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Groundwater Pollution Prevention in Southeast Minnesota's Karst Region

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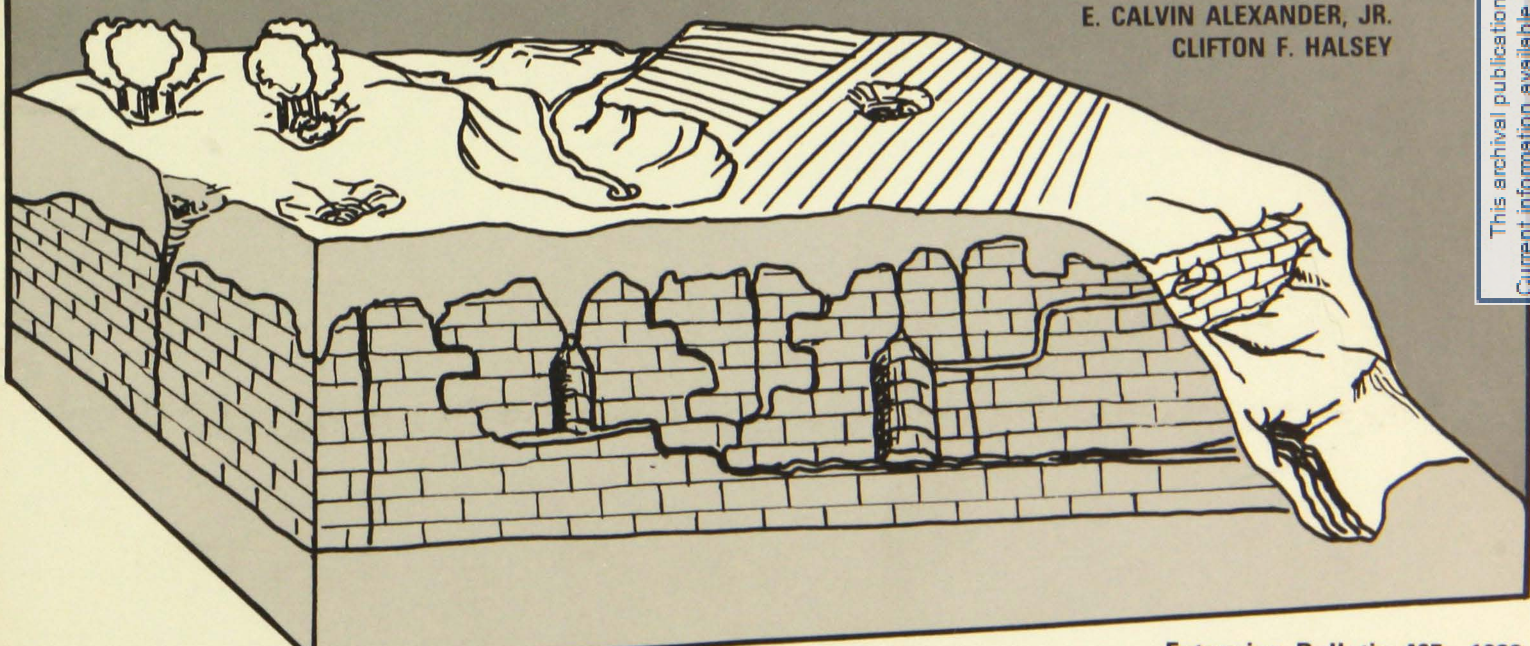

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Groundwater Pollution Prevention in Southeast Minnesota's Karst Region

Jeffrey St. Ores, E. Calvin Alexander, Jr., and Clifton F. Halsey*

Introduction

Approximately three-fourths of Minnesota's groundwater is contained in aquifers (water-bearing rock formations) underlying southeast Minnesota. Some of these aquifers underlie terrain classified as karst. Other aquifers, because of their cracked and jointed nature, can be considered karst aquifers.

Karst aquifers and aquifers underlying karst features are extremely susceptible to contamination. Reported cases of typhoid fever in Illinois, infectious hepatitis in Michigan, phenol poisoning in Wisconsin, and gastrointestinal illness in Missouri have all been tied to the rapid transmission of the particular disease agents through karst aquifers to the suspected water supplies.

S.P. Kingston, a former Minnesota health official, noted in 1943 that the regional groundwater system in southeast Minnesota is particularly vulnerable to contamination from many sources including surface runoff, domestic sewage, and industrial waste. Kingston, investigating an outbreak of typhoid fever in Fillmore County, concluded that infectious organisms were transmitted from the source of contamination to the wells of the infected individuals via cavernous and fissured underground limestone deposits (karst aquifers).

Many shallow wells in southeast Minnesota contain coliform bacteria and high nitrate levels—both indicators of possible contamination. Some southeast springs also contain these substances as well as traces of pesticides. Even aquifers hundreds of feet deep are considered in danger of contamination.

This publication describes the nature of karst areas and groundwaters, the extreme sensitivity of these groundwaters to many human everyday activities, and procedures which can reduce groundwater pollution potentials.

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Glossary

Agronomic rate: Amount of added nutrients (generally N, P, and K) necessary to sustain a "reasonable" anticipated crop yield. The supplemental source could be manure or inorganic fertilizer.

Aquifer: A geologic formation which yields useful amounts of groundwater. An aquifer must have an appreciable porosity and permeability and must contain drinkable water. In southeast Minnesota the bedrock aquifers are the sandstones and the karst limestones and dolomites. The alluvial sands and gravels may also yield useful amounts of groundwater —particularly in the valleys.

Aquitard: A geologic formation which does not yield useful amounts of groundwater and which retards the movement of groundwater between aquifers above and below it.

Blind valley: A valley which has no surface outlet. Blind valleys terminate in bedrock walls and are formed by disappearing streams.

Blowing well: A well which alternately blows air in and out. The movement of air indicates that the well has intersected a significant air-filled void in the subsurface.

Closed surface depression: A depression in the surface of the land surrounded by a closed contour. In a karst region such depressions often indicate the presence of a buried sinkhole.

Coarse (sandy) soils: Coarse-textured soils have a large proportion of sand-sized mineral particles. The soil is generally characterized by large pore (air) spaces and less total pore space area (relative to loams and clays). Large pores decrease the soil's ability to hold water. Reduced pore area decreases the quantity of water that can be stored at one time. Both characteristics result in rapid downward or lateral movement of water and some contaminants toward fractured limestone bedrock.

1) Coarse sands and gravels are extremely coarse.
2) Medium to fine sands and loamy sands are coarse.
3) Sandy loams and fine sandy loams are medium coarse.

Disappearing streams: A stream which sinks completely underground. The flow may sink at one or more discrete points, stream sinks, and/or it may disappear gradually over a length of the stream bed, a stream sieve. A disappearing stream is a direct connection between the surface and groundwaters.

Karst region: In this publication refers to the area underlain by carbonate bedrock. Includes, but is not limited to, that portion of southeast Minnesota exhibiting terrain classified as karst.

Losing stream: A stream which loses part of its flow into the subsurface. The loss can occur through stream sinks, or stream sieves, or both.

Normal household amounts: Refers to the amount of liquid wastes that can legally be placed in certified sanitary landfills. No absolute values have been established. But, for example, a partially full or full 5-gallon pesticide container is not a normal amount. An empty container of bleach would be a normal amount. Spent motor oil, antifreeze, and similar substances should be recycled rather than placed in landfills.

Permeability: In soil, refers to the ease with which gasses, liquid, or plant roots pass through a bulk mass of soil or a layer of soil (after Brady 1974. *The Nature and Property of Soils*).

Shallow or thin soils: Shallowness is a relative term depending on soil use. Twenty inches or less is generally considered shallow for taxonomic or soil naming purposes. However, the following definitions should be considered for use in karst aquifer protection relative to depth to limestone or water tables.

1) 50 feet or less is shallow if cesspools are being used and impermeable clay or hard bedrock layers do not separate limestone from the bottom of the cesspools.
2) 20 feet or less of coarse- to medium-textured soils is shallow if waste lagoons or holding ponds are used (measured from bottom of structures).
3) 5-10 feet of most soils is shallow if lagoons or holding ponds are used. 5-10 feet of extremely coarse- to coarse-textured soils is shallow when considering manure application, particularly waste irrigation, and manure storage methods other than lagoons or ponds.
4) 3-5 feet of coarse- to medium-coarse-textured soils are shallow when considering any activity.
5) Less than 3 feet of any soil texture is shallow for any potentially polluting activity.

Shallow well: A well which receives water from the near-surface aquifer. The aquifer tapped by each well is determined by the local geology, the depth of the well, and the construction of the well. A properly cased and grouted well only 100 feet deep may act as a deep well and avoid the surface aquifer. Conversely, an improperly constructed well 400 feet deep may be acting as a shallow well if it receives most of its water from the near surface aquifer.

Sinkhole: A closed, usually circular, depression which forms in karst areas. Sinkholes are formed by the removal of material from beneath by underground water flow. Sinkholes are *dug from the bottom* by groundwater. Sinkholes provide a direct conduit connecting surface waters with underground waters.

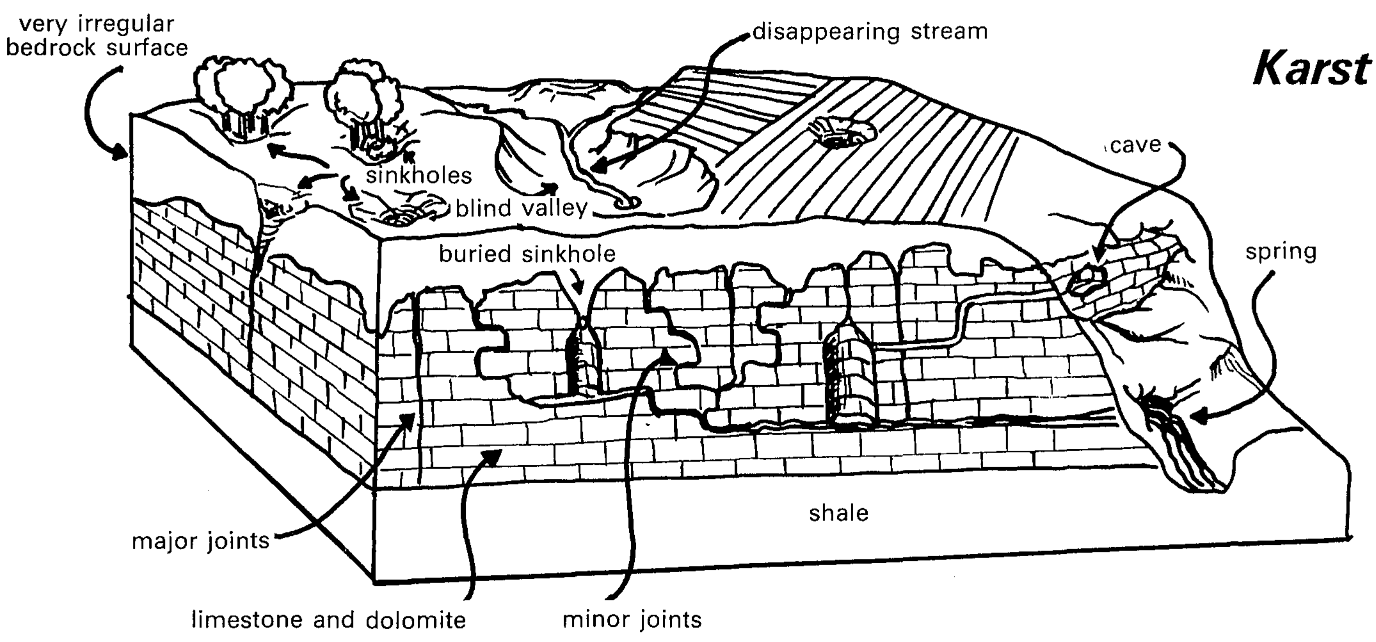
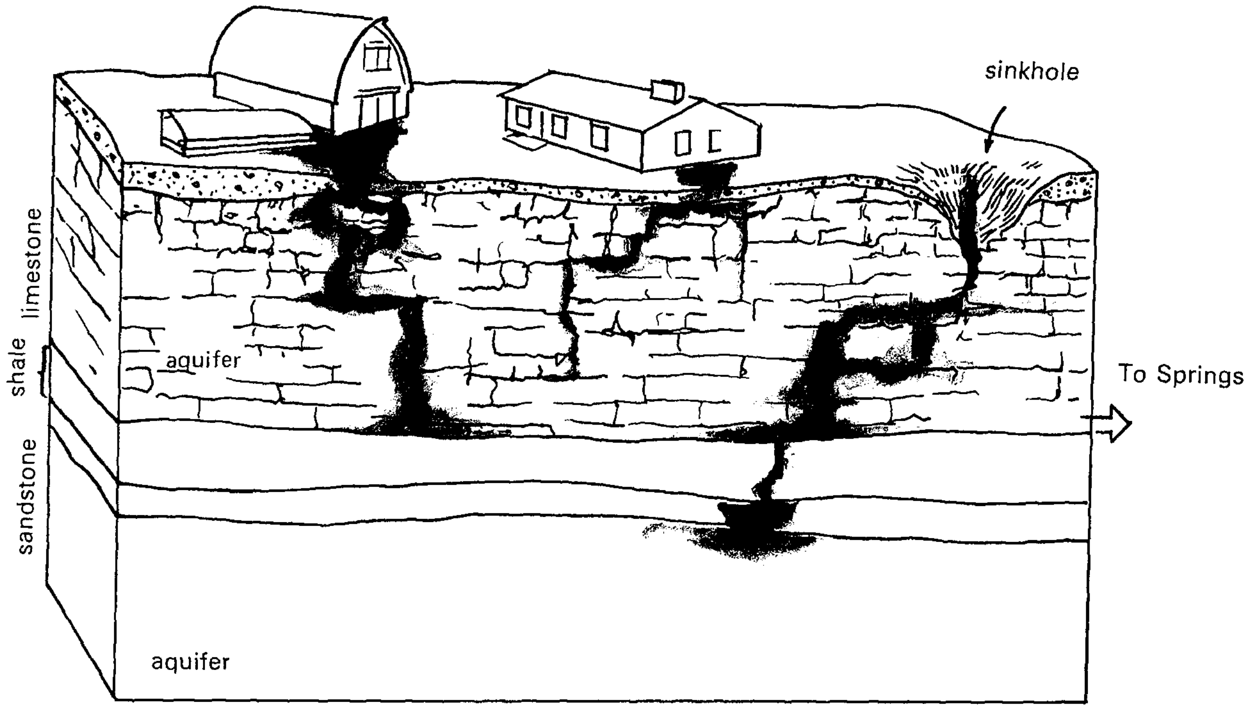


Figure 1. Block diagram showing terrain and subsurface features of karst.

Karst is a geologic term for a land area characterized by streams which disappear underground (disappearing streams) or which lose most of their flow into the ground (losing streams); valleys which have no surface outlet (blind valleys); caves, springs, and circular depressions in the earth referred to as sinkholes (figure 1). Karsts develop in areas where bedrock near the earth's surface is soluble in groundwater. The bedrock, generally limestone (calcium carbonate) or dolomite (calcium and magnesium carbonate), is normally fractured and contains numerous cracks, crevices, channels, and caves.

Karsts typically have very little flowing surface water. Most of the precipitation that starts running across the soil surface quickly disappears into underground drainage. After flowing underground for varying distances, the water will usually return to the surface in the form of springs. Runoff entering the ground via sinkholes, disappearing, and losing streams can become groundwater in hours or just minutes. Contaminants in this runoff, including soil and chemicals attached to soil, will also become part of the groundwater as evidenced by the number of shallow

Figure 2. Contaminant movement through shallow soils, limestone bedrock and sinkholes.



southeast Minnesota wells which yield soil-rich water after heavy rainfalls.

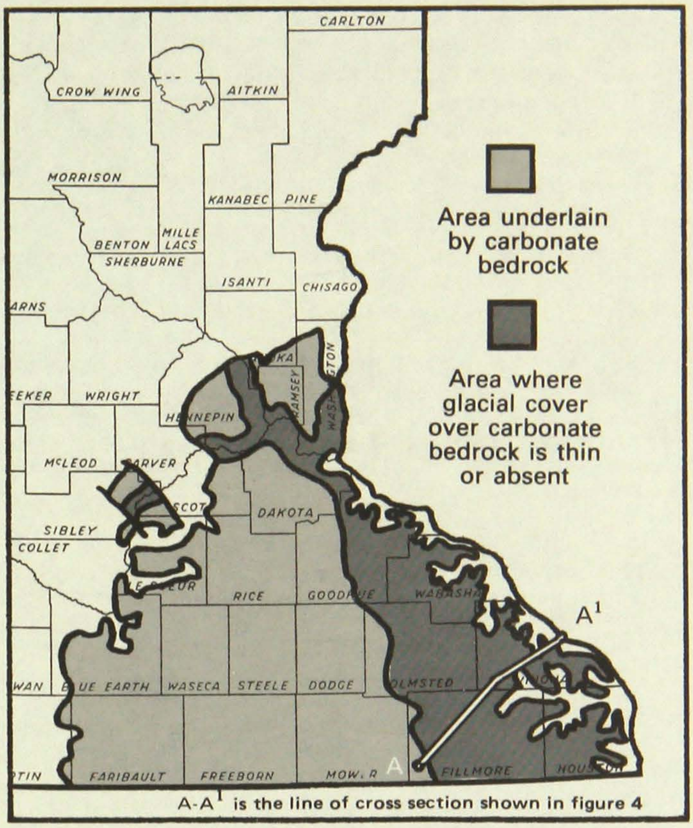
Karst aquifers are fractured and partially dissolved limestone or dolomite bedrock containing quantities of groundwater. Groundwater flowing through the cracks and channels of karst aquifers does not come in contact with as many mineral particles as does groundwater flowing through nonkarst aquifers such as sandstone. So, not only does karst aquifer groundwater flow rapidly (flows have been measured in miles per day versus the inches or feet per year common to sandstones), but contaminants in the groundwater are not readily filtered out. As a result, contaminants can reach domestic wells located miles from the source of contamination.

Karst aquifers can underlie both karst and areas not displaying karst features. Varying thicknesses of soil separate these aquifers from the ground surface. The overlying soil and soil organisms are natural filters of water and contaminants moving down toward the aquifers. But the thinner and coarser the soil, the less the amount of purification. Additionally, sinkholes and disappearing streams can bypass this natural purification process by creating direct links between the ground surface and aquifers. Consequently, karst aquifers underlying only a few feet of soil or aquifers underlying karst are easily contaminated (figure 2).

Figure 3 shows the areas in Minnesota underlain by limestones and dolomites (karst aquifers). A series of these aquifers as well as sands and muds were deposited on top of one another millions of years ago as a sequence of oceans advanced and retreated across southeast Minnesota. The sands became sandstone aquifers and the muds became shales, which now function as aquitards or confining bedrock layers which restrict water movement and partially protect underlying aquifers from contamination. The karst and sandstone aquifers and shale aquitards are not level but rise gently in several directions, including toward the Mississippi River. Figure 4 illustrates the series of aquifers and aquitards present in an area extending from Mower County northeast toward the Mississippi River. Note the rise of the formations and the division of the aquifers into upper, middle, and lower aquifers.

A few million years ago, giant ice sheets began to advance and retreat across part of southeast Minnesota. These glaciers left thick deposits of clay, sand and gravels covering the sandstones, shales, limestones, and dolomites. But the latest group of glaciers did not cover extreme southeast Minnesota (the figure 3 area indicated as glacial cover thin or absent). The absence of the glacial deposits in this area and centuries of erosion have resulted in a thin protective cover overlying aquifers. Additionally, the rising upper aquifers and aquitard have been completely worn away in many portions of the Mississippi River border counties (note the right side of figure 4). Karst has developed in areas (for example, Fillmore and Olmsted Counties) having deep river valleys and a relatively thin, but still present, soil layer covering *upper* aquifers.

Figure 3. Karst region.



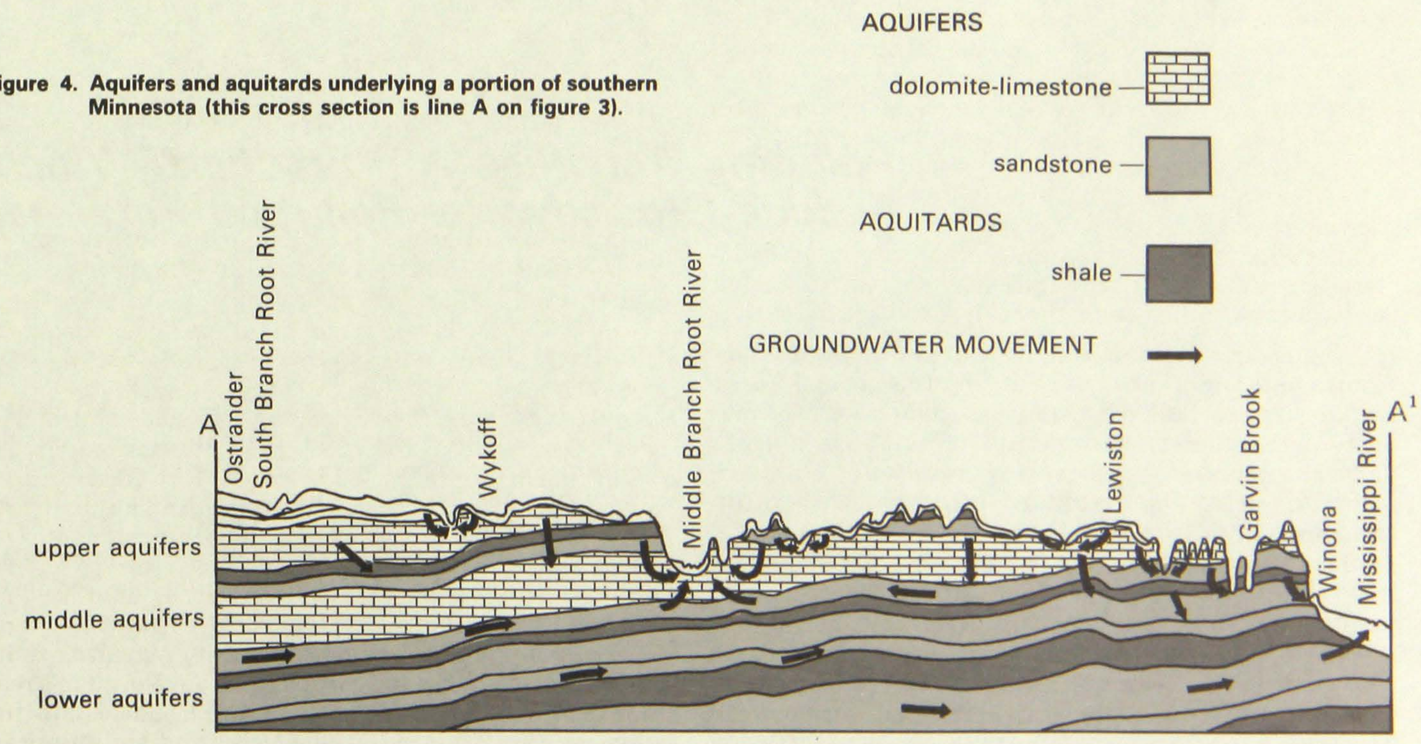
All of the area indicated in figure 3 as underlain by carbonate bedrock is sensitive to groundwater contamination. Sensitivity is lowest where both the protective glacial deposits and upper aquitard are present (the light shaded area in figure 3). Yet, scattered spots of high sensitivity occur in this western half. Pockets of shallow soils exist, and activities such as home site development and quarrying can strip away soil and decrease the distance between aquifers and the soil surface.

The eastern and northern portions of southeast Minnesota (dark shading, figure 3) are very susceptible to groundwater contamination. This high susceptibility is due in part to the occasional occurrence of karst terrain but is primarily due to the more frequent occurrence of shallow soils overlying karst aquifers. Shallow soils in parts of the Mississippi River border counties are particularly critical because they overlie *middle* karst aquifers (as noted, the upper aquifers and more important, the protective upper aquitard have disappeared).

In summary, the entire area underlain by carbonate bedrock is sensitive to groundwater pollution. But this sensitivity varies. Each piece of land (for example 40 acre segment) and underlying soil and rock formations should be examined, both to detect the presence of groundwater contamination and to determine the potential to contaminate groundwater at that particular spot. This publication cannot provide information based on such an intensive evaluation program.

However, table 1 summarizes southeast Minnesota features which indicate susceptibility to groundwater contamination. Table 2 lists human activities which

Figure 4. Aquifers and aquitards underlying a portion of southern Minnesota (this cross section is line A on figure 3).



(Source: Adapted from Hydrologic Investigations Atlas HA-548, 1975) can contribute to contamination. Use of the two tables can help in the initial evaluation of a rural area. The presence of any listed feature or activity indicates potential for pollution to take place at that particular spot and implies need for a closer look. However, only periodic well water sampling will determine the actual presence of groundwater contamination because activities occurring miles away can affect the quality of water in many wells.

Table 1. Karst features indicating high groundwater pollution potential

Indicators of direct connections from the soil surface to groundwaters.

- Sinkholes.
- Disappearing or losing streams.
- Blind valleys (see glossary).
- Closed surface depressions (see glossary).
- "Blowing" wells and wells that turn murky after storms.

Indicators of minimal separation between limestone or dolomite bedrock and the soil surface.

- Outcrops of bedrock.
- Shallow soils above bedrock (see glossary).
- Lack of surface drainage.

Table 2. Activities or structures that can contribute to groundwater pollution

1. Disposing of *any material* in sinkholes, streams, or drainageways leading to these features.
2. Cesspools.
3. Drywells (seepage pits) less than 50 feet above limestone bedrock or groundwater.
4. Drainfields with bottoms less than three feet above limestone bedrock.
5. Malfunctioning and poorly maintained septic tanks and drainfields.
6. Bypassing malfunctioning septic systems by pumping wastes into the nearest ravine, sinkhole, stream, or field.
7. Disposing of materials accumulating in septic tanks (septage) other than as called for by MPCA guidelines.
8. Improperly constructed and grouted active water wells.
9. Uncapped and unsealed abandoned water wells.
10. Pasturing animals in or near disappearing streams and sinkholes.
11. Manure storage areas and outdoor animal confinement areas not having a good soil surface seal or situated such that runoff carries pollutants from these areas to wells, sinkholes, streams or drainageways leading to wells, sinkholes, or streams.
12. Applying more manure and fertilizer than soils and crops can retain or use.
13. Applying manure and fertilizers at high runoff times to areas draining to sinkholes and disappearing streams.
14. Disposing of normal household amounts of flammable, toxic, and explosive "household" wastes in other than a certified sanitary landfill, recycling facility or waste recovery plant.
15. Runoff and erosion on crop and pastureland.
16. Disposal of full or partially full pesticide containers or contents of the containers in any area including landfills which has not been designed to contain or treat such chemicals.
17. Formulating pesticides and/or washing application equipment within 200 feet of wells, sinkholes and streams or drainageways leading to these features.
18. Failure to triple rinse "empty" pesticide containers followed by disposal of containers other than at certified sanitary landfills, drum reconditioners or recycling facilities.
19. Lack of anti-siphoning devices on pesticide applicator filling equipment.
20. Leaking above or below ground fuel, manure, silage or other storage facilities.
21. Others (see text).

Polluting Activities and Practices Which Reduce Groundwater Pollution Potential

Almost any human activity can result in groundwater contamination if the nature of karst and karst aquifers is not realized. Activities include those conducted by urbanites, suburbanites, units of government, and commerce and industry. However, this publication addresses activities associated primarily with rural residences and farms (table 2).

There are many well-known practices which can be used to minimize groundwater pollution potential in rural areas. These practices are discussed in the following pages. However, all the practices do not apply to every southeast Minnesota acre. Consultations with experts (see listing at the end of this publication) will help determine if and what practices are necessary in a particular area.

SINKHOLES

Sinkholes must not be used as disposal sites because sinkholes are direct conduits to groundwater. Placing anything in sinkholes or runoff entering sinkholes is almost like putting that material into wells. Unfortunately, garbage, herbicide cans, old railroad ties, debris from burned buildings, and other materials have been observed in sinkholes in southeast Minnesota. Feedlots draining to sinkholes have also been noted.

Attempts to eliminate sinkholes by plugging with sand and other fill materials can prove ineffective. Subsurface water and soil processes responsible for sinkhole formation may be accelerated by improper filling procedures. Contact university geologists trained in karst phenomenon and United States Department of Agriculture-Soil Conservation Service (USDA-SCS) staff for help in determining if sinkhole plugging will work.

Diverting potentially polluted runoff. Keeping runoff away from sinkholes is a pollution control practice, provided the diverted water does not trigger new sinkhole formation. Again, it is important for geologists and SCS or local Soil and Water Conservation District (SWCD) staff to help determine the feasibility of diversion.

Fencing around sinkholes. This practice protects animals from possible injury; discourages dumping of materials into holes; and may result in natural vegetation growing up around sinkholes.

Growing natural vegetation around a sinkhole. Natural vegetation creates a buffer zone which filters pollutants out of runoff. Guidelines for buffer zones have not been developed, but new guidelines applicable to feedlots may prove worthwhile. Alternatively, research indicates that forest or grass buffer strips from 50-100 feet wide greatly reduce nitrogen concentrations in runoff. Widths down to 13 feet have also proved effective. Perhaps 25 feet should be a minimum width around sinkholes.

HOME SEWAGE TREATMENT

Based on rural population, there could be at least 15,000 home sewage treatment systems just in Fillmore, Houston, Wabasha, and Winona Counties. A number of these systems were likely installed without knowledge of karst, and do not use sufficient soil for adequate treatment. Such systems may be a major source of groundwater contamination.

Agricultural Extension Service publications (see page 18) discuss in detail, system evaluation, design, and maintenance. The publications and local extension agents, SCS staff, zoning administrators, and regional Minnesota Pollution Agency (MPCA) staff should be consulted for specific information.

Systems. Common sewage systems are septic tanks and drywells, septic tanks and drainfield trenches or beds, and cesspools.

- *Cesspools* can no longer be legally installed. Raw sewage is discharged into a leaky tank. The soil around the cesspool eventually seals and the sewage surfaces, constituting a health hazard. Or the cesspool is in contact with fractured bedrock and the sewage discharges without treatment.

- *Drywells* (alternately called leaching pits or seepage pits and incorrectly called cesspools) are small confined areas receiving wastes from septic tanks. Dry wells can be a poor choice in karst areas because sewage from drywells encountering fractured bedrock can move directly into channels leading to groundwater. Individual Sewage Treatment System Standards (WPC-40) of the MPCA states that seepage pits shall not be installed "in areas where limestone or any geological formation characterized by similar fault patterns is covered by less than 50 feet of earth."

  Additionally, drywells should not be installed in the following instances: where domestic water wells shallower than 50 feet are used; in soils having a percolation rate slower than 30 minutes per inch or where the percolation rate of any soil layer contacting the drywell side or bottom is faster than 0.1 minutes per inch; or when barrier rock such as clay and nonfractured bedrock or the known level of the groundwater table would be less than 3 feet below the drywell bottom.

- *Soil absorption fields* such as drainfield trenches or beds are subsurface systems which receive effluent from septic tanks. Drainfield trenches are 18-36-inch-wide excavations on the contour into which trench rock (¾-2½ inches) and a 4-inch distribution pipe are placed. The trench rock is backfilled with the removed topsoil. A slime layer of organisms, called an organic mat, forms at the contact point between the trench rock and the underlying soil. Both the organic mat and the soil treat the effluent. But at least 3 feet of aerated soil below the trench bottom is necessary for adequate treatment. Less than 3 feet of suitable soil between the trench and underlying fractured bedrock or sandstone can result in inadequate removal of pathogens (disease causing agents) from sewage and subsequent movement of those pathogens into the groundwater. Soils having percolation rates between 0.1 and 60 minutes per inch are generally considered suitable for efficient operation of a soil absorption field.

- *Mound systems* are options for use in shallow soil areas. Effluent from a septic tank is directed to a seepage bed elevated above the original ground surface by carefully selected fill materials which maintain acceptable separation distances between the bed and shallow fractured bedrock. NCR Bulletin 130 discusses mound systems, as well as other alternative systems to use in problem soil areas.

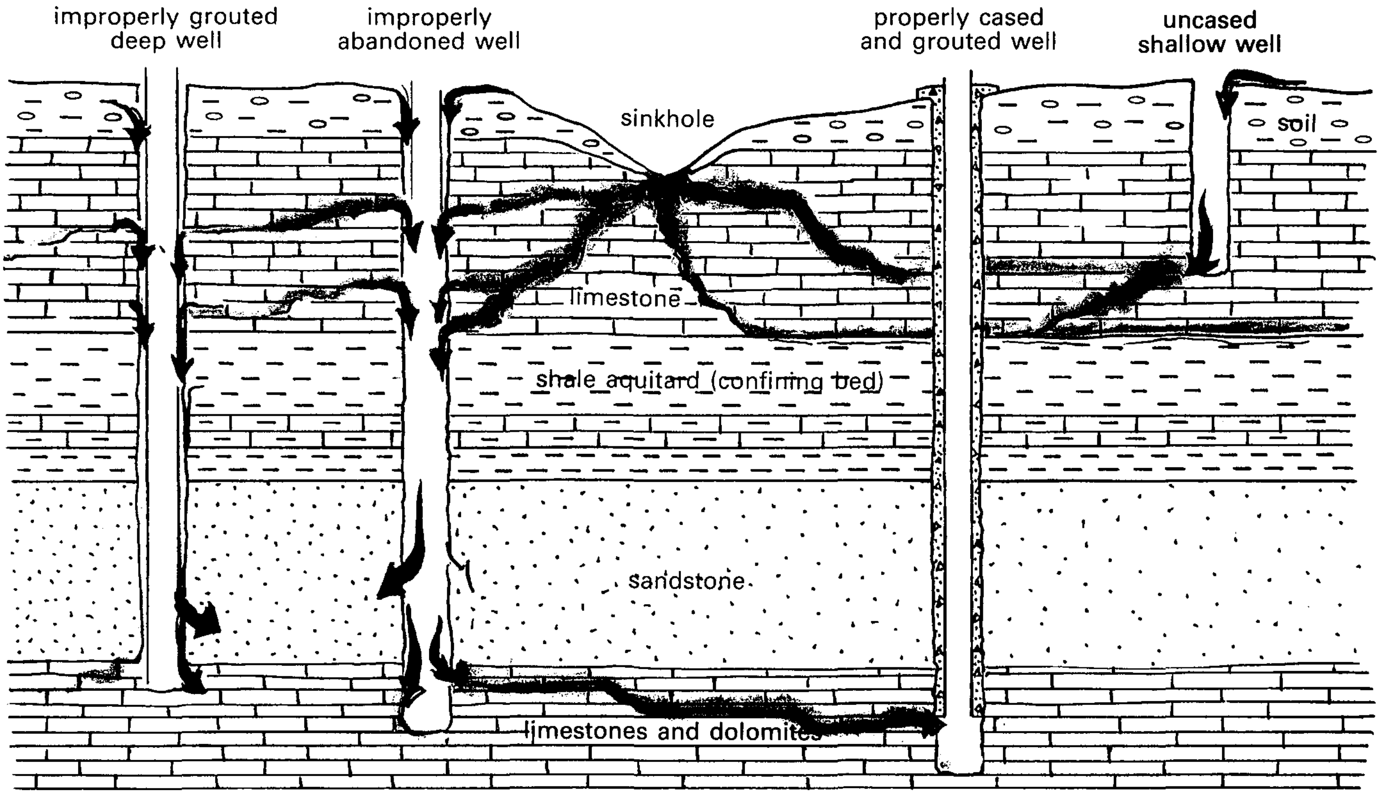
System use and maintenance. Garbage such as coffee grounds, cooking fats, disposable diapers, wet-strength paper towels, rags, and other materials which disintegrate slowly should not be put in sewage systems. These materials will rapidly fill septic tanks and if not removed periodically will flow to and clog drywells or soil absorption fields. Materials from sink garbage disposals can also clog a treatment system.

Septic tanks must be maintained and periodically cleaned out (preferably by professionals). Failure to remove accumulated materials (septage) from septic tanks can clog the system's soil absorption area. Waste may then be discharged to the ground surface and run into a stream or sinkhole if the system fails because of clogging.

Disposal of septic tank septage. Septage removed from septic tanks should be treated as a fertilizer and disposed of according to MPCA guidelines for septage disposal. Never discharge septage into quarries, ravines, sinkholes, and other karst features.

Malfunctioning systems. Have a malfunctioning treatment system immediately repaired. Running a pipe to the nearest field, ditch, or other area is not a solution to a plugged system.

Figure 5. Contamination of wells through improperly constructed or abandoned wells.



(Adapted from: Problems relating to safe water supply in southeastern Minnesota. Report to the Legislative Commission on Minnesota Resources from the Minnesota Department of Health)

WELLS

Proper well construction and abandonment procedures are essential in southeast Minnesota. Minnesota's Water Well Construction Code (7MCAR), instituted in the mid 1970s, addresses all aspects of proper well construction, maintenance, and abandonment. It further requires that wells be constructed only by drillers licensed by the Minnesota Department of Health.

Construction. Improperly constructed wells are a major pathway of pollutant movement to groundwater. Well boreholes are generally larger than well casings. A conduit is created linking the soil surface or upper soil formations to lower aquifers if the space between the wellhole walls and casings is not sealed or grouted properly (figure 5). Additionally, deteriorating and leaking casings allow materials to enter and move down the well itself. Contaminated runoff or contaminants in the upper soil layers can and will move toward wells and down the outside or inside of the well casing under the conditions just discussed.

There are, based on Minnesota Department of Health estimates, at least 14,000 active water wells in that portion of southeast Minnesota indicated on figure 3 dark shading. Estimates of the number of active wells, which need improvement or redrilling, range as high as 10,000 in the four county area of Fillmore, Houston, Wabasha, and Winona. These wells may have been drilled into shallow polluted aquifers, improperly grouted or sealed, or constructed with poor quality casing. Wells constructed prior to passage of the Water Well Construction Code are most suspect. Many existing wells should be evaluated for adequacy and, if necessary, repaired or replaced.

New well construction must comply with code requirements. Among other things, wells drilled through a number of aquifers must be sealed off from any contaminated aquifers encountered. Any spacing between boreholes and casing or between various casings must be adequately grouted and sealed. No openings should exist linking the ground surface to aquifers other than that through which water is produced. Only approved casing material should be used. Well tops should generally extend above ground and the site should be graded to divert runoff away from the well top.

Well location. Runoff, depending on site conditions, can drain toward well tops. Shallow subsurface water can also move toward wells. For these reasons, wells should be located away from potential contamination sources. At a minimum, insure that wells are located at least:

- 150 feet from a chemical preparation or storage area
- 100 feet or greater (depending on conditions) from below grade manure storage areas if these areas are in compliance with MPCA regulations
- 75 feet from cesspools, leaching pits, and drywells
- 50 feet from septic tanks, subsurface sewage disposal fields, graves, livestock yards and buildings, and manure storage piles

Wells with casings less than 50 feet deep and not encountering at least 10 feet of impervious soil should be located at least 150 feet from cesspools, leaching pits, or dry wells and at least 100 feet from a subsurface disposal field or manure storage pile.

Abandoned wells. Abandoned wells are another major source of concern. Any abandoned well which has not been filled, sealed, and covered properly is a potential pathway for pollutant movement to groundwater. Contaminants can move directly down the well itself.

Estimates of the number of abandoned wells in southeast Minnesota range as high as 9,000. Many of these have not been filled and sealed properly. The seriousness of the problem cannot be overstated. Persons knowing locations of abandoned wells should contact district or state health officials. An accurate count of abandoned wells will help officials assess the magnitude of the problem and develop programs to correct it.

Wells to be abandoned. Wells when being abandoned must be abandoned in accordance with the state code. This means doing the following:

- notifying health officials of abandonment procedures
- disconnecting the well from the system
- plugging the well hole according to the code procedures
- permanently sealing the top of the well according to code procedures

Well water testing. Have well water periodically tested for contaminants and record the results. Groundwater pollution trends may be detected before the water becomes undrinkable. Contact county community health service for well sampling instructions.

LIVESTOCK PRODUCTION

Local SWCDs and SCS technicians, and geologists, extension agents, and MPCA staff should be contacted for help in evaluating pollution potential of livestock production activities and selecting pollution control practices (including manure disposal plans).

Unconfined livestock. Animals are allowed free access to or may be pastured near disappearing and losing streams and sinkholes (figure 6). Wastes from these animals can move into the groundwater system. Practices to keep livestock away from streams and sinkholes should be used and include: well-located livestock watering facilities, vegetated buffer strips, and fencing.

Confined livestock. This section pertains to areas where animals are concentrated, including housed or partially housed animals and outdoor confinement areas such as beef feedlots, outdoor dairy feeding operations, and sow feeding pens.

Southeast Minnesota has a high density of animals (number of animals per square mile), a relatively large number of feedlots, and relatively great potential for runoff. Runoff can carry contaminants from feedlots and manure storage areas to sinkholes, disappearing and losing streams, and wells. High pollution potential exists when livestock are confined near these karst features and wells, and precautions have not been taken to prevent contaminants from entering the features. It is estimated that there are 480 total feedlots discharging wastes to streams and lakes in just Goodhue, Wabasha, Winona, Olmsted, and Houston Counties.

Feedlots and manure storage areas located on shallow sandy soils overlying fractured limestone can also pollute if the lot or storage area floors have not been sealed. Contaminants can move downward in the soil profile toward groundwater.

There are a number of practices which can reduce pollution potentials associated with confined animals.

- Runoff originating outside the lot can be diverted away from the lot or manure storage area.
- Down spouts and gutters on farm buildings can reduce the amount of runoff flowing across the lot.

Figure 6. Livestock pastured near a stream.

- Lot or manure storage area floors can be sealed. Paving may be necessary when limestone is only a few feet deep. Animal traffic can compact unpaved lot floors. This compaction reduces movement of water and contaminants into the soil and downward toward groundwater. Remove manure carefully from compacted unpaved lot floors. Avoid disturbing the lower 3-4 inch mixture of compacted soil and manure during manure scraping operations.
- Manure can be stored in storage tanks or above ground silos. These facilities when made of concrete or steel provide good assurance against leaching or runoff.
- Locate lots away from sinkholes, streams, and shallow sandy soils.
- Wastes from lots or animal housing can be collected, stored, and sometimes treated with holding ponds, settling basins, lagoons, and oxidation ditches. These structures should have sealed bottoms (either naturally or artificially sealed) particularly in areas where limestone is only a few feet deep. One group of scientists, however, (see Extension Handbook MWPS-18) suggests avoiding the use of lagoons when the lagoon bottom would be less than 20 feet above limestone (depending on soil type).

Proper land application of manure. This practice is as important as proper storage. Nitrates from manure can move downward (leach) toward fractured limestone if plants haven't used the nitrates and water is moving down in the soil. Disease bearing (pathogenic) organisms, if present in manure, can leach toward fractured limestone if the organisms are alive, soils are relatively sandy, and water is moving downward.

Additionally, nitrates and pathogens can move to sinkholes, wells, and disappearing streams by runoff and soil loss. Nitrate movement occurs primarily when manure is applied on actively melting snow or thawing ground or irrigated at a rate which causes runoff. Pathogen movement occurs when soil loss and runoff occur, provided the organisms are present and alive.

The potential for groundwater contamination from land-applied manure is real in karst areas. But this potential can be minimized by developing and following a sound manure disposal plan. Such a plan should recommend methods, timing, and amount of manure applications for individual fields based on characteristics of those fields.

The following recommendations should be considered when developing a manure disposal plan. The first three apply to all areas in southeast Minnesota and if followed, will greatly reduce pollution potential. The last six apply to especially critical areas which occur in some fields or portions of fields.

1. Apply at rates no greater than necessary to satisfy plant phosphorus (P) or potassium (K) or nitrogen (N) needs in a single year (agronomic rates). But do not exceed the agronomic rate for N. First, the N, P, and K nutrient need for the crop to be grown should be determined by the use of soil tests, with credit given for contributions from preceding legumes and past manure application. Then the amount of manure, and perhaps supplementary fertilizer, to meet this nutrient need, can be calculated based on the available nutrient content of manure after it has undergone collection, storage, and any treatment operations occurring on the farm. Periodic manure testing will help determine manure nutrient content. Publication MWPS-18 can also be consulted to obtain average nutrient values of manure.

Sometimes, areas may exist on the farm where manure can be applied at greater than agronomic N rates without the potential for excessive leaching or runoff to occur. But on-farm investigation will be necessary to locate such areas.

2. Incorporate manure soon after application (when soil depth, crop life stage, and tillage technique permit).

3. When irrigating animal wastes, apply light applications which do not exceed the soil's capabilities to retain the liquid (depth to limestone bedrock or local water tables and soil water holding capacities, percolation rates, and moisture content must be considered).

4. Limit or avoid applications including irrigated applications within 200 feet of wells, disappearing streams, and sinkholes (100 feet from sinkholes for non-irrigated wastes). Increase this distance to 300 feet (200 feet from sinkholes for non-irrigated wastes) on slopes greater than 6 percent.

5. Avoid applications on saturated soils, actively melting snow, or thawing ground on fields upslope from sinkholes, streams, and drainageways.

6. Limit or avoid applications on alfalfa fields or pastureland draining to sinkholes and disappearing streams.

7. Avoid applications on coarse sands and gravels which do not have fine clays or impermeable rocks underlying and separating the sands from limestone or local water tables.

8. Avoid applications on coarse to fine sands and loamy sands when depth to bedrock is less than 10 feet and on sandy loams when less than 5 feet. If applications are necessary, space them out throughout the year (when workload and crop life stage permit) and reduce rates below estimated crop nitrogen needs (supplement with fertilizer).

9. Limit or avoid applications on fields or portions of fields where limestone is less than 2 feet deep (refers to limestone bedrock rather than to soil containing scattered pieces of limestone). Delay incorporation as long as possible if applications are necessary. Avoid injecting manure directly into limestone.

Special recommendations may be necessary when an entire farm is a critical area (for example, all fields contain numerous sinkholes). Such recommendations can only be made with on-farm inspections, but for example could include suggestions to apply manure on fields sloping to sinkholes if the applications occurred when chances of runoff were low; or to store and treat manure prior to application.

Milkhouse and milking parlor wastes. A considerable quantity of wastes can be generated from milkhouses or milking parlors. The quantity depends on the operation, but for example, a 100-unit cow operation with automatic washing equipment can use over 800 gallons of water per day for washing operations. Wastes can include feed, bedding, hoof dirt, medicines, residual cleaning chemicals, milk, and milk solids such as fat, albumin, and lactose.

Proper disposal of these wastes is essential and is discussed in Agricultural Engineering M-sheet 159. Portions of the following text are adapted from that sheet.

Milkhouse or milking parlor wastes should be discharged to a settling tank and from there be land-applied or stored in a lagoon and land-applied later (however the cautions discussed earlier regarding lagoon use should be noted). The settling tank must be frequently cleaned out to remove manure, feed, bedding, soil, and other solids.

Subsurface treatment of milkhouse or parlor wastes has generally proved unsuccessful. Milk solids do not settle out or decompose in a septic tank but rather flow to the drainfield trench or drywell and plug the system.

Large barns have rest rooms for human waste. These human wastes must be treated separately from parlor or milkhouse wastes by using the home sewage treatment systems discussed earlier in this publication.

Figure 7. Refuse-filled sinkhole in southeast Minnesota.
(Photo courtesy of the *Journal of Freshwater*, Navarre, Minnesota)

Land spreading of milkhouse or milking parlor wastes should be done in accordance with MPCA guidelines on septage disposal or the wastes should be treated as manure and disposed of as discussed previously.

Dead Animals. Leaving dead animals on the soil surface or disposing of them in the nearest ravine, gully, sinkhole, or quarry can be hazardous. The Minnesota Board of Animal Health requires that carcasses be burned, buried, or rendered. Rendering is preferable in karst areas.

HOUSEHOLD WASTES

The average household generates considerable quantities of waste in a year. Wastes include relatively harmless and solid materials, such as paper, wood, metal cans, and food debris; and more hazardous, generally liquid materials, such as solvents, adhesives, cleansers, lighter fluids, spent oil, paint thinners, and antifreeze.

Improper disposal of household wastes will pollute groundwater and is occurring in southeast Minnesota. Sinkholes, quarries, ravines, and dumps which cannot adequately contain wastes are being used as disposal sites (figure 7). This improper disposal need not occur because a number of good waste management practices exist.

Resource recovery. This is of major importance at the household level. Pollution is eliminated; landfills do not rapidly fill and nutrients, minerals, and other resources are conserved.

- *Composting,* discussed in Agricultural Extension Service Soils Fact Sheet 12, decomposes vegetable and other organic portions of garbage. Construction and use of compost heaps recovers nutrients, requires limited effort, and should be practiced.
- *Recycling* solvents, waste oils, glass, aluminum, and newspaper is equally important. A list of recycling facilities in southeast Minnesota is presented in this publication.

Waste reduction. Avoid disposable items when reusable ones are available. Prolong the life expectancy of materials.

Waste recovery and treatment plants. These plants replace or supplement landfills. Resources are recovered or treated rather than disposed of untreated. These facilities require commitment by local government and residents.

Certified sanitary landfills. Refuse which has not been recovered can be disposed of in these containment areas. Landfills are designed to hold solid and nonhazardous wastes. But normal household amounts (see glossary) of hazardous wastes are generally allowed in landfills. Only *certified* landfills have been found suitable for waste containment. The amount of wastes placed in them should be minimized by exercising options previously discussed.

Home disposal sites. Such sites are a final but least preferable waste management technique. Nonhazardous materials, which for some reason have not been recycled or recovered, can be disposed of on the homestead. The site must be kept sanitary, and filled, and covered. At least 5 feet of slowly permeable soil should separate the bottom of the site from water tables or limestone. Ravines, gullies, quarries, sinkholes, and similar features are *not* suitable. Hazardous materials such as empty pesticide containers should not be placed in homestead sites.

TILLAGE, EROSION, AND RUNOFF

Cropland and pastureland erosion rates are usually higher in the southeast than elsewhere in Minnesota. Runoff values are among the highest and the ability of runoff and soil particles to move off the field, is as great, if not greater than, anywhere else in the state.

High runoff and erosion rates are a problem in areas of sinkholes, disappearing, and losing streams. Contaminants contained in runoff move rapidly to these features and from there to groundwater. Erosion in areas where limestone bedrock is shallow is also critical because the protective soil covering the bedrock is lost.

The primary reason for excessive cropland soil loss is fall turnplow (moldboard) tillage followed by repeated secondary tillage. Approximately 70 percent of southeast Minnesota cropland is farmed this way. Erosion on sloping pastureland is caused primarily by overgrazing, poor maintenance of vegetation, and occasionally by failing to exclude livestock from critical areas.

SWCD, USDA-SCS, and local Agricultural Extension Service personnel should be contacted for help in determining the need for and installing of erosion and runoff control practices.

Tillage. Conservation tillage is of prime importance in southeast Minnesota. Any tillage system which limits the amount of soil turned over (inverted) and leaves enough crop residues remaining after planting to cover 25 percent of the soil surface is defined as conservation tillage. The term "system" is stressed because the type of tillage can vary over time depending on past, current, and projected future crops. Specifically, different types of conservation tillage can be used or rotated, depending on the crop rotation.

Agricultural Extension Bulletin 479 deals with soil conditions and crop rotations best suited to the various types of conservation tillage. Till-planting on ridges is one conservation tillage system adaptable to a number of crops and soil conditions. No-till is adaptable to only select conditions. Additionally, no-till's effects on runoff and deep leaching of nitrates have not been clearly defined. The use of no-till must, therefore, be carefully evaluated.

Use of Bulletin 479 and consultation with local experts will aid in the selection of a conservation tillage system resulting in crop yields or net incomes comparable to those from moldboard plowing.

Other cropland erosion and runoff controls. These include contouring, strip-cropping, diversions, terraces, grassed waterways and rotations (row crop, small grain, and meadow). *Diversion and terrace construction and use should not leave limestone bedrock exposed and the amount of runoff trapped or diverted should not trigger sinkhole formation or allow direct entry of nitrate rich water into limestone.*

Waterways, diversions, and terraces should not drain into disappearing or losing streams or sinkholes.

Pastures. These should be kept properly stocked and well vegetated. Local USDA-SCS and SWCD staff should be contacted to determine if livestock exclusion from critical, erodible slopes will also be necessary.

PESTICIDES

Field applications and handling of these chemicals can contaminate karst aquifers. Extension Bulletin 428 discusses all aspects of pesticide use. Agricultural Chemicals Fact Sheet 17 discusses in detail pesticide container disposal.

Field applications. Practices which encourage runoff and erosion are primarily responsible for movement of applied chemicals toward sinkholes and disappearing streams. But sprayed liquids and applied dusts can drift under favorable conditions (for example, when temperatures are high or air is gusty and turbulent, such as between 2 and 4 p.m.). Applying in close proximity to karst features increases the likelihood of spray drift or chemical enriched soil and water entering these features.

A number of practices can reduce chances of pesticides entering groundwater.

- *Estimating chemical needs.* Proper identification of pests and an understanding of crop and pest life stages are important. Misnaming a pest and applying the wrong chemical or applying the right chemical before it is needed can result in poor control and a need for additional applications. The Agricultural Extension Service has several publications on pest identification. Pest scouting programs are also being developed which help in pest identification and selection of control practices.

- *Even applications.* Sprayer equipment should be well-maintained and cleaned to prevent leakage as well as uneven applications. Sprayers should be properly calibrated to insure application of the right amount of pesticide in the right area. Extension Bulletin 428 or Agricultural Chemicals Fact Sheet 5 describes calibration procedures. Procedures or tables may also have

Table 3. Relative mobility of pesticides in soils (adapted from Helling et al. 1971. Advan. in Agon. 23: 147-240)

Mobility Class*				
5	4	3	2	1
Dalapon** (Dowpon, Basfapon)	Picloram (Tordon 22K)	Propachlor (Bexton, Ramrod)	Bensulide (Betasan)	Chloroxuron (Norex, Tenoran)
Dicamba (Banex, Banvel)	MCPA	Prometone (Pramitol)	Prometryne (Prefas)	DCPA (Dacthal, Fatal)
Chloramben (Amiben, Vegeben)	Amitrole (Weedazol)	Naptalam (Alanap)	Diuron (Karmex, Dynex)	*Lindane*
	2,4-D	2,4,5-T	Linuron (Lorox, Afalon)	*Phorate* (Thimet, Rampart)
		Propham (Chem-Hoe, IFC)	EPTC (Eptam, Ordram)	*Parathion*
		Diphenamid (Dynid, Enide)	Vernolate (Vernam)	*Disulfoton* (Dimaz)
		Atrazine (AAtrex)	Chlorpropham (Furloe, CIPC)	Diquat (Ortho-Diquat)
		Simazine (Princep, Aquazine)	*Azinphosmethyl* (Carfene)	*Zineb*
		Alachlor (Lasso)	*Diazinon* (Basudin, Diazitol)	*Chloroneb* (Demosan, Tersan-SP)
		Ametryne (Evic)		Trifluralin (Treflan)
				Benefin (Balan, Balfin)
				Toxaphene (Motox, Toxakil)

*Class 5 compounds (very mobile) to Class 1 compounds (immobile) are in the scheme of Helling and Turner (1968). Within each class, pesticides are ranked in estimated decreasing order of mobility.

**Names of herbicides are set in roman type; insecticides, fungicides, and acaricides are in *italics*.

been included with the equipment or may be available from a pesticide dealer.

- *Use of mobile pesticides.* This should be minimized in areas of shallow soils over bedrock. Table 3 gives the relative downward mobility of some pesticides.
- *Rotate pesticides.* This reduces pests' ability to develop resistance to pesticides and reduces chances of chemical accumulation in the environment.
- *Minimize spray drift.* Extension Bulletin 428 and Folder 548 discuss procedures for minimizing spray drift.
- *Buffer strips.* Avoid applying chemicals in close proximity to sensitive areas (for example, sinkholes). A 50 foot no application area or a width consistent with vegetated buffer zones discussed earlier can serve as guidelines until research indicates differently.

Handling. The greatest misuse of pesticides occurs in the handling processes.

- *"Empty" pesticide* containers are seldom empty. Some undiluted chemical remains, Disposing of unrinsed "empty" containers or partially full or full containers in sinkholes, ravines, disappearing streams, and quarries, places chemicals in close proximity to pathways leading to groundwater. Disposal of empty containers in sinkholes and other karst features does occur in southeast Minnesota. Emptying the contents of full or partially full containers into these features or into roadside ditches is even more hazardous.

"Empty" containers should not be used to store food, feed, or water. Glass, metal, or plastic containers should be triple rinsed and this rinse water added to the makeup water of the applicator (when water is the carrier). The triple-rinsed containers as well as paper bag containers should then be disposed of in certified sanitary landfills. Metal containers can also be sent to drum reconditioners for recycling. Crush or puncture triple-rinsed metal containers before sending to a landfill.

Some landfill operators have been unwilling to accept containers fearing that the containers have not been triple rinsed. But the Minnesota Department of Agriculture is currently developing a container disposal certification program. Farmers will be encouraged to certify that they have triple-rinsed containers; reconditioners and landfill operators may then more willingly accept containers. Southeast farmers should join this program when it gets started.

Partially full or full containers which for some reason cannot be used, should if possible, be returned to the seller or manufacturer. Alternatively, a materials exchange site could be established. Consequently, farmers needing a chemical that others have in surplus can contact one another. If this is not possible, store the chemicals in a safe area and contact local officials, MPCA personnel, or the Minnesota Department of Agriculture for instructions. The stored containers should be periodically checked for leaks. Caches of arsenic based and other highly toxic pesticides should be called to MPCA officials' attention.

- *Formulation, tankfilling, and equipment washing activities,* if performed near disappearing streams, sinkholes and open-topped or improperly grouted wells can be hazardous because spilled chemicals, tank overflow, or wash water have only a short distance to travel to groundwater. These activities should be located at least 200 feet from wells, sinkholes, drainageways, ponds, and streams, and should not be sited on coarse soils overlying shallow bedrock. Never leave a sprayer unattended while the tank is being filled.
- *Lack of anti-siphoning devices* on tank filling equipment can result in dilute pesticide formulation moving down yard hydrant pipes into the soil and fractured limestone bedrock and then to groundwater (if the hydrant is shut off and the filling hose remains in the tank). Backflow in filler hoses can also occur when water pumps are used which have no devices preventing backflow (for example, pumping from a stream). Tank fillers should be equipped with anti-siphoning devices.
- *Pesticide storage* should be in original containers with labels intact. Never store pesticides with livestock feed, minerals, or other feed supplements. Pesticide storage areas should be separate and isolated from other facilities, as well as lockable. The area should be high and dry.
- *Disposal of excess chemicals in the sprayer* can be hazardous if the chemicals are indiscriminately dumped in one location—particularly in drainageways leading to sinkholes or disappearing streams or on shallow coarse soils. Carefully computing the amount of chemical formulation necessary to treat the target area and preparing no excess eliminates this problem. Excess chemicals, if remaining, should not be released in one spot. Waste pesticide solutions should preferably be land-applied at the same rate as for the target area and away from karst features.

Additionally, pesticide users may wish to consult university soil scientists to see if a portion of the farm could be used for excess applicator chemicals disposal. The area should not drain to sinkholes, well tops, or surface waters. Soil depth over limestone should be great and percolation rates should be moderately low. Cultivated fallow of the dedicated area may be necessary.

FERTILIZER USE

Excessive nitrogen fertilizer application. Applying more nitrogen fertilizer than crops can use during a year can result in excess nitrogen moving downward in the soil. Groundwater contamination can occur if the soils are sandy and the water table or limestone bedrock is near the soil surface (for example, 3-5 feet). Extension Bulletin 416 recommends fertilizer rates for various crops and yield goals. The nitrogen supplying power of soil organic matter and preceding leguminous crops is considered in the recommendations. Applying at recommended rates reduces chances of groundwater contamination—unless the expected crop yield is greatly overestimated.

Timing and manner of application. Nitrogen applied to soils at low crop demand periods (for example, late fall, winter, and spring) has the potential to leach downward if nitrogen is in the soluble nitrate form and water is moving downward in the soil profile (ammonium nitrate contains half nitrate and most other forms of fertilizer nitrogen eventually are converted to nitrate).

Applying nitrogen fertilizer to frozen ground, and at times of high runoff can result in nitrogen moving to sinkholes and streams when the site of application is near these features.

Usually, nitrogen fertilizer should not be applied on frozen ground or during the fall on coarse-textured soils (sands to loamy sands). Fall nitrogen fertilization should also be minimized on other soil types if possible. If not possible, select a nitrogen form that is not highly mobile. Incorporate nitrogen fertilizer, when possible, on high runoff fields draining to sinkholes and disappearing streams.

STORAGE FACILITIES

Leaking or ruptured storage tanks containing fuel oil, animal or human wastes, silage or chemicals result in contaminants moving toward groundwater. Underground tanks in areas of shallow soil over limestone bedrock result in only a few feet of soil separating potential leaks from channels leading to groundwater. Lack of periodic tank inspection unnecessarily increases risks.

Above ground storage facilities should be used in shallow soil areas. Periodic maintenance and inspection of both above and below ground tanks, including silos, is important. Leaks should be identified and controlled.

Summary

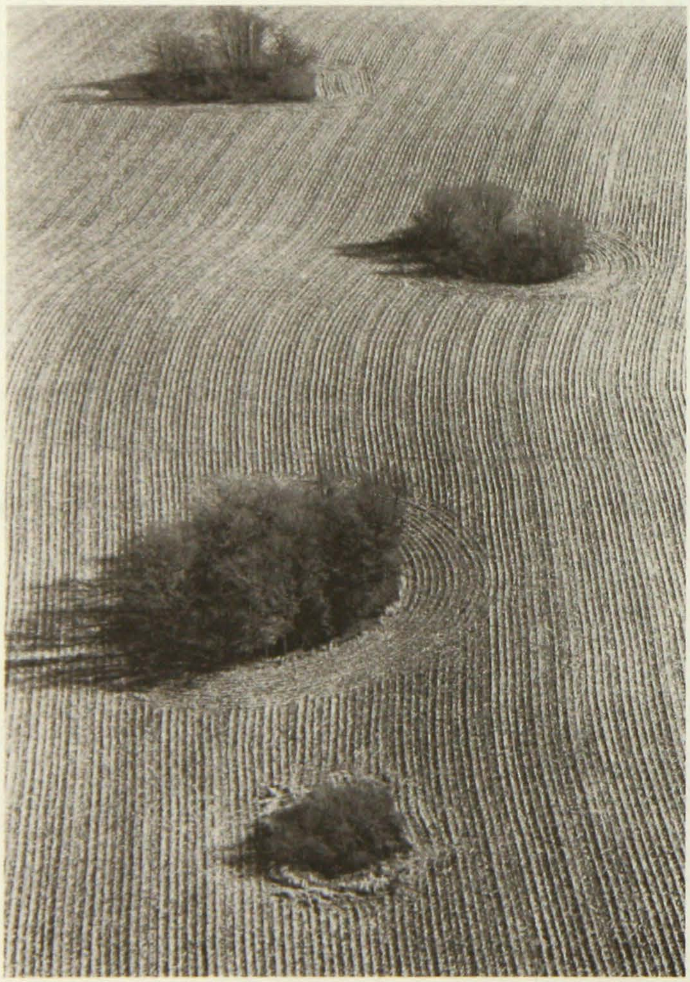


Figure 8. Sinkhole-dotted field in southeast Minnesota.
(Reprinted with permission from the *Minneapolis Tribune*)

Groundwater in southeast Minnesota's karst area is extremely susceptible to pollution. Shallow groundwater contamination is occurring. Contamination of deep, high-quality waters can also occur. Shallow aquifers will continue to be contaminated and deep aquifers will likely become contaminated if measures are not taken to reduce pollution.

The nature of karst areas permits many activities to contribute to groundwater pollution as well as allowing one individual to affect the quality of many individuals' well water. Consequently, all southeast Minnesota residents must consider the sensitive nature of karst areas when performing everyday activities and take measures when necessary to avoid groundwater contamination.

Practices listed in this publication can reduce pollution potential. Some require little effort to perform; others require commitment of time and money. Local experts should be consulted, however, to determine the need for and selection of the appropriate practice(s) for specific circumstances.

Finally, southeast Minnesota residents may wish to consider the development of local groundwater protection programs. Such programs might help offset the cost to individual landowners for some of the more expensive practices and insure that all individuals take measures to protect groundwater. Options for local government involvement include participation in feedlot pollution control programs; regulations governing home sewage treatment systems; development and implementation of waste recovery, recycling, or disposal plans; expanded well water testing and abandoned well identification programs; and sinkhole protection guidelines.

Helpful Agencies

Agency	Sinkholes	Home sewage treatment	Wells	Livestock and feedlots	Erosion and runoff control	Pesticides	Fertilizers	Geology
LOCAL								
Soil and Water Conservation Districts	■			■	■			
Agricultural Extension Service	■	■	■	■	■	■	■	■
County Health and/or Zoning		■	■	■				
USDA-Soil Conservation Service (SCS)	■	■	■	■	■			■
USDA-Agricultural Stabilization and Conservation Service (ASCS)				■	■			■
REGIONAL								
Minnesota Department of Health Southeast District 1220 4th Ave. Southwest Rochester, MN 55901 (507) 285-7289		■	■					
Minnesota Pollution Control Agency 1200 S. Broadway Rochester, MN 55901 (507) 285-7343		■		■		■		
STATE								
Minnesota Department of Agriculture Agronomy Services Division 90 West Plato Blvd. St. Paul, MN 55155 (612) 296-6121				■		■	■	
Minnesota Department of Health Division of Environmental Health 717 Delaware St. Southeast Minneapolis, MN 55440 (612) 296-5338			■					
Minnesota Geological Survey 1633 Eustis St. St. Paul, MN 55108 (612) 373-3372	■		■					■
Minnesota Pollution Control Agency 1935 West County Road B2 Roseville, MN 55113 (612) 296-7373		■		■		■		

Other Educational Materials

PUBLICATIONS

University of Minnesota Agricultural Extension Service publications can be obtained from local county extension offices or the Bulletin Room, 3 Coffey Hall, 1420 Eckles Ave., University of Minnesota, St. Paul, MN 55108.

Composting

University of Minnesota Agricultural Extension Service

Building a Compost Heap. Soils Fact Sheet 12

Minnesota Pollution Control Agency

Composting for a Better Garden and a Better Environment

Erosion Control

University of Minnesota Agricultural Extension Service

Tillage—Its Role in Controlling Soil Erosion by Water. Folder 479

Estimating the Effects of Crop Residue Mulches on Soil Erosion by Water. Folder 477

Grassed Waterways—Construction and Maintenance. Folder 480

Modern Terraces for Soil Conservation. Folder 499

Feedlots and Manure

University of Minnesota Agricultural Extension Service

Livestock Waste Facilities Handbook. Midwest Plan Service-18

Using Manure as a Fertilizer. Folder 168

Tax Benefits for Animal Pollution Control. Agricultural Engineering Fact Sheet 20

Minnesota Environmental Quality Board (101 Capitol Square Building, St. Paul, MN 55101)

Environmental Issues Relating to Animal Feedlots

Fertilizer

University of Minnesota Agricultural Extension Service

Fertilizer Recommendation Tables for Guide to Computer Programmed Soil Test Recommendations in Minnesota. Bulletin 416

Home Sewage Treatment

University of Minnesota Agricultural Extension Service

Town and Country Sewage Treatment. NCR Bulletin 130

Shoreland Sewage Treatment. Bulletin 394

How to Run a Percolation Test. Folder 261

Treatment and Disposal of Milkhouse and Milking Parlor Wastes. M-159

Minnesota Pollution Control Agency (1935 West County Road B2, Roseville, MN 55113)

Land Application and Utilization of Septage—Recommended Guidelines

Landfills and Recycling

Minnesota Pollution Control Agency

Recycling Information

Some Things Don't Belong in Your Trash Can

Operating a Recycling Program: A Citizen's Guide

Pesticides

University of Minnesota Agricultural Extension Service

Pesticide Applicator's Manual. Bulletin 428

How to Calculate Herbicide Rates and Calibrate Herbicide Applicators. Agricultural Chemicals Fact Sheet 5

Herbicide Spray Drift. Folder 548

Pesticide Storage and Formulation Shed. Agricultural Chemicals Fact Sheet 4

Fire Hazards of Stored Pesticides on Farms. Agricultural Chemicals Fact Sheet 1

Pesticides and Pesticide Container Disposal. Agricultural Chemicals Fact Sheet 17

Wells

University of Minnesota Agricultural Extension Service

Private Water Systems Handbook. MWPS-14

Chlorination of Private Water Supplies. M-156

Iowa State University Cooperative Extension Service (Ames, Iowa 50011)

Good Wells for Safe Water

Office of the State Register, Department of Administration, Documents Section (117 University Ave., St. Paul, MN 55155)

Minnesota Code of Agency Rules. Department of Health Water Well Construction Code (7MCAR: 1.210-1.224)

FILMS

Secrets of Limestone Groundwater. 13 minutes. Indiana University (available from Minnesota Agricultural Extension Service, Communication Resources)

TAPE-SLIDE SETS

Inquire at Minnesota Agricultural Extension Service, Communication Resources, about *Groundwater Pollution in Southeast Minnesota's Karst Region*, a companion to this publication.

Recycling Facilities in Southeast Minnesota

(check business hours with each)

DAKOTA COUNTY

Metals

Coca-Cola
Town's Edge Shopping Center
Farmington 55024
(507) 388-2951
aluminum

Coca-Cola
Mun. Liquor-Holyoke Ave
Lakeville
(507) 388-2951
aluminum

Glass

Hampton B&B 4-H Club
c/o Vernon Hupf-260th St
Randolph 55065
(507) 263-2705

Alcorn Beverage Co.
7879 218th St W
Lakeville 55044
(612) 469-5555

Faith Lutheran Church
7095 Upper 163rd St
Rosemount 55068
(612) 432-4658

Donal Tutewoht
23142 Denmark Ave
Farmington 55024
(612) 463-7489

Tim Turek
14809 Chili Ave W
Rosemount 55068
(612) 423-2888

Full service

Stoffel Beverage Co.
1272 W 8th St
Hastings 55033
(612) 437-6466
glass, aluminum

John Ginther
1226 Eddy
Hastings 55033
(612) 437-3570
glass, aluminum

Trinity Lutheran Church
413 Main St
Farmington 55024
(612) 463-8922
paper, glass

DODGE COUNTY

Metals

Coca-Cola
American Legion
Dodge Center
(507) 388-2951
aluminum

Coca-Cola
Municipal Parking Lot
Kasson-Mantorville
(507) 388-2951
aluminum

Darrel Quesnel
RR 1, Box 264A
Dodge Center 55927
(507) 374-6660
paper, corrugated, cans
scrap metal, glass

Lin's Used Iron
502 3rd St. SE
Dodge Center 55427
(507) 374-2439
scrap metals, aluminum
cans (not steel cans)

GOODHUE COUNTY

Metals

Coca-Cola
Hub Red Owl
Zumbrota 55066
(507) 388-2951
aluminum

Reynolds Aluminum
Pamida Store-Hwy 61 & Tylan Rd
Red Wing 55066
(800) 288-2525
aluminum

Coca-Cola
Pamida-Hwy 61 & Tylan Rd
Red Wing
(507) 388-2951
aluminum

Coca-Cola
Cannon Mall
Cannon Falls 55009
(507) 388-2951
aluminum

Buf's Truck Parts
Hwy. 56
Cannon Falls 55009
(507) 263-2226
scrap metal, aluminum cans

Glass

George Lucius
1005 W Hauffman St
Cannon Falls 55009
(507) 263-2594

Erwin Buck
610 Lincoln Ave
Zumbrota 55992
(507) 732-5836

MOWER COUNTY

Paper

First Methodist Church
204 1st Ave N
Austin 55912
(507) 433-8839

Pacelli School
311 4th St NW
Austin 55912
(507) 437-3278

Metals

Coca-Cola
Oak Park Mall
Austin 55912
(507) 388-2951
aluminum

Reynolds Aluminum
K-Mart Parking Lot
Austin 55912
(800) 228-2525
aluminum

Chas. Dubinsky & Co.
10th Dr. & 8th Ave. SE
P.O. Box 29
Austin 55912
(507) 433-3496
all metals

Gopher Distributing Co
Hwy 218 N
Austin 55912
(507) 437-3278
aluminum

Crowley Beverage Co.
617 NE 11th St
Austin 55912
(507) 433-8295
aluminum

Full Service

Delmar Ellis
Rt. 5
Austin 55912
(507) 437-1893
cans, glass, paper

OLMSTED COUNTY

Metal

Gopher Distributing Co
1640 SE 3rd Ave
Rochester 55901
(507) 288-4211
aluminum

Reynolds Aluminum
Apache Mall-Hwy 52 & 14
Rochester 55901
(800) 228-2525
aluminum

Rochester Iron & Metal
1950 3rd Ave. SE
Rochester 55901
(507) 288-3228
sheet iron, beverage cans, scrap metals
(not steel cans or wire)

Coca-Cola
Apache Mall-Hwy 52 & 14
Rochester 55901
(507) 388-2951
aluminum

Coca-Cola
Boyum Foods
Stewartville 55976
(507) 388-2951
aluminum

Chaddock Truck Parts
832 14th St. NW
Rochester 55901
(507) 288-3346
scrap tin

Sexton Auto Parts & Salvage
Route 2 Box 139
Rochester 55901
(507) 282-3777
scrap metal, aluminum and steel cans

Paper

S.E. Minnesota Recycling
4802 8th St. SW
Rochester 55901
(507) 289-7510
newspaper

Glass

Rodney Watson
809 1st St SE
Rochester 55901
(507) 282-7710

Full Service

Hemker Recycling
1214 1st St NE
Rochester 55901
(507) 282-4729
glass, paper, aluminum

RICE COUNTY

Metal

Reynolds Aluminum
Faribault Plaza-Hwy 65 & Division
Faribault 55021
(800) 228-2525
aluminum

Coca-Cola
Faribault 55021
(507) 388-2951
aluminum

Harley's Auto
510 NW 20th St
Faribault 55021
(507) 334-8290
metals: all kinds

Kelley's Auto Parts
Faribault 55021
(507) 334-7035
scrap metals, batteries, aluminum cans

Viking Auto Salvage
N. Hwy. 3
Northfield 55057
(507) 645-5819
(612) 332-0660
scrap metals, aluminum and steel cans

Glass

Sunrisers 4-H Club
Rt 2
Northfield 55057
(507) 645-8185

Full Service

Consolidated Catholic Schools
Home and Schools Assoc.
Faribault 55057
glass, aluminum, newspaper, flattened cardboard

STEELE COUNTY

Metal

Coca-Cola
Prairie House Parking Lot
Blooming Prairie 55917
(507) 388-2951
aluminum

Coca-Cola
Cedar Mall
Owatonna 55060
(507) 388-2951
aluminum

Reynolds Aluminum
Pamida Store
Owatonna 55060
(800) 228-2525
aluminum

Glass

H & S Distributing Co
670 24th Ave NW
Owatonna 55060
(507) 451-4169

Owatonna Redemption Center
1031 S Oak
Owatonna 55060
(507) 451-1320

Full Service

Owatonna Reclamation Center
453 Clearview Place
Owatonna 55060
(507) 451-8846
glass, newspaper, aluminum, tin

Cumberland Hide & Fur, Wool & Metal Co.
Box 408 Route 3
Owatonna 55060
(507) 451-7607
all nonferrous metals, aluminum cans

Owatonna Scrap Iron & Metal
P.O. Box 72
Owatonna 55060
(507) 451-1470
all metals

Poly Plastic
18th St.
Owatonna 55060
(507) 451-8650
plastics, cars, newspaper, cardboard, office paper

WABASHA COUNTY

Metal

Coca-Cola
Super Valu
Lake City 55041
(507) 388-2951
aluminum

Coca-Cola
Lannings Red Owl
Plainview 55964
(507) 388-2951
aluminum

Lake City Auto Parts
Lake City 55041
(612) 345-4224
scrap metals (no cans)

WINONA COUNTY

Metal

William Miller Scrap Iron & Metal
222 W. 2nd St.
Winona 55987
(507) 452-2067
metals

S. Weisman & Sons, Inc.
450 W. 3rd St.
Winona 55987
(507) 452-5847
aluminum

Glass

Winona Distributing Co.
4450 6th St
Goodview 55987
(507) 454-1355