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A Regional Ground-Water Quality Characterization of the Rockford Area, Winnebago County, Illinois:

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Illinois State Water Survey
Illinois State Geological Survey

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HAZARDOUS WASTE RESEARCH AND INFORMATION CENTER
Illinois State Water Survey Division
1808 Woodfield Drive
Savoy, Illinois 61874

HWRIC RR-027

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A REGIONAL GROUND-WATER QUALITY CHARACTERIZATION OF THE ROCKFORD AREA, WINNEBAGO COUNTY, ILLINOIS:

An Assessment of Volatile Organic Compounds and Selected Trace Metals

by

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CONTENTS

CONTENTS (Concluded)

TABLES

FIGURES

ABSTRACT

This report summarizes an investigation of regional ground-water quality in the Rockford area in north-central Illinois. The investigation was launched to determine if regional ground-water contamination, principally by volatile organic compounds (VOCS), has occurred in the Rockford area. A number of investigations conducted by local and state agencies have documented the presence of VOCs in the ground water at several locations in or near the city of Rockford, Illinois. An estimated 300 wells, including 16 public water supply wells, have been affected by the presence of organic compounds in over 20 instances of ground-water contamination in Winnebago County documented since 1970.

Analysis of ground-water samples was undertaken in a 76-square-mile area around Rockford to examine the potential for regional contamination of ground water by hazardous substances. Sixty-nine private domestic and industrial wells were sampled and analyzed for 18 VOCs and 4 trace metals. Results of these determinations were compiled along with information from previous investigations, including Illinois Environmental Protection Agency sampling results from 48 local municipal water wells, to determine areas of ground-water contamination within the study area. Ground-water (depth-to-water) measurements were also obtained, and a map of the potentiometric surface of the sand and gravel aquifer was prepared to determine the direction of ground-water movement. The locations of industrial facilities that may be handling hazardous substances were also mapped.

Total VOC concentrations found in the sampled wells ranged from nondetectable to over 500 $\mu g\ L^{-1}$. Of the 69 wells sampled, ten contained 5 $\mu g\ L^{-1}$ or more total VOCs. Of those ten, seven contained concentrations in excess of the U.S. Environmental Protection Agency (USEPA) Recommended Maximum Contaminant Level (RMCL) of 5 $\mu g\ L^{-1}$ for trichloroethene (TCE) in drinking water. Two of those wells also exceeded the USEPA lifetime health advisory of 70 $\mu g\ L^{-1}$ for cis-1,2-dichloroethene. None of the wells sampled exceeded the RMCL for any of the four trace metals.

Despite the fact that several wells were found to contain VOCs, the preponderance of information collected during this study shows that regional contamination of ground water in the Rockford area has not occurred. Much of the ground water used by the residents and industry in the Rockford area was found to be of satisfactory quality with regard to VOCs and selected trace metals. However, this information should not minimize the problems identified in several parts of Rockford.

One area in southeast Rockford is significantly contaminated with VOCs. Over 100 homes in the area obtain water from shallow wells

completed in the sand and gravel. Several of these wells produced water with total VOC concentrations in excess of 100 μg l^{-1}. The USEPA RMCL for many of these contaminants is only 5 μg l^{-1}. A more detailed investigation of this area conducted by the Winnebago County Health Department in 1984 produced similar results. Data collected from these two investigations show that the contamination extends approximately two miles from 20th Street west to the Rock River. A nearby public water supply well, Rockford Unit Well 35, is finished much deeper in the sand and gravel and also exhibits elevated VOC concentrations. The area is bordered by a variety of industrial facilities that may have introduced the contaminants into the ground water.

More specific information on the contaminated area is needed to develop water supply alternatives for the residents of the area and to provide better management of the ground-water resource for public and industrial use. Follow-up investigations should be conducted to determine the source, magnitude, and extent of contamination in southeast Rockford. The response of contaminant movement to various pumping patterns created by the numerous high-capacity wells in the area should be evaluated. Such investigations will provide information important to the implementation of possible ground-water protection measures in the Rockford area.

A methodology for the investigation of regional ground-water quality is also presented in the report. This methodology is presented as a guide for planning and executing similar investigations in Illinois. This methodology should help to provide some consistency in the design of such efforts undertaken by other groups or agencies in the state.

EXECUTIVE SUMMARY

This report describes an investigation of regional ground-water quality in the Rockford area in north-central Illinois. A summary of the hydrogeology of the area is also presented. The investigation was launched to determine if regional ground-water contamination, principally by volatile organic compounds (VOCs), has occurred in the Rockford area. A number of investigations conducted by local and state agencies have documented the presence of VOCs in the ground water at several locations in or near Rockford. An estimated 300 wells, including 16 public water supply wells, have been affected by the presence of VOCs in over 20 instances of ground-water contamination in Winnebago County documented since 1970.

The Rockford region is an area well-suited for an investigation of the effects of hazardous substances on regional ground-water quality. The area contains an abundance of potential contaminant sources situated over highly productive and sensitive aquifers. These conditions made Rockford one of the few regions in the state to be highlighted on both the sand-and-gravel and shallow-bedrock targeting maps developed as part of a hazardous substance monitoring strategy for Illinois (Wehrmann and Le Seur, 1985).

Ground water in the Rockford area is primarily derived from three different, though in many areas hydraulically connected, geologic units. These aquifers are (1) the Pleistocene glacial drift, composed predominantly of outwash sands and gravels in the Rock Bedrock Valley; (2) the Ordovician dolomites, the "shallow" bedrock encountered in the uplands overlooking the river valley; and (3) the Cambrian sandstones, the "deep" bedrock encountered beneath the dolomite in the uplands but comprising the bedrock surface beneath most of the outwash deposits in the deeper portions of the Rock Bedrock Valley. Ground water from these three formations provides 100 percent of the supply (nearly 47 million gallons per day) for public, industrial, and domestic use in Winnebago County.

Based on the targeting maps prepared as part of the hazardous substance monitoring strategy (Wehrmann and Le Seur, 1985), sampling of ground water was undertaken in a 76-square-mile area around Rockford. Analyses were performed for eighteen VOCs and four trace metals. The chemicals for which analyses were performed were:

- Barium
- Benzene
- Cadmium
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- Chromium
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- 1,1-Dichloroethane
- 1,2-Dichloroethane
- cis-1,2-Dichloroethene
- trans-1,2-Dichloroethene
- Ethylbenzene
- Lead
- Methylene chloride
- Tetrachloroethene
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- Trichloroethene
- Toluene

Primarily because of the high cost of analysis, which is normally borne by the individual well owner, domestic wells often are not sampled for VOCs. Therefore, emphasis was placed on the sampling of domestic wells. Sixty-three domestic wells and six industrial wells were sampled for this study. Ground-water (depth-to-water) measurements were also obtained, and a map of the potentiometric surface of the sand and gravel aquifer was prepared to determine the direction of ground-water movement. In addition, the locations of industrial facilities potentially handling hazardous substances were mapped. To determine areas where ground water is contaminated, information from these efforts was compiled along with VOC data from 48 local municipal wells (sampled by the Division of Public Water Supplies, Illinois Environmental Protection Agency) and with data from previous state and local ground-water investigations.

Total VOC concentrations found in the sampled wells ranged from nondetectable to over 500 µg L^{-1}. Of the 69 wells that were sampled, 10 were found to contain 5 µg L^{-1} or more total VOCs. Of those 10, seven contained concentrations in excess of the U.S. Environmental Protection Agency (USEPA) Recommended Maximum Contaminant Level (RMCL) of 5 µg L^{-1} for trichloroethene (TCE) in drinking water. Two of those wells also exceeded the USEPA lifetime health advisory of 70 µg L^{-1} for cis-1,2-dichloroethene. None of the wells sampled exceeded the RMCL for any of the four trace metals.

Despite the fact that several wells were found to contain VOCs, the information collected during this study shows that regional contamination of ground water in the Rockford area has not occurred. Much of the ground water used by Rockford-area residents and industry was found to be of satisfactory quality with regard to VOCs and selected trace metals. However, this information should not minimize the problems identified in several parts of Rockford.

In particular, an area in southeast Rockford is significantly contaminated with VOCs. Over 100 homes in the area depend on private, shallow wells for domestic water. A nearby public water supply well, Rockford Unit Well 35, is finished deeper in the sand and gravel and also exhibits elevated concentrations of VOCs. The area is bordered by a variety of industrial facilities that may have introduced the contaminants to the ground water. Most of the domestic wells in this area also were sampled by the Winnebago County Health Department in 1984. At that time, several wells were found to contain total VOC concentrations in excess of 100 $\mu g\ l^{-1}$. Results of the Health Department's findings were confirmed by this study.

All of the wells in the southeast Rockford area are completed in sand and gravel. According to ground-water elevation data collected during this study, the principal direction of ground-water movement in southeast Rockford is from the uplands on the east to the Rock River on the west. This westerly direction of movement is supported by well water analyses within the zone of contamination extending from 20th Street west to the Rock River, a distance of approximately two miles. If contaminants in this area have moved with the ground water at an average rate of 2 feet per day, it would have taken approximately 15 years for the contaminants to travel this distance.

Because of the extremely slow rate at which ground water moves, the situation is not likely to improve quickly if left unattended. More specific information on the contaminated area is needed to develop water supply alternatives for the residents of the area and to provide better overall management of the ground-water resource for public and industrial use. Follow-up investigations should be conducted to determine the source, magnitude, and extent of contamination in the southeast Rockford area. Sampling of domestic wells by the County Health Department and the State Water Survey provides a basis for defining the extent and magnitude of the problem. However, greater concentrations of contaminants may be present in the aquifer above or below the depths at which most of the domestic wells are finished. The contamination of Rockford Unit Well 35, finished in the basal sand and gravel deposits over 100 feet below the domestic wells, appears to be related to the problems being experienced in the shallower wells. It is also possible that contaminants found in Rockford Unit Wells 7A and 38, located about a mile to the north, are related to the domestic well contamination. Therefore, the response of contaminant movement to various conditions of pumpage by high-capacity wells in the area should be evaluated.

In addition to the deep sand and gravel wells, VOCs have been found in a number of "deep" sandstone bedrock wells. Although many of these wells are over 1,000 feet deep, they often are not sealed from overlying, water-bearing formations. Contaminants may have been transported downward with ground water from overlying contaminated zones or introduced by more direct means such as leaky well casings or waste disposal through abandoned wells. The effect of thick layers of fine-grained geologic materials present within the valley fill materials (e.g., lacustrine clays) on contaminant movement also must be closely examined. The downward migration of contaminants through these layers may have affected sand and gravel wells constructed in the basal deposits of the Rock Bedrock Valley and sandstone wells constructed beneath the valley.

The results of such research will provide information important to the implementation of future ground-water protection measures in the Rockford area and potentially the whole state. Siting procedures for new industrial and waste disposal facilities are becoming increasingly reliant upon the presence of thick sequences of fine-grained materials. However, such materials may have little effect on the movement of VOCs or other organic-compound contaminants. It may be necessary to also require engineered features, such as leachate collection and treatment and hydraulic gradient control, to adequately protect the ground water.

A methodology for the investigation of regional ground-water quality is also presented in the report. This methodology is presented as a guide for the planning and execution of future similar investigations in Illinois. This methodology should help to provide consistency in the design of such efforts that may be undertaken by any number of different groups or agencies across the state. The methodology is the result of the experience gained through this investigation and should be recognized as a working model that can be adapted and improved for different geohydrologic conditions.

The methodology involves a phased approach to finding areas of ground-water contamination within an area of investigation and identifying the source(s) of that contamination. It is structured as though an investigator is literally "starting from scratch" with little or no background information. The approach emphasizes compiling and developing existing information into a conceptual framework of the ground-water system. As new information is collected and assimilated, knowledge should be gained on the effects of geologic and anthropogenic influences on the movement and quality of ground water within a region.

CHAPTER 1. INTRODUCTION

A number of investigations conducted by local and state agencies have documented the presence of volatile organic compounds (VOCs) in the ground water at several locations in or near the city of Rockford, a major urban area in northern Illinois. At least four public water supply wells and over 100 private wells in Rockford and surrounding towns have been closed or their use curtailed because of contamination by VOCs. The discovery of VOCs in ground water in these wells has created great concern about the extent and degree to which ground water may be contaminated, the possible occurrence of other instances of ground-water contamination, and the potential health effects associated with such contamination.

The discovery of such ground-water contamination incidents portends a potentially greater problem, one of regional aquifer contamination. Pollution of large areas of an aquifer or aquifers (as opposed to local instances of contamination) can have a great effect on present and future water supplies. This is particularly important in Winnebago County, where ground water provides 100 percent of the supply (over 47 million gallons per day) for public, industrial, and domestic use. In addition, the overlapping or commingling of contaminant plumes, generated by a host of diverse contaminant sources, greatly reduces the ability to distinguish individual sources. Without the ability to determine specific sources, protection of the ground-water resource is severely limited.

These concerns led the Illinois State Water Survey (ISWS) to undertake a regional characterization of ground-water quality in the Rockford area. Two principal objectives were outlined as part of this project:

First, a regional ground-water quality investigation was undertaken to gather information on hazardous substances in drinking water. For the purposes of this project, 18 VOCs and 4 trace metals were chosen as indicators of ground-water contamination by hazardous substances. Because of an ongoing state program to sample all public water supply wells for VOCs and because private water wells have not commonly been sampled for VOCs, this project emphasized sampling of private water wells. Information from the public and private well sampling efforts and other previous state and local ground-water investigations was evaluated with regard to locations of hazardous-substance-related activities and regional geology and ground-water hydrology. Where possible, the relationships between present ground-water quality conditions and the geohydrologic and anthropogenic factors which are responsible for creating the current conditions were considered.

Second, a methodology useful for regional hazardous-substance ground-water data-gathering efforts in other potential problem areas of the state was prepared. Several areas for hazardous-substance monitoring were highlighted in work completed by the ISWS for Illinois Public Act 83-1268 (Wehrmann and Le Seur, 1985). The formulation of a methodology useful for conducting regional (i.e., between 10 and 100 square miles) investigations of ground-water quality in other areas of the state is important. A consistent sampling program must be established so that results of investigations from different areas are comparable and are scientifically sound.

This report summarizes a regional ground-water-quality investigation for the Rockford area. A methodology useful for conducting similar investigations in other parts of Illinois is also provided. The methodology followed during this investigation included a reconnaissance of regional ground-water quality by quantifying the presence of hazardous substances in ground water. Where possible, the presence of these compounds was linked to the distribution of hazardous-substance-related activities and the direction of ground-water movement.

Background

The issue of hazardous waste constituents in ground water has come to the attention of many citizens and government officials in recent years. News reports constantly remind us of new discoveries of ground-water contamination across the nation, including in Illinois. In response to these problems, a number of changes have been instituted in the way hazardous materials are handled, stored, and disposed. Even municipal landfills, for instance, now are designed with compacted clay liners; some also include leachate collection systems, which were unheard of 15 years ago. Increased knowledge of the hazards many materials pose to our health and environment has led to the creation of a variety of new laws and programs directed toward minimizing the potential for hazardous waste impacts on ground water.

Regulations have been passed which more strictly control the design and monitoring of underground tanks used for storing hazardous materials. Standards on disposal site ground-water monitoring and drinking-water quality have been tightened. Laws banning the landfilling of many hazardous wastes have also been passed. Along with such legislation, funds have been made available to pay for the cleanup of hazardous waste sites when responsible parties cannot be found or are unable to pay.

As useful and necessary as these regulations are, however, they do not comprise a concerted, comprehensive ground-water protection strategy. Each rule or program focuses on only a small facet of ground-water protection, often addressing a particular source of potential ground-water contamination. While it is true that many sites around the country were contaminated prior to the passage of pertinent legislation, many others also have become contaminated since these regulations have been in effect (Office of Technology Assessment, 1984). Further, it has been pointed out that contamination could result even from a facility operating in compliance with existing regulations (Schiffman, 1985). Therefore, it appears likely that many more sites will become contaminated in spite of these regulations.

Site-specific "facility" monitoring has generated information with which the effects of some operations on local ground-water quality can be determined. Nonetheless, the effects of these and other activities on regional ground-water quality are mostly unknown. It is likely that the myriad activities which take place in our urban environment have adversely affected ground-water quality in portions of the state. Concern over this issue appeared to underlie the passage of Illinois Public Act 83-1268, which, in part, directed the Department of Energy and Natural Resources (DENR) to "provide a preliminary assessment of current levels of contamination of the groundwater in the State by hazardous substances." However, one of the principal findings of the DENR investigation was that "an assessment of Illinois ground-water quality specifically related to hazardous substances is not possible given the level of information currently available" (Shafer, 1985).

Part of the problem of identifying the effects of hazardous-substance-related activities on ground-water quality and linking those effects to particular sources arises from the numerous and varied sources of contaminants which may have affected ground-water quality over the past 50 to 75 years. But, as the DENR investigation found, the principal difficulty in assessing hazardous-waste impacts on ground-water quality is that the data are far too limited in spatial and temporal coverage and constituent detail to permit a hazardous-waste-related impact assessment (Broten and Johnson, 1985; Helfrich et al., 1985). Without such basic information, associations between ground-water quality, particularly regional ground-water quality, and specific hazardous-substance activities cannot be made.

Statewide assessments of both the potential impact of hazardous-substance-related activities on regional ground-water quality and the effectiveness of the numerous regulations aimed at ground-water protection will take many years to accomplish. A variety of hazardous-substance-activity and ground-water-quality databases will need to be evaluated and, in some cases, developed. Because of the geographic distribution of Illinois' ground-water resources as well as the distribution of activities which may potentially contaminate those resources, regional ground-water monitoring efforts appear to contain an advantage over statewide sampling programs. Through a regional monitoring program, concentrated efforts can be directed toward areas with a high potential for contamination. "Blanket" statewide sampling of a limited number of wells (e.g., public water supply wells) is bound to be less effective at determining areas of contamination because of the resources expended in areas unlikely to be contaminated.

The development of a methodology which will establish the best approaches to source identification and ground-water-quality determination on a regional basis will further increase the effectiveness of regional monitoring. Companion ground-water monitoring and hydrogeological assessment programs also will create a baseline for judging the effectiveness of ground-water protection strategies. Effective plans for ground-water protection must include programs for regional ground-water monitoring and hydrogeological assessments to supplement current statewide and site-specific monitoring programs.

The Illinois Statewide Monitoring Program

A statewide ground-water monitoring network has been designed to assess the **ambient** ground-water quality of principal aquifers in Illinois (O'Hearn and Schock, 1984). [Principal aquifers were defined as geologic formations capable of yielding more than 100,000 gallons per day per square mile and covering more than 50 square miles.] The basic functions of the proposed monitoring network are to evaluate the occurrence and significance of long-term trends in ground-water quality in principal aquifers and to initiate specialized studies in areas of suspect water quality. These functions serve to identify potential problem areas for current and future potable water supplies.

This recommended monitoring network is broad in scale and, if implemented, will require the close cooperation of a number of state and federal agencies. The Ground-Water and Aquatic Chemistry Sections of the ISWS, the Groundwater Section of the Illinois State Geological Survey (ISGS), the United States Geological Survey (USGS), and the Division of Public Water Supplies in the Illinois Environmental Protection Agency (IEPA) have all contributed to interagency efforts to initiate this statewide ground-water monitoring network.

As part of this effort, the IEPA embarked on a program of sampling approximately 100 public water supply wells across the state. The wells were sampled three times on a quarterly schedule during 1984. Chemical analyses were limited to the determination of dissolved mineral constituents and trace inorganic constituents. For the fourth quarterly sampling round in early 1985, the suite of chemical analyses was expanded to include a number of organic parameters including total organic carbon (TOC), total organic halogens (TOX), volatile chlorinated compounds (e.g., chloroform, trichloroethylene), and volatile aromatic compounds (e.g., PCB's, pesticides). Since this initial effort, IEPA has expanded the sampling program to include all 3,427 public water supply wells in Illinois. It is expected that it will take nearly four years to complete the first round of sampling (IEPA, 1986). As of September 1986, approximately one-third of the wells had been sampled by IEPA. Preliminary results indicate that about 12 percent of the samples contained greater than 1 $\mu g\ l^{-1}$ total VOC (R. P. Clarke, Manager, Groundwater Section, Division of Public Water Supplies, IEPA, personal communication, 1986). Follow-up investigations are being conducted at wells confirmed to be contaminated.

Information on organic compounds in raw public ground-water supplies will greatly expand the data currently available for linking hazardous-substance activities to deterioration of ground-water quality. This information will help to determine the current conditions against which any observed changes in water quality can be evaluated. As predicted by O'Hearn and Schock (1984), the presence of contaminants in a ground-water sample has required more detailed follow-up data collection and interpretation than a statewide public well survey alone could provide. This includes resampling to confirm analytical results, possibly abandoning or curtailing the use of a well if the concentrations of contaminants found are thought to present a significant risk to users, identifying the source of contamination, developing an alternative supply, and eventually remediating the contaminated ground water.

As useful and as necessary as the IEPA survey is, however, much of the information necessary to identify areas with contaminated ground water may not be collected. The usefulness of these data will be limited by the distribution of public water supply wells, the depths at which these wells are finished, and the difficulties with which "representative" ground-water samples can be collected from high-capacity wells. It was further recognized that some portions of the state are more likely to be contaminated than others because of the sensitivity of the geology and the density of overlying potentially contaminating activities. Therefore, sampling efforts ought to be directed toward those areas. Identifying these areas was the essential element in a scheme developed by the ISWS to focus the needed data-gathering efforts in areas where significant ground-water resources are most likely to be affected by hazardous-substance-related activities (Wehrmann and Le Seur, 1985).

The Hazardous Substance Monitoring Strategy

The recognition that it is impractical and unnecessary to monitor ground water beneath all areas and within all water-bearing formations of the state at the same level of detail led to the formulation of a hazardous-substance ground-water monitoring strategy. The approach was designed to emphasize regions in which the resource and the most people are potentially at risk. Areas which received the highest priority in the strategy were 1) those having significant public ground-water withdrawals where large populations may be potentially affected, 2) those where the aquifers are sensitive to ground-water contamination, and 3) those which are proximate to high levels of potentially contaminating activities.

The targeting process used to prioritize areas within the state for intensive study was based on four criteria:

1) current ground-water withdrawals of greater than 100,000 gallons per day per township,

2) potential significant ground-water withdrawals (identified as aquifers capable of yielding greater than 100,000 gallons per day per square mile and covering an area greater than 50 square miles),

3) potential hazardous-substance sources (more than 2.0 hazardous-substance-related facilities per square mile), and

4) aquifers highly susceptible to contamination (where permeable deposits occur within 50 feet of land surface).

Two state maps were produced overlaying areas selected on the basis of these four criteria. One map was for sand and gravel aquifers and one for shallow bedrock aquifers. Areas where all four criteria were satisfied were targeted for ground-water data collection. Targeted areas included essentially all of the state's major urban, industrial centers. These areas include, but are not limited to, the Greater Chicago area, Joliet, Kankakee, Peoria-Pekin, Rock Island-Moline, Quincy, East St. Louis, and Rockford-Belvidere.

Study Area Description

The Rockford region is an area particularly well-suited for an investigation of regional ground-water quality impacts due to hazardous substances. The abundance of potentially contaminating activities over the highly productive and sensitive aquifers in the area made Rockford one of the few regions in the state to be highlighted on both the sand-and-gravel and shallow-bedrock targeting maps developed for the hazardous-substance monitoring strategy previously described. [Maps of the prioritized areas in Winnebago County for the two aquifers appear in figures 19 and 20, pages 42 and 43].

The region contains plentiful ground-water resources and depends heavily on those resources for water supply (Smith and Larson, 1948; Hackett, 1960). According to Kirk et al. (1985), nearly 47 million gallons of ground water are withdrawn each day for public, industrial, and domestic uses in Winnebago County. Excluding surface water withdrawals for electrical power generation, ground water provides 100 percent of the water for use in Winnebago County.

Unfortunately, the qualities that make these resources so highly productive also make them highly sensitive to contamination from surface and near-surface activities (Berg et al., 1984a and 1984b). The sensitivity of these resources is evidenced by the numerous contamination instances which have been documented in the immediate area (Shuster, 1976; Dept. of Environmental Health, 1984; Gibb et al., 1984; Wehrmann, 1984). The long period of industrial development in

Rockford, which has involved production of a wide variety and quantity of wastes for nearly 100 years, logically plays an important role in the ground-water quality problems being faced today (Colten and Breen, 1986).

The study area for this project (figure 1) was defined by using enlarged portions of the previously mentioned statewide ground-water monitoring prioritization maps (figures 19 and 20). Because these maps incorporate geologic (aquifer sensitivity) and hydrologic (current and potential ground-water use) information, prioritized areas tend to follow natural geohydrologic boundaries. The high-priority areas shown in figure 19 closely follow the outline of the sand and gravel aquifer within the Rock River valley. For ease of mapping, section and township boundaries were used to describe the study area. The study area chosen, therefore, includes the principal sand and gravel resources within the Rockford area as well as upland areas containing ground water within the shallow bedrock.

The study area includes nearly all of the cities of Rockford and Loves Park, as well as the village of Machesney Park. Covering approximately 76 square miles, the area consists of a gently rolling topography with some steep terrain at the Rock River valley wall. Land surface elevations vary from a high of 850 feet above mean sea level (msl) on the eastern edge of the study area to a low of 690 feet msl along the Rock River. The topography is higher again to the west, approximately 800 feet msl.

Rockford and Loves Park maintain municipal water departments, while Machesney Park is served principally by the North Park Water District, a publicly owned water system that operates independently of the village. The North Park Water District also serves portions of Loves Park and several outlying areas. A number of small areas within the corporate limits of these municipalities have not been incorporated and continue to maintain private on-site water and wastewater disposal systems. These areas served as the basis for sampling within many portions of the study area.

This report summarizes previously uncompiled information on the geology, ground-water hydrology, and ground-water quality of the Rockford region. Information collected through previous investigations and ongoing programs is described first to provide a framework for this investigation. Through integration of regional geohydrologic information with potential contaminant sources and previously known areas of contamination, qualitative concepts concerning the movement of contaminants through the area began to emerge. This conceptual "model" provided guidance to the selection of wells for sampling and to the interpretation of data collected during the investigation.

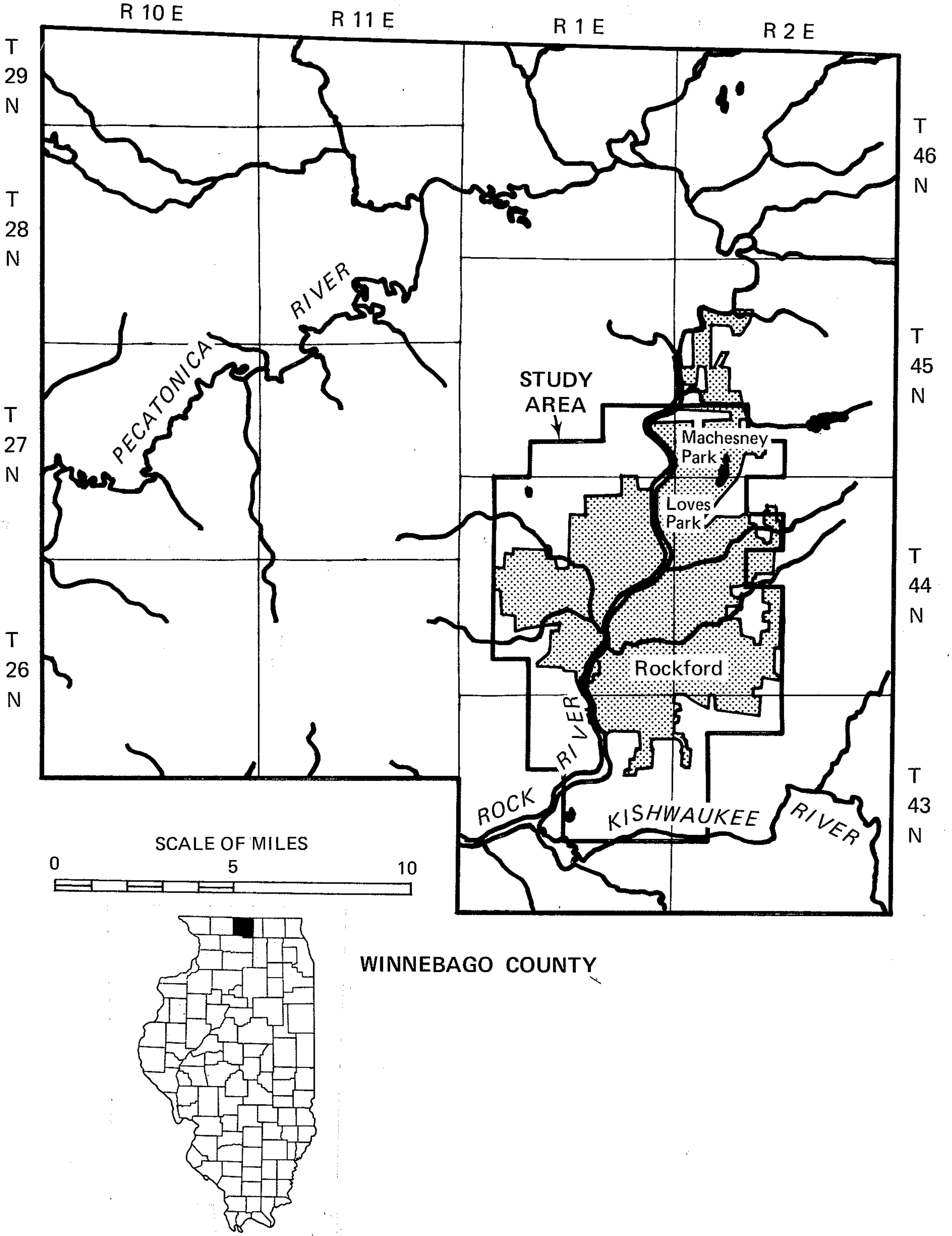

Figure 1. Location of study area

CHAPTER 2. GEOLOGY, GROUND-WATER HYDROLOGY, AND GROUND-WATER QUALITY IN THE ROCKFORD AREA

A Summary of Available Information

Geology of the Rockford Area

Previous studies on the geology and hydrogeology of Winnebago County, Illinois (Smith and Larson, 1948; Hackett, 1960; Berg et al., 1984a) have considered the entire county. Additional geologic information on the immediate area around Rockford was evaluated during this investigation to determine the presence of fine-grained materials within the sand and gravel aquifers which may influence regional ground-water movement and quality in the Rock River valley.

The geology of Winnebago County is characterized by unconsolidated Quaternary material unconformably underlain by a 2500-foot section of Paleozoic sedimentary rock. The Quaternary deposits are composed of glaciofluvial sand and gravel, lacustrine silt and clay, eolian silt (loess), and till. The Paleozoic sedimentary rocks of Cambrian and Ordovician age are interbedded deposits of sandstone, shale and dolomite. The bedrock surface is unconformable with the Quaternary deposits because of erosion that formed the deeply incised and well-developed preglacial Rock Bedrock Valley, which trends north-south through Winnebago County.

Bedrock Geology

In Winnebago County the bedrock units consist of more than 2,000 feet of Cambrian sandstones and less than 600 feet of Ordovician dolomite (figure 2). The Cambrian System consists of seven formations; from the oldest to the youngest they are the Mt. Simon Sandstone, Eau Claire Formation, Ironton and Galesville Sandstones, Franconia Formation, and Potosi Dolomite. The Ordovician System is composed of the following three groups: the Ancell (consisting of the Glenwood Formation and St. Peter Sandstone), the Platteville, and the Galena.

The Mt. Simon Sandstone, the basal zone of the Eau Claire Formation (Elmhurst Sandstone), and the Ironton-Galesville Sandstone are the principal water-yielding units within the Cambrian System. The Mt. Simon Sandstone is a poorly sorted, very fine- to very coarse-grained, silty, friable sandstone. The Eau Claire Formation, which consists of impermeable dolomitic shales, sandy dolomites, and dolomitic or argillaceous sandstones, separates the Mt. Simon from the Ironton and Galesville. The Ironton and Galesville Formations are difficult to separate hydrogeologically and are considered to be a single unit referred to as the Ironton-Galesville Sandstone (Hackett, 1960). The Galesville Sandstone is a clean, fine- to medium-grained well-sorted

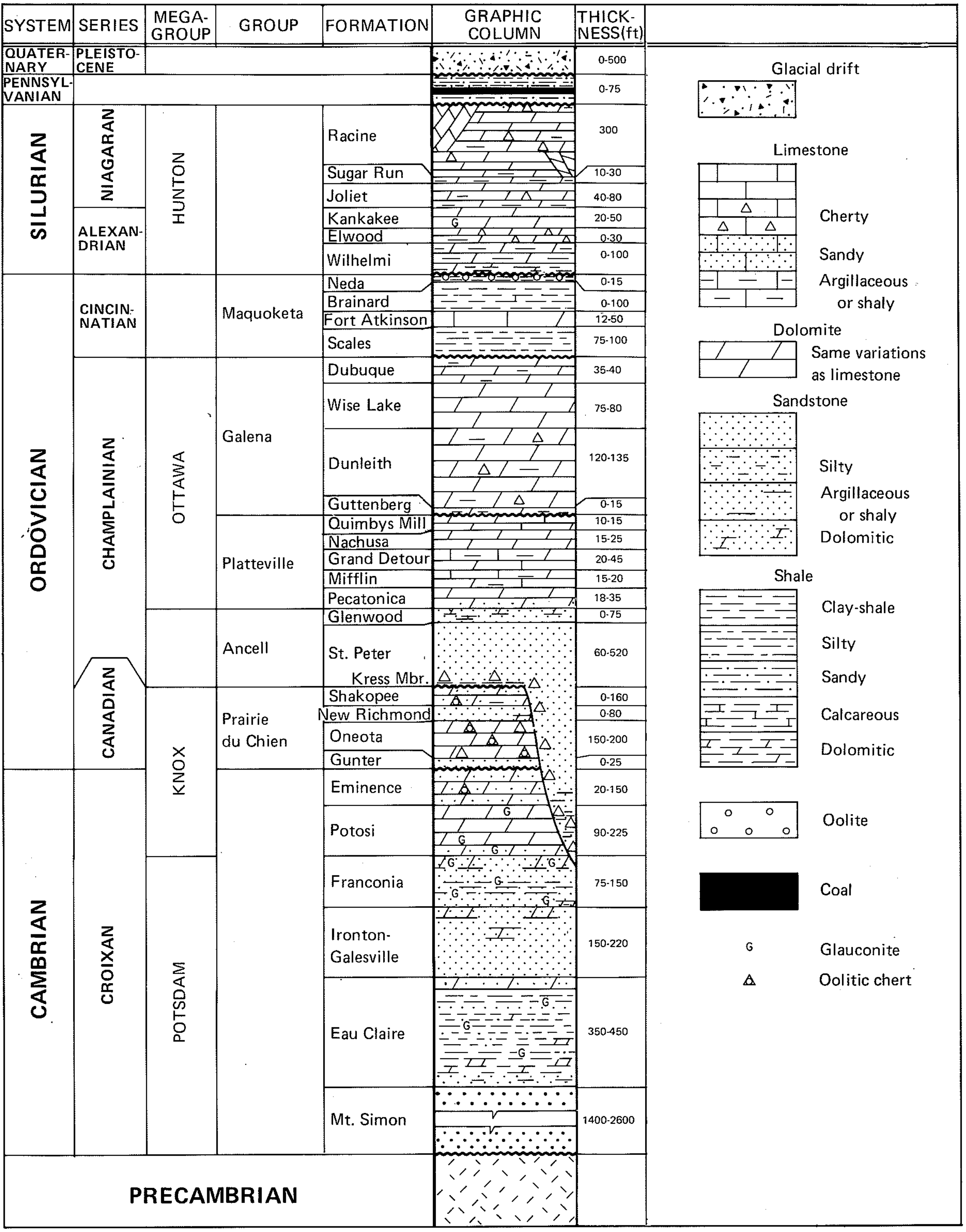

Figure 2. Stratigraphic column for the Rockford area (from Kolata et al., 1978)

sandstone overlain by the Ironton Sandstone. The Ironton Sandstone is a fine- to very coarse-grained, commonly dolomitic sandstone.

The Franconia and Potosi Formations overlie the Ironton-Galesville. The Franconia consists primarily of fine-grained sandstone, interbedded siltstone and shale, and silty dolomite. The Potosi Formation is a finely crystalline dolomite with small amounts of clay, silt, or sand. The fine-textured nature of the Franconia suggests that it is non-water-yielding, whereas the Potosi dolomitic beds may yield water locally from fractures. These formations separate the Cambrian aquifers from the overlying Ordovician-aged St. Peter Sandstone.

The St. Peter Sandstone is composed of a fine- to coarse-grained sandstone which is locally silty and argillaceous. The unit has a relatively uniform lithology with a high intergranular porosity and hydraulic conductivity (permeability). These properties are responsible for the high yields of this aquifer.

The overlying Glenwood Formation is composed of interbedded dolomite, sandstone, and shale. Its base is a sandstone that is often indistinguishable from the underlying St. Peter. This basal sandstone zone may provide some water to wells drilled into the underlying aquifers, but the Glenwood in general is too impermeable to be a significant aquifer.

The Glenwood Formation is overlain by dolomites of the Platteville and Galena Groups. The Platteville Group is composed of fine crystalline dolomite which is dense and partly argillaceous. The Galena is usually a medium- to coarse-grained, partly cherty dolomite and is more thickly bedded than the Platteville. The water-yielding character of these dolomites is the result of a well-developed joint and fracture system. These aquifers are a principal source of residential water supplies outside of the Rock Bedrock Valley.

Glacial Geology

Glacial deposits overlie the jointed and fractured Galena-Platteville Dolomite on the uplands and the porous and permeable St. Peter Sandstone in the Rock River Valley (figure 3). Glacial deposits of the Glasford Formation in the Rockford area are composed of five till members (the Esmond, Oregon, Fairdale, Ogle and Kellerville) and related outwash materials (figure 4). These deposits comprise two-thirds of the valley fill. The younger Winnebago Formation has three members (the Argyle and Nimtz Tills and the Beaver Creek Sand) which are present mostly on upland surfaces. The Argyle, Nimtz, Oregon, and Ogle Tills comprise most of the upland surficial materials.

The bedrock uplands are characterized by a thin (less than 5 feet) veneer of eolian material overlying tills which occasionally contain interbedded lenses of outwash sands and gravels (see figures 6-8). Most of the tills in the Rockford area are sandy except for the Esmond Till,

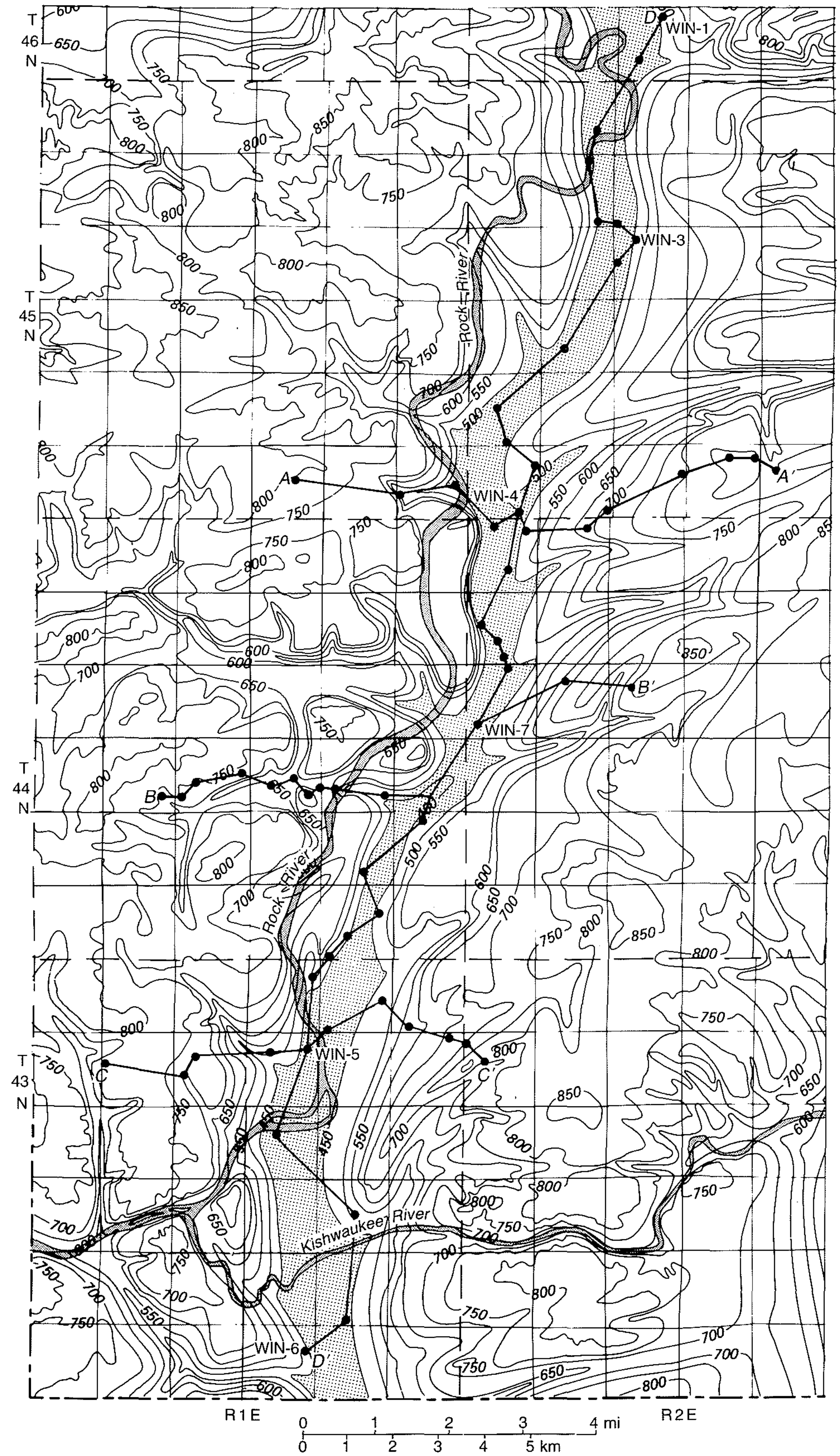

Figure 3. Bedrock topography of the Rockford area (after Berg et al., 1985) and locations of cross sections. Light shading represents the lowest portion of the ancestral Rock River, and dark shading represents the modern Rock River.

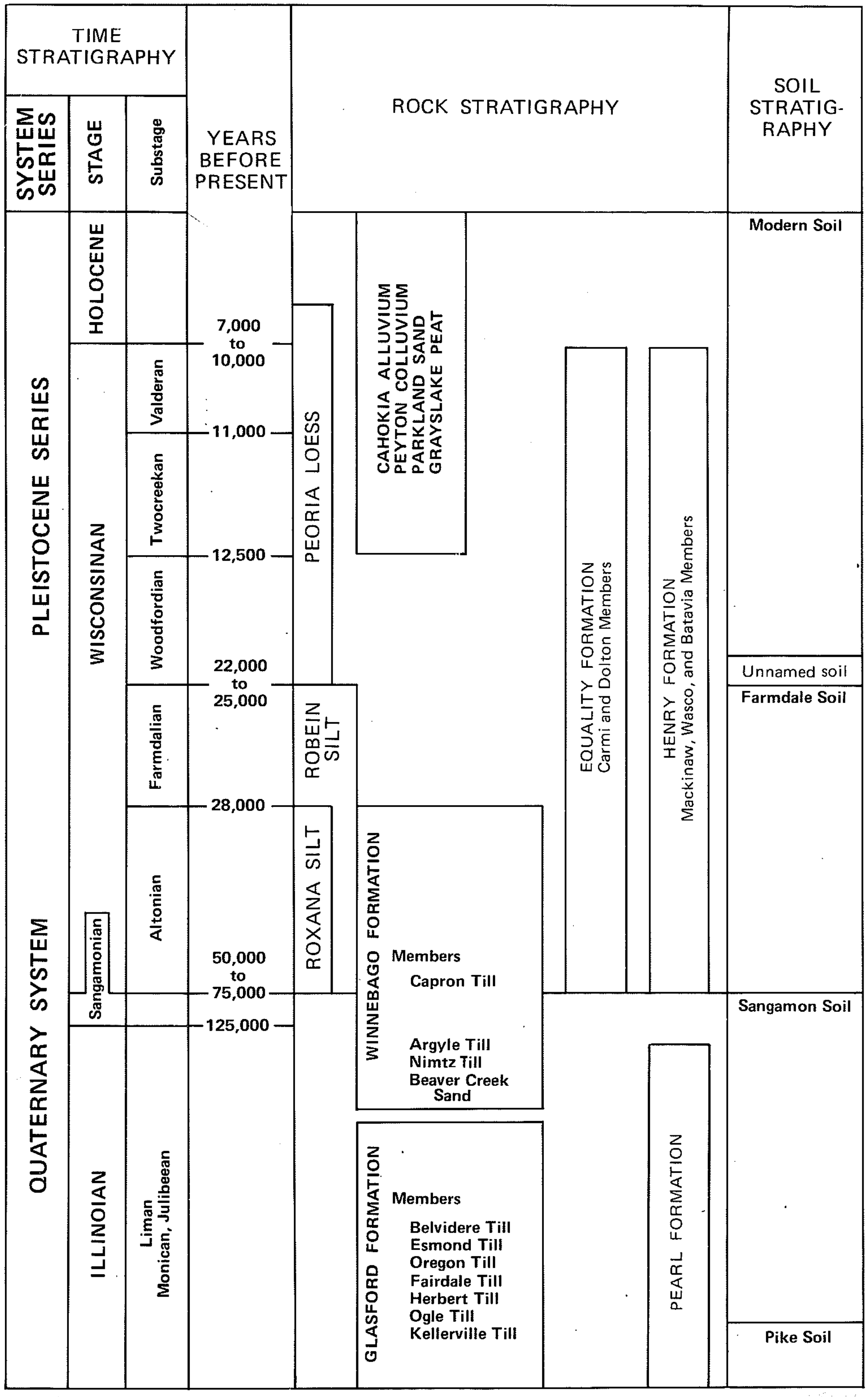

Figure 4. Stratigraphic classification of Quaternary deposits of central-northern Illinois (from Berg et al., 1985)

which is a silty clay. To the west of the Rock Bedrock Valley, the drift on the uplands is usually less than 20 feet thick, but in a few locations it is up to 100 feet thick where an ancient tributary valley to the Rock Bedrock Valley is present. The drift varies from 50 to 150 feet thick on the uplands east of the valley.

The Rock Bedrock Valley contains about 250 feet of glacial drift. The modern Rock River valley is superimposed above the ancient Rock Bedrock Valley except in two locations (figure 3). At Rockford, the present river flows across the bedrock uplands west of the bedrock valley axis. In Section 14, T. 43 N., R. 1 E., the modern river turns southwestward as the trend of the bedrock valley continues southward.

The surficial deposits along the Rock River consist of modern silts and sands -- the Cahokia Alluvium. Beneath the alluvium, the unconsolidated glacial materials in the valley consist predominantly of sand and gravel outwash and lacustrine clays and silts deposited directly from glacial meltwaters and, to a lesser extent, glacial tills deposited directly from glacial ice. The glacial ice position relative to the valley trend established the type and distribution of valley-fill sediments. During periodic discharges of glacial meltwater, the Rock valley, unimpeded by glacial ice advancing from the north or east, acted as a conduit and was filled by stratified outwash. When the meltwater drainage system was blocked by glacial ice, a lake formed until the flow was diverted to a new ice-marginal stream or until the ice receded. Lacustrine deposits of clay, silt, and very fine sand represent the numerous ponding events that occurred in the valley. These fine-grained deposits are found at similar elevations throughout the valley, suggesting that they are related to a continuous deposition within a single glacially dammed lake. Their lateral discontinuities are a result of later erosion and subsequent outwash deposition.

The thin layers of till in the valley fill represent deposition directly from the ice as the glacier moved across the valley. Lateral discontinuities of tills are due to erosion as well as nondeposition. In the west-to-east cross sections (figures 6-8), these lenses consist of Fairdale, Oregon, and Esmond Tills (for a key to symbols used on the cross sections, see figure 5). In the extreme north on cross section D-D', a lens of Kellerville Till is present (figure 9).

The lacustrine beds are primarily associated with the Fairdale and Oregon Tills. In particular, two Oregon lacustrine beds are continuous across the valley, as seen in cross sections A-A', B-B', and C-C' (figures 6-8), as well as north and south along the valley trend (figure 9, cross section D-D'). Other lacustrine beds present in the valley fill are associated with the Banner Formation, and the Kellerville and Esmond Tills. The lacustrine beds associated with the Banner Formation are shown in cross section B-B' (figure 7) and at the extreme north and south ends of cross section D-D' (figure 9).

Symbol	Unit	Lithology
wia	Argyle	pinkish or buff-tan; often friable sandy till
win	Nimtz	gray-brown or buff; often compact sandy or sandy loam till
wib	Beaver Creek Sand	sand and gravel outwash
ge	Esmond	grayish brown silty clay till
gor	Oregon	pinkish brown or buff sandy loam till
gf	Fairdale	yellowish brown sandy loam till
gk	Kellerville	brown clay loam to silt loam till
–l	Lacustrine	fine-grained sediments associated with a specific till
–o	Outwash	sand and gravel deposits associated with a specific till
c	Cahokia Alluvium	sand, silt, and clay deposited by modern rivers and streams
pl	Parkland sand	windblown (eolian) sand
pr	Peoria Loess and Roxana Silt	windblown (eolian) silt
hm	Henry Formation	Mackinaw Member sand and gravel
ec	Equality Formation	Carmi Member lake silts and clays

▨ till

▨ outwash sand and gravel

▨ lacustrine clay

▨ lacustrine silt-clay

▨ lacustrine sandy silt -sandy clay

▨ organic materials or buried soil

TD—total depth

ww—water well boring

WIN #—ISGS test boring

TB—tollway boring

Figure 5. Legend for geologic cross-sections A-A' through D-D'

The outwash sands and gravels range from fine- to very coarse-grained and are poorly to well sorted. The lower portion of the outwash valley fill, below the Oregon-related sediments, is outwash related to the Banner Formation and the Fairdale and Kellerville Tills. The thickness of sediment between the Oregon-related deposits and the bedrock increases from 100 feet in the north to 150 feet in the south because of the downgradient bedrock valley incision and subsequent sediment infilling.

The pre-Illinoian Banner Formation at the north end of cross section D-D' (figure 9) is a well-sorted, medium-grained sand or very coarse-grained sand and medium gravel. Although absent near Rockford, to the south it is a medium- to coarse-grained sand with a little gravel.

The Kellerville outwash is present only in the north, where it is a silty fine sand with occasional beds of well-sorted, medium- to coarse-grained sand. At the most northern data point on cross section D-D' (figure 9), the Kellerville unit is composed of outwash, lacustrine deposits, and till. The thickness of outwash deposits within the Kellerville increases considerably to the south where the lacustrine deposits thin out.

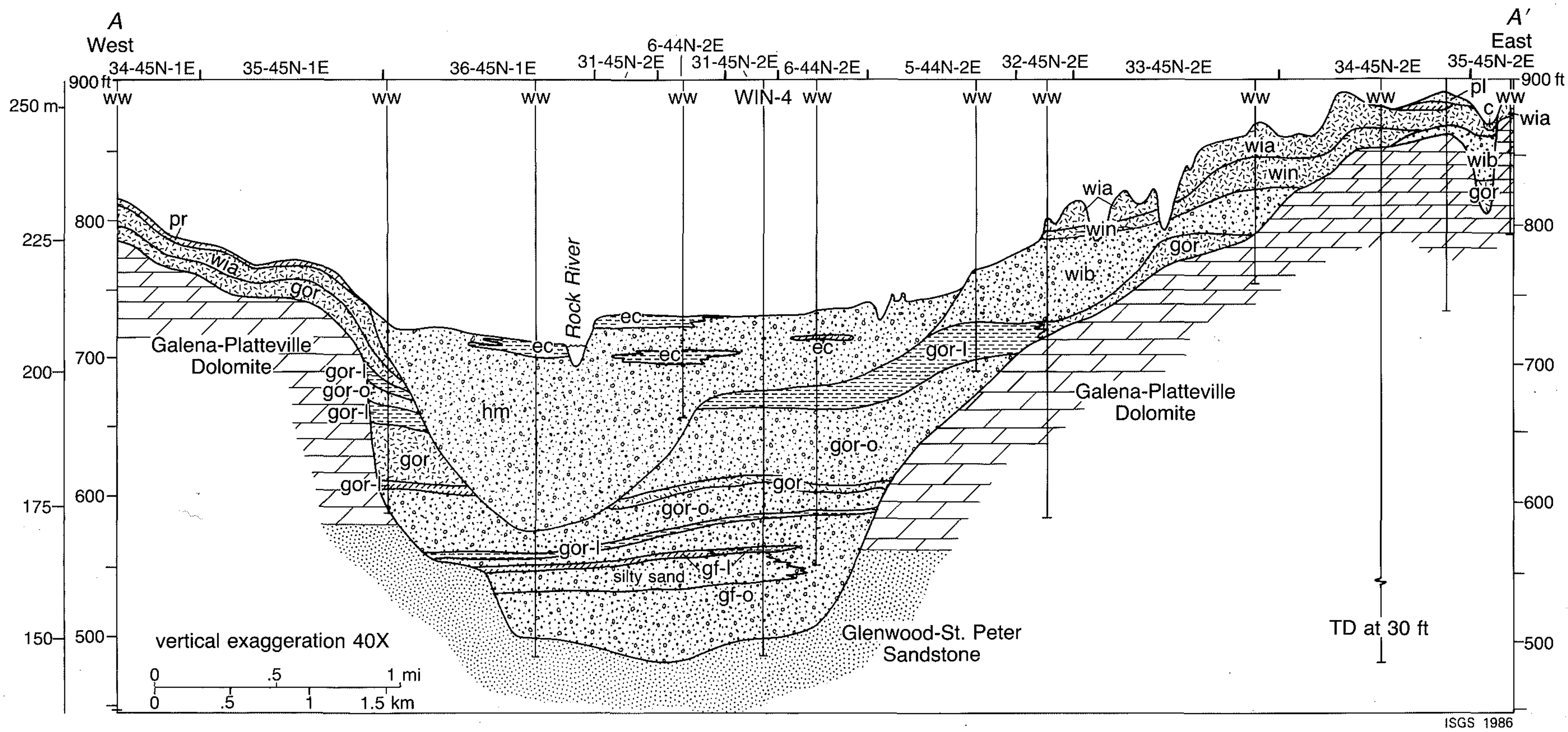

Figure 6. West-east cross section A-A' through North Park area (See figure 5 for a key to the symbols used)

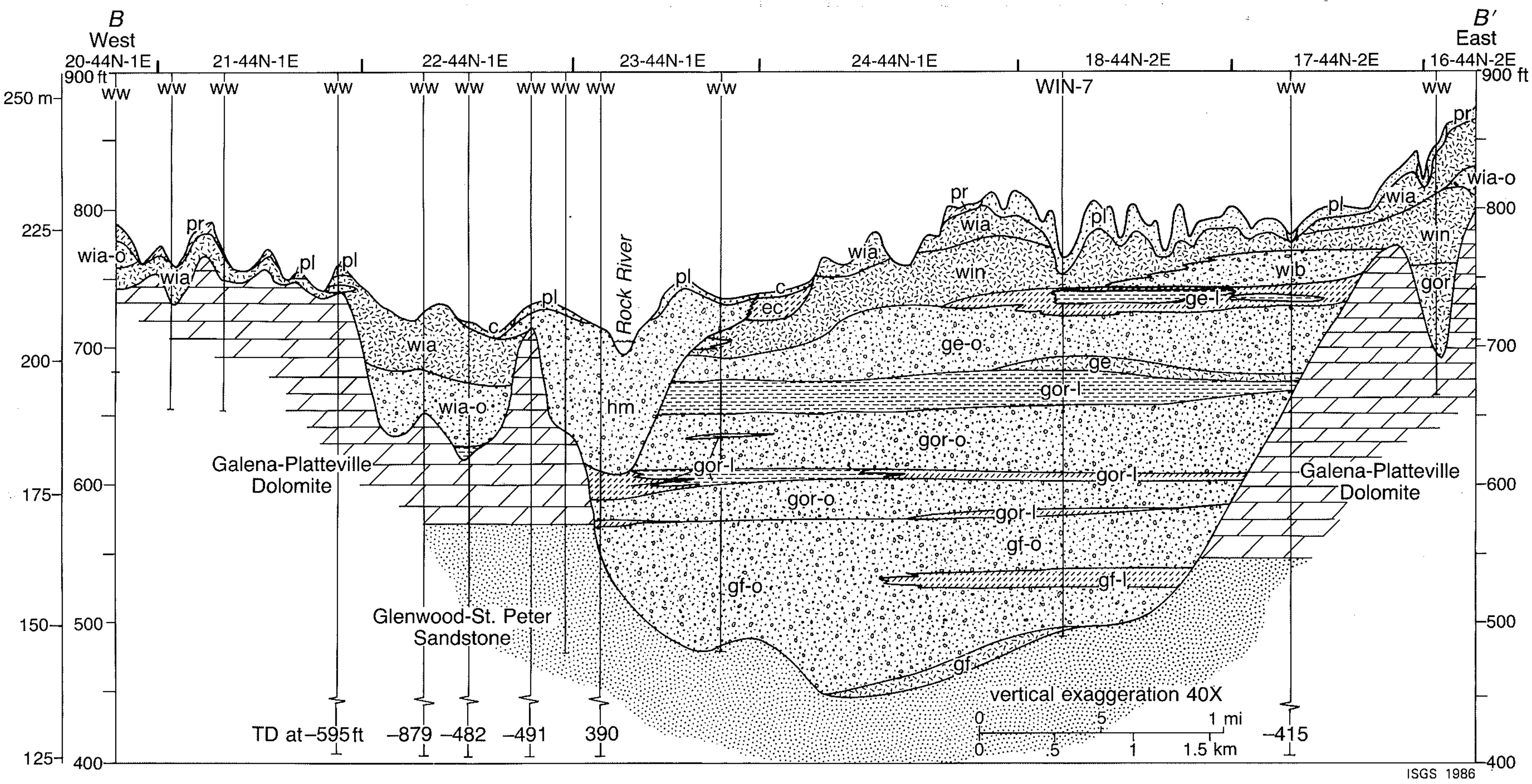

Figure 7. West-east cross section B-B' through central Rockford (See figure 5 for a key to the symbols used)

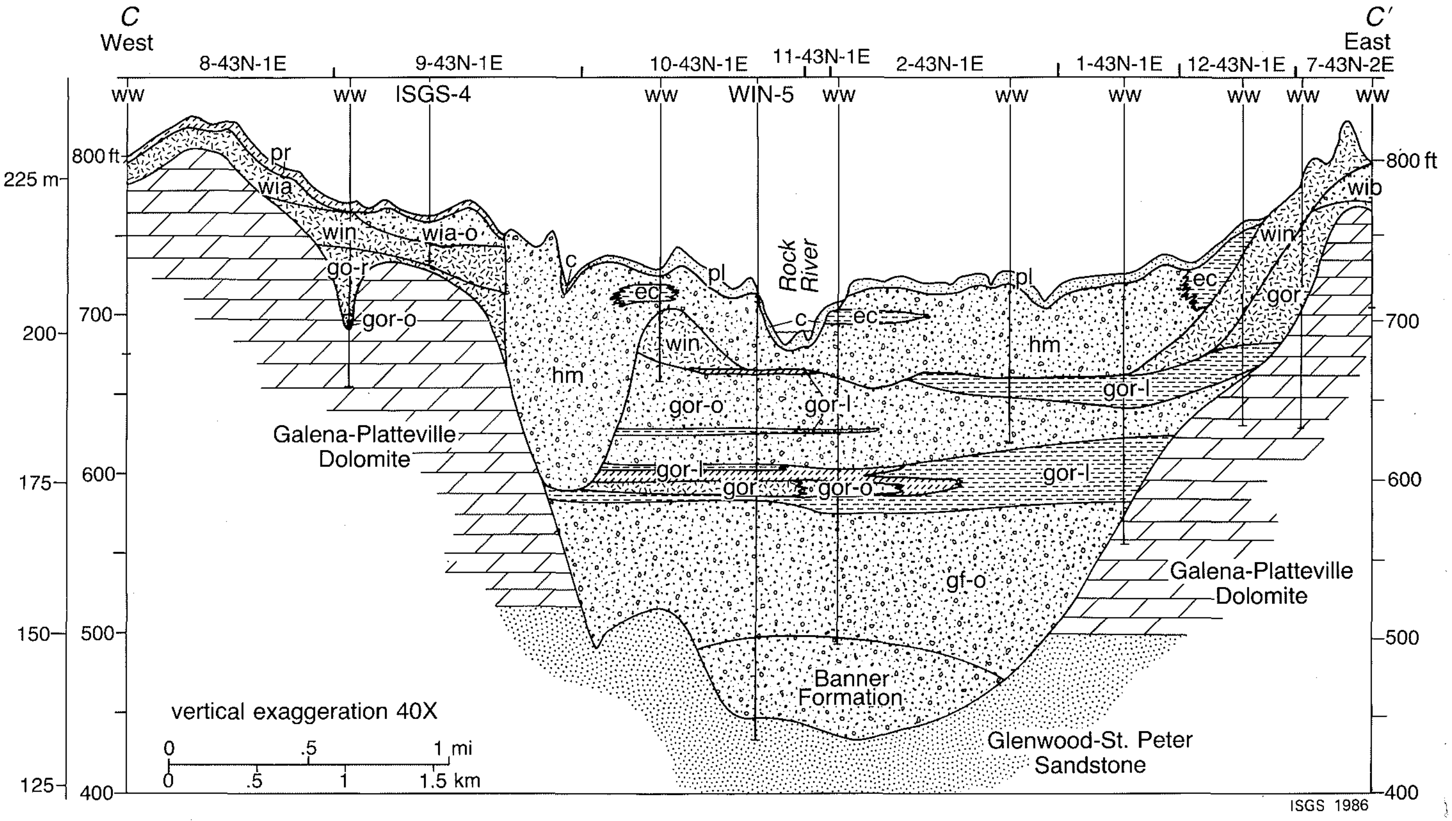

Figure 8. West-east cross section C-C' through southern Rockford (See figure 5 for a key to the symbols used)

The outwash associated with the Fairdale Till Member occurs in the southern portion of the study area as a medium- to very coarse-grained sand and gravel with some beds of well-sorted, coarse sand with fine gravel. The most northerly extent of the Fairdale is in the southern half of T. 45 N., R. 2 E., where the outwash is a fine to coarse gravelly sand with a few beds of pea gravel.

The deposits related to the Oregon Till consist of outwash and lacustrine deposits with thin till stringers. The amount of fine-grained lacustrine material increases to the south as the outwash sands and gravels thin out. The continuity of these thin fine-grained units is disturbed by later meltwater erosion and outwash deposition. The outwash is composed of a silty sand with gravel at the north and south ends of cross section D-D' (figure 9). The outwash shown in the central portion of figure 9 is characterized by well-sorted coarse-grained sand with some fine gravel or fine to coarse sand with gravel.

Much of the upper part of the valley fill consists of outwash sands and gravels of the Mackinaw Member of the Henry Formation (figure 9). The Mackinaw Member is the youngest glacial outwash and includes sediments deposited in the valley during late deglaciation. It is variable in texture, ranging from a poorly sorted fine- to coarse-grained sand and gravel to a well-sorted fine sand or coarse sand with fine gravel. The three west-east cross sections (figures 6-8) illustrate the thickening of the Henry Formation outwash deposits over portions of the valley in the west. The erosion of the older fine-grained valley fill, such as the tills or lacustrine beds, caused the valley fill in the west to be coarse-grained and uniform.

Many high-capacity wells serving municipal and industrial users have developed their supplies in the deeper portions of the outwash sands and gravels, presumably Fairdale or Banner outwash in the southern portion of Rockford, and Kellerville or Banner outwash in the northern portion of the study area. While overlying fine-grained deposits appear to be fairly continuous across the Rock Bedrock Valley, little is known about vertical movement of ground water and, consequently, about contaminant transport through these deposits. A discussion of what is known about ground water within the study area follows.

Ground-Water Hydrology of the Rockford Area

Ground water in the Rockford area is derived primarily from three different, though in many areas hydraulically connected, geologic units. These aquifers are: 1) the Pleistocene glacial drift, comprised predominately of outwash sands and gravels in the Rock Bedrock Valley; 2) the Ordovician dolomites, the "shallow" bedrock encountered in the uplands overlooking the river valley; and 3) the Cambrian sandstones, encountered beneath the dolomite in the uplands but comprising the bedrock surface beneath most of the outwash deposits in the deeper portions of the Rock Bedrock Valley. Ground water from these three formations provides 100 percent of the supply for public,

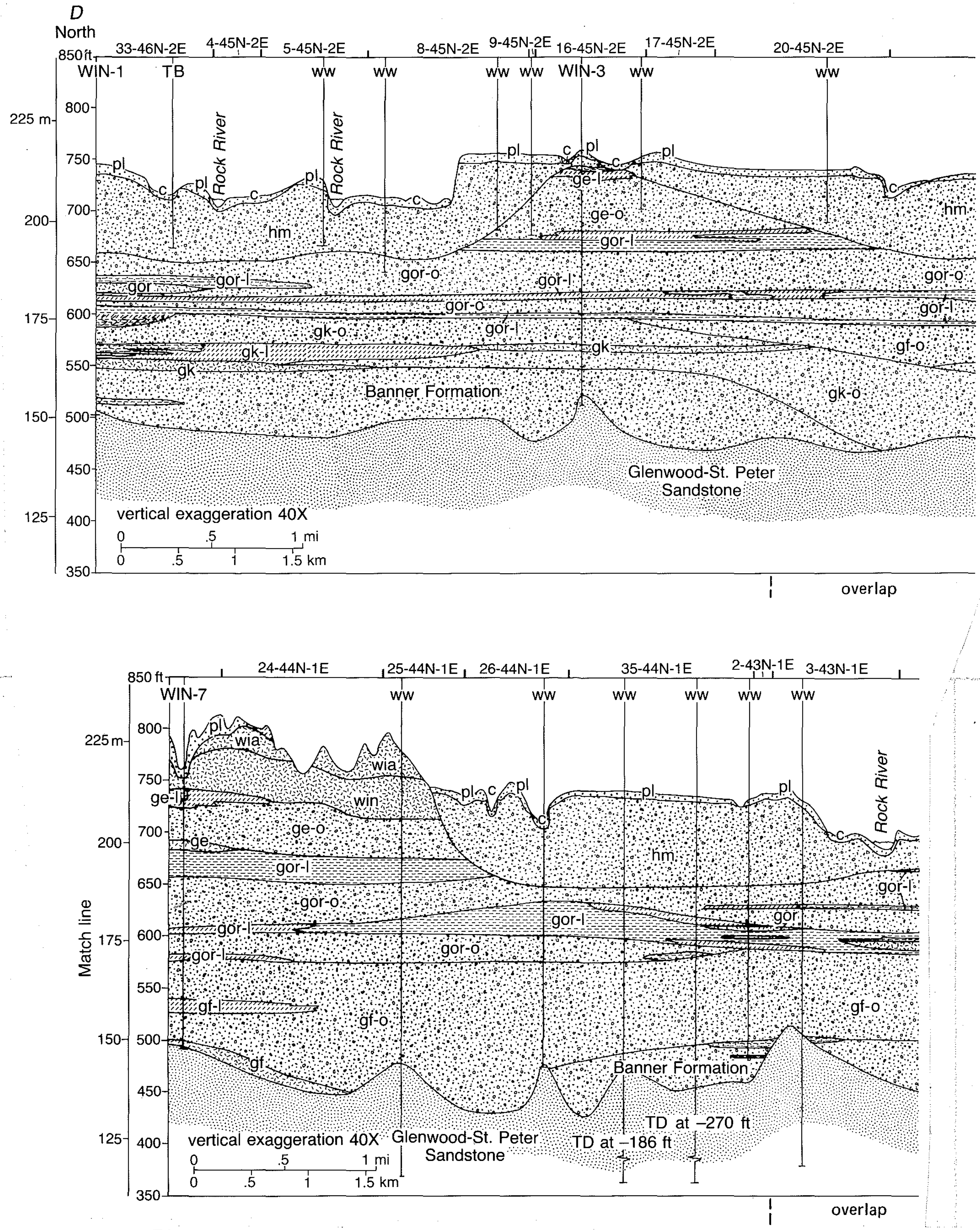

Figure 9. North-south cross section D-D' through the Rock Bedrock Valley from Roscoe to near the Ogle County line (See figure 5 for a key to the symbols used)

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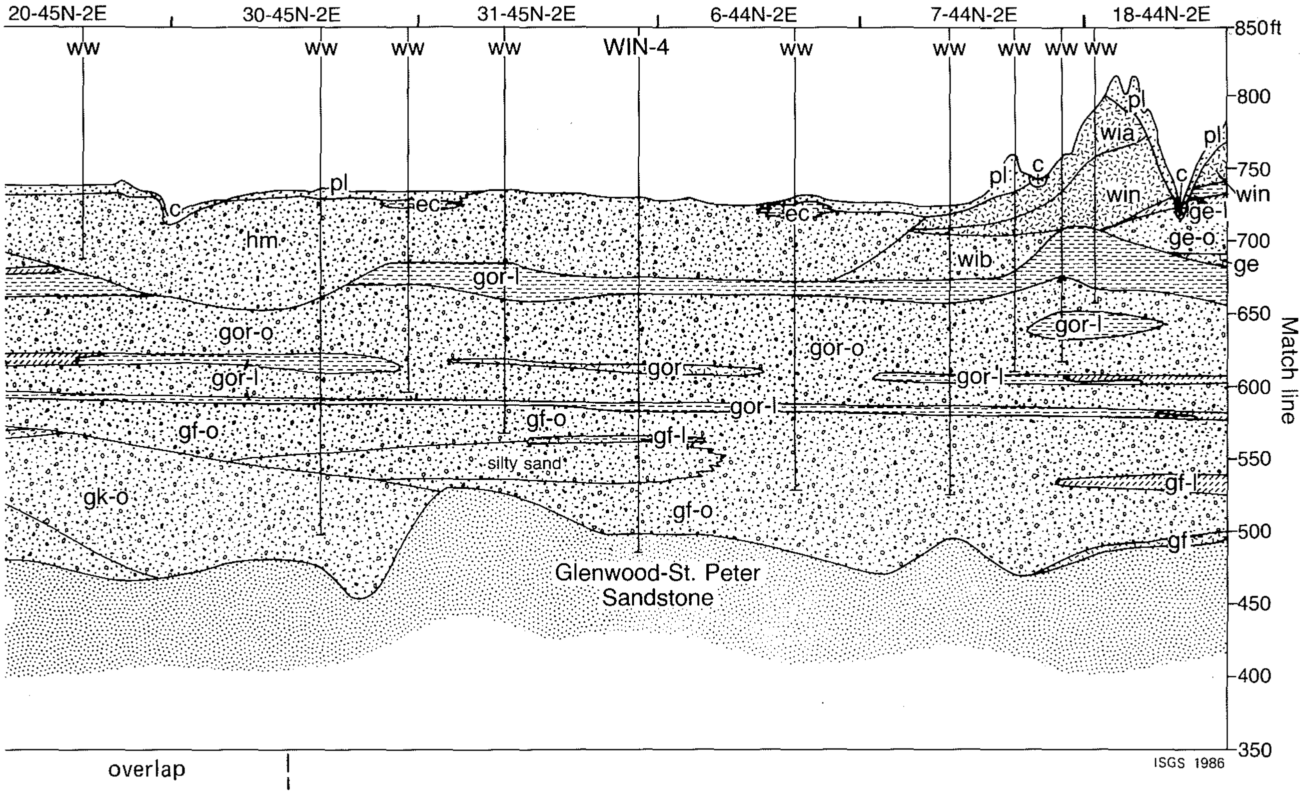

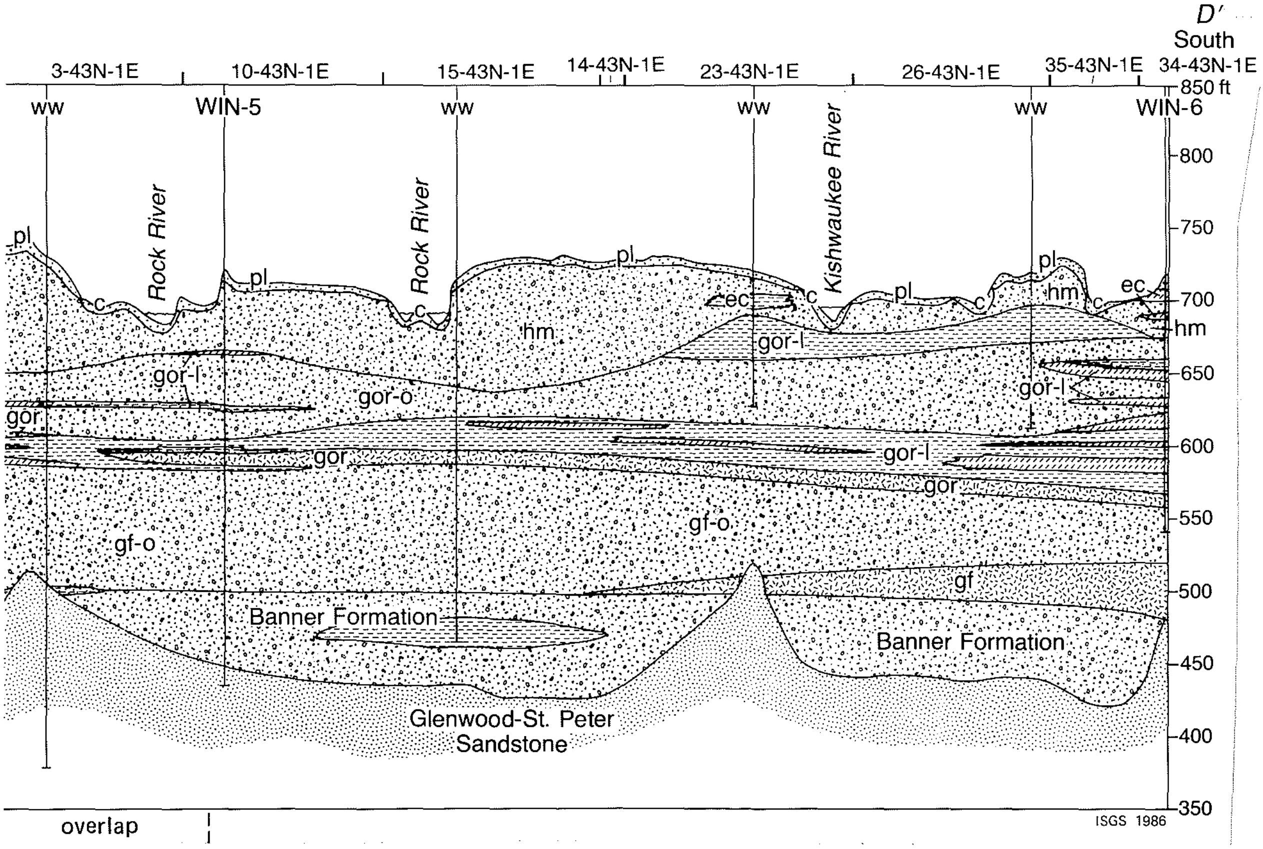

Figure 9. Concluded

industrial, and domestic use (excluding water for electrical power generation) in Winnebago County.

Ground-Water Withdrawals

The greatest amount of ground water is developed from sand and gravel and deep bedrock aquifers. The following table is based, in part, on data compiled by the ISWS (Kirk et al., 1985).

Table 1. Estimated 1984 Ground-Water Withdrawals
(For Townships 43 and 44 North, Ranges 1 and 2 East)

	Ground-Water Withdrawals* for			
Major Aquifer System	Public Supply	Self-Supplied Industry	Domestic Supply	Aquifer Total
Sand and gravel	10.638	1.346	0.661	12.645
Silurian-Devonian	0.068	1.038	1.983	3.089
Cambrian-Ordovician	17.417	1.920	0.132	19.469
Total (all aquifers)	28.123	4.304	2.776	35.203

* In million gallons per day

To estimate domestic ground-water withdrawals, a computation was made of the difference between 1980 Census figures for the number of occupied housing units in Rockford and Loves Park (59,060) and the total number of connections to public water systems within the area of interest (45,957 as estimated by the Rockford and Loves Park Water Departments and a number of privately maintained mobile home parks and apartments). This number was then multiplied by the average number of occupants per household in the city of Rockford (2.26) and an average per capita consumption (89.3 gallons per day for northwestern Illinois, Kirk et al., 1985). A breakdown of withdrawals by aquifer system was estimated by using the percentage of domestic wells completed within that aquifer type as defined by a count of well records within the study area on file at the ISWS.

Withdrawals for public water supply comprise 80 percent of the ground water used within the study area during 1984. Over 55 percent of the total amount of ground water withdrawn was derived from Cambrian-Ordovician (deep bedrock) aquifers; another 36 percent was derived from sand and gravel sources which usually occur in thick sequences within the Rock Bedrock Valley. In the northern half of the study area (figures 6, 7, and 9), ground water is withdrawn from five sand and gravel units: the Mackinaw Member of the Henry Formation (hm); the Beaver Creek sand (wib); Esmond outwash (ge-o); Oregon outwash (gor-o); and Argyle outwash (wia-o). In the southern half of the study area (figures 7, 8, and 9), the dominant sand and gravel aquifers are the Mackinaw Member of the Henry Formation (hm), the Oregon outwash (gor-o), the Fairdale outwash (gf-o), and the Banner Formation. Sand and gravel and deep bedrock aquifers supply 38 and 62 percent, respectively, of the water for public water supplies, while shallow bedrock aquifers contribute less than 0.25 percent. These figures may not truly reflect shallow bedrock contributions to municipal supplies, as many bedrock wells classified as "deep" actually are open to the "shallow" bedrock as well and therefore also remove water from shallower formations. (A discussion of different types of well construction appears in a later section.) Such aquifer contributions were not accounted for when wells were classified by aquifer type.

An historical view of municipal ground-water withdrawals, principally water provided by the cities of Rockford and Loves Park, and the North Park Public Water District (excluding mobile home parks and apartment buildings on private supplies) is shown in figure 10. Total annual withdrawals peaked in 1973 at just over 14 billion gallons (approximately 38 million gallons per day); 1985 withdrawals are quite similar to those experienced in the mid-1960's. The distribution of withdrawals by aquifer for public water supply is shown in figures 11 through 14. Figures 11 and 12 show total 1985 withdrawals by sand and gravel and bedrock municipal wells, respectively. The diameters of the circles are used to represent total annual pumpage in million gallons per year. Figures 13 and 14 show similar maps for total municipal withdrawals for 1965 from the sand and gravel and bedrock aquifers, respectively.

Withdrawals from the sand and gravel aquifer occur within the Rock River valley, whereas bedrock withdrawals occur primarily outside of the valley. Even though total withdrawals for 1965 and 1985 are similar, the distribution of withdrawals from individual wells is not the same. Approximately 1.5 billion gallons more water is derived from bedrock sources now than in 1965, while approximately 0.9 billion gallons less water is derived from the sand and gravel now than in 1965. Withdrawals from the bedrock have shifted from the west to the east side of the river, while withdrawals from the sand and gravel have generally become more evenly distributed along the river valley. The shift in pumpage, particularly from the sand and gravel, may be due to a reduced need for water, improved management of the resource by distribution of the demand over a larger area, and the discovery of contamination in several wells, notably Rockford Unit Wells 7A, 8A, 14 and 19. This will be discussed in a later section.

The shallow dolomite bedrock and the glacial sand and gravel aquifers provide ground water to most domestic wells. Obviously, sand and gravel wells predominate in areas where the sand and gravel is present; dolomite wells predominate in the bedrock uplands where the sand and gravel is not typically present. Of the 2,552 domestic wells on record at the ISWS within the study area, 1,826 or approximately 70 percent are shallow dolomite bedrock wells. Sand and gravel wells comprise 595 or only about 25 percent of the domestic wells recorded.

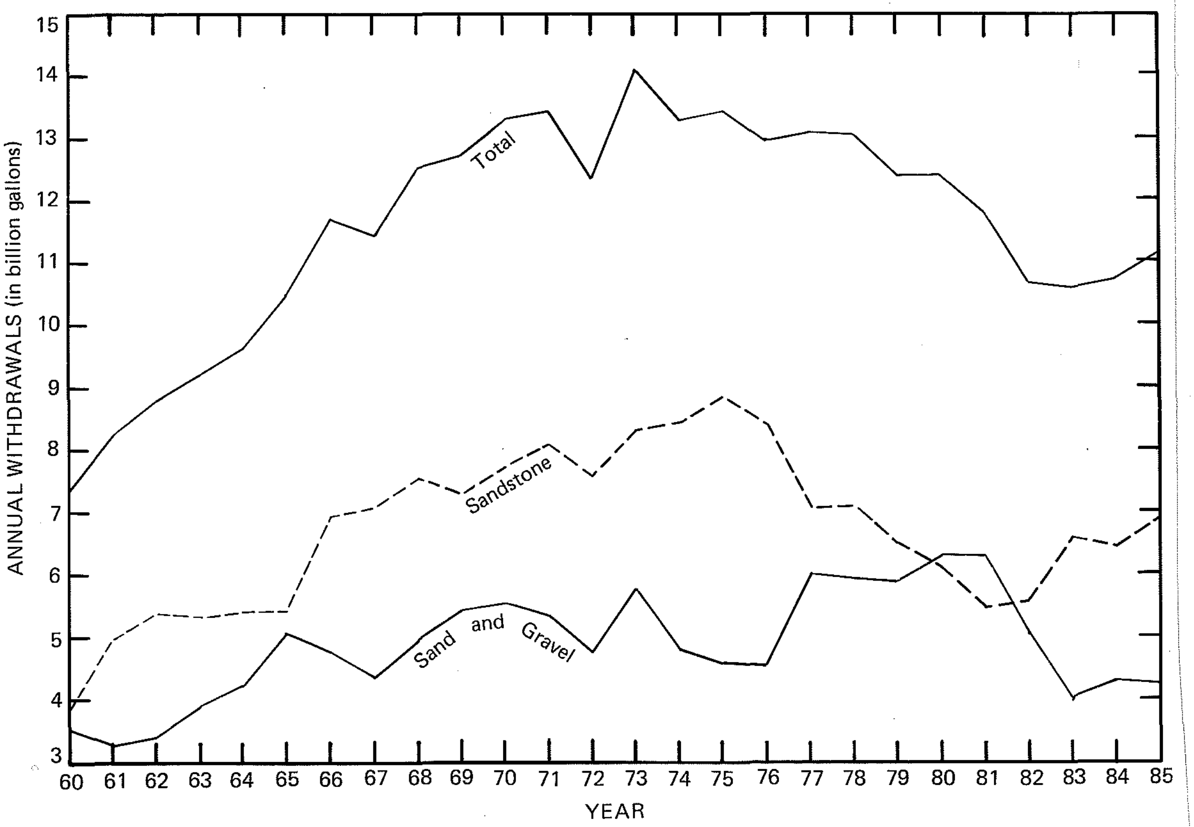

Figure 10. Total annual ground-water withdrawals from municipal wells within the study area

It is likely that a greater percentage of sand and gravel wells actually exists, because many domestic supplies have been developed by means of shallow "sandpoint" type wells. Most of these wells predate regulations requiring submission of well records. Also, such wells can be constructed without the use of specialized drilling equipment, circumventing the hiring of a driller, and similarly circumventing record submission requirements. Most of the domestic sand and gravel wells are completed in shallower deposits such as the Mackinaw Member of the Henry Formation (hm) and Oregon outwash (gor-o). Toward the northern portion of the study area, shallow sand and gravel wells may also be completed in Argyle outwash (wia-o) or Esmond outwash (ge-o). The remaining wells, approximately 5 percent, are finished in deeper bedrock formations.

The reason for the preponderance of shallow bedrock wells for domestic use is not difficult to understand. Rockford, Loves Park, and North Park are located along the present course of the Rock River, and most of the homes built within city limits are served by public water. The areas not served by public water are built on the uplands above the Rock River valley, and here the shallow bedrock is the most readily available source of ground water. While the deep bedrock is available

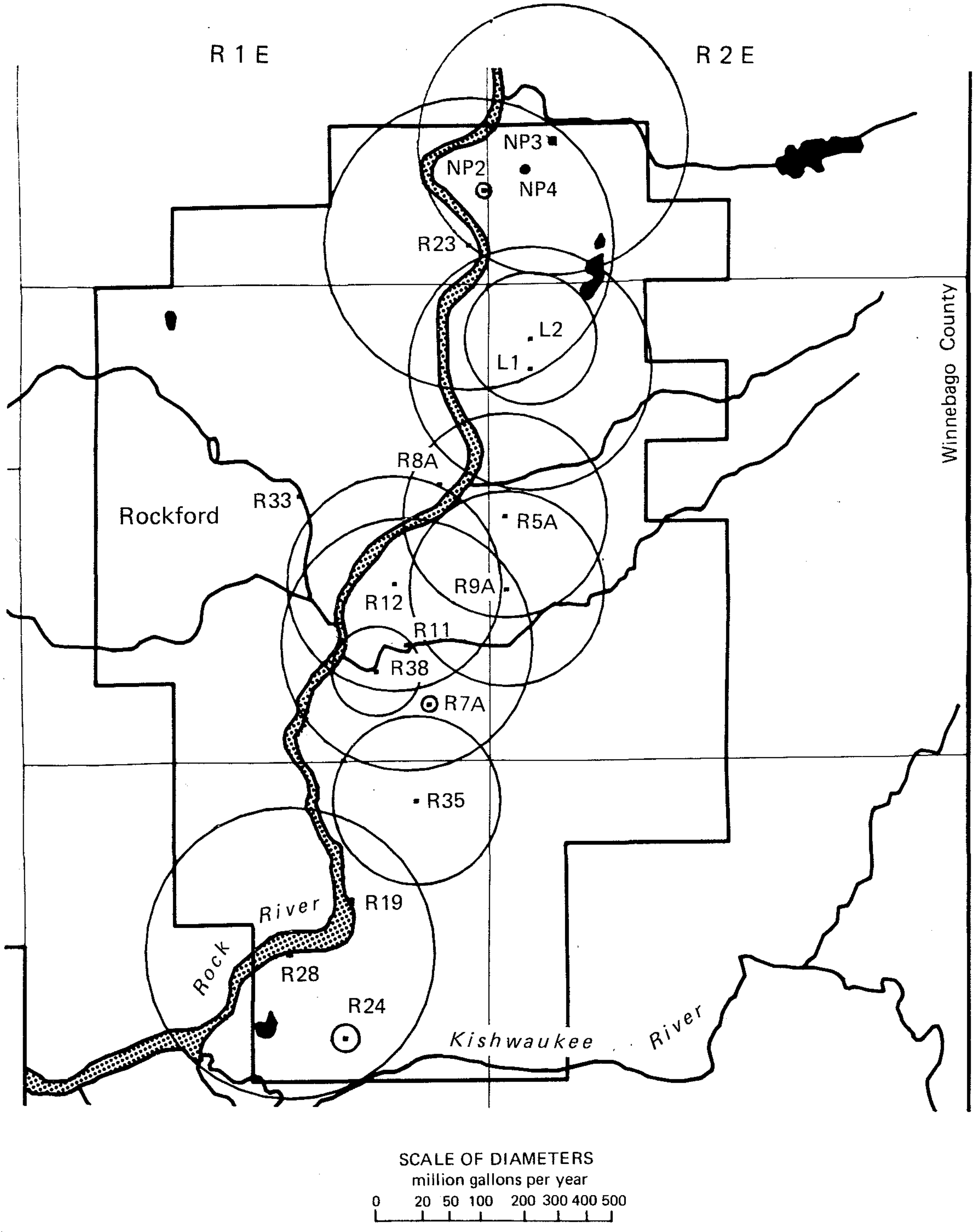

Figure 11. Distribution of municipal withdrawals from the sand and gravel aquifer in the Rockford area in 1985

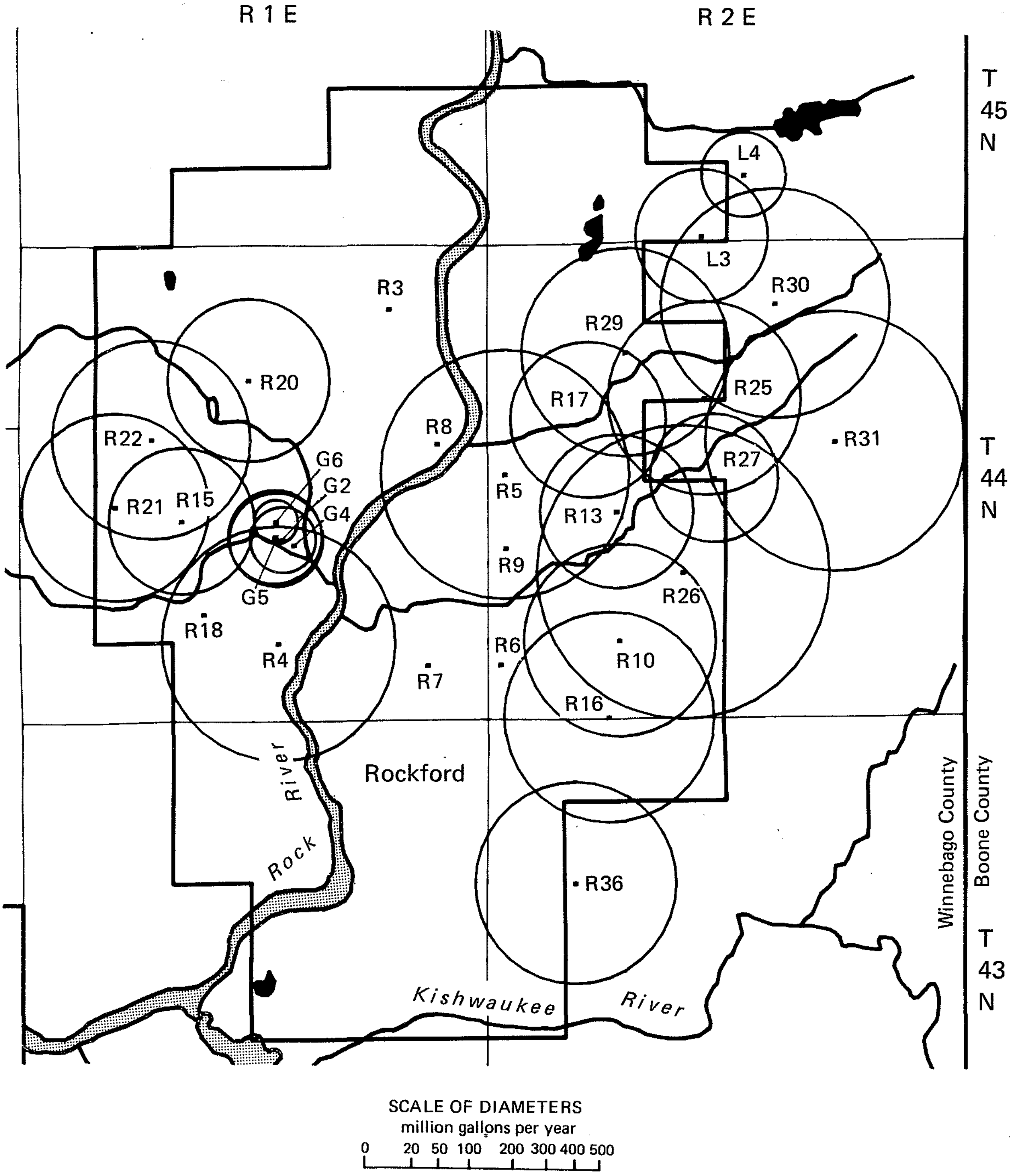

Figure 12. Distribution of municipal withdrawals from bedrock aquifers in the Rockford area in 1985

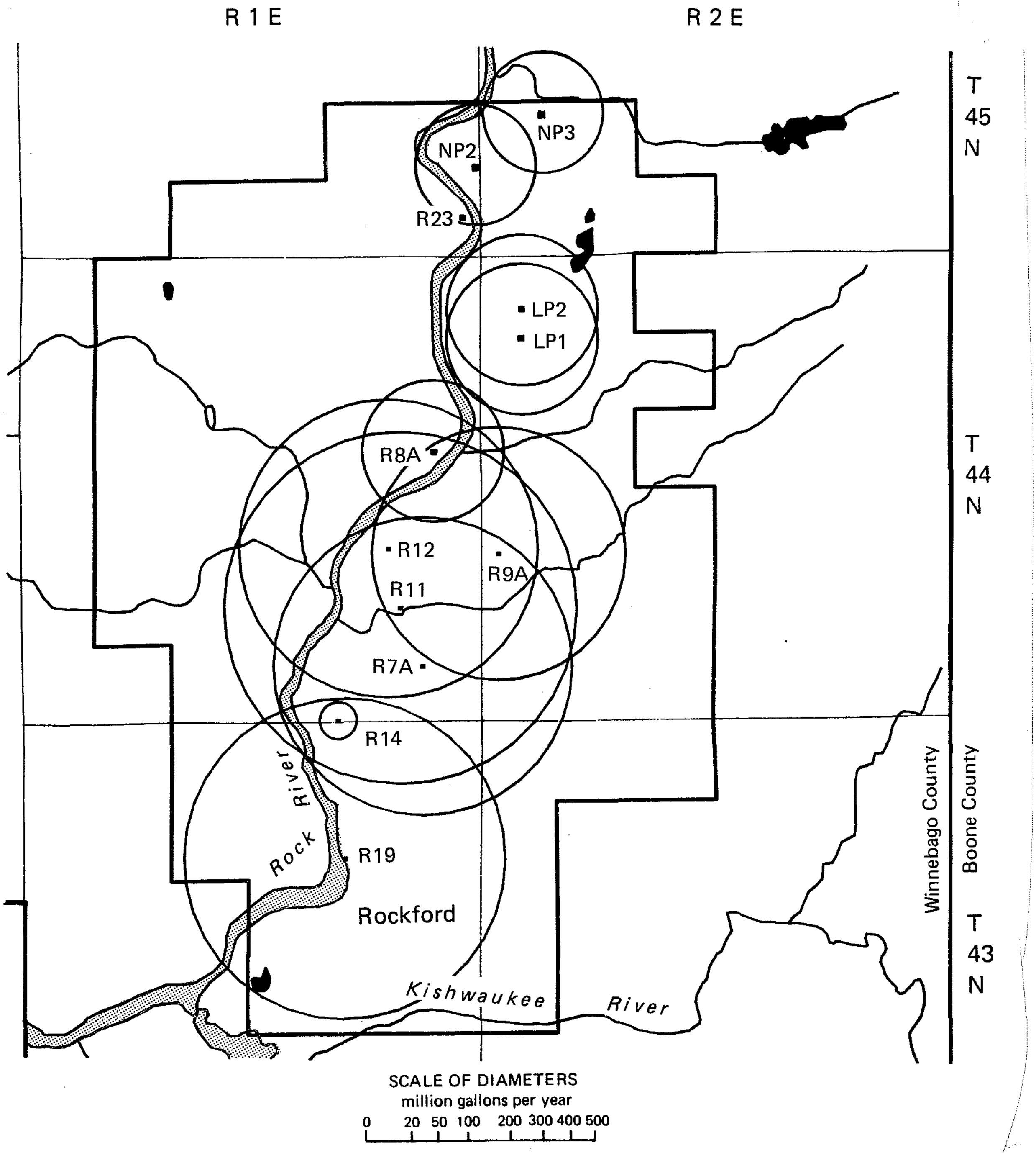

Figure 13. Distribution of municipal withdrawals from the sand and gravel aquifer in the Rockford area in 1965

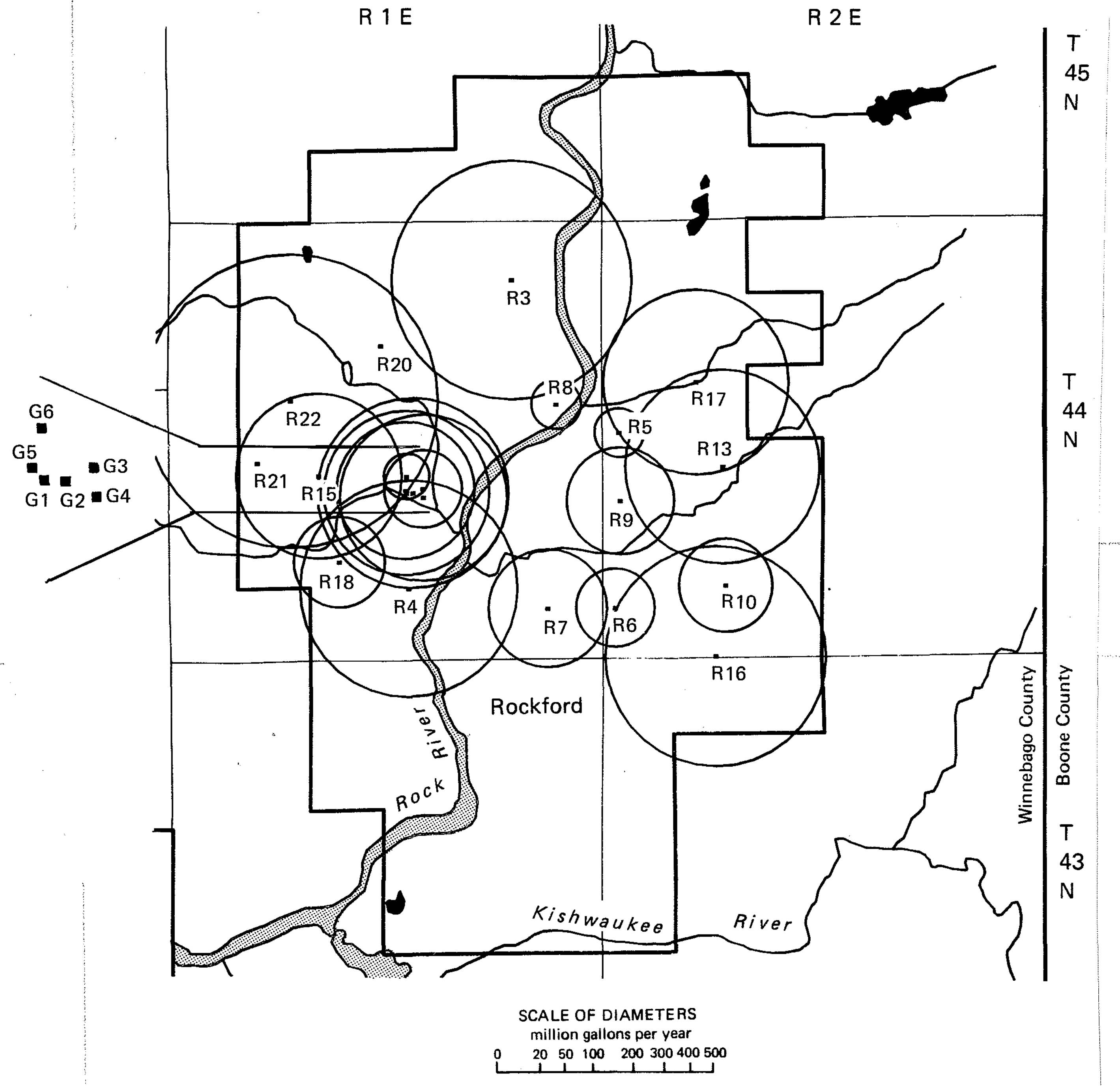

Figure 14. Distribution of municipal withdrawals from bedrock aquifers in the Rockford area in 1965

to develop as a source for domestic supplies, the costs of doing so are prohibitively high.

If the number of homes within the study area potentially served by private domestic wells (computed earlier as 13,000) is accurate, then the 2,552 well records in the ISWS files account for about 20 percent of the existing wells. This percentage seems realistic given that many of the unaccounted-for wells were probably drilled before reporting requirements were instituted or are of the sandpoint variety, which have tended to escape state registration.

Well Construction in the Rockford Area

Four types of wells are generally found within the study area. These are depicted in figure 15. Well construction methods depend primarily on the aquifer in which the well is to be completed. Two of the well types are constructed in unconsolidated materials (sand and gravel) and use a "well screen" to allow water to enter the well without collapsing the well bore. The other two well types are typical for wells constructed in consolidated rock (dolomite and sandstone) and differ principally in the depth to which they are completed.

Sandpoint wells (figure 15a) are simply driven or pounded into the ground to a desired depth. Typically, these wells are quite shallow, usually less than 50 feet deep, and are equipped with a "jet" or suction-lift pump. Suction lifts cannot exceed 1 atmosphere (about 33 feet of water at 700 feet mean sea level, the ground surface elevation in the lower topographic regions of Rockford) and, therefore, pumping ground-water levels cannot practically exceed 25 feet to maintain adequate pressure with the household plumbing. Sandpoint wells occur most often in the older portions of Rockford and utilize the shallow sand and gravel deposits situated along the Rock River and accompanying terraces (labelled hm, wib, and ge-o on figures 6 through 9). Quite often these wells are situated in the basements of the houses for which they supply water. Because of the shallow depth, ground water from these wells has a high potential for contamination. Several of these types of wells were sampled during this study to investigate the quality of shallow ground water.

Most public and industrial wells completed in the sand and gravel are drilled rather than driven (figure 15b). These wells are larger in diameter to provide greater production rates and are deeper, often exceeding 200 feet in portions of the Rock Bedrock Valley. Figure 15b is a cross section of Rockford Unit Well 8A; other large capacity industrial and public wells are constructed in a similar manner. Typically, the hole is drilled to full depth, after which the drilling tools (the bit and drill stem) are removed from the hole. The hole is kept open during and after drilling by use of "drilling mud" or by maintaining a greater water pressure within the borehole than there is in the aquifer. After the drilling tools are removed from the hole, the well casing and screen are lowered section-by-section into the

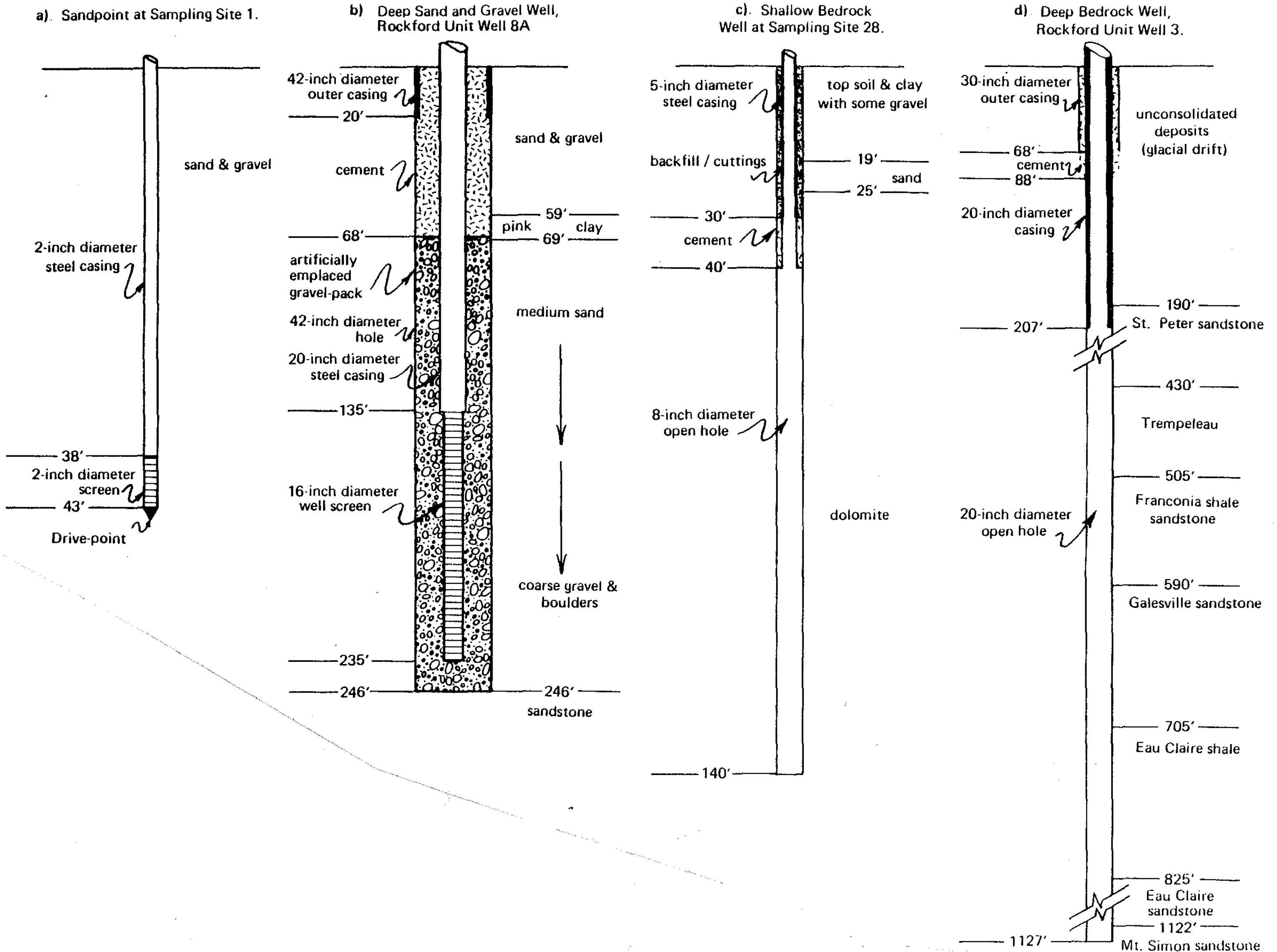

Figure 15. Types of well construction in the Rockford area

hole. Specially graded gravel (called a gravel-pack) selected to be compatible with the openings in the well screen is then used to fill the annulus between the well screen and borehole to some depth above the well screen. The remainder of the annular space between well casing and the borehole, from the top of the gravel-pack to near ground surface, is commonly backfilled with "native" materials (material removed during drilling). Concrete or cement is used to finish the top of the annulus to prevent leakage of surface waters down along the well casing. As depicted in figure 15b, Rockford Unit Well 8A was constructed with 100 feet of 16-inch-diameter well screen and 135 feet of 20-inch-diameter steel casing inside a 42-inch-diameter borehole. A gravel-pack was placed around the screen up to a depth of 68 feet; the remainder of the annulus was cemented. The well is capable of producing over 1,000 gallons of water per minute (gpm), as are many other public and industrial water supply wells completed in the sand and gravel.

As previously discussed, most of the domestic wells situated on the bedrock uplands are completed in the shallow dolomite bedrock (figure 15c). These wells, being constructed in a consolidated bedrock formation, do not require a screen to hold back the formation while allowing water to enter the well. A steel casing is used to hold back the overlying unconsolidated deposits (in Illinois, the well construction code requires the casing to be at least 40 feet long); an open borehole in the bedrock follows. Often, the hole is drilled just into the bedrock, whereupon the casing is lowered and cemented into position. After the cement has set, the hole is deepened to the desired depth. In this instance, a 5-inch-diameter casing penetrates 15 feet into the dolomite bedrock to a total depth of 40 feet and is followed by 100 feet of open hole. After drilling, the well was pumped at 15 gpm, a rate quite sufficient for a domestic water supply.

Although often larger in diameter and deeper than shallow bedrock wells, wells completed in deep bedrock are constructed in a similar fashion to their shallower counterparts (figure 15d). Notice in this case that the deeper well (in this instance Rockford Unit Well 3) penetrates several geologic formations. Water is withdrawn from several aquifers, rather than only one, thus increasing the total yield of the well. At this well, casing is set 17 feet into the bedrock to an overall depth of 207 feet. A 20-inch-diameter open borehole follows to a depth of 1127 feet, just penetrating the upper surface of the Mt. Simon Sandstone. Records show that this well and many other municipal and industrial wells like it can produce in excess of 1,000 gpm.

It is important to know as much as possible about the construction features of wells that are included in a sampling program. Water-level information will be dependent on the depth of the well, its screened or open length, and the aquifer the well is completed in. Contour maps created from water-level information should not combine data points from different aquifers unless it can be shown that the formations are hydraulically interconnected. Water quality information will also vary with depth, screen length, and aquifer. Therefore, data used to determine ground-water flow directions, spatial and temporal influences on ground-water quality, and location of potential contaminant sources must be produced from wells of similar aquifer and depth.

Aquifer Properties and Ground-Water Movement

Ground-water contour maps produced from data collected in 1965-1966 reveal much about ground-water movement in the Rockford study area (Sasman et al., 1966). Potentiometric surface maps for the sand and gravel and underlying St. Peter Sandstone aquifers for 1965-1966 are shown in figures 16 and 17, respectively. In the sand and gravel, ground-water elevations fall from 830 feet msl just east of Rockford to 690 feet msl along the Rock River. For the most part, the contours parallel the Rock River; however, the contours are distorted from this pattern in three principal areas: an area in the southeast part of T.44N., R.1E. along the Rock River; an area near the river in the northwest part of T.44N., R.2E; and the area in the extreme northern portion of the study area in T.45N., along the line between R.1E. and R.2E.

Ground-water movement, being in a direction perpendicular to the ground-water elevation contours, was from the uplands above the river valley toward the Rock River. In the vicinity of major withdrawals, however, the contour lines became distorted as ground water was diverted to pumping wells. A comparison of the three aforementioned areas with the locations of municipal sand and gravel withdrawals shows that the contours probably were distorted because of ground-water pumpage. The three-circular shaped contours at the extreme northern edge of the study area can be attributed to Rockford Unit Well 23 and North Park Public Water District Wells 2 and 3. The circular contour just south of these three cones of depression is the cone created by Loves Park Wells 1 and 2. Finally, the flat area along the river described by the thumbshaped 690-foot contour line is probably the result of overlapping cones created by Rockford Unit Wells 7A, 11, 12 and 14, as well as a number of industrial wells not shown on the graphic display of municipal withdrawals. These four municipal wells produced 2.9 billion gallons of water in 1965, an average of 7.8 million gallons per day and nearly 57 percent of the total 1965 municipal pumpage from the sand and gravel aquifer in the Rockford area. Ground water was withdrawn from the Fairdale outwash in all four wells and also from the Oregon outwash in Unit Wells 7A and 14.

Similarly, ground-water flow patterns in the St. Peter Sandstone reflect ground-water movement toward the Rock River. Ground-water elevations in 1965 ranged from 800 feet msl in eastern Rockford to 680 feet msl along the Rock River. Again, some distortion of the contours occurs near the Rock River in the central part of the study area. In this instance the two circular-shaped contours in figure 17, located

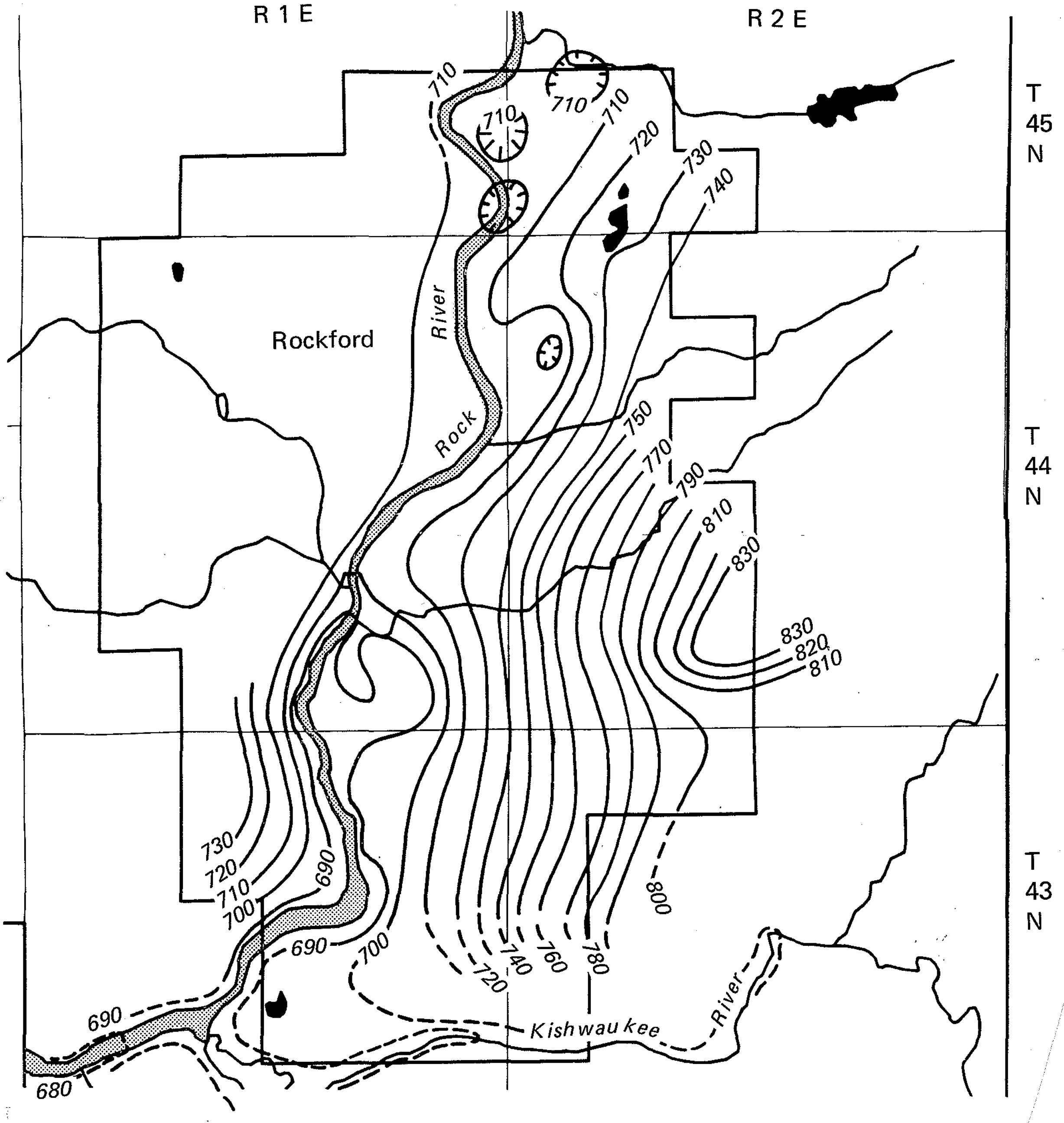

Figure 16. Potentiometric surface of the sand and gravel aquifer in the Rockford area, 1965-1966 (from Sasman et al., 1966)

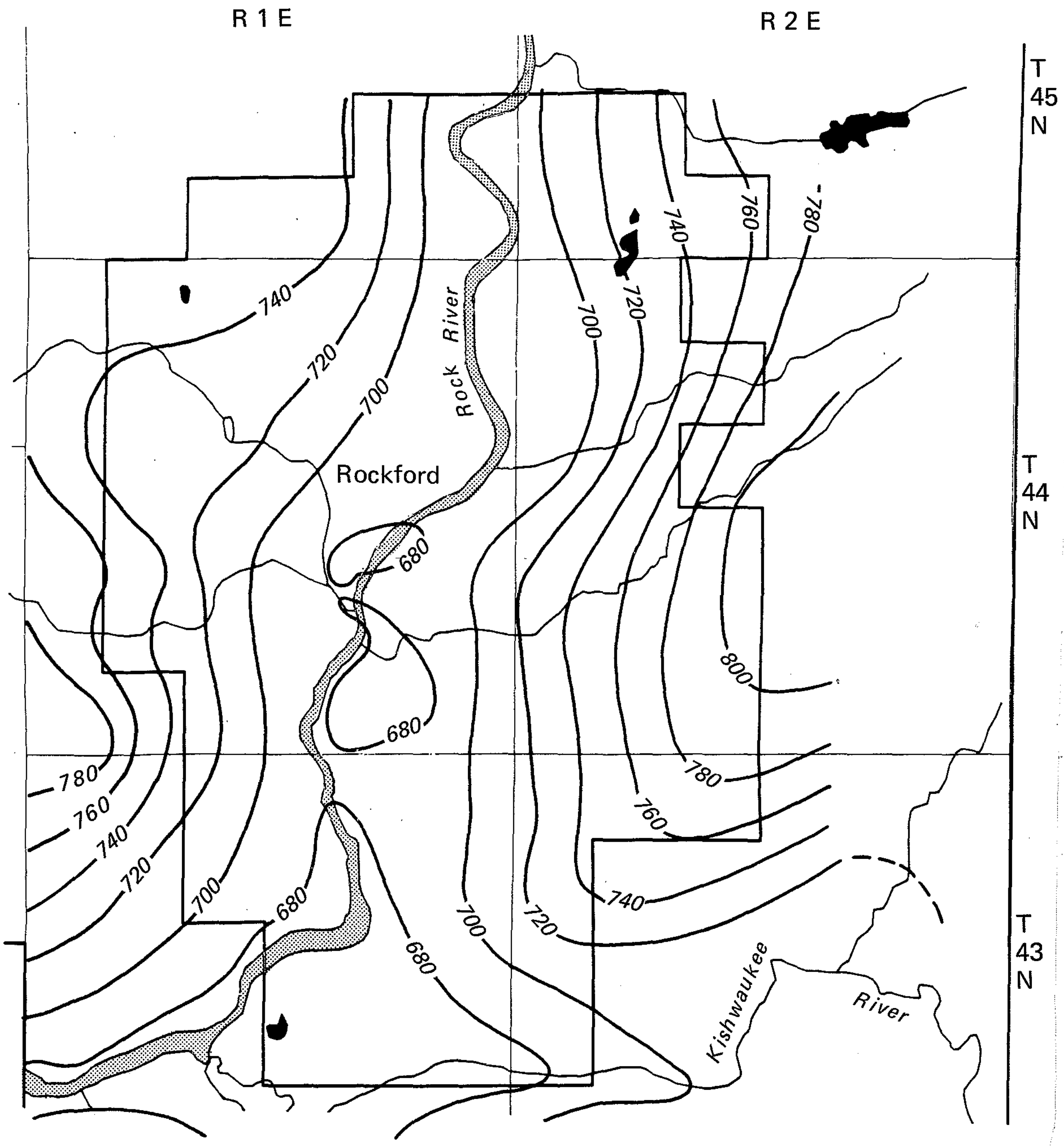

Figure 17. Potentiometric surface of the St. Peter Sandstone in the Rockford area, 1965-1966 (from Sasman et al., 1966)

within Sections 22, 23, 26, 27, 34, and 35, T.44N. and R.1E., reflect areas of significant pumpage for industrial use. While estimates for industrial withdrawals in 1965 are not known, estimates made for 1963 withdrawals (Sasman et al., 1966) show that over 0.9 mgd was withdrawn from industrial deep bedrock wells in these six sections, approximately one-fourth of the total 1963 industrial pumpage for the Rockford area. Industrial withdrawals from the deep bedrock for these same six sections in 1984 (Kirk et al., 1985) totaled 0.4 mgd, approximately one-fifth of all the industrial withdrawals from the deep bedrock within the study area.

The quantity of water percolating through a given cross section of an aquifer is proportional to the hydraulic gradient (slope) of the potentiometric surface and the transmissivity of the aquifer. This amount of water can be calculated by using the following form of the Darcy equation:

$$Q = T \cdot I \cdot L \qquad (1)$$

where

Q = discharge, in gallons per day (gpd)
T = aquifer transmissivity, the product of the hydraulic conductivity (K) and aquifer thickness (m), in gallons per day per foot (gpd/ft)
I = hydraulic gradient, in feet per foot (ft/ft)
L = width of cross section through which discharge occurs, in feet (ft)

Equation 1 can be modified to describe the rate (velocity) of ground-water movement by dividing the entire equation by the area (A) of the cross section through which flow is taking place:

$$Q/A = (T \cdot I \cdot L)/A \qquad (2)$$

The ground-water discharge rate divided by the cross-sectional area (Q/A) is the ground-water velocity. Division of the product of aquifer transmissivity (T) and cross-sectional length (L) by the cross-sectional area (A) leaves the aquifer hydraulic conductivity as follows:

$$v = I(T \cdot L)/A = I(K \cdot m \cdot L)/(m \cdot L) = (K \cdot I)/(7.48) \qquad (3)$$

where

v = rate of ground-water movement, in feet per day (ft/dy)
A = cross-sectional area of aquifer through which ground-water flow is calculated, equal to the aquifer thickness (m) times cross section width (L), in square feet, ft^2
K = aquifer hydraulic conductivity, in gallons per day per square foot (gpd/ft^2)
7.48 = gallons per cubic foot conversion factor

This mathematical expression is based on the assumption that flow occurs through the entire cross section of geologic materials without regard to solids and pores. Actually, flow is limited to the pore spaces available to transmit water. The actual, "interstitial," flow velocity is:

$$v_a = v/n = (K \cdot I)/\ (7.48n) \qquad (4)$$

where

v_a = advective or interstitial pore velocity, in ft/dy
n = effective porosity, or the percent of the porous material which consists of interconnected pore spaces (the spaces which contribute to ground-water flow), unitless

To solve this equation, three quantities must be known or determined: 1) the hydraulic gradient, 2) the hydraulic conductivity of the material through which the water is moving, and 3) the effective porosity of the material. The hydraulic gradient can be determined from ground-water contour maps, such as those shown in figures 16 and 17, by determining the change in elevation and the distance over which that change takes place. The effective porosity is essentially an estimated parameter because the interconnected pore space in many porous media has not been measured. In coarse-grained materials such as the sand and gravel aquifer beneath Rockford, the effective porosity can be closely estimated as the specific yield, the ratio of the volume of water which drains by gravity to the total volume of saturated porous material. For these materials, an effective porosity in the range of 20 to 30 percent is common.

The remaining parameter needed to calculate the ground-water flow rate is the hydraulic conductivity. Hydraulic conductivities can be determined by a variety of methods. The usual approach is by conducting a well production test -- pumping a well at a constant rate and measuring the aquifer response to pumpage in terms of the drop in water levels in the pumped well and surrounding observation wells (Theis, 1935; Wenzel, 1942; Jacob, 1944). In some cases, the hydraulic conductivity can be estimated from specific-capacity data (Walton, 1962). A summary of well production test analyses and well specific-capacity data used to evaluate the hydraulic conductivity of the sand and gravel aquifer in the Rockford area appears in Appendix A. Analyses of drawdown versus time data by nonleaky (Theis) and leaky artesian type-curve or Jacob ("straight-line") methods should be considered to provide hydraulic property values that are superior to values provided by specific-capacity analytical methods. However, time-drawdown data are not available for many of the wells in the Rockford area. Regardless, the sand and gravel aquifer has hydraulic conductivities in excess of 1,000 gpd/ft^2 ($5 \cdot 10^{-3}$ cm/sec) and is considered highly permeable.

On the basis of the slope of the potentiometric surface determined from figure 16 (0.003 to 0.0075 ft/ft), an average hydraulic conductivity of 1,500 gpd/ft^2, and an average aquifer thickness of 100 feet, there may be as much as 2.25 to 6 million gallons of ground water per day per mile discharging from the sand and gravel to the Rock River. Calculations of ground-water discharge based on 7-day, 10-year low flow measurements on the Rock River (Singh and Stall, 1973) support these estimates. The rate of ground-water movement under these conditions, assuming an average hydraulic conductivity of 1,500 gpd/ft^2, ranges from 2 to 6 feet per day.

The potentiometric maps (figures 16 and 17) clearly establish that ground water is moving from the uplands toward the Rock River, in spite of major withdrawals. The maps also indicate that this occurs in the bedrock as well as the sand and gravel. Recharge to shallow sand and gravel occurs locally in response to rainfall and snowmelt. What is less clear is how ground water is moving vertically in the deeper deposits. The calculations discussed in a preceding paragraph indicate that a tremendous amount of ground water discharges to the Rock River. It is logical to assume that the St. Peter Sandstone provides some recharge to the deeper sand and gravel outwash deposits (i.e., the Fairdale, Kellerville, and Banner Formation outwash) while overlying fine-grained deposits probably impede recharge from shallower sands and gravels. However, comparison of the potentiometric surface of the St. Peter Sandstone (figure 17) and the sand and gravel potentiometric surface (figure 16) shows that the hydraulic head in the sand and gravel along the river in the southern portion of the study area is 690 feet msl while the head in the underlying St. Peter is only 680 feet msl, indicating that downward vertical movement from the sand and gravel to the bedrock may be occurring. Local areas of downward movement certainly could be caused by ground-water withdrawals from the bedrock by municipal and industrial wells. On the other hand, it could be argued that the heads in both aquifers are essentially equal given the thickness of aquifer over which the potentiometric heads are integrated (i.e., 100 or more feet of well screen or open borehole length) and the level of detail the maps provide (e.g., 10- to 20-foot contour intervals).

Therefore, the vertical movement of ground water within the study area is relatively unclear. Recharge to the deeper sand and gravel deposits may be derived from shallower deposits as well as the underlying bedrock. Vertical movement downward to the deeper sand and gravel deposits will depend on the continuity of the overlying fine-grained materials, the hydraulic conductivity of these materials, and the hydraulic gradient across them. How this affects ground-water movement and, ultimately, contaminant transport will require more detailed investigation. As will be discussed in upcoming sections of the report, the contamination of several municipal wells finished in these deeper deposits raises questions about the influence of overlying fine-grained materials on contaminant transport within the area.

Potential Sources of Hazardous-Substance Ground-Water Contamination

As a basis for determining areas of potential organic compound contamination and, ultimately, for selecting wells to sample for such compounds, it is important to know the locations where hazardous-substance-related activities occur and the types of compounds these activities use. Because of the variety of ways in which hazardous substances are generated and used, a broad definition of what constitutes a hazardous-substance-related activity must be used. According to Shafer (1985), "hazardous substance activities are activities that involve the generation, use, distribution, storage, treatment, and/or disposal of hazardous chemical compounds that may, or may not, be considered wastes." Although it is recognized that many hazardous substances are used in the home (IEPA, 1985; Boston Metropolitan Area Planning Council, 1982), only industrial and commercial facilities likely to handle large quantities of hazardous materials were selected for mapping.

The locations and descriptions of facilities involved in these types of activities were compiled as part of the Hazardous Waste Database (Schock et al., 1985b) maintained by the Illinois Hazardous Waste Research and Information Center (HWRIC). The statewide maps of hazardous-substance activities produced as part of the report published under the requirements of P.A. 83-1268 (Shafer, 1985) were products of the initiation of that database. In that study, the intensity of hazardous-substance activities, based on the density of mapped facilities, was used as a criterion for prioritizing areas to monitor for hazardous ground-water contaminants in Illinois (Wehrmann and Le Seur, 1985). Such mapping also served as a basis for determining the study area for the project (see "Study Area Description" in the introduction to this report).

Standard Industrial Classification (SIC) code descriptors were used as the principal identifiers of hazardous-substance-related industrial or commercial activities. The SIC code is used to generally describe an establishment's primary economic activity (U.S. Office of Management and Budget, 1972). The code was not intended to describe specific chemicals used in, or wastes produced by, an establishment; attempts to link SIC codes to potential contaminants have been only moderately successful (Epstein et al., 1982; USEPA, 1982c, 1984). However, in creating the Hazardous Waste Database for Illinois, a link was established between SIC code and <u>potential</u> hazardous-substance-related activity. This was accomplished by using the SIC codes of known hazardous-substance-related activities (Resource Conservation and Recovery Act [RCRA] notifiers) with establishments in the study area using the same SIC codes.

The locations of facilities with selected "RCRA-like" SIC codes were plotted on a map of the study area (figure 18). These facilities are classified within the SIC code descriptions which appear in Appendix B. The SIC codes displayed in Appendix B represent the bulk of "RCRA-like" SIC's for the Rockford area and were selected to give a representative view of potentially contaminating activities within the study area.

A total of 689 facilities appear on the map. Most of these facilities (482) are classified in SIC codes 34, 35, and 36. These three SIC's contain all types of metal manufacturing, including electronic and heavy machinery, metal fasteners, and electroplating services. Much of the industrial waste generated in Rockford has been related to these types of industries (Colten and Breen, 1986).

Previous maps of potentially contaminating activities have been general in nature (Schock et al., 1985a). As previously mentioned, mapping of the intensity of activity within an area, as defined by the number of facilities per square mile, was done on a statewide basis and used on a regional scale in delimiting the area of study for this project. Mapping of specific facility locations within the study area was recognized as much more useful for selecting well sampling sites and for relating known ground-water contamination problems to potential contaminant sources. The plotting of facility location by street address provided a clearer picture of the location of particular types of activities occurring within specific areas.

As shown on figure 18, most of the potentially contaminating activities occur in a band covering the central business district of Rockford and stretching toward the southeast corner of T.44N., R.1E. Another high density area occurs in Loves Park near the northwest corner of T.44N., R.2E. Gibb et al. (1984) and Colten and Breen (1986) clearly point out these same general areas as containing a high potential for ground-water contamination due to the presence of significant numbers of contaminant sources. A review of ground-water contamination incidents in the Rockford area, as discussed in the next section of this report, indicates that these areas not only do indeed exhibit a high <u>potential</u> for contamination but that they are actually contaminated to varying degrees. These areas also tend to correlate very well with what is known about regional geologic sensitivity and ground-water movement within the study area.

Survey of Available Ground-Water Quality Data

Pollution control and water supply agencies were asked to provide any records containing ground-water-quality information (see Appendix

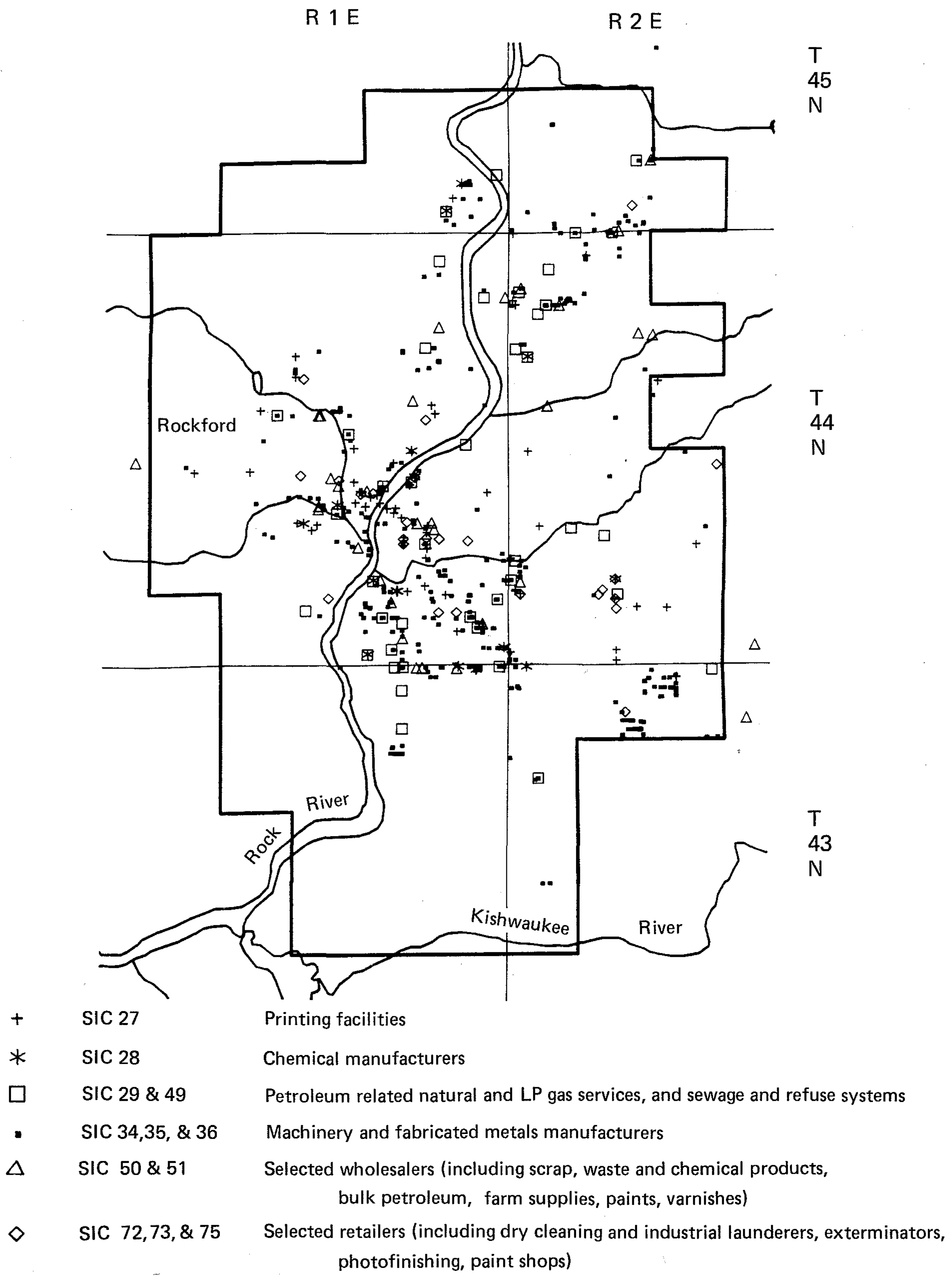

Figure 18. Locations of potential ground-water contaminant sources within the study area by Standard Industrial Classification (SIC) code

C). Compilations of chemical analyses of ground water and supporting information were obtained from the State Health Department, the Illinois Environmental Protection Agency, the Loves Park Water Department, the North Park Public Water District, the Rockford Sanitary District, the Rockford Water Department, and the County Health Department. These data were used, in part, to delineate areas for sampling and to determine what VOCs and trace metals had been found in previous ground-water samples. Analyses performed on new private well water samples then could be directed toward those same VOCs and trace metals.

Instances of ground-water contamination documented by these records are summarized in Appendix D. The locations of these sites with respect to the appropriate map of prioritized areas for monitoring in sand and gravel or shallow bedrock are shown in figures 19 and 20.

The Rockford Water Department (RWD) supplied descriptions of well construction, mineral analyses (including trace elements), and VOC analyses for 42 municipal wells. The RWD began monitoring the concentrations of 33 VOCs in their raw water supplies after the discovery of VOCs in Unit Well 7A in December 1981. Since May 1983, municipal wells with total VOC (TVOC) levels over 10 $\mu g\ l^{-1}$ have been sampled on a monthly basis. Wells with concentrations from trace amounts to 10 $\mu g\ l^{-1}$ have been sampled every two months. Wells found to contain no VOCs were checked twice to confirm the analytical results and are sampled infrequently, with samples being collected in different seasons in different years. The RWD analyses for VOCs and trace metals are summarized in table 2. The averages of the sums of VOC concentrations are listed for each well, rather than the concentrations of individual compounds. In this manner, those wells which chronically contain high concentrations of VOCs can be seen. Notations of the particular VOCs detected and the concentrations of elevated trace metals found in each well are also included in table 2. VOC analyses were not available for Unit Wells 3 or 31 or for Group Well 4.

In the reports supplied by the RWD, some concentrations below detection limits were listed as "0 $\mu g\ l^{-1}$" while others were listed as less than a particular number, e.g., "<5 $\mu g\ l^{-1}$". All such determinations, listed as below some detection limit, were considered as zeroes for averaging. For this reason, TVOC concentrations in the well water actually may be greater than the concentrations listed in table 2. For example, on July 25, 1983, water obtained from Unit Well 8 contained 1,1,1-trichloroethane, tetrachloroethene, and trichloroethene in concentrations of 16, 550, and 213 $\mu g\ l^{-1}$, respectively. These concentrations are considerably above the detection limits for all of these compounds. The sample report also listed 1,1-dichloroethene and trans-1,2-dichloroethene concentrations as "<5 $\mu g\ l^{-1}$." Thus, the TVOC concentration for that date was computed as 779 $\mu g\ l^{-1}$, even though it may have been as great as 789 $\mu g\ l^{-1}$. However, this process has only a minor effect on the relative magnitude of the average TVOC concentrations shown in table 2.

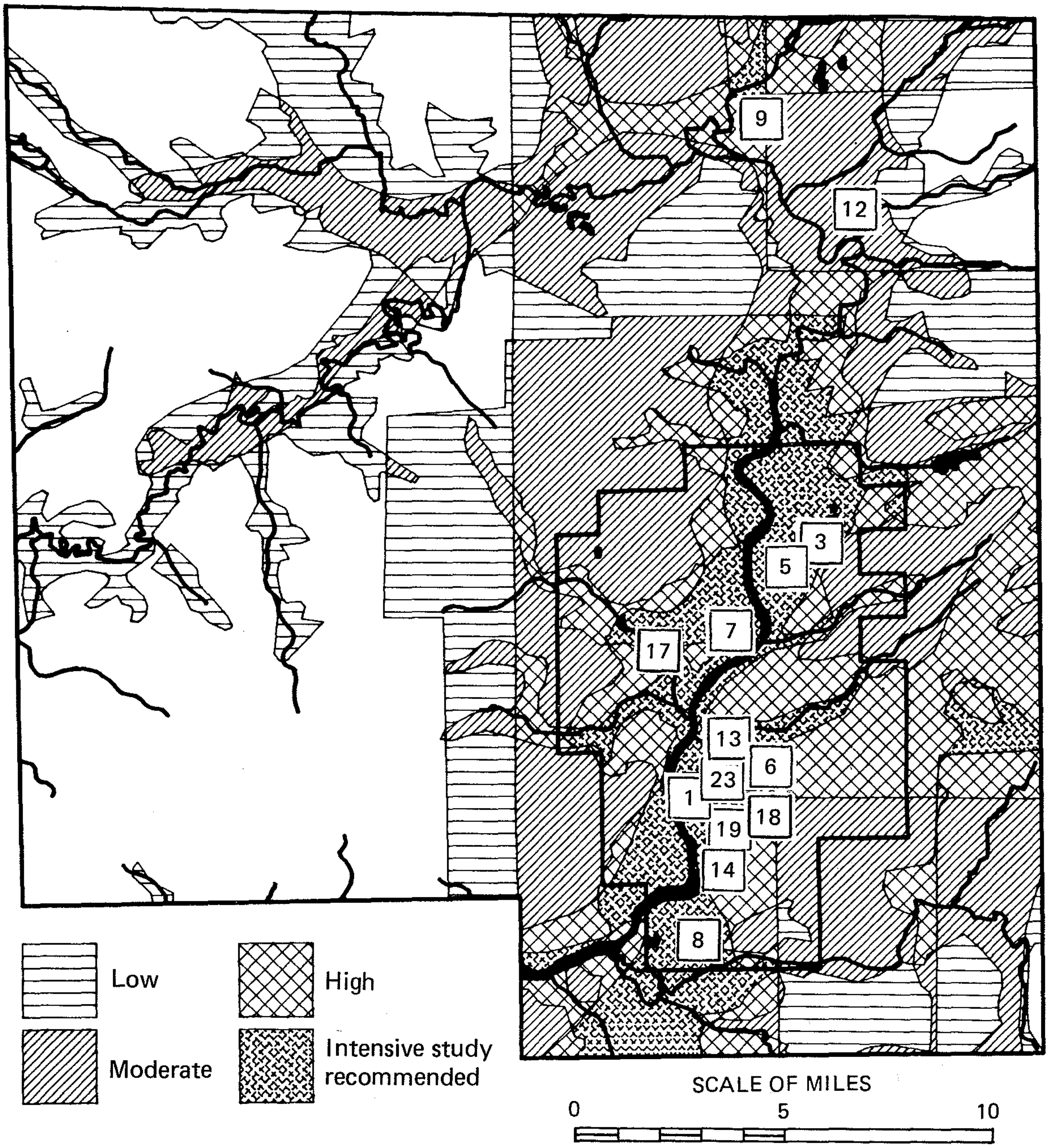

Figure 19. Previously identified sites of ground-water contamination in sand and gravel aquifers in Winnebago County (site descriptions are given in Appendix D; shading represents prioritized areas for ground-water monitoring of hazardous substances in sand and gravel as described by Wehrmann and Le Seur [1985]).

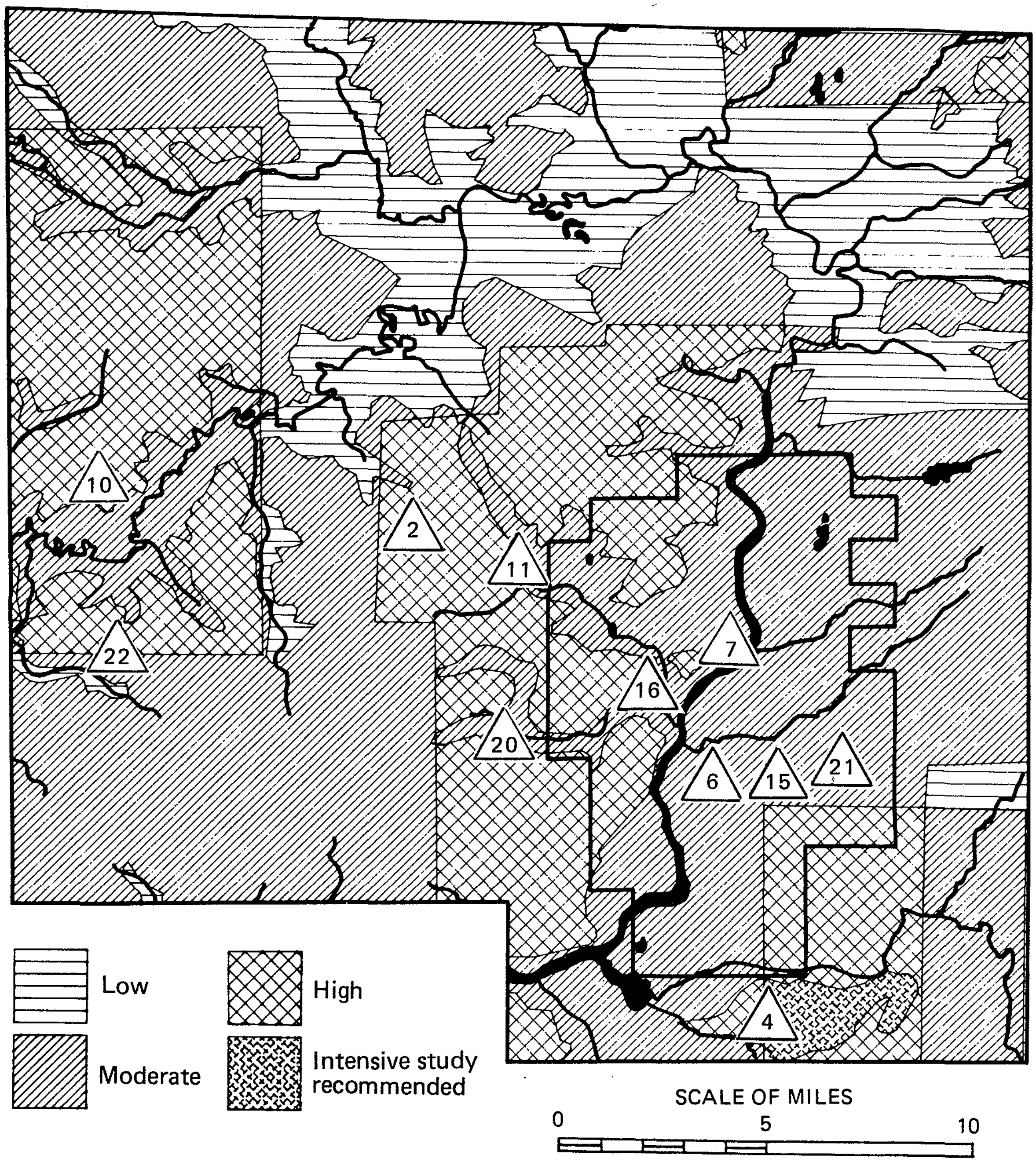

Figure 20. Previously identified sites of ground-water contamination in shallow bedrock aquifers in Winnebago County (site descriptions are given in Appendix D; shading represents prioritized areas for ground-water monitoring of hazardous substances in the shallow bedrock as described by Wehrmann and Le Seur [1985]).

Table 2.

Results of Rockford Water Department VOC and Trace Metals Analyses February 1982 - October 1985

Well[a]	Total Depth (ft)	Avg. TVOC[b] ($\mu g\ l^{-1}$)	Compounds & Elements[c]
U4	1219	6	TCE
U5	1312	0.2	1 $\mu g\ l^{-1}$ PCE detected in only one of six samples
U5A	298	0.2	1 $\mu g\ l^{-1}$ PCE detected in only one of six samples
U6	1372	10	TCA
U7	1503	2	MC & VC only identified compounds
U7A	200	7	TCE & PCE in most samples
U8	1502	532	TCE, PCE, TCA
U8A	245	133	TCE, PCE, TCA
U9	1600	4	6 of 7 samples < 5 $\mu g\ l^{-1}$ TVOC; 17 $\mu g\ l^{-1}$ MC in one sample
U9A	240	0	
U10	1426	0	
U11	245	4	TCA
U12	251	1	TCE
U13	1457	7	CLF, BDCM, CDBM
U15	1355	0	Cu 920 $\mu g\ l^{-1}$, Pb 69 $\mu g\ l^{-1}$ in Nov. 1978
U16	1313	18	TVOC=129 $\mu g\ l^{-1}$ on 2/4/85; =0 in 6 of 7 samples
U17	1195	0	
U18	1380	0	
U19	176	29	TCE
U20	1200	23	TVOC=169 $\mu g\ l^{-1}$ on 3/19/84; <10 $\mu g\ l^{-1}$ in 7 of 8 samples
U21	1205	0	
U22	1381	0	
U23	93	0.4	TVOC ≤2 $\mu g\ l^{-1}$ in all samples
U24	219	29	TCE, cDCE, tDCE
U25	1288	48	3 of 6 samples contained no VOCs. Samples with detected VOCs coincide with pump repairs
U26	1326	0	
U27	1280	0.2	1 $\mu g\ l^{-1}$ PCE detected in only one of six samples
U28	233	0	
U29	1357	0	
U30	1325	0	
U33	94	18	TCE, cDCE, tDCE
U35	214	21	TCE, cDCE, tDCE, 11DCE, 11DCA, TCA

Table 2. (Concluded)

Well[a]	Total Depth (ft)	Avg. TVOC[b] ($\mu g\ l^{-1}$)	Compounds & Elements[c]
U36	1505	0	
U38	236	39	TCE, cDCE, tDCE, 11DCE, 11DCA, TCA, PCE
G1	1600	0.5	TVOC = 0 $\mu g\ l^{-1}$ in 11 of 12 samples; 6 $\mu g\ l^{-1}$ MC in one sample
G2	1600	12	TCE, 11DCE, TCA, PCE
G4	1600	-	Cr 420 $\mu g\ l^{-1}$; no VOC data
G5	1615	4	TCE, PCE
G6	1605	11	TCE, cDCE, tDCE, 11DCE, TCA, PCE, CLF

Notes: [a] U indicates unit well; G indicates group well

[b] Unweighted average of total concentrations of 32 volatile organic compounds in all samples collected between February 1982 and October 1985.

[c] BDCM = bromodichloromethane; CDBM = chlorodibromomethane; CLF = chloroform; Cr = chromium; Cu = copper; 11DCA = 1,1-dichloroethane; 11DCE = 1,1-dichloroethene; cDCE = cis-1,2-dichloroethene; tDCE = trans-1,2-dichloroethene; MC = methylene chloride; Pb = lead; PCE = tetrachloroethene; TCA = 1,1,1-trichloroethane; TCE = trichloroethene; TVOC = total volatile organic compounds; VC = vinyl chloride.

Those wells which contained an average of 10 μg l^{-1} or greater TVOC were included as sites of contamination in Appendix D and appear in figures 19 and 20. The 10 μg l^{-1} delimiter was based on an assumed 5 μg l^{-1} limit of quantitation for individual compounds. Because TVOC may be the sum of two or more concentrations, a 10 μg l^{-1} limit was chosen as a firm basis for citing contamination. Rockford municipal wells with an average TVOC exceeding 10 μg l^{-1} include the following (site numbers in parentheses can be found in Appendix D and on figures 19 and 20):

Unit Well 6 (site 15)
Unit Wells 8 and 8A (site 7)
Unit Well 19 (site 14)
Unit Well 24 (site 8)
Unit Well 33 (site 17)
Unit Well 35 (site 18)
Unit Well 38 (site 13)
Group Wells 2 and 6 (site 16).

Unit Wells 16, 20, and 25 are not considered to be contaminated, even though their average TVOC concentrations exceeded 10 μg l^{-1}, because they did not exhibit chronically high TVOC concentrations. For example, water from Unit Well 16 was found to contain 129 μg l^{-1} TVOC on February 4, 1985, but no VOCs on six other dates. Similarly, water from Unit Well 20 contained 169 μg l^{-1} TVOC on March 19, 1984, but less than 10 μg l^{-1} TVOC in 7 other samples. Fluctuations in ground-water quality parameters, such as these, may have been caused by variations in sampling, storage, and analytical procedures or by differences in presampling, "environmental" conditions. Outside influences appear to have affected the water quality in Unit Well 25, where TVOC concentrations jumped from 0 to 207 μg l^{-1} following pump repairs. TVOC concentrations quickly fell to 4 μg l^{-1} after one week and were below detection limits thereafter.

Presampling conditions also appear to be affecting the water quality in Unit Wells 7 and 7A. In these cases, however, environmental conditions have caused the wells to be considered contaminated even though their respective average TVOC concentrations, as shown in table 2, were only 2 and 7 μg l^{-1}. TVOC concentrations in these wells have been found to be much greater when the wells have been running for long periods prior to sampling. For example, in 1981, when the wells were being used almost continuously, the Winnebago County Health Department (WCPHD) collected samples which contained 25 and 1167 μg l^{-1} TVOC in Wells 7 and 7A, respectively. Since then, the RWD has found that TVOC concentrations can be kept below 10 μg l^{-1} by turning off the wells for several days before turning them back on for short periods (G. Brettrager, Director, RWD, personal communication, October 3, 1985). During the period over which the data were compiled for Table 2, this operational technique was maintained to keep TVOC concentrations below 10 μg l^{-1}. Thus, the TVOC concentrations were kept artificially low and give the appearance of not being a severe problem.

Results of IEPA analyses for VOCs in ground waters from the Rockford municipal wells are briefly summarized in table 3. Only those wells which yielded water with TVOC concentrations exceeding 10 μg l^{-1} and individual compounds whose concentrations exceed 5 μg l^{-1} are

Table 3.

Results of IEPA Analyses of Rockford Area Municipal Wells with TVOC Concentrations Greater than 10 μg l^{-1} [a]

Well[b]	Sample Date	TVOC (in μg l^{-1})	Individual VOC's over 5 μg l^{-1} (in μg l^{-1})[c]
U8	05/06/86	553.0	TCE 152.0, TCA 11.0, PCE 385.0
U8A	10/30/85	16.5	PCE 15.0
U12	10/30/85	12.0	TCA 9.2
U33	10/29/85		DCE 8.5
G2	12/10/85	10.5	---
G6	12/10/85	19.5	TCE 7.2, TCA 5.5
LP1	05/08/86	46.0	tDCE 36.0
LP2	05/08/86	39.0	tDCE 32.0

[a] Rockford Unit Well 35 was not sampled

[b] U denotes Rockford Unit Well
G denotes Rockford Group Well
LP denotes Loves Park Well

[c] TCE = trichloroethene; TCA = 1,1,1-trichloroethane; PCE = tetrachloroethene; tDCE = trans-1,2-dichloroethane; DCE = cis- or trans-1,2-dichloroethane (cis- or trans-isomer not specified)

shown. Table 4 compares the IEPA analyses with the RWD analyses from the dates closest to those of the IEPA analyses. For table 4, only compounds found at concentrations greater than 1μg l^{-1} by either agency are listed. The IEPA results generally agree with the RWD analyses. Wells that had relatively low average TVOCs in the RWD analyses also were low in the IEPA sampling. Similarly, wells that contained more than 10 μg l^{-1} in the IEPA sampling were wells that also had relatively high average TVOCs in the RWD analyses.

Most trace metal concentrations determined by IEPA were below drinking water standards; however, the standards for lead (50 μg l^{-1}) and chromium (50 μg l^{-1}, if in the +6 oxidation state) were sometimes exceeded. Unit Well 15 contained lead concentrations of 69 and 51 μg l^{-1} in 1978 and 1979. Group Well 4 contained chromium concentrations of 420 μg l^{-1} in December 1978, which declined to 80 μg l^{-1} in February 1979. Because of these apparently elevated trace metal concentrations, lead and chromium were chosen for private ground-water supply analyses as part of this project.

The RWD monitoring program is designed to protect consumers from exposure to chlorinated organic compounds by screening raw water supplies. It is not designed to delineate ground-water contaminant plumes. Therefore, the data must be carefully interpreted, particularly in relation to the construction of the water supply wells. In most instances, the bedrock wells constructed for Rockford's water supply penetrate several aquifers. For example, Unit Well 3 is cased from ground surface to 207 feet and is an open hole from 207 feet to 1,127 feet (see figure 15d). The well is open to six geologic formations and produces a mixture of ground water from different water-bearing strata. If one of the six aquifers tapped by Unit Well 3 was contaminated, the contaminants could potentially be diluted below analytical detection limits by uncontaminated water from the other aquifers. Thus, the contamination would not be detected. If contaminants were detected, it would be difficult to determine which aquifers were contributing contaminated water to the well.

Even with sand and gravel wells, contamination problems can be complex. Unit Well 8A, screened from 135 to 235 feet, is completed over a much narrower depth range than Unit Well 3 (see figure 15b). This well has chronically yielded contaminated water. Because the well is completed in only one aquifer, probably the Fairdale outwash, it appears that this aquifer is contaminated. However, upward leakage from the underlying bedrock may be responsible for the presence of the contaminants. More detailed, depth-discrete analyses are needed to determine at what depths and concentrations the contaminants occur.

Another factor to consider in using municipal well data is the variations in contaminant concentrations caused by pumpage, recharge, and "source strengths" (e.g., spills vs. steady leaks). For example, the TVOC concentrations in Unit Well 8 varied from 74 to 821 μg l^{-1}, with a relative standard deviation of 47 percent, in 15 samples collected over a period of 26 months. The length of time the well was

Table 4.

Results of Rockford Water Department and Illinois Environmental Protection Agency Analyses of Municipal Well Waters

		RWD Analysis		IEPA Analysis	
Well[a]	Compound	Date	Conc. ($\mu g/l^{-1}$)[b]	Date	Conc. ($\mu g/l^{-1}$)
U4	trichloroethene	3/4/85	0	2/1/85	3.9
U7A	tetrachloroethene	8/26/85	4	10/25/85	3.4
		9/30/85	<1		
	trichloroethene	8/26/85	6	10/25/85	2.4
		9/30/85	<1		
U8A	tetrachloroethene	9/30/85	20	11/1/85	15.0
	trichloroethene		<1		1.2
U11	1,1,1-trichloroethane	1/28/85	0	11/1/85	5.0
U15	trichloroethene	12/17/84	0	12/13/85	2.0
	tetrachloroethene		0		2.3
U20	1,1,1-trichloroethane	2/4/85	2	12/31/85	<0.1
	dichloromethane		2		<0.1
U23	1,1,1-trichloroethane	10/7/85	<1	11/1/85	1.7
U30	tetrachloroethene	9/23/85	<1	12/13/85	0.2
U33	cis-1,2-dichloreoethene	9/30/85	20	11/1/85	8.5[c]
G1	chloroform	10/7/85	0	12/13/85	1.7
G2	1,1,1-trichloroethene	9/9/85	2	12/13/85	2.4
	trichloroethene		6		4.8
	tetrachloroethene		4		2.6
G5	trichloroethene	9/9/85	1	12/13/85	2.4
	trichloroethene		5		7.2

Notes: [a] U and G designate unit and group wells, respectively

[b] RWD data summaries listed concentrations as integers

[c] IEPA report does not specify cis- or trans- isomer

idle before sampling, the length of time (and rate) of pumping prior to sampling, and the distance to the contaminant source or plume all can affect the concentration of contaminants found in a particular water sample. Thus municipal wells, because of their construction and operation, generally will not provide water-quality data sufficient to delineate contaminant plume geometry or to identify contaminant sources. However, municipal well data are useful for a regional investigation indicating general areas of contamination identifying contaminants and, possibly, concentration ranges.

The Loves Park Water Department also provided results of analyses of their raw waters. Chlorinated solvents in concentrations similar to those in Rockford ground water were found in two of Loves Park's four wells (Wells 1 and 2, site 5). Monitoring wells, installed and sampled by IEPA downgradient from the Sand Park landfill (site 3) and just northeast of Loves Park Well 2, were found to contain the aromatic hydrocarbons benzene and chlorobenzene. Barium and cadmium concentrations as high as 12.5 mg l^{-1} and 10 μg l^{-1}, respectively were also detected in the monitoring wells. The USEPA drinking water standards for barium and cadmium are 1 mg l^{-1} and 10 μg l^{-1}, respectively. Therefore, barium and cadmium were selected, along with lead and chromium, as metals to monitor in this investigation.

The Winnebago County Public Health Department (WCPHD) provided analyses of water samples from several sites. Domestic wells in southeast Rockford (Site 18) had concentrations of 1,1,1-trichloroethane and 1,1-dichloroethene as high as 138 and 147 μg l^{-1}, respectively. The USEPA-proposed maximum contaminant levels (MCLs) for these compounds are 200 and 7 μg l^{-1}, respectively. Other VOCs were found at lower concentrations. Complaints received at the WCPHD about tastes and odors in the waters from domestic wells led to the discovery of leaking gasoline storage tanks at two service stations. Monitoring wells near one service station (site 19) yielded waters with volatile aromatic compounds ranging from 40 to 110 μg l^{-1}. Domestic wells near another service station (site 21) showed purgeable organic carbon concentrations as high as 246 μg l^{-1}. Water samples from monitoring wells near one manufacturer (site 23) had trichloroethene concentrations ranging from 10 to 16 μg l^{-1} and total organic halogen (TOX) concentrations ranging from less than 5 to 122 μg l^{-1}. (Note: TVOC is the total mass of volatile organic compounds, whereas TOX is the total mass of halogens, mostly chlorine, in the volatile organic compounds. Therefore, TOX concentrations are less than TOV concentrations in all water samples. For this reason, only a rough comparison is possible between waters for which TVOC has been determined and waters for which only TOX has been determined.) Monitoring wells on the grounds of another facility (site 11) yielded ground water with concentrations of benzene, toluene, total xylenes, and tetrachloroethene as high as 28,000, 760, 3,200, and 1,200 μg l^{-1}, respectively. Domestic wells downgradient from a large waste disposal site (site 4) exhibited concentrations of 1,2-dichloroethene and tetrachloroethene as high as 580 and 170 μg l^{-1}, respectively, with other VOCs at lower concentrations.

Two domestic wells near petroleum bulk storage terminals in eastern Winnebago Township (site 20) showed evidence of ground-water contamination. Granular activated carbon filters were installed to remove VOCs from the waters from these wells. Analyses of the effluents from these filters showed purgeable organic carbon and purgeable organic halide concentrations as high as 673 and 584 $\mu g\ l^{-1}$, respectively. The contaminant concentrations in untreated ground water must have been at least as high as these.

Altogether, 23 instances of ground-water contamination from a wide variety of chemicals are cited in Appendix D. An estimated 300 wells have been affected by these chemicals. Sixteen of the wells are public water supply wells. Most contaminant concentrations are below present or anticipated drinking water standards (discussed in a following section, "Potential Health Risks"), but the mere presence of these contaminants suggests the potential for more serious ground-water quality problems.

What is especially disturbing about several of these incidents is the occurrence of contamination at apparently great depths. Given the geologic sensitivity of most of this area (Berg et al., 1984b) and the haphazard manner in which industries historically have disposed of their waste materials (Colten and Breen, 1986), the contamination of shallow wells in highly industrialized areas, such as in southeast Rockford, could be expected. The discovery of similar contaminants in deeper sand and gravel wells, such as Unit Wells 7A, 35, and 38, all of which are finished in the lower 100 feet of the Rock Bedrock Valley, means that contaminants may have moved downward in portions of the sand and gravel aquifer.

CHAPTER 3. METHODS AND PROCEDURES FOR COLLECTING NEW GROUND-WATER QUALITY DATA

Well Selection

Several factors were considered in the selection of private wells for sampling. The ISWS well files were reviewed and wells located within the study area were selected, with consideration given to well type (domestic, industrial, public), geographic location, well depth, and well construction information.

To avoid a duplication of sampling efforts, samples from public wells were not collected for this investigation. All of the Rockford, Loves Park, and North Park municipal wells were sampled between October 1985 and May 1986 as part of the IEPA statewide VOC public well sampling program. In addition, the RWD routinely monitors for organic compounds in their municipal wells. Conversely, private wells are not often sampled for the presence of VOCs. This is partly because there are not enough laboratories capable of analyzing the samples, and analyses are expensive (a VOC scan, including compound identification, can cost more than $500). Therefore, the sampling of private domestic and industrial wells was emphasized for this project.

The geographic distribution of potential sampling areas within the study area was established carefully. Interpretive tools, such as water-elevation contour maps and water-quality maps, are most useful when they are based on data from sampling points that have a uniform spatial distribution. Widespread coverage also allows sample collection from several different geologic terrains (e.g., sand and gravel, sand and gravel overlain by silt, and dolomite) and from regions that have not been previously sampled.

During the review of potential sampling sites, it became apparent that there was not a uniform spatial distribution of wells across the study area. In the major urban industrial areas adjacent to the Rock River, most businesses, homes, and industries are serviced by city water. Many industrial wells in this region were closed as city water became available. In addition, private well locations tend to fall into clusters inside unincorporated areas scattered within the city limits of Rockford. These clusters form "islands" (which are not served by public water) within the incorporated areas of Rockford. These regions were identified through review of ISWS well records, Rockford city maps, and field reconnaissance.

Beyond this regional coverage, further emphasis was concentrated in the vicinities of previously identified contaminant plumes. The Winnebago County Health Department, in an effort to determine the risks posed to private well users by organic compounds, has sampled over 100 domestic wells for VOC analyses within Rockford since 1983. (The majority of these wells fall within the area described as site 18 in Appendix D). The results of such efforts were valuable for identifying private wells in and near known contaminated areas. Potential wells were selected hydraulically upgradient and downgradient from known contaminated areas to assess the potential migration of contaminants beyond currently identified bounds. Wells were also selected within known ground-water contamination plumes to compare the data with the water quality data previously collected by other agencies.

Most domestic wells in the Rockford area have been completed at depths of less than 250 feet because of the presence of highly productive, shallow aquifers. The sensitivity of shallow aquifers to contamination from surface and near-surface activities made these aquifers the primary target for sampling. Shallow aquifers were also the subject of the statewide mapping of hazardous-substance-monitoring priority areas described in the introduction of this report. Therefore, to test the usefulness of this mapping effort, the sampling of shallow aquifers was emphasized. While there has been documented contamination of wells as deep as 1,600 feet (e.g., Rockford Unit Wells 7 and 8), these cases may be related to the presence of contaminants in nearby shallow wells (e.g., Rockford Unit Wells 7A and 8A). To maintain the emphasis on shallow aquifers, wells less than 250 feet deep were selected initially.

The well records on file at the ISWS were searched to locate nonpublic wells within the study area that were less than 250 feet deep. Once wells were located, they were further screened on the basis of the information available on the well record. Desirable information included a geologic log, a street address, and well construction information, particularly the well depth and the open interval. The geologic log and construction information indicate which aquifer, or aquifers, the well is receiving water from and provide a record of depth and thickness of the geologic materials penetrated. Documentation of the geologic materials, e.g., the presence of fine-textured materials (clay and silt) above the water-producing zone, can be useful in interpreting the hydrogeology and water quality of sampled wells. A street address of the well owner was needed both to locate the well and to aid correspondence with the owner regarding well sampling and analytical results.

A preliminary list of 223 candidate wells was compiled on the basis of the selection criteria. Names and addresses of well owners identified on the well records were checked against telephone listings in the Rockford City Directory to confirm the current well owner. Many potential sites were discarded, as the address on the log was clearly not the location of the well. For example, in many instances the name and address of the subdivision developer is listed instead of the actual homeowner who purchased the lot from the developer. Because of the clustering of wells in certain residential areas, addresses on the well records were needed to specifically match the well record to a well in the field.

Letters were mailed to 133 well owners whose locations could be verified. Of these 133 wells, 115 were domestic wells and 18 were owned by industries. The letter (Appendix E) explained the purpose of the project and asked the owners to return an enclosed postcard giving their permission for a water sample to be collected and a water level measurement to be taken from their wells.

Of the original 133 letters that were mailed to well owners or operators, 50 responses were received. Forty-three of the respondents gave permission for their wells to be sampled. Non-respondents for whom telephone numbers were available were subsequently contacted. This follow-up generated three additional positive responses.

The postcards returned by well owners proved to be quite useful when the home or industry was approached for sampling. Recognition of the returned postcard by the well owner/operator allowed quick access to the well and collection of the water sample. To achieve a representative number of sampled wells in each neighborhood, several homeowners were also solicited on a door-to-door basis during field sample collection. This effort provided an additional 29 wells to the total number sampled. Selection of wells in the field produced data for several wells for which there was little or no background information. However, it was generally possible to deduce the well depth and the aquifer developed on the basis of information for neighboring wells.

The clustering of wells in small areas around Rockford greatly limited our ability to distribute sampling points uniformly across the study area. Generally, where one private well was found, several wells were available to sample. Where an area is served by public water supply or is uninhabited (e.g., vacant lots and cultivated fields), no wells were available to sample. Therefore, as the number of wells that could potentially be sampled increased, the spatial distribution of the wells within the study area did not expand to provide significantly more information on regional ground-water quality. For this reason, only 69 private wells were sampled. Along with the sample results from the 48 municipal wells within the study area, this was considered adequate to characterize ground-water quality around Rockford.

Altogether, 63 domestic and 6 industrial wells were sampled. A summary of information related to the wells appears in Appendix F (note that well site 31 was not sampled). The locations of these wells are shown on figure 21. In figure 22, the 48 Rockford, Loves Park, and North Park Public Water District municipal wells sampled by IEPA are shown superimposed on the 69 private well sampling locations. Sampling sites are classified by the aquifer the well penetrates: sand and gravel, shallow bedrock (the Galena-Platteville Dolomite), and the deeper sandstone bedrock (the Glenwood-St. Peter Sandstone and underlying units). Many municipal wells designated as "deep bedrock" are also open to the shallow bedrock but generally receive most of their water from the deeper, higher-yielding formations. Domestic shallow bedrock wells, on the other hand, may be finished in the upper portion of the Glenwood-St. Peter Sandstone, but receive most of their water from the Galena-Platteville Dolomite. The only well site for which an aquifer

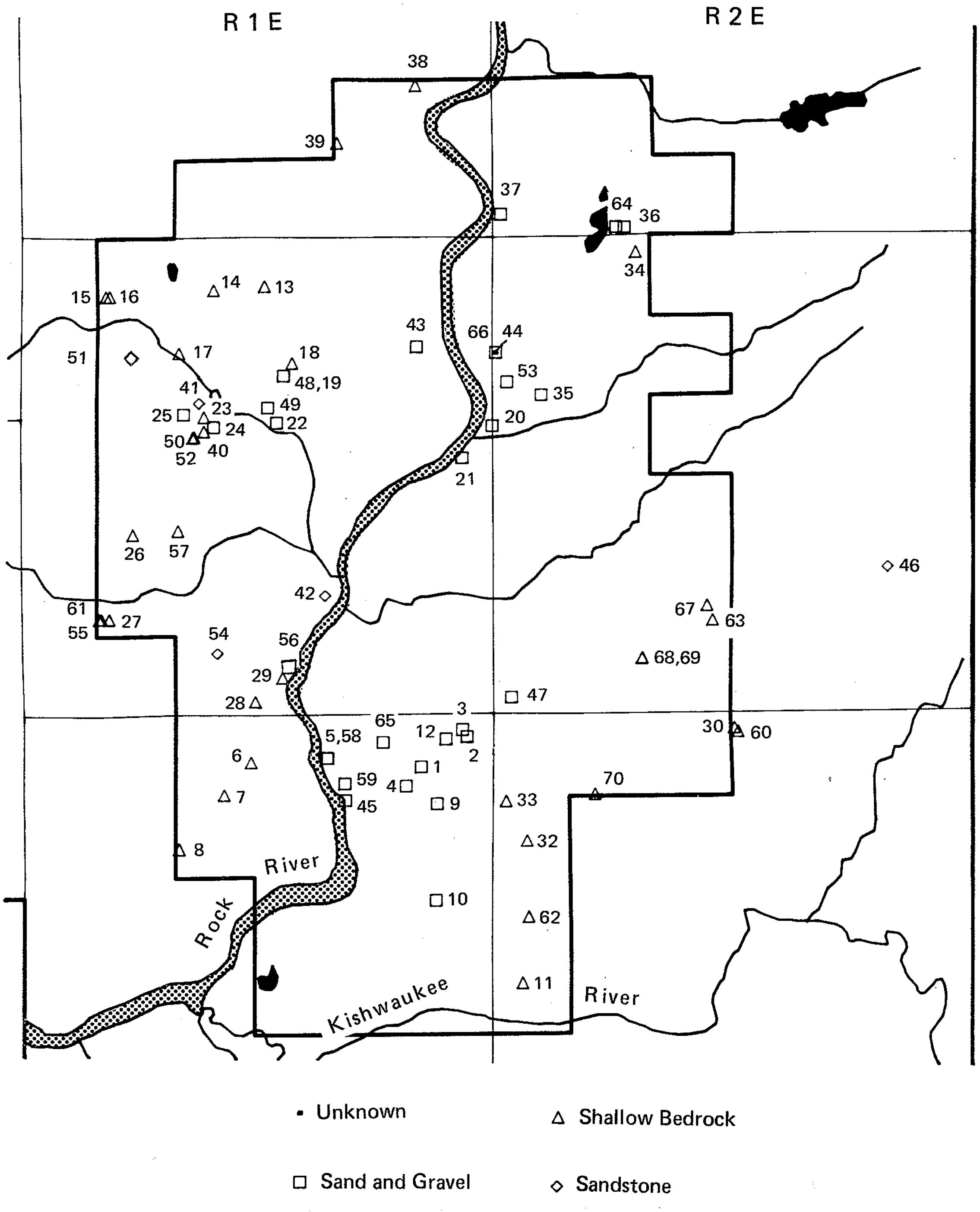

Figure 21. Locations of private wells sampled for the study (a summary of well information appears in Appendix F)

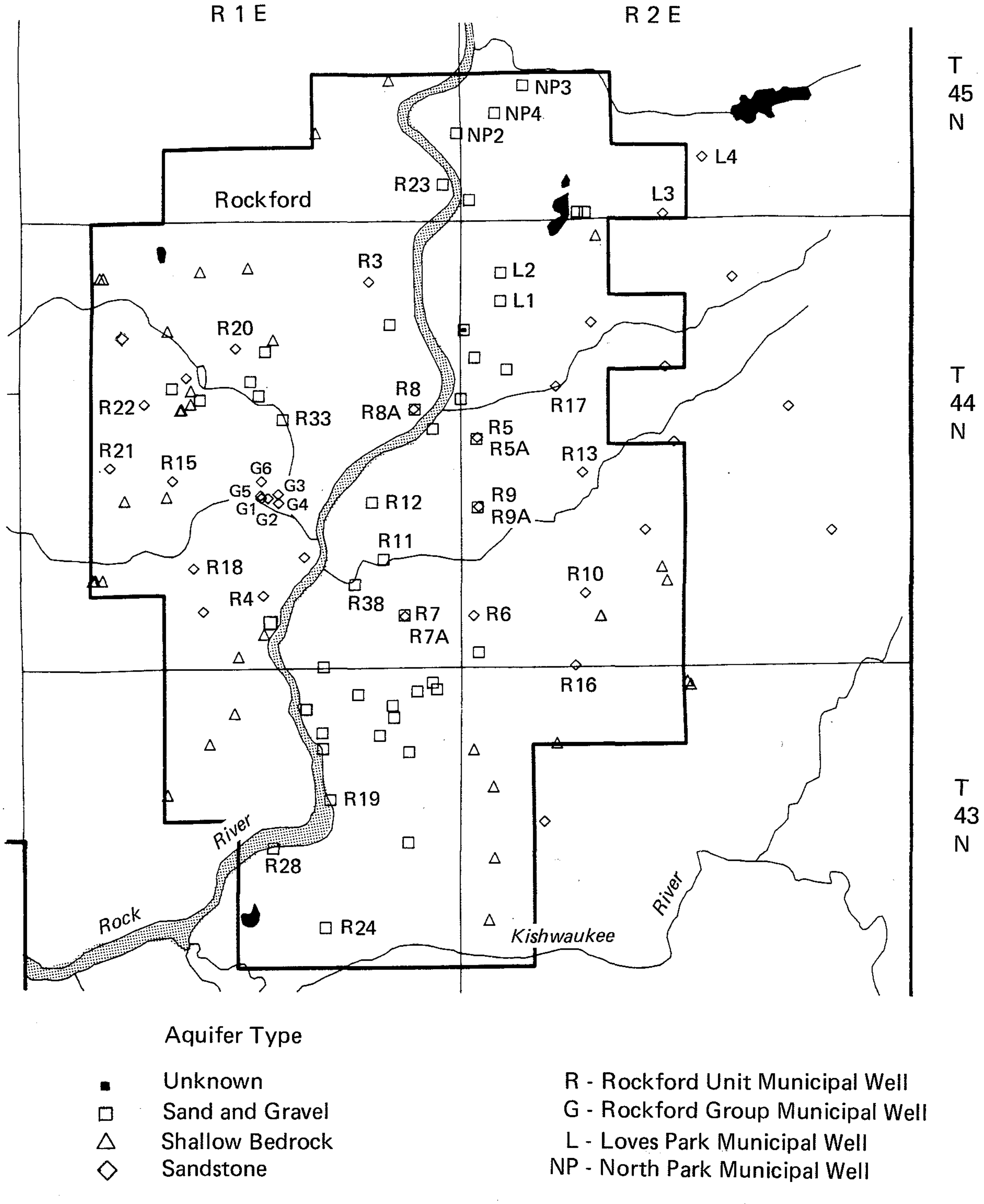

Figure 22. Locations of municipal wells sampled by IEPA superimposed on private well site locations

classification was not assigned was site 44. The sampling point at this industrial facility was found to be a mixture of waters from three wells tapping different aquifers. Figures 21 and 22 reveal the clustering of private wells near and outside the city limits. Because of this clustering near the city boundaries, information on ground-water quality within the central part of Rockford is based principally on samples collected by the IEPA from public water supply wells.

Ground-Water-Level Measurements

Whenever possible, a water-level measurement (depth-to-water reading) was taken at the well prior to water sample collection. Care was taken to ensure that the well was not operating while the water-level measurement was being taken, so that nonpumping or "static" ground-water elevations were computed. In this manner, the regional effects of ground-water flow can be determined. Depth-to-water measurements were made by lowering a chalked steel surveyor's tape into the well casing until the water surface was reached. By subtracting the wetted portion of the tape, as marked by the wet chalk, from the known foot mark held at the top of the well casing, the depth-to-water can be calculated. Depth-to-water measurements were corrected to depth below ground by subtracting the well casing height above land surface.

Ground-water elevations then were computed by subtraction of the depth-to-water below ground from land surface elevations. Land surface elevations were interpreted from the 10-foot contour intervals displayed on the 7.5-minute USGS topographic map. A statistical test was performed on the calculated ground-water-elevation data to determine if inaccuracies produced by the interpretation of land surface elevations (± 5 feet) would substantially affect the resultant ground-water contours. Each ground-water elevation was perturbed according to a normally distributed random variate calculated such that there was a 99 percent chance that its value was within 5 feet (plus or minus) of the actual field-computed value. Ten new ground-water elevations were computed for each well site where a water level had been taken. Ten different contour maps were then made by using the perturbed elevations to see if significant differences from maps prepared from the original data could be discerned. No significant differences were found. It was concluded that, for this case, 10-foot contour intervals on the topographic maps were sufficient to determine ground-water surface elevations.

Water Sampling and Analysis

Water samples for VOC determinations were collected in 40-milliliter (ml) glass vials sealed with Teflon-lined septa held on by screw caps. The vials were washed with detergent, rinsed with distilled water, dried, and heated overnight at 450°C to oxidize/volatilize any residual organic matter. The septa were washed with detergent and soaked in distilled water three times for at least one hour each time.

Water samples for metal determinations were collected in 125-ml polypropylene bottles. The bottles were cleaned by washing them with detergent, rinsing them with deionized water, letting them stand for at least one week filled with 1 percent (by volume) HNO_3 in deionized water, and letting them stand for at least one month filled with deionized water. Prior to a sampling trip, the bottles were emptied, rinsed with deionized water, and then had 1 ml of reagent grade HNO_3 added to preserve the samples.

Water samples were taken primarily from outside faucets at private homes and from inside faucets or sampling taps at industrial facilities. Whenever possible, the sample was collected at a point ahead of any treatment process. In a few situations this was not possible, and the sampling location and treatment process were recorded. At each collection point, the water was allowed to run for approximately 15 minutes to flush stagnant water from the plumbing. This should be sufficient to purge the well, pressure tank, and piping in most household systems. A flow rate was estimated by running the water into an 8-liter bucket and measuring the time required to fill the bucket. Domestic-well flow rates averaged approximately 24 liters per minute. Industrial wells were usually operating before being visited for sampling, so flushing of the well and plumbing was not necessary. Nevertheless, the sampling tap and filter were flushed for 15 minutes, as was done with the domestic wells.

After the system was flushed, the flow rate at the sample collection point was reduced to allow a 40-mL vial to be filled without agitation or bubbling, which could cause a loss of volatile solutes. The vial was filled in such a manner that the meniscus formed by the water protruded above the lip of the vial; the vial was subsequently capped so that no air was trapped in the vial. If an air bubble was found after capping, the vial was emptied and refilled. VOC samples were immediately placed on ice for transportation to the laboratory. Upon arrival at the laboratory, they were stored at 4°C until they were analyzed. Duplicate samples were collected from approximately 20 percent of the wells sampled.

After the VOC sample vial was filled, another sample was collected for metals determinations. Water was run through 0.1-micrometer inline filter for 5 minutes to leach potential soluble metals from the filter. During this flushing process, the air bleed valve on the filter holder was left open to allow water to run out the vent while approximately 100 mL min^{-1} ran through the filter. This was done to decrease the possibility of rupturing the filter while allowing a high enough flow rate to collect the sample in a reasonable time. Difficulty was encountered in regulating the flow rate through the filter with the bleed valve closed. Domestic faucets are designed to deliver several gallons per minute, not 100 ml per minute (approximately 0.025 gpm).

After collection of the sample, the filter holder was rinsed with deionized water. A new filter membrane was used for each sampling site.

VOC concentrations were determined according to USEPA methods for purgeable halocarbons and purgeable aromatic hydrocarbons (USEPA, 1982a, 1982b). The VOCs were detected by photoionization and Hall detectors used in series. The Hall detector is selective for halocarbons, and the photoionization detector responds to aromatic compounds and some halocarbons under the conditions used for this study. A list of the compounds for which analyses were performed is shown in table 5.

Quality assurance measures for VOC samples included trip blanks (vials filled with distilled water and carried from the laboratory to the field and back with the sample vials), storage blanks, trip standards, field duplicate samples, and laboratory duplicates and spikes. For metal samples, the measures used included field duplicate samples, trip blanks, and laboratory splits and spikes.

The holding time specified for volatile organic compound determinations is 14 days (USEPA, 1982a, 1982b). Of the 84 water samples (including field duplicates and trip blanks) that were analyzed as part of this investigation, 55 were held for 15 days or longer because of instrument malfunctions. For these 55 samples, the average holding time was 25 days, the standard deviation was 16 days, and the maximum holding time was 54 days. Even though the holding times for 65 percent of the samples exceeded the specified time, there are two reasons to believe that there were no significant losses of volatile solutes. First, Friedman et al. (1986) found that storage of water samples for 34 days did not significantly decrease recoveries of bromoethane, chlorobenzene, chloroethane, dichlorobromomethane, ethylbenzene, and vinyl chloride. Two of these compounds, chlorobenzene and ethylbenzene, were among the compounds determined in the present study. The other compounds that Friedman examined have similar physiochemical properties, such as boiling point and vapor pressure at room temperature, to those of the remaining compounds determined in the present study. Therefore, the results of Friedman et al. (1986) suggest that losses of volatile solutes probably were not serious.

The second reason for believing that no significant losses of volatile solutes occurred is that field standards for this investigation that were held longer than 14 days showed the same recoveries of the various volatile solutes as the field standards that were analyzed within 14 days of sample collection.

Therefore, all of the water samples are believed to have provided useful data to indicate areas of uncontaminated and contaminated ground waters.

Cadmium (Cd), chromium (Cr), and lead (Pb) values were determined by graphite furnace atomic absorption spectrophotometry. Reported values are the means of duplicate analyses of each sample. Method detection limits (95 percent confidence level) were determined from replicate analyses of calibration standards containing 0.25 µg L^{-1} Cd, 5.0 µg L^{-1} Cr, and 2.5 µg L^{-1} Pb, according to the method of Glaser et al. (1981). Concentrations reported at the detection limits (less than given values) may be ± 100 percent of the given value. Compensation for nonspecific background absorption for cadmium and lead was accomplished with Smith and Hieftje (1983) background correction. Barium (Ba) was determined through flame emission spectrophotometry. Reported values are the means of eight replicate 3-second integrations.

Table 5.
Volatile Organic Compounds Analyzed
(In order of elution)

Methylene chloride
Trans-1,2-dichloroethene
1,1-dichloroethane
Cis-1,2-dichloroethene
Chloroform
1,2-dichloroethane and 1,1,1-trichloroethane (coelute)
Carbon tetrachloride
Trichloroethene
1,1,2-trichloroethane
Tetrachloroethene
Benzene
Toluene
Chlorobenzene
Ethylbenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
1,2-dichlorobenzene

Background interferences in the samples were significant during the determination of Ba because of the emission of CaOH at the same wavelength (553.5 nm). Background correction for this interference was accomplished by diluting the sample by a factor of 4 and subtracting the CaOH emission measured on a second instrumental channel at a non-barium absorbing wavelength (552.0 nm). The detection limit for diluted samples was 0.016 mg L^{-1}. None of the samples were below this concentration level.

All trip blanks contained concentrations below detection limits for Ba, Cd, Cr, and Pb. An acid blank was prepared and stored in a polyproplylene bottle identical to the sample bottles. Analyte concentrations for this acid blank were also below detection limits for all four metals. Eight of the samples (10 percent) were split in the laboratory. The samples were shaken, and half of the sample was poured into an acid-cleaned polypropylene bottle. There were no significant analyte concentration differences between split samples.

Quality control check samples (QCS) were analyzed to validate calibration curves. USEPA Water Pollution QCS, Trace Metals I, WP284, Concentration 2, at a 1:20 dilution was used for cadmium, chromium, and lead. USEPA Water Supply QCS, WS378, at two concentrations, was used for barium. No significant biases were found.

CHAPTER 4. FIELD RESULTS

Ground-Water Elevations

Ground-water elevations were determined at 43 of the 69 private wells sampled during this study. Depth-to-water measurements could not be determined at many of the remaining 26 sites because the wells were of the shallow "sand-point" type construction. Opening the well seal for a water-level measurement on this type of well would have broken suction on the pump, rendering the well unusable until the pump could be primed (see "Well Construction in the Rockford Area"). The exclusion of sandpoints from the sampling program would have eliminated several localities within the study area where sand points were the predominant (sometimes only) type of well being used. In terms of a regional sampling effort, this would have compounded the problems created by the clustering of private wells, by further reducing the amount of ground-water-quality information to be gathered over large portions of the Rockford area. Because the emphasis of this project was to evaluate ground-water quality, particularly where geohydrologic conditions are susceptible to contamination, it was judged preferable to collect ground-water samples from these shallow wells than to exclude the wells simply because hydrologic (that is, water-level) information could not be gathered at those wells.

Ground-water elevation data were plotted onto maps of the study area for contouring. These data also include measurements taken from public water supply wells by RWD personnel during our sampling period. Water-level measurements were collected from wells completed in different aquifers, principally the shallow bedrock (26 wells) and the sand and gravel (20 wells). Ground-water elevations computed from water-level measurements in shallow bedrock wells (figure 23) in the northwest portion of the study area were found to be at or near land surface, far above the top of the aquifer, indicating artesian conditions. Similar conditions appear to be prevalent in the other shallow bedrock wells, most notably in the southeastern portion of the study area. These wells appear to be removed from the general vicinity of the Rock River, an understandable condition considering that the shallow bedrock is not typically present in the river valley.

However, several shallow bedrock wells just west of the Rock River in the southwest portion of the study area contain lower ground-water elevations that appear to agree more closely with ground-water elevations found in the sand and gravel. Again, though, as the distance from the river becomes greater, a steep increase in the elevation of the ground water in the shallow bedrock can be seen (note the 763 feet msl data point in the southwesternmost well and the 785 feet msl point in the west-central part of the study area). The large differences in the shallow bedrock ground-water elevations make contouring extremely difficult, if not entirely speculative. It appears that the transition

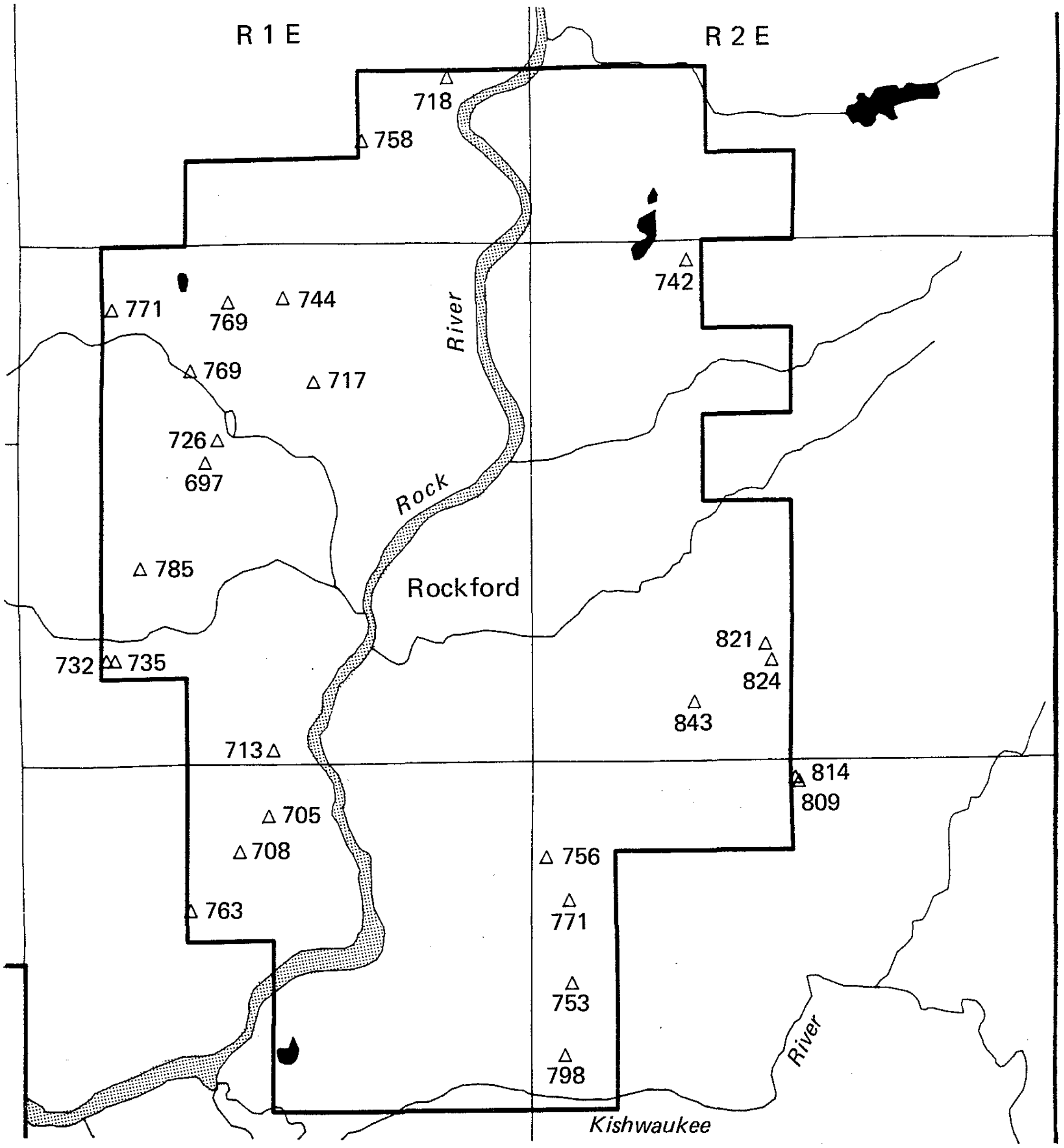

Figure 23. Ground-water elevations in shallow bedrock wells

from areas where artesian conditions prevail to those where water-table conditions prevail occurs quite rapidly and may be due to rapid changes in the bedrock surface elevation and influences from large ground-water withdrawals by municipal and industrial wells. Without further information on ground-water elevations in intervening areas, ground-water elevations in the shallow bedrock were considered too uncertain for contouring.

Elevations of the ground-water surface in the sand and gravel aquifer (figure 24) were found to fall in a much more consistent pattern. Only four ground-water elevations were determined for the sand and gravel west of the Rock River, but these four elevations are consistent with what might be expected for regional ground-water movement toward the river, as depicted by the 1965-1966 ground-water contour map (figure 16). As shown in figure 24, the ground-water surface elevation falls from 729 feet msl in the west-central part of the study area to 702 feet msl along the west bank of the river, signifying ground-water movement downgradient toward the Rock River. Unfortunately, the data points fall in a fairly straight line from west to east and do not provide a complete description of the ground-water surface for the area west of the Rock River.

Better areal coverage was achieved on the eastern side of the river. Again, ground-water elevations increased with distance from the river. This is most clearly seen in the northeast corner of T.43N., R.1E. on figure 24 where ground-water elevations fluctuate around 690 feet msl, rise to 704 or 705 feet to the east, and then rise to 720 feet in the southwest corner of T.44N., R.2E.

Contours of the ground-water surface east of the Rock River were prepared by using a contouring software package (GEOSOFT^{R}). Surface water elevations for the Rock River were added for vertical control in the contouring routine. River stage information was supplied by the Rockford Sanitary District at their Kishwaukee Avenue treatment plant, and by the United States Geological Survey at their Rockton gaging station. Rock River elevations were interpolated between these upstream and downstream stations. A low-head dam between the Walnut Street and College Avenue bridges in Rockford gave additional vertical control from which to interpolate Rock River elevations.

The resulting ground-water elevation contours for the sand and gravel appear in figure 24. Comparison of this map with the 1965-1966 map shows that current ground-water elevations are quite similar to what they were 20 years ago. This may be due to the fact that ground-water withdrawals are essentially the same as they were in 1965-1966. The 690-, 700-, and 710-foot contour intervals follow quite similar patterns in both figures. Differences in the two contour maps may result primarily from insufficient data for the more recent map with which to confirm individual data points and to faithfully extend contours. Better resolution of the ground-water surface most probably

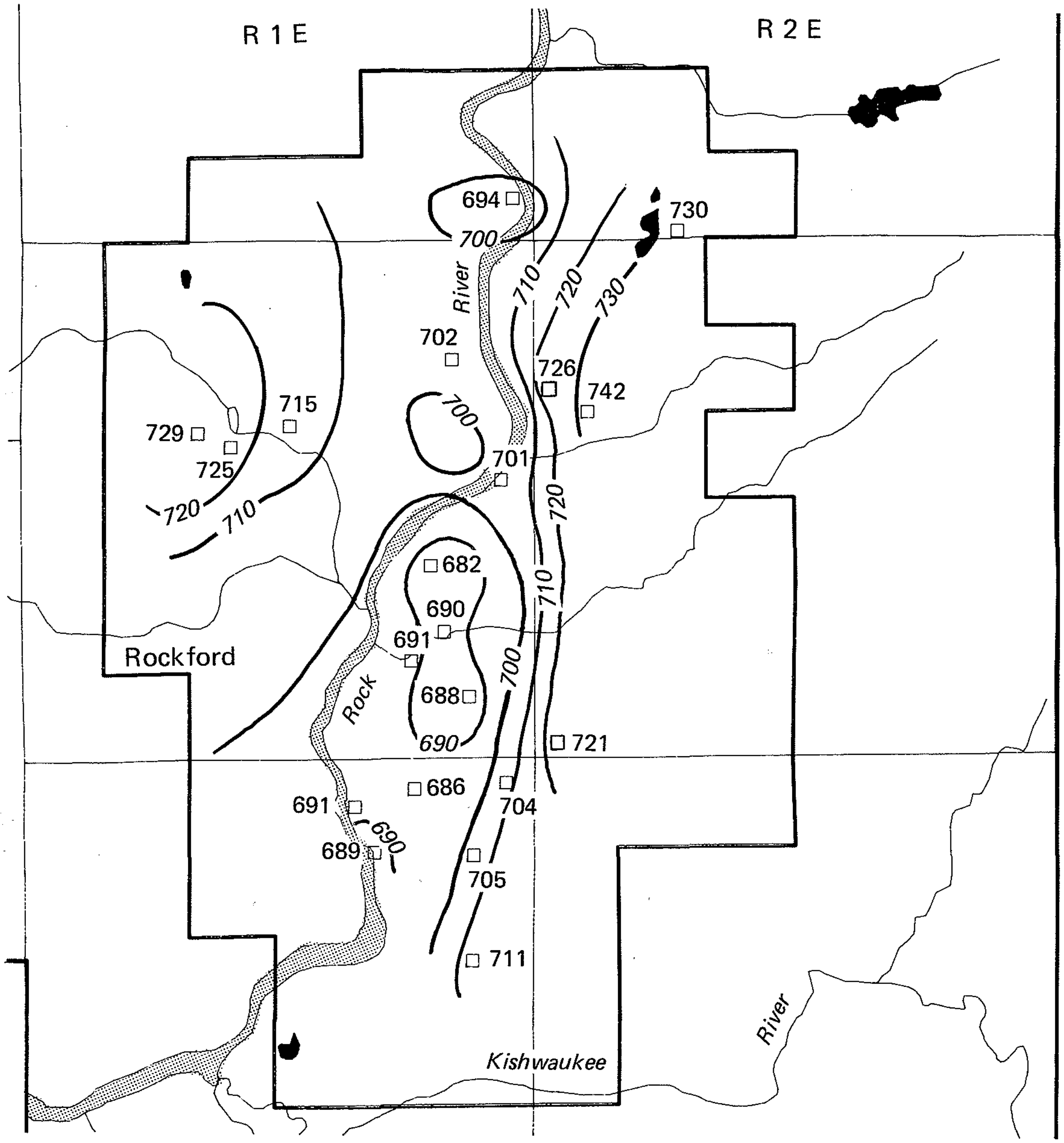

Figure 24. Potentiometric surface of the sand and gravel aquifer at Rockford, 1986

would have been achieved if water levels had been obtained from more wells. The maps prepared in 1965-1966 contained 44 separate water-level elevation readings for the sand and gravel ground-water contour map, over twice as many data points as used for the latest map (20).

Nevertheless, the data show that the Rock River does act as the sink for regional ground-water discharge. Contaminants entering the ground-water system will generally move toward the river under the influence of regional ground-water flow. However, local areas of influence caused by large ground-water withdrawals, as shown in figures 11 and 12, may induce contaminant movement along flow paths not shown on either figures 16 or 24.

Results of Chemical Determinations

The results of the VOC determinations are presented in tables 6 and 7. Samples containing no detectable VOCs are not presented. Duplicate field samples are denoted by a change in letter suffix following the sample site number; repeated sample numbers denote laboratory replicates. The lowest concentration for reliable quantitation of the various compounds was approximately 5 $\mu g\ L^{-1}$. Concentrations that are reported as less than 5 $\mu g\ L^{-1}$ but greater than zero may be only approximately correct; however, the compounds can be considered to have been positively detected. Samples from 28 of the 69 sites had detectable chlorinated hydrocarbon concentrations, while 9 of the sites had detectable aromatic hydrocarbon concentrations.

Ten water samples contained 5 $\mu g\ L^{-1}$ or more of at least one of the following compounds: 1,1-dichloroethane (11DCA), cis-1,2-dichloroethene (c12DCE), chloroform (CLF), 1,1,1-trichloroethane (TCA) + 1,2-dichloroethane (12DCA) (these two compounds coelute), trichloroethene (TCE), and tetrachloroethene (PCE) (see table 6). No water samples contained aromatic compounds at concentrations above the limit of quantitation of 5 $\mu g\ l^{-1}$ (table 7).

Six other VOCs were detected at low concentrations (i.e., less than 5 $\mu g\ L^{-1}$, usually less than 1 $\mu g\ L^{-1}$) in 9 samples (table 6). These compounds, with the number of sites in which they were detected in parentheses, were:

trans-1,2-dichloroethene, t12DCE (2)
1,1,2-trichloroethane, 112TCA (3)
benzene, BZ (3)
toluene, TOL (3)
1,2-dichlorobenzene, 12DCB (2)
1,4-dichlorobenzene, 14DCB (2)

Neither carbon tetrachloride, chlorobenzene, nor ethylbenzene were detected in any samples. Methylene chloride (MC) was found in all

Table 6.

Volatile Halocarbon Determinations for Private Well Sites

Concentration ($\mu g\ L^{-1}$)

ISWS Site^{a}	t12DCE	11DCA	c12DCE	CLF	12DCA +TCA^{b}	TCE	112TCA	PCE
1A	0.1^{c}			1.3		0.9		
2A		56.4	96.1	11.7	294.0	69.6	0.5	1.0
2B			86.3	85.4		60.8		0.7
3A		2.1	1.3	0.2	5.8	0.4		
3C								
4A					0.6			0.3
4C					0.3			0.3
5A		0.2		0.1	0.2	1.0		0.2
9A							0.1	
10A					1.4			
12A		25.7	31.1		92.5	30.6		
13A				3.2				
24A					0.5			
28A					0.4	1.5		
37A				0.2	1.0			
40A				0.4	0.3	0.1		
41A								0.5
41B				0.9				
42A		4.4	3.7	0.2	0.9	31.0		10.4
45B		1.4			0.8	0.6		0.2
45B		1.2			0.8	0.8		0.2
46A				7.2				
46A				7.8				
47A		1.7			106.8			
47B		2.0			106.4	0.7		
47B		1.6			93.4	0.5		
52B				0.2	0.3			
54A								
54B		1.9						
55A				0.7				
56A						0.5		
58A	0.1		406.2		0.5	96.3	0.2	
58A	0.1		383.7		0.5	96.6	0.2	

Table 6. (Concluded)

ISWS Site[a]	t12DCE	11DCA	c12DCE	CLF	12DCA +TCA[b]	TCE	112TCA	PCE
59A		2.2	1.4	0.6	2.6	12.6		0.1
61C				0.2				
64A					0.7			
65		25.3	16.6	1.1	11.2	14.6		
66		12.3	34.2		51.0	32.8		

[a] No volatile halocarbons were detected at sites 6-8, 11, 14-23, 25-27, 29-36, 38, 39, 43, 44, 48-51, 53, 57, 60, 62, 63, or 67-70. Well 31 was not sampled.

[b] 12DCA and TCA coelute.

[c] If listed concentration is less than 5 μg l^{-1}, compound was detected but was below level of quantitation.

Note: Blank spaces indicate that the compounds were not detected at those sites.

t12DCE = trans-1,2-dichloroethene; 12 DCA + TCA = 1,2-dichloroethane + 1,1,1-trichloroethane; 11 DCA = 1,1-dichloroethane; TCE = trichloroethene; c12DCE = cis-1,2-dichloroethene; 112TCA = 1,1,2-trichloroethane; CLF = chloroform; PCE = tetrachloroethene.

Table 7.

Volatile Aromatic Hydrocarbon Determinations for Private Well Sites

Concentration (μg L^{-1})

Site[a]	BZ	TOL	14 DCB	12 DCB
2B	0.4[b]			
33A				0.6
45B				1.1
45B		0.5		0.5
46A		0.3		
58A	0.2			
58A	0.3			
59A		0.4		
60A			2.87	
60A			2.87	
61C			0.6	
62A	0.3			

[a] No volatile aromatic compounds were detected at sites 1, 3-32, 34-44, 47-57, or 63-70. Well 31 was not sampled.

[b] If listed concentration is less than 5 μg/L, compound was detected but was below level of quantitation.

Note: Blank spaces indicate that the compounds were not detected at those sites.

BZ = benzene; TOL = toluene; 14 DCB = 1,4-dichlorobenzene; 12 DCB = 1,2-dichlorobenzene.

samples and blanks at variable concentrations, and 1,3-dichlorobenzene (13DCB) was found in most samples and blanks at less than 0.5 µg L^{-1}. It appears, therefore, that these compounds probably came from laboratory contamination. For this reason, MC and 13DCB are not listed in tables 6 and 7 and were not considered to be ground-water contaminants.

Six sites which showed high concentrations of TCE, a common industrial solvent, also contained high concentrations of c12DCE and traces of t12DCE, two products of reductive dechlorination of TCE. 1,2-dichloroethene (12DCE) has some industrial uses as a solvent for fats, phenol, and camphor. A mixture of the cis and trans forms is probably used. The Rockford Sanitary District (RSD) maintains a file of industries that connect to the Rockford sewer system and the chemicals and materials that they handle. Neither 12DCE nor 11DCA are listed in the RSD file. It is quite possible, therefore, that the presence of 12DCE and 11DCA at some locations may be due to the transformation of TCE and TCA. Similarly, four of the six samples containing high concentrations of trichloroethane, another common solvent, also contained high concentrations of 1,1-dichloroethane, a product of dechlorination of trichloroethane.

Figure 25 shows the locations of the private wells sampled during this study which contain TVOC concentrations greater than 10 µg l^{-1}. Of the ten sites with relatively high VOC concentrations, seven are located in the southeast Rockford area (well sites 2, 3, 12, 47, 58, 59, and 65), one is located in central Rockford along the west bank of the Rock River (well site 42), one is located just east of the river in Loves Park (well site 66), and the last well site, 46, is located in extreme eastern Rockford. The VOC concentration at well site 46 is not suspected to be related to a ground-water contamination problem. Rather, it is suspected to be the result of a water treatment process which could not be circumvented during sampling. The sample at this site was collected from an inside faucet after iron removal and chlorination processes. The presence of low levels of chloroform has been shown to be a product of chlorination of organic materials naturally present in many surface and ground waters (Symons et al., 1975; Jolley, 1978).

Trace metal concentrations are listed in table 8. Barium was detected in all samples but one, with concentrations ranging from 85 to 527 µg L^{-1}. These concentrations are typical for ground water in the Rockford area. Therefore, only extremely high Ba concentrations (in the milligrams per liter range), such as those found downgradient from the Sand Park Landfill (site 3 in Appendix D and on figure 19) would indicate ground-water contamination. Cadmium (Cd), lead (Pb), and chromium (Cr) were detected in 13, 1, and 10 samples, respectively. Most of the samples with detectable Cd, Cr, and Pb were from southeast and northwest Rockford. However, the detected concentrations for these three metals were very low, below 5 µg l^{-1} in all but one sample.

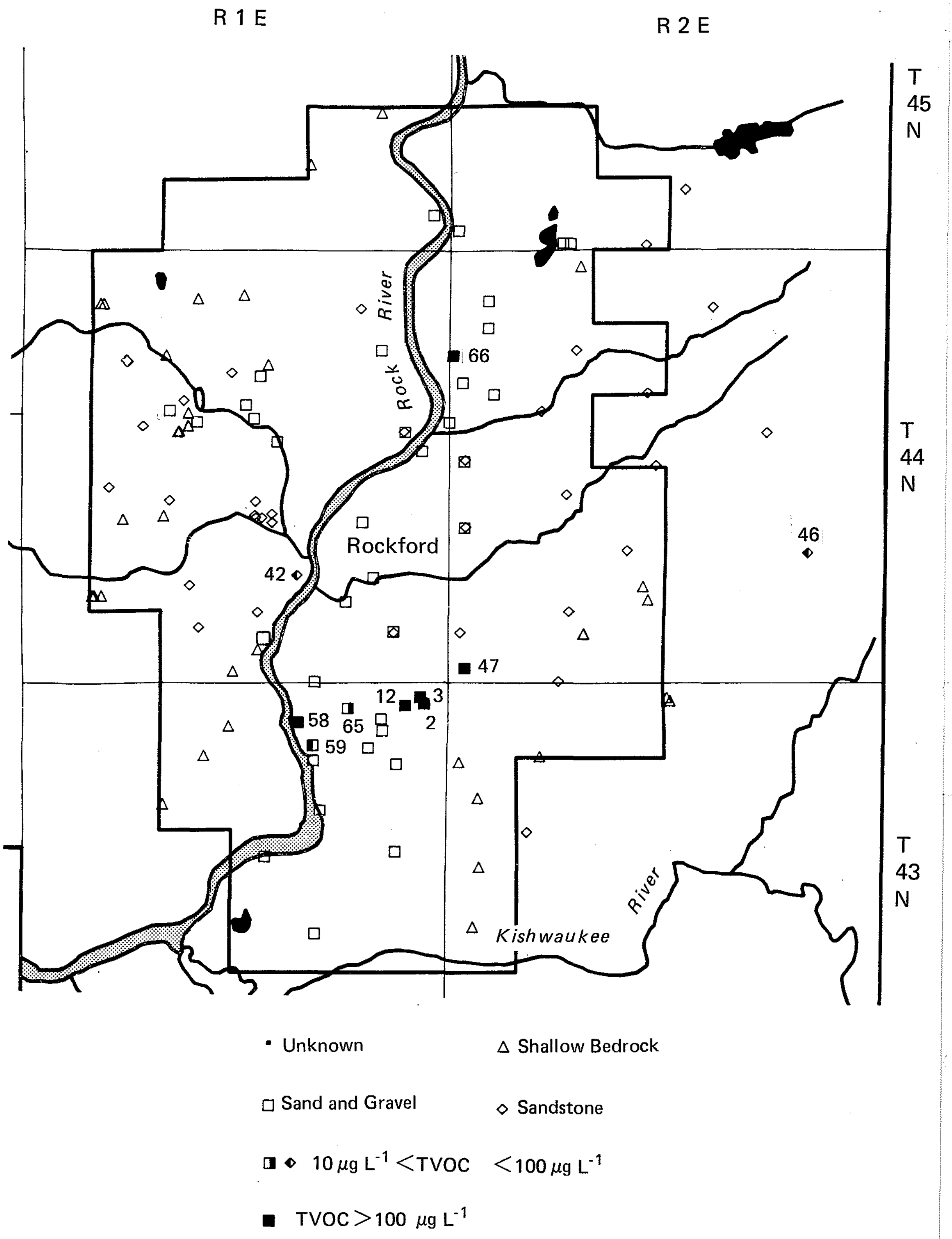

Figure 25. Locations of private wells sampled that have total volatile organic compound concentrations greater than 10 $\mu g\ l^{-1}$

Table 8.
Trace Metal Determinations for Sampled Private Wells
(in $\mu g\ l^{-1}$)

ISWS Site	Pb	Cd	Cr	Ba
1B		0.26		254
2C				214
3B		0.59		237
4B		0.16		248
4D		0.15		247
5B		0.16		348
6B				206
7A		0.15		208
8				229
9B				219
9B				228
10B				223
11C		0.05		253
11D				243
12B				
13B				202
14B				210
15C				101
15D				173
16B				183
17B				264
17B			1.3	249
18B				188
19C				174
19D				174
20B				269
21B		0.28		321
22B			1.8	222
23C				267
23D				284
24B			1.7	317
25B				275
25B				269
26B				247
27B				233
28B				174
30B				235
30D				242
32C				163
32D				166
33B				174
34B				186
35B				270
35B				252

Table 8. (Concluded)

Trace Metal Determinations for Sampled Private Wells (in µg l^{-1})

ISWS Site	Pb	Cd	Cr	Ba
36B				213
37B				196
38B		0.07		206
39				194
40B		0.05	1.5	250
42B				409
43				191
44B				527
45A	7.5			316
46B				219
47C				145
47D		0.31		148
48B				136
50B				221
51B				095
52A		0.14		252
53B				228
54C			1.5	141
54D			1.4	145
55B				205
55B				205
58B			1.6	163
59			2.0	187
60B			4.8	168
61B				183
61D				176
62B				160
63A		0.14		235
64B				175
65				160
67B				151
67B				152
68B				091
69C				085
70C			1.6	178

Note: Blank space indicates metal was not detected. Detection limits were Pb 1.1 µg l^{-1}, Cd 0.05 µg l^{-1}, Cr 1.3 µg $^{-1}$, Ba 6 µg l^{-1}.

Metals samples were not collected at sites 29, 41, 49, 56, 57, and 66. Well 31 was not sampled.

CHAPTER 5. DISCUSSION

Areas of Ground-Water Contamination

A total of 69 private domestic and industrial wells located throughout the Rockford area were sampled for this project. To determine the effects of surface and near-surface activities on ground-water quality, emphasis was placed on sampling wells finished in the shallow bedrock or sand and gravel aquifers. Only four wells were sampled that are greater than 250 feet deep; 32 sampled wells are less than 100 feet deep. Analyses for 18 VOCs and 4 trace metals were conducted to provide information on the occurrence of hazardous-substance-related contaminants in the ground water.

Results of these analyses were compiled with information from previous investigations, including IEPA sampling of 48 municipal water wells in the study area, to determine general areas of ground-water contamination. Figure 26 shows the locations of the private wells sampled for this study which contained TVOC concentrations greater than 10 $\mu g\ l^{-1}$ and of sites previously known to contain contaminated ground water. The compiled information does not support a finding for regional ground-water contamination. Three areas, consisting of eight well sites sampled during this investigation, do warrant further discussion. Proceeding from north to south across the study area, the three areas include well sites 66, 42, 2, 3, 12, 65, 58, and 59.

Well site 66, located in the northern portion of the study area, is an industrial well completed in sand and gravel near Loves Park Wells 1 and 2 (Appendix D, site 5) and the Sand Park Landfill (Appendix D, site 3). Contamination at well site 66 may be related to the problem at the Loves Park municipal wells. TCY, 11DCE, and c12DCY have been found at both locations. Generally lower concentrations of these contaminants have been exhibited in the Loves Park wells than were determined at well site 66. This could, however, be due to a difference in sampling procedures and the date of sampling.

Contaminants detected in monitoring wells at the Sand Park Landfill are quite different from those found at well site 66 and Loves Park Wells 1 and 2; therefore, the landfill does not appear to be the source of the contaminants found at these two sites. As depicted in figure 18, a fairly large number of potentially contaminating activities surround this area in the northwest corner of T.44N., R.2E.

Well site 42 is another industrial well in which high VOCs were detected. Located along the west bank of the Rock River in central Rockford, this well penetrates the Glenwood-St. Peter Sandstone to a total depth of 450 feet. The presence of TCY and PCY in this "deep" bedrock well, which is similar to several of Rockford's municipal bedrock wells (such as Unit Wells 6, 7, and 8 and Group Wells 2 and 6

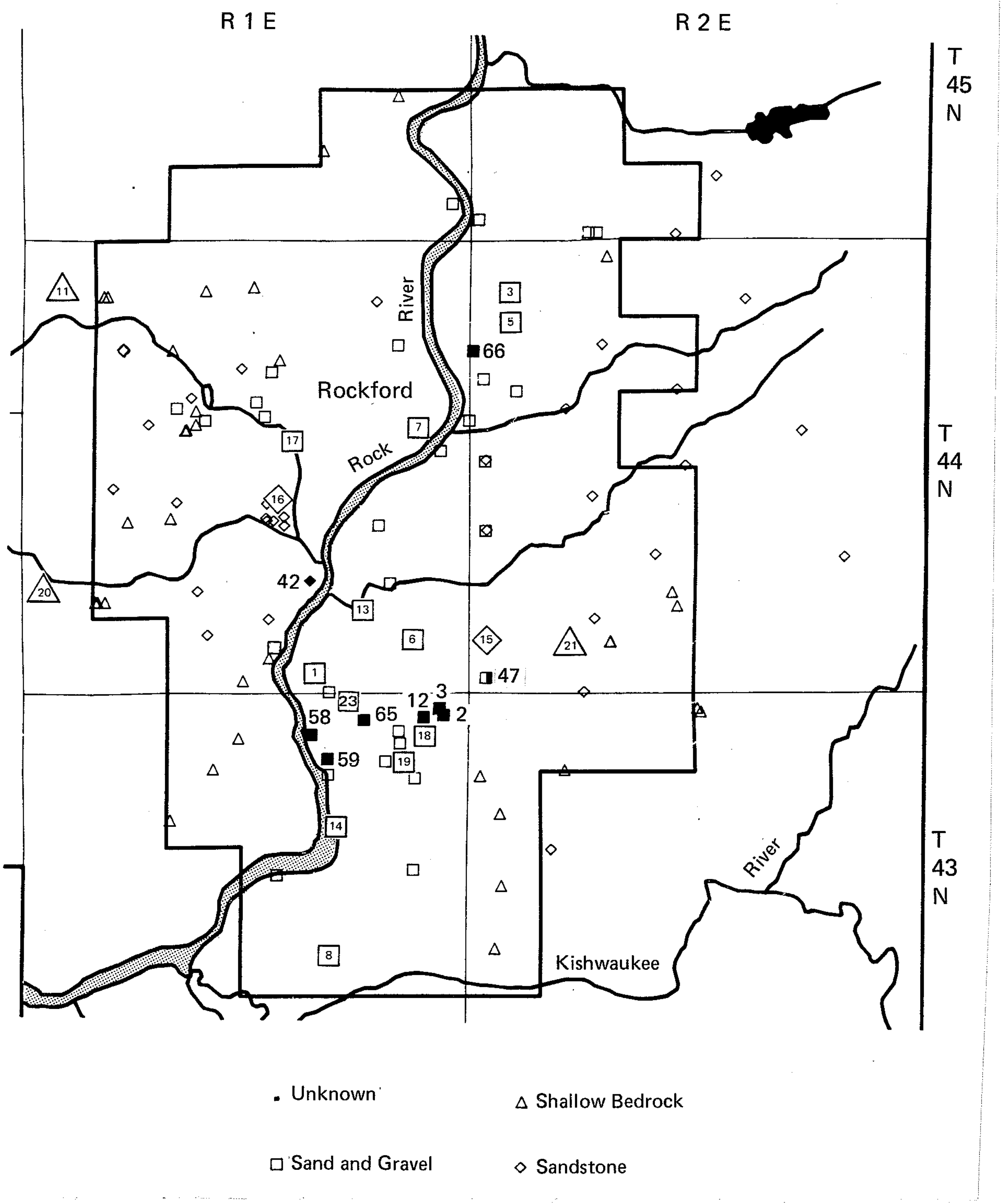

Figure 26. Locations of previously identified sites of contamination and private wells sampled that have high total volatile organic compound concentrations (numbers inside symbols correspond to contamination site numbers in Appendix D and on figures 19 and 20)

(sites 15, 6, 7, and 16, respectively, in Appendix D) may indicate greater contamination of the sandstone than previously suspected. The origin of contamination in the deeper bedrock formations will be difficult to determine. Further investigation of the quality of the water in the sand and gravel in this area is warranted, as this water may be contributing to the problem in the underlying bedrock. More detailed investigations also should be made of the adequacy of measures taken in the abandonment of industrial wells in this part of Rockford. Leakage of contaminants through improperly sealed casings and boreholes is possible.

Analyses of ground-water samples from private well sites 2, 3, 12, 47, 58, 59, and 65 show that ground water beneath an area of southeast Rockford contains significant concentrations of volatile organic compounds and possibly elevated concentrations of trace metals. These seven sites, along with Rockford Unit Well 35 (site 18 in Appendix D) describe a contaminant plume or a coalescence of plumes that stretches over 2 miles from well site 47 in the southwest corner of T.44N., R.2E. to well sites 58 and 59 along the east bank of the Rock River. This same direction of movement is confirmed by the potentiometric surface of the sand and gravel aquifer (figure 24), which shows that the movement of ground water is east to west from the river uplands toward the Rock River. The addition of data from other wells sampled during a previous investigation shows more clearly the east to west orientation that contaminant movement has taken. If contaminants in this area have moved with ground water at an average rate of 2 feet per day, it would have taken approximately 15 years for the contaminants to travel this distance.

All of these wells are completed in glacial outwash (sand and gravel) associated with drainage along the Rock Bedrock Valley (Berg et al., 1984a; Hackett, 1960). The area is unique in that all of the homes lie within unincorporated "islands" surrounded by incorporated Rockford. Over 100 homes in the area depend on private wells for domestic water supplies, while several blocks away, water is supplied by the Rockford municipal water department. The use of several public water supply wells in this area has been curtailed because of the presence of VOCs in the raw water. Rockford Unit Well 35, in particular, is located very close to well site 12 and has chronically exhibited concentrations of total VOCs in excess of 10 μg l^{-1}.

Unit Wells 7A and 38 (sites 6 and 13, respectively, in Appendix D), located over a mile north of Unit Well 35, have also experienced varying concentrations of VOCs, depending on the length of operation of the wells. The area is bordered by a variety of industrial facilities which may pose significant potential risk to the quality of the ground-water resource. As shown in figure 18, in the southeast corner of T.44N., R.1E. these facilities occur in a particularly dense pattern just north of the contaminated area, and the occurrence of ground-water contamination by VOCs in this area lends credibility to the significant potential hazard these facilities pose to the environment. Again, the pattern of ground-water flow regionally described by figure 24 would tend to further support this. Given changes in local flow patterns caused by large withdrawals, such as those from public wells, it is entirely possible that contaminants introduced by facilities to the north or east could have migrated to the affected area.

The detected Cd, Cr, and Pb concentrations, particularly at sites 1, 3, 4, 5, and 45 in southeast Rockford, may have been caused by ground-water contamination. Many industries in the Rockford area handle these metals or their salts and are therefore potential sources of contamination (see figure 18). Several of these sites also exhibited high concentrations of VOCs. However, these metals occur naturally in some ground-water systems. Without knowledge of the natural variabilities of their concentrations in the ground water in the Rockford area, it is not valid to ascribe the detected trace metal concentrations to contamination.

Potential Health Risks

In this section, the concentrations of the various organic and metallic substances found in the Rockford-area ground water are examined from the perspective of potential adverse health effects.

Health advisories, i.e., estimates of concentrations of contaminants that may have adverse effects on human health, have been calculated by the USEPA. The data that the calculations were based on were gathered through comprehensive literature reviews of toxicological and epidemiological studies. Health advisories are intended to serve as technical guides for persons who are responsible for the protection of public health. They are not legally enforceable standards. According to the USEPA (1985a-m), health advisories are calculated from "data describing non-carcinogenic end points of toxicity" (e.g., decreased white blood cell count). Hence, by definition, they do not estimate carcinogenic risks. Carcinogenic risks are estimated separately. Short-term health advisories are calculated by using equation 5:

$$HA = [(NOAEL \text{ or } LOAEL) \times BW \times T] / [UF \times C] \qquad (5)$$

where NOAEL and LOAEL are the no observed adverse effect and lowest observed adverse effect levels, respectively, with the dimensions of mg kg^{-1} day^{-1}, BW is bodyweight (weights for adults and children are assumed to be 70 kg and 10 kg, respectively), T is exposure time (usually the period of the experiment from which NOAEL is taken), UF is an uncertainty factor (typically 100 or 1000), and C is daily water consumption (two liters for adults and one liter for children). For volatile compounds, it may be necessary to assume that only a fraction of exposure is from drinking water. Thus, if it is assumed that 20 percent of exposure to a volatile contaminant is from drinking water, then the uncertainty factor in the denominator must be multiplied by a factor of five. The USEPA does not calculate health advisories for long-term or lifetime exposure to known carcinogens.

To estimate the long-term or lifetime exposure to carcinogenic substances, the concentration of a carcinogen that would produce one excess tumor in a population (e.g., 10,000 people) has been calculated by the EPA by using a linearized multistage model. Carcinogenic risks, like health advisories, are calculated on the basis of data from animal experiments and epidemiological studies. The EPA estimates represent the upper 95 percent confidence limit and are "unlikely to underestimate the probable true risk" (USEPA, 1985a-m).

Table 9 compares the results of the present study with 10-day and lifetime health advisories, concentrations predicted to produce one excess tumor in a population of 10,000, recommended maximum contaminant levels, and proposed ground-water standards for the state of Wisconsin (Wisconsin Division of Health, 1985). Concentrations predicted to produce one excess tumor per 100,000 and per 1,000,000 are calculated by dividing the concentrations in Table 9 by 10 and 100, respectively.

Trichloroethene exceeded its RMCL value at well sites 2, 12, 42, 58, 59, 65, and 66. Tetrachloroethene exceeded its RMCL at well site 42. At well site 2, the sum of 1,2-dichloroethane and 1,1,1-trichloroethane, which coelute under the conditions of our analyses, was 294 $\mu g\ l^{-1}$. Because the RMCL's for these two compounds are 5 $\mu g\ l^{-1}$ and 200 $\mu g\ l^{-1}$, respectively, at least one of the compounds exceeded its RMCL. At well sites 12, 47, 65, and 66, the total concentrations were greater than 5 $\mu g\ l^{-1}$, so the RMCL for 1,2-dichloroethane may have been exceeded. None of the compounds were present at concentrations predicted to produce one excess tumor in a population of 10,000. However, the chlorinated ethenes and ethanes that exceeded their RMCL's also exceeded "carcinogenic" concentrations for populations of 100,000 to 1,000,000 at the same sites.

Use of Statewide Maps for Regional Studies

A synopsis of 23 known ground-water contamination problems discovered in Winnebago County appears in Appendix D. The locations of these sites with respect to the prioritized areas for monitoring of hazardous substances in sand and gravel and shallow bedrock aquifers are shown on figures 19 and 20, respectively.

Multiple aquifers appear to be involved in a few situations. At sites 6 and 7, contamination has been detected in municipal wells

Table 9.
Comparison of Contaminant Concentrations Measured in Private Wells with USEPA Drinking Water Health Advisories and Standards[a]

Contaminant	Maximum Concentration, Present Study	Health Advisories		One Excess Tumor per 10,000	USEPA Recommended Maximum Contaminant Level	Wisconsin Recommended Ground-Water Standard
		10-day[b]	Lifetime[c]			
1,2-dichloroethane[d]		740	CARC[e]	95	5	1
1,1,1-trichloroethane[d]	294	35000	1000	1680	200	200
trichloroethene	96.6	f	260	200	5	2.8
tetrachloroethene	10.4	34000	1940	350	5	3.5
trans-1,2-dichloroethene	0.1	f	70	f	g	g
cis-1,2-dichloroethene	406.2	1000	70	f	g	g
benzene	0.4	233	CARC[e]	70	5	0.7
toluene	0.5	6000	2000	f	2000	343
dichlorobenzene[h]	0.6	f	62	f	620	g
barium	527	f	1500	NC[e]	1500	1000
cadmium	0.59	8	18	f	50	10
chromium	4.8	1400	120	NC[e]	120	50
lead	7.5	f	10	f	20	50

a Concentrations in micrograms per liter ($\mu g\ l^{-1}$).
b 10-day health advisories calculated for 10-kg child.
c Lifetime health advisories calculated for 70-kg adult.
d These compounds coelute.
e CARC and NC indicate carcinogenic and noncarcinogenic. Lifetime health advisories not calculated for carcinogens.
f Insufficient data for calculation.
g Substance not considered in EPA RMCL or Wisconsin standards.
h All isomers of dichlorobenzene.

developed in the sand and gravel and deep sandstone aquifers (Rockford Unit Wells 7 and 7A and Unit Wells 8 and 8A). It is possible that the contaminated water being produced by these wells originated in the shallower sand and gravel aquifer, which is in hydraulic communication with the underlying sandstone. However, well records reveal that Wells 7 and 8 are cased through the St. Peter Sandstone and draw water from the underlying Ironton-Galesville, Eau Clair, and Mt. Simon Formations. Therefore, it is more likely that contamination of the deeper aquifers may be occurring by leakage along or disposal of wastes through improperly abandoned deep wells. More detailed investigation of ground-water flow patterns and deep well drilling and abandonment records must be conducted to determine the cause(s) for these problems.

At site 16, VOC contamination has been detected in Rockford Group Wells 2 and 6. Here, also, multiple aquifer contamination is possible. Although Group Wells 2 and 6 are approximately 1600 feet deep, they are cased only 15 and 32 feet into the shallow dolomite, respectively. Because of the well-creviced nature of the shallow dolomite, there is good hydraulic communication with the overlying sand and gravel. Therefore, leakage of contaminants through the sand and gravel into the shallow bedrock aquifer and subsequent mixture with water pumped from deeper aquifers may have occurred.

Excellent correlation of areas mapped as "high" and "intensive" priority with known sites of contamination in the sand and gravel can be seen. For the sand and gravel aquifer, twelve of the fourteen sites are found to be within areas targeted for intensive study, and another site falls within a high-priority area. All twelve sites falling within the intensive priority category are within the study area of this investigation. Slightly less correlation exists with the shallow bedrock prioritization map. Only one of eleven sites on the shallow bedrock map falls within an intensive priority area, while five others fall within high priority areas. The rest fall within the moderate category.

Part of the reason for the poorer correlation in the shallow bedrock stems from the way in which the original prioritization maps were created. One of the principal criteria in the mapping and overlaying process was ground-water withdrawals in excess of 100,000 gallons per day per township. Pumpage in the Rockford area is principally derived from sand and gravel and "deep" bedrock wells. Shallow bedrock wells, while plentiful in the Rockford area, are not used for large ground-water supplies. However, most of the so-called "deep" bedrock wells are not sealed through the overlying shallow bedrock formations and, therefore, also derive water from the shallow bedrock. If pumpage from these wells (see figure 12) were reclassified as also coming from the shallow bedrock, most of the area currently classified as of moderate priority would be reclassified into the high-priority category, and areas categorized as of high priority would be upgraded to intensive. This would place ten of the eleven sites shown on figure 20 in intensive or high areas, five sites (2, 4, 11, 16, and 20) in the intensive category, and five sites (6, 7, 10, 15, and 21) in the high classification.

In terms of future regional ground-water monitoring investigations, it is equally important to note that no known sites fell into areas categorized as low priority. This is extremely important because it supports the previous statewide prioritization effort to predict where contamination of important ground-water supplies is likely to occur. Similarly, the prioritization scheme appears to be effective in predicting that classification of areas as low-priority does not neglect serious ground-water contamination problems.

CHAPTER 6. RECOMMENDATIONS FOR FURTHER STUDY

This study left a number of topics open for further investigation. Of paramount importance is the initiation of follow-up investigations to resolve the incidents of ground-water contamination discussed throughout this report. In particular, the source, magnitude, and extent of contamination needs to be determined at many of these sites. Without such information, the ability to make effective decisions regarding future actions concerning resource management and ground-water remediation will be greatly limited, if not extremely speculative. Left unattended, some sites may become worse.

For example, little has been done to specifically define the source of contamination in the southeast Rockford area. Sampling of domestic wells by the WCPHD and the ISWS provides a basis for defining the extent and magnitude of the problem. However, the domestic wells in this area tap a limited zone within the aquifer. Higher concentrations than those determined from domestic well samples may reside in the aquifer above or below the depth at which most of these wells are finished. The depths at which various contaminants are found will affect the design of ground-water remediation alternatives. Further, remediation alternatives are bound to fail if the source is not removed or at least controlled.

In the southeast Rockford area, the solvents trichloroethene and 1,1,1-trichloroethane have been found along with their products of reductive dechlorination, cis- and trans-1,2-dichloroethene, and 1,1-dichloroethane. Microbial degradation of various halogenated organic compounds has been observed under conditions of denitrification, sulfate reduction, and methanogenesis (Bouwer and Wright, 1986). If such anoxic conditions exist and, therefore, conditions are suitable for reductive dechlorination of organic compounds, it may be possible to calculate effective rate constants for in situ dechlorination. A detailed investigation to determine the proportion of solvents and degradation products present downgradient from the source and the rate of ground-water movement would be necessary.

More specific information is also needed to develop water supply alternatives for the residents of the area and to provide better overall management of the ground-water resource for public and industrial use. The contamination of Rockford Unit Well 35 appears to be connected to the problems being experienced by the domestic wells in the area. It is possible that contaminants found in Unit Wells 7A and 38, located about a mile to the north, are related to the domestic well contamination. Therefore, the response of contaminant movement to various conditions of pumpage by these municipal wells and other high-capacity wells in the area also should be evaluated.

In addition to the deep sand and gravel wells, VOCs have been found in a number of "deep" sandstone bedrock wells. Although many of these wells are over 1,000 feet deep, they often are not sealed from overlying, water-bearing formations. Contaminants may have been transported downward with ground water from overlying contaminated zones or introduced by more direct means such as leaky well casings or waste disposal through abandoned wells. The effect of thick layers of fine-grained geologic materials (e.g., lacustrine clays) on contaminant movement also must be closely examined. The downward migration of contaminants through these layers may have affected sand and gravel wells constructed in the basal deposits of the Rock Bedrock Valley and sandstone wells constructed beneath the valley.

The results of such research will provide important information for the implementation of future ground-water protection measures in the Rockford area and possibly the whole state. Siting procedures for new industrial and waste disposal facilities are becoming increasingly reliant upon the presence of thick sequences of fine-grained materials. However, such materials may have little effect on the movement of VOCs and related organic compound contaminants. It may be necessary to also require engineered features, such as leachate collection and treatment and hydraulic gradient control, to adequately protect the ground-water.

CHAPTER 7. METHODOLOGY FOR REGIONAL GROUND-WATER QUALITY CHARACTERIZATION INVESTIGATIONS

Several regions in Illinois have been targeted for hazardous-substance ground-water monitoring investigations (Shafer, 1985). These include many of the major urban areas of Illinois such as the greater Chicago area, Joliet, Peoria-Pekin, East St. Louis, Rock Island-Moline, and Kankakee. As part of the project described by this report, a methodology has been provided as a guide for the planning and execution of future regional ground-water quality characterization studies within Illinois. This methodology will help provide consistency in the design of such efforts that may be undertaken by any number of different groups or agencies across the state. The methodology is the result of our knowledge and the experience gained through this initial effort in the Rockford area. Because each study area will possess some unique conditions, the methodology should be thought of as a working model that can be adapted and improved for individual situations.

Table 10 outlines the major parts of the methodology discussed in this section. The methodology generally describes a phased approach to finding areas of ground-water contamination within an area of investigation and identifying the source(s) of that contamination. The methodology is structured as though an investigator is literally "starting from scratch" with little or no background information. The process emphasizes the compilation and development of existing information into a conceptual framework of the ground-water system. As new information is collected and assimilated, knowledge should be gained on the effects of geologic and anthropogenic influences on the movement and quality of the ground-water within the region. A more detailed description of the methodology follows.

Table 10. Summary of Methodology for Regional Ground-Water Quality Characterization

Phase One - Year One

1. Delineate the study area
2. Compile existing ground-water information
3. Assess the spatial distribution, types, and numbers of wells
4. Assess existing information
5. Select wells for sampling and water-level measurement
6. Sample and analyze water from an initial well set
7. Assess initial results and determine additional sampling sites
8. Evaluate and summarize accumulated data

Phase Two - Year Two

1. Determine areas in need of further study and design monitoring network
2. Install preliminary set of monitoring wells
3. Collect and analyze samples and assess data from preliminary wells
4. Install, collect, and analyze samples from additional monitoring wells
5. Evaluate and summarize the monitoring effort

Phase One

1. Delineate the Study Area

Utilize the P.A. 83-1268 state monitoring priority maps as a preliminary guide to determine the bounds of the study area. The two state maps created under the direction of Illinois Public Act 83-1268 (Shafer, 1985) used geohydrologic and potential contaminant source criteria to highlight areas for investigation. Areas prioritized for intensive study qualified under four criteria:

1) current ground-water withdrawals of greater than 100,000 gallons per day per township,
2) potential significant ground-water withdrawals, identified as aquifers capable of yielding greater than 100,000 gallons per day per square mile and covering an area greater than 50 square miles,
3) a high degree of potential hazardous-substance sources (more than 2.0 hazardous-substance-related facilities per square mile), and
4) the presence of aquifers highly susceptible to contamination, where permeable deposits occur within 50 feet of land surface.

The superposition of these criteria provides an indication of where ground water is most susceptible to contamination by hazardous substances. Areas were categorized as "high" monitoring priority if they met three criteria, while those characterzied as "intensive study needed" met all four criteria. These targeted regions can be the focal areas for local or regional ground-water monitoring. As was done for this project, portions of the state prioritization maps can be extracted and enlarged for the region of interest (see figures 19 and 20). Because these maps incorporate geologic and hydrologic criteria, they should provide natural boundaries to a potential study area and can serve as base maps for preliminary mapping purposes.

2. Compile Existing Ground-Water Information

Coordinate a meeting of all local officials from agencies involved in all areas potentially relating to ground-water. These agencies may include: state and local health departments, municipal and/or private water and wastewater departments, the IEPA (including the Divisions of Land Pollution Control and Public Water Supplies), the Attorney General's Office, the Office of Fire Marshall, city or regional planning commissions, local university staff and environmental groups, the ISGS, the ISWS, and the USGS.

Such a meeting has two purposes: to brief the agencies about the project and to request relevant information they may have pertaining to ground water. Information of interest includes all types of geohydrologic data such as those from well logs, water-level measurements, consultants' reports, pumping records for city wells, reports of actual or potential sources of ground-water contamination, and chemical analyses of ground-water samples.

Local officials are valuable resource people, especially if they have been directly involved in ground-water quality investigations of their own. Their involvement will help to avoid the duplication of previously accomplished tasks and may assist in gaining increased participation from local residents and other agencies not previously identified as possible resources.

3. Assess the Spatial Distribution, Types, and Numbers of Wells

Review well log files to determine the number, spatial distribution, and types of wells in the area of interest. Of basic importance to a regional ground-water quality reconnaissance and sampling study is knowledge of the locations of wells in the area and the depth those wells reach (i.e., the aquifer developed by each well). Records of wells are maintained at the ISWS and ISGS and by some local health departments. In addition, local drillers maintain records of the wells they have constructed.

During this project, it was found that wells generally were clustered in particular areas because either the aquifer is limited in extent or adjacent areas are served by city water. If existing wells are to be the sole source of ground-water samples, it is important to know the spatial distribution of potential sampling sites. It was also found that many more wells need to be identified as potential sampling sites than will be required to satisfy the sampling requirements of the project. In Rockford, more than 220 wells were chosen to form a candidate list from which only 69 were sampled. This margin was needed because it was recognized that many wells would not be sampled because they were no longer operational, the address listed on the well record was not the location of the well, or the owner/operator did not wish to have the well sampled.

4. Assess Existing Information

Compile and interpret information from local officials, SWS files, and published reports. If possible, it is important to establish general trends in ground-water flow direction and to gain a regional perspective on areas of ground-water recharge and discharge. These areas may change with season or temporal events (e.g., floods on major rivers). Historical pumpage information, particularly major ground-water withdrawals by municipal and industrial wells, may be important to the interpretation of the direction of ground-water flow. These trends provide a foundation for determining the general direction of contaminant transport.

If any contaminants have been identified in ground water, these areas should be plotted on the preliminary ground-water flow map. In addition, the locations of potential or known sources of contamination should be plotted. Depending on the focus of the investigation, information on potential contaminant sources such as septic systems, underground storage tanks, surface impoundments, landfills, and abandoned wells (many of which were not contained within the P.A. 83-1268 strategy) could be included. Historical records of ground-water quality should be examined for trends that may be indicative of contamination. Even though this investigation was directed toward the presence of volatile organic compounds in ground water, attention should be paid to other constituents which may precede or coincide with these contaminants. This includes such inorganic parameters as hardness, chloride, sulfate, and nitrate and less specific organic indicators such as total organic carbon (TOC) and total organic halogen (TOX). These types of information, when combined with ground-water flow direction, help to indicate which regions are upgradient and downgradient from known or potential regions of ground-water contamination or hazardous-substance activities. This map should be compared with the map showing the spatial distribution of domestic wells (developed in step 3). If there are wells in close proximity to potential sources or known regions of contamination, these wells should be highlighted for sampling.

5. Select Wells for Sampling and Water-Level Measurement

Compile a list of names and addresses of well owners. At a minimum it is necessary to have a geological log, to know the depth and screened interval of the well, and to obtain the correct address of the well owner. Names and addresses of prospective well owner/operators can be checked against telephone listings for verification. The final list should contain enough sites to compensate for at least 50 percent negative responses or non-responses.

The well selection process begins with identifying all the wells within the study area. This will include all private, industrial, and municipal wells of all depths, aquifers, and capacities. It is preferable to sample wells for which the depth and open interval can be documented so that the aquifer supplying the water sample is known. However, in some areas this may not be possible. In Rockford, many of the private wells within city limits are old (predating current well-permitting procedures) and of the shallow sand point variety. However, knowing where these wells were located, the geology of the area, and the type of well construction provided adequate information for determining the likely depth of these wells and the aquifer tapped.

Areas of potential, or likely, contamination should also be identified. The identification of such areas will be the result of combining information on potential contaminant sources (e.g., industrial activity), the likely direction of shallow ground-water movement, and areas of sensitive geology (shallow aquifers overlain by permeable materials). Much of this information was used to prepared the P.A. 83-1268 statewide maps, but refinements on a smaller scale can help to locate areas of concern within the study area. For example, the sand and gravel deposits along the entire Rock River valley were highlighted for intensive study (see figure 19), but the major proportion of potential contaminant sources within the study area for this project occurred in southeastern Rockford, a much smaller area (see figure 18).

With the above information and knowing where all the wells are located, candidate wells for sampling can be selected. Generally, if the regional investigation is geared toward identifying ground-water contamination due to surface and near-surface activities (as opposed to, for example, regional investigations on the effects of deep-well waste injection), emphasis should be placed on shallow wells finished in susceptible aquifers. Wells not completed in such aquifers should be eliminated from consideration for sampling. Further, wells completed in deeper portions of an aquifer might be held aside for later consideration with the idea that if shallower wells are nearby, the shallower wells are more likely to have been affected than deeper wells. Deeper wells may be selected if a general indication of ground-water quality is desired or if some indication of the raw water quality of a drinking water source is needed. High-capacity municipal and industrial wells remove water from over a much larger area than domestic wells, and therefore samples collected from such wells will be an integration of the water quality over the larger area. [If such a well shows contamination, where did the contaminated water originate? If the well does not show contamination, were contaminant concentrations diluted below detection levels?] This will limit the usefulness of the resulting water quality analysis and should be recognized in the selection process.

6. Sample and Analyze Water from an Initial Well Set

If possible, an initial set of wells should be sampled early within the project schedule. To provide adequate background information, initial samples should be analyzed for a broad spectrum of constituents. This would include analyses for all major anions and cations, as well as less specific organic analyses (e.g., total organic carbon, total organic halogen, and total volatile organic compounds). Sampling early within the study accomplishes two objectives. First, it provides a staged approach to the collection of new water quality and hydrologic data with which to evaluate areas for further investigation. Follow-up investigations can be used to verify the results of the initial sampling and to expand the coverage of wells in a particular area. Second, it provides an opportunity for field and lab personnel to acquaint themselves with sampling and analysis procedures pertinent to the area of investigation and the contaminants of concern. As in all sampling projects, coordination between field and laboratory personnel is extremely important. Sample collection, storage, and transport procedures should be consistent with the analyses to be performed. The methods outlined within this report are appropriate for VOC and trace-metal sampling and analysis. If additional chemical parameters are involved, other sampling procedures may be necessary (see Barcelona et al., 1985). Where possible, ground-water-level measurements should be taken in sampled wells (see the "Methods and Procedures" section).

Which wells are selected for the initial round of sampling will depend on the goal of the sampling program. Generally, an early sampling round should strive to provide a reasonably uniform spatial distribution across the study area and possibly provide additional information in areas where contamination problems are likely to exist. The number of wells selected for this round will also depend on budgetary constraints as well as laboratory constraints (i.e., the ability of the laboratory personnel to handle a particular number of samples).

7. Assess Initial Results and Determine Additional Sampling Sites

Integrate new information with previously compiled data to select additional sites for sampling. The analytical results of the initial sampling should be evaluated to guide the selection of additional sampling sites. Analytical results, as well as ground-water elevations, should be mapped. Do the results appear to be consistent? Does a pattern emerge? Where would the collection of more data be most useful or provide the greatest benefit for the effort?

Obviously, the preliminary data is most useful for focusing sampling efforts in locations where contaminants are detected. If no contamination is detected from the initial sampling round, new locations for sampling should be sought. Selecting wells in a different spatial distribution or selecting wells at a different depth in a particular location may uncover previously undetected contamination.

If the preliminary results indicate previously unknown sites of contamination, additional sampling is warranted to confirm those results. Confirmation may include resampling the same well but ought to include the sampling of neighboring wells to help put bounds on the size of the problem. To save time and money, sampling and analysis should be directed toward the contaminant(s) of concern (for example, there is no need to collect samples for metals determinations if VOCs are found). If nearby wells do not indicate contamination, the problem may be extremely localized (e.g., leaking underground home heating oil tank, improper construction of septic system, poorly abandoned or faultily constructed domestic well). If nearby wells show signs of contamination, the investigation will need to expand outward to determine the limits of the contamination.

The focus of follow-up work will be predicated on the need and the type of additional data that must be collected. Would more water quality information be useful in an area to delimit an area of contamination? Or would additional ground-water-level information be more helpful for determining ground-water-elevation contours and the direction of ground-water movement? If the initial sampling effort indicates that more than one area is contaminated, follow-up efforts will need to be correspondingly divided and the amount of information about one particular area will be, of necessity, less detailed. Again, the amount of effort put into follow-up sampling will depend to a large degree on the resources available.

8. Evaluate and Summarize Accumulated Data

Evaluate all data; summarize findings on the occurrence of existing and potential future areas of ground-water contamination. Ground-water-elevation contour maps should be completed with the additional information gathered in step 7. The data should be sufficient to determine the direction of ground-water movement within the study area. Water quality parameters should also be plotted on maps such as figure 24. Where data are sufficient, larger-scale maps may be used to provide more detail. The locations of potential ground-water contamination sources also should be plotted on maps (such as figure 18 and others such as those prepared by Colten and Breen [1986] and Colten [1985]). With these types of maps, patterns should be looked for that will establish relationships between sources of contamination, the direction of ground-water movement, and areas determined to contain contaminated ground-water. Given the direction of ground-water movement, wells downgradient from known areas of contamination and wells not sampled within the contaminated zone should be identified.

In addition, the overall methodology used to direct the project should be assessed and recommendations for changes to improve the methodology should be made. For example, because of the large amount of existing information on ground-water quality in the Rockford area provided by local and regional agencies, the collection of ground-water samples for this project was delayed until late in the project schedule so that the available data could be assimilated prior to well selection. However, the selection of well sites was ultimately dictated by where the wells happened to be located, not by determinations of locations where the likelihood of contamination was greatest or for which no previous data existed. Therefore, the amount of previously collected information did not have as much influence on the well site selection process as had been expected. Field sampling conducted earlier in the project would potentially have allowed more time for sampling in problem areas and might have provided more ground-water-elevation data points with which to develop an elevation contour map for the shallow bedrock. The methodology now includes collection of ground-water samples earlier in the project schedule (step 6) as a basis for additional sampling later in the project.

Phase Two

1. Determine Areas in Need of Further Study and Design Monitoring Network

Review Year One findings and determine regions in need of more intensive data gathering. Areas with identified ground-water contamination are the focus of this phase. Collection of detailed hydrologic, geologic, and chemical data in two (or three) dimensions may be necessary in specific locations to a) provide additional information on the extent and movement of contamination, b) identify a source of contamination, or c) evaluate the feasibility of potential ground-water remediation measures. Investigative techniques to satisfy such objectives can differ substantially in sophistication (Keeley et al., 1986).

Sampling of additional existing wells in the area should be conducted, especially if those wells are used for drinking water purposes. The use of existing water supply wells may help to put boundaries on the extent of a contamination problem, but often these wells are not adequate for the collection of detailed hydrogeologic data. Monitoring wells, specifically drilled and constructed for ground-water sampling, can provide the necessary detailed information.

A monitoring well network should be designed to meet the goal of the monitoring program. The number of wells which must be drilled and the data to be collected from them to properly characterize a contaminant plume will depend to a large extent on the complexity of the contaminant distribution and potential contaminant sources. This and all following steps in the monitoring program should not be attempted by those unfamiliar with current ground-water monitoring techniques, particularly if hazardous wastes are involved.

2. Install Preliminary Set of Monitoring Wells

Drill and emplace monitoring wells using materials and procedures appropriate for the contaminants of concern. The drilling and construction of a set of preliminary monitoring wells follows the staged approach to sampling prescribed in Phase One. Potential well locations and depths will depend on the adequacy of existing information. Geologic samples should be collected during drilling to help determine the depth at which wells should be completed. These samples should be retained for later laboratory analyses. Proper materials and procedures for monitoring well construction are described in a number of publications (Barcelona et al., 1983, 1985; USEPA, 1977, 1986).

3. Collect and Analyze Samples and Assess Data from Preliminary Wells

Collect and analyze ground-water samples from monitoring wells and selected water supply wells. As with monitoring well drilling and construction, proper sampling and analysis procedures should be followed (Barcelona et al., 1985). Ground-water levels in sampled wells should be measured, and hydrologic tests should be performed on selected wells to determine rate and direction of ground-water movement. For localized investigations such as this, a topographic level survey should be made of the wells in which water-level measurments are taken to accurately determine ground-water elevations. The chemical and hydrologic data should be assessed in regard to the goal of the monitoring project.

4. Install, Collect, and Analyze Samples from Additional Monitoring Wells

Install and sample additional monitoring wells at sites chosen to provide the needed data requirements. If it is found that the monitoring data are not sufficiently detailed to describe the spatial or temporal ground-water elements of concern, it may be necessary to locate and install additional monitoring points. Previously mentioned guidelines concerning well installation, ground-water sampling, and analysis must continue to be followed to insure the integrity of the collected data.

5. Evaluate and Summarize the Monitoring Effort

Making use of additional monitoring points, assimilating the data collected from those and previous installations, and determining if the goal of the project has been satisfied is a repetitive process which may take several iterations to complete. Hopefully, sufficient data eventually will be collected that merit summarization in a collection of findings and recommendations for future action. A final report may include several of the following items:

a. A general to detailed description of the study area
b. A summary of ground-water levels measured in wells (well hydrographs)
c. Ground-water contour maps describing the direction of ground-water movement within the study area
d. A description of the geology of the study area, including geologic cross sections constructed from monitoring well logs and geologic samples, supplemented with nearby-well data and regional information
e. Results of hydrologic tests, such as well production tests performed on water supply wells and slug tests performed on monitoring wells

f. Results of chemical analyses in tabular and mapped form, describing the concentrations of compounds/elements found, the locations of the wells sampled, and the change in concentrations over time
g. Results of physical, chemical, and hydraulic tests performed on geologic core samples, such as tests to determine hydraulic conductivity, grain size, clay content, percent organic carbon, cation exchange capacity, and sorption-desorption
h. A description of the rate of ground-water movement through geologic materials in the study area, based on results of ground-water contour maps and hydraulic tests
i. A summary of the extent of contamination, wells affected, wells likely to become affected and when, the source or sources of contamination, and the potential for remediation

Predictive tools such as ground-water flow and solute transport modeling may also be part of the final analysis. The goal of the monitoring program should provide the framework for the types of investigations conducted.

REFERENCES

Barcelona, M. J., J. P. Gibb, J. A. Helfrich, and E. E. Garske, 1985. Practical Guide for Ground-Water Sampling. Illinois State Water Survey Contract Report 374, Illinois State Water Survey, Champaign, 94 pp.

Barcelona, M. J., J. P. Gibb, and R. A. Miller, 1983. A Guide to the Selection of Materials for Monitoring Well Construction and Ground-Water Sampling. Illinois State Water Survey Contract Report 327, Illinois State Water Survey, Champaign, 78 pp.

Berg, R. C., J. P. Kempton, and A. N. Stecyk, 1984a. Geology for Planning in Boone and Winnebago Counties, Illinois. ISGS Circular 531, Illinois State Geological Survey, Champaign, 69 pp.

Berg, R. C., J. P. Kempton, and K. Cartwright, 1984b. Potential for Contamination of Shallow Aquifers in Illinois. ISGS Circular 532, Illinois State Geological Survey, Champaign, 30 pp.

Berg, R. C., J. P. Kempton, and L. R. Follmer, 1985. Illinoian and Wisconsinan Stratigraphy and Environments in Northern Illinois: the Altonian Revised. Midwest Friends of the Pleistocene 32nd Field Conference, Guidebook 19, Illinois State Geological Survey, Champaign, 177 pp.

Boston Metropolitan Area Planning Council, 1982. A Guide to the Safe Use and Disposal of Hazardous Household Products. Boston, MA.

Bouwer, E. J., and J. P. Wright, 1986. "Anoxic Transformations of Trace Halogenated Aliphatics." Preprint extended abstract, presented before the Division of Environmental Chemistry, American Chemical Society, New York, NY, April 1986.

Broten, M. D., and A. M. Johnson, 1985. "Illinois Regional Ground-Water Quality Assessment." In An Assessment of Ground-Water Quality and Hazardous Substance Activities in Illinois with Recommendations for a Statewide Monitoring Strategy (PA 83-1268). Illinois State Water Survey Contract Report 367, J. M. Shafer, ed., Illinois State Water Survey, Champaign, pp. 45-78.

Colten, C. E., 1985. Industrial Wastes in the Calument Area, 1869-1970: An Historical Geography. Illinois Hazardous Waste Research and Information Center Research Report 001, Illinois State Water Survey, Champaign, 124 pp.

Colten, C. E., and G. E. Breen, 1986. Historical Hazardous Waste Disposal Practices in Winnebago County, Illinois: 1870-1980. Illinois Hazardous Waste Research and Information Center Research Report 011, Illinois State Water Survey, Champaign, 125 pp.

Department of Environmental Health, Winnebago County Department of Public Health, 1984. Special Notice: Southeast Rockford Groundwater Contamination. Rockford, October 1984.

Epstein, S. S., L. O. Brown, and C. Pope, 1982. Hazardous Waste in America. Sierra Club Books, San Francisco, 593 pp.

Friedman, L. C., L. J. Schroeder, and M. G. Brooks, 1986. "Recovery of Several Volatile Organic Compounds from Simulated Water Samples: Effect of Transport and Storage." Environ. Sci. Technol., 20:826-829.

Gibb, J. P., M. J. Barcelona, S. C. Schock, and M. W. Hampton, 1984. Hazardous Waste in Ogle and Winnebago Counties: Potential Risk Via Groundwater Due to Past and Present Activities. Illinois State Water Survey Contract Report 336, Illinois State Water Survey, Champaign, 66 pp.

Glaser, J. A., D. L. Foerst, G. D. McKee, S. A. Quave, and W. L. Budde, 1981. "Trace Analyses for Wastewaters." Environ. Sci. Technol., 15:1426-1435.

Hackett, J. E., 1960. Ground-Water Geology of Winnebago County, Illinois. Illinois State Geological Survey Report of Investigation 213, Illinois State Geological Survey, Champaign, 63 pp.

Helfrich, J. A., M. J. Barcelona, and T. R. Holm, 1985. Regional Ground-Water Contamination. Illinois Hazardous Waste Research and Information Center Research Report 005, Illinois State Water Survey, Champaign, 36 pp.

Illinois Environmental Protection Agency, 1985. Hazardous Household Products. IEPA Office of Chemical Safety, Springfield, 2 pp.

Illinois Environmental Protection Agency, 1986. A Plan for Protection of Illinois Groundwater. Submitted to the Governor, Illinois General Assembly, and the Pollution Control Board, January 1986, 65 pp.

Jacob, C. E., 1944. "Notes on Determining Permeability by Pumping Tests under Water-Table Conditions." U.S. Geological Survey mimeographed report.

Jolley, R. L., ed., 1978. Water Chlorination: Environmental Impact and Health Effects. Ann Arbor Science, Ann Arbor, MI.

Keeley, J. F., M. D. Piwoni, and J. T. Wilson, 1986. "Evolving Concepts of Subsurface Contaminant Transport." Journal WPCF, 58(5):349-357.

Kirk, J. R., K. J. Hlinka, R. T. Sasman, and E. W. Sanderson, 1985. *Water Withdrawals in Illinois, 1984*. Illinois State Water Survey Circular 163, Illinois State Water Survey, Champaign, 43 pp.

Kolata, D. R., T. C. Buschbach, and J. D. Treworgy, 1978. *The Sandwich Fault Zone of Northern Illinois*. Illinois State Geological Survey Circular 505, Illinois State Geological Survey, Champaign, 26 pp.

Office of Technology Assessment, 1984. *Protecting the Nation's Groundwater from Contamination*, Volume I. OTA-O-233, U.S.G.P.O., Washington D.C., 244 pp.

O'Hearn, M., and S. C. Schock, 1984. *Design of a Statewide Ground-Water Monitoring Network for Illinois*. Illinois State Water Survey Contract Report 354, Illinois State Water Survey, Champaign, 76 pp.

Sasman, R. T., N. Columbus, and W. C. Walton, 1966. "ISWS Open Files, Rockford Area Study." Illinois State Water Survey, Batavia, Illinois.

Schiffman, A., 1985. "The Trouble with RCRA." *Ground Water*, 23(6):726-734.

Schock, S. C., M. F. Washburn, and A. L. Zahn, 1985a. "Current Hazardous Materials Activities in Illinois." In *An Assessment of Ground-Water Quality and Hazardous Substance Activities in Illinois with Recommendations for a Statewide Monitoring Strategy (PA 83-1268)*. Illinois State Water Survey Contract Report 367, J. M. Shafer, ed., Illinois State Water Survey, Champaign, pp. 34-44.

Schock, S. C., A. L. Zahn, M. W. Washburn, and A. M. Johnson, 1985b. *Initiation of Hazardous Waste Research and Information Database*. Illinois Hazardous Waste Research and Information Center Research Report 006, Illinois State Water Survey, Champaign, 41 pp. plus appendices.

Shafer, J. M., ed., 1985. *An Assessment of Ground-Water Quality and Hazardous Substance Activities in Illinois with Recommendations for a Statewide Monitoring Strategy (PA 83-1268)*. Illinois State Water Survey Contract Report 367, Illinois State Water Survey, Champaign, 119 pp.

Shuster, K. A., 1976. *Leachate Damage Assessment: Case Study of the Peoples Avenue Solid Waste Disposal Site in Rockford, Illinois*. EPA 530/SW-517, NTIS PB-261-067, 35 pp.

Singh, K. P., and J. B. Stall, 1973. The 7-Day 10-Year Low Flows of Illinois Streams. Illinois State Water Survey Bulletin 57, Illinois State Water Survey, Champaign, 24 pp.

Smith, H. F., and T. E. Larson, 1948. Ground-Water Resources in Winnebago County with Specific Reference to Conditions at Rockford. ISWS Report of Investigation 2, Illinois State Water Survey, Champaign, 35 pp.

Smith, S. B., Jr., and G. M. Hieftje, 1983. "A New Background-Correction Method for Atomic Absorption Spectrometry." Appl. Spectroscopy, 37:419-424.

Symons, J. M., T. A. Bellar, J. K. Carswell, J. De Marco, K. L. Kropp, G. G. Robeck, D. R. Seeger, C. J. Slocum, B. L. Smith, and A. A. Stevens, 1975. "National Organics Reconnaissance Survey for Halogenated Organics." Journal AWWA, 67 (11):634-647.

Theis, C. V., 1935. "The Relation between the Lowering of Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage." Trans. Am. Geophys. Union: 16th Annual Meeting, part 2.

USEPA, 1977. Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities. Office of Solid Waste, Cincinnati, 269 pp.

USEPA, 1982a. Purgeable Halocarbons--Method 601. USEPA, Environmental Monitoring and Support Laboratory, Cincinnati, OH.

USEPA, 1982b. Purgeable Aromatics--Method 602. USEPA, Environmental Monitoring and Support Laboratory, Cincinnati, OH.

USEPA, 1982c. RCRA Risk/Cost Policy Model Project. Prepared by ICF, Inc., Clement Assoc. and SGS Eng., Inc. for USEPA, Office of Solid Waste, Washington, D.C.

USEPA, 1984. National Survey of Hazardous Waste Generators and Treatment, Storage and Disposal Facilities under RCRA in 1981. Document No. EPA/530-SW-84-005, Washington, D.C.

USEPA, 1985a. Draft Health Advisory for Barium. Office of Drinking Water, Washington, D.C.

USEPA, 1985b. Draft Health Advisory for Benzene. Office of Drinking Water, Washington, D.C.

USEPA, 1985c. Draft Health Advisory for Cadmium. Office of Drinking Water, Washington, D.C.

USEPA, 1985d. *Draft Health Advisory for Chromium*. Office of Drinking Water, Washington, D.C.

USEPA, 1985e. *Draft Health Advisory for Ortho-, Meta-, and Para-dichlorobenzenes*. Office of Drinking Water, Washington, D.C.

USEPA, 1985f. *Draft Health Advisory for 1,2-dichloroethane*. Office of Drinking Water, Washington, D.C.

USEPA, 1985g. *Draft Health Advisory for cis-1,2-dichloroethylene*. Office of Drinking Water, Washington, D.C.

USEPA, 1985h. *Draft Health Advisory for trans-1,2-dichloroethylene*. Office of Drinking Water, Washington, D.C.

USEPA, 1985i. *Draft Health Advisory for Lead*. Office of Drinking Water, Washington, D.C.

USEPA, 1985j. *Draft Health Advisory for Tetrachloroethylene*. Office of Drinking Water, Washington, D.C.

USEPA, 1985k. *Draft Health Advisory for Toluene*. Office of Drinking Water, Washington, D.C.

USEPA, 1985l. *Draft Health Advisory for Trichloroethane*. Office of Drinking Water, Washington, D.C.

USEPA, 1985m. *Draft Health Advisory for Trichloroethylene*. Office of Drinking Water, Washington, D.C.

USEPA, 1986. *RCRA Ground-Water Monitoring Technical Enforcement Guidance Documents*. Office of Solid Waste and Emergency Response Document No. 9950.1, U.S.G.P.O., Washington D.C., 208 pp. plus appendices.

U.S. Office of Management and Budget, 1972. *Standard Industrial Classification Manual*. U.S.G.P.O., Washington, D.C., 649 pp.

Walton, W. C., 1962. *Selected Analytical Methods for Well and Aquifer Evaluation*. Illinois State Water Survey Bulletin 49, Illinois State Water Survey, Champaign, 81 pp.

Wehrmann, H. A., 1984. *An Investigation of a Volatile Organic Chemical Plume in Northern Winnebago County, Illinois*. ISWS Contract Report 346, Illinois State Water Survey, Champaign, 83 pp.

Wehrmann, H. A., and L. P. Le Seur, 1985. "Recommendations for a State-Wide Hazardous Substance Ground-Water Monitoring Plan." In An Assessment of Ground-Water Quality and Hazardous Substance Activities in Illinois with Recommendations for a Statewide Monitoring Strategy (PA 83-1268), Illinois State Water Survey Contract Report 367, J. M. Shafer, ed., Illinois State Water Survey, Champaign, pp. 79-94.

Wenzel, L. K., 1942. "Methods of Determining Permeability of Water-Bearing Materials, with Special Reference to Discharging Well Methods." U.S. Geological Survey Water Supply Paper 887.

Wisconsin Division of Health, 1985. Public Health Related Groundwater Standards. Summary of Scientific Support Documentation for NR 140.10. Wisconsin Division of Health, Madison, WI.

Appendix A. Hydraulic Properties of the Sand and Gravel Aquifer at Rockford

Well ID	Name	Date of Test	Well Depth (ft)	Length of Test (min)	Static Water Level (ft)	Pumping Rate (gpm)	Observed Specific Capacity (gpm/ft)	Aquifer Trans-missivity (gpd/ft)	Hydraulic Conduc-tivity (gpd/ft^2)	Method of Analysis
T43N, R1E										
2.4g	Rockford Screw	1963	180	300	39	726	145.2	250,000	1,600	Sp. Cap.
2.7a	Rock. San. Distr.	1978	215	1440	10.8	1045	94.0	175,000	2,000	Sp. Cap.
11.7c5	Rockford No. 19	1964	177	255	13	1823	250.	364,000	1,900	Sp. Cap.
						--	--	450,000	2,300	Jacob
11.7c1	Camp Grant No. 1	1941	185	150	9	250	9.4	13,000	250	Sp. Cap.
11.8d	Camp Grant No. 2	1941	170	37	10	255	20.4	27,000	500	Sp. Cap.
11.7d	Camp Grant No. 3	1941	164	300	11	290	25.2	30,000	800	Sp. Cap.
11.7c2	Camp Grant No. 4	1941	163	180	10.75	300	20.7	32,000	600	Sp. Cap.
11.7c3	Camp Grant No. 5	1941	168	60	12.75	300	25.5	25,000	800	Sp. Cap.
11.7c4	Camp Grant No. 6	1963	154	4320	20.6	640	16.	31,000	300	Sp. Cap.
11.7c1	C.G.#1 (Obs # 1)	--	185	--	10.4	--	--	193,000	2,000	Leaky Art
11.8d	C.G.#2 (Obs # 2)	--	170	--	8.7	--	--	188,000	1,800	Leaky Art
11.7d	C.G.#3 (Obs # 3)	--	164	--	8.2	--	--	167,000	1,600	Leaky Art
11.7c	C.G.#4 (Obs # 4)	--	163	--	7.9	--	--	210,000	1,800	Leaky Art
11.7c	C.G.#5 (Obs # 5)	--	168	--	7.1	--	--	262,000	2,400	Leaky Art
11.7h	San Distr. TW1-70	1970	212	1200	14	1050	130	205,000	1,000	Sp. Cap.
15.5e	Rockford No. 28	1968	233	240	20	1970	87	114,000	500	Sp. Cap.
						--	--	268,000	1,260	Jacob
T44N, R1E										
13.6e	Rockford No. 8A	1959	235	360	29	1900	316.7	488,000	4,900	Sp. Cap.
35.1e	National Lock Co.	1948	263	?	50	1613	268.8	478,000	4,600	Sp. Cap.
36.7e	Rockford No. 7A	1947	200	66	36	1365	71.8	81,000	1,000	Sp. Cap.
T44N, R2E										
6.2e	Barb-Colman No. 2	1962	172	600	29.6	754	79.4	142,000	1,300	Sp. Cap.
6.4c	Loves Park	1952	203	80	25	197	98.5	130,000	1,000	Sp. Cap.
6.5c	Loves Park No. 2	1955	190	1170	30	1900	152.0	255,000	1,900	Sp. Cap.
6.8h	Meadow Mart Sh Ctr	1953	76	480	26	160	40.0	56,000	1,100	Sp. Cap.
7.4e	American Chicle Co	1963	213	270	57	500	50.0	67,000	1,700	Sp. Cap.
7.5h	Loves Park No. 1	1957	196	120	27	2180	272.5	398,000	3,000	Sp. Cap.
7.7e	Woodward Gov No. 6	1969	177	720	25	1750	60.4	91,000	800	Sp. Cap.
19.6b	Rockford No. 9A	1961	236	180	116	1760	117.3	166,000	2,500	Sp. Cap.
T45N, R1E										
25.1a1	North Park	??	230	480	24	1250	227.3	422,000	8,500	Sp. Cap.
25.1a2	North Park	1956	109	150	30	500	33.3	50,000	600	Sp. Cap.
36.2d1	Rockford No. 23	1965	93	421	9.8	1162	160	238,000	2,900	Sp. Cap.
						--	--	369,000	4,400	Jacob
36.2d2	Obs. Well M	--	49.5	--	6.6	--	--	123,000	1,500	Leaky Art
36.2d3	Obs. Well S	--	43	--	6.8	--	--	195,000	2,400	Leaky Art
T45N, R2E										
30.2g	North Park No. 3	1963	230	?	24	2000	333.3	548,000	4,900	Sp. Cap.
31.1e	North Park No. 1	1954	167	510	26.5	730	22.7	38,000	450	Sp. Cap.

[a] Well is identified according to location by: Township, Range, Section, and 10-acre plot within section.

[b] Sp. Cap. refers to Specific Capacity analysis of pumping water levels and rate of pumpage.
Jacob refers to semilogarithmic analysis of drawdown vs. time.
Leaky Art. refers to leaky artesian type-curve (logarithmic) analysis of drawdown vs. time.

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Appendix B. Descriptions of Selected SIC Codes Associated with Potential Hazardous-Substance-Related Activities

SIC Code	Description of Activity
27	Printing, publishing, and allied industries including newspapers, periodicals, commercial printing (e.g., letterpress, lithographic, engraving)
28	Chemicals and allied products including industrial inorganic chemicals, plastics, medicinal chemicals, pharmaceutical preparations, paints, varnishes, lacquers, and agricultural chemicals
29	Petroleum refining and related industries
34	Fabricated metal products (except machinery and transportation equipment) including hand tools, hardware, screw machine products, bolts, nuts, screws, rivets, washers, electroplating, anodizing, steel springs, wire products, and pipe
35	Machinery (except electrical) including internal combustion engines, farm and construction machinery, machine tools (metal cutting and forming, dies), industrial machinery (pumps, compressors, fans, gears)
36	Electrical and electronic machinery, equipment, and supplies including motors, generators, radio and television equipment, electronic components, and electrical equipment for internal combustion engines
49	Electric, gas, and sanitary services including natural gas distribution, liquefied petroleum (LP) gas distribution, sewerage systems, and refuse systems
50	Wholesale trade of selected durable goods, particularly scrap and waste materials
51	Wholesale trade of selected nondurable goods including chemicals and allied products, petroleum (bulk stations), farm supplies (agricultural chemicals), paints, and varnishes
72	Personal services, particularly dry cleaning plants and industrial launderers
73	Business services, particularly disinfecting and exterminating services, photofinishing laboratories, and research and development laboratories
75	Automotive repair, services, and garages, particularly tire retreading and repair, and paint shops

Appendix C. Summary of Ground-Water Information Received from State and Local Officials

AGENCY	CONTACT	INFORMATION
Illinois Department of Public Health	Roger Ruden, Regional Manager	Ground-water quality data from three contamination sites in Rockford
IEPA, Div. Land Pollution Control	Robert Wengrow, Regional Manager	Logs and ground-water quality data from Rockford/Loves Park monitoring wells
IEPA, Div. Public Water Supplies	Robert Clarke, Manager, Groundwater Section	VOC analyses for all public ground-water supplies in Winnebago County
Loves Park Water Dept.	Stephen Urbelis, Superintendent	Water quality and well information
North Park Public Water District	Dennis Leslie, General Manager	Ground-water pumpage, quality and chlorination data for North Park city wells
Rockford Sanitary District	Robert Steidel, Industrial Surveillance Foreman	Wastewater discharge permit information
Rockford Water Dept.	George Brettrager, Superintendent John Crooks, Analyst	Logs, VOC data, and location map for Rockford city wells, well production data, ground-water elevations
Winnebago County Health Department	Maichle Bacon, Dir. Environ. Health	Ground-water quality data from 16 contamination sites in Winnebago County

Appendix D. Known Incidents of Ground-Water Contamination in Winnebago County

Site No.	Site Name and Location	Aquifer Type Affected	Date First Identified (Info. Source)	Number of Wells Sampled	Comments	Compounds Identified[a]
1.	Peoples Avenue Landfill, Peoples Ave. & Magnolia,	Sand & gravel	Late 60's to early 70's (WCPHD)	Rockford Municipal Well 14, 4 industrial wells (Quaker Oats), and 4 domestic wells	All wells abandoned, industry connected to public water, site under USEPA inves.	Very high inorganic contaminants (e.g., TDS, 800 mg l^{-1}); presence of VOC's suspected due to use as landfill by industry
2.	Tipton Landfill, Telegraph & Eddie Roads, Burritt Township	Galena-Platteville Dolomite	1968 IDPH memo documents presence of barrels; IEPA sampled in mid-70's (IDPH, WCPHD, ISGS)	5 monitoring wells and 2 domestic wells	Site underwent USEPA Superfund preliminary investigation	Methylene chloride, tetrachloroethane, phenol
3.	Sand Park Landfill, Riverside Blvd. east of Forest Hills Road, Loves Park	Sand & gravel	Suspected May 1971 (WCPHD, IEPA)	6 on-site monitoring wells; potentially affecting Loves Park Municipal Wells 1 & 2, see Site 5	USEPA and IEPA investigation	Barium (1900), cadmium (10), benzene (3), chlorobenzene (4)
4.	Acme Solvent/Pagel Pit Landfill, Lindenwood Road, southern Rockford Township	Galena-Platteville Dolomite	April 1981 (IEPA, IDPH)	Approximately 30 monitoring wells and 5-6 domestic wells	USEPA Superfund site	Trans-dichloroethene (440) 1,1,1-trichloroethane (30) trichloroethene (46) 1,1-dichloroethane (50) tetrachloroethene (49)
5.	Loves Park Municipal Wells 1 and 2, Walker Ave., southwest of Sand Park Landfill, Loves Park	Sand & gravel	#1 March '82 #2 Dec. '81 (LP, WCPHD)	2 public wells	Possibly related to Sand Park Landfill, Site 3	1,1-dichloroethane (14) trans-dichloroethene (41) trichloroethene (11) 1,1,1-trichloroethane (19) cis-1,2-dichloroethene (32)
6.	Rockford Municipal Wells 7 and 7A, 11th St. and 18th Ave., Rockford	7: 1503' deep (deep sandstone); 7A: 200' deep (sand & gravel)	Dec. 1981 (RWD, WCPHD)	2 public wells	Well 7A closed. Source of contamination	trichloroethane (6) tetrachloroethene (6)
7.	Rockford Municipal Wells 8 and 8A, Auburn and Camp Ave., Rockford	8: 1502' deep (deep sandstone); 8A: 246' deep (sand & gravel)	Feb. 1982 (RWD, WCPHD)	2 public wells	Well 8A closed. Source of contamination	trichloroethane (70) tetrachloroethene (199)

Appendix D. (Continued)

Site No.	Site Name and Location	Aquifer Type Affected	Date First Identified (Info. Source)	Number of Wells Sampled	Comments	Compounds Identified[a]
8.	Rockford Unit Well 24, Cessna Drive, south of Greater Rockford Airport	Sand & gravel	Feb. 2, 1982 (RWD)	1 public well	One of the first wells sampled by RWD as part of their own VOC monitoring program	Trichloroethene (22) cis-dichloroethene (19) trans-dichloroethene (83)
9.	Watts Ave./Beloit Corp., Rockton	Sand & gravel (WCPHD, IEPA)	Spring 1982	10 monitoring wells and 18 domestic wells	IEPA current investigation, 8 new monitoring wells drilled in 1986	1,1-dichloroethane (19) 1,1,1-trichloroethane (340) trichloroethene (89)
10.	Frink's Industrial Waste, Pecatonica Road, 2 miles north of Pecatonic	Galena-Platteville Dolomite	Summer 1982 (WCPHD, ISGS IEPA	15 monitoring wells and 6 to 7 domestic wells		1,1-dichloroethane, trans-dichloroethene 1,1,1-trichloroethene, trichloroethene, tetrachloroethene, xylene, toluene, pentane
11.	Pierce Chemical Company, Meridian Road, northwest Rockford Township	Galena-Platteville Dolomite	1982 or 1983 (WCPHD)	1 domestic well	Domestic well replaced by Pierce Chemical	benzene (28,000) toluene (760) xylenes (3200) tetrachloroethene (1200)
12.	Hononegah Country Estates and Moorehaven Subdivisions, Roscoe	Sand & gravel	Jan.-Feb. '83 (WCPHD, ISWS IDPH)	Approximately 17 on-site monitoring wells, and about 144 domestic wells	All affected domestic wells replaced with a central deep well system by Warner Electric Brake & Clutch Co.	Principally trichloroethene (from trace to over 2000), with several related compounds
13.	Rockford Unit Well 38, Sand Avenue at Keith Creek	Sand & gravel	May 16, 1983 (RWD)	1 public well	One of several municipal wells sampled by RWD in May '83 containing VOC's	1,1,1-trichloroethane (25) trichloroethene (20) 1-1-dichloroethane (12)
14.	Rockford Unit Well 19, west end of Lockheed Lane	Sand & gravel	May 23, 1983 (RWD)	1 public well	Sampled by RWD as part of their ongoing VOC monitoring program	Trichloroethene (42)

Appendix D. (Concluded)

Site No.	Site Name and Location	Aquifer Type Affected	Date First Identified (Info. Source)	Number of Wells Sampled	Comments	Compounds Identified[a]
15.	Rockford Unit Well 6, 19th Ave. near 22nd St.	"Deep" sandstone & G-P Dolomite	May 23, '83 (RWD)	1 public well	Sampled by RWD. Cased only 17 ft. into dolomite	1,1,1-trichloroethane (13)
16.	Rockford Group Wells 2 & 6, West Cedar St. near Stanley St.	"Deep" sandstone & G-P Dolomite	June 20,'83 (RWD)	2 public wells	Sampled by RWD. Cased approx. 15 ft. into dolomite	Trichloroethene (18)
17.	Rockford Unit Well 33, Arthur Ave. east of Kent Creek	Sand & gravel	June 20,'83 (RWD)	1 public well	Sampled by RWD.	cis-dichloroethene (22) trans-dichloroethene (33)
18.	"Southeast Rockford," near 11th St. and Harrison Ave., Rockford	Sand & gravel	June 12,'84 (WCPHD, IDPH)	More than 100 wells and Rockford Unit Well 35	Contaminant source unknown.	1,1-dichloroethane (53) 1,1,1-trichloroethene (138)
19.	Steve's Standard Amoco Station, 11th St. and Sandy Hollow, Rockford	Sand & gravel	Feb. 10,'85 (WCPHD)	11 monitoring wells	Leaking gasoline storage tank	ethylbezene (70) toluene (110) xylenes (120)
20.	Bulk storage terminals, Cunningham and Meridian Roads, eastern Winnebago Township	Galena-Platteville Dolomite	Feb. 15,'85 (WCPHD)	At least 2 domestic wells	Problems suspected as early as 1968	purgeable organic carbon (5260) purgeable organic halogens (584)
21.	Anderson Phillips 66 Station, Charles St. and Hillcrest Road, Rockford	Galena-Platteville Dolomite	Feb. 25,'85 (WCPHD)	1 domestic well, others possible	Leaking gasoline storage tank	purgeable organic carbon (246) purgeable organic halogens (16)
22.	Six Oakes Mobile Home Seward Township	Galena-Platteville Dolomite	Summer, 1985 (WCPHD, IEPA)	1 public well	Contaminant source unknown	unidentified VOC's (150-200)
23.	Rockford Products, Inc. Harrison Ave. and Kishwaukee St.	Sand & gravel	Jan., 1985 (WCPHD, IEPA)	3 monitoring wells	Seepage pond suspected source	trichloroethene (16)

[a] Concentrations of compounds detected are enclosed in parentheses. All concentrations in $\mu g\ l^{-1}$, unless otherwise noted.

p 110
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Appendix E. Sample Letter Sent to Prospective Well Owners to Request Sampling

State Water Survey Division

ENR

2204 Griffith Drive
Champaign, Illinois 61820
217/333-2210

Illinois Department of
Energy and Natural Resources

April 18, 1986

Dear Rockford-area well owner/operator:

In our continuing effort to assess ground-water quantity and quality in the State of Illinois, the Illinois State Water and Geological Surveys have initiated a project to collect water samples and measure ground-water levels in the Rockford area this spring. Approximately 150 wells have been chosen for this study.

This letter is to seek your permission to collect a water sample and measure the water level in your well. **All water samples will be collected by our scientists from an outside faucet.** Collection of the samples involves running your tap for 10 to 15 minutes to flush the water lines and then filling several sample bottles. Results of the chemical analyses on the water will be furnished to you free as soon as they are available. If you have ever been concerned about the quality of the water you drink, this is an excellent opportunity to have your well water completely analyzed at no charge.

Measuring the water level in your well is a fairly simple procedure that is done by removing the cap on the well casing and lowering a steel measuring tape down the well into the water. The procedure takes only 10 to 15 minutes. We ask that the well pump not be turned on while a water level measurement is being made. **Only qualified personnel will be allowed to open your well.**

The cooperation of area residents and businesses in past research projects conducted by the Illinois State Water and Geological Surveys has been outstanding. Your help in this major field effort will be greatly appreciated and will contribute to the success of a truly landmark investigation of ground-water quality in the Rockford community.

Please fill out the enclosed postcard and return by May 2. Your well is one of a select number of wells chosen for this study, so we are relying upon your response to make this effort successful. Sampling is expected to begin the second week in May and continue for two to three weeks. Questions about the study can be directed to Allen Wehrmann (217/333-0493) or Linda Le Seur (217/333-5383) at the Illinois State Water Survey in Champaign.

Sincerely,
ILLINOIS STATE WATER SURVEY

H. Allen Wehrmann

H. Allen Wehrmann
Associate Hydrologist
Phone: (217) 333-0493

HAW/psh

Appendix F. Summary of Information on Sampled Private Wells

Well Site No.	Location	Well Depth (feet)	Aq. Type	Depth to Water (ft. below gnd.)	Date Sampled	Remarks[a]
1	43N01E01.8c	43	sg		6/03/86	Sandpoint
2	43N01E01.3e	63	sg	37.9	6/10/86	
3	43N01E01.5h	43	sg		6/10/86	Sandpoint
4	43N01E02.1a	?	sg		6/03/86	Sandpoint
5	43N01E03.2c	30	sg		6/03/86	Sandpoint
6	43N01E03.7d	135	ls	36.7	5/26/86	
7	43N01E05.4a	100	ls	37.4	6/02/86	
8	43N01E09.8c	115	ls	13.0	6/02/86	
9	43N01E12.5g	?	sg	35.7	6/02/86	Sg likely aquifer
10	43N01E13.7g	71	sg	25.2	6/10/86	
11	43N02E19.6f	220	ls	82.5	6/10/86	
12	43N01E01.5f	52	sg		6/03/86	Sandpoint
13	44N01E03.8d	255	ls	72.3	5/27/86	
14	44N01E04.3c	84	ls	9.1	5/27/86	
15	44N01E05.8c	?	ls	0.7	5/27/86	Ls likely aquifer
16	44N01E05.7b	121	ls		5/27/86	
17	44N01E08.3e	240	ls	31.9	5/28/86	
18	44N01E10.5f	100	ls	11.7	5/27/86	
19	44N01E10.6c	30	sg		5/28/86	Sandpoint?
20	44N01E13.1f	132	sg		6/11/86	Could not open
21	44N01E13.3d	49	sg	31.8	6/12/86	
22	44N01E15.7f	26	sg		5/28/86	City water?
23	44N01E16.6g	135	ls	4.2	5/28/86	
24	44N01E16.5f	55	sg	4.7	5/28/86	
25	44N01E16.8g	50	sg	0.8	5/28/86	
26	44N01E20.5c	150	ls	23.6	6/02/86	
27	44N01E29.8b	125	ls	70.4	5/29/86	
28	44N01E33.3b	140	ls	68.2	5/28/86	
29	44N01E34.5e	85	ls		5/29/86	Could not open
30	44N02E04.1f	180	ls	27.6	6/03/86	
31	Not sampled					
32	43N02E07.5c	130	ls	45.1	6/02/86	
33	43N02E07.7h	120	ls	25.1	6/02/86	
34	44N02E05.1f	105	ls	80.4	6/11/86	
35	44N02E18.4h	92	sg	60.7	6/11/86	
36	45N02E32.3a	40	sg	19.8	6/11/86	Sandpoint
37	45N02E31.8c	42	sg		6/11/86	Sandpoint
38	45N01E26.2h	100	ls	16.9	5/27/86	
39	45N01E26.8b	125	ls	20.8	5/28/86	
40	44N01E16.6e	70	ls		5/28/86	Depth uncertain
41	44N01E16.7h	160	ss	13.0	6/12/86	
42[b]	44N01E27.1d	460	ss	147	5/29/86	Airline msrmnt.
43	44N01E12.8f	50	sg	23.4	5/28/86	
44[b]	44N02E07.8e	?	?		6/12/86	3 well mixture
45[b]	44N01E11.7g	?	sg	10.4	6/03/86	Sg known aquifer
46[b]	44N02E26.2g	600	ss		6/03/86	Pretreated

Appendix F. (Concluded)

Well Site No.	Location	Well Depth (feet)	Aq. Type	Depth to Water (ft. below gnd.)	Date Sampled	Remarks[a]
47	44N02E31.7b	?	sg	59.6	6/11/86	Sg likely aquifer
48	44N01E10.6c	?	sg		5/28/86	Sandpoint
49	44N01E15.8g	80	sg	7.9	5/28/86	
50	44N01E16.7d	100	ls		5/28/86	
51	44N01E08.5d	195	ss	48.9	5/27/86	
52	44N01E16.8d	140	ls	33.8	5/27/86	
53	44N02E07.7b	?	sg	9.9	5/29/86	
54	44N01E33.6g	273	ss		5/29/86	
55	44N01E29.8b	125	ls	72.3	5/29/86	
56	44N01E34.6f	?	sg		5/29/86	Sandpoint
57	44N01E20.1b	170	ls		6/02/86	
58	43N01E03.2c	?	sg	6.8	6/03/86	Sg likely aquifer
59[b]	44N01E11.7h	?	sg		6/03/86	Sg known aquifer
60	44N02E03.8f	?	ls		6/03/86	Ls likely aquifer
61	44N01E29.8b	?	ls		6/04/86	Ls likely aquifer
62	43N02E18.6d	?	ls	43.1	6/10/86	Ls likely aquifer
63	44N02E28.3b	160	ls	29.3	6/11/86	
64	45N02E32.2a	89	sg		6/11/86	
65	43N01E02.4f	85	sg	45	6/11/86	Depth to H_2O (from owner)
66[b]	44N02E07.8e	?	sg		6/12/86	Sg known aquifer
67	44N02E28.4c	?	ls	26.1	6/12/86	Ls likely aquifer
68	44N02E32.1f	?	ls		6/12/86	Ls likely aquifer
69	44N02E32.1f	101	ls	21.4	6/12/86	
70	43N02E05.7a	150	ls		6/12/86	Depth from owner

[a] Sg = sand and gravel; Ls = limestone/dolomite

[b] Industrial or commercial, high capacity well. All other wells are used for domestic purposes.