STATE OF MICHIGAN

JOHN ENGLER, Governor

DEPARTMENT OF AGRICULTURE

P.O. BOX 30017 • LANSING, MICHIGAN 48909
611 W. OTTAWA • LANSING, MICHIGAN 48933
DAN WYANT, Director

December 18, 1997

5 9 6 9 '97 DEC 19 P2:05

Dockets Management Branch (HFA-305)
Food and Drug Administration
12420 Parklawn Drive, Room 1-23
Rockville, MD 20857

RE: Docket 97N-0451

Dear Sir or Madam:

Thank you for providing the Michigan Department of Agriculture (MDA) the opportunity to comment on the draft document entitled Produce Food Safety Guidance. We appreciate the cooperative working relationship that our two agencies share. The MDA strongly supports the development of voluntary guidelines which the produce industry can use to minimize risks of bacterial contamination. We look forward to working with the Food and Drug Administration (FDA) and our other partners to develop guidelines which can be actively supported by regulators, industry groups, and consumers.

Ensuring the safety of fresh fruits and vegetables is vitally important to Michigan which ranked fourth among the states in fruit exports and sixth in vegetables (1996 USDA data). Our 2,500 fruit and 2,100 vegetable growers produce over 50 fresh fruit and vegetable crops.

The majority of our growers plant a diversity of crops on a small number of acres each year. For example, in 1995-96 over half of Michigan's vegetable growers planted 25 or fewer acres. The unique food safety educational needs of small volume producers have been widely recognized. We feel that it is critically important that federal and state agencies work together to develop a cooperative educational process which effectively communicates and meets the needs of these individuals.

97N-0451

E
C23

RECYCLED PAPER

My staff has reviewed the Produce Food Safety Guidance document and their specific comments are attached. However, some key issues were raised by the comments:

1) The stated purpose of the document is to assist growers and operators to improve the safety of produce. However, several sections of the document read as if the target audience is the scientific community. We suggest that the terminology and sentence structure be simplified in order to more effectively communicate with producers.

2) Given the importance of providing scientifically sound guidance, and the short time being allowed for the development of this document, the MDA strongly suggests that recommendations which do not reflect consensus opinions be eliminated from the document.

3) MDA suggests FDA adopt a structured risk management strategy (risk assessment, mitigation, and communication) to guide this process. The principles of risk management have been used extensively in the fruit and vegetable industry to manage chemical residue risks. We feel that appropriate use of risk management principles will give producers a better sense of the relative significance of the various sources of potential contamination, of what is known, what remains unknown, and will highlight areas where further research is needed.

4) Broaden the guidance to address both chemical and microbiological food safety.

MDA has found that the methods used to communicate risk reduction messages to fruit and vegetable growers are extremely important. To meet past educational and training needs of our fresh fruit and vegetable industries, Michigan has forged effective partnerships between our state's universities, state agencies, local governments and food industry associations. Together, we have assisted our state's agricultural producers to meet increasingly stringent standards for environmental stewardship, chemical residue avoidance, and microbiological safety. I have attached, for your information, copies of some of the educational materials which effectively communicates risk reduction information to agricultural producers. The material includes:

1) Several "Generally Accepted Agricultural and Management Practices" which have been developed under Michigan's Right to Farm Act. Attached is a copy of the "Generally Accepted Agricultural and Management Practices for Nutrient Utilization" which outlines manure management practices designed to protect surface waters and groundwater supplies.

2) Michigan's Farmstead Assessment System (Farm*A*Syst) which is a cooperative effort between the MDA, Michigan State University Extension, and local soil conservation districts. This voluntary program uses two educational tools to communicate with producers: informative fact sheets which convey key concepts

and information, and self assessment tools which producers use to apply background information to their operations. More than 6,500 Michigan farms have been reached by this program in that last three years. We have found this to be a very effective way of motivating producers to identify potential risks and then take risk reducing actions. An example of the program's effectiveness in the groundwater protection area is the proper sealing of approximately 2,600 abandoned wells over the past three years.

MDA appreciates FDA's desire to obtain input from state governments during the development of this document. Food safety continues to be a top priority for us. We feel confident that the guidance will prove to be valuable to Michigan's fruit and vegetable growers if we insure the practicality and effectiveness of each recommendation being made. Michigan has an extensive network of professionals with years of experience working with the fruit and vegetable industry. We encourage FDA to utilize this network as we continue to work together to providing the American consumer with a safe, wholesome, high quality, affordable supply of fresh fruits and vegetables.

Sincerely,

Dan Wyant

Dan Wyant
Director

Attachments

Michigan Department of Agriculture Comments to Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables
Working Draft; November 25, 1997

1. **Technical Terminology:** Examples of terminology which may not communicate effectively with many agricultural producers include: "vegetative cells" (p. 8 x. Sanitize), "vehicle for spreading localized contamination" (p. 8 II. Water), "fecal-oral" (p. 21 IV. Sanitation and Hygiene), "jaundice" (p.23 2.1 Personal Health, second to last bullet), "mitigating procedures" (p.27 2.0 Control of Potential Hazards). Extensive citations of foodborne bacterial species (example: p.22, 2.1 Personal Health) may not be particularly informative to agricultural producers. We have found that straight forward, easy to understand language is most readily accepted by growers.

2. **Broad Generalizations Warranting Clarification**

   A. **p.23, 2.1 Personal Health, second to last bullet**. "The supervisor, or the person in charge, should consider ways to monitor the health of their employees and take steps to reduce the chance of food borne illness. For example, disposable rubber or similar gloves, leak-proof band aids, or other corrective measures for minor cuts should be provided for use as necessary by personnel who may have contact with produce." We concur that fruit and vegetable producers should minimize the potential for employees to contaminate fresh produce with foodborne pathogens. This guidance does not clearly state how this goal will be achieved.

   In Michigan, the vast majority of tree fruits are harvested and/or processed by part-time, short-term, or migrant laborers. This is also often true in the processing and packaging of row crops which are mechanically harvested (e.g., celery and carrots). The MDA feels that there is insufficient time to consider the educational, linguistic, economic, and cultural factors which must be addressed in order to provide meaningful guidance in the areas of health monitoring and the use of disposable gloves. We suggest that this issue should be more appropriately addressed in commodity-specific guidance.

   B. **p.23, 2.2 Training, first bullet**. "Smoking or eating in areas where fresh produce is present can contaminate the produce because of the potential that the hands and food-contact surfaces may become contaminated. Insanitary, personal practices such as scratching the head, placing the fingers in or about the mouth or nose, and indiscriminate and uncovered sneezing or coughing may contaminate fresh produce or any handling equipment". This broad recommendation has its origin in the food service and food processing industries. Producers will question its applicability to field harvesting operations. If the recommendation is made, it is important to provide some indication as to the relative importance of head touching while harvesting versus improper handwashing after going to the bathroom.

C. **p.27, 1.0 Microbial Hazard.** "Anything that comes in contact with the food has the potential for being a source of pathogenic microorganisms... Pathogenic microorganisms may be found on the floors, walls, ceilings, and drains in the packinghouse and on the surfaces of processing equipment." We question how growers can control bacteria that are everywhere. We recommend establishing sanitation priorities that assist growers in minimizing risk. Our Apple Cider Pilot Project partnership with Michigan State University and FDA has proved very valuable in providing cider producers guidance regarding sanitation priorities.

D. **p.26, 2.5 Animal Control, first paragraph and p.21,3.0 Animal Feces, last bullet.** "Growers should assess the prevalence and likelihood of uncontrolled animal access to fields in order to reduce the potential for contamination of crops by fecal material." The growing population of free ranging white-tailed deer in Michigan is an example of an identified wildlife problem for which farmers have limited control options. The guidance should acknowledge the practical and legal limitations which producers.

3. **Suggested additional wording (in bold)**: Page 19, Bullet #3 "scheduling manure applications on adjacent fields **or to sites where produce may come into contact with manure** to maximize the time between application to those fields and harvest of fresh market produce."

MICHIGAN STATE UNIVERSITY EXTENSION

FARM•A•SYST
Farmstead Assessment System

Fact Sheet #1

Reducing the Risk of Surface and Groundwater Contamination by

Improving Drinking Water Well Condition

1. Well Location

Whether a well taps water just below the ground or hundreds of feet deep, its location is a crucial safety factor. A safe place for a well depends on factors such as surface drainage, groundwater flow, and location of sources of potential contamination. A well downhill from a livestock yard, a leaking tank, or a septic system runs a greater risk of contamination than a well on the uphill side of these pollution sources.

Surface slope does not always indicate the direction a contaminant might flow once it gets into the ground. However, in shallow aquifers, groundwater flow is often in the same direction as surface water flow.

In fact, shallow groundwater and surface water are often connected with one feeding the other. Whether water was from surface water into groundwater or from groundwater to surface water may depend on the time of year and the amount of precipitation received recently. If the aquifer supplying water to your farmstead well is deep, its slope may be different from that of the land surface. Finding out about groundwater movement on your farm may require special monitoring equipment.

Isolation distances

A safe well is isolated from sources of potential contamination and benefits from the natural protection provided by soil. However, state well codes may not mention some farmstead activities and structures. Milkhouse waste water is not addressed unless it is handled in a soil absorption system or manure storage facility. When no distances are specified, provide as much separation as possible between your well and any potential contamination source. This is especially important if your farmstead is on highly permeable soils or shallow soil overlying limestone bedrock, or if the contamination source or activity presents a high risk of surface and groundwater contamination.

Well isolation requirements in current codes apply to all newly constructed wells. Existing wells are required by law only to meet isolation requirements that were in effect at the time the well was constructed. Make every effort, however, to exceed "old requirements," and strive to meet current regulations whenever possible. Figure 1 shows some isolation distance requirements for Michigan farmsteads.

Both soil and slope can make siting a well a tricky business. Keep in mind that isolation distances required by state and local codes are minimums. You may want to choose greater distances in some cases, depending on factors at your site. This will help provide reasonable assurance that your well will not be contaminated by farmstead activities in the future. Also consider contamination sources on adjacent properties.

Changing the location of your well in relation to contamination sources may protect your water supply, but not the ground or surface water itself. Any condition likely to cause contamination of any water source should be improved, even if your well is far away from the potential source. Contamination of surface or groundwater is a violation of Michigan law.

Simply separating your well from a contamination source may reduce the chance of contamination, but it does not guarantee that the well will be safe. Storm water and groundwater can carry bacteria, oil products, pesticides, and other contaminants from one place to another. Wells located in the path of contaminated surface water run a risk of contamination from overland flow washing into an improperly sealed well. Some wells become contaminated as a result of contaminated water entering the aquifer a great distance away. The degree of risk depends on the depth of the aquifer and the well intake.

WELL

50 feet
- animal shelter, barn or animal yard
- feed handling system
- feed storage facility
- filter strip
- fuel storage with secondary containment
- septic tank
- sewer lines
- silo
- soil absorption unit (drain field, mound, etc.)
- surface water such as ponds and streams

75 feet
- runoff holding pond
- manure hopper or reception pit, liquid tight
- manure storage facility

150 feet
- fertilizer storage facility
- pesticide storage facility
- sprayer mixing and loading pad

300 feet
- fuel storage, both buried and above ground, without secondary confinement

For sources not addressed: Provide as much separation as possible from well.

Figure 1: Minimum Isolation Distances Between Well and Potential Farmstead Sources of Contamination for New Well Installation

2. Well Construction

Poor well design can allow groundwater contamination by allowing rain or snowmelt to reach the water table without filtering through soil. Wells located in pits, or without grout or a cap can allow surface water to carry bacteria, pesticides, fertilizer, or oil products into your drinking water supply. Proper well design reduces the risk of contamination by sealing the well from anything that might enter it from the surface. A diagram of a typical domestic well installation can be seen in Figure 2.

The way in which a well was constructed, even if the design is sound, affects its ability to keep out contaminants. Several things that should be checked are described in the

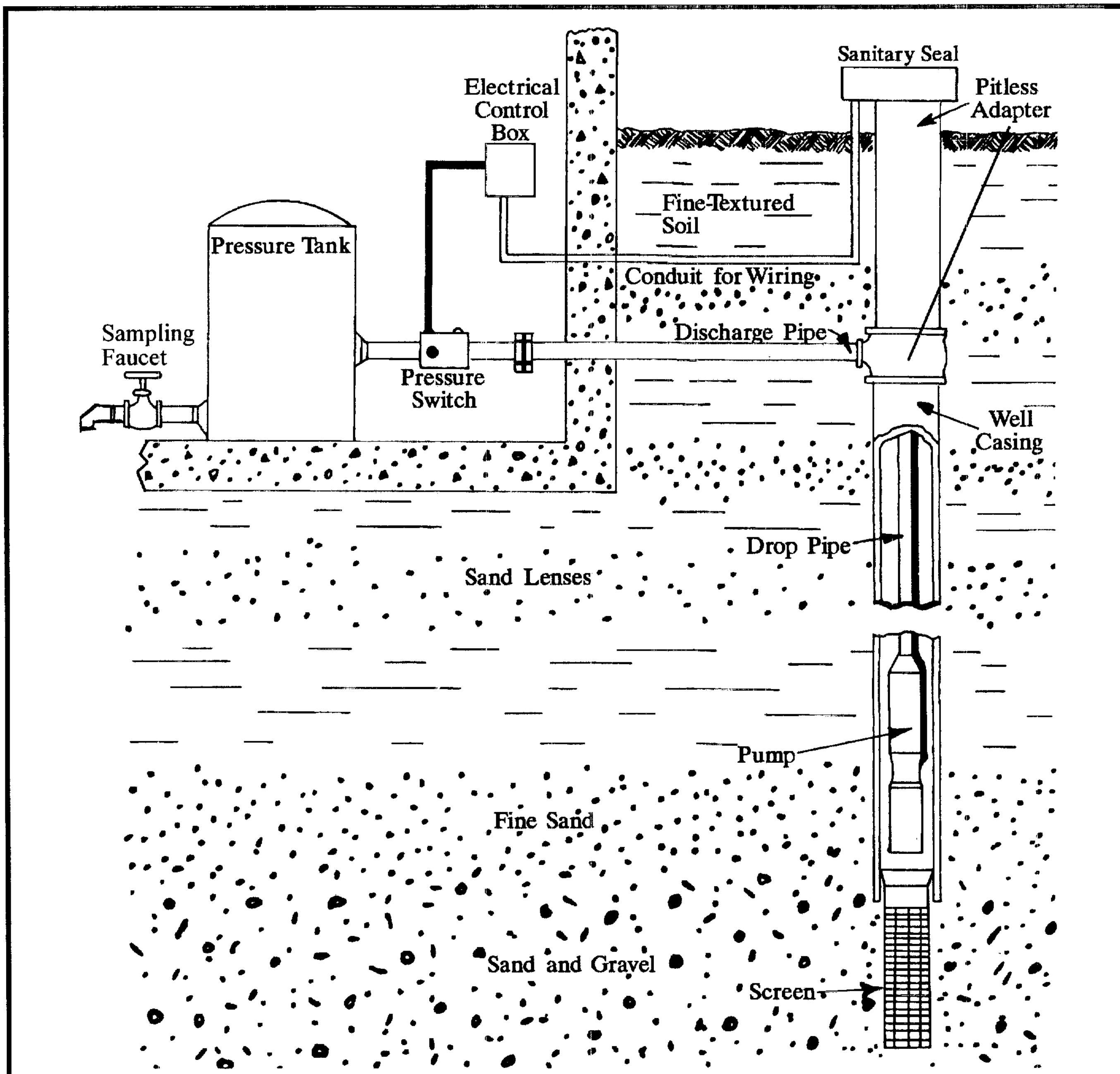

Figure 2: Typical domestic well installation with discharge pipe extending into the home. *Source: Adapted from Planning Your Well: Guidelines for Safe, Dependable Drinking Water, University of Illinois-Champaign Cooperative Extension Service. December 1988.*

following sections. Well construction information may be available from the driller who put in the well, the previous owner, or the water well record. The driller, your local health department office or the Michigan Department of Natural Resources, Geological Survey Division, can attempt to locate the water well record for you.

This overview of well construction and inspection can help you understand your drinking water contamination risk. Contact a registered well driller or pump installer for more information. A representative from your local health department or the Water Supply Division of the Michigan Department of Public Health (MDPH) can also help interpret the construction requirements of the state well code.

Casing and well cap

During construction, the well driller installs a steel or plastic pipe called a casing to prevent collapse of the borehole. The space (called the annulus) between the casing and the sides of the hole provides a direct channel for surface water (and contaminants) to reach the water table. To seal off that channel, the driller fills the annulus with a sealing material called grout (cement, concrete, or bentonite clay, depending on the geologic materials encountered). Both grout and casing prevent contaminants from seeping into the well.

You can visually inspect the condition of your well casing for holes or cracks at the surface, or you can inspect the inside of the casing with a light. If you can move the casing by pushing it, you may have a problem with your well casing's ability to keep out contaminants. In areas with shallow (less than 20 feet from ground level) fractured bedrock, check on the condition of your well casing by listening for water running down into the well. (Pump should not be running.) If you hear water running, there could be a crack or hole in the casing, the casing depth may be inadequate, or the annulus may not be sealed. Any of these situations are risky.

To prevent surface contaminants from flowing into the well casing, the driller installs a tight-fitting, vermin-proof well cap to prevent easy removal by children or entry by insects or surface water. The cap should be firmly installed, with a screened vent incorporated into it so that air can enter the well. Check that the well cap is in place and tightly secured. Wiring should be in conduit. If your well has a vent, be sure that it faces the ground, is tightly connected to the well cap or seal, and is properly screened to keep insects out. The well code requires a vermin-proof cap or seal for all wells.

Casing depth and height

The casing should extend to a minimum depth of 25 feet. Your local health department sanitarian or an MDPH specialist can advise you on these minimum requirements. Meeting well code minimums does not guarantee a safe water supply; you may want to exceed minimum casing depth.

Typically, the well casing extends 1 to 2 feet above ground level to prevent surface water from running down the casing or on top of the cap and into the well. The well code requires that at least 12 inches of casing pipe extend above the final grade of the land.

Well age

The age of a well is an important factor in predicting the likelihood of contaminants entering the well. A well constructed before 1925 is likely to be at the center of the farmstead. It may be a shallower well and is probably surrounded by many potential contamination sources. Older wells are more likely to have thinner casings that may be corroded through. Even wells with modern casings that are 30 to 40 years old are subject to corrosion and perforation. Older well pumps are also more likely to leak lubricating oils which can get into the well. If you have an older well, you may want to have it inspected by a qualified well driller.

Well type

Dug wells pose the highest risk of allowing drinking water supply contamination because they are shallow and often poorly protected from surface water. A dug well is a large-diameter hole (usually more than 2 feet wide), which is often constructed by hand.

Driven-point (sand point) wells are constructed by driving assembled lengths of pipe into the ground and pose a moderate to high risk. These wells normally have a small diameter (2 inches or less) and are less than 50 feet deep. They can be installed only in areas of relatively loose soils, such as sand.

All other types of wells, including those constructed by a combination of jetting and driving, are drilled wells. Drilled wells for farm use are commonly 4 to 8 inches in diameter, but older wells may be 2-inch.

Well depth

Shallow wells draw from groundwater sources nearest the land surface which may be directly affected by farmstead activities. Also, rain and surface water that soak into the soil are more likely to carry contaminants into shallow wells than into a deeper well. Local geologic conditions determine how long it takes for this to happen. In some places, this process happens quickly; in weeks, days, or even hours. Areas with shallow soil over fractured bedrock or sand and gravel aquifers are particularly vulnerable. Even areas having deep sands over fractured bedrock are vulnerable to contamination.

On the other hand, deep clay soils don't allow contaminants to quickly reach the water table. They may prevent contamination or delay the day when a well "turns bad." If you have a deep well (more than several hundred feet below the water table), the groundwater supplying your well may have traveled a considerable distance underground over a long time, offering greater protection to the well.

3. Managing and Maintaining Existing Wells

Just as you wouldn't let a tractor run too long without an oil change, your well deserves the same kind of attention. Good maintenance means testing the water every year, keeping the well area clean and accessible, keeping potential contaminants as far away as possible, and periodically having a qualified well driller or pump installer check the well components.

Management for your existing well

Existing wells were most likely located according to traditional practices or regulations at the time of construction. While these wells may still be legal, you may want to consider how your well conforms to current standards, which are based on new knowledge about surface and groundwater contamination and well water quality. These standards can be found in the state private well regulations.

You might want to move activities such as pesticide mixing, tank rinsing, or gasoline storage farther away from your well. You may also want to look at upgrading wells, getting rid of well pits, installing caps, or extending casings. Property transfer forms include language regarding underground petroleum storage tanks and well water safety.

Changing the location of certain farm practices may prove to be expensive and time consuming. You can't move a livestock yard or a silo overnight. You should, however, change the way you manage such structures to control contaminants until you can meet minimum separation distance requirements.

> If your silo is close to your well, for example, you may want to install a system for collecting any juices draining from freshly ensiled forage. You can install concrete curbs to direct livestock yard runoff away from the well. Any diverted runoff should be properly handled to prevent surface water contamination also.
>
> Short-term manure piles are another example of a potential contaminant that can be easily addressed. They pose a risk of well contamination by bacteria or nitrates. Locate manure pits on clay soil, or better yet, on a concrete slab to reduce the chance of polluting your drinking water. Also protect piles from rain to reduce runoff. Diverted runoff should be properly handled to prevent surface water contamination.
>
> Other management changes you may want to consider include moving traffic areas and chemical or gasoline storage areas away from the well and upgrading or improving management of your septic system. Protecting surface water quality helps ensure good quality drinking water as surface and groundwater are often connected.

Backflow prevention

Backflow or backsiphoning from pesticide mixing tanks can cause chemicals to flow back into the well through the hose. Use an anti-backflow device when filling pesticide sprayer tanks to prevent the chemical mixture from flowing back into the well and contaminating groundwater. Inexpensive anti-backflow devices for hoses used to fill farm sprayers should be available from irrigation or spray equipment suppliers. Keep the hose out of the tank when filling the pesticide sprayer even if you have an anti-backflow device.

> Consider purchasing an inexpensive plastic nurse tank. A nurse tank is filled with water at the well and then used to fill the sprayer away from the farmstead--and away from the well. (See ***Farm•A•Syst*** Worksheet and Fact Sheet #2, *Pesticide Storage and Handling* for more information about preventing well contamination from pesticide mixing and loading practices.)

You should also consider anti-backflow devices on all faucets with hose connections or maintain air gaps between hoses or faucets and the water level. Otherwise, you risk having water in laundry tubs, sinks, washing machines, pressure washers, outside hydrants, and swimming pools flowing back through the plumbing and contaminating your water supply.

Water supplies that have cross-connections between them (connections between two otherwise separate pipe systems, such as potable and nonpotable) also put your drinking water at risk.

All backsiphon and spill events must be reported to the appropriate state or local government agency. To report these events and to receive advice and assistance in remedying backsiphoning, call your Local Health Department, the Michigan Department of Natural Resources, or the Water Supply Division, Michigan Department of Public Health (see *Contacts and References*).

Water testing

The quality and safety of a water supply from existing wells can be checked by annual testing. This also applies to surface water sources. Although you cannot have your water tested for every conceivable contaminant, some basic tests can indicate whether or not other problems exist.

At a minimum, test your water supply annually for coliform bacteria and nitrate. A good initial set of tests for a private well also includes hardness, chloride, sulfate, sodium, fluoride, and iron.

In addition, you may chose to obtain a broad scan of your water quality for a number of contaminants. Both state and private labs offer a screening for metals, inorganic chemicals, volatile organic chemicals (VOC's), herbicides/pesticides, and coliform bacteria. A laboratory certified by the Michigan Department of Public Health is recommended for testing any well providing drinking water. A list of Michigan Department of Public Health Certified Labs is available from the Water Supply Division, MDPH. Lab fees vary.

Test results may not include specific contaminants that exist near your farm--the most commonly used pesticides in your area, for example. You should test for contaminants that are most likely at your farmstead. Test for lead if you have lead pipes or soldered copper joints. Test for volatile organic chemicals if there has been a nearby use or spill of oil, petroleum products, or solvent. While testing for pesticides can be very expensive, the expense may be justified if:

- your well has nitrate levels over 10 mg/l (reported as nitrate nitrogen, NO_3-N).
- a pesticide spill has occurred near the well, or backsiphonage is suspected to have occurred.
- your well is shallow, has less than 25 feet of casing, or is located in sandy soil downslope from croplands where pesticides are used.

You may seek further advice on appropriate tests to run from your county extension office or health department, or an MDPH specialist.

You should test your water more frequently if:

- there are unexplained illnesses in the family
- there are pregnancies in the family

- there are noticeable changes in livestock or poultry performance
- your neighbors find a particular contaminant in their water
- you have a spill or backsiphonage of chemicals or petroleum products near your well or on your farmstead
- you apply chemicals, manure, or whey to your fields within 100 feet of your well
- your livestock operation inspectors require it
- surface water nearby has possibly been contaminated

You can have your water tested by both public and private laboratories. A list of certified labs is available from the Water Supply Division, Michigan Department of Public Health.

Follow the lab's instructions for water sampling to assure accuracy of results. Use the container provided and return samples promptly. Bacteria sample bottles are sterile and must be returned within specified time limits.

Because many materials, including bacteria and nitrate-nitrogen, are naturally present in minor amounts in water or can vary seasonally, you may want to contact a specialist for help in interpreting test results.

Bacteria and nitrates are two important indicators. They can cause health problems at excessive levels and also may suggest problems with the well's location or construction. Hardness and pH indicate how corrosive the water may be to your plumbing system.

Keep in mind that off-farm activities off farm can also affect your groundwater. Chemical spills, changes in land use and the presence of landfills can increase the chance of contaminants getting into your water. You may want to talk with a specialist about the need for additional testing if your water has a high nitrate or bacteria level.

It is also important to record test results and to note changes in water quality over time. In addition to water analysis test results, you should keep records of other details to determine what is happening with your water system. These include well construction details and dates and results of maintenance on the well and pump.

Well maintenance

Well equipment doesn't last forever. Every 10 to 20 years, your well may require mechanical attention from a qualified well driller or pump installer. Follow these additional maintenance practices:

- Do not use gasoline or lawn and agricultural chemicals near your well.
- Do not mix pesticides, rinse sprayer equipment or discard empty pesticide containers near your well.
- Protect wells from household wastewater treatment systems.

4. New Wells

New wells are expensive, but they are a good investment for the future. Getting the most from such an investment means locating the well away from contamination sources and working to maintain the quality of the well. Some simple principles:

- Maintain the minimum isolation distances required by state and local codes. Michigan's well construction code (Part 127 of Act 368 of the Public Acts of 1968, Michigan's Public Health Code) contains these minimum isolation distances along with other requirements for drinking water wells.
- Locate your well on ground higher than surrounding sources of contamination such as fuel tanks, livestock yards, septic systems, or pesticide mixing areas. Where practical, locate the well as far as possible from contamination sources, and never closer than the minimum isolation distances specified in the well code.
- If the well cannot be placed in a naturally high spot, build soil up around the well so surface water drains away from it.
- Avoid areas that are prone to flooding.
- Groundwater flow generally follows surface drainage patterns and generally flows from upland areas and discharges in a surface water body. Unless you know the exact direction of groundwater flow on your property, locate the well so that contamination sources are between the well and the nearest creek, river, or lake. In all cases, locate your well on ground higher than surrounding contamination sources such as fuel tanks, livestock yards or pesticide mixing areas.
- Make the well accessible for pump repair, cleaning, testing, and inspection.
- Hire a competent, licensed well driller and pump installer. Make sure the driller disinfects the well with chlorine after construction and tests the water for bacteria after drilling (as required by state law) and provides you with detailed information about the well's depth and construction.
- Maintain good records of the well's construction information for future reference.

5. Unused Wells

Most farms have abandoned wells. Old home sites or wells once pumped by windmills are common. No one knows how many abandoned wells there are, although estimates range in the hundreds of thousands.

If not properly filled and sealed, these wells can provide a direct conduit for contaminants to reach groundwater. Records show that one abandoned well was improperly buried, with only a stone covering the top of the casing. This well caused severe contamination of drinking water from a well on the same property. The unused well was near an animal yard and a sewage absorption field.

A registered well driller or pump installer should be hired to close these wells; effective well plugging calls for experience with well construction materials and methods, as well as a working knowledge of the geology of the well site. You may, however, do your own well abandonment work. A license is not required, but you must meet the minimum well code requirements when you abandon and fill a well.

Special equipment is often required to remove old pumps and piping and to properly install sealing material inside the well. Use of inappropriate materials and methods can lead to settling, collapse and continued groundwater contamination. If plugging materials are improperly installed in a well, repairing defective work is nearly impossible.

The most obvious places for finding unused wells are under an old windmill, in an area where a farmstead used to be, or where pipes are sticking out of the ground.

You may not know the history of your property, so unused well locations may not be obvious. A depression in the ground may indicate an old well. Also, wells were often drilled in house basements, under front steps, or near old cisterns.

State well regulations require reporting well plugging. These regulations also explain well-closing requirements.

Remove pump, piping and any other obstructions from the well.

The well must be chlorinated before it is sealed. The entire length of the well should then be sealed to prevent surface water from entering the groundwater and to prevent contaminant movement from one aquifer to another.

Close the entire length of unused wells with slurries of cement or clay.

The goal of proper sealing is to restore as closely as possible the geologic conditions that existed before the well was constructed.

Proper well closing takes time and money. Costs will vary with the well depth, diameter, and geology of the area. Spending a few hundred dollars to plug an unused well near your home may prevent contamination of your drinking water.

Contact your local health department sanitarian or the Water Supply Division, Michigan Department of Public Health for additional information and well closure report forms.

CONTACTS AND REFERENCES

Who to call about . . .

Certified well water testing laboratories

A listing is available from the Water Supply Division, Michigan Department of Public Health, P. O. Box 30195, Lansing, Michigan 48906. Telephone: (517) 335-9216.

Interpreting well water test results

Local Health Department offices or the Water Supply Division, Michigan Department of Public Health. Telephone: (517) 335-9216.

Drinking water quality standards

U. S. Environmental Protection Agency's Safe Drinking Water Hotline. Call toll free 1-800-426-4791 from 8:30 a.m. to 5:00 p.m. Eastern time.

Water Supply Division, Michigan Department of Public Health at (517) 335-9216.

Local Health Department offices.

Approved water treatment devices

Use only those devices certified by the National Sanitation Foundation (NSF), an independent testing laboratory.

Requirements for installation of treatment devices

Before installing treatment devices on water supplies contaminated with nitrates, heavy metals, VOC's, pesticides, microorganisms, and other health-related contaminants in excess of health standards, contact your Local Health Department or the Water Supply Division, Michigan Department of Public Health at (517) 335-9216.

Locating possible sources of contamination

Well drilling contractors, pump installers, DNR district office water supply specialists, or local health department sanitarians. Besides locating contamination sources, they can also recommend improvements.

Well construction or inspection

Your Local Health Department sanitarians (list attached) or registered well drillers or pump installers.

A copy of your water well record (construction report)

Contact the well drilling contractor who drilled the well, your Local Health Department office, or the Geological Survey Division, Michigan Department of Natural Resources, 735 East Hazel Street, Lansing, Michigan 48912, phone (517) 334-6921. Be prepared to provide the legal description (county, township, range, section, and quarter section) of the well's location. (If your farm covers more than one section, make a note of that in case well drillers reported the wrong section.) If known, provide the year the well was installed and the owner's name at the time.

Well abandonment

Contact your local health department or the Water Supply Division, Michigan Department of Public Health at (517) 335-9216.

What to read about...

Groundwater, groundwater flow

Introduction to Michigan's Water Resources. MSU Institute of Water Research.

What is Groundwater? Michigan State University - Cooperative Extension Service (CES). WQ35.

Groundwater Contamination. Michigan State University - CES. WQ34.

Understanding Groundwater: Michigan's Hidden Resource. Michigan State University - CES. WQ33.

Wells, private water systems

A Guide to Home Water Treatment. Michigan State University - CES. WQ21.

Home Water Treatment Using Activated Carbon. Michigan State University - CES. WQ23.

Distillation for Home Water Treatment. Michigan State University - CES. WQ22.

Reverse Osmosis for Treatment of Drinking Water. Michigan State University - CES. WQ24.

Nitrate: A Drinking Water Concern. Michigan State University - CES. WQ19.

Private Water Systems Handbook. Midwest Plan Service. MWPS-14.

Publications available from...

1. The Michigan State University Institute of Water Research, 334 Natural Resources Building, Michigan State University, East Lansing, MI 48224, (517)353-3742.
2. Your county extension office or directly from the Bulletin Office, 10B Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039, (517)355-0240.
3. Plan Service secretary, 217 A.W. Farrall Hall, Michigan State University, East Lansing, MI 48824-1323, (517)353-3297.

MICHIGAN STATE UNIVERSITY EXTENSION

MSU is an Affirmative-Action/Equal-Opportunity Institution. Extension programs and materials are available to all without regard to race, color, national origin, sex, disability, age or religion. ■ Issued in furtherance of Extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Gail L. Imig, extension director, Michigan State University, E. Lansing, MI 48824. ■ This information is for educational purposes only. References to commercial products or trade names does not imply endorsement by the MSU Extension or bias against those not mentioned. This bulletin becomes public property upon publication and may be printed verbatim with credit to MSU. Reprinting cannot be used to endorse or advertise a commercial product or company.
Produced by Outreach Communications and printed on recycled paper using vegetable-based inks.
New 3:94-5M-TCM-SP. Price $1.00, FILE 28.361 (Water Quality)

MICHIGAN STATE
UNIVERSITY
EXTENSION

FARM•A•SYST
Farmstead Assessment System

FAS 1

Worksheet #1

Assessing the Risk of Surface and Groundwater Contamination from

Drinking Water Well Condition

Why should I be concerned?

About 95 percent of this country's rural residents use groundwater to supply their drinking water and farmstead needs. Wells are designed to provide clean water. If improperly constructed and maintained, however, they can allow pathogens, pesticides, fertilizer, oil products or other contaminants to enter your groundwater. These contaminants can put family and livestock health at risk.

There are documented cases of well contamination from farmstead activities near drinking water wells. The condition of your well and its proximity to contamination sources determine the risk it poses to the water you drink. For example, a cracked or corroded well casing allows pathogens, nitrates, oil and pesticides to enter the well more easily. A spill of pesticides being mixed and loaded near the well could result in the contamination of your family's drinking water supply. Feedlots, animal yards, septic systems, fertilizer applications and waste storage areas could release large amounts of nitrate into your well.

Preventing well water contamination is very important. Once the groundwater supplying your well is contaminated, it is very difficult to clean up. The only options may be to treat the water, drill a new well, or obtain water from another source. Contaminants on your property can also affect your neighbors' wells, posing a serious health threat to your neighbors and serious liability questions for you.

The goal of Farm•A•Syst is to help you assess your current practices and determine how well you are protecting the groundwater that supplies your drinking water and surrounding surface water.

How will this worksheet help me protect my drinking water?

- It will take you step by step through your drinking water well condition and management practices.
- It will rank your activities according to the way they might affect the groundwater that provides your drinking water and surrounding surface waters.
- It will provide you with easy-to-understand rankings that will help you analyze the "risk level" of your drinking water well condition and management practices.
- It will help you determine which of your practices are reasonably safe and effective, and which practices might require modification to better protect water sources.

How do I complete the worksheet?

Follow the directions at the top of the chart on the next page. It should take you about 15-30 minutes to complete this worksheet and figure out your ranking.

Focus on the well that provides drinking water for your home or farm. If you have more than one drinking water well on your farmstead, fill out a worksheet for each one.

Glossary

Drinking Water Well Condition

These terms may help you make more accurate assessments when completing Worksheet #2. They may also help clarify some of the terms used in Fact Sheet #2.

Abandoned well: A well whose use has been permanently discontinued; a well which is in such disrepair that its continued use for the purpose of obtaining groundwater is impractical; a well which is a threat to groundwater resources; a well which is or may be a health or safety hazard.

Air gap: An air space (open space) between the hose or faucet and water level, representing one way to prevent backflow of liquids into a well or water supply.

Anti-backflow (anti-backsiphoning) device: A check valve or other mechanical device to prevent unwanted reverse flow of liquids back down a water supply pipe into a well.

Aquifer: Zone in which readily extractable water saturates the pores of the geologic formations.

Backflow: The unwanted reverse flow of liquids in a piping system.

Backsiphonage: Backflow caused by formation of a vacuum in a water supply pipe.

Casing: Steel or plastic pipe installed while drilling a well, to prevent collapse of the well bore hole and entrance of contaminants, and to allow placement of a pump or pumping equipment.

Cross-connection: A link or channel between pipes, wells, fixtures or tanks carrying contaminated water and those carrying potable (safe for drinking) water. Contaminated water, if at higher pressure, enters the potable water system.

Drilled wells: Wells not dug or driven, including those constructed by a combination of jetting or driving. These wells are normally 4 to 8 inches in diameter.

Driven-point (sand point) wells: Wells constructed by driving assembled lengths of pipe into the ground with percussion equipment or by hand. These wells are usually smaller in diameter (2 inches or less), less than 50 feet deep, and can be installed in areas of relatively loose soils, such as sand.

Dug wells: Large-diameter wells often constructed by hand.

Groundwater: Subsurface water in a zone of saturation.

Grout: Slurry of cement or clay used to seal the space between the outside of the well casing and the bore hole, or to seal an abandoned well.

Milligrams per liter (mg/l): The weight of a substance measured in milligrams contained in one liter. It is equivalent to 1 part per million in water measure.

Parts per million (ppm): A measurement of concentration of one unit of material dispersed in one million units of another.

Pathogens: Disease-causing organisms (bacteria, viruses, and parasites).

Water table: The upper level of groundwater in a zone of saturation. Fluctuates with climatic conditions on land surface, and with aquifer discharge and recharge rates.

Well cap (seal): A device used to cover the top of a well casing pipe.

Worksheet #1

Drinking Water Well Condition: Assessing Drinking Water Contamination Ri

1. Use a pencil. You may want to make changes.
2. For each category listed on the left that is appropriate to your farmstead, read across to the right and circle the statement that **best** describes conditions on your farmstead. (Skip and leave blank any categories that don't apply to your farmstead.)
3. Then look above the description you circled to find your "rank num (4, 3, 2 or 1) and enter that number in the blank under "your rank."
4. Directions on overall scoring appear at the end of the worksheet.
5. Allow about 15-30 minutes to complete the worksheet and figure o your risk ranking for well management practices.

	LOW RISK (rank 4)	LOW-MOD RISK (rank 3)	MOD-HIGH RISK (rank 2)	HIGH RISK (rank 1)	Y F
LOCATION					
Position of drinking water well in relation to pollution sources	Upslope from all pollution sources. No surface water runoff reaches well. Surface water diverted from well.	Upslope from or at grade with pollution sources. No surface water runoff reaches well.	Downslope from most pollution sources. Some surface water runoff may reach well.	***Settling or depression near casing. Surface water runoff from livestock yard, pesticide and fertilizer mixing area, fuel storage or farm dump reaches well.***	
Isolation distances between well and farmstead contamination sources*	Meets or exceeds all state minimum required isolation distances.	Meets most minimum isolation distances.	Meets minimum isolation distances only for sources required to be at least 50 feet from well.	***Does not meet all minimum isolation distances for sources required to be at least 50 feet from well.****	
Soil and/or subsurface potential to protect groundwater	Fine-textured soils (clay loams, silty clay) or fine textured soils (silt loam or loam). Water table or fractured bedrock deeper than 25 feet.	Fine-textured soils (clay loams, silty clay) or medium-textured soils (silt loam, loam). Water table or fractured bedrock shallower than 25 feet.	Medium- or coarse-textured soils. Water table or fractured bedrock deeper than 25 feet.	Coarse-textured soils (sands, sandy loam). Water table or fractured bedrock shallower than 25 feet.	

Boldface type: Besides representing a higher-risk choice, this practice may also violate Michigan well codes.

* See page 2 of Fact Sheet #1, *Improving Drinking Water Well Condition.*

surface, and with aquifer discharge and recharge rates.

Well cap (seal): A device used to cover the top of a well casing pipe.

2

	LOW RISK (rank 4)	LOW-MOD RISK (rank 3)	MOD-HIGH RISK (rank 2)	HIGH RISK (rank 1)	YOUR RANK
CONDITION**					
Condition of casing and well cap (seal)	No holes or cracks. Cap tightly secured. Screened vent.	No defects visible. Well vented but not screened.	No holes or cracks visible. Cap loose.	***Holes or cracks visible. Cap loose or missing. Can hear water running.***	___
Casing depth (from well record)	Casing more than 25 feet deep and extending through a confining protective layer of soil such as clay.	Casing terminates above any confining formation, but is at least 25 feet in depth. Fine-textured soils	Casing terminates above any confining formation, but is at least 25 feet in depth. Coarse-textured soils	Casing terminates less than 25 feet from the ground surface. Or no casing.	___
Casing height above land surface	More than 12 inches above grade.	***8–12 inches above grade.***	***At grade or up to 8 inches above.***	***Below grade or in pit or basement.***	___
Well age	Less than 20 years old.	21–50 years old.	51–70 years old.	More than 70 years old.	___
Well type	Drilled with grout around casing	Drilled	Driven-point (sand point)	Dug well	___
MANAGEMENT					
Backflow prevention	Anti-backflow devices installed on all faucets with hose connections. No cross-connections	Anti-backflow devices installed on some faucets with hose connections.	No anti-backflow devices. Air gap maintained.	No anti-backflow devices. Air gap not maintained. Cross-connections exist.	___
Unused well	No unused, unsealed wells.	Unused wells capped and protected.	Unused, unsealed well in field. Not capped or protected.	Unused, unsealed well at farmstead. Not capped or protected.	___
Water testing	Consistent satisfactory water quality. Bacteria, nitrate and other tests meet standards.	Occasional deviation from standards with bacteria, nitrate and other tests.	Bacteria, nitrate and other tests mostly do not meet standards.	No water tests done. Noticeable changes in color, clarity, odor or taste (after rainstorms).	___

Boldface type: Besides representing a higher-risk choice, this practice may also violate Michigan well codes.
** See page 4 of Fact Sheet #1 for minimum construction requirements.

TOTAL [ ]

Use this total to calculate risk ranking on back page of worksheet.

What do I do with these rankings?

Step 1: Begin by determining your overall well management risk ranking. Total the rankings for the categories you completed and divide by the number of categories you ranked.

______ divided by ______ equals		[ ]		Carry your answer out to one decimal place.
total of rankings	# of categories ranked	risk ranking		

3.6-4=low risk; 2.6-3.5=low to moderate risk; 1.6-2.5=moderate to high risk; 1-1.5=high risk

This ranking gives you an idea of how your well management practices **as a whole** might be affecting your drinking water. This ranking should serve only as a **very general guide, not a precise diagnosis.** Because it represents an **averaging** of many individual rankings, it can mask any **individual** rankings (such as 1's or 2's) that should be of concern. (See Step 2.)

Enter your boxed well management risk ranking on page 1 of Worksheet #12. Later you will compare this risk ranking with other farmstead management rankings. Worksheet #11 will help you identify your farmstead's site conditions (soil type, soil depth and bedrock characteristics), and Worksheet #12 will show you how these site conditions affect your risk rankings.

Step 2: Look over your rankings for individual activities:

- **Low-risk** practices (4's): ideal; should be your goal despite cost and effort
- **Low-to-moderate-risk** practices (3's): provide reasonable surface and groundwater protection
- **Moderate-to-high-risk** practices (2's): inadequate protection in many circumstances
- **High-risk** practices (1's): inadequate; pose a high risk of polluting surface and groundwater

Regardless of your overall risk ranking, any individual rankings of "1" require immediate attention. Some concerns you can take care of right away; others could be major—or costly—projects, requiring planning and prioritizing before you take action.

Find any activities that you identified as 1's and list them under "High-Risk Activities" on pages 6-7 of Worksheet #12.

Step 3: Read Fact Sheet #1, *Improving Drinking Water Well Condition*, and consider how you might modify your farmstead practices to better protect your drinking water.

FARM•A•SYST
Farmstead Assessment System

The Farmstead Assessment System in Michigan is a multiagency cooperative effort to increase awareness and encourage correction of potential water quality problems around the farmstead. The Farm•A•Syst materials are based on similar materials developed in Wisconsin and Minnesota with assistance from the United States Environmental Protection Agency, Region V.

Topics in the ***Farm•A•Syst*** series include

#1	Well Condition	#7	Manure Storage
#2	Pesticide Storage and Handling	#8	Livestock Yards Management
#3	Fertilizer Storage and Handling	#9	Silage Storage
#4	Petroleum Product Storage	#10	Milking Center Wastewater
#5	Hazardous Waste Management	#11	Site Evaluation
#6	Household Wastewater Management	#12	Overall Assessment

Local Health Department Environmental Health Offices

Allegan County	(616)673-5411
Barry-Eaton District	(517)543-2430
Bay County	(517)894-0645
Benzie County counties: Branch-Hillsdale	(616)882-4409
St. Joseph District	(517)279-9561
Calhoun County	(616)996-1241
Cass County	(616)782-7007
Central Michigan District counties: Arenac, Clare, Gladwin, Osceola, Roscommon	(517)773-5921
Chippewa County	(906)635-0413
Delta-Menominee District	(906)786-4111
Dickinson-Iron District	(906)774-1868
Gennesee County	(313)257-3603
Gd. Traverse County	(616)922-4833
Huron County	(517)269-9721
Ingham County	(517)887-4312
Ionia County	(616)527-3250
Jackson County	(517)788-4433
Kalamazoo County	(616)383-8942
Kent County	(616)774-3089
Lapeer County	(313)667-0392
Leelanau County	(616)922-4833
Lenawee County	(517)264-5201
Livingston County Luce, Mackinac & Alger	(517)546-9850
Schoolcraft District	(906)293-5107
Macomb County	(313)469-5236
Manistee-Mason District	(616)845-7381
Marquette County	(906)475-4195
Mecosta County	(616)592-0130
Midland County	(517)832-6679
Mid-Michigan District counties: Montcalm, Clinton, Gratiot	(517)831-5237
Monroe County	(313)243-7155
Muskegon County	(616)724-6208
Oakland County	(313)858-1320
Ottawa County	(616)393-5645
Saginaw County	(517)771-0830
St. Clair County	(313)987-5306
Sanilac County	(313)648-4098
Shiawassee County	(517)743-2390
Tuscola County	(517)673-8114
Van Buren County	(616)621-3143
Washtenaw County	(313)994-2492
Wayne County	(313)326-4900
Western Upper Peninsula Dist. counties: Baraga, Gogebic, Houghton, Ontonagon	(906)482-7382
District Health Department #1 counties: Crawford, Kalkaska, Missaukee, Wexford	(616)839-7167
District Health Department #2 counties: Alcona, Iosco, Ogemaw, Oscoda	(517)345-5020
District Health Department #3 counties: Antrim, Charlevoix, Emmet, Otsego	(616)547-6523
District Health Department #4 counties: Alpena, Cheboygan, Montmorency, Presque Isle	(517)356-4507
District Health Department #5 counties: Lake, Newaygo, Oceana	(616)689-7300

MICHIGAN STATE UNIVERSITY EXTENSION

MSU is an Affirmative-Action/Equal-Opportunity Institution. Extension programs and materials are available to all without regard to race, color, national origin, sex, disability, age or religion. Issued in furtherance of Extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Gail L. Imig, extension director, Michigan State University, E. Lansing, MI 48824. ■ This information is for educational purposes only. References to commercial products or trade names does not imply endorsement by the MSU Extension or bias against those not mentioned. This bulletin becomes public property upon publication and may be printed verbatim with credit to MSU. Reprinting cannot be used to endorse or advertise a commercial product or company.

Produced by Outreach Communications and printed on recycled paper using vegetable-based inks.

New 3:94-5M-TCM-SP. Price $1.00, FILE 28.361 (Water Quality)

GENERALLY ACCEPTED AGRICULTURAL AND MANAGEMENT PRACTICES FOR MANURE MANAGEMENT AND UTILIZATION

ADOPTED BY
MICHIGAN AGRICULTURE COMMISSION
LANSING, MICHIGAN

JUNE 1997

In the event of an agricultural pollution emergency such as a chemical/fertilizer spill, manure lagoon breach, etc., the Michigan Department of Agriculture and/or the Michigan Department of Natural Resources should be contacted at the following emergency telephone numbers:

Michigan Department of Agriculture: 800/405-0101
Michigan Department of Natural Resources: 800/292-4706

If there is not an emergency, but you have questions on the Michigan Right To Farm Act or items concerning a farm operation, please contact the Michigan Department of Agriculture, Right To Farm Program, P. O. Box 30017, Lansing, Michigan 48909, (517) 241-0236.

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	RUNOFF CONTROL AND WASTEWATER MANAGEMENT	2
	Storage Ponds for Runoff Control	3
	Land Application of Runoff	3
	Infiltration Areas	3
	Pasture Systems	4
III.	ODOR MANAGEMENT	5
	Feed Materials	6
	Manure	6
	Stacked Solid Manure	7
	Outside Lots	8
	Manure Storages and Acceptable Covers	8
	Manure Treatment Systems	9
	Treatment Lagoons and Ponds	9
	Composting	10
	Methane Digestors	11
	Application of Manure to Land	11
IV.	CONSTRUCTION DESIGN FOR MANURE PONDS AND LAGOONS	12
	Construction Design	12
	Seepage Control for Earthen Basins	12
V.	MANURE APPLICATION TO LAND	12
	Soil Fertility Testing	13
	Fertilizer Recommendations	13
	Manure Analysis	14
	Manure Nutrient Loadings	14
	Manure Nutrient Loadings on Pasture Land	16
	Method of Manure Application	17
	Timing of Manure Application	19
	Management of Manure Applications to Land	19
VI.	REFERENCES	26

Amount Printed: 500 Total Cost: $586.10 Cost per Copy: $1.17

Section I. INTRODUCTION

Like all other segments of our economy, agriculture has changed significantly during the past fifty years and will continue to change in the future. The trend toward larger facilities (the overwhelming majority being family owned) has resulted in farm operations being more capital intensive and less labor intensive. Larger farm size offers marketing advantages and generally lower unit cost of production compared to smaller-sized operations. However, increased numbers of animals in livestock operations bring new management challenges dealing with manure and odors generated.

Animal agriculture in Michigan must have the flexibility and opportunity to change agricultural enterprises and to adopt new technology as it becomes available to remain viable and competitive in the market place. If a healthy, growing livestock industry in Michigan is to be assured, efforts must continue to address the concerns of livestock producers and their neighbors, particularly in two areas: (1) producers who use generally accepted manure management practices in their livestock operations should be protected from harassment and nuisance complaints and (2) persons living near livestock operations which do not follow generally accepted agricultural and management practices need to have concerns addressed when odor nuisance or water quality problems occur.

Technical recommendations for livestock manure and wastewater management practices have been consolidated in two major sources of information. These are the Natural Resources Conservation Service (NRCS) Field Office Technical Guide, or (NRCS-FOTG) (see USDA-NRCS in the References section) and the Midwest Plan Service Livestock Waste Facilities Handbook, or MWPS-18 (Midwest Plan Service, 1985). Each has published waste management specifications and management guides that are a consensus of agricultural engineers and professionals working in the waste management field. Because these documents are dynamic and periodically reviewed and updated, they contain current state-of-knowledge guidance on generally accepted management practices for livestock operations which will not be duplicated here. These documents provide more in-depth information about the manure management practices which are presented in this document. Other documents that specifically relate to recommendations contained in this paper are the National Pork Industry Handbook and Fertilizer Recommendations for Field Crops (Christenson et al, 1992) and Vegetable Crops (Warncke et al, 1992) in Michigan each available from Michigan State University Extension (MSU-E).

A manure management system is a coordinated combination of structural components and management practices necessary to control and use manure and other by-products of livestock production in a manner that minimizes adverse impacts on the environment. A manure management system plan briefly describes the manure and lists the associated components and practices. The system plan does not include any detailed designs or construction drawings. A successful manure management system is the result of sound planning, design, construction, operation and maintenance.

The recommendations described in the above references and these practices reflect the best judgment of professional livestock producers and professionals who assist livestock producers with designing and managing their operations to be good stewards of the environment. An important aspect of generally accepted agricultural and management practices requires that the producer manage the manure and wastewater handling system in a manner that minimizes any negative effect on the environment. This requires that the producer consider the total management aspects of the manure handling system rather than only parts of the system. A good record keeping system helps the producer record the past history of manure management, so that future management of the system will be enhanced and can provide a factual basis for documenting sound environmental stewardship. The generally accepted agricultural and management practices which follow are those that should be incorporated in most situations. However, adverse weather conditions may, in part, prevent responsible livestock operators from adhering to these practices for a short duration of time.

Also, no two livestock operations in Michigan can be expected to be the same due to the large number of variables which, together, determine the nature of a particular operation. These variables include such items as the kind and number of livestock, type of housing and manure handling system, feed rations used, type of manure application equipment, soil types and landscape features on the farm, crops grown, etc. These manure management practices are reasonable and accomplishable for the majority of livestock producers without creating a competitive disadvantage to the Michigan livestock industry.

Section II. RUNOFF CONTROL AND WASTEWATER MANAGEMENT

Rainfall and snowfall-induced runoff from uncovered livestock facilities requires control to protect neighboring land areas and prevent direct discharge to surface waters. Livestock facilities which require runoff control include all holding areas where livestock density precludes sustaining vegetative growth on the soil surface.

1. **Facilities may be paved, partially paved around waterers and feed bunks, or unpaved.**

2. **Runoff control is required for any facility if runoff from the lot leaves the owner's own property. This would include runoff to a neighbor's land, a roadside ditch, a drain ditch, stream or lake.**

Storage Ponds for Runoff Control

Runoff control can be achieved by providing facilities to collect and store the runoff for later application to cropland. The quantity of water to be handled in the runoff control facility can be minimized by diverting roof runoff and offsite runoff away from livestock areas to a drainage system independent of the manure management system.

3. Runoff storage ponds should be designed dependent upon the utilization plan, plus contain the runoff from the maximum 25-year, 24-hour storm event rainfall for the area. Storage ponds must be constructed to reduce seepage loss to acceptable levels.

The NRCS-FOTG or MWPS-18 can be consulted for detailed design information. See Section IV "Construction Design for Manure Ponds and Lagoons" for more information.

Land Application of Runoff

Equipment must be available for land application of stored runoff water. Land application should be done when the soil is dry enough to accept the water.

4. Application rates should be determined based upon the ability of the soil to accept and store the water and the ability of plants growing in the application area to utilize nutrients in the near term. Land application should be done when the water can be beneficially used by a growing crop. Sprinkler irrigation methods will provide uniform application of liquid with minimum labor requirements. Directing lot runoff through a structure for settling solids can reduce odor from the liquid during storage and application to the land (see NRCS-FOTG & MWPS-18).

SEE SECTION III FOR ODOR MANAGEMENT PRACTICES.

Infiltration Areas

5. An alternative to a storage pond is a structure for settling solids and an infiltration area (or vegetative filter) for handling lot runoff. The vegetated area may be either a long, grassed, slightly sloping channel, or a broad, flat area with little or no slope surrounded by a berm or dike. All outside surface water should be excluded from the infiltration area so that the only water applied is lot runoff and direct precipitation.

Vegetation should be maintained and harvested at least once per year to prevent excessive nutrient buildup in the soil of the infiltration area.

Design information about infiltration areas (such as sizing, establishment, and maintenance) is available in the NRCS-FOTG, MWPS-18, or the Pork Industry Handbook (MSU Extension Bulletin E-1132 by Vanderholm and Nye, 1987). These systems are not practical for every situation.

Pasture Systems

Pasture land is land that is primarily used for the production of forage upon which livestock graze. Pasture land is characterized by a predominance of vegetation consisting of desirable forage species (see Moline et al, 1991; Moline and Plummer, 1991a, 1991b). Sites such as loafing areas, confinement areas or feedlots which have excessive livestock densities that preclude a predominance of desirable forage species are not considered pasture land.

6. **Stocking densities and management systems should be employed which ensure that desirable forage species are present with an intensity of stand sufficient to slow the movement of runoff water and control soil erosion and movement of manure nutrients from the pasture land (NRCS-FOTG).**

7. **Livestock should be excluded from actual contact with streams or water courses except for controlled crossings and accesses for water (NRCS-FOTG).**

As authorized by the Riparian Doctrine, producers are entitled to utilize surface waters traversing their property. However, this use is limited to activities which do not result in water quality degradation. The goal for controlling livestock access to surface waters is to prevent water quality degradation. Livestock impact water quality by the erosion of sediment and nutrients from stream banks and by the direct deposition of manure nutrients, organic matter and pathogens.

Direct deposition is effectively prevented by restricting livestock to controlled access locations. Banks are effectively stabilized by maintaining vegetation or as in the case of controlled watering accesses and crossings, stream banks and beds may be stabilized with appropriate protective cover such as concrete, rocks, crushed rock, gravel or other suitable cover. In addition to addressing environmental and public health aspects, controlling livestock access to surface water and providing alternate drinking water sources may improve herd health by reducing exposure to water and soil borne pathogens.

8. **Runoff from pasture feeding and watering areas should travel through a vegetated area of at least 66 feet before it travels into a surface water course.**

9. **Milk parlor and milk house wastewater shall be managed in a manner to prevent direct discharge into surface water.**

Section III. ODOR MANAGEMENT

Odor perception is a subjective response to what people detect, through their sense of smell, in the air they breathe. While there is no scientific evidence that odorous gases that escape from livestock operations are toxic at the concentrations experienced by neighbors, they can become an annoyance or a nuisance to neighbors.

1. **Livestock producers should plan, design, construct and manage their operations in a manner that minimizes odor impacts upon neighbors.**

The goal for effective odor management is to reduce the frequency, intensity, duration, and offensiveness of odors, and to manage the operation in a way that tends to create a positive attitude toward the operation. Because of the subjective nature of human responses to certain odors, recommendations for appropriate technology and management practices is not an exact science. The recommendations in this section represent the best professional judgement available.

The proximity of livestock operations to neighbors and populated areas is usually the most critical factor in determining the level of technology and management needed to minimize odor impacts upon neighbors. Therefore, site selection is an important factor in minimizing odor impacts for and upon neighbors. The more remote the livestock operation, the better the likelihood that odors will not become an annoyance for neighbors; and therefore a lower level of technology and management will adequately manage odors at the livestock facility. However, the distance which a livestock operation should be located from neighboring land uses to effectively control odors is not easily established. No scientific basis exists for determining such distances quantitatively, nor is there any commonly held community consensus in Michigan at this time for what these distances should be.

The principles, upon which the most common and effective techniques for odor control are based, include: (1) reducing the formation of odor causing gases and (2) reducing the release of odorous gases into the atmosphere. The degree to which these principles can be applied to the various odor sources found in livestock operations depends on the level of technology and management which can be utilized. The following subsections discuss the most common and predominant odor sources which are feed materials and manure.

Feed Materials

Using fermented feeds such as corn or hay silage is an acceptable animal husbandry practice throughout Michigan for dairy and beef cattle, horses, sheep and goats. Some odors associated with the storage and feeding of these materials are normal for these livestock operations.

2. **The odor of these fermented feed materials such as corn or hay silage can be minimized by harvesting and storing them at an appropriate dry matter content (generally greater than 33 percent dry matter).**

The practice of feeding food processing by-products; e.g. cull potato, dairy whey, pastry by-products, sugar beet pulp and sweet corn husks, to livestock is a generally accepted practice. This is especially common where livestock operations exist within close proximity to food processing facilities. Using these materials for livestock feed diverts useful by-products (that can pose a substantial load on local sewage treatment plants and a major problem for food processing plants) from the waste stream and converts them into a valuable resource. Properly handled in a livestock operation, these feeds pose no threat to the environment. These products may require special feed handling systems and may substantially increase or change the manure generated by the animals to which they are fed. Some of these by-products, and the manure produced from their consumption by livestock, can generate rather offensive and intense odors. In these situations, feed handling and manure management practices should be used to control and minimize the frequency and duration of such odors. Human garbage can only be fed under permit in Michigan. (P.A. 173 of 953 as amended).

Manure

Fresh manure is usually considered to be less odorous than anaerobically decomposing manure. Fresh manure emits ammonia but in general is not accompanied by other products of decomposition which contribute to odors.

3. **Frequent (daily or every few days) removal of manure from animal space coupled with storage or stacking and followed by application to crop land at agronomic rates is an acceptable practice throughout Michigan.**

Manure odors are generally those associated with the anaerobic (in the absence of oxygen) decomposition of organic material by microorganisms. The intensity of odors depends upon the biological reactions that take place within the material, the nature of the excreted material (which is dependent upon the species of animal and its diet), the type of bedding material used and the surface area of the odor source. Sources of decomposing manure can include stacked solid manure, outside lots when manure is allowed to accumulate, uncovered manure storages, manure treatment systems, and land application areas.

Stacked Solid Manure

4. **Solid manure that may contain bedding materials and/or is dried sufficiently, such as that from poultry, cattle, sheep, swine, horse and fur-bearing animal facilities can be temporarily stacked outside the livestock building.**

Odors from such manure storages are minimal except when disturbed as for land application. Provisions to control leachate and runoff from surrounding areas need to be in place to protect groundwater and surface waters. (See Section III and Chapter 6 of MWPS-18 for alternative design concepts and details). Livestock operations may utilize a variety of bedding materials as part of their manure management system. The use of straw, hay, sand, sawdust, wood shavings, waste paper, or other suitable materials, either individually or in combination, as livestock or poultry bedding is a common generally accepted practice. Bedding materials should be of an appropriate size to maximize absorptive properties and to prevent blowing and dispersion when subsequently applied to crop land. Waxed paper, aluminum foil and plastics should not be with bedding material.

Outside Lots

Outside open lots with or without shelters are acceptable for raising livestock in Michigan. In these systems, manure is deposited over a relatively large surface area per animal (compared to a roofed confinement system for example) and begins to decompose in place. The soil compaction that occurs on outside lots limits movement of water and nutrients from the lot toward groundwater. Odor impacts can be mitigated by keeping the lot surface as dry as possible, thus limiting the microbiological activity that generates odors. Providing adequate lot slopes, lot orientation that takes advantage of sunlight, diverting up-slope runoff water away from the lot, and using recommended stocking densities will enhance drying of the lot surface. The MWPS-18, Pork Industry Handbook, and Michigan Beef Production Notebook provide details and alternatives to accomplish this. Most feed additives and odor control chemicals applied to feedlot surfaces have not been demonstrated to be effective in reducing odors from feedlots in humid areas such as Michigan.

In spite of good facilities design and management, odors may be generated from outside livestock lot systems. The intensity of these odors is somewhat proportional to the surface area of the odor producing sources. The frequency of impact and offensiveness to neighbors is often related to the distance to neighbors' houses and their location relative to prevailing winds.

5. **New outside lot systems should not be located in close proximity to residences and other odor-sensitive land uses. They should not be located uphill along a confining valley leading toward residences. New residences or other sensitive land uses should not be located within close proximity to outside lot facilities.**

<u>Manure Storages and Acceptable Covers</u>

6. **Use covered manure tanks if technically and economically feasible.**

7. **Where possible, do not locate manure storage in close proximity to residential areas.**

The primary objective of storage is to temporarily store the manure before application to land. However, some biological activity occurs in these storages and the gases generated can be a source of odors. If storage facilities are left uncovered, the potential for manure odors to be carried away by air movement will increase. Various types of covers can be used to prevent wind driven air from coming into direct contact with a liquid manure surface and incorporating odors.

Acceptable covers that can retard odor escape from manure storages include the following:

a) **Natural fibrous mats similar to those which develop on liquid manure storages receiving manure from beef and dairy cattle fed a high roughage diet.**

b) **Slotted flooring or other underbuilding tanks. Ventilation must be provided in the building to prevent accumulation of noxious and flammable gases.**

c) **A flexible plastic or similar material that covers the liquid surface and is of such strength, anchorage and design that the covering will not tear or pull loose when subjected to normal winds that have an average recurrence interval of 25 years. Gas escape**

ports should be provided which allow any gas that may evolve to escape.

d) **A solid covering such as concrete, wood, plastic or similar materials that covers the entire liquid surface and is of such strength, anchorage and design that they will withstand winds and expected vertical loads. Adequate air exchange should be provided which will prevent the occurrence of explosive concentrations of flammable gases.**

Manure Treatment Systems

A biological treatment system is designed to convert organic matter (feed, bedding, manure) in animal wastes to more stable end products. Anaerobic processes occur without free oxygen and liquefy or degrade high BOD (biochemical oxygen demand) wastes. They can decompose more organic matter per unit volume than aerobic treatment processes. Aerobic processes require free oxygen and are generally considered uneconomical for livestock operations. They are helpful in reducing odor. Facultative microorganisms can function either anaerobically or aerobically, depending on their environment. Extreme environmental changes alter microbial activity. When microorganisms are stressed by the environment, waste treatment processes can malfunction and odors may become more intense.

Treatment Lagoons and Storage Ponds

Anaerobic treatment lagoons are generally earthen basins containing diluted manure and are designed to provide degradation of the organic material. Well-designed and managed, anaerobic lagoons can be short-term odor sources. The occurrence of purple sulfur fixing bacteria can significantly reduce odors from an anaerobic treatment lagoon. The intensity of odors is usually greatest during the early spring and occasionally in the fall.

Aerobic treatment of manure liquids can be accomplished by natural or mechanical aeration. In a naturally-aerated system, such as a facultative oxidation pond, an aquatic environment occurs in which photosyntheses from algae and surface aeration from the atmosphere provide an aerobic zone in the upper regions of the pond. A transition zone occurs below this aerobic zone that has a limited amount of oxygen. This is the facultative zone where bacteria can live either with or without oxygen. At the bottom, there may be a sludge layer that is anaerobic. The processes that occur in the aerobic zone have a low odor potential. The odorous compounds that are created in the facultative and anaerobic zones are converted to low odor forms in the aerobic zone. For a naturally-aerated system to function properly, design specifications and quantities of manure solids to be treated must be closely followed.

An aerobic lagoon should be loaded at a rate no higher than 44 pounds of ultimate BOD day/acre. The material in the pond should be dilute enough to allow light to penetrate 3 to 4 feet into the water. The lagoon should be a minimum of 4 feet deep to prevent rooted vegetation from growing from the bottom of the lagoon, and may be deeper to allow for accumulation of sludge.

Mechanically aerated systems can be used to treat animal manures to control odors, decompose organic material, remove nitrogen, conserve nitrogen or a combination of these functions. When adequate oxygen is supplied, a community of aerobic bacteria grow that produce materials with low odor potential. Alternative treatment systems to accomplish mechanical aeration include facultative lagoons, oxidation ditches, or completely-mixed lagoons.

Effluent from treatment lagoons and storage ponds should be land applied to avoid long-term and extensive ponding and to utilize manure nutrients at agronomic rates (see Section V). Construction design for treatment lagoons and storage ponds should conform to the recommendations in Section IV.

Composting

Composting is a self-heating process carried on by bacteria, actinomycetes and fungi that decompose organic material in the presence of oxygen. Composting of organic material including livestock manures can result in a rather stable end product that does not support extensive microbial or insect activity, if the process and systems are properly designed and managed. The potential for odors during the composting process depends upon the moisture content of the organic material, the carbon-nitrogen ratio, the presence of adequate nutrients, the absence of toxic levels of materials that can limit microbial growth, and adequate porosity to allow diffusion of oxygen into the organic material for aerobic decomposition of the organic material. Stability of the end product and its potential to produce nuisance odors, and/or be a breeding area for flies, depends upon the degree of organic material decomposition and the final moisture content. Additional information and guidance about alternatives for composting manures are available in the "On-Farm Composting Handbook" (Rynk, 1992).

The occurrence of leachate from the composting material can be minimized by controlling the initial moisture content of the composting mixture to less than 70% and controlling water additions to the composting material from rainfall. Either a fleece blanket or a roofed structure can be used as a cover to control rainfall additions or leachate from composting windows. If the composting process is conducted without a cover, provisions must be made to collect the surface runoff and either be temporarily stored (see Section IV) and applied to land (see Section V), added to composting material for moisture control during the composting process or applied to grassed infiltration areas (see Section II).

A fleece blanket is a non-woven textile material made from synthetic fibers such as polypropylene. The non-woven texture of a fleece blanket prevents rainfall from penetrating into the composting material, but allows the necessary exchange of carbon dioxide and oxygen.

Methane Digestors

Methane can be produced from animal wastes by anaerobic digestion. This process converts the biodegradable organic portion of animal wastes into biogas (a combination of methane and carbon dioxide). The remaining semi-solid is relatively odor free but still contains all the nitrogen, phosphorus, and potassium originally present in the animal manure, although some of the nitrogen can be lost after storage in a holding pond.

Anaerobic digestion is a stable and reliable process, as long as the digester is loaded daily with a uniform quantity of waste, digestor temperature does not fluctuate widely, and antibiotics in the waste do not slow biological activity.

Major problems with digestors include manure handling -- pumping, grinding, mixing, and screening miscellaneous debris. Gas leakage (methane is explosive at 5%-15% in air) and pipe and valve corrosion have also been problems. To reduce these problems, obtain competent engineering design and purchase quality materials.

Application of Manure to Land

The following list of practices may be used to reduce odor in the application of manure to land. Appropriate implementation will help reduce complaints of odors.

8. **Avoid spreading when the wind is blowing toward populated areas.**

9. **Avoid spreading on weekends/holidays when people are likely to be engaged in nearby outdoor and recreational activities.**

10. **Spread in the morning when air begins to warm and is rising, rather than in late afternoon.**

11. **Use available weather information to best advantage. Turbulent breezes will dissipate and dilute odors. Hot and humid weather tends to concentrate and intensify odors, particularly in the absence of breezes.**

12. **Take advantage of natural vegetation barriers, such as woodlots or windbreaks, to help filter and dissipate odors.**

13. **Establish vegetated air filters by planting conifers and shrubs as windbreaks and visual screens between cropland and residential developments.**

14. **Incorporate manure into soil during, or as soon as possible after, application. This can be done by (a) soil injection or (b) incorporation within 48 hours after application. However, incorporation may not be feasible where manures are applied to pastures or forage crops, such as alfalfa, or where no-till practices are used (see Section V).**

Irrigation of manure to land can be an effective land application method for delivering manure to land in a short period of time without the potential damage to soil structure that can occur with other methods. However, the process can be odorous for a short period of time.

Section IV. CONSTRUCTION DESIGN FOR MANURE PONDS AND LAGOONS

<u>Construction Design</u>

1. **Construction design for manure storage and treatment facilities should meet specifications and guidelines found in the NRCS-FOTG. Additional publications that can be used are the National Pork Industry Handbook fact sheets E-1341 (Sweeten et al, 1981) and E-1399 (Melvin et al, 1987) from MSU Extension and the Concrete Manure Storages Handbook, (MWPS-36).**

<u>Seepage Control for Earthen Basins</u>

2. **To protect groundwater from possible contamination, utilize liners that meet specifications and guidelines in the NRCS-FOTG. Liners include natural existing soil (Barrington and Jutras, 1985; Barrington et al, 1987a, 1987b), bentonite or similar high swell clay materials, compacted earthen liners, and flexible membranes.**

Section V. MANURE APPLICATION TO LAND

One of the best uses of animal manure is as a fertilizer for crop production. Recycling plant nutrients from the crop to animals and back to the soil for growth of crops again is an age-old tradition. Depending on the species of animal, 70-80% of the nitrogen

(N), 60-85% of the phosphorus (P), and 80-90% of the potassium (K) fed to animals as feed will be excreted in the manure and potentially available for recycling to soils.

Livestock operations can generate large amounts of manure and increase the challenge of recycling manure nutrients for crop production. Good management is the key to ensure that the emphasis is on manure utilization rather than on waste disposal. Utilizing manure nutrients to supply the needs of crops and avoiding excessive loadings achieves two desirable goals. First, efficient use of manure nutrients for crop production will accrue economic benefits by reducing the amounts of commercial fertilizers needed. Second, water quality concerns for potential contamination of surface waters and groundwater can best be addressed when nutrients are applied at agronomic rates.

The following management practices are suggested for livestock producers to help them achieve the type of management that will accomplish these two goals. However, adverse weather conditions may, in part, prevent responsible livestock producers from adhering to these practices for a short duration of time. In addition to effective nutrient management and water quality protection, applying manure to land warrants close attention to management practices so potential odor problems can be minimized or avoided. Section III contains odor control measures which should be implemented as part of the land application program.

Soil Fertility Testing

1. **All fields should be sampled at least every three years, and the soils tested to determine where manure nutrients can best be utilized.**

One goal of a well-managed land application program is to utilize soil testing and fertilizer recommendations as a guide for applying manures. This will allow as much of the manure nutrients as possible to be used for supplying crop nutrient requirements; then any additional nutrients needed can be provided by commercial fertilizers. Therefore, soil testing and manure analysis information can assist the producer in using manure nutrients for the greatest economic benefit. Additional information on soil sampling and soil testing can be found in MSU Extension (MSU-E) bulletins (Christenson et al, 1992; Meints and Robertson, 1983; Warncke, 1988; and Warncke et al, 1992).

Fertilizer Recommendations

2. **Use fertilizer recommendations, consistent with those of Michigan State University, to determine the total nutrient needs for crops to be grown on each field that could have manure applied.**

Fertilizer recommendations made by MSU-E are based on the soil fertility test, soil texture, crop to be grown, a realistic yield goal (average for past 3-5 years), and past crop management. (See Christenson et al, 1992; Vitosh, 1996; Vitosh et al, 1995; and Warncke et al, 1992.) Fertilizer recommendations can then be utilized by the livestock producer to help identify on which fields manure nutrients will have the greatest value in reducing the amounts of commercial fertilizers needed, thereby returning the greatest economic benefit.

Manure Analysis

3. **To determine the nutrient content of manure, analyze it for percent dry matter (solids), ammonium N (NH_4-N), and total N, P and K.**

Several factors which will determine the nutrient content of manures prior to land application are: (a) type of animal species, (b) composition of the feed ration, (c) amount of feed, bedding, and/or water added to manure, (d) method of manure collection and storage, and (e) climate. Because of the large variation in manure nutrient content due to these factors, it is not advisable to use average nutrient contents provided in publications when determining manure nutrient loadings for crop production. The best way to determine the nutrient content of manure and provide farm-specific information is to obtain a representative sample(s) of that manure and then have a laboratory analyze the sample(s). In order to establish "baseline" information about the nutrient content of each manure type on the farm, sample and test manures for at least a two year period. MSU-E can provide information on collecting representative manure samples and where to send samples for analysis.

Manure Nutrient Loadings

4. **The agronomic (fertilizer) rate of N recommended for crops (consistent with Michigan State University N fertilizer recommendation), should not be exceeded by the amount of available N added, either by manure applied or by manure plus fertilizer N applied and/or other sources. The available N per ton or per 1000 gallons of manure should be determined by using a manure analysis and the appropriate mineralization factors (see Manure Management Sheet #2, MSU-E Bulletin E-2344 by Jacobs et al, 1992b) for organic N released during the first growing season following application and the three succeeding growing seasons.**

Excessive manure applications to soils can: (a) result in excess nitrate-N (NO_3-N) not being used by plants or the soil biology and increase the risk of NO_3-N being leached down through the soil and into groundwater; (b) cause P to accumulate in the upper soil profile and increase the risk of contaminating surface waters with P where runoff/erosion occurs; and (c) create nutrient imbalances in soils which may cause poor plant growth or animal nutrition disorders for grazing livestock. The greatest water quality concern from excessive manure loadings, where soil erosion and runoff is controlled, is NO_3-N losses to groundwater. Therefore, the agronomic fertilizer N recommendation should never be exceeded.

The availability of N in manure for plant uptake will not be the same as highly soluble, fertilizer N. Therefore, total manure N cannot be substituted for those in fertilizers on a pound-for-pound basis, because a portion of the N is present in manure organic matter which must be decomposed, before mineral (inorganic) forms of N are available for plant uptake.

The rate of decomposition (or mineralization) of manure organic matter will be less than 100% during the first year and will vary depending on the type of manure and the method of manure handling. Therefore, in order to estimate how much of the total manure N in each ton or 1000 gallons of manure will be available for crops (and a credit against the N fertilizer recommendation), some calculations are needed. The total N and NH_4-N content from the manure analysis can be used with the appropriate mineralization factors to calculate this value. Management tools to assist with these calculations include (a) Manure Management Sheet #2, MSU-E Bulletin E-2344 (Jacobs et al., 1992b), (b) bulletins MM-2 and MM-3 from the Animal Manure Management Resource Notebook (Jacobs, 1995a, 1995b), or (c) the MSU Nutrient Management computer program (MacKellar et al, 1996).

In addition to the amount of plant available N provided during the first year after a manure application, more N will be released from the residual organic matter not decomposed the first year. This additional decomposition and release of N will occur during the second, third and fourth years and should be estimated and included as a N credit against the fertilizer recommendation to avoid excessive N additions to the soil-plant system. At the present time, organic N released (mineralized) during the second, third and fourth cropping years is estimated to be 50%, 25%, and 12.5%, respectively, of the amount released the first year. To assist with the calculations for estimating this carryover N from previous manure applications, the same management tools listed in the preceding paragraph can be used.

5. **If the soil test level for P reaches 150 lb/acre (Bray P1), manure applications should be reduced to a rate where manure P added does not exceed the P removed by the harvested crop. (If this manure rate is impractical due to manure spreading equipment or crop production management, a quantity of manure P equal to the amount of P removed by two crop years can be used for the first crop year, if no additional fertilizer or manure P is applied**

for the second crop year.) If the (Bray P1) test reaches 300 lb/acre or higher, manure applications should be discontinued until nutrient harvest by crops reduces P test levels to less than 300 lb/acre. To protect surface water quality against discharges of P, adequate soil and water conservation practices should be used to control runoff and erosion from fields where manure is applied.

While the availability of N in manure may be considerably less than 100%, the availability of P and K in manure has normally been considered to be close to 100%. Periodic soil testing can be used to monitor the contribution to soil fertility levels, made by manure P and K, but soil tests have not been very effective to determine the amount of N a soil can provide for plant growth.

When manures are applied to supply all the N needs of crops, the P needs of crops will usually be exceeded, and soil test levels for P will increase over time. If soil test P levels reach 300 lb/acre (Bray P1), the risk of losing soluble P and sediment-bound P by runoff and erosion (i.e., nonpoint source pollution) increases. Therefore, adequate soil and water conservation practices to control runoff and erosion should be implemented. For example, conservation tillage can enhance infiltration of water into soils, thereby reducing runoff, soil erosion, and associated P loadings to surface waters. Nevertheless, if soil test P levels reach 300 lb/acre (Bray P1), no more manure (or fertilizer) P should be applied until nutrient harvest by crops reduces P test levels to less than 300 lb/acre.

To avoid reaching the 300 lb/acre (Bray P1) test level, manure application rates should be reduced to provide the P needs of crops rather than providing all of the N needs of crops and adding excess P. Therefore, if the soil test level for P reaches 150 lb/acre (Bray P1), manure applications should be reduced to a rate where manure P added does not exceed the P removed by the harvested crop. The quantity of manure P_2O_5[1] that should be added can be estimated from Tables 1 and 2, using a realistic yield goal for the crop to be grown. For example, if a yield of 120 bu/acre for corn grain is anticipated, the amount of manure P_2O_5 added to this field should be limited to no more than 42 lb/acre (120 bu/acre X 0.35 lb P_2O_5/bu nutrient removal rate).

If the rate of manure application based on P removal by the crop is lower than the manure spreader can physically apply or is not realistic when planning for crop production management, the rate of manure application can be increased. The higher rate of manure application can be the P removal for two crop years, as long as this rate does not exceed the N fertilizer recommendation for the first crop grown after the manure is applied. If this higher rate of manure application is used, no fertilizer or manure P should be applied the following crop year.

---

[1] Fertilizer P recommendations are given in, and fertilizer P is sold as, pounds of phosphate (P_2O_5).

Manure Nutrient Loadings on Pasture Land

In pasture systems where the grazed forage is the sole feed source for livestock, nutrients from manure deposited by the grazing livestock will not exceed the nutrient requirement of the pasture forage. These types of pasture systems may require supplemental nutrient applications to maintain forage quality and growth.

Pasture systems utilizing supplemental feed (e.g., swine farrow/finish) often result in manure nutrient deposition in excess of pasture forage requirements. Therefore, nutrient management with rotation to harvested forage or row crops is necessary. Available nutrient deposition should be quantified based on livestock density and nutrient mineralization factors. Manure nutrient loadings should be based on the rotational crop nutrient requirement consistent with those recommended by Michigan State University, as noted above.

Method of Manure Application

6. **Manures should be uniformly applied to soils. The amount of manure applied per acre (gallons/acre or tons/acre) should be known, so manure nutrients can be effectively managed.**

As is true with fertilizers, lime and pesticides, animal manures should be spread uniformly for best results in crop production. Also, in order to know the quantity of manure nutrients applied, the amount of manure applied must be known. Determining the gallons/acre or tons/acre applied by manure spreading equipment can be accomplished by a variety of ways. One method is to measure the area of land covered by one manure spreader load or one tank wagon of manure. A second method is to record the total number of spreader loads or tank wagons applied to a field of known acreage. With either approach, the capacity of the spreader (in tons) or the tank wagon (in gallons) must be known, and some way to vary the rate of application will be needed such as adjusting the speed of travel or changing the discharge settings on the manure spreading equipment. Guidance is available from the MSU-E to help determine the rates of manure application that a livestock producer's equipment can deliver.

Incorporating manure immediately (i.e., within 48 hours following surface application) will minimize odors and ammonia (NH_3) loss. When manures are surface applied, available N can be lost by volatilization of NH_3. These losses will increase with time and temperature and will be further increased by higher wind speeds and lower humidities. Therefore, injecting manures directly into the soil or immediately incorporating surface-applied manure will minimize NH_3 volatilization losses and provide the greatest N value for crop production. Table 3 shows potential volatilization losses when manures are applied to the soil and allowed to dry on the surface before incorporation. When dilute effluents from lagoons that contain low solids (<2%) are applied/irrigated at rates that do

Manure Nutrient Loadings on Pasture Land

In pasture systems where the grazed forage is the sole feed source for livestock, nutrients from manure deposited by the grazing livestock will not exceed the nutrient requirement of the pasture forage. These types of pasture systems may require supplemental nutrient applications to maintain forage quality and growth.

Pasture systems utilizing supplemental feed (e.g., swine farrow/finish) often result in manure nutrient deposition in excess of pasture forage requirements. Therefore, nutrient management with rotation to harvested forage or row crops is necessary. Available nutrient deposition should be quantified based on livestock density and nutrient mineralization factors. Manure nutrient loadings should be based on the rotational crop nutrient requirement consistent with those recommended by Michigan State University, as noted above.

Method of Manure Application

6. Manures should be uniformly applied to soils. The amount of manure applied per acre (gallons/acre or tons/acre) should be known, so manure nutrients can be effectively managed.

As is true with fertilizers, lime and pesticides, animal manures should be spread uniformly for best results in crop production. Also, in order to know the quantity of manure nutrients applied, the amount of manure applied must be known. Determining the gallons/acre or tons/acre applied by manure spreading equipment can be accomplished by a variety of ways. One method is to measure the area of land covered by one manure spreader load or one tank wagon of manure. A second method is to record the total number of spreader loads or tank wagons applied to a field of known acreage. With either approach, the capacity of the spreader (in tons) or the tank wagon (in gallons) must be known, and some way to vary the rate of application will be needed such as adjusting the speed of travel or changing the discharge settings on the manure spreading equipment. Guidance is available from the MSU-E to help determine the rates of manure application that a livestock producer's equipment can deliver.

Incorporating manure immediately (i.e., within 48 hours following surface application) will minimize odors and ammonia (NH_3) loss. When manures are surface applied, available N can be lost by volatilization of NH_3. These losses will increase with time and temperature and will be further increased by higher wind speeds and lower humidities. Therefore, injecting manures directly into the soil or immediately incorporating surface-applied manure will minimize NH_3 volatilization losses and provide the greatest N value for crop production. Table 3 shows potential volatilization losses when manures are applied to the soil and allowed to dry on the surface before incorporation. When dilute effluents from lagoons that contain low solids (<2%) are applied/irrigated at rates that do not cause ponding, most of the NH_4-N will likely be absorbed into the soil and retained for additional information (see Jacobs, 1995a, 1995b, or Jacobs et al, 1992). Surface application of manures via irrigation or other methods without incorporation provides alternatives to producers using reduced or no-till soil management, supplemental irrigation of crops, application to land with established pasture or other forages, etc.

7. **Manures should not be applied to soils within 150 feet of surface waters or to areas subject to flooding unless: (a) manures are injected or surface-applied with immediate incorporation (i.e., within 48 hours after application) and/or (b) conservation practices are used to protect against runoff and erosion losses to surface waters.**

8. **Liquid manures should be applied in a manner that will not result in ponding or runoff to adjacent property, drainage ditches, or surface water.**

To reduce the risk of runoff/erosion losses of manure nutrients, manures should not be applied and left on the soil surface within 150 feet of surface waters. Manures that are injected or surface applied with immediate incorporation can be closer than 150 feet as long as conservation practices are used to protect against runoff and erosion. A vegetative buffer between the application area and any surface water is a desirable conservation practice. Manure should not be applied to grassed waterways or other areas where there may be a concentration of water flow, unless used to fertilize and/or mulch new seedlings following waterway construction.

Manure should not be applied to areas subject to flooding unless injected or immediately incorporated. Liquid manures should not be applied in a manner that will result in ponding or runoff to adjacent property, drainage ditches or surface water. Therefore, application to saturated soils, such as during or after a rainfall, should be avoided.

9. **As land slopes increase from zero percent, the risk of runoff and erosion also increases, particularly for liquid manure. Adequate soil and water conservation practices should be used which will control runoff and erosion for a particular site, taking into consideration such factors as type of manure, bedding material used, surface residue or vegetative conditions, soil type, slope, etc.**

As land slopes increase, the risk of runoff and erosion losses to drainage ways, and eventually to surface waters, also increases. Soil and water conservation practices should be used to control and minimize the risk of nonpoint source pollution to surface waters, particularly where manures are applied. Injection or surface application of manure with immediate incorporation should generally be used when the land slope is greater than 6%. However, a number of factors such as liquid vs. solid or semi-solid manures, rate of application, amount of surface residues, soil texture, drainage, etc. can influence the degree of runoff and erosion associated with surface water pollution. Therefore, adequate soil and water conservation practices to control runoff and erosion at any particular site are more critical than the degree of slope itself.

Timing of Manure Application

10. Where application of manure is necessary in the fall rather than spring or summer, using as many of the following practices as possible will help to minimize potential loss of NO_3-N by leaching: (a) apply to medium or fine rather than to coarse textured soils; (b) delay applications until soil temperatures fall below 50° F; and/or (c) establish cover crops before or after manure application to help remove NO_3-N by plant uptake.

Ideally, manure (or fertilizer/other source) nutrients should be applied as close as possible to, or during, periods of maximum crop nutrient uptake to minimize nutrient loss from the soil-plant system. Therefore, spring or early summer application is best for conserving nutrients, whereas fall application generally results in greater nutrient loss, particularly for NO_3-N on coarse textured soils (i.e., sands, loamy sands, sandy loams).

11. Application of manure to frozen or snow-covered soils should be avoided, but where necessary, (a) solid manures should only be applied to areas where slopes are six (6) percent or less and (b) liquid manures should only be applied to soils where slopes are three (3) percent or less. In either situation, provisions must be made to control runoff and erosion with soil and water conservation practices such as vegetative buffer strips between surface waters and manure treated soils.

Winter application of manure is the least desirable in terms of nutrient utilization and prevention of nonpoint pollution. Frozen soils and snow cover will limit nutrient movement into the soil and greatly increase the risk of manure being lost to surface waters by runoff and erosion during thaws or early spring rains. When winter application is necessary, appropriately-sized buffer strips should be established and maintained between surface waters and frozen soils where manure is applied to minimize any runoff and erosion of manure from reaching surface waters. Particular attention to soil slopes and manure application rates can help prevent runoff and erosion from frozen and/or snow covered soils where manure is applied.

Management of Manure Applications to Land

12. Records should be kept of manure analysis, soil test reports, and rates of manure application for individual fields.

Good recordkeeping demonstrates good management and will be beneficial for the producer.

Records should include manure analysis reports and the following information for individual fields:

a. soil fertility test reports;

b. date(s) of manure application(s);

c. rate of manure applied (e.g. gallons or wet tons per acre);

d. previous crops grown on the field; and

e. yields of past harvested crops.

An important ingredient of a successful program for managing the animal manure generated by a livestock operation is "planning ahead". An early step of a manure application plan is to determine whether enough acres of cropland are available for utilizing manure nutrients without resulting in excess nutrient application to soils.

Tables 4 and 5 from MWPS-18 can help in making preliminary estimates of manure quantities and manure nutrients produced by different types of livestock and N losses during handling and storage of manures before they are applied. This information (or preferably manure analysis and actual quantities of manure for a particular farm) can be used to compare the quantity of available manure nutrients against the quantity of nutrients removed by the crops to be grown in the livestock operation. Manure Management Sheet #1, MSU-E Bulletin E-2344 (Jacobs et al, 1992b), and the MSU Nutrient Management computer program (MacKellar et al, 1996) can assist with this type of inventory. If the quantity of manure nutrients being generated greatly exceeds the annual crop nutrient needs, then alternative methods for manure utilization should be identified. For example, cooperative agreements with neighboring landowners to provide additional land areas to properly utilize all of the manure nutrients may be necessary.

Another consideration is to use good judgment when planning manure applications in conjunction with normal weather patterns, the availability of land at different times during the growing season for different crops, and the availability of manpower and equipment relative to other activities on the farm which compete for these resources. Having adequate storage capacity to temporarily hold manures can add flexibility to a management plan when unanticipated weather occurs, preventing timely applications. Nevertheless, unusual weather conditions do occur and can create problems for the best of management plans.

Finally, good recordkeeping is the "back bone" of a good management plan. Past manure analysis results will be good predictors of the nutrient content in manures being applied today. Records of past manure application rates for individual fields will be helpful for estimating the amount of residual N that will be available for crops to use this coming growing season. Changes in the P test levels of soils with time due to manure P additions can be determined from good records, and that information can be helpful in anticipating where manure rates may need to be reduced and when additional land areas may be needed. Recordkeeping systems, such as that described in MSU-E Bulletin E-2340 (Jacobs et al, 1992a), or available as a microcomputer program called MSU Nutrient Management (MacKellar et al, 1996), may be helpful in accomplishing this goal. The Nutrient Management program can easily calculate manure application rates for individual fields that follow the nutrient application criteria recommended in these manure management Generally Accepted Agricultural and Management Practices.

Table 1. Nutrient removal (lb/unit of yield) by several Michigan field crops.[1]

Crop		Unit	N	P_2O_5	K_2O
			---- lb per unit ----		
Alfalfa	Hay	ton	45[2]	10	45
	Haylage	ton	14	3.2	12
Barley	Grain	bushel	0.88	0.38	0.25
	Straw	ton	13	3.2	52
Birdsfoot Trefoil	Hay	ton	48	12	42
Bromegrass	Hay	ton	33	13	51
Canola	Grain	bushel	1.9	0.91	0.46
	Straw	ton	15	5.3	25
Clover-grass	Hay	ton	41	13	39
Corn	Grain	bushel	0.90	0.35	0.27
	Grain[3]	ton	26	12	6.5
	Stover	ton	22	8.2	32
	Silage	ton	9.4	3.6	7.8
Dry Edible Beans	Grain	cwt	3.6	1.2	1.6
Oats	Grain	bushel	0.62	0.25	0.19
	Straw	ton	13	2.8	57
Orchardgrass	Hay	ton	50	17	62
Potatoes	Tubers	cwt	0.33	0.13	0.63
Red Clover	Hay	ton	40	10	40
Rye	Grain	bushel	1.1	0.41	0.31
	Straw	ton	8.6	3.7	21
Sorghum-Sudangrass	Hay	ton	40	15	58
(Sudax)	Haylage	ton	12	4.6	18
Soybeans	Grain	bushel	3.8	0.88	1.4
Sugar Beets	Roots	ton	4.0	1.3	3.3
Wheat	Grain	bushel	1.2	0.62	0.38
	Straw	ton	13	3.3	23

[1] Source: Fertilizer Recommendations for Field Crops in Michigan. (Christenson, et al, 1992)
[2] Legumes get most of their nitrogen from air.
[3] High moisture grain.

Table 2. Approximate nutrient removal (lb/unit of yield) in the harvested portion of several Michigan vegetable crops.[1]

Crop	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	--- lb/cwt[2] ---			--- lb/ton[2] ---		
Asparagus	0.67	0.20	0.50	13	4.0	10
Beans, snap	1.2	0.12	0.55	24	2.4	11
Broccoli	0.20	0.05	0.55	4.0	1.0	11
Cabbage	0.35	0.08	0.35	7.0	1.6	7.0
Carrots	0.17	0.09	0.34	3.4	1.8	6.8
Cauliflower	0.33	0.13	0.33	6.6	2.6	6.6
Celery	0.25	0.10	0.80	5.0	2.0	16
Cucumbers	0.10	0.06	0.18	2.0	1.2	3.6
Lettuce	0.24	0.10	0.45	4.8	2.0	9.0
Muskmelon	0.42	0.10	0.55	8.4	2.0	11
Onions	0.25	0.13	0.24	5.0	2.6	4.8
Peas, shelled	1.0	0.23	0.50	20	4.6	10
Peppers	0.20	0.07	0.28	4.0	1.4	5.6
Pumpkins	0.20	0.06	0.34	4.0	1.2	6.8
Sweet Corn	0.42	0.14	0.28	8.4	2.8	5.6
Squash	0.18	0.08	0.33	3.6	1.6	6.6
Tomatoes	0.20	0.04	0.35	4.0	0.8	7.0

[1] Source: Fertilizer Recommendations for Vegetable Crops in Michigan. (Warneke et al, 1992)

[2] 1 ton = 20 cwt

Table 3. Ammonium nitrogen volatilization losses for surface application of solid and semi-solid manures.[1]

Days Before Incorporation	Retention Factor (RF)	Loss Factor (LF)
0-1 day	0.70	0.30
2-3 days	0.40	0.60
4-7 days	0.20	0.80
>7 days	0.10	0.90

[1] Source: Recordkeeping System for Crop Production. (Jacobs et al, 1992a)

Table 4. Manure and manure nutrients produced by different livestock species.[1]

Animal Species	Type and Average Size (lb)		Production (per day)			
			Manure	Nutrients (lb)		
			(ft^3)	N	P_2O_5	K_2O
Dairy Cattle		150	0.19	0.06	0.023	0.048
		250	0.32	0.10	0.045	0.084
		500	0.66	0.20	0.082	0.169
		1,000	1.32	0.41	0.166	0.325
		1,400	1.85	0.57	0.232	0.458
Beef Cattle		500	0.50	0.17	0.127	0.145
		750	0.75	0.26	0.191	0.229
		1,000	1.00	0.34	0.250	0.289
		1,250	1.20	0.43	0.318	0.373
	Beef Cow		1.05	0.36	0.273	0.313
Swine	Nursery Pig	35	0.038	0.016	0.0118	0.012
	Growing Pig	65	0.070	0.029	0.0223	0.024
	Finishing Pig	150	0.16	0.068	0.050	0.054
	Finishing Pig	200	0.22	0.090	0.068	0.071
	Gestating Sow	275	0.15	0.062	0.048	0.048
	Sow and Litter	375	0.54	0.230	0.173	0.181
	Boar	350	0.19	0.078	0.059	0.061
Sheep		100	0.062	0.045	0.015	0.039
Horse		1,000	0.75	0.27	0.105	0.205
Poultry (per 100 birds)	Chicken Broilers	2	0.24	0.24	0.123	0.09
	Chicken Layers	4	0.35	0.29	0.250	0.14
	Turkey[2]	16	1.40	1.16	1.00	0.56

[1] Source: Livestock Waste Facilities Handbook. (Midwest Plan Service, 1985).
[2] Values for turkeys estimated by multiplying the "Chicken Layers" values times four.

Table 5. Nitrogen losses during handling and storage.[1]

Manure Type	Handling System	Nitrogen Lost (%)
Solid	Daily scrape & haul	15-35
	Manure pack	20-40
	Open lot	40-60
	Deep pit (poultry)	15-35
Liquid	Anaerobic pit	15-30
	Above-ground	10-30
	Earth storage	20-40
	Lagoon	70-80

[1] Source: Livestock Waste Facilities Handbook. (Midwest Plan Service, 1985).

VI. REFERENCES

Barrington, S.F., and R.S. Broughton. Designing earthern storage facilities for manure. Agricultural Engineering Department. McGill University, Montreal, Quebec, Canada H9X 1C0.

Barrington, S.F., and P.J. Jutras. 1985. Selecting sites for earthen manure reservoirs. p. 386-392. In Agricultural Waste Utilization and Management, Proceedings of the Fifth International Symposium on Agricultural Wastes. Dec. 16-17, 1985. Hyatt Regency, Chicago, IL.

Barrington, S.F., P.J. Jutras, and R.S. Broughton. 1987a. The sealing of soils by manure. I. Preliminary investigations. Can. Agric. Eng. 29:99-103.

Barrington, S.F., P.J. Jutras, and R.S. Broughton. 1987b. The sealing of soils by manure. II. Sealing mechanisms. Can. Agric. Eng. 29:105-108.

Best Management Practice Manual. Agricultural Best Management Practices Manual for Michigans Nonpoint Source Pollution Program. 1994. MDNR Document.

Christenson, D.C., D.D. Warncke, M.L. Vitosh, L.W. Jacobs, and J.G. Dahl 1992. Fertilizer recommendations for field crops in Michigan. Ext. Bull. E-550A, Mich. State Univ., East Lansing, MI.

Ellis, B.G., and R.A. Olson. 1986. Economic, agronomic and environmental implications of fertilizer recommendations. North Central Regional Research Publication No. 310, Agr. Exp. Sta., Mich. State Univ., East Lansing, MI.

Graves, R.E. (ed.). 1986. Field application of manure. Document FA, Manure management for environmental protection. Pennsylvania Department of Environmental Resources, Commonwealth of Pennsylvania, Harrisburg, PA.

Jacobs, L.W. 1989. Analysis and utilization of manure for crop production. Mimeo. Dept. of Crop and Soil Sciences, Mich. State Univ., East Lansing, MI.

Jacobs, L.W. 1995a. Utilization of animal manure for crop production. Part II. Manure application to cropland. Bulletin MM-2, Animal Manure Management Resource Notebook. Available at County MSU Extension offices.

Jacobs, L.W. 1995b. Utilization of animal manure for crop production. Part III. Worksheet to calculate manure application rates. Bulletin MM-3, Animal Manure Management Resource Notebook. Available at County MSU Extension offices.

Jacobs, L.W., S.U. Böhm, and B.A. MacKellar. 1992a. Recordkeeping system for crop production. Ext. Bull. E-2340, Mich. State Univ., East Lansing, MI.

Jacobs, L.W., S.U. Böhm, and B.A. MacKellar. 1992b. Recordkeeping system for crop production-Manure Management Sheets. Ext. Bull. E-2344, Mich. State Univ., East Lansing, MI.

MacKellar, B.M., L.W. Jacobs, and S.U. Böhm. 1994. Michigan State University Nutrient Management (MSUNM), An Agricultural Integrated Management Software (AIMS) Microcomputer Program. CP-036, Version 1.1. MSU Bulletin Office, 10B Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039.

Madison, F., K. Kelling, J. Peterson, T. Daniel, G. Jackson, and L. Massie. 1986. Guidelines for applying manure to pasture and cropland in Wisconsin. Ext. Bull. A3392, University of Wisconsin-Extension, Madison, WI.

Meints, V.W., and L.S. Robertson. 1983. Soil sampling for no-till and conservation tillage crops. Ext. Bull. E-1616, Mich. State Univ., East Lansing, MI.

Melvin, S.W., F.J. Humenik, and R.K. White. 1987. Swine waste management alternatives. National Pork Industry Handbook, Ext. Bull. E-1399, Mich. State Univ., East Lansing, MI.

Michigan Beef Production Notebook. Department of Animal Science, 113 Anthony Hall, Mich. State Univ., East Lansing, MI.

Midwest Plan Service. 1979. Concrete manure tank design. Pub. TR-3, Midwest Plan Service, Iowa State Univ., Ames, IA.

Midwest Plan Service. 1983. Circular concrete manure tanks. Pub. TR-9, Midwest Plan Service, Iowa State Univ., Ames, IA.

Midwest Plan Service. 1985. Livestock waste facilities handbook, 2nd Ed. MWPS-18, Midwest Plan Service, Iowa State Univ., Ames, IA.

Moline, W.J., J.M. Middleton, and R. Plummer. 1991. Grasses and legumes for intensive grazing in Michigan. Ext. Bull. E-2307, Mich. State Univ., East Lansing, MI.

Moline, W.J., and R. Plummer. 1991a. Hay and pasture for horses in the North Central United States. Ext. Bull. E-2305, Mich. State Univ., East Lansing, MI.

Moline, W.J., and R. Plummer. 1991b. Pasture calendars for the North Central United States. Ext. Bull. E-2304, Mich. State Univ., East Lansing, MI.

Rynk, R. 1992. On-farm composting handbook. NRAES-54, Northeast Regional Agricultural Engineering Service, Ithaca, NY.

VI. REFERENCES

Barrington, S.F., and R.S. Broughton. Designing earthern storage facilities for manure. Agricultural Engineering Department. McGill University, Montreal, Quebec, Canada H9X 1C0.

Barrington, S.F., and P.J. Jutras. 1985. Selecting sites for earthen manure reservoirs. p. 386-392. In Agricultural Waste Utilization and Management, Proceedings of the Fifth International Symposium on Agricultural Wastes. Dec. 16-17, 1985. Hyatt Regency, Chicago, IL.

Barrington, S.F., P.J. Jutras, and R.S. Broughton. 1987a. The sealing of soils by manure. I. Preliminary investigations. Can. Agric. Eng. 29:99-103.

Barrington, S.F., P.J. Jutras, and R.S. Broughton. 1987b. The sealing of soils by manure. II. Sealing mechanisms. Can. Agric. Eng. 29:105-108.

Best Management Practice Manual. Agricultural Best Management Practices Manual for Michigans Nonpoint Source Pollution Program. 1994. MDNR Document.

Christenson, D.C., D.D. Warncke, M.L. Vitosh, L.W. Jacobs, and J.G. Dahl 1992. Fertilizer recommendations for field crops in Michigan. Ext. Bull. E-550A, Mich. State Univ., East Lansing, MI.

Ellis, B.G., and R.A. Olson. 1986. Economic, agronomic and environmental implications of fertilizer recommendations. North Central Regional Research Publication No. 310, Agr. Exp. Sta., Mich. State Univ., East Lansing, MI.

Graves, R.E. (ed.). 1986. Field application of manure. Document FA, Manure management for environmental protection. Pennsylvania Department of Environmental Resources, Commonwealth of Pennsylvania, Harrisburg, PA.

Jacobs, L.W. 1989. Analysis and utilization of manure for crop production. Mimeo. Dept. of Crop and Soil Sciences, Mich. State Univ., East Lansing, MI.

Jacobs, L.W. 1995a. Utilization of animal manure for crop production. Part II. Manure application to cropland. Bulletin MM-2, Animal Manure Management Resource Notebook. Available at County MSU Extension offices.

Jacobs, L.W. 1995b. Utilization of animal manure for crop production. Part III. Worksheet to calculate manure application rates. Bulletin MM-3, Animal Manure Management Resource Notebook. Available at County MSU Extension offices.

Jacobs, L.W., S.U. Böhm, and B.A. MacKellar. 1992a. Recordkeeping system for crop production. Ext. Bull. E-2340, Mich. State Univ., East Lansing, MI.

Jacobs, L.W., S.U. Böhm, and B.A. MacKellar. 1992b. Recordkeeping system for crop production-Manure Management Sheets. Ext. Bull. E-2344, Mich. State Univ., East Lansing, MI.

MacKellar, B.M., L.W. Jacobs, and S.U. Böhm. 1994. Michigan State University Nutrient Management (MSUNM), An Agricultural Integrated Management Software (AIMS) Microcomputer Program. CP-036, Version 1.1. MSU Bulletin Office, 10B Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039.

Madison, F., K. Kelling, J. Peterson, T. Daniel, G. Jackson, and L. Massie. 1986. Guidelines for applying manure to pasture and cropland in Wisconsin. Ext. Bull. A3392, University of Wisconsin-Extension, Madison, WI.

Meints, V.W., and L.S. Robertson. 1983. Soil sampling for no-till and conservation tillage crops. Ext. Bull. E-1616, Mich. State Univ., East Lansing, MI.

Melvin, S.W., F.J. Humenik, and R.K. White. 1987. Swine waste management alternatives. National Pork Industry Handbook, Ext. Bull. E-1399, Mich. State Univ., East Lansing, MI.

Michigan Beef Production Notebook. Department of Animal Science, 113 Anthony Hall, Mich. State Univ., East Lansing, MI.

Midwest Plan Service. 1979. Concrete manure tank design. Pub. TR-3, Midwest Plan Service, Iowa State Univ., Ames, IA.

Midwest Plan Service. 1983. Circular concrete manure tanks. Pub. TR-9, Midwest Plan Service, Iowa State Univ., Ames, IA.

Midwest Plan Service. 1985. Livestock waste facilities handbook, 2nd Ed. MWPS-18, Midwest Plan Service, Iowa State Univ., Ames, IA.

Moline, W.J., J.M. Middleton, and R. Plummer. 1991. Grasses and legumes for intensive grazing in Michigan. Ext. Bull. E-2307, Mich. State Univ., East Lansing, MI.

Moline, W.J., and R. Plummer. 1991a. Hay and pasture for horses in the North Central United States. Ext. Bull. E-2305, Mich. State Univ., East Lansing, MI.

Moline, W.J., and R. Plummer. 1991b. Pasture calendars for the North Central United States. Ext. Bull. E-2304, Mich. State Univ., East Lansing, MI.

Rynk, R. 1992. On-farm composting handbook. NRAES-54, Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Sweeten, J.M., C.L. Barth, R.E. Hermanson, and T. Loudon. 1981. Lagoon systems for swine waste treatment. National Pork Industry Handbook, Ext. Bull. E-1341, Mich. State Univ., East Lansing, MI.

Vanderholm, D.H., and J.C. Nye. 1987. Systems of runoff control. National Pork Industry Handbook, Ext. Bull. E-1132, Mich. State Univ., East Lansing, MI.

USDA. 1979. Animal waste utilization on cropland and pastureland. A manual for evaluating agronomic and environmental effects. USDA Utilization Research Rep. No. 6, October, 1979 (also EPA-600/2-79-059), U.S. Dept. of Agriculture and Natural Resource Conservation Service, Washington, D.C.

USDA. 1983. Water quality field guide. NRCS-TP-160, September, 1983. U.S. Dept. of Agriculture and Natural Resources Conservation Service, Washington, D.C.

USDA. 1992. Agricultural waste management field handbook. U.S. Dept. of Agriculture and Natural Resources Conservation Service, Washington, D.C.

USDA-NRCS. Field Office Technical Guide. U.S. Department of Agriculture and Natural Resources Conservation Service, East Lansing, MI.

Vitosh, M.L. 1996. MSUFR--Michigan State University Fertilizer Recommendations. Version 3.0 for IBM PC and IBM compatible computers. CP-001, MSU Bulletin Office, 10B Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039.

Vitosh, M.L., J.W. Johnson, and D.B. Mengel. 1995. Tri-state fertilizer recommendations for corn, soybeans, wheat and alfalfa. Extension Bulletin E-2567, Michigan State University, East Lansing, MI 48824-1039.

Warncke, D.D. 1988. Sampling soils for fertilizer and lime recommendations. Ext. Bull. E-498, Mich. State Univ., East Lansing, MI.

Warncke, D.D., D.R. Christenson, L.W. Jacobs, M.L. Vitosh, and B.H. Zandstra. 1992. Fertilizer recommendations for vegetable crops in Michigan. Ext. Bull. E-550B, Mich. State Univ., East Lansing, MI.

Listed below is the committee to make the annual review for the Generally Accepted Agricultural and Management Practices for Manure Management and Utilization.

[illegible] Davis
[illegible]DA-NRCS
[illegible] S. Harrison Road
[illegible] 101
[illegible] Lansing, MI 48823
[illegible] 337-6681

Geoffery List
Michigan Department of Environmental Quality
Waste Management Division
P.O. Box 30241
Lansing, MI 48909
(517) 373-8750

[illegible] G. Hogberg
[illegible] State University
[illegible] of Animal Science
[illegible] Anthony Hall
[illegible] MI 48824
[illegible]

Howard Person
Michigan State University
Department of Agricultural Engineering
225 Farrall Hall
East Lansing, MI 48824
(517) 353-4619

[illegible] Jacobs
[illegible] State University
[illegible] Soil Science
[illegible] Plant & Soil Science
[illegible] MI 48824

Gerald Schwab
Michigan State University
Department of Agricultural Economics
317A Agriculture Hall
East Lansing, MI 48824

[illegible]
[illegible] Bureau
[illegible] West Saginaw
[illegible] MI 48917
[illegible] 323-7000

Wayne Whitman
Michigan Department of Agriculture
Environmental Stewardship Division
P.O. Box 30017
Lansing, MI 48909
(517) 335-5849

[illegible]
[illegible]higan State University
[illegible] Development
[illegible] Resources
[illegible] 48824
[illegible]-1910

Thad Cleary
Michigan Department of Environmental Quality
Surface Water Quality Division
P.O. Box 30273
Lansing, MI 48909
(517) 335-0172

in This Space

UPS Tracking Label and your address label

UPS Next Day Air
UPS Worldwide Express
Shipping Document

UPS DRIVER

- Record 6-Digit UPS Shipper Number From Box 1.
- If Box 1 Is Blank Or The Number Is More Than 6 Digits, Record The Number From Box 2.

WEIGHT AND ZONE	WEIGHT	DIMENSIONAL WEIGHT	ZONE
	LTR		104

[X] NEXT DAY AIR [ ] WORLDWIDE EXPRESS (INTERNATIONAL)
[ ] DOCUMENTS ONLY
[ ] SATURDAY PICKUP [ ] SATURDAY DELIVERY

SHIPMENT FROM

UPS SHIPPER NO. 1: 4 5 9 1 1 0 2: -

N209 3910 02 0 DELIVERY 1

N209 3910 02 0 EXPORT 2

N209 3910 02 0 EXPORT 1

REFERENCE NUMBER
INDEX NO: 50011

Food & Dairy Dv.
TELEPHONE 517-373-1100

MICHIGAN DEPARTMENT OF AGRICULTURE
611 W OTTAWA STREET - FLOOR 4
LANSING MI 48933

[ ] BILL RECEIVER

UPS Next Day Air EXTREMELY URGENT **1**

DELIVERY TO

Document Mgt. Branch (HFA-305) TELEPHONE 301/443-1164
Food & Drug Administration
12420 Parklawn Dr. Room 1-23
Rockville, MD ~~20857~~ 20857

N209 3910 02 0 DELIVERY 2

N209 3910 02 0
TRACKING NUMBER

DATE OF SHIPMENT 12/18/97

010191120 3/97 M United Parcel Service, Louisville, KY