DATCP 2022-1

Advancing the Use of Nitrate and Neonicotinoids Findings to Inform Groundwater Protection and Improvement Strategies

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Project Summary

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Project ID: DATCP2022-1

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Background/Need: Nitrate and neonicotinoids are two types of pollutants that can be found in groundwater. Nitrate contamination can occur naturally or as a result of human activities such as agricultural practices and waste disposal. Neonicotinoids, on the other hand, are a type of pesticide that is widely used in agriculture to protect crops from insects. Both nitrate and neonicotinoids have been linked to negative impacts on the environment and human health. The Central Sands region of Wisconsin is an area with high susceptibility to groundwater contamination and a high percentage of land use devoted to agricultural procedures. Since many residents of the Central Sands rely on groundwater resources for their drinking water, it is a priority for federal and state agencies and local governments to assess the state of groundwater contamination and reduce the levels of nitrate and neonicotinoids in groundwater. To better coordinate efforts, in 2018 six counties in the Central Sands region of Wisconsin (Adams, Juneau, Marquette, Portage, Waushara, and Wood) decided to form the Central Sands Groundwater County Collaborative (CSGCC). While nitrate and neonicotinoids data points have been continuously collected for decades in the CSGCC region, no compilation of such data has been ever attempted. Creating a comprehensive and accessible database will help stakeholders in decision-making for protecting both the environment and public health.

Objectives: The main objective of our work was to compile nitrate and neonicotinoids data collected in groundwater of the Central Sands region of Wisconsin in a unique GIS database. We also aimed to identify spatial and temporal gaps in the data and evaluate which factors are primarily affecting groundwater contamination in the area.

Methods: We compiled over 100,000 nitrate and over 2,000 neonicotinoids (clothianidin, imidacloprid, and thiamethoxam) data points collected in the groundwater throughout the CSGCC region in the last 70 years. Each data point carries information on sampling location, sampling location resolution (at least with a resolution of a section) and sampling date. In addition to the contaminants' concentrations, we also retrieved information on the characteristics of the wells from which the samples were collected. Through a process of data comparison, we determined if a well characteristic was accurate or not. We merged the multiple datasets only after a thorough process of duplicate check, and after discarding data points collected after water treatment systems. The resulting datasets were included in a GIS database along with neonicotinoids sample results in surface water, addresses, biosolid spreading, manure storage locations, soil properties, land use, septic system, and wells of the CSGCC region. The water quality datasets have a resolution to a section. The database (*Central Sands County Collaborative - Nitrate and neonicotinoids database*) and its description can be found at the following link: https://doi.org/10.48358/dwhy7257. A gap analysis was conducted on the nitrate and neonicotinoids data points collected in private and monitoring wells. Logistic regression models were used to establish if well characteristics, agricultural land use, number of septic systems (for nitrate data), and soil properties affect the probability of detecting nitrate at a concentration exceeding the drinking water standard of 10 mg/L or the probability of detecting neonicotinoids.

Results and Discussion: Average concentration maps were created for nitrate (also at different time intervals) and neonicotinoids. The highest nitrate and neonicotinoids concentrations are located along the regional groundwater divide and in an area NE of Juneau County. Gap analysis highlighted that the amount of nitrate samples increased since 1953 but remained stable overall since the early 2000s.

Neonicotinoid data points began to be collected only after 2008, and sampling continued to increase since then. Through GIS we also produced a map showing which sections with at least one well or septic system have never been sampled for nitrate (or we couldn't find any record of sampling) or have not been sampled for nitrate in the last five years. We were not able to conduct a similar spatial gap analysis on the neonicotinoids data as very few and sparse data points have been collected so far. No consistent increasing or decreasing linear trends were found for average nitrate data within each township of the CSGCC region. Neonicotinoids detection and exceedances of chronic and aquatic life benchmarks for invertebrates increased over time. Through the logistic regression model, we examined how certain factors affect nitrate and neonicotinoids concentration. Below is a summary of the statistical analysis findings for each variable. *Positive trend* indicates that the probability of the stated event (shown on y-axis of Figure 5, for example) increases as the value of a variable (shown on x-axis of Figure 5, for example) increases. *Negative trend* indicates that the probability of the stated event (y-axis) decreases as the value of the variable increases.

Variable	**Probability Nitrate > 10 mg/L**	**Probability of neonicotinoids detection**
Well age	Positive trend	No relationship
Well depth	Negative trend	Negative trend
Percent agricultural land use	Positive trend	Positive trend
Number of septic systems	Negative trend (see manuscript for explanation)	Not applicable
Soil hydraulic conductivity	Positive trend	Positive trend
Soil clay content	Negative trend	Negative trend
Soil organic matter	Negative trend	Negative trend

Conclusions/Implications/Recommendations: Due mostly to data incompleteness, data inconsistency, and lack of data accuracy, we found data merging extremely challenging. We recommend that each entity invested in data collection performs data validation before storing and sharing the data. Overall, neonicotinoids and nitrate data compilation are ongoing and continuous processes that require collaboration between various stakeholders. We believe that the database produced by this study will be extremely valuable to the researchers, policymakers, and members of the public for understanding and mitigating the impacts of groundwater contamination, and for protecting the quality and availability of groundwater resources. In addition to data compilation, we also focused on effective communication and dissemination of information on nitrate and neonicotinoids contamination. To this aim, we created the *Groundwater Quality Resource Guide - Focus on Nitrate and Neonicotinoids* document (Appendix D of this report) with a detailed compilation of all available online resources on the matter. This tool will assist in the development of educational materials, which can help raise public awareness and knowledge about groundwater contamination issues.

Key Words: Nitrate, Neonicotinoid, Clothianidin, Imidacloprid, Thiamethoxam, Central Sands, Dataset, Data merging, GIS database, Groundwater, Water quality, Wisconsin.

Funding: This project was funded through the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP2022-1).

Final Report: A final report containing detailed information on this project is included in the Groundwater Project Repository of the Wisconsin Groundwater Research and Monitoring Program (WGRMP). The report is available for download at this link: https://www.wri.wisc.edu/research-archives/datcp2022-1-final-report/

Introduction

Since the late 1980s, the Central Sands region of Wisconsin has been identified as one of the most susceptible areas to groundwater contamination in the United States (Nolan, et al., 1998). Potable water in the Central Sands is primarily sourced from a highly permeable and shallow unconfined sand and gravel aquifer, composed of sediments deposited during the last ice age (100,000-20,000 years ago) (Hart, et al., 2020). In this region, well-drained soils with low organic matter content promote rapid infiltration of conservative contaminants, making groundwater highly susceptible to contamination from surface activities.

Dairies and food production activities in Wisconsin generate $104.8 billion annually in revenue (Wisconsin Department of Agriculture, Trade and Consumer Protection, 2022). However, it is estimated that the spreading of animal waste products, such as manure, and the use of fertilizers contribute about 90% of the nitrate load in Wisconsin (Shaw, 1994). In the Central Sands region, over 30% of the total land is devoted to agricultural procedures. While it is acknowledged that agriculture operations favor regional economic development, questions are continuously raised about their impact on water quality. Nitrate (NO_3) contamination and its toxicity to humans and terrestrial and aquatic systems have long been of great concern to government entities, industry, and residents of the Central Sands region of Wisconsin. Nitrate pollution in groundwater and surface water can cause severe illness to adults and infants but also affect local ecosystems by promoting noxious algae growth, and loss of biodiversity (Bundy, et al., 1994; Camargo, et al., 2005; Gulis, et al., 2002; Knobeloch, et al., 2013; Marco, et al., 1999; Vitousek, et al., 1997; Ward, et al., 1996).

However, nitrate is not the only contaminant of concern in the Central Sands region. In the late 1990s, several neonicotinoid-based products were registered in the United States (U.S. Environmental Protection Agency, 2022). Neonicotinoids are a class of insecticides widely applied as seed treatments on major Wisconsin crops, such as corn, soybeans, beans, potatoes, small grains, vegetables, fruit crops, and more. The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP), recently summarized neonicotinoids data collected in groundwater from 2008 to 2016. Three neonicotinoid compounds, i.e. clothianidin, imidacloprid, and thiamethoxam, were detected above laboratory reporting limits across the State. The majority of the detects were found in wells and streams of the Central Sands region (Wisconsin Department of Agriculture, Trade and Consumer Protection, 2019). While it's known that neonicotinoids have an adverse effect on pollinators, aquatic life, and mammals, recent research also suggested that these compounds may affect human health (Van der Sluijs, et al., 2013; Anderson, et al., 2015; Tomizawa, et al., 2000; Han, et al., 2018).

Numerous studies and efforts in the last twenty years have been focused on determining the extent of the nitrate and neonicotinoids contaminations in the Central Sands region and what factors increase the vulnerability to contaminations (Burdett, et al., 2018; Center for Watershed Science and Education, University of Wisconsin - Stevens Point, 2022; Masarik, et al., 2018; University of Wisconsin - Stevens Point, 1994; Wisconsin Department of Agriculture, Trade and Consumer Protection, 2019; DeVita & McGinley, 2021). Throughout the years, multiple individual datasets have been created by federal and state agencies, researchers, and local governments. However, a comprehensive dataset, that would include all the sampling efforts of the last decades, was previously not available. The purpose of this study is to assemble all the available nitrate and neonicotinoids data points and create a single, unique database for visualization and analysis. We aim to identify spatio-temporal gaps in the data and evaluate the relationships between nitrate and neonicotinoid concentrations and factors such as land use, well, and soil properties. This dataset and the findings of this study will guide future sampling efforts and support the decision making of the Central Sands Groundwater County Collaborative (CSGCC), a coalition of six counties of the Central Sands region (Adams, Juneau, Marquette, Portage, Waushara, and Wood), instituted in 2018.

Procedures and Method

Several thousand nitrate and neonicotinoids data points were retrieved from public and private sources. Comparison between the information reported from several datasets, data quality check, data deduplication, and discarding of measurements collected in treated systems, reduced the total number of data assembled. In total, we compiled 106,629 nitrate data points collected in wells between June 1953 and February 2022 with a location resolution of at least a Public Land Survey System section (referred as section hereafter). Of these, 32,652 were collected in Public Water Systems (Municipal Community, Other-than-municipal community, Transient non-community, Non-transient non-community); the remaining were collected from private potable, private non-potable, and monitoring wells. We also compiled 2,537 groundwater neonicotinoids data points collected from June 2008 to August 2021 in private and monitoring wells. The nitrate and neonicotinoids data points along with other data, such as well characteristics, land use, soil properties, etc. were included in the *Central Sands County Collaborative - Nitrate and neonicotinoids database* (https://doi.org/10.48358/dwhy7257). ArcMap Pro and Python scripts were used for data analysis and mapping.

Nitrate and neonicotinoids data compilation

Publicly available datasets for nitrate (nitrate as nitrogen or nitrate plus nitrite as nitrogen), and neonicotinoids (clothianidin, imidacloprid, and thiamethoxam) concentrations were retrieved from the following sources:

- Drinking Water System Portal (Wisconsin Department of Natural Resources, 2022a)
- Groundwater Retrieval Network (Wisconsin Department of Natural Resources, 2022b)
- Juneau County Groundwater Screening Investigation (Environmental Protection Agency, 2019)
- USGS Water-Quality Data for the Nation (United States Geological Survey, 2022)
- Water Quality Portal (National Water Quality Monitoring Council, 2022)
- Well Water Quality Viewer: Private Well Data for Wisconsin (University of Wisconsin – Stevens Point, 2022)

Additional nitrate and neonicotinoids data points were obtained from the following:

- Adams County
- Department of Geoscience at the University of Wisconsin - Madison
- Juneau County
- Portage County
- Wisconsin Department of Agriculture, Trade and Consumer Protection
- Wisconsin Department of Natural Resources
- Wood County
- University of Wisconsin Stevens Point (DeVita & McGinley, 2021) (the sample date for the measurements collected with POCIS was assigned to be the mid date between the deployed and retrieved dates)

Since most of the Public Water Systems (PWS) wells are part of a network of wells that cover a broader area, it would be challenging to relate the contamination levels found in an individual well to a specific location. For this reason, we decided to focus our data analysis on the nitrate and neonicotinoids data collected in other than PWS wells (private and monitoring wells). The nitrate data points collected in PWS is still included in the *Central Sands County Collaborative - Nitrate and neonicotinoids database* . We, unfortunately, had to discard about 10,000 nitrate data points where no decimal was specified. We realized that some of the measurements reported in one of the datasets did not report the decimal point (for example a 21.8 mg/l was reported as 218 mg/L).

Recovering and combining well information

For each measurement, we kept, at the minimum, nitrate or neonicotinoids concentrations, sample date, and well location. To better understand the relationship between contaminations and well characteristics, we also attempted to retrieve information on total well depth, casing bottom depth, static water level, construction date, and construction type. Most of the water quality datasets listed in the previous section did not carry information on well characteristics, despite reporting in some cases the Wisconsin Unique Well Number (WUWN). Our primary approach for recovering well characteristics consisted of 1) merging multiple datasets that specified well characteristics for each WUWN; 2) establishing a one-to-one relationship based on the WUWN between the merging product of point 1 and the water quality datasets.

The first step of the merging strategy consisted of comparing the information reported from the datasets listed in the previous section and a Wisconsin Geological and Natural History Survey (WGNHS) groundwater database (GDB). The GDB database includes well coordinates and well characteristics for some of the wells of the CSGCC area but also specifies the resolution of the well location (meters, centroid of a town or a county, or unverified location). By comparing the datasets, we found that not only incongruous well characteristics were reported, but also different well locations were assigned to individual wells. To reconcile differences among datasets, we adopted the following strategies for the well location and the well characteristics.

Well location. We kept a specific PLSS section value for each well location if the value reported was consistent among datasets or only one value was available. For each measurement, we also specified the source of the data and the resolution of the location, i.e., if the PLSS section was derived from latitude and longitude points, address geolocation, section/township/county/state centroid, etc. If incongruous values were reported for each well location, we kept the information with the highest location resolution. For this study, we discarded data points sampled in wells that were reported with a location resolution worse than a section. For example, we initially compiled over 80,000 nitrate measurements in other than PWS (mostly private and monitoring wells). Of these, over 5,000 measurements were collected in wells with a location resolution of a “State centroid”, meaning that these wells could be located anywhere in the State and in other counties than the CSGCC ones.

Well characteristics. We kept a specific value for each well location or characteristic (PLSS section, well depth, casing depth, static water level, construction type, or construction date), and marked each field as accurate if the value reported was consistent among datasets or only one value was available. If incongruous values were reported for each well characteristic, we flagged the field as non-accurate, and we kept the information according to the following hierarchy: keep the value from the WGNHS dataset; if the above-mentioned dataset is not available, keep the value from the DNR datasets; if above-mentioned datasets are not available, keep the value from individual county datasets. We also flagged some well characteristics as not accurate if the well depth reported was shallower than the static water level or the casing bottom depth, or if the construction date was reported to be after the sampling date. Table 1 summarizes the count of well characteristics marked as accurate for each water quality dataset. Valid information on well characteristics have been found only for less than half of the other than PWS wells.

Well depth values	Static water level values	Casing bottom values	Construction date	Construction type	Total	Data type
33,614 (45%)	26,907 (36%)	29,526 (40%)	29,562 (40%)	10,097 (14%)	73,977	Nitrate other than PWS
857 (34%)	630 (25%)	702 (28%)	744 (29%)	292 (12%)	2,537	Neonicotinoids other than PWS

Table 1. Well characteristics marked as accurate for each water quality dataset (Nitrate in other than Public Water Systems (PWS), Neonicotinoids in other than PWS.

Using the WGNHS well database (GDB, private), the Groundwater Retrieval Network (Wisconsin Department of Natural Resources, 2022b), and the nitrate datasets mentioned in the previous paragraph, we created a dataset with the wells and respective well info located in the CSGCC counties. We will hereafter refer to this dataset as the WDB dataset (short for well database). We estimated that over 67,000 wells are located in the CSGCC counties (including PWS and potential abandoned wells). Of these wells, over 46,000 have private use.

Duplicate check

In over 70 years of sampling, water quality data has been shared among different agencies and a single data point may have been included in several datasets. When multiple records are combined, a duplicate check and a deduplication process are necessary to minimize errors in the data analysis and interpretation. Since neonicotinoids data points were mostly provided by DATCP, and only two measurements were compiled from the USGS water quality website, we only performed a duplicate check for the nitrate data. The duplicate check strategy consisted of comparing pairs of datasets based at least on well location (PLSS section), nitrate level, and sample date. Since nitrate levels were often reported with different decimal approximations, we also compared data using the nearest integer nitrate level. If the information on sample ID or WUWN were reported in the pair of datasets, we also used these for performing the duplicate check. Whenever duplicates were found, we discarded the data with the least amount of information.

Discarding data collected after treatment systems

To evaluate the true state of the groundwater quality, we attempted to discard samples collected from treated water, i.e., collected after a treatment system. We did not have a direct way to assess if nitrate and neonicotinoids measurements were collected from untreated water. We assumed all the samples were collected from untreated systems. However, the UWSP and the Portage County water quality datasets include some information on hardness, alkalinity, and conductivity. We flagged samples as treated if they had measurements with a low nitrate value, alkalinity and hardness values less than 20 mg/L as $CaCO_3$, and conductivity values <50 µS/cm. Treated measurements were discarded from our datasets.

Other data compiled

For this study, we focused on assessing how factors like well characteristics, soil properties, and land use affect nitrate and neonicotinoids contamination in groundwater. We described how we retrieved information on well characteristics in the section “Recovering and combining well information”. Soil data for the CSGCC area were downloaded from the USDA Web Soil Survey (United States Department of Agriculture, 2022). Since soil properties vary in the three dimensions, we needed a strategy to simplify the statistical analysis process. For each soil map unit (mukey), we kept the soil component (or series) with the highest occurring percentage. A soil component is characterized by several horizons, with different thicknesses and soil properties. We calculated the average hydraulic conductivity, organic matter content, and clay content weighted by the thickness of each horizon. By knowing the area of each section and the area of the different soil map units within a section, we estimated the percentage of coverage of each map unit within a section. The hydraulic conductivity, organic matter content, and clay content were averaged, weighted by the percentage of map unit coverage within a section.

Wiscland 2.0 was used as the land use dataset (Wisconsin Department of Natural Resources, 2019). By knowing the area of each section and the agricultural area within each section, we estimated the percentage of agricultural land use per section. To identify historical changes in agricultural land use, we also adopted the same approach to estimate the percentage of agricultural land use pre 1950 for each section. To this scope, we used the agricultural land use map derived by the Bordner Survey (Forest Landscape Ecology Lab, University of Wisconsin-Madison, 1935).

To create a comprehensive database, we also compiled information on address points, area served by municipal wells, biosolid spreading, manure storage locations, septic systems, and spills. The data is included in the *Central Sands County Collaborative - Nitrate and neonicotinoids database*.

Gap analysis

One of the main goals of this study is to identify spatio-temporal gaps in the data. Because neonicotinoids data points were only recently collected, and the data coverage is still limited to a few sections, we focused gap analysis mainly on the nitrate dataset. Spatio-temporal gap analysis could be used to assess if contamination trends can be identified over time and to drive future sampling strategies. To these aims, we developed section-averaged nitrate concentrations maps at time intervals of 10 and five years (1953-1967, 1968-1977, 1978-1987, 1988-1992, 1992-1996, 1997-2001, 2002-2006, 2007-2011, 2012-2016, 2017-2022). We estimated the total amount of nitrate measurements collected, wells sampled, and sections sampled over time. By knowing the number of sections sampled and the number of sections located in each CSGCC county, we calculated the percentage of sections sampled per county over time.

The CSGCC well dataset and the septic systems dataset were used to develop a map with the count of wells and septic systems per section. Knowing which sections have wells and/or septic systems and in which section nitrate data was collected, we identified the sections (with at least one well or a septic system) that were never sampled, and the sections that were not sampled in the last 10 years.

Identifying trends in the data

With over 70 years of nitrate data collected and extensive time-series data, we aimed to identify trends in the data. We primarily focused on assessing if a linear upward, downward trend or no trend existed in nitrate concentrations over time. To this goal, we estimated the average nitrate concentration for each sampling year for each township. Linear regression was used to establish if the average nitrate concentrations increased, decreased, or remained stable over time.

To track the extent of the nitrate contamination with depth, we also explored the relationship between nitrate concentrations and the casing bottom depth minus the static water table (at the time of construction). We only considered nitrate measurements collected in wells where we recovered accurate records on water table depth and casing bottom depth.

Statistical analysis

Logistic regression models are statistical methods to determine the probability of an event given an input variable. The probability of an event must have a binary outcome, such as yes or no, or true or false. Each test will produce a p-value, which is a measure of how likely real the relationship between the two variables is. If the p-value is less than 0.05, the relationship is statistically significant and the null hypothesis (that the two variables are related) is true. In our case, the event is either having nitrate concentrations above 10 mg/L (Enforcement Standard established by the Wisconsin Administrative Code NR 140), or having neonicotinoids concentrations above laboratory reporting limits, i.e., detected. The input variables we consider for the two events are: well age (year 2022 minus well construction year), well depth, soil properties, number of septic systems (for nitrate only), percent of agricultural land use per section. For establishing the relationship between agricultural land use and nitrate contamination in groundwater, we only considered the sections that with same percentage of agricultural land use over time (with a tolerance of ± 10%). We identified these sections by comparing the agricultural land use in the 1930s of the Bordner Survey (Forest Landscape Ecology Lab, University of Wisconsin-Madison, 1935) with the recent agricultural land use layer of Wiscland 2.0 (Wisconsin Department of Natural Resources, 2019).

Results: nitrate

Nitrate concentrations in the CGSCC counties

Nitrate concentrations above 10 mg/L are localized along a regional groundwater divide, in a region, trending N-S, that includes several sections of Adams, Portage, and Waushara County. Figure 1 shows the average nitrate concentration per section. This map includes all the nitrate data collected in private and monitoring wells from 1953 to 2022. Outwash, end moraine, and tunnel channel deposits are predominant in this area (Hart, et al., 2020). Concentrations of nitrate in groundwater above drinking water standards are also found in several sections of northeast Juneau County.

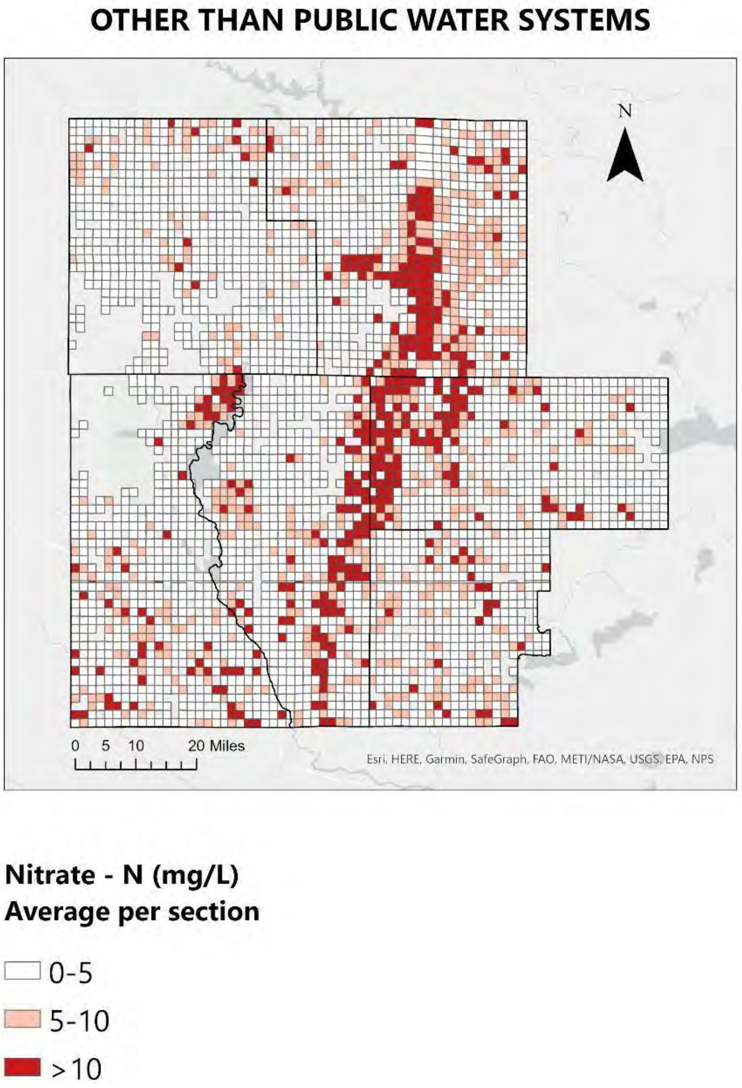

Figure 1. Nitrate concentration (mg/L) averaged for each PLSS section.

Gaps in the data

Overall, nitrate sampling remained constant since the early 2000s. Nitrate sampling has, however, not always been the same among the six CSGCC counties. Figure B 1 in Appendix B shows the number of measurements, wells, and sections sampled for nitrate from 1953 to 2021 (time intervals of five years). We excluded the 2022 measurements because we only compiled data points until February 2022. The number of wells is only an estimate since not all the data is reported with a WUWN. Before the 1970s, we have records of very few nitrate samples in the CSGCC counties. Sampling started to rapidly increase after 1980. Between 2006 and 2011, less data points were collected, and fewer wells were sampled compared to previous years. As shown in Figure B 2 of Appendix B, we have records of nitrate data collected in Portage County starting from the late 1960's. Sampling in the remaining counties ramped up only after 1980. Currently, all the CSGCC counties have a similar percentage of section sampled (calculated using the total number sections per county), and hence a similar coverage of data. Detailed maps of nitrate concentrations over time are provided in Figures B 3 to B 12 of Appendix B.

Using the WDB (well database, see section “Recovering and combining well information”), and the septic systems dataset, we identified the sections in the CSGCC counties with at least one well or one septic system. We then compared these sections with the ones where nitrate records were found. As a result of the comparison, we developed a map estimating in which sections nitrate data points were never collected, and in which sections nitrate data points have not been collected in the last 10 years (Figure 2).

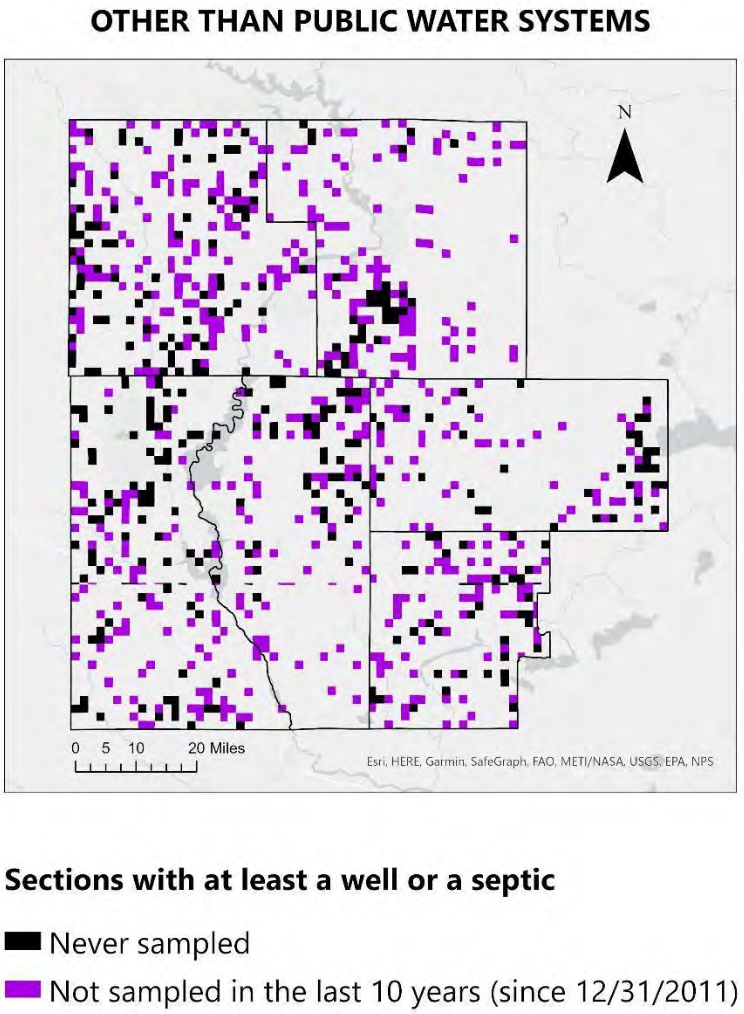

Figure 2. Sections (with at least one well or a septic system) where nitrate data points were never collected (black) or have not been collected in the last 10 years (purple).

Trends (or no trends) in the data

No clear upward or downward linear trends between yearly-averaged nitrate concentration and year of sampling were found for most of the townships in the CSGCC counties. For example, Figure 3 shows the yearly average nitrate concentration versus the sampling year for the township 14N8E in Waushara County. The goodness of fit is very low ($R^2 = 0.063$), and the average nitrate concentration is overall on a stable trend at least since 2003.

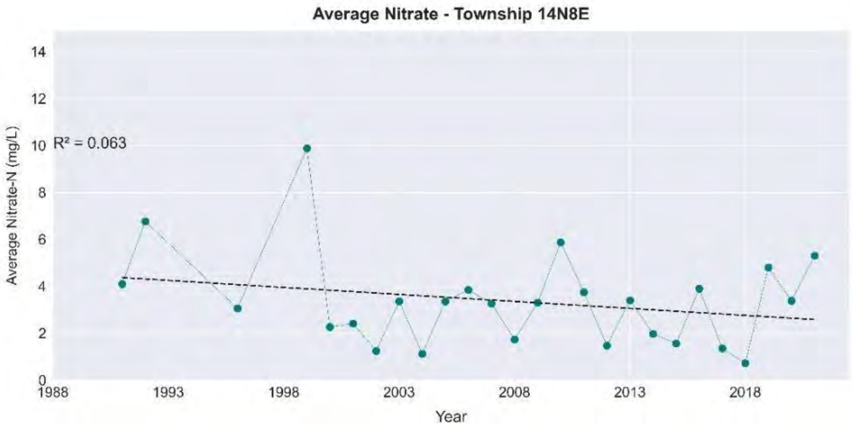

Figure 3. Yearly average nitrate concentration in the township 14N8E. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship.

To track the extent of the nitrate contamination with depth, we plotted individual measurements collected in each township (points) versus the difference between the casing bottom depth and the static water level. The difference has positive values if the casing bottom is reported to be shallower than the static water table. Vice versa, the difference has a negative value if the casing bottom depth is deeper than the water table. Each data point was also colored based on the sample collection date: older measurements are colored in red, more recent measurements are colored in blue. For example, Figure 4 highlights that nitrate concentrations over 10 mg/L in the township 14N8E were found at a maximum depth of 80 feet below the water table. Most recent measurements (dark blue) show that exceedances of nitrate drinking water standards are found at a maximum depth of 50 feet below the water table. This type of plot can be also used to quickly estimate the number of nitrate samples collected and timing of sampling for each township.

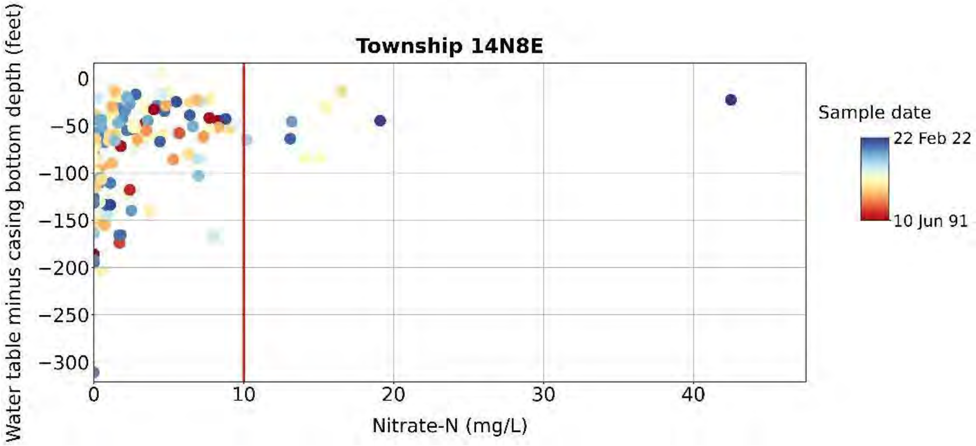

Figure 4. Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

Plots of Figures 3 and 4 for other townships in the CSGCC counties can be found in Appendix C. If graphs are not shown for a certain township, less than four data points were available in that township.

Factors influencing nitrate contamination

The probability of having nitrate above drinking water standards is higher if the well is an older well. Figure 5 shows the result of the binomial logistic regression between the probability of having nitrate greater than 10 mg/L and the well age (year 2022 minus the well construction year). For example, if the well is about 60 years old, there is a 15% probability that the nitrate is greater than 10 mg/L.

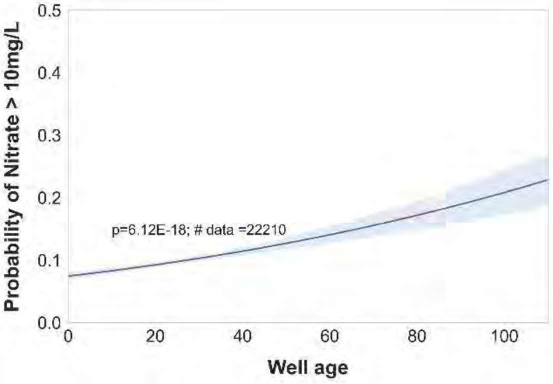

Figure 5. Probability of having nitrate concentrations greater than 10 mg/L based on the well age (positive trend). The p-value is less than 0.05. We used 22,210 data points to check this relationship. Blue shaded area is the 95% confidence interval.

The probability of having nitrate above drinking water standards decreases as the well depth increases (Figure 6). For example, if the well is over 300 feet deep, there is almost a 0% probability that the nitrate concentration is greater than 10 mg/L.

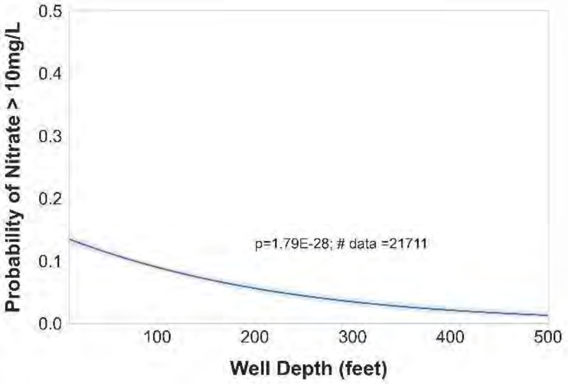

Figure 6. Probability of having nitrate concentrations greater than 10 mg/L based on the well depth (negative trend). The p-value is less than 0.05. We used 21,711 data points to check this relationship. Blue shaded area is the 95% confidence interval.

Weighted soil hydraulic conductivity, clay content and organic matter are also factors influencing the nitrate concentrations in the CSGCC counties. The probability that nitrate is greater than 10 mg/L increases as the weighted soil hydraulic conductivity increases (Figure B 16 of Appendix B). On the contrary, the probability that the nitrate concentration exceeds the drinking water standards is lower as the weighted clay content or organic matter content increases (Figures B 17 and B 18 of Appendix B). Maps of weighted hydraulic conductivity, soil content, and organic matter are included in Figures B 13, B 14, and B 15 of Appendix B.

The number of septic systems per section doesn't seem to influence the nitrate contamination in the CSGCC counties. Figure 7 shows the probability that nitrate is greater than 10 mg/L decreases if the number of septic systems per section increases. This is because the sections with high nitrate concentration (Figure 1) do not correspond to the sections with high number of septic systems (Figure B

19 of Appendix B). Since septic systems are dependent on land use, multivariate models may be better tools to use to discern how the effect of the number of septic systems versus the land use.

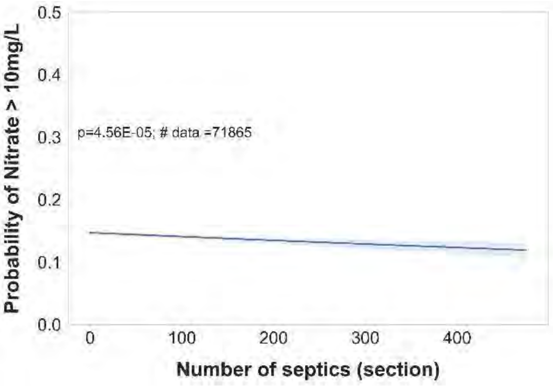

Figure 7. Probability of having nitrate concentrations greater than 10 mg/L based on the number of septic systems per section (negative trend). The p-value is less than 0.05. We used 71,856 data points to check this relationship. Blue shaded area is the 95% confidence interval.

Nitrate concentrations in groundwater are likely to exceed the drinking water standards as the percent of agricultural land use per section increases (Figure 8). For example, if the agricultural land use within a section is greater than 80%, the probability of having nitrate concentrations greater than 10 mg/L ranges between about 50% and 70%. To establish this relationship, and avoid bias due to the timing of sampling, we only considered the sections that did not have a change in percentage of agricultural land use over time (see paragraph "Statistical analysis"). The historical percentage of agricultural land use is included in Figure B 20 of Appendix B. The percentage of agricultural land use estimated by Wiscland 2.0 is included in Figure B 21 of Appendix B.

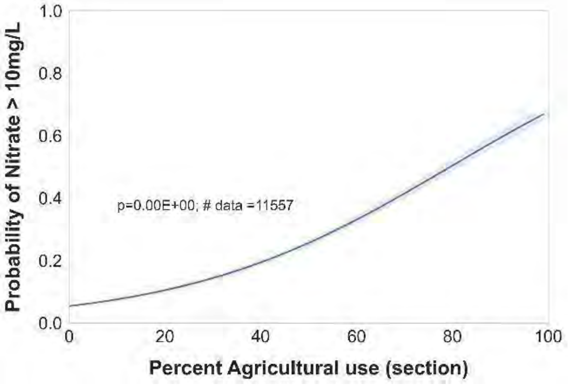

Figure 8. Probability of having nitrate concentrations greater than 10 mg/L based on the percentage of agricultural land use per section (positive trend). The p-value is less than 0.05. We used 11,557 data points to check this relationship. Blue shaded area is the 95% confidence interval. Only sections that did not change percentage of agricultural land use over time were considered (tolerance of ± 10%, comparison between the Bordner Survey and Wiscland 2.0)

Results: neonicotinoids

Neonicotinoids concentrations in the CGSCC counties

A total of 842, 845, and 850 groundwater samples were respectively tested for clothianidin, imidacloprid, and thiamethoxam between 2008 and 2021. Samples were collected in the same areas where high nitrate concentrations were found. Maps of clothianidin, imidacloprid, and thiamethoxam concentrations in groundwater are shown in Figures 9, 10, and 11.

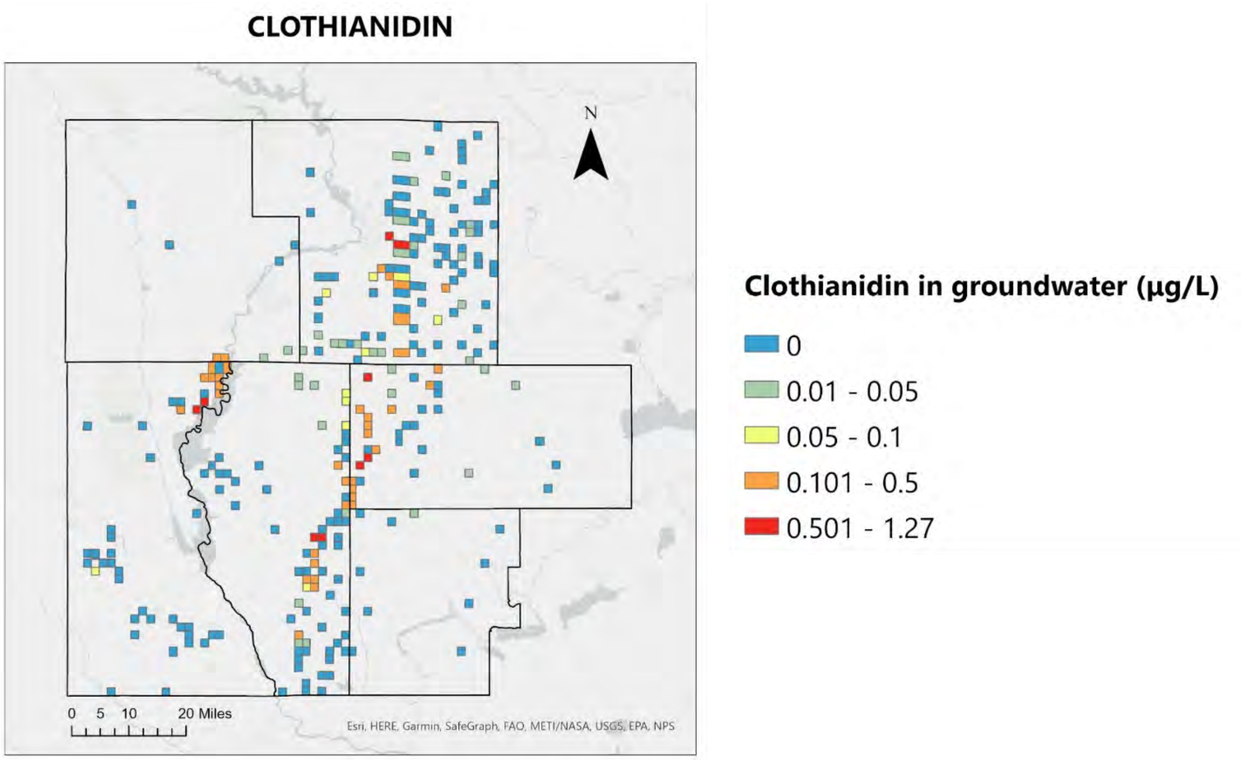

Figure 9. Clothianidin concentrations in groundwater.

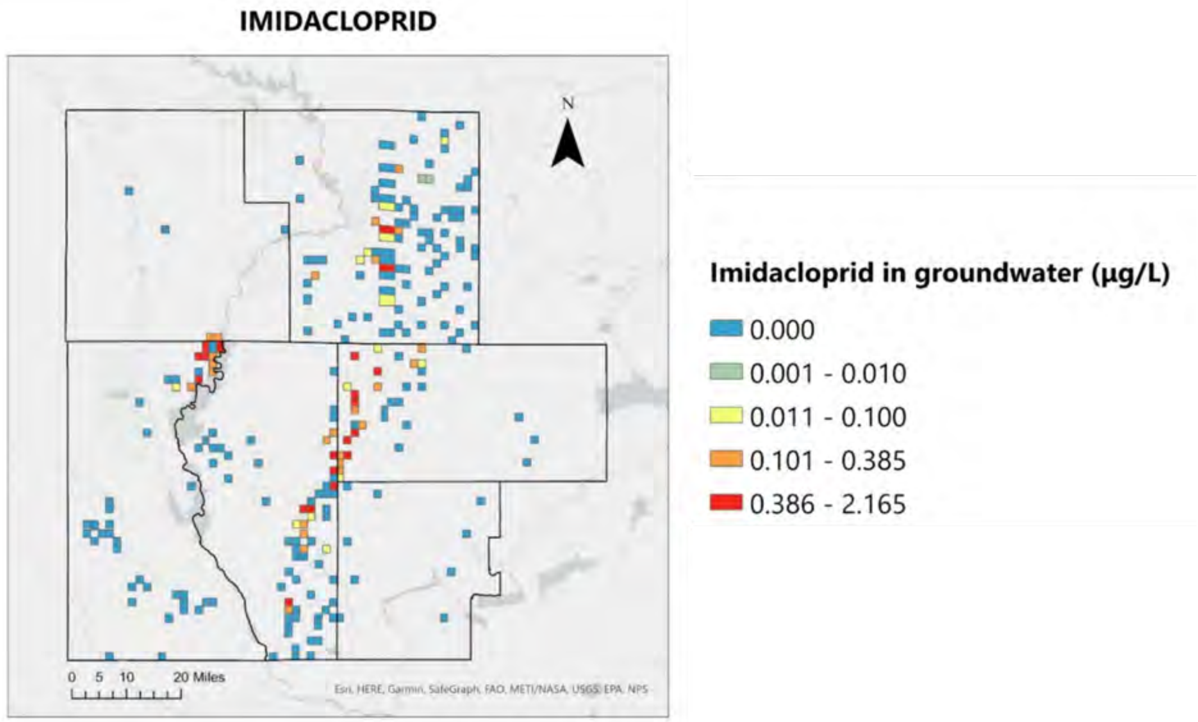

Figure 10. Imidacloprid concentrations in groundwater.

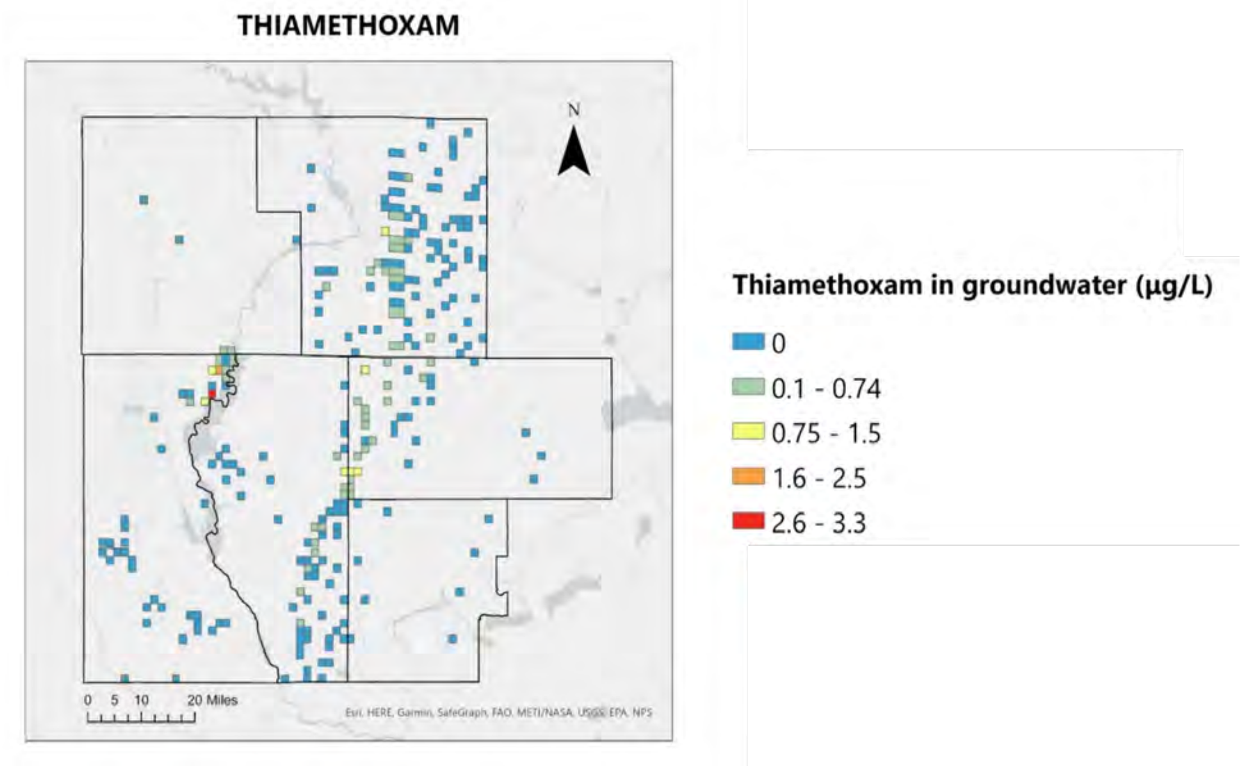

Figure 11. Thiamethoxam concentrations in groundwater.

Imidacloprid is the neonicotinoid compound that more often was detected in groundwater and more often exceeded the EPA chronic and acute Aquatic Life Benchmarks (ALB) for invertebrates (Table 2) compared to clothianidin and thiamethoxam. These trends, however, are not confirmed by surface water data: thiamethoxam is the most detected compound in surface waters (see Figures B 25 to B 27 and Table B 1 of Appendix B).

GROUNDWATER	Clothianidin	Imidacloprid	Thiamethoxam
Detected %	40	44	34
Exceeds ALB chronic %	37	44	10
Exceeds ALB acute %	0	15	0

Table 2. Summary of neonicotinoids' groundwater detection rates and percentage of samples exceeding the EPA chronic and acute Aquatic Life Benchmarks (ALB) for invertebrates. Clothianidin chronic and acute ALBs are 0.05 and 11 µg/L, respectively. Imidacloprid chronic and acute ALBs are 0.01 and 0.385 µg/L, respectively. Thiamethoxam chronic and acute ALBs are 0.7 and 17.5 µg/L, respectively.

More clothianidin, imidacloprid, and thiamethoxam data points have been collected in groundwater since 2008. The number of detects increased over time for each neonicotinoid compound; since 2019 clothianidin and imidacloprid have been detected in over 50% of the samples collected (Figure 12).

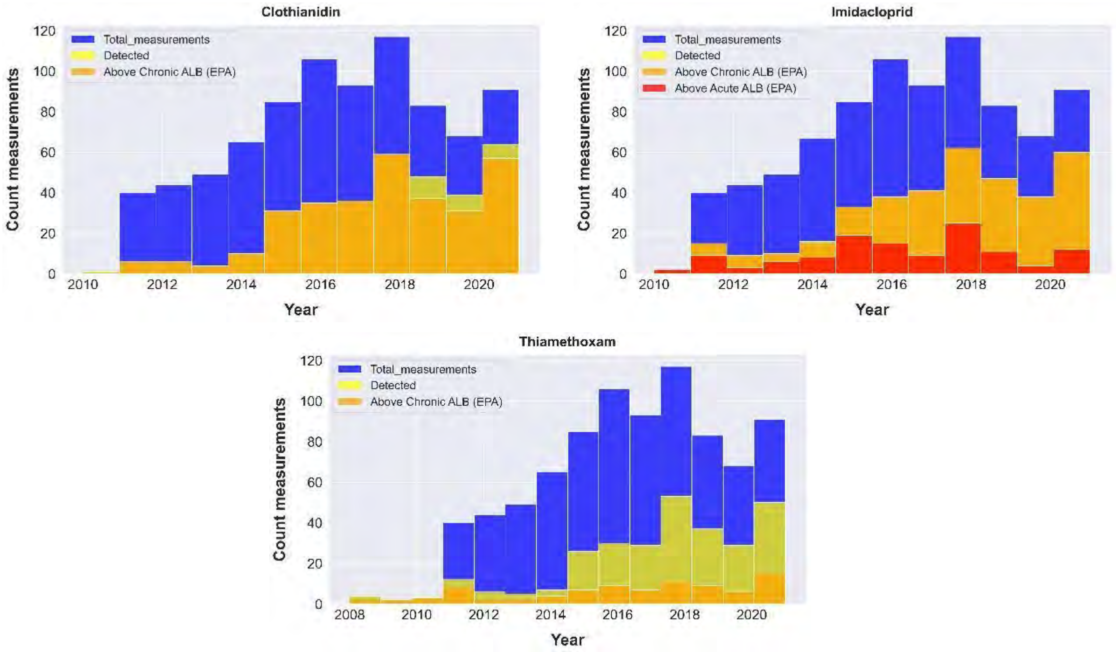

Figure 12. Count of total measurements, detects, and samples above chronic and acute EPA Aquatic Life Benchmarks (ALBs) for clothianidin, imidacloprid and thiamethoxam from 2008 to 2021.

Factors influencing neonicotinoids contamination

No relationship was found between neonicotinoid detection and well age (Figure B 28). The probability of detecting clothianidin, imidacloprid or thiamethoxam decreases as the well depth increases (Figure B 29). Soil properties seem also to influence neonicotinoids detection. The probability of detecting clothianidin, imidacloprid, or thiamethoxam in groundwater is higher when the soil hydraulic conductivity is higher, and the clay content and the organic matter content are lower (Figures B 30 to B 32). As for nitrate, the percentage of agricultural land use also affects the probability of detecting neonicotinoids: the higher the agricultural land use percentage, the higher the probability of neonicotinoids detection (Figure B 34).

Outreach

Outreach for the project was completed by a County Health Department and County Land and Water Conservation Departments from Adams, Juneau, Marquette, Portage, Wood, and Waushara Counties. At the beginning of the project outreach largely consisted of letting the public know about the project and its goals and objectives. This was completed through press releases to local media, letters to state government officials serving the six counties, and introductory presentations on the project in each of the counties. A website describing the project was developed and is linked on each of the County's websites for access to information (Wood County, University of Wisconsin - Madison, 2021).

As the project progressed, there was a desire to identify underserved audiences to ensure that we appropriately share information. A survey of the six counties was designed to identify underserved audiences within each County. This information was compiled into a PowerPoint database that identifies the locations of underserved audiences, outreach priorities for these audiences, potential communication and outreach challenges as well as areas where outreach already exists with these audiences.

For ease of communication and outreach about the project with both underserved audiences and special interest groups, an inclusive media contact list and special interest group contact list were developed and shared with the six counties. Special interest groups were invited to a mid-project update to learn more about the project and the findings.

An important component of the project outreach was developing the *Groundwater Quality Resource Guide - Focus on Nitrate and Neonicotinoids* (Appendix D). The guide is intended to serve as a compilation of currently available information regarding groundwater, nitrate, and neonicotinoids. The resources are intended to guide readers directly to the scientists, experts, agencies, groups, or relevant authorities on topics ranging from basic hydrology, historical overview, regulatory framework, strategies communities can employ, and more. For each topic, we wanted to introduce a variety of perspectives and approaches to consider when addressing groundwater contamination by nitrate and neonicotinoids. This guide is intended to serve a variety of audiences but provides extra focus on information pertinent to local decision-makers.

Conclusions and recommendations

We compiled over 70,000 nitrate and over 2,000 neonicotinoids data points collected in the private and monitoring wells of the Central Sands region of Wisconsin in the last 70 years. For each data point, in addition to compound concentration, we stored at least the location of the well location (with a resolution of a section) and sampling date. Additional neonicotinoids sample results in surface water, nitrate sample results in public water systems, well characteristics and locations, addresses, biosolid spreading, manure storage locations, soil properties, land use, and septic system were also collected and included in the *Central Sands County Collaborative - Nitrate and neonicotinoids database*. To combine data from multiple sources into a single dataset and ensure the accuracy and usefulness of the merged data, we paid close attention to data quality. Data formatting, data consistency (of the unit, decimal approximation, the information provided, etc.), data accuracy, and duplicate check were crucial steps in ensuring the quality of the data. Since most of the water quality datasets contained incomplete or incongruent information, data merging represented the largest challenge of this study. We suggest all the stakeholders, involved in data compilation, include data validation as a mandatory step before storing or sharing data.

Once the data merging was completed, we calculated the average nitrate or neonicotinoids concentration per section (Figures 1 and 11). The highest average nitrate and neonicotinoid concentrations in the CSGCC area were found along the regional groundwater divide and NE of Juneau County. Our nitrate results agree with what is shown in the Well Water Quality Viewer (University of Wisconsin – Stevens Point, 2022). This suggests that although the Well Water Quality Viewer contains fewer data points than what we considered for this study, it still includes a statistically significant sample size.

Gap analysis of the data highlighted that the number of samples increased over time for both nitrate and neonicotinoids. Nitrate data collection remained overall stable since the early 2000s. Through GIS we also identified which sections with at least a well or a septic system have never been sampled for nitrate (or we couldn't find any record of sampling) or have not been sampled in the last 5 years. This information could be extremely valuable to drive future sampling strategies in the CSGCC area. We were not able to conduct a spatial gap analysis on the neonicotinoids data since very few data points have been collected so far.

While we assessed that neonicotinoid detections increased starting from 2019 in the CSGCC area, we were not able to consistently identify increasing or decreasing trends in the groundwater nitrate concentration. Trends may be identified if future sampling strategies would focus not only on sampling wells where data is not currently available but also on resampling wells at consistent time intervals. We also summarized nitrate data for each township in graphs (Appendix C) that includes key information for estimating the number of data collected per township, the extent of the contamination below the water table, and if recent data is available for that area. These graphs may be used by stakeholders to better drive decisions on targeted sampling programs or to better assess which solution should be adopted in a certain area for providing safe drinking water (replacing the well with another well with deeper casing below the water table, treatment systems, etc).

Logistic regression models were used to assess what factors (well characteristics, land use, soil properties) mainly influence nitrate or neonicotinoids contamination in groundwater. We found that the percentage of agricultural land use within a section is the factor that highly affects the probability of detecting nitrate at concentration over the enforcement standard (10 mg/L). The higher the percentage of agricultural land use, the higher the probability that the nitrate concentration exceeds 10 mg/L. Clothianidin, imidacloprid, or thiamethoxam's probability of detection depends mostly on the percentage of agricultural land use per section and on soil properties. The higher the percentage of agricultural land use, the higher the probability that the neonicotinoids are detected. The higher the soil hydraulic conductivity, the higher the probability that the neonicotinoids are detected. The higher the clay content or organic matter content in the soil, the lower the probability that the neonicotinoids are detected. These conclusions may be used to drive targeted sampling and remediation strategies.

The product of this study provides a foundation upon which to build future collaboration. While this study ended, data compilation on nitrate and neonicotinoids contamination is an ongoing process that requires collaboration between various stakeholders, including researchers, policymakers, and members of the public. By working together and using the best available methods, we can better understand and address nitrate and neonicotinoid contamination to protect public health and safety.

Acknowledgment

We would like to thank Nancy Turyk and Lynn Markham for their contribution to the project. Peter Schoephoester, Ian Orland, Elizabeth Ceperley, and Grace Graham assisted with data checks and database publication. The authors would also like to thank all the members of the advisory committee for this project: Brian Austin, Jennifer Brand, John Exo, Jennifer Hauxwell, Krista Hood, Carrie Laboski, Kevin Masarik, Mark McColloch, and Stan Senger. Townships graphs of Appendix C were produced after personal communication with Matthew Silver. We appreciated the help and support of several DNR, USGS, and UW-Stevens Point staff: Jennifer Filbert, Aaron Fisch, Abby Johnson, Dave Johnson, Paul Juckem, and Alexis Peter.

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The *Central Sands County Collaborative - Nitrate and neonicotinoids database* is available for download at https://doi.org/10.48358/dwhy7257.

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Appendix A

Presentations and Awards (presenting authors underlined)

Romano C.R. (monthly from September 2021 to June 2022). CSGCC nitrate and neonicotinoids project updates. CSGCC Monthly meeting. Virtual and in-person meetings at the Hancock Agricultural Research Station (Hancock, WI). Number of attendees ≈ 20 to 30.

Romano C.R. (February 2022). *Nitrate gap analysis for the CGSCC project – preliminary results.* Citizens (Wood County) Groundwater Group Meeting. Virtual meeting. Number of attendees ≈ 15.

Romano C.R., Bradbury K.R., Parsen M.J., Sandwick N.D., McNelly J. (March 2022). *Nitrate and Neonicotinoid levels in the Central Sands Region of Wisconsin: what we know from decades of sampling.* 45th Annual Meeting - Wisconsin Section of the American Water Resources Association (AWRA). Virtual meeting. Number of attendees (at the presentation) ≈ 50.

Romano C.R. (March 2022). *Nitrate and Neonicotinoid levels in the Central Sands Region of Wisconsin: what we know from decades of sampling.* WPVGA Water Task Force Meeting. In-person meeting at the Heartland Farms (Hancock, WI). Number of attendees ≈ 20 to 30.

Romano C.R. (Anticipated April 2023). *Advancing the Use of Nitrate and Neonicotinoids Findings to Inform Groundwater Protection and Improvement Strategies – Final presentation*. In-person meeting with CSGCC counties and other stakeholders. Number of attendees ≈ 50 to 100.

Impact of Work

We compiled thousands of nitrate and neonicotinoid data collected in the groundwater of the Central Sands County Collaborative (CSGCC) region for the last 70 years. We create a publicly available database that not only includes nitrate and neonicotinoids data but also key information (well characteristics, land use, etc.) that are fundamental for data interpretation. This data compilation effort has no precedent in Wisconsin. In addition, to provide a comprehensive database, we created graphical tools (maps, graphs) and identified which factors influence nitrate or neonicotinoids contamination in the groundwater of the area. These will aid in the development of targeted sampling and mitigation strategies to ensure safe drinking water for all. Throughout the project, we communicated progress and findings with the CSGCC counties and other stakeholders. Please refer to the section "Outreach" of the report for more details on the communication strategy of this project.

Appendix B

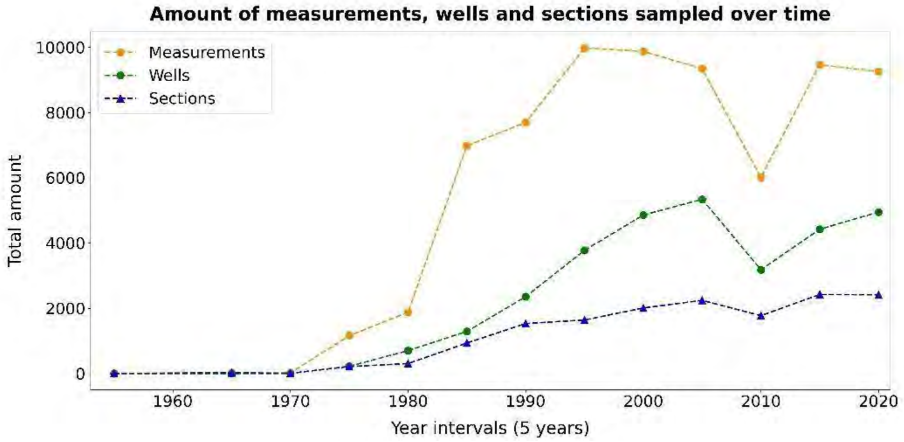

Figure B 1. Count of nitrate measurements collected (orange), wells sampled (green), and section sampled (blue) from 1953 to 2021.

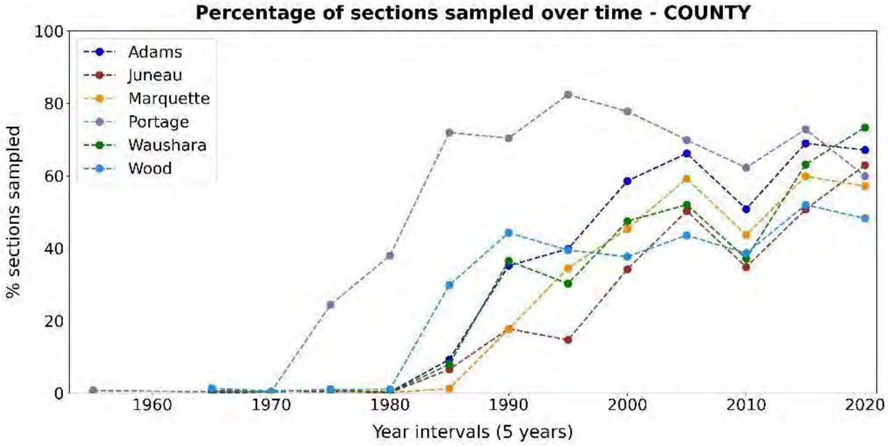

Figure B 2. Percentage of sections sampled per county from 1953 to 2021.

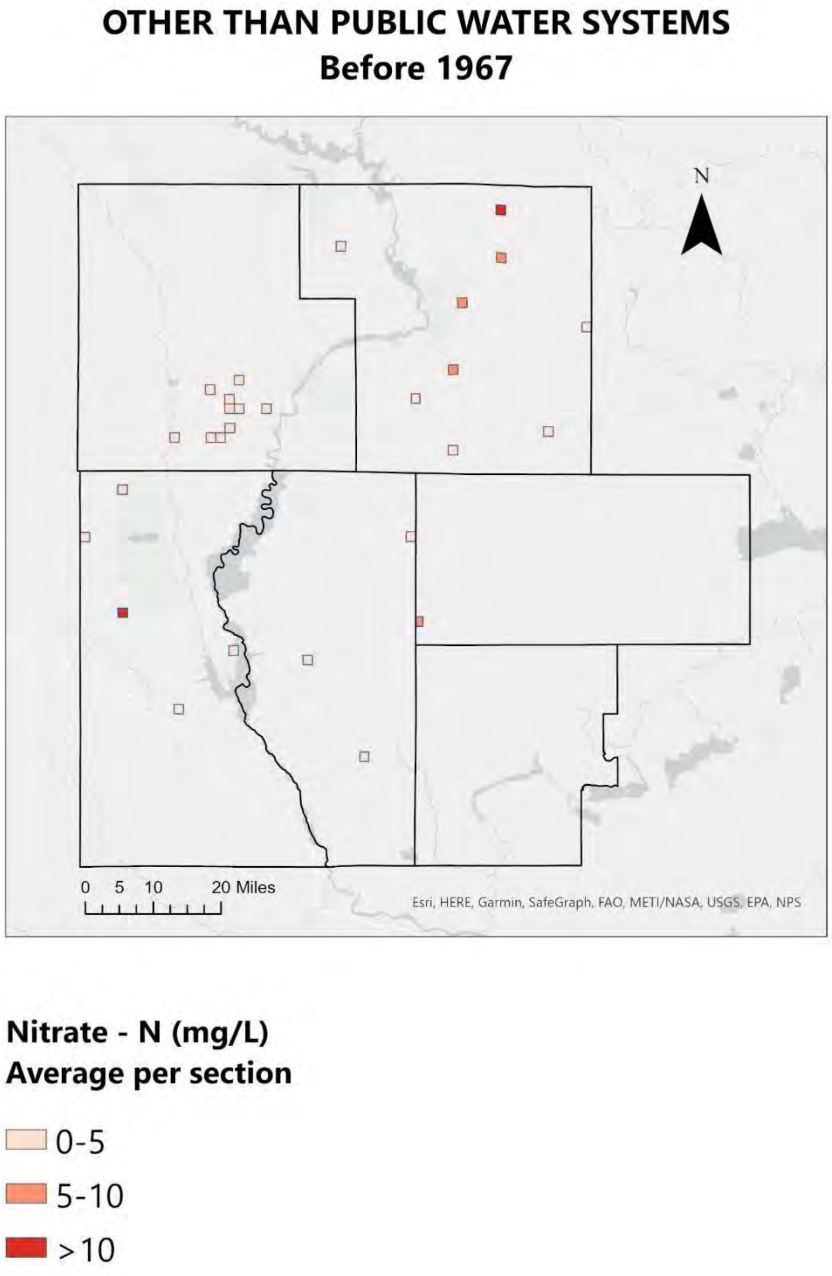

Figure B 3. Nitrate concentration averaged for each PLSS section, before 1967.

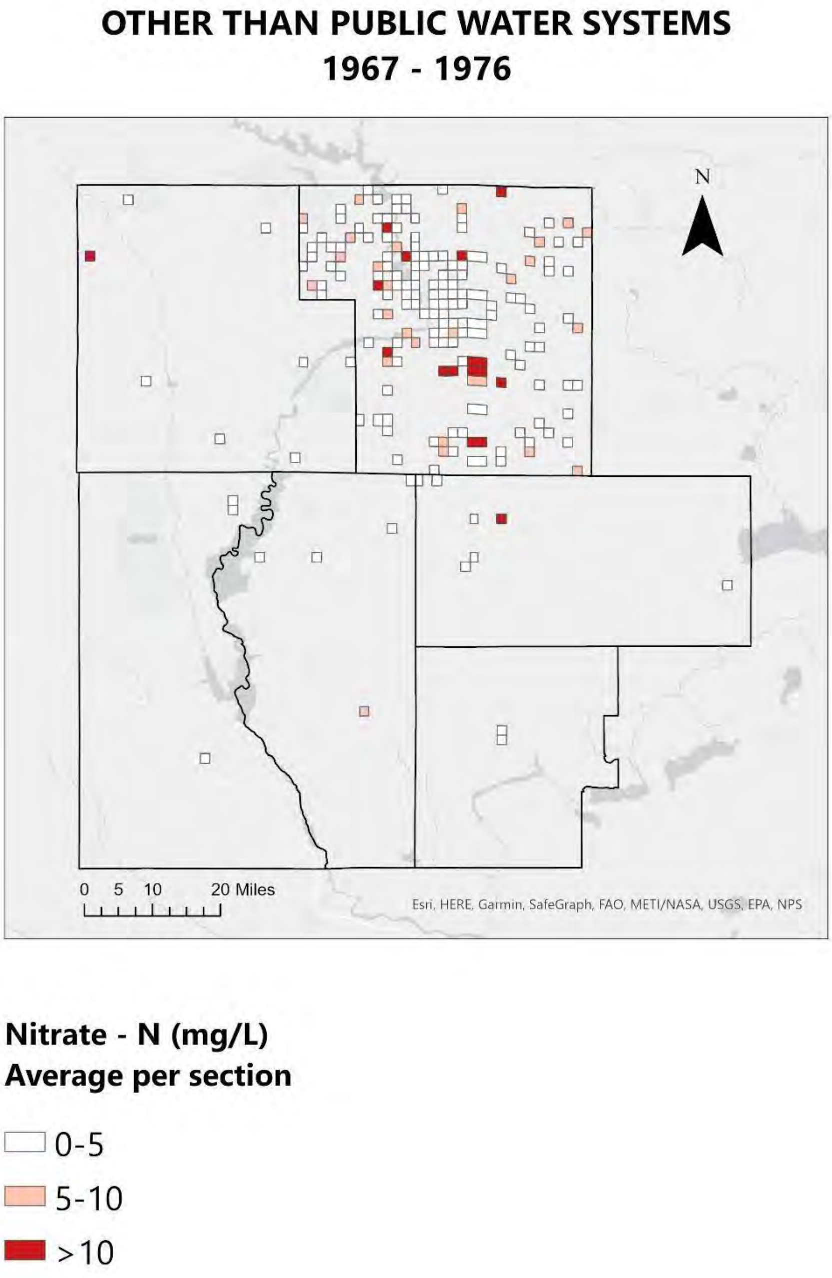

Figure B 4. Nitrate concentration averaged for each PLSS section, from 1967 to 1976.

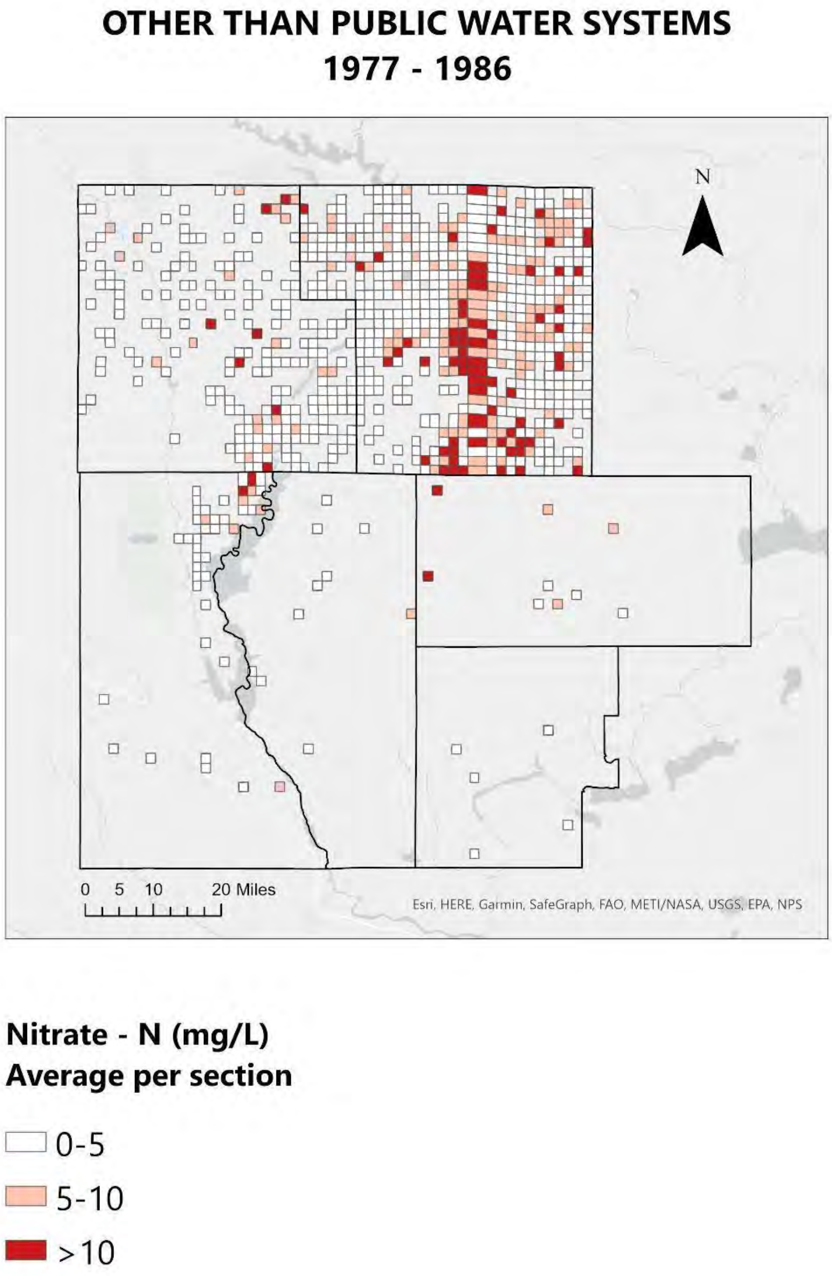

Figure B 5. Nitrate concentration averaged for each PLSS section, from 1977 to 1986.

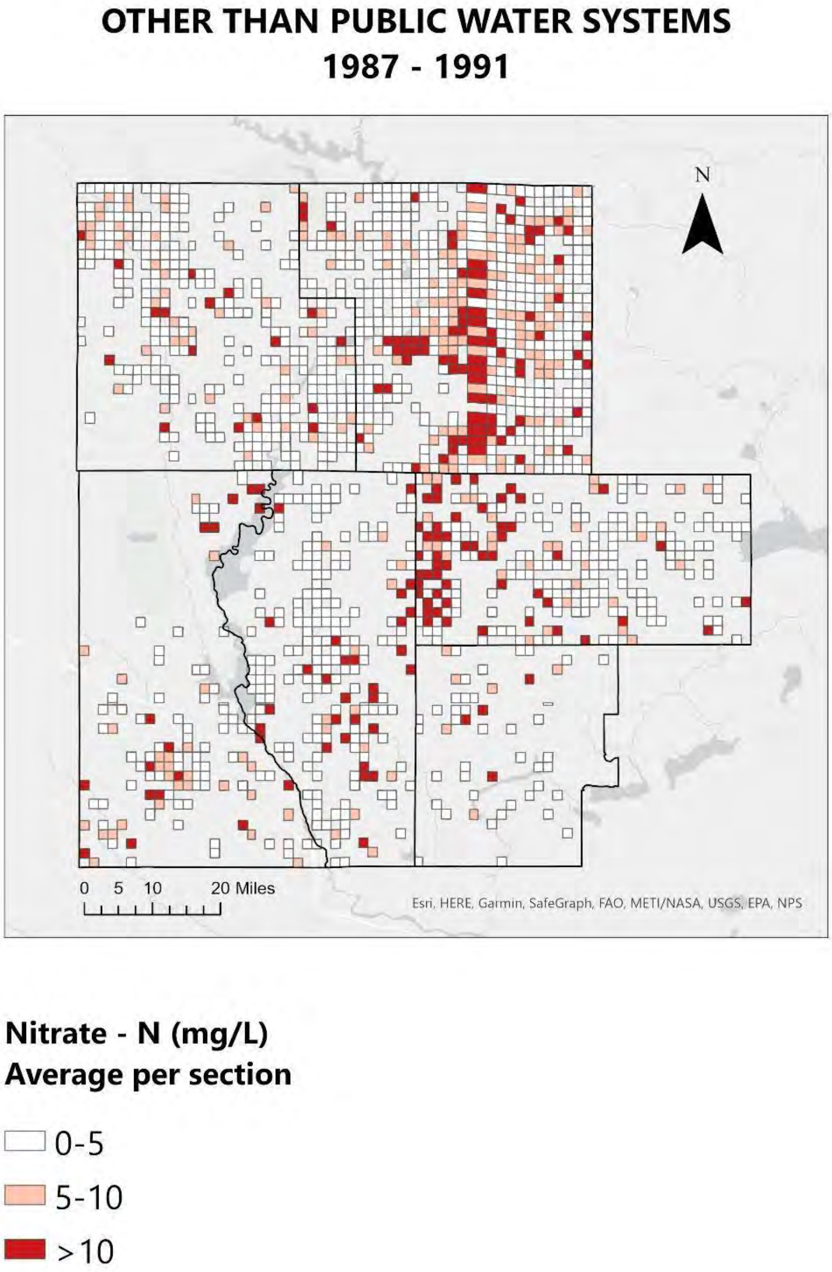

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Figure B 6. Nitrate concentration averaged for each PLSS section, from 1987 to 1991.

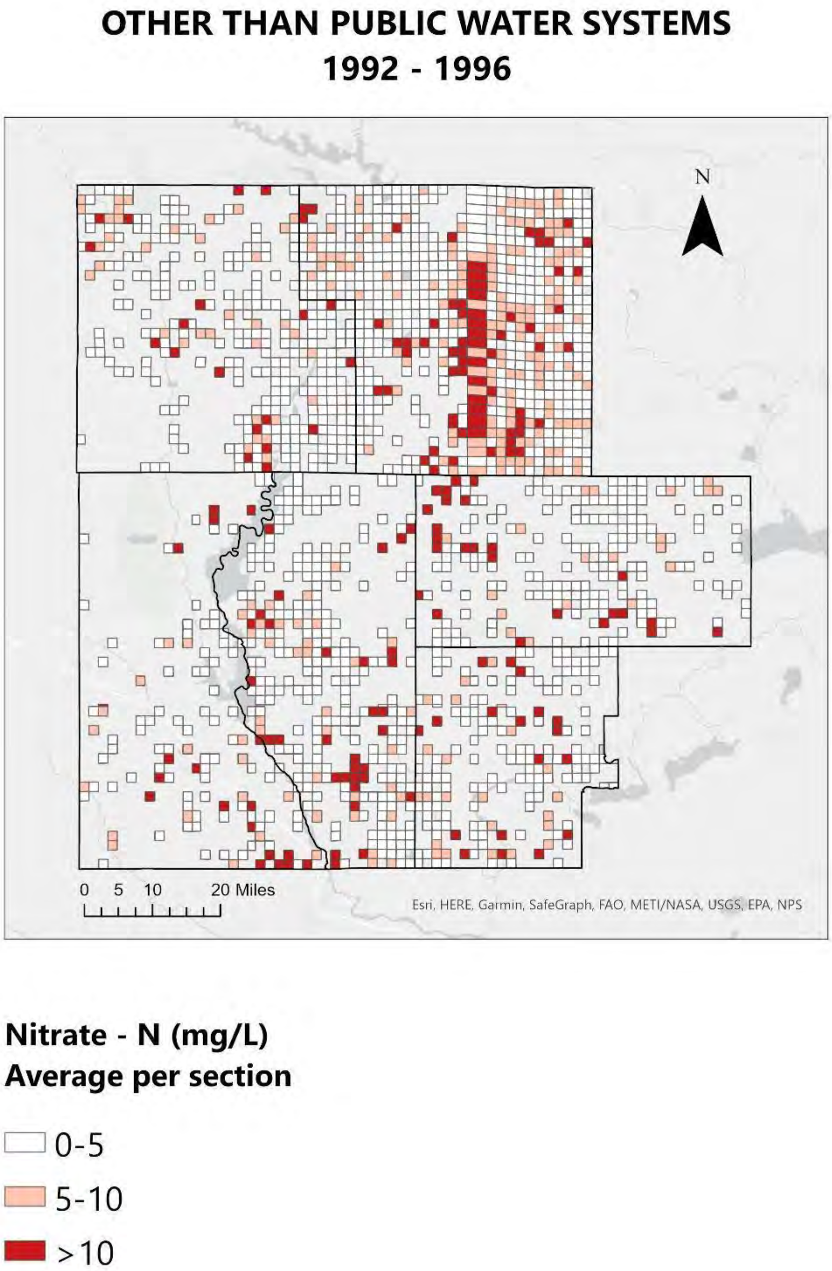

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Figure B 7. Nitrate concentration averaged for each PLSS section, from 1992 to 1996.

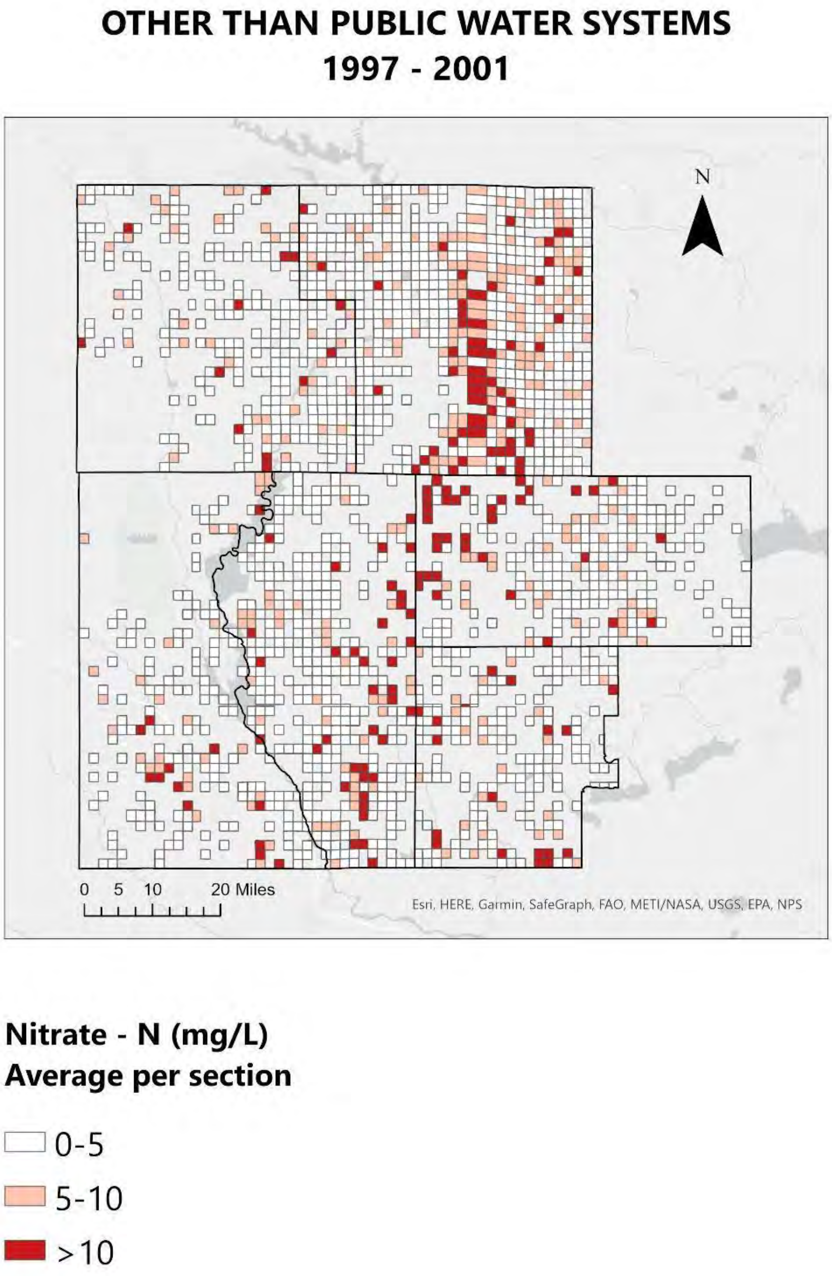


Figure B 8. Nitrate concentration averaged for each PLSS section, from 1997 to 2001.

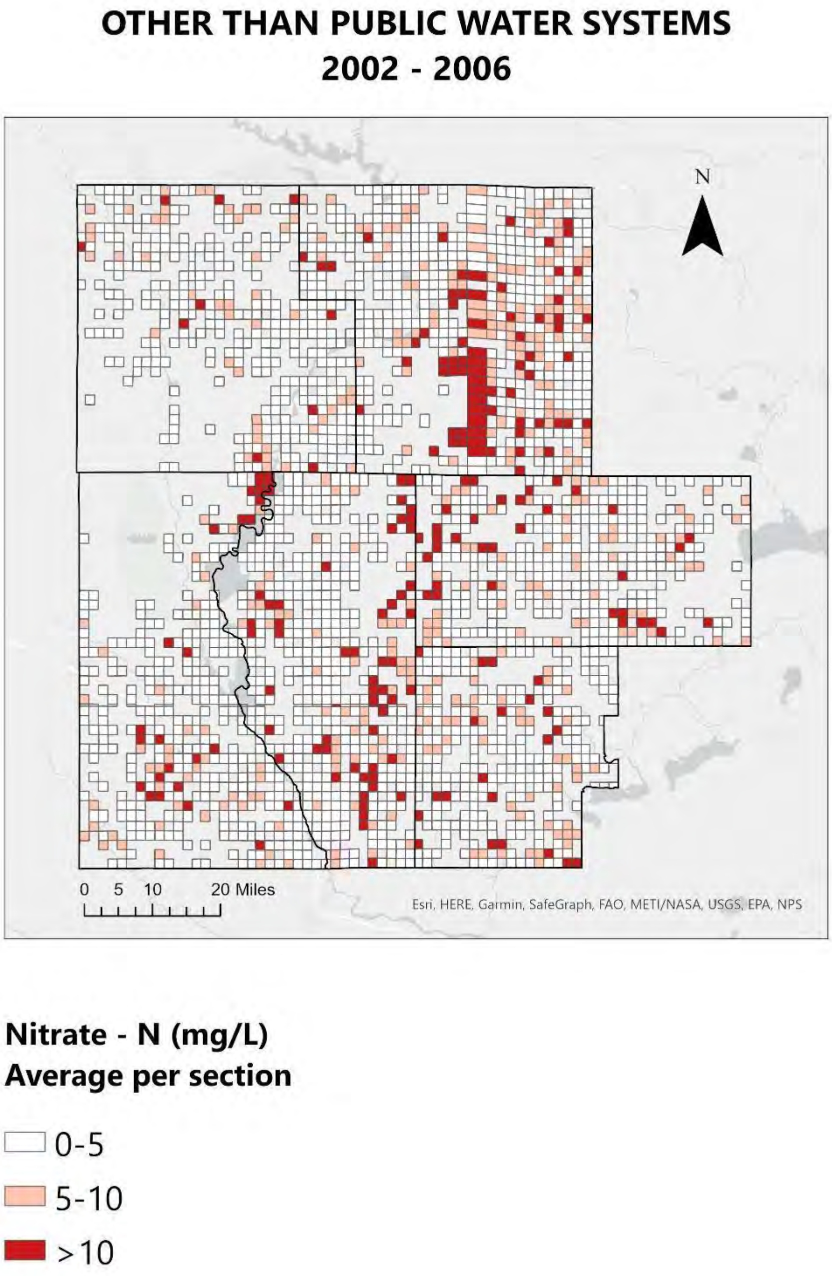


Figure B 9. Nitrate concentration averaged for each PLSS section, from 2002 to 2006.

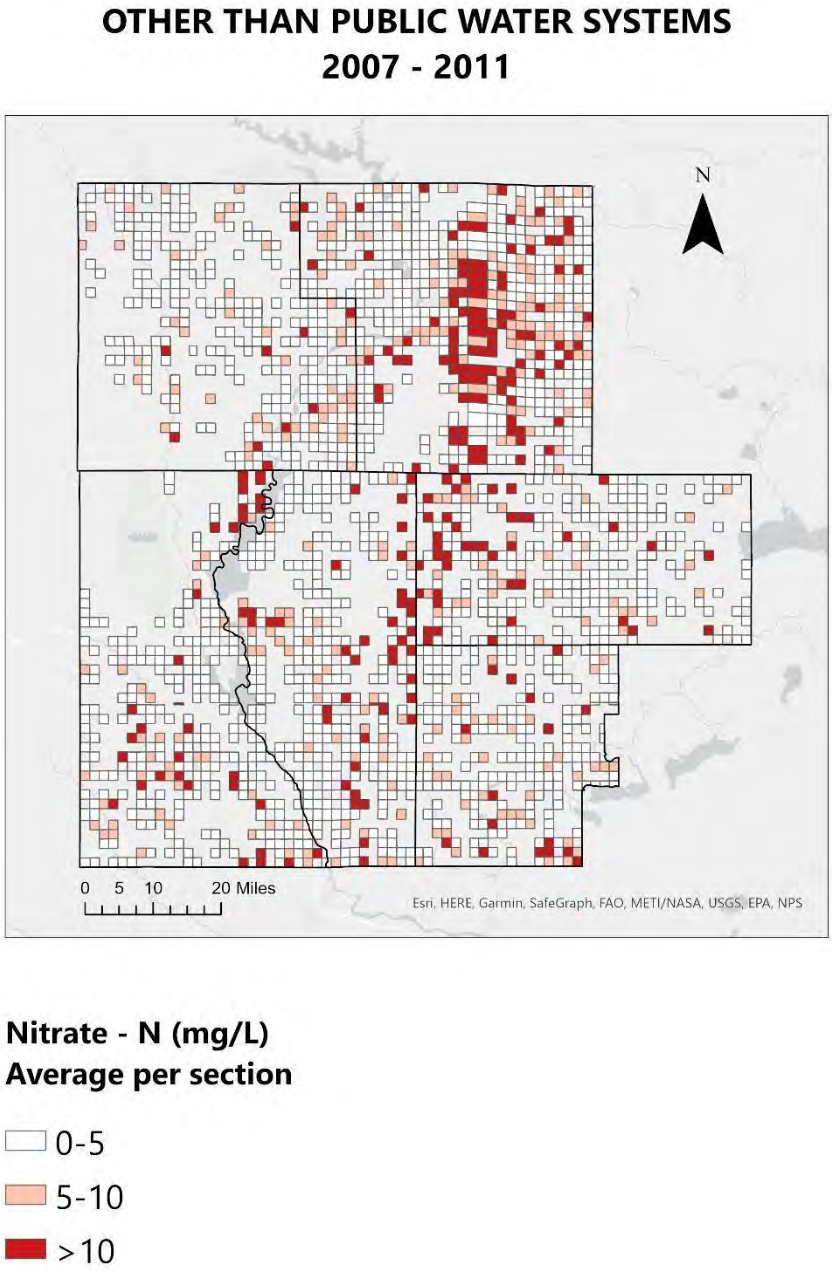


Figure B 10. Nitrate concentration averaged for each PLSS section, from 2007 to 2011.

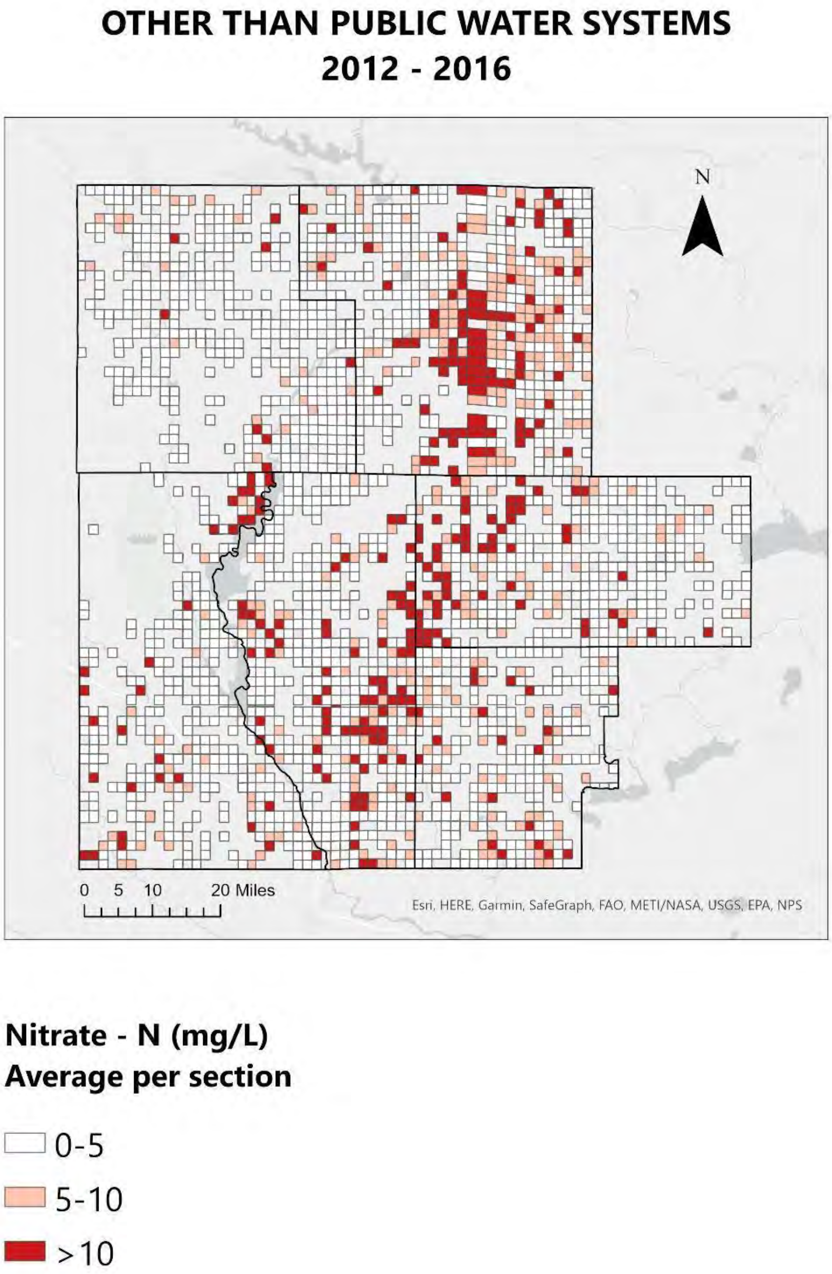


Figure B 11. Nitrate concentration averaged for each PLSS section, from 2012 to 2016.

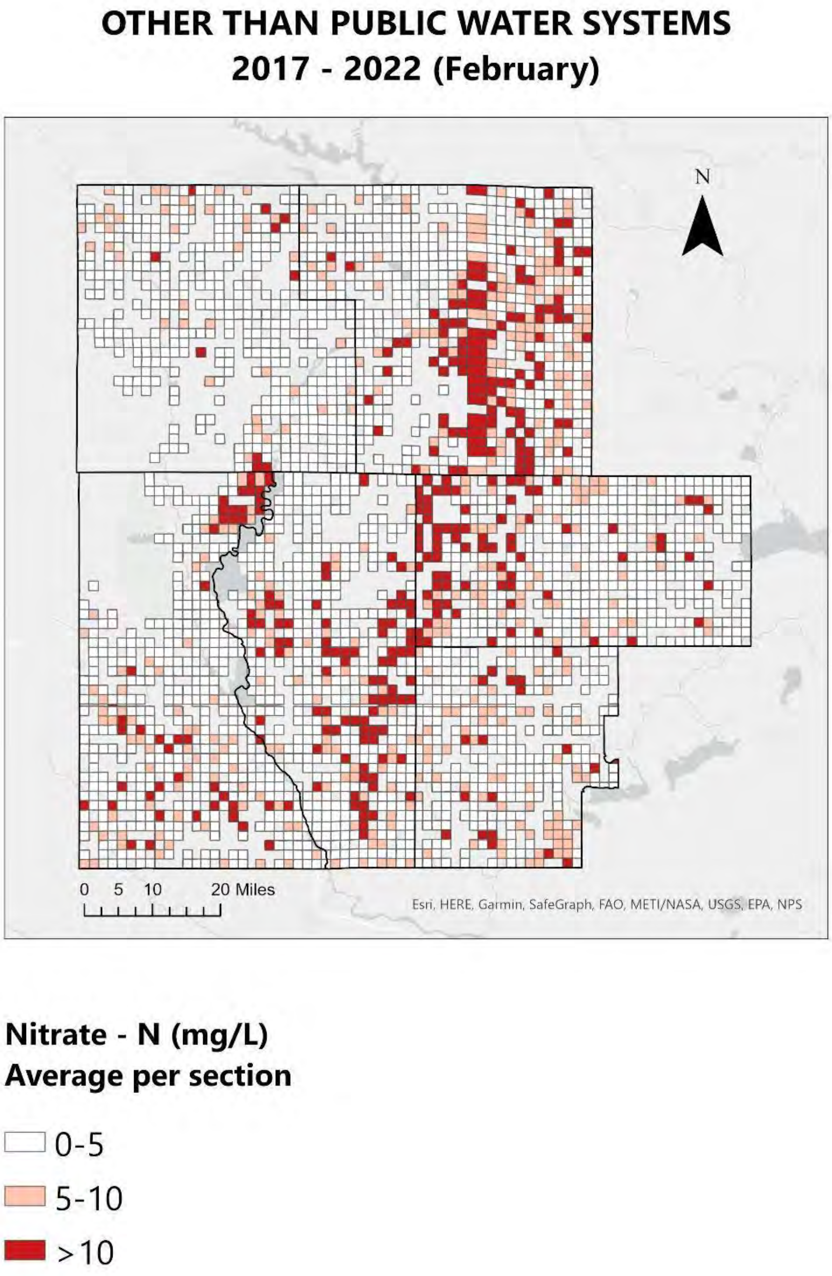


Figure B 12. Nitrate concentration averaged for each PLSS section, from 2017 to 2022.

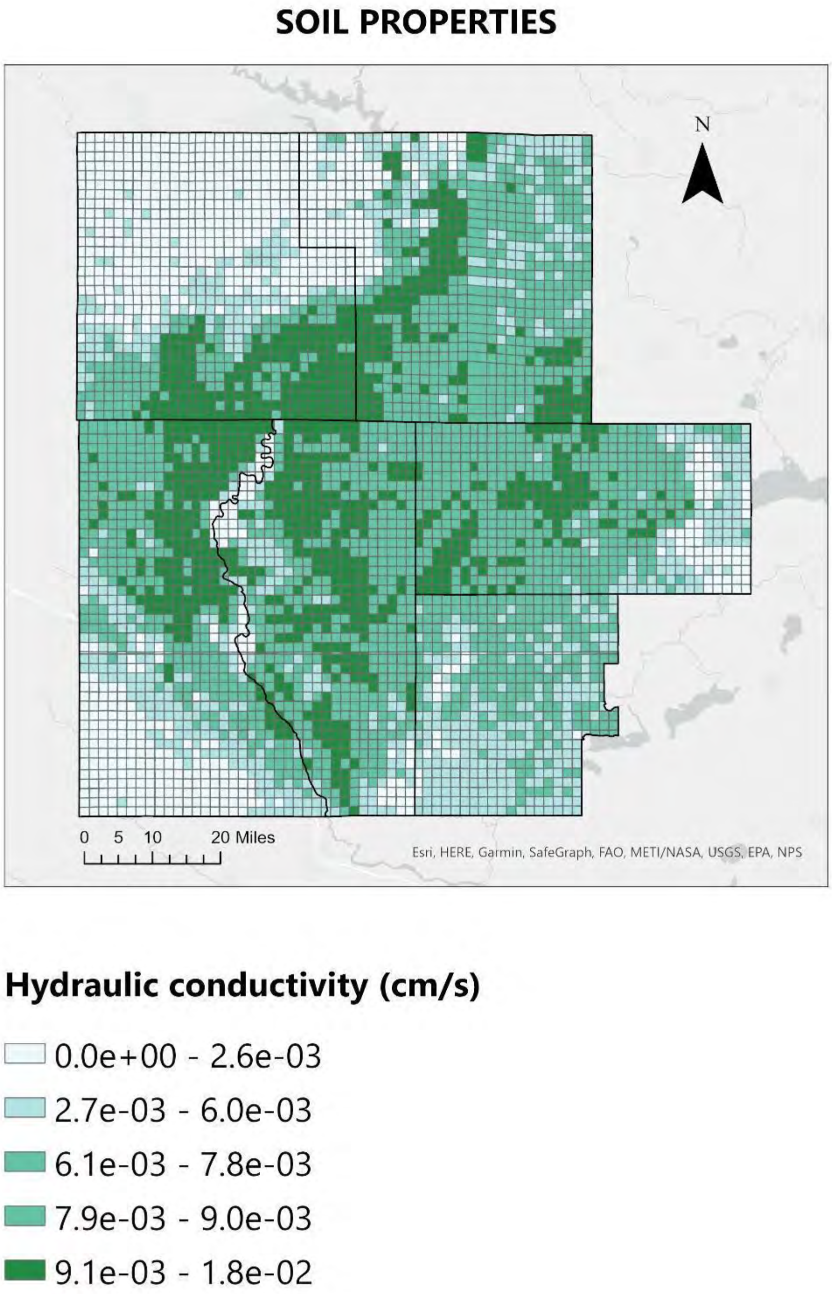


Figure B 13. Weighted average hydraulic conductivity for each section of the CSGCC counties.

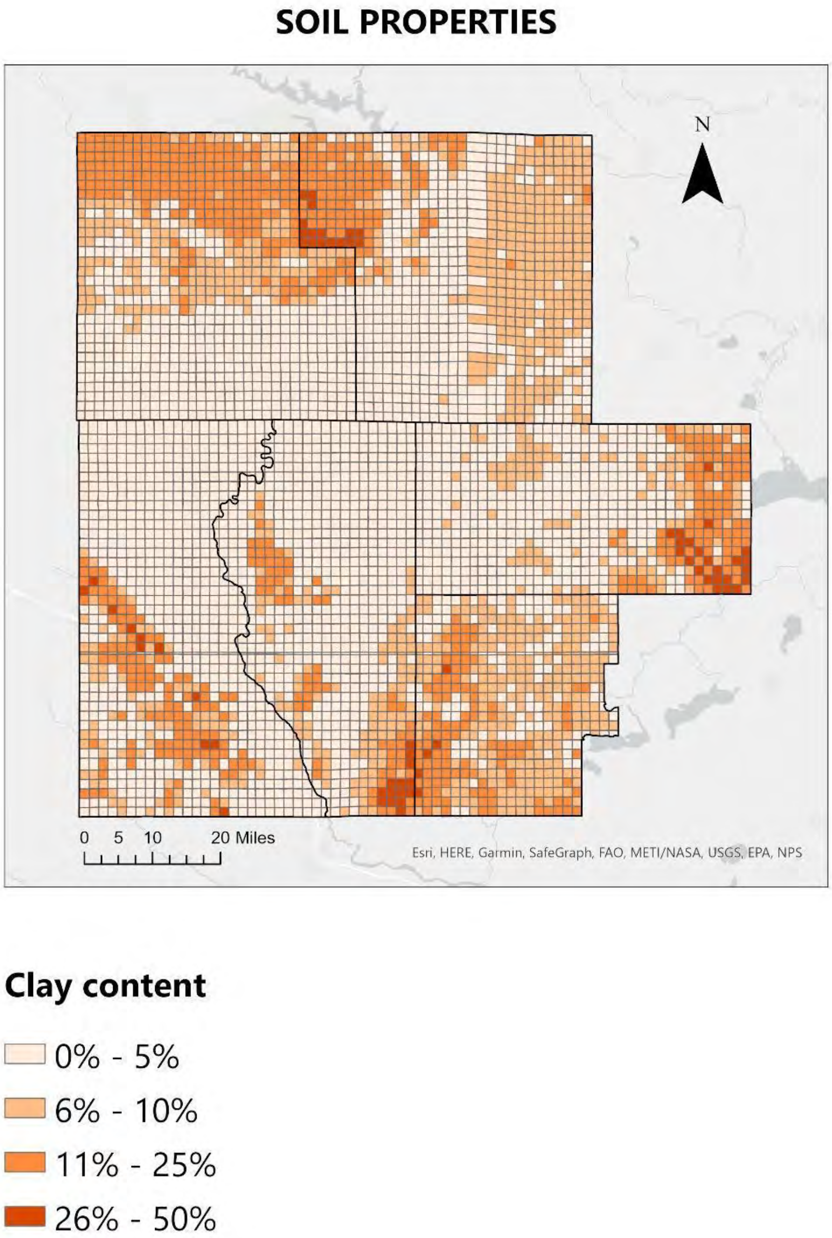


Figure B 14. Weighted average clay content for each section of the CSGCC counties.

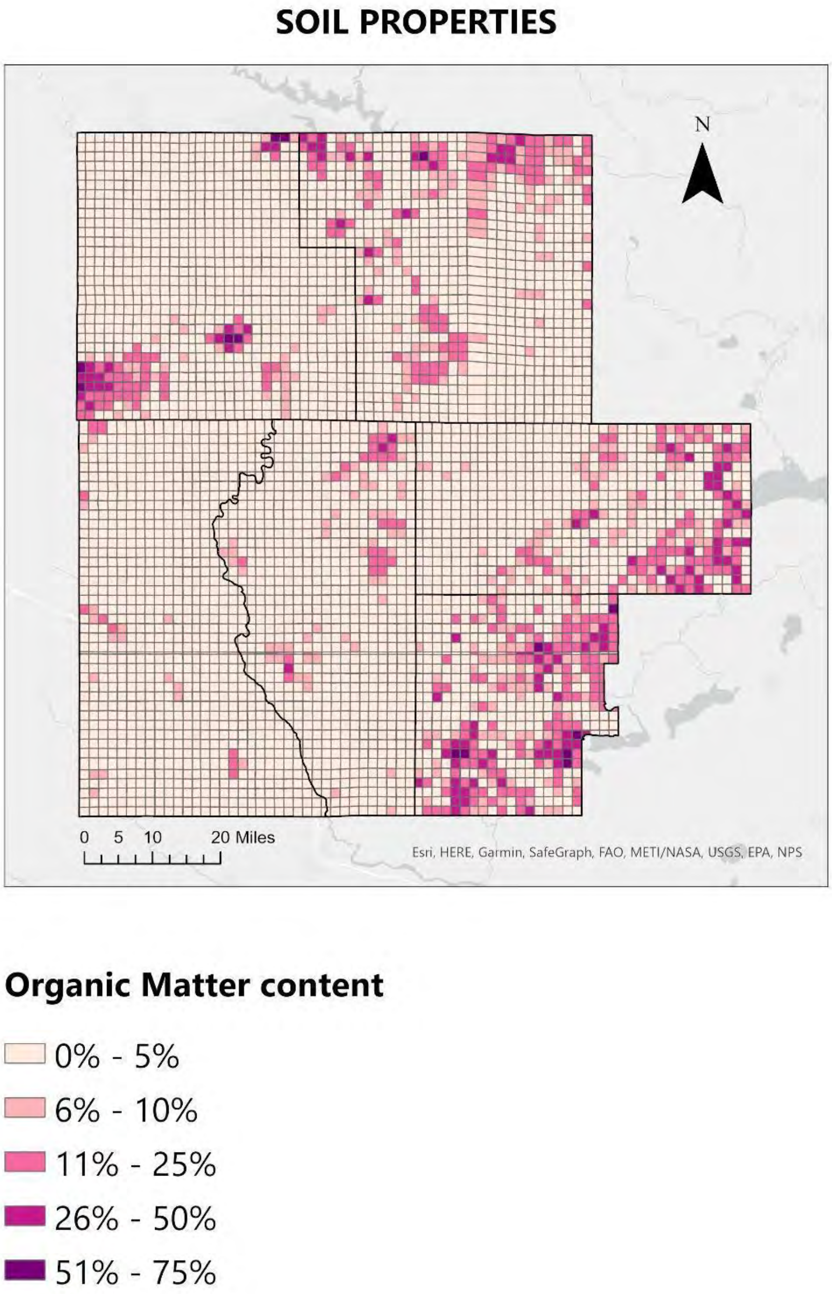


Figure B 15. Weighted average organic matter content for each section of the CSGCC counties.

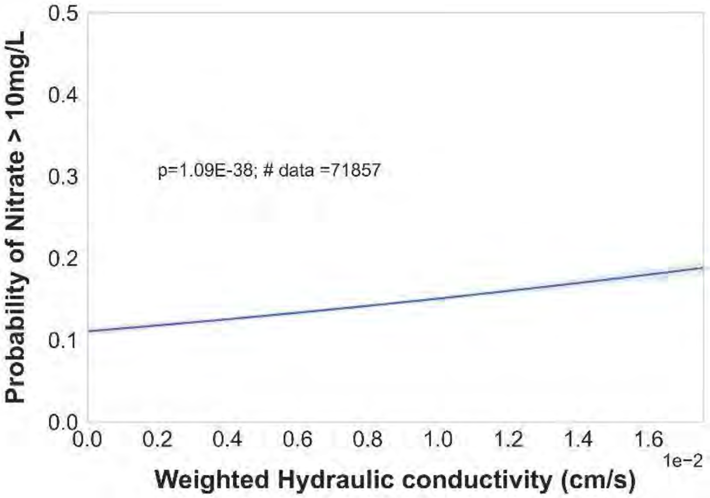


Figure B 16. Probability of having nitrate concentrations greater than 10 mg/L based on the soil weighted hydraulic conductivity (positive trend). The p-value is less than 0.05. We used 71,857 data points to check this relationship. Blue shaded area is the 95% confidence interval.

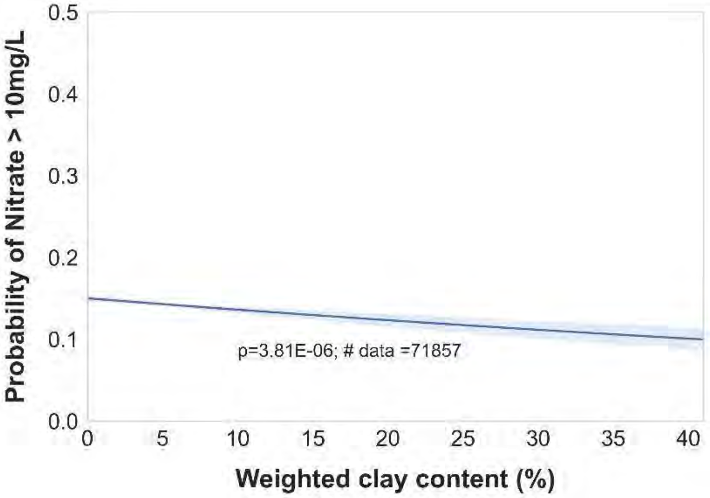


Figure B 17. Probability of having nitrate concentrations greater than 10 mg/L based on the soil weighted clay content (negative trend). The p-value is less than 0.05. We used 71,857 data points to check this relationship. Blue shaded area is the 95% confidence interval.

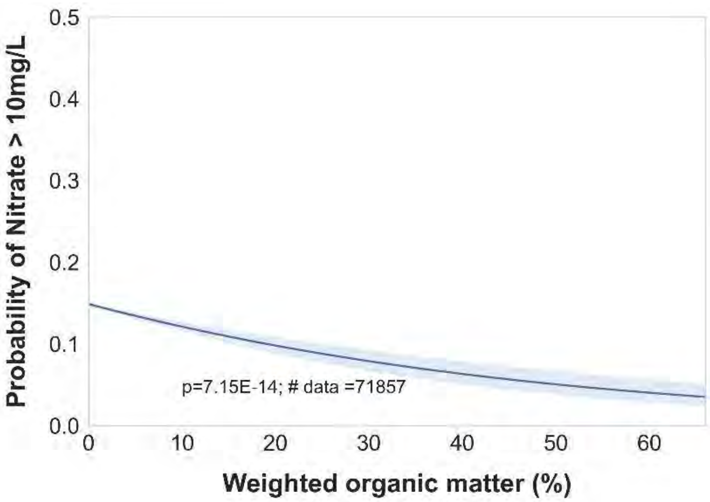
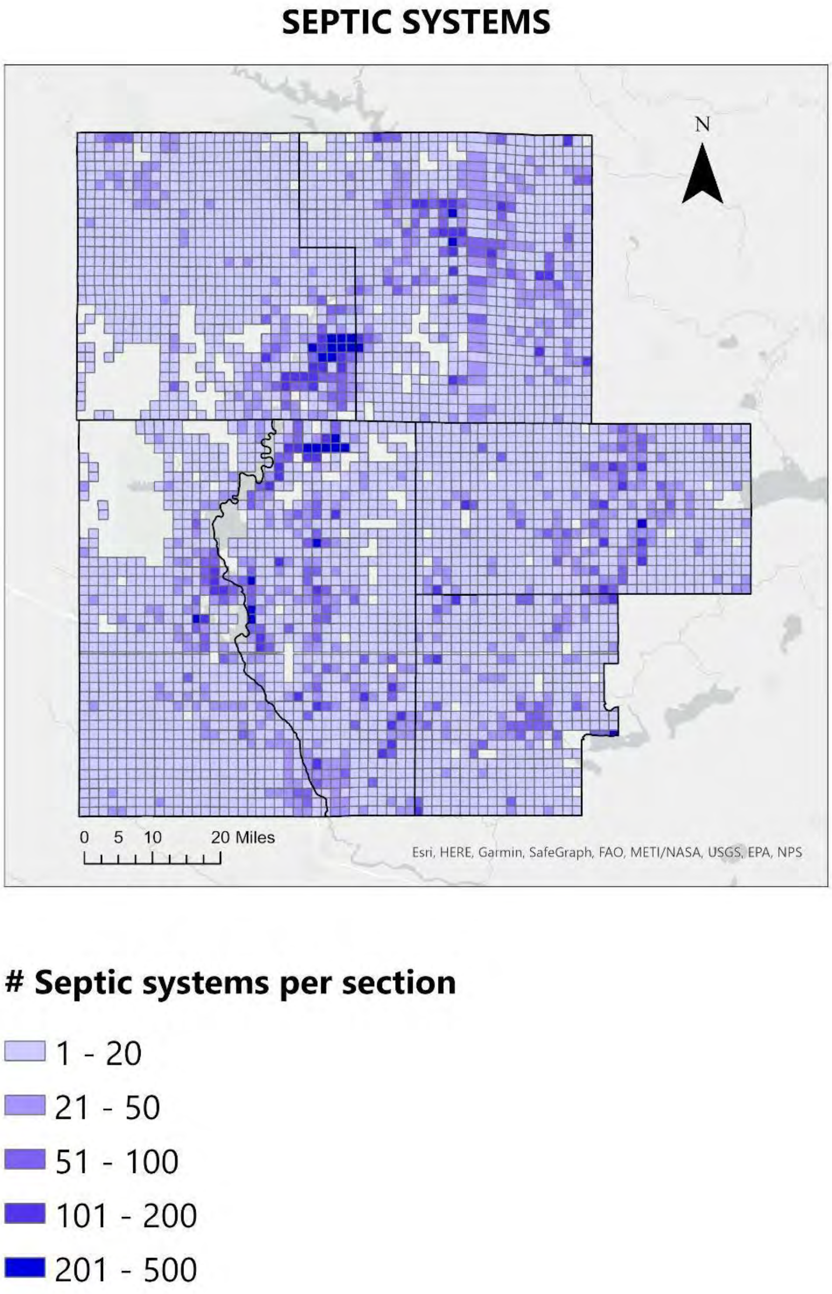


Figure B 18. Probability of having nitrate concentrations greater than 10 mg/L based on the soil weighted organic matter content (negative trend). The p-value is less than 0.05. We used 71,857 data points to check this relationship. Blue shaded area is the 95% confidence interval.



Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS

Figure B 19. Number of septic systems for each section of the CSGCC counties.

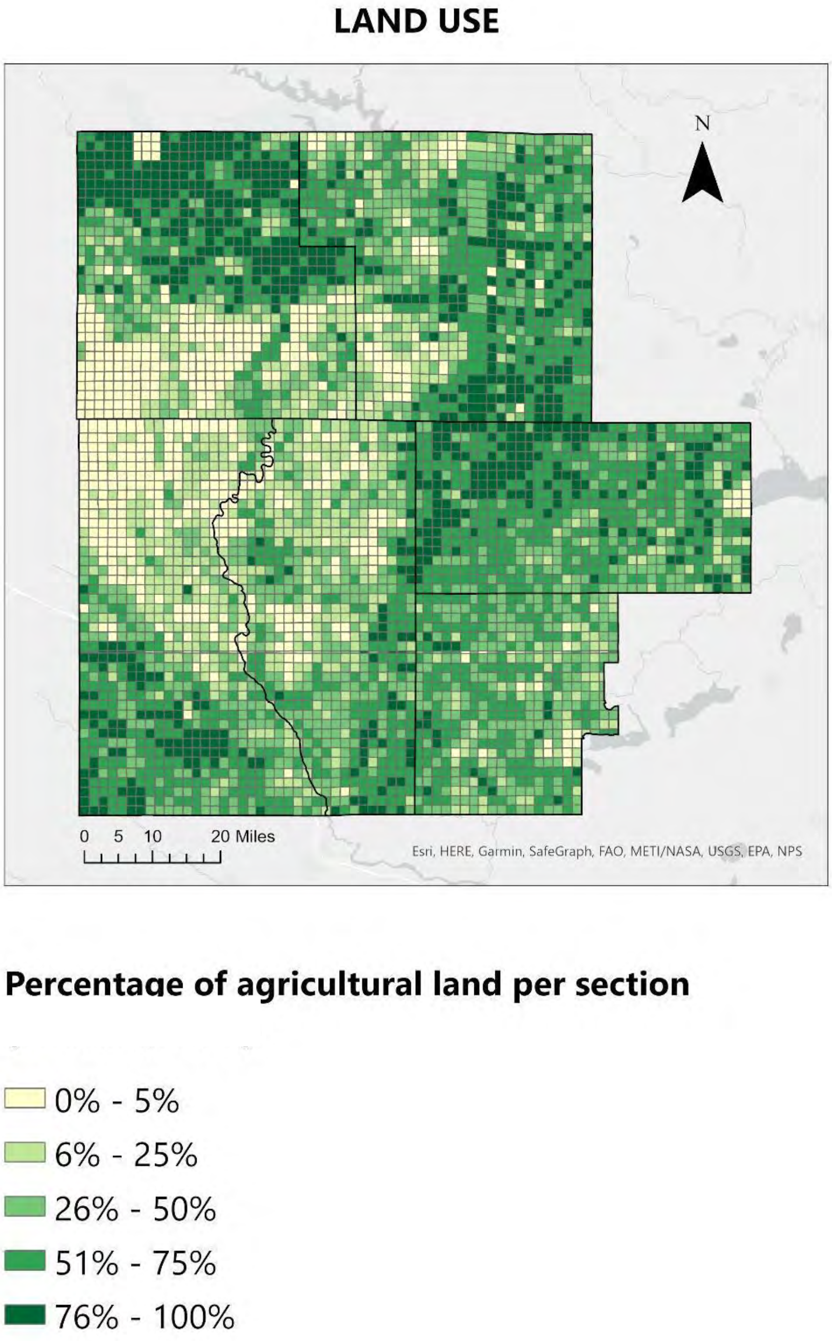


Figure B 20. Percentage of agricultural land use for each section of the CSGCC counties. Original agricultural land use dataset is the Bordner Survey (Forest Landscape Ecology Lab, University of Wisconsin-Madison, 1935).

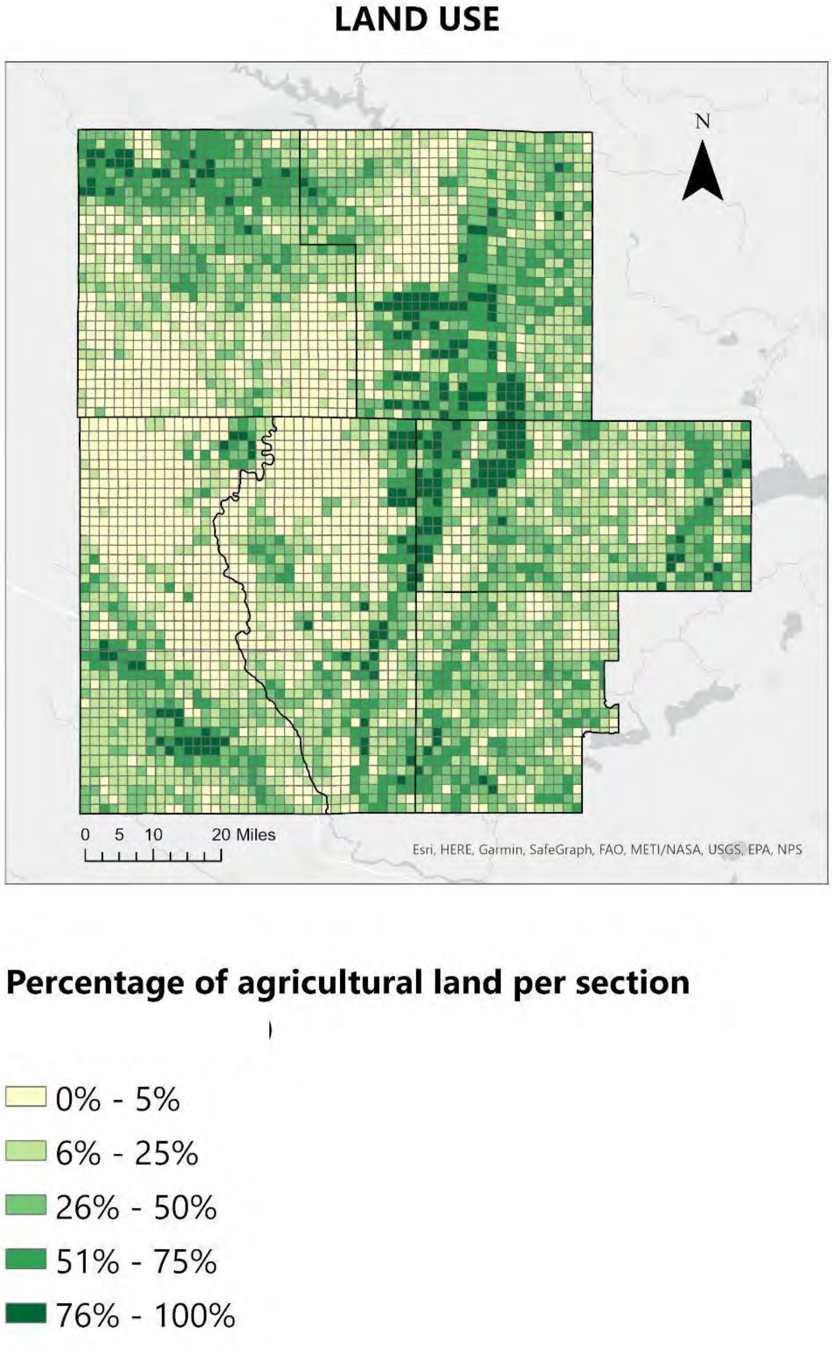


Figure B 21. Percentage of agricultural land use for each section of the CSGCC counties. Original agricultural land use dataset is Wiscland 2.0 (Wisconsin Department of Natural Resources, 2019).

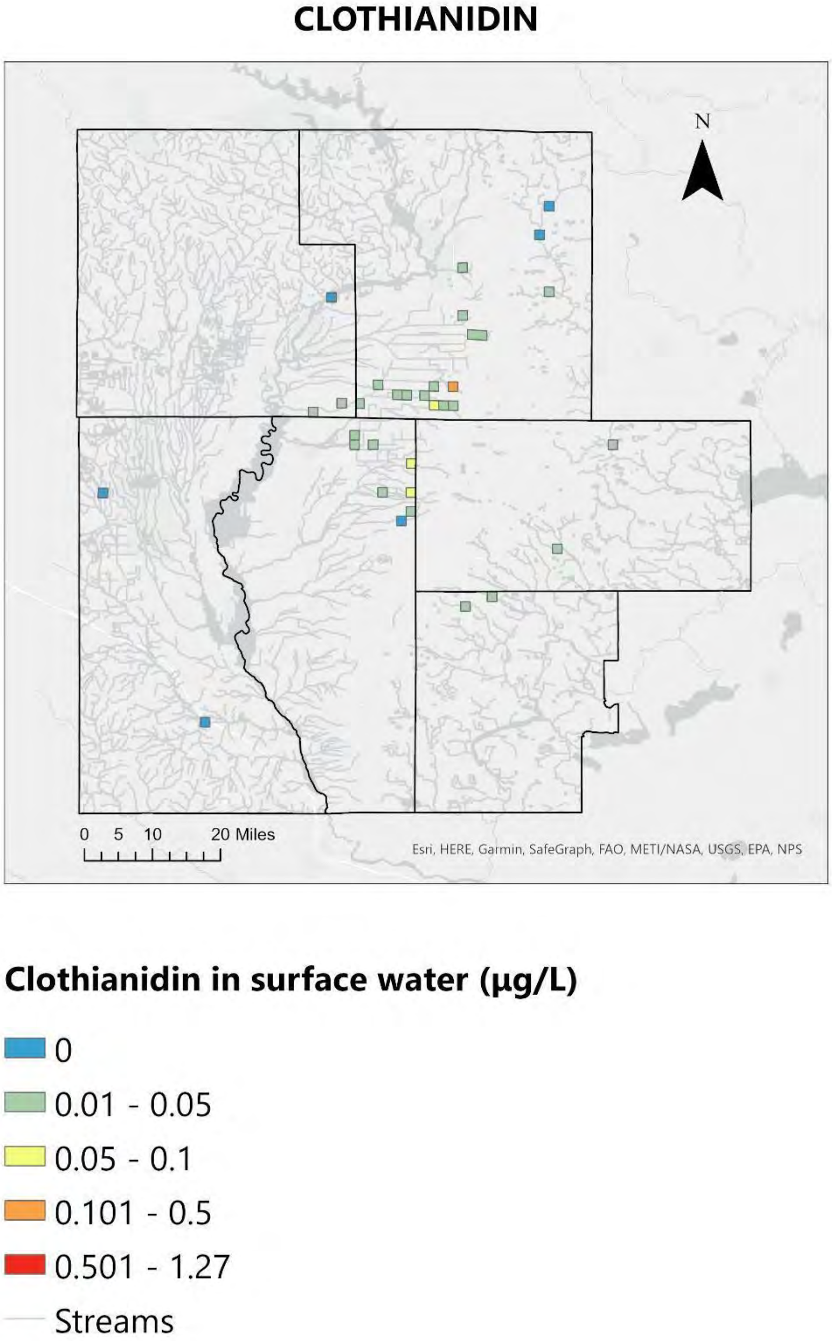
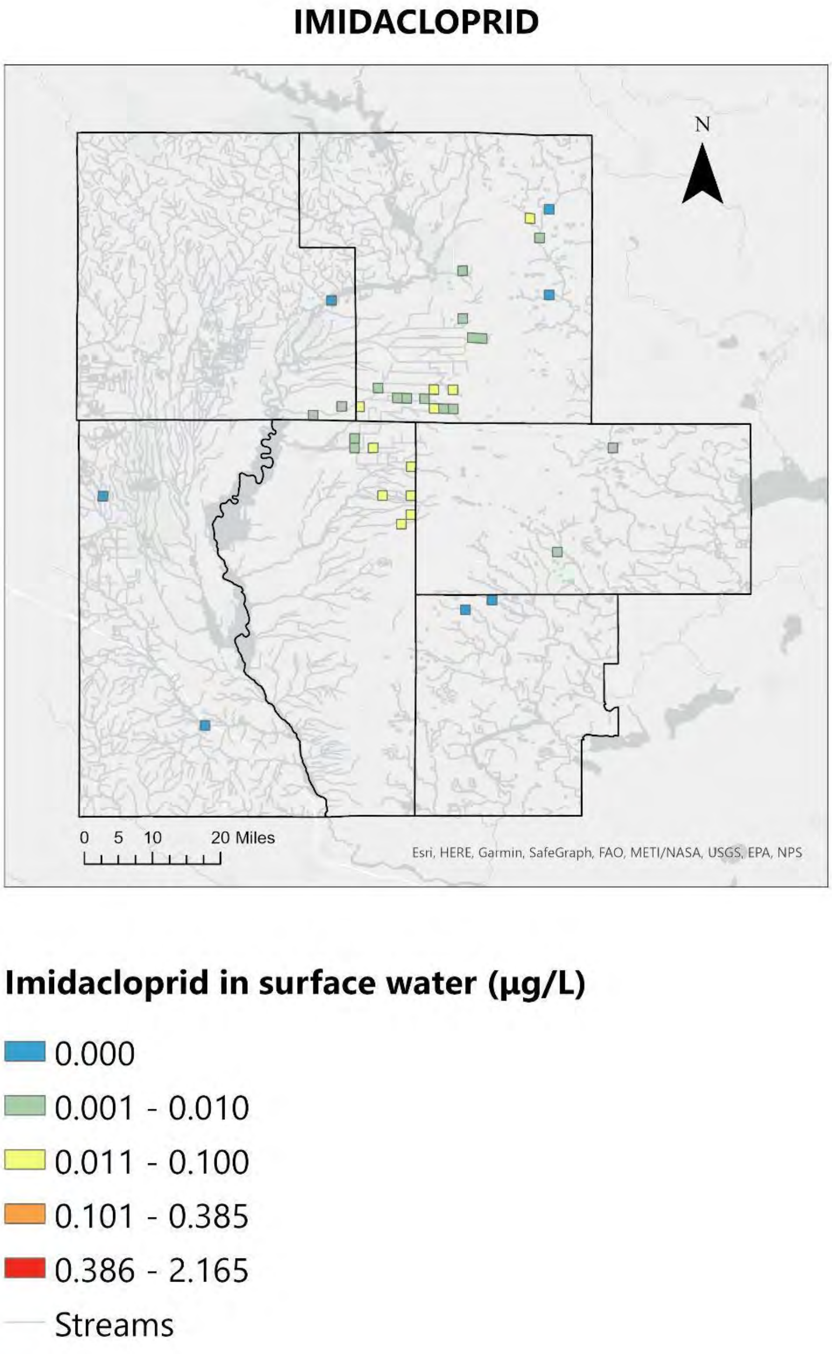


Figure B 25. Clothianidin concentrations in surface water.



IMIDACLOPRID

Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS

Figure B 26. Imidacloprid concentrations in surface water.

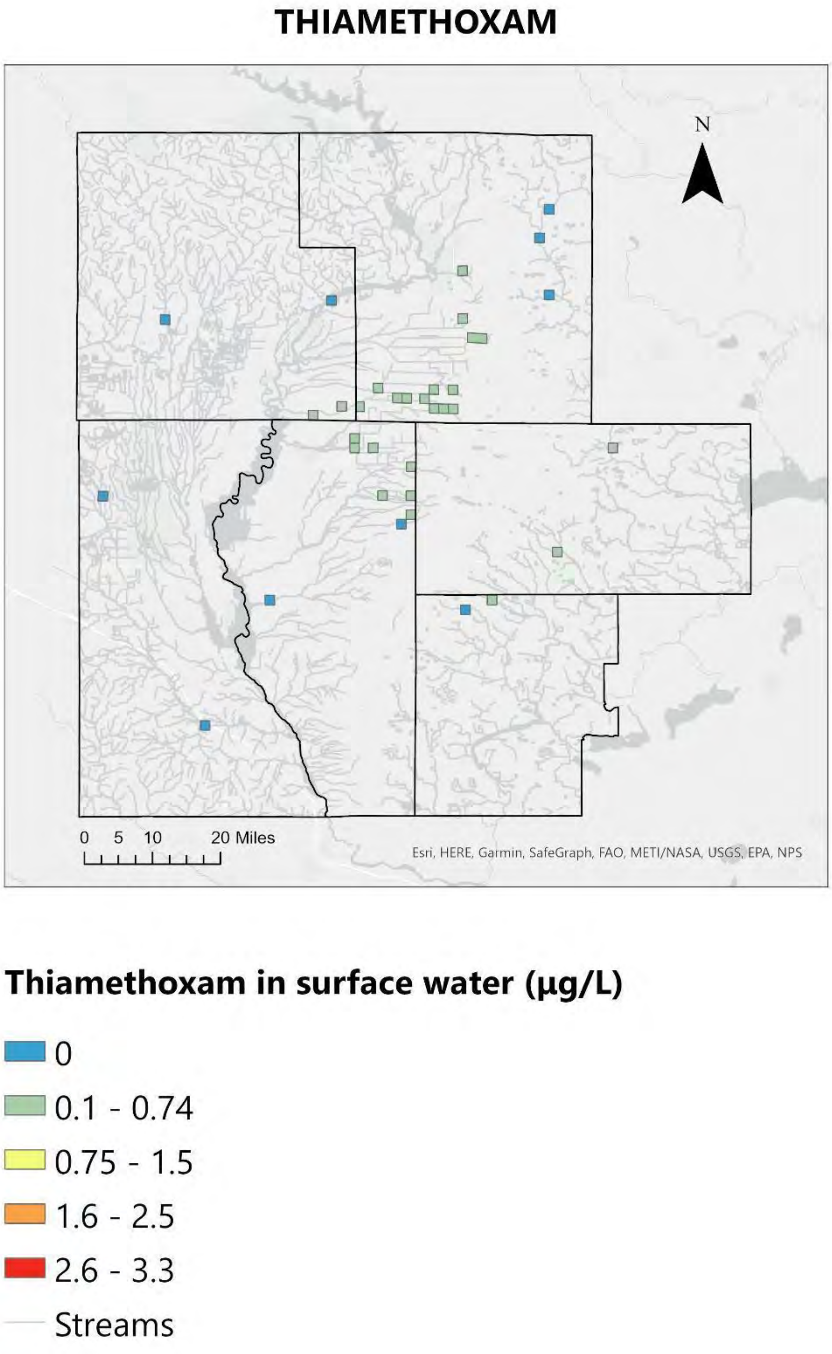


Figure B 27. Thiamethoxam concentrations in surface water.

SURFACE WATER	Clothianidin	Imidacloprid	Thiamethoxam
Detected %	55	53	70
Exceeds ALB chronic %	4	25	0
Exceeds ALB acute %	0	0	0

Table B 1. Summary of neonicotinoids' detection rates in surface water and percentage of samples exceeding the EPA chronic and acute Aquatic Life Benchmarks (ALB) for invertebrates. Clothianidin chronic and acute ALBs are 0.05 and 11 µg/L, respectively. Imidacloprid chronic and acute ALBs are 0.01 and 0.385 µg/L, respectively. Thiamethoxam chronic and acute ALBs are 0.7 and 17.5 µg/L, respectively.

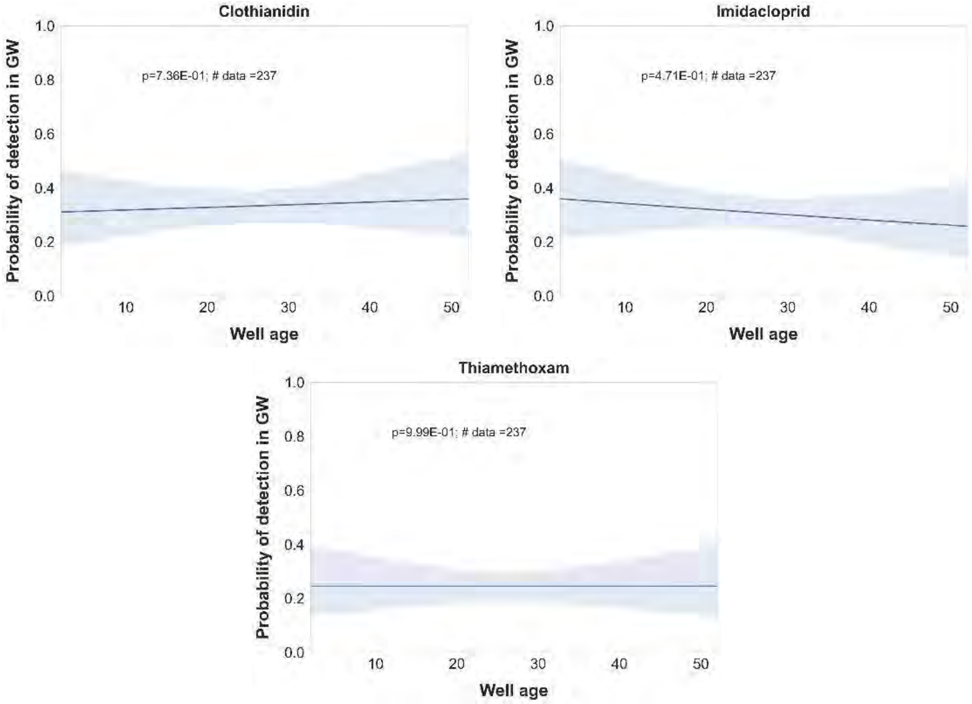


Figure B 28. Probability of clothianidin, imidacloprid or thiamethoxam detection in groundwater based on the well age (no relationship). The p-value is greater than 0.05. We used 237 data points to check this relationship. Blue shaded area is the 95% confidence interval.

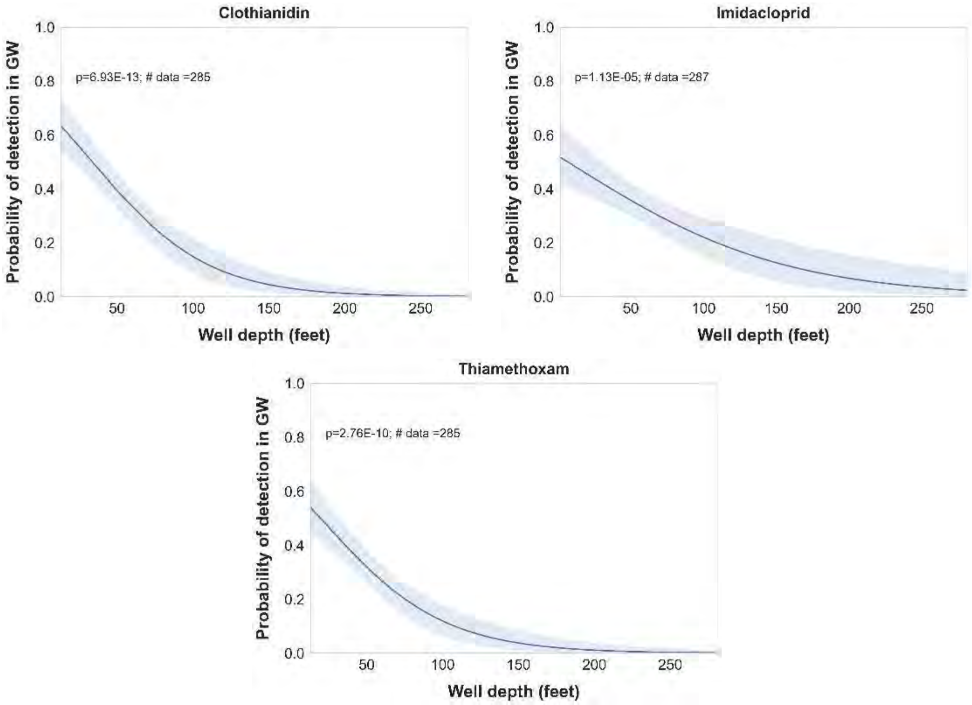


Figure B 29. Probability of clothianidin, imidacloprid or thiamethoxam detection in groundwater based on the well depth (negative trend). The p-value is less than 0.05. We used 285 data points to check this relationship. Blue shaded area is the 95% confidence interval.

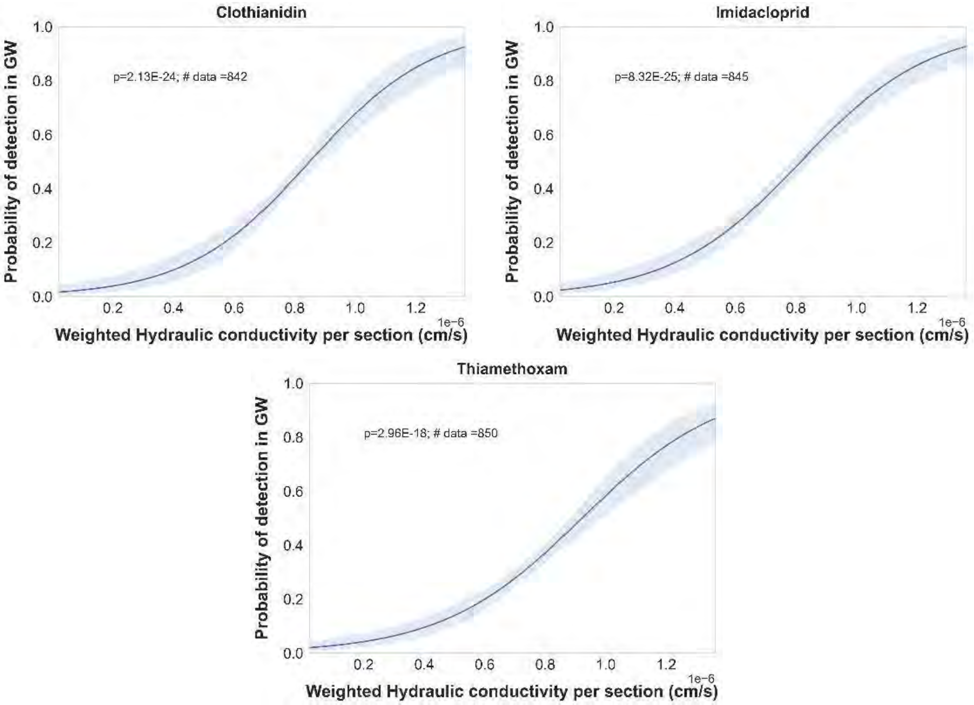


Figure B 30. Probability of clothianidin, imidacloprid or thiamethoxam detection in groundwater based on the weighted average hydraulic conductivity (positive trend). The p-value is less than 0.05. About 850 data points were considered for each relationship. Blue shaded area is the 95% confidence interval.

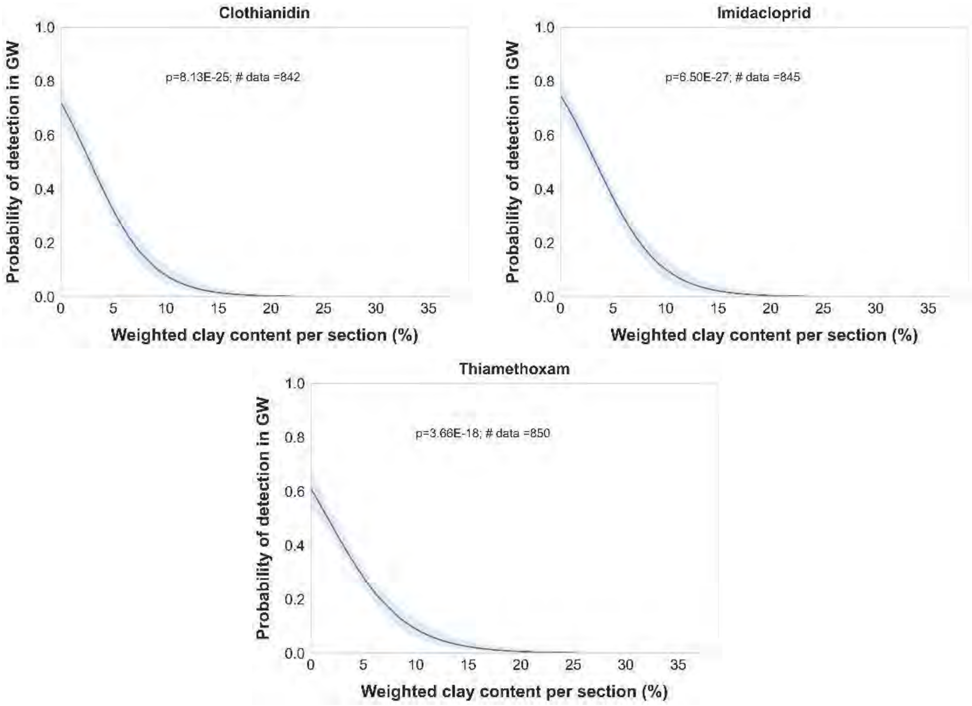


Figure B 31. Probability of clothianidin, imidacloprid or thiamethoxam detection in groundwater based on the weighted average clay content (negative trend). The p-value is less than 0.05. About 850 data points were considered for each relationship. Blue shaded area is the 95% confidence interval.

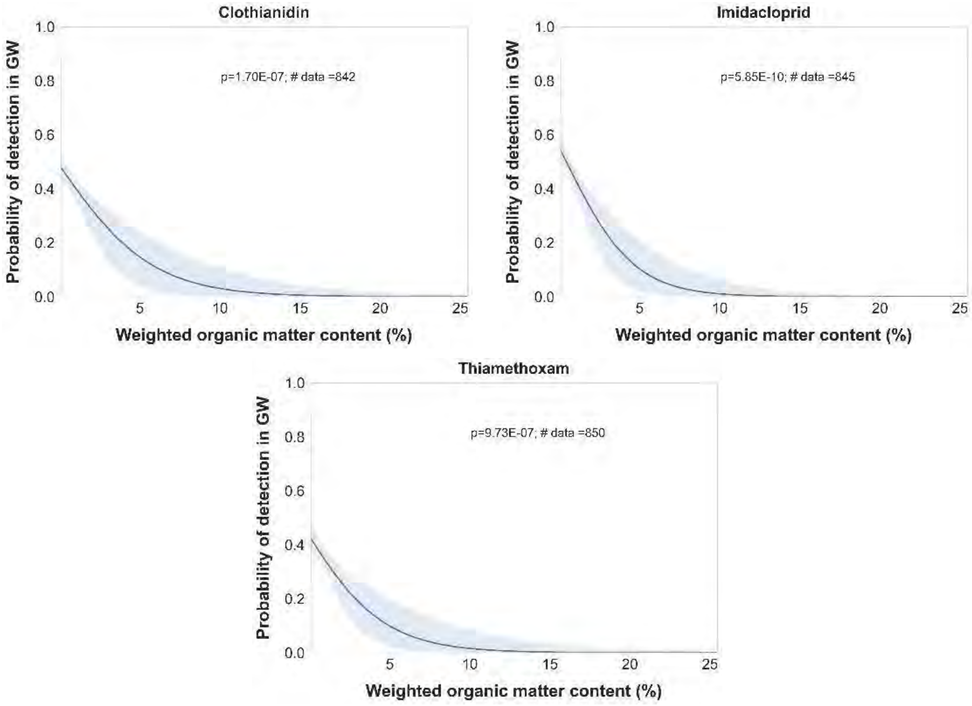


Figure B 32. Probability of clothianidin, imidacloprid or thiamethoxam detection in groundwater based on the weighted average organic matter content (negative trend). The p-value is less than 0.05. About 850 data points were considered for each relationship. Blue shaded area is the 95% confidence interval.

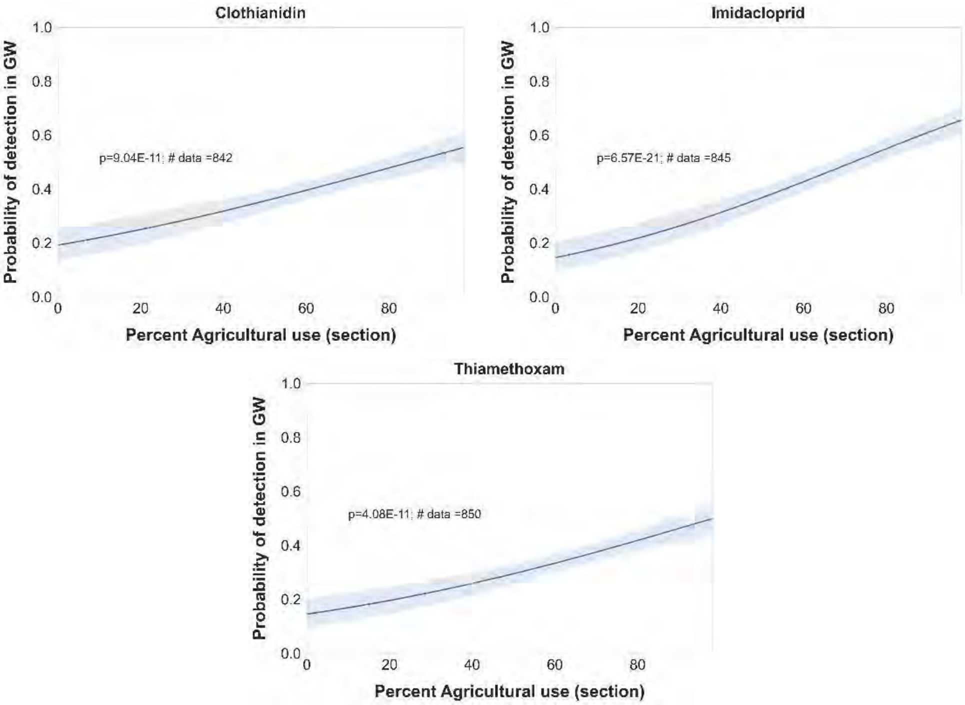
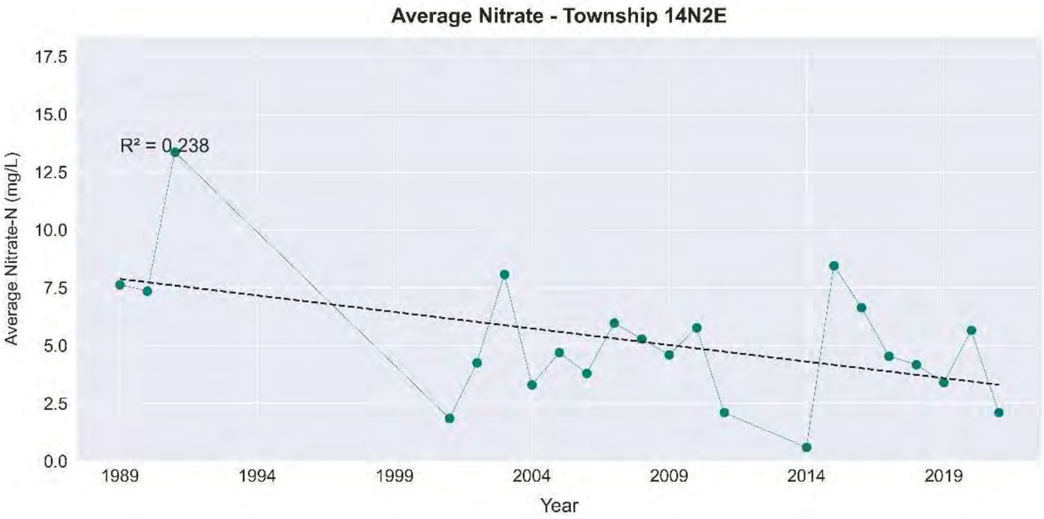


Figure B 33. Probability of clothianidin, imidacloprid or thiamethoxam detection in groundwater based on the percentage of agricultural land use per section (positive trend). The p-value is less than 0.05. About 850 data points were considered for each relationship. Blue shaded area is the 95% confidence interval.

Appendix C – Township plots



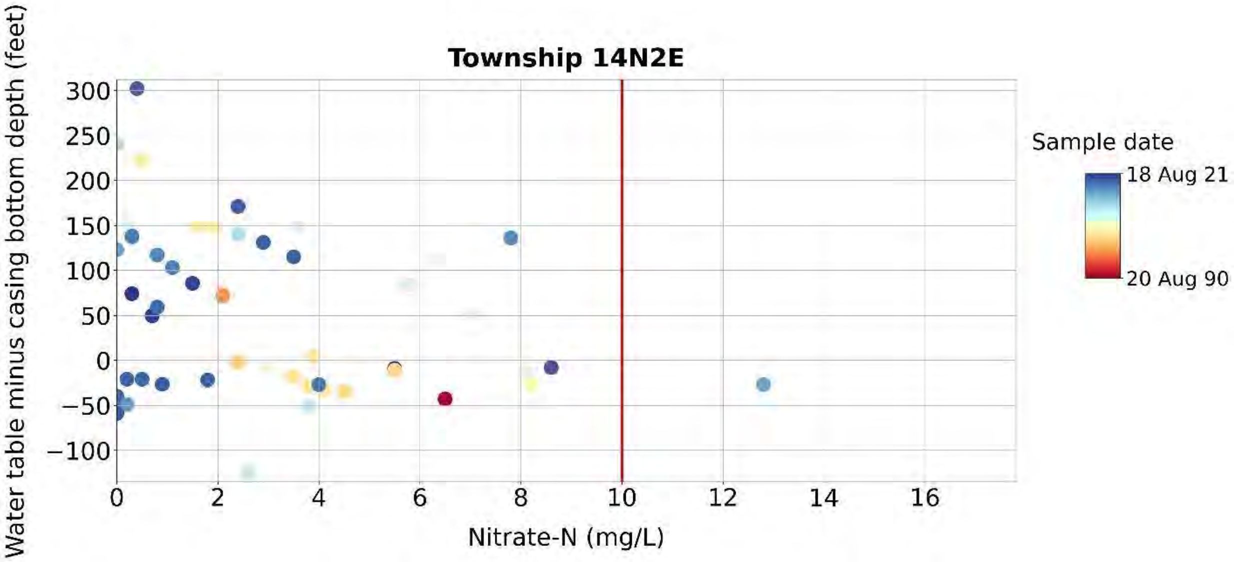
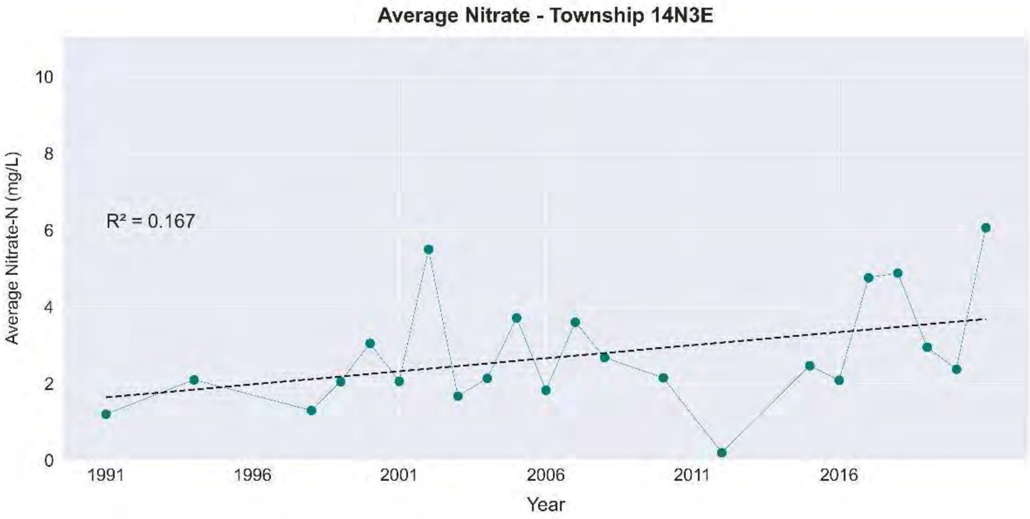


Figure C 1. Township 14N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



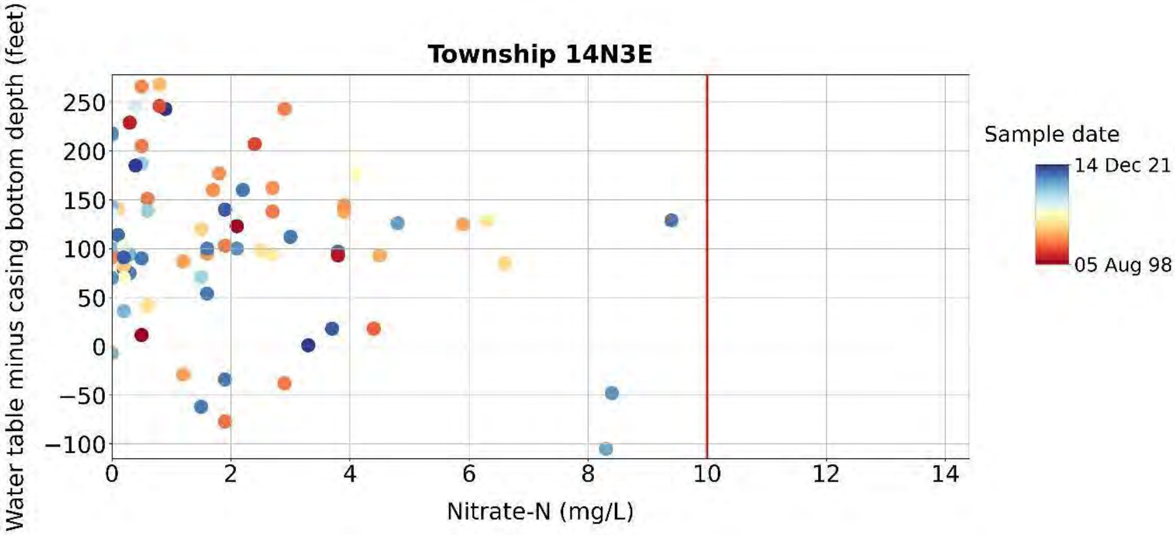
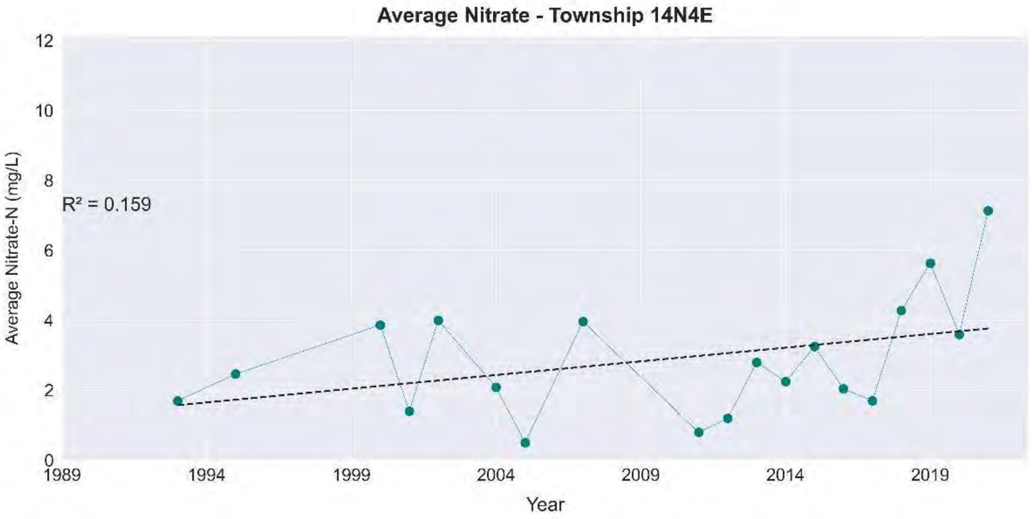


Figure C 2. Township 14N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



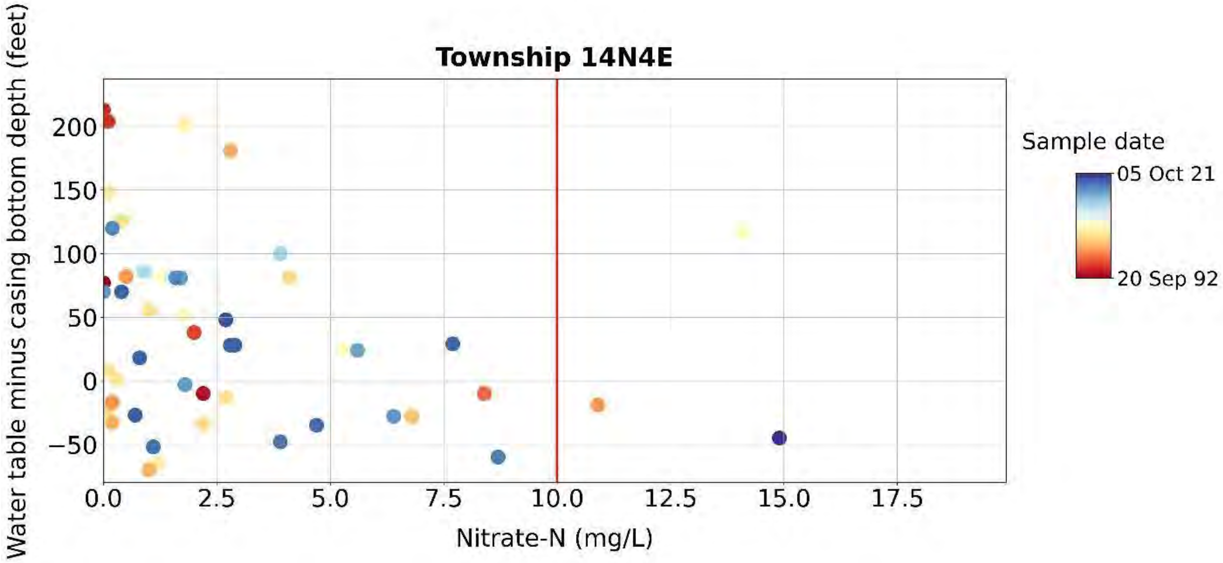
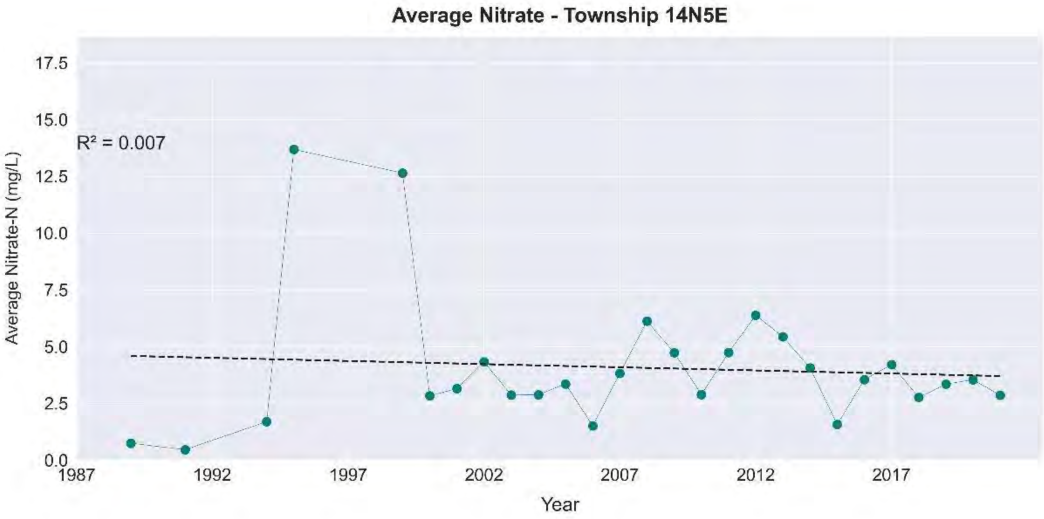


Figure C 3. Township 14N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



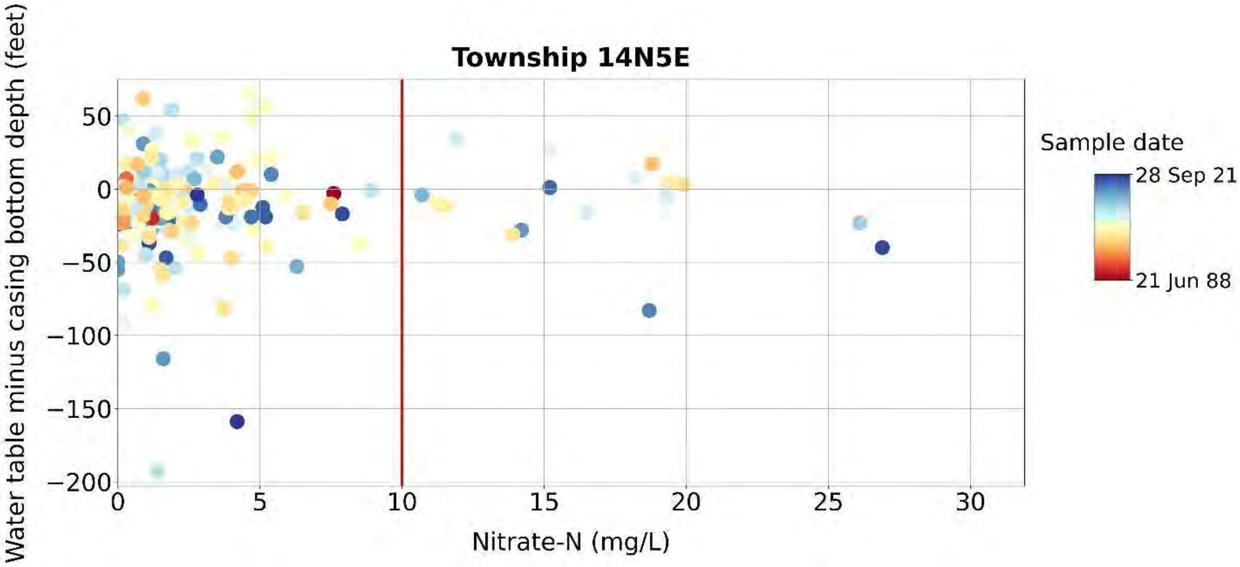
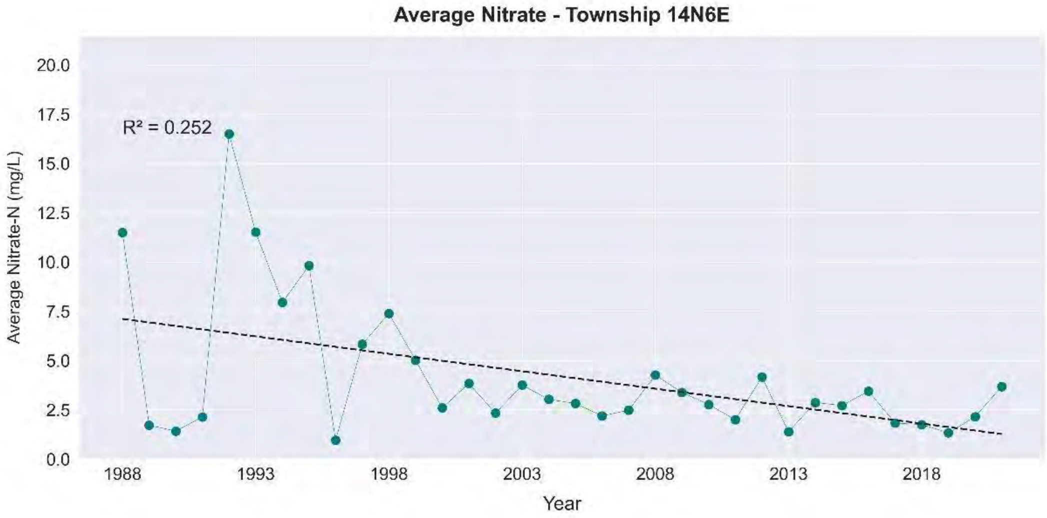


Figure C 4. Township 14N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



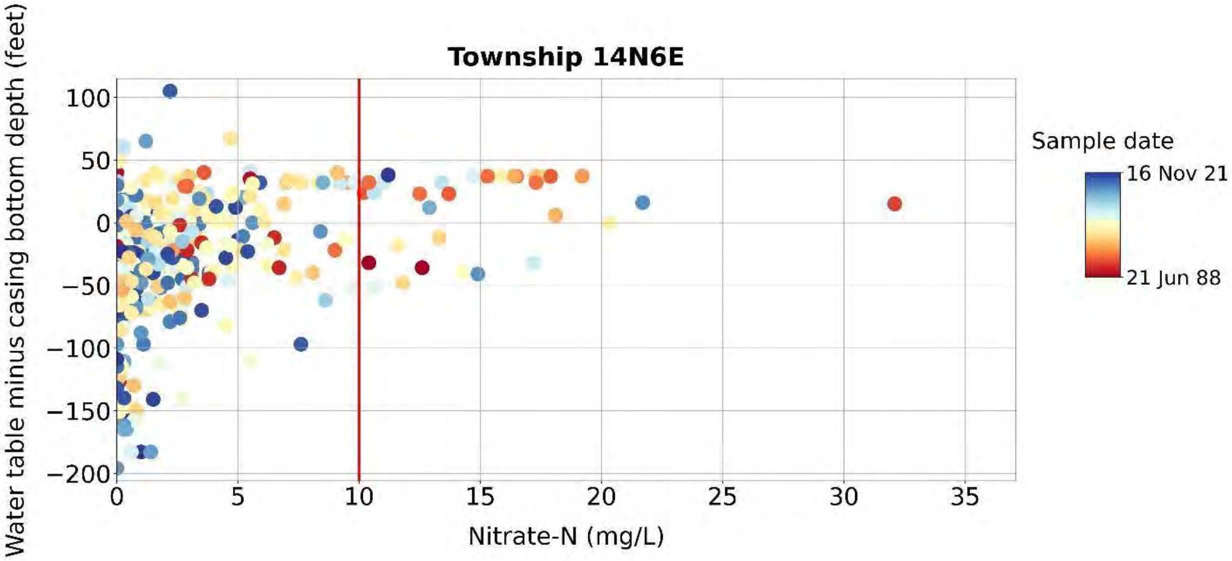
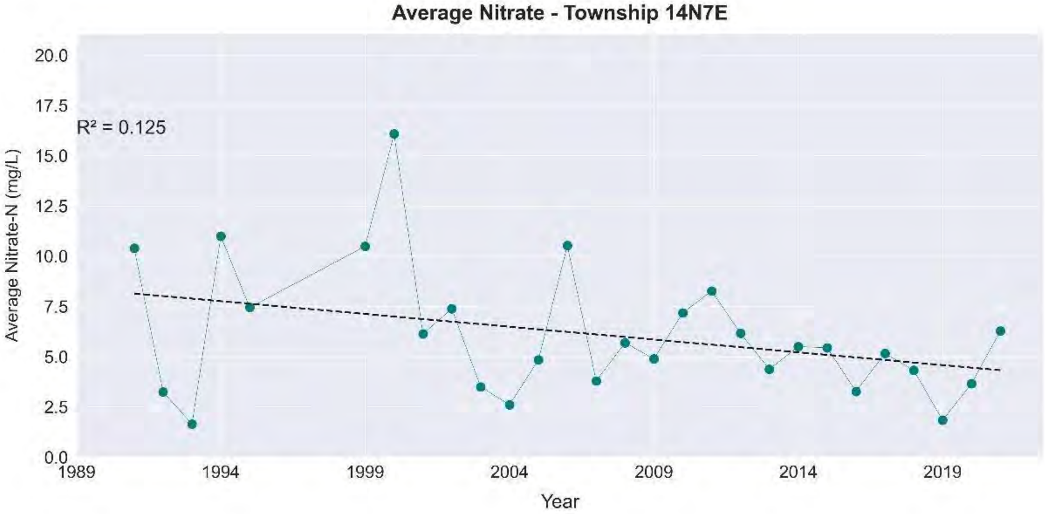


Figure C 5. Township 14N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



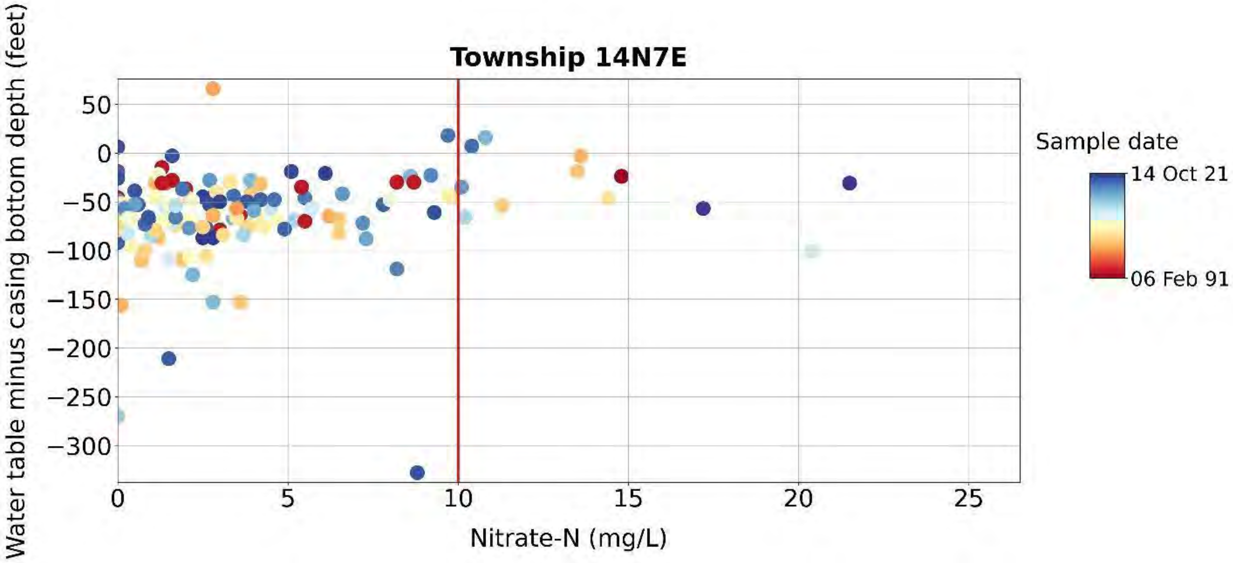


Figure C 6. Township 14N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

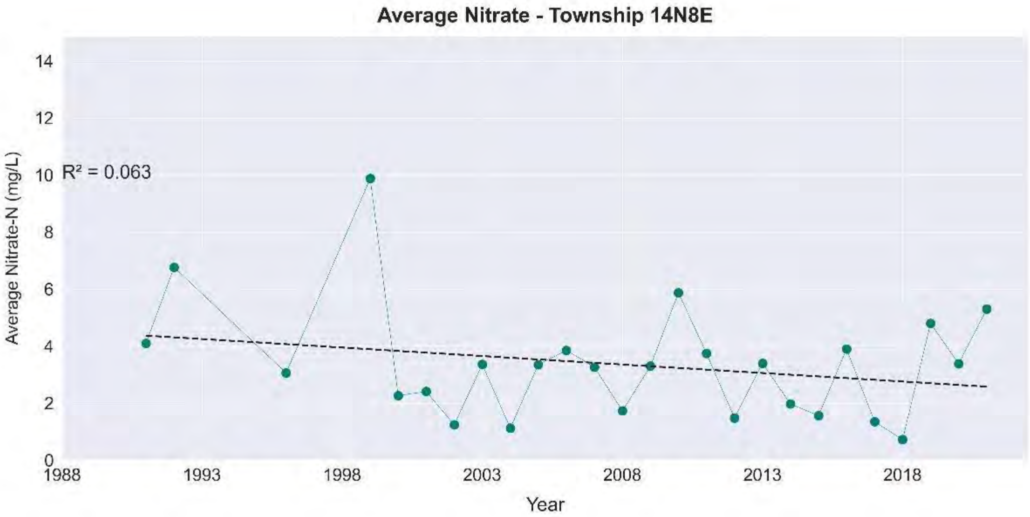
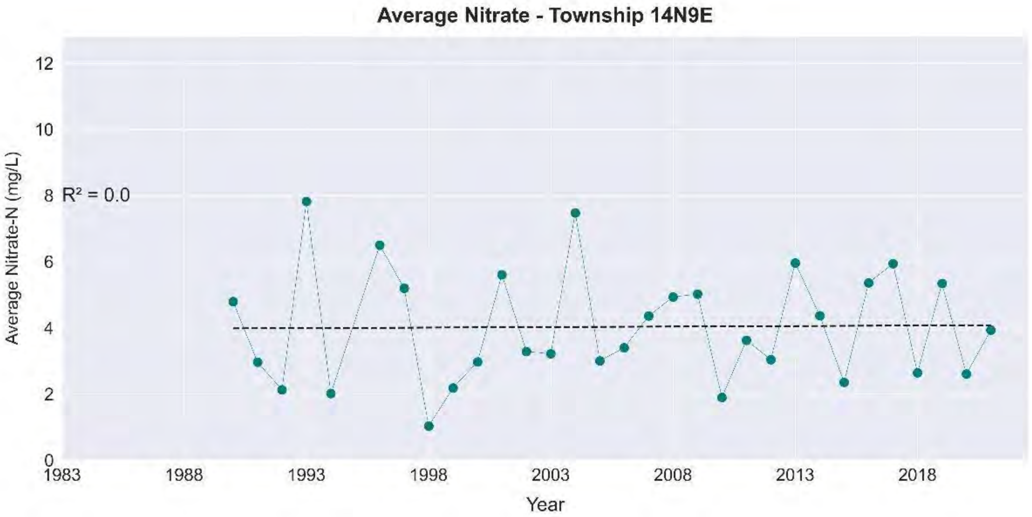


Figure C 7. Township 14N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



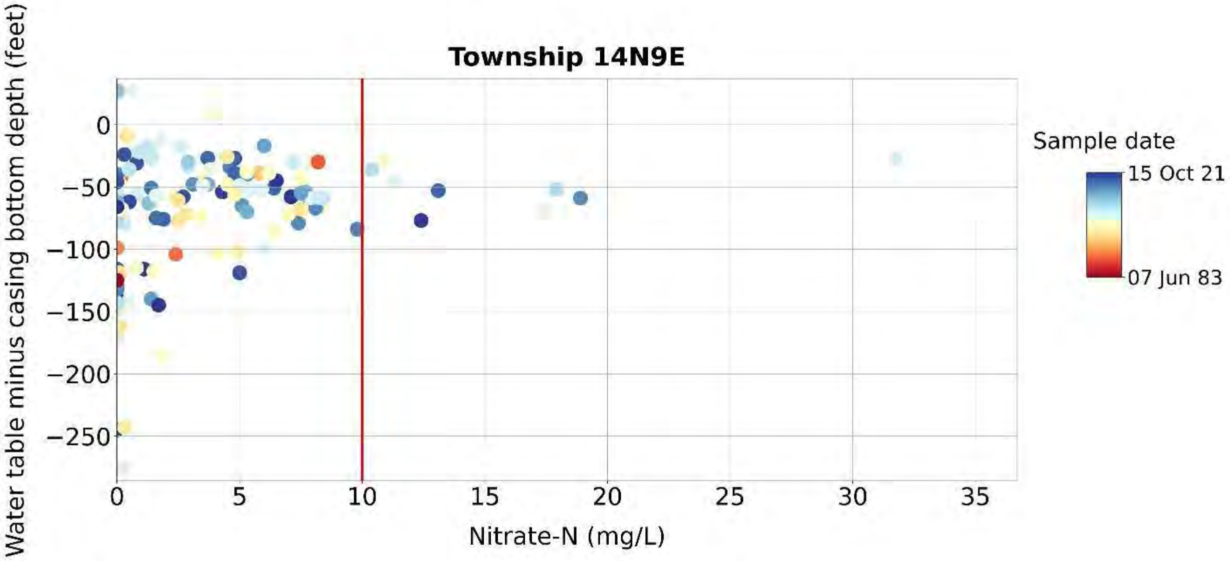
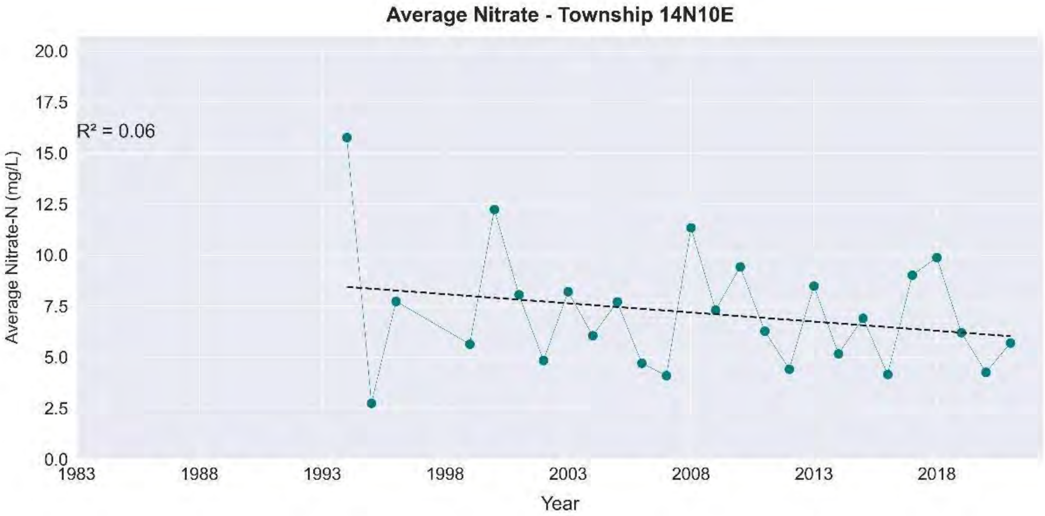


Figure C 8. Township 14N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



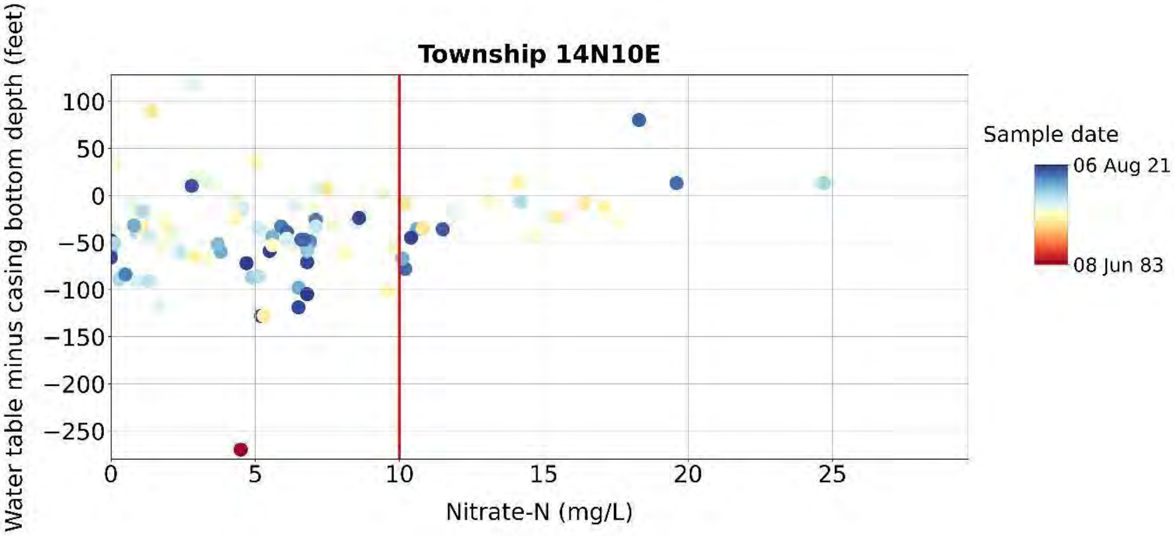
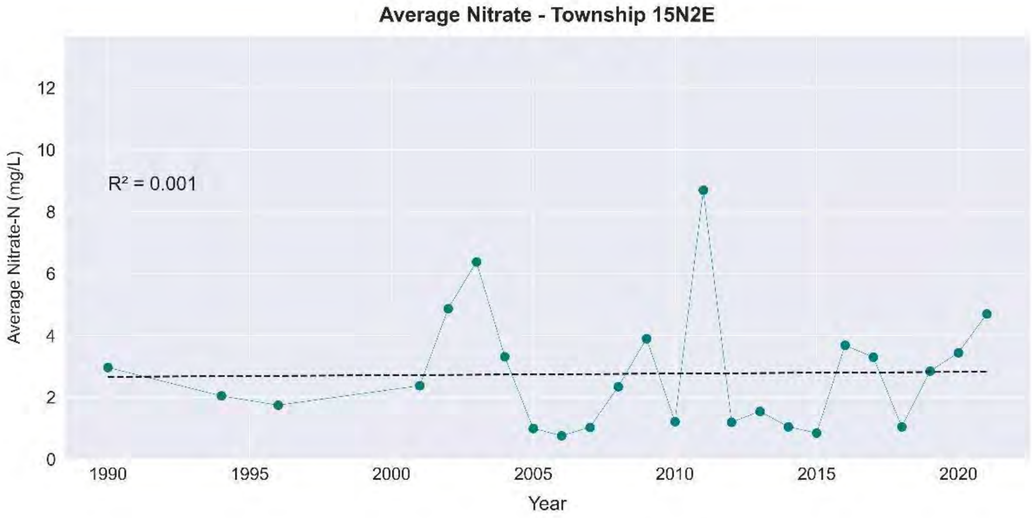


Figure C 9. Township 14N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



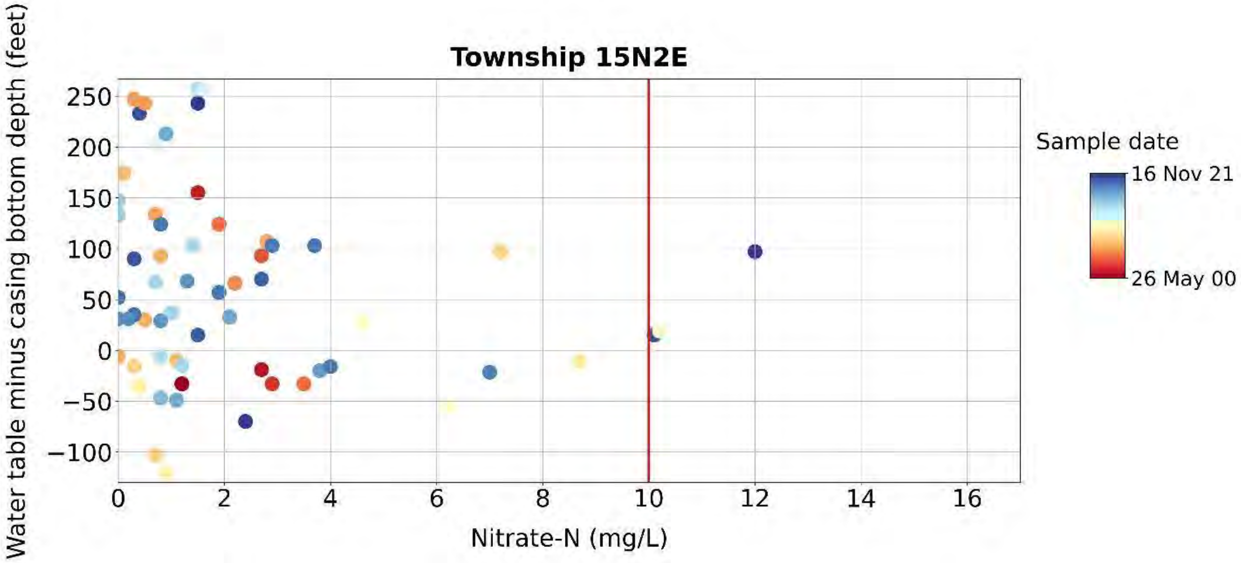
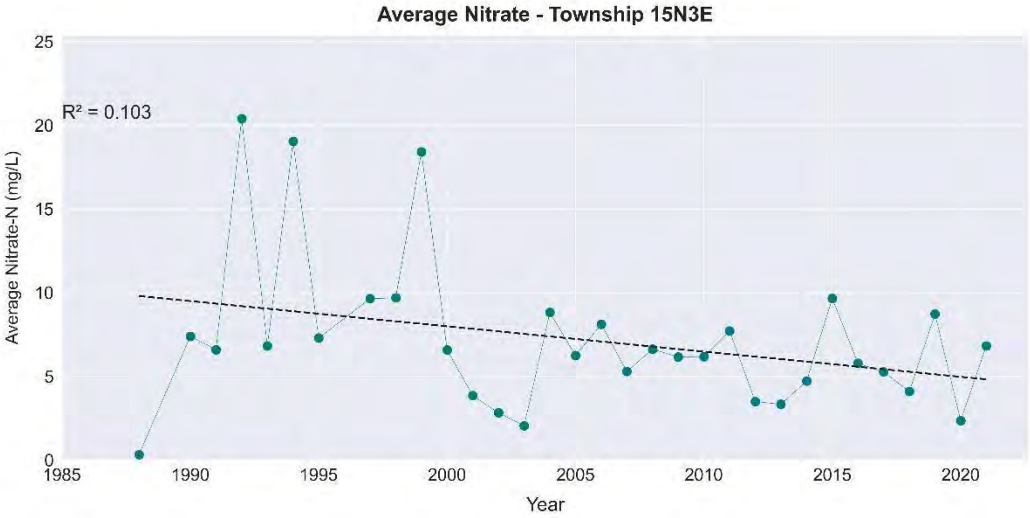


Figure C 10. Township 15N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue *color.*



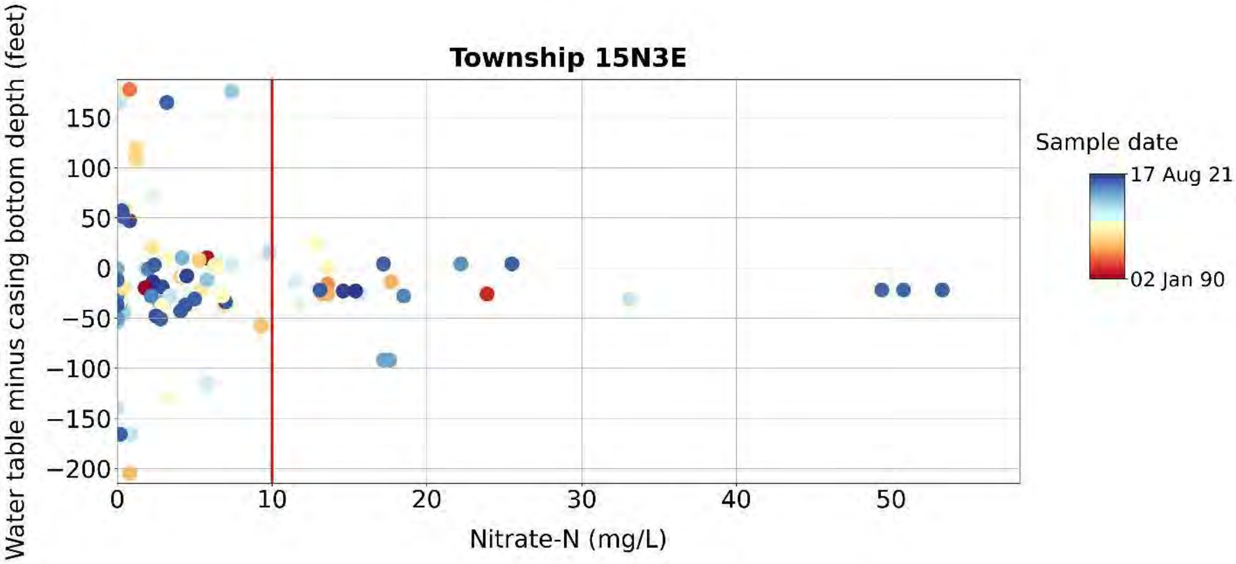
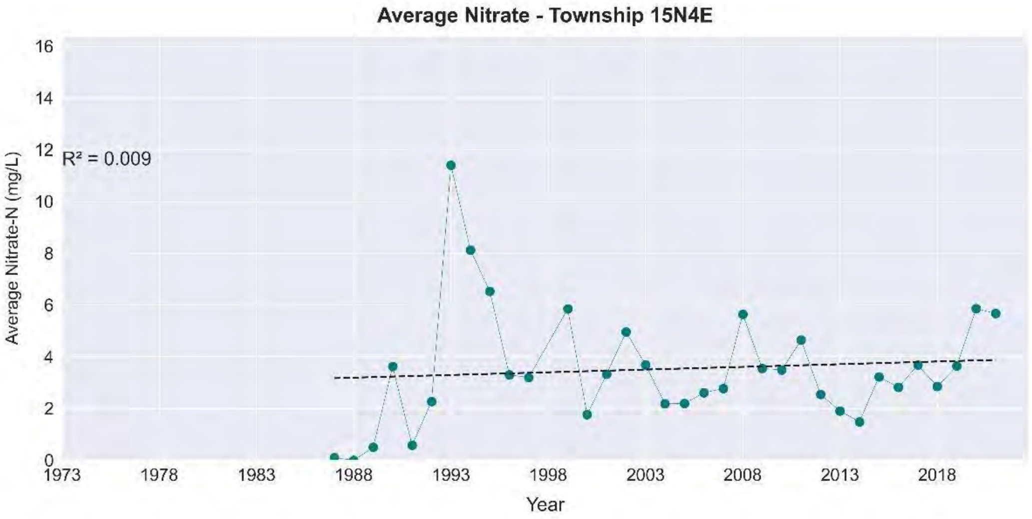


Figure C 11. Township 15N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



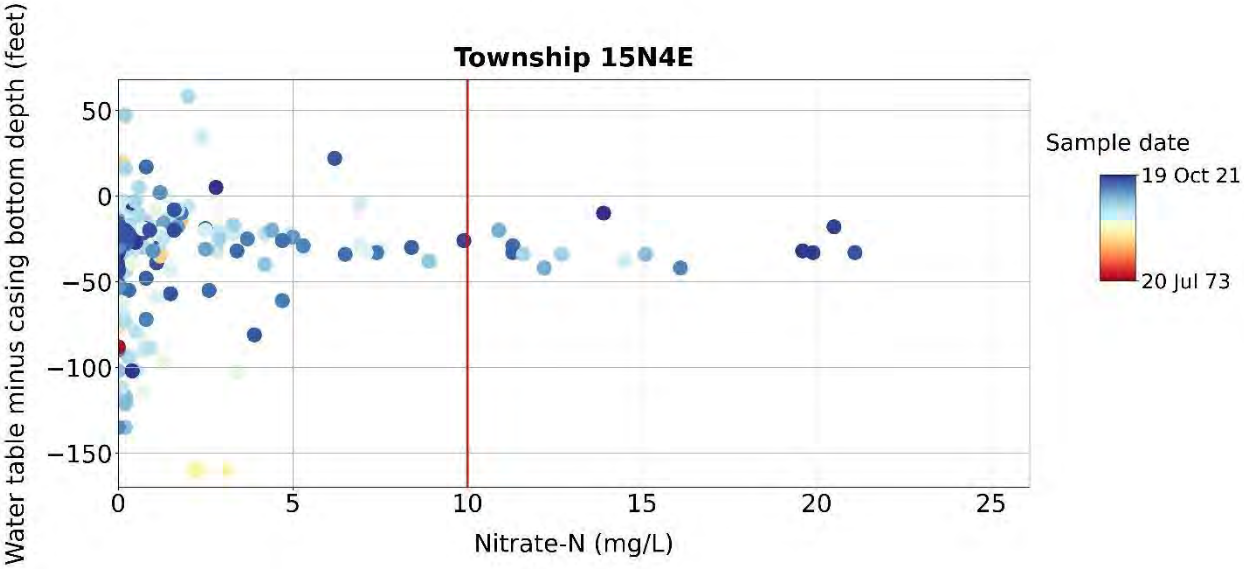
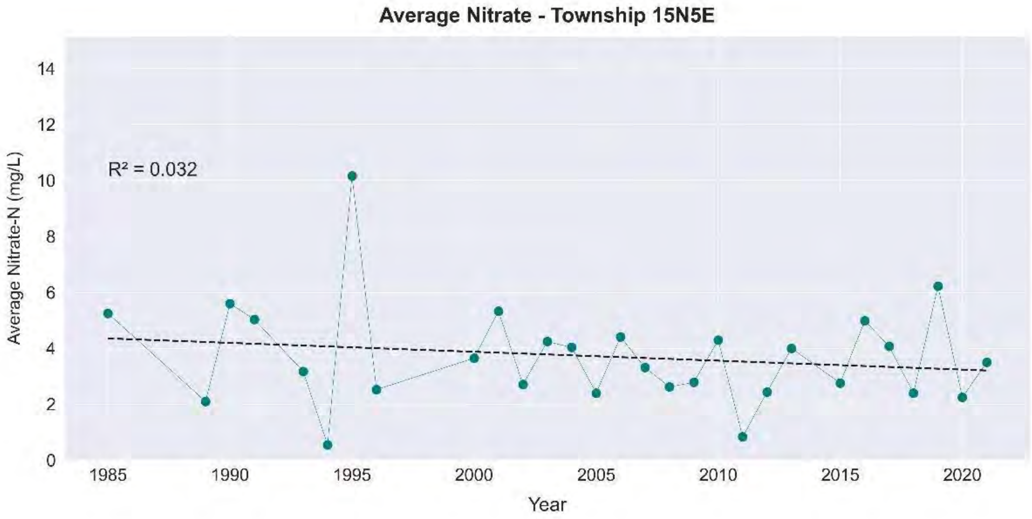


Figure C 12. Township 15N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



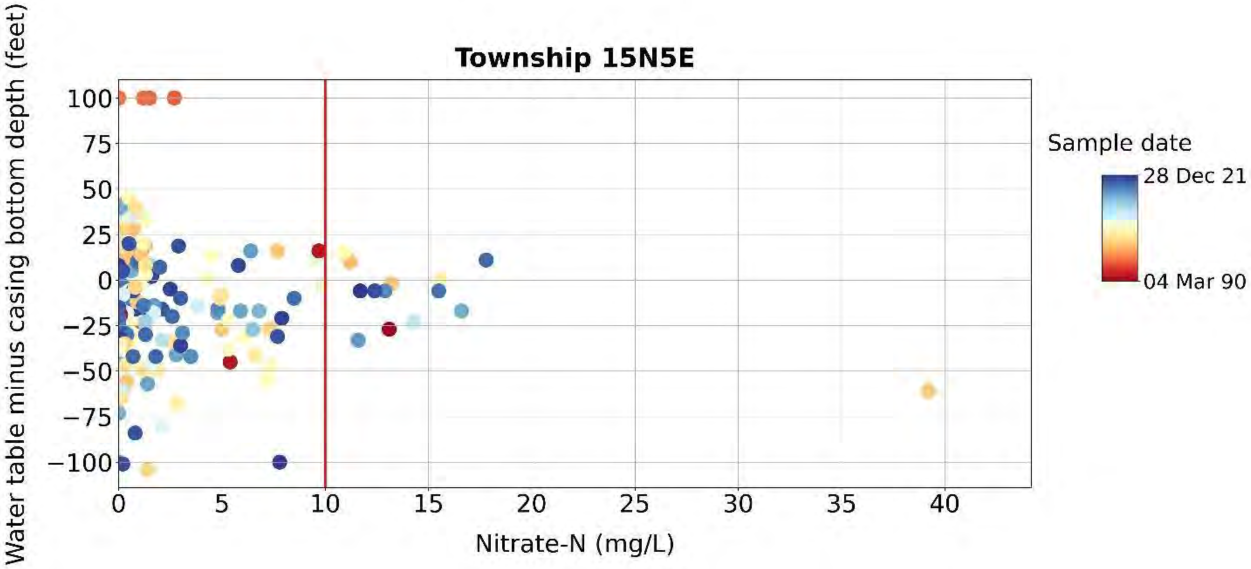
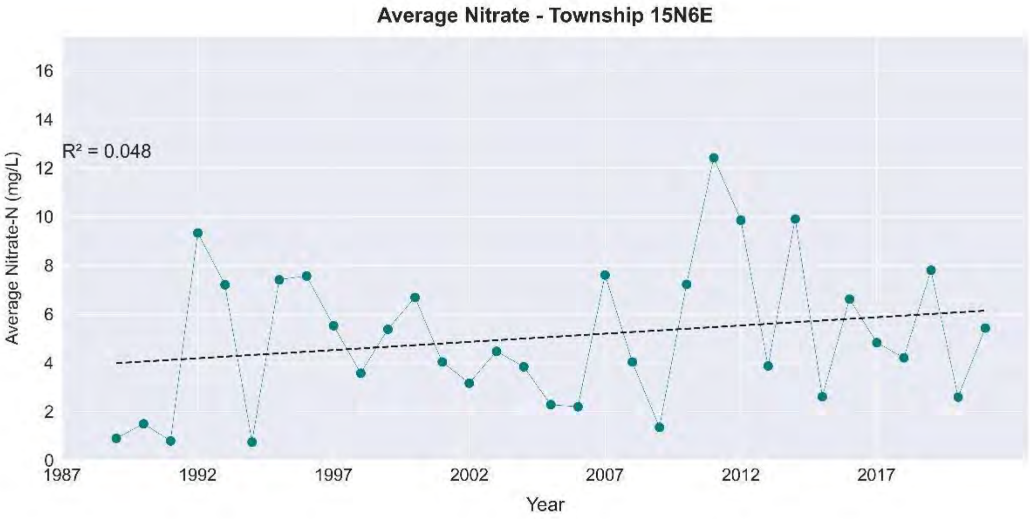


Figure C 13. Township 15N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



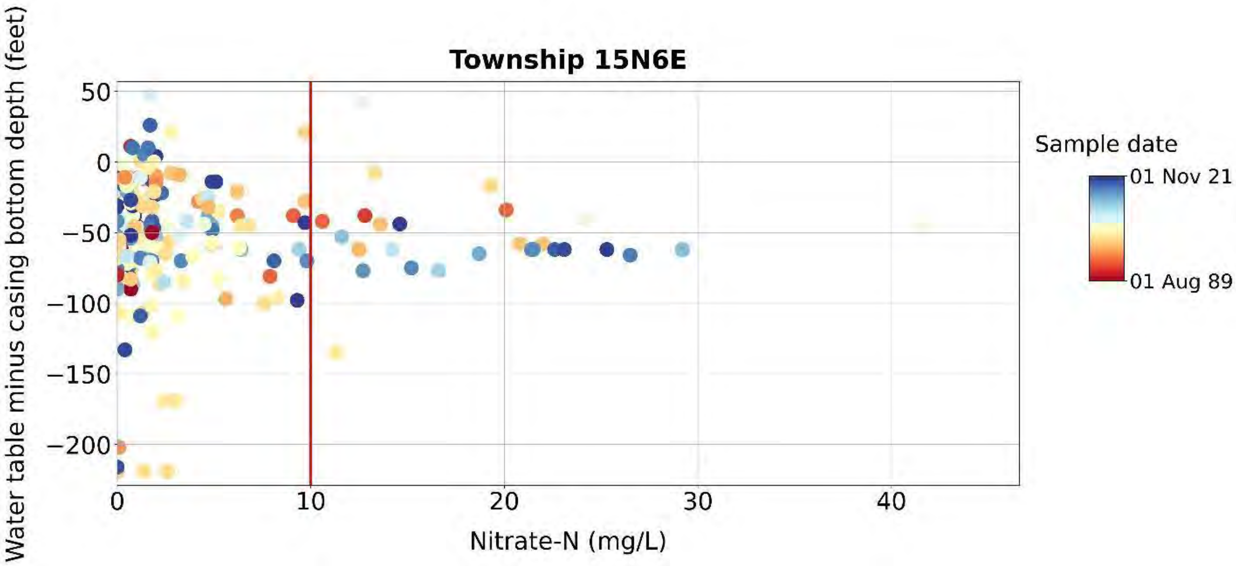
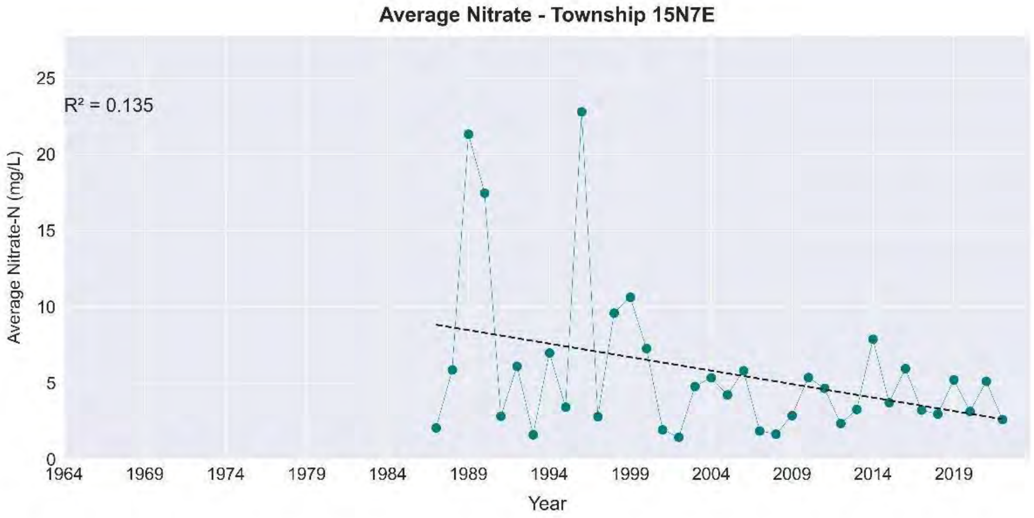


Figure C 14. Township 15N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



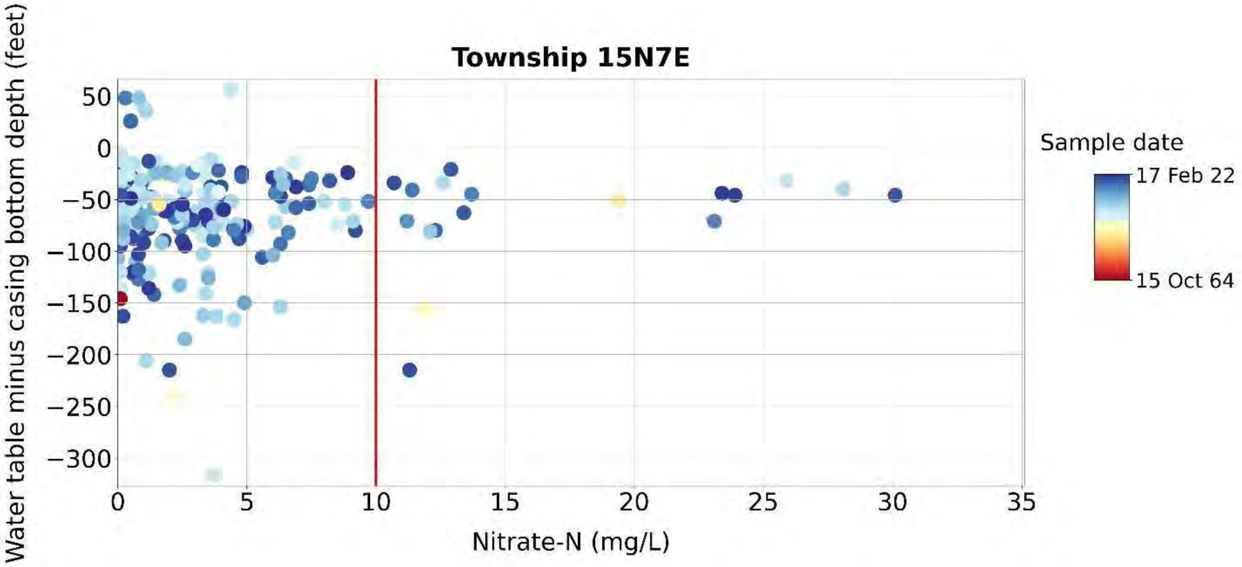
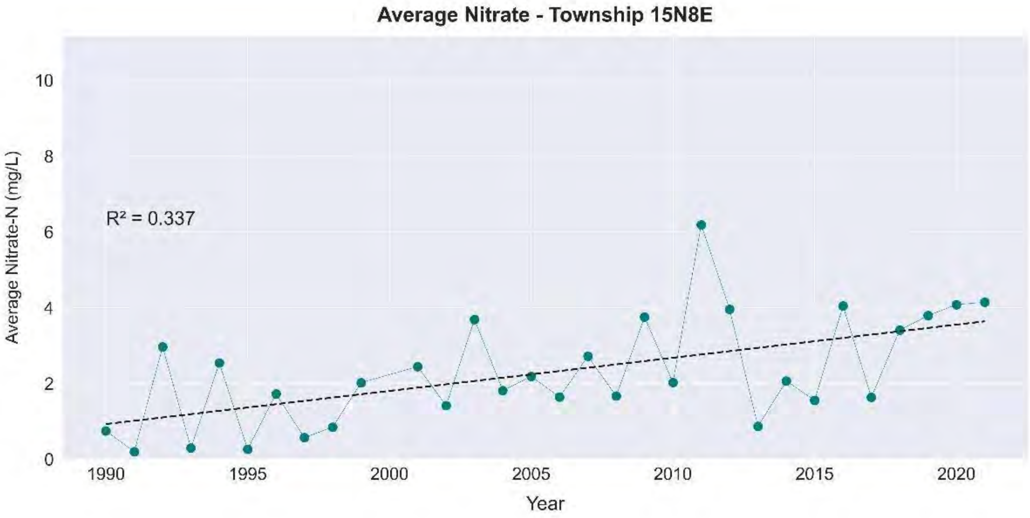


Figure C 15. Township 15N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



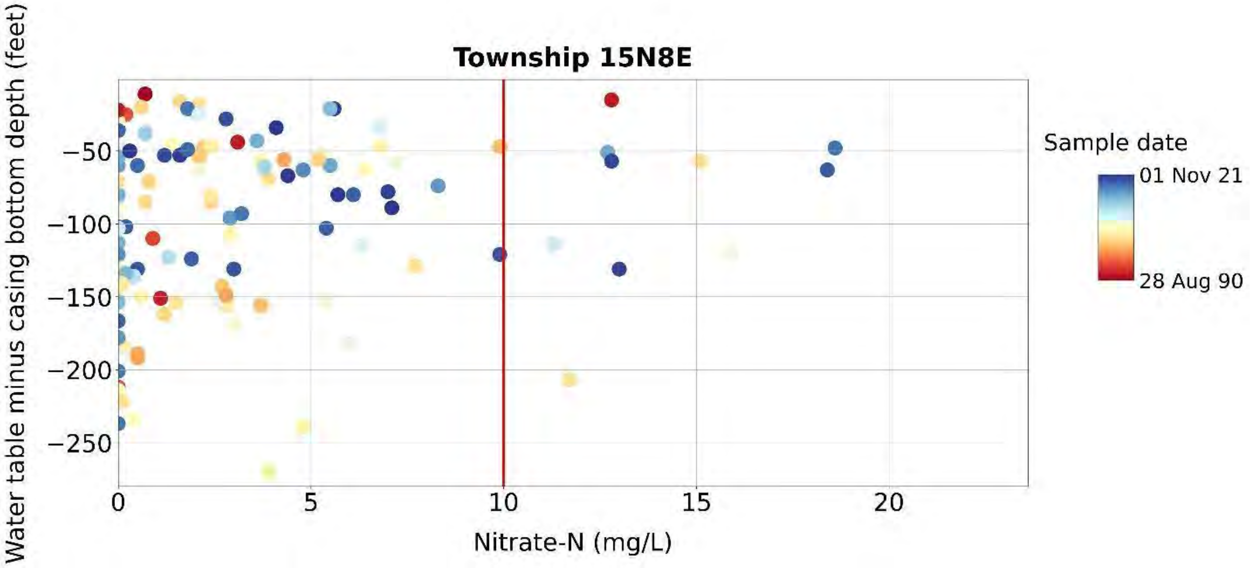
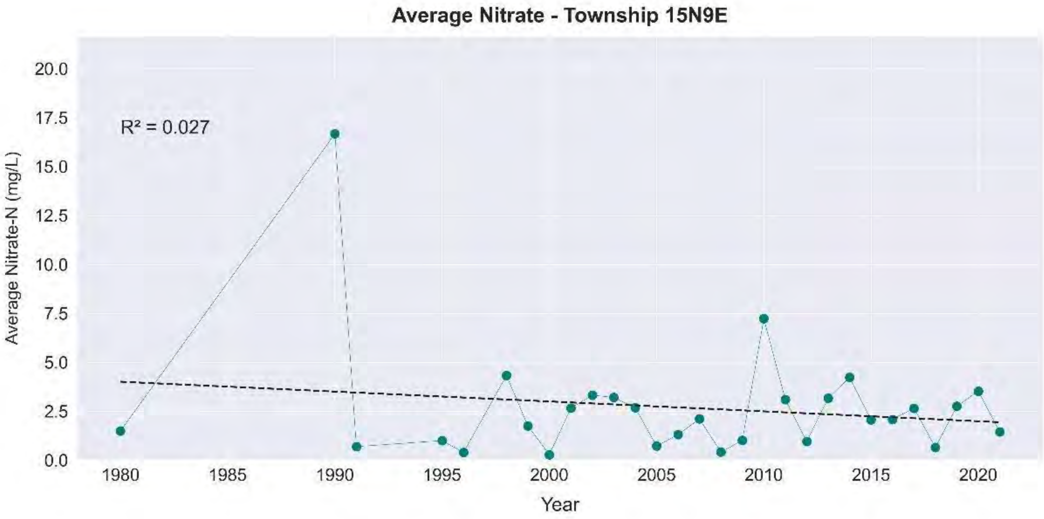


Figure C 16. Township 15N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



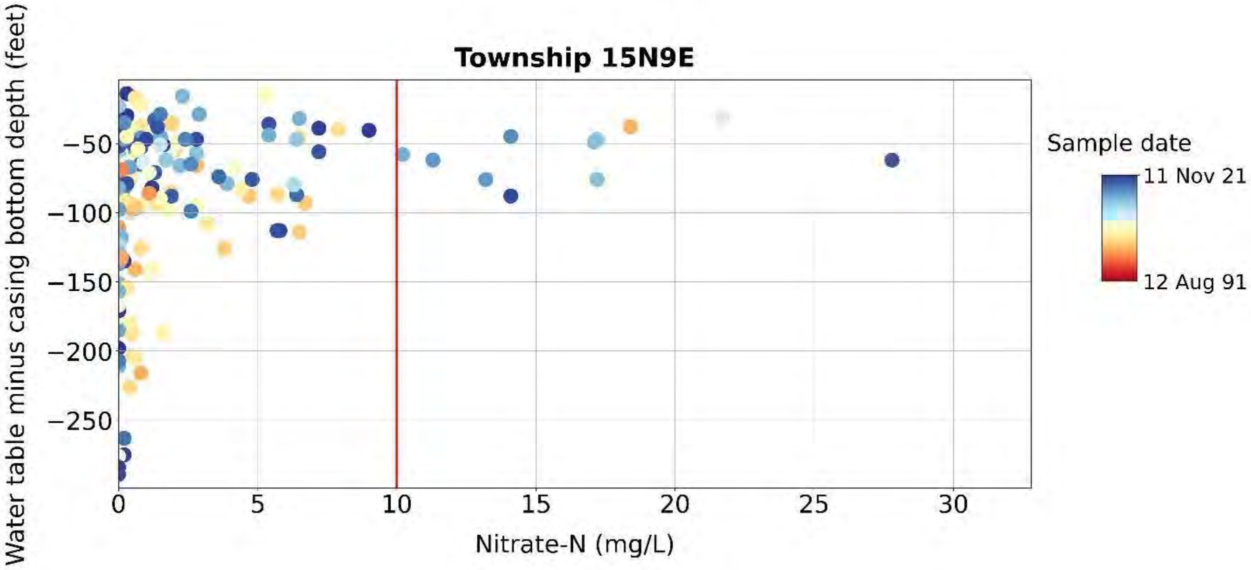
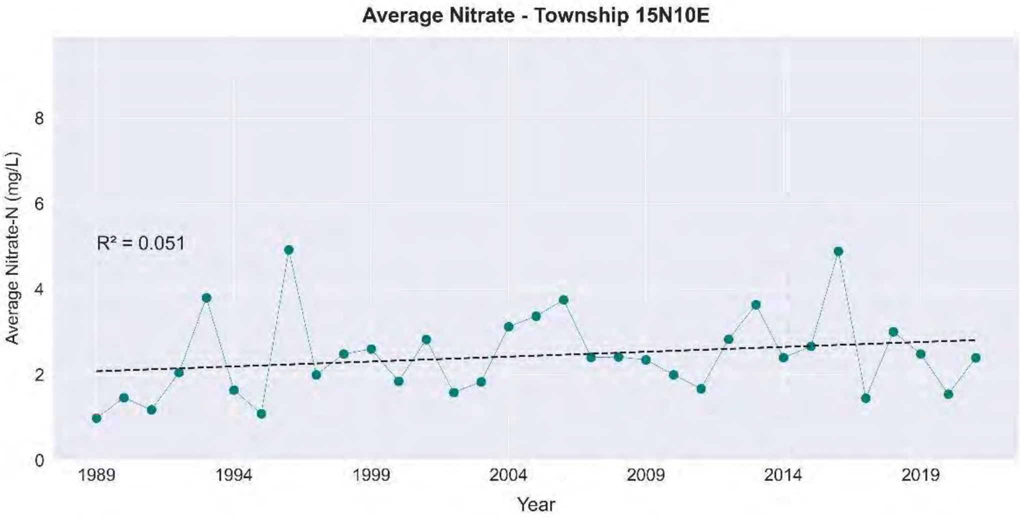


Figure C 17. Township 15N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



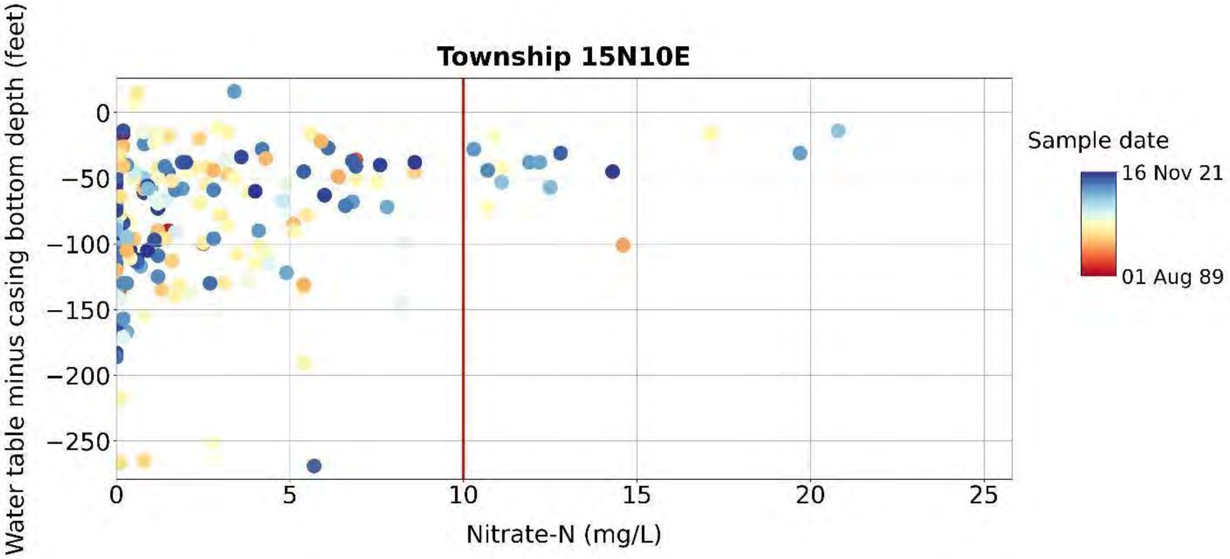
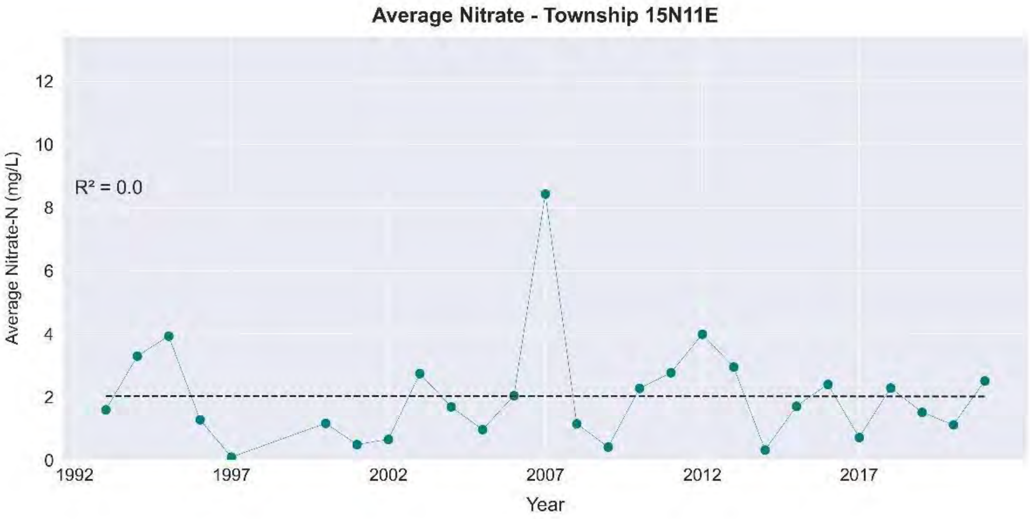


Figure C 18. Township 15N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



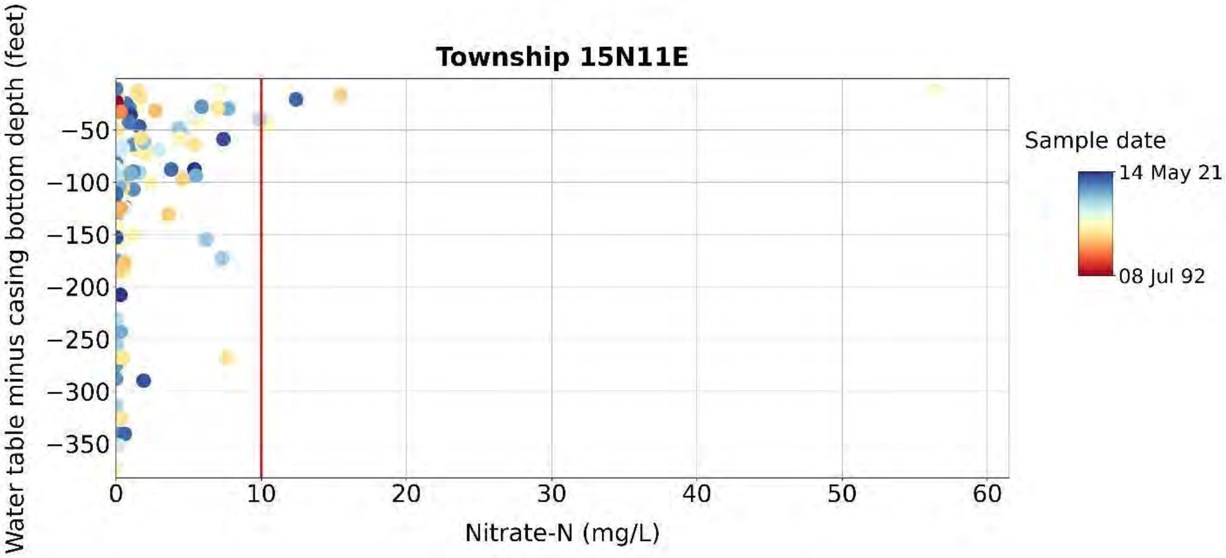
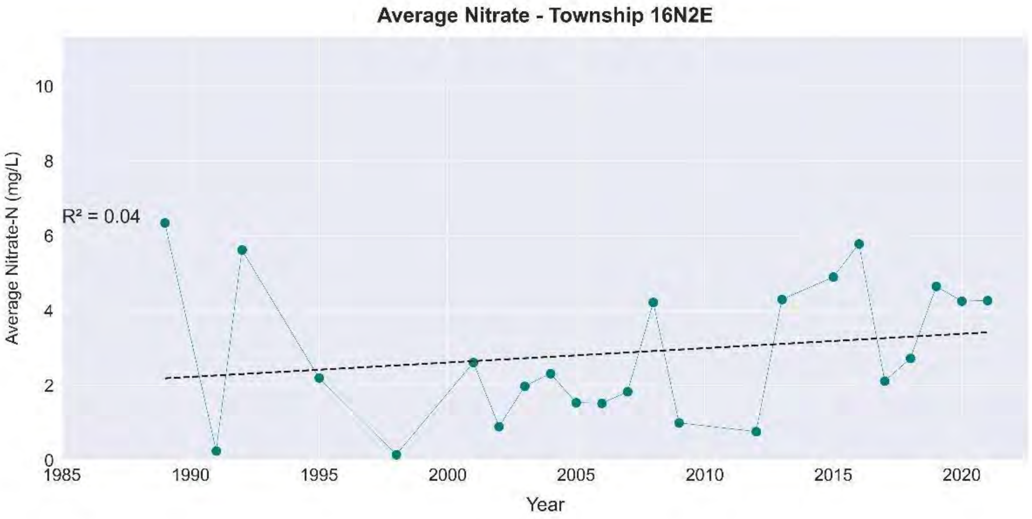


Figure C 19. Township 15N11E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



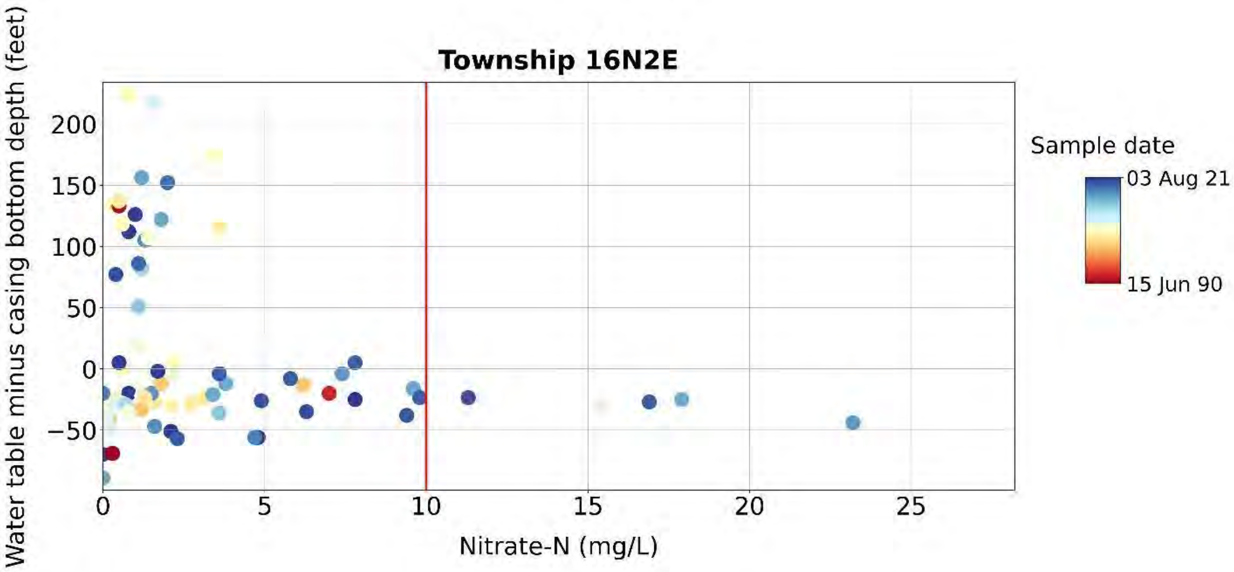
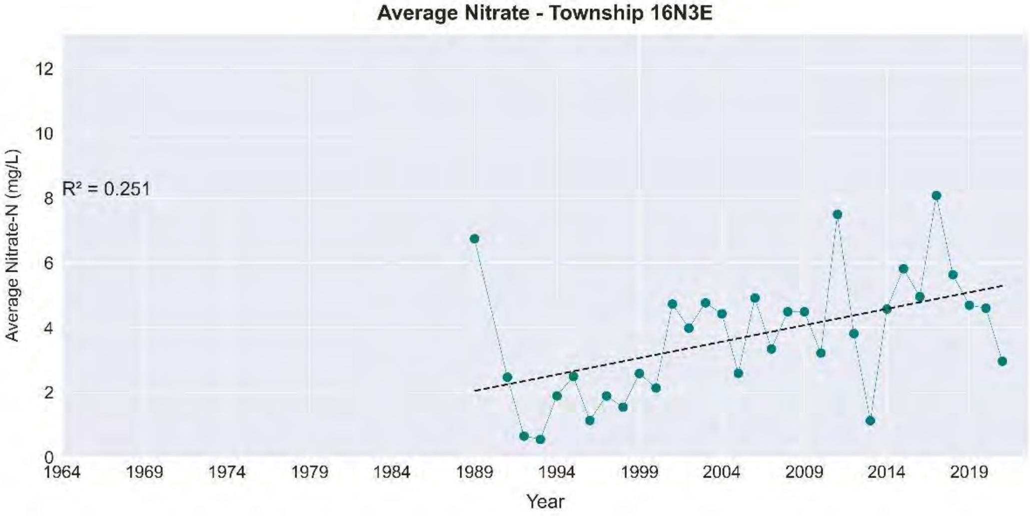


Figure C 20. Township 16N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



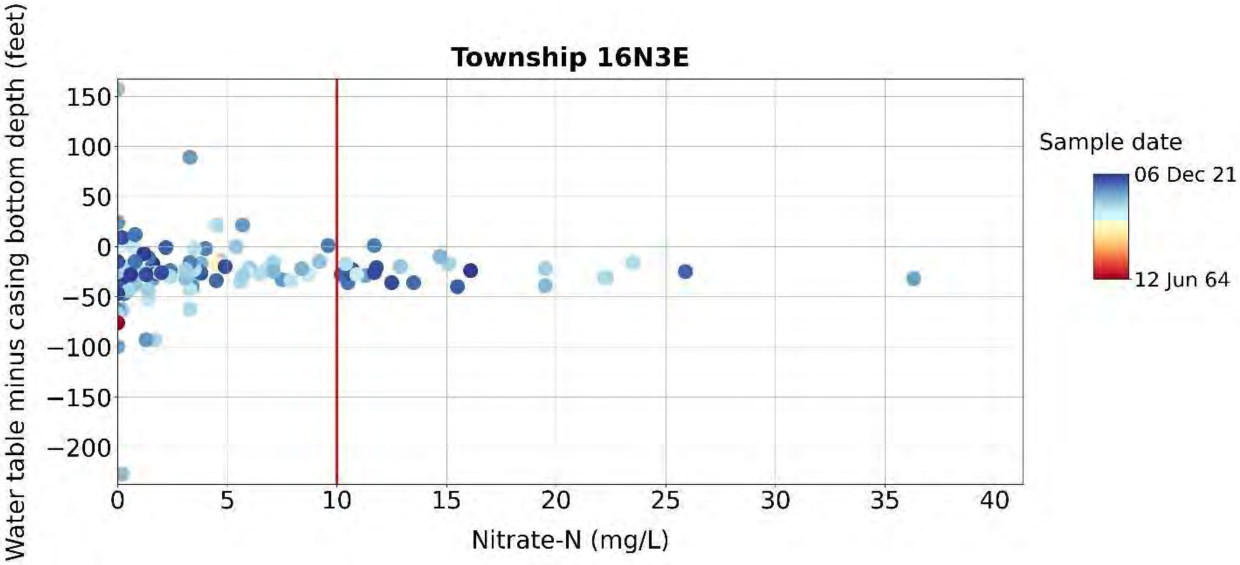
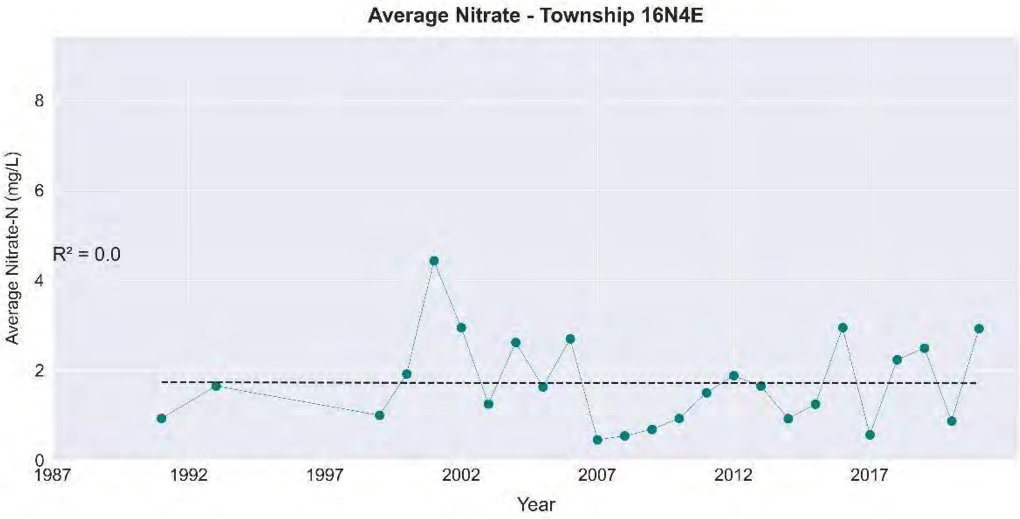


Figure C 21. Township 16N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 *is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.*



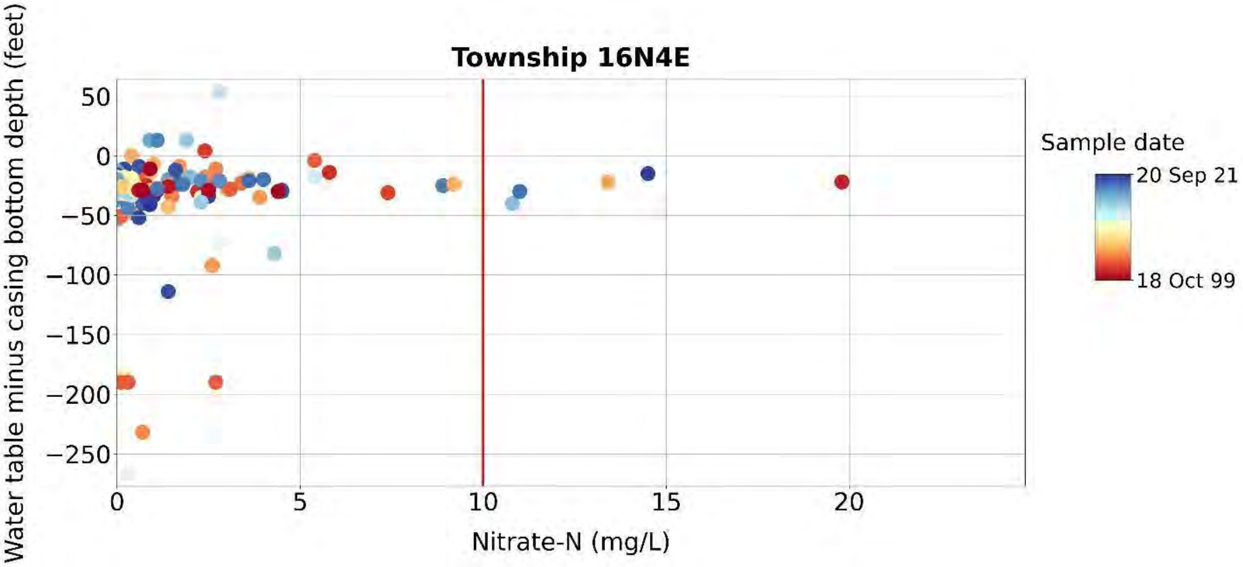
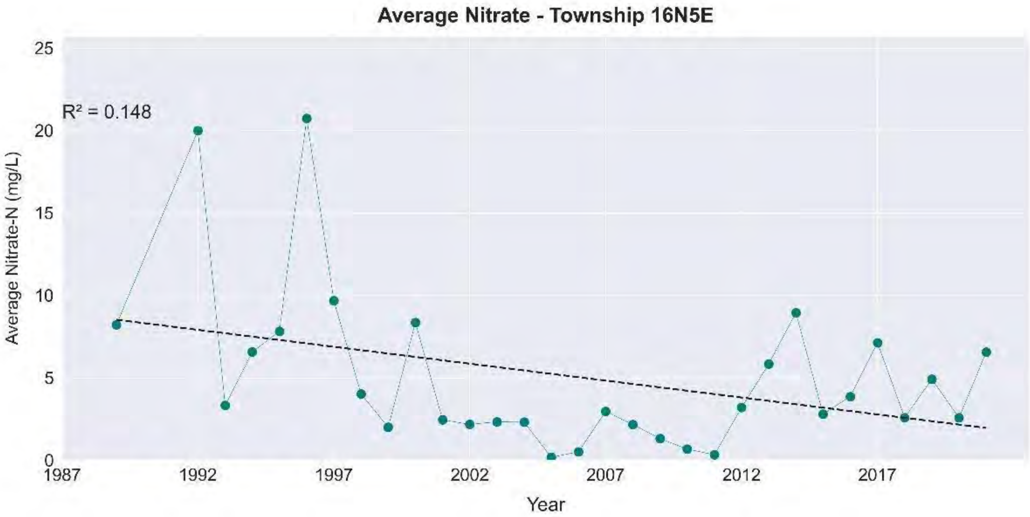


Figure C 22. Township 16N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



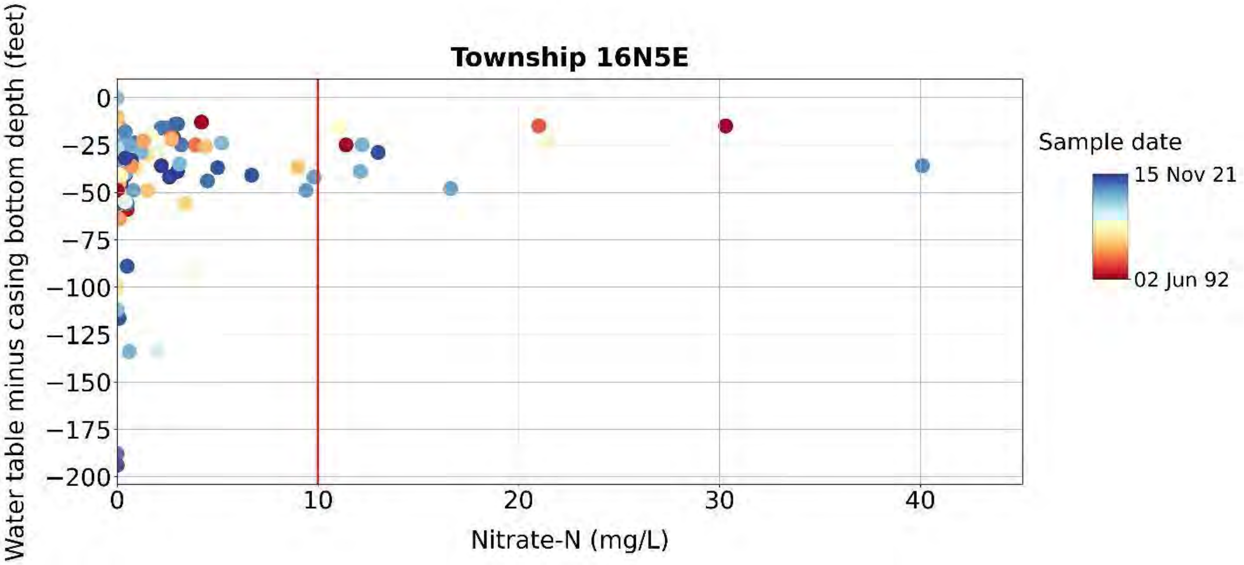
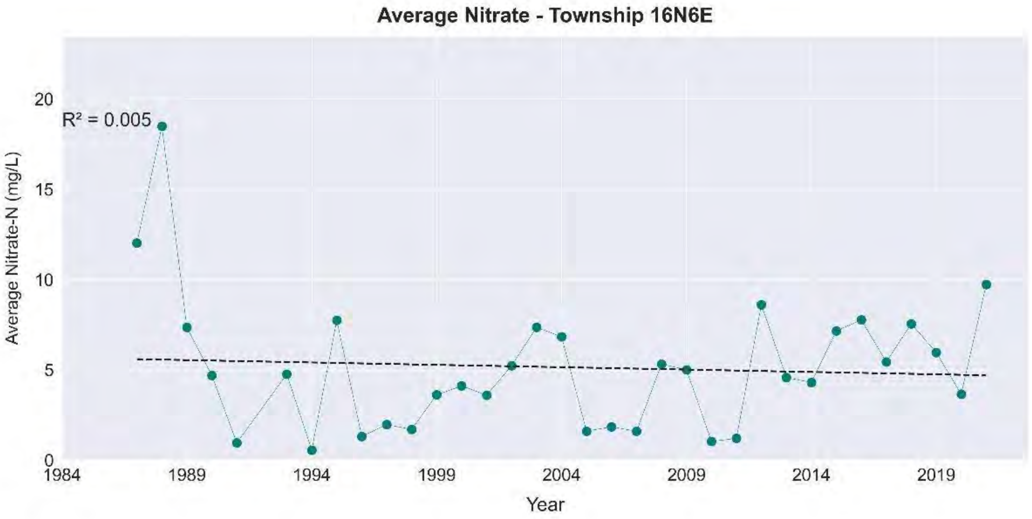


Figure C 23. Township 16N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



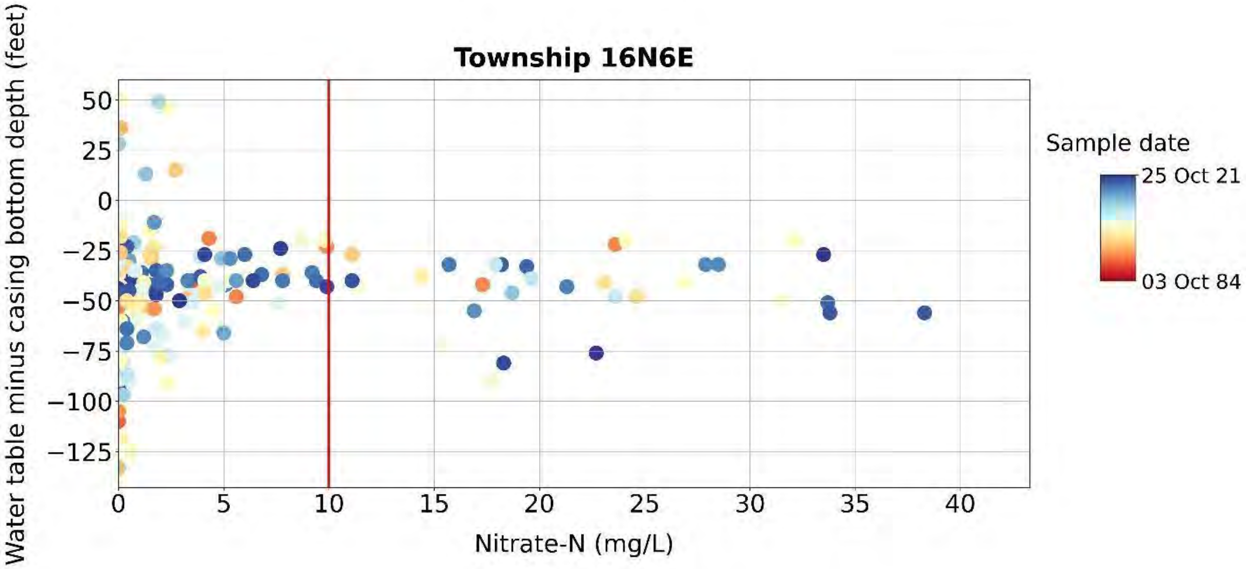
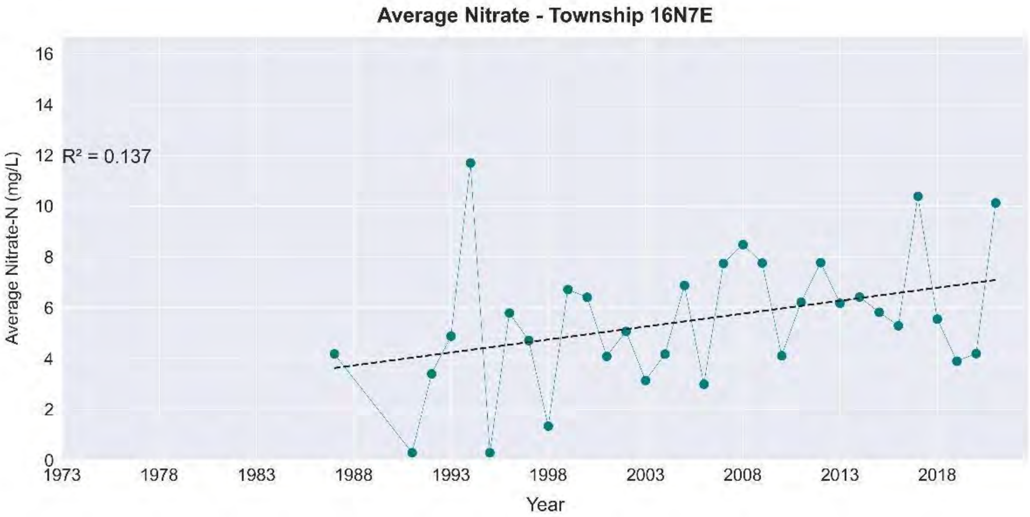


Figure C 24. Township 16N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



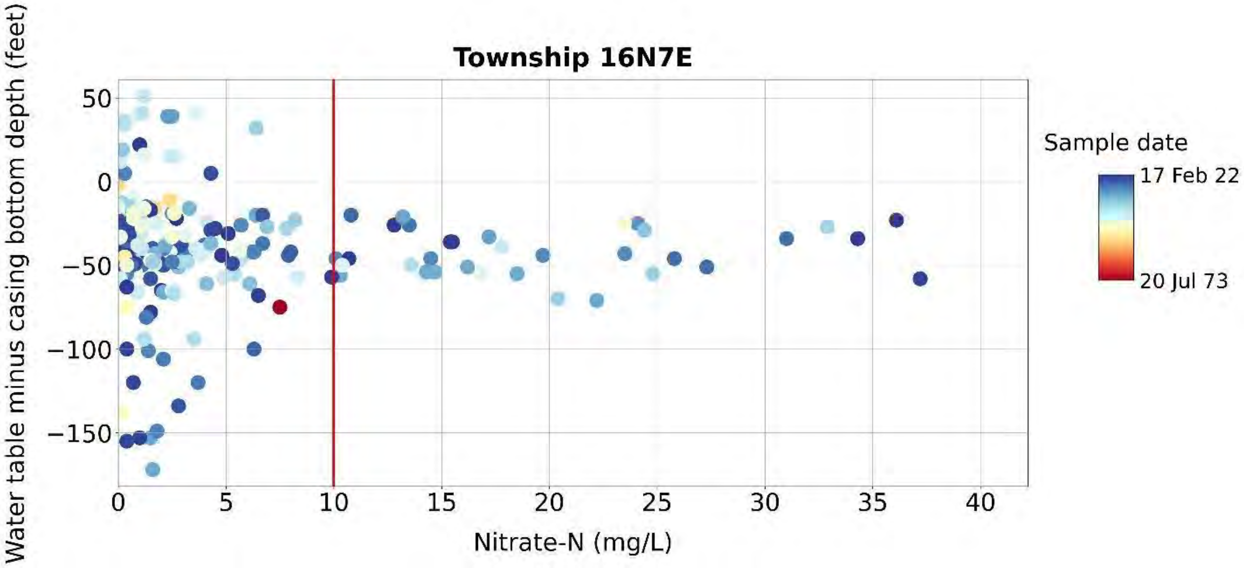
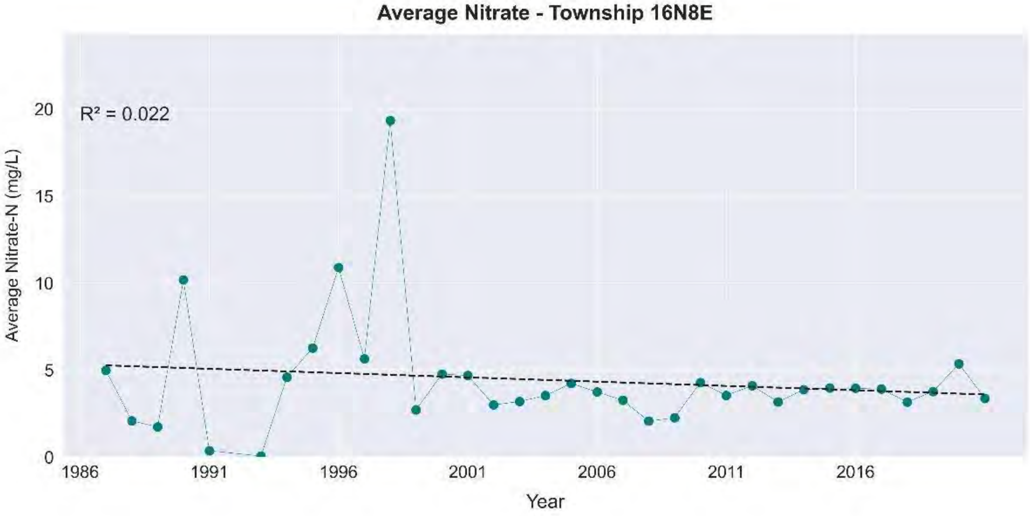


Figure C 25. Township 16N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



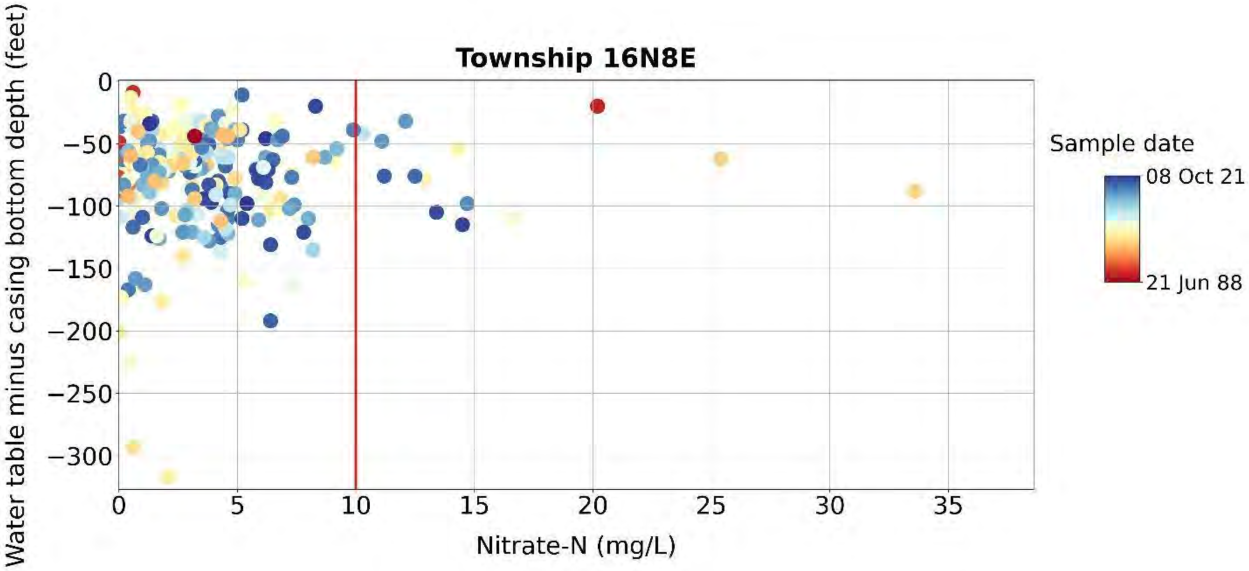
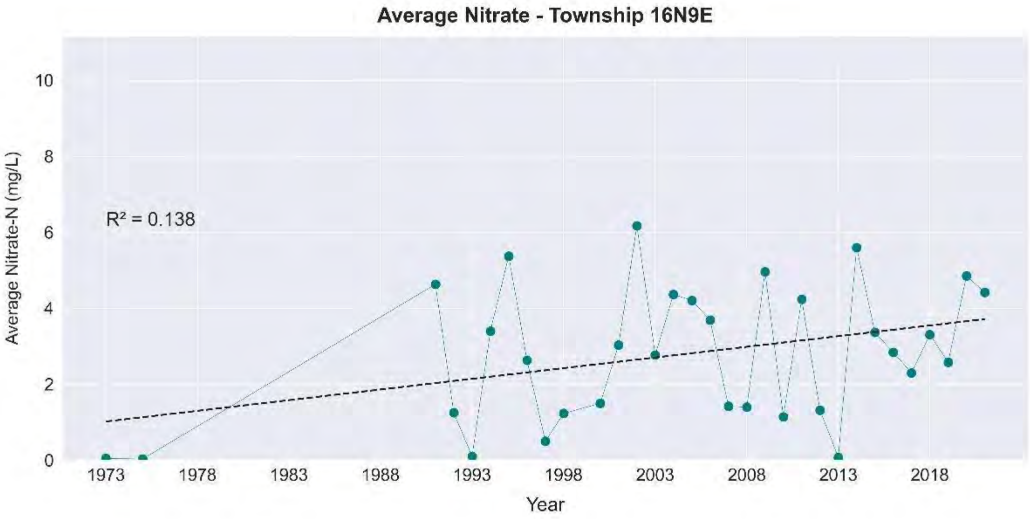


Figure C 26. Township 16N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



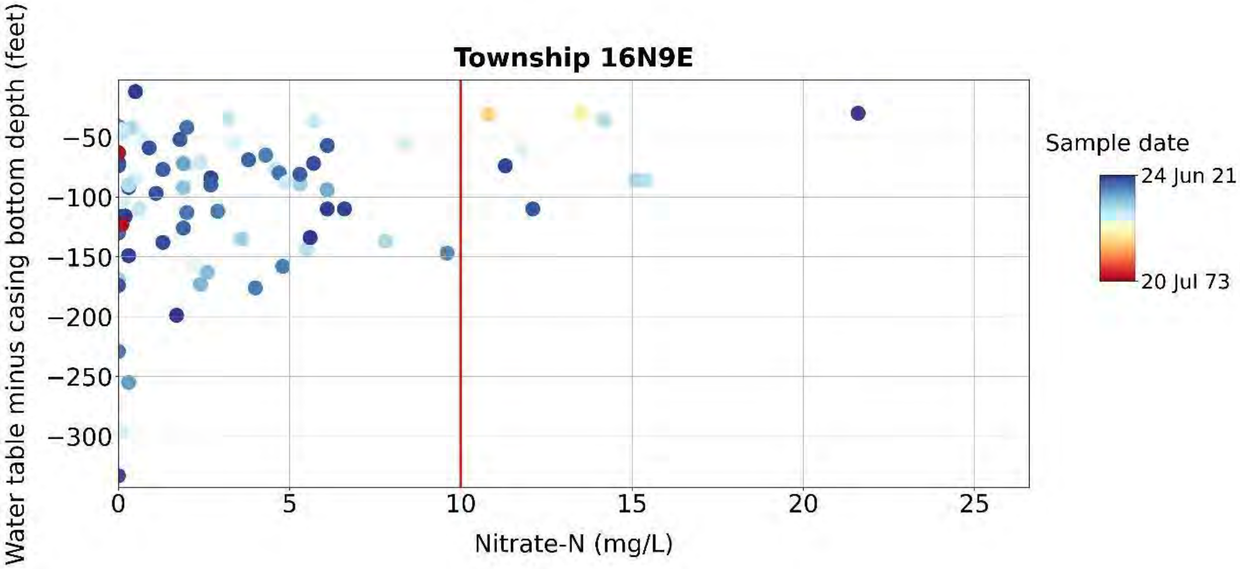


Figure C 27. Township 16N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

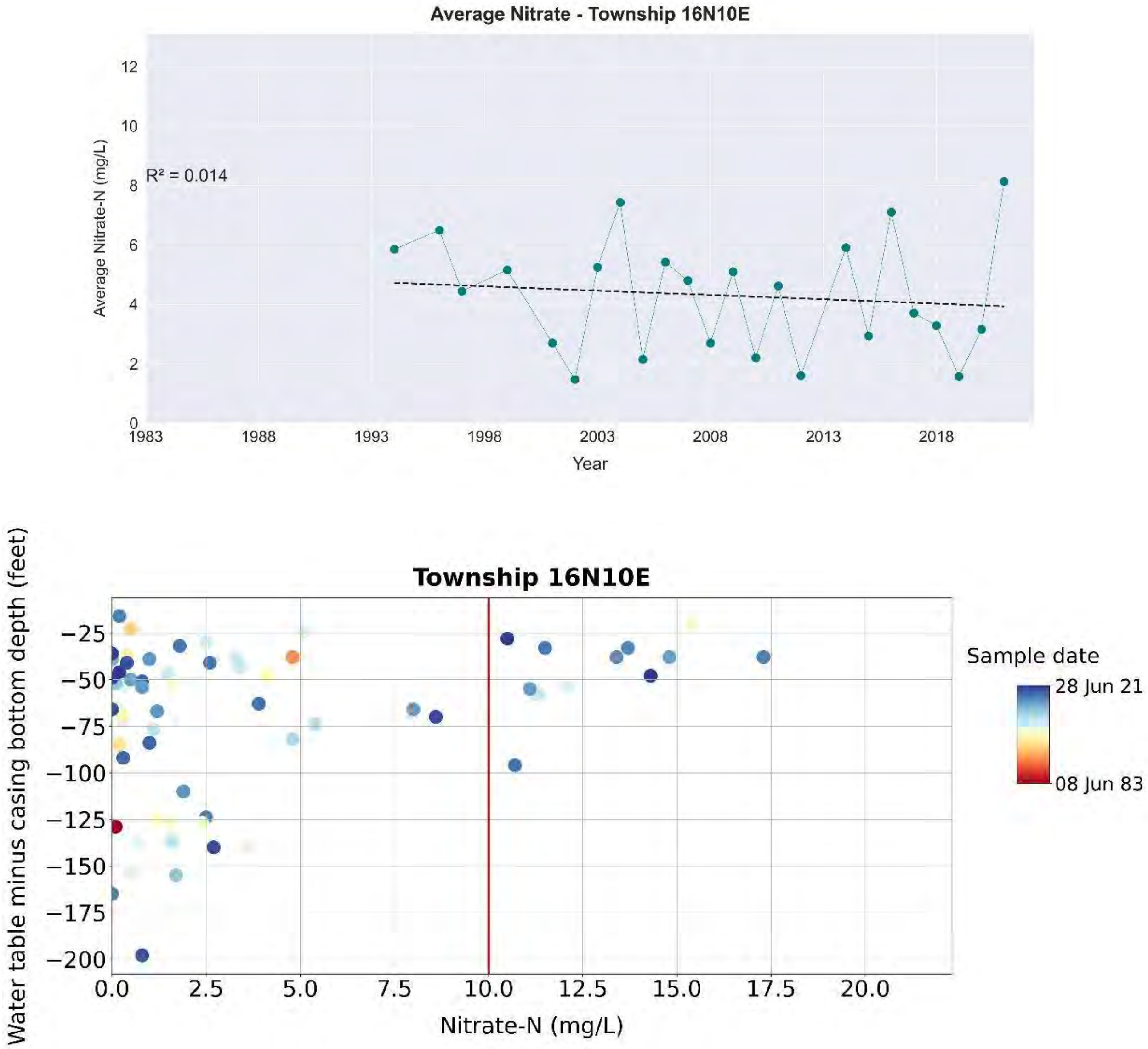
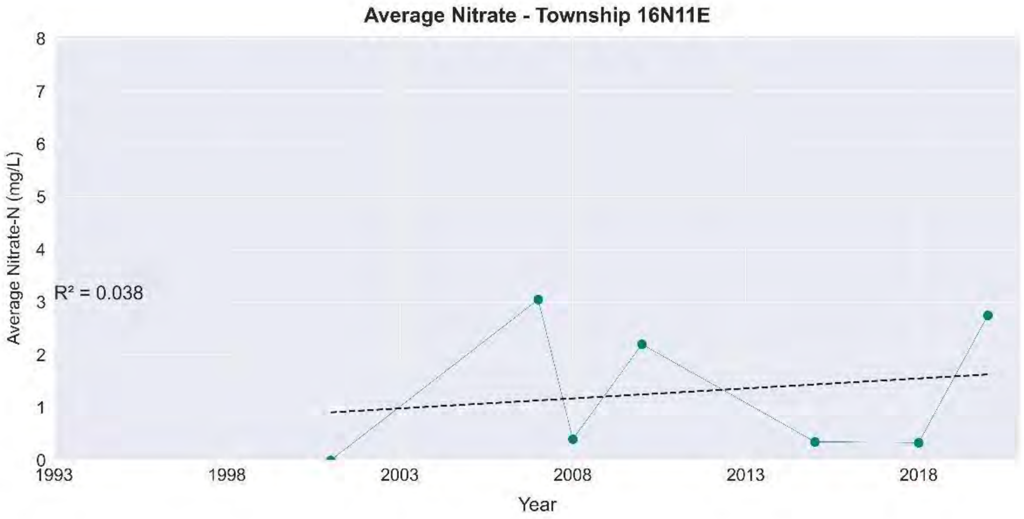


Figure C 28. Township 16N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



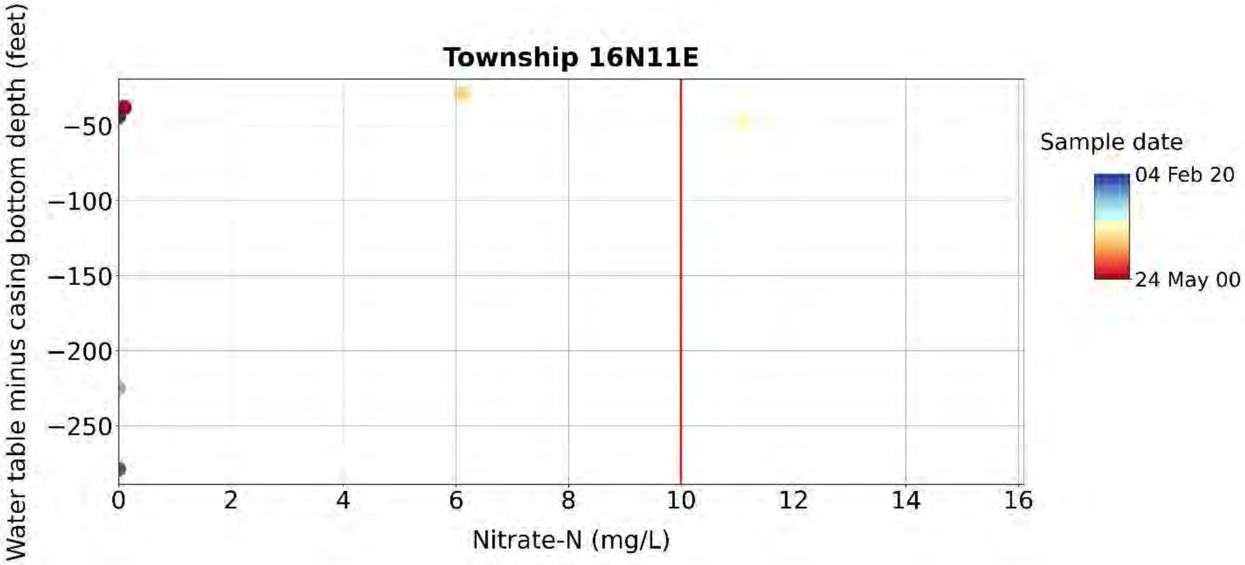
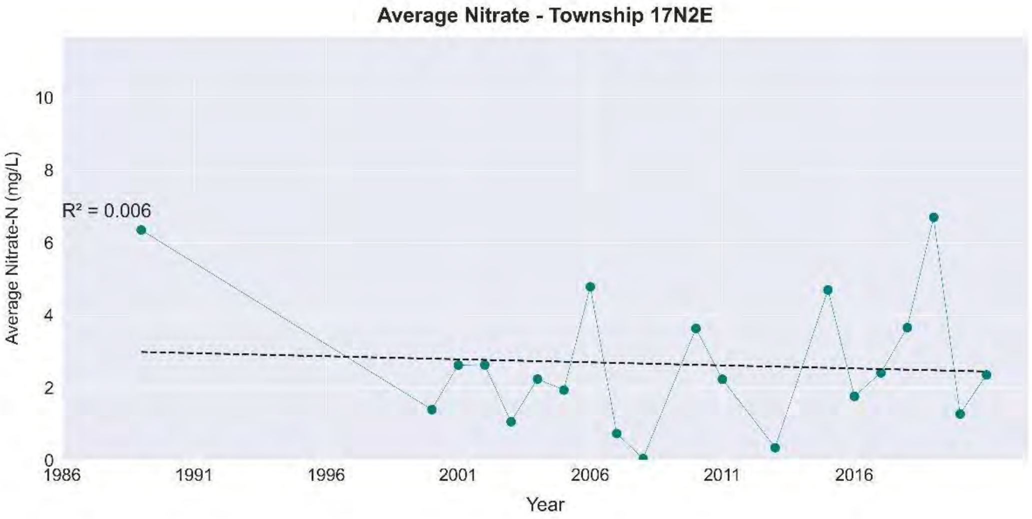


Figure C 29. Township 16N11E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



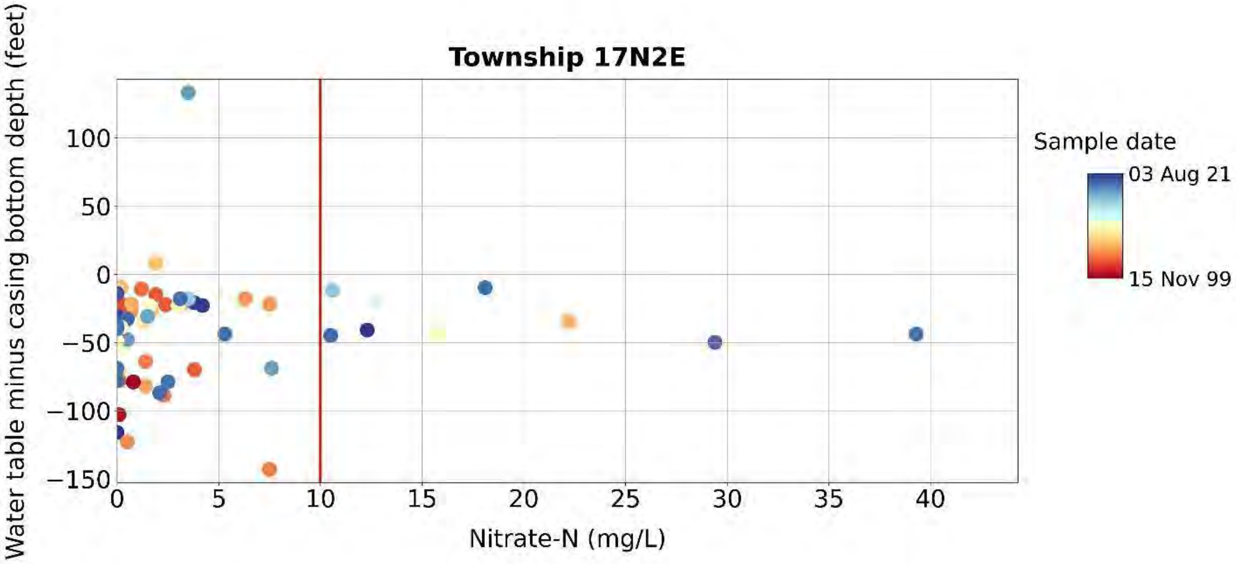
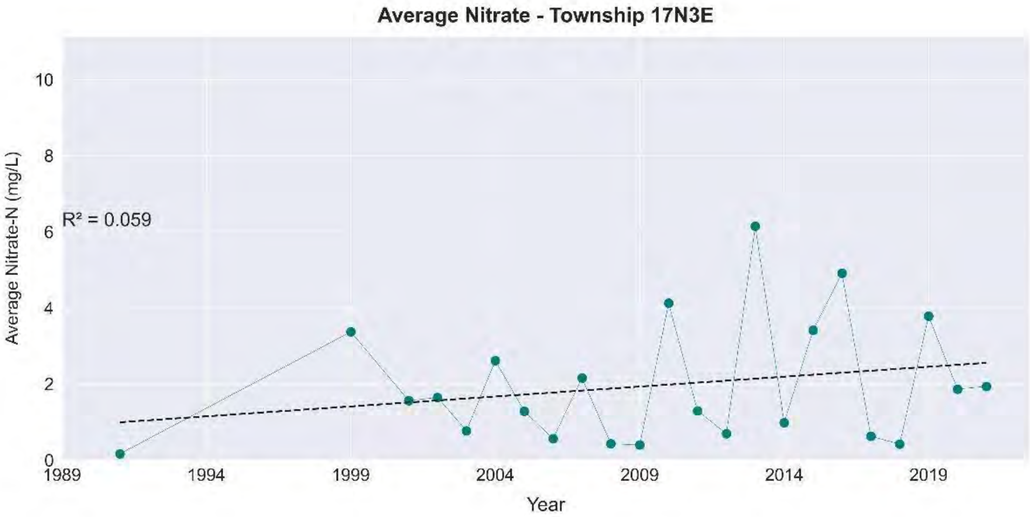


Figure C 30. Township 17N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



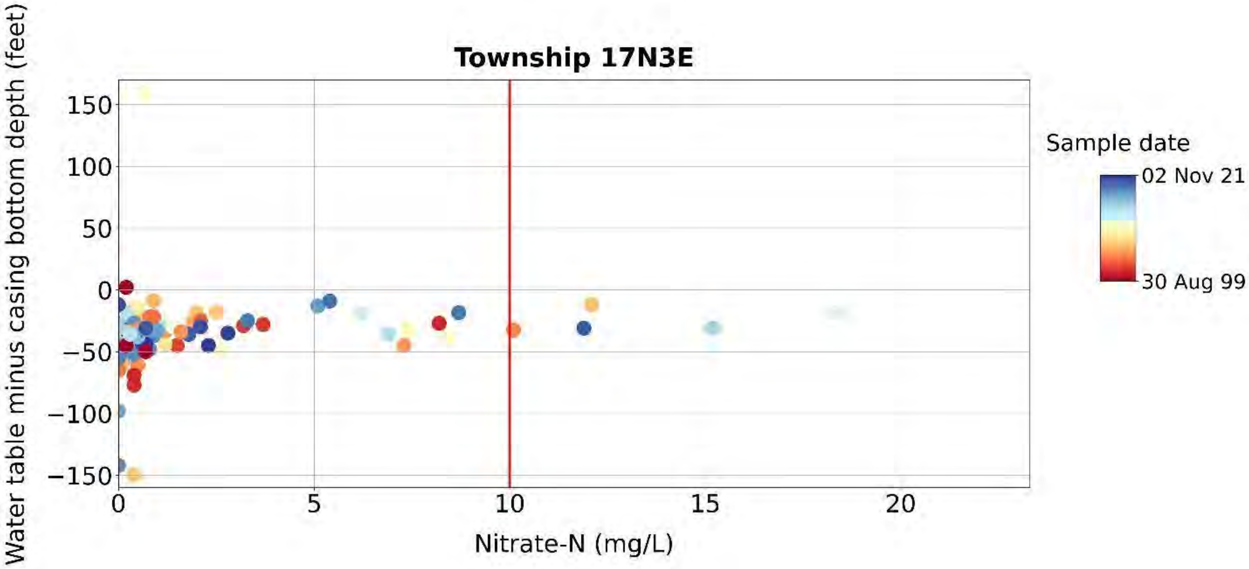
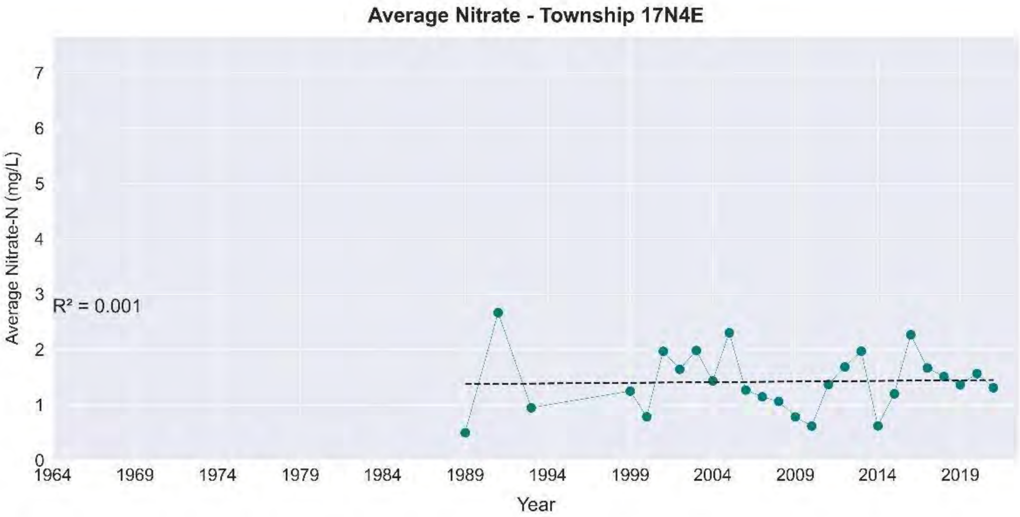


Figure C 31. Township 17N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



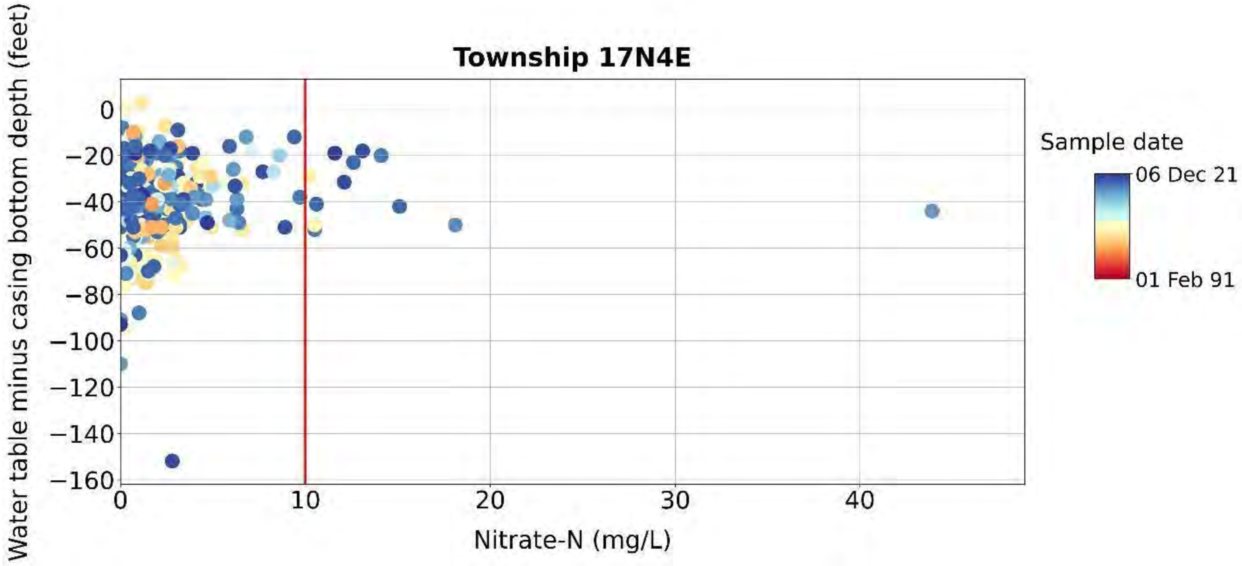
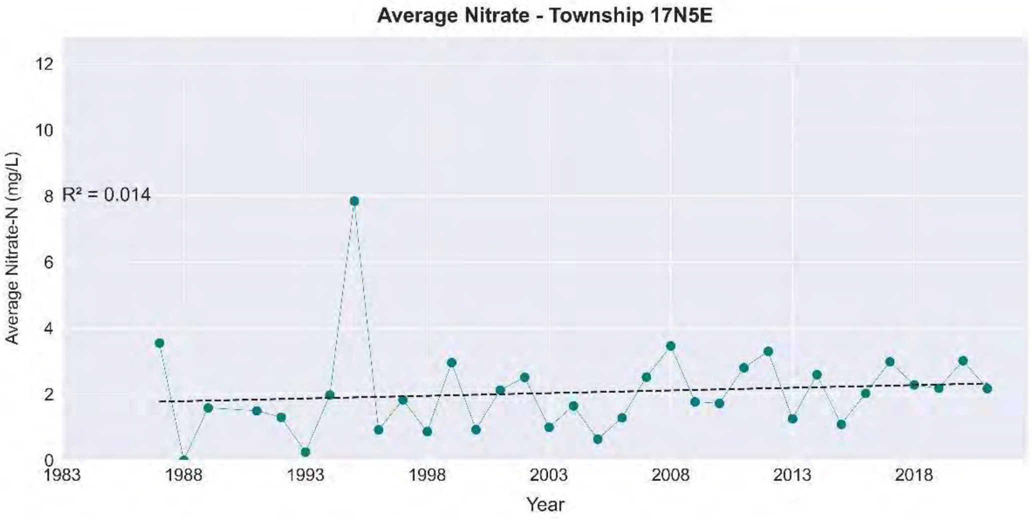


Figure C 32. Township 17N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



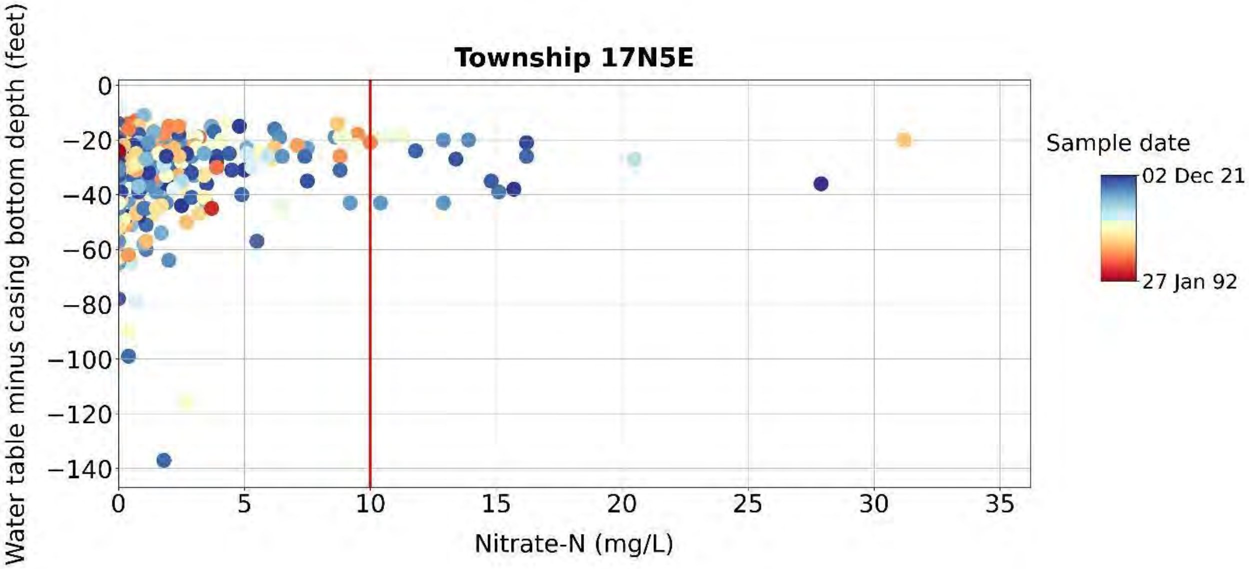
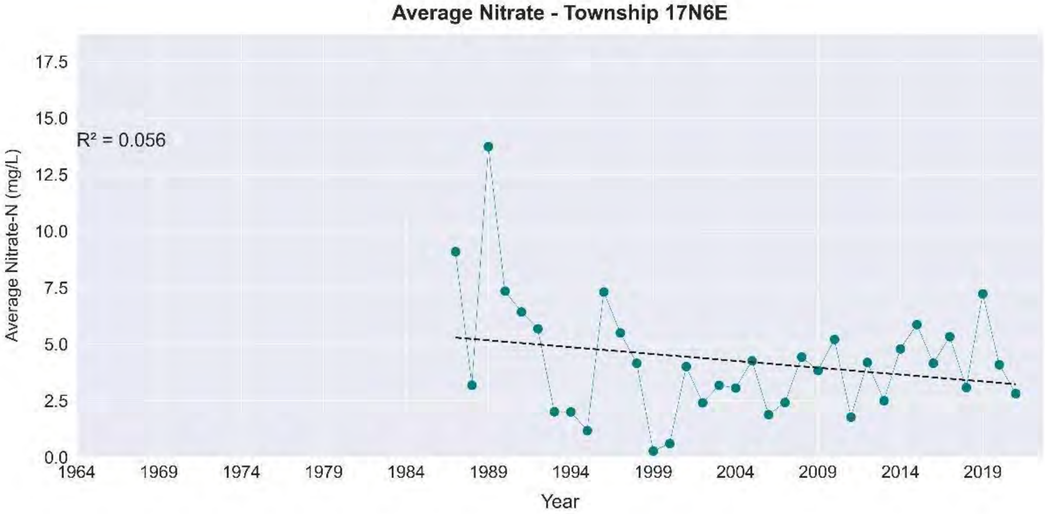


Figure C 33. Township 17N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



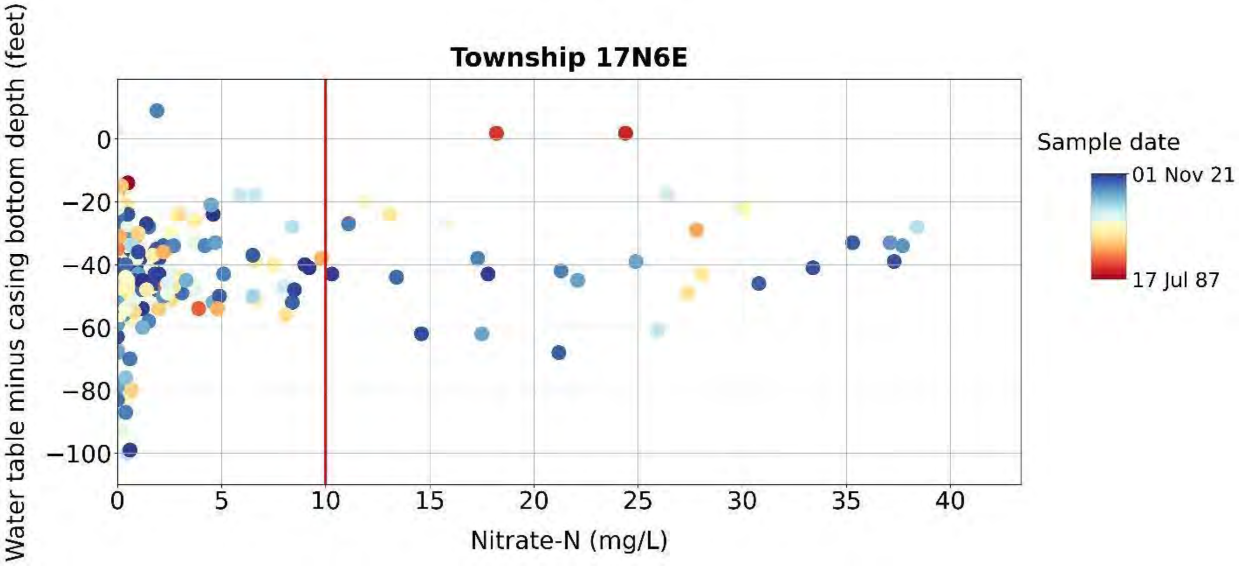
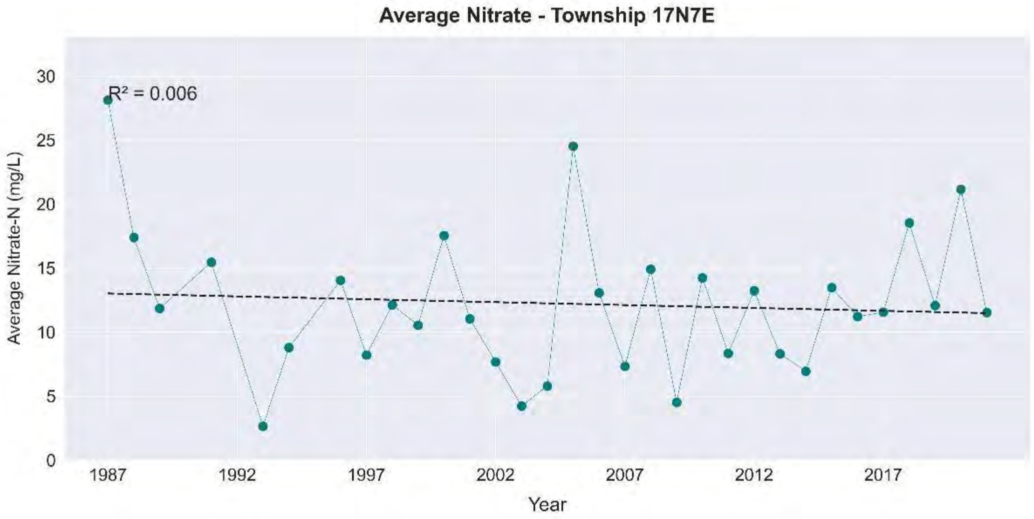


Figure C 34. Township 17N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



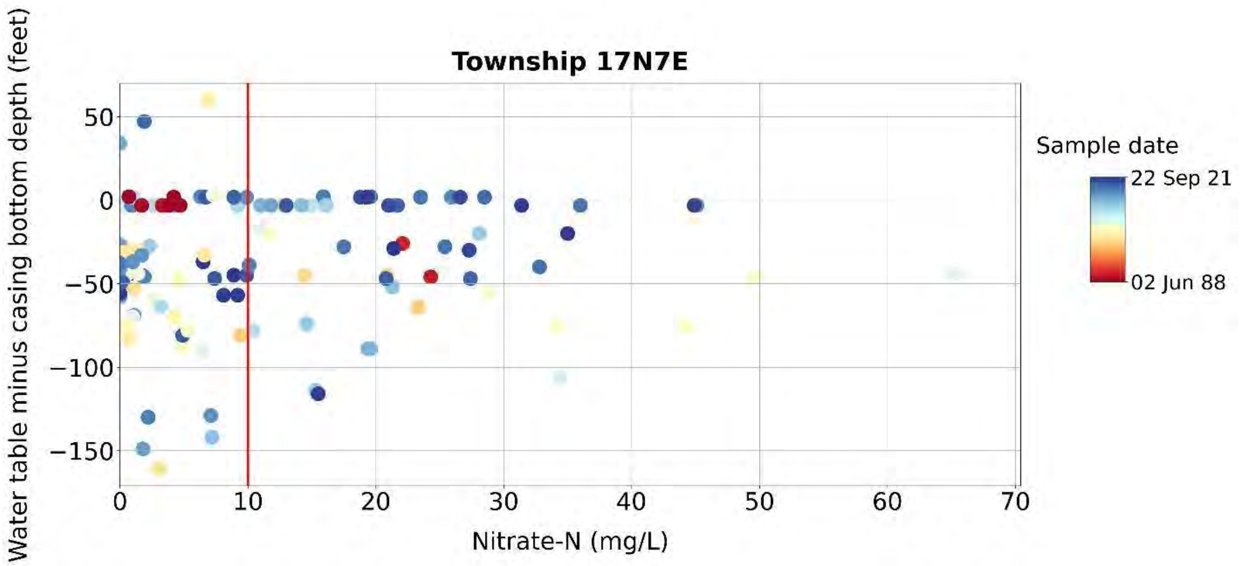
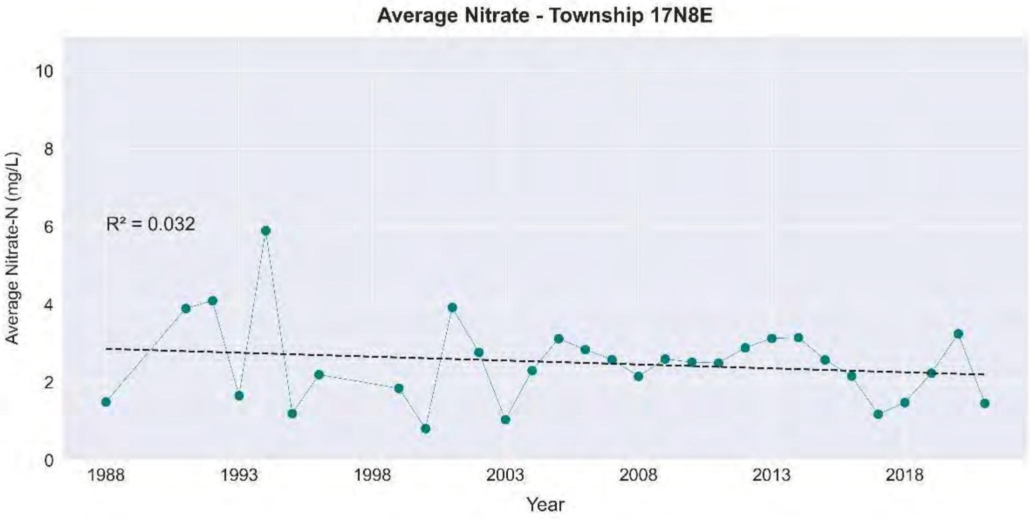


Figure C 35. Township 17N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



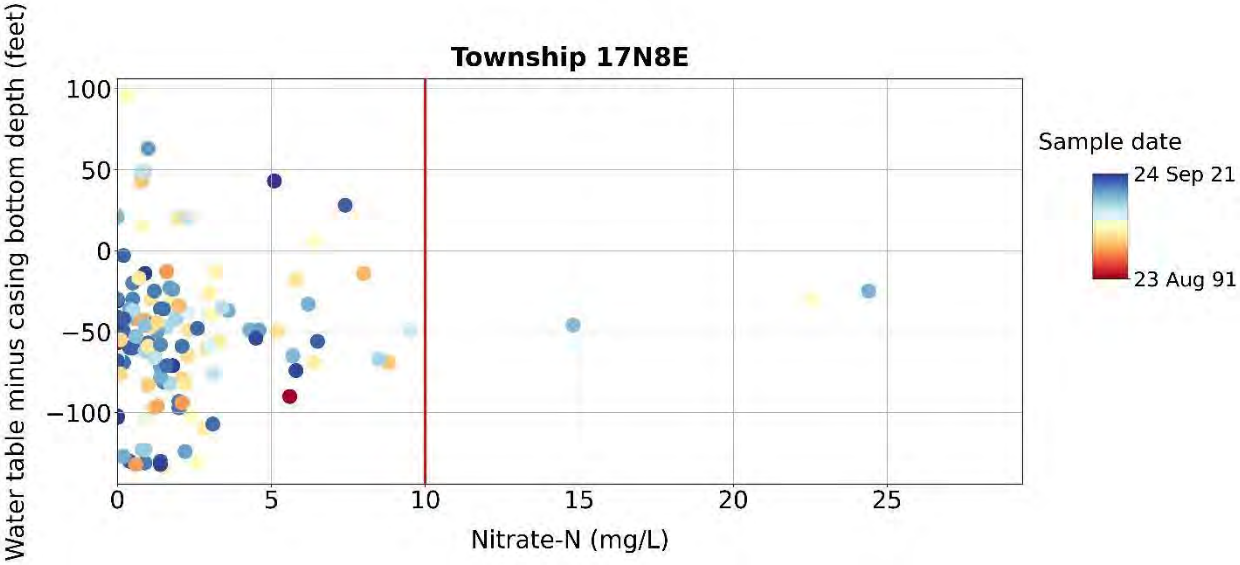
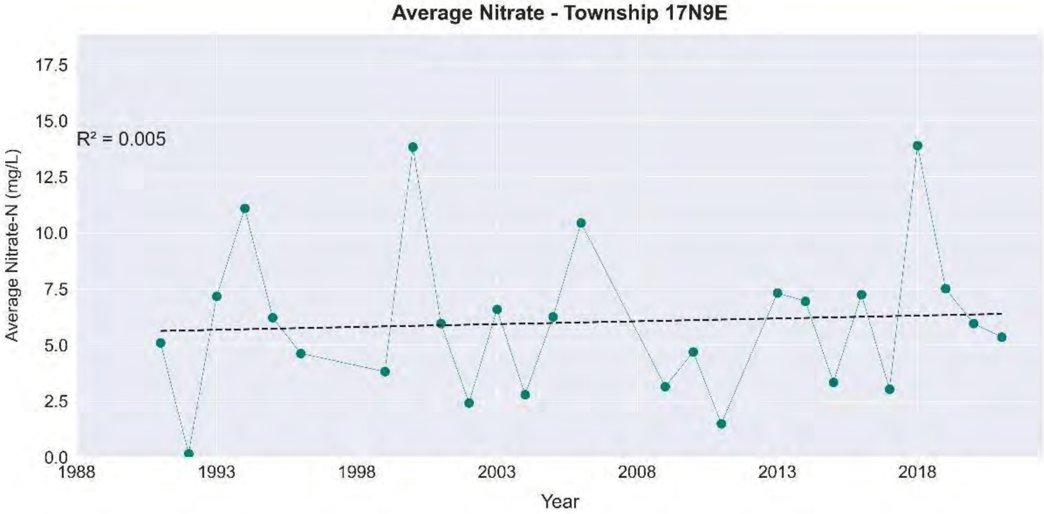


Figure C 36. Township 17N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



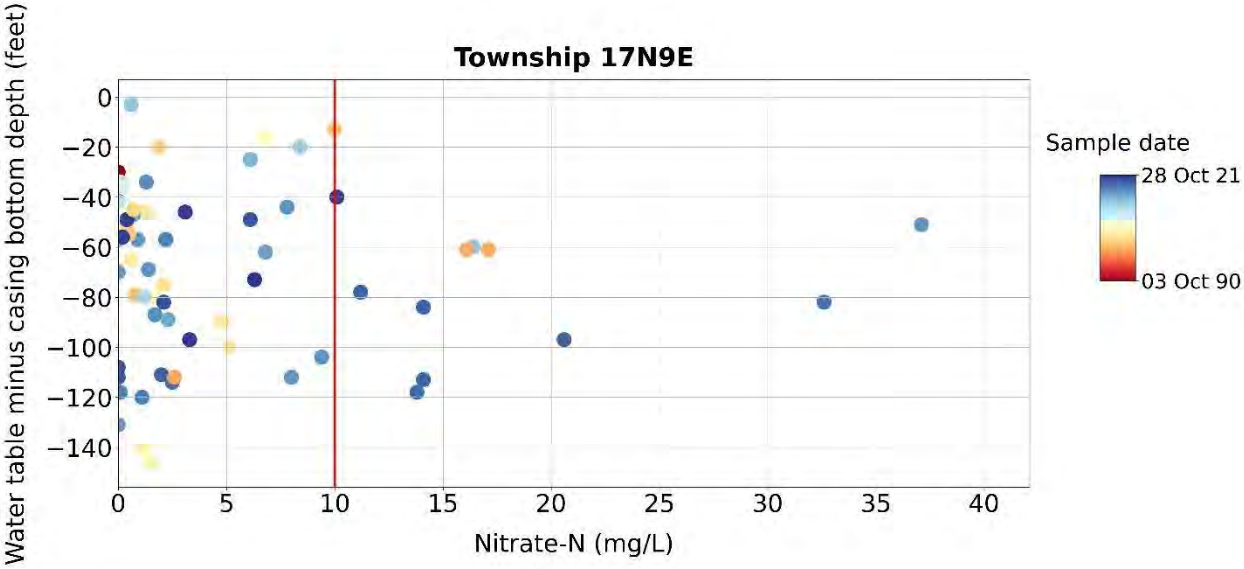
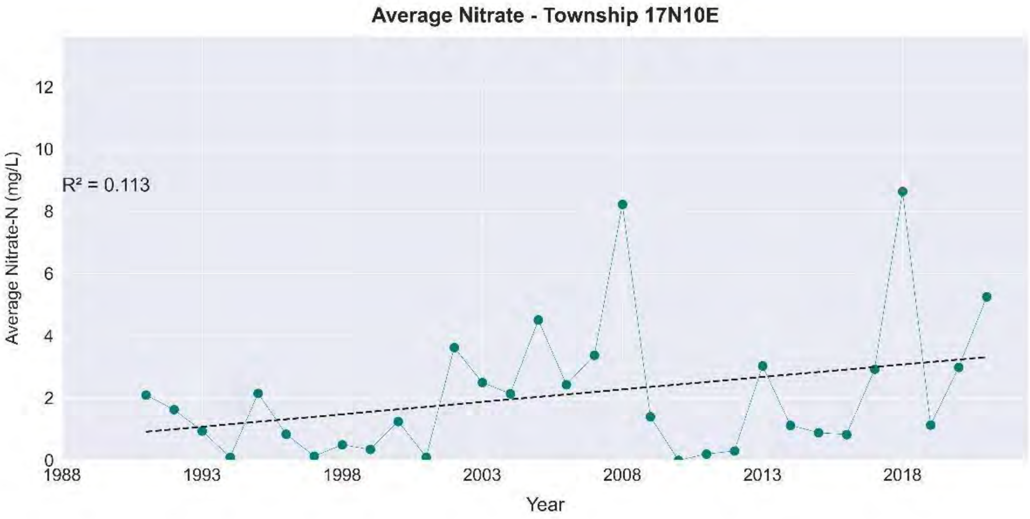


Figure C 37. Township 17N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



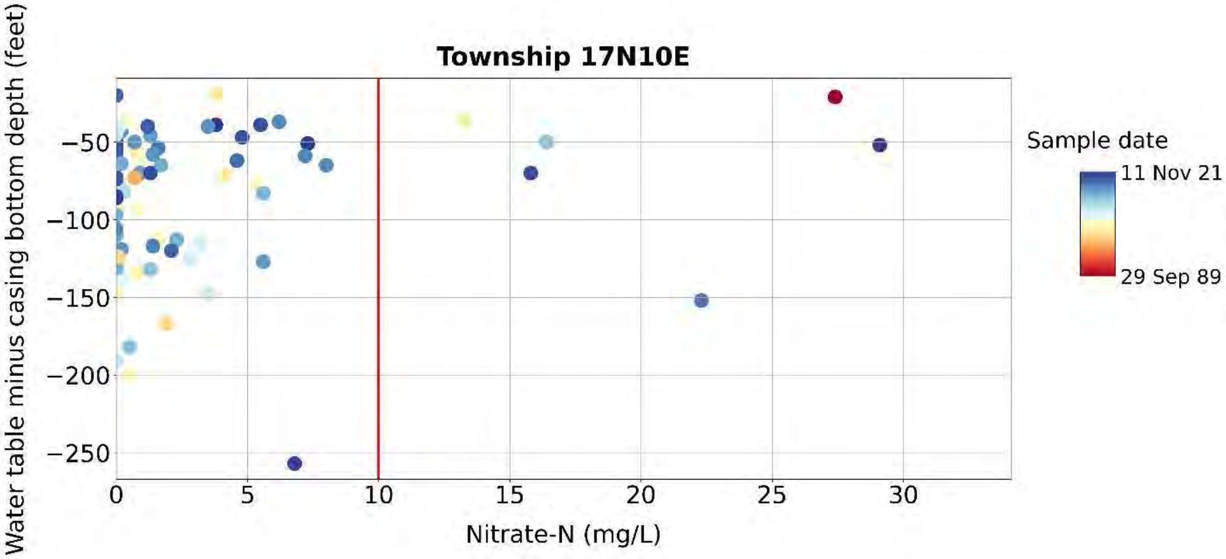
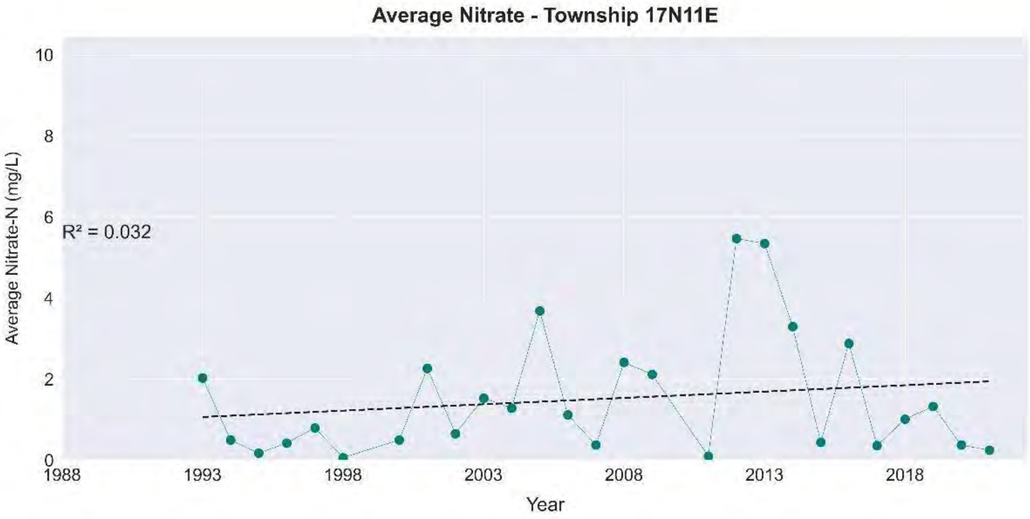


Figure C 38. Township 17N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



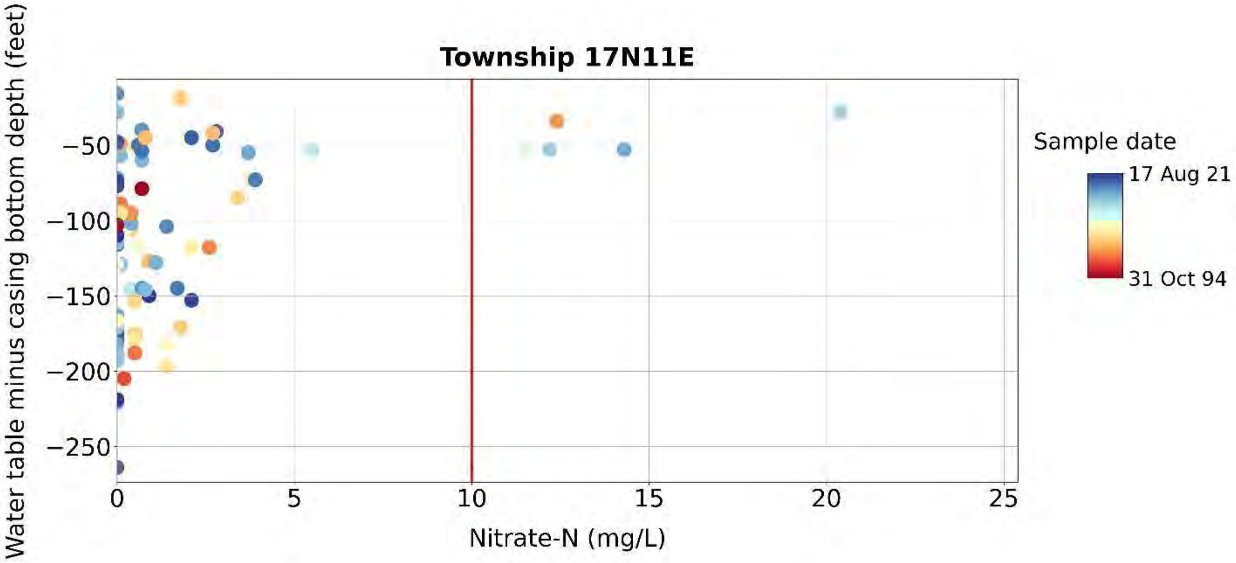
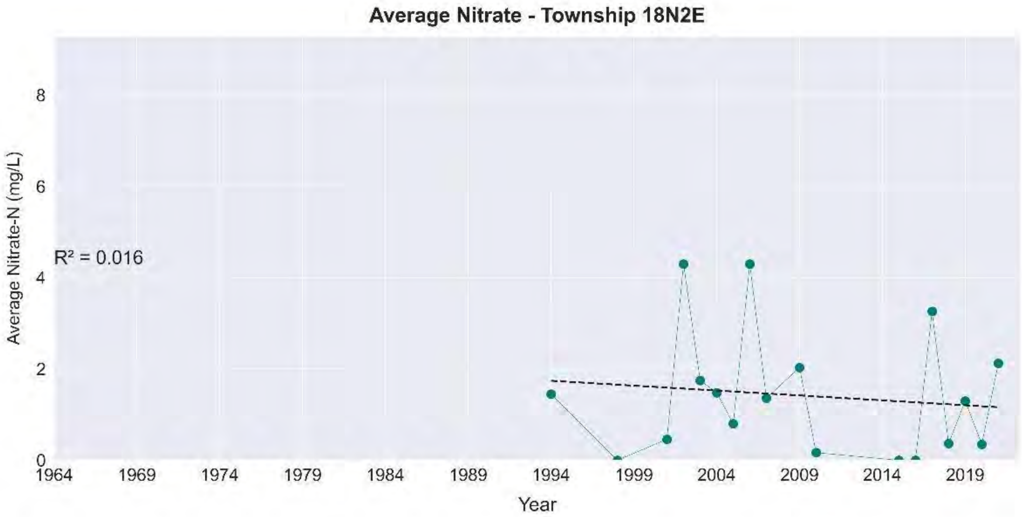


Figure C 39. Township 17N11E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



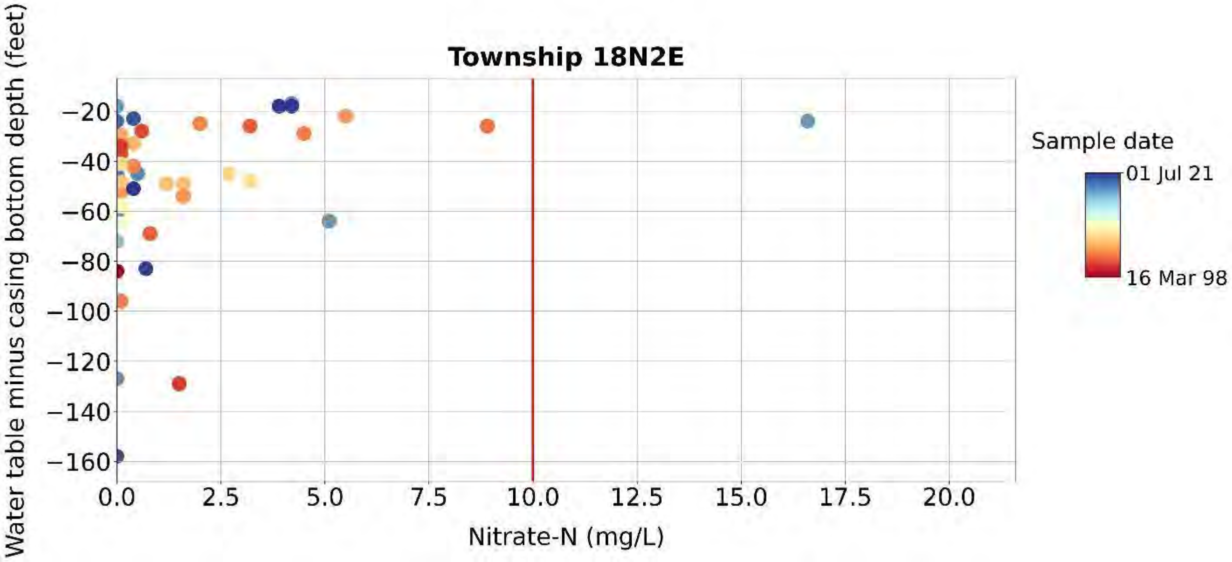


Figure C 40. Township 18N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

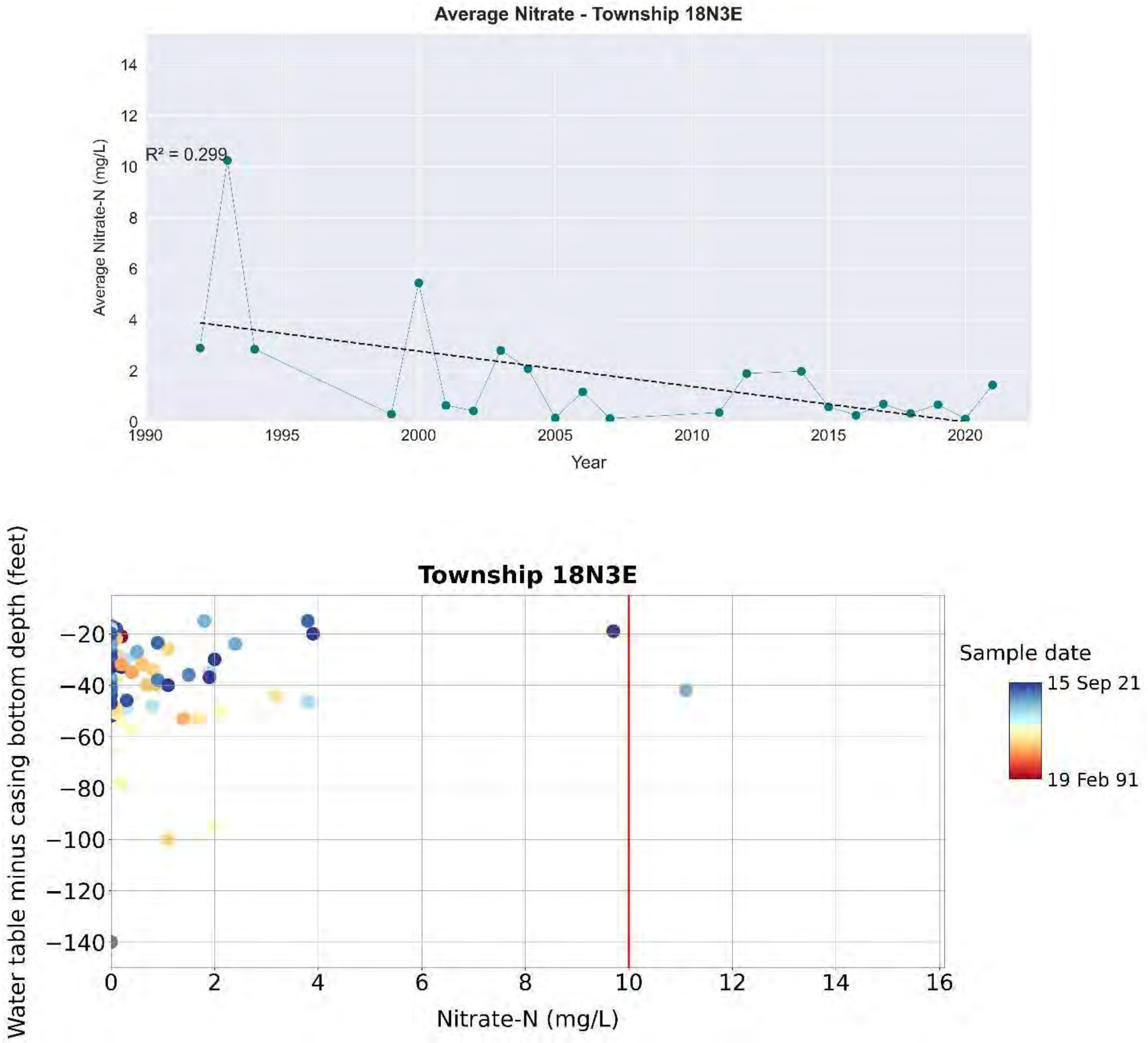
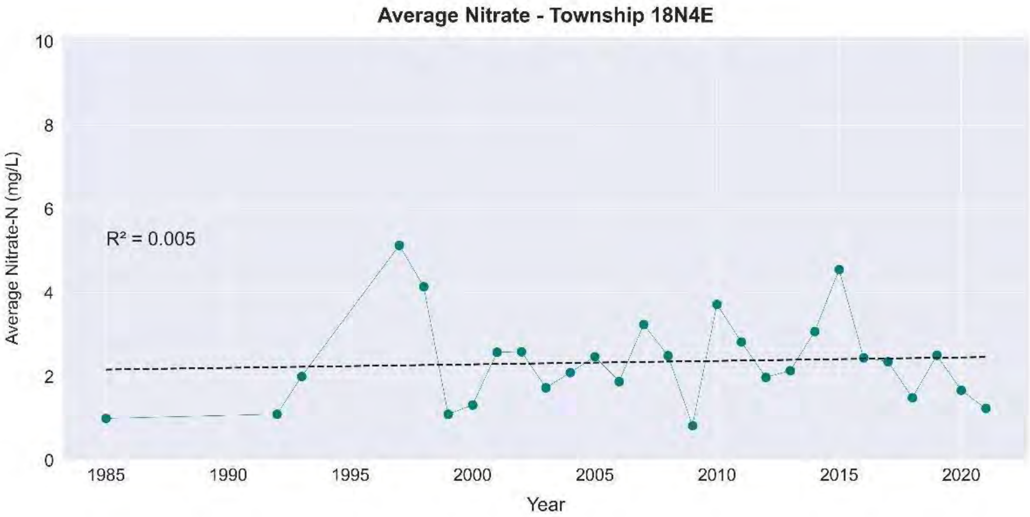


Figure C 41. Township 18N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



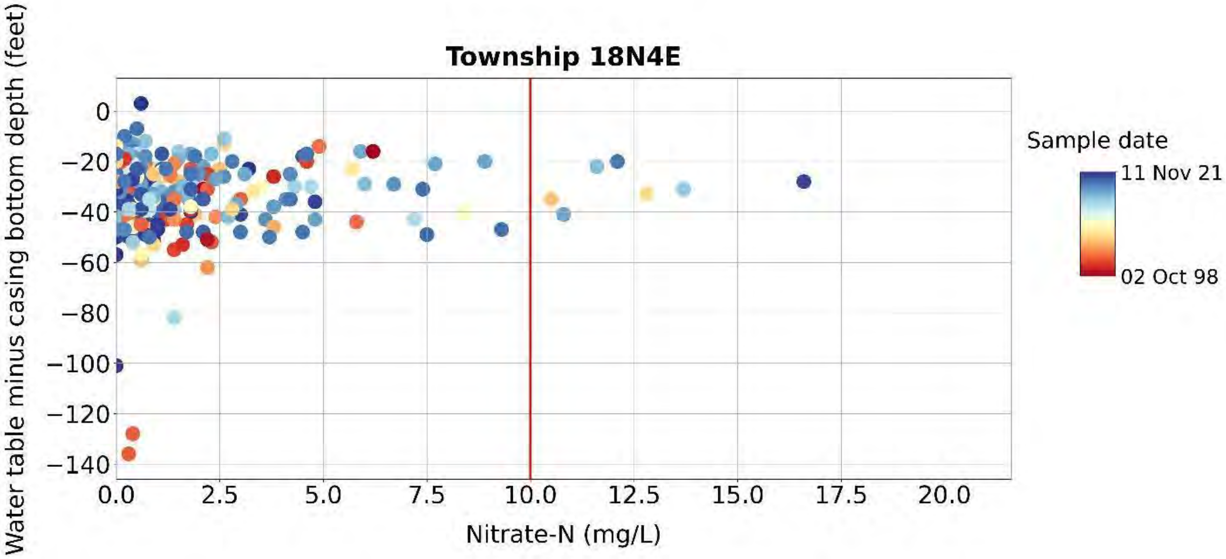
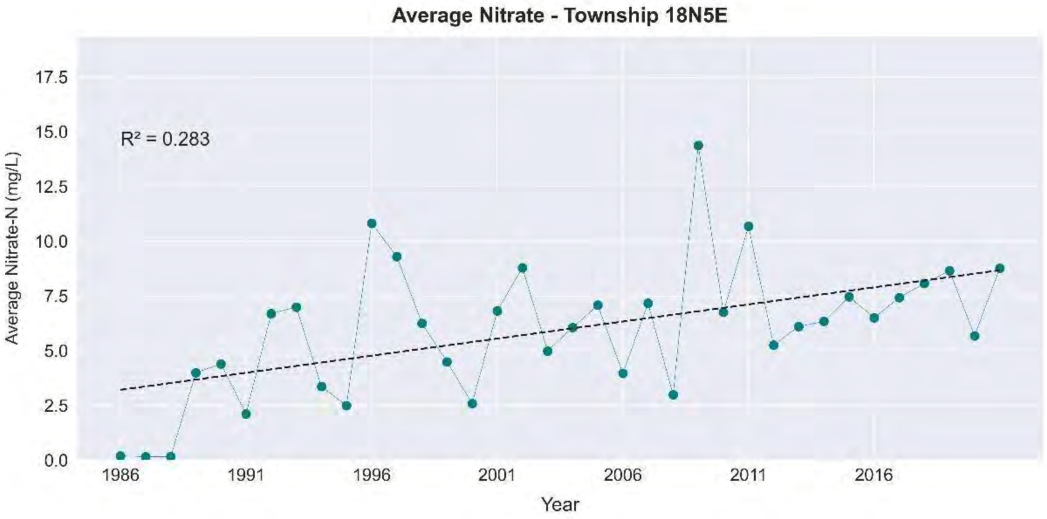


Figure C 42. Township 18N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



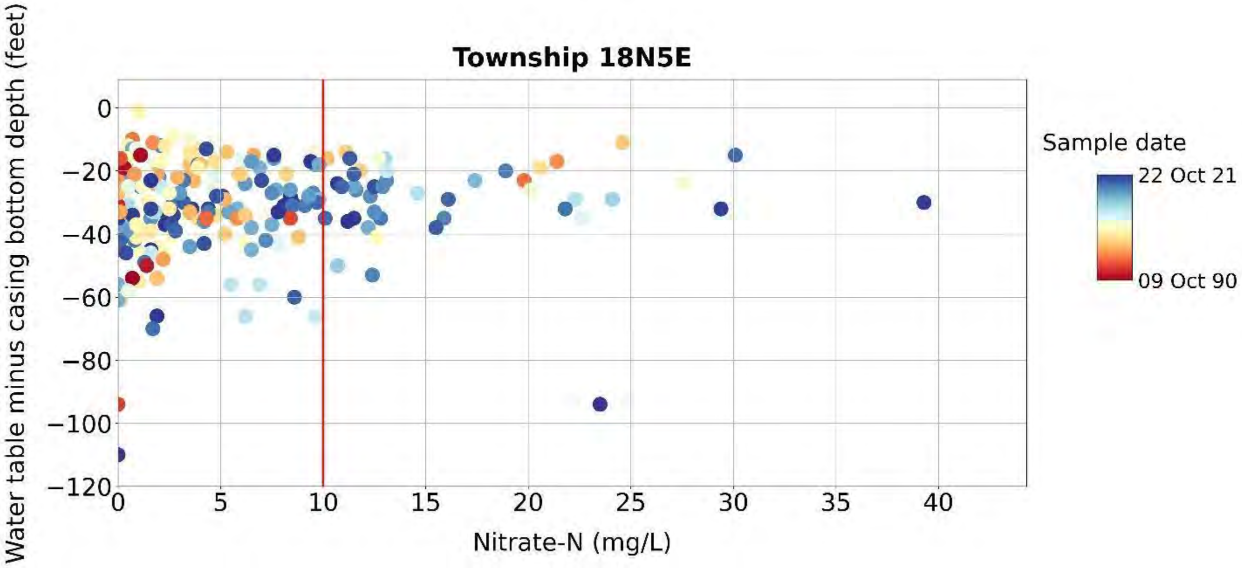
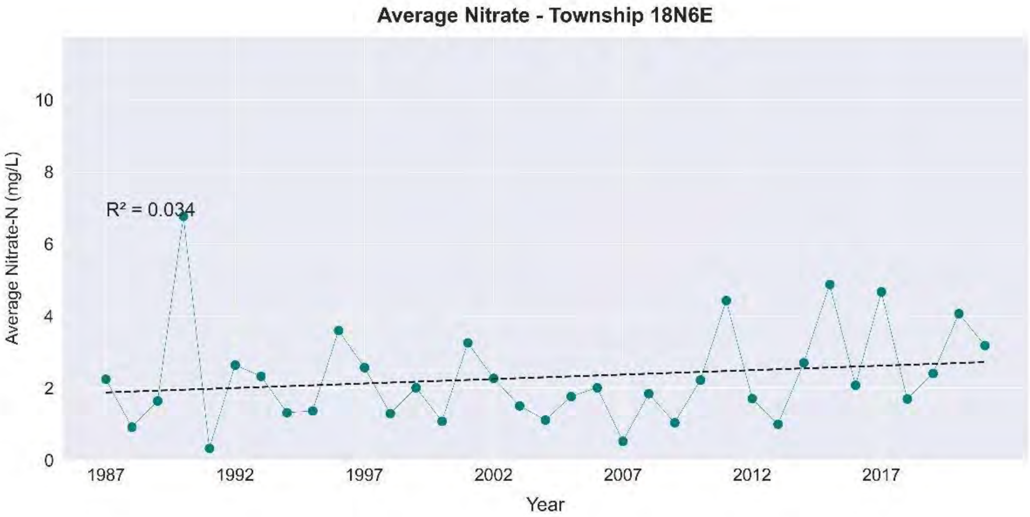


Figure C 43. Township 18N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



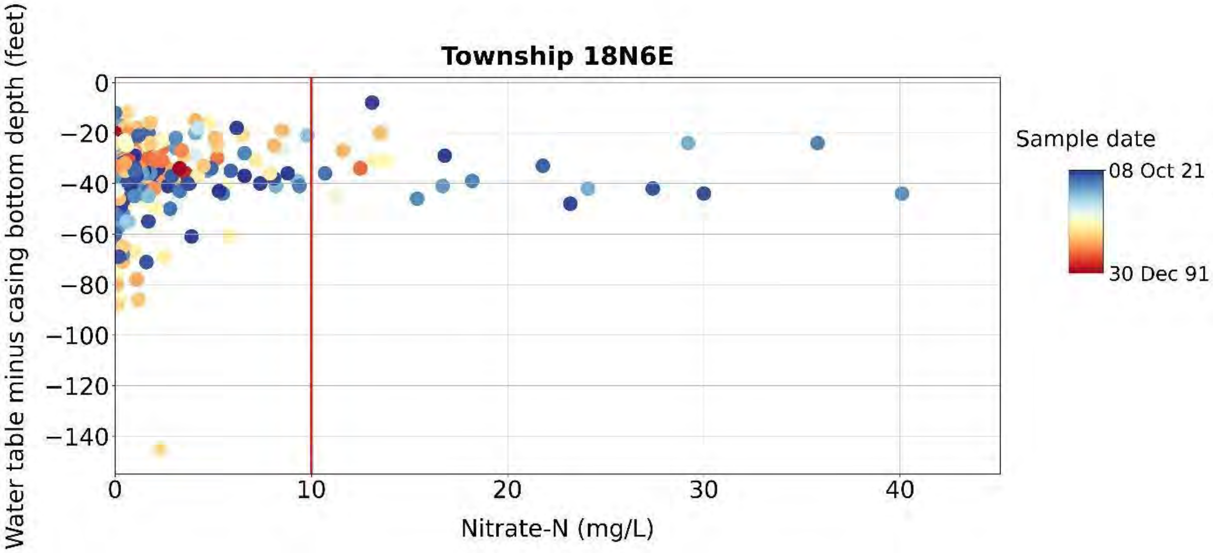
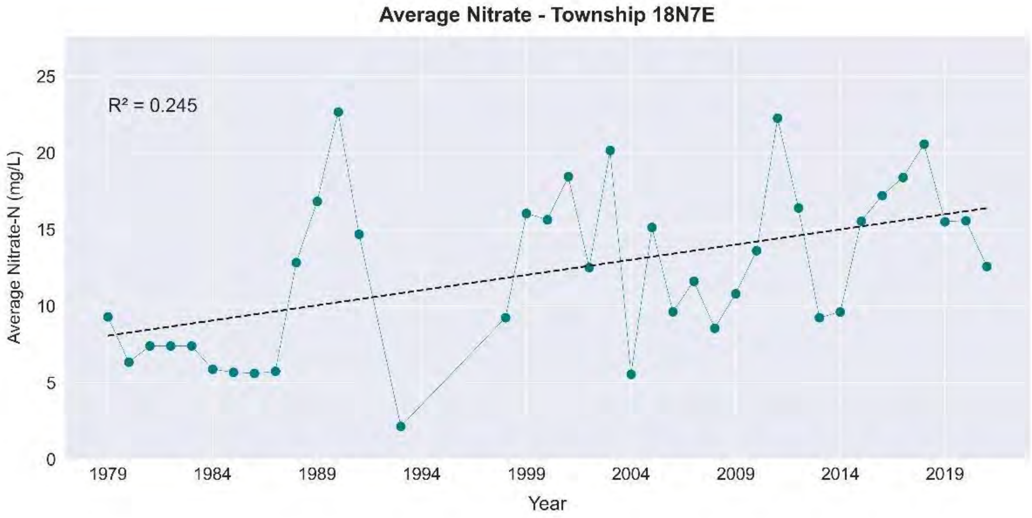


Figure C 44. Township 18N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



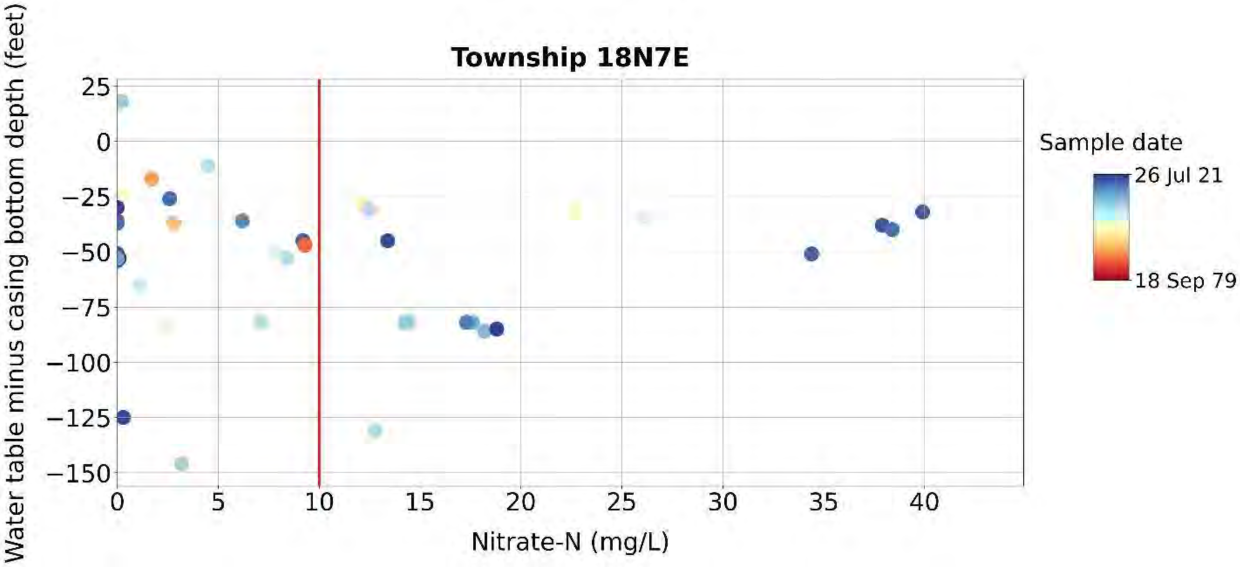
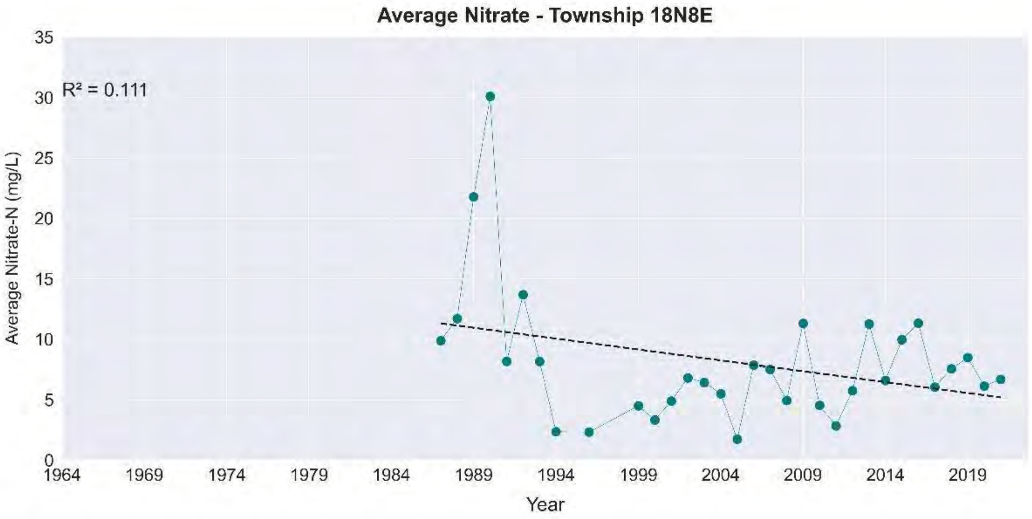


Figure C 45. Township 18N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



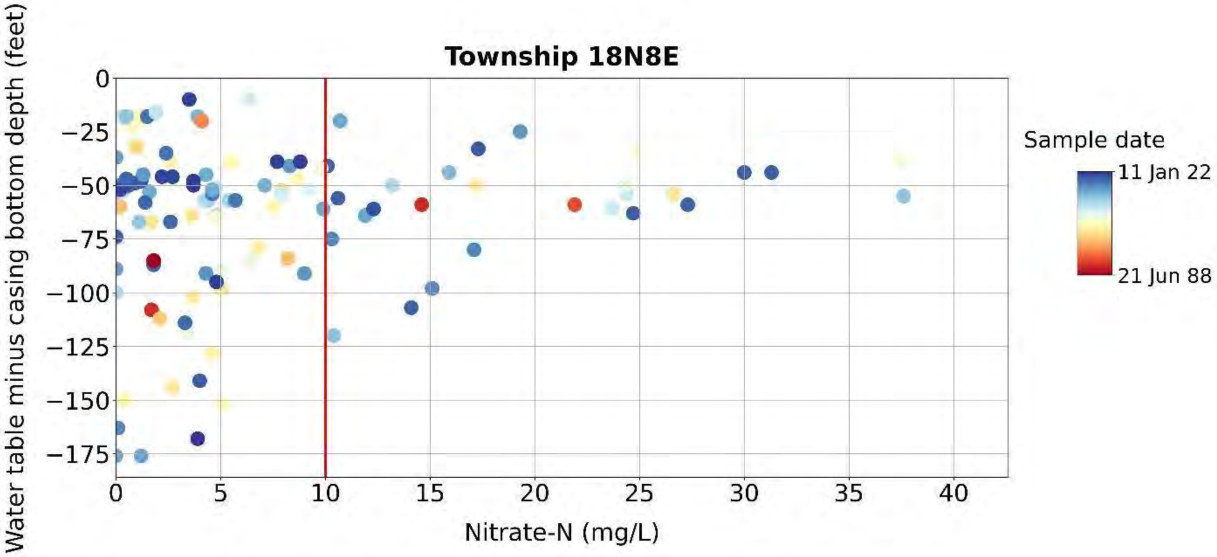
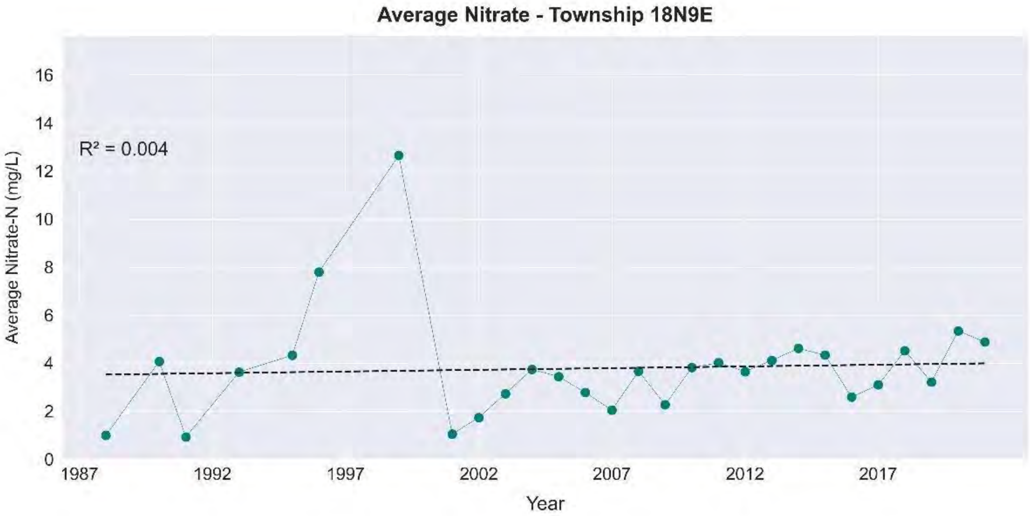


Figure C 46. Township 18N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



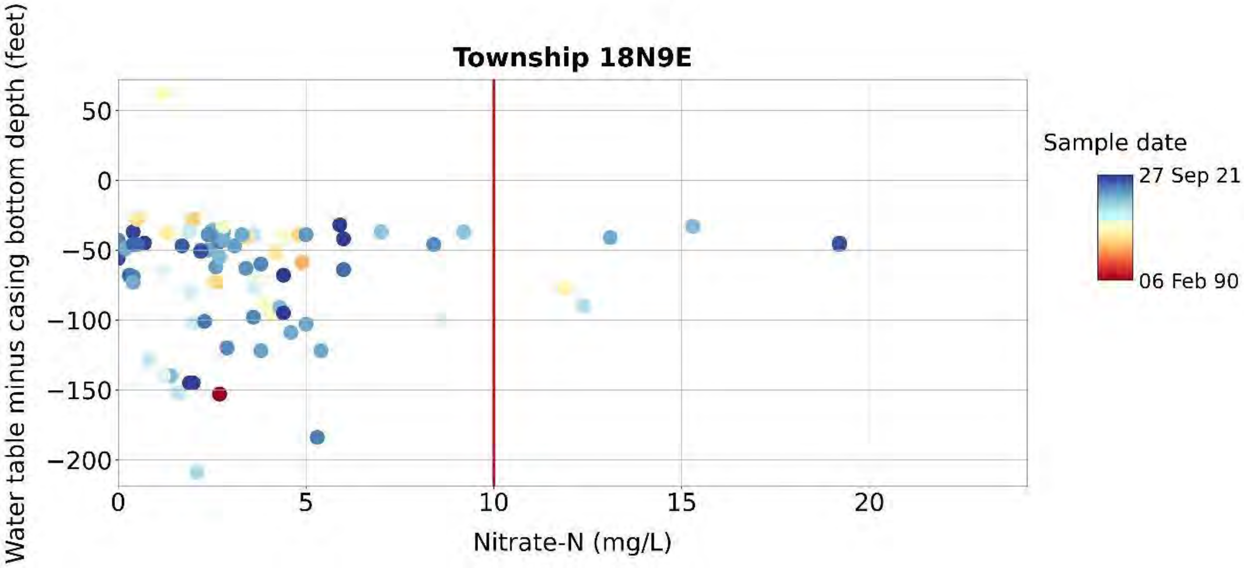
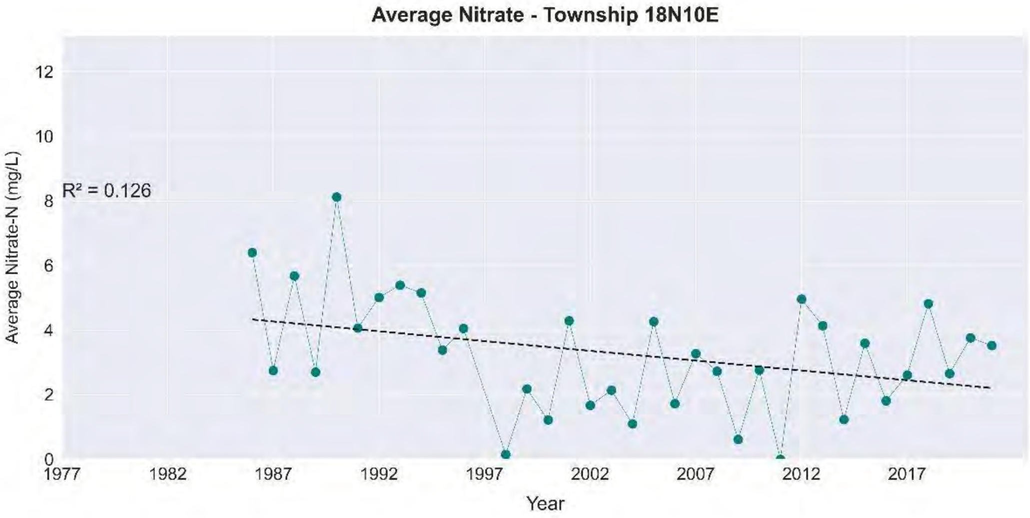


Figure C 47. Township 18N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



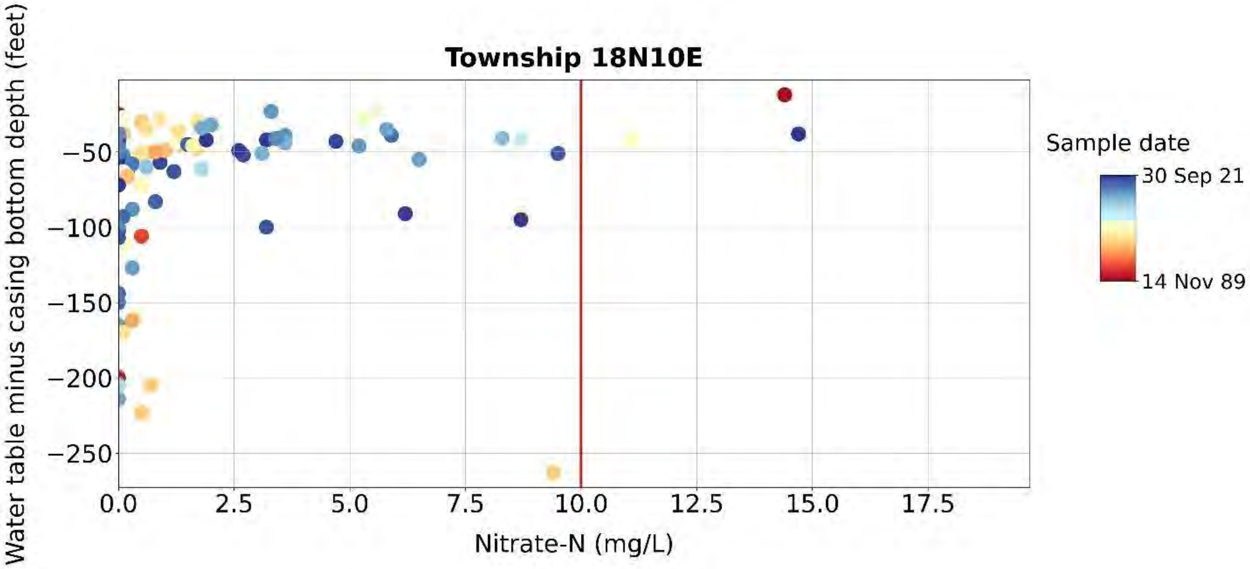
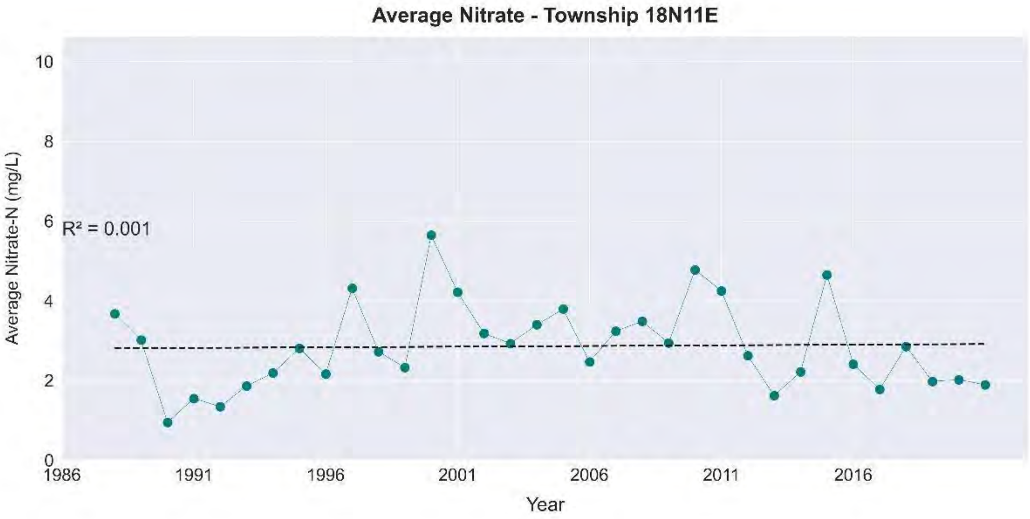


Figure C 48. Township 18N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



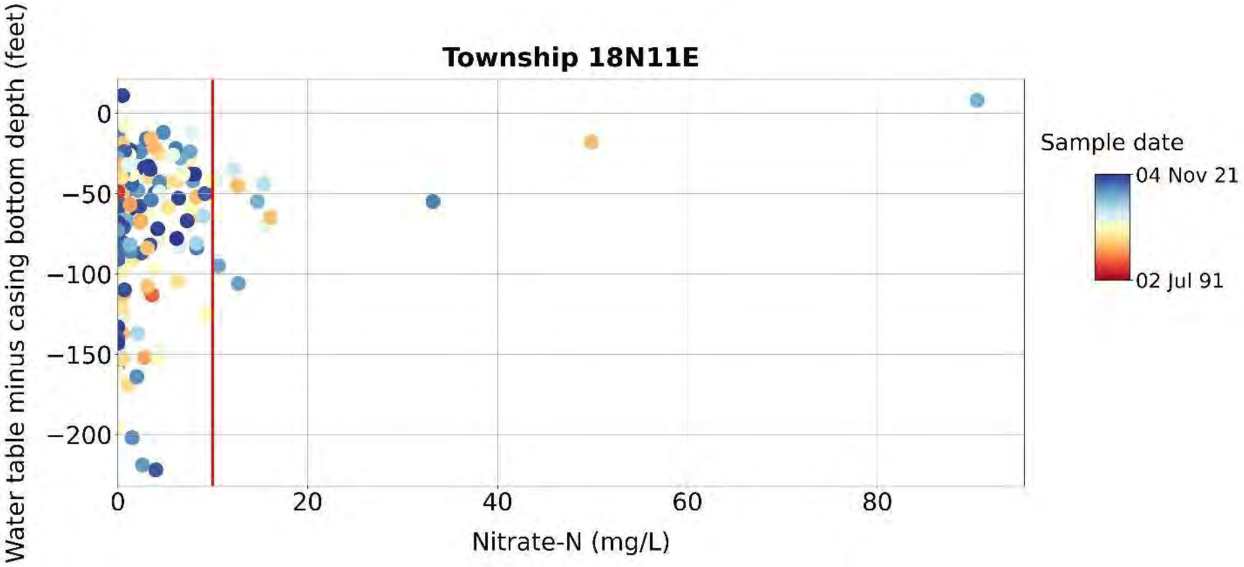
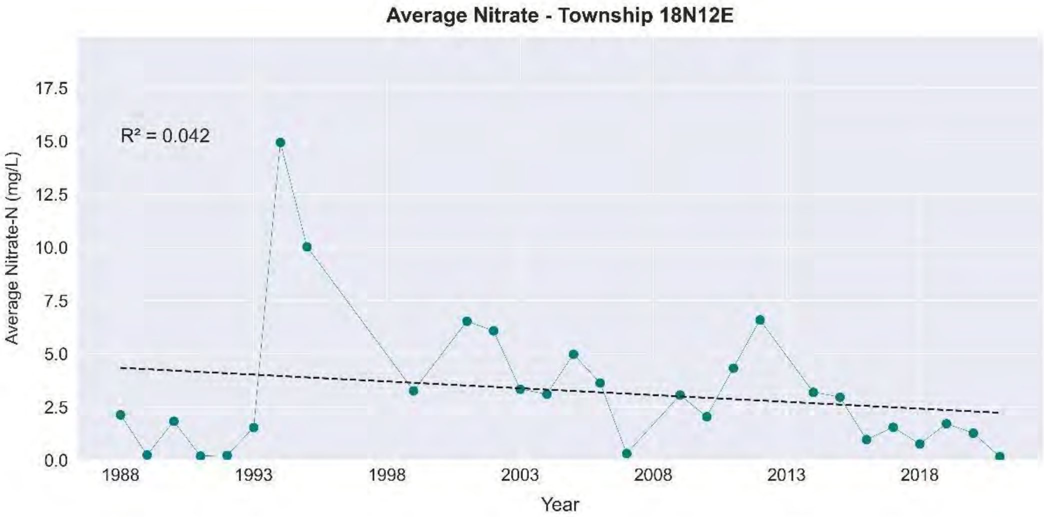


Figure C 49. Township 18N11E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



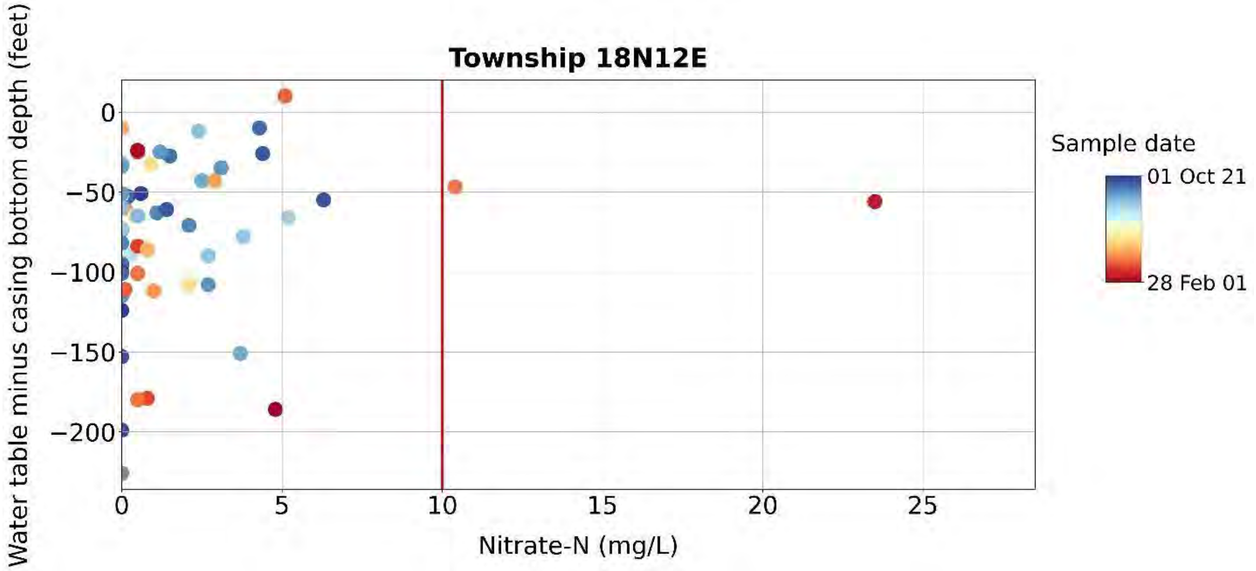
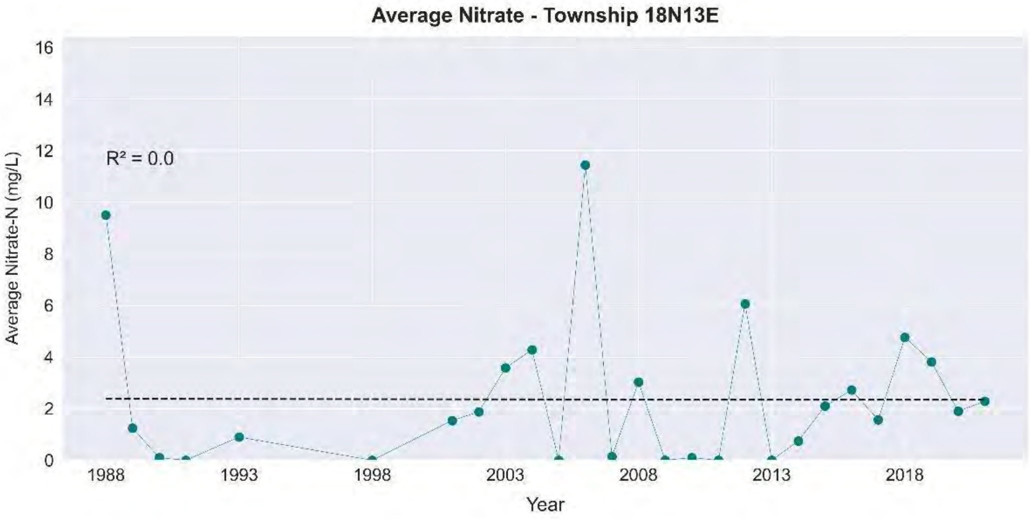


Figure C 50. Township 18N12E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



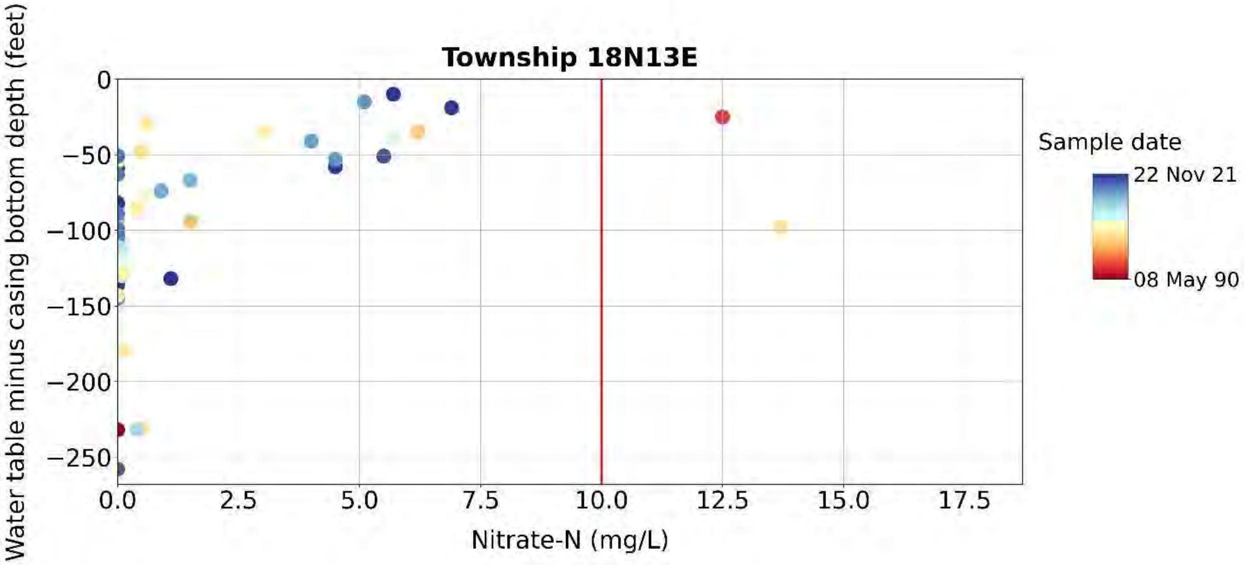
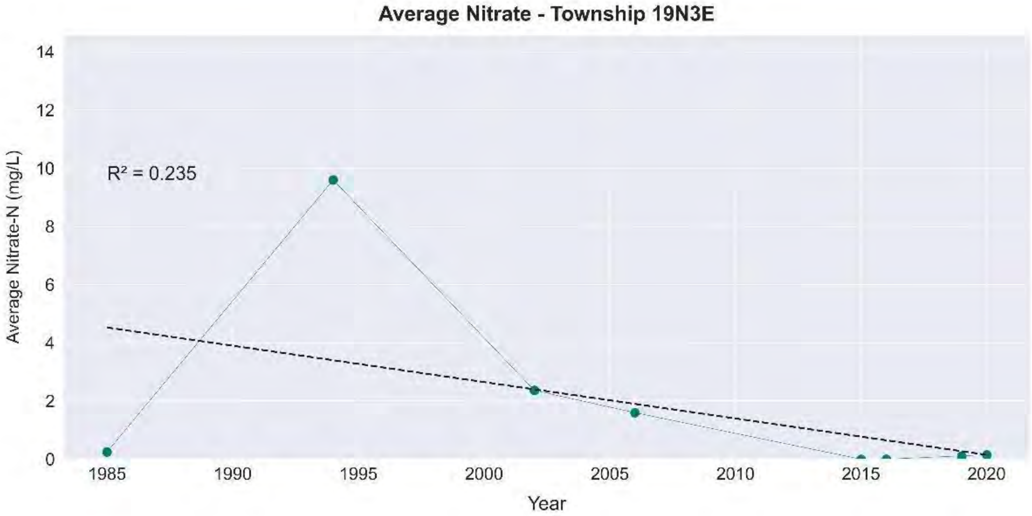


Figure C 51. Township 18N13E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



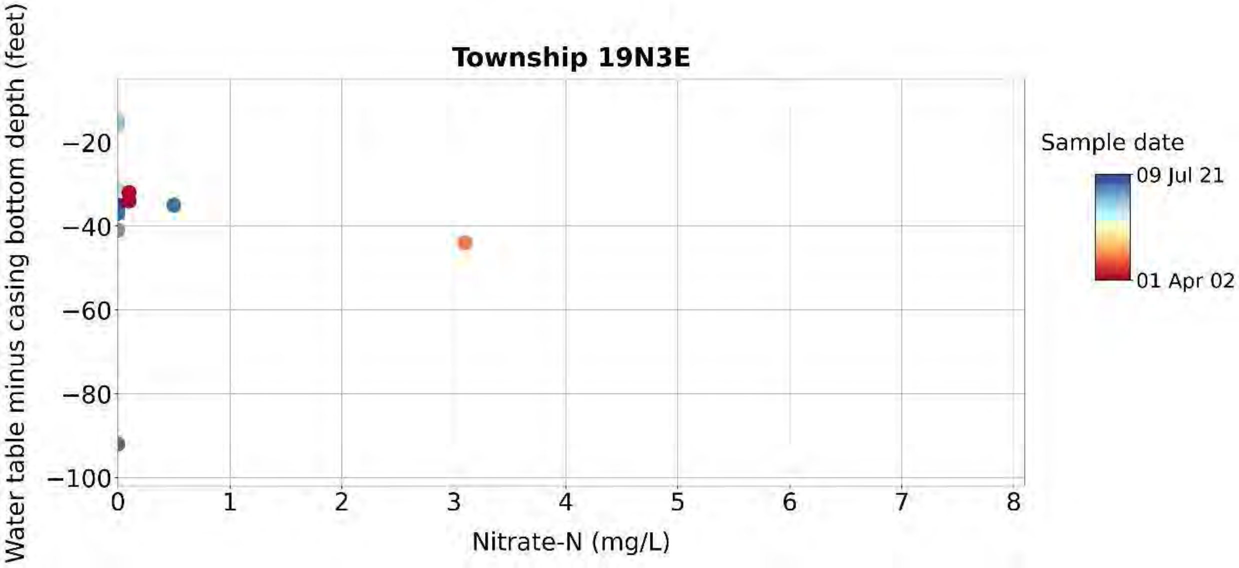
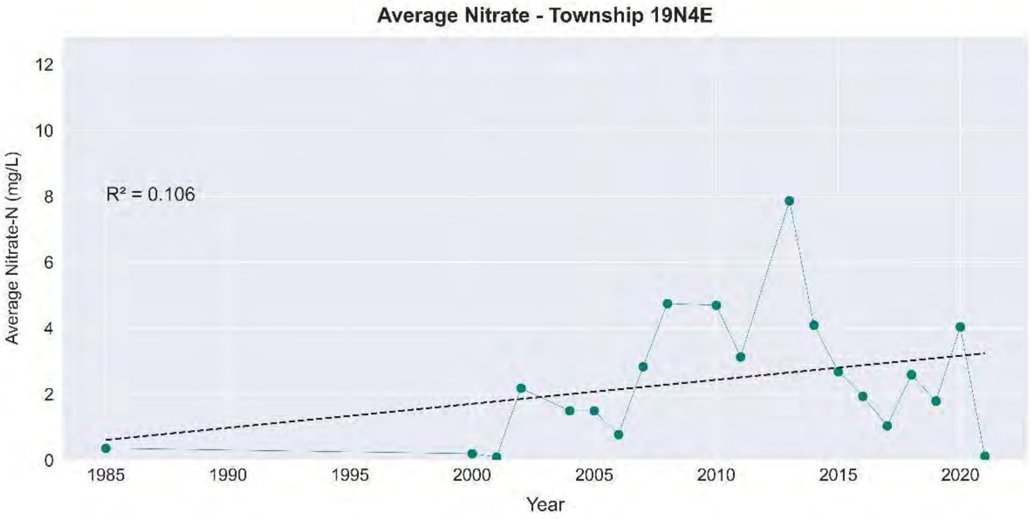


Figure C 54. Township 19N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



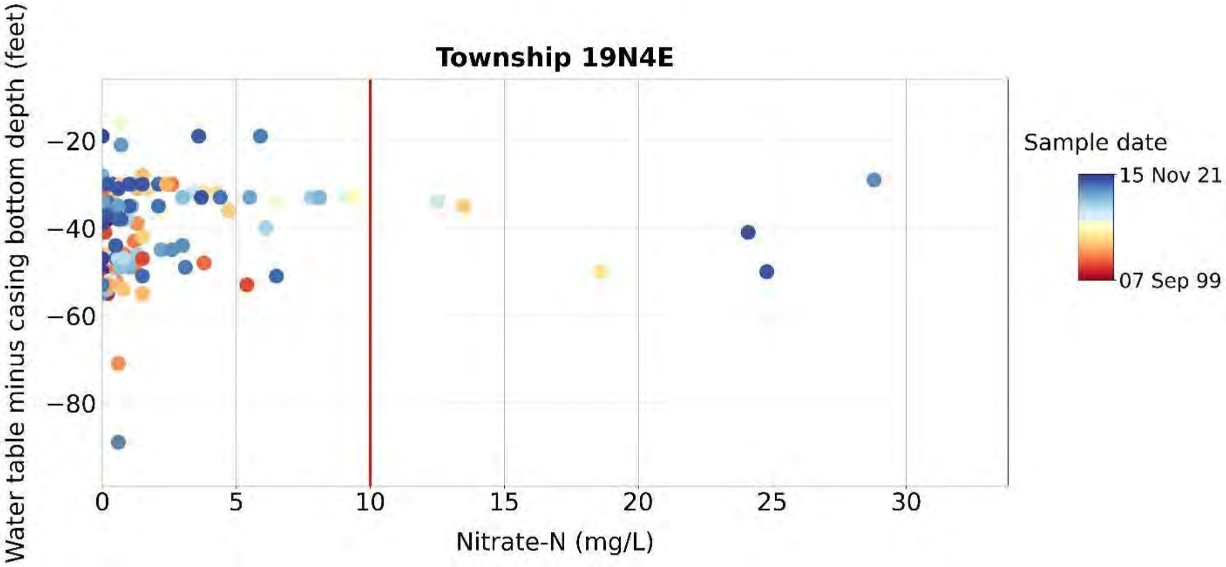
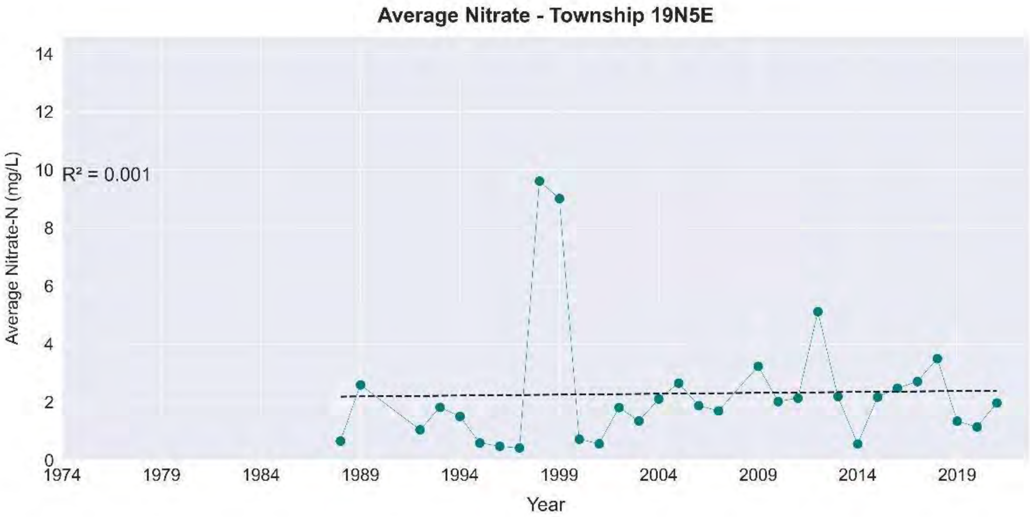


Figure C 55. Township 19N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



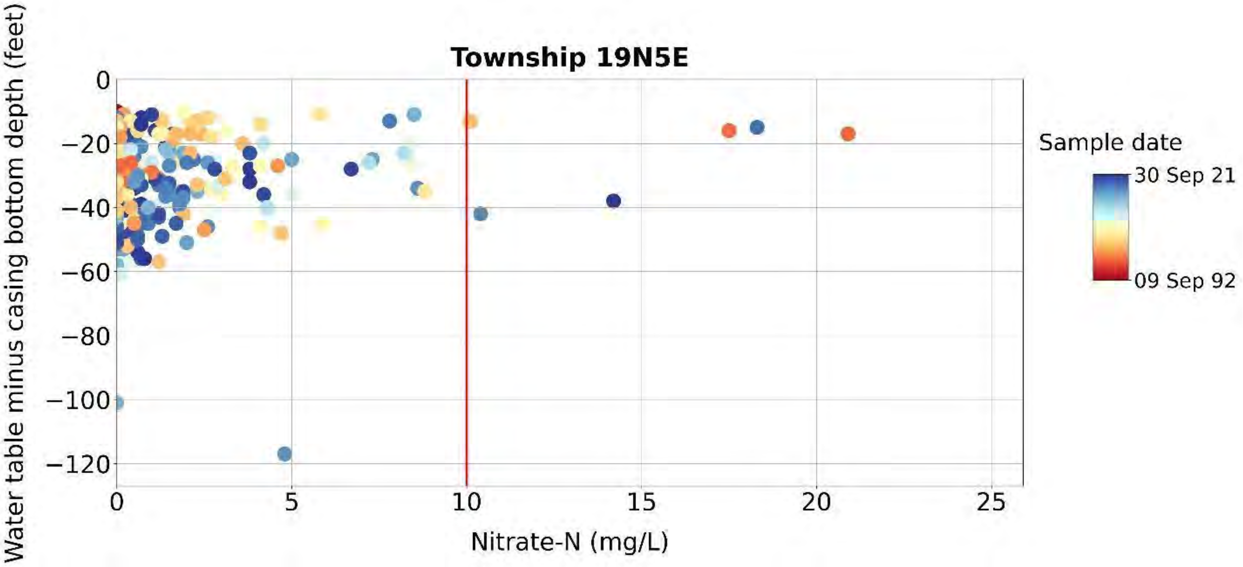
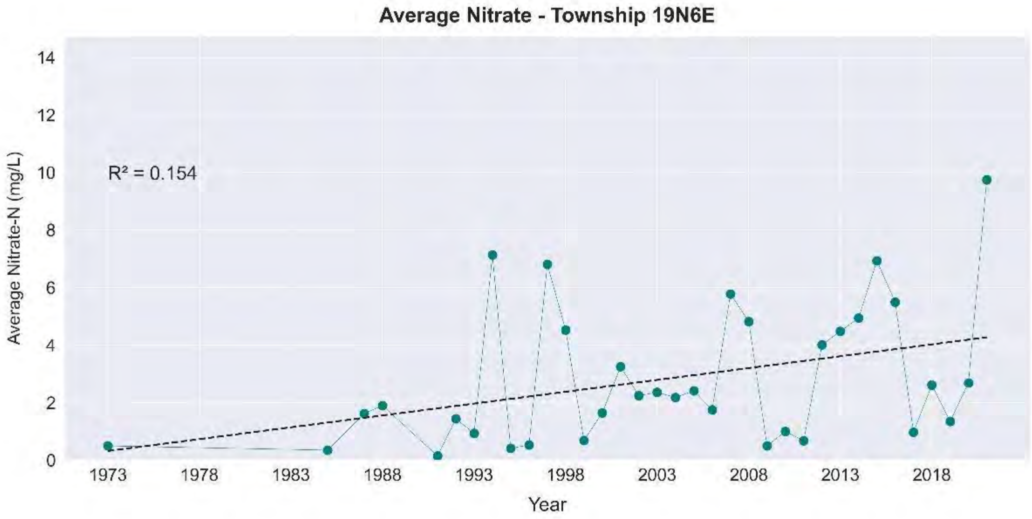


Figure C 56. Township 19N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



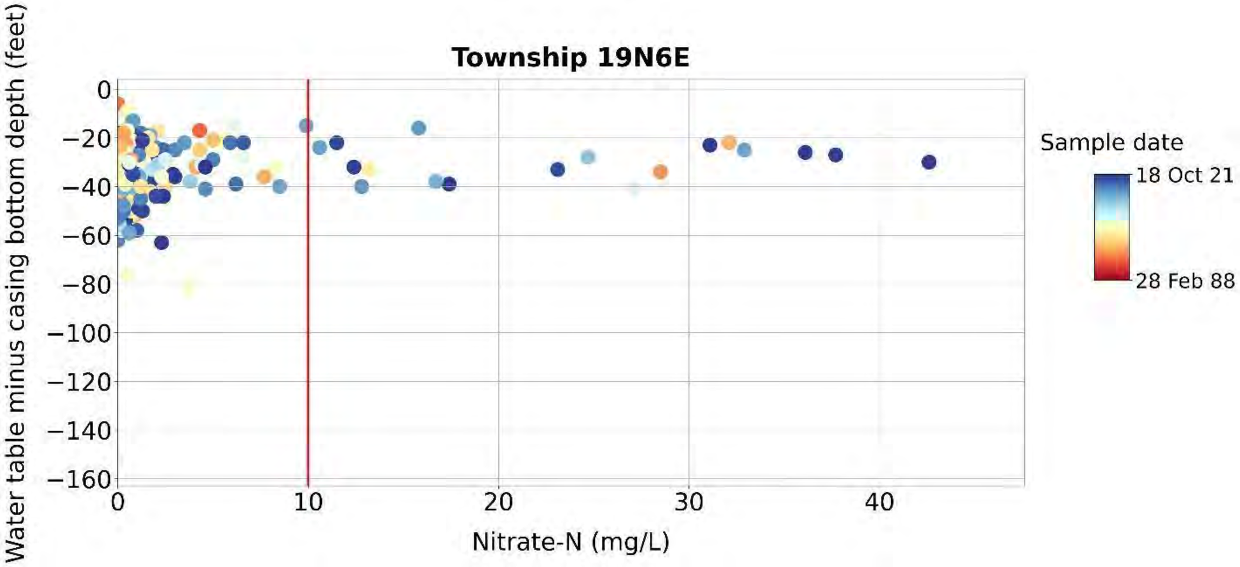
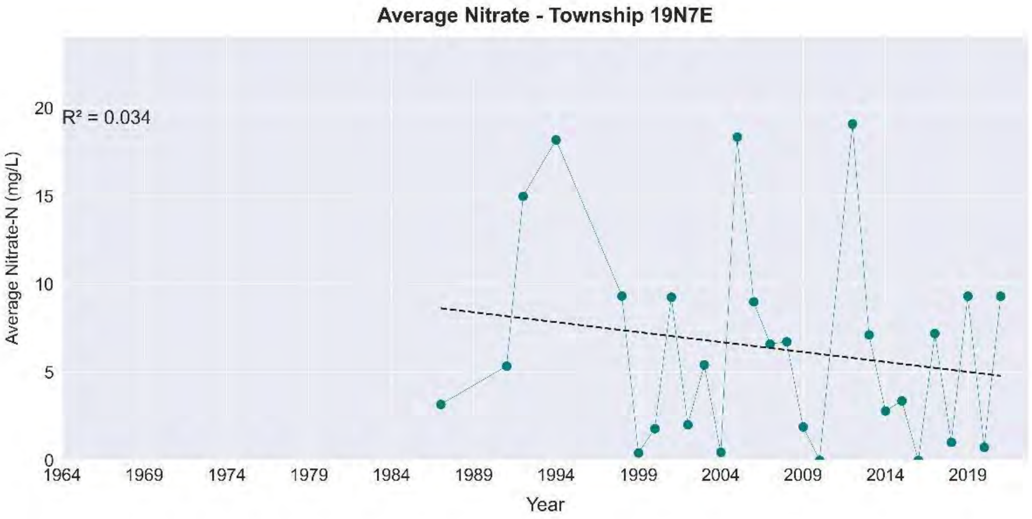


Figure C 57. Township 19N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



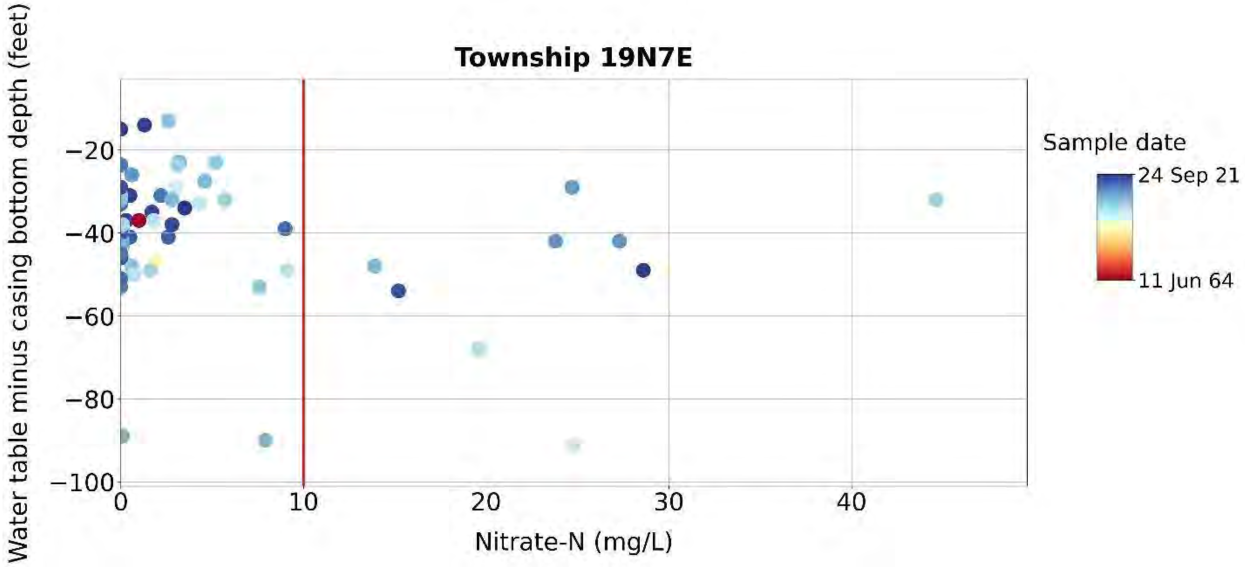
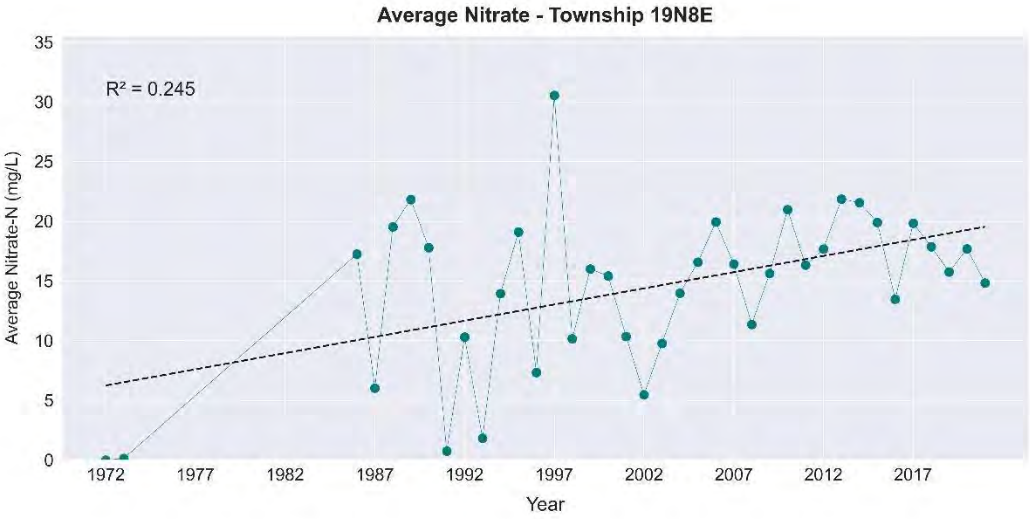


Figure C 58. Township 19N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



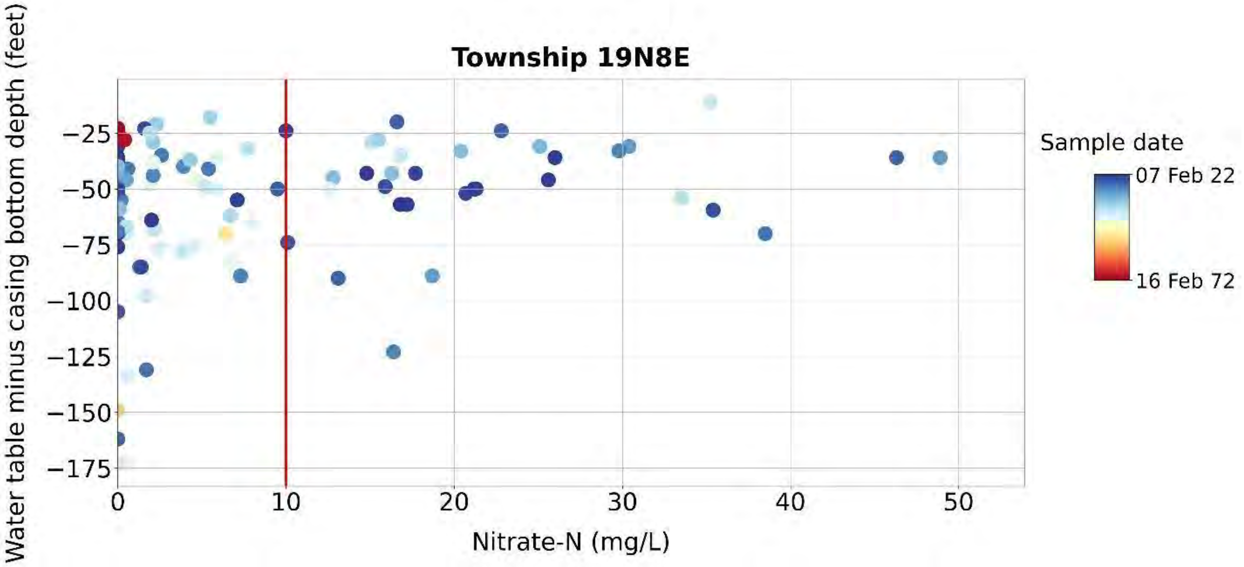
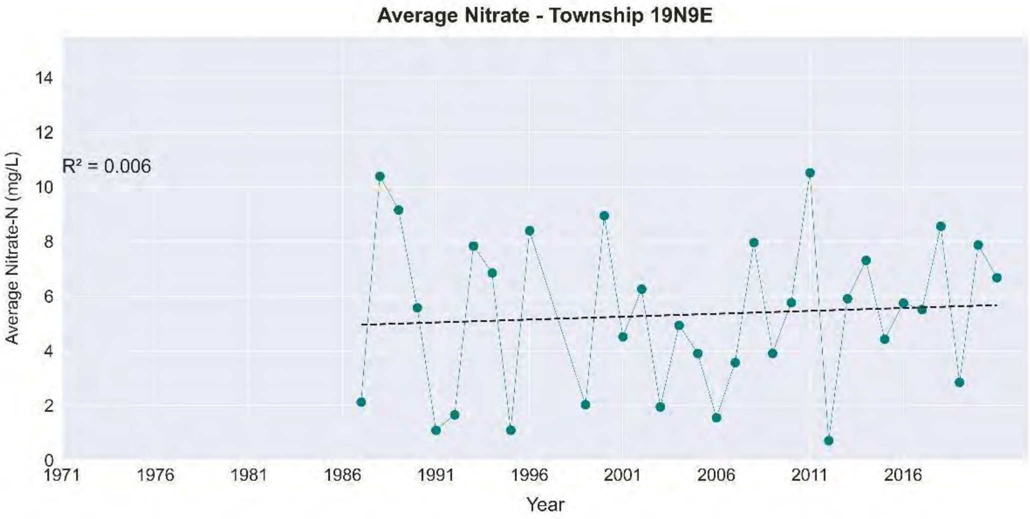


Figure C 59. Township 19N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



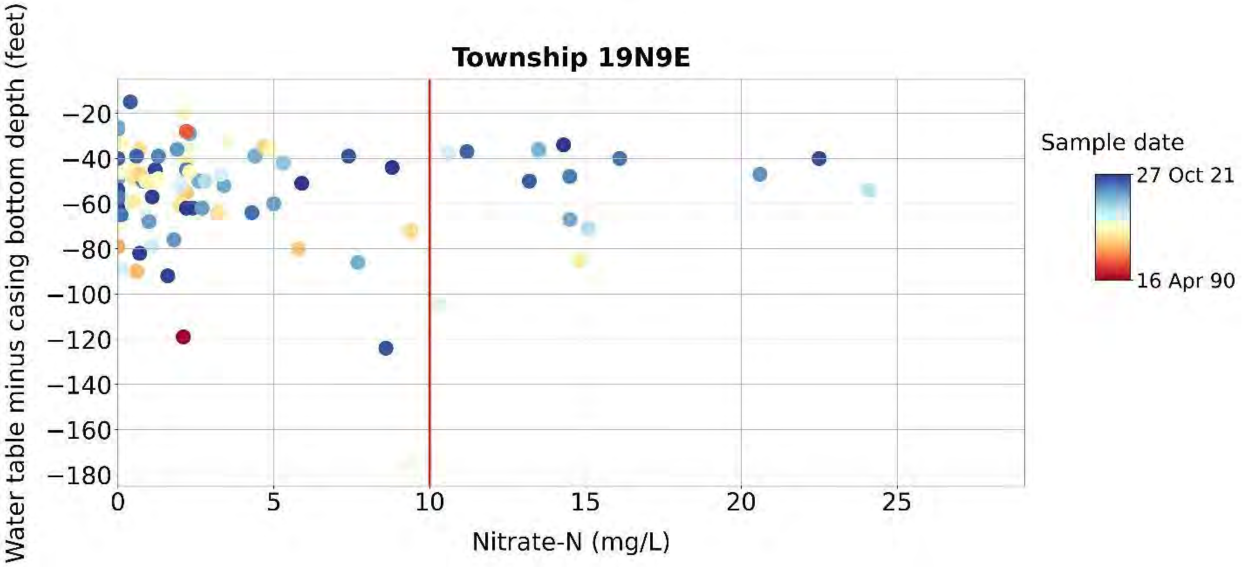
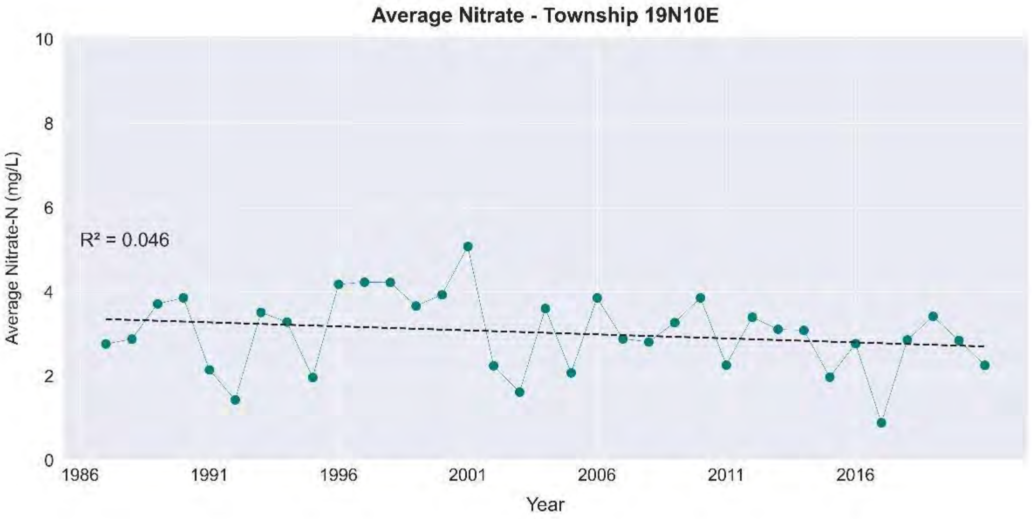


Figure C 60. Township 19N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



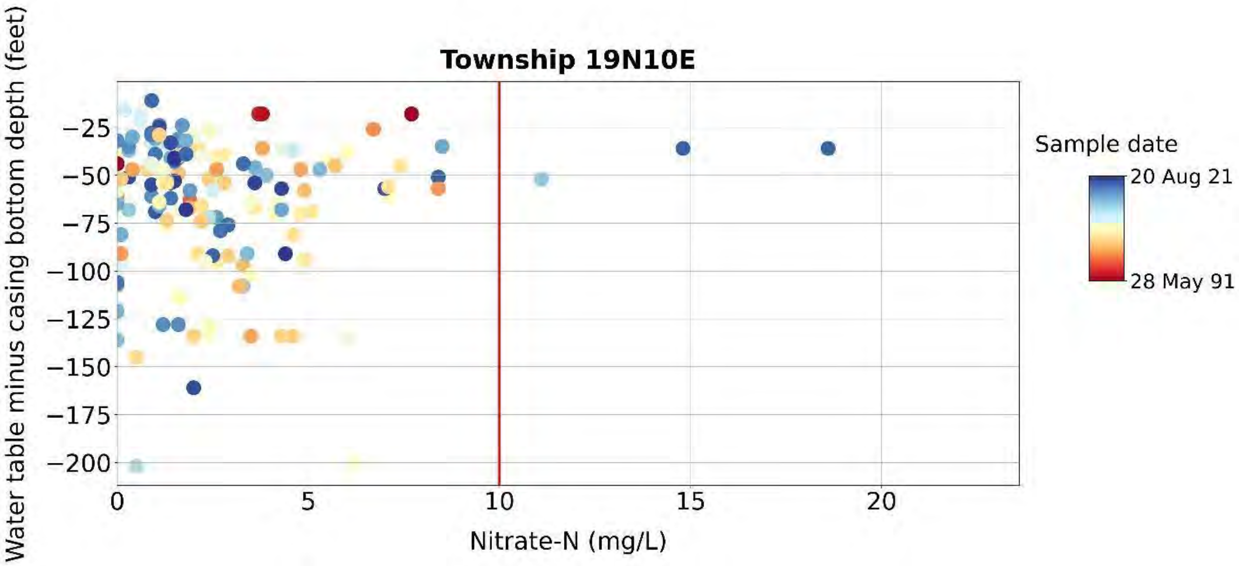
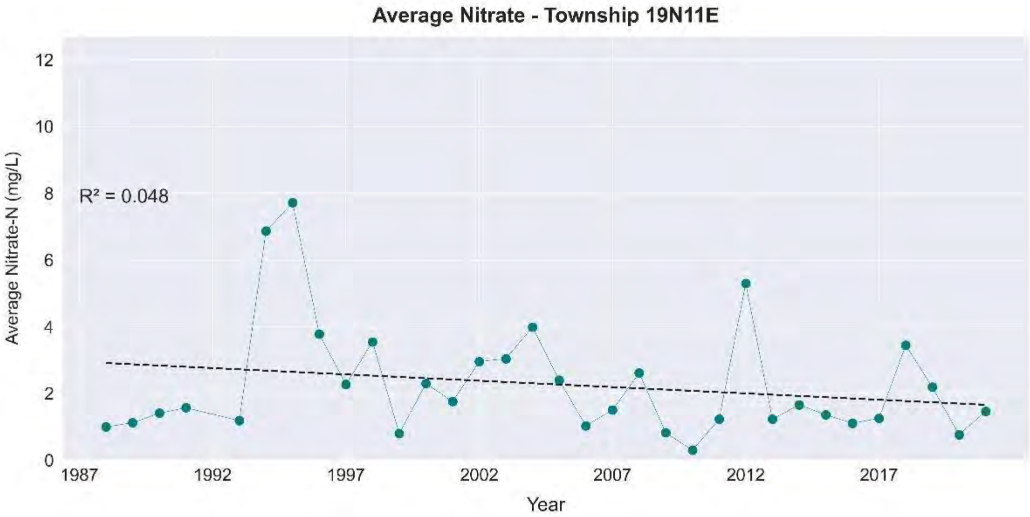


Figure C 61. Township 19N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



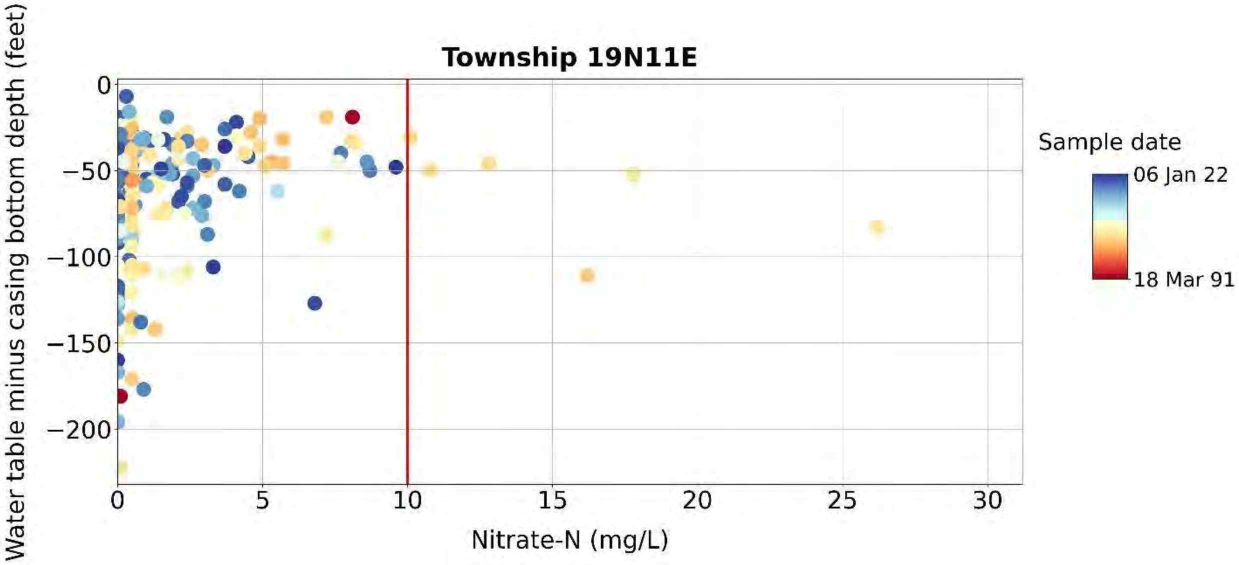
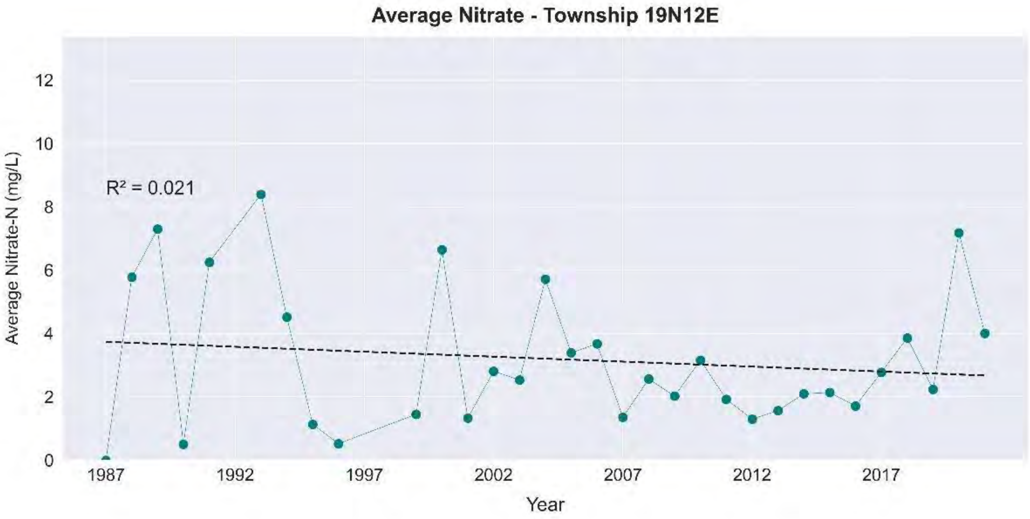


Figure C 62. Township 19N11E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



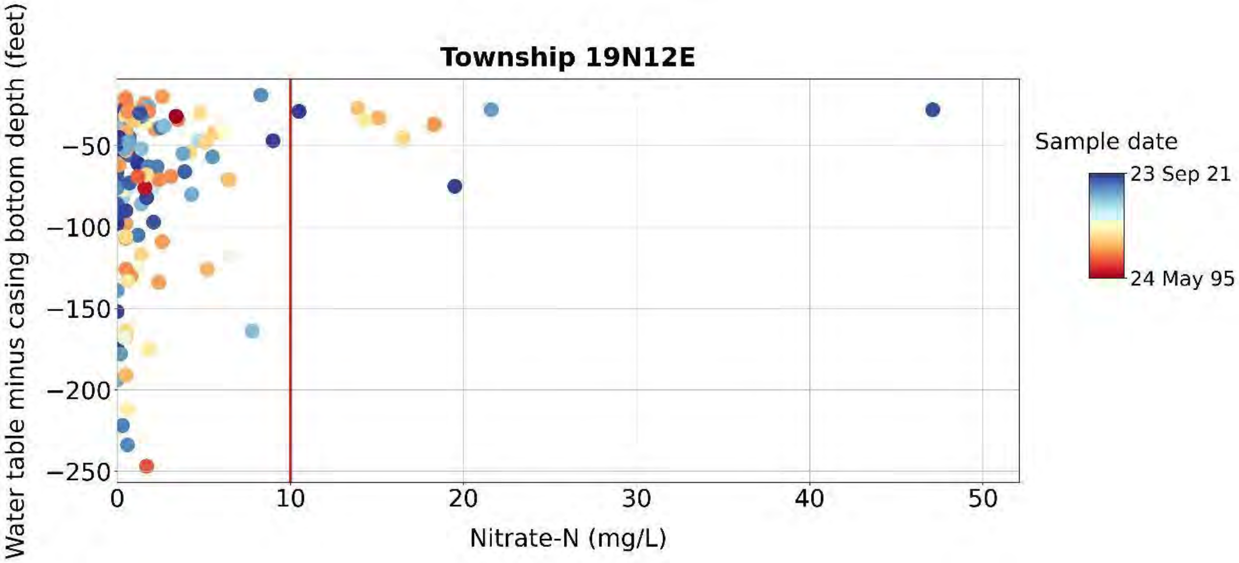
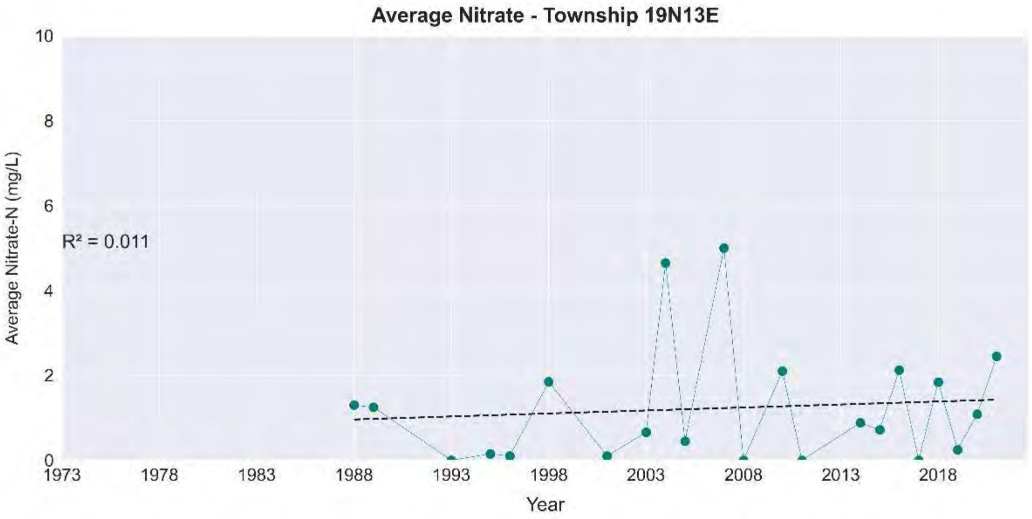


Figure C 63. Township 19N12E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



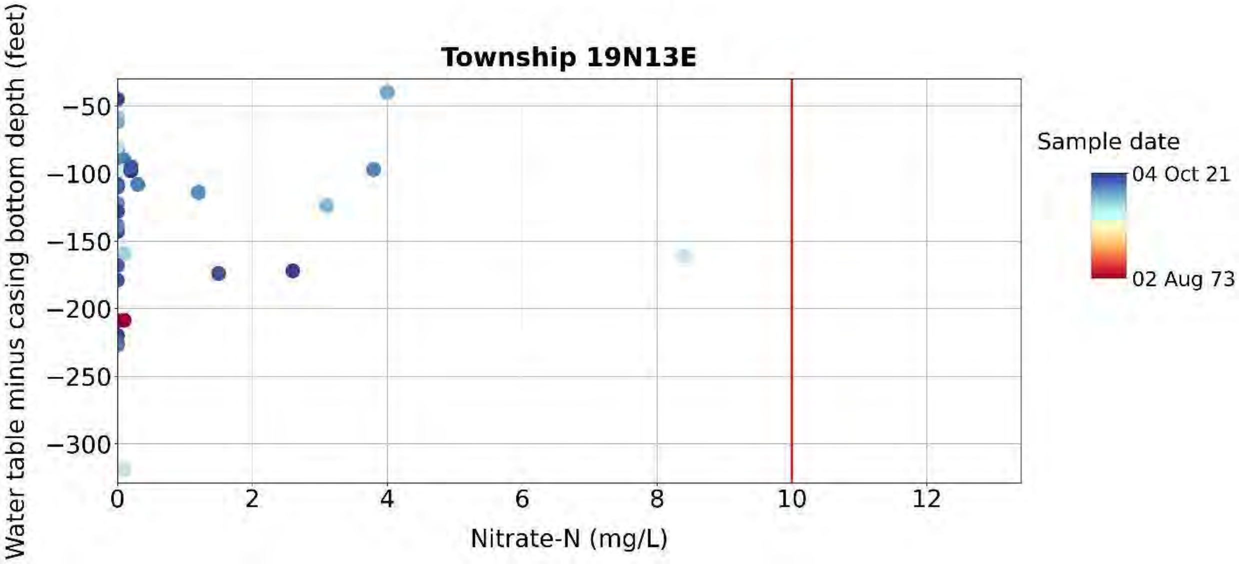
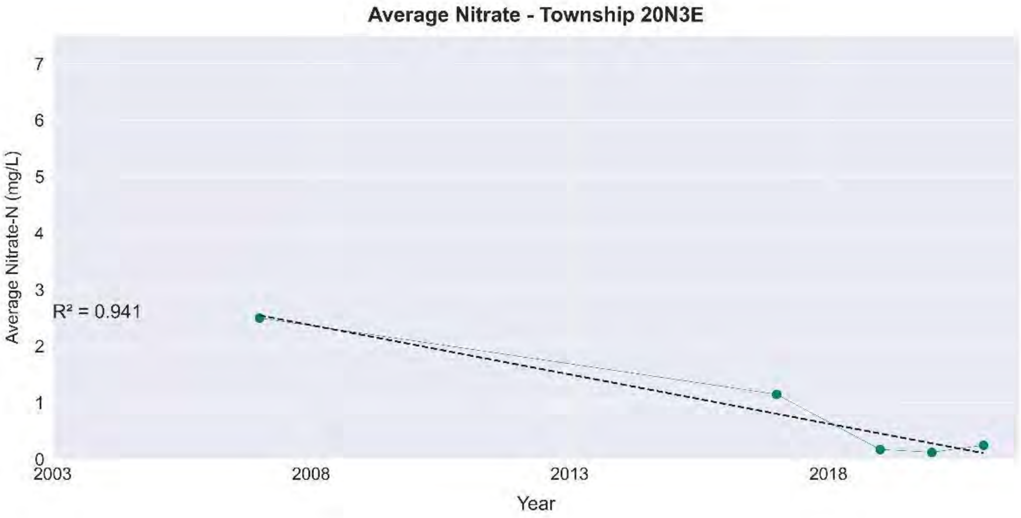


Figure C 64. Township 19N13E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



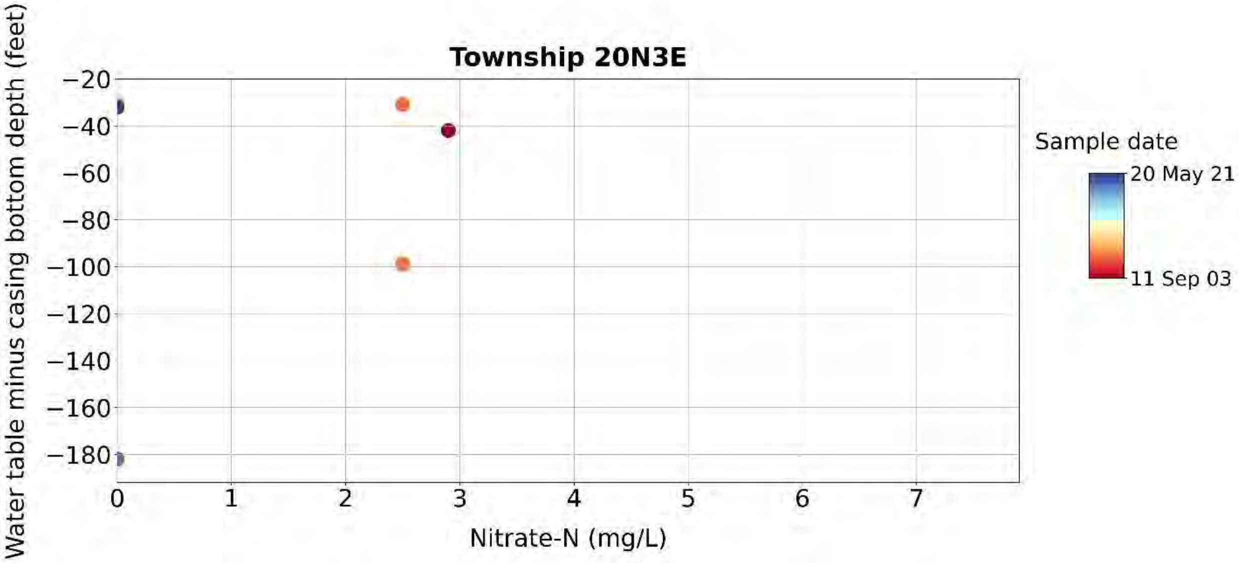
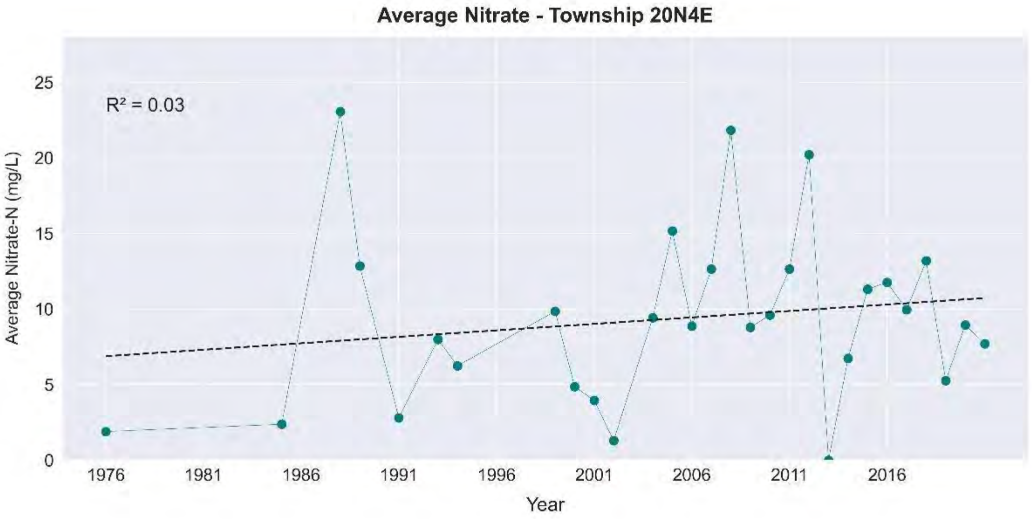


Figure C 66. Township 20N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



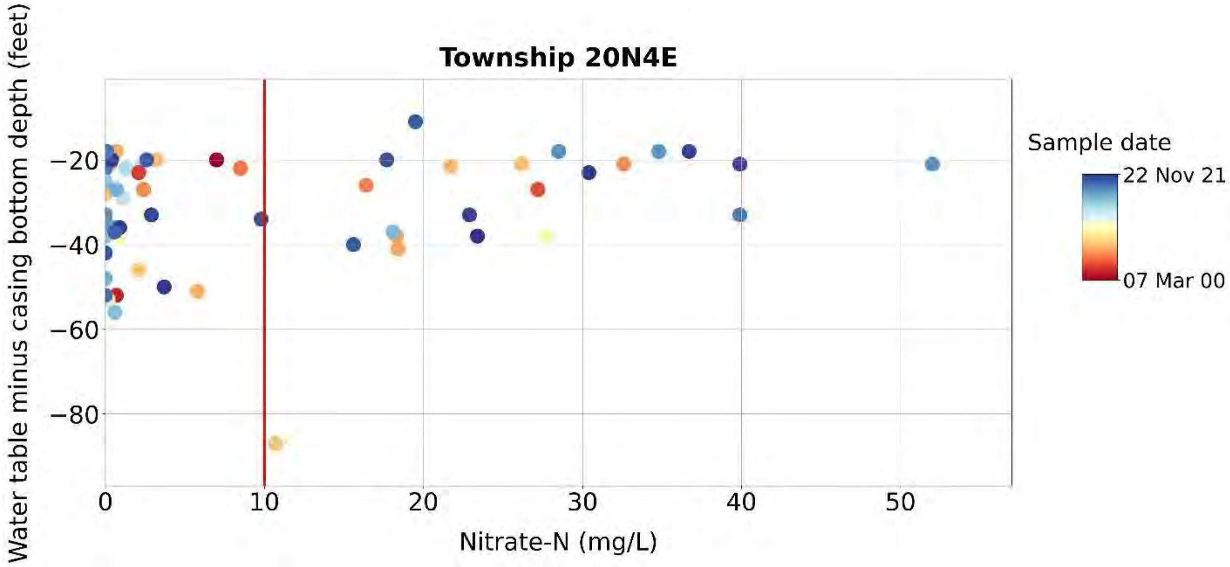
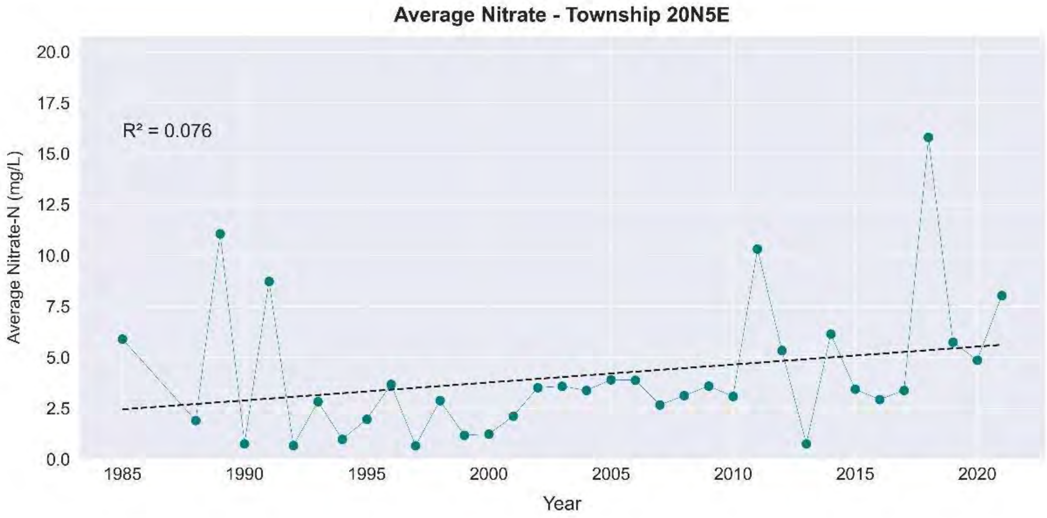


Figure C 67. Township 20N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



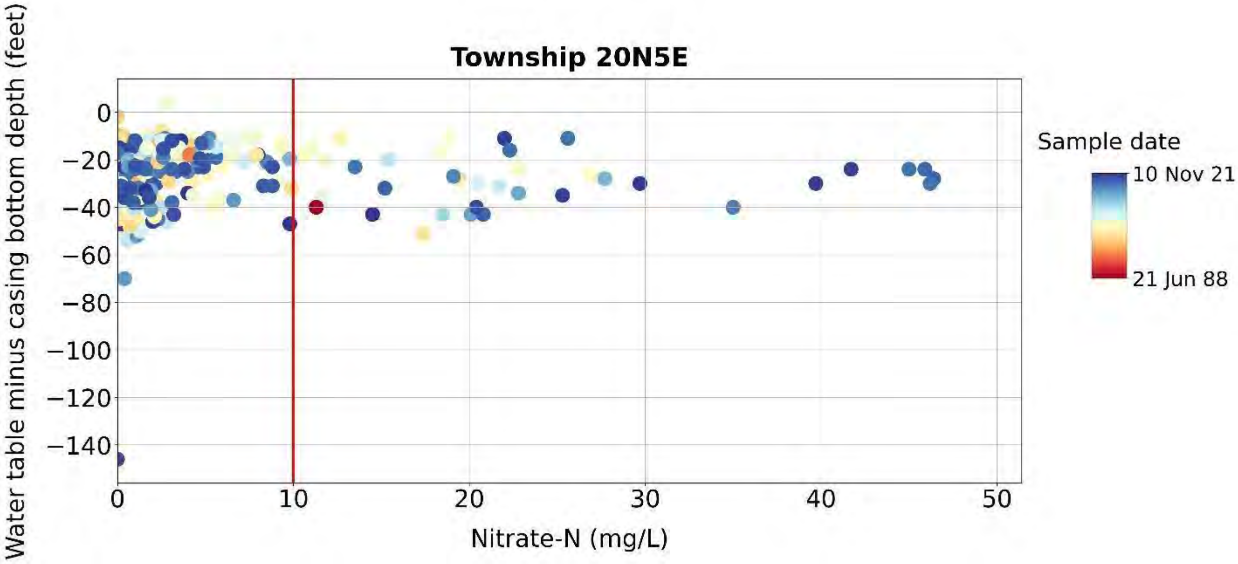
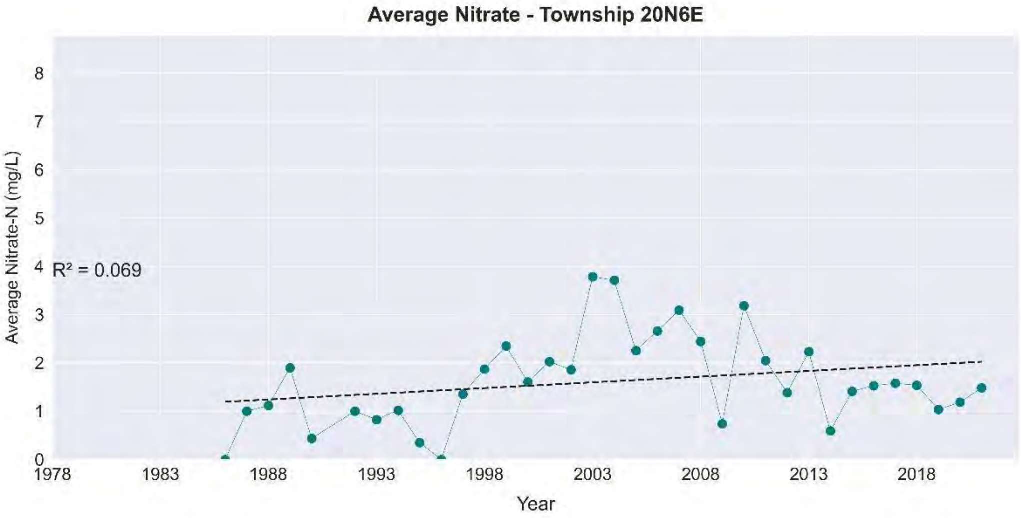


Figure C 68. Township 20N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



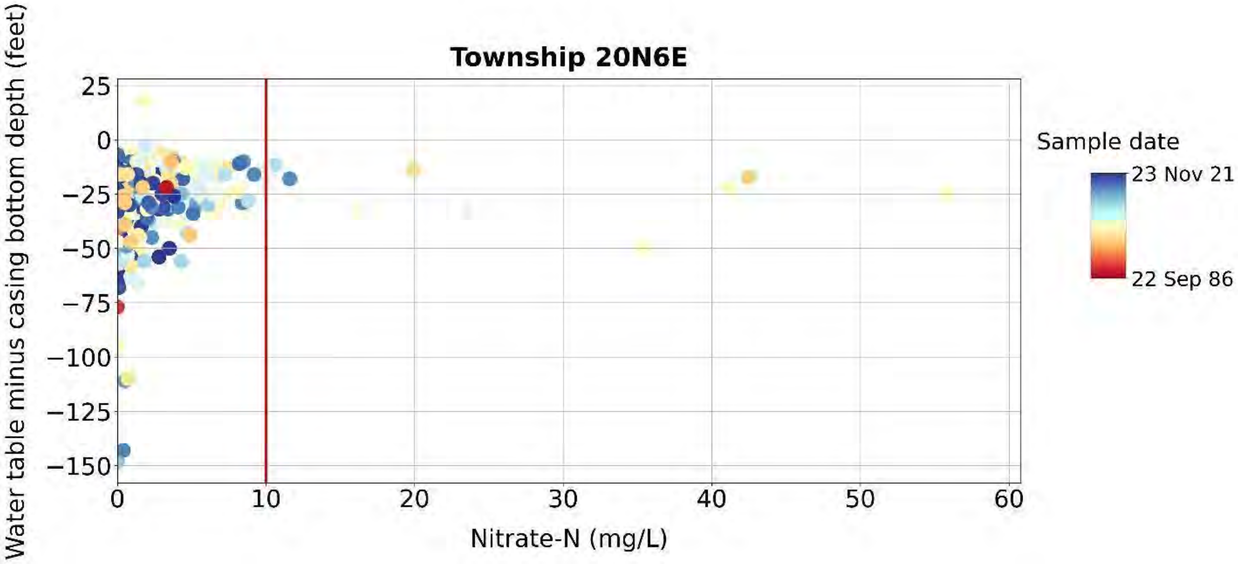
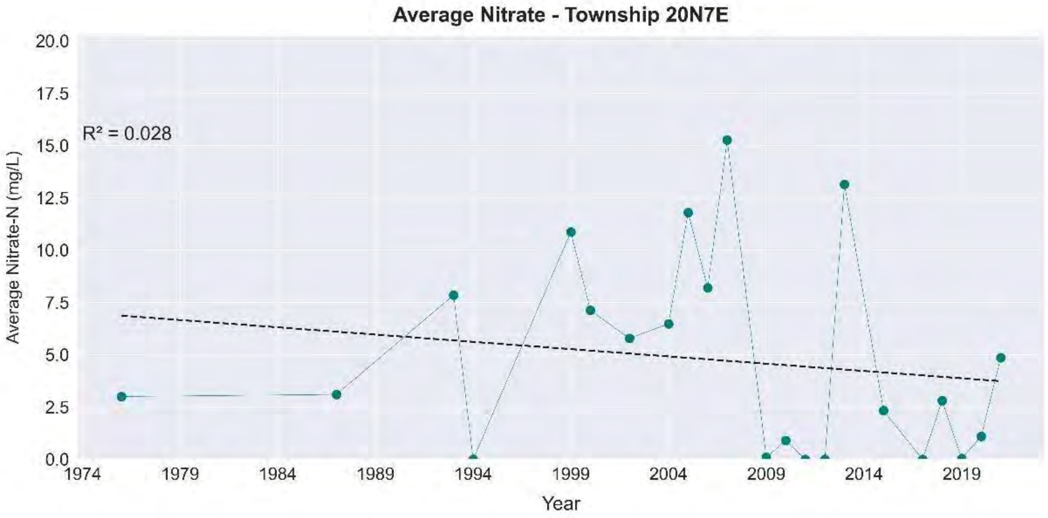


Figure C 69. Township 20N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



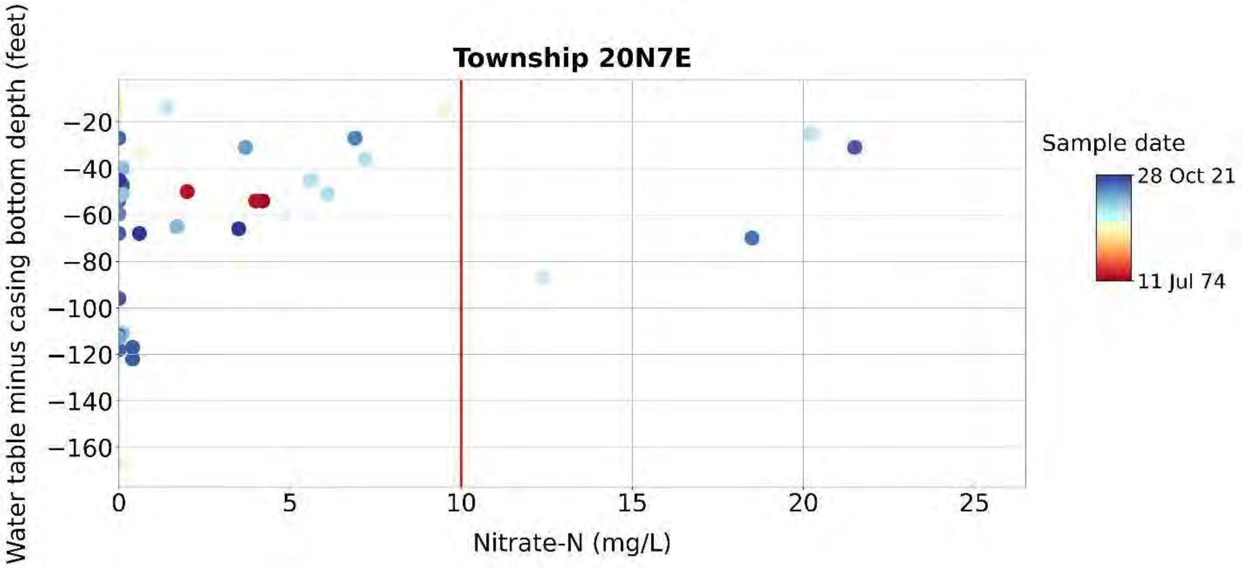
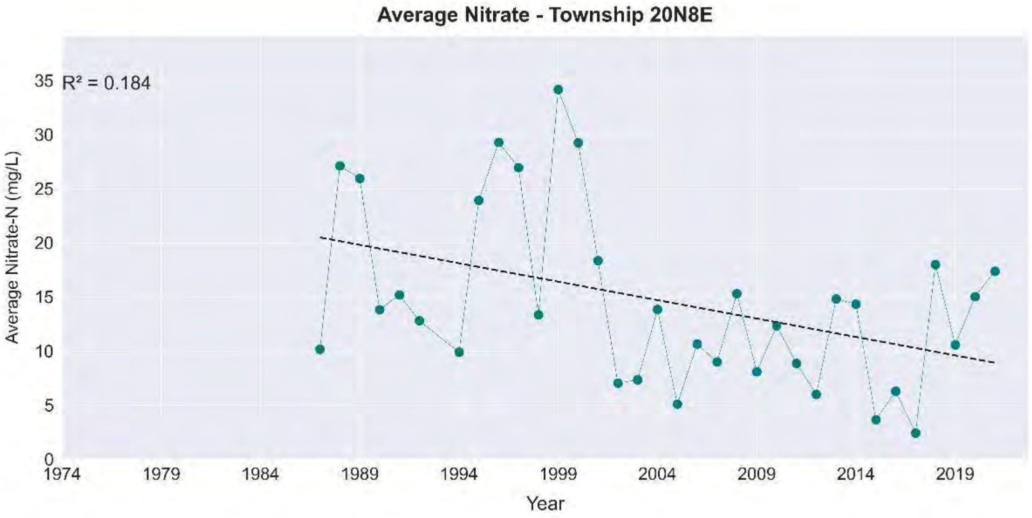


Figure C 70. Township 20N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



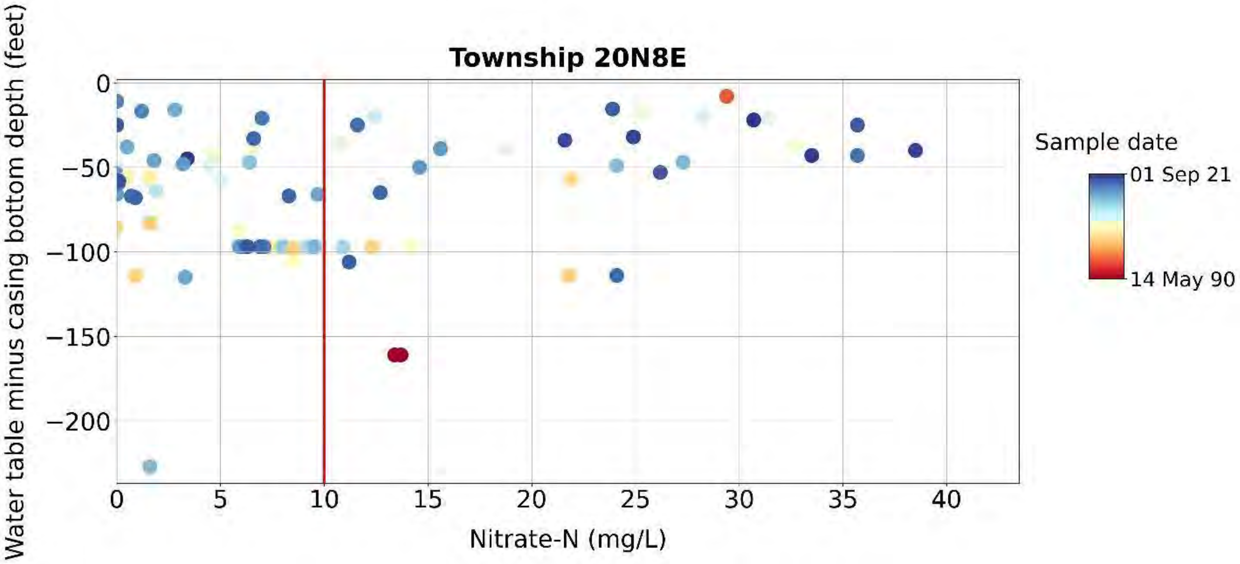
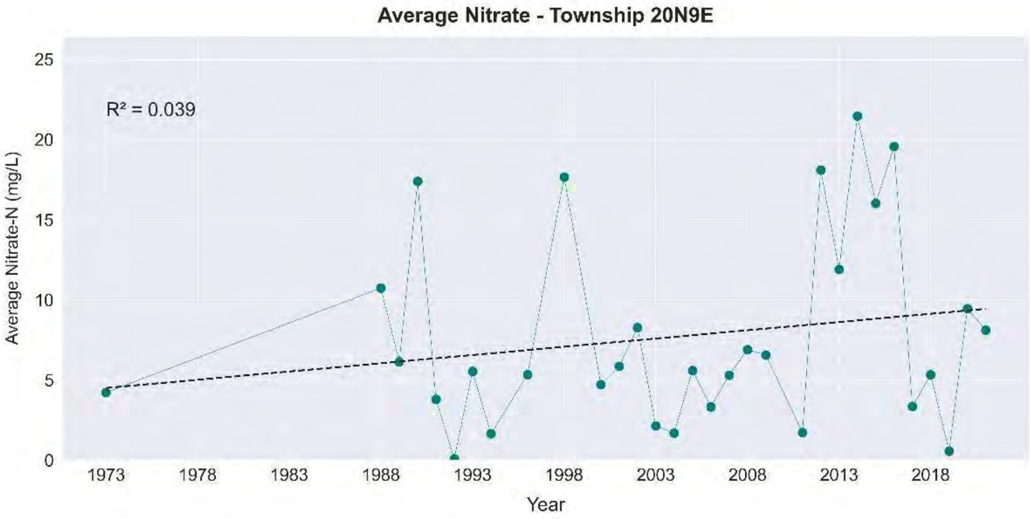


Figure C 71. Township 20N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



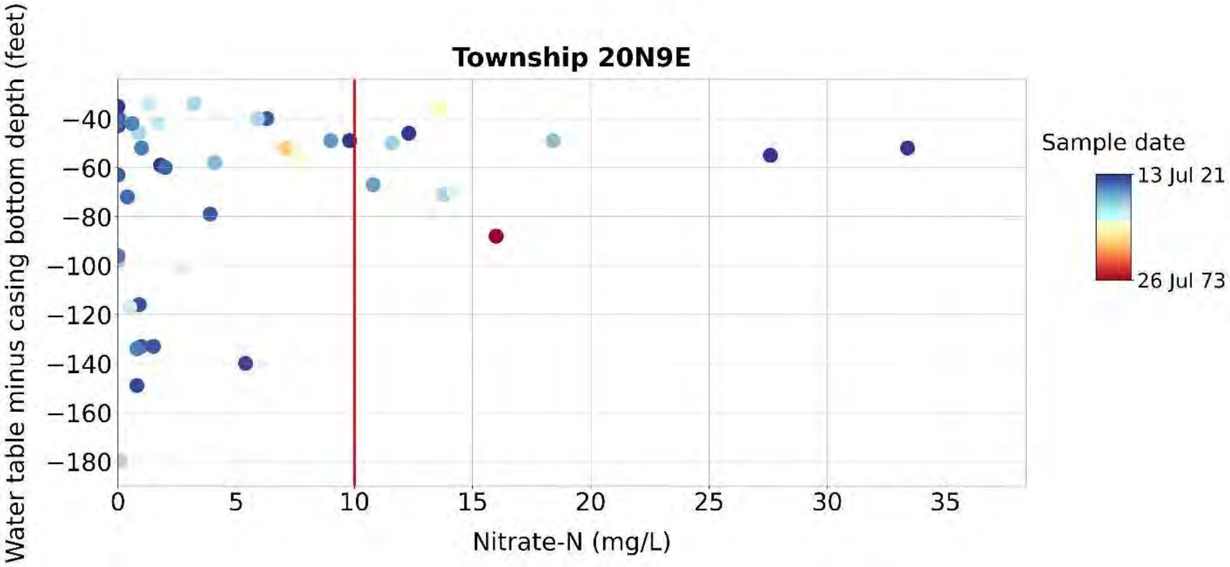
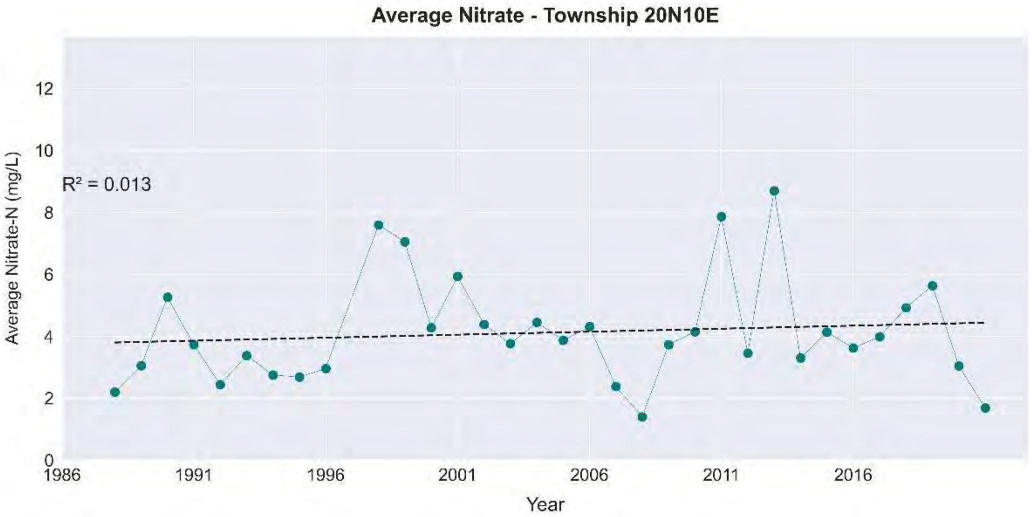


Figure C 72Township 20N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



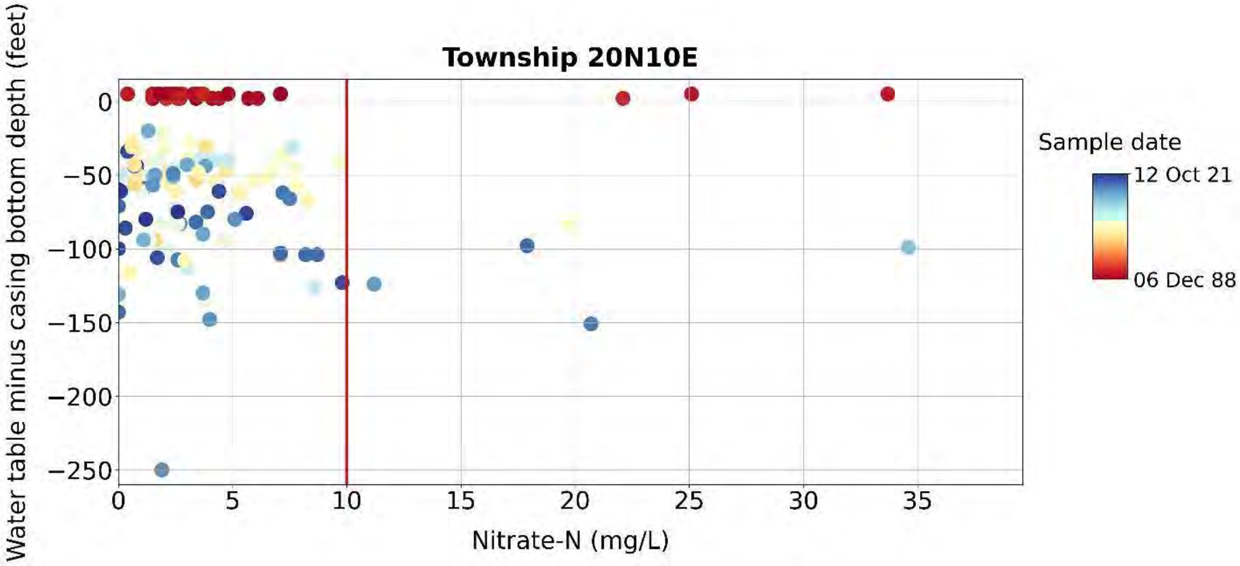
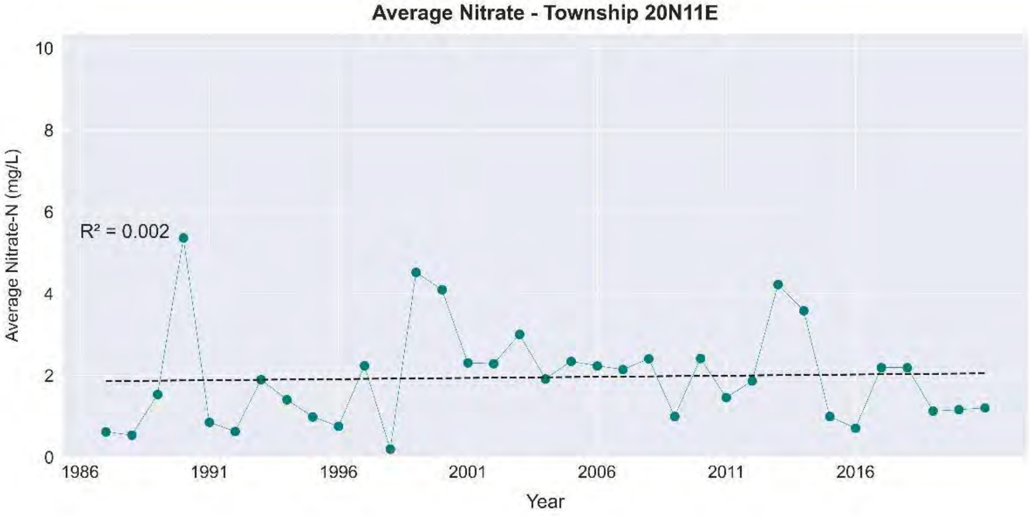


Figure C 73. Township 20N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



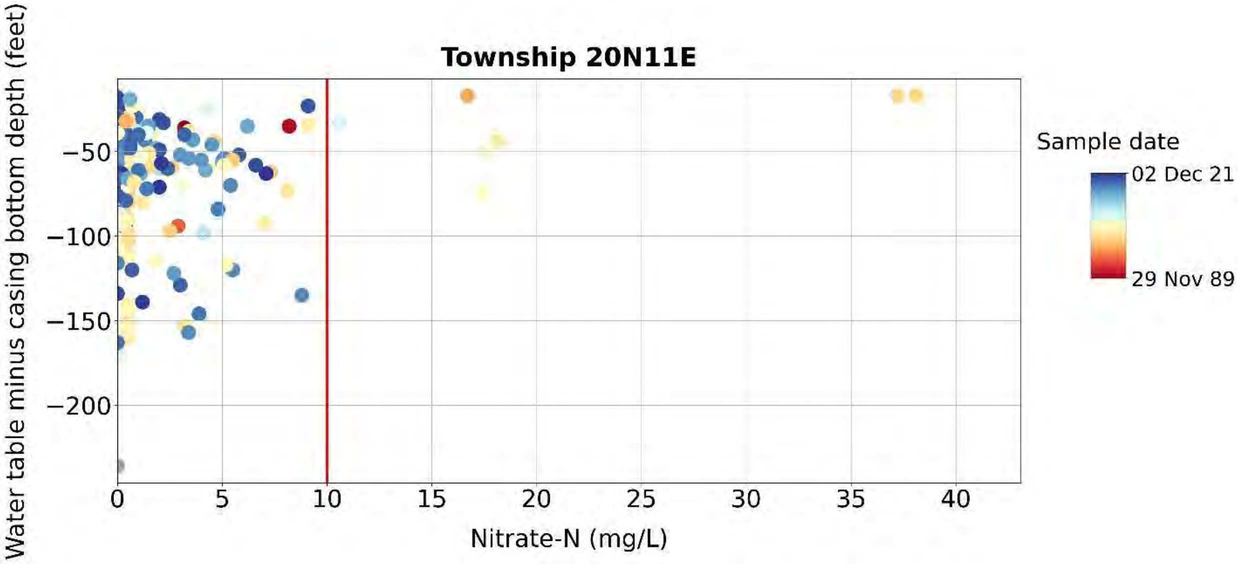
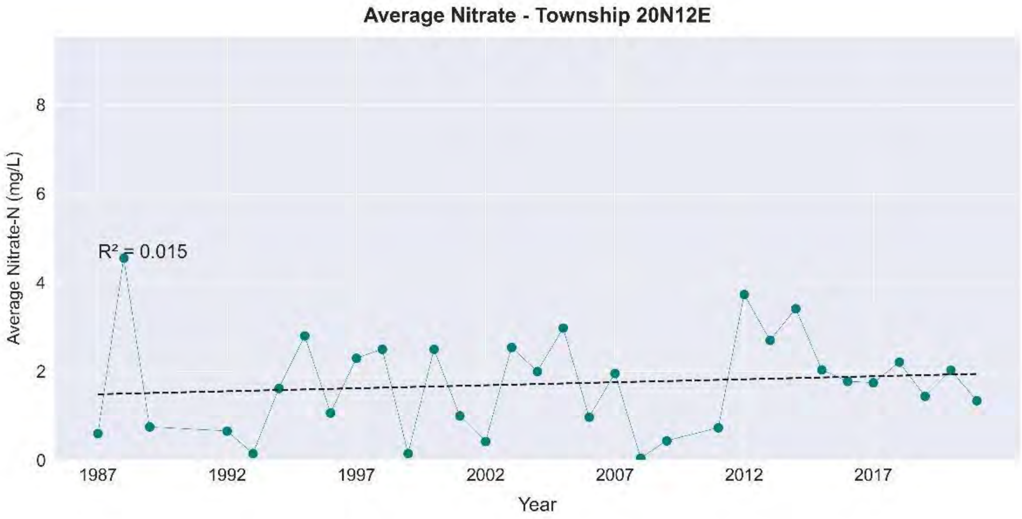


Figure C 74. Township 20N11E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



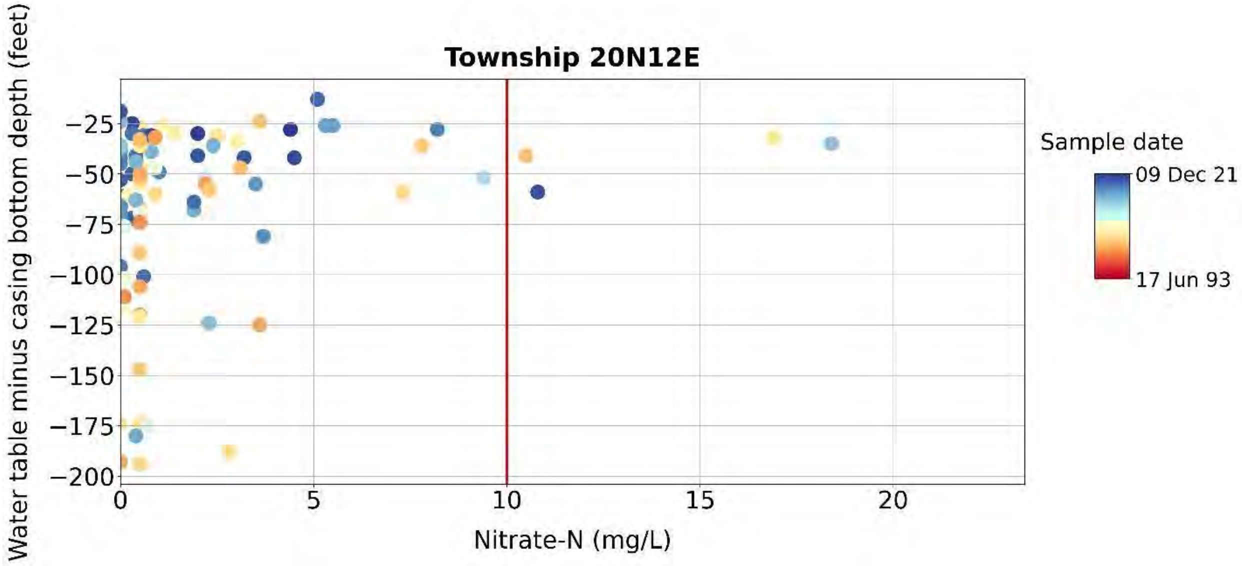
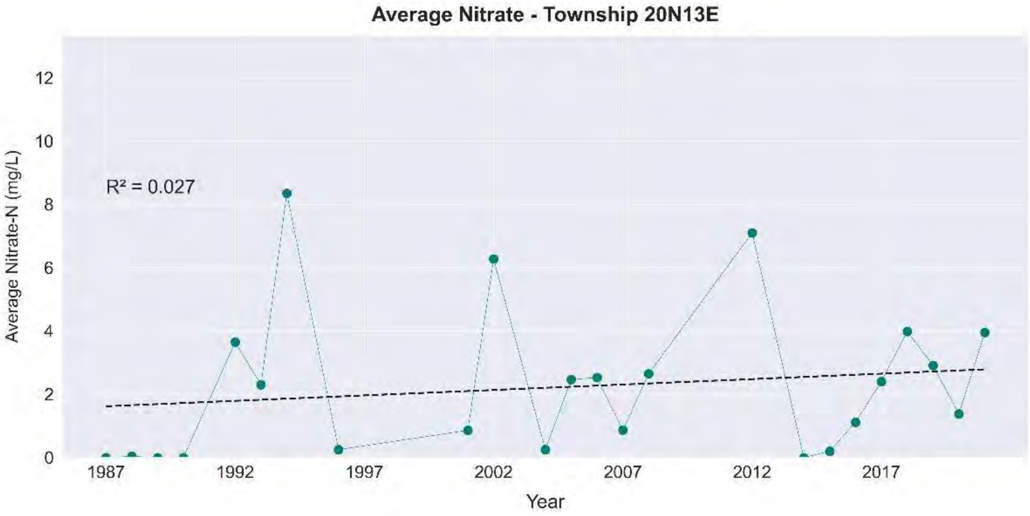


Figure C 75. Township 20N12E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



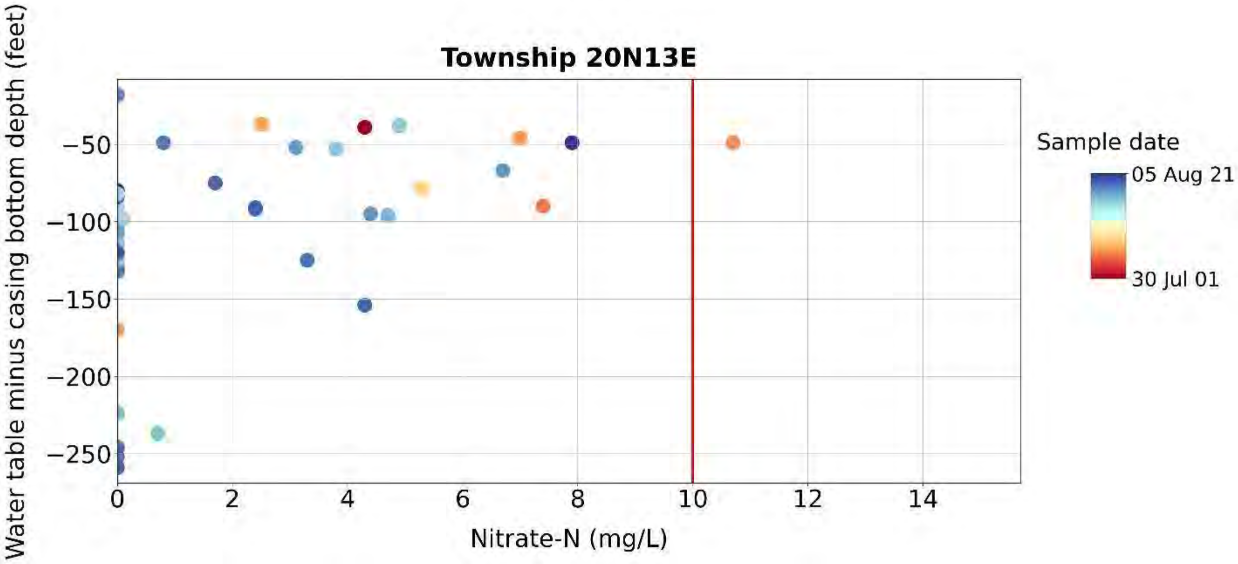
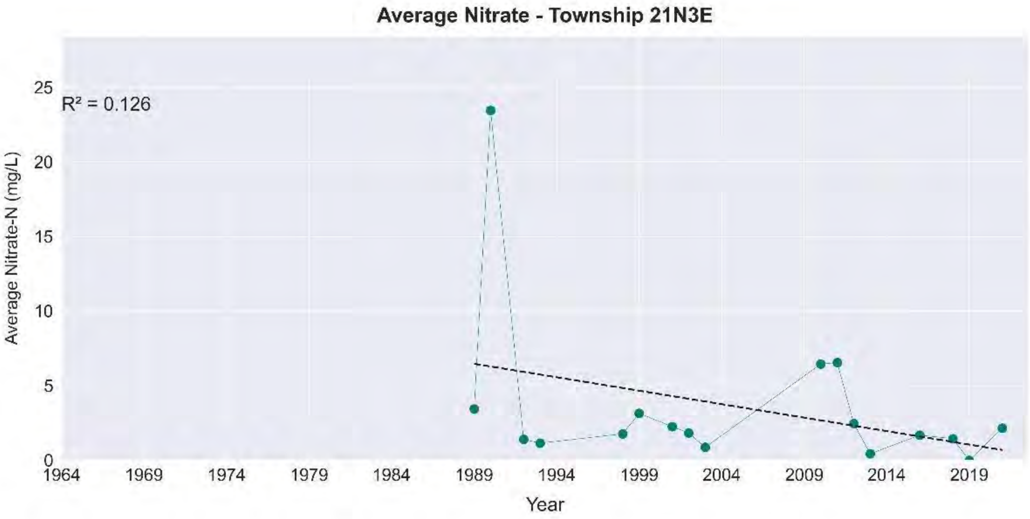


Figure C 76. Township 20N13E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



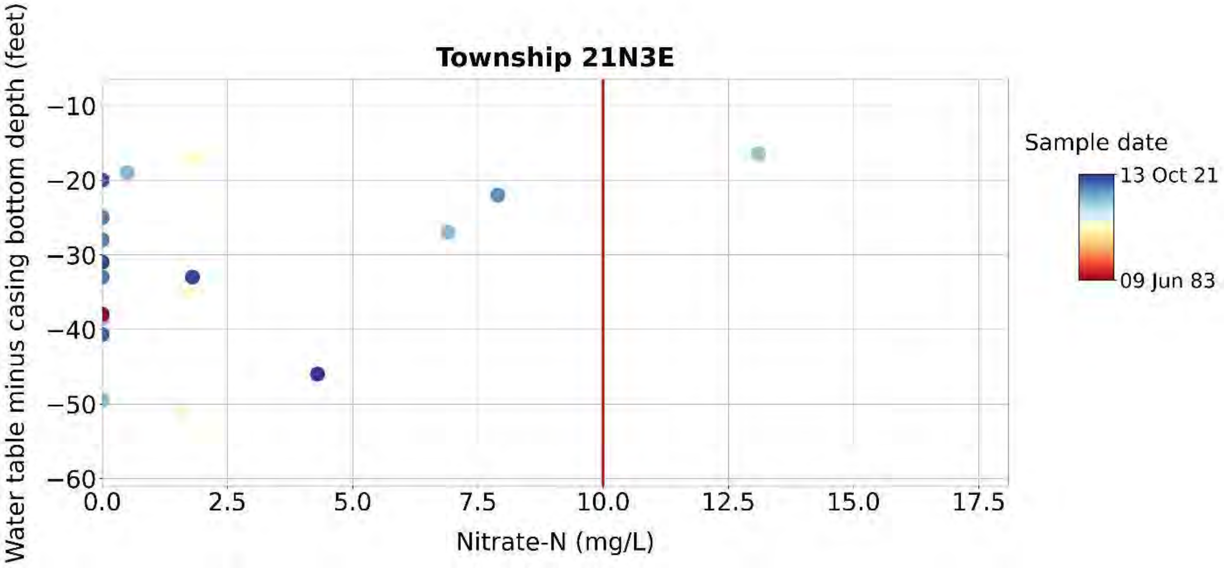
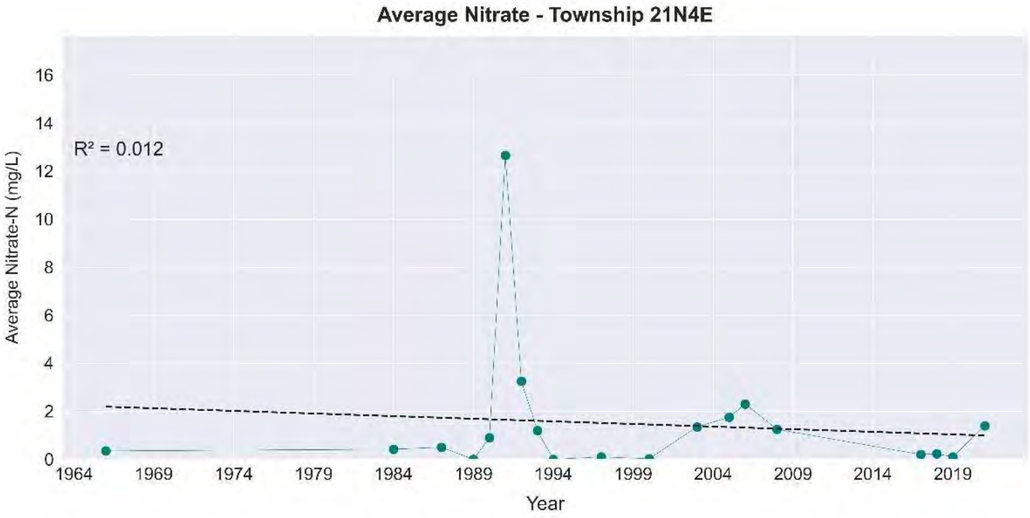


Figure C 77. Township 21N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



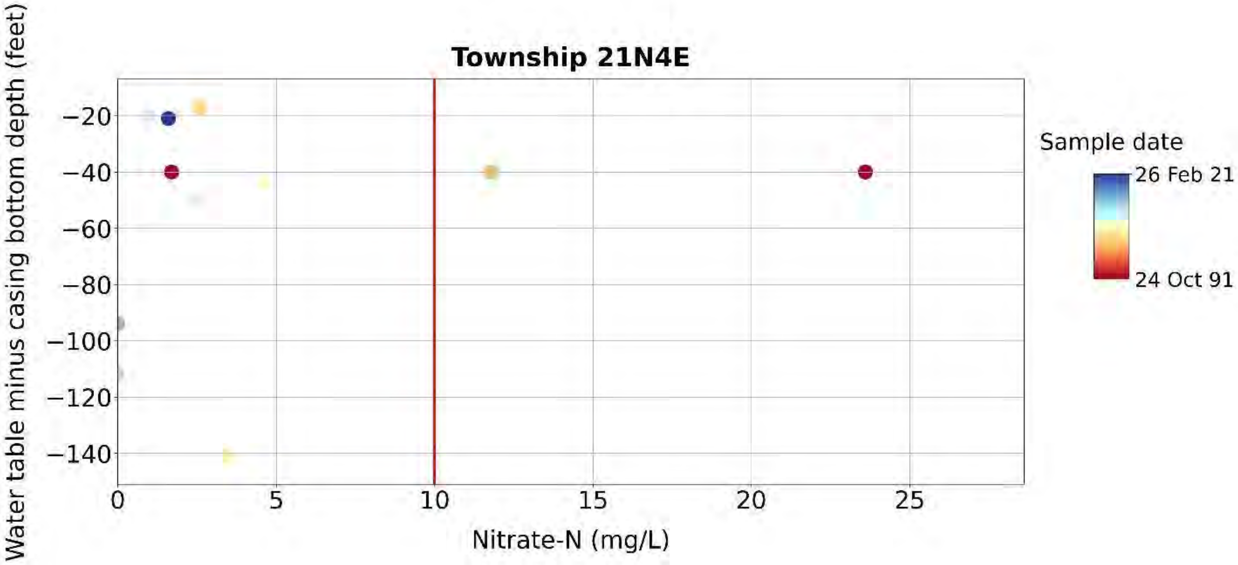
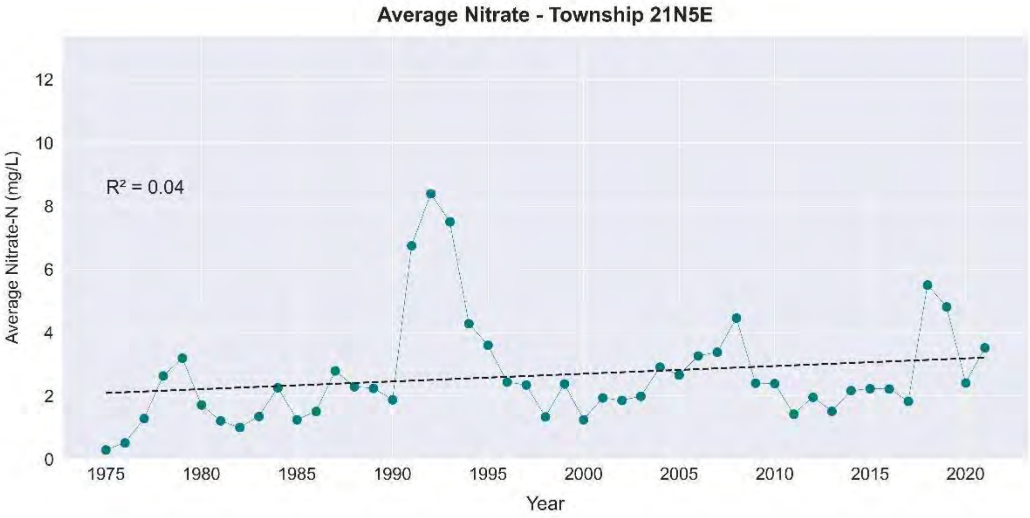


Figure C 78. Township 21N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



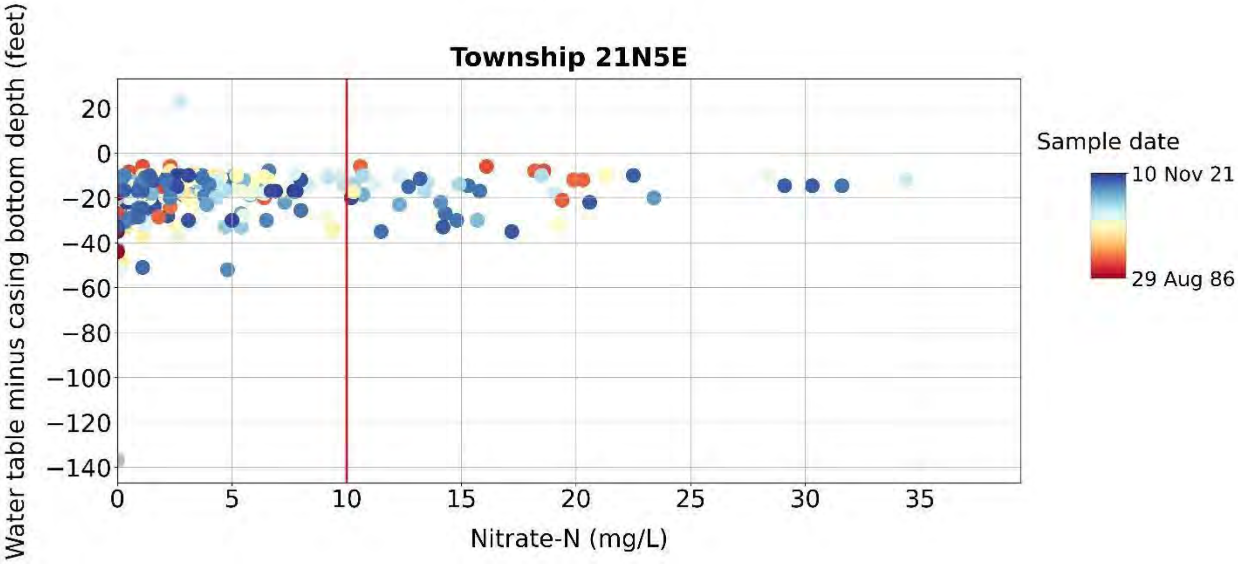
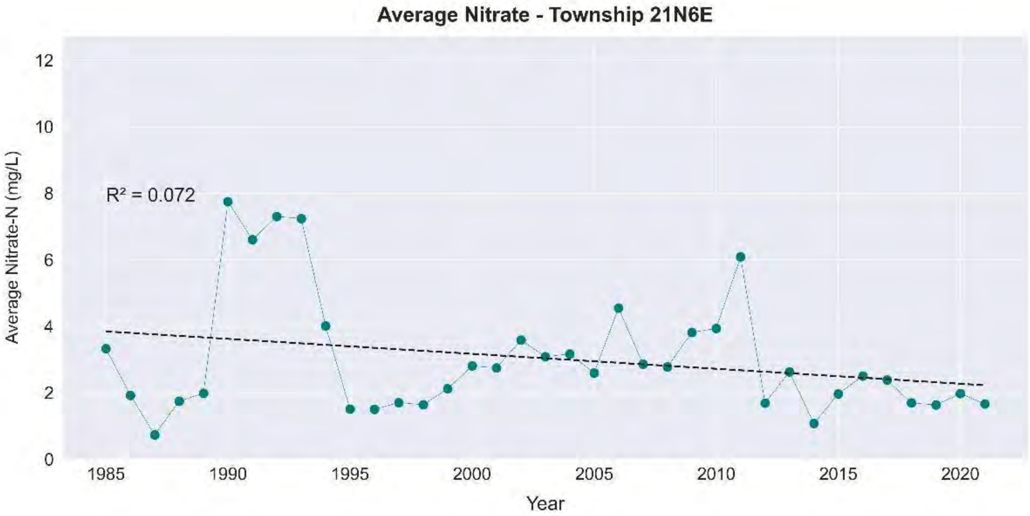


Figure C 79. Township 21N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



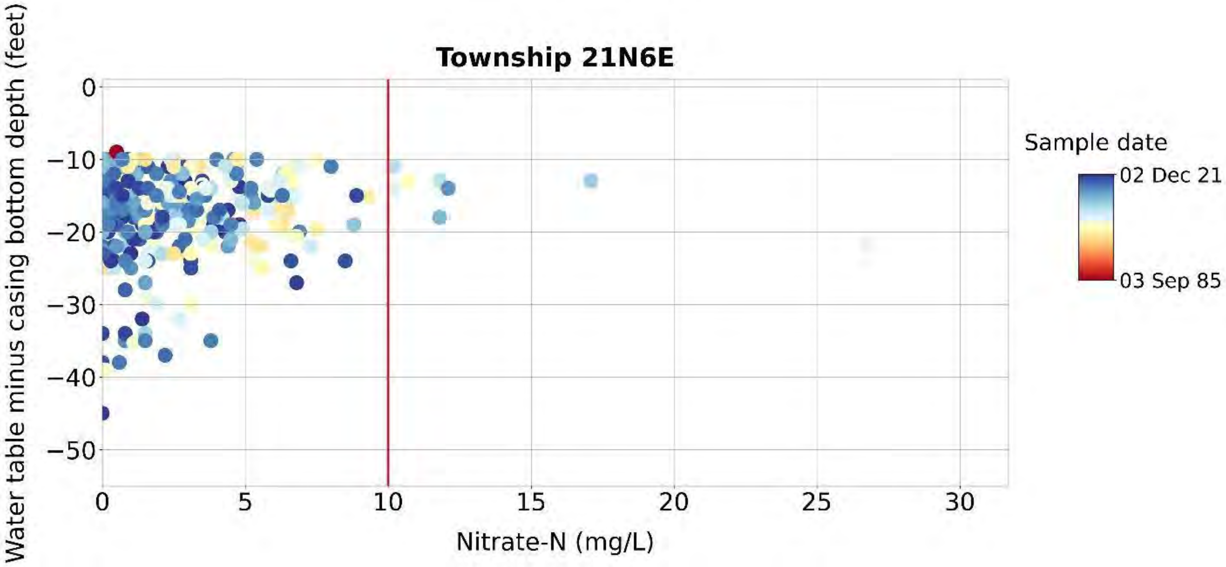


Figure C 80. Township 21N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

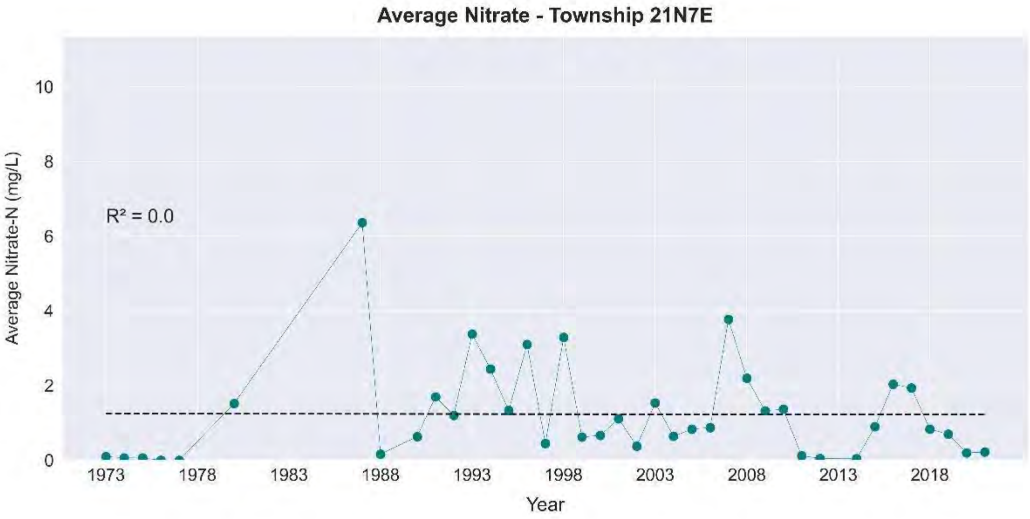
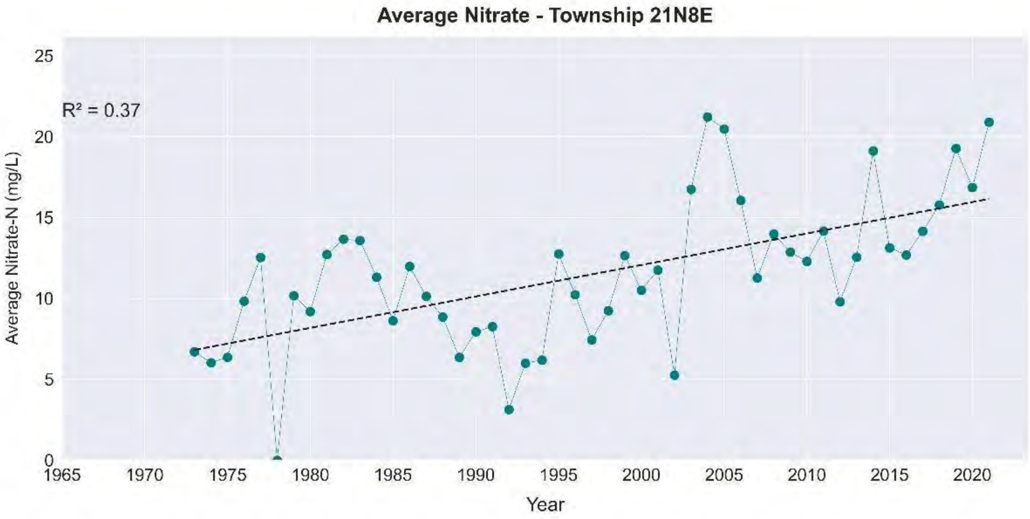


Figure C 81. Township 21N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



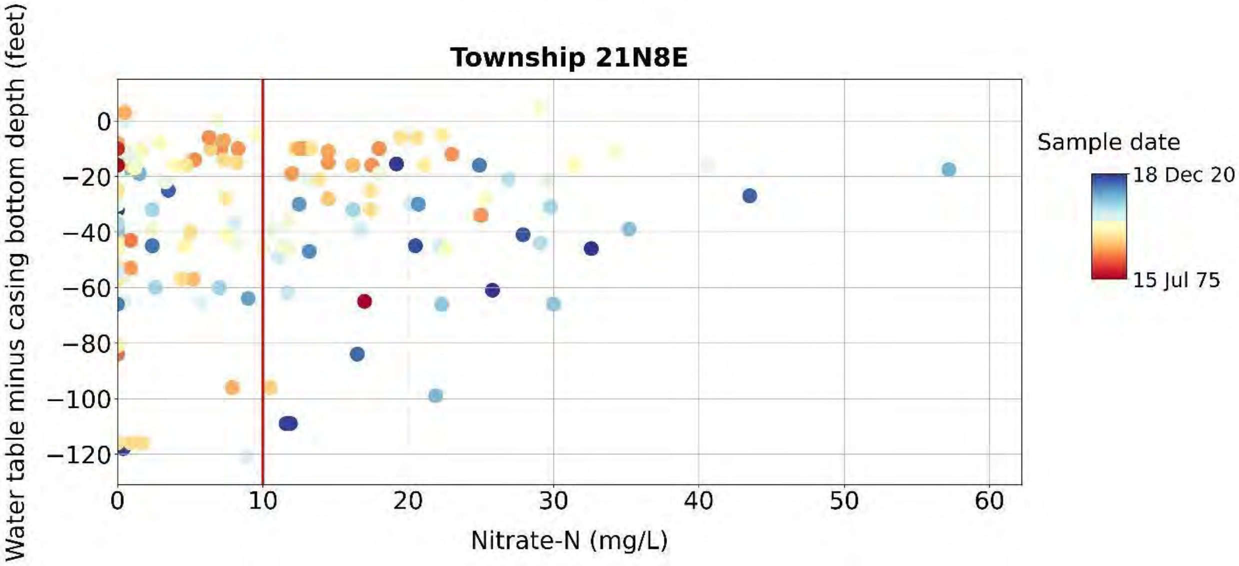
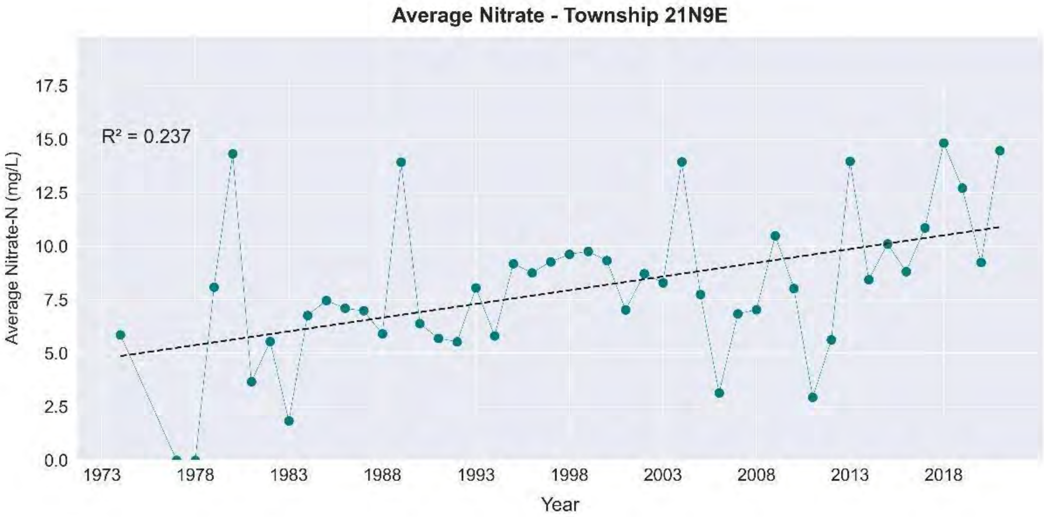


Figure C 82. Township 21N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



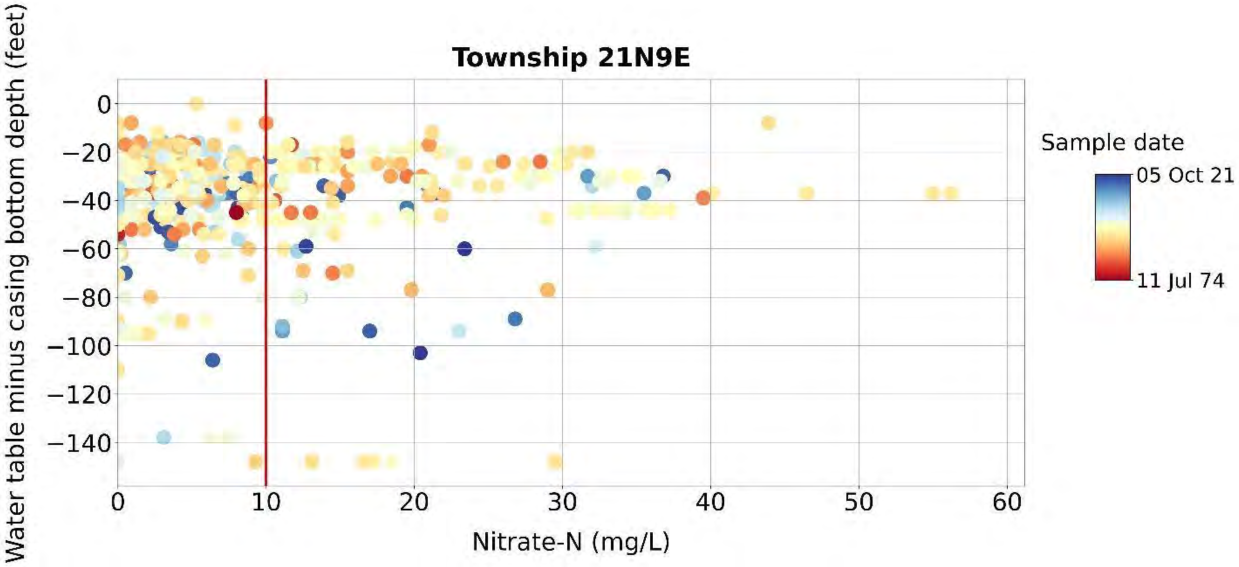
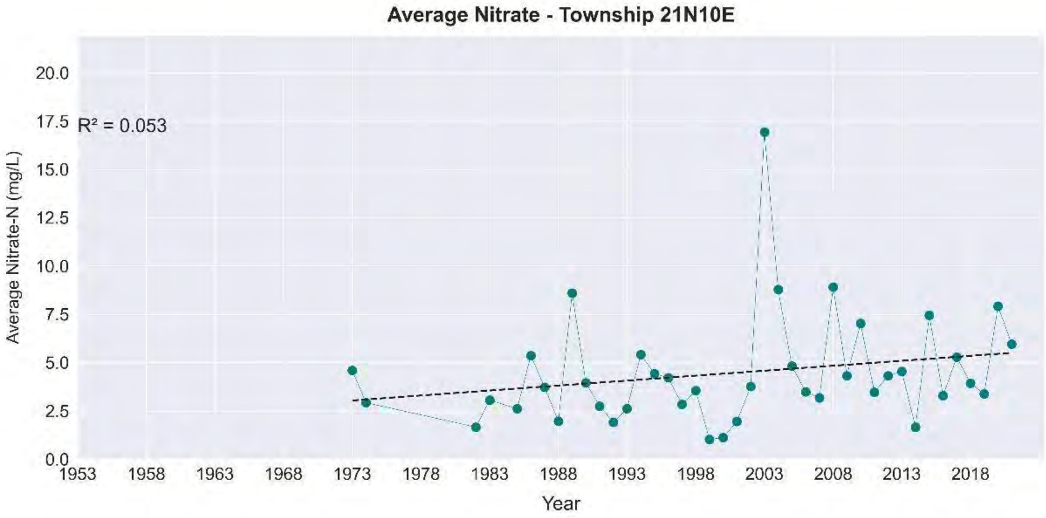


Figure C 83. Township 21N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



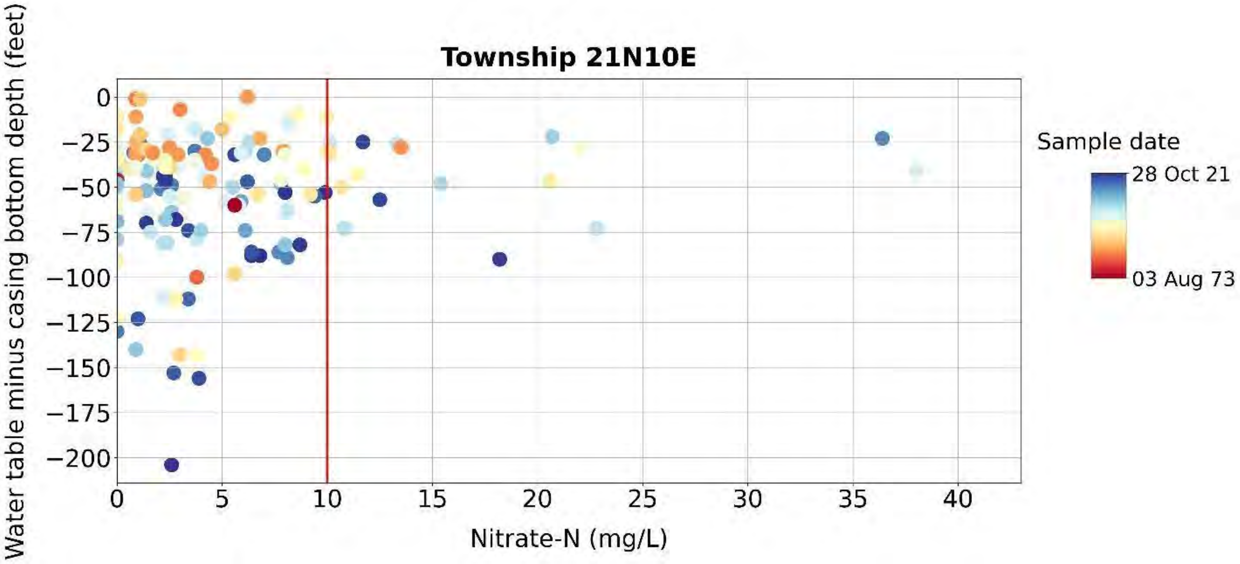
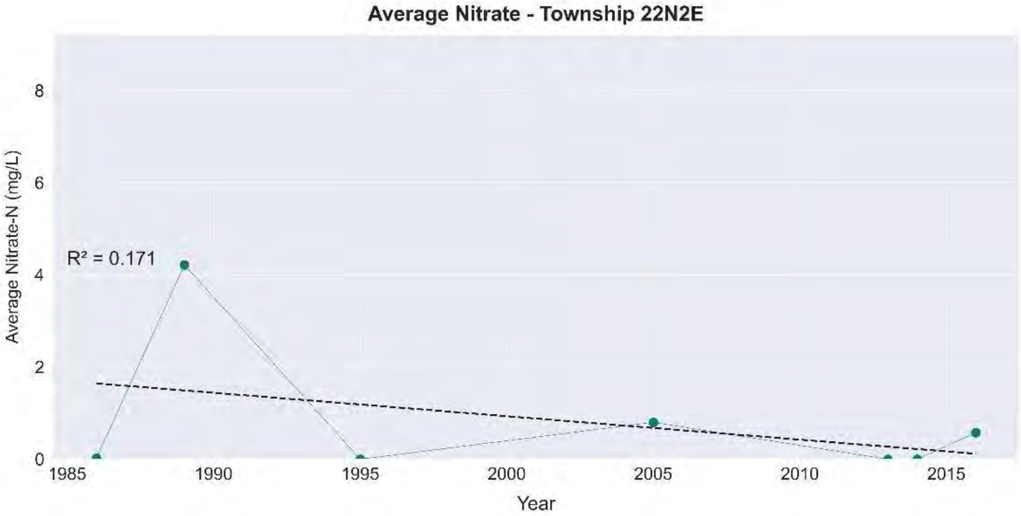


Figure C 84. Township 21N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



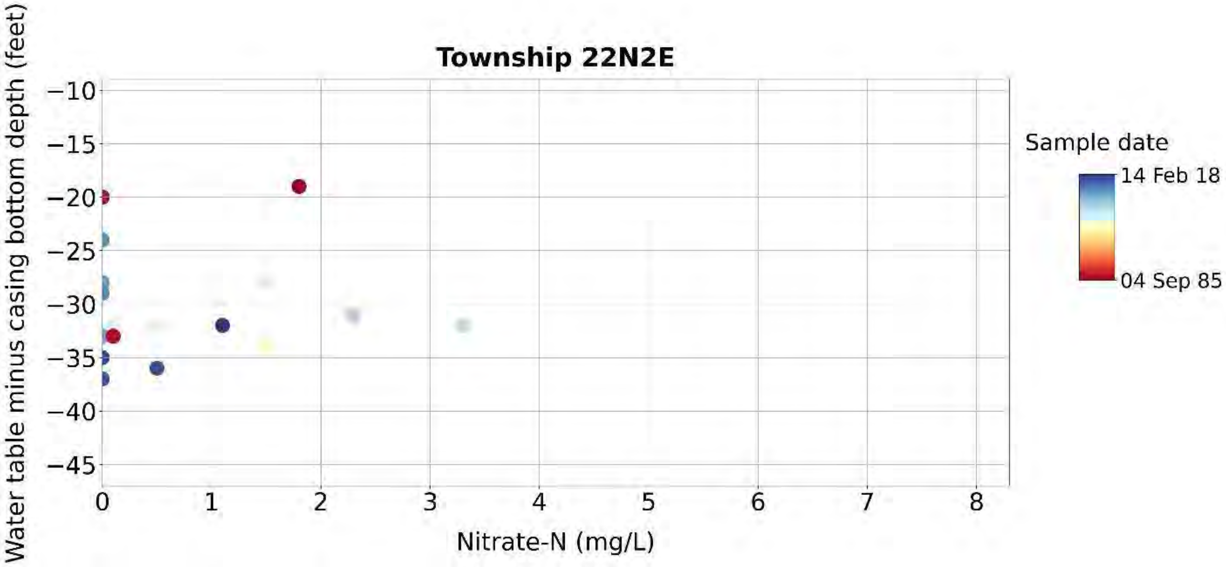
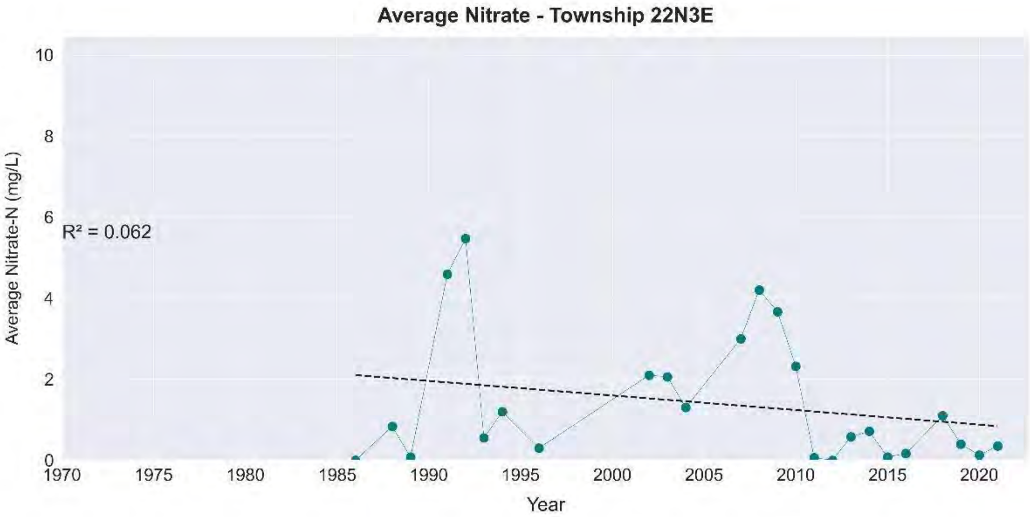


Figure C 85. Township 22N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



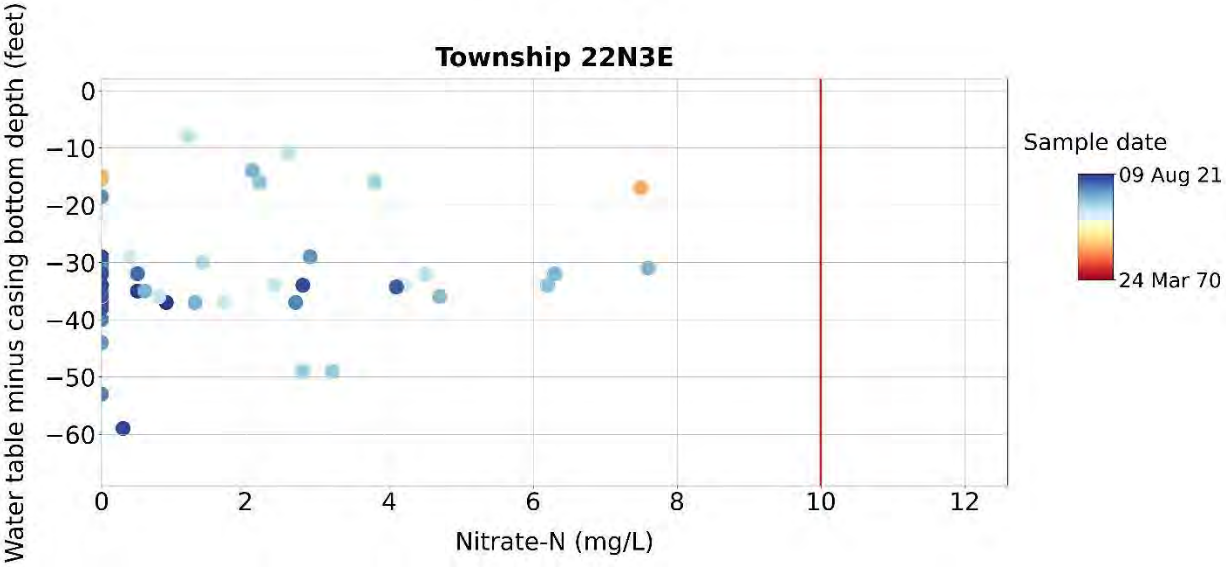
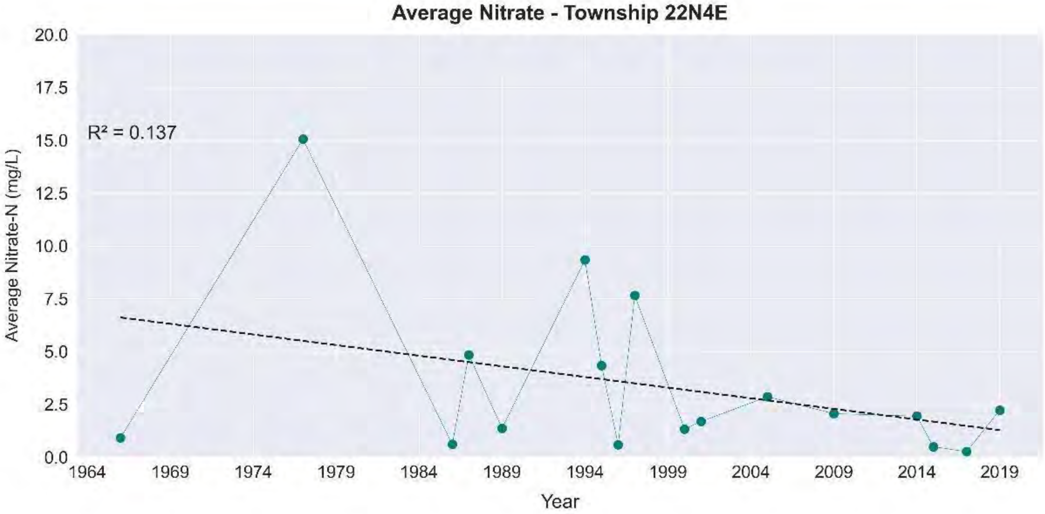


Figure C 86. Township 22N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



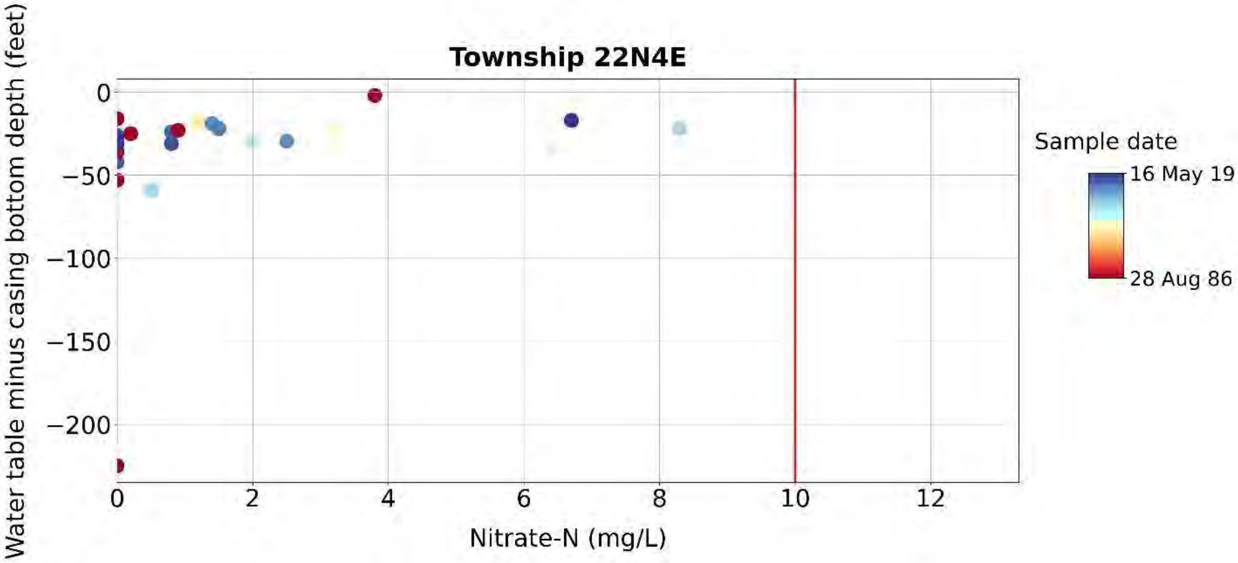


Figure C 87. Township 22N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

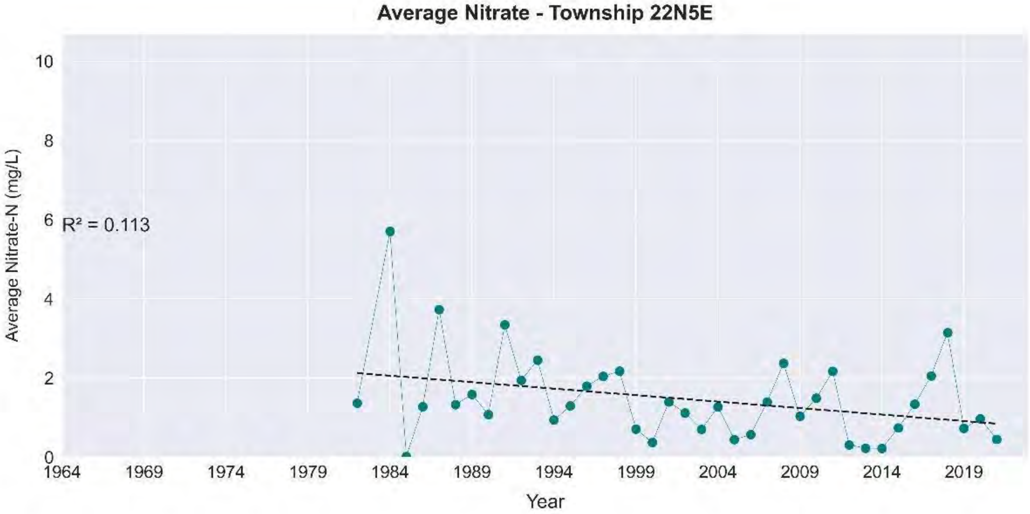


Figure C 88. Township 22N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

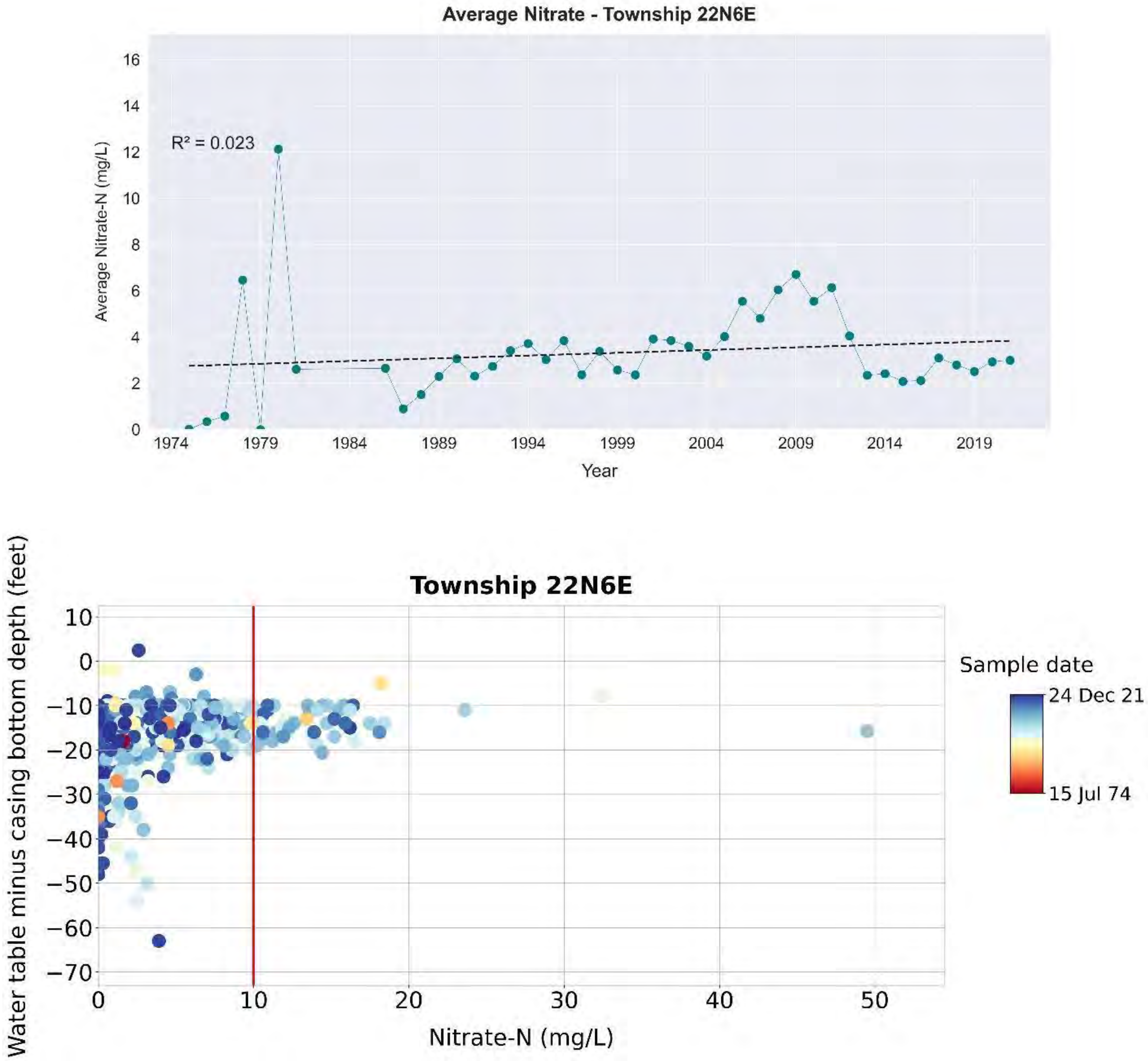
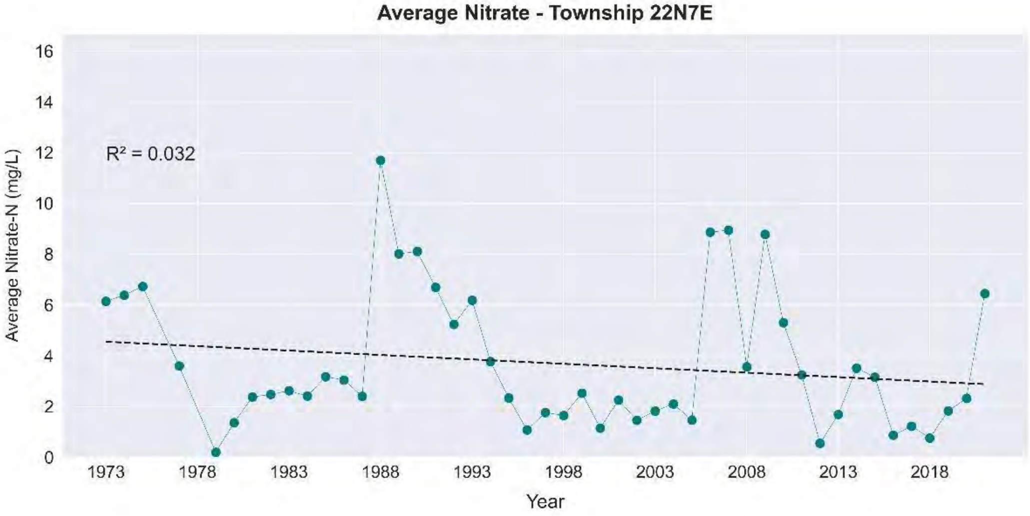


Figure C 89. Township 22N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



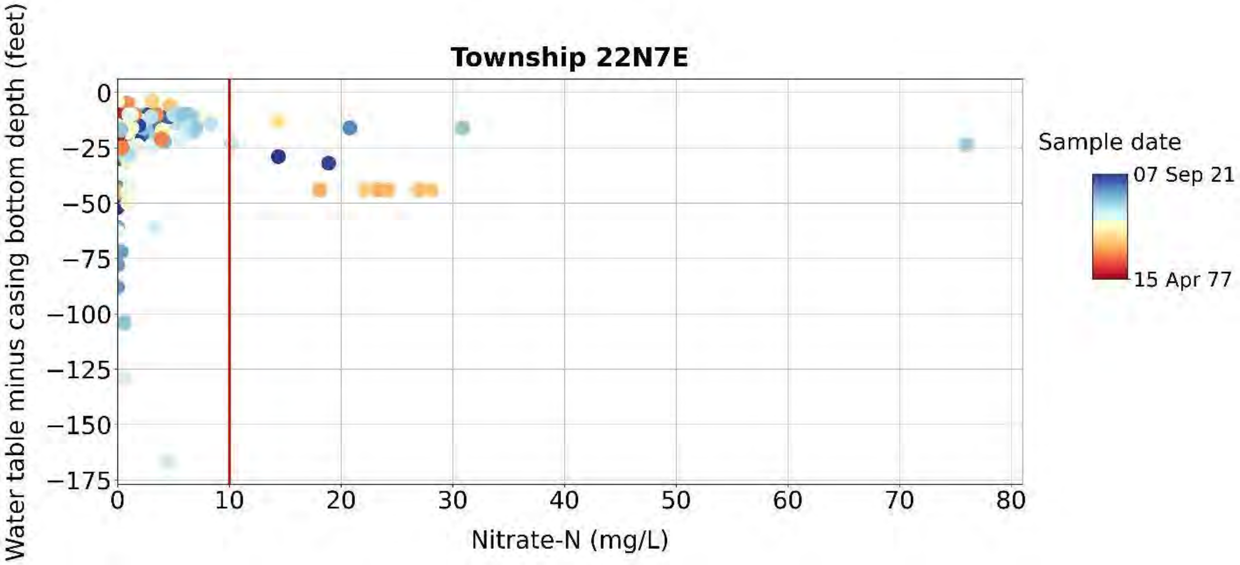
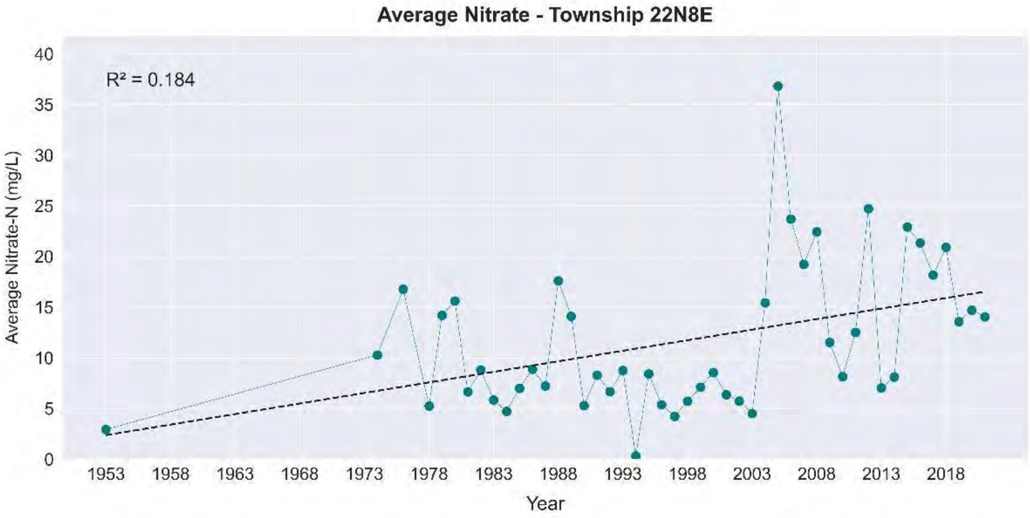


Figure C 90. Township 22N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



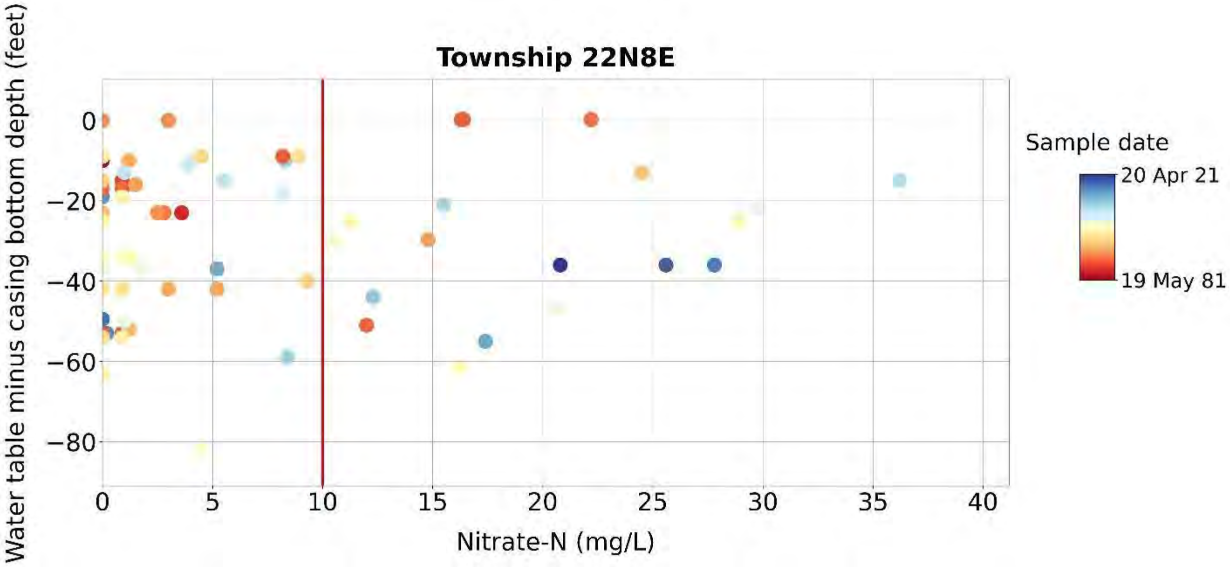
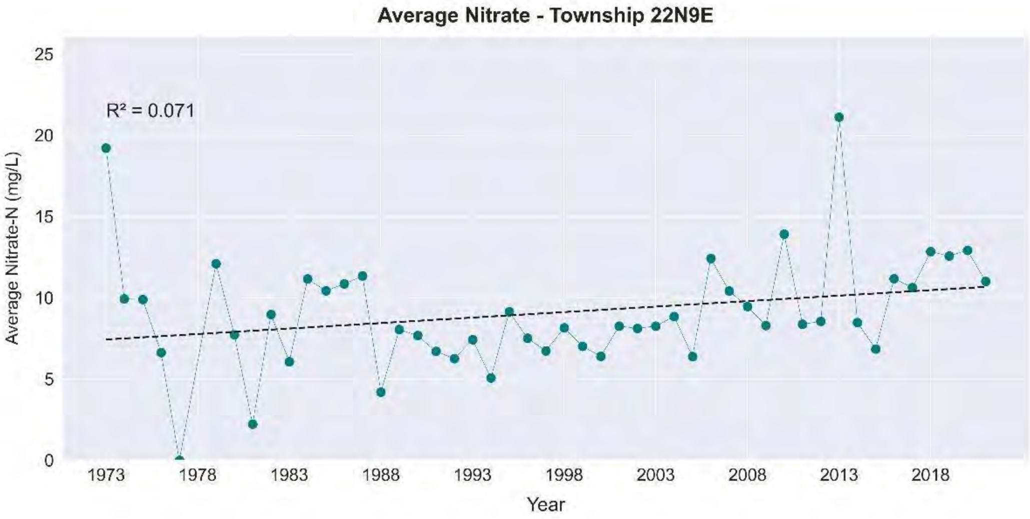


Figure C 91. Township 22N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



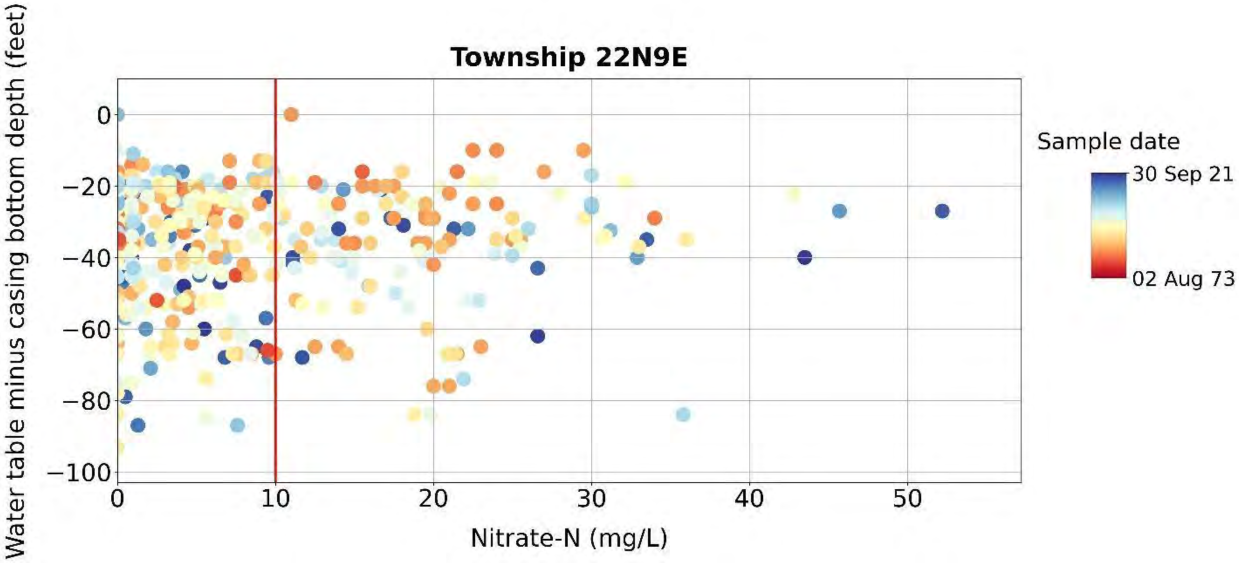
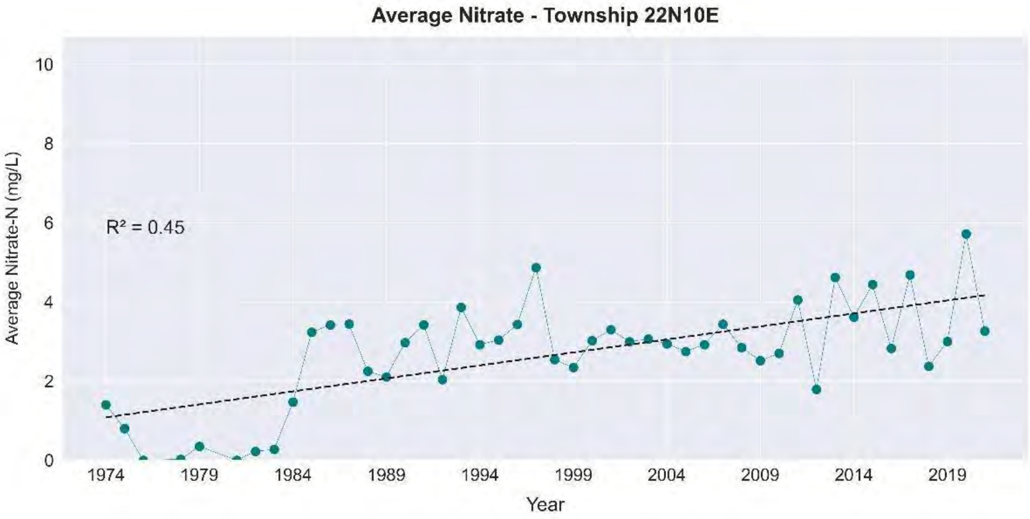


Figure C 92. Township 22N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



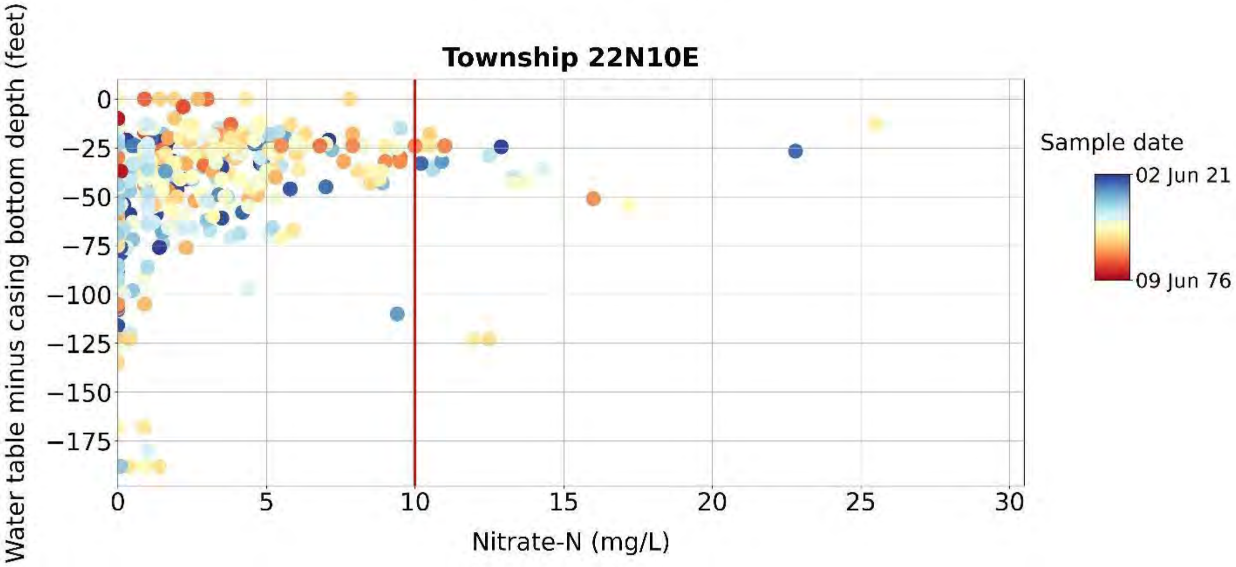
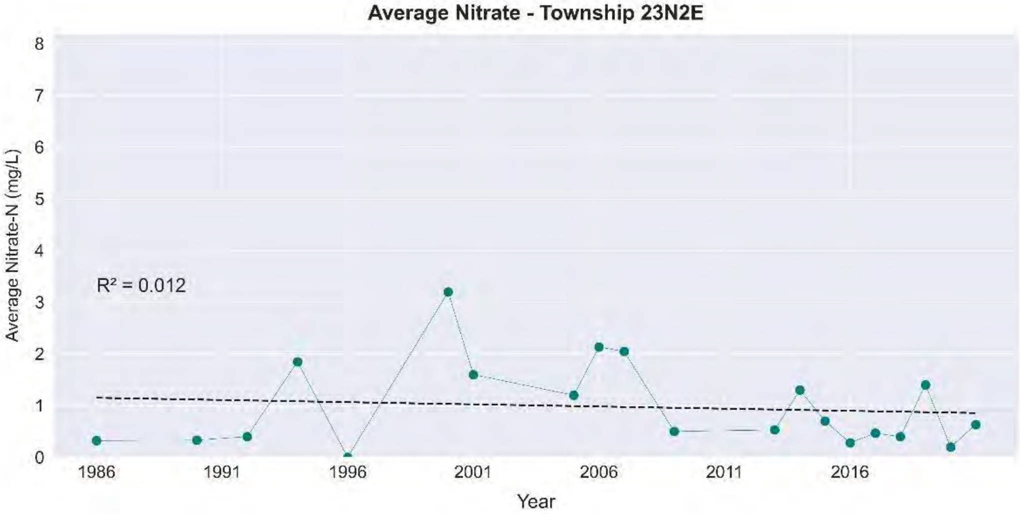


Figure C 93. Township 22N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



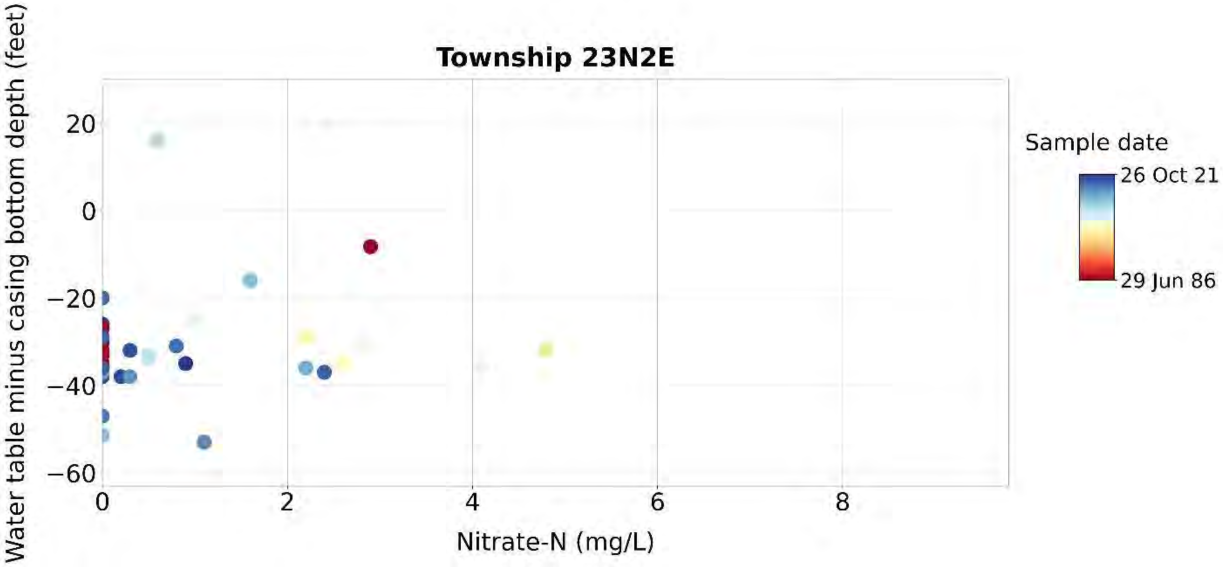
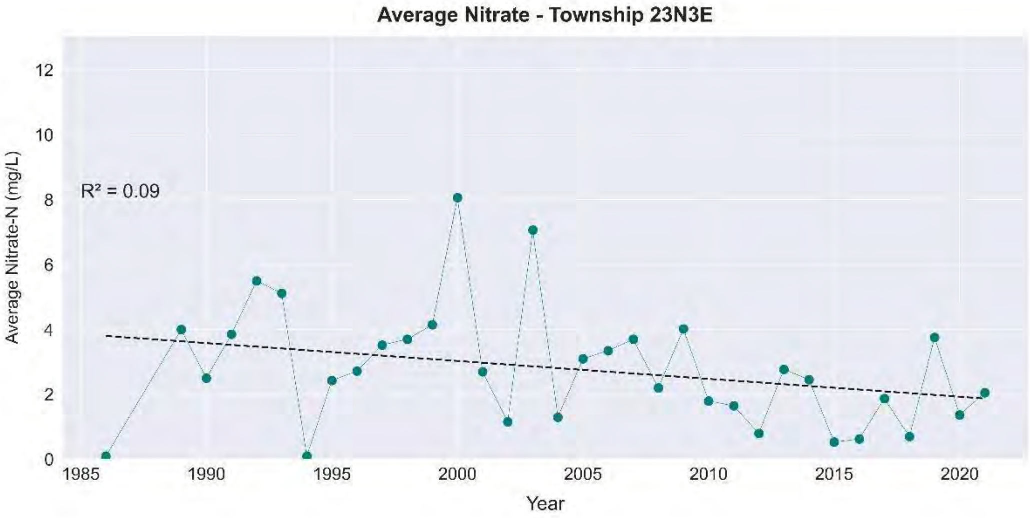


Figure C 94. Township 23N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



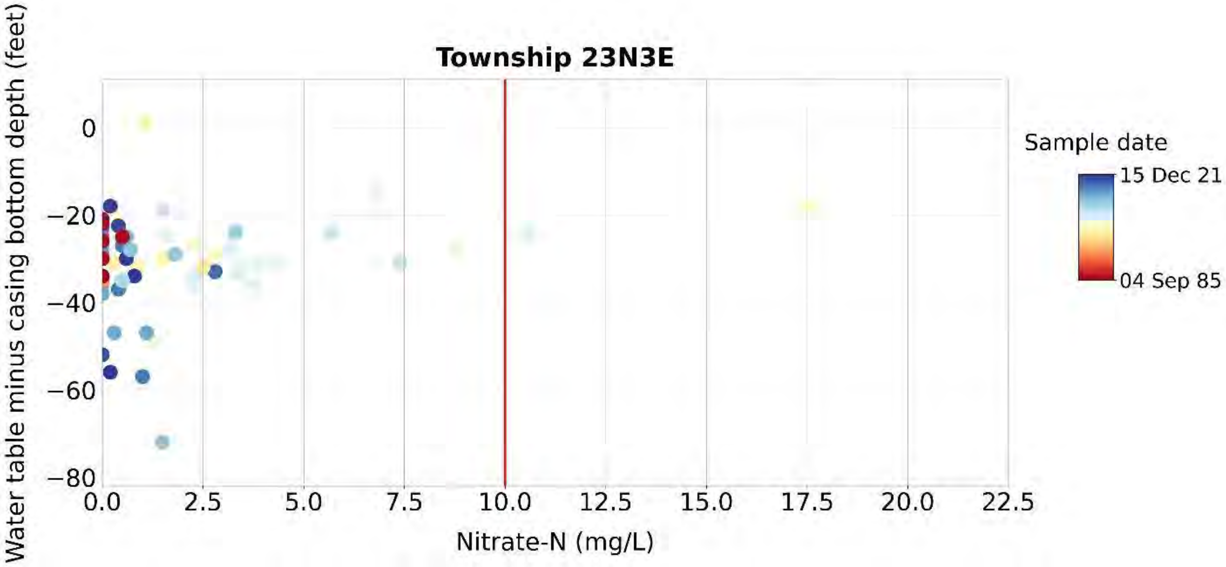
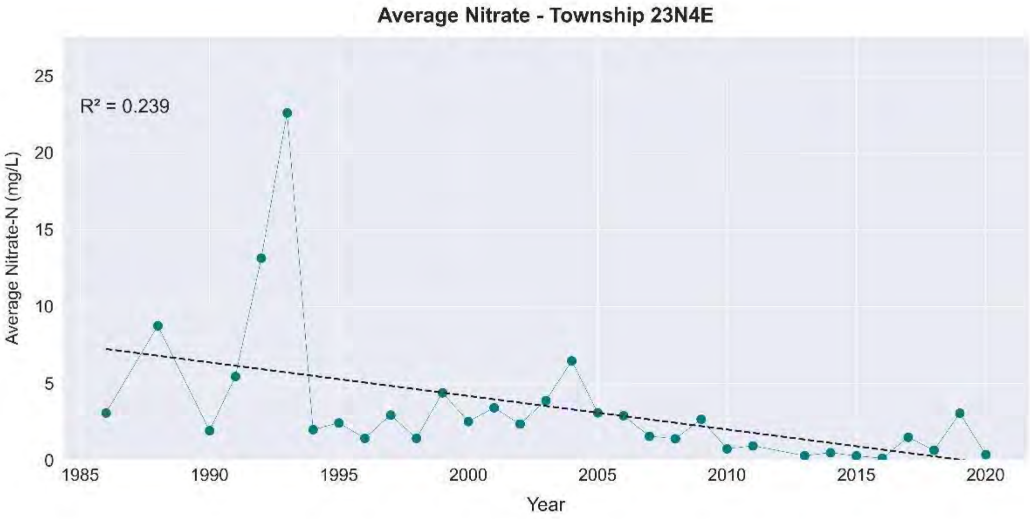


Figure C 95. Township 23N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



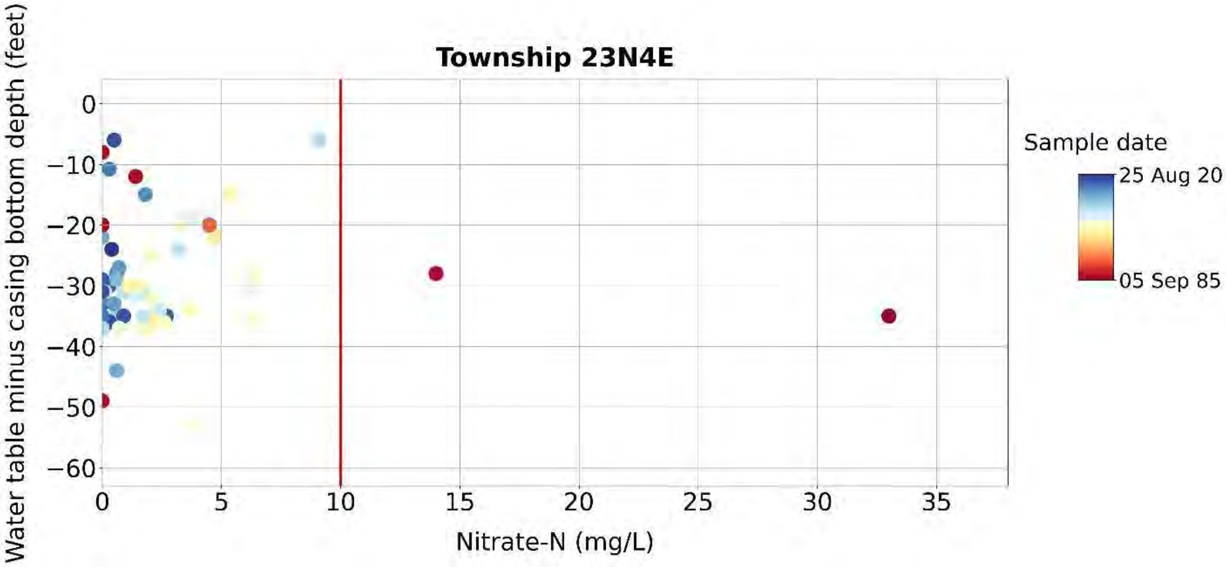
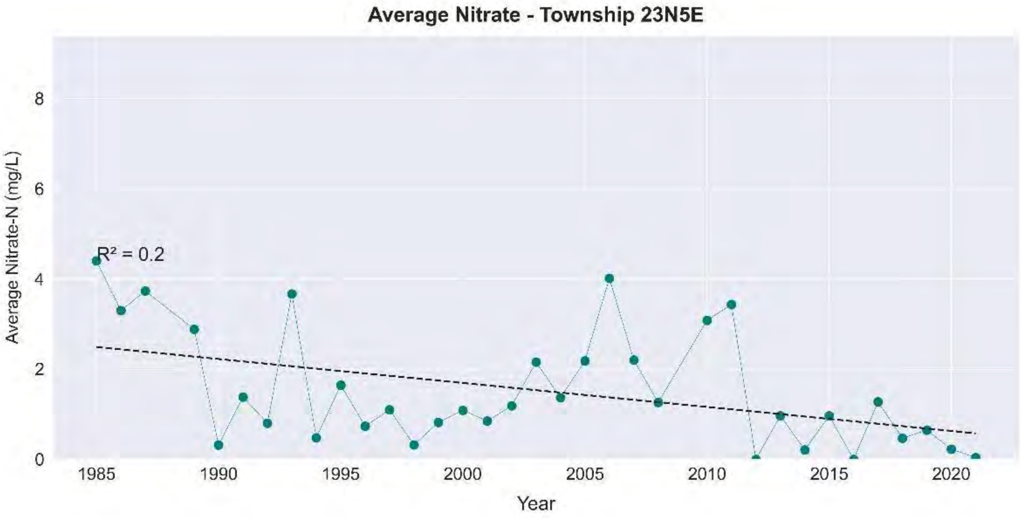


Figure C 96. Township 23N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



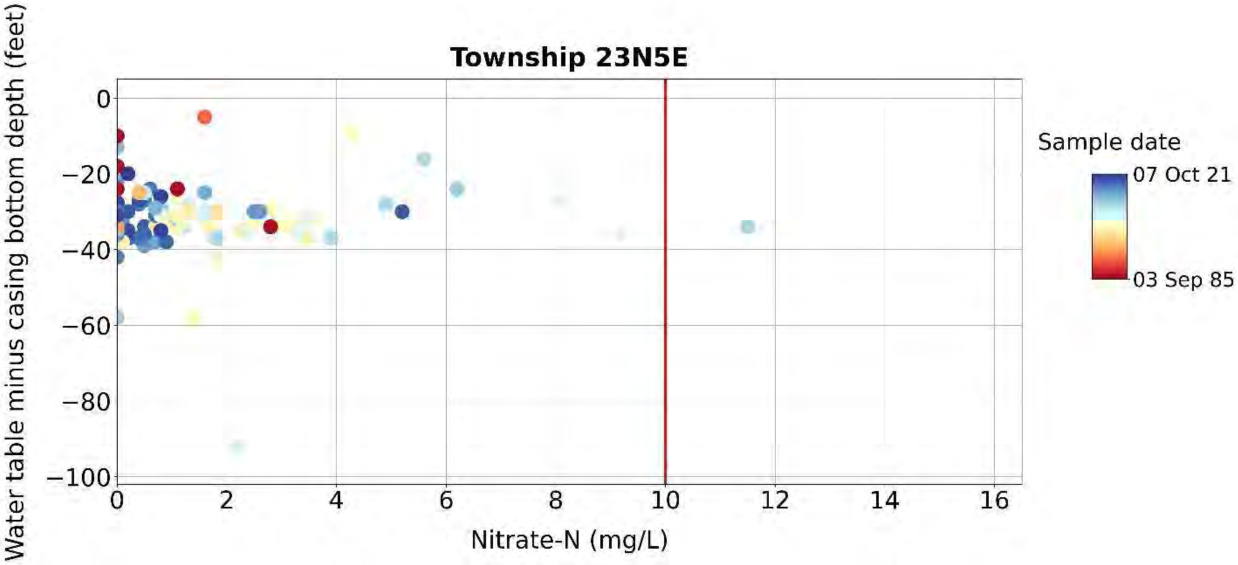
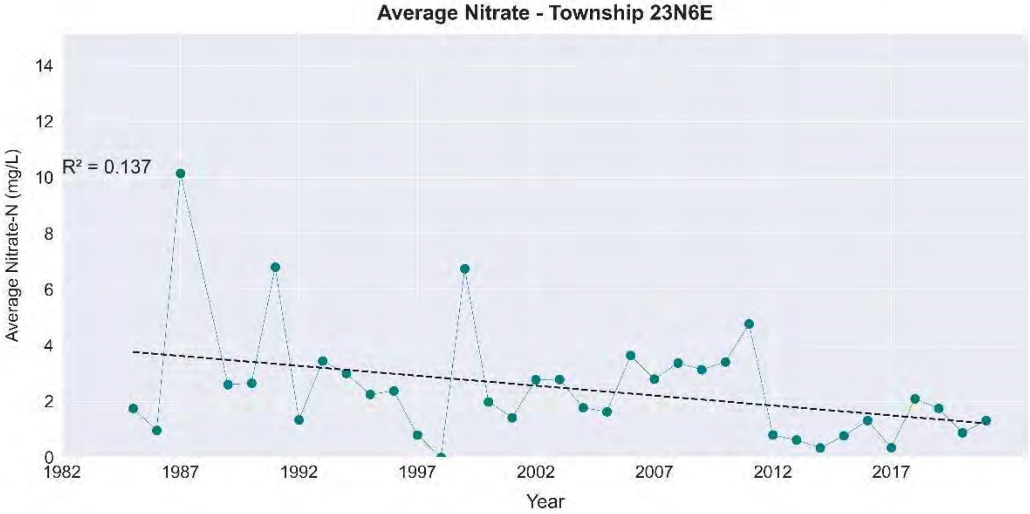


Figure C 97. Township 23N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



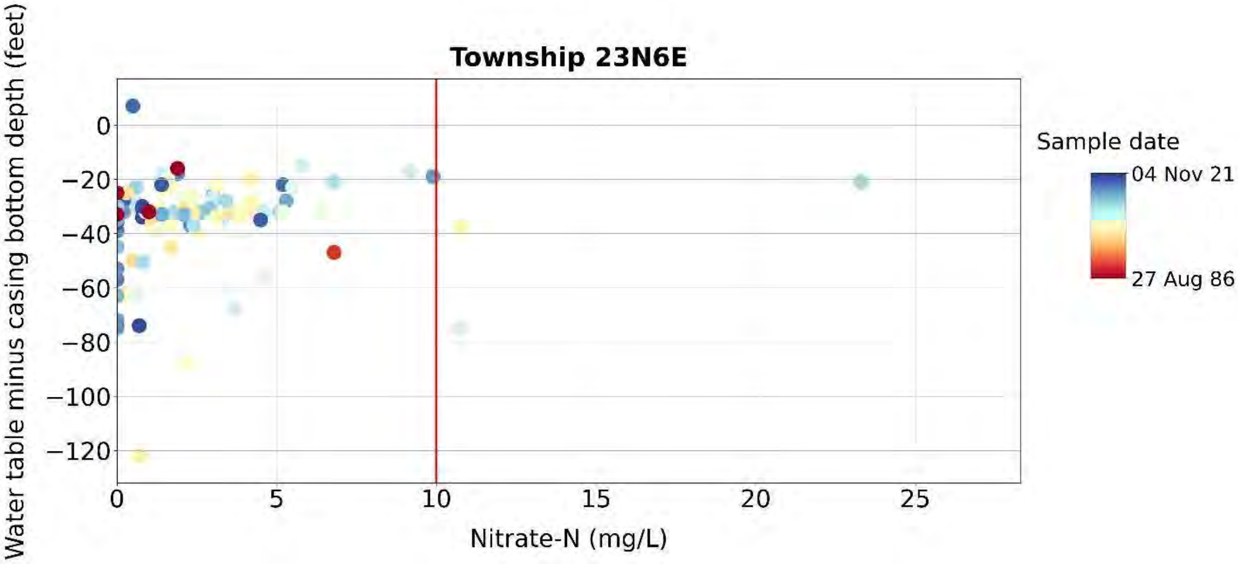
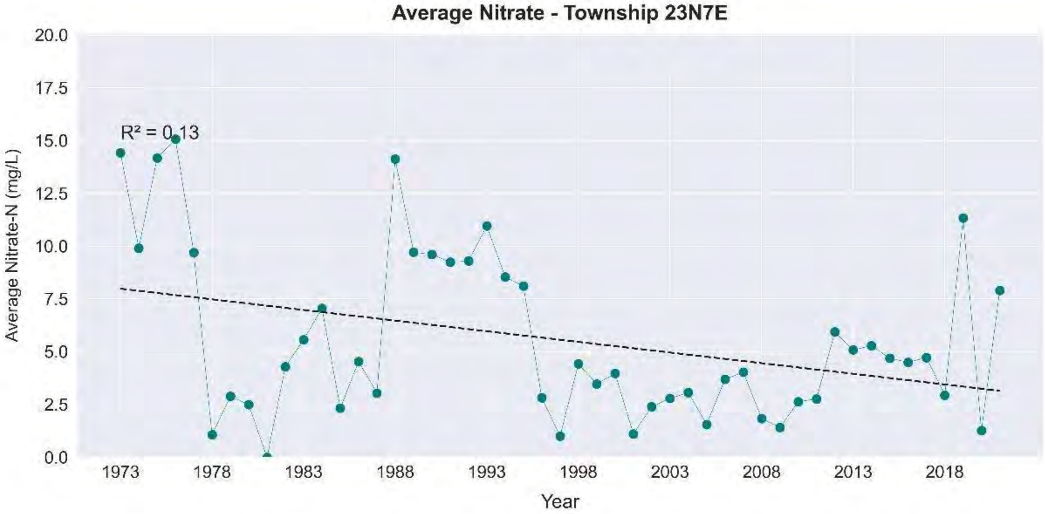


Figure C 98. Township 23N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



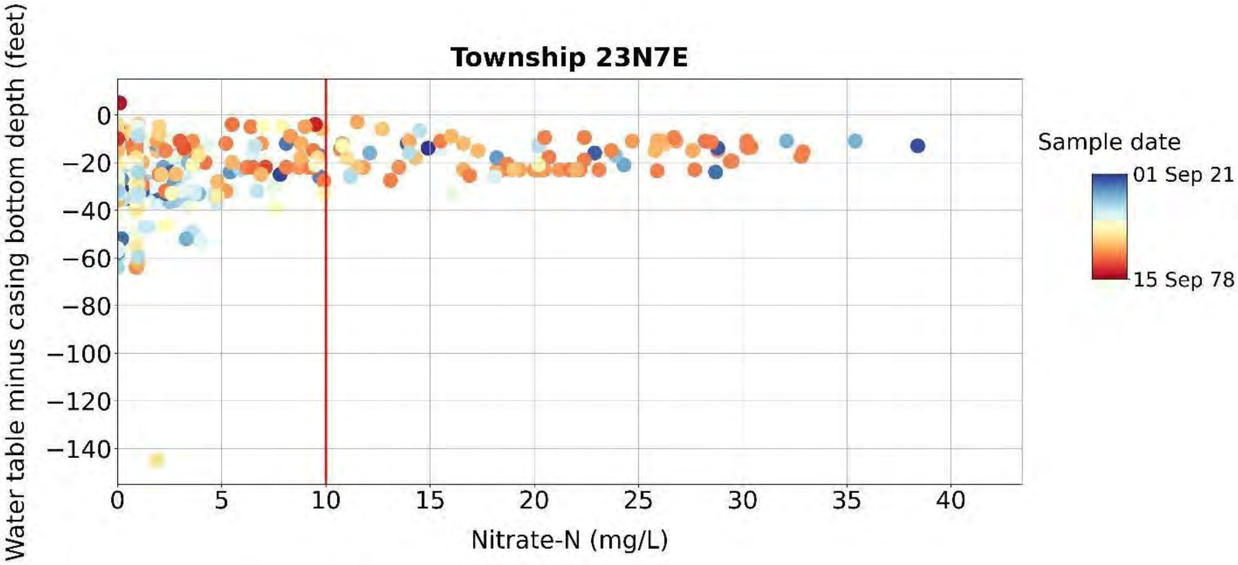
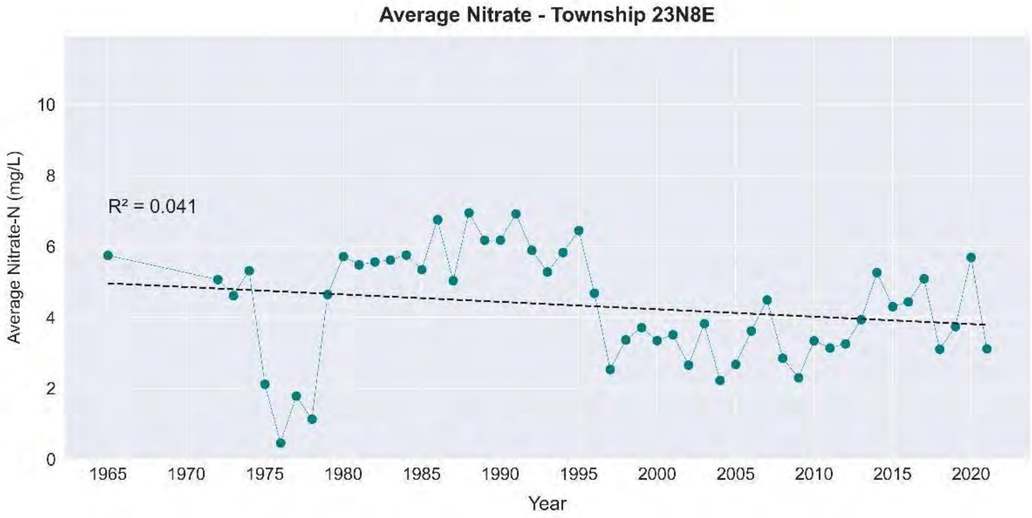


Figure C 99. Township 23N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



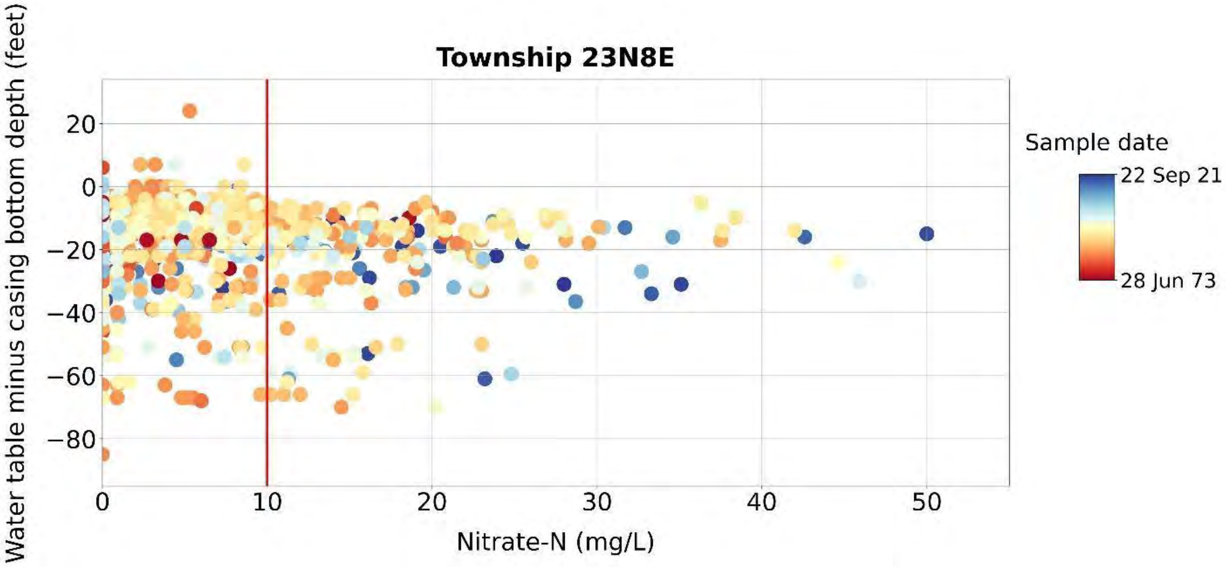


Figure C 100. Township 23N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

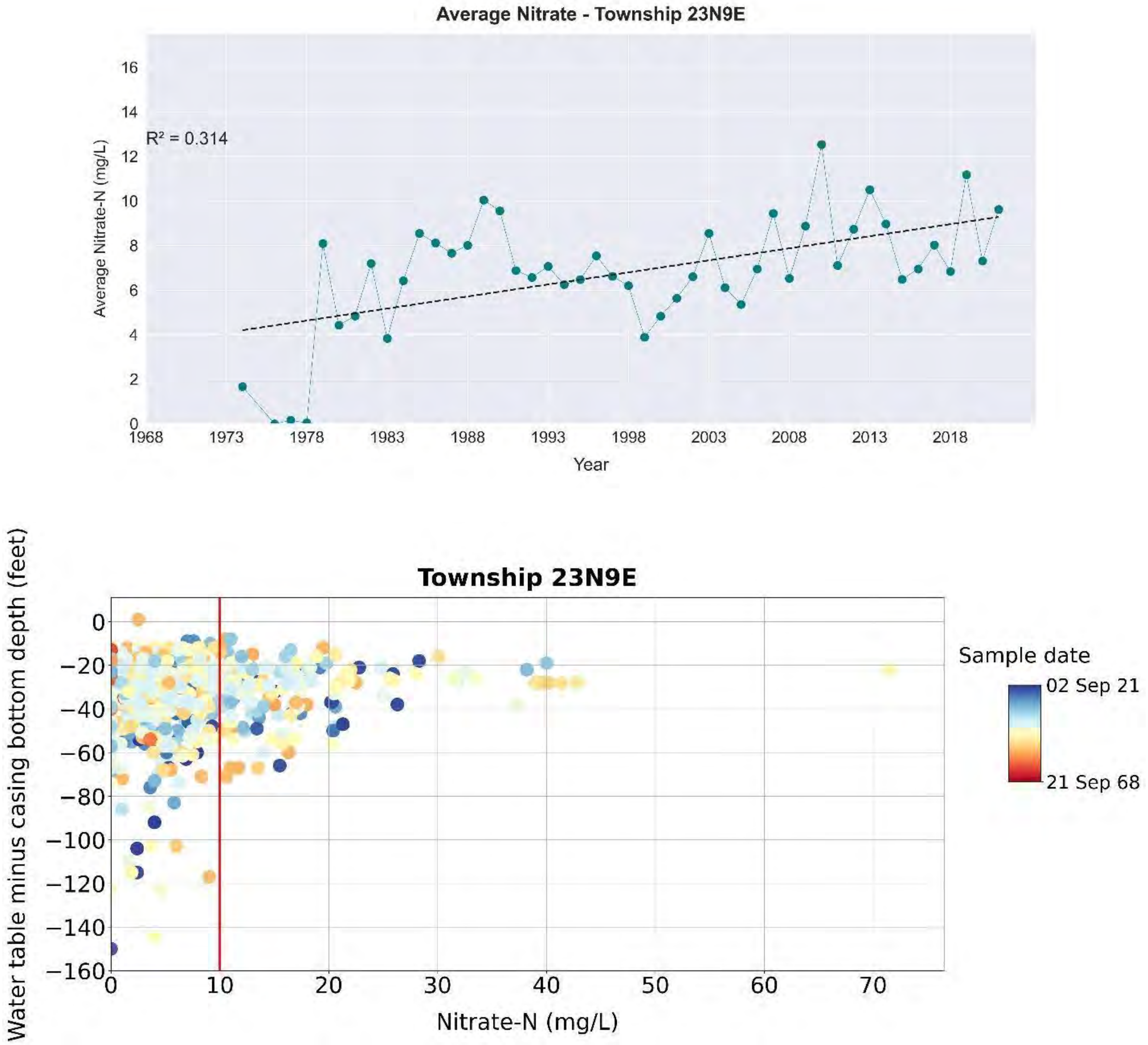
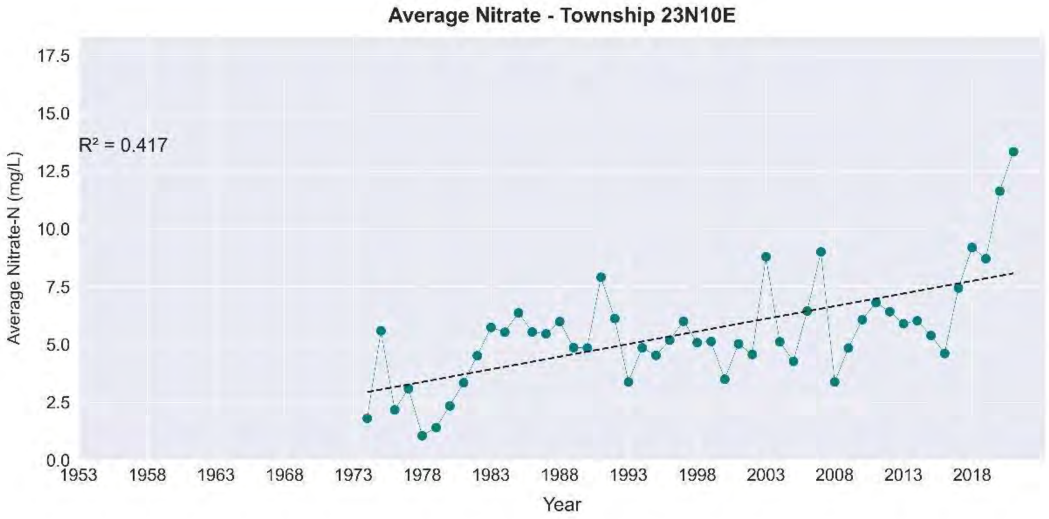


Figure C 101. Township 23N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



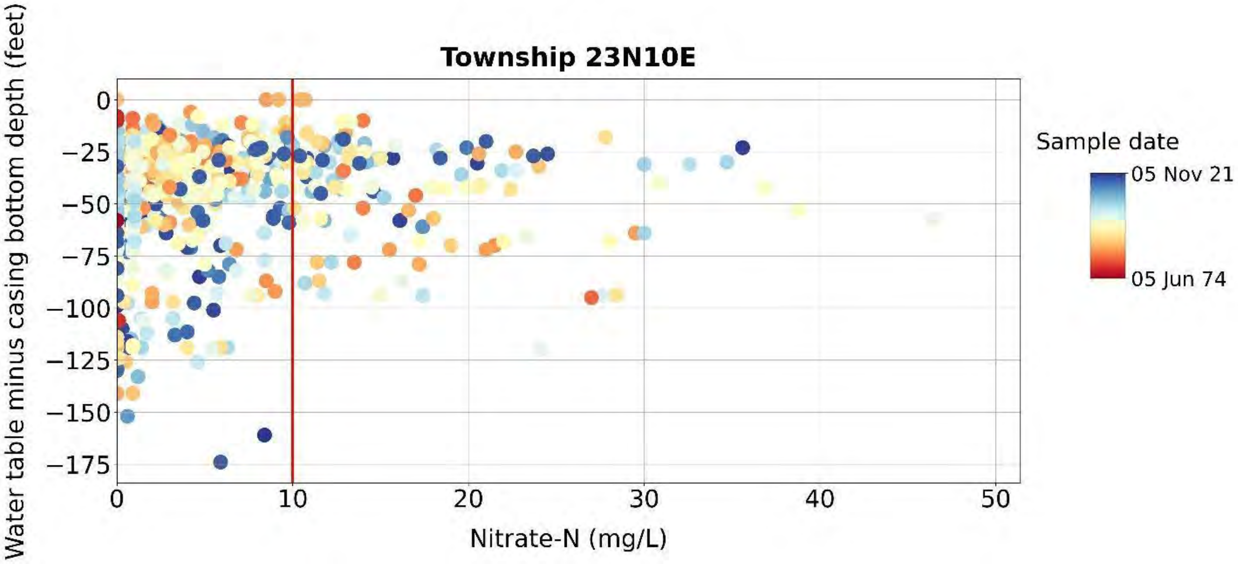
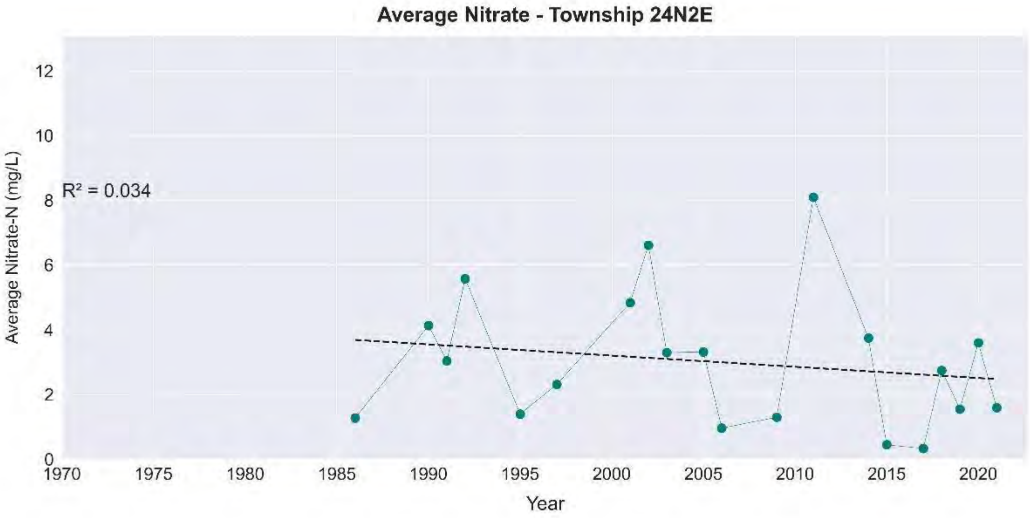


Figure C 102. Township 23N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



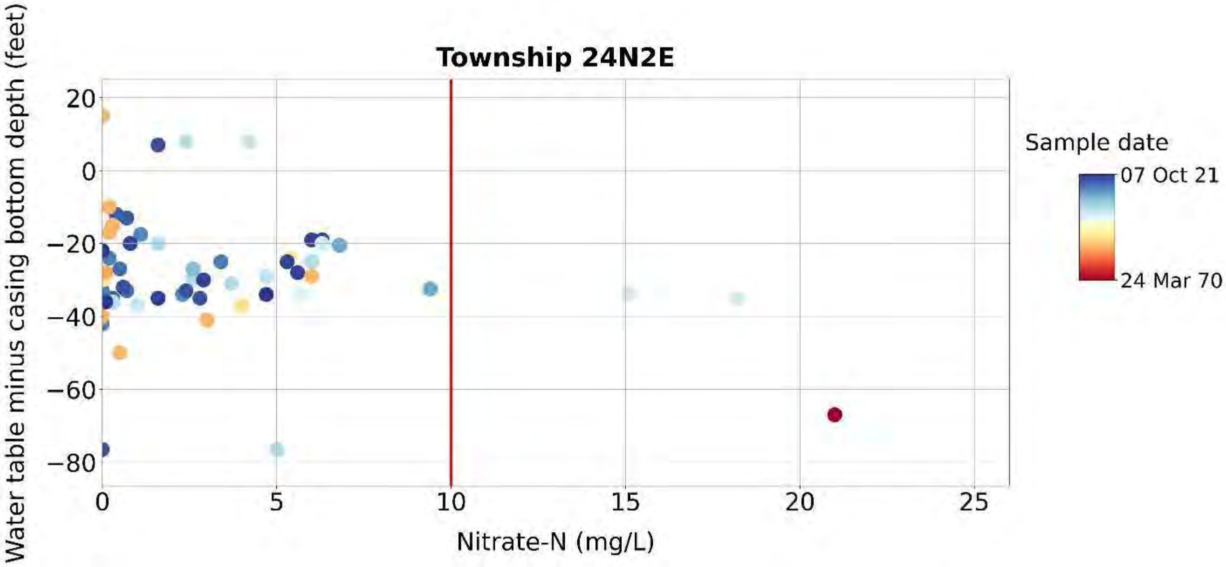
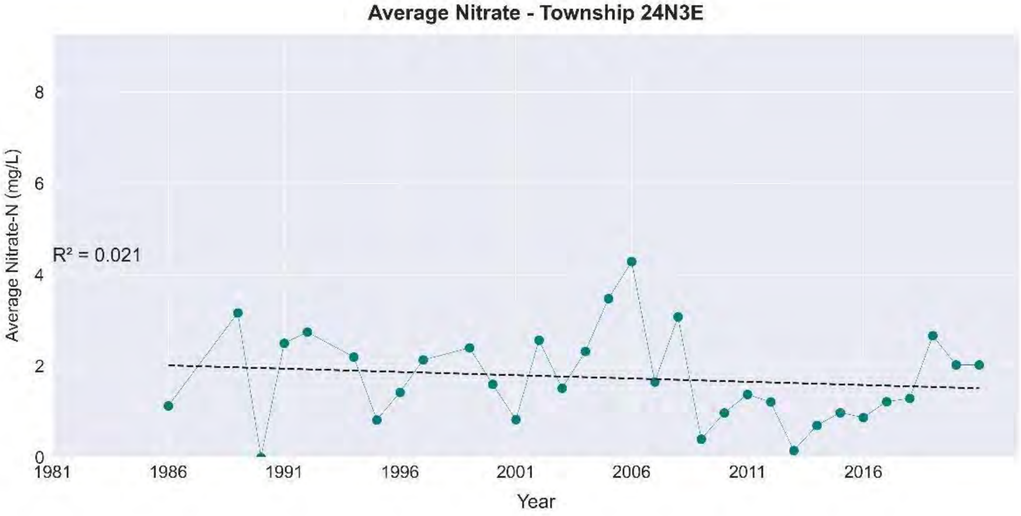


Figure C 103. Township 24N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



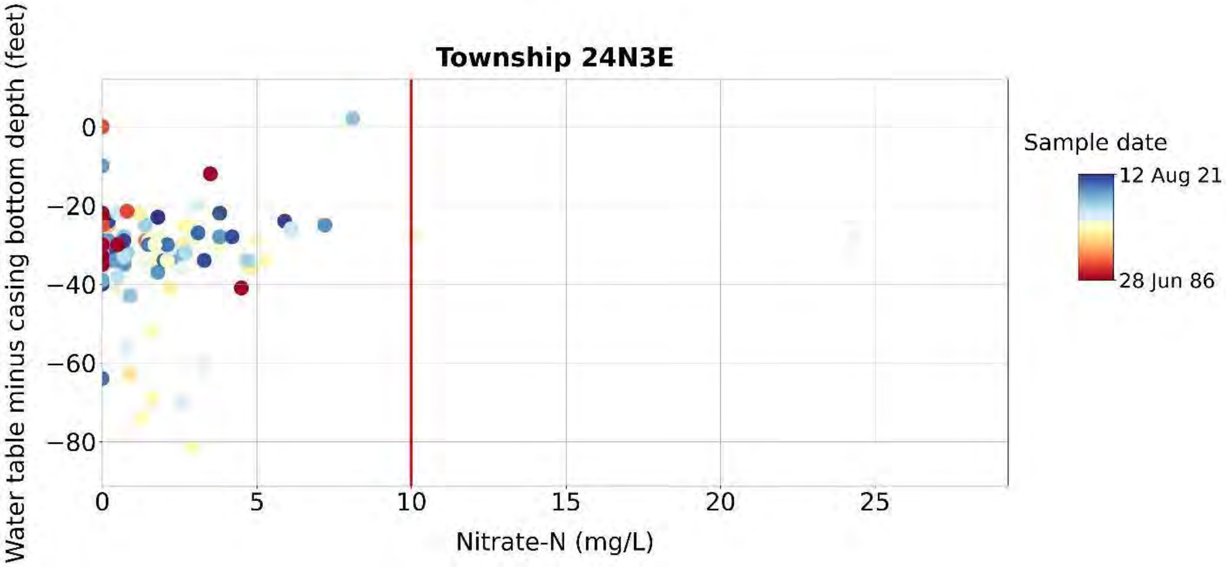
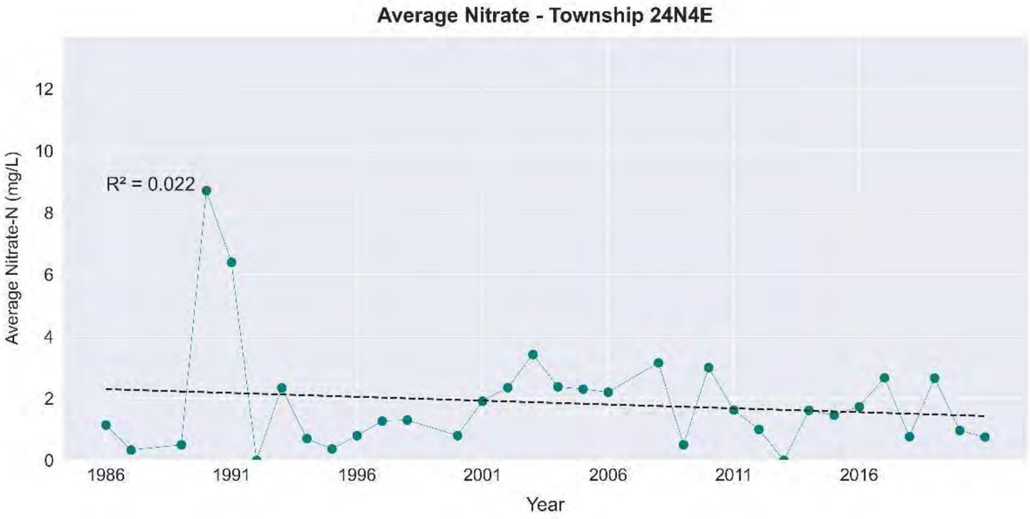


Figure C 104. Township 24N3E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



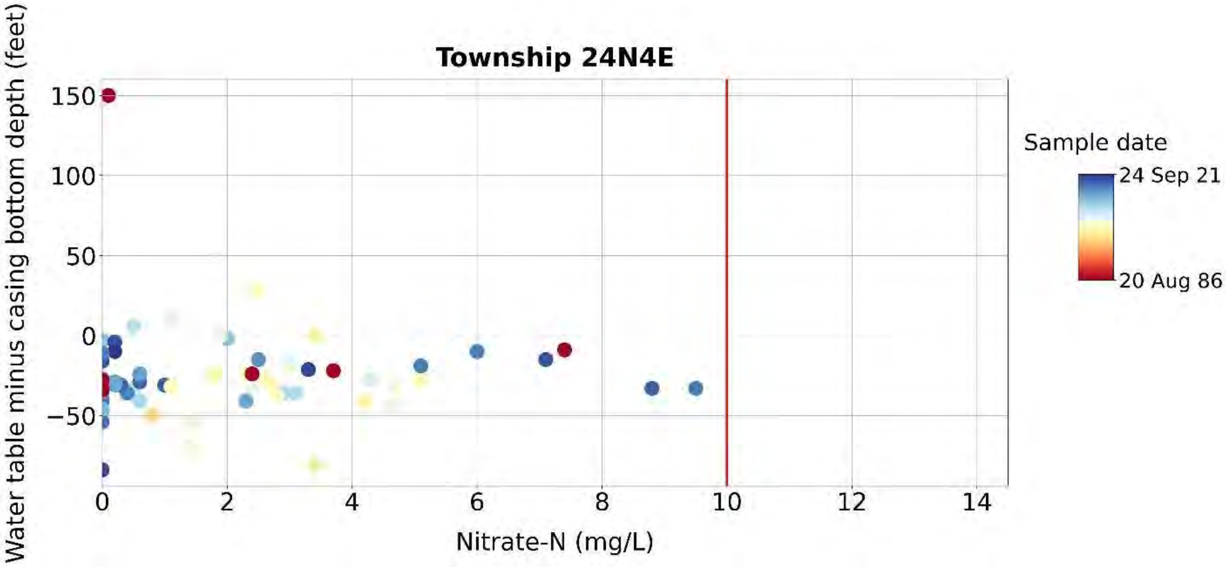
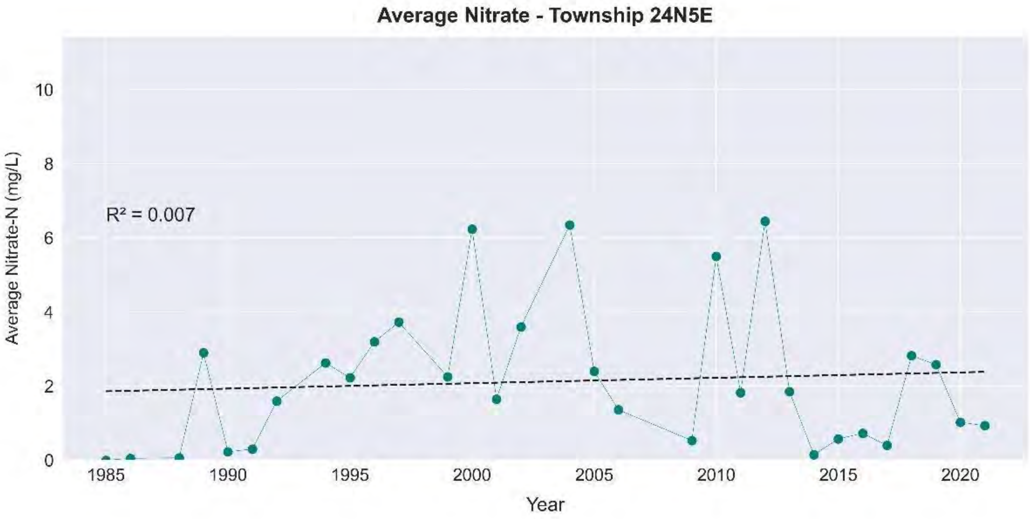


Figure C 105. Township 24N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



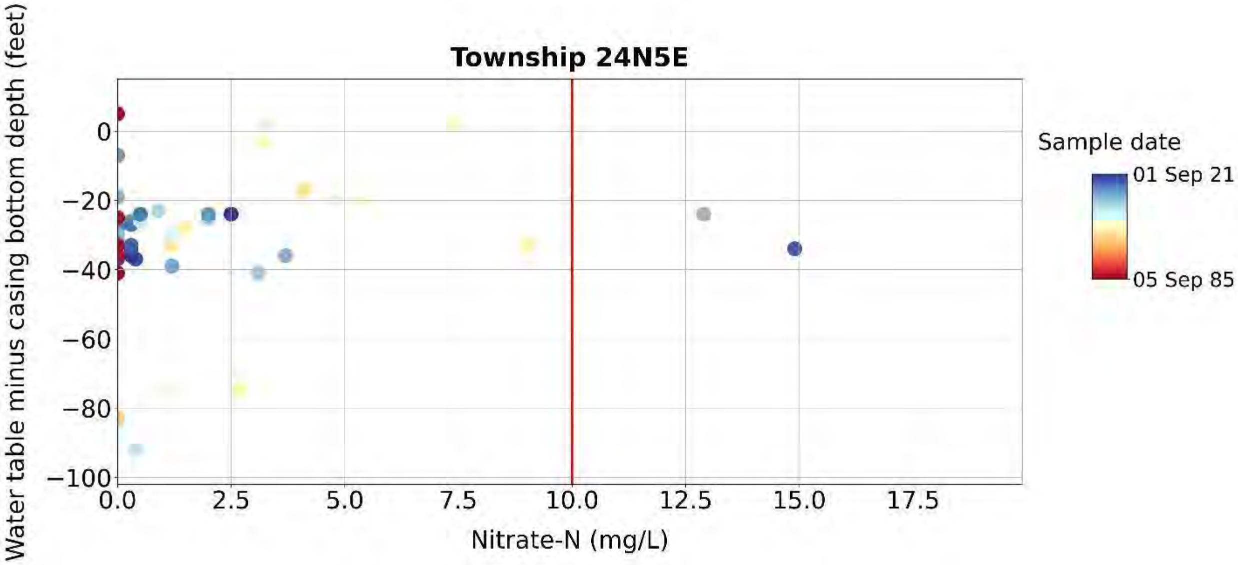
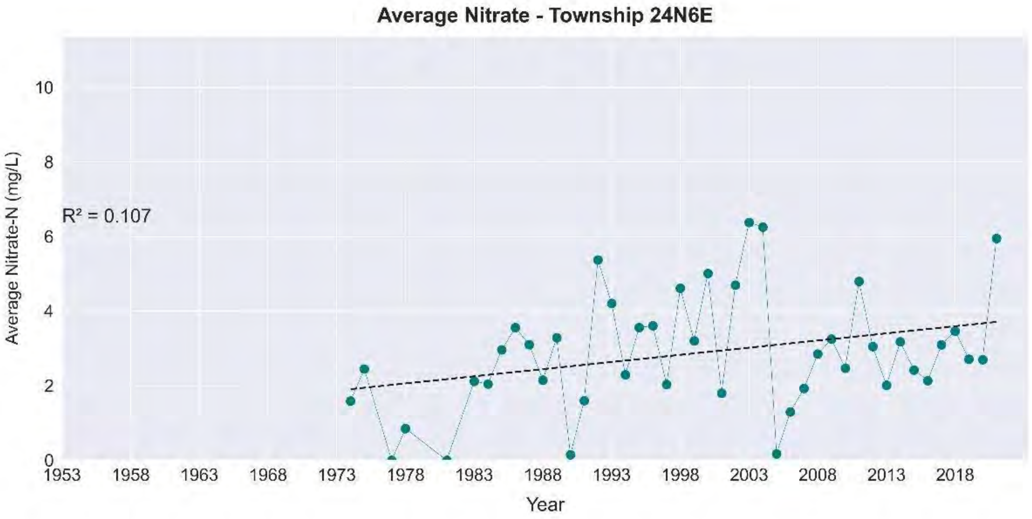


Figure C 106. Township 24N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



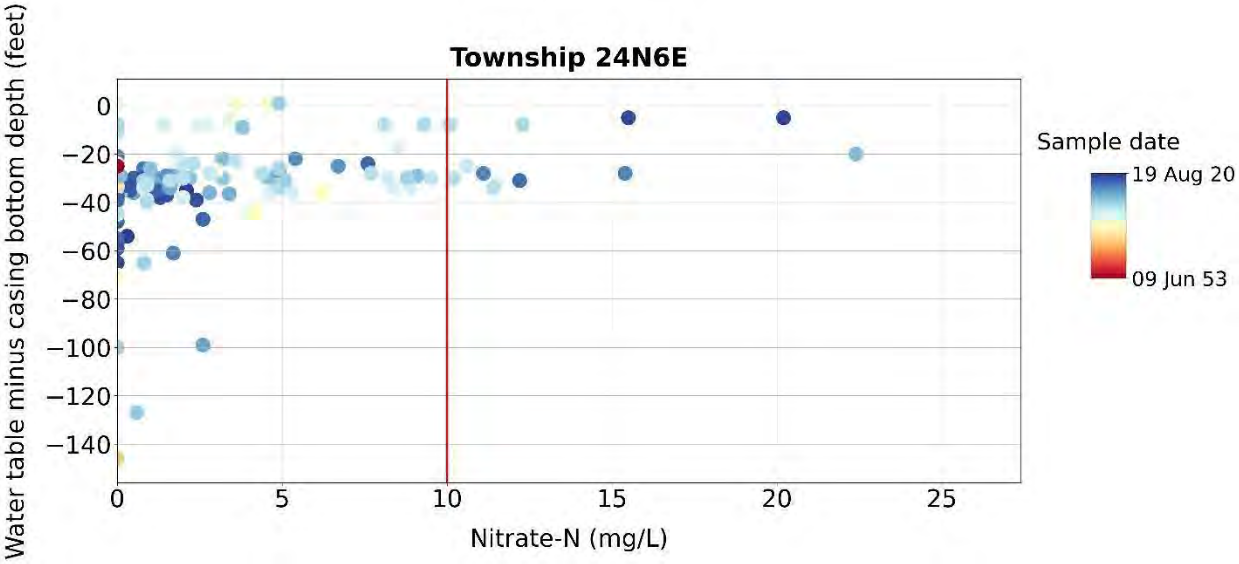
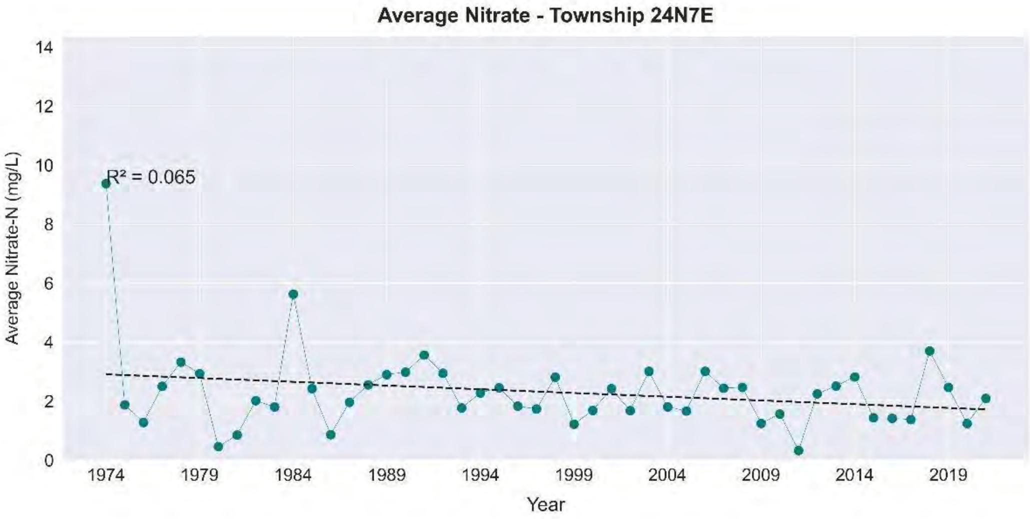


Figure C 107. Township 24N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



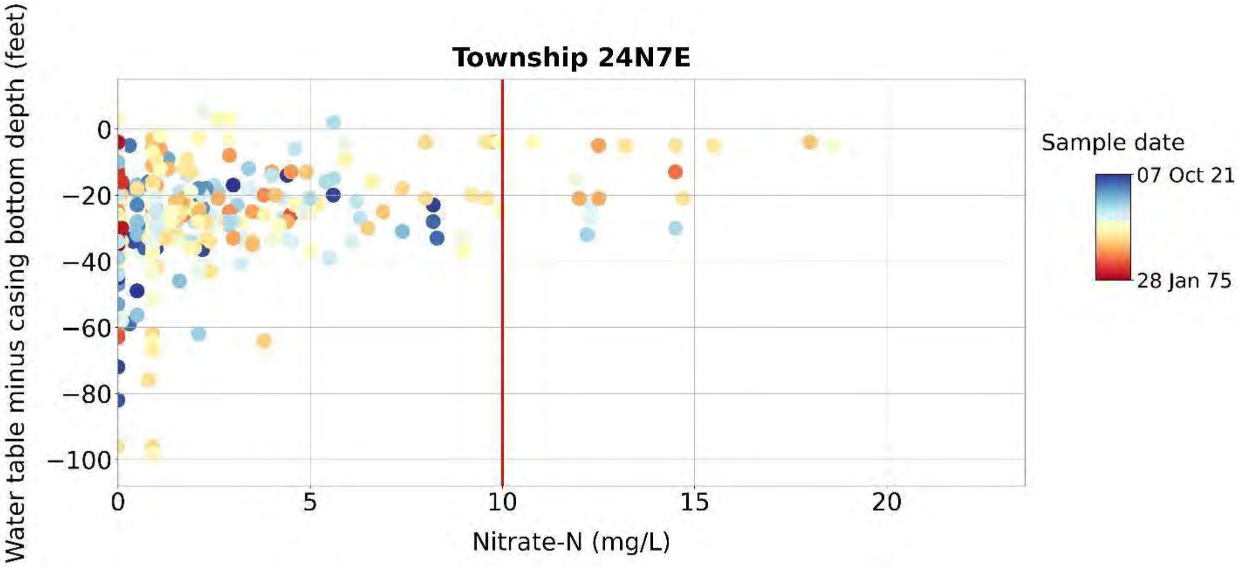
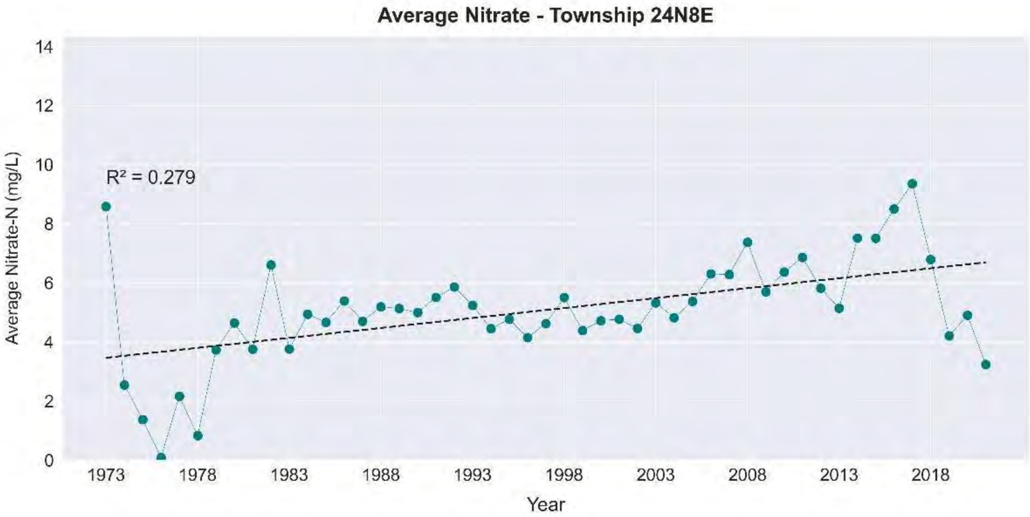


Figure C 108. Township 24N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



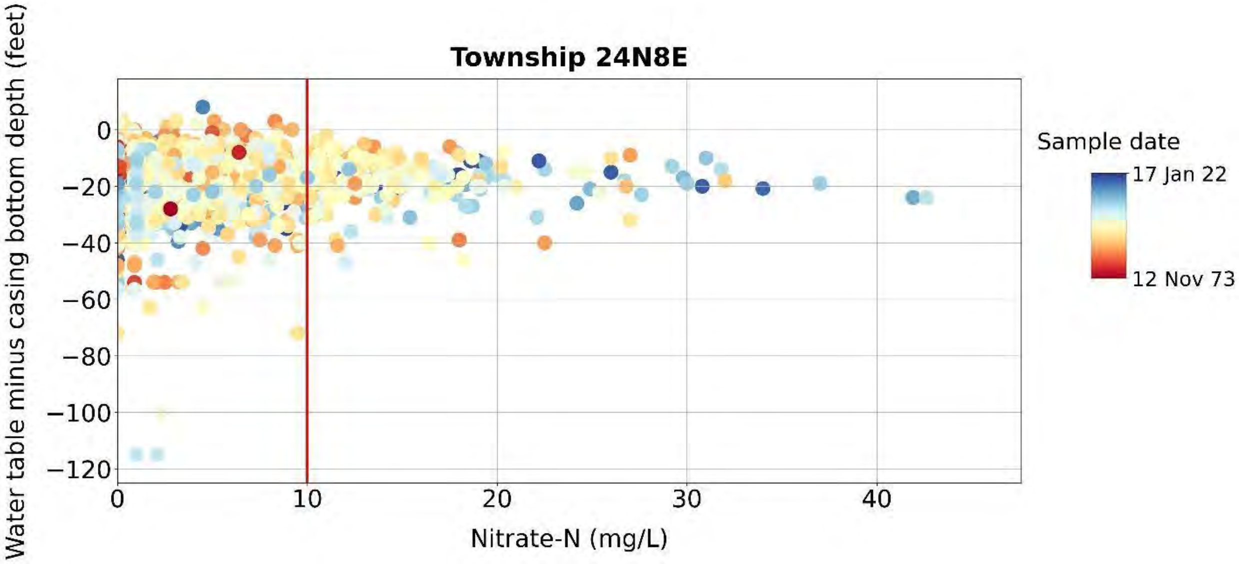


Figure C 109. Township 24N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

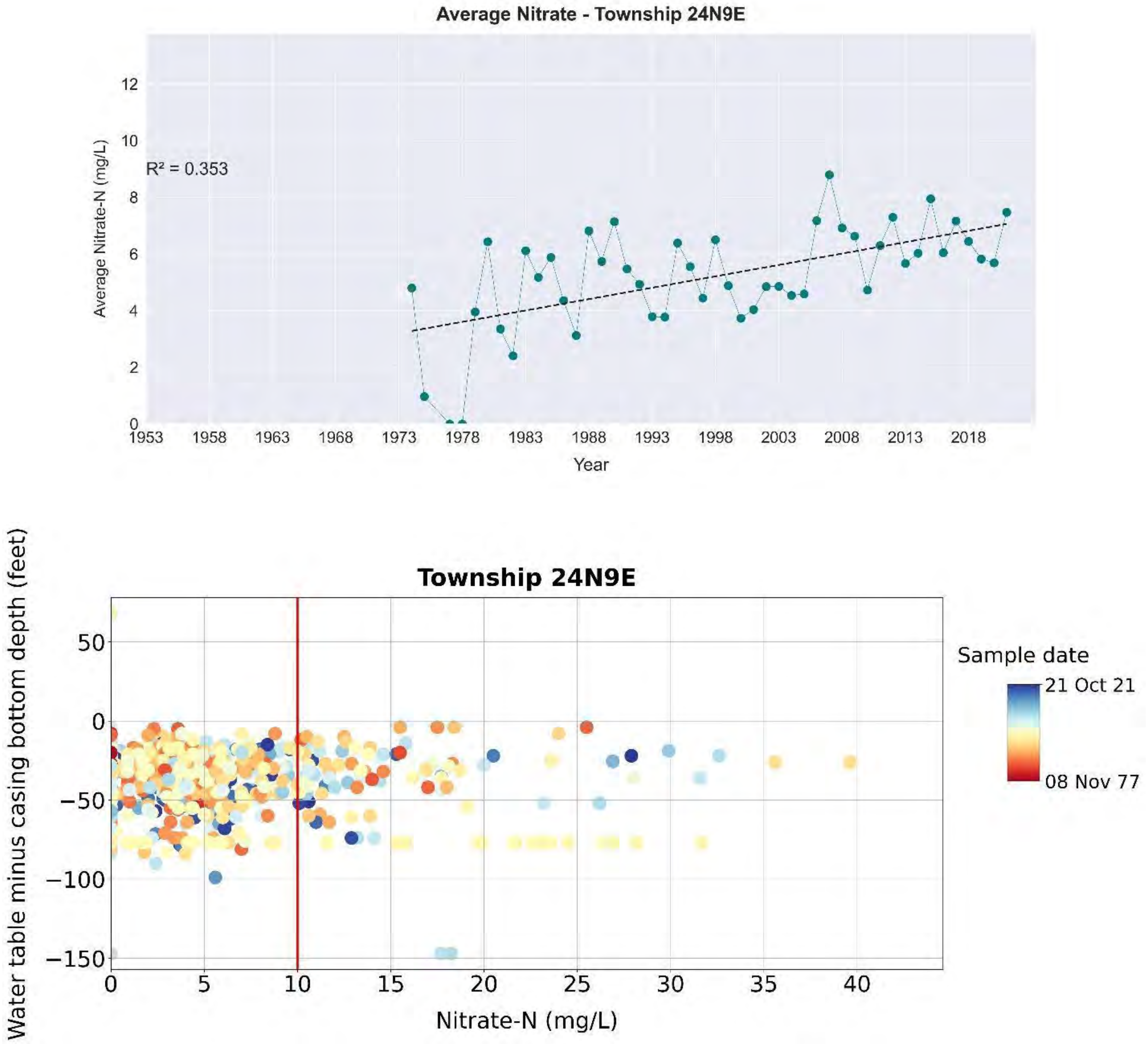
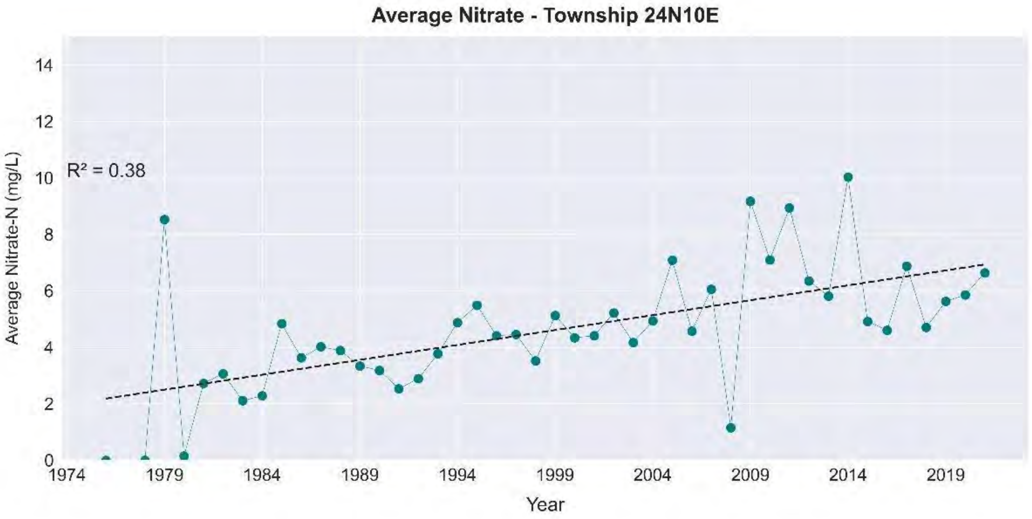


Figure C 110. Township 24N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



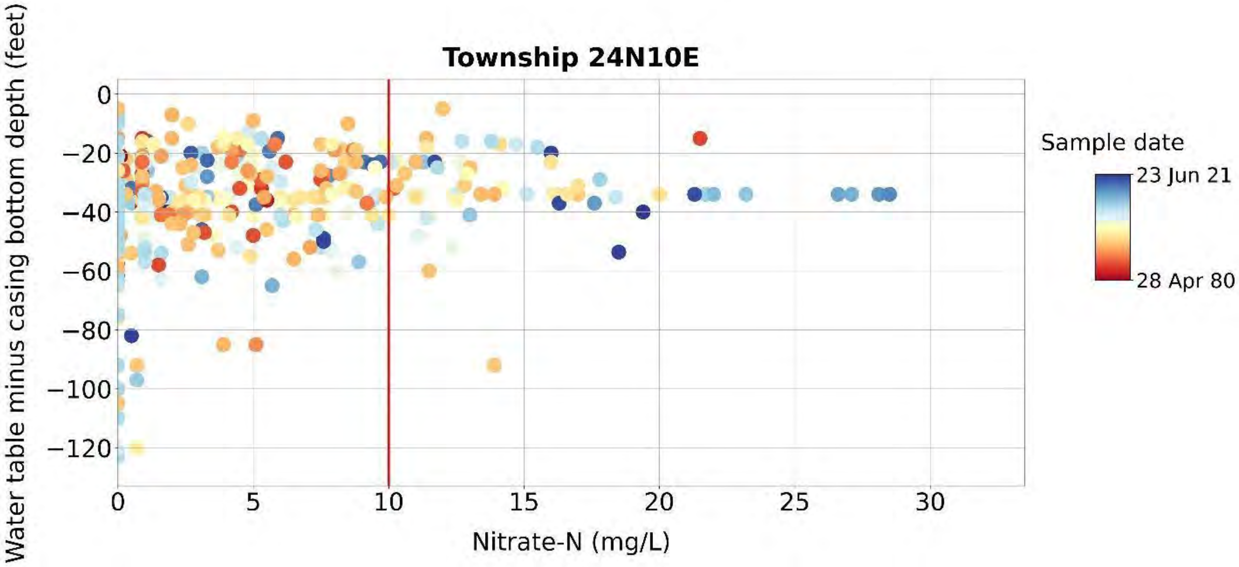
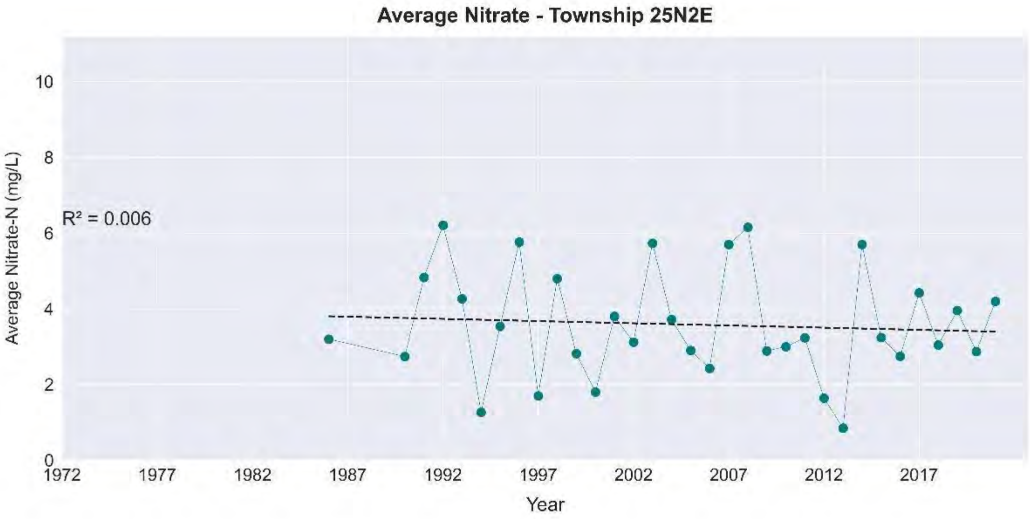


Figure C 111. Township 24N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



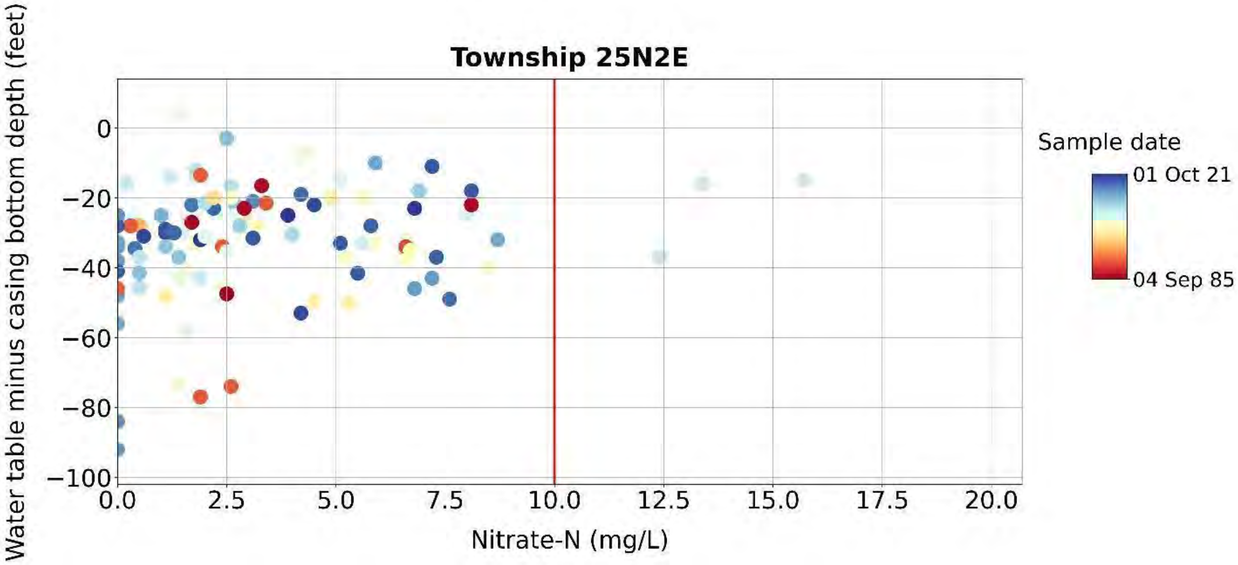
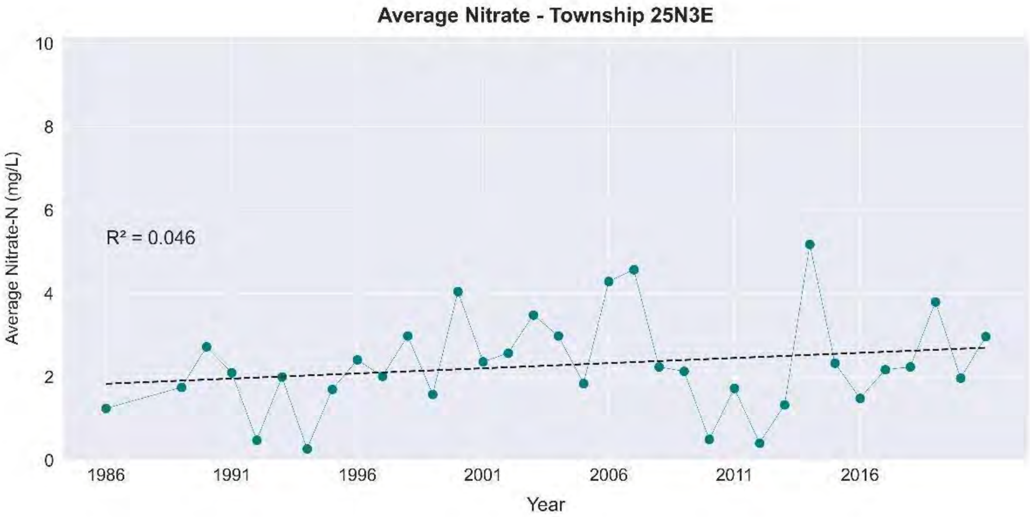
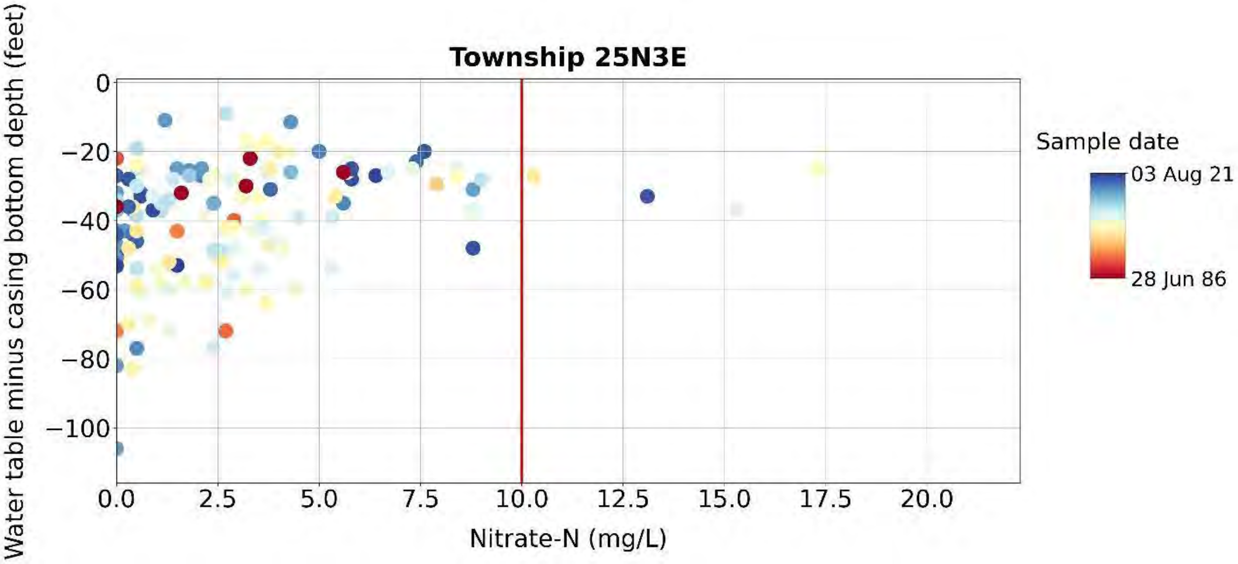


Figure C 112. Township 25N2E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.





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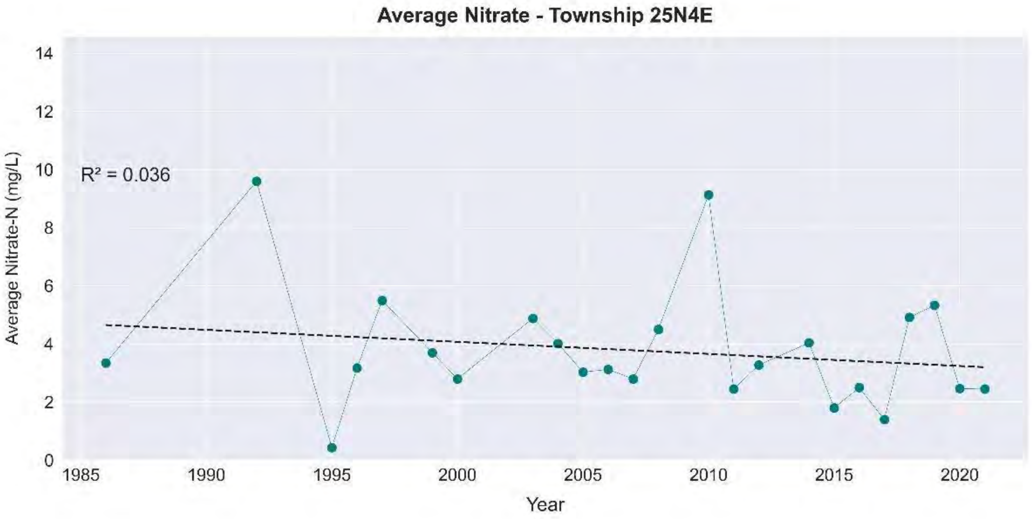


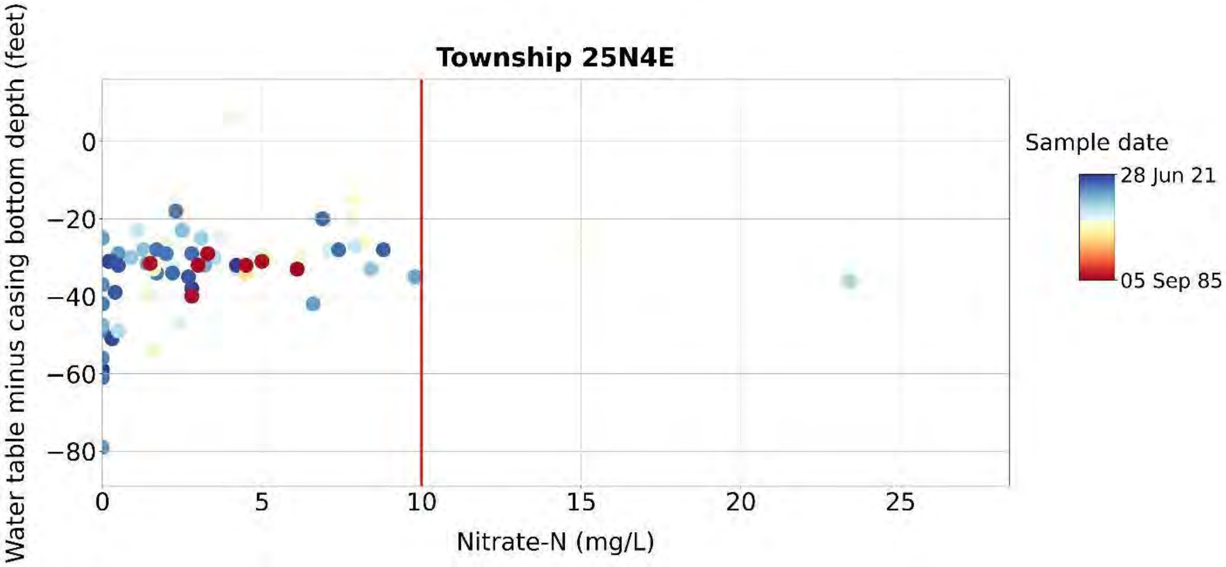
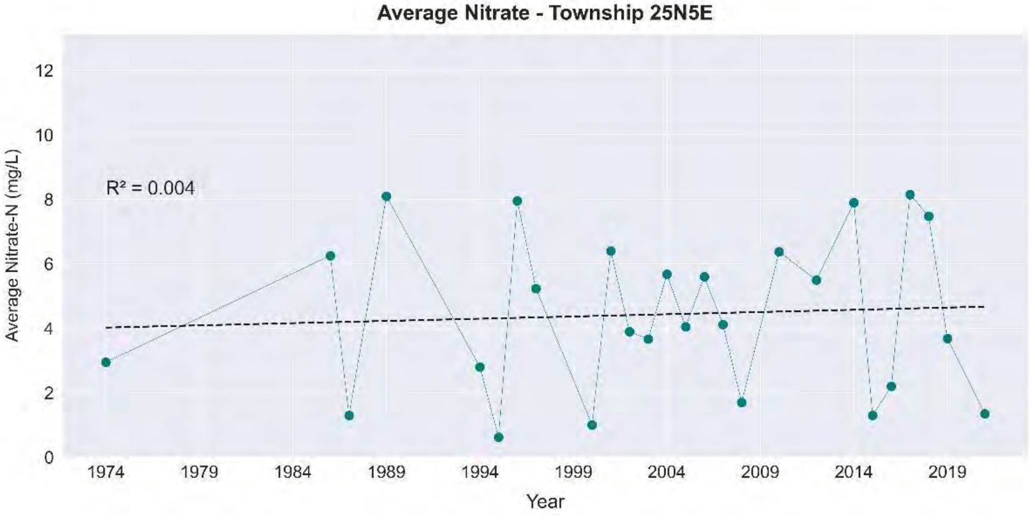


Figure C 114. Township 25N4E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



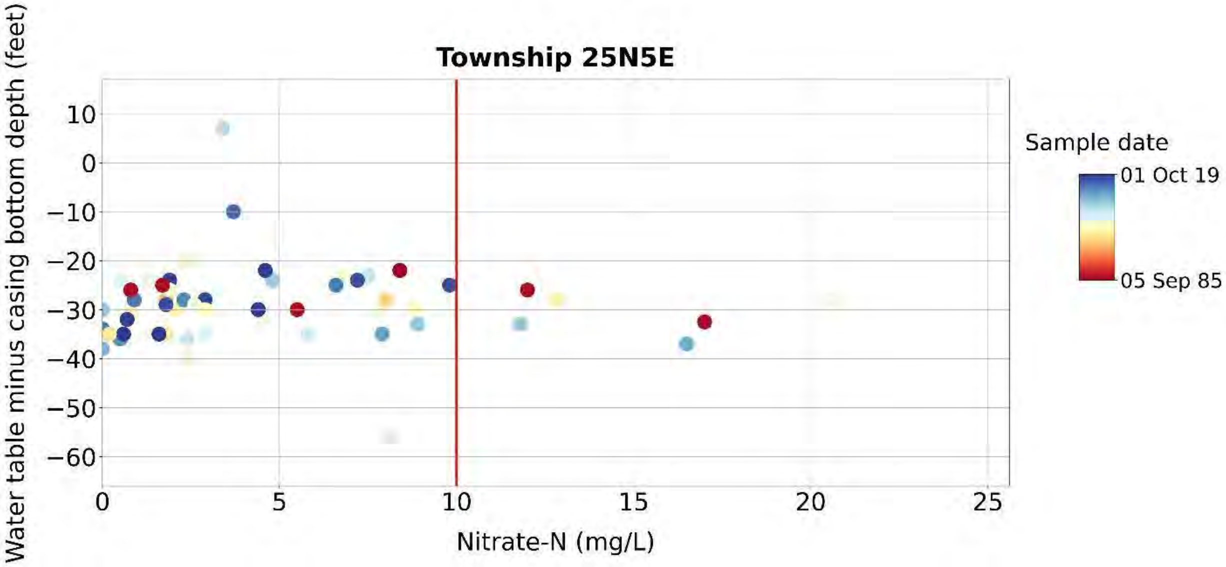
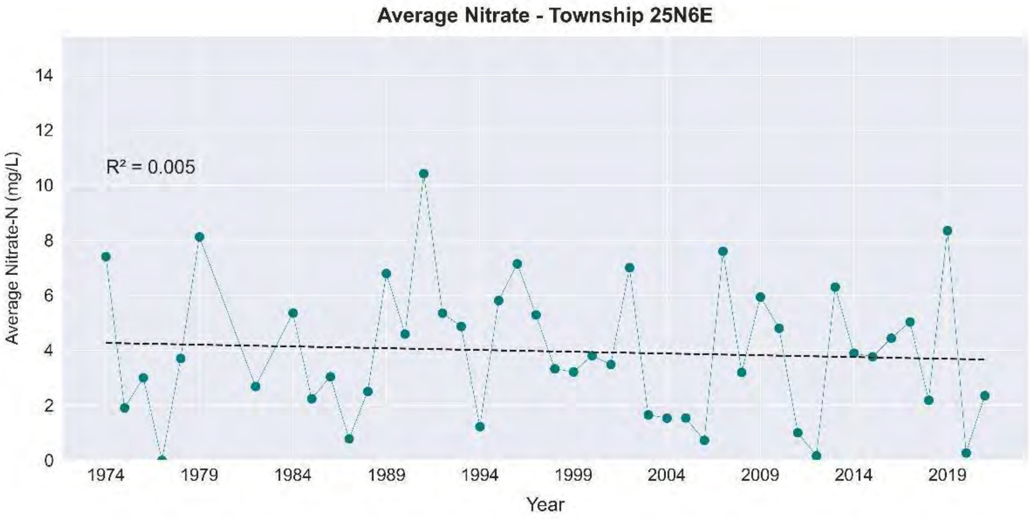


Figure C 115. Township 25N5E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



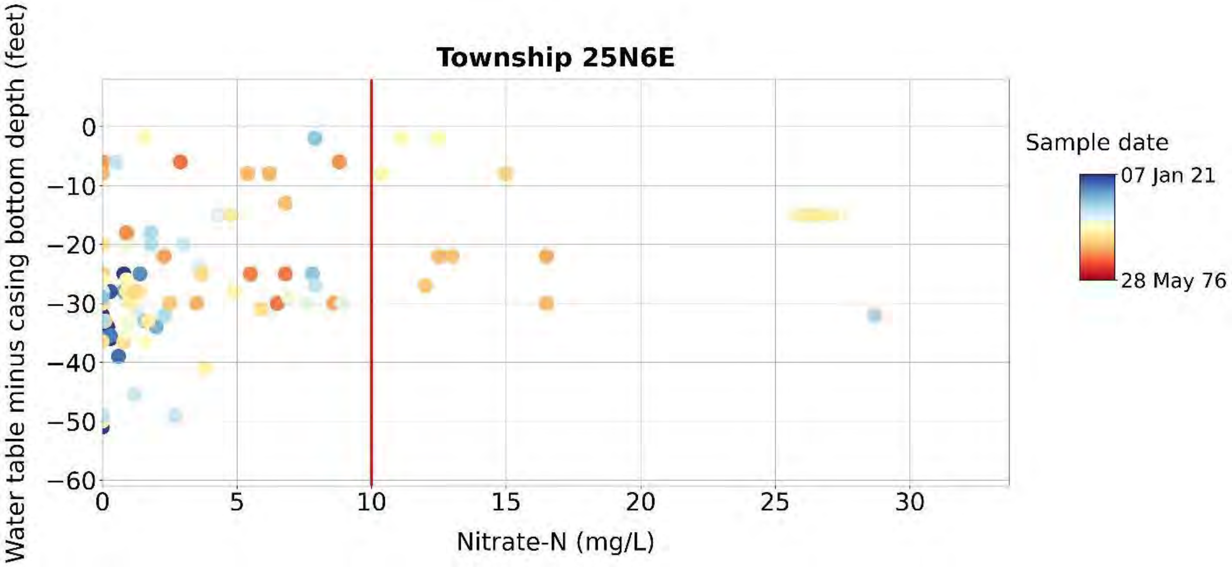
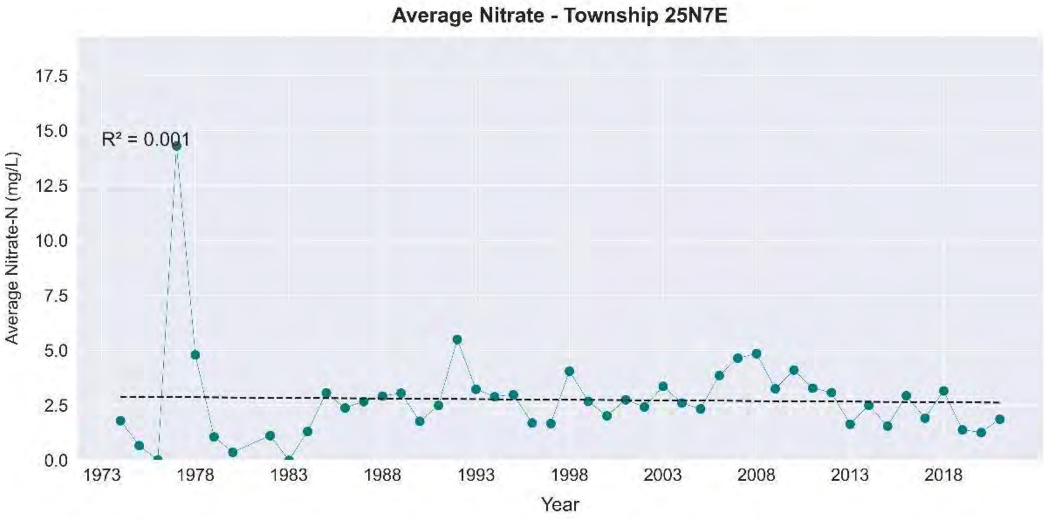


Figure C 116. Township 25N6E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



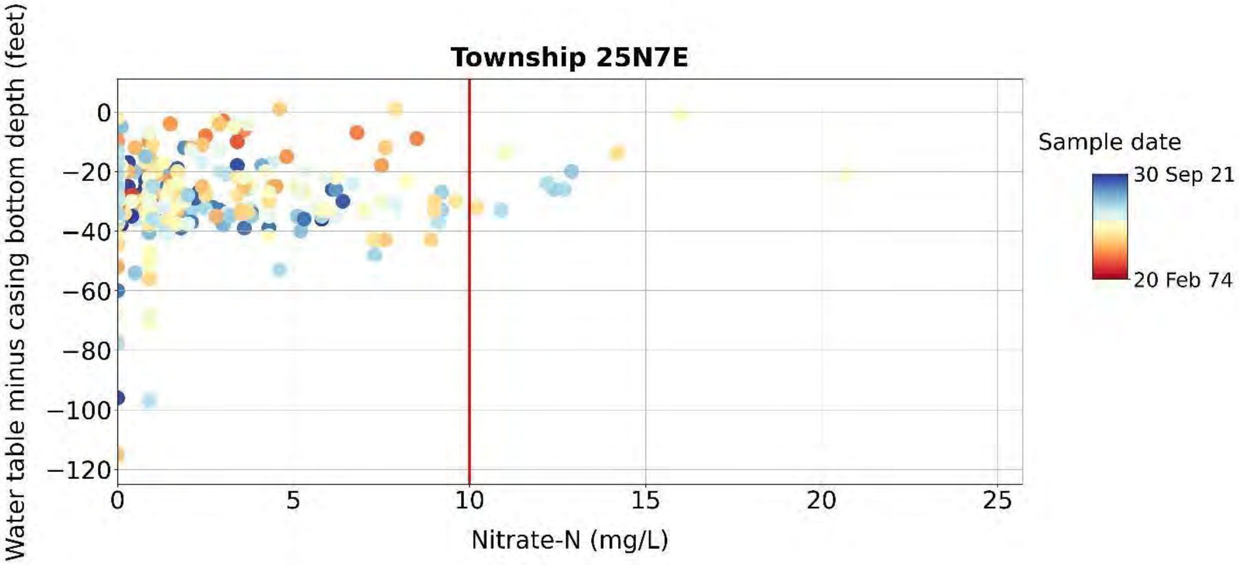
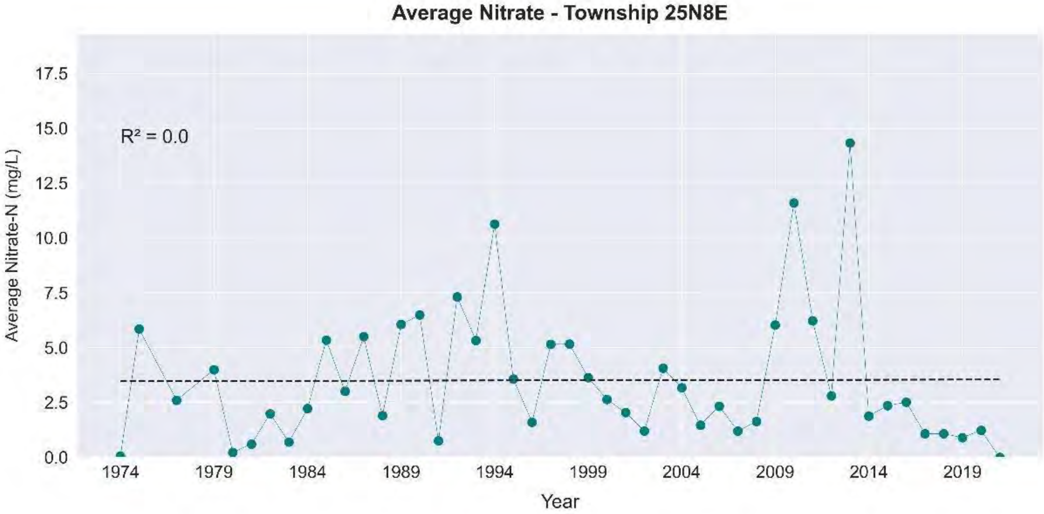


Figure C 117. Township 25N7E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



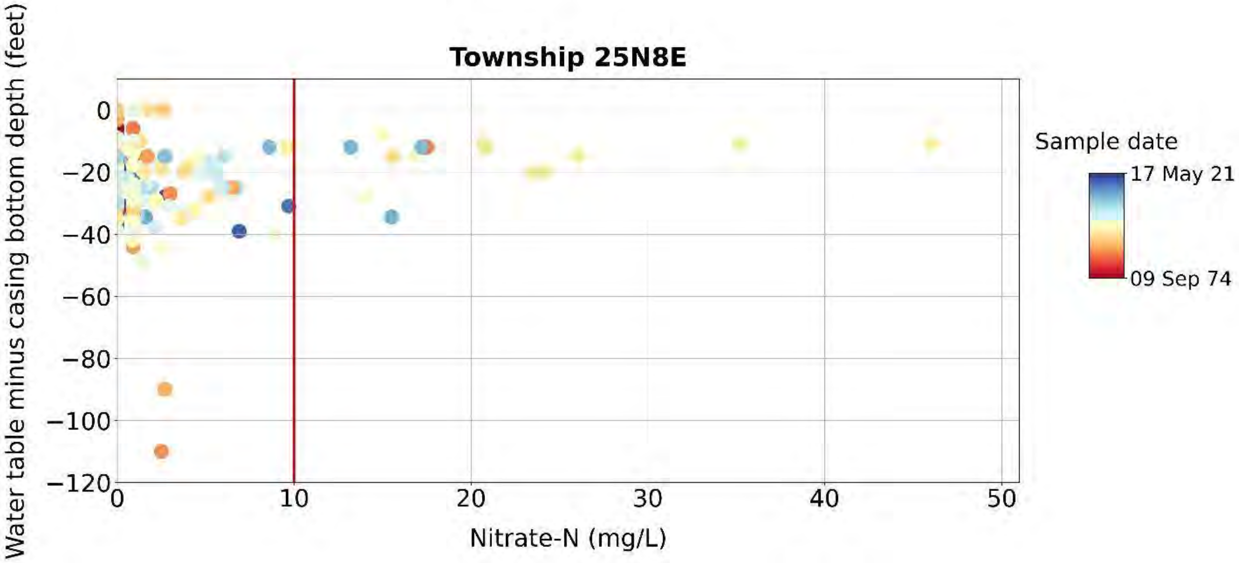
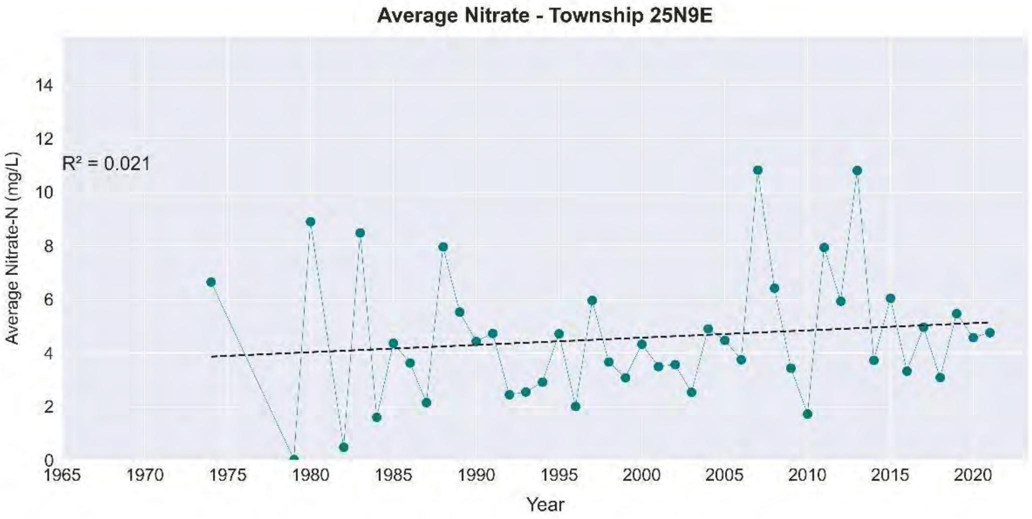


Figure C 118. Township 25N8E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



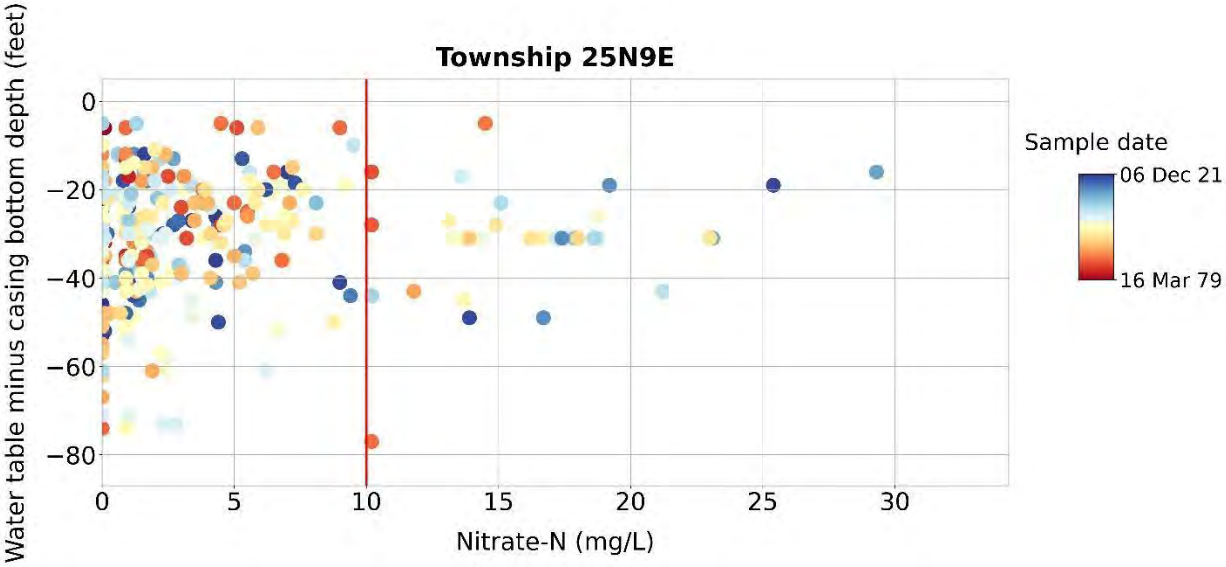
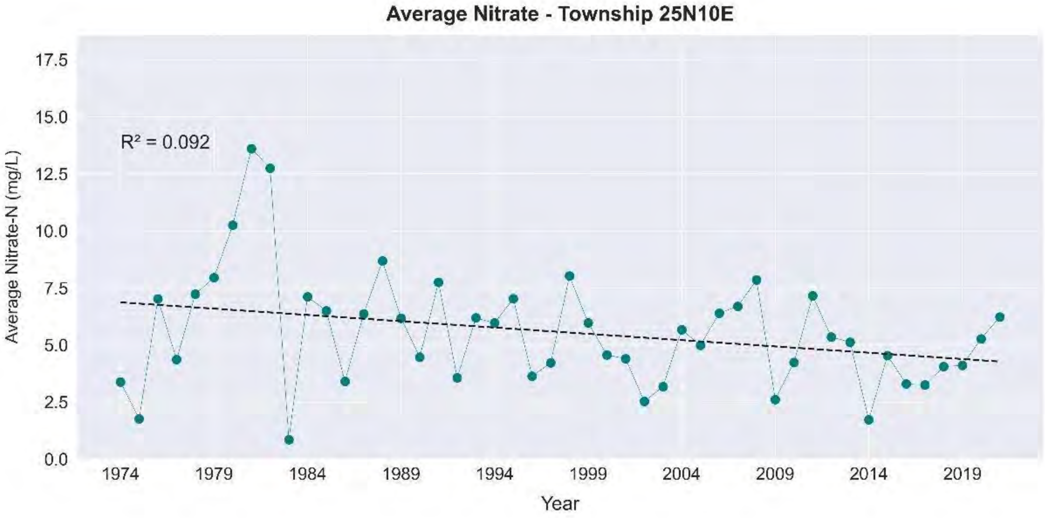


Figure C 119. Township 25N9E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.



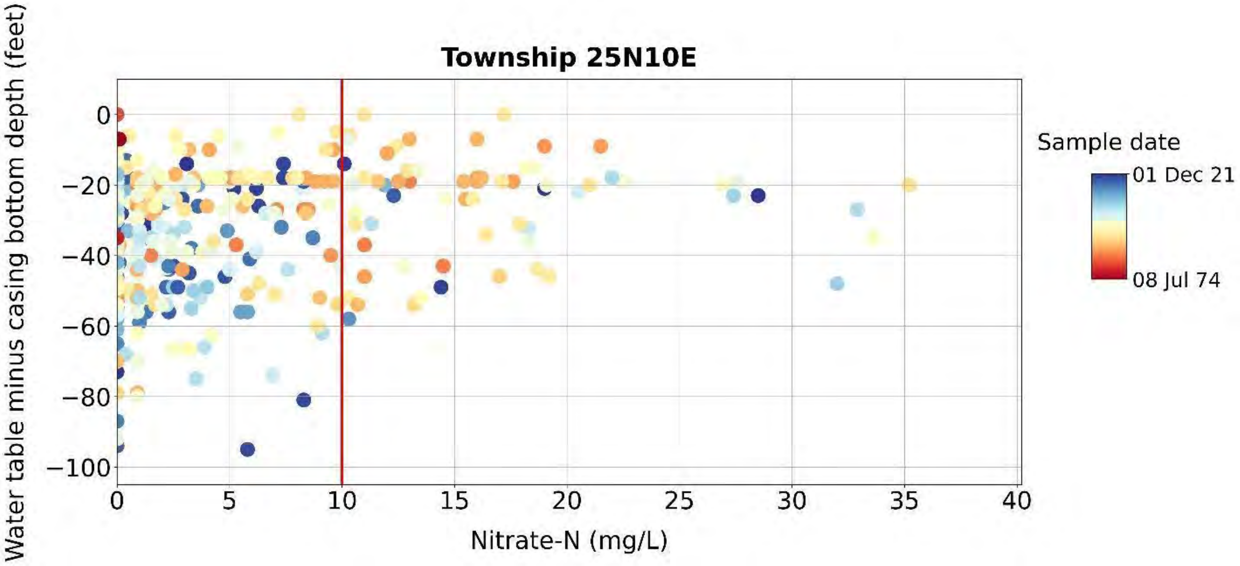


Figure C 120. Township 25N10E. (top) Yearly average nitrate concentration versus year of sampling. Dashed line indicated linear regression of the data. R^2 is the goodness of fit of the linear relationship. (bottom) Nitrate concentration versus the difference between the static water table and the casing depth. Color refers to the sampling date: the oldest measurements are marked with a red color, the most recent measurements are marked with a blue color.

Appendix D

Groundwater Quality Resource Guide

Focus on Nitrate and Neonicotinoids

Developed by: Mike Parsen, Jen McNelly, and Nathan Sandwick, 2023

Contents

Introduction

Purpose and Intended Audience(s)

The task of effectively managing groundwater requires ongoing attention and local capacity for strategic management. In any community with access to groundwater resources, people have compelling reasons to attend to its preservation and protection.

Managing this resource in a way that meets the needs of both present and future generations is a task that is easier said than done. To assist those working to meet such expectations, this guide links to relevant resources that may enhance ones understanding of the groundwater system, its history, hydrogeology and known pollutants; as well as ones understanding of what communities' capacity to manage the resource, relevant authorities and regulations, and modern public management approaches. While some of the resources apply statewide or beyond the state's borders, the focus was on the Central Sands Region of Wisconsin.

This resource guide represents one component of the overarching project: *Advancing the usability of nitrate and neonicotinoid findings to inform strategies for groundwater protection and improvement*, funded by the Wisconsin Department of Trade, Agriculture, and Consumer Protection (DATCP) in autumn 2021.

The guide is intended to serve as a companion compilation of currently available information regarding groundwater, nitrate, and neonicotinoids, which satisfy the stated objective of developing "a guidance of optional practices, policies, and regulations for residential, agricultural, industrial, and municipal uses."

While the proposal ambitiously contemplated a generational update to Born, Yanggen, and Zaporozec's 1987 publication: "A guide to groundwater quality planning and management for local governments", we decided to instead assemble a collection of online resources, which guide readers directly to the scientists, experts, agencies, groups, or relevant authority on a particular topic. We also sought to introduce a variety of perspectives and approaches to consider when addressing groundwater contamination by nitrate and neonicotinoids. In this way, rather than attempting to reproduce, rephase, or synthesize resources, this guide seeks to highlight the work of others and encourage direct communication and collaboration between those engaged in finding solutions to improving groundwater quality. Furthermore, it is our hope that this guide can serve as a living document that might grow to include additional voices, viewpoints, emerging research findings, and other relevant resources.

Navigating this Guidance

This guide is organized into 10 chapters and intended as a framework for readers to explore different topics related to groundwater, nitrate, and neonicotinoids. The first four chapters introduce baseline information about these topics while subsequent chapters examine different issues, challenges, and potential directions for future action. Depending on readers' familiarity with the groundwater, nitrate, and neonicotinoids, we encourage users of this guide to jump between chapters in search of the information they seek.

This is a list of chapters contained in this guide:

- Basics of Hydrogeology and Nitrate and Neonicotinoids in Groundwater
- Historical Overview of the Central Sands Region, Land-Use, and Fertilizer Application
- The Situation Today – Why We Care about Nitrate and Neonicotinoids in Groundwater
- Regulatory History and Current Framework
- Critique of Policies, Programs, and Market Mechanisms: Strengths and Limitations
- Alternative Approaches in Other States
- Recommendations for Action
- What Can Communities Do?
- Community Capacity for Effective Groundwater Management
- Data Sources and Data-Visualization Tools

Acknowledgements

Authors would like to thank Nancy Turyk, Carla Romano, Ken Bradbury, and Lynn Markham for their contributions and feedback in development of this guide. Authors would also like to thank Kevin Masarik (Center for Watershed Science and Education, UW-Stevens Point) and John Exo (Division of Extension, UW-Madison) for their feedback and comments during the review stages of this guide.

Basics of Hydrogeology and Nitrate and Neonicotinoids in Groundwater

Introduction

This section presents background information about the geology and groundwater resources of Wisconsin, with an emphasis on the Central Sands Region, and provides an overview of hydrogeologic fundamentals. This section also serves as an introduction to nitrate and neonicotinoids and how these substances cycle through the environment and groundwater. The following presentations, reports, and resources have been selected due to their relevance to these topics.

General Overview of Geology and Groundwater Resources of the Central Sands Region

Central Sands Lakes Study: Annotated Bibliography

Webpage: *https://wgnhs.wisc.edu/catalog/publication/000960/resource/wofr201804*

This publication by the Wisconsin Geological and Natural History Survey (WGNHS), UW-Madison, was prepared as part of the Central Sands Lakes Study, with an emphasis on water quantity concerns, but serves as a resource for better understanding available research related to the hydrogeologic setting of the Central Sands Region. Resources are subdivided by county, making it easy to search for and find relevant content.

Irrigable Land Inventory - Phase I Groundwater Related Information

Webpage: *https://wgnhs.wisc.edu/catalog/publication/000467*

This publication by the Wisconsin Geological and Natural History Survey (WGNHS), UW-Madison, contains hydrogeologic information for counties within the Central Sands Region Wisconsin. It includes water-table elevation maps for Adams, Jackson, Juneau, Marathon, Marquette, Monroe, Portage, Waupaca, Waushara, and Wood counties, a regional aquifer potential map covering all counties, a page-size aquifer-potential map for each county, and a 13-page report.

Groundwater Contamination Susceptibility in Wisconsin

Webpage: *https://wgnhs.wisc.edu/catalog/publication/000420*

This publication by the Wisconsin Geological and Natural History Survey (WGNHS), UW-Madison, maps the susceptibility of different areas of Wisconsin to groundwater contamination. The susceptibility rating incorporates information about the type of bedrock, depth to bedrock, depth to water table, soil characteristics, and characteristics of surficial deposits.

Bedrock Geology of Wisconsin

Webpage: *https://wgnhs.wisc.edu/catalog/publication/000390*

This map, published by the Wisconsin Geological and Natural History Survey (WGNHS), UW-Madison, details the bedrock geology of Wisconsin.

Wisconsin Aquifers

Webpage: *https://wgnhs.wisc.edu/water-environment/wisconsin-aquifers/*

This webpage, published by the Wisconsin Geological and Natural History Survey (WGNHS), UW-Madison, describes the aquifers of Wisconsin and provides a framework for understanding what aquifers are and where different aquifers are located across the state.

Wisconsin Hydrogeology - Video

Webpage: https://go.wisc.edu/e3ondd

Presentation by Ken Bradbury, former State Geologist and Emeritus Professor at the WGNHS (UW-Madison), on the hydrogeology of Wisconsin. This talk provides an excellent overview of Wisconsin's aquifers and provides context for understanding groundwater-related concerns around the state.

General Overview of Hydrogeology and Nitrate in Groundwater

Groundwater and Nitrate Presentation

Webpage: *https://www.pbs.org/video/university-place-nitrate-wisconsins-groundwater/*

In this presentation that aired on University Place, a local public television program presented by PBS Wisconsin in 2016, Kevin Masarik (Groundwater Education Specialist, Center for Watershed Science and Education, UW-Stevens Point) covers groundwater basics, explains how nitrate enters and moves through the groundwater system, and outlines challenges in preventing and addressing nitrate contamination to groundwater and drinking water resources across Wisconsin and beyond.

Visualization of Groundwater Flow, Highlighting Connection between Aquifers, Wells, Lakes, and Rivers

Webpage: *https://www.youtube.com/watch?v=Xegyj2cxgkY*

In this video, Kevin Masarik (Groundwater Education Specialist, Center for Watershed Science and Education, UW-Stevens Point) uses a sand-tank model to physically demonstrate how groundwater moves through aquifers and is often directly connected to surface water features.

Nitrate

Nitrate in Groundwater - Factors that Determine Nitrate Groundwater Quality

Webpage:
https://widnr.widen.net/s/qht87nsqwh/data_on_nitrate_in_groundwater_and_factors_that_determine_groundwater_quality

In this talk to the Wisconsin DNR's NR151 Technical Advisory Committee on 2/27/2020, Kevin Masarik (Groundwater Education Specialist, Center for Watershed Science and Education, UW-Stevens Point) provided an overview of data on nitrate in groundwater and described factors that determine groundwater quality

Nitrate in Drinking Water Fact Sheet – Wisconsin DNR, 2017

Webpage: *https://dnr.wi.gov/files/PDF/pubs/DG/DG0001.pdf*

This Wisconsin DNR factsheet provides a brief overview of what nitrate is, how it enters groundwater, and describes the health risks of consuming water with high concentrations of nitrate. Additional resources are listed for well owners and those seeking more information about nitrate contamination of drinking water.

Nitrate in Private Wells, Wisconsin Department of Health Services (DHS) Webpage

Webpage: *https://www.dhs.wisconsin.gov/water/nitrate.htm*

This Wisconsin DHS webpage provides an overview of the health impacts of nitrate contamination in groundwater from birth defects, thyroid disease, and colon cancer. A variety of resources are included for addressing nitrate in private wells.

Nitrate in Groundwater: A Continuing Issue for Wisconsin Citizens, Wisconsin DNR Publication (1999)

Resource: ***Appendix A - Nitrate in Groundwater***

While over 20 years old, this publication summarizes available information regarding nitrate in groundwater with a focus on the extent of nitrate contamination, costs related to nitrate pollution, and the sources and trends of nitrate contamination.

Nitrate - 2022 Report to the State Legislature by the Wisconsin Groundwater Coordinating Council

Webpage: *https://dnr.wisconsin.gov/sites/default/files/topic/Groundwater/GCCGWQuality/Nitrate.pdf*

This annual summary addresses myriad topics related to nitrate in Wisconsin's groundwater, including: the extent of elevated nitrate in groundwater, human health concerns, biotic effects, aquifer vulnerability for nitrate contamination, groundwater nitrate trends. Topics discussed also include what is being done to address nitrate in Wisconsin's groundwater, decision-support tools for farmers and other stakeholders, and outlines additional resources and references.

- Links to older versions of GCC (Groundwater Coordinating Council) reports to the state legislature dating back to 1985 are available the following Wisconsin DNR webpage: *https://dnr.wisconsin.gov/topic/Groundwater/GCC/reportArchives.html*

Nitrate Webinar Series – Wisconsin DNR and UW-Madison

Webpage: *https://dnr.wisconsin.gov/newsroom/release/47586*

This 2022 online seminar series, presented by the Wisconsin DNR, UW-Madison Division of Extension and College of Agriculture and Life Sciences, addresses the science and economics of approaches farmers can use to minimize nitrogen losses to groundwater.

- Online seminar recordings are available here, on the Wisconsin DNR's Agricultural Nonpoint Source Pollution webpage: *https://dnr.wisconsin.gov/topic/Nonpoint/aboutAgNPS.html*

Neonicotinoids

Pesticides in Drinking Water – Wisconsin DNR Fact Sheet (2019)

Webpage: *https://dnr.wi.gov/files/PDF/pubs/DG/DG0007.pdf*

This Wisconsin DNR factsheet provides a brief overview of what pesticides are, how they enter groundwater, and describes the health risks of consuming water containing pesticides. Additional resources are listed for well owners and those seeking more information about pesticide contamination of drinking water.

Wisconsin DATCP Proposed Cycle 10 Groundwater Standards Webinar Series

Webpage: *https://datcp.wi.gov/Documents/NeonicotinoidsCycle10.pdf*

This one-page 2020 publication explains why neonicotinoids are used and how they enter groundwater, including many resources for learning more.

Wisconsin DATCP Summary of Neonicotinoid Prevalence in Wisconsin Groundwater and Surface Water

Webpage: *https://datcp.wi.gov/Documents/NeonicotinoidReport.pdf*

This 2019 report presents a detailed summary of groundwater and surface water test results for neonicotinoid insecticides from 2008-2016. The report also provides information about the use of neonicotinoids in Wisconsin agriculture and the types of testing and monitoring programs in place.

Research Documenting Widespread Detections of Neonicotinoid Contaminants in Central Wisconsin Groundwater

Webpage: *https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0201753*

In this journal article, researchers describe findings of their study to investigate the spatial extent and magnitude of neonicotinoid contamination in groundwater in and around areas of irrigated commercial agriculture in central Wisconsin.

Pesticides - 2022 Report to the State Legislature by the Wisconsin Groundwater Coordinating Council

Webpage:
https://dnr.wisconsin.gov/sites/default/files/topic/Groundwater/GCCGWQuality/Pesticides.pdf

This annual summary addresses multiple topics related to pesticides in Wisconsin's groundwater, including: what pesticides are, the extent of pesticides in groundwater, actions taken by the Groundwater Coordinating Council, future work, updates on groundwater standards for pesticides, and outlines several additional resources and references.

- Links to older versions of GCC reports to the state legislature dating back to 1985 are available the following Wisconsin DNR webpage: *https://dnr.wisconsin.gov/topic/Groundwater/GCC/reportArchives.html*

Historical Overview of the Central Sands Region, Land-Use, and Fertilizer Application

Introduction

This section provides a general history of the Central Sands Region with an emphasis on the history of landscape modification, land use and irrigation, and the application of fertilizer and neonicotinoids throughout the region.

Early History

Webpage: *https://www.pbs.org/video/early-history-sckqiu/*

This video segment on early history, presented by PBS Wisconsin in 2021 as part of the episode "Wisconsin Hometown Stories: Stevens Point" introduces the history of the Menomonie people whose ancestral territory encompassed what is today the Stevens Point area. The video then discusses the role of the Treaty of the Cedars, established in 1936, as a transformative force that opened vast tracts of land for rapid expansion of the timber industry along the Wisconsin River.

Land-Use History of the Central Sands

Coastal Bordner Survey Explorer for Wisconsin

Webpage: *https://maps.sco.wisc.edu/BordnerCoastal/?featureType=polygons&basemap=streets*

The Coastal Bordner Survey Explorer is part of the Wisconsin Time Machine Project that was developed by the Forest Landscape Ecology Lab, in the Department of Forest and Wildlife Ecology (UW-Madison), the Wisconsin State Cartographer's Office in the Department of Geography (UW-Madison) with support by the National Oceanic and Atmospheric Administration (NOAA), and the Wisconsin Coastal Management Program. This interactive viewer displays historic features (including land use and land cover) extracted from the 1930s Wisconsin Land Economic Inventory maps, also known as the "Bordner" Survey maps. While the survey does not cover all of Wisconsin, it includes data for counties in the Central Sands.

- Learn more about the Bordner Survey here: *https://maps.sco.wisc.edu/BordnerCoastal/about/*

History of Land Use and Irrigation – Central Sands Lakes Study

Webpage: *https://widnr.widen.net/view/pdf/z8j5lsfp00/DG_CSLSAppendixF_2021.pdf?t.download=true*

This publication, released by the Wisconsin DNR in 2021 as part of the Central Sands Lakes Study (CSLS), summarizes the history of land-use and irrigation within the Central Sands Region of Wisconsin.

Irrigation Revolution

Webpage: *https://pbs.org/video/irrigation-revolution-a5anpd/*

This video segment on irrigation, presented by PBS Wisconsin in 2021 as part of the episode Wisconsin Hometown Stories: Stevens Point, introduces the history of how irrigation transformed the Central Sands Region into one of the most productive agricultural areas of the country.

Little Plover River Pump Test Video

Webpage: *https://www.youtube.com/watch?v=GW9cYdIT8iM*

This archival video of a pump test conducted by the U.S. Geological Survey and Wisconsin Geological and Natural History Survey (WGNHS), UW-Madison from 1963, demonstrates the connection between groundwater and surface water in the Central Sands Region. During this period, the region was undergoing rapid land-use changes as irrigation intensified to meet the demand for increased vegetable production. This increase in agricultural irrigation practices across the Central Sands served as the impetus for this pump test.

- U.S. Geological Survey link to Open-File Report 63-134, titled: “Movie on Little Plover River project - A study in sand-plains hydrology”: *https://pubs.er.usgs.gov/publication/ofr63134*
- U.S. Geological Survey Water-Supply Paper 1811, titled: “Hydrology of the Little Plover River Basin” references the video recording: *https://pubs.usgs.gov/wsp/1811/report.pdf*

Fertilizer Applications Since the 1950s

Long-Term Shifts in U.S. Nitrogen Sources and Sinks Revealed by the New TREND-Nitrogen Data Set (1930-2017)

Webpage: *https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020GB006626*

This publication by Byrnes and others (2020) documents how nitrogen fluxes have increased dramatically over the last century using data collected at the county-scale across the contiguous United States. This study allows data to be accessed and summarized by county, providing a better historical understanding of how much nitrogen has been applied to the landscape and how much has been removed by crop production.

Characterizing Dominant Field-Scale Cropping Sequences for a Potato and Vegetable Growing Region in Central Wisconsin

Webpage: *https://www.mdpi.com/2073-445X/11/2/273*

This publication by Heineman and Kucharik (2022) documents the prevailing field-scale crop-rotation practices for potatoes and other vegetables from 2008-2019 for the Central Sands Region of Wisconsin. The analysis suggests that intensified potato and vegetable production practices contribute to increased application of fertilizers and other substances needed to reduce pest and disease pressure.

UW-Madison Extension Nutrient Application Guidelines

Webpage: *https://dnr.wi.gov/regulations/opcert/documents/UWEXA2809.pdf*

This publication by Laboski and others (2006) represents the current nutrient application guidelines, originally developed in the early 1960s and revised multiple times over the decades. The publication outlines soil testing procedures and recommended application rates for nitrogen, phosphorus, and a variety of secondary and micronutrients. Tables identify specific application rates for nitrogen by crop and these recommendations provide context for understanding what nutrients are being applied and why they are being applied, namely, to increase production yields of various agricultural crops.

The Situation today – Why We Care about Nitrate and Neonicotinoids in Groundwater

Introduction

This section provides an overview of how nitrate and neonicotinoids are impacting groundwater resources in Central Wisconsin and the challenges that local communities are facing in dealing with these issues. The following presentations, reports, and resources have been selected to help illustrate the importance of these issues in local communities.

Local examples

Water-Quality Taskforce

Webpage: *https://www.wsaw.com/content/news/Task-force-hearing-highlights-connection-between-fertilizing-practices-and-groundwater-contamination-513170701.html*

Webpage: *https://legis.wisconsin.gov/2019/committees/assembly/STF-WQ*

These websites provide background information on the Speakers Task Force on Water Quality that was convened in 2019 to gather information and make policy recommendations to better assess and improve the quality of both surface water and groundwater in Wisconsin. Testimony that the Task Force heard from throughout the state and the final report with recommendations can be found on the legislative website above.

Nelsonville and CSGCC (Central Sands Groundwater County Collaborative) study

Webpage: *https://www.wsaw.com/2021/06/10/central-sands-groundwater-county-collaborative-combining-data-further-nitrate-contamination-research/*

This news story talks about the CSGCC Project and how it is working to address water quality concerns in the Central Sand Region of Wisconsin. It introduces water-quality issues being faced by residents in the Village of Nelsonville, Portage County.

Small Solutions to Big Problems

Webpage: *https://www.wsaw.com/2021/07/01/research-turns-focus-toward-finding-solutions-nitrate-contaminated-groundwater/*

News story on groundwater research conducted by Kevin Masarik (Groundwater Education Specialist, Center for Watershed Science and Education, UW-Stevens Point), examining nitrate leaching under different seasons and cropping conditions in the Central Sands, hoping it can provide recommendations to reduce nitrate leaching.

Nitrate in Water Widespread, Current Rules No Match for It

Webpage: *https://wisconsinwatch.org/2015/11/nitrate-in-water-widespread-current-rules-no-match-for-it/*

Wisconsin Watch article from 2015, highlighting the reality and challenges with nitrate contamination of groundwater, particularly in rural areas where private well owners endure most of the cost.

Farms, Fertilizer, and the Fight for Clean Water - Edge Effects Podcast

Webpage: *https://podcasts.apple.com/us/podcast/farms-fertilizer-and-the-fight-for-clean-water/id1174721985?i=1000565783929*

This podcast was published on June 9, 2022 by Edge Effects, a digital magazine about environmental issues produced by graduate students at the Center for Culture, History and Environment (CHE), a research center within the Nelson Institute for Environmental Studies at the UW-Madison. This podcast examines nitrate pollution in the Central Sands Region of Wisconsin, focusing on the Nelsonville area in Portage County. It discusses both the challenges of nitrate pollution and the health consequences.

Water Quality and Health Impacts in Wisconsin – Sierra Club

Webpage: *https://www.sierraclub.org/sites/www.sierraclub.org/files/sce-authors/u2196/Water%20Quality%20White%20Paper-final.pdf*

A report from the John Muir Chapter of the Sierra Club that discusses different water-quality concerns across the state of Wisconsin, including nitrate contamination. Specific health concerns associated with nitrate contamination are also discussed, which represent a major cause for concern for local municipalities.

Producer Led Watershed Councils

Webpage: *https://datcp.wi.gov/Pages/Programs_Services/ProducerLedProjectSummaries.aspx*

Producer Led Watershed Groups are working to improve Wisconsin's soil and water quality by supporting and advancing producer-led solutions that increase on-the-ground practices and farmer participation in local watershed efforts. The linked page provides overviews of and links to all producer led watershed groups that have been funded throughout Wisconsin.

Clean Water Now for Wisconsin – Local Referendum Effort

Website: *https://voteforcleanwater.com/*

Clean Water Now for Wisconsin is an effort coordinated by the River Alliance of Wisconsin to pass referendums in counties throughout Wisconsin that asks local voters: “Should the State of Wisconsin establish a right to clean water to protect the following: human health, the environment, and the diverse cultural and natural heritage of Wisconsin?” The link explains more about the project and details which counties have already passed or are planning referendums for inclusion in future elections.

Regulatory History and Current Framework

Introduction

This section outlines some of the historical legal framework that has shaped management strategies for groundwater in the Central Sands Region of Wisconsin. This section also introduces the current legal framework within which communities need to operate when addressing groundwater issues and challenges.

Federal rules

Federal Water Act - 1972

Webpage: *https://www.epa.gov/laws-regulations/summary-clean-water-act*

The basis of the Clean Water Act (CWA) was enacted in 1948 and was called the Federal Water Pollution Control Act but was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1972.

Current Law Relating to Water Quality

Webpage: *https://docs.legis.wisconsin.gov/misc/lc/information_memos/2019/im_2019_03*

As required by the Federal Clean Water Act (CWA), Wisconsin established surface-water quality standards for water bodies. This Wisconsin Legislative Council Memo provides a good overview.

Wisconsin rules

Wisconsin Act 410, Wisconsin's Comprehensive Groundwater Protection Act

Wisconsin Act 410, enacted in 1983, created Chapter 160 under Wisconsin statutes. The following links provide an overview of Wisconsin Groundwater Law including the establishment of groundwater quality standards under NR 140, of the Wisconsin Administrative Code:

Webpage:
https://dnr.wisconsin.gov/sites/default/files/topic/Groundwater/GCC/WIgroundwaterLaw.pdf

Summary of the Wisconsin Groundwater Law by the Wisconsin Groundwater Coordinating Council

Webpage: *https://dnr.wisconsin.gov/topic/Groundwater/GWLaw.html*

Summary of Wisconsin Groundwater Law by the Wisconsin DNR

Wisconsin's Nutrient Reduction Strategy: A Framework for Nutrient Reduction and Management

Agency Report: *https://dnr.wi.gov/water/wsSWIMSDocument.ashx?documentSeqNo=163205586*

Developed in 2013, this state agency-level strategy builds on existing programs and requirements.

Nitrate loading to groundwater – Nonpoint source pollution

Under Wisconsin Groundwater Law, no agency has responsibility for nor the ability to enforce nitrate loading to groundwater because no enforcement component was incorporated into the law. That said, Wisconsin DNR oversees several programs related to nonpoint source pollution.

Webpage: *https://dnr.wisconsin.gov/topic/Nonpoint*

This Wisconsin DNR webpage presents information and resources related to nonpoint source pollution. Main topics include:

Urban Nonpoint Source Pollution

Webpage: *https://dnr.wisconsin.gov/topic/Nonpoint/aboutUrban.html*

Agricultural Nonpoint Source Pollution

Webpage: *https://dnr.wisconsin.gov/topic/Nonpoint/aboutAgNPS.html*

NR151 Rules Changes for Nitrate

Webpage: *https://dnr.wisconsin.gov/topic/nonpoint/nr151nitrate.html*

Nine Key Element Plans

Webpage: *https://dnr.wisconsin.gov/topic/Nonpoint/9keyElement*

What You Can Do

Webpage: *https://dnr.wisconsin.gov/topic/Nonpoint/whatyoucando.html*

Wisconsin DNR Nonpoint Source Pollution Program Contacts

Webpage: *https://dnr.wisconsin.gov/topic/Nonpoint/NPScontacts.html*

Concentrated Animal Feeding Operations

Webpage: *https://dnr.wisconsin.gov/topic/cafo*

Groundwater and Drinking Water Standards Administered and Enforced by Wisconsin DNR

Webpage: *https://dnr.wisconsin.gov/topic/DrinkingWater/ownerOperator.html*

This webpage provides information for public water system owners and operators. This includes links to select sections of Wisconsin DNR Administrative Code 800 Environmental Protection – Water Supply, include NR 809 (Safe Drinking Water), NR 810 (Operation/Maintenance of Public Water Systems), NR 811 (Operation/Design of Community Water Systems), and NR 812 (Well Construction and Pump Installation)

Webpage: *https://docs.legis.wisconsin.gov/code/admin_code/nr/100/140*

Water Law Resources Presented by UW-Madison Law Library

Webpage: *https://researchguides.library.wisc.edu/c.php?g=125280&p=819873*

A wide variety of resources cover the topics of Wisconsin Law and Regulation; Great Lakes Compact; Federal Law and Regulation, Federal and Native American Reservation Rights; Water Service and Supply Organizations; International Laws, Treaties and Cases; State Water Laws; Climate Change Resources.

Critique of Policies, Programs, and Market Mechanisms: Strengths and Limitations

Introduction

A wide range of resource management policies and approaches each have strengths and limitations. What are they? What are some other approaches adopted elsewhere? In what context is any given approach most promising? What are the implications of dynamic market forces and emerging land use trends? Resources in this section provide insights on such questions. Practices are enabled and constrained by resource availability, regulation, markets, contracts, and social expectations among other factors.

Voluntary Conservation

Resources in this subsection explore voluntary adoption of farming practices intended to protect water quality, including nutrient management, and the effectiveness of incentives intended to encourage adoption.

Taking Stock of Voluntary Nutrient Management: Measuring and Tracking Change

Webpage: *https://doi.org/10.2489/jswc.67.1.51*

This research article, titled "Taking stock of voluntary nutrient management: Measuring and tracking change" by K.D. Genskow was published in the January 2012 edition of the Journal of Soil and Water Conservation. The study examines changes in nutrient management behaviors and perceptions among farmers who participated in educational workshops focused on understanding and developing nutrient management plans.

An Economic Assessment of Policy Options to Reduce Agricultural Pollutants in the Chesapeake Bay

Webpage: *https://www.ers.usda.gov/publications/pub-details/?pubid=45209#*

This research article titled: "An economic assessment of policy options to reduce agricultural pollutants in the Chesapeake Bay" by Marc Ribaudo, Jeffery Savage, and Marcel Aillery was published in June 2014 by the U.S. Department of Agriculture, Economic Research Service. The study found that "…incentives for water quality improvements are the most efficient, assuming necessary information on pollutant delivery is available for each field" and that, as an alternative approach, "Policies that directly encourage adoption of management systems that protect water quality […] are the most practical, given the limited information that is generally available…"

Improving the Efficiency of Voluntary Water Quality Conservation Programs

Research Article: Improving the Efficiency of Voluntary Water Quality Conservation Programs. Jeffrey Savage and Marc Ribaudo. Land Economics. February 2016, 92 (1): 148–166. ISSN 0023-7639; E-ISSN 1543-8325

While reaffirming that "performance-based approaches were the most efficient," authors of this study further assert that "the efficiency of technology-based approaches was improved by targeting cropland with features indicative of low marginal abatement costs."

Reconstructing the Good Farmer Identity: Shifts in Farmer Identities and Farm Management Practices to Improve Water Quality

Webpage: *https://doi.org/10.1007/s10460-012-9381-y*

This research article titled: "Reconstructing the good farmer identity: Shifts in farmer identities and farm management practices to improve water quality" by Jean McGuire, Lois Wright Morton, and Alicia D. Cast was published in 2013 in the journal of Agriculture and Human Values. This article offers relevant insights from the social sciences upon interviewing people who had been involved in farmer-led performance-based watershed groups in Iowa. The authors explore values of productivity and conservation.

Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin (A2809)

Webpage: *https://learningstore.extension.wisc.edu/products/nutrient-application-guidelines-for-field-vegetable-and-fruit-crops-in-wisconsin-p185*

This field guide titled: "Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin (A2809)" was published by Division of Extension (UW-Madison) and provides nutrient application guidelines and outlines the assumptions underlying the guidelines. (Updated periodically. Check for latest version.)

Healthy Grown Potato Program

Webpage: *https://wisconsinpotatoes.com/healthy-grown/*

This article provides an overview of the Healthy Grown potato program, Eco-brand, with an emphasis on integrated pest management (IPM) farming practices and ecological restoration on large-scale farms. A certification process is mandatory to market products (potatoes and onions) as Healthy Grown.

Strategies to Reduce Nitrate Leaching into Groundwater in Potato Grown in Sandy Soils: Case Study from North Central USA

Webpage: *https://link.springer.com/article/10.1007/s12230-010-9131-x*

This article serves as a literature review, including references to over 150 peer-reviewed articles, covering both conventional and innovative strategies for potato production. The focus is on ways to reduce nitrogen leaching in sandy soils through improved management of nitrogen application, irrigation, and cropping practices. As stated in the article: "The amount of fertilizer-N should be decided based on an integrated evaluation of soil organic matter content, soil texture, residual soil N, crop residues, credit to organic N sources, crops to be grown including varieties and crop physiological needs, cropping systems, yield potential, water management, and N concentrations in irrigation water. Research advances have no quick fix for controlling NO_3 leaching to groundwater. However, the best combination of proven strategies can reduce leaching potential significantly."

Prospects for Diversified Rural Landscapes

This subsection indicates prospects for land-use change driven by climate disruption and emerging market opportunities. Such factors are beyond the scope of much local control yet may impact groundwater quality.

Implications of Climate Change, other Trends

Webpage: *https://wicci.wisc.edu/*

The Wisconsin Initiative on Climate Change Impacts (WICCI) has developed assessment reports that explain how Wisconsin's climate is changing. Working groups continue to identify implications and adaptation measures pertinent to sectors and concerns. WICCI is a statewide collaboration of scientists and stakeholders formed as a partnership between UW-Madison's Nelson Institute for Environmental Studies and the Wisconsin Department of Natural Resources.

Alternative Practices in Production Agriculture

Webpage: *https://doi.org/10.1007/s10460-020-10077-x*

This research article titled: "The urgency of transforming the Midwestern U.S. landscape into more than corn and soybean" by L.S. Prokopy, B.M. Gramig, A. Bower was published in 2020 in the Journal of Agriculture and Human Values. In this study, researchers speak to the need for a re-envisioned Midwestern landscape and increased diversity in agricultural systems (farms, landscapes, and markets) and argue that farmers, rural communities, and the environment would be more resilient with multifunctional working landscapes such as: "incorporating small grains and/or forage crops into extended rotations; replacing some input-intensive corn-soybean acres with perennial bioenergy crops, including agroforestry; integrating grazed livestock into systems that may include feed grains, winter cover crops, or perennial crops/forages; horticultural food crops; and/or increased use of edge of field nutrient loss reduction practices targeted to less productive, highly vulnerable lands."

Characterizing Dominant Field-Scale Cropping Sequences for a Potato and Vegetable Growing Region in Central Wisconsin

Webpage: *https://doi.org/10.3390/land11020273*

This research article titled: "Characterizing Dominant Field-Scale Cropping Sequences for a Potato and Vegetable Growing Region in Central Wisconsin" by E.M. Heineman, C.J. Kucharik was published in 2022 in the journal Land. This study examines the dominant field-scale cropping sequences from 2008 to 2019 for the Central Sands Region of Wisconsin and observes that adopting more widespread use of four- or five-year rotations of potato with crops that require zero or less N fertilizer could reduce groundwater nitrate concentrations and improve water quality.

Grasslands 2.0 - Restoring Grassland Agriculture

Webpage: *https://pbswisconsin.org/watch/university-place/grassland-20-restoring-grassland-agriculture-5mjocy/*

In this presentation titled: "Grasslands 2.0 - Restoring Grassland Agriculture" that aired on University Place, a local public television program presented by PBS Wisconsin in 2022, Randy Jackson, Professor in the Department of Agronomy at UW-Madison, describes the USDA-funded project focused on transforming agriculture in the upper-Midwest from grain-based to grassland-based livestock production.

Additional resources:

- Grasslands 2.0 webpage: https://grasslandag.org/
- Grasslands 2.0 collaborator team: https://grasslandag.org/our-team/
- Heifer Grazing Compass: https://grasslandag.org/the-heifer-grazing-compass/

New Tool Shows Wisconsin Farmers Financial Benefits of Letting Cows Graze

Webpage: *https://www.wpr.org/new-tool-shows-wisconsin-farmers-financial-benefits-letting-cows-graze*

Webpage: *https://grasslandag.org/the-heifer-grazing-compass/*

The report about the Grasslands 2.0 Heifer Grazing Compass tool was featured on Wisconsin Public Radio in May 2022.

Savanna Institute

Webpage: *https://www.savannainstitute.org/*

The Savanna Institute works with farmers and scientists to lay the groundwork for widespread agroforestry adoption in the Midwest United States. Its mission is to catalyze the development and adoption of resilient, scalable agroforestry.

Solar Farms

Solar farms may be an alternative to high-input farming on some sites. Attitudes towards such projects vary. While host communities may be able to influence certain aspects of such projects, they lack authority to deny large-scale solar farms regulated as public utilities.

Webpage:
https://www.alliantenergy.com/cleanenergy/ourenergyvision/solargeneration/wisconsinsolar/woodcountysolarproject

The proposed Golden Sands Dairy operation in the Town of Saratoga (Wood County) met resistance by local community members expressing concerns about groundwater quality. The land is now slated to become the home of a 150-Megawatt electricity generation site managed by Alliant Energy.

Webpage: *https://www.mge.com/our-environment/green-power/solar-power/mge-solar-projects*

The Badger Hollow Solar Farm, in Iowa County, Wisconsin, is under development and will result in a 300-Megawatt solar farm.

Local Government Authorities: Powers and Limitations

Zoning and Subdivision Authorities

Zoning or Subdivision Regulation? It Can Matter!

Website: *https://files.constantcontact.com/719b6d0b001/b90b247b-7b1b-4490-9e58-3a6aae4797a8.pdf*

This article offers an overview of zoning and subdivision regulatory authority and summarizes a Wisconsin Supreme Court decision reviewing the framework used to determine whether a regulation is a zoning or subdivision regulation.

Home Rule

"Home Rule" refers to the authority of local governments to govern themselves in local matters not explicitly constrained by state law. Under Wisconsin law, counties have limited "organizational or administrative" home rule powers. Cities and villages have broad home rule authority, though it is at times reduced by court decisions and emergence of state laws that further limit local powers. Towns usually require specific statutory authorization to exercise powers.

Statute: *https://docs.legis.wisconsin.gov/statutes/statutes/59/ii/03*

Wisconsin State Statute 59.03 (along with 59.04) establishes the limited administrative home rule authority of Wisconsin counties.

Comment: *http://www.lwm-info.org/DocumentCenter/View/948/6-16-Claire-Legal-Comment-home-rule-june-2016?bidId=*

This legal comment explains the substantial home rule authority of Wisconsin’s cities and villages.

Website: *https://www.lwm-info.org/628/Home-Rule*

General information about home rule in Wisconsin.

Alternative Approaches in Other States

Introduction

This section outlines nitrogen management strategies that other states have employed. While these are from other states and vary in scope from statewide to regional or local, they may provide useful strategies that could potentially be implemented in Wisconsin on a variety of scales.

Iowa Nutrient Reduction Strategy

Website: *https://www.nutrientstrategy.iastate.edu/*

The Iowa Nutrient Reduction Strategy is a science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico. It is designed to direct efforts to reduce nutrients in surface water from both point and nonpoint sources in a scientific, reasonable, and cost-effective manner.

Minnesota

Minnesota Nitrogen Fertilizer Management Plan

Website: *https://www.mda.state.mn.us/chemicals/fertilizers/nutrient-mgmt/nitrogenplan/nfmpabout*

The Nitrogen Fertilizer Management Plan lays out an approach to prevent and respond to nitrate pollution in groundwater from nitrogen fertilizer. The original Nitrogen Fertilizer Management Plan was developed in 1990. The Plan went through a revision process from 2010 to 2014. The revised Plan includes new scientific information about groundwater protection and is better aligned with current water resource programs and activities.

The Plan:

- Includes activities to protect private and public wells
- Involves communities and local farmers in problem solving
- Includes testing nitrate levels in private wells
- Emphasizes education on the nitrogen best management practices (BMPs)
- Offers other voluntary options beyond the BMPs
- Includes regulatory measures

Minnesota Clean Water, Land and Legacy Amendment

Website: *https://www.legacy.mn.gov/about-funds*

In 2008, Minnesota's voters passed the Clean Water, Land and Legacy Amendment (Legacy Amendment) to the Minnesota Constitution to: protect drinking water sources; to protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat; to preserve arts and cultural heritage; to support parks and trails; and to protect, enhance, and restore lakes, rivers, streams, and groundwater.

The Legacy Amendment increased the state sales tax by three-eighths of one percent beginning on July 1, 2009 and continuing until 2034. The additional sales tax revenue is distributed into four funds as follows: 33 percent to the clean water fund; 33 percent to the outdoor heritage fund; 19.75 percent to the arts and cultural heritage fund; and 14.25 percent to the parks and trails fund

To learn about specific projects that reduce nitrogen and were funded through this funding source you can visit: *https://www.legacy.mn.gov/projects?search_api_fulltext=nitrate*

Nebraska

Nitrate in Nebraska

Website: *https://water.unl.edu/category/nitrate*

This website hosted by the University of Nebraska-Lincoln Institute of Agriculture and Natural Sciences describes all things related to nitrate in Nebraska, including sources, health impacts, research, and current projects.

Nitrate Working Group

Website: *https://water.unl.edu/article/nitrate/nebraska-nitrate-working-groups-summary-and-call-action*

For the past several decades, organizations across Nebraska have taken the lead on a variety of programs seeking to address the increasing nitrate concentration in the state's groundwater. The Nitrate Working Groups were convened with the purpose of complimenting these individual programs by finding common efforts which partner organizations can prioritize and collaboratively address

California

California Nitrate Project – Addressing Nitrate in California's Drinking Water

Website:
https://static1.squarespace.com/static/5e83c5f78f0db40cb837cfb5/t/5f3f5dfb52d3b85a99adec70/1597988378322/Addressing+Nitrate+in+California%E2%80%99s+Drinking+Water.pdf

In 2008, California Senate Bill SBX2 1 (Perata) was signed into law (Water Code Section 83002.5), requiring the State Water Resources Control Board (State Water Board), in consultation with other agencies, to prepare a Report to the California Legislature to "improve understanding of the causes of [nitrate] groundwater contamination, identify potential remediation solutions and funding sources to recover costs expended by the State… to clean up or treat groundwater, and ensure the provision of safe drinking water to all communities." The University of California prepared this Report under contract with the State Water Board as it prepares its Report to the Legislature.

Recommendations for Action

Introduction

This section outlines resources that have provided recommendations and/or "next steps" that could be taken to address both nitrate and neonic issues in groundwater. Resources provide background information and overview of the water quality issues across the state but also….

Wisconsin Counties Association Magazine, March 2019

Webpage: *https://www.wicounties.org/magazine/march-2019/*

The March 2019 issue of the Wisconsin Counties Association magazine was devoted entirely to clean drinking water. It provides general background information on water quality but also highlights what Counties throughout the state are doing to try and address the issue of clean drinking water.

Wisconsin Land + Water 2017 Food, Land and Water Report

Webpage: *https://wisconsinlandwater.org/assets/article/Food-Land-Water-Report-Rev.-1_WEB-compressed.pdf*

This report discusses the situation today but also includes recommendations for next steps and pragmatic actions that can be taken with all stakeholders at the table

Food, Land and Water: Can Wisconsin Find its way?

Resource: ***Appendix B - Food Land and Water - Can Wisconsin Find its Way?***

Prepared by James Matson, who retired in 2011 after 28 years as chief legal counsel for the Wisconsin Department of Agriculture, Trade, and Consumer Protection

This 2016 report served as the kick-off document that was shared with committee members participating in the Wisconsin Food, Land and Water Project that resulted in release of the 2017 Wisconsin Land + Water 2017 Food, Land and Water Report

Nitrate in Wisconsin Waters – A Wisconsin's Green Fire Policy Analysis

Webpage: *https://wigreenfire.org/2019/wp-content/uploads/2019/07/WGF-Nitrates-in-Wisconsin-Waters-Final-07-16-2019-1-1.pdf*

This policy analysis compiled by Wisconsin Green Fire provides recommendations for dealing with nitrate contamination at its sources.

Wisconsin Groundwater Coordinating Council Report to the Legislature

Webpage:
https://dnr.wisconsin.gov/topic/Groundwater/GCC#:~:text=REPORT%20TO%20THE%20LEGISLATURE,-

Wisconsin%20Groundwater%20Coordinating&text=The%20Groundwater%20Coordinating%20Council%20prepares,for%20the%20preceding%20fiscal%20year

Each year the Wisconsin Groundwater Coordinating Council prepares a report that summarizes the activities and actions of the Council, describes the state of groundwater resources in the state and their management, and makes recommendations. The report is broken down into sections with special sections dedicated to nitrate and neonicotinoids. The link above will also allow you to view reports from previous years.

What Can Communities Do?

Introduction

This section identifies types of actions Wisconsin communities can take to manage groundwater. It provides resources and tools that local communities may utilize to address water quality issues and concerns. None of these tools will single-handedly solve groundwater contamination issues but can be useful in taking steps to understand the issues a community faces and begin addressing concerns.

Resources in this section are sorted according to the purpose of activities, notably: 1) planning and design, 2) operating, supervising, evaluation, and 3) teaching and learning (and collaborating with researchers).

General Zoning

Zoning refers to the use of the public regulatory power, or police power, to specify how land may be used and developed. The intent of zoning is to balance individual property rights with the rights of the public to a healthy, safe, and orderly living environment.

Zoning Fundamentals

Webpage: *https://www3.uwsp.edu/cnr-ap/clue/Pages/Webinars/Spring%202022/Zoning-Fundamentals_S2022.aspx*

This online seminar presented by the Center for Land Use Education at UW-Stevens Point looks at what zoning is and why most Wisconsin communities have adopted it. It also covers the roles of different local government bodies in adopting, amending, and administering zoning

Zoning as a Tool to Protect Groundwater

Resource: ***Appendix C - Zoning for Groundwater Protection***

This Power Point presentation by Lynn Markham, Land Use Specialist with the Center for Land Use Education at UW-Stevens Point, goes a step further to specifically look at how zoning can be used to address groundwater concerns and/or protect groundwater. This presentation also examines current zoning policies in place within six counties in the Central Sands Region

General planning

A plan can provide a factual and objective basis that supports local decision making and can provide guidance for the future. Some communities create plans specifically for their local groundwater resources. These plans often outline goals, objectives, and specific actions that can be taken to address groundwater resources and/or challenges in a community. Below there are examples of groundwater specific plans and planning efforts.

Portage County Groundwater Management Plan

Website: *https://www.co.portage.wi.us/home/showpublisheddocument/12349/636449557824970000*

Marathon County Groundwater Management Plan

Website:
https://www.co.marathon.wi.us/Portals/0/Departments/CPZ/Documents/grounddwaterplan2001_reduced.pdf

Dane County Water Quality Plan

Website: *https://www.carpcwaterqualityplan.org/about/dane-county-water-quality-plan/*

Eau Claire County Groundwater Management Plan

Website:
https://www.eauclairecounty.gov/home/showpublisheddocument/25741/636699310364070000

Comprehensive planning

A comprehensive plan states a municipality's development goals and outlines public policies for guiding future growth. Comprehensive plans can be used to address groundwater concerns or protect groundwater in the future, which are addressed in the resources and examples below.

Development of Tools to Address Groundwater in Comprehensive Planning

Website: *https://www3.uwsp.edu/cnr-ap/clue/Documents/groundwater/GroundwaterReport.pdf*

A report on a project by the U.S. Geological Survey and Center for Land Use Education at UW-Stevens Point. The project reviewed 79 comprehensive plans completed in WI. The first phase reviewed the plans for how groundwater was addressed within the 9 elements of each plan. Phase two evaluated the goals, policies, and groundwater data in each of the plans. The report also includes five case studies of Wisconsin communities that have implemented groundwater protection and remediation measures utilizing comprehensive planning.

Protecting Wisconsin Groundwater Through Comprehensive Planning

Website: *https://wi.water.usgs.gov/gwcomp/find/index.html*

An online database of groundwater data and policies for each County in Wisconsin. The data contained in the database is dated (database was last updated in 2008) but can still serve as a valuable resource on what may be available in our local area.

Groundwater and Its Role in Comprehensive Planning

Website: *https://www3.uwsp.edu/cnr-ap/watershed/Documents/fact1.pdf*

A factsheet published by the Wisconsin Groundwater Coordinating Council on how groundwater can be addressed or incorporated into communities' comprehensive plans. This includes how land use impacts groundwater, suggestions for how communities can limit their impact on groundwater, and relationships between comprehensive planning elements and groundwater.

Five Steps to Integrate Groundwater into Your Comprehensive Plan

Website: *https://wi.water.usgs.gov/gwcomp/integrate/index.html*

This online resource, compiled by the U.S. Geological Survey and Center for Land Use Education at UW-Stevens Point, walks you through five step-by-step actions on how to incorporate groundwater into your local comprehensive plan, as well as providing additional resources that can aid your efforts.

Wisconsin's Top Five Groundwater Planning and Policy Recommendations

Website: *https://wi.water.usgs.gov/gwcomp/integrate/develop.html*

The following five recommendations and supporting resources are identified in Step 3 (Develop groundwater goals, objectives, and policies) from the above link:

1. Adopt wellhead protection plans and ordinances for municipal wells,
2. Identify and properly seal unused wells,
3. Educate private well users,
4. Encourage farmers to reduce inputs of potential groundwater contaminants,
5. Examine groundwater quantity issues and encourage water conservation practices.

Examples of Comprehensive Plans that Include Groundwater

Below are examples of City and County Comprehensive Plans that include elements of groundwater and groundwater management in their discussion and/or goals and actions:

Portage County Comprehensive Plan

Website: *https://www.co.portage.wi.us/department/planning-zoning/planning-section/comprehensive-planning/portage-county*

Marathon County Comprehensive Plan

Website: *https://www.co.marathon.wi.us/Portals/0/Departments/CPZ/Documents/MarathonCountyComp2016_2019.pdf*

Wood County Comprehensive Plan

Website: *https://www.co.wood.wi.us/Departments/PZ/Doc/5-WCAgriculturalElement-Final9-16-09.pdf*

City of Bayfield, Wisconsin Comprehensive Plan

Website: *https://www.cityofbayfield.com/uploads/1/1/1/5/11158030/2019-2029_city_of_bayfield_comprehensive_plan_-_final.pdf*

Water Resource Management Planning

U.S. Environmental Protection Agency (EPA) Nine Key Element Watershed Plans (Wisconsin DNR-Implemented)

Website: *https://dnr.wisconsin.gov/topic/Nonpoint/9keyElement*

Watershed plans consistent with EPA's nine key elements provide a framework for improving water quality in a holistic manner within a geographic watershed. The nine elements approach helps assess the contributing causes and sources of nonpoint source pollution, involves key stakeholders, and prioritizes restoration and protection strategies to address water quality problems. The nine key element watershed plans provide a different level and framework for planning.

Scenario Planning

Scenario planning is a practice through which communities plan for an uncertain future by exploring multiple possibilities of what might happen. The practice guides planners, community members, and other stakeholders through considerations of various futures and how to effectively respond to and plan for them.

Consortium of Scenario Planning

Website: *https://www.lincolninst.edu/news/press-releases/lincoln-institute-land-policy-launches-consortium-scenario-planning*

Provides an overview of the Consortium and the role it can play in scenario planning.

Opening Access to Scenario Planning

Website: *https://resilientwest.org/wp-content/uploads/opening-access-to-scenario-planning-tools-full-v2.pdf*

This report examines the current state of scenario planning, the promise of scenario planning tools to help us prepare for the future, the challenges to expanding their use, and their potential for open access to improve the planning process. It makes specific recommendations to advance the use of scenarios and scenario planning tools, including development of an online platform to facilitate collaboration, capacity building, and open-source activities among scenario tool developers, urban planners, and other tools users.

Strategic Water Sampling and Monitoring

Water sampling efforts and groundwater monitoring can be used to create a better overall understanding of the issues that a community faces and/or answer specific questions relating to potential contamination issues. The resources below describe how a community can begin monitoring or testing, why testing of wells is important and specific examples of monitoring and testing projects used by counties and communities throughout the Central Sands Region of Wisconsin.

A Guide to Organizing a Community Drinking Water Testing and Education Program

Website: *https://www3.uwsp.edu/cnr-ap/watershed/Documents/Drinking%20Water%20Program%20Manual%202005.pdf*

A guide to organizing a community drinking water testing program that includes a needs analysis and step-by-step instructions for how to set up and execute such a program. It also discusses how communities can utilize the results from programs.

How to Launch a Community Well Testing Program

Resource: ***Appendix D - Community Well Testing Program***

Presentation slides highlighting the considerations a community should make before considering testing, sources of data, and examples of different testing strategies and what the data from these strategies can show.

County Sampling and Monitoring Projects

The list below provides links to the water quality monitoring projects each county has been working on. These range from regular water quality sampling efforts to one-time programs

- Adams County
  Website: *https://www.co.adams.wi.us/departments/land-water-conservation/well-testing-program*
- Waushara County
  Website: *https://www.co.waushara.wi.us/pview.aspx?id=44957&catid=636*
- Portage County
  Website: *https://www.co.portage.wi.us/department/planning-zoning/portage-county-well-water-quality-project*
- Wood County
  Website:
  https://www.woodcountywi.gov/Departments/LandConservation/WellWaterTesting.aspx

Public Drinking Water Database

Website: *https://dnr.wi.gov/dwsviewer*

Both current and historic public drinking water sources in Wisconsin are routinely sampled for water quality (typically annually). This information is publicly available through an online viewer. This may be one of the few sources of water quality data available to a municipality where routine sampling on the same well is conducted. This can be valuable in assessing any potential trends in water quality.

Public Drinking Water System Trends

Website: *https://shiny.theopenwaterlog.com/nitrate_trends/*

The Center for Watershed Science and Education at UW-Stevens Point has developed an online app that has statistically analyzed public drinking water systems throughout Wisconsin to determine whether there are statistically significant increasing or decreasing trends in nitrate concentrations over time.

Encourage Private Well Sampling

Regular testing is important because water quality can change and routine testing establishes a record of water quality that may help identify and solve future problems. While landowners with private wells are responsible for the quality of their water they are generally not required to test. Nevertheless, testing is highly encouraged to ensure the water is safe to drink.

Wisconsin Department of Health Services Well Testing Information Website

Website: *https://www.dhs.wisconsin.gov/water/private.htm*

Wisconsin Department of Health Service's factsheet on the importance of private well sampling and resources for private well owners.

Wisconsin Department of Health Services Drinking Water webpage

Website: *https://www.dhs.wisconsin.gov/water/drinking.htm*

Website with information about drinking water from the Wisconsin Department of Health Services. Discusses the potential impacts on health.

Wisconsin Department of Natural Resources Test Your Water Annually

Website: *https://dnr.wisconsin.gov/topic/Wells/privateWellTest.html*

A list of resources regarding recommended water tests, certified labs, how to collect samples, discussion on test results, and a diagnostic tool to help identify water quality concerns.

Water Testing Facts – U.S. Environmental Protection Agency

Website: *https://www.epa.gov/sites/default/files/2015-11/documents/2005_09_14_faq_fs_homewatertesting.pdf*

EPA's document on the importance of water testing and how to collect a sample.

Certified Water Testing Labs in Wisconsin

Website: *https://dnr.wisconsin.gov/topic/labCert/certified-lab-lists*

Wisconsin DNR's list of certified water labs, what they test for, and how they are certified in Wisconsin.

Consider Alternatives for Safe Drinking Water

Information about the merits of private wells and treatment options, municipal water supply and treatment options, and alternatives such as procurement of bottled water.

Conversion to Municipal Water Supply (from system of private wells)

Information for communities that may be considering installation of a municipal water supply for households otherwise served by private wells.

Wisconsin DNR Public Drinking Water Systems

Website: *https://dnr.wisconsin.gov/topic/SmallBusiness/DrinkingWater.html*

This website provides an overview of the different classifications of public drinking water systems in Wisconsin and has an extensive FAQ (frequently asked questions) page regarding public drinking water systems.

Wisconsin DNR Public Drinking Water System Database

Website: *https://dnr.wi.gov/dwsviewer*

To view existing and historic public drinking water systems in the state you can visit the Wisconsin DNR's database of Public Drinking Water Systems. This database also contains well construction information for public drinking water wells and water quality sampling data.

Wisconsin Rural Water Association

Website: *https://www.wrwa.org/*

The Wisconsin Rural Water Association (WRWA) is one of the leading organizations in the state that aids rural communities on all water related issues. They can provide information, training, and resources for communities dealing with drinking water and wastewater issues. Assisting, educating, and representing our members in the water and wastewater industries.

Water and Wastewater Funding Sources

Website: *https://dnr.wisconsin.gov/aid/Sources.html*

A list of potential funding sources for municipalities and individuals who are facing issues with water systems and/or wells.

Private Well Water Treatment Options

Information for private well owners on treatment options that are available and what might best serve their needs.

Choosing A Water Treatment Device

Website: *https://oconto.extension.wisc.edu/files/2014/11/Choosing-a-Water-Treatment-Device.pdf*

An extensive factsheet designed to help well owners determine the quality of their home drinking water, and to show techniques available for improving it.

Choosing Home Water Filters and Other Water Treatment Systems

Website: *https://www.cdc.gov/healthywater/drinking/home-water-treatment/water-filters/step3.html*

A U.S. Center for Disease Control (CDC) website aimed at helping homeowners determine what water filter and/or treatment system might work the best to address water quality concerns.

Improving Your Private Well Water Quality

Website: *https://www3.uwsp.edu/cnr-ap/watershed/Documents/Improving%20your%20private%20well%20water%20quality.pdf*

This publication describes options for improving private residential well water quality, including water treatment methods.

Examples of Community Actions

This section provides examples from communities in Wisconsin that have addressed groundwater and/or drinking water concerns.

Vote for Clean Water

Website: *https://voteforcleanwater.com/*

This movement seeks to form community action groups to advocate for changes and pass referenda to create change at the grass roots level. In spring 2021, Marquette Co. (73%), Portage Co. (77%), and Wood Co. (76%) approved “Clean Water Now for Wisconsin” referendums. In spring 2022, Adams Co residents did so as well.

Portage County Groundwater Citizen Advisory Committee

Resource: ***Appendix E - List of Proposed Nitrate Actions from Portage County GCAC***

Portage County has established a unique Groundwater Citizen Advisory Committee made up of 27 municipal representatives from across the County. These representatives are a recommending body to the Portage County Board of Supervisors on groundwater related issues.

In May of 2022, the Portage County Groundwater Citizen Advisory Committee compiled a list of potential actions that the County Board Supervisors could consider acting on to address nitrate contamination in groundwater.

To learn more about the Portage County Groundwater Citizen Advisory Committee and their work, visit: *https://www.co.portage.wi.us/department/planning-zoning/water-resources/gcac*

Kewaunee County Public Health and Groundwater Protection Ordinance

Resource: ***Appendix F - Addressing Groundwater Quality in Kewaunee County***

Website: *https://www.kewauneeco.org/i/f/files/Ordinances/Chapter%2030.pdf*

In 2014, county residents overwhelmingly passed the Public Health and Groundwater Protection Ordinance. The presentation slides included in Appendix F, outline how Kewaunee County came to develop the ordinance and what has happened since its implementation.

City of Waupaca Cropping Agreements

Website: *https://www3.uwsp.edu/cnr-ap/clue/Documents/groundwater/casestudies/Waupacacroppingagreement.pdf*

Website: *https://confluence.journalism.wisc.edu/2015/01/16/nitrate-levels-rise-as-officials-push-for-a-solution/*

The City of Waupaca municipal water utility worked with local farmers within the well-head protection zones for wells to modify land-use practices

Community Capacity for Effective Groundwater Management

Introduction

Community capacity involves aspects of community competence and empowerment, or a "community's ability to pursue its chosen purposes and course of action" [1]. This section includes resources that may help groundwater management professionals and others determine an appropriate focus and approach for building community capacity through their work. Beyond what Wisconsin communities can do already, a few more abstract resources in this section suggest possibilities for greater community competence, authority, influence, and/or assurance. Some may interest resource managers looking to expand the range of tools and potential actions for effective use by communities.

Building Community Capacity: Environment, Structure, and Action to Achieve Community Purposes (G3840). David Hinds, 2008. University of Wisconsin Cooperative Extension.

Webpage: *https://learningstore.extension.wisc.edu/products/building-community-capacity-environment-structure-and-action-to-achieve-community-purposes-p1402*

"This publication reviews the difference between development in a community and development of a community, the importance of knowledge and purpose, and key distinctions between form and function." "The publication also proposes a model for conceptualizing community capacity, comprised of three interdependent elements: (1) community environment; (2) community structures; and (3) purpose-based action." "The work concludes with presentation of a framework for purpose-based action, comprised of five purposeful approaches, accompanied by a discussion of the skills, tools, and roles needed to pursue them in achieving community purposes."

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[1] Fawcett, S., Paine-Andrews, A., Francisco, V. T., Schultz, J. A., Richter, K. P., Lewis, R. K., Williams, E. L., Harris, K. J., Berkley, J. Y., Fisher, J. L., and Lopez, C. M. (1995). Using empowerment theory in collaborative partnerships for community health and development. American Journal of Community Psychology 23(5), 677-697.
See also: Chaskin, 1999. Defining community capacity: A framework and implications from a comprehensive community initiative. The Chapin Hall Center for Children at the University of Chicago.

Global Perspectives on Groundwater Governance and Management Challenges

Towards Inclusive Water Governance: OECD (Organization for Economic Cooperation and Development) Evidence and Key Principles of Stakeholder Engagement in the Water Sector

Webpage: *https://doi.org/10.1007/978-3-319-43350-9_3*

This chapter within Freshwater Governance for the 21st Century, emphasizes stakeholder engagement as a principle of groundwater governance and addresses the need for better understanding emerging issues related to stakeholder engagement.

Citation: Akhmouch, A., Clavreul, D. (2017). Towards Inclusive Water Governance: OECD Evidence and Key Principles of Stakeholder Engagement in the Water Sector. In: Karar, E. (eds) Freshwater Governance for the 21st Century. Global Issues in Water Policy, vol 6. Springer, Cham. *https://doi.org/10.1007/978-3-319-43350-9*

Addressing the Groundwater Governance Challenge

Webpage: *https://doi.org/10.1007/978-3-319-43350-9_11*

This chapter within Freshwater Governance for the 21st Century introduces concepts of governance, policy, and management; distinguishes various management instruments (technical instruments, managerial and planning instruments, regulatory instruments, and economic instruments); and describes four components of groundwater governance (actors, legal frameworks, policies, and information/knowledge).

Citation: de Chaisemartin, M. et al. (2017). Addressing the Groundwater Governance Challenge. In: Karar, E. (eds) Freshwater Governance for the 21st Century. Global Issues in Water Policy, vol 6. Springer, Cham. *https://doi.org/10.1007/978-3-319-43350-9*

Local Governance and Management

Clarifying Roles: Naming and Framing Local Issues

Better Results by Linking Citizens, Government, and Performance Measurement (1999)

Article: *https://icma.org/sites/default/files/4929_.pdf*

This short and accessible article offers a research-based conceptual model for effective governance featuring three core elements (performance measurement, citizen engagement, and government policy and implementation) and linkages among them.

Marshall, Martha; Wray, Lyle; Epstein, Paul; Grifel Stuart. Better Results by Linking Citizens, Government, and Performance Measurement. PM. Public Management, 1999, Vol.81 (10), p.12-12 *https://icma.org/sites/default/files/4929_.pdf*

Readiness

Community Groundwater Management Readiness Questionnaire

Resource: ***Appendix G – Community Groundwater Management Readiness Questionnaire***

A questionnaire designed to help interested community groups and individuals recognize several key aspects of preparedness, and to identify some areas to work on to bolster the effectiveness of groundwater management efforts. Questions can also serve as a warm-up for a workshop aimed at building a shared understanding of issues and opportunities, and potential roles and responsibilities among people engaged in community-based strategic groundwater management efforts. (Developed by Nathan Sandwick, Division of Extension, UW-Madison. 2022.)

Principles of Good Governance

Assessing Principles of Good Governance: The Case of Lake Wausau, Wisconsin

Research Article: *https://doi.org/10.1111/j.1936-704X.2019.03314.x*

A paper describing interviews and content analysis of water-related policies and plans used to assess good governance principles (transparency, effectiveness, equity, accountability, and appropriate scale) for Lake Wausau in central Wisconsin.

Kristin Floress, Aaron Thompson, and Cherie LeBlanc Fisher. Assessing Principles of Good Governance: The Case of Lake Wausau, Wisconsin. Journal of Contemporary Water Research and Education. First published September 2019.

Resources for Public Sector Management Professionals

Wisconsin Certified Public Manager® (CPM) Program

Training: *https://localgovernment.extension.wisc.edu/about-the-cpm-program/*

The CPM Program is a nationally accredited management development program that prepares managers in federal, state, and local government and in tribal and nonprofit organizations for the challenges and unique demands of the public management profession.

Public Management and Administration: An Introduction

Book: Public Management and Administration: An Introduction (4th Edition) by Owen E. Hughes. Palgrave Macmillan, New York. 2012.

This book introduces and assesses the principles and theories underlying changes in the management of the public sector.

How Professionals Can Add Value to Their Communities and Organizations

Article: *https://icma.org/sites/default/files/1625_.pdf*

This short article speaks to modern expectations for local government professionals and features six professional practices that add value.

Data Sources and Data-Visualization Tools

Introduction

These are additional tools available to communities to learn about their groundwater. These are all sources of data.

List of select tools

Water Quality Portal – U.S. Geological Survey

Webpage: *https://www.waterqualitydata.us/*

The Water Quality Portal (WQP) is the premiere source of discrete water-quality data in the United States and beyond. This cooperative service integrates publicly available water-quality data from the U.S. Geological Survey, the Environmental Protection Agency, and over 400 state, federal, tribal, and local agencies

National Water Information System (NWIS) – U.S. Geological Survey

Webpage: *https://waterdata.usgs.gov/nwis*

These pages provide access to water-resources data collected at approximately 1.9 million sites in all 50 States, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

The U.S. Geological Survey investigates the occurrence, quantity, quality, distribution, and movement of surface and underground waters and disseminates the data to the public, State and local governments, public and private utilities, and other Federal agencies involved with managing our water resources.

Surface Water Integrated Monitoring System (SWIMS) – Wisconsin DNR

Webpage: *https://dnr.wisconsin.gov/topic/SurfaceWater/SWIMS*

The Surface Water Integrated Monitoring System (SWIMS) is a Wisconsin DNR system that archives chemistry (water, sediment, fish tissue) data, physical data, biological (macroinvertebrate, aquatic invasives) data and more. SWIMS is the state's repository of monitoring data for Clean Water Act work and is the source of data sharing through the Water Quality Exchange Network.

Water Quality Viewer – Center for Watershed Science and Education, UW-Stevens Point

Webpage: *https://www3.uwsp.edu/cnr-ap/watershed/Pages/WellWaterViewer.aspx*

This interactive viewer serves as an educational tool for better understanding the spatial distribution of key water-quality parameters across the State, including Bacteria, Chloride, Nitrate, pH, and Total Hardness, to name a few.

Nitrate in Wisconsin Public Water Systems – Center for Watershed Science and Education, UW-Stevens Point

Webpage: *https://www3.uwsp.edu/cnr-ap/watershed/Pages/nitrate_trends.aspx*

Public water systems must submit annual nitrate samples to the Wisconsin Department of Natural Resources. The Center recently created an interactive mapping tool to help analyze and view historical data for these systems.

Bureau for Remediation and Redevelopment Tracking System (BRRTS) – Wisconsin DNR

Webpage: *https://dnr.wi.gov/botw/SetUpBasicSearchForm.do*

This Wisconsin DNR platform, BRRTS on the Web (BOTW), allows users to search for information on the investigation and cleanup of environmental contamination in Wisconsin.

Detailed Table of Contents

Appendix A

Nitrate in Groundwater

Nitrate in Groundwater - A Continuing Issue for Wisconsin Citizens

by

The Nutrient Management Subcommittee of the Nonpoint Source Pollution Abatement Program Redesign

March, 1999

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Executive Summary

This paper summarizes the information available concerning nitrate in Wisconsin's groundwater. Previous papers have summarized the sources and concerns related to nitrate in groundwater (Bundy et al, 1994); the occurrence of nitrogen in groundwater and best management practices to reduce nitrate pollution (DATCP, 1989); and nitrogen application rates (Bundy et al, 1994). This paper provides additional information on the extent of nitrate pollution, the costs resulting from nitrate pollution and nitrate pollution sources and trends.

Nitrate is the most widespread groundwater contaminant in Wisconsin. It has a federal Maximum Contaminant Level (MCL) and Wisconsin groundwater enforcement standard (ES) of 10 parts per million as nitrate-nitrogen. The standards are based on the risk of methemoglobenemia in infants.

About 10% of Wisconsin's 800,000 private wells have nitrate-nitrogen concentrations exceeding the ES. Exceedences are not uniform across the state, however. Nitrate is rarely detected in areas with few pollution sources, such as much of northern Wisconsin. It is more frequently detected in wells located in agricultural parts of the state. A DATCP study showed exceedence rates between 17-26% in some agricultural districts. Data collected by researchers at the University of Wisconsin at Stevens Point showed exceedence rates greater than 60% in localized agricultural areas. On a statewide basis, about 90% of the nitrate detected is from agricultural sources (fertilizer, manure, and legumes). Septic systems and other sources contribute 9% and 1% respectively.

Private well owners in Wisconsin have paid an estimated 3 to 5 million dollars to repair or replace private wells, treat nitrate in drinking water or obtain bottled water. Currently, fifteen municipalities are required to treat their source water to reduce nitrate levels in their public water supplies. Installation of nitrate removal systems has cost these communities more than 10 million dollars. Ongoing maintenance and chemicals will cost citizens several thousand dollars per year per system.

There is compelling research that shows the problem is getting worse as older, cleaner groundwater is discharged naturally and replaced by newer groundwater with higher levels of nitrate. Environmental effects that can't be corrected using water treatment devices, such as eutrophication and fish mortality, will get worse. As groundwater quality changes and more wells are affected, costs to private well owners and municipalities will increase.

Introduction

The Department of Natural Resources (DNR) and the Department of Agriculture Trade and Consumer Protection (DATCP) agree that nitrate is the most widespread groundwater contaminant in Wisconsin and that the problem is increasing in extent and severity. Nitrogen is necessary for plant growth, and adding nitrogen fertilizer increases yield for most non-legume crops. This paper presents available information on the extent and potential effects of nitrate contamination of Wisconsin's groundwater.

What is nitrate?

Nitrate (NO_3^-) is one of the chemical forms of nitrogen. It coexists with other forms of nitrogen in a complex cycle. Nitrogen in soil and water originates from atmospheric deposition, applications of fertilizer, manure, waste material and dead plant and animal tissue. Under aerobic conditions, nitrate is a fairly stable form of nitrogen. Ammonium (NH_4^+) and organic nitrogen frequently convert quickly to nitrate.

Most of the nitrogen on earth is in the atmosphere, which consists of 78% N_2 gas. Other forms of nitrogen, originating mainly from power plant emissions, internal combustion engines, fertilizer and manure, also occur in the atmosphere. These include nitrogen oxides (NO_x and N_2O), nitric acid (HNO_3) and ammonia (NH_3). Atmospheric nitrogen interacts with the earth's surface when N_2 is "fixed" (changed chemically) by legumes or lightening, or when pollutants are washed-out in precipitation.

In most natural systems, inorganic nitrogen is a scarce nutrient. Plants efficiently use available nitrate and losses to groundwater and surface water are minimal. In agricultural systems, nitrate is added to increase profitability and production of non legume crops. It may be present in amounts exceeding what plants are able to use. As a result, excess nitrate can leach into groundwater or be washed into surface water. Nitrate in soil and water may also eventually cycle to the atmosphere by direct volatilization mainly under anaerobic conditions through a process called "denitrification"

What is groundwater?

Groundwater is the water under the earth's surface that flows freely through tiny pores and cracks in rock and soil and can be pumped from wells. Groundwater supplies 70% of the water used in Wisconsin households and the municipal water used by 608 cities and villages. Groundwater is important not only because it supplies drinking water but also because it provides water to streams, lakes and wetlands.

What is the current status of nitrate in Wisconsin groundwater?

According to a recent study by DATCP, an estimated 10% of Wisconsin wells exceed the groundwater enforcement standard of 10 parts per million (ppm) as nitrate-nitrogen (LeMasters and Baldock, 1997). A Centers for Disease Control (CDC) study showed that 6.5 % of wells in Wisconsin had nitrate-nitrogen levels greater than the standard (CDC, 1998). Databases maintained by DNR, DATCP and other state and federal agencies show 9-14% of wells have nitrate-nitrogen at levels greater than the standards. Concentrations of nitrate in groundwater are not uniform across the state. Nitrate is rarely detected in forested areas while contamination levels are generally higher in agricultural parts of the state. The DATCP study showed that in predominantly agricultural districts, 17-26% of wells had nitrate-nitrogen levels exceeding the groundwater enforcement standard. Locally, greater than 60% of wells located in some agricultural areas vulnerable to groundwater contamination have nitrate-nitrogen levels greater than the enforcement standard. Septic systems can cause nitrate pollution in high-density unsewered subdivisions.

Why are we concerned about nitrate in groundwater?

Human Health

Nitrate can cause a condition called methemoglobenemia or “blue-baby syndrome” in infants under six months of age. Nitrate in drinking water used to make baby formula is converted to nitrite in the stomach. Nitrite changes hemoglobin in blood (that part of the blood that carries oxygen to the body) to methemoglobin depriving the infant of oxygen. In extreme cases it can cause death. While methemoglobenemia is a serious condition when it occurs, the number of cases treated prior to hospitalization has not been documented and is thought to be low. In 1992, a confirmed non-fatal case of methemoglobenemia due to nitrate contaminated groundwater occurred in Trempeauleau County, Wisconsin (Schubert et. al., 1997). An unconfirmed case of methemoglobenemia due to high nitrate in drinking water was reported in July 1998 in Columbia County (Knobeloch, 1998).

Several investigators have studied the chronic health and reproductive impacts of nitrate contaminated drinking water. Recent studies have implicated nitrate exposure as a possible risk factor associated with lymphoma, gastric cancer, hypertension, thyroid disorder and birth defects. In addition, a recent investigation conducted by local public health officials in La Grange County, Indiana implicated nitrate-contaminated drinking water as the possible cause of several miscarriages (Schubert et.al., 1997).

Livestock Health

Nitrate intake by dairy cattle is related to the levels found in forage and drinking water. According to research conducted on dairy cattle (Crowley, 1974), nitrate-nitrogen in drinking water at levels under 10 ppm is safe for animal and humans. Between 10-20 ppm nitrate-nitrogen, water is safe for livestock unless their feed has high nitrate levels. Problems for livestock can occur between 20-40 ppm nitrate-nitrogen if feed contains more than 1,000 ppm. If well water is between 40-100 ppm nitrate-nitrogen, feed should be low in nitrate, well balanced and fortified with vitamin A. At levels between 100-200 ppm nitrate-nitrogen in water, poor appetite occurs. If nitrate-nitrogen is over 200 ppm in water, acute nitrogen poisoning and death is likely in swine.

Aquatic Life

Nitrate does not appear to be acutely toxic to adult fish except at extremely high concentrations where mortality is due to salinity effects (USEPA, 1977). However, available research indicates that nitrate concentrations lower than the drinking water standard cause substantial egg and fry mortality in some salmonid fish species (Kincheloe et al., 1979). When rearing trout or warm water species, the US Fish and Wildlife Service recommends nitrate levels not exceed 3 ppm (Piper, et. al., 1982). Tadpoles exposed to nitrate at the drinking water standard show decreased appetite, sluggishness and paralysis prior to death (Hecnar, 1995).

Surface Water

Groundwater can carry nitrogen (in the form of nitrate) into surface water bodies. Plant–available nitrogen and phosphorus in surface water promotes excessive growth of weeds and algae. This process is called “eutrophication.” Nitrate supplied by groundwater discharge may cause increases in rooted aquatic plants (Lillie and Barko, 1990, Rodgers, et. al., 1995). Available data from Wisconsin showed that in 8% of randomly selected lakes, nitrogen was probably the nutrient controlling aquatic weed growth (Lillie and Mason, 1983). Other data from the same study showed that weed growth in up to16% of Wisconsin lakes might be limited by nitrogen in the water.

There is compelling evidence that the amount of nitrate entering surface water from groundwater is increasing. A long term study carried out at the Deep Loess Research Station in Iowa showed that after 26 years of fertilizer application, nitrate levels in groundwater entering surface water increased from 5 ppm to 23 ppm. Currently, 16% of the nitrate applied within that study area enters surface water from groundwater as baseflow (Steinheimer et. al., 1998). A similar pattern has been seen in the Little Plover River where nitrate-nitrogen has increased from 1-2 ppm in the 1960s to 8 ppm at present. Figure 1 shows increasing nitrate-nitrogen levels in the Little Plover River since 1966 (Albertson and Shaw, 1998).

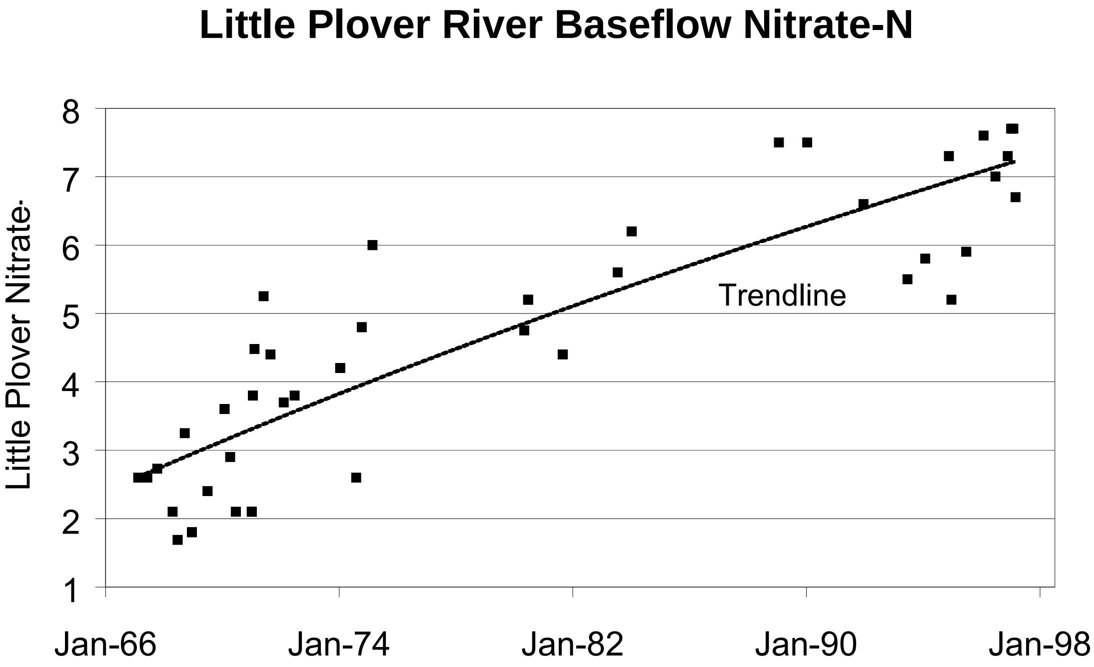

Figure 1. Increasing nitrate-N in Little Plover River baseflow (Albertson and Shaw, 1998).

Nitrate discharge via surface and groundwater has been implicated in the development of a hypoxic (oxygen depleted) area termed the “dead zone” in the Gulf of Mexico. The dead zone is a 6,500 square mile area with oxygen levels too low to support life. Sediment cores from the dead zone show that since the 1950’s, nitrogen levels in offshore sediments have doubled with the increased use of fertilizers in the Mississippi Basin.

Atmosphere

Nitric oxide (NO) emissions from soils result from microbial activity. Soil nitric oxide may contribute as much as 15% to the total nitric oxide emissions budget in the United States. Nitric oxide combines with ozone (O_3) causing depletion of the ozone layer.

Nitrous Oxide (N_2O) accounts for less than 1% of all green house gas emissions, however, it has 270 times the warming potential of carbon dioxide (CO_2). In Wisconsin, fertilizer application accounted for 48% of 1990 N_2O emissions, whereas fertilizer use accounted for 32% of 1990 national emissions. Because Wisconsin is an agricultural state, fertilizer use contributes a higher percentage of N_2O emissions than nonagricultural states (USDOE, 1993).

What are the sources of nitrate to groundwater?

An estimated 2040 million pounds of nitrogen are deposited on Wisconsin's surface annually from agriculture, the atmosphere, septic systems and other sources (Shaw, 1994). Approximately 80% of this originates from agricultural sources divided almost equally among legumes, manure and commercial fertilizer (See Figure 2). Another 18% of the nitrogen comes from atmospheric sources including combustion of gasoline in automobiles, the breakdown of nitrogen fertilizers and manure, and lightning. The remaining 2 % comes from septage, sludge disposal and other sources.

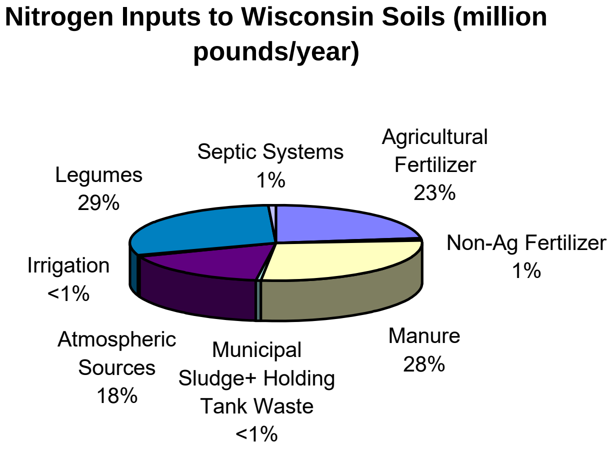

Figure 2. Nitrogen inputs to Wisconsin soils total 2040 million pounds per year from various sources (after Shaw, 1994).

Roughly 10% of the total nitrogen added to Wisconsin soils each year leaches to groundwater as nitrate. Ninety percent of this is from agriculture, 9% from septic systems and 1% from other sources (See Figure 3). Though agriculture is the largest source on a statewide basis, other sources can be locally important. Nitrate loading from septic systems in dense, unsewered subdivisions can be as high as some of the most intensive farming operations (Shaw, 1994).

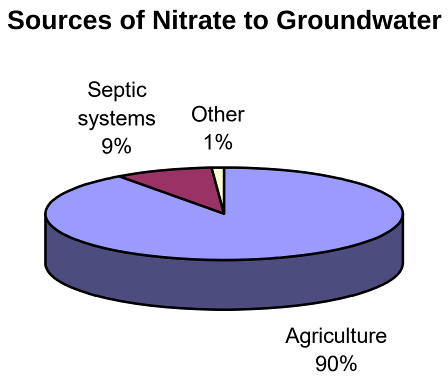

Figure 3. Sources of nitrate to groundwater (Shaw, 1994).

Between 1960 and 1978 fertilizer sales increased dramatically in Wisconsin and the US. In 1960, approximately 27,600 tons of nitrogen were sold in Wisconsin. Annual consumption rose to 220,000 tons in 1978 and has remained fairly constant between 225 - 250 thousand tons applied per year. This was almost a ten-fold increase over twenty years (See Figure 4).

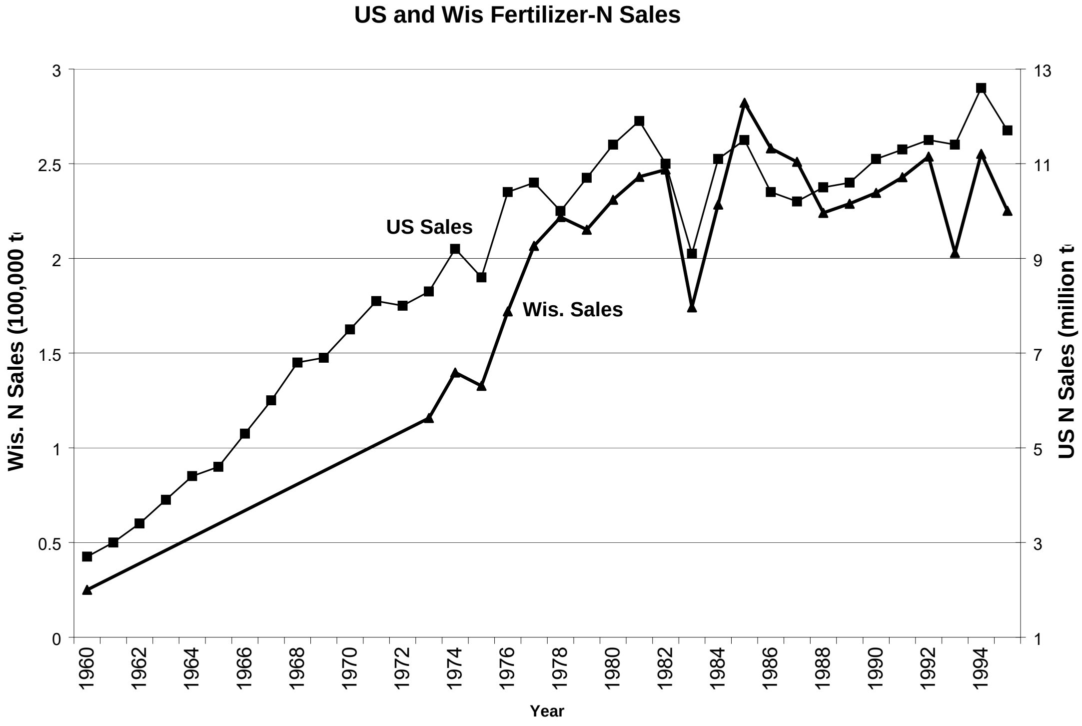

Figure 4. Increasing US and Wisconsin fertilizer-N sales over time.

While nitrogen is needed to increase plant productivity and farm profitability, Wisconsin farmers frequently apply more nitrogen to crops than is necessary to optimize yields. A survey of more than 1500 Wisconsin farmers found that two out of three farmers purchased more nitrogen fertilizer than their crops needed (Shepard et al, 1997). Farmers on average used an excess of 40 pounds per acre of nitrogen beyond University of Wisconsin recommendations for growing corn. This average number is conservative in that it doesn't account for residual soil nitrate, it only accounts for first-year legume and manure nitrogen credits, it assumes no incorporation of manure and the lowest value was used when a range was presented for manure or legume credits. At a cost of approximately $.23 per pound, Wisconsin farmers are spending $9.20 per acre on nitrogen beyond University of Wisconsin Extension recommendations.

How long has the problem been around?

Nitrate pollution at very low levels has probably existed in Wisconsin waters since settlement times. However, both in Wisconsin and other agricultural states, increasing nitrate pollution is a relatively recent phenomenon and is correlated with the increasing use of nitrogen fertilizers over the last 30-40 years (Hallberg, 1989; Hallberg et al 1989). Figure 5 shows a direct link between increasing nitrogen inputs on agricultural lands and water quality in the Big Springs, Iowa watershed.

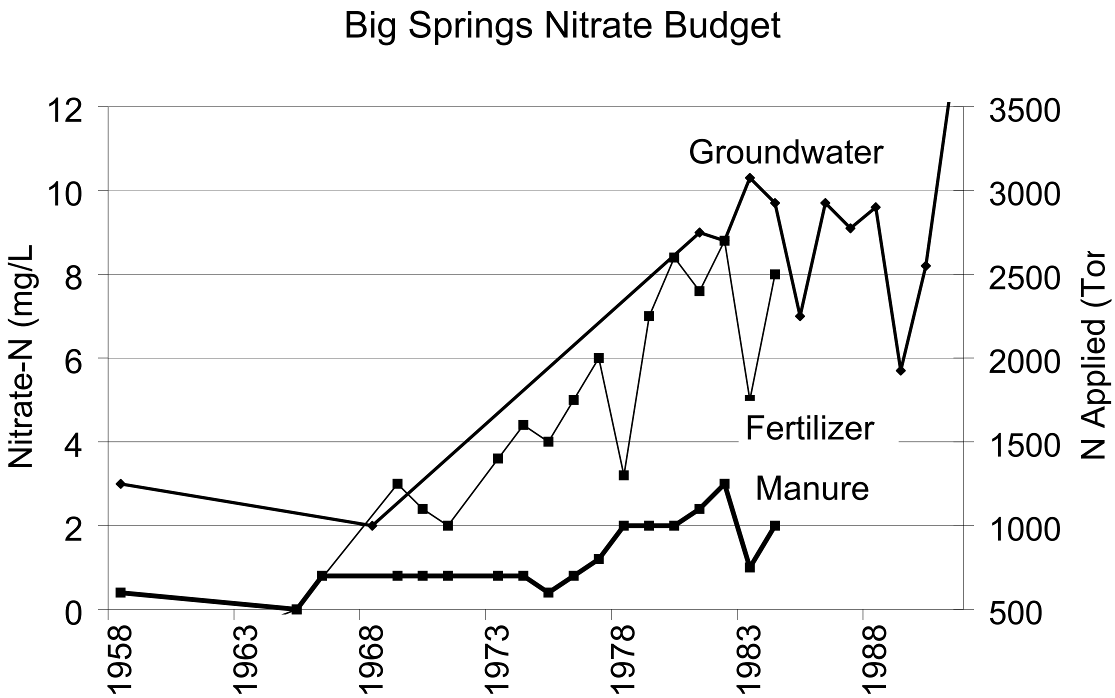

Figure 5. Data from the Big Springs Watershed in Iowa showing a correlation between increasing nitrate-nitrogen concentration in groundwater and increased fertilizer and manure application (Hallberg, 1989).

Similar patterns have since been observed in Wisconsin and Iowa in stream baseflow (Mason et al, 1990; Alberson and Shaw, 1998; Steinheimer et al,1998) and in some wells with long-term records such as the Village of Whitings municipal well located in Central Wisconsin (See Figure 6).

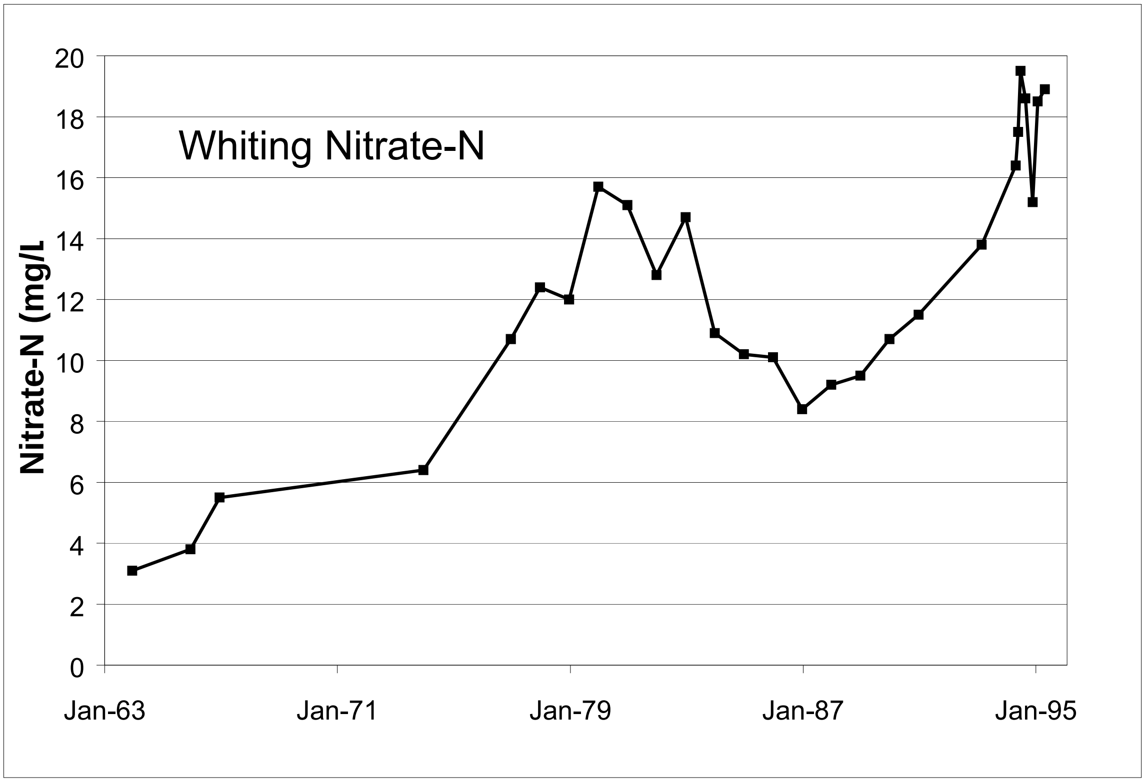

Figure 6. Increasing nitrate-nitrogen in the Village of Whiting's public water supply well.

What's the future for nitrate in groundwater?

Without a reduction in nitrate loading to groundwater, nitrate concentration in Wisconsin groundwater will likely increase and nitrate pollution will likely affect larger areas and larger volumes of groundwater and surface water. This is because, in many parts of Wisconsin, older groundwater originating before the use of chemical fertilizers and having low levels of nitrate is being discharged. It is being replenished with newer, high nitrate, groundwater. The net effect is that the average nitrate concentration in Wisconsin groundwater will likely continue to increase.

What are the tangible costs of nitrate pollution and who bears them?

The tangible cost of nitrate contamination of groundwater can be measured as the cost of water treatment for public, noncommunity (waysides and schools for example) and private well systems. These costs are borne by taxpayers, utility customers and well owners. Groundwater is the source of water for most of the 608 public water supply well systems in Wisconsin. Municipal wells are regulated under the Safe Drinking Water Act, which requires nitrate-nitrogen levels to be below the maximum contaminant level of 10 ppm. At least fifteen of these systems have been required to install nitrate removal systems or drill new wells at a total cost to municipal taxpayers in excess of 10 million dollars. This amount does not include the annual cost of maintaining the systems. For example, the Village of Whiting's anion exchange treatment system cost over $630,000 to install and an additional $9,400 per year for salt. In addition, 1.2 million gallons of water are needed for regeneration of the system. This water is wasted as it is not potable after regenerating the system.

Wells used by schools, churches and businesses are called noncommunity wells. Noncommunity wells are classified as non-transient, meaning the well serves the same people everyday, and transient, meaning the well is used by different people everyday. Fifty-four of the approximately 1,000 non-transient wells in Wisconsin have nitrate levels greater than 10 ppm and 118 of 10,000 transient wells exceed 10 ppm. The cost of water treatment for these systems ranges from $600-$2,500 per well. A conservative estimate of the cost ($600 per well) to well owners is over 1 million dollars. This doesn't include the cost of operation. These wells are regulated under the Safe Drinking Water Act and must have nitrate levels below the MCL of 10 ppm nitrate-nitrogen. Wells are sampled for nitrate annually or quarterly, depending on the population served.

Approximately 800,000 households in Wisconsin use private well water. The groundwater standards for private wells are set under Chapter NR 140 Wis. Adm. Code and regulated under Chapter NR 812 Wis. Adm. Code. The Department of Health and Family Services investigated the cost to families with high nitrate concentrations in private wells (Schubert et. al., 1997) Of 562 well owners who responded to the survey, 70% took no action to reduce their exposure to nitrate contaminated groundwater. Nearly everyone who took action did so because of the presence of a pregnant woman or infant in the household. The most common action taken was the purchase of bottled water at an annual cost of roughly $200. Several families installed nitrate removal systems at an average cost of $850. One family repaired their existing well at a cost of $750. Two families installed new wells. Their costs averaged $7800. Assuming that between 10% and 6.5% of the 800,000 private wells in the state have nitrate concentrations greater than the enforcement standard for nitrate, private citizens have paid between $5.7 and $3.7 million for the cost of mitigating high nitrate levels in groundwater. Between $626,000 and $407,000 of that is spent annually by well owners purchasing bottled water.

What's the current legal framework for addressing nitrate in groundwater?

The Groundwater Law

The Groundwater Law (1983, Wis. Act 410) is the overriding Wisconsin statute which establishes authority for groundwater protection and numerical enforcement standards applicable to all Wisconsin agencies and programs. The enforcement standard is the health-based concentration of a substance at which a facility regulated by state agencies must take action to reduce the level of the substance in groundwater. Once enforcement standards are established, all state agencies must manage their regulatory programs to comply. Private wells are regulated under Chapter 160, Wis. Stats. However, nitrate is handled differently than other substances of public health concern. Under sec. 160.25(3), Wis. Stats., a regulatory agency in not required to impose a prohibition or close a facility when nitrate-nitrogen levels attain or exceed the enforcement standard if the agency determines that this occurred in whole or in part because (a) high background levels of nitrate or (b) the additional concentration does not represent a public welfare concern.

The Safe Drinking Water Act
The maximum contaminant level (MCLs), set by USEPA, is the level of a contaminant at which no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety. The MCL for nitrate-nitrogen is 10 ppm - the same as Wisconsin's enforcement standard. Public water supplies, transient and non-transient noncommunity wells monitor for nitrate and must meet the MCL

What are current management strategies for nitrate pollution?
There are four entities involved in agricultural nitrogen management efforts in Wisconsin:

- The University of Wisconsin-Madison and the University of Wisconsin-Extension provide research information and educational programs on nutrient management largely through the Department of Soil Science in College of Agriculture and Life Sciences. The University of Wisconsin's Nutrient and Pest Management program is an educational effort based on soil testing programs and University of Wisconsin Extension Soil fertility recommendations by soil type and crop.
- The Nonpoint Source Water Pollution Abatement Program cost shares the use of best management practices to protect water quality by reducing the amount of nutrients from urban and rural sources.
- The Agricultural Conservation Program is a federal program administered to restore and protect land and water resources and preserve the environment. This program uses cost sharing of best management practices and outreach efforts to reduce nutrient loads from agriculture.
- County land conservation departments provide nutrient management planning funded by DATCP's Land and Water Resource Management grants.

The DNR wastewater program regulates the discharge of nitrogen containing wastewater and biosolids to the land surface and potentially to groundwater. The wastewater program regulates:

- Discharge of municipal and industrial wastewater to land treatment systems such as spray irrigation systems, seepage cells and ridge and furrow systems.
- Discharge of municipal and industrial sludges, biosolids and industrial liquid wastes through land application.
- Discharge of septage through land application.
- Impacts on groundwater from wastewater treatment and storage lagoons leaking in excess of groundwater standards.

Disposal of animal waste (manure) from concentrated animal facilities is also regulated. Facilities with over one thousand animal units must have a Wisconsin Pollutant Discharge Elimination permit as required under chapter NR 243 Wis. Adm. Code. Chapter NR 243 does the following:

- Establishes design standards and accepted animal waste management practices for the large animal feeding operations category of point sources.
- Establishes the criteria under which the DNR issues a permit to other animal feeding operations, which discharge pollutants to waters of the state.

The Department of Commerce under COMM 83 Wis. Stats regulates private septic systems. Currently COMM 83 is under revision. The private septic system program does the following:

- Establishes design standards and accepted waste management practices for private septic systems.
- Establishes the criteria under which sanitary permits are issued to build private septic systems, which discharge pollutants to waters of the state.
- Establishes soil site evaluation standards for placement of septic systems.

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Appendix B

Food Land and Water –
Can Wisconsin Find Its way?

Food, Land and Water: Can Wisconsin Find Its Way?

Our food system is under stress, and so are the natural resources that sustain it.
Where do we go from here?

By James Matson*

Feeding Wisconsin

Without food, there is no life. And without land and water, there is no food. Our daily food needs bind us to the earth just as surely as if we were trees. We forget that at our peril.

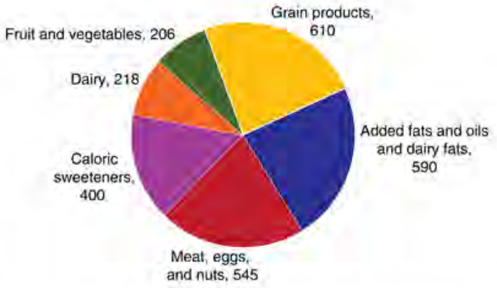
Photo courtesy of The Lake Today

Wisconsin now has nearly 6 million people, and there may be 7 million when today's children retire.[1] Most of us live in cities and suburbs, with no farms in sight. Together, we in Wisconsin consume (or waste) about 30 million pounds of food *every single day*.[2] Our cities have about a week's supply of food on hand at any given time.[3] Our food supply must be replenished without fail, every day of every year, for all generations to come.

Our food supply depends on land and water. Wisconsin consumes (or wastes) about 30 million lbs. of food every day, and our population is growing. Our cities have about one week's supply of food on hand at any given time.

Although food is a basic necessity, our diet is partly a matter of personal choice; and our choices strongly affect our environmental "footprint." In the year 2000, the average U.S. resident consumed (or wasted) about 593 pounds of milk and dairy products, 428 pounds of vegetables, 263 pounds of meat and poultry, 280 pounds of fruit, 200 pounds of grain products, 250 eggs, 152 pounds of added sweeteners, and 75 pounds of added fats and oils.[4]

Grain and animal products provide most of the energy (calories) in our diet. Food calories are essential for life, but most of us consume far more than we need. In the year 2000, the U.S. consumed nearly 25% more calories *per person* than we did in 1970.[5] Refined grain products, fats, oils, and added sweeteners accounted for nearly all of the increase.[6]



Daily calories per capita by food group, 2010

Added fats and oils and caloric sweeteners are added to foods during processing or preparation. They do not include naturally occurring fats and sugars in food (e.g., fats in meat or sugars in fruits).
Source: USDA, Economic Research Service, Loss-Adjusted Food Availability Data.

Our diet is partly a matter of choice, and our choices strongly affect our environmental "footprint." Grain and animal products provide most of the energy calories in our diet. In 2000, the U.S. consumed 25% more calories per person than we did in 1970.

Chart: USDA-ERS

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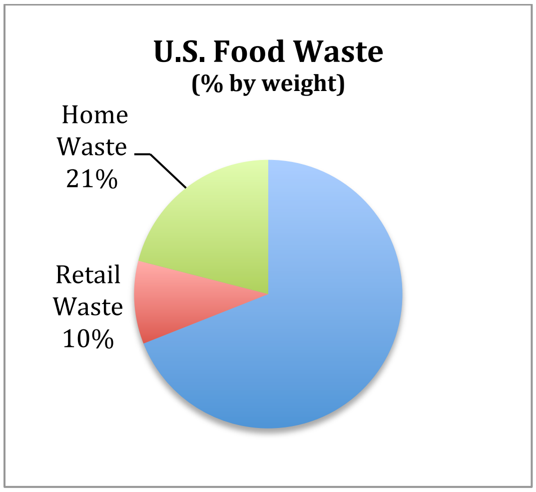
* James Matson retired in 2011 after 28 years as chief legal counsel for the Wisconsin Department of Agriculture, Trade and Consumer Protection.

Much of the U.S. food supply is wasted. In 2010, we wasted about 31% of our food by weight, including 10% at retail and 21% in our homes.[7] That amounts to 1,249 Calories (kcal) per person per day. The top wasted food groups were meat, poultry and fish (30% of waste), vegetables (19% of waste) and dairy (17% of waste).[8] About 30 million *tons* of food are dumped in U.S. landfills each year – enough to feed everyone in Wisconsin for about 5 years.[9] Meanwhile, nearly 15% of U.S. households suffer from food insecurity.[10] When we waste food, we are also wasting land, water, energy and farm inputs. The U.S. government has called for voluntary efforts to reduce food waste by 50% in 15 years.[11]



The U.S. wastes almost 1/3 of its total food supply. We dump about 30 million tons of food in landfills each year – enough to feed everyone in Wisconsin for 5 years. When we waste food, we also waste land, water, energy and farm inputs.

Chart based on USDA-ERS data.

Food from Far Places

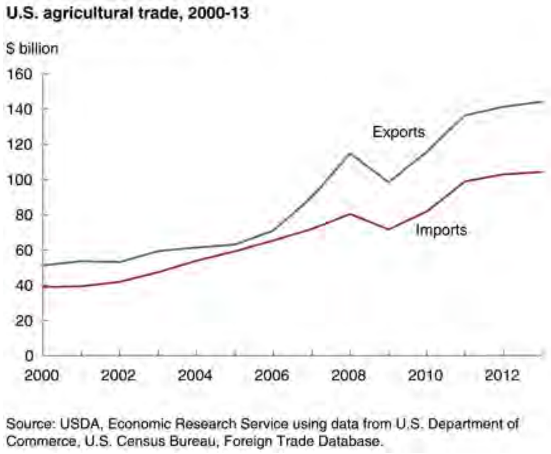
Although our food comes from the land, much of that land is located outside Wisconsin. Wisconsin is part of a vast worldwide food system, and is both an importer and exporter of food. As "America's Dairyland," we ship 90% of our dairy products (mainly cheese) to other states and foreign countries[12] – bringing dollars back home. But like the rest of the U.S., we get nearly half of our fresh vegetables from a single distant location – the now drought-stricken state of California.[13] Over the years, food production has become far more geographically specialized. Most of our food now travels many hundreds, if not thousands, of miles.

Much of our food now comes from foreign countries. U.S. food imports *doubled* in the last decade, to over $104 billion in 2013.[14] The U.S. now imports about 17% by volume of its total food supply,[15] including 50% of our fresh fruit (especially bananas and grapes), 20% of our fresh vegetables (mainly from Mexico), and up to 90% of our seafood (about half produced by aquaculture, and much illegally caught).[16] About two-thirds of our apple juice comes from China.[17] Nearly 116,000 foreign facilities ship food to the U.S. (over 13,000 in Japan and 10,000 in China alone).[18] U.S. authorities inspect less than 2% of all food import shipments.[19]

Feeding the World

The U.S. *exports* even more food than it imports. We are the world's biggest food exporter, and much of that food comes from the rich prairie soil of the Upper Midwest – one of the world's most important agricultural resources. We export about 20% by volume of all U.S. farm products[20] – including 50% of our wheat, 40% of our soybeans, 20% of our corn, 20% of our processed vegetables, 20% of our pork and poultry, and 16% of our milk products.[21] We produce far more of these food staples than we need for domestic consumption alone.

U.S. agricultural exports nearly *tripled* in the last decade, to over $175 billion in 2014.[22] Wisconsin participated in this export surge. In 2014, Wisconsin exported more than $3.6 billion worth of agricultural products to more than 145 countries.[23] Wisconsin food exports grew by nearly 14% in 2014, continuing an upward trend.[24] Wisconsin *dairy* exports to foreign countries grew by 41% in 2013 alone.[25]



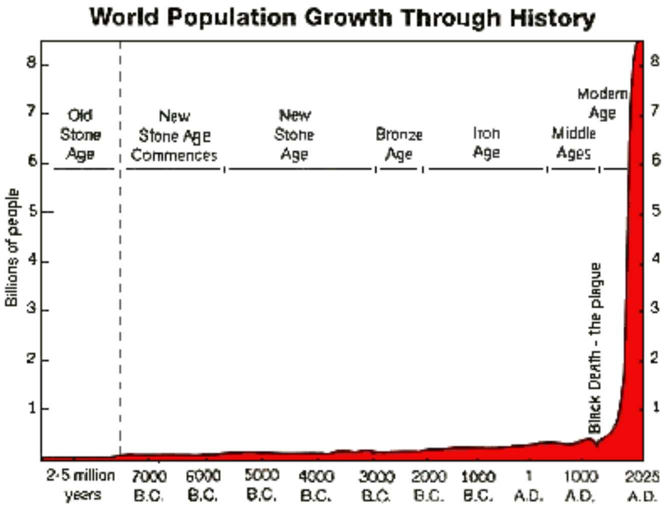
Source: USDA, Economic Research Service using data from U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Database.

Most Wisconsin food products are shipped out of the state, and most of what we eat comes from beyond our state borders. Food production is geographically specialized, and food travels long distances. The U.S. imports and exports more food than ever before.

Chart: USDA-ERS

Our food system, like our financial system, is now heavily exposed to the world market. A change in Chinese consumption, a poor crop in Brazil, or a dairy surplus in New Zealand can have a big impact on commodity prices and land use decisions in Wisconsin. The world food market, like the world financial market, is highly volatile. For example, the world corn price dropped 50% from its 2012 record high after U.S. farmers increased corn output by 30%.[26] But despite short-term volatility, global food demand has been growing steadily over the long haul.

In the last 100 years (just one long human lifetime), the Wisconsin population has more than *doubled*, the U.S. population has more than *tripled*, and the world population has more than *quadrupled.*[27] World population, now at 7.3 billion, is projected to reach 9 or 10 billion by 2050.[28] Although population growth rates are now slowing in most countries, population totals are still climbing. Demographic momentum and greater longevity will continue to drive population growth through the mid-21st Century, unless there is an unforeseen catastrophe.



Population growth and dietary shifts are driving a surge in world food demand. Our food system, like our financial system, is now heavily exposed to the world market.

A long view of human population growth.

Chart: The Population Reference Bureau (1994).

Changing diets are also having a big impact on food demand. Rising nations like China want more animal protein in their diets, and they can now afford to pay for it on world markets. World meat production *quadrupled* over the last 50 years, and world milk production *doubled*.[29] China's *per capita* dairy consumption grew more than five-fold between 1991 and 2011 alone.[30] By one U.N. estimate, the world may consume 73% *more* meat and eggs and 58% *more* dairy products by 2050.[31]

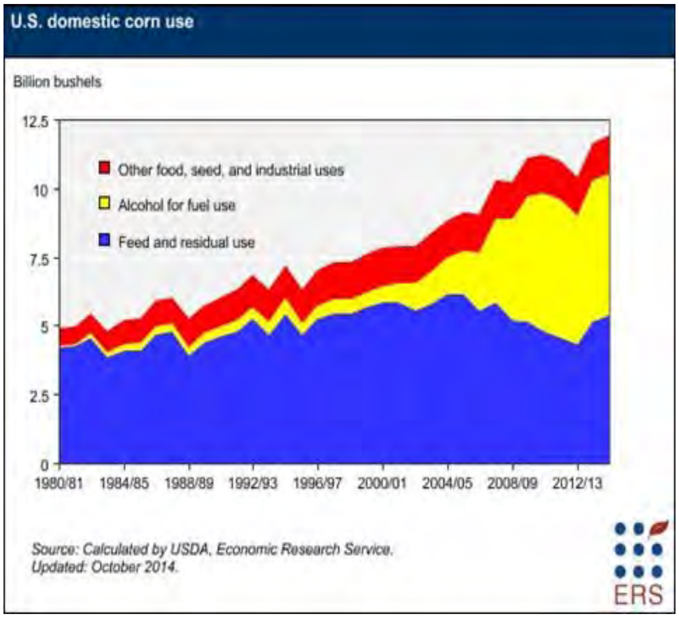
A diet high in animal protein (such as the U.S. diet) typically requires far more land, water and crop production than a diet based on plant protein alone, because livestock require a lot of feed.[32] In fact, the biggest cash crops in the U.S. – corn and soybeans – go mainly to feed livestock.[33] At least half of our total corn crop (including exported corn) goes for livestock feed, as does most of our soybean crop.[34]

Feeding Our Cars and Our Waistlines

U.S. *cars* also compete with livestock and people as corn consumers. Ethanol fuel production now claims 30-40% of the entire U.S. corn crop,[35] or 11-15% of the *world* corn crop (in 2014, the U.S. produced almost 37% of the world's corn).[36] Federal ethanol mandates have spurred a rise in U.S. corn acreage,[37] displacing other crops and land uses such as pasture and grassland.[38]

Only about 10% of the total U.S. corn crop goes directly to human food, and most of that goes for refined oils and sweeteners.[39] High fructose corn syrup, a leading ingredient in soda, fruit drinks and processed foods, now provides much of the added sugar in the U.S. diet. In 1945, Americans drank 4 times more milk than soft drinks; but by 1997, Americans drank 2.5 times more soft drinks than milk.[40] A sugar-heavy U.S. diet is fueling an obesity and diabetes epidemic.[41]

If current use (and waste) trends continue, the world will need to produce *twice as much* grain and forage by 2050 to meet rising food, feed and bio-fuel demands.[42] Without higher production or a change in crop uses, or both, world food and feed prices could go through the roof. That will affect food security and social stability – especially in volatile countries like Egypt, Pakistan and Nigeria that spend nearly half of their household income on food.[43]



If current use (and waste) trends continue, the world may need to produce twice as much grain by 2050 to keep food prices stable. But food production is already testing the limits of our land and water resources.

Today, most U.S. corn goes for livestock feed and car fuel. Only about 10% of the U.S. corn crop goes directly to human food (mostly refined oils and sweeteners).

Cars consume a growing share of our corn crop.

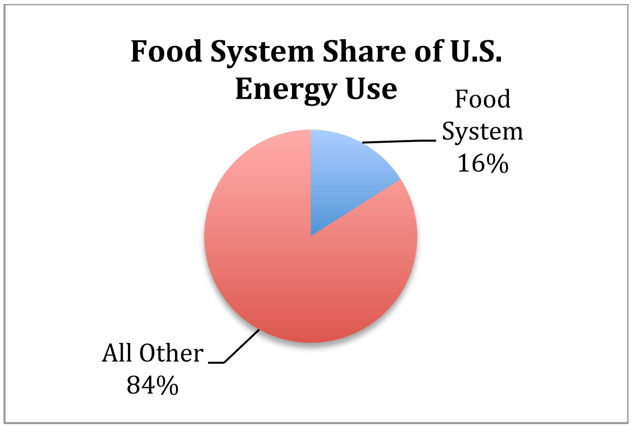
Chart: USDA-ERS. Chart does *not* include exported corn, which accounts for up to 20% of the U.S. corn crop and goes mainly for livestock feed in other countries.

Current agricultural production is already testing the limits of our land and water resources. Even with improved technology and management, further growth will come at increasing cost to the environment. While surging demand may be an economic boon to some, it will almost surely increase environmental stress in Wisconsin and throughout the world.

Food, Energy and Greenhouse Gas

In 1918, within memory of a few people alive today, horses and mules did much of our nation's work and consumed 25% of all U.S. crop production.[44] But the age of animal power has ended in the U.S. and much of the world. Since 1918, the U.S. has dramatically increased economic output by substituting fossil fuel and energy-driven technology for animal and human labor. The U.S., with 5% of the world's population, now consumes about 20% of the world's annual fossil fuel production (all uses).[45]

The U.S. food system, like the rest of the U.S. economy, uses a lot of energy. According to one careful USDA study, the food system (farm through home kitchen) now accounts for about 16% of all U.S. energy use.[46] The vast majority of that energy comes, ultimately, from fossil fuel.[47] It now takes about 7-10 Calories (kcal) of fossil fuel to produce, process and deliver just *one* Calorie (kcal) of food energy to our bodies.[48] We live, almost literally, on fossil fuel.



From farm through home kitchen, the U.S. food system accounts for about 16% of all U.S. energy use.

We use about 7-10 Calories of fossil fuel to produce, process and deliver each food Calorie that we consume. We live, almost literally, on fossil fuel.

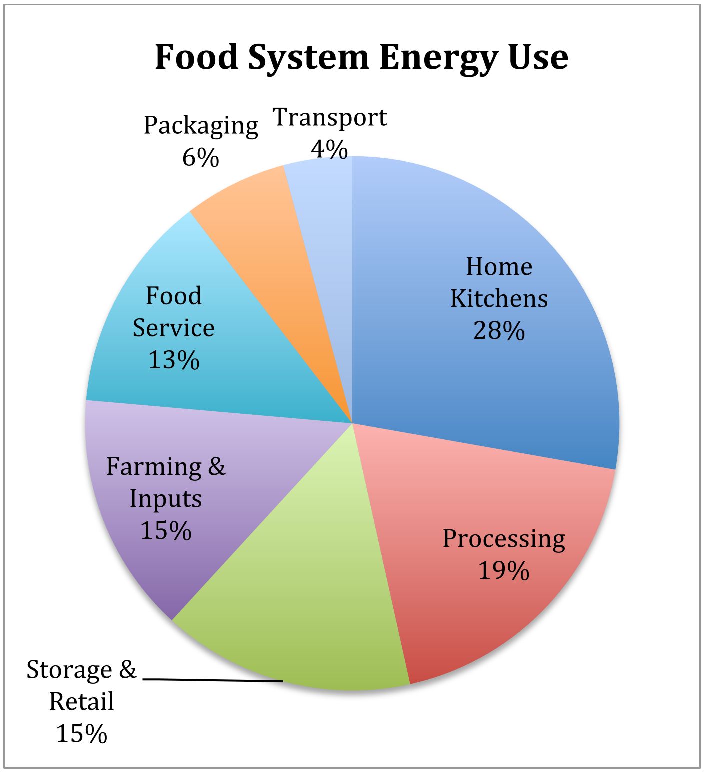
Chart based on Canning, et al., "Energy Use in the U.S. Food System," USDA-ERS, ERR-94 (March 2010)

Household energy uses related to food (home refrigerators, freezers, stoves, dishwashers, microwaves, garbage disposals, food processors, toasters, grocery store trips and the like) are, by far, the biggest energy users in the U.S. food system.[49] Household uses account for about 28% of all food system energy use, followed by commercial food processing at 19%.[50]

Farming, including energy embodied in farm inputs like fertilizer and pesticides, accounts for just 15% of all food system energy use. Non-household transportation accounts for just 4%.[51] Relatively low-cost, fuel-efficient bulk transportation has contributed to the "de-localization" and even globalization of our food system. In many cases, it costs less to transport food from specialized production sites in California, Mexico or even China than to produce it locally.

When we burn fossil fuel, we produce carbon dioxide, one of several "greenhouse gases" that contribute to global warming.[52] The U.S. is one of the world's top greenhouse gas emitters,[53] and a significant share of that greenhouse gas comes from our food system. Assuming that the U.S. food system (farm through home kitchen) accounts for 16% of U.S. fossil fuel use, it also accounts for roughly 16% of U.S. *carbon dioxide* emissions.[54] Those carbon dioxide emissions represent about 13% of all U.S. greenhouse gas emissions.[55]

Farms also emit nitrous oxide (mainly from nitrogen fertilizer and livestock manure) and methane (mainly from cattle digestive processes and livestock manure), which together represent 9% of all U.S. greenhouse gas emissions.[56] All told, the U.S. food system (farm through home kitchen) accounts for roughly 22% of U.S. greenhouse gas emissions.



Home kitchens are the biggest energy users in the U.S. food system.

The U.S. food system, from farm through home kitchen, accounts for roughly 22% of all U.S. greenhouse gas emissions.

Chart based on Canning, et al., "Energy Use in the U.S. Food System," USDA-ERS, ERR-94 (March 2010).

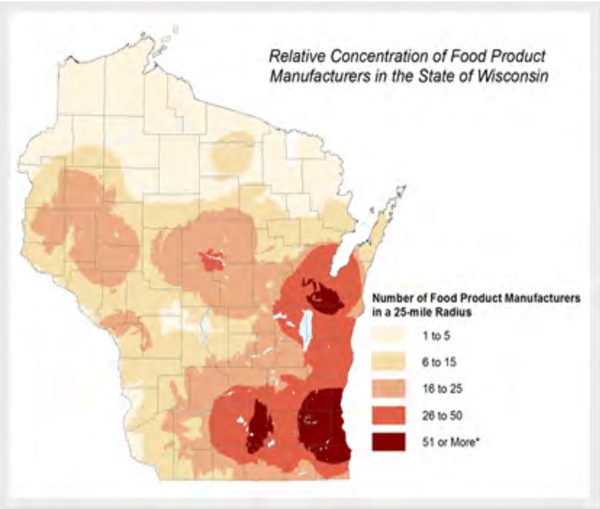
Ethanol has been widely touted as a bio-fuel alternative to fossil petroleum.[57] Indeed, corn ethanol now provides about 10% of all U.S. car fuel.[58] But a lot of fossil energy is needed to grow, harvest, transport and process the corn used to make that ethanol. The net energy balance is improving; but, on average, fossil energy inputs still offset about half the energy provided by corn ethanol.[59]

Producing car fuel on the world's best farmland also poses big dilemmas, including "food vs. fuel," "cars vs. livestock" and "cars vs. soil and water conservation" dilemmas. Emerging technology may make it possible to produce ethanol from alternative materials, such as switch grass or woody brush, that can be grown on more marginal land with fewer inputs and less erosion; but there are many obstacles to viable commercial production.

Food and the Wisconsin Economy

Agriculture and food processing are important to Wisconsin's economy. While other industries suffered during the recession that began in late 2007, Wisconsin agriculture generally benefited from strong world demand and high commodity prices (although prices have retreated lately).

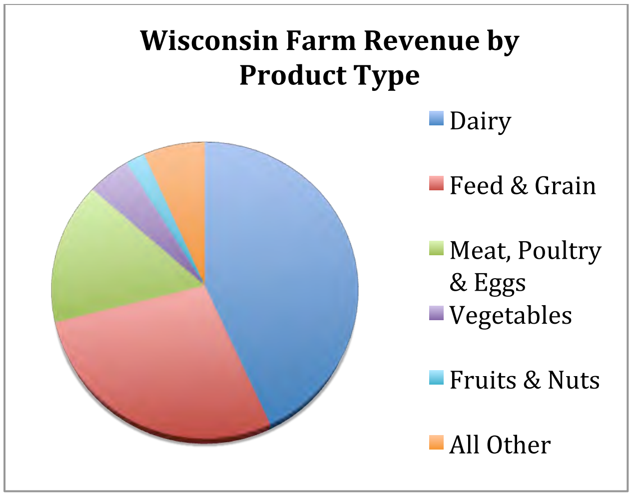
Agriculture and food processing contributed $88 billion to Wisconsin's economy in 2012 (up from $60 billion in 2007), and provided 12% of the state's jobs (up from 10% in 2007).[60] Much of that contribution came from farm supply and wholesale food processing activities, not just farming. Farming itself accounted for about $20.5 billion (less than one-fourth) of the $88 billion total.



Agriculture, farm supply and wholesale food processing activities contributed $88 billion to Wisconsin's economy in 2012, up from $60 billion in 2007. Farming itself accounted for about $20.5 billion (less than one-fourth) of the $88 billion total.

Map: UW-Extension (2009)

Wisconsin food industries depend heavily on livestock. The dairy industry alone generated over $43 billion in economic activity in 2012.[61] Wisconsin is the nation's 2nd leading milk producer, and leads the nation in cheese manufacturing.[62] Meat and poultry processing (including beef from culled dairy animals) is the state's 4th largest manufacturing industry.[63] Most of Wisconsin's farm revenue comes from the production of milk, meat and livestock feed (including grain and forage crops). Of course, livestock producers also *buy* feed, so high feed prices (which help grain producers) can hurt their bottom line.



Wisconsin food industries depend heavily on livestock. Most of our farm revenue comes from milk, meat, poultry, and livestock feed (including grain and forage crops).

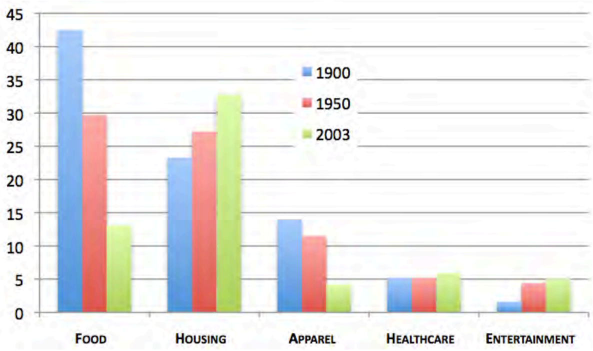
Chart based on USDA-NASS statistics, 2012.

Wisconsin grows 57% of the nation's cranberries, and is among the nation's top producers of corn, potatoes, livestock forage crops (such as alfalfa) and processed vegetables (such as snap beans and sweet corn).[64] Wisconsin has a major brewing industry, and we are a national leader in value-added products such as artisan cheese, craft beer, specialty meats and organic food.

In Wisconsin, as elsewhere, there is growing consumer and community interest in "local food." But at this moment, "local food" accounts for just a fraction of what we eat. Direct farm-to-consumer sales account for *less than half of 1%* of all U.S. agricultural sales,[65] and Wisconsin is steadily losing farmland near its population centers.[66] For most of the year, we get our fresh fruits and vegetables from warmer places. Despite our worthy "local food" aspirations, there has been a broad overall trend toward "de-localization" of our food system.

A Changing Food System

The average U.S. household now spends about 10% of its annual budget on food, compared to over 40% in 1900.[67] By contrast, non-industrialized countries spend nearly *half* of their household income on food (the percent varies by country).[68]



U.S. Household Spending

Industrialized food production has helped the U.S. feed a growing population at reduced per capita cost. But large enterprises now dominate our food system.

Chart courtesy of *The Atlantic* (April 5, 2012). In this chart, household healthcare costs do not include government-paid or employer-paid health insurance benefits.

Industrialized food production has helped us feed a growing population at reduced *per capita* cost. It has also brought us convenience, and a wide array of food products. The average U.S. supermarket now carries more than 42,000 items from all over the world.[69] But farmers and consumers are now tied to a concentrated food system in which large global enterprises play a commanding role. That can affect Wisconsin's economy and environment, for better or worse. The pork industry is a case in point:

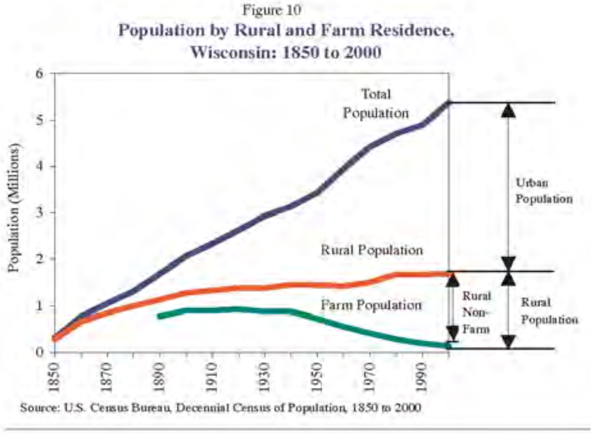
- Just 4 companies slaughter nearly 70% of all U.S. hogs.[70] The largest (Smithfield) is Chinese, and the 3rd largest (JBS) is Brazilian.[71] JBS proposes to buy the 4th largest (Cargill Pork Packing), which would further increase concentration and bring half the U.S. pork industry under foreign control.[72]
- Plants that slaughter over a million hogs per year (per plant) now supply 95% of the U.S. market (compared to 27% in 1976).[73] A single North Carolina plant slaughters 8 million hogs a year.[74]
- Just 100 farm operators – mainly located near processing centers in western Iowa, southwestern Minnesota and North Carolina – now raise over half of all U.S. hogs. Each raises *at least* 50,000 hogs a year.[75]
- The total number of U.S. hog farms fell by 90% in just 30 years, from 1980 to 2010.[76]
- In Wisconsin, small hog farms nearly disappeared when processing facilities were consolidated near more intensive hog production areas in other states.[77]

Our food now comes from fewer, bigger, and more highly specialized farms. Just 2% of U.S. farms now account for well over 50% of all U.S. farm product sales.[78] More than half of the farms with annual gross sales under $350,000 are operating at a loss.[79] Most farm household income now comes from *off-farm* sources,[80] and fewer than half of all farm operators consider farming to be their primary occupation.[81]

The share of our population that lives on farms has been falling for well over a century. In the mid-1800's, nearly 70% of Wisconsin residents lived on farms (and produced their own, very "local" food).[82] But Wisconsin's farm population fell to 35% by 1920, to 10% by 1970, and to less than 2% (including "hobby farms") by the start of the 21st Century.[83]

Farm families now constitute only 8% of Wisconsin's *rural* population;[84] and they, like urban residents, buy their food at supermarkets, convenience stores and fast-food restaurants. Today, Wisconsin has only 10,000 dairy farms, compared to 140,000 in 1950.[85] "America's Dairyland" now has over twice as many *prisoners* as dairy farm operators.[86]

In Wisconsin, just 13% of farms now account for 76% of farm product sales and 43% of all farmland.[87] The average Wisconsin farm operator is over 57 years old, and absentee owners now control 34% of all Wisconsin farmland.[88] These trends have had a huge impact on rural communities, and they are likely to affect farm conservation in the years to come.



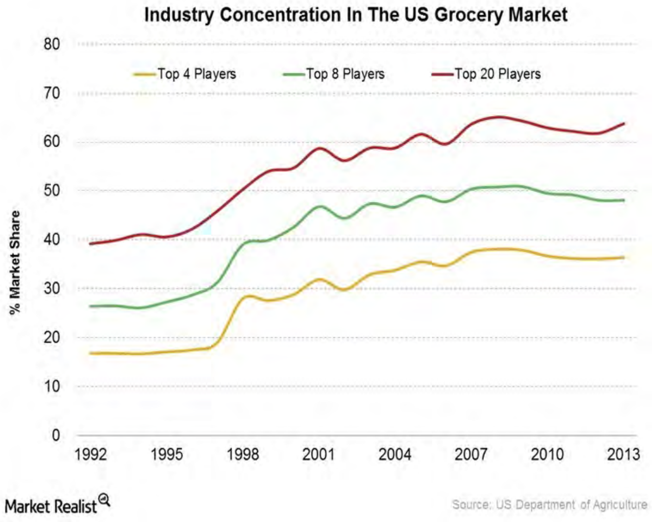
Just 13% of Wisconsin farms now account for 76% of Wisconsin farm product sales, and operate 43% of all Wisconsin farmland. Absentee owners now control 34% of Wisconsin farmland. Farm families constitute less than 8% of Wisconsin's RURAL population.

Chart: Wisconsin Bluebook, 2003-04.

Market Power

Today, few consumers produce even a tiny fraction of their own food; and few farmers sell food directly to consumers.[89] Farmers *and* consumers depend on a vast "food pipeline" that includes commodity dealers, trade brokers, slaughter plants, dairy plants, food processing plants, grain warehouses, food storage facilities, railroads, trucking networks, wholesale distributors, and retail food chains. Industrial networks also supply farmers with seed, fertilizer, pesticides and other inputs. Many of these networks have a global reach, and are now dominated by a handful of global players.

In today's food system, big companies shape food production practices right down to the farm level. The top 4 food retailers (led by Wal-Mart) now control nearly 40% of the U.S. grocery market, compared to just 17% in 1992.[90] They buy from a limited number of favored suppliers, and their procurement demands affect the entire food system. Leading fast-food chains (like McDonald's) cast an equally long shadow, as do their beef and poultry suppliers (like Tyson's). Restaurants now claim 50% of our retail food dollars, compared to just 25% in 1955.[91]



The food industry is increasingly concentrated. For better or worse, major food companies shape food production practices right down to the farm level.

Concentration in the U.S. Retail Grocery Market (1992-2013).

Chart: USDA, reproduced by Market Realist

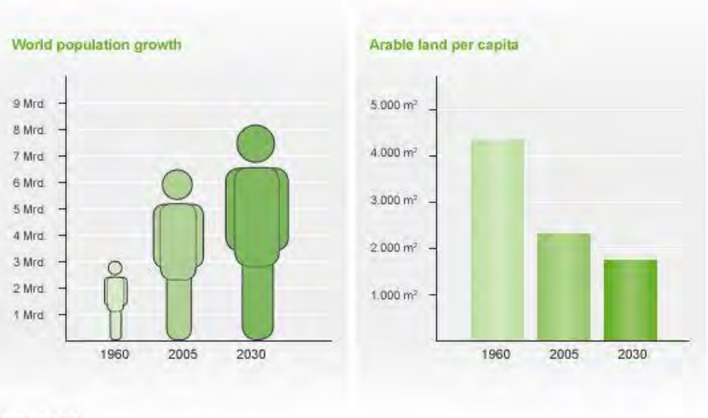
Concentration extends to the genetic foundation of our food supply. Just 2 companies (Monsanto, DuPont, and entities they control) now supply about 70% of all U.S. corn seed (up from 45% in 2004) and 60% of all U.S. soybean seed (up from 40% in 2004).[92] They also hold patents on most of the seed sold by their competitors.[93] Patents (and corn hybridization) prevent farmers from reproducing seed, as they once did.[94] In 1982, soybean farmers still produced 50% of their own seed; today, they produce almost none.[95] Farmers are now mostly captive seed buyers, rather than independent seed producers.

Meanwhile, the steady consolidation of food processing industries has transformed whole sectors of the farm economy (the pork industry is just one example). Many food processors procure farm products under advance contracts with chosen farmers, rather than in open market transactions. The contracts often control farming practices in great detail. Processors use contracts to drive down their supply costs, minimize their financial risks, and tailor farm products to fit their processing, marketing, food safety and "public image" needs (including, potentially, their animal welfare and environmental "image" needs). Farmers who want a contract must meet processor specifications. Contract requirements may affect farming methods for better or worse.

Food and Land

Agriculture uses more land than any other human activity, so it naturally has a big impact on the environment. Nearly 40% of the world's land area is now devoted to agriculture, compared to just 7% in 1700.[96] Even so, farmland availability has not kept pace with exploding world population and food demand. Nearly all of the world's useful farmland is already under production, and further conversion of marginal lands (such as rain forest, wetlands, and dry grassland) will come at great expense to the environment. There will be no more "new" continents to exploit. Our future will depend on saving what we have, and using it wisely.

Today, the world has only *half as much farmland per capita* as we did just 50 years ago.[97] That *per capita* loss is mainly due to a doubling of world population. But good farmland is also being lost to development, drought, erosion, salinization, declining fertility, over-grazing and environmental degradation. The U.S. is no exception. In less than 3 decades, from 1982 to 2010, more than 24 million acres of U.S. farmland were lost to development alone.[98] That is equivalent to nearly 70% of the total land area of Wisconsin.



Source: FAO

Today, the world has only half as much farmland per capita as it did just 50 years ago. In less than 3 decades, the U.S. lost more than 24 million acres of farmland to development. That is equivalent to nearly 70% of the total land area of Wisconsin.

Chart: United Nations (FAO).

About 40% of Wisconsin's total land area is still devoted to farming, not counting forest production.[99] But Wisconsin has been losing 20-30 thousand acres of farmland *each year*, mainly to development.[100] That includes some of the best farmland in the state.[101] All told, over 777 thousand acres of Wisconsin rural land (including over 520 thousand acres of farmland) were converted to development from 1982 to 2007.[102] That is an area the size of Dane County.

Wisconsin has been losing over 20 thousand acres of farmland each year. From 1982 to 2007, over 777 thousand acres of Wisconsin rural land (including 520 thousand acres of farmland) were converted to development. That is an area the size of Dane County.

Map: Wikimedia

Despite growing food demand, Wisconsin is targeting substantially *less* farmland for preservation than it did in the 1980's.[103] Land use conflicts are growing as farms become more industrialized, as sprawling "checkerboard" development turns unbroken stretches of farmland into disjointed scraps, and as more homes are located near large-scale farming operations. Some farm operators are finding it hard to expand and modernize, because suitable land is in short supply.

Food and Water

Agriculture is a huge consumer of water, as well as land. In fact, agriculture accounts for up to 80% of consumptive water use in the U.S.[104] In western states, which rely heavily on irrigation, water shortages have reached crisis proportions. In California, which accounts for 12% of all U.S. farm production,[105] some of the world's best farmland is now being idled by drought. California groundwater levels have dropped by 30 million acre-feet in the last 3 decades, as farmers have pumped more water to meet growing food and specialty crop demands (including rapidly growing Asian demand).[106]

Almonds are a widely cited example. California now produces 82% of the *world's* almonds.[107] Almonds – a favorite of health-conscious consumers – are the state's second leading crop by acreage, and first by export value.[108] About 600 gallons of water are needed to grow just *one pound* of almonds.[109] As surface water irrigation sources have dwindled, much of that water has been pumped – essentially free of charge – from underground aquifers.[110] Despite groundwater depletion and drought, California farmers have responded to surging world demand by *doubling* their water-intensive almond production over the last decade.[111]

In a sense, California is mining its water reserves and sending them elsewhere in the form of food. All told, California may now be "exporting" about 500 gallons of "virtual" water per resident per day.[112] Some aquifers may require thousands of years to replenish, if they can be replenished at all.

The same problem exists, on an even larger scale, in the historic "Dust Bowl" region of the southern plains – where agriculture now depends on irrigation water pumped from the great Ogallala aquifer. The water now being pumped from the Ogallala began its underground journey over 10,000 years ago, at the end of the last Ice Age.[113] At current pumping rates, the great aquifer – which took thousands of years to fill – will be largely depleted within 30 years.[114]

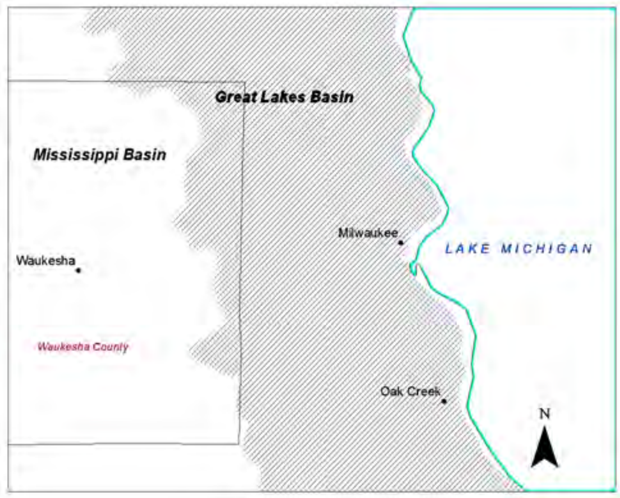
Wisconsin has abundant water compared to California and the southern plains, and we are less dependent on irrigation. But irrigation is important in Wisconsin's Central Sands region, which accounts for most of our high-value potato, vegetable and cranberry production, and a significant share of our grain and dairy production. In the Central Sands, crop irrigation and new dairy operations have contributed to a rapid proliferation of high capacity wells.

Agriculture is, by far, the nation's biggest water user. Wisconsin has abundant water compared to many states, and we are less dependent on irrigation. But irrigation is important in some areas, such as the Central Sands, where the rapid growth of high capacity wells is affecting groundwater and surface water levels.

Map courtesy of the Natural Resources Foundation of Wisconsin

The Central Sands region now has over 3,231 high capacity wells of various kinds, compared to only 100 in the 1950's.[115] High capacity wells are now having a significant cumulative impact on groundwater and surface water levels, including lake and trout stream levels.[116] But agriculture is only part of the problem. Urban development is also putting stress on groundwater supplies, in the Central Sands and elsewhere.[117]

In Waukesha County, an explosion of urban development has depressed groundwater levels and degraded groundwater quality, to the point that the City of Waukesha and surrounding suburbs now want to import drinking water from Lake Michigan.[118] Over 40 million people already depend on the Great Lakes for drinking water.[119] But Waukesha's situation is complicated because – like many other thirsty locations in the U.S. – the city lies *outside* the Great Lakes watershed. The Waukesha case is a reminder of the potentially huge demands on our Great Lakes, one of the world's most important fresh water resources.

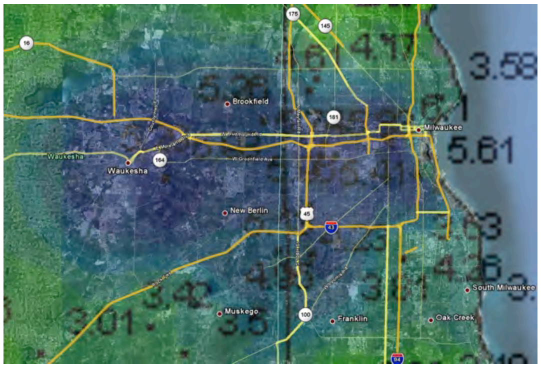


Rapid urban development has depleted groundwater in Waukesha, which now wants to import drinking water from Lake Michigan. But, like many thirsty locations in the U.S., Waukesha and its suburbs lie OUTSIDE the Great Lakes watershed.

The Waukesha case reminds us of the potentially huge demands on our Great Lakes, one of the world's most important fresh water resources.

Map courtesy of Kaye LaFond, Circle of Blue

While some Wisconsin communities face groundwater shortages, many communities contend with *too much* water in the form of surface runoff – especially after major storm events. Storm water management has become a serious and hugely expensive problem throughout Wisconsin. The problem is aggravated by suburban sprawl, farmland loss, and a recent pattern of heavier storms (possibly related to global warming).

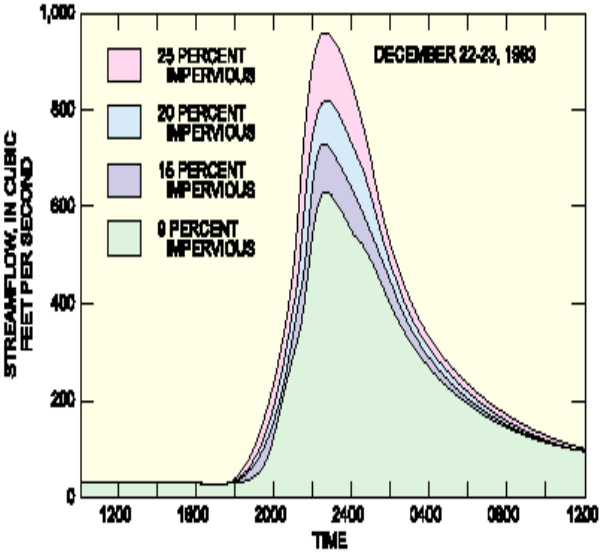


Storm water management has become a big problem throughout Wisconsin. The problem is aggravated by suburban sprawl, farmland loss, and a recent pattern of heavier storms.

Waukesha-Milwaukee Flood Event (2009).

Image: National Weather Service Forecast Office

Farms, forests and wetlands play an important role in absorbing rainfall, replenishing groundwater, and mitigating floods. As those lands are converted to urban and suburban uses (impervious roofs and pavement), destructive surface runoff and flooding problems will grow.[120]

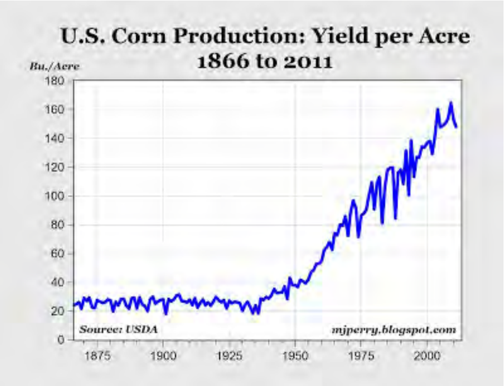


Farms, forests and wetlands absorb rainfall and mitigate floods. As those lands are converted to urban and suburban uses (impervious roofs and pavement), destructive runoff and flooding problems will grow.

U.S. Geological Survey computer simulation shows how storm water discharges increase when impervious surfaces (roofs and pavement) cover more of a watershed.[121] Local hydrology varies.

Intensive Crop Production

Despite a rapidly shrinking *per capita* land base, farmers have met soaring crop demand by producing far more *per acre* of land. Since 1930, for example, average U.S. corn yields have risen from under 30 bushels per acre to over 160 bushels per acre (some farms can now produce well over 200 bushels per acre).[122] The U.S. now produces *5 times more corn* than it did in 1950, on roughly the same acreage.[123] The increase comes from high-yield genetics, hybridization, close uniform planting, mechanization, irrigation, geographic specialization, and extensive use of fertilizers and pesticides, among other things.



Despite a shrinking per capita land base, farmers have met soaring crop demand by producing far more per acre of land.
But the push for higher crop yields has had environmental side effects.

Chart: USDA, reproduced by mjperry.blogspot.com

High crop yields come at a cost. Farmers (and their bankers) consider the cost of prime farmland, premium patented seed, state-of-the-art machinery, irrigation systems, fertilizer, pesticides, and other yield enhancing inputs for which farmers must pay market prices. But intensive, high-yield production has other costs that are not captured in farm financial statements. Consider the following "hidden" costs that affect us all:

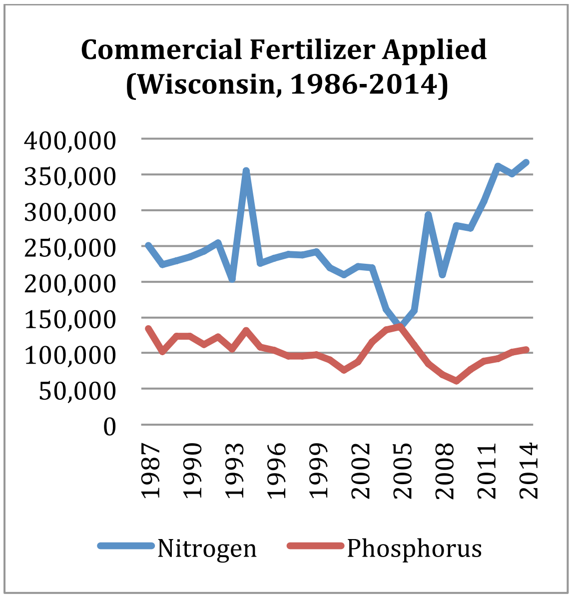
- Added crop nutrients (nitrogen and phosphorus) are the most widespread pollutants of our lakes and streams.[124]
- Nearly 34% of Wisconsin's private drinking wells contain detectable pesticide residues.[125]
- 20-30% of private drinking wells in Wisconsin's heavily farmed areas contain nitrates in excess of the state's enforcement standard.[126]
- Crop irrigation is drawing down groundwater and surface water levels in some parts of Wisconsin.[127]
- Unbroken plantings of genetically uniform crops are reducing bio-diversity, eliminating important pollinators, and increasing systemic vulnerability to pests and disease.[128]
- Routine applications of widely used pesticides are speeding the evolution of tougher crop pests.[129]

Nitrogen pollution

Crop nutrients are at the root of some of our nation's biggest water pollution problems. Crops require key nutrients, including nitrogen and phosphorus. Today's high-yield crop varieties require even more of these nutrients. Some crops, like corn, are especially heavy consumers; and irrigation increases their nutrient appetite. Farmers add nutrients, in the form of commercial fertilizer or manure, to ensure that crops are well fed and produce abundant yields.

Nitrogen fertilizer, first synthesized in the early 1900's, now supplies up to half the nitrogen required by crops worldwide.[130] Without it, the world's food supply and population would collapse.[131] U.S. farmers now apply *five times more nitrogen fertilizer* than they did in 1960.[132] But only part of that nitrogen finds its way to crop roots, even when it is carefully applied with the best technology.[133] Some of the "unused" nitrogen is released to the atmosphere as nitrous oxide, a greenhouse gas;[134] and some is leached to groundwater and surface water as nitrate pollution.[135] A "good" crop nutrient can thus become a "bad" environmental pollutant. Heavy nitrogen applications increase pollution risks.

From 2004 to 2013, Wisconsin farmers more than *doubled* their nitrogen fertilizer applications (*not* counting manure).[136] Much of that nitrogen went to feed bigger corn crops (in 2013, Wisconsin farmers planted 14% more corn acres than they did in 2004).[137] But much of it ended up as greenhouse gas, or in our water.



Commercial fertilizer provides important crop nutrients, including nitrogen and phosphorus. But some of those nutrients end up as pollutants.

Wisconsin farmers more than doubled their nitrogen fertilizer applications over the last decade.

Chart does *not* include manure applications, which also add nitrogen and phosphorus.

Chart based on data from DATCP annual fertilizer sales tonnage reports (less than 5% non-farm).

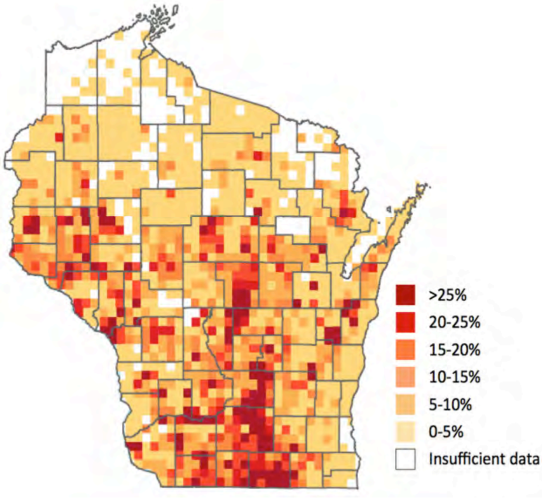
Fertilizer costs money, so farmers have some incentive to conserve.[138] But farmers also want to apply plenty of nutrients to ensure that crops reach their full potential. When crop prices are high relative to nitrogen prices, it usually pays farmers to apply more nitrogen.[139] It also pays to apply more nitrogen to irrigated crops, including those grown on sandy soils that are prone to nitrate leaching.[140]

Even when nitrogen is applied at relatively conservative economic rates recommended by University of Wisconsin agronomists, there can be significant nitrate leaching to groundwater.[141] In one series of studies, UW researchers found that 20% of the nitrogen applied to corn at recommended rates, on prime soil, eventually leached to groundwater.[142] Losses can be *much higher* when farmers (or their fertilizer suppliers) apply at higher rates or under less favorable conditions.[143]

Nitrate contamination is Wisconsin's most pervasive groundwater pollution problem, and it has increased in extent and severity.[144] About 200 million lbs. (100,000 tons) of nitrate enter Wisconsin groundwater each year.[145] There are various natural and human sources, but roughly 90% of the nitrate comes from farms.[146] Nitrate stays in groundwater for years or decades; so concentrations may increase, over time, in deep drinking water aquifers.[147]

Nitrate in drinking water can cause a number of health problems including "blue baby syndrome," a potentially fatal condition that affects infants under 6 months old.[148] At least 9% of all Wisconsin private wells already exceed the state enforcement standard for nitrate, and the rate is much higher in the heavily farmed areas of southern Wisconsin.[149] In those areas, 20-30% of private wells already exceed the enforcement standard.[150] About a third of all Wisconsin families get their drinking water from private wells.[151]

Nitrate contamination also affects community drinking water supplies. In a 2012 survey, 47 Wisconsin communities reported well contamination above the state nitrate enforcement standard (up from 14 in 1999), and 74 communities reported that contamination levels were increasing.[152] As of 2012, Wisconsin communities had spent over $32.5 million on remedial actions.[153] In an Iowa case that is drawing national attention, the Des Moines water utility is now suing farm drainage districts over nitrate contamination of the Raccoon River, the city's drinking water source.[154]



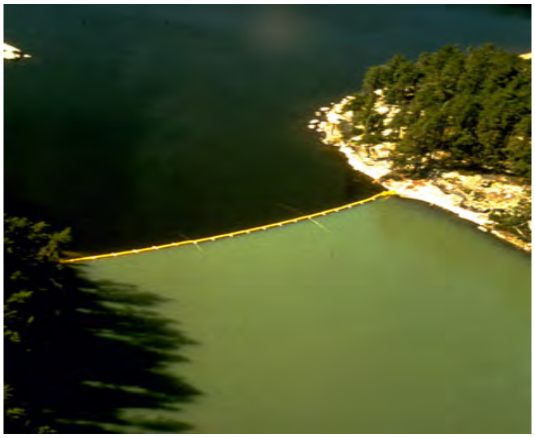
Nitrate, leached mainly from nitrogen-rich farm fields, is Wisconsin's most pervasive groundwater contaminant. Heavy nitrogen applications increase nitrate pollution risks.

Map shows percent of local groundwater samples above state drinking water standard for nitrate (10 mg/L). High concentrations reflect soil, geology, crop and irrigation patterns.[155]

Map: University of Wisconsin-Stevens Point, Center for Watershed Science and Education[156]

Phosphorus pollution

A second major crop nutrient, phosphorus, is also a serious water pollution problem. High levels of nitrogen and phosphorus pose a double-barreled threat to surface water quality – causing lake eutrophication, algae blooms and coastal "dead zones."[157] Phosphorus, in particular, plays a decisive role in the potentially toxic algae blooms that choke lakes throughout Wisconsin.[158] The excess phosphorus comes mainly, though not exclusively, from farm erosion and runoff.[159]



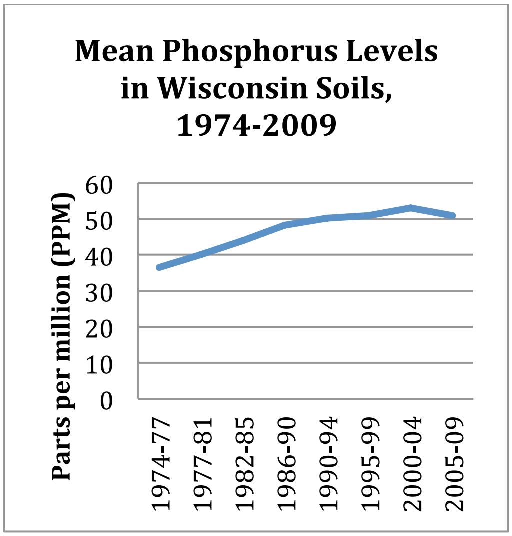
Phosphorus runoff, mainly from farms, plays a decisive role in lake eutrophication and algae blooms.

Split Lake Experiment: Phosphorus added to one side of the lake triggers a heavy algae bloom.

Experimental Lake 226, Ontario, Canada. Whole lake experiment conducted under the auspices of the Fisheries Board of Canada.

Hundreds of Wisconsin watersheds have been classified as "impaired watersheds" under the federal Clean Water Act, because of high phosphorus levels.[160] Urban sewage districts and other "point source" dischargers now face millions of dollars in phosphorus control costs because of high watershed phosphorus levels caused mainly by "nonpoint" farm runoff, which the Clean Water Act does not regulate.[161]

Phosphorus binds to soil particles, so it can build up in the soil over time. Wisconsin's mean soil phosphorus level has been increasing for decades, as a result of regular fertilizer and manure applications (local conditions vary).[162] A relentless tide of soil erosion carries phosphorus to lakes and streams, where it feeds the growth of algae and aquatic weeds. Pollution risks grow when farmers fail to control soil erosion,[163] or when they add unnecessary phosphorus to soils that are already phosphorus-rich.[164] Intensive row cropping and heavy storms make matters worse.



Wisconsin soil phosphorus levels have been rising for decades, due to fertilizer and manure applications (local conditions vary). Soil erosion from farm fields carries phosphorus to lakes and streams, where it feeds algae and weeds.

Pollution risks grow when farmers fail to control erosion, or add too much phosphorus to soils that are already phosphorus-rich. Intensive row cropping and heavy storms make matters worse.

Chart based on University of Wisconsin-Madison Soil Testing Laboratories, *Wisconsin's Historical 5-Year Summary Database.* Since 2009, the last year shown on this chart, annual Wisconsin phosphorus fertilizer applications have nearly *doubled*.

Pesticide pollution

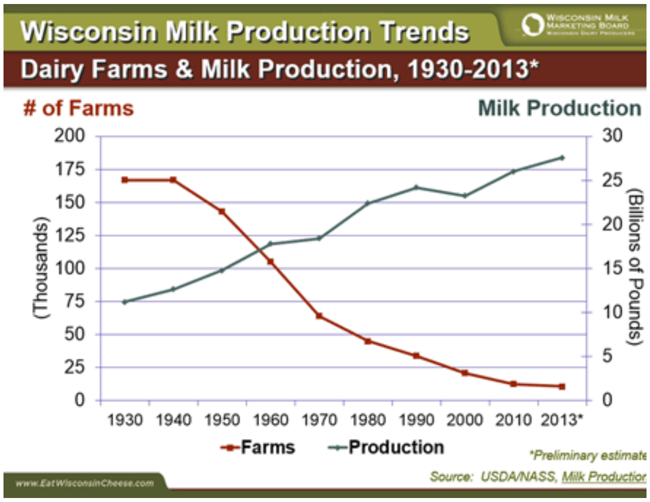
Pesticides, like crop nutrients, are essential for today's high-yield agriculture. But pesticides also pose risks. Farmers minimize those risks by applying pesticides according to federally approved labels and state rules.[165] But unforeseen problems can sometimes occur. Atrazine is a case in point.

For nearly 40 years, atrazine was the nation's most widely used corn herbicide. Farmers applied atrazine, year in and year out, per label directions. Few suspected that the herbicide might be contaminating groundwater. But beginning in the 1980's, tests on 13,000 Wisconsin drinking water wells showed that 40% of the tested wells were contaminated with atrazine or its metabolites (including 8% above state enforcement standards).[166] Contamination levels fell only after Wisconsin banned atrazine use on more than a million acres, and restricted application rates statewide.[167] Other pesticides have also been found in groundwater.[168] In fact, nearly 34% of all Wisconsin wells contain detectable residues of one or more pesticides (alachlor and metolachor are now the most frequently found).[169]

"Roundup-Ready" GMO corn helped to alleviate the atrazine problem, because it allowed farmers to use glyphosate ("Roundup") herbicide without damaging corn plants.[170] Glyphosate, which is not prone to groundwater leaching, soon replaced atrazine as the dominant corn herbicide. But the GMO revolution had other effects: About 90% of U.S. corn and 93% of U.S. soybeans now contain patented GMO traits (especially the "Roundup-Ready" trait),[171] and ingredients from those crops are now found in over 70% of U.S. processed foods.[172] By inserting patented GMO traits (just 1 or 2 genes) into seeds containing *thousands* of ancient genes, seed companies tightened their proprietary grip over the (once public) corn and soybean gene pool.[173] Widespread use of glyphosate also hastened the spread of aggressive, glyphosate-resistant weeds that require additional pesticide applications.[174]

Intensive Livestock Production

Livestock production, like crop production, has undergone a profound revolution. Specialized breeding, automation, scientific feeding, antibiotics,[175] production-enhancing pharmaceuticals,[176] industrial-style management, and economies of scale have dramatically increased production efficiency. Today, for example, Wisconsin has 40% *fewer* dairy cows and 93% *fewer* dairy farms than we did in 1950; yet we produce 80% *more* milk.[177] Milk production per cow has *tripled* since 1950, and there is no end in sight.[178] But the production revolution has had an unsettling impact on farms and rural communities, and has deeply affected our relationship to farm animals and the environment.

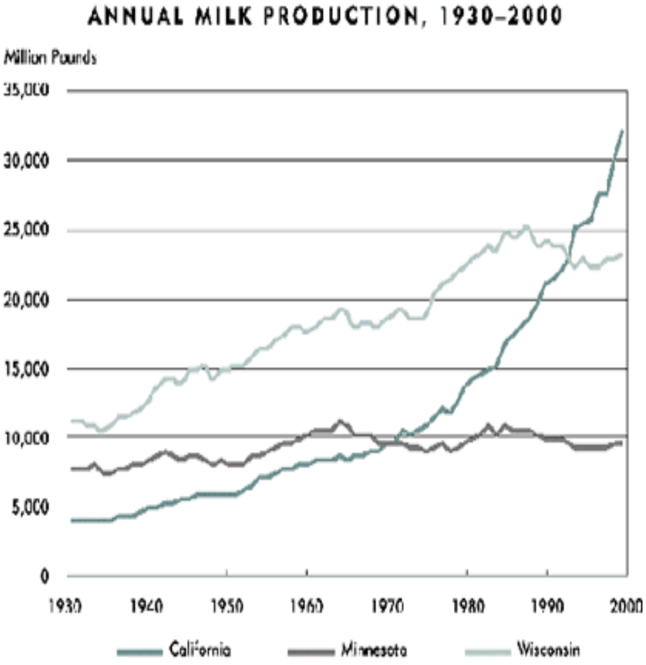


A production revolution has profoundly altered the U.S. livestock industry. Today, Wisconsin has 40% fewer dairy cows and 93% fewer dairy farms than we did in 1950, yet we produce 80% MORE milk. Milk production per cow has TRIPLED, and there is no end in sight.

Chart: Wisconsin Milk Marketing Board, based on USDA-NASS.

Large confinement facilities now account for much of our nation's beef, pork, poultry, egg and dairy production. These facilities, which often house thousands of closely confined animals, are designed to produce large quantities of a commercially uniform product in the shortest possible time, at the lowest possible per-unit cost.[179] Today, a 5.3 lb. chicken can be produced in 35 days on about 8 lbs. of feed.[180] Thirty years ago, it took over 7 lbs. of feed to produce a 3 lb. chicken in the same time.[181]

California pioneered industrial-scale dairy farming in the 1980's, and by 1994 it rocketed past Wisconsin to become the top U.S. milk producing state. California now produces *50% more milk* than Wisconsin, even though Wisconsin has 5 times more dairy farms than California.[182] The average California dairy farm has over 1,000 cows, compared to just 124 in Wisconsin.[183] But Wisconsin is moving in California's direction. Wisconsin now has about 300 dairy CAFOs (herds with more than 700 cows),[184] and our largest CAFO has about 8,000 cows.[185] CAFOs comprise just 3% of Wisconsin dairy herds, but now produce 30% of Wisconsin's milk.[186]



California pioneered industrial-scale dairy farming in the 1980's, and soon rocketed past Wisconsin as the top U.S. milk producing state.

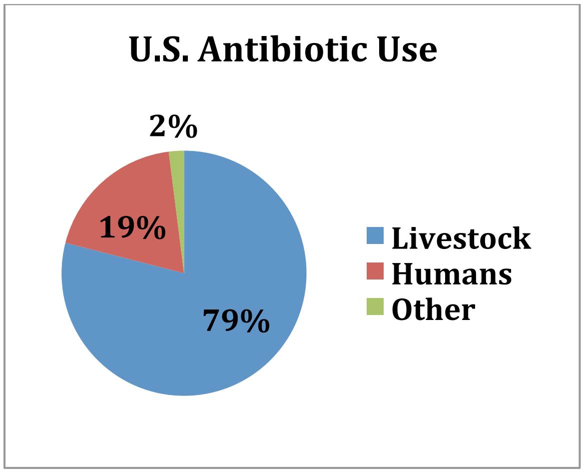
Wisconsin output fell briefly, but is now growing again – partly because of larger dairy herds. Just 300 CAFOs (3% of Wisconsin dairy farms) now produce 30% of Wisconsin's milk.

Chart: USDA

Modern livestock production is a "high wire act." The performance is stunning; but there is little room for error, and the risks are palpable. Large facilities require capital investments that are impossible for many farmers. Heavy animal waste concentrations pose new health and environmental threats. Animal confinement practices (especially in the pork and poultry industries) have raised contentious animal welfare issues. And crowded populations of genetically uniform animals can be easy targets for disease.[187]

The livestock industry now accounts for nearly 80% of all U.S. antibiotic use.[188] North Carolina *alone* uses more antibiotics on livestock (mainly swine and poultry) than our entire nation uses on humans.[189] According to the U.S. Centers for Disease Control (CDC), this heavy antibiotic use is speeding the evolution of drug-resistant pathogens.[190] Livestock operators use antibiotics to treat and prevent disease; but in some livestock sectors, operators also feed antibiotics on a routine basis to promote animal growth – a practice that CDC opposes.[191]

Antibiotics are *not* routinely fed to dairy cows, but are used to treat common conditions like mastitis. Farmers may not ship milk from cows that are undergoing treatment.[192] Wisconsin dairy plants must test for a range of antibiotic residues, and must discard tainted milk (the farmer incurs the loss).[193] The amount of discarded milk has fallen steadily over the past 5 years, from 7.87 million pounds (2010) to 4.44 million pounds (2014), even as Wisconsin's total milk production has grown.[194] Discarded milk represents less than 1/10 of 1% of all Wisconsin milk production.



The livestock industry accounts for nearly 80% of all U.S. antibiotic use. Routine antibiotic use can speed the evolution of drug-resistant pathogens, which can threaten animal and human health.

Chart based on use estimates cited in Hollis and Ahmed, "Preserving Antibiotics, Rationally," New England Journal of Medicine (December 26, 2013).

When things go wrong in a large, integrated livestock production system, they can go wrong in a big way. That was illustrated in 2015, when a deadly bird flu virus ravaged the Upper Midwest poultry industry.[195] The flu strain was carried to the U.S. by wild migratory birds. Despite standard biosecurity precautions, the disease entered large poultry facilities (some housing *millions* of birds) and spread rapidly among the closely confined and genetically homogeneous fowl. Normal supply and distribution networks became potential highways for further spread between facilities.[196]

By the time the bird flu epidemic subsided in June 2015, nearly 50 million chickens and turkeys had died or been killed to prevent further disease spread.[197] Millions of birds were "composted in place" in the facilities where they died, because there were few other disposal options. The disease cost nearly $1 billion and 6,000 jobs in Iowa alone (farm operator losses were partly indemnified by U.S. taxpayers).[198] Other states, including Minnesota and Wisconsin, were also hit hard. U.S. egg prices rose dramatically, and at least 75 nations restricted imports of U.S. poultry products. Some poultry operators lost up to 5 million birds each.

Modern livestock production can be a "high wire act." In 2015, a deadly bird flu virus ravaged the Upper Midwest. The disease spread quickly among large poultry facilities (some housing millions of birds). Nearly 50 million chickens and turkeys died. The disease cost nearly $1 billion and 6,000 jobs in Iowa alone. Losses were partly indemnified by U.S. taxpayers.

A Bird Flu Victim.

Photo: Dr. D. Swayne, USDA. Reproduced courtesy of the Center for Public Health and Food Security, Iowa State University

Although this particular bird flu strain did not threaten humans, other strains have been known to cause dangerous human flu epidemics. The outbreak reminds us that we do not, and cannot, live in a "hermetically sealed package." Our food system is part of an infinitely complex biological world; and, like our financial system, it is subject to many unpredictable risks.[199] In biology, as in finance, diversification is a hedge against risk. When we "put all of our eggs in one basket," we may be asking for trouble.

America's Dairyland: Milk and Manure

Wisconsin turned to dairying in the late 1800's, after wheat monoculture had exhausted the state's virgin soils. Dairying offered environmental, as well as economic advantages. Dairy forage crops and pasture provided better erosion control, and helped to restore soils exhausted by "cash grain" monoculture. Dairy cows also provided two valuable commodities on a daily basis: milk and manure. Nutrient-rich milk fed families, and nutrient-rich manure helped to rejuvenate tired farm soils.

Cows could eat grass and other plant material that humans could not digest. The cows extracted nutrients like nitrogen and phosphorus, and used some of those nutrients to make milk. The cows also returned lots of nutrients and organic matter to the farm soil in their manure. By 1915, Wisconsin was the nation's leading dairy state,[200] and cows were producing a steady supply of organic fertilizer for Wisconsin crops.

Small dairy farms were once the bedrock of rural Wisconsin. Farm families kept only as many cows as they could milk by hand, and feed from their own farms. As late as 1950, the average Wisconsin dairy farm had just 15 cows.[201] In 1950, Wisconsin had far more cows than it does today;[202] but the cows were smaller, and produced less milk and manure per cow. They also deposited manure on 140 thousand farms compared to just 10 thousand today,[203] so manure was more evenly distributed around the state.

Emerson Brooks Papers.
Special Collections, National Agricultural Library.

In 1950, Wisconsin had 140 thousand dairy farms compared to 10 thousand today, and the average dairy farm had just 15 cows. Today, manure production is far more geographically concentrated.

Image: USDA, National Agricultural Library

After World War II, everything changed. Rural electrification, powerful farm machinery, automated milking, bulk milk handling and transportation, high production genetics, scientific feeding, and intensive farm management transformed the dairy industry. Forward-looking dairy farmers had strong economic incentives to expand, and they did. Wisconsin produced more milk on bigger, more efficient farms, even as farm numbers declined.

Wisconsin milk production grew steadily until the last decade of the 20th Century. But then it stalled in the face of discontinued federal price supports and powerful low-cost competition from California – a state that had taken dairy industrialization to a whole new level.[204] Wisconsin's decline lasted nearly a decade, and our famous cheese industry was at risk. But we eventually regained our competitive footing, partly by scaling up our farms to meet California's industrial dairy challenge. Drought and higher feed costs also reduced California's initial cost advantage.[205]

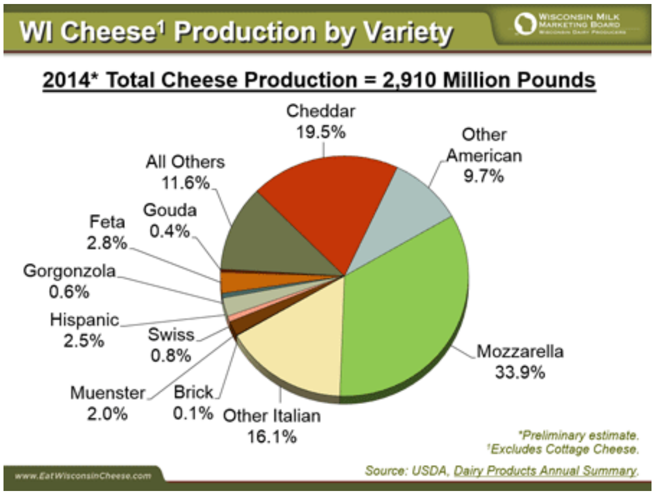
More Milk, Cheese *and* Manure

Today, Wisconsin is producing more milk than ever before. We now produce nearly 28 billion pounds of milk a year – a 25% increase in just 10 years.[206] Wisconsin agricultural leaders have announced a goal of 30 billion pounds by 2020.[207] Higher milk production has boosted our cheese industry, which needs an ample milk supply in order to grow and stay competitive.

Wisconsin is now producing more milk than ever before, on bigger and more efficient farms. We now produce nearly 28 billion pounds of milk a year – a 25% increase in just 10 years. Higher milk production has boosted our cheese industry.

Photo: UW-Madison, Center for Integrated Agricultural Systems

Ninety percent of Wisconsin's milk goes for cheese, and 90% of that cheese is consumed outside the state.[208] Wisconsin cheese production grew by nearly 21% over the last decade, reaching 2.9 billion lbs. in 2014.[209] Wisconsin is America's top cheese state, producing 26% of all U.S. cheese.[210]



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Wisconsin cheese production grew by nearly 21% over the last decade.

Wisconsin is America's top cheese state, producing 26% of all U.S. cheese.

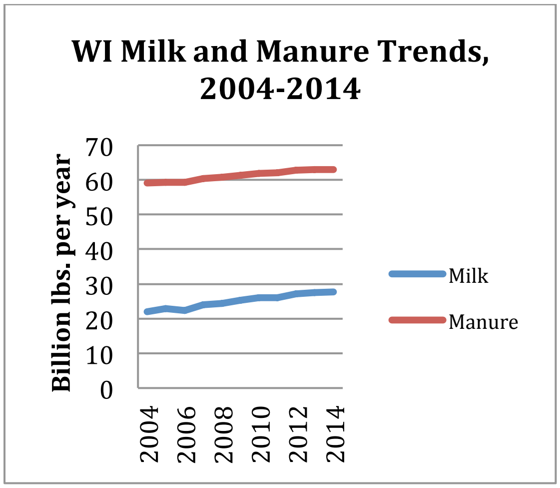
Chart: Wisconsin Milk Marketing Board, based on USDA-NASS.

Wisconsin leads the nation in artisan cheese production (specialty cheeses now comprise 23% our total cheese output).[211] But the vast majority of our cheese goes for mass-market uses, such as pizza. Many competitors make mass-market cheese, and would love to grab Wisconsin's slice of the pie. Competing dairy ingredients come from as far away as New Zealand.

Wisconsin leads the nation in artisan cheese; but most of our cheese goes for mass-market uses, such as pizza. Many competitors would love to grab Wisconsin's slice of the pie.

Photo: Scott Bauer, USDA-Agricultural Research Service, Image K7633-3 (via Wikimedia Commons, public domain)

As Wisconsin produces more milk and cheese, it also produces more manure. Wisconsin cows now produce roughly 64 billion pounds of manure (feces and urine, as excreted) each year[212] – about 7% more than a decade ago.[213] Manure is still a valuable fertilizer, but it has become a serious environmental challenge in some places.

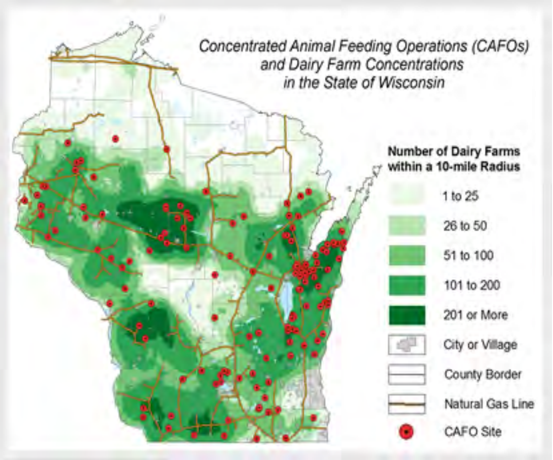


More milk means more manure. Manure is still a good fertilizer, but it has become a serious environmental challenge in some places.

Chart: Wisconsin manure estimate based on a Holstein cow regression equation (Weiss, 2004), using Wisconsin cow numbers and average milk per Wisconsin cow (USDA statistics).[214] This calculation conservatively includes lactating cows and dry cows, but not replacement heifers or calves.

A similar calculation using an ASABE (American Society of Agricultural and Biological Engineers) formula yields comparable figures, especially for recent years.[215] The ASABE formula yields higher manure totals (about 64.5 billion lbs. in 2014, compared to 63 billion lbs. using the Weiss formula), but a slower rate of growth over the period 2004-20

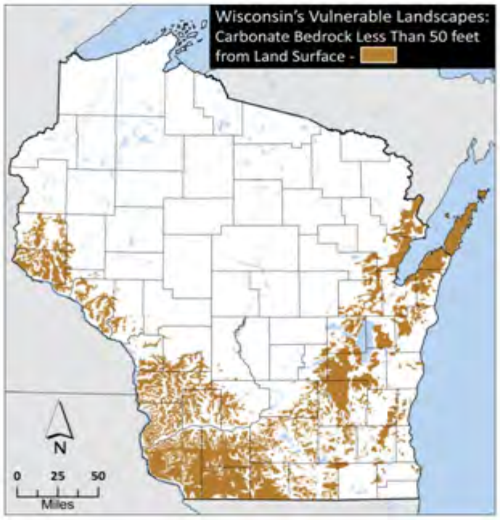
Dairy growth has been focused in certain areas, and has been especially strong near cheese manufacturing hubs in northeastern Wisconsin. In high growth areas, manure concentrations are becoming more acute.



Dairy growth has been focused in certain areas, and has been especially strong near cheese manufacturing hubs in northeastern Wisconsin. In high growth areas, manure concentrations are becoming more acute.

Map: UW-Extension (2009)

Some dairy growth areas have unique environmental problems, such as shallow karst bedrock that can allow direct manure runoff to groundwater. Dairy growth is also colliding with suburban sprawl in some places. More manure is being spread on less land, often near homes and drinking wells.



Some dairy growth areas have shallow karst bedrock that can allow direct manure runoff to groundwater. Dairy growth is also colliding with suburban sprawl in some places. More manure is being spread on less land, often near homes and drinking wells.

Shallow Karst Bedrock Areas

Map courtesy of the Wisconsin Geological and Natural History Survey

Managing Manure

Today's dairy farms are concentrating bigger cow populations in year-around confinement facilities, rather than on pasture. The cows eat lots of nitrogen-rich and phosphorus-rich feed, transported from distant locations. Some operators add more phosphorus to feed, to improve cow reproductive performance. Not surprisingly, the cows produce big pools of manure that are rich in nitrogen, phosphorus and other potential water pollutants. In some cases, the manure may also contain pathogens that can threaten livestock or (more rarely) human health.[216] As dairy farms get bigger, they create larger local pools of manure.[217]

In some ways, today's large dairy farms resemble human cities. And like human cities, they pose special waste management challenges. A 1,000 cow dairy herd produces about as much fecal waste (total solids, BOD, nitrogen and phosphorus equivalents) as a city of 25 or 30 thousand people (think Neenah, Stevens Point, Superior, Sun Prairie or West Bend).[218] But dairy waste, unlike human waste, is typically spread on land in untreated form (there are some exceptions).[219] In most areas, the soil can safely assimilate the waste – but only if it is not overloaded.

A 1,000 cow dairy herd produces about as much fecal waste as Stevens Point, a city of 25,000 people. Dairy waste is typically spread on land in untreated form. In most areas, the soil can safely assimilate the waste – but only if it is not overloaded.

Aerial View of Stevens Point.

Image: www.ViewFromAbove.com, use courtesy of View From Above…Aerial Photography

Modern dairy farms collect, store and apply manure in liquid form.[220] Automated systems collect the excreted manure (feces and urine), together with milking parlor wash water and other diluting materials. Dilution reduces the *concentration*, but not the total *quantity*, of nitrogen and phosphorus in the liquid manure. Dilution adds weight and volume, making the manure more expensive to store and haul.[221]

Liquid manure is kept in large storage tanks (or in-ground "lagoons") until it can be applied. At least 10 million gallons of storage capacity are normally needed for 1,000 cows for one year.[222] Without adequate planning and investment, herd expansions on farms of all sizes can outrun manure storage capacity.[223] Farmers with inadequate storage capacity may be forced to spread manure when runoff risks are high (especially in winter). Spills from overflowing or defective storage facilities can also cause acute pollution discharges and fish kills (there were 38 recorded spills in 2013).[224]

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Dairy Manure Lagoon - California

Image: University of California-Davis

Even under optimal conditions, safe manure disposal requires an adequate land base. A 1,000 cow dairy operation may need well over 2 thousand acres of land for safe manure spreading (circumstances vary).[225] Some dairy operators may struggle to find enough "spreadable" acreage. In some places, where surging manure production is coming up against suburban sprawl and fragile environments, dairy operators and their neighbors may be confronting a manure disposal crisis.

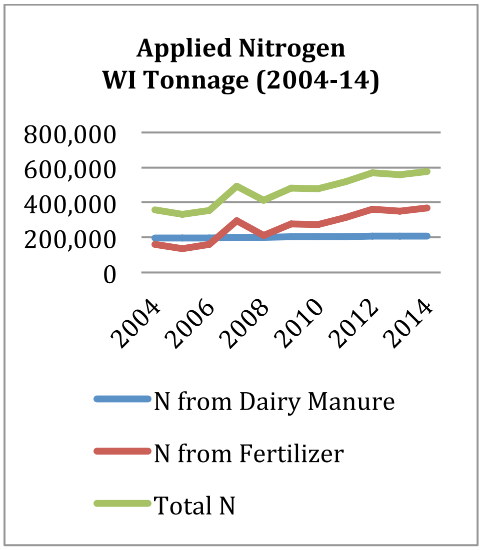
As local application sites get harder to find, dairy operators or their hired commercial haulers must haul manure over longer distances. A dairy operation with 1,000 cows must haul about 12 million gallons of liquid manure a year,[226] and some operators now haul manure as far as 60 miles.[227] Manure is heavy, and hauling is expensive, so there can be a tendency to apply too much manure on nearby fields.[228] That increases water pollution risks.

A 1,000 cow dairy operation hauls about 12 million gallons of manure a year, and may need well over 2 thousand acres of land for safe manure disposal. Manure is expensive to haul, so there may be a tendency to apply too much manure on nearby fields. That increases water pollution risks.

Photo: UW-Extension (Discovery Farms)

Managing Nutrients

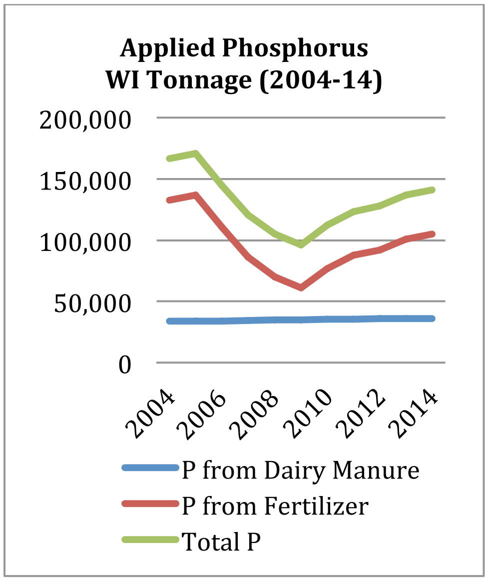
Although dairy manure is a big source of nitrogen and phosphorus in some parts of the state,[229] imported commercial fertilizer is a much bigger statewide source.[230] In 2014, dairy manure supplied roughly 209 thousand tons of nitrogen[231] and 36 thousand tons of phosphorus to Wisconsin farms,[232] while imported fertilizer provided up to 367 thousand tons of nitrogen and 105 thousand tons of phosphorus.[233] Although imported commercial fertilizer supports Wisconsin crop production, a portion of the imported nutrients will end up polluting Wisconsin lakes and groundwater.



In 2014, dairy manure supplied about 209 thousand tons of nitrogen to Wisconsin cropland, while imported commercial fertilizer supplied up to 367 thousand tons.

Chart: Nitrogen from manure was estimated by multiplying total annual manure production by the average weight of nitrogen per lb. of manure (derived from ASABE).[234] Fertilizer tonnage was obtained from DATCP annual fertilizer tonnage reports (less than 5% non-agricultural tonnage).

Both manure and commercial fertilizer carry water pollution risks. Manure tends to be over-applied near production locations, because it is expensive to haul and store. Surface applications, particularly in winter, can also pose direct runoff risks. Commercial fertilizer is more convenient, and can be applied more precisely, but its chemical form makes it susceptible to rapid leaching and runoff. Some of the nutrients in manure are released more gradually, because they are tied to organic matter.



In 2014, dairy manure supplied about 36 thousand tons of phosphorus to Wisconsin cropland, while commercial fertilizer provided up to 105 thousand tons.

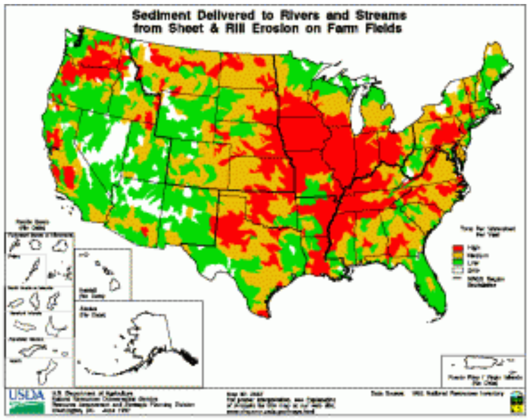
Chart: Phosphorus from manure was estimated by multiplying total annual manure production by the average weight of phosphorus per lb. of manure (derived from ASABE).[235] Fertilizer tonnage was obtained from DATCP annual fertilizer tonnage reports (less than 5% non-agricultural tonnage)

In order to minimize pollution risks, today's farmers need sound nutrient management plans.[236] It is important for farmers to test their soils, calculate reasonable nutrient needs based on cropping plans, determine the amount of land required for safe manure disposal, and credit nutrient contributions from all sources – including, but not limited to, manure and fertilizer.[237] Without careful planning, operators can easily apply too much manure and fertilizer. They can also pay for nutrients that they don't really need. Only about 30% of Wisconsin farms have written nutrient management plans at this time.[238]

Soil Erosion and Nonpoint Pollution

During the 1930's "Dust Bowl" era, President Franklin D. Roosevelt famously warned that "A nation that destroys its soils, destroys itself."[239] But soil erosion continues to undermine our agricultural land base, and is a major emerging threat to global food production.[240] The U.S. soil erosion problem centers on the Upper Midwest Farm Belt, one of the most important soil resources on the planet.

The U.S. soil erosion rate, while lower than that of many countries, is still far above the rate at which soil can be naturally replenished.[241] By some estimates, the U.S. may be losing an average of one inch of topsoil every 35 years.[242] A third of our native topsoil may already be gone.[243]



By some estimates, the U.S. may be losing an inch of topsoil every 35 years. A third of our native topsoil may already be gone. Erosion is especially severe in the Upper Midwest Farm Belt, one of the world's most important soil resources.

Erosion Map: USDA

Soil erosion from farms is perhaps the largest water pollution delivery system in the U.S.[244] Of the billions of tons of soil lost from U.S. farms each year, up to 60% may end up in surface waters.[245] Along with the sediment comes pollution from fertilizer, pesticides and manure. Farm runoff from the Upper Midwest is largely responsible for a vast "dead zone" in the Gulf of Mexico,[246] now the size of Connecticut.[247]

Closer to home, farm runoff is also contributing to a "dead zone" in Green Bay – the scenic arm of Lake Michigan where Europeans first encountered Wisconsin's native people in 1634.[248] Hundreds of other Wisconsin lakes and streams have been designated as "impaired waters" because of high phosphorus and sediment loads caused by soil erosion.[249]

Phosphorus plays a decisive role in the algae blooms that choke many of our lakes. The algae blooms hinder enjoyment of the lakes, and can sometimes be toxic to humans and pets. In 2014, a large toxic algae bloom in Lake Erie shut down the entire municipal drinking water supply for Toledo, Ohio.[250] Like Toledo, several Wisconsin cities (including Milwaukee) get their drinking water from Great Lakes surface waters.

Soil erosion is the primary vehicle by which phosphorus moves from farms to lakes. Phosphorus loading causes lake eutrophication and potentially toxic algae blooms.

In 2014, a toxic Lake Erie algae bloom shut down the entire municipal water supply of Toledo, Ohio.

Satellite photo: NOAA

The Wisconsin DNR and U.S. EPA have done a vulnerability assessment of Wisconsin watersheds based on emerging climate, land use, population and water use trends.[251] The following map shows where soil erosion and nonpoint pollution may have the biggest adverse impact on Wisconsin residents in the years ahead:

Wisconsin soil erosion rates are now higher than at any time since the 1980's, mainly due to cropping changes and more extreme weather events. Climate change modeling suggests that, without strong preventive action, erosion rates could double by 2050.

Soil Erosion Projection: High Impact Areas

Map: Wisconsin DNR and U.S. EPA

Although the U.S. made significant progress on erosion control after the 1930's "Dustbowl" era, much of that progress now hangs in the balance. Wisconsin soil erosion rates are now higher than at any time since the 1980's, mainly due to cropping changes and more extreme weather events.[252] Climate change modeling suggests that Wisconsin soil erosion rates could double by 2050 without stronger preventive action.[253]

Powerful economic forces have undermined erosion control efforts. In response to high crop prices over the last decade, U.S. farmers have shifted millions of acres *out of* pasture and perennial grass, and *into* corn and other row crops that are more susceptible to erosion (Wisconsin is no exception). Since 2008, U.S. farmers have shifted more than 5 million acres out of the federal Conservation Reserve Program alone.[254] The heavy shift to cash grain monoculture has also reduced crop rotation strategies that limit erosion.

Agriculture and the Native Environment

Agriculture, by its very nature, converts complex native ecosystems to narrower human-centered uses. Wisconsin agriculture has developed, over many years, by converting native prairie, woodland and wetland ecosystems to human food production. The land now supports *many* more people, but at a cost. Many beautiful and important things have been lost.

Agriculture, by its very nature, converts complex native ecosystems to narrower human-centered uses. The U.S. has converted nearly 100% of its native prairie to agriculture and development. Much of our original prairie soil – some of the best soil in the world – has already been lost to erosion.

Native prairie.

Image: Wis. Dept. of Natural Resources

Native prairies were especially important in building and retaining the fertile topsoil on which U.S. agriculture now depends. Prairies were home to a diverse community of plants and animals, including native pollinators, and sequestered huge amounts of carbon in their deep root systems.

In the 19th and 20th centuries, the U.S. (including Wisconsin) converted nearly 100% of its native prairie to agricultural and other uses. From a greenhouse gas perspective, that was tantamount to cutting down the entire Amazon rainforest.[255] In the years that have followed, much of the native prairie soil – perhaps the most important soil resource on the planet – has been blown or washed away.

Finding a Way Forward

In 1851, the brash young State of Wisconsin adopted a one-word motto: *"Forward."*[256] On its face, the motto seems to contemplate a direct, pre-ordained march toward a Manifest Destiny. But a deeper reading – more suited to the complex world in which we now find ourselves – begins with a question: *"Which way forward?"* In a democratic society, this reading commits us to an ongoing quest, and a solemn social compact. It says that here, in Wisconsin, we will work *together* – as free, respectful, and *responsible* citizens – to find and follow a wise path toward our shared future.

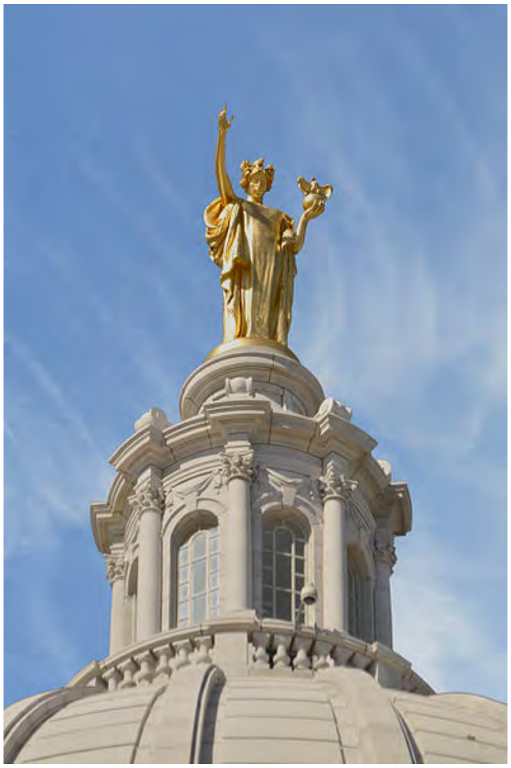
Which Way Forward?

Raising the "Wisconsin" Statue to the Capitol Dome: A Daunting Shared Task

Image: Wisconsin Historical Society
Raising "Wisconsin" Statue (Image 9566)
Used by Permission

As we look forward together, we might ask ourselves the following questions:

- What makes Wisconsin a good place to live, work and raise our children?
- What things about our state do we cherish most deeply?
- How important are food, land and water?
- What is our vision for the future of Wisconsin food, land and water?
- Are we moving toward our vision, or away from it? Where does our current path lead?
- Can we realize our vision? If so, how? What will it take?
- What legacy will we leave to future generations?
- What does "Wisconsin" stand for? What image and values do we want to project as a state, a community, an industry, a business, a landowner or a citizen?
- How do our personal or business choices affect others? How do they affect our shared future?
- What can *I* do? What can *we* do?
- How can we work *together* to make Wisconsin a shining example for generations to come?



How can we work TOGETHER to make Wisconsin a shining example for generations to come?

"Wisconsin" atop the Capitol Dome.

Photo Courtesy of Richard A. Hurd
(via Wikimedia Commons)

March 28, 2016

NOTES

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[1] *See* Egan-Robinson, "Wisconsin's Population: The State, Its Counties and Municipalities, 2010-2040," UW-Madison Applied Population Laboratory, Prepared for the Wis. Dept. of Administration, Demographic Services Center (December 2013).

[2] Based on U.S. Department of Agriculture (USDA) statistics related to average U.S. per capita food consumption. *See* USDA *Agriculture Factbook* (2001-02), Chapter 2, "Profiling Food Consumption in America."

[3] Based on statement related to major U.S. cities by Tom McGinn DVM, U.S. Department of Homeland Security, before the House Committee on Homeland Security, Subcommittee on Management, Investigations and Oversight, July 9, 2007.

[4] USDA *Agriculture Factbook* (2001-02), Chapter 2, *supra.*

[5] *Ibid.*

[6] *Ibid*.

[7] Buzby et al., "The Estimated Amount, Value, and Calories of Post-Harvest Food Losses at the Retail and Consumer Levels in the United States," USDA-Economic Research Service (USDA-ERS), Economic Information Bulletin No. EIB-121 (February, 2014). Estimating waste by weight has its shortcomings, because it may include things like cooking loss. Even so, the waste is considerable.

[8] *Ibid.*

[9] U.S. Environmental Protection Agency (EPA) estimate, cited in Craven-McGinty "The Challenge in Taking a Bite Out of Food Waste," Wall St. Journal, August 29, 2015.

[10] Coleman-Jensen et al., "Food Security in the United States in 2013," USDA-ERS Economic Research Report No. ERR-173 (September 2014).

[11] "Food Retailers, Agriculture Industry, and Charitable Organizations Support First National Goal to Reduce Food Waste by 50 Percent by 2030," USDA news release (September 16, 2015).

[12] Wisconsin Milk Marketing Board staff estimate, cerca 2008.

[13] USDA-ERS website at Home/Topics/In the News/California Drought: Farm and Food Impacts/California Drought: Crop Sector. *Compare* USDA-National Agricultural Statistics Services (USDA-NASS), "Vegetables, 2014 Summary" (January 2015); USDA-NASS, "California Agricultural Statistics" (2013). California accounted for over half of all U.S. fresh vegetable *production* in 2014, but not all of that production is *consumed* in the U.S.

[14] USDA-ERS website at Home/Topics/International Markets and Trade/ U.S. Agricultural Trade (January 2015). See downloadable table of U.S. agricultural trade by calendar year.

[15] *Ibid*, at "Import Share of Consumption."

[16] *See* U.S. Food and Drug Administration (FDA) news release (April 23, 2012); National Oceanic and Atmospheric Administration (NOAA) *FishWatch* website at http://www.fishwatch.gov/sustainable-seafood/the-global-picture (last visited January 2016). *See* also Promod et al., "Estimates of Illegal and Unreported Fish in Seafood Imports to the USA," *Journal of Marine Policy*, Vol. 48 (September 2014) at 102-113, which estimates that 20-32% of wild seafood imported to the U.S. is illegally caught.

[17] Gale and Huang, "Chinese Apple Juice Export Growth Follows Investments in the Industry," USDA-ERS *Amber Waves* Magazine (March 14, 2011).

[18] FDA import registration statistics, 2014. Registration numbers are down from the years prior to 2011 because many (possibly inactive) registrants failed to renew their import registrations when required to do so under the federal Food Safety Modernization Act (signed January 4, 2011).

[19] "Globalization in Every Loaf," *New York Times* (June 16, 2007). See also *Food Safety News*, June 3, 2012.

[20] USDA-ERS website at Home/Topics/International Markets & Trade/U.S. Agricultural Trade/Export Share of Production (visited January, 2014).

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[21] *See* USDA-ERS website chart at http://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/agricultural-trade.aspx ("Export Share of U.S. Farm Production, 2009-11," last updated April, 2014). The 20% corn export share (higher than the apparent percentage shown on the chart) is based on corn statistics at http://www.ers.usda.gov/topics/crops/corn/background.aspx (January, 2015). The milk export share is based on total milk solids, including those in manufactured dairy products. *See* U.S. Dairy Export Council, export trade data at http://www.usdec.org.

[22] Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) news release (February 12, 2015). See also USDA – Economic Research Service (USDA-ERS) website, at Home/Topics/International Markets and Trade/U.S. Agricultural Trade, for downloadable table of U.S. agricultural trade by calendar year.

[23] DATCP news release (February 12, 2015).

[24] *Ibid.*

[25] DATCP news release (February 19, 2014).

[26] *See* Newman, "Weak Crop Prices Hit Farm Incomes," *Wall Street Journal* (November 25, 2015). According USDA-National Agricultural Statistics Service (USDA-NASS), U.S. farmers produced about 10.76 billion bushels of corn in 2012 (down from the preceding year, partly because of drought). When world corn prices rose in response to short supplies, U.S. farmers increased corn acreage and production – producing 13.99 billion bushels in 2013, 14.22 billion bushels in 2014, and 13.59 bushels in 2015 (September 11, 2015 estimate). Average annual U.S. corn production over the 2013-15 period was nearly *30% higher* than in 2012 (27% higher than 2011). The U.S. now produces *5 times more corn per year* than in it did in1954, when it produced about 2.71 billion bushels. See production trend table at National Corngrowers Association, *World of Corn* website, http://www.worldofcorn.com/#us-corn-production (visited January, 2016).

[27] Compare U.S. Census Bureau estimates of Wisconsin, U.S. and world populations for 1915 and 2015.

[28] United Nations, *World Population Prospects: The 2012 Revision* (2013).

[29] United Nations, Food and Agricultural Organization (FAO) statistics.

[30] "Thirsty Exports," *National Geographic* (May, 2015), citing other sources.

[31] United Nations (FAO) projection cited in National Academy of Sciences, "The Critical Role of Animal Science Research in Food Security and Sustainability" (2015), at 1.

[32] See, e.g., Southgate et al., *The World Food Economy* (2007), at 221.

[33] *See* USDA-ERS website background summaries for corn and soybeans at http://www.ers.usda.gov/topics/crops/corn/background.aspx (last updated October 16, 2014) and http://www.ers.usda.gov/topics/crops/soybeans-oil-crops/background.aspx (last updated October, 2012). In 2013, the U.S. corn crop had a farm value of $61.68 billion (compared to $43.65 billion for soybeans, $14.67 billion for wheat, $1.68 billion for sorghum, and $1.32 billion for barley). *See* National Corn Growers Association, *World of Corn* website at http://www.worldofcorn.com/#us-select-crop-value (January 2016).

[34] USDA statistics. Soybeans are normally crushed to produce meal and oil. Almost all of the meal is used for livestock feed (the oil has various uses, including food and feed uses). Over half of our total corn crop, including nearly all of our exported corn, goes for feed. Feed uses account for a smaller share of domestically used corn, because a large share of our domestically used corn goes for ethanol production.

[35] According to USDA-ERS, ethanol production accounted for 44% of U.S. *domestic* corn use in 2014. *See* http://www.ers.usda.gov/media/866543/cornusetable.html. That probably overstates ethanol's share of the *total* U.S. corn crop, because it does *not* account for U.S. corn that is exported for feed (up to 20% of the total U.S. crop); nor does it account for ethanol production byproducts, known as distiller's grains or DDGs, that are used for feed. DDGs represent about 30% by weight of the corn used in ethanol production process. According to statistics published by the National Corngrowers Association, it appears that the 2014 corn crop was used roughly as follows: 60% feed, including domestic feed corn, DDGs (most used for feed), and exported corn (most used for feed); 31% ethanol (net of DDGs); and 9% food and other uses (mainly corn oil and sweeteners). *See* National Corngrowers Association, *World of Corn (2015)* at http://www.ncga.com/upload/files/documents/pdf/publications/WOC-2015.pdf.

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[36] *See* National Corngrowers Association, *World of Corn (2015)* at http://www.ncga.com/upload/files/documents/pdf/publications/WOC-2015.pdf.

[37] For a chart showing corn acreage trends, see USDA-NASS website (January 2015) at Home/Charts and Maps/Field Crops, "Corn Acreage by Year, U.S." *See also* the acreage trend chart on the National Corngrowers Association website, *The World of Corn* at http://www.ncga.com/worldofcorn.

[38] A recent University of Wisconsin-Madison study suggests that, between 2008 and 2012, about 5.7 million acres of U.S. grassland were converted to crop production (most to corn and soybeans). Lark et al., "Cropland Expansion Outpaces Agricultural and Biofuel Policies in the United States," *Environmental Research Letters*, 10-4 (April 2, 2015).

[39] USDA-NASS statistics. *See also* the National Corngrowers Association, "Corn Usage By Segment," *World of Corn (2015)* at http://www.worldofcorn.com/#corn-usage-by-segment. Corn statistics refer to "field corn," which represents the overwhelming majority of all corn grown in the U.S. "Sweet corn" is a much smaller specialty crop grown for direct human consumption in fresh, canned or frozen form. In 2014, according to USDA statistics, U.S. farmers planted 90.6 *million* acres of "field corn" and only 555 *thousand* acres of "sweet corn" (includes "sweet corn" for fresh market *and* processing) – a ratio of over 163 acres of "field corn" to every acre of "sweet corn." Wisconsin is a leading "sweet corn" state, and an important "field corn" state.

[40] Gallo, "Food Advertising in the United States," chapter 9 of *America's Eating Habits; Changes and Consequences*, United States Department of Agriculture, Economic Research Service, Agriculture Information Bulletin No. (AIB750), May 1999, at p. 142 (Figure 4).

[41] See, e.g., "Sugary Drinks and Obesity Fact Sheet," Harvard School of Public Health, available at http://www.hsph.harvard.edu/nutritionsource/sugary-drinks-fact-sheet/ (last visited November 2015); Sifferlin, "This Is the No. 1 Driver of Diabetes and Obesity," *Time* (January 29, 2015), citing DiNicolantonio et al., "A Principle Driver of Type 2 Diabetes Mellitus and Its Consequences, *Mayo Clinic Proceedings* (March 2015); and Corliss, "Eating too much sugar increases the risk of dying with heart disease," Harvard Health Publications, Harvard Medical School (February 6, 2014), citing Yang et al., "Added Sugar Intake and Cardiovascular Diseases Mortality Among U.S. Adults, *JAMA Internal Medicine* (April 2014).

[42] *See, e.g.,* Southgate et al., *supra* at 33-34; Deepak K. Ray et al., *Yield Trends Are Insufficient to Double Global Crop Production by 2050,* PLoS ONE 8-6 (online journal, June 19, 2013). Some federal officials have projected even higher production requirements. For example, in a speech to The Atlantic's Food Summit, on April 26, 2011, USDA Deputy Secretary Kathleen Merrigan spoke of the need to increase world food production by *70%* by mid-century.

[43] See University of Washington chart illustrating, for various countries, the estimated share of annual income spent on food: http://wsm.wsu.edu/researcher/wsmaug11_billions.pdf.

[44] USDA, *1960 Yearbook of Agriculture*, at p. 4.

[45] U.S. Department of Energy (2014). The U.S. percentage has declined in recent years, as China and other countries have increased their usage.

[46] Canning et al., "Energy Use in the U.S. Food System," USDA Economic Research Service, ERR-94 (March 2010). The study results are generally consistent with those cited in note 48, *infra*. *See also* Smil, *Energy at the Crossroads* (MIT Press 2005), at 54. According to Canning, et al., over 80% of the *increase* in total annual U.S. energy use between 1997 and 2002 was food-related. About half of that was due to population growth and higher food consumption, and half to energy intensification. Commercial food processing was a major growth area, as households "out-sourced" more food preparation to commercial processors (possibly limiting some energy use in home kitchens).

[47] According to the U.S. Department of Energy, more than 82% of all U.S. energy comes from fossil fuel (the rest comes from nuclear, solar, hydro and biofuel sources). *See* "U.S. Sources and Uses of Energy," U.S. Department of Energy (2013). Food sector energy source patterns are, presumably, comparable to other sectors of the economy.

[48] Hendrickson, "Energy Use in the U.S. Food System: A Summary of Existing Research and Analysis," University of Wisconsin Center for Integrated Agricultural Systems (2004); Heller and Keoleian, "Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System," Report No. CSS00-04, Center for Sustainable Systems, University of Michigan (2000). Most electrical energy is currently derived from generating facilities powered by fossil fuel.

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[49] Canning, et al., *supra.*

[50] *Ibid.*

[51] *Ibid.*

[52] Greenhouse gases include carbon dioxide, methane and nitrous oxide, among others. Carbon dioxide accounts for 82% of all greenhouse gases generated by human activity in the U.S. *See* U.S. EPA, "U.S. Greenhouse Gas Inventory Report: 1990-2013," at http://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (October 5, 2015).

[53] *See* World Bank statistics for 2011. China produces more total greenhouse gas than the U.S.; but on a per capita basis, the U.S. produces nearly 3 times more than China. *See* Ge et al., "6 Graphs Explain the World's Top Emitters," World Resources Institute (November 25, 2014).

[54] This estimate assumes that the 16% food system share of total U.S. energy use is allocated among energy sources (electricity, natural gas, motor fuel, etc.) in approximately the same proportions as the other 84% of U.S. energy use. It is somewhat difficult to isolate food system shares of U.S. energy use and carbon dioxide emissions, because they are often subsumed in other common energy use categories such as transportation or electrical generation.

[55] Carbon dioxide accounts for 82% of all U.S. greenhouse gas emissions. *See* "U.S. Greenhouse Gas Inventory Report 1990-2013," note 52 *supra.* If the food system accounts for 16% of U.S. carbon dioxide emissions, it follows that those carbon dioxide emissions represent 13% of all U.S. greenhouse gas emissions.

[56] U.S. EPA, "Sources of Greenhouse Gas Emissions" (Agricultural Sector Emissions)," at http://www3.epa.gov/climatechange/ghgemissions/sources/agriculture.html (October 5, 2015).

[57] About 10 years ago, major petroleum companies began using ethanol as an environmentally-friendly substitute for MTBE, an octane-enhancing gasoline additive that was found to be a serious water pollutant. Federal ethanol blending mandates and subsidies subsequently expanded the use of ethanol as a motor fuel – not just an octane-enhancing gasoline additive. The U.S. currently produces about 14 billion gallons of ethanol per year (U.S. Energy Information Administration, 2014).

[58] Harder and Newman, "U.S. Quotas Give Boost to Ethanol Producers," *Wall Street Journal* (December 1, 2015). Although ethanol subsidies have now expired, the blending mandate continues. On November 30, 2015, EPA reduced the blending mandate, but not by as much as originally proposed.

[59] This energy balance estimate is a nationwide average figure (ethanol production efficiency varies by region and production facility). *See* Gallagher, et al., "2015 Energy Balance for the Corn-Ethanol Industry" (February, 2016). This study was sponsored by USDA, Office of the Chief Economist, Office of Energy Policy and New Uses, and is available at http://www.usda.gov/oce/reports/energy/2015EnergyBalanceCornEthanol.pdf. *Compare* an earlier USDA study by Shapouri et al., "The Energy Balance of Corn Ethanol: An Update," USDA-ERS Agricultural Economic Report #813 (2002), which suggested a less favorable energy balance. Much of the fossil energy used in corn production and processing comes from non-petroleum fossil fuel sources, such as natural gas.

[60] Deller, "Contribution of Agriculture to the Wisconsin Economy," University of Wisconsin-Extension (September, 2014).

[61] *Ibid.*

[62] Wisconsin Milk Marketing Board, based on USDA-NASS statistics.

[63] Memo from Prof. Steven Deller, University of Wisconsin-Extension, to Jeff Swenson, DATCP (March 19, 2007).

[64] USDA-NASS statistics.

[65] USDA-ERS, "Trends in Local and Regional Food Systems: A Report to Congress" (January 2015), p. 5 (Table 2), showing figures for 2002-2012. "Local food" is hard to define: it includes, but is not necessarily limited to, food that farmers market directly to local consumers. According to USDA, only about 7% of farms do any direct marketing to consumers. Farms with less than $75,000 in annual gross farm income accounted for 85% of "local food" farms in 2012, but accounted for only 13% of "local food" sales. Farms with more than $350,000 in annual gross farm income accounted for only 5% of "local food farms" in 2012, but accounted for 67% of "local food" sales (see report summary).

[66] *See* American Farmland Trust, Farmland Information Center at www.farmlandinfo.org/.

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[67] USDA-ERS (1929-present) and U.S. Bureau of Labor Statistics (1901-present).

[68] DeHoyos and Lessen, *Food Shares in Consumption: New Evidence Using Engel Curves,* World Bank (2008), p. 5.

[69] Food Marketing Institute, "Supermarket Facts" (2016), citing statistics from 2014.

[70] U.S. Government Accounting Office (GAO), *Agricultural Concentration and Agricultural Commodity and Retail Food Prices,* GAO-09-746R (2009); Food and Water Watch, Iowa Farmers Union, Missouri Rural Crisis Center, National Farmers Union, "The Anticompetitive Effects of the Proposed JBS-Cargill Pork Packing Acquisition" (July 2015). According to the latter study, if the proposed JBS-Cargill acquisition deal is approved, the percentage of hogs slaughtered by the top 4 firms would increase to over 75%.

[71] Smithfield alone slaughters about 27% of all U.S. hogs. Food and Water Watch, Iowa Farmers Union, Missouri Rural Crisis Center, National Farmers Union, "The Anticompetitive Effects of the Proposed JBS-Cargill Pork Packing Acquisition" (July 2015).

[72] *Ibid.*

[73] USDA, Grain Inspection, Packers and Stockyards Administration (GIPSA), *Packers and Stockyards Statistical Report, 2006 Reporting Year* (published in 2008).

[74] Smithfield Annual Report (2009) and Duke University Report on *North Carolina and the Global Economy* (2010).

[75] Key and McBride, *The Changing Economics of U.S. Hog Production*, USDA Economic Research Report No. 52 (2007), cited in Wise and Trist, "Buyer Power in U.S. Hog Markets: A Critical Review of the Literature," Tufts University, Global Development and Environment Institute Working Paper No. 10-04 (2010) at p. 6.

[76] USDA Secretary Vilsack, *USDA/DOJ Workshop on Agriculture and Antitrust Enforcement Issues* (December 8, 2010) pdf transcript at p. 41.

[77] At least one very large hog operation is now planning to locate in the Bayfield, WI area, near Lake Superior, in order to escape a new swine disease (porcine epidemic diarrheal virus, or PEDv) that recently killed up to 10% of the pigs (mainly piglets) in states where hog operations are now heavily concentrated. The Bayfield siting controversy is described in Bergquist, "Proposed hog megafarm causes a stir in Bayfield County, *Milwaukee Journal-Sentinel* (June 27, 2015). The disease outbreak is described in "Virus Kills Millions of American Pigs, Pushing Up Pork Prices," *National Geographic*, May 1, 2014.

[78] USDA-ERS, "Structure and Size of U.S. Farms" (2010).

[79] USDA-ERS, "Farm Household Income" (2014). The group medium income of farms selling less than $350,000 per year is negative, which is to say that more than half of the farms in that group are operating at a loss.

[80] *Ibid.*

[81] USDA-NASS Census of Agriculture (2012). See Census Highlights, "Farm Demographics."

[82] Nesbit, *The History of Wisconsin Volume III, Urbanization and Industrialization 1873-1893* (State Historical Society of Wisconsin,1985), p. 1.

[83] Wisconsin Bluebook, 2003-04, p. 109 (chart).

[84] *Ibid*, p. 109.

[85] USDA-NASS statistics.

[86] In 2012, Wisconsin had over 22 thousand prisoners in state prisons alone (this does not include county jail inmates, federal prisoners, or offenders supervised in the community). Wisconsin Legislative Fiscal Bureau, Information Paper 56, January 2013.

[87] USDA Census of Agriculture, 2007. Many large Wisconsin dairy farms (as well as meat and food processing plants) now rely heavily on immigrant labor.

[88] USDA statistics, 2012.

[89] *See* USDA-ERS, "Trends in Local and Regional Food Systems: A Report to Congress" (January 2015), According to USDA, direct farm-to-consumer sales represent only 0.4% of all agricultural sales. Only about 7% of farms do any direct marketing to consumers. Farms with less than $75,000 in annual gross farm income accounted for 85% of "local food farms" in 2012, but accounted for only 13% of "local food" sales. Farms with more than $350,000 in annual gross farm income accounted for only 5% of "local food" farms in 2012, but accounted for 67% of "local food" sales.

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[90] USDA-ERS, "Retail Trends" at http://www.ers.usda.gov/topics/food-markets-prices/retailing-wholesaling/retail-trends.aspx. *Compare* Agricultural Marketing Resource Center, "Grocery Industry" (February, 2010). Wal-Mart, one of the world's biggest companies, now controls over 20% of the U.S. grocery market.

[91] Nation's Restaurant News (December 19, 2005).

[92] Matson, Tang and Wynn, "Seeds, Patents and Power: The Shifting Foundation of Our Food System" (November 1, 2014) at 25, citing other sources. Paper may be downloaded, free of charge, from the Social Science Research Network (SSRN) at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2525120.

[93] *Ibid*, at 25-27.

[94] *Ibid*, at 25-27.

[95] *Ibid*, at 24.

[96] James Owen, "Farming Claims Almost Half Earth's Land, New Maps Show," *National Geographic News* (December 9, 2005), citing research by the University of Wisconsin-Madison, Center for Sustainability and the Global Environment.

[97] United Nations, Food and Agriculture Organization (FAO) statistics. See FAO graph reproduced in this document.

[98] "The 2010 NRI: Changes in Land Cover/Use," American Farmland Trust. Based on USDA National Resources Inventory (NRI).

[99] American Farmland Trust, Farmland Information Center (2015), at http://www.farmlandinfo.org.

[100] *Ibid.*

[101] *Ibid.*

[102] *Ibid*.

[103] Compare current and past county farmland preservation plans certified under Wisconsin's farmland preservation program (Wis. Stats. Ch. 91, administered by DATCP).

[104] USDA-ERS, "Irrigation and Water Use" (updated 2013).

[105] Based on cash farm receipts. USDA-NASS, "California Farm Receipts Reach New High in 2010," *California Farm News* (2010).

[106] Krieger, "California Drought: San Joaquin Valley sinking as farmers race to tap aquifer," San Jose Mercury News (March 29,2014).

[107] Almond Board of California, *2013 Almond Almanac*, available at http://www.almonds.com/sites/default/files/content/attachments/2013_almanac.pdf.

[108] *Ibid.*

[109] Davidow and Malone, "How 'Virtual' Water Can Help Ease California's Drought," *Wall Street Journal* (March 21, 2015).

[110] *Ibid.*

[111] Almond Board of California, *supra.*

[112] Davidow and Malone, *supra.*

[113] McNeill, *Something New Under the Sun: An Environmental History of the 20th Century World* (Norton paperback edition, 2001), at 151.

[114] *Ibid*, at 154.

[115] Wisconsin Department of Natural Resources (DNR) statistics, cited in "Big farms, frac mines could feel force of judge's groundwater ruling," *The Cap Times* (Madison, WI, September 20, 2014).

[116] Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015); Wisconsin Initiative on Climate Change Impacts, *Central Sands Hydrology Working Group Report* (2011).

[117] *See*, for example, Lesk, "Hull residents want $233K from city over well," *Stevens Point Journal* (September 16, 2015).

[118] *See* Flescher, "With Shrinking Aquifer in Poor Shape, Waukesha Yearns for Lake Michigan Water," *Wisconsin State Journal* (October 9, 2013). On January 7, 2016, the Wisconsin DNR forwarded Waukesha's diversion application to the other Great Lakes states and the Canadian provinces of Ontario and Quebec. Before the City of Waukesha can begin a diversion, all eight Great Lakes states and provinces must approve the application.

[119] *Ibid.*

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[120] According to the U.S. Geological Survey, Wisconsin Water Science Service Center, "Increased runoff from impervious surfaces causes dangerous floods, severe erosion damage to our stream channels, diminished recharge of groundwater, and degraded habitat for our fisheries. These same impervious surfaces can transport the many pollutants deposited in urban areas, such as nutrients, sediment, bacteria, pesticides, and chloride. In the worst cases, the amount of pollutants in urban runoff are high enough to prevent us from being able to swim or fish in our local waters."

[121] United States Geological Survey, computer simulation of a Pennsylvania watershed at http://pa.water.usgs.gov/reports/fs067-98.html (visited November, 2015).

[122] USDA-NASS statistics.

[123] USDA-NASS statistics. In 1950, the U.S. produced about *2.8 billion* bushels of corn on roughly 83 million harvested acres. In 2014, the U.S. produced about *14 billion* bushels of corn on about 83 million harvested acres. For charts showing production and acreage trends, see National Corn Growers website at http://www.worldofcorn.com/#/.

[124] U.S. EPA, "Agricultural Nonpoint Source Fact Sheet" EPA 841-F-05-001 (March 2005); "National Water Quality Inventory: Report to Congress; 2004 Reporting Cycle" (January 2009).

[125] DATCP, "Agricultural Chemicals in Wisconsin Groundwater" (2008).

[126] Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[127] Wisconsin Initiative on Climate Change Impacts, *Central Sands Hydrology Working Group Report* (2011).

[128] *See*, e.g., National Research Council, *Managing Global Genetic Resources: Agricultural Crop Issues and Policies* (National Academies Press 1993). In one global study of 39 crops, researchers found that the abundance of pollinator bees was on average 76% higher in "diversified" fields than in monoculture fields. Kennedy et al., "A global quantified synthesis of local and landscape effects on wild bee pollinators in agroecosystems," *Ecology letters* 16.5 (2013), 584-599.

[129] *See*, e.g., National Research Council, *Impact of Genetically Engineered Crops on Farm Sustainability in the U.S.* (National Academies Press 2010).

[130] Smil, "Detonator of the Population Explosion," *Nature* (Vol. 400, July 29, 1999). Nitrogen fertilizer is synthesized from atmospheric nitrogen, using large amounts of fossil fuel (typically natural gas).

[131] *Ibid.*

[132] *See* USDA-ERS, "Fertilizer Use and Markets," at http://www.ers.usda.gov/topics/farm-practices-management/chemical-inputs/fertilizer-use-markets.aspx (last visited January, 2016). Nitrogen fertilizer sales increased from 2.7 million tons in 1960 to 12.8 million tons in 2011. Sales growth continued in 2012 and 2013 (see the Fertilizer Institute trend data at https://www.tfi.org/statistics/fertilizer-use (last visited January 2016).

[133] According to one study, only about 37% of the fertilizer nitrogen applied to corn is taken up by crop roots. Cassman et al., "Agro-Systems, Nitrogen Use Efficiency, and Nitrogen Management," University of Nebraska–Lincoln, Department of Agronomy and Horticulture Faculty Publications, *DigitalCommons@University of Nebraska-Lincoln*, available at http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1356&context=agronomyfacpub (last visited January, 2016). The fate of the "unused" nitrogen is complex, but a significant share finds its way to air (partly as nitrous oxide) and to water (as nitrate).

[134] *See* U.S. EPA, "Sources of Greenhouse Gas Emissions" (Agricultural Sector Emissions)," at http://www3.epa.gov/climatechange/ghgemissions/sources/agriculture.html (last accessed October 5, 2015).

[135] *See* Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[136] Based on DATCP annual fertilizer tonnage reports, showing statewide sales of commercial fertilizer. The reports include separate breakdowns of N and P tonnage. N applications are now at historically high levels. P applications declined from 2004-2009; but since 2009 they have rebounded to typical pre-2004 levels.

[137] USDA-NASS annual reports of Wisconsin corn acres planted.

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[138] *See* University of Wisconsin nutrient management information and recommendations at http://ipcm.wisc.edu/downloads/nutrient-managment/ (last accessed November 2015). Wisconsin has adopted nutrient management planning requirements for farms (based, in part, on UW agronomic recommendations); however, compliance obligations are normally contingent on cost-sharing. *See* Wisconsin Administrative Code ch. ATCP 50. Only about 30% of Wisconsin farms actually have written nutrient management plans. *See* DATCP, "Wisconsin Making Inroads in Managing Manure," DATCP News Release (April 14, 2015).

[139] *See*, e.g., University of Wisconsin recommendations for economically optimal nitrogen applications to corn at http://ipcm.wisc.edu/download/pubsNM/NitrogenGuidelinesConrWisconsinMRTN.pdf (last accessed November 2015).

[140] *See* higher UW nitrogen recommendations for corn on sandy irrigated soils, compared to other soils, at http://ipcm.wisc.edu/download/pubsNM/NitrogenGuidelinesConrWisconsinMRTN.pdf (last accessed November 2015).

[141] *See* Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[142] *Ibid.*

[143] *Ibid.*

[144] *Ibid.* However, some studies suggest that contamination may be stabilizing – at least in some areas. For example, a recent Dane County study suggests that the *highest* nitrate levels in that county may have decreased over the past 30 years (although base levels may be trending upward). McDonald, et al., "Characterizing the sources of groundwater nitrate in Dane County, Wisconsin," Report to the Wisconsin Department of Natural Resources, October 29, 2015. Key findings are summarized in Verburg, "Major study of contaminated water shows progress, challenges ahead." *Wisconsin State Journal* (January 17, 2016).

[145] Shaw, "Nitrogen Contamination Sources: A Look at Relative Contributions," Conference Proceedings: *Nitrate in Wisconsin's Groundwater: Strategies and Challenges* (May, 1994).

[146] *Ibid.*

[147] U.S. Geological Survey, *Nutrients in the Nation's Streams and Groundwater 1992-2004,* USGS Circular 1350 (September 2010).

[148] Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[149] *Ibid.*

[150] *Ibid*

[151] *Ibid.*

[152] *Ibid.*

[153] *Ibid.*

[154] The Iowa case has highlighted the potential importance of farm drainage tiles and pipes as mechanisms for the delivery of nitrate and other pollutants to surface waters. *Board of Waterworks Trustees of the City of Des Moines v. Sac County Board of Supervisors et al*., U.S. District Court for the Northern District of Iowa, Western Division, Case No. 5:15-CV-04020.

[155] Masarik, "Nitrate in Wisconsin's Groundwater – What, Why and Where," University of Wisconsin seminar (*Wednesday Night at the Lab*, Madison, WI, January 20, 2016).

[156] Center for Watershed Science and Education (CWSE), *WI Well Water Viewer*, University of Wisconsin-Stevens Point. Available online: http://www.uwsp.edu/cnr-ap/watershed/Pages/WellWaterViewer.aspx (accessed April 2015).

[157] Phosphorus tends to play a more decisive role in fresh water eutrophication and algae growth, while nitrogen may play a more decisive role in the creation of salt water "dead zones" such as the one in the Gulf of Mexico (see notes 245 and 246, *infra*).

[158] *See* Wisconsin DNR, "Reducing Phosphorus to Clean Up Lakes and Rivers" (Revised December 22, 2014).

[159] *Ibid.*

[160] *Ibid.*

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[161] Under the Clean Water Act, phosphorus pollution "point sources" may need to install costly phosphorus pollution controls *OR* pay others to achieve equivalent phosphorus reductions in the same phosphorus-impaired watershed (e.g., by reducing "nonpoint" phosphorus runoff from farms). Wisconsin offers a possible alternative for some affected point sources (see Wis. Stats. ss. 283.16 and 283.84(1)(c)). The costs to affected point sources will, in any case, be significant.

[162] *See* University of Wisconsin-Madison Soil Testing Laboratories, *Wisconsin's Historical 5-Year Summary Database*. *See also* Bundy et al., "Implementing Nutrient Management Practices in Wisconsin," Presentation to the American Society of Agronomy (November 4, 2003).

[163] Wisconsin has adopted soil erosion control standards for farms, but compliance obligations are usually contingent on cost-sharing. *See* Wisconsin Administrative Code Chapter ATCP 50.

[164] Wisconsin has adopted nutrient management standards (including phosphorus management standards) for farms; but compliance obligations are usually contingent on cost-sharing. *See* Wisconsin Administrative Code Chapter ATCP 50. Only about 30% of Wisconsin farms currently have written nutrient management plans. *See* DATCP, "Wisconsin Making Inroads in Managing Manure," DATCP News Release (April 14, 2015).

[165] Pesticides and labeled uses must be registered with the U.S. EPA. Wisconsin has also adopted extensive rules related to pesticide handling and use (see Wis. Adm. Code chs. ATCP 29 and 30).

[166] Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[167] *See* Wisconsin Administrative Code ch. ATCP 30, subch. VIII.

[168] *See* Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[169] *Ibid.,* citing 2007 DATCP statistical survey of Wisconsin groundwater. Metabolites of alachlor and metolachlor (herbicides also used on corn) are now the most widely detected pesticide residues in Wisconsin drinking water wells.

[170] Monsanto originally patented "Roundup" herbicide, as well as the "Roundup-Ready" GMO seed trait.

[171] *See* Matson, Tang and Wynn, "Seeds, Patents and Power: The Shifting Foundation of Our Food System" (November 1, 2014), at 26*,* citing other sources. Paper may be downloaded, free of charge, from the Social Science Research Network (SSRN) at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2525120.

[172] Linda Bren, "Genetic Engineering: The Future of Foods?" U.S. Food and Drug Administration, *FDA Consumer Magazine 37-6* (November-December, 2003), citing estimate by the Grocery Manufacturers of America related to GMO ingredients in processed foods. Nearly all of those GMO ingredients are from crops containing the "Roundup Ready" GMO trait.

[173] *See* Matson, Tang and Wynn, "Seeds, Patents and Power: The Shifting Foundation of Our Food System" (November 1, 2014). Paper may be downloaded, free of charge, from the Social Science Research Network (SSRN) at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2525120.

[174] *See* National Research Council, *Impact of Genetically Engineered Crops on Farm Sustainability in the U.S.* (National Academies Press 2010). Widespread use of another GMO trait, which incorporates the natural insecticide bacillus thuringiensis (Bt) into corn, soybeans and other crop plants, has likewise spurred the evolution of pests that are resistant to Bt.

[175] The livestock industry currently accounts for about 80% of all U.S. antibiotic use. Statistics for 2011, cited by Dr. David Kessler, former FDA Commissioner (NY Times Op-Ed, March 27, 2013). See also Hollis and Ahmed, "Preserving Antibiotics, Rationally," *New England Journal of Medicine* (December 26, 2013). Antibiotics are used to treat disease. In some livestock sectors (though not in the dairy industry), they are also routinely fed to livestock to promote animal growth.

[176] The introduction of genetically-engineered bovine growth hormone (rBST), used to increase milk production by dairy cows, sparked a major controversy in Wisconsin and other states (see Wis. Stats. s. 97.25).

[177] Approximate percentage increase based on USDA-NASS milk production statistics. See production trend chart at USDA-NASS, "Wisconsin Agricultural Statistics" (2014), p. 39.

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[178] USDA-NASS, Wisconsin Cattle and Milk Review (February 2013), graph showing "Number of Milk Cows vs. Milk Per Cow: Wisconsin 1950-2012." See also USDA-NASS statistics (Feb. 3, 2015) at http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/mkpercow.pdf. Today's cows are bigger, consume more feed, and are bred for high milk production. Milk production per cow continues to increase steadily (some top cows can now produce at nearly 3 times the current state average).

[179] For an analysis of scale-related production costs in the dairy industry, see MacDonald et al., "Profits, Costs, and the Changing Structure of Dairy Farming," USDA-ERS Economic Research Report No. 47 (September, 2007).

[180] Bundy, "The Future of Food is Chicken," *Wall Street Journal* (December 5-6, 2015), citing data from Virginia Tech.

[181] *Ibid.*

[182] USDA-NASS statistics. California has about 1,650 dairy farms, compared to nearly 10,000 in Wisconsin.

[183] USDA-NASS statistics. Herd sizes in some western states are even larger than those in California. As of 2010, average herd sizes in selected western states were as follows: New Mexico (2,293), Arizona (1,609), Nevada (1,120) and California (1,026).

[184] Based on DNR water pollution control permits issued to CAFOs.

[185] Behrends, "Wisconsin's largest dairy started as a family farm," *Agri-View* (February 26, 2015).

[186] Per Wisconsin Dairy Business Association.

[187] Today's livestock are bred mainly for high production. That has reduced the genetic diversity of some livestock (including dairy cattle and chickens), which may increase their collective susceptibility to disease. See, e.g., Notter, "The Importance of Genetic Diversity in Livestock Populations of the Future," *Journal of Animal Science,* 77: 61-69 (1999); Muir et al., "Genome-Wide Assessment of Worldwide Chicken SNP Genetic Diversity Indicates Significant Absence of Rare Alleles in Commercial Breeds," *Proceedings of the National Academy of Sciences* (2008). With modern methods, genetic diversity can be reduced within a fairly short time period. For example, with artificial insemination, a single prize dairy bull can have over 500,000 offspring. See "A Breeder Apart: Farmers Say Goodbye to a Bull that Sired 500,000 Offspring," *Wall St. Journal* (January 14, 2015).

[188] Statistics for 2011, cited by Dr. David Kessler, former FDA Commissioner, in a *New York Times* Op-Ed article (March 27, 2013). See also Hollis and Ahmed, "Preserving Antibiotics, Rationally," *New England Journal of Medicine* (December 26, 2013).

[189] *Ibid.* It should be noted that many of the antibiotics used on livestock are different from those used on humans. *See* note 190, *infra.*

[190] "Antibiotic Resistance Threats in the United States, 2013," U.S. Department of Health and Human Services, Centers for Disease Control (2013). Some antibiotics are used to treat or prevent disease, but many are fed to promote animal growth. The CDC report says that the latter practice is unnecessary, and should be phased out. It also urges more limited use of livestock antibiotics for treatment purposes. In 2015, FDA moved to reduce agricultural use of antibiotics that are also used on humans, but *not* those used only on livestock. *See* "FDA Moves to Combat Superbugs," *The Wall Street Journal* (June 3, 2015).

[191] "Antibiotic Resistance Threats in the United States, 2013," U.S. Department of Health and Human Services, Centers for Disease Control (2013).

[192] *See* Wis. Adm. Code ch. ATCP 60. Wisconsin rules implement federal policies adopted by FDA and the National Conference on Interstate Milk Shipments (NCIMS).

[193] *Ibid*.

[194] DATCP summary statistics, based on required reports from dairy plants.

[195] *See*, generally, *The Poultry Site* at http://www.thepoultrysite.com/bird-flu/bird-flu-news.php; Fry, "What the worst bird flu outbreak in U.S. history means for farms," *Fortune* (June 25, 2015); Newton and Kuethe, "Economic Implications of the 2014-2015 Bird Flu." *farmdoc daily* (5):104, Dept. of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign (June 5, 2015).

[196] USDA, Animal and Plant Health Inspection Service (USDA-APHIS), "Epidemiologic and Other Analyses of HPAI-Affected Poultry Flocks" (June 15, 2015). *See also* Sifferlin, "Bird Flu: Everything You Want to Know About the Outbreak," *TIME* web story (May 13, 2015), citing USDA staff communication.

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[197] *See* notes 195 and 196, *supra.*

[198] *See* notes 195 and 196, *supra. See also* "Economic Impact of Highly Pathogenic Avian Influenza (HPAI) on Poultry in Iowa," prepared for the Iowa Farm Bureau by Decision Innovation Solutions (August 2015).

[199] Much of the biological world is, of course, invisible to the naked eye. Bacteria and other microorganisms are everywhere – in the air, in the water, in the soil, in our bodies, and on the food we eat. Their total mass may be 5 to 25 times greater than the total mass of all animal life on earth. (*See* Postgate, *Microbes and Man*, Cambridge Univ. Press, 1992.) Microorganisms are essential for all plant and animal life, including human life. But under the right conditions, some can threaten our food supply and our health.

[200] Wisconsin Milk Marketing Board, "Wisconsin's Dairy Heritage."

[201] USDA-NASS statistics.

[202] According to USDA-NASS statistics, Wisconsin had over 2.1 million cows in 1950, compared to about 1.27 million today.

[203] Dairy farm numbers per USDA-NASS statistics.

[204] *See* Cropp, "Wisconsin Cheese Plant Capacity and Future Milk Production," University of Wisconsin – Madison (July 2007); "Rethinking Dairyland," University of Wisconsin-Madison, Dept. of Agricultural and Applied Economics, Marketing and Policy Briefing Paper #78B (September, 2002), at 2. *See also* Short, "Characteristics and Production Costs of U.S. Dairy Operations," USDA-ERS Statistical Bulletin No. 974-6 (February, 2004).

[205] *See* Brat, "Big Milk Market Goes Sour," *Wall Street Journal* (October 9, 2015).

[206] Wisconsin Milk Marketing Board, "2015 Dairy Data" (based on USDA-NASS production estimate for 2014). Percentage increase is based on USDA-NASS statistics. See production trend chart at USDA-NASS, "Wisconsin Agricultural Statistics" (2014), at 39.

[207] *See* DATCP website, "Dairy 30x20 Initiative to Grow Wisconsin Dairy," at http://datcp.wi.gov/Farms/Dairy_Farming/index.aspx.

[208] Wisconsin Milk Marketing Board staff estimates.

[209] Wisconsin Milk Marketing Board statistics for 2004-2014, based on USDA statistics. Wisconsin produced about 2.4 billion lbs. of cheese in 2004, and 2.9 billion in 2014.

[210] USDA-NASS statistics (2015).

[211] USDA-NASS statistics (2015). Wisconsin produces about *45%* of the nation's specialty cheese.

[212] Annual Wisconsin dairy manure production estimates were obtained by 2 separate methods that yielded comparable results. The *first method* used a regression equation for a typical Holstein herd (Weiss, 2004), but substituted total Wisconsin cow numbers and average milk per Wisconsin cow (USDA statistics). The calculation conservatively included lactating cows and dry cows, but *not* replacement heifers or calves (it assumed a 305 day lactation period per cow). This method estimated 2014 Wisconsin dairy manure output (feces and urine as excreted, without dilution) at 63 billion lbs. The Weiss regression formula is: Lbs. of manure/cow/day = 106 + .5[Lbs. of milk/cow/day]. See Weiss, "Factors Affecting Manure Excretion by Dairy Cows," Proceedings of the Cornell Nutrition Conference (2004), at 11-20. The *second method* used Wisconsin cow numbers (USDA statistics) and a standard per-cow manure production formula [ASABE] for lactating and dry cows. This second method, like the first, ignored manure produced by calves and replacement heifers. This method estimated 2014 Wisconsin dairy manure production (feces and urine as excreted, without dilution) at 64.5 billion lbs. (slightly higher than the 63 billion lbs. estimated by the first method). ASABE assumes that a lactating cow produces 150 lbs. of manure/day (305 days per year), and a dry cow produces 83 lbs. of manure/day (60 days per year). *See* American Society of Agricultural and Biological Engineers (ASABE), D384.2, *Manure Production and Characteristics.*

[213] The 7% increase in manure production from 2004 to 2014 was estimated using the *first method* [Weiss] described in note 212 *supra*. The second estimation method (ASABE) yields higher total manure volumes over the entire period from 2004 to 2014, but a slower rate of growth.

[214] See methodology, note 212 *supra*.

[215] See methodology, note 212 *supra*.

[216] *See*, generally, EPA website, Agriculture 101, Environment, Pathogens; Ebner, "CAFO's and Public Health: Pathogens and Manure," Purdue University Extension (2007).

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[217] "While dairy farms of all sizes have the potential for substantial excess nutrient production, the potential appears to increase noticeably among larger dairy operations, particularly for phosphorus and as herd sizes exceed 1,000 cattle of all types. As dairy farming continues to consolidate into larger operations, this problem will likely become more widespread." MacDonald et al., "Profits, Costs, and the Changing Structure of Dairy Farming," USDA-ERS, *ERR 47* (September 2007), at 25.

[218] *See* Fleming and Ford, "Human versus Animals – Comparison of Waste Properties," University of Guelph, Canada (2001).

[219] A few large dairy farms do treat their manure to some degree, and at least one county (Dane) has experimented with subsidized manure treatment facilities that serve multiple farms. *Manure digesters* are used to produce bio-fuel (methane) from manure, and can help to reduce manure odor and pathogen risks; but they do *not* make manure "disappear." Additional steps are needed to extract nutrients and water, and each step adds significant cost. Treatment costs are only partially offset by the value of extracted bio-fuel, nutrients and other by-products, at today's prices. Only the very largest dairy farms are capable of financing and operating their own manure treatment systems at this time, and there are obstacles to sharing manure treatment services between farms. Public subsidies, which shift manure treatment costs to taxpayers, may tend to favor some dairy operations to the exclusion of others. They may also send the wrong "price signals" to dairy operators – encouraging them to over-expand and produce "too much" manure, because manure treatment and disposal costs are shifted to the taxpaying public. In theory, dairy farmers might be willing to pay "user fees" for treatment services that reduce their manure storage, hauling or management costs; but, for a variety of reasons (including limited implementation of nutrient management standards), private markets for such services do not yet exist. Farmer cooperatives and dairy processors, which have an important stake in the matter, could conceivably help to develop shared manure treatment business models. But current market conditions are less than favorable. *See*, for example, Kesmodel, "Bull Market Fades for Manure Power," *Wall Street Journal*, February 19, 2016.

[220] Per communication from the Wisconsin Land and Water Conservation Association.

[221] *See* U.S. Biogas LLC, "Springfield Community Digester Nutrient Concentration System Feasibility Report - Dane County" (October, 2013). According to the U.S. Biogas study, the average hauling cost is roughly $.015 per gallon (costs vary). In Dane County alone, farmers spend over $3.5 million to haul and apply manure each year. A dairy farm with 1,000 cows hauls about 11.5 million gallons of manure per year, at an average cost of roughly $173,000. Total costs increase as manure is hauled further.

[222] Per USDA-Natural Resource Conservation Service (USDA-NRCS) Technical Guide 313 (Waste Storage Facility).

[223] If a new or expanding herd will have 1,000 or more "animal units" (about 700 cows), it must obtain a state CAFO permit and meet manure storage and management standards. *See* Wis. Adm. Code ch. NR 243. No state permit is required for herds below 1,000 "animal units." However, a county, town or municipality *may* adopt a livestock facility siting ordinance that requires new or expanding facilities over 500 "animal units" (about 350 cows) to obtain a *local* permit. Permit applicants must meet state standards for manure storage and handling, nutrient management, runoff control, odor and setbacks. *See* Wis. Adm. Code ch. ATCP 51. For a map showing local jurisdictions that have adopted livestock facility siting ordinances, see DATCP website at http://datcp.wi.gov/Environment/Livestock_Siting/. Many counties have also adopted construction standards for manure storage facilities.

[224] *See* "Manure Spills in 2013 the Highest in Seven Years Statewide," *Milwaukee Journal-Sentinel* (December 5, 2013).

[225] 2010 DATCP staff estimate, based on "typical" livestock operation and applicable nutrient management standards.

[226] *See* U.S. Biogas LLC, note 221 *supra.*

[227] Per communication from the Wisconsin Land and Water Conservation Association.

[228] *See* U.S. Biogas LLC, note 221 *supra*.

[229] Dairy farms are the main source, but by no means the only source, of livestock manure in Wisconsin. Other kinds of manure, such as poultry manure, are important in some areas. Poultry manure can present serious management problems because of its geographic concentration and high phosphorus content.

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[230] The synthetic nitrogen and phosphorus fertilizer used in Wisconsin originates from production facilities located outside the state. See The Fertilizer Institute, "U.S. Fertilizer and Mining Facilities at a Glance," available at http://www.kochfertilizer.com/pdf/TFI2009USProduction.pdf (visited February 2016). According to the Fertilizer Institute document, more than half of all nitrogen fertilizer used in the U.S. originates from foreign sources (the U.S. is the world's biggest importer of fertilizer).

[231] Method for estimating *nitrogen* from dairy manure: From American Association of Agricultural and Biological Engineers (ASABE), ASAE D384.2 (2005), Table 1.b., calculate average lbs. of nitrogen per lb. of manure (feces and urine, without dilutants) excreted by a lactating cow (calculation disregards potentially different nitrogen content of manure from dry cows, calves and replacement heifers). This calculation yields a unit-less ratio = 0.006618. Multiply this ratio by Wisconsin annual dairy manure production (estimated by the first method described in note 212, *supra*) to estimate total annual lbs. of nitrogen from dairy manure (rough estimate). Convert from lbs. to tons (to facilitate comparison with nitrogen fertilizer tonnage). For 2014, this calculation yields a statewide nitrogen contribution, from dairy manure, of about 209,000 tons.

[232] Method for estimating *phosphorus* from dairy manure: From American Association of Agricultural and Biological Engineers (ASABE), ASAE D384.2 (2005), Table 1.b., calculate average lbs. of phosphorus per lb. of manure (feces and urine, without dilutants) excreted by a lactating cow (calculation disregards potentially different phosphorus content of manure from dry cows, calves and replacement heifers). This calculation yields a unit-less ratio = 0.001147. Multiply by Wisconsin annual dairy manure production (estimated by the first method described in note 212, *supra*) to estimate total annual lbs. of phosphorus from dairy manure (rough estimate). Convert from lbs. to tons (to facilitate comparison with phosphorus fertilizer tonnage). For 2014, this calculation yields a statewide phosphorus contribution, from dairy manure, of about 36,000 tons.

[233] DATCP annual fertilizer tonnage report for 2014 (less than 5% non-farm use).

[234] See methodology, note 231 *supra.*

[235] See methodology, note 232 *supra.*

[236] Wisconsin has adopted nutrient management planning standards and requirements for farms, but compliance obligations are normally contingent on cost-sharing. *See* Wisconsin Administrative Code ch. ATCP 50. For information on nutrient management planning, see Wisconsin Department of Agriculture, Trade and Consumer Protection, "Nutrient Management," at http://datcp.wi.gov/Farms/Nutrient_Management/index.aspx.

[237] On many farms, soils already contain high levels of phosphorus. Legume crops, like soybeans and alfalfa, supply some of their own nitrogen needs by extracting nitrogen from the atmosphere. Some farms also get nutrients from treated municipal sewage products, such as Milwaukee's *Milorganite* or Madison's *Metrogrow*. Note that in areas where treated sewage products are used, they contribute a relatively small share of farm nutrients compared to commercial fertilizer and manure. *See* "A Clean Future for the Yahara Lakes: Solutions for Tomorrow, Starting Today," a joint report by Dane County, the City of Madison, DNR and DATCP (2010).

[238] *See* DATCP, "Wisconsin Making Inroads in Managing Manure," DATCP News Release (April 14, 2015).

[239] President Franklin D. Roosevelt, Letter to All State Governors on a Uniform Soil Conservation Law, February 26, 1937.

[240] *See* Arts and Church, "Soil Erosion – The Next Crisis?" *Wisconsin Law Review*, Volume 1982, No. 4 (1982); Pimental et al., "Environmental and Economic Costs of Soil Erosion and Conservation Benefits," *Science*, New Series, Vol. 267, No. 5201 (Feb., 1995), 1117-1123. See, also, the alarming (or alarmist?) *Scientific American* article quoting a senior United Nations Food and Agriculture Organization (FAO) official at http://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/.

[241] Pimental et al. (1995), note 240 *supra*.

[242] *See* discussion in Arts and Church, note 240 *supra*, at 545-52*.*

[243] *Ibid.*

[244] *See* U.S. EPA, "Nutrient Pollution: Sources and Solutions," available at http://www2.epa.gov/nutrientpollution/sources-and-solutions (April, 2015). Other citations can be found in Porter, et al., note 246 *infra*.

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[245] USDA, 1989, cited in Pimental et al., note 240 *supra.*

[246] *See* Porter, et al., "Reducing hypoxia in the Gulf of Mexico: Reimagining a more resilient agricultural landscape in the Mississippi River Watershed," *Journal of Soil and Water Conservation* (May-June, 2015), 70-3, at 63A. *See also* "Moving Forward on Gulf Hypoxia," U.S. EPA Fact Sheet available at http://water.epa.gov/type/watersheds/named/msbasin/upload/2008_08_26msbasin_hypoxia_fs_508_0808.pdf; "Officials in Columbus discuss Midwest's role in Gulf of Mexico dead zone," *The Columbus Dispatch* (June 12, 2015).

[247] CNN News, "Gulf of Mexico 'Dead Zone' is the Size of Connecticut" (August 5, 2014).

[248] Egan, "Dead zones haunt Green Bay as manure fuels algae blooms," *Milwaukee Journal-Sentinel* (September 13, 2014).

[249] *See* Wisconsin DNR, "Reducing Phosphorus to Clean Up Lakes and Rivers" (Revised December 22, 2014).

[250] *See*, e.g., Wines, "Behind Toledo's Water Crisis A Long-Troubled Lake Erie" *New York Times* (August 4, 2014).

[251] Wisconsin DNR and U.S. EPA, "Wisconsin Integrated Assessment of Watershed Health" (March 2014).

[252] Wisconsin Initiative on Climate Change Impacts, *Soil Conservation Working Group Report* (2011).

[253] *Ibid.*

[254] Zuckerman, "Plowed Under," *The American Prospect*, 2014.

[255] University of Wisconsin Soils Department lecture, 2013 (Emeritus Prof. Kevin McSweeney).

[256] Wisconsin State Historical Society, Classroom Material "Wisconsin State Symbols," available at http://www.wisconsinhistory.org/Content.aspx?dsNav=N:4294963828-4294963805&dsRecordDetails=R:CS2908.

Appendix C

Zoning for Groundwater Protection

ZONING AS A TOOL IN GROUNDWATER PROTECTION

JANUARY 4, 2022

CENTRAL SANDS GROUNDWATER COLLABORATIVE

LYNN MARKHAM, LAND USE SPECIALIST

Center for Land Use Education
College of Natural Resources
University of Wisconsin-Stevens Point

Extension
UNIVERSITY OF WISCONSIN-MADISON

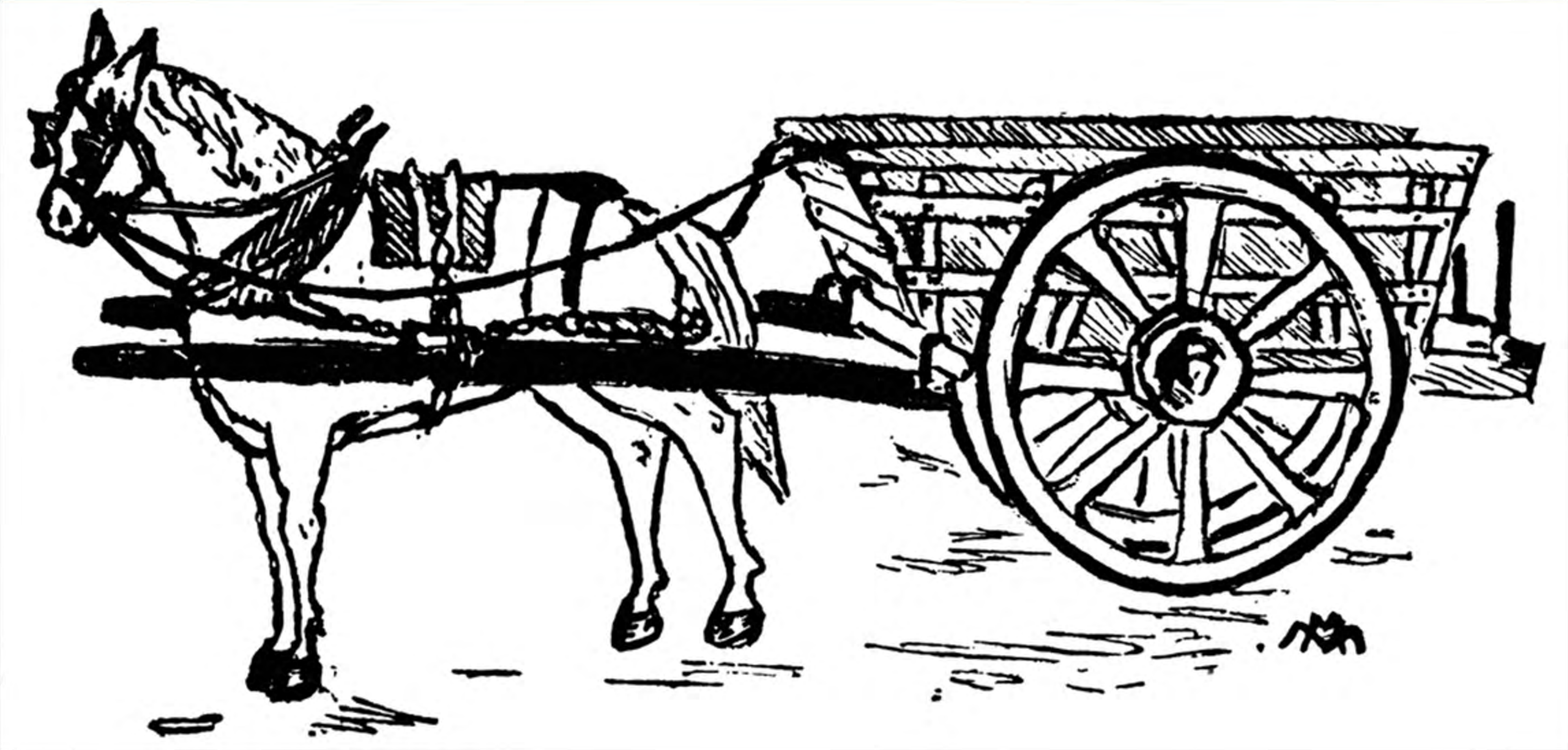
SUMMARY

- Zoning has strengths and weaknesses related to protecting groundwater
- Weaknesses
  - Limited ability to address existing problematic land uses
  - Zoning doesn't determine which crops are grown in ag districts, even though they have different amounts of nitrogen leaching to groundwater
- Strengths
  - Can use wellhead protection ordinances to protect municipal/community wells
  - Can set minimum lot sizes to space out residential septic systems and protect private well water quality from septic systems
  - Can list high nitrogen uses as conditional or prohibited uses (e.g. fertilizer plants, landfills, feedlots, cemeteries, golf courses, possibly CAFOs)
  - Can geographically separate high nitrogen uses from wells - theoretically

- Can be changed at any time by elected officials (town-county zoning). Land purchases are more certain long-term protection, and more expensive.

Comprehensive plan = Goals

Zoning = Way to achieve goals

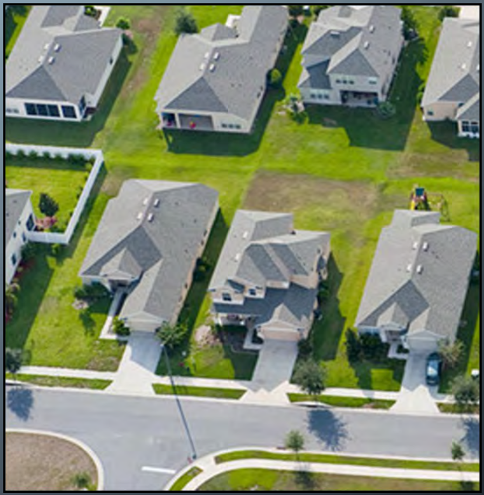


Guiding Document

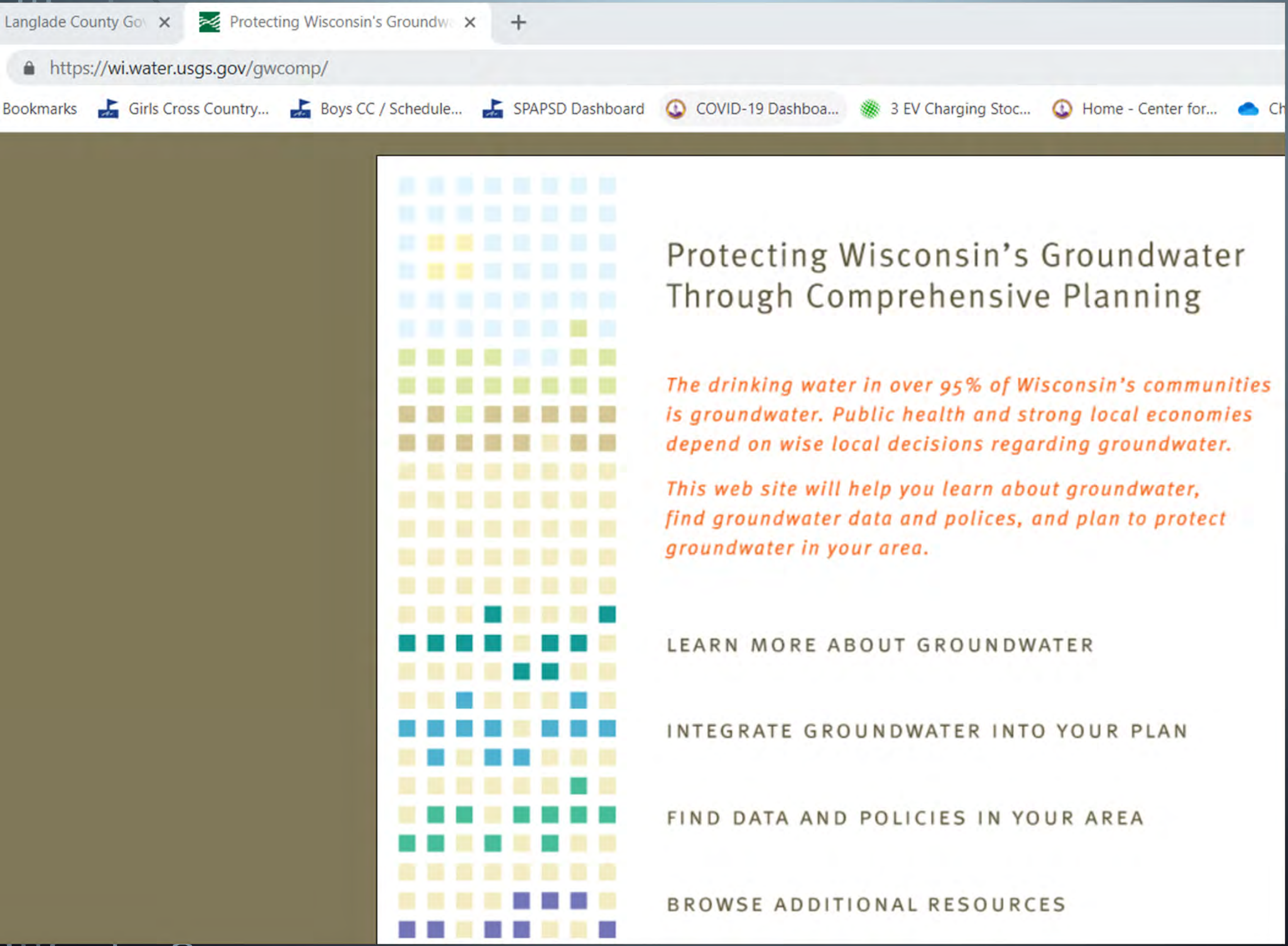
Comprehensive Plan

Regulatory Tools to Implement the Plan

Zoning Ordinance



Subdivision Ordinance



Protecting Wisconsin's Groundwater Through Comprehensive Planning

The drinking water in over 95% of Wisconsin's communities is groundwater. Public health and strong local economies depend on wise local decisions regarding groundwater.

This web site will help you learn about groundwater, find groundwater data and polices, and plan to protect groundwater in your area.

LEARN MORE ABOUT GROUNDWATER

INTEGRATE GROUNDWATER INTO YOUR PLAN

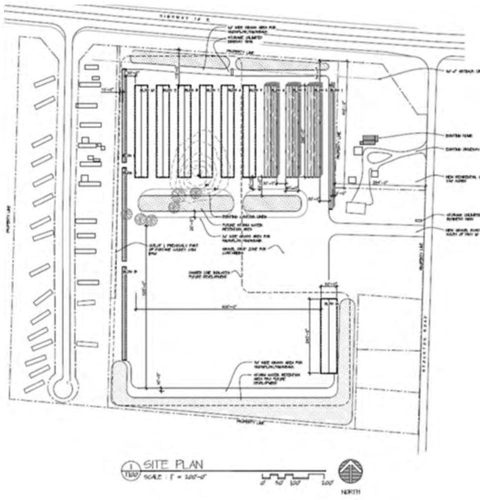
FIND DATA AND POLICIES IN YOUR AREA

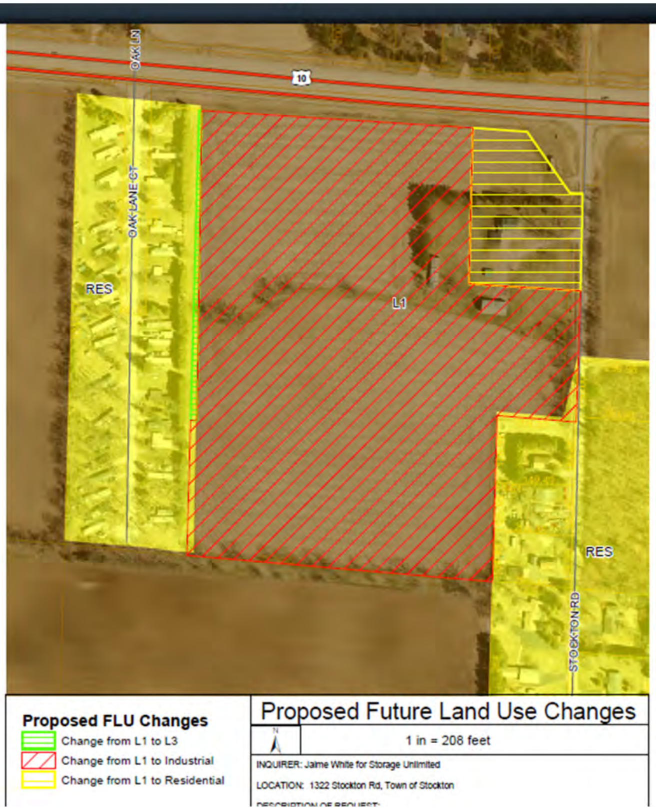
BROWSE ADDITIONAL RESOURCES

Policy suggestions for updating comp plans.
Note: Data on this website is old. Use Well Water Quality Viewer for data.

EXAMPLE OF USING YOUR PLAN TO PROTECT GROUNDWATER

- Plans are only valuable if they are used in making decisions
- Changes to zoning are required to be <u>consistent</u> with the comprehensive plan
- Portage County used their comp plan to guide groundwater protection conditions for a new proposed development that required a change in zoning





Proposed FLU Changes

- 🟩 Change from L1 to L3
- 🟥 Change from L1 to Industrial
- 🟨 Change from L1 to Residential

Proposed Future Land Use Changes

INQUIRER: Jaime White for Storage Unlimited

LOCATION: 1322 Stockton Rd, Town of Stockton

DESCRIPTION OF REQUEST:

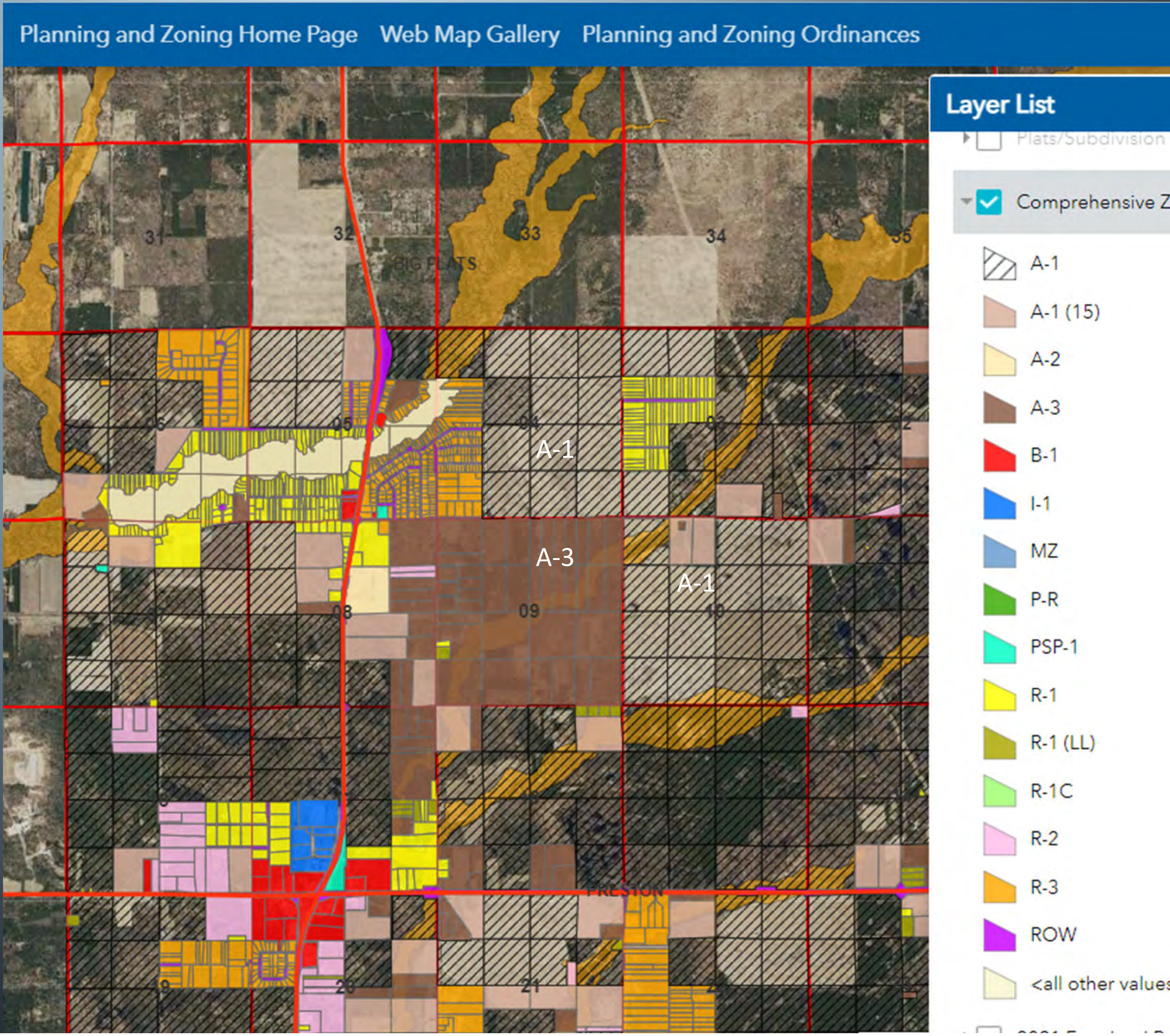
WHAT DO ZONING AND SUBDIVISION REGS DO?

- Sets the development pattern
  - Density
  - Land Uses
  - Building envelope dimensions (setbacks, height, etc.)
  - Roads
- Impacts how our communities look and how they function

HOW DOES ZONING WORK?

A zoning ordinance contains two parts:

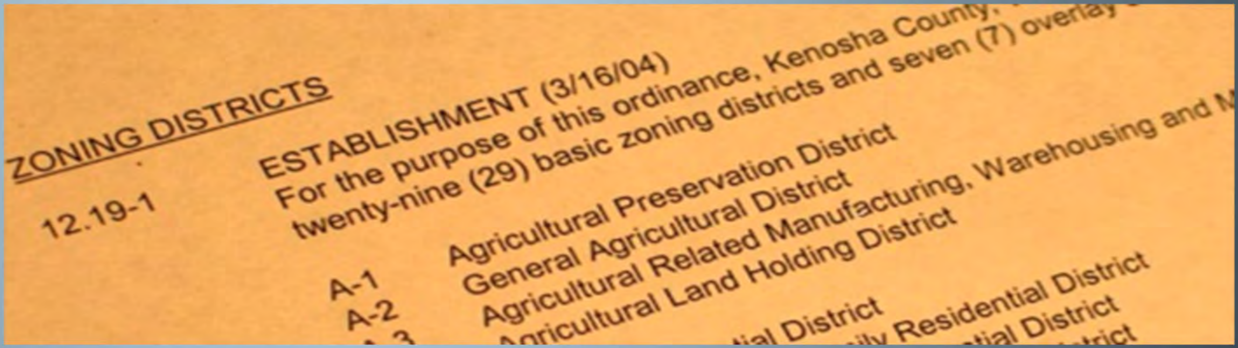
<u>Zoning Map</u> divides the community into districts



A zoning ordinance contains two parts:

Zoning Text

- purposes
- uses allowed in each district
- dimensional standards i.e. lot size, setbacks, etc.
- requirements related to parking, signage, landscaping, etc.

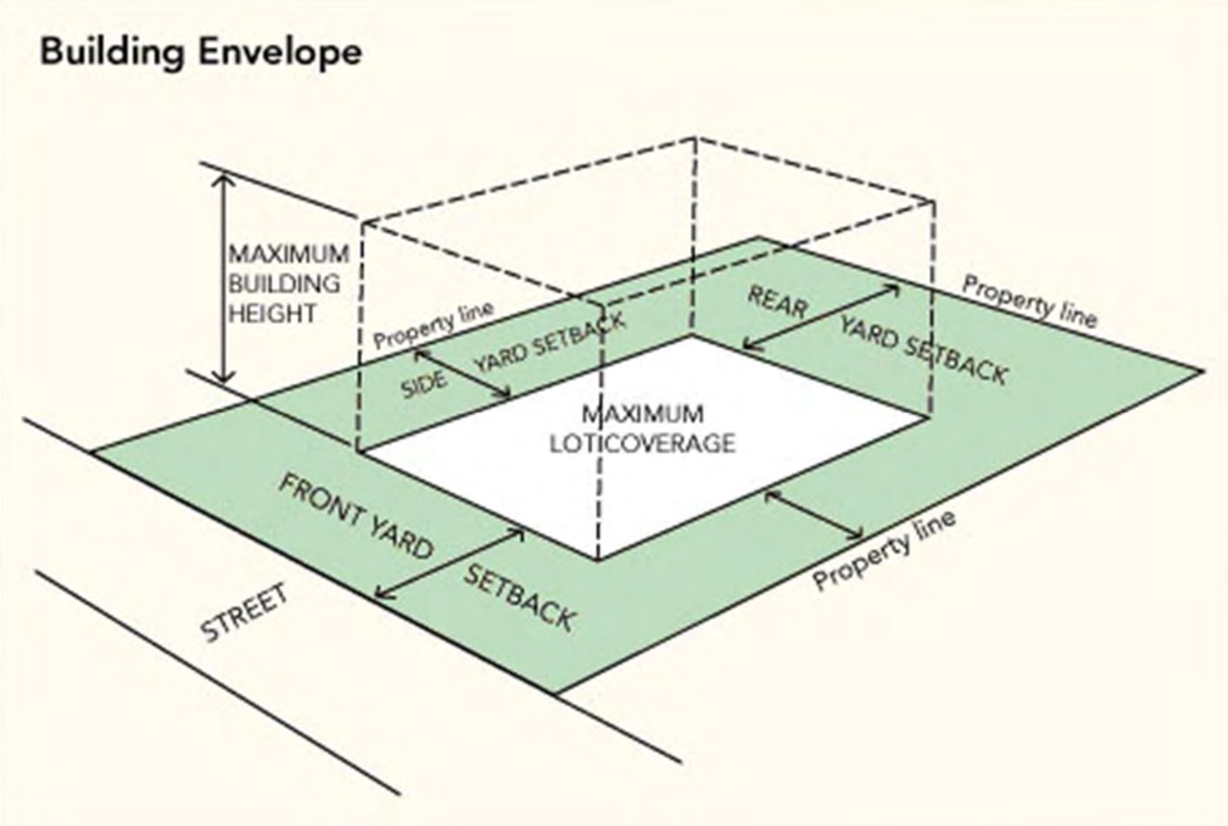


ZONING DISTRICTS

12.19-1 ESTABLISHMENT (3/16/04)

For the purpose of this ordinance, Kenosha County,
twenty-nine (29) basic zoning districts and seven (7) overlay

A-1 Agricultural Preservation District
A-2 General Agricultural District
Agricultural Related Manufacturing, Warehousing and
Agricultural Land Holding District



Building Envelope

USES FOR EACH DISTRICT:

Permitted Use

Use is listed and allowed by right in all parts of the zoning district

Granted by zoning administrator

Conditional Use

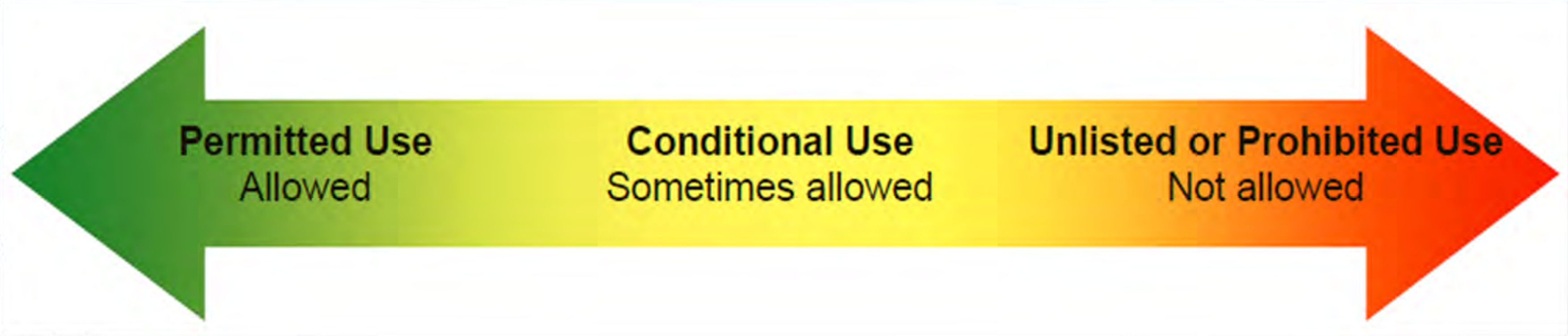
Use is listed for the district and may be allowed if suited to the location

Decided by zoning board, plan commission, or governing body

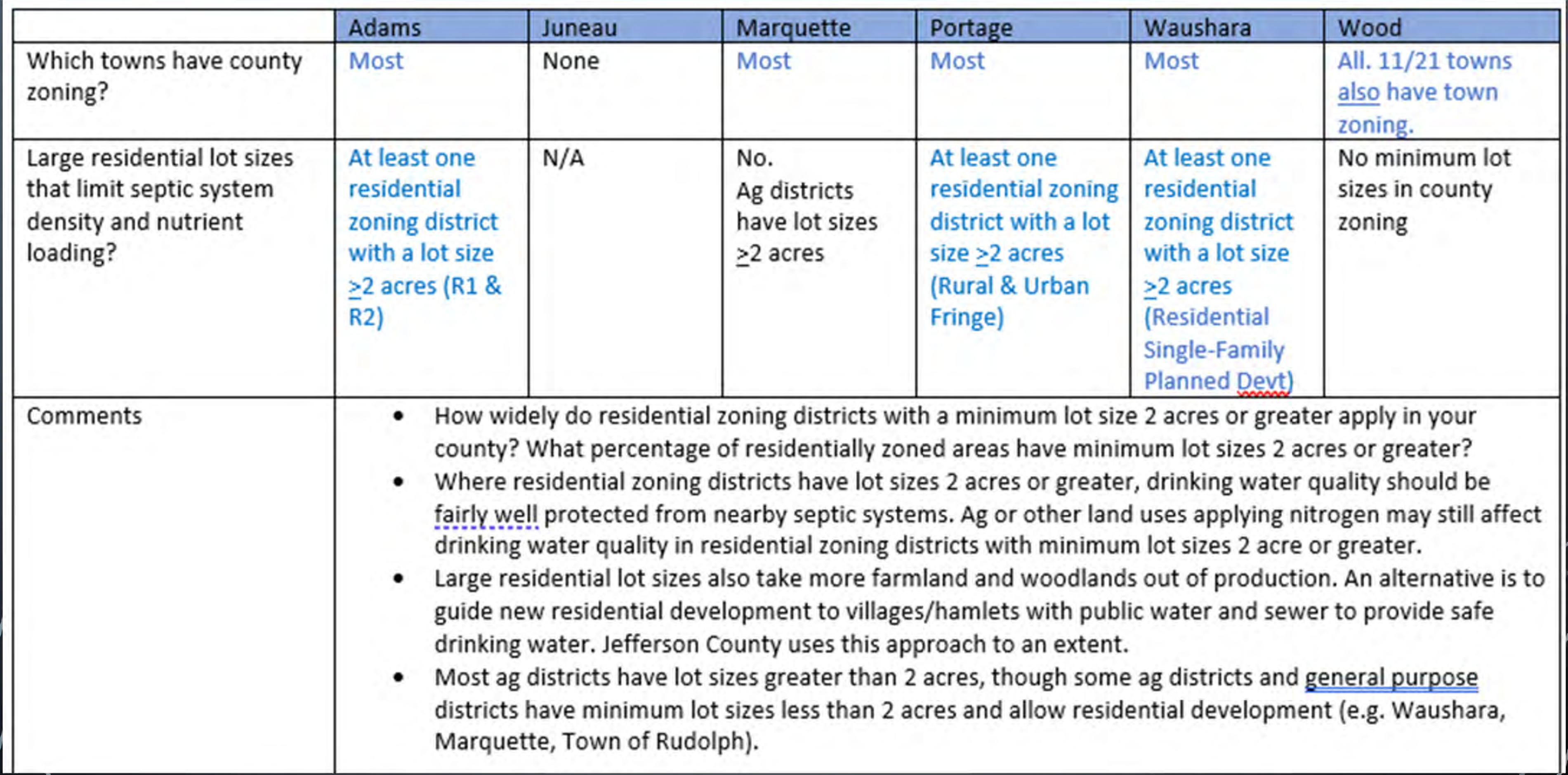
Prohibited Use

Use is not listed for the district or is expressly prohibited

May apply for rezone or use variance, if allowed



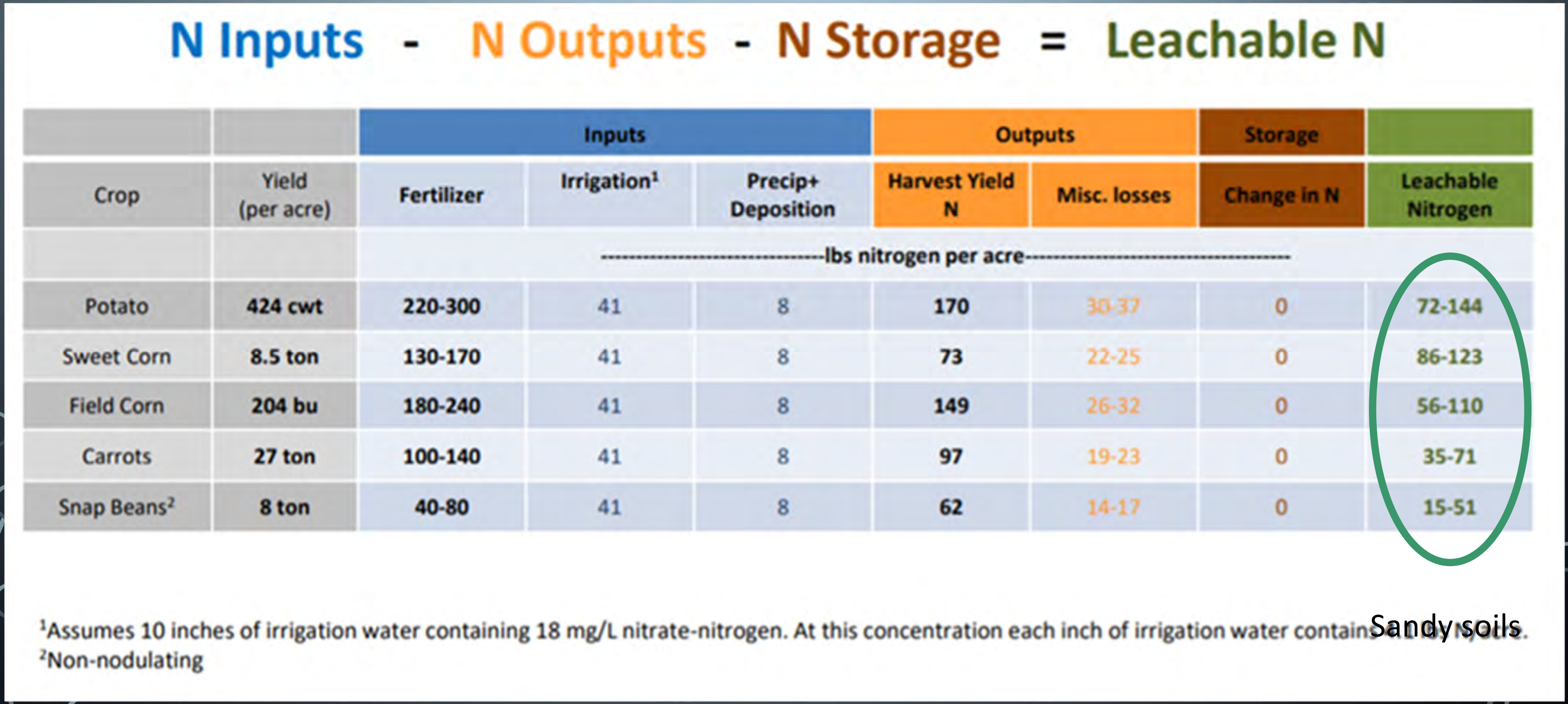
COUNTY SURVEY RESULTS



	Adams	Juneau	Marquette	Portage	Waushara	Wood
Which towns have county zoning?	Most	None	Most	Most	Most	All. 11/21 towns also have town zoning.
Large residential lot sizes that limit septic system density and nutrient loading?	At least one residential zoning district with a lot size ≥2 acres (R1 & R2)	N/A	No. Ag districts have lot sizes ≥2 acres	At least one residential zoning district with a lot size ≥2 acres (Rural & Urban Fringe)	At least one residential zoning district with a lot size ≥2 acres (Residential Single-Family Planned Devt)	No minimum lot sizes in county zoning
Comments	• How widely do residential zoning districts with a minimum lot size 2 acres or greater apply in your county? What percentage of residentially zoned areas have minimum lot sizes 2 acres or greater? • Where residential zoning districts have lot sizes 2 acres or greater, drinking water quality should be fairly well protected from nearby septic systems. Ag or other land uses applying nitrogen may still affect drinking water quality in residential zoning districts with minimum lot sizes 2 acre or greater. • Large residential lot sizes also take more farmland and woodlands out of production. An alternative is to guide new residential development to villages/hamlets with public water and sewer to provide safe drinking water. Jefferson County uses this approach to an extent. • Most ag districts have lot sizes greater than 2 acres, though some ag districts and general purpose districts have minimum lot sizes less than 2 acres and allow residential development (e.g. Waushara, Marquette, Town of Rudolph).					

DIFFERENT CROPS LEACH DIFFERENT AMOUNTS OF NITROGEN TO GROUNDWATER

- Ag zoning districts do <u>not</u> differentiate based on how much nitrogen is leached to groundwater



N Inputs - N Outputs - N Storage = Leachable N

		Inputs			Outputs		Storage	
Crop	Yield (per acre)	Fertilizer	Irrigation[1]	Precip+ Deposition	Harvest Yield N	Misc. losses	Change in N	Leachable Nitrogen
		------------------------------lbs nitrogen per acre------------------------------						
Potato	424 cwt	220-300	41	8	170	30-37	0	72-144
Sweet Corn	8.5 ton	130-170	41	8	73	22-25	0	86-123
Field Corn	204 bu	180-240	41	8	149	26-32	0	56-110
Carrots	27 ton	100-140	41	8	97	19-23	0	35-71
Snap Beans[2]	8 ton	40-80	41	8	62	14-17	0	15-51

Sandy soils

[1] Assumes 10 inches of irrigation water containing 18 mg/L nitrate-nitrogen. At this concentration each inch of irrigation water contains

[2] Non-nodulating

Kevin Masarik, Groundwater Specialist

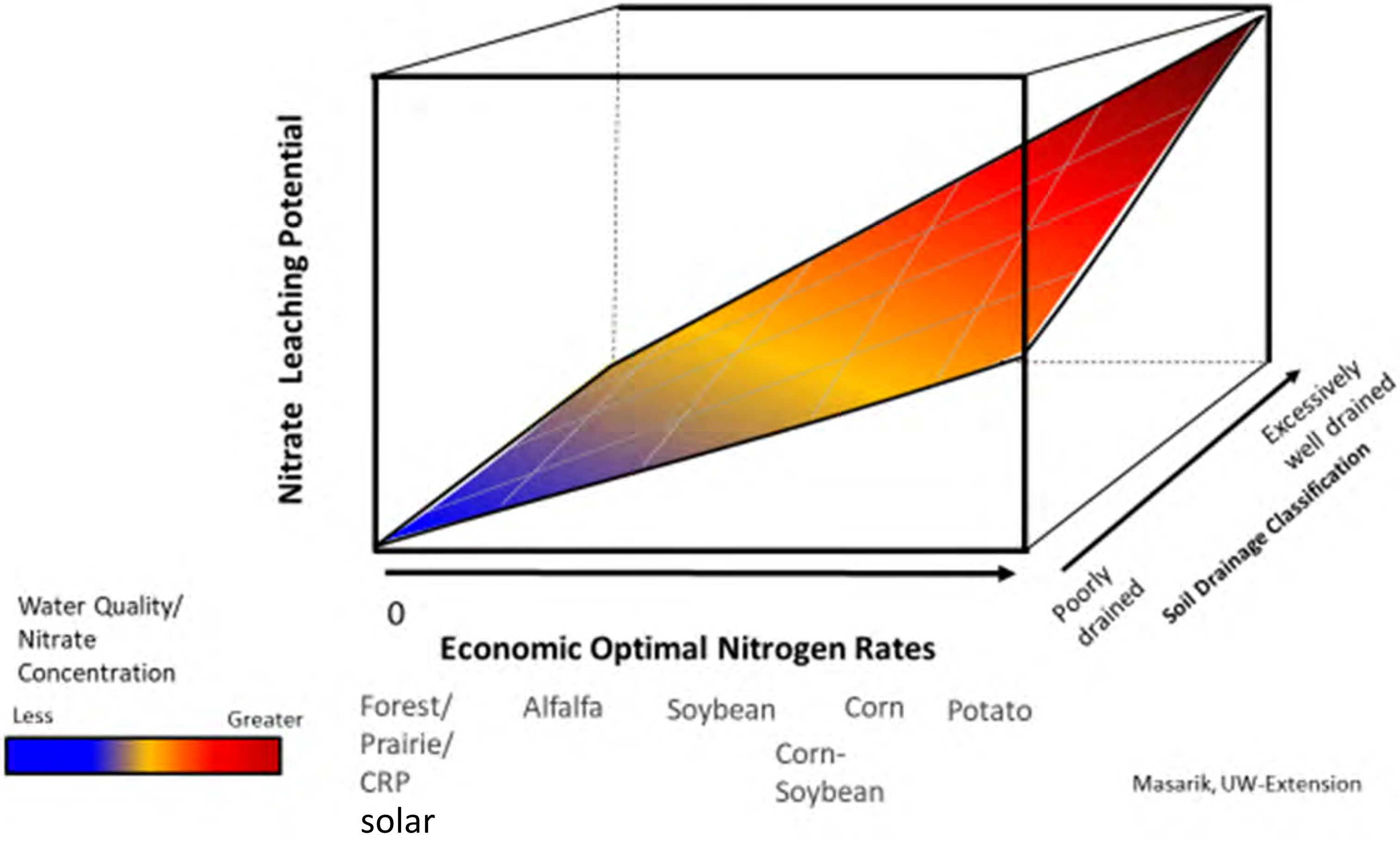
Comparing Land-use Impacts

	Corn[1] (per acre)	Prairie[1] (per acre)	Septic [2] System
Total Nitrogen Inputs (lb)	169	9	20-25
Nitrogen Leaching Loss (lb)	36	0.04	16-20
Amount N lost to leaching (%)	20	0.4	80-90

1 Data from Masarik, Economic Optimum Rate on a silt-loam soil, 2003

2 Data from Tri-State Water Quality Council, 2005 and EPA 625/R-

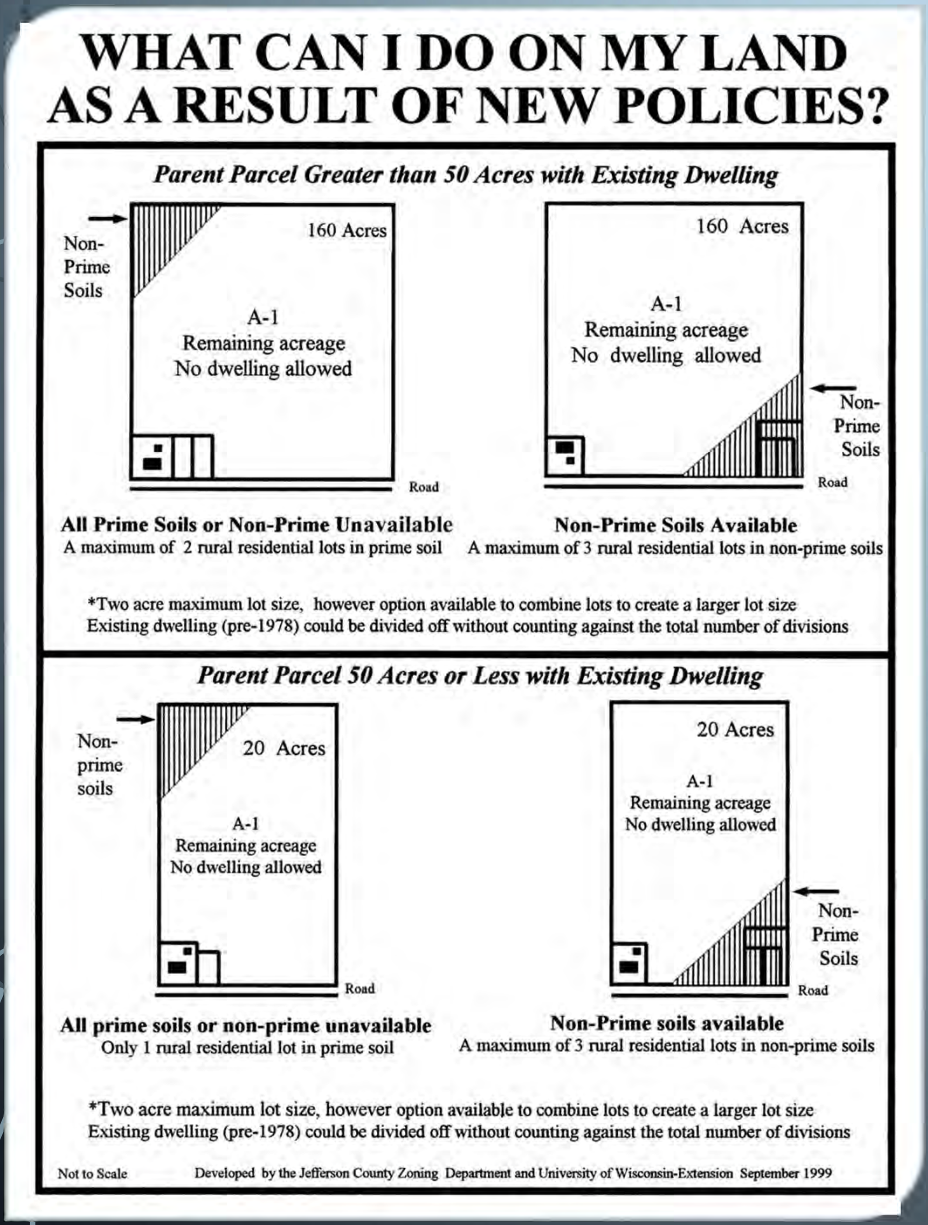
Nitrate Leaching Potential



Masarik, UW-Extension

- Different crops on the same soil have different rates of nitrate leaching that vary from year to year based on fertilizer inputs, yield, and weather
- Nitrate leaching below the same crop can vary depending on soil type and location in the state
- Zoning doesn't determine which crops are grown. LWCD and FSA offices can affect this topic.

Kevin Masarik, Groundwater Specialist, send PowerPoint and



WHAT CAN I DO ON MY LAND AS A RESULT OF NEW POLICIES?

Parent Parcel Greater than 50 Acres with Existing Dwelling

All Prime Soils or Non-Prime Unavailable
A maximum of 2 rural residential lots in prime soil

Non-Prime Soils Available
A maximum of 3 rural residential lots in non-prime soils

*Two acre maximum lot size, however option available to combine lots to create a larger lot size
Existing dwelling (pre-1978) could be divided off without counting against the total number of divisions

Parent Parcel 50 Acres or Less with Existing Dwelling

All prime soils or non-prime unavailable
Only 1 rural residential lot in prime soil

Non-Prime soils available
A maximum of 3 rural residential lots in non-prime soils

*Two acre maximum lot size, however option available to combine lots to create a larger lot size
Existing dwelling (pre-1978) could be divided off without counting against the total number of divisions

Not to Scale

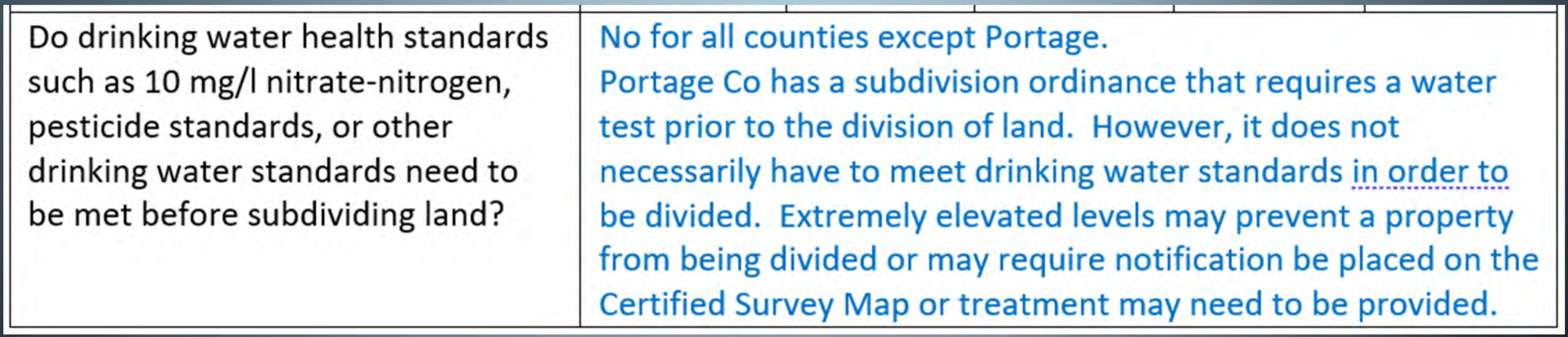
Developed by the Jefferson County Zoning Department and University of Wisconsin-Extension September 1999

LIMITED RESIDENTIAL ALLOWED IN A-1 ZONING DISTRICTS

- Farmland preservation
- Fewer new residential lots in A-1 zoning districts which may have high nitrate levels

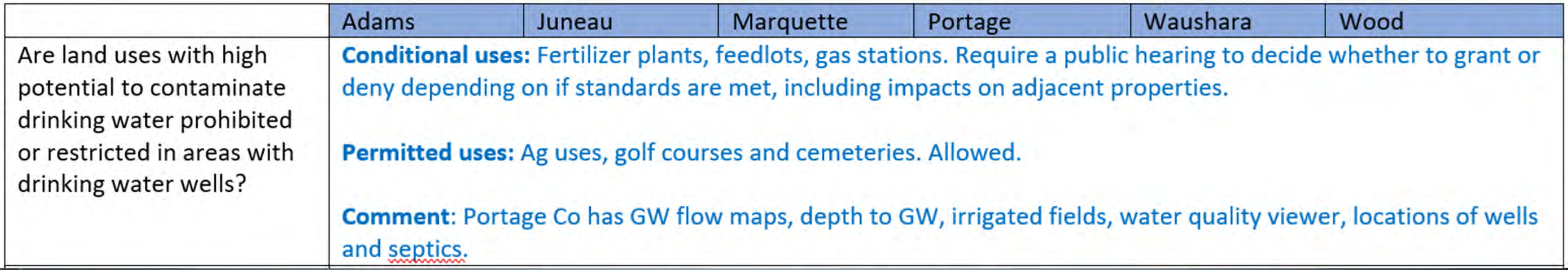
SURVEY RESULTS

Limiting new residential lots where drinking water is not safe



Do drinking water health standards such as 10 mg/l nitrate-nitrogen, pesticide standards, or other drinking water standards need to be met before subdividing land?	No for all counties except Portage. Portage Co has a subdivision ordinance that requires a water test prior to the division of land. However, it does not necessarily have to meet drinking water standards in order to be divided. Extremely elevated levels may prevent a property from being divided or may require notification be placed on the Certified Survey Map or treatment may need to be provided.

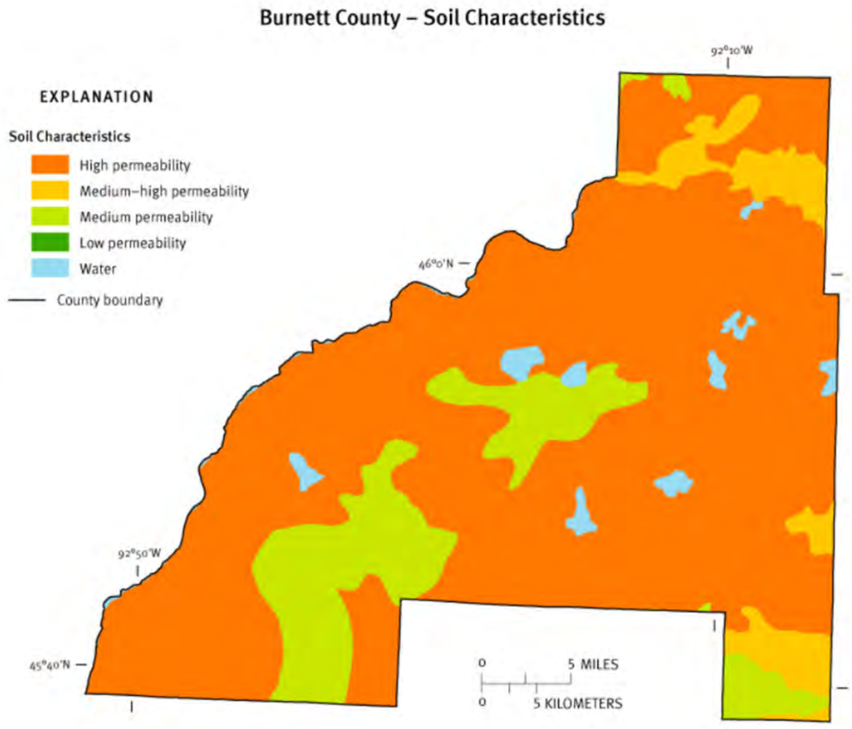
CAN USE ZONING TO MAKE LAND USES WITH HIGH NITROGEN LEACHING CONDITIONAL OR PROHIBITED USES



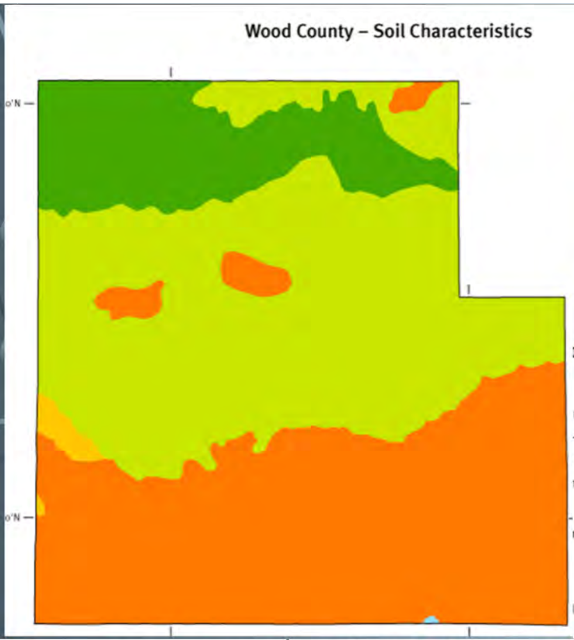
	Adams	Juneau	Marquette	Portage	Waushara	Wood
Are land uses with high potential to contaminate drinking water prohibited or restricted in areas with drinking water wells?	**Conditional uses:** Fertilizer plants, feedlots, gas stations. Require a public hearing to decide whether to grant or deny depending on if standards are met, including impacts on adjacent properties. **Permitted uses:** Ag uses, golf courses and cemeteries. Allowed. **Comment**: Portage Co has GW flow maps, depth to GW, irrigated fields, water quality viewer, locations of wells and septics.					

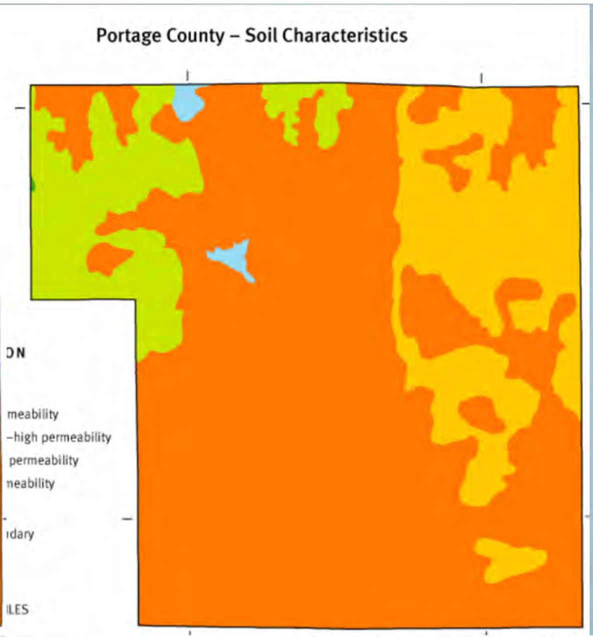
- Review the permitted, conditional, and unlisted/prohibited uses listed for each zoning district in your ordinance. Compare your zoning maps with your groundwater susceptibility/soil maps. Do they need to be updated to protect groundwater qualiy?
- 2017 Act 67 says if a CUP meets standards in ordinance it must be granted

BURNETT COUNTY PLANS TO USE GW SUSCEPTIBILITY MAPS AND ZONING TO LIMIT WHERE NEW CAFOS CAN BE LOCATED

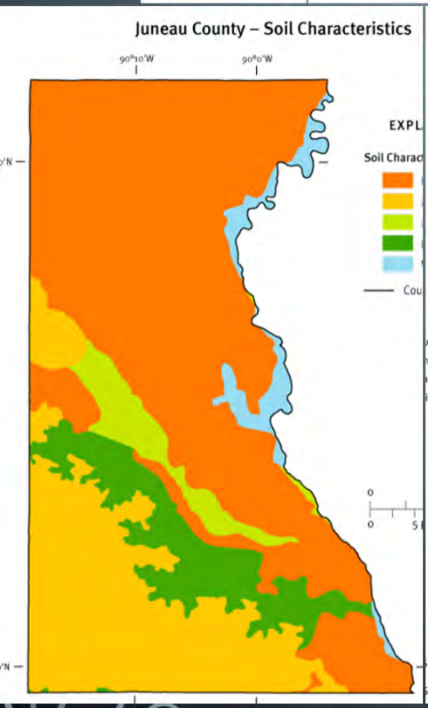


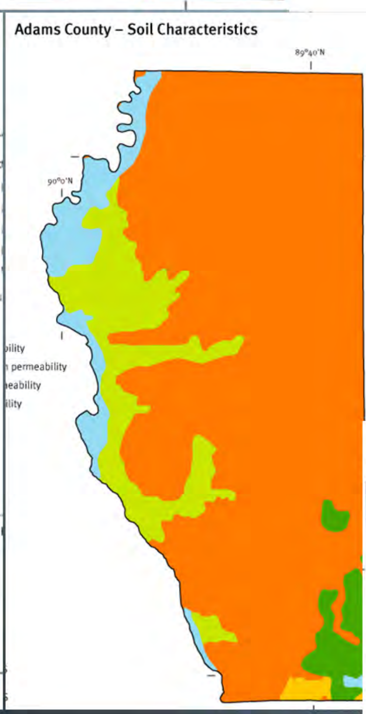
- About 80% of Burnett County is less than 20 feet to the water table and has highly permeable soils
- Burnett County has three ag districts
- Not much exclusive ag zoning (A1) is located in the sandy soil areas of the county
- Land use committee is working on a proposal to allow CAFOs (1000 animal units or more) only in A1, and limit animal units in other ag districts to 250 or 500

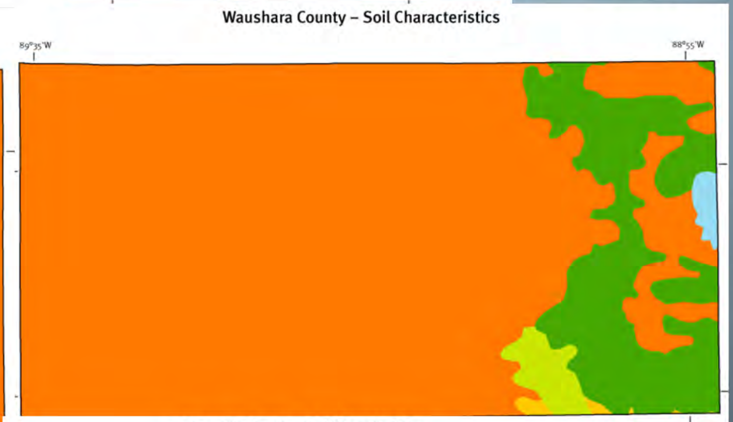

Wood County – Soil Characteristics

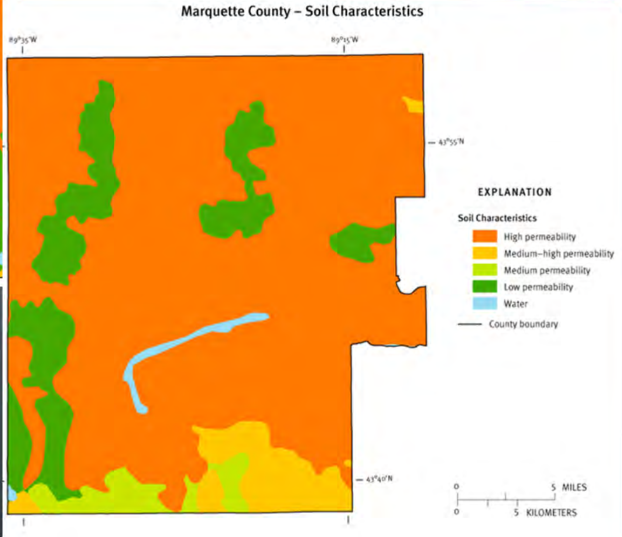

Portage County – Soil Characteristics

- All counties in CSGCC have areas of highly permeable soils, and some areas with lower permeable soils
- Areas with lower permeable soils are likely safer places for land uses that are potential sources of GW contamination
- Zoning can be used to determine where NEW land uses will be located (e.g. fertilizer plant, manufacturing)


Juneau County – Soil Characteristics

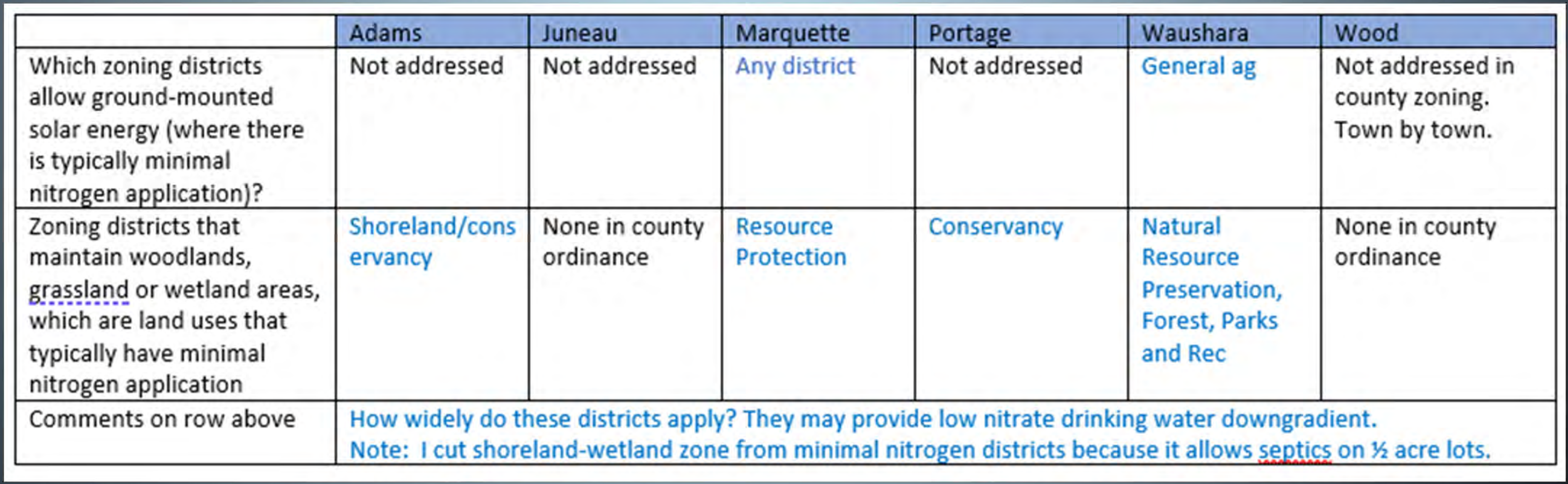

Adams County – Soil Characteristics


Waushara County – Soil Characteristics


Marquette County – Soil Characteristics

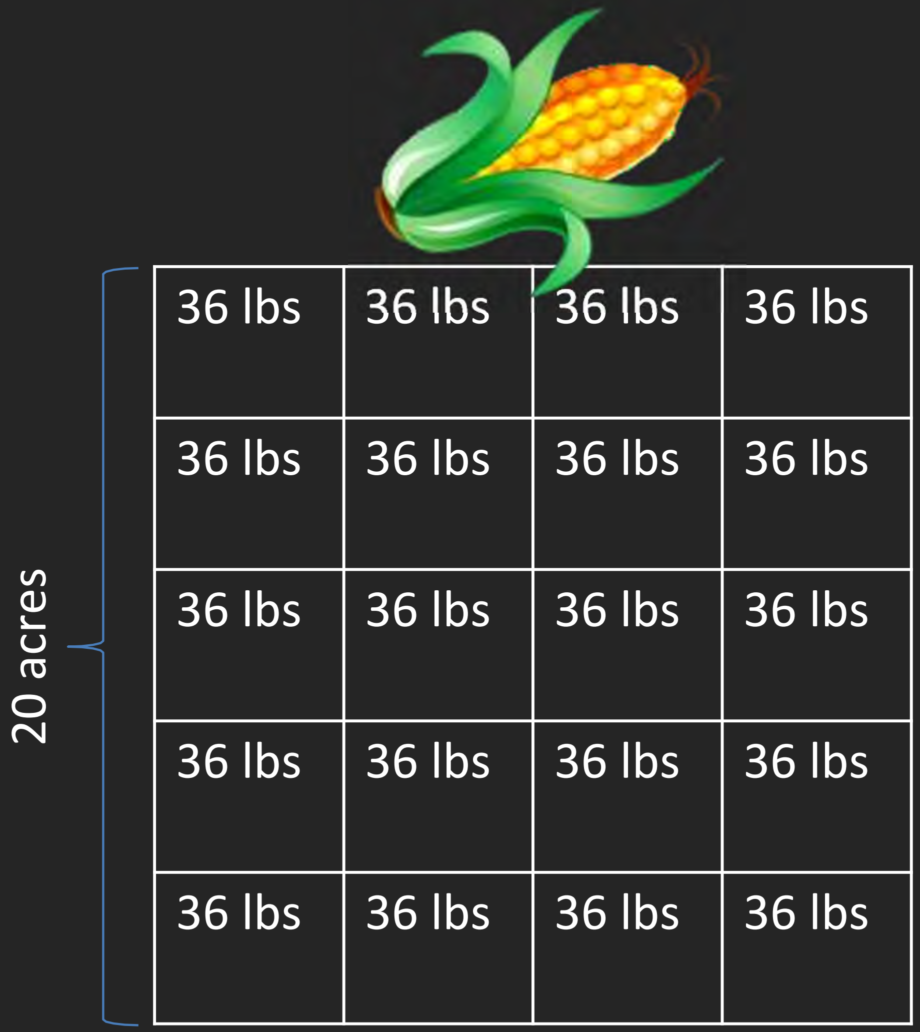
SURVEY RESULTS

- Zoning districts that maintain or allow low nitrogen land uses
- GW downgradient of these areas may be protected & low nitrate. Map?

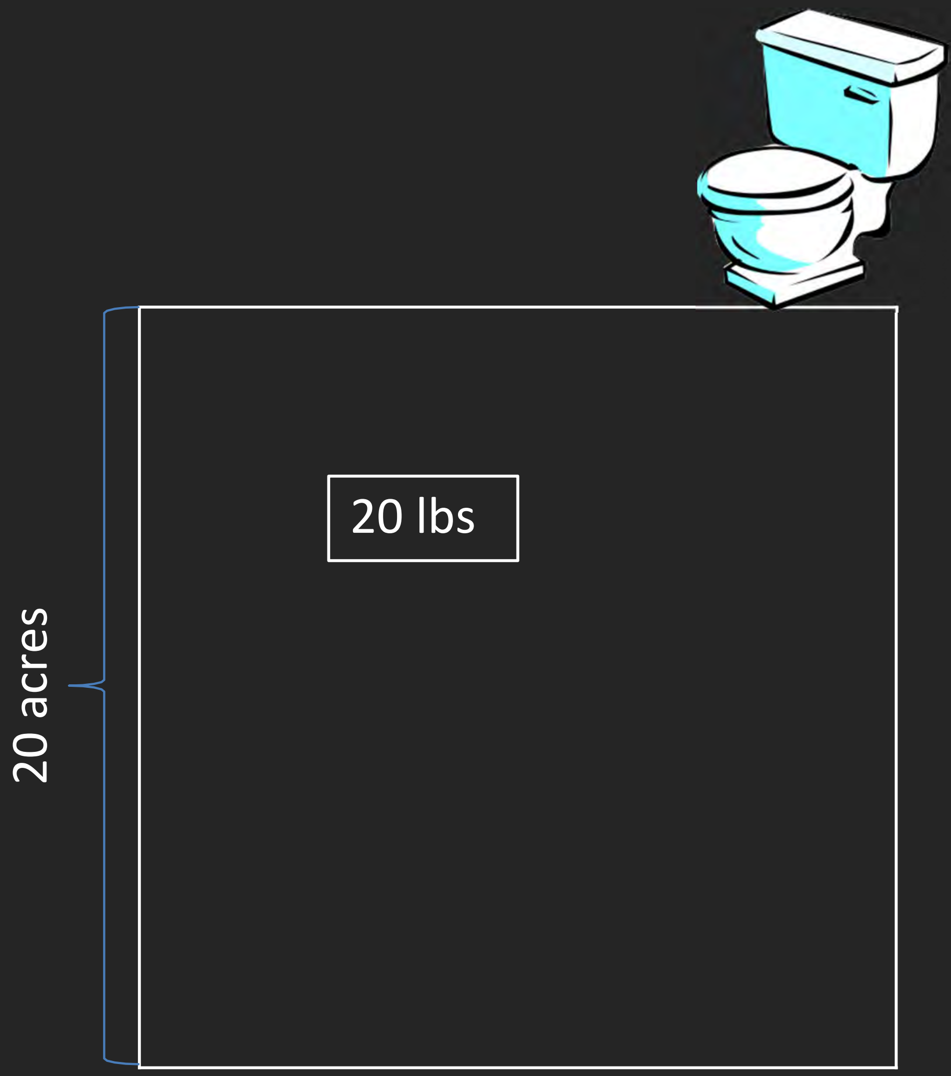


	Adams	Juneau	Marquette	Portage	Waushara	Wood
Which zoning districts allow ground-mounted solar energy (where there is typically minimal nitrogen application)?	Not addressed	Not addressed	Any district	Not addressed	General ag	Not addressed in county zoning. Town by town.
Zoning districts that maintain woodlands, grassland or wetland areas, which are land uses that typically have minimal nitrogen application	Shoreland/conservancy	None in county ordinance	Resource Protection	Conservancy	Natural Resource Preservation, Forest, Parks and Rec	None in county ordinance
Comments on row above	How widely do these districts apply? They may provide low nitrate drinking water downgradient. Note: I cut shoreland-wetland zone from minimal nitrogen districts because it allows septics on ½ acre lots.					

Comparing Land-use Impacts



36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs



36 lbs/ac x 20 acres = 720 lbs

16 mg/L

20 lbs/septic system x 1 septic systems = 20 lbs

1/36th the impact on water quality

0.44 mg/L

Assuming 10 inches of recharge -

Masarik, UW-Extension

Comparing Land-use Impacts

20 acres

36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs

36 lbs/ac x 20 acres = 720 lbs

20 acres

20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs

20 lbs/septic system x 36 septic systems = 720 lbs

Using these numbers: 36 septic systems on 20 acres (0.55 acre lots) needed to achieve same impact to water quality as 20 acres of corn

Masarik, UW-Extension

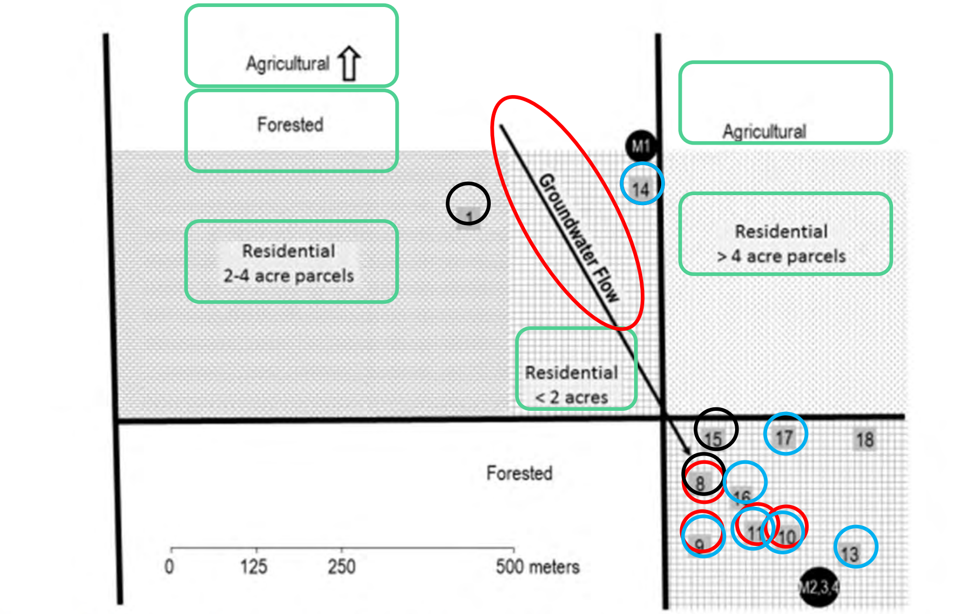
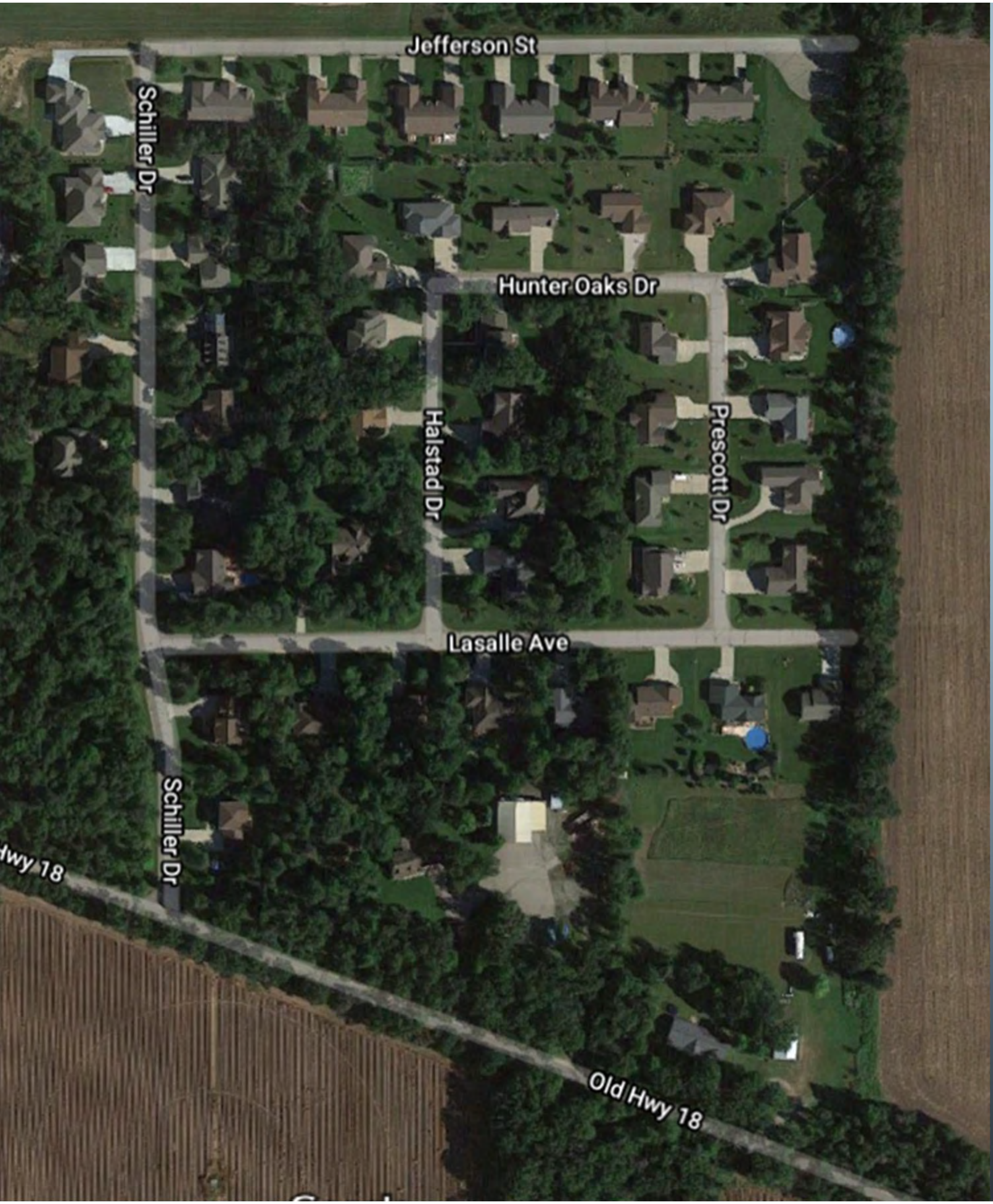


Figure 2. North study area showing land uses and density of homes in the residential areas. Numbered squares show location of private wells sampled and dark circles show the location of the monitoring wells.

UNSEWERED RESIDENTIAL AREAS

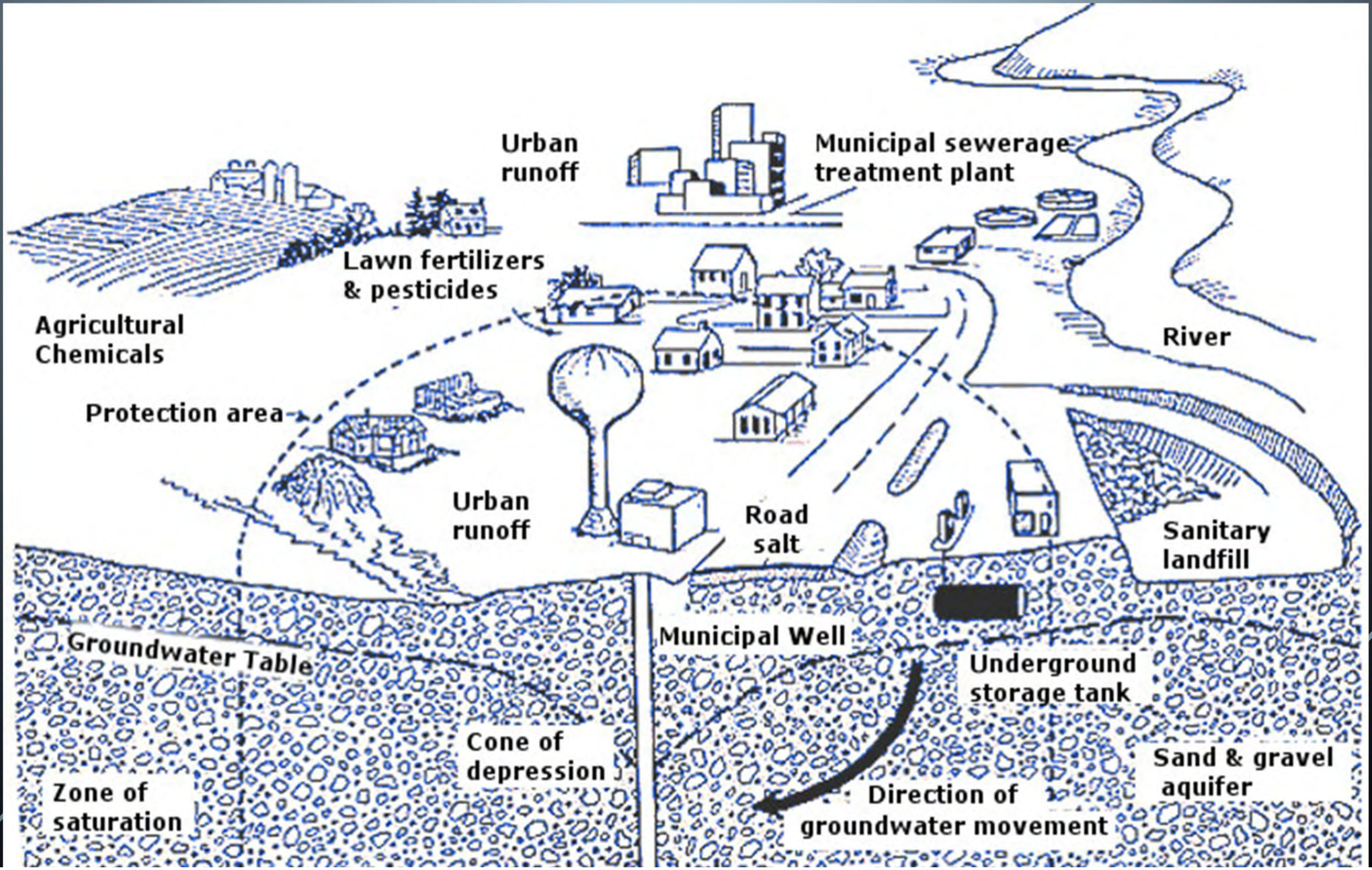
- In a sandy area with unsewered lot sizes less than 2 acres, nitrate levels were:
  - 7 wells 2-10 ppm = blue circles
  - 3 wells over 10 ppm= black circles
  - 1 well less than 2 ppm
- Sulfamethoxazole, a human antibiotic = red circles
- Let me know if you'd like a copy of this study



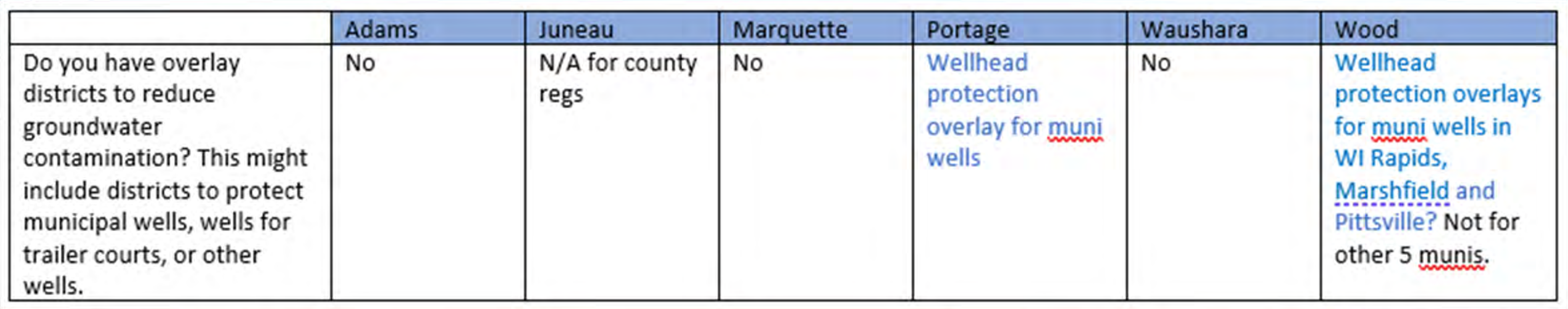
RESIDENTIAL ZONING FOR UNSEWERED DEVELOPMENT

- Zoning can be used to set unsewered minimum residential lot sizes at 2 or more acres to limit well contamination by nitrate and pharmaceuticals from nearby septics

Wellhead protection ordinance



SURVEY RESULTS



	Adams	Juneau	Marquette	Portage	Waushara	Wood
Do you have overlay districts to reduce groundwater contamination? This might include districts to protect municipal wells, wells for trailer courts, or other wells.	No	N/A for county regs	No	Wellhead protection overlay for muni wells	No	Wellhead protection overlays for muni wells in WI Rapids, Marshfield and Pittsville? Not for other 5 munis.

ENVIRONMENT INVESTIGATES

Ford megasite atop 'recharge zone' for underregulated Memphis Sands aquifer

An area that provides drinking water for more than a million people depends on company and state for protection

BY: **ASHLI BLOW** - JANUARY 3, 2022 5:01 AM

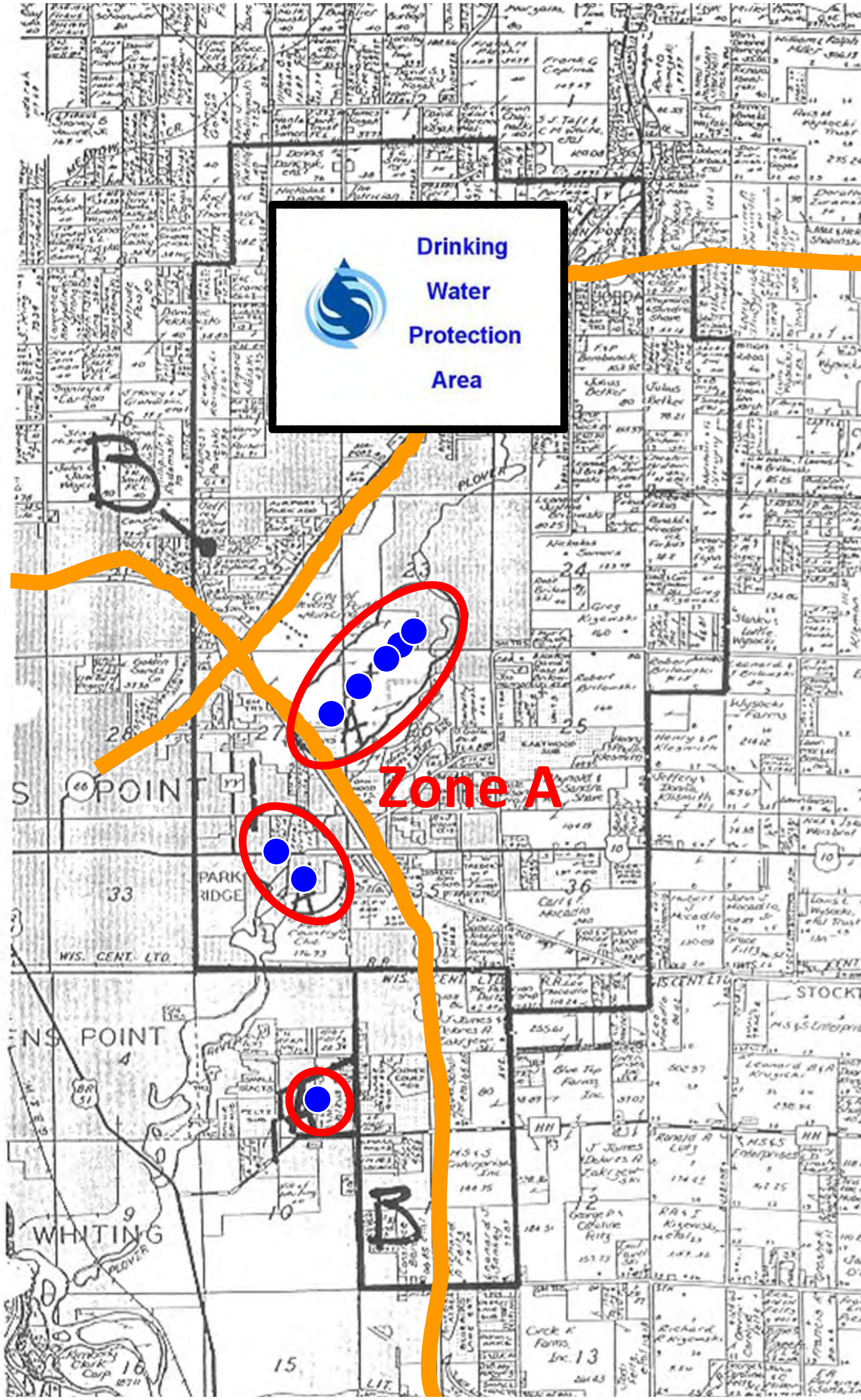
Satellite image of a portion of the Megasite of West Tennesseee. (Tennessee Department of General Services.)

Wellhead Protection Ordinance

Zone A – allows only land uses with low potential to pollute drinking water such as unfertilized parks

Zone B – allows more land uses but not gas stations, fertilizer plants, cemeteries, etc.

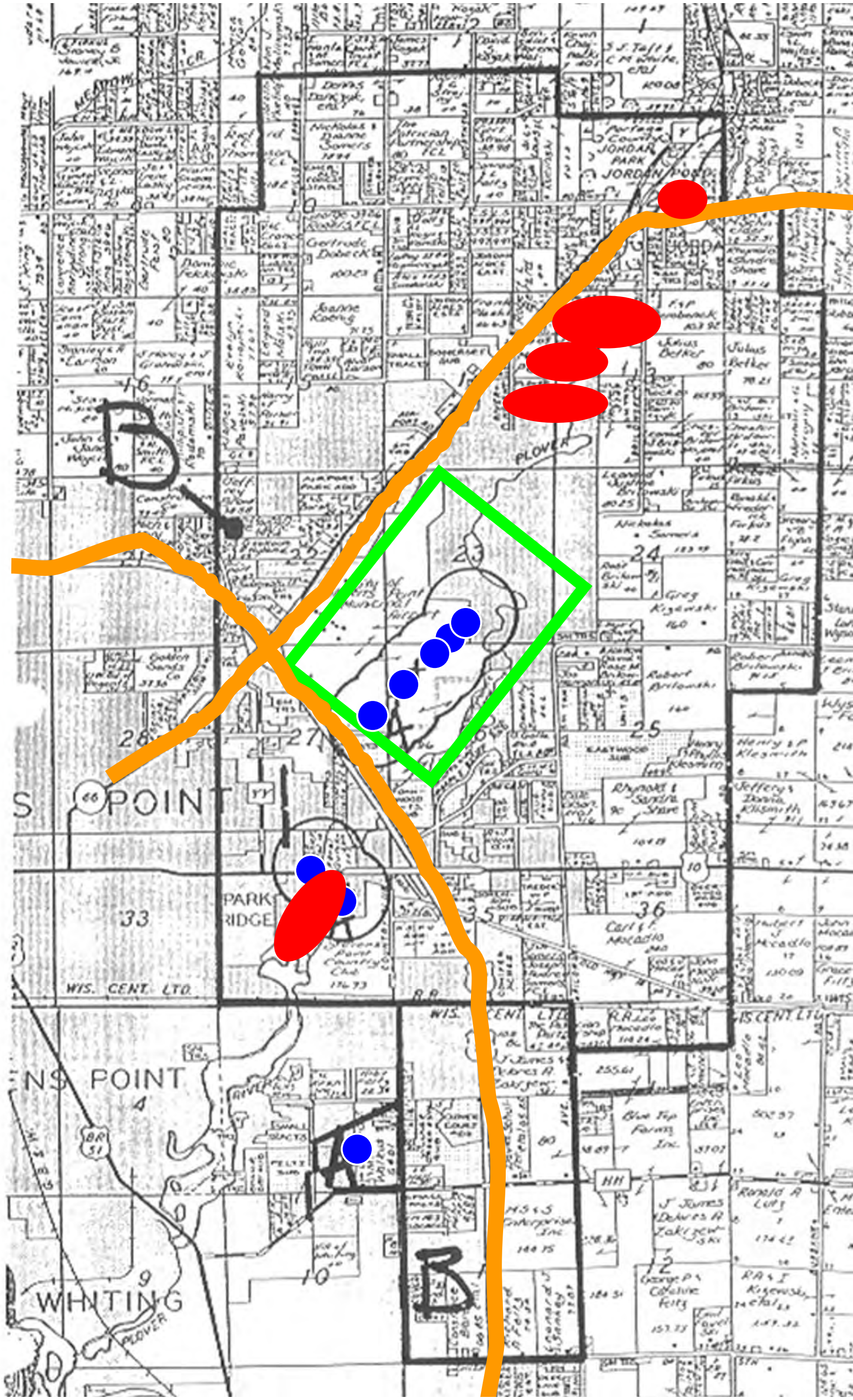
Municipalities can save $ by keeping their drinking water safe



Other approaches to wellhead protection

- Purchase and lease of lands around the wells:
  - City forested recreation area
  - Izaak Walton League lodge and shooting range
  - Boy Scout camp
  - Conservation easement

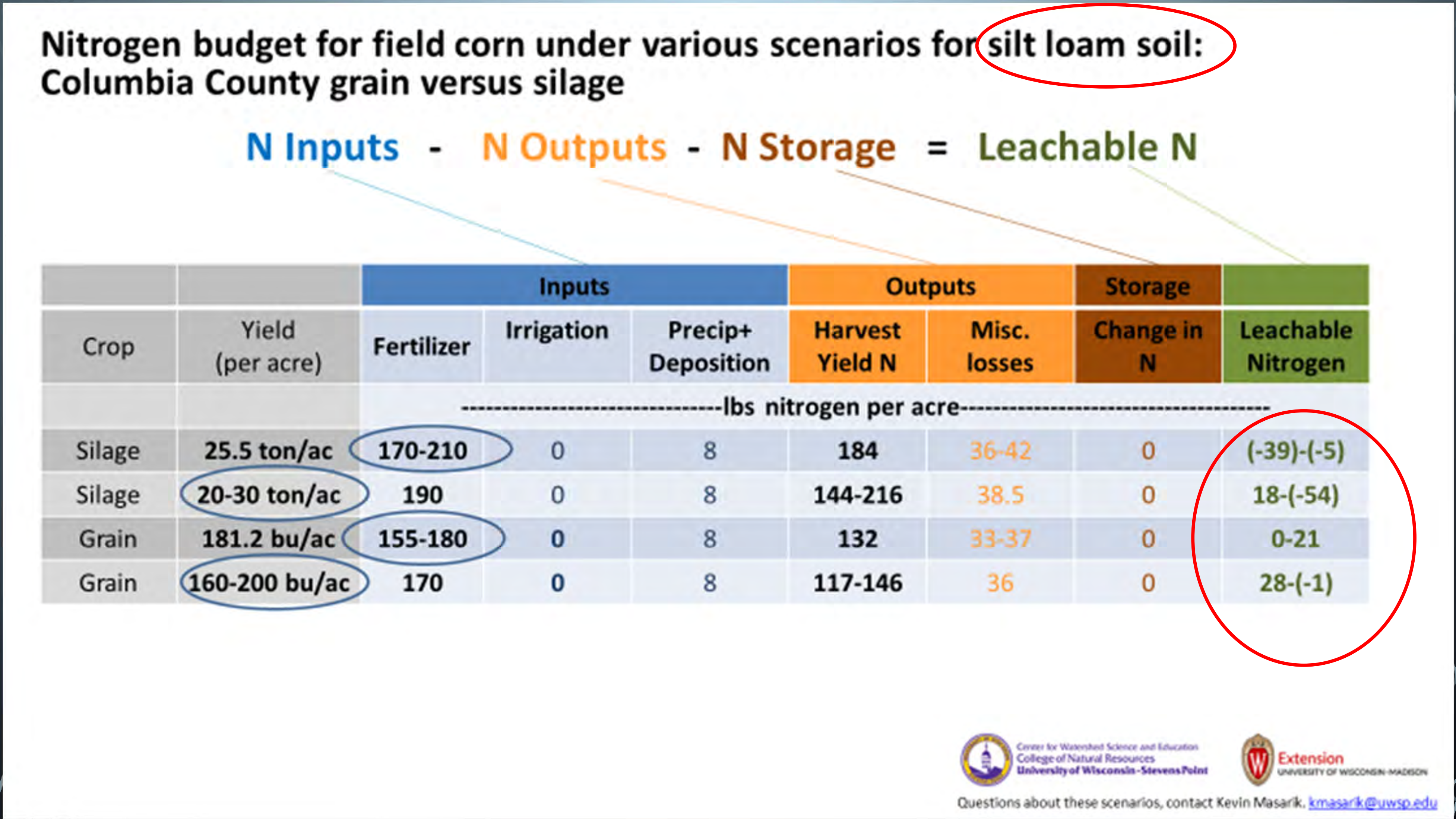
ARPA funding?



SUMMARY

- Zoning has strengths and weaknesses related to protecting groundwater
- Weaknesses
  - Limited ability to address existing problematic land uses (e.g. fertilizer plant with regular spills); can limit building expansions
  - Zoning doesn't determine which crops are grown in ag districts, even though they have different amounts of nitrogen leaching to groundwater
- Strengths
  - Can use wellhead protection ordinances to protect municipal/community wells
  - Can set minimum lot sizes to space out residential septic systems and protect private well water quality from septic systems
  - Can list high nitrogen uses as conditional or prohibited uses (e.g. fertilizer plants, landfills, feedlots, cemeteries, golf courses, possibly CAFOs)
  - Can geographically separate high nitrogen uses from wells - theoretically

- Can be changed at any time by elected officials (town-county zoning). Land purchases are more certain long-term protection, and more expensive.



Nitrogen budget for field corn under various scenarios for silt loam soil: Columbia County grain versus silage

N Inputs - N Outputs - N Storage = Leachable N

		Inputs			Outputs		Storage	
Crop	Yield (per acre)	Fertilizer	Irrigation	Precip+ Deposition	Harvest Yield N	Misc. losses	Change in N	Leachable Nitrogen
		------------------------------lbs nitrogen per acre------------------------------						
Silage	25.5 ton/ac	170-210	0	8	184	36-42	0	(-39)-(-5)
Silage	20-30 ton/ac	190	0	8	144-216	38.5	0	18-(-54)
Grain	181.2 bu/ac	155-180	0	8	132	33-37	0	0-21
Grain	160-200 bu/ac	170	0	8	117-146	36	0	28-(-1)

Center for Watershed Science and Education
College of Natural Resources
University of Wisconsin-Stevens Point

Extension
UNIVERSITY OF WISCONSIN-MADISON

Questions about these scenarios, contact Kevin Masarik, kmasarik@uwsp.edu

NOT ALL AG IS THE SAME

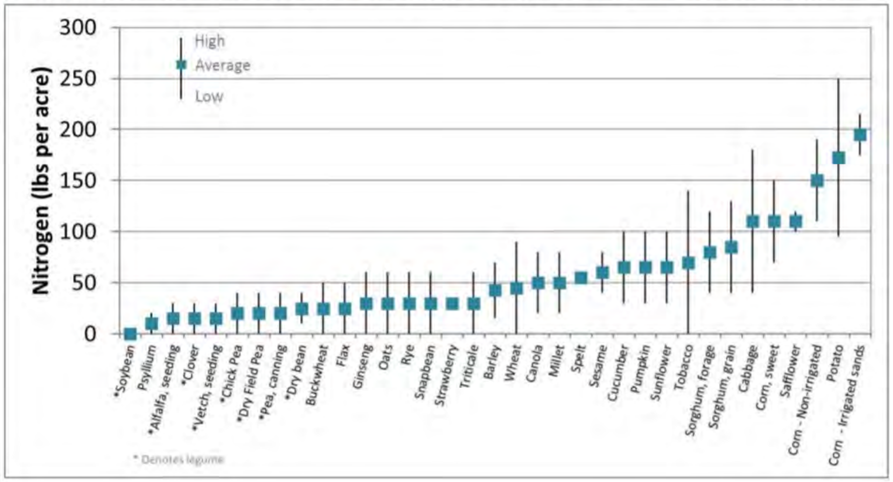
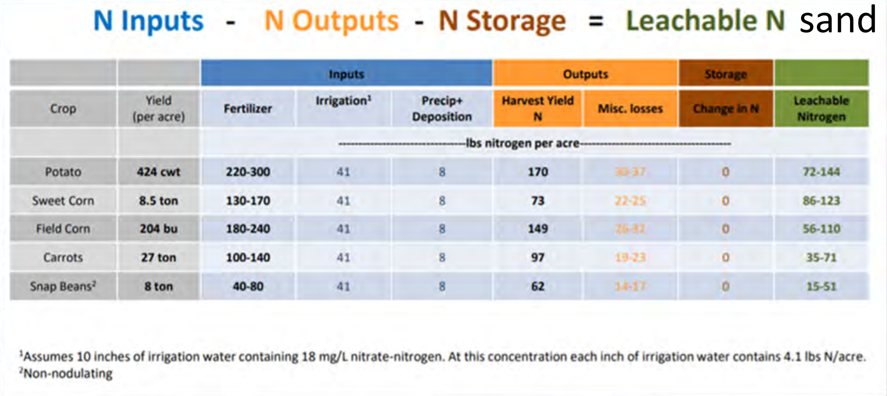


Figure 10. Nitrogen recommendations for various Midwestern crops (Laboski and Peters, 2012). Nitrogen recommendations vary depending on percent soil organic matter and nitrogen:corn price ratio.


N Inputs - N Outputs - N Storage = Leachable N sand

		Inputs			Outputs		Storage	
Crop	Yield (per acre)	Fertilizer	Irrigation[1]	Precip+ Deposition	Harvest Yield N	Misc. losses	Change in N	Leachable Nitrogen
		---lbs nitrogen per acre---						
Potato	424 cwt	220-300	41	8	170	30-37	0	72-144
Sweet Corn	8.5 ton	130-170	41	8	73	22-25	0	86-123
Field Corn	204 bu	180-240	41	8	149	26-32	0	56-110
Carrots	27 ton	100-140	41	8	97	19-23	0	35-71
Snap Beans[2]	8 ton	40-80	41	8	62	14-17	0	15-51

[1] Assumes 10 inches of irrigation water containing 18 mg/L nitrate-nitrogen. At this concentration each inch of irrigation water contains 4.1 lbs N/acre.
[2] Non-nodulating

- Ag zoning districts do <u>not</u> differentiate based on how much N is leached to GW
- Amount of N leaching to GW depends on:

1) Which crops are grown

2) Other factors:

- N application
- Soils
- Irrigation
- Harvest yields

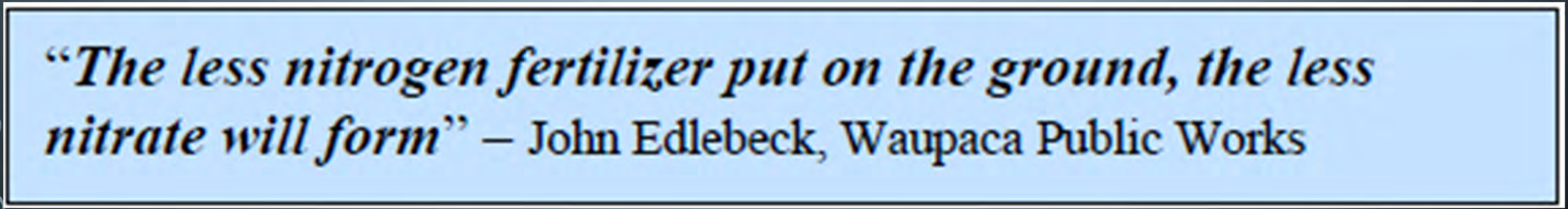
Cropping agreements to reduce nitrates

- City of Waupaca had nitrate levels inching up towards the health standard

- Adopted wellhead protection ordinance and installed monitoring wells

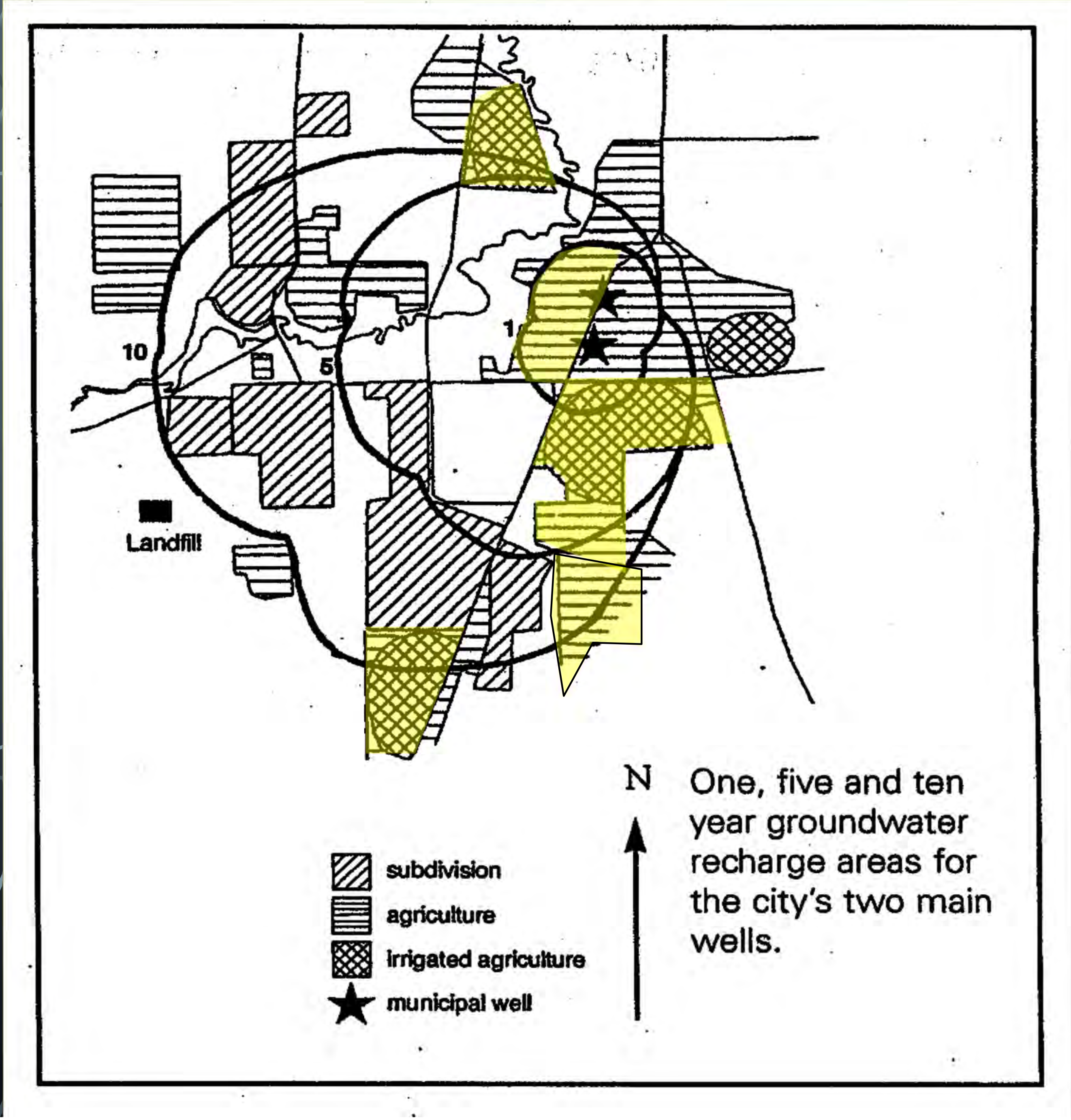
CROPPING AGREEMENTS

- Joe Edlebeck, former public works director, values drinking water and said "conserving water is the right thing to do"



"The less nitrogen fertilizer put on the ground, the less nitrate will form" – John Edlebeck, Waupaca Public Works

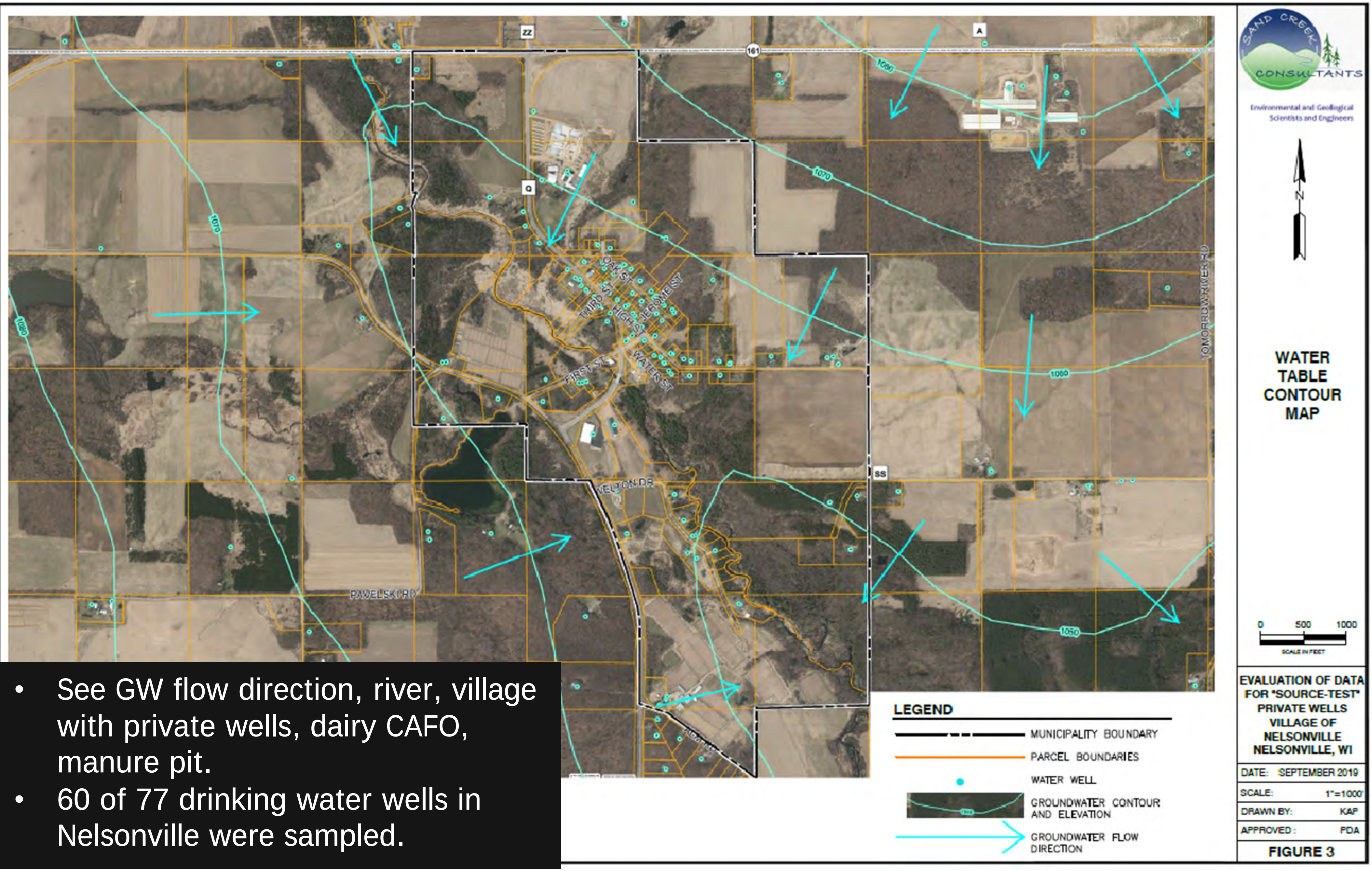
- Rewards farmers for growing less nitrogen demanding crops (beans instead of corn)
  - Farmers are paid ~$20 per acre per year
  - Three parcels, 550 acres enrolled
  - Could also be used for other pollutants of concern



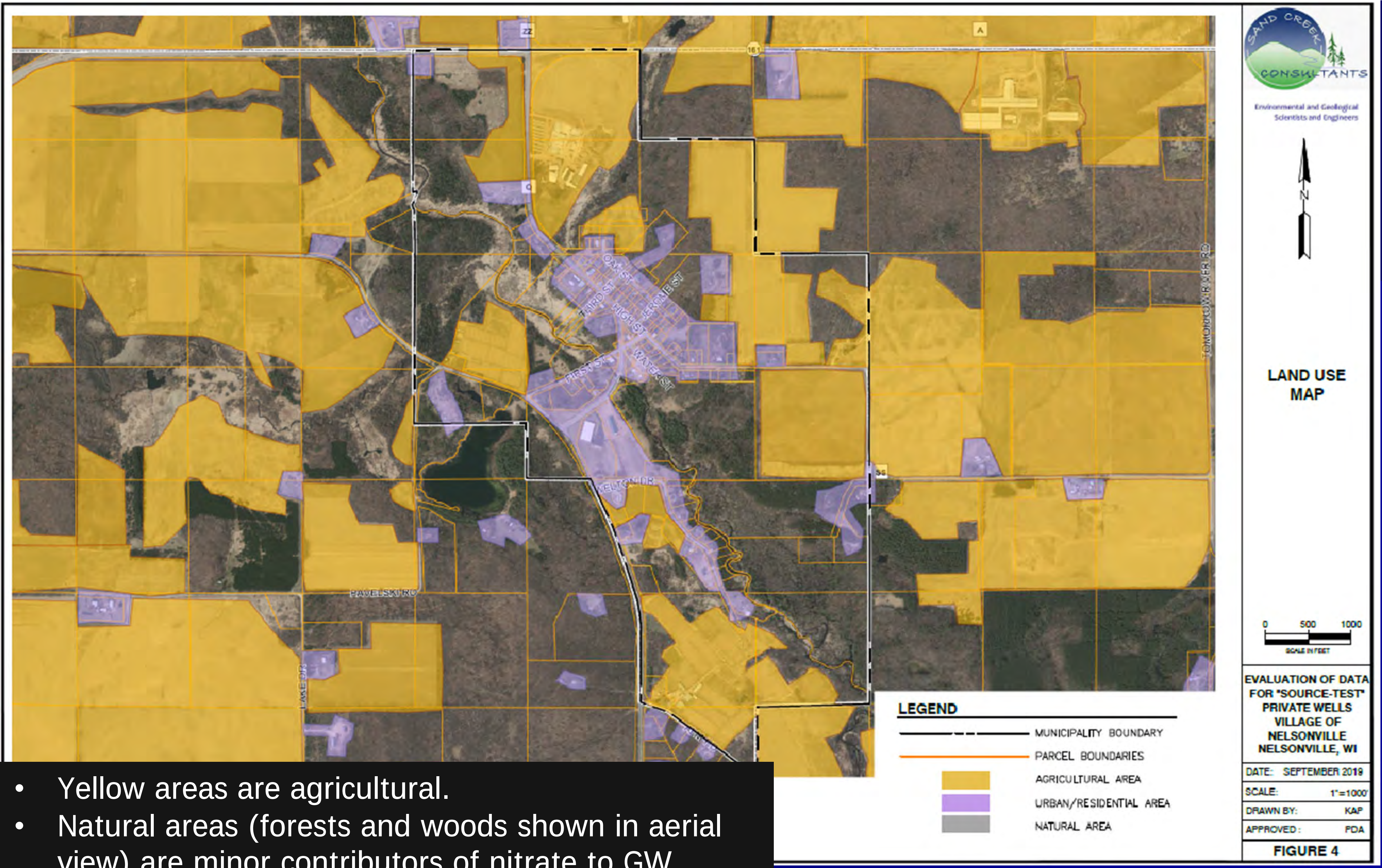
One, five and ten year groundwater recharge areas for the city's two main wells.

Map of recharge areas with cropping agreement parcels highlighted in yellow

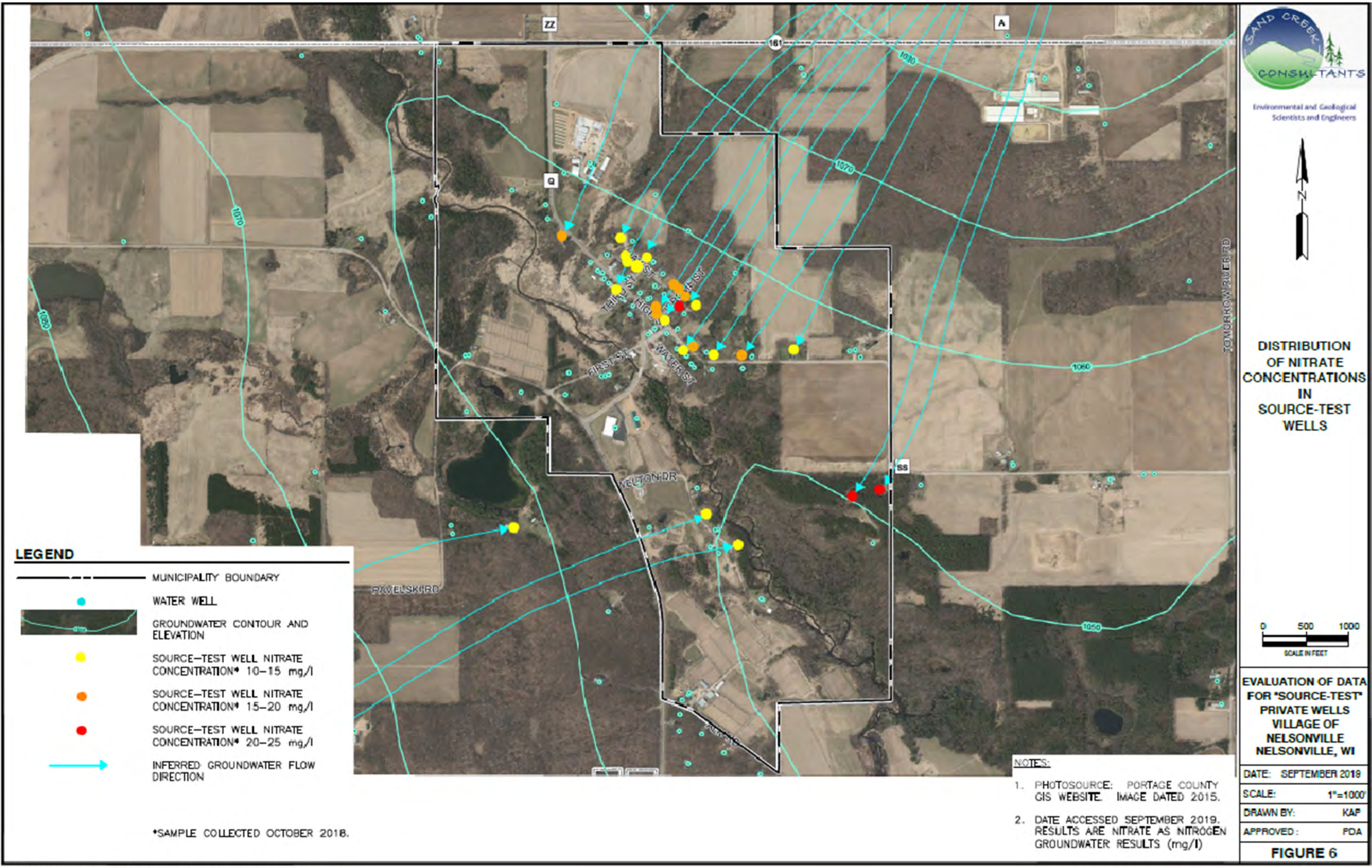
Nelsonville groundwater results



- See GW flow direction, river, village with private wells, dairy CAFO, manure pit.
- 60 of 77 drinking water wells in Nelsonville were sampled.



- Yellow areas are agricultural.
- Natural areas (forests and woods shown in aerial view) are minor contributors of nitrate to GW.
- Nitrate from residential areas (white) is dependent primarily on septic density (lot size).
- Due to sandy soils in Nelsonville area, up to 50% or more of N applied to ag land is lost to GW.



*SAMPLE COLLECTED OCTOBER 2018.

NOTES:

1. PHOTOSOURCE: PORTAGE COUNTY GIS WEBSITE. IMAGE DATED 2015.
2. DATE ACCESSED SEPTEMBER 2019. RESULTS ARE NITRATE AS NITROGEN GROUNDWATER RESULTS (mg/l)

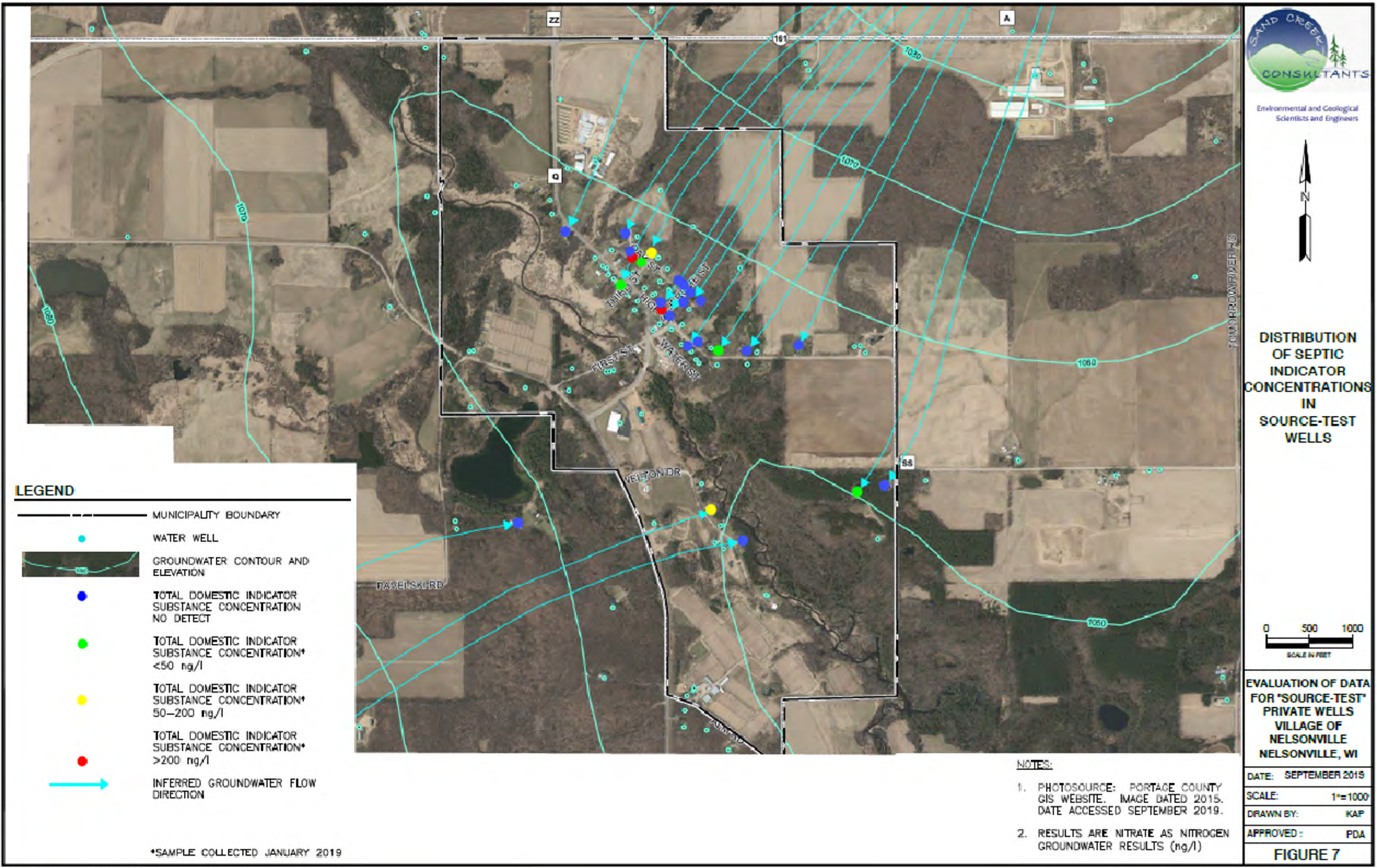
DISTRIBUTION OF NITRATE CONCENTRATIONS IN SOURCE-TEST WELLS

EVALUATION OF DATA FOR "SOURCE-TEST" PRIVATE WELLS
VILLAGE OF NELSONVILLE
NELSONVILLE, WI

DATE:	SEPTEMBER 2018
SCALE:	1"=1000'
DRAWN BY:	KAP
APPROVED:	PDA

FIGURE 6

- 28 of 60 wells had nitrate above 10 ppm (yellow, orange or red dots), the safe drinking water limit. 47% over limit.



LEGEND

MUNICIPALITY BOUNDARY

● WATER WELL

GROUNDWATER CONTOUR AND ELEVATION

● TOTAL DOMESTIC INDICATOR SUBSTANCE CONCENTRATION NO DETECT

● TOTAL DOMESTIC INDICATOR SUBSTANCE CONCENTRATION* <50 ng/l

● TOTAL DOMESTIC INDICATOR SUBSTANCE CONCENTRATION* 50–200 ng/l

● TOTAL DOMESTIC INDICATOR SUBSTANCE CONCENTRATION* >200 ng/l

→ INFERRED GROUNDWATER FLOW DIRECTION

*SAMPLE COLLECTED JANUARY 2019

NOTES:

1. PHOTOSOURCE: PORTAGE COUNTY GIS WEBSITE. IMAGE DATED 2015. DATE ACCESSED SEPTEMBER 2019.
2. RESULTS ARE NITRATE AS NITROGEN GROUNDWATER RESULTS (ng/l)

DISTRIBUTION OF SEPTIC INDICATOR CONCENTRATIONS IN SOURCE-TEST WELLS

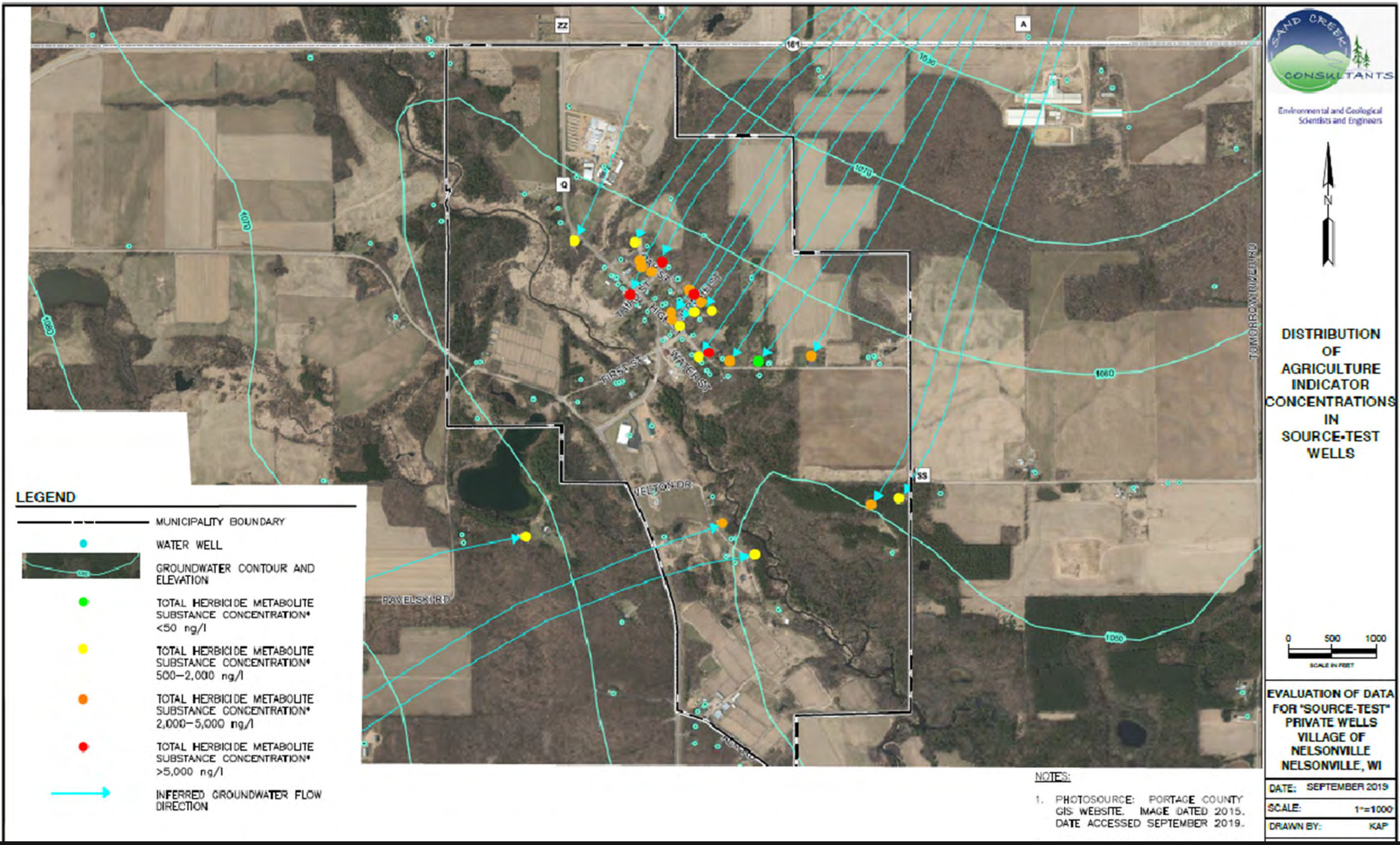
EVALUATION OF DATA FOR "SOURCE-TEST" PRIVATE WELLS VILLAGE OF NELSONVILLE NELSONVILLE, WI

DATE: SEPTEMBER 2019
SCALE: 1"=1000'
DRAWN BY: KAP
APPROVED: PDA

FIGURE 7

Is nitrate in wells coming from septic systems?

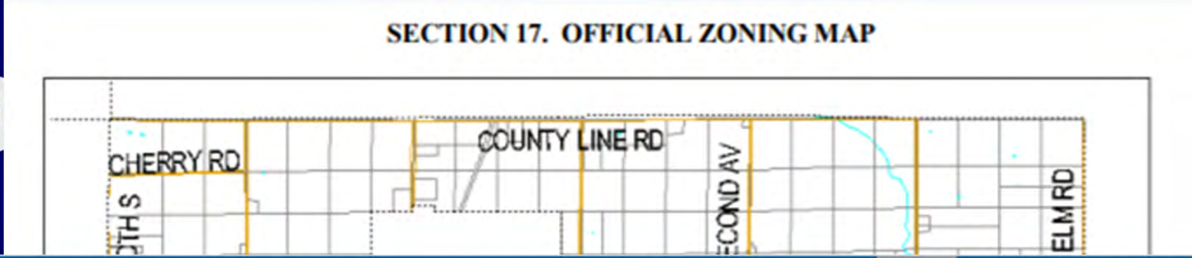
- 4 of 25 wells had strong evidence of septic indicators (yellow or red dots).



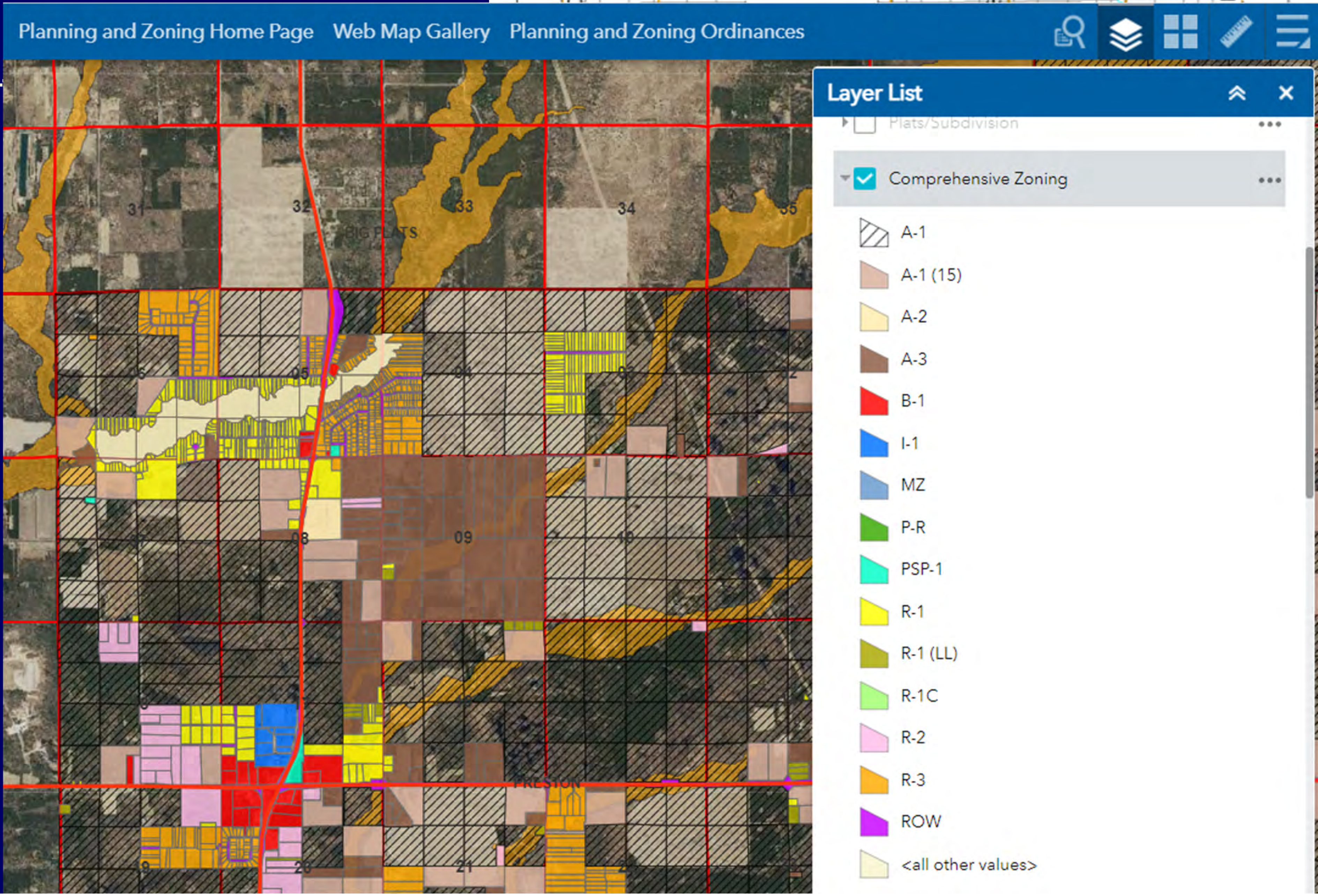
Conclusions

- Ag is the dominant land use in the recharge area for Nelsonville's wells, and ag practices often result in significant loss of nitrate to groundwater.
- The vast majority of nitrate in Nelsonville drinking water is from ag sources.
- Agricultural herbicide metabolites in 24 of 25 wells with high nitrate support this conclusion.

Zoning map



SECTION 17. OFFICIAL ZONING MAP



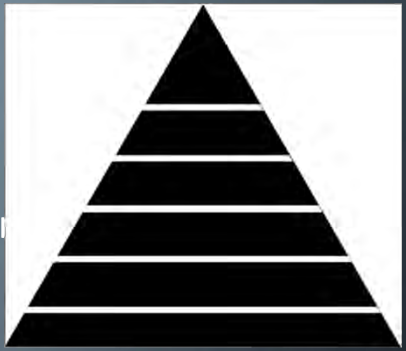
Planning and Zoning Home Page | Web Map Gallery | Planning and Zoning Ordinances

Layer List

- Plats/Subdivision
- ☑ Comprehensive Zoning
  - ▨ A-1
  - ■ A-1 (15)
  - ■ A-2
  - 🟫 A-3
  - 🟥 B-1
  - 🟦 I-1
  - ■ MZ
  - 🟩 P-R
  - ■ PSP-1
  - 🟨 R-1
  - ■ R-1 (LL)
  - ■ R-1C
  - ■ R-2
  - 🟧 R-3
  - 🟪 ROW
  - ■ <all other values>

ZONING FEATURES

- Regulates use
  - Division of the community into districts or zones with different rules for different zones
  - Primary purpose: to protect single-family homes from other uses
  - Cumulative or pyramidal zoning
    - When single-family homes allowed into all or most other zones
    - One-family district at top and each successive district allowing all othe above it plus some additional ones



- Regulates intensity or density
  - Four basic measures:
    - Dwelling unit per acre
    - Minimum lot size
    - Floor area ratio (ratio of floor area of building to the land area of the lot [FAR 2 = twice land area of lot])
    - Maximum height restrictions

Other approaches to wellhead protection

- County, town or muni parks without fertilizer or pesticide use e.g. Chippewa Falls
- Areas downgradient of forests and prairies are protected (Wood and Juneau counties have county forests)

SHARED WELLS OR SEPTICS

	Adams	Juneau	Marquette	Portage	Waushara
Are shared wells allowed or incentivized in your ordinance?	Ordinance does not regulate wells	Yes	We do not regulate wells	No	No
Are shared septic systems allowed or incentivized in your ordinance?	Yes. State code.	Yes	Allowed under DSPS 383 and the County cannot be more restrictive	No	

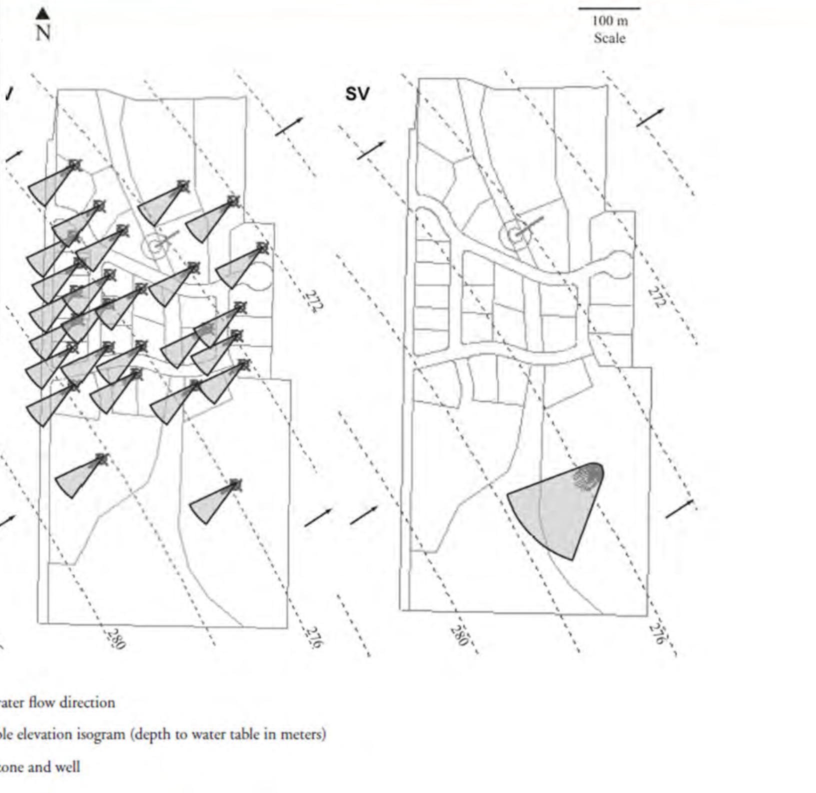
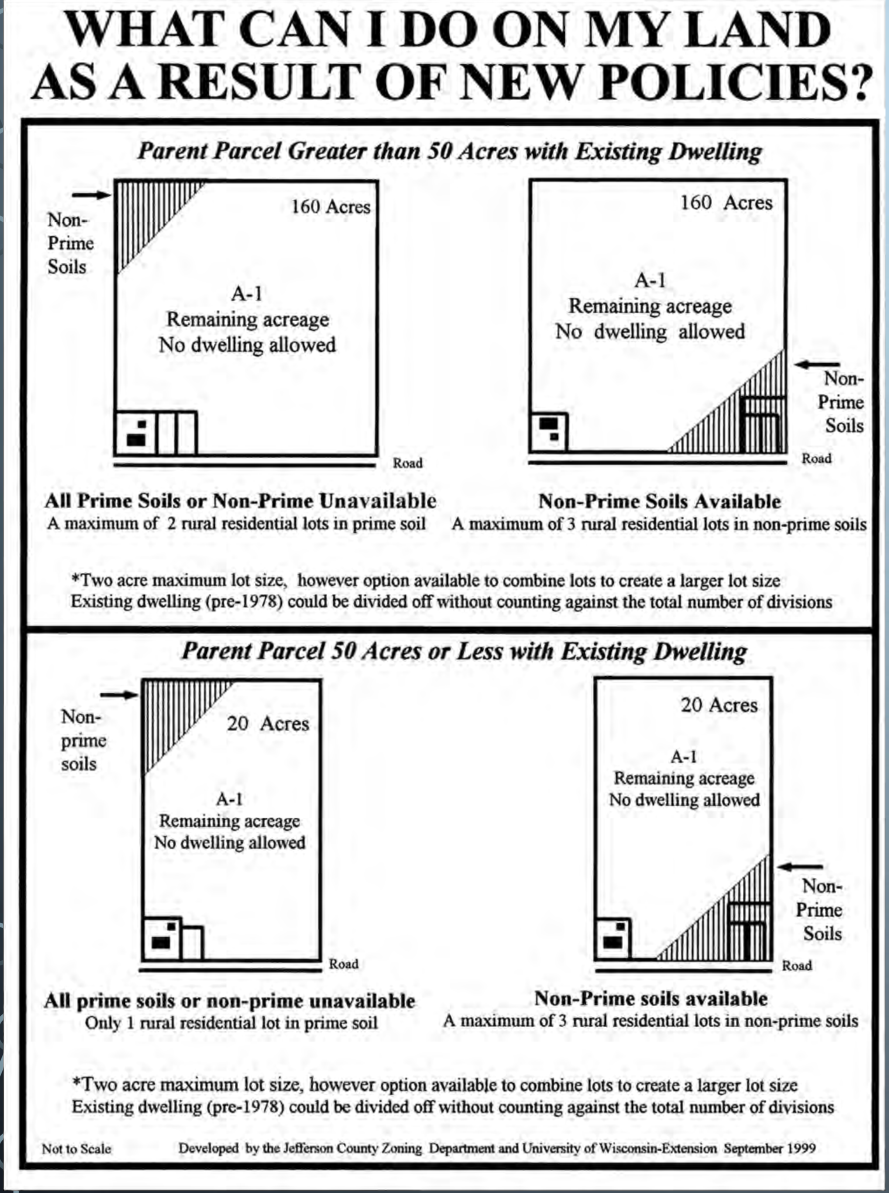


Figure 5. Simulated two-year time-of-travel capture zones for individual wells and community wells.

Note:
Solid lines delineate the boundaries of the ELVE and SV subdivisions and the SV parcels and rights-of-way. These capture zones assume, as safety factors, that the groundwater flow path could have been ±15 degrees from what was modeled, and that groundwater could have travelled three times further than modeled.



WHAT CAN I DO ON MY LAND AS A RESULT OF NEW POLICIES?

Parent Parcel Greater than 50 Acres with Existing Dwelling

All Prime Soils or Non-Prime Unavailable
A maximum of 2 rural residential lots in prime soil

Non-Prime Soils Available
A maximum of 3 rural residential lots in non-prime soils

*Two acre maximum lot size, however option available to combine lots to create a larger lot size
Existing dwelling (pre-1978) could be divided off without counting against the total number of divisions

Parent Parcel 50 Acres or Less with Existing Dwelling

All prime soils or non-prime unavailable
Only 1 rural residential lot in prime soil

Non-Prime soils available
A maximum of 3 rural residential lots in non-prime soils

*Two acre maximum lot size, however option available to combine lots to create a larger lot size
Existing dwelling (pre-1978) could be divided off without counting against the total number of divisions

Not to Scale

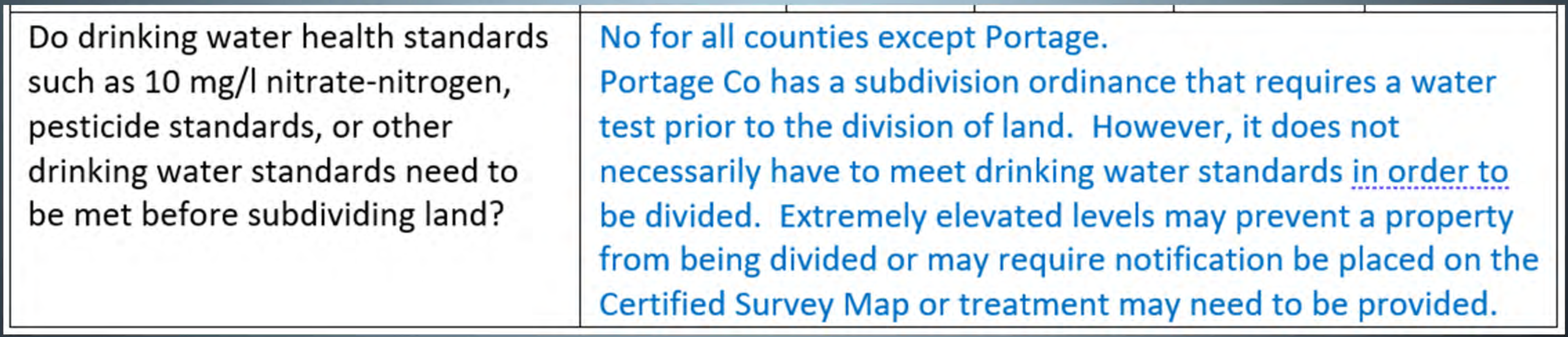
Developed by the Jefferson County Zoning Department and University of Wisconsin-Extension September 1999

LIMITED RESIDENTIAL ALLOWED IN A-1 ZONING DISTRICTS

- Farmland preservation
- Fewer new residential lots in A-1 zoning districts which may have high nitrate levels

SURVEY RESULTS

Limiting new residential lots where drinking water is not safe



Do drinking water health standards such as 10 mg/l nitrate-nitrogen, pesticide standards, or other drinking water standards need to be met before subdividing land?	No for all counties except Portage. Portage Co has a subdivision ordinance that requires a water test prior to the division of land. However, it does not necessarily have to meet drinking water standards in order to be divided. Extremely elevated levels may prevent a property from being divided or may require notification be placed on the Certified Survey Map or treatment may need to be provided.

Appendix D

Community Well Testing Program

How to Launch a Well Testing Program:

Considerations and examples of from around Wisconsin

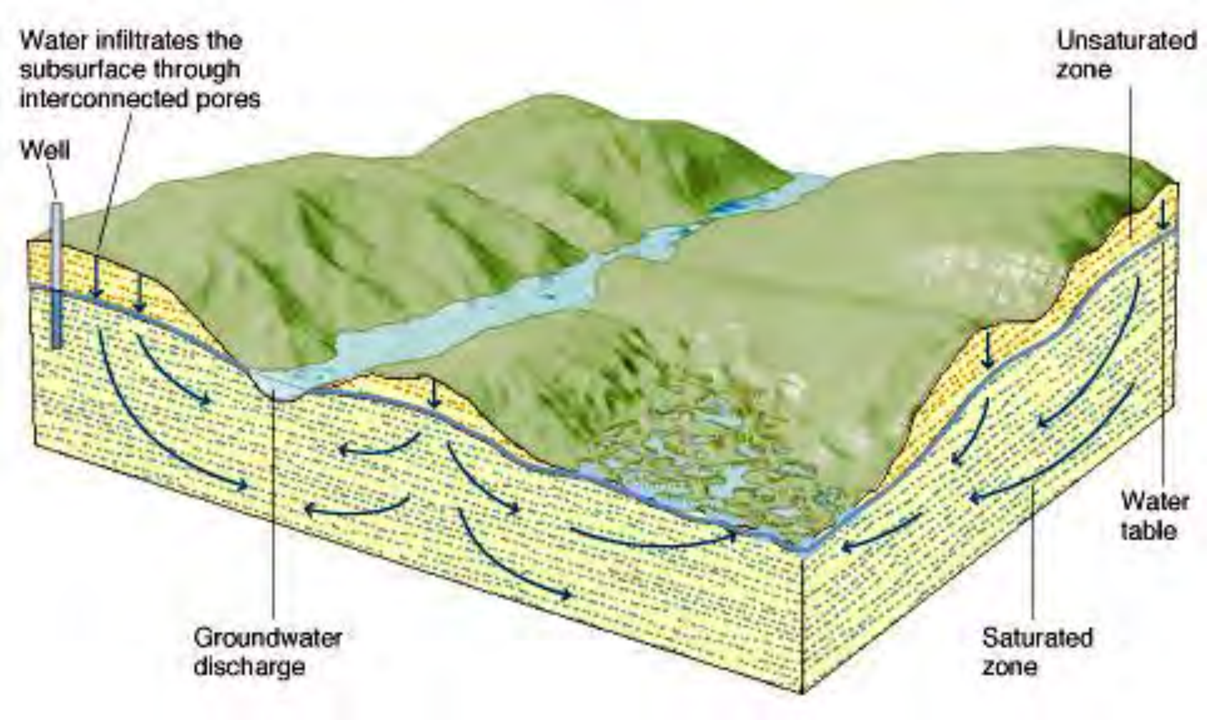
Kevin Masarik & Dan Masterpole

Center for Watershed Science and Education
College of Natural Resources
University of Wisconsin-Stevens Point

Extension
UNIVERSITY OF WISCONSIN–MADISON

Chippewa County
"Stewardship for Sustainability"
Land Conservation and Forest Management

Groundwater 101



Source: Unknown

Public vs. Private Water Supplies

Public Water Supplies

- Regularly tested and regulated by drinking water standards.

Private Wells

- Not required to be regularly tested.
- Not required to take corrective action
- Owners must take special precautions to ensure safe drinking water.

http://www.wisconsinwatch.org/2013/05/22/20-years-after-fatal-outbreak-milwaukee-leads-on-water-testing/

FAQs about groundwater/well water testing

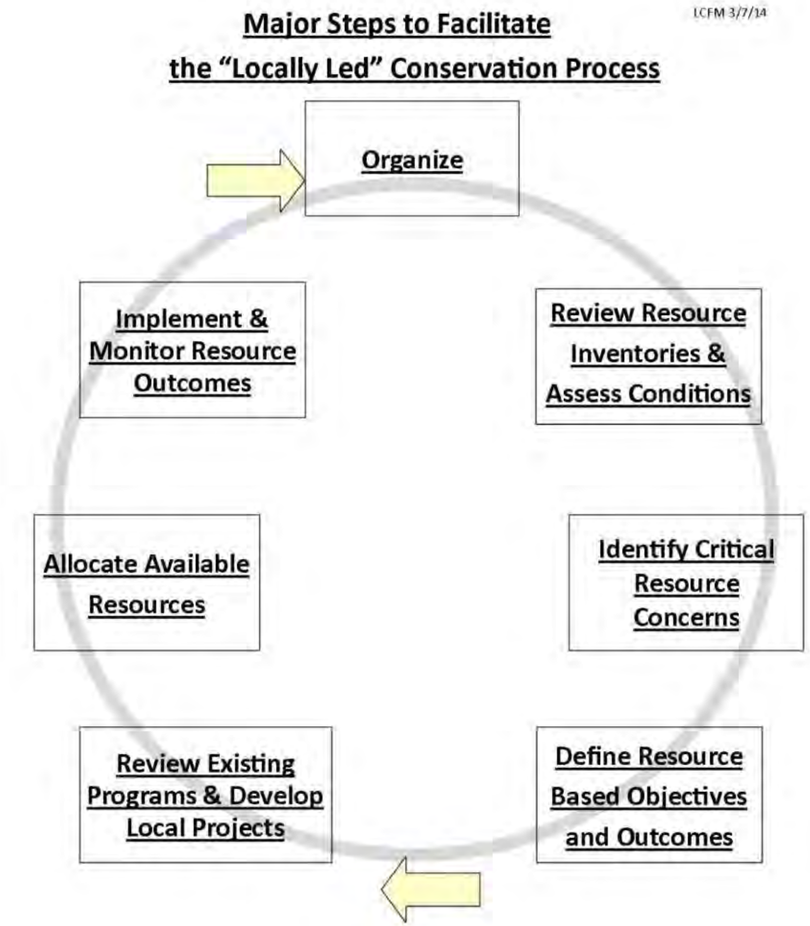
- How much does it cost?
- When can we get started?
- Are there grants or other funding available to cover costs?
- Why start a groundwater monitoring program?

More than one monitoring approach

- Soils
- Geology
- Land cover
- Industries
- Well/septic system density
- Access to funding / staffing resources
- Different goals and/or objectives

Before starting a groundwater monitoring program

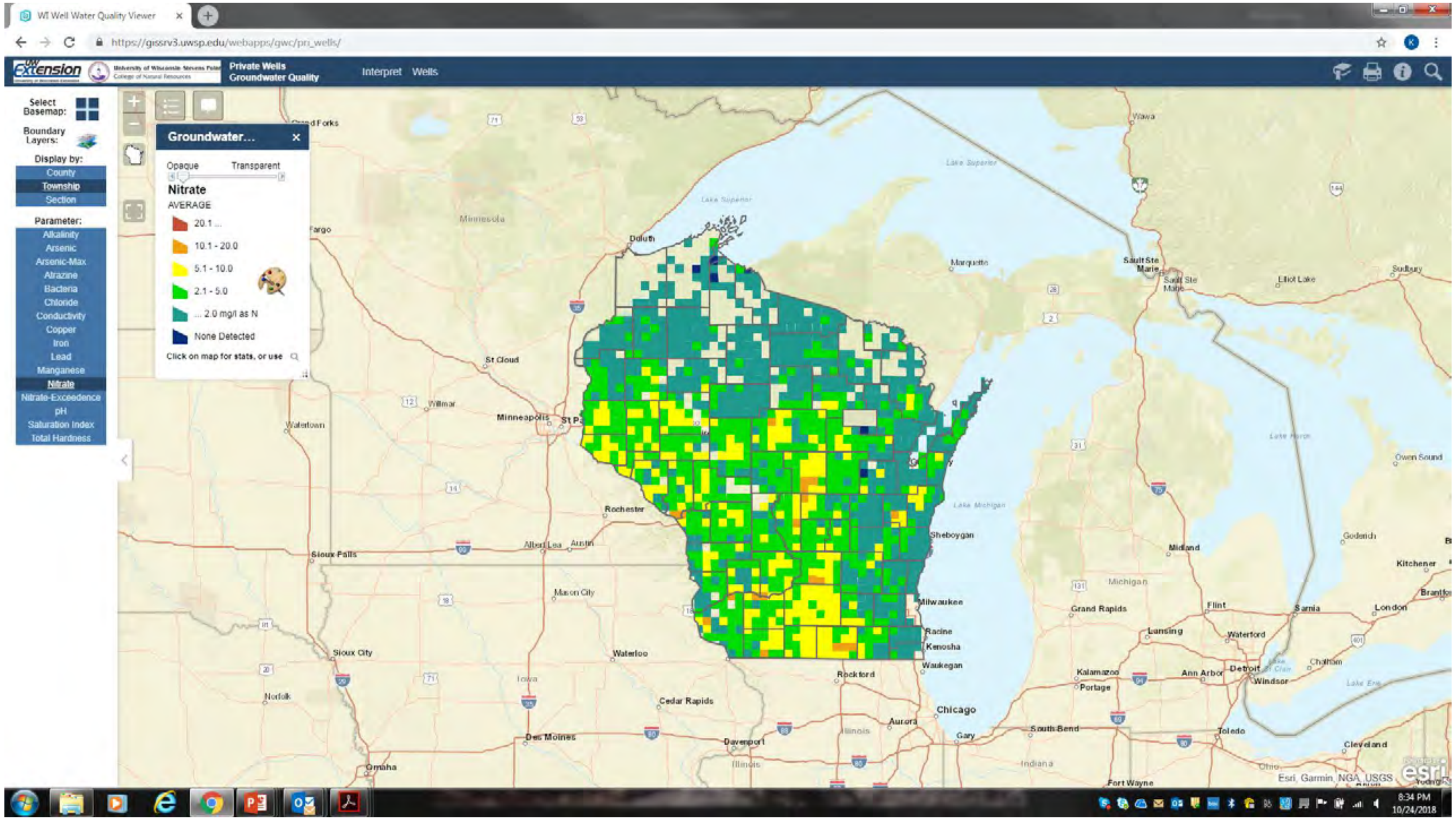
- Should be able to answer a few key questions:
  - What is it that you want to learn or accomplish?
  - Are interests at a county-wide scale or site specific?
  - What information exists already?
  - What is motivating people's concerns or interest in groundwater monitoring?



Major Steps to Facilitate the "Locally Led" Conservation Process

LCFM 3/7/14

You might be surprised what baseline data already exists



https://www.uwsp.edu/cnr-ap/watershed/Pages/WellWaterViewer.aspx

Before starting a groundwater monitoring program

- Define and build consensus around some goals for what you are hoping to do with the information:
    - Build knowledge to inform groundwater management
    - Establish baseline understanding of current groundwater quality
    - Understand how groundwater is changing over time – trends
    - ***Educate rural landowners on owning, testing and maintaining a well***

This Photo by Unknown Author is licensed under CC BY-SA-NC

Deciding what to test for?

Influenced by geology

- *Arsenic ($)*
- *Manganese ($)*
- Total Hardness ($)
- pH ($)
- Iron ($)
- *Strontium ($)*
- *Fluoride ($)*
- Others…

Influence by land use activities:

- *Nitrate ($)*
- Chloride ($)
- *Atrazine-type pesticide screen ($)*
- *Pesticides ($$$)*
- Pharmaceuticals/Personal Care products ($$$)
- *Viruses ($$$)*
- *E.coli bacteria ($)*
- Others…

Can be influenced by well construction and/or geology

- *Coliform Bacteria*

Those in orange italic denotes test parameter with potential health implications

Data considerations

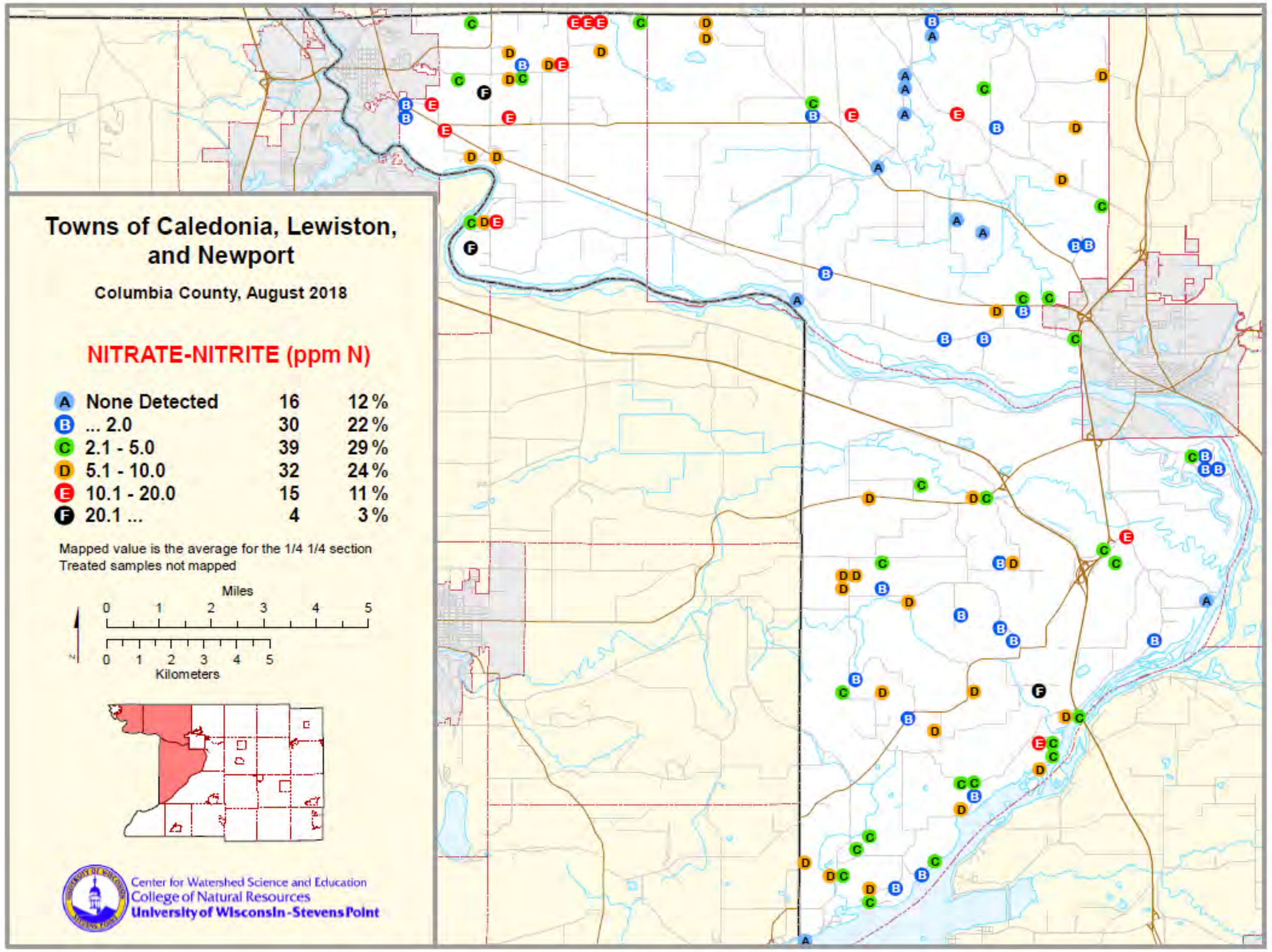
- Data storage, security and integrity
  - Whose data is it?
  - Expectations for privacy - who has access to it?
  - Who is responsible for maintaining and ensuring quality?
  - What format/program will be used to store it?
- Essential parameters to collect and maintain:

  For each well sampled:
    - Sample date
    - Wisconsin Unique Well Number (if known – post 1988)
      - Well construction report
    - Well address
    - Spatial coordinate (i.e. legal description, parcel number, lat-long, etc.)

  For each parameter tested
    - Water chemistry result
    - Limit of detection (LOD) or qualifier if below LOD
    - Testing Method

Voluntary approach – Example 1

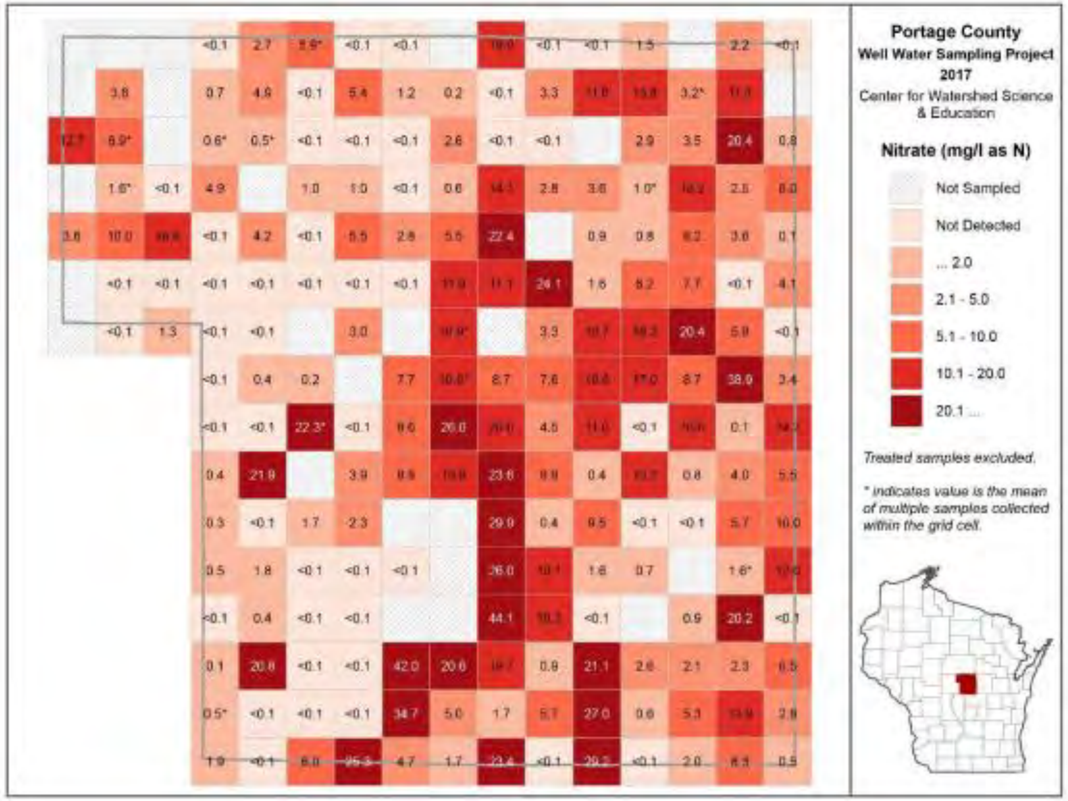
- UW-Extension Model
  - Anyone in designated area can participate
  - Cost usually incurred by homeowner
    - Lowest cost option
    - Other than staff time/mailing costs no direct costs to county
  - Recruitment:
    - Direct mailing is best, traditional & social media can also be used to advertise
      - Pre-registration encouraged
      - ~10% participation when direct mailing is used



Spatially distributed – Example 2

Gridded sampling design to ensure equal distribution

- Considerations
  - Size of the grid cells
  - Not necessarily a well in every cell
  - Randomly select well from each grid cell but participation not guaranteed
  - <u>More</u> upfront development work when selecting and recruiting participants
- Cost generally <u>not</u> incurred by homeowner
- Recruitment strategy
  - Direct mailing
    - Follow up with non-responders
    - Recruit additional participants if initial recruitment was unsuccessful
- Sampled by homeowner ($) or staff ($$)

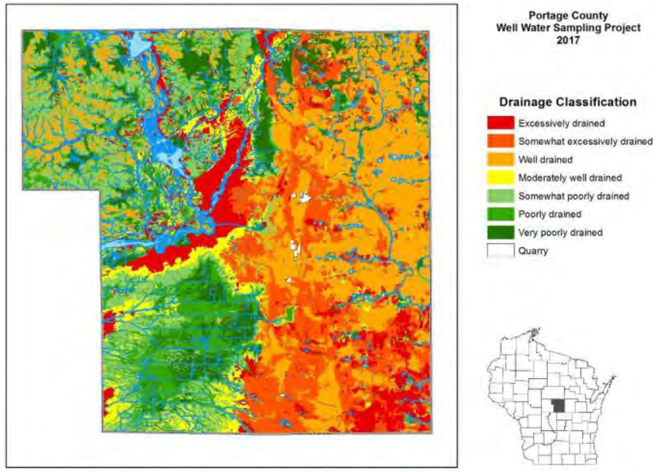


Special thanks to Portage County and Jen McNelly

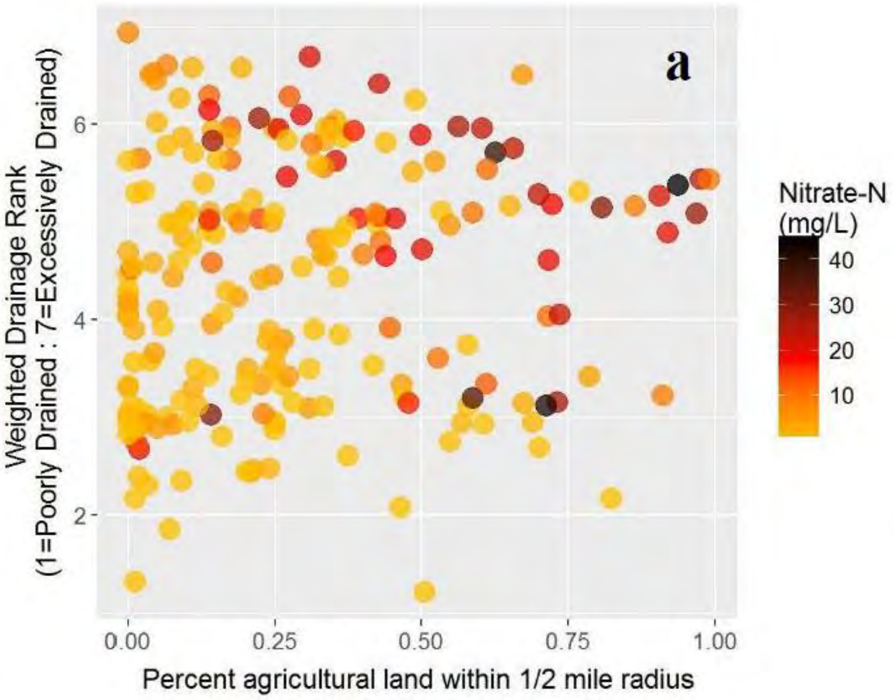
Explaining Nitrate Variability

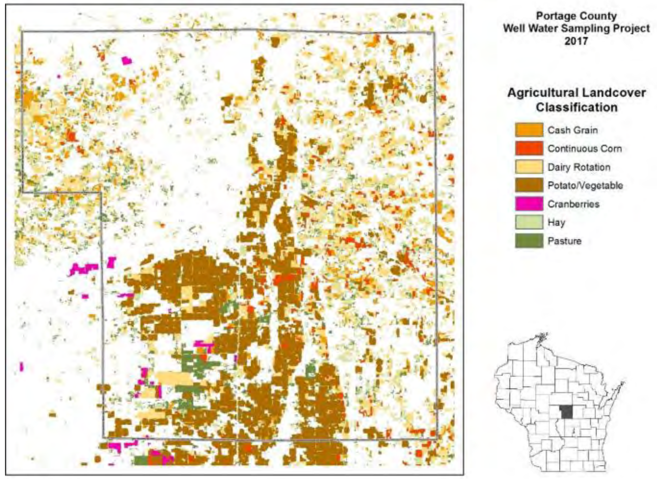
Multiple Linear Regression Results:

- The model is able to explain almost one-third of variability in nitrate concentrations.
- Very strong evidence of positive, linear relationships to potato/vegetable (irrigated land) ($p<0.001$) and weighted drainage rank ($p<0.001$)
- Strong evidence to continuous corn ($p=0.006$)
- Weak evidence to dairy ($p=0.060$)



Source: Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture Soil Survey Geographic (SSURGO) Database

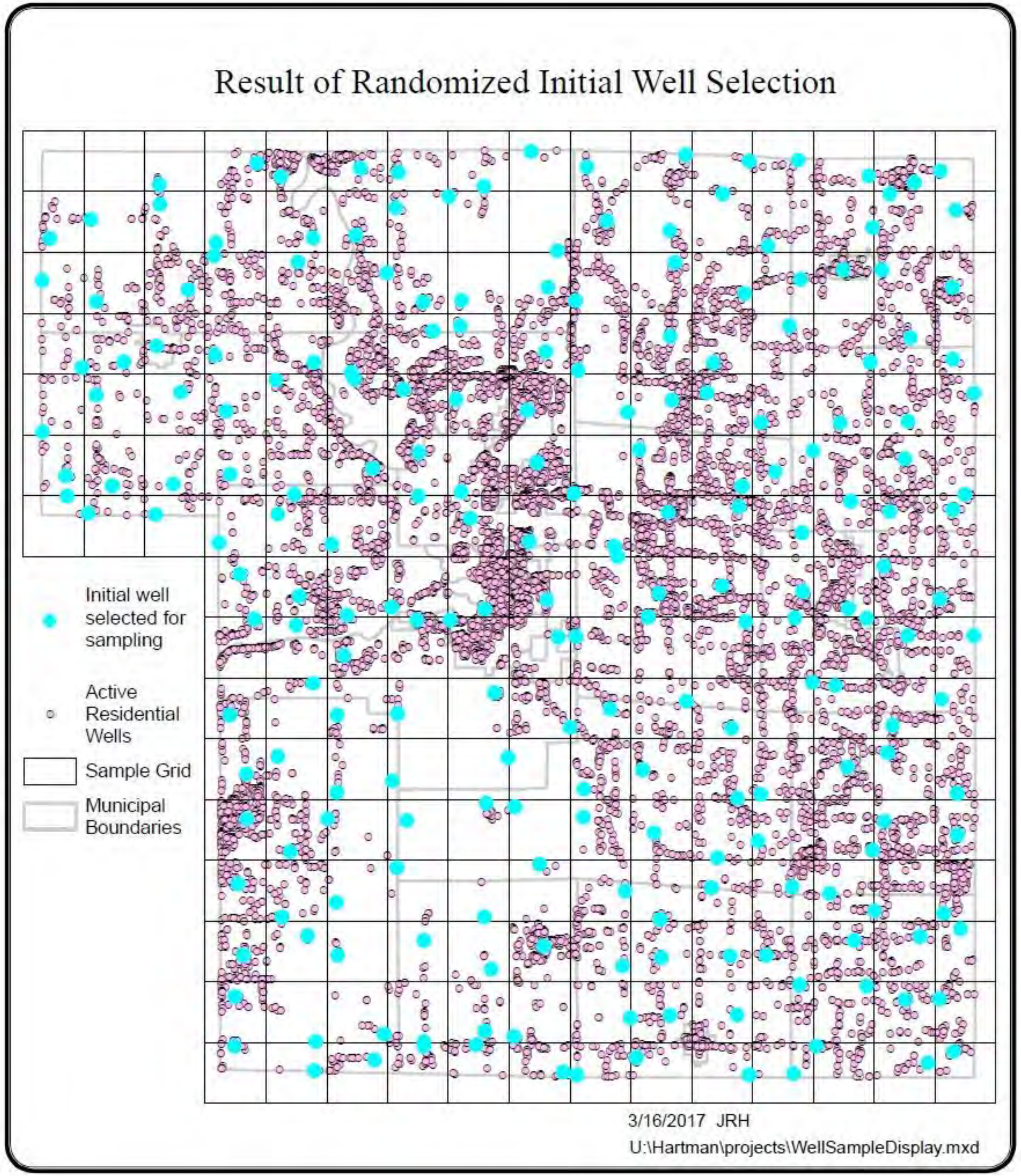


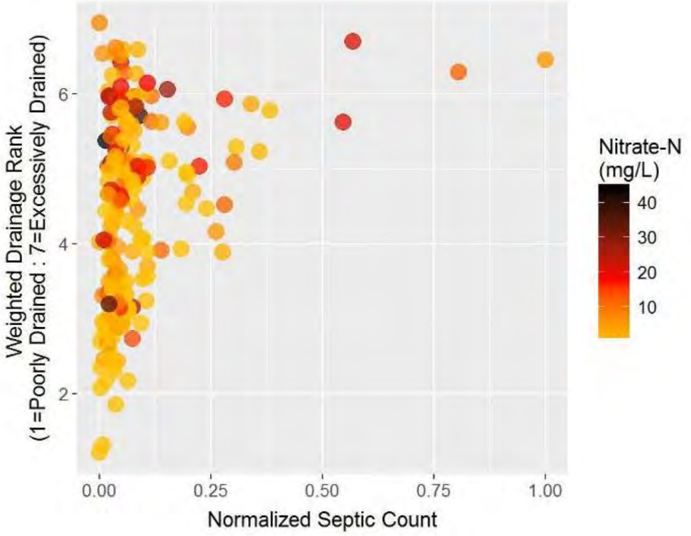


Source: Wiscland 2.0

Random Well Selection

- Each grid space 2 miles x 2 miles (4 square miles)
- 229 total grid spaces
- 202 grid spaces were sampled
- One well per grid space was randomly selected
- A total of 214 wells were sampled

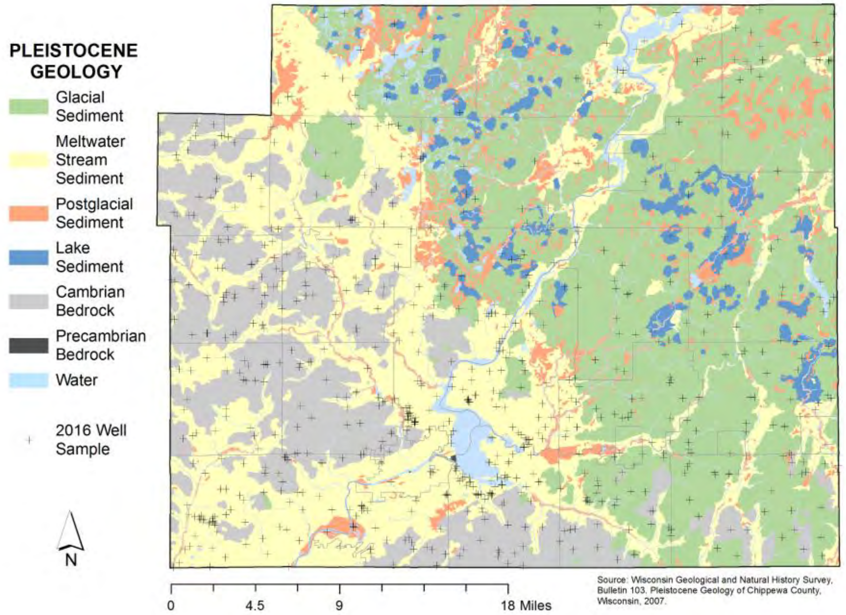




Spatially Representative

Select wells that are representative of the area of interest

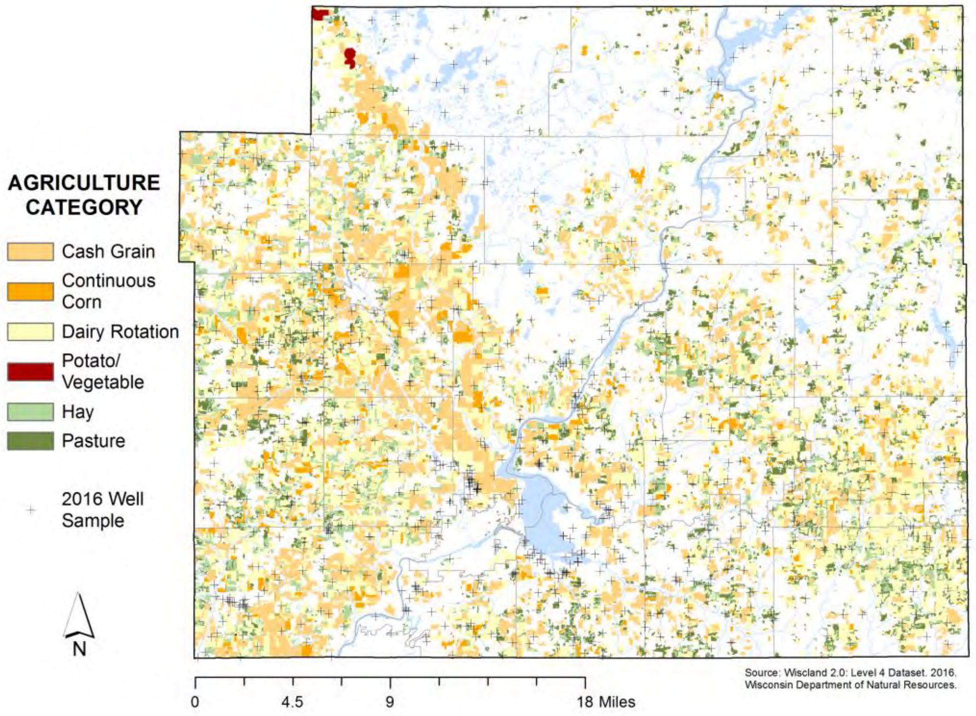
- Selection Considerations:
  - Geology, soils, land cover, well/casing depth, septic system density, etc.
  - Most upfront development work when selecting and recruiting participants
- Cost generally not incurred by the homeowner
- Recruitment:
  - Direct mailings
    - Follow up with non-responses
    - Recruit additional participants if initial recruitment was unsuccessful
- Sampled by homeowner ($) or staff ($$)



Source: Wisconsin Geological and Natural History Survey, Bulletin 103, Pleistocene Geology of Chippewa County, Wisconsin, 2007.

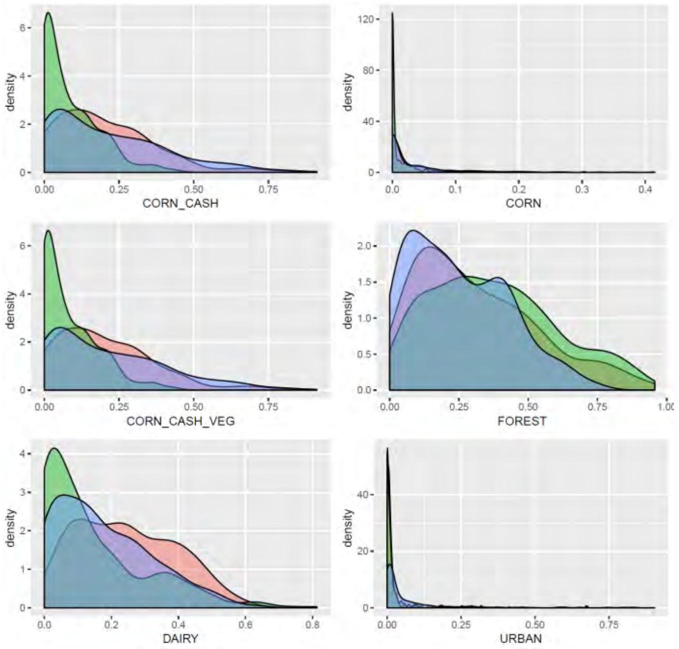
Analyte	Cambrian (n=170)					Glacial Sediment (n=207)					Meltwater Stream Sediment (n=360)				
	Mean	StDev	Median	Min	Max	Mean	StDev	Median	Min	Max	Mean	StDev	Median	Min	Max
Alkalinity (mg/L as $CaCO_3$)	**28**	34	**16**	2	268	**121**	73	**137**	5	358	**48**	42	**32**	4	289
Arsenic (mg/L)	**<0.003**	0.001	**<0.003**	<0.003	0.005	**<0.003**	0.001	**<0.003**	<0.003	0.008	**<0.003**	0.001	**<0.003**	<0.003	0.007
Calcium (mg/L)	**15.8**	9.0	**15.0**	<0.2	50.4	**37.3**	24.8	**36.3**	<0.2	207.7	**22.2**	15.3	**20.7**	<0.2	139.5
Chloride (mg/L)	**18.6**	18.2	**12.8**	0.9	102.2	**35.6**	118.4	**11.8**	0.8	1520	**27.3**	41.7	**14.2**	0.6	451
Conductivity (umhos/cm)	**168**	109	**139**	26	759	**359**	399	**302**	29	5220	**222**	156	**192**	31	1561
Iron (mg/L)	**0.066**	0.345	**0.055**	<0.004	4.092	**0.427**	1.106	**0.032**	<0.004	6.963	**0.495**	2.061	**0.019**	<0.004	22.1
Magnesium (mg/L)	**5.2**	4.2	**4.2**	<0.2	31.7	**13.8**	10.3	**13.2**	<0.2	87.9	**7.8**	5.7	**7.0**	<0.2	43.7
Manganese (mg/L)	**0.025**	0.088	**0.005**	<0.002	0.014	**0.166**	0.325	**0.010**	<0.002	1.849	**0.138**	0.572	**0.005**	<0.002	7.17
Nitrate (mg/L)	**5.9**	4.7	**5.0**	<0.1	29.6	**3.6**	4.3	**1.9**	<0.1	18.1	**6.4**	6.3	**4.8**	<0.1	34.9
Phosphorus (mg/L)	**0.359**	0.333	**0.301**	<0.004	1.813	**0.080**	0.135	**0.040**	<0.004	1.334	**0.126**	0.203	**0.028**	<0.004	1.11
pH (standard units)	**6.3**	0.7	**6.18**	406	9.78	**7.2**	0.7	**7.36**	5.17	8.31	**6.8**	0.5	**6.70**	5.48	8.87
Potassium (mg/L)	**4.5**	14.9	**2.1**	<0.2	167.9	**1.6**	1.4	**1.2**	<0.2	9.7	**1.5**	2.2	**1.2**	<0.2	38.4
Sulfate (mg/L)	**9.9**	6.3	**8.2**	0.8	37.1	**10.8**	8.0	**9.5**	<0.2	58.6	**7.8**	4.7	**6.9**	<0.2	31.9
Total Hardness (mg/L as $CaCO_3$)	**61**	37	**56**	<4	211	**150**	103	**147**	<4	881	**88**	61	**80**	<4	529

Very closely represent land-use at the County level

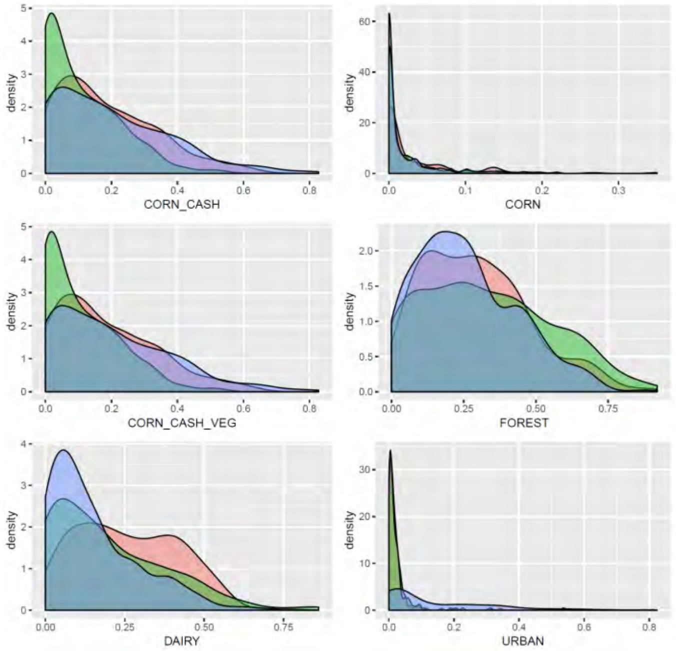


Source: Wiscland 2.0: Level 4 Dataset. 2016. Wisconsin Department of Natural Resources.

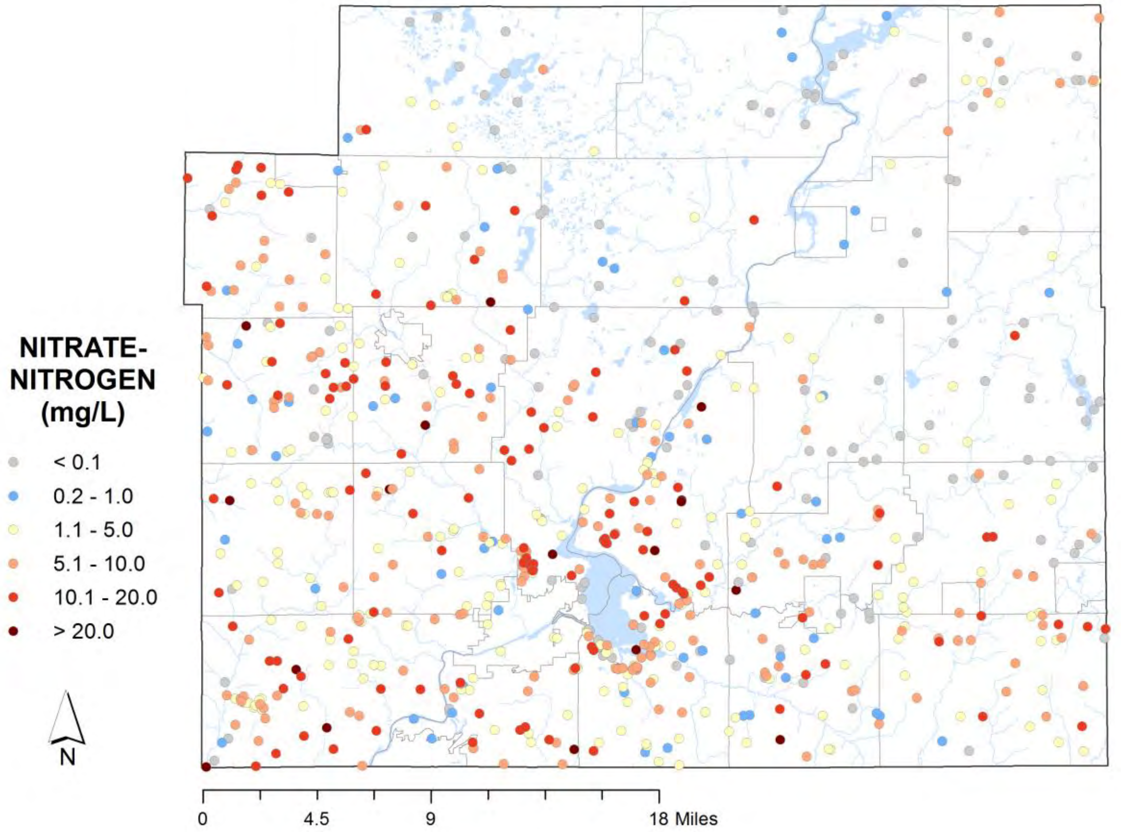
County-wide land-use using 1 sq. mile grid

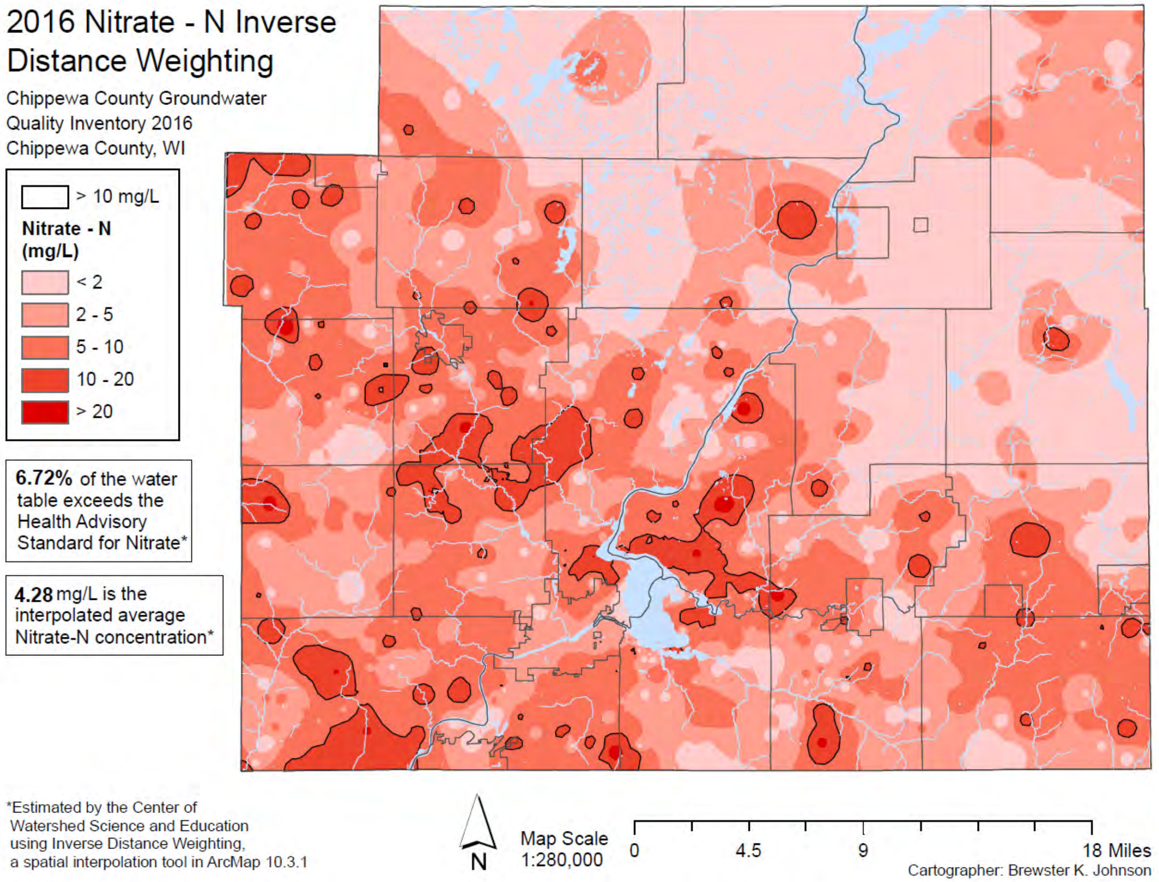


Land-use within ½ mile of 744 wells



Chippewa County Nitrate



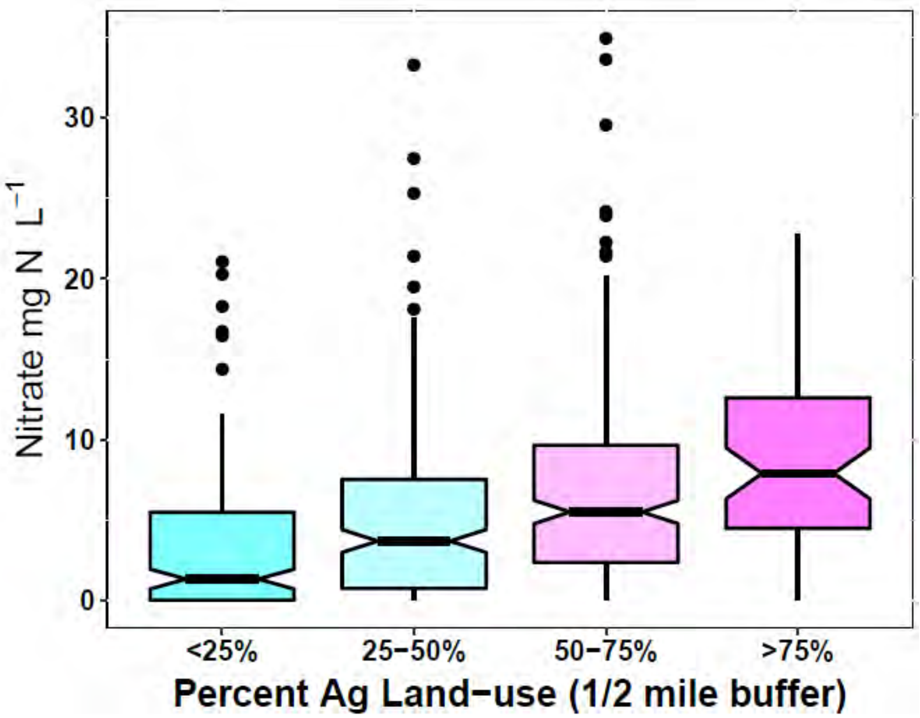


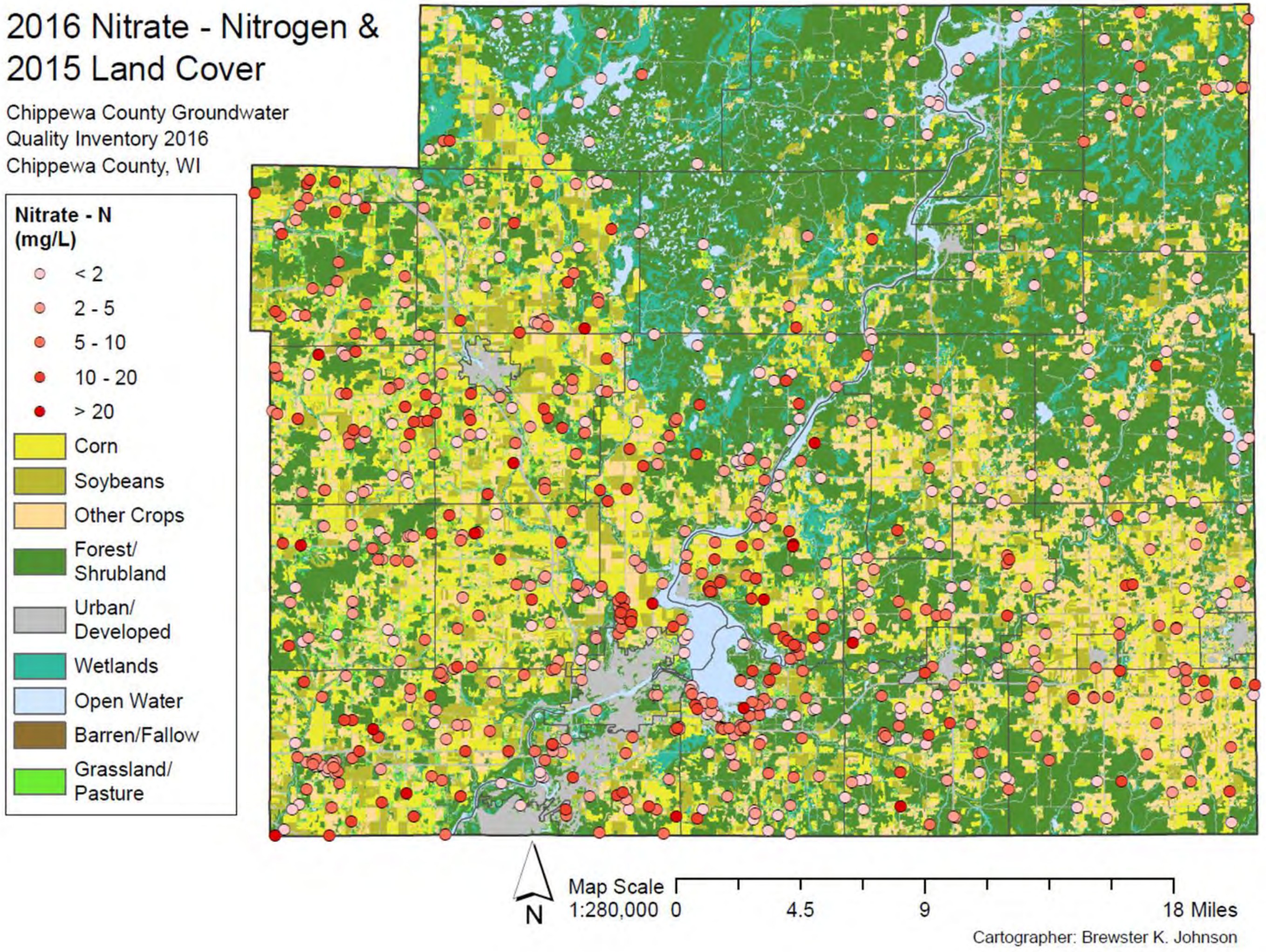
6.72% of the water table exceeds the Health Advisory Standard for Nitrate*

4.28 mg/L is the interpolated average Nitrate-N concentration*

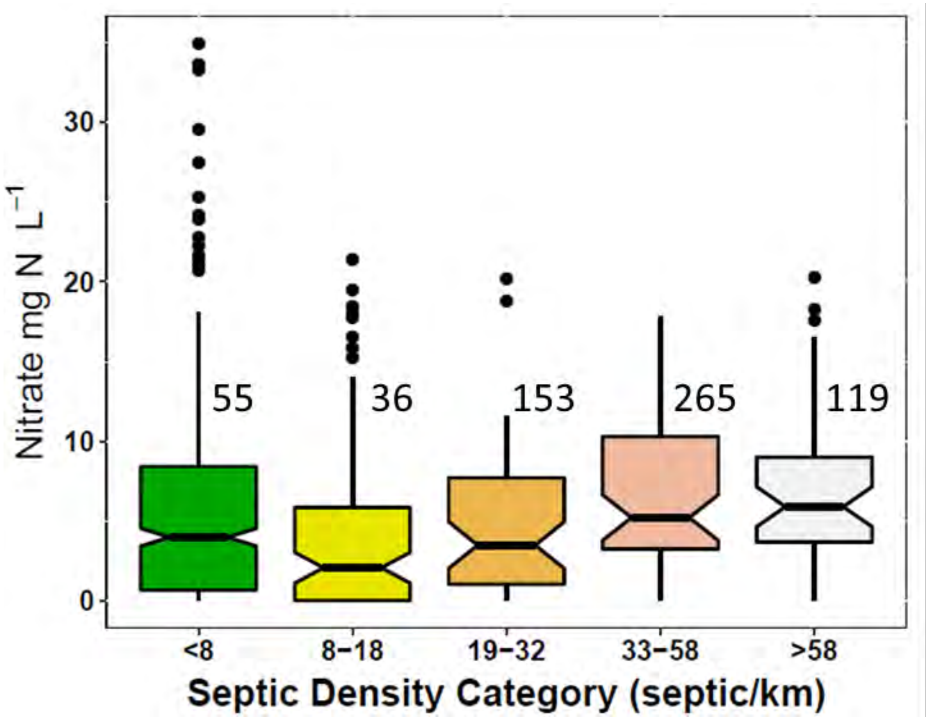
*Estimated by the Center of Watershed Science and Education using Inverse Distance Weighting, a spatial interpolation tool in ArcMap 10.3.1

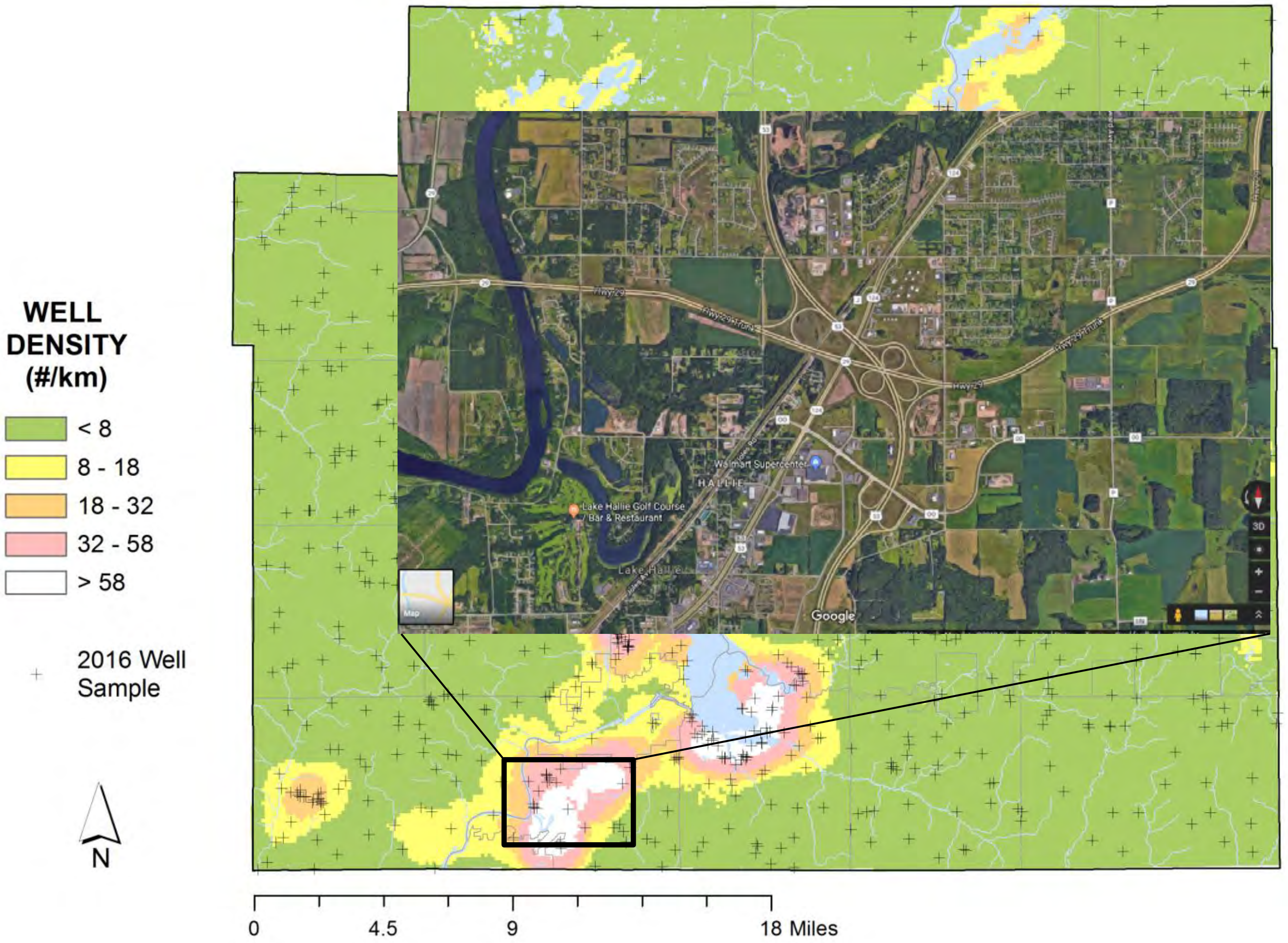
Chippewa County: Nitrate by % Agriculture



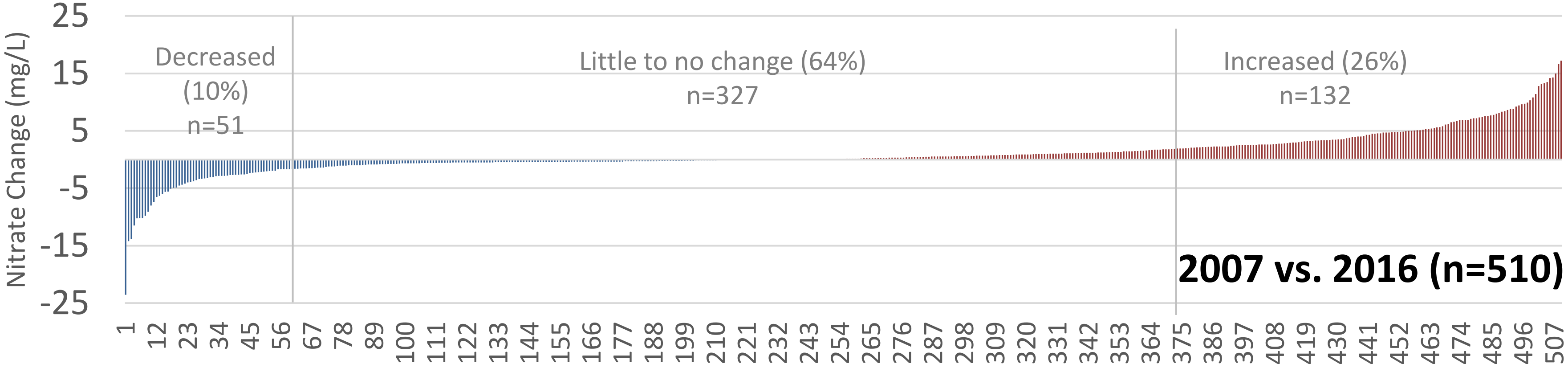


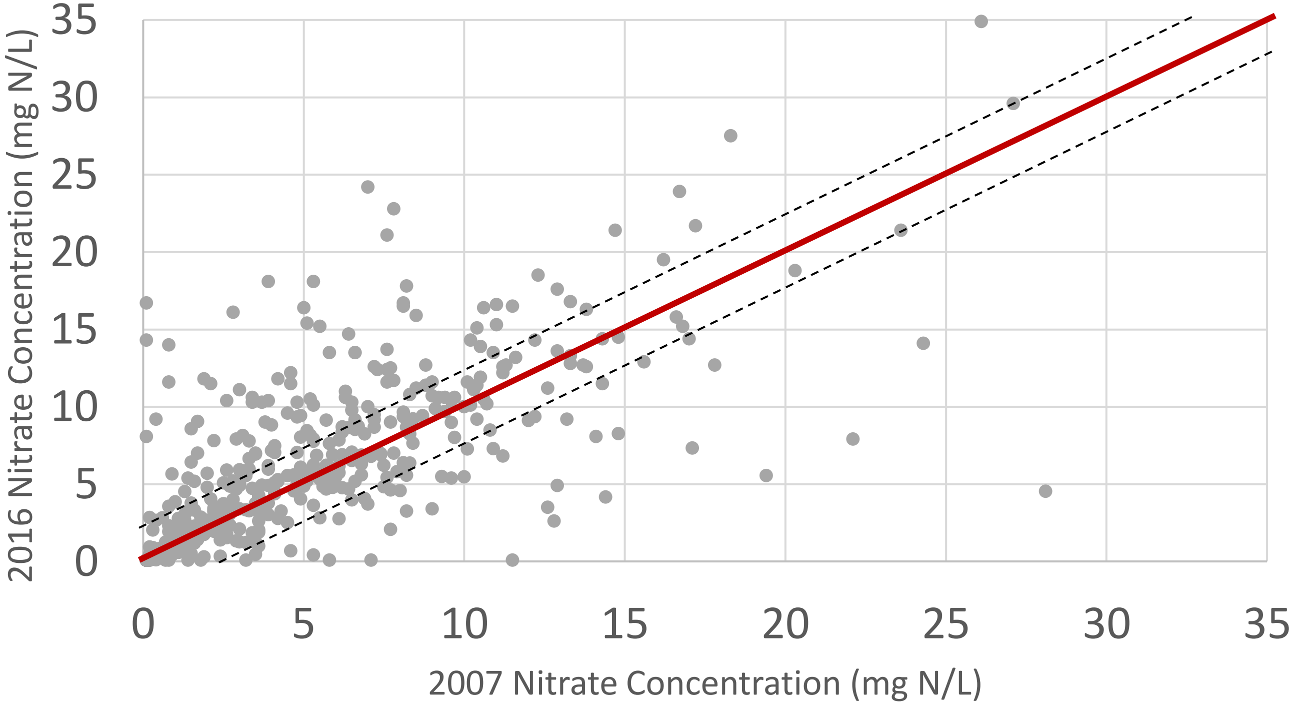
Chippewa County: Nitrate by Septic Density





Comparing nitrate concentrations over time



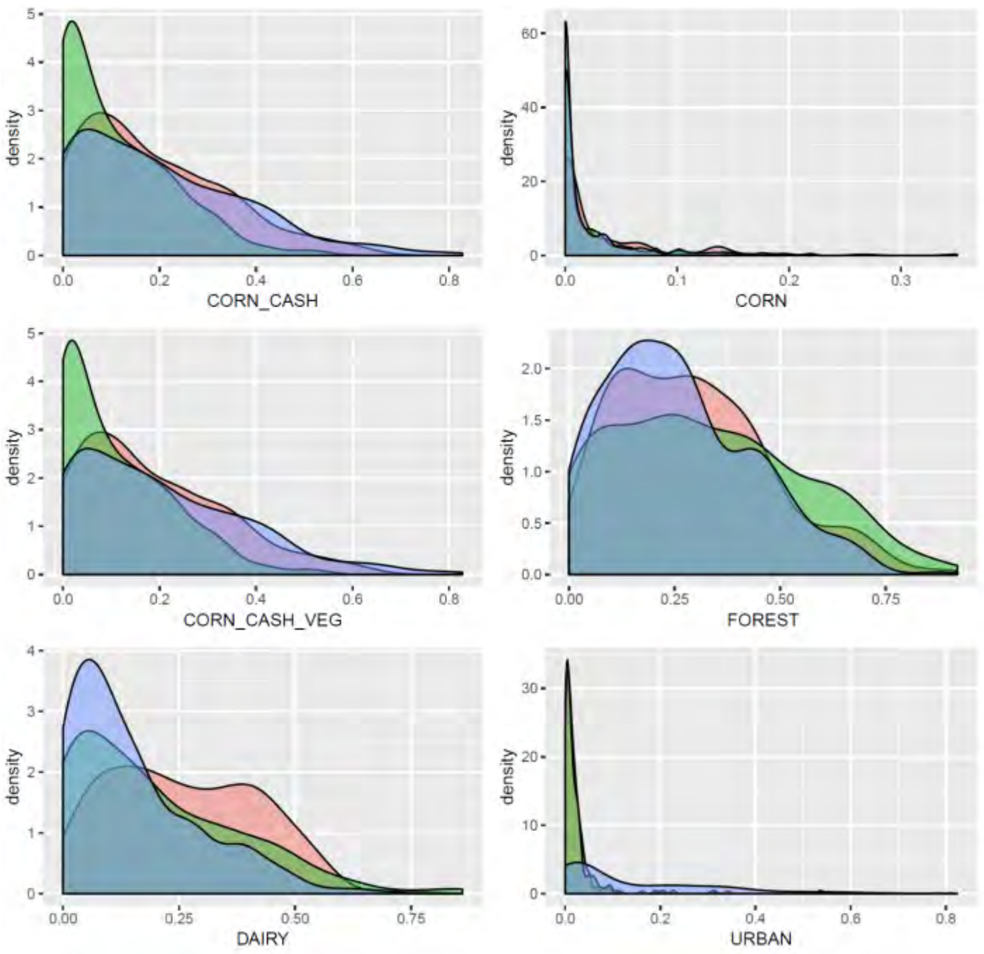


Year	Nitrate Average (mg N/L)	Greater than 10 mg/L
1985	4.2	11.3%
2007	4.7	12.3%
2016	5.5	18.3%

Investigating Trends:
Chippewa Groundwater Quality Index

Stratified by geology

- 210 wells to be tested annually
  - 70 wells each from each stratum (Cambrian, Meltwater Stream Sediment, Glacial)
  - Wells will be selected to obtain representative land cover distribution
  - Wells with known well construction



Investigating Trends:

Goal is to have annual statistics to be able to track changes over time:

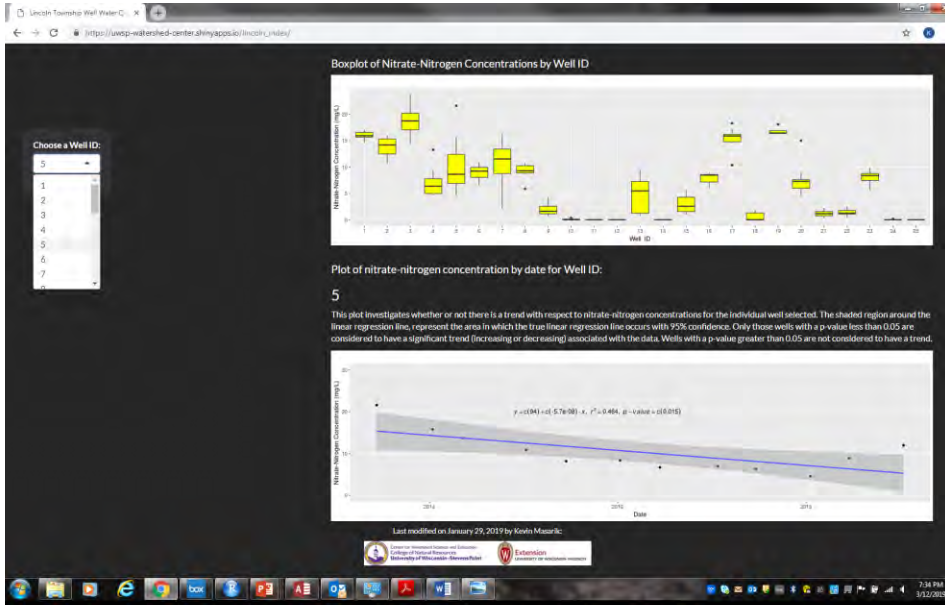
- Nitrate, Chloride, Alkalinity, Conducitivity
- Moving long-term averages by County, Stratum, Agricultural Categories, Septic Density, etc.
- Investigate interannual variability
- Understand trends in individual wells
  - Identify wells that are increasing/decreasing/staying the same
  - Understand contributing factors

NITRATE

This figure represents the average concentration for the analyte of interest by sample date. The first three sample dates only represent the initial ten wells that were monitored. Starting in 2015, the number of wells tested was expanded to twenty-five wells.

The figure below illustrates box plots of sample results by sample date. The bold line represents the median concentration, while the box and whiskers help to describe the sample distribution.

Last modified on January 29, 2019 by Kevin Masarik



Boxplot of Nitrate-Nitrogen Concentrations by Well ID

Plot of nitrate-nitrogen concentration by date for Well ID:

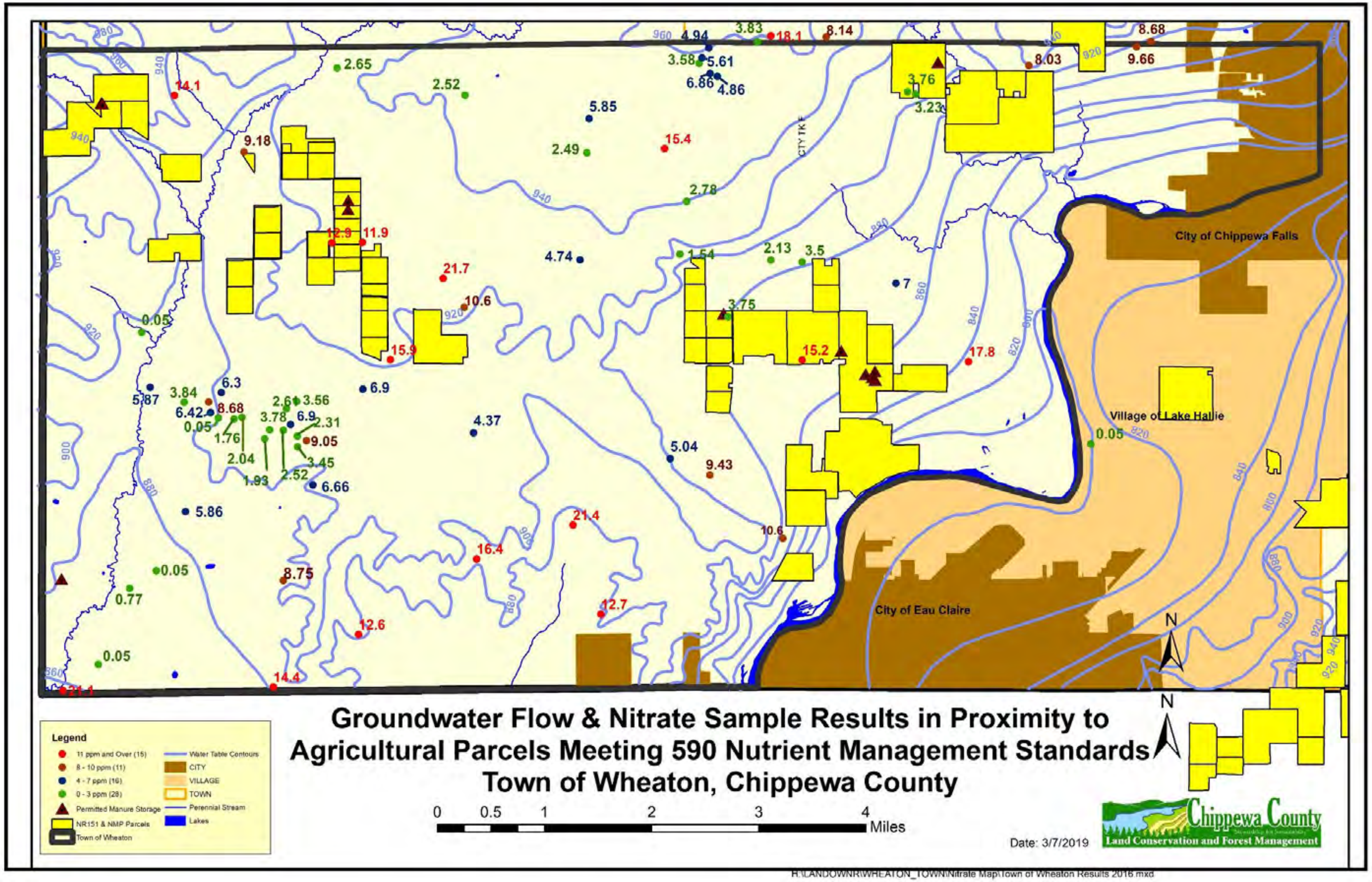
5

This plot investigates whether or not there is a trend with respect to nitrate-nitrogen concentrations for the individual well selected. The shaded region around the linear regression line, represent the area in which the true linear regression line occurs with 95% confidence. Only those wells with a p-value less than 0.05 are considered to have a significant trend (increasing or decreasing) associated with the data. Wells with a p-value greater than 0.05 are not considered to have a trend.

Last modified on January 29, 2019 by Kevin Masarik

Examples from Town of Lincoln, Kewaunee County

Using the data: County perspective

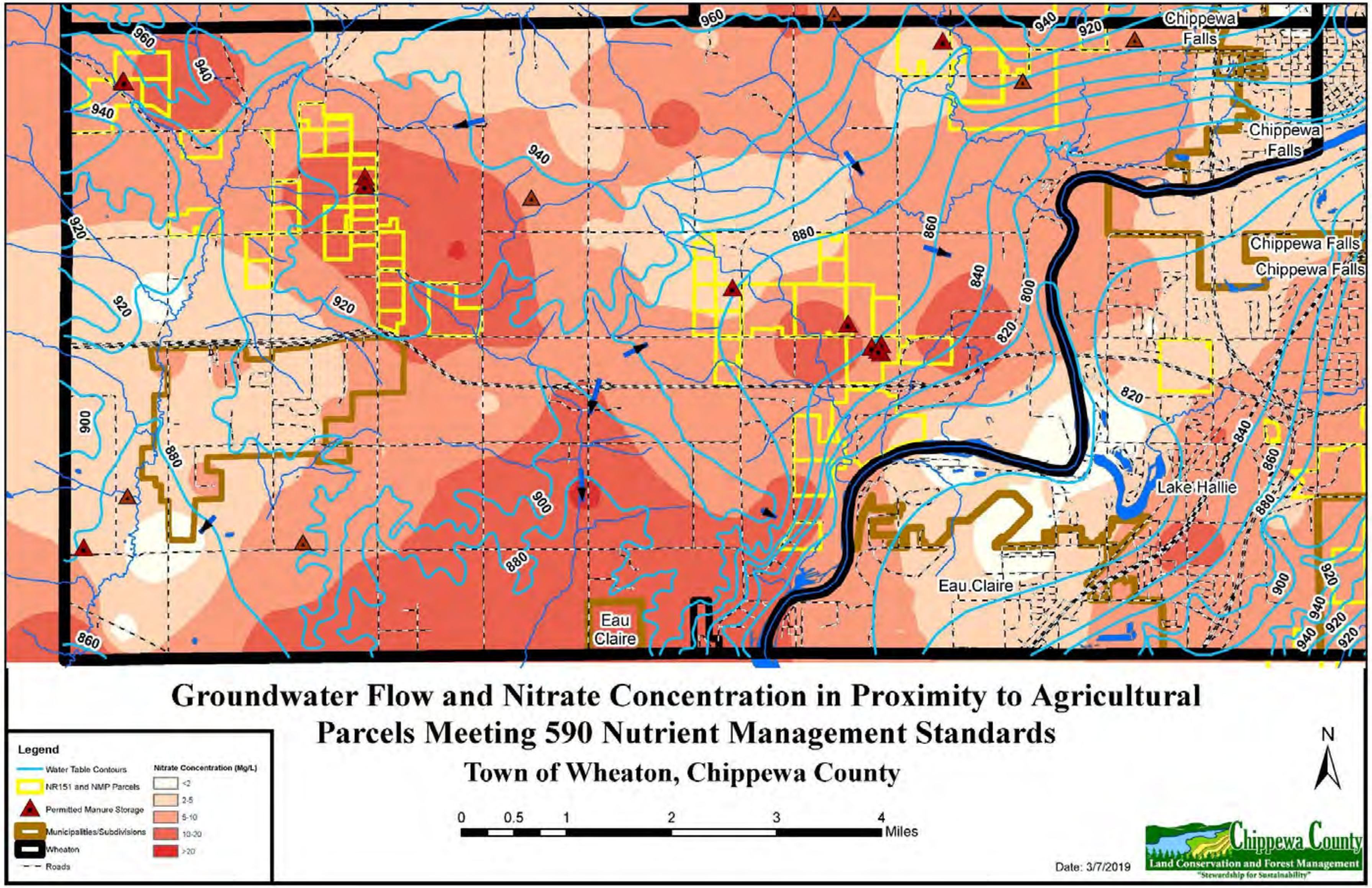


Groundwater Flow & Nitrate Sample Results in Proximity to Agricultural Parcels Meeting 590 Nutrient Management Standards
Town of Wheaton, Chippewa County

Date: 3/7/2019

R:\LANDOWNR\WHEATON_TOWN\Nitrate Map\Town of Wheaton Results 2018.mxd

Using the data: County perspective

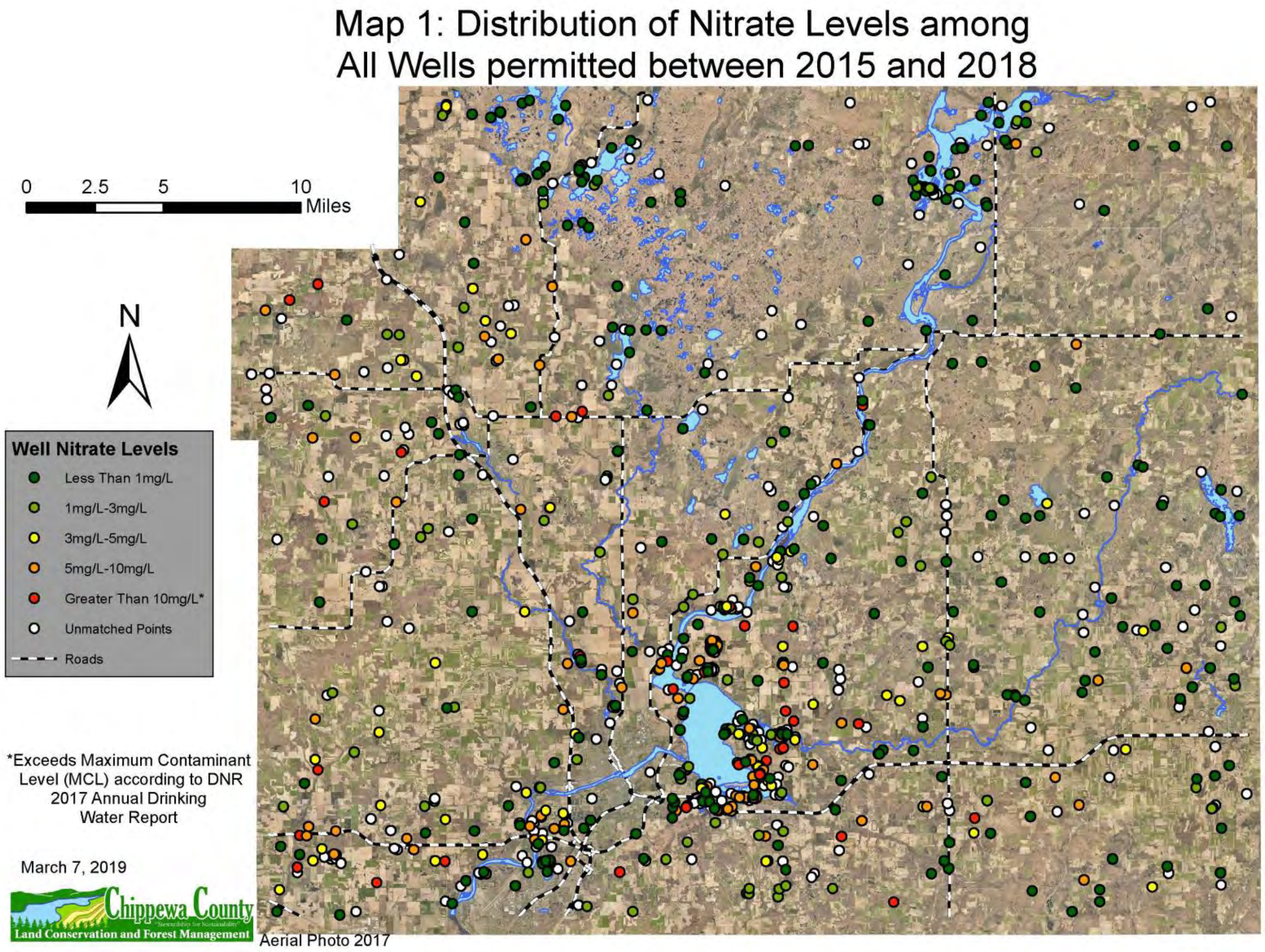


Groundwater Flow and Nitrate Concentration in Proximity to Agricultural Parcels Meeting 590 Nutrient Management Standards

Town of Wheaton, Chippewa County

Date: 3/7/2019

Using the data: County perspective



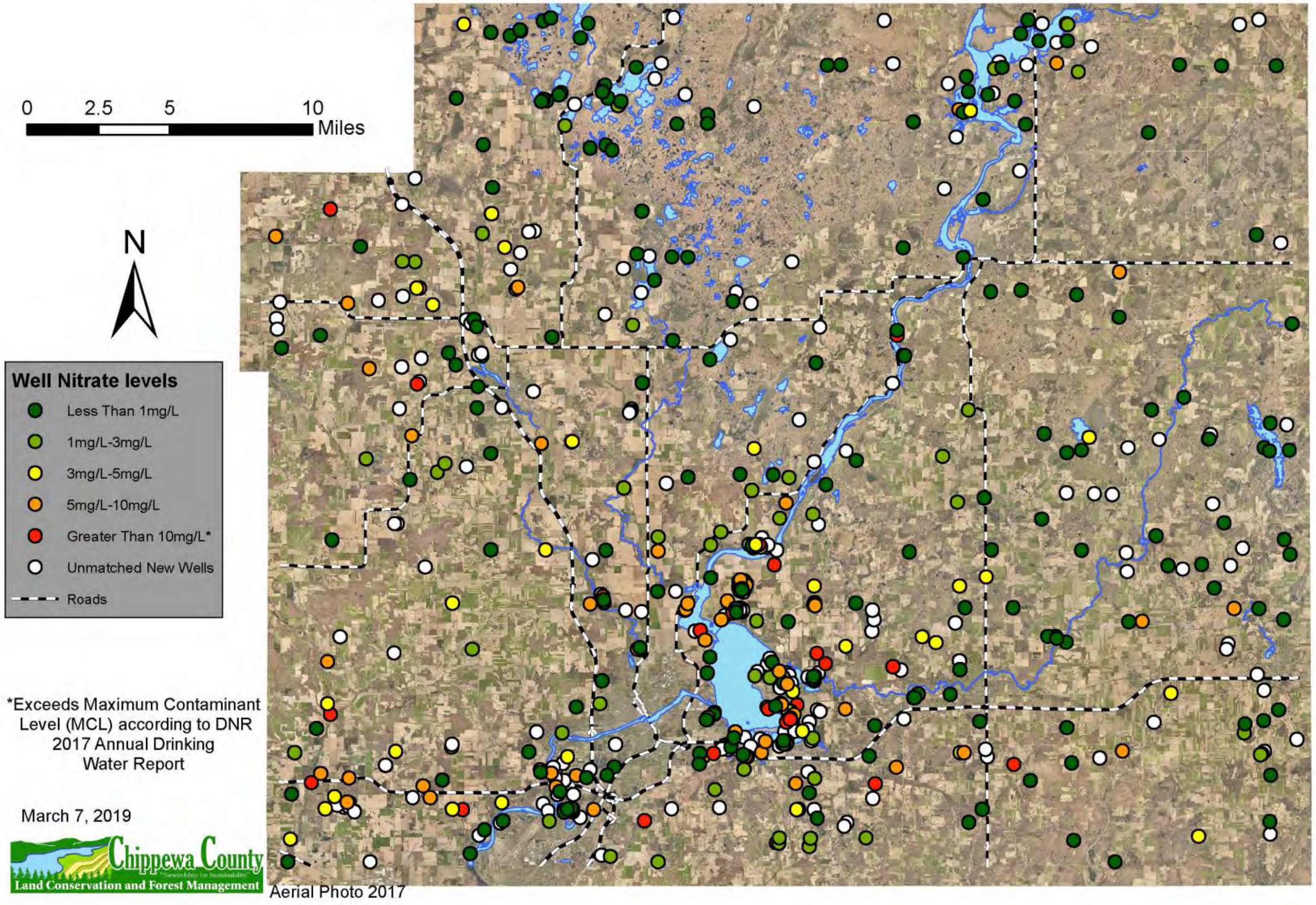
Map 1: Distribution of Nitrate Levels among All Wells permitted between 2015 and 2018

*Exceeds Maximum Contaminant Level (MCL) according to DNR 2017 Annual Drinking Water Report

March 7, 2019

Aerial Photo 2017

Using the data: County perspective



Map 2: Distribution of Nitrate Levels among New Wells Permitted between 2015 and 2018

*Exceeds Maximum Contaminant Level (MCL) according to DNR 2017 Annual Drinking Water Report

March 7, 2019

Aerial Photo 2017

Appendix E

List of Proposed Nitrate Actions from Portage County GCAC

PLANNING AND ZONING DEPARTMENT

1462 STRONGS AVENUE, STEVENS POINT, WI 54481 • PHONE: 715-346-1334 • FAX: 715-346-1677

To: Land and Water Conservation Committee

From: Portage County Groundwater Citizen Advisory Committee
Water Resource Specialist Jennifer McNelly

Date: February 21, 2022

R.e.: Response to January Request for Potential Actions to Address Nitrate Contamination

At the January Land and Water Conservation Committee meeting Supervisor Neville requested that the Portage County Groundwater Citizen Advisory Committee (GCAC) forward potential actions that the Land and Water Committee could consider and discuss that would potentially address elevated nitrate concentrations in the County's groundwater.

Below you will find a list of potential actions that could help address nitrate concentrations. GCAC discussed each of these actions and felt they were appropriate to include. They did not limit actions to those that would be easy to implement or those that had a likelihood of adoption. They also did not choose actions based on how big of an impact they would have. Instead, they decided to offer up an inclusive list.

Agricultural Efforts

- ➢ Work with WPVGA and vegetable processors to encourage varieties of snap beans that utilize inoculated seed to promote colonization of rhizobia, which would eliminate the need for nitrogen fertilization
- ➢ Encourage the revision of UW nutrient application recommendations so that they consider water quality impacts and not just economic profitability.
- ➢ County leadership to help create a market for "groundwater friendly" crops such as alfalfa, clover and/or soybeans by working with the private sector to locate a processing facility in the County.
- ➢ Encourage and provide assistance for the formation of additional farmer-led groups promoting the understanding and use of best management practices. Farmers for Tomorrow, a farmer led council recently formed to adopt and promote conservation practices in the Tomorrow River Watershed to reduce nitrate leaching.
- ➢ Provide incentives to producers who utilize nitrogen reducing best management practices
- ➢ Target incentives in areas that would have the largest impacts on private residential wells
    - o Work with corporate entities to provide incentives
    - o Showcase farmers that are implementing nitrogen reduction strategies

- Encourage the use of nutrient management planning that accounts for nitrogen (nitrogen budgeting), including crediting nitrogen in irrigation water
- Limit how much nitrogen is applied to crops
- Limit where nitrogen is applied
- Limit when nitrogen is applied (IE no fall applications of nitrogen)
- Change the crops that are grown to less nitrogen intense crops

Regulatory Efforts

- Have policymakers set an N value that must be met (This would be similar to the DNR's proposed NR 151 revision)

Zoning Ordinance Changes

- Establish a new zoning district based on soil types susceptible to water contamination. This district could limit nutrient applications, type of crops/farming allowed, and/or require the use of best management practices.
- Establish a new zoning district based on water quality test results. This would theoretically be the same as the Atrazine prohibition areas. Potential activities within these areas could include limiting nutrient applications, types of crops/farming allowed, and/or require the use of best management practices.

Subdivision Ordinance Changes

- Require that every lot that undergoes a division to have a water test if a well is present.
  - Bacteria and Nitrate for sure, possibly a pesticide scan?
  - If sample exceeds standard a notation should be made on the CSM or possibly the deed.
- A subdivision of land could be denied if a returned samples contaminant levels are so high that the water is not able to be treated to the point that it would meet drinking water standards.
- If nitrate levels are high on the property, could there be an additional requirement to add additional treatment onto existing and any new septic systems on the property being divided?

POWTS Ordinance Changes

- Require the use of additional treatment on systems to reduce/remove nitrates from effluent.

Educational Efforts

- Youth education.
- Hold a groundwater "summit" or roundtable discussion (in cooperation with Wood County, possibly other adjacent Counties), inviting industries, residents, water lab personnel to discuss options for reducing nitrates.

Financial Efforts

- Subsidized cost for individual water treatment systems?
- Promote and participate in public and private fund raising for water quality solutions
- Pursue funding to incentivize agricultural activities that are of benefit to water resources
    - More widely promote the use of existing cost-share funding through the Portage County Land and Water Conservation Division for conservation facilities and practices.
    - Advocate for subsidies (by Portage County or corporate entities) promoting slow-release commercial nitrogen to eliminate excessive nitrate leaching from increasingly frequent intense storm events.
- Increase funding to the Land Preservation Fund and expand the mission to purchase conservation easements for the protection of groundwater.
    - Look at cost sharing to off-set the cost water quality testing and treatment system and/or well replacement for affected well owner.

Lawn Efforts

- Prohibit lawn fertilization
- Limit the amount of fertilizers applied to lawns
- Eliminate law fertilization on County properties
- Work with lawn fertilization companies to reduce nitrates applied to properties
- If there are certain governmental units that want to limit lawn fertilizers, provide assistance
- Work with willing landowners to replace lawns with native vegetation

Scientific Study/Research

- The AmaizeN model should be explored by UWEX to verify validity for reduced nitrogen applications on irrigated corn production.
- Utilize new nitrogen budgeting tools being developed by UW-Madison
- Encourage participation in local research on nitrogen reduction strategies

Additional Actions to be Considered

- Explore municipal services to outlying areas

Appendix F

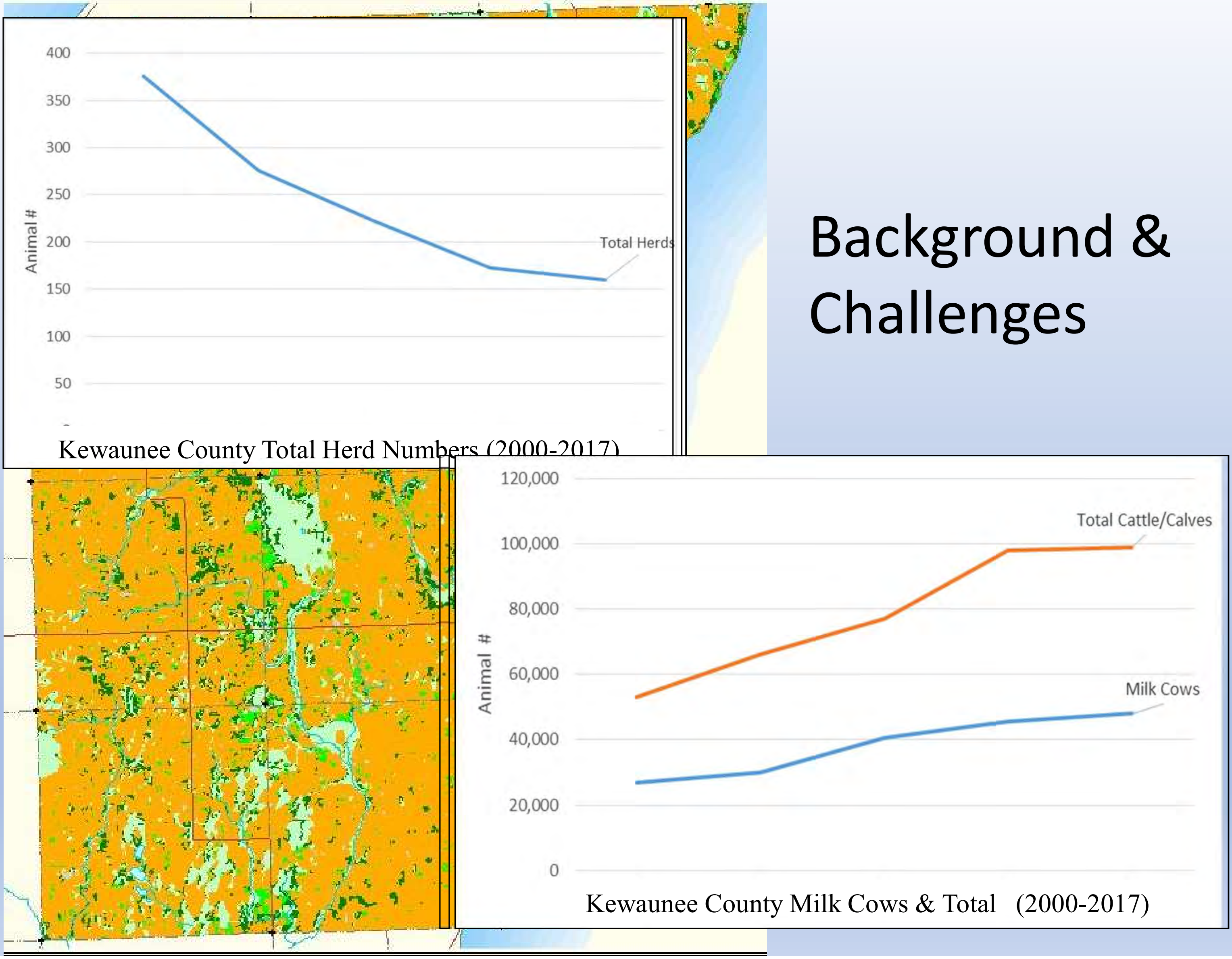
Addressing Groundwater Quality in Kewaunee County

Addressing Groundwater Quality in Kewaunee County

Davina Bonness
County Conservationist

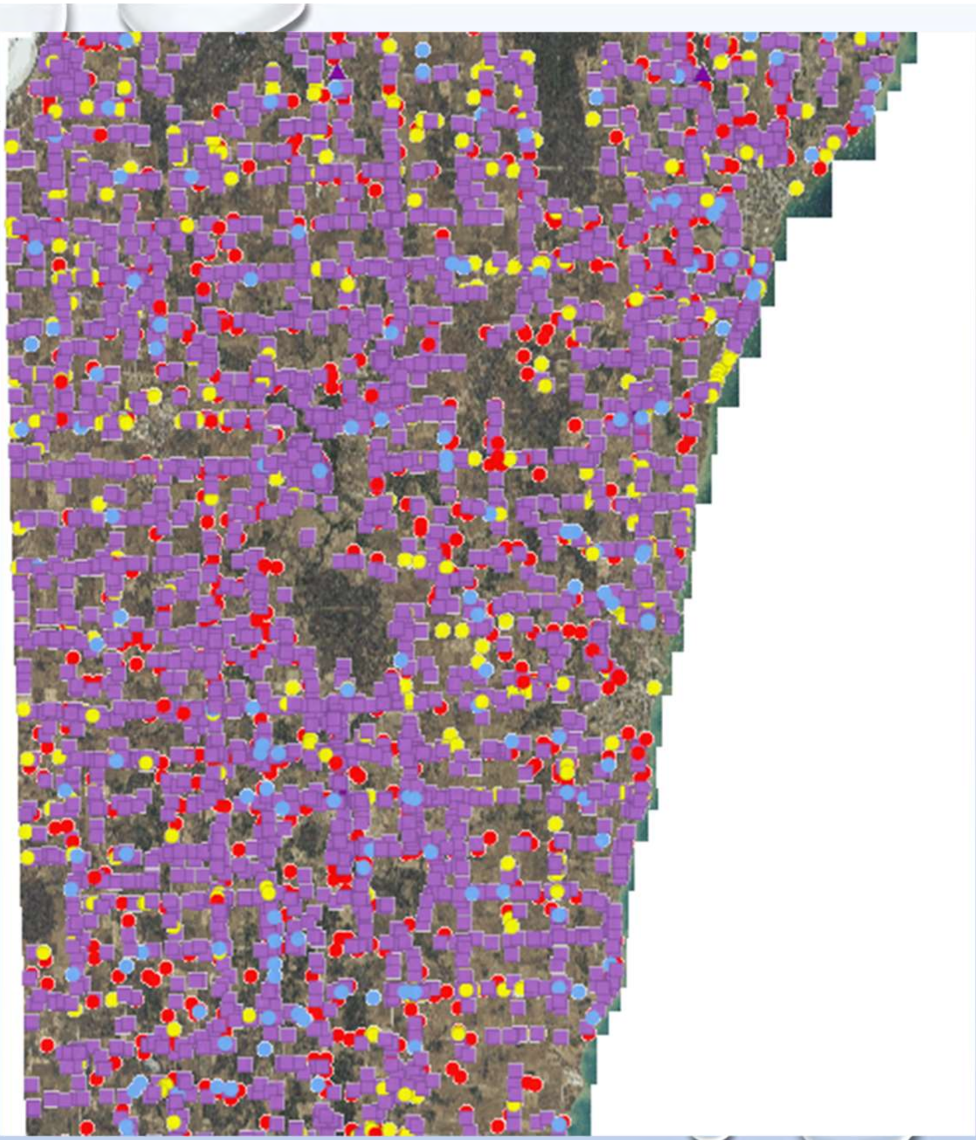
Presentation 1 - July 2022

Background & Challenges



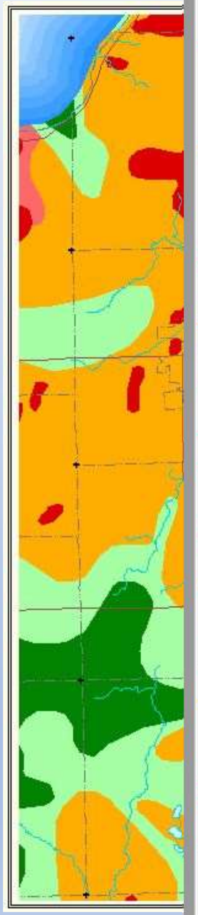
Kewaunee County Total Herd Numbers (2000-2017)

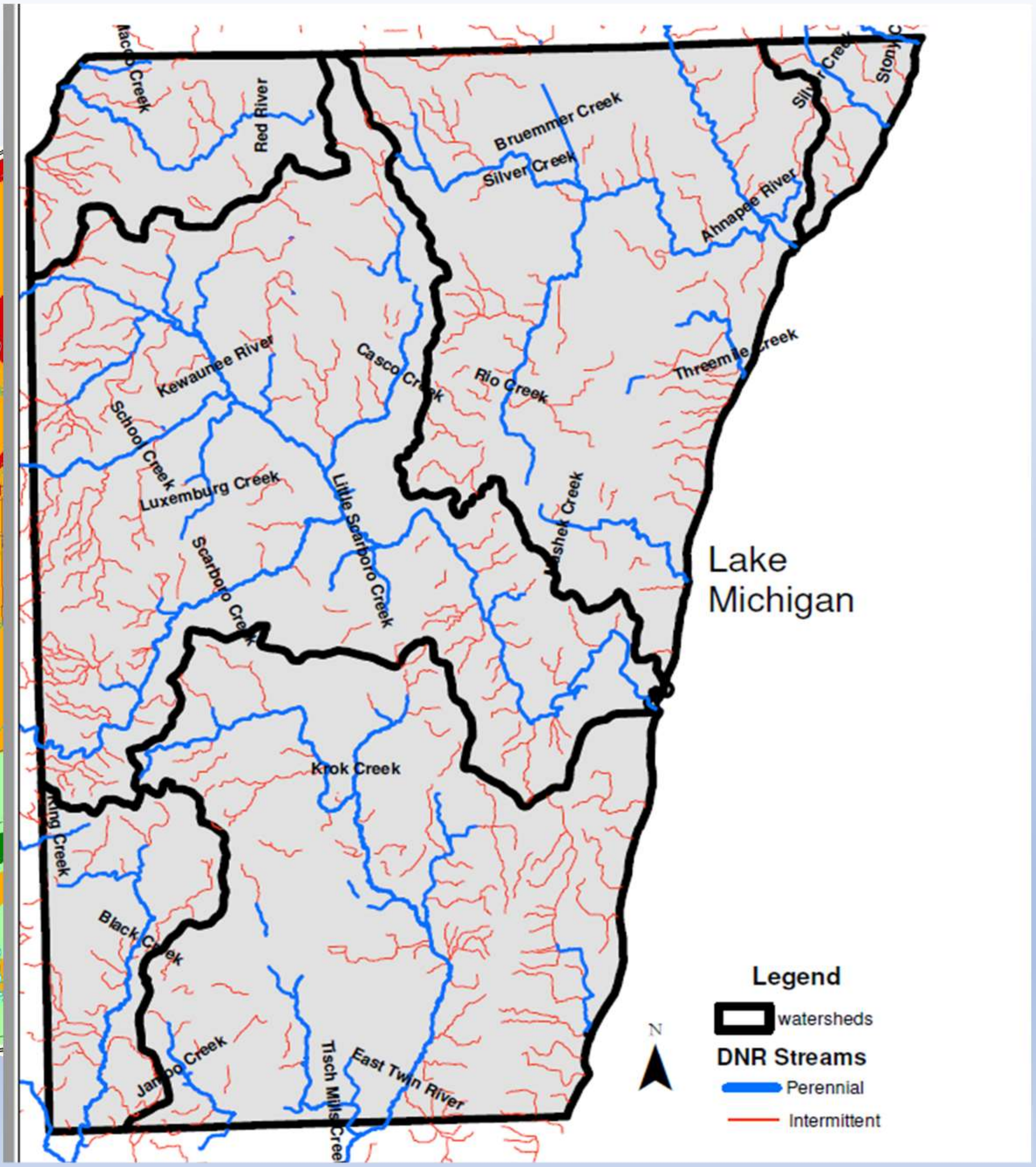
Kewaunee County Milk Cows & Total (2000-2017)



Kewaunee County Rural Sprawl

- 4822 septic systems in the county & private wells





Vast Network of Surface Water Resources

Thin Soils Over Creviced Bedrock: Fracture Traces

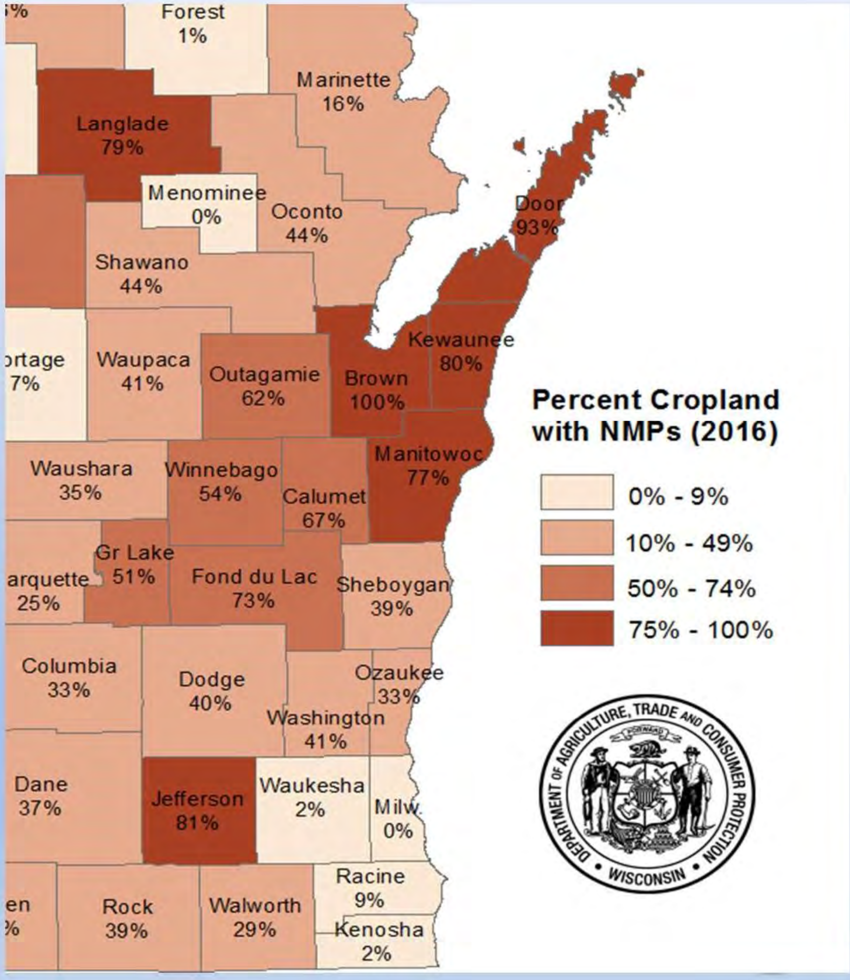
Sinkholes in Agricultural Fields

Implementation of Current WI State Standards

in 2010

VERY IMPORTANT STARTING POINT!

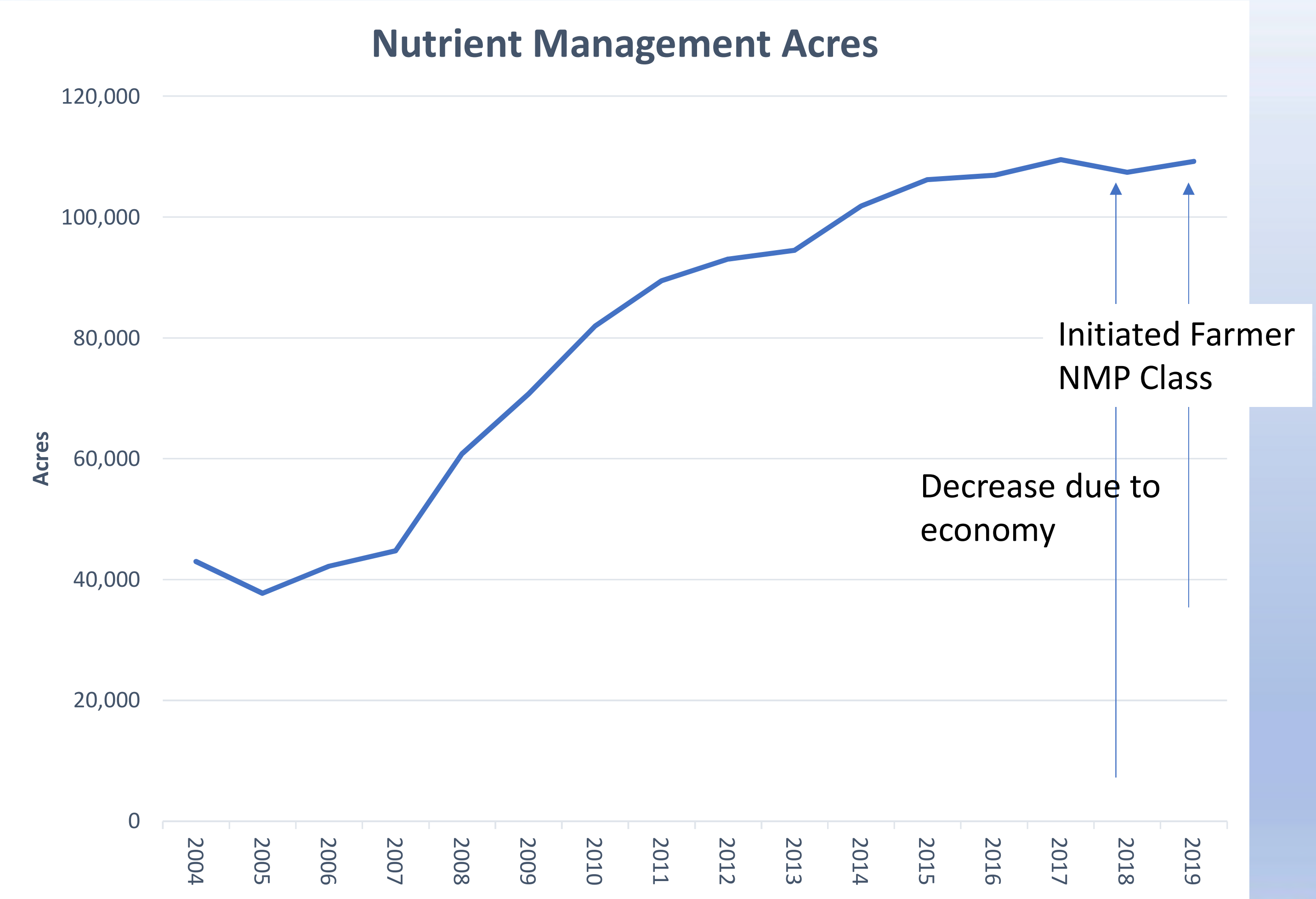
Nutrient Management



~80% of cropland acres in
Kewaunee County
and

NR 151 Walkover
~ 97,000 acres are in
compliance with state standards
& prohibitions

All farms are walked every 4
years for compliance

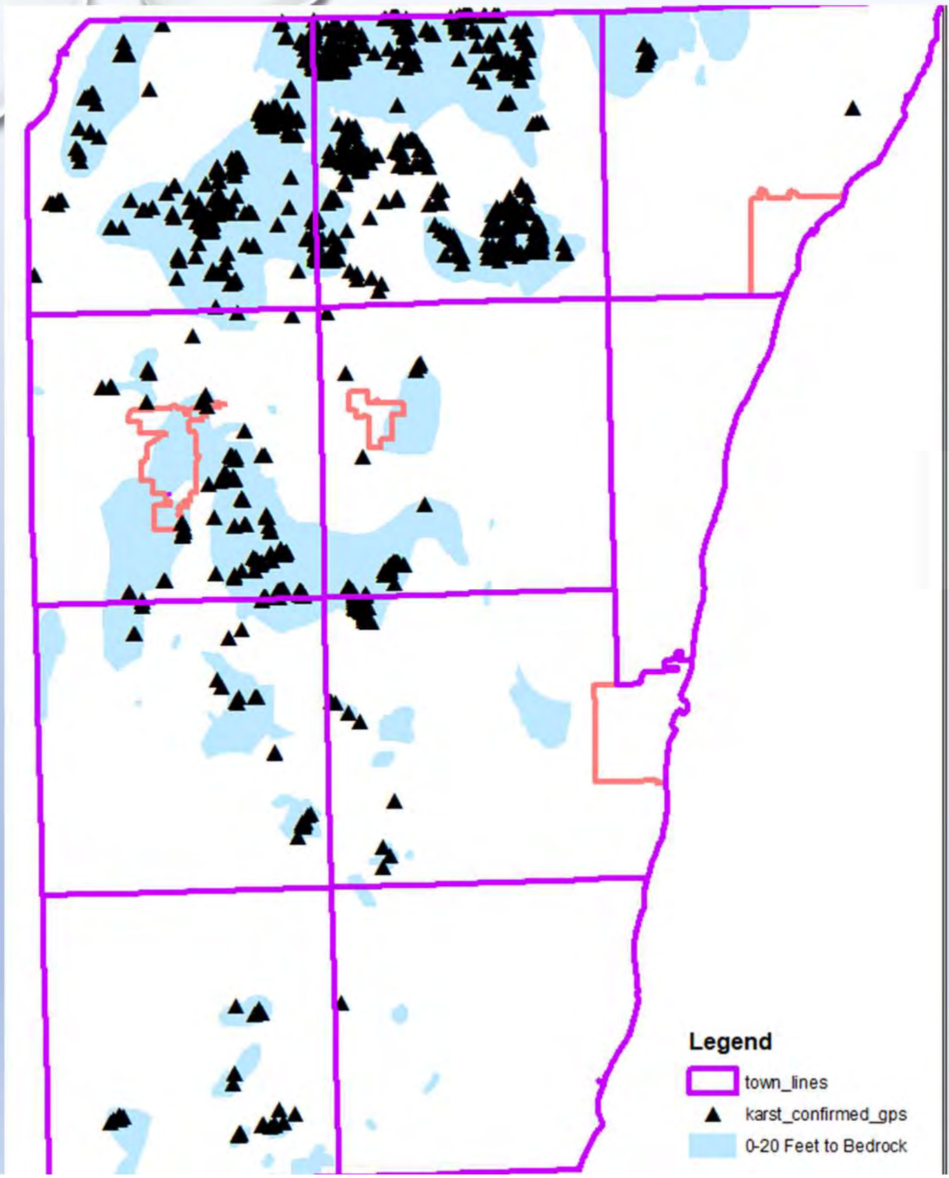


Initiated Farmer NMP Class

Decrease due to economy

NR151Walkovers: “Boots on the ground”

Boots on the Ground
--cost-sharing

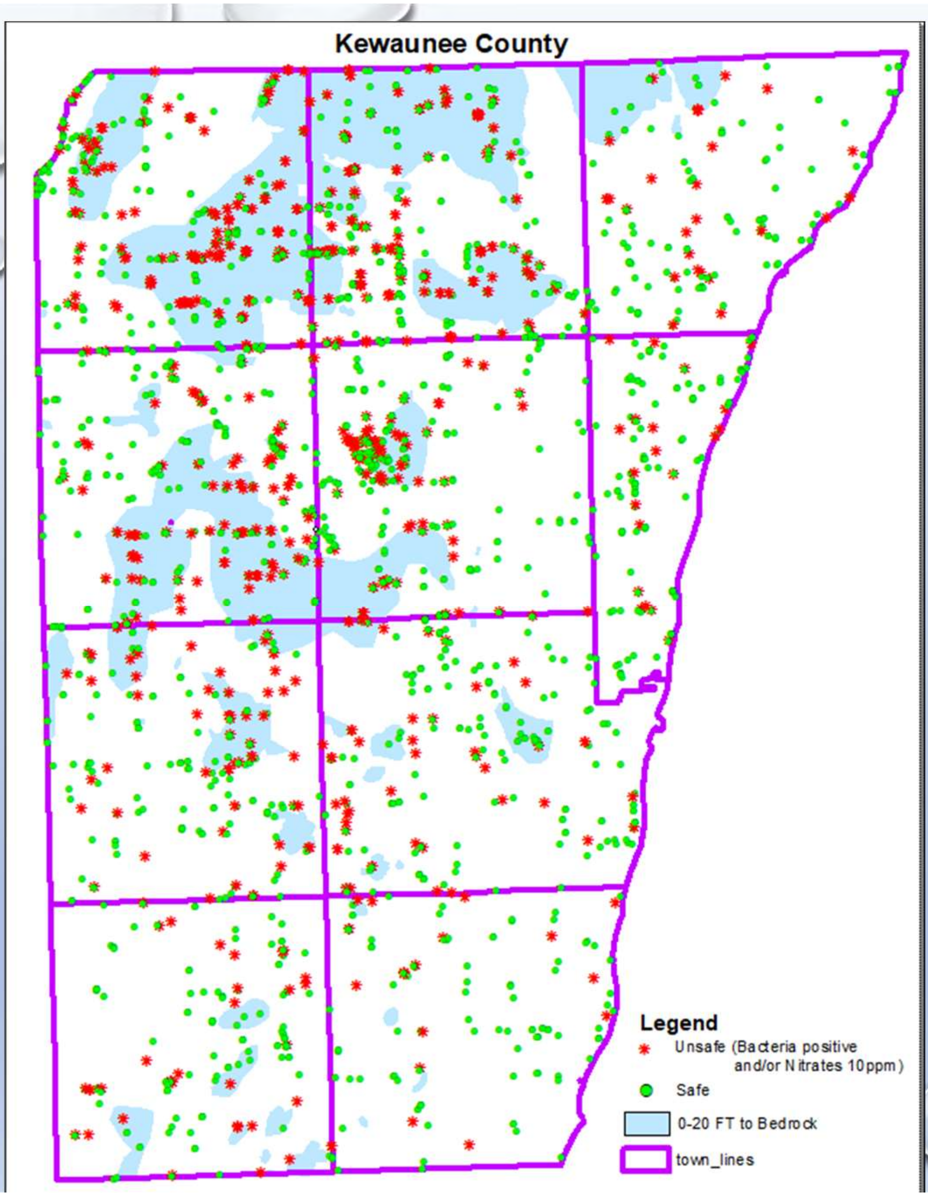


Karst Inventory

Over 1500 features added since 2010 walkovers began

DATCP online mapping database (SNAP PLUS)

In NMPs with adequate setbacks



2004-2020:

VOLUNTARY WELL TESTING RESULTS

Clearly….

Current regulations
covering land application of wastes
were inadequate
for protecting human health
in the County’s shallow soil depth to carbonate bedrock landscapes.

Now….Insert Public Pressure

MONDAY | JULY 27 | 2015

MOSTLY SUNNY | HIGH 87 | LOW 67 | DETAILS, 12A

Star-News

PRESS-GAZETTE

12-16-13

GREENBAYPRESSGAZETTE.COM

A GANNETT COMPANY

'You have the worst-case scenario here,' water expert says

Page A2

KEWAUN

Re

By Alyssa B

Kewaunee Cou

A family

STAR-NEWS

was GISed, isplayed with a system, and 50

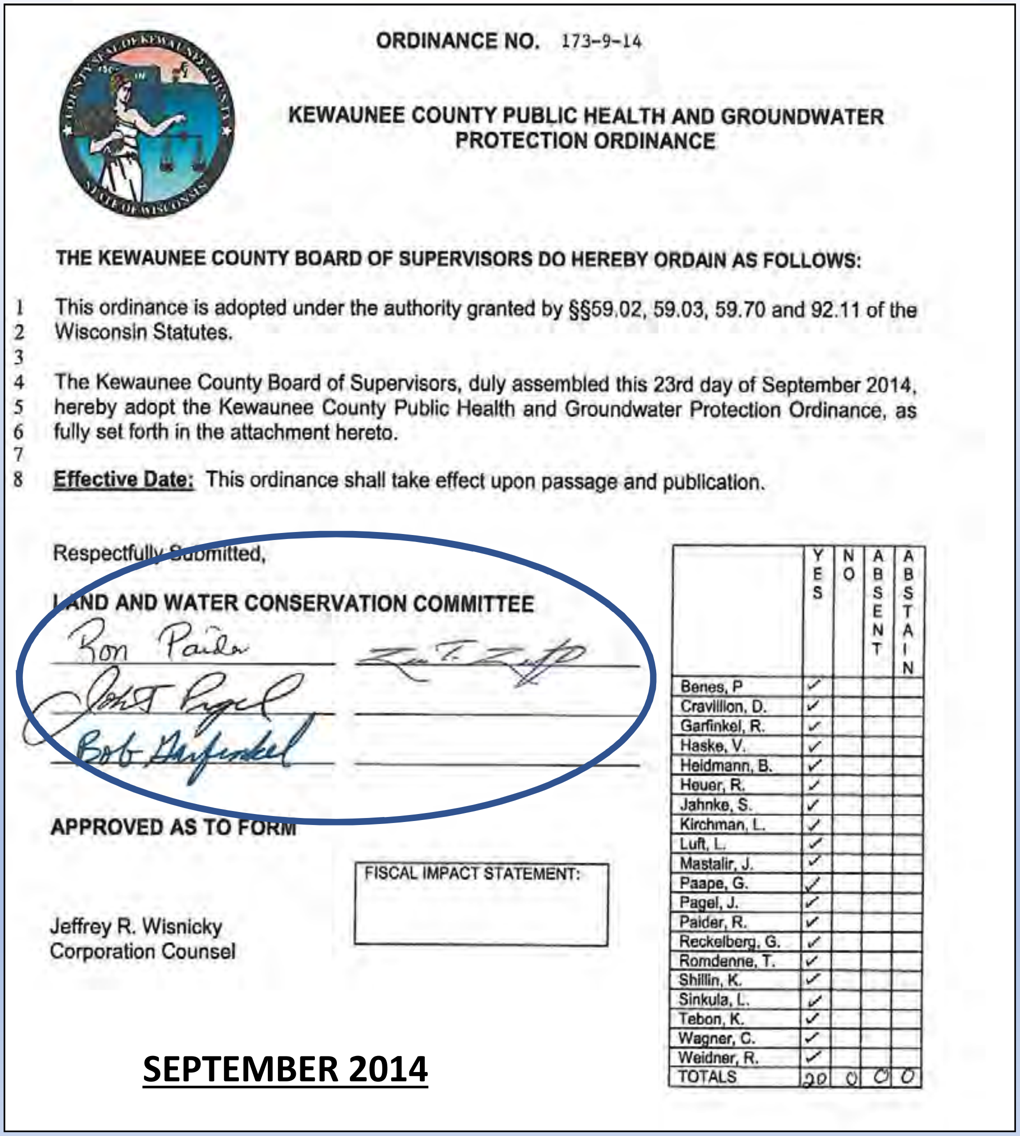
Brown Water Events & Manure Spills

OCTOBER 2016

2014 --Public Health & Groundwater Protection Ordinance was drafted

(1st & only County in Wisconsin)

Promote the **public health**, safety and general welfare of the citizens of Kewaunee County through proper land use and management on geographically vulnerable areas.



ORDINANCE NO. 173-9-14

KEWAUNEE COUNTY PUBLIC HEALTH AND GROUNDWATER PROTECTION ORDINANCE

THE KEWAUNEE COUNTY BOARD OF SUPERVISORS DO HEREBY ORDAIN AS FOLLOWS:

This ordinance is adopted under the authority granted by §§59.02, 59.03, 59.70 and 92.11 of the Wisconsin Statutes.

The Kewaunee County Board of Supervisors, duly assembled this 23rd day of September 2014, hereby adopt the Kewaunee County Public Health and Groundwater Protection Ordinance, as fully set forth in the attachment hereto.

Effective Date: This ordinance shall take effect upon passage and publication.

Respectfully Submitted,

LAND AND WATER CONSERVATION COMMITTEE

Ron Paider

John T Pagel

Bob Garfinkel

APPROVED AS TO FORM

Jeffrey R. Wisnicky
Corporation Counsel

FISCAL IMPACT STATEMENT:

	YES	NO	ABSENT	ABSTAIN
Benes, P	✓			
Cravillion, D.	✓			
Garfinkel, R.	✓			
Haske, V.	✓			
Heidmann, B.	✓			
Heuer, R.	✓			
Jahnke, S.	✓			
Kirchman, L.	✓			
Luft, L.	✓			
Mastalir, J.	✓			
Paape, G.	✓			
Pagel, J.	✓			
Paider, R.	✓			
Reckelberg, G.	✓			
Romdenne, T.	✓			
Shillin, K.	✓			
Sinkula, L.	✓			
Tebon, K.	✓			
Wagner, C.	✓			
Weidner, R.	✓			
TOTALS	20	0	0	0

SEPTEMBER 2014

KEWAUNEE

KC Star - September 27, 2014

County Board OK's groundwater protection ordinance, 20-0

Next step is town-level referendums in spring

By Alyssa Bloechl
Kewaunee County Star-News

The Kewaunee County Board of Supervisors unanimously approved a Public Health and Groundwater Protection Ordinance on Sept. 23.

The 20-0 vote was greeted by applause from the gallery.

"This has been a lot of work by a lot of people," County Board Chairman Ron Heuer said. "We need to work together to promote agriculture. I don't want see agriculture affected negatively. Neither do I want to see families being not protected."

He went on to say he believes the board has taken a big step forward, but there is still work to be done.

Twelve citizens approached the board with comments before the vote, including those for passing the ordinance and some who said it was written incompletely.

"I know that it is not thorough enough, I'm not sure if it was the right process, and I hope there is a better way," Algoma dairy farmer Randy Ebert said during comments.

He went on to say he thinks it is important to create long-term plans to support and guide farmers on this issue while elected officials and communities change.

[illegible] Treml, a former resident of Kewaunee County, told her story of [illegible] contamination and why she wanted to see the ordinance pass.

"My entire family was

2004," Treml said. "During litigation, part of our settlement with the farmer to ask for him simply to stop spreading liquid manure from months of Nov.

event, and not one well test came back unsafe with those restrictions in place."

Other local farmers approached the board look-

cleared up.

State Assembly candidate Joel Kitchens and state Senate candidate Dean DeBroux both made statements in favor of the

ties were submitted to the board prior to the meeting.

The board also discussed terms of the ordinance once a motion was on the floor. Both dates of land application and snow removal from farms were discussed, but no action was taken to amend the document.

This ordinance, the first of its kind, limits the spreading of manure and wastes on land 20 feet to bedrock during the time period of Jan. 1-April 15, when groundwater is recharging.

The next step is the ordinance will go to referendum during the spring 2015 election. Each town within Kewaunee County will have the chance to vote to adhere to the ordinance or not. If it passes, it would take effect in January 2016.

In other business before the County Board:

» Tracy Nollenberg was appointed to the position of Kewaunee County emergency management director.

» Laura Giddley gave the annual report for the Violence Intervention Project. She talked about what the program offers, citing that in 2013, 136 victims of domestic abuse and 73 of sexual abuse in Kewaunee County were served by their program. VIP is marking 25 years of service to the county this year.

» Appointments were made to the Local Emergency Planning Committee.

» A resolution passed 19-1 approving the collective bargaining agreement with the Kewaunee County Courthouse employees. There is no fiscal impact from this decision.

» A resolution passed 19-1 approving the colle

PHOTOS BY ALYSSA BLOECHL/KEWAUNEE COUNTY STAR-NEWS

Dick Swanson advocates for the passage of the Kewaunee County public health and groundwater protection ordinance during the Sept. 23 County Board meeting. He placed two jugs of water, one brown and one clear (not necessarily from Kewaunee County wells), in front of Chairman Ron Heuer.

Algoma dairy farmer Randy Ebert addresses the Kewaunee County Board about his concerns regarding a new groundwater protection ordinance. He said it may have passed too quickly and suggested creating a more extensive plan with more guidance and support for farmers. The measure passed unanimously.

of

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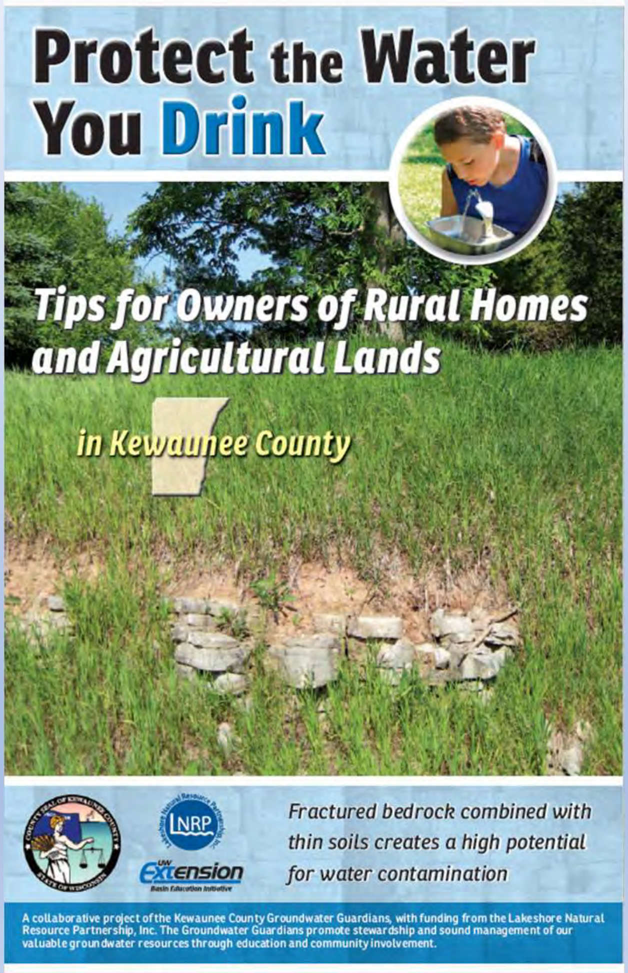
Education / Outreach (2015-2016)



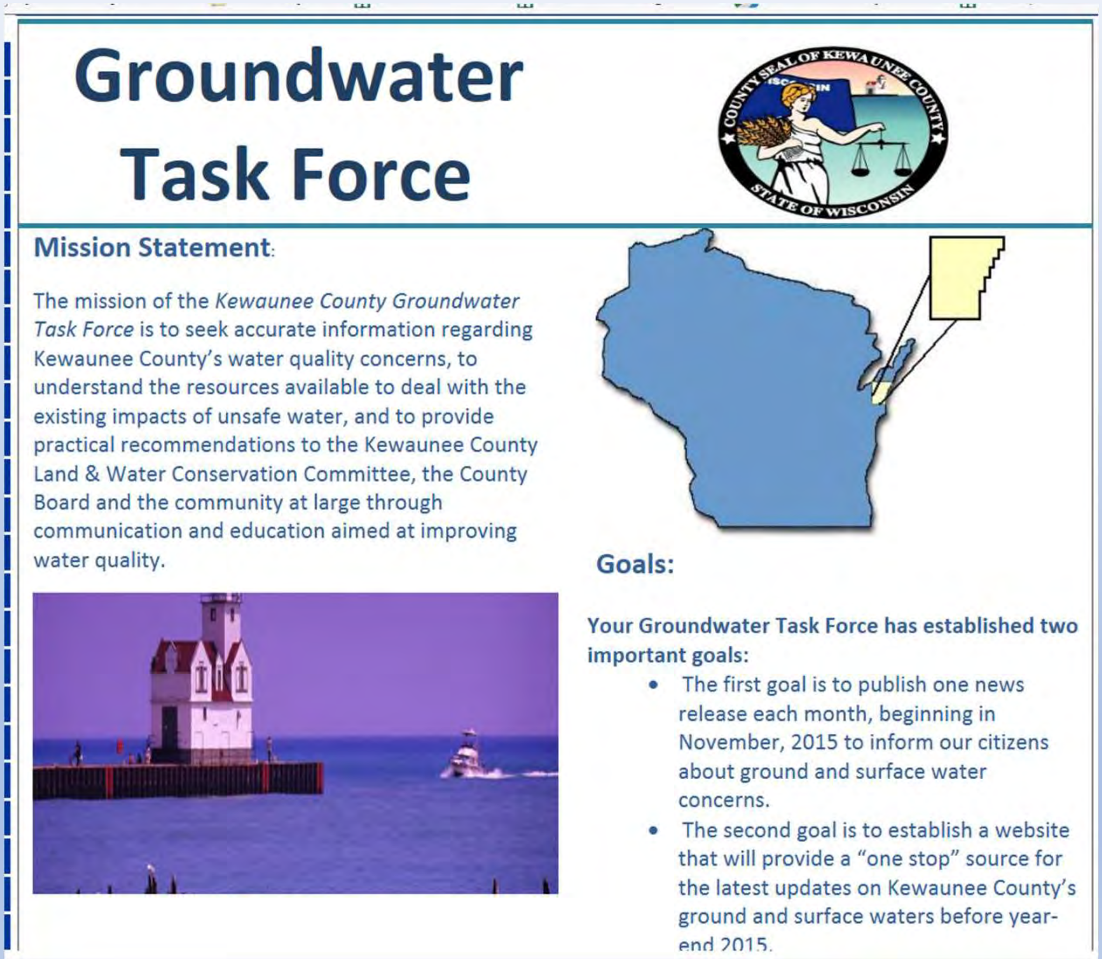
Protect the Water You Drink

Tips for Owners of Rural Homes and Agricultural Lands

in Kewaunee County

Fractured bedrock combined with thin soils creates a high potential for water contamination

A collaborative project of the Kewaunee County Groundwater Guardians, with funding from the Lakeshore Natural Resource Partnership, Inc. The Groundwater Guardians promote stewardship and sound management of our valuable groundwater resources through education and community involvement.



Groundwater Task Force

Mission Statement:

The mission of the *Kewaunee County Groundwater Task Force* is to seek accurate information regarding Kewaunee County's water quality concerns, to understand the resources available to deal with the existing impacts of unsafe water, and to provide practical recommendations to the Kewaunee County Land & Water Conservation Committee, the County Board and the community at large through communication and education aimed at improving water quality.

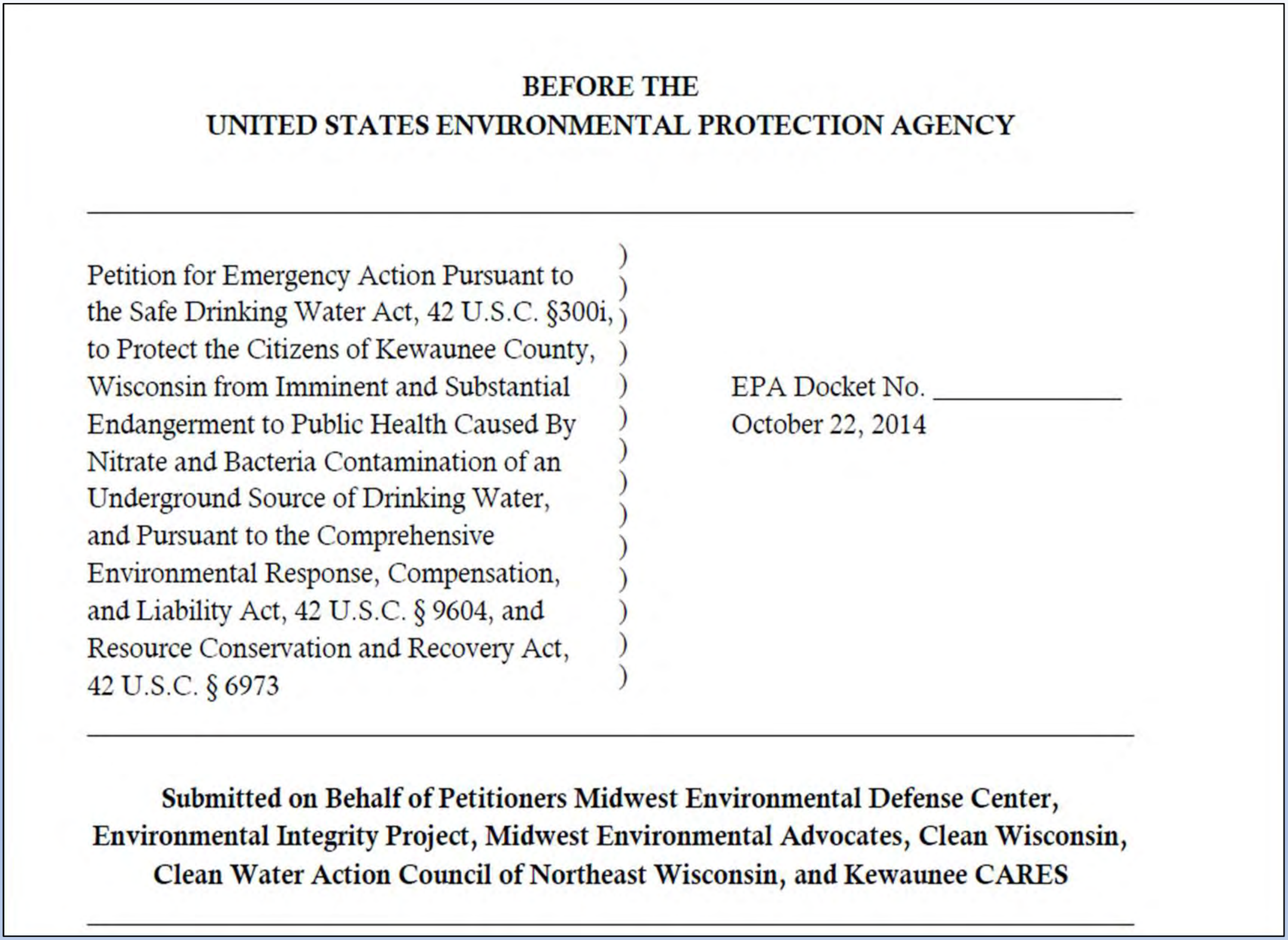
Goals:

Your Groundwater Task Force has established two important goals:

- The first goal is to publish one news release each month, beginning in November, 2015 to inform our citizens about ground and surface water concerns.
- The second goal is to establish a website that will provide a "one stop" source for the latest updates on Kewaunee County's ground and surface waters before year-end 2015.

Public, Environmental Groups & Farmers

October 2014: EPA Petition



BEFORE THE
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Petition for Emergency Action Pursuant to the Safe Drinking Water Act, 42 U.S.C. §300i, to Protect the Citizens of Kewaunee County, Wisconsin from Imminent and Substantial Endangerment to Public Health Caused By Nitrate and Bacteria Contamination of an Underground Source of Drinking Water, and Pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act, 42 U.S.C. § 9604, and Resource Conservation and Recovery Act, 42 U.S.C. § 6973

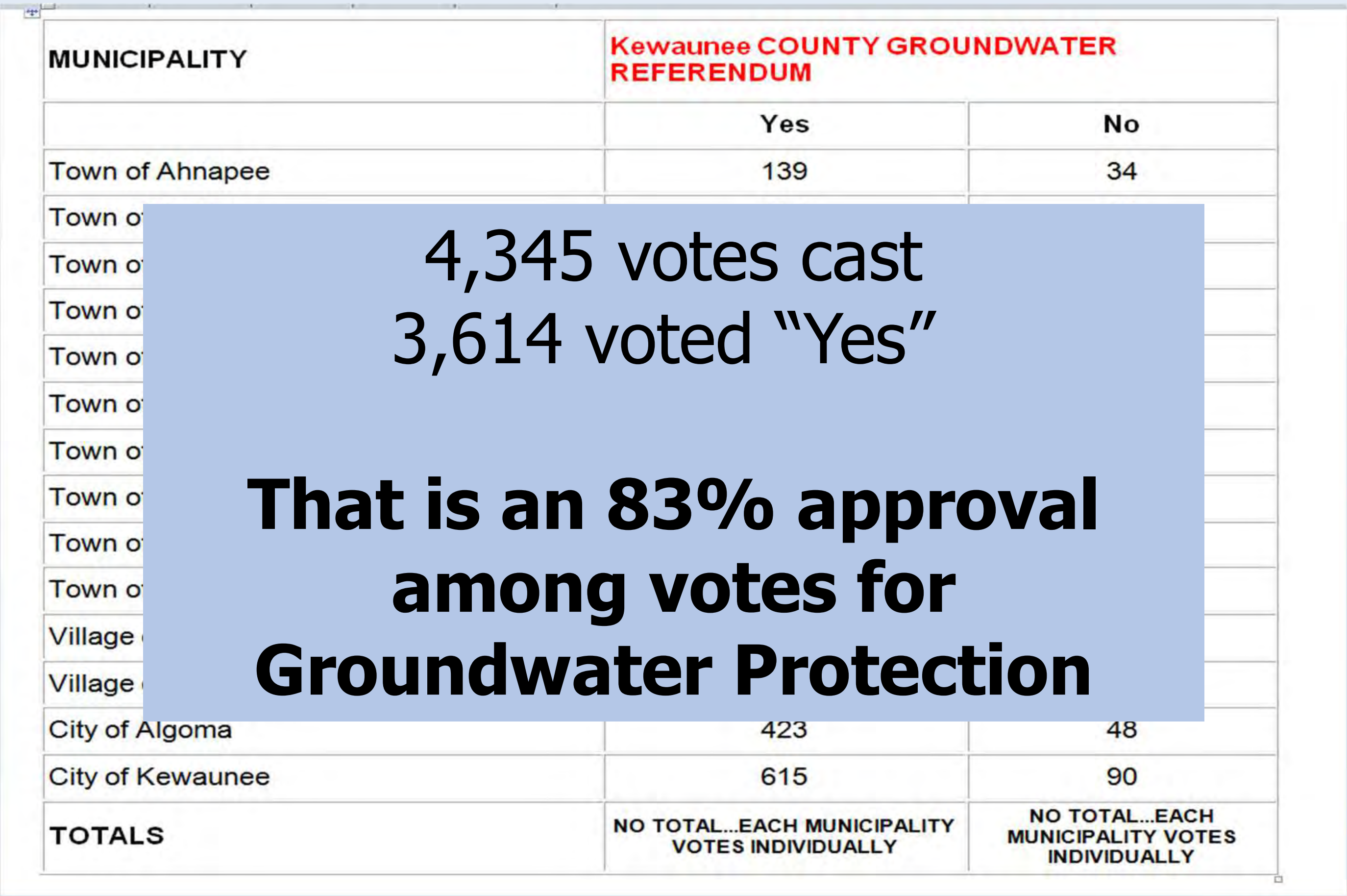
EPA Docket No. ______________
October 22, 2014

Submitted on Behalf of Petitioners Midwest Environmental Defense Center, Environmental Integrity Project, Midwest Environmental Advocates, Clean Wisconsin, Clean Water Action Council of Northeast Wisconsin, and Kewaunee CARES

Request that **EPA invoke its emergency authority under section 1431 of the Safe Drinking Water Act,** 42 U.S.C. § 300i, as well as **to address** the imminent and substantial endangerment to public health in Kewaunee County, Wisconsin from **widespread and pervasive groundwater contamination from nitrate and bacteria**

5 Petitioners

April 7th, 2015
Kewaunee County Voters Decided:



MUNICIPALITY	Kewaunee COUNTY GROUNDWATER REFERENDUM	
	Yes	No
Town of Ahnapee	139	34
Town o		
Town o		
Town o		
Town o		
Town o		
Town o		
Town o		
Town o		
Town o		
Village		
Village		
City of Algoma	423	48
City of Kewaunee	615	90
TOTALS	NO TOTAL...EACH MUNICIPALITY VOTES INDIVIDUALLY	NO TOTAL...EACH MUNICIPALITY VOTES INDIVIDUALLY

4,345 votes cast
3,614 voted "Yes"

That is an 83% approval among votes for Groundwater Protection

Became effective
January 1st - 2016

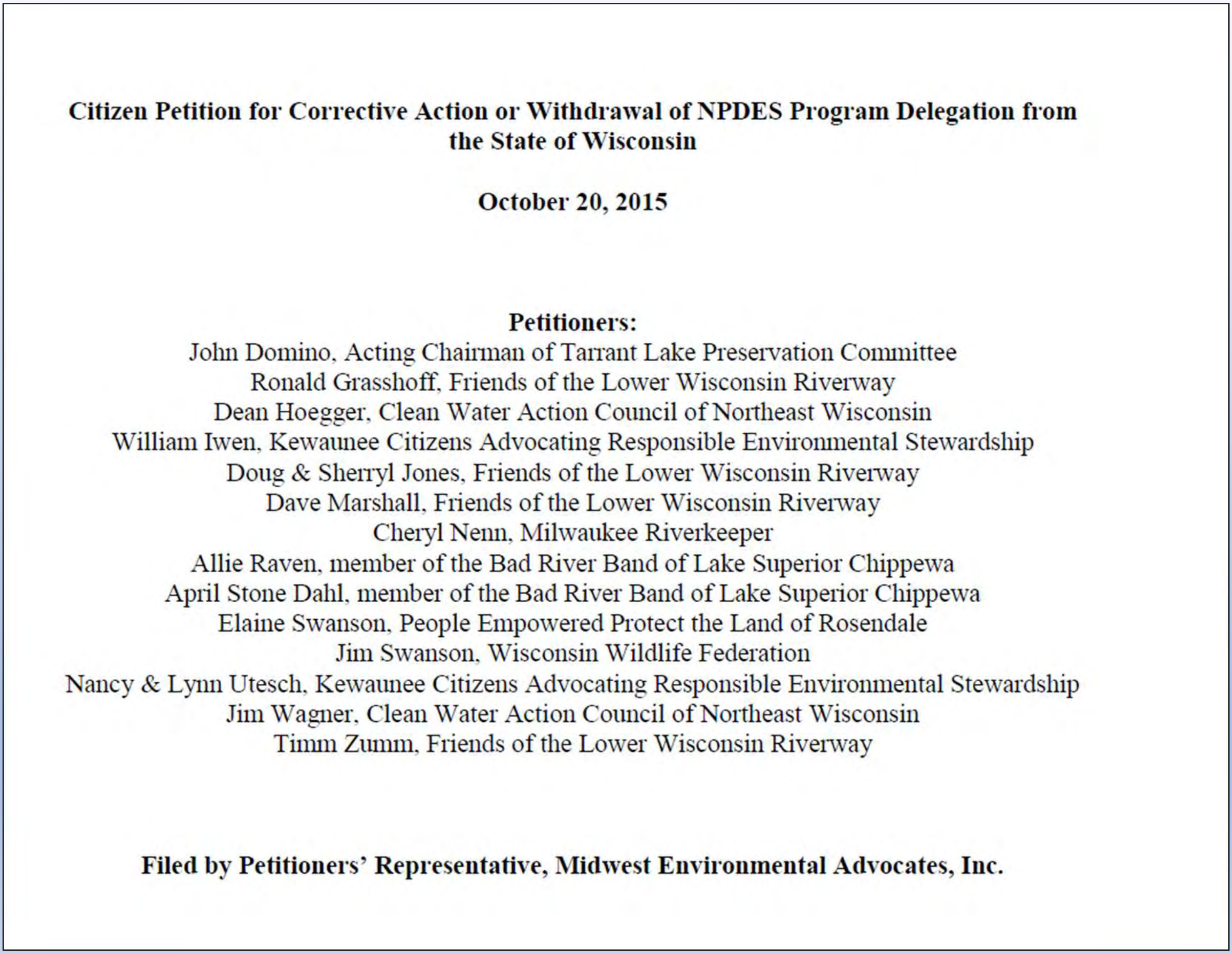
Door/Kewaunee Legislative Days

April 2015

ASKED…Protect the Public’s Drinking Water in At-Risk Karst Geo-Region

Request State of Wisconsin: Develop and advance legislation revising WI Statutes 281.16 and WI Administrative Code NR 151 to authorize the development of agricultural nonpoint water quality standards and prohibitions unique to the **Karst Geo-Region** natural resource potential and limitations, to protect groundwater quality in areas of Door and Kewaunee Counties

October 2015: EPA Petition



Citizen Petition for Corrective Action or Withdrawal of NPDES Program Delegation from the State of Wisconsin

October 20, 2015

Petitioners:
John Domino, Acting Chairman of Tarrant Lake Preservation Committee
Ronald Grasshoff, Friends of the Lower Wisconsin Riverway
Dean Hoegger, Clean Water Action Council of Northeast Wisconsin
William Iwen, Kewaunee Citizens Advocating Responsible Environmental Stewardship
Doug & Sherryl Jones, Friends of the Lower Wisconsin Riverway
Dave Marshall, Friends of the Lower Wisconsin Riverway
Cheryl Nenn, Milwaukee Riverkeeper
Allie Raven, member of the Bad River Band of Lake Superior Chippewa
April Stone Dahl, member of the Bad River Band of Lake Superior Chippewa
Elaine Swanson, People Empowered Protect the Land of Rosendale
Jim Swanson, Wisconsin Wildlife Federation
Nancy & Lynn Utesch, Kewaunee Citizens Advocating Responsible Environmental Stewardship
Jim Wagner, Clean Water Action Council of Northeast Wisconsin
Timm Zumm, Friends of the Lower Wisconsin Riverway

Filed by Petitioners' Representative, Midwest Environmental Advocates, Inc.

Petitioners request that the **EPA withdraw the authority of the Wisconsin Department of Natural Resources ("DNR") to administer the state-delegated National Pollutant Discharge Elimination System ("NPDES")** program if the DNR does not promptly correct permitting program deficiencies as outlined in this Petition.

14 Petitioners throughout Wisconsin

2015 DNR Workgroups:

1. Short Term Recommendations
2. Compliance
3. Best Management Practices
4. Communications
5. Alternative Practices

DNR Workgroups: Stakeholders

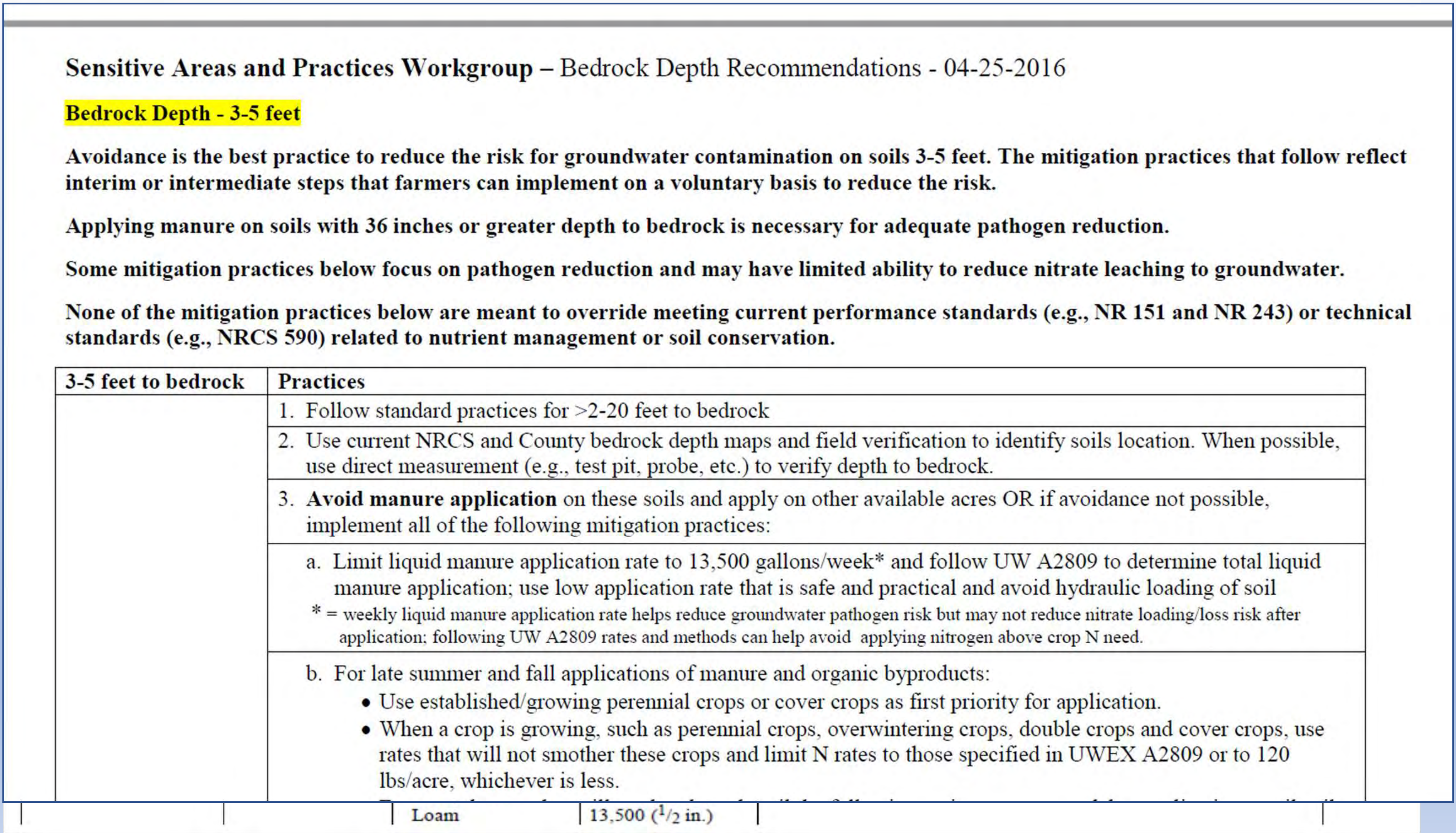
Department of Natural Resources
Environmental Protection Agency
County Land & Water Conservation Departments
Small Farmers & Large Farmers
Custom Manure Applicators
Midwest Environmental Advocates
Certified Crop Advisors
Clean Water Action Council
DATCP (Dept Agriculture Trade & Consumer Protection
NRCS (Natural Resources Conservation Service)
County Board Members
Citizens of Kewaunee County
Zoning Department
Public Health
Kewaunee Cares
UW-Extension

Short – Term Recommendations
What can we do Now!

- **DNR**
  - Investigate streamlining the **creation of Special Areas of Eligibility for Well Compensation** in Kewaunee County.
  - Use its authority under **Chapter NR738 to provide emergency water** supplies to well owners impacted by offsite livestock bacterial or Nitrate contamination in Kewaunee County.
- Numerous recommendations for the **State Legislature**
- **Local Groups / Citizens**
  - Agricultural producers consider making **emergency water supplies** available to owners of wells impacted by livestock contamination.
- **Kewaunee County:**
  - Develop protocol to immediately **provide emergency drinking water** for owners of wells impacted by offsite livestock contamination until safe water can be obtained
  - Provide informational materials to county well owners that include **easy-to-use contact information and maintenance checklists**.

Compliance Recommendations:

- **DNR / County / EPA**
  - Conduct more **land application audits/oversight** in sensitive areas.
  - Additional EPA, DATCP, County, and NRCS staff may also be relevant to: More **timely complaint response and enforcement**.
  - More **stringent review of CAFO emergency land spreading** variance by DNR.
  - Targeted focus on **proper well abandonment** of non-compliant wells or wells no longer used. DNR
  - Require all land applicators to have, at a minimum, on set of **spreading restriction maps and written instructions present during manure applications**.
  - Additional EPA, DATCP, County, and NRCS staff may also be relevant to: **Review nutrient management plans**.



Sensitive Areas and Practices Workgroup – Bedrock Depth Recommendations - 04-25-2016

Bedrock Depth - 3-5 feet

Avoidance is the best practice to reduce the risk for groundwater contamination on soils 3-5 feet. The mitigation practices that follow reflect interim or intermediate steps that farmers can implement on a voluntary basis to reduce the risk.

Applying manure on soils with 36 inches or greater depth to bedrock is necessary for adequate pathogen reduction.

Some mitigation practices below focus on pathogen reduction and may have limited ability to reduce nitrate leaching to groundwater.

None of the mitigation practices below are meant to override meeting current performance standards (e.g., NR 151 and NR 243) or technical standards (e.g., NRCS 590) related to nutrient management or soil conservation.

3-5 feet to bedrock	Practices
	1. Follow standard practices for >2-20 feet to bedrock
	2. Use current NRCS and County bedrock depth maps and field verification to identify soils location. When possible, use direct measurement (e.g., test pit, probe, etc.) to verify depth to bedrock.
	3. **Avoid manure application** on these soils and apply on other available acres OR if avoidance not possible, implement all of the following mitigation practices:
	a. Limit liquid manure application rate to 13,500 gallons/week* and follow UW A2809 to determine total liquid manure application; use low application rate that is safe and practical and avoid hydraulic loading of soil * = weekly liquid manure application rate helps reduce groundwater pathogen risk but may not reduce nitrate loading/loss risk after application; following UW A2809 rates and methods can help avoid applying nitrogen above crop N need.
	b. For late summer and fall applications of manure and organic byproducts: • Use established/growing perennial crops or cover crops as first priority for application. • When a crop is growing, such as perennial crops, overwintering crops, double crops and cover crops, use rates that will not smother these crops and limit N rates to those specified in UWEX A2809 or to 120 lbs/acre, whichever is less.

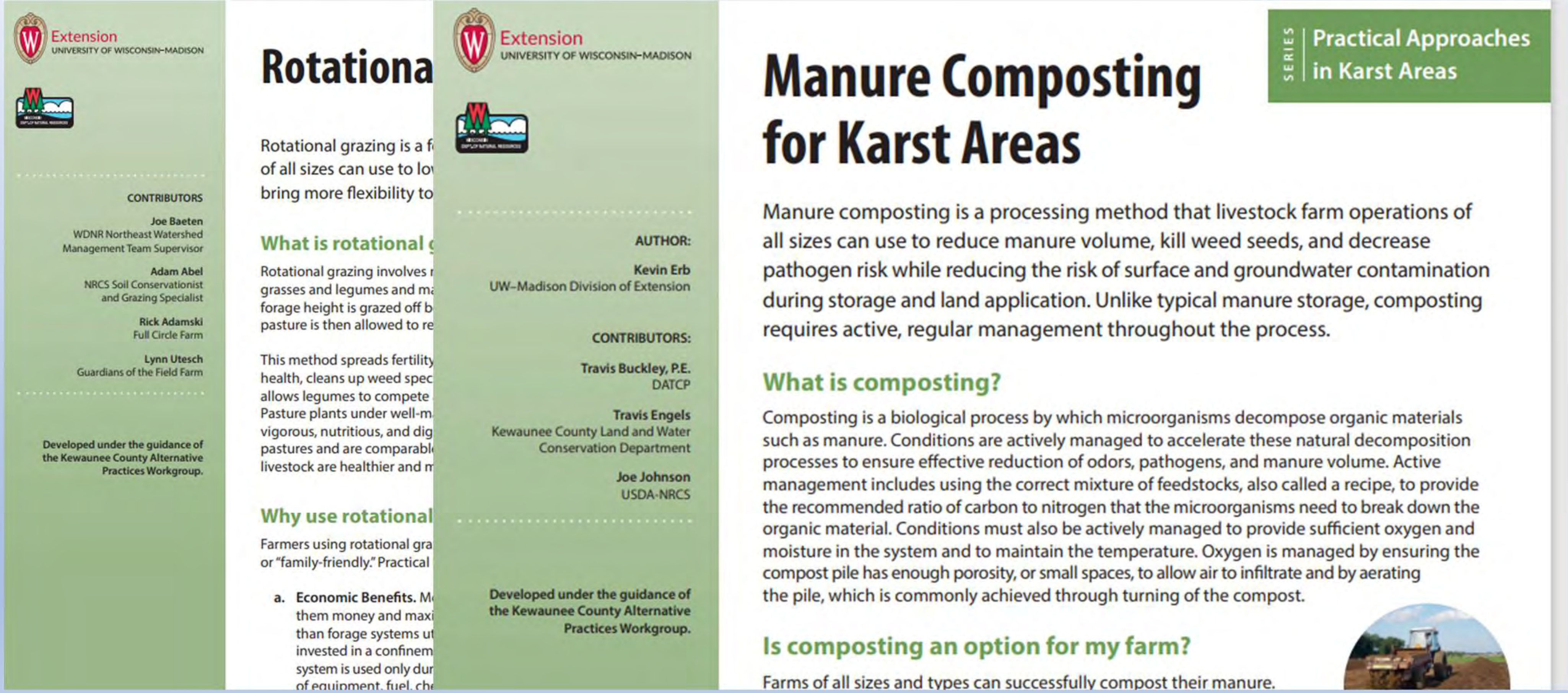
		Loam	13,500 ($^1/_2$ in.)	

Communications Work Group

Information / Education – How to get the word out?

Groundwater Task Force

Alternative Technology:



Extension
UNIVERSITY OF WISCONSIN–MADISON

CONTRIBUTORS

Joe Baeten
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Management Team Supervisor

Adam Abel
NRCS Soil Conservationist
and Grazing Specialist

Rick Adamski
Full Circle Farm

Lynn Utesch
Guardians of the Field Farm

Developed under the guidance of the Kewaunee County Alternative Practices Workgroup.

Rotationa

Rotational grazing is a f
of all sizes can use to lo
bring more flexibility to

What is rotational g

Rotational grazing involves r
grasses and legumes and ma
forage height is grazed off b
pasture is then allowed to re

This method spreads fertility
health, cleans up weed spec
allows legumes to compete
Pasture plants under well-m
vigorous, nutritious, and dig
pastures and are comparabl
livestock are healthier and m

Why use rotational

Farmers using rotational gra
or "family-friendly." Practical

a. **Economic Benefits.** M
them money and maxi
than forage systems u
invested in a confinem
system is used only dur
of equipment, fuel, ch

Extension
UNIVERSITY OF WISCONSIN–MADISON

AUTHOR:

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UW–Madison Division of Extension

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DATCP

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Kewaunee County Land and Water
Conservation Department

Joe Johnson
USDA-NRCS

Developed under the guidance of the Kewaunee County Alternative Practices Workgroup.

SERIES | Practical Approaches in Karst Areas

Manure Composting for Karst Areas

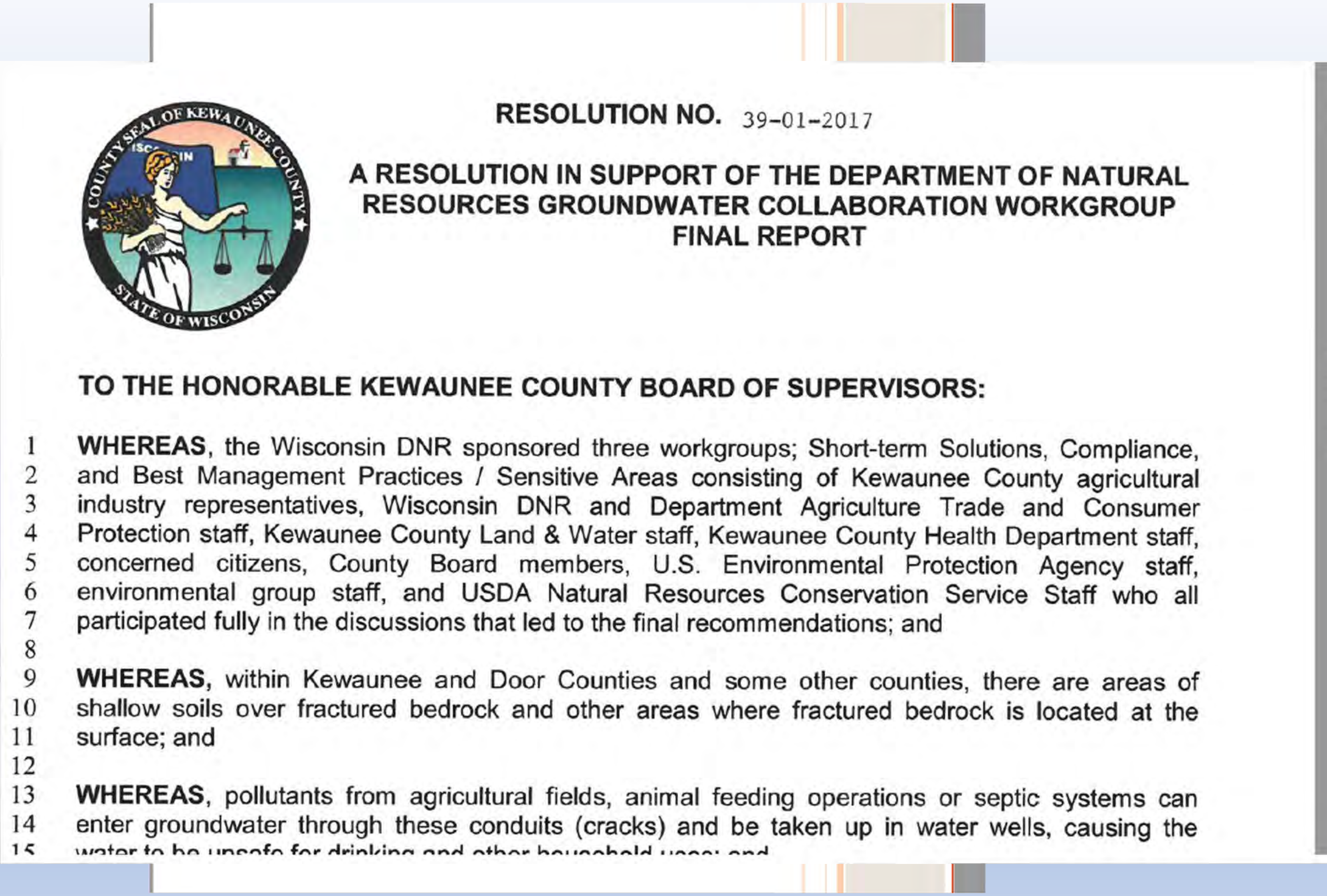
Manure composting is a processing method that livestock farm operations of all sizes can use to reduce manure volume, kill weed seeds, and decrease pathogen risk while reducing the risk of surface and groundwater contamination during storage and land application. Unlike typical manure storage, composting requires active, regular management throughout the process.

What is composting?

Composting is a biological process by which microorganisms decompose organic materials such as manure. Conditions are actively managed to accelerate these natural decomposition processes to ensure effective reduction of odors, pathogens, and manure volume. Active management includes using the correct mixture of feedstocks, also called a recipe, to provide the recommended ratio of carbon to nitrogen that the microorganisms need to break down the organic material. Conditions must also be actively managed to provide sufficient oxygen and moisture in the system and to maintain the temperature. Oxygen is managed by ensuring the compost pile has enough porosity, or small spaces, to allow air to infiltrate and by aerating the pile, which is commonly achieved through turning of the compost.

Is composting an option for my farm?

Farms of all sizes and types can successfully compost their manure.



RESOLUTION NO. 39-01-2017

A RESOLUTION IN SUPPORT OF THE DEPARTMENT OF NATURAL RESOURCES GROUNDWATER COLLABORATION WORKGROUP FINAL REPORT

TO THE HONORABLE KEWAUNEE COUNTY BOARD OF SUPERVISORS:

WHEREAS, the Wisconsin DNR sponsored three workgroups; Short-term Solutions, Compliance, and Best Management Practices / Sensitive Areas consisting of Kewaunee County agricultural industry representatives, Wisconsin DNR and Department Agriculture Trade and Consumer Protection staff, Kewaunee County Land & Water staff, Kewaunee County Health Department staff, concerned citizens, County Board members, U.S. Environmental Protection Agency staff, environmental group staff, and USDA Natural Resources Conservation Service Staff who all participated fully in the discussions that led to the final recommendations; and

WHEREAS, within Kewaunee and Door Counties and some other counties, there are areas of shallow soils over fractured bedrock and other areas where fractured bedrock is located at the surface; and

WHEREAS, pollutants from agricultural fields, animal feeding operations or septic systems can enter groundwater through these conduits (cracks) and be taken up in water wells, causing the water to be unsafe for drinking and other household uses; and

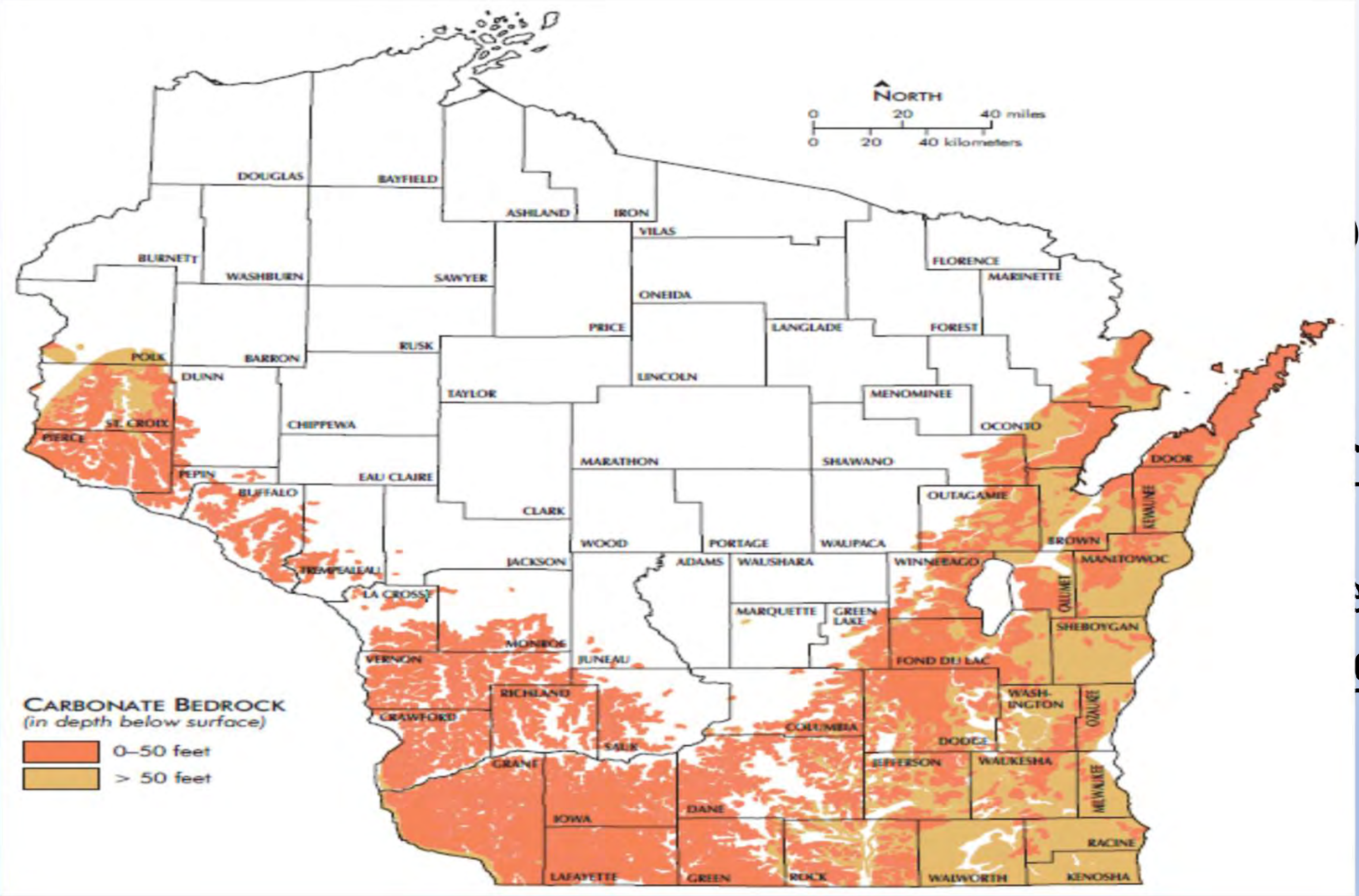
WE DO
ESE
ONS???

Borchardt et al (2021) Research Microbes: Identifying the Fecal Source

Host	Microorganism	Wells	Concentration (gene copies/L)
Human-specific	Adenovirus A	1	1
	Bacteroidales-like Hum M2	7	< 1 – 1050
	Human *Bacteroides*	27	< 1 – 34
	Cryptosporidium hominis	1	qualitative
	All	**30**	
Bovine-specific	*Bacteroidales*-like Cow M2	2	29 - 915
	Bacteroidales-like Cow M3	4	3 – 49818
	Bovine *Bacteroides*	36	< 1 – *42398*
	Bovine polyomavirus	8	< 1 – 451
	Bovine enterovirus	1	2
	All	**40**	

Not detected: [human-specific] adenovirus B & C, D, F, enterovirus, human polyomavirus, norovirus GI & GII
[bovine-specific] coronavirus, bovine diarrheal virus 1 & 2

Host	Microorganism	Wells	Concentration (gene copies/L)
Non-specific	*Campylobacter jejuni*	1	< 1
	Cryptosporidium parvum	8	qualitative
	Cryptosporidium spp.	16	qualitative
	Giardia lamblia	2	< 1
	Pathogenic *E. coli* (*eae* gene)	1	4
	Pathogenic *E. coli* (*stx1* gene)	1	16
	Pathogenic *E. coli* (*stx2* gene)	1	1
	Pepper mild mottle virus	13	2 - 3811
	Rotavirus A (*NSP3* gene)	17	< 1 – 4481
	Rotavirus A (*VP7* gene)	7	< 1 – 732
	Rotavirus C	3	45 – 1301
	Salmonella (*invA* gene)	3	< 1 – 13
	Salmonella (*ttr* gene)	5	5 – 59
	All	**42**	
	Total positive wells	**80**	**< 1 - 49818**


NORTH
0 20 40 miles
0 20 40 kilometers
DOUGLAS
BAYFIELD
ASHLAND
IRON
VILAS
BURNETT
WASHBURN
SAWYER
FLORENCE
MARINETTE
ONEIDA
PRICE
LANGLADE
FOREST
POLK
BARRON
RUSK
DUNN
LINCOLN
TAYLOR
MENOMINEE
ST. CROIX
CHIPPEWA
OCONTO
PIERCE
MARATHON
SHAWANO
DOOR
PEPIN
EAU CLAIRE
BUFFALO
OUTAGAMIE
KEWAUNEE
CLARK
WOOD
PORTAGE
WAUPACA
BROWN
JACKSON
ADAMS
WAUSHARA
WINNEBAGO
MANITOWOC
TREMPEALEAU
LA CROSSE
CALUMET
MARQUETTE
GREEN LAKE
SHEBOYGAN
MONROE
JUNEAU
VERNON
FOND DU LAC
RICHLAND
WASH-INGTON
OZAUKEE
CRAWFORD
COLUMBIA
SAUK
DODGE
GRANT
JEFFERSON
WAUKESHA
MILWAUKEE
IOWA
DANE
RACINE
LAFAYETTE
GREEN
ROCK
WALWORTH
KENOSHA
CARBONATE BEDROCK
(in depth below surface)
0–50 feet
> 50 feet

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ck.

NR 151 Technical Advisory Committee

http://dnr.wi.gov/topic/nonpoint/nr151strategy.html

Department of Natural Resources
Environmental Protection Agency
WI Cattleman Association
WI. Farm Bureau
WI. Dairy Business Association
WI Clean Water Association
WI Rivers Association
Clean Water Action Council
Nature Conservancy
Natural Resources Conservation Association
Dept. Agricultural Trade & Consumer Protection
County Land & Water Conservation Staff
Small & Large Farmers
Milk-Source
Certified Crop Advisors
UW-Extension
UW-Oshkosh – Geology
Public Health

Multi-Stakeholder Groups

WDNR: NR 151 Rule Revision Timeline

Fall 2016 - **Spring** 2017

- Tech. Advisory Committee (TAC)
- Preparation of proposed rule
- Solicitation of information for economic impact analysis

Summer 2017

- Public hearings on proposed rule and economic impact analysis

Fall 2017 - **Winter** 2018

- NRB meeting for adoption
- Rule approved by governor

Winter 2018

- Legislative review/hearings

Summer 2018

- Rule signed by DNR Secretary, rule published

Door/Kewaunee
Legislative
Days

April 2017

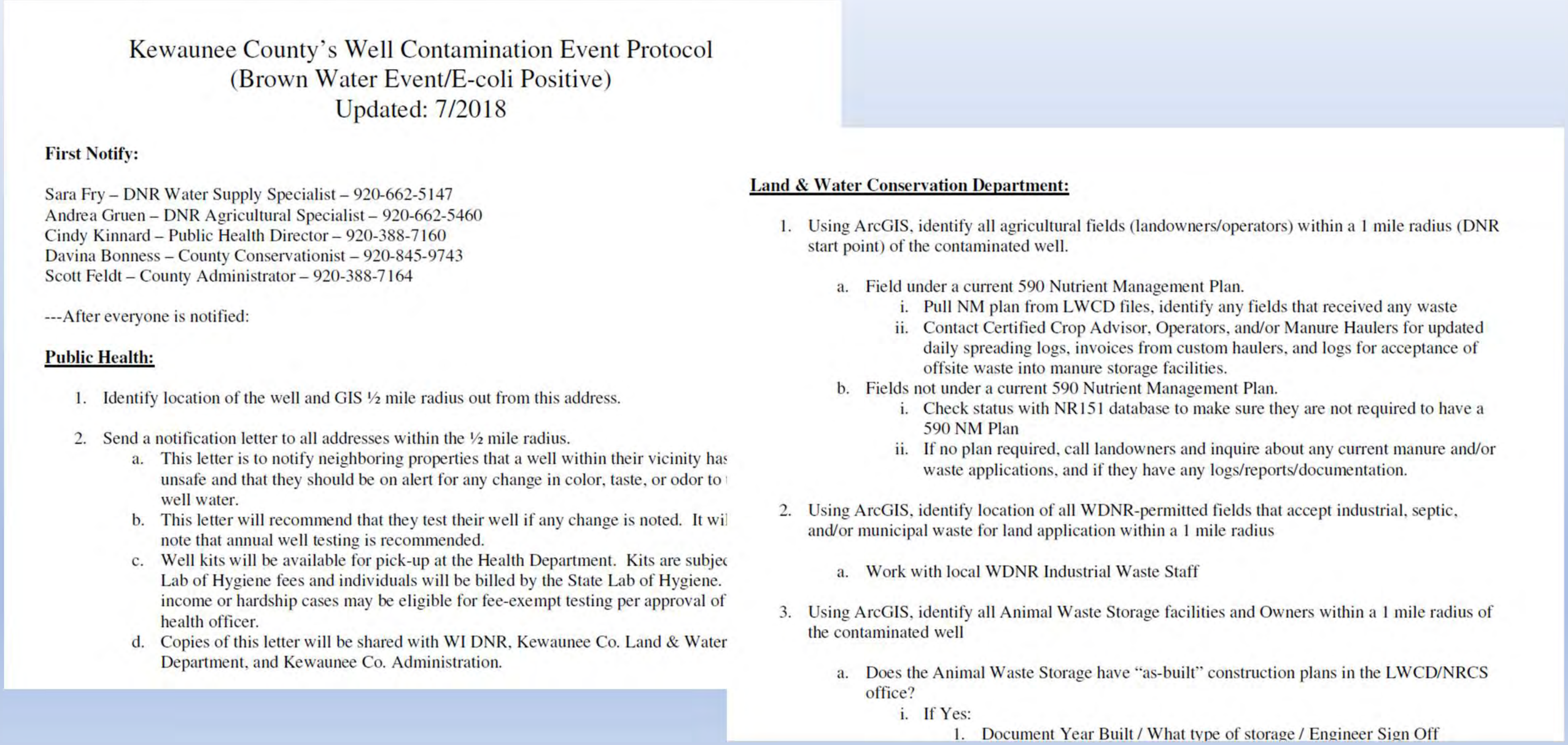
OUR ASK:

- To Support the New NR151 Standards and Prohibitions when they come before the Legislators for Door & Kewaunee County.
- And a Big Thank you for opening NR151

In the Mean Time….

Kewaunee County took our own steps
to protect our Groundwater

WELL CONTAMINATION PROTOCOL: 2015



Kewaunee County's Well Contamination Event Protocol
(Brown Water Event/E-coli Positive)
Updated: 7/2018

First Notify:

Sara Fry – DNR Water Supply Specialist – 920-662-5147
Andrea Gruen – DNR Agricultural Specialist – 920-662-5460
Cindy Kinnard – Public Health Director – 920-388-7160
Davina Bonness – County Conservationist – 920-845-9743
Scott Feldt – County Administrator – 920-388-7164

---After everyone is notified:

Public Health:

1. Identify location of the well and GIS ½ mile radius out from this address.

2. Send a notification letter to all addresses within the ½ mile radius.
    a. This letter is to notify neighboring properties that a well within their vicinity has unsafe and that they should be on alert for any change in color, taste, or odor to well water.
    b. This letter will recommend that they test their well if any change is noted. It wi note that annual well testing is recommended.
    c. Well kits will be available for pick-up at the Health Department. Kits are subjec Lab of Hygiene fees and individuals will be billed by the State Lab of Hygiene. income or hardship cases may be eligible for fee-exempt testing per approval of health officer.
    d. Copies of this letter will be shared with WI DNR, Kewaunee Co. Land & Water Department, and Kewaunee Co. Administration.

Land & Water Conservation Department:

1. Using ArcGIS, identify all agricultural fields (landowners/operators) within a 1 mile radius (DNR start point) of the contaminated well.
    a. Field under a current 590 Nutrient Management Plan.
        i. Pull NM plan from LWCD files, identify any fields that received any waste
        ii. Contact Certified Crop Advisor, Operators, and/or Manure Haulers for updated daily spreading logs, invoices from custom haulers, and logs for acceptance of offsite waste into manure storage facilities.
    b. Fields not under a current 590 Nutrient Management Plan.
        i. Check status with NR151 database to make sure they are not required to have a 590 NM Plan
        ii. If no plan required, call landowners and inquire about any current manure and/or waste applications, and if they have any logs/reports/documentation.

2. Using ArcGIS, identify location of all WDNR-permitted fields that accept industrial, septic, and/or municipal waste for land application within a 1 mile radius
    a. Work with local WDNR Industrial Waste Staff

3. Using ArcGIS, identify all Animal Waste Storage facilities and Owners within a 1 mile radius of the contaminated well
    a. Does the Animal Waste Storage have "as-built" construction plans in the LWCD/NRCS office?
        i. If Yes:
            1. Document Year Built / What type of storage / Engineer Sign Off

CURRENT APPLICATIONS

No Growing Crops & Usually
During Spring & Fall
When Recharge is occurring

Waste Irrigation Ordinance: Chapter 37
Adopted November 2017

- “Low Pressure”
- Average Height 18 inches off ground
- Drop Nozzles
- GIS Data sent directly to LWCD
- If crop growing – must be under crop canopy
- No SPRAY, NO BIG GUNS

Currently 4 townships outright ban all irrigation

NOZZLE HEIGHT
-less than 18” or below crop canopy

Now Can Spread Manure Applications over months when crops can use nutrients

Waste Hauler Certification
“DRAFT Chapter 38”

- County Permit required to transport, handle, store or apply manure
- All Commercial and Private Haulers
- All operations > 250 A.U ~1.6 million gallons manure
- Certification / Educational Program Req.
- Only Liquid manure applicators
- GIS real time data to our office

Stayed as Voluntary

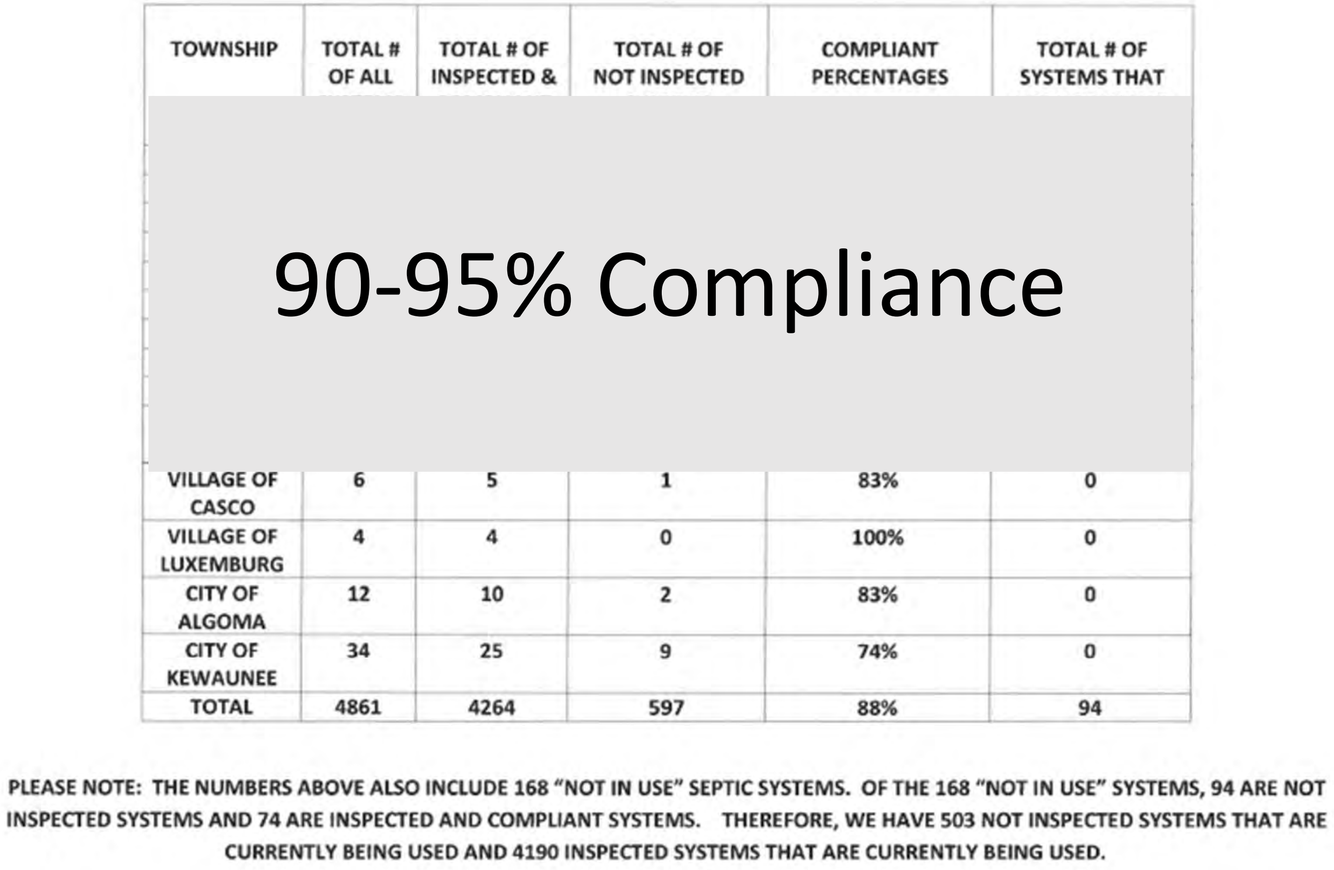
Agricultural Performance Standards (NR151) Chapter 39: September 2018

- Locally adopted ALL NR151 WITH including all NR151 Silurian Dolomite Standards

- Travis will present on this topic in the afternoon

Septic compliance

90-95% Compliance



TOWNSHIP	TOTAL # OF ALL	TOTAL # OF INSPECTED &	TOTAL # OF NOT INSPECTED	COMPLIANT PERCENTAGES	TOTAL # OF SYSTEMS THAT
VILLAGE OF CASCO	6	5	1	83%	0
VILLAGE OF LUXEMBURG	4	4	0	100%	0
CITY OF ALGOMA	12	10	2	83%	0
CITY OF KEWAUNEE	34	25	9	74%	0
TOTAL	4861	4264	597	88%	94

PLEASE NOTE: THE NUMBERS ABOVE ALSO INCLUDE 168 "NOT IN USE" SEPTIC SYSTEMS. OF THE 168 "NOT IN USE" SYSTEMS, 94 ARE NOT INSPECTED SYSTEMS AND 74 ARE INSPECTED AND COMPLIANT SYSTEMS. THEREFORE, WE HAVE 503 NOT INSPECTED SYSTEMS THAT ARE CURRENTLY BEING USED AND 4190 INSPECTED SYSTEMS THAT ARE CURRENTLY BEING USED.

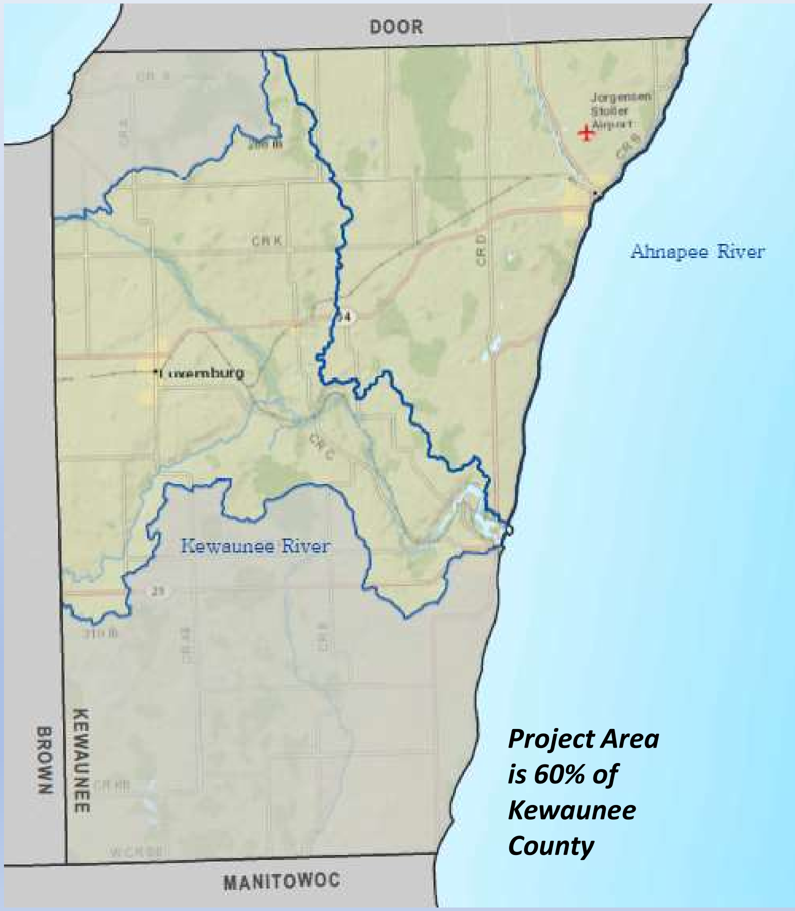
PARTNERSHIPS

NRCS Partnership & Watershed Planning

Ahnapee & Kewaunee River Watershed Conservation Plan

The Kewaunee watershed plan is the first in recent history for Wisconsin NRCS

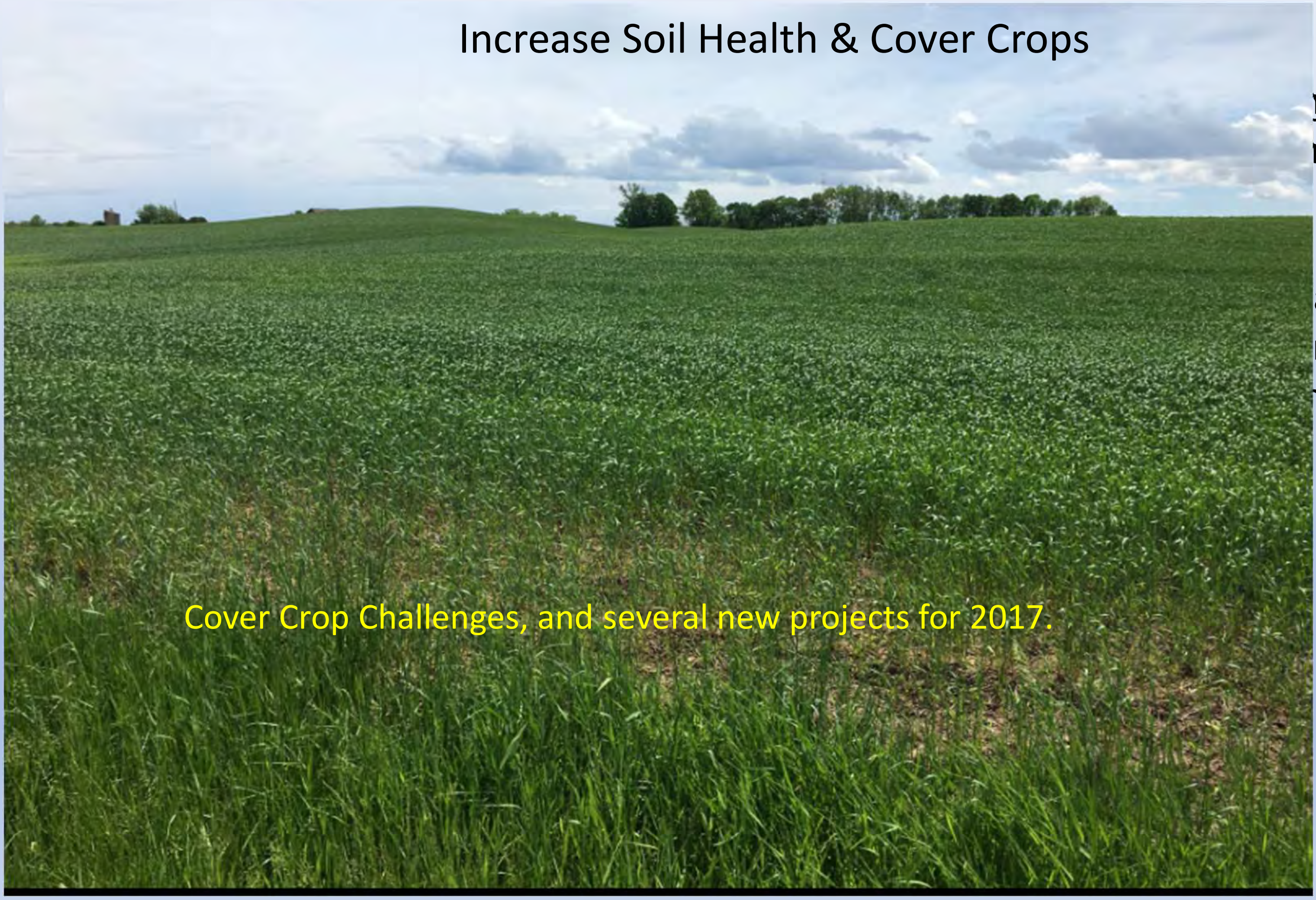
Approved: September 2018



Project Area is 60% of Kewaunee County

USDA United States Department of Agriculture

Partnerships



Increase Soil Health & Cover Crops

Cover Crop Challenges, and several new projects for 2017.

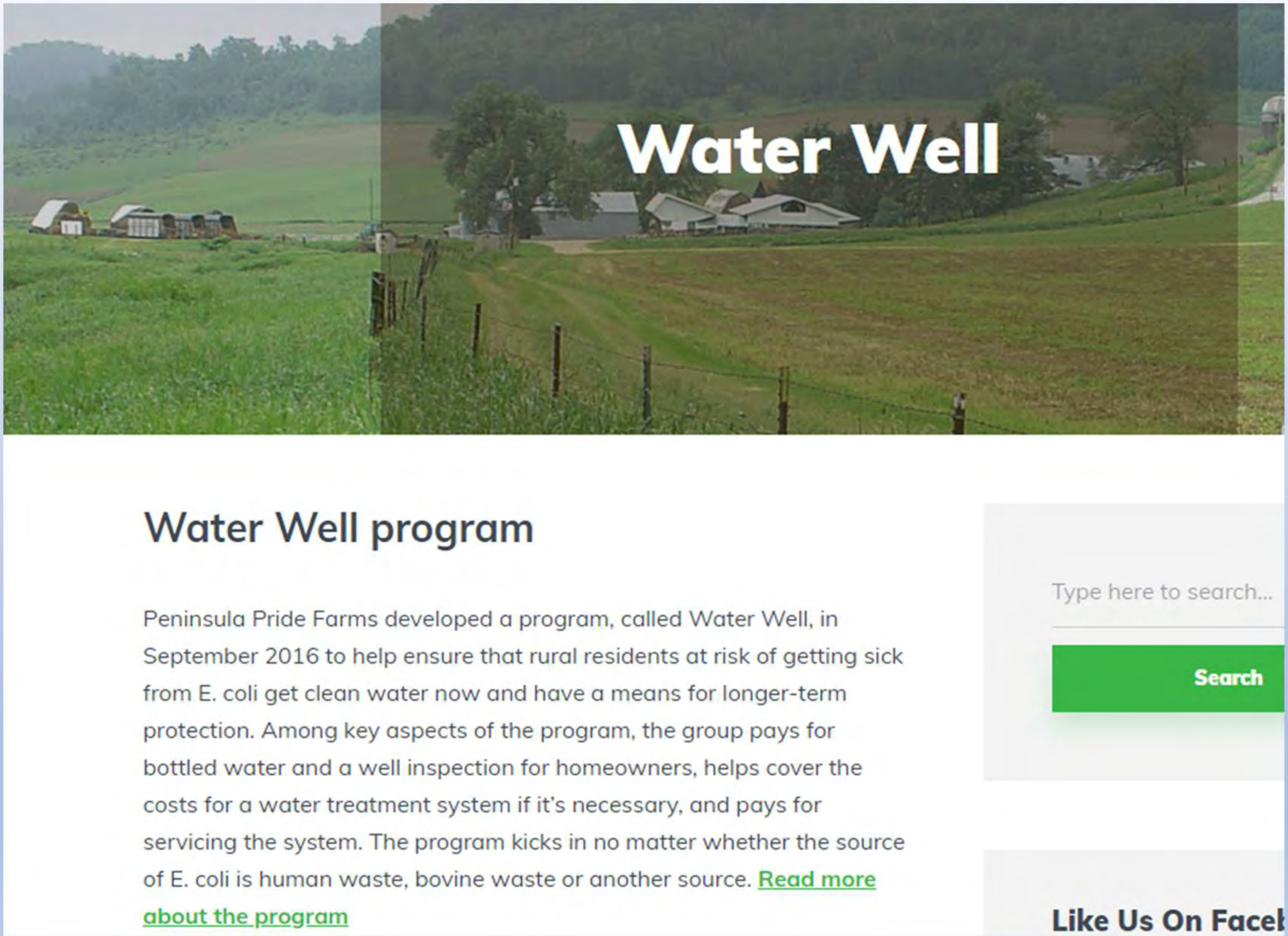
<u>n Farms</u>

nnounced: May 25, 2017)

Partnership Launches New arm Network in Kewaunee and n cooperation with the farmer-led ninsula Pride Farms

Partnerships

PPF
&
Public Health
&
Land
Conservation



Water Well program

Peninsula Pride Farms developed a program, called Water Well, in September 2016 to help ensure that rural residents at risk of getting sick from E. coli get clean water now and have a means for longer-term protection. Among key aspects of the program, the group pays for bottled water and a well inspection for homeowners, helps cover the costs for a water treatment system if it's necessary, and pays for servicing the system. The program kicks in no matter whether the source of E. coli is human waste, bovine waste or another source. Read more about the program

September 2016)

Clean water program for E-coli positive wells

EDUCATION / OUTREACH

ARM-LWR-480 (06/1

Sec. 92.05(3)(

ATCP 50.04(3

County name:

Township (T

Name of qualified n

Circle the planner's

1. NAICC-CPCC
2. ASA-CCA
3. ASA-Profession
4. SSSA-Soil Scie
5. DATCP approv
6. Other credentia

Circle r

1. Are th
   a. Field
   b. Areas peren vegeta
   c. Areas
   d. Areas Water perenn and no contril
   e. Areas

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Inspection Checklist

Runoff Other:

ttee/Farm Name:

ator Name:

rop:

SNOWING

DRY

OTHER:

OTHER:

S NO

L GROUNDWATER NONE

THANK YOU & QUESTIONS?

Davina Bonness
County Conservationist
920-845-9743
bonness.davina@kewauneeco.org

Moving Forward…

Davina Bonness
County Conservationist

Presentation 2 - July 2022

1. Has Kewaunee Made Any Progress?

2. How Is It Going?

3. Verification?

YES!!!!! Since Fall 2018….

- Over 500 acres not being spread on 0-2’ (non-cafo’s)
- 1000’s of acres of cover crops (PPF & their cost sharing programs, demo farms, soil health education)
- Split Applications / Increased Setbacks / Calls before hauling
- Meeting with Haulers in Spring / Fall
- Increased communication
- Well Testing Percentages

Overview 2021 & 2022: Coastal Management Grant

Acknowledgements

Funded by:

- Wisconsin Coastal Management Program and the National Oceanic and Atmospheric Administration, Office for Coastal Management under the Coastal Zone Management Act, Grant # AD219129-022.23

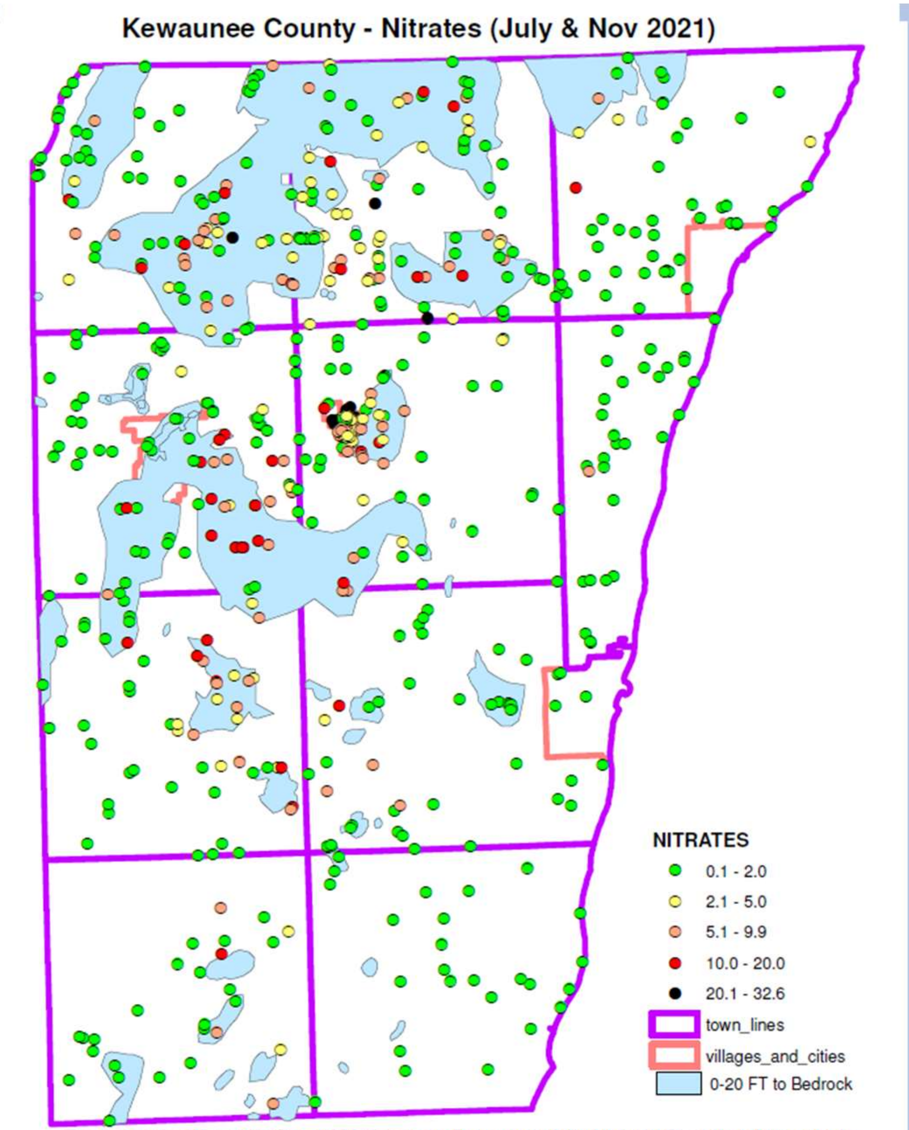
- Peninsula Pride Farms

Other partners include:

- Kewaunee County Land & Water Conservation Department
- Groundwater Guardians
- University of Wisconsin – Stevens Point Water Environmental Analysis lab

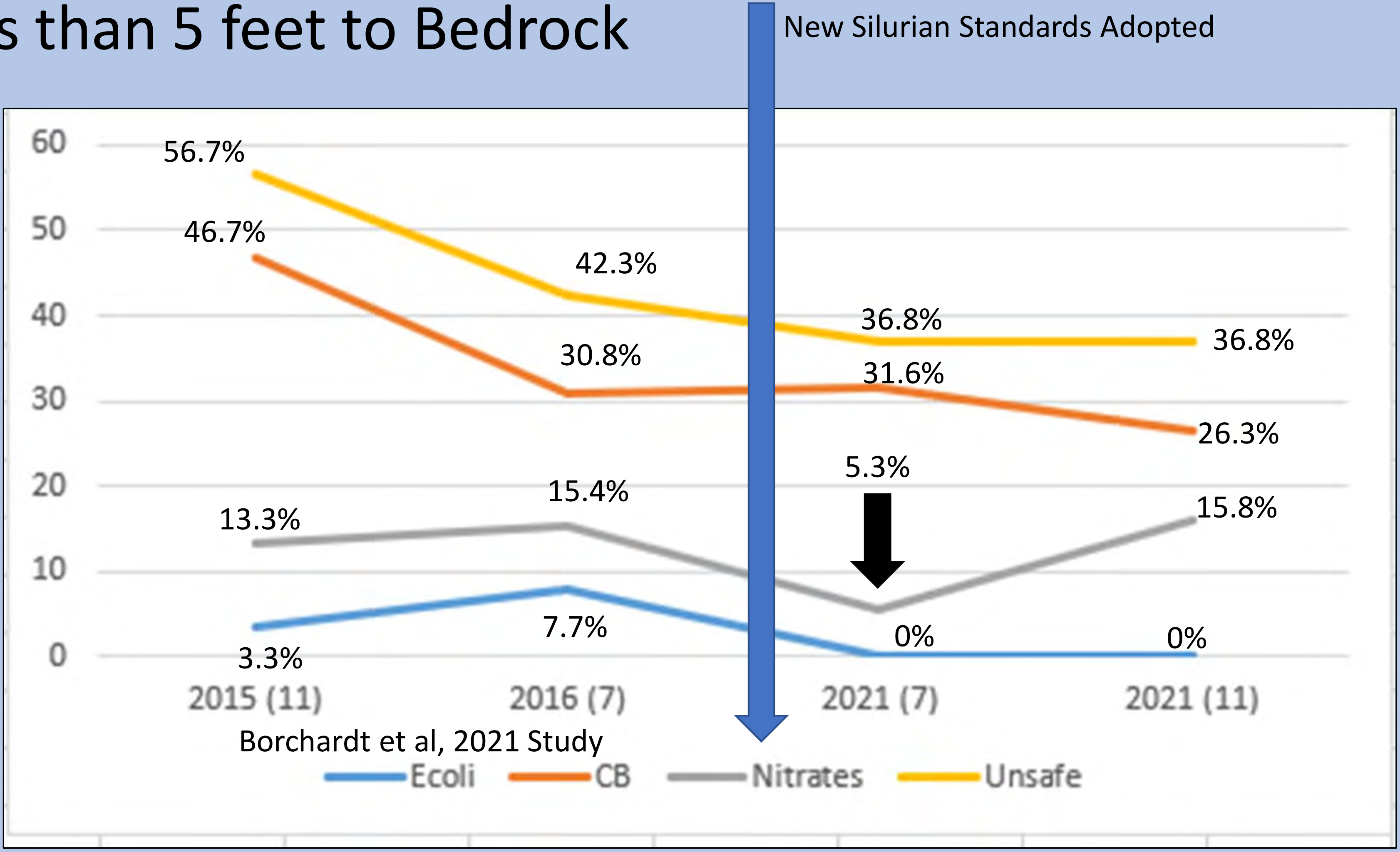
Wisconsin Coastal
Management Program

2021 Results



Funded by the Wisconsin Coastal Management Program and the National Oceanic & Atmospheric Administration, Office for Coastal Management under the Coastal Zone Management Act, Grant #AD219129-022.23

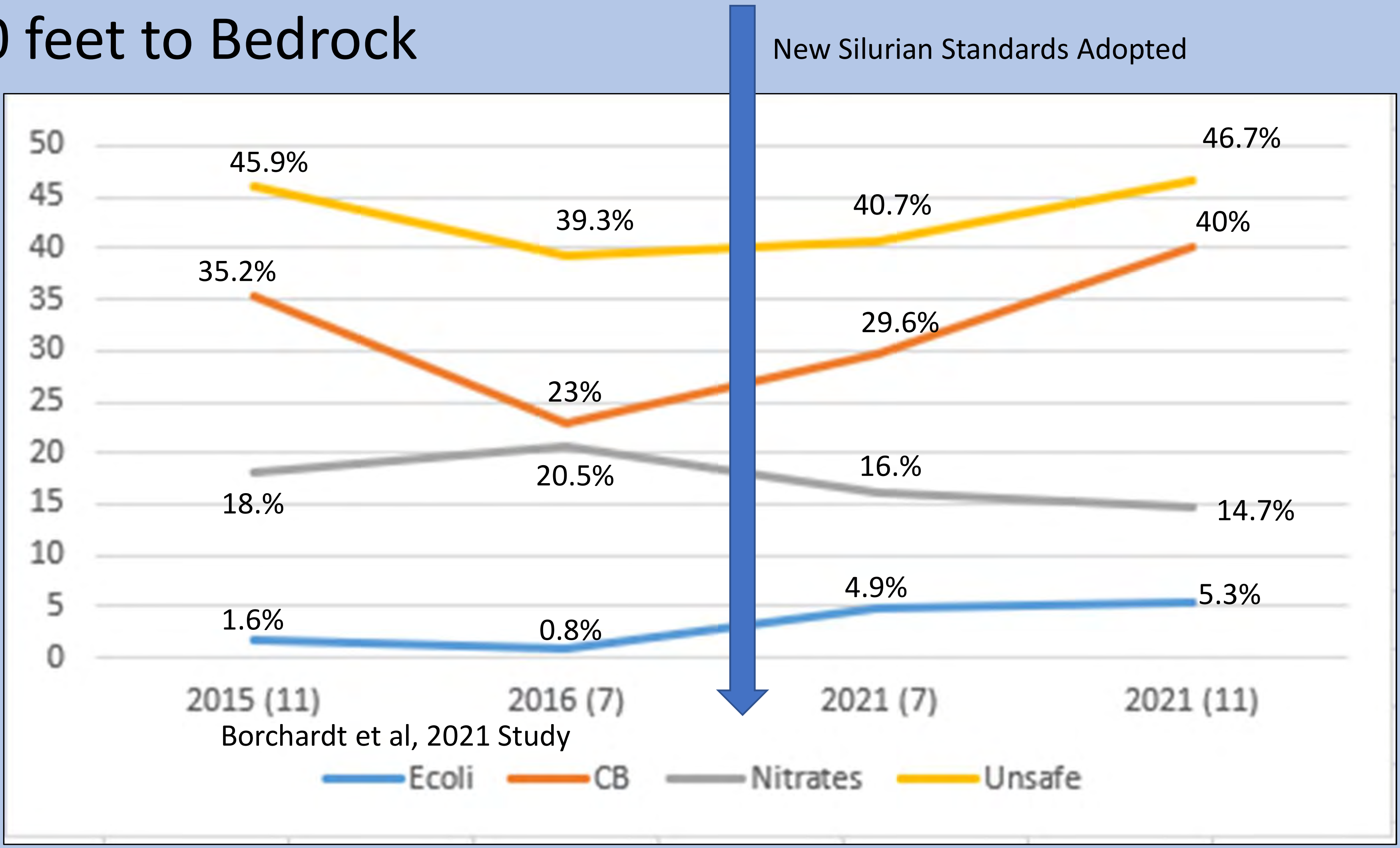
Less than 5 feet to Bedrock



Borchardt et al, 2021 Study

***Contamination Rates (percent) as unadjusted for depth to bedrock; compared to the unadjusted rates of Borchardt et al (2021)*

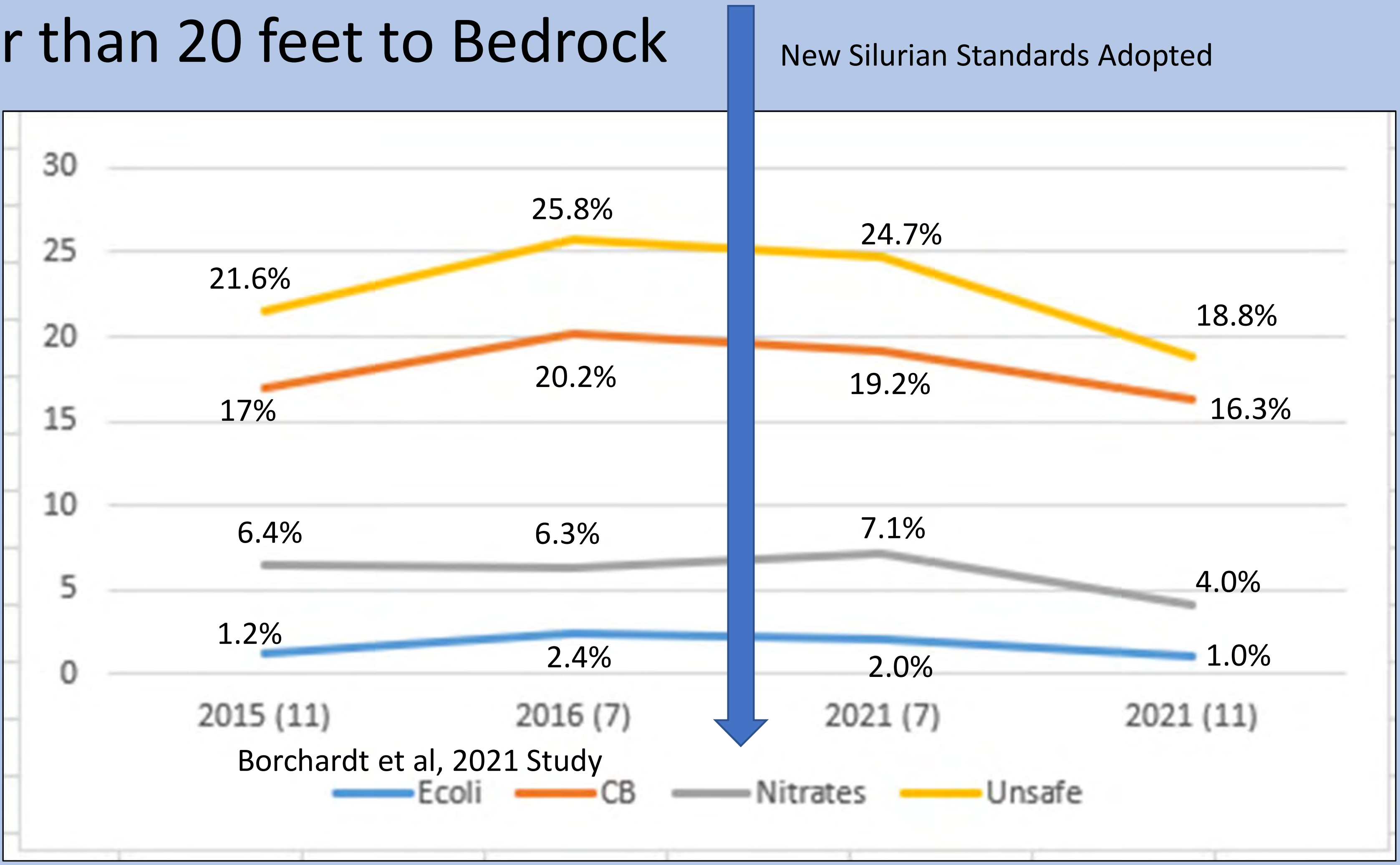
5 to 20 feet to Bedrock



New Silurian Standards Adopted

***Contamination Rates (percent) as unadjusted for depth to bedrock; compared to the unadjusted rates of Borchardt et al (2021)*

Greater than 20 feet to Bedrock

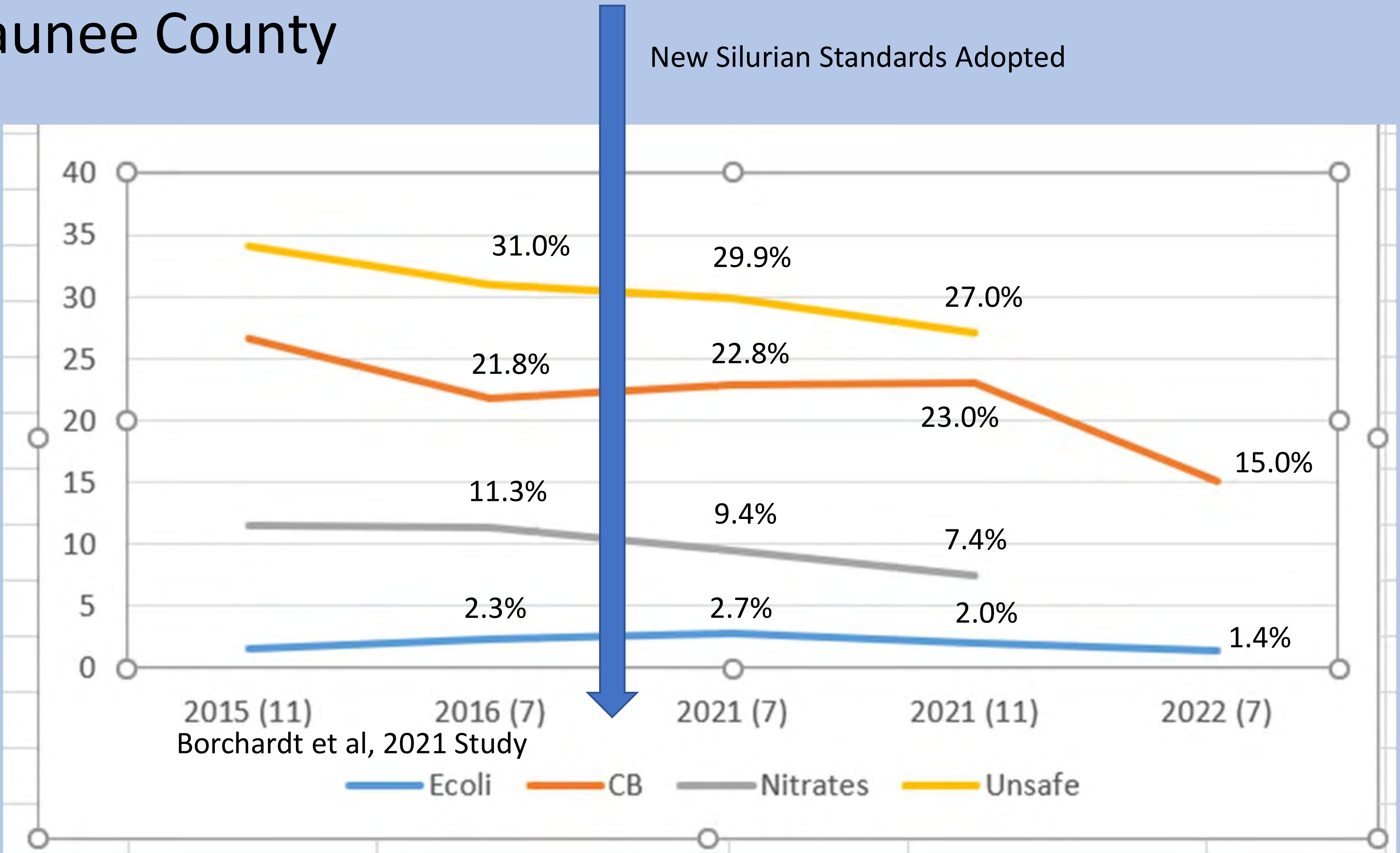


New Silurian Standards Adopted

Borchardt et al, 2021 Study

***Contamination Rates (percent) as unadjusted for depth to bedrock; compared to the unadjusted rates of Borchardt et al (2021)*

Kewaunee County

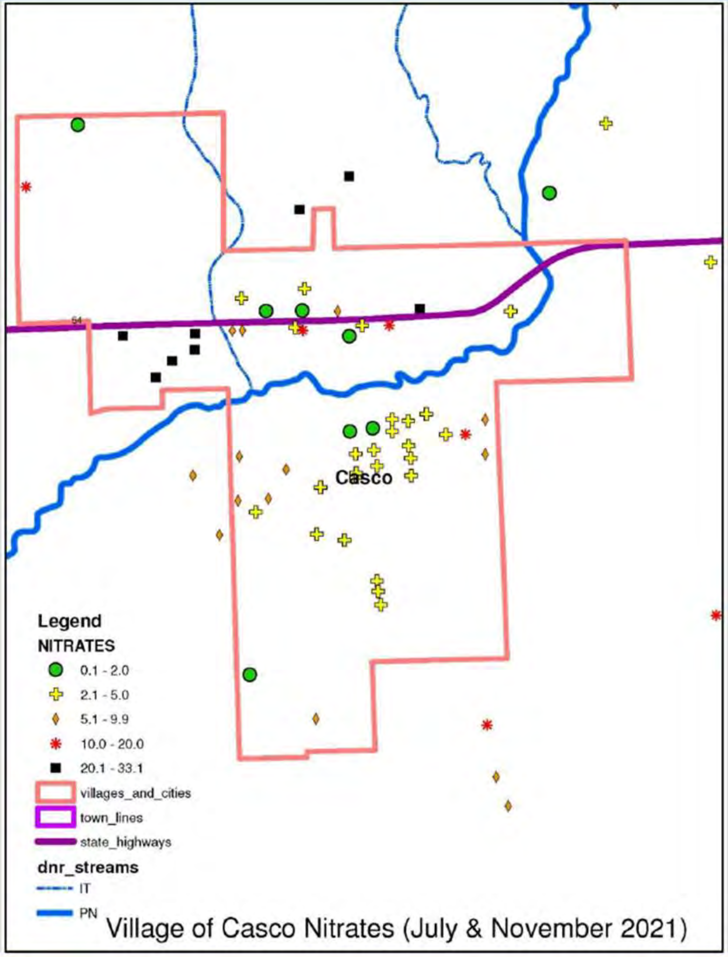


New Silurian Standards Adopted

Borchardt et al, 2021 Study

Taking it a step further…..in 2022

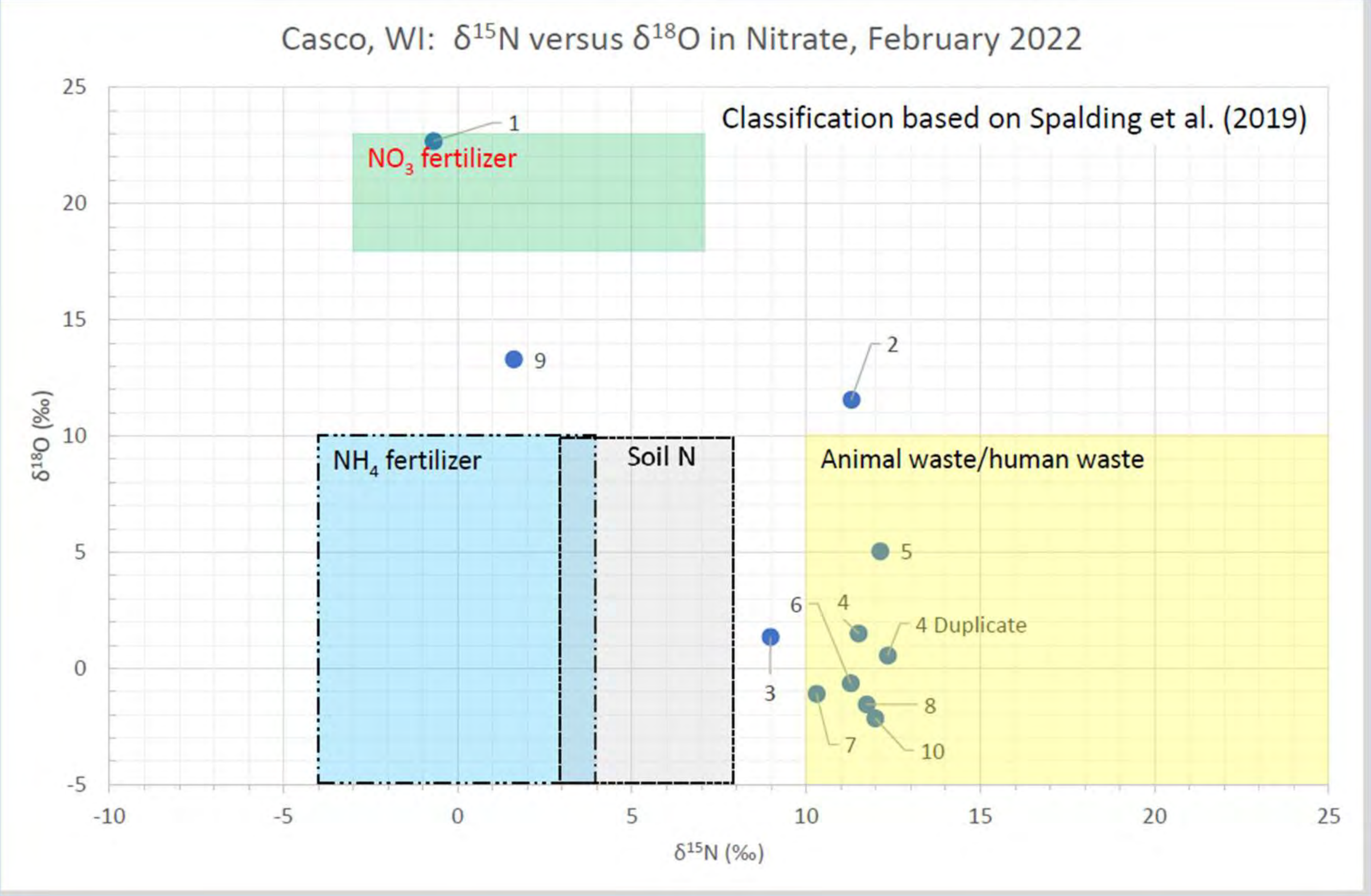
2021
Groundwater Nitrate Concentrations (mg/L)



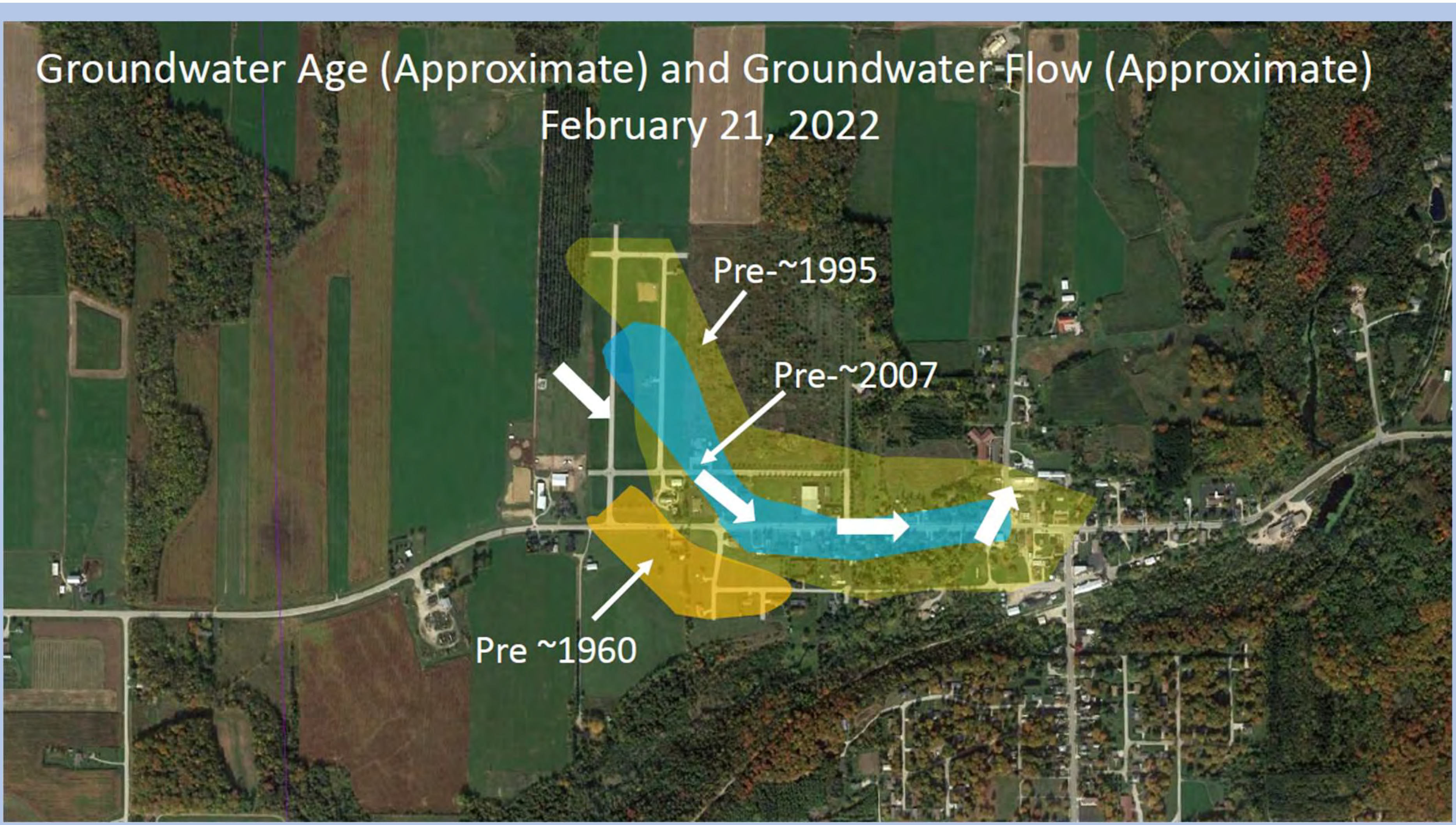
Village of Casco Nitrates (July & November 2021)

Preliminary Isotopic Investigation of Sources of Nitrate in Groundwater Casco, Kewaunee County, Wisconsin

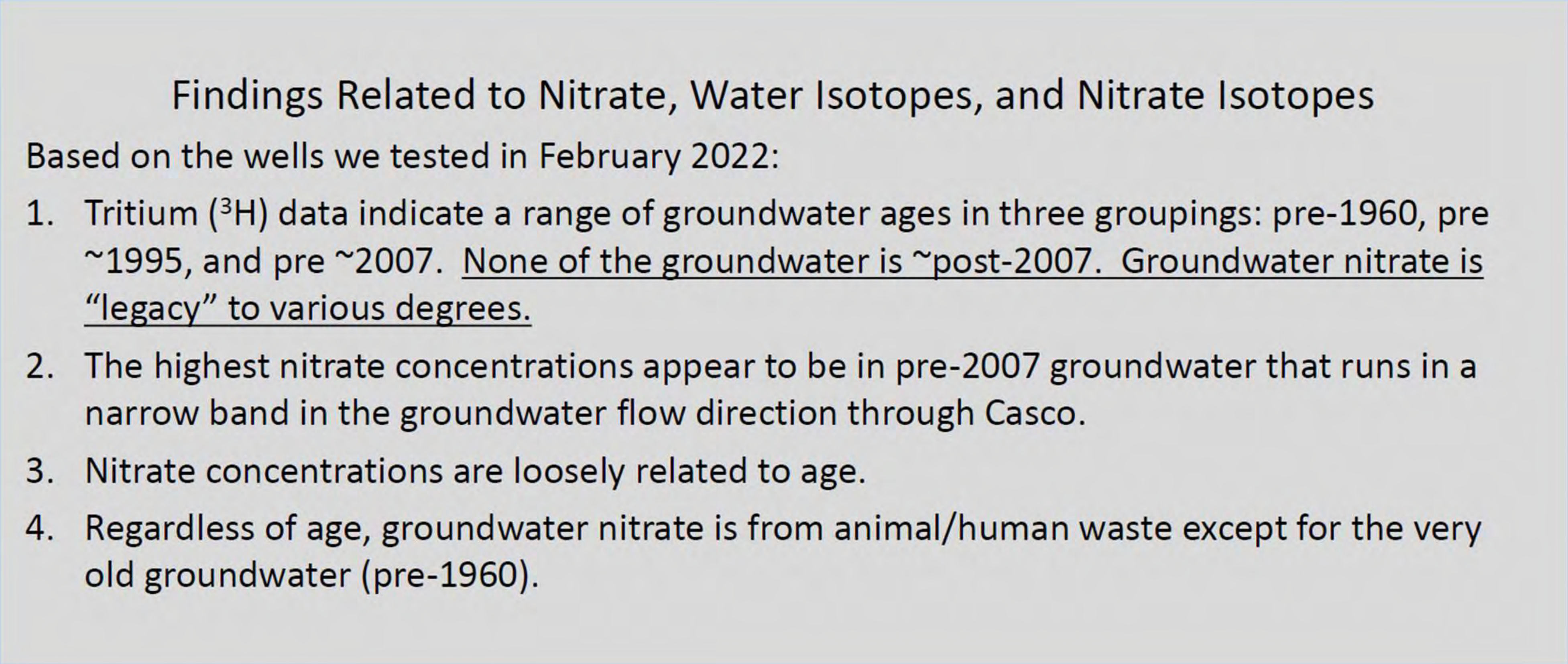
- 10 wells tested Feb 21, 2022
- Hired Dragun Corporation (Michigan based company)
  - Dr. Michael Sklash and Dr. Fatemeh Vakili
- Determine source(s) of nitrates
  - Chemical fertilizer
  - Animal waste/human
- Age of Nitrates
  - Legacy
  - Recent
- June 2022 Report (on website)



Nitrate isotopes indicate that most of the nitrate originated from animal/human waste.
Dr. Michael Sklash and Dr. Fatemeh Vakili (Dragun Corporation) June 2022



Dr. Michael Sklash and Dr. Fatemeh Vakili (Dragun Corporation) June 2022



Findings Related to Nitrate, Water Isotopes, and Nitrate Isotopes

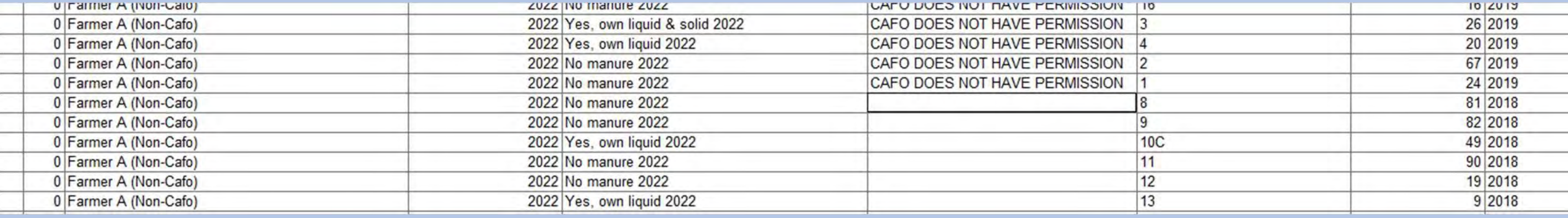
Based on the wells we tested in February 2022:

1. Tritium (^{3}H) data indicate a range of groundwater ages in three groupings: pre-1960, pre ~1995, and pre ~2007. <u>None of the groundwater is ~post-2007. Groundwater nitrate is “legacy” to various degrees.</u>
2. The highest nitrate concentrations appear to be in pre-2007 groundwater that runs in a narrow band in the groundwater flow direction through Casco.
3. Nitrate concentrations are loosely related to age.
4. Regardless of age, groundwater nitrate is from animal/human waste except for the very old groundwater (pre-1960).

Dr. Michael Sklash and Dr. Fatemeh Vakili (Dragun Corporation) June 2022

2022: Nutrient Management Verification

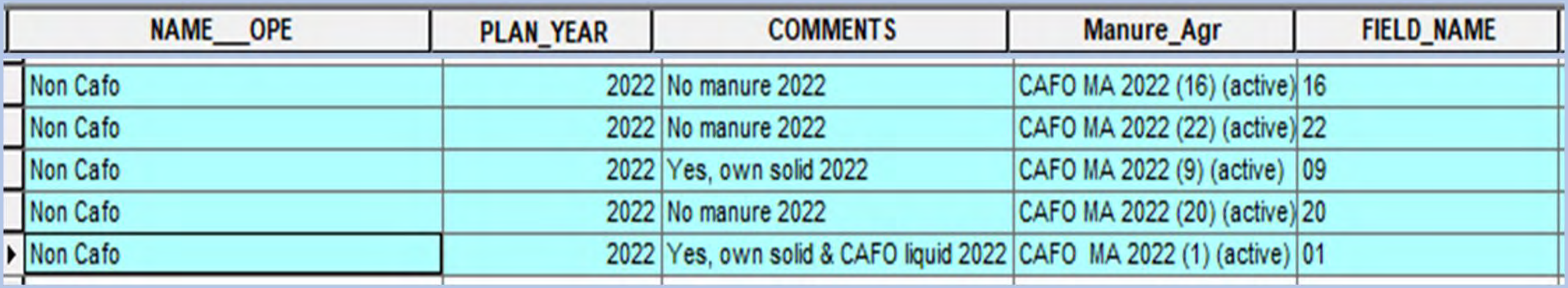
- Sparked by Complaints / Farmland Preservation Compliance
- Verify all manure agreements have permission per landowner/renter.



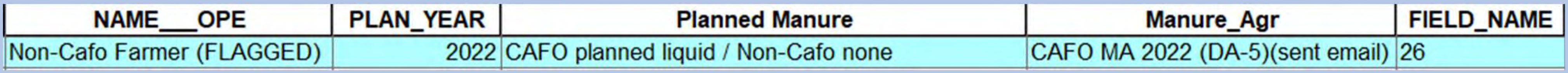
0	Farmer A (Non-Cafo)	2022	No manure 2022	CAFO DOES NOT HAVE PERMISSION	16	16	2019
0	Farmer A (Non-Cafo)	2022	Yes, own liquid & solid 2022	CAFO DOES NOT HAVE PERMISSION	3	26	2019
0	Farmer A (Non-Cafo)	2022	Yes, own liquid 2022	CAFO DOES NOT HAVE PERMISSION	4	20	2019
0	Farmer A (Non-Cafo)	2022	No manure 2022	CAFO DOES NOT HAVE PERMISSION	2	67	2019
0	Farmer A (Non-Cafo)	2022	No manure 2022	CAFO DOES NOT HAVE PERMISSION	1	24	2019
0	Farmer A (Non-Cafo)	2022	No manure 2022		8	81	2018
0	Farmer A (Non-Cafo)	2022	No manure 2022		9	82	2018
0	Farmer A (Non-Cafo)	2022	Yes, own liquid 2022		10C	49	2018
0	Farmer A (Non-Cafo)	2022	No manure 2022		11	90	2018
0	Farmer A (Non-Cafo)	2022	No manure 2022		12	19	2018
0	Farmer A (Non-Cafo)	2022	Yes, own liquid 2022		13	9	2018

Nutrient Management: 2022 Verification

- Cross reference all manure planned applications (Non-cafo to Cafo)



NAME__OPE	PLAN_YEAR	COMMENTS	Manure_Agr	FIELD_NAME
Non Cafo	2022	No manure 2022	CAFO MA 2022 (16) (active)	16
Non Cafo	2022	No manure 2022	CAFO MA 2022 (22) (active)	22
Non Cafo	2022	Yes, own solid 2022	CAFO MA 2022 (9) (active)	09
Non Cafo	2022	No manure 2022	CAFO MA 2022 (20) (active)	20
Non Cafo	2022	Yes, own solid & CAFO liquid 2022	CAFO MA 2022 (1) (active)	01

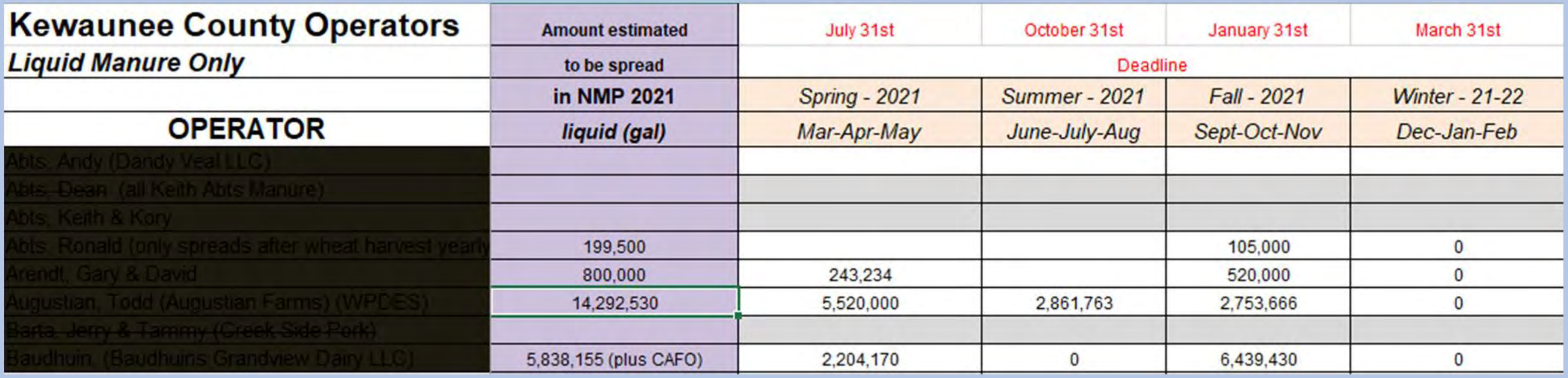


NAME__OPE	PLAN_YEAR	Planned Manure	Manure_Agr	FIELD_NAME
Non-Cafo Farmer (FLAGGED)	2022	CAFO planned liquid / Non-Cafo none	CAFO MA 2022 (DA-5)(sent email)	26

- Sent email to both CCA's. Non-cafo CCA did not know about the manure application from CAFO…updated the non-cafo NMP – now they match & compliant plans.

Master Spreading Record Keeping

From NMP



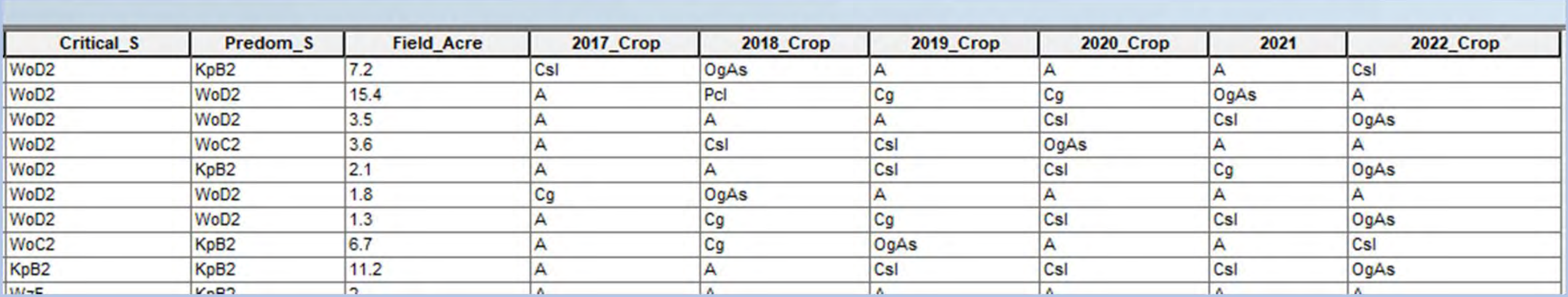
Kewaunee County Operators	**Amount estimated**	July 31st	October 31st	January 31st	March 31st
Liquid Manure Only	**to be spread**	Deadline			
	in NMP 2021	*Spring - 2021*	*Summer - 2021*	*Fall - 2021*	*Winter - 21-22*
OPERATOR	***liquid (gal)***	*Mar-Apr-May*	*June-July-Aug*	*Sept-Oct-Nov*	*Dec-Jan-Feb*
[redacted]					
[redacted]					
[redacted]					
[redacted]	199,500			105,000	0
[redacted]	800,000	243,234		520,000	0
[redacted]	14,292,530	5,520,000	2,861,763	2,753,666	0
[redacted]					
[redacted]	5,838,155 (plus CAFO)	2,204,170	0	6,439,430	0

Since Fall 2017 – and cross reference back to NMP -- compare

Verification Cont.

Cross reference both Non-Cafo and CAFO Plans for:

FIELD_NAME	PPM_P	YEAR_SOIL_	SOIL_LOSS_	ROT__AVG__	ROT__AVG_P
16	15	2020	5	3.9	4
22	13	2020	5	3.2	3
09	15	2020	5	4.1	4
20	7	2020	5	0.9	1
01	47	2020	5	4.6	5



Critical_S	Predom_S	Field_Acre	2017_Crop	2018_Crop	2019_Crop	2020_Crop	2021	2022_Crop
WoD2	KpB2	7.2	Csl	OgAs	A	A	A	Csl
WoD2	WoD2	15.4	A	Pcl	Cg	Cg	OgAs	A
WoD2	WoD2	3.5	A	A	A	Csl	Csl	OgAs
WoD2	WoC2	3.6	A	Csl	Csl	OgAs	A	A
WoD2	KpB2	2.1	A	A	Csl	Csl	Cg	OgAs
WoD2	WoD2	1.8	Cg	OgAs	A	A	A	A
WoD2	WoD2	1.3	A	Cg	Cg	Csl	Csl	OgAs
WoC2	KpB2	6.7	A	Cg	OgAs	A	A	Csl
KpB2	KpB2	11.2	A	A	Csl	Csl	Csl	OgAs

What Have we Learned?

1. We are Not Done Yet! But moving in a positive direction
2. Stop the “Misinformation”
3. Work together “Same Table” for open “respectful” conversations
4. Trust takes time to EARN
5. Field Days: farmers and the public, educate <u>together</u>
6. Listen:
   1. What is the person really saying? What are the <u>Fears</u>?
   2. Develop trust-based relationships
7. Research the Problem … Facts / Documentation…no Opinion
8. Keep pushing and get your State Legislatives involved….you need policymakers to invest in your County.

What do we need?

1. Full Funding of DATCP Staffing Grant
2. Collaboration among Counties / Regions
3. Increase Funding for Conservation Projects to implement Cost Sharing programs
4. Increase Groundwater Monitoring & Testing Programs
5. Expand Assistance to Landowners Affected by Groundwater Contamination
6. Assistance in Continuing to Implement the DNR Kewaunee County Workgroup Recommendations

THANK YOU & QUESTIONS?

Davina Bonness
County Conservationist
920-845-9743
bonness.davina@kewauneeco.org

Appendix G

Community Groundwater Management Readiness Questionnaire

Community Groundwater Management Readiness Questionnaire

Introduction: Groundwater is an important source of drinking water for people throughout much of Wisconsin. Protecting groundwater from numerous potential sources of contaminants is a very important challenge. While state and federal policies exist to help protect groundwater, communities must also play an active role to ensure adequate protection. So it is important that communities are well-prepared to deal with a variety of management challenges. This questionnaire is designed as a collaborative self-assessment and diagnostic tool, **not** a community-wide survey.

Scope and intended outcome: Questions in this version generally pertain to clarity and alignment of roles, groundwater issues, goals, strategies, and public engagement. It is hoped that this questionnaire - with follow-up discussion - may foster a shared understanding of areas that are strong and other areas that may need attention in order to ensure the effectiveness of community management efforts.

Intended audience/respondents: Potential respondents (and primary audience) for this collaborative self-assessment questionnaire include local government elected officials, public service professionals, members of the public, business managers, and leaders of civic organizations - particularly those actively engaged or at least interested and familiar with any community-based groundwater resource management efforts to date. Questions assume respondents are somewhat familiar with local groundwater quality issues and community-based efforts to address them. (This questionnaire is **not** intended for the general public.)

Suggested use: This questionnaire (modified if need be) may be completed by individuals actively engaged in collaborative groundwater management efforts within a community, such as a municipality, county or region. It may be filled-out individually by an agreed-upon deadline, with discussion to follow. Group review and discussion of combined responses may help establish a shared understanding of several key aspects of preparedness and groundwater resource management effectiveness, and to identify some areas to work on. While questions themselves could be discussed as a group, assigning the questionnaire as homework prior to discussion is recommended in that it may allow for much more productive use of limited time for group discussion. A summary of individuals' independent responses can serve as a much better starting point for discussion, greatly reducing the risk of key perspectives going entirely overlooked. And while the questions themselves may be thought-provoking for an individual, the questionnaire is likely more useful when used by a working group in order to foster constructive group discussion. It is the discussion that may serve to establish a shared understanding of what to work on to build community capacity to manage groundwater effectively.

Extension
UNIVERSITY OF WISCONSIN–MADISON

Prepared March, 2023 by Nathan Sandwick,
Community Development Educator

ROLES IN GROUNDWATER MANAGEMENT

Which of the following *best* represents the perspective you bring to groundwater quality management?

- ☐ Elected official
- ☐ Local government professional
- ☐ Resident or member of the general public
- ☐ Business operator
- ☐ Civic organization leader/volunteer
- ☐ Expert / professional outside of local government (groundwater or other relevant field)

With regard to community groundwater management efforts: who (so far) has effectively performed any of the following activities in your community?

(Fill-in all that apply. "Local government professionals" may include conservationists, public health officials, community planners, and others.)

	Elected Officials	**Local Government Professionals**	**Citizens / Organizations**
Frame issues	○	○	○
Identify potential solutions	○	○	○
Secure funding	○	○	○
Lead by example	○	○	○
Enforce standards	○	○	○
Set goals	○	○	○
Set objectives	○	○	○
Create programs	○	○	○
Oversee programs	○	○	○
Monitor progress	○	○	○
Evaluate policies and programs	○	○	○
Develop management plans	○	○	○
Implement plans, policies and programs	○	○	○

Which of the following groups in your community would you say are committed to the task of leading or contributing the development and implementation of a community-wide strategy for managing groundwater? *(Check all that apply.)*

- ☐ A majority of local government officials
- ☐ Local government professionals
- ☐ Residents and the general public
- ☐ Business leaders
- ☐ Civic organizations

CLARITY OF COMMUNITY ISSUES

How would you rate the following?

On a scale of 1 (poor) to 5 (excellent)

	1 poor	**2**	**3**	**4**	**5 excellent**
Current quality of groundwater sources of drinking water in my community	○	○	○	○	○
Ability of my community to ensure quality drinking water for years to come, in light of…					
future population projections	○	○	○	○	○
other trends	○	○	○	○	○
other foreseeable challenges	○	○	○	○	○

To what extent do you disagree or agree with the following statements?

On a scale of 1 (strongly disagree) to 5 (strongly agree), speaking for yourself.

	1 strongly disagree	**2 disagree**	**3 neither agree nor disagree**	**4 agree**	**5 strongly agree**
I am concerned about groundwater quality conditions	○	○	○	○	○
I am concerned about potential threats to groundwater quality	○	○	○	○	○

I am motivated to help address groundwater management issues	○	○	○	○	○
I am knowledgeable about the groundwater system	○	○	○	○	○
I am knowledgeable about current groundwater quality	○	○	○	○	○
My concerns about groundwater quality are widely-shared throughout the community.	○	○	○	○	○
Many others in my community are well-informed of the current condition of our groundwater.	○	○	○	○	○

Regarding your community, which of the following is a concern to you, and/or to your community?

> *Fill-in the dot in the first column if you yourself are concerned, and in the second column if the concern is recognized in an adopted community plan, policy, program, or other action/decision by a local government board or committee. (All that apply. If you don't know, leave it blank.)*

	A concern of your own	**A community concern**
There are known areas (hotspots) where groundwater is highly-contaminated.	○	○
We don't know enough about groundwater quality or areas where contaminants are highly-concentrated..	○	○
Many residents on private wells don't test their water often enough to ensure that their water is safe.	○	○
A heavy reliance on bottled water for drinking imposes costs or other household concerns.	○	○
A heavy reliance on treatment of private well water imposes costs or other household concerns.	○	○
Infrastructure or operating costs associated with public water systems.	○	○
Pollutants in groundwater threaten to increase the cost of treatment required to ensure that it is safe to drink.	○	○

Lack of assurance that all available groundwater is safe to drink without treatment.	○	○
A substantial number of people reside in areas where groundwater is often unsafe to drink without treatment.	○	○
Our current zoning does not prevent land uses that could contaminate groundwater used for drinking.	○	○
Our current zoning does not effectively keep new rural residential development away from areas where groundwater pollution is likely.	○	○
Our current regulations do not effectively prevent groundwater pollution in areas where many residents rely on clean groundwater.	○	○
High levels of anxiety about groundwater quality among the general public. (Such that the anxiety itself is problematic.)	○	○
General lack of awareness among the general public about actual conditions.	○	○

GOALS AND PERFORMANCE MEASUREMENT

Which of the following would you say is true in that it accurately describes the situation in your community? *(Check all that apply.)*

- ☐ Community groundwater management goals and objectives are clear, coherent and well-articulated.
- ☐ The community has clearly-identified its groundwater management issues.
- ☐ Community leaders understand the issues and the consequences of inaction.
- ☐ Adopted goals are aligned with concerns of engaged residents and other community stakeholders.
- ☐ Goals are established based on input from a broad base of residents and other community stakeholders.
- ☐ It is fairly clear how local government policies and programs could help advance some adopted goals.
- ☐ It is fairly clear how voluntary efforts by residents, businesses and/or civic organizations could help advance some adopted goals.

STRATEGIC VISION AND MANAGEMENT

Note: Questions in this section generally pertain to community strategies, policies or programs *typically* established by local governments or through community planning efforts convened by or in close collaboration with local governments.

Which of the following would you say is true in that it accurately describes the situation in your community? *(Check all that apply.)*

- ☐ The community has carefully considered the impacts of activities allowed within various zoning districts, adopted plans or regulations to separate incompatible land uses, and established a clear understanding of where activities that pollute groundwater may or may not be allowed.
- ☐ The community embraces a forward-looking approach to groundwater management.
- ☐ The community is prepared to devote attention and resources to strategy implementation.
- ☐ Groundwater management efforts leverage community strengths.
- ☐ Groundwater management efforts respond to current and anticipated opportunities and challenges.
- ☐ Objectives are appropriate. Accomplishing them would advance stated goals.
- ☐ Local government is adept at accomplishing objectives and advancing goals.
- ☐ Local government is adept at addressing contentious community issues.
- ☐ Local government is adept at constructively engaging the public in community planning, problem-solving, and strategy implementation.
- ☐ Leaders of groundwater management efforts are cognisant of political authority.
- ☐ There is political will within the local government to exercise its authority to address groundwater pollution. (To exercise local control.)
- ☐ There is political will within the local government to influence state or federal policies groundwater pollution. (To take action to influence policies that impact our groundwater or enable/constrain our local capacity to protect groundwater.)

PUBLIC ENGAGEMENT

Which of the following would you say is true in that it accurately describes the situation in your community? *(Check all that apply.)*

- ☐ Public information and community outreach is commonplace among community groundwater management efforts, and adequately-resourced.
- ☐ Outreach efforts commonly include recommended actions for individuals, households, businesses and organizations.
- ☐ The general public is not sufficiently-concerned about groundwater quality due to lack of awareness of actual conditions and practices. (Greater awareness could elevate concerns.)

☐ The general public is overly-concerned about groundwater quality due to lack of awareness of actual conditions and practices. (Greater awareness could be reassuring.)

☐ Individuals, businesses and/or civic organizations are active in protecting groundwater.

☐ Most households, business and/or civic organizations have adopted viable practices to minimize any adverse impacts on groundwater quality.

☐ Community strategies, goals, performance measures, policies and programs to protect groundwater are **widely-supported** by individuals, business and civic organizations.

☐ Individuals, businesses and/or civic organizations have been constructively **engaged in the establishing goals** or other elements of community strategies to protect groundwater.

☐ Individuals, businesses and/or civic organizations have been constructively **engaged in implementing** community strategies to protect groundwater.

[End of Questionnaire]

Acknowledgements:

Listed here are several sources of information and guidance that informed the development of this questionnaire.

Grant, Robert M. (2008) Contemporary Strategy Analysis, 6th Edition (Oxford: Blackwell) in Hughes, 2012.

Hughes, Owen E. (2012) *Public Management & Administration: An Introduction,* 4th Edition (New York: Palgrave Macmillan).

Marshall, Martha; Wray, Lyle; Epstein, Paul and Grifel, Stuart. (1999) *Better Results by Linking Citizens, Government, and Performance Measurement.* PM. Public Management, 1999, Vol.81 (10), p.12-12 https://icma.org/sites/default/files/4929_.pdf

Nutt, Paul C. and Backoff, Robert W. (1992) Strategic Management of Public and Third Sector Organizations: A Handbook for Leaders (San Francisco: Jossey-Bass) *in Huges, 2012.*

UW-Extension. (2009) *Governing Body Assessment Assessment Tool* (pp. A4-79 to A4-82) and *Community Organizational Assessment Tool* (pp. A4-83 to A4-86) contained within appendices for *UW-Extension Training Program on Strategic Planning: local government & community applications*, as adapted by Professor Robert D. Bright from materials prepared by the Citizens Involvement Training Program, University of Massachusetts, Amherst. Revised April 1996, and November, 1995 respectively.