continue research on high nitrate in private wells in Wisconsin.

Atrazine and desethyl atrazine (an atrazine metabolite) were the most frequent agricultural indicators detected in this study. In the state of Wisconsin, atrazine and atrazine metabolites are present in approximately 23% of private wells compared to 15% in this study (Department of Agriculture, Trade and Consumer Protection [DATCP], 2017). The benefit of analyzing private well water samples for atrazine and nitrate is identifying the nitrate source. If atrazine and nitrate

are both present in a sample, the likely source of nitrate is a nearby agriculture field. Although our study did not validate direct sources of atrazine in positive well water samples, there is evidence to suggest atrazine contamination was from herbicide application on nearby crops. At the time of sampling, atrazine was not prohibited by DATCP except for one <3,000 acre area in southeast Eau Claire County (DATCP, 2018). Additionally, atrazine is historically a widely used herbicide on corn and 73% of households in this study with a crop \leq 300 ft. from their well reported the crop was corn (Wisconsin Groundwater Coordinating Council Report to the Legislature, 2018; note the survey records a one-time snapshot of crops present and does not account for crop rotation patterns). The methods used for sample analysis in this study utilized already-existing equipment in a certified public health laboratory. The research team recognizes not all public health departments have a laboratory and there are some limitations to these methods. However, the team believes that the methods developed here fit a mid-range price for health departments able to make some capital investments for exploratory groundwater quality work.

Aim 4: Gather and analyze data to provide meaningful information for decision makers

The percentage of samples above the USEPA nitrate drinking water MCL found in this study (22%) is commensurate with other regional studies. In areas with abundant agriculture in Wisconsin, much like Eau Claire County, 17-26% of private wells contain nitrate above the USEPA MCL (LeMasters and Baldock, 1997). Researchers in Hastings, MN found 25% of private and public drinking water wells had nitrate concentrations above the USEPA MCL (Hastings is 1.5 h west of Eau Claire County) and deemed this a water quality “problem” for the area (Dakota County Environmental Management, 2003). Across the state of Wisconsin, 10% of private wells on average are above the nitrate MCL (LeMasters and Baldock, 1997). Results from this study show Eau Claire County has 12% more private wells above the USEPA nitrate drinking water MCL than the state of Wisconsin, suggesting there is a larger nitrate contamination problem in Eau Claire County private wells.

Private wells are not subject to routine water quality monitoring by the USEPA or delegated agencies. If our findings are generalized across Eau Claire County, 22% of households on private well systems may unknowingly have nitrate in their drinking water above the USEPA MCL. The rate of nitrate contamination in Eau Claire County private wells does not appear to be restricted by well age. No correlation exists between well construction year and nitrate concentration. As residential development in Eau Claire County continues outside the boundaries of municipal water supply, ongoing nitrate monitoring of new private wells should be prioritized.

For existing private wells in Eau Claire County with nitrate >10 mg/L, the homeowners are notified after testing and point-of-use or whole-house system installation is recommended by ECCCHD. However, left to their own devices, 70% of Wisconsin homeowners did not act to reduce nitrate exposures from drinking water in a study by the Wisconsin Department of Health and Family Service (Schubert et al., 1997). When action to reduce nitrate exposure was taken by homeowners in the study population, the most common solutions were purchasing bottled water and installing a point-of-use nitrate treatment system. The average cost of purchasing bottled water or installing a point-of-use treatment system at the time of the Schubert et al. study was \$200/year and \$850/year, respectively. Present-day estimates for bottled water (1 gal/day) are approximately \$475/person. Reverse osmosis systems are available for a one-time cost of as little as \$200, plus the cost of installation and replacement filters (annual cost estimate of \$50-\$120, depending on usage). However, the cost of these mitigation options may be prohibitive for some county residents. In order to make access to safe, clean drinking water

more equitable, affordable nitrate mitigation resources should be made available and advertised to households in Eau Claire County with nitrate ≥ 10 mg/L. Considering the time, effort, and environmental impact of purchasing bottled water, the cost of installing and maintaining a point-of-use treatment system is arguably the preferable option for households. Due to the high number of households with nitrate concentrations ≥ 10 mg/L, Eau Claire County is an ideal location to test the efficacy of a private well nitrate remediation program that would offer and aggressively advertise nitrate remediation options to homeowners with well water at or above the USEPA nitrate MCL. There is also a need for prioritizing education and outreach about the importance of monitoring nitrate levels in at-risk private wells (5-9 mg/L nitrate) in Eau Claire County.

The nitrate problem in Wisconsin's private well water is well documented (Bundy et al. 1994; Chern, Kraft and Postel, 1999; LeMasters and Baldock, 1997; Shaw, 1994). Solutions presented to resolve the nitrate problem in Wisconsin have traditionally focused on reducing nitrate fertilizer overuse on crops. Although this is an important part of the solution, direct action is needed to protect homeowners from the adverse health effects associated with consuming water with nitrate ≥ 10 mg/L. Since most Wisconsin homeowners (70%) do not act on their own to reduce nitrate exposures from drinking contaminated well water, local public health authorities must develop and implement interventions. Funds should be allocated to public health authorities in Eau Claire County to promote and subsidize point-of-use drinking water treatment systems in homes with nitrate ≥ 10 mg/L. The efficacy of this approach could be studied as a pilot for other counties in Wisconsin experiencing a similar rate of nitrate contamination ≥ 10 mg/L in private well water.

The results of this study can also be used to inform county-wide land use, zoning, and permitting decisions among county staff and policy makers. Specifically, groundwater quality has recently arisen as a topic of concern in conversations regarding subdivision lot sizes and a concentrated animal feeding operation moratorium or ordinance. This study will also inform continued conversations regarding addressing other emerging contaminants through a public health lens. Already, data from this study was included in the 2018 State of Groundwater Report developed by the Eau Claire Groundwater Advisory Committee and presented to the Eau Claire County Board in August 2018. This information will also be presented to the Eau Claire Board of Health in September 2018. Through the development of the State of Groundwater Report, the committee identified several priorities related to the future of groundwater in Eau Claire County, including expanding outreach to realtors and serving as the default testing service for real estate transactions at the ECCCHD certified public health lab, defining and identifying environmentally sensitive areas, reviewing and potentially modifying ordinances and regulations to protect groundwater quality and quantity, expanding water quality testing across the county to areas where minimum testing has been conducted (approximately 4500 private wells remain untested), and expanding groundwater education efforts to provide additional information to home buyers, builders and realtors regarding private well and septic testing and maintenance.

References

- Al-Qudah, K.M., L.M. Rousan, and K.I. Ereifej. 2009. Nitrate/nitrite poisoning in dairy cattle associated with consumption of forages irrigated with municipally treated wastewater. *Toxicological & Environmental Chemistry*, v. 91. 163-170.
- Böttcher, J., O. Strebel, S. Voerkelius, and H.-L. Schmidt. 1990. Using isotope fractionation of nitrate-nitrogen and nitrate-oxygen for evaluation of microbial denitrification in a sandy aquifer. *Journal of Hydrology*, v. 114. 413-424.
- Bundy, L.G., L. Knobeloch, B. Webendorfer, G. Jackson, and B.H. Shaw. 1994. Nitrate in Wisconsin groundwater: Sources and concerns. Publ. G3054. University of Wisconsin-Extension, Madison, WI.
- Chern, L., G. Kraft, and J. Postle. 1999. Nitrate in groundwater: A continuing issue for Wisconsin citizens. Nutrient Management Subcommittee of the Nonpoint Source Pollution Abatement Program Report March 1999. Wisconsin Department of Natural Resources, Madison, WI.
- Department of Agriculture, Trade and Consumer Protection (2017). Wisconsin Groundwater Quality: Agricultural Chemicals in Wisconsin Groundwater. Wisconsin Department of Agriculture, Trade and Consumer Protection, Water Quality Section. Retrieved September 2, 2018 from: https://datcp.wi.gov/Pages/Programs_Services/GroundwaterReports.aspx
- Department of Agriculture, Trade and Consumer Protection (2018). Atrazine Prohibition Areas. Retrieved September 5, 2018 from <https://datcpgis.wi.gov/maps/?viewer=pa>
- Dakota County Environmental Management (2003). Hastings Area Nitrate Study. Retrieved August 20, 2018 from <https://www.co.dakota.mn.us/Environment/.../HastingsAreaNitrateStudy.pdf>
- Kraft, G.J., B.A. Browne, W.M. DeVita, and D.J. Mechenich. 2004. Nitrate and pesticide residue penetration into a Wisconsin Central Sand Plain aquifer. Retrieved September 12, 2018 from https://www.uwsp.edu/cnr-ap/watershed/documents/penetration_sandplain.pdf
- LeMasters, G. and J. Baldock (1997). A Survey of Atrazine in Wisconsin Groundwater, Final Report, WI Department of Agriculture, Trade and Consumer Protection.
- Protecting Wisconsin's Groundwater Through Comprehensive Planning (2007). Eau Claire County Full Report. Retrieved September 11, 2018 from https://wi.water.usgs.gov/gwcomp/find/eauclaire/index_full.html
- Shaw, Byron (1994). Nitrogen Contamination sources: A Look at Relative Contributions, IN: Conference Proceedings: Nitrate in Wisconsin's Groundwater: Strategies and Challenges, May 10, 1994, Central Wisconsin Groundwater Center (UWEX), Golden Sands RC&D, WI Dept of Natural Resources and WI Dept. of Health and Social Services.
- Schubert, C., L. Knobeloch, H. Anderson, C. Warzecha, and M. Kanarek (1997). Nitrate-Contaminated Drinking Water Followback Study, Submitted to the WI Dept. of Natural Resources and the WI Groundwater Coordinating Council. Department of Preventive Medicine, University of Wisconsin-Madison and the WI Department of Health and Family Services. 17 pages.
- Spalding, R.F., M.E. Exner (1993). Occurrence of Nitrate in Groundwater—A Review. *J. Environ. Qual.* V. 22, 392-402.
- Wisconsin Department of Agriculture, Trade and Consumer Protection (2002). Groundwater Quality: Agricultural Chemicals in Wisconsin Groundwater
- Wisconsin Groundwater Coordinating Council Report to the Legislature (2018). Nitrate. Retrieved September 10, 2018 from <https://dnr.wi.gov/topic/groundwater/documents/gcc/gwquality/nitrate.pdf>
- Wisconsin Groundwater Coordinating Council Report to the Legislature (2018). Pesticides. Retrieved September 5, 2018 from <https://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/pesticides.pdf>

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Appendix 1: Well Construction and Land Use Survey

Well Information and Potential Nitrate Source Inventory Form

General Information

Site ID number: _____

Date of Visit: _____ Township _____

Well Unique Number (6 digits): _____ Property Address: _____

GPS location of well: Latitude: _____ Longitude: _____

Owner Name: _____

Owner Phone: _____

Owner Address: *if different from above* _____

Owner E-mail: _____

Investigator Name: _____

Please answer the following questions to the best of your ability

1. Is this well used for drinking water?

- a) YES
- b) NO

2. Well Construction Type (Circle one)

- a) Drilled
- b) Sand point
- c) Hand-dug
- d) Not sure
- e) Other (specify) _____

3. Well Construction Date (MM/YYYY) _____

4. Well Depth (Feet): _____

5. Well Diameter (Inches): _____

6. How high does the well extend above ground? (Feet): _____

7. Well Information collected from (Circle one or both):

- a) Well Log (**Attach**)
- b) Verbal (Indicate Person): _____

- 8. Is there a point-of-use water treatment system installed in the house not including a water softener? (Reverse Osmosis, Activated Charcoal, etc.)**
- a) YES
 - b) NO
 - c) Not sure
- 9. Which direction does the landscape slope? (Circle all that apply and multiple directions if NE, SW, etc.)**
- a) North
 - b) South
 - c) East
 - d) West
- 10. Is there obvious damage or disrepair to the well, such as the well cap, concrete pad/base, or other features?**
- a) YES
 - b) NO
 - c) Not sure
- 11. Is there more than one well (operating or abandoned) on this property?**
- a) YES
 - b) NO
 - c) Not sure
 - d) If yes, list well type and Unique No. if available: _____
- 12. Is there a septic system on site?**
- a) YES
 - b) NO
 - c) Not sure
 - If yes, what is the distance and direction from the well? _____
- 13. If yes to Q12, what type of septic system? (circle one)**
- a) Conventional septic tank
 - b) Trench/drainfield
 - c) Pressure bed
 - d) Mound
 - e) At-grade
 - f) Other (specify) _____
 - g) Not sure
- 14. Is there a historic/abandoned septic system on site?**
- a) YES
 - b) NO
 - c) Not sure
 - If yes, what is the approximate distance to the well? (Feet) _____

15. Is fertilizer stored on this property?

- a) YES
- b) NO
- c) Not sure

- If yes, what is the approximate distance to the well? (Feet) _____

16. Has fertilizer been stored on the property in the past?

- a) YES
- b) NO
- c) Not sure

- If yes, what was the approximate distance and direction from the well? (feet; cardinal directions) _____

17. What is the most prominent soil type at the well site?

- a) Sand
- b) Clay
- c) Silt

18. Is there a landfill within 5 miles of the well?

- a) YES
- b) NO
- c) Not sure

19. Is there a surface water source (pond, lake, river, stream, etc.) within a half-mile of the well?

- a) Yes
- b) NO
- c) Not sure

20. Are crops grown within 300 ft. of the well? (300 ft. = 100 yards; just under the length of a football yield)

- a) YES
- b) NO
- c) Not sure

21. If yes to Q.20, what type of crops? (Circle all that apply)

- a) Apples
- b) Alfalfa
- c) Barley
- d) Beans
- e) Cherries
- f) Cabbage
- g) Carrots
- h) Corn
- i) Cucumber
- j) Oats
- k) Peas
- l) Potatoes
- m) Soybeans
- n) Wheat
- a) Other (specify) _____
- o) Not sure

22. If yes to Q.20, have any of the following herbicides/pesticides been applied in the last year within 300 ft. of the well? (Circle all that apply)

- a) AAtrex
- b) Bicep
- c) Harness Extra
- d) Cinch
- e) Dual
- f) Accent
- g) Gold
- h) Hornet
- i) Harness
- j) Accent Gold
- k) Other (specify) _____
- l) Not sure

23. If yes to Q.20, how is the cropland irrigated? (Circle all that apply)

- a) Sprinkler
- b) Drip
- c) Flood
- d) Precipitation only
- e) Other (specify) _____
- f) Not sure

24. If yes to Q.20, how are herbicides/pesticides applied? (Circle all that apply)

- a) Aerial
- b) Chemigation
- c) Mixer/loader (mixing into application equipment or nurse vehicle)
- d) Seed treatment
- e) Soil fumigation
- f) Other (specify) _____
- g) Not sure

25. If yes to Q.20, how are fertilizers applied? (Circle all that apply)

- a) Aerial
- b) Chemigation/fertigation
- c) Manure spray irrigation
- d) Mixer/loader (mixing into application equipment or nurse vehicle)
- e) Other (specify) _____
- f) Not sure

26. Are you the fertilizer applier?

- a) YES
- b) NO

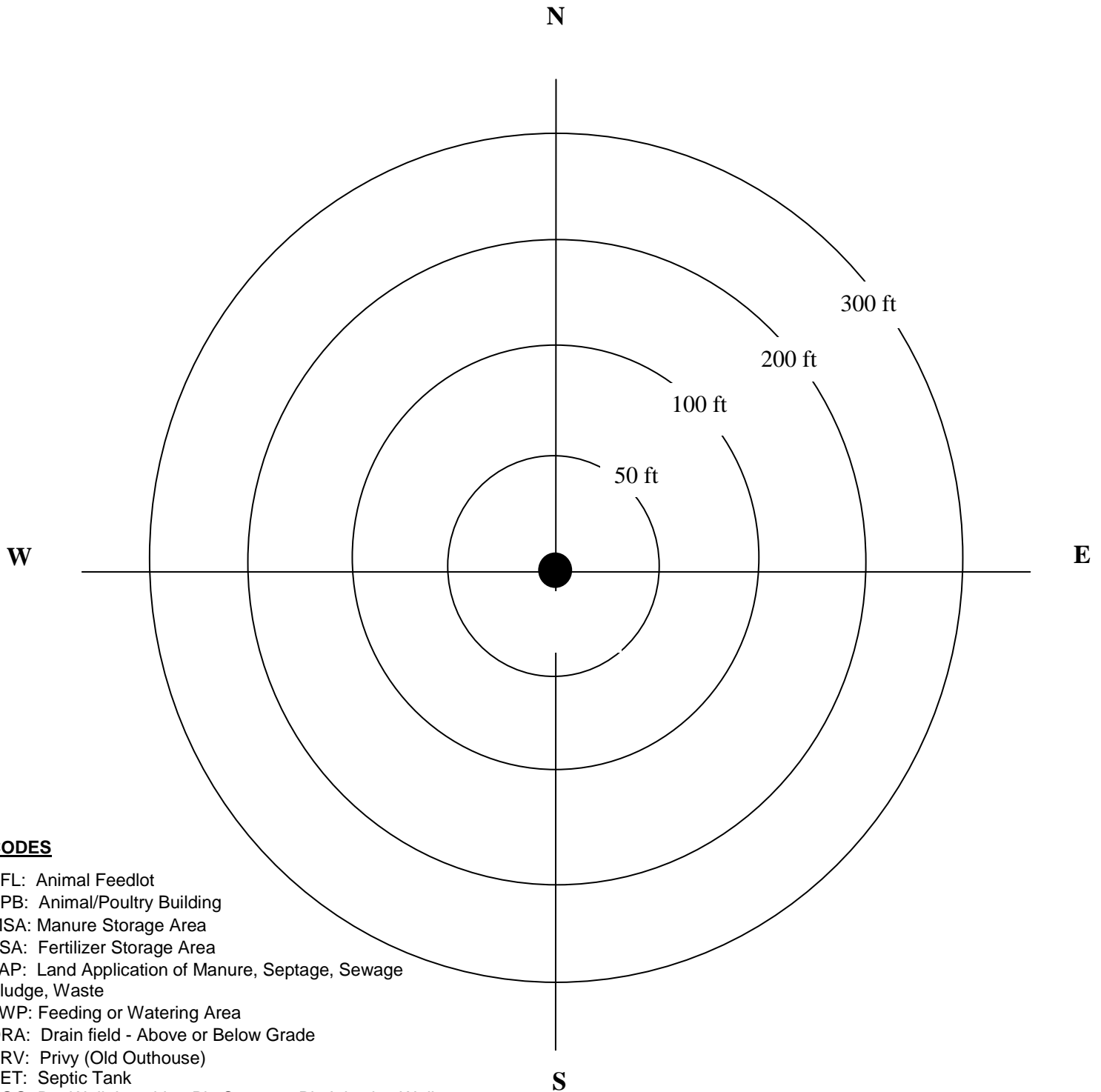
27. If yes to Q. 26, do you know about the UW-Extension Nitrogen (N) Rate Guidelines?

- a) YES
- b) NO

28. If yes to Q. 26, is fertilizer applied on the cropland according to UW-Extension Nitrogen (N) Rate Guidelines?

- a) YES
- b) NO
- c) Not sure

29. Source Codes and Distances: (*typical city block is 300'*) **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
- AW: Abandoned well
- T: Trees