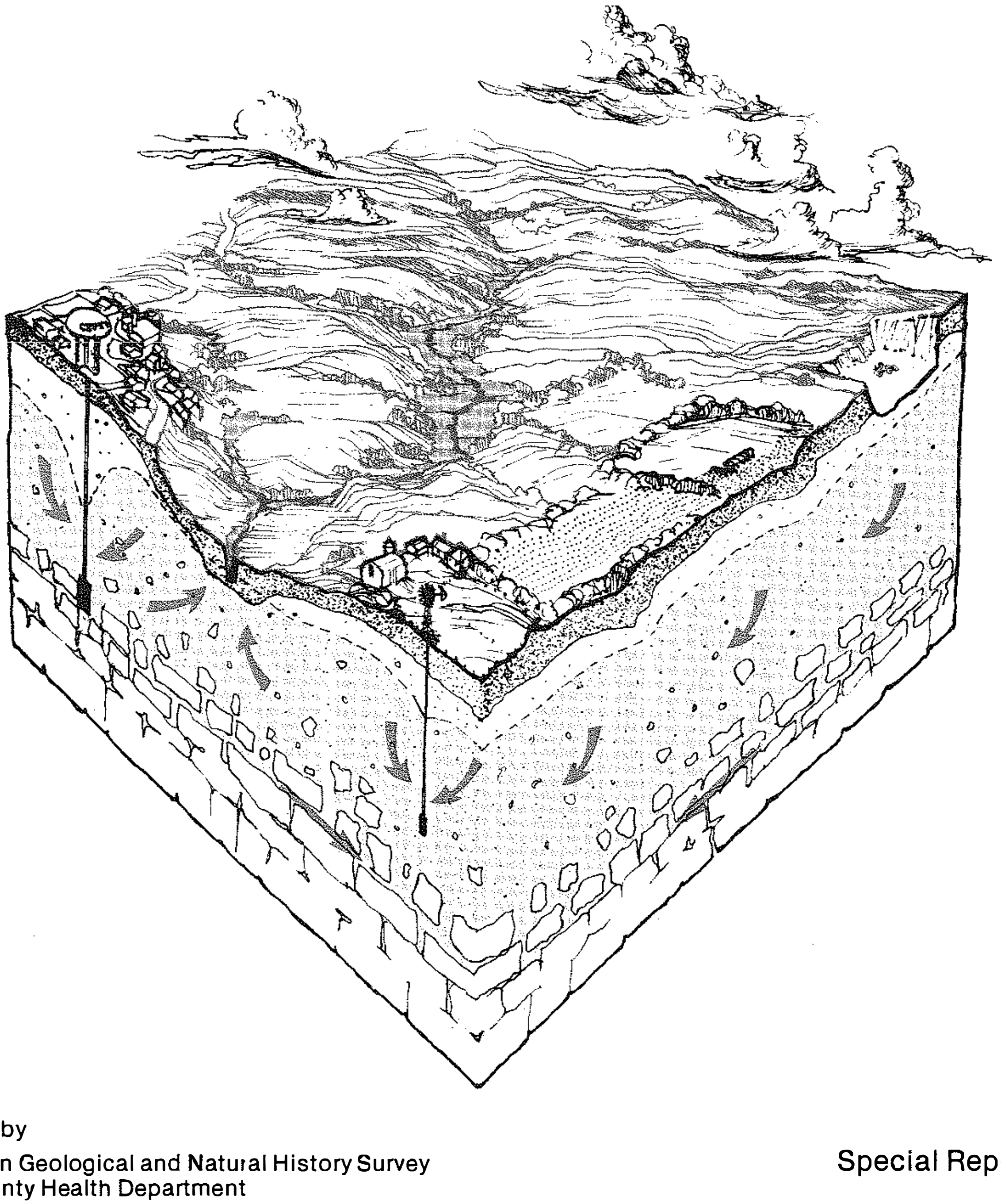
Groundwater Protection Principles and Alternatives for Rock County, Wisconsin



Prepared by
Wisconsin Geological and Natural History Survey
Rock County Health Department
University of Wisconsin-Extension
Wisconsin Department of Natural Resources

Special Report 8

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PREFACE

This report was prepared under a cooperative agreement between the Wisconsin Geological and Natural History Survey and the Rock County Health Department.

The project involved an inventory and analysis of all potential pollution sources in Rock County and analysis of their impact on groundwater; an analysis of land use trends and their relationship to groundwater quality; analysis and interpretation of the soil, geological and hydrological data; development of a three-tier system for evaluating the vulnerability of the environment to pollution; the delineation of areas especially susceptible to groundwater pollution; an analysis of existing state regulatory programs relating to groundwater; an outline of the major approaches and management tools that can be employed to address groundwater problems; and the selection of specific management strategies and alternatives that the county can pursue in its groundwater protection program.

In order to accomplish the complex, interdisciplinary objectives of the project, WGNHS invited the UW-Extension Environmental Resources Center and Wisconsin Department of Natural Resources to cooperate on the project and formed a team of specialists from various disciplines to work on the report. We thank all the team members for their diligent efforts to complete this unusual, original study to which they freely contributed a significant amount of time and energy.

The scope of this project was intentionally extended beyond the traditional responsibilities of WGNHS given by Wisconsin Statues: to provide basic resource information on "... the geology, water, soils, plants, fish and animal life of the state and... (to) continue the topographic mapping of the state..." Thus, in addition to providing basic resource information that can be used for groundwater protection planning, this report also provides an interpretation of this information for planning purposes and offers general management options and groundwater protection alternatives.

The project was designed, on the one hand, to demonstrate how the basic data collected by WGNHS can be used for practical purposes, and on the other, to show Wisconsin counties how to go about gathering and analyzing technical data, conducting a pollution potential inventory, doing an institutional and management analysis, and setting protection strategies and alternatives. We hope that this report will serve counties in Wisconsin, and elsewhere, as a useful guide and reference book in their efforts to protect a vital and treasured resource -- groundwater.

Meredith E. Ostrom
Director and State Geologist

COOPERATION AND ACKNOWLEDGMENTS

This report is a collective effort of a team of Survey staff, university specialists, and state and local agency personnel. The Wisconsin Geological and Natural History Survey (WGNHS) thanks all who participated in the formulation of the project and contributed to the various parts of the final report: Stephen Born, Department of Urban and Regional Planning, UW-Madison, and UW-Extension; Gary Jackson, James Peterson, and Douglas Yanggen, Environmental Resources Center (ERC), UW-Extension; David Holman, Rock County Division of Environmental Health (DEH); Robin Schmidt and Steven Skavroneck, Wisconsin Department of Natural Resources (DNR); and Ronald Hennings and Alexander Zaporozec, WGNHS; and to Phil Blazkowski and Jule Stroick, Rock County Planning and Development Department, who drafted the section on land use, and to Frederick Madison, WGNHS, who developed the soil evaluation system and wrote the section on soils and their ability to protect groundwater.

We appreciate the assistance of others who cooperated in the collection of basic information or contributed valuable ideas: Dennis Nehring, Rock County Agricultural Agent; Steve Schraufnagel, Rock County Planning and Development Department; Donna Johnsen, intern, Rock County Health Department; Floyd Stautz, DNR; Conrad Shepp, U.S. Soil Conservation Service; James Petersen and Richard Proost, UW-Extension; and Paul Gempler, John Jablonski, Jill Jefferson, and Juliana Potter, students, UW-Madison.

Acknowledgement is given to all who reviewed the final draft of the report (see appendix A); especially to David Fredrickson, Wisconsin Department of Industry, Labor & Human Relations (DILHR); Dennis Keeney and Gerhard Lee, Department of Soil Science, UW-Madison; William Lane, Dane County Regional Planning Commission; William Lontz, Northern Area Office, UW-Extension, Hayward; the members of the Agricultural Resource Management Division, Wisconsin Department of Agriculture, Trade & Consumer Protection (DATCP); and the staff of DNR bureaus of Solid Waste Management, Wastewater Management, Water Resources Management, and Water Supply, and Southern District of DNR, who offered valuable suggestions.

Successful completion of the report is due to WGNHS staff members Margy Blumenthal, Roxanne Miller, Jerilyn Ruhland, and Kathie Zwettler, who typed the many versions of the report; Mike Czechanski, who advised on the format of illustrations; Brenda Haskins-Grahn, who produced the figures; to Chuck Holzbog, who designed the cover illustration; and to Patricia Robinson, Department of General Engineering, UW-Madison, and Monika Thompson, who edited the final manuscript.

Groundwater Protection Principles and Alternatives for Rock County, Wisconsin

ABSTRACT

Rock County has good quality groundwater and does not have serious and widespread pollution problems at this time; therefore, efforts should be concentrated on protecting the quality of groundwater in the county and preventing its degradation by potential pollutants.

Groundwater pollution is caused by many human activities above, at, and below the ground. The inventory and assessment of potential pollution sources in Rock County shows that the quality of the county's groundwater most commonly can be affected by inadequate waste disposal practices, improper storage of industrial and agricultural chemicals, spills and leaks of hazardous materials, and excessive application of fertilizers and pesticides.

Groundwater pollution by human activities cannot be completely eliminated, but it can be minimized. Strategies for groundwater pollution control must be based on an understanding of hydrogeological and environmental characteristics of the county, effective use of land regulations, and best management practices. They must also be sensitive to socioeconomic factors and the governmental and political situation in the county.

The natural environment can restrain the introduction of pollutants into the groundwater. Existing information on the county's soil and rock materials was compiled, and a system was developed to evaluate the capacity of the environment to attenuate pollutants. The system consists of three components: interpretation of the soil's ability to attenuate pollutants, evaluation of the vulnerability of subsurface materials to pollution, and determination of the direction and rate of groundwater flow. The evaluation resulted in identification of those areas that are especially susceptible to groundwater pollution, as well as those that are least vulnerable. This classification can be used as a time- and cost-saving tool for preliminary screening of various areas for differing uses.

The environment alone does not provide adequate protection of groundwater against pollution because some pollutants will reach groundwater regardless of how favorable the environmental factors may be. Therefore, it is important to control pollution at the source, rather than rely on the attenuation capacity of the environment. The report lists major approaches and management tools that can be used to address potential groundwater problems. They include both regulatory and non-regulatory management options. Among the regulatory options discussed are the existing state regulatory programs, local land use controls (zoning and subdivision regulation), and local ordinances. Non-regulatory approaches include educational and training programs, voluntary best management practices, community efforts to reduce waste volumes, and governmental coordination.

The report identifies specific actions the county can take to minimize the pollution potential of identified land uses and pollution sources through a combination of state regulatory programs, local regulatory options, and non-regulatory strategies. Additionally, it recommends management alternatives for special management areas (naturally vulnerable areas, well-protection zones, potential problem areas). Focusing on these special management areas will allow the county to set priorities and to concentrate limited resources in key locations. Finally, the report encourages Rock County to include monitoring of water quality trends and potentially polluting sources in its groundwater protection plan as a complement to state programs.

The inventory and analysis of pollution sources, environmental characteristics, and available management techniques was done specifically for Rock County to provide local officials and citizens essential information and management alternatives needed to develop a county groundwater protection plan. However, much of the information contained in the report is general and can be used by other counties in the development of their own groundwater protection plans.

CONTENTS

PLATES

FIGURES

TABLES

Chapter I.

INTRODUCTION

Goals and Objectives of Study

The goals of this project were to provide technical assistance and environmentally sound management recommendations for a county program to protect groundwater for present and future uses.

The primary objectives were to do the following:

1. Identify existing approaches to local groundwater protection that can be applied to Rock County.
2. Inventory existing and potential sources of pollution in Rock County, assess the risks they present to groundwater quality, and outline available regulatory and non-regulatory options and approaches to control these sources.
3. Inventory existing groundwater problems, and identify areas most susceptible to groundwater pollution.
4. Develop groundwater protection strategies and alternatives, especially for selected, pollution sensitive areas of the county.

Scope and Limits of Study

This report is a technical and institutional analysis of available information and management strategies. It makes no specific policy recommendations, but provides both the technical information and management alternatives needed for planning efforts and future decision making in Rock County. We hope that this report will also serve as a guide and framework for other Wisconsin counties in their efforts to protect groundwater. A summary of this report, published separately, is available upon request free of charge.

The analysis presented in this report is based on literature review, data gathered during the inventory of pollution sources, and an overview of applicable legislation and management tools. Basic soil, geologic, groundwater, and water quality data were obtained from WGNHS files and from the following reports: a county report on groundwater (LeRoux 1963), hydrologic investigations atlases HA-360 (Cotter and others 1968) and HA-453 (Hindall and Skinner 1973), a county soil survey report (USDA 1974), and an evaluation of groundwater quality of the county (Zaporozec 1982).

This report describes the most important factors that need to be known to protect groundwater in Rock County from pollution and explains in nontechnical terms some basic principles and procedures by which threats to groundwater can be assessed, countered, or prevented. However, some aspects of groundwater protection are highly technical. Even though the authors tried to minimize the use of technical jargon, in some cases such terms are necessary. Those are defined in the glossary.

All technical studies have limitations. Because of time and money constraints, only already existing basic data and information were used in this study. Therefore, the validity of some conclusions may be subject to change with an expanded data base.

Background of Study

Rock County is located at the border of Wisconsin and Illinois, halfway between the Mississippi River and Lake Michigan (fig. 1). It consists of 20 townships and is nearly rectangular, measuring approximately 30 miles west to east and 24 miles north to south. Its total area is 726.8 mi^2 (465,000 acres), of which 5.6 mi^2 are covered by water (1981-82 Wisconsin Blue Book, p. 718).

Groundwater is a vitally important natural resource of Rock County that must be used wisely and protected for the general welfare and health of the county population. Rock County has adequate supplies of groundwater to support its growing population, strong agricultural base, and viable, diverse manufacturing and resource-oriented industry. Ninety-nine percent of water used for municipal, rural, and industrial purposes comes from groundwater reservoirs (Lawrence and Ellefson 1982). Presently only 18 percent of the total amount of water that infiltrates to become groundwater is being withdrawn; it is estimated that this number will increase to 22 percent by the year 2000 (Zaporozec 1982).

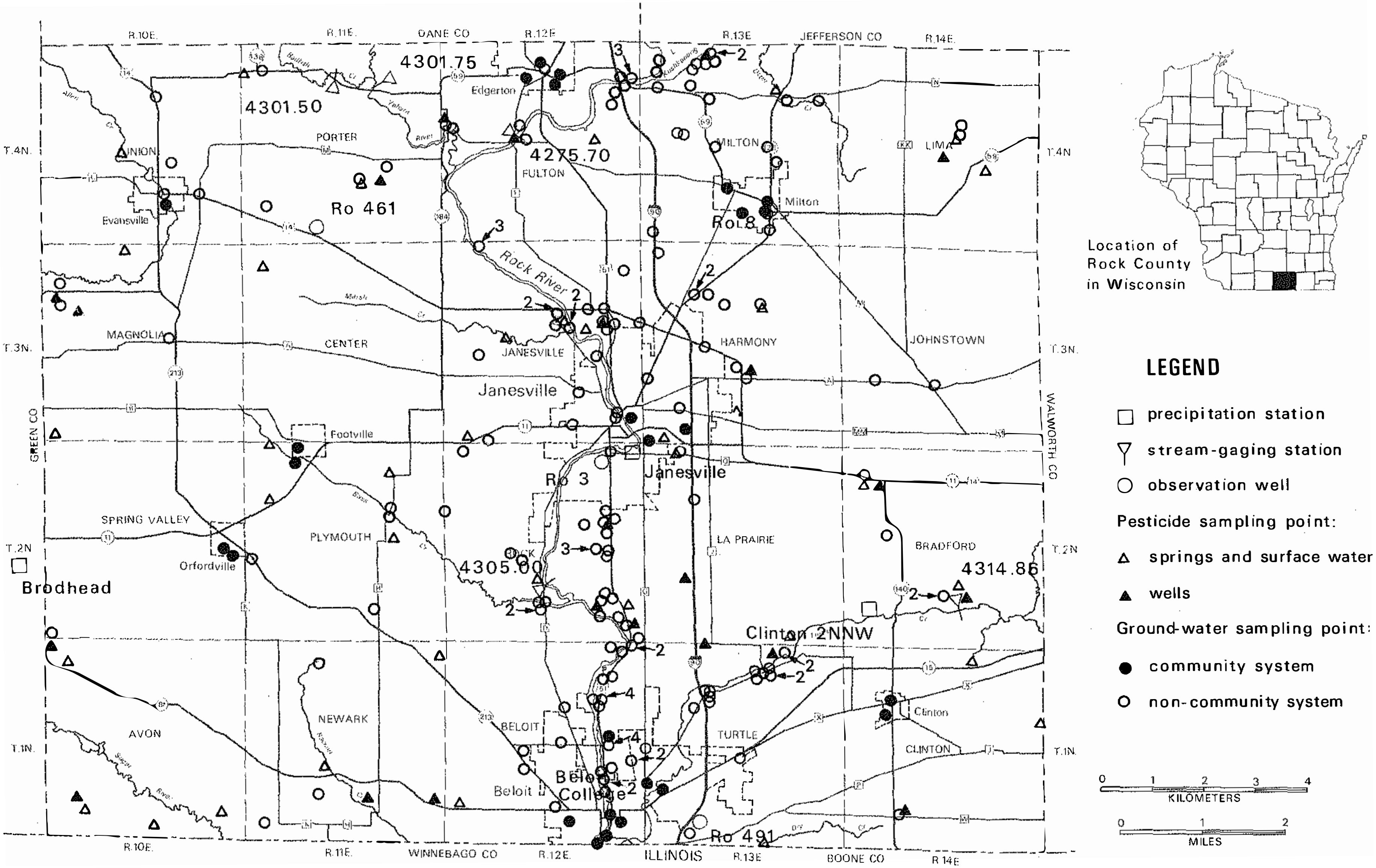
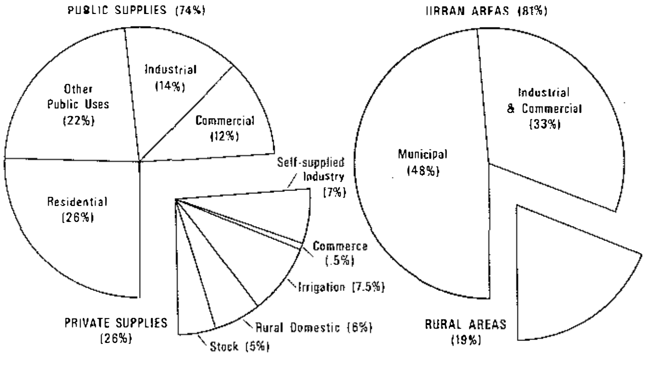


Figure 1. Location map of Rock County with monitoring stations

Groundwater in Rock County is used for many purposes. In 1979 the largest share was used for public water supplies (Lawrence and Ellefson 1982): 20.7 million gallons per day (mgd), which is 74 percent of all water used (fig. 2A). The other three major water uses--rural (including domestic and livestock consumption), irrigation, and self-supplied industry and commerce--used the remaining 26 percent (7.3 mgd) and were supplied from private sources. About four fifths of the total amount of groundwater used was pumped in urban areas (fig. 2B), primarily in the heavily populated and industrialized area along the Rock River. The main pumpage centers and principal groundwater users are shown in figure 3.



A HOW WATER WAS USED

B. WHERE WATER WAS CONSUMED

Figure 2. Groundwater uses in Rock County in 1979 (source: Lawrence and Eleffson 1982)

The overall natural quality of groundwater in Rock County is good and it is suitable for many uses, but requires softening for some purposes to remove excessive hardness (Zaporozec 1982). The groundwater in Rock County is a very hard, calcium-magnesium-bicarbonate type, with a median hardness around 320 milligrams per liter (mg/l). The chemical quality of water from the four main aquifers is similar, and generally it is better than the quality required by federal and state drinking water standards. However, iron, manganese, and nitrate concentrations may locally exceed maxima allowed by the standards.

Rock County does not have serious, large-scale pollution problems at this time. Nitrate is the most common identifiable pollutant, and its concentrations create health concerns in the county. An unusually large amount of nitrate in well water may indicate pollution from septic systems, fertilizers, or barnyards. Even when nitrate is not a problem in itself, it may serve as an indicator that the water contains harmful bacteria or other pollutants. Nitrate concentrations in excess of the recommended limit of 10 mg/l of nitrate-nitrogen (NO_3-N)* can be found in a number of places in the county (see fig. 17), and the mean concentration in Rock County is the highest in the state (Wis. DNR 1980). This higher-than-average occurrence of nitrate in certain areas suggests that highly productive agriculture has an impact on groundwater quality. Higher concentrations occur more frequently in rural areas where the groundwater pollution potential is larger because of barnyard runoff, storage and spreading of animal wastes, use of fertilizers, and greater number of septic systems, and where the wells are shallow. Urban areas are supplied by deeper public wells that are less likely to be affected by local pollution.

Although Rock County has abundant good quality groundwater, the aquifers are close to the land surface, and their limited natural protection make them vulnerable to pollution. Pollution can come from a wide variety of sources, including agriculture, chemical storage on and below the land surface, and discharges of wastewater from septic systems.

Because of a lack of adequate data on groundwater quality and on the potential dangers to groundwater from various land and water uses and waste disposal practices, the Rock County Board of Supervisors asked the Rock County Division of Environmental Health (DEH) to initiate a study of groundwater quality. In August 1979 the DEH approached the Wisconsin Geological and Natural History Survey (WGNHS) with a request to study the groundwater quality of Rock County on a cooperative basis. A formal agreement was signed in December 1979, with each party to bear half the cost of the project. The study was completed in 1982 (Zaporozec 1982) and provided technical information on groundwater uses and problems, and also provided the technical basis for the development of a groundwater protection program.

In 1981, the DEH recommended adoption of a public health ordinance that recognized groundwater pollution as a public nuisance (Rock Co. 1981). This ordinance is being used to control sources of groundwater pollution until prevention measures can be developed.

In January 1984, the DEH initiated a cooperative study with WGNHS and county agencies to provide technical assistance for a county groundwater protection program and to consider the different management strategies for preventing or minimizing groundwater pollution. The WGNHS invited the UW-Extension Environmental Resources Center (ERC) and the Wisconsin Department of Natural Resources (DNR) to cooperate in the study and formed a team of specialists from various disciplines to develop this report. Brief biographies of the authors are attached in appendix A.

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* In this report, valence of dissolved elements is not indicated unless specifically necessary for the context.

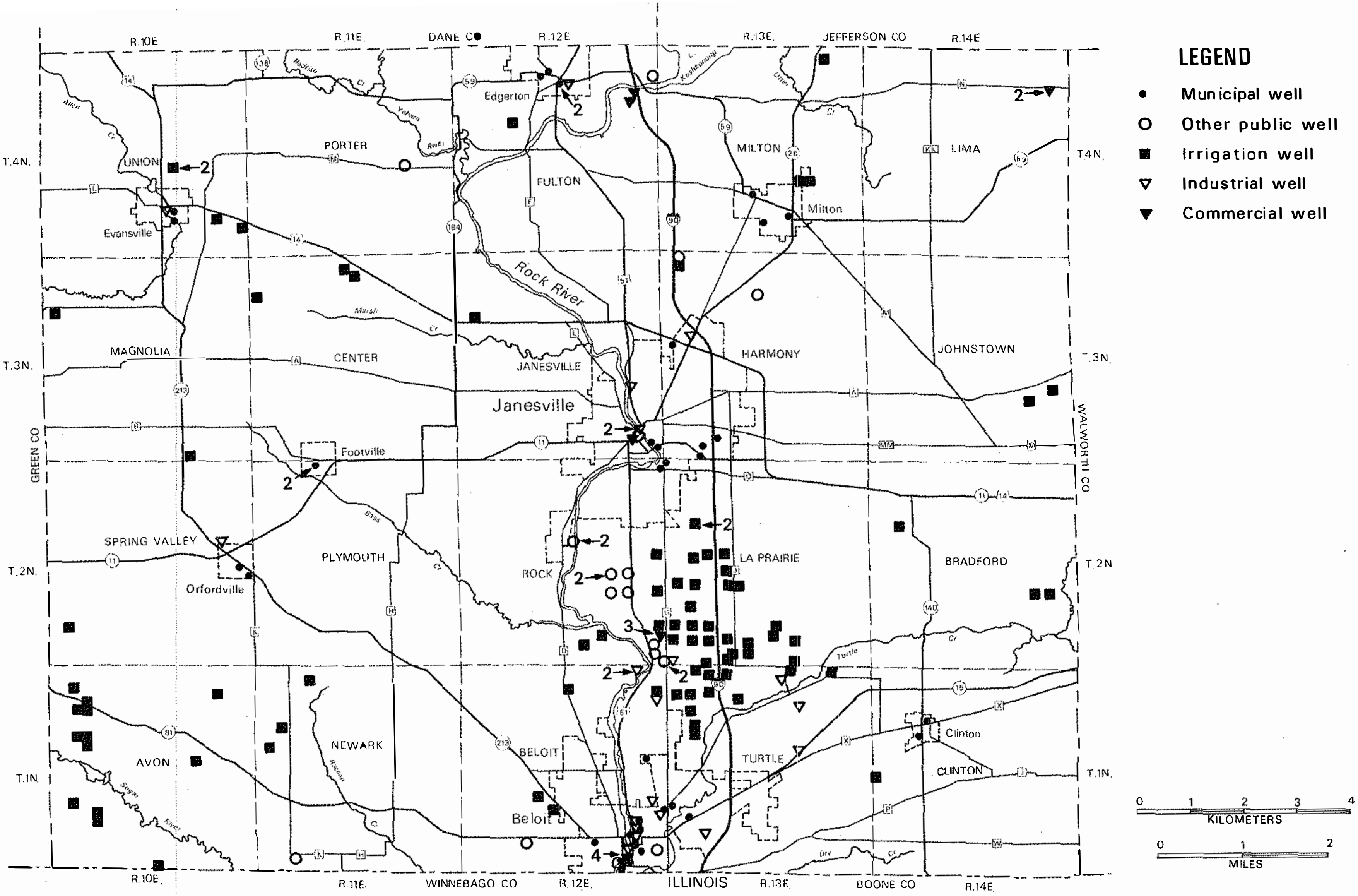

Figure 3. Major groundwater users in Rock County in 1984 (source: Wis. Department of Natural Resources)

Chapter II.

INVENTORY AND ASSESSMENT OF POTENTIAL POLLUTION PROBLEMS

Introduction

The sources of groundwater pollution are many and varied. In addition to some natural processes, practically every type of human-installed facility or structure and most human activities can eventually contribute to groundwater pollution. Thus, a local groundwater planning effort must begin by identifying and assessing those activities and practices that may affect the quality of groundwater. Since people are agents of groundwater pollution, many of the sources and causes of groundwater pollution are found in and near population centers. The type, duration, and intensity of human activities will determine the degree of risk that is posed to groundwater quality. Field investigations, and in some cases very detailed studies, may be necessary to determine if potential pollution problems exist. However, many human activities are closely integrated into our economic and cultural way of life, and may indeed be necessary. Practices such as disposal of municipal sewage sludge and application of agricultural fertilizer to increase crop yields are examples of such activities. Management strategies to reduce the impacts of such essential activities on groundwater quality are likely to be aimed at modifying the practices rather than eliminating them. Because prevention is the key to groundwater protection, this study has attempted to inventory and assess a broad array of activities that might be of concern.

This chapter characterizes the activities and practices that may affect groundwater quality and outlines the nature of pollution that may result from them. It also describes the nature and extent of potential groundwater pollution sources in Rock County and estimates their relative significance. Such estimates represent an informed judgment based on the likelihood of groundwater quality impairment and the size of the population that may be at risk. No attempt has been made, however, to rank quantitatively the various potential pollution sources in the county. An illustration of such a ranking procedure, based on one local environmental health official's approach to assess comparative risk potential from different pollution sources, is attached in appendix B.

Land Use Trends

Groundwater pollution potential is intimately related to human activities on the land overlying aquifers, and this section describes patterns and trends in land use in Rock County. These trends may provide insights into the nature of future changes and their influence on groundwater quality.

The basic settlement pattern of Rock County was established during the 1800s. Transportation networks--such as roads, railroads, and rivers--greatly influenced the location and size of urban development. Six rural centers and two urban centers, Janesville and Beloit, evolved in the county. The railroads, and later the 1-90 interstate system, provided the stimulus for an array of markets, services, and employment opportunities. Although both of these cities were relatively compact in their early developmental stages, they have begun to sprawl considerably in recent years. The rural centers--Clinton, Edgerton, Evansville, Footville, Milton, and Orfordville--still show a relatively low density and even distribution of development. New rural residential development is, however, occurring along rivers, lakeshores, and major roads in surrounding agricultural towns.

The twenty townships in Rock County are experiencing varying degrees of land use changes. All of them have remained primarily agricultural with the exception of the seven townships along the urban Rock River/I-90 corridor, which are experiencing residential, commercial, and industrial development pressures. Figure 4 shows the major categories of land uses in the county as of 1984.

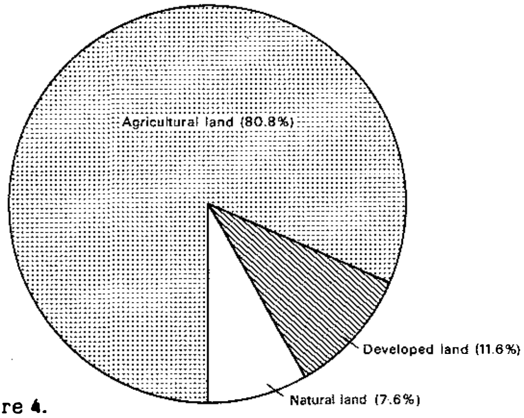

Figure 4.
Distribution of major land uses in Rock County in 1984 (source: Rock County Planning and Development Department)

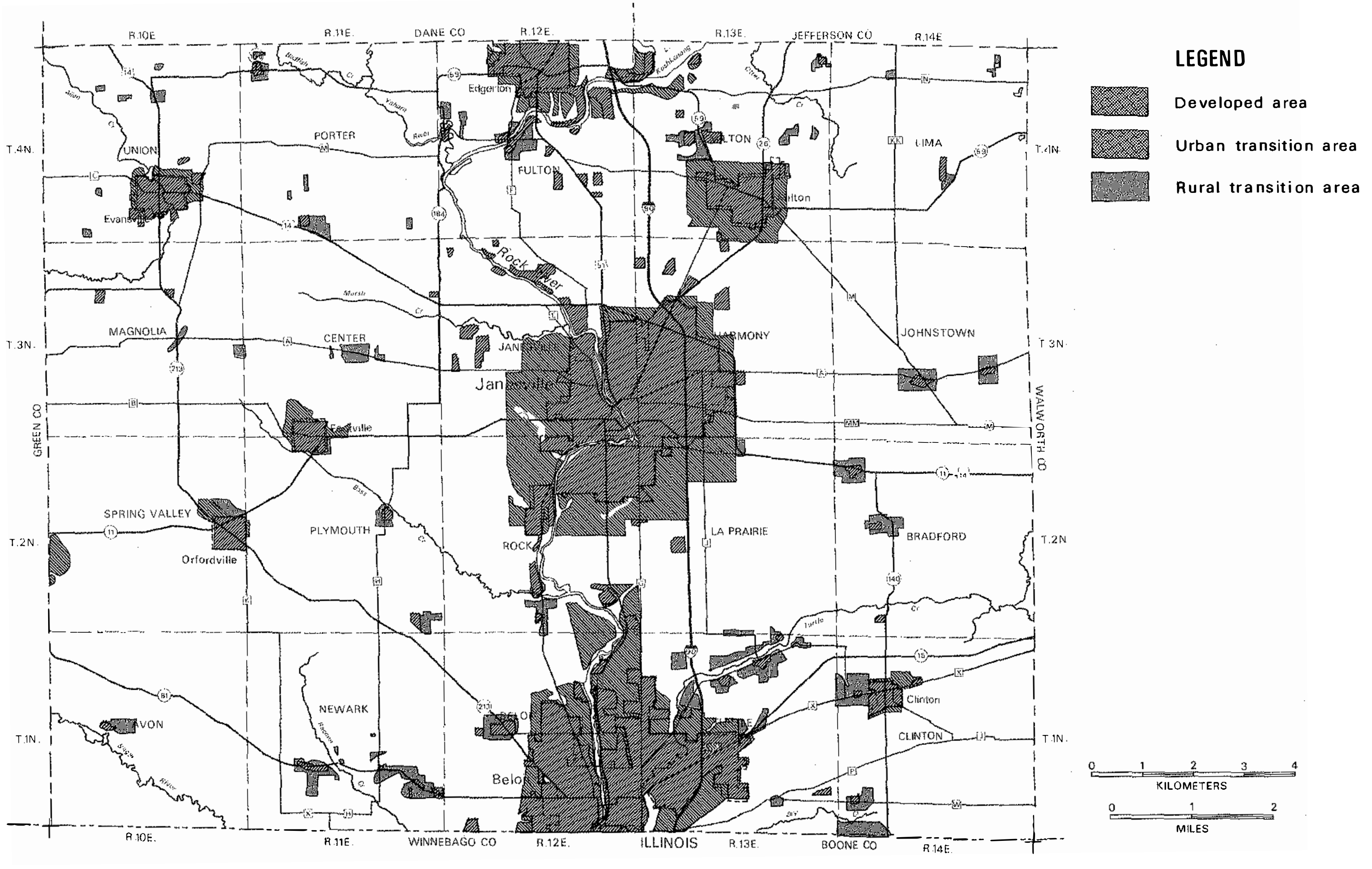

Figure 6. Land in development in Rock County, 1979 (from: Rock County Farmland Preservation Plan, 1979)

Historically, Rock County has been predominantly agricultural. Figure 5 shows agricultural acreage in Rock County from 1900 to 1982. Agricultural land use peaked in 1945, following the drainage of many wetlands. Since then, the amount of land in agricultural use has decreased by about 77,000 acres. The greatest decrease (1964-1969) can be attributed to rural development and annexation to incorporated municipalities. Nevertheless, agriculture is still the primary land use activity in all twenty townships. In 1984, approximately 376,000 acres (81 percent of the county's total area) were in farm use.

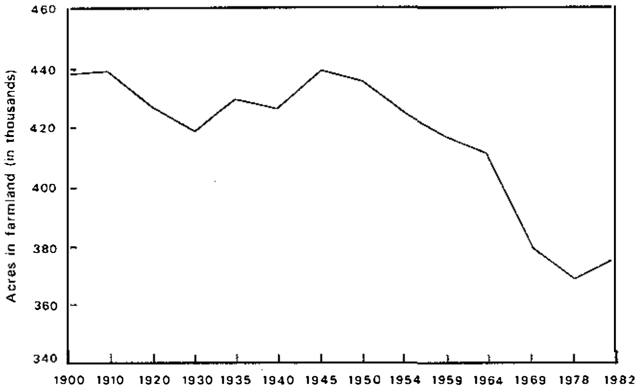

Figure 5. Land in agriculture in Rock County, 1900-1982 (source: U.S. Bureau of Census)

Although the annual rate of decrease in farmland has slowed somewhat since early in the 1970s, the trend of farmland displacement continues. The urban-corridor towns of Harmony, Fulton, Turtle, Janesville, Milton, Beloit, and Rock accounted for over 3,600 acres, or 62 percent of the total farmland decline from 1973 to 1980 (Fodroczi and others 1981). Areas away from the county's urbanized core are also experiencing the conversion of agricultural land to other uses. Most of this land use conversion is due either to the growth of smaller cities, villages, and rural centers (fig. 6) or to agriculture-related commercial development.

Rural development is increasing in many areas of the county. It includes all land used for human activities other than farming, such as residential, commercial, industrial, and other development. From 1973 to 1980, almost 70 percent of rural development took place in the seven townships along the Rock River/I-90 corridor (fig. 7). The most significant gains occurred in the towns of Fulton, Milton, and Janesville (over 200 acres). The only major increase outside of the urban corridor was in the town of Clinton. The total amount of developed land was approximately 54,000 acres (12 percent) in 1984.

Between 1973 and 1980, the amount of land classified as natural (woods, surface waters, and vacant land) increased by 1,260 acres or 3.5 percent. This increase is primarily from improved methods of calculating land use acreage. Also, some land previously classified as agricultural has been allowed to grow back to a natural state because of limited agricultural capability. As a result, the total amount of natural land was more than 35,000 acres (7 percent of the county's total area) in 1984. Of this natural land, about 10 percent is surface water. Towns with the most natural acreage (more than 2,500 acres) are Milton, Fulton, Janesville, Avon, and Spring Valley (Fodroczi and others 1981) where the abundant natural cover is due to the Johnstown moraine and the Rock and Sugar rivers with their large wooded peripheries. Towns with the least amount of natural cover are LaPrairie, Clinton, Union, and Bradford (less than 1,000 acres). The absence of significant natural land area in these townships results primarily from intensive agricultural activities.

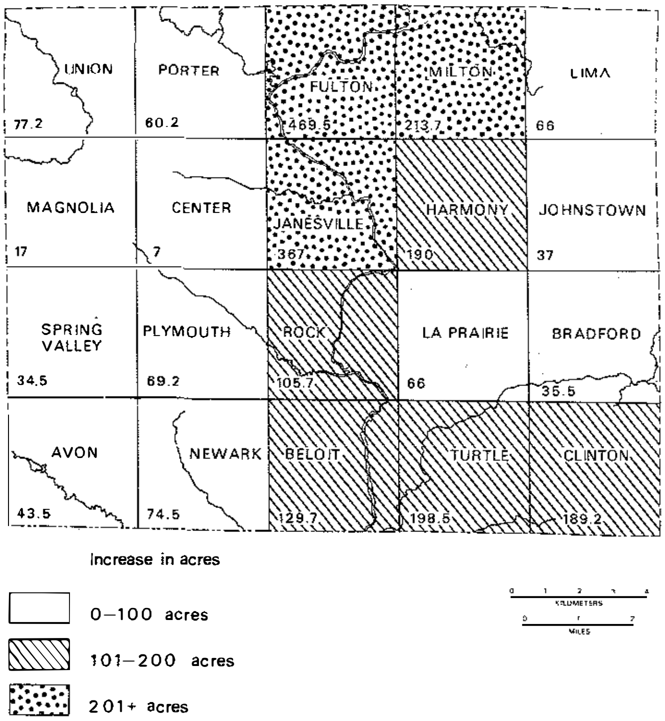

Figure 7. Distribution of increases in developed land in Rock County, 1973-1980 (from: Fodroczi and others 1981)

Rock County will probably remain primarily agricultural. Development will continue in the seven townships along the Rock River/I-90 corridor, but the rural centers, with the exception of Clinton, will remain low-density villages and cities. Urban sprawl in Janesville and Beloit is expected to continue along the major access roads to the cities.

Rock County's two urbanized centers, six rural centers, and twenty agriculture-based townships face potential groundwater quality problems. The existing and potential problems vary according to the differing land uses in these areas. In urban areas, groundwater pollution problems may result from tanks used for storing petroleum products and industrial and agricultural chemicals, from industrial and solid waste disposal sites, and from municipal sewers. In rural residential areas, failing private sewage systems may pollute groundwater and cause health problems. In agricultural areas, fertilizer and pesticide storage and application, manure storage pits, land disposal of waste, and abandoned or improperly constructed wells may contribute to groundwater pollution.

Inventory of Potential Sources of Pollution

Introduction

The inventory of potential pollution sources is an essential step in developing local groundwater protection programs, and the process can be tailored to the specific needs and resources of individual counties. Ideally, information on the location, type, volume, etc. for all potential sources of pollution should be available. In reality, varying levels of data are available for different sources. For example, information on animal feedlots or chemical storage tanks can be gathered, but it may require more effort and time than for other categories of sources. Local government may stage data-gathering for the inventory to reflect local perceptions of problems and priorities. Thus, the inventory might focus on only a few potential sources initially, with the possibility of updating, expanding, or adding more detail at a later time.

During the inventory in Rock County we found that agricultural data (number and location of animal herds, crop rotation practices, fertilizer and pesticide application practices, irrigation scheduling, etc.) are not easily obtainable in the form needed to evaluate the impact of agriculture on groundwater. A better system of agricultural data-gathering is needed at both state and county levels.

In this study we did not attempt an exhaustive inventory of all possible human activities that may affect groundwater in Rock County. Table 1 includes potential groundwater pollution sources commonly found in Rock County and considered to have the most significant impact. These sources are arranged according to their place of origin relative to the land surface because the system used in this report to evaluate groundwater vulnerability differentiates between the effects of pollution sources located on the surface and the effects of those located below the surface. The soil provides the first layer of defense against pollution sources on the land surface. Therefore, soil attenuation capacity (see plate 1) is used to evaluate the impact of pollution sources at or near the land surface. The potential impacts of sources below the land surface require an evaluation of subsurface vulnerability to pollution (see plate 2).

Potential pollution sources are not discussed in the order of their importance or significance, but are grouped into four general categories: waste disposal, agricultural activities, materials storage and handling, and other activities. About one half of the potential pollution sources in Rock County are waste-related; the other half are related to non-waste activities (table 1). The results of the inventory of pollution sources conducted for this study in 1984 are presented in summary form and include for each source: a statement of the problem, a list of pollutants produced, a description of the source, and an estimate of the relative significance of the source. For further details, contact the Rock County Health Department, Division of Environmental Health, in Janesville, where all the original findings and location maps are filed.

Land Disposal of Solid Waste

Solid waste disposal is an important potential groundwater pollution source. Continuous or intermittent contact between refuse and water produces an undesirable liquid called leachate. Landfill leachate is defined as a grossly polluted liquid characterized by high concentrations of dissolved chemicals, high chemical and

Table 1. Activities which may create groundwater quality problems in Rock County

POTENTIAL POLLUTION SOURCES	WASTE-RELATED				NON-WASTE			
PLACE OF ORIGIN	Municipal	Industrial	Agricultural	Other	Municipal	Industrial	Agricultural	Other
At or near the land surface	-- Sludge disposal(N) --		Feedlots(P) Manure storage(P) & spreading(N)	Septage disposal(N) Junkyards(P)	Salt piles(P)	-Above and on the ground storage of chemicals(P)- Stockpiles(P) Spills(P)	Irrigation(N) Fertilizing(N) Pesticides(N Silage(P)	Highway deicing(L) Lawn fertilizing(N)
Below the land surface	-- Landfills(P) -- Wastewater impoundments(P) Seepage cells(P) Sanitary sewers(L)		Manure pits(P)	Septic systems(P)		Underground tanks(P) Pipelines(L)		Improperly constructed & abandoned wells(P) Overpumping (induced pollution)(P)

Note: P-point source; N-nonpoint source; L-line source biological oxygen demand, and hardness. Leachate composition is extremely variable, and a function of the composition of refuse and the volume of water. It may also contain substances leached out from hazardous materials illegally discarded at the sites. The threat to groundwater from waste disposal sites depends on the nature of leachate, the availability of moisture in contact with refuse, the type of soil through which the leachate passes, and the hydrogeology of the site. Because Rock County lies in a humid climatic zone, most waste disposal sites will eventually produce leachate. Disposal site success depends on how leachate production and movement is prevented or minimized (either by engineering design or by locating the site in a more protective environment).

In 1984, Rock County had 10 active landfills (table 2). Some of the active sites were converted from old dumps; some are new, designed according to DNR criteria. New disposal sites now must be lined and equipped with a leachate collection system that channels the leachate and runoff from the site into an impermeable holding area that does not allow infiltration. Currently, there is one such site in the county.

Rock County also has many abandoned solid waste sites that were run as open dumps before that practice ceased in the early 1970s. During an inventory conducted by Rock County in 1969 (Rock Co. 1970), 123 old solid waste disposal sites were documented (fig. 8). All of these sites may have the potential to degrade groundwater quality in their vicinities because they predate state rules regulating the siting, design, and operation of landfill sites. Not much is known about the physical characteristics of the sites and the nature of wastes deposited in them. Therefore, in 1984, DNR began a statewide inventory of solid waste disposal sites (Bakken and Giesfeldt 1985). To date, 45 abandoned landfills in Rock County have been identified. The second stage of DNR inventory is to inspect and evaluate selected abandoned sites. This will help to identify sites that are polluting the environment and to evaluate the seriousness of identified problems.

The groundwater pollution potential of old landfills varies widely, depending upon what was placed in the landfill. Sites containing only domestic waste and very small amounts of chemicals are a lower risk than those containing large amounts of chemicals. In addition, sites without leachate collection systems, from which all leachate infiltrates to the groundwater, pose a greater risk to groundwater--unless infiltration is inhibited by a natural protective clay layer.

Junkyards

Until 1981 junkyards were licensed by the DNR as part of the solid and hazardous waste program. Junkyards handle hazardous materials from various automotive parts and accessories--including grease, oil, solvents, and battery acids. Well-operated junkyards handling these substances properly minimize groundwater pollution problems. DNR's authority to license junkyards was removed by the Wisconsin Legislature in May 1981, but it continues to regulate hazardous materials at junkyards under the Hazardous Substance Spill Law (sec. 144.76, Wis. Statutes). There are 52 junkyard sites scattered throughout Rock County (see fig. 8), including those closed and currently in operation.

Wastewater Impoundments and Seepage Cells

The disposal of municipal or industrial liquid wastes is not a major source of pollution in the county. Most communities collect both municipal and industrial wastes and treat them in sewage treatment plants before releasing the effluent to streams. Only a few communities and industries use lagoons or basins for disposal of liquid wastes (see fig. 11). Data from the Wisconsin Pollutant Discharge Elimination System

Table 2. Active landfills in Rock County in 1984*
(source: DNR)

Facility Name	License Number	Location** T.	R.	Sec.	¼Sec.	Capacity (1,000 yd^3)
City of Evansville	2874	04	10	16	SE/SE	< 50
Town of Union	2463	04	10	16	SE/SE	< 50
Town of Porter	20	04	11	27	SW/NW	< 50
Edgerton Sand & Gravel Co.	347	04	12	10	SW/NE	> 500
Town of Milton	598	04	13	33	NE/NW	50 - 500
Towns of Magnolia & Center	2003	03	10	12	SW/SE	< 50
City of Janesville	2822	03	12	24	SE	> 500
Town of Plymouth	797	02	11	15	NE/SE	< 50
Wis. Power & Light-Rock River	728	01	12	01	NE/NW	50 - 500
Town of Turtle	1980	01	13	03	NE/NW	50 - 500

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* For current status of landfills, please inquire at DNR.
** Shown on figure 8.

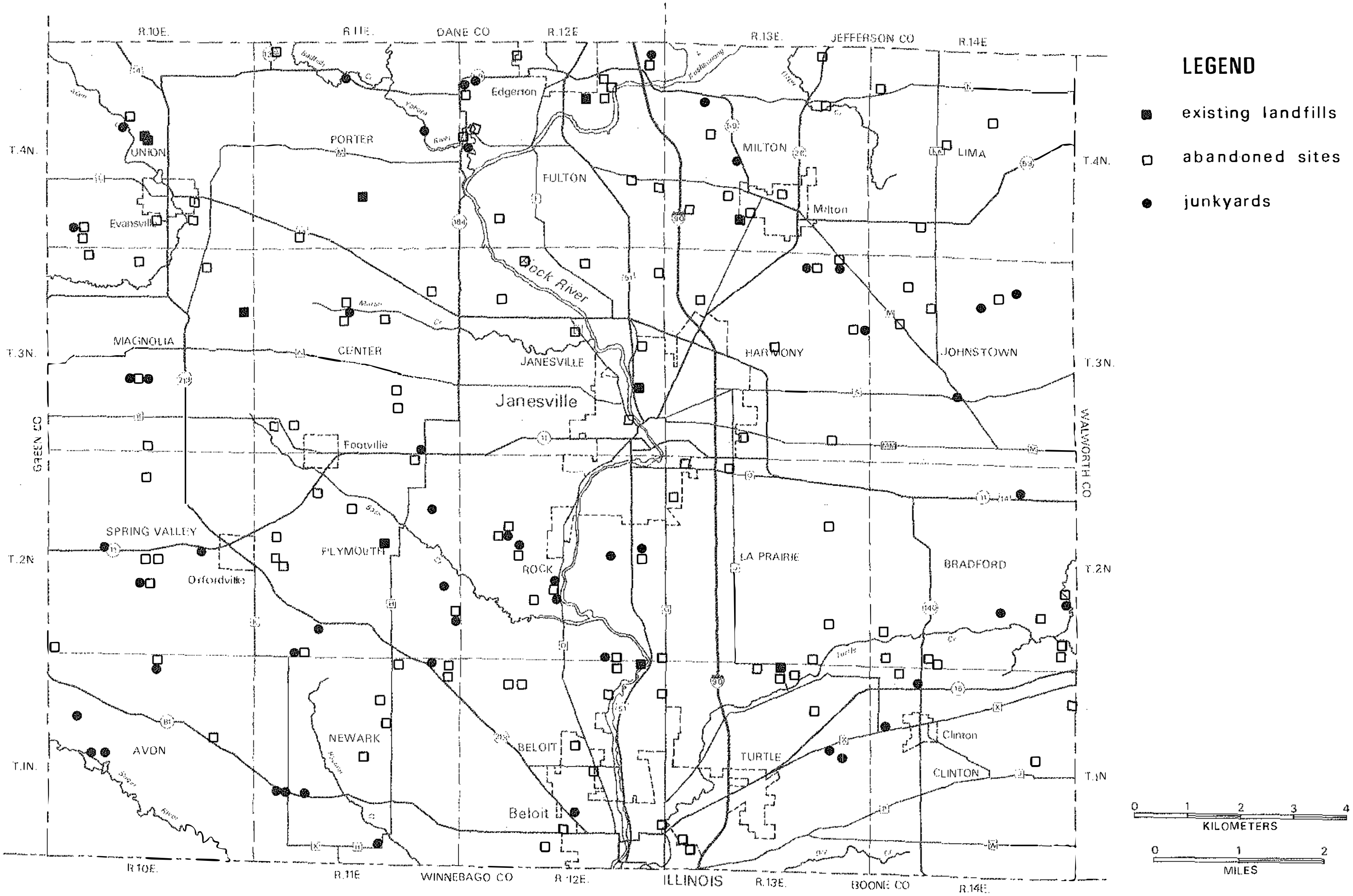


Figure 8. Solid waste disposal sites in Rock County (source: Rock Co. 1970, Bakken and Giesfeldt, 1985)

(WPDES) program show that use of lagoons or ponds is generally limited to low-hazard wastes, specifically wastewater (table 3). Low-hazard wastes from municipalities may introduce BOD, nitrate, and some other pollutants into the groundwater.

Some sewage treatment plants first use treatment lagoons for oxidation and settling, then seepage cells (absorption ponds), which allow the treated wastewater to filter into the ground. If properly sited, operated, and maintained, these seepage cells should cause no groundwater pollution. However, sometimes nitrate, ammonia, sulfate, and heavy metals from the seepage cells can reach the groundwater in significant concentrations. The retention time in the seepage lagoons is usually sufficient to ensure very low levels of bacteria and viruses. However, there is a concern that municipal sewage may contain industrial and household chemicals which are not removed in the lagoons.

Rock County has two municipal sewage treatment plants (Evansville and Milton) that use seepage cells for effluent disposal (table 3). Both treatment plants are required to monitor groundwater to evaluate the impact of the seepage cells on its quality. The DNR is also conducting a special study at Evansville to determine the impact of the seepage cells.

Sanitary Sewers

Many miles of sanitary sewers are located in cities, villages, and sanitary districts throughout Rock County (fig. 9). Infiltration of groundwater into sewers has been the subject of much investigation because the excess flow can overload the sewage treatment plant. On the other hand, little attention has been paid to exfiltration, the leakage of sewage into the ground, because the resulting loss of flow is frequently ignored or considered an asset by the treatment plant operator. From a groundwater pollution standpoint, however, exfiltration can be a problem in some areas. Pollutants of concern are nitrate or other forms of nitrogen, bacteria, and any hazardous materials that may have been introduced into the sewer.

Leaking sanitary sewers are probably not a major source of groundwater pollution in Rock County. More often than not, groundwater leaks into sewers rather than sewage leaking out. Pressure sewers and force mains have a greater potential for leakage than gravity sewers, but they represent a small portion of the total length of sewer line in the county and are usually well maintained and inspected.

Private Wastewater Systems

Private wastewater systems are used to dispose of household wastes. A conventional private wastewater system consists of a septic tank and a soil absorption field. A septic tank is a water-tight tank placed underground. Household wastes are discharged from the house into the tank, where most solids, called sludge, fall to the bottom of the tank where they are partially digested by bacteria. The liquid waste, called septic tank effluent, flows from the septic tank to the soil absorption field where it is purified as it moves through the soil. Only certain types of soils can purify effluent, however. If the soil has many large pores, the effluent can move through the soil very quickly and is not held long enough to be purified. The effluent is also not purified if the soil is not deep enough. Groundwater pollution can then occur as the unpurified effluent enters it.

Pollutants of concern from septic system discharges are nitrate, bacteria, viruses, and hazardous materials. Even in properly functioning septic systems, some nitrate is discharged to the groundwater, and closely spaced septic systems may contribute nitrate in excess of the recommended drinking water standard (10 mg/l of NO_3-N). Serious problems can occur when septic systems are placed in sand-and-gravel deposits with a shallow water table or in areas with creviced bedrock near the surface. In such cases the effluent reaches the groundwater virtually untreated.

Over 13,500 septic systems are located throughout the county. Assuming 500 square feet for each absorption field, the total septic system discharge area in the county is only about 150 acres. If the system is properly installed

Table 3. Disposal of liquid waste in Rock County, 1985
(source: DNR WPDES permit program)

Location*	Owner	Facility	Waste Type
Town of Union (Evansville)	City of Evansville	Absorption ponds	Municipal sewage effluent
Town of Milton (Milton)	City of Milton	Absorption ponds	Municipal sewage effluent
Town of Plymouth (Hanover)	Town of Plymouth Sanitary Dist.	Sewage pond	Domestic sewage effluent
Town of La Prairie (Southeast of Janesville)	Seneca Foods Corp.	Spray irrigation	Screened process wastewater from vegetable processing facility

* Shown on figure 11.

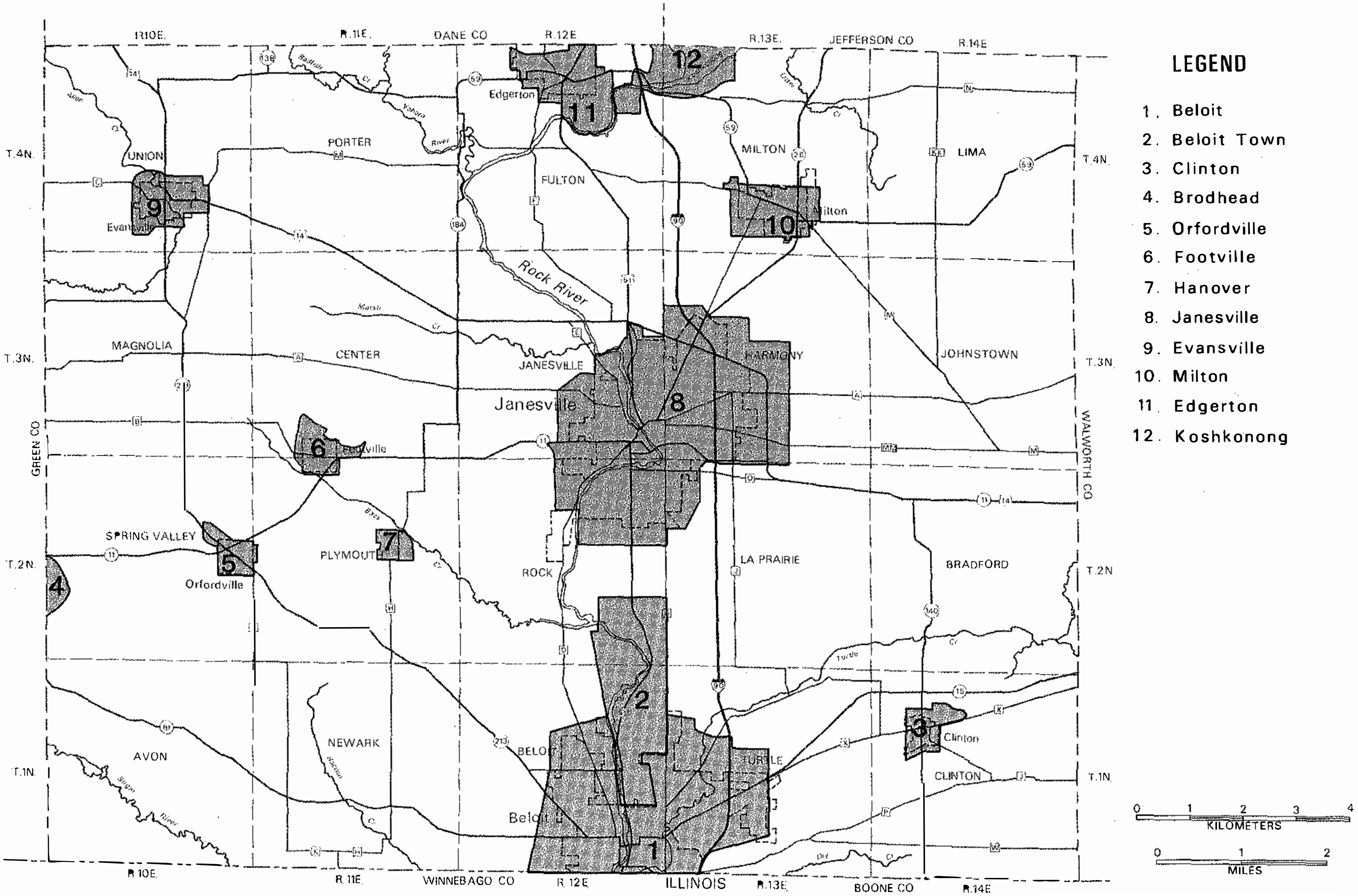


Figure 9. Public sewer service areas of Rock County, 1984 (source: Rock County Planning and Development Department)

in suitable soil and located a sufficient distance from a water supply source, some pollutants are removed or attenuated before they reach the water supply. However, local groundwater pollution may occur in areas of concentrated rural residential development where individual septic systems are densely spaced. The large number of septic systems in areas with limestone at shallow depths has caused significant bacterial groundwater contamination in the west Beloit area (Holman 1984). Figure 10 identifies rural residential development areas with concentrated on-site wastewater disposal systems.

Sludge and Septage Application

Sludge is an organic, non-sterile by-product of treated wastewater. It is composed mostly of water (up to 99 percent of its weight) and organic matter. Both industrial and municipal sludge may contain hazardous chemicals and metals removed by the wastewater treatment process. Metals often found in sludge at variable concentrations include arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. The types and concentrations of metals found in sludge depend upon the source of the wastewater. Most of the metals in sludge come from industrial sources. Other constituents of sludge which may have an impact on the groundwater are nitrogen, chloride, and pathogenic bacteria and viruses.

Pollution of groundwater from land application of municipal sludge depends upon the concentration of pollutants in the sludge, the application rate, the physical and chemical soil properties, the amount of precipitation, and the distance to the water table. Coarse-textured soils, a shallow water table, and high rates of precipitation favor groundwater pollution. Approximately 5,700 acres of land are used for the disposal of municipal sewage sludge in Rock County, most of them in the southern half of the county (fig. 11). Most of the sites are located near cities and villages to minimize the cost of transporting sludge from municipal treatment plants.

Septic tank pumpings, commonly referred to as septage, are a mixture of sludge, fatty materials, and wastewater. They may contain significant amounts of pathogenic organisms, nutrients, solvents, and oxygen-demanding material. Land spreading is the most frequently used septage disposal method. Septage disposal sites were not documented in this study because of the many locations used and the lack of state or local records of septage disposal sites.

The impact of municipal-sludge spreading on groundwater in Rock County is probably minimal because sites are located according to established criteria. If sludge is spread at appropriate rates on good sites (Keeney and Walsh 1975), groundwater pollution is minimized. On the other hand, land disposal of septage is largely uncontrolled and may create groundwater quality problems if septage is dumped illegally in ditches or spread in naturally vulnerable areas.

Animal Feedlots

Feedlots, loosely defined as outdoor areas where animals are concentrated for feeding or other management purposes, are common throughout Rock County. The principal pollutants associated with feedlots are nitrogen, phosphorus, chloride, oxygen-demanding material, and microorganisms. Feedlots may also cause objectionable odor and taste.

A detailed inventory of the county feedlots (location, number, animal type and numbers, etc.) is not available. However, since manure production is the major concern, valuable information can be derived from available livestock and poultry statistics for 1976 through 1984 (table 4) . Dairy cattle and swine are the principal types of livestock in the county. In 1984 24,300 milk cows, 4,000 beef cows, 46,000 hogs, 2,700 sheep, and 11,900 chickens produced manure in Rock County. The number of dairy herds in the county is likely to drop in the next five to ten years, but the total number of milk cows is not likely to decrease significantly. This means livestock would be concentrated into fewer, larger herds (Crowley 1984). The average number of beef cows is expected to remain near 5,000. The numbers of hogs is likely to remain within the range shown for 1982 to 1984. It is not

Table 4. Rock County livestock and poultry inventory, 1976-1984
(source: Wis. Agricultural Reporting Service 1977-1985)

	1976	1977	1978	1979	1980	1981	1982	1983	1984
Milk cows and heifers calved	27,900	27,700	27,600	27,600	27,600	27,600	*25,100	*24,600	*24,300
Beef cows and heifers calved	6,500	5,500	4,400	4,900	5,100	5,400	**4,800	**4,700	**4,000
Hogs	54,500	57,900	67,900	77,700	71,200	58,000	45,000	47,000	46,000
Sheep	5,500	4,400	4,300	4,700	5,700	5,800	5,800	3,800	2,700
Chickens									
Layers	—	—	—	—	35,000	26,700	25,000	11,800	11,900
All chickens	174,000	170,500	146,500	76,000	42,500	—	—	—	—

* Includes dry cows; does not include immature livestock.
** Beef cows only, not calves or feeders.

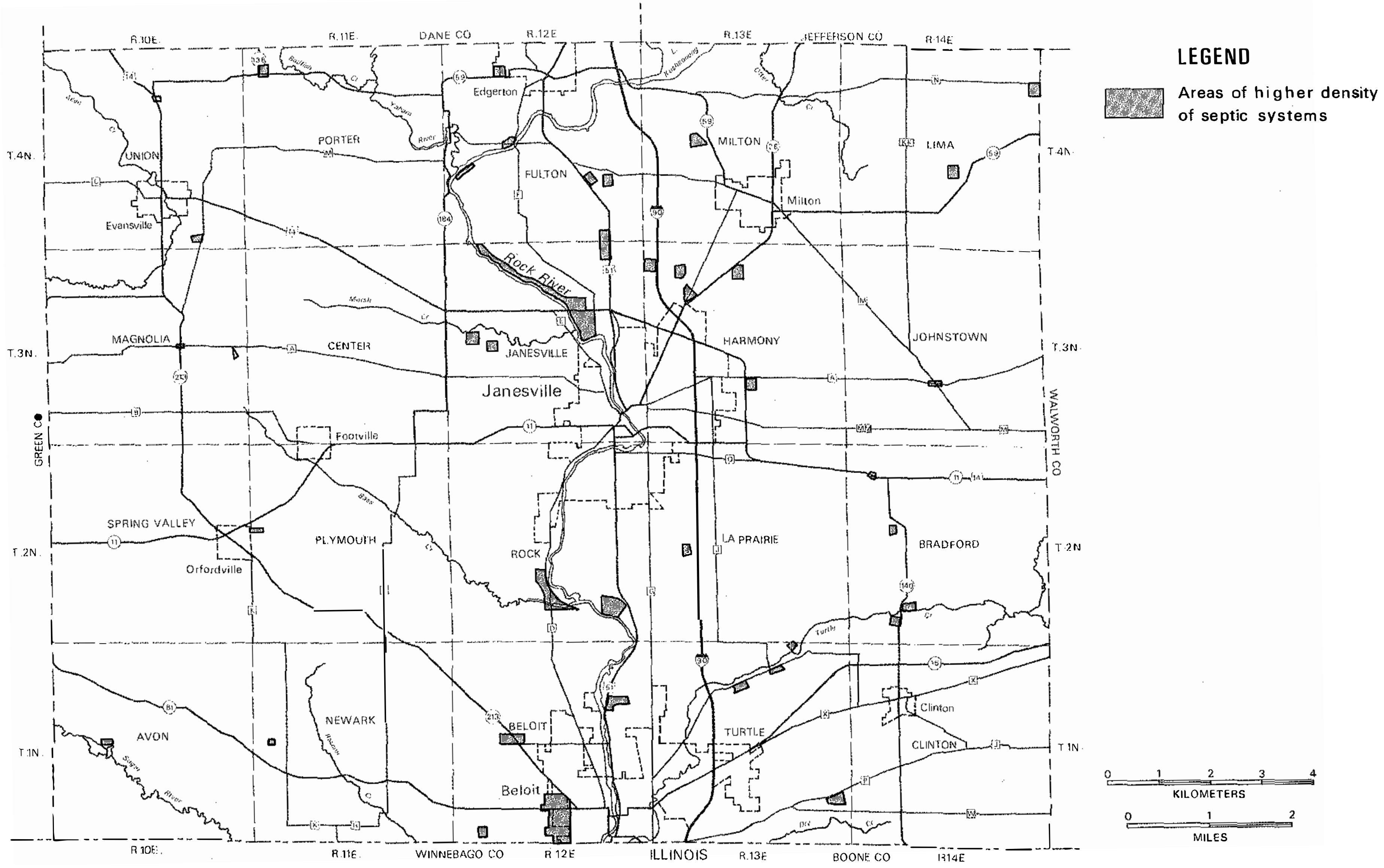


Figure 10. Areas of higher density of septic systems in Rock County (1984 inventory)

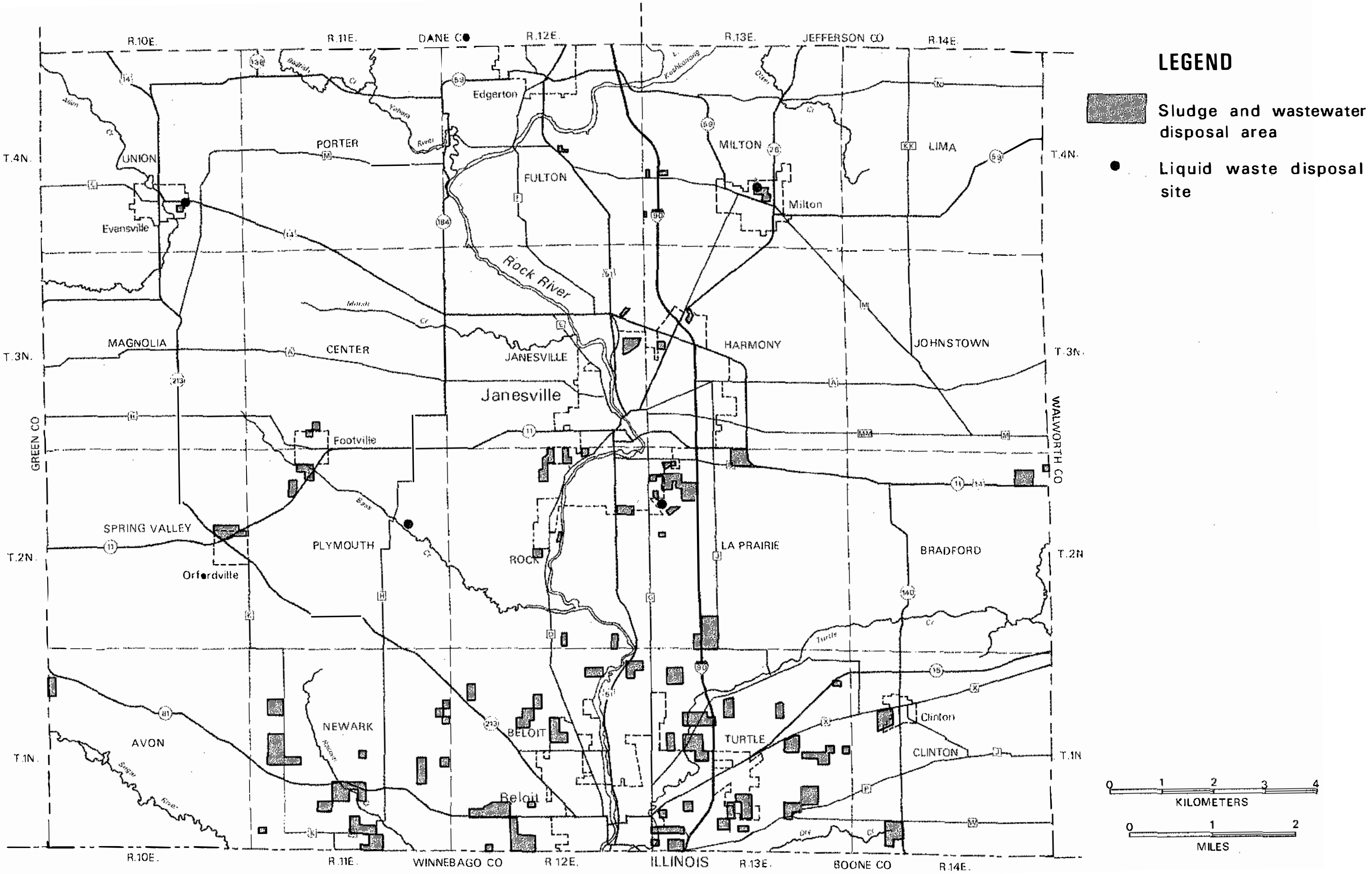


Figure 11. Sludge and wastewater disposal in Rock County (1984 inventory)

anticipated that sheep numbers will increase substantially, and no net growth is expected in the poultry industry.

Using the data for 1983 from table 4, manure production and nitrogen (N), phosphorus (P),and potassium (K) components were estimated. Rock County livestock produced about 32 million ft^3 (or 990,000 tons) of manure in 1983. Amounts of N, P, and K available annually from animal manure were estimated to be 10.4, 2.3, and 7.0 pounds, respectively (Petersen 1984). The relationship between water quality and productive use of manure depends upon the management practices for each feedlot. The potential for groundwater pollution will depend on the volume of waste produced at a given site and the waste handling practices.

Livestock Waste Storage

Livestock waste produced, stored, and disposed of on dairy, beef, hog, sheep, and poultry farms are potential sources of groundwater pollution. The primary pollutants are nitrate, chloride, and bacteria. High levels of livestock waste pollution may also cause discoloration, odor, and taste problems in drinking water supplies, and in extreme cases, bacterial contamination.

A detailed inventory of livestock waste storage facilities in Rock County could not be obtained at the time of this study, but estimates are that there are currently 20-40 sealed, aboveground waste storage facilities; 15-25 earthen pits (Bobolz 1984); and 20-30 underground, concrete-lined storage facilities (Nehring 1984).

In general, properly designed, located, and managed livestock waste storage facilities have little potential for causing significant groundwater pollution. However, improperly designed and located or poorly managed facilities can cause significant problems. In wet or snowy weather, farmers who normally spread their manure daily may store manure in temporary stacks in fields or near the farmstead. Rock County has had one complaint of a large spill from an aboveground manure storage tank; however, there is no indication that it polluted the groundwater. The Rock County Health Department has closed one earthen manure pit that was excavated in dolomite rock and polluted a well. Following the closure of the pit, which was not properly designed and located, pollution of the well stopped.

Land Spreading of Livestock Waste

Careless practices such as these can permit land-spread livestock waste to pollute groundwater: 1) spreading livestock waste at rates that exceed crop nitrogen needs, 2) not crediting nitrogen from livestock waste when calculating crop fertility needs, or 3) locating water wells where surface runoff can transport wastes to the well (polluted runoff may infiltrate along the well casing if it is not properly grouted).

Livestock wastes are spread on about 40,000 acres of cropland in Rock County (Petersen 1984). They are generally applied at rates that meet crop nitrogen requirements and have little potential for causing groundwater pollution problems.

Fertilizer Application

The overapplication of nitrogen-based fertilizers to agricultural land usually results in a portion of the fertilizer leaching through the soil. Nitrate is highly soluble in water and is not appreciably attracted to soil particles. This excess nitrogen does not contribute to crop yield and may lead to groundwater pollution.

Commercial fertilizers include a variety of types and concentrations of nitrogen, phosphorus, potassium, and trace elements, most of which are intended to improve plant growth and market value. While both nitrogen and phosphorus may contribute to eutrophication of surface waters, the nitrogen component of fertilizer has generated the most concern about groundwater. The drinking water quality standard of 10 mg/l of nitrate-nitrogen (NO_3-N) is commonly exceeded in shallow rural domestic wells in the county (Wis. DNR 1980). Deeper wells are less likely to show high NO_3-N concentrations (Zaporozec 1982).

Commercial fertilizers are used on nearly all of the more than 300,000 acres of cropland in Rock County (U.S. Bureau of Census 1982), as well as on gardens, lawns, and other urban lands. No inventory of areal fertilizer use, application rates, or formulations is available for the county.

Storage, transportation, and use of nitrogen fertilizers in Rock County presents a high potential for raising the concentration of NO_3-N in groundwater above background levels.

Pesticide Application

Pesticides are widely used in the county for insect and weed control in corn and soybean production, but no data suggest their widespread presence in groundwater at this time. Potential problems seem not to be in the application of pesticide but rather in its storage, handling, and transport. If applied properly, most approved pesticides are generally taken up by plants or broken down to harmless substances by soil organisms, sunlight, or chemical reactions and usually do not pose a threat to groundwater. The greatest potential for pollution exists in irrigated sandy soils or thin soils over creviced bedrock. Sandy soils have rapid infiltration rates, and the pesticide does not have enough time to break down before reaching the groundwater. Pesticides attached to sediments may infiltrate the open, connected joints in dolomites and add to groundwater pollution. In 1982, the Rock County Division of Environmental Health (DEH), in cooperation with the UW-Stevens Point, sampled and tested selected surface water points, springs, and drinking water wells (see fig. 1). No pesticide residues were detected. Because of the extensive use of pesticides, we recommend continued monitoring.

The pollutants that may result from pesticide application are the pesticides themselves or their breakdown products. Pesticides include a wide array of chemical types but generally fall into three broad categories: chlorinated hydrocarbons, organo-phosphates, and carbamate pesticides, the last being the most water-soluble. The pesticides most commonly used in Rock County are listed in table 5.

Table 5. Pesticides most commonly used in Rock County (from: Zaporozec 1982, p. 75)

Insecticides	Herbicides
Counter (terbufos)	Amiben (chloramben)
diazinon	atrazine
Dyfonate (fonofos)	Banvel (dicamba)
Furadan (carbofuran)	Basagran (bentazon)
Imidan (phosmet)	Bladex (cyanazide)
Lorsban (chlorpyrifos)	Dual (metolachlor)
malathion	Eradicane (EPTC + safener)
Mocap (ethoprop)	Lasso (alachlor)
Sevin (carbaryl)	Lasso + Lorox (linuron)
Thimet (phorate)	Princep (simazine)
	Sencor or Lexone (metribuzin)
	Surflan + Sencor or Lexone
	Sutan$^+$ (butylate + safener)
	2,4-D amine or ester

Note: The chemicals are listed under commercial names (starting with a capital letter) when applicable. Their common names start with a lower case letter.

Pesticides may potentially be used on every acre of open land in Rock County, especially on agricultural land. Pesticides are also used on urban lawns and gardens, roadside ditches, power line right-of-ways, for wood preservation, and in some cases in woodlots where major pest problems occur.

Pesticide pollution of groundwater is not a documented problem in Rock County at this time. Proper management of pesticides is necessary to avoid groundwater pollution now and in the future, especially during handling, storage, and transport of pesticides. A guide produced by Farmland Industries (1982) gives soil persistence of various agricultural chemicals at common use rates.

Irrigation

Irrigation can contribute to groundwater pollution in two ways. First, irrigated water may carry through the soil into the groundwater potential pollutants (fertilizers and pesticides) that are applied to fields. Second, the malfunction or lack of back-siphoning valves may permit back flow to the well of chemicals applied through the irrigation system. To date there has been no evidence of agricultural irrigation causing groundwater pollution in Rock County, but intensive monitoring has not been conducted.

According to DNR irrigation-well permit records, there are about 86 irrigation wells in Rock County (see fig. 3). The majority are located between Beloit and Janesville in outwash material, but irrigation wells are also located on less permeable soils throughout Rock County. Irrigation wells are used mostly to irrigate cash crops including corn, soybeans, sweet corn, and peas (these crops require frequent application of fertilizers and pesticides). Irrigated acreage grew from about 100 acres on 5 farms in 1964 to more than 8,000 acres on 44 farms in 1978, and in 1982 dropped to a little over 7,000 acres (U.S. Bureau of Census 1982).

Materials Storage

Many solids and liquids are placed on the ground for temporary storage. Examples are stockpiles of raw materials, chemicals, products, and waste at industrial sites; piles of raw materials awaiting use and waste placed for temporary storage at construction sites; stockpiles of chemicals, manure, agricultural products, and half-empty containers in agricultural areas; and stockpiles of salt for road deicing. Some materials are kept in the open, and some are kept in enclosures. Many of these materials are hazardous and even toxic. If the stored material or waste contains water-soluble products, they will leach out when exposed to rain and infiltrate into the ground, which may lead to groundwater pollution.

Aboveground tanks are used in Rock County for storage of various chemicals for industrial, commercial, and agricultural uses. For convenience, the inventory and problem analysis of aboveground tanks is presented together with that of underground storage tanks in the following section.

Chemical Storage Tanks

Storage and transmission of a wide variety of fuels and chemicals is inherent in many industrial, commercial, and individual activities. Petroleum and petroleum products are the most common potential pollutants. Throughout Wisconsin, underground gasoline and oil storage tanks installed during the 1950s and early 1960s have now reached or exceeded their expected 20-to-30-year life span. Some have begun to leak and pollute the groundwater because they were not required to be constructed of corrosion-resistant materials. Leaks in buried tanks and pipelines at industrial facilities are a particular problem because they may go unnoticed for some time. Gasoline, being less dense than water, generally floats on the groundwater surface and may penetrate into basements, sewers, wells, and springs, rendering drinking water unsafe and causing explosion and fire hazards.

Rock County has at least 690 chemical storage tanks exceeding 500 gallons in capacity (fig. 12). There are 424 known underground tanks and 266 aboveground tanks. The number of aboveground and underground tanks, by size, is shown in figure 13a. Most tanks store petroleum products and fertilizers (fig. 13b), but some large storage tanks contain industrial chemicals and pesticides. Petroleum products are stored in both aboveground and underground tanks, but only aboveground tanks are used to store fertilizers and industrial chemicals. Most of the pesticides are also stored aboveground; only one underground tank in the county is used to store pesticides.

The large volume and high concentration of hazardous materials that can be released from a storage tank in a small area creates a very high on-site pollution risk. Presently, there are few controls or regulations for preventing groundwater pollution from chemical tanks. Chemical tanks are usually not inspected for corrosion damage, inside or outside. Leaks are not usually detected until a large amount of chemical has been released. The

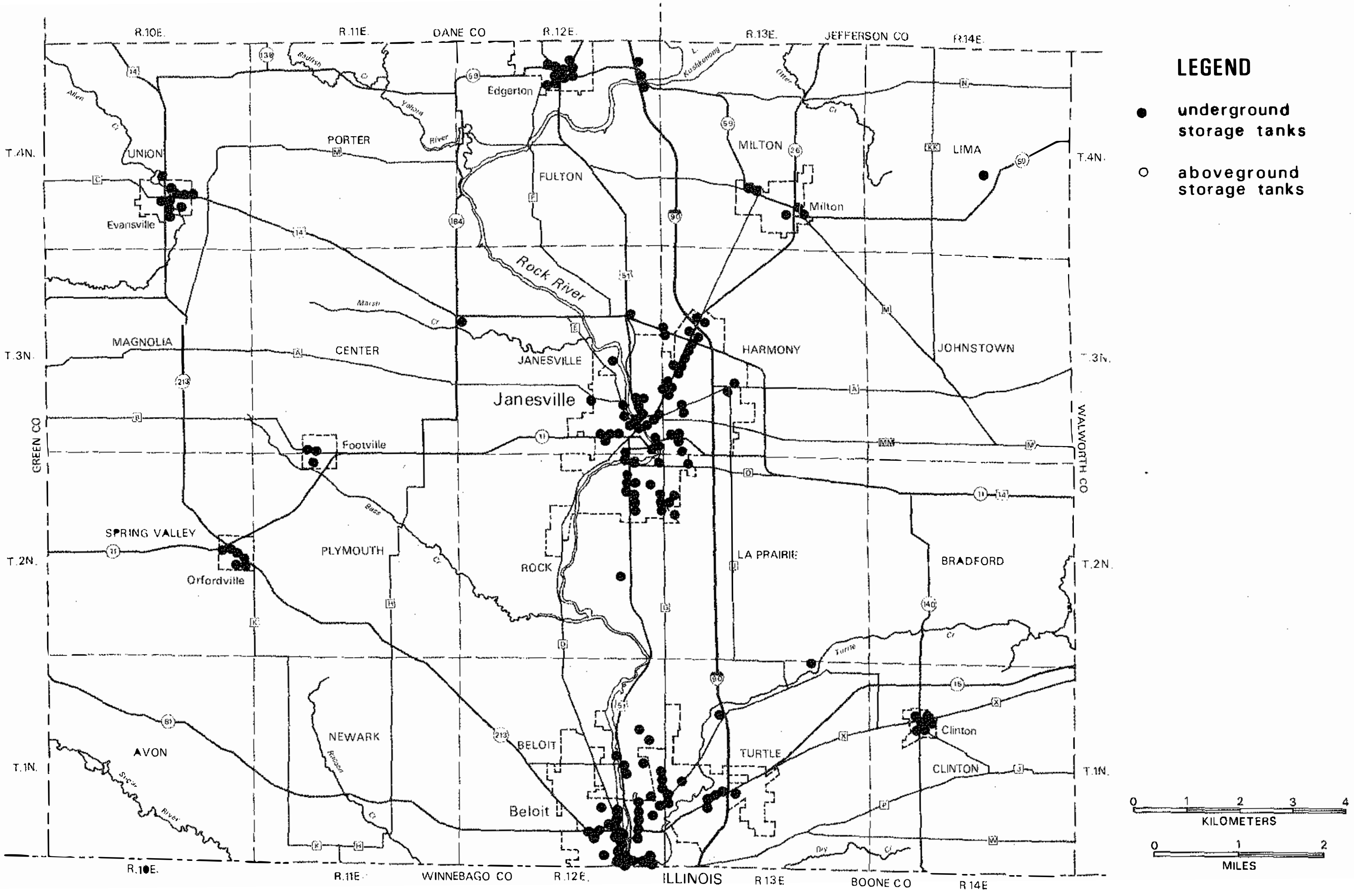


Figure 12. Storage tanks of hazardous materials in Rock County (capacity 500 gallons or more; 1984 inventory)

majority of the chemical tanks are in urban areas on main roads within the municipalities and, as a result, relatively close to public water supply wells.

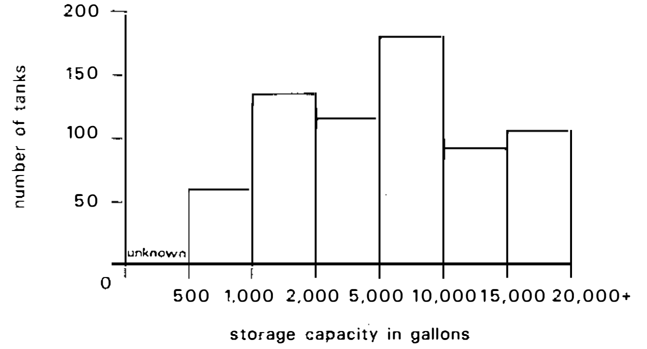


Figure 13a. Number of storage tanks in Rock County, by size (1984 inventory)

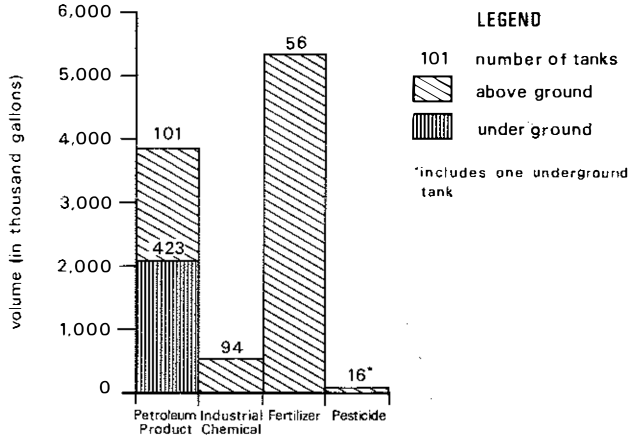


Figure 13b. Volume and number of storage tanks in Rock County, by product (1984 inventory)

Transmission Pipelines

Leaks in petroleum-product transmission lines are also a potential source of groundwater pollution. Rock County has several hundred miles of underground transmission pipelines (fig. 14). All except 3½ miles of pipeline carry natural gas or propane gas. The 3½-mile pipeline in Lima Township carries crude oil from Superior, Wisconsin to Illinois.

Transmission pipelines are not a significant source of groundwater pollution in Rock County. All but 3½ miles of the pipeline carry gas products, which in the case of a spill or leakage would vaporize, rather than infiltrate into the ground.

Spills of Hazardous Materials

More than 400 accidental or intentional spills of hazardous materials are reported in Wisconsin every year--more than 1 per day. An undetermined number of additional spills and illegal dumpings go unreported. Petroleum products are the pollutants by far most commonly involved in spills. Spills can occur anywhere at any time; on site or off site, on highways, runways, waterways or railroads. Fortunately, many spills are small and can be cleaned up quickly before much of the substance reaches the groundwater. Unfortunately, in many cases the first people on the scene of a hazardous spill are not trained to deal with it properly.

A total of 77 spills in Rock County have been recorded by the DNR and the Rock County Health Department since 1968 (fig. 15). These incidents consisted of 37 petroleum product spills, 12 pesticide spills, and 28 other chemical spills. The volume of petroleum spills ranged from 5 gallons to 18,000 gallons. Pesticide spills ranged from 30 gallons to 500 gallons, and were mostly in a diluted mixture used for pesticide application. The size of fertilizer spills ranged from 50 gallons to 2,900 gallons. Spills of other chemicals were mostly related to industry and chemical manufacture. The locations of spills are scattered throughout Rock County, but most occurred along highways and within urban areas near chemical storage tanks (fig. 15).

The number of hazardous spills indicates that the existing preventive controls are not working to the degree necessary to protect groundwater. There is a high risk to adjacent wells for groundwater pollution if spills are not adequately cleaned up. If a spill is not cleaned up immediately and reaches the groundwater, the cost of remedial action (if available) can be very high. Because of the lack of remedial technology, some spills cannot be cleaned up. Better management of all facilities and equipment used for storage of hazardous materials, careful transport of these materials, and immediate handling of spills by trained individuals can help minimize the risk of polluting groundwater.

Storage and Use of Salt for Road Deicing

Salt storage, road salting, and snow dumping are all commonly used in Rock County to deice roads and improve winter driving conditions. These activities may result in high salt concentrations in both ground and surface water. Of these activities, salt storage in uncovered piles appears to be the most critical with respect to groundwater pollution. Rainfall can dissolve the salt, which may then seep into shallow aquifers. High salt concentrations can pose a health concern to anyone restricted to a low sodium diet.

Rock County currently has 12 covered salt storage piles, 10 uncovered salt-sand mixture storage piles, and 10 known snow dumping sites (fig. 16), most located in urban areas. There are more than 1,250 miles of highway in the rural areas of Rock County where salt can be washed to adjacent lands and infiltrate to the groundwater. In developed areas, much of this runoff is collected and discharged to surface water.

Highway deicing as a potential source of groundwater pollution in rural areas is less important than other sources. Salt storage sites should be designed to reduce surface water runoff and minimize infiltration of salt to the groundwater. Providing shelters and barns helps prevent groundwater pollution.

Abandoned and Improperly Constructed Wells

Water wells, under certain conditions, can be conduits for groundwater pollution. Typical examples are wells with casing that has been corroded or ruptured, or wells in

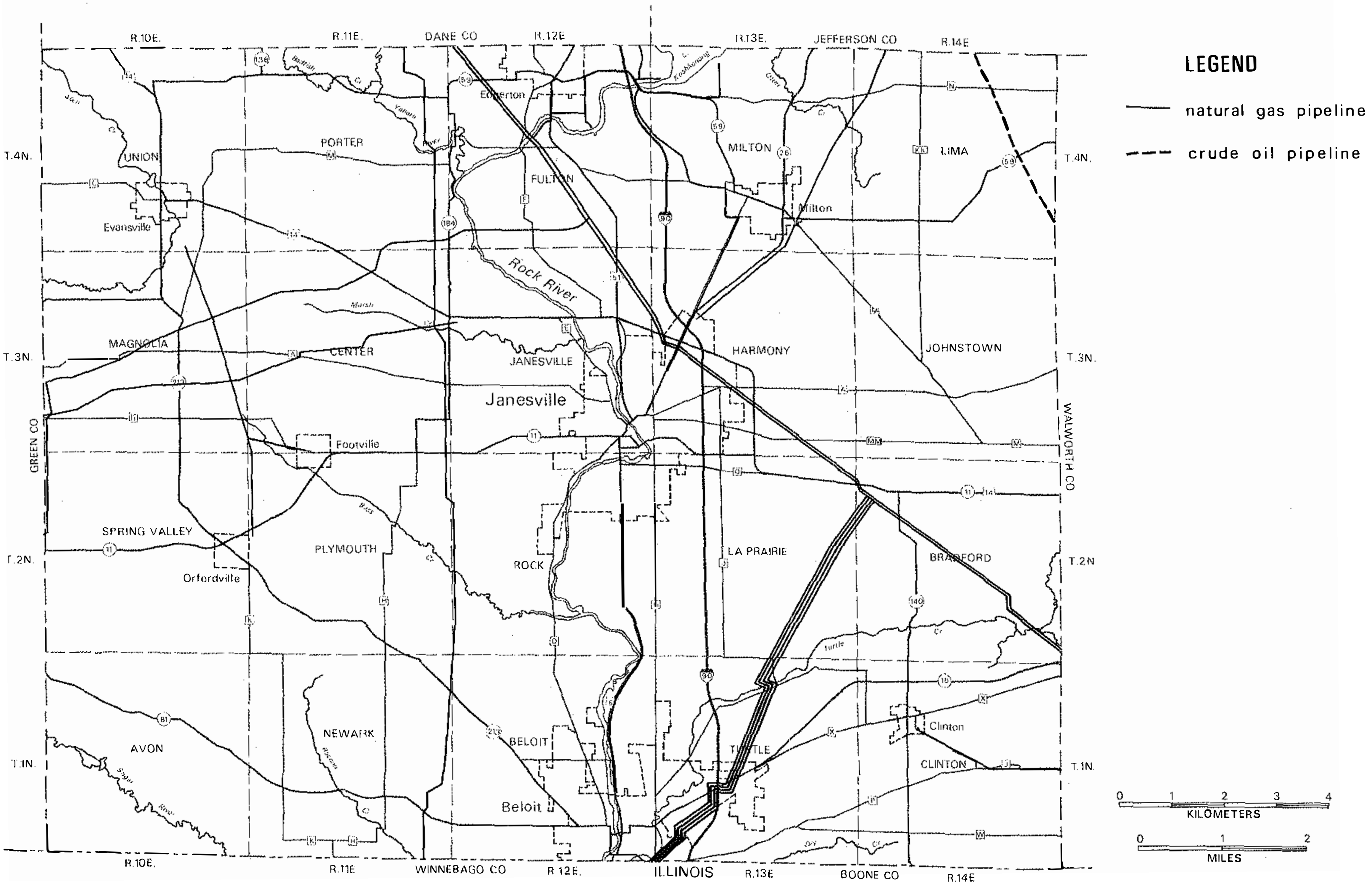


Figure 14. Long-distance pipelines in Rock County (1984 inventory)

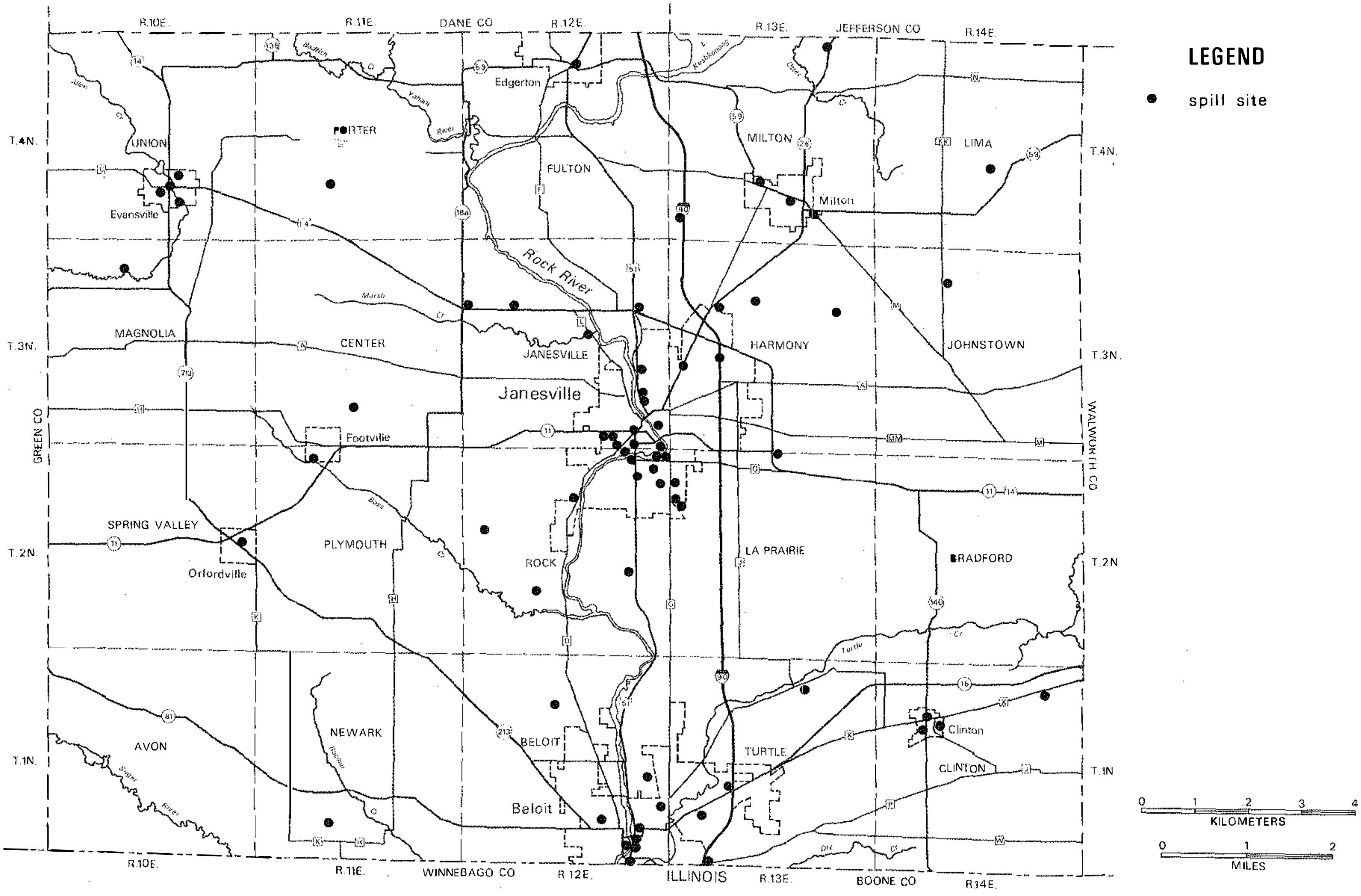


Figure 15. Recorded spills of hazardous materials in Rock County, 1968-1984 (1984 inventory)

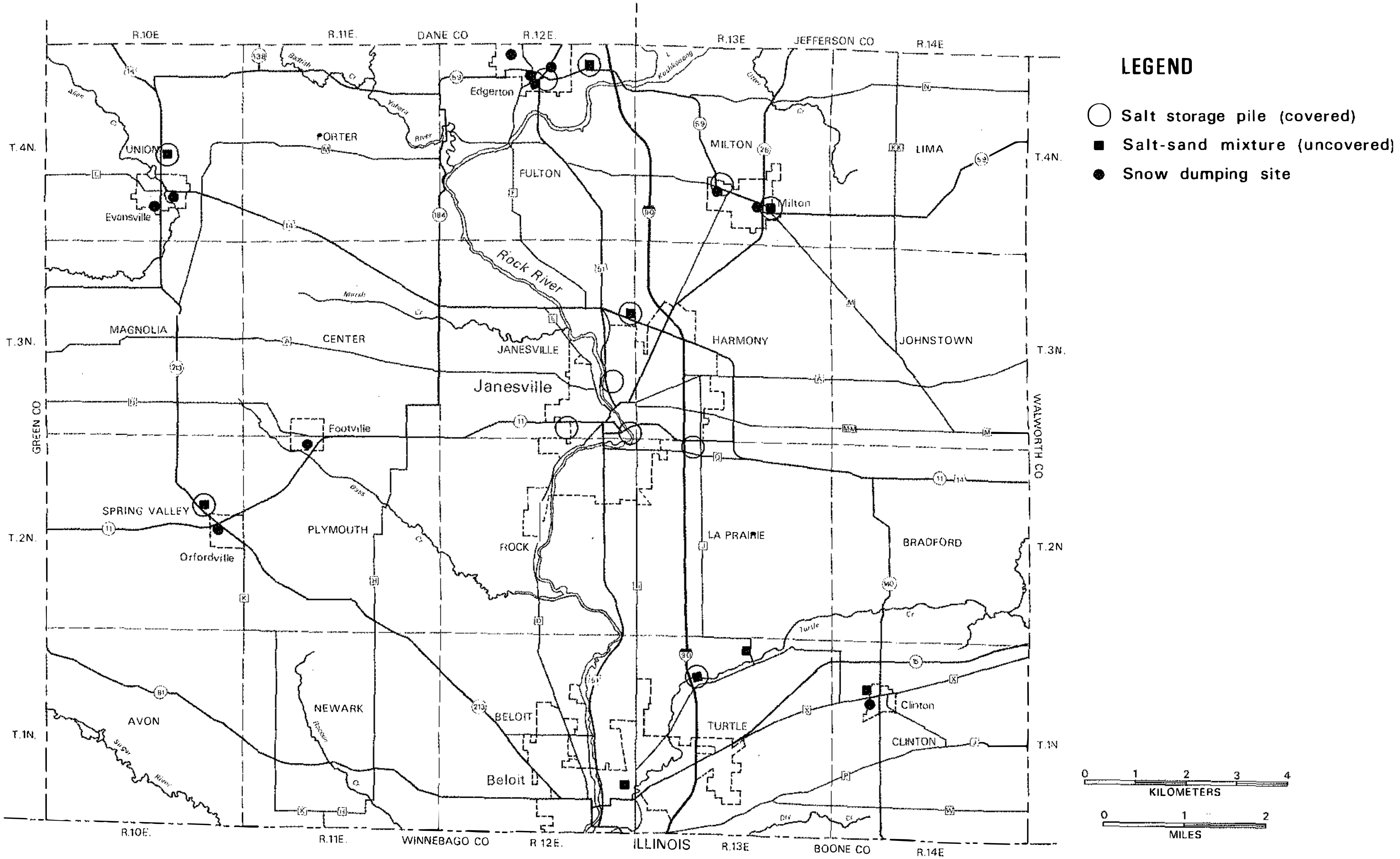


Figure 16. Salt piles and snow dumping sites in Rock County (1984 inventory)

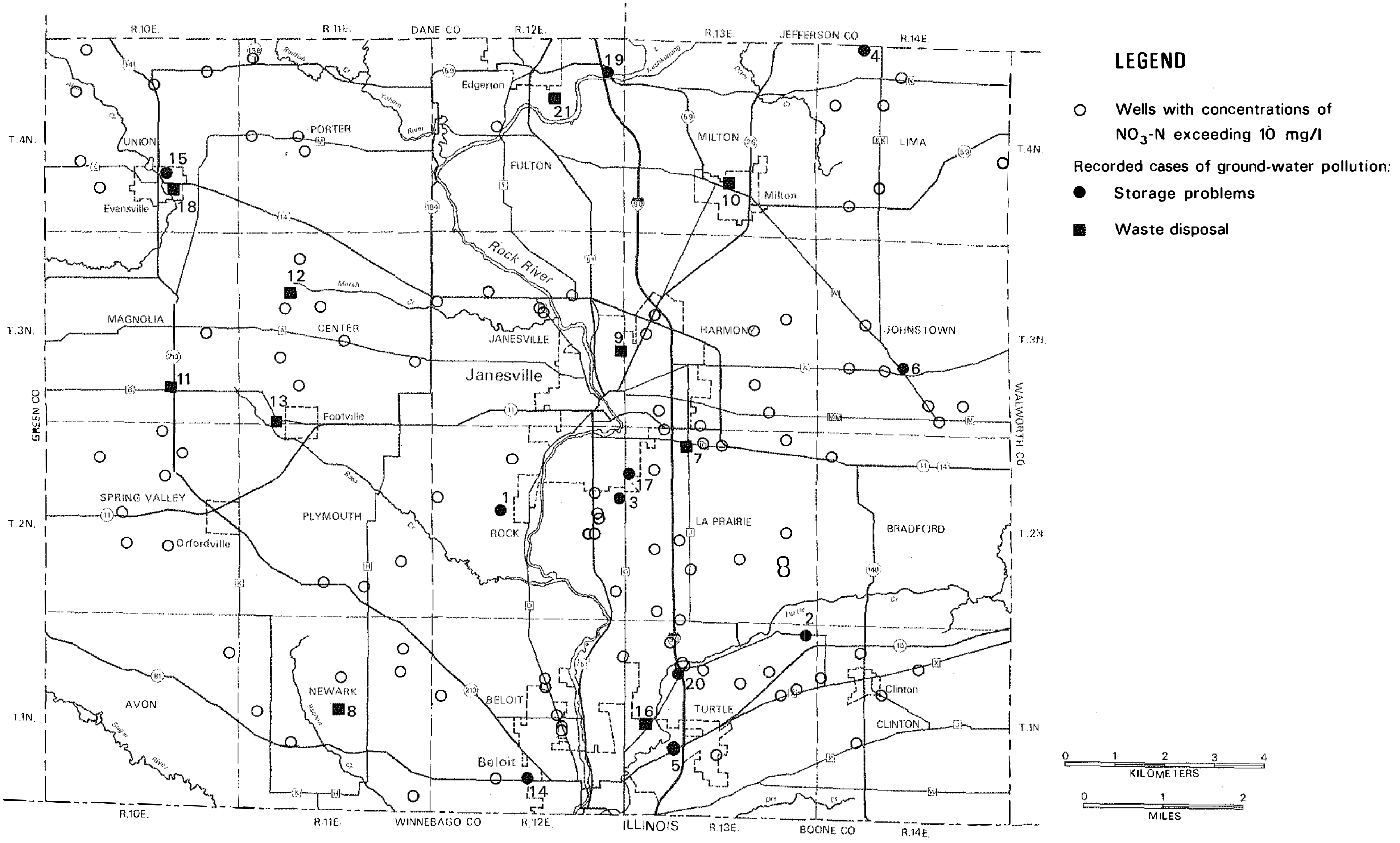


Figure 17. Recorded incidents of groundwater pollution in Rock County (source: Calabresa 1981, Holman 1984, Zaporozec 1982)

which the surface casing has not been adequately sealed to prevent drainage of pollutants from the land surface to the well. Unplugged abandoned wells also pose a major threat to groundwater because they permit water containing pollutants to migrate freely from one aquifer to another or from the land surface to an aquifer.

Wisconsin's well code (chap. NR 112, Wis. Adm. Code) governs well construction and plugging of abandoned wells and prohibits the use of any well for disposal of waste and sewage, or for surface drainage. However, the code does not require well drillers to report the drilling of a new well to replace a polluted well. This requirement, which would help keep track of potential groundwater pollution problems, is under consideration for inclusion in the revised well code.

There have been few cases of polluted wells reported in Rock County. The number of polluted wells, their locations, and the types of pollutants involved are described in the next section.

Recent Groundwater Problems

Twenty-one groundwater pollution cases (fig. 17) have been documented by the DNR (Calabresa 1981) and by the Rock County DEH (Holman 1984). All cases were related either to waste disposal activities (numbers 3 to 8 and 13 to 15) or to storage problems (numbers 9 to 13, 16, 18, and 21). The most often reported pollutant was gasoline near underground storage tanks (numbers 2 to 5, 19, and 20). Other pollutants included bacteria and landfill leachate (3 occurrences each), silage juice and pesticides (2 occurrences each), inorganic chemicals from municipal sewage, nitrate from a manure pit, heavy metals, paint solvents, and volatile organic compounds (1 occurrence each). Documentation of these pollution cases is on file at the Rock County DEH.

In most of the documented pollution cases, the extent of pollution is unknown. Except for gasoline pollution in the Morgan Terrace subdivision of the city of Beloit and leachate occurrence around the city of Janesville landfill (for references, see Zaporozec 1982), the incidents were not investigated in detail. However, those cases recorded by the Rock County DEH were inspected in the field. Only one of these incidents prompted remedial action to renovate the subsurface environment. DNR ordered removal of 3 feet of contaminated soil at a chromium plant in Beloit (no. 14 on fig. 17) to reduce the leaching of chromium into groundwater (Holman 1984).

Figure 17 also shows the locations of wells sampled during 1979-1981 that contained more than 10 mg/l of NO_3-N. The 1979-1981 investigation of wells showed that almost 27 percent of the samples (108 samples) exceeded the established maximum drinking water standard of 10 mg/l NO_3-N and that 21 of these contained more than 20 mg/l (Zaporozec 1982). More than one half of the samples (55 percent) contained betweeen 1.0 and 9.9 mg/l, and only 18 percent had less than 1.0 mg/l. The concentrations ranged betweon less than 0.5 and 46 mg/l. The median value for the county was 6.0 mg/l.

Chapter III.

ENVIRONMENTAL ASSESSMENT

Availability of Data

Knowledge of the physical environment is necessary to develop a sound program for managing the county's groundwater and protecting its quality. The physical environment may provide an opportunity for attenuating the entering pollutants; thus properties of soil and rock are important to consider in developing a groundwater protection plan. Current knowledge of the physical environment was adequate for developing a system to evaluate potential threats to groundwater quality in Rock County. The background information in this chapter sets the stage for a close examination of groundwater pollution threats.

This study has relied on already existing data; no new data were collected for the evaluation of the physical environment and its potential to attenuate or restrict pollutants. As a result, the evaluation corresponds to the level of detail of the available data (table 6). The analysis is based on data collected in 1980-81 as part of the groundwater quality study of Rock County (Zaporozec 1982) and on data from previous investigations (Cotter and others 1969, Hindall and Skinner 1973, LeRoux 1963, USDA 1974).

County planners and officials will need better knowledge of the distribution and composition of surficial deposits before rendering site-specific recommendations in a county groundwater protection plan. As table 6 points out, some of the data available at the time of this study are not adequate for a detailed evaluation of the physical environment. Specifically, data on the bedrock and surficial geology used in this study at a scale of 1:100,000 was originally mapped at a scale of 1:1,000,000. Hence interpretations made on the basis of this data must be made with caution, recognizing that information mapped at 1:1,000,000 lends itself for regional investigations rather than detailed county investigations. Rock County may wish to consider conducting geologic mapping at a scale of 1:100,000 in the future in order to make more detailed assessments of the geologic and hydrogeologic characteristics.

Physical Environment and Its Function in Pollution Attenuation

Soils

Soils usually comprise only the upper three to five feet of unconsolidated materials at the earth's surface. They support the growth of plants and trees; are the basis of agricultural production; and provide the foundation for houses, roads, and buildings. They also serve, if properly used, as treatment and recycling facilities for wastes from individual homes, livestock and poultry farms, and municipal and industrial sewage treatment plants.

Soils in Rock County are formed primarily from materials transported by the glaciers that moved across the land many thousands of years ago (till), carried off the ice by meltwaters (outwash), or deposited by the wind, which picked up fine-grained materials washed out from the glacier and redeposited them on the land surface (loess). Some soils are also formed from alluvium and from peat and muck.

Soil characteristics (slope, depth, texture, and permeability) are among the most significant factors determining the rate and extent of groundwater recharge and the degree of natural protection against pollution. The texture of most of the soils in Rock County (silt loams, loams, sandy loams) is medium to moderately coarse, which allows water to move through them easily. Except for the shallow soils in the southwestern part of the county, the soils are moderately deep (25 to 40 in.) or deep (over 40 in.). This enables percolating water to have longer contact time with the soil particles, thus providing better protection against pollutants carried in those waters.

In areas of coarse-textured soils, water moves in and through the soils very quickly, providing rapid recharge of aquifers. However, contact between the soil particles and percolating water is minimal, allowing little attenuation of pollutants. This is particularly significant in permeable soils on irrigated outwash plains. Irrigation water may carry excess amounts of chemicals applied on irrigated fields (fertilizers and pesticides) through the soil very quickly. Once these pollutants pass through the soil layer, which is usually only the surface three to five feet, they move basically unchanged to the groundwater.

Surficial Geology

Underlying the soil are the sediments consisting of Pleistocene glacial and fluvial deposits (till and outwash) and of weathered and disintegrated bedrock material and alluvial deposits of Recent age. Till deposited during the several advances of continental ice sheets (about 10,000 to 30,000 years ago) consists of unsorted and unstratified clay, silt, sand, and gravel, including boulders. Outwash, deposited by meltwater streams beyond active glacier ice (fig. 18), consists largely of sand and gravel with some cobbles, boulders, and silt and is well sorted and stratified.

When the ice disappeared, silt-sized material called loess was deposited by the wind on top of the till and outwash, usually to depths of one to three feet. In parts of the county not covered by the glacier, loess was deposited directly on top of the sandstone or dolomite bedrock. Loess usually forms a protective layer against potential pollutants resulting from activities on the land surface.

Surficial deposits in Rock County vary greatly in both thickness and lithology within short distances. Depth to bedrock ranges from zero to more than 400 feet (Zaporozec 1982). Thicknesses over 200 feet occur in the deep preglacial valleys of the Rock and Yahara rivers and other streams in the western part of the county. In the eastern part, the thickness is generally less than 100 feet. The sediments are very thin or absent primarily in the southwestern part of the county and on hilltops elsewhere.

The detailed composition of surficial deposits is not known because no new geologic mapping or fieldwork has been done. However, studies done in conditions similar to Rock County, suggest that the till is either loamy, sandy, or slightly gravelly with varying ratios of sand, silt, and clay. Analyses of surficial deposits in eastern Wisconsin, performed by the UW-Madison Department of Soil Science (Lee 1985), show that, on the average, till composition was 68 percent sand, 23 percent silt, and 9 percent clay. The analyzed samples averaged 24 percent gravel, of which 80 percent were calcareous pebbles. Outwash deposits probably consist of well-sorted and stratified coarse sand and gravel of high permeability. The estimated characteristics of surficial deposits indicate that the surface materials in Rock County do not offer effective, immediate protection against pollution that may result from activities below the land surface. These deposits have at least moderate permeability and may not inhibit travel of pollutants unless a sufficient travel distance is available. The potential for groundwater pollution is reduced where the unconsolidated material is thick or the water table is deeper, and pollutants have more time to attenuate.

Bedrock Geology

Bedrock underlying Pleistocene deposits in Rock County consists largely of stratified sandstone, with a lesser amount of carbonate rocks (limestone and

Table 6. Availability of data for the evaluation of physical environment in Rock County

Data Needed	Data Availability		Source of Data
	Adequate	Limited	
SOILS			
Soil map	x		Soil survey maps 1:20,000
Soil material and its properties:	x		Soil interpretation sheets
surface and subsoil texture	x		"
permeability	x		"
pH	x		"
content of organic matter	x		"
Drainage characteristics	x		"
Depth of the solum	x		"
SURFICIAL GEOLOGY			
Glacial deposits		x	General map 1:500,000
Type of material		x	General description
Permeability		x	Inferred from general description
Thickness	x		Map 1:100,000 (contours: 5, 20, 50, 100 and more ft)
BEDROCK GEOLOGY			
Geologic map		x	Map 1:1,000,000
Type of material		x	General description
Permeability		x	Inferred from general description of rocks
GROUND WATER			
Depth to groundwater	x		Map 1:100,000 (contours: 10 and 50 ft)
Groundwater elevation	x		Map 1:63,360 (from LeRoux 1963)
Slope of the water table	x		Inferred from the 1963 map
Direction of groundwater flow	x		Inferred from the 1963 map
Components of groundwater flow (recharge and discharge areas)	x		Inferred from the 1963 map and from topographic maps

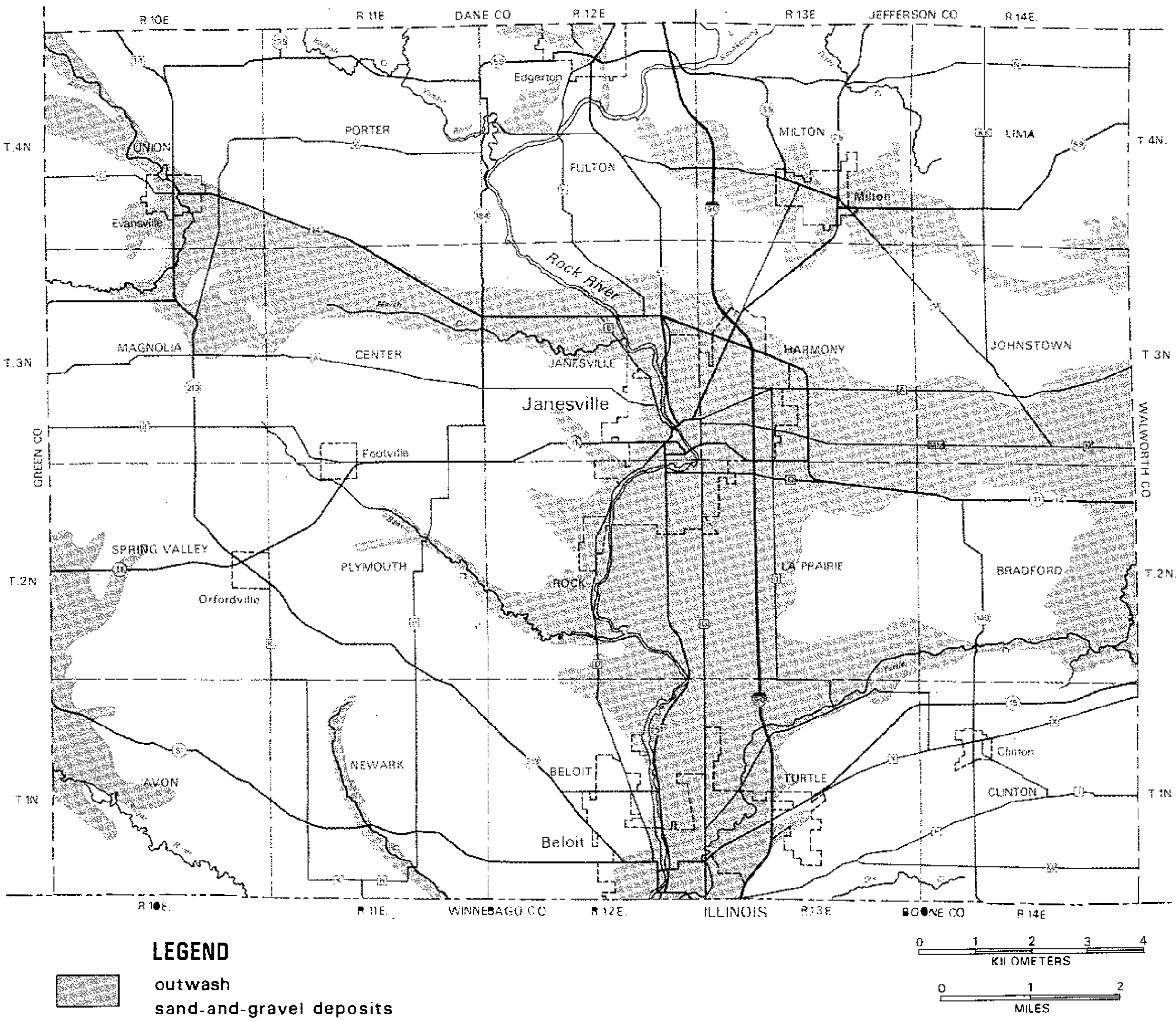


Figure 18. Generalized outwash boundaries, Rock County (from Zaporozec 1982)

dolomite--a magnesium rich limestone), and some shale. The properties of bedrock can only be estimated from the average values in other areas. The sedimentary rocks have a wide range of permeability--from highly permeable, fractured dolomite, in which water can move unhindered through interconnected fractures and solution openings, to less permeable, fine-grained sandstone. Movement of pollutants in fractured dolomite is uninhibited, and pollutants can readily spread over a large area. The smaller pores of sandstones restrict movement of pollutants and encourage chemical and physical interactions between rock material and water-carrying pollutants.

Groundwater

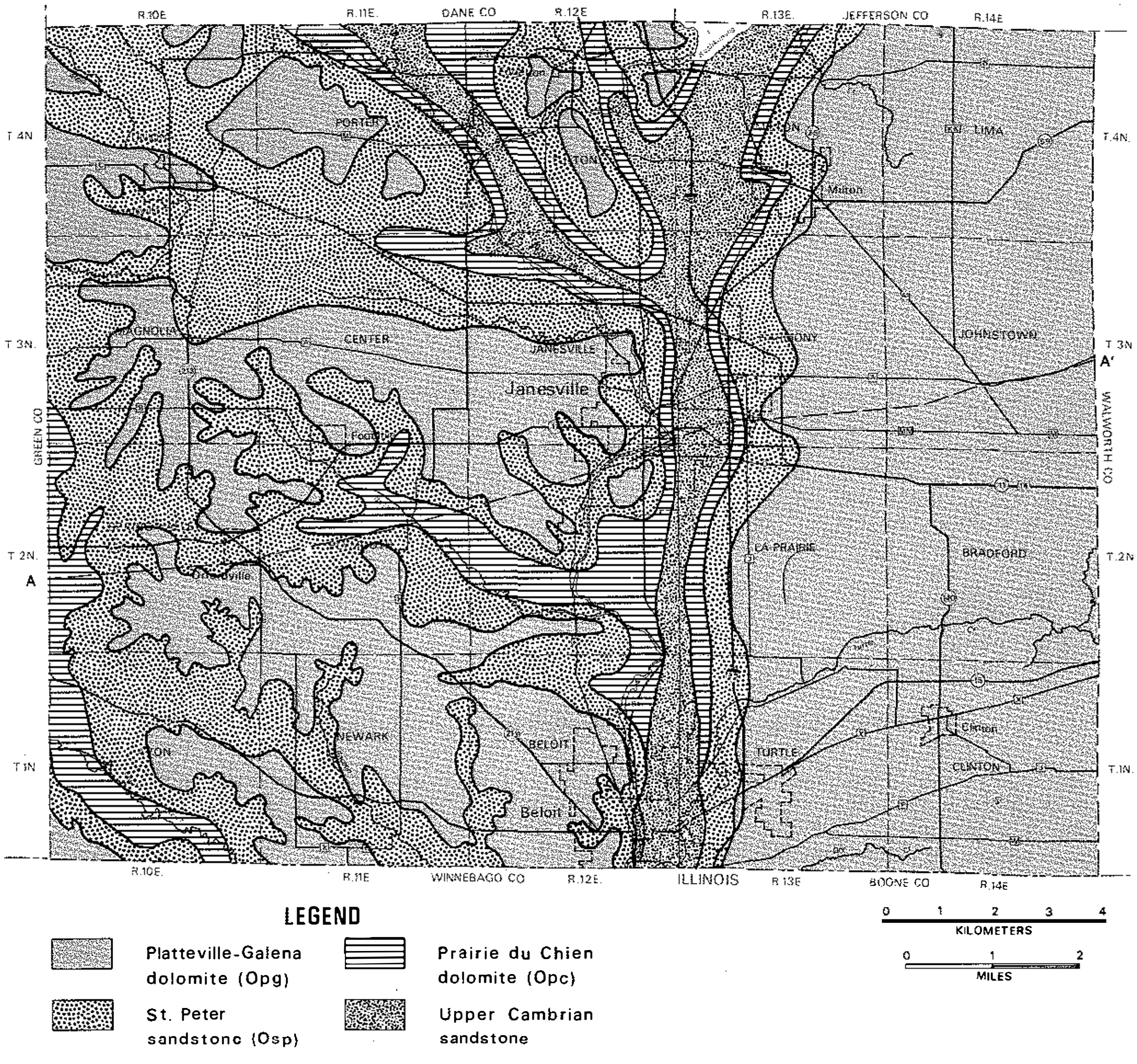
Aquifers.--Outwash deposits in stream valleys and in buried, bedrock valleys are very productive sources of groundwater in Rock County and must be protected against pollution. Water yields of more than 500 gallons per minute (gpm) can be obtained from many of the sand-and-gravel deposits in the preglacial valleys of the Rock and Yahara rivers and Bass Creek (Devaul 1975a). All high-capacity industrial wells in the Beloit area and most irrigation wells are constructed in these aquifers (see fig. 3).

Bedrock formations--the Platteville-Galena dolomite, St. Peter sandstone, Prairie du Chien dolomite, and Upper Cambrian sandstone (fig. 19)--may act as a single aquifer or, when separated by less permeable layers, as several aquifers of moderate to large yields. Yields of 1,000 gpm or more can be obtained from Cambrian sandstone throughout the county (Devaul 1975b). However, this deepest aquifer is generally not utilized for water supplies except by municipalities with deep wells. Although the specific capacities of wells in Cambrian sandstone are relatively low (5 to 20 gpm/ft), the great saturated thickness of this unit (over 1,000 ft) permits the construction of high-capacity wells (LeRoux 1963). The map on figure 19 illustrates the hypothetical exposure of bedrock formations if all the soil and other overlying unconsolidated materials were to be removed.

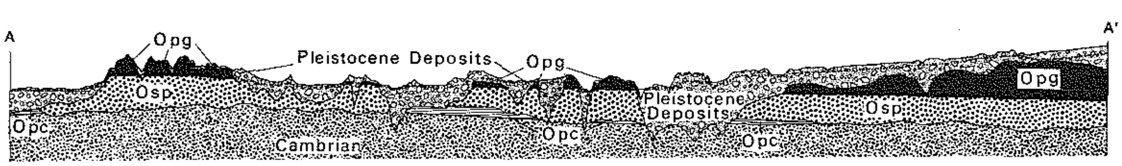
Adequate supplies of groundwater for domestic, stock, and commercial uses are available from the Platteville-Galena and the St. Peter formations. The

Platteville-Galena dolomite is an important aquifer in the area east of the Rock River (fig. 19). Yields depend on the size and degree of interconnection of rock fractures and range from 10 to 100 gpm. West of the Rock River, the principal aquifer is the St. Peter Formation (fig. 19), which consists of fine- to medium-grained sandstone. Groundwater moves through the small pores between the grains as well as along fractures. The permeability of the formation is quite high, and the yields may exceed 100 gpm.

The character of aquifers, especially the size and interconnection of the openings through which the water passes, is very important to the pollution attenuation process. Aquifers composed of fine-grained material (fine sand or sandstone) possess large surface areas which promote sorption processes. They also encourage dilution by dispersion because of the large number of small openings through which the groundwater must flow. Clay is very effective in removing pollutants because it contains only very small openings and its particles have great capacity for adsorption and ion exchange. Aquifers with large openings, such as coarse sand or gravel, permit pollutants to advance rapidly underground with little reduction in concentration. Till generally removes significant amounts of pollutants as water moves slowly downward through the clay, silt, and sand of which the till



A. Map



B. Cross section

Figure 19. Generalized map and cross section of bedrock aquifers in Rock County (source: Mudrey and others 1982, Zaporozec 1982)

is largely composed. In some places, however, water has formed more or less definite tubular channels through the till material. If such channels are intercepted by septic tank or another source of pollution, the water may become highly polluted and carry pollutants for relatively long distances. Groundwater in dolomite can be easily polluted and becomes unfit for use because it moves downward along cracks, fractures, and solution channels, which are ineffective in removing pollutants.

Subsurface Occurrence of Water.--Water in the subsurface may be divided into zones of aeration (unsaturated zone) and saturation (fig. 20). The zone of aeration consists of small openings filled partially with water and partially with air. In the zone of saturation all openings are filled with water. Biological, chemical, and physical processes determine the placement of boundaries between the zones and subzones.

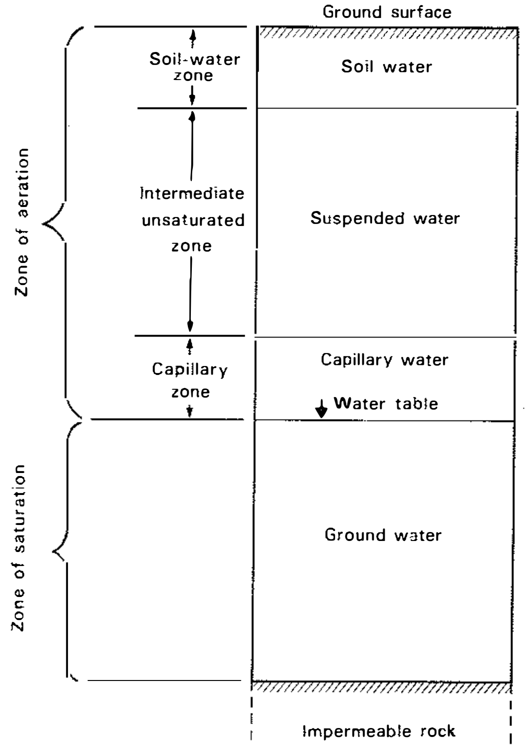


Figure 20. Relationship between unsaturated and saturated zones

In the soil-water zone, biological processes effectively remove a large number of human-introduced chemicals. The soil-water zone also includes the root zone, which has the greatest variety and magnitude of biological activities. It is in the root zone that significant amounts of chemicals are broken down by microorganisms or chemical and physical processes and taken up by plants. Activities in this zone closest to the surface determine the eventual fate of most introduced substances and the resulting groundwater quality.

Lesser biological activity occurs in the intermediate unsaturated zone, where additional pollutants may be removed by various chemical and physical processes such as ion exchange or adsorption. The main function of this zone is to provide additional attenuation and to delay the arrival of a pollutant to the water table. The type of material, the depth to the water table, and amount of annual recharge play an important part in the environment's ability to attenuate pollutants moving through the unsaturated zone to the water table. A soluble, nonreactive material spilled or applied on the land surface may not appear in the saturated zone for some time after the event.

The saturated zone extends from the upper surface of saturation down to underlying impermeable rock. The upper surface of the zone of saturation is called the water table. In the saturated zone, physical and chemical processes dominate over biological processes. Because soluble pollutants move with the groundwater as it flows, the important physical features of this zone are the direction and rate of groundwater flow.

The surface of the zone of saturation--the water table--is not stationary and changes with location and time. The water table usually resembles a flattened form of the surface topography and tends to be closer to the land surface in less permeable materials and in valleys or lowlands (discharge areas). It is farther from the land surface in relatively permeable materials and beneath upland hills and ridges (recharge areas).

Based on well drillers' reports, the depth to groundwater ranges from zero to about 200 ft below the land surface (fig. 21). Several wells in the Rock River valley are flowing wells (with water level above the land surface). In most of the county, water can be found at depths between 10 and 70 ft. Shallow water levels, within 10 ft of the surface, occur in stream valleys, and deeper levels, over 70 ft, occur at higher elevations (above 950 ft). Four wells are currently included in the statewide groundwater observation network. Their locations are shown in figure 1.

Groundwater Movement.--Groundwater flows from higher places (uplands, recharge areas) to lower places (lowlands, discharge areas) as shown in figure 22. In a recharge area, the movement of water is downward, away from the water table. In a discharge area, water moves upward, toward the water table. Between these end areas, groundwater flow is predominantly horizontal.

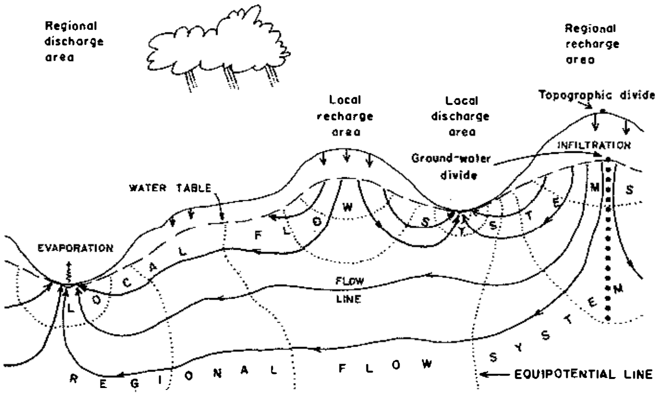


Figure 22. Idealized groundwater flow system (from: Zaporozec 1982)

The following discussion of groundwater flow and its direction and rate is based on previously collected data (LeRoux 1963), on findings from other areas, and on

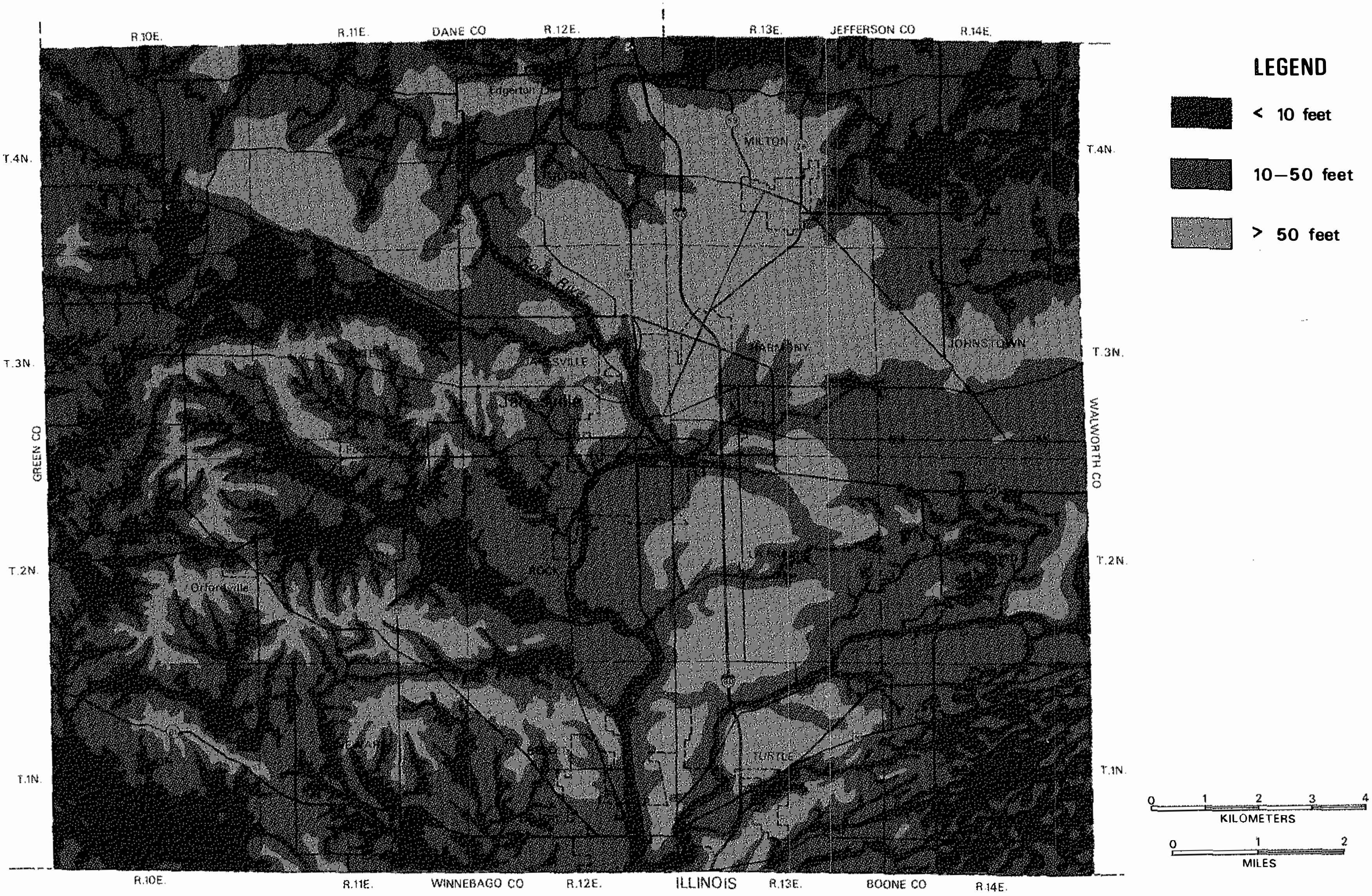
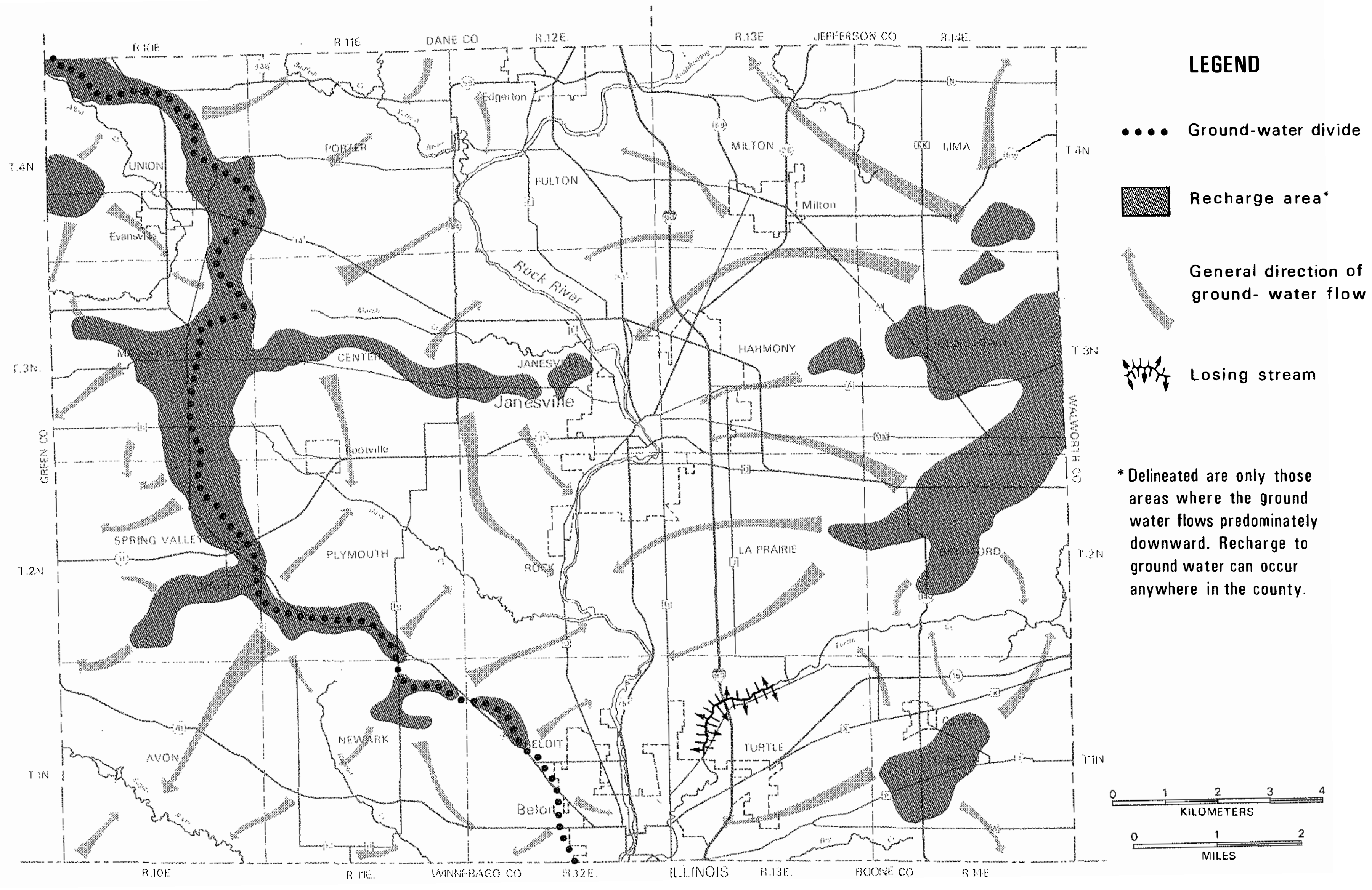


Figure 21. Depth to water, Rock County



*Delineated are only those areas where the ground water flows predominately downward. Recharge to ground water can occur anywhere in the county.

Figure 23. Major recharge areas of bedrock aquifers in Rock County (from: Zaporozec 1982)

indirect indicators of groundwater flow readily available from topographic maps (surface topography and surface water bodies).

Groundwater flow systems are complex and multilayered. In the intervening areas between the major recharge areas (fig. 23) and the major discharge areas (the major streams of the county) are many local systems where groundwater flows from a local recharge area to a local discharge area. These shallow, local flow systems have short flow paths. In western Rock County, the recharge area shown in figure 23 is a major groundwater divide. West of it, groundwater flows toward the Sugar River and toward the smaller streams; east of it, groundwater flows generally toward the Rock and Yahara rivers and Bass Creek. In eastern Rock County, groundwater generally flows toward the Rock River, except in the southeast where it flows toward Turtle Creek.

Much of the water in the subsurface originates in the county and infiltrates the ground within a radius of a few tens of miles from where it is found. This means that most pollutants released into the groundwater in the county will discharge to wells or surface water within the county boundaries. Movement of groundwater is very slow because the water has to squeeze through an intricately branched network of interconnected open spaces that offer natural frictional resistance to the flow. In Rock County, groundwater generally moves less than one foot per day except near pumping wells (compared to the flow in streams, which is measured in feet per second). Because of this slow movement, pollutants travelling with groundwater may remain undetected for a long time.

Evaluation of Groundwater Vulnerability to Pollution

Processes Affecting Pollutant Fate and Transport

The potential for groundwater pollution depends upon the attenuation that takes place between the source of pollution and the aquifer. The attenuation of most pollutants as they travel through the unsaturated zone and groundwater system is affected by a variety of naturally occurring chemical reactions and biological and physical processes that often cause the pollutant to change its physical state or chemical form. These changes may lessen the severity of pollution or amounts of pollutants. Once pollutants reach the saturated zone (an aquifer), fewer mechanisms attenuate pollutant concentrations than in the unsaturated zone. The chemical processes in the subsurface are complex and may work individually or in combination to provide varying degrees of attenuation, depending on site-specific soil and aquifer characteristics as well as on the individual pollutants in the system. Therefore, although the importance of these chemical reactions in attenuation of pollutants is widely recognized, predicting how much attenuation will take place in a particular environment is still difficult (Aller and others 1985). Attenuation processes can be bypassed completely if a pollutant is introduced directly into the aquifer.

The degree of attenuation that occurs depends upon 1) the grain size and physical and chemical characteristics of the material through which the pollutant passes, 2) the time the pollutant is in contact with the material through which it passes, and 3) the distance that a pollutant has traveled through the unsaturated zone (Aller and others 1985). In general, the longer the time and the greater the distance of travel, the greater the potential for attenuation. Similarly, the greater the surface area of the material through which the pollutant passes, the greater the effect of attenuation. Movement of groundwater is slower in rocks with large surface areas, such as those found in a porous medium, than in rocks where water movement is primarily through faults and fracture channels.

Evaluation System

Many methodologies have been developed to evaluate the groundwater pollution potential of existing or planned facilities and activities (particularly land disposal of wastes) or the vulnerability of the environment to pollution (for example, Aller and others 1985, LeGrand 1980). These methodologies are usually critical-factor-oriented and combine all critical factors into one final rating system. In developing a system for Rock County, we have used a somewhat nontraditional approach, which separates the physical environment into three components depending upon the intended use or activity and the fate of pollutants in the subsurface. Each component is mapped separately and can be used individually or in combination.

The evaluation system is designed to assess the ability of the environment to attenuate potential pollutants and is based on the following three interpretive maps:

1. Soil map
2. Subsurface map
3. Groundwater flow map

The soil map is most useful for evaluating the ability of the soil column to attenuate pollutants resulting from activities on and/within 5 ft of the land surface.

The subsurface map evaluates the capacity of the environment to attenuate pollutants resulting from activities below the soil zone or pollutants that penetrated the soil zone.

The groundwater flow map helps to evaluate the general movement of pollutants that reach the groundwater flow system and also helps define protection zones around major water supply points.

Using three separate components allows the system to be use-specific, since the impact of various land uses or activities on groundwater is evaluated according to the place of origin. It is also easy to update. The system is based on the existing resource information in the county, but it can incorporate new or more detailed data as they become available.

Figure 24 schematically shows the main components of the physical environment in Rock County as they are considered in the evaluation system. The soil column and its attenuation potential (shown on plate 1) represents the first line of defense against pollutants moving toward the groundwater. The subsurface map (plate 2) shows the ability of subsurface materials, below the soil column, to

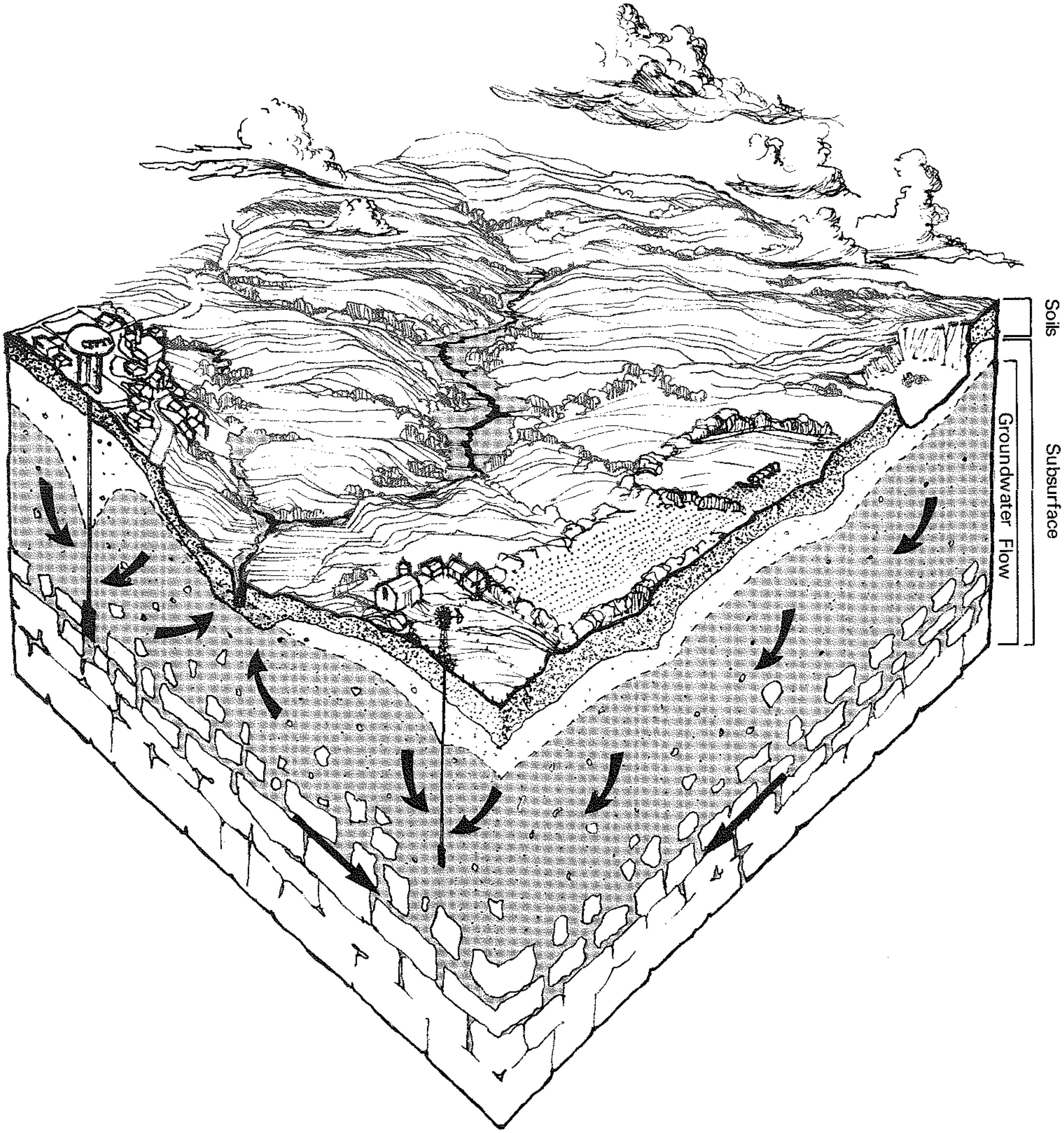


Figure 24. Relationship between the three components of the system for evaluating the groundwater vulnerability to pollution in Rock County (arrows indicate general direction of groundwater flow)

attenuate pollutants, representing the second line of defense against pollutants. The groundwater flow map, the third component in the evaluation system, shows where and when pollutants that reach the groundwater may become a problem in existing or future water wells.

In summary, the evaluation system used in this study provides a tool for assessing the ability of the environment to attenuate pollution and for predicting potential problems once pollution has reached the groundwater. Even though the soil and subsurface materials maps show the ability of these materials to attenuate pollution, classification of areas into most or least vulnerable to pollution is intended as a time- and cost-saving guide for screening and planning purposes only. The maps in no way replace the need for detailed on-site investigation. They do, however, reduce the number of areas to be studied in detail by identifying the most vulnerable and least vulnerable areas. The evaluation of pollution potential of the environment is only a supplemental tool in a groundwater protection program. The pollution control efforts should be concentrated on regulating land uses and on controlling pollution at the source.

Soils and Their Ability to Protect Groundwater

Soils are classified on the basis of observable and measurable properties. These properties are selected in such a way that soils that form in similar ways are grouped together. The current national system of classifying soils is described in the Rock County soil survey report (USDA 1974, p. 150-151).

For interpretive purposes, soils are often grouped together on the basis of similar responses to management and treatment. The U.S. Soil Conservation Service (SCS) has used a land- capability classification that groups soils according to their potentials and limitations for sustained crop production. This system utilizes diverse factors such as soil characteristics, management practices, and climate (temperature and moisture, specifically). Soil maps produced by SCS are particularly useful for agricultural and engineering purposes, wastewater disposal, and recreational uses of land.

For assessing the potential of the soil to attenuate pollutants, we developed a different grouping of soils based on their physical and chemical characteristics involved in the attenuation process. (The process by which soil removes pollutants is very complex and not fully understood, but involves such tasks as immobilizing toxic metals contained in municipal sewage sludge and removing bacteria from animal wastes). Information needed for this assessment was taken entirely from the Rock County soil survey report (USDA 1974). For evaluative purposes, only physical and chemical characteristics of the soil solum--specifically the A and B horizons--were used. Seven physical and chemical characteristics were selected for each soil series and assigned a relative weight to a maximum of 10 (table 7). The weighted values indicate relative importance of each characteristic. The least significant factors have weights of 1; the most significant, a weight of 10.

The weighted values were summed for each soil series mapped in the county, and the series with similar total point scores were grouped into four soil associations, reflecting different attenuation potentials (appendix C). Approximate acreage and proportional extent of each association is given in appendix C. Rankings are based on soils in their natural state. Human-induced changes, such as tilling or ditching, may affect the attenuation potential of a particular soil; and where there has been extensive alteration, a reassessment may be required. The following paragraphs explain the selected characteristics.

Soil texture is a measure of the percentage of sand-, silt-, and clay-sized particles present in a representative sample of a given soil horizon. It is a good indicator of the rate of water movement through the soil, of the ability of the soil to supply both water and nutrients for plant uptake, and of the erosion potential of the soil. The textures of both the surface (A) and subsoil (B) horizons are included in the ranking system.

The organic matter content of the soil is important because it increases the ability of the soil to hold nutrients, water, and complex heavy metals and to adsorb organic materials such as pesticides. In addition, it provides a valuable energy source for soil microorganisms, which play an important part in the breakdown of organic wastes and pesticides.

The pH level of a soil is included because these breakdown processes function better at pH values between 6 and 7.

The depth of the soil solum, which is the combined thickness of the A and B horizons, is an important factor because the effectiveness of the soil as a treatment/recycling system depends on the amount of contact time that water-transported pollutants have with the mineral and organic constituents of the soil. A deep, medium-textured, well-aerated soil offers the best opportunity for soil water to percolate through with maximum contact between potential pollutants and the mineral and organic constituents.

The rate at which water moves through the soil is critical. A standard measure of this rate is soil permeability, or the vertical hydraulic conductivity. Unfortunately, this measure is based on saturated flow, which rarely occurs, and is, therefore, not a particularly good assessment of what actually happens. Soils in their natural state have both large and small pores through which water can move. Under saturated flow in a medium-textured soil, water moves through the larger pores at a relatively rapid rate. In most instances, however, soil water moves as unsaturated flow through the smaller soil pores at a slower rate, which increases the potential for pollutant attenuation. Thus, a standard permeability rate for a medium-textured soil would tend to underestimate the soil's ability to treat and recycle waste. To estimate the rate of water movement through the subsoil (B) horizon, we used various characteristics--including the textural classification at the family level in the soil taxonomy, the type and grade of structure, and the soil consistency. Four classes were established representing the range of rates of water movement commonly encountered in soils.

Natural soil drainage class is a measure of the nature and extent of soil wetness. The terms used suggest not only where the water stands in the soil solum but also how much of the time in any given year a particular soil will be wet.

Two kinds of soils fall into the first association, which has the least potential for protecting groundwater, namely very shallow soils (less than 10 in.) of varying textures, which occupy hilltops and steep sideslopes over bedrock, and medium- and coarse-textured soils immediately adjacent to perennial or intermittent streams (plate 1). Neither group is particularly well suited for any intensive land use. Many of the very shallow soils in Rock County are forested and are thus protected. They should not be subjected to other uses because they have a very low capability to attenuate pollutants. Soils adjacent to waterways can occasionally be farmed, but they are often subject to flooding and extreme soil wetness. Animal wastes could be applied at modest rates if they are incorporated into the wet soil immediately. These soils, however, are best left undisturbed, as they can provide a valuable buffer strip to protect surface water from runoff pollution.

The second soil association (plate 1), which provides marginal protection for groundwater, includes several different groups: coarse-textured soils, 20 to 40 in. deep; medium-textured soils, less than 20 in. deep; and medium-textured soils, 20 to 40 in. deep but which are naturally wet or poorly drained. These are critical soils because they are used extensively, particularly for agricultural production, and they must be managed very carefully. Animal waste applications, for example, should be closely tied to crop needs so that excess nutrients are not available to leach to the groundwater. These soils are not suited for the application of municipal sludges.

The remaining two soil associations consisting of deep (more than 40 in.), medium- and fine-textured soils (plate 1) are well suited for a wide variety of land uses. The major difference between the two lies in the organic matter content and pH of the surface (A) horizon; the

Table 7. Ranking system for evaluating the attenuation potential of soils in Rock County (Fred Madison, 1985)

Physical/Chemical Weighted Characteristics	Classes	Values
Texture [1] - Surface (A) horizon	l, sil, scl, si	9
	c, sic, cl, sicl, sc	8
	lvfs, vfsl, lfs, fsl	4
	s, ls, sl, organic materials, and all textural classes with coarse fragment class modifiers	1
Texture [1] - Subsoil (B) horizon	c, sic, sc, si	10
	scl, l, sil, cl, sicl	7
	lvfs, vfsl, lfs, fsl	4
	s, ls, sl, organic materials, and all textural classes with coarse fragment class modifiers	1
Organic matter content [2]	Mollisols[4]	8
	Alfisols	5
	Entisols; Inceptisols	3
	Histosols; Aquic suborder; and Lithic, Aquollic, and Aquic subgroups	1
pH-Surface (A) horizon	≥ 6.6	6
	< 6.6	4
Depth of soil solum (A + B horizons)	> 40 in.	10
	30-40 in.	8
	20-30 in.	3
	< 20 in.	1
Permeability [3] - Subsoil (B) horizon	very low	10
	moderate	8
	high	4
	very high	1
Soil drainage class	well drained	10
	well to moderately well drained	7
	moderately well drained	4
	somewhat poorly, poorly, and very poorly drained; and excessively well drained	1

---

[1] Soil textural classes: l = loam, sil = silt loam, scl = sandy clay loam, si = silt, c = clay, sic = silty clay, cl = clay loam, sicl = silty clay loam, sc = sandy clay, lvfs = loamy very fine sand, vfsl = very fine sandy loam, lfs = loamy fine sand, fsl = fine sandy loam, s = sand, ls = loamy sand, sl = sandy loam.

[2] Based on the ordinal level of the soil classification system; soils are penalized if they are wet or less than 20 in. thick over bedrock.

[3] Based on the particle-size class at the family level of the soil classification system, type and grade of structure, and consistence.

[4] For the descriptions of soil orders and other classes see USDA 1974.

fourth association (best attenuation potential) has higher organic matter content and higher pH than the third association (good attenuation potential). Deep, silty soils of the fourth association, formed under prairie grasses, are best suited for mitigating the impacts of today's common and accepted land use practices.

Plate 1 shows that a large part of the county is covered by soils that have good potential for attenuating pollutants. Large tracts of the best soils are concentrated especially in the flat, east central and southeastern parts of the county underlain by loess. In these areas, suitable places for land disposal of sludge and septage may be found. Soils having a very low potential for attenuating pollutants are found primarily in the southwestern part of the county.

Evaluation of Subsurface Materials

An evaluation system was developed to assess the relative attenuation capacity of the subsurface below the first 5 feet from the surface. The information can be used to evaluate the land suitability for activities that put waste or potentially hazardous materials below the soil zone and also to evaluate the second line of defense to materials placed on or into the soil.

For the evaluation of the subsurface attenuation potential, we chose conventional resource suitability analysis, consisting of a series of overlays. The basic process used in this analysis is to develop a series of individual maps showing various rock types and depth to groundwater and superimpose them to identify a degree of suitability to attenuate pollutants. The combination of the characteristics and position of geologic materials and position of the water table establishes the vulnerability of an aquifer to pollution. By comparing sequences of geologic materials, we established a rating of the relative pollution potential for aquifers in any part of the county (fig. 25).

Permeability and Thickness of Rock Materials (below the first 5 ft)	Thickness of the Unsaturated Zone (ft below surface)		
	>50	10-50	>10
Dolomite within 20 ft from the surface (any overburden)	1	1	1
Thick (over 50 ft) sand and gravel (over any bedrock)	2	1	1
Sandstone within 20 ft from the surface (any overburden)	2	1	1
Dolomite overlain by medium-thick (20-50 ft) sand and gravel	2	1	1
Sandstone overlain by medium-thick (20-50 ft) sand and gravel	2	2	1
Dolomite overlain by medium-thick (20-50 ft) till	3	2	1
Sandstone overlain by medium-thick (20-50 ft) till	3	2	2
Thick (over 50 ft) till (over anything)	3	3	2

Increasing Pollution Potential ↑

Increasing Pollution Potential →

Scale: 1 - greatest potential, 2 - moderate potential, 3 - least potential

Figure 25. System for evaluating pollution potential of subsurface materials in Rock County

In developing the system, we used a conceptual rather than quantitative approach. The selection of individual rock categories and their depth involves a large degree of professional judgement. Also, the system is not pollutant-specific, and some pollutants may penetrate the rock materials regardless of their character or depth.

The evaluation system (fig. 25) is based on the permeability of rock materials (both consolidated and unconsolidated) and the depth to bedrock and to groundwater. Because of the lack of data on subsurface permeability, the rock types (dolomite, sandstone, till, and sand and gravel) serve as surrogates for permeability ranges. These parameters were selected because they are easily obtainable and fairly represent, in a generalized way, all the important factors of the attenuation process (adsorption, dilution, transport distance, etc).

A series of maps was constructed to show how the rock types are distributed throughout the county, both horizontally and vertically. These maps outlined areas where the individual rock types occur within 20 ft of the land surface, between 20 to 50 ft of the surface, and more than 50 ft below the surface. These particular depth limits are not absolute; they were given by the existing resource maps of the county.

The maps showing geologic factors (the rock types and the depth to bedrock) were overlayed with a map showing depth to groundwater (thickness of the unsaturated zone). This map outlined the areas of the county where the groundwater is less than 10 ft, within 10 to 50 ft, and more than 50 ft from the land surface (see fig. 21). The resulting composite map showed three areas, which were classified as 1 - most vulnerable, 2 - moderately vulnerable, and 3 - least vulnerable to pollution (plate 2). The first category, which has the least potential for protecting groundwater, includes areas where bedrock is close to the surface (less than 20 ft) and the water table is shallow (less than 10 ft) or areas underlain by thick outwash sand and gravel. Category 3, which has the best potential for attenuating pollutants, includes areas underlain by till at least 20 ft thick with the water table more than 50 ft deep. The intermediate category 2 includes a variety of hydrogeologic conditions between the two extremes.

The resulting subsurface vulnerability map (plate 2) shows that a large part of the county's subsurface has a high pollution potential. Areas most vulnerable to pollution are those underlain by outwash deposits (a broad strip of land bordering the northern third of the county and extending south along the Rock River valley) and areas where dolomite or sandstone are near the land surface (parts of the eastern third and southwestern quarter of the county). Areas with the best potential for attenuation of pollutants are found in the northern third, in the central part west of Janesville, in the southeastern corner, and in isolated areas in the southwestern part of the county.

Groundwater Flow

Components 1 and 2 of the evaluation system rely on a protection strategy--the ability of the soil and subsurface materials to attenuate pollutants. However, in some cases pollutants enter the groundwater and move with it as it flows. In such cases, determining the direction and rate of groundwater flow becomes important as a way to predict the fate of pollutants in the aquifer and the threats to groundwater users down flow from pollution sources.

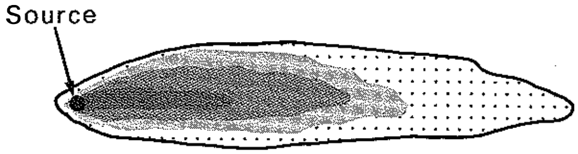
If it were possible to see zones of pollutants travelling in a groundwater system from an aerial view, most would appear very small in relation to the total area of groundwater flow. Pollutants from point sources travel in a relatively compact and well-defined body, called plume, along flow lines within the aquifer. The shape and size of a plume depends upon the local geology, the groundwater flow, the type and concentration of pollutants, the continuity of the supply of pollutant, and any modifications of the groundwater flow system by man. Even though nonreactive pollutants travel in the groundwater along the flow lines, dispersion causes the pollutants to spread in directions transverse to the flow lines as well as along the flow lines. The pollution plume develops an elliptical shape as pollutants are transported through the system, because dispersion is stronger in the direction of flow than in the direction perpendicular to the flow lines. This is illustrated in figure 26.

The first two cases (figs. 26a and 26b) show a continuous release of pollutants that generates uninterrupted downgradient plumes. The plume will tend to be long and thin (fig. 26a) where groundwater is moving relatively rapidly. Where the flow rate is low, the pollutant will tend to spread more laterally to form a wider plume (fig. 26b). Intermittent sources create a series of individual plumes moving one behind the other. The rate of pollution attenuation depends on the type of pollutant and continuity of its supply and on the attenuation processes involved. As the pollution plume from a one-time source (a slug of pollution) moves, the pollutant concentration level gradually decreases (fig. 26c). Pollutants in groundwater tend to be removed or reduced in concentration with time and distance traveled (Everett 1980).

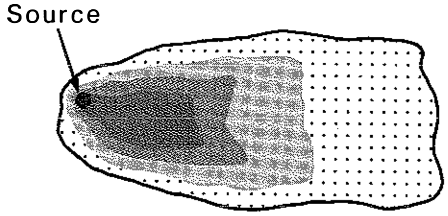
Specific statements cannot be made about the distances that pollutants will travel because of the wide variability of aquifer parameters, types of pollutants, and wide range of interactions between pollutants and aquifers. Generally, in aquifers composed of fine-grained unconsolidated materials, pollutants such as bacteria, viruses, organic materials, some pesticides, and most radioactive substances are reduced by attenuation processes (primarily adsorption) in less than 300 feet (Everett 1980). But most common ions in solution move unimpeded through the aquifers, subject only to dilution by mixing and chemical processes.

Pollution Sensitive Areas

Different land uses and associated activities vary in their potential to pollute groundwater from the relatively innocuous to those involving hazardous substances. In addition, certain areas are particularly susceptible to pollution. In this study, we divided these pollution sensitive areas into three groups: naturally vulnerable areas, well-protection zones, and potential problem areas.

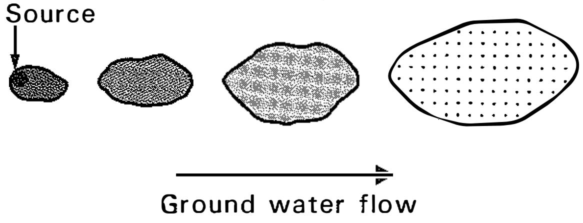


A. Continuous source, rapid flow



B. Continuous source , slow flow

(Pollutant is less concentrated at the margins and increases toward the source.)



C. One-time source

(A slug of pollution moves with ground water and expands with a lower concentration.)

Figure 26. Types of pollution plumes (plan view)

Naturally Vulnerable Areas

Areas vary in terms of their vulnerability to groundwater pollution. Some locations are naturally more sensitive because the soils, subsoils, and/or bedrock do not provide adequate protection, and the potential exists for rapid movement of pollutants to groundwater. These are primarily areas of thin soils, coarse and permeable soils, sand and gravel, fractured dolomite, a high water table, or some combination of these factors. To identify areas particularly susceptible to the rapid percolation of pollutants to groundwater, the most vulnerable categories from the soil and subsurface attenuation capacity maps (plates 1 and 2) were combined on plate 3. These areas (dark on plate 3) have no significant potential for attenuating pollutants and require special attention because certain land uses, eventual accidents, or mishandling of hazardous materials, may create serious pollution problems in those areas.

Other areas of concern (shown on plate 3 as crosshatched) are the recharge areas of deep aquifers located in areas of inadequate subsurface protection. These critical recharge areas were delineated by superimposing recharge areas from figure 23 over the areas of least attenuation potential on plates 1 and 2. If a pollutant is introduced in these recharge areas, resulting pollution may eventually spread through the entire aquifer.

Delineating naturally vulnerable areas does not mean that the introduction of pollutants in other areas should be of less concern. However, the classification can be used for screening areas that need protection most or first.

Well-Protection Zones

The composite map of pollution sensitive areas (plate 3) also shows the location of municipal wells in Rock County. The map scale and lack of data do not allow exact delineation of the areas where the water reaching municipal wells was originally recharged. Pollutants introduced in the vicinity of pumping wells may enter the wells relatively quickly and pollute the water supplies. The delineation of well-protection zones is described in detail in chapter V.

The areas outside the well-protection zones of wells indicated on plate 3 should not, however, be left unprotected. Other public wells and household or farm wells are located throughout the entire county. The purpose of identifying specific well-protection zones is to provide a tool for setting priorities to protect the largest water-using population.

The following wells are located close to potential sources of pollution and may be considered prime candidates for well-protection zones:

Beloit	City wells # 5 and # 10
Clinton	City well # 3
Edgerton	City well # 2
Evansville	City wells # 1 and # 2
Janesville	City wells # 1, # 2, and # 3
Orfordville	City wells # 1 and # 2

Potential Problem Areas

Overlaying the most vulnerable categories from the soils and subsurface pollution potential maps (plates 1 and 2) with maps showing the location of individual potential pollution sources or polluting land use activities (figures 8, 10, 11, 12, 14, 15, and 16) produces potential problem areas also shown on plate 3. However, this is not intended to suggest that the potential problem areas designated on plate 3 are the only areas in which groundwater quality problems might occur. All inventoried pollution sources shown on the figures mentioned above have a potential to create groundwater quality problems. (An attempt to quantify their potential risks to groundwater is included in appendix B.) Plate 3 merely shows the potential problem areas of highest priority at the time of the study. Hence, this map should be used only as a planning tool; as a guide to areas that should be addressed first in a groundwater protection plan. Not shown are the areas of suspected pollution where pollutants may have already entered the groundwater.

Further, each of the potential pollution sources located in pollution vulnerable areas has a different risk depending upon the potential pollutants and the design, construction, and maintenance of facilities. Therefore, additional monitoring and/or investigation will be necessary to determine what degree of risk to groundwater, if any, the individual sources present.

Potential problem areas are mostly concentrated in the Janesville-Beloit urban corridor, where there is a large concentration of potential pollution sources, especially storage tanks. Numerous recorded spills in these areas (see fig. 15) indicate the potential for groundwater pollution. The risk of polluting groundwater is very high because these areas are underlain by a highly permeable sand-and-gravel aquifer, which serves as a source of municipal water supplies. Similar potential problem areas, although on a smaller scale, are in Edgerton, in the eastern part of Evansville, and in the southern part of Orfordville.

Chapter IV.

MANAGEMENT TECHNIQUES AND OPTIONS

Approaches to Local Groundwater Protection

Increasingly, local governments, along with state and federal agencies, have an important role to play in effective groundwater management and protection. Many communities and local units of government around the country have developed programs to protect their groundwater. A literature review summarizing some of the approaches used by local governments across the country was published as a companion volume to this report (Potter 1984) and was helpful in developing this chapter, as were a wide range of other documents and relevant experience. DiNovo and Jaffe (1984) provide detailed examples of the various regulatory approaches communities may use to protect groundwater.

The planning process followed in this project has included many elements -- an inventory and assessment of the county's groundwater-related natural resources; an analysis of demands for and uses of groundwater; a compilation of existing and potential sources of groundwater pollution; identification of those areas that are especially susceptible to groundwater pollution; and an assessment of groundwater problems in the county, with an emphasis on the most significant. This part of the report outlines the major approaches and management tools for addressing groundwater problems. The choice of particular approaches and tools, of course, derives from the management objectives identified by the county; thus this section can be viewed as a "menu," from which to choose elements of a strategy tailored specifically for Rock County.

Techniques that can be used in groundwater protection programs include regulatory and non-regulatory approaches, although in practice, most programs are a mix of these. Regulatory approaches involve placing a system of legal constraints on land uses or on particular activities that are potential sources of groundwater pollution. Non-regulatory approaches include such activities as public education, voluntary best management practices, governmental coordination, and inspection and training programs. Other programs may include emergency spill response plans, monitoring to identify water quality problems, and others.

There is no one "correct" way to design a groundwater management program. Clearly an effective approach must reflect local needs and concerns, and must be embraced by those who will carry it out. Whatever approach is chosen, it must address identified problems and achieve the goals and objectives of the management program efficiently and with minimal disruptive conflict. Community goals and objectives must be identified before specific management program techniques can be selected or carried out. Groundwater protection programs raise two fundamental questions. First, what precisely needs to be protected? Second, what degree of protection does the resource require? The answers to these questions will shape the selection and the stringency of specific management policies for the program.

This chapter first outlines the existing state regulatory framework, including relevant provisions of the state's new groundwater and related waste-management laws. It then inventories and assesses potential local governmental roles and tools --both regulatory and non-regulatory. The chapter concludes by briefly discussing monitoring and inventory requirements, local government's responsibility to set an example for groundwater protection in its own operations, and some of the organizational considerations that must be addressed in undertaking a local program.

Existing State Regulatory Framework

A number of state regulatory programs affect groundwater directly or indirectly. These are discussed for individual potential pollution sources (along with an agency responsible for regulating these sources) that are grouped into the same four categories as in chapter II: waste disposal, agriculture, hazardous materials and waste, and other activities. We hope that the summary of existing state programs will help local officials avoid regulatory overlap and fashion complementary protective measures. Table 8 presents a summary of existing state regulations related to groundwater protection.

Waste Disposal

Land disposal of solid waste - DNR. Sec. 144.435(1), Wis. Statutes, authorizes the Department of Natural Resources (DNR) to prepare and adopt minimum standards for the location, design, construction, sanitation, operation, and maintenance of solid waste disposal sites and facilities. Sec. 144.44 (4)(f), Wis. Statutes, authorizes

Table 8. Summary of state regulatory controls of pollution sources

Activity	Regulator	Wis. Stat.	Adm. Code	Focus of Regulations
WASTE DISPOSAL				
Municipal and industrial landfills	DNR	144	180 185	Licensing of all sites; standards for location, design, operation, construction, monitoring, and abandonment.
Environmental repair fund	DNR	144 160		Proposed rules will focus on development of an environmental response plan: inventory sites that might pollute; develop a hazard ranking system; identify remedial actions to be taken. Also applies to hazardous waste disposal facilities.
Municipal and industrial wastewater	DNR	147	110 206 214	DNR regulates through WPDES permit process. NR 110 governs municipal sewage lagoons; NR 206 land disposal of municipal wastewater; and NR 214 land disposal of industrial wastewater.
Sanitary sewers	DILHR	145	82	DILHR regulates laterals.
	DNR	144	110	DNR regulates interceptors and collectors.
Private wastewater systems	DILHR	145 236	83 85	DILHR regulates siting, design, installation, and inspection of systems and licensing of installers and evaluators. State inspection system (vs. local) is required for large-scale systems.
	DNR	144	113	DNR can prohibit tanks in areas where they cause a water quality problem.
Municipal sludge disposal	DNR	147	110 204	NR 110 requires approval of land for sludge disposal; NR 204 regulates land spreading of sludge.
Septage and holding tank waste disposal	DNR	146	113 206	DNR licenses persons for holding-tank maintenance and waste disposal and regulates land spreading of domestic wastewater.
AGRICULTURE				
Animal waste management	DATCP	92	165	New ag program for animal waste management.
	DNR	162 147	112 243	DNR regulates the distance of wells from concentrated feeding operations. New rules can require operators to obtain WPDES permit and require monitoring wells in critical conditions.
Fertilizer bulk storage	DATCP	94 160	162	Proposed rules will apply to fertilizer bulk storage by manufacturers and distributors (after Jan. 1, 1986).
Pesticide storage, transportation, and use	DATCP	94	29	Rules require good handling practices and prohibit direct (or possible indirect) entry of pesticides into the groundwater; also has aldicarb restrictions and groundwater sampling requirements.
	DATCP	160	163	Proposed rule for pesticide bulk storage parallels that of fertilizer bulk storage.
	DNR		80	DNR can prohibit use of pesticide; Pesticide Review Board review is required.
HAZARDOUS MATERIALS AND WASTE				
Hazardous waste	DNR	144	181	State regulatory program exceeds minimum RCRA requirements.
Engine waste oil	DNR	144	183	Requirements for location, design, and operation of facilities.
Chemical storage tanks	DILHR	101 160	10	Leak detection program, plan review, tank inspection and approval, design and construction standards, and record-keeping.
Spills	DNR	144	158	Contingency plan required for emergency response to waste spills. DNR has authority to request remedial action.
OTHER ACTIVITIES				
Well construction and abandonment	DNR	144 162	112 111	DNR licenses well drillers and pump installers, specifies well design and construction, sets minimum separating distances between wells and potential pollution sources, and requires proper abandonment of all wells.
Drinking water standards	DNR	144 162	109	DNR sets drinking water standards and public water supply monitoring requirements.
Well compensation	DNR	160	123	New program lets DNR provide partial reimbursement for replacing contaminated wells.
Groundwater standards	DNR	160	140	New rule sets up a two-tiered system of numerical standards for polluting substances enforced by DNR.
	DATCP	160	161	Proposed DATCP rule establishes the regulatory and enforcement actions which the DATCP will take to protect groundwater against pollution from agricultural activities.
	DOT	160	277	New rules are being developed to deal with road-salt storage sites.

DNR to require groundwater monitoring. Chap. NR 180, Wis. Adm. Code, contains the DNR rules for these activities. DNR must approve the feasibility report and plan of operation and abandonment for new and expanded sites. Chap. NR 185, Wis. Adm. Code, specifies the planning requirements. DNR can impose conditions deemed necessary to protect groundwater on the operation and abandonment of the landfill. Monitoring of new sites is required, and monitoring of public and private wells in the area may also be required.

Environmental repair fund - DNR. The environmental repair law of 1983 (sec. 144.442, Wis. Statutes) calls for administrative rules to be developed by May 1986 to cover investigation and cleaning of waste disposal sites and facilities. The rules will focus mainly on an environmental response plan to accomplish the following: outline methods for compiling and maintaining an inventory of all sites and facilities in the state having the potential to cause environmental pollution; develop a hazard ranking system for these sites and facilities; establish methods and criteria for determining remedial actions to be taken; establish a process for balancing remedial-action costs with the associated benefits; and specify the roles and responsibilities of federal, state, and local units of government.

Junkyards - none. DNR's authority to license junkyards was removed by Chap. 374, Laws of 1981. DNR can investigate sites and respond to emergency cases involving imminent risks to health and environment.

Wastewater disposal - DNR. Chap. 147, Wis. Statutes, requires any person discharging pollutants into the waters of the state to obtain a Wisconsin Pollution Discharge Elimination System (WPDES) permit from DNR. Chap. NR 110, Wis. Adm. Code, governs the design standards and site selection requirements for sewage treatment lagoons. Chap. NR 206, Wis. Adm. Code, covers land disposal of municipal wastewater, including effluent limitations and monitoring requirements for discharges of liquid waste to land disposal systems, such as seepage pond systems, ridge and furrow systems, spray irrigation systems, and surface spreading systems. Chap. NR 214, Wis. Adm. Code, contains regulations for the land application and disposal of liquid industrial waste and by-products.

Sanitary sewers - DILHR (private); DNR (others). The Department of Industry, Labor, and Human Relations (DILHR), through chap. ILHR 82, Wis. Adm. Code, regulates all lateral connections, requiring them to be "water tight." DNR, through chap. NR 110, Wis. Adm. Code, regulates all interceptor and collector sewers. The DNR code establishes, among other things, leakage criteria and well-separation distances from sewers.

Private wastewater systems - DILHR; DNR. Siting, design, installation, and inspection of all private wastewater systems and licensing of site evaluators, installers, and inspectors falls under the regulatory framework of DILHR (chaps. ILHR 83 and 85, Wis. Adm. Code). Specific authorizing statutes include chaps. 145 and 236, Wis. Statutes. DILHR or DNR (chap. NR 113, Wis. Adm. Code) can prohibit the installation and use of septic tanks in any area where their use would impair water quality (sec. 144.025(2)(9), Wis. Statutes). In those areas, DNR must prescribe alternative methods of waste disposal. For large-scale (cluster or small community systems) (over 8,000 gal/day) additional procedures must be followed. County government works with DILHR issuing permits, inspecting systems, and conducting existing system inspections.

Municipal sludge disposal - DNR. Chap. NR 110, Wis. Adm. Code, contains requirements for sludge handling and approval of land for disposal of sludge. The DNR regulates land spreading of municipal sludge through chap. NR 204, Wis. Adm. Code, which requires a permit, establishes site criteria, specifies minimum distances from wells, and sets application rates.

Septage disposal - DNR. Chap. 146, Wis. Statutes, makes the DNR responsible for licensing persons for holding-tank maintenance and waste disposal (chap. NR 113, Wis. Adm. Code), while DILHR regulations (chap. ILHR 83, Wis. Adm. Code) address the siting and integrity of septic and holding tanks. This program is in the process of being overhauled. The new groundwater law requires municipal treatment plants, under certain circumstances, to accept septage from licensed septage disposers to minimize disposal of septage on frozen lands. New rules in chap. NR 206, Wis. Adm. Code, prohibit the land spreading of holding-tank wastes if the tank is within 20 miles of a sewage treatment plant that can accept the wastes.The law modifies the state septage disposal regulations and gives counties the authority to regulate septage disposal concurrently with the state regulations.

Agriculture

Concentrated animal feeding operations - DATCP; DNR. Cost-sharing exists for livestock waste storage facilities through the nonpoint source abatement program in priority watersheds and through the Wisconsin Farmers Fund (chap. Ag 165, Wis. Adm. Code). Chaps. 147 and 162, Wis. Statutes and chap. NR 112, Wis. Adm. Code regulate the placement of wells in relation to feeding operations. There is also a WPDES category for feedlot operations and a new rule (chap. NR 243, Wis. Adm. Code) regulating animal waste management for large operations. Under this rule, DNR may require monitoring wells in critical conditions.

Fertilizer bulk storage - DATCP. As a result of the groundwater law and sec. 94.645, Wis. Statutes, the Department of Agriculture, Trade, and Consumer Protection (DATCP) has created chap. Ag 162, Wis. Adm. Code. The rule applies to bulk storage of fertilizer by manufacturers and distributors, but not to on-farm storage. The major emphasis is on liquid fertilizer because of the greater risk involved, but the rule also contains general provisions for dry fertilizer. The rule contains standards for storage containers and appurtenances, loading areas, and secondary containment (diking), along with requirements for record-keeping, inspection, maintenance, and development of a response plan for incidental discharges for each facility. The rule includes both new and existing facilities. Although the rule has not been enacted as yet, it is in the final stage of review and will go into effect Jan. 1, 1986. Full compliance with the provisions of the rule would have to be accomplished by Jan. 1, 1988.

Pesticide storage, transportation, and use - DATCP; DNR. Early DATCP authority in the regulation of pesticides was not aimed specifically at protection of groundwater; however, recent ammendments to chap. Ag 29, Wis. Adm. Code (Pesticide Use and Control), are specific to this purpose. The aldicarb rule is one such example. DATCP rules (chap. Ag 29, Wis. Adm. Code) prohibit direct entry of pesticides into groundwater by requiring "good handling practices"; and indirect entry (resulting from use, misuse, or improper storage) of a pesticide into groundwater is, in some cases, a violation of regulations. Secs. 94.67 through 94.71, Wis. Statutes, and chap. Ag 29, Wis. Adm. Code, also state the labeling requirements for pesticide manufacturers and certification requirements for applicators. The certification process is intended to ensure that applicators are trained in proper use of pesticides to reduce the potental risk to groundwater.

The groundwater law also requires DATCP to draft regulations for bulk storage of pesticide. This rule, proposed chap. Ag 163, Wis. Adm. Code, parallels that of fertilizer bulk storage (proposed chap. Ag 162, Wis. Adm. Code) and includes liquid pesticide in containers larger than 55 gallons or solid pesticide in undivided quantities greater than 100 pounds. Variances from the fertilizer bulk storage rules do exist, however, where different chemical properties and other concerns warrant such changes. As with the bulk fertilizer rule, full compliance with the provisions of the rule (which goes into effect Jan. 1, 1986) must be accomplished by Jan. 1, 1988.

Hazardous Materials and Waste

Hazardous waste - DNR. Secs. 144.60 and 144.62, Wis. Statutes, set the state hazardous waste management policy. The rules (chap. NR 181, Wis. Adm. Code) permit transportation, storage, treatment, and disposal of hazardous waste only by licensed operators, and encourage reuse and reduction of hazardous wastes. DNR can prohibit methods of treatment or disposal to protect public health, safety, and environment. Secs. NR 181.41, 181.44, and 181.47, Wis. Adm. Code, contain the environmental and health standards and rules for landfills and surface impoundments, which are similar to those for solid waste facilities. New amendments to the RCRA program will be incorporated into the state program. Chap. NR 183, Wis. Adm. Code, sets requirements for engine waste oil collection, storage, and transportation. Operational requirements include emergency procedures in case of a leak or spill.

Petroleum storage tanks - DILHR. DILHR, in cooperation with local fire departments, operates the plan review program and tank inspection and approval program and sets the construction, operation, and maintenance procedures at tank sites through sec. 101.09, Wis. Statutes, and chaps. ILHR 10 (formerly Ind 8) and Ind 43, Wis. Adm. Code. DILHR also operates a record-keeping system, is completing an audit of old tank locations, and has the authority to establish a leak detection program. As mandated by 1983 Wis. Act 410, Wisconsin's groundwater law, DILHR is rewriting chap. ILHR 10, Wis. Adm. Code--the code that defines several provisions for tank storage of flammable and combustible liquids. The new code incorporates groundwater protection into DILHR's program. Registration of new and existing tanks, tank installation methods, construction standards, inventory procedures, and monitoring requirements are included in the code.

Spills - DNR. Sec. 144.76, Wis. Statutes, deals with hazardous substance spills (it defines hazardous substances very broadly), and chap. NR 158, Wis. Adm. Code, requires contingency plans for emergency response to spills of hazardous substances. Spillers must notify DNR when a spill occurs, abate the spill, and restore the environment to the extent possible.

Wells

Well construction and abandonment - DNR. Secs. 144.04 and 162.01, Wis. Statutes, authorize DNR to set standards, rules, and regulations for obtaining pure drinking water. Sec. 144.025(2)(e), Wis. Statutes, mandates DNR to regulate well construction, installation, and operation of wells where the capacity of withdrawal of all wells on one property is in excess of 100,000 gallons per day. Under chap. 162, Wis. Statutes, DNR licenses drillers and pump installers for drinking water wells. Drillers of non-potable wells need not be licensed. Chaps. NR 111 and 112, Wis. Adm. Code, contain the requirements for the operation and design of public water systems and for private well construction and pump installation. Sec. 111.26, Wis. Adm. Code, requires that municipalities develop ordinances requiring the proper abandonment of all unused, noncomplying, or unsafe wells within the area served by their water systems. Sec. NR 112.21, Wis. Adm. Code, provides the specifications for proper abandonment of private potable and non-potable high capacity wells. The Wisconsin well construction and pump installation code (chap. NR 112, Wis. Adm. Code) is expected to undergo a major revision in 1986.

Monitoring - DNR. DNR has the authority to establish rules to administer the federal Safe Drinking Water Act. The rules are contained in chap. NR 109, Wis. Adm. Code, which also sets primary and secondary maximum contaminant levels for certain parameters for public water supply systems. The rules also contain requirements for testing, reporting, notifying the public, and obtaining variances and exemptions. DNR also has established a monitoring program that is part of the new groundwater law.

Contaminated well compensation - DNR. The well compensation program (chap. NR 123, Wis. Adm. Code) offers owners of contaminated private water supplies partial reimbursement for replacing or reconstructing wells, connecting to a public or other private water supply, or as a last resort, chemically treating the contaminated water. Costs for water tests and for bottled or trucked water as a temporary, alternate water supply are also grant-eligible. The rule is currently being revised.

Wisconsin Groundwater Standards

Wisconsin's new groundwater protection law, 1983 Wis. Act 410 (chap. 160, Wis. Statutes) requires the development and implementation of a two-tiered system of numerical standards for substances that could pollute groundwater. Chap. NR 140, Wis. Adm. Code, has been promulgated to meet this requirement. "Enforcement standards" are levels of specific pollutants that cannot be legally exceeded. When an enforcement standard is exceeded, a state agency must enforce actions that will achieve compliance with the standard or prohibit continuation of the activity. "Preventative action limits"

(PALs) are set at a certain percentage of the enforcement standards. PALs function as an early warning device to alert state agencies that low levels of pollution are developing and that some actions may be necessary to prevent pollution levels from increasing. PALs also are used to establish design and management criteria for some facilities and activities. Designing facilities (such as landfills) and carrying out activities (such as pesticide application) in ways that meet the PALs make it less likely that pollutant levels will reach the higher enforcement standards.

Under chap. 160, Wis. Statutes, DILHR, DATCP, DNR, and the Department of Transportation (DOT) must identify substances that have been or are likely to be detected in the groundwater, and that result from activities regulated by those state agencies. The Department of Health and Social Services (DHSS) and DNR then develop recommendations for preventive action limits and enforcement standards for those substances that are of public health and welfare concern. Each regulatory agency is responsible for compliance with groundwater standards in its own area of authority by adopting rules identifying actions the agency will take if standards are exceeded. DNR has adopted the preventive action limits and enforcement standards for each substance in chap. NR 140, Wis. Adm. Code. Similarly, DATCP drafted chap. Ag 161, Wis. Adm. Code. This rule establishes the regulatory and enforcement actions which the DATCP will take both in response to groundwater pollution and to protect groundwater from future pollution. The new groundwater law also requires regulation of storage of materials that may pollute groundwater. For example, DATCP has developed rules regulating fertilizer and pesticide storage; DILHR is developing rules governing underground petroleum storage tanks; and DOT is preparing rules covering road salt storage sites (Trans. 277, Wis. Adm. Code).

Local Regulatory Options

Introduction

Local regulations that control where various land uses can be located, that specify the types of activities permitted and the manner of carrying them out, and that regulate the density of use can play an important role in groundwater protection.

In addition to considering what to regulate and how to regulate it, it is necessary to determine which unit of government has the authority to adopt a particular regulation. Two basic questions must be answered: 1) has that type of local government been empowered to act?; and 2) has the state preempted local authority? Generally, cities and villages have home-rule powers allowing them to regulate unless there is a statute indicating they may not (for example, matters primarily of statewide concern). Towns with village powers may exercise such powers except those "which conflict with statutes relating to towns and town boards." Towns without village powers and counties, on the other hand, must find a statute authorizing them to regulate.

In some cases the law gives the state sole authority to adopt certain types of regulations. For example, under the groundwater law (1983 Wis. Act 410), the state has preempted the right to set groundwater quality standards. On the other hand, the law authorizes counties to adopt well codes and ordinances controlling land disposal of septage and thus enables them to administer state regulations. Cities, villages, towns and counties, are now also specifically authorized to adopt zoning to protect groundwater. The law also requires state regulation of bulk storage of fertilizers, pesticides, and road salt, but it does not indicate whether these responsibilities can be shared with local government. Generally, the state has preempted regulatory authority where 1) state statute expressly withdraws local power, 2) the ordinance logically conflicts with state legislation, or 3) the ordinance defeats the purpose or goes against the spirit of state legislation.

The following discussion emphasizes the county regulatory role because this report focuses on groundwater protection at the county level. However, county government must coordinate its regulatory activities with those of other local governments and the state. Discussion with representatives of state agencies can help clarify the extent to which state regulations have preempted local authority, can avoid unnecessary duplication of regulations, can provide technical assistance, and can help coordinate administrative details in terms of permits, inspection, and enforcement. An example would be how best to fit county regulation of hazardous materials with state regulation of hazardous waste.

Coordination between the county and the towns and incorporated municipalities in Rock County is equally important. Changes in the county zoning ordinance must be approved by the towns affected. Well-protection regulations generally have to be adopted by cities and villages because the county authority does not extend inside municipal corporate limits unless the county has a health department (which has such authority under chap. 140, Wis. Statutes). Authority to administer the DILHR code relating to underground petroleum tanks belongs to city, village, and town fire departments. Here the county role can be to suggest what additional regulatory provisions should be considered.

The county must be authorized by specific statute to adopt regulations, unlike cities and villages, which have broad home-rule powers. The county has specific groundwater-related regulatory authority in the areas of zoning, well codes, and spreading of septage. We have interpreted the authority granted to counties to adopt and administer sanitary codes (sec. 59.07(51), Wis. Statutes) as a source of additional powers. We believe it can be used to protect the public health and safety by regulating activities that could pollute groundwater, and we use it as the basis for suggesting the county could adopt a hazardous materials ordinance and regulate certain aspects of livestock waste management. A more conservative interpretation of the statutes might disagree with our conclusion; the county should consult with its legal advisor for a definitive opinion.

This section outlines several local regulatory options. The discussion of each of the regulatory programs includes: A) the general elements of the program, B) legal considerations including local regulatory authority, C) advantages and D) limitations of each measure, and E) an evaluation of the applicability of the program.

Yanggen and Webendorfer (1984) describe local land use regulatory options for groundwater protection in a greater detail.

Zoning

A. Elements--Zoning can be used to regulate land use to protect groundwater quality. Several methods are available:

1. General approach -- review ordinance to make activities involving hazardous materials conditional uses and review zoning district boundaries, e.g., make sure that the industrial zoning district is located a safe distance from municipal wells.
2. Naturally vulnerable areas -- establish an overlay district where the potential exists for rapid movement of pollutants to groundwater.
3. Well-protection districts -- regulate potential pollution sources near municipal wells via an overlay district.
4. Potential problem areas -- delineate and regulate areas where potential pollution sources are concentrated in naturally vulnerable areas or where land uses are down flow from sources of suspected pollution.

B. Legal authority -- Cities, villages, towns, and counties are authorized to adopt zoning to protect groundwater and can use any or all of the elements named above. A conditional use may also be regulated in terms of how the activity is carried out, i.e. control over the plan of operations. How certain activities may be conducted may sometimes also be regulated by the state, e.g., solid waste disposal and fertilizer and pesticide storage . In some instances, the state may have the sole authority to regulate how the activity is carried out. Stringency of regulations must relate to potential severity of harm in order to avoid infringing on constitutionally protected property rights.

C. Advantages -- Zoning is preventive and ensures that officials take groundwater into account when development is proposed. Groundwater concerns can be fit into an existing regulatory framework with permits, enforcement, and administration. Delineating special management areas through the use of overlay zoning districts can match the zoning use restrictions to the pollution potential.

D. Limitations -- Uses in existence before passage of zoning or its amendment are permitted to continue as nonconforming uses. Some states permit amortization of nonconforming uses, they require that the uses conform to the ordinance within a specified time or else be removed. Wisconsin courts have never decided whether this may be done. Zoning does not regulate the manner in which permitted uses or nonconforming uses may be carried out. This type of control applies only to conditional uses.

E. Evaluation -- Zoning is an important tool to control new land uses to protect groundwater.

Subdivision Regulation

A. Elements -- Subdivision regulation controls division of land into lots for sale or development, and can require proper stormwater and groundwater management. Traditionally, subdivision regulation has focused on residential development, but it can also apply to commercial and industrial development.

B. Legal authority -- Groundwater protection is clearly authorized. Cities, villages, towns, and counties can all adopt regulations, and cities and villages can regulate outside their corporate limits. If municipal extraterritorial, town, and county subdivision regulations all apply to the same property, the most stringent provisions take precedence.

C. Advantages -- Municipalities can regulate 3 miles (1st, 2nd, and 3rd class cities) or 1 to 1½ miles (4th class cities and villages) outside their corporate limits. Subdivision regulation can control lot size and to some extent, the type of land use permitted, particularly if the regulation is used to implement a plan.

D. Limitations -- Subdivision regulation only applies where a new parcel is created. For example, if an industry were located on an existing 10-acre underdeveloped parcel, subdivision regulation would not apply unless the parcel were further divided. This regulation is better suited to controlling how lands are developed than to controlling the type of uses permitted and the way these uses are carried out.

E. Evaluation -- Subdivision regulation is important to supplement zoning where new parcels are created.

Regulation of Land Spreading of Municipal Sludge

A. Elements -- The regulation involves controls to prevent pollutants in the sludge from reaching the groundwater. The site criteria and application rates must be identical to DNR rules (chap. NR 204, Wis. Adm. Code).

B. Legal Authority -- Although the state has exclusive authority to regulate, DNR generally does not challenge local regulations if they are sound.

C. Advantage -- Regulation of land spreading of municipal sludge can be used to control an important pollution source, and local government is in the best position to inspect the conduct of spreading at sites.

D. Limitation -- The legal authority of the county to regulate is unclear.

E. Evaluation -- The county could request that DNR prohibit land disposal of municipal sludge in vulnerable areas and well-protection zones and allow for concurrent local authority to inspect operation of sites.

Regulation of Land Spreading of Septage

A. Elements -- The groundwater law (1983 Wis. Act 410) specifically authorizes county regulation of the land disposal of septage. The site criteria and disposal procedures specified in the septage ordinance must be identical to DNR rules (chaps. NR 113 and NR 206, Wis. Adm. Code), and the ordinance must also require a soil test and annual license for each site. The county must maintain records of soil tests, site licenses, inspections, and enforcement actions.

B. Legal authority -- Chap. 146.20(5m), Wis. Statutes, states that a county may apply to the DNR for authority to regulate land disposal of septage. The county must include an ordinance and a description of its administrative capabilities with the application.

C. Advantage -- Proper disposal of septage is important to protect groundwater, and local government is in a better position than the state to make on-site investigation.

D. Limitation -- This program cannot currently be implemented because the exact details of what will be required of local regulatory programs are unclear.

E. Evaluation -- Adoption of a county-level septage regulation should be investigated when the DNR administrative rules spelling out the revised state and local regulatory roles are promulgated (probably late summer of 1986).

Livestock Waste Ordinance

A. Elements -- Livestock waste ordinance requires animal waste storage facilities and their management to meet technical standards.

B. Legal authority -- County regulation of earthen animal waste storage facilities is clearly authorized by sec. 92.16, Wis. Statutes. Other types of facilities can probably be adopted as part of a sanitary ordinance under sec. 59.07(51), Wis. Statutes.

C. Advantages -- If a county adopts an ordinance under sec. 92.16 Wis. Statutes, and a county animal waste management plan under sec. 92.15, Wis. Statutes, farmers are eligible for special cost-sharing for barnyard runoff systems and livestock waste storage facilities under the Wisconsin Farmers Fund.

D. Limitations -- It is not clear whether waste management regulations adopted under sec. 59.07(51), Wis. Statutes, must be solely health-related. This is not an area traditionally regulated and regulations may encounter resistance from those affected.

E. Evaluation -- Animal waste storage ordinance may address only a fraction of the problem, bypassing the larger issue of managing livestock waste from confined feeding and holding areas. The earthen animal waste storage ordinance must apply countywide, but other animal waste management regulations could be limited to critical areas.

Hazardous Materials Ordinance

A. Elements -- Hazardous materials ordinance identifies hazardous materials and requires initial and periodic reporting by new and existing enterprises that store, use, or dispose of these materials. It establishes standards for materials storage, handling, and disposal and requires contingency plans in case of spills. It also provides for inspection and enforcement.

B. Legal authority -- Current DNR regulations apply to hazardous waste and spills of hazardous substances. Small amounts of waste (less than 100 kg of hazardous waste per month) are exempt from state regulations. State government has probably not preempted local power to regulate "virgin" materials; local authority is not clear in regard to amounts of waste smaller than those regulated by the DNR. The U.S. Environmental Protection Agency (EPA) must prepare rules for generators of the amounts greater than 100 and less than 1,000 kg per month before March 31, 1986, and in the meantime such waste must be disposed of only at state-approved sites.

C. Advantage -- The ordinance can be applied to existing as well as new uses. It provides detailed control over storage and handling activities and fills in important gaps in state regulations.

D. Limitations -- Self-reporting by existing facilities may be ineffective. Counties would have to control hazardous materials under their authority to adopt sanitary regulations, but municipalities could use statutory home-rule powers. Identifying the materials to be regulated and setting storage standards requires technical expertise, and inspection can be time consuming and expensive.

E. Evaluation -- Local governments should consider such an ordinance if state regulations are deemed inadequate. The ordinance could be designed to apply only to areas adjacent to municipal wells or to other vulnerable areas, and inspection could be limited to spot-checking of the most hazardous sources in vulnerable areas.

Underground Storage Tank Ordinance

A. Elements -- An underground storage tank ordinance would supplement DILHR regulations for underground petroleum storage tanks by requiring annual testing of tanks 10 years or older if they are located in well-protection zones or naturally vulnerable areas. An ordinance should include underground tanks for non-petroleum products as well.

B. Legal authority -- DILHR regulations recognize local fire chiefs as authorized deputies and could authorize other deputies. DILHR regulations recognize that local government can set additional requirements in applicable building codes, local zoning, and similar ordinances. A new draft of state administrative regulations (chap. ILHR 10, Wis. Adm. Code) is currently being prepared that would include mandatory testing of tanks every 5 years and removal of tanks no longer in use.

C. Advantage -- Local records could be used to supplement a DILHR inventory of abandoned underground tanks, and local inspectors could make on-site inspections.

D. Limitations -- Inspection may be time consuming, expensive, and may require technical expertise. The extent to which the county could set requirements for existing tanks beyond what the state requires is unclear. The potential source of authority is sec. 59.07(51), Wis. Statutes, sanitary regulations.

E. Evaluation -- Local deputies may need special training, and close coordination with DILHR may be necessary to make sure that all underground tanks presently in use receive periodic testing and that abandoned tanks are located, inspected, and removed. Highest priority could be given to tanks in special management areas.

County Well Code

A. Elements -- County ordinance (well code) may require a permit before constructing, reconstructing, or rehabilitating a private well or installing a pump.

B. Legal authority -- Sec. 59.067, Wis. Statutes, allows DNR to authorize counties to adopt and enforce a well construction or pump installation ordinance or both. Well codes must strictly conform to DNR rules (chap. NR 112, Wis. Adm. Code), and the DNR may revoke county authority if the code is improperly enforced or not in compliance with the administrative rules. Cities, villages, and towns cannot adopt well codes.

C. Advantages -- Inspection of location and installation of wells can logically be part of county ordinance for conformance with zoning and septic tank codes. The ordinance should also cover abandonment of unused wells (a potential conduit for pollution).

D. Limitations -- Such inspection would in most cases require additional county staff and special staff training. The ordinance must apply countywide.

E. Evaluation -- The DNR expects the new administrative code to be completed in early 1986. When it is available, the county will be better able to estimate the workload and expenditures required to enforce county well code.

Local Non-Regulatory Programs

This section describes a set of actions usually thought of as voluntary. It should be noted, however, that many of these programs commonly supplement regulatory programs--for example, information programs developed in support of regulating underground storage tanks. This section emphasizes the deployment of these programs in voluntary groundwater protection efforts.

Education/Information

Educational programming should be a component of any effort to protect groundwater. A strong educational program will aid citizens and land managers in improving their understanding of the relationship of their land use activities to groundwater protection. Knowledge of the groundwater basics, the sources and nature of pollution threats, and optional management measures is essential if local units of government and citizens are to support and participate in an effort to protect groundwater. Programs can range from those explaining very general principles of groundwater protection to specific programs on toxic-materials handling for small businesses. Programs can take many forms, from traditional films, slide shows, and handbooks to intensive workshops featuring interactive computer graphics. Public media (newspaper, radio) also may be an effective means of reaching the public. Educational materials and programs can be targeted for specific audiences with defined concerns about groundwater and related management activities.

A substantial amount of educational material has been developed in recent years and used throughout the state. A list of materials is available from UW-Extension ("How to Develop Extension Education on Groundwater"), and could readily serve as part of a "groundwater education tool kit."

A multifaceted educational program would include:

1. Basic information on the groundwater resource. -- Individuals making management decisions must have a basic understanding of how groundwater moves, how land use activities can influence groundwater quality, what happens once groundwater is polluted, and how difficult it is to clean up polluted groundwater.
2. Drinking-water quality education. - To a great extent citizens are concerned about water quality because they recognize they must have a safe drinking-water supply. Once citizens recognize that land use activities in their area can affect the quality of their drinking water, they will be more likely to take action to protect groundwater. By improving public understanding that well water should be tested annually and by helping people to understand how to interpret the test results, educational programs will help individual citizens to become more aware of the importance of their role in groundwater management.
3. Specialized educational programs. - Specific educational programs should be directed at activities that pose a significant risk to groundwater, such as solid waste disposal and storage of petroleum products or other potentially toxic substances. Examples of such programs would be voluntary courses through local schools for storers, handlers, and haulers of hazardous waste, in which coursework could be aimed at such concerns as safety, spill prevention, and so forth; or educational programs for individual farmers on such topics as integrated pest management and fertility management.

Waste Reduction

Many communities are evaluating methods to reduce the volume of solid waste that they put in landfills each year. Waste-reduction measures mean lower costs, energy savings, and reduced environmental problems associated with solid waste management (especially reduction in the amount of potential pollutants).

Recycling. - Readily recyclable materials--newspaper, corrugated cardboard, glass, aluminum, and ferrous metals--constitute about 55 percent by weight of municipal solid waste. Recycling saves energy; it saves resources by reducing the need to use raw materials; it protects the environment by reducing pollution (air, water, and land); and it saves and makes money. Recycling requires participation by local residents, either mandatory or voluntary. Counties can play a major role in setting up recycling centers and can act as a source of information for citizens and businesses interested in participating in a recycling program.

Reclaiming Waste Oil. - A new law passed by the Wisconsin Legislature mandates that persons who sell motor oil must either post a sign directing consumers to the nearest waste-oil collection site or set up a collection center themselves. The exact number of waste-oil collection centers each county or municipality must operate depends on population size. The DNR has developed general standards for the design and location of these collection sites to prevent harm to the environment (chap. NR 183, Wis. Adm. Code). Counties can encourage participation in these collection centers through education and information and can set up additional collection centers if necessary.

Household Hazardous Waste Collection/Disposal Programs. -- Typically, household hazardous waste is disposed of with the rest of the household trash, causing risks in waste collection and disposal (especially with respect to groundwater pollution from municipal landfills). Community pilot programs (such as project Clean Sweep) aimed at safe collection and disposal of household hazardous waste are becoming increasingly popular as a way of dealing with this problem in an environmentally sound manner. Most of the successful programs involve hiring a waste-service contractor to handle actual collection and disposal of the waste. These programs are important to educate the public about the hazards to their health and to the environment of improper waste disposal. Some issues to be addressed in starting a community household hazardous-waste collection program include identifying the quantities and character of the waste, determining proper management (both in terms of efficiency and safety) of the program, and considering some economic and legal issues. Funding is available from the DNR until June 30, 1986 for counties or communities to initiate a waste collection program.

Domestic Wastewater

Improper management of waste associated with domestic on-site waste disposal systems represents a groundwater threat in many areas. County government can take actions that would encourage municipalities to accept septage at their sewage treatment plants. While this kind of intergovernmental persuasion can often be difficult, the results can justify the effort.

Clusters of failing private wastewater systems can cause bacterial and viral pollution of groundwater. Nitrate pollution may result even from properly operated systems. Areas with problems can be identified, and the county can encourage the formation of sanitary districts where appropriate. Town sanitary districts are special-purpose units of government designed to provide sewage treatment, stormwater drainage, water systems, and/or refuse disposal facilities and services. Wisconsin statutes provide several different procedures for the creation of town sanitary districts. They may be created either through a petition process and action of a town board or by order of the DNR. District powers are derived primarily from secs. 60.30 through 60.316, Wis. Statutes. Sanitary districts can plan, construct, and maintain sewage treatment facilities. They may sell services to users outside their boundaries and contract with other municipalities for services. In addition, districts may issue regulations, such as requiring the installation of private sewage systems, to promote and preserve public sanitation. Town sanitary districts are granted powers to raise revenues to finance their expenditures, either directly from district residents via property taxes and special assessments, or by user or service charges. Sanitary districts also can finance debt and receive federal or state grants and loans.

Agricultural Best Management Practices

Agricultural practices have a long tradition of being changed only by voluntary actions of farmers managing their own land. The exception to this is the handling of hazardous materials, which is regulated at the state and federal level. The following agricultural best management practices (BMPs) will help improve crop-livestock production and management and minimize the potential for groundwater pollution. Technical assistance for farmers wishing to apply them is available from the UW-Extension as well as from state and federal agencies.

Livestock Waste Management. -- The following principal factors in livestock waste management should be considered for groundwater protection:

1. The proper design, siting, and management of waste storage facilities, especially in areas with thin soils and limiting hydrogeologic conditions.

2. Application of livestock waste to cropland at rates that do not exceed the nitrogen requirements of the crops to be grown.

3. Management of barnyards or livestock holding areas to minimize the potential for groundwater pollution.

Fertility Management. -- As a best management practice, fertility management normally results in the efficient use of fertilizer. This is particularly important for nitrogen, a major crop nutrient that may pollute groundwater. An efficient fertilizer program should consider several factors important in reducing excessive fertilizer application and the potential for groundwater pollution. First, such programs should be based on soil test results. Soil tests indicate the site and crop-specific nutrient needs. Fertilizer should be added only at rates needed to meet the crop's needs. Second, the timing of fertilizer application is important. The efficient use by crops of nitrogen fertilizer can usually be increased by splitting the application, applying some nitrogen at planting and additional amounts at the time of greatest crop uptake. Similarly, placement of fertilizer affects efficiency of nutrient use. Fertilizers should be placed to maximize crop uptake and minimize leaching. Finally, with respect to nitrogen, the form of fertilizer can be important.

Pest Control. -- Effective pest control is essential for profitable crop production. The use of integrated pest management (IPM) programs is the most effective approach available to minimize the use of chemical pest controls. IPM utilizes pest, crop, and weather data in making pest control recommendations. It promotes the use of non-chemical control methods such as pest-resistant varieties, crop rotation, tillage practices, and adjusted planting/harvesting dates. The use of IPM recommendations ensures that pesticides are used only when clearly needed to prevent economic losses. Using this system, pesticides are not only applied at the most effective times, but also at the proper rates and only to targeted areas. IPM stresses proper calibration and operation of application equipment and adherence to all safety precautions. To make this program more usable for growers, crop and pest-specific educational materials are needed on IPM scouting procedures, economic thresholds, and treatment alternatives.

Crop Rotation. -- Food crop rotation programs are effective in suppressing pests that have a short survival period. Reduced pest activities can reduce pesticide use, thereby reducing the potential for groundwater pollution. It should be noted, however, that not all crop rotation programs that produce the desired groundwater protection benefits are economically feasible for growers. The major questions that must be looked at more closely are which rotations have the greatest potential for protection of the environment without causing significant reductions in grower net returns and what the options are for production where groundwater protection objectives might not be achieved under any rotation scheme.

Tillage Practices. -- In some situations, tillage practices can influence groundwater quality. For example, conservation tillage practices are being used to control wind and water erosion. In some situations, this has caused an increase in several insect and disease problems, which may result in more chemicals being used to control these problems. In a given situation, it may be advisable to substitute clean plowing for conservation tillage practices in order to protect groundwater.

Pesticide Container and Rinse-Water Disposal.-- The improper disposal of pesticide containers and rinse water from application equipment can cause groundwater pollution. Currently, triple-rinsed pesticide containers can legally be disposed of at landfill sites. It is generally recommended that sprayer rinse water be sprayed back on agricultural fields. This is not always easily accomplished. The development of approved on-farm rinse-water disposal systems would help ensure that rinse water and pesticides are properly disposed of.

Irrigation Scheduling. -- In general, more intensive agricultural management is practiced under irrigated conditions. Irrigation scheduling is an effective way to ensure that crop water requirements are met and that over-application of irrigation water does not result in leaching of nutrients or pesticides to groundwater. This is accomplished by balancing the amount of water applied through irrigation with the amount of water supplied through natural rainfall to meet the water requirements of a particular crop.

Groundwater Monitoring, Testing, and Information Management

Some counties, through health or other line departments (departments with specific programmatic responsibilities), may initiate a groundwater sampling program in conjunction with, or as a supplement to, state programs. Any such program must necessarily use standardized sample- collection procedures and certified laboratory analyses if the information is to be of use. Counties may also encourage private well owners to have their wells tested regularly for bacteria and nitrates (through drinking-water education programs, for example). Enormous amounts of data can be generated from such testing programs and, along with other kinds of information collected by local governments, can pose a formidable problem in data coordination and information management.

To successfully cope with this requires developing an adequate, centralized state data base of groundwater resource information that is accessible to others interested in using and sharing information. This means keeping good records of all information collected, such as water quality information, soil information, geologic information, and so on. It also means maintaining accurate information on the location of wells, septic systems, potentially polluting land uses, and areas of groundwater pollution incidents. Having the information is not useful unless it is stored in a form that can be retrieved, it includes sufficient geolocators to make the information relevant, and others are aware of and have access to the information. Local units of government considering automation of land resource information should consider how to incorporate groundwater-related data into their systems, while trying to maximize compatibility with state data systems as well.

Planning and Inventory

Most local units of government are involved to one degree or another in planning activities related to land use within their jurisdictions. One very important component of the planning process is the inventory of existing land uses and practices and the identification of areas that may require special consideration because of natural resource characteristics. Chapters II and III represent the inventory and assessment phase of the groundwater planning process for Rock County. Inventories of abandoned landfill sites, sewage lagoons, storage tanks, and particular agricultural practices are types of information that can more accurately and easily be collected and updated at the local level.

Often local efforts are a key complement to state actions. The case of abandoned landfills is illustrative. Many of these abandoned landfills were sited before the existence of design criteria and regulations aimed at groundwater protection. The DNR has undertaken an inventory of abandoned landfill sites in Wisconsin (based on available records) and a public campaign to solicit information. But DNR staff recognize that there are probably many additional sites that their efforts have failed to uncover. Local government has a better chance of locating these additional sites--given its more intimate knowledge of the local situation and its good relationship with local residents. For example, the DNR inventory listed 45 abandoned sites in Rock County (Bakken and Giesfeldt 1985), while the county found 114 abandoned sites and junkyards in 1969 (Rock Co. 1970). County staff can also concentrate their efforts on identifying previous spill sites and farm disposal sites that probably received inadequate attention in statewide inventory efforts. The county can also canvass industries in the county to identify former waste disposal sites.

Agricultural land uses are another type of inventory information better collected at the local level. Agricultural land uses should be inventoried to identify cropping trends and the locations of pesticide handling and use, livestock waste storage facilities, and major barnyards or livestock holding areas. General information on fertilizer and pesticide use in the county may be used to determine geographic and historical trends. Such information is typically not collected or analyzed by the DATCP or the DNR, but may be available to local agencies. At a minimum, there will probably be a need to organize and update available data in such a way that it can be used in a groundwater management program. These inventories can be used to help specify the need for future groundwater management activities, including application of best management practices, education, monitoring, and research.

Inventory work associated with land use planning will also identify areas of special concern. For example, geographic areas where septic systems should not be permitted or important groundwater recharge areas within environmental corridors where development should be controlled can be delineated.

Local Government's Coordination and Proprietary Role

Coordinating local governmental planning functions represents another management opportunity. For some management options, it may be necessary to seek the cooperation of other local governments in the management effort. Many local units of government are presently engaged in planning activities that will influence existing and future land uses. Soil erosion control plans, areawide water quality management plans, priority watershed plans, forest land plans, animal waste management plans, and others have the potential to affect groundwater by encouraging certain land uses and management practices and discouraging others. There is an opportunity to link these planning efforts with activities to protect groundwater. Coordinating or integrating various single-purpose plans to accomplish several objectives simultaneously represents both a challenge and a chance for real accomplishment at the local level.

It is difficult for local government to undertake a groundwater management program with significant effects on the citizenry if that government's management of its own operations does not set a stellar example of good housekeeping. Local government operations can be highly visible and must lead the way. Landfill operations, waste reduction, storage and handling of hazardous waste by governmental employees, salt storage, road deicing, facilities management, and personnel training for spills and emergencies are all things that local government must address in its role as "owner/operator" if its attempts to influence the actions of others in order to protect groundwater are to be taken seriously.

Program Implementation

The number of actions that could be pursued in attempting to protect groundwater at the local level is large. Deciding what should be done is the challenge facing local government. Once a plan identifying alternative possible actions has been prepared, the local governing body must review recommendations and select measures it wishes to see implemented. These policy choices will typically be made by the county board of supervisors or a subcommittee of the board. The lead staff role for program implementation may be assigned to a line department or to a coordinating committee involving several organizational units with groundwater-related responsibilities. Provision should be made for a public information and involvement program; lead responsibility might be assigned to local educational agencies, in cooperation with operational units. Some local units will almost routinely establish a citizen advisory committee to participate in plan selection and implementation. Local government will have to establish a viable means for coordinating state and local actions, as well as interagency activities at the local level. Based on experience elsewhere, it seems prudent for the county board or its subcommittee to oversee and reassess program implementation continuously to maximize the chances for achieving the objectives of the management effort. A final note: even though this report focuses on county government, comparable arrangements could be outlined for any municipality.

Chapter V.

PROTECTION STRATEGIES AND ALTERNATIVES

This report has documented those practices and land uses which pose potential threats to groundwater quality (chap. II); identified "vulnerable areas" where groundwater pollution risks are higher due to environmental factors (chap. III); and described the general "toolkit" available to local governments in Wisconsin for better management and protection of their groundwater resources (chap. IV). This final chapter outlines specific actions that Rock County can take to protect its groundwater from each potential pollution source. Figure 27 summarizes available protection strategies for control of potential pollution sources in matrix form. This chapter also describes protective measures for special management areas, and notes county needs and options for monitoring groundwater quality, as a complement to state programs. Rather than presenting the traditional "recommended plan," this report outlines action choices available to county policy-makers.

Management Alternatives for Controlling Potential Pollution Sources

Potential pollution sources and activities are not ranked in any order of relative risk to health and well-being of citizens or to the environment of Rock County. However, one local environmental health official's ranking of potential pollution sources and their potential risk to groundwater based on available data is given in appendix B. For the purpose of discussion, the potential pollution sources and management strategies available for their control are divided into four groups: waste disposal, agricultural activities, hazardous materials, and other activities as shown on figure 27. The discussion of each source or activity includes: A) the significance of the potential pollution for Rock County, B) relevant state authorities and actions, C) local regulatory options, and D) non-regulatory strategies. The discussion is based on the analysis presented in chapters II through IV, and the reader is referred to these chapters for details.

	GROUNDWATER PROTECTION CONTROL ALTERNATIVES	REGULATORY					NON-REGULATORY							OTHER			
	POTENTIAL POLLUTION SOURCES	Permits	Land Use Controls	Construction Standards	Use Restrictions	Inspection & Testing	Guidelines	Design & Maintenance Criteria	Minimizing Input of Pollutants	Education	Voluntary BMP	Governmental Coordination	Training & Demonstration	Monitoring	Research & Inventory	Remedial Action	Emergency Response
WASTE DISP.	Solid waste sites	●	●	●		●	●	●				●		●	●	●	●
	Junkyards					●				●	●						
	Surface impoundments	●		●		●		●					●	●	●		
	Sanitary sewers		●	●		●		●				●					
	Septic systems	●	●	●	●	●		●		●							
	Sludge & septage spreading	●				●	●						●				
AGRIC.	Livestock waste storage	●		●		●	●	●		●	●			●	●		
	Fertilizer & manure spreading						●		●	●	●			●			
	Pesticides				●		●		●	●	●		●		●		
	Irrigation					●				●	●						
HAZ. MATERIALS	Domestic hazardous materials									●			●				
	Aboveground storage	●	●	●		●		●		●	●				●	●	●
	Underground storage	●	●	●		●		●		●	●	●	●	●	●	●	●
	Transmission pipelines	●	●	●		●		●				●				●	●
	Spills					●	●	●		●		●		●	●	●	●
OTHER	Salt piles & deicing								●		●	●	●	●			
	Well construction & abandonment	●		●				●		●		●					

Figure 27. Protection strategies available for control of potential pollution sources in Rock County

Solid Waste Disposal Sites and Junkyards

A. Findings -- Leachate from solid waste disposal sites is potential groundwater pollutant. To date, a total of 123 abandoned and 10 existing solid waste disposal sites have been identified in Rock County. Leachate has been detected in the groundwater at several sites in the county.

B. State authorities -- The DNR, through chaps. NR 180 and 185, Wis. Adm. Code, regulates the siting, construction, operation, monitoring, and closure of landfills. The DNR is currently inventorying abandoned landfills and will be determining their potential impact on the environment (Bakken and Giesfeldt 1985). In the past, junkyards have been regulated as solid waste facilities. Because of the lack of documented pollution problems resulting from these activities, DNR's authority to regulate junkyards was removed.

C. Local regulatory options -- The state solid waste management rules preempt local controls. Rock County can amend its zoning and subdivision ordinances to require developers in areas of known abandoned waste sites to install monitoring wells to determine if landowners' water is being affected. The burden of proof would be on the developer to document that groundwater in the area is not polluted. The county can consider establishing an inspection program of automobile salvage yards (under the hazardous materials ordinance or under sec. 59.07(38), Wis. Statutes) to ensure proper handling of hazardous materials remaining at the sites after salvaging of automobile parts and to prevent illegal dumping of such materials at junkyards.

D. Non-regulatory options -- Intergovernmental cooperation is essential to deal with the problem of pollution from abandoned sites. Efforts can be made to open channels of communication between the state and county government regarding management strategies, monitoring, remedial actions, and information-sharing. For example, the county can ask to become actively involved in the ongoing state inventory of abandoned solid waste sites and in the risk assessment process. Higher-risk sites, from the county's perspective, can be identified as needing monitoring.

Municipal Wastewater Disposal

A. Findings -- Sewage treatment plants may use treatment lagoons for oxidation and settling and then seepage cells, which allow the treated wastewater to filter into the ground. Poorly sited or operated facilities may cause pollution of groundwater by nitrate, ammonia, and trace elements. Also, municipal sewage may contain industrial chemicals that are not removed in the lagoons. Rock County has two municipal seepage lagoons for effluent disposal; both are being monitored to determine if they affect the groundwater.

B. State authorities -- State regulations govern the disposal of liquid waste and control sanitary sewers. The current rules governing municipal sewage lagoons (chaps. NR 110 and 206, Wis. Adm. Code) are being revised to reflect the new groundwater law. Chap. NR 214, Wis. Adm. Code, contains regulations for the land application and disposal of liquid industrial waste and by-products.

C. Local regulatory options -- There is no apparent county regulatory role.

D. Non-regulatory options -- The county can consider developing an inventory and characterization of surface wastewater impoundments and seepage cells (updated annually) and recommending sites for monitoring to the state. Through governmental cooperation, the county can ask municipalities to report the results of tests of high-pressure sewer lines.

Private Wastewater Systems

A. Findings -- There are relatively few reported or known cases of groundwater pollution resulting from poorly located or maintained private wastewater systems in Rock County. However, significant bacterial contamination has been detected around large concentrations of septic tanks in an area of shallow dolomite in west Beloit. There may be other, unreported pollution cases in Rock County. Discharge from densely spaced septic tanks is a major potential source of nitrate.

B. State authorities -- The siting, installation, and inspection of septic systems takes place at the county level under the regulatory framework of the DILHR (chaps. ILHR 83 and 85, Wis, Adm. Code). State regulations also provide for licensing soil testers and system installers.

C. Local regulatory options -- The county has the authority to inspect existing systems for soil suitability before issuing any building permit. It also has adopted an ordinance requiring mandatory maintenance of new and repaired systems (Rock Co. 1981).

D. Non-regulatory options -- The county can 1) educate the users of septic systems on the dangers of dumping hazardous materials in their septic systems; 2) recommend that the DILHR restrict or ban the sale and use of toxic chemical additives to septic tanks and of septic tank cleaners containing toxic chemicals and eventually require that domestic wastewater be tested for toxic materials; and 3) recommend that those owners of septic tanks who have a private water supply well have their water tested for nitrate, especially if the household includes pregnant women or infants under 6 months of age.

Land Disposal of Sludge and Septage

A. Findings -- Groundwater problems associated with the land application of sludge and septage depend on the concentrations of potentially polluting constituents in the sludge or septage, the application rate, the physical and chemical soil properties, and the distance to the water table. In Rock County, no pollution problems resulting from spreading sludge and septage have been documented.

B. State authorities -- The DNR regulates the land application of sludge from municipal sewage treatment plants through chap. NR 204, Wis. Adm. Code. The DNR also has the authority to prohibit land spreading of sludge at sites where there may be an adverse effect on groundwater quality. Septage application is regulated by chap. NR 113, Wis. Adm. Code, and holding-tank waste disposal by chap. NR 206, Wis. Adm. Code.

C. Local regulatory options -- The county can ask the DNR to keep sludge spreading out of special management areas under the DNR's authority to prohibit spreading (discussed above). The county can review DNR administrative code standards for the optional county septage program and then decide whether to administer this program.

D. Non-regulatory options -- The county can develop educational and training programs for septic and holding-tank owners and septage haulers to educate them on the importance of proper septage and holding-tank waste pumping and disposal.

Livestock Waste Storage and Management

A. Findings -- The number of livestock herds in Rock County is decreasing, but the size of herds is increasing. This results in larger quantities of livestock waste being handled at a given site. The use of livestock waste storage facilities to improve the management and handling of livestock waste is increasing in the County. When properly designed and managed, waste storage facilities help to protect groundwater quality. Improper design and location, however, can lead to significant groundwater problems.

B. State authorities -- For large animal feedlots (more than 1,000 animal units; 1 animal unit = 1,000 lbs) and smaller operations where pollution problems have been documented, the DNR has regulatory authority through chap. NR 243, Wis. Adm. Code. These rules allow the DNR to require that specific livestock waste management procedures be followed and to require operators to obtain a WPDES permit. The DATCP administers the Wisconsin Farmers Fund (chap. Ag 165, Wis. Adm. Code), which makes farmers in counties that develop animal waste management plans and livestock waste storage ordinances eligible for cost-sharing for installation of manure storage facilities.

C. Local regulatory options -- The county has the authority to develop an ordinance requiring that all earthen animal waste storage facilities meet minimum design and siting criteria under sec. 92.16, Wis. Statutes. Similar requirements for other types of facilities can probably be adopted under the authority of sec. 59.07(51), Wis. Statutes. The ordinance could also specify standards for land application of livestock waste.

D. Non-regulatory options -- County University Extension and County Land Conservation personnel can continue to provide information to livestock producers on recommended procedures to maximize crop utilization of nutrients available from livestock waste. In developing a countywide livestock waste management plan, the county can undertake an inventory of all existing livestock waste operations and storage facilities. The county can consider requiring the operators to monitor all feedlots with more than 300 animal units and all those located in vulnerable areas.

Fertilizer and Livestock Waste Spreading

A. Findings -- Rock County groundwater often has high levels of nitrate (see fig. 17). Two potential major sources of nitrate are agricultural fertilizer and livestock waste. The overapplication of nitrogen in any form usually results in increasing the amount of nitrate available for leaching to groundwater.

B. State authorities -- Currently no state regulations govern the land application of fertilizer or livestock waste. New rules for handling and bulk storage of fertilizers are being prepared by the DATCP (chap. Ag 162, Wis. Adm. Code).

C. Local regulatory options -- The county can regulate land application of livestock waste as part of an animal waste management ordinance.

D. Non-regulatory options -- The use of soil tests and the best available research-based information on rates, timing, and methods of nitrogen-fertilizer application can help reduce potential groundwater pollution problems. Intensified educational efforts to encourage farmers to recognize and credit nitrogen from sources other than commercial fertilizer, including livestock waste, whey, and nitrogen fixed by legume crops, will help minimize the potential for increased levels of nitrate pollution from agricultural activities. An additional step would be for the county to work with farmers in a voluntary reporting program to document the types, methods, and amounts of materials applied to fields.

Pesticide Storage, Handling, and Use

A. Findings -- Intensive agricultural and urban activities in Rock County result in extensive use of pesticides to control a wide array of pest problems. Limited monitoring to date seems to suggest that proper land application of pesticides has not yet resulted in groundwater pollution. However, sites where commercial applicators handle large quantities of pesticides present a significant potential for groundwater pollution.

B. State authorities -- The State Pesticide Review Board registers pesticides. Recent groundwater legislation (1983 Wis. Act 410) has required that the DATCP promulgate rules for handling and bulk storage of pesticides (chap. Ag 163, Wis. Adm. Code). Additional requirements of this law mandate the DATCP to identify pesticides that have the greatest potential for contaminating groundwater. The DATCP is working with the DNR and the DHSS to establish groundwater standards and preventive action limits for these substances (chap. Ag 161, Wis. Adm. Code). Implementation and enforcement of rules should reduce the potential for groundwater pollution. No rules effectively govern the disposal of pesticide containers, residual pesticides, or rinse water.

C. Local regulatory options -- Even though the county has no direct regulatory authority in this area (except its Public Health Nuisance Ordinance), it can identify the locations where commercial applicators are storing and handling large quantities of pesticides and request the DATCP or the DNR to monitor and regulate them where appropriate.

D. Non-regulatory options -- Research has shown that a substantial number of private applicators are not calibrating pesticide application equipment accurately. The county can intensify education to assist applicators in properly maintaining and calibrating such equipment. Substantial progress has been made in developing integrated pest management practice recommendations for major crops grown in Rock County. Efforts to advise farmers of these recommendations should continue. When possible, field days and demonstrations of IPM scouting procedures should be conducted, and information on the availability of IPM scout services should be supplied to farmers.

Irrigation

A. Findings -- The use of irrigation to enhance crop production is increasing in Rock County. The potential for groundwater pollution from agricultural practices often increases with the use of irrigation for several reasons. First, irrigation is usually done on soils with rapid permeability and low natural protective ability. Second, irrigated crops are generally managed for higher levels of productivity. Increased rates of water application and higher rates of fertilizer or pesticide application mean increased potential for nitrate or pesticides to be leached out of the root zone and into the groundwater, especially if major storm events follow application of irrigation water. Third, fertilizers and pesticides may be applied directly through irrigation systems. If these systems are not equipped with back-flow preventers, fertilizers or pesticides may back-siphon down the irrigation well and pollute groundwater. Proper irrigation techniques, along with other best management practices, will keep the potential for groundwater pollution to a minimum.

B. State authorities -- The DNR regulates irrigation wells with a capacity of more than 100,000 gpd (chaps. 144 and 162, Wis. Statutes) and requires that back-siphoning valves be installed on irrigation systems where fertilizers and pesticides are injected and applied through the system and that the valves be inspected annually. However, no coordinated program insures that this inspection is conducted.

C. Local regulatory options -- The county's authority to develop local inspection programs is unclear. A potential source of authority can be found in a county hazardous materials ordinance, in turn based upon the powers given to the county to adopt a sanitary code under sec. 59.07(51), Wis. Statutes.

D. Non-regulatory options -- The UW-Extension has developed an irrigation scheduling program. This program has been piloted in Rock County, and most growers are using the irrigation scheduling procedures to determine when to irrigate and how much water to apply. Research has also been conducted on how much production will increase under irrigation. Soil test recommendations have been modified in light of the additional nutrient needs of crops managed for these higher levels of production. Educational efforts to inform and advise farmers of the latest irrigation scheduling findings and nutrient recommendations should continue.

Household Hazardous Materials and Waste

A. Findings -- Most homes generate small quantities of potentially troublesome chemical materials. These include unused automotive products, pesticides, paint products, solvents, and household cleaners. If spilled or poured on the ground or down the drain (and eventually discharged through septic systems), they can directly infiltrate to groundwater.

B. State authorities -- Currently, there are no hazardous waste sites in Wisconsin where these unused chemicals can be safely disposed of.

C. Local regulatory options -- There is no apparent county regulatory role.

D. Non-regulatory options -- An informational component of the county groundwater protection program can include educational materials (brochures, newspaper articles) regarding proper handling and disposal of hazardous materials used in households. The county can contract with a licensed hazardous-waste hauler to accept the unused chemicals. Periodically, local municipalities can organize "Operation Clean Sweep" projects urging citizens to bring any unused hazardous materials accumulating in basements and garages to a centralized location for safe disposal. The county can consider organizing a demonstration program based on the experience of the city of Madison or other locations.

Aboveground Storage of Hazardous Materials

A. Findings -- Aboveground storage tanks present substantially lower pollution potential than underground tanks because they can be inspected for corrosion and leaks from the outside. Small leaks can be detected before they develop into large leaks, and the spills resulting from leaks can be contained and more easily cleaned up. Installation of containment structures helps reduce the risk of pollution from leaks and spills at aboveground storage tanks.

B. State authorities -- Current state regulatory activities include the regulation of aboveground petroleum product storage tanks by the DILHR (chap. ILHR 10, Wis. Adm. Code). DATCP regulates bulk storage of fertilizers and pesticides. The following section on underground storage tanks describes the new rules being developed for both underground and aboveground storage of hazardous materials.

C. Local regulatory options -- The county can consult with the DILHR and the DATCP to determine the extent to which additional local regulations may be desirable to supplement state regulations.

D. Non-regulatory options -- The county can develop an information and education programs on the potential dangers from the storage of hazardous materials. The county can encourage voluntary management options such as containment structures, equipment maintenance, operation and safety procedures, and contingency spill plans. The county can also assist in the inventory and registration of all hazardous-materials storage tanks and their contents.

Underground Storage Tanks and Pipelines

A. Findings -- Underground tanks for storage of hazardous materials in Rock County have the greatest potential to pollute groundwater by developing leaks due to material failure through corrosion or to poor operating practices. Leaking underground storage tanks (acronym: LUST) are potentially far more damaging to groundwater than leaking aboveground tanks. First, the volume of liquid which can be lost from an underground tank is not limited to the volume of the tank: if the leak is small enough and the turnover of the liquid in the tank is rapid enough, the leak may continue unnoticed for a long time until it manifests itself in wells, basements, or surface water. Second, potential pollutants are closer to the underlying groundwater and below the biologically active soil layer where attenuation of the pollutants might take place.

B. State authorities -- The DILHR has the authority to regulate underground tanks for storage of flammable and combustible liquids. The existing regulations (chap. Ind 8, Wis. Adm. Code) are currently being revised and will require registration and periodic testing of tanks (chap. ILHR 10, Wis. Adm. Code). City, village, or town fire chiefs administer the rules as DILHR's designated deputies. The state has no authority over oil pipelines, and the Public Service Commission regulates natural gas pipelines. The federal government is presently examining the adequacy of standards for hazardous liquid pipelines. Therefore, it is difficult for the state or county to act in its own right.

C. Local regulatory options -- The county can help coordinate local underground storage tank inspections and can investigate the possibility of establishing underground storage tank ordinances setting additional requirements beyond those set by the state.

D. Non-regulatory options -- The county can establish an inventory program to complement state programs. Besides inventorying the location of tanks, their contents, age, and construction material, the county or a municipality can establish a program to monitor tanks located close to municipal wells and in other sensitive areas. Some of the monitoring sites may be suggested for inclusion in a state groundwater monitoring program. County staff can develop information and education programs, primarily brochures and pamphlets for distributors, service station operators, and farmers. These programs should focus on the magnitude and seriousness of the problems of leaking tanks, how they can pollute groundwater and endanger drinking water supplies, and how the pollution can be prevented. County staff can also develop a voluntary training program for fire officials and tank inspectors, similar to that described above under local regulatory options.

Spills of Hazardous Materials

A. Findings -- Spills are an inherent danger of all activities related to the storage, handling, and transport of hazardous materials. Therefore, special measures are necessary to prevent hazardous materials from spilling and potentially entering the groundwater. Rock County has had 77 spills reported since 1968.

B. State authorities -- Current Wisconsin law places spills under the jurisdiction of the DNR (chap. 158, Wis. Adm. Code), which requires contingency plans where preventive measures are deemed inadequate. DATCP rules governing the storage, handling, and transport of pesticides (chap. Ag 29, Wis. Adm. Code) also call for the preparation of contingency plans. Preventive controls are included in state laws regulating transportation of hazardous materials.

C. Local regulatory options -- The county can require contingency cleanup plans for facilities storing and handling hazardous materials under its zoning and other regulatory authority. The county can set an example by requiring such plans for any of its departmental operations that might result in a spill.

D. Non-regulatory options -- The county can monitor spill sites in the high-risk areas (see plate 3) and spill sites near municipal and other public water supply sources. The county can help coordinate emergency responses and remedial actions taken by state or local officials. This can include summarizing the results of remedial actions, reporting problems to the state, and mapping spill sites. Information and education programs should describe emergency steps to be taken in case a spill occurs and explain cleanup procedures.

Storage and Use of Salt for Highway Deicing

A. Findings -- Not enough information is available to determine the impact of salt storage and highway deicing on groundwater in Rock County.

B. State authorities -- Currently, no regulations govern the storage of salt used for highway deicing. The DOT is required to establish standards for salt storage under the provisions of the new groundwater law (proposed chap. Trans 277, Wis. Adm. Code).

C. Local regulatory options -- No county regulatory measures are recommended at this time.

D. Non-regulatory options -- The best tool for controlling potential problems is governmental cooperation since all salt storage areas belong to, and all deicing is being done by, government in one form or another. The county can set an example by providing its own storage areas with adequate cover and containment structures and by introducing best management practices for salt application. It can also consider setting up a monitoring program in sensitive areas to determine if the storage or use of salt for deicing has an effect on groundwater in the county.

Water Wells

A. Findings -- Water wells, under certain conditions, can be conduits for groundwater pollution (see chapter II). Abandoned wells that are not properly sealed pose a great threat to groundwater because they permit water containing pollutants to migrate freely from one aquifer to another or from the land surface to an aquifer. Intentional dumping of waste into abandoned or unused wells can also be a problem.

B. State authorities -- The DNR regulates well construction and abandonment (chap. NR 112, Wis. Adm. Code) and also requires well drillers to be registered. The rules are currently being revised to include provision for county administration of this program.

C. Local regulatory options -- The county can review DNR requirements for a county well code program to determine whether it wishes to administer one. It can also ask the DNR to require well drillers to indicate on the well construction report if a well was replaced or deepened because of pollution.

D. Non-regulatory options -- Currently, well drillers must send well construction reports to DNR to be filed. Files of well driller's reports are also maintained by the WGNHS and are accessible to anyone interested. The county can ask the DNR to supply copies of well drillers' reports and then establish its own file on water wells. The county can also work with the DNR to report misuse or abuse of wells and help identify abandoned or unused wells in the county. The county can develop information and education programs to alert the public to the danger of dumping waste or other materials into abandoned or unused wells.

Special Management Areas

The previous section considered various land uses and activities in terms of their potential to pollute groundwater. This section focuses on special management areas--those locations in the county that have a high susceptibility to pollution and that should receive high priority in a groundwater management program. The shift is thus from the uses themselves to the places where they occur. Three types of special management areas considered for Rock County include:

1. Naturally vulnerable areas--those locations particularly susceptible to groundwater pollution because the soils, subsoils, and bedrock do not provide adequate protection against the rapid movement of pollutants to groundwater;

2. Well-protection zones--the areas contributing groundwater to an existing or planned public well;

3. Potential problem areas--places where potentially polluting uses are concentrated in naturally vulnerable areas or areas where pollutants have entered the groundwater.

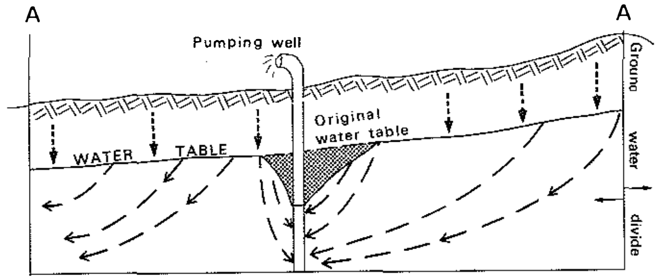
Special management areas allow local governments to concentrate limited resources in key locations and set priorities in terms of the geographic scope of programs. The discussion that follows describes the three special management areas in more detail along with the regulatory techniques most appropriate to each.

Naturally Vulnerable Areas

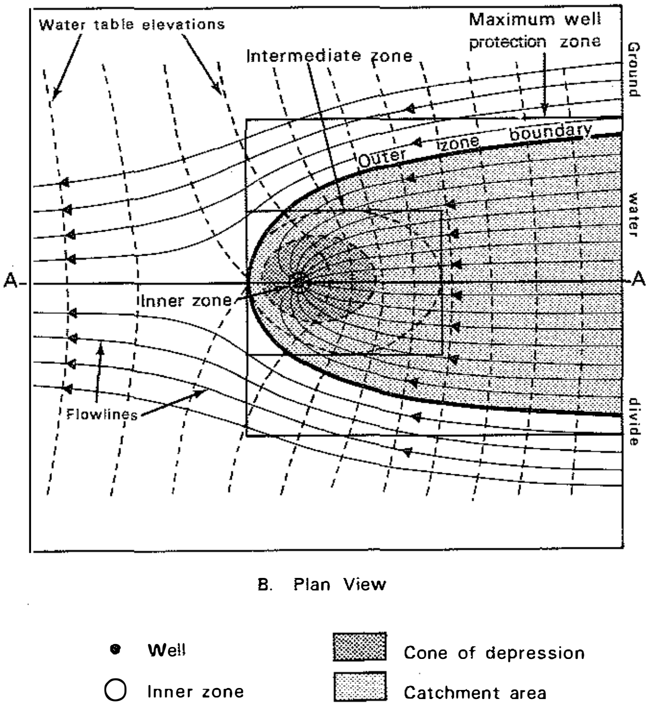
Interpretation of the soil and geologic data in chapter III indicated naturally vulnerable areas in Rock County (plate 3). By delineating vulnerable areas, it is possible to relate the stringency of controls to the severity of the threat of groundwater pollution. The most stringent control is to prohibit a use; less stringent measures would make it a conditional use to determine whether it is appropriate for a particular location, set lower densities of development, or impose site and operating standards. One regulatory approach would be to create a vulnerable-area overlay zoning district (groundwater protection zone). Within this zoning district all potentially polluting uses would be made conditional uses. When a conditional use is proposed, the applicant would be required to show that appropriate safeguards will be used to protect groundwater. If the applicant declined to provide the required information, the use would be prohibited.

Well-Protection Zones

All drinking water in Rock County is supplied from groundwater. These essential supplies may be protected by delineating well-protection zones, in which potentially polluting uses and practices are controlled. This scheme is most appropriate for protecting municipal wells in water table aquifers such as the sand-and-gravel aquifer in the county. Well-protection zones identify the land areas contributing groundwater to a well. The protected area may be subdivided into several management zones, depending on local hydrogeologic conditions (fig. 28) and local acceptability. The delineation of appropriate management zones involves a substantial degree of judgment. Important considerations include the hydrogeologic factors affecting attenuation, existing and proposed land uses, and the effect of restrictions on land values. In some cases it may be necessary to adjust the zone boundaries to respond to political or administrative factors in addition to hydrogeologic ones.



A. Cross Section



B. Plan View

Figure 28. Well-protection zones

The smallest zone, the inner zone of protection, is the immediate area around the well with a minimum radius of about 50 feet. In Wisconsin, the minimum, inner zone boundary is defined by the requirements of chap. NR 111, Wis. Adm. Code, which states that for wells serving municipalities and subdivisions "a lot or parcel of land shall be reserved for the construction of the well, which has minimum dimensions of 100 feet by 100 feet." This zone should be protected against all human activities.

The largest zone, the outer zone of protection, may cover the entire catchment contributing groundwater to a well. This catchment area (zone of contribution) is the upgradient part of the aquifer recharge area inside which flow lines move toward the well; outside the catchment area, flow lines are unaffected by pumping the well (fig. 28).

In some cases the catchment area may be too large to allow effective management. One way to reduce its size to manageable proportions is to select a smaller portion of the catchment area as an intermediate zone of protection. This zone can include, for example, the "cone of depression" around the well, which includes that portion of the catchment area in which groundwater elevations are lowered by pumping. Any well, when pumped, creates a cone of depression. When pumping is started, the original water table in the vicinity of a pumped well drops (fig. 28). The surface projection of the cone of depression is circular or oval depending on the slope of the water table. The size and shape of each cone varies depending upon the pumping rate, duration of pumping, slope of the water table, and recharge within the zone of influence of the well. Pollutants entering the ground above the cone of depression can move rapidly to the well and thus pose the greatest threat. Therefore, this area should always be protected against undesirable uses.

Other limits of the intermediate protection zone extending beyond the cone of depression can be expressed in terms of time or distance. This is based on the concept that pollution tends to be attenuated more the longer the time and the farther the distance travelled. The limits of all zones should be visibly marked.

The following regulatory options illustrate techniques that can be used for controlling activities that are potentially threatening to the quality of the municipal water supply.

1. Place the area of the cone of depression in a conservancy zone, which permits only those uses that do not alter the natural character of the area in a way that affects groundwater. However, zoning must allow some reasonable use of the land in order to avoid an invalidation in court on the basis that private property rights have been taken. In some cases, it may be necessary to purchase certain development rights.

2. Zone the land within the cone of depression for residential use served by public sewer and water. These basic zoning districts can then be supplemented by an overlay district that prohibits potentially polluting activities such as those involving hazardous materials.

3. Establish several well-protection overlay zones with the most stringent controls on the area making the most immediate contribution to the well. Further away from the well (i.e., outside the cone of depression but within the catchment area) prohibited uses can be made conditional uses and higher densities can be allowed. An additional overlay district within the catchment area may be warranted in some cases, located farther away from the well than the previous zone and having less stringent standards for conditional uses.

Potential Problem Areas

Potential problem areas involve two general situations: 1) areas where uses that could cause pollution--particularly storage and handling of hazardous materials--are concentrated in areas most vulnerable to pollution (plate 3) and 2) areas of suspected pollution where pollutants may already have entered the groundwater.

Vulnerable areas warrant special attention because there spills can most easily reach the groundwater. An example, cited earlier in chapter III, is the Janesville-Beloit corridor, which has a high concentration of storage tanks and sludge disposal sites. This area is underlain by a highly permeable sand-and-gravel aquifer that is a source of municipal water supplies. Zoning can help prevent further problems from developing to the extent that these locations are regulated as vulnerable areas or well-protection zones. Zoning, however, applies primarily to proposed new development, rather than to existing uses or activities. Potential problem areas are, by definition, locations where development already exists. Regulations that require a permit to engage in or continue certain activities that may pollute groundwater are thus needed. Examples of these kinds of regulations (discussed in the section on local regulatory options) include controls over land spreading of sludge and septage, a hazardous materials ordinance, and an underground tank ordinance. These regulations apply to existing as well as proposed uses. The issues of local statutory authority and state preemption, as well as administrative considerations, make it important to consult state agencies in preparing these regulations.

The purpose of identifying and regulating the areas of suspected pollution is to restrict development "down flow" from a suspected pollution source unless the developer can ensure an adequate supply of safe water. Information needs can vary substantially, depending upon the nature of the problem. If development is proposed in the vicinity of a suspected pollution source such as an abandoned dump, the basic information needed is the direction of groundwater flow, the shape of a pollution plume, and the nature of the pollutants. With this information, government can establish special regulatory limits down flow of the site where particular attention is paid to groundwater quality. For example, in the case of a residential development, subdivision regulations can require the developer to monitor water quality and post a long-term performance bond along with an agreement to provide a safe private water supply.

In some cases a pollution plume may be encountered. Identification of areas likely to be affected by the plume depends on an assessment of the groundwater flow system and on the character of the pollution itself. Different pollutants have different breakdown rates and different patterns of dispersion and dilution, and represent different hazards. Estimating the path of a pollution plume through the groundwater system can be complicated by aquifer characteristics, the influence of pumping wells, and many other considerations. Models of different levels of complexity have been developed for predicting pollutant transport and dispersion. The complex technical information needs of plume identification and management may put it beyond the scope of local efforts and may require the services of a specialized consulting firm. In some instances the only alternatives to plume management may be connection to a safe public water supply or hauling of water where public water supply is not available.

Monitoring Needs

Since no preventive system for controlling groundwater pollution is "fool-proof," groundwater must be monitored. The major goal of monitoring is to determine if sources of potential pollution are managed within limits necessary to meet drinking water and groundwater standards in Rock County.

We must emphasize that monitoring <u>does not protect</u> groundwater quality; it only <u>measures</u> groundwater quality. Monitoring programs are used to measure the effectiveness of protection efforts and to signal the need for remedial action programs.

Monitoring in Rock County can be done at two levels:

1. monitoring for early warning, which establishes water quality trends, detects the presence or absence of pollutants, and determines the need for further monitoring;

2. monitoring of pollution sources, which involves the measurement of groundwater quality around potentially polluting sources; this may evaluate the threat of the source, help determine extent of damage, and identify remedial action.

Monitoring for Early Warning

Detective monitoring should be the starting point from which to build a countywide monitoring program. It should involve the coordination of existing monitoring programs in the county and additional monitoring of existing wells and springs. No drilling of new monitoring wells is required.

This monitoring can take advantage of the periodic testing that must be conducted for public water supply wells under the federal Safe Drinking Water Act (SDWA) of 1974. By assuming the primary enforcement responsibility under the SDWA, the DNR assumed the responsibility for monitoring the community and noncommunity water systems that supply water to the public (see fig. 1). The community systems are tested, in a 3 to 5 year period, for several inorganic chemicals as listed in chap. NR 109, Wis. Adm. Code, for nitrate and fluoride concentrations, and for coliform bacteria. They are also tested at least once for radioactivity and volatile organic compounds (VOC). Monitoring of noncommunity systems includes nitrate and coliform bacteria on a 5-year basis.

Because of the nature of groundwater pollution, random countywide monitoring would be of little use in detecting individual cases of pollution. A sampling network using wells scattered over the county is likely to miss most pollution occurrences and thus produce misleading results. However, countywide monitoring of the overall quality of groundwater will help to determine changes and trends in the background groundwater quality, to detect the effects of areawide, nonpoint sources (like fertilizer application, which may result in increasing nitrate concentration), and to determine the quality of groundwater coming from adjacent counties.

The county should continue to monitor well water for nitrate content and to warn well owners of possible health hazards of high nitrate concentrations. Monitoring for nitrate and overall trends in water quality can be done on existing wells, preferably those with available well construction reports. As a first step, the county can start monitoring those wells found to have nitrate-nitrogen concentrations in excess of the standard 10 mg/l (see fig. 17) during the 1980-81 investigation (Zaporozec 1982) and can select a few more in townships with inadequate areal coverage: Fulton, Milton, Magnolia, Janesville, Bradford, Avon, and Clinton.

Monitoring of Pollution Sources

Because it is not feasible to monitor all sources of potential pollution, the program should concentrate on identifying the most important sources, such as those located in naturally vulnerable areas (see plate 3). If there are nearby water supply wells that may potentially be threatened by pollutants coming from such sources, immediate steps should be taken to check their quality and to continue monitoring for the pollutants characteristic of these sources. In essence, the design of a pollution source monitoring system becomes a financial allocation problem, with the goal of developing a cost-effective monitoring program that will contribute most to the county's groundwater management program.

The degree of monitoring required by the DNR for waste disposal sites varies with the sites. Currently, four sites in Rock County have monitoring systems required by the DNR--the city of Janesville sanitary landfill, Edgerton landfill, and two seepage lagoons for the cities of Evansville and Milton.

The county can establish, in cooperation with other municipalities and agencies, monitoring of tanks and spills of hazardous materials located close to municipal wells or in the most vulnerable areas. Some of the monitoring sites may be suggested for inclusion in a state groundwater monitoring program. The county can also consider setting up monitoring of the impact of highway deicing in pollution sensitive areas.

Besides considering its own monitoring, the county can become involved in state monitoring programs--for example, in the selection of monitoring sites around landfills, surface impoundments, and seepage areas placed in high-risk areas. Also, the county can request the DNR or the DATCP to conduct monitoring around abandoned landfills in which toxic materials have been identified and in pollution-risk areas where commercial applicators are storing and handling large quantities of pesticides.

In special cases, as a part of its land use permitting authority, the county can require installation of monitoring wells for proposed developments. The county can require the operators of feedlots with more than 300 animal units located in critical recharge areas to install monitoring wells, or the developers in areas of known abandoned waste sites to determine if groundwater in the area is polluted.

Monitoring Requirements and Specifications

An effective monitoring program must recognize the dynamic nature of groundwater systems as affected by both natural phenomena and human-induced changes. Therefore, the program must be continuous, although its scope and relative emphasis will change over time. Costs will vary directly with the purpose and therefore the level of the monitoring program: the more information desired, the higher the costs will be. The total monitoring effort should also be related to the costs of dealing with undetected problems and the chances that they will occur.

Reliable monitoring is very technical work, and the design and evaluation of monitoring systems requires trained personnel. Technical assistance to aid in developing a county monitoring program is available from the WGNHS, the USGS, and the DNR. Design and evaluation should be contracted with a reliable consulting firm.

Recommendations

If Rock County decides to proceed with a local groundwater protection program, what are the next steps to be taken? First, the county will have to decide how to organize internally to review the results of this study and formulate an action program. An important element of this local planning effort will be the development of a public involvement and educational strategy. Decisions about the timing and content of public educational programming will be critical. This report can serve as a point of departure in discussing the groundwater resource and its use and problems, and options for action with county citizens. This process should lead to the identification of the most serious and highest priority groundwater pollution problems and sources and special management areas to be addressed in the county's program. Also there is a need to consider comprehensive approaches to groundwater and surface water management, which do not achieve one set of objectives only at the expense of another.

Some management program options may include requests by the county for action by state authorities or by local governmental units. Instititutional arrangements for intergovernmental coordination will have to be devised to successfully undertake much of any program, e.g., well-protection zoning with municipalities, groundwater monitoring in conjunction with state agencies, and so on. Of course, the county's management priorities and specific work plans will have to be developed with an eye towards local fiscal constraints and the possibilities for funding from other governmental units with complementary groundwater-related interests.

In undertaking a groundwater protection program, the county must be willing to make a long-term commitment to protecting its groundwater resource. The time and effort it takes to put such a program into place is an important consideration in developing a county groundwater protection program.

Clearly the governmental officials and citizens of Rock County will make up their own minds about how to proceed and which items should receive priority. The following merely provides an example of actions, not in any priority order, that Rock County can include in its groundwater protection program.

Some management program options may include requests by the county for action by state authorities or by local governmental units. Instititutional arrangements for intergovernmental coordination will have to be devised to successfully undertake much of any program, e.g., well-protection zoning with municipalities, groundwater monitoring in conjunction with state agencies, and so on. Of course, the county's management priorities and specific work plans will have to be developed with an eye towards local fiscal constraints and the possibilities for funding from other governmental units with complementary groundwater-related interests.

In undertaking a groundwater protection program, the county must be willing to make a long-term commitment to protecting its groundwater resource. The time and effort it takes to put such a program into place is an important consideration in developing a county groundwater protection program. Clearly the governmental officials and citizens of Rock County will make up their own minds about how to proceed and which items should receive priority. The following merely provides an example of actions, not in any priority order, that Rock County can include in its groundwater protection program.

- Develop informational and educational programs relating to major potential pollution sources.
- Meet with the DNR to explore the possibility of a joint program regulating the storage, handling, and disposal of hazardous materials.
- Develop a program to inventory, inspect, and regulate underground storage tanks in conjunction with the DILHR.
- Identify more precisely those agricultural activities involving disposal of animal waste and heavy usage of fertilizers and pesticides and require monitoring as appropriate.
- Identify the Janesville-Beloit corridor as a special management area and initiate actions suggested in this report.
- Undertake a well-protection program in cooperation with Rock County municipalities.
- Adopt appropriate land use controls down flow from all abandoned landfills and meet with the DNR to establish priorities for monitoring landfills.
- Discuss groundwater protection efforts with business, industry, agriculture, governmental units, and the general public.

CONCLUSION

In this report, we have taken as a given the primary goal of protecting present and future groundwater supplies in the aquifers of Rock County. The aim of a local groundwater management program must be to prevent groundwater pollution and to protect public health. At the outset of this report, we indicated that the goals of this project were to provide environmentally sound management recommendations and technical assistance to Rock County in order to develop a county groundwater protection program. We have done this by

- Inventorying the sources of potential groundwater pollution in the county and assessing the relative importance of these sources. This has been done in varying levels of detail, dependent upon data availability and time constraints; some additional inventory needs are noted. This additional work can be done in stages depending on the priority county officials and citizens assign to the need for further information.

- Identifying those areas of the county most susceptible to pollution of groundwater, based on natural vulnerability and use factors. Certain types of special management areas, for example, well-protection zones, will require further, more specific delineation.

- Identifying and assessing regulatory and non-regulatory tools and approaches that can be used to address different sources and types of groundwater pollution problems.

- Suggesting specific action alternatives that the county can pursue in its groundwater protection program. The choice of actions undertaken by the county obviously depends upon local priorities and perceptions of groundwater problems and on the feasibility of local management.

As county officials focus on the options of greatest interest to Rock County in terms of implementation, we anticipate assisting the county in assessing the feasibility, the fiscal aspects, and the probable impacts and effectiveness of the proposed programs. University Extension and the Department of Natural Resources are prepared to provide follow-up technical assistance and supporting analysis and to help the county to face the challenges of developing and implementing a local groundwater protection plan.

REFERENCES CITED

Aller, L., and others, 1985.
DRASTIC: A standardized system for evaluating ground water pollution potential using hydrogeologic settings: U.S. Environmental Protection Agency Report EPA/600/2-85/018, 163 p.

Bakken, J., and Giesfeldt, M.F., 1985.
Locating and repairing abandoned waste sites: Wis. Dept. of Natural Resources, p. B38-B39 and C25.

Bobolz, L., personal communication, December 21, 1984.
Rock County Water and Land District Conservationist, Janesville, Wis.

Calabresa, T.A., 1981.
An assessment of Wisconsin's groundwater availability and quality; a special report to the DNR Secretary (in preparation).

Cotter, R.D., and others, 1969.
Water resources of Wisconsin, Rock-Fox River Basin: U.S. Geological Survey, Hydrologic Investigations Atlas HA-360, 4 sheets.

Crowley, J. W., personal communication, December 14, 1984.
UW-Madison, Dairy Science Department.

Devaul, R.W., 1975a.
Probable yields of wells in the sand-and-gravel aquifer, Wisconsin: Wis. Geological and Natural History Survey/U.S. Geological Survey map, scale 1:1,000,000, 1 sheet.

Devaul, R.W., 1975b.
Probable yields of wells in the sandstone aquifer, Wisconsin: Wis. Geological and Natural History Survey/U.S. Geological Survey map, scale 1:1,000,000, 1 sheet.

DiNovo, F., and Jaffe, M., 1984.
Local groundwater protection, Midwest region: Amer. Planning Assoc., Chicago, Ill., 327 p.

Everett, L.G. (editor), 1980.
Groundwater monitoring: General Electric Co., Schenectady, NY 12300, 440 p.

Farmland Industries, 1982.
Co-op agricultural chemicals product guide: Farmland Industries, Kansas City, MO, 179 p.

Fodroczi, J., and others, 1981.
1980 land use study, Rock County, Wisconsin: Rock County Planning, Economic & Community Development Dept., Janesville, Wis., 83 p.

Hindall, S.M., and Skinner, E.L., 1973.
Water resources of Wisconsin, Pecatonica-Sugar River Basin: U.S. Geological Survey, Hydrologic Investigations Atlas HA-453, 3 sheets.

Holman, D., personal communication, 1984.
Groundwater pollution--case histories: Rock County Health Department, Janesville, Wis.

Keeney, D.R., Lee K.W., and Walsh, L.M., 1975.
Guidelines for the application of wastewater sludge to agricultural land in Wisconsin: Wis. Dept. of Natural Resources Technical Bulletin 88, 36 p.

Lawrence, C.L., and Ellefson, B.R., 1982.
Water use in Wisconsin, 1979: U.S. Geological Survey, Water-Resources Investigations 82-444, 98 p.

Lee, G., personal communication, August 7, 1985.
UW-Madison, Department of Soil Science.

LeGrand, H.E., 1980.
A standardized system for evaluating waste-disposal sites: National Water Well Association, Worthington, Ohio, 42 p.

LeRoux, E.F., 1963.
Geology and ground-water resources of Rock County, Wisconsin: U.S. Geological Survey, Water-Supply Paper 1615-X, 50 p.

Mudrey, M.G., Jr., Brown, B.A., and Greenberg, J.K., 1982.
Bedrock geologic map of Wisconsin: Wis. Geological and Natural History Survey, scale 1:1,000,000, 1 sheet.

Nehring D., personal communication, 1984.
Rock County Agricultural Agent, Janesville, Wis.

Petersen, J.B., personal communication, 1984.
UW-Extension, Agricultural Engineering, Madison, Wis.

Potter, J., 1984.
Local ground-water protection: A sampler of approaches used by local governments: Wis. Geological and Natural History Survey Misc. Paper 84-2, 17 p.

Rock County, 1970.
A study of solid waste disposal and a roadside count of unlicensed automobiles and unused machinery in Rock County, Wisconsin, 1969: County Planning and Zoning Committee, Janesville, Wis.

Rock County, 1979.
Rock County agricultural preservation plan (draft): County Planning Department, Janesville, Wis.

Rock County, 1981.
County of Rock Traffic and General Ordinances, Chapter XIII. Public Health.

U.S. Bureau of Census.
U.S. Agricultural Census: 1964, 1969, 1974, 1978, and 1982.

U.S. Dept. of Agriculture, 1974.
Soil survey of Rock County, Wisconsin: USDA, Soil Conservation Service, 160 p. and 56 soil map sheets.

Wisconsin Agricultural Reporting Service.
1977-1985, 1977-1984 Wisconsin agricultural statistics: Wis. Dept. of Agriculture in coop. w/USDA, Madison, Wis.

Wisconsin Department of Natural Resources, 1980.
Nitrate levels in small public water systems of Wisconsin: Wis. Dept. of Natural Resources, Bureau of Water Quality, 12 p.

Yanggen, D., and Webendorfer, B., 1984.
Groundwater protection through local land use controls: UW-Extension Publ. G3341, (preliminary draft).

Zaporozec, A., 1982.
Ground-water quality of Rock County, Wisconsin: Wis. Geological and Natural History Survey Information Circular 41, 92 p.

GLOSSARY

Many words used in this document are technical in nature. This glossary defines the most unfamiliar words used. Some of the terms are also defined the first time they appear in the text. The definitions given here are not necessarily authoritative.

Adsorption	The ability of the surface of solids of the rock and soil particles (especially clays) to attract a layer of ions from the solution.
Alluvial deposits	The materials laid down in river channels or on floodplains.
Animal unit	One animal unit equals 1,000 lbs. animal weight equivalent.
Aquifer	A saturated permeable geologic formation that contains and will yield significant quantities of water.
Attenuate (pollution)	To reduce the severity of pollution; to lessen the amount of pollutants.
Bedrock	Solid rock overlain by unconsolidated material.
Cambrian	The oldest period of the Paleozoic Era (from about 500 to 600 million years ago).
Fluvial	Produced by river action.
Formation	The primary geologic unit consisting of a succession of strata useful for mapping or description of subsurface conditions.
Ion exchange	Chemical reaction through which the ions attracted to a solid surface are replaced by other ions in water solution.
Loess	Silt-sized material deposited by the wind.
Moraine	An accumulation of rock material by direct action of glacier ice.
Ordovician	The second oldest period of the Paleozoic Era (from about 440 to 500 million years ago).
Outwash	Sediment deposited by glacier meltwater streams beyond active glacier ice.
Permeability	The ability of a rock or soil to transmit water.
pH	A measure of acidity and alkalinity of water on a scale from 0 to 14; with 7 representing neutrality, numbers less than 7 increasing acidity, and numbers greater than 7 increasing alkalinity.
Pleistocene	The earlier of the two most recent geologic epochs, in which glacial activity was very frequent (for this reason also called glacial epoch); about 10,000 to 1 million years ago.
Pollution	Introduction of undesirable substances (pollutants), by natural processes or human actions, leading to alteration or degradation of natural conditions.
Quaternary	The most recent geologic era beginning approximately 1 million years ago, including the Pleistocene and Recent epochs.
Soil	The top five feet or less of materials at the land surface.
Specific capacity	A measure of the effectiveness of a well. It is calculated from the discharge of a pumping well (pumping rate) divided by the drawdown of the well.
Strata	A section of subsurface geologic formation that consists throughout of approximately the same kind of rock material; layers of sedimentary rocks.
Till	Unsorted sediment deposited by a glacier (incorrectly called drift).
Water table	The upper surface of the saturated zone (appears as the level at which water stands in a well penetrating the unconfined aquifer).

APPENDIX A

Authors and Reviewers

Biographies of Authors

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APPENDIX B

Groundwater Potential Pollution Risk Assessment Index

By

DAVID HOLMAN, M.S., R.S.

A literature review in 1984 and the Rock County inventory and analysis of pollution sources indicated that it would take many years and thousands of dollars to study specific on-site pollution sources to assess the pollution risks to drinking-water supplies. This indicated that if we are to protect groundwater through prevention, we must develop a system to predict the risk of our present and potential groundwater pollution sources as soon as possible. This is needed to make environmentally sound and cost-effective management recommendations to prevent further groundwater pollution and to correct the pollution problems we have today.

The objective of this risk index system is to provide the maximum amount of information for predicting the potential risk of groundwater pollution sources in the shortest time with the least money and personnel resources.

Risk Index System Concept

The significant risk factors of a groundwater pollution source include both the potential risk factors associated with the pollution source and the potential risk factors associated with natural and artificial controls needed to prevent the pollutant from reaching and polluting the groundwater (table B1).

The pollution source risk index system indicates the projected potential risk level for comparing and ranking the pollution sources in regard to pollution of groundwater used for drinking water (table B4). The index system analyzes two levels of potential risk: 1) the potential risk of an individual pollution source to pollute a nearby well used for drinking water purposes, and 2) the potential risk of various pollution sources to pollute the groundwater to a level that a community cannot use it for drinking water in its natural state.

Interpretation of Risk Index Numbers

Groundwater Pollution Source Risk Index Numbers
(see table B2)

1. A high pollution source risk index number indicates high potential risk of the pollutant source to pollute a nearby well within a short period of time following the discharge of the pollutant.

2. A low pollution source risk index number indicates low potential risk of the pollutant source to pollute a nearby well over a long period of time following the discharge of the pollutant.

Community Groundwater Pollution Risk Index Number
(see table B3)

1. A high community risk index number indicates a potentially high risk of polluting the community groundwater supply over a long period of time. High community risk is associated with large amounts of high-level risk pollutants or a large amount of low-level risk pollutants with a large acreage of discharge within the community.

2. A low community risk index number indicates a low potential risk of polluting the community's groundwater supply. Low community risk numbers are associated with low-level risk pollutants and/or low amounts of pollutant discharge or small amounts of discharge acreage for high risk pollutants.

Groundwater Protection Management Recommendations from Results of Risk Index for Rock County, Wisconsin

1. Where there is a projected high potential pollution risk of pollution for the individual sources and/or the community and known pollution sites are found in the community, the following management strategies are recommended:

   a. Provide a cost-benefit study to develop environmentally sound and cost-effective prevention controls and regulations as soon as possible to prevent additional groundwater pollution from affecting nearby public or private water supplies.

   b. Prevent new pollution sites from occurring and provide a cost-benefit study for known pollution sites and, where necessary, provide remedial action.

2. Where there is a projected high community potential pollution risk for a pollution source and no known pollution sites are found in the community, the following management strategies are recommended:

a. Establish a monitoring program for high-risk pollution sources to provide additional information on the impact of pollutants on community water supplies.

b. Develop and implement a long-term groundwater protection plan to eliminate or reduce the long-term risk of polluting the groundwater supply used for drinking water. This plan should include a cost-benefit analysis of protecting the groundwater.

c. State and federal agencies should develop a groundwater pollution risk index system to provide a uniform method for projecting potential groundwater pollution risk to enable environmentally sound and cost-effective decisions. This is necessary to protect the groundwater as a source of drinking water before it becomes polluted to a level that it cannot be used as drinking water.

Limitations of Risk Index System

The risk index system was developed only for ranking and comparing potential pollution sources and the risks they might pose to groundwater and/or the community water supplies. The index system should not be used for evaluating on-site problems or designing on-site groundwater preventive controls. Other methods, such as the LeGrand method (1980), should be used to evaluate on-site risks.

The system should be improved and new research adapted to computer use for developing a fast-action index system that will assist in making recommendations to prevent groundwater pollution problems and improve groundwater quality management.

Future Use of Risk Index System

The system may be used for:

1. Ranking and comparing potential groundwater pollution risks in other communities.
2. Ranking and comparing potential groundwater pollution risks between communities and/or geologic areas.
3. Assisting in developing local, state, and federal groundwater quality protection plans.

Table B1. Groundwater pollution risk index system

Potential Pollution Source Risk Factor (A x B x C)	x	Potential Pollution Control Risk Factors (E x F x G)	=	Groundwater Pollution Source Risk Index Number

$$\frac{\text{Pollution Source Risk Index}}{1{,}000} \times \text{Discharge Acreage} = \text{Community Groundwater Pollution}$$

Pollution Source Risk Factors	Risk Index Number Risk Weight*
A. Potential toxicity of pollutant discharged:	
Toxic chemicals	3
Bacteria and viruses (pathogenic)	2
Materials affecting taste, flavor, or color	1
B. Potential concentration of pollutant discharged:	
50% to 100% - high concentration	3
10% to 50% - moderate concentration	274
Less than 10% - low concentration	1
C. Potential loading rate of pollutant discharge:	
over 1.0 gal/sq.ft./day	3
.5 to 1.0 gal/sq.ft./day	2
0 to 0.5 gal/sq.ft./day	1
D. Potential frequency of pollutant discharge:	
30 - 365 day/yr	3
8 - 30 day/yr	2
0 - 7 day/yr	1

Pollution Control Risk Factors	Risk Index Number Risk Weight*
E. Level of natural protection:	
Discharge to geologic formations	3
Discharge into soil	2
Discharge to surface of soil	1
F. Level of prevention control and/or regulations:	
Low level	3
Moderate level	2
High levei	1
G. Relative distance from public water supplies**	
Within 1/2 miles	3
Within 2 miles	2
Within 5 miles	1

* Risk weight: high risk-3; moderate risk-2; low risk-1.

** Up flow source is more critical than down flow source.

Table B2. Groundwater pollution source risk index

Potential Source of Pollution	Pollution Source Risk Factors (A x B x C x D)	x	Pollution Control Risk Factors (E x F x G)	=	Groundwater Pollution Source Risk Index Number
Underground chemical tanks	(3 x 3 x 3 x 1) = 27		(3 x 3 x 3) = 27		729
Aboveground chemical tanks	(3 x 3 x 3 x 1) = 27		(1 x 2 x 3) = 6		162
Toxic and hazardous spills	(3 x 3 x 3 x 1) = 27		(1 x 2 x 3) = 6		162
Transmission pipes (toxic materials)	(3 x 3 x 1 x 1) = 9		(3 x 2 x 1) = 6		54
Irrigation return flow	(3 x 2 x 3 x 1) = 18		(3 x 2 x 2) = 12		216
Manure spreading	(2 x 1 x 1 x 1) = 2		(1 x 2 x 2) = 4		8
Fertilizer application	(1 x 1 x 1 x 1) = 1		(1 x 3 x 2) = 6		6
Pesticide application	(3 x 1 x 1 x 1) = 3		(1 x 2 x 2) = 4		12
Animal feedlots or manure stored on unsuitable soils	(2 x 2 x 1 x 2) = 8		(1 x 3 x 2) = 6		48
Manure storage (aboveground)	(2 x 2 x 2 x 1) = 8		(1 x 2 x 1) = 2		16
Manure pits (unlined)	(2 x 2 x 1 x 3) = 12		(3 x 3 x 1) = 9		108
Old landfills without leachate collection system	(3 x 2 x 1 x 3) = 18		(3 x 3 x 3) = 27		486
Junkyards	(3 x 1 x 1 x 1) = 3		(1 x 2 x 1) = 2		6
Private sewage systems	(2 x 1 x 2 x 3) = 12		(2 x 2 x 2) = 8		96
Sludge and septage disposal	(2 x 2 x 1 x 2) = 8		(2 x 2 x 2) = 8		64
Sewage effluent seepage areas	(2 x 2 x 3 x 3) = 36		(2 x 1 x 1) = 2		72
Sanitary sewers	(2 x 2 x 1 x 1) = 4		(2 x 1 x 3) = 6		24
Salt and fertilizer piles (uncovered)	(1 x 2 x 1 x 2) = 4		(1 x 2 x 3) = 6		24
Highway deicing	(1 x 1 x 1 x 2) = 2		(1 x 2 x 3) = 6		12

Table B3. Community groundwater pollution risk index

Potential Source of Pollution	Pollution Source Risk Index Number 1,000	x	Discharge Areas in Acres*	=	Community Groundwater Index Number
Underground chemical tanks	.729		83		61
Aboveground chemical tanks	.162		85		14
Toxic and hazardous spills	.162		5		<1
Transmission pipes (toxic materials)	.054		6		>1
Irrigation return flow	.216		13		3
Manure spreading	.008		30,000		240
Fertilizer application	.006		316,900		1,901
Pesticide application	.012		256,200		3,074
Animal feedlots or manure stored on unsuitable soils	.048		472		22
Manure storage (aboveground)	.016		40		>1
Manure pits (unlined)	.010		10		1
Old landfills without leachate collection system	.486		605		294
Junkyards	.006		510		3
Private sewage systems	.096		154		15
Sludge and septage disp.	.064		5,685		366
Sewage effluent seepage areas	.072		15		1
Sanitary sewers	.024		640		15
Salt and fertilizer piles (uncovered)	.024		5		<1
Highway deicing	.012		3,030		36

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*Number of sources x estimated potential discharge area, or: projected number of acres of discharge from known or projected land use data

Table B4. Ranking of pollution sources in Rock County according to risk index

Potential Pollution Source Risk*	Potential Community Groundwater Pollution Risk**
1. Underground chemical tanks	1. Pesticide application
2. Old landfills without collection system	2. Fertilizer application
3. Irrigation return flow	3. Sludge and septage disposal
4. Accidental toxic on-site spills collection system	4. Old landfills without
5. Accidental off-site toxic spills	5. Manure spreading
6. Aboveground chemical tanks	6. Underground chemical tanks
7. Manure pits (unlined)	7. Highway deicing
8. Private sewage systems	8. Animal feedlots
9. Sewage effluent seepage areas	9. Sanitary sewers
10. Sludge and septage disposal	10. Private sewage systems
11. Transmission pipes (toxic materials)	11. Aboveground chemical tanks
12. Animal feedlots	12. Irrigation return flow
13. Salt and fertilizer piles (uncovered)	13. Junkyards
14. Sanitary sewers	14. Accidental off-site toxic spills
15. Manure storage (aboveground)	15. Sewage effluent seepage areas
16. Highway deicing	16. Manure pits (unlined)
17. Pesticide application	17. Accidental toxic on-site spills
18. Manure spreading	18. Transmission pipes (toxic materials
19. Fertilizer application	19. Manure storage (aboveground)
20. Junkyards	20. Salt and fertilizer piles (uncovered)

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* Potential Pollution Source Risk: Potential risk to lower drinking-water quality of nearby wells to a level that the groundwater is unsuitable to drink in its natural state.

** Potential Community Groundwater Pollution Risk: Potential risk to lower the quality of drinking water to a level that the groundwater in the community is unsuitable to drink in its natural state.

APPENDIX C

Soil Series in Rock County
Listed by Attenuation Potential

	Least Potential	Marginal Potential	Good Potential	Best Potential
Sum of Weighted Values	0-30	31-40	41-50	51+
	Adrian Billett (mottled subsoil variant) Dickman Eleva Gotham Houghton Marsh Maumee Palms Rock land Rodman Rollin Rotamer Watseka	Aztalan Billett Brookston Casco Colwood Darroch Elburn Hayfield Kane Locke Lorenzo Mahalasville Marshan Millington Navan Oshtemo Otter Sebewa Sogn Wauconda	Edmund Hebron Junea Rockton Rotamer St. Charles	Dresden Durand Flagg Griswold Jasper Kidder Ogle Pecatonica Plano Ringwood Sisson Troxel Warsaw Westville Whalan Winnebago Worthen Zurich
Acreage*	31,490	106,970	62,730	254,515
Percent* of Total	6.8%	23.2%	13.6%	55.2%

*The remaining 5,735 acres (or 1.2%) include alluvial land and gravel pits.

Groundwater Protection Principles and Alternatives for Rock County, Wisconsin

EXECUTIVE SUMMARY
of Special Report 8

Prepared by

Wisconsin Geological and Natural History Survey
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May 1985

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EXECUTIVE SUMMARY

Groundwater Protection Principles and Alternatives for Rock County, Wisconsin

Introduction

This summary provides a brief overview of a report titled "Groundwater Protection Principles and Alternatives for Rock County, Wisconsin" (WGNHS Special Report 8, November 1985). The Rock County Health Department initiated the project that led to the publication of this report; it was a collaborative effort of a team consisting of University of Wisconsin Extension specialists, staff of the Wisconsin Geological and Natural History Survey, and state and local agency personnel. Copies of the report may be purchased from the Map and Publication Sales Office, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin, 53705 (608-263-7389).

Purpose and Scope

Local governments, along with state and federal agencies, have an important role in designing and implementing effective groundwater management and protection programs. This project was undertaken to provide technical assistance and environmentally sound management recommendations for a county program to protect groundwater for present and future uses. While the report focuses on Rock County, Wisconsin, we hope that the general planning approach developed in this project will also serve as a guide and framework for other counties in Wisconsin, and elsewhere, in their efforts to protect groundwater.

The primary objectives were to:

1. Identify existing approaches to local groundwater protection that can be applied to Rock County.

2. Inventory existing and potential sources of pollution in Rock County, assess the risks they present to groundwater quality, and outline available regulatory and non-regulatory approaches to control these sources.

3. Inventory existing groundwater problems and identify areas most susceptible to groundwater pollution.

4. Develop groundwater protection strategies and alternatives, especially protection alternatives for selected, pollution sensitive areas of the county.

This report is a technical and institutional analysis of available resource information and management strategies. It describes the most important factors that need to be assessed to protect groundwater from pollution and sets out some basic principles and procedures by which threats to groundwater can be evaluated, countered, or prevented.

The sources of groundwater pollution are many and varied. In addition to some natural processes, practically every type of human-installed facility or structure and most human activities may eventually contribute to groundwater quality problems (fig. 1). Thus, a local groundwater planning effort must begin by identifying and assessing those activities, practices, and trends that may affect the quality of groundwater. The report characterizes the activities and practices that might affect groundwater quality and outlines the nature of pollution that might result from them.

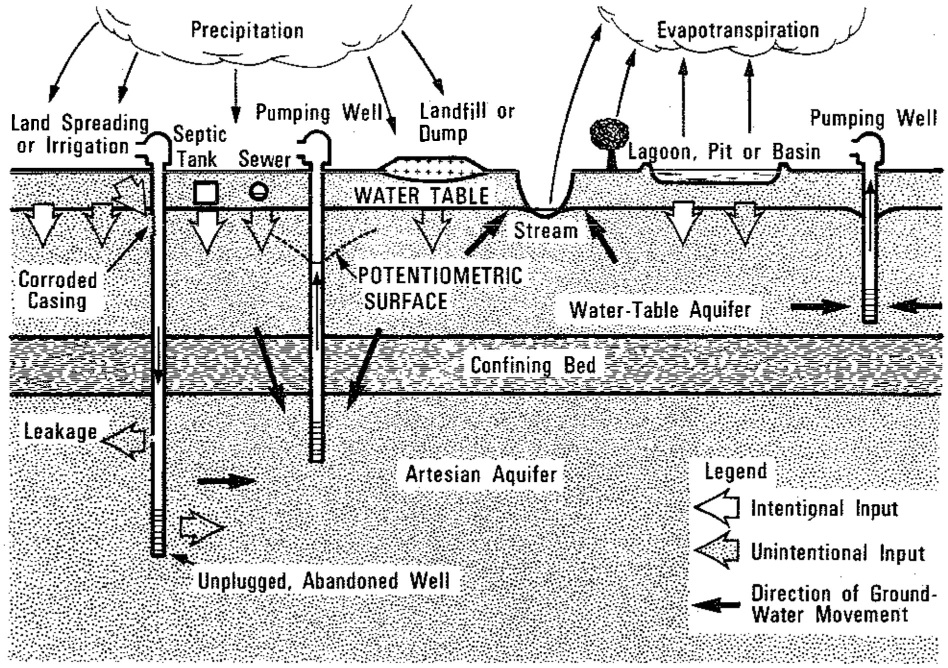


Figure 1.
General mechanisms of the entry of pollutants to ground water

While human activities are primarily responsible for sources of groundwater pollution, the physical environment provides an opportunity for pollutants to be attenuated before they reach the groundwater. Thus, a detailed understanding of the properties of the soils and underlying rock units is necessary to develop a sound groundwater quality protection program. For this project, data availability and current knowledge of the physical environment were judged adequate for developing a system to evaluate potential threats to groundwater. We recognize, however, that more detailed geologic information may be required at some future time for specific management and protection purposes.

Any local groundwater protection program should be developed within a framework of federal and state regulations. Also, local units of government can draw on a range of regulatory and non-regulatory approaches and management tools. This report outlines the major approaches and management tools and thus provides a "menu" from which a strategy can be chosen to suit the management objectives of a particular county.

Finally, the report identifies specific actions Rock County can take to minimize the pollution potential of the identified land uses and pollution sources through a combination of state regulatory programs, local regulatory options, and non-regulatory strategies. Additionally, the report recommends management alternatives for special management areas (naturally vulnerable areas, well-protection zones, potential problem areas). Focusing on these special management areas will allow the county to set priorities and to concentrate limited resources in key locations.

Methodology

Inventory of Potential Pollution Sources

Potential pollution sources in Rock County were grouped into four general categories: waste disposal, agricultural activities, materials storage and handling, and other activities. The inventory of pollution sources includes for each source a statement of the problem, a list of pollutants produced, a description of the source, and an estimate of its relative significance. This estimate represents an informed judgment based on the likelihood of groundwater quality impairment and the size of the population that may be at risk. We have made no attempt, however, to rank quantitatively the potential pollution sources in the county. An illustration of such a ranking procedure, based on the county environmental health director's attempt to assess comparative risk potential from different pollution sources, is provided in one of the appendices. Maps of all inventoried pollution sources are included in the report in a reduced form. Original maps are on file with the Rock County Health Department in Janesville.

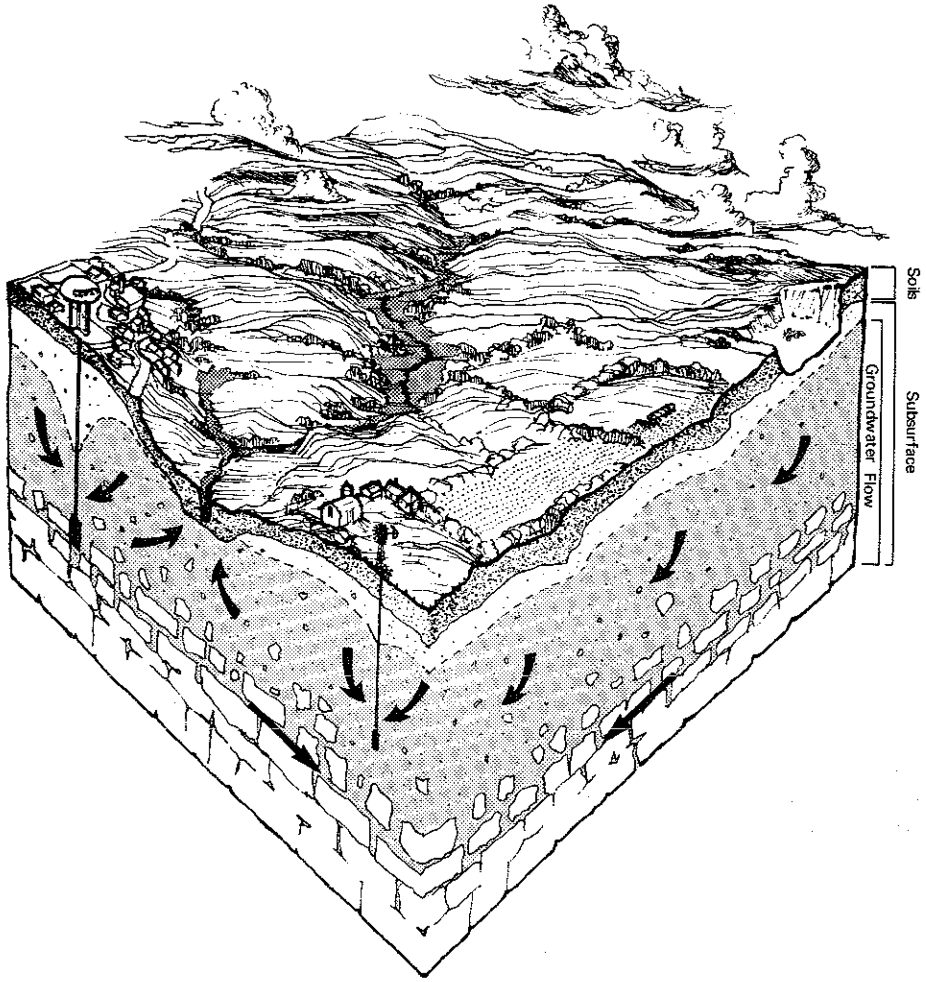
System for Evaluating Groundwater Susceptibility to Pollution

Many methodologies have been developed to evaluate the groundwater pollution potential of existing or planned facilities and activities or the environment's vulnerability to pollution. In this project, we used a somewhat nontraditional approach. This approach separates the environment into three components (soils, geologic framework, and groundwater flow), and gives consideration to the intended use or activity and the fate of pollutants in the subsurface.

The system used in this study is based on the ability of soils and subsurface materials to attenuate pollutants and on the direction and rate of groundwater flow. Figure 2 schematically shows the main components of the physical environment in Rock County that are considered in the system. Each component was mapped separately, and the resulting maps can be used individually or in any combination. A set of these three maps is available in the full report. Using these three components allows the evaluation system to be use-sensitive, that is, the impacts of various land uses or activities are evaluated according to their places of origin.

The soil map helps evaluate impacts of activities above or within the soil zone. It was developed on the basis of soil properties that may play a role in attenuating groundwater pollutants. Seven physical and chemical characteristics were selected for each soil series and were given weighted values. These values were summed, and soils with similar total point scores were grouped into four soil associations which, in turn, reflect differing attenuation potentials.

Figure 2.
Schematic diagram showing the relationship of the three components of the physical environment used in the system for evaluating groundwater pollution potential in Rock County (arrows indicate general direction of groundwater flow)



The subsurface map helps evaluate impacts of uses below the soil zone but above the water table. The evaluation system used to assess the relative attenuation capacity of the subsurface (more than five feet below the surface) is based on the permeability of rock materials (both consolidated and unconsolidated) and the depth to bedrock and groundwater. The vulnerability map, constructed from maps of these factors, shows areas that are most, moderately, and least vulnerable to pollution.

The third component of the evaluation system, the groundwater flow map, helps evaluate the movement of pollutants that reach the groundwater flow system and also helps to define protection zones around significant water supply points.

However, the environment alone does not provide adequate protection against groundwater pollution because some pollutants will reach groundwater regardless of how favorable the environmental factors may be. Therefore, it is important to influence land-use patterns and to control pollution at the source, rather than to rely solely on the attenuation capacity of the environment.

The first two maps showing the capacity of the soil and subsurface materials to attenuate pollutants, combined with the inventory maps of individual potential pollution sources, were used to delineate areas sensitive to groundwater pollution (fig. 3). These areas are divided into naturally vulnerable areas, well-protection zones, and potential problem areas. Naturally vulnerable areas are those areas that lack adequate protection because of their soil, subsoil, and/or bedrock characteristics. Well-protection zones are those areas contributing groundwater to existing or planned public wells. Potential problem areas are where naturally vulnerable areas coincide with existing sources of pollution or potentially polluting land-use activities. These places and activities require special attention because potential pollution sources, accidents, or mishandling of materials in such areas may create serious pollution problems.

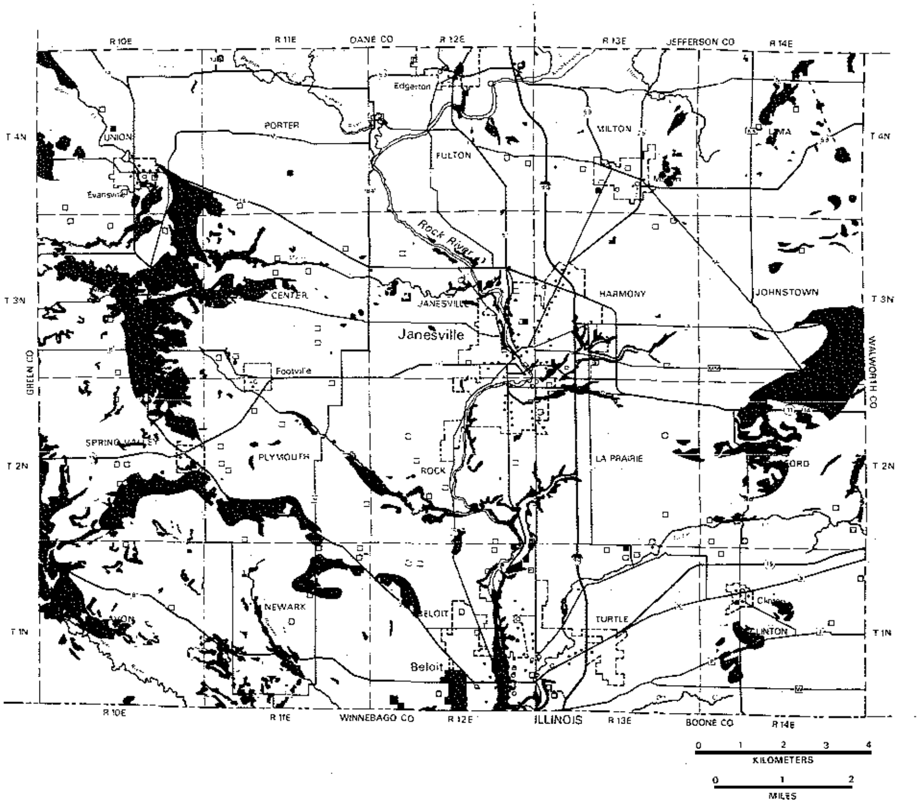


Figure 3.
Extent of priority potential problem areas in Rock County

Figure 3 indicates pollution sensitive areas only in general and does not specify individual areas or potential pollution sources. It is included to illustrate the extent of potential problem areas in Rock County. For the specifics, see plate 3 of the report.

Management Techniques and Options

Local governments, along with state and local agencies, have an important role to play if effective groundwater management and protection programs are to be implemented. In designing such programs, local government officials need to understand the state regulatory framework. States have the basic responsibility for water quality management and local programs should complement state efforts. Wisconsin has a number of state regulatory programs that deal with groundwater directly or indirectly. The report reviews programs pertaining to individual potential pollution sources, and identifies the agencies responsible for regulating these sources. Programs are outlined under the categories of waste disposal, agriculture, hazardous materials, and wells. An understanding of the coverage of these state programs helps local officials to fashion complementary protective measures.

In designing a groundwater protection program, local governments may choose from a range of approaches and management tools to address groundwater problems. The appropriate choice of tools derives from the management objectives identified by the county. There is no "correct" way to design a local groundwater protection program. An effective approach must reflect local needs and concerns and must be embraced by those who will carry it out. Therefore, local governments must identify community goals and objectives before selecting specific management programs and techniques.

Techniques that can be used in local groundwater protection programs include regulatory and non-regulatory approaches; in practice, most programs are a mix of these. Regulatory approaches involve placing legal constraints on land uses or on particular activities that are potential sources of groundwater pollution. Non-regulatory approaches include such activities as public education, voluntary best management practices, inspection and training programs, governmental coordination, emergency spill response programs, and monitoring to identify water quality problems.

Protection Strategies and Alternatives

Based on the inventory of potential threats to groundwater and on the "toolkit" available to local governments in Wisconsin, this report identifies a specific set of actions for each potential pollution source. They are summarized in figure 4. The report also discusses each source or activity and assesses the relative significance of the potential pollution, relevant state authorities and actions, local regulatory options, and non-regulatory strategies.

Figure 4.
Protection strategies available for control of potential pollution sources in Rock County

	GROUNDWATER PROTECTION CONTROL ALTERNATIVES / POTENTIAL POLLUTION SOURCES	REGULATORY							NON-REGULATORY					OTHER			
		Permits	Land Use Controls	Construction Standards	Use Restrictions	Inspection & Testing	Guidelines	Design & Maintenance Criteria	Minimizing Input of Pollutants	Education	Voluntary BMP	Governmental Coordination	Training & Demonstration	Monitoring	Research & Inventory	Remedial Action	Emergency Response
WASTE DISP.	Solid waste sites	●	●	●		●	●	●				●		●	●	●	●
	Junkyards					●				●	●						
	Surface Impoundments	●		●		●		●					●	●	●		
	Sanitary sewers		●	●		●		●				●					
	Septic systems	●	●	●	●	●		●		●							
	Sludge & septage spreading	●				●	●						●				
AGRIC.	Livestock waste storage	●		●		●	●	●		●	●			●	●		
	Fertilizer & manure spreading						●		●	●	●			●			
	Pesticides				●		●		●	●	●		●		●		
	Irrigation					●				●	●						
HAZ. MATERIALS	Domestic hazardous materials									●			●				
	Aboveground storage	●	●	●		●		●		●	●				●	●	●
	Underground storage	●	●	●		●		●		●	●	●	●	●	●	●	●
	Transmission pipelines	●	●	●		●		●				●				●	●
OTHER	Spills					●	●	●		●		●		●	●	●	●
	Salt piles & daicing								●		●	●	●	●			
	Well construction & abandonment	●		●				●		●		●					

The report also recommends special management alternatives for those locations in the county that should receive high priority in a groundwater protection strategy. Special management areas allow local governments to concentrate limited resources in key locations and to set priorities in terms of the geographic scope of programs. Three types of special management areas are considered: naturally vulnerable areas, well-protection zones, and potential problem areas.

By delineating areas that are particularly susceptible to pollution because of soils, subsoils, bedrock, and groundwater conditions, it is possible to relate the stringency of controls to the severity of the threat to groundwater. For example, one regulatory approach for protecting naturally vulnerable areas is to create an overlay zoning district and to make all potentially polluting uses within that district conditional uses.

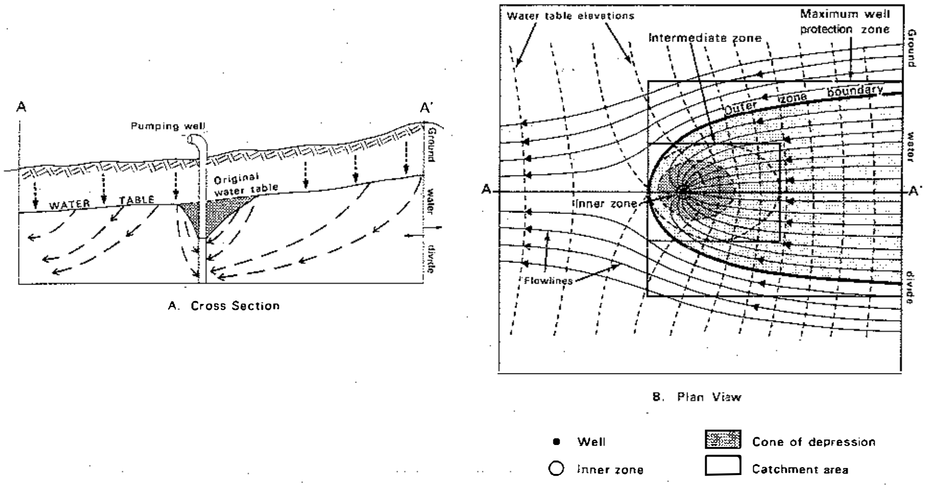


Figure 5. Well-protection zones

Large municipal drinking water supplies can be protected by delineation of well-protection zones in which potentially polluting uses or practices are controlled. These protected areas may be subdivided into several management zones such as the inner, intermediate, and outer zones of protection, depending on local hydrogeologic conditions (fig. 5).

Potential problem areas are defined as places where activities that could cause pollution, particularly handling and storage of hazardous materials, are located in areas most vulnerable to pollution or as areas of suspected pollution, where pollutants may have already entered the groundwater. Zoning can help prevent further problems from developing in areas of proposed new development. In already developed areas, regulations that require a permit to engage or continue in certain activities may be needed. Examples of these kinds of regulations include control over land spreading of sludge and septage, a hazardous materials ordinance, and an underground tank ordinance.

Findings

Rock County is located at the border of Wisconsin and Illinois. Its total area is approximately 727 square miles, of which about 6 square miles are covered by water. Groundwater is a vitally important natural resource of Rock County; ninety-nine percent of water used for municipal, rural, and industrial purposes comes from groundwater reservoirs.

Rock County has abundant groundwater supplies. Presently, about 20 percent of the water that infiltrates to the groundwater is being withdrawn. The overall natural quality of groundwater in Rock County is good, although it is very hard and requires softening for many uses. The chemical quality of the groundwater in the county is generally much better than required by federal and state drinking water standards. Although Rock County has an abundance of good quality groundwater, the close proximity of the aquifers to the land surface and their limited natural protection make them vulnerable to pollution.

Rock County does not have serious, large-scale pollution problems at this time. Nitrate is the most common identifiable pollutant, and its concentrations in private wells create certain health concerns in the county. Large amounts of nitrate in well water may indicate pollution from fertilizers, barnyards, or septic tanks. Twenty-one groundwater pollution cases have been documented in the county, all of which were related either to waste disposal activities or to storage problems. The most often reported pollutant was gasoline near underground storage tanks. Other pollutants included coliform bacteria, inorganic chemicals, nitrate, ammonia, phenols, sulfates, pesticides, paint solvents, and volatile organic compounds. Although in most of these cases the actual extent of pollution is unknown, pollution was probably minor and local. Only in one instance was remedial action taken to renovate the subsurface environment.

Land-use trends suggest that Rock County will remain primarily agricultural, although development will continue to occur along the Rock River/I-90 corridor. Rock County's two urbanized centers, six rural centers, and twenty agriculture-based towns may all face potential groundwater quality problems. The existing and potential problems vary according to the land use. In urban areas, groundwater pollution problems may be primarily caused by underground storage tanks and waste disposal sites. Potential problem areas are mostly concentrated in the Janesville-Beloit urban corridor, where there is a large concentration of storage tanks and sludge disposal sites. Numerous recorded spills in these areas indicate the potential for groundwater pollution. The risk of polluting groundwater is particularly high because these areas overlie highly permeable sand-and-gravel aquifers, which serve as sources for municipal water supplies. Health problems may also result from failing private septic systems in rural residential areas. Fertilizer and pesticide storage and application, manure storage pits, land disposal of waste, and abandoned or improperly constructed wells are possible groundwater pollution sources in agricultural areas.

To protect the abundant supply of high quality groundwater Rock County enjoys at this time, local government could pursue a number of avenues as suggested in the report. Deciding what should be done is the challenge facing the citizens of the county. In undertaking a groundwater protection program, the county must be willing to make a long-term commitment to protecting its groundwater resource. The time and effort it takes to put such a program into place is important to consider in developing a county groundwater protection program.

Recommendations

If Rock County decides to proceed with a local groundwater protection program, the following initial steps will help make it effective. The county should decide how to organize internally to review the results of this study and to formulate an action program. The review process should lead to selecting goals and objectives of the county's groundwater protection program and to identifying the most serious pollution sources, highest priority groundwater pollution problems, and special management areas to be addressed in the county's program. Institutional arrangements for intergovernmental coordination will have to be devised to successfully undertake and implement much of any program. And finally, the county should develop a public involvement and educational strategy.

The citizens and governmental officials of Rock County will certainly make up their own minds on how to proceed and how to decide which items should receive first priority. The following merely provides an example of actions, not in any priority order, that Rock County can include in its groundwater protection program.

- Develop informational and educational programs relating to major potential pollution sources.
- Meet with the Department of Natural Resources to explore the possibility of a joint program regulating the storage, handling, and disposal of hazardous materials.
- Develop a program to inventory, inspect, and regulate underground storage tanks in conjunction with the Department of Industry, Labor, and Human Relations.
- Identify more precisely those agricultural activities involving disposal of animal wastes and heavy usage of pesticides and fertilizers and incorporate them in the broader monitoring program.
- Identify the Janesville-Beloit corridor as a special management area and initiate actions suggested in this study.
- Undertake a well-protection program in cooperation with Rock County municipalities.
- Adopt appropriate land-use controls down flow from all abandoned landfills and meet with DNR to establish priorities for monitoring landfills.
- Discuss groundwater protection efforts with business, industry, agriculture, governmental units, and the general public.

The choice of actions undertaken by the county obviously depends upon local priorities and perceptions of groundwater problems and the feasibility of local management.