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Wisconsin Groundwater Management Practice Monitoring Project No. 34

GROUNDWATER
Wisconsin's buried treasure

Wisconsin Department of Natural Resources

BARRON COUNTY
NITRATE STUDY

Prepared by
Wisconsin Department of
Natural Resources
August, 1987

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Acknowledgements

The bulk of data collection, interpretation, and presentation was completed by William McKinley, a temporary employee of the Department of Natural Resources working under the supervision of Water Supply Specialist, David Hanson. Others providing assistance and advice in completing the study were Alex Zaporozec with the Wisconsin Geological and Natural History Survey; Barron County Zoning Administrator, Dale Thorsbakken; and Barron County Agricultural Agent, Don Drost. Also providing support and review were DNR Water Supply Staff Specialist, Dave Herrick and Jeff Schmoller of the Department Bureau of Water Resources. A special thanks goes to the individual landowners who allowed their wells to be sampled and inspected.

INTRODUCTION

Barron County is located in NW Wisconsin. The county's twenty-five townships cover a total area of 864 square miles. The topography is gently rolling hills which taper to outwash plains along the Yellow and Red Cedar Rivers.

Agriculture is the principal industry in Barron County and the population is mostly rural. Dairy farming, turkey raising, and vegetable farming are the most important agricultural activities. Recreation is also an important industry. In many parts of the county agricultural activities are intensely practiced in close proximity to both heavily used recreational areas and concentrations of permanent rural residences.

Approximately 55% of the county's population is rural and is served by private wells. Two major aquifers (water producing geological formations) provide the county's well water. The shallower sand and gravel aquifer overlies the sandstone aquifer throughout the county. While they are separate geological units, the groundwater between them is hydraulically interconnected.

In recent years, the public has become increasingly concerned over the potential impact of agricultural activities on well water quality. In response, Barron County, Wisconsin Geological and Natural History Survey, and Department of Natural Resources have collected numerous samples from county wells. These have been analyzed for nitrate which when found in elevated concentrations may indicate contamination of groundwater by agricultural practices.

Nearly 800 wells were sampled between 1980 and 1986. Approximately 20% of the wells sampled in the intensely farmed and irrigated outwash plains of Prairie Lake and Barron Townships, were found to exceed the safe drinking water standard of 10 milligrams per liter nitrate. Also, many wells in Dallas Township, an important agricultural area, were found to exceed the nitrate standard.

Due to the need for additional information to accurately assess the problem in the three townships, the Department of Natural Resources conducted a follow-up study in 1986. The objective of the study was to evaluate the relationship of nitrate concentrations to well construction and location. Items evaluated were well depth, casing depth, casing penetration into the groundwater, water table depth, soil type, land use, drainage, water bearing formation, and overall well construction. The following report discusses and summarizes the study findings.

METHODS

The first step in initiating the study was a review of the past data collected by the Wisconsin Geological and Natural History Survey, Barron County, and the Department of Natural Resources. Hundreds of nitrate samples were taken from various water supply sources between 1980-1986. However, valuable well construction information was usually not collected for the sampled wells.

It was therefore important to obtain accurate well construction data via the well construction reports that well drillers are required to file with the DNR. All well construction reports that existed for each of the three townships were reviewed and approximately 50 drilled wells were selected for inspection and sampling in each township. For comparison purposes a number of driven point wells were also selected.

The Field Inspection

A field inspection of each sampled well was conducted. Pertinent items noted during the inspection were changes in the well construction since the date on the well construction report, separation distances and drainage patterns from possible pollution sources such as septic or holding tanks, soil absorption units, underground fuel tanks, lakes or streams, animal yards, barn gutters, manure stacks, liquid manure storage, or any other visible onsite contamination.

NITRATE AND ITS SIGNIFICANCE IN GROUNDWATER

Nitrogen is a critical element in the development of all life forms. It is essential to the production of amino acids which are constituents of plant and animal proteins.

Most plants utilize ammonia and nitrate as their sources of nitrogen. Nitrate is a compound of nitrogen and oxygen. Its concentration in groundwater is commonly expressed as milligrams per liter (mg/l) nitrate-nitrogen. Nitrate is water soluble and therefore can be easily leached, especially through light sandy soils, into the groundwater.

Major sources of nitrate to the soil and subsequently to groundwater include land spreading of manure and wastewater sludges, application of commercial fertilizers, land disposal of municipal and industrial wastewater, private septic tanks and drainfields, and natural sources such as nitrogen fixation by bacteria.

Wisconsin has adopted a drinking water standard of 10 mg/l for nitrate-nitrogen. This standard is mandatory for public water supplies and is used as a public health advisory for private water supplies. This level was set because of the relationship between nitrate in drinking water and infant methemoglobinemia. Methemoglobinemia or "Blue Baby Syndrome" occurs when excess amounts of nitrate is converted in an infant's stomach to nitrite. Nitrite reduces the capability of the infant's blood to carry oxygen. Infants under six months of age are most susceptible but because of the individual differences in infants, many are not affected. If an infant is affected, his skin becomes blue, similar to the color of the blood vessels located close to the skin.

Adults can consume large quantities of nitrate in drinking water or food with no known ill effects. The adult stomach contains strong acids which prohibit the growth of bacteria which converts nitrate to the more toxic nitrite. Infants, however, are more susceptible because their stomach juices are less acidic. Water with a nitrate concentration exceeding 10 milligrams per liter should not be given to infants under six months of age either directly or in formula.

Adults and older children consume far more nitrate in food than they do in water. Drinking water normally contributes only a very small percentage of the total nitrate intake. The following example illustrates this point: in 100 grams of beets which is approximately 4 oz., there are 301 milligrams nitrate-nitrogen. This would be equivalent to 30.1 liters or 8 gallons of water with a concentration of 10 mg/l, the state limit. Other selected vegetables that contain high nitrate levels are celery, collard greens, cale, iceburg lettuce, mustard green, fresh radishes, spinach and turnip.

The following factors determine the amount of nitrate which becomes dissolved in the groundwater:

1) The depth of soil between the ground surface and the water table; 2) the soil's ability to attenuate nitrate (heavier soils generally attenuate nitrate better than light soils; 3) slope of the land surface and related drainage; 4) type of crops grown and their nitrogen usage; 5) and the significance of the nitrate sources.

Elevated concentrations of nitrate in groundwater are found when sources contribute more than can be attenuated by the soil, used by plants, drained away by surface runoff, and/or dispersed and transported by groundwater flow.

NITRATE CONTAMINATION IN BARRON COUNTY

Combinations of conditions which foster nitrate contamination of the groundwater exist in the townships of Prairie Lake, Barron, and Dallas.

The intensely farmed and irrigated outwash areas adjacent to the Yellow and Red Cedar Rivers are particularly vulnerable. In these areas soils are light, very permeable, and attenuate nitrate poorly (see appendix A). The water table is close to the land surface and an abundant supply of groundwater is readily available for agricultural and domestic use. Compounding the problem is the significant number of permanent rural residences, commercial establishments, and recreational facilities (particularly in the Chetek area) located in close proximity to agricultural areas. Nitrate from agricultural, commercial, and domestic sources is readily flushed to the groundwater through the light soils. Irrigation, necessary to accommodate use of the light, well drained soils, aggravates the situation by intensifying the flushing of nitrate to the groundwater.

The abundant supply of easily obtained groundwater; the same condition which accommodates agriculture, also encourages the utilization of shallow domestic and commercial wells. Nitrate concentrations are highest near the surface of the groundwater and diminish with depth. This is due to dilution and dispersion associated with groundwater flow and recharge. Thus nitrate contamination of wells, especially shallow ones, commonly occurs in the outwash areas of Prairie Lake and Barron Townships.

Nitrate contamination also exists in portions of Dallas Township. Soils are generally heavier than the outwash areas and groundwater deeper. Problems in the township are most evident where lighter soils, shallower groundwater, agricultural activities, and concentrations of residences coincide. Again, the shallower wells are the most vulnerable to nitrate contamination.

NITRATE AND WELL CONSTRUCTION

Proper well construction and location provide means to minimize nitrate contamination of water supplies. Important well construction features relative to potential contamination include well type, aquifer type, well depth, and casing penetration of the aquifer.

Drilled wells account for 120 of the 150 wells surveyed in Prairie Lake, Barron, and Dallas Townships. The remaining 30 wells are driven points. The intakes of the wells are located in either the sand and gravel or sandstone aquifers (water bearing formations). The sand and gravel aquifer overlays the sandstone aquifer and varies in thickness from a maximum of about 20 feet in Dallas Township, 70 feet in Prairie Lake Township, to greater than 120 feet in areas of Barron Township. Information available for 91 of the drilled wells show 63 to be drawing water from the sandstone aquifer and the remaining 28 from the sand and gravel aquifer. The driven point wells terminate at various depths in the sand and gravel aquifer.

Depth of the well is the distance from the top of the casing to the bottom of the well including casing, open bore hole, or screen (see figure 1). Well depth was determined from the well construction reports for the drilled wells surveyed. The average depth of the 63 wells drilled into the sandstone aquifer is 111.3 feet. The 28 wells terminating in the sand and gravel aquifer average 69.6 feet in depth.

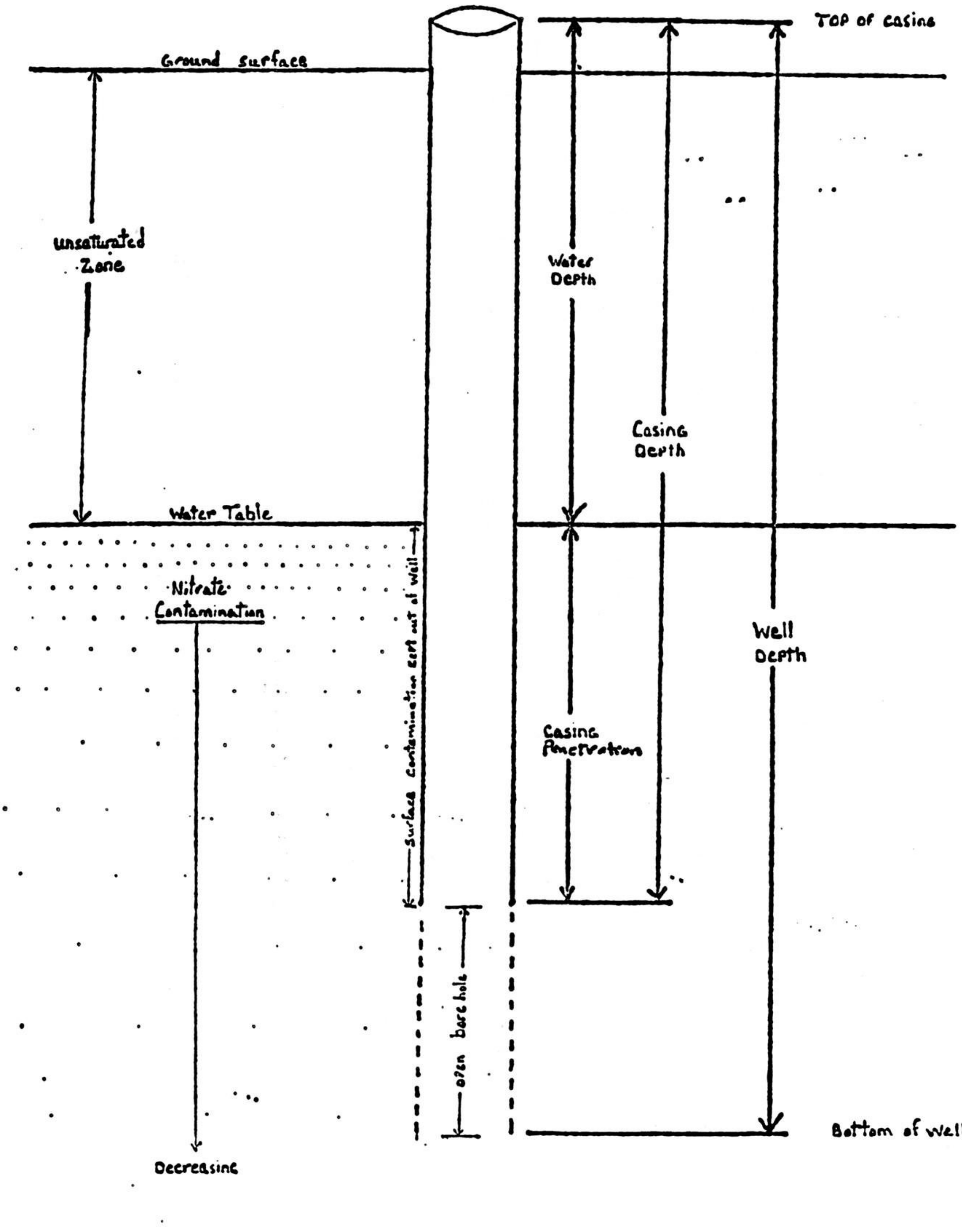
The depth of casing penetration of the aquifer is an important construction feature. It is expressed as the distance in feet from the water table to the bottom of the casing (see figure 1). This number is positive when the casing extends below the water table and negative when it ends above the water table. Casing penetration for the surveyed wells varied from +123 feet to -49 feet.

Generally, three situations exist regarding casing penetration. They are:

1. Bedrock is not encountered. Sand and gravel is the water bearing formation, the entire well is cased, and a well screen is almost always used.

2. Bedrock is encountered before or after the water table but the casing terminates below the water table, an open bore hole continues for some distance and a well screen is not used.

Figure 1. Drilled Well Construction



3. During drilling, bedrock is encountered before groundwater. In certain situations the well driller will case the well just into the bedrock and continue drilling an open bore hole into the rock formation. In the study area the rock formation penetrated by the non-sand and gravel screened wells is sandstone.

The depth of casing penetration into the aquifer determines where within the aquifer water is being drawn. For example, a well drilled deeply into an aquifer with minimal casing and a deep open bore hole, may be drawing water from the entire depth of the bore hole including the top of the aquifer. On the other hand, a shallower well drilled into the same aquifer, cased to a deeper depth, would draw water from deeper within the aquifer.

Figure 2 is a graphic illustration of why casing penetration is so important. It points out well construction situations encountered throughout the study.

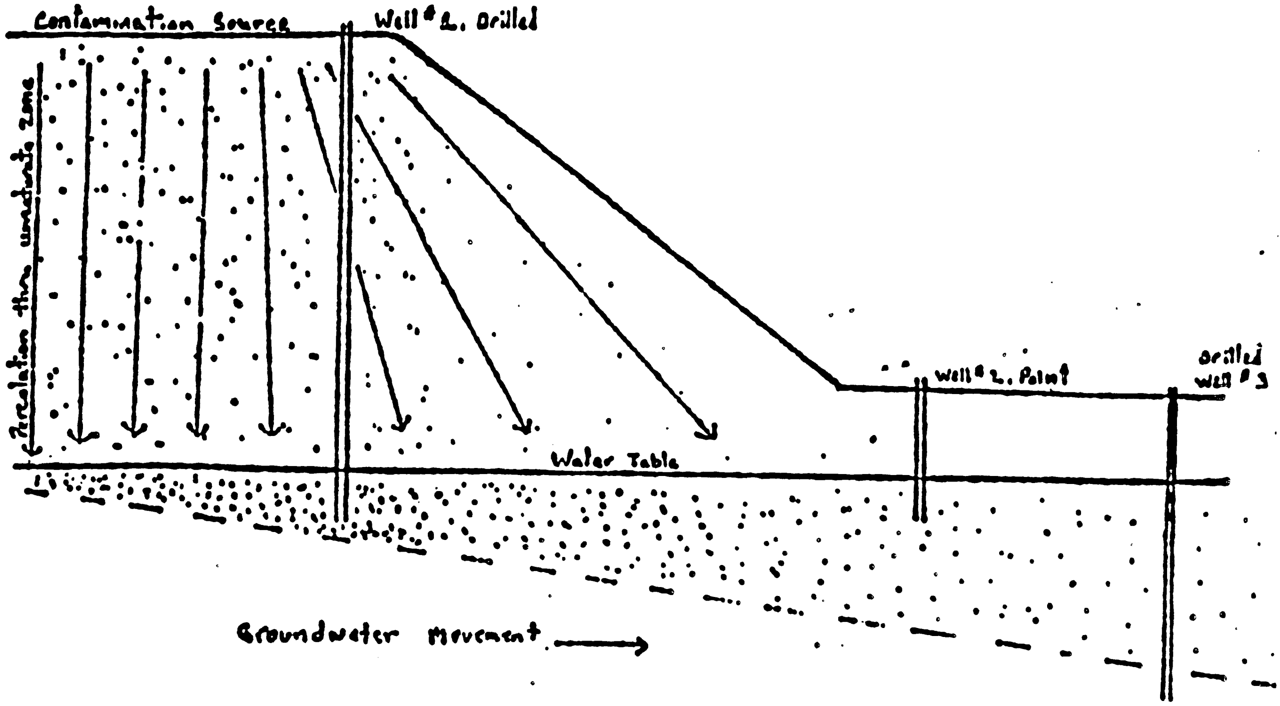
Well #1 is a drilled well near several onsite contamination sources. The depth to groundwater is great because of the surface elevation. The well is terminated shortly after penetrating the water table and is drawing nitrate contamination from the pollution plume where its concentration is greatest.

Well #2 is downgradient from well #1 in both surface elevation and groundwater elevation. This is a driven point well which terminates in the contamination plume near the groundwater surface.

Well #3 was drilled deep enough to avoid the pollution plume and therefore is producing better quality water than well 1 or 2. Both well 1 and 3 are the same depth but the water quality is vastly different.

These situations are presented to demonstrate the possibilities that exist in the unseen, underground water resource that 100% of Barron County residents rely on. Although these are hypothetical situations, they undoubtedly exist.

Figure 2. Well Elevation and Groundwater Quality



The average nitrate concentration for all wells surveyed in the three townships was 5.1 mg/l. Drilled wells had an average concentration of 4.2 mg/l and driven points 9.0 mg/l.

As expected, driven point wells tapping the relatively shallower depths of the sand and gravel aquifer were found to have an average nitrate concentration considerably higher than that of the deeper drilled wells. This was especially evident in Barron and Dallas Townships where the nitrate concentration for driven point wells averaged nearly five times that of drilled wells. In Prairie Lake Township where drilled wells are relatively shallow due to the elevated groundwater, the nitrate concentration of point wells averaged about 35% higher than the value for drilled wells.

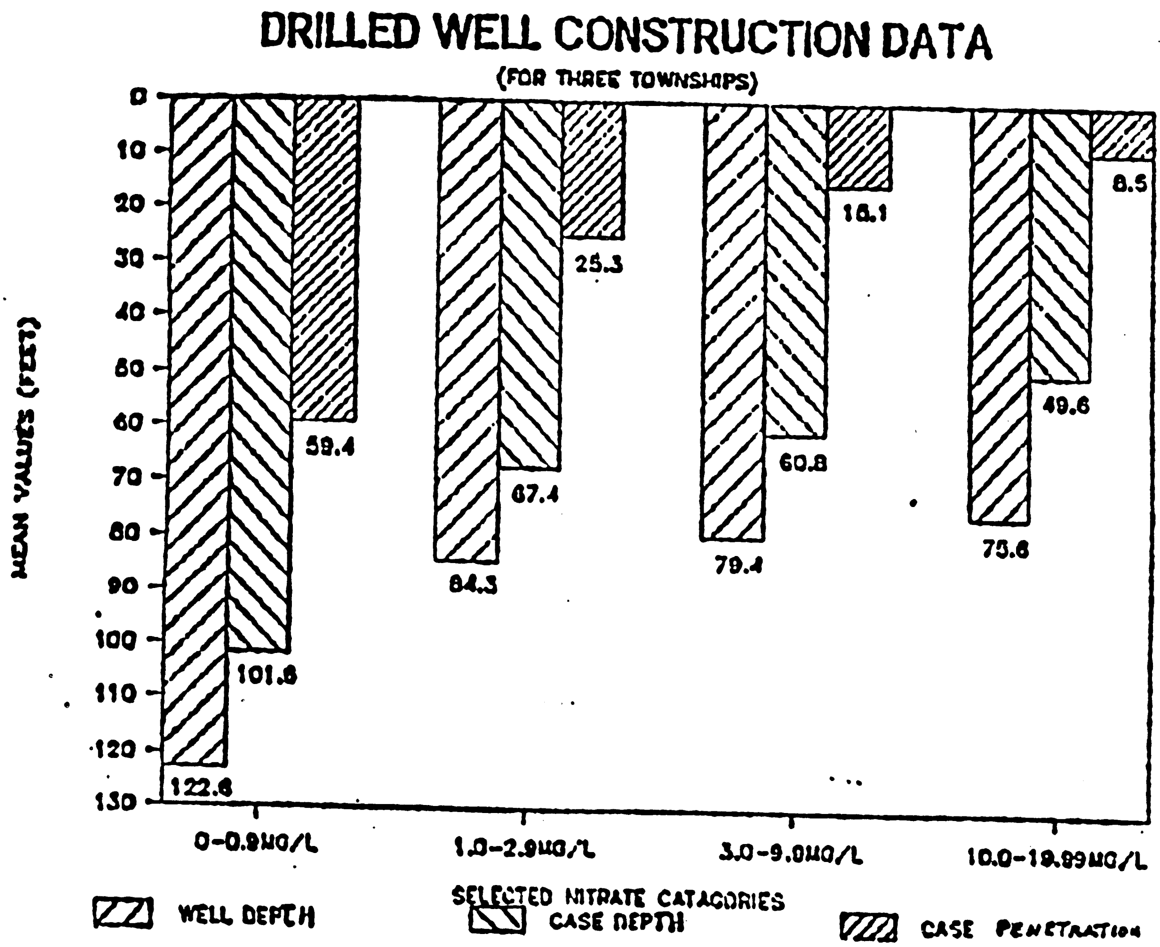
For drilled wells, nitrate concentration varied with well depth, casing depth, and the extent of casing penetration into the aquifer.

In both Barron and Dallas Townships total depth of drilled wells averages about 104 feet. All drilled wells surveyed in Dallas Township tap the sandstone aquifer. Drilled wells in Barron Township were found to be placed equally in the sand and gravel and sandstone aquifers. The average nitrate concentration did not vary between the type of aquifer utilized.

In Prairie Lake Township the total depth of drilled wells averages about 77 feet. Those utilizing the sand and gravel aquifers average approximately 54 feet in depth, while those tapping the sandstone aquifer average 88 feet. The average nitrate concentration of those wells terminating in sand and gravel was 6.9 mg/l as compared with 4.5 mg/l for those drilled into sandstone aquifer. Sandstone wells cased below the water table produced water with a nitrate value of 4.1 mg/l as compared to 5.5 mg/l for wells with the casing terminating above the water table.

Figure 3 displays average well depth, casing depth, and casing penetration of the aquifer for different nitrate concentration categories. It illustrates that nitrate levels decrease as well depth increases. It also points out the importance of casing the well adequately into the aquifer. Generally, the deeper the casing penetrates the aquifer the lower the nitrate concentration.

Figure 3.



TOWNSHIP SUMMARY & CONCLUSIONS

Appendix B summarizes nitrate data and construction information for the wells studied in the three townships. Soil score as discussed in Appendix A is also summarized.

The town of Barron, the most populated of the three townships, was sampled at 70 different locations. The mean nitrate level was 4.0 mg/l, the lowest of the three (see Appendix C). Point wells averaged 12.9 mg/l while drilled wells averaged 2.0 mg/l nitrate-nitrogen.

The outwash area north of Barron (sections 21, 22, 23, and 24) is somewhat of a problem area. This is an important agricultural and residential area where conditions such as land use, soil type, drainage and high groundwater make it susceptible to nitrate contamination. Wells with elevated nitrate concentrations were generally found to be shallow drilled or driven points.

Sampling in Dallas Township did not reveal any widespread problem areas. High nitrate concentrations seemed to be limited to scattered shallow point wells. The mean nitrate concentration for the 32 sampled wells was 5.7 mg/l (see Appendix D). Point wells averaged 12.2 mg/l while drilled wells averaged 3.8 mg/l nitrate-nitrogen. In the township, bedrock (sandstone) is generally close to the land surface. The overlying sand and gravel aquifer, where present, is thin and wells utilizing it are very shallow. These wells are very susceptible to nitrate contamination from onsite sources such as failing septic systems, barnyard drainage, and manure pits. The instance of elevated concentrations in most cases are probably due to these onsite situations rather than widespread aquifer contamination from intense agricultural activity and/or extensive concentrations of rural residences.

Forty-six wells were sampled in Prairie Lake Township. The mean nitrate concentration was 6.5 mg/l, the highest of the three townships (see Appendix E). Problems were found to be most acute in the outwash area east of the Red Cedar River and west of Prairie Lake, north of Chetek. As previously discussed this area is intensely farmed and irrigated. It is also an important recreational and residential area with numerous drilled and point wells tapping the shallow sand and gravel aquifer. Problems with high nitrate concentrations are most evident with these shallow wells. Generally, deeper wells, particularly those drilled and cased into the sandstone aquifer, produce water well below the 10 mg/l nitrate standard. Point and drilled wells utilizing the sand and gravel aquifer averaged 8.4 mg/l and 6.2 mg/l nitrate-nitrogen. The average nitrate concentration for wells drilled into the sandstone aquifer was 4.5 mg/l.

Numerous factors interacting determine to what extent the groundwater is contaminated by nitrate. Evaluating and addressing these factors presents a complex task relative to controlling nitrate contamination at its sources.

Data generated from this study suggests, at this point, the best protection from nitrate contamination of a water supply is a properly constructed well. Driven point wells, in all three townships, were found to be very susceptible to contamination. Relatively shallow drilled sand and gravel wells, especially in Prairie Lake Township, were also found to produce water with elevated nitrate concentrations. Considering all three townships, the wells least susceptible to nitrate contamination are those drilled into sandstone and cased below the water level.

Review of Past Sample Data

Twenty-eight sampling points selected for this study had been sampled previously by Barron County Zoning or the Wisconsin Geological and Natural History Survey.

The mean nitrate value for the group in this study was 6.7 milligrams per liter. The mean nitrate value for previous samples taken was 6.0 milligrams per liter. This difference is not intended to indicate nitrate levels are increasing with time. There are seasonal fluctuations of nitrate values especially in very shallow wells located in areas where the groundwater is near the surface. The samples in this study were taken over a period of three months (September through November, 1986). The previous samples were collected over a period of three years (83-85) and nine months throughout those three years. Therefore, a valid conclusion or trend prediction cannot accurately be made.

In a document entitled "Groundwater Monitoring Report, a Non-community Well Nitrate Resampling", prepared by the Wisconsin Department of Natural Resources in June of 1986 the following conclusion is drawn regarding changes in nitrate levels over time. When comparing 4,323 paired samples drawn in 1979-80 and in 1985, averaging multiple samples taken from the same facility, it was found the mean nitrate values to be 3.5 mg/l and 3.4 mg/l respectively. This suggests the change in water quality in regard to nitrate contamination is not statistically significant. Furthermore, a small number of facilities had dramatic changes in nitrate levels that can only be explained by well construction or replacement. By dropping the same sample data of facilities that decreased more than 20 mg/l from the paired samples (total of 9 facilities, i.e. less than 1/2 of 1% of all paired samples) the change in nitrate levels is even less significant.

RECOMMENDATIONS

Homeowners, particularly in the agricultural areas of Barron County should be made aware of the vulnerability of shallow wells to contamination by landuse practices. Sampling results from driven point wells in the three townships studied indicates their susceptibility to contamination. Therefore, installation of point wells should be discouraged in areas where contamination is likely. In the three townships, critical areas would include the following: 1) sections 21, 22, 23, & 24 of Barron Township; 2) Prairie Lake Township east of the Red Cedar River; 3) areas where on-site contamination sources make a shallow well vulnerable to pollution.

It should be stressed, elevated nitrate concentrations do not themselves pose a significant health risk to the general population above the age of six months. More importantly, they indicate the vulnerability of the groundwater to contamination by other pollutants such as pesticides, petroleum products, volatile organic compounds, and other chemicals which all do pose a significant health concern.

Barron County, through the implementation of NR 145 (county delegation of the Private Water Supply Program) should consider using a well siting permit system as a means to control placement of wells in vulnerable areas. Contact afforded by a permit program could be used to educate and inform the public on the importance of properly constructed and placed wells.

An educational program which would provide information to farmers and turkey growers on how to minimize the impact of agricultural practices on groundwater quality should be implemented. Such a program could be developed by the Barron County Agricultural Extension Service, utilizing the expertise of staff affiliated with the UW Central Wisconsin Groundwater Institute at Stevens Point.

Barron County has an abundant supply of excellent quality groundwater and at present does not have extensive or serious pollution problems. Sampling investigations, though, have shown that groundwater in certain areas of the county is vulnerable to contamination. To further assess the situation, Barron County should consider the development of a groundwater management plan such as the one prepared for Rock County by the Wisconsin Geological and Natural History Survey, the County Health Department, University of Wisconsin - Extension, and the Wisconsin Department of Natural Resources. Such a document would serve to:

1. Fully identify and inventory threats to groundwater quality (i.e. landfills, land disposal wastewater treatment facilities, agricultural practices, buried fuel tanks, private waste disposal systems, manure storage structures).

2. Identify actions available for the county to take to minimize the impact from pollution sources.

3. Identify areas vulnerable to groundwater contamination. Special concern should be given to the identification and protection of recharge and catchment areas serving community wells.

4. Establish a monitoring program to assess trends in groundwater quality. Such a program should be dependent on data collected from wells with accurate well construction information. A monitoring network could include wells sampled in this project. The data base developed for this project could also be utilized to track trends in groundwater quality. Any county sampling network should be tied into the state's Groundwater Information Network (GIN) now in the process of being developed.

5. As a vehicle to educate the general public concerning the groundwater issues.

6. As an information source for licensed well drillers. Information contained in the document could be used by drillers in determining potential for contamination in a specific area. Appropriate construction methods could then be instituted to maximize well protection.

Appendix A

Soils vs. Nitrate Contamination

Well locations were plotted on township soil survey maps provided by the Barron County SCS. Each soil series was placed in one of four categories based on its nitrate attenuation potential. Each soil was given a numerical score equal to the category number it fell into. See Table 4 below:

Table 4. Soil Series in Barron County Listed by Attenuation Potential *

Soil Score			
1	2	3	4
Least Potential	Marginal Potential	Good Potential	Best Potential
Alluvial land	Adolph	Arland	Antigo
Boone	Almena	Brill	Campia
Chetek	Altoona	Chaseburg	Onamia
Cloquet	Auburndale	Crystal Lake	Otterholt
Milaca (Amery)**	Barronett	Freeon	Santiago
Cloquet-Peat Complex	Burkhardt	Gale	
Omega	Comstock	Hixton	
Peat & Muck	Freer	Spencer	
Pitted Outwash	Milaca (Amery)*		
Riverwash	Poskin		
Stoney steep land	Scott Lake		
Terrace Escarpment			
Wallkill			
Warman			

* Prepared by Alex Zaporozec, Wisconsin geological and Natural History Survey

** Modern Soil series name

Appendix B

GENERAL WELL DATA
(Mean Values - Three Townships)

Nitrate Nitrogen (NO_3-N) in MG/L

	0 - 0.9 MG/L		1.0 - 2.9 MG/L		3.0 - 9.9 MG/L		10.0 - 19.9 MG/L		20 MG/L	
Parameter*	Number of Samples	$\bar{X}$	Number of Samples	$\bar{X}$	Number of Samples	$\bar{X}$	Number of Samples	$\bar{X}$	Number of Samples	$\bar{X}$
Well Depth	31	123	26	84	40	79	9	76	N/A	
Casing Depth	29	102	25	67	35	61	7	50	N/A	
Depth to water	28	43	25	39	38	43	7	47	N/A	
Casing Penetration	28	59	22	28	35	18	6	3	N/A	
Casing Elev.	31	1132	23	1125	45	1094	12	1088	N/A	
Soil Score**	35	3	31	3	53	2	20	2	4	2
NO_3 (MG/L)	35	0.5	35	1.9	54	5.6	21	13.3	4	21.3

* Well depth, casing depth and depth to water are measured in feet. All elevations are measured in feet above mean sea level. Casing penetration is measured in feet below the water table. Average signified by $\bar{X}$.

** See Appendix A

Appendix C

BARRON TOWNSHIP
GENERAL WELL DATA

Nitrate Nitrogen (NO_3-N) in MG/L

	0 - 0.9 MG/L		1.0 - 2.9 MG/L		3.0 - 9.9 MG/L		10.0 - 19.9 MG/L		20 MG/L
Parameter*	Number of Samples/ $\bar{X}$		Number of Samples/ $\bar{X}$		Number of Samples/ $\bar{X}$		Number of Samples/ $\bar{X}$		Number of Samples/$\bar{X}$
Well Depth	23	129	10	90	12	71	2	44	N/A
Casing Depth	21	108	10	84	10	67	2	41	N/A
Depth to water	21	43	10	39	11	43	2	20	N/A
Casing Penetration	21	65	8	45	10	24	2	21	N/A
Casing Elev.	21	1156	8	1564	11	1140	2	1107	N/A
Soil Score**	25	3	14	3	18	3	8	3	N/A
NO_3 (MG/L)	25	0.5	17	2.0	19	5.6	8	13.4	N/A

* Well depth, casing depth and HOH depth are measured in feet. All elevations are measured in feet above mean sea level. Casing penetration is measured in feet below the water table. Average signified by $\bar{X}$.

** See Appendix A

Appendix D

DALLAS TOWNSHIP
GENERAL WELL DATA

Nitrate Nitrogen (NO_3-N) in MG/L

	0 - 0.9 MG/L		1.0 - 2.9 MG/L		3.0 - 9.9 MG/L		10.0 - 19.9 MG/L		20 MG/L	
Parameter*	Number of Samples	$\bar{X}$	Number of Samples	$\bar{X}$	Number of Samples	$\bar{X}$	Number of Samples	$\bar{X}$	Number of Samples	$\bar{X}$
Well Depth	4	142	5	99	13	92	N/A		N/A	
Casing Depth	4	110	5	75	11	60	N/A		N/A	
Depth to Water	4	63	5	41	11	65	N/A		N/A	
Casing Penetration	4	47	5	34	11	-5	N/A		N/A	
Casing Elev.	4	1122	5	1122	16	1147	N/A		N/A	
Soil Score**	4	4	6	2	18	3	3	1	1	3
NO_3 (MG/L)	4	0.6	6	1.6	18	5.6	3	14.8	1	24.0

* Well depth, casing depth and HOH depth are measured in feet. All elevations are measured in feet above mean sea level. Casing penetration is measured in feet below the water table. Average signified by $\bar{X}$.

** See Appendix A

Appendix E

PRAIRIE LAKE TOWNSHIP
GENERAL WELL DATA

Nitrate Nitrogen (NO_3-N) in MG/L

	0 - 0.9 MG/L		1.0 - 2.9 MG/L		3.0 - 9.9 MG/L		10.0 - 19.9 MG/L		20 MG/L	
Parameter*	Number of Samples/	$\bar{X}$	Number of Samples/	$\bar{X}$	Number of Samples/	$\bar{X}$	Number of Samples/	$\bar{X}$	Number of Samples/	$\bar{X}$
Well Depth	4	68	11	72	15	75	6	88	N/A	
Casing Depth	4	55	10	47	14	58	5	53	N/A	
Depth to Water	3	18	10	36	14	31	5	59	N/A	
Casing Penetration	3	37	9	11	14	27	4	-1	N/A	
Casing Elev.	6	1053	10	1100	17	1077	8	1087	N/A	
Soil Score**	6	1	11	2	17	1	9	2	3	2
NO_3 (MG/L)	6	0.5	11	1.9	17	5.6	9	13.1	3	20.7

* Well depth, casing depth and HOH depth are measured in feet. All elevations are measured in feet above mean sea level. Casing penetration is measured in feet below the water table. Average signified by $\bar{X}$.

** See Appendix A

050866- Barron County Nitrate
Study