Factors Influencing High Nitrate Levels in Groundwater in Eau Claire County

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1. Introduction:

High concentrations of nitrates in groundwater are a common problem for many counties in Wisconsin. Nitrate can enter the groundwater through numerous sources, including fertilizers, septic tanks, animal waste, and decaying plant material (WDNR, 2003). Nitrate can cause serious health problems in young children, including methemoglobenemia, which can be fatal in infants under one year of age (Knobeloch, 2000). High nitrate concentrations have also been linked to increased rates of cancer and diabetes (Moltchanova et al., 2004). Nitrate in the groundwater can also be a problem when groundwater flows into surface water. In surface water, nitrate concentrations in excess of 30 mg/L cause stress on aquatic species, resulting in inhibited growth and immune deficiencies. High nitrate levels can also cause large algae blooms, resulting in eutrophication (Lenntech, 2009.).

Nitrates are especially problematic for the approximately 20% of homeowners in Wisconsin who use private wells for their drinking water (WDNR, 2006), since nitrate is usually only detectable through laboratory analysis of a water sample, and many homeowners test their water supplies infrequently. In Eau Claire County, the Eau Claire City-County Health Department (ECCCHD) is the agency most frequently used to test nitrate concentrations in private wells, and they have determined that approximately 15% of the wells they sampled have nitrate concentrations that exceed the state enforcement standard of 10 mg/L (ECCCHD, 2009). This study seeks to better understand the factors contributing to high nitrate concentrations in Eau Claire County so that better groundwater management practices might be implemented to reduce the impact of nitrate contamination.

2. Methods:

ECCCHD employees provided groundwater tests results for nitrate concentrations in private wells from a combination of sources, including Health Department Laboratory and County Land Records data. The data were provided as two Excel data sets that contained the street address, city, sample location, and nitrate level in mg/L; one data set contained approximately 3,700 records acquired from 1999-2004, while the other contained approximately 2,100 records acquired from 2005-2009. For each record, the address and city code were imported to ArcGIS and then geocoded to project the data points onto an Eau Claire County map for geospatial analysis. For each data set, nitrate concentrations for each category were characterized as low (< 2 mg/L), medium (2 – 10 mg/L, or high (> 10 mg/L) based on the state preventative action limit (PAL = 2 mg/L) and enforcement standard (ES = 10 mg/L/). The data sets acquired from 1999-2004 and from 2005-2009 were analyzed separately to observe how nitrate levels have changed over time.

Nitrate concentrations for both data sets were evaluated based on the land use, elevation of the water table, depth to bedrock, and the soil's ability to attenuate contaminants for each record. These parameters were determined for each point by importing or constructing ArcGIS maps of these parameters (Figures 1-4). Using ArcGIS, the number of records having low, medium, or high nitrate concentrations was determined for each category of the evaluation parameters. The number of data points from each category was imported to Excel where histograms and graphs were generated.

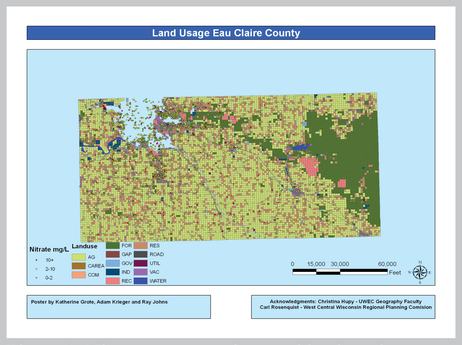

Figure 1: Nitrate concentrations and land use in Eau Claire County.

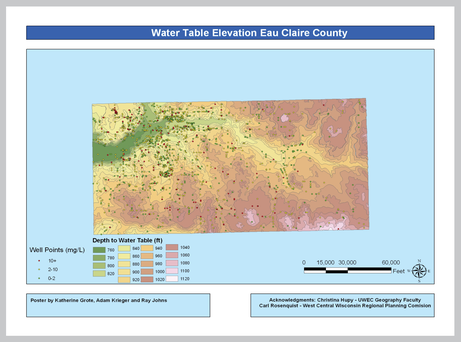

Figure 2: Nitrate concentrations and depth to water table in Eau Claire County.

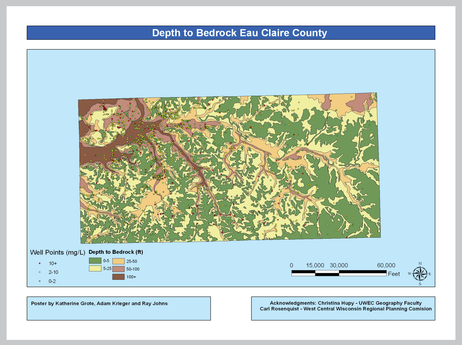

Figure 3: Nitrate concentrations and depth to bedrock in Eau Claire County.

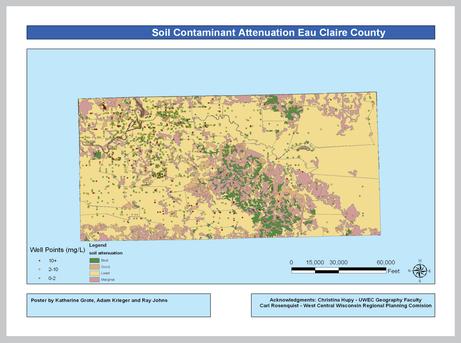

Figure 4: Nitrate concentrations and soil's ability to attenuate contaminants in Eau Claire County.

3. Results:

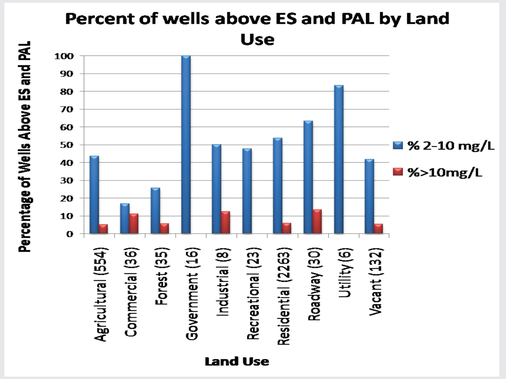

Figure 5: Nitrate levels compared to land use from 1999-2009. The numbers in parentheses indicate the total number of samples in each land use category. This graph combines data from the 1999-2004 and 2005-2009 data sets, since the 2005-2009 data sets had very few points in any category other than residential and agricultural use. This graph shows that residential areas show a greater percentage of wells with nitrate concentrations exceeding either the PAL or the ES than do agricultural areas. Land used for utilities, commercial, industrial, and roadway uses show higher concentrations than most other categories, perhaps due to the relatively dense development expected in these areas. However, it should be noted that the number of samples from these land use types is fairly small, so additional data might show a different trend.

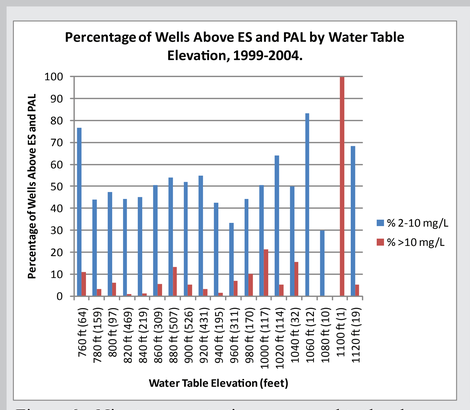

Figure 6a: Nitrate concentrations compared to the elevation of the water table in feet above MSL, 1999-2004. The numbers in parentheses indicate the total number of samples in each water table elevation category.

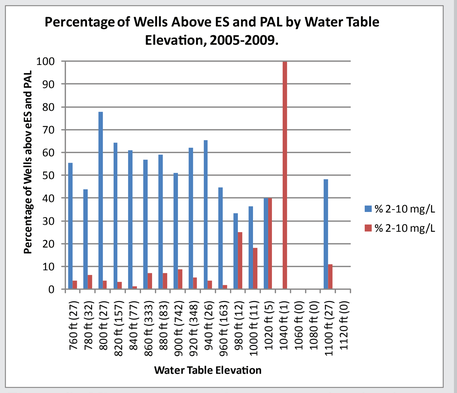

Figure 6b: Nitrate concentrations compared to the elevation of the water table in feet above MSL, 2005-2009. The numbers in parentheses indicate the total number of samples in each water table elevation category.

Figure 6: Figures 6a and 6b do not show a definitive trend between water table elevation and nitrate concentrations, suggesting that factors other than water table elevation have a greater influence on nitrate pollution. Additional data analysis using these results to estimate nitrate concentration as a function of depth to water table is underway, and it is expected that this comparison might provide more definitive trends. Comparison of the percentages of wells showing high nitrate concentration in Figures 6a and 6b shows that nitrate concentrations have increased in Eau Claire County over the time period investigated in this project.

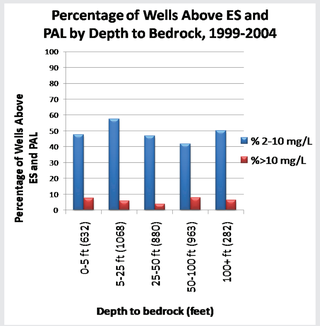

Figure 7a: Nitrate concentrations compared to the depth to bedrock in feet, 1999-2004. Numbers in parentheses indicate the total number of samples in each bedrock depth category.

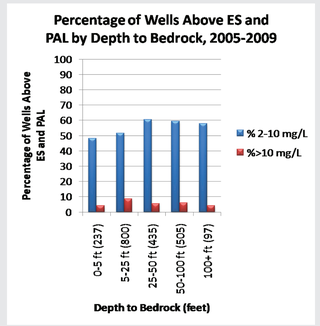

Figure 7b: Nitrate concentrations compared to the depth to bedrock in feet, 2005-2009. Numbers in parentheses indicate the total number of samples in each bedrock depth category.

Figure 7: Figures 7a and 7b show that depth to bedrock does not appear to be a significant factor controlling nitrate concentrations; no discernable patterns relating nitrate concentration to depth to bedrock were noted.

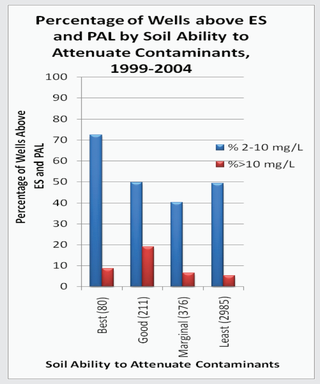

Figure 8a: Nitrate concentration compared to the soil's ability to attenuate contaminants from 1999-2004. Numbers in parentheses indicate the total number of samples in each category.

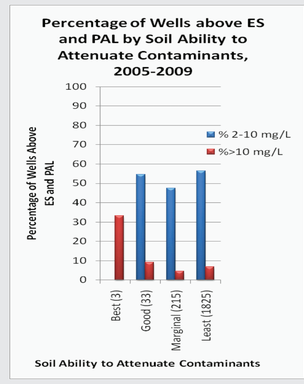

Figure 8b: Nitrate concentration compared to the soil's ability to attenuate contaminants from 2004-2009. Numbers in parentheses indicate the total number of samples in each category.

Figure 8: Figures 8a and 8b show that in general, soils that were rated as having "best" or "good" ability to attenuate contaminants had the highest levels of nitrate contamination. This result was opposite what was expected, so additional research is needed to explain these results. Further investigation is currently underway to determine whether land uses associated with high nitrate concentrations are more concetrated in areas with a higher ability to attenuate contaminants.

4. Conclusions:

From the data analysis performed thus far, it appears that land use has the greatest impact on nitrate concentrations in the groundwater. Land uses associated with dense development (industrial, commercial, government use) tend to have the highest nitrate concentrations, although agricultural and residential areas may also have significant nitrate contamination. In Eau Claire County, residential nitrate concentrations rose relative to agricultural concentrations when the 1999-2004 and 2005-2009 data sets were compared. The increase in high nitrate levels in residential areas may reflect the increased development of rural areas into subdivisions with 1-2 acre lots. These homes are closer together than traditional rural homes, while still generally having private wells and septic systems. Additionally, the subdivisions are often built on former agricultural land, so the area may have been at risk for nitrate contamination before the homes were built.

Additional data analysis is ongoing to better explain some results observed thus far. These analyses include a case-by-case assessment of the wells plotted in "roadways" to determine the true land use category for these wells, the development of a map of depth to the water table, and an investigation of the land use categories associated with soils with relatively high ability to attenuate contaminants. It is hoped that these additional analyses will provide more information on the geologic controls on nitrate concentration.

5. References:

ECCCHD (Eau Claire City-County Health Department), personal communication with Courtney Johnson, 2009.

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Moltchanova, E., M. Rytkonen, and A. Kousa, Zinc and Nitrate in the groundwater and the incidence of Type I diabetes in Finland, Diabetic Medicine, 21, pg 256-261, 2004.

WDNR (Wisconsin Department of Natural Resources), Condition of the Groundwater Resource, GCC Report to the Legislature, 2006.

WDNR, Nitrate in Drinking Water, Publication number WS-001, 2003.

6. Acknowledgements:

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