ORIGINAL

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APR 24 2001
STATE OF ILLINOIS
Pollution Control Board

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
AMENDMENTS TO LIVESTOCK	)	
WASTE REGULATIONS	)	R01-28
(35 ILL. ADM. CODE 506)	)	(Rulemaking-Land)
	)	

NOTICE OF FILING

Dorothy M. Gunn, Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street, Suite. 11-500
Chicago, Illinois 60601

AND THE ATTACHED SERVICE LIST
(Via U. S. Mail)

Carol Sudman,
Hearing Officer
Illinois Pollution Control Board
600 South Sixth Street, Suite 402
Springfield, Illinois 62704

PLEASE TAKE NOTICE that I have today filed with the Office of the Clerk of the Pollution Control Board the Appearance of the Illinois Environmental Protection Agency, a Motion to file Testimony and the Testimony of Daniel L. Heacock , a copy of which is herewith served upon you.

ENVIRONMENTAL PROTECTION AGENCY
OF THE STATE OF ILLINOIS

By: Connie L. Tonsor

Connie L. Tonsor
Associate Counsel
Division of Legal Counsel

DATED: April 23, 2001

Illinois Environmental Protection Agency
1021 North Grand Avenue East
Post Office Box 19276
Springfield, Illinois 62794-9276
(217) 782-5544

THIS FILING IS SUBMITTED ON RECYCLED PAPER

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APPEARANCE

The undersigned, as one of its attorneys, hereby enters her Appearance on behalf of the Illinois Environmental Protection Agency.

ILLINOIS ENVIRONMENTAL
PROTECTION AGENCY

By: Connie L. Tonsor
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MOTION TO FILE TESTIMONY

Now comes the Illinois Environmental Protection Agency ("Illinois EPA") by one of its attorneys, Connie L. Tonsor and moves that the Illinois Pollution Control Board ("Board") accept the attached testimony of Daniel L. Heacock in the above encaptioned matter.

1. On January 22, 2001, the Illinois Department of Agriculture filed proposed rules concerning the design and construction of livestock waste handling facilities.

2. On February 21, 2001, the Board set the matter for hearing and established dates for the pre-filing of testimony.

3. On March 27, 2001, the Hearing Officer set April 30, 2001 as the second hearing date. The order set April 23, 2001 as the date for pre-filed testimony.

WHEREFORE, for the reasons set forth above, the Illinois EPA respectfully moves that the Board accept the attached testimony of Daniel L. Heacock.

Respectfully submitted,

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

By: *Connie L. Tonsor*
Connie L. Tonsor
Associate Counsel

DATED: April 23, 2001

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P.O. Box 19276
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TESTIMONY OF DAN HEACOCK

QUALIFICATIONS

My name is Dan Heacock. I am employed by the Illinois Environmental Protection Agency ("Agency") as the manager of the Facility Evaluation Unit in the Watershed Management Section of the Bureau of Water. The duties of the Facility Evaluation Unit include reviewing NPDES applications and providing technical assistance for the livestock waste management program administered by the Illinois EPA. I have been employed in the permit programs of the Bureau of Water or Division of Water Pollution Control since 1985. My experience with the livestock waste management programs of the Agency began with my employment with the Agency. I have participated in the Livestock Management Advisory Committee meetings during the development of the proposed amendments to Part 506 and the Illinois Department of Agriculture's Part 900 rules. I am a graduate of the University of Illinois in Agricultural Engineering. I am a registered professional engineer in Illinois.

INTRODUCTION

The Agency participated in the development of this proposal through the Livestock Management Advisory Committee and appreciates the opportunity to further that participation by offering comments and this testimony concerning the proposed revision of 35 Ill. Adm. Code 506. My testimony will: (1) discuss two areas of substantive concern regarding the detection of voids and construction in karst areas, and the installation and operation of perimeter drainage tubing; (2) seek clarification of one area; and (3) address other matters that may require clarification due to typographical errors or other reasons.

REGULATORY REVIEW

Section 506.103

The provision for species other than listed in the proposed regulation requires the Department to determine mature animal weight. Immature livestock should be included in the calculation of animal units at a livestock management facility.

Section 506.104

The ASAE standard for anaerobic lagoons was revised in December 1998 and is now referenced as ASAE EP 403.3 DEC98. The ASAE standard for manure storages was revised in December 1998 and is now referenced as ASAE EP 393.3 DEC 98. The regulations should be revised to reference the most current standards for manure lagoons and manure storages. Section 13(b)(2) and (b)(3) of the Livestock Management Facilities Act requires use of the updated standards for manure storages.

Section 506.204

The ASAE publishes all of its standards annually in a single volume, resulting in changes to the page numbering of unchanged standards, as new standards are added or modified. The section numbers of the standards remain the same unless the standard is revised and issued with a new standard number. Therefore, the Agency recommends that references to page numbers, used in the regulations, be changed to section numbers of the standards to eliminate ambiguity regarding the standard referenced.

Section 506.204(g)(3)

The ASAE EP 403.3 DEC98 "Design of Anaerobic Lagoons for Animal Waste Management" clarifies the method of determining the total volume of the lagoon by specifically including runoff and precipitation generated between manure removal events. The proposed regulations do not specifically list this runoff and precipitation as additional volumes, although the runoff and precipitation generated, which are tributary to a lagoon for a storage period of 270 days, should be accounted for in the calculation of the amount of waste generated in the same 270-day period. The Illinois EPA suggests that for clarity, these volumes be listed in the proposed regulation. We recommend that Section 506.204(g)(3)(C) be replaced with: "Runoff and wash down volumes generated during a 270-day period including all runoff and precipitation from lots, roofs and other surfaces where collected precipitation is directed into the lagoon, plus all the washdown liquids that are directed into the lagoon. In no case shall this volume be less than the precipitation and runoff generated by a 25-year, 24-hour storm event and directed to the lagoon; and"

Section 506.205(a)

Proposed Section 506.205(a) adds a cross-reference to Section 506.203(d) and deletes a cross-reference to Section 506.204(d). The Agency proposes removing the deletion of Section 506.204(d). Section 506.203(d) is shown as repealed in the proposed regulations, and the stricken reference, Section 506.204(d), appears to be the correct reference.

Section 506.206(a)

Proposed Section 506.206(a) adds a cross-reference to Section 506.203(d) and deletes a cross-reference to Section 506.204(d). The Agency proposes removing the deletion of Section 506.204(d). Section 506.203(d) is shown as repealed in the proposed regulations, and the stricken reference, Section 506.204(d), appears to be the correct reference.

Section 506.207(b)

This provision requiring rigid construction materials should be applicable to lagoons constructed on the land surface not just to lagoons constructed below the pre-construction land surface in karst areas. A non-rigid lagoon could be constructed on the land surface. Requiring a rigid structure will provide additional assurance that a collapse causing groundwater contamination will not occur.

Section 506.208(d)

Section 506.208(d) concerns groundwater-monitoring wells. The reference to Section 506.205 Liner Standards appears that it should be replaced with a reference to Section 506.206 Groundwater Monitoring.

Section 506.303

The last sentence of 506.303(a) should be revised for clarity to include the term "volume" as follows, "In addition, the design volume of livestock waste storage structures that handle the waste in liquid or semi-solid form shall include the following:"

The regulations do not specifically list as an additional volume the runoff and precipitation generated and tributary to the livestock waste handling facility for a period of 150 days. This runoff and precipitation is livestock waste and should be included in the calculation of the livestock waste volume generated during a period of 150 days and listed in the regulations for the calculation of the total volume of the livestock waste handling facilities. The Illinois EPA suggests that for clarity, this volume be added to the list of additional volumes in the proposed regulation and recommends that Section 506.303(a) (1) and (2) be replaced with:

"(1) Runoff volumes generated during a 150-day period including all runoff and precipitation from lots, roofs and other surfaces where collected precipitation is directed into the storage. In no case shall this volume be less than the precipitation and runoff generated by a 25-year, 24-hour storm event and directed to the livestock waste handling facility; and

(2) the volume of all washdown liquids generated during the 150-day period that are directed into the livestock waste handling facility."

Section 506.304(c)

The Agency recommends that this subsection be revised to include:

- Specifications for the maximum allowable horizontal separation between the perimeter drainage tubing and the livestock waste handling facility. The drainage tubing must be located near the structure to effectively lower the water table below the livestock waste handling facility to prevent floatation. The following language should be added:

> "The perimeter drainage tubing must be located at a horizontal distance that provides sufficient drainage to maintain the water table elevation below the bottom of the livestock waste handling facility."

- A required sampling port. The drainage tubing may receive and transport livestock waste that has leaked from the nearby livestock waste storage structure. A subsurface drain discharge may be discovered discharging livestock waste with several possible sources of livestock waste upstream. A sampling port located on-site immediately downstream of the subsurface drain around the livestock waste handling facility, would provide easy access for sampling and inspection to determine if the particular facility is or is not causing the discharge of livestock waste. Additionally, early detection of such a discharge by sampling or inspection of the sampling port would provide the facility a better opportunity to initiate actions to contain the livestock waste or prevent a discharge to waters of the state.
- A reference to how the "seasonal high water table" may be determined (this may require the addition of a definition in Section 506.103). If the water table rises above the livestock waste handling facility bottom, the livestock waste handling facility can be damaged by floatation, possibly causing a discharge. Therefore, it is critical to know accurately the seasonal high water table elevation when no subsurface drainage is installed.
- A provision for the diversion of livestock waste that may be discharged from the drainage tubing, away from surface waters, to a field or collection area, pending collection and appropriate disposal. If the subsurface drainage tubing receives livestock waste, a means to contain the waste and prevent discharge to waters of the state would need to be implemented.

Section 506.310(c)(3)

This Section requires the certification by the Licensed Professional Engineer of the liners for livestock facilities located near aquifer materials. Does this provision require certification of Sections 506.310 and 506.304 requirements for liners? The Agency is uncertain from the language of the proposal and recommends that the certification by the Licensed Professional Engineer include both Sections 506.310 and 506.304 requirements because the provisions of both sections are important to the prevention of groundwater contamination by livestock waste.

Section 506.312(b)

This provision requiring rigid construction materials should be applicable to livestock waste handling facilities constructed on the land surface not just to livestock waste handling facilities constructed below the pre-construction land surface in karst areas. A non-rigid livestock waste handling facility could be constructed on the land surface. Requiring a rigid structure will provide additional assurance that a collapse causing groundwater contamination will not occur.

Sections 506. 207 and 506.312

These sections regard the construction of lagoons and non-lagoons in karst areas. The Agency is concerned that if a single boring is made to a maximum depth of 20 feet below the waste handling structure bottom elevation, as is proposed in these new sections of Part 506, a void may be present below the proposed livestock waste handling structure and still be undetected.

Agency research has revealed the following:

Jannick, et al., 1992, reported that of 14 wastewater lagoon sites in southeastern Minnesota located over karstic bedrock and with 30 meters or less of overburden soil or till over the bedrock, 2 had failed in the twenty years preceding 1992. An interim guidance document titled "Constructing New Manure Storage Systems in the Karst Region" (Minnesota Pollution Control Agency, March 2000), reports that 3 of 22 municipal wastewater treatment ponds failed in the karst region of southeast Minnesota between 1974 and 1992. The report also indicates that one manure storage system had manure seepage into fractured bedrock occurring so rapidly that the storage system did not ever need to be pumped.

The IDNR- ISGS Illinois Map 8 "Karst Terrains and Carbonate Rocks of Illinois," incorporated by reference in Section 506.104(a)(3), shows that karst areas with sinkholes exist in areas with drift over the bedrock of 50 feet or less. Small areas of the Salem Plateau and Lincoln Hills karst areas are shown on the map to have sinkholes in areas where drift thickness is greater than 50 feet over the bedrock. In the report "Karst Regions of Illinois" by Panno, et al (1997) for the Salem Plateau karst area, the bedrock is reported to be typically less than 15 meters (or approximately 49 feet) below the surface, although some areas exceed this depth. In the Lincoln Hills karst region the report indicates that many of the sinkholes in this region occur in "relatively thick loess deposits." Most sinkholes form in drift thickness of less than 20 feet below the surface in the North Central Karst region according to the report by Panno. The formation of sinkholes appears to occur in areas with depth to bedrock up to 50 feet or more in Illinois. Benson and La Fountain, 1984, state that 1000 borings conducted on a grid would be needed for a 90% probability to detect a void of 2.3 meters in size on a one acre site.

The Agency concludes, therefore, that if a single boring is made to a maximum depth of 20 feet below a waste handling structure bottom elevation a void may be present below the proposed structure and still be undetected. The Agency recommends a more comprehensive investigation based on several sources of data. Such systems are described below from information on programs in Minnesota and Missouri.

The State of Minnesota adopted regulations in October, 2000 regarding the location of manure storage structures in karst areas. The regulations as adopted require that certain facilities:

- have a minimum separation from bedrock of twenty to forty feet for earthen liners, based on the size of operation and type of structures,
- use rigid structures or composite earthen/synthetic liners,

- limit the size of manure storage structures to 250,000 gallons,
- prohibit manure storage structures if the bedrock is within 5 to 15 feet of the livestock waste handling structure bottom, or
- relocate away from the karst features.

Minnesota also convened a workgroup of engineers that were not state regulatory personnel to determine what should be required for livestock facilities located in karst areas (Minnesota Pollution Control Agency, 2000, Minnesota Pollution Control Agency, 2001). The report from that workgroup indicates the following:

- that in 5 instances earthen manure storage structures have failed due to sinkhole development in states other than Minnesota,
- Minnesota and other states also have had non-livestock wastewater treatment ponds fail due to sinkhole development,
- In all cases the failures have occurred when there is no liner or the liner is designed to seep at greater than the Minnesota requirements for earthen soil liners. The seepage rate requirement is 1/56th inch per day. 1/56th inch per day is equivalent to a 2 feet thick liner with a hydraulic conductivity of 1×10^{-7} cm/sec with an operating depth of livestock waste of 8.6 feet.

The Minnesota workgroup issued the report "Recommendations of the Technical Workgroup-Liquid Manure Storage Structures in the Karst Region" on December 20, 2000. The report concludes that the following be required:

- no new earthen manure storages located in areas where carbonate bedrock is less than 50 feet from the ground surface and the upper bedrock is fractured or other geologic strata where soil collapse or sinkhole formation occurs,
- construction of manure storage structure is not allowed if voids are encountered in the construction of the structure or soil inspection,

- minimum bedrock separation of five feet for concrete tanks, dual lined basins, composite lined basins and above-ground tanks with concrete floors,
- a secondary liner with a leachate collection system if bedrock separation is less than 5 feet,
- soil inspections during construction,
- diversion of fresh water away from the perimeter of manure storages,
- annual liner inspections,
- monitor manure levels, and
- emergency response plans.

The Missouri Department of Natural Resources regulations require that each site for a earthen wastewater pond, including livestock waste facilities, be subject to a geological evaluation. These evaluations are conducted by the Missouri Department of Natural Resources. If the facility has severe geological limitations, the wastewater pond (i.e., livestock waste lagoon or holding pond) may be prohibited unless liner technology and/or more detailed investigation and analysis can demonstrate that the proposed pond will not cause groundwater contamination. If the geological evaluation indicates high collapse potential, then the ponds are generally prohibited (Missouri Code of State Regulations, 1999).

The Missouri system provides for the evaluation and designation of a score for the following eight factors in making an assessment of the earthen lagoon collapse potential of a site. A site is scored if greater than 50% of the top twenty feet of bedrock is limestone, dolomite or calcareous sediments and the wastewater pond bottom is underlain by less than 20 feet of unconsolidated material on top of the bedrock. A site is not scored for an assessment of earthen lagoon collapse potential if the earthen lagoon bottom is underlain by 20 feet or more of unconsolidated material (other than relict bedrock residuum or alluvium). Listed with each factor is the condition that is scored the highest for potential wastewater pond collapse as shown below:

Factor	Most Severe Condition
Gaining or losing stream,	Losing
Depth to water table	Greater than 50 feet
Thickness of relict bedrock residuum above consolidated bedrock	40 to 100 feet
Characteristics of upper 20 feet of bedrock and/or surficial material	Bedrock with significant voids > 10 feet below surface, or unconsolidated material consisting of relict bedrock structures or alluvium with losing conditions associated with this type of bedrock
Proximity of nearest sinkhole	Within 500 feet
Proximity of nearest underground opening	Beneath the wastewater pond
Surface area of wastewater pond	More than 4 acres
Maximum operating depth of liquid	Greater than 20 feet

Section 2.5 of the report "Recommendations of the Technical Workgroup- Liquid Manure Storage in the Karst Region" provides a summary of that workgroup's review of requirements of manure storage structures located in karst areas of ten states with karst geology. The factors or restrictions used by Florida, Pennsylvania, Indiana, Ohio, Missouri, Kentucky, Wisconsin, Iowa and two other unidentified states surveyed included:

- size of the manure storage structure,
- use of rigid materials, above ground storage or impermeable liners,
- liner permeability requirements,
- prohibition of earthen liners,
- setbacks from sinkholes of 150 to 500 feet,
- site assessment to determine relative risk, and
- depth to bedrock

I have attached a chart comparing the Part 506 proposal with the Minnesota and Missouri regulations and workgroup report.

The presence of voids below the structure presents the greatest threat in karst areas to the integrity of the waste storage structure. Based on the above information regarding karst, a single soil boring to a depth of 20 feet will not be sufficient to reliably detect voids located near the manure storage structure that can cause failure of manure storage structures. Additional borings would provide more assurance that voids are not present. Multiple borings should be conducted to a depth of at least 50 feet or to the bedrock to detect the presence of voids.

Alternatively, if a single boring to 20 feet or to bedrock is used as proposed, additional requirements would provide methods to prevent groundwater contamination due to failures of manure storage structures into fractured bedrock. Examples of these additional requirements are: preventing the location of manure storage structures or requiring the use of secondary liners with leachate collection in areas of shallow soils over bedrock, requiring material and liners based on depth to bedrock, limitations on the size of manure storage structures, diversion of fresh water away from manure storage areas, and prohibitions based on detection of voids during construction.

I have used the following materials, which will be offered as exhibits in this proceeding:

•Benson, R. C. and La Fountain, L. J., 1984. Evaluation of subsidence or collapse potential due to subsurface cavities. Proceedings of the First Multidisciplinary Conference on Sinkholes. Orlando, Florida

•Jannick, N. O. , Alexander, E. C., and Lanherr, L. J., 1992. The Sinkhole Collapse of the Lewiston, Minnesota Waste Water Treatment Facility Lagoon. Proceedings of the Third Conference on Hydrogeology, Ecology, Monitoring and Management of Ground Water in Karst Terranes, National Groundwater Management Association.

•Minnesota Pollution Control Agency, March 20, 2000. Constructing Manure Storage Systems in the Karst Region. Interim Guidance Document. Minnesota Pollution Control Agency, Saint Paul, MN.

•Minnesota Pollution Control Agency, December 20, 2000. Recommendations of the Technical Workgroup- Liquid Manure Storage in Karst Region To the Minnesota Senate and House Agriculture and Rural Development Committees. Minnesota Pollution Control Agency, Saint Paul, MN.

•Minnesota Pollution Control Agency, January 17, 2001. Karst Workgroup Recommendations- Legislative Fact Sheet. Minnesota Pollution Control Agency, Saint Paul, MN.

•Missouri Code of State Regulations, 1999. 10 CSR 20-8.200 Division 20-Clean Water Commission, Secretary of State, State of Missouri.

•Missouri Department of Natural Resources, Division of Geology and Land Survey. Waste Water Treatment Site - Geologic Evaluation. Rolla, Missouri.

•Missouri Department of Natural Resources, Division of Geology and Land Survey. Assessment of Earthen Lagoon Collapse Potential. Rolla, Missouri.

•Missouri Department of Natural Resources, Division of Geology and Land Survey, August 15, 1994. Guidelines for Assessment of Earthen Lagoon Collapse Potential. Rolla, Missouri.

•Panno, S. V., Weibel, C. P. and Li, W. 1997. Karst Regions of Illinois, Open File Series 1997-2. Illinois Department of Natural Resources-Illinois State Geological Survey.

•Panno, S. V. and Weibel, C. P. 1997. Karst Terrains and Carbonate Rocks of Illinois. Illinois Department of Natural Resources-Illinois State Geological Survey.

•State of Minnesota. Minnesota Rules, Chapter 7020.

http://www.revisor.leg.state.mn.us/arule/7020/2100.html

This concludes my testimony, I would be happy to answer any questions that you may have.

By: *Daniel L. Heacock*

Daniel L. Heacock

April 23, 2001

Illinois Environmental Protection Agency

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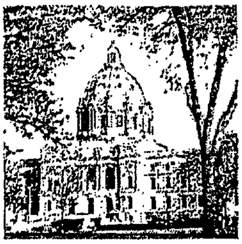

Legislative FACT SHEET

January 17, 2001

Minnesota Pollution Control Agency

Karst Workgroup recommendations

Introduction

Due to its unique karst geology (fractured limestone bedrock overlaid with shallow soil, often with sinkholes), much of southeastern Minnesota represents a sensitive environment for contamination of ground water and surface waters. One of the environmental concerns about karst geology is the potential for sinkholes to form below wastewater- or manure-storage structures, causing contaminants to be channeled directly into the ground water. Sinkholes have formed below three poorly lined municipal wastewater-treatment ponds in Minnesota and at several poorly lined wastewater and liquid manure storage areas in other states. Ground water contamination problems have also resulted from chronic seepage of liquid manure into cracks in the bedrock that are directly connected to aquifers.

Background

Recognizing the environmental sensitivity of the karst region, the Minnesota Pollution Control Agency (MPCA) recently incorporated into rule (Chapter 7020) several standards for construction of liquid manure-storage systems in areas prone to sinkhole development. In response to the rule changes, the Legislature requested that a workgroup be convened to review and propose standards related to this topic according to the requirements in section 13 of 2000 Session Laws, Chapter 435.

The MPCA convened a workgroup consisting of 10 engineers, none of whom are employed by state regulatory agencies, in accordance with the guidelines set forth by the Legislature, which specified that engineers in the workgroup be from the private sector. At the request of the workgroup, two or more hydrogeologists experienced in the karst region were present at each meeting to advise on issues pertaining to karst geology, soils and hydrogeology. The workgroup met over eight days between August and November. The workgroup did not build from existing MPCA policy, but rather took a fresh look at standards needed for the karst region.

The workgroup considered areas "susceptible to soil collapse or sinkhole formation," to include all land where the depth to carbonate bedrock is less than 50 feet, and the uppermost bedrock is fractured carbonate materials or other bedrock where soil collapse or sinkhole formation occurs.

Karst Workgroup recommendations

Following considerable study of technical information from Minnesota and other states, the workgroup developed several standards for these areas.

Location restrictions

- Maintain a 300-foot setback from sinkholes.
- Relocate site if subsoil inspections during excavation indicate soil subsidence or sinkhole development.
- Avoid construction over mapped caves that become registered with the state.

Design specifications

- Use dual liners, concrete liners or above-ground, glass-fused metal tanks.
- Limit maximum capacity of a single cell to three million gallons (no total-capacity limit per farm and no restrictions based on animal-unit numbers).
- Maintain a five-foot minimum separation between manure and bedrock, with some exceptions.

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- Convey roof and site runoff waters away from the manure-storage area.

Identifying and responding to failures

- Monitor manure levels regularly and conduct an annual inspection of the liner.
- Develop an emergency response plan.

The workgroup recommended that the proposed standards replace existing MPCA rules pertaining to design standards in areas susceptible to sinkhole formation. It also suggested that these recommendations be reviewed and refined after further sinkhole-formation studies are completed.

Similarities between recommendations and existing regulations

Many similarities can be found when comparing current Minn. R. ch. 7020 and workgroup recommendations for areas susceptible to soil collapse or sinkhole formation. For example, both the existing rules and workgroup recommendations:

- establish 300-foot setbacks from sinkholes.
- include major restrictions for use of cohesive soil liners alone.
- allow for use of concrete-lined, dual-lined and above-ground storage.
- establish a similar minimum soil thickness needed above bedrock for use of concrete, composite and above-ground liners at small to moderate-size feedlots.

Differences between recommendations and existing regulations

- Current rules for minimum separation-to-bedrock restrictions vary from five to 15 feet for concrete pits, dual-lined basins and above-ground tanks, depending on the type of liner and the number of animal units on the farm. The workgroup recommends that separation to bedrock be a minimum of five feet, except for two types of designs where separation to bedrock can be less than five feet.
- MPCA rules allow cohesive soil liners alone where there is a substantial soil thickness (*e.g.*, 20 to 40 feet). between manure and bedrock The workgroup recommends that no cohesive soil liners be used alone without another liner in areas with less than 50 feet from ground surface to carbonate bedrock until further geologic study identifies the areas with less than 50 feet to bedrock that have a low potential for soil collapse or sinkhole formation.
- MPCA rules set a 250,000-gallon limit per storage cell in areas where there are four or more sinkholes within 1,000 feet. No other storage-capacity limits are set in rules. The workgroup recommends a three-million-gallon limit in all areas susceptible to sinkhole formation

Recommendations for additions to existing regulations

Other recommendations that the workgroup made are consistent with MPCA policy and past permit conditions, but are not currently established in rule for all new liquid-manure-storage facilities in sinkhole-prone areas. The workgroup proposes that the following be added to state rules for areas susceptible to sinkhole formation:

- inspections of subsoil during construction,
- diverting fresh water away from the manure-storage area,
- annual liner inspections,
- monitoring of manure levels and
- emergency response plans.

What's next?

The MPCA intends to implement workgroup recommendations in the following ways:

1) Study technical information from the workgroup proposals as a basis for future rule revisions.
2) Issue permits with the workgroup standards until the rule can be revised (where an equivalent level of environmental protection is achieved).
3) Modify MPCA guidelines to reflect workgroup proposals.
4) Discuss with other agencies how and when to implement recommendations for further study.

For more information

If you have any questions or would like more information about the Karst Workgroup's recommendations, call David Wall at (651) 296-8440 or e-mail him at david.wall@pca.state.mn.us .

Recommendations of the Technical Workgroup

Liquid Manure Storage in the Karst Region

To the

Minnesota Senate and House
Agriculture and Rural Development Committees

December 20, 2000

Convened by the Minnesota Pollution Control Agency

Printed on recycled paper containing at least 20% fibers from paper recycled by consumers.

Acknowledgements

We extend our sincere thanks to the dedicated technical workgroup members who gave a considerable amount of time and effort to attend numerous meetings and review materials. The Minnesota Pollution Control Agency (MPCA) gratefully acknowledges private sector engineers that voluntarily contributed their time and attention through this unfunded directive. The workgroup and MPCA gratefully acknowledge the public sector staff from the Natural Resources Conservation Service, University of Minnesota, Minnesota Department of Health, Minnesota Extension Service, Minnesota Department of Natural Resources, Minnesota Geological Survey and Iowa Geological Survey who participated in this endeavor. The workgroup would like to express their sincere thanks to those who traveled great distance to supply information and testimony to the workgroup.

Table of Contents

Executive Summary

Much of the karst region of southeastern Minnesota represents a sensitive environment for contamination of ground water and surface waters, due largely to:

- shallow soils above highly fractured bedrock;
- rapid transport of water into and through the subsurface;
- sinkholes and other openings to the fractured bedrock;
- hydrogeology that is highly variable and difficult to predict; and
- an interconnected system of surface water and ground water.

One of the environmental concerns in karst regions is the potential for sinkholes to form below wastewater or manure storage structures, causing contaminants to be directly channeled into the ground water. Excessive seepage from liquid impoundments can cause underlying soil to wash into bedrock fractures, leading to an eventually soil collapse or sinkhole formation. Low permeability liners reduce the likelihood of sinkhole formation below liquid storage areas.

Sinkholes have developed under three poorly lined municipal wastewater treatment ponds in the karst region, draining several million gallons of wastewater into the ground water below. In addition, several cropland runoff retention ponds established for erosion control have also failed when sinkholes developed under the ponds. No liners of any sort were used for construction of these runoff retention ponds. Sinkhole development below liquid manure storage systems has not been known to occur at the hundreds of structures in southeastern Minnesota, but has occurred in at least five instances in other states with karst geology. Other karst states have also had failures of wastewater treatment ponds into sinkholes. All failures in Minnesota and other states have been associated with earthen storage ponds having either no liner, or a soil liner designed to seep more than current Minnesota requirements for cohesive soil liners.

Ground water contamination problems can also result from chronic seepage of liquid manure moving into fractured bedrock (without sinkhole formation). Well water was severely contaminated at one southeastern Minnesota farm when liquid manure continuously leaked through a soil liner into the fractured bedrock immediately below the earthen basin. Long-term chronic seepage into fractured bedrock can add bacteria, viruses and other potential contaminants to the uppermost bedrock aquifers.

Recognizing the potential for both chronic and catastrophic failure of liquid manure storage systems in the karst region, the Minnesota Pollution Control Agency (MPCA or Agency) established guidelines for construction of liquid manure storage systems in areas susceptible to soil collapse or sinkhole formation. The agency encourages producers and design engineers to follow these guidelines. Some of the standards in the guidelines were incorporated into MPCA proposed revisions to Minn. R. ch. 7020, governing animal feedlots and the storage, transportation, and utilization of manure. Prior to going into effect on October 23, 2000, the revised rule underwent an extensive public review process involving oversight by an Administrative Law Judge. The MPCA made several changes to the rules in response to comments from the public and the Judge. In addition, the Minnesota Legislature reviewed the proposed rules and passed legislation requiring changes to several parts of the proposed rules (2000 Session Laws, Chapter 435). No changes were made by the MPCA or the Legislature to proposed rules pertaining to manure storage in areas susceptible to sinkhole formation. However, the Legislature requested that a workgroup be convened to review and propose standards related to this topic. The legislation in section 13 of 2000 Session Laws, Chapter 435, states:

> "The commissioner of the Pollution Control Agency shall convene a workgroup consisting of representatives from Natural Resources Conservation Services and private sector licensed professional engineers, including individuals with expertise in hydraulics, structural systems, and geology, to review and propose design standards for liquid manure storage facilities in areas susceptible to soil collapse and sinkhole formation. This review shall include an evaluation of whether such standards should be volume based or animal unit based."

The MPCA responded to the legislation by convening a workgroup consisting of ten engineers with collective backgrounds in structural engineering; hydraulics; geology; design and construction of liquid manure storage systems in the karst region; assessing seepage through manure storage system liners; geotechnical evaluation; alternative liners for liquid containment; and liner reinforcement. All workgroup recommendations were made by the ten engineers forming the workgroup, none of whom are employed by state regulatory agencies. At the request of the workgroup, two or more hydrogeologists experienced in the karst region were present at each meeting to advise on issues pertaining to karst geology, soils and hydrogeology.

The workgroup was specifically asked by the legislature to target standards for liquid manure storage in areas "susceptible to soil collapse or sinkhole formation." The workgroup considered areas "susceptible to soil collapse or sinkhole formation," to include all land where the depth to carbonate bedrock is less than 50 feet, and the uppermost bedrock is fractured carbonate materials or other geologic strata where soil collapse or sinkhole formation occurs. In areas not susceptible to soil collapse or sinkhole formation, the workgroup recommends that the same rules should apply for liquid manure storage design, construction and operation as throughout the rest of the state.

A shortcoming noted by the workgroup with existing information is the lack of geostatistical analyses indicating the likelihood of soil collapse to occur in a given area. The Minnesota Geological Survey, University of Minnesota and Department of Natural Resources are currently examining the relationship between the presence of karst features and associated geologic conditions. The recommended measures in this report are intended to serve as interim standards until the study is completed and the standards can be revised to more specifically reflect a geostatistical evaluation of sinkhole formation.

The workgroup did not build from existing MPCA policy, but rather took a fresh look at needed standards for the karst region. Existing MPCA policy was only briefly considered during the workgroup process. Workgroup recommendations made in this report reflect the best professional judgement of the workgroup members made after considerable study and discussion of available information on this topic.

The workgroup recommends the following protective measures for areas susceptible to soil collapse or sinkhole formation. These measures are meant to be used in addition to the existing protective measures required by the MPCA throughout the state. These standards pertain to 1) location restrictions, 2) design, and 3) identifying and responding to failures. The standards can be summarized as follows:

Location restrictions

- Maintain a 300-foot setback from sinkholes;
- Relocate site if subsoil inspections during excavation indicate soil subsidence or sinkhole development;
- Avoid construction over mapped caves that become registered with the State;

Design specifications

- Use dual-liners, concrete liners or above ground glass-fused metal
- Limit maximum capacity of a single cell to three million gallons (no total capacity limit per farm and no restrictions based on animal unit numbers);
- Maintain a five-foot minimum separation between manure and bedrock, with some exceptions;
- Convey roof and site runoff waters away from the storage area;

Identifying and responding to failures

- Monitor manure levels regularly and conduct an annual inspection of the liner; and
- Develop an emergency response plan.

The workgroup recommends that the proposed standards in this report replace existing MPCA rules pertaining to design standards in areas susceptible to sinkhole formation. They also suggest that these recommendations be reviewed and refined after completing further study of the likelihood of sinkhole formation under various geologic conditions.

Many similarities can be found when comparing Minn. R. ch. 7020 and workgroup recommendations for areas susceptible to soil collapse or sinkhole formation. For example, both the rules and the workgroup recommendations:

- establish setbacks from sinkholes of 300 feet;
- include major restrictions on use of cohesive soil liners alone;
- allow for use of concrete lined, dual-lined and above ground storage; and
- establish a similar minimum soil thickness needed above bedrock for use of concrete, composite and above ground liners at small to moderate-sized feedlots;

Yet, the specific criteria for some of the recommendations are different. Current MPCA rules for separation to bedrock restrictions vary from five to fifteen feet for concrete pits, dual-lined basins and above ground tanks, depending on the type of liner and the number of animal units on the farm. Whereas, the workgroup recommends that separation to bedrock be a minimum of five-feet, except for two types of designs where separation to bedrock can be less than five feet. MPCA rules allow cohesive soil liners alone where there is a substantial soil thickness between manure and bedrock (e.g., 20 to 40 feet). The workgroup recommends no cohesive soil liners to be used alone without another liner in areas with less than 50 feet from ground surface to carbonate bedrock until further geologic study identifies the areas with less than 50 feet to bedrock that have a low potential for soil collapse or sinkhole formation.

Other workgroup recommendations, such as inspections of subsoil during construction and diverting freshwater away from the manure storage area, are not stated in MPCA rules but are consistent with MPCA guidelines. The MPCA requires manure storage system designs to include plans for periodic inspection of the liner. This is consistent with, but not as specific as workgroup recommendations to require regular monitoring of manure levels and annual liner inspections. The workgroup recommended emergency response plan requirements for all new liquid manure storage systems constructed in areas susceptible to sinkhole formation. Emergency response plans are currently required by MPCA rules at feedlots with 1000 or more animal units.

Another difference between current MPCA policy and workgroup recommendations relates to storage capacity limits. MPCA rules set a 250,000 gallon limit per storage cell in areas with four or more sinkholes within 1000 feet. No other storage capacity limits are set in rules; however, recommended guidelines suggest limits that vary with the liner type and geologic conditions. The workgroup recommends a three million gallon limit in all areas susceptible to sinkhole formation, regardless of proximity of karst features (with the exception of the 300 foot setback requirement from sinkholes).

The workgroup emphasized that further work is needed to:

- Determine the geostatistical probabilities of soil collapse in different types of geologic settings;
- Study pathogen transport through soils below liquid manure storage systems in the karst region;
- Develop generic emergency response plans that can then be tailored for specific feedlot operations;
- Conduct research and demonstration projects on alternative manure management approaches that do not rely on liquid storage;
- Conduct regular monitoring and inspections of existing liquid manure storage systems; and
- Collect, manage, analyze, interpret and map geologic and hydrogeologic information needed for engineers designing liquid storage basins in karst areas.

Chapter 1 - Introduction

1.1 Workgroup Charge and Scope

In December 1999, the Minnesota Pollution Control Agency (MPCA) proposed revisions to rules (Minn. R. ch. 7020) governing animal feedlots and the STORAGE, TRANSPORTATION, AND UTILIZATION of manure. The rule revision updated the 20-year old rules and modified the approach to permitting feedlots. The rule revision also added technical standards for such activities as land application of manure, manure transportation, open lot discharges, manure storage closure, stockpiling, and construction of liquid storage systems. Several new requirements specifically addressed construction of liquid manure storage systems in areas susceptible to sinkhole formation.

Prior to going into effect on October 23, 2000, the revised rule underwent an extensive public review process involving oversight by an Administrative Law Judge. The MPCA made several changes to the rules in response to comments from the public and the Judge. In addition, the Minnesota State Legislature reviewed the rules and passed legislation requiring further changes to the proposed feedlot rules (2000 Session Laws, Chapter 435). No changes were made to the rules pertaining to manure storage in areas susceptible to sinkhole formation. However, the legislature requested that a workgroup be convened to review and propose standards related to this topic. The legislation in section 13 of 2000 Session Laws, Chapter 435, states:

> "The commissioner of the Pollution Control Agency shall convene a workgroup consisting of representatives from Natural Resources Conservation Services and private sector licensed professional engineers, including individuals with expertise in hydraulics, structural systems, and geology, to review and propose design standards for liquid manure storage facilities in areas susceptible to soil collapse and sinkhole formation. This review shall include an evaluation of whether such standards should be volume based or animal unit based. The commissioner shall submit the findings and recommendations of the workgroup to the Senate and House Agriculture and Rural Development Committees by October 31, 2000."

In response, the MPCA convened a technical workgroup to address the specific issues required in the legislation. The workgroup focused on standards for water quality protection that are directly related to the design and construction of liquid manure storage systems in areas susceptible to soil collapse or sinkhole formation. Several issues were considered to be beyond the scope of the workgroup, including in-depth analysis about economics and affordability, extensive investigation of current water quality throughout southeastern Minnesota, and the socio-political ramifications of implementing these recommendations as state law. Risks associated with manure application to fields, liquid manure spills and air emissions were also considered to be beyond the scope and charge of the workgroup (yet these issues are linked to manure storage techniques).

This document discusses workgroup recommendations made for new liquid manure storage areas and major modifications made to existing structures. The workgroup did not address standards for existing liquid manure storage systems currently operating in the karst region.

The MPCA requested and was granted an extension of the report deadline from October 31, 2000, to January 4, 2001.

1.2 Workgroup Members

The MPCA convened a workgroup consisting of individuals who collectively met the requirements of the legislation. The group includes engineers with expertise in the areas of structural engineering, hydraulics, and geology. In addition, engineers were selected who have experience in the following areas: a) designing and constructing liquid manure storage systems in the karst region, b) studying seepage through manure storage system liners, c) evaluating geotechnical information, and d) using alternative liners and liner reinforcement for liquid containment systems.

The ten engineers in the workgroup are listed below. Their education, experience, expertise, addresses and phone/e-mail is included in Attachment A.

Dr. Randal Barnes, P.E. - University of Minnesota, Department of Civil Engineering
Dr. Chuck Clanton, P.E., P.S.S. (alternate Dr. Kevin Janni, P.E.) - University of Minnesota, Department of Biosystems and Agricultural Engineering
Mr. Pete Fryer, P.E. - Joint Powers Board, working in association with NRCS and SWCDs
Mr. Stephan Gale, P.E. - Gale-Tech Engineering
Mr. Art Kalmes, P.E. - Polaris Group
Mr. Robert Mensch, P.E. - Mensch Engineering
Mr. Larry Roehl, P.E. - WHKS & Co.
Mr. Rob Romocki, P.E. - Natural Resources Conservation Service
Mr. Scott Swanberg, P.E. - Natural Resources Conservation Service
Mr. Colby Verdegan, P.E. - Chosen Valley Testing

The MPCA understood the intent of the legislation was for the recommendations to be made by the people from organizations specified in the legislation. All workgroup recommendations included in this report were made by the ten workgroup engineers. The recommendations in this report were not made by the state agency regulatory staff participating in this process. This is very different from a rule-making process where state agencies, local government, private organizations and the public at large provide input into the environmental regulation development process.

The workgroup engineers requested that hydrogeologists experienced in the karst region be present at all meetings. A minimum of two hydrogeologists experienced in the karst region were present at each meeting to advise on issues pertaining to karst geology, soils and hydrogeology. The hydrogeologists included:

Mr. Jeff Green, P.G. - Minnesota Department of Natural Resources
Mr. Bruce Olsen, P.G. - Minnesota Department of Health
Mr. Dave Wall, P.S.S., P.G. - Minnesota Pollution Control Agency

In addition, five other geologists and hydrogeologists with karst expertise were invited to attend one of two meetings held on September 7 and October 2, 2000. These individuals included:

Dr. Calvin Alexander - University of Minnesota, Dept. of Geology and Geophysics
Mr. Robert Libra - Iowa Geological Survey
Dr. Tony Runkel - Minnesota Geological Survey
Mr. Robert Tipping - Minnesota Geological Survey
Dr. Mike Trojan - Minnesota Pollution Control Agency

Mr. Roger Steinberg, Minnesota Extension Service, assisted with meeting facilitation.
Mr. Dave Wall, Minnesota Pollution Control Agency, coordinated workgroup activities and developed the report as directed by the workgroup.

1.3 Workgroup process and principles

The workgroup did not build from existing MPCA policy, but rather took a fresh look at needed standards for the karst region. Existing MPCA policy was only briefly considered during the workgroup process.

The workgroup held all-day meetings on eight days between August 10 and November 27, 2000. Notes from each meeting were incorporated into written summaries that were reviewed and refined by workgroup members following each meeting. Written resource materials were handed out to workgroup members as supplemental information for review and consideration during development of the recommended standards (see Bibliography in Attachment B).

The following background topics were studied by the workgroup during the first four meetings:

- Mechanisms potentially leading to chronic and catastrophic failure when operating liquid manure storage systems in the karst region;
- Environmental consequences of manure storage failures in karst areas;
- Environmental consequences of unachievable standards;
- Standards for liquid manure storage in karst areas outside of Minnesota;
- Historical record of failed and successful waste storage systems in karst regions;
- Minnesota's karst-related standards for other types of contaminant containment;
- Ground water impacts from liquid manure storage systems;
- Site characterization techniques; and
- Perspectives from MPCA, Minnesota Department of Health, Minnesota Department of Natural Resources;

Prior to the development of recommended standards, the workgroup spent considerable time discussing the criteria and principles to use as a basis for developing the standards. The workgroup agreed that the standards should protect the environment from both chronic problems resulting from seepage out of the liquid manure storage system, and from catastrophic problems resulting from a soil collapse below the storage system. The workgroup decided that the design standards needed to be developed in conjunction with standards for construction, operation and monitoring.

Workgroup discussions about risk management led to the conclusion that no matter how a system is engineered, there will still be a potential for environmental failure. The workgroup suggested that the goal should not be to develop standards that prevent all risk of pollution, but that the standards should be developed to greatly reduce the potential for environmental problems. The workgroup sought to develop standards that will minimize risks to water quality to the maximum extent practical, while considering the following criteria:

1. Maintain the level of environmental risk at or near the level of risk as for other non-karst areas of Minnesota (particularly as it pertains to chronic seepage effects on water quality).

2. Prevent acceleration of soil collapse below a manure storage system (compared to conditions prior to construction) that could result from seepage out of the storage system or poor surface water drainage conditions on the land surface near the manure storage system.

3. Allow for construction activities that would provide a greater level of environmental protection than existing operating conditions, or the "next best alternative" that would exist if there was to be no construction (e.g. to allow for new liquid manure storage systems that will replace old unlined basins or to correct a serious manure runoff problem to surface waters).

4. Do not construct storage systems in areas or in ways likely to lead to failure, based on an understanding of the processes that can lead to failure.

5. Use best available technology when the best available technology is needed to meet the above objectives and is considered feasible.

6. Develop standards that will not preclude the continued operation of animal agriculture throughout much of the karst region (e.g. maintain standards that are within economic reason).

The recommendations in this report reflect the best professional judgement of workgroup members made after considerable study and discussion of existing resources related to this topic.

As required by Minnesota Statutes Section 3.197, the cost to convene the workgroup, develop the recommendations and write, print and distribute the report, including all public and private sector contribution of time, is $48,956 ($21,356 MPCA and 27,600 non-MPCA).

Chapter 2 - Background

2.1 Environmental concerns of liquid manure storage in karst areas

Much of Southeastern Minnesota is considered a "karst" landscape (Figure 1). Karst is a geologic term for a landscape area created over soluble rock with efficient drainage. The underlying carbonate[1] bedrock in karst regions dissolves over long periods of geologic time to produce solution enlarged joints and cracks. These features can result in rapid transmission of contaminants from the land's surface to the ground water below. Karst areas often have features such as sinkholes,[2] caves, springs, and blind valleys.[3] However, the lack of these features does not mean that an area does not have "karst" geology. The extent of karst feature development varies tremendously across southeastern Minnesota, and often changes abruptly within a scale of hundreds of feet.

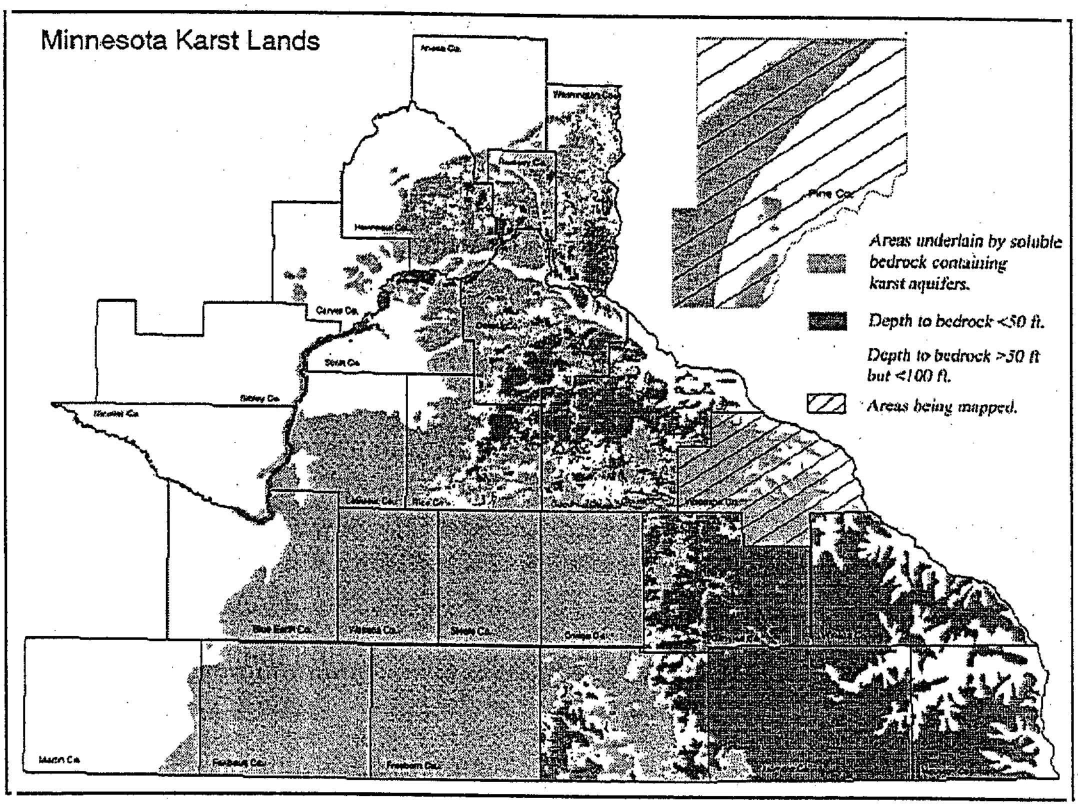

Figure 1 Minnesota Karst Lands - Most karst features are found in areas with less than 50 feet of sedimentary cover over bedrock (from Gao et al., 2000 in draft)

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[1] Carbonate bedrock – typically dolostone or limestone.

[2] Sinkhole – surface depression caused by collapse of soil or overlying formation above fractured or cavernous bedrock, or such depressions that have been filled.

[3] Blind valley – valleys that have no surface outlet and water from the stream or intermittent stream enters the ground.

Karst conditions represent a sensitive environment for contamination of the upper aquifers and surface waters. Some of the heightened environmental concerns characteristic of karst areas include:

1. *Shallow soils above bedrock* – reducing the chance for treatment and attenuation of contaminants introduced at the land surface;
2. *Highly fractured bedrock* - potentially leading to rapid contaminant transport to other underground locations or streams, and making it very difficult to collect, remove and treat contaminants after moving into bedrock;
3. *Soil collapse/sinkhole development* - that can lead to failure of liquid impoundment structures;
4. *Existing Sinkholes and other openings into the ground* – that can funnel contaminants in surface runoff directly into the ground water;
5. *Interconnected system of surface and ground water* – so that contaminants entering ground water can be rapidly transported to surface waters, and visa-versa;
6. *Steeply sloping landscapes* – accelerating surface runoff and erosion;
7. *Large number of wells in the uppermost bedrock aquifer* – so that many private domestic water sources and some public water sources are vulnerable to contamination;
8. *Highly variable and unpredictable geology* – leading to a lower level of certainty regarding contaminant transport.

Several concerns have been raised in recent years regarding the construction and operation of liquid manure storage systems in Minnesota's karst region. Four potential water quality risks associated with liquid manure storage systems in the karst region are described below. The first and second risks could lead to long-term chronic problems, whereas the third risk is a catastrophic failure.

1. Seepage of contaminants through the storage facility and underlying soil to fractured bedrock and subsequently to ground water;
2. Soil subsidence below the structure which breaches the integrity of the liner, causing slow continuous leaking of manure from the storage system to ground water; and
3. A sinkhole forming below a manure storage system causing either a rapid flow of manure directly into ground water, or a collapse in a basin sidewall resulting in a release of manure onto the ground surface where it could then flow to streams.
4. Surface runoff of liquid manure from the storage area to sinkholes, blind valleys, losing streams or areas with very thin soils above bedrock (e.g. resulting from a spill, overflow, or sidewall failure).

Manure entering ground water will threaten drinking water supplies as it travels toward streams. Most of the people in southeastern Minnesota rely on ground water for drinking water supplies. Manure entering ground water will ultimately discharge into streams within a period of time ranging from hours to decades depending on the site-specific hydrogeology. The karst region of Minnesota maintains a large number of high quality trout streams. A rapid discharge of a large quantity of manure into a stream will destroy the aquatic life for a stretch of the stream until the stream is rejuvenated. Ultimately the discharge will also increase contaminant loading into the receiving waters of the Mississippi River system. Manure that travels in the ground water for a longer period before discharging into streams will be more diluted and may not destroy aquatic life, but can still contribute to stream pollution upon discharge into the stream.

Basin overflows and discharges from manure storage structures have been problems at some facilities in Minnesota. Another potential water quality risk from liquid manure storage systems is a failure of earthen basin sidewalls to hold liquid manure. This type of risk appears to be minimal with systems permitted in Minnesota, given that sidewall failures are not known to have occurred in Minnesota at any of the over 2500 earthen basin facilities permitted by the MPCA.

2.2 Historical record of failed and successful waste storage systems in karst regions

Hundreds of manure storage systems have been constructed in the karst region in Minnesota and have been in operation for several years to several decades. The Natural Resources Conservation Service (NRCS) and Soil and Water Conservation Districts (SWCDs), which provided assistance with the design and construction of many of these systems, is not aware of any catastrophic failures of liquid manure storage systems into sinkholes in Minnesota. However, the NRCS and SWCDs are aware of several cropland runoff retention ponds for erosion control that have failed into sinkholes. Runoff retention ponds are typically constructed without any sort of a liner and are not designed to minimize seepage.

The MPCA is aware of one instance in Fillmore County, Minnesota, where manure seepage through a soil liner into fractured bedrock occurred at such a rapid rate that the storage system did not ever need to be pumped and the farmer's well was severely contaminated. During the original construction of the earthen basin, the soil was reportedly excavated to depths exceeding those in the approved design plan. A new well and installation of a synthetic liner corrected the problem for that producer. There have been few farms with ongoing monitoring or documentation of manure levels throughout southeastern Minnesota to gain an understanding of how frequently excessive seepage problems occur in areas with shallow soils above bedrock.

The workgroup contacted people in ten other states with karst geology to find out if there have been any sinkholes forming below liquid manure storage systems in these other states. Sinkholes have developed below four earthen hog manure storage systems in Kentucky, as reported in Crawford, 1998. In Florida, a sinkhole developed in a new storage system after the basin was filled with water to check for problems. No other known sinkhole-related manure storage failures were reported by the other states for manure storage.

Sinkholes have formed below municipal wastewater treatment ponds in Minnesota. Between 1974 and 1992, sinkholes opened below three of the twenty-two municipal wastewater treatment ponds in Minnesota's karst region. Sinkholes developed in Altura's ponds in 1974 during construction and in 1976 when it first filled to capacity (Alexander and Book, 1984). A sinkhole developed in a Lewiston pond in 1991 after eighteen years of use (Jannik et al., 1992). Several sinkholes developed in a Bellchester pond in 1992 after twenty-two years of use (Alexander et al., 1993). The amounts of partially treated wastewater draining into sinkholes at the three respective sites was 3.7, 2.3, and 7.7 million gallons. The ponds were constructed of earthen materials with a designed seepage rate not to exceed 3,500 gallons per acre per day (note that the current minimum design standard for manure storage with soil liners is 500 gal/ac/d and is 50 gal/ac/d for composite liners). Several sinkholes are located within about a mile from all three sites, yet no sinkholes were mapped within about a quarter of a mile from the sites. The environmental consequences of these failures were not thoroughly studied. Sinkholes have also formed below municipal wastewater treatment ponds in Missouri (Aley et al., 1972) and Pennsylvania (Bachir et al., 1999).

These failures clearly demonstrate the potential for sinkholes to develop in southeastern Minnesota when large quantities of liquids are stored in sinkhole prone areas with minimal barriers between the liquid and underlying materials. Similar problems can develop when storing liquid manure above permeable liner materials. It should be noted that allowable design seepage rates for cohesive-soil lined manure storage systems in Minn. R. ch. 7020 is more protective than the standards used for the failed municipal wastewater pond construction. It is also important to consider that the contaminant concentrations in manure are often over 100 times greater than municipal wastewater pond liquids. Thus, the environmental consequences of a catastrophic manure release will be much worse than a similar release from a municipal pond failure.

2.3 Benefits of livestock agriculture in the karst region

Livestock agriculture and liquid manure storage can benefit water quality in the karst region, helping to offset some of the risks to water quality. For example, manure application to land in row crop production can enhance soil properties and reduce soil erosion. Hayland and pastureland associated with dairy and beef cattle operations result in little losses of sediment, pesticides, phosphorus, and oxygen demanding substances. If dairy and beef operations leave southeastern Minnesota, then much of the pasture and hay ground would be converted to row crop agriculture. Erosion rates would be expected to dramatically increase as land is converted to row crop agriculture.

The trends to construct new and expanded feedlot facilities and the associated liquid manure storage system may potentially result in enhanced protection of surface water quality. Liquid manure storage structures increase management flexibility, making it easier to apply at proper rates and to avoid winter-time manure application. Many of the older feedlot facilities in southeastern Minnesota are located next to streams and do not have containment of manure or manure-contaminated runoff. Most facilities with new liquid manure storage structures have total containment of manure so that there is no manure in rainfall and snowmelt runoff waters leaving the feedlot area.

2.4 Minnesota policy on liquid manure storage in karst areas

Minnesota Rules pertaining to construction of liquid manure storage systems are found in Minn. Rules Chapter 7020.2005 and 7020.2100 (attachment C). These rules went into effect on

October 23, 2000. The minimum requirements specific to the karst region are found in the following sections of Chapter 7020.

7020.2005 subpart 1 – setback from sinkholes
7020.2100 subpart 2, Item A – storage capacity limit in high risk areas
7020.2100 subpart 2, Item B – Separation to bedrock and liner design requirements
7020.2100 subpart 2, Item C – Exceptions for feedlots with less than 300 animal units
7020.2100 subpart 4, Item A(3) and (4) – soil investigation depth requirements
7020.2100 subpart 4, Item A(7) – karst feature identification requirements

The MPCA has also developed interim guidelines that incorporate the minimum standards in the revised feedlot rules and additional recommended site specific evaluations and measures to safeguard water quality (attachment D). A comparison of the current MPCA policy with workgroup recommendations is included in Chapter 4 of this report.

The Minnesota Environmental Quality Board recently modified their rules to include a provision for the karst region. Minn. Rules Chapter 4410.4300 subpart 29, requires that an Environmental Assessment Worksheet (EAW) be completed when there is an expansion of more than 500 animal units or a new feedlot is constructed with more than 500 animal units, and a karst feature exists within 1000 feet of the proposed site. Karst features specified in the rule include sinkholes, caves, resurgent springs, disappearing springs, karst windows, blind valleys, or dry valleys.

2.5 Other states' standards for liquid manure storage in karst areas

The workgroup reviewed the liquid manure storage system policies of ten other states with karst geology. The requirements for other states can be summarized as follows:

- The requirements vary greatly among the various states;

- Very few multi-million gallon manure storage systems are being constructed in areas that have a high degree of karstification. (For example, Florida's climate and cropping systems are such that they can typically apply manure year-round and therefore they do not need large manure storage systems. In northern U.S. karst states, most of the farms in the karst regions are reportedly small.)

- Most states rely largely on the design engineers to determine the needed measures for protection, and many of the engineers are recommending concrete, above ground storage or impermeable liners. In Florida, Pennsylvania and Indiana, concrete liners are used at most of the manure storage systems constructed in karst areas. Above-ground manure storage is typical in Ohio's karst region.

- Many states allow cohesive soil liners to be constructed in karst regions if the liner has a permeability less than either 1X10-6 cm/sec or 1X10-7 cm/sec. Missouri does not allow cohesive-soil liners alone in areas where a geologic assessment identifies severe karst risks and in some areas of moderate risk. Iowa's laws state that for operations exceeding 200,000 pounds of swine or poultry or 400,000 pounds of bovine (approximately 1333 finishing hogs or 400 cows), earthen basins (using only a cohesive soil liner) shall not be located on a site that exhibits karst features such as sinkholes or solution channeling.

- Kentucky, Missouri, Wisconsin, and Iowa have setbacks from sinkholes of 150, 300, 400 and 500 feet, respectively.

- Missouri, Florida, and Wisconsin require a site assessment to determine the relative risk of the site before determining the needed type of liner system.

- Depth to bedrock requirements vary. Some states did not report to have minimum depth to bedrock standards. Other states set minimum separation to bedrock from 2 to 4 feet, with additional separation needed if using a cohesive soil liner alone (i.e. 10 or 20 feet). For example, Iowa's separation to bedrock laws (which apply only to larger feedlots) require four feet of soil above bedrock for use of a composite liner, and ten feet where only a soil liner is used. Iowa does not specify a bedrock separation for concrete.

Chapter 3: Workgroup Recommendations

3.1 Defining areas susceptible to soil collapse or sinkhole formation

The workgroup was asked by the Minnesota State Legislature to propose standards for "areas susceptible to soil collapse or sinkhole formation." Until further geologic refinements can be completed, the areas determined by the workgroup as potentially susceptible to soil collapse and sinkhole formation include all land where the depth to carbonate bedrock is less than 50 feet and the uppermost bedrock is fractured carbonate materials or other geologic strata where soil collapse or sinkhole formation occurs (e.g. New Richmond Sandstone or base of the St. Peter Sandstone). In addition, land with more than 50 feet to bedrock may also be considered susceptible to sinkhole formation if karst features exist within 1000 feet of the proposed site, and geologic conditions near the karst features are similar to geologic conditions at the proposed site. Karst features include sinkholes, blind valleys, mapped caves registered in accordance with recommendation B, resurgent springs, karst windows, blind valleys and dry valleys. The workgroup recognized that there is a wide range of soil collapse risks within all lands considered by the workgroup to be "susceptible to soil collapse or sinkhole formation."

In areas not susceptible to soil collapse or sinkhole formation, the workgroup recommends that the same rules should apply for liquid manure storage design, construction and operation as throughout the rest of the state. These low risk areas include land where there is over 50 feet of soil, unconsolidated sandstone, and shale above carbonate bedrock and no karst features exist within 1000 feet.

The workgroup made the following recommendations in regards to defining areas susceptible to soil collapse or sinkhole formation:

Recommendation A - The workgroup recommends that the Minnesota Geological Survey complete investigations to determine areas where there is less than 50 feet of soil above bedrock, and to assess the geologic conditions in these areas that indicate susceptibility to soil collapse and sinkhole formation (please also see related recommendations for further study in Chapter 6).

Recommendation B - The workgroup recommends that where published maps showing areas with less than 50 feet to consolidated bedrock are not available, that such maps be developed by the Minnesota Geological Survey.

3.2 Recommended standards for areas potentially susceptible to soil collapse or sinkhole formation

The workgroup made several recommendations for additional protective measures in areas considered to be potentially susceptible to soil collapse or sinkhole formation. The workgroup suggests that the recommended standards replace existing Minnesota rules pertaining to design standards in areas susceptible to soil collapse or sinkhole formation. The recommendations are intended to be in addition to minimum statewide standards set in Minn. Rules Chapter 7020. A comparison of workgroup recommendations with existing MPCA policy for karst regions is included in Chapter 4. A discussion of workgroup considerations and justification related to these recommendations is included in Chapter 5.

The workgroup recommendations for areas susceptible to soil collapse or sinkhole formation include several standards that should be added to existing statewide minimum requirements. These added standards pertain to 1) location restrictions, 2) design specifications, and 3) identifying and responding to failures, as follows:

3.2.1 Location restrictions

The workgroup agreed on the following three recommendations concerning sites where construction of liquid manure storage systems should be prohibited. The workgroup discussion pertaining to these recommendations is found in section 5.1.

Recommendation C - The workgroup recommends that liquid manure storage systems not be constructed directly over sinkholes or within 300 feet from the outside edge of sinkholes. For the purposes of this recommendation, sinkholes refer to surface depressions caused by collapse of soil or overlying formation above fractured or cavernous bedrock, or such depressions that have been filled.

Recommendation D - The workgroup recommends requiring a construction inspection of the soil subgrade by a licensed geologist, soil scientist or engineer with education and experience in karst geology. An inspection form should be completed by an inspector and submitted to the design engineer so that it can be part of the construction report. Construction should not be allowed in areas where subsoils have moved into fractured bedrock so as to cause voids in the soil or a downward movement of topsoil. If the inspector identifies possible indications of potential soil subsidence or sinkhole development, including soil voids, piping, channels, or topsoils found at deeper depths, then the inspector must notify the MPCA and design engineer so than an evaluation can be made of whether the site must be moved to an alternative location.

Recommendation E - The workgroup recommends that the state establish an official registration process for caves and determine the location of land areas which could affect the registered caves. The workgroup recommends that liquid manure storage systems be prohibited from being constructed over mapped and registered caves.

Recommendation F - The workgroup recommends that the state complete research of statistical probabilities of soil collapse in different types of geologic settings. The topic of location restrictions should be revisited after obtaining a better understanding of the statistical relationship between geologic conditions and soil collapse.

3.2.2 Design Specifications

The following protective measures are recommended for areas susceptible to soil collapse or sinkhole formation. These measures are meant to be used in addition to the existing protective measures required by the MPCA throughout the entire state.

Recommendation G – The workgroup recommends that the liquid manure storage system design be one of the following:

(i) A dual-lined or composite-lined manure storage system consisting of one of the following combinations of materials: a) compacted cohesive soil liner meeting MPCA standards over a geomembrane or geosynthetic liner, or b) two geomembrane liners separated by enough material so that a puncture of one layer is unlikely to penetrate the other liner. These designs should include five feet or more of soil between the manure and bedrock, including any soil used for part of the liner system.

(ii) Concrete-lined manure storage area, and five feet or more of soil between the manure and bedrock;

(iii) Above ground tanks with concrete floors, and five feet or more of soil between the top of the concrete and bedrock.

(iv) Concrete lined with a secondary geomembrane liner for leachate collection. Leachate, tank leakage and rain water percolating down through backfill, shall be collected in a tile above the plastic liner and conveyed by non-perforated pipe or tile to a grassed daylight outlet at least 50 feet from the manure storage area. A separate perimeter drainage tile may be required to control the elevation of the water table or saturated soils. No minimum separation distance from the bedrock is established, except that the plastic liner shall be placed on a cushion of soil or sand with a thickness determined by the design engineer.

(v) Above-ground tanks with concrete floors and a secondary geomembrane liner for leachate collection. Any seepage liquids and rain water percolating through backfill, shall be collected in a tile above the plastic liner and conveyed by non-perforated pipe or tile to a grassed area at least 50 feet from the manure storage area. No minimum separation distance from the bedrock is established, except that the plastic liner shall be placed on a cushion of soil or sand with a thickness determined by the design engineer.

Recommendation H –Design plans shall indicate the method for regular measurement of liquid manure levels in association with Recommendation K(1).

Recommendation I – The workgroup recommended that at sites susceptible to soil collapse, a new or modified liquid manure storage area should be limited to a maximum of three million gallons. A storage area is considered a single cell that is spaced far enough from adjacent cells so that a sinkhole forming below one cell will not affect the integrity of the adjacent cell(s). If cells are connected by pipes and designed such that if one cell drains the other one will also drain, then the total capacity of the individual cells should be no greater than 3 million gallons.

Recommendation J - The workgroup recommends that design plans show how barn roof runoff, rain water percolating through uncompacted backfill, tile line waters, and surface runoff near the liquid manure storage area will be intercepted, collected and conveyed away from the liquid manure storage area. All pipes conveying water must not outlet within 50 feet of the manure storage area and must discharge onto sloping land such that no ponding of water occurs within 300 feet of the liquid manure storage area.

3.2.3 Identifying and responding to failures

To help ensure that the manure storage areas are operating as intended by the design engineer, and to minimize the risk of environmental damage from any failed systems, the workgroup strongly recommended the following requirements.

Recommendation K - The workgroup recommends that at sites susceptible to soil collapse, inspections and monitoring be conducted as follows:

(1) An annual visual inspection of the storage system should be conducted after pump-down, except that inspections should not be required in confined spaces such as the interior of earthen basins that have a membrane cover for odor control, concrete pits under slat floor barns and other covered storage areas; and

(2) Manure levels should be checked and documented at least weekly within drinking water supply management areas where the aquifer is vulnerable, and at least monthly for other areas (preferably weekly at all sites, where possible).

Recommendation L - The workgroup recommends that an emergency response plan be required at all feedlots in areas susceptible to soil collapse. The plan should include notification procedures and action steps for any spill or loss of liquid manure from the structure.

Chapter 4: Comparison of workgroup recommendations with current Minnesota policy

4.1 Comparison overview

Minnesota rules pertaining to construction of liquid manure storage systems are found in Minn. R. ch. 7020.2005 (attachment C). The MPCA has also developed interim guidelines that incorporate the minimum standards in the revised feedlot rules and additional recommended site specific evaluations and measures to safeguard water quality (attachment D). The workgroup understood that the intent of the legislation was for the workgroup to take a fresh look at needed standards for the karst region, and thus not focus on existing MPCA policy. Therefore, existing MPCA policy was only briefly considered during the workgroup process. Following the finalization of the workgroup proposals, the MPCA drafted this Chapter 4 comparison of current MPCA policy to workgroup proposals.

The Table below shows a comparison summary of MPCA requirements in rules, recommendations in MPCA guidelines, and how existing policy compares to recommendations developed by the workgroup.

Issue	MPCA minimum requirements for karst areas as stated in rules Chapter 7020	MPCA recommended guidelines	Workgroup Recommendation for rules
Prohibited Sites for liquid manure storage	300 feet from sinkholes (7020.2005 subp. 1)	300 feet from sinkholes	300 feet from sinkholes (existing and filled) and over registered caves
Areas where rules are the same as the rest of the state.	Areas not susceptible to soil collapse or sinkhole formation (no further definition of these areas is included in the rules)	Same as rules. Guidelines indicate the types of conditions where there is a low risk of soil collapse.	Areas where there is at least 50 feet of unconsolidated materials above carbonate bedrock and also no karst features within 1000 feet.
Maximum storage capacity in areas susceptible to sinkhole formation	250,000 gallon limit per cell where four or more sinkholes exist within 1,000 feet. No other capacity limits. Some exceptions for feedlots with less than 300 animal units correcting pollution problems.	Same as rules. In addition, one million gallon limit per farm is recommended for areas with a high risk of soil collapse, as defined in the guidelines.	Three million gallons per storage cell. No maximum limit per farm.
Use of cohesive soil liners (with no secondary liner) in areas susceptible to soil collapse	Permitted only in areas with a separation distance between manure and bedrock of 20, 30 and 40 feet for operations with <300, 300-1000, and >1000 animal units, respectively. Some exceptions if <300 AU.	Same as rules. In addition, only recommended for use where the risk of soil collapse is considered low in accordance with the guidelines.	Do not allow earthen liners alone in areas susceptible to soil collapse until further geologic study is completed

Issue	MPCA minimum requirements for karst areas as stated in rules Chapter 7020	MPCA recommended guidelines	Workgroup Recommendation for rules
Use of concrete liners and composite liners (2 foot cohesive soil liner overlain by a geomembrane liner) in areas susceptible to soil collapse	Permitted in areas with at least 5 to 15 feet of separation to bedrock, varying with the size of the farm (in animal units). Some exceptions for feedlots with less than 300 animal units correcting pollution problems.	Same as rules. In addition, these liners are not recommended for storage of more than about 2 million gallons where the risk of soil collapse is considered high in accordance with the guidelines.	Permit in areas with at least a five foot separation to bedrock.
Use of concrete liners over secondary liners in areas susceptible to soil collapse	Permitted where separation to bedrock is at least 5 and 10 feet for operations with less than and more than 1,000 animal units, respectively. Some exceptions for feedlots with less than 300 animal units correcting pollution problems.	Same as rules	Permitted as long as secondary liner is geomembrane material and a ground surface outlet is installed for any drainage waters. No minimum separation to bedrock.
Site Investigation	Soil investigations to a depth that verifies minimum separation to bedrock requirements and karst feature identification within a half mile of the proposed site.	Same as rules. Site investigation methods and analysis are included in the guidelines.	Soil investigations to a depth that verifies separation to bedrock requirements will be met. Identify all existing and filled sinkholes to ensure that all setbacks and other laws are being met.
Monitoring	Design plans must include a plan for operation, periodic inspection and maintenance of the storage area. Specific plans to be decided by the design engineer.	Regular inspections for liner damage, seepage problems, or soil collapse.	Weekly to monthly monitoring of manure levels. Annual inspections following manure removal.
Construction Requirements	Numerous requirements for all areas of the state. No specific requirements for karst areas.	In addition to statewide requirements, inspect subsoil during construction for possible karst features	In addition to statewide requirements, inspect subsoil during construction for possible karst features
Water infiltration near the storage area	No requirements in rules.	Grading and routing water so that freshwater from roof runoff and other collected precipitation does not infiltrate near the storage area.	Grading and routing water so that freshwater from roof runoff and other precipitation does not infiltrate near the storage area.
Emergency Response Plan	Not specific to karst region. All feedlots with over 1,000 animal units must develop an emergency response plan.	Not included in current guidelines.	Plans needed for all new or modified liquid storage in areas susceptible to soil collapse.

Many of the workgroup recommendations are generally consistent with MPCA policy. For example, both MPCA rules and workgroup recommendations:

- establish 300 foot setbacks from sinkholes;
- include major restrictions on use of cohesive soil liner used alone without other liners;
- allow for use of concrete lined, composite lined and above ground storage in karst areas;
- establish a similar degree of separation to bedrock conditions for use of concrete, composite and above ground liners for small to moderate-sized feedlots; and
- include site investigation requirements for soil investigations.

Yet, several of the workgroup proposals are found in MPCA recommended guidelines, but not in MPCA rules (mandatory).

The workgroup proposals generally fall into three categories:

1) *Workgroup proposed additions to MPCA rules* - recommendations that are not currently included in Minn. Rules Chapter 7020, but that are generally consistent with MPCA guidelines and past permit requirements;

2) *Recommended alternative standards to MPCA rules* - recommendations to replace existing provisions of MPCA rules with new standards; and

3) *Proposals for further study* - recommendations for additional research, study or work that will provide clearer justification for modifying/refining design standards, and that will better enable engineers to locate and design liquid manure storage systems in karst regions.

Each of these three categories are discussed below.

4.2 Workgroup proposed additions to MPCA rules

Several workgroup recommendations are not currently included in Minn. Rules Chapter 7020. The workgroup recommended that the following be added to MCPA requirements for liquid manure storage systems in areas susceptible to soil collapse or sinkhole formation:

Recommendation D – Construction inspections of subsoils for karst features (currently in guidelines, not in rules)
Recommendation J – Design and construct to convey surface runoff away from manure storage areas (currently in guidelines, not in rules)
Recommendations H and K – Manure level monitoring and inspections and design plans showing method of manure level monitoring (currently in rules, but not as specific as workgroup recommendations)
Recommendation L - Emergency response plans for all new liquid manure storage constructed in areas susceptible to soil collapse or sinkhole formation (currently emergency response plans are required statewide for 1000 or more animal units).

4.3 Recommended alternative standards to MPCA rules

Two of the workgroup recommendations are different from existing MPCA policy: 1) storage cell capacity limits, and 2) separation to bedrock requirements. The workgroup recommended that their proposed standards replace related existing MPCA rule provisions.

4.3.1 Storage cell capacity limits

Current MPCA rules - MPCA rules set a 250,000-gallon limit per storage cell in areas with four or more sinkholes within 1000 feet (7020.2100, subpart 2, Item A). No other storage capacity limits are set in MPCA rules. The MPCA allows exceptions to the 250,000-gallon limit, if the farm has less than 300 animal units and the storage system is needed to correct a pollution hazard (see 7020.2100 Subpart 2, Item C). Roughly two to ten percent of land in the counties with karst geology have sinkhole densities that would trigger the 250,000-gallon limit. Few liquid manure storage systems have been proposed in high sinkhole density areas (e.g., more than 4 sinkholes within 1000 feet) in recent years. MPCA guidelines recommend storage capacity limits that vary with the liner type and an assessment of the karst geology conditions.

It should also be noted that a mandatory environmental assessment worksheet (EAW) is required before an expansion of 500 or more animal units when one or more sinkholes is within 1,000 feet of a proposed site (Minn. R. 4410.4300, subp. 29). A discretionary EAW may be requested by the MPCA for other sites below the 500 animal unit threshold if the agency determines that the project may have the potential for significant environmental effects (Minn. R. 4410.5400).

Workgroup recommendation - The workgroup recommends a three million gallon limit in all areas susceptible to sinkhole formation (recommendation I). The workgroup proposes that the three million-gallon limit be the only storage capacity requirement at this time. The three million-gallon limit for all areas susceptible to sinkhole formation would replace the MPCA rule in 7020.2100, subpart 2, item A. Workgroup recommendation I could be considered to be more restrictive than MPCA rules for areas outside of high sinkhole density zones (e.g., 3 million-gallon cell capacity limit, instead of no limits in the current rules). However, recommendation I is less restrictive than MPCA rules for high sinkhole density areas (e.g., allowing a three million-gallon cell capacity limit instead of a 250,000 gallon limit). Both MPCA rules and workgroup recommendations prohibit construction within 300 feet of a sinkhole. A comparison of MPCA rules and workgroup proposals for different situations is included below (Table 4.1).

Table 4.1 Single-cell manure storage capacity limits

Site Conditions	MPCA Policy	Workgroup Proposal
Four or more sinkholes w/in 1000 ft. No pollution hazard or more than 300 animal units (AU)	250,000 gallon limit in rule	3 million gallons
Four or more sinkholes w/in 1000 ft. Feedlot has less than 300 AU and is correcting a pollution hazard	No limit in rules. Guidelines suggest total farm manure storage capacity limits based on liner type and geologic conditions.	3 million gallons
One or more sinkholes w/in 1000 ft. and more than 500 AU	EAW required. Guidelines suggest total farm manure storage capacity limits based on liner type and geologic conditions	3 million gallons
Less than four sinkholes within 1000 ft. and No EAW required	No limit in rules Guidelines suggest total farm manure storage capacity limits based on liner type and geologic conditions	3 million gallons

4.3.2 separation to bedrock requirements

Current MPCA rules for separation to bedrock restrictions vary from 5 to 15 feet for concrete pits, dual-lined basins and above ground tanks, depending on the type of liner and the number of animal units on the farm. Whereas, the workgroup recommends that separation to bedrock be a minimum of five feet for these same types of manure storage systems, except for two types of designs where no minimum separation to bedrock is necessary. MPCA rules allow cohesive soil liners alone where there is a substantial soil thickness between manure and bedrock (e.g., 20 to 40 feet). The workgroup recommends no cohesive soil liners to be used alone without another liner in areas with less than 50 feet from ground surface to carbonate bedrock. However, the workgroup recommended review and potential revising of this requirement after further geologic study identifies the areas with less than 50 feet to bedrock that have a low potential for soil collapse or sinkhole formation.

A more specific comparison of MPCA rules and workgroup recommendations related to separation distances between manure and the underlying bedrock is shown below (Table 4.2).

Table 4.2 Comparison of separation to bedrock restrictions (all units in feet)

	Composite, Concrete, above ground tanks		**Concrete w/geomembrane or above ground tank with geomembrane**		**Soil liners only (assuming basin is 10 feet below ground surface)**	
	MPCA Rules	Work-group	MPCA Rules	Work-Group	MPCA Rules	Work-Group
Less than 300 AU	5	5	5	Engineer determines Soil cushion	20	40
300 to 999 AU	5-10	5	5	Engineer determines Soil cushion	30	40
1000 or more AU	10-15	5	10	Engineer determines Soil cushion	40	40

4.4 Proposals for further study

The remaining workgroup proposals pertain to areas needing further research, study or work, including:

Recommendation A - Assessing geologic conditions that indicate susceptibility to soil collapse and sinkhole formation (use this information for future revisions to rules).

Recommendation B - Developing/completing maps showing areas with less than 50 feet to bedrock (tool for engineers, producers, state/local agencies).

Recommendation E - Developing registration and mapping process for caves (joint MDNR and MGS effort).

Recommendation F - Researching statistical probabilities of soil collapse in different geologic settings (use this information for various policy decisions).

Several other recommendations for further study are also included in Chapter 6, including:

- Studying pathogen transport below liquid manure storage areas
- Developing template emergency response plans
- Exploring and demonstrating alternatives to liquid manure
- Conducting inspections of existing liquid manure in karst areas
- Collecting, analyzing, interpreting and mapping karst feature information

Chapter 5: Workgroup Considerations and Justification

5.1 Location Restrictions

The workgroup considered whether there are sites where liquid manure storage systems should not be constructed, no matter how small the storage system is, or how it is designed?" Several potential site restrictions were discussed, including a) over a known sinkhole, b) in high risk geographic areas such as sinkhole plains, c) over known caves, d) in close proximity to conduits to ground water, e) in vulnerable wellhead protection areas for municipal wells, and f) near private wells.

The workgroup agreed that the only criteria that should be used in state rules to prohibit construction are a) directly over or within 300 feet of a sinkhole or b) over a registered cave. There was discussion about the possibility of building on top of sinkholes by using void spanning concrete designs or geogrids to span a distance of twice the depth to bedrock (assuming a slope no greater than 45 degrees on the sinkhole sidewalls). However, the workgroup decided that manure storage systems can usually be moved to be more than 300 feet from sinkholes and there are uncertainties about sinkhole diameter and practical limits (e.g. 10-20 feet) of void spanning reinforcement.

Prior to setting the 300 foot setback, the workgroup considered using a 50-foot setback from sinkholes since sinkholes in Minnesota rarely expand to have a diameter of over 50 feet. In addition, the workgroup did not have geostatistical evidence indicating that new sinkholes are more apt to form 50 feet from an existing sinkhole than 300 feet from an existing sinkhole. However, the workgroup agreed that a 50-foot setback does not provide a sufficient margin of safety. Several examples were cited regarding subsurface conduits that extended well beyond 50 feet from existing sinkholes. The workgroup decided that 300 feet provided a greater margin of safety. A 300 foot setback from sinkholes exists in current MPCA rules for all new feedlots, not just liquid manure storage construction. A 300-foot setback is also more consistent with other states where setbacks range between 150 and 500 feet.

The workgroup discussed whether construction should be prohibited over known caves, due to the potential for bedrock collapses over the cave and the potential for long-term damage to the cave ecosystem. The workgroup agreed that preservation of certain caves is important, and they agreed on the concept of prohibiting construction of liquid manure storage directly over large cavernous openings directly below the ground. However, several concerns were raised about automatically prohibiting construction over known caves. Some of the concerns include:

a) The likelihood of bedrock collapse is small, particularly if the cave is deep within the bedrock;
b) Caves are networks of conduits and it is too difficult to define the areas where caves are located. A manure spill into one conduit that is not mapped as a cave can lead to a cave;
c) Defining what should be considered a cave and where the caves are located is difficult and subjective, and would likely result in conflict and disagreement among those who want the feedlot and those who do not want a new manure storage system in a given area; and

d) Individuals may know of caves, but they do not tell anybody because they do not want others exploring these caves.

The workgroup reviewed the restriction in Kentucky prohibiting construction of liquid manure storage directly over mapped cave systems associated with national or state parks. This concept was generally supported among the workgroup if the caves were clearly mapped and commercial caves were also included. The workgroup recommended that before sites are prohibited due to the proximity of caves, the legislature should initiate a process to register and map existing caves. Additionally, the workgroup suggested that the state develop recommendations regarding how these caves should be protected (see also related discussion in Chapter 6).

The workgroup discussed the possible need to define high risk-zones within the general areas considered to be susceptible to soil collapse (e.g. in sinkhole plains). For such high risk areas, there was discussion of possibly using geophysics to identify voids and then require void spanning designs where geophysics indicate anomalies or potential voids in the soils/geology. The workgroup agreed that there is currently not enough understanding about the geostatistics and probability of new sinkhole development to be able to specify zones around karst features where these additional measures should be required. The workgroup considered using geophysics to better define site risks, but concluded that the decision to use geophysics should be left to the design engineer given that this work does not provide assurances of a safe site and can be quite costly.

The workgroup agreed that there should be no special provisions for wellhead protection areas, watersheds with trout streams, or land near state parks, other than adopting the protective measures for all land susceptible to soil collapse.

5.2 Areas with similar water quality risks as the rest of the state

The workgroup consulted karst geologists who have studied SE Minnesota to determine the geologic conditions where sinkholes rarely form. Such areas include land where there is more than 50 feet of unconsolidated materials above bedrock. Sinkholes can still form even when there is over 50 feet of cover materials, but the likelihood of soil collapse or sinkhole formation is very low in these areas. The workgroup decided that areas with over 50 feet to bedrock and no karst features within 1,000 feet should be excluded from restrictions for areas "susceptible to soil collapse or sinkhole formation."

The workgroup also suggested that there can be areas with less than 50 feet of unconsolidated material above bedrock, and yet still not be susceptible to soil collapse. For example, in areas where there is a substantial thickness of Decorah shale, sinkholes are not likely to form. However, the workgroup was unsure at this time about the minimum thickness of Decorah shale to prevent sinkhole formation. The workgroup recommends that the Minnesota Geological Survey identify other geologic conditions where sinkholes are not likely to form (in the zones with less than 50 feet to consolidated bedrock).

The workgroup highly recommended that maps be developed to clearly identify areas where the depth to consolidated bedrock is less than 50 feet. A preliminary map (with some missing counties) was developed showing areas where there is less than 50 feet of soil cover above fractured bedrock (see Figure 1). Larger scale maps should be developed for individual counties or townships where such maps have not been completed. The workgroup also agreed that at sites where it is not certain from the maps that there is over 50 feet of cover (i.e., fringe areas), then borings and/or further geologic analysis should be conducted to demonstrate the presence of over 50 feet of unconsolidated materials.

5.3 Liner Types

The workgroup recognized that excessive seepage through liners can cause underlying soil to be washed into fractures in the bedrock, and thus induce sinkhole development. One of the primary ways the workgroup sought to minimize risk of catastrophic failure is to use liners that are durable and have very low seepage rates. These liners also have the benefit of reducing chronic risks associated with bacteria/virus movement into fractured bedrock.

The workgroup first listed the main types of liquid storage systems and ranked these systems from highest to lowest risk, based mostly on the seepage rate, durability and ease with which leaks are visible. The workgroup suggested the following, beginning with highest risk:

1. Structures without any type of a liner

2. Earthen basins (2 foot cohesive soil liner)

3. a) Earthen basins (3-4 foot cohesive soil liner), or
   b) Geosynthetic liner with NO underlying clay liner

4. a) In-ground concrete (cast in place w/inspections was considered to be better than precast), or
   b) HDPE (high density Polyethylene) or other plastic-type geomembranes with NO underlying clay liner

5. Dual lined systems
   a) composite liner – geomembrane underlain by cohesive soil liner
   b) concrete underlain by a geomembrane

6. Double-composite lined systems – geomembrane underlain by cohesive soil liner which is then underlain by another geomembrane

7. Systems with very low seepage rates and where major seepage problems are visible:
   a) Above-ground glass-fused metal tank
   b) Above-ground concrete tank

The workgroup also discussed the use of void spanning materials to reinforce geomembrane and composite types of liner systems. Reliable materials have been used and tested extensively for landfills that span voids that are between 10 and 20 feet in diameter. There are some products that have not been found to work well and other products that are more reliable. Mr. Gale noted that the most reliable material is polyester geotextiles or geogrids made by one of three companies 1) Tensar, 2) Mirafi, and 3) Heusaer, all of which can reportedly be installed for $5 to $15 per square yard. However, additional excavation costs will also be incurred since the geotextile/geogrid must be installed beneath the earthen berms. Reinforced concrete can also be used to span voids; however the cost of reinforced void spanning concrete makes it essentially not feasible for manure storage systems.

Initially, the workgroup discussed the possibility of requiring different liner standards depending on the geologic risk of soil collapse found at the site. For example, the workgroup could recommend clay liners at the moderately low risk sites, composite and concrete liners at moderately high-risk sites and the use of void spanning reinforcement for extremely high risk situations. However, the workgroup decided to recommend the same liner requirements in all areas considered susceptible to sinkhole formation, due largely to the lack of clear-cut scientifically justifiable criteria available at this time for assigning different levels of soil collapse risk. In addition, substantial leakage from liquid storage systems has induced sinkhole formation in areas that do not have much evidence of previous soil collapse. Another point was made that many sinkholes have been filled and we can not rely entirely on existing sinkholes as indicators of future collapse at a specific site.

In areas susceptible to sinkhole formation, the workgroup agreed that standard compacted cohesive soil liners alone should generally not be allowed. While cohesive soil liners can be more effective in limiting seepage if they are installed under optimum conditions, the workgroup still had concerns about liner durability and seepage rates that could lead to soil collapse in the karst region. One alternative type of earthen liner design was suggested as a possible option for the karst region. This alternative design would include seven feet of earthen materials, including three feet of compacted cohesive soils (< 1*10-7 cm/sec) overlain by four feet of soil. The four feet of overlying soil would protect the clay liner from problems of desiccation, freeze/thaw, roots, and erosion. Some workgroup members stated that a spillway would be needed so that the basin did not get filled above the elevation of the clay- liner. Concerns about this spillway were also expressed. The workgroup was doubtful whether this type of design would be preferred by anyone instead of a composite-lined system.

The workgroup also discussed the possibility that a cohesive soil liner could be used without a geomembrane if sufficiently thick soils existed below the basin to greatly reduce the seepage from entering the fractured bedrock directly below the basin. Some workgroup members suggested that sites with less than 50 feet of soil cover should not necessarily be prohibited for use of cohesive soil liners alone. The workgroup seemed to believe that there was some merit to considering use of cohesive soil liners alone in areas with less than 50 feet to bedrock. The workgroup decided to wait for more geostatistical information to be completed in order to identify under what soil/geologic conditions soil collapse is unlikely in zones with less than 50 feet to bedrock (and then to reconsider allowing construction of cohesive soil liners alone in such zones).

The workgroup agreed that a dual-lined or composite-lined manure storage area should be allowed in areas susceptible to soil collapse if one of the following combinations of materials is used: a) compacted cohesive soil liner meeting MPCA standards overlain by a geomembrane or geosynthetic liner, or b) two geomembrane liners separated by enough material so that a puncture of the upper layer is unlikely to penetrate the second liner. These types of liners have very low seepage rates, and if one liner is damaged, a secondary liner is in place to retard seepage through the damaged areas. The workgroup also agreed that concrete liners and glass-fused metal or concrete tanks should be allowed in areas susceptible to soil collapse or sinkhole formation. These types of liners are durable and have leakage rates that are very low. The workgroup estimated that the costs of constructing a dual-liner with clay and geomembranes are approximately $1 more per square foot.

The workgroup strongly recommended that further investigations be conducted to gain a better understanding of the likelihood of soil collapse under different geologic conditions, and that the recommendations in this report be reviewed and adjusted in the future to correspond with the more specific geologic criteria.

5.4 Separation to bedrock

The workgroup emphasized that the types of liners allowed in areas susceptible to soil collapse would result in very little seepage, but that there would still be a small amount of seepage. The primary purpose of separation to bedrock requirements are to 1) allow for adsorption of viruses and bacteria onto soil particles until they die-off, or 2) slow the time of travel of liquids so that bacteria and viruses will likely die prior to the liquids entering fractured bedrock. In addition, the soil separation to bedrock will also allow for some attenuation of nutrients and other contaminants associated with manure. Once contaminants enter fractures in the bedrock, there will be very little contaminant treatment. The workgroup generally believed that five feet of soil should likely be sufficient to attenuate bacteria from low seepage rates if there is at least a couple feet of the underlying materials are unsaturated. However, the workgroup also recognized that more research is needed on pathogen transport below manure storage areas and that the five-foot separation should only be used until further research better supports different requirements.

The workgroup discussed the difference between saturated and unsaturated soils below the storage area. Saturated soils or seasonally saturated soils below the basin are characteristic of low permeability soils. Bacteria and viruses are less likely to be adsorbed onto soil particles under saturated conditions; however, the rate of water flow will be reduced in situations where there is a perched water table, providing additional time for bacteria and virus die-off.

The recommendations for separation distance to bedrock for the different liner types were based on the best professional judgement of the workgroup members after considering studies of pathogen transport, seepage through liners, and the practical issues associated with limited soil thickness conditions in the karst region.

The workgroup recommended that construction of certain dual-lined manure storage systems that collect and drain seepage liquids be allowed directly on top of bedrock. With this type of a liner, the hydraulic pressures on the secondary liner will be alleviated, and the risks of seepage through this secondary liner will therefore be very low. A blanket of soil is needed to separate the liner from bedrock to prevent punctures and to allow for differential settlement over uneven bedrock. The thickness of this soil blanket is to be determined by the design engineer or manufacturer of the liner.

5.5 Feedlot size and storage capacity

The workgroup discussed possible options to factor feedlot size/capacity into making decisions about design standards. The workgroup addressed whether design standards should vary with a) number of animal units on the farm, b) number of animal units contributing to an individual storage system, c) total capacity of liquid manure storage at the farm, d) capacity of the individual storage cell, e) none of the above." The workgroup agreed that design standards should vary with capacity of the individual storage cell. Risk is related to the consequence of failure and the probability of failure. As the capacity of the storage system cell increases, the consequences of a failure are generally expected to be worse, reasoned the workgroup.

The workgroup considered several issues before deciding on the best alternative. One consideration was that by setting standards based on cell capacity, we may be encouraging design and use of under-sized manure storage basins, possibly leading to storage system overflow and/or winter application of manure. However, the group reasoned that winter application is not prohibited in state rules and more storage cells can be added if necessary. The workgroup also considered that multiple cells with sloping sidewalls will create more surface area than one individual cell, thereby, increasing the probability of failure compared to one larger cell. More surface area of storage also can create more odor and gaseous emissions into the air. However, the group still agreed after considering these issues that the capacity of the individual cell was the best variable to use in setting standards.

The group also agreed that to be considered an individual cell, a certain separation distance between cells should be maintained. The needed separation distance should be inversely related to depth to bedrock, and directly related to storage system seepage rates- and risks related to the local geology.

The workgroup also pointed out that if two cells are connected by pipes and designed such that if one cell drains the other one will also drain, then the capacity of the two cells should be added and considered as one cell. An overflow pipe can be used to prevent this situation.

After the workgroup decided that standards should vary with cell capacity, the next question was should there be a sliding scale of storage cell capacity limits, or would it be best to set one limit that could be used throughout all areas susceptible to soil collapse? They decided that a single threshold would be best. They reasoned that the consequences of a large manure release (e.g. 20-million gallons) would be much greater than the consequences of a small release (e.g. 20,000 gallons). However, the workgroup had a difficult time selecting one threshold number since there was a poor understanding of the consequences related to releasing various amounts of manure into the ground water or surface waters. Because the workgroup did not believe they could justify specific thresholds based solely on consequences of release alone, the workgroup decided to base cell capacity limits on storage needs of small to moderate sized farms.

The NRCS compiled liquid manure storage capacity information for manure storage systems designed by the NRCS from 1994 to 1998. The average capacity of Dairy and Beef liquid manure storage systems was roughly 1.3 million gallons and the maximum was 2.6 million gallons. These systems were designed to correct problems associated with manure runoff from feedlots. The workgroup also reviewed the annual manure storage needs for a 300 animal unit dairy operation. The 300 animal unit farm is a commonly used threshold in federal and state rules. The workgroup concluded that about 3 million gallons was needed for a dairy operation with 300 animal units. Swine manure storage needs are much less per animal unit than dairy. Based on the NRCS designs and the storage needs for a 300 animal unit dairy, the workgroup suggested two numbers as possible thresholds for maximum storage capacity of a single cell – 3 million gallons and 1.5 million gallons. If they had to pick one number, the group agreed that the better number was 3 million gallons per storage cell. The workgroup agreed that by using either number economic hardship for producers would be minimized, except possibly for large dairies where multiple cells would be needed.

Overall, the workgroup did not have good scientific information to believe that a 3-million gallon release was much worse than a 1.5-million gallon release. Several workgroup members expressed a desire to keep the maximum cell capacity as low as possible without significant hardship to producers. One concern raised about setting small cell capacity limits is that many smaller existing dairy and beef farms do not have enough space near the barns to split the storage systems into multiple cells (e.g., they are adjacent to hills, have shallow depths to bedrock, or the barns are adjacent to other features that limit room for the storage basins). The workgroup agreed that multiple cells, when added together, should be allowed to exceed three million gallons (e.g. no capacity limits per farm).

The workgroup also debated the merits of requiring the manure storage system to hold at least seven months of manure production. The reason for this recommendation was to ensure that the producer will have enough storage capacity to be able to apply manure at a time of year when the manure could be immediately incorporated, thereby avoiding winter application. The workgroup felt this was justified for the karst region given the number of conduits to ground water, rapid contaminant transport, and potentially rapid ground water/surface water interaction.

Two concerns were raised in regards to the seven-month minimum storage recommendation. First, many small farmers often request a smaller storage area to reduce feedlot runoff to streams in a way that is affordable. When small storage systems are used, the farmers will still be applying manure throughout the year, but manure runoff to streams can be greatly reduced. Second, a seven-month capacity minimum was proposed for the purpose of better manure spreading practices, and consideration of manure application practices was not part of the directive given to the workgroup by the legislature. The workgroup decided to highly recommend a **seven-month minimum storage design capacity**, but not to make this a requirement for all feedlots where a manure storage system is constructed.

5.6 Diverting surface runoff

The primary goal of requiring liners with very low seepage rates is to limit the possibility of soils below the manure storage system from being washed into underlying fractures, thereby inducing soil collapse. Infiltration of precipitation waters near the manure storage system can also accelerate sinkhole development. If excessive infiltration of water occurs near the manure storage system, then a sinkhole could develop below the manure storage system. Therefore, the workgroup considered it important to convey precipitation falling on the barn roofs and land near the manure storage system to a location that is not likely to affect sinkhole development near the manure storage system.

The workgroup discussed whether the recommended requirements should specify how far from the manure storage system that freshwater runoff needs to be routed or diverted away from the site. At many sites, the land is sloped sufficiently to carry freshwater away from the site without the need for below ground pipes. The workgroup considered it important that pipes carrying water discharge at least 50 feet from the manure storage area, and that the site is planned so that no ponding of waters occurs within 300 feet of the manure storage area.

5.7 Construction requirements

The workgroup reviewed the new (Chapter 7020) rules related to statewide standards for construction of liquid manure storage systems. The workgroup thought that statewide requirements for construction, inspections, testing and reporting are fairly comprehensive, but recommended that two requirements should be added for all manure storage systems constructed statewide, as follows: **1) for all liner construction, the installer of the liner should certify that the subgrade preparation is acceptable and that all necessary testing of the liner was completed in accordance with the design engineer plans and specifications, and 2) the manufacturer of liners should provide certification of material specifications.**

The workgroup also considered what additional construction standards may need to be added specifically for construction in the karst region. The workgroup concluded the only construction-related requirement that should be recommended specifically for the karst region is for construction inspection of the soil subgrade by a licensed geologist, soil scientist or engineer with education and experience in karst soils/geology. An inspection form should be completed by the inspector and submitted to the design engineer so that it can be part of the construction report. The purpose for this inspection is to identify karst features such as soil piping or other conditions indicative of potential soil subsidence. If such features are identified, then the site would need to be moved, or potentially void-spanning reinforcement could be added to the design.

5.8 Monitoring

The workgroup considered three types of possible monitoring: 1) visual inspections of the manure storage area, 2) regular monitoring of manure levels, and 3) monitoring of ground water quality below the manure storage systems. The workgroup agreed that inspections and monitoring of manure levels were important and should be required. However, the workgroup agreed that water quality in the subsurface below liquid manure storage systems should not be monitored more extensively in the karst region than elsewhere in Minnesota (e.g., through the use of monitoring wells, lysimeters, spring sampling and/or perimeter tile lines). The workgroup concluded that the water quality monitoring would often not provide useful information, the money for monitoring would be better spent on installing highly protective liners, and monitoring contamination in karst geology can be fairly complicated and costly.

The workgroup believed that routine inspections are important to make sure that the liner has not been damaged. Inspections are most useful after the manure has been pumped out of the storage system. Several suggestions were made about who should conduct an annual inspection (county feedlot officer (CFO), MPCA, dairy inspectors, feedlot owner, private party). One suggestion was to have the feedlot owner conduct the inspection and then mail the inspection form to the MPCA or county feedlot officer. The CFO or MPCA could follow-up with an inspection as time and priorities allow. The workgroup agreed that inspection of the interior of concrete pits covered by barns should not be required due to the durability of concrete and the human dangers involved in the inspection process.

The workgroup thought that manure level monitoring and documentation should be conducted to ensure that the manure storage system is operating as expected and to detect potential releases of manure into the environment (and thus take measures as specified in an emergency response plan). Some possible methods of checking levels suggested by the workgroup include a) measure on the concrete ramp, b) installing a liquid level monitoring pipe, or c) use of pressure transducers. Total costs for a pressure transducer and data recorder were reported to be about $6,000 to $8,000. An article was provided by a workgroup engineer showing how a manure-level monitoring pipe could be installed. The workgroup agreed that the method of measuring manure levels should be left up to the design engineer and feedlot owner. The workgroup also agreed that the frequency of manure level monitoring should be greater in drinking water supply management areas for public wells where the aquifer is vulnerable to contamination. The workgroup had varying opinions about the recommended frequency of manure level measurement. Some thought that weekly measurements was best, and others believed weekly measurements were excessive and unnecessary, except in vulnerable drinking water supply management areas.

5.9 Emergency Response Plan

The workgroup believed that each farmer with liquid manure storage systems in sinkhole prone areas should be required to develop an emergency response plan for the farm. The workgroup suggested that southeastern Minnesota counties and the state should work together to develop generic emergency response plans that can then be individually tailored for specific sites. The feedlot owner should develop and submit to the MPCA or delegated county a plan for how the owner will respond if it appears that manure levels have been decreasing or there is other evidence of a manure release. The emergency response plan should include notification procedures for informing the MPCA, Minnesota Department of Health, local authorities, and others in the event of a manure release.

Chapter 6 - Recommendations for further study

The workgroup recommends to the legislature that the following additional work be conducted:

1. Determine the geostatistical probabilities of soil collapse in different types of geologic settings;

2. Study pathogen transport through soils below liquid manure storage systems;

3. Develop generic emergency response plans that can then be tailored for specific feedlot operations;

4. Conduct research and demonstration projects on alternative manure management approaches that do not rely on liquid storage.

5. Conduct regular monitoring and inspections of existing liquid manure storage systems constructed in areas susceptible to sinkhole formation or soil collapse to determine whether any major seepage problems are occurring at these sites; and

6. Collect, manage, analyze, interpret and map geologic information needed by engineers designing liquid storage basins in karst areas. A more specific description of this recommendation is included below:

   The Minnesota Geological Survey (MGS) was established in 1872 to serve as the state's repository for geological information. The MGS is part of the N.H. Winchell School of Earth Sciences at the University of Minnesota and has no regulatory authorities. As such, it is in a unique position to critically evaluate geological information and make unbiased interpretations regarding the physical geology of an area. It is appropriate that MGS serve as the focal point to store and provide geological information needed by engineers who design liquid manure storage basins in sensitive karst areas. The potential roles for the MGS include:

   1. *Prepare maps showing depth to bedrock –*

      Depths to bedrock greater than 50 feet are generally considered to greatly reduce the likelihood that collapse of a liquid storage basin will occur as a result of the piping of unconsolidated deposits into karst bedrock.

      Depth to bedrock maps showing areas where there is less than 50 feet of cover over karst bedrock have been prepared for Dakota, Fillmore, Goodhue, Olmsted, Rice, Scott, Wabasha, and Washington Counties (1/100,000 scale or 1 inch equals about 1.6 miles)

      MGS has the capability to prepare maps showing where there is less than 50 feet of cover over karsted bedrock for Blue Earth, Carver, Dodge, Faribault, Freeborn, Houston, Le Sueur, Nicollet, Pine, Steele, and Waseca, Winona counties.

MGS needs the resources to evaluate additional data describing depth to bedrock so that county depth to bedrock maps can be updated and the data base of subsurface data can be maintained and made accessible to the public. Maps should be made available to the public through a web site.

2. *Karst database* -

Develop and maintain a data base of karst features that can be used to determine the design requirements for liquid manure storage basins in sensitive karst areas. MGS is developing this data base and intends to make it available to the public through a web site. The following items need to be integrated with this effort to address the data needs of state feedlot regulations:

- prepare formal definitions of karst features that will be used by state and local agencies including sinkhole, karsted bedrock, blind valley, resurgent spring, cave, and karst feature;
- coordinating the collection, evaluation, and dissemination of information describing a karst feature;
- implement a formal procedure for 1) determining and documenting the existence of a karst feature and 2) updating the karst features data base;
- educate permitting staff to use karst features data to support decision making; and
- maintain the karst features data base on a web site.

Other Considerations -

The agency responsible for protecting caves needs to be identified. MGS responsibilities do not address issues relating to 1) protection of a cave as a natural resource or 2) protection of plant and animal communities that populate the cave. The mission of the Minnesota Department of Natural Resources might be a better match to address these issues. However, there are inter-agency issues relating to designating a cave as being "protected" that should be considered in any future actions:

- identify a lead agency responsible for 1) designating a "protected" cave and 2) integrating cave protection with the land and water resource protection efforts of other state and local agencies;
- designate formal criteria that will be used to designate a "protected" cave;
- determine the protocol for mapping a cave so that the cave can be referenced when making regulatory decisions; and
- make the area overlying a "registered and protected" cave publicly available (possibly using the MGS karst features data base).

Attachment A
Information about Workgroup Members

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Education:
B.S. Agricultural Engineering, Iowa State University
M.S. Civil Engineering, University of Missouri - Columbia

Experience:
- Designed animal waste storage lagoons in southeastern Minnesota
- Evaluated and designed alternatives for sinkhole treatments
- Involved in design and construction of landfill liner leachate collection and cover system.
- Grew up on a farm in southeast Minnesota

Areas of Expertise:
- Water resources (storm water management, flood control, hydrology, hydraulics)
- General civil (system design, plans, specifications, grading, utilities, drainage)

Rob Romocki, P.E.

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Education:
B.S. Engineering, Cornell University – 1977
Master of Engineering, Cornell University - 1978

Experience:
- Twenty-two years working as an engineer with the NRCS at several locations in the state.
  - Thief River Falls, 1978-82 – Civil Engineer working in Area 1, northwest Minnesota. Worked with LO on waste system, WWAVS, grade stab. str.
  - Mora, 1982-84 – Project Engineer for Knife Lake Dam
  - Lewiston, 1984-87 – Civil Engineer for Garvin Brook Watershed
  - Rochester, 1987-92 – Project Engineer for South Zumbro Watershed
- Licensed P.E. in Minnesota.

Areas of Expertise:

- Soil and water conservation practices (design and construction)
- Flood control structures (design and construction)
- Animal waste storage systems (design and construction)

Dr. Chuck Clanton, P.E., P.S.S.

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Education:
B.S. Agricultural Engineering – Nebraska
B.S. Animal Science – Nebraska
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Ph.D. Agricultural Engineering – Minnesota

Experience:

- Twenty-one years teaching/research in manure management

Areas of Expertise:

- Manure characterization and nutrient management
- Odor and gases emission and control
- Soil and concrete sealing by manure

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M.S. Mining Engineering, Colorado School of Mines
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Experience:

- Two years – U.S. Navy ROICC
- Two years – Instructor at Colorado School of Mines
- Thirteen years – Professor (Assistant and Associate) at the University of Minnesota, Department of Civil Engineering

Areas of Expertise:
- Geotechnical engineering
- Ground water modeling
- Geologic site characterization

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Experience:
- Twenty-five years consulting experience

Areas of Expertise:
- Liner design – clay and geosynthetic for individual and public facilities
- Reinforcement design – void spanning
- Soil borings/geophysical site evaluations

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Areas of Expertise:
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Experience:
- Working with SWCDs by determining farmer needs, designing and constructing BMP's best suited to sites
- Engineering consultant business in metro area for watershed districts. Surface water hydrology/hydraulics and water quality protection projects and review.
- Surface water runoff from project work and erosion control/water quality protection
- Engineer working in karst area designing manure storage systems and erosion control projects.

Areas of Expertise:
- Engineering of structures involving conservation and protection of soil and water resources.
- Design and construction of various types of manure facilities on existing farmsteads.

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Education:
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Experience:
- Six years teaching and researching farm buildings – Kansas State University
- Started consulting office in 1968 working with livestock producers
- Six years with UNDP-FAO pig farm development in Singapore
- Dairy farm project in Indonesia
- Extensive work with Minnesota livestock producers manure storage and feedlot permits

Areas of Expertise:
- Feedlot planning
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Experience:

- Design – Livestock waste handling systems
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- Ag. Research, NDSU and USMARC, Clay Center, NE
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Experience:

- University of Minnesota Biosystems and Agricultural Engineering faculty – 1980 to present.

Areas of Expertise:

- Livestock housing systems
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Attachment B

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ABSTRACT

Karst occurs in Illinois where bedrock exposures and subcrops consist of carbonate rocks. Approximately 25% of Illinois' bedrock is carbonate rock, and of that area, approximately 35% (equals 9% of the state) includes the state's five karst regions. The highest degree of karstification occurs in southwest and southern Illinois where the Mississippian limestones are predominant. Karst encountered in Illinois, as classified by their dominant landforms, included sinkhole karst, cave karst, and pseudo-sinkhole and pseudo-cave karst that resulted from human modifications to the land. Only natural karst terrains are studied herein, and only the most karstified areas are described in detail.

The carbonate bedrock of Illinois was the focus of our efforts because these rocks are susceptible to karst development. Carbonate bedrock is either exposed at land surface or covered by relatively thin glacial till (diamicton), loess, and other unlithified sediment around the margins of the Illinois Basin, and along the flanks of structures within the basin. Karstic features are concentrated in five regions: (1) the Driftless Area of northwest Illinois, (2) north-central Illinois, (3) the Lincoln Hills of the western Illinois, (3) the Salem Plateau of southwest Illinois, and (5) the Shawnee Hills of southern Illinois. A few caves and sinkholes occur in northeastern Illinois, and in La Salle and Douglas Counties in carbonate rocks associated with either the LaSalle Anticlinorium or the northeast flank of the Illinois Basin (Kankakee Arch).

INTRODUCTION

Background

Carbonate rock comprises approximately 25% of the bedrock surface in Illinois. Of the area underlain by carbonate rocks, 35% of that area (equals 9% of the state) is included in the five regions that contain evidence of numerous karstic features at the land surface. The term "karst" is defined by Ford and Williams (1989) as "...terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well developed secondary porosity." Features that typify karst terrain include closed depressions (sinkholes), caves, large springs, fluted rock outcrops (Ford and Williams, 1989), blind valleys and swallow holes (White, 1988).

Carbonate rocks generally have low primary porosity and permeability; however, secondary porosity (fractures) permits the rapid transport of large volumes of water into and through the rock. The movement of surface waters (rainwater and snowmelt), through soil, and into fractures in soluble carbonate bedrock is responsible for the development of karst terrains. Because of the microbial generation of carbon dioxide in the soils overlying carbonate rock, infiltrating water becomes acidic prior to entering fractures, joints and bedding planes in carbonate rocks. Small amounts of calcite and/or dolomite (the dominant minerals in carbonate rock) dissolve in accordance with the following simplified reactions:

$$\text{Calcite: } CaCO_3 + H^+ \leftrightarrow Ca^{2+} + HCO_3^-$$

$$\text{Dolomite: } CaMg(CO_3)_2 + 2H^+ \leftrightarrow Ca^{2+} + Mg^{+2} + 2HCO_3^-$$

until the water approaches saturation with respect to the solubility of these mineral phases (White, 1988). The slow dissolution of carbonate minerals over thousands to hundreds of thousands of years gradually enlarges joints, fractures, and pathways along bedding planes through which water moves. Some pathways become large conduits or caverns through which groundwater flows to points of discharge (e.g., springs). Continued enlargement of the conduits eventually can result in the collapse of overlying rock and soil. Surface erosion eventually results in fragmentation and finally, destruction of the conduit system (White, 1988).

The relatively large interconnected pores present in fissured or karstified carbonate rock allow rapid movement of water into and through the rock bodies. These rock bodies often constitute locally important aquifers in Illinois; however, fissured and karst aquifers are very susceptible to surface-derived contamination. Recharge to karst aquifers often is rapid (analogous to water movement to drainage tiles) and carries with it materials (often macroscopic) from the land surface that include human and animal wastes, pesticides, urban runoff, and other waste products associated with the human culture of a region. In contrast, recharge to non-karst aquifers typically undergoes a slow migration through materials (e.g., thick, clay-rich glacial diamicton) that generally provide sufficient time and environment for chemical, biological, and physical degradation and retardation of pollutants. Unfortunately, residents who draw groundwater from karst aquifers for domestic use risk ingesting contaminants. Rare and endangered species that inhabit underlying caves are also at risk from chemical and bacterial contamination in groundwater. In addition, knowing where karst terrain is present in Illinois is important when conducting regional geological screening for citing facilities such as waste disposal sites and low-level nuclear waste repositories. Thus, it is important to identify the locations of karst terrain in the state for water-resource protection and regulatory purposes.

Purpose

The purpose of this investigation was to prepare a state-wide map and detailed maps of the karst terrains of Illinois and to describe the geologic and hydrogeologic controls of karstification. The detailed karst maps presented herein were prepared from a smaller-scale map of the state of Illinois (Weibel and Panno, in press) (Figure 1).

METHODOLOGY

Karst Maps

Karst maps were constructed for the state on the basis of landforms observed on 7.5-minute (1:24,000) topographic maps and stereo pairs of U.S. Department of Agriculture aerial photographs (1:20,000), bedrock lithology, cave locations, and sinkholes indicated on Natural Resources Conservation Service (formerly the Soil Conservation Service) county soil survey maps. Areas mapped as karst were field checked by the authors. As discussed above, carbonate bedrock is most susceptible to dissolution, particularly where it occurs at or near the land surface. The occurrence of caves in an area was used as an indicator of karst terrain. A map of the caves of Illinois found in carbonate rock was constructed using a confidential inventory of 313 caves (compiled by J.E. Gardner of the Illinois State Natural History Survey from his work and from a data base prepared by the Illinois State Museum). The term "cave" is defined as "any natural cavity or series of cavities beneath the surface of the earth. Such cavities are usually classified as caves only if they are large enough to permit entrance by humans" (Mohr and Polson, 1966). A literature search also was conducted for karstic features observed within the state and neighboring states. Karst regions were delineated on the basis of the location of indicator sinkholes, caves, and carbonate rock, without regard for the thickness and nature of Quaternary overburden. Because all carbonate

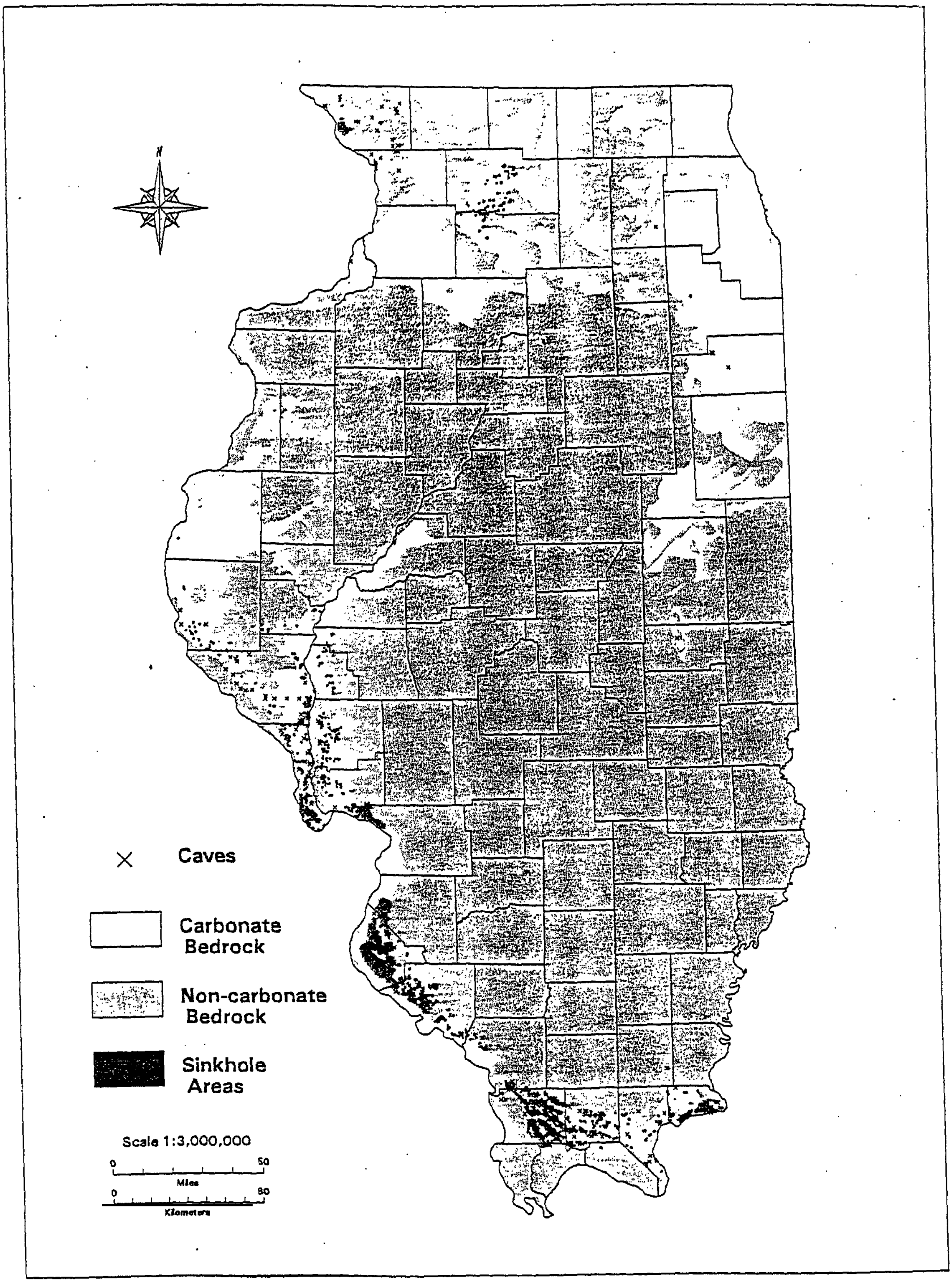


Figure 1. Map of the bedrock geology of Illinois showing sinkholes and caves (modified from Weibel and Panno, in press).

rock in the state shows some degree of dissolution (usually along joints and bedding planes), no area is described as "karst" unless it was identified as having a karst aquifer with associated karstic features.

Cross Sections

Cross sections of the areas containing carbonate bedrock and karstic features (Figure 2) were constructed to examine relationships between bedrock formations and karstification. The cross sections are schematic and were based on the following: 1) well records available at the Geological Records Library of the Illinois State Geological Survey (ISGS), 2) published references describing the geology of the surficial sediment, bedrock surface and subsurface, and 3) unpublished cross sections from the ISGS Map Library. Formation codes used in the cross sections are explained in Figure 3.

DISCUSSION

The focus of this investigation is on the carbonate bedrock of Illinois because these are the rocks most susceptible to karstic development. These rocks are either exposed or subcrop at the bedrock surface beneath glacial deposits around the margins of the Illinois Basin on the flanks of the Kankakee, Mississippi River, Pascola, and Wisconsin Arches, and the Ozark Dome, and, within the Illinois Basin, on the crest of the LaSalle Anticlinorium in east-central Illinois (Figure 2). Karstic features are concentrated in north-central Illinois, the Driftless Area, the Lincoln Hills, the Salem Plateau, and the Shawnee Hills (Figures 1, 2). Sinkholes and caves found in Kane, Kankakee, La Salle, and Douglas Counties are rare and generally isolated, and occur in carbonate rocks associated with the LaSalle Anticlinorium and Kankakee Arch.

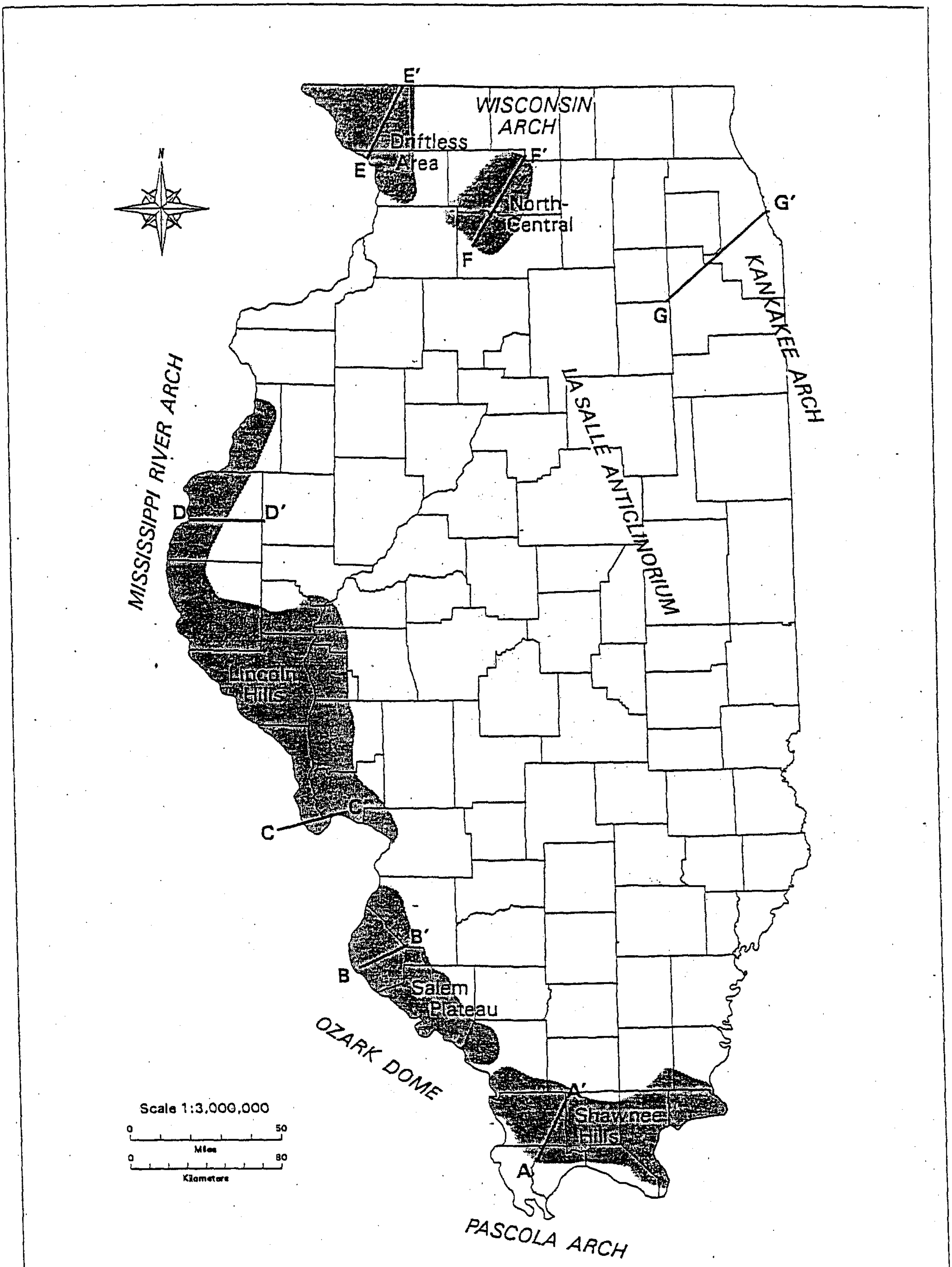


Figure 2. Map showing locations of cross-sections, karst regions, and major structures (in italics) of the Illinois Basin.

REGIONAL KARST MAPS

Caves

Predominantly Noncarbonate Bedrock

Predominantly Carbonate Bedrock

Sinkhole Areas

REGIONAL MAPS AND CROSS-SECTIONS

Q-P = Quaternary, consisting mostly of Pleistocene deposits
Penn = Pennsylvanian
Mcu = Mississippian, upper Chesterian (includes Vienna, Menard, Clore, Kinkaid)
Mcl = Mississippian, lower Chesterian (includes Renault, Ridenhower, Beech Creek, Glen Dean)
Mvu = Mississippian, upper Valmeyeran (includes St. Louis, Ste. Genevieve)
Mvm = Mississippian, middle Valmeyeran (includes Salem)
Mvl = Mississippian, lower Valmeyeran (includes Burlington, Keokuk)
Mk = Mississippian, Kinderhookian
Du = Devonian, Upper
Dm = Devonian, Middle (includes Grand Tower, Lingle)
Dl = Devonian, Lower(includes Bailey, Backbone)
S = Silurian (includes Kankakee, Sexton Creek, Hopkinton)
Ou = Ordovician, Upper
Om = Ordovician, upper Middle (includes Platteville, Galena, Kimmswick)
Oma = Ordovician, lower Middle
Ol = Ordovician, Lower (includes Shakopee)
C = Cambrian

Figure 3. Explanation for symbols, shadings, and abbreviations used in cross sections and regional karst maps. Stratigraphic units are modified from Willman et al. (1967). Relevant stratigraphic units mentioned in the text are contained within parentheses.

In the Illinois Basin, only Paleozoic-age rocks contain carbonate strata, whereas younger Mesozoic and Cenozoic rocks lack carbonate strata. Rock units that are karstified include (from oldest to youngest) limestones and dolomites of the Lower and Middle Ordovician and of the Silurian Alexandrian and Niagaran Series, limestone of the Lower and Middle Devonian Series, limestones of the Mississippian Valmeyeran and Chesterian Series, and the LaSalle Limestone of the Pennsylvanian Missourian Series (Figure 4). The most intensely karstified limestones occur within the Mississippian-age strata. The regions that contain numerous karstic features (particularly caves and sinkholes) are described in detail below. The geology and hydrogeology of each region are also discussed and formations that have undergone karstic development are described. Formation codes, symbols, and shadings used on the regional maps are explained in Figure 3.

Shawnee Hills Karst Region

Sinkholes and caves are abundant in the karst of the Shawnee Hills of southern Illinois. The Shawnee Hills karst region (Figures 2, 5, 6, 7) includes Jackson, Union, Johnson, Pope, Saline and Hardin Counties. A few sinkholes and caves are associated with the Lower Devonian Bailey and Backbone Limestones and Middle Devonian Grand Tower and Lingle Limestones in the west part of the Shawnee Hills. Most sinkholes and caves occur in soil overlying and within Mississippian Valmeyeran and Chesterian rocks (Figure 8A). Sinkholes are common to abundant in areas where bedrock is dominated by the Salem, St. Louis, Ste. Genevieve, Glen Dean, and Menard Limestones, and are found throughout most of the Shawnee Hills. Sinkholes also are commonly associated with the Haney Limestone Member of the Golconda Formation and the Kinkaid Limestone in the west part of the region. Karstic features are relatively rare in the Renault Limestone, Downeys Bluff Limestone Member of the

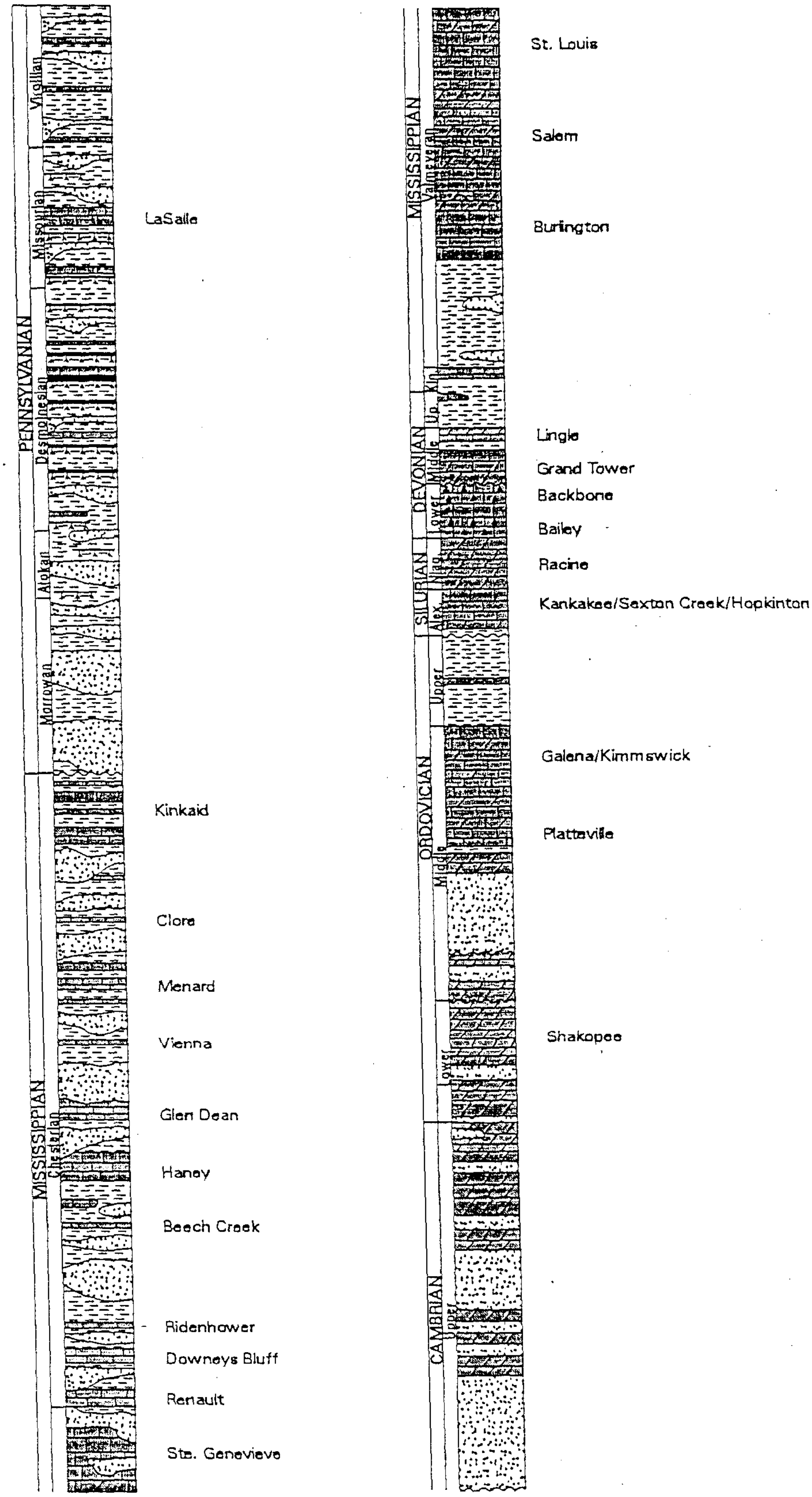


Figure 4. Generalized stratigraphic column of Paleozoic strata in Illinois, modified from Bell et al.(1961). Carbonate units are shaded gray. Known karstification zones are indicated by the stratigraphic names

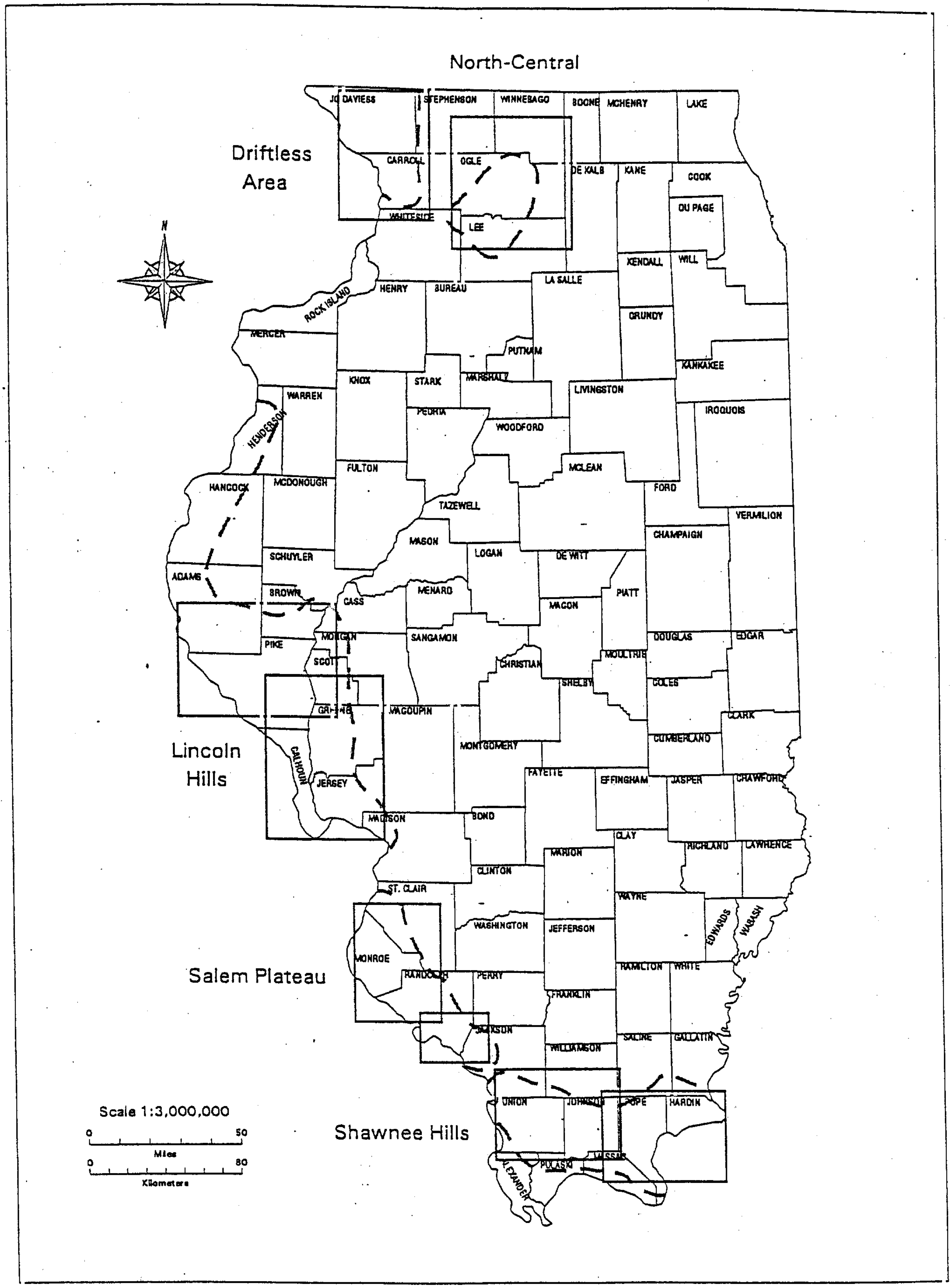


Figure 5. Index of regional karst maps, outlined by boxes. Dashed lines indicate extent of karst regions.

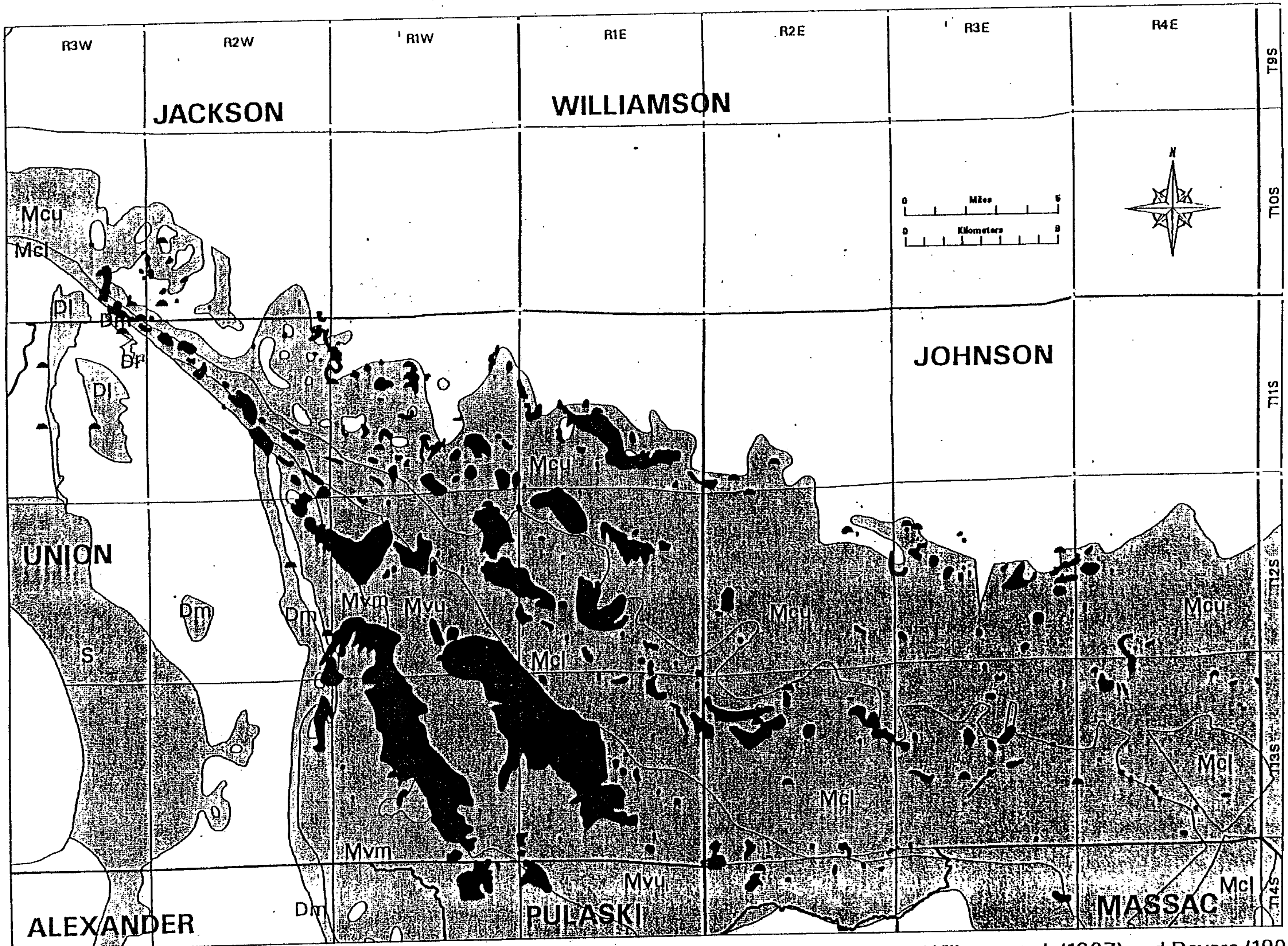


Figure 6. Karst map for the west part of the Shawnee Hills karst region. Geology modifed from Willman et al. (1967) and Devera (1993).

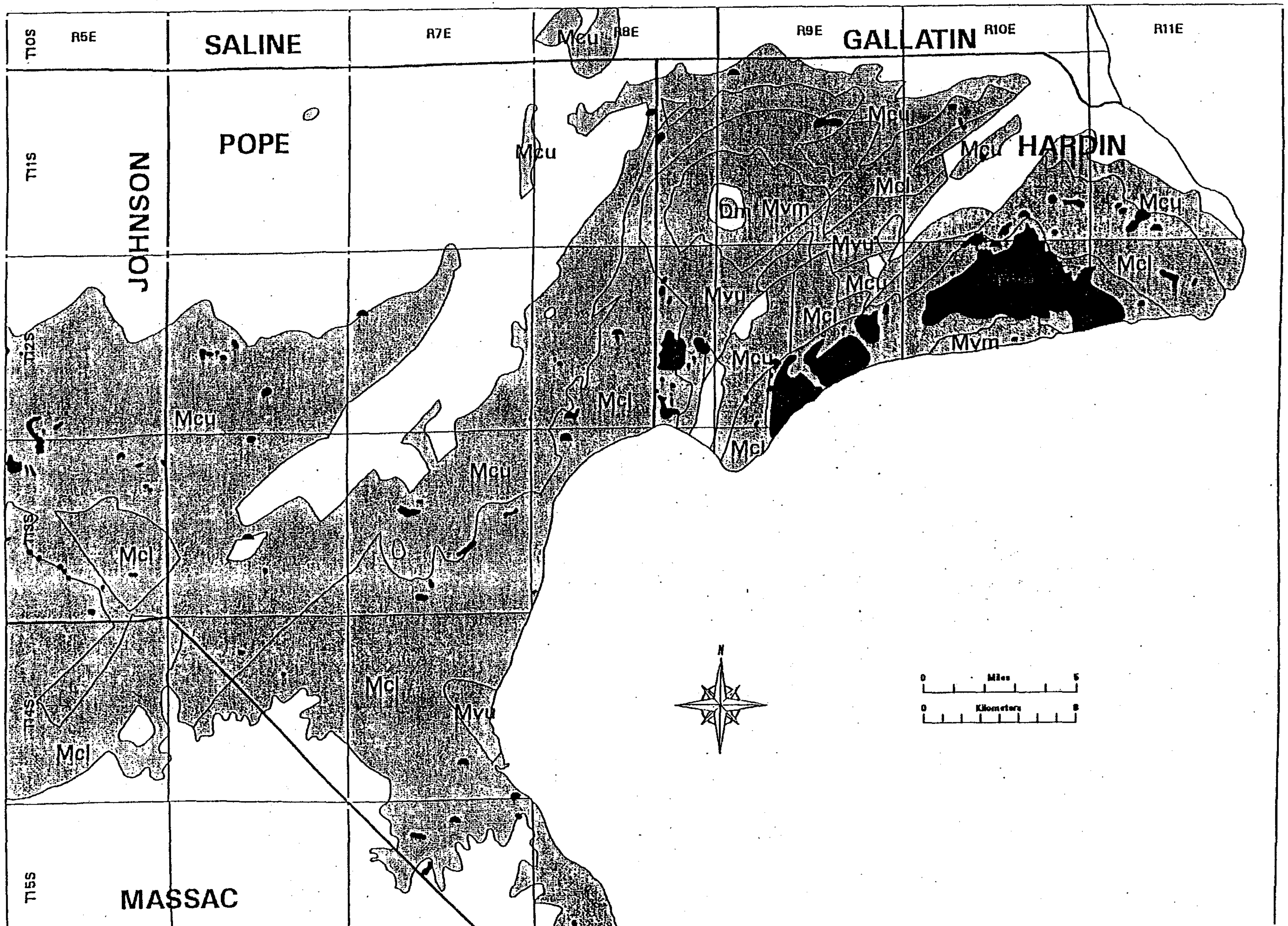
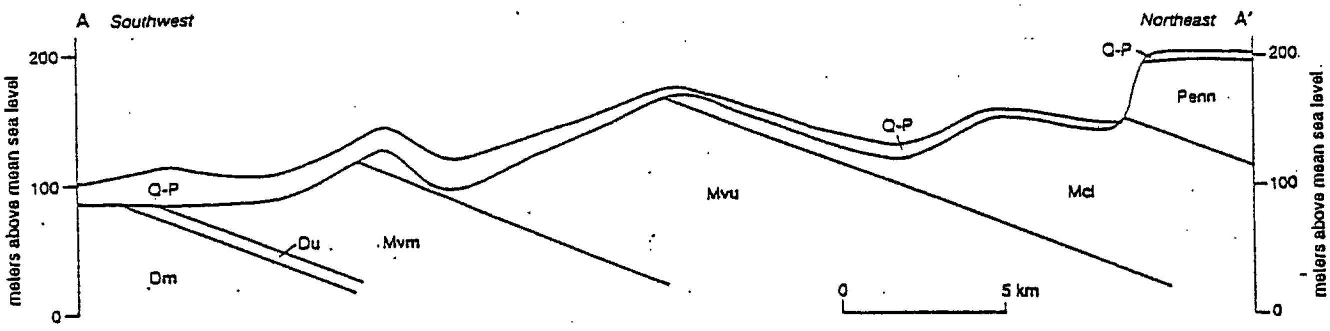
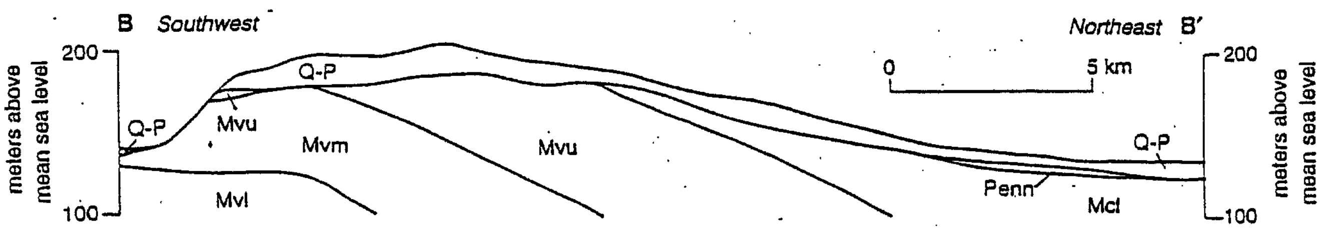


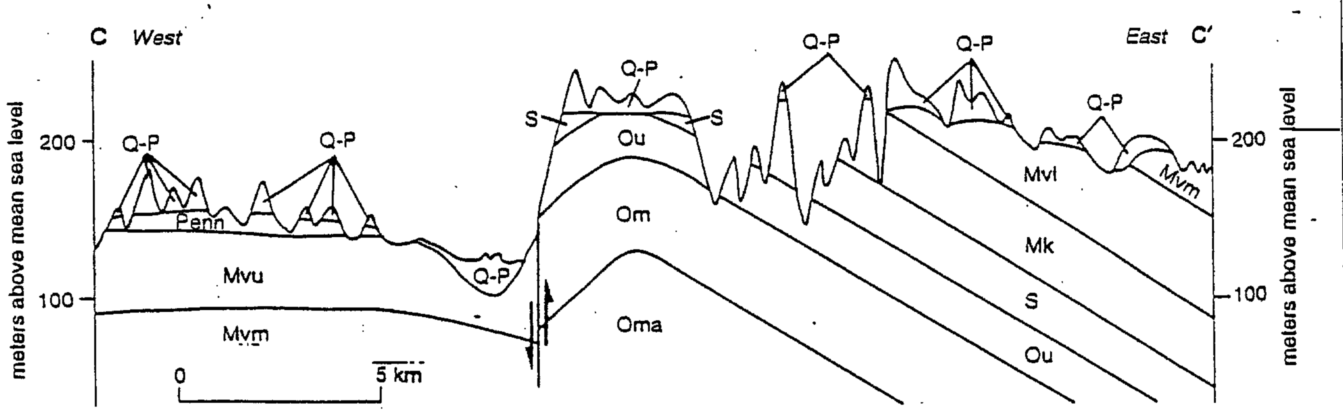
Figure 7. Karst map for the east part of the Shawnee Hills karst region. Geology modifed from Willman et al. (1967).



A. Cross-section of the Shawnee Hills karst region, modified from Weller and Ekblaw (1940) and Willman et al. (1967).



B. Cross-section of the Salem Hills Plateau karst region, modified from Weller and Weller (1939) and Willman et al. (1967).



C. Cross-section of the south part of the Lincoln Hills karst region, modified from Baxter (1965, 1970), Reinertsen and Treworgy (1991), Rubey (1952), Schultz (1993), Treworgy (1979), Whiting and Stevenson (1965) and Wilson and Odom (1959).

Figure 8. Cross-sections A-A', B-B', and C-C'.

Paint Creek Formation, Vienna Limestone, and the Clore Formation. In most places the Vienna Limestone is too thin for the significant surface expression of karstic features. Within the Clore Formation, sinkholes generally are found in the Ford Station Limestone Member, which contains the thickest limestone in the formation. Sinkholes in the Kinkaid Limestone are most commonly within the Goreville Limestone Member, but can occur within the Negli Creek Limestone Member and, in the west part of the Shawnee Hills, within the Cave Hill Shale Member where its carbonate content is higher. The Goreville is absent in the east part of the Shawnee Hills area. A few sinkholes are associated with the Hardinsburg Sandstone which probably formed as a result of dissolution of the underlying Haney Limestone Member. In the west portion of the Shawnee Hills, some sinkholes occur where thin Pennsylvanian Caseyville Sandstone forms the bedrock surface. We suggest that these sinkholes formed as a result of dissolution of the underlying Goreville Limestone Member of the Kinkaid Limestone.

Groundwater in the counties of the Shawnee Hills karst region is available from sources that include Silurian and Devonian carbonate rocks, Mississippian Valmeyeran limestones, and Mississippian Chesterian limestones and sandstones. Solution-enlarged crevices of Valmeyeran limestones, and faulting and crevice development in the Chesterian rocks enhanced the permeability of these rocks. The carbonate rocks of the Shawnee Hills karst region are used for rural, municipal and industrial water supplies (Pryor, 1956).

Salem Plateau Karst Region

The region adjacent to the Mississippi River just south of East St. Louis is often referred to as the "sinkhole plain" because it contains a high density of sinkholes (Figures 5, 9, 10). It is also part of the Salem Plateau Section of the physiographic provinces of Leighton et al.

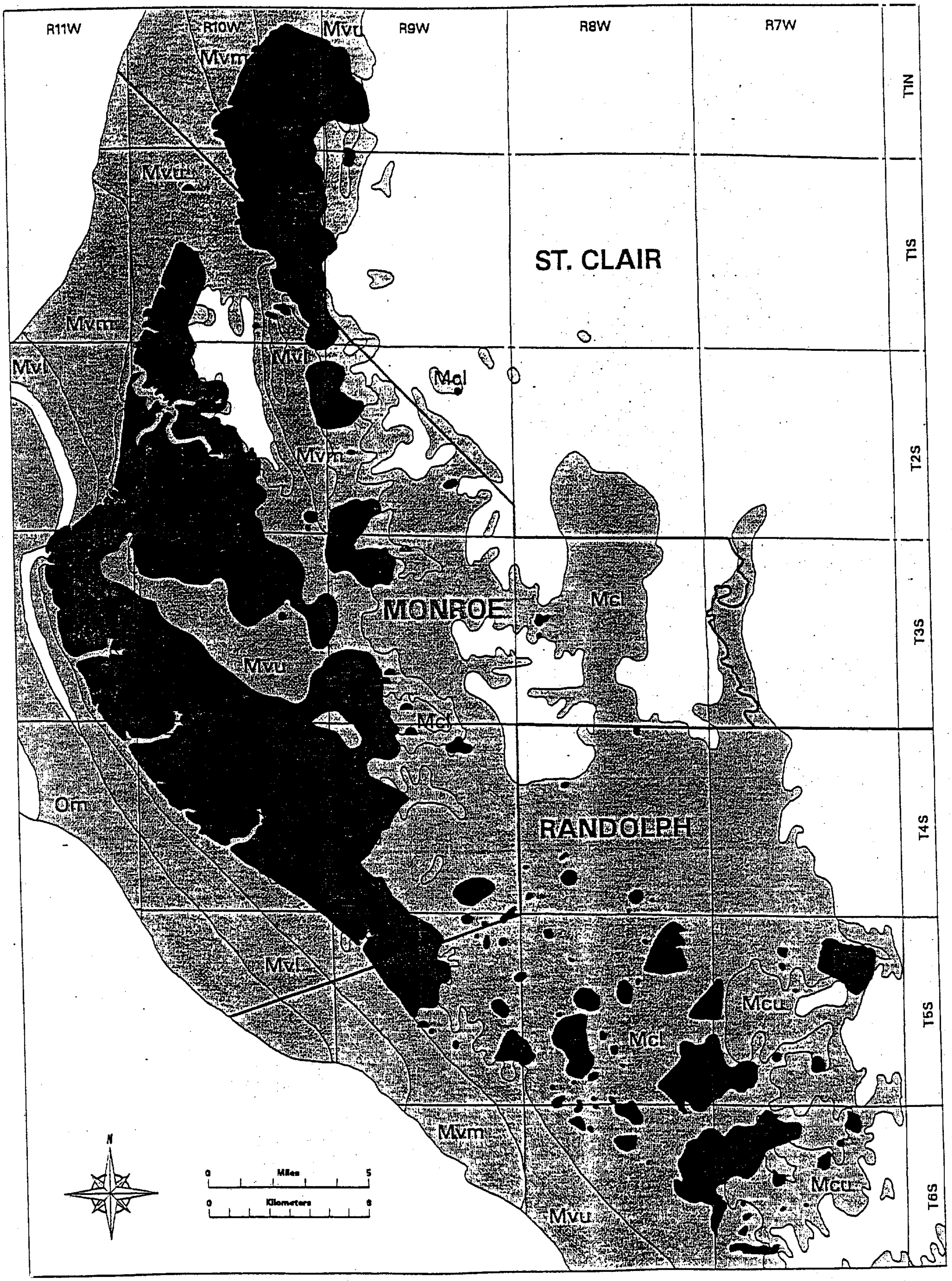


Figure 9. Karst map for the north part of the Salem Plateau karst region. Geology modifed from Willman et al. (1967).

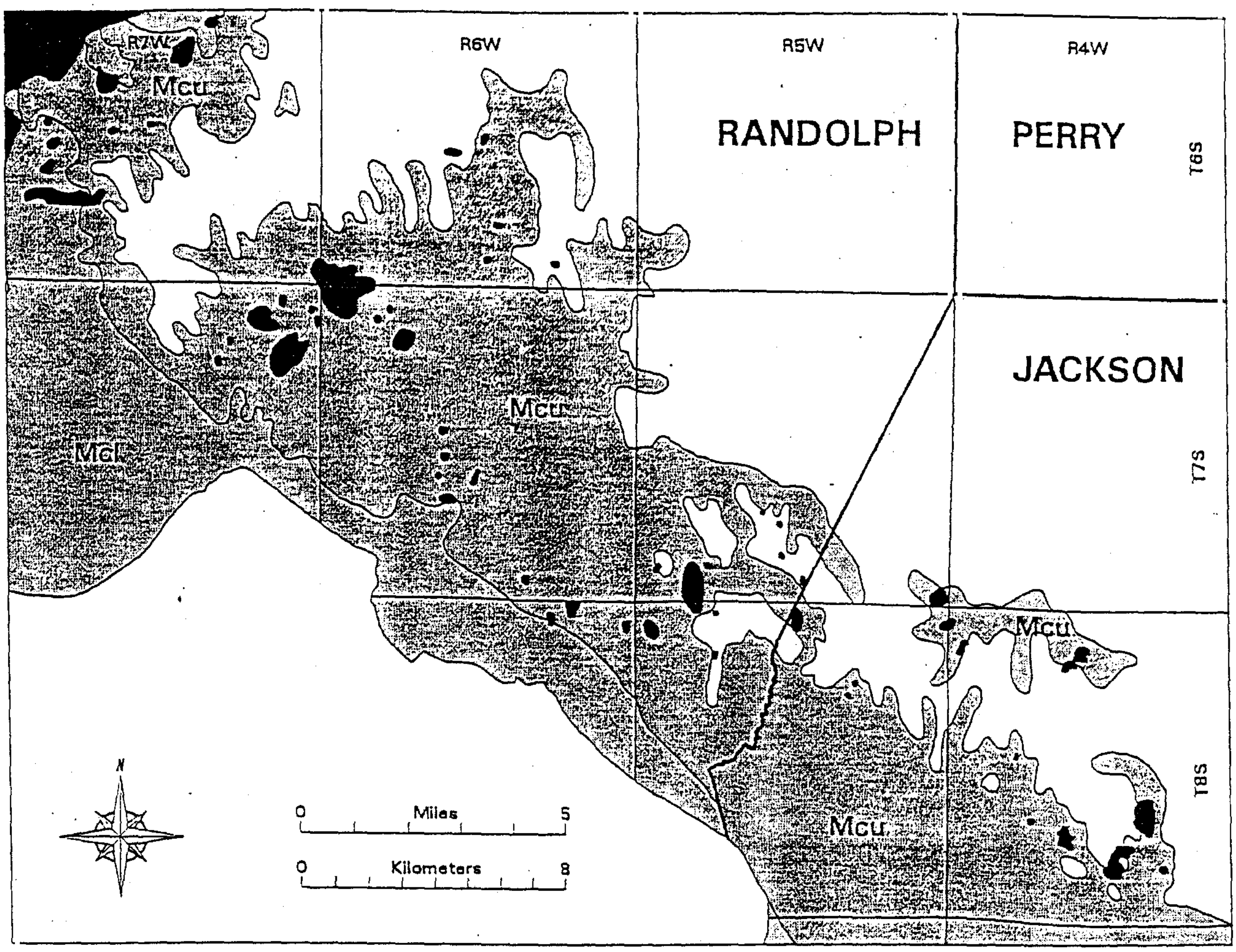


Figure 10. Karst map for the south part of the Salem Plateau karst region. Geology modifed from Willman et al. (1967).

(1948). Approximately 10,000 sinkholes, numerous karst springs, and the largest caves in Illinois are found in this region (Panno, 1996). The bedrock geology of St. Clair, Monroe, and Randolph Counties consists of Mississippian and Pennsylvanian limestone, dolomite, sandstone, shale, claystone and coal (Figure 8B). The structural geology of the area (anticlines), relatively thin glacial drift, and close proximity to the Mississippi River are responsible for the exposure of these rocks in these counties. Drift thickness in this area is typically less than 15 m, but may exceed 15 m in and adjacent to stream valleys (Horberg, 1950).

Caves and sinkholes occur in Mississippian strata ranging from the Valmeyeran Salem Limestone to the Chesterian Kinkaid Limestone. Many of the sinkholes (Weller, 1939) and probably many of the caves occur in the St. Louis Limestone. Solution features in the St. Louis are primarily responsible for the widespread karst topography in the west part of the region. The trends of long caves in this region are parallel or subparallel to the axial trend of major structures in the area. Anticlines, synclines and major cave systems trend northwest-southeast in St. Clair and Monroe Counties. Many caves in this area formed as surface waters entered bedding planes at outcrops and through fissures in near-surface bedrock. Dominant routes for the waters migrating along bedding planes eventually formed small conduits (typically about 10 cm in diameter) that down cut over time to form large solution cavities. The remnants of these initial conduits are visible in parts of Illinois Caverns and Foglepole Cave in Monroe County. These caves are relatively large in diameter (5 m or greater), and extensive (several have more than 5 km of traversable passages). They are typical of the "branchwork" type (per classification scheme of Palmer, 1991), and form as solution tributaries along bedding planes in the limestone bedrock; thus, their passages are characteristically sinuous in plan view.

Sinkholes also are abundant in areas underlain by the Salem and Ste. Genevieve Limestones and are often connected to underlying cave systems. Sinkholes are rarely associated with the Downeys Bluff Limestone Member of the Paint Creek Formation, Beech Creek Limestone Members (and perhaps in the overlying Fraileys Shale Member) of the Golconda Formation, and Vienna Limestone. The few sinkholes associated with the Cypress Sandstone probably formed by dissolution and collapse of the underlying Ridenhower Member of the Paint Creek Formation.

Groundwater resources in these counties occur in the Valmeyeran strata that include the St. Louis Limestone and the overlying Aux Vases Sandstone. Springs and wells in the St. Louis are sources of groundwater for domestic and rural supplies in the west part of the karst region. The Aux Vases Sandstone underlies part of this region, and in the east, forms the bedrock surface below thin glacial drift. This sandstone is also a reliable source of groundwater in this region. The thin glacial drift, however, does not offer much protection for shallow groundwater supplies in this area. Wells drilled through the overlying Chesterian karst aquifer and into the underlying Aux Vases Sandstone typically are not cased through the karstic zone and localized contamination may occur by this route (Panno et al., 1996).

Lincoln Hills Karst Region

Karstic features in the Lincoln Hills karst region (Figures 5, 11, 12) occur in Adams, Pike, Calhoun, Greene, Jersey, and Madison Counties in Middle Ordovician Kimmswick Limestone, Silurian (Alexandrian Series) Sexton Creek Limestone, and Mississippian (Valmeyeran Series) Burlington, Salem, St. Louis, and Ste. Genevieve Limestones (Lamar, 1928; Rubey, 1952) (Figure 8C, 13A). Rubey (1952) and Baxter (1965) described the lithologies of the carbonate strata of the region. The Kimmswick Limestone dominantly

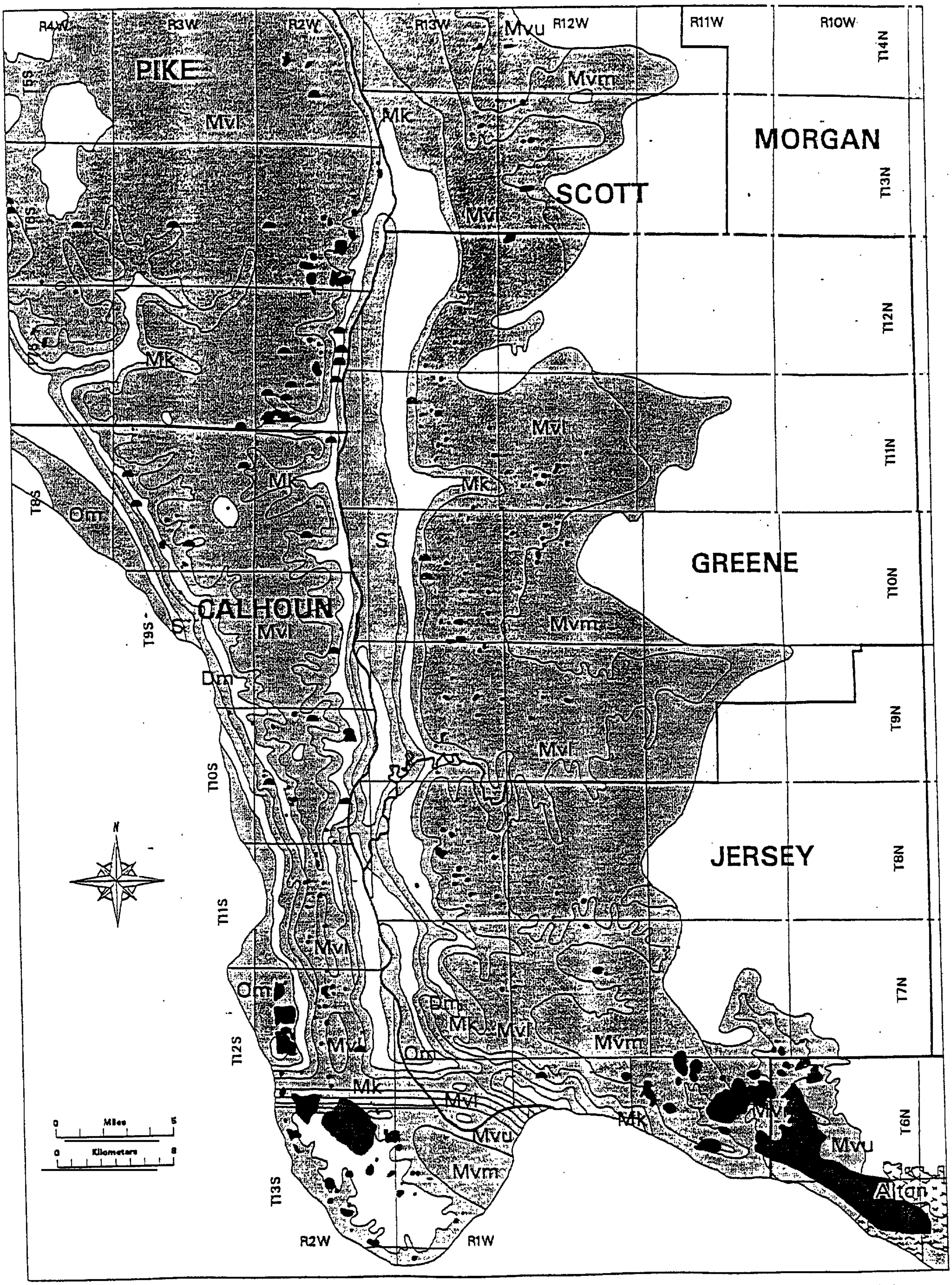


Figure 11. Karst map for the south part of the Lincoln Hills karst region. Geology modifed from Willman et al. (1967).

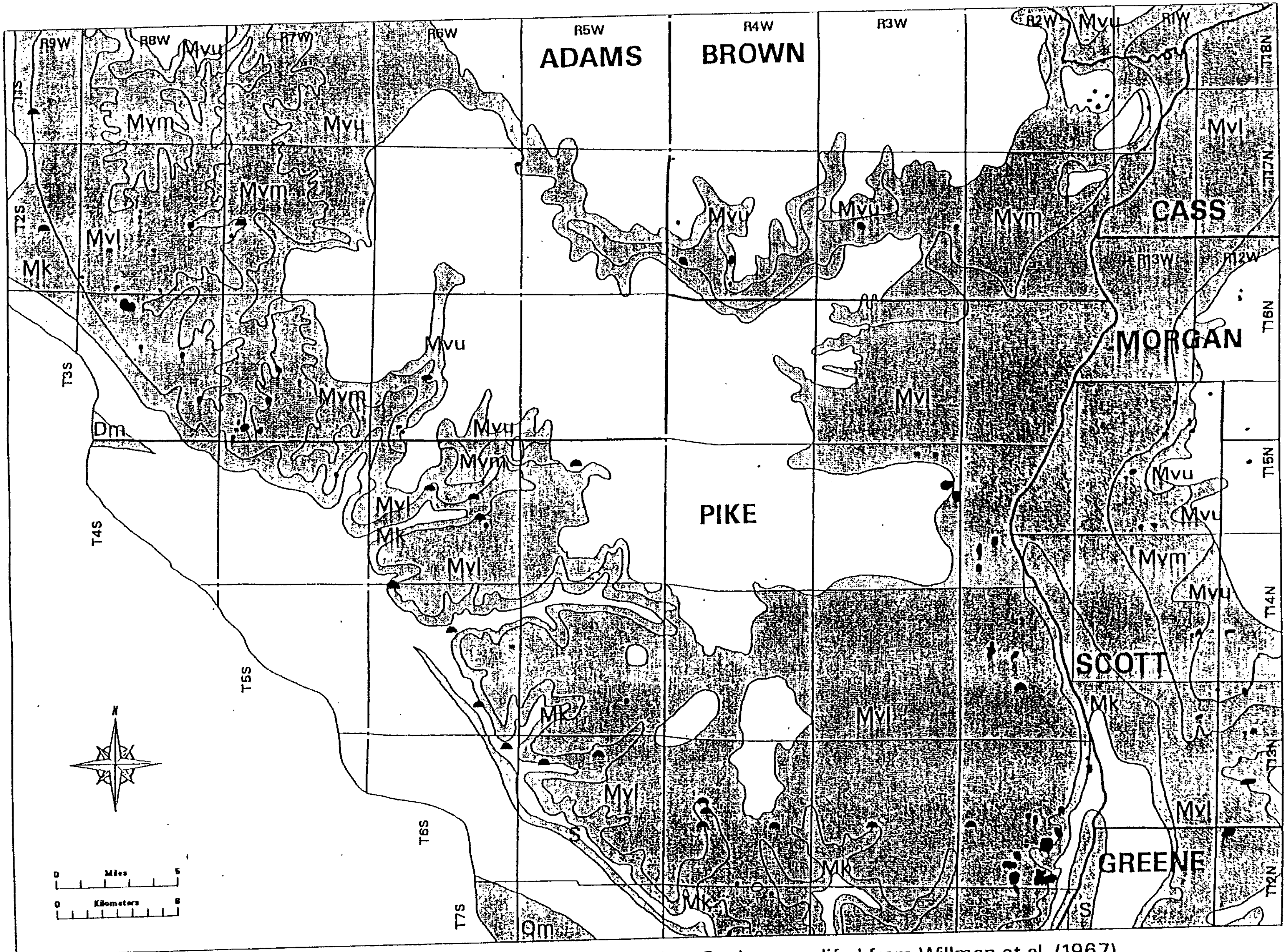
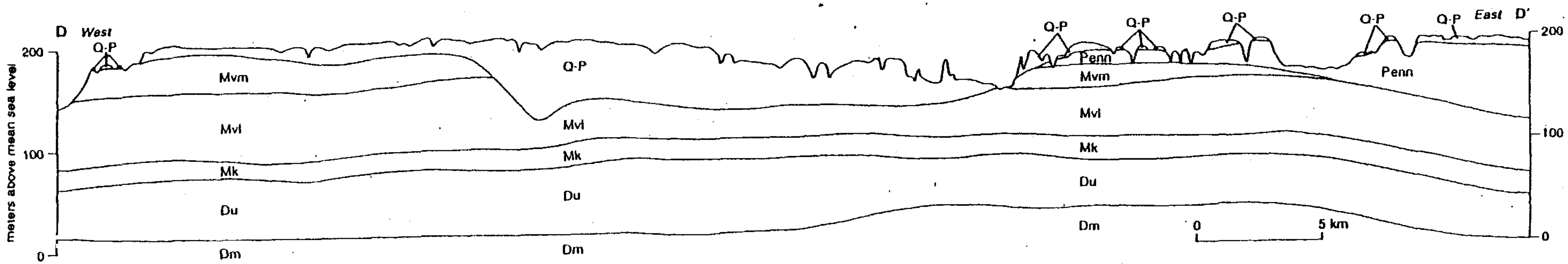
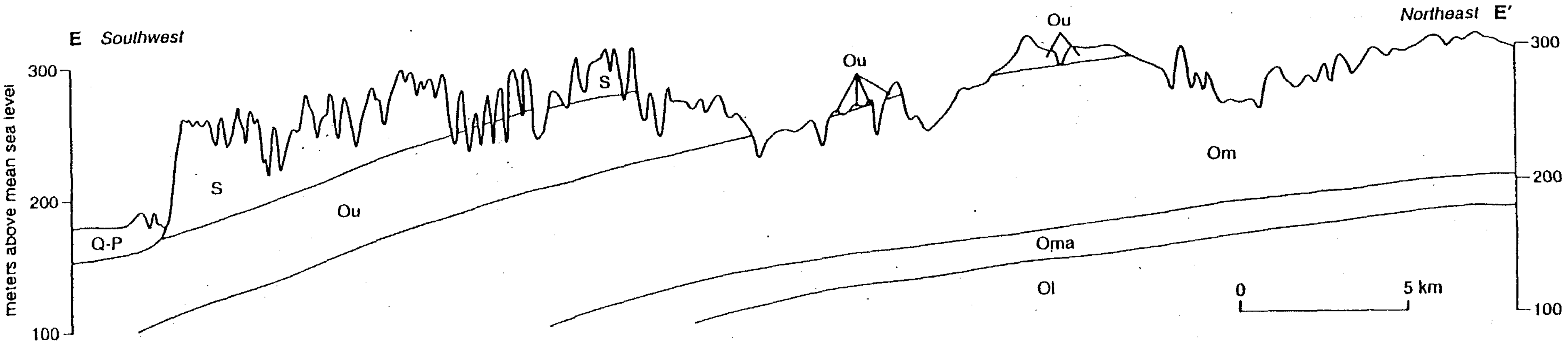


Figure 12. Karst map for the north part of the Lincoln Hills karst region. Geology modifed from Willman et al. (1967).



A. Cross-section of the north part of the Lincoln Hills karst region, modified from Harvey (1964), Hinds (1917), Krey (1924), Morse and Kay (1915), Wanless (1957), and Whiting and Stevenson (1965).



B. Cross-section of the Driftless Area karst region, modified from Willman et al. (1967).

igure 13. Cross-sections D-D' and E-E'.

consists of fine- to coarse-grained, massive limestone. The Sexton Creek Limestone ranges from a fine-grained limestone in the north part of the area to a porous dolomite in the south part. The Burlington is a cherty, coarse-grained, crinoidal limestone. The overlying Keokuk Limestone is lithologically similar and is difficult to distinguish in many places. The Keokuk probably contains karstic features, although this investigation has not verified such occurrences. The Salem consists of a coarse-grained limestone that locally contains dolomite. The overlying St. Louis Limestone is dominated by fine- to very fine-grained, cherty limestone, but also contains variable amounts of dolomite, conglomeratic limestone, and arenaceous and oolitic limestone. The Ste. Genevieve Limestone consists of very fine- to medium-grained limestone that locally varies from being argillaceous, to arenaceous, and to oolitic.

Most of the sinkholes in the west part of the Lincoln Hills karst region occur in either the Kimmswick or St. Louis Limestones (Rubey, 1952). The sinkholes in the east part of the region, in and near Alton, are associated primarily with the St. Louis and Ste. Genevieve Limestones (Figures 3, 11). Many of the sinkholes occur in relatively thick loess deposits that overly the limestones and appear to have formed by stoping of the loess into voids in the limestone. Some of these sinkholes, particularly in southernmost Calhoun County, contain a thin layer of Pennsylvanian strata between the underlying limestone and the overlying loess (Rubey, 1952). Sinkholes in this region are typically shallow, bowl-shaped depressions, many of which contain trees or are filled with water and surrounded by trees.

Sand and gravel, dolomite, limestone, and sandstone aquifers are used in the Lincoln Hills karst region for domestic water supplies. Wells and springs in the Mississippian Burlington and Keokuk Limestones are the main sources of domestic water from bedrock. Wells also have been drilled into Devonian and Silurian rocks, but these are not as productive.

The Salem-St. Louis limestone interval in Jersey County is sufficiently thick and creviced to serve as a supply for rural wells (Bergstrom and Zeizel, 1957).

Driftless Area Karst Region

Near-surface and exposed carbonate bedrock in the Driftless Area of northwest Illinois (Jo Daviess and northwest Carroll Counties) are of Middle Ordovician or Silurian age (Figures 13B, 14). The Middle Ordovician Platteville Group is composed of very fine-grained limestone mottled with dolomite. The Galena Group overlies the Platteville Group and consists of limestone and dolomite, except for a basal shaley limestone and dolomite interval (Willman et al., 1975). Karstic features also occur in Silurian (Alexandrian and Niagaran Series) bedrock. The Silurian is divided into the Mosalem, Tete des Morts, Blanding, and Hopkinton Formations (Willman, 1973; Bunker et al., 1985). These rocks are medium- to coarse-grained, locally cherty dolomite (Heyl et al., 1959). Most, if not all, of the sinkholes in this area occur in the Niagaran Hopkinton Formation (Brian Witzke, Iowa Geological Survey, personal communication).

Both caves and sinkholes are indicators of karst terrain in the Driftless Area; however, caves are the dominant feature in this region (Figures 5, 14) in Illinois. Most of the caves occur in the Galena Group (Trowbridge and Shaw, 1916; Heyl et al., 1959; Brown and Whitlow, 1960). Bretz and Harris (1961) described a cave in Carroll County in Silurian dolomite, probably in strata younger than the Hopkinton Formation. The caves are predominantly solutionally-widened joints, according to descriptions by Bretz and Harris (1961), and Webb et al. (1994). Caves of this type are referred to as "network" caves (Palmer, 1991), are fracture-controlled, and often follow solution features along near-vertical fracture planes.

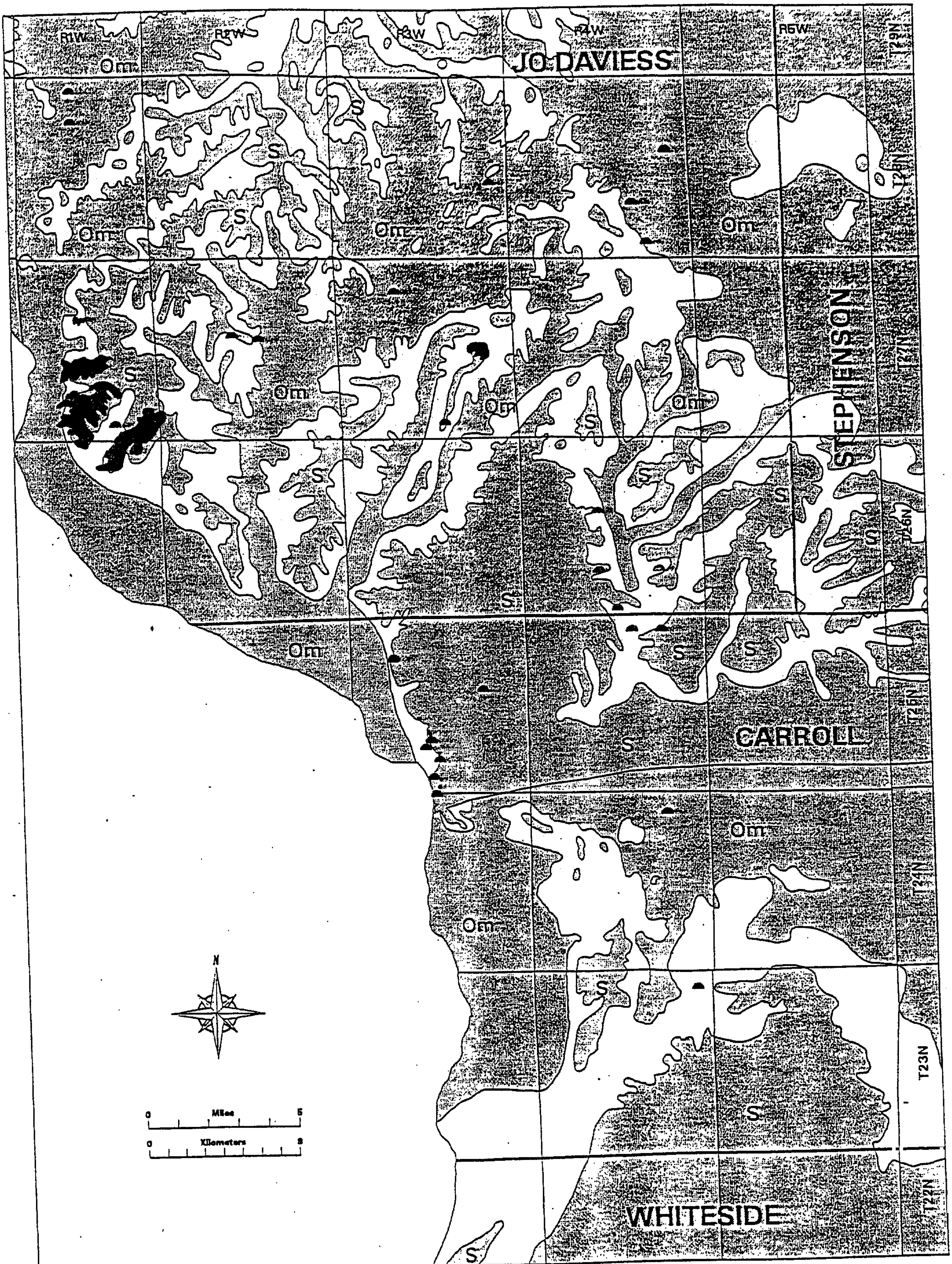


Figure 14. Karst map for the Driftless Area karst region of northwest Illinois. Geology modifed from Willman et al. (1967) and Kolata and Buschbach (1976).

Few sinkholes in this area are evident on topographic maps and aerial photos. However, both Trowbridge and Shaw (1916) and Heyl et al. (1959) reported sinkholes to be locally common in Silurian rocks. We observed several sinkholes of this diameter and of smaller sizes in regolith underlain by Hopkinton dolomite. Heyl et al. (1959) noted that sinkholes are larger (averaging about 30 m in diameter) and more abundant in the Silurian dolomite than in the Ordovician Galena Group. We did not study any sinkholes in the Ordovician strata in this area. The number of sinkholes associated with Ordovician rocks drastically increases towards the northwest into Iowa where these strata are less dolomitic (Heyl et al., 1959; Hallberg and Hoyer, 1982). The relationship between soils type and thickness (from stack unit maps by Berg and Kempton, 1988), and the locations of sinkholes shown on our maps indicates that sinkholes mostly occur in areas dominated by loess, silt and diamicton of the Quaternary Glasford Formation. They are most common in areas where these materials are less than 6 m thick, and within one to two kilometers of a stream valley. In the Driftless Area, sinkholes are most common adjacent to the Mississippi River valley. Sinkholes commonly occur near stream valleys because of the gradual lowering of the piezometric surface (i.e., the water table) near low-lying areas by surface erosion and the associated collapse of formerly water-saturated sediments (cover-collapse sinkholes) into solution-enlarged fissures. This mechanism was proposed by Ford (1964) for sinkhole formation in the Mendip Hills of Britain.

The limestones and dolomites of the Platteville and Galena Groups, where they are not overlain by shale of the Maquoketa Group, are an important source of groundwater in northwest Illinois, and in most of the northern third of the state. Groundwater occurs in joints, fractures, and solution cavities. Groundwater also occurs in Silurian dolomite on ridges where it is perched on underlying Maquoketa shale. This dolomite similarly contains crevices and solution features that provide groundwater for farm and domestic supplies (Hackett and Bergstrom, 1956).

North-Central Karst Region

An area that straddles the Rock River in Ogle and Lee Counties in north-central Illinois comprises the North-Central karst region (Figures 5, 15). Carbonate bedrock units in north-central Illinois consist of the Lower Ordovician Shakopee Dolomite of the Prairie du Chien Group and the Middle Ordovician Platteville and Galena Groups (Figure 16A). Because of the north-south trending Wisconsin Arch, these rocks are exposed along the tributaries of the Rock River from near Rockford (Winnebago County) to near Dixon (Ogle County) (Willman et al., 1967). The rocks are also exposed in road cuts and quarries on the south side of Rockford, and in road cuts north of Freeport (Stephenson County). Knappen (1926) first described the lithology of these strata near Dixon. The Shakopee Dolomite is a fine-grained, porous, argillaceous dolomite which locally contains shale and sandstone. The Galena Group consists of a porous, cherty, very fine-grained to very coarse-grained dolomite. The Platteville Group consists of a very fine- to coarse-grained, interbedded dolomite and limestone that locally contains argillaceous intervals. The Galena-Platteville interval has an average thickness of approximately 115 m (Foster, 1956).

Sinkholes are the principle evidence for karstic development in the Byron-Dixon area and occur mostly in near-surface or exposed carbonate bedrock (Bretz, 1923; Knappen, 1926). A few sinkholes also occur in soils overlying the St. Peter Sandstone, but we suggest that these are due to dissolution of the underlying Shakopee Dolomite and collapse of both the overlying sandstone and soil. Knappen reported that over 75% of the sinkholes occur where limestone of the Platteville Group is overlain by loess and silt, and diamicton of the

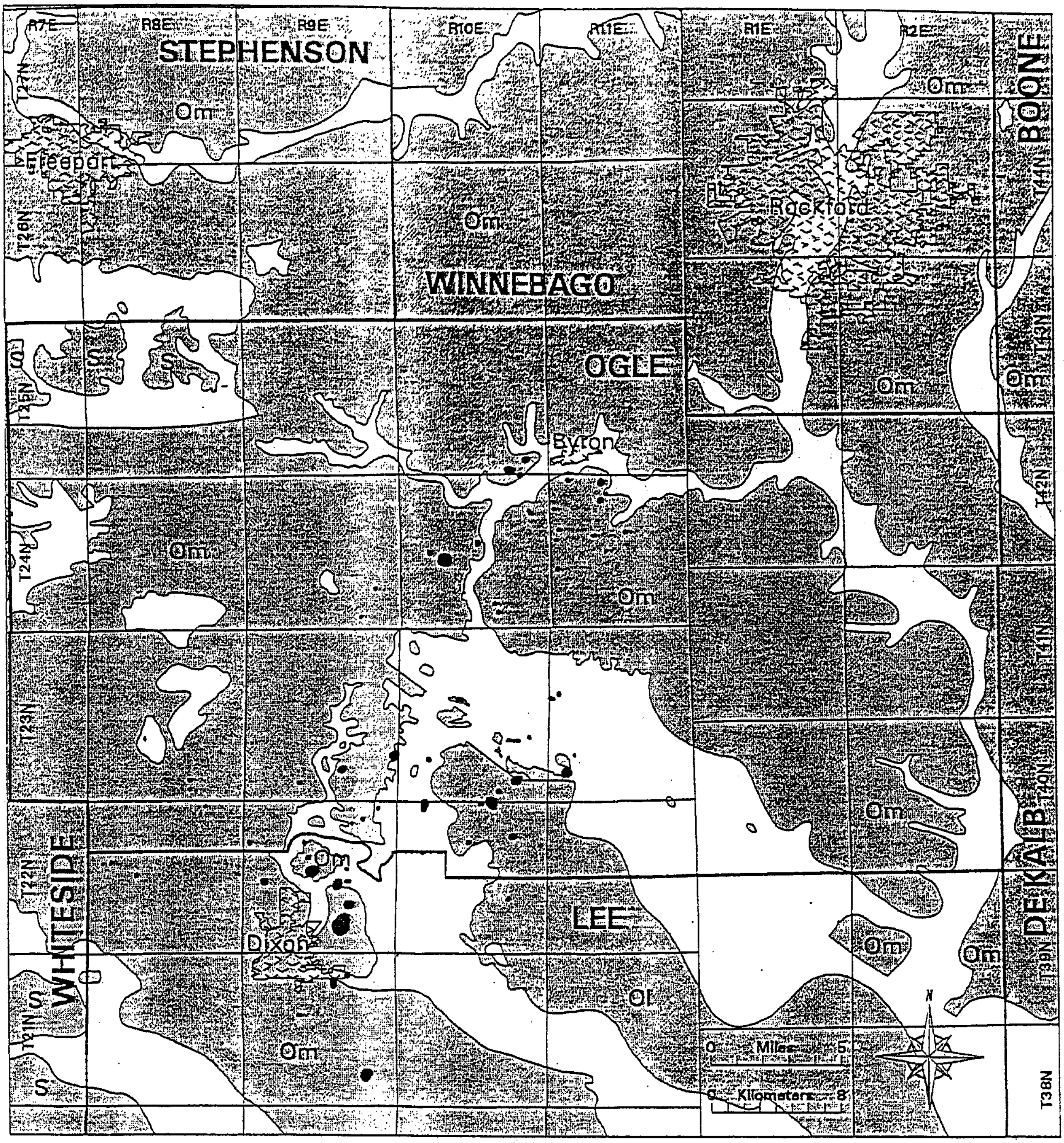
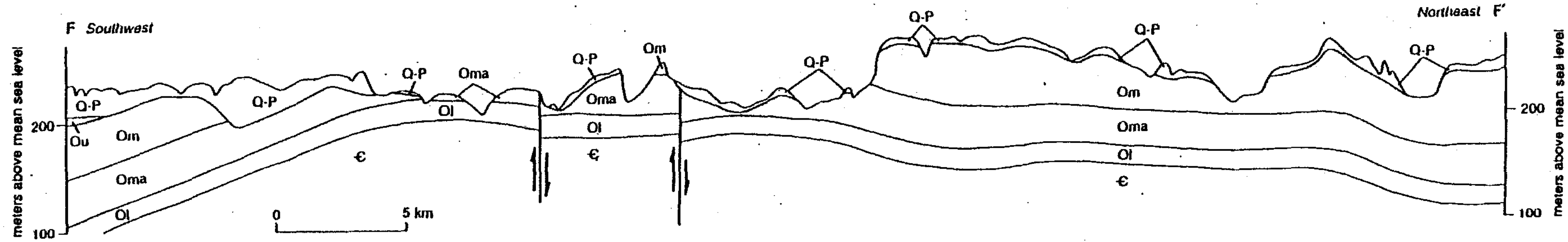
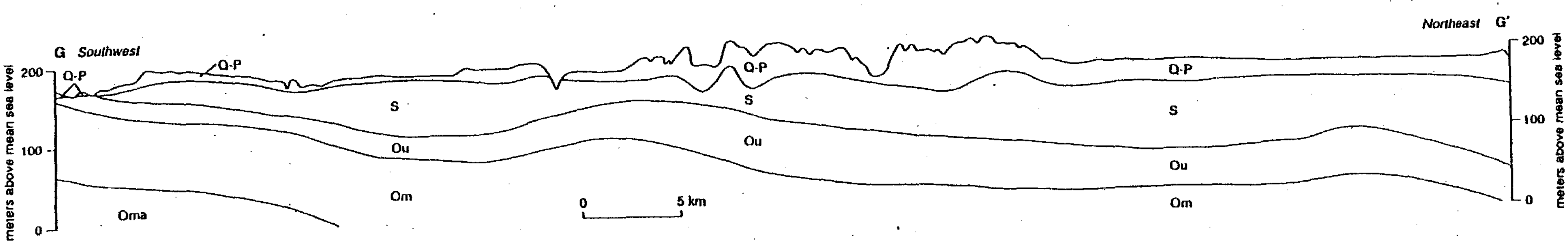


Figure 15. Karst map for the North-Central karst region. Geology modifed from Willman et al. (1967) and Kolata et al. (1978).



A. Cross-section of the North-Central karst region, modified from Bretz (1923), Kolata et al. (1978), Knappen (1926), Reinertsen (1990), and Templeton and Willman (1952).



B. Cross-section of northeastern Illinois, modified from Bretz (1939, 1955), Buschbach and Heim (1972), Culver (1923), Fisher (1925), and Savage (1925).

Figure 16. Cross-sections F-F′ and G-G′.

Quaternary Glasford Formation. Comparison of the karst maps of this paper with stack-unit maps developed by Berg and Kempton (1988) indicates that sinkholes commonly occur in areas where the bedrock is dominated by this stratigraphic sequence, where the overlying Quaternary cover is less than 6 m thick, and are located within several kilometers of stream valleys associated with the Rock River. The proximity of sinkholes to the stream valleys may be the result of reactivation of paleokarstic features. The gradual lowering of the piezometric surface (i.e., the water table) as stream valleys erode downward and the associated collapse of formerly water-saturated sediments (cover-collapse sinkholes) into solution-enlarged fissures may also be a factor in this area.

There are no verified cave entrances in the North-Central karst region; however, quarrying operations reportedly destroyed a cave in limestone of the Platteville Group northeast of Dixon (Knappen, 1926). We observed a sediment-filled cave opening in the Gregory-Anderson Co. quarry on the south edge of Rockford. At the northeastern edge of the region, Bretz (1923) referred to an unverified cave reportedly located south of Rockford near the Winnebago-Ogle county border. Bretz also reported several occurrences of open cavities (probably solution features) in the limestone that were encountered during the drilling of water wells.

Solution-enlarged fissures are common in the road cuts and quarries near Rockford and Freeport. They range in width from 0.25 m in road cuts along Interstate 39 to 8 m wide in the Gregory-Anderson Co. quarry. Despite the common occurrence of fissures in this region, we only mapped sinkholes in the Byron-Dixon area (Figure 15).

Groundwater in north-central Illinois is available in the Galena-Platteville dolomite where joints, fractures, and solution cavities are present and interconnected over a relatively large areal extent. Mills et al. (1993) reported that groundwater flow in the Galena-Platteville aquifer was primarily through "...subvertical fractures and subhorizontal zones of solution," the latter of which are probably stratigraphic breaks. They noted that hydraulically connected subhorizontal solution features have been identified that extend laterally for at least 1.2 km. The availability of water from these strata is adequate for domestic, farm, municipal, and industrial use (Foster, 1956); however, water-producing zones are distributed irregularly (vertically and horizontally) due to the irregular nature and distribution of the cavities (Csallany and Walton, 1963).

Other areas containing karstic features

Karstic features have been documented in carbonate bedrock in areas outside of the five karst regions. These areas are mostly covered with unlithified Quaternary deposits. In addition, some of the features occur in carbonate bedrock in areas where the bedrock is overall predominantly noncarbonate.

Northeast Illinois

The bedrock of northeast Illinois contains a few, widely dispersed karstic features. This area is most covered with regolith and outcrops are few in number and size. The paucity of karstic features in a relatively large area (from Lake to Kankakee Counties) and definite evidence of widespread extant karstification processes are the reason for not referring to this area as a karst region.

Silurian (Alexandrian and Niagaran Series) rocks comprise most of the bedrock surface in this area. These rocks are on the northeast flank of the Kankakee Arch, the axis of which plunges to the southeast and separates the Illinois Basin from the Michigan Basin (Visocky et al., 1985). These rocks are typically buried under 30 m or more of clayey diamicton and lake sediments (Figure 16B). In this area, the Alexandrian Series (lowermost Silurian) is divided into the Wilhelmi, Elwood, and Kankakee Formations which are chiefly composed of dolomite (Willman, 1973). The Wilhelmi Formation is an argillaceous dolomite with coarse silt, fine sand and shale partings near its base. The Elwood Formation is an abundantly cherty, pure to slightly argillaceous dolomite. The Kankakee Formation is a relatively pure dolomite that also contains shale partings. The younger Niagaran Series (middle Silurian) is divided into the Joliet, Sugar Run and Racine Formations. The lithology of these formations ranges from pure dolomite to silty, argillaceous and cherty dolomite containing some thin shale beds. Reefs occur locally in the Racine Formation (Willman, 1973). The upper surface of the Niagaran Series dolomite is an erosional surface (Willman, et al., 1975) and is creviced in outcrop.

Otto (1963) and Buschbach and Heim (1972) interpreted the buried Silurian dolomite of northeast Illinois as a karstic surface on the basis of seismic refraction, borehole, and outcrop data. The latter study covered over 2000 square kilometers of the greater Chicago area, most of Cook County, east Du Page County, and part of northern Will County. Buschbach and Heim described the bedrock as "...a dissected surface with numerous hills, northeast-southwest to east-west trending valleys that slope to the east, and enclosed depressions." Rare and typically small caves occur in Kane and Kankakee Counties where Silurian dolomite is exposed along stream valleys. Zeizel et al. (1962) stated that "enlargement of joints, fractures, and bedding planes by solution has taken place" typically at or near the bedrock surface. Otto (1963) prepared a detailed map of the bedrock surface near Joliet where abundant karstic features had been exposed in a deep excavation for a power plant site. Conversely, in the younger Niagaran dolomite, Bloom (1978) described only minor karstic features found along and interpreted to be controlled by joints and bedding planes.

During our field work, we found solutionally widened fractures and caves exposed in quarries, excavations, and a few natural bedrock exposures. These caves and fractures are typically filled with very fine-grained material that renders these features ineffective as conduits. However, exhumation and flushing of fill materials could result in the rejuvenation of a conduit system. Solutionally-widened fractures, sinkholes, solution features (i.e., horizontal grooves), and caves were observed in Lehigh Quarry, Kankakee River State Park (Kankakee County). Active sinkholes and sinking ephemeral streams occur near the Illinois River in Will County. Sediment in some karstic features in the Racine Formation in the Lehigh Quarry describe by (Bretz, 1940) contained early to middle Pennsylvanian spores. Much of the buried bedrock surface in northeast Illinois may be classified as paleokarst (per classification scheme of White, 1988). Karstic features such as those along Rock Creek in Kankakee County in the Kankakee Formation may have been exposed by erosion and be classified as exhumed karst. The active sinkholes in Will County may be classified as sinkhole karst.

The Silurian dolomite aquifer in northeast Illinois is the most productive aquifer of the Upper Bedrock Aquigroup (which also includes the Ordovician Galena-Platteville interval and the Ancell aquifer). Specific yields for this aquifer are dependent on the distribution and intensity of crevicing, and the size of the fracture openings. Consequently, specific yields from this aquifer are extremely variable (Visocky et al., 1985). The most productive part of the Silurian dolomite aquifer is the upper 15 m where solution-enlarged fractures are prevalent (Zeizel et al., 1962).

Douglas County

A cave entrance in an abandoned barrow pit and dissolution features in an active quarry are indicators of karst near the village of Tuscola in Douglas County. During excavation of a barrow pit for material to be used in the construction of the adjacent interstate highway, a small cave was encountered. This pit is just east of Tuscola and the cave was in the floor, which consisted of Devonian limestone. The cave was relatively small but was not filled with sediment, suggesting that karstification processes are active. In a nearby quarry, about 1.5 km east, solutionally widened joints occur in Devonian limestone but appear to be filled with sediment. These karstic features occur in an isolated outcrop/subcrop of limestone, surrounded by predominantly noncarbonate bedrock, at the axis of the LaSalle Anticlinorium. Further study is required to determine additional details on these karstic features and if a karst aquifer is present.

La Salle County

Several sinkholes and a cave are indicators of karst in a small area near the villages of La Salle and Oglesby in La Salle County. A few sinkholes occur in the Late Pennsylvanian LaSalle Limestone southeast of Oglesby. The LaSalle Limestone is the thickest limestone in the otherwise noncarbonate dominated Pennsylvanian strata of Illinois. This limestone is rarely used as a source for groundwater and only for domestic use (R. Brower, ISGS, personal communication).

The cave occurs in the Lower Ordovician Shakopee Dolomite and is about 1.5 km east of La Salle. In this area, the Shakopee is a more widespread bedrock than the LaSalle Limestone, but it is only locally utilized as a groundwater source. Most deep wells obtain water from sandstone strata above and below this dolomite. Where either the LaSalle or the Shakopee are used as aquifers, joints/fractures provide the porosity and they may be solutionally enlarged.

PSEUDO-KARSTIC FEATURES

Karst-like or pseudo-karstic features similar to sinkholes occur in areas where the collapse of abandoned underground mine tunnels have resulted in pit subsidence and associated piping of soil. Soil piping may also take place where drainage in poorly consolidated materials such as loess and sand intersects underground cavities and progressively erodes materials along its flow path. Mine collapse and soil piping often form pit subsidence that may be indistinguishable from sinkholes in true karstic areas.

Underground mines (Figure 17), that act as drains for infiltrating surface water and groundwater, have been responsible for the formation of sinkholes and other subsidence phenomena in Illinois. As shallow (less than 60 m) room and pillar mines collapse, concomitant collapse of overlying poorly consolidated materials, and/or soil piping into these cavities may form sinkholes in overlying terrains (e.g., Bauer et al., 1993). The mines also may be responsible for groundwater and surface water contamination due to their efficiency in transporting surface-derived contaminants to groundwater and surface waters. Underground mines are located in Ordovician rocks in Jo Daviess County, zinc and lead ores were extracted, in Mississippian rocks in Pope and Hardin Counties, where fluorspar was extracted, and in the predominantly noncarbonate Pennsylvanian rocks, where coal was extracted. Coal mining is responsible for most of the mined out areas in Illinois. The locations of these areas are discussed in Treworgy et al. (1989) and Damberger et al. (1984).

Soil piping occurs as a result of surface water draining rapidly through the soil into an open space (e.g., mine openings, fissures associated with mine-collapse). As the pressure of the infiltrating water increases in the soil, the soil fails and collapses into the openings. Eventually, cavities are formed at depth along the flow path as the soils collapse or stope

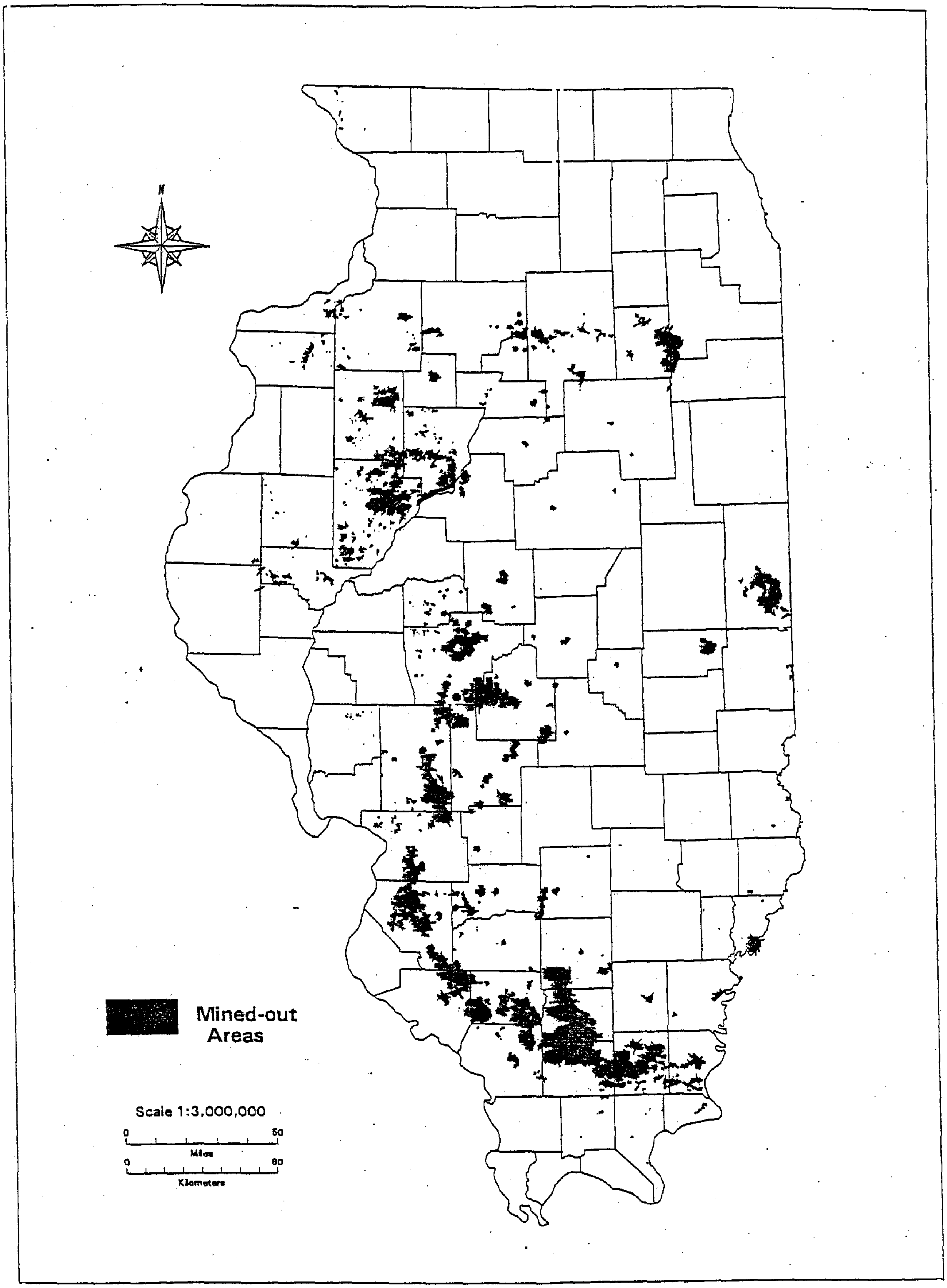


Figure 17. Map showing mined-out areas where psudo-karst features are likely to occur.

upward into the overlying materials. Continuous upward stoping of soil eventually results in the formation of a sinkhole at the surface (e.g., White, 1988).

CONCLUSIONS

Approximately 25% of the bedrock surface of Illinois is carbonate rock, and approximately 9% includes the five karst regions. In these regions, which are on the margins of the Illinois Basin and along structures within the basin, carbonate bedrock is either exposed or subcrops beneath glacial diamicton, loess, and other sediments. Karstic features are concentrated in the Driftless Area in northwest Illinois, north-central Illinois, the Lincoln Hills of the west part of the state, the Salem Plateau of southwest Illinois, and the Shawnee Hills of southern Illinois. A few caves and sinkholes are found in northeast Illinois, and La Salle and Douglas Counties, and are associated either with carbonate rocks along the LaSalle Anticlinorium or the northeast flank of the Illinois Basin (Kankakee Arch).

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Minnesota Rules, Chapter 7020.

7020.0100 [**Repealed**, 25 SR 834]
Current as of 11/01/00

7020.0200 SCOPE.

This chapter governs the storage, transportation, disposal, and utilization of animal manure and process wastewaters and the application for and issuance of permits for construction and operation of animal manure management and disposal or

Minnesota Rules, Chapter 7020.

7020.0100 [Repealed, 25 SR 834]
Current as of 11/01/00

7020.0200 SCOPE.

This chapter governs the storage, transportation, disposal, and utilization of animal manure and process wastewaters and the application for and issuance of permits for construction and operation of animal manure management and disposal or utilization systems for the protection of the environment. This chapter does not address wastes from fish. This chapter does not preempt the adoption or enforcement of zoning ordinances or plans by counties, townships, or cities.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00.

7020.0205 INCORPORATION BY REFERENCE.

For the purposes of parts 7001.0020 and 7020.0200 to 7020.2225, the documents in items A to L are incorporated by reference. These documents are not subject to frequent change.

A. Annual Book of American Society for Testing and Materials (ASTM), Part 4, ASTM D 1557, Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop. 1978 Edition. This publication is available through the Minitex interlibrary loan system.

B. Annual Book of American Society for Testing and Materials (ASTM), Part 4, ASTM D 4318, Test Method for Liquid Limit, and Plasticity Index of Soils. 1984 Edition. This publication is available through the Minitex interlibrary loan system.

C. Annual Book of American Society for Testing and Materials (ASTM), Part 4, ASTM D 422, Method for Particle-Size Analysis of Soils. 1972 Edition. This publication is available through the Minitex interlibrary loan system.

D. Annual Book of American Society for Testing and Materials (ASTM), Part 4, ASTM D 698, Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (304.8-mm) Drop. 1978 Edition. This publication is available through the Minitex interlibrary loan system.

E. Code of Federal Regulations, title 40, part 412, Feedlots Point Source Category. This publication is available through the Minitex interlibrary loan system.

F. Code of Federal Regulations, title 40, section 122.23, Concentrated Animal Feeding Operations. This publication is available through the Minitex interlibrary loan system.

G. Protected Waters and Wetlands Maps, 1999. Minnesota Department of Natural Resources, Division of Waters. These maps are available through the Minnesota Bookstore, 117 University Ave., St. Paul, MN 55155. These maps are available for viewing at the County Auditor's offices, County Soil and Water Conservation District offices, Watershed District offices, Minnesota Department of Natural Resources offices, and through the Minitex interlibrary loan system at the Minnesota Department of Natural Resources Internet site at the following address: http://www.dnr.state.mn.us/waters/wetlands/pwi/index.html.

H. United States Geological Survey Quadrangle Maps, 7.5- and 15-minute maps, United States Department of the Interior Geological Survey, 1999. These maps are available through the Minitex interlibrary loan system from the Minnesota Pollution Control Agency library. They are available for viewing at the Minnesota Department of Administration and county offices, and may be ordered from the United States Geological Survey Internet site at the following address: http://mappings.usgs.gov/mac/findmaps.html.

I. Minnesota Natural Resources Conservation Service Practice Standard, Waste Storage Pond (Code No. 425), November 1991, or Waste Storage Facility (Code No. 313), January 1998. This publication is available through the Minitex system.

J. Feedlot Inventory Guidebook, Minnesota Board of Water and Soil Resources, June 1991. This publication is available through the Minitex interlibrary loan system.

K. Annual Book of American Society for Testing Materials (ASTM), part 4, ASTM D 2922, Test Method for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth). 1996 Edition. This publication is available through the Minitex interlibrary loan system.

L. An Evaluation System to Rate Feedlot Pollution Potential, United States Department of Agriculture, Agricultural Research Service, April 1982. This publication is available through the Minitex interlibrary loan system.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.0250 **SUBMITTALS AND RECORDS.**

Subpart 1. **Accuracy of submittals.** An owner who fails to submit relevant facts or who has submitted incorrect information in a submittal shall, upon becoming aware of the failure or incorrect information, promptly submit to the commissioner or county feedlot pollution control officer the supplementary facts or corrected information.

Subp. 2. **Record retention, access to records, and inspections.**

A. A person required to keep records under this chapter shall maintain at the animal feedlot or manure storage area, or at the person's business address, for three years from the date the record was made, unless otherwise specified, all information required to be recorded under applicable state and federal rules. The person shall make these records available for examination and copying upon request of the commissioner, county feedlot pollution control officer, or agent of the commissioner and shall, upon request, submit these records to the commissioner, county feedlot pollution control officer, or agent of the commissioner within 30 days.

B. A person storing, transporting, disposing, or utilizing animal manure or process wastewaters shall provide the commissioner, county feedlot pollution control officer, or agent of the commissioner access to the animal feedlot, the animal holding area, the manure storage area, or other areas where manure or process wastewaters are stored, in transport, or utilized, including allowing the collection of samples, and records to the extent provided under Minnesota Statutes, section 115.04, or other law, upon presentation of credentials.

C. Nothing in this subpart limits the commissioner's or agency's authority under Minnesota Statutes, section 115.04, or other law.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.0300 DEFINITIONS.

Subpart 1. **Scope.** All terms employed in this chapter for which definitions are given in Minnesota Statutes, sections 115.01 and 116.06, have the meanings given in those sections. For the purposes of this chapter, the terms specified in this part have the meanings ascribed to them.

Subp. 1a. **Aboveground manure storage area.** "Aboveground manure storage area" means a manure storage area for which all portions of the liner are located at or above the elevation of the natural ground level.

Subp. 2. **Agency.** "Agency" means the Minnesota Pollution Control Agency as established in Minnesota Statutes, chapter 116.

Subp. 3. **Animal feedlot.** "Animal feedlot" means a lot or building or combination of lots and buildings intended for the confined feeding, breeding, raising, or holding of animals and specifically designed as a confinement area in which manure may accumulate, or where the concentration of animals is such that a vegetative cover cannot be maintained within the enclosure. For purposes of these parts, open lots used for the feeding and rearing of poultry (poultry ranges) shall be considered to be animal feedlots. Pastures shall not be considered animal feedlots under these parts.

Subp. 4. **Animal manure or manure.** "Animal manure" or "manure" means poultry, livestock, or other animal excreta or a mixture of excreta with feed, bedding, precipitation, or other materials.

Subp. 5. **Animal unit.** "Animal unit" means a unit of measure used to compare differences in the production of animal manure that employs as a standard the amount of manure produced on a regular basis by a slaughter steer or heifer for an animal feedlot or a manure storage area, calculated by multiplying the number of animals of each type in items A to I by the respective multiplication factor and summing the resulting values for the total number of animal units. For purposes of this chapter, the following multiplication factors shall apply:

A. dairy cattle:

(1) one mature cow (whether milked or dry);

(a) over 1,000 pounds, 1.4 animal unit; or

(b) under 1,000 pounds, 1.0 animal unit;

(2) one heifer, 0.7 animal unit; and

(3) one calf, 0.2 animal unit;

B. beef cattle:

(1) one slaughter steer or stock cow, 1.0 animal unit;

(2) one feeder cattle (stocker or backgrounding) or heifer, 0.7 animal unit;

(3) one cow and calf pair, 1.2 animal unit; and

(4) one calf, 0.2 animal unit;

C. one head of swine:

(1) over 300 pounds, 0.4 animal unit;

(2) between 55 pounds and 300 pounds, 0.3 animal unit; and

(3) under 55 pounds, 0.05 animal unit;

D. one horse, 1.0 animal unit;

E. one sheep or lamb, 0.1 animal unit;

F. chickens:

(1) one laying hen or broiler, if the facility has a liquid manure system, 0.033 animal unit; or

(2) one chicken if the facility has a dry manure system:

(a) over five pounds, 0.005 animal unit; or

(b) under five pounds, 0.003 animal unit;

G. one turkey:

(1) over five pounds, 0.018 animal unit; or

(2) under five pounds, 0.005 animal unit;

H. one duck, 0.01 animal unit; and

I. for animals not listed in items A to H, the number of animal units is the average weight of the animal in pounds divided by 1,000 pounds.

Subp. 5a. **Concentrated animal feeding operation or CAFO.** "Concentrated animal feeding operation" or "CAFO" means animal feedlots meeting the definition of a CAFO in Code of Federal Regulations, title 40, section 122.23.

Subp. 6. **Certificate of compliance.** "Certificate of compliance" means a letter from the commissioner or the county feedlot pollution control officer to the owner of an animal feedlot or manure storage area stating that the feedlot or manure storage area meets agency requirements.

Subp. 6a. **Commencement of construction.** "Commencement of construction" means to begin or cause to begin, as part of a continuous program, the placement, assembly, or installation of facilities or equipment; or to conduct significant site preparation work, including clearing, excavation, or removal of existing buildings, structures, or facilities, necessary for the placement, assembly, or installation of facilities or equipment at:

A. a new or expanded animal feedlot; or

B. a new, modified, or expanded manure storage area.

Subp. 7. [Repealed, 25 SR 834]

Subp. 7a. **Commissioner.** "Commissioner" means the commissioner of the Minnesota Pollution Control Agency whose duties are defined in Minnesota Statutes, section 116.03.

Subp. 7b. **Composite liner.** "Composite liner" means a manure storage area liner which is designed to achieve a theoretical seepage rate of 1/560 inch per day or less and consists of a geomembrane liner, geosynthetic clay liner, or other comparable material, laid over a constructed cohesive soil liner having a thickness of two feet or greater.

Subp. 7c. **Compost.** "Compost" means a humus-like product derived from the controlled microbial degradation of organic material. Only manure that has completed the composting processes described in part 7020.2150, subpart 2, is compost.

Subp. 8. **Corrective or protective measure.** "Corrective or protective measure" means a practice, structure, condition, or combination thereof which prevents or reduces the discharge of pollutants from an animal feedlot or manure storage area to a level in conformity with agency rules.

Subp. 8a. **Construction short-form permit.** "Construction short-form permit" means a permit issued for an animal feedlot or manure storage area according to parts 7020.0505 and 7020.0535.

Subp. 9. **County feedlot pollution control officer.** "County feedlot pollution control officer" means an employee or officer of a delegated county who is knowledgeable in agriculture and who is designated by the county board to perform the duties under part 7020.1600.

Subp. 9a. **Delegated county.** "Delegated county" means a county that has applied for and received authorization pursuant to part 7020.1600, subpart 3a, item C, to implement an animal feedlot program.

Subp. 9b. **Design engineer.** "Design engineer" means a professional engineer licensed in the state of Minnesota or a Natural Resources Conservation Service (NRCS) staff person having NRCS approval authority for the project.

Subp. 9c. **Discharge.** "Discharge" means the addition of a pollutant to waters of the state, including a release of animal manure, manure-contaminated runoff or process wastewater from an animal feedlot, a manure storage area, or an animal manure land application site by leaking, pumping, pouring, emitting, emptying, dumping, escaping, seeping, leaching, or any other means. Discharge includes both point source and nonpoint source discharges.

Subp. 10. [Repealed by amendment, L 1987 c 186 s 15]

Subp. 11. **Domestic fertilizer.** "Domestic fertilizer" means:

A. animal manure that is put on or injected into the soil to improve the quality or quantity of plant growth; or

B. animal manure that is used as compost, soil conditioners, or specialized plant beds.

Subp. 11a. **Expansion or expanded.** "Expansion" or "expanded" means construction or any activity that has resulted or may result in an increase in the number of animal units that an animal feedlot is capable of holding or an increase in storage capacity of a manure storage area.

Subp. 12. **Floodplain.** "Floodplain" means the areas adjoining a watercourse which have been or hereafter may be covered by a large flood known to have occurred generally in Minnesota and reasonably characteristic of what can be expected to occur on an average frequency in the magnitude of the 100 year recurrence interval.

Subp. 12a. **Flow distance.** "Flow distance" means the distance runoff travels from the source of the runoff to waters of the state.

Subp. 13. **Interim permit.** "Interim permit" means a permit issued by the commissioner or the county feedlot pollution control officer in accordance with parts 7020.0505 and 7020.0535.

Subp. 13a. **Intermittent streams.** "Intermittent streams" means all water courses identified as intermittent streams on United States Geological Survey quadrangle maps.

Subp. 13b. **Manure-contaminated runoff.** "Manure-contaminated runoff" means a liquid that has come into contact with animal manure and drains over land from any animal feedlot, manure storage area, or animal manure land application site.

Subp. 14. **Manure storage area.** "Manure storage area" means an area where animal manure or process wastewaters are stored or processed. Short-term and permanent stockpile sites and composting sites are manure storage areas. Animal manure packs or mounding within the animal holding area of an animal feedlot that are managed according to part 7020.2000, subpart 3, are not manure storage areas.

Subp. 15. **New animal feedlot.** "New animal feedlot" means an animal feedlot or manure storage area:

A. constructed, established, or operated at a site where no animal feedlot or manure storage area existed previously; or

B. that existed previously and has been unused for five years or more.

Subp. 15a. **New technology.** "New technology" means an alternative construction or operating method to those provided in parts 7020.2000 to 7020.2225. New technology construction or operating methods must achieve equivalent environmental results to the requirements in parts 7020.2000 to 7020.2225.

Subp. 16. **National Pollutant Discharge Elimination System permit or NPDES permit.** "National Pollutant Discharge Elimination System permit" or "NPDES permit" means a permit issued by the agency for the purpose of regulating the discharge of pollutants from point sources including concentrated animal feeding operations (CAFOs).

Subp. 17. **Owner.** "Owner" means all persons having possession, control, or title to an animal feedlot or manure storage area.

Subp. 18. **Pastures.** "Pastures" means areas where grass or other growing plants are used for grazing and where the concentration of animals is such that a vegetation cover is maintained during the growing season except in the immediate vicinity of temporary supplemental feeding or watering devices.

Subp. 18a. **Permanent stockpiling site.** "Permanent stockpiling site" means a manure storage area where manure is stored or processed that does not meet the requirements of part 7020.2125, subpart 2.

Subp. 19. **Permit.** "Permit" means a document issued by the agency or county animal feedlot pollution control officer which may contain requirements, conditions, or schedules for achieving compliance with the discharge standards and requirements for management of animal manure construction or operation of animal holding areas or manure storage areas. Permits issued under this chapter are NPDES, state disposal system, interim, and construction short-form permits.

Subp. 19a. **Pollution hazard.** "Pollution hazard" means an animal feedlot or manure storage area that:

A. does not comply with the requirements of parts 7020.2000 to 7020.2225 and has not been issued an SDS or NPDES permit establishing an alternative construction or operating method; or

B. presents a potential or immediate source of pollution to waters of the state as determined by inspection by a county feedlot pollution control officer or agency staff taking into consideration the following:

(1) the size of the animal feedlot or manure storage area;

(2) the amount of pollutants reaching or that may

reach waters of the state;

(3) the location of the animal feedlot or manure storage area relative to waters of the state;

(4) the means of conveyance of animal manure or process wastewater into waters of the state; and

(5) the slope, vegetation, rainfall, and other factors affecting the likelihood or frequency of discharge of animal manure or process wastewater into waters of the state.

Subp. 19b. **Process wastewaters.** "Process wastewaters" means waters and/or precipitation, including rain or snow, which comes into contact with manure, litter, bedding, or other raw material or intermediate or final material or product used in or resulting from the production of animals, poultry, or direct products, such as milk or eggs.

Subp. 20. [Repealed, 25 SR 834]

Subp. 20a. **Separation distance to bedrock.** "Separation distance to bedrock" means the distance between stored manure and fractured bedrock.

Subp. 21. **Shoreland.** "Shoreland" means land, as defined in Minnesota Statutes, section 103F.205, subdivision 4, located within the following distances from the ordinary high water elevation of public waters:

A. land within 1,000 feet from the normal high water mark of a lake, pond, or flowage; and

B. land within 300 feet of a river or stream or the landward side of floodplain delineated by ordinance on such a river or stream, whichever is greater.

Subp. 21a. **Short-term stockpiling site.** "Short-term stockpiling site" means a manure storage area where manure is stored or processed according to part 7020.2125, subparts 1 to 3.

Subp. 22. **Sinkhole.** "Sinkhole" means a surface depression caused by a collapse of soil or overlying formation above fractured or cavernous bedrock.

Subp. 23. **Special protection area.** "Special protection area" means land within 300 feet of all:

A. protected waters and protected wetlands as identified on Department of Natural Resources protected waters and wetlands maps; and

B. intermittent streams and ditches identified on United States Geological Survey quadrangle maps, excluding drainage ditches with berms and segments of intermittent streams which are grassed waterways.

Subp. 24. **State disposal system permit or SDS permit.** "State disposal system permit" or "SDS permit" means a state permit that may be processed in accordance with parts 7001.0040; 7001.0050; 7001.0100, subparts 4 and 5; and 7001.0110.

Subp. 25. **Unpermitted or noncertified liquid manure storage area.** "Unpermitted or noncertified liquid manure storage area" means a liquid manure storage area that is in operation and:

A. the owner does not have an agency or delegated county permit or certificate of compliance for the manure storage area and was required to apply for and obtain a permit or certificate of compliance prior to the construction or operation of the manure storage area; or

B. the owner has not complied with the preoperational requirements of part 7020.2100 or permit requirements, if applicable.

Subp. 26. **Waters of the state.** "Waters of the state" means all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, reservoirs, aquifers, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface or underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state or any portions of the state.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: L 1987 c 186 s 15; 25 SR 834
Current as of 11/01/00

7020.0350 REGISTRATION REQUIREMENTS FOR ANIMAL FEEDLOTS AND MANURE STORAGE AREAS.

Subpart 1. **Registration data.** After January 1, 2002, the agency and all delegated counties shall maintain registration data for animal feedlots and manure storage areas. The registration data must include the information required in a Level II feedlot inventory as described in the Feedlot Inventory Guidebook and must contain the following:

A. date the registration form was completed;

B. name and address of all owners of the animal feedlot, manure storage area, or pasture;

C. facility location according to township, county, section, and quarter section;

D. permit or certificate number for owners who have been issued an agency or delegated county feedlot permit or certificate of compliance;

E. types of animal holding areas including pastures, confinement barns, and open lots;

F. number and types of animals in the areas listed in item E;

G. identity of surface waters within 1,000 feet of the facility;

H. presence and type of manure storage areas;

I. shortest distance from an animal holding area or manure storage area to a well; and

J. the name of the person that completed the registration form.

Subp. 2. **Owners required to register.**

A. Owners of the following facilities are required to register with the commissioner or delegated county, except as provided in item B:

(1) an animal feedlot capable of holding 50 or more animal units, or a manure storage area capable of holding the manure produced by 50 or more animal units; and

(2) an animal feedlot capable of holding ten or more and fewer than 50 animal units, or a manure storage area capable of holding the manure produced by ten or more and fewer than 50 animal units, that is located within shoreland.

B. An owner of a livestock facility located on county fairgrounds is not required to register, in accordance with Laws 2000, chapter 435, section 10, paragraph (c), clause (6).

Subp. 3. **Initial registration schedule and requirements.** Owners required to register under subpart 2 shall comply with at least one of the following by January 1, 2002:

A. the owner shall submit the information in subpart 1, on a form provided by the commissioner, to the commissioner or delegated county feedlot pollution control officer;

B. the owner shall submit a permit application to the commissioner or delegated county after October 23, 2000; or

C. the owner shall be listed on a feedlot inventory that:

(1) is a Level II or Level III inventory as described in the Feedlot Inventory Guidebook that contains the information under subpart 1, items A and E to J;

(2) is current as of October 1, 1997;

(3) contains the information required under subpart 1, items B to D; and

(4) has been submitted to the commissioner.

Subp. 4. **Registration requirements after January 1, 2002.** Owners of animal feedlots and manure storage areas who are required to register under subpart 2 shall comply with items A and B, as applicable.

A. Owners of facilities not in operation prior to January 1, 2002, shall register with the commissioner or delegated county prior to or upon commencement of operation. Owners shall comply with at least one of the following:

(1) the owner shall submit the information in subpart 1, on a form provided by the commissioner; or

(2) the owner shall submit a permit application to the commissioner or delegated county.

B. Owners shall update their registrations prior to the registration update deadlines which shall be established by adding four-year increments to the initial registration deadline of January 1, 2002. Owners shall register at least once during each of the four-year registration update intervals by meeting one of the following:

(1) the owner shall comply with item A, subitem (1) or (2); or

(2) the owner shall be listed on a feedlot inventory that:

(a) is a Level II or Level III inventory as described in the Feedlot Inventory Guidebook that contains the information under subpart 1, items A and E to J;

(b) has been updated within the applicable four-year registration interval;

(c) contains the information required under subpart 1, items B to D and K; and

(d) in its updated form has been submitted to the commissioner, including the information in unit (c).

Subp. 5. **Notification.** The agency or delegated county shall:

A. notify owners at least 90 days prior to the scheduled registration update deadlines about reregistration; and

B. send a receipt of registration to owners within 30 days of receipt of the registration by the agency or the delegated county.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.0355 PERMITS AND CERTIFICATES ISSUED PRIOR TO OCTOBER 23, 2000.

Subpart 1. **SW-A permits.** All owners with SW-A permits shall comply with the permitting requirements in parts 7020.0355 to 7020.0535. Upon application for a permit under parts 7020.0405 to 7020.0535, the SW-A permit must be reconsidered pursuant to this chapter and chapter 7001. Any SW-A permit terms and conditions that are inconsistent with the requirements of parts 7020.2000 to 7020.2225 are superseded as of October 23, 2000.

Subp. 2. **Certificates of compliance.** All owners with certificates of compliance shall comply with the permitting requirements in parts 7020.0355 to 7020.0535.

Subp. 3. **Interim A and interim B permits.** An owner with an Interim A or Interim B permit that has not expired on October 23, 2000, shall comply with items A and B.

A. If the requirements for which an Interim A permit was issued are not complete on October 23, 2000, the owner shall apply, prior to the expiration date of the Interim A permit, for a construction short-form, SDS, or NPDES permit as required under part 7020.0405.

B. If the requirements for which an Interim B permit was issued are not complete on the expiration date of the Interim B permit, the owner shall comply with part 7020.0535, subpart 5, except that the owner shall complete the notification requirement prior to the expiration date of the Interim B permit.

Subp. 4. **NPDES and SDS permits.** NPDES and SDS permits issued prior to October 23, 2000, remain in effect to the extent provided by the issued permit terms and conditions.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834

* **NOTE:** This part was originally adopted at 25 SR 834 as *7020.0400. It was renumbered editorially.
Current as of 11/01/00

7020.0405 PERMIT REQUIREMENTS.

Subpart 1. **Permit required.** Four types of permits are issued under this chapter and chapter 7001: interim permits, construction short-form permits, SDS permits, and NPDES permits. The owner shall apply for a permit as follows:

A. an NPDES permit for the construction and operation of an animal feedlot that meets the criteria for CAFO;

B. unless required to apply for a permit under item A, an SDS permit under the following conditions:

(1) the construction and operation of an animal feedlot or manure storage area that has been demonstrated not to meet the criteria for CAFO and is capable of holding 1,000 or more animal units or the manure produced by 1,000 or more animal units;

(2) the facility does not comply with all applicable requirements of parts 7020.2000 to 7020.2225 and the pollution hazard cannot be, or has not been, corrected under the conditions in part 7020.0535 applicable to interim permits;

(3) the owner is proposing to construct or operate a new technology. An SDS permit is required for new technology operational methods while these operational methods are employed; or

(4) the facility is one for which conditions or requirements other than those in parts 7020.2000 to 7020.2225 were assumed:

(a) as a mitigation measure in an environmental impact statement; or

(b) in obtaining a negative declaration in an environmental assessment worksheet;

C. unless required to obtain a permit under items A and B, an interim permit for:

(1) facilities identified as a pollution hazard; or

(2) an animal feedlot or a manure storage area with a capacity of 300 or more animal units prior to applying manure or process wastewater:

(a) on land where the soil phosphorus test levels exceed the levels in part 7020.2225, subpart 3, item C;

(b) on land in special protection areas with slopes exceeding six percent; or

(c) in a drinking water supply management area where the aquifer is designated vulnerable under chapter 4720; or

D. unless required to obtain a permit under items A to C, a construction short-form permit for an animal feedlot or manure storage area proposing to construct or expand to a capacity of 300 animal units or more, or the manure produced by 300 animal units or more. However, if a facility is determined to be a pollution hazard and the owner is proposing to expand to a capacity of 300 animal units or more, or the manure produced by 300 animal units or more, the owner shall apply for an interim permit under item C.

Subp. 2. **Expansion and stocking limitations.** Prior to expansion, an owner required to apply for a construction or operating permit under subpart 1 shall have obtained the permit, or permit modification, as applicable. An owner issued an interim permit that authorizes construction for an expansion shall not stock the expansion prior to the fulfillment of all permit conditions related to the correction of the pollution hazard for which the interim permit was issued.

Subp. 3. **No permit required.** The owner of an animal feedlot or manure storage area is not required to apply for a permit for:

A. a feedlot or manure storage area that meets the requirements of part 7020.2003, subparts 4 to 6;

B. a short-term stockpile or compost site if the owner is not an owner of an animal feedlot or manure storage area other than a short-term stockpile or composting site;

C. a livestock facility located on county fairgrounds; or

D. a change in an existing facility that consists solely of a change in ownership of the building, grounds, or feedlot.

Subp. 4. **Change of ownership.** Prior to the change in the ownership or control of an animal feedlot or manure storage area issued a permit under this chapter, the new owner shall submit to the commissioner or county feedlot pollution control officer the information required in item A or B, as applicable. If the commissioner or county feedlot pollution control officer determines that the new owner meets the requirements for obtaining the permit, then the commissioner or the county feedlot pollution control officer shall issue the permit to the new owner. The new owner shall submit:

A. a request for permit modification according to part 7001.0190 for facilities covered under an SDS or NPDES permit; or

B. a change of ownership form provided by the commissioner.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.0500 [Repealed, 25 SR 834]
Current as of 11/01/00

7020.0505 PERMIT APPLICATIONS AND PROCESSING PROCEDURES.

Subpart 1. **Submittals.** Permit applications must be submitted according to items A and B. An application is complete when all applicable information in subpart 4 and application fees under parts 7002.0250 and 7002.0310 have been received by the commissioner or the county feedlot pollution control officer, as appropriate. Incomplete permit applications must not be processed by the commissioner or delegated county feedlot pollution control officer.

A. NPDES and SDS permit applications must be submitted to the agency in accordance with this part and chapter 7001, with a copy submitted to the delegated county.

B. Interim permit and construction short-form permit applications must be submitted to the agency or delegated county in accordance with this part and part 7020.0535.

Subp. 2. **Permit application submittal schedule.** An owner of an animal feedlot or a manure storage area required to apply for a permit under part 7020.0405, subpart 1, shall apply in accordance with the following schedule:

A. the following facilities that are in existence on or before October 23, 2000, must submit a permit application by June 1, 2001:

(1) a CAFO; and

(2) an animal feedlot capable of holding 1,000 animal units or more or a manure storage area capable of holding the manure produced by 1,000 animal units or more for which the owner has demonstrated that the facility does not meet the CAFO criteria;

B. a CAFO as determined through the case-by-case determination process under Code of Federal Regulations, title 40, section 122.23(c), shall submit a permit application by the submittal deadline established by the commissioner's written request. The owner has at least 30 days to submit the permit application;

C. an animal feedlot or a manure storage area that is new or expands after October 23, 2000, and required to apply for an SDS or NPDES permit, shall submit a permit application at least 180 days prior to the planned date of commencement of construction or expansion;

D. an animal feedlot or a manure storage area that is new or expanding after October 23, 2000, and is required to apply for a construction short-form permit, shall submit a permit application at least 90 days prior to the planned date of commencement of construction or expansion; and

E. a facility determined to be a pollution hazard shall submit a permit application by the submittal deadline established by the commissioner or the county feedlot pollution control officer's written request. The owner has at least 15 days to submit the permit application.

Subp. 3. **Permit application format.** A permit application for an NPDES, SDS, interim, or construction short-form permit must be on a form provided by the commissioner or the county feedlot pollution control officer.

Subp. 4. **Content of permit application.**

A. An application for a permit must contain the following:

(1) the names and addresses of the owners and the signature of at least one of the owners;

(2) the legal name and business address of the facility, if different than the owner;

(3) the location of the facility by county, township, section, and quarter section;

(4) a list of all animal types, and the maximum number of animals of each animal type that can be confined within each lot, building, or area at the animal feedlot;

(5) a list of all existing and proposed manure storage areas, including plans and specifications as required in part 7020.2100 for proposed liquid manure storage areas and part 7020.2125 for permanent stockpile sites;

(6) the total number of animal units the facilities listed in subitems (4) and (5) will be capable of holding after completing construction or expansion;

(7) the soil type or texture and depth to saturated soils at the facility as identified in the USDA Soil Survey Manual or a site-specific soils investigation. If applicable, submittal of the soils investigation information required in parts 7020.2100 to 7020.2225 meets this requirement;

(8) an aerial photograph showing the location of all wells, buildings, surface tile intakes, lakes, rivers, and watercourses within 1,000 feet of the proposed facility;

(9) the number of acres available for land application of manure;

(10) if applying for an SDS or NPDES permit or interim permit under part 7020.0405, subpart 1, item C, subitem (2), a manure management plan that meets the requirements under part 7020.2225, subpart 4;

(11) if applicable, a description of all conditions that make the facility a pollution hazard and a description of the corrective and protective measures proposed to correct the pollution hazard;

(12) if applying for an NPDES permit, a supplemental federal application form.

B. In addition to the requirements of item A, a permit application for an animal feedlot capable of holding 1,000 animal units or more or a manure storage area capable of holding the manure produced by 1,000 animal units or more must contain:

(1) an air emission plan that includes:

(a) methods and practices that will be used to minimize air emissions resulting from animal feedlot or manure storage area operations including manure storage area start-up practices, loading, and manure removal;

(b) measures to be used to mitigate air emissions in the event of an exceedance of the state ambient hydrogen sulfide standard; and

(c) a complaint response protocol describing the procedures the owner will use to respond to complaints directed at the facility, including:

i. a list of each potential odor source at the facility;

ii. a determination of the odor sources most likely to generate significant amounts of odors; and

iii. a list of anticipated odor control strategies for addressing each of the significant odor sources; and

(2) an emergency response plan that includes a description of the procedures that will:

(a) contain, minimize, and manage an unauthorized discharge;

(b) provide notification to the proper authorities; and

(c) mitigate any adverse effects of an unauthorized discharge.

C. In addition to the requirements of items A and B, an owner proposing to construct or expand an animal feedlot or a manure storage area shall also submit, on a form provided by the commissioner, certification and documentation that the owner has notified the local zoning authority, as required under part 7020.2000, subpart 5, of the proposed new or expanded animal feedlot or manure storage area, or that no such local zoning controls exist.

D. In addition to the requirements of items A to C, an owner proposing to construct or expand an animal feedlot with the capacity of 500 animal units or more or a manure storage area with the capacity to hold the manure produced by 500 animal units or more shall also certify and document, on forms provided by the commissioner, that the notification requirements under part 7020.2000, subpart 4, have been met.

E. The owner of an animal feedlot or a manure storage area shall submit additional information relating to the facility design, construction, or operation as requested by the commissioner or county feedlot pollution control officer to evaluate compliance with applicable federal and state rules.

Subp. 5. **Application processing.** Permit applications must be processed according to items A to C.

A. NPDES and SDS permits must be processed according to the procedures under this part and part 7001.0020, item F.

B. The agency and delegated county shall issue, reissue, revoke and reissue, or modify a permit according to part 7001.0140 and other applicable agency rules.

C. Construction short-form and interim permit applications must be processed in accordance with parts 7020.0505 and 7020.0535. County feedlot pollution control officers shall also process permit applications according to part 7020.1600, subpart 4a.

Subp. 6. **Application for variance.** Any person may apply for a variance from any requirement of parts 7020.2000 to 7020.2225 in order to avoid undue hardship. A variance must be applied for and acted upon by the agency according to Minnesota Statutes, section 116.07, subdivision 5, and other applicable statutes and rules.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834

Current as of 11/01/00

7020.0535 CONSTRUCTION SHORT-FORM AND INTERIM PERMITS.

Subpart 1. **Applicability.** This part applies to owners who apply for construction short-form and interim permits required under part 7020.0405.

Subp. 2. **Permit applications submitted prior to October 23, 2000.** If an owner has submitted a complete permit application for construction of an animal feedlot or a manure storage area prior to October 23, 2000, and is eligible for a construction short-form permit, the owner may request to have the original application voided, returned, or, upon receipt of a construction short-form permit application by the commissioner or county feedlot pollution control officer, to have the original application submittals incorporated into the construction short-form permit application. Complete construction short-form permit applications submitted under this subpart must be considered received by the commissioner or county feedlot pollution control officer on the date the original completed permit application for an agency permit was received.

Subp. 3. **Delegated county procedures for denial and revocation.**

A. In the case of a denial of a permit application by the county feedlot pollution control officer, the applicant must be informed in writing by the county of the reasons for denial and must be informed of appeal procedures under chapter 7001.

The applicant shall retain all rights of fundamental fairness afforded by law and the applicant may make an appeal to the agency to review the county's action. The denial by a county shall be without prejudice to the applicant's right to an appearance before the agency to request a public hearing or to file a further application after revisions are made to meet objections specified as reasons for denial.

B. In order for a delegated county to revoke a permit, a copy of the permit together with a written justification for revocation must be submitted to the commissioner for review. The commissioner shall, after receipt of the justification for revocation from the county, review the matter within 60 days to determine compliance with applicable agency rules. The county must receive written approval of the permit revocation from the commissioner before taking action. If a revocation has been approved by the commissioner, the applicant must be informed in writing by the county of the reasons for revocation and the applicant shall retain all rights of appeal afforded under chapter 7001. Revocation without reissuance of the permit must follow the requirements under part 7001.0180.

Subp. 4. **No circumvention.** An owner who obtains a construction short-form or interim permit is subject to enforcement action for construction or operation without a permit if the commissioner or county feedlot pollution control officer later determines that the animal feedlot or a manure storage area does not qualify for the construction short-form or interim permit that was issued and that the owner is required to apply for and obtain an SDS or NPDES permit.

Subp. 5. **Duration of construction short-form and interim permits.** All construction short-form and interim permits expire within 24 months of the date of issuance. If the work for which a construction short-form permit was issued is not complete upon expiration of the permit, the expiration date of the permit may be extended by no more than 24 months if the owner complies with items A and B. If the pollution hazard for which an interim permit was issued is not corrected upon expiration of the permit, the expiration date may be extended by no more than 90 days if:

A. the facility is currently eligible for the same permit; and

B. the owner notifies the commissioner or county feedlot pollution control officer at least 90 days prior to the expiration of the permit. The notification shall include:

(1) the name of the owner, and the name of the facility if different from the owner;

(2) the permit number;

(3) the reason the work may not be completed prior to expiration of the permit;

(4) the estimated amount of time required to complete the work; and

(5) if the animal feedlot under construction or expansion will be capable of holding 500 animal units or more, or the manure storage area under construction or expansion will

be capable of holding the manure produced by 500 animal units or more when completed, the notification requirements under part 7020.2000, subpart 4, on a form provided by the commissioner, submitted to the commissioner or delegated county feedlot pollution control officer. In addition to the information required under part 7020.2000, subpart 4, the notification must include the date on which the original permit was issued and the new proposed completion date.

Subp. 6. **Construction short-form permit content.** A construction short-form permit issued by the commissioner or county feedlot pollution control officer must state: "The permittee shall comply with Minnesota Rules, parts 7020.2000 to 7020.2225, and all applicable requirements." The permit must also identify at least the following information:

A. the permit number;

B. the owners' names and addresses;

C. the legal name of the animal feedlot, or manure storage area if different from that of the owner;

D. the location of the facility by county, township, section, and quarter section;

E. the existing and proposed animal types and types of animal holding areas;

F. the maximum number of animal units authorized at the facility after construction or expansion is complete; and

G. the types of existing and proposed manure storage areas. Design plans and specifications for proposed manure storage areas shall be incorporated by reference into the permit.

The general conditions in part 7001.0150, excluding subpart 3, item P, must be incorporated by reference in all construction short-form permits.

Subp. 7. **Interim permit content.** An interim permit issued by the commissioner or county feedlot pollution control officer must include at least the information in subpart 6 and the following:

A. the corrective and protective measures required to bring the facility into compliance with parts 7020.2000 to 7020.2225;

B. the schedule under which the corrective and protective measures must be completed; and

C. additional requirements related to the specific site or operation as determined necessary to ensure compliance with applicable rules and requirements.

Subp. 8. **Expansion stocking limitations.** An owner issued an interim permit that authorizes construction for an expansion shall not stock the expansion prior to the fulfillment of all permit conditions related to the correction of the pollution hazard for which the interim permit was issued.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.0600 [Repealed, 25 SR 834]
Current as of 11/01/00

7020.0700 [Repealed, 25 SR 834]
Current as of 11/01/00

7020.0800 [Repealed, 25 SR 834]
Current as of 11/01/00

7020.0900 [Repealed, 25 SR 834]
Current as of 11/01/00

7020.1500 SCOPE.

Any Minnesota county board may, by resolution, assume responsibility for processing applications for animal feedlot permits as authorized by Minnesota Statutes, section 116.07, subdivision 7. The provisions of parts 7020.1500 to 7020.1900 shall govern the exercise of approval and supervising authority by the agency with respect to the processing of animal feedlot permit applications by a county.

STAT AUTH: MS s 116.07 subd 7
Current as of 11/01/00

7020.1600 AUTHORITIES AND REQUIREMENTS FOR DELEGATED COUNTIES.

Subpart 1. **Scope.** A county delegation process consists of the following:

A. the county board resolution;

B. commissioner authorization;

C. a delegation agreement signed by the county board and commissioner;

D. periodic review of the delegation agreement; and

E. when applicable, withdrawal from the program by the county board or revocation of authorization to administer the program by the commissioner.

Subp. 2. **County feedlot pollution control officer requirements.** A delegated county animal feedlot program shall require the county feedlot pollution control officer to:

A. administer animal feedlots and manure storage areas registration programs according to part 7020.0350;

B. locate and register all animal feedlots and manure storage areas that remain unregistered by the date required under part 7020.0350;

C. distribute permit application and registration forms to owners required to make application for a permit. Permit application forms must contain the information required in part 7020.0505, subpart 3;

D. review permit applications and issue construction short-form and interim permits in accordance with part

7020.0535; and in the approved delegation agreement;

E. inspect all animal feedlots and manure storage areas in accordance with the approved delegation agreement;

F. review and process complaints;

G. provide assistance to owners in completing permit applications;

H. maintain a record of all correspondence and material relating to permit applications, inspections, and complaints;

I. maintain a record of all notifications received from livestock production facility operators claiming the hydrogen sulfide ambient air quality standard exemption, including the days the exemption was claimed and the cumulative days used, as provided in Minnesota Statutes, section 116.0713, paragraphs (b) and (c);

J. submit an annual report to the commissioner by April 1 of each year, in a format requested by the commissioner, that includes the following:

(1) all newly acquired and updated registration information required under part 7020.0350;

(2) inspection summary information from the previous year;

(3) permitting summary information from the previous year, including information regarding permits for facilities with fewer than 1,000 animal units that are CAFOs under Code of Federal Regulations, title 40, part 122, appendix B(b);

(4) complaint and complaint response summary information from the previous year;

(5) outreach and education summary information from the previous year; and

(6) summary of the progress toward achieving the goals identified in the approved delegation agreement and, if applicable, proposed adjustments to the goals or plans to meet the goals in the approved delegation agreement;

K. complete the required county feedlot pollution control officer training necessary to perform the duties described under this part assigned to the county feedlot pollution control officer; and

L. forward to the commissioner all permit applications, inspection reports, and all other applicable documents for the facilities identified in subpart 4, item B.

Subp. 3. [Repealed, 25 SR 834]

Subp. 3a. **Resolutions and delegation agreements.** To assume responsibility for administering the delegated county feedlot program under this part, a Minnesota county board shall complete the requirements in items A to D. Counties that have received delegation authorization from the commissioner prior to

October 23, 2000, may administer the delegated county feedlot program provided that the requirements of item B are completed by June 1, 2001. Delegation agreements must be reviewed and revised by the commissioner and the county annually to determine if the requirements of item B are being fulfilled and to establish new goals.

A. Submit to the commissioner a resolution duly adopted by the county board requesting permission to administer the animal feedlot program in the county.

B. Submit to the commissioner, for review and approval, a delegation agreement that contains:

(1) inspection goals for facilities capable of holding fewer than 300 animal units or the manure produced by fewer than 300 animal units:

(a) at existing facilities for the purposes of identifying pollution hazards;

(b) at new and expanding facilities for which construction activities have commenced; and

(c) for determining compliance with discharge standards and schedules for existing open lot facilities eligible under part 7020.2003, subparts 3 to 6;

(2) inspections conducted at facilities capable of holding 300 to 999 animal units or the manure produced by 300 to 999 animal units for the facilities meeting the conditions under subitem (1), units (a) and (b);

(3) permitting goals;

(4) registration goals, including locating and registering facilities that remain unregistered after the date required under part 7020.0350;

(5) scheduled compliance goals, coordinated with county local water plans, for bringing feedlot operations into compliance with the applicable standards under parts 7020.2000 to 7020.2225, including the compliance dates of part 7020.2003, subparts 5, item B, and 6, item A, considering the following:

(a) type and extent of the pollution hazard at feedlot operations;

(b) availability of private and public financial resources for cost-share grants and low-interest loans; and

(c) availability of private and public technical and administrative assistance;

(6) complaint response and resolution goals;

(7) owner assistance goals; and

(8) staffing levels available to achieve the stated goals.

C. Receive written authorization from the commissioner to administer the program identified in subpart 1.

D. Designate a county feedlot pollution control officer as having the primary responsibility for the animal feedlot permit program and charge the person with the duties in subpart 2.

Subp. 4. [Repealed, 25 SR 834]

Subp. 4a. **Permit application processing procedures.** The processing of permit applications by a delegated county shall be conducted according to the procedures in items A to D.

A. The county feedlot pollution control officer shall process permit applications and issue construction short-form and interim permits according to this part and part 7020.0535, except as directed in item B.

B. The county feedlot pollution control officer shall forward to the commissioner for issuance all permit applications and all other applicable documents, comments, and recommendations for the following:

(1) all facilities that are required to apply for a permit under part 7020.0405, subpart 1, item A or B;

(2) all facilities where all animal manure is not used as domestic fertilizer;

(3) all facilities capable of holding 500 or more animal units or the manure produced by 500 or more animal units that are proposing liquid manure storage areas within 1,000 feet of an open or filled sinkhole, a known cave, a resurgent spring, a disappearing stream, a karst window, or a blind valley;

(4) all facilities with 500 or more animal units that are within a vulnerable drinking water supply management area, as described on a Minnesota Department of Health approved wellhead protection plan; and

(5) all facilities for which an application for a variance under part 7020.0505, subpart 6, is submitted.

C. The county feedlot pollution control officer may forward to the commissioner any permit application when technical assistance or permit issuance by the commissioner is desired with a statement of the action desired from the agency. The commissioner shall process all complete permit applications forwarded by the county with a request to issue a permit, and shall notify the county of the status of the review and of any intended action.

D. The county feedlot pollution control officer shall forward to the commissioner permit applications for facilities that are eligible for the exemption under part 7020.2100, subpart 2, item C, for review and approval before a permit can be issued by the county feedlot pollution control officer.

Subp. 5. [Repealed, 25 SR 834]

Subp. 6. **Withdrawal by county from review process.** A delegated county no longer wishing to have delegation authority shall submit a resolution to the commissioner stating its reasons for withdrawal and the effective date of withdrawal.

Subp. 7. **Revocation of county review authority.** If the agency finds that a county program is not meeting the requirements of this chapter, the agency may, after giving the county written notice and an opportunity to respond, revoke its approval of the county's delegation.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: L 1987 c 186 s 15; 17 SR 1279; 25 SR 834

* **NOTE:** Subparts 3a and 4a were originally adopted at 25 SR *834 as subparts 3 and 4. They were renumbered editorially.
Current as of 11/01/00

7020.1700 PROCEDURAL RULES AND APPEALS.

All requests for hearings, appeals, and other procedural matters not specifically provided for herein shall be governed by the agency rules of procedure, the rules of the Office of Administrative Hearings, and other applicable statutes and rules.

STAT AUTH: MS s 116.07 subd 7
Current as of 11/01/00

7020.1800 SEVERABILITY.

If any provision of parts 7020.1500 to 7020.1900 or the application thereof to any person or circumstances is held to be invalid, such invalidity shall not affect other provisions of parts 7020.1500 to 7020.1900 or application of any other part which can be given effect without application of the invalid provision. To this end the provisions of all parts and subparts herein and the various applications thereof are declared to be severable.

STAT AUTH: MS s 116.07 subd 7
Current as of 11/01/00

7020.1900 VARIANCES.

Any person may apply for a variance from any requirements of parts 7020.1500 to 7020.1900. Such variances shall be applied for and acted upon by the agency in accordance with Minnesota Statutes, section 116.07, subdivision 5, and other applicable statutes and rules.

STAT AUTH: MS s 116.07 subd 7
Current as of 11/01/00

7020.2000 OVERVIEW.

Subpart 1. **In general.** An owner of an animal feedlot or a manure storage area, and any person storing, transporting, disposing, or utilizing animal manure, or process wastewaters, shall comply with parts 7020.2000 to 7020.2225.

Subp. 2. **Animal manure and wastewaters not used as domestic fertilizer.** Animal manure or process wastewaters not used as domestic fertilizer must be treated or disposed of in accordance with applicable rules. An owner not using manure or process wastewaters as domestic fertilizer shall apply for a permit according to part 7020.0405, subpart 1, item A or B.

Subp. 3. **Manure packs and mounding.** Manure accumulations created by manure packs or mounding must be managed such that a pollution hazard is not created or maintained. Land application must be in accordance with part 7020.2225.

Subp. 4. **Notification of proposed construction or expansion.** An owner of an animal feedlot or manure storage area proposing to construct or expand an animal feedlot capable of holding 500 or more animal units, or a manure storage area capable of holding the manure produced by 500 or more animal units, shall no later than ten business days after the application is submitted to the agency or delegated county, provide notice to each resident and each owner of real property within 5,000 feet of the perimeter of the proposed feedlot by:

A. publishing in a newspaper of general circulation within the affected area a notification containing the following information:

(1) the names of the owners or the legal name of the facility;

(2) the location of the facility by county, township, section, and quarter section;

(3) species of livestock and total animal units;

(4) types of confinement buildings, lots, and areas at the animal feedlot; and

(5) the types of manure storage areas;

B. sending a written notice to them containing the information in item A, subitems (1) to (5), delivered by first class mail or in person; or

C. providing equal or greater notification required as part of obtaining a county conditional use permit.

Subp. 5. **Government notifications of proposed construction or expansion.** An owner proposing to construct or expand an animal feedlot or manure storage area shall notify the government authorities listed in items A and B. Notification must be on a form provided by the commissioner and include the information in subpart 4, item A, subitems (1) to (5).

A. The commissioner, or in a delegated county the county feedlot pollution control officer, at least 30 days prior to commencement of construction of a new animal feedlot or manure storage area or an expansion of an existing animal feedlot capable of holding fewer than 300 animal units or a manure storage area capable of holding the manure produced by fewer than 300 animal units after construction. Notification under this item is complete if the owner is proposing construction or modification of a liquid manure storage area and has submitted plans and specifications in accordance with part 7020.2100, subpart 4.

B. All local zoning authorities, including county, town, and city zoning authorities, of the proposed construction or expansion at least 30 days prior to commencement of construction of a new feedlot or manure storage area or an expansion of an existing animal feedlot or manure storage area.

Subp. 6. **Record of livestock owners and manure sources.**

Owners of animal feedlots or manure storage areas that raise livestock that are not owned by them or store manure not produced at their facilities must record and retain on file the names of the livestock or manure source owners for at least the most recent three years.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.2002 AMBIENT AIR QUALITY STANDARD APPLICABILITY.

The owner of an animal feedlot is exempt from the state ambient air quality standards during the removal of manure from barns or manure storage facilities pursuant to the limitations in Minnesota Statutes, section 116.0713, paragraphs (b) and (c). Nothing in this part limits the emergency powers authority of the Minnesota Pollution Control Agency in Minnesota Statutes, section 116.11.

The operator of a livestock production facility that claims exemption from the state ambient air quality standards shall notify the commissioner or county feedlot pollution control officer. Notification must include:

A. the names of the owners or the legal name of the facility;

B. the location of the facility by county, township, section, and quarter section;

C. the facility's permit number, if applicable; and

D. the anticipated start date and the anticipated number of days of removal of manure from barns or manure storage facilities.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.2003 WATER QUALITY DISCHARGE STANDARDS.

Subpart 1. **Animal feedlots and manure storage areas.** Animal manure, manure-contaminated runoff, or process wastewater from any animal feedlot, including CAFOs, or manure storage area is prohibited from flowing into a sinkhole, fractured bedrock, well, surface tile intake, mine, or quarry.

Subp. 2. **CAFOs and facilities with 1,000 animal units or more.** An owner of an animal feedlot that is a CAFO or is capable of holding 1,000 animal units or more, or a manure storage area capable of holding the manure produced by 1,000 animal units or more, shall comply with the effluent limitation requirements of Code of Federal Regulations, title 40, part 412.

Subp. 3. **Other facilities.** An owner of an animal feedlot or a manure storage area shall comply with the effluent limitations in part 7050.0215 unless the animal feedlot or the manure storage area is subject to the effluent limitation requirements in subpart 2 or if the owner of the animal feedlot is subject to and meets all of the requirements in subpart 4.

Subp. 4. **Eligible open lot feedlots capable of holding fewer than 300 animal units.** Owners of animal feedlots capable of holding fewer than 300 animal units and having open lots meeting the eligibility requirements in items A to D shall comply with subparts 5 and 6. If the facility expands to a capacity of 300 or more animal units, the facility is not eligible under this subpart. This subpart applies only to open lots that existed on October 23, 2000; discharges from other parts of the animal feedlot, including manure storage areas, must comply with the effluent limitations in part 7050.0215 and other applicable federal and state requirements.

A. The animal feedlot is not a new animal feedlot.

B. The animal feedlot has manure-contaminated runoff from one or more open lots that discharge to waters of the state and:

(1) the manure-contaminated runoff does not create or maintain an immediate threat to human health or the environment; and

(2) the facility has not been designated a CAFO.

C. The owner has registered the animal feedlot in accordance with part 7020.0350.

D. The owner has submitted a certification, on a form provided by the commissioner, agreeing to comply with subparts 5 and 6. The certification form shall contain a provision for a conditional waiver of civil penalties for past violations of part 7050.0215 caused solely by passive manure-contaminated runoff from open lots and for failure to apply for a permit provided the owner maintains compliance with subparts 5 and 6.

Subp. 5. **Interim corrective measures for eligible open lots.** An owner meeting the eligibility requirements of subpart 4 shall:

A. operate and manage the animal feedlot to minimize discharges from eligible open lots at all times; and

B. comply with the following by October 1, 2005:

(1) install and have operational:

(a) diversions that prevent precipitation and snowmelt from building roofs and upslope land from flowing onto or through the animal feedlot or manure storage area; and

(b) vegetated buffer areas or filter strips that have 100 feet or more of nonchannelized flow through perennial grasses or forages for all runoff from the open lots; or

(2) install and have operational interim corrective and protective measures that have been demonstrated, through completion of "An Evaluation System To Rate Feedlot Pollution Potential" (the model) by a person who has completed training in use of the model, to achieve a 50 percent or greater reduction in discharges of phosphorus and biochemical oxygen demand loading. The percent reduction in discharges must be based on a comparison of the corrective and protective measures

in operation at the facility on October 23, 2000, and the proposed interim corrective and protective measures and practices. The owner shall maintain records of the model results until completing the requirements of subpart 6, and make the model results available to the commissioner or county feedlot pollution control officer upon request.

Subp. 6. **Final corrective measures for eligible open lots.** An owner meeting the requirements of subpart 4 shall:

A. except as required in item B, comply with part 7050.0215 for all eligible open lots by October 1, 2010; and

B. if the owner is proposing an expansion, comply with subpart 2 or 3, as applicable, prior to an increase in the number of animal units at the animal feedlot.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.2005 LOCATION RESTRICTIONS AND EXPANSION LIMITATIONS.

Subpart 1. **Location restrictions.** Except as provided in items A and B, a new animal feedlot or a manure storage area must not be constructed within shoreland, a floodplain, 300 feet of a sinkhole, 100 feet of a private well, or 1,000 feet of a community water supply well or other wells serving a public school as defined under Minnesota Statutes, section 120A.05, a private school excluding home school sites, or a licensed child care center where the well is vulnerable according to part 4720.5550, subpart 2.

A. An animal feedlot or a manure storage area located in shoreland meeting the requirements of part 7020.0300, subpart 15, item B:

(1) that has been unused for less than ten years is a pollution hazard and may resume operation after applying for and obtaining an interim permit under part 7020.0405, subpart 1, item C; or

(2) that has been unused for ten years or more must not resume operation.

B. A new animal feedlot or manure storage area may be constructed within 1,000 feet of a community water supply well or other well serving a public school as defined under Minnesota Statutes, section 120A.05, a private school excluding home school sites, or a licensed child care center if the following three conditions are met:

(1) the Minnesota Department of Health has approved a drinking water supply management area for the well under part 4720.5360;

(2) the animal feedlot or manure storage area is not within the drinking water supply management area; and

(3) the animal feedlot or manure storage area is not within 200 feet of the well.

Subp. 2. **Shoreland expansion limitations.** An existing animal feedlot or manure storage area located in shoreland may not expand to a capacity of 1,000 animal units or more or the manure produced by 1,000 animal units or more. An existing animal feedlot or a manure storage area expanding in shoreland shall not locate any portion of the expanded animal feedlot or the manure storage area closer to the ordinary high water mark than any existing portion of the animal feedlot or the manure storage area.

Subp. 3. **Floodplain expansion limitations.** An existing animal feedlot or a manure storage area located in a floodplain may not expand.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.2010 TRANSPORTATION OF MANURE.

Animal manure hauled on federal, state, or local highways, roads, or streets must be hauled in such a way as to prevent manure from leaking, spilling, or otherwise being deposited in the right-of-way. Manure deposited on a public roadway must be removed and properly disposed of by the hauler of the manure.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.2015 LIVESTOCK ACCESS TO WATERS RESTRICTION.

Subpart 1. **CAFOs and facilities capable of holding 1,000 or more animal units.** Animals of a CAFO or of a facility capable of holding 1,000 or more animal units must not be allowed to enter waters of the state.

Subp. 2. **Non-CAFO animal feedlots.** Except as required in subpart 1, by October 1, 2001, animals of a non-CAFO animal feedlot must be fenced to prohibit entry to, and must not be allowed to enter, a lake classified by the Minnesota Department of Natural Resources as a natural environment lake, recreational development lake, or a general development lake, as defined in part 6120.3000.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.2025 ANIMAL FEEDLOT OR MANURE STORAGE AREA CLOSURE.

The owner of an animal feedlot or a manure storage area is responsible for closure and shall:

A. within one year of ceasing operation, remove and land apply manure and manure-contaminated soils from manure storage areas and animal holding areas in accordance with part 7020.2225;

B. as soon as practicable after completing the requirements of item A, reduce soil nitrogen by growing alfalfa, grasses, or other perennial forage for at least five years; and

C. within 60 days after final closure, submit a certified letter to the commissioner or county feedlot pollution control officer stating that the animal feedlot or the manure storage area has been closed according to the requirements in this part. The letter must identify the location of the animal feedlot or the manure storage area by county, township, section, and quarter section.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.2100 LIQUID MANURE STORAGE AREAS.

Subpart 1. **General.** This part describes site restrictions and requirements for design, construction, maintenance, and operation of liquid manure storage areas. An owner shall submit a permit application, as applicable, under part 7020.0405, subparts 1 and 2. Except as required in subpart 2, all liquid manure storage areas must be designed, constructed, and operated in accordance with subparts 3 to 7. An owner of a liquid manure storage area that has been unused for a period of three years or more shall, prior to using the structure for storing manure or process wastewaters, have a design engineer evaluate and prepare a report on the condition of the liner and include this report with a permit application submitted according to part 7020.0405.

Subp. 2. **Site restrictions.** Except as provided in item C, the construction or expansion of a liquid manure storage area is prohibited in the areas identified under part 7020.2005 and items A and B.

A. A manure storage area with a capacity of more than 250,000 gallons in an area where geologic conditions are suitable for sinkhole development and where four or more sinkholes exist within 1,000 feet of the proposed site.

B. In areas which are susceptible to soil collapse or sinkhole formation, the minimum separation distance to bedrock and the manure storage area liner design standards under subpart 3, item B, and prohibitions must be in accordance with subitems (1) to (3).

(1) Animal feedlots capable of holding fewer than 300 animal units or manure storage areas capable of holding manure produced by fewer than 300 animal units that contribute to liquid manure storage areas at the facility must comply with the following:

(a) where the separation distance to bedrock is less than five feet, construction of a liquid manure storage area is prohibited; and

(b) where the separation distance to bedrock is five feet or more and less than 20 feet, the manure storage area liner must be concrete-lined, aboveground, or composite-lined according to subpart 3, item B, subitem (2) or (3).

(2) Animal feedlots capable of holding 300 or more and fewer than 1,000 animal units and manure storage areas capable of holding the manure produced by 300 or more and fewer

than 1,000 animal units that contribute to liquid manure storage areas at the facility shall comply with the following:

(a) except as provided in unit (c), where the separation distance to bedrock is less than ten feet, construction of a liquid manure storage area is prohibited;

(b) where the separation distance to bedrock is ten feet or more and less than 30 feet, the manure storage area liner must be concrete-lined, aboveground, or composite-lined according to subpart 3, item B, subitem (2) or (3); and

(c) where the separation distance to bedrock is five feet or more and less than ten feet, the manure storage area must be:

i. an aboveground manure storage area;

ii. concrete-lined with a secondary liner consisting of a synthetic liner, HDPE liner, or one foot or greater cohesive soil liner; or

iii. composite-lined with at least a three-foot compacted cohesive soil liner under the synthetic liner.

(3) Animal feedlots capable of holding 1,000 or more animal units or manure storage areas capable of holding the manure produced by 1,000 or more animal units that contribute to liquid manure storage areas at the facility shall comply with the following:

(a) except as provided in unit (c), where the separation distance to bedrock is less than 15 feet, construction of a liquid manure storage area is prohibited;

(b) where the separation distance to bedrock is 15 feet or more and less than 40 feet, the manure storage area liner must be concrete-lined, aboveground, or composite-lined according to subpart 3, item B, subitem (2) or (3); and

(c) where the separation distance to bedrock is ten feet or more and less than 15 feet, the manure storage area must be:

i. an aboveground manure storage area;

ii. concrete-lined with a secondary liner consisting of a synthetic liner, HDPE liner, or one foot or greater cohesive soil liner; or

iii. composite-lined with at least a three-foot compacted cohesive soil liner under the synthetic liner.

C. Where construction or modification is required to correct a pollution hazard at an existing animal feedlot capable of holding fewer than 300 animal units, construction or modification is not prohibited. Construction or modification under this item must not result in an expansion of the animal feedlot capacity to hold more than 300 animal units or the manure storage area capacity to hold the manure produced by 300 animal units or greater.

Subp. 3. **Design standards.**

A. A new or modified liquid manure storage area at an animal feedlot capable of holding 1,000 animal units or more or the manure storage area capable of holding the manure produced by 1,000 animal units or more must be designed to provide a minimum of nine months of storage capacity.

B. Liquid manure storage area liners must comply with the following:

(1) non-concrete-lined manure storage areas must be designed and constructed to achieve a maximum theoretical seepage rate of not more than 1/56 inch per day throughout the design life of the manure storage area;

(2) concrete-lined manure storage areas must be designed and constructed with: water stops or joint sealant materials at all construction joints; sealing of all cracks which may extend through the concrete liner with appropriate sealing materials; and a floor having a concrete thickness of not less than five inches. The floors must have:

(a) steel reinforcing based on subgrade drag theory in American Concrete Institute, Slabs on Grade, ACI-360; or

(b) fiber reinforcing, for which the design engineer must specify the type of fibers and the dosage rate in subpart 4, item F;

(3) composite-lined or aboveground manure storage areas must be designed and constructed to achieve a maximum theoretical seepage rate of not more than 1/560 inch per day throughout the design life of the manure storage area; and

(4) aboveground manure storage areas located in areas not subject to the site restrictions under subpart 2, may be designed and constructed according to seepage standards under subitem (1) or (2), as applicable.

C. Water supply systems, fuel lines, electrical conduit, or other equipment not solely functioning as part of the manure handling or transfer system must not be designed or constructed to penetrate the liner of a liquid manure storage area. Piping and equipment functioning as part of the manure handling or transfer system which penetrates the liner of a liquid manure storage area must be identified in the design plans and specifications. The design plans and specifications must include details on the location and purpose of the penetrations, dimensions of the penetrations, and the methods and materials used to provide a seal between each penetration and the liner.

Subp. 4. **Design plans and specifications.** The owner shall prepare and submit to the commissioner or county feedlot pollution control officer design plans and specifications meeting the requirements of items A to N with a permit application or at least 90 days prior to the commencement of construction. Design plans and specifications, except plans and specifications for concrete-lined manure storage areas having a capacity of 20,000 gallons or less, must be prepared and signed by a design engineer.

A. Results and interpretation of a site and soils investigation that includes the information and requirements in subitems (1) to (10).

(1) An analysis of foundation soils for suitability for the proposed manure storage area including conditions that may lead to failure of constructed dikes or walls.

(2) Soil profile information in subitem (5) that must be obtained and recorded at a minimum of two locations within the boundaries of the proposed manure storage area for the first one-half acre of surface area. A minimum of one additional location is required for each additional one acre of surface area for the manure storage area.

Sufficient soil records must be obtained to represent the range of soil conditions throughout the proposed manure storage area site.

(3) Except as required in subitem (4), the information in subitem (5) must be recorded to a depth of at least five feet below the bottom of the proposed liquid manure storage area and to a depth that allows verification of separation to bedrock requirements in accordance with subpart 2, item B. Each borehole completed under this item must be sealed throughout the entire depth by a method that will ensure that the borehole does not become a preferential flow path for vertical groundwater transport.

(4) In areas that are susceptible to soil collapse or sinkhole formation, the information in subitem (5) must be recorded to a depth of at least ten feet below the bottom of the proposed liquid manure storage area, or until bedrock is encountered.

(5) Each soils record must identify the soil texture, depth to the regional water table, and depth to the seasonal high water table.

(6) The soil profile information must be obtained by a method that can identify abrupt changes in soil texture and sand lenses throughout the soil profile.

(7) In areas susceptible to soil collapse or sinkhole formation, a map of the proposed site showing the location of all open and filled sinkholes, depression areas in the landscape, known caves, resurgent springs, disappearing streams, karst windows, and blind valleys within one-half mile of the proposed site location.

(8) An evaluation of potential for groundwater intrusion and damage to the storage area liner.

(9) Where a perimeter drainage tile system is required to control the elevation of the water table or saturated soils in accordance with item J, the design plans and specifications for the drain tile system must include provisions to:

(a) lower the elevation of the water table or saturated soils to below the bottom of the manure storage area liner;

(b) locate the drainage tile a horizontal distance of at least one foot outside the footing of a concrete-lined manure storage area;

(c) install a dedicated drain tile system for each manure storage area; and

(d) install a dedicated tile riser, manhole, or other access which allows collection of tile-water samples for each dedicated drain tile system.

(10) Additional information relating to the proposed manure storage area as requested by the commissioner to evaluate compliance with federal and state rules.

B. The following information if the proposed manure storage area is located in a Minnesota Department of Health approved drinking water supply management area as delineated according to chapter 4720:

(1) the location of the animal feedlot, manure storage area, and land application sites on a map of the Minnesota Department of Health approved drinking water supply management area;

(2) a copy of the vulnerability assessment of the drinking water supply management area from an approved wellhead protection plan according to part 4720.5210, subparts 2 and 3;

(3) a description of the vulnerability of the specific sites for manure storage areas and land application as described in the vulnerability assessment; and

(4) a copy of all parts of the drinking water supply management area plan which pertain to animal feedlots, manure storage areas, and land application of manure.

C. The estimated storage capacity by volume and time period based on the volume of manure, manure-contaminated runoff, and process wastewaters generated.

D. In addition to the designed storage volume in item C, allowance for the greater capacity of the following for manure storage areas open to precipitation or subject to discharge of runoff into the manure storage area:

(1) a volume capacity for precipitation and runoff without overflow for a 25-year, 24-hour or greater precipitation or rainfall event; or

(2) a freeboard depth of not less than one foot.

E. A plan for a preconstruction conference that includes the design engineer, contractors, the owner, and the inspector required under subpart 6.

F. Specifications for the liquid manure storage area liner according to the applicable liner design standard identified under subparts 2 and 3.

G. When soil is used as a liner material, location and volume of liner soil available, testing protocol, and predesign test results for soil plasticity index, sieve analysis, and optimal moisture content.

H. A site plan that identifies the locations of predesign soil investigations conducted under item A relative to the proposed manure storage area.

I. Plan details and specifications for all liner penetrations according to subpart 3, item C.

J. Measures for control of water table or saturated soils.

K. A quality assurance and quality control plan that includes specifications for inspections and ASTM testing methods and frequencies.

L. Specifications for liner material protection from damage during construction or subsequent facility operation resulting from the following:

(1) drying and cracking during and after liner construction;

(2) manure agitation and pumping;

(3) freezing and thawing;

(4) hot and cold weather construction;

(5) erosion; and

(6) other physical damage.

M. Special site considerations.

N. A plan for operation, periodic inspection, and maintenance of the manure storage area including schedules and descriptions of:

(1) routine inspections, maintenance, and recordkeeping to be completed to identify and document damage to the liner from the factors listed in item L;

(2) methods to be used to repair areas of damaged liner;

(3) methods used to monitor the liquid level in the basin to evaluate proper operation and adequate available storage capacity; and

(4) routine inspections of perimeter tile line outlets and inspection manholes to ensure proper operations of the system.

Subp. 5. **Construction and notification requirements.**

A. The owner shall construct the manure storage area according to the design plans and specifications submitted to the commissioner or the county feedlot pollution control officer. Proposed engineering changes or modifications to the design plans and specifications, related to the liner specifications, location, depth, or separation distance to bedrock, must be submitted to the commissioner or county feedlot pollution control officer prior to commencement of construction related to the proposed change.

B. An owner shall notify the commissioner or county feedlot pollution control officer and the design engineer of intent to construct a minimum of three business days prior to commencement of construction. Notification must be completed by letter, telephone, or facsimile and include:

(1) the permit number, if applicable;

(2) the owner's name, and the name of the facility if different than the owner;

(3) the site location by county, township, section, and quarter section;

(4) the design engineer's name; and

(5) the name of the contractor responsible for installing the liner.

C. An owner shall notify the commissioner or county feedlot pollution control officer within three business days following completion of construction of the manure storage area liner. Notification for vertical concrete-lined walls under this item must be completed before backfilling the walls. Notification information must meet the requirements in item B.

D. The owner shall submit a construction report to the commissioner or county feedlot pollution control officer within 60 days of the completion of any new or modified manure storage area. The report must be prepared and signed by the design engineer and must contain an assessment of whether the completed manure storage area conforms to the design plans and specifications submitted to the commissioner or county feedlot pollution control officer. The commissioner may require manure removal from the manure storage area and corrective actions if the construction report indicates that the completed manure storage area does not conform to the design plans and specifications.

Subp. 6. **Inspections of liquid manure storage areas.** An owner constructing a liquid manure storage area, except for a concrete-lined manure storage area with a capacity of 20,000 gallons or less, shall have inspections completed during the construction process which comply with items A to D.

A. The inspector must be one or more of the following:

(1) a professional engineer licensed in the state of Minnesota or a person working under the professional engineer's direct supervision;

(2) a qualified Natural Resources Conservation Services staff person; or

(3) if the manure storage area has a concrete liner, an American Concrete Institute or Minnesota Department of Transportation concrete field testing technician grade/level I certified and concrete field inspector level II certified.

B. During construction of each manure storage area under this subpart, the inspector shall record on a form provided by the commissioner, observations related to conformance to the design plans and specifications and construction standards of the following:

(1) subgrade conditions prior to liner placement including soil texture, strength and moisture content, and presence of any frozen soils;

(2) location and proper functioning of the perimeter drainage tile system, if required, and inspection/monitoring access;

(3) for all concrete-lined manure storage areas:

(a) reinforcing steel size, grade, spacing, cover, and that steel is free of loose rust, oil, or other debris;

(b) concrete quality including air entrainment, temperature, and strength;

(c) handling, placement, consolidation, and finishing of concrete;

(d) curing and protection of concrete after placement, including hot and cold weather protective measures;

(e) location, forming, and surface preparation of construction, contraction, and expansion joints;

(f) placement of flexible waterstop materials in joints; and

(g) application of surface applied or injected crack and joint sealant materials;

(4) repair of construction defects; and

(5) conformance to the liner penetration prohibitions under subpart 3, item C.

C. The contractor responsible for installation of the liner shall certify on a form provided by the commissioner that the manure storage area was constructed in conformance with the design plans and specifications and construction standards for all applicable stages of construction in item B.

D. The owner shall ensure that the following information is submitted to the design engineer for incorporation into the construction report required in subpart 5, item D:

(1) the name and qualifications of the inspector;

(2) the inspection form required in item B; and

(3) the liner contractor's certification form required in item C.

Subp. 7. **Operation and maintenance.** The owner of a manure storage area shall operate and maintain the manure storage area according to the operation and maintenance plan submitted in accordance with subpart 4, item N.

STAT AUTH: MS s 115.03; 116.07; 122.23

HIST: 25 SR 834
Current as of 11/01/00

7020.2110 UNPERMITTED OR NONCERTIFIED LIQUID MANURE STORAGE AREAS.

Subpart 1. **Schedule for facilities capable of holding 1,000 animal units or more or construction after June 3, 1991.** An owner who has a facility capable of holding 1,000 or more animal units and who uses an unpermitted or noncertified liquid manure storage area, or who uses an unpermitted or noncertified liquid manure storage area for which construction commenced after June 3, 1991, shall, by October 1, 2001:

A. reconstruct the manure storage area according to part 7020.2100;

B. complete closure of the manure storage area according to part 7020.2025 and notify the commissioner or county feedlot pollution control officer at least three days prior to the date when the manure storage area will be closed. Notification must be completed by letter, telephone, or facsimile and include:

(1) the permit number, if applicable;

(2) the owner's name, and the name of the facility if different than the owner;

(3) the site location by county, township, section, and quarter section; and

(4) the dates when closure will take place;

C. except as provided in item D, submit a copy of the original design plans and specifications for the manure storage area that were prepared by a design engineer prior to the actual time of construction and a construction certification report signed by a design engineer that certifies that the liquid manure storage area was designed and constructed according to applicable rules and regulations and standard engineering principles and practices at the time of construction;

D. if the original plans and specifications for a Natural Resources Conservation Service (NRCS) or Soil Conservation Service (SCS) designed liquid manure storage area are no longer available, the owner must submit a certification by the manager of the NRCS office which was responsible for the design and oversight of the project, that the project was constructed according to the NRCS or SCS design plans and specifications and construction oversight; or

E. conduct and submit the results of a water balance test that demonstrate the manure storage area is properly sealed to achieve a seepage rate of 1/56 inch per day or less.

Subp. 2. **Schedule for facilities with capacity to hold fewer than 1,000 animal units.** Except as required in subpart 1 or as provided in subpart 3, an owner who uses an unpermitted or noncertified liquid manure storage area with the capacity to hold fewer than 1,000 animal units or the manure produced by fewer than 1,000 animal units shall, by October 1, 2005:

A. complete one of the provisions under subpart 1, items A to C; or

B. have a design engineer or professional soil scientist licensed in the state of Minnesota conduct a soils investigation and submit a soils investigation report to the commissioner or county feedlot pollution control officer that complies with the following:

(1) the soils report must demonstrate that the liquid manure storage area meets Minnesota Natural Resources Conservation Service Practice Standard, Code No. 425, November 1991, or Code No. 313, January 1998, design and construction criteria for:

(a) sealing and lining waste storage ponds;

(b) vertical separation to groundwater; and

(c) vertical separation to bedrock;

(2) the soil profile information in subitem (5) must be obtained and recorded for at least two equally spaced locations around the perimeter of the liquid manure storage area for each quarter acre of manure storage surface area or portion thereof, and be within a horizontal distance of not more than 50 feet outside the top of the manure storage area sidewall;

(3) except as required in subitem (4), the information in subitem (5) must be recorded to a depth of at least five feet below the bottom of the liquid manure storage area;

(4) in areas that are susceptible to soil collapse or sinkhole formation, the information in subitem (5) must be recorded to a depth of at least ten feet below the bottom of the liquid manure storage area, or until bedrock is encountered;

(5) each soils record must identify the soil texture, depth to the regional water table, and depth to the seasonal high water table; and

(6) the soil profile information must be obtained by a method that can identify abrupt changes in soil texture and sand lenses of one-half inch or greater throughout the soil profile.

Subp. 3. **Schedule for open lot feedlots with fewer than 300 animal units.** Owners meeting the eligibility requirements under part 7020.2003, subpart 4, that must complete closure or reconstruction of the manure storage area according to subpart 1, item A or B, shall comply with items A and B.

A. By October 1, 2005, the owner shall notify the commissioner or county feedlot pollution control officer that the manure storage area will be closed or reconstructed by October 1, 2010. Notification must be completed by letter, telephone, or facsimile and also include:

(1) the owner's name, and the name of the facility if different than the owner; and

(2) the site location by county, township, section, and quarter section.

B. By October 1, 2010, the owner shall complete closure or reconstruction.

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7020.2120 POULTRY BARN FLOORS.

Subpart 1. **General.** This part describes the requirements for construction and recordkeeping for poultry barn floors. Owners of poultry barns at which abandonment of the facility exposes the barn floor shall remove and land apply all manure and manure-contaminated soil according to part 7020.2225.

Subp. 2. **Construction requirements for concrete-lined or asphalt-lined floors.** All new concrete-lined or asphalt-lined poultry barn floors must be constructed and maintained according to the following:

A. the floor thickness must be a minimum of 3.5 inches for concrete and a minimum of two inches for asphalt;

B. the floors must be inspected by the owner or operator after each cleaning of the poultry barn floors; and

C. cracks and joints, which may extend through the concrete-lined or asphalt-lined floor, must be sealed.

Subp. 3. **Construction requirements for soil-lined floors.** All new soil-lined poultry barn floors must be constructed and maintained according to items A to E.

A. The completed thickness of the constructed soil liner must be:

(1) 12 inches or more of compacted soil; or

(2) eight inches or more of compacted soil placed over an underlayment that consists of:

(a) three inches of sand consisting of at least 80 percent particles passing a number 4 sieve, less than ten percent particles passing a number 200 sieve, and no particles greater than one inch. Particle size analyses must be performed according to ASTM D-422; or

(b) a geo-textile fabric that weighs at least 12 ounces per square yard and has a minimum hydraulic conductivity of 0.30 cm/sec.

B. Soils used for construction of the floor must meet the following requirements:

(1) have at least 30 percent particles passing a number 200 sieve, less than 20 percent retained on a number 4 sieve, and no rocks greater than three inches in diameter. Particle size analyses must be performed according to ASTM D-422;

(2) have a plasticity index greater than seven percent according to ASTM D-4318;

(3) be placed in a minimum of two lifts, each lift being a minimum of four inches of in-place thickness;

(4) be maintained at a moisture content of zero to five percent above optimum as determined by ASTM D-698 or ASTM D-1557 during construction; and

(5) be compacted:

(a) with at least three passes of a sheepsfoot or padfoot-type compaction equipment with feet that extend through the loose lift of soil into the previous lift; or

(b) until achievement of 90 percent of standard proctor density. The density must be verified according to ASTM 2922, at a frequency of one sample per 3,000 square feet.

C. The poultry barn floor must be placed at least three feet above bedrock or the water table.

D. The soil liner must be refurbished with at least a two-inch lift of soils meeting the requirements of item B, prior to the floor thickness being diminished by two inches from the thickness required in item A.

E. Cracks that may extend through the floor must be repaired.

F. The floor must not be saturated at any time during the service life of the floor.

Subp. 4. **Construction requirements for polyvinyl chloride (PVC) lined floors.**

A. A seamless or factory seamed PVC liner having a thickness of not less than 30 mils must be placed at a depth of at least six inches below the final elevation of the poultry barn floor.

B. The upper six inches of the floor must be constructed of protective material that meets manufacturer's recommendations and provides adequate protection of the PVC liner. This protective layer must not consist of any particles that will inflict damage to the liner.

Subp. 5. **Recordkeeping.** The owner shall record and retain on permanent file the results of all testing required in subpart 3 and make these records available to the commissioner or county feedlot pollution control officer upon request.

Subp. 6. **Notifications of construction.** An owner shall notify the commissioner or county feedlot pollution control officer of intent to construct a minimum of three business days prior to commencement of construction and within three business days following completion of construction. Notification must be completed by letter, telephone, or facsimile and include:

A. the permit number, if applicable;

B. the owner's name, and the name of the facility if different than the owner;

C. the site location by county, township, section, and quarter section; and

D. the name of the contractor responsible for installing the floor.

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7020.2125 MANURE STOCKPILING SITES.

Subpart 1. **General.** This part describes requirements for permitting, design, construction, location, operation, and maintenance of short-term and permanent stockpiling sites. Stockpiling sites must comply with part 7020.2005 and items A to D.

A. Manure stockpiling sites must be located and constructed such that manure-contaminated runoff from the site does not discharge to waters of the state.

B. Manure must not be placed on a stockpiling site unless a three-to-one horizontal-to-vertical ratio can be maintained or the manure has, at least, a 15 percent solids content.

C. The use of rock quarries, gravel or sand pits, bedrock, and any mining excavation sites for stockpiling manure is prohibited.

D. The size of a short-term stockpile must not exceed a volume based on agronomic needs of the crops on 320 acres of fields and must not exceed the agronomic needs of the crops on the tract of land on which the stockpile is to be applied. The agronomic needs of the crops must comply with the application rates in part 7020.2225.

Subp. 2. **Additional requirements for short-term stockpiling.** By October 1, 2001, all short-term stockpile sites must:

A. have the manure removed from the site and land applied in accordance with part 7020.2225, within one year of the date when the stockpile was initially established;

B. have a vegetative cover established on the site for at least one full growing season prior to reuse as a short-term stockpiling site except for the following:

(1) sites located within the confines of a hoofed-animal open lot at a facility having the capacity to hold fewer than 100 animal units; and

(2) sites where manure is stockpiled for fewer than ten consecutive days and no more than six times per calendar year;

C. not be located within:

(1) 300 feet of flow distance and at least 50

feet horizontal distance, to waters of the state, sinkholes, rock outcroppings, open tile intakes, and any uncultivated wetlands which are not seeded to annual farm crops or crop rotations involving perennial grasses or forages;

(2) 300 feet of flow distance to any road ditch that flows to the features identified in subitem (1) or 50 feet of any road ditch where subitem (1) does not apply;

(3) 100 feet of any private water supply or unused and unsealed well and 200 feet from any private well with less than 50 feet of watertight casing and that is not cased through a confining layer at least ten feet thick; and

(4) 100 feet from field drain tile that is three feet or less from the soil surface;

D. maintain a minimum distance of two feet between the base of the stockpile and the seasonal high water table or saturated soils, as identified in the most recent USDA/NRCS soil survey manual or based on a site-specific soils investigation; and

E. be prohibited:

(1) on land with greater than six percent slope;

(2) on land with slopes between two and six percent, except where clean water diversions and erosion control practices are installed; and

(3) on soils where the soil texture to a depth of five feet is coarser than a sandy loam as identified in the most recent USDA/NRCS soil survey manual or based on a site-specific soils investigation.

Subp. 3. **Recordkeeping for short-term stockpile sites.** The owner of the short-term stockpile site shall maintain records for each stockpile site containing the information in items A to E. Records must be kept on file for at least three years for all short-term stockpiling by the owner of the animal feedlot at which the manure was produced and be made available to the commissioner or county feedlot pollution control officer upon request. The records must include:

A. the location of the stockpile;

B. the date on which each stockpile was established;

C. the volume of manure stockpiled;

D. the nutrient analysis of the manure; and

E. when the stockpiled manure was land applied.

Subp. 4. **Additional requirements for permanent stockpile sites.** By October 1, 2001, all permanent stockpile sites must comply with this part. The owner shall also install a liquid manure storage area according to part 7020.2100 to collect and contain manure-contaminated runoff, if necessary to comply with the requirements of part 7020.2003. An owner shall submit a permit application, as applicable, under part 7020.0405, subpart 1.

A. The owner shall comply with part 7020.2005.

B. The stockpile site liner must:

(1) have a completed thickness of at least two feet and be constructed of soils having a hydraulic conductivity of 1 x 10^{-7} cm/sec or less upon completion of construction; or

(2) have other liner materials which achieve a hydraulic conductivity less than 1 x 10^{-7} cm/sec.

C. The site must be constructed using diversion structures, elevated platform construction, or other devices to prevent surface waters from entering and passing through the stockpile site. Where upgradient slopes are greater than two percent, clean water diversions must be constructed that surround at least the three upgradient sides of the stockpile site. Diversions must be of sufficient height to prevent outside water from passing over them during snowmelt or rainfall events less than the 25-year, 24-hour storm event.

D. A permanent stockpile site must be operated and maintained in a manner so as to protect the integrity and structural reliability of the manure storage area.

E. An owner shall notify the commissioner or county feedlot pollution control officer of intent to construct a minimum of three days prior to commencement of construction and within three days following completion of construction. Notification must be completed by letter, telephone, or facsimile and include:

(1) the permit number, if applicable;

(2) the owner's name, and the name of the facility if different than the owner;

(3) the site location by county, township, section, and quarter section; and

(4) the name of the contractor responsible for installing the permanent stockpile liner.

F. The owner shall comply with subpart 2, item D.

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7020.2150 MANURE COMPOST SITES.

Subpart 1. **General.** An owner composting only manure at a manure compost site shall comply with subparts 2 and 3. An owner composting manure and solid wastes shall comply with part 7035.2836, subparts 4 to 7. An owner composting dead animals shall comply with part 1719.4000.

Subp. 2. **Operational requirements.** An owner of a manure compost site meeting the requirements of subpart 1 shall comply with items A to C.

A. The owner shall comply with part 7020.2125.

B. If operating a compost site under part 7020.2125, subparts 1 to 3, the owner shall comply with part 7020.2125, subpart 4, item C.

C. The owner shall produce finished compost by a process to further reduce pathogens (PFRP). The temperature and retention time for the material being composted must be monitored and recorded each day. The owner shall comply with one of the PFRP methods in subitems (1) to (3).

(1) The windrow method for reducing pathogens consists of an unconfined composting process involving periodic aeration and mixing. Aerobic conditions must be maintained during the compost process. A temperature of 55 degrees Celsius must be maintained in the windrow for at least three weeks. The windrow must be turned at least once every three to five days.

(2) The static aerated pile method for reducing pathogens consists of an unconfined composting process involving mechanical aeration of insulated compost piles. Aerobic conditions must be maintained during the compost process. The temperature of the compost pile must be maintained at 55 degrees Celsius for at least seven days.

(3) The enclosed vessel method for reducing pathogens consists of a confined compost process involving mechanical mixing of compost under controlled environmental conditions. The retention time in the vessel must be at least 24 hours with the temperature maintained at 55 degrees Celsius. A stabilization period of at least seven days must follow the enclosed vessel retention period. Temperature in the compost pile must be maintained at least at 55 degrees Celsius for three days during the stabilization period.

Subp. 3. **Recordkeeping and reporting requirements.** An owner of a manure compost site that is required to apply for and obtain a permit under part 7020.0405, subpart 1, item A or B, must:

A. analyze mature manure compost and maintain records of the results for:

(1) pH;

(2) moisture content;

(3) particle size;

(4) NPK ratio; and

(5) soluble salt content; and

B. if the owner's NPDES or SDS permit requires submittal of an annual report, include the following information in the annual report:

(1) the quantities and sources of manure and bulking agents delivered to the facility;

(2) temperature and retention time data for all compost produced; and

(3) the information recorded under item A.

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7020.2225 LAND APPLICATION OF MANURE.

Subpart 1. **In general.**

A. Manure and process wastewater must not be applied to land in a manner that will:

(1) result in a discharge to waters of the state during the application process, except that manure and process wastewater application is allowed onto seasonally saturated soils that are seeded to annual farm crops or crop rotations of perennial grasses or legumes; or

(2) cause pollution of waters of the state due to manure-contaminated runoff.

B. Manure and process wastewater application into road ditches is prohibited.

C. All manure and process wastewater applications to land must meet the requirements of this part except where specifically exempted.

D. When ownership of manure or process wastewater is transferred from an animal feedlot with capacity of 300 or more animal units or a manure storage area capable of holding the manure produced by 300 or more animal units for application to land not owned or leased by the owner of the animal feedlot or the manure storage area, any person receiving the manure or the process wastewater shall:

(1) comply with the manure management plan completed by the owner of the animal feedlot where the manure or process wastewater was produced; and

(2) complete the manure management plan requirements in subpart 4, item D, except for provisions that were completed by the owner of the animal feedlot where the manure or process wastewater was produced.

Subp. 2. **Manure nutrient testing requirements.** Manure from all manure storage areas storing manure produced from more than 100 animal units must be tested by the owner of the animal feedlot for nitrogen and phosphorus content in accordance with items A to E, except that item A is not required for manure storage areas storing manure produced by fewer than 300 animal units.

A. For manure storage areas storing manure from 300 or more animal units, the manure must initially be tested once per year for at least three years.

B. Manure must be retested following changes in conditions affecting manure nutrient content including unusual climatic conditions, or changes in manure storage and handling, livestock types, or livestock feed.

C. Ongoing testing must continue at least once every four years unless more frequent testing is required under item B or in a permit.

D. The nutrient analysis must be conducted using a laboratory certified by the Minnesota Department of Agriculture or commissioner-approved on-farm sampling and analysis.

E. Sampling must be conducted so that a representative sample is obtained in accordance with University of Minnesota Extension Service recommendations.

Subp. 3. **Nutrient application rate standards.** Items A and B apply to all manure and process wastewater application sites. Item C applies only to animal feedlots with a capacity of 300 or more animal units and manure storage areas capable of holding the manure produced by 300 or more animal units.

A. Manure and process wastewater application rates must be limited as described in subitems (1) to (3) so that the estimated plant available nitrogen from all nitrogen sources does not exceed expected crop nitrogen needs for nonlegume crops and expected nitrogen removal for legumes.

(1) Expected crop nitrogen needs, crop nitrogen removal rates, and estimated plant available nitrogen from manure and legumes must be based on the most recent published recommendations of the University of Minnesota Extension Service or of another land grant college in a contiguous state.

(2) Estimated plant available nitrogen from organic nitrogen sources, including manure, may deviate up to 20 percent from University of Minnesota Extension Service, or of another land grant college in a contiguous state, estimates where site nutrient management history, soil conditions, or cool weather warrant additional nitrogen application. When crop nitrogen deficiencies are visible or measured, remedial nitrogen applications above the 20 percent deviation can be made.

(3) Nitrogen sources include commercial fertilizer nitrogen, soil organic matter, irrigation water, legumes grown during previous years, biosolids, process wastewater, and manure applied for the current year and previous years.

B. Nutrient application rate standards for land in special protection areas must meet the requirements in subpart 6, item B, subitem (2), if applicable.

C. For land receiving manure or process wastewater from animal feedlots capable of holding 300 or more animal units or manure storage areas capable of holding the manure produced by 300 or more animal units, soil samples from the upper six inches must be collected at a minimum frequency of once every four years and analyzed for phosphorus using the Bray P1 or Olsen test. If soil phosphorus levels exceed the levels in subitems (1) and (2), then the owner must complete a manure management plan in accordance with subpart 4, item D, and submit it with a permit application to the agency or delegated county for review in accordance with subpart 4, item B, subitem (1).

(1) Fields in special protection areas or within 300 feet of open tile intakes that have an average soil phosphorus test level exceeding 75 ppm using the Bray P1 test or 60 ppm using the Olsen test.

(2) Fields outside the special protection areas and more than 300 feet from open tile intakes that have an average soil phosphorus test level exceeding 150 ppm using the Bray P1 test or 120 ppm using the Olsen test.

Subp. 4. **Manure management plan requirements.** Item A indicates who must prepare a manure management plan and when the plan must be prepared. Item B lists when manure management plans must be submitted to the agency or delegated county for review. Item C describes when the manure management plan must be reviewed and revised. Item D lists the required elements of a manure management plan. Item E describes exceptions to manure management plans when manure ownership is transferred.

A. An owner or operator of an animal feedlot shall prepare and retain on file a manure management plan that complies with item D according to the following schedule:

(1) upon application for an NPDES, SDS, interim, or construction short-form permit for a facility capable of holding 100 or more animal units;

(2) an owner of an animal feedlot capable of holding 300 or more animal units that is not required to obtain an NPDES, SDS, interim, or construction short-form permit shall prepare or update a manure management plan prior to January 1, 2005, when a manure management plan does not meet the requirements of this part or reflect current operations and the manure is applied by someone other than a commercial animal waste technician or a certified private manure applicator; and

(3) once a manure management plan is required for a facility, a plan that meets the requirements under this subpart must be retained on file at the animal feedlot or manure storage area.

B. A manure management plan that complies with the requirements of item D must be submitted to the commissioner or delegated county when any one of the following conditions applies:

(1) when an owner submits a permit application to the commissioner for an NPDES, SDS, or an interim permit under part 7020.0405, subpart 1, item C, subitem (2); or

(2) the manure management plan is requested by the commissioner or county feedlot pollution control officer.

C. The manure management plan must be reviewed by the owner each year and adjusted for any changes in the amount of manure production, manure nutrient test results, fields available for receiving manure, crop rotations, or other practices which affect the available nutrient amounts or crop nutrient needs on fields receiving manure.

D. Except as provided in item E, the manure management plan must contain:

(1) a description of the manure storage/handling system and the expected annual amount of manure and nutrients which will need to be land applied;

(2) application methods, equipment, and calibration procedures;

(3) acreage available for manure and process wastewater application including maps or aerial photos showing field locations and areas within the fields that are suitable for manure or process wastewater application;

(4) a description of nutrient testing methods and frequency and the expected nutrient content of the manure to be applied;

(5) planned manure application rates and assumptions used to determine these rates, including assumptions of crop nitrogen and phosphorus needs and nitrogen and phosphorus supplied from all manure and nonmanure sources;

(6) total nitrogen and phosphorus amounts from manure and nonmanure sources to be applied per acre on each field and for each crop in the rotation when applied in accordance with the planned manure or process wastewater application rates established under subitem (5);

(7) expected first and second year plant available nutrients from the manure and process wastewater;

(8) expected months of application;

(9) a description of protective measures to minimize the risk of surface water and groundwater contamination when applying manure or process wastewater in a floodplain, special protection area, soils with less than three feet above limestone bedrock, drinking water supply management areas where the aquifer is designated vulnerable under chapter 4720, and land within 300 feet of all surface tile intakes, sinkholes without constructed diversions, and uncultivated wetlands. Protective measures include, but are not limited to, soil and water conservation measures, timing of application, methods of application, manure application rates, and frequency of application;

(10) for application onto frozen or snow-covered soil, the following information about the fields that may receive the manure or process wastewater:

(a) field location;

(b) land slopes;

(c) proximity of fields to surface waters;

(d) expected months of application for each field; and

(e) tillage and other conservation measures used to minimize risk of manure-contaminated runoff;

(11) a description of how phosphorus from manure is to be managed to minimize phosphorus transport to surface waters resulting from soil phosphorus build-up to levels described in subpart 3, item C;

(12) plans for soil nitrate testing in accordance with University of Minnesota Extension Service recommendations; and

(13) type of cover crop to be planted when manure is to be applied in June, July, or August to fields that have been harvested and would otherwise not have active growing crops for the remainder of the growing season.

E. When ownership of manure from an animal feedlot capable of holding 300 or more animal units or a manure storage area capable or holding the manure produced by 300 or more animal units is to be transferred for application to fields not owned or leased by the owner of the animal feedlot or manure storage area, the owner of the animal feedlot where the manure was produced need not include the requirements in item D, subitems (3), (5) to (7), and (10) in the owner's manure management plan. Any person receiving the manure shall comply with subpart 1, item C.

Subp. 5. **Recordkeeping.** Item A establishes the length of time that records must be kept. Items B and C indicate the information needed in records depending on the size and location of the facility.

A. Any person applying or receiving manure or process wastewater from a facility capable of holding 100 or more animal units shall maintain records of the amount of manure or process wastewater application on file:

(1) for the most recent six years for manure or process wastewater application within special protection areas; and

(2) for the most recent three years on land not covered under subitem (1).

B. For an animal feedlot capable of holding 300 or more animal units or a manure storage area capable of holding the manure produced by 300 or more animal units, or where manure or process wastewater is applied from an animal feedlot capable of holding 100 or more animal units or a manure storage area capable of holding the manure produced by 100 or more animal units in a drinking water supply management area where the aquifer is designated vulnerable under chapter 4720, records kept in accordance with item A must contain the following information:

(1) field locations and cropland acreage where manure is applied;

(2) volume or tonnage of manure applied on each field;

(3) manure test nitrogen and phosphorus content, as required by subpart 2;

(4) dates of application;

(5) dates of manure incorporation when incorporating within ten days;

(6) expected plant-available amounts of nitrogen and phosphorus released from manure and commercial fertilizers on each field where manure is applied;

(7) a description of changes to the manure management plan, including documentation of the justification

for any remedial nitrogen applications that exceed the nitrogen rate standard in subpart 3; and

(8) soil nutrient test results.

C. For an animal feedlot or a manure storage area with a capacity of 100 or more animal units and fewer than 300 animal units, where manure or process wastewater will not be applied in a drinking water supply management area in which the aquifer is designated vulnerable under chapter 4720, records kept in accordance with item A must contain the following:

(1) information necessary to credit the nitrogen available for crop growth that is supplied by manure and process wastewater applications; and

(2) manure and process wastewater test results for nitrogen and phosphorus content, if required in subpart 2.

D. Where manure or process wastewater from animal feedlots or manure storage areas with a capacity of 300 or more animal units is transferred for application to fields not owned or leased by the owner of the animal feedlot which produced the manure, the owner of the animal feedlot or the manure storage area from which the manure is produced must meet the following requirements:

(1) the manure and process wastewater records for the most recent three years must be kept on file and must contain the following information:

(a) the volume or tonnage of manure or process wastewater delivered;

(b) the nutrient content of the manure or process wastewater delivered;

(c) the name and address of any commercial hauler or applicator who received the manure or process wastewater; and

(d) the location where the manure or process wastewater was applied and rate of application; and

(2) commercial applicators spreading manure or process wastewater onto land not owned or leased by the owner of the animal feedlot or the manure storage area from which the manure or process wastewater is produced shall keep records, in accordance with subitem (1). A copy of these records must be submitted to the owner of the animal feedlot or the manure storage area from which the manure or process wastewater is produced no later than 60 days following land application.

Subp. 6. **Manure and process wastewater application requirements in special protection areas.**

A. Manure or process wastewater must not be applied to frozen or snow-covered soils in special protection areas.

B. Manure or process wastewater applied to unfrozen soils in special protection areas must comply with subitem (1), (2), or (3).

(1) A vegetative buffer must be maintained that:

(a) consists of perennial grasses or forages;

(b) is a minimum of 100 feet wide along lakes and perennial streams and 50 feet wide in other special protection areas; and

(c) does not receive manure applications from any animal feedlot or manure storage area.

(2) The following practices must be complied with:

(a) no application within 25 feet of the protected water, protected wetland, intermittent stream, or drainage ditch in the special protection area;

(b) inject or incorporate within 24 hours and prior to rainfall; and

(c) apply at a rate and/or frequency which will not allow soil phosphorus levels to increase over any six-year period with the following exception: soil phosphorus may be increased to 21 ppm (Bray P1) or 16 ppm (Olsen) when soil testing indicates soil phosphorus test concentrations are less than these values.

(3) Other agency-approved practices must be implemented that have been demonstrated through research by a land grant college to provide an equal degree of water quality protection as the measures in subitems (1) and (2).

C. Manure and process wastewater application by a traveling gun, center pivot, or other irrigation equipment that allows liquid application of manure to travel more than 50 feet in the air is prohibited in special protection areas.

Subp. 7. **Manure and process wastewater application for land within 300 feet of open tile intakes.** Manure and process wastewater applied within 300 feet of open tile intakes, and where manure-contaminated runoff may flow into the open tile intake, must be injected or incorporated within 24 hours of application according to the schedule in items A and B unless other agency-approved water quality protection management practices are implemented in accordance with item C.

A. All liquid manure and process wastewater applied within 300 feet of open tile intakes must be injected or incorporated within 24 hours of application beginning October 23, 2000.

B. All manure and process wastewater applied within 300 feet of open tile intakes must be injected or incorporated within 24 hours of application when applied after October 1, 2005.

C. Other agency-approved practices must be implemented that have been demonstrated through research by a land grant college to provide an equal degree of water quality protection as injection or incorporation within 24 hours.

Subp. 8. **Manure and process wastewater application near sinkholes, mines, quarries, and wells.**

A. Manure and process wastewater must not be applied to land within 50 feet of an active or inactive water supply well, sinkhole, mine, or quarry.

B. Manure and process wastewater must be incorporated within 24 hours of surface application when applied to land that slopes toward a sinkhole and is less than 300 feet from the sinkhole except that no setback incorporation is necessary where diversions prevent manure-contaminated runoff from entering the sinkhole.

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THE SINKHOLE COLLAPSE OF THE LEWISTON, MINNESOTA WASTE WATER TREATMENT FACILITY LAGOON

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ABSTRACT

On February 20, 1991, city workers discovered a sinkhole collapse in the Lewiston, MN waste water treatment facility (WWTF) lagoons. The collapse apparently occurred during the preceding few days and drained an estimated 7.7 million gallons of partially treated effluent into the local ground water system. A temporary dike was constructed to isolate the sinkhole from the rest of the lagoon. Subsequent, ad hoc testing for coliform bacteria and nitrates did not detect evidence of effluent from the lagoon in nearby residential wells. Following a shallow (20 foot penetration) geophysical investigation using ground penetrating radar and an electromagnetic survey, the city decided to fill the sinkhole and to erect a dike around the collapse. The collapse was repaired in May, 1991 and the lagoon returned to full operation.

The 1991 Lewiston collapse follows the nearby, 1974 and 1976 collapses of the Altura, Minnesota WWTF lagoon (Liesch, 1977; Alexander and Book, 1984). Two of the 7 to 10 WWTF lagoons constructed on the Ordovician Prairie du Chien Group carbonates in the southeastern Minnesota karst terrain have catastrophically failed in less than 20 years. That corresponds to a failure rate of over 20% for these million dollar WWTFs -- so far. The federal programs that cost-shared the bulk of the construction expenses for these WWTFs no longer exist. The cost of potential damages, remediation, and/or replacement of these WWTFs falls directly on the state and local units of government.

INTRODUCTION

Southeastern Minnesota is an active karst area. Geomorphic features associated with the karst include sinkholes, enlarged joints, numerous springs, disappearing streams, cave systems, and dry valleys. There are problems with ground-water quality ranging from occasional high levels of selected parameters to chronic sub-standard drinking water conditions in the hydrogeologically sensitive area.

The region is characterized by farms, small towns, and a few moderate-sized cities. Many of the community centers have waste treatment facilities that consist of a series of settling ponds, or lagoons. Lewiston, Minnesota is one of the small towns located within this karst region. This paper documents the failure of one of Lewiston's ponds due to the instantaneous collapse of a sinkhole.

PHYSICAL SETTING

Topography

Lewiston is located in southeast Minnesota, in Winona County (Figure 1). The region surrounding Lewiston is characterized by gently rolling hills and swales with local relief of about 20 m (Figure 1). Sinkholes and dry valleys are evident at the surface. A very thin soil, ranging in thickness from 0 to about 15 m, covers the bedrock. The source material for the soil is both residuum and/or glacial tills and loess.

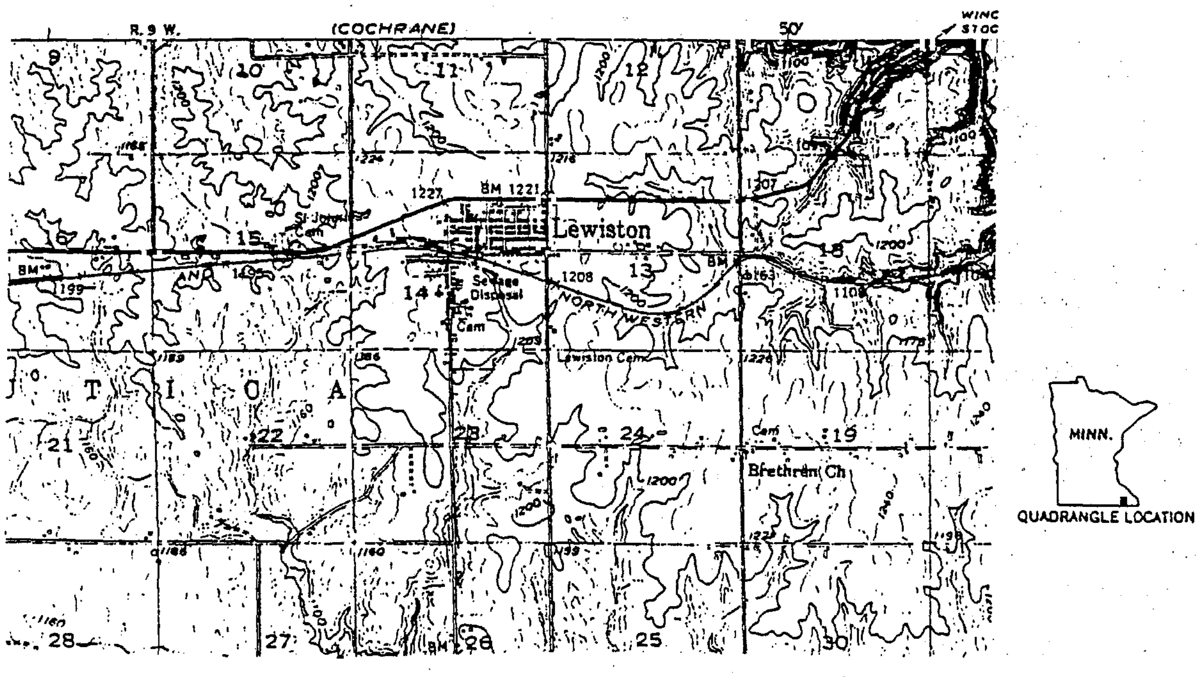


Figure 1. Portion of the topographic map in the vicinity of Lewiston, Lewiston, Minnesota Quadrangle.

Climate

At present, the area has a temperate climate, with a mean annual temperature of 7.6^0, and an annual precipitation of 75 cm (NOAA, 1978). This region has experienced climatic changes, most recently, the changes that resulted in Pleistocene glaciation.

Geology

The region is underlain by a series of lower Ordovician and Cambrian sandstone and carbonate units (Figure 2). The units were deposited in nearshore to shallow-sea environments, and exhibit typical vertical and lateral facies changes associated with sedimentation during Transgression and regression of the shallow sea. The strata dip gently to the southwest towards the center of the Hollandale Embayment (Mossler and Book, 1984). The units of most concern are the Jordan Sandstone and the Oneota Dolomite.

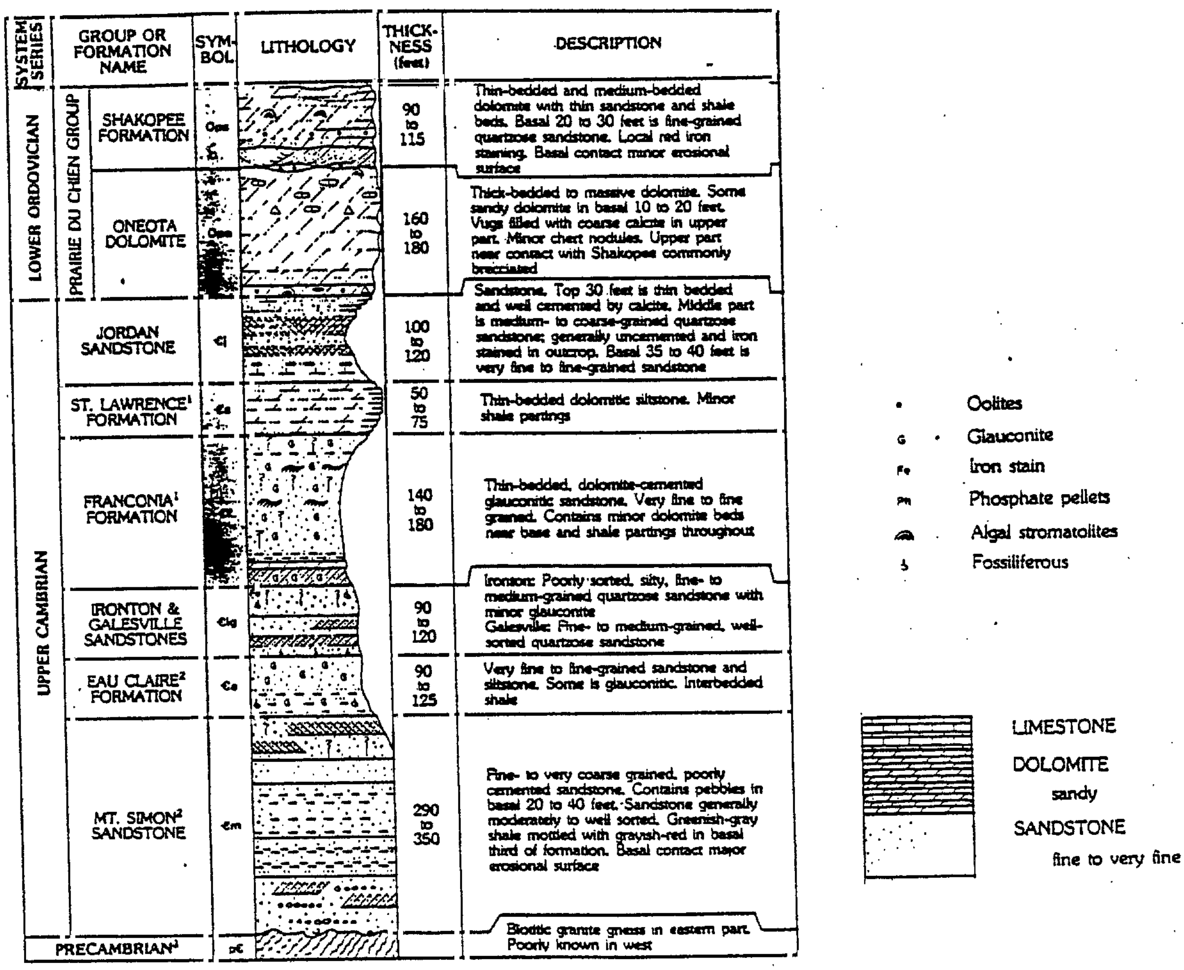


Figure 2. Generalized stratigraphic section in the Lewiston, Minnesota area. Adopted from Mossler and Book (1984).

The Jordan Sandstone is Cambrian in age and averages 30 m in thickness. The Jordan is a massive, upward-grading, fine- to coarse-grained friable sandstone. Upward in the unit, it becomes progressively more indurated with carbonate and siliceous cements, first forming lenses and concretions and then well-bedded, highly lithified strata.

The Ordovician Prairie du Chien Group conformably overlies the Jordan (Figure 2). The Prairie du Chien is composed of the Oneota Dolomite and upper Shakopee Formation. The Oneota Dolomite is about 60 m thick, and is fine- to medium-grained, thick- to thin-bedded to massive, with calcite-filled vugs in the upper portion, and minor chert nodules throughout the unit (Mossler and Book, 1984). Both drill cores and outcrops reveal that the dolomite is highly jointed and has undergone extensive solution. The dolomite is vuggy to cavernous particularly in the upper portion.

The Shakopee Formation is subdivided into the lower New Richmond Sandstone member and the upper Willow River Dolomite member. The latter is not present in the area and is not discussed further. The New Richmond Sandstone of the Shakopee Formation is a fine- to medium-grained quartzose sandstone with infrequent interbedded medium-grained arenaceous carbonate beds. This sandstone unit averages about 6 m in thickness, is friable, extensively jointed, easily eroded, and does not form many outcrops.

Hydrology

Surface flow is in small headwater channels of the Whitewater and Root Rivers. The channels are characterized by meander development and easily erodible banks. Some surface run off flows into sinkholes. Regional ground-water flow is east-northeast toward the Mississippi River. Local ground-water flow is toward discharge points such as small tributaries or springs.

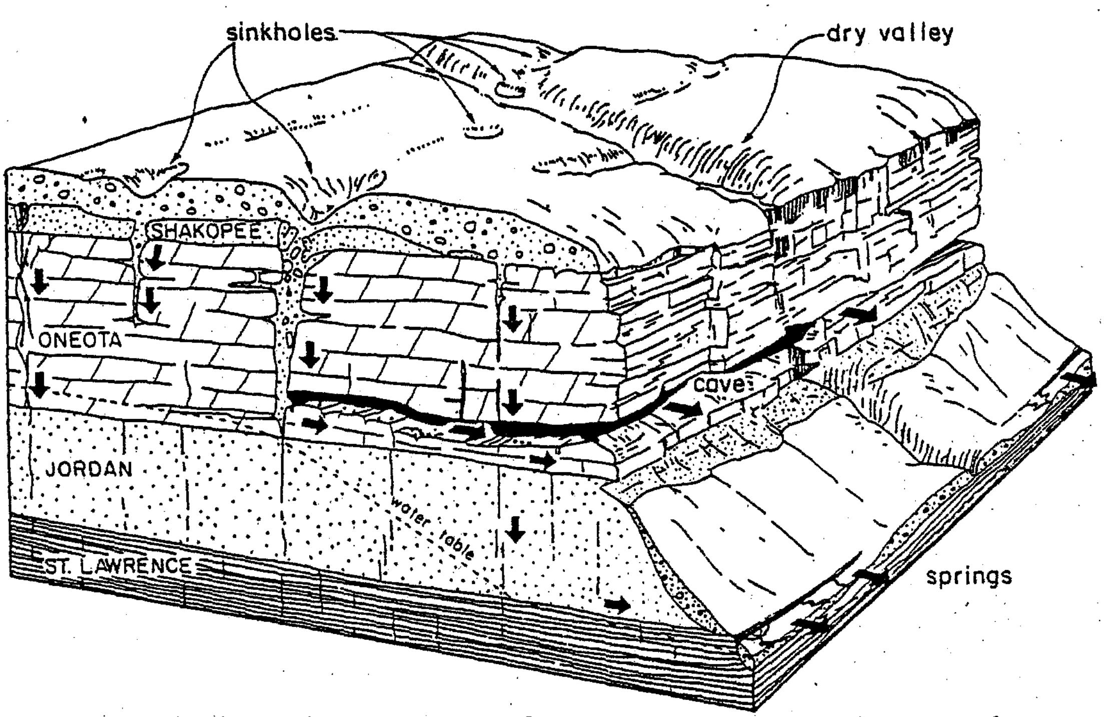
Joints are common throughout the Jordan Sandstone and springs in the well-lithified portions tend to discharge directly from joints. In the more friable lower part, springs are often a combination of discrete flow from joints and diffuse flow from numerous seeps. The Jordan is a major source of water for wells in the area.

Only a few springs, confined to discharge from well-developed joints, have been mapped in the Oneota. Few wells in the area rely solely on the Oneota as a water supply. However, many older wells are open holes through the Oneota. The New Richmond Sandstone member of the Shakopee Formation has a few springs which emerge form the New Richmond/Oneota contact. The New Richmond is not a significant aquifer in the area.

Karst Features

Numerous karst features such as sinkholes, enlarged joints, springs, dry valleys, and small caves have formed in the Oneota Formation of the Prairie du Chien Group (Figure 3). Sediment-filled solution cavities are common features in outcrops and quarry walls that expose the Oneota Dolomite. The karstification of the Oneota probably began during the Ordovician and has continued intermittently until the present. The region would be classified as fluviokarst according to the scheme used by Sweeting (1973) because both karst and fluvial processes have contributed to the development of the features that are evident, or that are being exhumed.

Sinkholes are by far the most dominant karst feature. Historically, if the holes are left in the natural state, they are either fenced-in and left to be naturally vegetated, or several have been used as backyard landfills. In the past, several have been filled with debris and soil and then used as farm land. Many of the sinkholes in the area have developed catastrophically, often in the spring of the year in response to unusually wet conditions. It appears that the sinkholes develop through the New Richmond Sandstone into the underlying Oneota Dolomite.



Typical relationships in Winona County between karst and topography

Figure 3. Block diagram of karst landforms in southeast Minnesota (Dalgleish and Alexander, 1984).

Lewiston, and the immediate vicinity, were classified as high probability of sinkhole development by Dalgleish and Alexander (1984). The classification was based on the observed density of sinkholes, together with information on the bedrock geology, surficial geology, and hydrogeology. Dalgleish and Alexander (1984) conclude that the carbonate bedrock is the primary control on sinkhole formation. Secondary controls include the type and thickness of the overburden, and the depth of the water table. Areas where the Oneota Dolomite is overlain by the sandstone member of the Shakopee Formation, such as in the vicinity of Lewiston, are the most susceptible to sinkhole development. Fractures in the noncalcareous sandstone act as conduits to preferentially direct surface water into the Oneota.

THE SINKHOLE COLLAPSE OF THE LEWISTON WASTE WATER TREATMENT FACILITY LAGOON

Background

The Waste Water Treatment Facility at Lewiston, (population ~1300) is constructed in an area that overlies the New Richmond Sandstone member of the Shakopee Formation and the Oneota Dolomite, and has less than 30 m of regolith. The Waste Water Treatment Facility consists of a series of settling ponds or lagoons which is commonly known as a "natural" treatment system (Figure 4). These types of systems are common in southeast Minnesota. The one at Lewiston is about 20 years old. Exposure of the waste water allows oxygen and sunlight, together with microorganism to "treat" the effluent after initial screening for large-sized solids. Machines or chemicals are not used. The treated water is then discharged to a surface-water channel. This natural purification takes about 6 months.

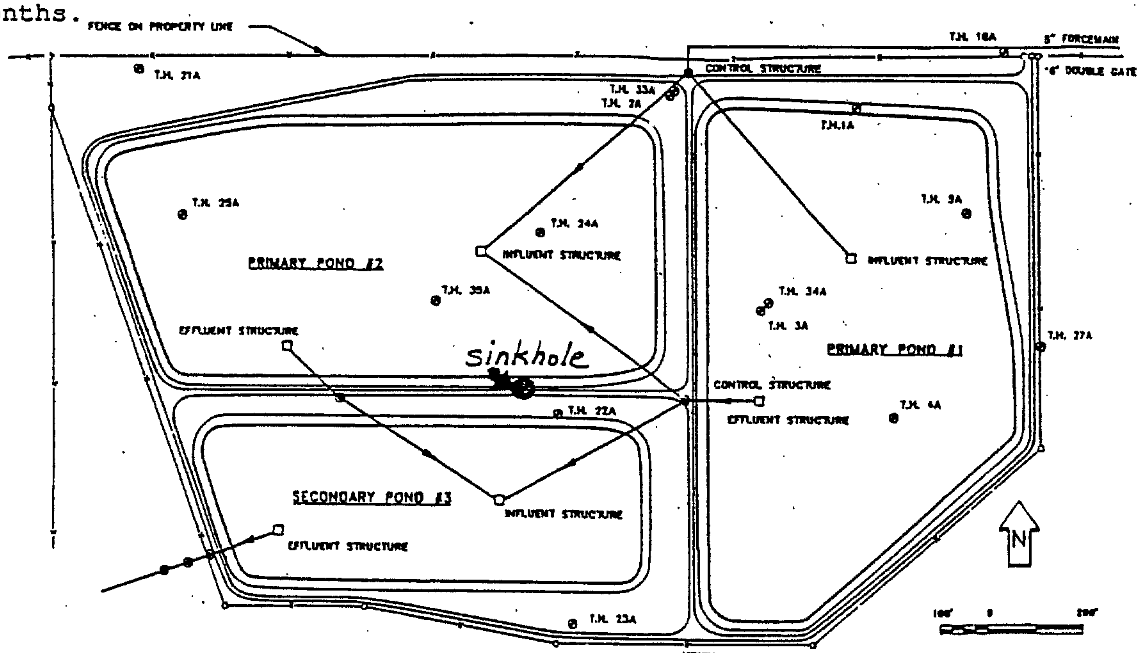


Figure 4. Schematic of the Lewiston WWTF (From Braun, Intertec, 1991)

According to the superintendent of the Lewiston's sewer and water system Lewiston had wanted a mechanical system 20 years ago, but was denied the request by the Minnesota Pollution Control Agency. Supposedly, the decision was based on the consensus that small towns could not afford the upkeep and the operating expenses of a mechanical plant (Rochester Post and Bulletin; February 27, 1991). Today, that opinion is not held by any state government agency. The change of opinion is based not on a town's new-found ability to afford a plant, but because of the ground-water quality problems associated with a karst terrain, and the documented failure of a similar lagoon system in Altura, Minnesota (Alexander and Book, 1984), which is about 10 km northwest of Lewiston.

Sinkhole collapse

On February 20, 1991, it was discovered that a sinkhole had opened on the edge of sewage lagoon Number 2 (Figure 4) at the Waste Water Treatment Facility at Lewiston, Minnesota. The sinkhole collapse caused a break in the dike enclosing the lagoon. The collapse left a hole that was approximately 12 m in diameter and 2-4 m in depth (Figure 5).

Figure 5. Photo of dike-side of sinkhole, on February 20, 1991. View is northwest. Photo courtesy of R. Dunsmoor, Winona County.

It is estimated that the collapse occurred on or about February 14, 1991. According to the records of city workers, approximately 7.7 million gallons of semi-treated sewage effluent were lost from Lagoon Number 2. The loss occurred over several hours to perhaps a day. The effluent entered the ground through a conduit at the bottom of the sinkhole. The waste water had been in the lagoon only about two months, and probably still contained bacteria and/or viruses because it was covered with ice which would prevent sunlight and heat from destroying them.

The sinkhole collapse at Lewiston has striking similarity to the collapse at the Altura Waste Water Treatment Facility as documented by Alexander and Book (1984). Both collapses formed in the Oneota Dolomite where it was overlain with the basal sandstone member of the Shakopee Formation. At both locations, sinkhole collapse was catastrophic. One of major differences is that the failure of the Altura lagoon was due to several sinkholes in the bottom of the lagoon, whereas, the failure of the Lewiston lagoon was due to a single sinkhole collapse near the edge of the lagoon which led to breaching of the dike.

Response to the problem

The water level in Lagoon Number was 2 was lowered and continued to be monitored so that further semi-treated water did not spill over into the sinkhole. A dam was built around the sinkhole in order to prevent surface run off from entering the hole.

Water-quality tests were performed on the city wells and on 11 private wells in the area. The results did not detect contamination from the effluent. Residents were advised to drink water from hot water heaters that had been cooled, until they could have their well tested. They were further advised to chlorinate their wells, and drink bottled water if they had any concerns.

Remediation of the problem

The city hired a consulting firm in early March to determine the size of the sinkhole and propose short term remediation. A shallow (6 m penetration) geophysical investigation used ground-penetrating radar and an electromagnetic survey to determine the limits of the observed sinkhole and possible fractures in the vicinity. An independent proposal to run a dye trace form the sinkhole in order to determine ground-water flow patterns was not adopted by the city. This was due in part to the concern of liability.

By mid May 1991, it was decided by city employees that the best response to the sinkhole collapse was to repair the dike and seal the sinkhole. Beginning May 21, 1991, the site was cleaned-up, and new dike was created about 15 m from the surface expression of the sinkhole. According to city employees, the sinkhole was excavated to within 1 m of bedrock. The hole was then filled and sealed by May 24, 1991.

POTENTIAL FAILURE OF OTHER WASTE WATER TREATMENT FACILITIES

The Minnesota Pollution Control Agency has compiled a list of towns in southeast Minnesota with waste-water pond facilities similar to that at Lewiston. The screening for the list included those sites which are situated over karstic bedrock and had less than 30 m of soil or till above the bedrock. The initial list, which is being refined at this time, includes 14 sites. Of those 14, 10 are considered to have high potential for failure, and 4, low potential. Of the 10 that have high potential for failure, 2 have had failures within the past 20 years. This corresponds to a failure rate of about 20%.

Costs for potential damages, repair and/or remediation for these Waste Water Treatment Facilities is now the responsibility of the local units of government. The Federal programs that cost-shared the bulk of the original construction costs have been severely reduced or phased out. It is recognized that the use of a lagoon system in a karst region can lead to catastrophic failures and potential health concerns. However, the sealing of the sinkholes not only in, or next to, sewage ponds, but in other sensitive areas, is often the remedial method of choice due to economics. A new sewage treatment plant would cost about 1.5 million dollars which is an exorbitant financial burden for a small town. These small towns are forced either to spend millions of dollars on new construction or risk potential liability suits. Neither choice is good.

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BIOGRAPHICAL SKETCHES

Nancy O. Jannik is an Associate Professor in the Department of Geology at Winona State University. She has a B.S. in geology (1976) from the College of William and Mary, a M.S. in geology (1980) from Rutgers University, and a Ph.D. in geosciences/hydrology (1988) from the New Mexico Institute of Mining and Technology. Her current research involves determining aquifer characteristics, aquifer interactions, and the inter-relationships between surface and ground water in the karst terrain of southeastern Minnesota. Her full address is as follows.

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CONSTRUCTING NEW MANURE STORAGE SYSTEMS IN THE KARST REGION

Interim Guidance Document
last revised 3-20-00

Minnesota Pollution Control Agency

PURPOSE OF THESE GUIDELINES

These guidelines are established by the Minnesota Pollution Control Agency (MPCA) to define the measures and considerations generally needed to ensure that, to the maximum extent practicable, ground water is protected when new liquid manure storage systems are constructed in the karst region. Minnesota rules 7060.0500 state that it is the "policy of the Minnesota Pollution Control Agency to control wastes as may be necessary to ensure that to the maximum practicable extent the underground waters of the state are maintained at their natural quality." Maintaining high quality ground water supplies is challenging in the karst region of southeastern Minnesota due to the rapid transport of contaminants from the land surface to ground water in this unique geologic setting. These guidelines are also intended to provide greater consistency during MPCA staff and County Feedlot Officers permitting decisions in the karst region.

This document incorporates minimum standards proposed in the revised feedlot rules (chapter 7020) and additional site-specific evaluations and measures needed to safeguard ground water in the karst region. The proposed feedlot rules for chapter 7020 will establish the minimum standards for depth to bedrock and define areas adjacent to sinkholes that are not suitable for construction of liquid manure storage systems. However, the proposed feedlot rules are not intended to define all considerations and measures needed to protect ground water from construction of new liquid manure storage systems in this region. A site-specific review process in this document defines what information must be considered in the case-by-case analyses to evaluate the water quality protection measures needed for specific site locations in the karst region.

It is important for livestock producers and their technical advisors to understand karst risk considerations early in the planning and site selection process. Some questions addressed in these guidelines include: 1) why are additional precautionary measures needed in the karst region? 2) what are the minimum depth to bedrock and sinkhole setback restrictions? 3) what site conditions pose the highest risk of failure? 4) what type of manure storage system designs are needed to protect ground water quality? and 5) what investigations and evaluations must be conducted prior to obtaining a feedlot permit application for construction of a liquid manure storage system in the karst region?

This document will be used as "interim" guidance until the proposed feedlot rules are finalized, pending legislation is resolved, and any resulting modifications are incorporated. The State Senate is currently proposing legislation directing the MPCA to convene a workgroup consisting of representatives from the Natural Resources Conservation Service and private sector engineers to review and propose design standards for liquid manure storage facilities in areas susceptible to soil collapse and sinkhole formation.

BACKGROUND

KARST REGION OF MINNESOTA

Much of Southeastern Minnesota is considered a "karst" landscape (Figure 1). Karst is a geologic term for a landscape area created over soluble rock with efficient drainage. The underlying carbonate bedrock in a karst region dissolves over time to produce solution enlarged joints and cracks. These features can result in rapid transmission of contaminants from the land surface to the ground water below. Karst areas are characterized by sinkholes, caves, springs, losing streams, and blind valleys. Sinkholes are surface depressions on the earth formed by a collapse of soil or bedrock; losing streams lose some of their flow into the ground; and blind valleys are valleys that have no surface outlet and the runoff waters enter the ground. The extent of karst feature development varies tremendously across southeastern Minnesota, and often changes abruptly within a few hundred feet.

Figure 1. Minnesota Karst Lands. These guidelines pertain to much of the land in the dark shaded areas (from Alexander, E.C. Jr., University of Minnesota).

BENEFITS OF LIVESTOCK AND MANURE STORAGE STRUCTURES

Livestock agriculture can benefit water quality in the karst region, helping to offset some of the risks to water quality. For example, manure applied to land in row crop production can reduce soil erosion. Hay land and pastures associated with cattle operations result in very little soil erosion and pesticide transport on the steeply sloping soils common in the karst region.

The trends to construct new and expanded feedlot facilities with liquid manure storage systems can potentially further enhance protection of surface water quality. Manure storage structures increase management flexibility, making it easier to apply at proper rates and to avoid winter-time manure application. Many of the older feedlot facilities are located adjacent to streams and do not have containment of manure or manure-contaminated runoff. Most facilities with new liquid manure storage structures have total containment of manure so that there is no manure in rainfall and snowmelt runoff waters leaving the feedlot area. Also, the liquid manure in containment structures is usually injected below the soil surface and is less subject to surface runoff compared to the soil surface spreading practices of many feedlot facilities without liquid manure storage.

RISKS OF MANURE STORAGE SYSTEMS IN KARST REGIONS

While liquid manure storage systems can benefit water quality, they can also pose several heightened risks. Three potential water quality risks associated with liquid manure storage systems in the karst region are described below. Two of the risk factors could lead to long-term (chronic) problems, whereas the third risk factor is associated with catastrophic failure. The water quality risks include:

1) seepage of contaminants through the liner and underlying soil to fractured bedrock and subsequently to ground water;
2) gradual soil subsidence or formation of a shallow sinkhole below the storage structure that breaches the integrity of the liner, causing slow and perhaps undetectable leaking of manure from the storage system to ground water; and
3) a larger sinkhole forming below a manure storage system leading to a rapid flow of manure into ground water or causing a collapse in a basin sidewall and a release of manure onto the ground surface.

Conditions stated in 2 and 3 above are referred to in this document as "soil collapses." In general, the potential for soil collapse increases as the seepage rate through the storage system liner increases. With high seepage rates, the seepage liquids can wash or erode underlying soils into fractures in the bedrock. As more soil moves down the fractures, the soil may either gradually subside or suddenly collapse. In some cases, the underlying bedrock can dissolve to the degree that it suddenly collapses, causing the soil above to also collapse. Soil collapses can also form in some areas with very low seepage rates due to natural processes occurring over the past centuries or from changes in water infiltration rates near the manure storage system.

Manure entering ground water will discharge into streams within a period of time ranging from hours to decades depending on the site-specific hydrogeology. The karst region of Minnesota maintains a large number of high quality trout streams. A rapid discharge of a large quantity of manure into a stream will destroy the aquatic life for a stretch of the stream and also result in increased nutrient loading into the receiving waters of the Mississippi River system. Manure that travels in the ground water for a longer period before discharging into streams will be more diluted and may not destroy aquatic life, but will threaten drinking water supplies as it travels toward the stream, and then still contribute to stream pollution upon discharge.

Using liners with very low seepage rates can reduce the probability of a soil collapse below a manure storage system. Risks of failure can also be reduced by such measures as proper siting of the storage facility on the landscape; minimizing the manure storage capacity; preventing excess infiltration of runoff waters around the storage facility; and maintaining a certain separation distance between the manure and fractured bedrock.

Basin overflows and intentional discharges from manure storage structures have been problems at some facilities in Minnesota. Enforcement of intentional manure overflows and direct discharges to waters has increased during recent years in an effort to curb blatant violations. Another potential water quality risk from liquid manure storage systems is failure of manure storage system sidewalls to hold liquid manure. Sidewall failures are not known to have occurred in Minnesota, possibly due to engineering review and regulation of construction activities.

SOIL SUBSIDENCE AND SINKHOLE DEVELOPMENT

Learning experiences from sinkholes forming under municipal wastewater treatment ponds

Between 1974 and 1992, sinkholes opened below three of the twenty-two municipal wastewater treatment ponds in Minnesota's karst region. Sinkholes developed in Altura's ponds in 1974 during construction and in 1976 when it first filled to capacity (Alexander and Book, 1984). A sinkhole developed in a Lewiston pond in 1991 after eighteen years of use (Jannik et al., 1992). Several sinkholes developed in a Bellchester pond in 1992 after twenty-two years of use (Alexander et al., 1993). The amount of partially treated wastewater draining into sinkholes at the three respective sites was 3.7, 2.3, and 7.7 million gallons. The ponds were constructed of earthen materials with a designed seepage rate not to exceed 3500 gallons per acre per day. Several sinkholes are located within about a mile from all three sites, yet no sinkholes have been identified within a quarter of a mile from the sites.

These failures clearly demonstrate the potential for sinkholes to develop in southeastern Minnesota when large quantities of liquids are stored in sinkhole prone areas with minimal barriers between the liquid and underlying materials. Similar problems can develop when storing liquid manure above permeable liner materials. It should be noted that the current maximum allowable design seepage rate for manure storage systems is more protective than the standards used for the failed municipal wastewater pond construction. It is also important to consider that the contaminant concentrations in manure are often over 100 times greater than municipal wastewater pond liquids, and thus the environmental consequences of a catastrophic manure release could be much worse than municipal pond failures.

In Minnesota, there have been no documented failures of manure storage systems due to sinkhole formation, but there have been several farm-field runoff retention ponds that have failed into sinkholes. Manure seepage into fractured bedrock occurred at one southeastern Minnesota farm at such a rapid rate that the storage system did not ever need to be pumped and the farmer's well was severely contaminated. In other states with karst geology, sinkholes have been documented to form below soil-lined manure storage systems.

Sinkhole Probability Mapping and Research

Sinkhole mapping and research completed during the past two decades has made it easier to determine the relative soil subsidence risks when siting new liquid manure storage systems in Southeastern Minnesota. Sinkhole probability maps have been completed for Winona County, Fillmore County, and Olmsted County (Dalgleish and Alexander, 1984; Alexander and Maki, 1988; Witthuhn and Alexander, 1995). A Karst Hydrology map has also been published for Leroy Township of Mower County (Green, Mossler, Alexander and Alexander, 1997). A Goodhue County sinkhole probability will be published soon. Additional hydrogeologic investigation has been conducted over much of the karst region and more karst hydrogeology maps are expected in the future for other counties.

The probability of sinkhole formation has been found to vary tremendously across the karst region. Some areas have in excess of 50 sinkholes per square mile and other areas have no sinkholes. Often high-density clusters of sinkholes are adjacent to areas with widely scattered individual sinkholes. Bedrock composition, position in the landscape, and thickness of glacial materials over bedrock have all been found to affect the likelihood of sinkhole formation.

Most sinkholes in southeastern Minnesota appear where there is less than about 50 feet of soil cover over carbonate and sandstone bedrock. The proximity of nearby sinkholes remain the single best predictor of new sinkhole development (Witthuhn and Alexander, 1995). Magdalene and Alexander (1995) concluded that on the scale of several kilometers, new sinkholes in Winona County tend to develop in the areas of existing sinkholes, especially near newly developed sinkholes. The risk of soil collapse has generally been found to increase in areas of ponded or intermittently flowing water, and in areas with indications of more extensive karstification, including areas with disappearing streams, caves, springs and solution cavities.

REQUIRED MEASURES PRIOR TO CONSTRUCTING A STORAGE SYSTEM

To meet the agency's water quality protection goals, the MPCA requires livestock producers to take several precautionary measures prior to obtaining a permit to construct a liquid manure storage system in the karst region. The measures are intended to prevent siting of a new system in areas that pose a high probability of failure, and to ensure that the system design and construction are best suited for the conditions at the proposed site. The investigations, evaluations and planning needed to manage risks related to manure seepage and soil collapse include the following:

- Investigate area for sinkholes and other karst features;
- Select potential construction sites in lower risk locations;
- Investigate site for soil characteristics;
- Evaluate soil collapse risk;
- Design storage system for the site-specific conditions; and
- Develop an inspection plan for construction activities.

A description of each of these measures is described below.

INVESTIGATING AREA FOR SINKHOLES AND OTHER KARST FEATURES

Site investigations for karst features are required when considering construction of liquid or semi-solid manure storage systems in areas with a sinkhole probability of "low to moderate" or greater in geologic atlases published by the Minnesota Geological Survey, University of Minnesota and/or Minnesota Department of Natural Resources. Where no sinkhole probability maps are available, site investigations for karst features are required on all land expected to have less than about 75 feet of soil above fractured bedrock.

Investigations of nearby sinkholes and other karst features are needed for three primary reasons: a) to determine whether an Environmental Assessment Worksheet (EAW) is needed for the site; b) to ensure that minimum setbacks from sinkholes will be met; and c) to enable selection of the best possible site location and evaluation of the soil collapse risk at potential site locations.

EAWs – The Minnesota Environmental Quality Board rules 4410.4300 specify that an EAW must be completed for construction of an animal feedlot facility of more than 500 animal units, or expansion of an existing animal feedlot facility by more than 500 animal units, if the facility is located within 1000 feet of a known sinkhole, cave resurgent spring, disappearing spring, karst window, blind valley or dry valley.

Sinkhole Setbacks – The second reason for the karst feature investigation is to ensure that minimum setbacks from sinkholes are met. These setbacks are designed to prevent construction where there is a very high risk of soil collapse. Two specific provisions in the proposed MPCA feedlot rules chapter 7020 identify minimum setback distances between sinkholes and new manure storage systems. Proposed rules 7020.2005, subpart 1, prohibit a new feedlot or manure storage area within 300 feet of a sinkhole. Proposed Minn. R. 7020.2100, subpart 2, prohibits construction of liquid manure storage systems with a capacity exceeding 250,000 gallons where four or more sinkholes are located within 1000 feet of the proposed site, except where geologic conditions are not suitable for sinkhole development, or where the manure storage system is constructed to address an existing pollution hazard at a feedlot with less than 300 animal units.

Use in selecting site and evaluating risks - The third reason for obtaining information about the locations of nearby sinkholes and karst features is for use in selecting the lowest risk site location and evaluating the risk of soil collapse. The proximity and characteristics of sinkholes, blind valleys, springs, caves, and other karst features from the proposed storage system can be used to help evaluate the risk of soil collapse.

The following investigations and information are needed prior to selecting a potential construction site. This information must accompany a permit application for constructing a liquid manure storage system in the karst region.

- *Sinkhole Maps* - Include a copy of published sinkhole location and/or probability maps showing the area within two miles of the proposed facility. If a sinkhole map shows the proposed manure storage site location to be in an area designated as "low" or "no" probability, then the other steps for the site investigation need not be completed. Sinkhole Probability maps are currently available from the Minnesota Geological Survey (612-627-4782) for Olmsted Co., Winona Co., Fillmore Co., and LeRoy Township of Mower Co..

- *Field Inspection* - Include a map of the proposed site showing the location of all small and large depressions in the landscape. At a minimum, all land within a 1000 feet radius of the potential manure storage structure location must be closely inspected. The best period of time to conduct this investigation is when crop-cover, leaf cover, and snow-cover are minimal.

- *Sinkhole/depression Characteristics* - Include a description of the following for all sinkholes, filled sinkholes and potential sinkholes: a) whether the sinkhole is currently open or has been filled; b) decade when formed, if known; c) position on landscape (show on topographic map); d) diameter and depth, and e) explanations about how the hole or depression formed if not believed to be a sinkhole.

- *Other karst features* - Include a description of other known karst features located within 1 mile of the proposed facility, including disappearing streams, caves, dry valleys, blind valleys, springs, solution cavities or dry valleys.

The following additional information is needed for liquid manure storage structures proposed in counties where a sinkhole location/probability map has not been prepared:

- *Soils Maps and Aerial Photos* - topographic maps, soil survey maps and aerial photos of all land within a one-mile radius of the site. All known open and filled sinkholes must be highlighted on these maps. Closed depressions identified on topographic maps are to be identified and inspected.

- *Land owner interviews* - a list of all long-term residents (living in area at least 15 years) and land owners in the area who were interviewed and asked about the location of existing and filled sinkholes located within a 1 mile radius of the proposed facility. All sinkholes or potential sinkholes (open or filled) are to be identified on a map or photo of the site.

- *Well Logs* - Geologic information from well logs within a 2 mile radius of the proposed site location

SELECTING POTENTIAL CONSTRUCTION SITES IN LOWER RISK LOCATIONS

After obtaining the information about nearby sinkholes and karst features, select potential construction site locations according to the following criteria:

- Locate the storage system as far as practically possible from topographic lows, depressions or ravines on the farm site, especially where such locations have historically received flowing water or water accumulation.

- Locate the storage system as far as practically possible from existing or historically filled sinkholes and other karst features in the area. Proposed MPCA rules 7020.2005, subpart 1, prohibit a new feedlot or manure storage area within 300 feet of a sinkhole.

- Avoid siting in sinkhole plains or other areas with high densities of sinkholes. Proposed rules 7020.2100 subpart 2 prohibit construction where there are four or more sinkholes within 1000 feet of the proposed site and the design capacity exceeds 250,000 gallons. Exceptions can be made where geologic conditions change drastically between the sinkholes and the proposed site such that the proposed site location is not suitable for sinkhole development. Exceptions are also allowed in the proposed rules where the manure storage system is constructed to address an existing pollution hazard at a feedlot with less than 300 animal units.

- To the extent possible, select potential construction site locations, which are situated in different parts of the landscape than where nearby sinkholes and other karst features are found.

- Select potential site locations expected to have the greatest thickness of fine-textured soils. The minimum allowable separation distances between manure and fractured bedrock are described in the following section.

INVESTIGATING SITE FOR SOIL CHARACTERISTICS

A soils investigation is needed at potential construction sites to: a) select areas which have soil conditions most protective of ground water, b) ensure that minimum separation distances from manure to fractured bedrock can be met, c) ensure that the appropriate soil materials are available for construction, and d) aid in evaluation of soil collapse risks and selecting appropriate designs.

A certain minimum soil thickness between liquid manure and bedrock is needed to allow treatment of manure seepage prior to the seepage reaching bedrock. The separation distance is also needed to minimize the risk of conduits forming in the soil between the liquid manure and fractures in the bedrock. In some cases, the soil separation may provide increased protection from soil collapse below the storage system.

The minimum vertical separation distance between liquid manure and fractured bedrock is identified in Table 1 for different types of liners and livestock numbers contributing to liquid manure storage on the farm. The separation distances in Table 1 are consistent with the proposed feedlot rule revision (Chapter 7020.2100, Subpart 2). Exceptions can be made for constructing manure storage systems to correct existing pollution hazards at feedlots with less than 300 animal units.

To determine whether the minimum separation distance will be met, the owner must conduct soil thickness investigations at a minimum of four locations for the first one-half acre of manure storage area surface area and a minimum of two additional locations for each additional acre. Soil thickness investigations can be conducted using soil borings, trenches, or geophysical surveys supported by information from borings. If the soil thickness investigations indicate an uneven bedrock surface or highly variable soil conditions, additional investigation can be required. The bedrock elevation is considered to be the highest elevation of encountered bedrock.

Table 1. Minimum separation distance requirements between liquid manure and fractured bedrock for different size feedlots (based on animal units) and type of liner construction.

Number of Animal Units contributing to liquid storage on the entire farm	Minimum separation distance when using earthen liners or unsealed concrete liners	Minimum separation distance when using composite* liners or sealed concrete*** liners	Minimum separation distance when using composite* liners with 3 feet compacted clay, above ground** or sealed concrete*** with a secondary liner under the concrete.
< 300 AU	20 feet	5 feet	5 feet
300 to 999 AU	30 feet	10 feet	5 feet
>1000 AU	40 feet	15 feet	10 feet

The following are descriptions of liner types listed in Table 1.

* A composite-lined storage system consists of at least two feet of compacted cohesive soil below a geomembrane (≥40 mil) liner.

** An above ground storage system such as a slurrystore.

*** Concrete-lined systems must include water stops or joint sealant materials at all construction joints, sealing of all cracks which may extend through the concrete, and a floor having a concrete thickness of not less than 5 inches, where the required area of steel reinforcing in the floor is based on subgrade drag theory in American Concrete Institute, Slabs on Grade, ACI-360.

EVALUATING SOIL COLLAPSE RISK

In many areas, the minimum sinkhole setback and soil thickness restrictions can be met, yet the proposed site can still have a high risk of soil collapse. Therefore, a site-specific evaluation is needed at proposed sites for storage systems to exceed a capacity of 250,000 gallons. Locations and characteristics of all nearby sinkholes and karst features are assessed in conjunction with information about soils and manure storage capacity. The evaluation of soil collapse risk is conducted to determine whether a more protective design is needed or whether the site poses such high risk that the location should not be used without a much more extensive geologic investigation.

The soil collapse risk factor is determined from available sinkhole probability map information, along with site specific soils, landscape function, geology, and sinkhole information. The following site-specific information is considered when determining the risk of soil collapse:

- density of sinkhole distribution;
- the topographic and geologic setting which sinkholes are found;
- patterns and characteristics of nearby sinkhole formation;
- type and condition of first encountered bedrock;
- depth to bedrock;
- soil and subsoil types;
- presence of other nearby karst features (e.g. disappearing streams, blind valleys, dry valleys, caves, springs, and karst features observed in exposed bedrock along roadways); and
- proximity of storage system to the nearest sinkhole or karst feature.

Characteristics indicative of various collapse risk categories are listed below, ranging in scale from 0 (lowest risk) to 7 (highest risk sites). While these general descriptions largely refer to proximity to sinkholes and sinkhole densities, the other site specific variables noted above are also evaluated for proposed sites in order to determine the most fitting risk category. The following descriptions are only intended to serve as general guidelines. The numbers 0 to 7 below correspond with the numbers in Figure 2 on page 12.

0 - Areas where the first encountered bedrock is not subject to sinkhole formation.

1 - Areas underlain by carbonate bedrock, but in which very few sinkholes are found. No known sinkholes exist within a one-mile radius of the proposed site, and the soils and geologic information indicate that there is minimal risk of sinkhole formation at the site under consideration.

2 - No sinkholes or buried sinkholes are known within a 1/2-mile radius of the proposed site. However, widely scattered sinkholes have been identified in the area and the depth to bedrock is less than about 50 feet.

3 - No sinkholes or buried sinkholes are known within a 1/4-mile radius of the site. However, there are scattered sinkholes (e.g. 2 - 5 sinkholes in a 1 mile radius of proposed site) and/or other geologic factors that make the area susceptible to sinkhole formation.

4 - Similar sinkhole densities as #5 risk zones, but the soils and other information about karst features indicate that the specific construction site has a lower sinkhole risk than the #5 risk category.

5 - There is typically either 1 sinkhole or buried sinkhole within a 1/4 mile radius or 2-4 sinkholes or buried sinkholes within a 1/2 mile radius and the soils and karst feature information indicates minimal protection.

6 - Sinkholes are common in the area (e.g. 2 to 4 sinkholes in a 1/4-mile radius or 5 or more sinkholes within a 1/2-mile radius).

7 - Sinkholes are the dominant landform, with typical sinkhole densities exceeding about 4 sinkholes in a 1/4-mile radius from any point.

DESIGNING STORAGE SYSTEMS FOR SITE SPECIFIC CONDITIONS

The type of storage system liner will be largely determined by the depth to bedrock requirements in Table 1. However, in areas with an elevated risk of soil collapse, the storage system design may need to be enhanced beyond the requirements in Table 1, and in some cases the site poses such high risk that the location should not be used without a much more extensive geologic investigation.

The MPCA recommends the use of design options that correspond with Figure 2. The storage capacity of all storage systems on the farm and the site specific soil collapse risk factor are both considered in the Figure 2 design options. The measures in table 2 are intended to be flexible enough to encourage application of sound judgment, innovation and experience. Other liner types and alternative designs can be considered by the agency during the permit application review process. Flexibility can also be given when a new manure storage structure is designed to correct existing surface or ground water pollution problems without a significant expansion in operation size. For example, at some existing operations, it can be better for the environment to have a new liquid containment structure built in a sinkhole prone area than to have direct feedlot runoff into streams or the continued use of an old structure that was constructed using less stringent standards. Other considerations for determining acceptable options include: maximum manure volume to be stored in any single manure storage structure, site history and management, planned contingency efforts, and specific properties of the soils.

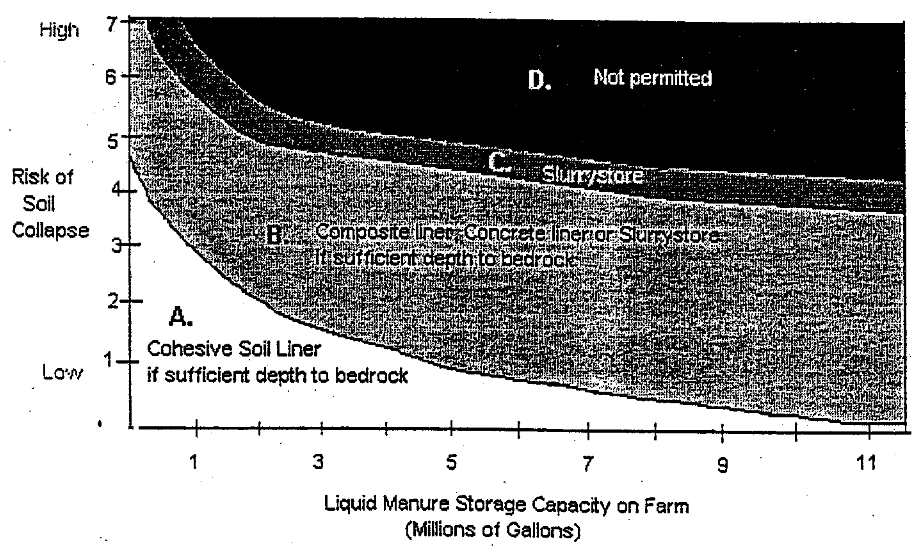
Figure 2. General guidelines for manure storage system options in different soil collapse risk zones. The soil collapse risk factor 0 to 7 in the figure is associated with the soil collapse risk factor described on pages 10 and 11. The Design capacity considers the combined storage capacity of all manure storage structures at the feedlot and manure storage facility.

A. Cohesive soil liner designed/constructed in accordance with MPCA standards can be used if the separation to bedrock restrictions are met.

B. Composite liner system or sealed concrete liner can be used if the minimum separation to bedrock is met. A composite liner system consists of a combination of compacted clay covered by an approvable geomembrane or geosynthetic liner. Sealed concrete-lined systems must include water stops or joint sealant materials at all construction joints, sealing of all cracks which may extend through the concrete, and a floor having a concrete thickness of not less than 5 inches, where the required area of steel reinforcing in the floor is based on subgrade drag theory in American Concrete Institute, Slabs on Grade, ACI-360.

C. Above ground storage (e.g. slurrystore)

D. Solid manure handling recommended. Liquid storage not permitted unless a more extensive geologic investigation indicates that the site is safe for construction of a liquid manure storage system.



Another design goal to reduce soil collapse risks is to minimize the amount of rainfall and roof runoff water infiltrating soils in the area of the storage system. This can be accomplished by sloping soils away from the manure storage system, and routing all barn-roof runoff and perimeter tile waters to a discharge point as far as possible from the manure storage system. The discharge point should be onto a sloped runoff channel or to some other area where ponding of water will not occur.

DEVELOPING AN INSPECTION PLAN FOR CONSTRUCTION ACTIVITIES.

A subsoil inspection is required when constructing manure storage systems (over 250,000 gallons) in areas suitable for sinkhole formation. This inspection is in addition to other construction inspections required for all regions of the state. A subsoil inspection is needed to provide greater assurance that the construction site is not in an area where soil collapse problems are imminent. The inspection must be conducted following removal of the soil B horizon to determine whether there is any indication of potential sinkhole development observed in the soil (piping, voids, channels, topsoil found at deeper depths or other indications of soil subsidence).

The subsoil inspection plan must include the following minimum elements:

- Who will conduct the inspection – a professional registered soil scientist or professional registered geologist experienced with karst is recommended;

- During what periods of construction the inspection will be conducted – recommended at least following removal of the soil B horizon;

If any indications of potential sinkhole development are observed, the permittee must notify the MPCA and the design engineer so that an evaluation can be made of whether the site must be abandoned or if alternative measures can be implemented to prevent future soil collapse.

POST CONSTRUCTION MANAGEMENT

Following the construction of the manure storage system, the permittee is responsible for on-going maintenance and operation in accordance with all specifications in the permit application. The storage system must be regularly inspected for liner damage, seepage problems or soil collapse. All damage must be immediately repaired. All seepage or soil collapse problems must be immediately reported to the Minnesota Pollution Control Agency. Report any spills or discharge incidents immediately to the duty officer at 1-800-422-0798.

Where manure is to be pumped from the manure storage system to be applied onto cropland, the requirements in proposed 7020.2225 must be met. These requirements include limits on maximum rate of application, precautionary measures when applying near waters or waterways, development of a comprehensive manure management plan, record keeping and plans for soil and manure testing. Proposed manure application rules specific to the karst region include:

- Manure must not be applied within 50 feet of a sinkhole. Manure must be immediately incorporated to land sloping toward a sinkhole and that is within 300 feet of the sinkhole. Exceptions are made where diversions prevent manure-contaminated runoff from entering the sinkhole.

- All manure management plans for feedlots or manure storage areas with a capacity of 300 or more animal units must include a description of measures to protect ground water when applying manure to soils with less than three feet above limestone bedrock.

FOR FURTHER INFORMATION

For further information about the use of these guidelines or other questions about feedlot and manure storage system construction in the karst region, please call the feedlot helpline at 1-877-333-3508.

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Evaluation of subsidence or collapse potential due to subsurface cavities

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ABSTRACT

Though the methodology to provide accurate location and assessment of subsurface cavities exists, the knowledge to properly implement the appropriate methodologies is fragmented.

Three key methods that may be used in subsurface investigations are:

- Direct sampling methods such as drilling and observation
- Indirect methods such as remote sensing and geophysics
- Statistical methods

It is critical to recognize that limited direct sampling (e.g., borings) will affect the accuracy of a site investigation. It is also important to understand how the indirect and statistical methods may be employed to improve the accuracy of an investigation by providing additional data in a cost effective manner. Methodology selection is dependent upon the area of investigation, the size, depth, and stability of the cavity system being investigated.

The above concepts and methods need to be incorporated into an integrated systems approach along with a working knowledge of geology, hydrology, geomorphology, geostatistics, geochemistry, soil mechanics, and rock mechanics as they apply to karst problems.

Selecting the appropriate methodology to accomplish these goals depends to a high degree on site-specific conditions. By selecting the most suitable methods and utilizing the synergistic benefits of an integrated systems approach, high levels of technical accuracy and cost effectiveness can be achieved.

Background

Subsidence or collapse due to the presence of subsurface cavities is a common problem in many areas of the continental United States. W.E. Davies of the United States Geological Survey estimates that 15% of the United States is composed of limestone or other soluble rock at the surface, and that 50 to 75% of the continental United States may be susceptible to solution and subsidence problems if deep, soluble rocks and pseudo-karst effects are included.

Subsurface cavities range in size from the small pore spaces between soil or rock particles to large, cavernous rooms within solid rock. Small cavities or pore spaces are important in that they can contribute to subsidence similar to that found in California's San Joaquin Valley. There, up to 8 meters of subsidence has occurred as a result of water withdrawal for irrigation purposes. Small cavities in rock with a characteristic diameter of approximately one meter often occur in abundance. Uncovered, this rock resembles swiss cheese. Large cavities of up to 100 meters or more in diameter can also occur. The ultimate collapse of these large cavities is responsible for many of the sinkhole lakes found throughout the State of Florida (see Figure 1).

Most large cavity systems can be described in terms of regular shapes such as vertical or horizontal planes associated with fractures or bedding planes, vertical or horizontal cylindrical conduits, and large rooms of approximately spherical shape. These cavities are the result of long term solution of the cavity walls at a rate of a few centimeters per 1000 years. Although small cavities can contribute to serious problems, only large cavities will be considered in this paper to simplify the discussion. The same philosophy of investigation and methodology can be scaled down to address any size cavity, even the pore space between soil.

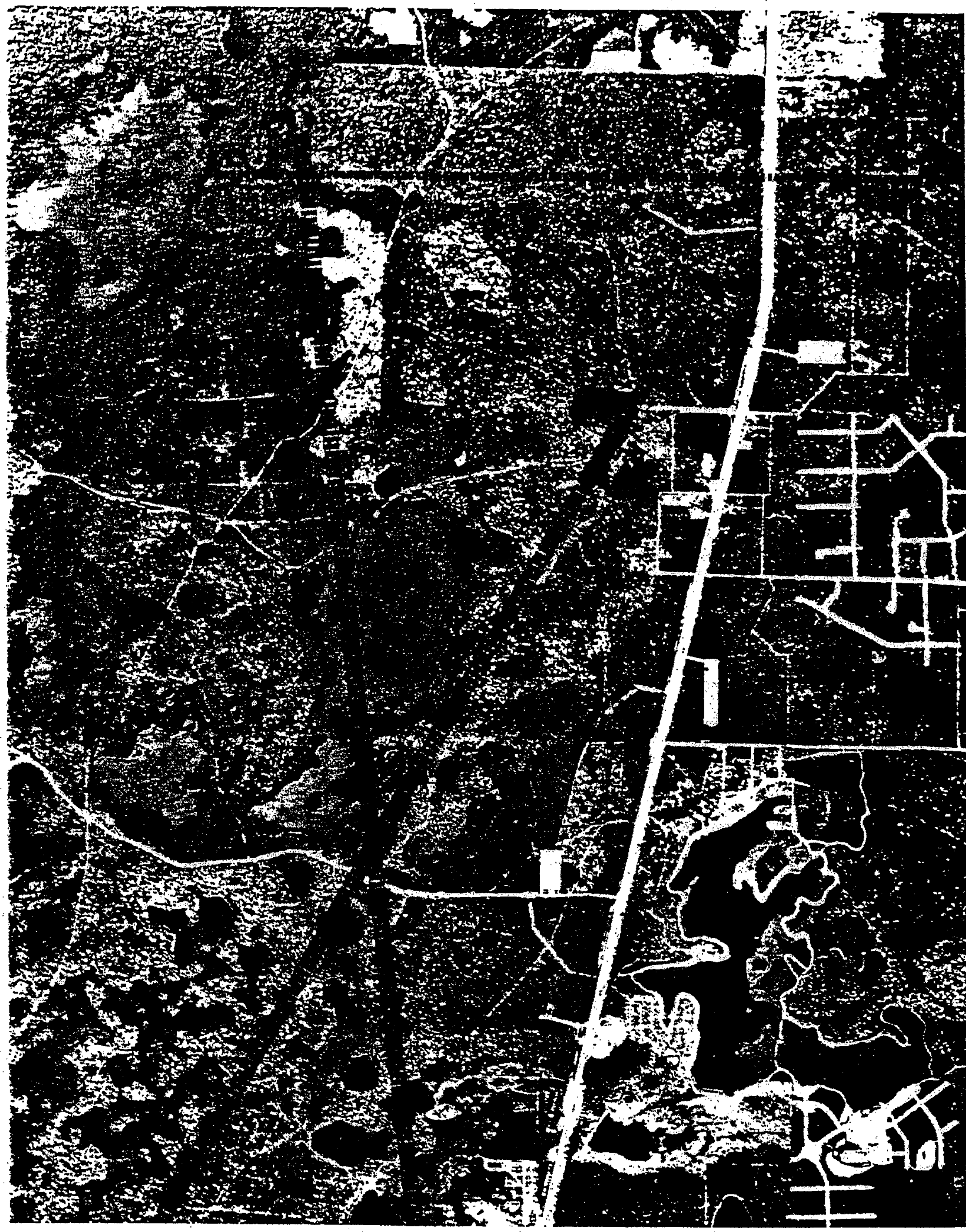


Figure 1: Aerial photo from the west coast of Florida showing numerous sinkhole lakes. Dashed lines indicate linear trends formed by the sinkhole lakes. Large cavities of up to 100 meters in diameter are found in this area where major collapse has occurred.

Causes of Collapse and Triggering Mechanisms

The cause and effect relationships of subsidence and collapse due to the presence of large cavities within rock are numerous. As limestone is dissolved by slightly acidic ground water and eroded, voids form. When voids enlarge to the point that the overhead supporting structure fails, surface collapse occurs. Collapse of the overhead rock and soil is accelerated by loading which may result from the static weight of the overburden, man-caused changes to the environment, rainfall, or a combination of factors, all of which represent increased static and/or dynamic loads to the overhead structure. Although it is safe to say that long term geologic conditions such as the natural solution and erosion of bedrock set the stage for the occurrence of subsidence and collapse, variation in rainfall and man-caused changes to the environment over the short term are by far the most significant factors that impact man's construction.

Changes in surface water runoff and ground water levels as a result of variations in rainfall are major factors in developing and triggering collapse. A lack of rainfall, for instance, results in lowered ground water levels causing a loss of buoyancy that leads to general soil stress, and ultimately, collapse. An abundance of surface water from increased rainfall, on the other hand, can accelerate vertical seepage, increase piping activity, and trigger collapse.

The effects of man-caused changes on the natural environment are the most important factor in developing and triggering collapse. Two of the most common collapse-precipitating activities are the withdrawal of ground water for residential and industrial use and the concentration of surface runoff or change in surface runoff patterns resulting from the construction of major roads, paved parking lots, or airport runways. Though many variables contribute to the ultimate cause of collapse, a singular event usually acts as the final triggering mechanism.

The following data obtained from the Florida Department of Transportation summarizes the causes of collapse. The majority of these statistics represent roadway-related collapses. Included in the data are 96 cases of collapse recorded over a 5 year period.

Blasting	5%	Construction	11%
Drilling	5%	Other or Unknown	11%
Low Water Table	8%	Heavy Rainfall	58%

It is not surprising that the figures show the dominant cause of collapse to be associated with heavy rainfall since excess surface water is concentrated by roadway drainage. Although limited, other nonroadway-related data compiled in 1977 shows many of Florida's large collapses to be associated with low ground water levels occurring predominately during April and May -- the last two months of Florida's dry season.

The key point made from these data are that within the lifetime of a manmade structure, 100 years or less, the solution of rock and even the mechanical erosion of rock have little to do with the final cause of collapse; they merely set the stage for the event at some time in the future. Furthermore, the factors contributing to collapse are not necessarily singular. In most cases, they appear to be cummulative and from many different causes.

Surface subsidence or collapse generally manifests itself within a limited area over or near a ruptured cavity and may take the form of a single, centralized collapse or a large collapse with numerous satellite sinkholes and fractures around the perimeter. One example of a single, centralized collapse is the Winter Park Sinkhole in Orange County, Florida. Examples of a major collapse with numerous satellite sinkholes and fractures around the perimeter are the December Giant in Shelby County, Alabama and the collapse that occurred in Hernando County, Florida during a water management district's well drilling attempt.

One common misconception is that a cavity is a singular occurrence. In general, this is not true, and in particular, it is not generally true for large cavities. Each "cavity" is a member of a large system of enlarged fractures, bedding planes, vertical pipes, horizontal conduits, and large rooms similar to those observed in caves throughout the world. In Florida, most cave systems are water-filled. Treating a cavity as a single entity for assessment or remedial purposes can only result in errors that may have significant impact in the future. Understanding the numerous cause and effect relationships of subsidence and collapse as a result of subsurface cavities is important. It will certainly lead to better forecasts about the behavior of cavities and the impact that environmental and man-caused factors have on them.

Methodologies Available for the Evaluation of Subsurface Cavities

Many cavities cannot be analyzed using a single methodology such as aerial photography or surface observations. Narrow, vertical fractures, and small cavities, for instance, may be virtually impossible to detect through a normal drilling program. Features such as piping over large, deep cavities can also go undetected in a normal field investigation. Missing such features can result in serious construction problems and subsequent, catastrophic failures. The technology and methodology to completely define the existence of both large and small cavities at any depth does exist. Though drilling is the most commonly used investigation tool, other approaches are necessary. The remote sensing geophysical and in situ methods are listed below. In addition, there are other tools that may be employed such as geomorphology and statistics.

POSSIBLE METHODOLOGIES FOR CAVITY DETECTION AND EVALUATION

Airborne or Satellite Spatial Methods

- Black and White Photography
- Color Photography
- Infra-Red Photography
- Thermal Imagery
- Radar Imagery
- Satellite Imagery
- Multispectral Satellite Imagery

Surface Methods

- Thermal Imagery
- Seismic Techniques (Various)
- Resistivity (Various)
- Electromagnetics (EM)
- Ground Penetrating Radar (GPR)
- Micro Gravity
- Magnetics

Downhole Methods

- Camera/Television
- Acoustic Scanning (Sonar)
- Dyes/Tracers
- Conventional Logging Tools
- Seismic Techniques
- Electromagnetics
- Ground Penetrating Radar
- Gravity
- Magnetics
- Geochemical
- Nuclear

In Situ Sensors

- Piezometers
- Pressure Sensors
- Thermal Sensors
- Acoustic Emission Sensors
- Displacement Sensors
- Precision Leveling

In addition to defining the presence of cavities at any depth, cavity stability can be measured, and, to a reasonable degree, cavity behavior can be predicted. Though the tools to do both detection and evaluation exist, they are seldom applied because of:

- limited budgets
- not knowing that the methods exist
- lack of knowledge about the methods and how to apply them
- lack of a single person or firm with the expertise to utilize them

Numerous conferences and papers have attempted to address the problems associated with subsurface investigation, subsidence, and cavity detection (see Bibliography). Most of these documents focus on one methodology to solve a problem. Since each methodology has advantages and disadvantages, and since improperly utilized methodology does not produce positive results, it follows that any single method can fail under a given set of field circumstances. Therefore, reliance on a single approach usually results in failure. This paper, in contrast, focuses on a broad, systematic approach that incorporates a range of skills and technology, then selectively applies them to bring about an economical and technically optimum solution. Every investigation requires a tailored, site-specific systems approach that takes into consideration the available budget and the required level of accuracy. In keeping with these concepts, cavity detection and evaluation methodology can be broadly grouped into the following four categories:

1. Direct measurement methods such as drilling or direct observation
2. Indirect measurement methods such as aerial photography or geophysical methods
3. Statistical methods such as those used to characterize direction, size, and spacing of cavities
4. Use of an effective systems approach.

Direct Measurement Methods

Direct measurement methods reveal the presence of subsurface voids through direct contact with the cavity. For example, a loss of fluid or a drill stem drop during drilling constitute direct measurement of the presence of a cavity. Visual observation of a cavity using a borescope or television camera also constitute direct measurement. Direct cavity hits by drilling are unusual for most subsurface investigations because the number of borings must be limited in order to be cost effective and the probability of hitting a cavity is low.

The number of borings required to provide an acceptable probability level for cavity detection can be estimated. By dividing the area of the site by the estimated area of the smallest cavity the investigator wishes to detect a site to cavity ratio is established. Then, statistical tables can be used to determine the number of borings for a given level of confidence. A simple example is shown in Figure 2. The larger the site to cavity size ratio, the greater the number of borings necessary to provide an acceptable level of confidence for cavity assessment at a given site.

A 10:1 site to cavity ratio involves a rather large cavity. For example, a one-acre site with a 10:1 ratio implies that a cavity of about 23 meters in diameter exists. It is not unusual for ratios of 100:1, 1000:1, or greater to occur. On a one-acre site, a 100:1 ratio implies that a cavity of about 7 meters in diameter exists, and a 1000:1 ratio implies that a cavity of about 2.3 meters in diameter exists. Even a cavity 2.3 meters in diameter can be significant on a one-acre site. The following example using a one-acre site and a 90% detection probability level shows the number of borings necessary to provide an acceptable level of confidence from direct detection drilling programs.

ONE-ACRE SITE WITH A 90% DETECTION PROBABILITY LEVEL

Cavity size of 23 meters (As/At=10):	Requires approximately 10 borings
Cavity size of 7 meters (As/At=100):	Requires approximately 100 borings
Cavity size of 2.3 meters (As/At=1000):	Requires approximately 1000 borings

This example assumes that uniform grid spacing is used to locate borings. If drilling locations are randomly selected, the number of borings required increases significantly. Although the use of this procedure assures a given level of confidence for cavity detection, the boundaries of the anomaly must still be defined. Defining them requires additional drilling. Furthermore, if the smallest cavity size estimated is too large, significant error will be induced into the program.

It is obvious, therefore, that the achievement of an adequate evaluation of complex subsurface conditions by borings alone is not generally practical. Neither is it cost effective. To provide such an evaluation would necessitate the installation of an excessive number of borings. While critical projects such as dams, tunnels, and nuclear plants may justify high density drilling and subsequent grouting, most investigations do not.

Based on the example given, it should be clear that most subsurface investigations do not begin to approach 100% accuracy. In fact, many investigations are probably less than 10 to 20% accurate. Yet, many professionals and their clients continue to think of subsurface investigations in terms of high accuracy. It is obvious that alternatives to direct measurement methods must be used if realistic cavity investigation programs are to be implemented.

Indirect Methods

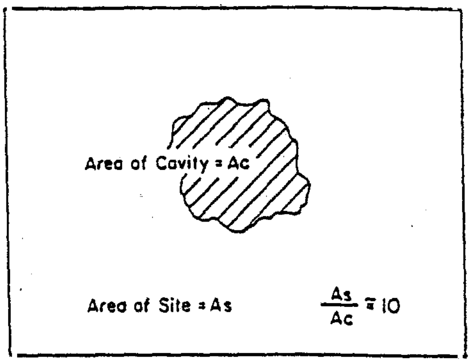
A drill stem drop during drilling indicates the presence of a cavity even though it has not been seen. A downhole television camera gives visual proof of a cavity's presence even though it may not be touched. Although these methods of direct measurement provide a high level of confidence in the subsurface information obtained, the information is localized and must be interpolated between sample points or extrapolated beyond them. At the sample points, a high level of confidence exists. Beyond each sample point, guesses must be made.

In order to fill in the low levels of confidence between sample points, various indirect measurement methods can be employed such as remote sensing or geophysical techniques. Where a drill stem drop allows a cavity to be detected and a downhole television camera allows it to be seen, indirect methods measure the physical, chemical, or electric anomalies associated with the cavity or the disturbed zone surrounding the cavity.

Using this approach, continuity between direct sample points can be provided to eliminate or at least minimize errors associated with interpolating and extrapolating information from direct sampling points. Better yet, boring locations can be selected based upon prior knowledge, thereby increasing the validity of data from a given number of borings. Just as a surgeon uses X-rays and CAT scans to locate a tumor before surgery, indirect methods can be used to indicate the presence of a cavity before a direct drilling program begins.

A large number of indirect measurement methods can be used to evaluate the presence of a cavity. Figure 3 shows the general application of indirect methods. The first two methods

A)



B)

Probability of Detection	As/Ac = 10	As/Ac = 100	As/Ac = 1000
100	16	160	1600
98	13	130	1300
90	10	100	1000
75	8	80	800
50	5	50	500
40	4	40	400
30	3	30	300

Figure 2: Figure A shows a site to cavity area ratio of approximately 10. Table B shows various site to cavity ratios and the probability of detecting a cavity with a given number of borings.

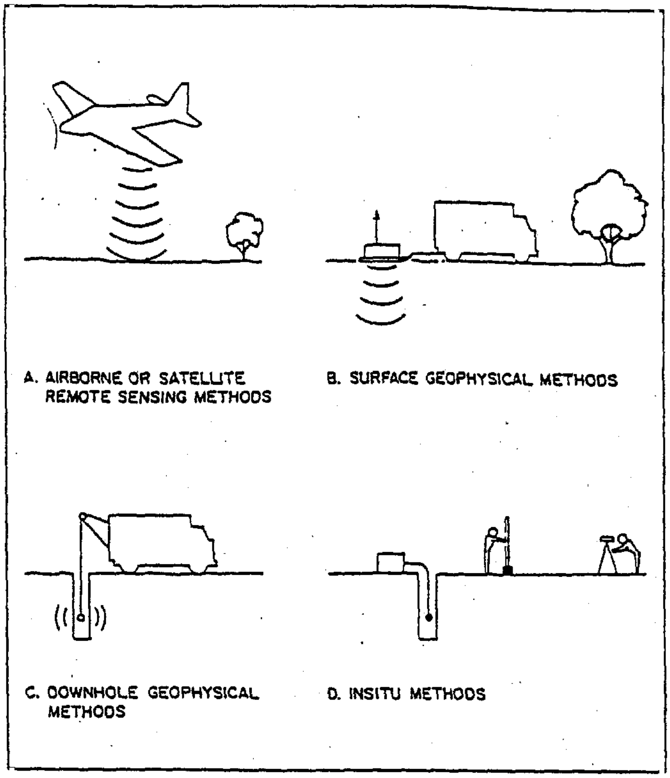


Figure 3: Four indirect methodologies for detection and evaluation of subsurface cavities.

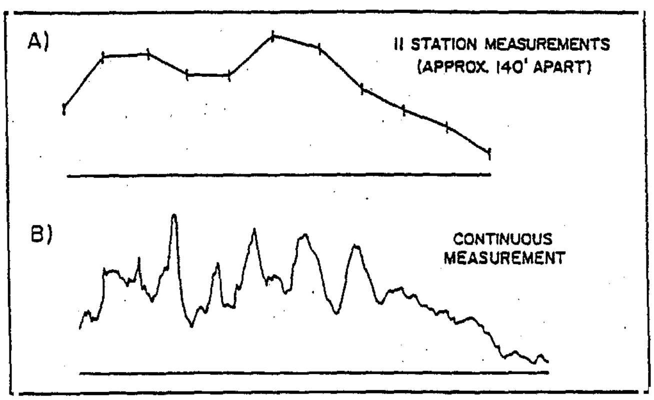


Figure 4: Comparison of station and continuous electromagnetic conductivity measurements along the same traverse. Continuous data shows fractures in rock based upon moisture content.

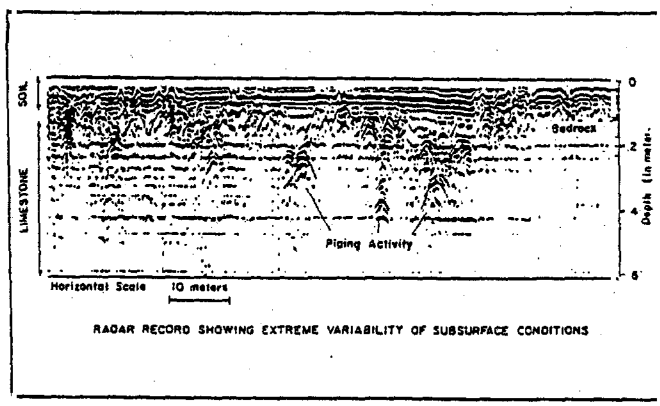


Figure 5: Ground penetrating radar record showing piping. This example illustrates the use of near surface indicators to locate and evaluate the activity of deep cavities. In this case, shallow piping activity indicates the presence of a major cavity system at a depth of 30 to 45 meters.

illustrated in Figure 3 are the airborne and surface geophysical methods. They provide the benefits of in situ, nondestructive measurements.

Airborne remote sensing is beneficial in terms of spatial coverage per unit time and cost; however, subsurface data can only be obtained through interpretation (see Figure 1). Surface geophysical methods, on the other hand, yield less spatial coverage per unit time and cost than airborne methods, but they significantly improve depth resolution while they provide subsurface information. A three-dimensional subsurface picture can often be generated using special measurement and imagery techniques. Surface geophysical methods are quite cost effective for shallow investigations, but resolution and the ability to define details decreases with increasing depth.

Downhole measurement methods also improve the resolution of local details. Furthermore, resolution does not decrease with depth as it does with surface geophysical methods. The volume of soil or rock sampled by downhole methods is usually much less than that attained by surface geophysical methods; however, it is much more than that achieved by drilling alone. The major benefit of downhole measurement methods is that detailed, continuous information may be acquired at significant depths. The cost per unit area of coverage is high, but existing boreholes can often be used to reduce the cost.

In situ sensors are another indirect measurement method. They can be implanted at a site and sampled periodically to detect changes in subsurface conditions. Sampling with in situ sensors can be done manually or electronically depending on the specific method employed. Generally, airborne, surface, and downhole methods provide a number of measurements at one point in time. These measurements are known as spatial measurements. In situ measurements provide a number of measurements in one place over a period of time. These measurements are known as temporal measurements. Though airborne, surface, and downhole measurements can be repeated periodically to yield a series of quasi-temporal measurements, and in situ measurements can be made at a number of locations to provide quasi-spatial measurements, there are limits to the compromises that can be made.

Continuous Surface Geophysical Techniques:

Two contemporary geophysical measurement techniques known as ground penetrating radar (GPR) and electromagnetic conductivity (EM) provide unique cavity detection capabilities in that they provide a means to obtain continuous subsurface information at rapid traverse speeds. For these reasons, they are effective for both reconnaissance and detailed site investigations.

The benefits of continuous subsurface sampling can be seen by comparing the two sets of data in Figure 4 which were taken from a dam site leakage investigation. The upper set of data in Figure 4 is comprised of discrete measurements taken at 11 points along a traverse line. These points are joined by a line to produce a data profile. The lower set of data is the result of continuous measurements taken along the same traverse line. Comparing the two data sets, it is obvious that continuous measurements are the most effective for sampling complex subsurface site conditions because they provide more detail. The peaks in the electromagnetic conductivity data shown in Figure 4B indicate the presence of fractures within the underlying rock. The benefits of rapid traverse speeds are lower cost and more detailed site coverage. In many cases, 100% site coverage can be economically obtained. Most detailed surveys are run at slow speeds of about 3 kilometers per hour, however, high speeds for less detailed, reconnaissance surveys are possible.

GPR is a reflection technique using high frequency electromagnetic radiation. GPR surveys produce graphic profiles of subsurface conditions that resemble the side walls of trench cuts. Figure 5 shows the radar record of a thin veneer of soil over limestone. Considerable piping can be seen in the data indicating the presence of a deep, active cavity. The reflections shown on the radar record are produced as a result of contrasts in the complex dielectric constant of individual, subsurface materials. This method provides the highest resolution of all surface geophysical methods. Depths of one to fifteen meters or more may be obtained; however, the depth of penetration is quite site-specific and depends upon soil conditions. In some cases, penetration depth is limited to 1 meter or less.

The EM conductivity technique permits rapid measurements of the bulk electrical conductivity of the subsurface to be made. EM conductivity values are a function of the site's porosity, permeability, saturation, natural subsurface materials, and the specific conductance of pore fluids. This measurement is similar to that made by the more familiar resistivity method, but is accomplished without ground/electrode contact. The EM method permits high lateral resolution profiling measurements to be made which are particularly effective for locating lateral anomalous conditions. Figure 6 shows the data resulting from an EM survey over fractured limestone. The high EM conductivity values indicate a fracture

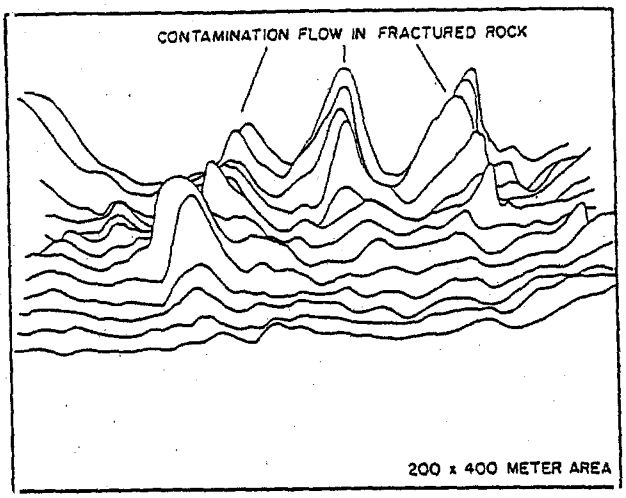


Figure 6: Parallel electromagnetic conductivity profiles showing migration of salt water in fractured limestone.

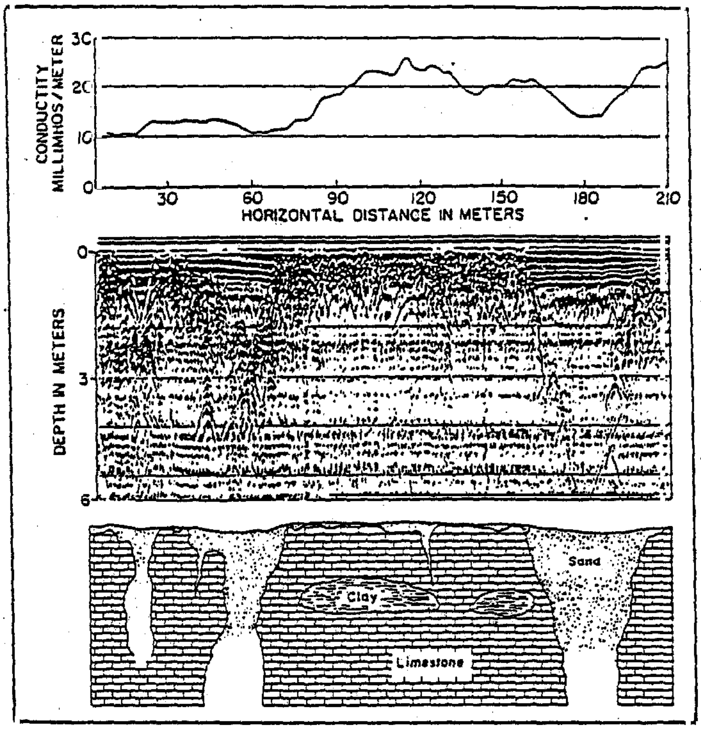


Figure 7: Electromagnetic conductivity (top) and ground penetrating radar (middle) profiles over karst terrain with a geologic cross section (bottom). Note the correlation between electromagnetic conductivity and ground penetrating radar data where paleo karst features occur.

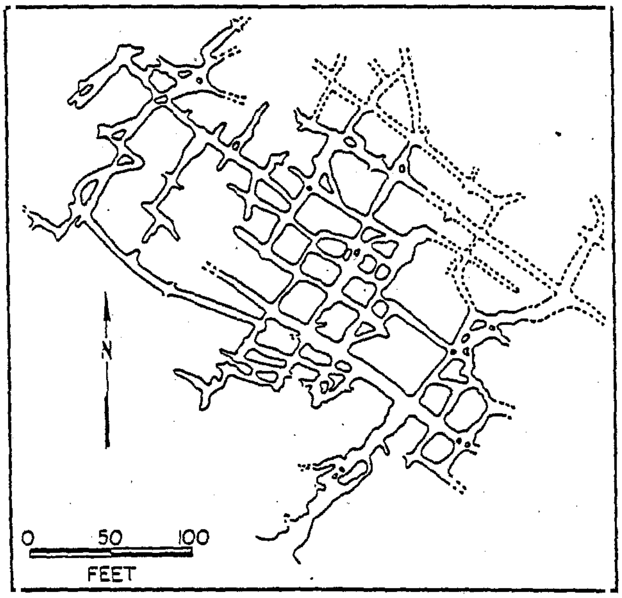


Figure 8: Plan view of cave system (W.E. Davies). Note the repeatable pattern that lends itself to statistical analysis.

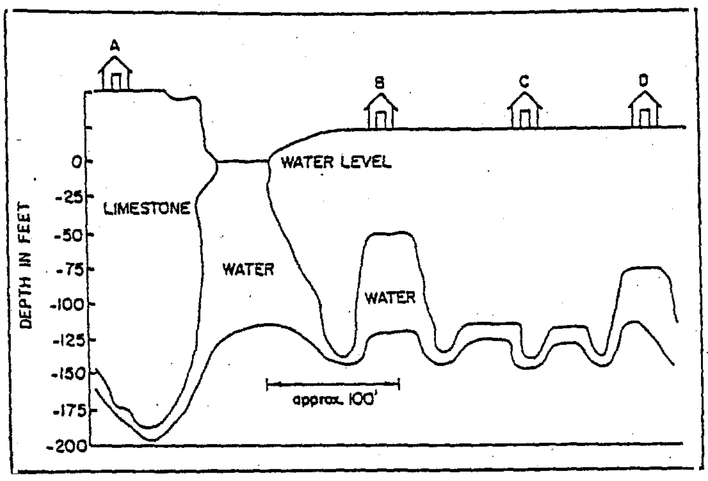


Figure 9: Schematic cross section of sinkhole cave system mapped by cave divers. Note the periodicity associated with cavity growth. Risk to structures built at points A and C may be low; however, structures built at points B and D have a distinctly higher risk of damage.

zone. The linear trends observed in the data are related to fluids moving within the fracture system. Locating these vertical fractures by drilling would be economically prohibitive.

While GPR and continuous EM conductivity techniques are typically limited to depths of 15 meters or less, considerable insight into problems occurring at deeper levels can be acquired through the use of near surface indicators.

Using Near Surface Indicators:

Long before subsidence or collapse occur, indicators at or near the surface generally appear. In other words, deep-seated cavities and fractures often show signs of their presence in the near surface before actual collapse occurs. For example, lineaments are commonly identified on aerial photos as evidence of deep-seated fractures or cavity systems (see Figure 1). Often, these fractures manifest themselves at the surface in subtle ways, such as by disturbed vegetation patterns. In such cases, the fracture or cavity is not observed directly, but its presence is implied by observing vegetation patterns -- a near surface indicator (NSI). Local piping of soil due to downward flow of surface water into fractures or cavities can often be detected by means of surface geophysical methods and the use of NSI. Identification of NSI provides a rapid and cost-effective means of locating deep cavities. In many cases, the use of NSI has been found extremely effective when used in conjunction with continuous sampling surface geophysical methods.

Synergism:

A synergistic increase in the certainty of interpretation occurs when many methods are combined into a systems approach. For example, geophysical methods such as GPR and EM conductivity may be combined to yield synergistic results. The EM conductivity values in Figure 7 are high over limestone due to interbedded clays and clay-filled pockets. Over paleosinks (old sinkhole collapses filled by the natural deposition of sands) filled with quartz sand, EM conductivity values are substantially lower. GPR data, located in the middle of Figure 7, shows a continuous cross section of the site to a depth of approximately 6 meters. A distinctive paleosink can be seen to the right side of the radar data. This sink is greater than 30 meters across. Smaller paleosinks and piping activity can be seen to the left. The combined results of the EM conductivity and GPR geophysical surveys using NSI and geologic knowledge about the local area were used to draw the interpretative section shown on the bottom of Figure 7. These data were used to accurately locate drilling locations. Consequently, "smart holes" were drilled instead of proceeding with a blind drilling program. Three borings along the 200-meter traverse confirmed the major collapse and active piping zones with a certainty well above 80%.

Statistical Methods

The approach for evaluating large areas is different in that they simply cannot be investigated at the same level of detail as localized areas. Other approaches, therefore, must be used. Assessing regional problems to maintain reasonable levels of accuracy in an investigation or mapping program depends heavily upon the integration of information from many sources to provide an overview of conditions that can be thought of as a statistical data base. For example, a lineament map can be developed from regional aerial photography (see Figure 1) or satellite imagery and used to characterize the extent and direction of fractures or karst activity in the region as well as to illustrate trends through a specific area of interest. Using regional data such as geologic and hydrologic information, aerial photo interpretation, and records of recent collapse, regional probability maps can be generated to show areas susceptible to collapse.

A few kilometers of continuous geophysical data obtained along easily accessible roads and fields can also provide a valuable statistical base from which to work. Based upon the presence, absence, or number of NSI encountered, a reasonable statistical assessment can be made. In addition, potential problem areas can also be identified for subsequent, detailed studies.

Cave explorers are an important source of critical information that can be used to evaluate local trends. The cave map in Figure 8 shows the orderly periodic nature of fractures and subsequent solution of limestone. This information is invaluable for planning a site investigation or predicting potential problems. The profile of a water-filled cave in Figure 9, mapped by cave divers, shows the potential of sinkhole collapse as roof sections spall and grow toward the surface, eventually resulting in failure. Here, the periodicity of the potential sinkhole collapse areas are clearly illustrated. Both the map and profile examples provide significant statistical information that can be used to evaluate the presence of a cavity system and the potential for local subsidence, piping, or collapse.

The presence of existing cavities is often confused with the activity of subsidence or

APPROACH \ SITE AREA	LOCAL (.1 sq.mi.)	INTERMEDIATE (1 sq. mi.)	REGIONAL (10 sq.mi. or more)
DIRECT MEASUREMENT	Primary	Secondary	Secondary
INDIRECT MEASUREMENT	Primary	Primary	Secondary
STATISTICAL MEASUREMENT	Primary (limited)	Primary	Primary

Figure 10: Applicability of direct, indirect, and statistical approaches to cavity investigations versus the scale of investigation. "Primary" indicates the cost-effective approach. "Secondary" indicates a support approach. Note: Areas are provided for relative comparison only.

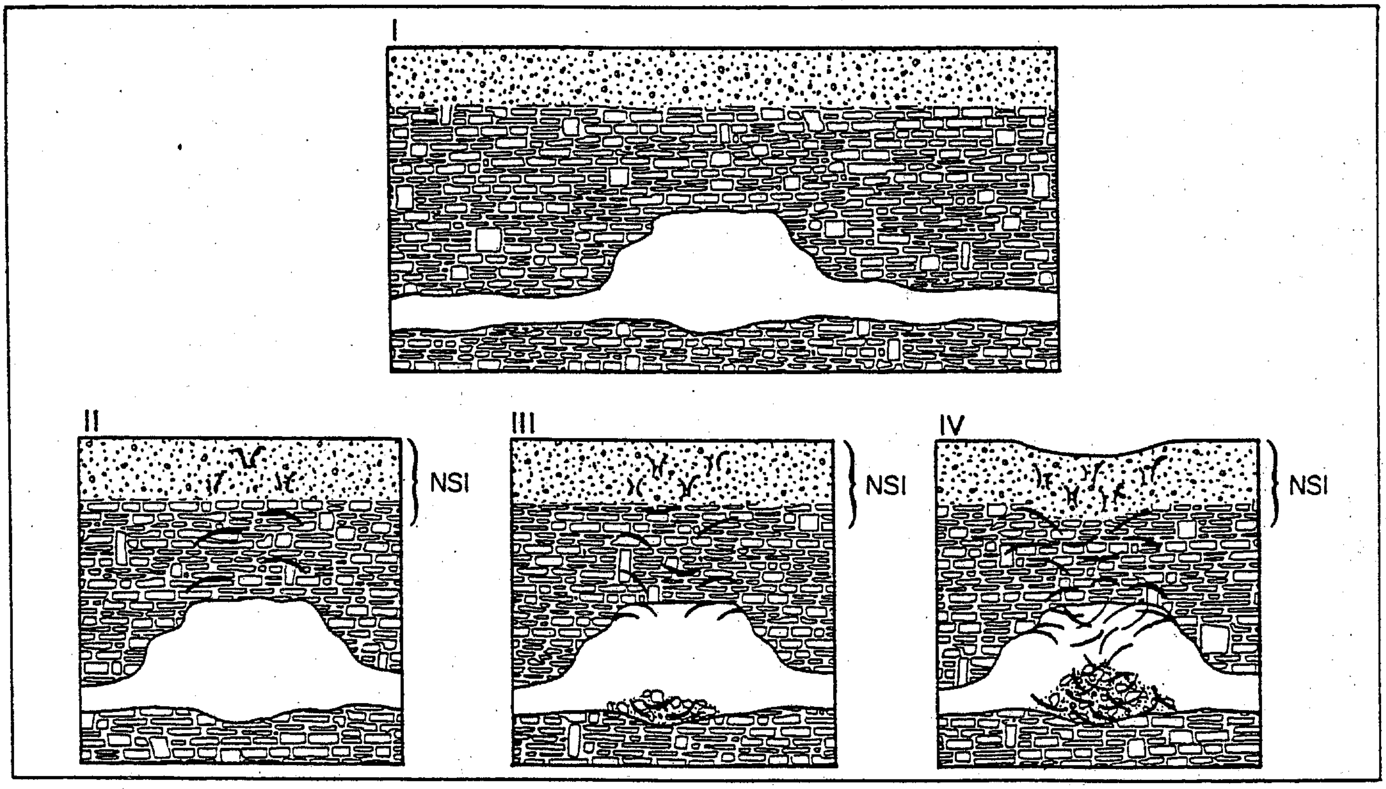


Figure 11: Characterization of cavity system stability. I - Totally stable cavity system and overburden. II - Stable cavity system with some overburden instability. III - Moderate cavity system and overburden instability. IV - Considerable cavity system instability resulting in gross overburden instability and small surface displacement. Note the presence of near surface indicators (NSI) in Stages II, III, and IV.

collapse. For example, Central Florida is clearly an area of active subsidence, whereas South Florida has very little active subsidence. The lack of active subsidence in South Florida does not imply that cavities do not exist, however. In fact, they do. Even though surface subsidence would be rare in South Florida due to the high water table, cavities exist and still present a problem for major structure construction or deep well injection.

An Effective Systems Approach

A wide scope of techniques are available for subsurface cavity detection and assessment. Yet, many practitioners continue to investigate for subsurface cavities with a limited number of borings.

Because no single method or approach can solve every problem, it is imperative that the practitioner understand the problem, the tools available, and how to produce the desired results. All methods have advantages and disadvantages; they all produce useful results when they are properly applied and fail when they are improperly applied. The selection of methods and the approach used should only be made by persons thoroughly familiar with the problems associated with cavity detection as well as the tools at his disposal. In addition to the methods available, the practitioner's professional training and years of in-field survey experience are essential to produce meaningful results. Tools are not an end-all answer, they are merely an aid to the experienced professional.

A number of key factors must be considered in order to construct an optimal systems approach. Four key factors are presented here. They are:

1. The area to be investigated
2. The size of the cavity
3. The stability of the cavity
4. The site perspective

The approach to be implemented is dependent upon the relative scale of the site investigation. Figure 10 illustrates how direct and indirect sampling methods, together with statistical approaches, can be used most effectively taking into consideration the size of the area being investigated. Drilling, for example, is a primary method employed for localized site investigations; however, as the area investigated increases, the sample density decreases, due to the cost and time involved, and accuracy is sacrificed. At that point, drilling becomes a secondary tool and the use of indirect and statistical methods must be employed to maintain an acceptable level of accuracy. Indirect sampling methods can be cost effectively applied to both small and intermediate-sized areas to fill in the information gaps between direct sample points. Here, the indirect methods become a primary tool. Over very large areas, they can only be applied on a statistical sampling basis and become of secondary importance. Various statistical approaches can be used effectively for regional and intermediate-sized investigations. While most statistical approaches may not yield site-specific results, there are a limited number of cases in which statistical data can be used effectively in site-specific local surveys.

Cavity size clearly impacts the approach as well. Assuming that all other factors and conditions are properly met and that the survey is well-designed, most measurement methods must still pass over or reasonably near the cavity in order to get a response. It is much like locating an object in the dark with a flashlight -- the light must shine on the object before it can be seen. The cavity must also be big enough to be seen. For example, a cavity 1 meter in diameter located at a depth of 100 meters cannot be detected from the surface. However, a cavity with a 10-meter diameter located at a depth of 10 meters can be detected from the surface. The size to depth ratio must be large enough and other system noise sufficiently low to permit detection. If the minimum size of the cavity of interest can be defined and the maximum depth of interest can be estimated, the optimum approach can be selected. If it cannot, it will at least be obvious where a given approach is deficient.

The stability of a cavity plays an important role in choosing an approach. Figure 11 shows four stages of cavity stability. They are summarized as follows:

Stage I: Those in which the cavity and the overburden are totally stable
Stage II: Those where some instability in the overburden has occurred
Stage III: Those with moderate instability in the cavity and overburden
Stage IV: Those with significant instability in the cavity and the overburden, yielding displacement and small surface subsidence.

<u>Stage I</u>: Stage I cavities are the most difficult to detect. Detection is primarily dependent upon the ability of the method to directly detect the cavity's presence since no NSI exist. The lack of piping in these types of cavities indicates a level of stability; therefore, they may not present a short term problem.

Although stage I cavities usually cannot be detected by airborne methods, surface geophysical methods have and can be used successfully to detect them. Generally, surface geophysical methods are dependent on the depth and relative size of the cavity. Typically, ratios less than 10, and as small as 1 may be required for reliable cavity detection. Statistical methods can also be applied to Stage I cavities to characterize the area and may sometimes be used to support local site investigations.

Stages II and III: Stages II and III cavities are more readily detected than Stage I cavities because of subtle changes that occur in the shallow overburden. By observing these changes, indirect detection of deep cavities is often possible. Both airborne and surface geophysical methods become quite effective for detecting and assessing these types of cavity conditions due to the presence of NSI. The NSI may include such manifestations as vegetation stress, temperature differentials, soil piping, and electrical properties of soil. Instability associated with these cavity types indicate that they are a potential hazard over the short term. Furthermore, construction activity over or near a Stage II or III site can trigger collapse.

Since NSI are shallow, these anomalies are more readily detected by airborne and surface geophysical methods. When airborne methods can be used, they are highly cost effective, particularly over large areas. Surface geophysical methods have a clear cost advantage and provide an improvement in resolution for site-specific investigations. Statistical methods can also be applied to Stage II and III cavities to characterize the area and may sometimes be used to support local site investigations.

Stage IV: Although surface subsidence is already underway in Stage IV cavities, it may go undetected by the naked eye due to little displacement and slow rates of occurrence. The instability associated with these types of cavities indicate that they are clearly a potential hazard over the short term. Furthermore, nearby construction or drilling can easily trigger collapse.

Stage IV cavities are even more readily detected using airborne and surface geophysical methods to detect NSI. As more subsidence and cracks occur in the near surface, indirect sensing methods are more easily applied because increased activity tends to emphasize the parameter or parameters being monitored.

When airborne methods can be used they are highly cost effective, particularly over large areas. Surface geophysical methods have a clear cost advantage and provide an improvement in resolution for site-specific investigations. Statistical methods can also be applied to Stage IV cavities to characterize the area and may sometimes be used to support local site investigations.

The Need for a Perspective:

Localized field investigations generally focus on the immediate area of concern and ignore the regional setting. Omitting the regional perspective as it relates to the local site can result in critical gaps in understanding the site. While the specific site of interest may only be one acre in size, knowledge of the regional setting is still important because the regional setting reveals information about geomorphology. For example, regional fracture trends may be observed in aerial photos and may extend to the local site, whereas knowledge of only the local site might not provide adequate insight into these trends. Information from a localized drilling program provide considerable detail, but they must be put into perspective by considering the regional setting. On the other hand, interpreting aerial photos on a regional basis without detailed results of local drilling to support a cause/effect interpretation can also be misleading.

Risk Assessment:

A risk assessment can be made for any site. The important question to ask is how site-specific and how accurate need the risk assessment be? A fairly accurate regional collapse probability map can be generated by considering geologic and hydrologic data as well as past level of activity. Such an assessment, however, is not applicable to site-specific problems within the region.

A reliable local approach would be to evaluate the presence of NSI at and around the site. NSI can be obtained from reconnaissance data using aerial methods or surface geophysical methods. An even more reliable approach would be based on a site-specific drilling program designed as a result of previous regional and geophysical knowledge obtained from the site.

It is important to recognize the inherent limitations of any investigation and balance them against realistic project objectives and constraints. Smaller sites of one acre can be assessed to high levels of confidence with total coverage in a reasonable time and economic framework. Larger sites must utilize geomorphology and statistical data to minimize the guessing involved in cavity detection. Total coverage is unrealistic over large areas due to time and cost restrictions. Something less than 100% coverage, therefore, must be acceptable, yet the confidence level must be maintained as high as possible. High levels of confidence with limited coverage can only be accomplished through considerable insight gained from experience.

Here, statistics, geology, geomorphology, and geometric patterns and trends become of great importance. If patterns can be established with some level of confidence, the location of high-probability hazard areas can be predicted. For example, Figure 9 shows that construction may be reasonably safe at points A and C with only a limited site investigation, but not at points B and D. Points B and D require a detailed site-specific stability analysis because they are in a high-risk area. Having established the location of the high and low-risk areas through the qualitative data of Figure 9, the site's construction suitability can be evaluated. More detailed investigations can be carried out until an acceptable level of confidence is achieved. Such an approach allows problem areas to be defined without 100% surface coverage. In many cases, effective detection of cavities or delineation of problem zones and site assessment stability can be accomplished with high levels of confidence at minimal cost before problems occur.

Four Levels of Site Investigation:
A site can be evaluated in various detail to yield different levels of data accuracy and assessment confidence. Each level of evaluation improves upon the previous information, coverage, and level of confidence. Many times only a preliminary, first order approximation is needed to determine whether a project is in a highly sensitive area or an area that is relatively safe. On the other hand, a project may require detailed information necessitating a much higher level of confidence; hence, a second, third, or fourth level of assessment. Unfortunately, the problem is all too often glossed over or ignored, and a first level assessment is sometimes all that is done.

Four levels of site investigation can be applied to cavity detection methods. They are:

1. Review of Existing Data: Aerial photos, geologic maps, general geologic/hydrologic literature, and any specific statistics or data that are readily available should be reviewed and analyzed to provide preliminary information on a site. The results of such assessments are only preliminary, however, and must be used with caution.

2. Site Visit: Site visits include a geologic and environmental visual inspection. Interviews with local land owners, drillers, contractors, quarry operators, county agents, and state and federal personnel can provide numerous unpublished details.

3. On-Site Reconnaissance Measurements: On-site reconnaissannce measurements may include aerial techniques or surface geophysics. If no drilling data is available from the local site, selected borings or "smart holes" whose locations are based upon previous reconnaissance work should be included. The methods selected should be effective reconnaissance tools and should be used as such.

4. Detailed Site Assessment: A detailed site assessment can be used to prove the existence of cavities in areas thought to be high risk or to prove the nonexistence of cavities in areas assigned as low risk. On small sites, the entire site may be examined by detailed methods to provide coverage approaching 100%. On larger sites, however, statistics and geomorphology must be used to locate areas of high and low risk. Sufficient measurements must be taken to achieve the selected level of program confidence.

The various levels of site investigation must be interactive, for, as local data is obtained, greater insight and resolution of details about the site is gained. After information is gained from Level III, it may be advisable to return to Level I and review any new possibilities. It is essential to have a flexible program with in-field analysis and feedback to optimize field activity throughout the overall program. Although remedial action and monitoring may follow a detailed site investigation, they are not included as part of this discussion.

The level of site assessment undertaken should be a function of:

- The known susceptibility of the site to subsidence
- The critical nature of construction
- The level of probability or confidence desired by the investigation
- The overall project economics

A complete systems approach should include all of the following:

1. The statistical spatial sampling requirements for an effective drilling and remote sensing program
2. The need for regional and local perspective
3. The use of indirect sampling with contemporary methods
4. Understanding the benefits of continuous data and making use of both airborne and surface sensors wherever appropriate
5. The use of near surface indicators (NSI)
6. The benefits of a well-planned and executed direct sampling drilling program
7. Application of various statistical approaches that may be applied to regional and local problems
8. Application of various measurement methods depending upon the size of the area
9. Having a working knowledge of the principles of geology, hydrology, geomorphology, geostatistics, geochemistry, soil mechanics, and rock mechanics as they apply to karst problems
10. Understanding the cost versus accuracy tradeoffs of site investigations
11. A blending of experience and judgement
12. On-site presence of key professional project personnel

Summary

An accurate evaluation of subsidence or collapse potential due to subsurface cavities requires an accurate definition of the problem area. While the methodology to solve the problem already exists, knowledge of its use and thorough understanding of the problem is fragmented. Furthermore, most programs are restricted by cost and schedule limitations. One of the major problems of subsurface evaluation continues to be the errors developed through a lack of perception and adequate sampling. In many cases, a balance between high-density spatial sampling requirements and cost-effective drilling programs can be achieved by combining the contemporary and traditional approaches discussed in this paper.

It is important to remember that no single method or approach will solve all site investigation problems. Although the methods referred to in this paper are founded on solid scientific principles, they can fail if they are improperly implemented or applied to the wrong problem. The process of proper implementation requires trained, experienced personnel. By selecting the most suitable methods and utilizing the synergistic benefits of an integrated systems approach, high levels of accuracy and cost-effectiveness can be achieved and the project can be done right the first time.

The technical methods and systems approach discussed in this paper have been successfully applied to a number of site investigation problems including reconnaissance and detailed surveys for the location of cavities, fractures, and differential soil conditions. Location and evaluation of rock fracture, subsurface cavities, and collapse potential have been evaluated using a model based upon these general principles. Both the techniques and the model have been tested in a number of locations in and out of the continental United States for nearly two decades. They have been proven effective for providing improved confidence levels, accuracy, cost-effectiveness, and for predicting hazardous geologic and man-induced conditions.

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GUIDELINES FOR ASSESSMENT OF EARTHEN LAGOON COLLAPSE POTENTIAL*
Revised 8/15/94

* This form needs to be completed only if the site is located in carbonate rock terrane or where nearby underground mining is present. (Carbonate Rock Terrane - means "a sedimentary rock sequence, formation or group of formations which has a significant (greater than 50%) portion of the uppermost 20 feet of bedrock composed of limestone, dolomite, or calcareous sediments".) A site is ~~not~~ considered to be carbonate rock terrane if the lagoon bottom is underlain by 20 feet or more of surficial material (other than relict bedrock structure residuum or alluvium).

A. BACKGROUND INFORMATION. Fill in data from Wastewater Treatment Site Report or Addendum on top of form.

1. STREAM CLASSIFICATION. From information given on Line 15 of the Waste Water Treatment Site form indicate if the stream is gaining or losing adjacent to the site. If there is uncertainty as to the gaining or losing nature of the stream and the watershed is greater than 100 acres, complete the Stream Classification System form.

Gaining streams are assigned a risk factor of "zero" and losing streams are assigned a risk factor of "four" by choosing the appropriate integer.

2. DEPTH TO WATER TABLE. This should be the vertical distance from the ground surface to the top of the subsurface water which is in the zone of saturation.

An estimate of the depth to the water table can be developed by examining sample and/or drillers logs for which the driller has measured the depth to the standing water level (SWL) in the area of interest. The SWL can be measured from existing wells on or adjacent to the site. Investigators conducting exploration on the site may have measured the SWL.

Indicate if the water table is equal to or less than 50 feet below the surface by choosing "zero"; or if the water table is greater than 50 feet below the surface by choosing "four".

3. RESIDUUM THICKNESS. This category is intended to assign a risk factor to residuum that exhibits relict bedrock structure. (Relict Bedrock Structure - is defined as "discontinuous chert or interbedded sandstone that remain somewhat intact as carbonate bedrock is dissolved by solution-weathering, thus preserving the texture and depositional fabric of the parent bedrock".)

If there is no relict bedrock structure present in the residuum, the residuum containing relict bedrock structure is from 0 to 10 feet thick, there is no residuum, or the site is underlain by glacial drift, choose "zero".

If the residuum containing relict bedrock structure is 10 to 40 feet thick, greater than 100 feet thick, or from 40 to 100 feet thick; choose "two", "four", or "eight" respectively. Estimates of residuum thickness at the site can be developed from information in the well log files and exposures of the soil and residuum profile in the area. More accurate information is provided by drilling or test pits dug at the site of the proposed lagoon.

4. PREDOMINANT CHARACTERISTICS OF THE UPPER 20 FEET OF BEDROCK AND/OR SURFICIAL MATERIAL. Pick the most appropriate characteristic for the entire 20 foot sequence below the lagoon bottom.

Solution-free bedrock, glacial drift, and alluvium with gaining conditions should be assigned a "zero" risk factor. (Types of bedrock with low permeability and little or no solution activity by water include: 1) most igneous and metamorphic rocks; 2) cyclothemic deposits of shale, limestone, coal, underclay, siltstone, and sandstone; 3) blanket deposits of clay and fine- to medium-grained, well-cemented sandstones; and 4) sequences of interbedded shale and argillaceous limestone.) Twenty feet of glacial drift, and alluvial deposits with gaining conditions should also be assigned a "zero" risk factor.

Limestone and/or dolomite bedrock with a weathered zone that is confined to the upper 10 feet of strata or that contain minor solution features should be assigned a risk factor of "two". (Minor Solution Features - are defined to be "voids, up to one foot wide, and are caused by solution of bedrock along bedding planes, contacts between soluble and insoluble strata, joint planes, fracture planes, and fault planes".) Residuum associated with this type of bedrock should also be assigned a risk factor of "two". Permeable, sandstone should also be assigned a risk factor of "two".

Limestone and/or dolomite bedrock that contain significant solution voids below the upper 10 feet of strata should be assigned a risk factor of "eight". (Significant Solution Voids - are defined as "those one foot in diameter or larger".) Residuum with relict bedrock structure associated with this type of bedrock, and alluvium with losing conditions should also be assigned a risk factor of "eight".

5. THE PROXIMITY OF SINKHOLES TO THE LAGOON. (A Sinkhole - is a "depression in the land surface that communicates with a subterranean passage developed by solution and/or collapse into the underlying bedrock".) The proximity of a sinkhole is determined by measuring the distance from the outside toe or the

nearest cut of the proposed lagoon to the nearest feature of the sinkhole. In order to be counted, a sinkhole must be developed in the same or similar geohydrologic setting that is present at the site.

No sinkholes within one mile of the proposed lagoon rate a risk factor of "zero". One to five sinkholes within one mile rate a risk factor of "one". Six to ten sinkholes within one mile of the proposed lagoon rate a risk factor of "two". More than ten sinkholes within one mile, or one sinkhole within 1/4 mile of the proposed lagoon rate a risk factor of "four". More than five sinkholes within one half mile, or one sinkhole within 500 feet of the proposed lagoon rate a risk factor of "eight".

6. PROXIMITY OF UNDERGROUND OPENINGS TO THE LAGOON. (Underground Openings - are "natural voids or man-made excavations under the surface of the earth that are large enough to permit human access and include caves, underground mines, and evidence of catastrophic collapse.") Count only the underground openings that are present in the same or lower stratigraphic units which are present at the site. Use cave and mine maps from DGLS files or use your own observations or the observations of other DGLS personnel. If interested parties supply information concerning underground openings, record the name of the person and the information given at the bottom of the form under Remarks. Detailed analyses may be presented by the applicant which may negate this factor. Remarks must discuss these analyses.

No evidence of underground openings within one half mile of the proposed lagoon rate a risk factor of "zero". Underground openings within one half mile of the proposed lagoon rate a risk factor of "two". Underground openings within 1/4 mile of the proposed lagoon rate a risk factor of "four". Underground openings within 500 feet of the proposed lagoon rate a risk factor of "eight". Underground openings beneath the proposed lagoon rate a risk factor of "sixteen".

7. SURFACE AREA OF THE LAGOON. Calculate the surface area of the wastewater in the proposed lagoon. In most cases, the surface area of the proposed lagoon will be given on the form used to request a geological evaluation of the site. Total the surface area of each cell if more than one cell is existing or proposed.

If the total surface area of wastewater is less than one acre, assign a risk factor of "one". For a total surface area from one to four acres, assign a risk factor of "two". For a total surface area greater than four acres, assign a risk factor of "four".

8. MAXIMUM OPERATING DEPTH OF LIQUIDS. In most cases, the maximum operating depth of liquids for the proposed lagoon will be given on the form used to request a geological evaluation of

the site. The maximum operating depth of existing lagoons can be estimated by measuring the vertical distance from the downstream toe to the emergency spillway or overflow pipe. This method may give an exaggerated estimate of the operating depth of liquids if the lagoon has been constructed on a steep slope. In cases where there are more than one cell, use the operating depth of the deepest lagoon.

For operating depths of less than five feet, assign a risk factor of "one". For operating depths from five to ten feet, assign a risk factor of "two". For operating depths from ten to fifteen feet, assign a risk factor of "three". For operating depths greater than fifteen feet, assign a risk factor of "four".

TOTAL THE RISK FACTORS. The site is classified as having slight collapse potential if the total is nine or less. The site is classified as having moderate collapse potential if the total is from 10 to 22. The site is classified as having severe collapse potential if the total is 23 or more. Enter the resulting collapse potential on line 16 of the Waste Water Treatment Site Form or Addendum. Although the computer database automatically tabulates the score, you are responsible to make sure the score is correct.

REMARKS: Include any additional information related to compilation or data included in this assessment, e.g. thorough documentation of estimates and assumptions.

Enter investigator's name and date in appropriate blanks.

(6) Ozone Generation. Ozone may be produced from either an air or an oxygen gas source. Generation units shall be automatically controlled to adjust ozone production to meet disinfection requirements.

(7) Piping and Connections. Piping systems should be as simple as possible, specifically selected and manufactured to be suitable for chlorine or ozone service, with a minimum number of joints. Piping should be well supported and protected against temperature extremes. The correct weight or thickness of steel is suitable for use with dry chlorine liquid or gas. Even minute traces of water added to chlorine results in a corrosive attack that can only be resisted by pressure piping utilizing materials such as silver, gold, platinum or Hasteloy C. Low pressure lines made of hard rubber, saran-lined, rubber-lined, polyethylene, polyvinylchloride (PVC) or Uscolite materials are satisfactory for wet chlorine or aqueous solutions of chlorine. Due to the corrosiveness of wet chlorine, all lines designed to handle dry chlorine should be protected from the entrance of water or air containing water. For ozonation systems, the selection of material should be made with due consideration for ozone's corrosive nature. Copper or aluminum alloy should be avoided. Stainless steel with a corrosion resistance of at least equal to grade 304 L should be specified for piping containing ozone in nonsubmerged applications. Unplasticized PVC, Type 1, may be used in submerged piping, provided the gas temperature is below one hundred forty degrees Fahrenheit (140°F) (60°C) and the gas pressure is low.

(8) Housing.

(A) Separation. If gas chlorination equipment, chlorine cylinders or ozone generation equipment are to be in a building used for other purposes, a gas-tight room shall separate this equipment from any other portion of the building. Floor drains from the chlorine room should not be connected to floor drains from other rooms. Doors to this room shall open only to the outside of the building and shall be equipped with panic hardware. The rooms shall be at ground level and should permit easy access to all equipment. Storage area should be separate from the feed area. Chlorination equipment should be situated as close to the application point as reasonably possible.

(B) Inspection Window. A clear glass, gas-tight window shall be installed in an exterior door or interior wall of the chlorinator or ozone generator room to permit the units to be viewed without entering the room.

(C) Heat. Rooms containing disinfection equipment shall be provided with a means of heating so that a temperature of at least sixty degrees Fahrenheit (60°F) (16°C) can be maintained but the room should be protected from excess heat. Cylinders shall be kept at essentially room temperature. The room containing the ozone generation units shall be maintained above thirty-five degrees Fahrenheit (35°F) (2°C) at all times.

(D) Ventilation. With chlorination systems, forced, mechanical ventilation shall be installed which will provide one (1) complete air change per minute when the room is occupied. For ozonation systems, continuous ventilation to provide at least six (6) complete air changes per hour should be installed. The entrance to the air exhaust duct from the room shall be near the floor and the point of discharge shall be so located as not to contaminate the air inlet to any buildings or inhabited areas. Air inlets shall be so located as to provide cross ventilation with air and at a temperature that will not adversely affect the chlorination of ozone generation equipment. The vent hose from the chlorinator shall discharge to the outside atmosphere above grade.

(E) Electrical Controls. Switches for fans and lights shall be outside of the room at the entrance. A labeled signal light indicating fan operation should be provided at each entrance, if the fan can be controlled from more than more one (1) point.

(9) Respiratory Protection. Respiratory air-pac protection equipment, meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) shall be available where chlorine gas is handled and shall be stored at a convenient location but not inside any room where chlorine is used or stored. Instructions for using, testing and replacing mask parts including canisters, shall be posted adjacent to the equipment. The units shall use compressed air, have at least thirty (30)-minute capacity and be compatible with the units used by the fire department responsible for the plant.

(10) Application of Chlorine or Ozone.

(A) Mixing. The disinfectant shall be positively mixed as rapidly as possible, with a complete mix being effected in three (3) seconds. This may be accomplished by either the use of turbulent flow regime or a mechanical flash mixer.

(B) Contact Period. For a chlorination system, a minimum contact period of fifteen (15) minutes at peak hourly flow or maximum rate of pumpage shall be provided after thorough mixing. Consideration should be given to running a field tracer study to assure adequate contact time. If dechlorination is required after complete mixing of the effluent with the chemical, no further contact time is necessary. The required contact time for an ozonation unit varies with the type of dissolution equipment used. Certain high rate devices require contact times less than one (1) minute to achieve disinfection while conventional dissolution equipment may require contact times similar to chlorination systems.

(C) Contact Tank. The chlorine or ozone contact tank shall be constructed so as to reduce short-circuiting of flow to a practical minimum. Baffles shall be parallel to the longitudinal axis of the chamber with a minimum length to width ratio of forty to one (40:1) (the total length of the channel created by the baffles should be forty (40) times the distance between the baffles). The tank should be designed to facilitate maintenance and cleaning without reducing effectiveness of disinfection. Duplicate tanks, mechanical scrapers or portable deck level vacuum cleaning equipment shall be provided. Consideration should be given to providing skimming devices on all contact tanks. Covered tanks are discouraged.

(11) Evaluation of Effectiveness.

(A) Sampling. Facilities shall be included for sampling the disinfected effluent after contact. In large installations, or where stream conditions warrant, provisions should be made for continuous monitoring of effluent chlorine residual.

(B) Testing. Equipment shall be provided for measuring chlorine residuals using accepted test procedures. Automatic equipment required by subsection (4)(C) of this rule may be used to meet the requirements of this subsection. Equipment shall also be required for measuring fecal coliform using accepted test procedures as required by 10 CSR 20-9.010.

AUTHORITY: section 644.026, RSMo Supp. 1988. Original rule filed Aug. 10, 1978, effective March 11, 1979.*

**Original authority 1972, amended 1973, 1987, 1993.*

10 CSR 20-8.200 Wastewater Treatment Ponds (Lagoons)

PURPOSE: The following criteria have been prepared as a guide for the design of wastewater treatment ponds (lagoons). This rule is to be used with rules 10 CSR 20-8.110–10 CSR 20-8.220 for the planning and design of the complete treatment facility. This rule *reflects the minimum requirements of the Missouri Clean Water Commission as regards adequacy of design, submission of plans, approval of plans and approval of completed sewage works. Deviation from these minimum requirements will be allowed where sufficient documentation is presented to justify the deviation. These criteria are taken largely from Great Lakes-Upper Mississippi River Board of State Sanitary Engineers* ***Recommended Standards for Sewage Works*** *and are based on the best information presently available. These criteria were originally filed as 10 CSR 20-8.030. It is anticipated that they will be subject to review and revision periodically as additional information and methods appear. Addenda or supplements to this publication will be furnished to consulting engineers and city engineers. If others desire to receive addenda or supplements, please advise the Clean Water Commission so that names can be added to the mailing list.*

Editor's Note: The secretary of state has determined that the publication of this rule in its entirety would be unduly cumbersome or expensive. The entire text of the material referenced has been filed with the secretary of state. This material may be found at the Office of the Secretary of State or at the headquarters of the agency and is available to any interested person at a cost established by state law.

(1) Definitions. Definitions as set forth in the Clean Water Law and 10 CSR 20-2.010 shall apply to those terms when used in this rule, unless the context clearly requires otherwise. Where the terms shall and must are used, they are to mean a mandatory requirement insofar as approval by the agency is concerned, unless justification is presented for deviation from the requirements. Other terms, such as should, recommend, preferred and the like, indicate discretionary requirements on the part of the agency and deviations are subject to individual consideration.

(2) Exceptions. This rule shall not apply to facilities designed for twenty-two thousand five hundred (22,500) gallons per day (85.4m^3) or less (see 10 CSR 20-8.020 for the requirements for those facilities).

(3) General. This rule deals with generally used variations of treatment ponds to achieve secondary treatment including controlled discharge pond systems, flow-through pond systems and aerate pond systems. Ponds utilized for equalization, percolation, evaporation and sludge storage will not be discussed in this rule.

(4) Supplement to Engineer's Report. The engineer's report shall contain pertinent information on location, geology, soil conditions, area for expansion and any other factors that will affect the feasibility and acceptability of the proposed project. The following information must be submitted in addition to that required in 10 CSR 20-8.110.

(A) Supplementary Field Survey Data.

1. The location and direction of all residences, commercial developments, parks, recreational areas and water supplies, including a log of each well if available within one-half (1/2) mile (0.8 km) of the proposed pond shall be included in the engineer's report.

2. Land use zoning adjacent to the proposed pond site shall be included.

3. A description, including maps showing elevations and contours, of the site and adjacent area shall be provided. Due consideration shall be given to additional treatment units and/or increased waste loadings in determining land requirements. Current United States Geological Survey and Soil Conservation Service maps may be considered adequate for preliminary evaluation of the proposed site.

4. The location, depth and discharge point(s) of any field tile in the immediate area of the proposed site shall be identified.

5. A geological evaluation of the proposed lagoon site prepared by the Division of Geology and Land Survey (DGLS) shall be submitted. To obtain this geological evaluation of the proposed site, the engineer shall submit the following information to the Department of Natural Resources, Division of Geology and Land Survey, P.O. Box 250, Rolla, MO 65401:

A. A layout sheet showing the proposed location. The layout shall include the legal description, property boundaries, roads, streams and other geographical landmarks which will assist in locating the site;

B. Size of the lagoon and/or approximate volume of waste to be treated;

C. Maximum cuts to be made in the construction of the lagoon; and

D. Location and depth of cut for borrow area, if any.

6. Sulfate content of the primary water supply shall be determined.

7. Data from all soil borings conducted by a professional soil testing laboratory to determine subsurface soil characteristics and groundwater characteristics, including elevation, at the proposed site and their effect on the construction and operation of a pond shall also be provided. All boring holes shall be filled and sealed. The permeability characteristics of the pond bottom and pond seal material shall also be studied. At the facility plan stage particle size analysis, Atterburg limits, standard Procter density (moisture-density relations) or permeability coefficient may be required on a case-by-case basis to reflect soil characteristics. At the twenty percent (20%) design stage, soil analysis of each representative soil material including particle size analysis, Atterburg limits, standard Procter density (moisture-density relations) and permeability coefficient of the compacted soil as measured in a falling head permeameter or other text procedure acceptable to the agency may be required. Soil borings may be required in each geological area to determine depth to piezometric surface and to bedrock. Recommendations of the DGLS will be used to establish the required tests at the facility plan and twenty percent (20%) design stages.

(B) Site Information.

1. Distance from habitation. Lagoon sites should be as far as practicable from habitation or any area which may be built up within a reasonable future period. The agency does not attempt to set any minimum distance from habitation since each case must be judged upon its own merits.

2. Prevailing winds. If practicable, ponds should be located so that local prevailing winds will be in the direction of uninhabited areas.

3. Surface runoff. Location of ponds in watersheds receiving significant amounts of stormwater runoff is discouraged. Adequate provisions must be made to divert stormwater runoff around the ponds and protect embankments from erosion.

4. Hydrology. Construction of ponds in close proximity to water supplies and other facilities subject to contamination should be avoided. A minimum separation of four feet (4') (1.2m) between the bottom of the pond and the maximum groundwater elevation should be maintained where feasible.

5. Groundwater pollution. Proximity of lagoons to water supply located in areas of porous soils and fissured rock formation shall be elevated to avoid creation of health hazards or other undesirable conditions. If the geological report from DGLS makes suggestions for remedial treatment of the site, the engineer shall comply with the suggestions. In some cases, the engineering geologist requests to visit the site during or after construction. When a request is made, the consulting engineer shall comply with the request.

(5) Basis of Design.

(A) Quality of Effluent. A controlled discharge stabilization pond (four (4)-cell) will be considered capable of meeting effluent limitations of thirty (30) mg/l biochemical oxygen demand (BOD_5) and thirty (30) mg/l suspended solids. Flow-through stabilization ponds (three (3)-cell), and aerated lagoon systems will be considered capable of meeting effluent limitations of thirty (30) mg/l BOD" and eighty (80) mg/l suspended solids. Flow-through lagoon systems and aerated lagoon systems followed by submerged sand filters will be considered capable of meeting effluent limitations of twenty (20) mg/l BOD_5 and twenty (20) mg/l suspended solids. Lagoons may be incorporated into irrigation systems or systems utilizing chemical coagulation and filtration to meet the requirements of 10 CSR 20-7.015(3)(A)3. Please refer to 10 CSR 20-7.015 Effluent Regulation for discharge requirements.

(B) Area and Loadings for Controlled Discharge Stabilization Ponds (four (4)-cell). Pond design for BOD_5 loadings shall not exceed thirty-four (34) lbs./acre/day (38 km per hectare per day) at the three-foot (3'-1.9m) operating depth in the primary cells. The primary cell shall be followed by a secondary cell having 0.3 the area of the primary cell and by two (2) storage cells. The two (2) storage cells shall have a volume above the two-foot (2'-0.6m) level for one (1) month's storage of average daily flow in each cell. At least one hundred twenty (120) days' detention time between the two-foot (2') level (0.6m) and the maximum operating depth shall be provided in the entire pond system. Flow can be based on one hundred (100) gallons per capita per day ($38m_3$/cap/d) or other values if data is presented to justify the rate. Primary and secondary cells shall be designed for water depths up to a maximum of five feet (5') (1.5m). The storage cell should be made as deep as possible up to a maximum depth of eight feet (8') (2.4m).

(C) Area and Loadings for Flow-through Stabilization Ponds (three (3) cell). Pond design for BOD_5 loadings shall not exceed thirty-four (34) pounds per acre per day (38 km per hectare per day). The second cell must be at least 0.3 the area of the first cell and the third cell 0.1 the area of the first cell. The first and second cells must have a variable operating level of between two feet (2') (0.6m) and five feet (5') (1.5m). The third cell must have a variable operating level of between two feet (2') (0.6m) and eight feet (8') (2.4m). Detention time of at least one hundred twenty (120) days must be provided. Flows of less than one hundred (100) gallons per capita per day (.38m^3/cap/d) may be used if data is presented to justify the lower rate.

(D) Aerated Lagoons. For the development of final design parameters it is recommended that actual experimental data be developed; however, the aerated lagoon design for minimum detention time may be estimated using the following formula:

$$t = \frac{E}{2.3\,K_1 \times (100\text{-}E)}$$

where:

t = detention time in the aeration cell in days;

E = percent of BOD_5 to be removed in an aerated pond; and

K_1 = reaction coefficient aerated lagoon, base 10.

For normal domestic sewage the K_1 value may be assumed to be .15 per day for Missouri conditions. The reaction rate coefficient for domestic sewage which includes some industrial waste, other waste or partially treated sewage must be determined experimentally for various conditions which might be encountered in the aerated ponds. Conversion of the reaction coefficient at other temperatures shall be based on experimental data. Raw sewage strength should also consider the effect of any return sludges. Also, additional storage volume should be considered for sludge and in northern climates, ice cover. Oxygen requirements generally will depend on the BOD_5 loading, the degree of treatment and the concentration of suspended solids to be maintained. Aeration equipment shall be capable of maintaining a minimum dissolved oxygen level of two (2) mg/l in the ponds at all times. Suitable protection from weather shall be provided for electrical controls. The aeration equipment shall be capable of providing 1.3 pounds of oxygen per pound of BOD_5(1.3 kg/kg BOD_5) removed. BOD_5 removal shall be based on warm weather rates. Aerated cells shall be followed by a polishing cell with a volume of 0.3 of the volume of the aerated cell (see 10 CSR 20-8.180 for details on aeration equipment).

(E) Multiple Units. Parallel cells should be considered for large installations. The maximum size of any cell should be forty (40) acres (16 ha). The system should be designed to permit isolation of any cell without disrupting service of the other cells.

(F) Pond Shape. The shape of all cells should be so that there are no narrow or elongated portions. Round, square or rectangular ponds with a length not exceeding three (3) times the width are considered most desirable. No islands, peninsulas or coves shall be permitted. Dikes should be rounded at corners to minimize accumulation of floating materials. Common dike construction, wherever possible, is strongly encouraged.

(G) Industrial Wastes. Consideration shall be given to the type and effects of industrial wastes on the treatment process. In some cases it may be necessary to pretreat industrial or other discharges. Industrial wastes shall not be discharged to ponds without assessment of the effects the substances may have upon the treatment processor discharge requirements in accordance with state and federal laws.

(H) Additional Treatment. Consideration should be given in the design stage to the utilization of additional treatment units as may be necessary to meet applicable discharge standards (see paragraph (4)(A)3. of this rule).

(6) Pond Construction Details.

(A) Embankments and Dikes.

1. Material. Dikes shall be constructed of relatively impervious material and compacted to at least ninety-five percent (95%) standard Procter density to form a stable structure. Vegetation and other unsuitable materials shall be removed from the area where the embankment is to be placed.

2. Top width. The minimum dike width shall be eight feet (8') (2.4m) to permit access of maintenance vehicles.

3. Maximum slopes. Inner and outer dike slopes shall not be steeper than three horizontal to one vertical (3:1).

4. Minimum slopes. Inner slopes should not be flatter than four horizontal to one vertical (4:1). Flatter slopes can be specified for larger installations because of wave action but have the disadvantage of added shallow areas being conducive to emergent vegetation. Outer slopes shall be sufficient to prevent surface runoff from entering the ponds.

5. Freeboard. Minimum freeboard shall be two feet (2') (0.6m). For very large cells, three feet (3') (1.0m) should be considered.

6. Design depth. The minimum operating depth should be sufficient to prevent growth of aquatic plants and damage to the dikes, bottom, control structures, aeration equipment and other appurtenances. In no case should pond depths be less than two feet (2') (0.6m). The design water depth for aerated lagoons should be ten to fifteen feet (10–15') (3–4.5m). This depth limitation may be altered depending on the aeration equipment, waste strength, climatic conditions and geologic conditions.

7. Erosion control. A justification and detailed discussion of the method of erosion control which encompasses all relative factors such as pond location and size, variations in operating depths, seal material, topography, prevailing winds, cost breakdown, application procedures, etc., shall be provided.

A. Seeding. The dikes shall have a cover layer of fertile topsoil with a minimum thickness of four inches (4") (10 cm) to promote establishment of an adequate vegetative cover wherever riprap is not utilized. Prior to prefilling (in accordance with paragraph (6)(C)3. of this rule), adequate vegetation shall be established on dikes from the outside toe to one foot (1') above the water line measured on the slope. Perennial-type, low growing, spreading grasses that minimize erosion and can be mowed are most satisfactory for seeding of dikes. In general, alfalfa and other long-rooted crops should not be used for seeding since the roots of this type are apt to impair the water holding efficiency of the dikes. Alternate dike stabilization practices may be considered if vegetative cover cannot be established prior to prefilling.

B. Additional erosion protection. Riprap or some other acceptable method of erosion control is required as a minimum around all piping entrances and exits. For aerated cell(s) design should ensure erosion protection on the slopes and bottoms in the areas where turbulence will occur. Additional erosion control may also be necessary on the exterior dike slope(s) to protect the embankment(s) from erosion due to severe flooding of a water course.

C. Alternate erosion protection. Alternate erosion control on the interior dike slopes may be necessary for ponds which are subject to severe wave action. In these cases riprap or an acceptable equal shall be placed from one foot (1') (.3m) above the high water mark to two feet (2') (0.6m) below the low water mark (measured on the vertical). This protection should also be provided in the storage cells of a controlled discharge (four (4)-cell) pond and the third cell of a flow-through pond (three (3)-cell) where large fluctuations in operating depths will occur.

(B) Pond Bottom.

1. Soil. Soil used in constructing the pond bottom (not including the seal) and dike cores shall be selected to avoid settlement. Soil shall be compacted with the moisture content between two percent (2%) below and four percent (4%) above the optimum water content and to the specified standard Procter density but no less than ninety-five percent (95%) standard Procter density.

(C) Seal.

1. Design. Ponds shall be sealed so that seepage loss through the seal is as low as practicably possible. Seals consisting of soils or synthetic liners may be used provided the permeability, durability, integrity and cost effectiveness of the proposed materials can be satisfactorily demonstrated for anticipated conditions. Bentonite, soda ash or other sealing aids may be used to achieve an adequate seal in systems using soil. Results of a testing program which substantiates the adequacy of the proposed seal must be incorporated into and/or accompany the engineering report. Standard ASTM procedures or other acceptable methods shall be used for all tests. Soils having a permeability coefficient of 10- cm/sec or less with a compacted thickness of twelve inches (12") (30.5 cm) will be acceptable as a lagoon seal for water depths up to five feet (5') (1.5m). For permeability coefficients greater than 10-- cm/sec or for heads over five feet (5') (1.5m) such as an aerated lagoon system, the following formula shall be used to determine minimum seal thickness:

$$t = \frac{H \times K}{5.4 \times 10^{-7} \text{ cm/sec}}$$

where:
K = the permeability coefficient of the soil in question;
H = the head of water in the lagoon; and
t = the thickness of the soil seal.

Units for H and t may be English or metric; however, they must be the same. For a seal consisting of an artificial liner, seepage loss shall not exceed the equivalent of the rate expressed in this paragraph.

2. Normal construction methods will include over-excavation below grade level of twelve inches (12") (30.5 cm), scarification and compaction of base material to ninety-five percent (95%) standard Procter density at moisture content between two percent (2%) below and four percent (4%) above optimum, and compaction of lifts generally not exceeding six inches (6") (15.2 cm) to ninety-five percent (95%) standard Procter density at moisture content between two percent (2%) below and four percent (4%) above optimum. Maximum rock size should not exceed one-half (1/2) of the thickness of the compacted lift. The cut face of dikes must also be over-excavated and compacted in lifts not to exceed six inches (6") (15.2 cm) per lift. Soils containing plastic clay may be excluded from this construction requirement on a case-by-case basis based on particle size analysis and Atterburg limits. In fact, with some clay soils, satisfactory construction cannot be obtained by over-excavation and recompaction. Construction control must include field density. A minimum of two (2) density tests per acre or not less than three (3) tests must be performed for the base and each lift. Permeability tests of field compacted material may be performed at the option of the consulting engineer.

3. Prefilling. The pond shall be prefilled in order to protect the liner, to prevent weed growth, to reduce odor, to allow measurement of percolation losses and to maintain moisture content of the seal. However, the dikes must be completely prepared as described in subparagraphs (6)(A)7.A. and/or B. of this rule before the introduction of water. If the lagoon bottom is allowed to dry, the seal must be recompacted as required in paragraph (6)(C)2.

4. Percolation losses. Measurement of percolation losses shall consider flow into and out of the lagoon, rainfall and evaporation, and changes in water level. Measured percolation losses in excess of one-sixteenth inch (1/16") (1.6 mm) per day will be considered excessive.

(D) Influent Lines.

. Material. Cast- or ductile-iron pipe should be used for the influent line to the pond. Unlined corrugated metal pipe should be avoided due to corrosion problems. Other materials selected shall be suited to local conditions. In material selection, consideration must be given to the quality of the wastes, exceptionally heavy external loadings, abrasion, soft foundations and similar problems.

2. Manhole. A manhole shall be installed prior to entrance of the influent line into the primary cell(s) and shall be located as close to the dike as topography permits. Its invert shall be at least six inches (6") (15 cm) above the maximum operating level of the pond and provide sufficient hydraulic head without surcharging the manhole.

3. Flow distribution. Flow distribution structures shall be designed to effectively split hydraulic and organic loads equally to the primary cells.

4. Influent line(s). The influent line(s) shall be located along the bottom of the pond so that the top of the pipe is just below the average elevation of the pond seal; however, the pipe shall have adequate seal below it.

5. Point of discharge. All primary cells shall have individual influent line(s) which terminate at approximately the center of the cell so as to minimize short-circuiting. Consideration should be given to multi-influent discharge points for primary cells of twenty (20) acres (8 hectares) or larger to enhance distribution of the waste load on the cell. All aerated cells shall have influent lines which distribute the load within the mixing zone of the aeration equipment. Consideration of multi-inlets should be closely evaluated for any diffused aeration systems.

6. Influent discharge apron. The influent line(s) shall discharge horizontally into the shallow saucer-shaped depression. The end of the discharge line(s) shall rest on a suitable concrete apron large enough so that the terminal influent velocity at the end of the apron does not cause soil erosion. A minimum size apron of two feet (2') (0.6m) square shall be provided.

(E) Control Structures and Interconnecting Piping.

1. Structure. Facilities design shall consider the use of multipurpose control structures, where possible, to facilitate normal operational functions such as drawdown and flow distribution, flow and depth measurement, sampling, pumps for recirculation, chemical additions and mixing and to minimize the number of construction sites within the dikes. As a minimum, control structures shall be accessible for maintenance and adjustment of controls; adequately ventilated for safety and to minimize corrosion; locked to discourage vandalism; contain controls to allow water level and flow rate control, complete shut off and complete draining; constructed of noncorrosive materials (metal on metal contact in controls should be of like alloys to discourage electrochemical reactions); and located to minimize short-circuiting within the cell and avoid freezing and ice damage. Recommended devices to regulate the water level are valves, slide tubes or dual slide gates. Regulators should be designed so that they can be preset to stop flows at any pond elevation.

2. Piping. All piping shall be of cast-iron or other acceptable materials. The piping should not be located within the seal. Seep collars shall be provided on drain pipes where they pass through the pond seal. Backfill around the drain pipe shall be placed and compacted in the same manner as the pond seal. Pipes should be anchored with adequate erosion control.

A. Drawdown structure piping.

(I) Multilevel outlets. The outlet structure on each pond cell, except aerated cells, shall be designed to permit overflow at one-foot (1') (30.5 cm) increments between the two foot (2'-61 cm) level and the maximum operating level. Suitable baffling shall be provided to prevent discharge of scum or other floating materials. Means must be provided to prevent unauthorized variance of the lagoon depth. A flap valve shall be provided at the outlet end of the final cell overflow or drain pipe to prevent entrance of animals or backwater from flooding.

(II) Pond drain. All ponds shall have emergency drawdown piping to allow complete draining for maintenance. These should be incorporated into the previously described structures. Sufficient pumps and appurtenances shall be made available to facilitate draining of individual ponds if ponds cannot be drained by gravity.

(III) Emergency overflow. To prevent overtopping of dikes, emergency overflow should be provided.

B. Hydraulic Capacity. The hydraulic capacity for constant discharge structures and piping shall allow for a minimum of two hundred fifty percent (250%) of the design flow of the system. The hydraulic capacity for controlled discharge systems shall permit transfer of water at a minimum rate of six inches (6") (15.2 cm) of pond water depth per day at the available head.

(7) Submerged Sand Filters.

(A) Applications. Submerged sand filters may be used for solids and BOD_5 removal following waste stabilization ponds and are considered to be both a third lagoon cell and solids removal facility when designed according to the parameters in subsection (7)(B) of this rule.

(B) Design Details.

1. Following nonaerated waste stabilization ponds, the loading shall not exceed five (5) gallons per day per square foot (.2m^3/m^2/day) of sand. Following aerated waste stabilization ponds, the loading shall not exceed fifteen (15) gallons per day per square foot (.6m^3/m^2/day) of sand.

2. Clean graded gravel, preferably placed in at least three (3) layers should be placed around the underdrains and to a depth of at least six inches (6") (15 cm) over the top of the underdrains. Suggested gradings for the three (3) layers are: one and one-half inches to three-fourths inch (1 1/2"-3/4") (3.8 cm-1.9 cm), three-fourths inch to one-fourth inch (3/4"-1/4") (1.9 cm—.6 cm) and one-fourth inch to one-eighth inch (1/4"-1/8")(.6 cm-.3 cm).

3. At least twenty-four inches (24") (0.6m) of clean washed sand should be provided. The sand should have an effective size of 0.3—1.0 mm and a uniformity coefficient of 3.5 or less.

4. Open-joint or perforated pipe underdrains may be used. They should be spaced not to exceed ten-foot (10') (3.0m) center-to-center.

5. The earth base of the filters should be sloped to the underdrains or the underdrains may simply be placed in the gravel base on the flat bottom of the basin.

6. The depth of liquid above the sand must be adjustable from one to five feet (1-5') (.3m-1.5m).

7. At least two (2) cells must be provided with the combined capacity equal to that necessary for the design loading.

8. A vehicle access ramp from the top of the embankment down to the sand surface and running along one (1) side of the filter is a desirable feature for periodic maintenance of the filter.

(8) Miscellaneous.

(A) Fencing. The pond area shall be enclosed with an adequate fence to discourage trespassing and prevent entering of livestock. Minimum fence height shall be five feet (5') (1.5m). The fence may be of the chain link or woven type. Fencing shall not obstruct vehicle traffic or mowing operations on the dike. A vehicle access gate of sufficient width to accommodate mowing equipment shall be provided. All access gates shall be provided with locks.

(B) Access. An all-weather access road shall be provided to the pond site to allow year-round maintenance of the facility.

(C) Warning Signs. Appropriate permanent signs shall be provided along the fence around the pond to designate the nature of the facility and advise against trespassing. At least one (1) sign shall be provided on each side of the site and one (1) for every five hundred feet (500') (150m) of its perimeter.

(D) Flow Measurement. Refer to 10 CSR 20-8.140(8)(G).

(E) Groundwater Monitoring. An approved system of groundwater monitoring wells or lysimeters may be required around the perimeter of the pond site to facilitate groundwater monitoring. The use of wells and/or lysimeters will be determined on a case-by-case basis.

(F) Laboratory Equipment. Refer to 10 CSR 20-8.140(8)(D).

(G) Pond Level Gauges. Pond level gauges shall be provided.

(H) Service Building. Consideration in design should be given to a service building for laboratory and maintenance equipment.

AUTHORITY: section 644.026, RSMo Supp. 1988. Original rule filed Aug. 10, 1978, effective March 11, 1979.*

**Original authority 1972, amended 1973, 1987, 1993.*

10 CSR 20-8.210 Supplemental Treatment Processes

PURPOSE: The following criteria have been prepared as a guide for the design of supplemental treatment processes. This rule is to be used with rules 10 CSR 20-8.110–10 CSR 20-8.220 for the planning and design of the complete treatment facility. This rule reflects the minimum requirements of the Missouri Clean Water Commission as regards adequacy of design, submission of plans, approval of plans and approval of completed sewage works. Deviation from these minimum requirements will be allowed where sufficient documentation is presented to justify the deviation. These criteria are taken largely from Great Lakes-Upper Mississippi River Board of State Sanitary Engineers Recommended Standards for Sewage Works and are based

ID #: ___-___

WASTE WATER TREATMENT SITE - GEOLOGIC EVALUATION

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
P.O. BOX 250, ROLLA, MISSOURI 65402 (573)368-2161

1. Project: ______________________ County: ______________

2. Location: ______________, Sec ___, T___, R___, Quad: ______________

3. Latitude: 0 Deg, 0 Min, 0 Sec Longitude: 0 Deg, 0 Min, 0 Sec

4. Owner: ______________________________

5. Requested by: ______________________________

6. Previous Reports: Not Applicable: ___
ID # ___-___ ID # ___-___ ID # ___-___ ID # ___-___ ID # ___-___
Date __/__/__ Date __/__/__ Date __/__/__ Date __/__/__ Date __/__/__

7. A) Were plans submitted? ___ B) Was site investigated by S.C.S.? ___

8. Facility Type: Mechanical Plant ___, Land Application ___, Marsh System ___, Earthen Holding Basin ___, Earthen Lagoon with Discharge ___, Other ___.

9. Waste Type: Animal ___, Human ___, Process/Industrial ___, Leachate ___, Other ___. Funding Source: Construction Grant ___, IWT___, WWL ___

GENERAL GEOLOGY

10. Date of Field Visit: __/__/__

11. Overall Geologic Limitations: Slight ___, Moderate ___, Severe ___.

12. Topography: 0-4% ___, 4-8% ___, 8-15% ___, Greater than 15% ___.
On: Broad Upland ___, Ridgetop ___, Hillslope ___, Narrow Ravine ___, Floodplain ___, Alluvial Plain ___, Terrace ___, Sinkhole ___.

13. Bedrock: ______________________________

14. Overburden (Soil): ______________________________

15. Receiving Stream Classification: Gaining ___, Losing ___, Not Applicable (No Discharge) ___.

16. Collapse Potential: Not Applicable ___, Slight ___, Moderate___, Severe ___.

17. Recommended Construction Procedures: Installation of Clay Pad ___, Compaction ___, Artificial Sealing ___, Diversion of Subsurface Flow ___, Rock Excavation ___, Limit Excavation Depth ___.

ID #: ___-___

REQUIRED GEOLOGIC EXPLORATION*

(Missouri Clean Water Commission - 10 CSR 20-8.200 Wastewater Treatment Ponds)

18. Determine Overburden (Soil) Properties: Particle Size Analysis ___, Atterberg Limits ___, Standard Proctor Density ___, Overburden Thickness ___, Permeability Coefficient - Undisturbed ___, Remolded ___.

19. Determine Hydrologic Conditions: Groundwater Elevation ___, Direction of Groundwater Movement ___, 100 Year Flood Level ___.

20. Notify Geologist: Before Exploration ___, During Construction ___, After Construction ___, Not Necessary ___.

21. Remarks:

* THIS DOCUMENT IS A PRELIMINARY GEOLOGIC REPORT. IT IS NOT A PERMIT. ADDITIONAL DATA MAY BE REQUIRED BY THE DEPARTMENT OF NATURAL RESOURCES PRIOR TO ISSUANCE OF A PERMIT. THIS REPORT IS VALID ONLY AT THE ABOVE LOCATION AND BECOMES INVALID ONE YEAR AFTER THE DATE BELOW.

22. Report by: ______________________________,

23. CC: ______________________________ Date ___/___/___

ID #: ___-___

ASSESSMENT OF EARTHEN LAGOON COLLAPSE POTENTIAL
MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
P.O. BOX 250, ROLLA, MO 65402 (573)368-2161

A. Project: ______________________ County: ______________________
Location: ______________, Sec __, T__, R__, Quad: ______________________

Latitude: __ Deg, __ Min, __ Sec Longitude: __ Deg, __ Min, __ Sec

1. STREAM CLASSIFICATION:

Gaining	0	X
Losing	4	

2. DEPTH TO WATER TABLE:

≤ 50 feet	0	X
> 50 feet	4	

3. RESIDUUM THICKNESS:

< 10 feet	0	X
≥ 10 and < 40 feet	1	
≥ 100 feet	2	
≥ 40 and < 100 feet	4	

4. PREDOMINANT CHARACTERISTICS OF THE UPPER 20 FEET OF BEDROCK AND/OR SURFICIAL MATERIAL:

Solution-free bedrock, glacial drift, or alluvium with gaining conditions	0	X
Bedrock with permeable weathered zone ≤ 10 feet thick, or minor solution features and/or associated residuum	2	
Bedrock with significant solution voids > 10 feet below bedrock surface, and/or residuum with relict bedrock structure, or alluvium with losing conditions	4	

5. PROXIMITY OF NEAREST SINKHOLE TO THE LAGOON:

≥ 1 mile distant	0	X
≥ 1/2 mi. but < 1 mi. distant	1	
≥ 1/4 mi. but < 1/2 mi. distant	4	
≥ 500 ft. but < 1/4 mi. distant	6	
Within 500 feet	8	

6. PROXIMITY OF NEAREST UNDERGROUND OPENING TO THE LAGOON:

No evidence ≤ 1/2 mile distant	0	X
≥ 1/4 but < 1/2 mile distant	2	
≥ 500 feet but < 1/4 mile distant	4	
< 500 feet but not beneath site	8	
Beneath the site	16	

7. SURFACE AREA OF THE LAGOON:

≤ 1 acre	1
> 1 acre and ≤ 2 acres	2
> 2 acres and ≤ 3 acres	3
> 3 acres and ≤ 4 acres	4
> than 4 acres	5

8. MAXIMUM OPERATING DEPTH OF LIQUIDS:

≤ 5 feet	1
> 5 feet and ≤ 10 feet	2
> 10 feet and ≤ 15 feet	3
> 15 feet and ≤ 20 feet	4
> 20 feet	5

TOTAL 0

Slight Potential: Total 2 to 9

Remarks:

____
____
____
____
____
____

Investigator: ______________ Date: __/__/__

STATE OF ILLINOIS) SS

COUNTY OF SANGAMON)

PROOF OF SERVICE

I, the undersigned, on oath state that I have served the attached APPEARANCE, MOTION TO FILE TESTIMONY AND TESTIMONY OF DANIEL HEACOCK upon the person to whom it is directed, by placing a copy in an envelope addressed to:

Dorothy M. Gunn, Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street, Suite 11-500
Chicago, Illinois 60601
(First Class Mail)

Carol Sudman
Hearing Officer
Illinois Pollution control Board
600 South Second Street
Suite 402
Springfield, Illinois 62704
(First Class Mail)

AND THE ATTACHED SERVICE LIST
(First Class Mail)

and mailing it from Springfield, Illinois on April 23, 2001 with sufficient postage affixed as indicated above.

Nancy J.D. Lamport

SUBSCRIBED AND SWORN TO BEFORE ME
this 23rd day of April, 2001

S. C. Ewart
Notary Public

"OFFICIAL SEAL"
STEPHEN C. EWART
Notary Public, State of Illinois
My Commission Expires 11/16/02

THIS FILING IS SUBMITTED ON RECYCLED PAPER

R01-28 Service List
Livestock Waste Management
Friday, April 20, 2001

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