VILLAGE OF NELSONVILLE WELL WATER QUALITY PROJECT

2019

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EXECUTIVE SUMMARY

Groundwater is the principal water supply for Portage County and the Village of Nelsonville. While those that use municipal water supplies have the benefit of regularly monitored drinking water that is is ensured to meet standards, private well owners must serve as their own water managers. They must decide when and what to test for and what to do if there is a problem. In an effort to establish baseline drinking water quality information within the Village of Nelsonville, Portage County Health and Human Services (HHS) and Planning and Zoning (P&Z) wrote an Environmental Health Tracking Grant.

In October and November of 2018 staff from Portage County HHS and P&Z solicited volunteers to have a free water sample collected and analyzed from their private well for nitrate-nitrogen, chloride, pH, alkalinity, total hardness and conductivity. All private well owners from within the Village were asked to participate with 60 of 77 wells being sampled. Following the first round of water quality testing, those wells that had nitrate-nitrogen concentrations exceeding the 10mg/L drinking water standard were asked to participate in a second round of testing that was looking at nitrate sources. This round analyzed samples for pharmaceuticals, personal care products, and herbicide metabolites. Twenty five of the 28 samples exceeding the drinking water standard for nitrate-nitrogen participated in the second round of testing. All samples were collected by Portage County HHS and P&Z staff and samples were analyzed at the state-certified Water and Environmental Analysis Lab.

The Village of Nelsonville groundwater can generally be characterized as slightly basic (average pH = 7.95), predominantly hard water (average total hardness = 282 mg/L as $CaCO_3$), and as having moderate alkalinity (average = 241 mg/L as $CaCO_3$). Overall, the water on average is well balanced and aesthetically pleasing. The aesthetic characteristics of the water are largely influenced by the geologic materials groundwater is stored and transported in, which is the unconfined aquifer that underlies the Village.

Nitrate is a common health-related contaminant found within the Village (average = 9.3 mg/L nitrate-nitrogen). Forty-seven percent of wells tested greater than the 10 mg/L drinking water standard; nearly four times the statewide average. Approximately 77% of wells tested measured greater than 2 mg/L, which provides evidence that land-use activities are having an effect on water quality in more than three quarters of the wells tested.

Chloride provides additional insight into the effects of land-use on water quality; background levels of chloride in groundwater are typically less than 10 mg/L. The average in the Village was 20.5 mg/L, again an indication of human land uses impacting water quality.

This study provides an important baseline of well water quality for the Village of Nelsonville. These results provide a foundation for future investigations on how or if groundwater is changing over time.

Lastly, it is important to acknowledge the Village of Nelsonville residents that agreed to have their wells sampled. Without their participation, this information would not have been possible.

INTRODUCTION TO GROUNDWATER (Excerpt from Portage County Well Water Quality – 2017 Masarik, K et al.)

Portage County receives on average about 32 inches of precipitation annually. Almost two thirds (roughly 20 inches) of this precipitation ends up back in the atmosphere by direct evaporation or by passing through plants in the process of transpiration. The remaining 12 inches either soaks into the ground past the root zone of plants or, may runoff directly into lakes, rivers, streams, or wetlands. The rate at which water soaks into the ground is determined mostly by the uppermost soil layer. Runoff is generated when rain falls (or snow melts) faster than water can infiltrate, or soak into the soil.

Fine-textured soils such as clay do not allow water to infiltrate very quickly. They generate more runoff than coarse-textured soils made up of mostly sand, which allow more infiltration. On average, only about 2 inches of water actually reaches Portage County lakes and rivers as runoff.

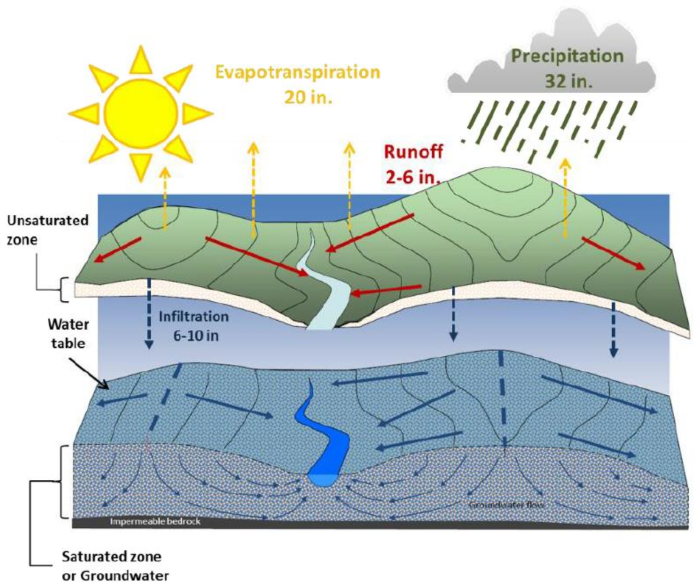

Figure 1. Contributions of various components of the water cycle within the Village of Nelsonville and Portage County. and Portage County. The unsaturated zone is separated from the groundwater to illustrate water table elevation. Changes in the water table elevation are used to infer groundwater flow direction.

The remaining 10 inches of annual precipitation is a good estimate of what actually infiltrates past the root zone of plants and ultimately becomes groundwater. The infiltrating water moves downward because of gravity until it reaches the water table, the point at which all the empty spaces between the soil particles or rock are completely filled with water. The water table represents the top of the groundwater resource. Groundwater moves very slowly between particles of sand and gravel or through cracks in rocks. Waterbearing geological units such as sand and gravel are called aquifers.

Groundwater is always moving. It is able to move because the empty spaces within aquifers are interconnected. The size and connectivity of the spaces within an aquifer determine how quickly groundwater moves, how easily it is contaminated, and how much water a well is able to pump.

Groundwater moves as a result of differences in energy. Water at any point in an aquifer has energy associated with it, and its movement can be predicted by measuring changes in energy between two locations. More simply, groundwater moves from high energy to low energy. One measurement of energy is groundwater elevation.

Groundwater elevation maps show the height of the top of the groundwater above a common measuring point, which is sea level. Those maps indicate that the water table is not flat; it is oftentimes a more muted version of the actual land surface. From a map of groundwater elevation, groundwater flow direction can be determined.

Groundwater generally moves from areas where the water table elevation is higher to areas where it is lower. In Portage County, surface waters are located in the areas where the water table intersects the land surface. Groundwater generally moves towards these low spots on the landscape, where it discharges to surface waters, such as a river, stream, lake, spring, or wetland. Because they are connected, scientists generally consider surface waters and groundwater as a single resource.

The water table elevations and approximate flow directions within the Village of Nelsonville can be seen in Figure 2, below. Groundwater elevations are based on depth to groundwater information collected during private well drilling.

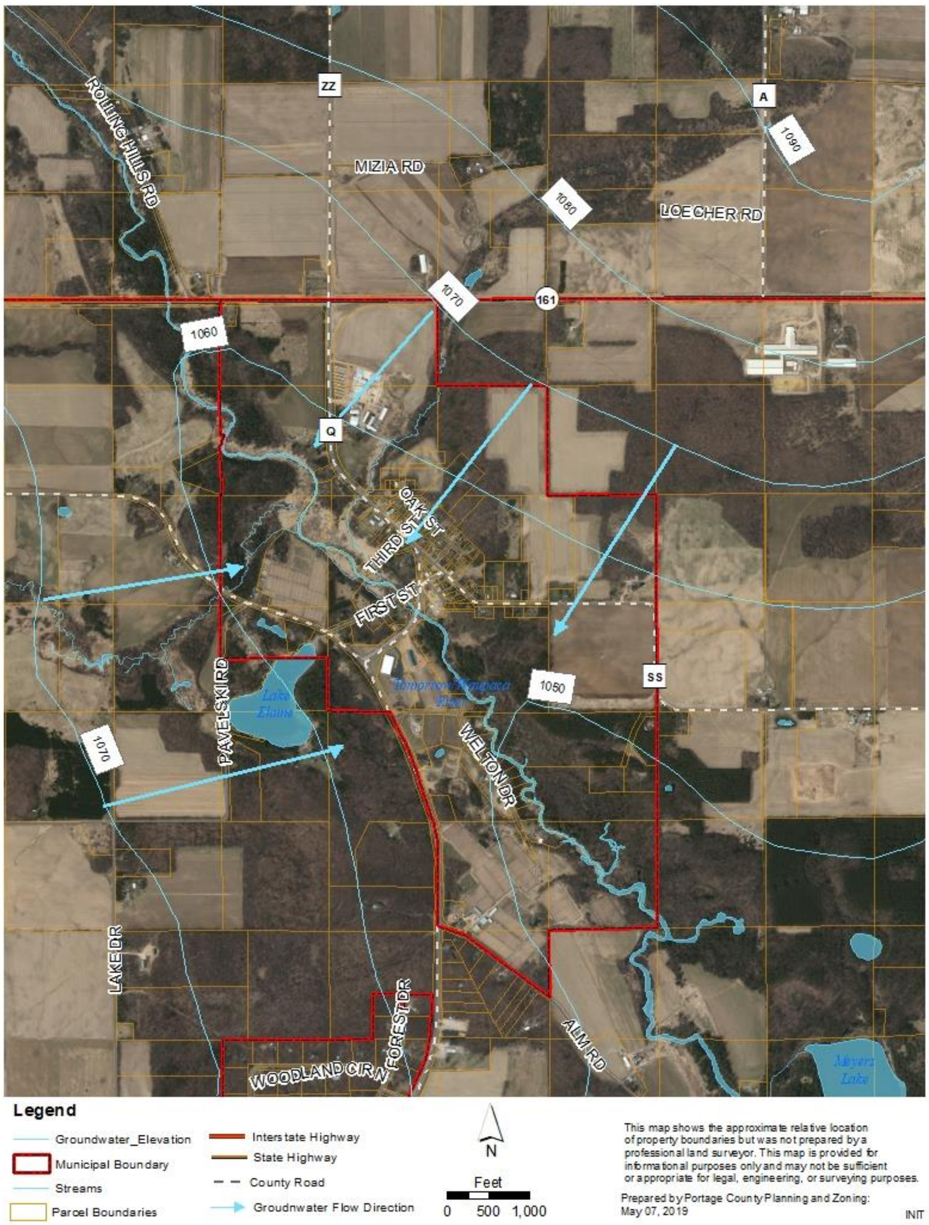

Figure 2. Approximate groundwater flow direction into the Village of Nelsonville based on groundwater elevation.

AQUIFERS

The geologic layers that hold and transmit groundwater are referred to as aquifers. The Village of Nelsonville has two aquifers: the sand and gravel aquifer and the crystalline bedrock aquifer. The sand and gravel aquifer is the primary aquifer for Village residents and industries.

The lowermost geologic unit found in the Village is Wolf River Granite, a crystalline bedrock, which is made up of igneous and metamorphic rocks that are billions of years old. Within the Village the depth to bedrock likely ranges between 100 to 200 feet below other geologic materials (Greenberg et al, 1986).

There is very little groundwater in the crystalline bedrock layer; it is generally a poor aquifer. Limited amounts of water can be found where the granite material has been weathered at the top, or where cracks and fractures can be found that connect to the layers above it.

The uppermost geologic layer consists of sand, silt, clay, gravel, cobbles, and even boulders. Since these materials are not cemented together, geologists refer to these as unconsolidated deposits. These deposits cover the bedrock layer found within the Village and serve as the primary source of groundwater. The spaces between the particles of sand and gravel are well connected and allow for abundant water storage and easy movement of groundwater through the aquifer. Hydrogeologists estimate that water in this aquifer moves horizontally about 1 to 2 feet per day.

WELLS (Excerpt from Portage County Well Water Quality – 2017 Masarik, K et al.)

All Village of Nelsonville residents rely on groundwater as their primary water supply. Wells are used to extract water from the ground for a variety of human activities. Residents within the Village rely on private wells which typically serve an individual home. High capacity wells are wells that can pump 70 gallons of water per minute or more. Often these wells are used to irrigate fields for growing crops or may be used by other industries and activities around the Village.

A water well is basically a vertical hole that extends into the soil and/or rock. Wells must be deep enough so that they extend past the water table into the groundwater aquifer. The groundwater may be very close to the land surface for people located close to a lake, river, or stream. However, for those located on the top of a hill, the groundwater is often located much deeper. A well in this situation must often be drilled much deeper if the well is to be successful at accessing water.

A well's casing and screen help to prevent the well borehole from filling in with sediment and other geologic material. The depth of casing or location of a well screen also determine where in the aquifer the well is receiving water from. Casing depth or screen location determines the capture zone or area of influence for a given well. As water is pumped or removed from the well, water contained in the spaces in adjacent rock or sand/gravel material replaces the water that was removed from the well. While people might like to think of groundwater as being very old, the truth is most water supplied to wells in Portage County is likely to be only a couple of years to maybe decades old.

Unlike high capacity municipal or irrigation wells, private residential wells generally don't use enough water to create a cone of depression or lowering of the water table. Assuming each individual in a household uses 50-100 gallons per day of water, this is not enough to greatly alter the flow direction of groundwater or cause a lowering of the water table around the well. We can think of private wells as simply intercepting groundwater along its normal flow path.

The capture zone of a well will be close to the well if pulling water from the top of the water table (Figure 7b) and may be greater and more difficult to determine for those wells cased deeper into the aquifer (Figure 7a).

Municipal systems are required to regularly test their water and have an obligation to ensure it meets government standards. In rural areas, meanwhile, residents are largely on their own because they rely on private wells for their daily water needs. Private well owners benefit from well construction regulations, but they do not benefit from the day-to-day oversight of municipal water systems.

Wells within the Village of Nelsonville range from shallow drive point wells that are only 20 feet deep to drilled wells that are more than 100 feet deep.

The state's well code, administered by the Wisconsin Department of Natural Resources, is based on the premise that a properly constructed well should be able to provide water free of bacteria without treatment. A mandated bacteria test performed after a well is first drilled is meant to verify if it is providing sanitary water at the time of construction. (Additionally, updates to the state well code now require new wells to be tested for nitrate.) Each owner must decide whether — and how — to verify their well continues to produce quality water.

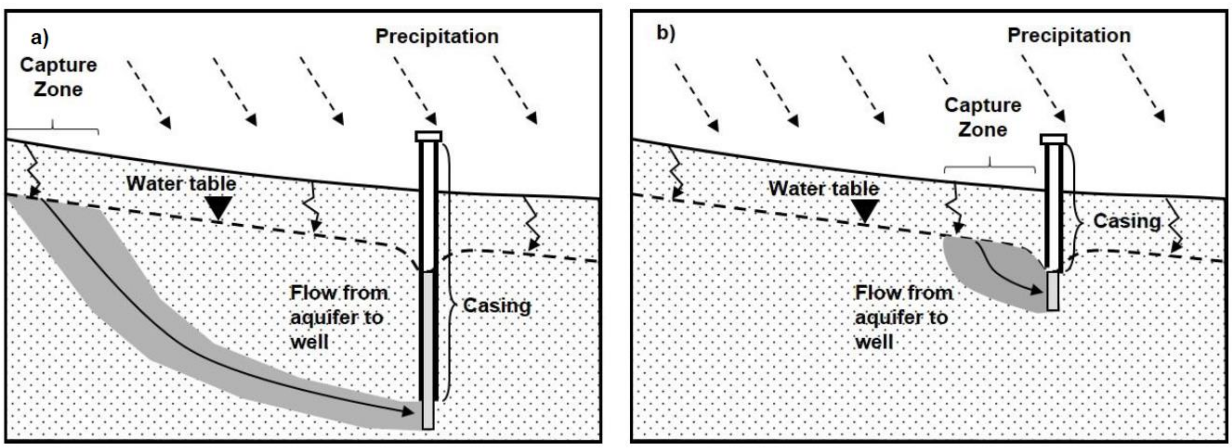

Figure 3. Diagram illustrating how well casing depth influences the capture zone for a well. Wells with a casing that extends further into the aquifer will tend to capture water from further away (a). Wells with a shallower casing depth will have a capture zone that is closer to the well (b).

WELL SELECTION, RECRUITMENT AND WATER QUALITY ANALYSIS

The goal of the Village of Nelsonville Water Quality Testing Project was to provide a free water quality test to every private well within the Village of Nelsonville. The Portage County Planning and Zoning Department used their GIS database of well information to identify 82 privately owned wells within the Village. This list was narrowed down to 77 wells, after those that were no longer is existence were removed. All 77 well owners within the Village were sent a letter asking them to attend one of two informational programs about the project and sign up for a time to have a water sample collected. Approximately 30 well owners attended one of the meetings and signed up for a time to have a sample collected. After the two informational meetings, Village of Nelsonville trustees went door to door signing up well owners who were interested in participating. An additional 30 private well owners were signed up for a total of 60 private wells. After the initial 60 wells were sampled, the remaining homeowners were sent another letter offering them one more opportunity to participate. There were no additional homes that expressed interested after the 2nd mailing.

Landowners that agreed to participate arranged a time and date with either Portage County staff or the Village of Nelsonville Trustees. Staff from the Portage County HHS or P&Z collected all of the water samples. Samples were collected from a faucet that was untreated, water was run for 10 minutes prior to sample collection, and samples were collected in an unacidified, 125 mL HDPE bottle. If homeowners authorized staff to collect a sample while the homeowner was not home, an outside faucet was used for sample collection. Following collection, samples were placed in a cooler with ice and transported back to the laboratory where they were stored in a refrigerator at 4 degrees Celsius until time of analysis. Samples were analyzed for pH, chloride, alkalinity, conductivity, total hardness, bacteria, and nitrate-nitrogen.

If permission was granted, County staff also conducted a visual inspection of the outside well casing and the inside well pump to ascertain the condition of the well and note deficiencies that may cause potential well contamination or did not currently meet state well code.

In January 2019, any private well owner who had a nitrate-nitrogen result over the drinking water standard of 10 mg/L was sent a letter asking if they wanted to participate in the nitrate-nitrogen source testing. If they were interested they contacted Portage County staff to set up a time and date for sample collection, similar to the first round. Of the 28 private well tests that exceeded 10 mg/L, 25 agreed to participate in nitrate-nitrogen source testing.

Portage County staff again collected all of the water samples. Samples were collected from a faucet that was untreated, water was run for 10 minutes prior to sample collection, and samples were collected in an unacidified, 1000 mL Glass bottle for PPCP and CAAM and a 45 ml vial for the DACT sample. If homeowners authorized staff to collect a sample while the homeowner was not home, an outside faucet was used for sample collection. Following collection, samples were placed in a cooler with ice and transported back to the laboratory where they were stored in a refrigerator at 4 degrees Celsius until time of analysis. The samples in the second round of testing were tested for acesulfame, sucralose, saccharin, acetaminophen, cotinine, caffeine, paraxanthine, carbamazepine, trimethoprim, sulfamethazine, sulfamethoxazole, venlafaxine, triclosan, alachlor OA, alachlor ESA, metolachlor OA, Metolachlor ESA, and diaminochlorotriazine.

All tests were performed at the Water and Environmental Analysis Lab which, is state certified to

- pH – SM 4500 H+
- Conductivity – SM 2510 B
- Hardness – SM 2340 C
- Alkalinity – SM 2320 B
- NO_2+NO_3-N – SM 4500-NO3 F
- Chloride – SM 4500-Cl G
- Coliform/E. coli – SM 9223 (Coli-lert method)
- Chloroacetanilide herbicide metabolites
- USGS open file report 00-182
- Pharmaceuticals and Personal Care Products – Nitka, et al. 2014
- Diaminochlorotriazine - Beacon Analytical ELISA method

perform analyses of interest. Analyses were performed using the following methodologies:

WELL WATER CHEMISTRY RESULTS AND INTERPRETATION

Mean (average), median, minimum and maximum values are reported in the tables below (Table 1) for entire village for each of the water quality tests performed in the first round of sampling. Table 2 shows the bacteria results for the Village. Table 3 and Table 4 provide the summary results of the herbicides, personal care products, and pharmaceuticals that were test in the nitrate-nitrogen source testing. These results are only for the subset of samples that exceeded the nitrate-nitrogen drinking water standard. Additional detailed information on each of the analytes can be found in the following sections and the summary statistics of the water quality sampling are located in Appendix A and B.

Table 1. Village of Nelsonville Well Water Quality Results

	pH	**Conductivity**	**Alkalinity**	**Total Hardness**	**Nitrate-Nitrogen**	**Chloride**
	Standard units	µmhos/cm	mg/L as $CaCo_3$	mg/L as $CaCO_3$	mg/L	mg/L
	n=60	n=60	n=60	n=60	n=60	n=60
Mean	7.98	595.58	240.77	281.82	9.34	20.51
Median	7.99	597	223	288	9.35	14.55
Min	7.64	348	158	0	<LOD	2.4
Max	8.33	1060	423	534	23.7	95.8

Table 2. Village of Nelsonville Bacteria Results

	Total Coliform Bacteria	**E. Coli Bacteria**
Sampled	60	2
Positive	2	1

Table 3. Village of Nelsonville Herbicide Test Results

Compound	Units	# of Detects	Range of Levels Found	Public Health Groundwater Quality Standard	Detection Limit	Explanation
Alachlor OA	ng/L	0	<LOD	None	0.08	Herbicide Breakdown Product
Alachlor ESA	ng/L	18	<LOD to 3494	20	0.08	Herbicide Breakdown Product
Metolachlor OA	ng/L	17	<LOD to 873	1300000*	0.08	Herbicide Breakdown Product
Metolachlor ESA	ng/L	24	<LOD to 6730		0.08	Herbicide Breakdown Product
DACT	μg/L	21	<LOD to 3.66	3.0	0.10	Herbicide Breakdown Product

* Metolachlor ESA and OA are regulated as the sum of the two chemicals.

Table 4. Village of Nelsonville Personal Care Products and Pharmaceuticals Test Results

Compound	Units	# of Detects	Range of Levels Found	Health Advisory Concentration	Detection Limit	Explanation
Sucralose	ng/L	4	<LOD to 923	None	25.0	Food Additive (artificial sweetener)
Acesulfame	ng/L	7	<LOD to 263.2	None	5.0	Food Additive (artificial sweetener)
Sulfamethoxazole	ng/L	2	<LOD to 21.2	100[†]	5.0[E]	Human Antibiotic
Saccharin	ng/L	0	<LOD	None	25	Food Additive (artificial sweetener)
Acetaminophen	ng/L	0	<LOD	None	35 [E]	Analgesic
Cotinine	ng/L	0	<LOD	None	3.0	Nicotine metabolite
Caffeine	ng/L	1	<LOD to 12.1	None	12.0	Stimulate
Paraxanthine	ng/L	0	<LOD	None	5.0	Caffeine metabolite
Carbamazepine	ng/L	1	<LOD to 6.4	None	2.0	Antiepileptic
Trimethoprim	ng/L	0	<LOD	None	5.0 [E]	Human Antibiotic
Venlafaxine	ng/L	0	<LOD	None	5.0 [E]	Antidepressant
Triclosan	ng/L	0	<LOD	None	75.0	Antimicrobial
Sulfamethazine	ng/L	0	<LOD	None	1.0	Bovine Antibiotic

[†]The advisory level shown for sulfamethoxazole was obtained through consultation with the Wisconsin Department of Health.

[E] = estimated detection limit.

BACTERIA

Bacteria often travels over the lands surface with rainwater or snowmelt and enters the ground where most is filtered out as the water travels through the soils. However, some strains of bacteria can survive a long time and can reach the groundwater through coarse soils, fractures, sink holes, and improperly constructed or located wells.

Bacteria can be both naturally occurring and human induced. Coliform bacteria are naturally occurring in soil and are found on vegetation and surface waters. While coliform bacteria does not cause illness or health risks for humans, its presence is an indication that a water system is at risk of more serious forms of contamination.

The presence of *Escherichia coli* or *E. coli* bacteria is an indication of fecal contamination of the groundwater. *E. coli* bacteria are present in the intestines of warm-blooded animals and are typically found in their fecal matter along with other pathogenic bacteria, viruses, and parasites which can cause illnesses.

Private homeowners are encouraged to test their wells for total coliform and *E. coli* bacteria. Private well systems should be free of all bacteria.

Of the 60 wells sampled for bacteria, within the Village of Nelsonville two were positive for total coliform bacteria. The two total coliform positive wells were further tested for E. coli bacteria and one tested positive. The well that tested positive for E. coli bacteria was a non-potable well, so no further action was required. However, the well owner was notified of the result.

NITRATE-NITROGEN

Nitrate is a chemical commonly found in agricultural and lawn fertilizer. It is also formed when waste materials such as manure, bio-solids or septic effluent decompose. Nitrate is the highly soluble in water and travels easily with groundwater, making it one of the most widespread groundwater contaminants in Wisconsin (Masarik, K et al, 2017).

Landscapes in which nitrogen is not added artificially (i.e. forests and grasslands) are generally nitrogen limited, meaning plants take up, or assimilate, all available nitrogen found in the soil. As a result, the natural level of nitrate-nitrogen we would expect to find in Wisconsin's groundwater is less than 2 mg/L (Masarik, K et al, 2017).

In other areas where nitrogen is applied to crops or landscapes as inorganic fertilizer, manure or other bio-solids, plants are usually not able to use all the nitrogen that is added. Even at the economic optimal rates recommended in a nutrient management plan, nitrogen can be lost to groundwater. Areas with sandy soils are especially susceptible to nitrate losses to groundwater because of how easily water is able to move past the root zone of plants to the groundwater (Masarik, K et al, 2017).

Septic systems are also a source of nitrate to groundwater. These systems are designed to settle out solids and deactivate bacteria and some pathogens in the wastewater that would make humans ill. These systems do not effectively remove nitrate, phosphorus, chloride and a host of other dissolved materials found in wastewater (Masarik, K et al, 2017).

The drinking water standard for nitrate-nitrogen is 10 mg/L. Water with concentrations greater than 10 mg/L of nitrate-nitrogen should not be used by infants, women who are pregnant or trying to become pregnant. The WI Dept. of Health Services recommends that all persons avoid long-term consumption of water with nitrate-nitrogen greater than 10 mg/L as a precaution to prevent potential health effects (Masarik, K et al, 2017).

Reverse osmosis, distillation or anion exchange are effective treatment methods to reduce nitrate levels. Those relying on treatment for health contaminants such as nitrate should periodically submit samples to ensure that the treatment device is reducing levels sufficiently to meet expectations for water quality (Masarik, K et al, 2017).

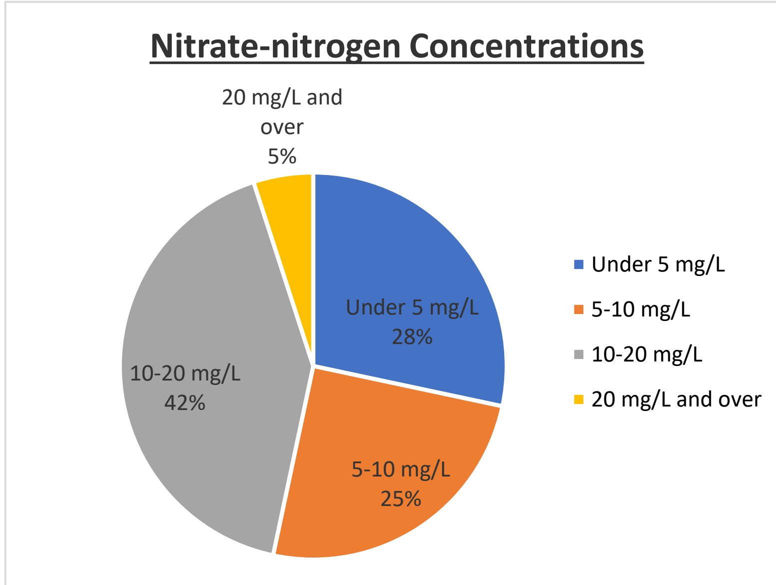

Figure 4. Percentage of samples in each Nitrate-nitrogen concentration category from the Village of Nelsonville.

Within the Village, forty-seven percent of samples measured nitrate-nitrogen concentrations above the drinking water standard (Figure 4). The rate of nitrate exceedances is more than 4 times the statewide estimate of 9% (DATCP, 2017). The average concentration with the Village was 9.34 mg/L and the median was 9.35 mg/L. Concentrations of nitrate above 2 mg/L indicate impacts from nearby land uses; and water may be more likely to contain other contaminants.

For comparison, the WI Well Water Viewer, a compilation of water quality results over time from a variety of state certified laboratories, shows a lower average concentration of 7.9 mg/L of nitrate-nitrogen and lower nitrate exceedance rates; 37% > 10 mg/L (CWSE, 2019) for the Village of Nelsonville.

Data collected for this project has similar methodologies to data collected in 2017 as part of a County-wide water quality sampling project in Portage County. Samples were collected from 214 wells from throughout the County. The nitrate-nitrogen results showed an average concentration of 6.5 mg/L and 24% of the samples collected exceeded the drinking water standard of 10/L.

At this point, there is not sufficient data for a comparison of results over time. This data will provide a baseline of data that can be used for future comparisons, should continued testing within the Village occur.

Nitrate-nitrogen concentrations were also analyzed using well location and construction information to see if any correlations or patterns in the results could be identified. Nitrate-concentrations were mapped to determine the spatial distribution of results. Elevated nitrate-nitrogen concentrations were found along Oak Street in the northern part of the Village, to the southeast of the Village and scattered along the Western side of the river. The lowest concentrations were found along the river (Figure 5). Further testing would be needed to determine exact groundwater flow, potential mixing of groundwater with the river and a more detailed analysis of spatial distribution of nitrate-nitrogen concentrations.

Of the 60 wells that were sampled, 38 (63%) had sufficient well construction information (total well depth, casing depth and depth to water) to look at nitrate-nitrogen concentrations compared to where in the aquifer the well was drawing water from. Results were broken into three categories of depth in the aquifer, including 0-20 ft, 20-50 ft, and over 50 ft into the aquifer. This is not total water depth but rather the distance between the noted depth of the water table in the well construction report and the depth at which the well casing ends.

Results showed that those wells who had shallow wells or wells that were drawing water from 20 feet into the aquifer or less had nitrate-nitrogen concentrations that ranged from 3.6 to 20 mg/L and an average concentration of 13.6 mg/L. Wells who were drawing water from 20-50 feet into the aquifer had nitrate-nitrogen concentrations that ranged from non-detectable to 23.7mg/L and had an average concentration of 10.18 mg/L. Wells that were pumping deep into the aquifer (50 feet or greater) had nitrate-nitrogen concentrations that ranged from non-detectable to 17.1 mg/L, with an average concentration of 4.2 mg/L. This provides support to the theory that wells that are pumping at a shallower depth in the aquifer may be more adversely impacted by nitrate-nitrogen within the Village than wells with a deeper pumping depth. However, it should be noted that there are concentrations both above and below the drinking water standard for nitrate-nitrogen in every category. Relocating a well to either a shallower or deeper level within the aquifer is not a guarantee of either better or worse water quality (Appendix C).

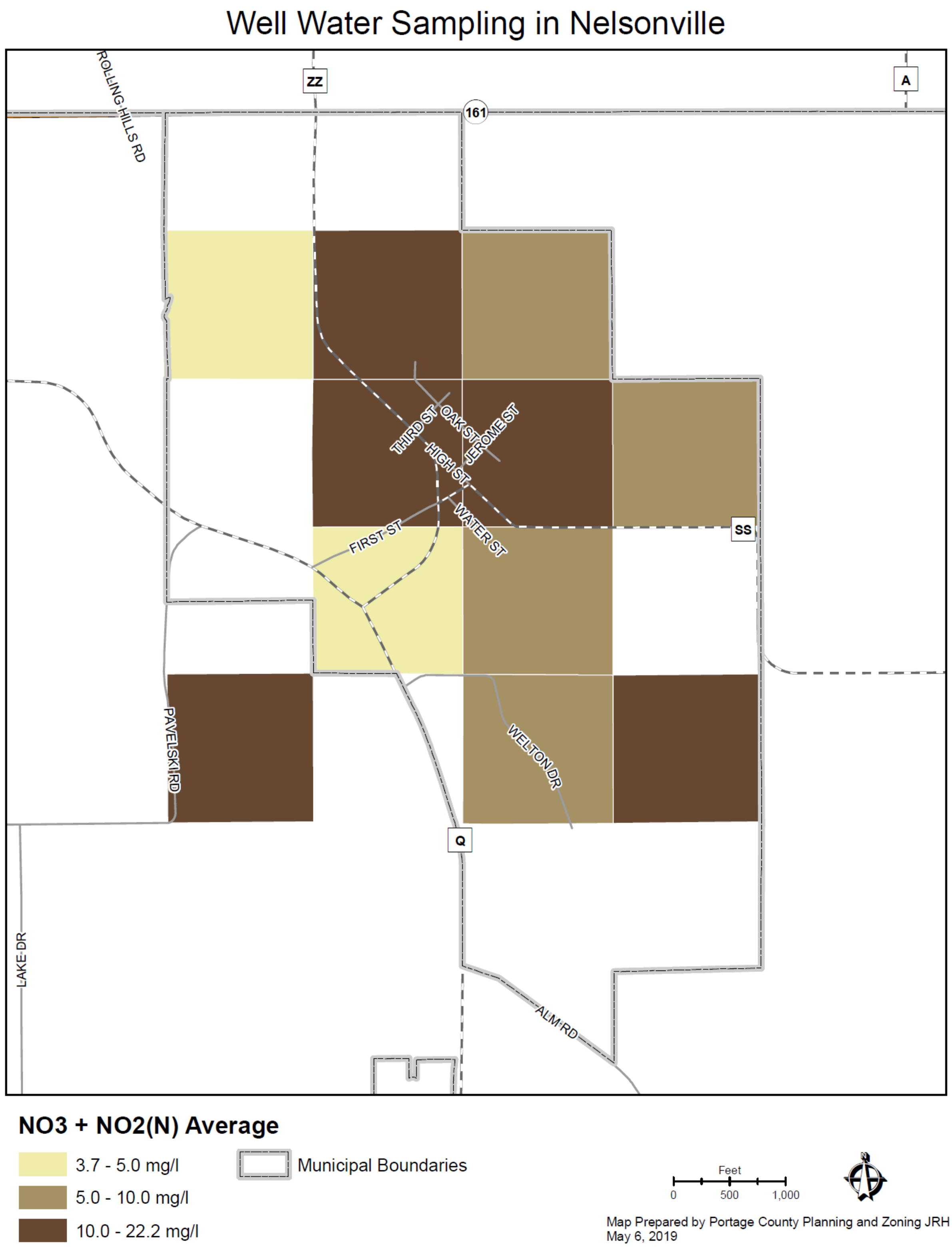

Figure 5. Average Nitrate-nitrogen concentration by 40 acre area within the Village of Nelsonville

PERSONAL CARE PRODUCT, PHARMACEUTICALS, AND HERBICIDE BREAKDOWN PRODUCTS

The purpose of the 2nd round of water quality testing was to try and determine potential sources that are contributing to elevated nitrate-nitrogen concentrations. Twenty eight of the sixty samples collected in the first round of water quality testing exceeded the nitrate-nitrogen drinking water standard of 10 mg/L. These 28 homeowners were asked to participate in the second round of nitrate-nitrogen source testing. Twenty-five private well owners agreed to the 2nd round of sampling.

The ability to assess the source of nitrate-nitrogen in a private well is somewhat complicated. The Water and Environmental Analysis Laboratory at the University Wisconsin-Stevens Point has the ability to determine the presence of human waste indicators such as pharmaceuticals and personal care products (PPCP). They can also identify chemicals unique to agricultural activities such as pesticides and pesticide metabolites (degradation products). The most commonly detected agricultural pesticides in Wisconsin's groundwater belong to a group known as chloroacetanilide herbicide metabolites (CAAMs) (DATCP, 2017).

Pharmaceuticals and personal care products

In research conducted at the Water and Environmental Analysis Lab, the artificial sweeteners acesulfame and sucralose are the most frequently detected of the PPCP compounds. Sulfamethoxazole (human antibiotic) is next in order of frequency. Artificial sweeteners are common in human foodstuffs, and very durable compounds. They can travel through a human gastrointestinal system and waste treatment system 95-99% intact. Therefore, they are good indicators of a human waste impact. All compounds tested for were chosen because they are able to be relatively easily detected, travel easily in groundwater and are exclusive to either human or bovine use. There are no health advisory limits in groundwater at this time for any of the PPCP compounds.

The presence of one or more of the artificial sweeteners along with any other PPCP compounds can be a strong indication of human waste impact. While the limits of detection (LOD) of PPCP compounds and artificial sweeteners vary, they are generally in the nanograms per liter(ng/L) or parts per trillion range. Detection of two or more PPCPs above 50 ng/L is also a strong indication of a human waste impact. A single detection of one compound at a level approaching (1-2 times) the LOD is not a strong indication of a septic system impact; in this event resampling and analysis should be conducted.

In the nitrate-nitrogen source testing that was completed within the Village, 8 of the 25 samples had a detect for at least one PPCP compound. Four samples had the presence of one or more of the artificial sweeteners and at least one other PPCP compound or two or PPCP compounds above 50 ng/L, which are indicative of human waste impacts. The remaining four samples only had one low-level detect for a single PPCP compound and these are not strong indicators for human waste impacts.

Chloroacetanilide herbicide metabolites

The presence of CAAMs in Wisconsin groundwater is evidence of an agricultural impact. These compounds are breakdown products of corn and soybean-related herbicides used extensively across the state. According to groundwater surveys conducted by the Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP), metolachlor ethane sulfonic acid (ESA) and alachlor ESA are the most frequently detected herbicide residues in groundwater in Wisconsin. Limits of detection of these compounds is approximately 0.08 ug/L (parts per billion) or 80 ng/L. Public Health Groundwater quality standards range from 20 ug/L or 20000 ng/L for alachlor ESA to 1300 ug/L or 1300000 ng/L for metolachlor ESA + oxanillic acid (OA).

While the presence of CAAMs can provide evidence of an agricultural impact to groundwater, it is not possible to determine an exact source or if the associated nitrate concentrations stem from organic (human or animal manure) or inorganic (commercial fertilizer) sources.

Results from within the Village showed that all 25 samples had a detect for at least one of the CAAM compounds, although none exceeded the drinking water standard. The ratio between metolachlor and alachlor detects and concentrations are similar to what DATCP has seen in its work throughout the state(DATCP, 2017). These results are indicative of agricultural land uses impacting the groundwater resources within the Village of Nelsonville.

Diaminochlorotriazine

Atrazine is a commonly used herbicide in Wisconsin. Over time atrazine breaks down into three other related chemicals, one of which is diaminochlorotriazine (DACT). The DACT screening tests for this one specific breakdown product, which can be used as another indicator of agricultural land use impacts to groundwater.

DACT is an important water quality parameter to watch and monitor as the Village currently lies within at atrazine prohibition area. Atrazine prohibition areas were established by DATCP in areas with where Atrazine concentrations above the drinking water standard were detected. It would be beneficial for the Village to continue to monitor DACT concentrations to see how they change over time.

The drinking water standard for Atrazine is 3 ug/L for the total of atrazine and its three breakdown products. Since DACT is only one of the breakdown products the screening does not account for the parent compound or other breakdown products. If the screening result is near or above 3 ug/L, it is likely that the drinking water standard has been exceeded.

Within the Village, 21 of the 25 samples detected DACT. One of the samples exceeded the atrazine drinking water standard of 3 ug/L. County staff are working have notified WI DACTP of the atrazine drinking water exceedance within the atrazine prohibition area. DATCP oversees the implementation of the prohibition areas.

The distribution of samples testing for PPCPs, CAAMS, and DACT were scattered throughout the Village. The only spatial pattern amongst the results that was evident was that on the eastern side of the river metolachlor was detected in higher concentrations and the one higher detect for alachlor was found on the western side of the river. The reason for this is that water in these two locations are coming from different directions, thus herbicide applications may have been different in these two areas. There was also limited well construction information available for the wells sampled in the second round, simply due to the smaller number of samples that were collected.

CHLORIDE

In most areas of Wisconsin, chloride concentrations are naturally low (less than 10 mg/L). Chloride is associated with human land uses. It is a component of potassium fertilizer, found in animal waste and other bio-solid amendments and can come from septic systems; as it is found in human waste and added to wastewater when water softeners discharge brine to septic systems. In addition, road salting can be a significant contributor to elevated chloride in groundwater (Masarik, K et al, 2017).

Chloride is not toxic, but some people can detect a salty taste at high levels. Chloride has no health standard. Levels more than 250 mg/L may cause a salty taste or cause corrosion of metal components within the plumbing system. If chloride levels are greater than 250 mg/L, there may also be elevated levels of sodium in the water (Masarik, K et al, 2017).

The average chloride concentration for the Village was 20.50 mg/L; higher than what we would typically expect for natural concentrations of chloride in groundwater, which is indicative of human influence on groundwater.

The Wisconsin Well Water Viewer indicates a slightly higher average concentration of chloride at 23.6 mg/L (CWSE, 2019). During the County-wide water quality study done in 2017 chloride concentrations ranged from 0.6 to 351 mg/L and had an average concentration of 22 mg/L.

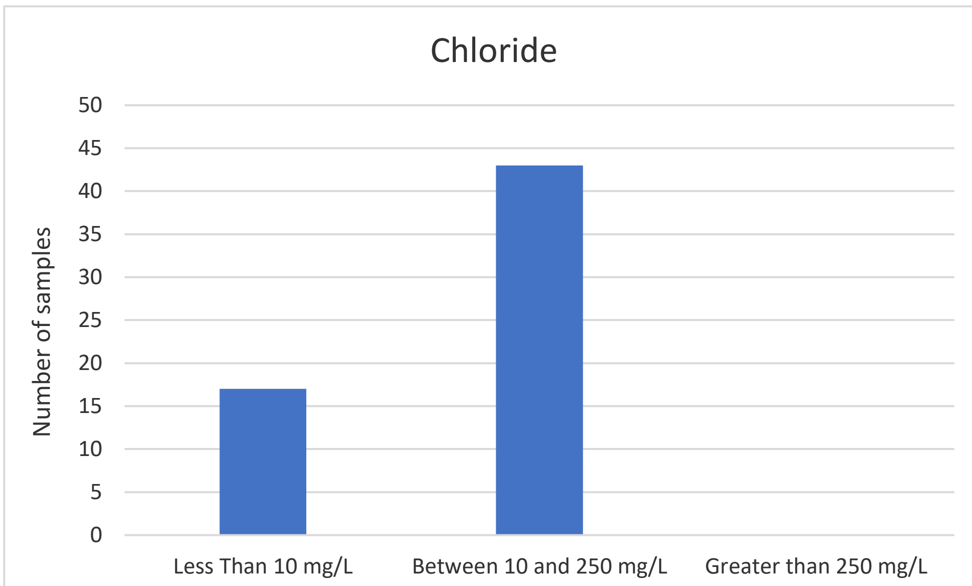

Figure 6. Number of samples in each category of chloride concentrations in Nelsonville, WI.

TOTAL HARDNESS

Hardness measures the amount of calcium and magnesium in water. It results primarily from dissolving limestone or dolomite minerals in the aquifer. Total hardness is mainly an aesthetic concern. Hard water causes scale deposits on fixtures, in pipes or water heaters. Water naturally low in hardness is often referred to as soft and can be corrosive. There are no health concerns related to drinking hard water (Masarik, K et al, 2017).

Water between 150 mg/L and 200 mg/L are generally ideal from an aesthetic point of view. Water less than 150 mg/L is considered soft while values greater than 200 mg/L are considered hard. Water softeners are commonly used to treat against the negative effects of hard water. The greater the total hardness value in well water, the more softener salt is needed to soften water.

The average total hardness concentration for the Village of Nelsonville was 281.5 mg/L. Wells from throughout the Village showed total concentrations that are indicative of hard water. There were a few results that had extremely low levels (below 4 mg/L) of total hardness, these samples most likely went through a water treatment device, such as a water softner, prior to sample collection.

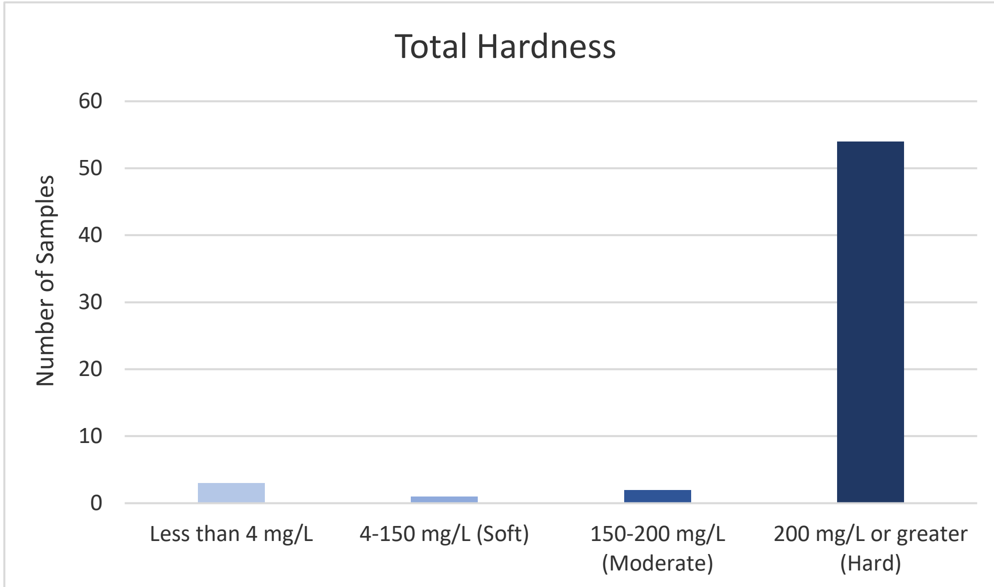

Figure 7. Number of samples in each category of total hardness in Nelsonville, WI.

ALKALINITY

Alkalinity measures the water's ability to neutralize acids. It results primarily from dissolving limestone or dolomite minerals in the aquifer. Water with alkalinity less than 150 mg/L is more likely to be corrosive. Alkalinity and total hardness should be roughly equal in groundwater because they form from the same minerals (Masarik, K et al, 2017).

The average alkalinity concentration found in samples from throughout the Village was 241mg/L. This is slightly lower than the average total hardness, which we would expect should be the same. Samples collected in the Village of Nelsonville follow a pattern that was also seen in the 2017 County-wide water quality sampling project, where total hardness was often greater than alkalinity, particularly in samples containing elevated levels of nitrate-nitrogen and chloride (Figure 8). Wells having elevated levels of nitrate and/or chloride show greater total hardness values than may be expected under natural conditions.

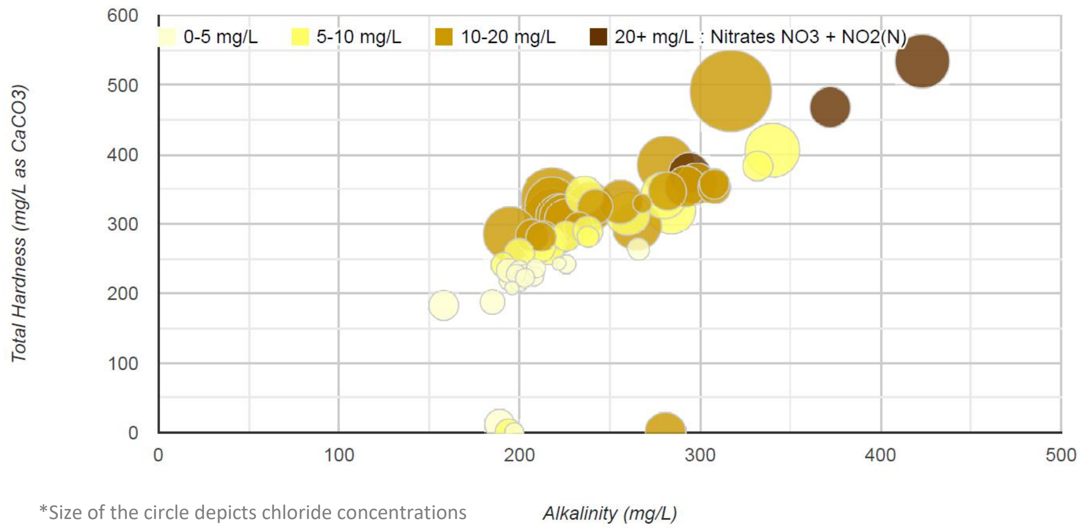

Figure 8. Alkalinity and total hardness often occur at roughly equal concentrations. Wells with elevated nitrate and/or chloride show greater total hardness values than may be expected under natural conditions. The size of the circle depicts chloride concentrations and the color of the circle depicts nitrate-nitrogen concentrations.

pH

A pH test is a measure of acidity. The lower the pH, the more corrosive the water. There is no health standard for pH, however corrosion of metal plumbing or fixtures is more likely to occur when pH levels are less than 7.0. Water greater than 7.0 is more likely to result in scaling. Low pH is more likely to result in elevated levels of copper and/or lead if those elements are included in your plumbing system. Acid-neutralizers are a type of treatment installed to counteract the negative effects (i.e. corrosion of plumbing components or blueish-green staining indicative of copper corrosion) that can result from low pH.

Wells within the Village of Nelsonville all had pH levels between 7.5 and 8.5, with the average being 7.9. These levels are indicative of hard water, similar to the total hardness results.

CONDUCTIVITY

Conductivity is a measure of the amount of total dissolved ions in water but does not give an indication of which minerals are present. Conductivity provides one more indicator of water quality, and changes in conductivity over time may indicate changes in overall water quality.

The dissolution of carbonate minerals often generates the bulk of ions associated with conductivity. As a result, conductivity is about twice the total hardness value in most uncontaminated waters. However, chloride and nitrate also contribute to conductivity measurements.

CONCLUSIONS

The Village of Nelsonville groundwater can generally be characterized as slightly basic (average pH = 7.95), predominantly hard water (average total hardness = 282 mg/L as CaCO3), and as having moderate alkalinity (average = 241 mg/L as CaCO3). The aesthetics of the groundwater are largely influenced by the geologic materials that comprise the unconfined aquifer.

However, there are indications that the groundwater is being impacted by human land uses. Forty-seven percent of the wells tested within the Village had nitrate-nitrogen concentrations that exceeded the state drinking water standard of 10 mg/L. Additionally, seventy-two percent of wells tested had chloride levels that exceeded natural background levels of 10 mg/L, which indicates impacts of human influenced land use. Those wells with elevated nitrate-nitrogen and/or chloride concentrations also tended to have slightly higher than expected total hardness levels.

When water quality testing results were compared to depth of pumping, those wells that were pumping at a depth of 20 feet or shallower in the aquifer had an average nitrate-nitrogen concentration of 13.6 mg/L, those drawing water from 20-50 ft within the aquifer had an average concentration of 10.18 mg/L, and those pumping water from greater than 50 feet in the aquifer had an average nitrate-nitrogen concentration of 4.2 mg/L.

Further testing was completed to explore the potential sources of nitrate-nitrogen within the Village. Those wells that had nitrate-nitrogen concentrations exceeding 10 mg/L were source tested for a suite of pharmaceuticals, personal care products and herbicide metabolites. Eight of the twenty-five wells sampled detected at least one personal care product or pharmaceutical and four of those had strong indicators for septic system effluent influences. All 25 samples had a detect for at least one herbicide metabolite. One of the samples exceeded the drinking water standard for DACT, the rest were below drinking water standards for all other metabolites. There were no detects for bovine antibiotics.

This study provides an important baseline of water quality within the Village of Nelsonville. These results highlight the main factors responsible for well water quality and provide a solid foundation for future studies that investigate how or if groundwater is changing over time.

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Greenberg, J.K., B.A. Brown.. 1986. Bedrock Geology of Portage, County Wisconsin. Wisconsin Geological Natural History Survey Information Circular 53. Plate 1. https://wgnhs.uwex.edu/pubs/000303/

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APPENDIX A – Summary Statistics from the Village of Nelsonville

Summary

UWEX Private Well Project

Village of Nelsonville - Portage County

2018

12/13/2018

9:20 AM

Total Number Samples: 60 Sample Dates: 11/5/2018 to 11/8/2018

Reason for Test		Last Test (yr)		Problems		Treatment Sys		Depth (ft) Well		Casing	Water	Well Diam (in)	
Curious	7 %	Never	0 %	Color	0 %	Softener	7 %	... 25	3 %	5 %	22 %	... 3	10 %
Problems	0 %	< 1	17 %	Taste	2 %	R/O	5 %	26-50	12 %	10 %	20 %	4 - 9	50 %
Regular	3 %	1 - 2	8 %	Odor	2 %	Carb Filt	2 %	51-100	25 %	22 %	3 %	10 - 18	2 %
Required	0 %	2 - 5	2 %	Corr	3 %	Neutral	0 %	101-150	12 %	10 %	0 %	18 +	0 %
Bac Retest	0 %	5 - 10	3 %	Health	0 %	Part Filt	0 %	151-200	0 %	0 %	0 %		
Disinfect	0 %	10 +	5 %	Other	5 %	Iron Filt	0 %	201 ...	0 %	0 %	0 %		
Infant...	5 %	Unk	10 %	None	33 %	Other	0 %						
Other	<1 %												

pH		
... 5.00	0	0 %
5.01 - 6.00	0	0 %
6.01 - 7.00	0	0 %
7.01 - 8.00	34	57 %
8.01 - 9.00	26	43 %
9.01 ...	0	0 %
Avg: 7.95	for	60 Samples

Conductivity (umhos/cm)		
... 100	0	0 %
101 - 250	0	0 %
251 - 500	18	30 %
501 - 750	35	58 %
751 - 1000	5	8 %
1001 ...	2	3 %
Avg: 596	for	60 Samples

Alkalinity (mg/L CaCO3)		
... 50	0	0 %
51 - 100	0	0 %
101 - 200	14	23 %
201 - 300	39	65 %
301 - 400	6	10 %
401 ...	1	2 %
Avg: 241	for	60 Samples

Total Hardness (mg/L CaCO3)		
... 50	4	7 %
51 - 100	0	0 %
101 - 200	2	3 %
201 - 300	28	47 %
301 - 400	22	37 %
401 ...	4	7 %
Avg: 282	for	60 Samples

Nitrate (mg/L as N)		
None Detected	8	13 %
... 2.0	3	5 %
2.1 - 5.0	6	10 %
5.1 - 10.0	15	25 %
10.1 - 20.0	25	42 %
20.1 ...	3	5 %
Avg: 9.3	for	60 Samples

Chloride (mg/L)		
None Detected	0	0 %
... 10	17	28 %
11 - 50	41	68 %
51 - 100	2	3 %
101 - 200	0	0 %
201 ...	0	0 %
Avg: 20.5	for	60 Samples

Saturation Index		
... -3.0	0	0 %
-2.9 - -2.0	0	0 %
-1.9 - -1.0	3	5 %
-0.9 - 0.0	1	2 %
0.1 - 1.0	56	93 %
1.1 ...	0	0 %
Avg: 0.3	for	60 Samples

Coliform Bacteria		
Bact Samples	60	
Pos Bacteria	2	3 %

E. coli Bacteria		
E. coli Samples	2	
Pos E. coli	1	50 %

Atrazine Screen* (ppb)		
None Detected	0	%
... 0.3	0	%
0.4 - 1.0	0	%
1.1 - 2.0	0	%
2.1 - 3.0	0	%
3.1 ...	0	%
Avg:	for	0 Samples

*Triazine screen before June 2008, then Diaminochlorotriazine (DACT).

APPENDIX B – Nitrate-Nitrogen Source Testing Results

University of Wisconsin-Stevens Point

College of Natural Resources
Center for Watershed Science and Education
Water and Environmental Analysis Lab

Stevens Point WI 54481-3897
Phone: 715-346-3209
Toll Free: 877-383-8378
www.uwsp.edu/cnr-ap/weal

PHARMACEUTICALS AND PERSONAL CARE PRODUCTS

PROJECT

SAMPLE MATRIX	Nelsonville Groundwater
LAB NUMBER	1800008
DATE SAMPLED	1/14-1/18/2019
DATE RECEIVED	1/14-1/18/2019

Lab ID#	Acesulfame (artificial sweetener)	Sucralose (artificial sweetener)	Saccharin (artificial sweetener)	Acetaminophen (analgesic)	Cotinine (nicotine metabolite)	Caffeine (stimulant)	Paraxanthine (caffeine metabolite)	Carbamazepine (antiepileptic)	Trimethoprim (human antibiotic)	Sulfamethazine (bovine antibiotic)	Sulfamethoxazole (human antibiotic)	Venlafaxine (antidepressant)	Triclosan (antimicrobial)
	Sample concentration parts per trillion (ng/L)												
1800008-01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1800008-02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1800008-04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1800008-05	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1800008-06	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1800008-07	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1800008-08	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

CHLOROACETANILIDE HERBICIDE METABOLITES

Lab ID#	Alachlor OA	Alachlor ESA	Metolachlor OA	Metolachlor ESA
	Sample concentration parts per trillion (ng/L)			
1800008-01	<LOD	**138**	**90**	**512**
1800008-02	<LOD	<LOD	**299**	**2268A**
1800008-04	<LOD	<LOD	<LOD	**324**
1800008-05	<LOD	<LOD	**111**	**1566**
1800008-06	<LOD	**458**	<LOD	**269**
1800008-07	<LOD	<LOD	**258**	**2466A**
1800008-08	<LOD	**208**	**141**	**1653A**

Lab ID#	Acesulfame (artificial sweetener)	Sucralose (artificial sweetener)	Saccharin (artificial sweetener)	Acetaminophen (analgesic)	Cotinine (nicotine metabolite)	Caffeine (stimulant)	Paraxanthine (caffeine metabolite)	Carbamazepine (antiepileptic)	Trimethoprim (human antibiotic)	Sulfamethazine (bovine antibiotic)	Sulfamethoxazole (human antibiotic)	Venlafaxine (antidepressant)	Triclosan (antimicrobial)	Alachlor OA	Alachlor ESA	Metolachlor OA	Metolachlor ESA
	Sample concentration parts per trillion (ng/L)													Sample concentration parts per trillion (ng/L)			
1800008-10	**14.1**	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**90**	**110**	**1430**
1800008-11	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**194**	**293**	**2344A**
1800008-12	**13.3**	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**103**	<LOD	**970**
1800008-13	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**873**	**6730A**
1800008-14	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**81**	**126**	**1860**
1800008-15	**35.3**	**47.8**	<LOD	<LOD	<LOD	<LOD	<LOD	**6.4**	<LOD	<LOD	**5.5**	<LOD	<LOD	<LOD	**684**	**366**	<LOD
1800008-16	**13.5**	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**541**	<LOD	**764**
1800008-17	<LOD	<LOD	<LOD	<LOD	<LOD	**12.1**	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**162**	**326**	**3409A**
1800008-18	**263**	**178**	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**21.2**	<LOD	<LOD	<LOD	**89**	**87**	**788**
1800008-19	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**112**	<LOD	**1141**
1800008-20	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**93**	**445**	**5661A**
1800008-21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**115**	**2084A**
1800008-22	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**89**	<LOD	**529**
1800008-23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**226**	<LOD	**383**
1800008-24	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**216**	**256**	**4766A**
1800008-25	**246**	**923**	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**117**	**280**	**3651A**
1800008-26	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	**3494A**	<LOD	**364**
Limit of detection	5.0	25.0	25E	35E	3.0	12.0	5.0	2.0	5E	1.0	5E	5E	75.0	80 E	80 E	80 E	80 E

E= Estimated

A = Sample concentration is above calibrated range (1600 ng/L)

APPENDIX C – Nitrate-Nitrogen Concentrations by Depth of Pumping in Aquifer

Depth of Pumping in Aquifer	Nitrate-nitrogen concentrations (mg/L)																		
O-20 ft	12.1	10.7	12.6	21	12.9	16.7	3.6	19.7											
20-50 ft	4.7	13.8	5.8	11.6	11.7	7.1	7.9	2	8.5	18.4	0	8.2	20.7	0	15.6	9.5	23.7	10.4	13.8
50+ ft	4.5	8.9	4.4	0	0	0.5	17.1	0	4.9	5.9	0								

	0-20 ft	20-50 ft	50+ ft
Min	3.6	0	0
Max	21	23.7	17.1
Average	13.663	10.17895	4.2