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GROUNDWATER
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Wisconsin Department of Natural Resources

The Prediction of Nitrate Contamination Potential using Known Hydrogeologic Properties

By

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EXECUTIVE SUMMARY

The occurrence of nitrate in ground water is a pervasive problem because of both the ion's stability and the ubiquity of nitrate sources. In an agricultural state such as Wisconsin, many water supply wells are probably close enough to a nitrate source that they could experience contamination. Because of this extent, the problem of nitrate contamination of ground water is difficult to deal with from a regulatory standpoint. It is fiscally unrealistic to monitor all wells in the State for nitrate. At the same time, it is politically unreasonable to force all well owners to conform to stringent (and expensive) well construction standards which might reduce the potential for nitrate contamination when not all wells are in susceptible areas. The problem thus is to determine if there is a way, using readily available information, to identify those areas where the potential for nitrate contamination of ground water is high. Such identification would allow the DNR to concentrate its monitoring efforts, more stringently regulate nitrate sources, and require tougher well construction standards in those areas.

The concentration of nitrate observed in a well is related to several factors:

1. The type, size, and proximity of a nitrate source.
2. The construction and maintenance of the well, and
3. The hydrogeologic characteristics of the flow system connecting the ground surface (where sources

are located) to the aquifer in which the well is finished.

Much information on the hydrogeologic characteristics in Wisconsin is readily available from well completion reports, soils maps and bedrock and water table maps. Furthermore, these characteristics are usually distributed in a spatially consistent pattern; they can be mapped. Conversely, relatively little information exists on nitrate sources other than possible locations. It is impossible to reliably quantify the magnitude of nitrate sources throughout the State at this time. In addition, well construction parameters are not consistently distributed throughout an area. Instead, they vary with the date of construction and the driller; in many areas they are distributed almost randomly. Therefore, the set of conditions most amenable to use in the identification of the distribution of the potential for nitrate contamination is hydrogeology.

This study has examined whether this potential for nitrate contamination or even nitrate concentrations can be predicted from known hydrogeologic conditions. From nitrate analyses stored in data bases at the DNR and the State Lab of Hygiene, four study and one test townships have been selected in southern and eastern Wisconsin. Chosen for their density of existing wells and high nitrate concentrations, these townships (Genesee/ North Prairie in Waukesha County, Sun Prairie/ DeForest in Dane County, Mequon in Ozaukee County, Beloit/Janesville in

Rock County and Sturgeon Bay in Dane County) represent a variety of ground water and land use conditions.

Observed nitrate concentrations have been related to the hydrogeologic conditions at wells via a multiple regression process. That process has produced equations relating nitrate concentrations to the hydrogeologic properties of aquifer type, depth to bedrock (thickness of unconsolidated materials at a well), depth to the potentiometric surface (thickness of unsaturated materials), amount of clay in the unconsolidated materials, soil permeability, and the specific capacity of the well (a parameter partly dependent upon the hydraulic properties of the aquifer). These parameters were selected because they are readily available and because they relate to the hydraulic connection between sources and aquifers:

Parameter	Data Source	Relation to nitrate movement
Aquifer type	Well completion report	Governs pattern of flow (diffuse vs. fracture)
Bedrock Depth	Completion report	Controls vertical distance nitrates must travel between well screen & ground surface.
Water Depth	Completion report Water table maps	Nitrification is enhanced in the unsaturated zone.
Amount of Clay	Completion report	High clay content reduces movement of water & nitrate to aquifer; promotes denitrification.
Soil permeability	Soil Maps	Low permeability soil inhibits nitrification process.
Specific capacity	Completion	Crude measure of aquifer permeability; relates to ease of delivery of nitrate to well.

The multiple regression equations developed have been tested as predictors of both mean nitrate concentration and nitrate contamination potential in the Sturgeon Bay area, Door County, WI.

The study has lead to the following conclusions:

1. Despite its size, the data base for nitrate contamination of ground water in Wisconsin is weak, primarily because most of the sampled wells have not been adequately identified to allow locating them. The vast majority of nitrate samples can be located no more closely than to the nearest section.

2. The same location problem exists, although to a lesser degree, with well completion reports on file with the DNR.

3. In both instances, the DNR and Lab of Hygiene should make every effort to require proper identification of a well's location to the quarter-quarter section.

4. Because of the poor location information, it was impossible to match more than 10% of the wells from which nitrate samples had been taken with their well completion reports. Consequently, it was not possible to compare nitrate concentrations with well construction conditions and it was even necessary to estimate the hydrogeologic conditions at a well-site from township-wide maps of each parameter.

5. Despite these problems, it has been demonstrated that nitrate concentrations in ground water are statistically related to hydrogeologic conditions:
   a. The relations are dependent upon the aquifer type,
   b. There is no significant difference among the relations for broad classes of land use (agricultural versus suburban communities),
   c. The relationships are statistically very significant, generally exceeding 90% confidence, but
   d. Hydrogeologic conditions can only explain about 20% of the total variability of nitrate concentrations in an area. The rest is due to variability in well construction, nitrate sources and sampling procedures.

6. The regression equations, with independent variables arranged in order from most to least important are:

   a. For porous, consolidated media (sandstones):

   $$NO_3 = -0.03(CT) - 0.24\ (SC) -1.03(SP) + 0.02\ (WL) + 12.06$$

   b. For fractured, consolidated media (dolomites)

   $$NO_3 = 0.12(SP) - 0.02\ (WL) +0.35(SC) - 0.04\ (CT) + 6.25$$

   c. For unconsolidated media (sands and gravels)

   $$NO_3 = 0.01(SP) + 0.84\ (WL) + 0.05\ (SC) -0.14\ (CT) + 4.22,$$

   where: NO_3 is nitrate concentration (mg/l),

   SP is soil permeability (in/hr),

   WL is depth to water table (ft),

   SC is specific capacity (gpm/ft), and

   CT is clay thickness (ft)

7. These equations have all been developed from data in townships where nitrate levels are high and thus where nitrate sources are common. As a consequence, the nitrate levels which they predict should be viewed as a nitrate contamination potential based on hydrogeologic conditions. The predicted values should generally equal or exceed observed nitrates, equalling them where nitrate sources exist, exceeding observed values where there are no sources.

8. At the Sturgeon Bay test site, the equation in 6b. above has been able to predict the average concentration for nitrate for all the well samples to within 24% (predicted = 6.3; observed = 5.1). The equations should thus be useful in accurately predicting an average nitrate concentration for a township - size area, if hydrogeologic conditions for that area are known.

9. The equations can be used to predict the potential mean nitrate concentrations in townships statewide. The predicted values are a relative measure of the hydrogeologic potential for nitrate contamination. Towns showing high potential

should be more closely scrutinized by the DNR for nitrate source control and well construction codes.

10. A map overlay technique has been presented that allows identification, within a township, of where the hydrogeologic potential for nitrate contamination is high. The procedure can be used wherever well construction reports are numerous and well-documented.
    a. In a test at Sturgeon Bay, the method showed a good ability to point out those areas where observed nitrates are high (presumably where sources exist).
    b. It also indicated many areas where the hydrogeologic potential for nitrate contamination is high, but nitrates are either low or unsampled. These are either areas where the monitoring array is inadequate to detect high nitrates or where no sources exist. These areas require as much regulatory attention as those where high nitrate concentrations have already been observed.

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ABSTRACT

Nitrate contamination of ground water supplies is a serious concern for the State of Wisconsin. This study investigates the viability of using known hydrogeologic parameters of an area to predict the nitrate contamination potential of ground water in the area. One township from each of Dane, Ozaukee, Rock, and Waukesha Counties was chosen for this nitrate study. The townships were chosen on the basis of both their mean nitrate-nitrogen concentrations and the number of exceedances of the 10 milligrams per liter nitrate-nitrogen concentration drinking water standard (EPA) in the non-private wells sampled by the Wisconsin Department of Natural Resources.

Existing nitrate analyses were provided by the Wisconsin Department of Natural Resources in Madison, Wisconsin. Due to the incomplete nature of the given nitrate data base, additional nitrate values were obtained from state and local agencies when available.

Initially, nitrate analyses were matched with hydrogeologic parameter values from corresponding well construction reports. Because of the difficulty encountered in the well construction report-matching process, hydrogeologic maps were generated using all well construction reports for the entire study region.

Hydrogeologic data was then obtained from the maps for those wells from which nitrate analyses but no corresponding well reports were available.

The compiled data set of hydrogeologic and nitrate values was analyzed using the multiple regression technique. The results from the analyses indicated that data sets must be grouped by aquifer type in order to give predicted nitrate values that are meaningful for a given site. Therefore, multiple regression equations were produced for dolomite, sandstone, and unconsolidated sediments aquifers. The most important hydrogeologic variables for predicting nitrate contamination for the different aquifer types were found to be: 1) dolomite--clay thickness, 2) sandstone--soil permeability and, 3) unconsolidated sediments-- depth to the static water level.

A test of the method used data from an independent test region (a portion of Door County) with the dolomite multiple regression equation to predict nitrate concentrations in the test region. The highest correlation r between predicted and observed nitrate concentrations for the test region was 0.60. For the test site, the following factors were found to contribute to the poor correlation between predicted versus observed nitrate concentration: 1) probable type of nitrate source (fertilizer versus non-fertilizer sources), and 2) the actual existence of a nitrate contamination source.

Although the study concentrates on the use of only hydrogeologic variables to predict nitrate concentration, well construction variables were found to be as important as hydrogeologic variables when predicting nitrate contamination potential. Source proximity, seasonal variations, and specific hydraulic properties of the hydrogeologic system should be included in future studies.

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INTRODUCTION

Objectives

There is already an overwhelming number of existing analyses for nitrate from ground water wells in Wisconsin. However, data are spread among a myriad of agencies and are often catalogued in a form which makes the information difficult to use.

Therefore, the main objective of this study is to utilize these extensive nitrate data and readily available hydrogeologic information to identify areas that are susceptible to ground water contamination by nitrate. The main premise of this study is that the nitrate contamination of ground water in Wisconsin is the result of a combination of cultural (proximity to a type of nitrate source), hydrogeologic and well construction factors. Therefore, the specific objectives for the study are to determine: 1) which hydrogeologic factors contribute to the susceptibility of ground water to contamination by nitrates, 2) whether the existing data base, in its present form, is sufficient to meet the first objective, and 3) whether the methods utilized in the study are viable. If the methods used in the study are successful in predicting nitrate contamination potential for chosen test sites, these methods will then be useful for nitrate studies at additional locations. Known or determined hydrogeologic parameters of any given site will be used in accordance with the study's methods to predict the potential for nitrate contamination of the ground water at the site.

Justification

Nitrate contamination of ground water is a serious problem. The nitrate-nitrogen concentration limit in public water supplies established by the U. S. Environmental Protection Agency in 1977 is 10 milligrams per liter (U. S. EPA, 1977). Nitrates are relatively stable in ground water and have an acute toxicity to humans and cattle (Piskin, 1973). In particular, methemaglobanemia and malformations of infants' central nervous systems and muscoskeletal systems are caused by consumption of certain quantities of nitrate contaminated water (Burden, 1961; and Dorsch, et. al., 1984). Similarly, Silver and Fielden (1980) discuss the possibility that nitrate may be converted to nitrite in the human gastrointestinal tract with subsequent formation of carcinogenic nitrosamines; health effects of long term exposure are serious.

The State of Wisconsin should be particularly concerned with contamination of its ground water supply by nitrate. First, a large portion of the state's population relies on the use of the ground water as opposed to surface water supplies. Second, the high percentage of agricultural land use makes Wisconsin an area of concern in regard to potential contamination of the ground water by nitrate from nitrogen fertilizers. Finally, the many rural areas in the state that have septic systems for sewage treatment are regions with the potential for nitrate contaminated ground water. These same rural residents usually rely on private wells for their water supply--often wells are situated very near contamination sources (septic systems).

Relatively little use has been made of the extensive nitrate data that are available, primarily because of the overwhelming amount and the widely dispersed nature of the data. Therefore, some sort of system must be established to determine which areas in the state are the most susceptible to contamination so that efforts to monitor problems can be better focused on areas where the potential for nitrate contamination is high.

In this study, readily available, regional hydrogeologic data will be used to predict where the likelihood of nitrate contamination potential is greatest (given a source). The final product will be a procedure to map the nitrate contamination potential for a region. From the resulting map, then, areas of high nitrate contamination potential could be dealt with in the following manner(s):

1. Nitrate sources within the area should be regulated or eliminated if possible.

2. Well construction codes should be reviewed--and strengthened where necessary--to reduce possible contamination.

3. Monitoring efforts should be concentrated in the problem areas and should include a systematic sampling of wells with recording of results and full name, address, and location by Township/Range and quarter-quarter section designation.

Previous Work

Numerous site specific nitrate studies have been conducted in the form of field and laboratory experiments. Hildebrand and Himmelbrau (1977) found the major sources for nitrate contamination to be 1) agricultural fertilizers, 2) septic tank systems, 3) waste treatment facilities, 4) feedlot wastes, 5) irrigation systems, and 6) natural sources from nitrogenous organics.

Various agricultural studies with some emphasis on nitrate contamination have been conducted. Studies were conducted by Pionke and Urban (1985) regarding the effect of agricultural land use on the quality of ground water. They studied 14 water wells over a 7.4 square kilometer watershed for a ten year period and found that the average concentration of nitrate as nitrogen was 1.2 mg/l underneath forestland and 7.4 mg/l underneath crop land. Piskin (1973) found that over-application of nitrogen fertilizer coupled with irrigation resulted in the leaching of nitrate to the ground water. In addition, Devitt, et. al. (1976) stated that the irrigation process created a downward hydraulic gradient and therefore allowed considerable leaching of amounts of nitrate from the soil horizon to the ground water system. Young and Hall (1977) mentioned that organically bound nitrogen was mineralized and leached following the plowing of soil that was previously permanent grassland. Spalding, et. al., (1982) used the existence of low nitrogen-15 values to suggest agricultural leachate as a source of nitrate contamination via the oxidation of soil humus. Areas of irrigated agriculture in the Central Wisconsin "sands" region and related nitrate contamination were studied by Saffigna and Keeney (1977). The above-background concentrations of nitrate-nitrogen found in their study closely reflected fertilizer and irrigation management practices for different parts of their study area (many growers fertilized in excess of recommendations).

Septic tank systems are another possible source of nitrate contamination. Brown, et. al. (1984) have concluded that much accumulated nitrogen is leached to the ground water system when a septic field dries out. Except for some ammonium adsorbed onto soil particles before its rapid conversion to nitrate, the effluent reached the water table in nitrate form (Moosburner and Wood, 1980).

A project was initiated in West Central Wisconsin in 1983 to determine the extent of nitrate contamination on a county-wide basis (Luloff, et. al., 1983). The project attempted to map nitrate information to determine if high nitrate values showed some correlation to a particular contaminant source or geologic feature. In 1985 a similar study was begun by Tinker (1987) but on a smaller scale. In Tinker's study septic system effluent was determined to be the cause of high nitrate concentrations in a subdivision of the City of Eau Claire, Wisconsin.

Urbanization may also be a source of increased nitrate concentration in ground water supplies via soil disturbing processes (Gray and Morgan-Jones, 1980). Moosburner and Wood (1980) suggested treating a residential region as a dispersed source area when dealing with regional pollution problems. Furthermore, fertilizers applied to lawns in residential areas may contribute significant amounts of nitrate to a ground water system (Porter, 1980).

Natural nitrogen can also impact a ground water system. An investigation by Kreitler and Jones (1975) used the natural variations of stable nitrogen isotopes (nitrogen-14 and nitrogen-15) to identify natural soil nitrate as the predominant nitrate source in Runnels

County, Texas. Strathouse, et. al. (1980), found that the organic nitrogen matter associated with fine-grained sediments from shales and "mudrocks" caused abnormally high concentrations of nitrate-nitrogen below the root zone. Another natural nitrogen source they discussed was a rock type with fixed ammonium bound to clay layer silicates.

Once a nitrate source exists, there is the question of whether or not nitrate contamination will reach a given aquifer. Gray and Morgan-Jones (1980) have stated that the nature of soil in the unsaturated zone and the thickness of that zone are the strongest controls on the nitrate contamination process. Nitrate leached from a source area will either be transported through the unsaturated zone or acted upon chemically/biochemically depending on the unsaturated zone's characteristics. For example, much of the nitrogen in septic tank effluent is in organic and ammonium forms, and in an oxygenated soil these forms can be converted by nitrification to nitrate that is subsequently leached to the ground water (Brown, et. al., 1984). A high degree of aeration facilitates the decay of the organic nitrogenous matter and the oxidation of ammonia, making the most favorable conditions for the formation of nitrate in the soil (Young and Hall, 1977). Piskin (1973) showed that hydraulic properties of the soil are a determining factor for the degree of nitrification or denitrification occurring above the water table. The low permeability of silty clay and clay soils accounted for the low concentration of nitrate in ground water due to the slower rates of ground water recharge to the aquifer.

Denitrification (the reverse chemical or biochemical process of nitrification) is desirable in terms of its ability to stop or limit the leaching of nitrate into the ground water system. Specifically, denitrification is the biological transformation of nitrate to gaseous forms of nitrogen (nitric oxide, nitrous oxide, elemental nitrogen) (Westerman and Tucker,1978). Denitrifying bacteria are generally heterotrophic so grow in both aerobic and anaerobic conditions.

The factors favoring the occurrence of biochemical denitrification include: 1) the availability of organic carbon energy sources for the denitrifying bacteria (Westerman and Tucker, 1978) which is in turn dependent on 2) the soil moisture content (Gambrell, et. al., 1975) and on 3) limited soil oxygen allowing the use of the oxygen content from nitrate by anaerobic respirating organisms (Young and Hall, 1977). The process of anaerobic respiration may be chemically expressed as follows:

$$5C_6H_{12}O_6 + 24NO_3^- = 6CO_2 + 24HCO_3^- + 18H_2O + 12N_2(g) \quad (1)$$

(Westerman and Tucker, 1978).

Non-biological processes of denitrification such as ammonia volatilization also occur and are influenced by complex combinations of: 1) soil texture, 2) adsorption site availability, 3) soil moisture content, 4) the species of ammonium salt present, 5) soil pH and 6) soil temperature (Westerman and Tucker, 1978).

METHODOLOGY

Introduction

When a nitrate source is available, the concentration of nitrate as nitrogen that will enter the ground water supply will depend on a variety of factors. Well construction practices, proximity to nitrate sources, and hydrogeologic parameters all are important in affecting the nitrate concentration at a given well site. However, because regional hydrogeologic information is readily available from well construction reports, agency reports, and maps, this study has attempted to isolate the influence of the hydrogeologic factors from the other factor types. Therefore, an attempt was made to derive a convenient system to predict the potential for nitrate contamination at a site based mainly on hydrogeologic factors.

The study was initiated with an already existing data base of nitrate-nitrogen analyses. When possible, well construction reports were matched with nitrate analyses in order to provide hydrogeologic information for each well sampled for nitrate concentration. When a well construction report could not be matched to a nitrate analysis, hydrogeologic information was obtained from maps generated using information from all locatable well construction reports for the study areas. The study areas are of one township/range in area according to the Western United States Land Survey System. This area is appropriate for the map generating process because in it hydrogeologic properties are averaged over a maximum of 1/16th of a square mile (or 1,742,400 square feet, 40 acres in area).

When the compilation of nitrate with matching hydrogeologic parameters was complete, statistical analyses were performed on the matched data set. Multiple regression analysis was used to determine both: 1) the rank order of importance of hydrogeologic variables in predicting nitrate contamination potential and 2) the raw coefficients to be multiplied against each hydrogeologic value from a specific site in order to predict nitrate contamination potential at that site.

Hydrogeologic Parameters Considered

The variables considered to be relevant to nitrate concentration in this study are as follows: 1) depth to static water level, 2) depth to bedrock, 3) the percentage of clay or thickness of clay in the sediments overlying bedrock, 4) soil permeability, and 5) specific capacity of the well. Previous studies have discussed the importance of the depth to water level (or thickness of the unsaturated zone) in controlling whether or not nitrate contamination will reach an aquifer system (Gray and Morgan-Jones, 1980).

Because nitrification occurs in a highly permeable soil (Brown, et. al., 1984), it follows that the thickness of the soil zone (i. e. depth to bedrock) and the permeability of that zone should be a relatively important factor in nitrate movement through an aquifer system. As nitrification is inhibited where poor soil drainage (low soil permeability) results in high soil water content (Gambrell, et. al., 1975), relative soil permeability is an important variable to considered in a nitrate contamination study. Because soil profiles with large amounts or layers of clay restrict water movement and promote anaerobic conditions favorable to denitrification (Devitt, et. al., 1976), the percent clay variable is relevant to a nitrate study. Finally, the specific capacity of the well dictates the rate and/or amount of ground water movement around the screened portion of a well, having an effect on the amount of dilution that will occur on a nitrate contaminant and the likelihood that nitrate can travel from a source. Specific capacity is defined as the well discharge per unit drop of water level in the well. It is not a constant, but is still a useful parameter because it describes the productivity of both aquifer and well in a single parameter (Bouwer, 1978). The coefficient of transmissivity of an aquifer is related to the specific capacity of a production well (Csallany and Walton, 1963), so specific capacity can be considered a crude measure of the hydraulic properties of an aquifer.

Data Sources

Nitrate data

Because nitrate analyses already exist for a plentiful number of water wells in Wisconsin, this study was initiated with the assumption that the existing nitrate data base would be sufficient for determining significant relationships between hydrogeologic variables and nitrate contamination potential. The Wisconsin Department of Natural Resources made their computerized nitrate data files available for the study. The files that were made available include: 1) a non-community DNR sampling project file ("non-private" wells sampled), and 2) a private well sampling file compiled by the State Lab of Hygiene (SLOH). The non-community nitrate file is compiled by the Wisconsin Department of Natural Resources from non-private wells that have been sampled one or more times (restaurants, gas stations, schools, stores, etc.). The SLOH file is compiled from wells sampled in private homes at the request of owners who may suspect a ground water contamination problem.

Hydrogeologic data

Hydrogeologic information is also needed for each sampled well. The main source for the hydrogeologic data is the well construction report, a form completed by the water well driller upon finishing a given well. The additional data sources that were consulted for hydrogeologic information include the following: 1) United States Geological Survey Water Supply Papers, 2) U. S. Department of Agriculture Soil Surveys (U. S. D. A., 1970, 1971, 1974, 1978), 3) Wisconsin Geologic and Natural History Survey Information Circulars, and 4) U. S. Geological 7 1/2 minute Topographic Quadrangles (See Appendix I for Quadrangles used).

Site Selection

Counties of interest

In order to select the townships to investigate during the study, the State of Wisconsin's nitrate contamination problems were first considered on a county by county basis. Two maps were scrutinized (Figures 1 and 2) to locate those counties that had a history of nitrate contamination of the ground water supply. Both maps were generated at the Wisconsin Department of Natural Resources using the nitrate data from non-community wells. The non-community (non-private) nitrate file was chosen to generate the maps because it is: 1) statewide in extent, 2) better documented in its location information than SLOH data and 3) less biased than SLOH data. The reason that the SLOH private well file is biased is because it primarily consists of analyses done at the request of well

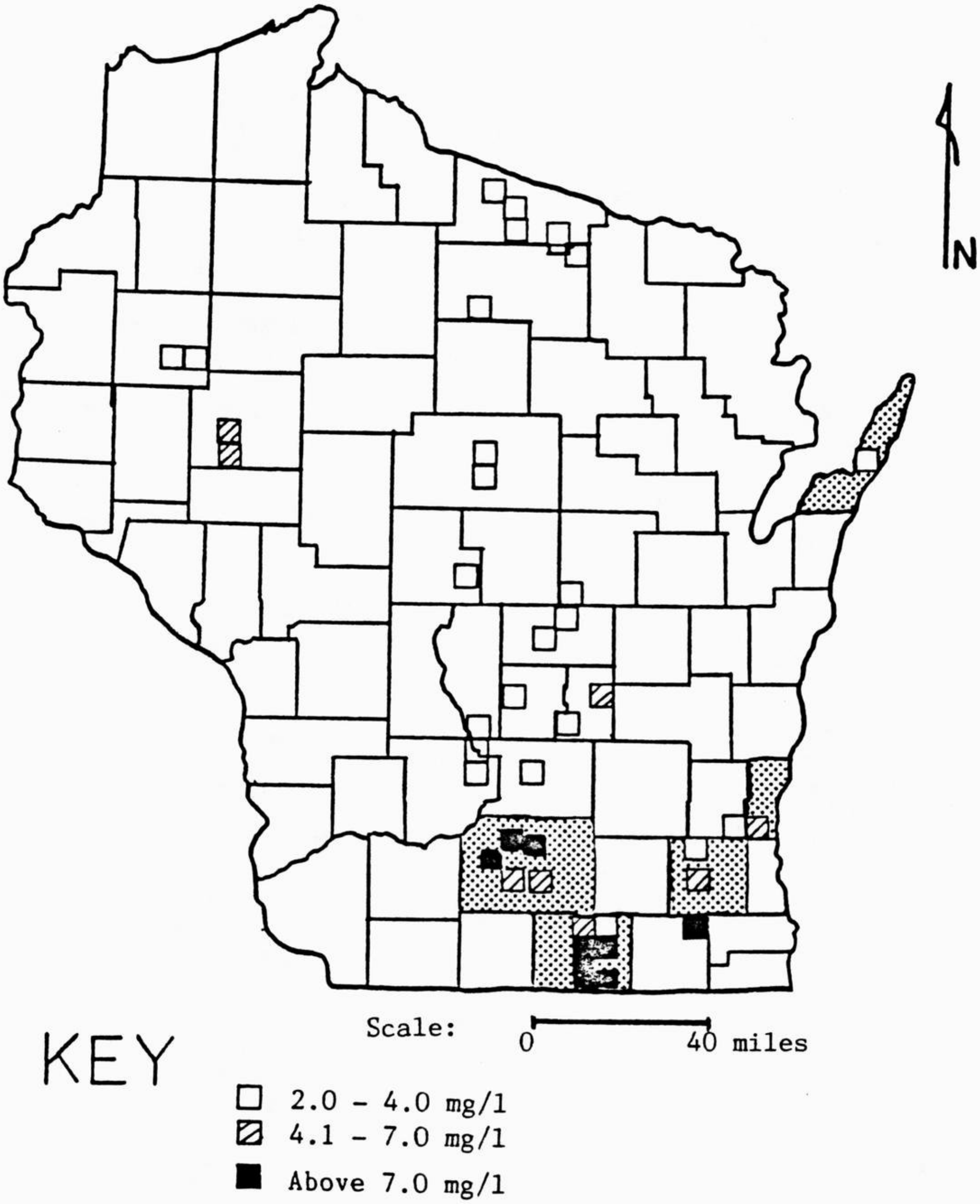


Figure 1. Mean nitrate as nitrogen value (mg/l) for those townships in the State of Wisconsin. Derived from non-community (non-private) well water samples during the Wisconsin DNR well sampling project. (Robert Strous, Department of Natural Resources, oral communication, 1986).

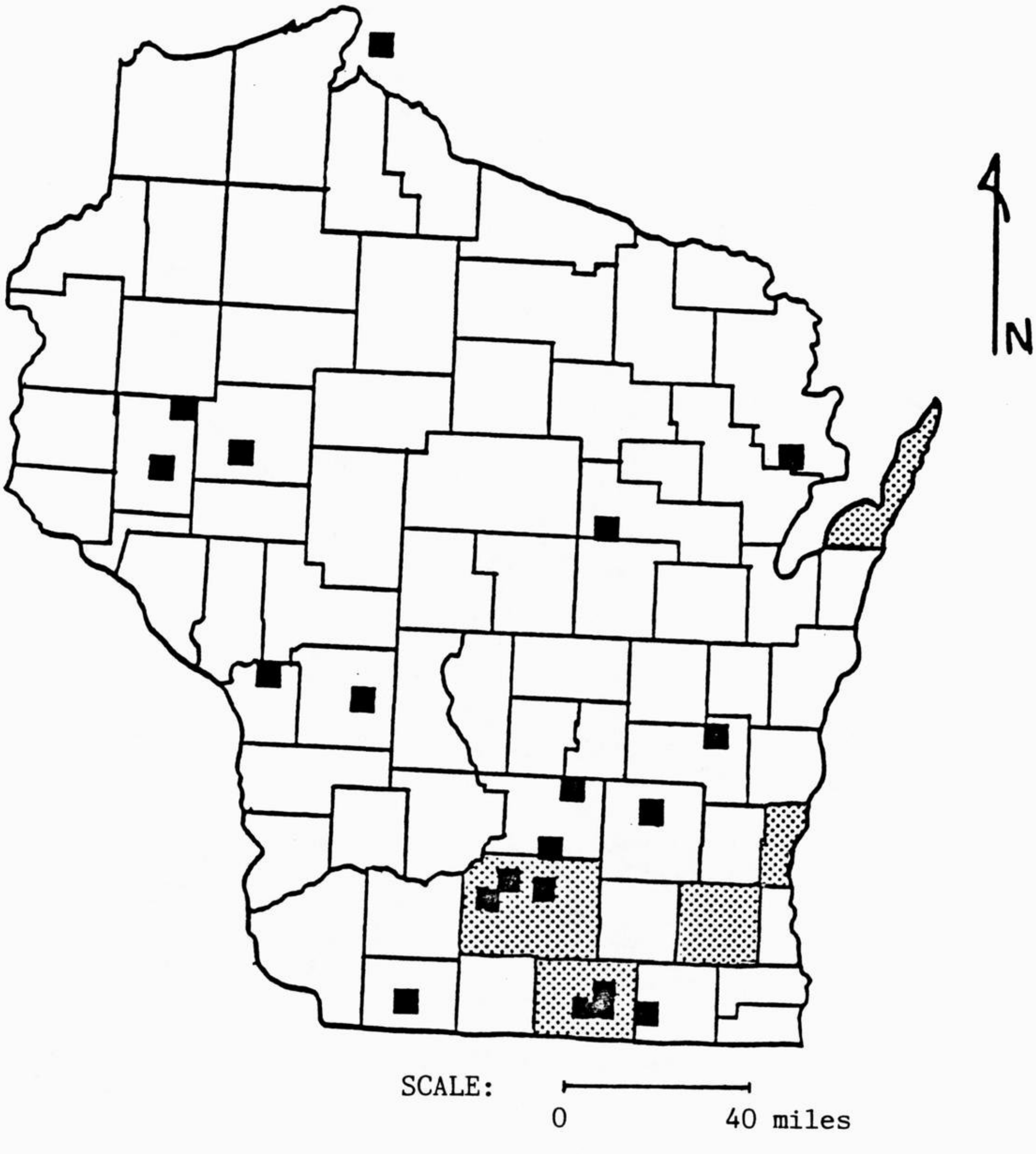


Figure 2. Townships in the State of Wisconsin (small black squares) that have ten or more non-community (non-private) well water samples that exceed the 10 mg/1 NO_3^--N drinking water limit. Determined by the Wisconsin Department of Natural Resources well water sampling project (Robert Strous, Department of Natural Resources, oral communication, 1986).

owners who may have suspected nitrate problems.

Five problem counties were then chosen on the basis of Figures 1 and 2 by noting which counties had at least some occurrence of high nitrate concentration as shown on either map. The mean nitrate-nitrogen concentration is depicted in Figure 1 in milligrams per liter for townships within each county. The townships in each county that have ten or more non-community well water samples which exceed the 10 mg/l nitrate-nitrogen drinking water limit are highlighted in Figure 2. As an additional criterion, a county was considered for the nitrate study only if it had a U. S. Department of Agriculture Soil Survey compiled and available for use. On the basis of all aforementioned considerations, the counties chosen for further study were Dane, Door, Ozaukee, Rock, and Waukesha (Figure 1).

Township selection

In order to chose the actual townships to be studied within the chosen counties, an arbitrary ranking system was set up (See Tables 1 and 2) to evaluate, on a township basis, two important nitrate parameters: 1) the mean nitrate-nitrogen concentration of all sampled non-community wells in the township, and 2) the number of available sampled wells. In other words, townships with high nitrate-nitrogen concentrations in ground water were deemed most appropriate for

TABLE 1 RANKING SYSTEM

An arbitrary scheme to rank a township's potential for further study based on the number of sample points and the average nitrate-nitrogen concentration within the township. Raw values taken both from mean nitrate-nitrogen concentration and from the actual number of sample points per township were ranked according to their frequency percentile. Rank numbers from each category were then added together. Proposed study townships were chosen partially on the basis of the combined rank number with higher ranks indicating greater potential for study. See results in Table 2.

MEAN NITRATE-NITROGEN CONCENTRATION

RANK	RAW VALUE (mg/l)	PERCENTILE
0	0--1.0	30%
1	1.1--1.9	50%
2	2.0--4.1	70%
3	4.2--6.9	90%
4	> OR = 7.0	

NUMBER OF SAMPLE POINTS PER TOWNSHIP

RANK	RAW VALUE	PERCENTILE
0	0--8.0	30%
1	9.0--15.0	50%
2	16.0--25.0	70%
3	26.0--58.0	90%
4	> OR = 59.0	

TABLE 2 RANKING OF TOWNSHIPS FOR FURTHER ANALYSIS POTENTIAL

Each township from its county of interest has been ranked on the basis of the mean nitrate-nitrogen concentration and the number of sample points according to the scheme in Table 1. The individual values are then summed to obtain the TOTAL RANK. *denotes study township.

Community Township Name	Mean NO_3^--N (mg/l) for all sample points	Number of sample points	NO_3^--N Rank	+	# of samples Rank	=	TOTAL RANK	
Waukesha County								
Big Bend	0.7	16	0		2		2	
Brookfield	0.5	102	0		4		4	
Delafield	1.8	39	1		3		4	
Dousman	1.4	11	1		1		2	
Eagle	1.1	23	1		2		3	
Elm Grove	0.5	20	2		0		2	
Genesee	2.0	7	2		0		2	*
Hales Corners	0.5	18	0		2		2	
Hartland	2.4	21	2		2		4	
Lannon	0.7	10	0		1		1	
Menomonee Falls	0.7	37	0		3		3	
Merton	6.2	3	3		0		3	
Mukwonago	1.1	26	1		3		4	
Muskego	0.5	70	0		4		4	
Nashota	3.2	13	2		1		3	
New Berlin	0.7	56	0		3		3	
North Lake	3.2	12	2		1		3	
North Prairie	7.6	18	4		2		6	*
Oconomowoc	1.7	57	1		3		4	
Okauchee	0.7	20	0		2		2	
Pewaukee	1.0	38	0		3		3	
Sussex	1.8	10	1		1		2	
Wales	1.8	12	1		1		2	
Waukesha	1.4	60	1		4		5	
Door County								
Aurora	6.9	1	3		0		3	
Bailey's Harbor	0.7	57	0		3		3	
Brussels	2.0	27	2		3		5	
Egg Harbor	1.6	46	1		3		4	
Ellison Bay	1.1	57	1		3		4	
Ephraim	0.5	42	0		3		3	
Fish Creek	0.6	70	0		4		4	
Forestville	0.5	8	0		0		0	
Sister Bay	1.1	25	1		2		3	
Sturgeon Bay	1.7	137	1		4		5	*
Washington Island	0.9	46	0		3		3	

TABLE 2 CONTINUED

Community Township Name	Mean NO_3^--N (mg/l) of all sample points	Number of sample points	NO_3^--N Rank	+	# of samples Rank	=	TOTAL RANK	
Ozaukee County								
Belgium	0.49	16	0		2		2	
Cedarburg	1.09	24	1		2		3	
Fredonia	1.4	12	1		1		2	
Grafton	1.2	12	1		1		2	
Mequon	0.74	81	0		4		4	*
Newburg	0.5	2	0		0		0	
Port Washington	0.5	15	0		1		1	
Random Lake	0.5	3	0		0		0	
Saukville	1.1	9	1		1		2	
Theinsville	0.7	42	0		3		3	
Waubeka	0.6	9	0		1		1	
Dane County								
Belleville	3.7	5	2		0		2	
Black Earth	2.0	3	2		0		2	
Blue Mounds	1.5	8	1		0		1	
Brooklyn	1.4	2	1		0		1	
Cambridge	2.3	16	2		2		4	
Cottage Grove	4.5	12	3		1		4	
Cross Plains	9.8	7	4		0		4	
Dane	0.9	5	0		0		0	
DeForest	3.4	25	2		2		4	*
Deerfield	9.6	5	4		0		4	
Edgerton	5.0	14	3		1		4	
Madison	4.6	108	3		4		7	
Marshall	4.0	6	2		0		2	
Mazomanie	2.4	7	2		0		2	
McFarland	2.7	14	2		1		3	
Middleton	6.6	16	3		2		5	
Mt. Horeb	5.3	14	3		1		4	
New Glarus	2.5	2	2		0		2	
Oregon	5.7	7	3		0		3	
Sauk City	1.6	25	1		2		3	
Stoughton	4.2	35	3		3		6	
Sun Prairie	7.4	23	4		2		6	*
Verona	5.5	13	3		1		4	
Waterloo	0.7	4	0		0		0	
Windsor	4.0	18	2		2		4	

TABLE 2 CONTINUED

Community Township Name	Mean NO_3^--N (mg/l) of all sample points	Number of sample points	NO_3^--N Rank	+	# of samples Rank	=	TOTAL RANK	
Rock County								
Afton	7.2	4	4		0		4	
Avalon	7.4	2	4		0		4	
Beloit	7.5	47	4		1		5	*
Brodhead	4.8	1	3		0		3	
Clinton	4.9	5	3		0		3	
Edgerton	5.1	25	3		2		5	
Evansville	6.2	5	3		0		3	
Hanover	5.7	4	3		0		3	
Janesville	6.2	88	3		4		7	*
Madison	2.9	4	2		0		2	
Milton	3.0	19	2		2		4	
Orfordville	5.0	4	3		0		3	
Whitewater	9.6	1	4		0		4	

study. Each of the two parameters was subdivided via a ranking scheme (Table 1). Then the values for each parameter for each township were ascertained and added to get a total rank value (Table 2). Townships with a total rank of 4 or greater were considered for the nitrate study.

The dominant land use prevalent in each township was also considered. Different land-use practices may have different associated nitrate sources and each type of nitrate source may contribute to ground water contamination in a different manner. Therefore, to attempt to minimize the influence of the land use factor in each township's statistical study, townships were chosen with one dominant land-use type, agricultural or suburban. Land use determinations were made through the use of topographic and land use maps and air photos. The following townships were chosen for the nitrate study (Table 2), locations of which are shown in Figure 3 (different community names are often used in the DNR nitrate data to describe the same regional township, therefore both communities are listed for the chosen Land Survey System township):

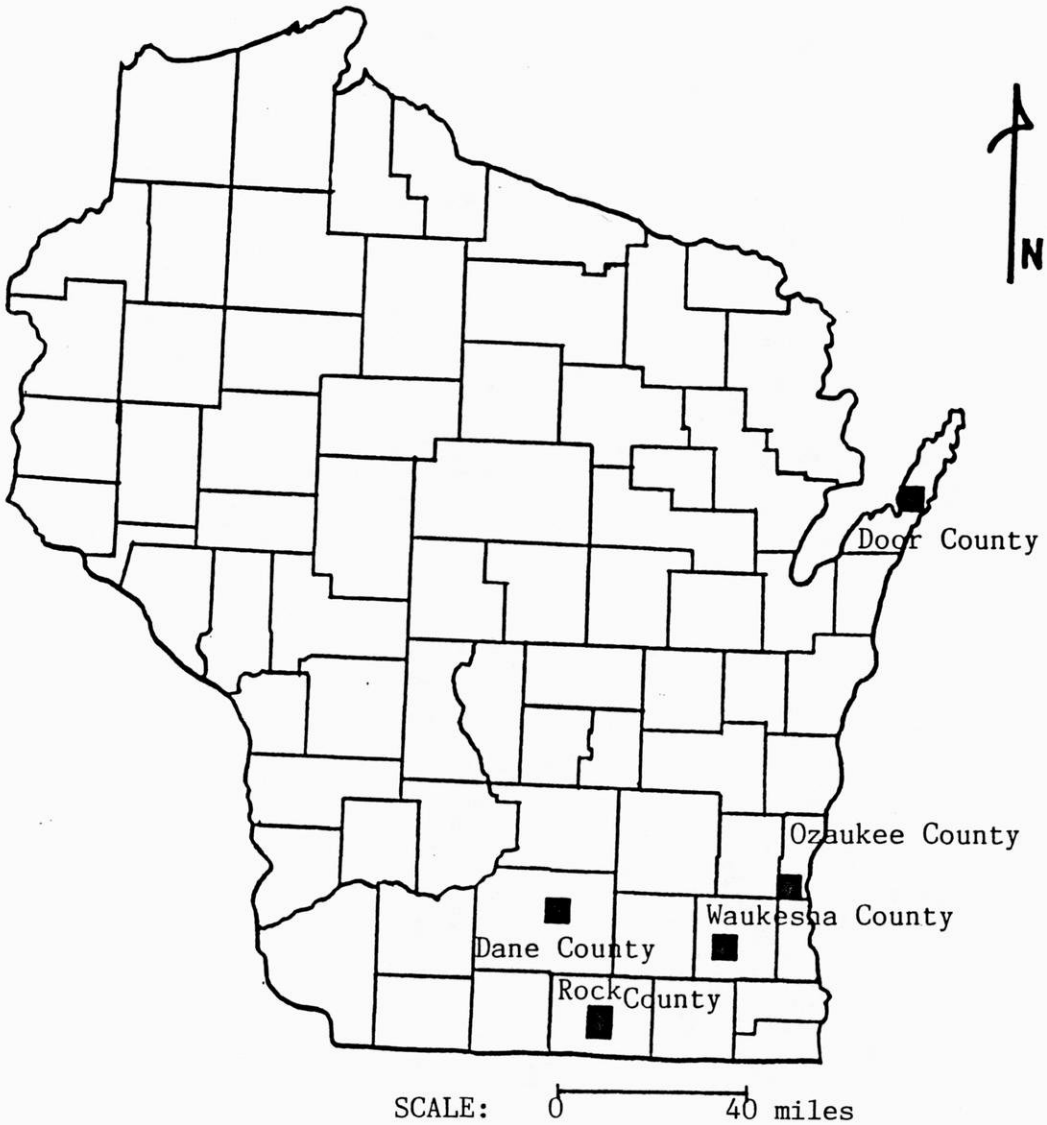


Figure 3. Map of all county boundaries in the State of Wisconsin with proposed study townships highlighted in black.

SUBURBAN County	Community Names	Land Survey System
Dane	Sun Prairie/Deforest	BURKE T8N R10E
Ozaukee	Mequon/Thiensville	MEQUON T9N R21E
Rock	Beloit/Janesville	ROCK/BELOIT T1,2N R12E

AGRICULTURAL County	Community Names	Land Survey System
Door	Sturgeon Bay	SEVASTOPOL T28N R26E
Waukesha	Genesee/North Prairie	GENESEE T6N R18E

The Door County site will be held out as a test site to be used later in the study for a test of the resulting methods.

Nitrate Data Compilation

Once the selection of the study townships was complete, ground water nitrate analyses from all possible sources were used in order to maximize the size of the well data set to be used in a statistical analysis of the relation of hydrogeologic variables to nitrate concentration. The availability of useful nitrate analyses varied by township depending upon: 1) the extent of nitrate sampling done in a township, and 2) the presence or absence of specific location information attached to each nitrate analysis. Specific location information is needed in order to later match the nitrate analysis to its correct well construction report to determine exact hydrogeologic and well construction information for the sampled wells.

Examples of the format of the DNR non-community nitrate file and of the State Lab of Hygiene (SLOH) nitrate file can be seen in Figures 4 and 5, respectively. It is evident from Figures 4 and 5 that location information is often sparse and sometimes non-existent for the DNR computerized non-community and SLOH nitrate files. For this reason, the majority of the nitrate data base that was originally thought to be sufficient to complete this study was ,in fact, not in useful form. Therefore, additional nitrate analyses were sought to expand each township's nitrate data base.

Initially, the nitrate data base for Sevastopol township was expanded by increasing the actual map area that was to be considered for the study. The resultant map area is shown in Figure 6 and includes some sections of the following townships:

TOWNSHIP NAME	TOWN/RANGE DESIGNATION
Sevastopol (original township)	Town 28N Range 26E
Sturgeon Bay	Town 27N Range 26E
Egg Harbor	Town 29N Range 26E
Jacksonport	Town 29N Range 27E
Sevastopol East Portion	Town 28N Range 27E

Because the data base was still small for statistical purposes, other agencies were consulted for additional nitrate values. The Door County Soil and Water Conservation Unit was conducting a ground water sampling project in conjunction with the Wisconsin Geological and Natural History Survey. Nitrate values and some matching well and formation information

EXAMPLE OF NON-COMMUNITY NITRATE FILE

SYSNAME	Town	Range	Section	QtrSec	QQSec
SUSSEX PLASTICS INC					
MANNIGANS CLUB A					
BURGER CHEF					
BROOKFIELD ACADEMY	0		0		
DALUMS UTILITY CO					
GERALD JONAS BUILDING	08	20E	26	SW	NE
KANDLERS RESORT	08	18E	13	NE	NW
KANDLERS RESORT	08	18E	13	NE	NW
TRIPLE T FOOD RANCH INC					
UNIVERSITY LAKE SCHOOL	0		0		
MUKWONAGO CO PARK-BATH HOUSE					
MUKWONAGO CO PARK-BATH HOUSE					
BROOKFIELD CONGREGATIONAL CH					
ST PAULS SCHOOL					
ST PAULS SCHOOL					
TY'S TAP					
LEPRECHAUN					
ELMBROOK CHURCH					
ELMBROOK CHURCH					
JOY AND MARTYS					
MUSKEGO PARK-PICNIC					
MUSKEGO PARK-PICNIC					
TALLINGERS INC					
WALES LAWN & GARDEN., INC	06	18E	04	SW	NW
WALES LAWN & GARDEN., INC	06	18E	04	SW	NW
CALVERY EVANGELICAL FREE CHR					
NAGAWAUKEE PK OFFICE W9	07	18E	21	NE	SW
NAGAWAUKEE PK OFFICE W9	07	18E	21	NE	SW
NAGAWAUKEE PK OFFICE W9	07	18E	21	NE	SW

Figure 4. An example of the location information available in the non-community nitrate file from the Wisconsin Department of Natural Resources. The non-community file is obtained by the sampling of non-private institutions (restaurants, gas stations, etc.) done by the DNR. Actual location of the well is questionable for many of the sampled wells. Township/Range/Section designation is only supplied for some of the wells. SYSNAME is the name of the establishment that was sampled for nitrate.

EXAMPLE OF SLOH NITRATE FILE

SMPDESC	CTYSTAT	TESTVAL
	STOUGHTON	0.5
	MT HOREB	0.6
	DEFOREST	3.5
	MAZOMANIE	0.6
DANE COUNTY HEALTH MADISON	SUN PRAIRIE	8.9
SAMTAX CROSS PLAINS	CROSS PLAINS	6.1
DANE COUNTY HEALTH MADISON		7.1
	COTTAGE GROVE	19
DANE COUNTY HEALTH MADISON	MCFARLAND	6.4
DANE COUNTY HEALTH MADISON	MARSHALL	0.5
DANE COUNTY HEALTH MADISON	WAUNAKEE	8.9
	STOUGHTON	0.5
	MCFARLAND	6.3
	OREGON	3.2
FRED COX COTTAGE GROVE NEAR WE	FITCHBURG	53
TERRILL DAWN MT HOREB	MT HOREB	7.7
DANE COUNTY HEALTH MADISON		0.5
DANE COUNTY HEALTH MADISON	MADISON	7.7
	MCFARLAND	17.7
DANE COUNTY HEALTH MADISON	WESTPORT	38
DANE COUNTY HEALTH MADISON		21
	MARSHALL	11.2
MADISON LAKE 2 MONONA	MADISON	0.02
MADISON LAKE 3 MENDOTA	MADISON	0.15
MADISON LAKE 4 MONONA	MADISON	0.02
MADISON LAKE 5 MENDOTA	MADISON	0.25
MADISON LAKE 6 MONONA	MADISON	0.15
MADISON LAKE 7 MENDOTA	MADISON	0.25
MADISON LAKE 8 MONONA	MADISON	0.03
MADISON LAKE 9 MENDOTA	MADISON	0.17
MADISON LAKE 10 MONONA	MADISON	0.02
MADISON LAKE 11 MENDOTA	MADISON	0.1
MADISON LAKE 12 MONONA	MADISON	0.02
BIG BUTTERNUT SURF	MADISON	0.02

Figure 5. An example of the State Lab of Hygiene (SLOH) nitrate data file available from the Wisconsin Department of Natural Resources. The SLOH file is compiled from nitrate analyses done at the request of private well owners who may suspect a nitrate contamination problem. Actual location of the well is questionable for all data points, making the file unuseable for this study's purposes. SLOH could not provide any additional location information because the private owner usually provides only a mailing address. SMPDESC is the name of the establishment or home that was sampled for nitrate, CTYSTAT is the community designation supplied by the owner and TESTVAL is the value of NO_3^--N (mg/l) resulting from the SLOH test.

Door County Expanded Study Region

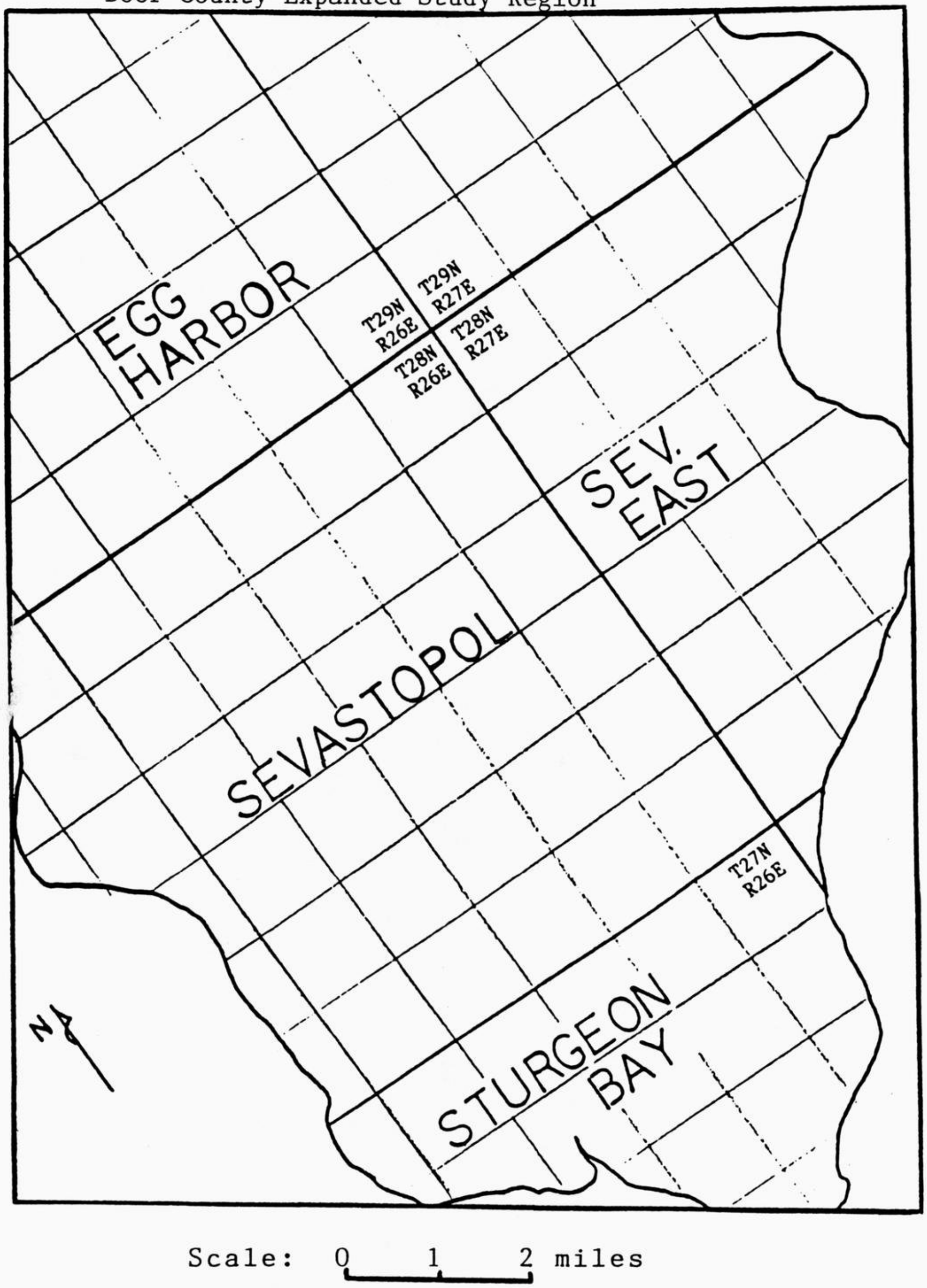


Figure 6. Region in Door County expanded for the study. Area is larger than one township (36 square miles) to include a larger number of locatable wells that were sampled for nitrate.

were made available for this study through communication with both departments (Blanchard, 1986, and Schuster and Weisbach, 1986, written and oral communication). In addition, water samples were taken in the field by this investigator in May of 1986.

Well construction information already on file with the U. S. Geological Survey in Madison, Wisconsin was used with the Survey's permission (Lidwin, unpublished data, 1986). In this way, hydrogeologic and well construction information would already be matched with each nitrate sample taken.

Well owners were contacted in the Sturgeon Bay area and water samples were collected from cooperative well owners. Then the water samples were analyzed electrometrically for nitrate in the State Soils Lab at the University of Wisconsin-Milwaukee.

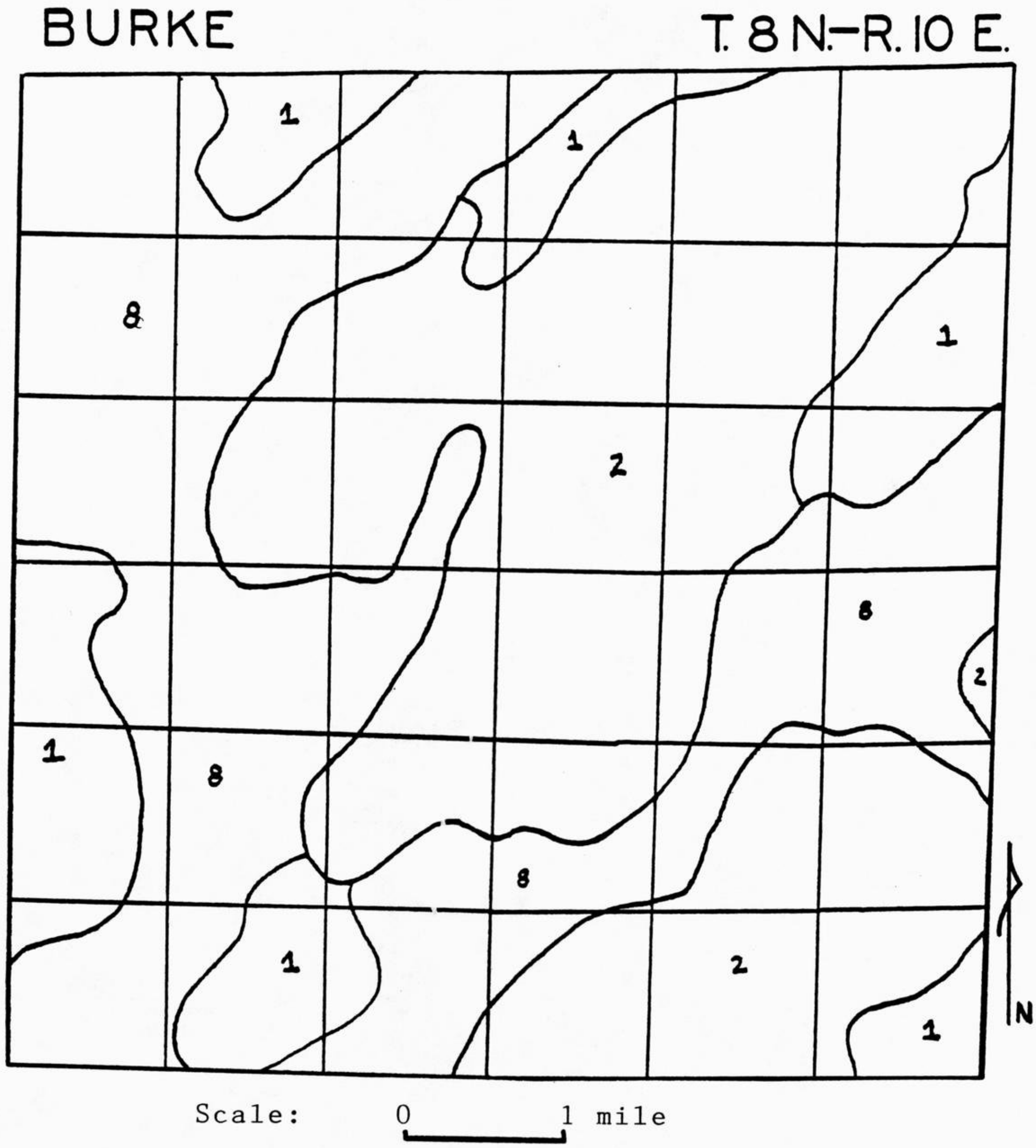
Similar procedures were followed to establish a nitrate data set for each studied township. However, the region in Door County was the only region where additional nitrate samples were taken in the field and also was the only expanded region. Additional nitrate values were sought from other city and county agencies but only for Genesee township were supplemental official data found. The Waukesha County Department of Health had nitrate data for the Genesee township (Waukesha County Department of Health, written and oral communication, 1986). Some additional nitrate values were also obtained for Mequon township from an unpublished Master's Thesis (Wehrheim, 1987). See Appendix III for index maps of well locations for all townships and data listings with nitrate values for all wells sampled in this study.

Hydrogeologic Data Compilation

In order to determine a statistically relevant relationship between hydrogeologic and well construction variables and nitrate contamination potential, the hydrogeologic and well construction information for each well sampled for nitrate had to be obtained. Soil type and permeability for each given well site were obtained from the U. S. Department of Agriculture Soil Survey Report maps. (An example of the soil map used for Burke Township is shown in Figure 7; soil maps for the other townships are found in Appendix X). However, permeabilities obtained from this source are limited in that they are valid only for the top few feet of the soil column. In any case, they are the most ubiquitous data available in counties for which soil maps exist.

Well Construction Report Matching

The well construction report was the source for the rest of the hydrogeologic and well construction data. Some well construction reports are on file with the Wisconsin DNR and are available in microfiche form. The reports are catalogued by county and further



KEY:

1 Dodge-St. Charles-McHenry Association: Well drained and moderately well drained, deep silt loams. Permeability 2.0 inches/hour.
2 Plano-Ringwood-Griswold Association: Moderately well drained, and well drained deep silt loams and loams. Permeability 2.7 in/hr.
3 Batavia-Houghton-Dresden Association: well drained and poorly drained, deep and moderately deep silt loams and mucks underlain by silt, sand and gravel. Permeability 5.2 inches/hour.

Figure 7. Soil type map for Burke Township, Dane County, Wisconsin, adapted from the U. S. Department of Agriculture Soil Conservation Survey for Dane County (1978).

subdivided into township, range and section designations, with some having quarter-section and quarter-quarter section designations.

The hydrogeologic variables that are ideally obtained from a well construction report are: 1) depth to static water level, 2) depth to bedrock, 3) thickness of clay strata within the unconsolidated sediments, and 4) specific capacity of the well. Well construction variables obtained for this study from the reports are: 1) depth of the well hole and 2) length of the cased portion of the well.

A typical example of a well completion report is shown in Figure 8. It is often impossible to match the correct well report with a given nitrate analysis due to: 1) incorrectness or lack of well location information on the report (e.g. no section number given, no quarter-quarter section designation given), 2) incompatibility between location information for the nitrate analysis and the well report (e.g. address only given versus quarter-quarter section), and 3) change in ownership or owner's name between the time the well was initially installed and the time the nitrate sample was taken. For example, a nitrate analysis or well location may only be accompanied by a street address or owner's name, both of which may change through time. Therefore, it may be virtually impossible to match the correct well construction

WELL CONSTRUCTOR'S REPORT TO WISCONSIN STATE BOARD OF HEALTH
See Instructions on Reverse Side

(3)

1. County OZAUKEE — Town ☒ Village ☐ City ☐ MEQUON (Check one and give name)

2. Location 1/4 MILE NORTH OF HY C ON HILLSIDE RD (Name of street and number of premise or Section, Town and Range numbers) — 3910-21E

RECEIVED MAR 7 1955 ENVIRONMENTAL SANITATION

3. Owner ☒ or Agent ☐ ALBERT MEISNIER (Name of individual, partnership or firm)

4. Mail Address 4071 NO GREEN BAY AVE (Complete address required)

5. From well to nearest: Building 15 ft; sewer — ft; drain — ft; septic tank 60 ft; — dry well or filter bed — ft; abandoned well — ft. —

6. Well is intended to supply water for: RESADENT

7. DRILLHOLE:

Dia. (in.)	From (ft.)	To (ft.)	Dia. (in.)	From (ft.)	To (ft.)
10	0	35	6	35	154

8. CASING AND LINER PIPE OR CURBING:

Dia. (in.)	Kind and Weight	From (ft.)	To (ft.)
6	STEEL pipe	0	67

9. GROUT:

Kind	From (ft.)	To (ft.)
PUDDLED CLAY	0	35

10. FORMATIONS:

Kind	From (ft.)	To (ft.)
CLAY	0	35
GRAVEL	35	67
LIME STONE	67	154

11. MISCELLANEOUS DATA:

Yield test: 24 Hrs. at 11 GPM.

Depth from surface to water-level: 35 ft.

Water-level when pumping: 40 ft.

Water sample was sent to the state laboratory at: MADISON (City) on FEB 28 1954

Construction of the well was completed on: FEBUARY 26 1954

The well is terminated 6 inches ☒ above, below ☐ the permanent ground surface.

Was the well disinfected upon completion? Yes X No

Was the well sealed watertight upon completion? Yes X No

Signature [signature] Registered Well Driller — 8410 W CALUMET RD Milw Wis (Complete Mail Address)

Please do not write in space below

Rec'd MAR 1 1955 No. 4696

Ans'd

Interpretation

	10 ml	10 ml	10 ml	10 ml	10 ml
Gas—24 hrs.	0				
48 hrs.	0				
Confirm					

Figure 8. Typical Example of a completed well construction report available from the Wisconsin Department of Natural Resources and used to obtain hydrogeologic and well construction information. Notice that on this example a location on a road is given, but neither the actual address nor a quarter-quarter section designation (Western U. S. Land Survey system) are given. The address shown is not that of the house in question. Rather it is the owner's address at the time he contracted to drill a well for a new house.

report with a given nitrate analysis, even if the correct report exists and is on file with the Wisconsin Department of Natural Resources.

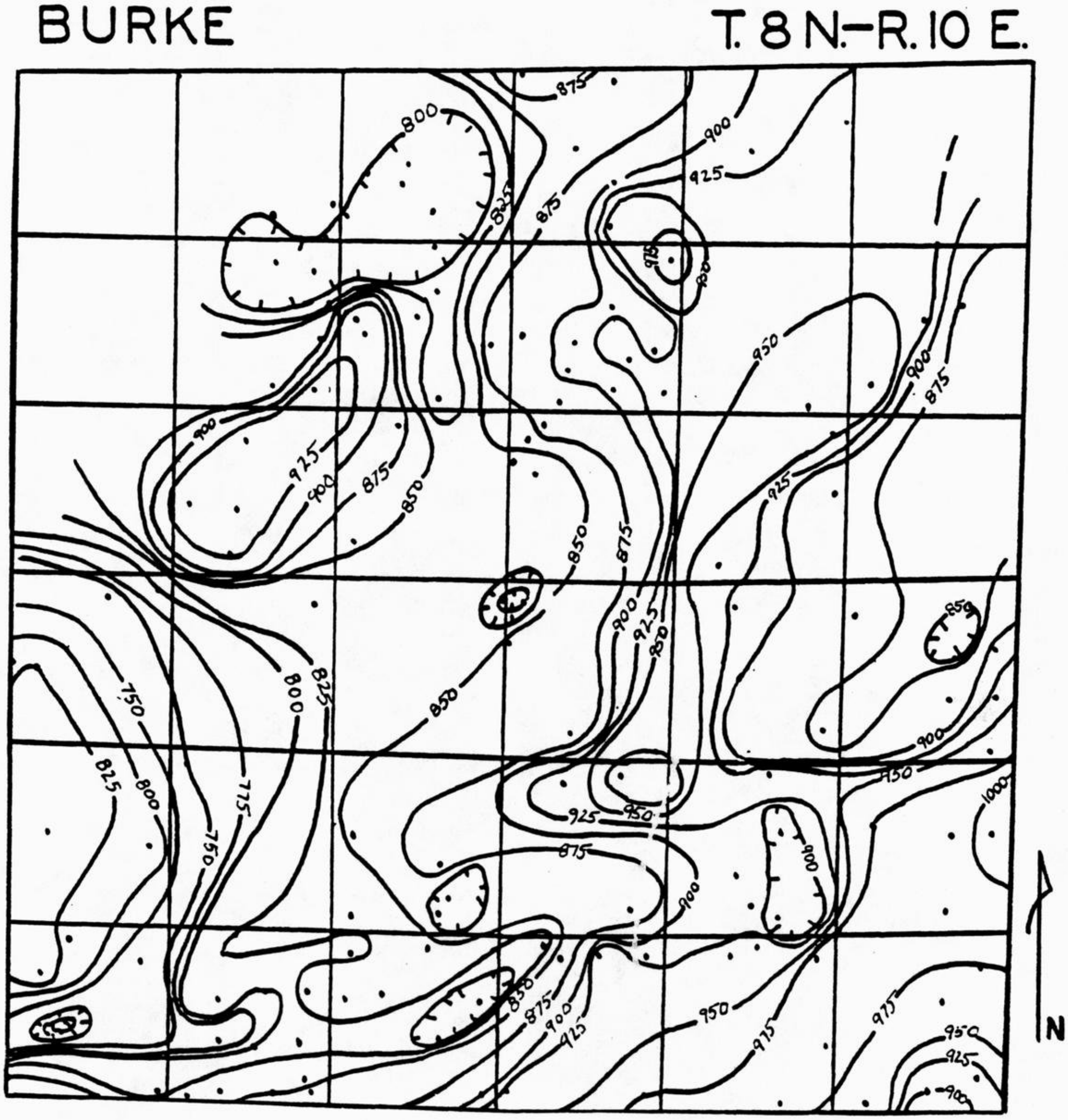
All possible matches were made between the nitrate value for a given well and its well construction report. However, the problem of matching well construction reports with nitrate values was very prevalent during the study. For example, ninety-three percent of the non-community nitrate file data for the Door County region were not useful due to one or more of the aforementioned problems. One-hundred percent of the State Lab of Hygiene Data could not be used due to insufficient location information given with each nitrate analysis.

Map Generation Process

Because the data set of nitrate values matched with correct well completion reports was still small after attempts to enlarge it, an additional effort was made to obtain hydrogeologic variable values for nitrate values without matched well reports. The method was developed to: 1) generate township-wide maps of hydrogeologic conditions, 2) locate the nitrate analyses positions on the maps, and then 3) extract a generalized value for the hydrogeologic parameter at each point. To do this, four maps were generated for each of the Burke, Genesee, Mequon, and Rock/Beloit study areas. The maps were generated using all DNR microfiche well construction reports that had location information down to the quarter-quarter section designation for each given township. Each locatable well was plotted on an index map and the hydrogeologic information was noted from each report well by well. After compilation of all the map generating data, contour maps were drawn of: 1) bedrock surface elevation, 2) potentiometric surface elevation, 3) percent clay in the unconsolidated sediments and 4) specific capacity.

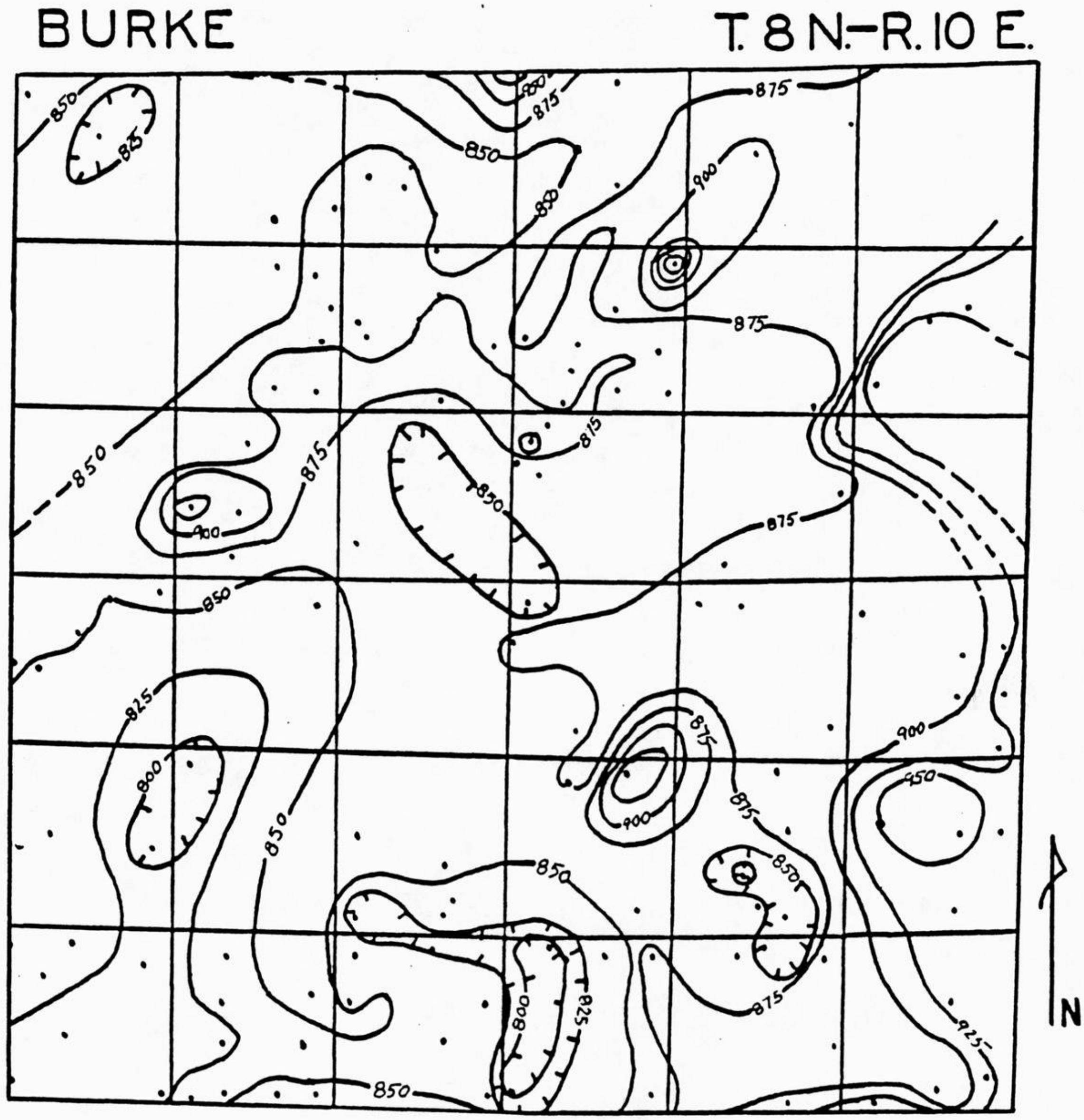
Figures 9-12 are the resultant maps for the Burke township. Maps for the other townships as well as all the data used to generate the maps and index maps of that data are found in Appendices IV - IX.

The potentiometric surface maps are based on the static water levels that are listed on the well construction report during the time of the well's completion. Therefore, uncertainties inherent in the potentiometric surface map values are as follows: 1) the "static" water level may change seasonally, 2) the static water level may change following prolonged discharge (pumping) or recharge to the aquifer, and 3) related to both 1) and 2), the water level values are obtained from well reports spanning tens of years of time. The bedrock surface elevation map is also based on depth to rock values from the well completion reports, but this parameter is more constant than the



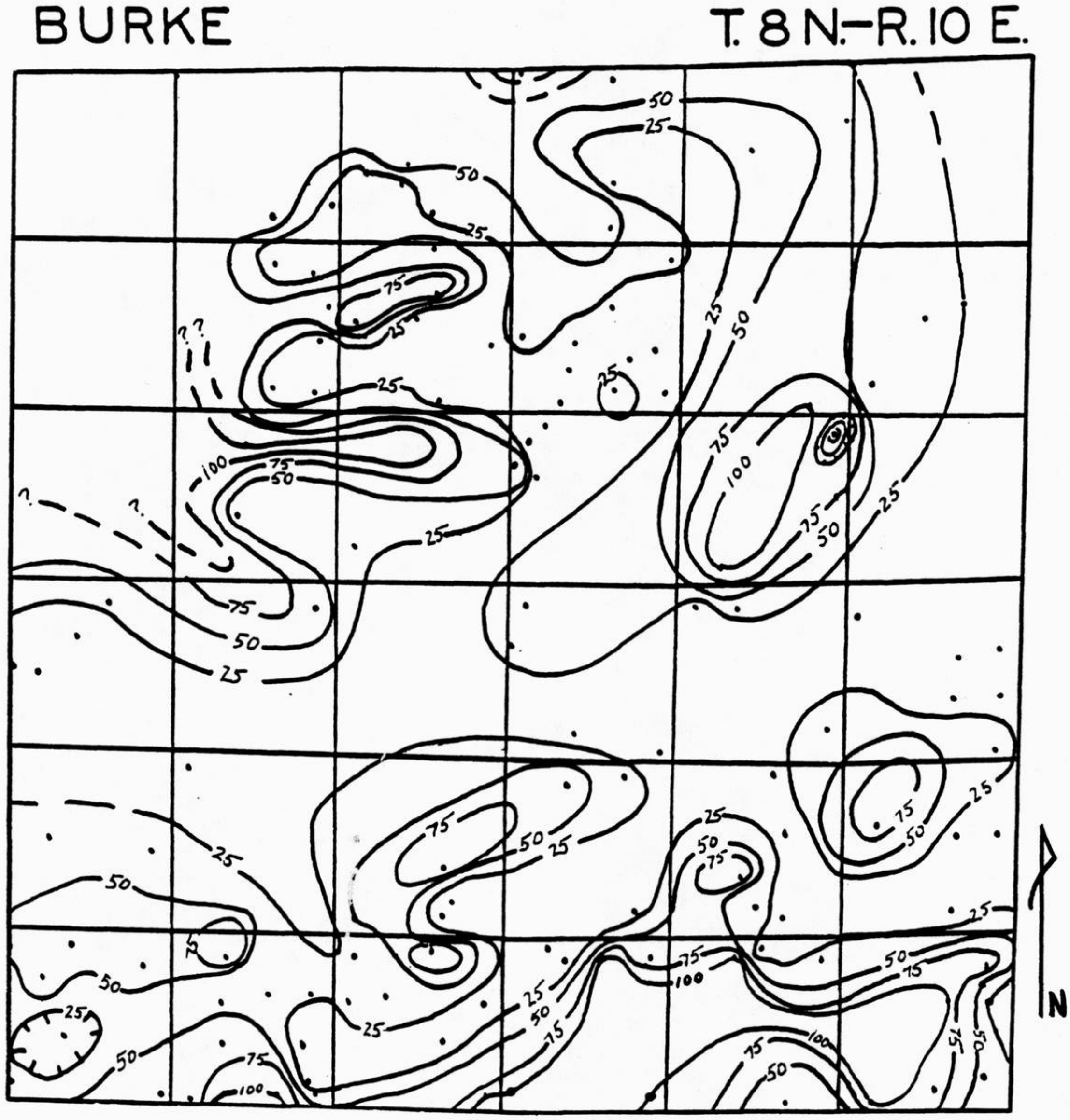
Scale: 0 1 mile

Figure 9. Map of bedrock elevation for the Burke Township (Dane County). The map was generated from all available well construction reports for the township that were located in terms of quarter-quarter section. The wells are indicated by dots. Bedrock elevations are in feet. Countour interval is 25 feet.



Scale: 0 ________ 1 mile

Figure 10. Map of potentiometric surface elvation for the Burke Township (Dane County). The map was generated from all available well construction reports for the township that were located in terms of quarter-quarter section. Elevations are in feet. The wells are indicated by dots. Contour interval is 25 feet.



Scale: 0 1 mile

Figure 11. Map of the percentage of clay in the sediments overlying bedrock for the Burke Township (Dane County). The map was generated from all available well construction reports for the township that were located in terms of quarter-quarter section and differentiated sand, gravel, and clay sediments. The wells are indicated by dots. Contour interval is twenty-five percentage points.

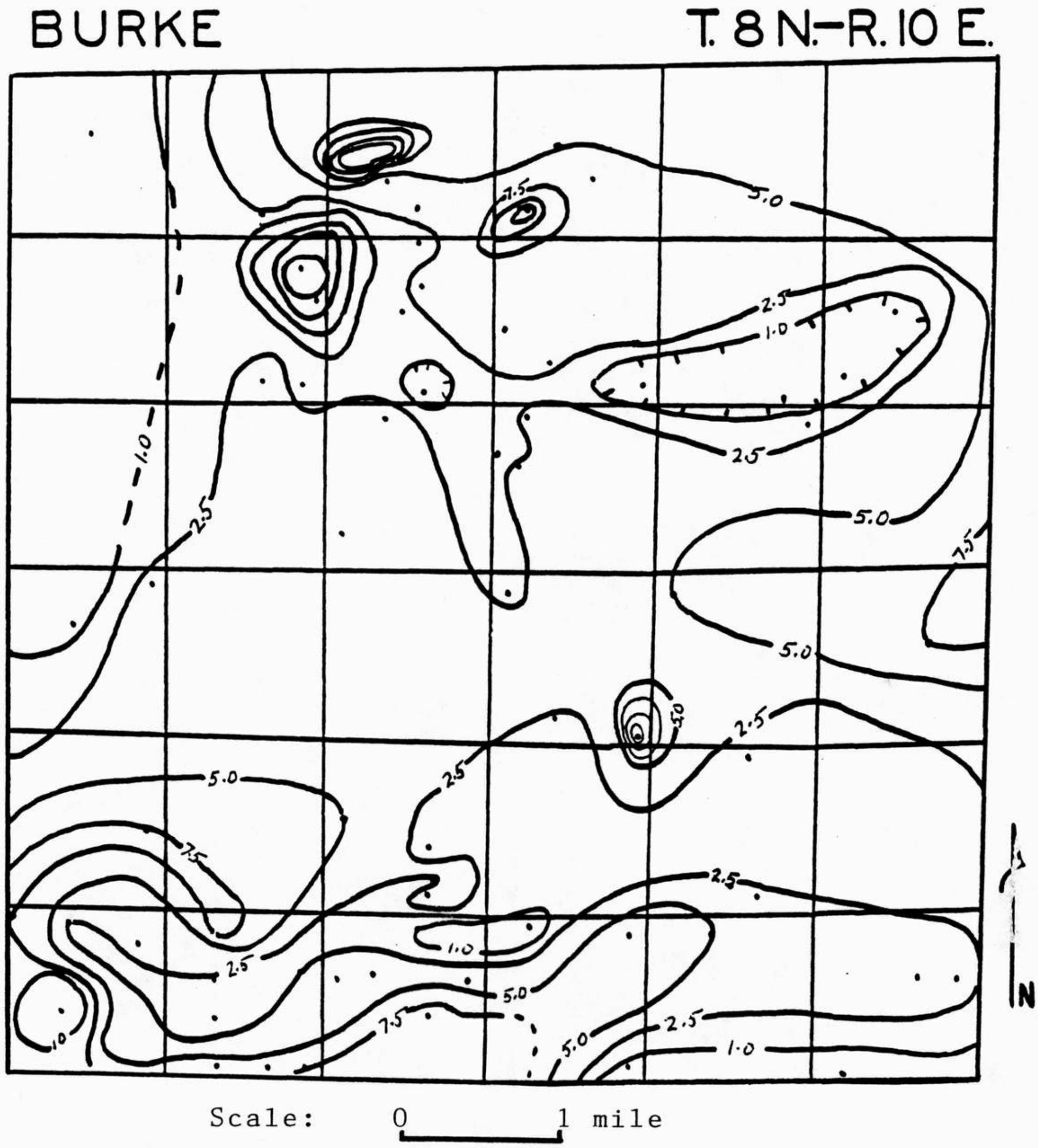


Figure 12. Map of Specific Capacity of the bedrock aquifer for the Burke Township (Dane County). The map was generated from all available well construction reports for the township that were located in terms of quarter-quarter section and also had yield tests of four hours duration and longer. Specific capacity in gallons per minute per foot of drawdown. Contour interval of 2.5 gpm/ft with the exception of the 1.0 gpm/ft contour. The wells are indicated by dots.

depth to the static water level parameter.

The values for percent clay in the unconsolidated sediments were obtained by dividing the total feet of clay labeled in the unconsolidated deposits at a given well site by the total feet of unconsolidated deposits at that site (depth to bedrock). The uncertainties involved in the percent clay calculation include: 1) different private well drillers may have different definitions of the word "clay", 2) if clay is a minute fine fraction of a sand or gravel unit, its presence (in percentage form) is not given on the well report and therefore, it is not included in the percent clay calculation.

It is debatable whether the specific capacity variable is actually a mappable parameter because it is influenced by: 1) hydraulic conductivities of an aquifer that may vary vertically, 2) the length of the uncased portion of the well hole (well screen length), 3) the radius of the well, and 4) the pumping time period (Csallany and Walton, 1963). In support of using mapped specific capacities it should be noted that, in this study, the specific capacity data are normalized to some of their possible variations. Only public and private water supply wells with 6 inch diameters were used for the specific capacity determinations (item #3, above). Only pumping yield test data that are from systems that had stabilized were used (yield test data on well construction report specifies stabilization and/or 4 hours or greater duration of test) to provide specific capacities that are normalized to pumping time period (item #4 above).

Graphs were made of specific capacity versus elevation of the well screen midpoint above sea level to analyze the importance of variable hydraulic properties that influence specific capacity in the vertical dimension in an aquifer (item #1 above). Figures 13-16 are for Genesee, Mequon, Burke, and Rock/Beloit townships. A stratigraphic control on the location of the midpoint of the well screen within the aquifer thickness would be desirable over a straight elevation based on feet above mean sea level. However, it was assumed that the stratigraphic changes over a 6 mile square region (a township's map size) were negligible for the purposes of this study. The screen midpoint elevations were obtained by the following relationship:

$$\text{Elevation of Screen Midpoint} = \text{Ground Surface Elevation} - \left[\text{Casing Length} - \frac{\left(\text{Total Depth of Well} - \text{Casing Length}\right)}{2}\right] \quad (2)$$

where ground surface elevations were obtained from U.S. Geological Survey 7 1/2 minute topographic quadrangles and the other information was obtained from well construction reports.

In the Genesee township plot (Figure 13), the majority of the wells are finished in dolomite bedrock.

WELL SCREEN MIDPOINT ELEVATION vs SPECIFIC CAPACITY: Genesee Township

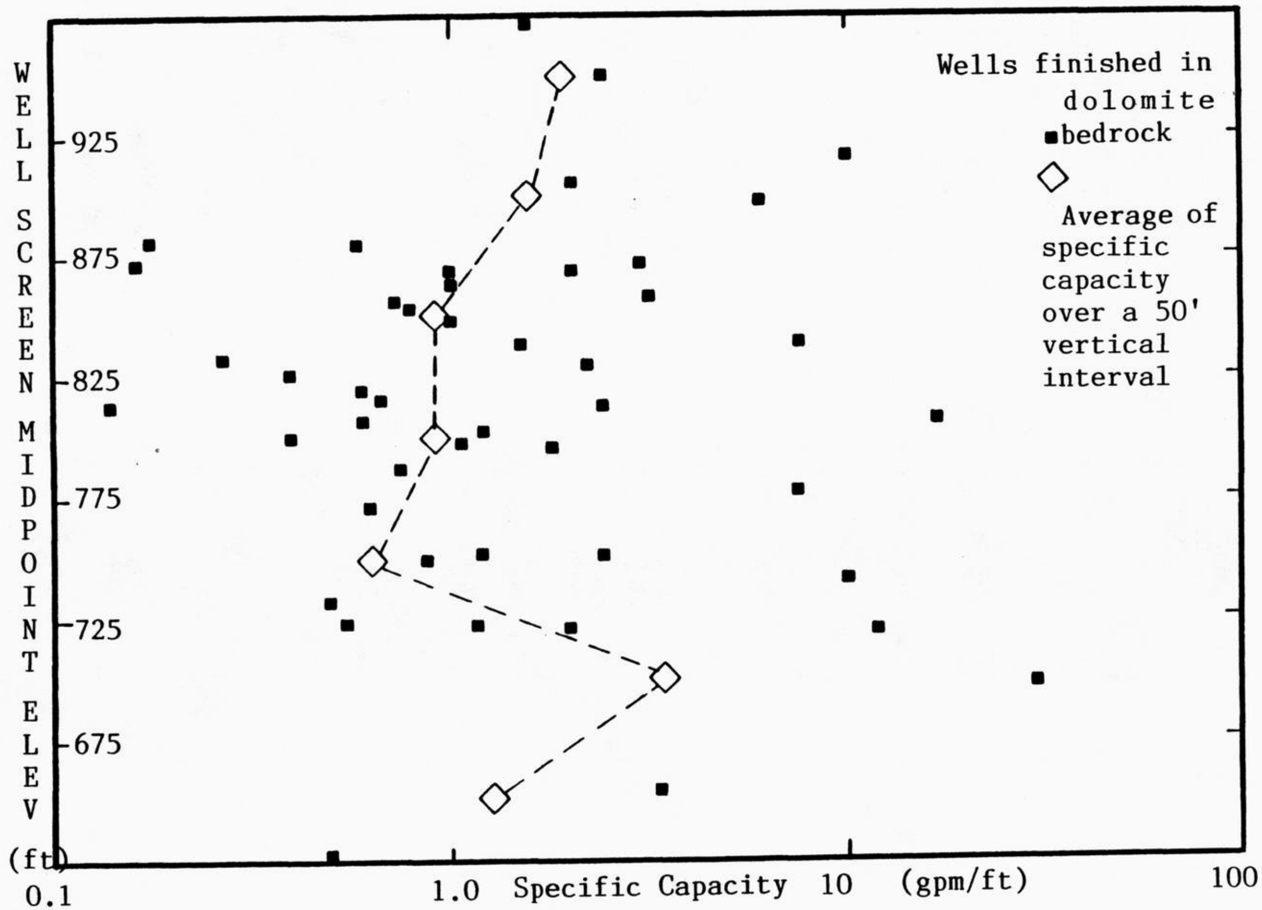


Figure 13. Graph of the elevation of the well screen (open portion) midpoint in wells finished in dolomite bedrock versus the log of the specific capacity derived from the yield test for the well. A slight decrease in specific capacity with depth is apparent from 925 feet in elevation to 725 feet, but the data points are sparse on the upper and lower regions of the graph which makes the trend questionable.

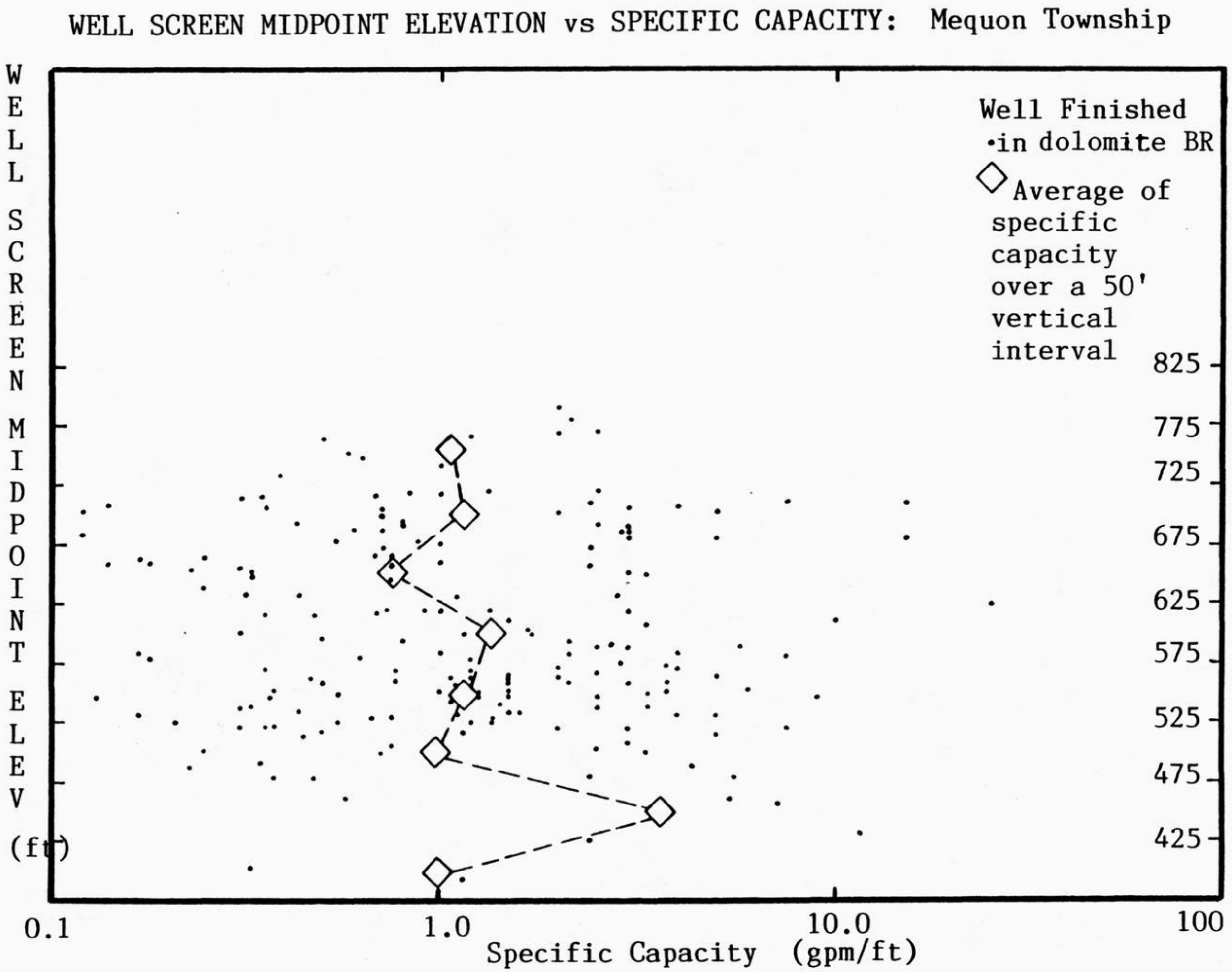


Figure 14. Graph of the elevation of the well screen (open portion) midpoint in wells finished in dolomite bedrock versus the log of specific capacity derived from yield test for the well. No apparent variation in the specific capacity with depth occurs.

WELL SCREEN MIDPOINT ELEVATION VS. SPECIFIC CAPACITY: Burke Township

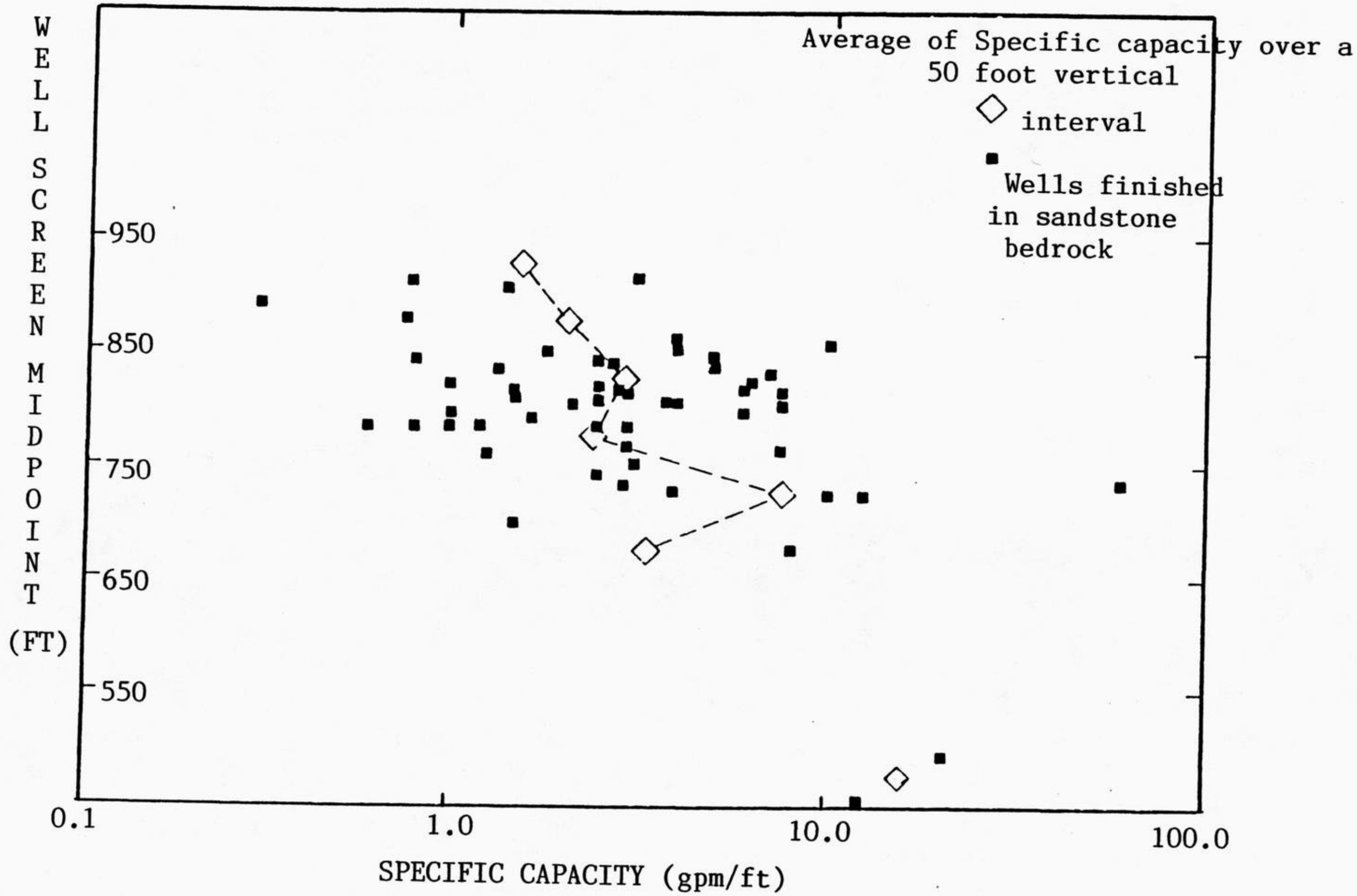


Figure 15. Graph of the elevation of the well screen (open portion) midpoint for wells finished in sandstone bedrock versus the log of specific capacity derived from yield test information for the well. The 50' specific capacity interval averages show an increase in specific capacity with depth.

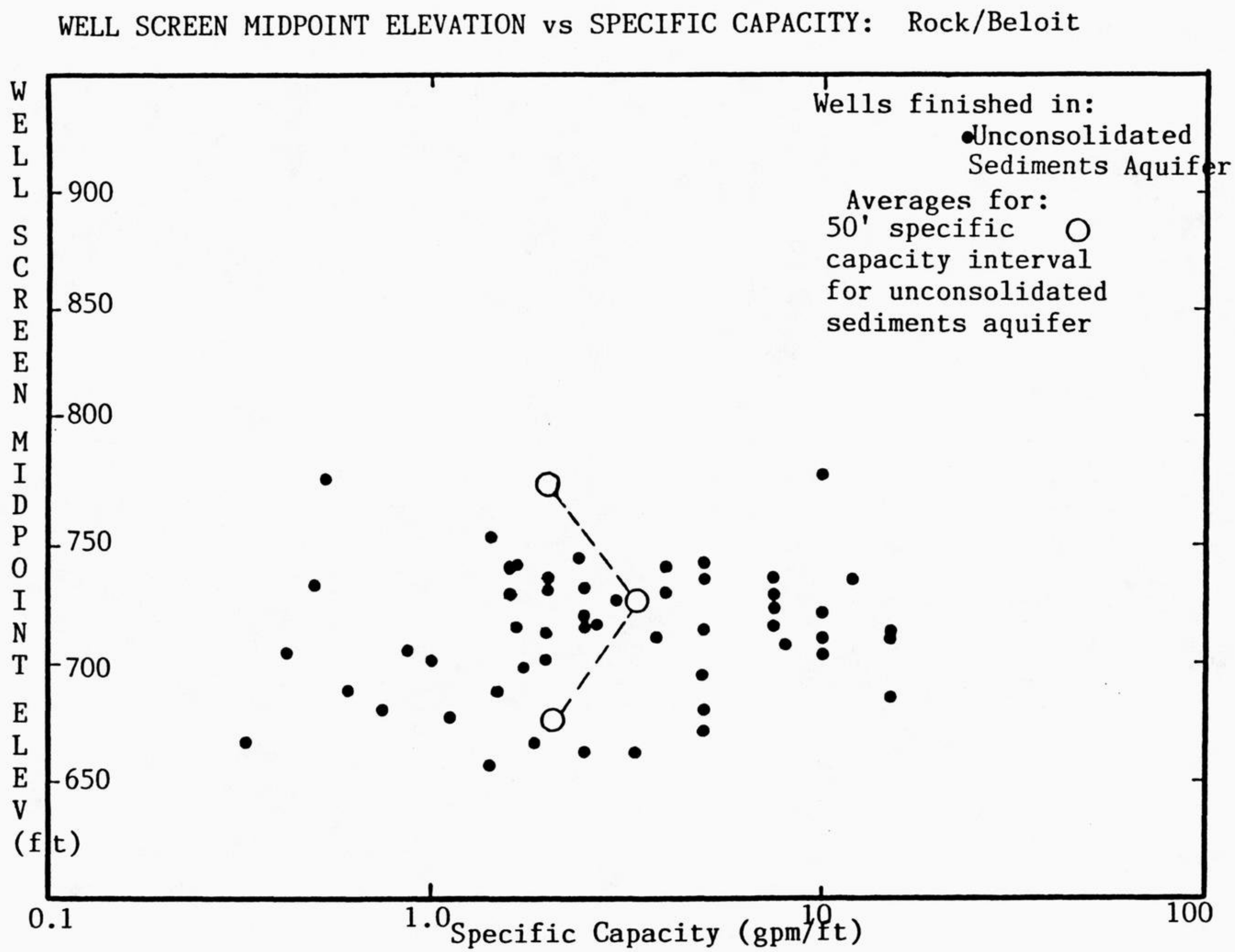


Figure 16. Graph of the elevation of the well screen midpoint (open portion) for wells finished in unconsolidated deposits in the Rock/Beloit study area. Fifty foot interval averages (open circles) show no consistent trend.

Therefore the calculated average for specific capacity over each fifty foot elevation interval (see Figure 13, average position is denoted by an open diamond shape) is an average based on only the dolomite wells' specific capacities. When the highest and lowest elevation interval averages are neglected due to the sparse number of data points in those intervals, a slight trend of decreasing specific capacity with depth is evident from 925 feet in elevation to 725 feet. However since the specific capacity variable (x-axis) has been plotted on a logarithmic scale, the actual total range of the specific capacity "trend" is from 0.64 gpm/ft to 1.6 gpm/ft which is a range of less than a factor of 3. If Figure 14 for the Mequon township (all wells finished in dolomite) is analyzed in the same manner, a range of 0.76 gpm/ft to 1.35 gpm/ft for the specific capacity "trend" is obtained which covers just more than a factor of 2. For a parameter which shows a range over 2 to 3 orders of magnitude, a "change" by a factor of 2 or 3 is inconsequential. Therefore, it has been assumed that specific capacity for the dolomite aquifer in Mequon and Genesee Townships can be treated as a vertical constant at a given map location.

Similarly, the wells depicted on Figure 15 for the Burke township are all finished in sandstone bedrock. The trend of specific capacity from the graph for Burke township is generally one of increasing specific capacity with deeper well screen midpoint elevations. Once again, the range of the specific capacity trend is from 1.82 gpm/ft to 6.2 gpm/ft which is a range covering just less than a factor of 4. Additionally, the data points for the lowest and highest 50 foot intervals are sparse, and an overall scattered pattern predominates. Again, the validity of treating specific capacity as a constant at a given map location is thus assumed for the Burke township.

The Rock/Beloit plot of specific capacity versus well screen midpoint (Figure 16) is for those wells finished in unconsolidated material. The data points do not show a consistent increasing or decreasing trend of specific capacity with depth and the range of specific capacity values is from 1.92 gpm/ft to 3.7 gpm/ft which is less than a factor of 2. Therefore, once again, specific capacity is treated as vertically invariant for a given map location for the Rock/Beloit study region.

Due to the lack of any clear trends in specific capacity with depth for any of the townships, it was assumed that a well's specific capacity within an aquifer is independent of its vertical position in the aquifer. Therefore, a two dimensional presentation of the variation in specific capacity is acceptable for the regions studied in this investigation.

Finally, the question of the effect of the length of the open portion of the well (well screen length) on specific capacity must be addressed. To normalize specific capacities to this factor, the specific capacity would be divided by the length of the well screen in each case. The normalizations were made on all the data points and then a fifth map was generated for each township of Specific capacity/(length of the well screen) (See example for Mequon Township, Figure 17). The patterns that are produced by the contour lines in Figure 17 (specific capacity normalized to well screen length) and Figure 18 (straight specific capacity) are very similar to one another. The highest values generally coincide on both maps. For example, all the regions contoured as having normalized specific capacities $\geq$ (50 gpm/ft/ft)/1000 in Figure 17 roughly coincide with regions in Figure 18 that are contoured as having straight specific capacities of $\geq$ 5 gpm/ft. The maps for the rest of the townships also have the same types of similarities and can be compared in Appendices VI through IX and XII. On the basis of the similarities, either straight specific capacities or specific capacities normalized to well screen lengths could be used for the statistical study. Raw specific capacities are easier to work with and were therefore chosen over the use of the "normalized" specific capacities.

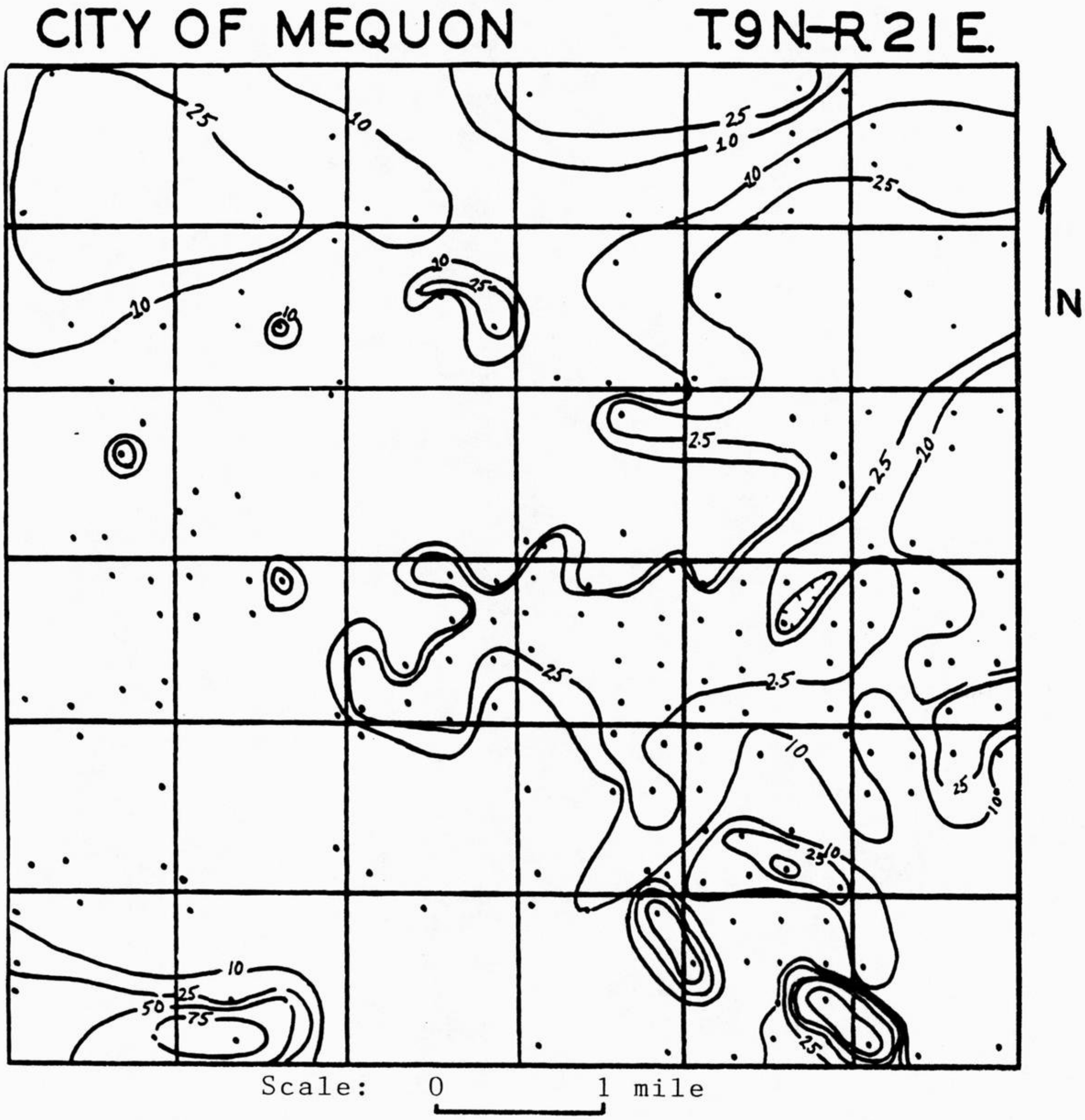


Figure 17. Map of normalized specific capacity of the wells in the bedrock aquifer for the Meqon Township (Ozaukee County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section and also had yield tests of 4 hours in duration and longer. Normalized specific capacity in (gallons per minute per foot of drawdown per foot of well screen length) X 1000. Contour intervals of 10, 25, 50, 75, etc. (gpm/ft/ft). Compare the general pattern to Figure 18 of straight specific capacity. The general patterns and the highest specific capacity regions coincide.

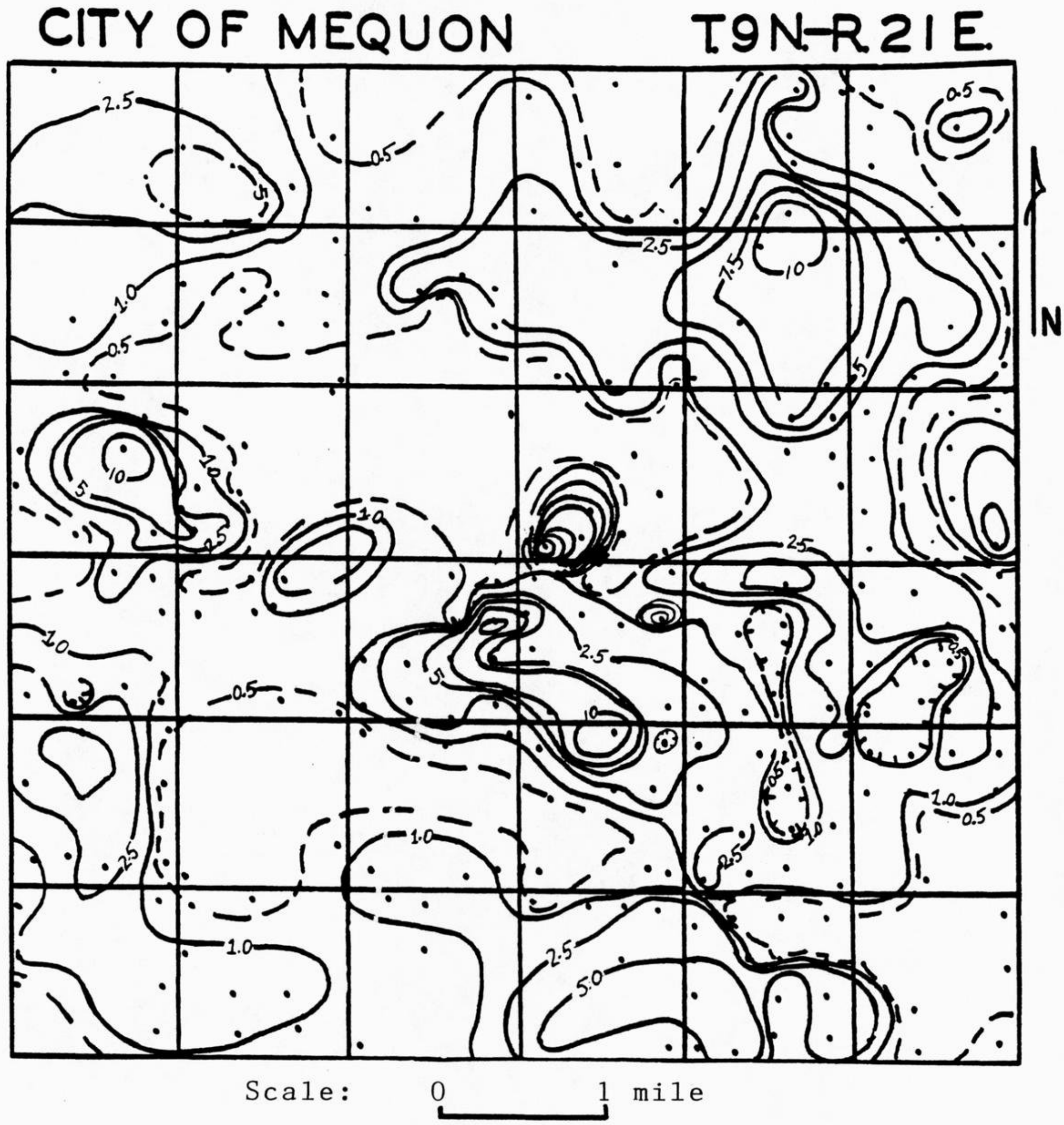


Figure 18. Map of specific capacity of the wells in the bedrock aquifer for the Mequon Township (Ozaukee County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section and also had yield tests of 4 hours in duration and longer. Specific capacity in gallons per minute per foot of drawdown. Contour interval of 2.5 gpm/ft with the exception of the 1.0 gpm/ft contour. Compare the general pattern to Figure 17 of specific capacity normalized to the length of the open portion of the well. The general patterns and the highest specific capacity regions coincide.

Statistical Analyses

The commercially prepared Lotus 123 (Lotus, 1985) spreadsheet program was used as a data bank in conjunction with an IBM AT Computer for all well and nitrate information. Appendix II lists the file of nitrate data with its corresponding hydrogeologic variables for all 5 study regions. Appendix XI lists the well construction parameters for all nitrate values with matching well construction reports. A statistical software package, STATS-2 (Statsoft, 1985), was used for performing the actual statistical analyses.

Multiple Regression Technique

In order to determine statistical relationships between hydrogeologic variables and the nitrate-nitrogen concentrations for a given region, the multiple regression analysis statistical technique was used. Multiple regression uses the values of several independent variables (i. e., hydrogeologic) to predict the value of one dependent variable (i. e., nitrate-nitrogen concentration). The multiple regression process uses a least squares solution to determine the best multiple regression equation. In other words, the process produces a best fit of the multiple regression line by determining the values of the b coefficients and the y-intercept of the regression line (see Equation 3 below) that will yield values of nitrate such that the sum of the squared deviations of the predicted nitrate values from actual nitrate values is at a minimum (Kachigan, 1982). One outcome of the process is the multiple regression equation that is used with the raw values of independent variables to predict the value of the dependent variable (nitrate concentration):

$$y' = a + b_1x_1 + b_2x_2 + \ldots b_kx_k, \qquad (3)$$

where: x_i = the raw value of the independent variable
k = the total number of independent variables
y' = the value of the dependent variable predicted by the equation
a = the y intercept of the regression line
b_i = the regression coefficient of variable x_i or the relative weight of x_i

(Kachigan, 1982).

The second outcome of the process is the multiple regression equation that provides the rank order of importance of each independent variable in predicting the dependent variable's value. The process standardizes the raw values of the independent variables in order to provide them their ranks of importance ("z scores"). Each independent variable in the standardized form of the multiple regression equation (Equation 4) has the same standard deviation and mean (Kachigan, 1982):

$$Z'_y = \beta_1 z_1 + \beta_2 z_2 + \cdots \beta_k z_k \qquad (4)$$

where: Z'_y = the standardized form (z-score) of the predicted/dependent variable

β_i = the relative weight of importance of variable i in its standardized form

k = the total number of independent variables

Analysis of Data Set

The multiple regression analysis as used for this study provided the following information that was useful: 1) an r-square value, 2) the rank order of importance of the hydrogeologic variables in predicting nitrate concentration (Equation 4), and 3) the equation to be used with the raw values of hydrogeologic variables to obtain a predicted value of nitrate concentration. The value of r-square is the portion of the variance in nitrate concentration accounted for by the variance in the independent variables. (Kachigan, 1982).

The progression of data analysis is depicted in Figure 19 in flow chart form. Initially, a multiple regression analysis was performed on the data file (called ALLDATA) consisting of all nitrate sample and hydrogeologic data points from all 4 townships (Burke, Genesee, Mequon, and Rock/Beloit). Next, similar runs were made but on subsets of data from each township. The results from the ALLDATA run and the individual township runs were compared by looking at the resulting

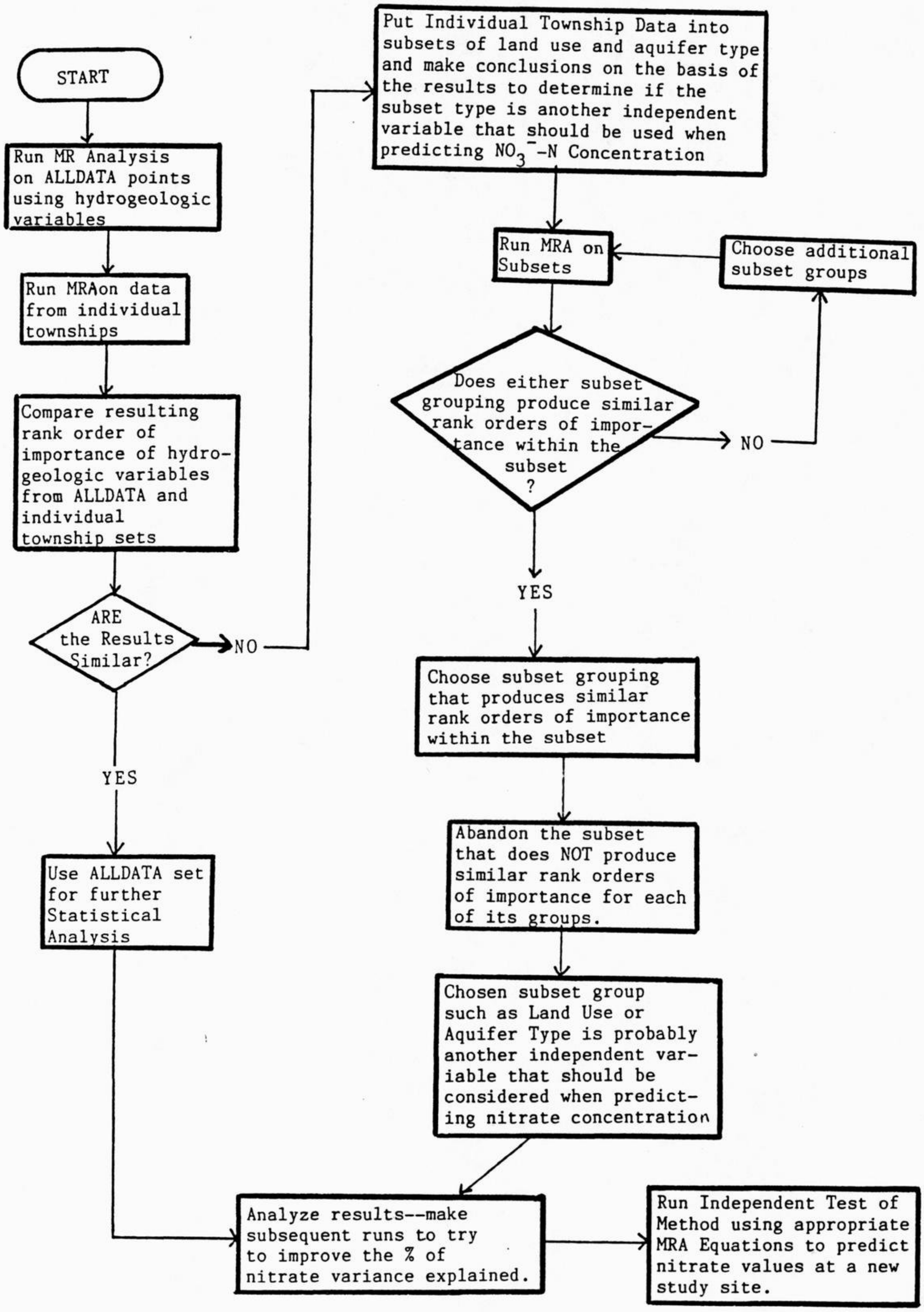


Figure 19. Flow chart showing progression of events used in analyzing the hydrogeologic and nitrate data set. MRA refers to Multiple Regression Analysis.

"rank order of importance" of the independent variables from each data set. If the rank orders of importance were similar or the same for both the ALLDATA and individual township data, then the ALLDATA file was considered as being representative of all of the data points regardless of location. Further analysis of the data was then performed using only the ALLDATA set. When the rank orders of importance were not similar, other subset groups were used to try to determine if there are additional independent variables that should be used when predicting nitrate concentration other than mere geographical location.

The two additional subsets of data that were analyzed in this investigation were grouped according to aquifer type and land use type. For the aquifer type group, dolomite, sandstone, and unconsolidated sediment subsets were compiled and analyzed. The land use group subsets were agricultural and suburban. Again, the rank orders of importance from multiple regression results were compared within subsets of the aquifer type group and within subsets of the land use type group. If rank orders of importance were dissimilar for the subsets within either group, then that group's characteristic (aquifer type or land use type) was probably an independent variable that should also have been considered when predicting nitrate concentration. Analysis then continued using the subsets of that group that was determined to be important as an independent variable. (If the rank orders of importance were similar for the subsets of either the aquifer type group or the land use type group then further analysis using the group's subsets was abandoned).

The data group(s) deemed appropriate to predict nitrate concentration were then analyzed further to improve the fit by increasing r-square, if possible. Finally, an independent test of the methodology was then initiated by using the multiple regression equation(s) generated to predict nitrate concentration in another township where hydrogeologic information and nitrate analyses are available. This township (Sevastopol, Figure 6) is independent of all the data sets included up to this point. Observed nitrate concentrations were regressed against predicted nitrate concentrations, and the resulting correlation coefficient was a measure of the effectiveness of the method.

As previously discussed, well construction practices were thought to be as important as hydrogeologic variables in influencing nitrate concentration in a region with a nitrate source. Although the main focus of this study was on the hydrogeologic factors, a final portion of the study methodology was to try to obtain an idea of the relative importance of well construction variables in predicting nitrate concentration. To this end, two more nitrate data groups were compiled. First a subset of only those data points that were derived using matched well construction reports for the hydrogeologic information was compiled. Two multiple regression analysis runs were performed on the data set using: 1) only hydrogeologic parameters as independent variables and 2) both hydrogeologic and well construction parameters as independent variables. The resulting equations and their r-square values (% of nitrate variance explained) were compared to each other to determine the relative importance of well construction practices.

RESULTS

The results of the initial step in the multiple regression analysis for this study are listed in Table 3. The initial step (Figure 19) sought to determine whether the compilation of <u>all</u> the data points from all of the townships (ALLDATA file) would yield similar, representative multiple regression results regardless of geographic location. The decreasing order of importance of the independent variables indicates that the clay thickness variable is the most important in predicting nitrate concentration (given a source) for the ALLDATA set and all of the townships except Burke. Soil permeability and depth to static water levels predominate the independent variable importance for the Burke file data. Because the Burke township results differ from the other townships and the ALLDATA set, it is possible that other independent variables besides those already utilized exist that should be used when predicting nitrate concentration. In other words, the ALLDATA set cannot be considered as being representative for data points at <u>any</u> location. Therefore, two other data groupings were analyzed and the results are shown in Table 4.

The first results listed in Table 4 are for the aquifer type data grouping. Again, a difference in the order of importance of the independent variables is apparent between the sandstone and unconsolidated

TABLE 3

Results of initial multiple regression runs. ALLDATA file combines data from all the townships. Similar rank orders of importance of the independent variables for all townships would indicate that the ALLDATA file could be used for further analysis. There is some agreement between ALLDATA and all of the townships except Burke. Each township, therefore, has some unique hydrogeologic features that affect nitrate concentration.

File Variables

1. Nitrate-nitrogen concentration in milligrams/liter
2. Soil permeability (inches per hour)
3. Depth to static water level (feet)
4. Specific capacity of well (gallons per minute per foot of drawdown)
5. Clay thickness (feet)

FILE NAME	DECREASING ORDER OF IMPORTANCE OF INDEPENDENT VARIABLES	# OF SAMPLES	% OF NITRATE VARIANCE EXPLAINED BY MR EQUATION GENERATED USING FILE'S DATA
ALLDATA	5, 4	152	15.2%
Rock/Beloit	5,2	26	12.1%
Mequon	5,2	52	25.0%
Genesee	5,3	41	21.5%
Burke	2,3	30	31.6%

TABLE 4

Results of multiple regression runs for file subgroups of land use and aquifer type. Similar rank orders of importance within a subgroup type indicate that the variable is not an additional independent variable that must be considered when predicting nitrate concentration. Differences in rank orders of importance indicate that the variable SHOULD be considered as another independent variable when predicting nitrate concentration. Results show that aquifer type must be considered when predicting nitrate concentration.

File Variables

1. Nitrate-nitrogen concentration (milligrams per liter)
2. Soil permeability (inches/hour)
3. Depth to static water level (feet)
4. Specific capacity of the well (gallons per minute per foot of drawdown)
5. Total clay thickness in the unconsolidated sediments (feet)

FILE NAME	DECREASING ORDER OF IMPORTANCE OF INDEPENDENT VARIABLES	# OF SAMPLES	% OF NITRATE VARIANCE EXPLAINED BY MULTIPLE REGRESSION EQUATION GENERATED USING FILE'S DATA
ALLDATA	5, 4	152	15.2%
Aquifer Type			
Dolomite	5, 4	88	18.8%
Sandstone	2, 3	42	21.5%
Unconsolidated	3, 4	24	21.4%
Land Use Type			
Suburban	5, 2	111	34.7%
Agricultural	5, 3	41	21.5%

groups and the ALLDATA and dolomite groups. Both the sandstone and unconsolidated groups show soil permeability and then depth to water level as being the most important predictive factors of nitrate concentration. Dolomite has clay thickness and specific capacity as its most important independent variables--identical to the ALLDATA results. Because of these differences, the importance of the independent variables is unique to aquifer type, and aquifer type should be considered as an additional independent variable when predicting nitrate concentration.

The next results listed in Table 4 are from the land use data grouping. Both the suburban and agricultural subsets' data result in clay thickness as being the most important independent variable in predicting nitrate concentration. Due to the similarity in the results, the qualification of land use type for a given data point on the basis of an agricultural or suburban qualification alone probably is not as important as the qualification into aquifer type.

A final aspect of nitrate concentration prediction that the data analysis step investigated was that of the relative importance of the use of well construction variables to predict nitrate concentration. The results of this investigation are shown in Table 5. Both multiple regression runs are on the same data sets but the second run included well construction

TABLE 5

Results of multiple regression analysis run to determine the relative importance of using well construction information to predict the nitrate concentration in addition to using hydrogeologic parameters. A data set was compiled of nitrate values with matching well completion reports. Multiple regression analysis was then performed on the data set, first using only hydrogeologic data for the independent variables and next using hydrogeology AND well construction values as the independent variables. The increased % of nitrate variance explained for the latter case indicates well construction IS important. Total depth of well was found to be the most important variable, followed by clay thickness and then specific capacity.

File Variables

1. Nitrate-nitrogen concentration (milligrams per liter)
2. Soil permeability (inches per hour)
3. Depth to static water level (feet)
4. Specific capacity of the well (gallons per minute per foot of drawdown)
5. Clay thickness (feet)
6. Total depth of well hole (feet)
7. Total depth of well that is cased (feet)
8. Depth well is cased into the aquifer (feet)

FILE NAME	DECREASING ORDER OF IMPORTANCE OF INDEPENDENT VARIABLES	# OF SAMPLES	% OF NITRATE VARIANCE EXPLAINED BY M. R. EQUATION GENERATED USING FILE'S DATA
Matched File Hydro variables only	5 Clay thickness 4 Specific capacity 3 depth to water	68	23.8%
Matched File Hydro + well construction variables	6 depth of well hole 5 clay thickness 4 specific capacity	66	39.0%

parameters as well as hydrogeologic values for the independent variables in the multiple regression process. The run with hydrogeology plus well construction explained 39.0% of the variance in nitrate concentration as opposed to 23.8% explained by the hydrogeologic variables alone. An additional 16.8% of the nitrate concentration variance was explained when using well construction parameters in addition to hydrogeologic variables. Therefore, well construction parameters are important in helping to predict nitrate concentration in a region where a source exists.

The equations that resulted after following the methodology in Figure 19 are shown in Table 6. Because aquifer type was found to be an important independent variable to consider when predicting nitrate concentration, Table 6 equations were generated from the data sets that were grouped by aquifer type. The results from the ALLDATA set (all data points from all aquifer types combined) were included for comparison.

The first equation to be listed that was generated by a given data set is the one where beta weights are the result. The beta weights provided the rank order of importance of each of the independent variables (See Multiple Regression Analysis section). In other words, if two beta weights are compared, the larger one's independent variable has a higher rank of

TABLE 6

Results from the multiple regression analysis used in this study's methodology. Results are grouped by aquifer type and compared to ALLDATA because aquifer type was found to be an important independent variable that should be considered when predicting nitrate concentration (Table 4). Results given in the form of coefficients. Beta coefficients represent RANK order of importance of independent variables. "b" coefficients are to be multiplied by the raw value of each corresponding hydrogeologic variable, and then all products are added to the y intercept ("y-int) to produce a predicted nitrate-nitrogen concentration value in milligrams per liter. SP= soil permeability in inches per hour, WL = depth to water in feet, SC = specific capacity in gpm/ft and CT = clay thickness in the unconsolidated sediments in feet.

Equation Generated from Data Set	Beta Weights				b coefficients				y-int	#of samples	r^2
	SP	WL	SC	CT	SP	WL	SC	CT			
ALLDATA	.05	-.008	+.10	-.33	.11	-.001	+.16	-.06	+7.05	152	.15
Dolomite wells	.07	-.12	+.20	-.27	.12	-.02	+.35	-.04	+6.25	88	.19
Unconsolidated wells	.04	+.37	+.30	-.22	.01	+.84	+.05	-.14	+4.22	24	.21
Sandstone wells	-.26	+.21	-.19	-.11	-1.03	+.02	-.24	-.03	+12.06	42	.22

importance in predicting nitrate contamination potential than the smaller. According to the beta weights, first total clay thickness and then specific capacity are the most important hydrogeologic variables for the dolomite data's equation (Table 6). Apparently clay thickness greatly influences the movement of nitrate through the unconsolidated sediments (i. e. the smaller the total thickness of clay, the higher the resulting nitrate concentration at the well screen). Once the nitrate enters the dolomite aquifer, specific capacity is the major control on nitrate movement (i. e., the higher the specific capacity, the higher the nitrate concentration that is drawn to the well). However, total clay thickness in the unconsolidated sediment is the most important hydrogeologic variable <u>overall</u> when predicting nitrate concentration for a dolomite aquifer. Soil permeability is the least important variable for the dolomite aquifer. This may be because the soil permeability determination is only based on the top few feet of the soil column relative to sometimes hundreds of feet of depth to the well screen.

The unconsolidated materials from which the data points of that category were taken are mainly sand and gravel outwash. The beta weights for the wells finished in unconsolidated material indicate that the depth to the static water level in the aquifer and the specific capacity are the two most important hydrogeologic variables to use when predicting nitrate concentration (Table 6). The positive designation for the beta weight of the static water level variable means that as the depth to the water level (or thickness of the unsaturated zone) increases, nitrate concentration increases. This seems intuitively correct for an unconsolidated sediments aquifer when it is remembered that a high degree of aeration facilitates the most favorable conditions for the formation of nitrate in unconsolidated sediments (Young and Hall, 1973). A thicker aerated zone may allow stabilization of the nitrate form once produced. Again, beta weights indicate that specific capacity is the most influential factor for the unconsolidated sediments aquifer once the nitrate reaches the saturated zone. Soil permeability is the least important hydrogeologic factor for the wells in the unconsolidated sediments when predicting nitrate concentration. The few feet of soil that the soil permeability parameter takes into account are probably not important relative to the tens or hundreds of feet of the aquifer depth to the well screen.

The beta weights for the data set from wells finished in sandstone bedrock show that soil permeability and depth to water level are the most important hydrogeologic variables to be considered when predicting nitrate concentraiton for the sandstone aquifer type (Table 6). It is unclear why soil permeability is most important for the sandstone aquifer and least important for the dolomite and unconsolidated sediment aquifers. Perhaps the sandstone acts more like a homogeneous and isotropic porous medium than do a fractured dolomite or more heterogeneous sand and gravel, and therefore soil permeability has a greater relative influence in the sandstone aquifers. The negative designation for the soil permeability beta weight indicates that as soil permeability decreases, nitrate concentration increases for this data set. It is also possible that the nitrate values or hydrogeologic data used for this aquifer type are incorrect values. Once again, depth to static water level is an important hydrogeologic factor for predicting nitrate concentration in sandstone aquifers. A thicker unsaturated zone yields higher nitrate concentrations because an oxygenated environment allows for the formation of nitrate from nitrogen forms (Young and Hall, 1973). The clay thickness variable is the least important variable in predicting nitrate concentration for the sandstone wells.

The second equation that is listed on Table 6 for each data set is the one with "b" coefficients. Each b coefficient is multiplied by the raw value of its corresponding independent variable (See Multiple Regression Analysis section). All the resulting products of b coefficients and hydrogeologic variables are then summed and added to the y intercept of the multiple regression line to produce a predicted nitrate value at a given data point.

The last result in Table 6 is the r-square result. This number indicates the percentage of observed nitrate variance that is explained by the best fit multiple regression line from contributions of the independent variables. The r-square result seems low on the whole and the reasons for this are investigated in the test of the method section.

TEST OF THE METHOD

A test of the method was initated using a region in Door County (See Figure 6 for location) as an independent study site where hydrogeologic information and nitrate values were available. The Door County data were first scrutinized to determine whether any anomalous situations existed at any of the well sites. One of the wells is situated on the site of a tree/garden nursery. Nitrogen products (fertilizers) are extensively used in such an establishment, probably both inside the greenhouse(s) and on the outdoor growing fields. Because of this extreme situation of a highly concentrated source, the data point was eliminated from the test site data.

The test ultilized some of the equations that were generated in the study from the multiple regression process to predict nitrate values at each data point. The predicted nitrate values were then correlated against nitrate concentrations actually observed at each data point in Door County. The equations used and the resulting correlation coefficients are shown in Table 7.

Because aquifer type was found to be an important independent variable in predicting nitrate concentration, the first equation used in the test was the one initially generated using only dolomite subset data

TABLE 7

Results from the independent test of the study method. The equations listed were used to try to predict nitrate concentrations for the Door County test site. All equations were generated without Door County data (true independent test). The correlation r is the resulting correlation coefficient between observed nitrate concentrations and nitrate concentrations as predicted from the given equation. R^2 is the percentage of predicted nitrate variance explained by the observed nitrate values. "p" is the significance level for the relationship in the data, i. e., the percent chance that the relationship shown is random.

Equation Designation	Data used to generate equation	r	R^2	p
A	All dolomite wells, hydrogeologic variables	0.50	25%	1.1%
A'	Same as A above but with values of ≤ 0.5 mg/1 NO_3^--N values deleted from the equation generating data. Equation used on only those observed nitrate values from Door County that were >1.0 mg/1 NO_3^--N.	0.58	34%	0.7%
B	ALLDATA	0.48	23%	1.5%
C	Same as A' above but logarithms of hydrogeologic and nitrate variables used to generate the equation; logarithms of observed nitrate in Door County used for predicted versus observed correlation.	0.60	34%	0.5%

(virtually all wells in Door County tap the Silurian dolomite aquifer). Recall from Tables 4 and 6 that the clay thickness and specific capacity variables were found to be the most important hydrogeologic variables when predicting nitrate concentration for a dolomite aquifer. Table 7 (Equation A) and Figure 20 depict the results of the dolomite equation. The resulting correlation coefficient between predicted and observed nitrate concentrations for the test site is r = 0.50. Notice that the lowest observed nitrate values plot too high on the predicted axis of the scattergram. It is possible that a nitrate contamination source does not exist at these locations, but that the hydrogeologic characteristics at the site would merit a relatively high nitrate concentration here, given a source. The intermediate observed nitrate values seem to have the best correlation between the predicted and observed values.

Another multiple regression equation was generated, Equation A' (Table 7), to try to improve the predicted versus observed nitrate correlation in the test region. Equation A' was generated from the same data set as Equation A (dolomite wells) but with those nitrate-nitrogen values of less than or equal to 0.5 milligrams per liter (the detection limit below which nitrate concentration cannot be accurately determined) deleted from the equation generating data set. Also,

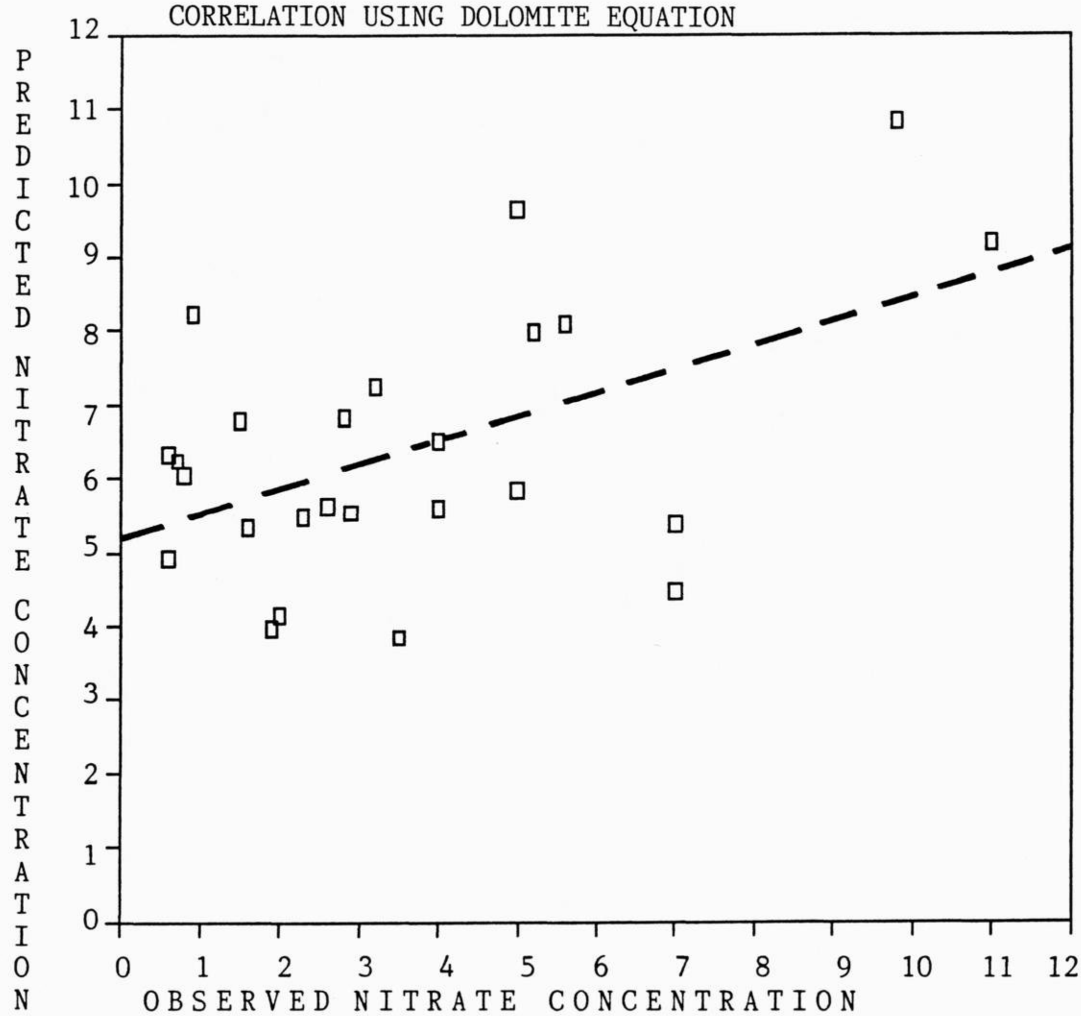


Figure 20. Predicted versus observed nitrate concentration correlation graph for Door County test site data. Predicted values from "dolomite" equation (Equation A, Table 7). Correlation r = 0.50, dashed line is the best fit line through data points.

the only test site (observed) nitrate values that were used were those points with $\geq$ 1.0 milligrams per liter nitrate-nitrogen. A correlation coefficient of r = 0.58 results and is shown in Table 7 and Figure 21. Apparently, the use of a multiple regression equation produces more favorable results for well sites with higher relative nitrate concentration and certain nitrate contamination sources (those wells having water with > 1.0 mg/l nitrate-nitrogen concentration). This situation occurs because nitrate concentration is always included as the dependent variable in the multiple regression process, and therefore is always predicted on the basis of the given hydrogeologic parameters. Therefore a nitrate concentration is always predicted for each well site, whether or not a nitrate contamination source exists. As a result, those well sites with no contamination source will always have a higher predicted nitrate concentration (>0.0) than the actual nitrate concentration observed at the site.

For comparison purposes, the equation that was generated using the ALLDATA set from all of the townships' data was used for another test with the independent site data (Equation B, Table 7.) The resulting predicted versus observed nitrate is shown in Figure 22 with a correlation coefficient of r =0.48. The correlation is not as good as that

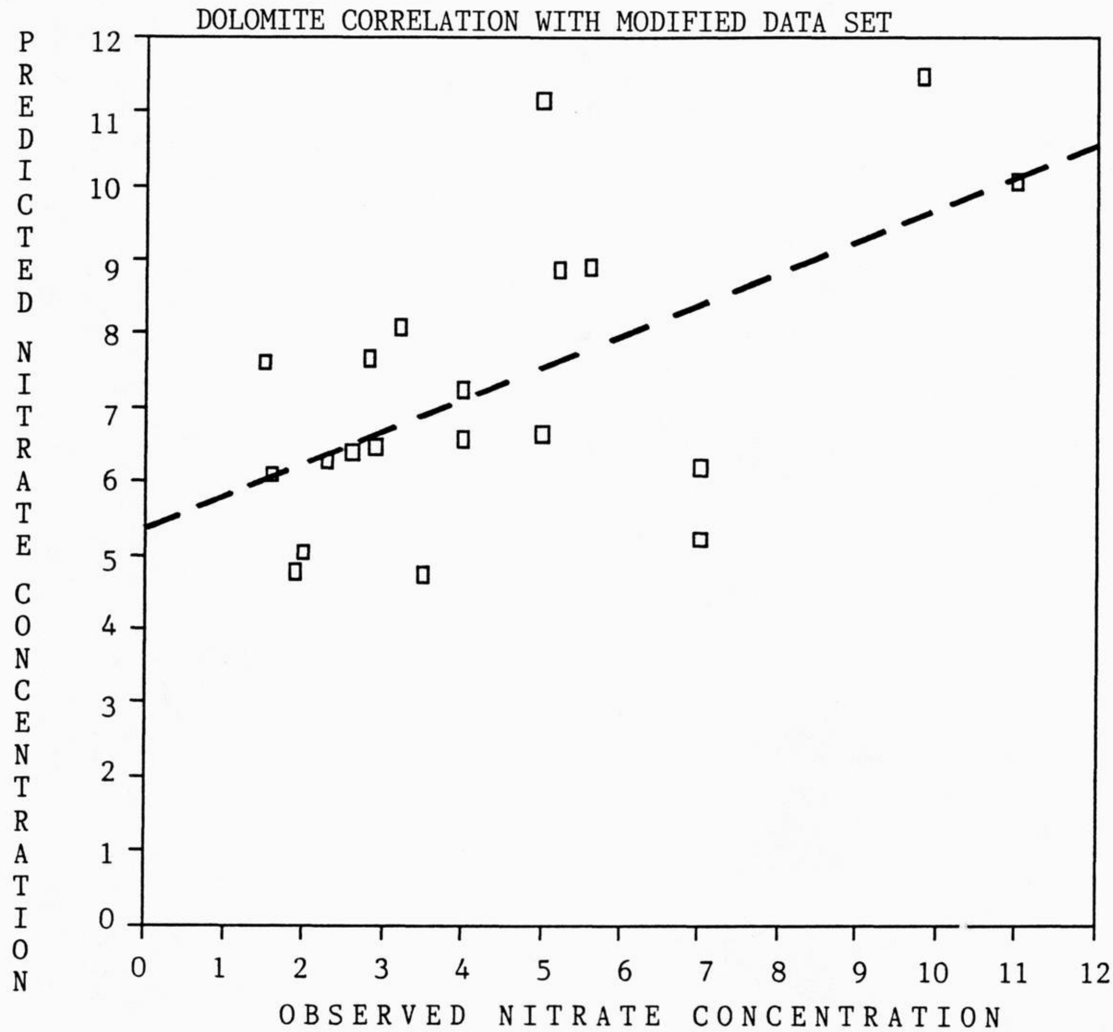


Figure 21. Predicted versus observed nitrate concentration correlation graph for Door County test site data. Predicted values from the dolomite equation, but with nitrate data points of $\leq$ 0.5 mg/l (the detection limit) deleted from the data set generating the equation. (Equation A', Table 7). Also, only those nitrate values for the test site that were >1.0 mg/l were used in the correlation. Correlation r = 0.58, dashed line is best fit line through data points.

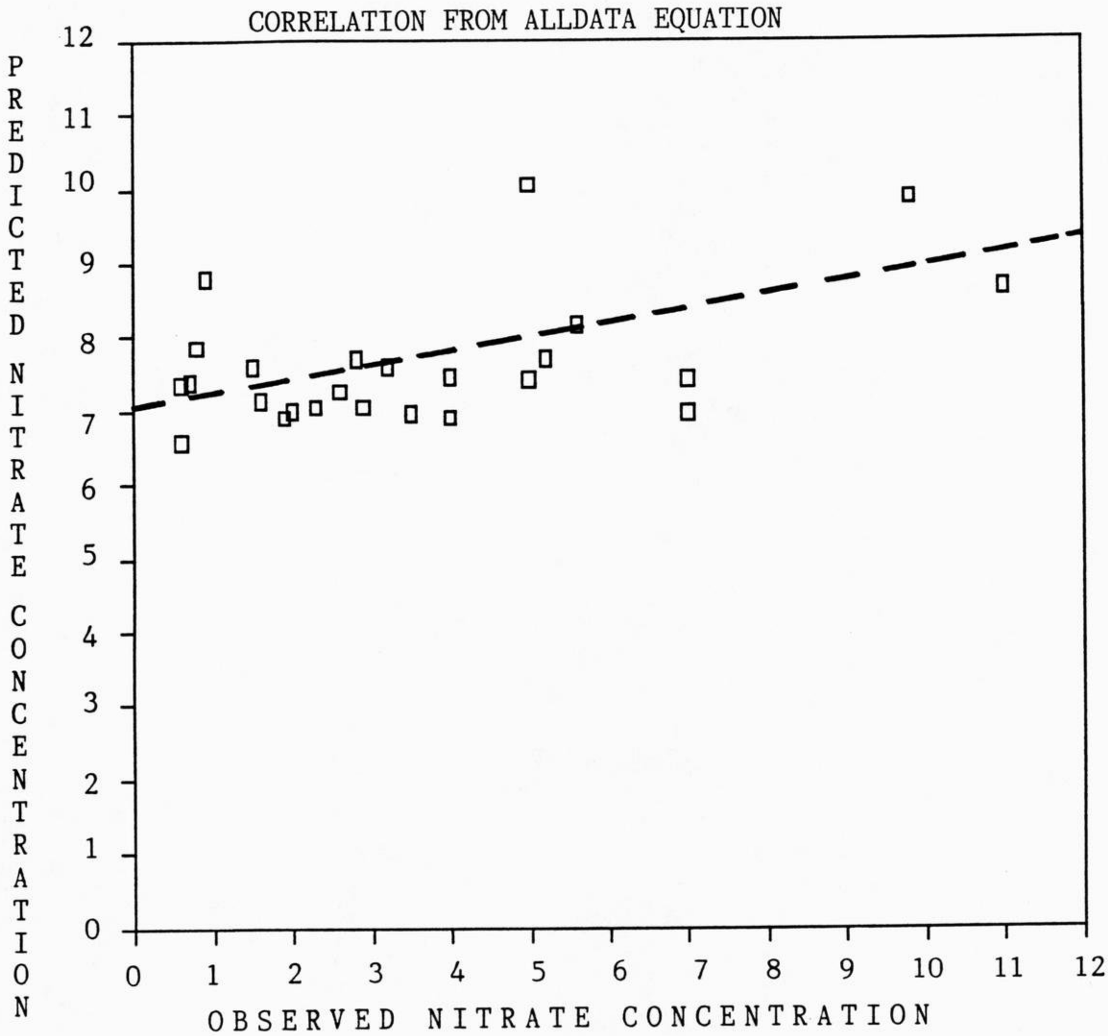


Figure 22. Predicted versus observed nitrate concentration correlation graph for Door County test site data. Predicted values from the ALLDATA equation (Equation B, Table 7). Correlation r = 0.48, dashed line is best fit line through data.

resulting from the more aquifer-type specific, dolomite equation. This could be due to a number of factors but, basically, the variance in the independent variables only explained 23% of the variance in nitrate concentration via <u>this</u> multiple regression equation (i. e., $r^2 = 0.23$, Table 7).

One should return to the beta weight results on Table 6 to analyze possibile reasons why the lower correlation coefficient occurs when using the ALLDATA equation as opposed to dolomite equation. Both ALLDATA and dolomite generated beta weights show the most important hydrogeologic variables for nitrate prediction as clay thickness first and specific capacity second. However, these are only the rank orders of important for both cases. The <u>relative</u> importance of clay thickness versus specific capacity is determined in each case by taking the ratio of the squares of the respective betas (Kachigan, 1982):

$$\text{ALLDATA:} \quad \frac{CT}{SC} = \frac{0.33^2}{0.10^2} = \frac{0.11}{0.01} = 10.9 \qquad (5)$$

$$\text{Dolomite:} \quad \frac{CT}{SC} = \frac{0.27^2}{0.20^2} = \frac{0.07}{0.04} = 1.8 \qquad (6)$$

Therefore, in the ALLDATA set, clay thickness was found to be more than 10 times as important as specific capacity when predicting nitrate concentration. ALternatively, clay thickness is only 1.8 times as important as specific capacity for the dolomite data set. The use of the ALLDATA equation to predict nitrate concentration for the test site places too much emphasis on the clay thickness variable, and not enough emphasis on the specific capacity variable--thus the lower correlation coefficient for this particular test. The overemphasis of the clay thickness variable is particularly damaging for this test site's results because the clay thickness variable has very little variation in Door County (see clay thickness map for the test area, Figure 33 in Implications section).

Yet another multiple regression equation was generated by using logarithms of the hydrogeologic variables (same data set as used for Equation A') to try to improve the predicted versus observed nitrate correlation for the test area (Equation C, Table 7). The correlation coefficient (Figure 23) that resulted from this process is r = 0.60; it shows a slight improvement over that produced by Equation A'. The use of logarithms on the raw data does not greatly improve or tighten the fit of the regression line, so it is hard to tell at this point whether logarithms should always be utilized with the multiple regression predicting process.

The best equation, acccording to this test, to predict nitrate concentration for the data points at the independent study site has the following characteristics: 1) the equation is "aquifer-lithology specific" and is therefore based on the dolomite well

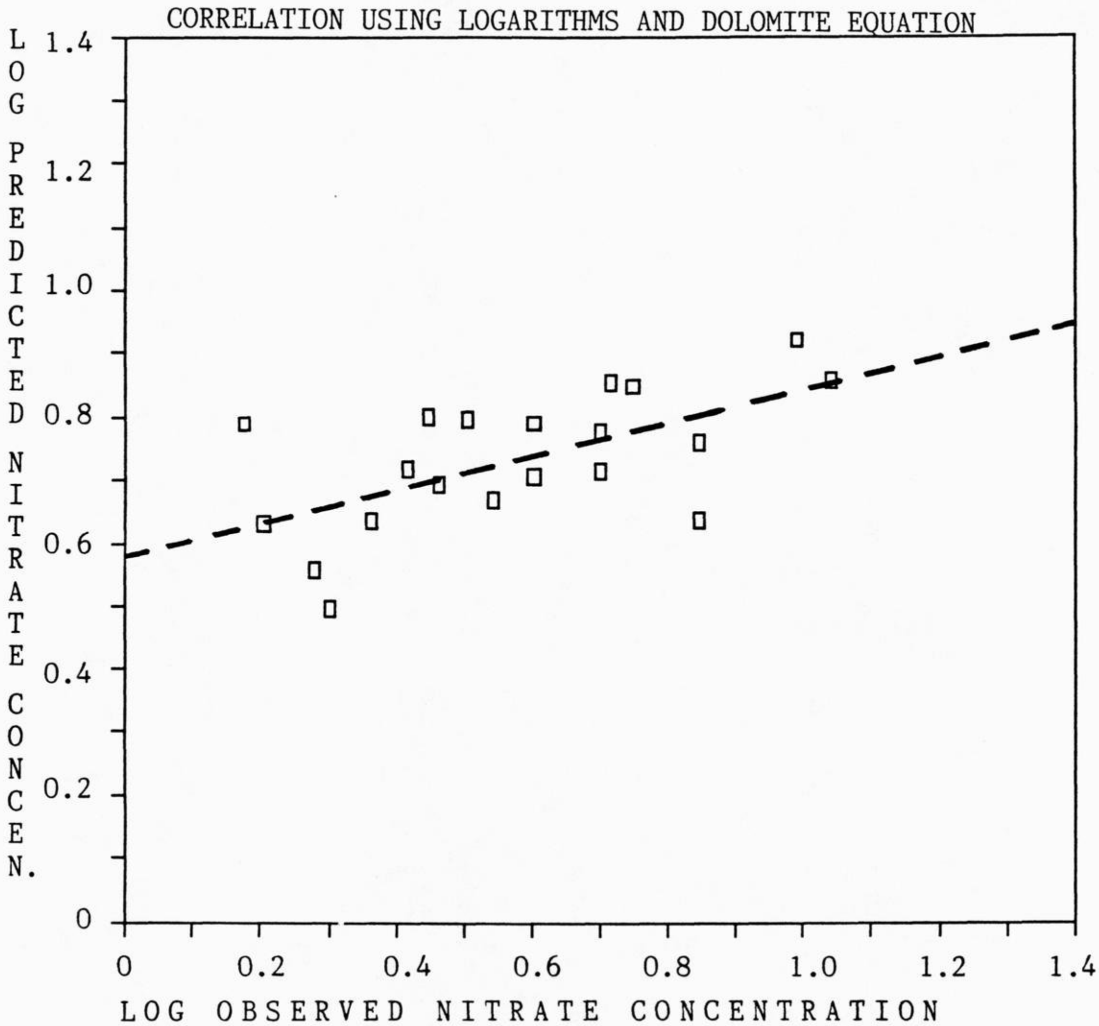


Figure 23. Logarithm of predicted nitrate concentration versus logarithm of observed nitrate concentration for the Door County test site data. Predicted values from the use of logarithms of hydrogeologic and nitrate data, same data set as Equation A' (This equation is Equation C, Table 7). Correlation r = 0.60, dashed line is best fit line drawn through data points.

data, 2) the equation is generated using only observed nitrate values above 0.5 milligrams per liter, 3) the equation works best predicting nitrate-nitrogen values that are $\geq$ 1.0 milligrams per liter, and 4) the equation works best when based on logarithms of hydrogeologic parameters.

It was desirable to determine the cause(s) of the "scatter" or "noise" on the predicted versus observed nitrate graphs. For example, it was thought that there may be some overlying pattern to the data that explains some of this noise. The pattern could be caused by a given data characteristic that is not accounted for in the multiple regression process. An example of such a pattern is shown in Figure 24 where "contour" lines of the additional data characteristic are parallel to and surrounding the best fit line through the data points (i. e., the scatter on the plot is due to a "family" of parallel/semi-parallel curves). However, if no extraneous patterns exist for the additional variable, that variable cannot account for the scatter on the correlation plot.

The first new variable that was considered in this process was the land use variable. Figure 21 data points were identified as "fertilized" nitrate source (F) or "non-fertilized" nitrate source (N) and the result is shown on Figure 25. Plat books, topographic maps, and a knowledge of site ownership

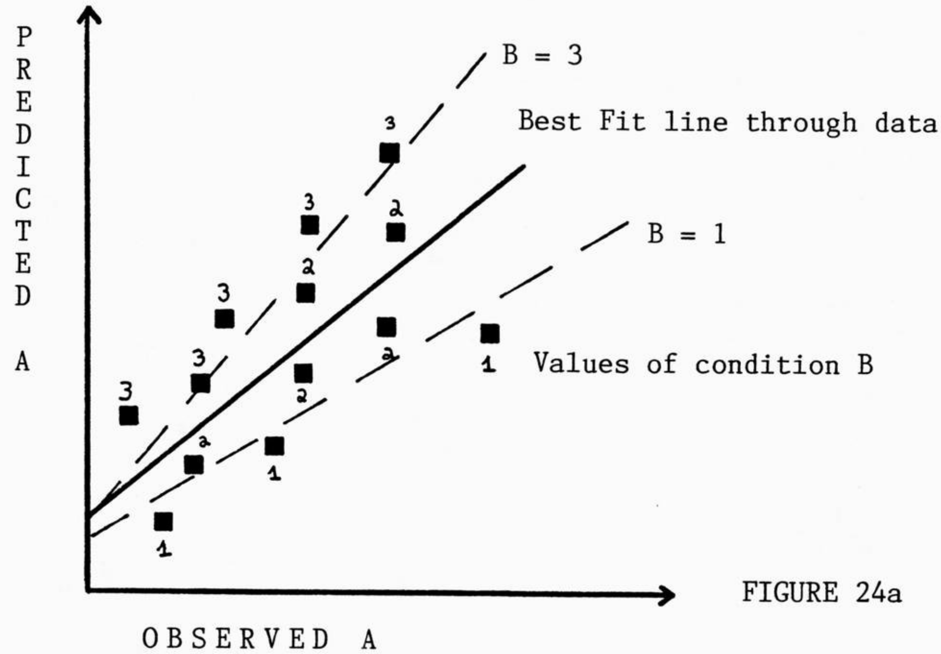


FIGURE 24a

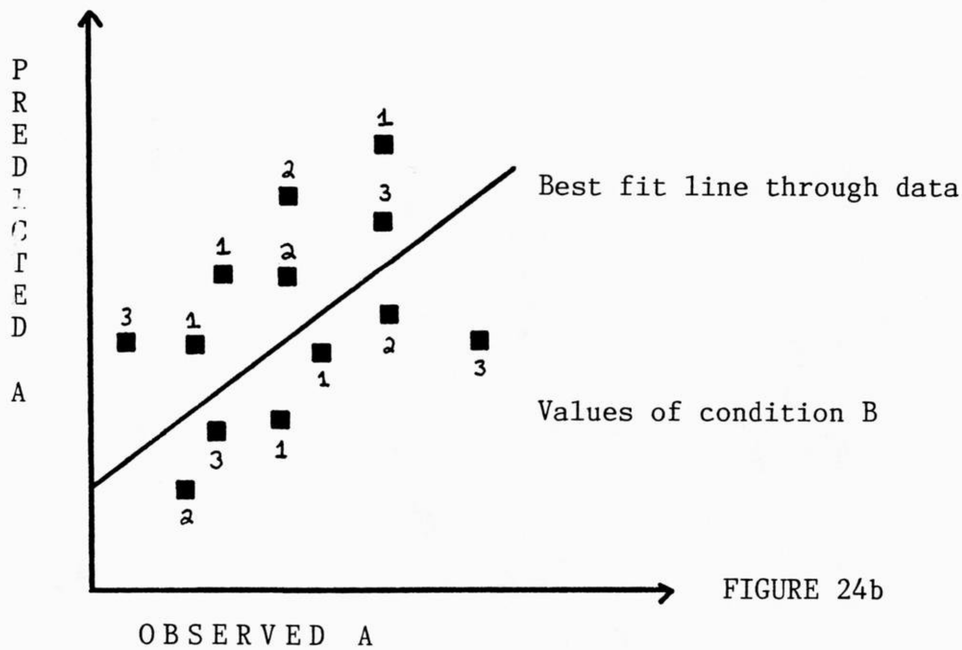
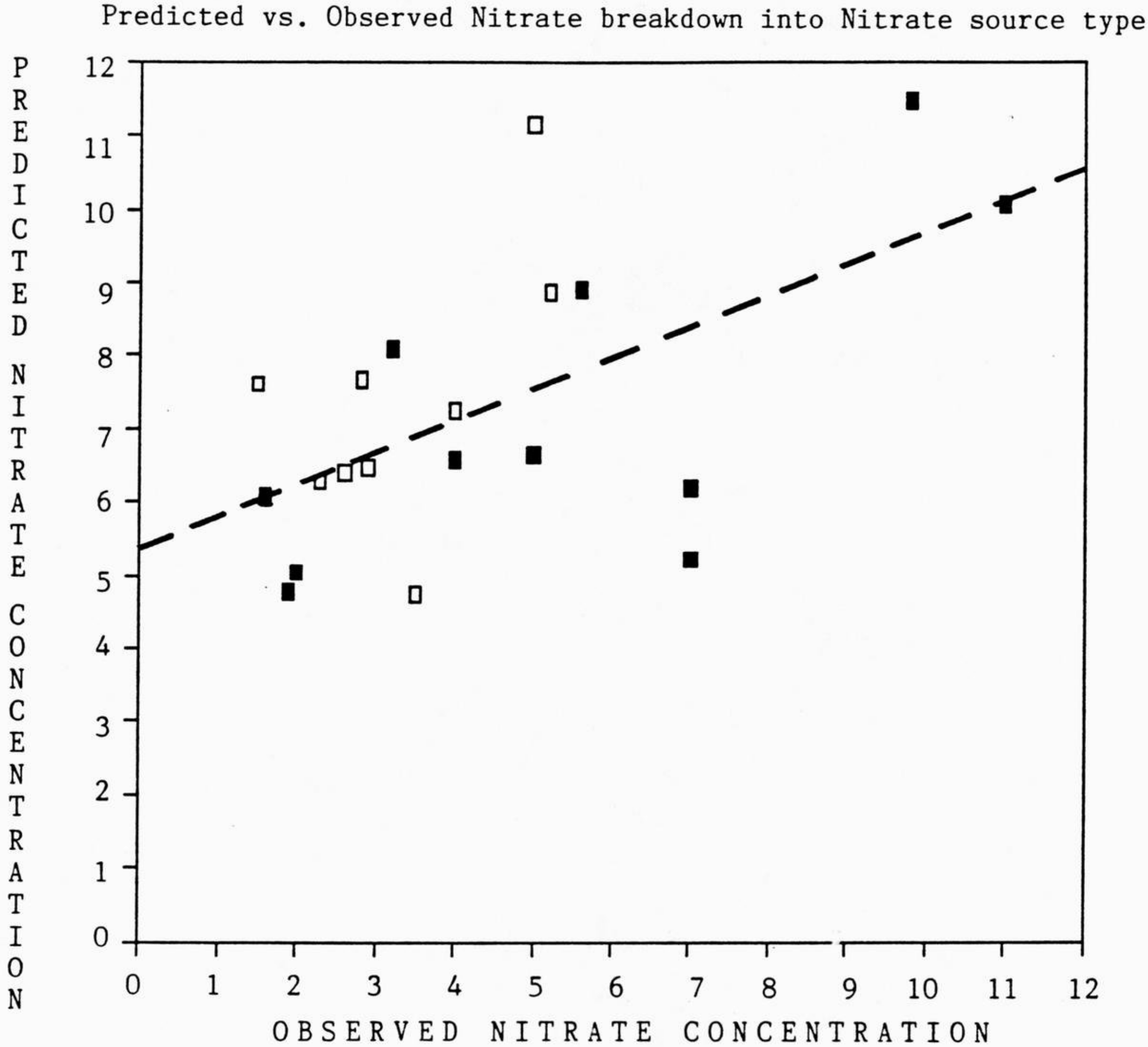


FIGURE 24b

Figure 24. Examples of "noise" patterns on correlated data. Numbers on data points represent the values of an additional parameter, B, that was not originally used to determine the predicted values of A. Figure 24a shows a pattern in which there is actually another, independent condition causing most of the scatter. A family of curves (dashed), rather than a single line (solid) should be drawn through this data. Figure 24b shows no underlying pattern of the additional condition, therefore that parameter cannot explain the scatter on the plot.



KEY: □ Non-fertilized nitrate sources: public establishments, residential areas, i., e., septic systems

■ Fertilized nitrate sources: agricultural sources probably natural fertilizers spread on growing fields.

Figure 25.
Breakdown of Figure 21 into probable nitrate sources of Fertilized versus non-fertilized groups. Characterizations determined using topographic quads and plat books, and knowledge of land/building ownership and use for Door County nitrate values. Public facilities such as restaurants, gas stations, stores, etc., and residential homes are considered to be "non-fertilizer" sources, i. e., septic tank systems, etc. Agricultural farm residences are considered to have "fertilizer" sources--evenly spread natural fertilizers used on growing fields.

were all used to make this characterization. Private farms were considered to be fertilized nitrate sources, and restaurants, gas stations, motels, stores, and residential areas were considered to be non-fertilized sources. Visual inspection shows that, for a given predicted nitrate concentration, the fertilized wells tended to have higher observed nitrate values than the non-fertilized wells. This facet of land use may explain some of the scatter in Figure 21. Correlation coefficients were then separately determined for both the fertilized and non-fertilized data points (Figures 26 and 27). The fertilized points have a correlation coefficient of $r = 0.72$ and the non-fertilized $r = 0.55$. It appears that the multiple regression equation predicts better for fertilized than for non-fertilized nitrate sources in this test site. Perhaps the fertilized regions represent a more evenly distributed nitrate source (fertilizers somewhat evenly spread on farm fields), and the non-fertilized are merely unevenly distributed point sources (septic tank systems).

Well construction variables were also considered as independent sources of scatter for the test site in Door County. Values of depth of well hole, depth the well is cased into the aquifer, length of casing and, open length of the well were plotted over Figure 25, and there are no evident patterns for any of the well

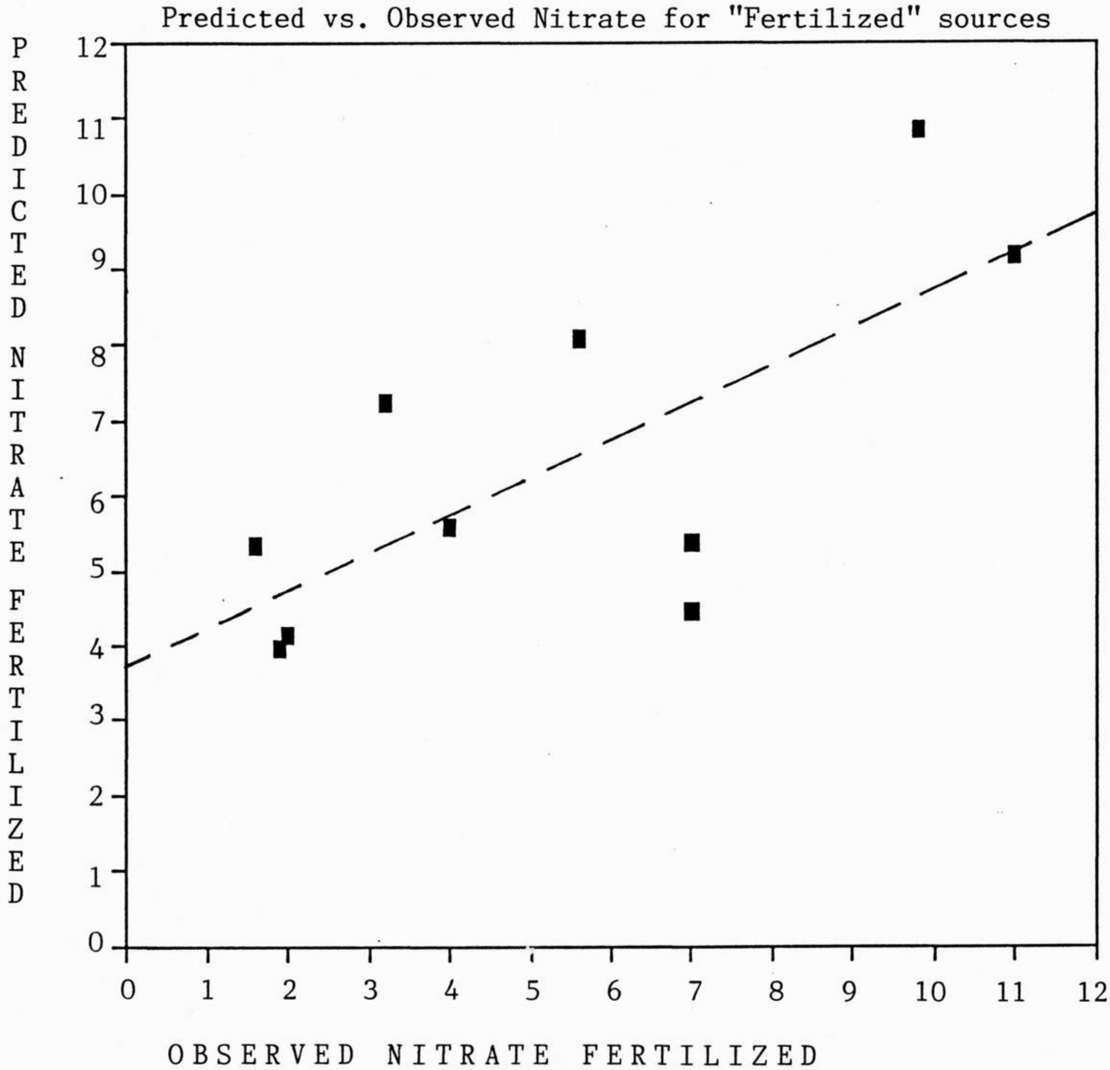


Figure 26. Predicted versus observed nitrate for Door County data points with a probable nitrate source from agricultural fertilizers. Correlation r = 0.72.

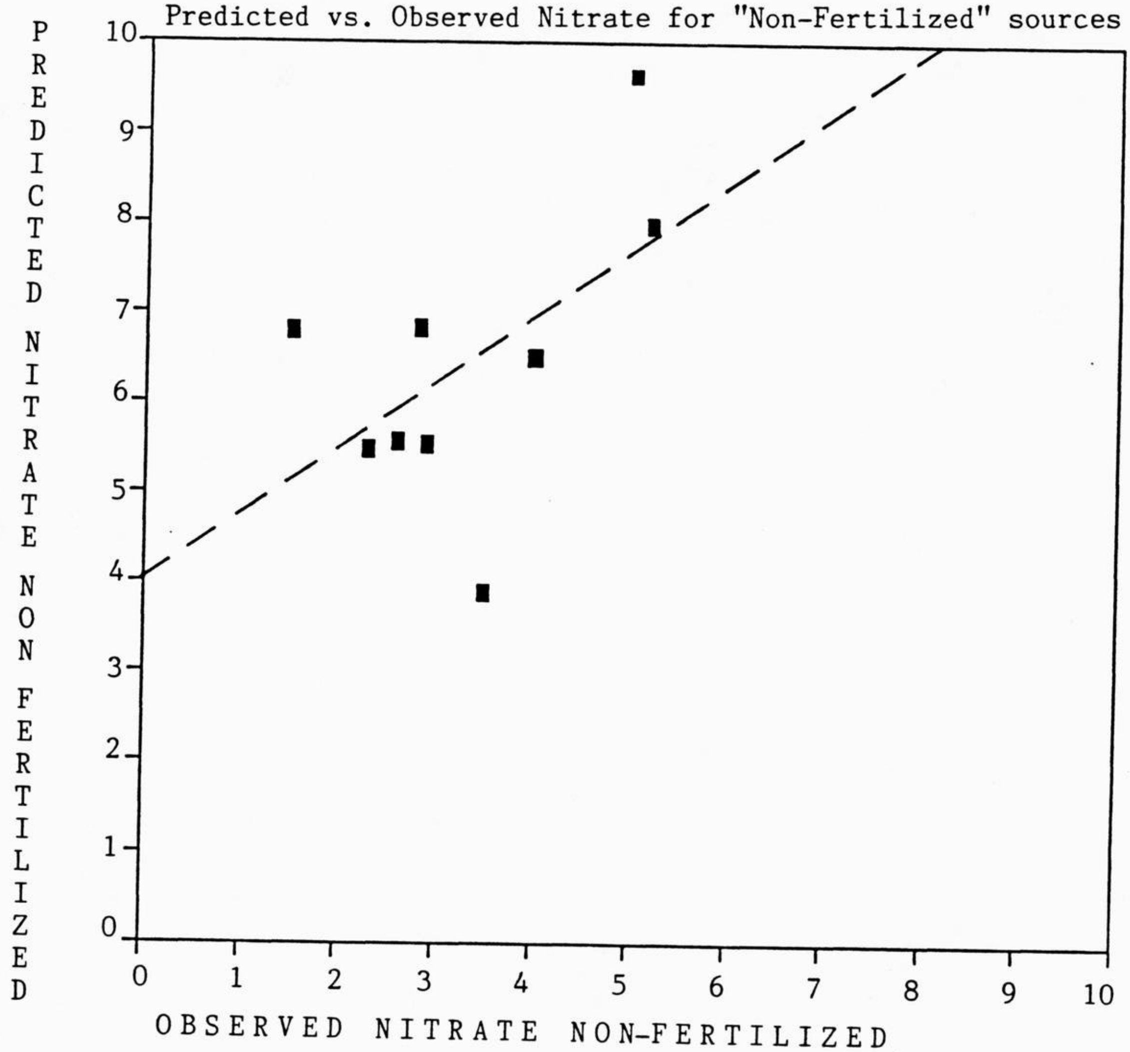


Figure 27. Predicted versus observed nitrate for Door County data points with no discernible nearby source of fertilizer. Correlation coefficient is r = 0.55.

construction variables as shown by this procedure. Therefore, the noise on Figure 21 cannot be explained by any of the well construction parameters, at least for this data set.

Another feature that is universal to Figures 20-23 is that the data points on the lower end of the observed nitrate axis plot too high on the predicted nitrate axis (i. e., the best fit line does not go through the origin). It seems that there are no nitrate contamination sources at the observed well sites, but hydrogeologic conditions there make the predicted nitrate values higher, as if sources existed at all data points. In other words, the multiple regression equation predicts the potential for nitrate contamination. If a source exists and hydrogeologic conditions are correct for contamination, high nitrates will result. The regression prediction is reasonable in areas where observed nitrates are higher than 1-2 milligrams per liter. If a source doesn't exist, however, the regression equation will still predict a high potential for contamination. But the observed concentration will be low. The regression equation cannot deal with the absence of a sourcce and therefore overpredicts nitrate concentrations. Thus, the regression equations must be viewed as predicting nitrate contamination potential, not absolute nitrate concentrations. It was found, then, that land use (type of nitrate source) and the existence or non-existence of a nitrate contamination source both contribute to the noise on the correlations of observed versus predicted nitrate concentration (Figure 21).

There are other types of variables that may be responsible for some of the scatter of the observed versus predicted nitrate plot, but that cannot be sufficiently quantified or determined from the data base used in this investigation. These may include: 1) actual proximity to an existing nitrate source, 2) seasonal nitrate variations, 3) individual hydraulic conductivities of the aquifer from well site to well site due to secondary porosity and/or fracture trend variations.

This test of the method, then, has only been partially successful in predicting nitrate contamination potential for the Door County test site. A maximum of 34% of the variance in nitrate concentration has been explained (Table 6) using the values of the hydrogeologic parameters at the test site as proposed by this method.

As an additional test of the method, average values of all the parameters from the Door County data were calculated and then used in the various equations (dolomite-generated, ALLDATA-generated, logarithm-generated) to predict an average nitrate value for the test site. The results of this test are shown in Table

8. For this test, the logarithm-generated equation (Table 6, Equation C) produced the best match between average predicted nitrate and average observed nitrate for Door County (See Table 8).

The results of this test agree with the previous test as shown in Table 7. The logarithm method produces the best results. However, this test provides a means of quantifying which of the equations is able to produce a valid nitrate average. The deviation of the predicted average nitrate from the observed average nitrate can be expressed as:

$$\frac{\text{OBSERVED NITRATE AVG} - \text{PREDICTED NITRATE AVG}}{\text{OBSERVED NITRATE AVG}} \times 100 \qquad (7)$$

The logarithm equation produces the lowest percent error, 5% (Table 8). In contrast, the ALLDATA equation produces the worst comparison to the observed nitrate average, 51% error. The use of the logarithm equation is also much better (5% error) than that of the same data set with which logarithms were not used (Table 8, Equation A', 17% error). This test method using averages, then, confirms the previous method's results. The average nitrate concentration value for the test site is predicted with the smallest deviation from the observed nitrate average when using an aquifer-type specific equation. Also, the lowest deviation is produced when logarithms of the hydrogeologic and nitrate values are used to first generate the multiple regression equation, and then to predict nitrate

TABLE 8

Results from the additional test of the study method. Averages for all hydrogeologic and nitrate values for Door County were used in the various equations generated from the data points as listed. Use of logarithm averages of the data produced the best results in this method.

Averages

	Average	Log Average
NO_3^--N	5.06	0.4594
Soil Permeability	4.52	0.4165
Specific Capacity	3.73	0.2799
Clay thickness	9.33	0.7634

EQUATION DESIGNATION	EQUATION GENERATED USING	Resulting Predicted NO_3^- (milligrams per liter)	Deviation of Predicted from observed
A	All hydrogeologic variables dolomite wells only	6.28	24%
A'	Same as equation A but with NO_3^--N values of $\leq$ 0.5 deleted from the set of generating data	5.91	17%
B	ALLDATA	7.62	51%
C	Logs of Data used in equation A'	5.30	5%

concentration by use of that equation.

Two tests have thus been used on the same test site data to examine the methodology developed in this investigation. The method has showed the best results when predicting average nitrate concentrations for a given region. The method, therefore, cannot predict nitrate concentration at a single well site. However, the method can be used to predict where nitrate contamination potential is highest in an area based on averages, and this was one of the main objectives of the study when initiated.

UTILIZATION OF THE METHOD

The primary purpose of the method that was developed in this investigation is to provide a way to predict where nitrate contamination potential is highest for a given location. This method is needed so that Wisconsin Department of Natural Resources monitoring efforts and/or regulations can be concentrated on the areas with the highest potential for nitrate contamination.

The method can be used in any location where hydrogeologic parameters are known. First, the appropriate multiple regression equation, according to aquifer lithology, is chosen (this study produced equations for dolomite, sandstone, and unconsolidated sediments). Second, the distribution of the main hydrogeologic parameters based on the equation results (see Table 4) are plotted on base maps for the site of interest. Next, two zones (or more, if appropriate) of lower and higher nitrate contamination potential are designated on each map according to the distribution of each map's hydrogeologic variable. Finally, the maps are overlain on one another. The regions with the highest potential for contamination by nitrate are then highlighted where both or all parameters have overlapping high nitrate potential zones. Intermediate and/or low potential zones can also be noted.

The aforementioned method was tried on the region used as a test site for this study. The region is located in Door County, Wisconsin, and is highlighted in Figure 28. The dolomite equation was used for this mapping method because all the wells in the test site are finished in the Silurian dolomite aquifer. Clay thickness and specific capacity are the most important hydrogeologic variables when predicting nitrate concentration according to the dolomite results (see Table 4). Maps of clay thickness and specific capacity for the Door County site are shown in Figures 29 and 30, respectively.

Clay thicknesses on Figure 29 of $\leq$ 10 total feet are designated as having a higher potential for nitrate contamination. The ten foot contour was chosen as the cut off for the zones based on the visual inspection of Figure 31 and of the clay thicknesses on the map (Figure 29). Two zones of clay thickness were chosen to represent low and high nitrate contamination potential based on visual inspection of the groups of data on Figure 31. The majority of the higher nitrate values on the graph occur where clay thicknesses range from 0 to 20 feet. However, it can be seen that the majority of the clay thicknesses in Door County are actually less than 10 feet (Figure 29). Therefore, zones of 0-10 feet and > 10 feet were chosen as nitrate contamination potential designations for the

LOCATION OF TEST SITE

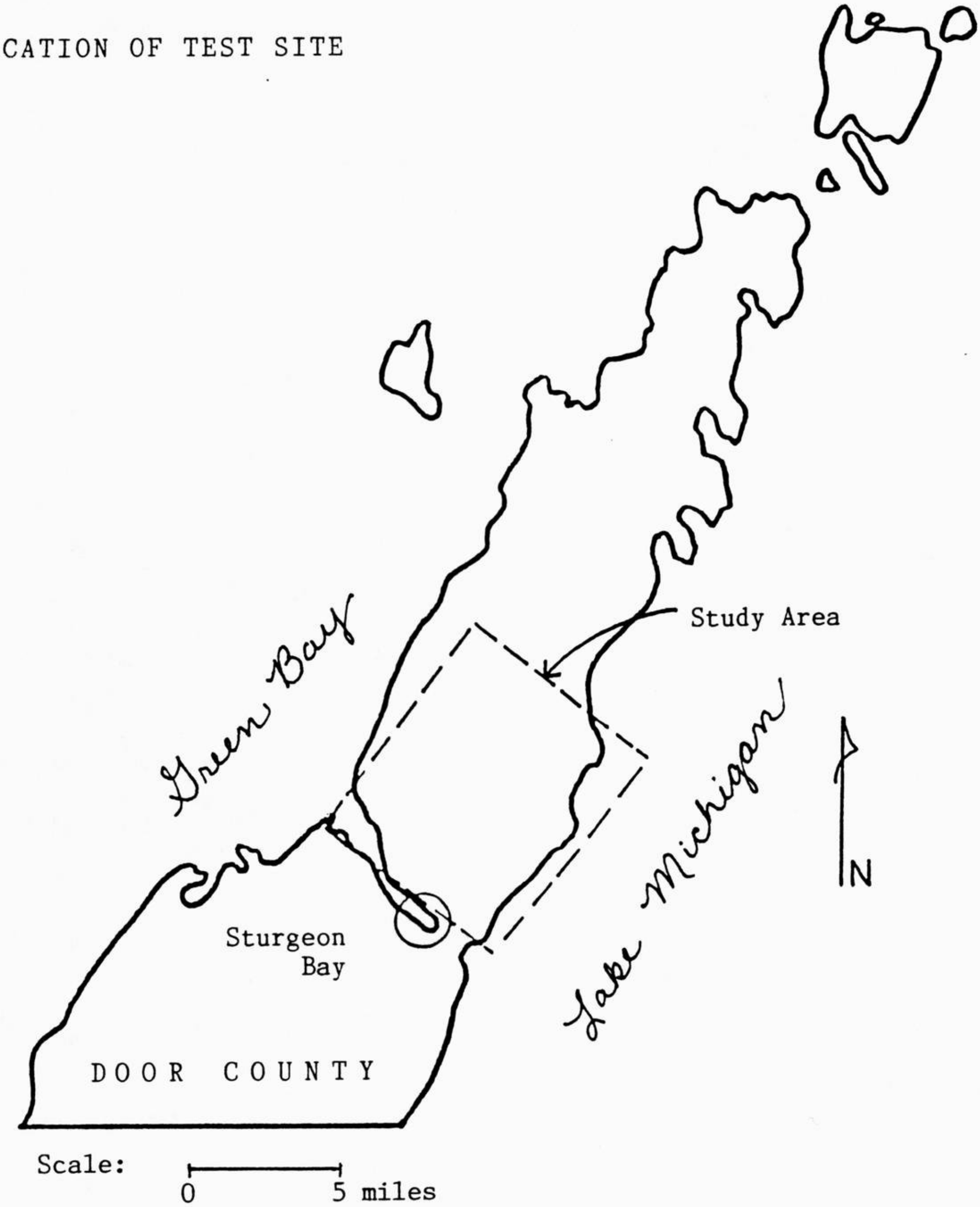
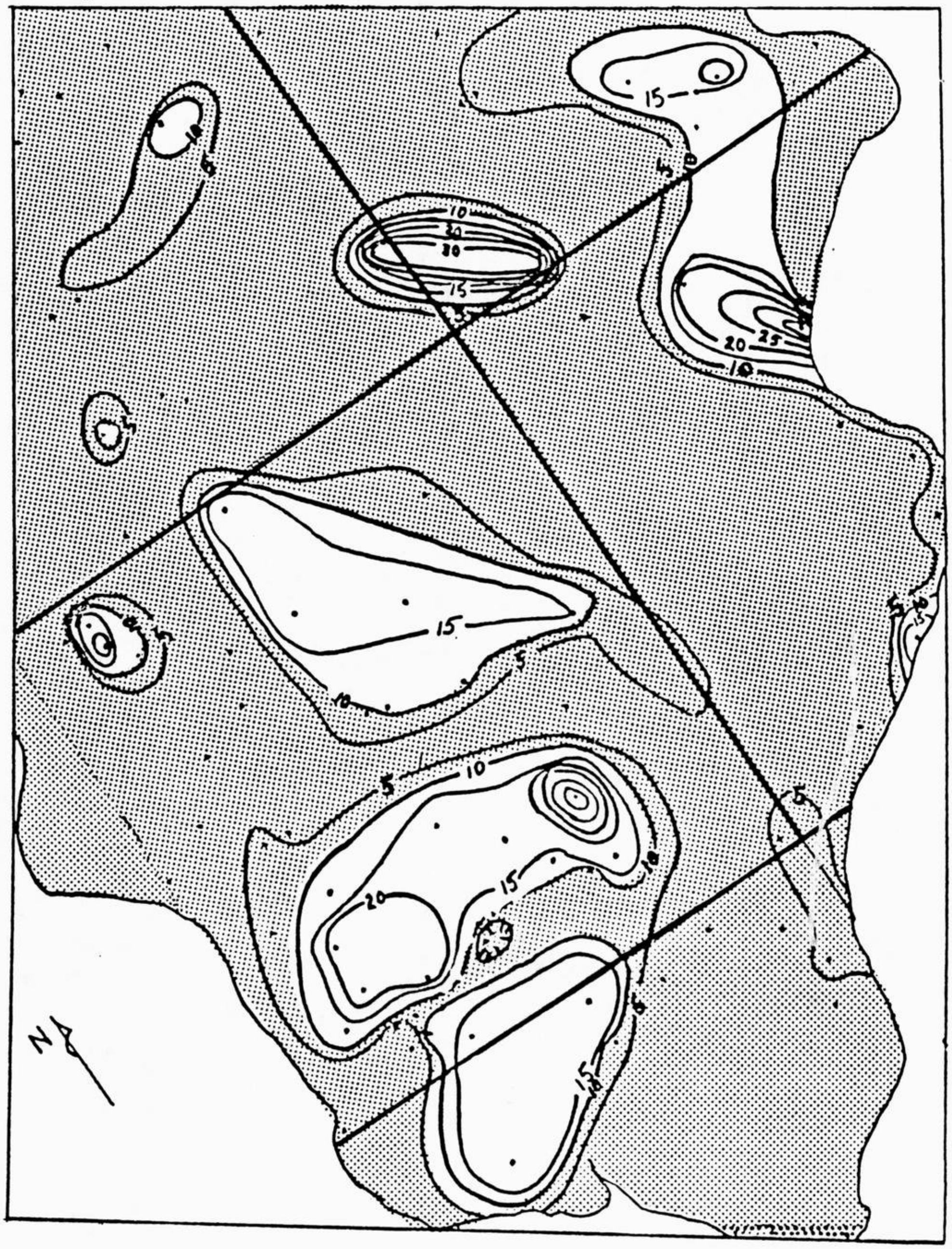


Figure 28. Location of the test site for this investigation in Door County, Wisconsin.

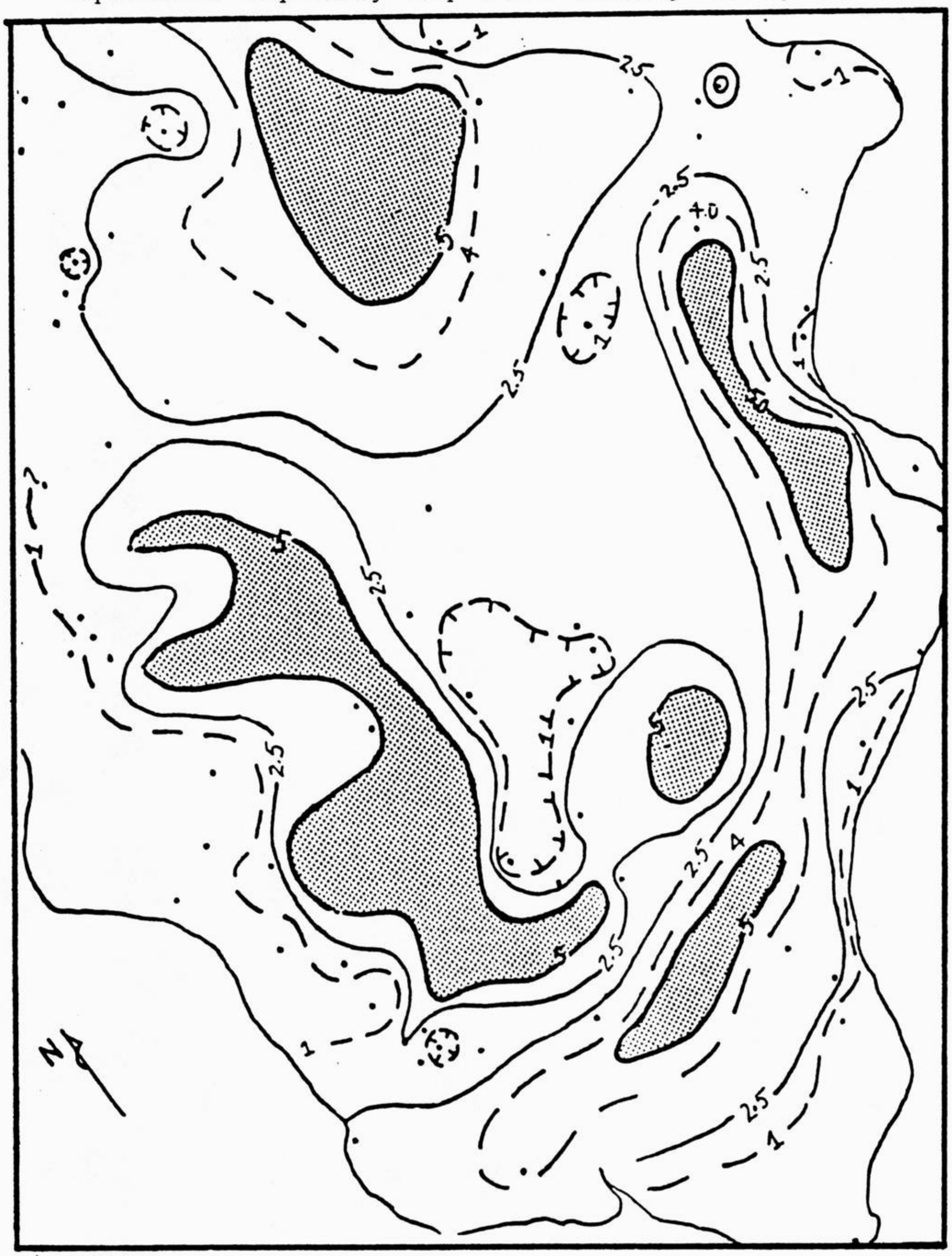
Clay Thickness Map for Door County



Scale: 0 2 miles

Figure 29. Map of the total feet of clay thickness in the unconsolidated sediments for the Door County test site (see location, Figure 28). All areas ≤ 10 feet of total clay thickness are shaded to indicate areas with greater potential for nitrate contamination based only on this hydrogeologic parameter.

Specific Capacity Map Door County Study Site



Scale: 0 2 miles

Figure 30. Map of specific capacity in gallons per minute per foot of drawdown for the Door County test site (see location, Figure 28). All areas $\geq$ 5 gpm/ft specific capacity are shaded to indicate areas with greater potential for nitrate contamination based only on this hydrogeologic parameter.

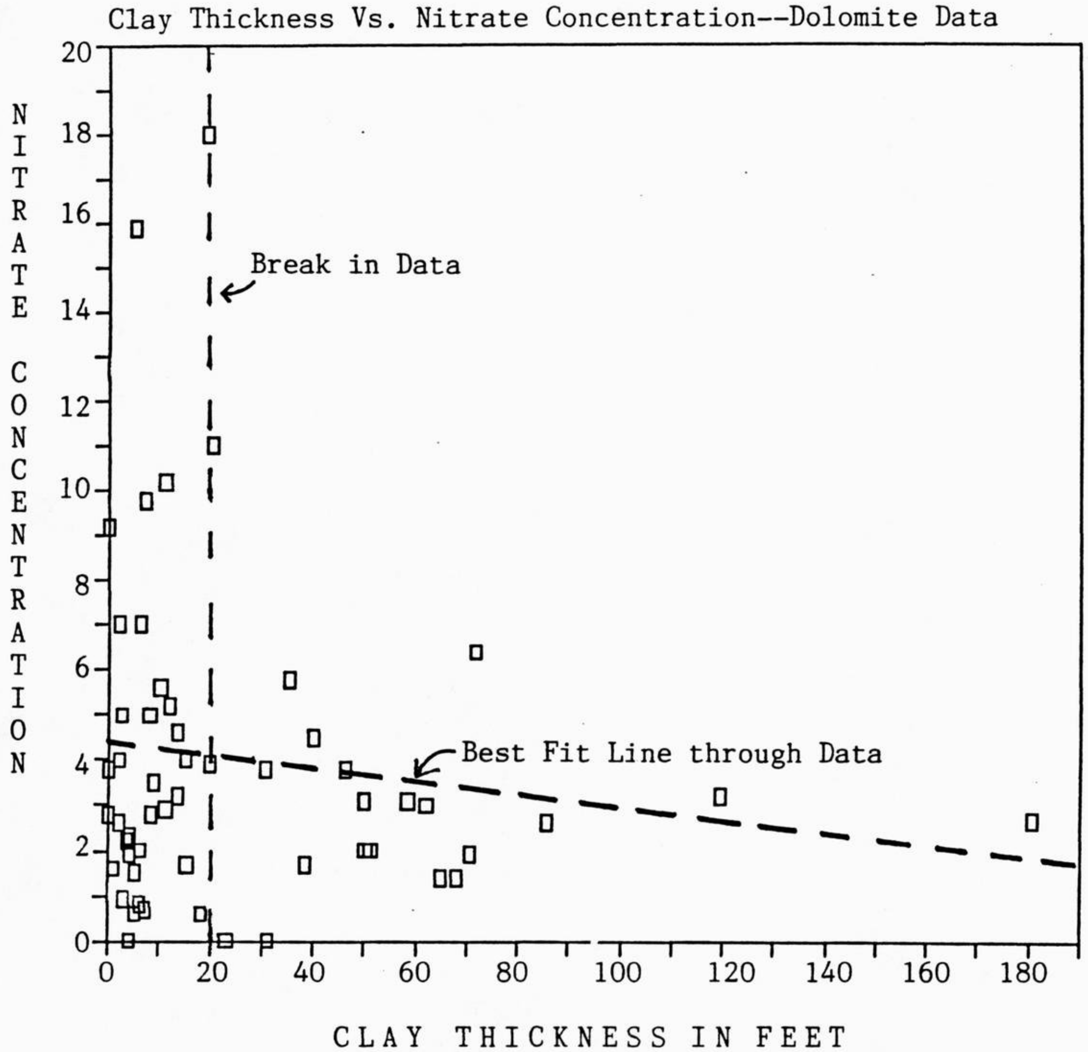


Figure 31. Graph of dolomite data used in this study where clay thickness is correlated against nitrate concentration. Two zones of 0-10' and > 10' of clay thickness were chosen to represent regions of higher and lower nitrate contamination potential, respectively, based on the groupings of data in this graph. The zones are used on a map of clay thickness (Figure 29) for the Door County test site.

clay thickness variable.

Specific capacities on Figure 30 of $\geq$ 5 gpm/ft are designated as having a high potential for nitrate contamination. The 5 gpm/ft contour was chosen as the cut off between low and high nitrate contamination potential based on visual inspection of Figure 32 and the large grouping of nitrate versus specific capacity data points around the origin. The grouping of nitrate values at $\leq$ 5.0 mg/l nitrate-nitrogen was considered to be a "low" nitrate concentration and > 5.0 mg/l a "high" nitrate concentration. The corresponding cut off for specific capacity is around 5 gpm/ft (Figure 32). Therefore, zones of 0-5 gpm/ft and > 5 gpm/ft were chosen as nitrate contamination potential designations for the specific capacity variable.

The two maps (Figures 29 and 30) are then overlain on one another to produce a composite nitrate contamination potential map for the test site (Figure 33). Three zones of contamination potential are designated on the test site map: low, intermediate, and high. The low zones (no shading) are in areas where <u>neither</u> the clay thickness or specific capacity variables have high nitrate potential designations from their respective maps. The intermediate zones (lighter degree of shading) are located where only <u>one</u> of the two variables has a high nitrate potential designation. Finally, the high zones (darker degree of shading) are

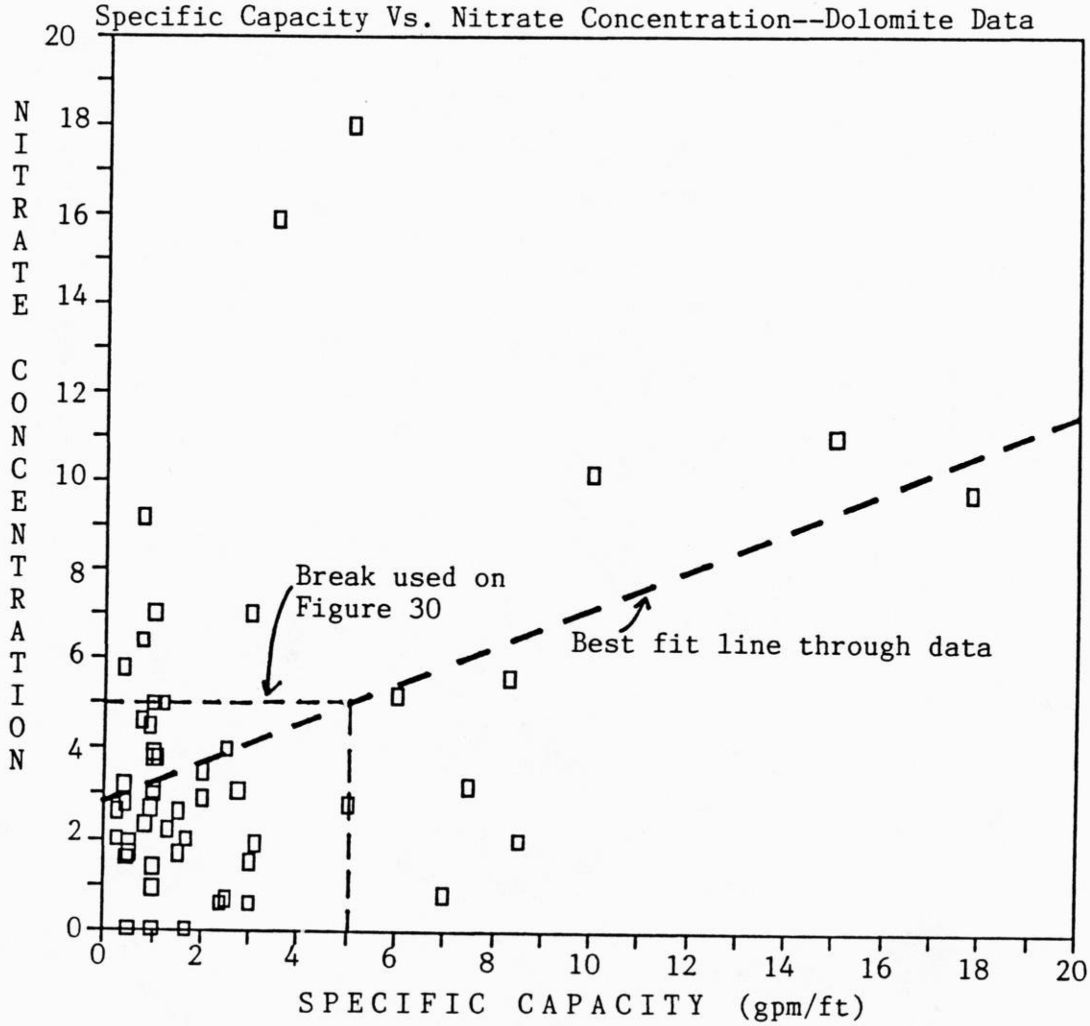
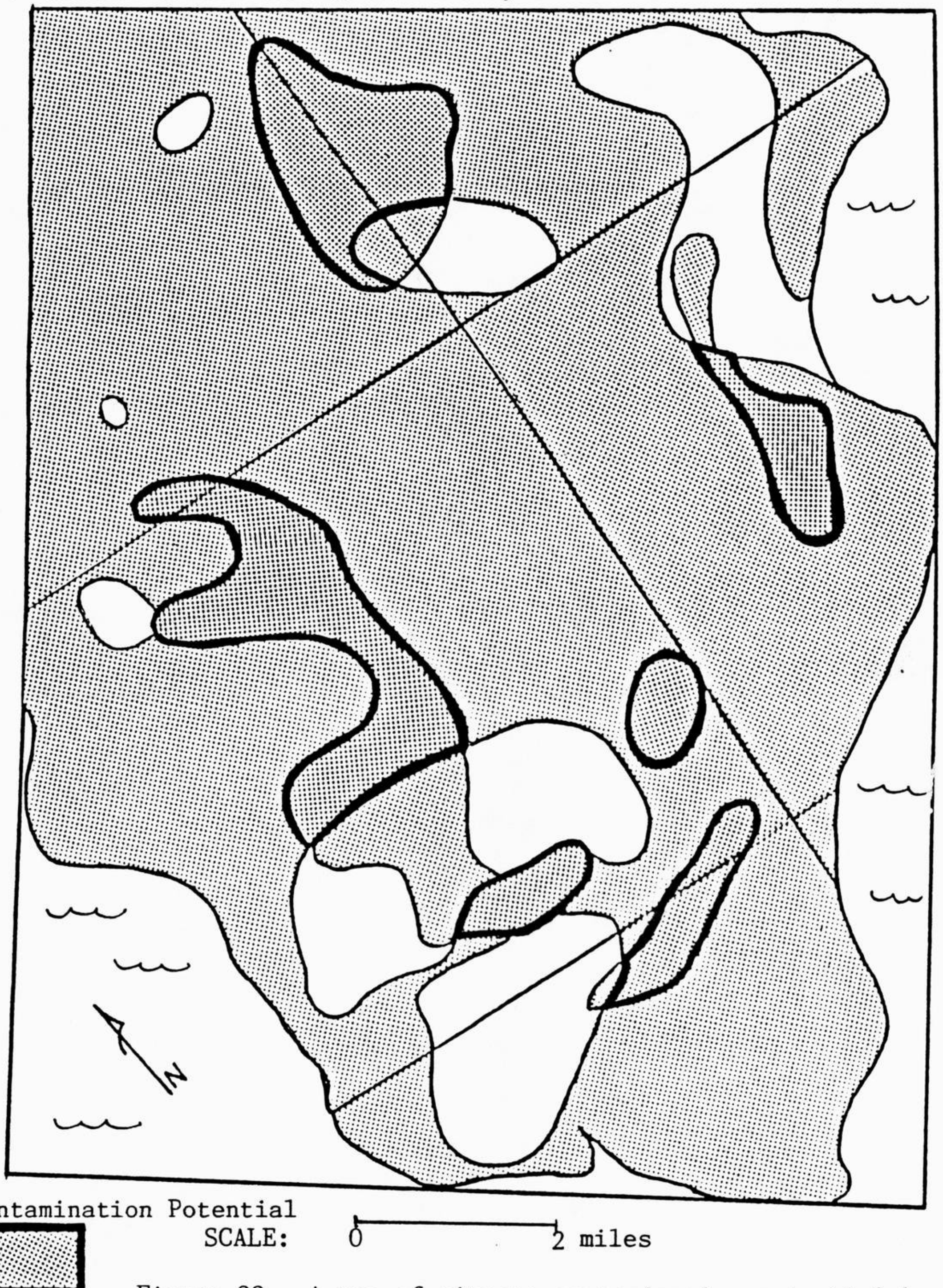


Figure 32. Graph of dolomite data used in this study where specific capacity is correlated against nitrate concentration. Two zones of 0-5 gpm/ft and > 5 gpm/ft were chosen to represent regions of low and high nitrate contamination potential, respectively, based on the group of data near the origin. The zones are used on a map of specific capacity (Figure 30) for the Door County test site.

Contamination Zones based on Clay Thickness--Door County Area



Contamination Potential

SCALE: 0 2 miles

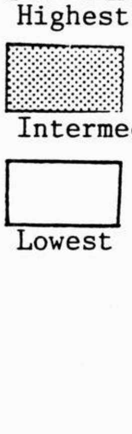


Figure 33. A map of nitrate contamination potential based on the distribution of clay thickness and specific capacity parameters (Figures 29 and 30). Low zones are in areas where neither the clay thickness or specific capacity variables have high nitrate potential designations. The intermediate zones are located where only one of the 2 variables has a high nitrate potential designation. The highest potential zones are located where both of the hydrogeologic variables (clay thickness and specific capacity) have higher nitrate potential designations.

located where <u>both</u> of the two variables (clay thickness and specific capacity) have the high nitrate potential designations.

Regulatory agencies can better focus their monitoring or well construction regulation efforts toward regions of intermediate to high nitrate contamination potential based on a composite map such as Figure 33. The actual nitrate concentration distribution for the test site is shown in map form on Figure 34. The map is drawn from all available test site nitrate values assuming that nitrate concentrations can be contoured between well sites. Note the non-uniform distribution of the data points on the map.

The actual nitrate distribution is drawn on the composite map of nitrate contamination potential to note the similarities and differences in the occurrence of high zones (Figure 35). The high nitrate concentration zone in the center of the map roughly coincides with the intermediate to high potential zone. The comparison is not perfect, but this is probably due, in part, to one or both of the following: 1) the non-uniform distribution of nitrate sampling points has distorted the shape and/or occurrence of the highest nitrate concentration zone, and 2) all the regions where nitrate contamination potential is highest may not have actual nitrate contamination sources that are drawn on by the wells.

Nitrate Concentration Distribution--Door County Test Area

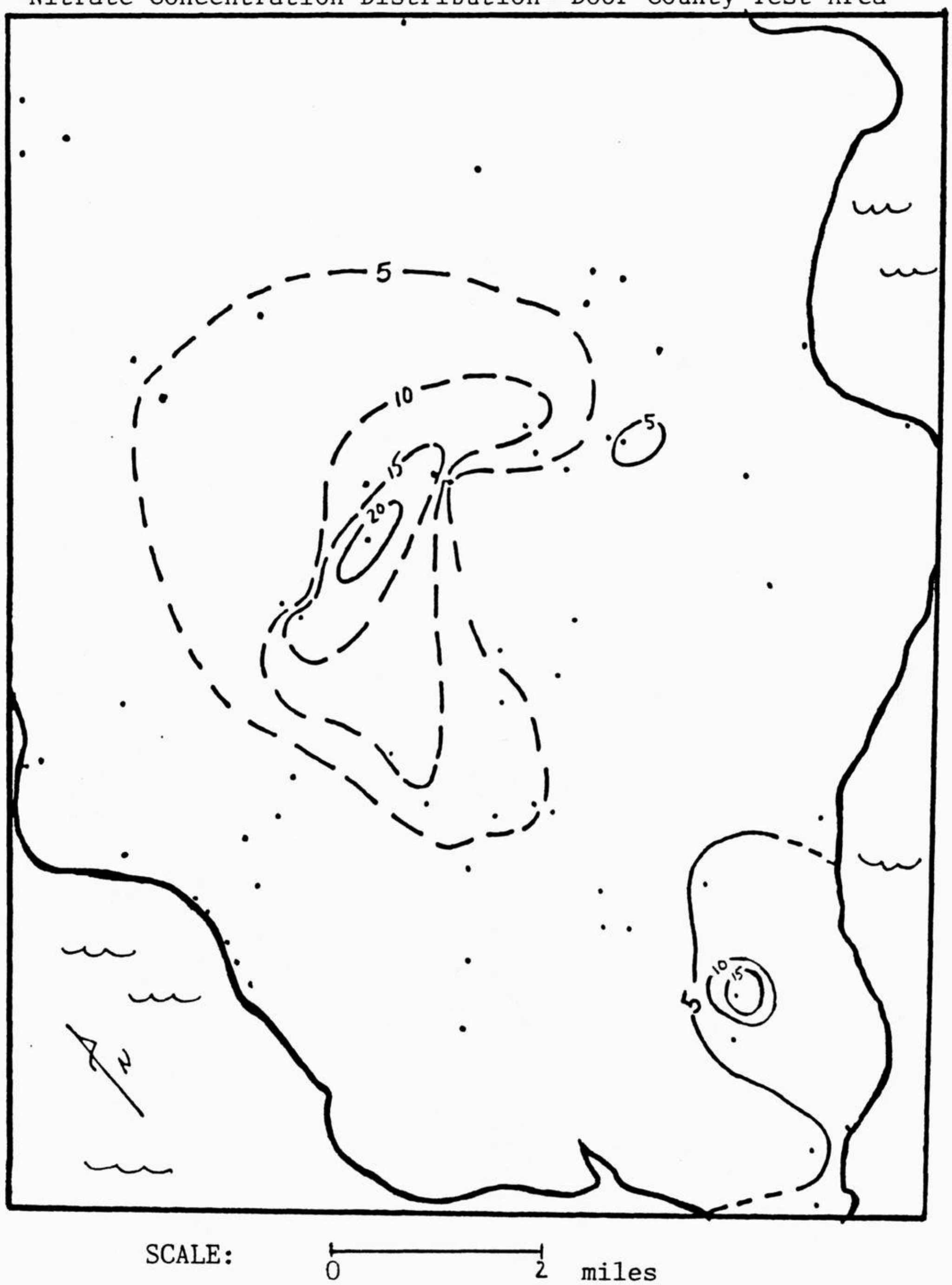
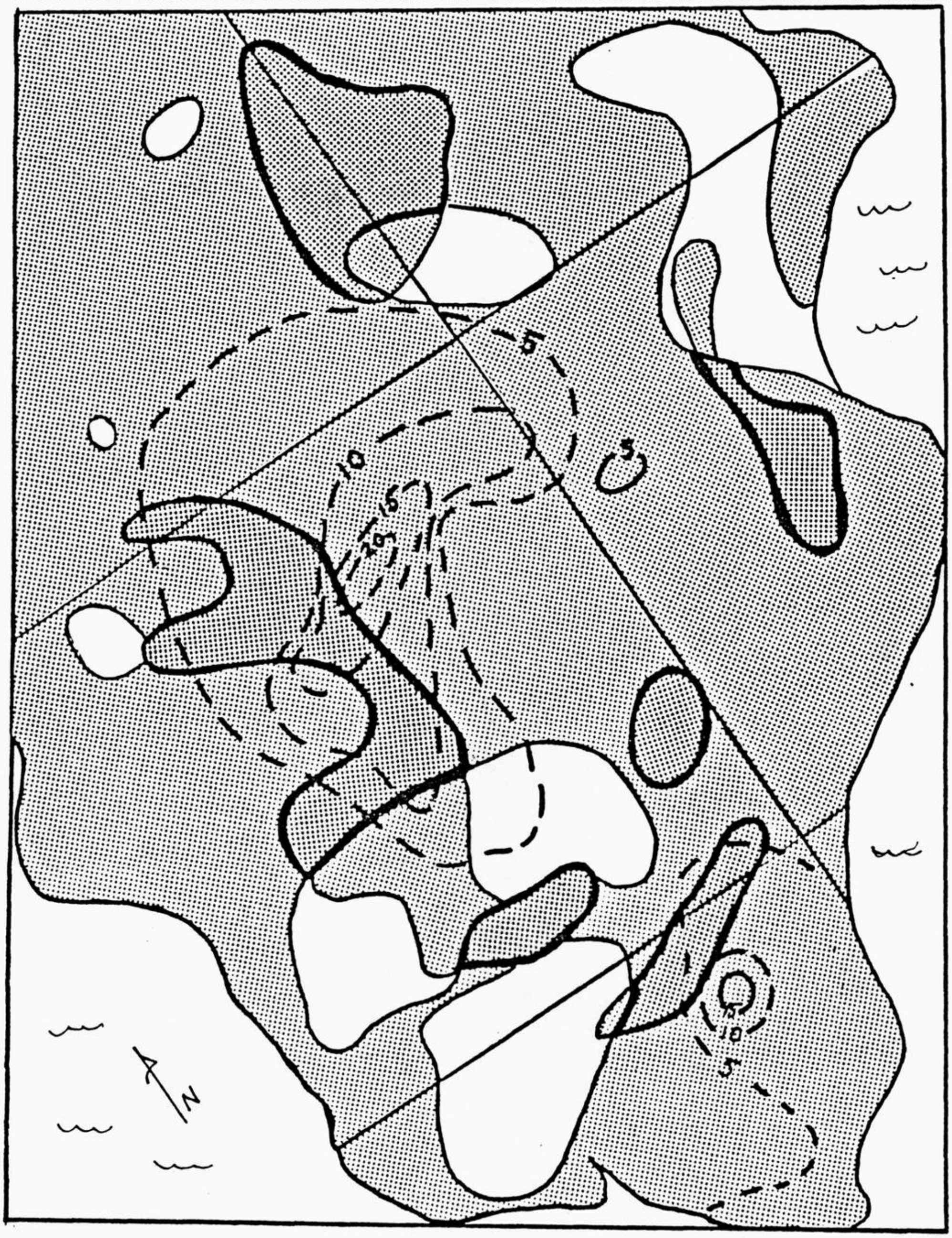


Figure 34. Map of actual distribution of nitrate concentration in ground water wells of the Door County test site. Map is drawn from all available nitrate analyses for the site.

Nitrate Contamination Potential with Nitrate Concentration Shown



KEY:

Highest

Intermediate

Lowest

SCALE: 0 — 2 miles

— — 5 — — NO_3^--N in mg/l

Figure 35. Map of actual nitrate concentration distribution (Figure 34) shown overlain on the potential for nitrate contamination (Figure 33). Highest zone of actual concentration coincides with an intermediate to high zone of nitrate contamination potential. Reasons for disagreements between actual highest concentration zones and highest potential zones include: 1) non-uniform distribution of nitrate analyses on the map, and 2) the possibility that nitrate contamination sources do not exist at all regions where potential for contamination is highest.

Another smaller zone of high nitrate concentration in the southeastern portion of the study area is also close to a high contamination potential zone (Figure 35). Clearly this method is not accurate enough to predict the contamination of specific well sites. Therefore, it should onlly be used to indicate townships (or perhaps portions of townships) which are susceptible to nitrate contamination. Following this general methodology, then, the process can be used elsewhere and in other aquifer types to predict nitrate contamination potential.

The methodology used in this study has some drawbacks and limitations. The study was initiated as a general, non-site specific study. However, results indicated that aquifer type must be considered when predicting nitrate contamination potential for an area, so data must be categorized by aquifer lithology in order to be meaningful. Also, well construction parameters were found to be just as important as hydrogeologic parameters in predicting nitrate contamination potential for a region, although they were not really used in the test of the study methodology.

The nitrate data that are available from the DNR must be improved by providing Land Survey System location designations down to quarter-quarter sections for each nitrate analysis. The improvement of the nitrate data base will facilitate easier matching of the corresponding well construction construction reports to each nitrate analysis, and hydrogeologic parameters can be more easily obtained for any similar studies in the future.

Further study is merited using some of the same methodology used in this investigation. Specifically, more townships with wells finished in unconsolidated sediments or sandstone should be investigated. The compilation of a more extensive data base from the sandstone and unconsolidated sediment aquifer types will produce better multiple regression equations for use in areas with those aquifer types.

A field study would also be appropriate where the actual hydrogeologic properties of one of the aquifer types are better defined or could be measured. Any field study that is attempted should try to determine a better definition of the hydraulic properties of both the aquifer and the unconsolidated materials. Such detailed information was not available from the data base that was used in this investigation, and therefore could not be quantified and used in the multiple regression process. If the hydraulic properties are more accurately defined it may be possible to explain more than 40 percent of the nitrate concentration variance from a given group of hydrogeologic data.

CONCLUSIONS

1. The nitrate data base (DNR non-community and SLOH nitrate files) used for this study was not complete enough for the purposes of this investigation. The majority of the nitrate analyses did not have any location designation whatsoever. To improve the usefulness of the nitrate information, locations of all the nitrate samples must be recorded using the Western United States Land Survey System down to quarter-quarter section designations.

2. The matching of well construction reports to locatable nitrate samples from the above data sources does not produce a number of data points sufficient to complete a statistical analysis. This is due in part to item #1 above, and is also due to insufficient location information provided by individual well contractors on the well construction reports.

3. The use of the multiple regression equation for a specific aquifer type (dolomite) produces the best correlation between predicted and observed nitrate-nitrogen concentrations for the Door County test area ($r = 0.60$). For prediction of nitrate concentration at other locations, data from the same aquifer type as the location in question should be used with this study's methodology.

4. The most important hydrogeologic variables for prediction of nitrate contamination potential for a dolomite aquifer based on results of this study are first the thickness of clay over the unconsolidated sediment column and then the specific capacity of the well.

5. The most important hydrogeologic variables for prediction of nitrate contamination potential for an aquifer of unconsolidated sediments are first the depth to the static water level and then the specific capacity.

6. The most important hydrogeologic variables for prediction of nitrate contamination potential for a sandstone aquifer are first the soil permeability and then the depth to the static water level.

7. Well construction parameters are important to consider in addition to hydrogeologic variables when predicting nitrate contamination potential for a given region. The addition of well construction variables into the multiple regression equation increases the percentage of the variance in predicted nitrate concentration produced by the independent variables.

8. The method produced a correlation coefficient (r) of 0.60 between observed and predicted nitrate concentrations for all data points of the Door County test region that had nitrate values of $\geq$1.0 mg/l nitrate as nitrogen.

9. When the data points were subdivided into the two categories of based on land use (fertilized or non-fertilized nitrate sources), correlation coefficients of 0.72 and 0.55 were obtained, respectively. The "fertilized" data points are probably representative of a more evenly distributed source than the "non-fertilized" data points. Therefore, fertilized land use data yields better results for this multiple regression process than non-fertilized land uses.

10. Factors found to be contributing to the scatter (low correlation coefficient) of predicted versus observed nitrate for the Door County test region were: 1) probable type of nitrate source as in #7 above, and 2) existence of an actual contamination source.

11. Possible additional reasons for low correlation coefficients for test site data that were not practical to consider in this study are: 1) proximity to nitrate source, 2) seasonal variations in nitrate concentration, 3) individual aquifer characteristics from well site to well site such as primary and secondary porosities, and fracture trend variations of the dolomite aquifer.

12. A map overlay method has been developed to predict regions of high nitrate contamination potential. The method successfully predicts regions of high contamination potential, but cannot predict nitrate concentration at specific well sites.

13. The method should be extrapolatable to other regions if the correct hydrogeologic variables are mapped and used in the overlay process according to the appropriate multiple regression equation results by aquifer type (items 4-5 above).

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APPENDIX I

Listing of U. S. Geological Survey $7\frac{1}{2}'$ Quadrangles used for topographic information.

<u>Door County Region</u>

Sturgeon Bay East
Jackson port
Sturgeon Bay West
Institute
Idlewild
Egg Harbor

<u>Dane County: Burke</u>

DeForest
Madison East
Sun Prairie
Cottage Grove

<u>Waukesha: Genesee</u>

Eagle
Genesee
Hartland
Oconomowoc East

<u>Rock County: Rock/Beloit</u>

Janesville West
Beloit

<u>Ozaukee County: Mequon</u>

Thiensville
Cedarburg
Five Corners
Menomonee Falls

APPENDIX II

Data file listing for all matched and unmatched wells: hydrogeologic variables only. Refer to Index maps in Appendix III for well locations. Hydrogeologic variables obtained from generated maps for unmatched data points (Appendices IV, V, Figures 9 - 12).

Key for Appendix

Column	Variable
ID	Map Identification number (see Index Maps, Appendix III)
NO_3	Mean nitrate-nitrogen concentration in milligrams per liter for sampled well
%CL	Percentage of clay in the unconsolidated sediments for those wells finished in bedrock, and % clay over the total well depth for wells finished in the unconsolidated materials
K	Soil Permeability in inches/hour from the U. S. Department of Agriculture Soil Survey (see references for specific listings)
TR	Depth to Bedrock (feet)
TW	Depth to Static Water Level (feet)
SC	Specific capacity in gallons per minute/ foot of drawdown for yield tests $\geq$ 4 hours in duration or from generated maps

NA = "not available"

BR = "bedrock"

UC = "unconsolidated

APPENDIX II CONTINUED

ID	NO_3	%CL	K	TR	TW	SC	
Rock/Beloit Township: MATCHED WELLS							
R1	2.7	3.5	3.83	57	20	0.94	Finished in BR
RR7	4.4	0.0	3.83	162	12	5.00	Finished in UC
R19	6.6	1.8	3.83	100	51	6.67	
R25	11.9	0.0	3.83	65	12	7.50	
R26	8.8	5.0	3.83	58	8	2.50	
R27	12.7	2.5	3.83	NA	55	10.00	
R28	13.3	16.7	3.83	NA	60	10.00	
R29	11.1	0.0	3.83	NA	55	16.90	
R30	3.2	6.7	3.83	NA	49	25.00	
RR41	5.6	5.0	3.83	NA	16	2.50	
Mequon Township: MATCHED WELLS							
RO-2-1	3.0	100.0	0.62	62	38	1.00	ALL IN BR
RO-3-6	2.6	81.2	0.62	80	47	NA	
RO-3-1	1.4	71.4	0.71	70	38	1.00	
RO-10-6	2.0	61.0	0.71	63	18	1.67	
RO-10-3	1.7	100.0	0.71	51	33	1.50	
RO-15-1	2.0	95.0	7.50	90	106	8.50	
RO-M-4	2.6	100.0	0.71	68	20	0.25	
RO-14-1N	1.4	80.0	0.71	226	31	1.00	
RO-4-3	2.7	60.0	0.71	51	31	0.95	
RO-4-2	3.8	54.0	0.71	108	60	1.00	
RO-9-2	3.1	0.0	3.40	23	14	2.75	
RO-9-1	2.8	84.0	0.71	85	55	0.43	
RO-M1	6.4	94.0	0.71	127	65	0.75	
RO-16-1	3.2	63.0	0.71	73	20	0.40	
RO-M3	3.8	71.0	3.40	70	38	1.00	
RO-14-1	3.1	25.0	7.50	NA	35	1.00	
RO-3	1.9	88.0	0.62	80	33	3.13	
RO-4	18.0	100.0	0.71	19	5	5.00	
RO-51	5.8	70.0	0.71	50	22	0.36	
RO-35	4.5	89.0	0.71	45	45	0.90	
RO-5	0.5	50.0	7.50	80	30	2.50	
RO-8	0.5	30.0	0.62	145	65	7.14	
RO-13	0.5	57.0	0.71	86	35	1.88	
R0-14	0.5	63.0	7.50	76	40	0.18	
RO-16	0.5	56.0	0.71	95	48	2.40	
R0-22	0.5	80.0	0.62	88	31	1.13	
RO-29	0.5	77.0	0.62	102	55	4.50	
RO-31	0.5	68.0	0.71	127	30	7.50	
RO-32	0.5	91.0	0.62	117	39	0.37	
RO-38	0.5	96.0	0.71	178	13	1.75	
RO-40	0.5	30.0	0.62	104	29	0.58	
RO-42	0.5	92.0	0.62	138	84	4.00	
RO-44	0.5	50.0	0.62	134	60	4.30	

APPENDIX II CONTINUED

ID	NO_3	%CL	K	TR	TW	SC	
Mequon MATCHED continued							
RO-53	0.5	50.0	7.50	100	48	7.80	ALL IN BR
RO-54	0.5	74.0	7.50	97	22	2.40	
RO-68	0.5	35.0	7.50	126	69	3.30	
RO-70	0.5	24.0	7.50	61	18	0.24	
RO-71	0.5	43.0	7.50	35	25	0.25	
RO-74	0.5	77.0	0.62	134	70	0.55	
RO-12	0.5	78.0	0.71	51	38	0.50	
Genesee Township							
RW-22	10.6	0.0	7.54	125	13	7.50	MATCHED
RW-23	8.6	0.0	7.54	127	15	0.50	FINISHED
RW-43	13.8	40.0	7.54	70	20	0.90	IN UNCONSOL
RW-44	11.2	40.0	7.54	69	19	1.70	
RW-50	13.1	20.0	7.54	127	17	2.50	
RW-2	4.6	15.0	1.38	88	60	0.73	FINISHED IN
RW-17	2.2	10.0	11.20	35	29	1.30	BEDROCK
RW-21	10.2	20.0	7.54	55	10	10.00	
RW-28	1.7	22.0	7.54	69	35	0.50	
RW-29	3.8	0.0	11.20	50	55	1.08	
RW-30	3.9	28.0	7.54	70	42	1.00	
RW-6	0.5	20.0	1.38	50	50	0.16	
RW-8	0.5	9.0	1.38	57	286	0.12	
RW-1	0.5	58.0	1.38	55	16	1.00	FINISHED IN UC
Burke Township							
D-1	3.5	5.0	2.70	61	23	2.85	ALL FINISHED IN
D-3	8.2	57.0	2.70	70	60	3.75	BEDROCK
D-4	5.2	100.0	2.70	5	78	1.50	
D-10	14.7	0.0	2.70	15	65	3.00	
D-13	5.0	81.0	2.70	27	55	6.00	
D-16	11.8	17.0	2.70	58	40	5.00	
D-18	7.5	100.0	2.70	6	80	2.80	
D-20	1.0	30.0	2.00	93	30	2.50	
D-26	4.8	90.0	2.00	25	38	15.00	
D-28	6.4	100.0	2.00	6	12	6.00	
D-29	2.1	0.0	5.20	43	3.5	NA	
D-33	2.0	58.0	5.20	60	8	6.00	
D-35	3.2	36.0	5.20	83	6	10.00	
Door Test Region Data							
DOOR-4	2.6	100.0	1.30	2	60	1.50	MATCHED
DOOR-3	5.2	75.0	3.30	16	12	6.00	ALL IN BEDROCK
DOOR-1	3.7	90.0	20.00	5	0	NA	SPEC CAP FROM GENERATED MAPS

APPENDIX II CONTINUED

ID	NO_3	%CL	K	TR	TW	SC	
Door All Matched Continued							
DOOR-8	0.8	100.0	1.30	6	128	7.00	GENERATED MAPS
DOOR-10	5.0	53.0	30.00	15	5	1.00	USED FOR SC'S
DOOR-11	0.7	100.0	3.30	7	48	2.50	
DOOR-12	0.9	100.0	16.00	3	5	1.00	
DOOR-24	8.0	95.0	4.00	43	25	NA	
DOOR-26	9.2	0.0	13.00	42	0	0.75	
AF1	3.2	90.0	1.30	15	60	7.50	
AF2	9.8	79.0	3.50	9	91	17.80	
AF3	11.0	80.0	3.30	25	93	15.00	
AF4	7.0	100.0	1.30	6	55	1.00	
AD5	1.9	100.0	1.30	4	120	0.50	
AH12	2.3	100.0	1.30	4	51	0.83	
AH17	1.6	100.0	1.30	1	58	0.45	
AK18	2.9	100.0	3.30	11	65	2.00	
AK29	8.5	78.0	1.30	19	40	NA	
AK38	10.7	NA	0.70	15	40	NA	
AH43	5.6	100.0	3.30	10	52	8.30	
AP39	3.5	80.0	2.20	11	147	2.00	
AP42	2.8	90.0	3.30	9	60	5.00	
AN36	0.6	86.0	2.20	21	80	2.40	
AK13	1.6	100.0	3.30	7	60	NA	
AK22	1.5	100.0	3.50	5	35	3.00	
AN21	0.6	100.0	1.30	5	45	3.00	
AG10	15.9	100.0	3.30	5	15	3.50	
DR173	16.0	NA	NA	6	160	1.10	
DR218	2.0	100.0	3.50	6	115	0.25	
DR172	17.0	NA	1.30	6	111	5.10	
DR168	7.0	100.0	1.30	2	144	3.00	
DR215	4.0	100.0	1.30	2	34	2.50	
DR216	10.0	NA	3.30	25	108	10.00	
DR178	4.0	100.0	3.30	15	62	2.50	
AK14	5.0	50.0	3.50	5	56	1.20	
AP40	0.0	100.0	1.30	4	129	1.67	
AP37	0.0	82.0	2.20	28	65	1.00	
DR184	0.0	52.0	13.00	60	12	0.50	
Rock/Beloit Township							
R-3	1.5	23.0	3.83	60	16	1.50	UNMATCHED
R-5	5.4	5.0	3.83	53	13	2.40	UNCONSOLIDATED
R-9	6.7	7.5	3.83	70	25	5.00	
R-11	10.7	11.0	3.83	55	5	1.66	
R-13	7.3	11.0	3.83	51	1	1.66	
R-14	10.0	6.0	3.83	10	10	2.00	
R-15	5.3	0.0	3.83	145	40	12.00	
R-17	12.4	10.0	3.83	53	3	1.66	
R-18	4.9	2.0	3.83	98	2	2.40	
R-21	10.1	0.0	3.83	65	12	7.50	

APPENDIX II CONTINUED

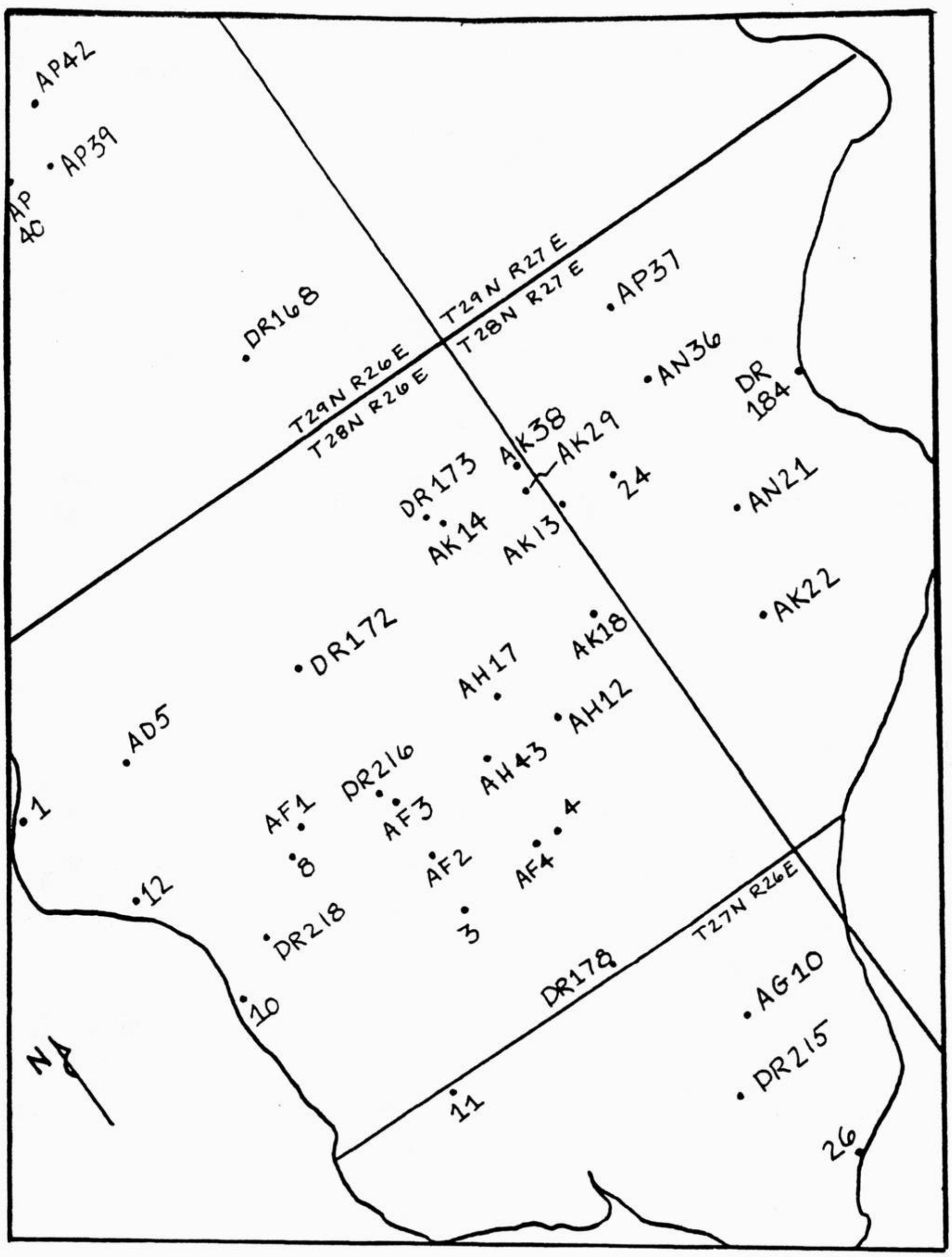
ID	NO_3	%CL	K	TR	TW	SC	
Rock/Beloit UNMATCHED continued							
R-24	6.5	0.0	3.83	135	45	7.80	IN UC
R-2	3.2	100.0	3.83	5	15	1.00	UNMATCHED
R-4	11.1	40.0	2.10	51	81	1.80	BEDROCK
R-8	8.8	NA	2.10	68	83	10.00	
R-10	13.8	0.0	3.83	28	10	0.90	
R-12	13.1	4.5	3.83	23	4	2.00	
R-20	13.0	10.0	3.83	35	8	0.50	
R-22	10.8	1.0	3.83	38	40	7.80	
R-23	9.8	15.0	3.83	15	64	7.40	
R-31	10.6	40.0	2.10	5	50	11.00	
R-34	4.9	4.0	3.83	23	3	10.00	
R-36	8.6	100.0	3.83	11	80	11.00	
R-39	12.3	25.0	3.83	10	9	0.75	
Mequon Township							
RO-3-1HB	6.5	70.0	6.50	65	32	NA	UNMATCHED
RO-3-5	16.2	75.0	7.50	55	13	NA	ALL IN BEDROCK
RO-4-4	4.2	79.0	5.30	120	10	0.85	
RO-4-5	1.4	75.0	0.71	85	10	0.20	
RO-10-1	11.2	95.0	0.71	16	45	6.50	
RO-10-2	1.3	65.0	7.50	50	5	2.50	
RO-10-4	3.1	85.0	7.50	54	52	2.73	
RO-10-5	7.5	40.0	7.50	45	15	3.00	
RO-11-5	10.7	45.0	0.62	65	24	8.50	
RO-14-2	3.8	50.0	7.50	53	8	1.50	
RO-46	1.2	50.0	7.50	101	19	1.10	
RO-59	9.9	90.0	0.71	44	100	2.50	
RO-65	0.7	35.0	7.50	75	15	1.00	
RO-73	4.7	80.0	0.71	39	45	0.50	
RO-50	0.5	95.0	0.62	146	80	3.50	
RO-52	0.5	77.0	7.50	115	40	3.00	
RO-57	0.5	84.0	7.50	54	21	1.50	
Genesee Township							
RW-3	1.1	40.0	1.38	55	57	1.50	UNMATCHED
RW-5	1.4	25.0	1.38	40	45	3.00	BEDROCK
RW-7	4.5	25.0	1.38	50	35	3.00	
RW10	8.6	18.0	7.54	95	20	12.00	
RW-11	7.6	20.0	7.54	135	28	0.50	
RW-12	9.3	19.0	7.54	126	13	7.50	
RW-13	13.2	26.0	7.54	70	20	5.00	
RW-14	9.2	19.0	7.54	124	24	0.50	
RW-19	10.4	22.0	7.54	66	11	14.00	
RW-20	9.0	19.0	7.54	65	25	15.00	
RW-25	9.6	22.0	7.54	75	10	7.50	

APPENDIX II CONTINUED

ID	NO_3	%CL	K	TR	TW	SC	
Genesee UNMATCHED continued							
RW-31	1.4	26.0	11.20	80	62	1.10	IN BEDROCK
RW-32	3.8	26.0	11.20	86	72	1.20	
RW-33	4.3	NA	7.54	160	60	NA	
RW-34	1.5	30.0	7.54	130	77	1.10	
RW-35	4.0	10.0	1.38	207	137	0.65	
RW-36	2.2	NA	1.38	135	92	NA	
RW-37	9.5	19.0	1.38	60	30	0.50	
RW-40	2.6	32.0	1.38	60	29	2.00	
RW-41	10.0	10.0	11.20	123	75	2.70	
RW-42	14.0	90.0	5.21	15	41	0.70	
RW-55	11.2	20.0	7.54	124	24	0.50	
RW-48	16.5	30.0	7.54	70	20	7.50	
RW-54	15.8	19.0	7.54	54	21	13.00	
RW-45	25.0	40.0	7.54	80	25	1.00	
RW-46	38.0	40.0	7.54	70	15	0.90	
RW-53	10.1	18.0	7.54	58	17	13.00	
RW-52	12.1	18.0	1.38	202	140	1.00	
RW-49	12.3	25.0	7.54	120	15	7.90	
RW-51	11.1	17.0	1.38	175	93	5.00	
Burke Township							
D-7	15.2	40.0	2.00	15	15	1.00	UNMATCHED
D-2	10.2	30.0	2.70	12	65	2.50	IN BEDROCK
D-6	5.5	95.0	2.70	40	160	1.00	
D-8	16.4	75.0	2.00	78	107	4.00	
D-11	12.4	5.0	2.70	25	105	5.00	
D-12	12.3	49.0	2.70	25	85	2.75	
D-19	6.7	5.0	2.70	15	95	5.00	
D-21	13.6	90.0	2.70	37	95	4.85	
D-22	6.7	0.0	2.70	30	80	2.70	
D-23	11.2	27.0	5.20	63	75	6.00	
D-24	12.4	5.0	2.70	20	100	5.00	
D-25	12.0	40.0	2.00	50	15	0.50	
D-27	6.4	15.0	2.70	57	52	2.50	
D-30	4.3	25.0	5.20	46	10	5.00	
D-31	3.0	21.0	5.20	45	5	6.00	
D-32	0.8	7.0	5.20	67	7	11.00	
D-34	5.9	5.0	5.20	85	5	3.50	
D-36	4.6	5.0	5.20	10	20	2.50	
D-17	0.5	NA	2.00	70	35	3.75	

APPENDIX III

Index maps for wells sampled for nitrate for each study township.



Scale: 0 1 2 miles

Figure III-1. Index map of wells sampled for nitrate in the Door County test region. See Appendix II for nitrate values and corresponding hydrogeologic information.

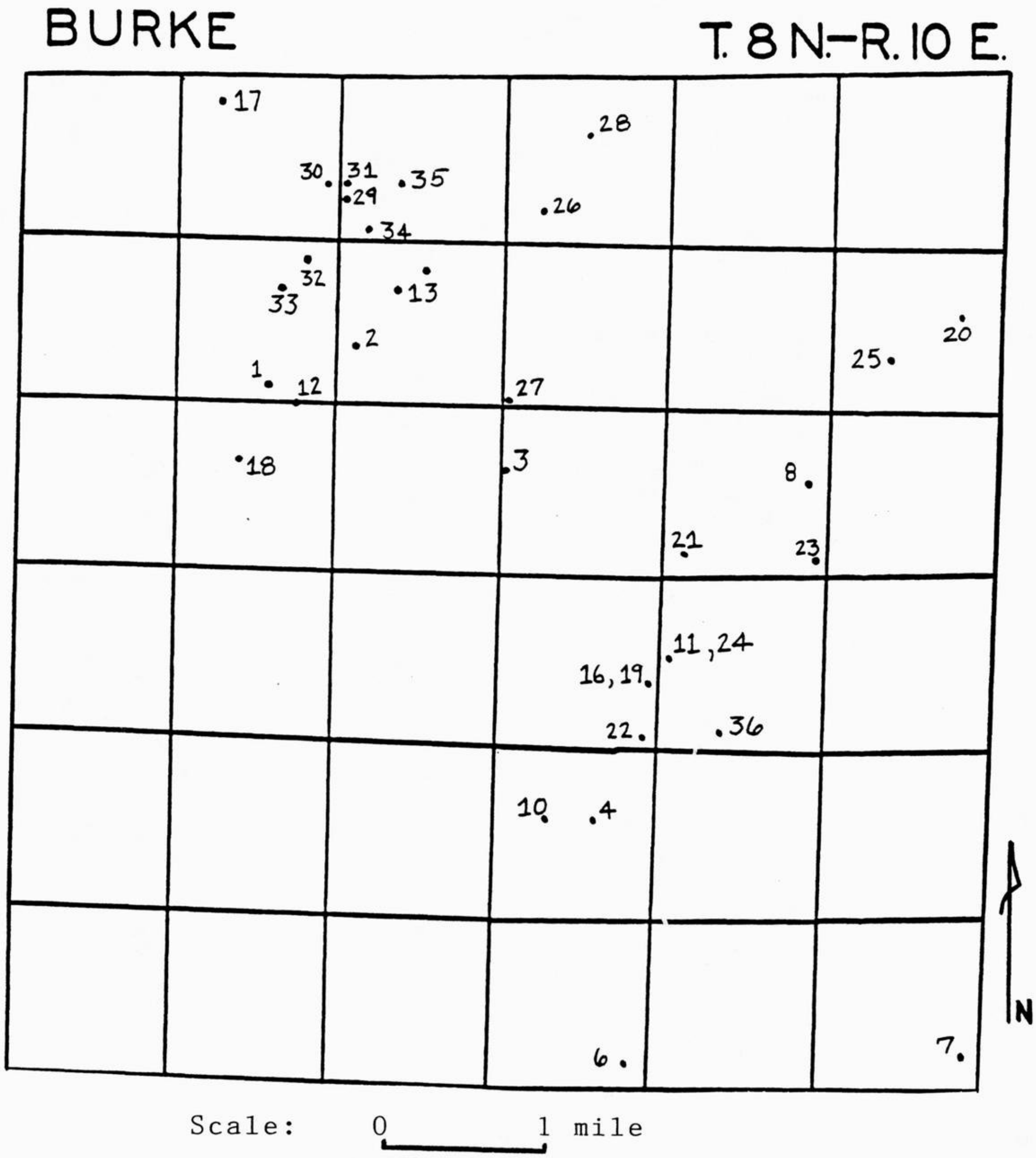
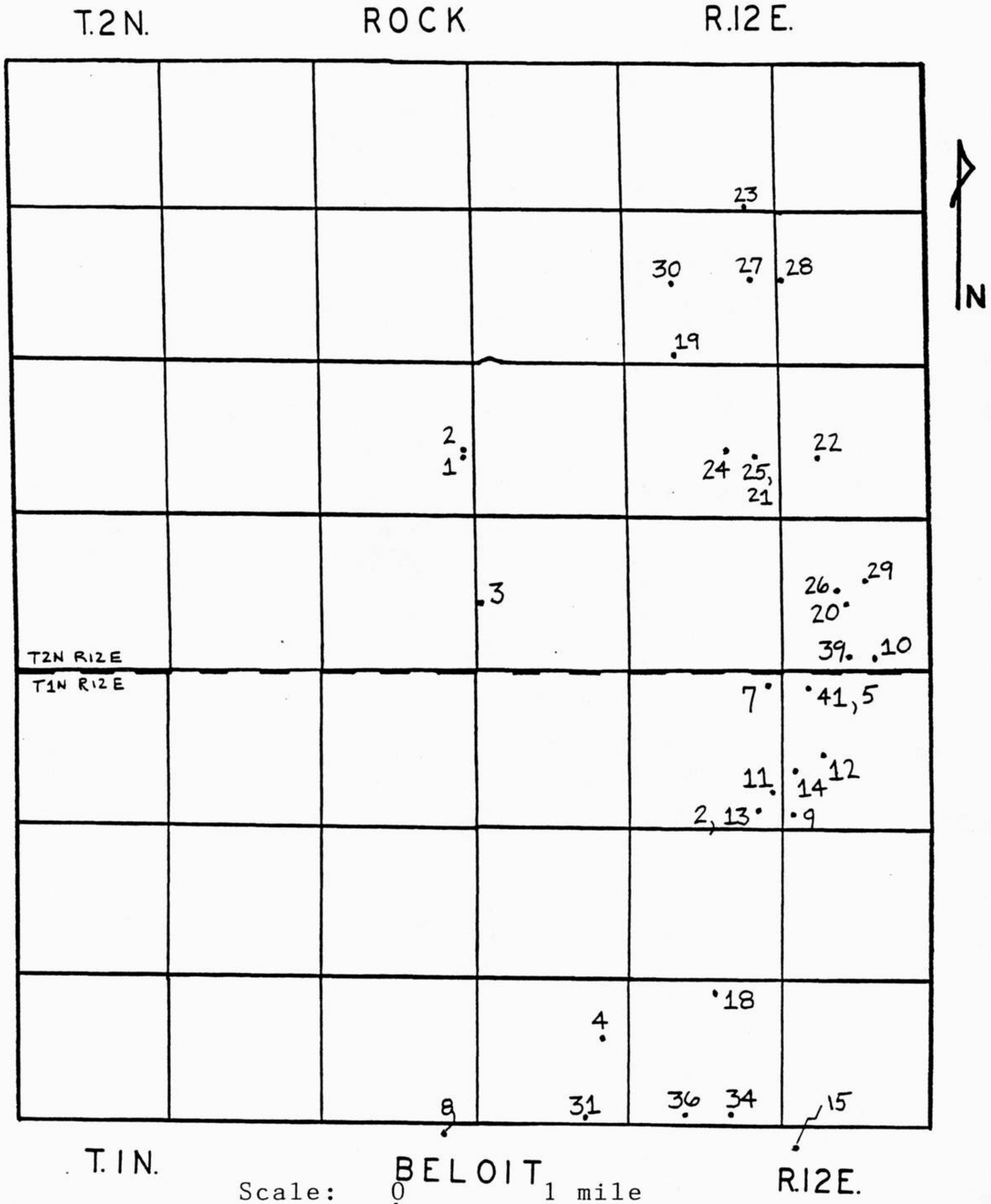


Figure III-2. Index map of wells sampled for nitrate in the Burke Township, Dane County, Wisconsin. See Appendix II for nitrate values and corresponding hydrogeologic information.



Scale: 0 1 mile

Figure III-3. Index map of wells sampled for nitrate in the Rock/Beloit Township, Rock County, Wisconsin. See Appendix II for nitrate values and corresponding hydrogeologic information.

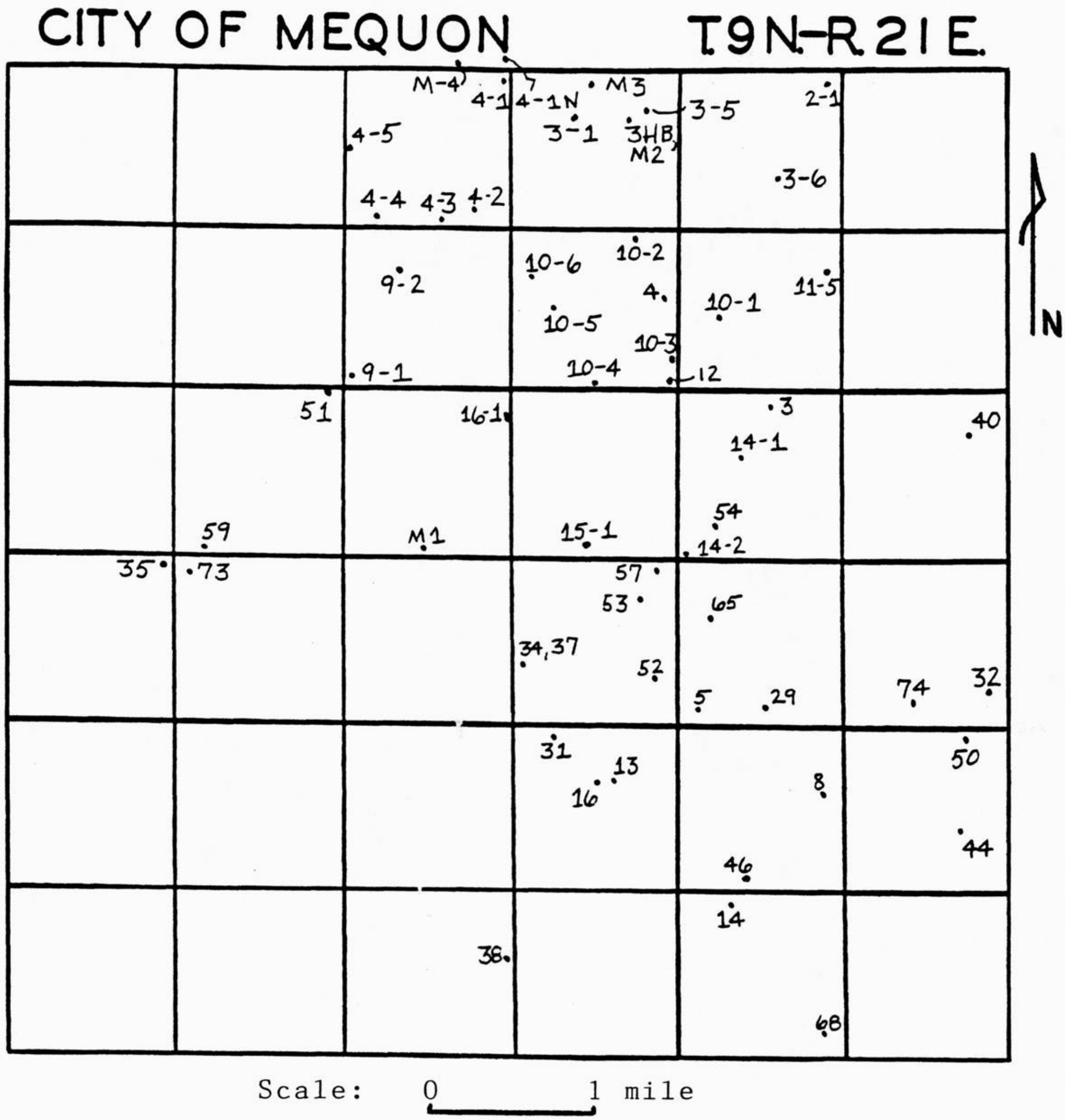


Figure III-4. Index map of wells sampled for nitrate in the Mequon Township, Ozaukee County, Wisconsin. See Appendix II for nitrate values and corresponding hydrogeologic information.

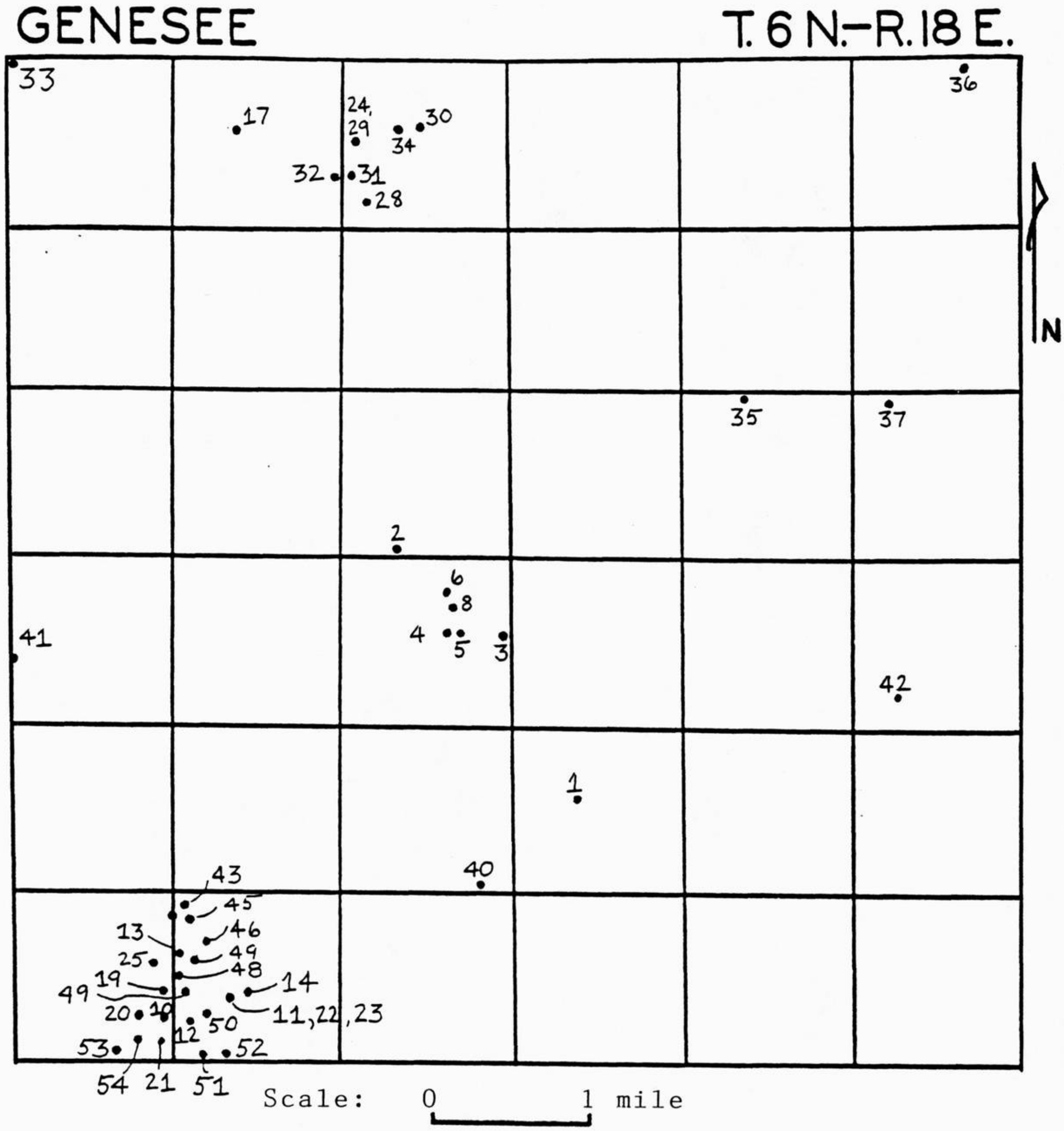


Figure III-5. Index map of wells sampled for nitrate in the Genesee Township, Waukesha County, Wisconsin. See Appendix II for nitrate values and corresponding hydrogeologic information.

APPENDIX IV

Data file listing for map generating information obtained from well construction reports. See Appendix V for index maps of well locations.

Key for Appendix

Column Code	Variable
ID	Map Identification Number (see index maps Appendix V.)
GS	Ground Surface elevation from US Geological Survey 7½' Quadrangle maps (See Appendix I for maps used).
TW	Depth to Static Water Level (feet)
TR	Depth to Bedrock (feet)
POT	Potentiometric Surface Elevation (feet)
BR	Bedrock Surface Elevation (feet)
%CL	Percentage of clay in the unconsolidated sediments for those wells finished in bedrock, and % clay over the total well depth for wells finished in the unconsolidated sediments.
SC	Specific Capacity in gallons per minute/foot of drawdown for yield tests $\geq$ 4 hours in duration.

NA = Not Available

* = Well finished in unconsolidated deposits

ERR = A mathematical division by zero has occurred. Specific capacity or %clay value is not available.

Note: where one well ID number has more than one set of data points (i. e., more than one well completion report's data was recorded for that particular quarter-quarter section) an average of all values was used when constructing the maps.

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
Rock/Beloit Township							
R1	770	15	-1	755	NA	0.08	NA*
R2	755	16	-1	739	NA	0.04	NA*
R3	810	56	-1	754	NA	0.04	12.00*
R4	760	28	15	732	745	4.33	0.25
R5	780	40	-1	740	NA	0.00	NA*
R6	780	8	-1	772	NA	0.13	ERR*
R6	780	6	-1	774	NA	0.00	1.67*
R7	770	30	-1	740	NA	0.05	15.00*
R8	763	56	-1	707	NA	0.00	NA*
R9	778	26	146	752	632	1.00	0.86
R10	785	15	-1	770	NA	1.00	ERR*
R11	810	28	180	782	630	0.68	NA
R12	795	16	155	779	640	0.95	0.27
R13	812	56	-1	756	NA	0.94	1.43*
R14	780	20	145	760	635	0.59	2.00
R15	802	55	-1	747	NA	0.60	NA*
R16	840	55	-1	785	NA	0.15	NA*
R17	NA	70	3	ERR	ERR	1.00	NA
R18	850	70	0	780	850	ERR	1.50
R19	NA	50	0	ERR	ERR	ERR	NA
R20	NA	107	118	ERR	ERR	0.00	2.50
R21	919	52	-1	867	NA	0.05	NA*
R22	910	74	34	836	876	1.00	1.67
R23	885	72	15	813	870	0.47	NA
R24	905	80	5	825	900	1.00	NA
R25	860	90	6	770	854	1.00	ERR
R26	910	62	60	848	850	0.62	4.00
R27	840	85	9	755	831	1.00	0.40
R28	870	90	10	780	860	1.00	1.88
R29	890	89	5	801	885	1.00	0.88
R30	840	100	6	740	834	1.00	ERR
R31	894	80	12	814	882	1.00	ERR
R32	855	74	0	781	855	ERR	1.17
R33	875	80	11	795	864	1.00	0.93
R34	880	52	3	828	877	1.00	NA
R35	820	100	5	720	815	1.00	0.75
R36	749	10	-1	739	NA	0.02	NA*
R37	770	12	-1	758	NA	0.02	NA*
R38	748	3	-1	745	NA	0.09	NA*
R39	790	23	-1	767	NA	0.24	NA*
R40	750	4	-1	746	NA	0.05	10.00*
R41	806	28	6	778	800	1.00	NA
R42	805	54	-1	751	NA	0.04	15.00*
R43	804	40	-1	764	NA	0.00	NA*
R43	804	52	-1	752	NA	0.08	4.00*
R44	790	50	-1	740	NA	0.03	3.75*
R45	795	41	-1	754	NA	0.05	NA*

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
R45	795	50	-1	745	NA	0.06	4.00*
R46	803	50	-1	753	NA	0.06	2.00*
R47	810	55	-1	755	NA	0.00	248.08*
R48	810	50	-1	760	NA	0.00	NA*
R49	808	42	-1	766	NA	0.06	NA*
R50	805	53	-1	752	NA	0.10	NA*
R51	800	72	1	728	799	1.00	NA
R52	750	8	-1	742	NA	0.05	NA*
R53	790	47	-1	743	NA	0.00	NA*
R54	750	45	-1	705	NA	0.03	5.00*
R54	750	46	-1	704	NA	0.04	ERR*
R55	780	50	-1	730	NA	ERR	ERR*
R55	780	45	-1	735	NA	0.00	2.67*
R56	750	5	-1	745	NA	0.04	2.00*
R57	790	42	-1	748	NA	0.09	NA*
R58	770	10	-1	760	NA	0.02	NA*
R59	788	36	-1	752	NA	0.03	NA*
R60	860	40	-1	820	NA	0.00	10.00*
R61	800	95	30	705	770	0.23	NA
R62	880	62	7	818	873	1.00	NA
R63	810	40	20	770	790	0.50	1.60
R64	830	25	10	805	820	1.00	2.00
R65	870	60	15	810	855	1.00	1.40
R66	895	45	10	850	885	1.00	0.75
R67	830	85	1	745	829	1.00	2.00
R68	830	22	8	808	822	1.00	5.00
R69	870	70	14	800	856	1.00	3.00
R70	890	105	24	785	866	1.00	2.14
R71	835	70	12	765	823	1.00	NA
R71	835	70	12	765	823	1.00	1.50
R72	905	75	94	830	811	0.85	NA
R73	886	14	4	872	882	1.00	NA
R74	832	35	99	797	733	0.86	2.50
R75	NA	31	0	ERR	ERR	ERR	NA
R76	830	60	-1	770	NA	0.00	ERR*
R77	802	63	-1	739	NA	0.00	ERR*
R78	802	50	-1	752	NA	0.04	NA*
R78	802	35	-1	767	NA	0.10	1.60*
R78	828	65	-1	763	NA	0.05	NA*
R79	833	60	-1	773	NA	0.02	NA*
R80	836	72	-1	764	NA	0.02	4.00*
R81	821	55	-1	766	NA	0.35	NA*
R82	801	39	-1	762	NA	0.07	NA*
R83	807	45	-1	762	NA	0.00	7.50*
R84	795	32	-1	763	NA	0.08	NA*
R84	795	50	-1	745	NA	0.15	NA*
R84	795	37	-1	758	NA	0.29	1.60*
R85	802	40	-1	762	NA	0.15	2.00*

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
R86	800	45	-1	755	NA	0.00	NA*
R87	810	40	-1	770	NA	0.03	5.00*
R88	802	37	-1	765	NA	0.02	NA*
R88	802	45	-1	757	NA	0.03	2.50*
R89	810	41	-1	769	NA	0.09	ERR*
R90	805	55	-1	750	NA	0.03	NA*
R90	805	65	54	740	751	0.02	1.67
R90	805	35	-1	770	NA	0.03	ERR*
R91	814	50	-1	764	NA	0.01	ERR*
R92	831	64	-1	767	NA	0.00	NA*
R92	831	50	-1	781	NA	0.02	2.40*
R92	831	75	-1	756	NA	0.00	ERR*
R93	765	6	-1	759	NA	0.48	ERR*
R94	795	35	60	760	735	0.00	NA
R95	802	25	-1	777	NA	0.00	NA*
R96	760	0	125	760	635	0.62	2.95
R96	760	10	-1	750	NA	0.44	1.88*
R97	760	35	-1	725	NA	0.22	NA*
R98	804	45	-1	759	NA	0.17	NA*
R98	804	54	217	750	587	0.82	NA
R98	804	55	-1	749	NA	0.09	1.50*
R99	804	40	-1	764	NA	0.54	0.50*
R100	810	35	-1	775	NA	0.86	1.43*
R101	815	40	8	775	807	1.00	2.00
R102	865	81	25	784	840	1.00	3.75
R103	862	75	-1	787	NA	0.59	1.00*
R104	870	85	154	785	716	1.00	NA
R105	861	85	138	776	723	0.36	2.00
R106	805	40	-1	765	NA	0.56	ERR*
R107	840	70	250	770	590	0.48	0.50
R108	823	72	-1	751	NA	0.05	NA*
R109	845	64	-1	781	NA	0.96	NA*
R110	840	68	-1	772	NA	0.94	1.71*
R111	840	52	249	788	591	1.00	ERR
R112	790	14	197	776	593	0.59	0.50
R113	835	48	-1	787	NA	0.12	NA*
R114	798	28	-1	770	NA	0.43	0.88*
R115	885	15	-1	870	NA	0.00	NA*
R116	842	35	-1	807	NA	0.28	0.53*
R117	800	20	-1	780	NA	0.76	ERR*
R118	772	44	-1	728	NA	0.00	NA*
R119	770	14	-1	756	NA	0.68	ERR*
R120	801	29	-1	772	NA	0.09	3.00*
R120	801	42	-1	759	NA	0.34	1.11*
R121	880	30	-1	850	NA	0.05	NA*
R122	805	30	-1	775	NA	0.02	NA*
R123	795	42	-1	753	NA	0.00	0.75*
R124	770	30	-1	740	NA	0.65	2.50*

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
R125	755	30	-1	725	NA	0.71	NA*
R126	770	52	-1	718	NA	0.45	NA*
R127	795	25	-1	770	NA	0.30	5.00*
R128	750	24	-1	726	NA	0.88	0.33*
R129	765	8	-1	757	NA	0.15	NA*
R129	765	12	-1	753	NA	0.48	3.33*
R130	770	23	160	747	610	1.00	NA
R131	790	45	-1	745	NA	0.00	5.00*
R132	799	77	-1	722	NA	0.20	ERR*
R133	810	55	-1	755	NA	0.03	ERR*
R134	800	45	-1	755	NA	0.02	8.00*
R135	810	60	-1	750	NA	0.14	10.00*
R136	755	6	-1	749	NA	0.05	7.50*
R136	755	10	-1	745	NA	0.08	NA*
R137	800	50	-1	750	NA	0.10	NA*
R138	750	5	-1	745	NA	1.50	7.50*
R139	765	14	-1	751	NA	0.12	NA*
R140	753	7	-1	746	NA	0.05	5.00*
R141	760	12	-1	748	NA	0.00	NA*
R142	765	12	-1	753	NA	0.00	7.50*
R143	790	9	-1	781	NA	0.10	NA*
R144	762	15	10	747	752	0.20	NA
R144	762	20	15	742	747	0.00	7.50
R145	750	25	-1	725	NA	0.00	NA*
R146	762	7	-1	755	NA	0.00	1.67*
R147	801	69	7	732	794	1.00	2.00
R148	815	65	3	750	812	1.00	0.50
R149	760	17	3	743	757	1.00	NA
R149	760	15	108	745	652	0.51	0.33
R150	775	20	-1	755	NA	0.02	NA*
R151	760	16	-1	744	NA	0.02	2.50*
R151	760	19	-1	741	NA	0.77	NA*
R152	760	19	-1	741	NA	0.04	10.00*
R153	770	67	20	703	750	0.20	1.20
R154	NA	40	-1	ERR	NA	0.95	NA*
R155	NA	20	-1	ERR	NA	0.00	ERR*
R155	NA	40	7	ERR	ERR	1.43	NA
R156	898	105	10	793	888	1.00	NA
R157	830	65	21	765	809	1.00	2.14
R158	860	75	24	785	836	0.83	NA
R159	840	60	0	780	840	ERR	NA
R160	850	70	3	780	847	1.00	3.00
R161	840	44	5	796	835	1.00	NA
R162	840	70	0	770	840	ERR	2.00
R163	850	40	-1	810	NA	0.85	NA*
R164	775	70	14	705	761	1.00	5.00
R165	830	25	3	805	827	1.00	NA
R165	830	62	5	768	825	1.00	3.75

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
R166	798	20	22	778	776	1.00	3.00
R166	798	35	12	763	786	1.00	4.00
R167	785	25	63	760	722	0.79	1.00
R168	830	40	8	790	822	1.00	2.00
R169	792	38	-1	754	NA	0.08	5.00*
R170	782	30	-1	752	NA	0.03	NA*
R170	782	45	-1	737	NA	0.00	2.00*
R171	789	38	-1	751	NA	0.31	NA*
R172	783	14	-1	769	NA	0.28	NA*
R173	792	55	-1	737	NA	0.03	NA*
R174	790	46	-1	744	NA	0.03	2.50*
R175	791	73	4	718	787	1.00	NA
R176	765	40	-1	725	NA	0.03	NA*
R177	770	17	-1	753	NA	0.05	NA*
R178	765	10	-1	755	NA	0.00	0.63*
R179	750	6	-1	744	NA	0.09	0.43*
R180	749	8	-1	741	NA	0.24	NA*
R181	755	6	-1	749	NA	0.10	NA*
R182	755	13	-1	742	NA	0.00	NA*
R183	790	20	-1	770	NA	0.00	NA*
R184	815	50	-1	765	NA	0.02	NA*
R185	754	8	-1	746	NA	0.05	2.50*
R186	821	55	-1	766	NA	0.08	15.00*
R187	815	70	-1	745	NA	0.02	NA*

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
Ozaukee County:			Mequon Township				
O1	725	27	86	698	639	0.52	0.69
O2	730	24	75	706	655	0.53	0.91
O3	720	45	68	675	652	0.74	ERR
O4	670	40	71	630	599	1.00	1.20
O5	725	36	90	689	635	0.62	NA
O6	770	42	84	728	686	0.95	NA
O7	750	62	53	688	697	1.00	15.00
O8	725	60	78	665	647	1.00	NA
O9	750	30	73	720	677	0.49	1.10
O10	740	44	104	696	636	0.29	0.77
O11	745	22	56	723	689	0.54	2.83
O12	720	30	64	690	656	0.64	NA
O13	790	40	106	750	684	0.39	NA
O14	795	38	89	757	706	0.22	NA
O15	778	39	54	739	724	0.56	NA
O16	730	22	50	708	680	0.54	0.36
O17	718	15	65	703	653	0.77	0.73
O18	750	43	62	707	688	0.48	NA
O19	779	45	155	734	624	1.00	1.50
O20	773	18	42	755	731	0.76	ERR
O21	838	20	99	818	739	1.00	0.83
O22	810	33	161	777	649	0.66	0.88
O23	833	15	107	818	726	0.51	0.14
O24	850	45	60	805	790	0.67	1.20
O25	840	47	78	793	762	0.51	5.00
O26	873	16	45	857	828	0.67	2.14
O27	878	24	61	854	817	0.89	2.50
O28	880	30	54	850	826	1.00	2.00
O29	860	18	65	842	795	0.48	NA
O30	870	10	-1	860	NA	NA	NA
O30	870	20	10	850	860	1.00	2.00
O31	840	37	65	803	775	0.49	0.35
O32	830	4	16	826	814	1.00	0.58
O33	810	19	19	791	791	1.00	0.71
O34	810	45	85	765	725	0.21	ERR
O35	810	11	92	799	718	1.00	0.71
O36	793	5	82	788	711	0.34	NA
O37	845	-1	57	NA	788	0.60	NA
O38	840	1	52	839	788	0.44	NA
O39	830	15	130	815	700	0.69	0.17
O40	780	4	73	776	707	0.86	3.33
O41	810	8	82	802	728	0.52	NA
O42	801	15	77	786	724	0.52	NA
O43	830	24	150	806	680	0.80	0.77
O44	770	42	136	728	634	1.00	0.13
O45	740	19	42	721	698	1.00	2.40
O46	810	14	23	796	787	0.00	NA

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
O47	780	40	80	740	700	0.79	3.00
O48	720	15	60	705	660	0.50	3.00
O49	765	53	74	712	691	0.41	0.32
O50	695	5	7	690	688	1.00	2.73
O51	721	38	51	683	670	0.78	NA
O51	721	45	62	676	659	1.00	0.32
O52	710	20	35	690	675	0.80	1.56
O53	725	34	14	691	711	1.00	ERR
O54	730	68	132	662	598	0.61	NA
O55	760	65	26	695	734	1.00	7.50
O56	750	41	14	709	736	1.00	ERR
O57	725	24	55	701	670	0.44	NA
O58	695	30	93	665	602	0.65	2.50
O59	715	45	129	670	586	0.80	ERR
O60	700	25	105	675	595	0.76	NA
O61	673	25	97	648	576	0.36	NA
O62	680	25	104	655	576	0.70	3.33
O63	710	33	73	677	637	0.49	NA
O64	700	32	84	668	616	0.56	1.15
O65	660	38	85	622	575	0,47	0.36
O66	680	49	113	631	567	0.66	1.36
O67	670	17	101	653	569	0.38	0.25
O68	700	28	97	672	603	0.57	NA
O69	658	15	-1	643	658	ERR	6.67
O69	658	11	46	647	612	0.22	NA
O70	660	20	-1	640	660	ERR	ERR
O70	669	7	78	662	591	0.51	NA
O71	700	40	123	660	577	0.49	NA
O72	705	46	109	659	596	0.69	NA
O72	705	40	121	665	584	0.83	1.50
O73	690	27	-1	663	690	ERR	NA
O73	690	29	104	661	586	0.00	0.58
O74	680	15	94	665	586	0.64	0.55
O75	670	32	95	638	575	0.43	NA
O76	705	35	128	670	577	1.00	1.50
O77	720	53	130	667	590	0.23	NA
O78	700	39	111	661	589	0.56	NA
O74	700	42	94	658	606	0.49	2.00
O79	720	92	175	628	545	1.00	7.50
O80	715	35	93	680	622	0.43	NA
O81	750	75	118	675	632	0.64	25.00
O82	760	48	93	712	667	0.54	NA
O82	760	75	133	685	627	0.53	1.00
O83	755	106	90	649	665	0.94	NA
O84	670	60	-1	610	670	ERR	7.50
O85	660	4	60	656	600	0.37	0.17
O86	670	10	49	660	621	0.51	NA
O87	680	21	62	659	618	0.39	NA

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
O88	670	18	54	652	616	0.24	ERR
O89	680	0	28	680	652	0.00	1.00
O90	735	20	-1	715	735	ERR	2.50
O91	760	20	73	740	687	0.63	NA
O92	805	50	42	755	763	0.67	0.43
O93	830	87	24	743	806	1.00	5.00
O94	855	17	55	838	800	0.64	0.39
O95	810	95	20	715	790	1.00	NA
O95	810	60	19	750	791	1.00	2.40
O96	815	28	12	787	803	1.00	NA
O97	800	22	50	778	750	0.70	0.36
O98	840	26	59	814	781	0.34	0.12
O99	880	110	127	770	753	0.63	NA
O100	825	10	42	815	783	0.71	1.00
O101	800	5	29	795	771	0.86	NA
O102	900	50	76	850	824	0.42	ERR
O103	820	28	101	792	719	0.18	0.54
O104	830	37	97	793	733	0.21	15.00
O105	830	45	27	785	803	0.89	2.89
O106	810	50	146	760	664	0.75	0.09
O107	795	13	8	782	787	0.00	2.00
O108	795	14	22	781	773	0.09	1.00
O109	780	15	4	765	776	1.00	0.80
O110	795	26	8	769	787	1.00	0.71
O111	830	41	43	789	787	0.77	NA
O111	830	36	48	794	782	0.88	0.63
O112	810	5	47	805	763	0.85	1.33
O113	781	8	39	773	742	0.77	0.31
O114	752	35	67	717	685	0.81	NA
O115	730	15	83	715	647	0.18	0.38
O116	805	60	60	745	745	0.83	0.75
O117	850	10	44	840	806	0.80	0.50
O118	840	58	53	782	787	1.00	0.60
O119	790	40	80	750	710	0.75	1.00
O120	760	60	53	700	707	0.75	3.00
O121	760	20	92	740	668	1.00	0.75
O121	760	30	21	730	739	1.00	2.40
O121	760	35	20	725	740	1.00	3.00
O122	760	55	66	705	694	1.00	3.00
O123	735	11	55	724	680	0.36	ERR
O123	735	27	101	708	634	0.62	1.67
O124	750	17	40	733	710	1.00	4.00
O124	750	40	64	710	686	0.31	3.00
O124	750	10	64	740	686	0.06	0.31
O125	780	65	141	715	639	1.00	3.00
O126	745	40	118	705	627	1.00	1.50
O127	780	65	54	715	726	1.00	7.50
O128	740	43	102	697	638	0.59	2.14

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
0129	780	80	105	700	675	0.24	NA
0129	780	55	115	725	665	0.35	0.25
0130	770	85	175	685	595	0.29	ERR
0130	770	71	145	699	625	0.39	10.00
0131	775	90	145	685	630	1.00	NA
0131	775	55	106	720	669	1.00	0.75
0132	765	34	75	731	690	0.11	0.23
0133	715	46	150	669	565	0.53	NA
0134	740	63	132	677	608	0.42	2.86
0135	695	30	111	665	584	0.54	NA
0136	670	42	94	628	576	0.63	ERR
0136	670	15	106	655	564	0.49	0.47
0137	700	61	110	639	590	0.60	ERR
0137	700	42	105	658	595	0.76	4.00
0138	669	63	121	606	548	1.00	2.50
0139	748	58	115	690	633	0.70	NA
0140	740	67	127	673	613	0.65	NA
0140	740	35	100	705	640	1.00	1.33
0141	750	83	150	667	600	0.60	1.71
0142	730	90	135	640	595	0.67	0.44
0143	665	15	43	650	622	0.84	1.50
0144	720	45	98	675	622	0.71	3.33
0145	700	3	85	697	615	0.41	5.71
0146	650	0	81	650	569	0.37	3.75
0147	675	52	93	623	582	0.71	1.09
0148	660	6	53	654	607	0.23	NA
0148	660	0	58	660	602	0.40	0.80
0149	690	40	80	650	610	1.00	NA
0149	690	44	90	646	600	1.00	10.00
0150	715	70	107	645	608	0.56	ERR
0150	715	73	120	642	595	0.95	1.25
0151	705	55	113	650	592	0.80	3.00
0152	660	6	73	654	587	0.74	1.00
0153	660	12	72	648	588	0.38	NA
0154	660	10	68	650	592	0.41	2.60
0155	679	32	94	647	585	0.98	5.00
0156	665	35	55	630	610	0.78	0.38
0157	675	19	65	656	610	0.74	2.50
0158	700	34	94	666	606	0.00	5.56
0159	715	80	128	635	587	0.77	0.67
0160	713	68	136	645	577	0.96	0.55
0161	702	53	145	649	557	0.62	NA
0162	705	78	127	627	578	0.83	0.31
0163	700	55	138	645	562	0.70	3.00
0164	679	60	118	619	561	0.82	NA
0164	679	45	107	634	572	0.42	1.50
0165	700	85	124	615	576	0.83	0.50
0166	680	60	130	620	550	0.67	1.00

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
O167	685	39	83	646	602	0.43	NA
O167	685	70	112	615	573	1.71	1.20
O168	655	35	95	620	560	0.63	1.60
O169	660	19	79	641	581	0.51	1.43
O170	663	29	116	634	547	0.52	0.23
O171	690	64	118	626	572	0.80	2.50
O172	675	90	112	585	563	0.71	0.75
O173	680	55	160	625	520	0.38	ERR
O174	720	85	144	635	576	0.92	NA
O174	720	100	149	620	571	0.67	1.20
O175	730	89	162	641	568	0.74	NA
O175	730	100	154	630	576	0.88	1.00
O176	700	44	150	656	550	0.93	0.71
O177	725	80	143	645	582	0.66	0.37
O178	700	100	150	600	550	1.00	1.00
O179	700	81	142	619	558	0.96	3.75
O180	695	80	147	615	548	0.93	2.40
O181	678	18	81	660	597	0.80	4.33
O182	670	16	98	654	572	0.51	1.11
O183	683	8	51	675	632	0.59	NA
O184	670	16	85	654	585	0.44	4.00
O185	650	20	80	630	570	0.38	2.14
O186	658	20	90	638	568	0.78	1.50
O187	650	26	75	624	575	0.71	NA
O187	650	25	77	625	573	0.78	0.48
O188	700	38	111	662	589	0.29	NA
O189	668	10	49	658	619	0.00	1.50
O190	665	0	68	665	597	0.59	3.00
O191	695	32	105	663	590	0.82	1.15
O192	660	46	108	614	552	0.56	NA
O193	709	65	145	644	564	0.00	7.14
O194	715	20	150	695	565	0.93	0.25
O195	780	30	63	750	717	0.32	0.80
O196	775	24	59	751	716	0.68	0.71
O197	730	53	136	677	594	0.62	NA
O198	730	60	126	670	604	0.79	0.50
O199	737	30	127	707	610	0.69	NA
O200	702	48	96	654	606	0.55	2.40
O201	680	23	69	657	611	0.70	4.00
O202	705	42	77	663	628	0.00	11.54
O203	670	22	63	648	607	0.51	0.79
O204	705	45	184	660	521	1.00	2.00
O205	733	35	-1	698	733	ERR	2.00
O206	717	13	109	704	608	0.53	NA
O207	780	58	145	722	635	0.41	NA
O208	775	60	140	715	635	0.00	ERR
O208	775	39	100	736	675	0.76	0.48
O209	745	65	154	680	591	0.84	ERR

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
0210	750	21	107	729	643	0.14	0.33
0211	738	5	57	733	681	0.32	0.33
0212	760	20	43	740	717	0.81	0.33
0213	840	93	46	747	794	0.96	NA
0213	840	60	29	780	811	1.00	1.20
0214	800	24	23	776	777	1.00	0.12
0215	770	15	54	755	716	0.61	NA
0216	745	6	73	739	672	0.34	0.44
0217	800	45	83	755	717	0.87	ERR
0218	800	25	4	775	796	1.00	3.00
0219	775	12	0	763	775	ERR	ERR
0220	779	18	102	761	677	0.78	0.68
0221	735	20	145	715	590	0.66	1.20
0222	740	19	71	721	669	0.55	NA
0223	765	10	66	755	699	0.92	1.00
0224	821	45	120	776	701	1.00	0.18
0225	760	10	32	750	728	0.47	2.50
0226	740	16	25	724	715	0.60	NA
0227	725	35	166	690	559	0.87	1.50
0228	720	18	146	702	574	0.89	1.07
0229	720	60	105	660	615	1.00	NA
0230	728	20	169	708	559	0.75	1.25
0231	725	15	84	710	641	0.76	NA
0232	735	10	104	725	631	0.58	0.50
0233	745	26	101	719	644	0.79	NA
0234	745	14	167	731	578	0.54	NA
0235	745	38	168	707	577	0.63	NA
0236	743	62	200	681	543	0.98	1.50
0237	750	40	179	710	571	1.00	NA
0238	679	0	151	679	528	0.96	5.00
0239	681	26	139	655	542	0.75	1.15
0240	717	23	99	694	618	0.81	0.18
0241	705	14	88	691	617	0.80	1.07
0242	662	0	96	662	566	0.83	ERR
0243	675	15	90	660	585	0.67	NA
0244	660	31	73	629	587	0.89	3.75
0245	662	40	103	622	559	0.78	ERR
0246	675	10	125	665	550	0.45	NA
0247	665	63	107	602	558	0.00	5.42
0248	660	30	104	630	556	0.65	0.75
0249	655	36	111	619	544	0.61	3.33
0250	659	35	103	624	556	0.92	0.33
0251	654	48	106	606	548	0.57	4.00
0253	659	16	105	643	554	0.00	5.00
0254	653	24	70	629	583	0.89	1.36
0255	665	94	219	571	446	0.68	NA
0256	660	26	72	634	588	0.31	0.07
0257	653	15	92	638	561	0.61	0.17

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
0258	651	3	94	648	557	0.48	0.45
0259	650	30	93	620	557	0.59	0.38
0260	663	52	93	611	570	0.96	0.36
0261	659	15	101	644	558	0.50	NA
0261	659	31	106	628	553	0.38	2.50
0263	650	12	84	638	566	0.42	0.21
0264	690	48	49	642	641	0.78	0.63
0265	653	23	121	630	532	0.83	0.31
0266	710	45	133	665	577	0.74	NA
0267	730	90	225	640	505	0.68	ERR

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
Waukesha County:			Genesee Township				
W1	870	15	34	855	836	0.00	NA
W2	960	2	92	958	868	0.00	NA
W3	900	80	84	820	816	0.44	NA
W4	1000	10	-1	990	NA	NA	NA*
W5	900	90	126	810	774	0.14	NA
W6	1010	30	-1	980	NA	NA	NA*
W7	990	70	130	920	860	0.81	0.40
W8	990	37	57	953	933	0.00	NA
W9	990	70	83	920	907	0.00	ERR
W10	1000	55	114	945	886	0.00	NA
W11	1000	45	68	955	932	0.00	NA
W12	990	45	71	945	919	0.00	NA
W13	995	30	80	965	915	0.25	1.07
W14	990	95	99	895	891	0.23	ERR
W15	995	45	73	950	922	0.27	1.00
W16	1050	84	128	966	922	0.31	0.18
W17	1040	32	67	1008	973	0.00	NA
W18	1020	33	73	987	947	0.00	NA
W19	1020	67	183	953	837	0.56	3.00
W20	1020	65	115	955	905	0.00	0.80
W21	995	33	69	962	926	0.00	NA
W22	1040	87	180	953	860	0.28	1.00
W23	945	20	53	925	892	0.47	1.00
W24	980	35	50	945	930	0.24	2.00
W25	1010	86	100	924	910	0.10	0.16
W26	950	29	-1	921	NA	NA	3.00 *
W27	990	50	82	940	908	0.00	1.09
W28	1035	89	93	946	942	0.54	NA
W29	950	25	-1	925	NA	NA	NA*
W30	1000	31	-1	969	NA	NA	2.40 *
W31	940	59	102	881	838	0.00	NA
W32	950	140	170	810	780	0.21	1.20
W33	1000	53	75	947	925	0.00	10.00
W34	980	31	-1	949	NA	NA	NA*
W35	965	20	34	945	931	0.00	NA
W36	970	20	-1	950	NA	NA	ERR *
W37	960	63	79	897	881	0.00	NA
W38	950	50	60	900	890	0.08	0.10
W39	1025	39	52	986	973	0.00	NA
W40	960	22	52	938	908	0.00	NA
W41	1000	32	72	968	928	0.00	NA
W42	1100	120	157	980	943	0.38	NA
W43	960	10	48	950	912	0.44	0.06
W44	980	48	74	932	906	0.19	0.27
W45	970	55	82	915	888	0.34	0.40
W46	970	155	170	815	800	0.02	0.00
W47	850	195	52	655	798	0.00	0.37

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
W48	950	20	74	930	876	0.00	0.60
W49	870	95	138	775	732	0.00	2.00
W50	860	41	60	819	800	0.22	ERR
W51	870	48	-1	822	NA	NA	NA *
W52	860	20	84	840	776	0.24	0.88
W53	870	38	44	832	826	0.00	NA
W54	880	54	62	826	818	0.24	0.63
W55	910	40	78	870	832	0.26	2.40
W56	950	18	67	932	883	0.12	0.59
W57	910	30	57	880	853	0.00	NA
W58	915	20	70	895	845	0.07	NA
W59	950	70	94	880	856	0.00	0.75
W60	1000	68	72	932	928	0.40	NA
W61	975	60	88	915	887	0.00	0.73
W62	985	66	69	919	916	0.00	0.05
W63	935	42	59	893	876	0.00	NA
W64	993	50	86	943	907	0.13	1.50
W65	1000	30	-1	970	NA	NA	0.28 *
W66	1000	33	75	967	925	0.00	NA
W67	990	40	74	950	916	0.20	NA
W68	990	225	70	765	920	0.30	NA
W69	1040	32	62	1008	978	0.00	1.54
W70	980	40	52	940	928	0.00	6.00
W71	1050	37	66	1013	984	0.00	NA
W72	1000	50	51	950	949	0.00	NA
W73	1060	83	100	977	960	0.42	2.40
W74	1050	70	118	980	932	0.17	NA
W75	1025	75	68	950	957	0.00	NA
W76	970	80	79	890	891	0.00	0.03
W77	960	35	59	925	901	0.34	NA
W78	975	48	80	927	895	0.00	NA
W79	980	60	82	920	898	0.00	NA
W80	890	15	10	875	880	0.00	1.20
W81	950	49	55	901	895	0.00	NA
W82	900	5	56	895	844	0.45	7.50
W83	910	22	48	888	862	0.25	3.33
W84	900	60	54	840	846	0.00	NA
W85	890	25	70	865	820	0.00	NA
W86	915	35	137	880	778	0.57	NA
w87	812	15	35	797	777	0.00	0.50
W88	805	20	34	785	771	0.35	ERR
W89	815	8	28	807	787	0.50	1.18
W90	845	25	15	820	830	0.00	NA
W91	845	35	2.5	810	842.5	0.00	NA
W92	900	50	-1	850	NA	NA	0.67 *
W93	820	12	84	808	736	0.46	ERR
W94	800	38	19	762	781	0.00	30.00
W95	845	45	2	800	843	1.00	0.56

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
W96	820	55	4	765	816	1.00	2.40
W97	820	6	92	814	728	0.00	NA
W98	808	215	60	593	748	0.07	NA
W99	812	3	36	809	776	0.78	10.00
W100	900	32	55	868	845	0.69	NA
W101	870	70	96	800	774	0.46	NA
W102	910	33	52	877	858	0.00	NA
W103	890	21	54	869	836	0.43	NA
W104	900	40	70	860	830	0.76	7.50
W105	900	65	100	835	800	0.03	1.80
W106	850	-1	27	NA	823	0.56	NA
W107	840	4	-1	836	NA	NA	1.33 *
W108	960	55	138	905	822	0.00	0.14
W109	945	39	-1	906	NA	NA	ERR *
W110	990	57	58	933	932	0.00	ERR
W111	970	75	55	895	915	0.05	3.00
W112	960	19	68	941	892	0.00	NA
W113	1040	130	125	910	915	0.02	2.00
W114	990	85	63	905	927	0.00	NA
W115	960	45	65	915	895	0.00	0.67
W116	1000	50	55	950	945	0.00	NA
W117	935	14	47	921	888	0.00	NA
W118	980	17	-1	963	NA	NA	NA *
W119	945	10	55	935	890	0.20	16.72
W120	950	45	55	905	895	0.00	NA
W121	990	30	41	960	949	0.44	NA
W122	980	100	162	880	818	0.19	0.60
W123	945	15	127	930	818	0.00	NA
W124	945	14	-1	931	NA	NA	ERR *
W125	940	12	55	928	885	0.49	2.20
W126	960	56	-1	904	NA	NA	2.50 *
W127	960	35	101	925	859	0.03	NA
W128	995	20	78	975	917	0.00	NA
W129	965	52	-1	913	NA	NA	ERR *
W130	930	35	81	895	849	0.00	NA
W131	905	82	-1	823	NA	NA	12.00 *
W132	895	26	-1	869	NA	NA	0.53 *
W133	850	68	-1	782	NA	NA	NA *
W134	880	20	96	860	784	0.00	NA
W135	860	80	165	780	695	0.48	0.50
W136	800	0	131	800	669	0.94	3.33

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
Dane County:		Burke Township					
D1	960	55	57	905	903	0.28	NA
D2	960	70	18	890	942	0.56	NA
D3	940	40	43	900	897	0.19	NA
	940	70	35	870	905	0.29	4.00
D4	970	95	10	875	960	1.00	NA
D5	900	50	40	850	860	0.25	ERR
D6	975	25	92	950	883	0.00	NA
D7	885	28	20	857	865	0.60	NA
D8	860	8	94	852	766	0.04	2.95
D9	865	15	105	850	760	0.48	3.93
D10	863	10	82	853	781	0.61	60.00
D11	860	4	60	856	800	0.00	100.00
D12	871	9	47	862	824	0.19	NA
D13	870	22	70	848	800	0.57	2.50
D14	850	50	-1	800	NA	NA	0.75
D15	870	8	-1	862	NA	NA	NA
D16	860	4	66	856	794	0.08	12.50
D17	861	8	60	853	801	0.67	10.00
D18	955	75	16	880	939	0.00	1.33
D19	920	23	61	897	859	0.05	2.86
D20	915	42	46	873	869	0.17	NA
D21	862	21	106	841	756	0.12	NA
D22	935	78	15	857	920	0.47	NA
D23	895	24	87	871	808	0.23	0.50
D24	935	70	52	865	883	0.15	ERR
D25	930	58	100	872	830	0.05	1.67
D26	920	57	12	863	908	0.83	NA
D27	890	54	155	836	735	0.26	1.50
D28	930	55	29	875	901	0.76	6.25
D29	970	110	91	860	879	0.11	NA
D30	980	108	72	872	908	0.14	2.73
D31	944	63	51	881	893	0.31	4.00
D32	1000	140	80	860	920	0.13	NA
D33	993	45	57	948	936	0.18	NA
D34	988	125	84	863	904	0.32	1.00
D35	990	115	60	875	930	0.00	NA
D36	982	110	72	872	910	0.00	2.50
D37	1020	140	118	880	902	0.00	NA
D38	1030	30	36	1000	994	0.28	ERR
D39	965	100	6	865	959	1.00	NA
D40	980	27	47	953	933	0.36	0.78
D41	970	16	12	954	958	0.42	0.30
D42	975	43	111	932	864	0.25	NA
D43	959	96	67	863	892	0.75	NA
D44	960	30	10	930	950	0.00	1.40
D45	973	95	35	878	938	1.00	ERR
D46	955	52	90	903	865	0.11	NA

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
D47	970	91	76	879	894	0.13	10.00
D48	920	52	86	868	834	0.58	2.14
D49	925	60	94	865	831	0.00	3.75
D50	890	28	38	862	852	0.26	3.00
D51	900	50	12	850	888	1.00	4.00
D52	955	20	15	935	940	1.00	ERR
D53	950	30	15	920	935	0.40	ERR
D54	940	80	6	860	934	1.00	NA
D55	933	60	8	873	925	1.00	ERR
D56	865	15	136	850	729	0.26	ERR
D57	921	49	112	872	809	0.06	1.00
D58	872	19	-1	853	NA	NA	0.78*
D59	862	7	-1	855	NA	NA	3.00*
D60	900	65	75	835	825	0.19	ERR
D61	868	24	31	844	837	0.71	ERR
D62	922	30	61	892	861	0.30	NA
D63	1005	80	30	925	975	0.00	20.50
D64	938	78	70	860	863	0.07	1.50
D65	900	70	92	830	808	0.46	1.25
D66	950	67	0	883	950	ERR	5.00
D67	925	35	60	890	865	0.33	NA
D68	980	90	61	890	919	0.30	NA
D69	994	60	46	934	948	0.22	NA
D70	1015	105	62	910	953	0.29	NA
D71	968	70	80	898	888	0.15	NA
D72	930	48	38	882	892	0.16	ERR
D73	950	60	110	890	840	0.00	7.50
D74	970	60	68	910	902	0.12	NA
D75	980	30	5	950	975	1.80	ERR
D76	1035	40	42	995	993	0.24	NA
D77	1045	100	15	945	1030	0.00	NA
D78	1010	80	22	930	988	0.00	NA
D79	945	54	0	891	945	ERR	1.82
D80	910	130	8	780	902	1.00	ERR
D81	906	25	24	881	882	0.00	ERR
D82	928	63	12	865	916	0.33	2.50
D83	950	115	65	835	885	0.20	NA
D84	940	64	10	876	930	0.60	ERR
D85	900	37	29	863	871	0.24	ERR
D86	1020	90	35	930	985	0.34	NA
D87	868	49	20	819	848	0.50	NA
D88	900	39	15	861	885	1.00	1.50
D89	860	22	103	838	757	0.10	2.50
D90	890	24	25	866	865	0.40	5.00
D91	860	27	73	833	787	0.00	3.33
D92	858	70	108	788	750	0.23	NA
D93	860	80	42	780	818	0.48	ERR
D94	880	35	38	845	842	0.26	NA

APPENDIX IV CONTINUED

ID	GS	TW	TR	POT	BR	%CL	SC
D95	850	38	33	812	817	0.30	NA
D96	850	38	44	812	806	0.68	NA
D97	890	47	57	843	833	0.70	ERR
D98	885	48	38	837	847	0.53	7.50
D99	890	46	75	844	815	0.67	2.50
D100	858	50	132	808	726	0.57	3.00
D101	855	38	207	817	648	0.00	12.42
D102	880	30	39	850	841	0.00	ERR
D103	860	10	63	850	797	0.49	ERR
D104	853	10	18	843	835	0.56	ERR
D105	860	26	19	834	841	1.00	6.00
D106	859	60	105	799	754	0.69	1.20
D107	880	19	30	861	850	1.00	6.00
D108	885	18	30	867	855	0.47	ERR
D109	860	50	59	810	801	0.00	NA
	860	30	44	830	816	0.18	ERR
D110	858	22	43	836	815	0.42	ERR
D111	855	23	30	832	825	1.00	7.50
D112	870	18	30	852	840	0.33	ERR
D113	860	25	40	835	820	0.38	NA
D114	880	30	48	850	832	0.42	ERR
D115	865	40	20	825	845	1.00	1.00
D116	855	14	68	841	787	0.12	8.00
D117	920	72	20	848	900	1.00	ERR
D118	857	54	19	803	838	0.26	ERR
	857	33	12	824	845	1.00	3.00
D119	870	7	95	863	775	0.24	ERR
D120	953	73	52	880	901	0.62	7.00
D121	940	160	10	780	930	1.00	ERR
D122	995	144	20	851	975	1.00	ERR
	995	179	24	816	971	1.00	0.81
D123	857	0	52	857	805	0.21	NA
	857	72	35	785	822	0.06	0.81
D124	880	71	19	809	861	0.21	ERR
D125	950	110	18	840	932	1.00	ERR
D126	1005	125	18	880	987	1.00	NA
D127	995	65	17	930	978	0.29	NA
D128	960	101	20	859	940	1.00	NA
D129	982	144	45	838	937	0.18	NA
D130	1010	120	22	890	988	0.45	NA
	1010	34	20	976	990	0.70	NA
D132	975	55	12	920	963	1.00	0.75
D133	945	60	44	885	901	0.91	NA
D134	NA	118	12	NA	NA	0.25	3.00
D135	NA	90	25	NA	NA	0.88	NA
D136	990	42	18	948	972	1.00	3.33

APPENDIX IV CONTINUED: KEY FOR DOOR COUNTY DATA

Data file listing for map generating information for Door County obtained from well construction reports. The only variable mapped for Door County is Specific Capacity--therefore the format for Door County Data is slightly different than for the other study sites as follows:

Column Code	Variable
ID	Map Identification Number (see index map Appendix V.)
TW	Depth to Static Water Level (feet)
TR	Depth to Bedrock (feet)
Q	Well Discharge of yield test in gallons per minute.
DD	Drawdown from yield test in feet.
T	Time of yield test in Hours.
WD	Well Depth in Feet
CS	Casing length in feet
SC	Specific Capacity in gallons per minute/foot of drawdown.

NA = Not Available

ERR = A mathematical division by zero has occurred. Specific Capacity is not available

ID	TW	TR	Q	DD	T	WD	CS	SC
Door County Test Region Data								
1	12	44	10	3	8	220	171	3.33
2	42	2.5	520	86	8	322	50	6.05
4	33	20	15	4	8	256	173	3.75
5	39	6	10	2	8	173	173	5.00
6	16.5	53	768	12	188.5	425	155	64.00
7	24	9	10	3	8	261	172	3.33
8	8	4	16.6	24	12	120	45	0.69
9	2.5	56	50	67.5	4	370	170	0.74
10	60	19	15	3	8	262	123	5.00
11	145	21	15	11	8	274	173	1.36
12	143	12	15	3	8	281	172	5.00
13	153	1	10	34	8	301	181	0.29
14	120	19	15	11	8	240	173	1.36
15	152	2	15	9	8	300	170	1.67
16	123	4	15	2	8	282	201	7.50
17	14	2	10	111	4	228	139	0.09
18	59	26	10	3	8	230	177	3.33
19	164	6	10	9	8	310	101	1.11
20	106	21	15	11	8	302	173	1.36
21	86	15	15	7	8	250	173	2.14
22	67	14	10	22	8	280	173	0.45
23	96	6	15	2	8	224	173	7.50
24	70	11	15	2	8	221	173	7.50
25	161	3	10	18	8	294	194	0.56
26	182	5	10	15	8	321	204	0.67
27	102	4	10	11	4	321	173	0.91
28	125	6	10	40	8	212	101	0.25
29	128	6	15	9	8	363	180	1.67
30	162	3	15	7	8	398	197	2.14
31	98	13	15	3	4	275	173	5.00
32	91	19	125	7	12	360	122	17.86
33	57	4	15	12	8	301	174	1.25
34	41	5	15	22	8	221	177	0.68
36	44	43	15	5	8	258	123	3.00
37	50	12	16	10	48	210	100	1.60
38	61	19	10	32	8	300	173	0.31
39	125	24	10	33	8	177	100	0.30
40	97	21	15	10	8	277	173	1.50
41	20	4	10	3	8	200	144	3.33
42	12	3	15	9	8	302	174	1.67
43	48	12	10	15	8	260	173	0.67
45	68	9	15	13	8	301	175	1.15
46	71	3	15	6	8	267	173	2.50
47	52	18	10	9	8	298	216	1.11
48	69	22	10	2	8	241	172	5.00
49	35	0	40	5	7	175	49	8.00
50	72	17	15	9	8	286	174	1.67

ID	TW	TR	Q	DD	T	WD	CS	SC
51	67	6	15	2	8	247	173	7.50
52	78	7	15	3	8	213	173	5.00
53	42	24	15	2	8	230	173	7.50
54	8	10	15	13	8	281	173	1.15
55	30	0.5	10	15	20	200	100	0.67
56	1	56	10	36	8	341	172	0.28
57	1	56	10	3	8	324	172	3.33
58	10	4	15	3	8	261	173	5.00
59	1	2	10	6	8	301	172	1.67
60	10	6	15	4	8	135	100	3.75
61	5	4	10	9	8	261	123	1.11
62	95	19	10	3	5	190	100	3.33
63	138	4	10	5	8	260	182	2.00
64	131	4	15	8	8	241	174	1.88
65	82	2	12	5	10	258	173	2.40
66	114	2	15	4	8	301	173	3.75
67	108	11	10	34	15	260	174	0.29
68	130	3.5	10	6	13	208	103	1.67
69	141	3	15	6	10	280	176	2.50
70	152	5	10	11	8	306	209	0.91
71	161	5	15	12	8	302	183	1.25
72	115	5	15	4	8	280	216	3.75
73	32	31	10	1	8	241	172	10.00
74	147	2	16	6	72	250	100	2.67
75	136	13	10	5	8	241	173	2.00
76	144	2	15	3	8	281	177	5.00
77	70	4	13	0	8	244	102	ERR
78	110	4	10	2	8	202	174	5.00
79	106	4	10	14	8	261	172	0.71
80	9	17	10	3	8	162	107	3.33
81	48	7	15	5	8	301	172	3.00
82	60	2	15	8	3	301	173	NA
83	0	31	15	3	8	281	173	5.00
84	3	14	10	9	8	321	173	1.11
85	6	15	10	6	8	254	132	1.67
86	8	24	10	1	8	241	133	10.00
87	8	4	15	39	10	301	144	0.38

APPENDIX V

Index maps for the data points used to generate the hydrogeologic maps for each study township from the use of well construction reports.

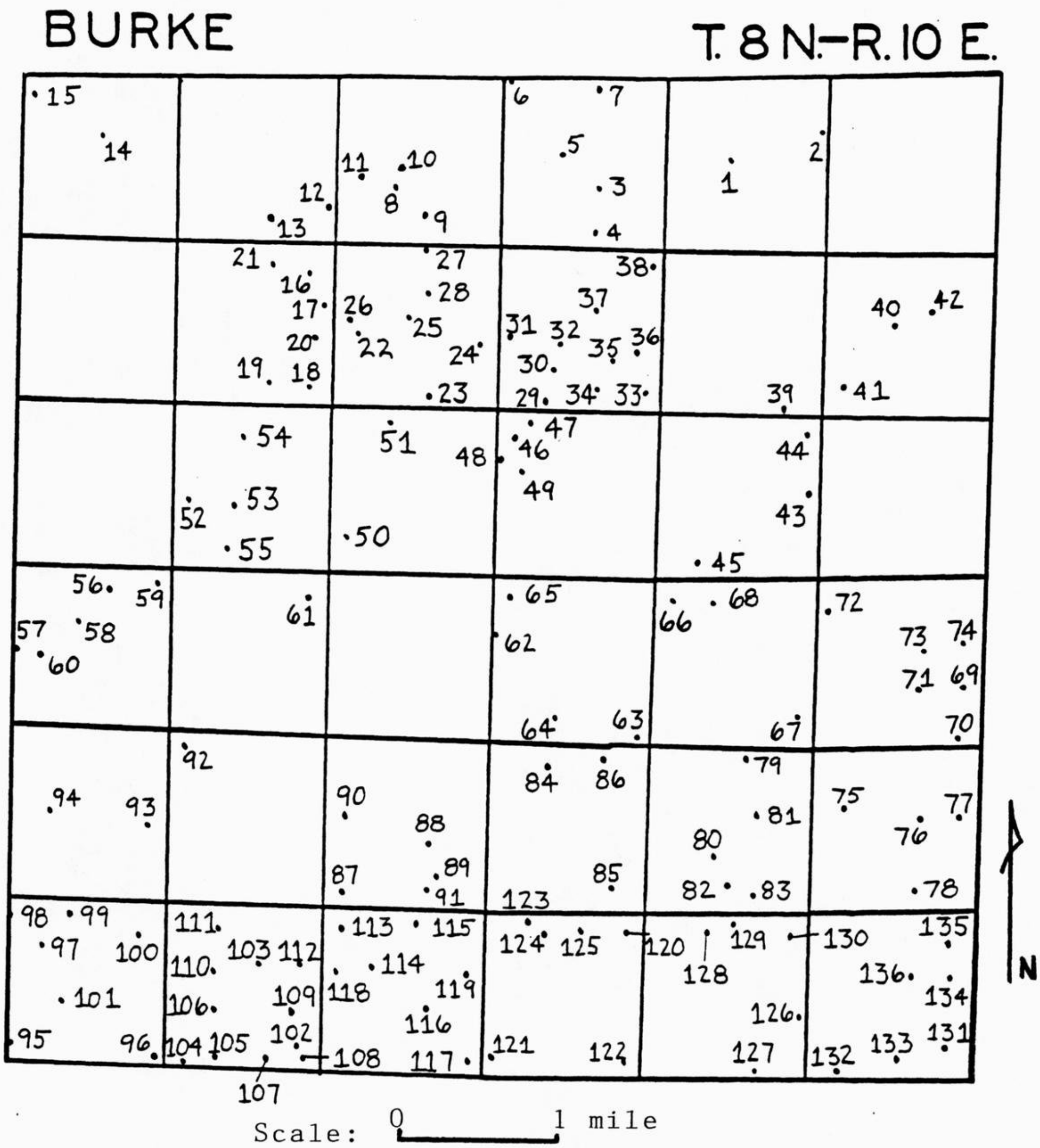
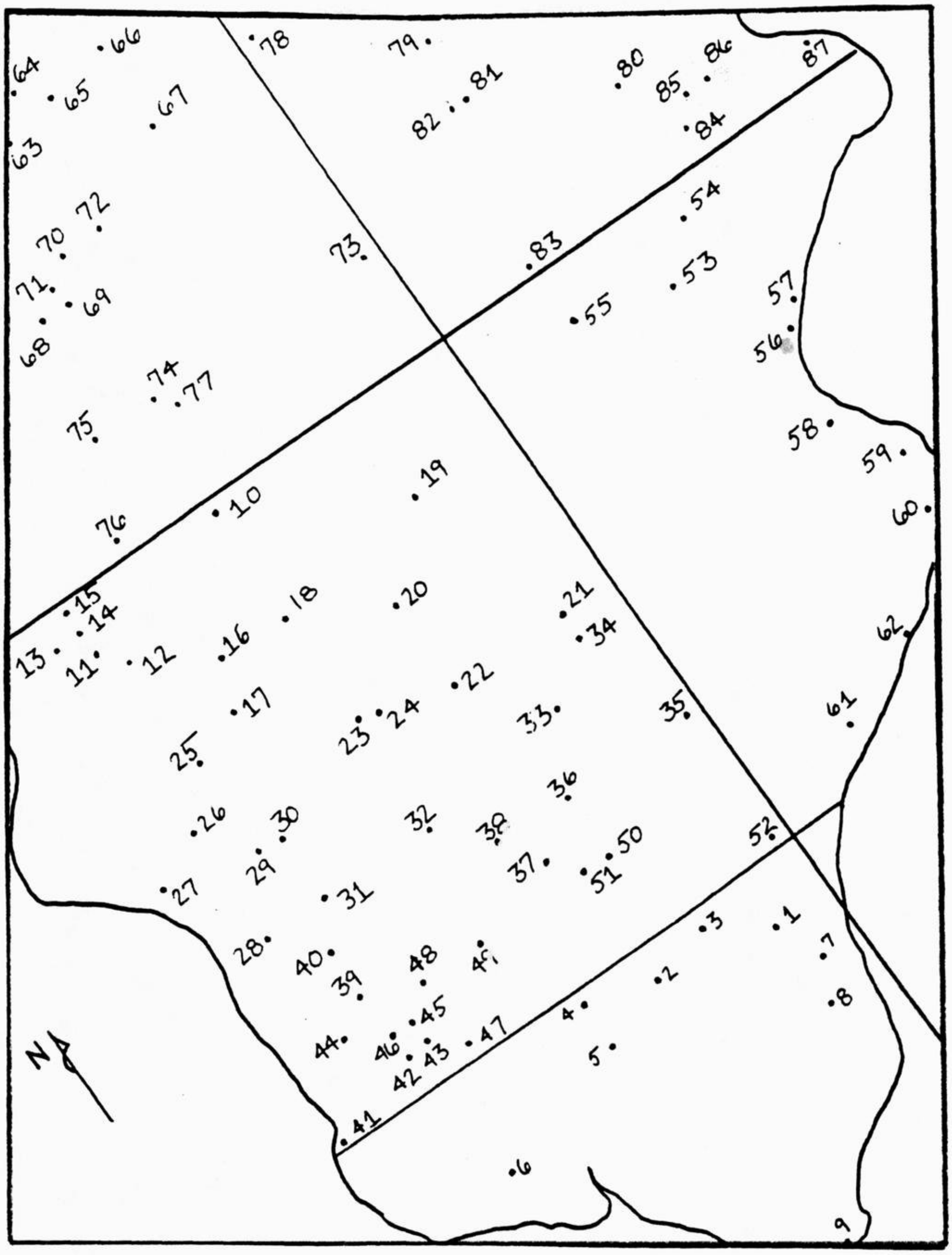


Figure V-1. Index map for data points used to generate the hydrogeologic maps for Burke Township, Dane County, Wisconsin. See Figures 9-12 in text for hydrogeologic maps, Appendix IV for map generating data.



Scale: 0 1 2 miles

Figure V-2. Index map for data points used to generate the specific capacity map for the Door County study region. See Appendix VI for the map, Appendix IV for map generating data.

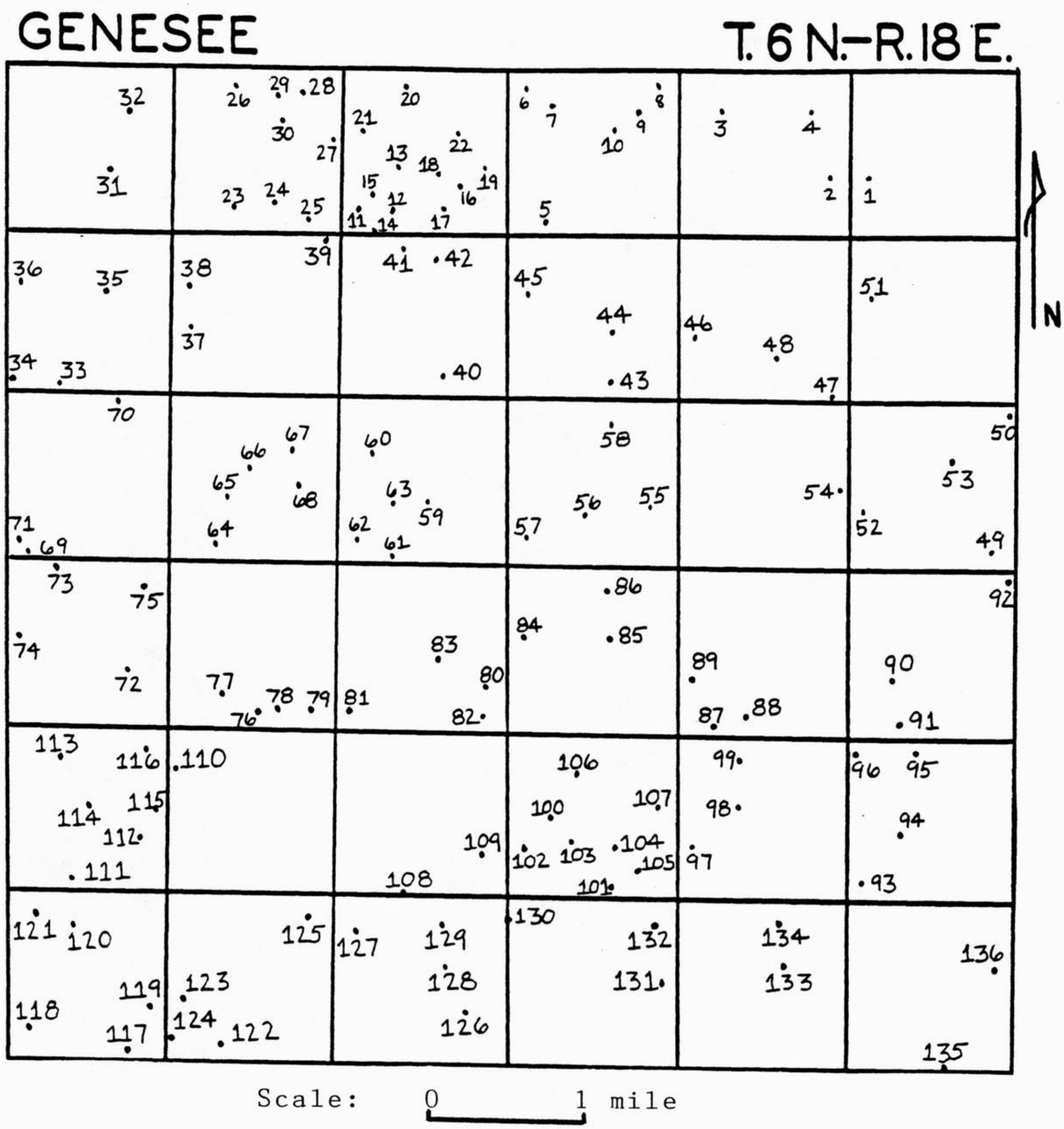
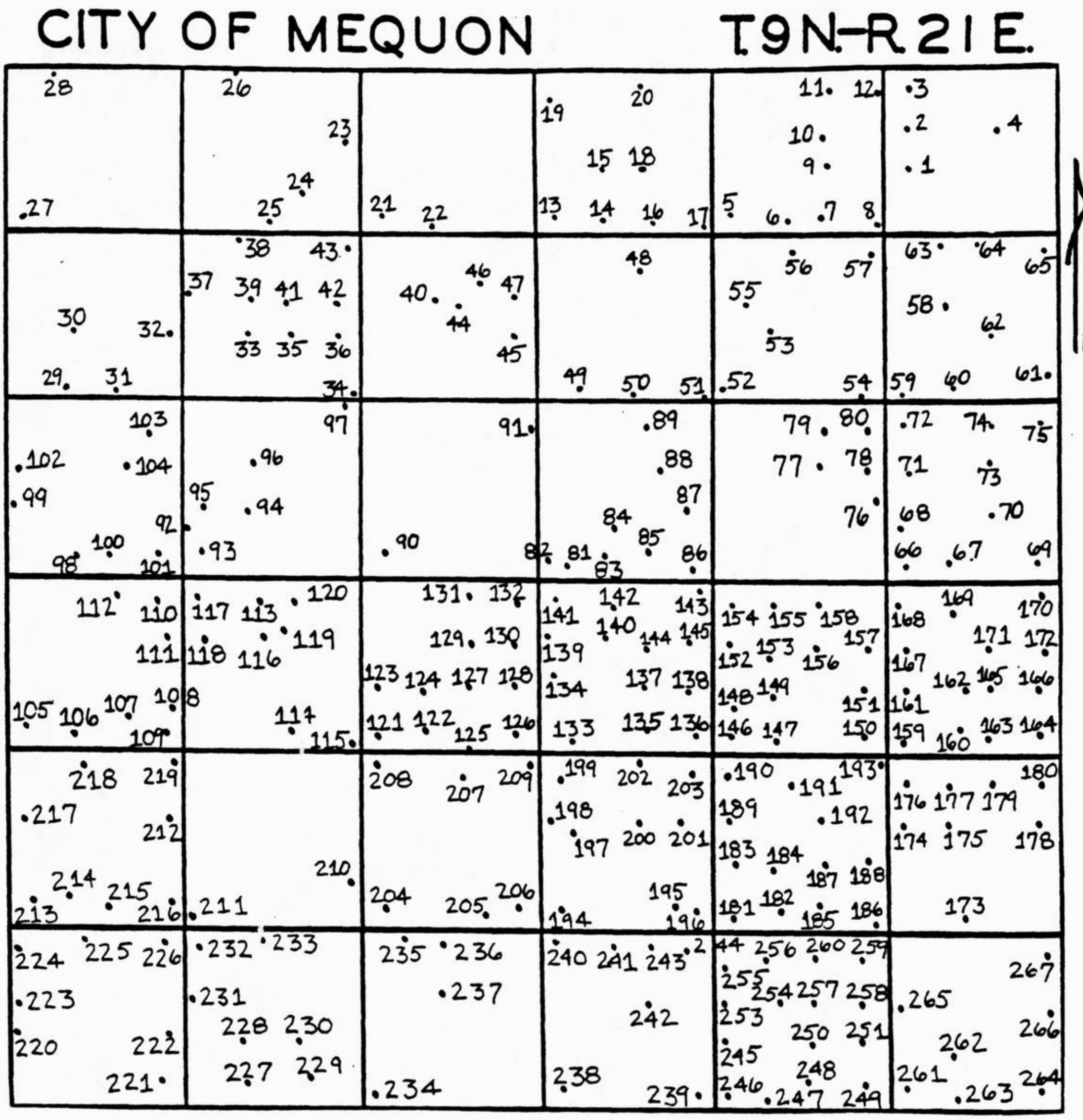


Figure V-3. Index map for data points used to generate the hydrogeologic maps for Genesee Township, Waukesha County, Wisconsin. See Appendix VII for hydrogeologic maps, Appendix IV for map generating data.



Scale: 0 1 mile

Figure V-4. Index map for data points used to generate the hydrogeologic maps for the Mequon Township, Ozaukee County, Wisconsin. See Appendix VIII for hydrogeologic maps, Appendix IV for map generating data.

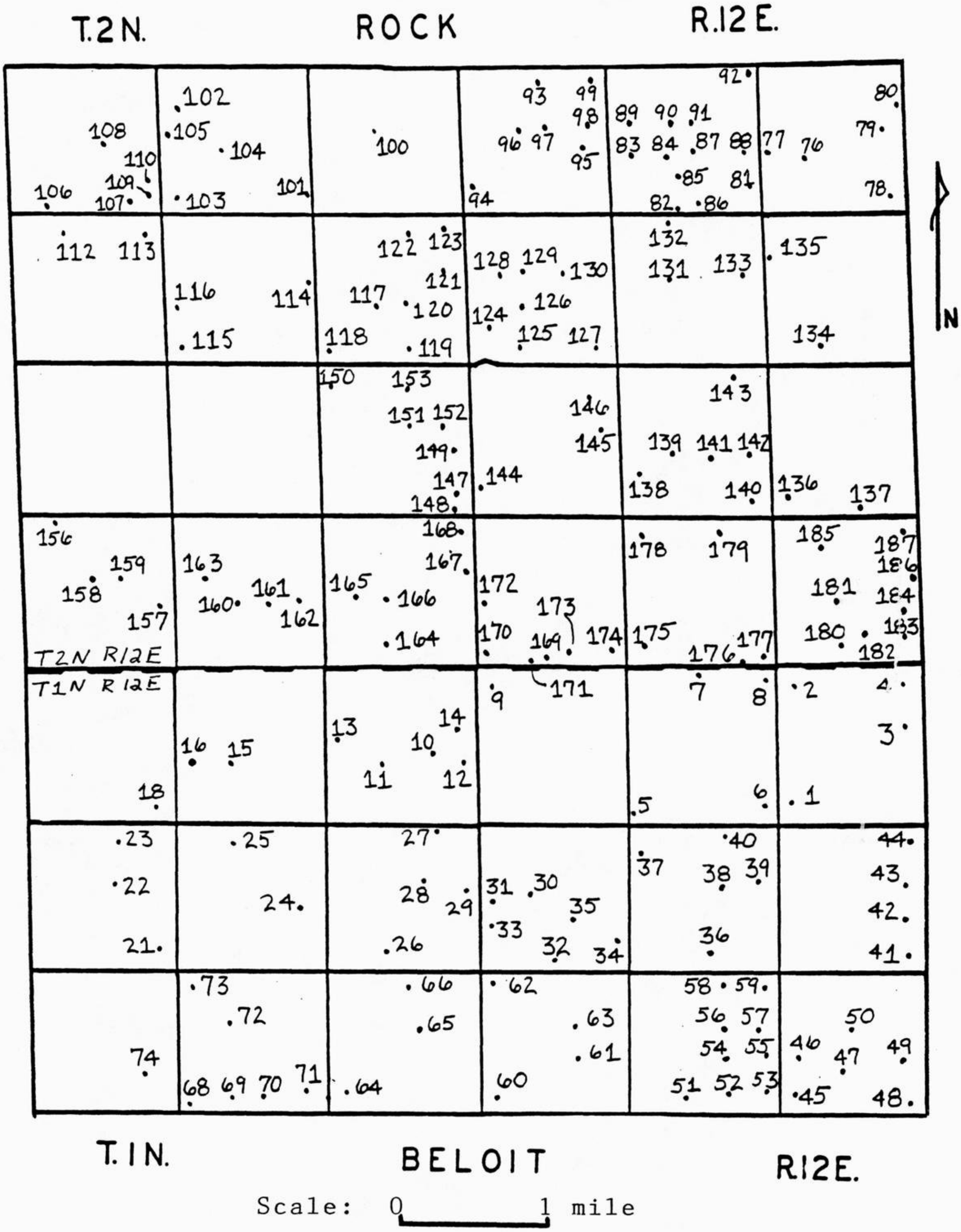


Figure V-5. Index map for data points used to generate the hydrogeologic maps for the Rock/Beloit study region, Rock County, Wisconsin. See Appendix IX for hydrogeologic maps, Appendix IV for map generating data.

APPENDIX VI

Specific capacity maps generated for the Door County study region.

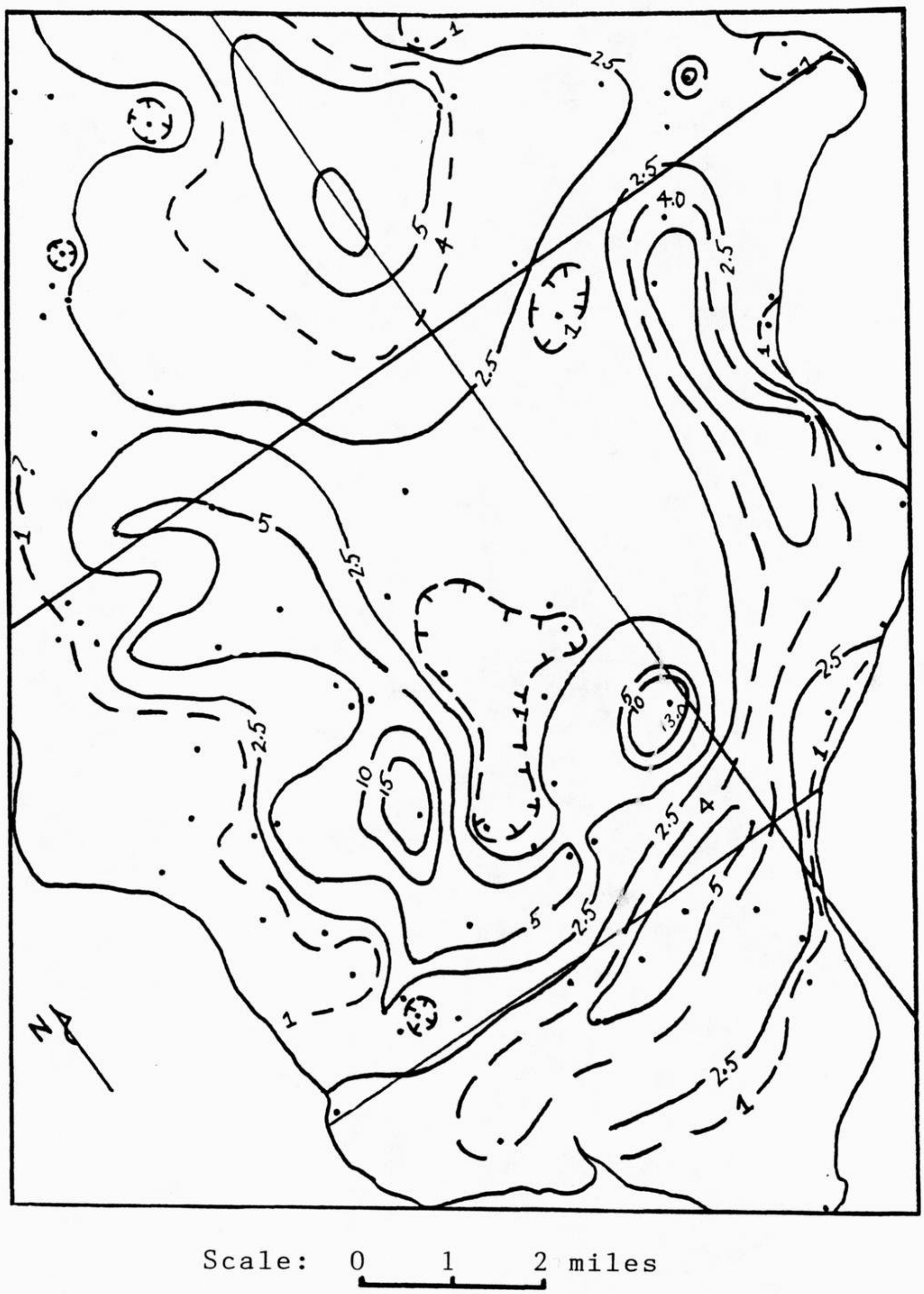
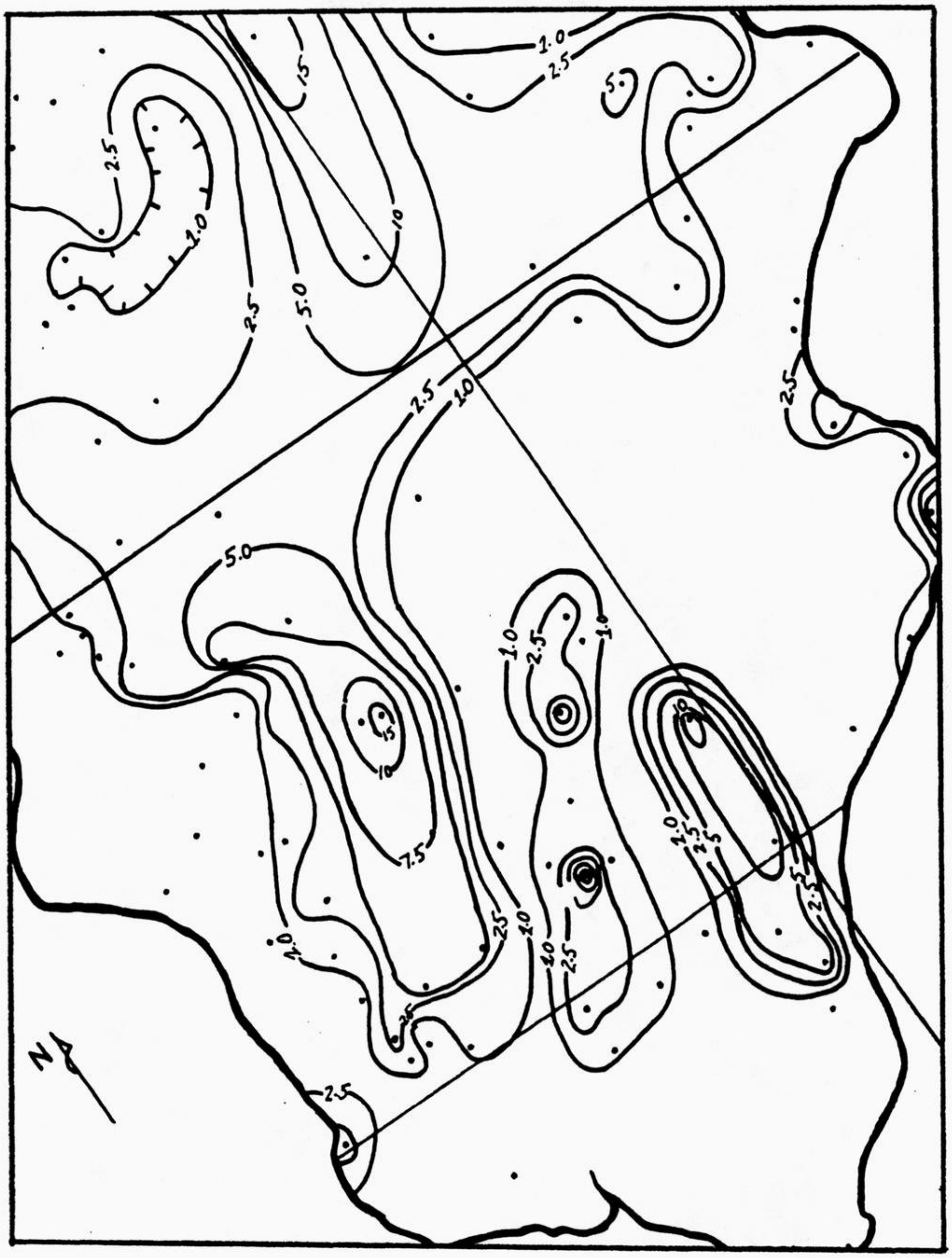


Figure VI-1. Map of specific capacity of wells in the dolomite bedrock aquifer for the Door County study region. Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section and also had yield tests of 4 hours duration and longer. Specific capacity in gallons per minute per foot of drawdown. Contour interval of 2.5 gpm/ft with the exception of the 1.0, 10, and 15 gpm/ft contours.



Scale: 0 1 2 miles

Figure VI-2. Map of specific capacity normalized to the length of the well screen for wells in the dolomite bedrock aquifer for the Door County study region. Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section and also had yield tests of 4 hours duration and longer. Normalized specific capacity in ((gallons per minute per foot of drawdown)/(length of well screen in feet)) X 100. Contour interval of 2.5 gpm/ft/ft except for the 1.0 gpm/ft/ft contour.

APPENDIX VII

Hydrogeologic maps generated for Genesee Township.

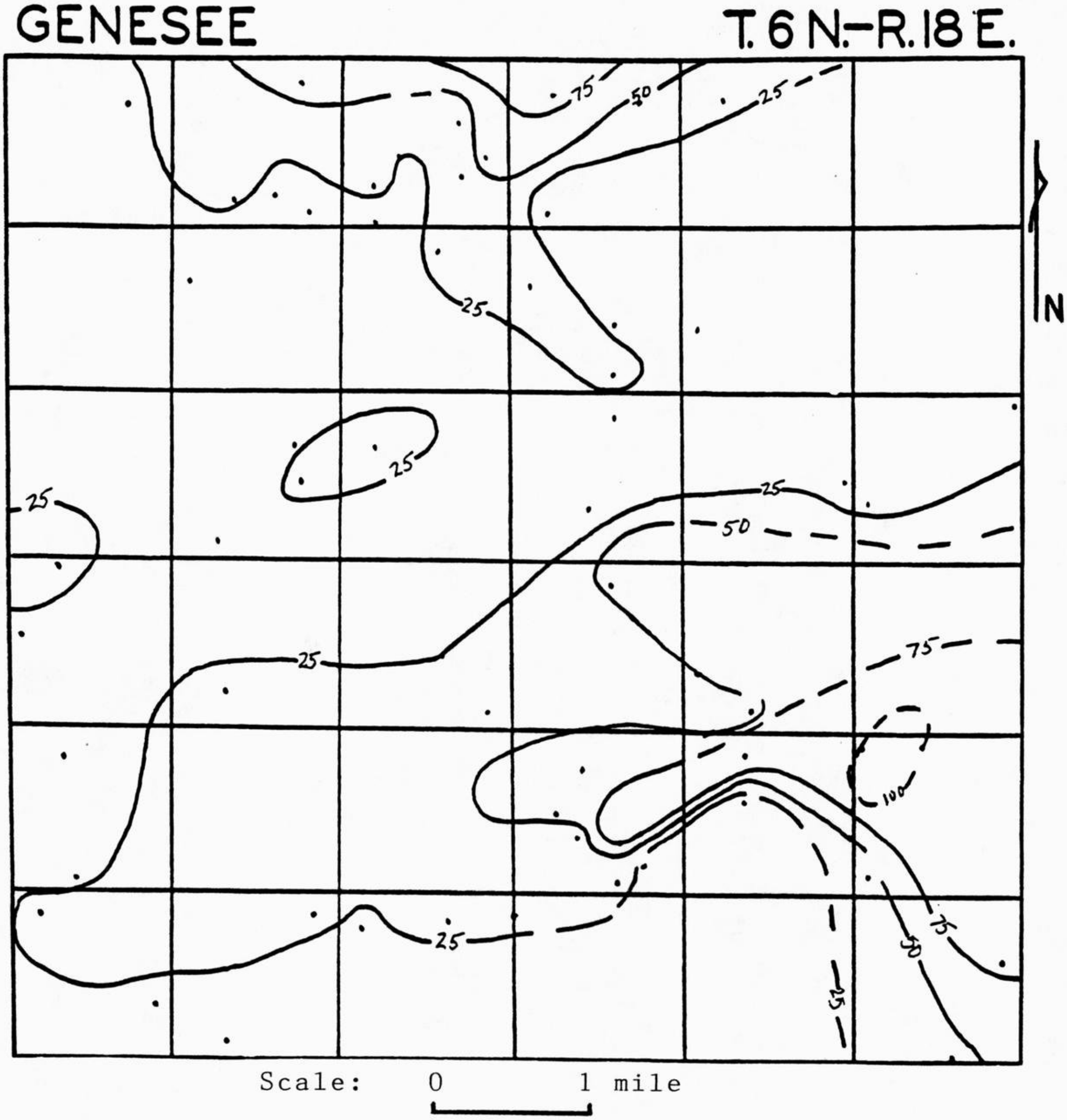
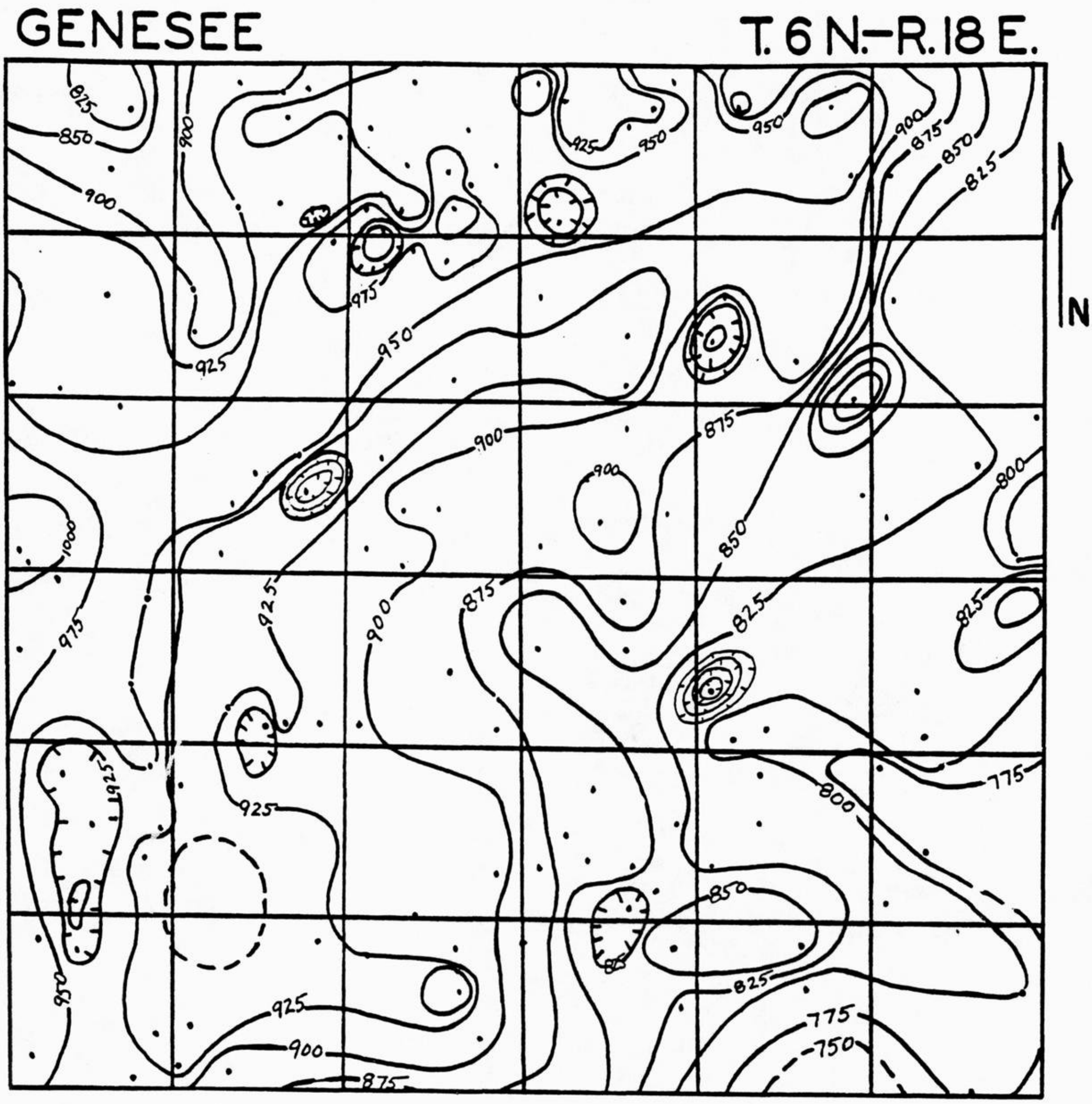


Figure VII-1. Map of the percentage of clay in the sediments overlying bedrock for the Genesee Township (Waukesha County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section and that differentiated sand, gravel, clay, etc. Contour interval is twenty-five percentage points. Percent clay = (total clay thickness)/(depth to bedrock).



Scale: 0 1 mile

Figure VII-2. Map of potentiometric surface elevation for the Genesee Township (Waukesha County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section. Elevations are in feet--contour interval is 25 feet.

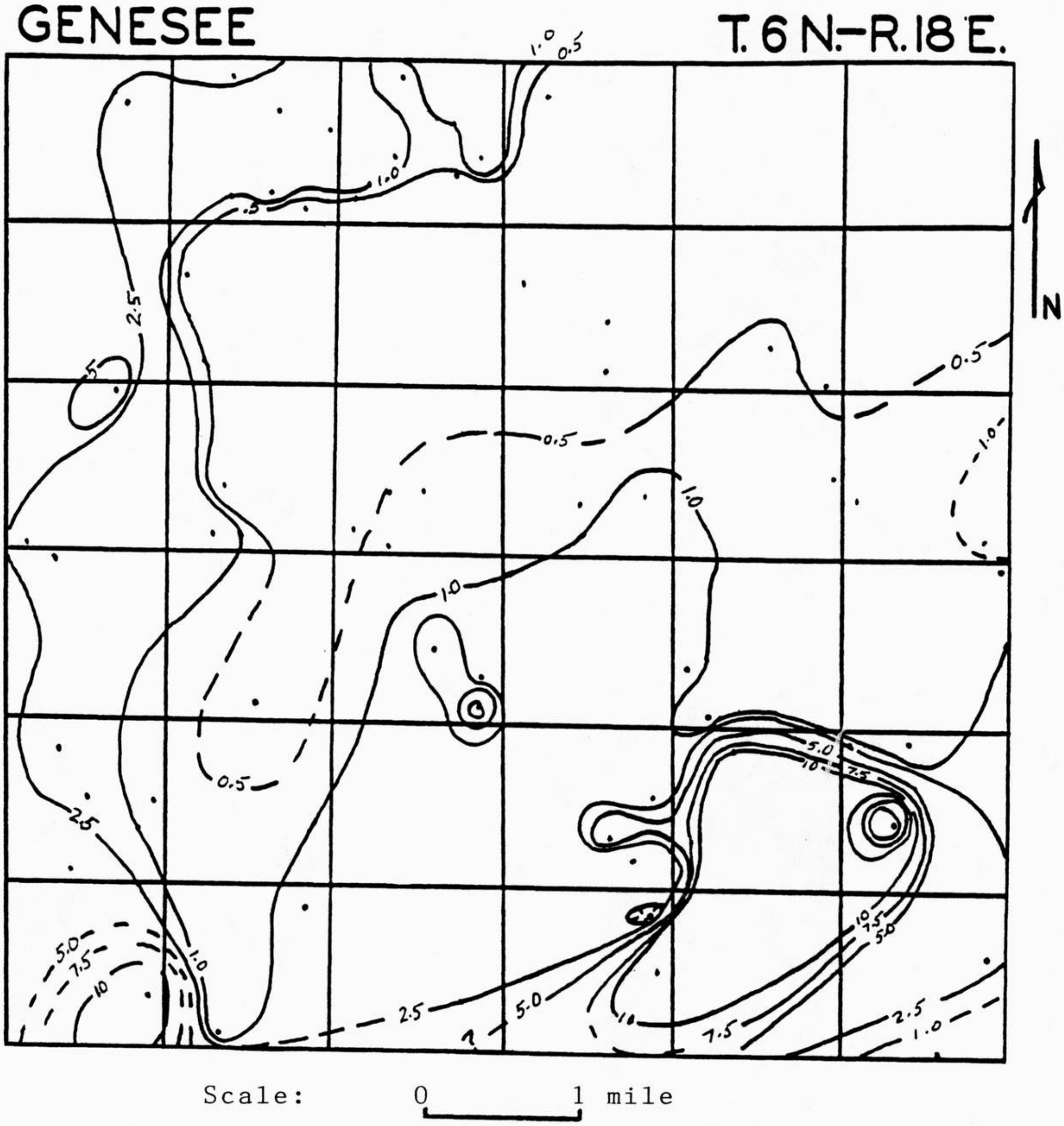
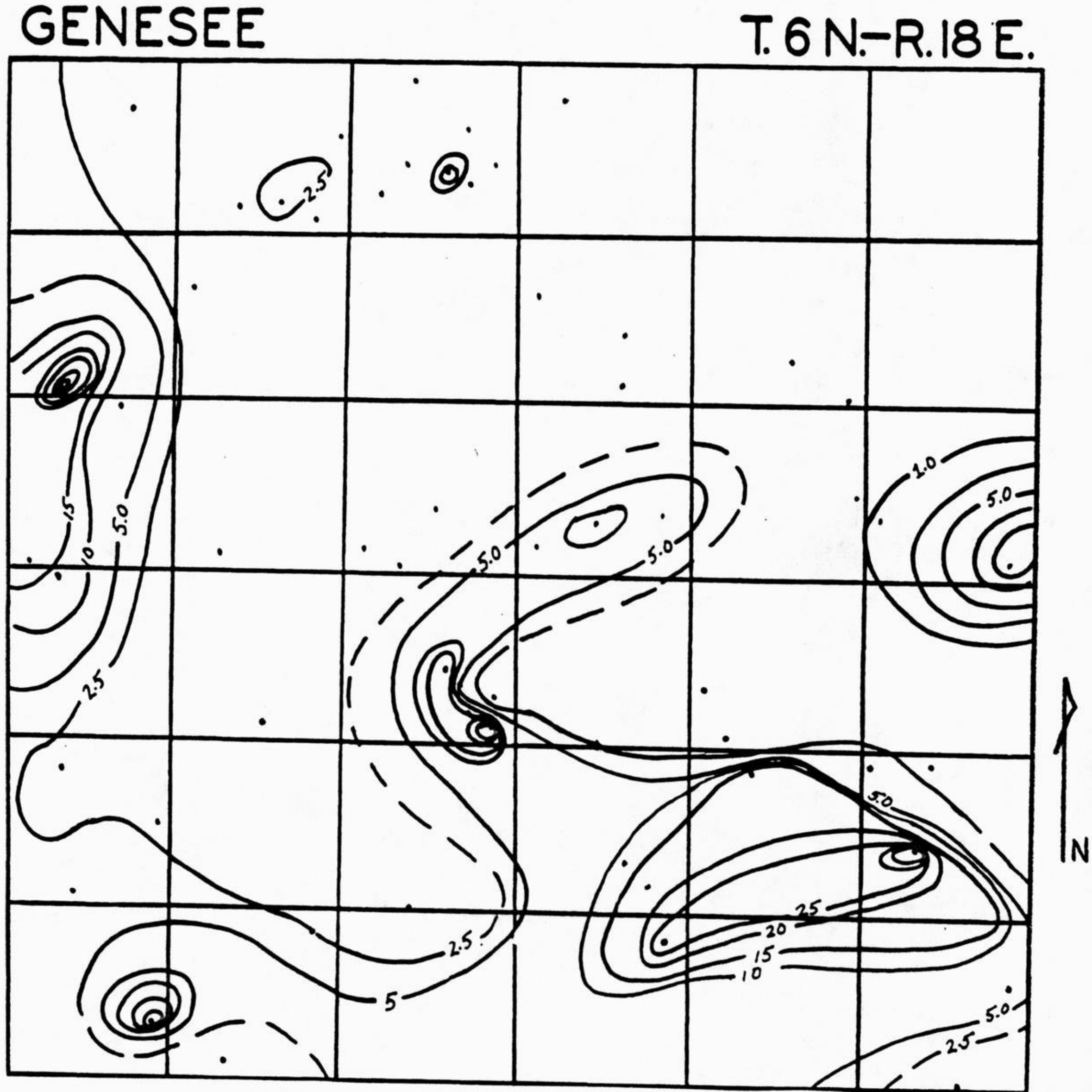


Figure VII-3. Map of specific capacity of wells in the Genesee Township (Waukesha County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section and also had yield tests of 4 hours duration and longer. Specific capacity in gallons per minute per foot of drawdown. Contour interval of 2.5 gpm/ft with the exception of the 0.5 and 1.0 gpm/ft contours.



Scale: 0 1 mile

Figure VII-4. Map of specific capacitynormalized to well screen length for wells in the Genesee Township (Waukesha County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section and also had yield tests of 4 hours duration and longer. Normalized specific capacity is in((gallons per minute per foot of drawdown)/(feet of well screen length)) X 100. Contour interval of 5 gpm/ft/ft with the exception of the 2.5 gpm/ft/ft contour.

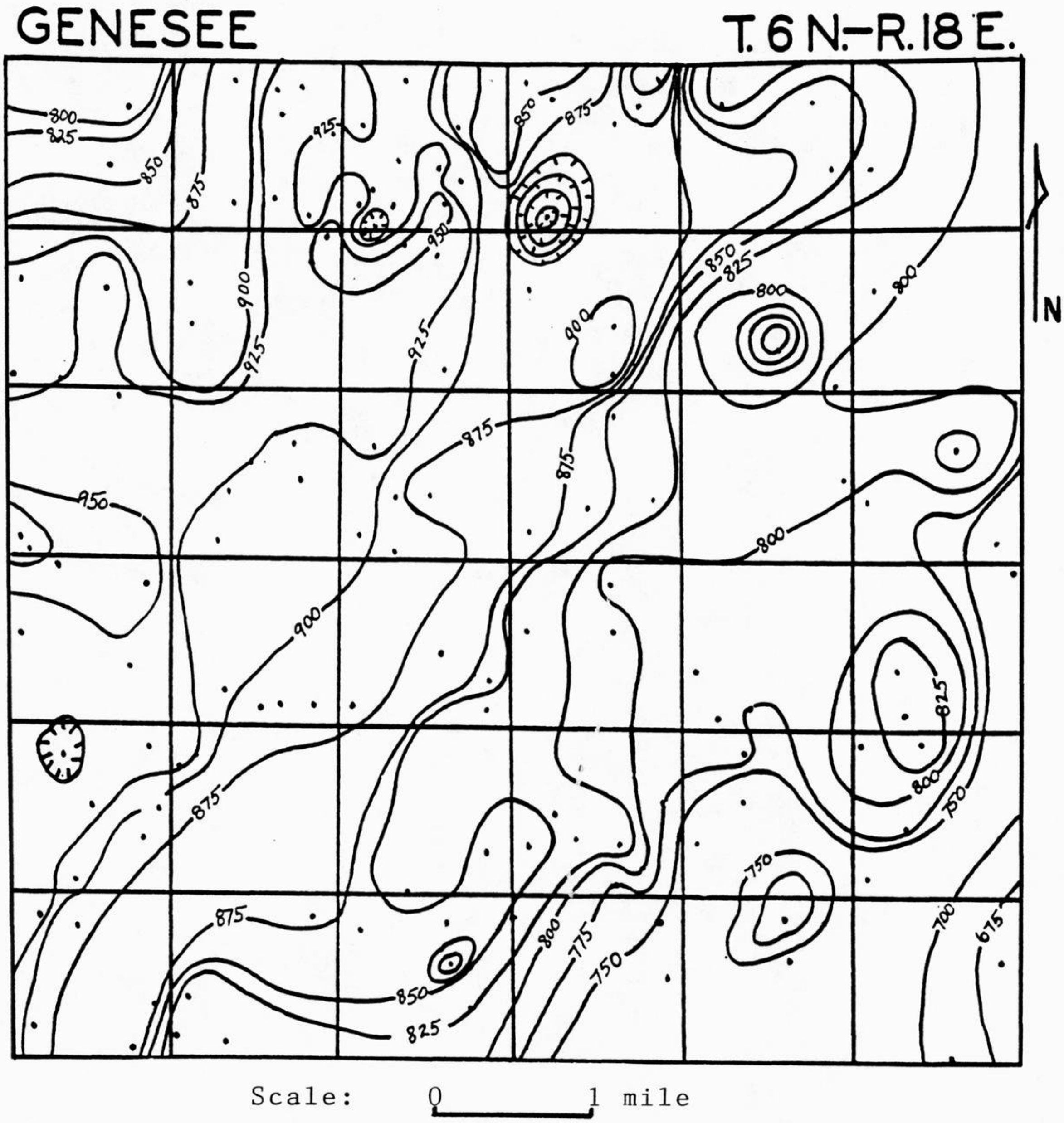
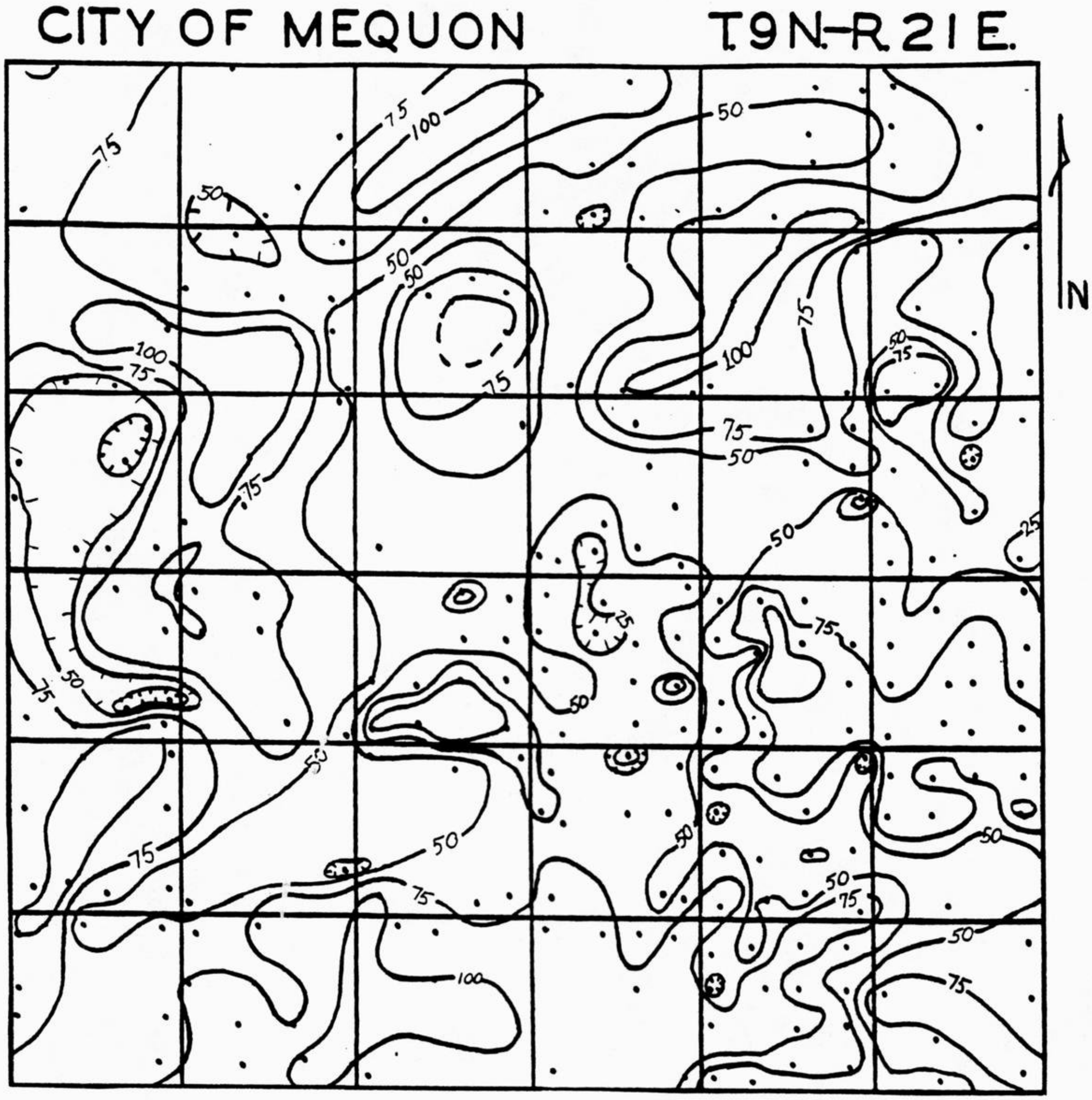


Figure VII-5. Map of bedrock elevation for the Genesee Township (Waukesha County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section. Bedrock elevations in feet-contour interval is 25 feet.

APPENDIX VIII

Hydrogeologic maps generated for Mequon Township.



Scale: 0 1 mile

Figure VIII-1. Map of the percentage of clay for the Mequon Township (Ozaukee County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section and that differentiated sand, gravel, clay, etc. Contour interval is twenty-five percentage points. Percent clay = (total thickness of clay)/(total depth to bedrock surface).

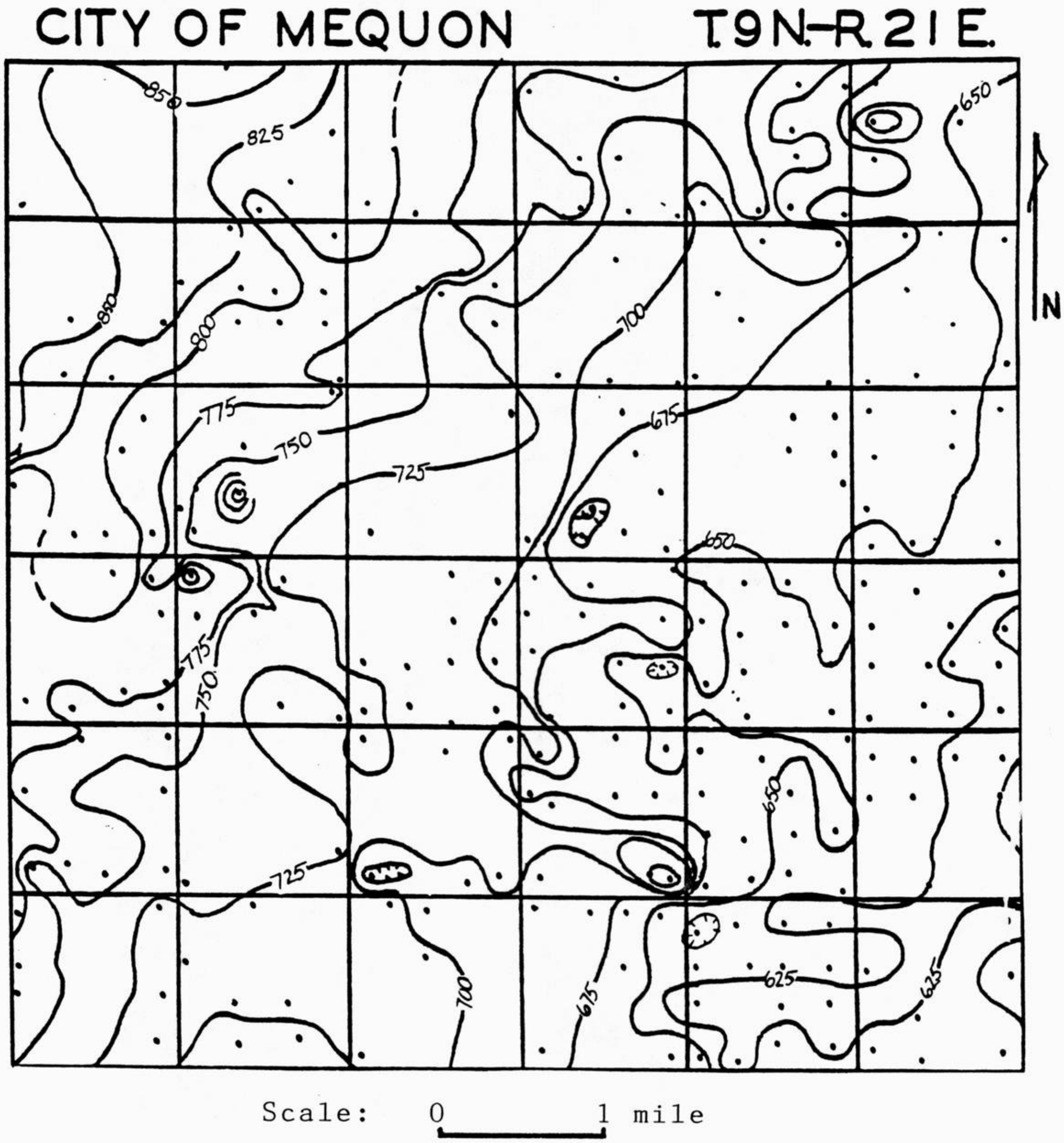


Figure VIII-2. Map of the potentiometric surface elevation for the Mequon Township (Ozaukee County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section. Elevations are in feet--contour interval is 25 feet.

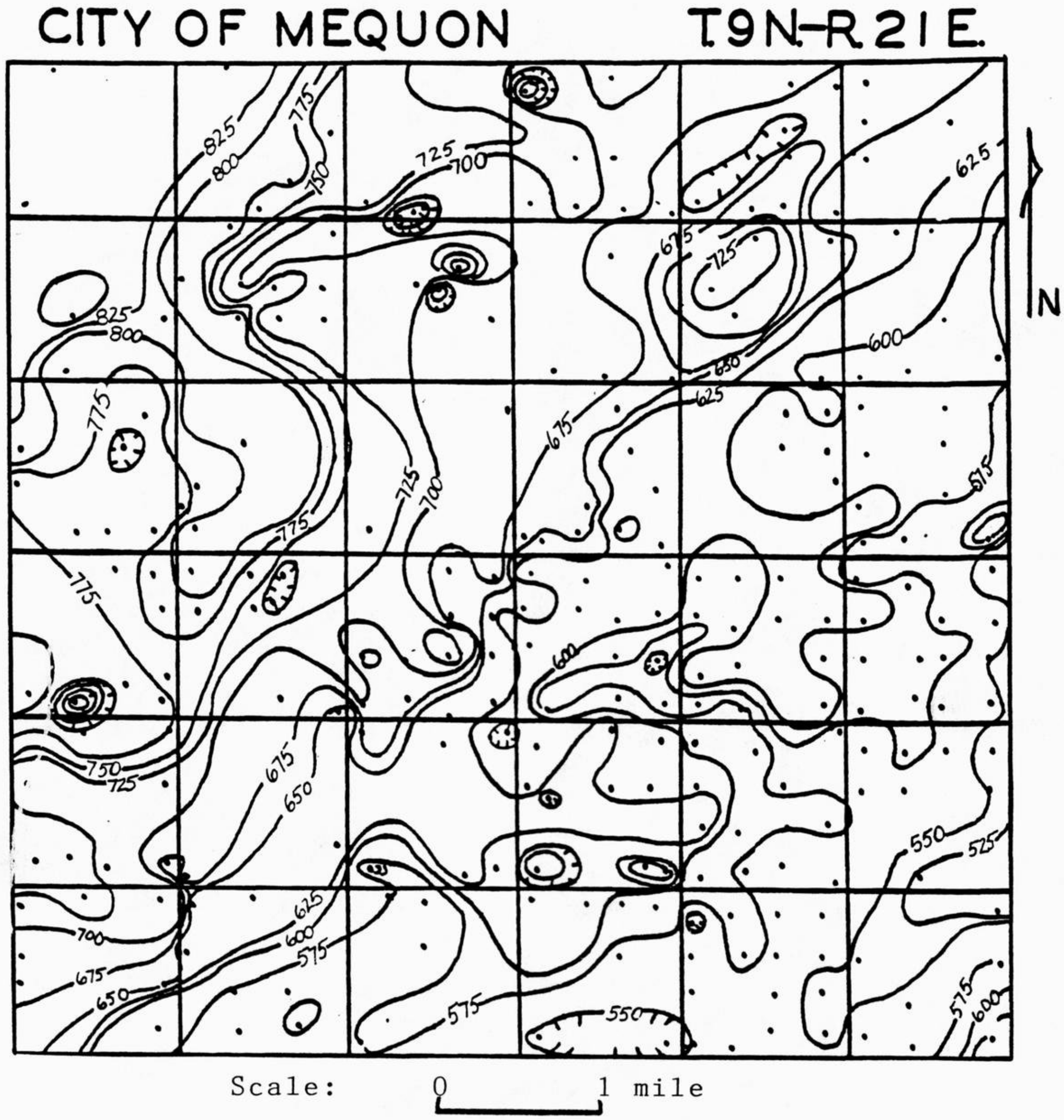


Figure VIII-5. Map of bedrock elevation for the Mequon Township (Ozaukee County). Map generated from all available well construction reports for the township that were located in terms of quarter-quarter section. Bedrock elevations in feet--contour interval of 25 feet.

APPENDIX IX

Hydrogeologic maps generated for the Rock/Beloit study township. There are two separate % clay maps for this township. The first is the percentage of clay over the well depth for wells finished in unconsolidated deposits, and the second is the percentage of clay over the depth to bedrock for those wells finished in bedrock.

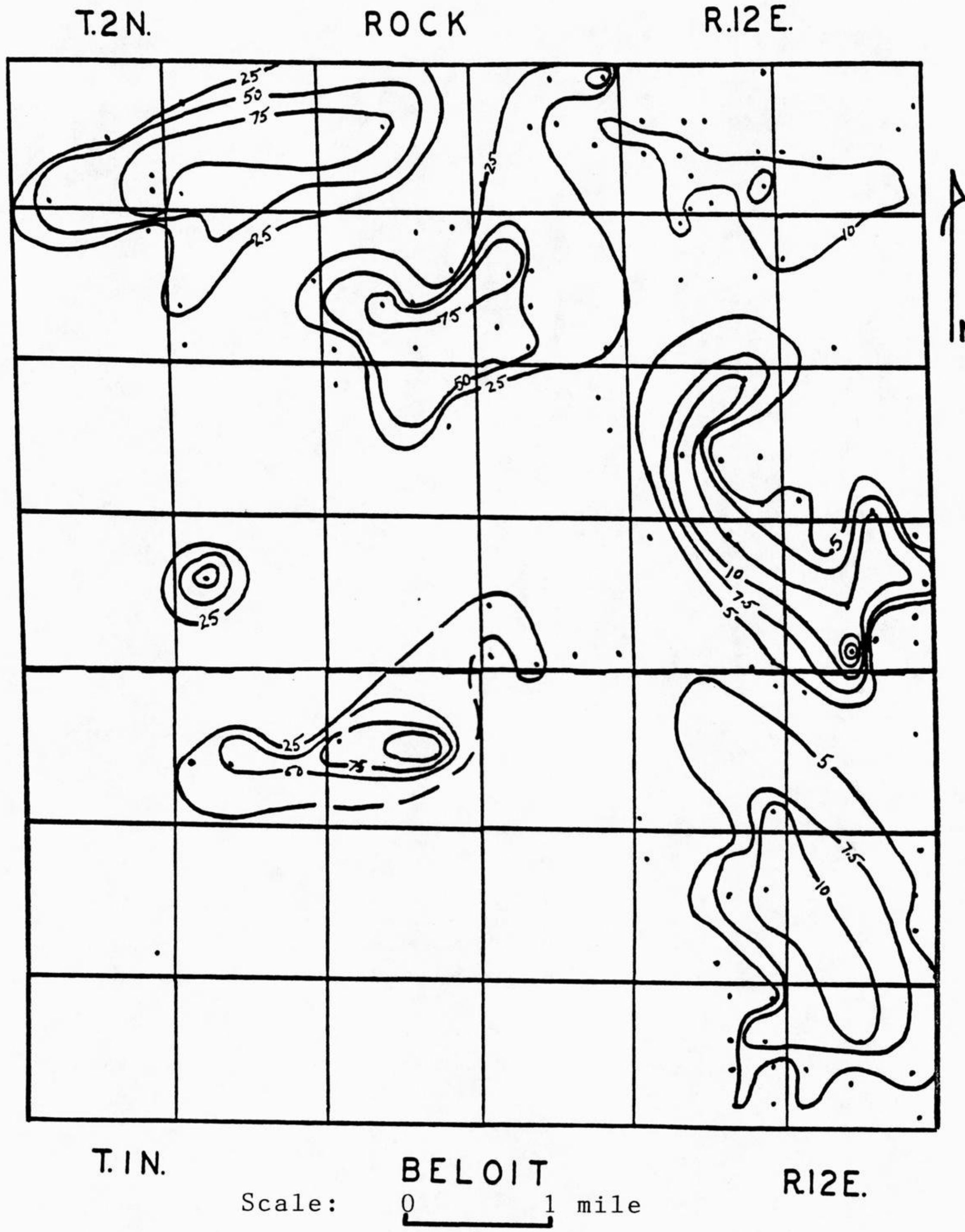


Figure IX-1. Map of the percentage of clay over the well depth for the Rock/Beloit study region (Rock County). Map generated from all available well construction reports for the region that were located in terms of quarter-quarter section and differentiated sand, gravel, clay, etc. Percent Clay = (Total clay thickness)/(well hole depth).

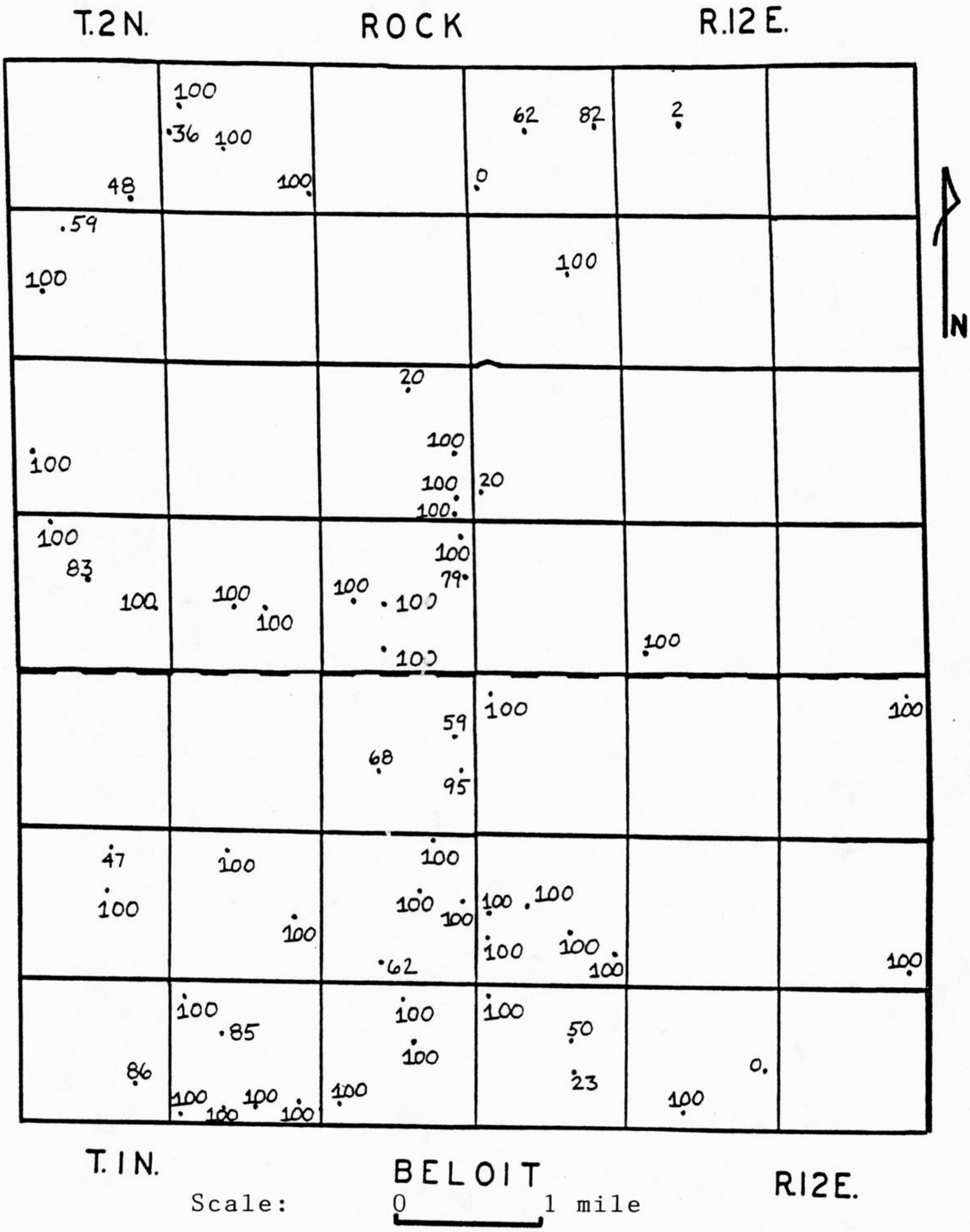


Figure IX-2. Map showing data points of the percentage of clay in the sediments overlying bedrock for the Rock/Beloit study region (Rock County). Map generated from all available well construction reports for the townships that were located in terms of quarter-quarter section and that differentiated sand, gravel, clay, etc., and that were cased into bedrock. Percent clay = (Total clay thickness)/(depth to the bedrock surface).

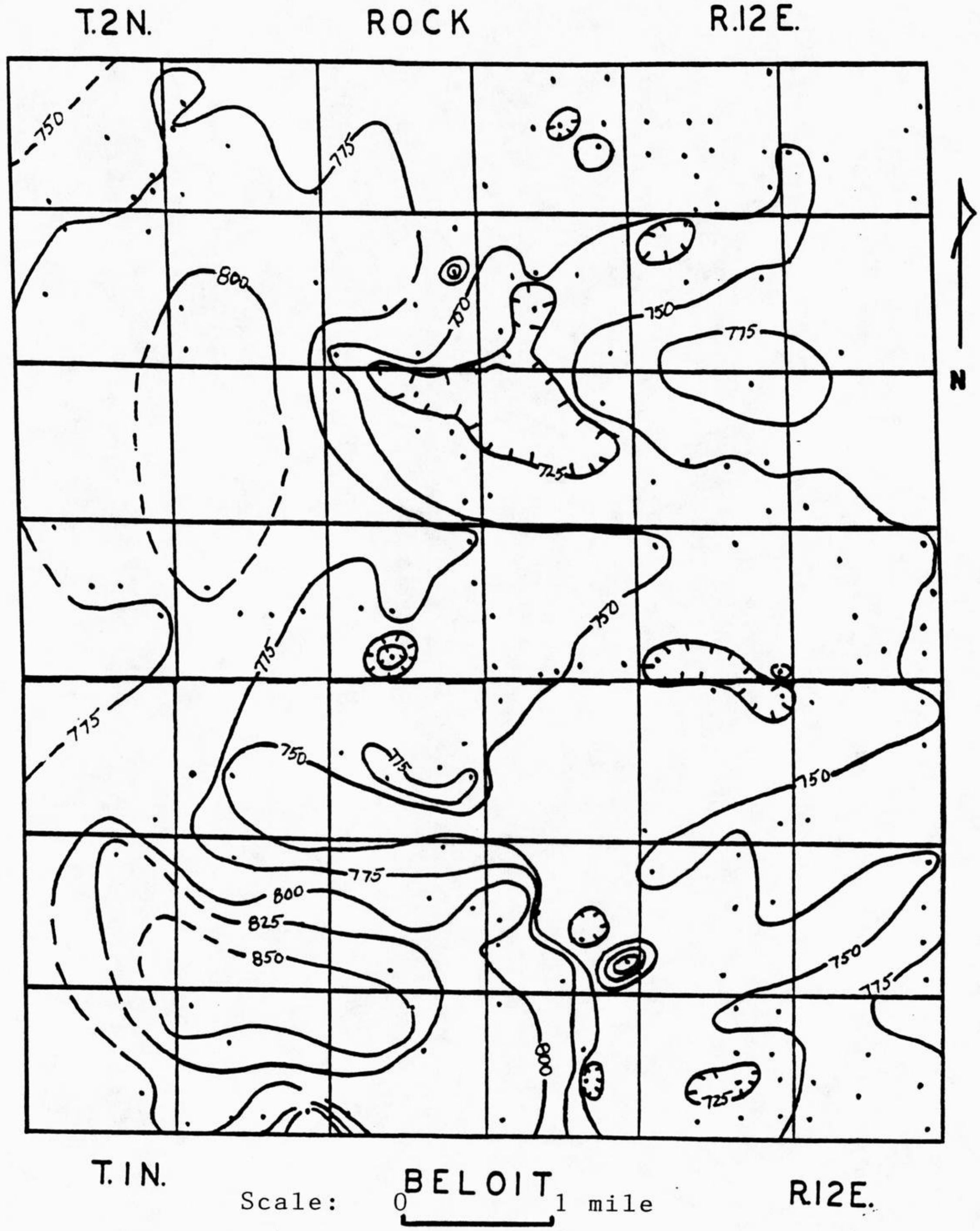


Figure IX-3. Map of potentiometric surface elevation for the Rock/Beloit study region (Rock County). Map generated from all available well construction reports for the region that were located in terms of quarter-quarter section. Elevations are in feet--contour interval is 25 feet.

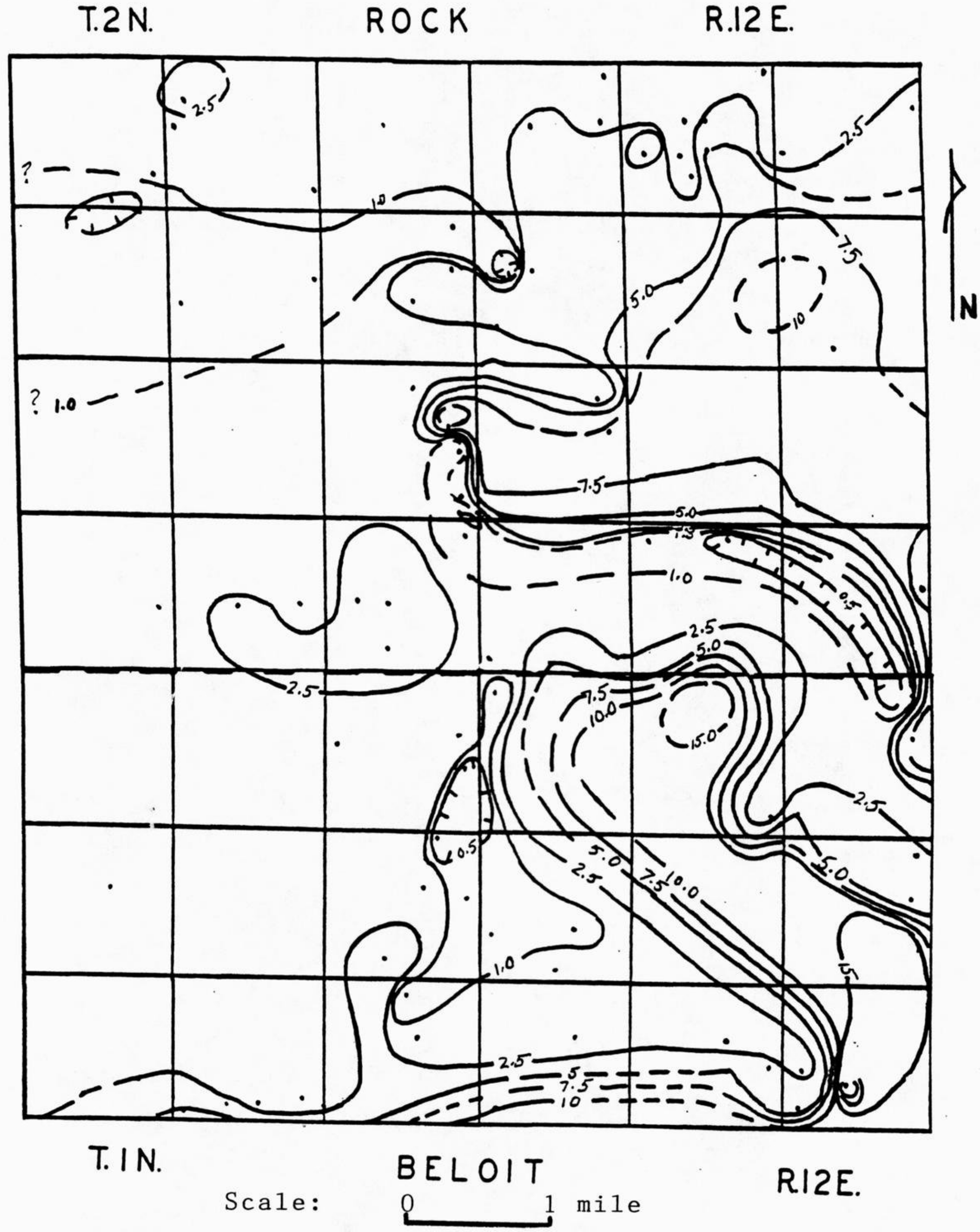


Figure IX-4. Map of specific capacity of wells in the unconsolidated sediments aquifer for the Rock/Beloit study region (Rock County). Map generated from all available well construction reports for the townships that were located in terms of quarter-quarter section and also had yield tests of 4 hours duration and longer. Specific capacity in gallons per minute per foot of drawdown. Contour interval of 2.5 gpm/ft with the exception of the 1.0 gpm/ft contour.

Figure IX-5. Map of specific capacity normalized to well screen length of wells in the unconsolidated sediments aquifer for the Rock/Beloit study region (Rock County). Map generated from all available well construction reports for the region that were located in terms of quarter-quarter section and also had yield tests of 4 hours duration and longer. Normalized specific capacity in gallons per minute per foot of drawdown per foot of well screen length. Contours of 0.5, 1.0, 2.0, and 5.0 gpm/ft/ft.

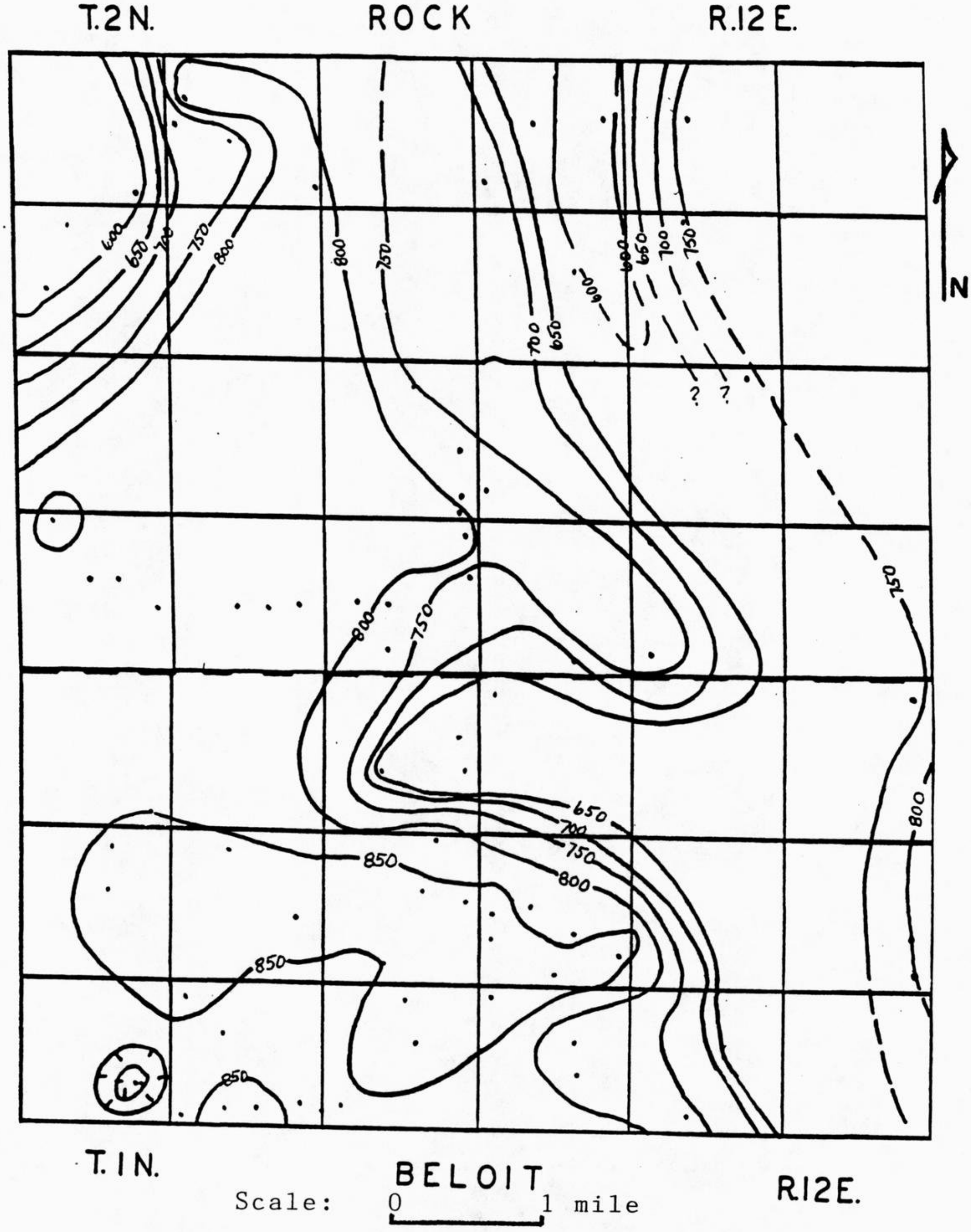
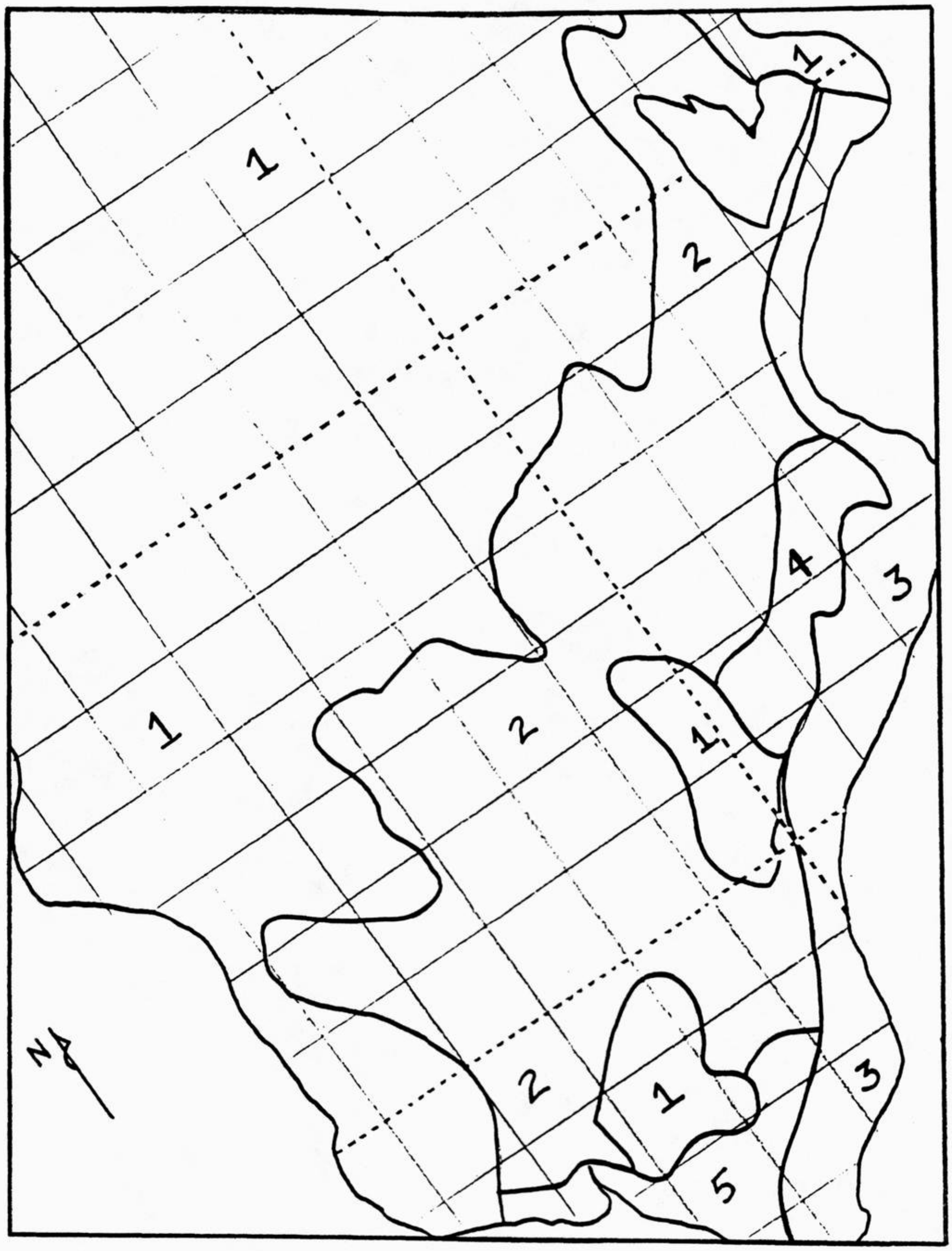


Figure IX-6. Map of the bedrock elevation for the Rock/Beloit study region. Map generated from all available well construction reports for the region that were located in terms of quarter-quarter section. Bedrock elevations in feet--contour interval of 25 feet.

APPENDIX X

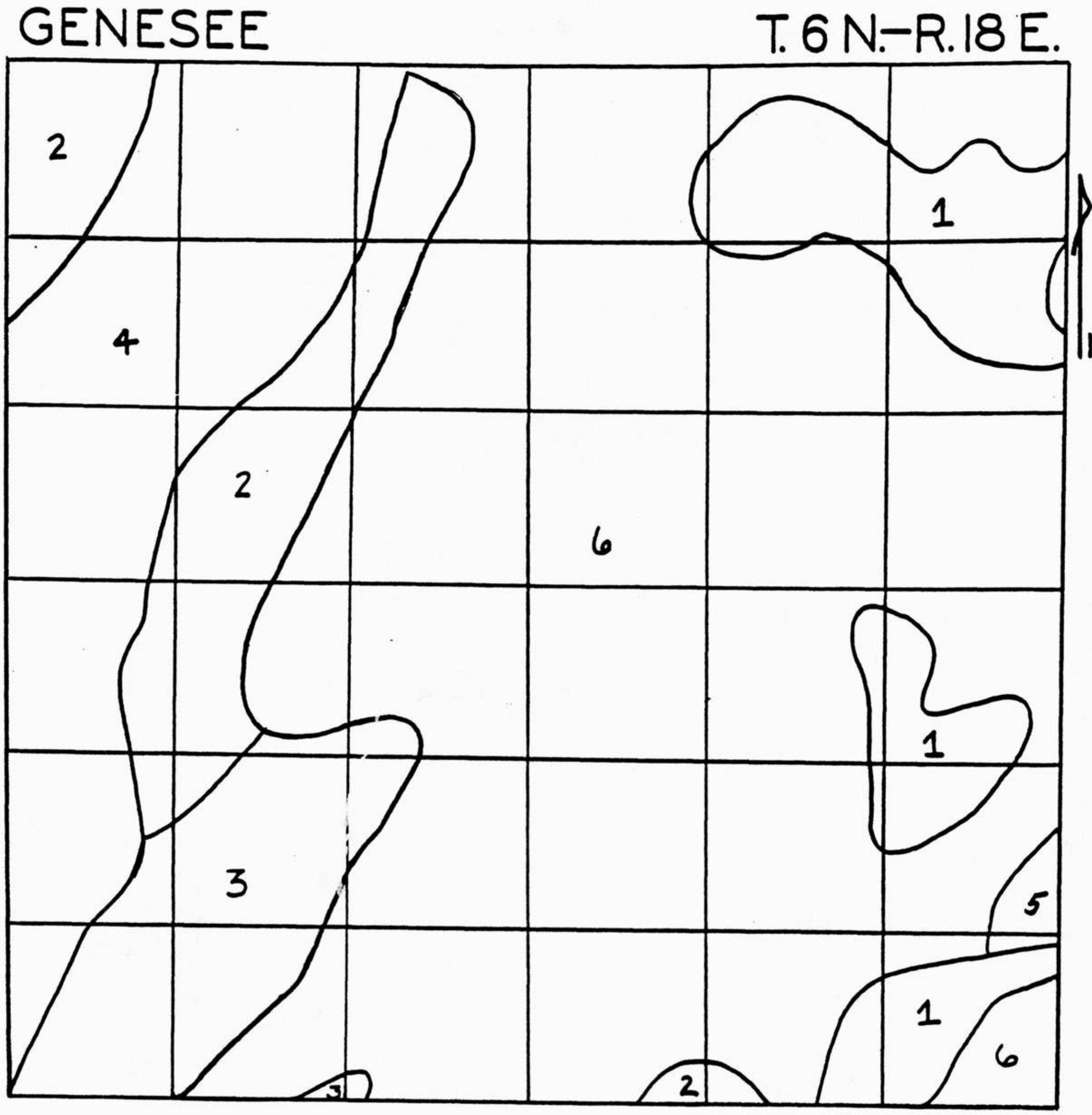
Soil Maps for study townships adapted from the U. S. Department of Agriculture Soil Surveys listed for each figure. Soil permeabilities are given in inches per hour.



Scale: 0 1 2 miles

Key: 1 Summerville-Longrie-Omena 2.33 in/hr permeability
2 Emmet-Solona-Angelica 2.32 in/hr
3 Rousseau-Kiva-Markey 10.3 in/hr
4 Carbondale-Cathro 1.8 in/hr
5 Deford-Yahara Variant-Carbondale 7.2 in/hr

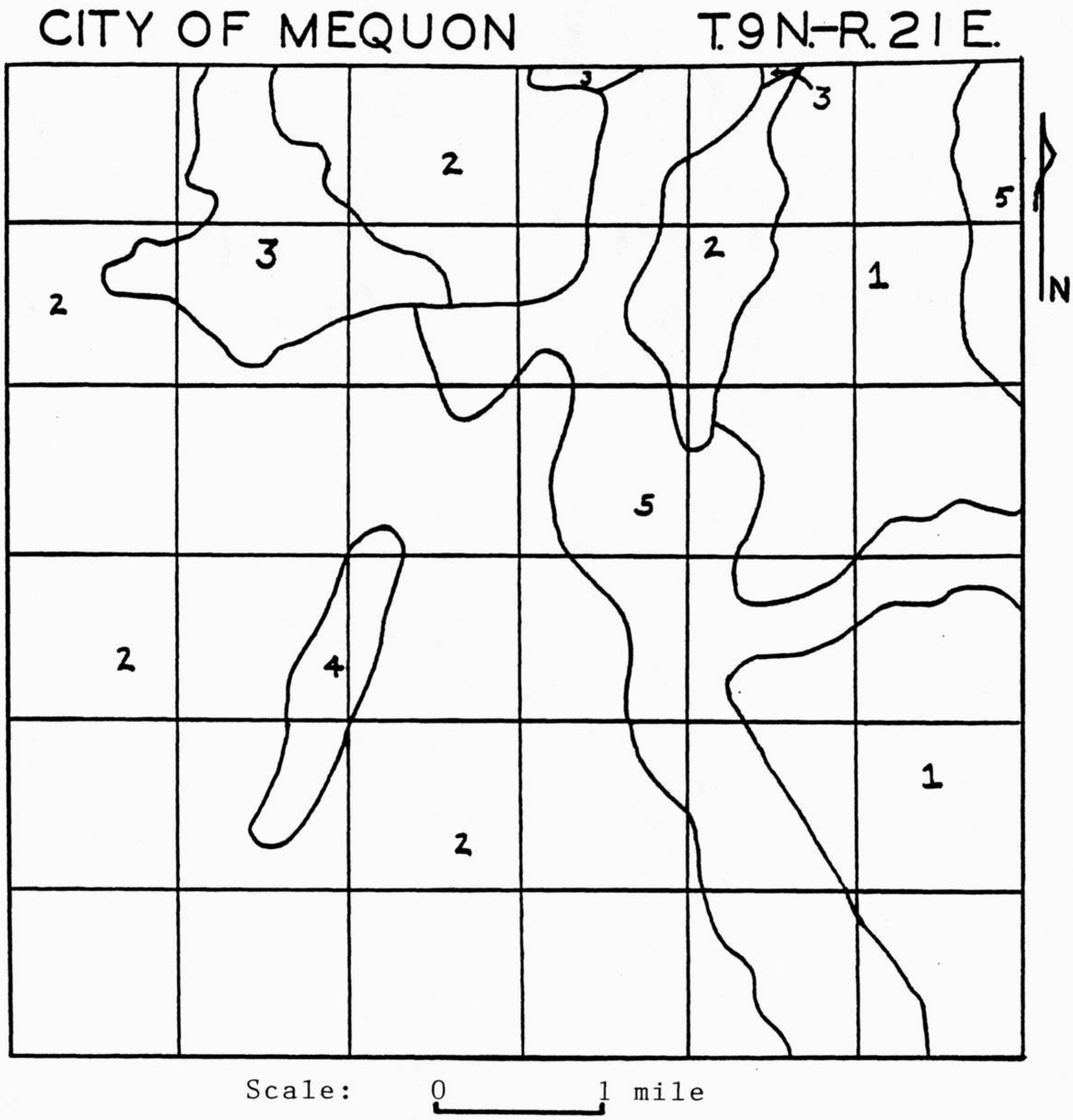
Figure X-1. Soil map for Door County Study region from the U. S. Department of Agriculture Soil Survey of Door County, 1978.



Scale: 0 1 mile

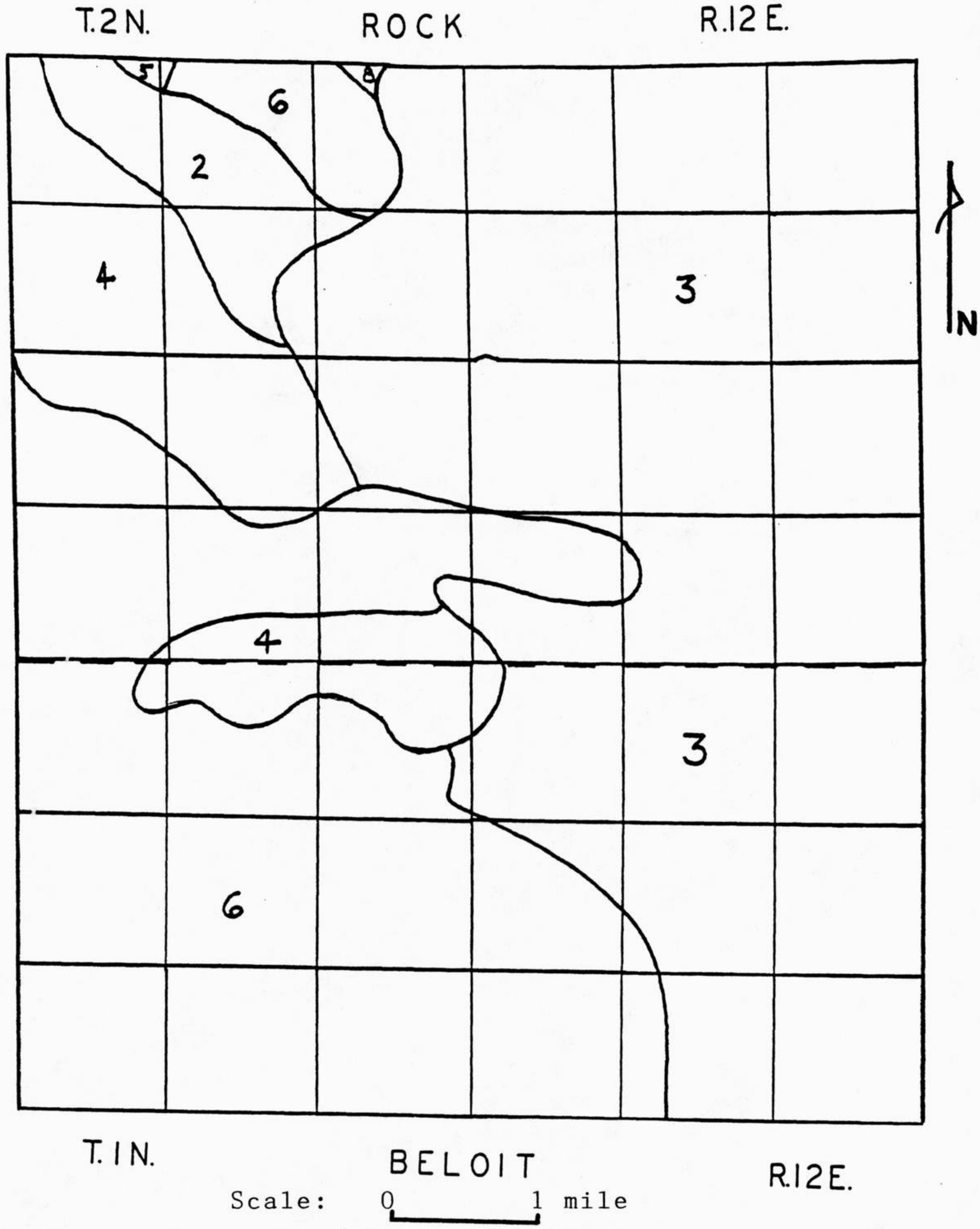
Key: 1 Houghton-Palms-Adrian 5.21 in/hr permeability
2 Fox-Casco 7.54 in/hr
3 Warsaw-Lorenzo 7.54 in/hr
4 Rodman-Casco 11.2 in/hr
5 Montgomery-Martinton-Hebron-Saylesville 0.62 in/hr
6 Hochheim-Theresa 1.38 in/hr

Figure X-2. Soil map for Genesee study Township from the U. S. Department of Agriculture Soil Survey of Waukesha County, 1971.



Key: 1 Kewaunee-Manawa 0.62 in/hr 4 Houghton-Adrian 5.3 in/hr
2 Ozaukee-Mequon 0.71 in/hr 5 Casco-Fabius 7.5 in/hr
3 Hochheim-Sisson-Casco 3.4 in/hr

Figure X-3. Soil map for Mequon study Township from the U. S. Department of Agriculture Soil Survey of Ozaukee County, 1970.



Key:
- 2 Dresden-St Charles-Warsaw 2.76 in/hr
- 3 Plano-Warsaw-Dresden 3.83 in/hr
- 4 Sebewa-Kane 5.27 in/hr
- 5 Pecatonica-Ogle-Durand 1.31 in/hr
- 6 Edmund-Rockton-Whalan 2.1 in/hr
- 8 Colwood-Sebewa 3.64 in/hr

Figure X-4. Soil map for Rock/Beloit study area from the U. S. Department of Agriculture Soil Survey of Rock County, Wisconsin.(1974).

APPENDIX XI

Data file listing for all matched wells: Well construction variables only. Refer to Index Maps (Appendix III) for well locations.

Key for Appendix

Column	Variable
ID	Map Identification Number (see Index Maps, Appendix III)
NO_3	Mean nitrate-nitrogen concentration in milligrams/liter for sampled well
WLD	Depth of well borehole (feet)
CSD	Depth of cased portion of well (feet)
CAQ	Depth well is cased into aquifer

NA = "not available"

BR = Bedrock

UC = Unconsolidated

APPENDIX XI CONTINUED

ID	NO_3	WLD	CSD	CAQ	
Rock/Beloit Township					
R1	2.7	120	96	39.0	Finished in BR
RR7	4.4	101	80	80.0	Finished in UC
R19	6.6	108	98	98.0	
R25	11.9	42	40	40.0	
R26	8.8	40	38	38.0	
R27	12.7	80	74	74.0	
R28	13.3	90	88	88.0	
R29	11.1	145	127	127.0	
R30	3.2	104	94	94.0	
RR41	5.6	100	100	100.0	
Mequon Township					
RO-2-1	3.0	178	62	62.0	ALL IN BR
RO-3-6	2.6	91	80	80.0	
RO-3-1	1.4	NA	NA	NA	
RO-10-6	2.0	280	63	63.0	
RO-10-3	1.7	110	51	51.0	
RO-15-1	2.0	223	90	90.0	
RO-M-4	2.6	NA	NA	NA	
RO-14-1N	1.4	232	227	1.0	
RO-4-3	2.7	145	52	1.0	
RO-4-2	3.8	358	108	108.0	
RO-9-2	3.1	135	23	23.0	
RO-9-1	2.8	176	85	85.0	
RO-M1	6.4	218	127	127.0	
RO-16-1	3.2	85	73	73.0	
RO-M3	3.8	165	70	70.0	
RO-14-1	3.1	124	124	124.0	
RO-3	1.9	313	80	80.0	
RO-4	18.0	113	63	44.0	
RO-51	5.8	136	52	2.0	
RO-35	4.5	218	45	45.0	
RO-5	0.5	105	80	80.0	
RO-8	0.5	361	145	145.0	
RO-13	0.5	400	86	86.0	
R0-14	0.5	245	76	76.0	
RO-16	0.5	455	96	1.0	
R0-22	0.5	300	90	2.0	
RO-29	0.5	462	102	102.0	
RO-31	0.5	200	127	127.0	
RO-32	0.5	606	117	117.0	
RO-38	0.5	185	178	178.0	
RO-40	0.5	350	104	104.0	
RO-42	0.5	319	138	138.0	
RO-44	0.5	365	134	134.0	

APPENDIX XI CONTINUED

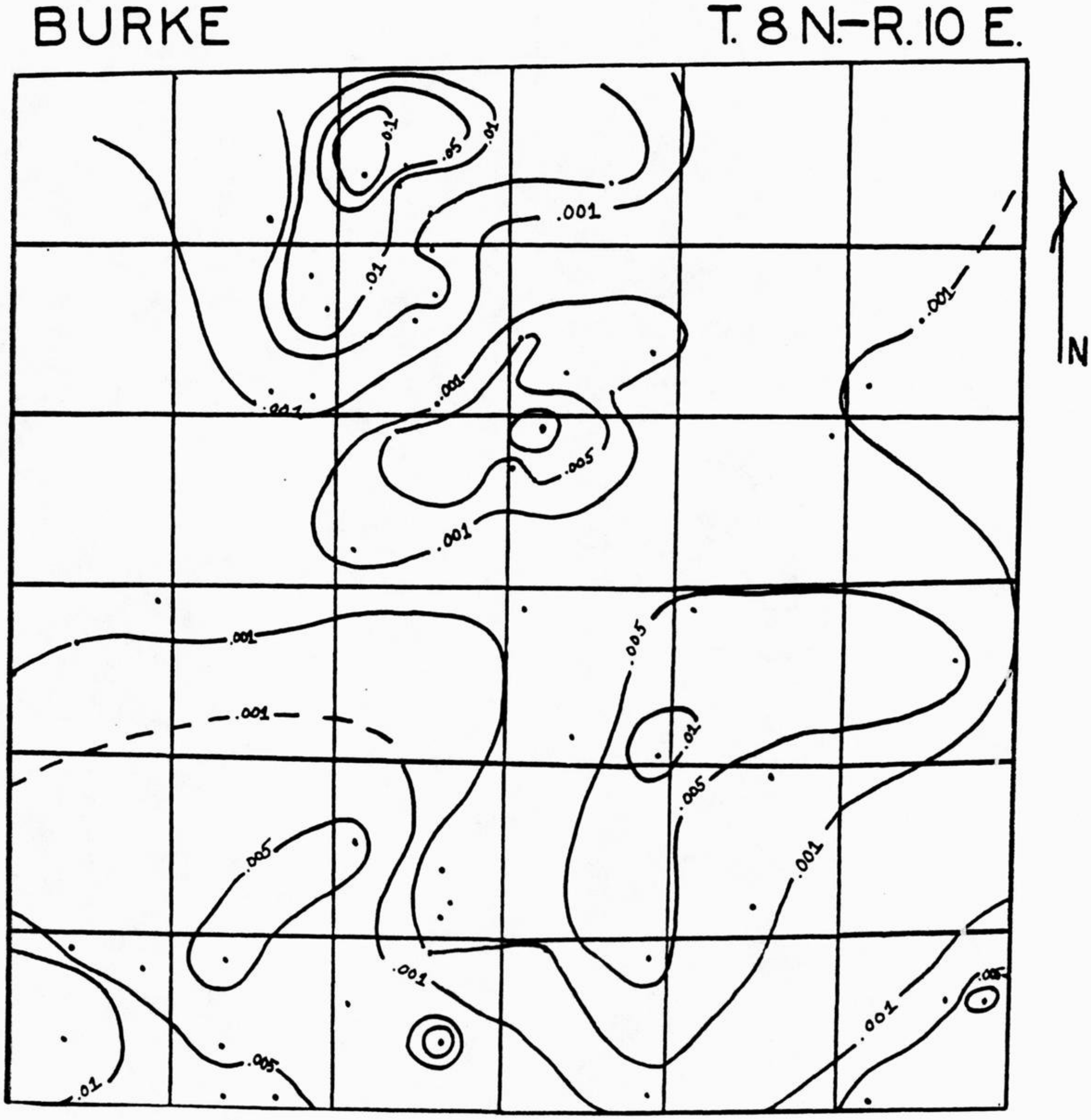
ID	NO_3	WLD	CSD	CAQ	
RO-53	0.5	206	100	100.0	
RO-54	0.5	125	97	97.0	
RO-68	0.5	425	126	126.0	
RO-70	0.5	295	61	61.0	
RO-71	0.5	230	50	15.0	
RO-74	0.5	188	134	134.0	
RO-12	0.5	153	51	51.0	
Genesee Township					
RW-22	10.6	48	48	48.0	MATCHED
RW-23	8.6	47	47	47.0	FINISHED
RW-43	13.8	56	57	57.0	IN UNCONSOL
RW-44	11.2	53	53	53.0	
RW-50	13.1	44	44	44.0	
RW-2	4.6	148	88	88.0	FINISHED IN
RW-17	2.2	241	42	7.0	BEDROCK
RW-21	10.2	120	56	1.0	
RW-28	1.7	160	69	69.0	
RW-29	3.8	182	53	3.0	
RW-30	3.9	175	70	70.0	
RW-6	0.5	348	66	16.0	
RW-8	0.5	680	71	14.0	
RW-1	0.5	54	54	54.0	FINISHED IN UC
Burke Township					
D-1	3.5	140	65	4.0	ALL FINISHED IN
D-3	8.2	140	94	24.0	BEDROCK
D-4	5.2	158	90	85.0	
D-10	14.7	125	60	45.0	
D-13	5.0	182	30	3.0	
D-16	11.8	148	71	13.0	
D-18	7.5	140	44	38.0	
D-20	1.0	140	111	18.0	
D-26	4.8	80	31	6.0	
D-28	6.4	78	40	34.0	
D-29	2.1	123	60	17.0	
D-33	2.0	182	91	31.0	
D-35	3.2	155	85	2.0	
Door Test Region Data					
DOOR-4	2.6	203	129	127.0	MATCHED
DOOR-3	5.2	204	170	154.0	ALL IN BEDROCK
DOOR-1	3.7	157	100	95.0	SPEC CAP FROM

APPENDIX XI CONTINUED

ID	NO_3	WLD	CSD	CAQ	
DOOR-8	0.8	363	180	174.0	GENERATED MAPS
DOOR-10	5.0	202	130	115.0	
DOOR-11	0.7	222	175	168.0	
DOOR-12	0.9	242	173	170.0	
DOOR-24	8.0	185	100	57.0	
DOOR-26	9.2	130	97	55.0	
AF1	3.2	284	170	155.0	
AF2	9.8	360	122	113.0	
AF3	11.0	249	170	145.0	
AF4	7.0	232	170	164.0	
AD5	1.9	249	171	167.0	
AH12	2.3	301	174	170.0	
AH17	1.6	272	171	170.0	
AK18	2.9	264	176	165.0	
AK29	8.5	202	170	151.0	
AK38	10.7	100	30	15.0	
AH43	5.6	176	100	90.0	
AP39	3.5	221	148	137.0	
AP42	2.8	242	195	186.0	
AN36	0.6	249	175	154.0	
AK13	1.6	234	170	163.0	
AK22	1.5	115	80	75.0	
AN21	0.6	242	172	167.0	
AG10	15.9	309	100	95.0	
DR173	16.0	310	101	95.0	
DR218	2.0	212	101	95.0	
DR172	17.0	210	100	94.0	
DR168	7.0	250	100	98.0	
DR215	4.0	112	100	98.0	
DR216	10.0	174	101	76.0	
DR178	4.0	171	80	65.0	
AK14	5.0	360	250	245.0	
AP40	0.0	242	173	169.0	
AP37	0.0	339	170	142.0	
DR184	0.0	200	100	40.0	

APPENDIX XII

Normalized Specific Capacity Map for Burke Township



Scale: 0 1 mile

Figure XII-1. Map of specific capacity normalized to well screen length for wells in the Burke Township (Dane County). Map was generated from all available well construction reports for the township that were located in terms of quarter-quarter section and also had yield tests of 4 hours duration and longer. Normalized specific capacity is in ((gallons per minute per foot of drawdown)/(feet of well screen length)). Contours are .001, .005, .01, .05, .1 gpm/ft/ft.

050843- The Prediction of Nitrate Contamination Potential Using Known Hydrologic Properties